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Energy From the West: Impact Analysis Report

Volume II: Site-Specific and Regional Impact Analyses

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Energy from the West

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FORWARD

The production of electricity and fossil fuels inevitably impacts Man and his environment. The nature of these impacts must be thoroughly understood if balanced judgements concerning future energy development in the United States are to be made. The Office of Energy, Minerals and Industry (OEMI), in its role as coordinator of the Federal Energy/Environment Research and Development Program, is responsible for producing the information on health and ecological effects - and methods for mitigating the adverse effects - that is critical to developing the Nation's environmental and energy policy. OEMI's Integrated Assessment Program combines the results of research projects within the Energy/Environment Program with research on the socioeconomic and political/institutional aspects of energy development, and conducts policy - oriented studies to identify the tradeoffs among alternative energy technologies, development patterns, and impact mitigation measures.

The Integrated Assessment Program has supported several "technology assessments" in fulfilling its mission. Assessments have been supported which explore the impact of future energy development on both a nationwide and a regional scale. Current assessments include national assessments of future development of the electric utility industry and of advanced coal technologies (such as fluidized bed combustion). Also, the Program is conducting assessments concerned with multiple-resource development in two "energy resource areas":

- o Western coal states
- o Lower Ohio River Basin

This report, which describes the impacts likely to be experienced when six energy resources are developed in eight western states, is one of three major reports produced by the "Technology Assessment of Western Energy Resource Development" study. (The other two reports describe the technologies likely to be used and analyze policy problems and issues that can be expected to arise.) The report is divided into two volumes. The first or summary volume introduces the study, describes the development alternatives which were assessed and summarizes the results of the impact analyses which were conducted. The second volume reports the detailed results of both site-specific and regional impact analyses. The report has been designed to be useful to laypersons as well as persons who have a professional interest in energy resource development. And results are presented in a way which make this report a useful planning handbook for both professional planners and interested citizens.

We would like to receive your comments concerning this report. Such comments will help us to improve the usefulness of the products produced by our Integrated Assessment Program.

Steven Reznek

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Acting Deputy Assistant
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PREFACE

This Impact Analysis Report has been prepared as part of "A Technology Assessment of Western Energy Resource Development" being conducted by an interdisciplinary research team from the Science and Public Policy Program (S&PP) of the University of Oklahoma for the Office of Energy, Minerals and Industry (OEMI), Office of Research and Development (ORD), U.S. Environmental Protection Agency (EPA). This study is one of several conducted under the Integrated Assessment Program established by OEMI in 1975. Recommended by an interagency task force, the purpose of the Program is to identify economically, environmentally, and socially acceptable energy development alternatives. The overall purposes of this particular study were to identify and analyze a broad range of consequences of energy resource development in the western U.S. and to evaluate and compare alternative courses of action for dealing with the problems and issues either raised or likely to be raised by development of these resources.

The Project Director was Irvin L.(Jack) White, Assistant Director of S&PP and Professor of Political Science, at the University of Oklahoma. White is now Special Assistant to Dr. Stephen J. Gage, EPA's Assistant Administrator for Research and Development. Michael D. Devine, now Project Director, supervised the final stages of producing this report.

R. Leon Leonard and Martha W. Gilliland have had primary management responsibility for producing this report. Leonard, now a Senior Scientist with the Radian Corporation in Austin, Texas, was a Co-Director of the research team, Associate Professor of Aeronautical, Mechanical, and Nuclear Engineering and a Research Fellow in S&PP while the study was being conducted. Gilliland is Executive Director of Energy Policy Studies, Inc., El Paso, Texas.

Steven E. Plotkin, now with the Office of Technology Assessment, was the EPA Project Officer.

Other S&PP team members are: Michael A. Chartock, a Co-Director of the research team and Associate Professor of Ecology; Steven C. Ballard, Assistant Professor of Political Science; Edward J. Malecki, Assistant Professor of Geography; Edward B. Rappaport, Visiting Assistant Professor of Geography; Frank J. Calzonetti, Research Associate in S&PP; Timothy A. Hall, Research Associate in S&PP; Gary D. Miller, Graduate Research Assistant (Civil Engineering and Environmental Science); Mark S. Eckert, Graduate Research Assistant (Geography); Dipak Kumar Sinha, Graduate Research Assistant (Aeronautical, Mechanical and Nuclear Engineering); and Michael E. Vanderpool, Graduate Research Assistant (Aeronautical, Mechanical, and Nuclear Engineering). Professors Ballard, Devine, Malecki, and Rappaport are also Research Fellows in S&PP.

Radian Corporation, Austin, Texas, has been a major contributor to this impact analysis report. C. Patrick Bartosh, Program Manager, has directed the Radian effort. Radian Personnel who contributed to the study are: B. Russ Eppright, Thomas W. Grimshaw, Milton Owen, Ken Choffel, Timothy J. Wolterink, Jim Sherman, James L. Machin, Dennis D. Harver, David Cabe, Sam A. Gavande, W.F. Holland, Carl Heinz Michelis, and Michael W. Hooper.

Water Purification Associates, Cambridge, Massachusetts, conducted a study of water requirements for steam-electric power generation and synthetic fuel plants; and the Center for Advanced Computation, the University of Illinois at Urbana-Champaign conducted a study of route specific costs comparisons of alternative transportation modes. Results of both studies have contributed to this report.

Several persons no longer with S&PP or Radian participated in the early stages of the research upon which this report is based. Three are now in graduate school at other universities: Cary N. Bloyd at Carnegie-Mellon University, Lori L. Serbin at Ohio University, and Patrick Kangas at the University of Florida. Gerald M. Clancy, William D. Conine and E. Douglas Sethness, Jr., have moved from Radian to other corporate positions.

ABSTRACT

This is the final impact analysis report of a three-year technology assessment of the development of six energy resources (coal, geothermal, natural gas, oil, oil shale, and uranium) in eight western states (Arizona, Colorado, Montana, New Mexico, North Dakota, South Dakota, Utah, Wyoming) during the period from the present to the year 2000. Volume I describes the purpose of the study and summarizes the results and conclusions of the analysis. In Volume II, more detailed analytical results are presented. Six chapters report on the analysis of site-specific impacts of deploying typical energy resource development technologies at sites representative of the kinds of conditions likely to be encountered in the eight-state study area. A seventh chapter of Volume II identifies localized impacts, which do not differ significantly from site to site. A last chapter focuses on regional impacts likely to occur across the eight states if energy resources are developed at two different levels from the present to the year 2000. In addition to these two volumes of the Impact Analysis Report, the Policy Analysis Report and the Energy Resource Development Systems Report are published separately.

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LIST OF ACRONYMS AND ABBREVIATIONS

AC	alternating current
acre-ft	acre-feet
acre-ft/yr	acre-feet per year
AOG	associations of government
AsH_3	arsine
AUM	animal units per month
BACT	best available control technology
bbl	barrel(s)
bbl/day	barrel(s) per day
bcf	billion cubic feet
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
BPT	best practicable technology
Btu	British thermal unit
Btu/bbl	British thermal units per barrel
BuRec	Bureau of Reclamation
CAA	Clean Air Act
$CaCO_3$	calcium carbonate
$CaSO_4$	calcium sulfate
cfs	cubic feet per second
CO	carbon monoxide
CO_2	carbon dioxide
dB	decibel
dBA	decibel(s) A-weighted
DC	direct current
EDA	Economic Development Administration
EHV	extra-high voltage
EPA	Environmental Protection Agency
ERDS	Energy Resource Development Systems
ESP	electrostatic precipitator
F	Fahrenheit
FDA	Food and Drug Administration
FERC	Federal Energy Regulatory Commission
FGD	flue gas desulfurization
FPC	Federal Power Commission
FWPCA	Federal Water Pollution Control Act
GACLA	Governors' Advisory Council on Local Affairs
GNP	gross national product
gpd	gallons per day
gpm	gallons per minute
HC	hydrocarbons
H_2S	hydrogen sulfide

kV	kilovolt(s)
kWh	kilowatt-hour(s)
lbs/ton	pounds per ton
LCRB	Lower Colorado River Basin
L_{dn}	day-night equivalent sound level
MESA	Mining Enforcement and Safety Administration
mg/ℓ	milligrams per liter
MMcfd	million cubic feet per day
MMgpd	million gallons per day
MMscfd	million standard cubic feet per day
MMtpy	million tons per year
MW	megawatt(s)
MWe	megawatt-electric
mph	miles per hour
NAAQS	National Ambient Air Quality Standards
NC	not calculated or not considered
NH_3	ammonia
NH_4Cl	ammonium chloride
NIOSH	National Institute of Occupational Safety and Health
NO	nitric oxide
NO_2	nitrogen dioxide
NO_x	oxides of nitrogen
NSPS	New Source Performance Standards
OPEC	Organization of Petroleum Exporting Countries
ORV	off-road vehicle
PAH	polyaromatic hydrocarbons
pCi/g	picocuries per gram
pCi/ℓ	picocuries per liter
pH	acidity/alkalinity
ppb	parts per billion
ppm	parts per million
PSD	prevention of significant deterioration
psi	pounds per square inch
psia	pounds per square inch atmosphere
Q	10^{15} British thermal units and/or quad(s)
Ra-226	Radium 226
Rn-222	Radon 222 gas
SEAS	Strategic Environmental Assessment System
SO_2	sulfur dioxide
S&PP	Science and Public Policy Program
SRI	Stanford Research Institute
tcf	trillion cubic feet
TDS	total dissolved solids
TOSCO	The Oil Shale Corporation
tpd	tons per day
tpy	tons per year
TSP	total suspended particulates
TVA	Tennessee Valley Authority
UCRB	Upper Colorado River Basin
μg	microgram(s)

$\mu g/m^3$	micrograms per cubic meter
UMRB	Upper Missouri River Basin
U_3O_8	uranium oxide and/or yellowcake
USGS	U.S. Geological Survey
WPA	Water Purification Associates
ZDP	zero discharge of pollutants

CONVERSION TABLE

BTU CONTENT OF ENERGY FORMS

Electricity: 1 kWh = 3413 Btu.

Natural gas: 1 cubic foot = 1000 Btu.

Petroleum: 1 barrel (bbl) = 42 gallons

crude oil--1 bbl = 5.8 million Btu;

distillate fuel--1 bbl = 5.8 million Btu;

residual fuel --1 bbl = 6.3 million Btu;

gasoline--1 bbl = 5.3 million Btu;

Uranium--1 pound U_{235} = 3.6×10^{10} Btu.

1 million = 10^6
1 billion = 10^9
1 trillion = 10^{12}

1 Quad = 10^{15} Btu
1 megawatt = 10^6 Watts
1 kilowatt = 10^3 Watts

ENERGY

UNITS	joule	cal	Btu	kWh
1 joule	1	2.389×10^{-1}	9.48×10^{-4}	2.778×10^{-7}
1 cal	4.186	1	3.97×10^{-3}	1.163×10^{-6}
1 Btu	1.055×10^3	2.52×10^2	1	2.93×10^{-4}
1 kWh	3.6×10^6	8.6×10^5	3.413×10^3	1

RATE

UNITS	Cubic Meter/Year	Gallon/Minute	Acre-Feet/Year
1 gallon/minute	1.9898×10^3	1	1.613
1 acre-foot/year	1.2335×10^3	6.2×10^{-4}	1

PRESSURE

UNITS	atmospheres	kilograms/square centimeter	pounds per square inch	N/m^2, Pa
1 atmosphere	1	1.033	1.469×10^1	1.03×10^5
1 pound/sq. inch	6.804×10^{-2}	7.03×10^{-2}	1	6894.76

LENGTH

UNITS	Meters	Feet	Yards	Miles
1 meter	1	3.28	1.093	6.21×10^{-4}
1 yard	9.14×10^{-1}	3.0	1	5.68×10^{-4}
1 mile	1.609×10^3	5.28×10^3	1.76×10^3	1

WEIGHT

UNITS	Kilogram	Pound	Metric Ton	Ton (Short)
1 kilogram	1	2.2046	1.0×10^{-3}	1.102×10^{-3}
1 metric ton	1.0×10^3	2.205×10^3	1	1.102
1 ton (short)	9.072×10^2	2.0×10^3	9.078×10^{-1}	1

VOLUME

UNITS	Liters	Cubic Feet	Acre-Feet	Gallons
1 liter	1	3.531×10^{-2}	8.107×10^{-7}	$2,642 \times 10^{-1}$
1 acre-foot	1.234×10^6	4.356×10^4	1	3.259×10^5
1 gallon (U.S.)	3.785	1.337×10^{-1}	3.068×10^{-6}	1

AREA

UNITS	Square Meters	Square Feet	Square Yards	Acres	Square Miles
1 square meter	1	1.076×10	1.196	2.471×10^{-4}	3.86×10^{-7}
1 square yard	8.361×10^{-1}	9.0	1	2.066×10^{-4}	3.228×10^{-7}
1 acre	4.047×10^3	4.35×10^4	4.84×10^3	1	1.562×10^{-3}
1 square mile	2.59×10^6	2.788×10^7	3.098	6.402×10^2	1

atm = atmospheres
psi = pounds per square inch
cal = calorie
N/m^2, Pa = Newton per square meter, Pascal
Btu = British thermal units
kWh = kilowatt hour

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The research reported here could not have been completed without the assistance of a dedicated administrative support staff. Members of the staff are an integral part of the interdisciplinary team approach employed by the Science and Public Policy Program. This staff is headed by Janice Whinery, Assistant to the Director, and Nancy Heinicke, Clerical Supervisor. Staff members are: Ellen Ladd, Cyndy Allison, Patti Mershon, Brenda Skaggs, Pam Odell, Judy Williams, and Julia Leonard. Sharon Pursel assisted as Clerical Supervisor in the production of the draft policy analysis report.

The research support staff is headed by Martha Jordan, Librarian. Research Team Assistants are David Sage, Mary Sutton, and Diane Dean. Lorna Caraway and Phil Kabrich assisted as Research Team Assistants in the final production of the report.

Nancy Ballard, graphics arts consultant, designed the title page.

Steven E. Plotkin, EPA Project Officer, and Terry Thoem, EPA, Denver, have provided continuing support and assistance in the preparation of this report.

An Advisory Committee and numerous individuals, corporations, government agencies, and public interest groups have assisted the team at various stages in the preparation of the report. The names of the members of the Advisory Committee are listed below. Others who have assisted are far too numerous to list here. Needless to say, no member of the Advisory Committee, consultant, or any other individual or agency is responsible for the content of this progress report. The report is the sole responsibility of the Science and Public Policy interdisciplinary research team conducting this study.

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PART II: SITE-SPECIFIC AND REGIONAL IMPACT ANALYSES

II.1 INTRODUCTION

This part of the report presents results of our analysis of the impacts likely to occur when western energy resources are developed. Chapters 4-9 report the results of site-specific impact analyses. Knowledge concerning some local impacts is so limited that they cannot be analyzed for each site; and some local impacts do not vary significantly on the basis of site-specific differences. These localized impacts are discussed in Chapter 10.[1] Regional impact analysis results are reported in Chapter 11.

The site-specific impacts analyzed in Chapters 4-9 are divided into four major categories: air; water; social and economic; and ecological. These and a transportation impact category are included in the regional impacts analyzed in Chapter 11. The methods and assumptions used in each of the four major categories are briefly described below.

II.2 IMPACT ANALYSIS METHODS[2]

II.2.1 Air Impact Analysis

Gaussian dispersion models were used to determine the ambient air impact of air emissions.[3] These models incorporate

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[1]They include some air quality impact categories (e.g., cooling tower salt deposition and fugitive dust), trace elements, solid waste treatment and disposal, noise, aesthetics, and health effects (both public health and occupational health and safety).

[2]A more detailed description of the methods used in the analysis of impacts can be found in White, Irvin L., et al. First Year Work Plan for a Technology Assessment of Western Energy Resource Development. Washington, D.C.: U.S., Environmental Protection Agency, 1976. More detailed assumptions are introduced in Chapters 4-9.

[3]For a description of the dispersion model, see White, Irvin L., et al. Energy From the West: A Progress Report of a Technology Assessment of Western Energy Resource Development. Washington, D.C.: U.S., Environmental Protection Agency, 1977, Appendix A.

modifications to measure impacts in rough terrain. When modeled results were compared with measured air quality data taken in the vicinity of the Navajo power plant near Page, Arizona, they were found to be accurate to within ±50 percent.

The air emissions modeled in this study originate from three types of sources: plants, mines, and urban populations. Emissions data for mines and facilities are from the _Energy From the West: Energy Resource Development Systems_ (ERDS) _Report_ prepared to codify baseline data for the project.[1] Urban emission rates were obtained by averaging per capita emissions for: Salt Lake City, Utah; Denver, Colorado; Albuquerque, New Mexico; Santa Fe, New Mexico; Phoenix, Arizona; Billings, Montana; Casper, Wyoming; and Rapid City, South Dakota.[2]

The dispersion modeling of the three types of emissions sources were each performed somewhat differently. Plants were modeled as a combination of elevated sources (stacks) and ground-level sources (fugitive emissions), and the mines and urban areas were modeled as ground-level sources. Since the dispersion conditions that create high concentrations from elevated sources are different from those that create high concentrations from ground-level sources, several different dispersion conditions were investigated for both types of sources at the plants and mines:

- _Short-Term (3 hours or less) Average Concentrations_. Conditions producing plume looping, terrain impaction, and limited vertical mixing were modeled to determine the peak concentrations from elevated sources; and, ground-based inversions and low wind speeds typical of stagnation conditions were modeled for ground-level sources.

- _Intermediate-Term (3-24 hours) Average Concentrations_. Realistic sequences of meteorological conditions were modeled that included the short-term dispersion conditions which produced the highest concentrations. The averaging time period was divided into an integral number of shorter term intervals with specific plant emissions and meteorological conditions which were assumed constant within a time interval but which could change from interval to interval. The short-term model was used to compute the concentrations at particular receptors, and the final concentration for

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[1]White, Irvin L., _et al_. _Energy From the West; Energy Resource Development Systems Report_. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[2]Data for smaller cities with populations comparable to those found in the eight-state study area were not available.

the desired averaging time was computed by averaging contributions from the individual time increments.

- Annual Average Concentrations.
  Concentrations, predicted using National Weather Service statistical data, were computed for a grid of receptors based on the frequency of occurrence of different sets of meteorological conditions.

The highest ground-level concentrations and averaging time for each pollutant were selected from these cases and are reported as "peak" values. Also computed for each facility were more typical concentrations that would be expected to occur downwind of the plant.

Sensitivity analyses were carried out on stack height, sulfur dioxide (SO_2) scrubber and electrostatic precipitator efficiencies, terrain characteristics, and plant size for the elevated sources by calculating dispersion and reporting ambient concentrations for different values of each of these variables.

The urban areas were modeled on an annual average basis using statistical meteorological data.[1] The peak concentrations for the shorter term averages were computed using Larsen's statistics.[2]

Projections of emissions from power plants were based on several assumptions about the characteristics of the coal to be used in each scenario. Table II-1 summarizes the sulfur and British thermal unit (Btu) content of the coal and SO_2 emission rates for each scenario. These data indicate that the coal found in the vicinity of each scenario varies with respect to sulfur and Btu content. Coal of average sulfur and Btu content was selected for use in each scenario. Emission rates also depend on the amount of sulfur retained in the ash, as indicated in Table II-1. For the scenarios analyzed, the emission factors were based on the assumption that none of the sulfur was retained in the ash.

II.2.2 Water Impact Analysis

Descriptions of the availability and quality of surface water and groundwater at each of the six sites and in the eight-state

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[1]U.S., Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service. Wind Distribution by Pasquill Stability Classes, Star Program. Ashville, N.C.: National Climatic Center, 1975.

[2]Larsen, Ralph I. A Mathematical Model Relating Air Quality Measurements to Air Quality Standards, Number AP-89. Washington, D.C.: U.S., Environmental Protection Agency, Office of Air Programs, November 1971.

TABLE II-1: COAL COMPOSITION FOR SITE SPECIFIC SCENARIOS

	SULFUR CONTENT (percent by weight)			Btu CONTENT (Btu per pound)[a]		SO_2 EMISSION RATE[b] (pounds of SO_2 per million Btu)	
SITE	AVERAGE	RANGE	PROJECTED FOR SCENARIO	AVERAGE	RANGE	TWENTY PERCENT SULFUR RETENTION	ZERO PERCENT SULFUR RETENTION
Kaiparowits[c]	.52	0.2-1.4	.5	10,800	10,600-11,000	.74	.93
Farmington[d]	.78	0.6-0.9	.7	8,580	7,930- 9,525	1.49	1.86
Rifle[e]	.50	0.4-0.7	.6	11,220	10,830-11,410	.71	.89
Gillette[e]	.62	0.3-0.9	.6	7,980	7,240- 8,540	1.20	1.50
Colstrip[e]	.80	0.3-1.8	.8	8,870	6,870- 9,500	1.44	1.80
Beulah[e]	.60	0.4-1.1	.8	7,070	6,830- 7,280	1.36	1.70

Btu = British thermal unit SO_2 = sulfur dioxide

[a]Btu content for Rifle is calculated for Rio Blanco County only. Btu figures apply to the particular case selected for use.

[b]The range of emission in this table reflects variations in sulfur retention in ash. This retained sulfur does not form SO_2. Sulfur retention in the combustion of western coals is generally higher than for eastern coals, but the amount of retention is variable.

[c]U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976.

[d]U.S., Department of the Interior, Bureau of Reclamation. Western Gasification Company Coal Gasification Project and Expansion of Navajo Mine by Utah International Inc., San Juan County, New Mexico: Final Environmental Impact Statement, 2 vols. Salt Lake City, Utah: Bureau of Reclamation, 1976.

[e]Ctvrtnicek, T.E., S.J. Rusek, and C.W. Sandy. Evaluation of Low-Sulfur Western Coal Characteristics, Utilization, and Combustion Experience, EPA-650/2-75-046, Contract No. 68-02-1302. Dayton, Ohio: Monsanto Research Corporation, 1975.

study area are based on secondary sources. Data on the water requirements for energy facilities are taken from two sources: the ERDS Report,[1] and Water Purification Associates' (WPA) Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States.[2] The ERDS Report's descriptions of water requirements are based on a variety of secondary sources and represent likely average water use. The WPA estimates are site-specific and are the minimum water requirements within the constraint of the economic cost of water. In other words, WPA's estimates are for the process design that would minimize water to the point where minimizing water use would increase economic cost, although it might be technologically feasible to reduce water requirements even further. The WPA report should be consulted for a description of how estimates were calculated.

Data on the consumptive use of water by energy-related population increases are based on actual per capita consumption rates in communities included in the six site-specific scenarios. For the eight-state regional scenario, a rate of 150 gallons per capita per day is used.

Localized impacts on water availability were identified by relating the consumptive use of water to local surface and groundwater availability. Basin-wide impacts on water availability were identified by relating total water requirements for facilities and population to total instream flows and current withdrawals.

The local water quality impacts of energy development were identified by relating development activities, such as construction and mining, to the local conditions. The land and aquifer disturbances, changes in runoff, and effluents resulting from these activities were analyzed.

Water availability analyses were conducted both at local and regional levels. Water quality changes were addressed mainly with respect to local sites, but some emphasis was placed on regional problems as well. The data necessary to evaluate the effects of specific facilities under various hydrologic conditions are being generated by a number of research projects currently underway.

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[1] See White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[2] Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

II.2.3 Social and Economic Analyses

A. Population, Schools, and Housing

Population impacts resulting from energy developments were estimated using the economic base or export-base model. This model distinguishes between export-oriented or basic employment and local service-related or nonbasic employment.[1] The driving assumption for regional impact analysis is that basic employment is the impetus for growth, to which the regional economy responds. This response takes the form of additional employment in the nonbasic sector and is known as the _multiplier_ effect.

In this study, employment multiplier values were chosen from studies of each site-specific locality, and population multipliers were derived from empirical results in the West,[2] discounting for working spouses (especially in service jobs). Populations were distributed in each local region, taking major local trade centers into account.

Both housing and school enrollment impacts were derived from local age-sex distributions. The 1970 age-sex structure was projected by aging surviving cohorts and adding newly arrived employees and their families, generally conforming to the age structures reported in the _Construction Worker Profile_.[3] Housing demand was assumed to approximate the number of males ages 20 and over in the local population. This is an aggregate approach which is intended to balance male dependents and single female households. School enrollment estimates assume that the 6-13 age group is elementary school age and the 14-16 age group is secondary school age. These result in enrollment underestimates of up to 20 percent in some cases but reflect the relative sizes expected fairly closely.

B. Materials and Equipment

The demand for industrial output for western energy development was examined only at the regional level using the Strategic

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[1] An alternative for economic base analysis is to focus on income, thereby defining the basic sector as that which brings income into the community. The definition of sectors is more difficult when income is used but provides a better framework for regions where nonwage income is important (e.g., retirement communities). For a comprehensive presentation of the model, see Tiebout, Charles M. _The Community Economic Base Study_. New York, N.Y.: Committee for Economic Development, 1962.

[2] Mountain West Research. _Construction Worker Profile_, Final Report. Washington, D.C.: Old West Regional Commission, 1976.

[3] _Ibid_.

Environmental Assessment System (SEAS).[1] The SEAS is an input-output model of the national economy. Three runs were performed and compared:

- A "Nominal Dirty" case which closely parallels the Nominal Development case of the Stanford Research Institute (SRI) model. One major exception was a higher level of oil shale development: 4.2 million barrels/day by 2000 rather than 2.5 million;

- A "Nominal Clean" case with the same scale of energy development but more strict environmental controls;

- A "Low Growth" case with the "dirty" or lax environmental control assumptions but a slower rate of western energy development than in the Nominal cases.

The sector-by-sector[2] comparison of Nominal Dirty and Low Growth indicates which industries' rates of output are most sensitive to varying levels of western energy development. Comparison of Nominal Dirty and Nominal Clean indicates which industries will be most involved in producing pollution control materials and equipment. Moreover, this latter comparison also provides, via SEAS Residuals Generation module, independent estimates of quantities of pollutants on a regional basis, for comparison with figures derived by the Science and Public Policy (S&PP) study team.

C. Financial Resources

For the site-specific analyses, fiscal impacts were examined by combining data on the sources of revenue with data on projected capital and operating expenditures at the city and county level. Sources of revenue included those associated with the energy facilities and the increased population. Tax rates and the kind of applicable taxes varied by site in accordance with state and local policy, but in general, the taxes considered included a property tax, sales tax, severance tax, energy conversion tax, and royalty payments on federally owned energy resources. Capital expenditures were projected for schools and sewage and water utilities using the population projections. Both revenues and expenditures were projected as a function of time in accordance with the timing of energy development and population increases to obtain projections of

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[1]Ball, Richard H., Project Officer. A Description of the SEAS Model. Washington, D.C.: U.S., Environmental Protection Agency, October 1977.

[2]SEAS divides the economy into 185 sectors.

deficits and surpluses. Bechtel's Energy Planning Model[1] was the source of the capital cost data for energy facilities; these capital cost data were used to estimate the property tax revenue generated by the energy facilities.

For the regional analysis, the same capital cost data were used in conjunction with the number of plants projected to come on-line each year in order to obtain the total investment costs for all plants for each year. In calculating return cash flow, it was assumed that each facility would return its investment[2] over a 30-year period at a 10 percent real discount ratio. Depreciation plus one-fourth of net income was assumed available to the firm for further investment, and that constituted the "return cash flow."

II.2.4 Ecological Methodology

As the first step in analyzing the ecological impacts of each scenario, a detailed characterization of the existing ecosystem was prepared. The background information gathered for the scenarios included: identifying presently operating limiting factors (e.g., rainfall, winter storms, etc.); identifying major natural or manmade stresses (e.g., periodic drought, sagebrush eradication, grazing); obtaining assessments of recent population trends for selected species of wildlife and relating them to known stresses (e.g., declining sharptail grouse populations because of habitat destruction by farming); mapping vegetation types throughout the scenario area; and mapping critical habitat for game and nongame species for which information is available (e.g., critical wintering areas, breeding, or mating display areas).

Analyzing the impacts of energy development on this dynamic baseline involved interpreting the direct and indirect effects on the availability and quality of habitat of the impacts found in the air, water, and social and economic analyses. This, in turn, required a general analysis of secondary changes in land-use patterns brought about by increasing populations. Specifically, areas likely to receive heavy pressure from backcountry recreationists (hikers, campers, fishermen, etc.) and from offroad vehicle use were identified, as well as areas vulnerable to strip development, recreational or second-home developments, and siting of new roads and highways. These land-use projections were based largely on input from responsible planning agencies, interpreted in the light of recent trends and values. In some scenarios, changes in

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[1]Carasso, M., _et al._ _The Energy Supply Planning Model_, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975. These data were converted to 1975 dollars.

[2]Including allowances for funds during construction which were not included in total capital requirements.

forestry practice and expansion of cropland, concurrent with but independent of energy development, are taken into consideration as they can substantially affect both terrestrial and aquatic communities. Working maps of forecast land-use changes were prepared to aid in evaluating the cumulative impact of energy-related stresses superimposed on other changes taking place within the same time period.

In preparing the assessments presented in the following chapters, all factors were quantified within reasonable limits. Scenario land requirements and secondary land-use changes were interpreted in terms of the relative amounts of affected habitat available in the scenario, and the location of areas were mapped as critical habitats. Impacts on livestock grazing were calculated on the basis of available estimates of range capacity. Withdrawals of water from rivers and streams were compared with recorded flows, although in no case were data appropriate to quantifying critical flow needs available. SO_2 ground-level concentrations were compared with published data on the sensitivity of affected plant species. However, the final conclusions as to the meaning of these impacts in conjunction with less quantifiable effects were based on technical judgment and the opinion of active professionals in the field.

Finally, the cumulative ecological impact of each scenario was summarized in terms of expected population trends for selected wildlife and fish species. Species evaluated included those of economic or recreational importance, rare or threatened species, and indicators of ecological change. An apparent bias throughout the scenarios toward game animals results not from an intent on the part of the investigators but because there frequently was insufficient information to do more than generalize about nongame forms.

II.3 INTERACTIONS AMONG CATEGORIES OF IMPACTS

Although separated for purposes of analysis, impact categories obviously interact with and thus affect one another. For example, population increases may generate increased air emissions, which in turn may affect health and the delivery of health services. When appropriate, the analyses reported in the following chapters attempt to take these interactive relationships into account by introducing an impact from one category into the analysis of another category of impacts. A final section in each of the following chapters summarizes impacts and identifies the technological and locational factors which can cause significant variations in impacts.

CHAPTER 4

THE IMPACTS OF ENERGY RESOURCE DEVELOPMENT AT THE KAIPAROWITS/ESCALANTE AREA

4.1 INTRODUCTION

The Kaiparowits/Escalante area of southern Utah is shown in Figure 4-1. Hypothetical energy resource development proposed in this area (Kane and Garfield counties) includes underground coal mining, mine-mouth electrical power generation, and export of electrical power via extra-high voltage (EHV) transmission lines to Arizona, California, and elsewhere in Utah.[1] The location of these facilities is shown in Figure 4-2.

The impacts of two 3,000 megawatt-electric (MWe) generating plants, one located near Escalante and one near Kaiparowits, and of the associated coal mines are evaluated separately; and a scenario which calls for construction of both facilities is analyzed. In the scenario, construction of the first 3,000 MWe generating plant began during 1975. The first plant will come on-line in 1983 and the second in 1987. Development of the coal mines to supply these plants began in 1976, and full production is scheduled for 1987. Details on Kaiparowits/Escalante coal, technological alternatives, and the scenario development schedule are summarized in Table 4-1. In all four impact sections of this chapter (air, water, social and economic, and ecological), the factors that produce impacts are identified and discussed for each mine and power plant. In the air and water sections, impacts caused by those factors are discussed for each mine-power plant combination and for the scenario which includes both mines and power plants constructed according to the scenario schedule. In the social and economic and ecological sections, only the impacts of the scenario are discussed. This distinction is made because social, economic, and ecological effects are, for the most part,

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[1]While this hypothetical development closely parallels facilities proposed by Southern California Edison, San Diego Gas and Electric, and Arizona Public Service (now cancelled) and the Intermountain Power Project in the Kaiparowits/Escalante area, it must be stressed that the development identified here is hypothetical. As with the others, this scenario was used to structure the assessment of a particular combination of technologies and existing conditions.

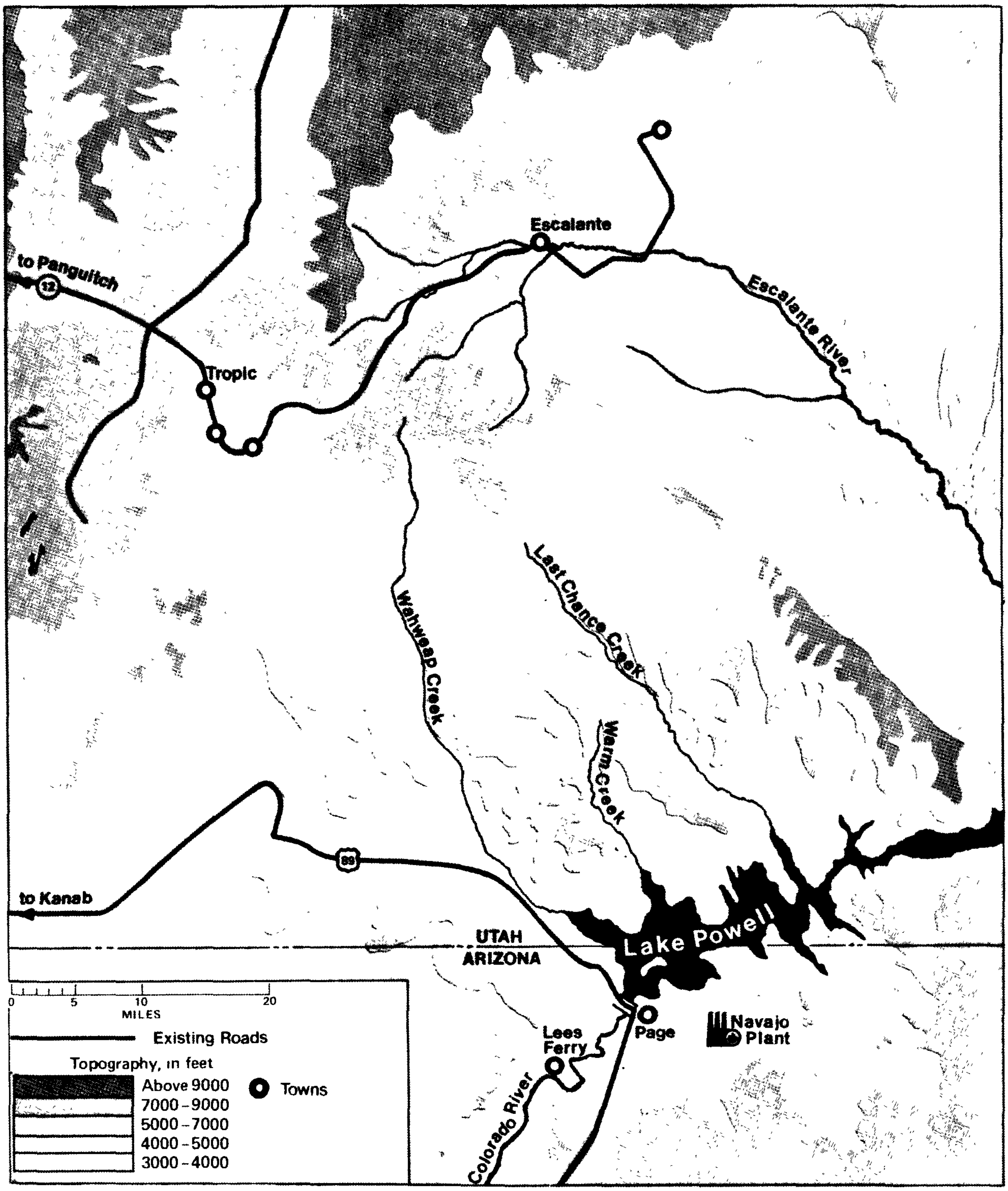

FIGURE 4-1: KAIPAROWITS/ESCALANTE AREA OF SOUTHERN UTAH

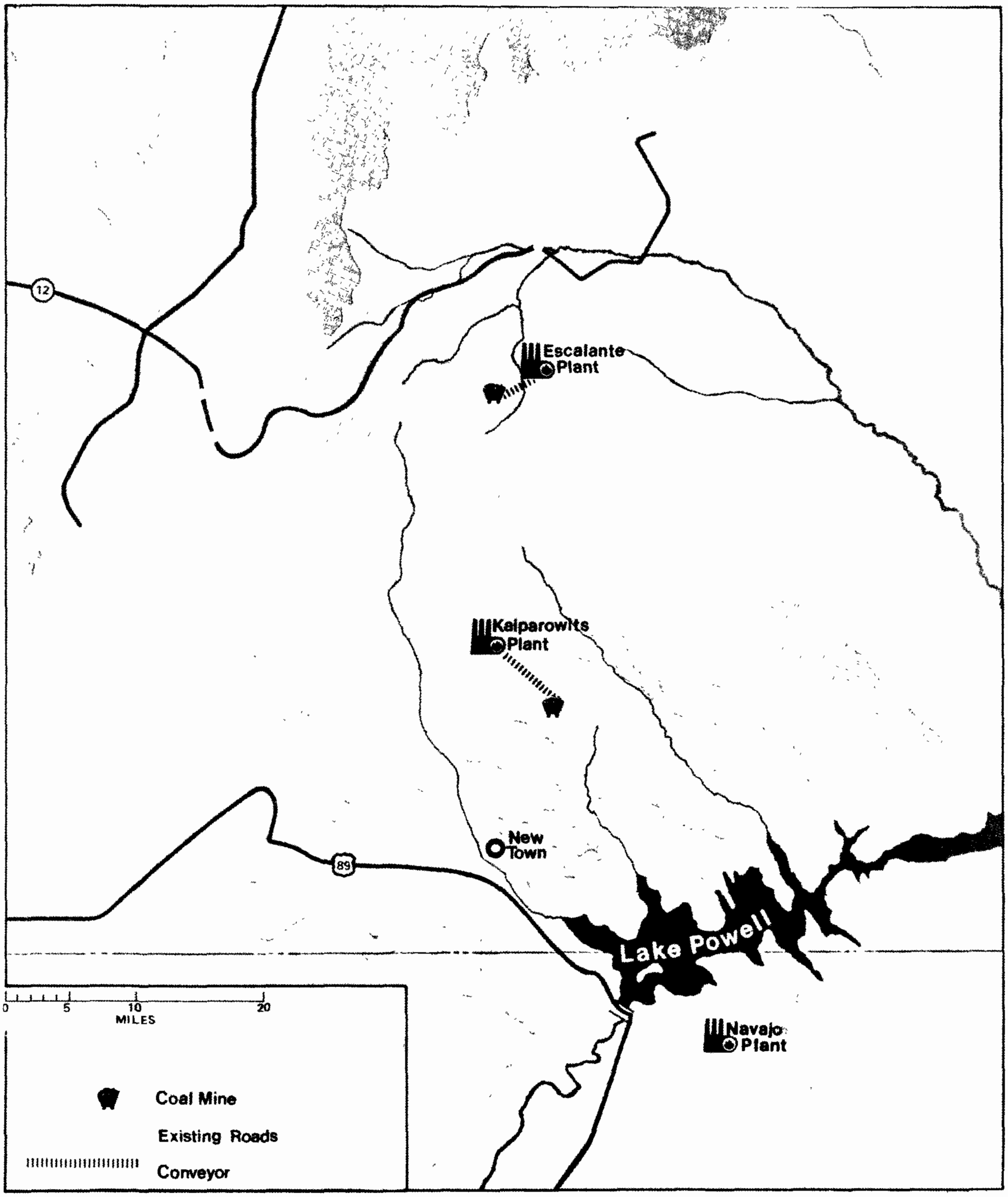

FIGURE 4-2: THE LOCATION OF HYPOTHESIZED ENERGY DEVELOPMENT FACILITIES IN THE KAIPAROWITS/ESCALANTE AREA

TABLE 4-1: RESOURCES AND HYPOTHESIZED FACILITIES AT KAIPAROWITS/ESCALANTE

	CHARACTERISTICS		
Resources	Coal[a]		
Coal (billions of tons)	Heat Content	10,000 Btu's/lb	
Resources 40	Moisture	14 %	
Proved Reserves 8	Volatile Matter	44 %	
	Fixed Carbon	40 %	
	Ash	9 %	
	Sulfur	0.5%	
	FACILITY SIZE	**COMPLETION DATE**	**LOCATION**
Technologies			
Extraction			
Fourteen underground room-and-pillar mines using continuous miners to produce 1.6 million tons each per year	1.6 MMtpy	1980	Kaiparowits
	1.6 MMtpy	1981	Kaiparowits
	3.2 MMtpy	1982	Kaiparowits
	4.8 MMtpy	1983	Kaiparowits
	1.6 MMtpy	1984	Escalante
	1.6 MMtpy	1985	Escalante
	3.2 MMtpy	1986	Escalante
	4.8 MMtpy	1987	Escalante
Conversion			
Two 3,000 MWe power plants, each consisting of four 750 MWe turbine generators of 34% plant efficiency and equipped with 99% efficient electrostatic precipitators, 80% efficient limestone scrubbers, and wet forced-draft cooling towers	750 MWe	1980	Kaiparowits
	750 MWe	1982	Kaiparowits
	1,500 MWe	1983	Kaiparowits
	750 MWe	1984	Escalante
	750 MWe	1986	Escalante
	1,500 MWe	1987	Escalante
Transportation			
Coal			
Conveyor belt from mines to each power plant (two main conveyors)		1980	Kaiparowits
		1984	Escalante
Electricity			
Two EHV lines for each 3,000 MWe plant	765 kV	1980	Kaiparowits
	765 kV	1984	Escalante

Btu's/lb = British thermal units per pound
MMtpy = million tons per year
MWe = megawatt-electric
EHV = extra-high voltage
kV = kilovolt

[a]U.S., Department of the Interior, Bureau of Land Management. _Draft Environmental Impact Statement: Kaiparowits Project_, 5 vols. Salt Lake City, Utah: Bureau of Land Management, 1975.

higher order impacts. Consequently, facility by facility impact discussions would have been repetitive in nearly every respect.

The Kaiparowits/Escalante area is generally characterized by a low population density, low average income, majority affiliation with the Church of Jesus Christ of Latter-day Saints (Mormon), and a predominant sentiment in favor of developing the area's resources.[1] The physical environment is characterized by limited seasonal precipitation, a topography which changes from benchlands in the South to mountains in the North, and vegetation which changes from desert shrubs in the South to pinyon-juniper woodlands and coniferous forests at higher elevations in the North.

A major influence on the area's economy has been the extensive federal ownership of land, particularly of recreation-oriented lands such as national parks.[2] During the summer there are frequently many more tourists in the area than permanent residents. As a result, the major sectors of economic activity are government, wholesale and retail trade, and services. Ranching is the major agricultural activity. Industrial development has been very limited.[3]

Groundwater and surface water are available in the area, the latter primarily from the Colorado River and Lake Powell. Air quality in the area is excellent, the major present pollutant being blowing dust.

Descriptive characteristics of the area are summarized in Table 4-2. Elaborations of these characteristics will be introduced as they are required to explain the impact analyses reported in this chapter.

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[1]See for example Myhra, David. "Fossil Projects Need Siting Help Too." Public Utilities Fortnightly, Vol. 99 (September 29, 1977), pp. 24-28.

[2]These include Bryce Canyon, Zion, Canyonlands, and Capitol Reef National Parks, Glen Canyon National Recreation Area, and Dixie and Kaibab National Forests.

[3]U.S., Department of Commerce, Bureau of Economic Analysis. "Local Area Personal Income." Survey of Current Business, Vol. 54 (May 1974, Part II), pp. 1-75.

TABLE 4-2: SELECTED CHARACTERISTICS OF THE KAIPAROWITS/ESCALANTE AREA

Environment	
Elevation	4,000-7,000 feet
Precipitation	6-10 inches annually in the south 20 inches annually in the north
Air Stability	Frequently prolonged winter stagnation
Vegetation	Salt desert shrub in the south; pinyon pine-juniper in the north
Social and Economic[a]	
Land Ownership	
Federal	87 %
State	8 %
City and County	≃.01%
Private	5 %
Population Density	0.7 per square mile
Unemployment[b]	
Kane County	7 %
Garfield County	15 %
Income	$2,900 per capita annual

≃ - approximately

[a]1970 data, Garfield and Kane Counties.

[b]1974 data.

4.2 AIR IMPACTS[1]

4.2.1 Existing Conditions

A. Background Pollutants

Air quality in the Kaiparowits/Escalante area is currently affected by the Navajo power plant located near Page, Arizona (Figure 4-1). Measurements of concentrations of criteria

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[1]The federal standards referred to in this section are those promulgated prior to the revisions mandated by the Clean Air Act Amendments of 1977, Pub. L. 95-95, 91 Stat. 685.

pollutants,[1] (shown in Table 4-3) taken prior to 1975 indicated nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) below detection thresholds of the monitoring equipment.[2] However, 24-hour particulate concentrations, ranging from 1 to 543 micrograms per cubic meter ($\mu g/m^3$), violate federal ambient standards during high winds due to blowing dust. Based on measurements taken at Page, Arizona, from 1970 to 1974, the annual average background levels chosen as inputs into the air dispersion model are: particulates, 20; SO_2, 10; NO_2, 4; oxidants (ozone), 60.[4]

B. Meteorological Conditions

The terrain in the Kaiparowits plateau area of southern Utah is topographically complex. Mesas, plateaus, mountains, hills, canyons, and basins complicate air flow and pollutant dispersion. This terrain can contribute to pollution concentrations which approach ambient standards from both elevated and ground-level emission sources.[5] Highest concentrations will occur when a plume

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[1]Criteria pollutants are those for which ambient air quality standards are in force: carbon monoxide (CO), nonmethane hydrocarbons (HC), oxides of nitrogen, oxidants, particulates, and SO_2. Although technically only nonmethane HC are covered by the standards, the more inclusive term "hydrocarbons" is generally used.

[2]Dames and Moore. Air Quality Monitoring and Meteorology, Navajo Generating Station--1974, Status Report, March 15, 1975, as cited in U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976; and Walther, E.G., et al. Air Quality in the Lake Powell Region, Lake Powell Research Project Bulletin No. 3. Los Angeles, Calif.: University of California, Institute of Geophysics and Planetary Physics, 1974.

[3]BLM. FEIS: Kaiparowits.

[4]These estimates are based on the Radian Corporation's best professional judgment. They are used as the best estimate of the concentrations to be expected at any particular time. Measurements of HC and CO are unknown. But high background levels of HC have been measured at other rural locations in the West and may occur here. Background CO levels are assumed to be relatively low.

[5]Elevated sources are tall stacks that emit pollutants several hundred feet above ground. Ground-level sources include towns, strip mines, and tank farms that emit pollutants close to ground level.

TABLE 4-3: AIR QUALITY MEASUREMENTS AT PAGE, ARIZONA (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	YEAR	LEVEL		AMBIENT STANDARDS[a]	
		DAMES & MOORE[b]	ARIZONA[c]	PRIMARY	SECONDARY
Particulate					
Annual	1972	29	31	75	60
	1973	27	52		
	1974	28	46		
24-hour[d]	Ranged from less than 1 to 543 μg/m³. High concentrations primarily due to soil dust.[a]			260	150
SO_2					
Annual	1973	NA	1	80	NA
	1974	NA	8		
24-hour[d]	1970 to 1974	26	NA	365	NA
	1973	NA	11		
	1974	NA	22		
3-hour[d]	1973	39	NA	NA	1,300
	1974	68	NA		
NO_2					
Annual	1973	NA	10	100	100
	1974	NA	24		
Oxidants					
1-hour[d]	1972	84	NA	160	160

μg/m³ = micrograms per cubic meter
NA = not available or applicable
SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide

[a]The Ambient Standards listed are the most stringent of either federal or state. For Utah, no state ambient air quality standards are more stringent than the federal ones. See White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[b]Data from Dames and Moore. Air Quality Monitoring and Meteorology, Navajo Generating Station--1974, Status Report, March 15, 1975, as cited in U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976.

[c]Data from Arizona, Department of Health Services, Bureau of Air Quality Control, as cited in BLM. FEIS: Kaiparowits.

[d]Not to be exceeded more than once a year.

impacts[1] on elevated terrain during stable conditions and when mixing of plumes is limited by air inversions at the plume height. Worst-case dispersion conditions are associated with stable conditions, low mixing depths,[2] persistent wind direction, and low wind speeds (less than 10 miles per hour). The frequency with which these conditions occur varies locally.

Meteorological conditions in the area are generally unfavorable for pollution dispersion (i.e., they are stable) about 43 percent of the time. More favorable, unstable conditions are expected to occur about 20 percent of the time. However, these unstable conditions can contribute to localized, short-term concentrations due to erratic plume movement (plume looping).

4.2.2 Factors Producing Impacts

The primary air emission sources in the Kaiparowits/Escalante scenario are two power plants, supporting underground mines, and the population which is projected to increase. The focus of this section is on emissions of criteria pollutants from the energy facilities.[3] The largest of these sources are the four 750 megawatt boilers at each power plant site.

Table 4-4 displays the emissions of five criteria pollutants from one 3,000 MWe power plant. The data assume that the stack gas scrubbing systems remove 99 percent of the particulates and 80 percent of the SO_2 in the coal and that the power plant is operating at full load. Comparison of emission rates (on a per million British thermal unit [Btu] basis) with New Source Performance Standards[4] (NSPS), also given in Table 4-4, indicates that a power plant with this level of control will more than meet NSPS for particulates and SO_2. To just meet NSPS, no SO_2 removal and 98.6 percent particulate removal would be required. If scrubbers remove none of the oxides of nitrogen (NO_x) generated in the

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[1]Plume impaction occurs when stack plumes impinge on elevated terrain because of limited atmospheric mixing and stable air conditions.

[2]Mixing depth is the distance from the ground to the upper boundary of pollution dispersion.

[3]Air impacts associated with population increases are discussed (Section 4.2.3) as those impacts relate to the scenario which includes all facilities constructed according to the hypothesized schedule.

[4]NSPS limits the amount of a given pollutant a stationary source may emit; the limit is expressed relative to the amount of energy in the fuel burned.

TABLE 4-4: COMPARISON OF EMISSIONS FROM ONE 3,000 MEGAWATT POWER PLANT WITH NEW SOURCE PERFORMANCE STANDARDS

POLLUTANT	POUNDS PER HOUR[a]	POUNDS PER 10^6 Btu's	
		EMISSION	NSPS
Particulates	2,100	0.07	0.1
SO_2	5,800	0.19	1.2
NO_x	15,000-25,000[b]	0.50-0.83[b]	0.7
CO	1,400	NA	NA
HC	420	NA	NA

NSPS = New Source Performance Standards
Btu = British thermal unit
SO_2 = sulfur dioxide
NO_x = nitrogen oxides
CO = carbon monoxide
NA = not available or not applicable
HC = hydrocarbons

[a]These data assume that the power plant is running at full load with 99 percent particulate removal and 80 percent SO_2 removal.

[b]NO_x range assumes 0 percent and 40 percent removal by scrubber.

boiler, then NO_x emissions will violate the NSPS.[1] The minimum NO_x removal to just meet NSPS is 16 percent.[2] In addition to those criteria pollutants emitted from each power plant, the 75,000 barrel storage tank at the plant, with standard floating roof construction, will emit up to 0.7 pounds of hydrocarbons (HC) per hour.

The power plants are cooled by wet forced-draft cooling towers. Each cell circulates water at a rate of 15,300 gallons per minute (gpm) and emits 0.01 percent of its water as a mist. The circulating water has a total dissolved solids (TDS) content of 7,120 parts per million (ppm). This results in a salt emission rate of 45,300 pounds per year for each cell (each power plant has 64 cells).

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[1]The amount of NO_x that scrubbers remove is uncertain; estimates range from none to 40 percent.

[2]The Clean Air Act Amendments of 1977, Pub. L. 95-95, 91 Stat. 685, § 109 require both an emissions limitation and a percentage reduction of SO_2, particulates, and NO_x. Revised standards have not yet been established by the Environmental Protection Agency.

Emissions from the underground coal mines are expected to be negligible. However, emissions will originate from coal piles, breaking and sizing operations, and transportation at the mines, even though dust suppression (water spray) will be used.[1]

4.2.3 Impacts

This section describes air quality impacts which result from each power plant taken separately[2] and from a scenario which includes the predicted impacts of both plants. For each power plant the effect on air quality of alternative stack heights, alternative emission control, and alternative plant sizes and locations is described. Interactions between facilities and impacts caused by the expected population increase are included in the scenario impact discussion. The focus is on concentrations of criteria pollutants (particulates, SO_2, NO_2, HC, and carbon monoxide [CO]). See Chapter 10 for a qualitative description of sulfates, other oxidants, fine particles, long-range visibility, plume opacity, and cooling tower fogging and icing.

A. Power Plant Impacts

Although construction processes may increase windblown dust, no other air quality impacts are associated with the construction of a power plant. Since periodic violations of 24-hour ambient particulate standards already occur due to blowing dust, the frequency of those violations can be expected to increase during power plant construction.

The majority of air quality impacts result from the operation of a power plant and depend on the degree of emission control imposed. Concentrations resulting from a base case, where control equipment is hypothesized to remove 80 percent of the SO_2 and 99 percent of all particulates, are discussed first, followed by a discussion of the effect on ambient air concentrations of alternative emission controls, alternative stack heights, alternative plant sizes, and alternative plant locations.

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[1]The effectiveness of current dust suppression techniques is uncertain. Separate research being conducted by the Environmental Protection Agency is investigating this question; a discussion of fugitive dust problems is given in Chapter 10.

[2]Air quality impacts caused by the underground mines are expected to be negligible in comparison with impacts caused by the power plants. However, the impact of fugitive dust originating from mines is uncertain and is discussed qualitatively in Chapter 10.

(1) Hypothesized Emission Control

Tables 4-5 and 4-6 summarize the concentrations of four pollutants predicted to be produced by the hypothesized plants at Kaiparowits and Escalante (both 3000 MWe, 80 percent SO_2 removal, and 99 percent particulate removal). Federal primary and secondary ambient air quality standards which regulate these pollutants directly[1] and Prevention of Significant Deterioration (PSD) increments which regulate the pollutants indirectly[2] are also included in the tables.

As the tables indicate, both typical and peak concentrations associated with either power plant are below ambient standards. Ambient standards are not exceeded in the immediate vicinity of the power plants or in the nearby towns of Glen Canyon City and Escalante. The Kaiparowits power plant meets all allowable Class II increments, but the Escalante plant exceeds Class II increments for 24-hour particulates, 24-hour SO_2, and 3-hour SO_2. Both plants violate all Class I increments except for annual particulates.

Since these plants exceed Class I increments, they must be located far enough away from Class I areas to allow emissions to be diluted by atmospheric mixing to the low concentrations allowed by Class I increments. The distance required for this dilution varies by facility type, size, emission controls, and meteorological conditions. In effect, this requirement establishes a "buffer zone" around Class I areas.[3]

Due to the complex terrain in the Kaiparowits/Escalante area, no one buffer zone size for potential Class I PSD areas can be

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[1]Primary standards are designed to protect public health; secondary standards are designed to protect public welfare.

[2]PSD increments are allowable increments of pollutants which can be added to areas of relatively clean air; that is, to areas with air quality better than that allowed by ambient air standards. They apply only to particulates and SO_2. There are three classes of increments. Class I increments are intended to protect the cleanest areas such as national parks and are the most restrictive. A Class II designation is for areas which have moderate, well controlled energy or industrial development and permits less deterioration than that allowed by federal secondary ambient standards. The Environmental Protection Agency initially designated all PSD areas Class II and established a petition and public hearing process for redesignating areas Class I or Class III.

[3]Note that the term buffer zone is in disfavor. We use it because we believe it accurately describes the effect of PSD requirements.

TABLE 4-5: POLLUTION CONCENTRATIONS FROM POWER PLANT AT KAIPAROWITS (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]				STANDARDS[b]			
			PEAK		AMBIENT		PSD	
	BACKGROUND	TYPICAL	PLANT	KAIPAROWITS	PRIMARY	SECONDARY	CLASS I	CLASS II
Particulate								
Annual	20		1.6	0.1	75	60	5	19
24-hour		2.3	18	4.4	260	150	10	37
SO_2								
Annual	10		4.4	0.1	80		2	20
24-hour		6.4	51	8	365		5	91
3-hour		19	229	12		1,300	25	512
NO_2[c]								
Annual	4		11-18[e]	0.1-0.2[e]	100	100		
HC[d]								
3-hour	unknown	1.4	46	1.1	160	160		

PSD = prevention of significant deterioration
SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide
HC = hydrocarbons

[a]These are predicted ground-level concentrations from the hypothetical power plant. Annual average background levels are considered to be the best estimates of short-term background levels. Most of the peak concentrations from the plant and mine combination are attributable to the mine, with the exception of annual SO_2 levels. Concentrations over Kaiparowits are largely attributable to the plant.

[b]The ambient standards listed are the most stringent of either federal or state. For Utah, no state ambient air quality standards are more stringent than the federal ones. "Primary" and "secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. PSD standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests.

[c]It is assumed that all oxides of nitrogen (NO_x) from plant sources are converted to NO_2.

[d]The 3-hour HC standard is measured at 6-9 a.m.

[e]This range represents two assumptions about the removal of NO_x by scrubbers. The first number assumes 40 percent is removed; the second number assumes none is removed.

TABLE 4-6: POLLUTION CONCENTRATIONS FROM POWER PLANT AT ESCALANTE (micrograms per cubic meter)

	CONCENTRATIONS[a]				STANDARDS[b]			
			PEAK		AMBIENT		PSD	
AVERAGING TIME	BACKGROUND	TYPICAL	PLANT	ESCALANTE	PRIMARY	SECONDARY	CLASS I	CLASS II
Particulate								
Annual	20		4	0.1	75	60	5	19
24-hour		2.3	105	16.8	260	150	10	37
SO_2								
Annual	10		11.2	0.4	80		2	20
24-hour		6.4	293	48	365		5	91
3-hour		19	1,060	95		1,300	25	512
NO_2[c]								
Annual	4		29.2-48.7[e]	0.9-1.5[e]	100	100		
HC[d]								
3-hour	unknown	1.4	58	0.7	160	160		

PSD = prevention of significant deterioration
SO_2 = sulfur dioxide
HC = hydrocarbons
NO_2 = nitrogen dioxide

[a]These are predicted ground-level concentrations from the hypothetical power plant. Annual average background levels are considered to be the best estimates of short-term background levels. Most of the peak concentrations from the plant and mine combination are attributable to the mine, with the exception of annual SO_2 levels. Concentrations over Kaiparowits are largely attributable to the plant.

[b]The ambient standards listed are the most stringent of either federal or state. For Utah, no state ambient air quality standards are more stringent than the federal ones. "Primary" and "secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. PSD standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests.

[c]It is assumed that all oxides of nitrogen (NO_x) from plant sources are converted to NO_2.

[d]The 3-hour HC standard is measured at 6-9 a.m.

[e]This range represents two assumptions about the removal of NO_x by scrubbers. The first number assumed 40 percent is removed; the second number assumes none is removed.

defined. However, the 3-hour SO_2 increment for Class I areas may be exceeded in Bryce Canyon National Park, located about 25 miles to the west[1] (Figure 4-3). Other nearby areas which have recently been designated Class I include Zion, Capitol Reef, Grand Canyon, and Canyonlands National Parks.

(2) Alternative Emission Controls

The base case control for the Kaiparowits/Escalante power plants assumed an SO_2 scrubber efficiency of 80 percent and an electrostatic precipitator (ESP) efficiency of 99 percent. The effect on ambient air concentrations of three additional emission control alternatives is illustrated in Table 4-7. These alternatives include a 95 percent efficient SO_2 scrubber in conjunction with a 99 percent efficient ESP, an 80 percent efficient SO_2 scrubber without an ESP, and alternatives in which neither a scrubber nor an ESP is utilized.

An examination of Table 4-7 reveals that removal of particulate control results in significant violations of National Ambient Air Quality Standards (NAAQS) for 24-hour and annual total suspended particulates (TSP) at both plants. Removal of the SO_2 scrubber at Escalante results in violations of all Class II PSD increments for SO_2 emissions and NAAQS for 3-hour and 24-hour SO_2 emissions. Removal of the SO_2 scrubber at Kaiparowits also results in violations of all Class II PSD SO_2 emission increments and the NAAQS 24-hour SO_2 emission standard. The Escalante power plant can meet Class II PSD increments with 95 percent SO_2 removal, but not with 80 percent SO_2 removal.

(3) Alternative Stack Heights

In order to examine the effects of alternative stack heights on air quality in the Kaiparowits/Escalante scenario, worst-case dispersion modeling was carried out for a 300-foot stack (lowest stack height consistent with good engineering practice), a 500-foot stack (an average or most frequently used height), and a 1,000-foot stack (a highest stack height). The results of this analysis are shown in Table 4-8. Emissions on each power plant are controlled by an 80 percent efficient SO_2 scrubber and a 99 percent efficient ESP; the 500-foot case was given previously as part of the base case.

A comparison of data in Table 4-8 with NAAQS indicates that the Kaiparowits power plant could operate well within the NAAQS SO_2 and TSP standards with a 300-foot stack. The Escalante power plant would violate the 3-hour SO_2 NAAQS with a 300-foot stack.

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[1]This estimate is based on the Radian Corporation's best professional judgment.

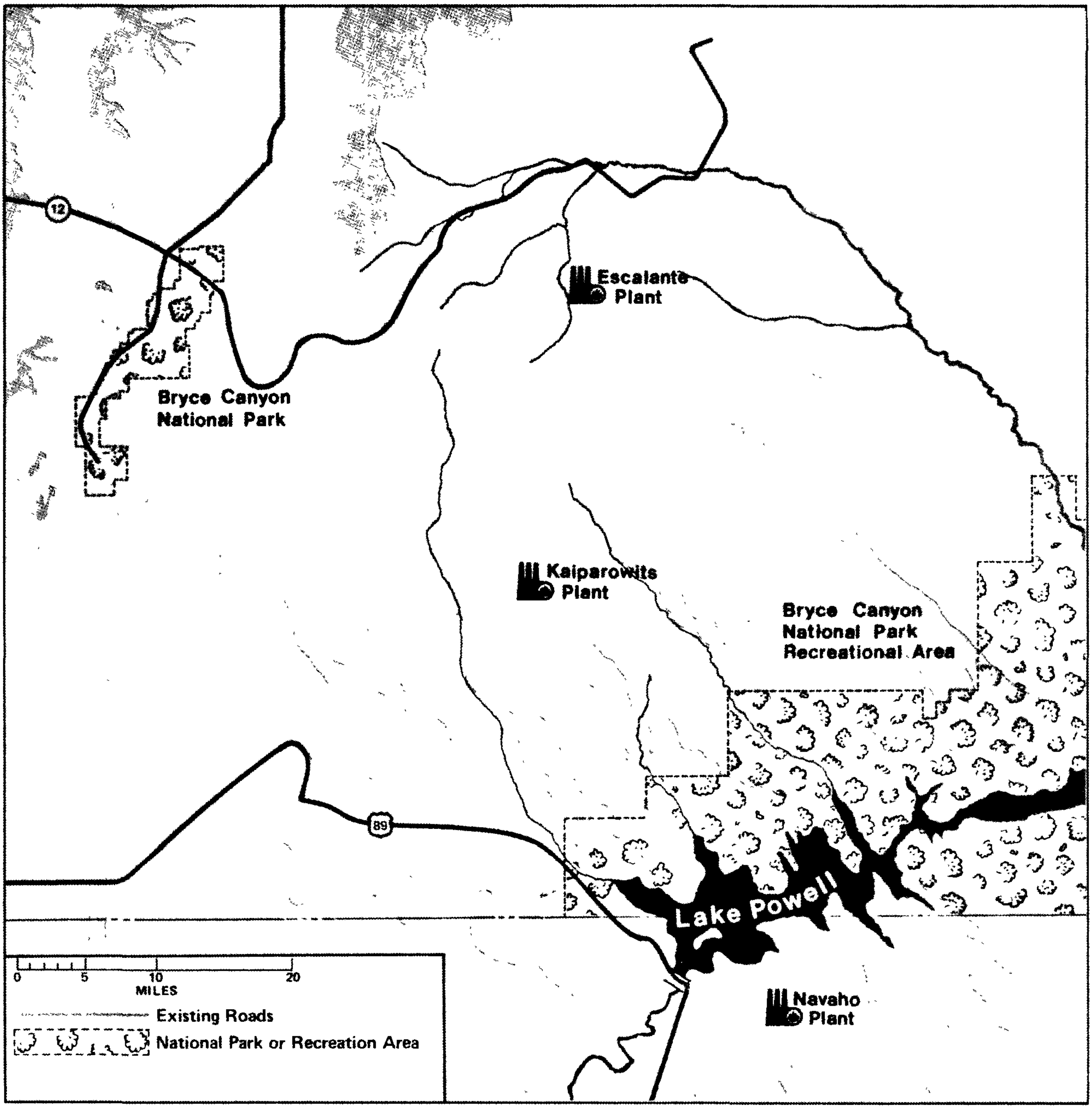

FIGURE 4-3: AIR IMPACTS OF ENERGY FACILITIES IN THE KAIPAROWITS/ESCALANTE SCENARIO

TABLE 4-7: AIR QUALITY IMPACTS RESULTING FROM ALTERNATIVE EMISSION CONTROLS AT KAIPAROWITS/ESCALANTE POWER PLANTS

SITE	AMOUNT OF CONTROL %		MAXIMUM POLLUTANT CONCENTRATION ($\mu g/m^3$)				
	SO_2	TSP	3-HR. SO_2	24-HR. SO_2	ANNUAL SO_2	24-HR. TSP	ANNUAL TSP
Escalante Power Plant	95	99	265	73	NC	105	4.0
	80	99	1060	293	11.2	105	4.0
	80	0	1060	293	11.2	10500[a]	400.0
	0	0	8497	1050	55.9	10470[a]	400.0
Kaiparowits Power Plant	95	99	57	13	NC	18	1.6
	80	99	229	51	4.4	18	1.6
	80	0	229	51	4.4	1800[a]	160.0
	0	0	814	377	22.0	1795[a]	160.0
APPLICABLE STANDARDS							
NAAQS							
(primary)			--	365	80	260	74
(secondary)			1300	--	--	150	60
Class II PSD Increments			512	91	20	37	19

$\mu g/m^3$ = micrograms per cubic meter
SO_2 = sulfur dioxide
TSP = total suspended particulates
HR. = hour
NC = not considered
NAAQS = National Ambient Air Quality Standard
PSD = prevention of significant deterioration

[a]Differences in 24-HR. TSP concentrations for the two cases in which no electrostatic precipitator is used are attributable to the fact that the stack temperature rises when the SO_2 scrubber is turned off, which produces a small increase in the effectiveness of the smoke stack, and a slightly lower TSP concentration.

TABLE 4-8: AIR QUALITY IMPACTS RESULTING FROM ALTERNATE STACK HEIGHTS AT KAIPAROWITS/ESCALANTE POWER PLANTS

SITE	SELECTED STACK HEIGHTS (feet)	MAXIMUM POLLUTANT CONCENTRATIONS ($\mu g/m^3$)		
		3-HR. SO_2	24-HR. SO_2	24-HR. TSP
Escalante Power Plant	300	2043	357	128.0
	500	1060	293	105.0
	1000	203	16	6.0
Kaiparowits Power Plant	300	280	65	23.4
	500	229	51	18.0
	1000	104	16	5.9
APPLICABLE STANDARDS				
NAAQS				
(primary)		--	365	260.0
(secondary)		1300	--	150.0
Class II PSD Increments		512	91	37.0

$\mu g/m^3$ = micrograms per cubic meter
HR. = hour
SO_2 = sulfur dioxide
TSP = total suspended particulates
NAAQS = National Ambient Air Quality Standards
PSD = prevention of significant deterioration

For the more stringent Class II PSD standards, the Escalante plant would violate all standards with both a 300- and a 500-foot stack, but would meet Class II increments with a 1,000-foot stack. The Kaiparowits power plant would meet all Class II PSD increments with a 300-foot stack.

(4) Alternative Plant Sizes

Because the base-case Escalante power plant in this scenario is expected to violate PSD Class II increments, even with 80 percent SO_2 removal and 99 percent particulate removal, the effect of alternative plant sizes was also analyzed; the results are given in Table 4-9. The Escalante plant would be able to meet all PSD Class II increments only if generation capacity were reduced from 3000 MWe to 750 MWe. At 1500 MWe, the plant violates 24-hour SO_2 and 24-hour TSP Class II PSD increments.

(5) Alternative Plant Locations

The complex terrain at the proposed Escalante site aggravates violations of Class II PSD increments during periods of plume impaction on that terrain. Thus, the effect of relocating the plant to a site where the terrain at and around the plant is flat was examined. A site along the ridge of the Kaiparowits Plateau to the southwest of the original Escalante site was used for flat terrain modeling. Table 4-10 shows that relocation of the power plant to flat terrain would result in compliance with all Class II PSD increments (assuming a 500-foot stack height, 80 percent SO_2 removal, and 99 percent removal of particulates).

(6) Summary of Power Plant Air Impacts

The frequency of current violations of the NAAQS particulate standards at the Kaiparowits/Escalante site will probably increase during the construction phase of the power plants (due to blowing dust). Once the plants are in operation, the 3000 MWe plant at Kaiparowits (80 percent SO_2 removal, 99 percent TSP removal, 500-foot stack height) would meet Class II PSD increments, the most stringent of applicable standards. The Escalante plant under the same stack height and emission control assumptions, would violate several Class II PSD increments. For that plant, all Class II PSD increments could be met by: increasing stack height to 1,000 feet; relocating the plant to flat terrain; or reducing plant capacity from 3,000 MWe to 750 MWe.

B. Scenario Impacts

This section discusses air quality impacts that may occur because of interactions between the two power plants and those that result as the population increases according to the manpower demands of the construction and operation schedule.

TABLE 4-9: AIR QUALITY IMPACTS RESULTING FROM ALTERNATIVE PLANT SIZES AT ESCALANTE POWER PLANT

UNIT SIZE (MWe)	NO. OF UNITS	PLANT CAPACITY (MWe)	MAXIMUM POLLUTANT CONCENTRATION ($\mu g/m^3$)		
			3-HR. SO_2	24-HR. SO_2	24-HR. TSP
750	1	750	266	73	26.2
	2	1500	532	147	52.5
	3	2250	798	220	78.8
	4	3000	1060	293	105.0
APPLICABLE STANDARDS					
NAAQS					
(primary)			--	365	260
(secondary)			1300	--	150
Class II PSD increments			512	91	37

$\mu g/m^3$ = micrograms per cubic meter
MWe = megawatt-electric
HR. = hour
SO_2 = sulfur dioxide
TSP = total suspended particulates
NAAQS = National Ambient Air Quality Standards
PSD = prevention of significant deterioration

TABLE 4-10: AIR QUALITY IMPACTS RESULTING FROM RELOCATING THE ESCALANTE POWER PLANT FROM A COMPLEX TO A FLAT TERRAIN[a]

TERRAIN CASE	MAXIMUM POLLUTANT CONCENTRATION ($\mu g/m^3$)		
	3-HR. SO_2	24-HR SO_2	24-HR. TSP
Complex	1060	293	105
Flat	242	37.7	13.5

$\mu g/m^3$ = micrograms per cubic meter
HR. = hour
SO_2 = sulfur dioxide
TSP = total suspended particulates

[a]Stack height is assumed to be 500 feet, 80 percent SO_2 removal, 99 percent TSP removal, 3000 megawatt-electric.

(1) To 1980

Neither hypothetical power plant is scheduled, in this hypothesized scenario, to be in operation in this time period. The scenario calls for construction of the Kaiparowits plant beginning in 1975 and of the Escalante plant in 1979. Few air quality impacts are caused by the construction itself; however, population increases will be substantial and concentrated in towns, including the Kaiparowits new town to be built north of Glen Canyon City, Utah. By 1980, this town is projected to have a population of approximately 3,350.[1] Increased emissions from a town this size are expected to result in concentrations of particulates, HC, CO, SO_2, and NO_2 only slightly higher than current background levels. Automobiles are a primary source.

(2) To 2000

The Kaiparowits power plant becomes operational in 1983 and the Escalante plant in 1987 (22 miles apart). No additional facilities are hypothesized for this scenario through the year 2000. Interaction of pollutants between these two plants may occur if the wind blows directly from one plant to the other. Effective concentrations were investigated for a worst-case situation where one plant was located 5 miles downwind from the other under flat terrain conditions. Maximum pollutant concentrations at 5 miles separation distance violate neither NAAQS nor Class II PSD increments.[2] Thus, short-term concentrations of criteria pollutants resulting from the interaction of plumes between the two plants would be less than that caused from one plant by plume impaction on high terrain.

When both plants are operating, visibility is expected to decrease from the current average of 70 miles at Navajo Point to 63 miles. In a worst-case situation, expected to occur infrequently, short-term visibilities could be reduced to between 4 and 9 miles, depending on the amount of SO_2 converted to particulates in the atmosphere.[3]

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[1] See Section 4.4 for population projections.

[2] Calculated maximum pollutant concentrations from the interaction of Kaiparowits and Escalante power plants at a separation distance of 5 miles include: 3-hr. SO_2, 392; 24-hr. SO_2, 64; and 24-hr. TSP, 22.8. Maximum concentrations of SO_2 and TSP were calculated using existing modeling runs for flat terrain conditions.

[3] Short-term visibility impacts were investigated using a "box-type" dispersion model. This particular model assumes that all emissions occurring during a specified time interval are uniformly mixed and confined in a box that is capped by a lid or stable layer aloft. A lid of 500 meters was used. The effect of SO_2 to sulfate conversion rates of 10 percent and 1 percent were modeled.

The Kaiparowits new town is expected to increase in population from 3,350 (1980) to 6,940 by 1990 and 7,290 by 2000. This will contribute to increases in pollution concentrations due solely to urban sources. Table 4-11 displays predicted 1990 concentrations of five criteria pollutants measured in the center of the town and at a point three miles from the center of town.[1] When concentrations from urban sources are added to background levels and to concentrations from the power plant (Tables 4-5 and 4-6), the HC levels exceed ambient standards.[2] No other standard is approached by these concentrations.

Current PSD increments are designed to restrict pollution from large point sources (e.g., power plants), not from urban sources (e.g., automobiles). If the same PSD criteria were applied to urban sources that are currently applied to industrial sources, population increases in the Kaiparowits new town would violate PSD increments for particulates (Table 4-11).

Concentrations of HC over Kaiparowits, which may be three times higher than the federal standard by the year 2000, are also likely to create an oxidant problem. Since oxidants may take as much as an hour to form, this problem will be less when wind conditions move pollutants rapidly away from the town.

C. Other Air Impacts

Nine additional categories of potential air impacts have been examined; that is, an attempt has been made to identify sources of pollutants and how energy development may affect levels of these pollutants during the next 25 years. These include sulfates, oxidants, fine particulates, long-range visibility, plume opacity, cooling tower salt deposition, cooling tower fogging and icing, trace element emissions, and fugitive dust emissions.[3] Although there are likely to be local impacts as a consequence of these pollutants, both the available data and knowledge about impact mechanisms are insufficient to allow quantitative site-specific analyses. Thus, these are discussed in a more general, qualitative manner in Chapter 10.

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[1] Concentrations in the year 2000 will be about 5 percent higher than for 1990.

[2] Ambient HC standards are violated regularly in most urban areas.

[3] No analytical information is currently available on the source and formation of nitrates. See Hazardous Materials Advisory Committee. Nitrogenous Compounds in the Environment, U.S., Environmental Protection Agency Report No. EPA-SAB-73-001. Washington, D.C.: Government Printing Office, 1973.

TABLE 4-11: POLLUTION CONCENTRATIONS DUE TO URBAN SOURCES AT KAIPAROWITS NEW TOWN IN 1990 (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]			STANDARDS[b]	
	BACKGROUND	MIDTOWN POINT[c]	RURAL POINT	PRIMARY	SECONDARY
Particulates					
Annual	20	16	4	75	60
24-hour	20	54	54	260	150
SO_2					
Annual	10	8	2	80	
24-hour	10	27	27	365	
3-hour	10	48	48		1,300
NO_2[d]					
Annual	4	26	6	100	300
HC					
3-hour	unknown	481	481	160	160
CO					
8-hour	unknown	1,606	1,606	10,000	10,000
1-hour		2,632	2,632	40,000	40,000

SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide
HC = hydrocarbons
CO = carbon monoxide

[a]These concentrations are predicted ground-level concentrations from urban sources. Background concentrations are taken from Table 4-4. "Rural points" are measurements taken 3 miles from the center of town.

[b]"Primary" and "secondary" are federal ambient air quality standards designed to protect the public health and welfare, respectively. In no case are Utah ambient air quality standards more stringent than federal ones. See White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[c]The 1980 concentrations are predicted to be only slightly higher than background. Concentrations in 2000 will be about 5 percent higher than 1990.

[d]It is assumed that 50 percent of oxides of nitrogen from urban sources are converted to NO_2.

4.2.4 Summary of Air Impacts

Two new 3000 MWe power plants are hypothesized in the Kaiparowits/Excalante region. Particulate standards are already periodically violated in the region due to blowing dust; mining and power plant construction activities would aggravate that problem.

In order to just meet NSPS for particulates and SO_2 each power plant would require 98.6 percent particulate removal but no SO_2 removal. However at that level of control, the Escalante plant would violate one primary and two secondary federal ambient standards, and both plants would exceed several Class II PSD increments. If no NO_x is removed by the scrubber systems, the NSPS for NO_x will be violated; at least 16 percent of the NO_x produced in the boiler must be removed if emissions are to meet NSPS. Ambient air standards for NO_x can be met by both plants if no NO_x is removed.

With the hypothesized emission control (80 percent SO_2, 99 percent particulate) and a 500-foot stack, neither plant would violate any federal ambient air standards; the Kaiparowits plant would not exceed any Class II increments; but the Escalante plant would exceed several short-term Class II increments. The Escalante plant causes violations primarily because it is hypothetically located in complex terrain where plume impaction occurs.

The Kaiparowits plant can meet Class II increments if the stack height were only 300 feet. The Escalante plant can meet Class II increments for SO_2 by increasing SO_2 scrubber efficiency to 95 percent. It can meet Class II increments for both SO_2 and particulates by increasing the stack height to 1000 feet, relocating the plant to flat terrain, or by decreasing plant capacity from 3000 MWe to 750 MWe.

Class I PSD increments would be violated by both plants, and a Class I buffer zone size cannot be established due to the complex terrain in the area. The closest Class I area where violations might occur is Bryce Canyon National Park (25 miles).

If both plants are built, visibility will be reduced at Navajo Point from 70 miles to 63 miles (on the average). In a worst-case situation, occurring infrequently, short-term visibilities could be reduced to between 4 and 9 miles. Even if the plants are spaced closer than the distance hypothesized (22 miles) plume interactions would not violate NAAQS or Class II increments (assuming both are located on flat terrain). Population increases in the Kaiparowits new town will add to pollution problems. Concentrations from urban sources are expected to violate the NAAQS for HC by 1990. If PSD increments were applied to urban sources, the Class II particulate increment would be violated.

4.3 WATER IMPACTS

4.3.1 Introduction

Surface water from Lake Powell will be the major water source for energy development in the Kaiparowits/Escalante region (see Figure 4-4). Precipitation in the Kaiparowits/Escalante area ranges from 6 to 10 inches per year in the southern areas to 20 inches in the Escalante mountains to the north. Annual snow fall ranges from 12 to 24 inches.[1]

This section identifies the sources and uses of water required for each power plant, the residuals that will be produced, and the water availability and quality impacts that are likely to result.

4.3.2 Existing Conditions[2]

A. Groundwater

Three aquifer systems are present in the Lake Powell area: small alluvial aquifers in deposits along rivers and streams; perched aquifers[3] in the coal-bearing Straight Cliffs geologic formation; and a regional aquifer in the deep Navajo Sandstone.

Alluvial aquifers are located in sand and gravel strata below valley stream beds. The water table in these shallow aquifers is generally less than 100 feet below the surface. The aquifers generally discharge into streams and are recharged by the streams and by underflow from perched aquifers. While the groundwater quality is generally good (depending on stream quality), the quantity of water available from alluvial aquifers is quite small.

The perched aquifers in the Straight Cliffs Formation, the formation in which the minable coal is located, are in sandstone bodies that are generally small and erratically distributed in shale. Water yields vary from less than 1 to about 50 gpm.

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[1]The moisture content of 1 inch of rain is equal to approximately 15 inches of snow.

[2]Available data for describing the natural ground and surface water conditions in the area are sketchy. The primary data source is the environmental impact statement prepared for the proposed Kaiparowits coal-fired power plant. U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976.

[3]Perched aquifers are small, usually localized aquifers that are above the true water table.

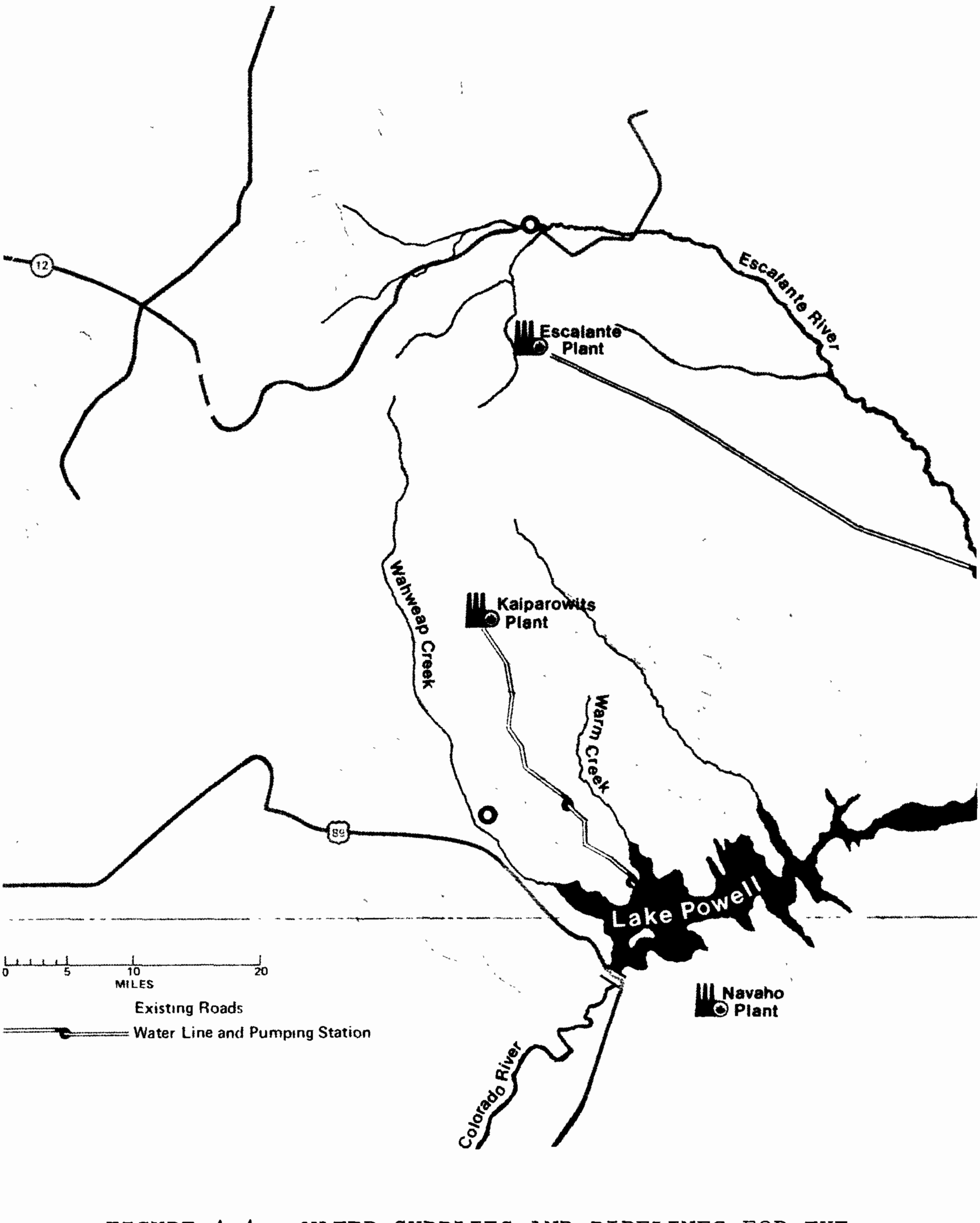

FIGURE 4-4: WATER SUPPLIES AND PIPELINES FOR THE KAIPAROWITS/ESCALANTE SCENARIO

These shallow aquifers are recharged by direct infiltration of precipitation, and discharge is from seeps and springs. The water in these aquifers, which is relatively poor quality (TDS range around 1,000 milligrams per liter, [mg/ℓ]), is used by livestock and wildlife.

The most important regional aquifer is located in the Navajo sandstone at a depth of 1,000 to 2,000 feet in the vicinity of the hypothetical power plants. This aquifer is not presently being used in the Kaiparowits area. At lower elevations along Wahweap Creek where the aquifer is quite shallow, wells yield from several hundred to more than 1,000 gpm. Recharge of this regional aquifer is in the area of sandstone outcrops, and most of the discharge is probably into Lake Powell. The quality of the groundwater in the aquifer varies from fresh to slightly saline (up to 3,000 mg/ℓ).

Although groundwater is used exclusively by some of the area's inhabitants, it is high in hardness and exceeds several of the recommended limits set for drinking water as shown in Table 4-12.

B. Surface Water

The only major perennial river in the Kaiparowits area is the Colorado River. Glen Canyon Dam, which forms Lake Powell, is located 16 miles up the Colorado River from Lee Ferry,[1] the official division between the Upper and Lower Colorado River Basin, and 5 to 10 miles downstream from the scenario site. At the normal water surface elevation, Lake Powell extends 186 miles up the Colorado River and 71 miles up the San Juan River.

The lake operates under the criteria established by the Secretary of the Interior to control flows in the Colorado River at Lees Ferry to meet conditions of the Colorado River Compact.[2] For hydroelectric power generation, a minimum pool elevation must be maintained. Normal releases are approximately 10 percent of the cumulative 10-year flow required by the Colorado River Compact (75 million acre-feet) plus an allocation of Upper Basin flow assumed to be required by treaty with Mexico.[3] This totals a

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[1]Lee Ferry, the designated division point on the river is located near the town of Lees Ferry, Arizona.

[2]Colorado River Compact of 1922, 42 Stat. 171, and 45 Stat. 1064, declared effective by Presidential Proclamation, 46 Stat. 3000 (1928).

[3]Treaty between the United States of America and Mexico Respecting Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, February 3, 1944, 59 Stat. 1219 (1945), Treaty Series No. 994.

TABLE 4-12: GROUNDWATER QUALITY DATA FOR KAIPAROWITS SCENARIO

SUBSTANCE	DRINKING WATER RECOMMENDED LIMITS[a] (mg/ℓ)	NAVAJO SANDSTONE AQUIFER		STRAIGHT CLIFFS FORMATION	
		SAMPLE WELL #19 (mg/ℓ)	SAMPLE[b] WELL #20 (mg/ℓ)	DRILL[c] HOLE #2 (mg/ℓ)	DRILL[c] HOLE #10 (mg/ℓ)
Arsenic	0.05			0.002	0.003
Barium	1.0			0.05	0.05
Cadmium	0.01			0.01	0.05
Chloride	250.0[d]	140.0	16.0		
Chromium	0.05[e]			0.02[f]	0.42[f]
Copper	1.0[d]			0.03	0.42
Cyanide	No Standard			0.005	0.005
Fluoride	1.4-2.4[g]	0.4			
Iron	0.3[d]	0.03	1.40		
Lead	0.05			0.13	0.58
Mercury	0.002			0.001	0.001
Nitrate	10.0[h]	0.53[i]	0.3[j]		
Selenium	0.01			0.001	0.005
Silver	0.05				
Sulfate	250.0[d]				
Zinc	5.0[d]			0.5	4.98
Dissolved Solids	500.0[d]	1,060.0	292.0		

mg/ℓ = milligrams per liter

[a]U.S., Environmental Protection Agency. "National Interim Primary Drinking Water Regulations." 40 Fed. Reg. 59566-88 (December 24, 1975). These regulations also include standards for turbidity, organic chemicals, and microbiological contaminants.

[b]U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976, p. II-147.

[c]Ibid., p. II-149.

[d]U.S., Environmental Protection Agency. "National Secondary Drinking Water Regulations." Proposed Regulations. 42 Fed. Reg. 17143-47 (March 31, 1977).

[e]As chromate (Cr^{+6}).

[f]Total chromium.

[g]Fluride standard varies according to the annual average of the maximum daily air temperature for the location in which the community water system is situated. The lowest level is for temperatures above 26.3° Centigrade (C), and the highest level is for temperatures below 12°C.

[h]Measured as nitrogen.

[i]Nitrate (NO_3^-) + nitrite (NO_2^-) as nitrogen.

[j]Nitrate (NO_3^-).

release of approximately 8.25 million acre-feet per year (acre-ft/yr). Basic storage and water quality data for Lake Powell are presented in Table 4-13. Water quality data can be compared to typical industrial boiler feed water quality requirements which are also shown.

The estimated 1975 surface water supply and uses in Utah's portion of the Colorado River are shown on Table 4-14. Irrigation is the largest water use. If both power plants are built, as called for in this hypothetical scenario, power generation water usage will be increased by a factor of 10 but will still be less than 20 percent of the volume used for agriculture.

The local surface water system directly affected by the Kaiparowits/Escalante energy development also includes several ephemeral and intermittent streams. Flow in these streams is generally the result of cloudbursts that occur frequently in late summer. The mean annual runoff for these streams is as follows:[1]

Stream	Acre-ft/yr[2]
Warm Creek	1,000
Wahweap Creek	2,000
Last Chance Creek	2,800
Escalante River	12,900

Peak flood flows in these creeks can be considerable. For example, where Coyote and Wahweap Creeks come together, flows have a 50 percent probability of attaining 2,000 cubic feet per second (cfs) once every two years.

Water quality in these ephemeral and intermittent streams has been sampled. Although the antecedent conditions were not reported, values for estimated flow and TDS during May 1974 were:[3]

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[1]U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976, Chapter 2, p. 2-156.

[2]One thousand acre-ft/yr corresponds to 1.38 cubic feet per second.

[3]BLM. FEIS: Kaiparowits, p. 2-157.

TABLE 4-13: STORAGE AND WATER QUALITY DATA FOR LAKE POWELL

PARAMETER	VALUE		
Minimum power pool elevation	3,490 feet above mean sea level		
Maximum water level	3,711 feet above mean sea level		
Dead storage	1,998,000 acre-feet		
Active storage below minimum power pool elevation	4,126,000 acre-feet		
Active storage above minimum power pool elevation	20,876,000 acre-feet		
	WATER QUALITY[a] (mg/ℓ)		TYPICAL BOILER FEED WATER[b] (mg/ℓ)
POLLUTANT	MINIMUM	MAXIMUM	
Dissolved solids	475.0	677.0	< 10.10
Calcium	58.4	85.0	0.10
Magnesium	21.7	29.8	0.03
Sodium	60.3	93.8	0.24
Potassium	3.5	5.1	< 0.01
Carbonate	0.0	23.1	
Bicarbonate	107.0	182.0	< 0.01
Chloride	38.0	70.3	< 10.00
Sulfate	197.0	281.0	0.14
Dissolved Oxygen	4.0	10.1	

mg/ℓ = milligrams per liter < = less than

[a]Water Quality Data from USGS Sampling Station No. 1, Colorado River Channel above Mouth of Wahweap Creek, unpublished, 1974, 1975.

[b]American Water Works Association, Inc. Water Quality and Treatment, 3rd ed. New York, N.Y.: McGraw-Hill, 1971, p. 510, Table 16-1. Some numbers derived from Table 16-1, assuming concentrating factor = 100, high pressure drum type boiler.

TABLE 4-14: ESTIMATED 1975 SURFACE-WATER RESOURCES AND USES FOR UTAH IN THE UPPER COLORADO RIVER BASIN
(1,000 acre-feet)

Average Annual Water Supply	
Utah's estimated share of Upper Colorado River flow[a]	1,322
Estimated 1975 Uses[b]	
Irrigation	521
Municipal and Industrial Including Rural	7
Minerals	9
Thermal Electric	8
Recreation and F&WL	8
Other	118
Reservoir Evaporation	194
Estimated Exports	112
Total Depletions	977
Net Available for Use	346

F&WL = Fish and Wildlife

[a]Assumes 5.8 million acre-feet per year available for use in the Upper Colorado River Basin, of which Utah is entitled to 23 percent.

[b]U.S., Department of the Interior, Bureau of Reclamation. Westwide Study Report on Critical Water Problems Facing the Eleven Western States. Washington, D.C.: Government Printing Office, 1975, pp. 374-75.

Stream	Flow (cfs)	Total Dissolved Solids (mg/ℓ)
Wahweap Creek	1.0	2,140
Warm Creek	very low	4,710
Last Chance Creek	very low	3,520
Escalante River	2.6	1,150[1]

Under the Upper Colorado River Basin Compact,[2] Utah is entitled to 23 percent of the water allocated to the Upper Basin after 50,000 acre-ft/yr is deducted for Arizona. Primarily because of variations in calculated values for total flow and the portion of the Mexican Treaty which may be allocated to the Upper Basin, Utah's share of the Upper Basin water is uncertain. The Department of the Interior's Water for Energy Management Team estimates that the Upper Basin states have about 5.8 million acre-ft/yr to divide among themselves. This would entitle Utah to 1,322,500 acre-ft/yr.

4.3.3 Factors Producing Impacts

The water requirements of and effluents from the energy facilities will cause water impacts. These requirements and effluents are identified in this section for each type of energy facility. Associated population increases also increase municipal water demand and sewage effluent; however, these are presented in Section 4.3.4 only for the scenario which includes both power plants and associated coal mines constructed according to the scenario schedule.

A. Water Requirements of Energy Facilities

The water requirements for energy facilities hypothesized in the Kaiparowits/Escalante region are shown in Table 4-15. Two sets of data are presented. The Energy Resource Development System (ERDS) Report data are based on secondary sources, including impact statements, Federal Power Commission (FPC) docket filings,

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[1]From U.S. Geological Survey Water Resource Data, transformed from specific conductance measurement to TDS using Hem, John D. <u>Study and Interpretation of the Chemical Characteristics of Natural Water</u>, 2nd ed., U.S. Geological Survey Water-Supply Paper 1473. Washington, D.C.: Government Printing Office, 1970, Figure 10.

[2]Upper Colorado River Basin Compact of 1948, Pub. L. 81-37, 63 Stat. 31 (1949).

TABLE 4-15: WATER REQUIREMENTS FOR ENERGY FACILITIES AT KAIPAROWITS (acre-feet per year)

TECHNOLOGY[a]	ERDS[b] WET COOLING	WPA[c] COMBINATIONS OF WET[d] AND DRY COOLING: HIGH WET	WPA[c] COMBINATIONS OF WET[d] AND DRY COOLING: INTERMEDIATE WET
Power Generation			
Kaiparowits	29,400	29,816	9,481
Escalante	29,400	29,816	9,481
	Cost range in which indicated cooling technology is most economic (dollars per thousand gallons)		
Power Plant	NC	< 3.65-5.90	>3.65-5.90

ERDS = Energy Resource Development System
WPA = Water Purification Associates
NC = no change

< = less than
> = greater than

[a]These values assume an annual load factor of 75 percent.

[b]White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[c]Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

[d]Combinations of wet/dry cooling were obtained by examining the economics of cooling alternatives for the turbine condensors. In the high wet case, the turbine condensors are all wet cooled; in the intermediate case, wet cooling handles 10 percent of the load on the turbine condensors and dry cooling handles 90 percent.

and recent published data accumulations,[1] and can be considered typical requirement levels. The Water Purification Associates data are from a study on minimum water use requirements and take into account certain opportunities to recycle water on site as well as the moisture content of the coal being used and local meteorological conditions.[2] As Table 4-15 indicates, the volume of water needed for each 3,000 MWe coal-fired power plant in the Kaiparowits/Escalante scenario is estimated at more than 29,800 acre-ft/yr, assuming wet cooling (the high wet cooling case on Table 4-15). If some dry cooling is used (the intermediate wet case on Table 4-15), water requirements could be reduced to 9,481 acre-ft/yr, a savings of 69 percent for each power plant. From an economic standpoint, the decision of which cooling technology to use depends upon the availability and price of water. If water costs less than $3.65 to $5.90 per thousand gallons, high cooling would be the most economically attractive. If water costs more than $3.65 to $5.90 per thousand gallons, intermediate cooling would be the most attractive alternative. If water costs only $0.25 per thousand gallons and intermediate cooling is used to conserve water, the added costs of electricity will be 0.1 to 0.2 cents per kilowatt hour.

Figure 4-5 indicates the manner in which the water requirement for a 3,000 MWe power plant at Kaiparowits or Escalante will be used. As indicated, the greatest amount of water will be consumed for cooling. Water for solids disposal and other uses (e.g., flue gas desulfurization (FGD) and mine dust control) consume about 2,000-3,000 acre-ft/yr depending on which estimates are used.

The water required for mining (from 1800 to 3300 acre-ft/yr) includes that for dust control (35 percent), coal washing (58 percent), service, fire, sanitary, and potable water (6 percent), and for revegetation of coal refuse (1 percent).

As shown in Figure 4-4, water intakes are to be located at Warm Creek for the Kaiparowits plant and in the flooded portion of

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[1]See White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming. These ERDS Reports are based on data drawn from University of Oklahoma, Science and Public Policy Program. Energy Alternatives: A Comparative Analysis. Washington, D.C.: Government Printing Office, 1975; Radian Corporation. A Western Regional Energy Development Study, Final Report, 3 vols. and Executive Summary. Austin, Tex.: Radian Corporation, 1975.

[2]Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

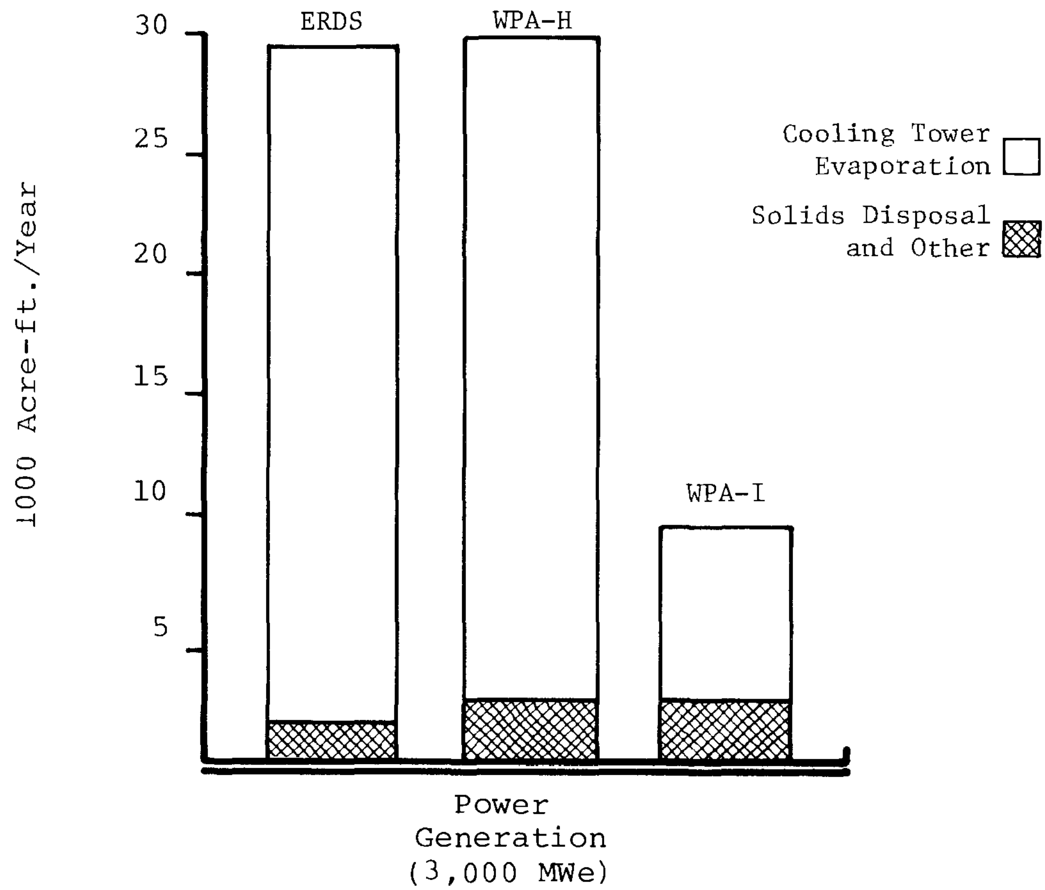

FIGURE 4-5: WATER CONSUMPTION FOR A 3,000 MEGAWATT-ELECTRIC POWER PLANT AT KAIPAROWITS/ESCALANTE, UTAH[a]

ERDS = Energy Resource Development System
WPA-H = Water Purification Associates-High Wet Cooling
WPA-I = Water Purification Associates-Intermediate Wet Cooling

The ERDS data is from White, Irvin L. et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming. The WPA data is from Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

the Escalante River at Willow Creek for the Escalante plant. Groundwater resources are not sufficient to meet the needs of the energy facilities.

Lake Powell is the designated source of surface water for the hypothetical energy development called for at the Kaiparowits site. To obtain the necessary water for energy development, the developer must acquire a water right from the state of Utah or purchase water from the holder of an existing water right and must enter into a contract with the Department of the Interior if water is to be drawn from the lake rather than from a naturally flowing watercourse within Utah.

B. Effluents from Energy Facilities

When operating at full capacity, each 3,000 MWe power plant in the Kaiparowits/Escalante scenario will produce more than 9,700 tons of solid effluents per day, including more than 70 tons of dissolved solids, 1,250 tons of dry solids, and 8,350 tons of wet solids. Table 4-16 shows the rate of solid effluent per day for a single power plant.

Dissolved solids are present in the ash blowdown effluent, the demineralizer waste effluent, and the FGD effluent.[1] The principal, dissolved constituents of wastewater which appear are calcium, magnesium, sodium, sulfate, and chlorine.

Wet solids from electric power plants are in the form of flue gas sludge, bottom ash, and cooling water treatment and waste sludge. Bottom ash is primarily oxides of aluminum and silicon. Calcium carbonate ($CaCO_3$) and calcium sulfate ($CaSO_4$) are the primary constituents of flue gas sludge. The cooling water treatment waste sludge is primarily $CaCO_3$. The amount of cooling water treatment waste is very small, compared to the bottom ash and flue gas sludge. Dry solid waste produced by power plants is primarily fly ash composed of oxides of aluminum, silicon, and iron.

The water in the effluent stream accounts for 6 percent of the total water requirements of each power plant. Dissolved and wet solids are sent to evaporative holding ponds and later

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[1]Demineralization is a method of preparing water for use in boilers producing an effluent composed of chemicals present in the source water. The bottom ash stream is the water used to remove bottom ash from the boiler. Bottom ash removal is done via a wet sluicing system using cooling tower blowdown water. Thus, the dissolved solids content of that stream is composed of chemicals from the ash and cooling water.

TABLE 4-16: EFFLUENTS FROM COAL CONVERSION PROCESS AT KAIPAROWITS/ESCALANTE[a]

FACILITY	SOLIDS[b] (tons per day)				WATER IN EFFLUENT[c] (acre-feet per year)
	DISSOLVED	WET	DRY	TOTAL	
Electric Power (3000 MWe)	73.5	8,368	1,274	9,715.5	1,898.9

MWe = megawatt-electric

[a]These data are from Radian Corporation. The Assessment of Residuals Disposal for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States, EPA Contract No. 60-01-1916. Austin, Tex.: Radian Corporation, 1978. The Radian Corporation report extends and is based on earlier analyses conducted by Water Purification Associates and reported in Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977

[b]These values are given for a day when the facility is operating at full load. In order to obtain yearly values, these numbers must be multiplied by 365 days and by the average load factor which is assumed to be 70 percent for power plants. The values given as solids do not include the weight of the water in which the solids are suspended or dissolved.

[c]The values for water discharged are annual and take into account the load factor. In order to obtain daily water discharge rate for a day when the facility is operating at full load, divide the yearly value by 365 days and by the load factor of 70 percent. The 1,898.9 acre-feet per year are equivalent to 1.7 million gallons per day.

deposited in landfills. Dry solids are treated with water to prevent dusting and deposited in a landfill.[1]

4.3.4 Impacts

This section describes water impacts which result from the underground mines, limestone quarries, and two 3,000 MWe power plants and from a scenario which includes construction of these facilities according to the hypothesized scenario schedule. The water requirements and impacts associated with expected population increases are also included in the scenario impact description.

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[1]The environmental problems associated with solid waste disposal in holding ponds and landfills are discussed in Chapter 10.

A. Underground Mine and Limestone Quarry Impacts

The construction and operation of an underground coal mine impact both groundwater and surface water. Construction of the mine openings may intersect some of the perched aquifers contained in the coal formation. As mining proceeds and mines are expanded, additional perched aquifers will be intersected. As a result, the groundwater flow patterns of these aquifers will be disrupted and local springs and seeps, important as water supplies for wildlife in the area, may dry up. To the extent that subsidence occurs, the resulting fractures in the overburden may, in turn, further disrupt the flow in perched aquifers. A potential effect of such flow disruption is the mixing of water from fresh and saline aquifers.

Runoff during mine operation is expected to be higher than during preconstruction conditions, and mine subsidence may change the patterns of surface drainage. This, in turn, affects wildlife and livestock watering locations.

The mining activities associated with one power plant will consume from 1,800 to 3,300 acre-feet of water per year. While this is not a large quantity relative to the requirements of the power plant, it nevertheless would not be available for other uses.

After mining ceases, there will be continuing surface topographic changes due to subsidence, and the land that has been temporarily revegetated (with application of water in excess of natural rainfall) may lose vegetation and erode.

The limestone quarry required for one power plant will require about 2 acre-feet of water per year. While groundwater is assumed to be the source of this water, its use may conflict with existing local water rights. Blasting disrupts groundwater flow and may cause nearby springs to dry up. Ponds created by quarry operations may trap surface water rather than release it to the surface streams in the area, resulting in reduced flows.

B. Power Plant Impacts

Construction activities at a power plant site will remove vegetation and disturb the soil. These activities affect surface water quality by increasing the sediment load in local runoff. This sediment loading of local creeks will be temporary, however, since retention facilities will trap runoff and direct it into the evaporation ponds after the plant begins operating. The equipment used during construction will require maintenance areas and petroleum products storage facilities. Areas for the storage of other construction-related materials, such as aggregate for a concrete batch plant, will also be required. All of these facilities constitute potential sources of contaminants in runoff. Runoff control methods call for channeling runoff from all of these sources to a holding pond for settling, reuse, and evaporation. Because the supply of water to this pond is intermittent, most of the water will probably evaporate. Water that does not evaporate may be used for dust control.

At the Kaiparowits site, the aggregate used in construction will come from alluvium that is also part of the shallow aquifer in the upper Wahweap Creek Canyon. Removal of that aggregate will reduce the storage capacity of the aquifer by approximately 200 acre-feet and create a pond, which may discharge into Wahweap Creek. Evaporative water loss from this pond will decrease the downstream groundwater supply. The likelihood of contamination of both the groundwater and surface water will be increased by livestock and wildlife use of the pond.

Electric generating facilities at both Kaiparowits and Escalante will cover land normally a part of the natural groundwater recharge system. Each plant will remove about 240 acres from natural runoff contributions, because of runoff control devices around critical areas and losses by catchments such as ponds. Removal of this amount of land will reduce recharge capacity by 48 acre-ft/yr which is about 0.12 percent of the total recharge capacity in the Kaiparowits Plateau.[1]

Fuel tanks at both sites will be surrounded by a berm designed to contain spills. In the event of a spill, fuel oil will saturate the ground within the bermed area and the soluble fractions could eventually enter the perched groundwater system and come out in unknown concentrations in springs and seeps.

A 65 acre emergency reservoir at each site will be lined to reduce natural pond leakage. Some leakage will occur and enter the groundwater system where it will recharge the local perched aquifers and provide additional water to downstream seeps and springs.

Some increased erosion of creek banks could occur where the water supply pipelines bridge creek beds. This impact can be avoided if banks are stabilized. Some additional creek bed erosion might occur due to increased pressure at the pipeline bridges during flood flows.

As noted previously, most of the water used by each power plant complex will come from Lake Powell. As indicated in Table 4-15, each 3,000 MWe plant (high wet cooled) will use more than

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[1]U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976.

29,800 acre-ft/yr, equivalent to 2.2 percent of Utah's share of the Upper Colorado River allocation. Since it is either consumed, evaporated in the cooling tower, or ponded, withdrawal of the water will, of course, mean that this water will no longer be available to other users in the Upper Colorado River Basin (UCRB).

The evaporation ponds are used as a final disposal site for the natural salts that occur in the power plant water supply and thus in its effluent. Concentration of salts in these ponds will be high, approximately 100,000 to 200,000 mg/ℓ. Thus, as these salts infiltrate through the pond liner into the groundwater system, they might, depending upon quantities and aquifer characteristics, raise the TDS of the water and make the water unfit for consumption by humans and, possibly, for livestock and wildlife as well. Springs and seeps fed by this contaminated groundwater could subsequently affect surface-water systems.

Water leaching from the ash disposal pond could enter the surface water system by migrating laterally along the low permeability mudstone to the canyon walls. As noted earlier, this water will contain trace toxic materials. The concentrations that reach the surface water are presumed small, but the transport mechanism for some of these materials through groundwater is unknown.

There will be no significant local surface water impacts directly from plant effluents because there will be no off-site discharge of effluents. The surface water flow volume to local streams will be reduced slightly as rainfall is trapped in the on-site waste retention ponds and by the associated runoff retention facilities.

After the plants are decommissioned, these ponds will remain. Unless the berms around the ponds are properly maintained, they may lose their protective vegetation, erode, and breach. Subsequently, the materials within the pond site will erode and enter the groundwater and surface water systems. Although Lake Powell is the original source of the salt materials in the evaporation ponds, the eventual reentry of the salt to the lake could affect local bottom organisms if salt concentrations are sufficiently high. Similarly, the addition of trace materials and solids from the ash disposal and tailings ponds can have an adverse effect.

C. Scenario Impacts

This section discusses water impacts that may occur because of interactions between the two power plants and those that result as the population increases according to the manpower demands of the construction-operation schedule.

Table 4-17 shows the water requirements of the population expected if both plants are built.[1] An estimated 10,753 acre-feet of water will be needed annually for the new town. This unusually high water demand is caused by the new town development plan which calls for extensive greenbelts and park facilities to attract necessary personnel to the area.[2]

Rural water demands will be met by individual wells that probably will not significantly affect the local aquifer. Municipal water requirements will be supplied by groundwater pumped from a well field in the Navajo Sandstone. Most of this withdrawal will probably be from bank storage of Lake Powell, so this source should be as reliable as the water supply of the lake. If it can be demonstrated that the groundwater used is part of Lake Powell bank storage,[3] the water will be considered Colorado River water and may be subject to the legal constraints of the applicable compacts. Also, existing local groundwater users could be affected by the new town's well field. These legal conflicts would have to be resolved before a new water right could be issued.

It is assumed that the rural population will use individual on-site waste disposal facilities (septic tanks and drainfields) and that waste treatment facilities will be required in urban areas. The wastewater generated by the population increase expected if both power plants are built is shown in Table 4-18.

Current treatment practices in Escalante and Panguitch consist entirely of septic tanks and drainage fields. Kanab has a two stage 0.2 million gallon per day (MMgpd) trickling filter operating at about 0.17 MMgpd. As a result of the increased populations, it is likely that municipal sewage treatment facilities will need to be built in Escalante and Panguitch as well as the new town. New facilities should use best practicable waste treatment technologies in order to conform to 1983 standards and should allow recycling or zero discharge of pollutants to meet 1985 goals.[4] The 1985 standard could be met by using effluents for industrial process make up water or for irrigating local farmland.

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[1] Population increases from secondary industries are not included in these estimates.

[2] U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976.

[3] Some water migrates into the banks of the lake and is stored there, hence the term "bank storage."

[4] Federal Water Pollution Control Act Amendments of 1972, Pub. L. 92-500, 86 Stat. 816 § 101, 301; 33 U.S.C.A. §§ 1251, 1311 (Supp. 1976).

TABLE 4-17: EXPECTED WATER REQUIREMENTS FOR INCREASED POPULATION

INCREASED WATER REQUIREMENT ABOVE 1975 LEVEL (acre-feet per year)					
YEAR[a]	KANAB[a]	PANGUITCH[b]	ESCALANTE[a]	PAGE[a]	KAIPAROWITS NEW TOWN[c]
1980	21.0	17.5	7.0	84	1,770
1990	63.0	105.0	567.0	476	10,266
2000	70.0	140.0	588.0	574	10,753

[a]Based on 125 gallons per capita per day.

[b]Based on 313 gallons per capita per day - Panguitch City Clerk.

[c]Based on 790 gallons per capita per day (approximately 125 gallons per capita per day for domestic use; 665 gallons per capita per day for greenbelt irrigation).

TABLE 4-18: EXPECTED WASTEWATER FLOWS FROM INCREASED POPULATION

INCREASED FLOW ABOVE 1975 LEVEL[a] (million gallons per day)					
YEAR	KANAB	PANGUITCH	ESCALANTE	PAGE	KAIPAROWITS NEW TOWN
1980	0.015	0.005	0.005	0.27	0.05
1990	0.045	0.030	0.410	0.66	1.16
2000	0.050	0.040	0.420	0.73	1.22

[a]Based on 100 gallons per capita per day.

(1) To 1980

Between the present and 1980, most activity will be centered on construction related to opening the first coal mines and the limestone quarry. Construction of the power plant and new town will also begin during this period. However, most urban growth during this period will be absorbed by existing communities, and local groundwater systems will not be affected significantly. As Table 4-17 indicates, additional demands on surface-water supplies are small. As Table 4-18 indicates, wastewater flows will increase as a result of population increases from construction activities. Existing facilities at Kanab should not be overloaded by this increase. Some surface water pollution may result from overloads and/or bypasses unless existing wastewater treatment facilities are expanded or new facilities built.

(2) To 2000

Both power plants will be constructed and in operation by 1990. In addition, ancillary activities, including coal mines and quarries, will be in full operation. The projected new town will also be built and occupied. These activities and facilities have several potential impacts on groundwater and surface water. No additional facilities are postulated beyond 1990; consequently, water impacts are assumed to remain the same for 1990 to 2000.

Combined mining activities will consume from 3,650 to 6,650 acre-feet of water per year and the power plants will consume about 59,600 acre-ft/yr assuming they are high wet cooled (see Table 4-13). For perspective, this is equivalent to about 2.2 percent of Utah's share of the Upper Colorado River allocation. It will not, of course, be available to other users in the UCRB. In addition, removal of quantities in this range from Lake Powell may have a salt-concentrating effect on the Colorado River. The Bureau of Reclamation (BuRec) estimates that salt increase caused by a project of similar size would be as much as 2.1 mg/ℓ at Imperial Dam. This increase would affect the agricultural users of the water through lower crop yields, causing an estimated annual loss of $230,000 per mg/ℓ of salt increases.[1]

The combination of both plants will remove about 480 acres from natural runoff contributions because of runoff control devices around critical areas and losses by catchments such as ponds. Removal of this amount of land will reduce recharge capacity by 96 acre-ft/yr which is about 0.25 percent of the total recharge in the Kaiparowits Plateau area.[2]

The Kaiparowits new town will be located over a part of the recharge area of the Navajo Sandstone aquifer. Total sewage from the proposed new town will be approximately 1.22 MMgpd. Sewer pipes

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[1]Utah State University, Utah Water Research Laboratory. Colorado River Regional Assessment Study, Part 1, Executive Summary, Basin Profile and Report Digest, for National Commission on Water Quality. Logan, Utah: Utah Water Research Laboratory, 1975, p. 2.

[2]U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976.

to collect the raw sewage will be placed in the permeable sandstone above the aquifer, and leaks in the pipes could result in groundwater pollution. If the solid waste disposal site for the new town is placed on the recharge zone, additional pollution could take place unless special precautions are taken.

As noted earlier, under present law, effluents from the sewage treatment plant may discharge to surface water until 1985. Effluents from the sewage treatment plant are assumed to be used in irrigated agriculture after 1985. If the treatment facility is operated properly, there should be no significant pollution from this practice.

Runoff will be increased by the construction of the new town by about 1,100 acre-ft/yr. This water will enter Wahweap Creek during storm flows and subsequently flow into Lake Powell.

Local water sources, such as springs and seeps, will be used in the construction of access roads and highways. This activity will require virtually all the water available from these sources. Highways and roads will increase runoff during storms with the increased volume likely to drain into Lake Powell.

(3) After 2000

After the plants are decommissioned, the facilities will remain even though they are not operating. The potential impacts discussed earlier for each mine-power plant complex are compounded by the presence of two complexes. Two impact types are particularly important in this postoperational phase: subsidence and pond dike failure. Subsidence over the underground mines will cause continuing topographic changes. Erosion of the pond dikes and subsequent release of salts and trace materials constitutes a water pollution hazard over long time periods.

4.3.5 Summary of Water Impacts

Water impacts are caused by: (1) the water requirements of and effluents from the energy facilities; (2) the water requirements of and wastewater generated by associated population increases; and (3) the coal mining process itself.

Assuming the power plants are high wet cooled, the total surface water requirement for each plant will be 29,800 acre-ft/yr. In combination, the surface water demand from Lake Powell, which has an average annual release of 8.25 million acre-ft/yr, could be as high as 59,600 acre-ft/yr. The use of intermediate wet cooling could reduce this demand by 69 percent. During the lifetime of the power plants, the use of water from Lake Powell will increase downstream salinity.

Effluents from each power plant averaging 1.7 MMgpd containing 9,700 tons of solids will be discharged into clay-lined, on-site evaporative holding ponds. Ponds may leak and increase the infiltration of pollutants from the ponds to the local groundwater.

The groundwater requirement for the new town and other urban and rural development could be as high as 12,000 acre-ft/yr, assuming both complexes are built. The water used for municipal supplies may be reused as irrigation water. The increased population will cause wastewater increases, totaling 2.5 MMgpd by 2000. The scenario municipalities which will probably require new treatment facilities are Escalante, Panguitch, and the new town.

The underground mining of 22.4 million tons of coal per year (the amount required by both power plants) will likely cause unplanned subsidence which will in turn affect surface water drainage and may affect groundwater flow patterns. Changes in natural flow in springs and seeps may change watering patterns for wildlife and livestock. Changes in runoff flows will occur as a result of vegetation removal, construction activities, and the facilities themselves. An increase in runoff is projected but it will vary seasonally and from year to year.

The physical impacts caused by the power plants and the facilities associated with them will remain after the plants are decommissioned. The subsidence effects, caused by underground mining discussed above, are irreversible. The limestone quarry will remain at the end of operations and will likely be filled with water during some period of the year. The alternative is a costly recontouring of the quarry site. More important is the ultimate destruction of the dikes around the evaporative holding ponds which contain the salt, ash, trace materials, and scrubber sludge. The likelihood of berm failure could be reduced if the dikes are maintained, the contents are removed to a leakproof container, or the ponds are drained, covered with soil, and revegetated.[1] Maintenance of the dikes will not eliminate pond leakage, however, and this is another potential long-term source of pollution. Pond liners will retard leakage but will not prevent it. Over the life of the plant, materials in the pond should not leach beyond the outer boundary of the liner. However, materials are likely, eventually, to leach through the liner and into the soil below.[2]

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[1]In some locations, it may be difficult to stabilize the areas that have been refilled.

[2]The environmental problems associated with solid waste disposal in holding ponds and landfills are discussed in Chapter 10.

4.4 SOCIAL AND ECONOMIC IMPACTS

4.4.1 Introduction

As described above, the hypothetical development for Kaiparowits/Escalante will occur in two counties of southern Utah: Garfield and Kane. Both are sparsely populated at present, but energy development will change this. Large numbers of workers, some with families, will begin to move into the area when construction of the energy facilities begins. The establishment of a new town near Glen Canyon City is part of the overall development in this scenario. The social and economic impacts that can be anticipated will result either directly or indirectly from the rapid population increase that will follow.

4.4.2 Existing Conditions

Kane and Garfield Counties comprise 9,201 square miles and in 1974 had a combined population of approximately 6,600 people. This is a density of 0.7 persons per square mile. Few roads serve the area, and many of these are unpaved or unimproved. No railroads or airlines presently serve the two-county area. Thus, the Kaiparowits Plateau is generally inaccessible, and any heavy vehicle traffic would require substantial highway improvement and construction.

Except for a recent increase, mainly in Kane County (Table 4-19), the population of the area has been static or declining for most of the past 35 years. The increase in Kane County appears to be related to the Navajo power plant just south of Glen Canyon City and may be temporary.[1]

Only the county seat of each county has a population over 1,000, Kanab in Kane County and Panguitch in Garfield County. Both towns are located in the extreme western part of their respective counties.

Very few people actually live in the Kaiparowits Plateau portion of the two counties. In fact, fewer than 700 people lived in Kane County outside of established towns (Table 4-19).

Ethnically, the area is quite homogenous; there is no black population and less than 1 percent are Indians. As is common in areas of the U.S. in which population is declining, young adults have tended to leave to seek economic opportunities elsewhere.

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[1]Wistisen, M.J., and G.T. Nelson. Kaiparowits Socio-Economic Study. Provo, Utah: Brigham Young University, Center for Business and Economic Research, 1973, p. 44.

TABLE 4-19: POPULATION OF KANE AND GARFIELD COUNTIES AND COUNTY SEATS, 1940-1974

LOCATION	1940	1950	1960	1970	1974[a]
Kane County	2,561	2,299	2,667	2,421	3,300
Kanab			1,645	1,381	1,550
Other towns			737	661	700
Garfield County	5,253	4,151	3,577	3,157	3,300
Panguitch		1,435	1,318	1,318	1,350
Other towns			1,856	1,570	1,600
Two County Total	7,814	6,450	6,244	5,578	6,600

Source: University of Utah, Bureau of Economic and Business Research.

[a]Estimated.

Net outmigration from Kane and Garfield Counties between 1960 and 1970 was 1,507 people.[1]

Table 4-20 shows the distribution of employment by industry in the two counties. The local economy of the Kaiparowits area is oriented more toward government, wholesale and retail trade, and services than is the national average. This is primarily because of tourist attractions in the area (including several national forests and parks) and a lack of major activity in other economic sectors. Agricultural activities in the area consist mainly of sheep and cattle production. Per capita income in the two-county area remains less than 80 percent of the Utah average, itself only 82 percent of the U.S. average.[2]

The Kaiparowits area was settled largely by Church of Jesus Christ of Latter Day Saints (Mormon) immigrants from other parts of Utah. Mormons still constitute the single largest religious group in the area.[3]

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[1]Bowles, Gladys K., Calvin L. Beale, and Everett S. Lee. Net Migration of the Population, 1960-70 by Age, Sex, and Color, Part 6: Western States. Washington, D.C.: U.S., Department of Agriculture, Economic Research Service, 1975, pp. 74-75.

[2]Kiholm, Janet. "Personal Income in Utah 1970-75." Utah Economic and Business Review, Vol. 36 (June 1976), pp. 1-6.

[3]Dotson, John L. "Duel in the Sun." Newsweek (October 27, 1975), p. 10.

Residents of the area are apparently overwhelmingly in favor of energy development. Southern Utah has lagged behind the rest of the state economically, and residents would like an opportunity to catch up--which is what energy development in this area seems to offer.[1] Further, economic opportunities would both help to keep the young people from leaving southern Utah and to allow relatives and friends to return.

Both Kane and Garfield Counties are governed by three-member boards of commissioners. Governmental services in these counties are limited; law enforcement is provided by two full-time law officers in each county. Both counties are serviced by joint city/county volunteer fire departments. Kane County has a planning commission, but Garfield County does not. Both counties have a master plan, and although only Kane County currently has a zoning ordinance, one is being drafted for Garfield County. Public education is provided by a single school district in each county. Public health services in Kane County include maintenance of a 31-bed hospital in Kanab; a 28-bed county hospital is now under construction in Panguitch to replace the old 16-bed facility there. Physicians are not available elsewhere in the two counties.

Panguitch is governed by a mayor and five councilmen. Two full-time policemen provide law enforcement, and the joint city/county volunteer fire department provides fire protection. Currently, the city has neither a professional city engineer nor a planner. However, the city owns and operates a water system and has a zoning ordinance.

Kanab, the seat of Kane County government, has a mayor and five councilmen. It employs three full-time policemen and, like Panguitch, participates in a joint volunteer fire department arrangement with the county. Unlike Panguitch, Kanab has a licensed city engineer. It does not have a professional planner, but the city does have a zoning ordinance. Kanab has both a city-owned and operated water and sewage treatment system, and an expansion to the water system is now underway. The other incorporated communities in the two counties have no municipal water or sewer systems.

Overall, Kane and Garfield Counties and the two small towns of Kanab and Panguitch appear to lack the resources necessary to deal effectively with energy development in the area. However, the counties have been attempting to upgrade their capabilities, particularly in planning. Both counties and their county seats also participate in Utah's system for intergovernmental planning

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[1]See U.S., Department of the Interior, Bureau of Land Management. _Final Environmental Impact Statement: Proposed Kaiparowits Project_, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976, pp. A-710 to A-726.

TABLE 4-20: EMPLOYMENT DISTRIBUTION IN KAIPAROWITS AREA, 1974

INDUSTRY	KANE COUNTY	GARFIELD COUNTY
Total Civilian Work Force	1,260	1,430
Total Employed	1,170	1,210
Agriculture	100	110
Mining	20	20
Contract Construction	15	15
Manufacturing	60	200
Transportation and Public Utilities	10	50
Wholesale and Retail Trade	200	135
Finance, Insurance, and Real Estate	25	20
Service and Miscellaneous	150	190
Government	200	310
All Other Nonagriculture	310	150
Total Unemployed	90[a]	220[b]

Source: University of Utah, Bureau of Economic and Business Research.

[a]7.1 percent.

[b]15.4 percent.

cooperation.[1] They also participate in the Kaiparowits Planning and Development Advisory Council which Governor Calvin L. Rampton established by executive order in August 1974.[2] The council was established to guide and coordinate activities related to energy development in Kane and Garfield Counties.

4.4.3 Factors Producing Impacts

Two factors dominate as the cause of social and economic impacts: the manpower requirements of energy facilities and the taxes levied on energy facilities. Tax rates are tied to capital costs, and/or the value of coal extracted, and/or the value of energy produced. Taxes which apply to the scenario facilities

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[1]This system is described in 4.4.4.

[2]The executive order is reprinted in U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976, pp. A-259 to A-260.

TABLE 4-21: MANPOWER REQUIREMENTS FOR ONE 3,000 MEGAWATT POWER PLANT AND ASSOCIATED COAL MINE[a]

YEAR FROM START	CONSTRUCTION WORK FORCE		OPERATION WORK FORCE		TOTAL IN ANY ONE YEAR
	MINE	POWER PLANT	MINE	POWER PLANT	
1		0			0
2	0	40			40
3	22	420			442
4	154	907			1,061
5	305	1,315			1,620
6	507	2,065			2,572
7	816	2,545	0	0	3,361
8	573	1,990	749	109	3,421
9	107	720	1,502	109	2,433
10	0	0	3,002	212	3,214
11			3,000	436	3,436
12			3,000	436	3,436

MWe - megawatt-electric

[a]Data are for a 3,000 MWe power plant and an underground coal mine large enough to supply that power plant (about 11.2 million tons per year) and are from Carasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975, data uncertainty is -10 to +20 percent.

hypothesized for Kaiparowits/Escalante are a property tax, sales tax, and royalty payments on federally owned coal.

Table 4-21 gives the manpower requirements of a 3,000 MWe power plant and an underground coal mine large enough to supply that power plant with coal. Note that manpower requirements for the operation of an underground coal mine exceed the peak construction requirements by 4 times, while the reverse is true for the power plant (peak construction manpower requirements exceed operation requirements). As a result, the manpower requirements for a combination underground coal mine-power plant build steadily; the maximum number of workers are employed during operation and no construction peak occurs.

The property tax and sales tax, which are tied to the capital costs of the facilities, and royalty payments, which are tied to the value of coal, generate revenue. The capital costs of one power plant and mine are given in Table 4-22. The total cost of one plant-mine combination is about 1,575 million 1975 dollars. Property tax, most of which goes to local government, is levied on

TABLE 4-22: CAPITAL RESOURCES REQUIRED FOR CONSTRUCTION OF FACILITIES (in millions of 1975 dollars)[a]

FACILITY	MATERIALS AND EQUIPMENT	LABOR AND MISCELLANEOUS	INTEREST AND CONSTRUCTION[b]	TOTAL
Power Plant 3,000 MWe	461	461	394	1,316
Underground Coal Mine 11.2 MMtpy	118	72	71	261

MWe = megawatt-electric MMtpy = million tons per year

[a]Data are adjusted assuming linearity to correspond to the facility size hypothesized in the scenario (a 3,000 MWe power plant with a 11.3 MMtpy mine) and are from Carrasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975.

[b]At 10 percent per year.

the cash value of the facility (approximately the total capital cost given in Table 4-22) after construction of the facility is completed. Sales tax, most of which goes to the state government, is levied on materials and equipment only (Table 4-22) as the materials and equipment are purchased during construction. The current sales tax rate in Utah is 4.75 percent, of which 4 percent goes to the state and 0.75 percent goes to the local government. The property tax rate is 1.82 percent in Kane County and 1.68 percent in Garfield County.[1] State and local governments also receive 50 percent of the royalty payment, which is 12.5 percent of the value of federally owned coal.[2]

4.4.4 Impacts

The nature and extent of the social and economic impacts caused by these factors depend on the size and character of the community or communities in which workers and their families live, on the state and local tax structure, and on many other social and economic factors. A scenario, which calls for two power plant complexes to be developed according to a specified time schedule (see Table 4-1), is used here as the vehicle through which the

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[1]This is the effective, average property tax rate. The actual rate is computed using a number of assessment ratios, since certain kinds of equipment (e.g., pollution control equipment) are taxed at different rates or may be exempt.

[2]This is the federal government's target rate; actual rates will vary from mine to mine.

TABLE 4-23: CONSTRUCTION AND OPERATION EMPLOYMENT FOR KAIPAROWITS SCENARIO, 1975-2000[a]

YEAR	FACILITY #1 (KAIPAROWITS SITE)		FACILITY #2 (ESCALANTE SITE)	
	CONSTRUCTION	OPERATION	CONSTRUCTION	OPERATION
1975	40			
1976	440			
1977	1,060			
1978	1,670			
1979	2,570	0	0	
1980	3,360	430	40	
1981	2,560	740	440	
1982	830	1,480	1,060	
1983	0	2,970	1,670	0
1984		2,970	2,570	430
1985		2,970	3,360	740
1986		2,970	2,560	1,480
1987		2,970	830	2,970
1988		2,970	0	2,970
1989 to 2000		2,970		2,970

Source: Carasso, M., et al. The Energy Supply Planning Model 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975.

[a]About 20-25 percent of construction and 80 percent of operation employment is attributable to the coal mining activity alone.

nature and extent of the impacts are explored. The discussion relates each impact type to the hypothetical scenario and includes population impacts, housing and school impacts, economic impacts, fiscal impacts, social and cultural impacts, and political and governmental impacts.

A. Population Impacts

Most of the social and economic impacts in the Kaiparowits/ Escalante scenario will result from population increases, initially during construction and later during operation of the facilities.

Construction of the first power plant was to have begun in 1975 and will extend into 1983. The direct employment projections used to evaluate population changes are shown in Table 4-23.

Population projections are shown in Table 4-24.[1] They indicate that Page, Arizona will attract the majority of the growth early in the development. Established schools and services in Page will attract many people, especially families with children. A 75 percent increase in size (to 10,440) is expected by 1980, after which only minor population changes should occur (Table 4-24). Kane County is expected to triple in population by 1983, after which growth will be gradual. Much of the increase should take place in the new town, where 2,000 people will live by 1979 and 6,500 by 1984. Kanab can expect a 40-percent increase by 1980; roadside sprawl of trailer homes is likely in the Glen Canyon City area, where the present population of about 20 will grow to 110 by 1980.

Garfield County will receive only minor impacts from the first mine and power plant development located to the south. However, after construction begins near Escalante in 1980, population will increase considerably. Between 1980 and 1987, when construction is completed, a 240-percent increase in the county population is expected, most of it at Escalante (11,000 population in 1987) but much of it also in and around the small towns along Utah Highway 12 (Table 4-25).

Age-sex distributions of population were estimated from 1970 data for Kane and Garfield Counties and age distributions of employees and family members from recent surveys in the West.[2] Page, Arizona, was assumed to have a structure similar to southern Utah. As it typical, the relative number of males is expected to be greatest during construction (1980-1985), and the proportion of the population in the 20-35 age group remains higher due to employment opportunities (Table 4-26).

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[1]Population changes were projected using economic base analysis, the data in Table 4-23, employment multipliers, and population multipliers. The employment multipliers used for the construction phase increased from 0.2 to 0.4 and, for the operation phase, from 0.2 to 0.5. The population/employee multipliers used were 2.2 for construction and 3.0 for operation. An average of 80 percent of the new employees in the area were assumed to be from outside the local area, a figure which may be high early in the development but which should be a reasonable average. A community choice model based on a town's population and distance from facility sites was used to allocate populations to towns in the area. The community choice model is described in Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, pp. 90-97. The assumed new town was allocated 500 people a priori in 1977 and 1978, after which its population changes also were subject to the model. The new town is assumed to be an incorporated community rather than a company town.

[2]Ibid.

TABLE 4-24: POPULATION ESTIMATES FOR PAGE AND COMMUNITIES IN KANE COUNTY, 1975-2000[a]

YEAR	PAGE, ARIZONA[b]	KANE COUNTY, UTAH				
		KANAB	NEW TOWN	GLEN CANYON CITY	OTHERS	TOTAL
1975	6,000	1,550	0	20	1,730	3,300
1976	5,820	1,660	0	25	1,745	3,430
1977	7,020	1,810	500	40	1,760	4,110
1978	7,850	1,910	1,250	60	1,780	5,000
1979	8.980	2,040	2,000	80	1,790	5,910
1980	10,440	2,200	3,350	110	1,800	7,460
1981	10,270	2,200	3,740	110	1,810	7,860
1982	9,660	2,150	3,910	100	1,820	7,980
1983	10,770	2,270	6,240	140	1,830	10,480
1984	11,100	2,340	6,500	150	1,840	10,830
1985	11,310	2,380	6,670	150	1,850	11,050
1986	11,430	2,410	6,750	150	1,860	11,170
1987	11,580	2,440	6,850	150	1,870	11,310
1988	11,590	2,440	6,830	150	1,880	11,300
1989	11,690	2,460	6,890	150	1,890	11,390
1990	11,780	2,480	6,940	150	1,910	11,480
1995	12,070	2,540	7,120	160	1,960	11,780
2000	12,370	2,600	7,290	160	2,010	12,060

[a]Natural increases of 0.8 percent annually through 1990 and 0.5 percent annually thereafter are incorporated. Given the scenario and data assumptions, the estimates in the table are within about 25 percent of conditions which could be expected.

[b]Page estimates include a decline from population associated with the Navajo power plant of 2,000 during 1975 and 1,000 during 1976.

TABLE 4-25: POPULATION ESTIMATES FOR COMMUNITIES IN GARFIELD COUNTY, 1975-2000[a]

YEAR	ESCALANTE	CANNONVILLE	TROPIC	HENRIEVILLE	PANGUITCH	BOULDER	OTHER	TOTAL
1975	650	110	330	150	1,370	90	600	3,300
1976	680	120	370	160	1,420	90	600	3,440
1977	750	150	430	190	1,520	100	610	3,750
1978	790	170	470	210	1,590	100	610	3,940
1979	840	190	530	240	1,670	110	620	4,200
1980	900	230	610	270	1,770	110	620	4,510
1981	1,390	230	640	280	1,800	120	630	5,090
1982	2,270	230	640	290	1,800	130	640	6,000
1983	3,300	270	720	330	1,910	140	640	7,310
1984	6,040	290	790	360	1,940	160	650	10,230
1985	8,600	310	820	300	2,000	170	650	12,850
1986	9,400	320	840	390	2,020	170	660	13,800
1987	11,000	320	860	400	2,050	180	660	15,470
1988	9,580	320	850	400	2,040	170	670	14,030
1989	9,660	320	850	400	2,060	170	670	14,130
1990	9,730	330	860	400	2,080	170	680	14,250
1995	9,980	330	880	410	2,130	180	700	14,610
2000	10,200	340	900	420	2,180	180	720	14,940

[a]Natural increases of 0.8 percent annually through 1990 and 0.5 percent annually thereafter are incorporated. Given the scenario and data assumptions, the estimates in the table are within about 25 percent of likely conditions.

TABLE 4-26: AGE-SEX DISTRIBUTION FOR PAGE AND KANE AND GARFIELD COUNTIES

AGE GROUP	1975	1980	1985	1990-2000
Female				
65 and over	.048	.020	.013	.013
55-64	.051	.034	.025	.021
35-54	.110	.102	.092	.085
25-34	.053	.127	.151	.156
20-24	.024	.045	.045	.042
17-19	.024	.029	.030	.029
14-16	.042	.023	.021	.024
6-13	.098	.061	.065	.074
0-5	.053	.041	.049	.057
Total	.503	.483	.491	.501
Male				
65 and over	.050	.021	.014	.013
55-64	.054	.038	.027	.022
35-54	.104	.110	.096	.084
25-34	.048	.140	.158	.155
20-24	.019	.049	.048	.041
17-19	.026	.033	.032	.029
14-16	.041	.022	.021	.023
6-13	.100	.062	.065	.074
0-5	.056	.042	.050	.058
Total	.498	.517	.509	.499

B. Housing and School Impacts

Housing and school enrollment impacts are obtained from population in the age structure estimates, assuming the age structure is the same throughout the area. The 6-13 age group is classified as elementary school age and the 14-16 age group is classified as secondary school age.[1] Housing demand is estimated from the proportion of the population which is male and 20 years of age and older.

Estimates of housing demand are generally high during construction and continue to rise slowly through 2000 (Table 4-27). By 1980 in this scenario, Kane County will need over 1,700 new homes,

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[1]These assumptions and their resulting estimates are associated with perhaps a ± 25 percent error given the population estimates.

TABLE 4-27: ESTIMATED HOUSING DEMAND IN KANE AND GARFIELD COUNTIES AND PAGE, 1975-2000

LOCATION	1975	1980	1985	1990	2000
Kane County	910	2,670	3,790	3,620	3,800
New Town	0	1,200	2,290	2,190	2,300
Page	1,650	3,740	3,880	3,710	3,900
Garfield County	910	1,610	4,430	4,490	4,710
Escalante	180	320	2,950	3,060	3,210

1,200 at the new town site alone (Figure 4-6). Judging from other western energy development sites, at least half of these could be mobile homes.[1] Garfield County is even more likely to have a large number of mobile homes, since the demand for housing in 1985 will be nearly five times the 1975 level (Figure 4-7). Escalante is the probable site for extensive mobile home location. Likewise, the expected growth of the very small towns in the area (Tables 4-24 and 4-25) will largely be accommodated by mobile homes.

School enrollment projections in Table 4-28 are rather low until the 1980's because short-term construction personnel do not all bring families and because many of those who do bring children will probably choose to live in Page, which balances the enrollment decline after completion of the Navajo power plant. Still, when the increased enrollment from Kaiparowits area impacts is balanced with the decline in population and enrollment from Navajo power plant, a net increase of only about 300 students by 1985 and 600 by 1990 is expected in Page.

The impact of this approximate 30 percent increase in enrollment by 1985 on Page will be relatively slight compared to the impacts anticipated in Kane and Garfield Counties (Figure 4-8). The enrollment increase in these two counties will be more than 100 percent by 1990. Further, this increase will occur in a part of the area where, except for Escalante, school facilities are not currently available. The financial impacts associated with providing education for this increased school-age population will be

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[1]Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 103.

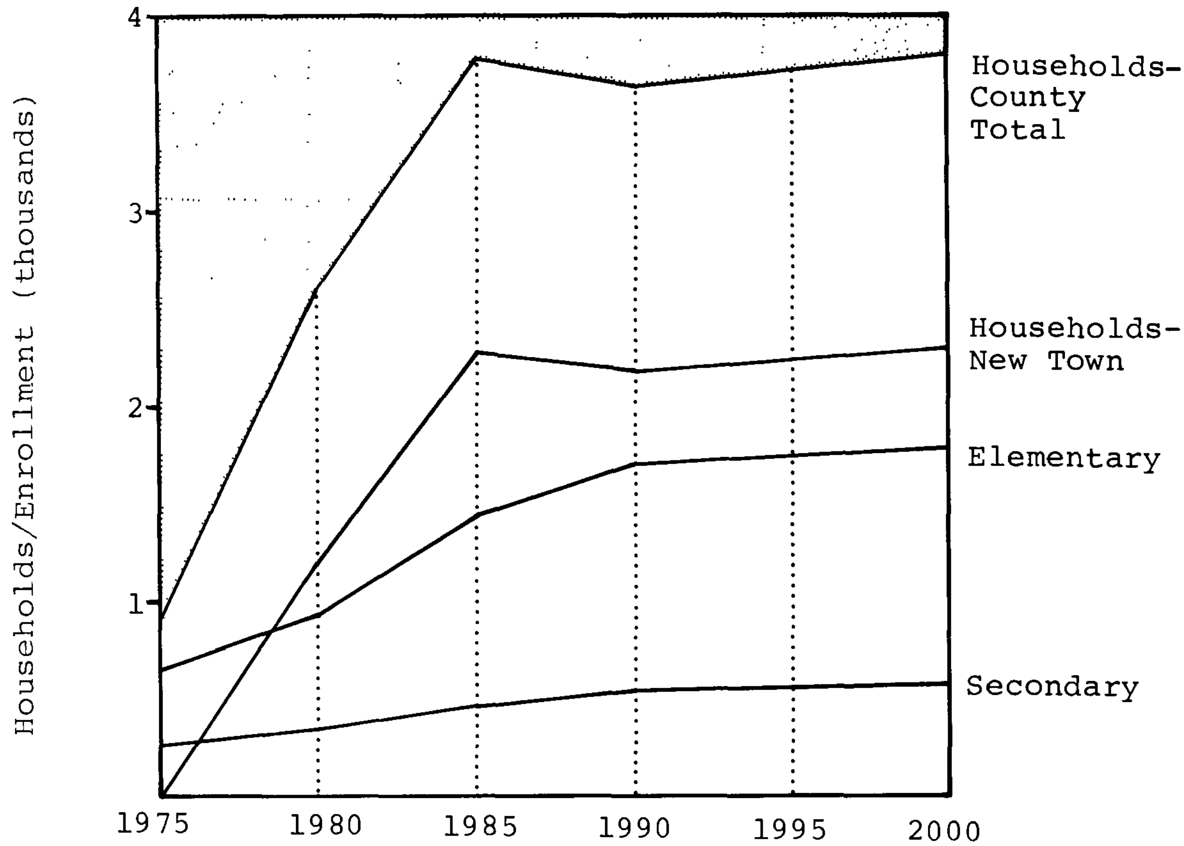

FIGURE 4-6: ESTIMATED HOUSEHOLDS AND SCHOOL ENROLLMENT IN KANE COUNTY, 1975-2000

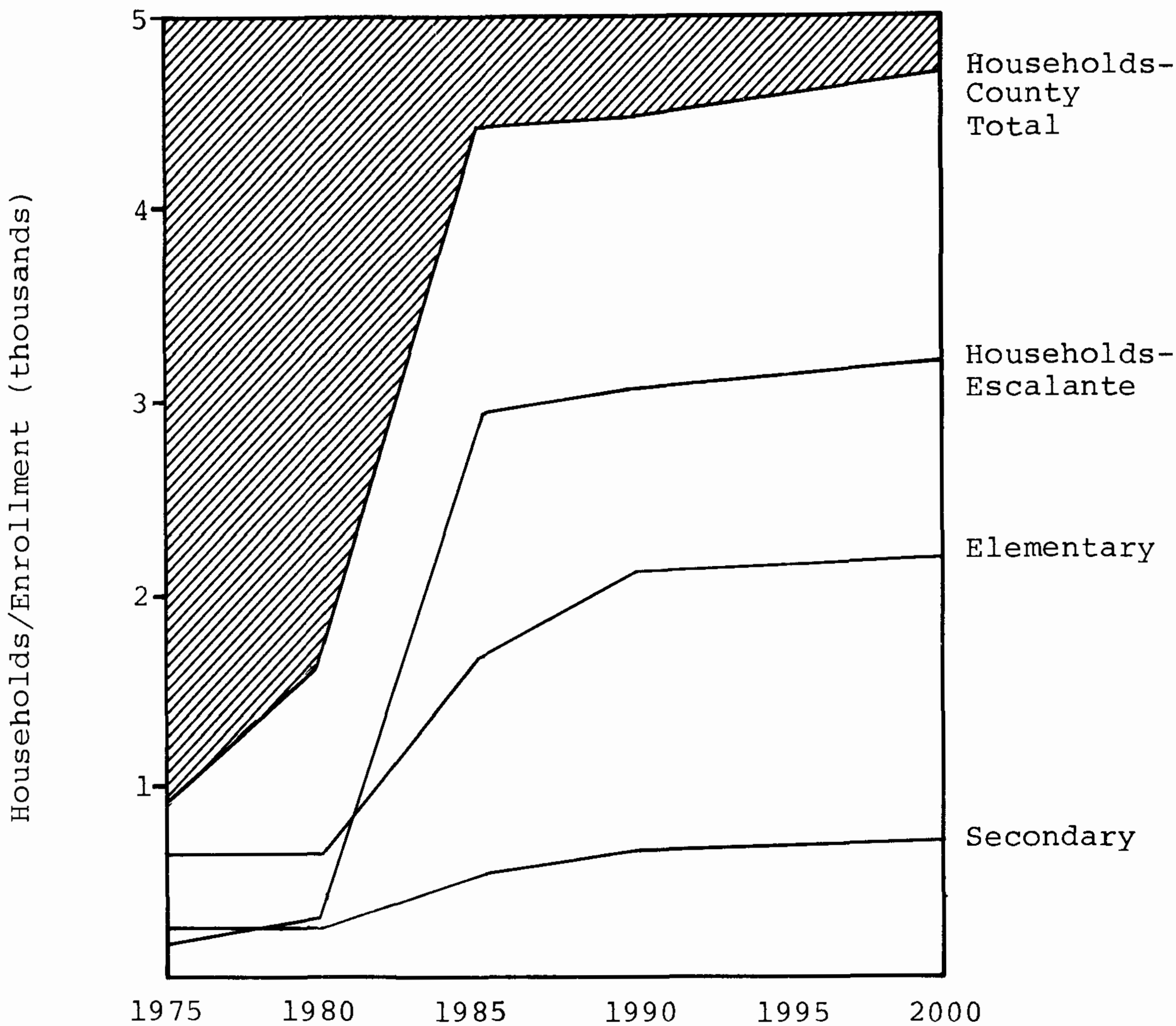

FIGURE 4-7: ESTIMATED HOUSEHOLDS AND SCHOOL ENROLLMENT IN GARFIELD COUNTY, 1975-2000

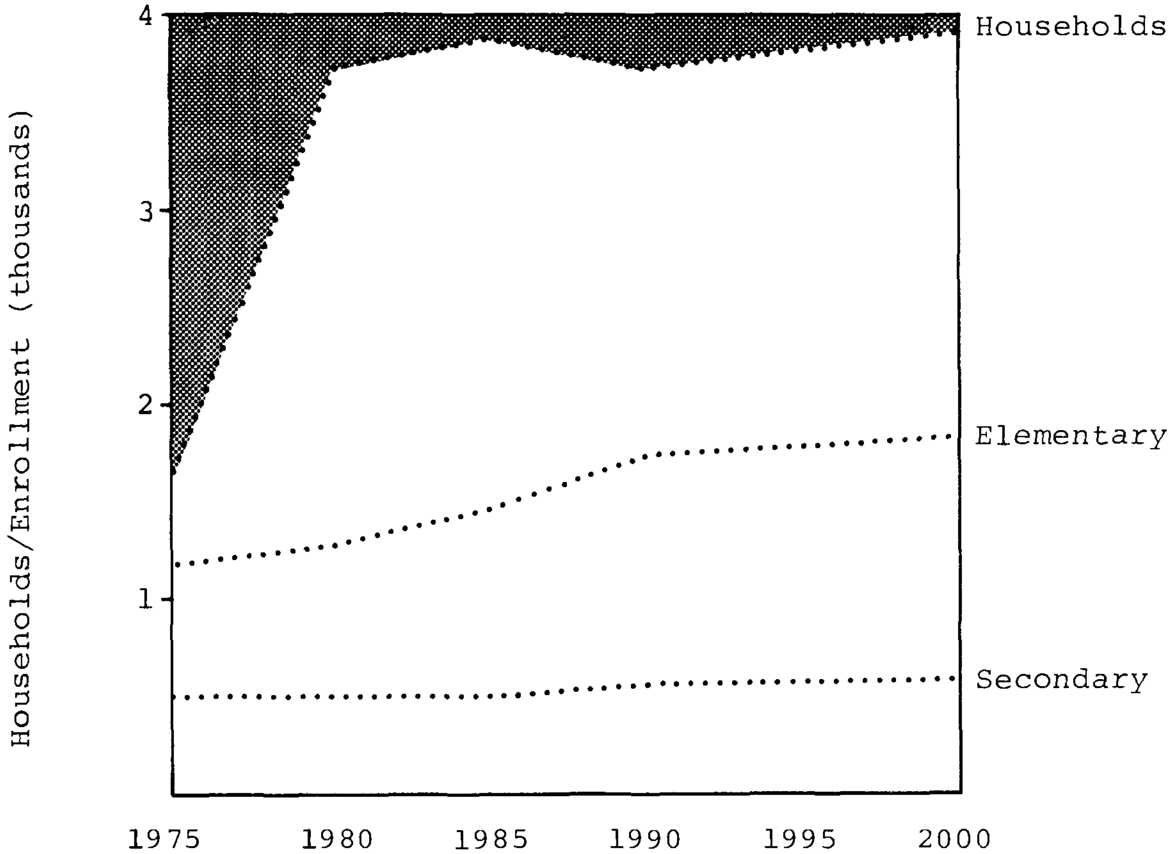

FIGURE 4-8: ESTIMATED HOUSEHOLDS AND SCHOOL ENROLLMENT IN PAGE, 1975-2000

TABLE 4-28: ESTIMATED SCHOOL ENROLLMENT IN KANE AND GARFIELD COUNTIES AND PAGE

SCHOOL	1975	1980	1985	1990	2000
Elementary					
Kane County	650	920	1,440	1,700	1,780
Page	1,190	1,280	1,470	1,740	1,830
Garfield County	650	650	1,680	2,100	2,200
Secondary					
Kane County	270	340	460	540	570
Page	500	500	500	550	580
Garfield County	270	270	540	670	700

felt primarily in Garfield County (Table 4-29), although the lead time is somewhat longer there than for Kane County. Overall, about $14 million will be needed for schools in southern Utah because of the energy development and about $2.7 million in Page.

C. Economic Impacts

One of the most immediate local impacts from energy development in the Kaiparowits/Escalante area will be a change in income distribution both because energy and construction workers tend to earn relatively high incomes and because local residents will be able to find employment in energy development or to establish retail businesses in the area. The income impact will be especially noticeable in southern Utah, where the per capita income is currently less than 70 percent of the national average.[1]

In making the income distribution projections, the patterns recently found in currently affected energy resource communities in the West were adopted.[2] The construction phase results in a 43 percent rise in median household income by 1985, including increased incomes for many long-time residents. This declines by

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[1]U.S., Department of Commerce, Bureau of Economic Analysis. "Local Area Personal Income." Survey of Current Business, Vol. 54 (May 1974, Part II), pp. 1-75; Kiholm, Janet. "Personal Income in Utah 1907-1975." Utah Economic and Business Review, Vol. 36 (June 1976), pp. 1-6.

[2]Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 50.

TABLE 4-29: FINANCIAL PROSPECTS FOR KANE AND GARFIELD COUNTIES AND PAGE SCHOOL DISTRICTS, 1975-2000

LOCATION	YEAR	ESTIMATED ENROLLMENT	CLASSROOMS AT 21/ROOM	CAPITAL EXPENDITURE REQUIRED (millions of dollars)[a]	OPERATING EXPENDITURE REQUIRED (millions of dollars)[b]
Kane County	1975	920	44[c]		1.2
	1980	1,260	60	0.8	1.6
	1985	1,900	90	2.4	2.5
	1990	2,240	107	3.3	2.9
	2000	2,350	112	3.6	3.1
Garfield County	1975	920	44[c]		1.2
	1980	920	44	0	1.2
	1985	2,220	106	3.2	2.9
	1990	2,770	132	4.6	3.6
	2000	2,900	138	5.0	3.8
Page	1975	1,690	80[c]		2.2
	1980	1,780	85	0.2	2.3
	1985	1,970	94	0.7	2.6
	1990	2,290	109	1.5	3.0
	2000	2,410	115	1.8	3.1

[a]Cumulative, based on $2,500 per pupil space. See Froomkin, Joseph, J.R. Endriss, and R.W. Stump. Population, Enrollment and Costs of Elementary and Secondary Education 1975-76 and 1980-81, Report to the President's Commission on School Finance. Washington, D.C.: Government Printing Office, 1971.

[b]Each year, based on current average of about $1,300 per pupil. See Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

[c]Estimated.

1990 but will remain 24 percent above current levels (Table 4-30 and Figures 4-9 and 4-10). The principal changes in the Kane and Garfield County income distribution will be a large relative decrease in low-income families and a predominance of families in the $15 - $25 thousand income range.

A second major impact will be an expansion in secondary employment, especially retailing. Any necessary industrial services are likely to be either provided within the mine-power plant complexes or imported from outside the Kaiparowits area. No other major industrial facilities are expected in the area from this scenario. Substantial increases in service employment to provide goods and services for the local population will be part of the overall impact of energy development. Because retail activities are market-oriented, their location is largely determined by the locations of customers and other businesses. Therefore, much of the early impact, at least through 1980, will occur at Page, where most energy workers will live and where businesses are already serving Navajo power plant workers and their families. However, much of the 1975-1980 impact on Page from Kaiparowits will have the effect of offsetting an economic decline during the phase-out of construction at the Navajo facility. Because of Page's current mix of goods and services and its importance to the southern Utah area before the Kaiparowits new town is built, a 75 percent increase in retail activity (based on the expected population increase) at Page is expected by 1990.

The Kaiparowits new town and, to a lesser extent Escalante, will provide lower order (frequently purchased, often lower cost) goods and services, while higher order retail activities will be relatively more numerous at Page and, to some extent, Flagstaff. Activities in the Kaiparowits/Escalante area towns by the mid-1980's are likely to include a bank, taverns, gas stations, food stores, restaurants, laundries, and probably clothing stores. However, no large-scale economic benefit to the Page and southern Utah area is likely to result because the goods purchased there will largely be manufactured and wholesaled outside the area. Flagstaff, Arizona, a rapidly growing city about 120 miles south of Page, is likely to benefit from increased wholesale activity. Salt Lake City and Phoenix should also benefit from increased wholesale and retail activity as well as from state sales and income tax receipts.

Local government expenditures will generally be manageable except for Escalante. The Kaiparowits new town could plan to meet public expenditure demands by including the energy facilities in

FIGURE 4-9: MEDIAN FAMILY INCOME, KANE AND GARFIELD COUNTIES, 1975-2000

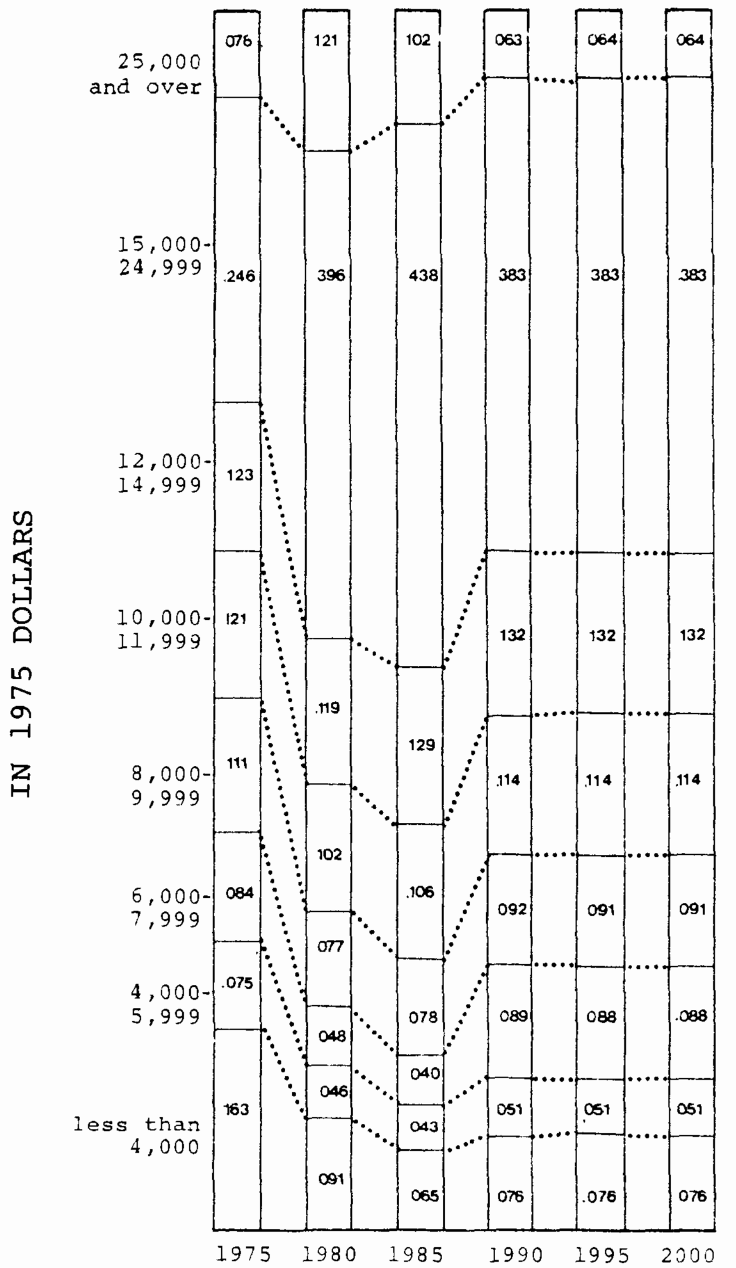

FIGURE 4-10: ESTIMATED ANNUAL INCOME DISTRIBUTION FOR KANE AND GARFIELD COUNTIES, 1975-2000

TABLE 4-30: PROJECTED INCOME DISTRIBUTION FOR KANE AND GARFIELD COUNTIES, 1975-2000 (Proportion of households in income categories)

YEAR	ANNUAL INCOME (1975 Dollars)								
	LESS THAN 4,000	4,000 TO 5,999	6,000 TO 7,999	8,000 TO 9,999	10,000 TO 11,999	12,000 TO 14,999	15,000 TO 24,999	25,000 AND OVER	MEDIAN HOUSEHOLD INCOME
1975	.163	.075	.084	.111	.121	.123	.246	.076	11,100
1980	.091	.046	.048	.077	.102	.119	.396	.121	15,030
1985	.065	.043	.040	.078	.106	.129	.438	.102	15,900
1990	.076	.051	.089	.092	.114	.132	.383	.063	13,800
1995	.076	.051	.088	.091	.114	.132	.383	.064	13,800
2000	.076	.051	.088	.091	.114	.132	.383	.064	13,800

Source: Data for 1975 are taken from U.S., Department of Commerce, Bureau of the Census. Household Income in 1969 for States, SMSA's, Cities, and Counties: 1970. Washington, D.C.: Government Printing Office, 1973, and inflated to 1975 dollars. Income distributions for construction, operation, and service workers are from Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 50, assuming that "other newcomers" are operation employees and that new service worker households have the same income distribution as long-time residents.

the Special Service Districts.[1] Page already has the Navajo power plant in its property tax base and has excess capacity in most of its public services. The new town's construction presumably would include sufficient capital facilities to handle all the expected population. Escalante, by means of Special Service Districts, also could use energy facility tax revenues but might have more trouble than other towns in having ready capital in time for the demand. This is discussed further in the section on fiscal impacts. In the view of some persons, the new roads, pipelines, transmission lines, and reduced visibility in the wilderness areas would also downgrade the scenic attractions of the area,[2] having serious implications for a region which is currently dependent on tourism for its economic livelihood.

Agriculture involves about 660 square miles in Kane and Garfield Counties (about 7 percent of the area), down from 740 square miles in 1967. Eight percent of the labor force works in agriculture, mainly cattle and sheep grazing operations. Little ranching takes place near the scenario facility sites, and it is unlikely that energy development would adversely affect agriculture. The amount of land now committed to national forest and other federal uses also indicates that not much increase in agriculture is likely in southern Utah. Smaller ranches will gradually go out of production or be consolidated into larger units, but this is a national trend not expected to be influenced by energy development.

Finally, the energy-related economic activity will result in inflation in local housing and labor markets, perhaps equal to the short-term increase in income. Project workers will be able to outbid long-time local residents for land (where private land is available) and for goods and services; some low-wage service workers will be attracted away from their present jobs. Some employees of existing businesses in the area can be expected to move to higher paying jobs in the energy facilities.

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[1] Special Service Districts in Utah can supply water, sewage, drainage, flood control, garbage, hospital, transportation, recreation, and fire protection services. They may include several noncontiguous areas, such as a power plant and a town separated by several miles, and may cross jurisdictional boundaries. See Section F, Political and Governmental Impacts.

[2] See Josephy, Alvin M. "Kaiparowits: The Ultimate Obscenity." Audubon Magazine, Vol. 78 (Spring 1976), pp. 64-90; Ives, Berry, and William Schulze. Boomtown Impacts of Energy Development in the Lake Powell Region, Draft Lake Powell Research Project Bulletin. Los Angeles, Calif.: University of California, Institute of Geophysics and Planetary Physics, 1976.

TABLE 4-31: PROPERTY TAX REVENUES
(millions of 1975 dollars)

JURISDICTION	1977	1980	1985	1990
Kane County[a]	2.8	15.6	21.8	21.8
Garfield County[a]	0	1	18.3	21.8
Escalante[b]	0	0.01	0.42	0.48
Coconino County, Arizona[b]	0.03	0.14	0.17	0.18

[a]Tax on energy facilities.

[b]Tax on residential and commercial development.

D. Fiscal Impacts

The largest fiscal impact of the energy development hypothesized in this scenario will arise from property taxes. Development expenditures are estimated to be $1,300 million for each power plant and $250 million for related coal mines at each site. This is equivalent to 32 percent of the currently assessed valuation in all of Utah.

Assuming that the current mill levy rates are maintained[1] and that the energy facilities are taxable at those levels, the energy facilities and related residential and commercial development will generate the property tax revenues shown in Table 4-31.

Only about 3 percent of the increased tax base in the area will be accounted for by residential and commercial development. All property taxes in Utah currently go to county and local governments. On the average, school districts get 59.8 percent.[2]

By law, property tax will be due on both mine structures and equipment (as calculated above) and on the coal resource when mined. However, nonmetallic mines located on land leased from public agencies have not been subjected to this "privilege tax" in the past. Because of this precedent and the heretofore arbitrary

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[1]Current levies are 1.82 percent of full cash value in Kane County and 1.68 percent in Garfield County. University of Utah, Bureau of Economic and Business Research. 1976 Statistical Abstract of Utah. Salt Lake City, Utah: University of Utah, Bureau of Economic and Business Research, 1976, Tables VII-16 and VII-17.

[2]*Ibid.*, Table VII-14.

TABLE 4-32: ALLOCATION OF FEDERAL COAL ROYALTIES
(millions of dollars)

FUND	1980	1985	1990	2000
State	1.8	10.2	18.3	22.2
Reclamation	1.5	8.1	14.7	17.8
Total (including others	3.7	20.3	36.7	44.5

application of taxes to other mineral deposits, no potential revenues are assumed from this source.[1]

Utah will derive some benefit from federal royalties. According to recently passed legislation, 12.5 percent of mine-mouth value has been set as a target for royalty collection, and of this amount 50 percent will be returned to the state.[2] (A portion of the state's share must be expended in the coal-impact area, but we have credited all of it to the state's account.) Using coal prices derived from the nominal case run of the Stanford Research Institute (SRI) model[3] (rising from $7.99/ton in 1975 to $13.71/ton by 2000, in constant dollars), and assuming that all of the coal is obtained through federal leases,[4] royalties shown in Table 4-32 may be expected.

Excise taxes will apply both directly to the energy facilities (a use tax on building materials, whether imported to the state or bought locally) and indirectly (sales tax on the workers' retail purchases). Construction activity will reach a peak in 1980, when

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[1]Bronder, Leonard D. Taxation of Coal Mining: Review with Recommendations. Denver, Colo.: Western Governors' Regional Policy Office, 1976, appendix on Utah.

[2]Bureau of National Affairs. Energy Users' Report, Current Developments No. 129 (January 29, 1976), pp. A-3 through A-4.

[3]Cazalet, Edward, et al. A Western Regional Energy Development Study: Economics, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

[4]Eight-seven percent of the land in these counties is federally owned.

TABLE 4-33: REVENUE FROM SALES AND USE TAXES[a]
(millions of 1975 dollars)

LOCATION	1977	1980	1985	1990
Utah				
State	4.1	14.2	11.3	1.4
Kane County	0.51	1.52	0.11	0.08
Garfield County	0.01	0.26	1.3	0.1
Arizona				
State	0.12	0.58	0.59	0.43
Page	0.02	0.07	0.07	0.05

[a]Distribution of retail sales assumed proportional to population.

$337 million of materials and equipment are installed. At a rate of 4 percent, Utah would gain $13.5 million in use tax revenue that year, and the counties would gain $1.7 million (at a 0.5 percent rate). After the completion of the energy facilities, only the sales tax would continue. The $46 million per year of retail sales[1] would yield $1.4 million for the state of Utah. These revenues are detailed in Table 4-33. Note that Page will not collect a use tax from the plants, only a sales tax from retail activity.

As a final source of revenue, localities can charge for basic services, most notably water and sewer. Taking the Utah average of $74.80 per capita for charges and miscellaneous fees by local government,[2] additional local revenues can be expected as shown in Table 4-34.

All the revenues cited in the preceding analysis are grouped by jurisdiction in Table 4-35 to provide a basis for comparison with expenditures.

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[1]Assuming that 56.0 percent of new personal income goes to taxable purchases. This is the average rate for the mountain states. See U.S., Department of Commerce, Bureau of the Census. The Statistical Abstract of the United States. Washington, D.C.: Government Printing Office, 1975, Tables 1317, 629.

[2]Inferred from University of Utah, Bureau of Economic and Business Research. 1976 Statistical Abstract of Utah. Salt Lake City, Utah: University of Utah, Bureau of Economic and Business Research, 1976, Table VII-8.

TABLE 4-34: GOVERNMENT FEES FOR SERVICES (millions of 1975 dollars)

COUNTY	1977	1980	1985	1990
Kane County	.06	.31	.58	.61
Escalante, Utah	.01	.02	.59	.68
Coconino, Arizona	.07	.32	.39	.42

TABLE 4-35: SUMMARY OF REVENUES FROM ENERGY DEVELOPMENT (millions of 1975 dollars)

LOCATION	1977	1980	1985	1990
Utah State[a]	6.1	20.0	33.6	26.1
Kane County	1.7	8.1	9.5	9.5
Kane School District	1.7	9.3	13.0	13.0
Garfield County	0.0	0.6	8.6	8.8
Garfield School District	0.0	0.6	10.9	13.0
Escalante	0.02	0.05	1.14	1.26
Arizona State	0.12	0.58	0.59	0.43
Arizona Local	0.12	0.53	0.63	0.65

[a]Including funds for discretionary allocation to local units.

As stated earlier, energy development will necessitate an expansion of public services, especially in the areas of education and water and sewage treatment, and thus will require substantial expenditures. In analyzing these requirements, standard accounting procedures were followed; capital and operating expenditures were identified separately. It was assumed, as stated previously, that $2,500 in capital costs will be incurred for each additional student. (School enrollment is the only substantial growth category foreseen in the decade of the 1990's, either in expenditures or revenues.) Other likely capital expenditures include $1,760 per capita for water and sewage facilities and $590 for other items[1] (mostly hospitals and parks). Table 4-36 shows the projected capital requirements of Kane and Garfield Counties resulting from the application of these figures to the appropriate population projections, by 5-year periods.

[1]THK Associates, Inc. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974.

TABLE 4-36: CAPITAL REQUIREMENTS OF LOCAL GOVERNMENTS BY QUINQUENNIA (millions of 1975 dollars)

LOCATION	1976 TO 1980	1981 TO 1985	1986 TO 1990	1991 TO 2000
Kane County	9.8	8.4	1.0	NA
Kane School District	0.8	1.6	0.8	0.3
Garfield School District	0.00	3.2	1.4	0.3
Escalante, Utah	0.59	18.1	2.66	NA
Page, Arizona[a]	10.64	2.53	1.9	NA

NA = not applicable, since no appreciable population increase.

[a]General government and schools.

For operating expenditures, it is assumed that Utah averages will be maintained.[1] The annual operating levels are projected in Table 4-37.

A comparison of these requirements with the previously tabulated revenue projections shows that Utah and many of its local jurisdictions will enjoy substantial, positive fiscal benefits by 1980 if current tax rates are maintained. For example, the Kane School District would receive additional property tax revenues of \$13.0 million per year by 1982, while only \$1.7 million per year in additional operating funds would be needed, even by 1990. The surplus will leave more than enough for the \$3.2 million in capital to be accumulated over the first 15 years. The situation is similar for county governments. The state government will eventually collect about twice as much as is needed for additional services (\$26.1 million per year versus \$12.3 million in 1990 and beyond). In fact, the disparity is even greater in the mid-1980's, when some \$11 million per year will be realized from the use tax on construction materials.

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[1]At \$1,300 per year per student for schools, \$197 per capita for other local functions, and \$645 for state government. See University of Utah, Bureau of Economic and Business Research. 1976 Statistical Abstract of Utah. Salt Lake City, Utah: University of Utah, Bureau of Economic and Business Research, 1976.

TABLE 4-37: INCREASES IN OPERATING EXPENDITURES OF SELECTED LEVELS OF GOVERNMENT (millions of 1975 dollars)

JURISDICTION	1977	1980	1982	1985	1990
Utah State	0.80	3.50	4.80	11.20	12.30
Kane County	0.16	0.82	0.92	1.53	1.61
Kane School District	0.18	0.44	0.77	1.27	1.72
Garfield School District	0.00	0.00	0.68	1.69	2.40
Escalante, Utah	0.02	0.05	0.32	1.57	1.79
Page, Arizona[a]	0.25	0.99	0.94	1.41	1.92

[a]General government and schools.

Municipalities, however, will experience negative fiscal impacts if higher levels of government do not subsidize them. Escalante and Page may be taken as examples of this problem. Excalante's new revenues will just about keep pace with operating expenditures until the mid-1980's, but later deficits will grow to about $530,000 per year ($1.79 million new expenditures versus $1.26 million new revenues). Moreover, Escalante must build new facilities at a rate of $3.62 million per year during 1981-1985 if the current quality of service is to be maintained. Fortunately, the capital requirements will decrease to $0.53 million per year in the late 1980's, and a negligible level thereafter, due to a leveling off of population growth.

Similarly, in Page, Arizona, operating deficits will widen continually, from $0.46 million in 1980 to $0.78 million in 1985 and $1.27 million in 1990.[1] Capital requirements will peak at $2.13 million per year in the late 1970's, decreasing to about $0.45 million through the 1980's.

The disparities between state, county, and municipality revenues arise because the state and county can tax energy developers directly but the municipality can tax only the new population. Counties levy property taxes and use taxes on the facilities; the state receives a share of federal coal royalties, the larger part of sales and use taxes, and an income tax. Thus, their revenues can grow faster than population (and hence costs) without any change in tax rates. However, as long as municipalities rely on population-determined taxes (residential property, utility fees,

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[1]Deficits include both school and general local government.

retail sales), they cannot expand revenues faster than population increases without raising their tax rates.

E. Social and Cultural Impacts

The major sociocultural impact resulting from the Kaiparowits/Escalante development will be a drastic alteration of the dominant lifestyle in the area. At present, communities are small, relatively isolated, and inhabited by persons who have established rural traditions[1] and strong religious beliefs. Residents of the communities are family and extended family oriented. The influx of individuals with different geographical, cultural, and religious origins, higher incomes, and a somewhat more urban perspective will provide a sharp contrast to the present population. Because these new residents will eventually outnumber the present population, changes in the dominant lifestyle will occur.

Religious and value differences could also be problems. The inhabitants of southern Utah are almost exclusively Mormon, whereas a large number of the immigrants will probably not be Mormon. Mormon standards may conflict with immigrant preferences, particularly with regard to intoxicants and smoking. Conflicts from these differences may well arise for immigrant school children. In addition, the evangelistic posture of the Mormon church could have an effect by generating both converts and conflicts. The lack of alternative churches in Utah may make Page a worship center because eight denominations, in addition to the Latter Day Saints, have congregations there.

Dissatisfactions with mobile home living and insufficient social services will produce impacts such as high divorce rates and other indications of community and family stress.[2] One aspect of this stress will be an increased crime rate. However, after construction activity is completed (by 1988), these local problems should decrease significantly.

Although community medical facilities appear capable of meeting projected needs to 1985, adequate medical personnel will

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[1]Minar, David W., and Scott Greer. The Concept of Community: Readings with Interpretations. Chicago, Ill.: Aldine, 1969.

[2]For a further discussion of boomtown problems, see Gilmore, John S. "Boom Towns May Hinder Energy Development." Science, Vol. 191 (February 13, 1976), pp. 535-40; Kneese, Allan V. "Mitigating the Undesirable Aspects of Boom Town Development," in Federation of Rocky Mountain States. Energy Development in the Rocky Mountain Region: Goals and Concerns. Denver, Colo.: Federation of Rocky Mountain States, 1975, pp. 74-76; and Talagan, D.P., and W.E. Rapp. "Mitigation of Social Impacts on Individuals, Families, and Communities in Rapid Growth Areas," in Ibid., pp. 71-74.

be difficult to retain because physicians generally are reluctant to live in isolated, nonmetropolitan areas. The two Utah counties will need 39 physicians by 1990 to meet the national average of one physician per 1,320 population.

Because the population increases in the area will be caused primarily by the energy development activities, a number of "company town" characteristics may develop in area communities. Work schedules, holidays, and vacations might well determine the hours for businesses in these communities, creating an impression of company domination. Company-owned buildings and vehicles will also contribute to this impression, creating resentment among some native residents. The new town near Glen Canyon City will probably show the greatest "company town" tendencies.

F. Political and Governmental Impacts

Population growth and economic development at Kaiparowits/ Escalante, almost of necessity, will increase the role of government in terms of demands for public service and facilities. As shown in the preceding analysis, most of these demands will fall on Kane and Garfield Counties, their localities, and to a lesser degree on Page, Arizona. The state government of Utah likewise will be affected, particularly with regard to legislative policies and programs, tax collection and distribution procedures, and other energy-related problems of statewide planning and growth management.

Immediate governmental impacts will occur as local communities, confronted with or anticipating rapid population increases, demand expenditures to provide essential services. In the case of Kane and Garfield Counties, the bulk of the population is located in the western half of each county. Most of the population increases, on the other hand, will take place in the resource areas, which are in the eastern parts of the area.

Although, as noted in the fiscal analysis, revenues in the two Utah counties will be adequate to provide service improvements, problems may occur relative to the timing and distribution of available tax monies for communities if higher levels of government do not subsidize them. For example, even though Escalante's new revenues appear to keep pace with operating expenditures until the mid-1980's, later deficits expand to $530,000 per year. Furthermore, Escalante must build new facilities at a rate of $3.62 million per year during 1981-1985 if present tax rates are maintained in this community.

The timing problem (i.e., the potential impact of lagging revenues) for localities might be averted if resource developers choose to prepay all or a portion of the taxes anticipated from the facility development and if such monies are distributed to the point of impact. However, as enacted in 1975, the Utah sales and use tax prepayment provision is restricted in several ways.[1] First, it is voluntary on the part of the developer and appears to give no incentive to the developer to prepay (e.g., in the form of discounts or interest on tax credits). Second and more critical to mitigating local impacts are restrictions limiting aid to "state-related public improvements," such as schools and highways. The preceding fiscal analysis shows that the agencies primarily concerned with these projects (e.g., school districts) will manage without such assistance. The problem for state programs is not one of time, for these jurisdictions have surplusses from the start; rather, the problem is that municipalities need help in meeting their front-end financing problems.

In addition to the above limitations, the process of distributing revenues collected through Utah's prepayment statute does not insure that the available funds will reach the point of need in a reliable manner. The Utah legislature is required to approve appropriations for public service projects to be funded, thereby increasing the length of time required for the disbursement of monies and raising the level of uncertainty as to their availability. This is especially significant because the legislature meets only once every 2 years.

There also appears to be some question as to the adequacy of the increased revenues which Page and Coconino County can expect to receive for purposes of service and facility improvements. In Page, Arizona, operating deficits widen continually during 1980-1990. Some fiscal adjustments may be required by the respective local and county governments because Arizona must depend on ad valorem property taxes and assessed valuations connected with population growth and increased sales taxes to finance public improvements.

Fiscal impacts and problems of tax distribution underscore the importance of adequate planning at every level of government. The planning capacity of Kane and Garfield Counties, as previously indicated, is limited. Only Kane County has a zoning ordinance and planning commission, and both staffs are small. The Kaiparowits Planning and Development Council was established to provide the two Utah counties access to additional professional planning expertise. In addition, the state has taken several earlier steps to reinforce the roles and capabilities of local officials by

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[1]Utah Code Annotated, §§ 63-51-1 et seq. (Cumulative Supplement 1975.)

developing a planning and coordination structure to assist localities.[1] Beginning in May 1970, eight multicounty planning districts (since reduced to seven) were established by executive order of the Governor. Members of the designated districts formed Associations of Government (AOG's), with Kane and Garfield joining the Five County AOG in southern Utah. Generally, membership in the Five County AOG is composed of elected city and county officials; however, it includes elected members of the school board and invited representatives of higher education and state legislators to sit ex-officio. The association decides what issues it chooses to deal with, what funds it accepts for these purposes, and whether it will undertake direct operation of programs. The AOG also sends representatives to the Governor's Advisory Council on Local Affairs (GACLA) to coordinate local involvement in the state government planning process.

Besides the GACLA, the governor of Utah has another statewide advisory group, the State Planning Advisory Committee, which seeks to coordinate the responses of state agencies to both federal and local issues and bring state agencies under a common set of priorities and policies.[2] This committee and the multicounty AOG serve additionally as state and area clearinghouses under the federal Office of Management and Budget A-95 review procedures.[3]

As described above, Utah's arrangements and procedures for intergovernmental coordination remain largely untested, at least in terms of the energy-related problems the state confronts in this scenario. Until the scenario unfolds over time, it will remain unknown whether the typical lag between the need for government planning and services and their provision will or will not prevail here. The fact that there is so much federal land in the

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[1]Information on the Utah intergovernmental planning structure is summarized mainly from Utah, State Planning Coordinator and Department of Community Affairs. Intergovernmental Planning and Coordination: The Utah Experience. Salt Lake City, Utah: State of Utah, 1975.

[2]To carry out its duties, the State Planning Advisory Committee has established three interdepartmental coordination groups within three major categories: Human Services, Economic and Physical Development, and Regulatory.

[3]Office of Management and Budget Circular A-95 establishes the requirement for states to provide the opportunity for governors and local officials to comment on applications for federal funds to undertake a variety of categorical programs, and requires agencies of the federal government to consider the comments of the general public in approving specific applications for funds. Numerous federal grants for facilities and services require A-95 review procedures as a condition for their award.

area suggests that proper planning in advance will be even more essential in this scenario than elsewhere.[1] It also suggests that the market for the best land could easily be bid out of reach of all but large, nonlocal interests. Further, the location and status of the Kaiparowits new town will raise numerous issues involving both the state and county governments, as well as federal-state relations.

Besides facility finances, another traditional category of government concern that may be affected by energy resource development is police protection; that is, increases in area crime due to energy-related development and population increase might result in law enforcement problems.[2] However, increases in crime appear to vary greatly from community to community and are not always perceived to be disproportionate.[3] Present law enforcement personnel will be insufficient for the communities likely to be affected, and salary disparities between area law enforcement and energy facility security jobs may result in loss of some community officers to the higher paid positions.

In addition to impacts noted above, energy development at Kaiparowits/Escalante may result in changes for traditional organized interests and could, over the long term, affect the power base of political groups and other parties-at-interest in energy-impacted communities. For example, the change in land use from ranching and tourism to urban, industrial, and residential activities will result in social and political stress in the area. Long-time residents whose way of life, and possibly livelihood, are threatened by energy development could become a political force that might make additional demands on the developers. Although the southern Utah mood is generally prodevelopment, some groups will be affected more adversely than others. Therefore, some political differences appear likely. These may well be exacerbated if, as is likely, newcomers displace natives on the

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[1]For example, police and fire protection and medical care involve important locational and accessibility criteria that must be considered. The unavailability of federal land could constrain such services to very nonoptimal sites if the best sites are either on federal land or are sold for other uses.

[2]Crime rates have often increased in other boom towns. See Coon, Randal C., et al. The Impact of the Safeguard Antiballistic Missile System Construction on Northeastern North Dakota, Agricultural Economics Report No. 101. Fargo, N.D.: North Dakota State University, Department of Agricultural Economics, 1976, pp. 15-16; Gilmore, John S. "Boom Towns May Hinder Energy Development." Science, Vol. 191 (February 13, 1976), pp. 535-40.

[3]Summers, Gene F., et al. Industrial Invasion of Nonmetropolitan America. New York, N.Y.: Praeger, 1976.

governing bodies of city and county governments and in such organizations as Parent Teachers Associations and Chambers of Commerce. If construction-related residents, who are known to be temporary, are perceived to be overly active politically, hostility can result.

4.4.5 Summary of Social and Economic Impacts

Manpower requirements and tax rates, especially those tied to the capital costs of the mine-power plant complexes, are major causes of social and economic impacts. The manpower requirement for the operation of an underground coal mine exceeds the peak construction requirement by four times, but the reverse is true for the power plant. As a result, the manpower requirements for the mine-plant combination build steadily; the maximum number of workers are employed during operation, and no construction peak occurs.

Property tax and sales tax, which are tied to energy facility capital costs, and royalty payments, which are tied to the value of the coal, generate revenue for the state and local government. Capital costs for a power plant-mine combination (two are hypothesized for the Kaiparowits/Escalante area) are about $1,575 million (1975 dollars). The property tax is levied on the cash value of each facility, and the sales tax is levied on the materials and equipment purchased. The current sales tax rate in Utah is 4.75 percent; the property tax rate is about 1.82 percent in Kane County and 1.68 percent in Garfield County. State and local governments will receive 50 percent of the royalty payments which are about 12.5 percent of the value of federally owned coal.

If development at Kaiparowits/Escalante proceeds according to the scenario hypothesized, it will result in an approximate 400 percent population increase in southern Utah (to more than 25 thousand people) by 1990. The largest local increases should occur in Escalante and at the Kaiparowits new town. However, much of the secondary employment personnel will be attracted to Page, Arizona. Housing and school needs will be greatest at Escalante, less at the new town (where the development plan should anticipate demand with several school buildings), and less at Page, where the increase will be fairly gradual and will balance with the downturn in activity from construction of the Navajo power plant.

A long-term impact on the age structure in the area will result, with younger workers and families moving into an area which has recently seen much out-migration by young adults. In the short term, an imbalance of males and females could cause social problems during project construction. The average income in the area will increase by at least 24 percent, and except for Coconino County and Page, governmental revenues will increase. Most of the impacts will occur in the eastern portions of the two counties, the area now least populated. This will intensify the need for planning and delivery of social services, and it may result in some tension between the new population in the east and the natives in the west.

Revenues generated by the development will support the expansion of public services and professional staff required in southern Utah. However, Page will not benefit directly and will suffer a net loss in providing services to the portion of the population increase expected to locate there.

By 1990, most of the negative economic impacts associated with population increases will have been absorbed. From this time forward, economic impacts will be almost entirely beneficial, especially in terms of tax revenues and personal income.

4.5 ECOLOGICAL IMPACTS

4.5.1 Introduction

The area considered for ecological impacts in the Kaiparowits/Escalante scenario extends northward from the Colorado River to include the Aquarius Plateau and Boulder Mountain. The western boundary is the Paria River, and the eastern boundary is the Henry Mountains. Topographically, the area is a series of benches or plateaus, separated by steep cliffs as much as 2,000 feet in height. The entire landscape rises gradually from 4,000 feet in the semiarid benchlands at Glen Canyon Dam to more than 10,500 feet on the relatively moist Aquarius Plateau. Elevational change, with associated rainfall variation of 6 to 20 inches per year, is the major factor determining the distribution of predominant plant communities. Within each community type, soil moisture largely determines the relative abundance of plant species.

4.5.2 Existing Biological Conditions

Biological communities in the Kaiparowits Plateau area are comprised primarily of plants and animals adapted for survival in a harsh, arid or semiarid environment.[1] Nevertheless, these populations fluctuate from year to year in response to climatic variations, especially in the amount of moisture. Slight variations in precipitation can cause major changes in the production of plants; in turn, the levels of plant productivity tend to place a ceiling on the potential abundance of animal life.

The flora of the Kaiparowits Plateau contains a blend of cold and warm desert species, resulting in a diversity of plant

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[1]U.S., Department of the Interior, Southwest Energy Federal Task Force. Southwest Energy Study, Appendix H: Report of the Biota Work Group. Springfield, Va.: National Technical Information Service, 1972, pp. 23-30. PB-232-104.

life. The dominant vegetation types in the immediate vicinity of the postulated energy facilities are pinyon-juniper woodland on the plateau and several desert shrub and grassland communities at lower elevations toward the Colorado River.[1] Some soilless, rocky areas are entirely barren. At the Kaiparowits facility site, pinyon and juniper trees cover up to 62 percent of the surface. Mountains to the north support coniferous forests that consist mostly of Ponderosa pine and Douglas fir.

Animal life is diverse but sparse, probably because accessible water is relatively scarce. Large mammals include mule deer, pronghorn antelope, bighorn sheep, mountain lions, coyotes, foxes, and bobcats.[2] Over 200 species of birds use the area at least seasonally, and about 60 species of smaller terrestrial vertebrates occur, including small mammals, reptiles, and amphibians.[3] The only rare or endangered species known to occur in the area directly affected by the scenario activities is the peregrine falcon, which occasionally appears in the summer.[4] Table 4-38 summarizes characteristic species of the major terrestrial habitat types in the scenario area.

The physical and chemical properties of Lake Powell make it a productive lake with a largely self-sustaining sport fishery. The lake supports about 19 species of fish via a food chain that includes a diversity of algae and invertebrates. The lake is primarily a warm water habitat, and fishes such as largemouth bass are abundant in the upper water layers and shallow bays. Deeper, cooler layers contain trout.

4.5.3 Factors Producing Impacts

Four factors associated with construction and operation of the scenario facilities (two 3,000 MWe power plants and their

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[1] U.S., Department of the Interior, Southwest Energy Federal Task Force. Southwest Energy Study, Appendix H: Report of the Biota Work Group. Springfield, Va.: National Technical Information Service, 1972, pp. 23-30. PB-232 104.

[2] Bighorn sheep occur in the Circle Cliffs area, which is the northern border of the Escalante River Valley.

[3] Some of the small mammals may be important to arid southwest ecosystems. For example, kangaroo rats help maintain nutrient cycles. Chew, R.M., and A.E. Chew. "Energy Relationships of the Mammals of a Desert Shrub (*Larrea tridentata*) Community." Ecological Monographs, Vol. 40 (1979), pp. 1-21.

[4] A colony of the endangered Utah prairie dog is located about 25 miles to the north, and another has been introduced in Bryce Canyon to the west.

TABLE 4-38: SELECTED CHARACTERISTIC SPECIES OF MAIN HABITAT TYPES IN KAIPAROWITS/ESCALANTE SCENARIO

COMMUNITY TYPE	CHARACTERISTIC PLANTS	CHARACTERISTIC ANIMALS
Salt and Desert Shrub and Grasslands	Blackbrush Spiny hopsage Shadscale Rabbitbrush Galleta grass Indian ricegrass	Pronghorn antelope Buffalo Canyon mouse Chukar Horned lark Side-blotched lizard Coyote Badger
Rugged Areas	Same as desert shrub	Bighorn sheep Rock squirrel Bat Birds of prey Mountain lion Bobcat
Pinyon-Juniper Woodland	Utah juniper Double-leaf pinyon Buffaloberry Cliffrose Sagebrush Indian ricegrass Blue grama	Mule deer Desert cottontail Bushytail woodrat Pinyon jay Chickadee Coyote Fox Mountain lion Bobcat
Plateau Coniferous Forest	Ponderosa pine Douglas fir Englemann spruce Aspen Gambel oak	Mule deer Black bear Wild turkey Band-tailed pigeon Beaver Chipmunk species Clark's nutcracker Dipper Coyote Bobcat

associated underground coal mines) can cause ecological impacts: land use, population increases, water use and water pollution, and air quality changes. With the exception of land use, the quantities of each of these associated with one mine-power plant complex were given in previous sections of this chapter. Land-use quantities are given in this section and the others are summarized. Land used by a 3,000 MWe power plant is about 2,4000 acres and by its associated underground coal mine, 1,590 acres.[1] Urban population in the scenario area is expected to increase due to the manpower required for construction and operation of the facilities. During construction, direct employment by one mine-power plant complex peaks at 3,360 workers 7 years after the start. During the operational phase, direct employment is about 6,440 workers. Each facility will demand from 18,000 to 30,000 acre-feet of water per year and contribute contaminants to surface and groundwater only as evaporative ponds leak or erode. In the vicinity of the Kaiparowits plant, ground level ambient air concentrations of SO_2 may be as high as 229 $\mu g/m^3$. In the vicinity of the Escalante plant, annual concentrations of SO_2 are 11.2 $\mu g/m^3$, and 3-hour concentrations are 1,060 $\mu g/m^3$.

4.5.4 Impacts

The nature of the ecological impacts caused by these factors depends on the plant and animal community type on which they are imposed. For example, the impact of land use depends on whether desert shrub, riparian, or pinyon-juniper communities are being used. Figure 4-11 shows the distribution of energy facilities and associated human activities likely to have the greatest impact on ecosystems. Some of these land-use trends are now evident or could occur regardless of energy-related growth. Their extent is directly related to the number of people drawn into the area by energy resource developments. A scenario, which calls for two complexes to be developed according to a specified time schedule (see Table 4-1), is used here as the vehicle through which the extent of the impacts are explored. Impacts caused by land use, population increase, water use and water pollution, and by air quality changes are discussed.

A. To 1980

During the 1975-1980 time period, construction of the Kaiparowits power plant will begin, with the labor force peaking in 1980. Construction activity during most of this time period will be limited to clearing the Kaiparowits plant site, building heavy duty access roads, and laying the plant water line. Table 4-39 shows the expected land use by the proposed energy facilities and urban population in Kane and Garfield counties from 1975-2000. Land use in 1980 by the urban population only (since neither of the plants or mines are completed) totals about 828 acres, approximately equally divided between pinyon-juniper woodland and shrub grassland. Table 4-40 summarizes these habitat losses.

The loss of 414 acres of pinyon-juniper and of salt-tolerant shrub grass land by 1980 (Table 4-40) in the scenario area would

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[1] Includes only that portion of the mine site to be occupied by surface structures.

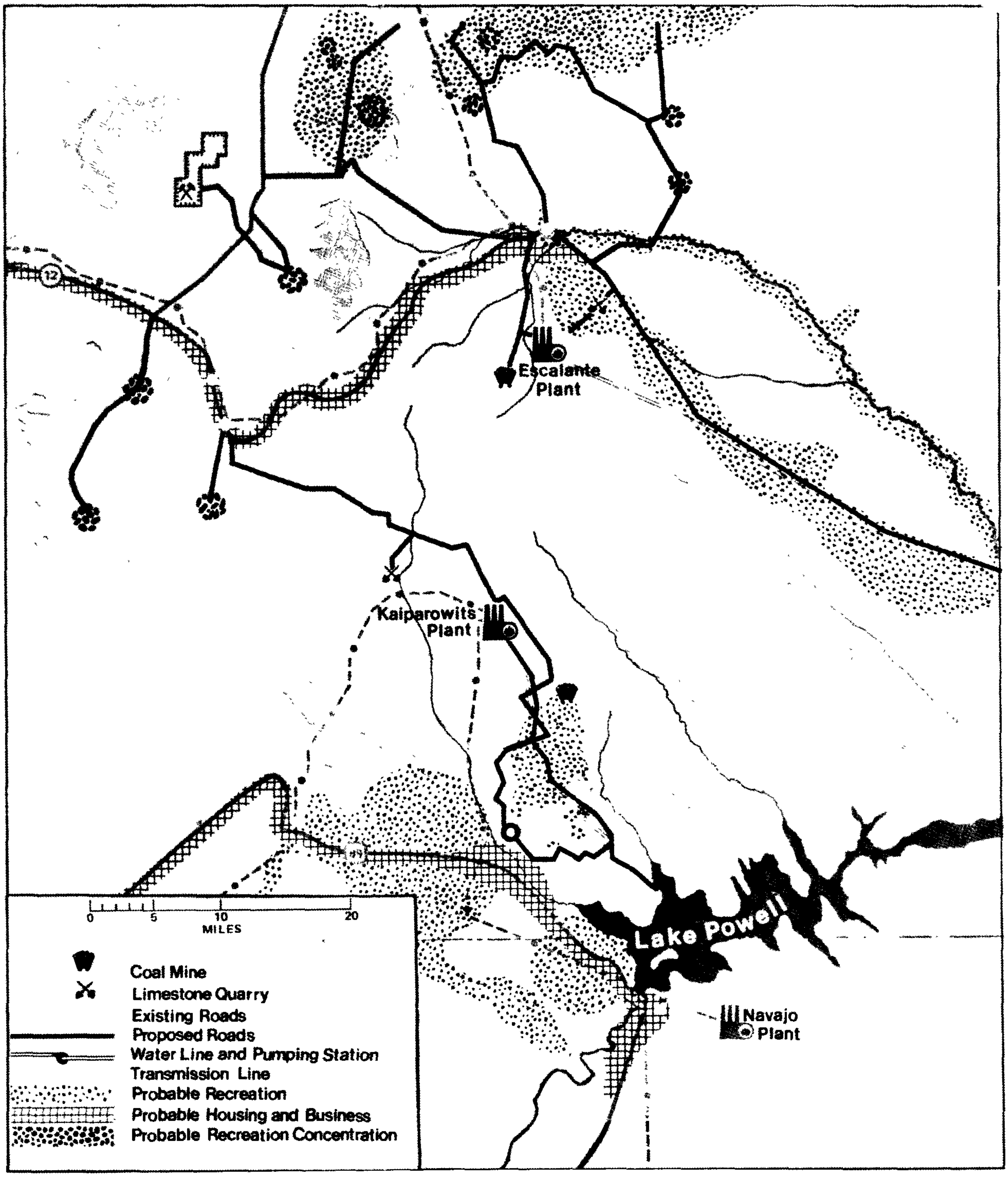

FIGURE 4-11: HUMAN ACTIVITIES IN THE KAIPAROWITS/ ESCALANTE AREA

TABLE 4-39: LAND USE IN KAIPAROWITS/ESCALANTE SCENARIO (acres)[a]

		1975	1980	1990	2000
By Energy Facilities					
1st Power Plant (3,000 MWe)				2,400	2,400
2nd Power Plant (3,000 MWe)				2,400	2,400
Underground Coal Mines (11.2 MMtpy)				1,590[c]	1,590
Underground Coal Mines (11.2 MMtpy)				1,590[c]	1,590
Subtotal				7,980	7,980
By Urban Population[b]					
Kane County					
Residential		165	373	575	603
Streets		33	75	115	121
Commercial		4	9	14	14
Public and Community Facilities		10	23	36	37
Industry		16	37	58	60
Subtotal		228	517	798	835
Garfield County					
Residential		165	224	712	747
Streets		33	45	142	149
Commercial		4	5	17	18
Public and Community Facilities		10	14	44	46
Industry		16	22	71	75
Subtotal		228	310	986	1,035
Subtotal		456	827	1,784	1,870
Total Land Use		456	827	9,764	9,850
Total Land in Scenario Area	5,888,640				
Kane County	2,570,240				
Garfield County	3,318,400				

MWe = megawatt-electric MMtpy = million tons per year

[a]Values in each column are cumulative up to year shown.

[b]Acres used by the urban population were calculated using population estimates in Tables 4-24 and 4-25 for Kane and Garfield counties, respectively, and assuming: residential land = 50 acres per 1,000 population; streets = 10 acres per 1,000 population; commercial land = 1.2 acres per 1,000 population; public and community facilities = 3.1 acres per 1,000 population; and industry = 5 acres per 1,000 population. Adopted from THK Associates, Inc. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974.

[c]Includes only that portion of the mine site to be occupied by surface structures.

TABLE 4-40: HABITAT LOSSES OVER TIME IN THE KAIPAROWITS/ESCALANTE SCENARIO (acres)

TYPE	1980	1990	2000
Pinyon-juniper	414	7,295	7,305
Salt-tolerant shrub grassland	414	1,844	1,844
Plateau conifers		447	447
Ponderosa pine			65
Sagebrush			11
Barren land		178	178
Total:	828	9,764	9,850

eliminate the forage normally utilized in a year by 4 to 5 cows with calves.[1] Normally, these lands are used for only 6 months in the winter or summer. Therefore, the maximum number of cow-with-calf units represented by this loss is 8 to 10. However, not all lands in the scenario area are grazed under the present Bureau of Land Management (BLM) program. Consequently, potential livestock reductions are less than this maximum.

Population increases during this period center in a new town to be built on East Clark Bench; the town is expected to have a population over 3,000 by 1980. Population in Kane County as a whole increases by 56 percent from 1975 to 1980. The higher levels of human activity during this construction phase will cause some local stress to wildlife. For example, increased access to the plateau will result in a significant increase in game poaching, a problem typically observed during construction periods in other western areas.[2] Poaching, together with the present steady downtrend in the Kaiparowits herd, could have measurable effects on total numbers. The new town is located in the range of the East Clark Bench antelope herd, which may ultimately disappear

[1]Carrying capacity for livestock has been assumed to be 10-15 acres of forage per month for a cow and calf in pinyon-juniper rangeland and 18-22 acres of forage per month for a cow and calf in salt-tolerant shrub-grassland.

[2]Unlike legitimate single-sex hunting, which is also likely to increase, poaching takes animals of both sexes and can affect the population's ability to maintain its numbers by reproduction.

from the area through the combined effects of poaching, harassment, and habitat deterioration. These antelope, numbering perhaps 25 or 30, are the remnants of an attempt at reintroduction. However, habitat quality, rather than available area, appears to limit their numbers, and they are expected to decline with or without the development of the new town. Birds of prey are also traditional targets for illegal shooting. The problem of illegal killing will worsen when the Cannonville-Kaiparowits highway is built. In addition, increased recreational demands may be expected and will likely exert their greatest influence on the desert ecosystem below the plateau rim. Extensive areas of the BLM land, which are potentially attractive sites for off-the-road vehicle (ORV) use, lie within easy access of Page and the new town. Heavy use of these areas may eventually result in extensive local erosion and accompanying vegetation loss.[1]

Since neither power plant is operating during this time period, impacts caused by water use or air quality changes are minimal.

B. To 1990

By the end of the second scenario decade, the Kaiparowits and Escalante plants will both be on-line, transmission lines will be built, and population will have risen sharply. Also during this time frame, the limestone quarry to supply the needs of power plant scrubbers will be opened.

In 1990, land use by the energy facilities will be 7,980 acres, and by the urban population, 1,984 acres (Table 4-39). The percentages of land in Kane and Garfield counties used by the energy facilities and by the urban population are 0.14 percent and 0.03 percent, respectively. Habitat loss by 1990 is principally pinyon-juniper woodland with smaller amounts of shrub-grassland, plateau conifers, and barren land, as shown in Table 4-40. The pinyon-juniper habitat supports a wide variety of vertebrate species and constitutes the bulk of the winter range of the Kaiparowits deer herd.[2] Deer are distributed unevenly over the plateau, in small groups which do not fully utilize the habitat available.

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[1]The seriousness of the impact of ORV use will depend on the success of efforts to control it on public lands, the kinds of trails made, and their manner of use. Where a trail is used infrequently and plant roots are not damaged, the vegetation may recover in one season. However, roads which climb slopes at steep angles and break the surface of the soil may begin to gully after about 5 years from infrequent but intense thunderstorms. U.S., Department of the Interior, Bureau of Land Management, Paria Unit Staff. Personal communication.

[2]Utah, Division of Wildlife Resources, Personal communication.

One estimate suggests that the proposed plant site may be used by some 60 deer seasonally, or year-round by roughly 20.[1] The cumulative total loss of pinyon-juniper woodland constitutes roughly 3 percent of the Kaiparowits deer range. Consequently, it is not expected that overall carrying capacity will be significantly reduced. In addition, a total of 1,220 acres of the pinyon-juniper habitat lost in this decade is claimed by transmission line rights-of-way. While vegetation is initially cleared entirely, regrowth in the absence of root competition from trees may be equal or superior to the original vegetation as wildlife forage, especially if the right-of-way is reseeded. This additional productive vegetational discontinuity will probably result in local increase in small vertebrate diversity. The limestone quarry lies adjacent to the range of a healthy antelope herd, but the bulk of the habitat to be disturbed is unsuitable for them.

Agricultural impacts will stem from the loss of grazing land. Excluding transmission line right-of-way, which may be reseeded and recover its grazing value, the 9,149 acres of forage (pinyon-juniper and salt-tolerant shrub grassland) used by the energy facilities and urban population by 1990 (Table 4-40) is equivalent to the yearly forage requirements of 48 to 70 cows with calves.[2] Not all of the land disturbed is normally allotted to grazing; therefore, these numbers are a maximum. Based on 6 month pasturing, this amount of forage might support 95-139 cows with calves.

Population increases during this period may be expected to affect habitat quality. By 1990 the population of Kane and Garfield counties will rise (with respect to 1975 population) 248 percent and 330 percent, respectively. The Kaiparowits new town will have about 7,000 residents in 1990. Page, Arizona, will act as a secondary focus of growth, and will have grown by a cumulative 33 percent by 1990. The town of Escalante will grow from 650 to about 9,700 in this period. These higher populations may be expected to influence habitat quality in a variety of ways. For example, increased traffic on new roads crossing the Kaiparowits Plateau will add to the yearly road kill of animals, especially since the proposed Cannonville-Glen County City highway right-of-way transects the present direction of deer migration. Increased access to the plateau will probably increase the amount of game poaching and extend it to a wider area. Cumulative effects could result in continued decline in deer numbers.

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[1]U.S., Department of the Interior, Bureau of Land Management. Draft Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976.

[2]Carrying capacity for livestock had been assumed to be 10-15 acres of forage per month for a cow and calf in pinyon-juniper rangeland and 18-22 acres in salt-tolerant shrub grassland.

Water for the two plants is pumped from Lake Powell and piped to the plant sites. The municipalities will use groundwater. Both of these withdrawals as well as coal mining within aquifers and discharge of municipal wastewater affect aquatic and terrestrial ecosystems.

Removal of water from Lake Powell for the Kaiparowits project has been predicted to result in salinity increases of roughly 2 mg/ℓ at Imperial Dam.[1] The present scenario would no more than double this effect, which could constitute approximately 0.3 percent of the salinity projected for the year 2000.[2] Thus, the impact of water withdrawal on downstream water use by wildlife will be negligible.

Mining and groundwater withdrawal for municipal use will probably bring about a decrease in discharge to springs and seeps over an unspecified portion of the area. These discharges have a strong influence on the distribution of many kinds of wildlife, such as deer, mourning doves, and numerous small birds and mammals with restricted ranges that require accessible water to sustain life. The cumulative effect on the plateau ecosystem of groundwater losses, depending on the extent to which accessible water sources are affected, will be a combination of redistribution of water dependent species away from depeleted springs or seeps and perhaps a decrease in their overall population.

The loss of water from these sources will be partially mitigated by the addition of surge ponds on the water lines and onsite raw water reservoirs. Reservoirs located in the pinyon-juniper zone might be used by a variety of wildlife, provided that deer-proof fencing is not used. However, these reservoirs will not replace natural springs and seeps that support vegetation. Surge ponds will be located in the desert ecosystem where they will constitute a distinct benefit if not restrictively fenced. Partridge, pheasant, or quail could establish new populations around these ponds, provided other habitat requirements are met.

Treated municipal wastes might be discharged into the Escalante River from the town of Escalante. These wastes usually contain large amounts of nutrients that can stimulate algal growth. The amount of discharge would be insufficient to maintain base

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[1]U.S., Department of the Interior, Bureau of Land Management. Draft Environmental Impact Statement: Proposed Kaiparowits Project, 5 vols. Salt Lake City, Utah: Bureau of Land Management, 1975.

[2]Published estimates range from 1,220 mg/ℓ (BuRec) to 1,340 mg/ℓ (Colorado River Board of California). Note that if water for energy development were instead used for agriculture, runoff from croplands would result in larger increases in downstream salinity.

flow in the dry summer period. Nuisance algal blooms, causing odors and reducing dissolved oxygen, could result if the effluent stagnates in pools. Adverse impacts of this kind would be greatest at periods of low flow.

After the two power plants begin operations, air pollutants of various kinds will enter the atmosphere. Ground-level concentrations of SO_2 are estimated to reach peak 3-hour average values of about 1,060 $\mu g/m^3$ where plume impaction on high terrain may occur (see Section 4.2). This concentration is equivalent to about 0.4 ppm, which is below acute damage levels for those desert plants which have been tested (acute damage has been measured in desert plants typically in the range of 2 to 10 ppm for 2 to 6 hour exposures). More sensitive desert species may exist but have not been tested. The potential for chronic damage may exist but there are insufficient data to support a conclusion. Generally, damage due to acid rainfall is not expected due to the low humidity and limited precipitation, although periods of active plant growth and increased susceptibility to acid rain may be related to the area's rainfall season.

C. To 2000

By 2000 land use by the energy facilities and urban population will total 9,850 acres, less than 0.2 percent of the amount of land in Kane and Garfield counties. Between 1990 and 2000, no additional land is required for the energy facilities themselves; but urban expansion continues to require habitat directly (see Table 4-40), and population increases continue to affect habitat quality indirectly. By 2000, the population of Garfield County and Kane County should more than triple the 1975 population (see Section 4.4). Thus, living space, water, and recreation needs in these counties will lead to both local and areawide changes in land use. ORV use, camping, hiking, and other activities will continue to affect vegetation locally and contribute to erosion. New trails to be developed by the Forest Service to accommodate increased recreational use will provide access to previously isolated areas.

Urban growth around Escalante, Page, and the Kaiparowits new town will result in an increase in ORV recreation on the deserts near Lake Powell. A new road planned to parallel Lake Powell's north shore will open access to new areas. In addition, poaching will continue along roads and near towns, although levels may decline somewhat after the Escalante construction peak. Residential growth will also result in fragmentation of habitat, particularly along highways following river valleys. If allowed to run free, dogs may also affect wildlife in the area.[1] The cumulative effect of these influences will be to reduce the abundance and diversity of wildlife within as much as 5 to 10 miles of residential centers.

Increased populations will add to the recreational pressure placed on the Dixie National Forest and nearby highlands. Major potential impacts include loss of vegetation cover, particularly around lakeshores and streambanks as a consequence of uncontrolled camping and ORV use associated with fishing. Some summer deer range could also be affected. Loss of shore vegetation, if not controlled by restricting use of these areas, can lead to erosion and siltation problems which could lower the production of fish in lakes already under stress from a long-term drying trend. Continuing growth in fishing pressure will, by this decade, have depleted naturally reproducing trout populations, and the fishery will probably be maintained exclusively by stocking. Small parcels of privately owned land within the National Forest are expected to be developed as recreational subdivisions. This change in use will disturb wildlife and tend to fragment winter deer range. Hunting will also increase, but it can be controlled by employing management practices such as setting hunting seasons, limiting the numbers of permits issued, and reducing bag limits. Demand, however, will probably exceed the amount of deer and, perhaps, upland game birds.

Some of the long-term changes which may occur as a result of the handling of wastewater from the power plants are potentially significant. For example, large wastewater impoundments may attract wildlife during dry periods, but it is not likely that animals will prefer the highly polluted water to the clean water in the plant source water reservoirs.[2] Also, materials leached from these ponds may enter groundwater. Although recent evidence suggests that trace metals do not migrate far through soils, some salts, such as sulfates and carbonates, may.[3] The fate of the soluble organic compounds is uncertain. After the facilities are abandoned, the chemicals left in the evaporation ponds may

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[1]Dogs have become a serious concern in some parts of Colorado; a review of the problem, from the sportsman's viewpoint, is given in Oertle, V. Lee. "What's Happening to Western States' Deer Hunting?" _Sports Afield_ (September 1975).

[2]Crawford, James C., and D.C. Church. "Response of Black-Tailed Deer to Various Chemical Taste Stimuli." _Journal of Wildlife Management_, Vol. 35 (November 1971), pp. 210-215.

[3]Holland, W.F., _et al_. _The Environmental Effects of Trace Elements in the Pond Disposal of Ash and Flue Gas Desulfurization Sludge_, Final Report, Electric Power Research Institute Research Project No. 202. Austin, Tex.: Radian Corporation, 1975, p. 3.

eventually enter surface waters from dike failure or erosion. If high concentrations enter the shallow bays of Lake Powell, for example, fish might be killed or avoid the contaminated areas.

Considerable concern has been expressed over the long-term contamination of Lake Powell by trace elements emitted in plant stack gases. For example, mercury can reach the lake from the facilities by direct fallout from emissions and by runoff. Calculations made for mercury deposition from the Kaiparowits plant alone range from 16 to 480 pounds of mercury entering the lake each year. These numbers are 1 to 27 percent of the present estimated rate of addition from natural sources. An unknown fraction of this input is converted to the organic form of mercury and enters the food chain. The emissions from the Escalante plant would contribute additional mercury, although the position of the site makes it likely that the amount would be less than that of Kaiparowits.

There is evidence to suggest that very small increases in mercury entering the aquatic food chain could result in elevations of mercury levels in fish tissues exceeding the limits set by the Food and Drug Administration (FDA) as safe for human consumption. Current levels in some predatory fish in Lake Powell exceed FDA standards of 500 parts per billion. Although based on limited knowledge, the movement of mercury in the form of an elemental vapor from power plant emissions into the aquatic food chain has been estimated to cause increases of 10 to 50 percent, depending on the number of plants, their location, and coal characteristics.[1] These estimates are based on limited data, however.

Arsenic additions from the facilities will deposit an estimated total of between 600 and 5,000 pounds of arsenic per year. Unknown fractions of this would enter Lake Powell. The effects of this amount of arsenic on both terrestrial and aquatic portions of the food chain are largely unknown.

Additional toxic substances will be emitted from the power plants, including about one thousand pounds of fluorides per year.[2] Manganese, chromium, nickel, and lead will be emitted in quantities comparable to the mercury releases. Expected ambient concentrations and effects of these materials on the ecosystem are

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[1]Standiford, D.R., L.D. Potter, and D.E. Kidd. Mercury in the Lake Powell Ecosystem, Lake Powell Research Project Bulletin No. 1. Los Angeles, Calif.: University of California, Institute of Geophysics and Planetary Physics, 1973, p. 16.

[2]U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 Vols. Salt Lake City, Utah: Bureau of Land Management, 1976, p. III-65.

TABLE 4-41: SUMMARY OF MAJOR FACTORS AFFECTING ECOLOGICAL IMPACTS

	1975-1980	1980-1990	1990-2000
Class A Impacts:	Increased recreational use of high plateaus Illegal shooting	Increased recreational use of high plateaus Illegal shooting	Increased recreational use of high plateaus
Class B Impacts:	Damage and harassment associated with ORV's in desert areas, habitat fragmentation, land-use, road kill, and harassment (urban influence) zone	Damage and harassment associated with ORV's in desert areas, urban influence, altered springs and seep discharge	Damage and harassment associated with ORV's in desert areas, urban influence, altered springs and seep discharge
Class C Impacts:	Direct habitat removal Grazing losses	Direct habitat removal Grazing losses "Criteria" air pollutant emissions Local eutrophication of Escalante River by municipal sewage discharge	Direct habitat removal Grazing losses "Criteria" air pollutant emissions
Unknown:		Addition of mercury and other trace elements to Lake Powell	Addition of trace elements to Lake Powell

ORV = off-the-road vehicle

largely unknown. Much larger quantities of the materials will either be removed from stack gases and deposited in the evaporative settling ponds or placed in ash disposal sites.

4.5.5 Summary of Ecological Impacts

Table 4-41 summarizes the impacts discussed in the preceding sections under three classes. Class C impacts are those which affect very small proportions (less than 3 percent) of the total available habitat of any given kind, and/or occur infrequently, although the effect may be locally severe. Class B impacts are more widespread and have effects which may noticeably alter the composition of the ecosystem or selectively affect a particular species. Class A impacts can potentially affect large proportions of a given habitat type or have severe impacts on populations of one or more species.

The cumulative impact of energy resource development on the ecosystem will most likely be to lower the diversity of wildlife locally, increase erosion, and contribute to the decline of several species. Specific populations of game animals and fish will experience selectively heavy stresses and decline in number. These impacts will result from the combined effects of direct habitat loss, habitat fragmentation, and diffuse human disturbances. Impacts on several major species are summarized in Table 4-42. Major contributors to these disturbances will include the following: habitat degradation in such areas as the high plateaus due to diffuse recreational activity; subdivision of lands for recreational developments; growth of residential and commercial land use and its influence on the quality of surrounding habitat; increased illegal hunting; and increased fishing in high plateau lakes.

Although these disturbances will not break down the structural and functional integrity of the ecosystems, local areas will probably experience internal adjustments affecting individual species populations. For example, development activities and anticipated increases in sport hunting for predators may minimize the importance of the mountain lion as a natural predator of mule deer, but coyotes (and possibly wild dogs) will assume greater importance as predators.

Cumulative adverse influences are also expected to result in a long-term decline of the Kaiparowits deer herd and probably will hasten the loss of antelope from East Clark Bench.[1] Illegal shooting could, over the long term, cause declines in populations of the larger birds of prey. Aquatic ecosystems in the Dixie National Forest may also be locally degraded unless access is controlled; this stress, coupled with heavy fishing pressure, will have a severe impact on resident reproducing trout populations.

With the introduction of the energy facilities and projected population increase of approximately 40,000 people, some long-term alterations of vegetation may occur on a local scale.

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[1]The influence of the scenario's impacts on habitat in the Dixie National Forest and on the benchlands just east of the Escalante River could render them less suitable or unsuitable for reintroduction of elk and antelope, now under consideration by the Utah Division of Wildlife Resources.

TABLE 4-42: FORECASTS OF POPULATION STATUS OF MAJOR SPECIES FOR THE KAIPAROWITS/ESCALANTE SCENARIO

	1980	1990	2000
Game Species			
Mule Deer	Slight aggravation of present decline in Kaiparowits Plateau herd unit due to poaching.	Continued low numbers on Kaiparowits Plateau due to combined influence of poaching, road kills. Slight decline in Boulder Mountain herd unit from increased access, poaching, habitat fragmentation.	Probable stabilization of both Kaiparowits and Boulder Mountain populations.
Antelope	Severe decline and possible loss of East Clark Bench herd.	Loss of East Clark Bench herd, other populations essentially unaffected.	No further change.
Bighorn sheep	Possible increase in numbers if Circle Cliffs introduction is successful.	Redistribution of sheep away from Lake Powell into side canyons. Increase in total numbers if reintroduction program continued.	Probable stabilization of distribution patterns; possible continued increase in overall numbers through natural reproduction as unexploited habitat is filled.
Buffalo	Potential losses from illegal shooting.	Continued illegal shooting pressure. If not controlled, could result in overall decline in Henry Mtns. herd.	Probable stabilization with cessation of construction activities.
Turkey	Little change; mortality from road-kill will be insufficient to reduce reproductive potential.	Slight to moderate increase due to forestry practices.	Stabilization or continued slight uptrend related to forest management.
Pheasant, Quail, Chukar	Slight reduction due to increased hunting pressure.	Possible new local populations near water line surge ponds, if adequate cover nearby, probably balanced by losses due to feral cats, habitat loss, hunting, for overall downtrend.	Continued downtrend.
Brook and rainbow trout (Aquarius Plateau and Boulder Mountain)	Decline of naturally reproducing populations of high plateaus.	Probable elimination of many naturally reproducing lake populations; overall decline unless stocking rate increased.	Continued decline, possibly worsened by habitat deterioration due to natural drying and erosion if lakeshores are not protected.
Rare or Endangered Species			
Peregrine falcon (occasional)	Potential loss of individuals from illegal shooting.	Potential loss of individuals from shooting	No further change.
Indicators of Attrition of Remote Habitats			
Mountain Lion	Slight to moderate decline through legal and illegal hunting.	Continued decline resulting in range contractions into the most inaccessible and rugged areas.	Reduction of mountain lion to small numbers occupying restricted ranges in the Circle Cliffs, Fiftymile Mountain, perhaps other rugged areas.
Dipper	Little change.	Decline in numbers along streamcourses used as access by hikers, or followed by trails.	May become very infrequent or absent from popular hiking, fishing areas.

[a] In this table, it has been assumed that natural population regulators such as disease, variations in forage production, and drought, remain roughly constant. Forecasts reflect scenario impacts alone.

Many of the immediate and direct impacts of construction activities and facility siting will probably have only short-term effects; other impacts may have more lasting effects. Some plant communities will be disrupted by immediate stresses and will undergo plant replacement or succession. Succession is not well understood in desert plant communities, perhaps because of the very long time required for change.[1] A series of successional stages will probably occur on those sites directly disrupted by energy development and damaged by ORV use and subsequent erosion, and their return to a climax stage of development may take many years.[2]

One potential long-term effect from energy development on future ecological systems may come from eventual accumulation of trace elements emitted from the power plants and entering the aquatic food chain in Lake Powell. However, incomplete understanding of the dynamics of the movements of trace elements (e.g., mercury) into and through the ecosystem make it difficult to predict the potential concentration in fish, although some studies indicate potentially significant increases. Also, the degradation of dikes enclosing the waste materials deposited in evaporation ponds may allow release of toxic compounds which will eventually enter the biological components of the ecological system.

Opening the area by providing easier access will be considered a benefit by some groups and a detriment by others. The wilderness character of the area will be largely lost; however, larger numbers of people will have access to the recreational and scenic benefits of the area.

4.6 OVERALL SUMMARY OF IMPACTS AT KAIPAROWITS/ESCALANTE

A major benefit resulting from the hypothetical energy development called for in the Kaiparowits/Escalante scenario will be the production of 6,000 MWe of electricity. This benefit will accrue more to people outside than inside the areas. Locally, the principal potential benefits are economic, including substantial increases in per capita income, retail and wholesale trade, and secondary economic development. In addition, Kane and Garfield Counties can receive substantial new tax revenues, and the

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[1]On dune sands in Idaho, a situation somewhat analogous to a desert, Chadwick and Dalke recognized five stages of succession: Stage 1 lasting about 30 years; Stage 2 lasting 20 to 70 years; Stage 3 lasting 50 to 70 years; and Stage 4 lasting 700 to 900 years before the final or climax stage becomes dominant. Chadwick, H.W., and P.D. Dalke. "Plant Succession on Dune Sands in Fremont County, Idaho." Ecology, Vol. 46 (Autumn 1965), pp. 765-780.

[2]Whitfield, C.J., and H.L. Anderson. "Secondary Succession in the Desert Plains Grassland." Ecology, Vol. 19 (April 1938), pp. 171-80.

state of Utah could benefit noticeably. These financial benefits can support the expansion of public services and professional staffs presently needed in southern Utah. Some persons, both locals and tourists, will consider new roads in previously inaccessible areas to be a benefit.

The impact analysis indicates that social, economic, and political impacts which could be expected in the Kaiparowits/Escalante area as a result of energy resource development tend to be a function of: the labor and capital intensity of the energy facilities and, when multiple facilities are involved, of scheduling their construction. These factors determine the pace and extent of migration of people to the scenario area as well as the financial and managerial capability of local governments to provide services and facilities for the increased population. Labor forces required for construction and operation of the scenario facilities increase the population in the scenario area directly and indirectly. More labor is required for construction of the facilities than for operation; thus, construction of the facilities can be scheduled to minimize the population instability. The capital intensity of the facilities determines the amount of revenue generated; a property tax and sales tax are tied to the capital costs of the facilities, and royalty payments are tied to the value of the coal. At the Kaiparowits/Escalante site, towns are small, a factor that tends to exacerbate negative impacts associated with population increases. If some of the labor force includes young people who had previously migrated out of the area as well as local unemployed laborers, population increases would not be as great nor would they include as many strangers to the community. Utilization of the local labor force mitigates negative social and political impacts.

Many of the major negative impacts that can be anticipated if all the energy facilities are constructed according to the hypothesized time schedule will result either directly or indirectly from the expected 300 percent population increase for southern Utah by 1990. Some local governments will be hard-pressed initially to provide the services required. Existing school, housing, health, and public safety services will be initially overwhelmed by the influx of workers and their families. Local governments in the area are generally not well-equipped to respond to the needs of this new population. However, planning capabilities are being upgraded, and the adequacy of existing controls, such as zoning, is now being assessed. These problems are surmountable, and the economic impacts of population increases will be predominantly positive by 1990. With the exception of Page, long-term revenues produced by the development will be more than adequate to pay for the necessary services and the required additions to the professional staffs of local governments.[1] Since it will not share in the direct tax revenues produced by the energy facilities, Page will subsidize services to those workers and their families who choose to live there.

Newcomers could outnumber natives very early during the development. As indicated in the social and cultural impacts discussion, the lifestyles of the natives and newcomers are likely to be quite different. While small in terms of numbers, at least some of the natives will consider the resultant political and social changes detrimental.

Air quality impacts of energy development in the Kaiparowits/ Escalante area result from emissions of pollutants from both the power plant and those associated with the population. At the Kaiparowits/Escalante site, SO_2 emissions from a power plant with no emission controls would meet the NSPS for SO_2 because coal in the Kaiparowits/Escalante area has a low sulfur content (0.5 percent). However, the complex terrain and poor dispersion potential characteristic of the scenario area would contribute to high ground-level concentrations of pollutants as a consequence of plume impaction. Even with emission control, the Escalante plant may produce air impacts which exceed significant deterioration standards for a Class II area. Visibility will also be adversely affected, especially during winter stagnation periods. Given the extensive recreational use of the area, particularly in the numerous nearby national parks and forests, this impact must be considered significant.

Power plant scrubbers are rated as 80 percent efficient in removing SO_2 in this analysis. However, scrubbers with 95 percent efficiency would be required to insure that no violation of Class II SO_2 standards occurs. Elimination of scrubbers would result in significant violations of anticipated nondegradation air quality standards and would violate short-term (3-hour and 24-hour) primary and secondary air quality standards.

Water impacts associated with energy development in the Kaiparowits/Escalante area are caused both by the water requirements of, and effluents produced by a power plant. Water related impacts associated with population increases are minor in comparison to those associated with a power plant. Since most of the water use by a power plant is for cooling, impacts which result from water consumption can be reduced greatly by the use of "intermediate wet" (a combination of wet and dry) cooling technology. Effluents from the facilities will be ponded to protect water

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[1]There might be problems due to a lag between the need to provide services and receipt of income. However, this problem is lessened by Utah's law permitting local governments to require the prepayment of taxes.

quality in the scenario area. However, the large withdrawals of water from Lake Powell may have a salt concentrating effect on the Colorado River.

Ecological impacts associated with energy development in the Kaiparowits/Escalante area depend on land use, population increases, water use and water pollution, and air quality changes. Loss of habitat on land used by facility structures and by the population is permanent. Habitat fragmentation and recreational activities will further reduce the carrying capacity of the characteristic community types (desert shrub grassland, desert grassland, and pinyon-juniper woodland) to support wildlife, both game and non-game animals. Reduced stream flow due to water withdrawn for energy development will reduce the amount of aquatic and riparian habitat, which is already very limited in the area. In addition, inadequately treated municipal sewage could cause excessive plankton growth. Additions of mercury into the Lake Powell ecosystem will exacerbate the problem of current mercury concentrations in some predatory fish which exceed the FDA standards. Finally, chronic or acute damage to crops and native plants in the scenario area may result due to poorly dispersed SO_2 emissions from the power plants.

CHAPTER 5

THE IMPACTS OF ENERGY RESOURCE DEVELOPMENT AT THE NAVAJO/FARMINGTON AREA

5.1 INTRODUCTION

Energy development proposed in the Navajo/Farmington area includes coal mining, electrical power generation, Lurgi and Synthane high-British thermal unit (Btu) gasification, Synthoil liquefaction, an underground uranium mine, and a uranium mill. The area within which development is to take place is shown in Figure 5-1; Figure 5-2 shows the location of specific facilities. Electricity generated in the area will be transported via extra-high voltage transmission lines to demand centers in Arizona, California, and New Mexico. The synthetic gas will be fed into existing pipeline networks in the Southwest, and the synthetic liquids will be pipelined to western and/or midwestern refineries. These facilities will be constructed between 1977 and 2000. The construction timetable and the technologies to be deployed are shown in Table 5-1.[1]

In all four impact sections of this chapter (air, water, social and economic, and ecological), the factors that produce impacts are identified and discussed separately for each energy facility type. In the air and water sections, the impacts caused by those factors are also discussed separately for each facility type and, in combination, for a scenario in which all facilities are constructed according to the scenario schedule. In the social and economic and ecological sections, only the combined impacts of the scenario are discussed. This distribution is made because social, economic, and ecological effects are, for the most part, higher order impacts. Consequently, facility-by-facility impact discussions would have been repetitive in nearly every respect.

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[1]While this hypothetical development may parallel developments proposed by the Public Service Company of New Mexico, Utah International, Inc., Western Gasification Company, Consolidation Coal Company, El Paso Natural Gas Company and others, it must be stressed that the development identified here is hypothetical. As with the others, this scenario was used to structure the assessment of a particular combination of technologies and existing conditions.

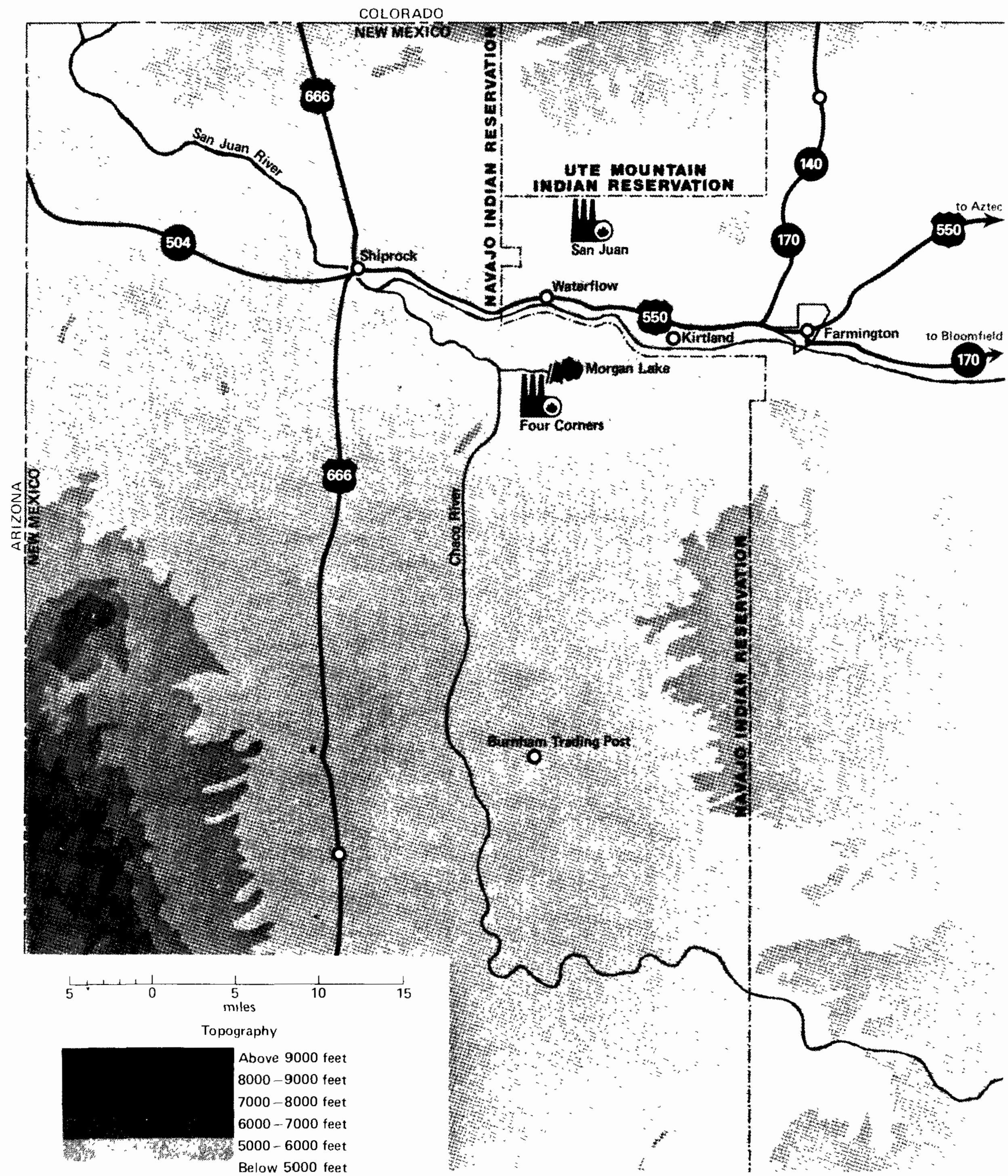

FIGURE 5-1: THE NAVAJO/FARMINGTON SCENARIO AREA

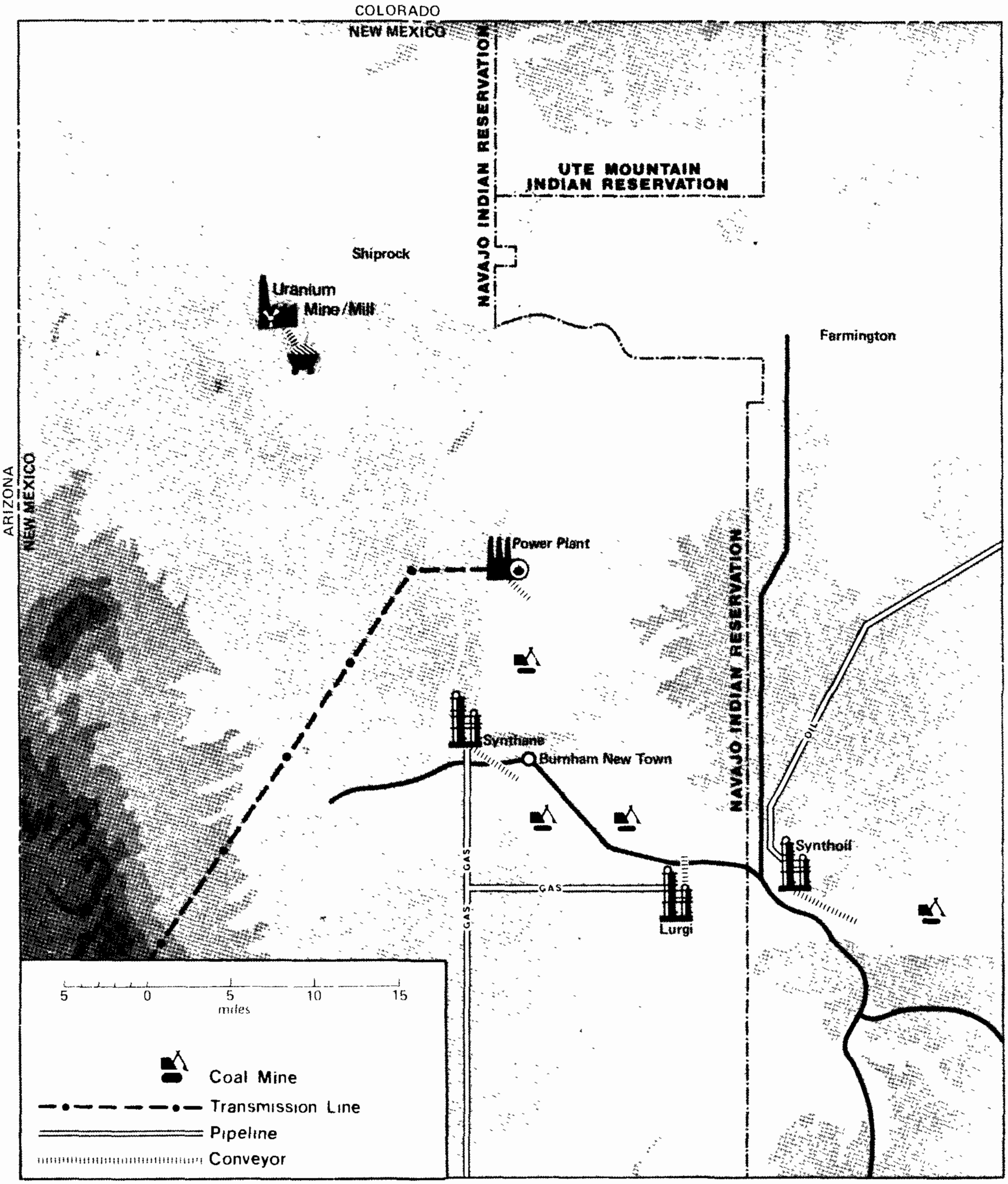

FIGURE 5-2: THE LOCATION OF ENERGY DEVELOPMENT FACILITIES IN THE NAVAJO/FARMINGTON AREA

TABLE 5-1: RESOURCES AND HYPOTHESIZED FACILITIES AT NAVAJO/FARMINGTON

Resources	CHARACTERISTICS		
Coal[a] (billions of tons)	Coal		
Resources 2.4	Heat Content	8,580 Btu's/lb	
Proved Reserves 1.9	Moisture	16 %	
	Volatile Matter	30 %	
	Fixed Carbon	34 %	
	Ash	19 %	
	Sulfur	0.7 %	

Technologies	FACILITY SIZE	COMPLETION DATE	FACILITY SERVICED
Extraction			
Four surface area mines of varying capacity using draglines	7.3 MMtpy	1979	Lurgi Plant
	12.2 MMtpy	1984	Power Plant
	6.6 MMtpy	1989	Synthane
	12.2 MMtpy	1989	Synthoil
One underground uranium mine	1,100 mt	1985	Uranium Mill
Conversion			
One Lurgi coal gasification plant operating at 73% thermal efficiency; nickel-catalyzed methanation process; Claus plant H_2S removal; wet forced-draft cooling towers	250 MMscfd	1980	
One 3,000 MWe power plant consisting of four 750 MWe turbine generators; 34% plant efficiency; 80% efficient limestone scrubbers; 99% efficient electrostatic precipitator; and wet forced-draft cooling towers	1,500 MWe	1984	
	1,500 MWe	1985	
One Synthane coal gasification plant operating at 80% thermal efficiency; nickel-catalyzed methanation process; Claus plant H_2S removal; wet forced-draft cooling towers	250 MMscfd	1990	
One Synthoil coal liquefaction plant operating at 92% thermal efficiency; Claus plant H_2S removal; wet forced-draft cooling towers	100,000 bbl/day	2000	
One Uranium Mill	1,000 mt	1985	
Transportation			
Coal			
Conveyor belts from mines to each facility			
Gas			
One 30-inch pipeline	250 MMcf	1980	Lurgi Plant
Oil			
One 16-inch pipeline	100,000 bbl/day	2000	Synthoil
Electricity			
Two EHV lines	765 kV	1984	Power Plant

Btu's/lb = British thermal units per pound
MMtpy = million tons per year
mt = metric tons
MMscfd = million standard cubic feet per day
H_2S = hydrogen sulfide
MWe = megawatt-electric
bbl/day = barrels per day
MMcf = million cubic feet
EHV = extra-high voltage
kV = kilovolts

[a]Nielsen, George F. Keystone Coal Industry Manual: 1974. New York, N.Y.: Mining Information Service, 1974, p. 477; proved reserves are calculated as 80 percent of the defined resources. Values are for strippable coal from the Navajo field.

In addition to this hypothetical energy development, the Navajo Indian Irrigation Project will become operational during the late 1970's. Because of its size, this development is also taken into account when impacts are analyzed.

Two distinctive cultures are found in the Navajo/Farmington area: the Indian culture centered on the Navajo Reservation, and the predominantly non-Indian culture centered in Farmington and Aztec. A similar division exists in the economy of the area.

San Juan County's non-Indian economy is diversified among several sectors of activity. Wholesale and retail trade, government, transportation and communications, mining, manufacturing, and agriculture are among the principal employers within the county. The Indian economy is predominantly agricultural.

The county is governed by a three-member board of commissioners and served by a professional manager. In 1975, a Planning and Research Department was established, primarily to assess and respond to needs arising from new developments within the county.

Services provided in the unincorporated sections of the county include police (a sheriff's department), fire (provided jointly with the state), and highway construction and maintenance. Public health care and public assistance are provided jointly by the county and state.

There are three incorporated urban areas in the county: Farmington, Aztec, and Bloomfield. Basic public services are provided in all three, and a separate school district serves each. Farmington's municipal power plant provides electricity to these communities and the rural area. The communities are comparatively isolated in northwest New Mexico, despite a history of continued growth and the widespread construction of permanent masonry buildings. No rail line services this area, and the principal highways serving the region are winding, two lane roads that make movement of large equipment and building materials difficult. Although historically conservative, Farmington and surrounding communities are nevertheless currently involved in expanding government services to improve water supplies, sewage treatment, airport facilities, and other municipal and county projects.

Although there are many unresolved questions concerning relationships between Indians and non-Indians (the applicability of state laws to Indians, the applicability of Indian laws to non-Indians, etc.), the Navajcs and Utes maintain local sovereignty over their reservation lands. The Navajo Reservation, on which several energy facilities will be located, is governed by a Tribal Council.[1] Members of the Council are elected from Chapters into which the Reservation is divided. A Chairman of the Tribal Council is elected at large.

Within the past few years, the Navajos have expanded the capabilities of the tribal government, largely in direct response to prospective energy development. For example, the Council is now served by a professional planning staff, and environmental and tax commissions have been established.

The reservation is predominantly rural. Shiprock, the only urban area in the New Mexico portion of the reservation, is unincorporated and governed by the Tribal Council.

The area to be developed is in the San Juan River Basin. The San Juan, one of several perennial streams in the area, will be the source of water for the proposed energy facilities. Although there is groundwater in the area, it is limited in quantity and generally of poor quality.

Rainfall averages only about 7 inches per year. This limits the amount and variety of vegetation, and the area contains mostly desert grasslands and shrubs. In some locations, overgrazing by Navajo-owned sheep has led to elimination of vegetation and serious soil erosion.

Air quality in the area is already affected by the San Juan and Four Corners power plants, refineries, and a variety of industrial facilities. Blowing dust also affects existing air quality. Selected descriptive characteristics of the area are summarized in Table 5-2. In each of the following sections, additional information is introduced as needed in the analysis of impacts.

5.2 AIR IMPACTS[2]

5.2.1 Existing Conditions

A. Background Pollutants

Air quality in the Navajo/Farmington area is currently affected by numerous emission sources, the largest of which are

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[1]Price, Monroe E. <u>Law and the American Indian</u>. Indianapolis, Ind.: Bobbs-Merrill, 1973; and Cohen, Felix S., ed. <u>Statutory Compilation of the Indian Law, Survey</u>. Washington, D.C.: Government Printing Office, 1940.

[2]The federal standards referred to in this section are those promulgated prior to the revisions mandated by the Clean Air Act Ammendments of 1977, Pub. L. 95-95, 91 Stat. 685.

TABLE 5-2: SELECTED CHARACTERISTICS OF THE NAVAJO/FARMINGTON AREA

Environment	
Elevation	6,000-9,000 feet
Precipitation	6-8 inches average annually
Air Stability	Air stagnation during fall and winter
Vegetation	Sparse grasses and shrubs with barren areas, pinyon and juniper in foothills
Social and Economic (San Juan County)	
Land Ownership	
Indian	60 %
Federal	30 %
State	5 %
Private	5 %
Population Density	11.3 per square mile
Unemployment[a]	8.2 %
Income[b]	$3,147 per capita annual

[a]1973 data.

[b]1972 data.

the Four Corners and San Juan Power Plants (Figure 5-1). Measurements of the concentrations of criteria pollutants[1] taken in 1974 in the Four Corners area indicate that 24-hour average particulate levels exceed both federal and New Mexico standards

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[1]Criteria pollutants are those for which ambient air quality standards are in force: carbon monoxide, nonmethane hydrocarbons (HC), nitrogen dioxide, oxidants, particulates, and sulfur dioxide. Although only nonmethane HC are technically covered by the standards, the more inclusive term "hydrocarbons" is generally used. The HC standard serves as a guide for achieving oxidant standards.

due to blowing dust.[1] However, measurements taken at the site of the proposed Western Gasification Company gasification plants[2] do not indicate violations of either particulate or sulfur dioxide (SO_2) standards. Based on measurements, the annual average background levels chosen as inputs to the air dispersion model are: SO_2, 20 micrograms per cubic meter ($\mu g/m^3$); particulates, 40 $\mu g/m^3$; and nitrogen dioxide (NO_2), 10 $\mu g/m^3$.[3]

B. Meteorological Conditions

The worst dispersion conditions for the Navajo/Farmington area are associated with stable air conditions, low wind speeds (less than 5-10 miles per hour [mph]), unchanging wind direction, and relatively low mixing depths.[4] These conditions are likely to increase concentrations of pollutants from both ground level and elevated sources. Since worst-case dispersion conditions differ

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[1]Utah Engineering Experiment Station. Air Pollution Investigation in the Vicinity of the Four Corners and San Juan Power Plants, Progress Report. Salt Lake City, Utah: March 1973, and amended by letter January 1974. As cited in U.S., Department of the Interior. Draft Environmental Statement for Proposed Modification of Four Corners Power Plant and Navajo Mine. Washington, D.C.: Government Printing Office, 1975.

[2]U.S., Department of the Interior, Bureau of Reclamation. Western Gasification Company (WESCO) Coal Gasification Project and Expansion of Navajo Mine by Utah International Inc., New Mexico: Final Environmental Statement, 2 vols. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1976.

[3]These estimates are based on the Radian Corporation's best professional judgment. They are used as the best estimates of the concentrations to be expected at any particular time. Measurements of hydrocarbons (HC) and carbon monoxide (CO) are not available in the rural areas. However, high-background HC levels have been measured at other rural locations in the West and may occur here. Background CO levels are now assumed to be relatively low. Measurements of long range visibility in the area are not available, but the average is estimated to be 60 miles. Others have estimated background visibility at 70-100 miles. See Nichelson, R. Progress Report, New Mexico Visibility Study. Santa Fe, N.M.: New Mexico, Environmental Improvement Agency, n.d.

[4]Mixing depth is the distance from the ground to the upward boundary of pollution dispersion.

at each facility location, predicted annual average pollutant levels vary among locations, even if the pollutant sources are identical. Meteorological conditions in the area are generally unfavorable for pollution dispersion more than 40 percent of the time. Hence, plume impaction and limited mixing of plumes caused by temperature inversions at plume height can be expected to occur regularly.[1] Good dispersion conditions are expected to occur about 30 percent of the time.[2]

As at most western sites, the potential for dispersion of pollutants in the Navajo/Farmington area varies considerably by season. During spring and summer, strong low-level winds (15-25 mph) enhance dispersion potential. During winter months, dispersion potential is often limited because of persistent high pressure areas near the surface over the Colorado River Plateau.

5.2.2 Factors Producing Impacts

The primary emissions sources in the Navajo/Farmington scenario are a power plant, three synthetic fuels conversion facilities (Lurgi, Synthane, and Synthoil), supporting surface coal mines, an underground uranium mine and mill, and population increases. The focus of this section is on emissions of criteria pollutants from the energy facilities.[3] Table 5-3 lists the amounts of the five criteria pollutants emitted by each of the facilities. In all cases, most emissions come from the conversion facilities rather than the mines. Most mine-related pollution originates from diesel engine combustion products, primarily nitrogen oxides (NO_x), hydrocarbons (HC), and particulates. Although dust suppression techniques are hypothesized to be used

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[1]See National Climatic Center. Wind Dispersion by Pasquill Stability Classes, Star Program for Selected U.S. Cities. Ashville, N.C.: National Climatic Center, 1975.

[2]Jordan, R.A. Joint Ambient Air Monitoring Project, Interim Report. Alburquerque, N.M.: Public Service Company of New Mexico, September 1973, and amended January 1974. As cited in U.S., Department of the Interior. Draft Environmental Statement for Proposed Modification of Four Corners Power Plant and Navajo Mine. Washington, D.C.: Government Printing Office, 1975.

[3]Air impacts associated with population increases are discussed forward (Section 5.2.3) as those impacts relate to the scenario, which includes all facilities constructed according to the hypothesized schedule.

TABLE 5-3: EMISSIONS FROM FACILITIES[a]
(pounds per hour)

FACILITIES[b]	PARTICULATES	SO_2	NO_x	HC	CO
Electrical Generation[c]					
Mine	17[d]	11	144	17	87
Plant	5,020	9,760	18,900--31,500[e]	524	1,744
Lurgi					
Mine	8[d]	5	68	8	41
Plant	N	516	649	47[f]	N
Synthane					
Mine	7[d]	5	63	7	38
Plant	8	3,524	5,052	94[f]	176
Synthoil[g]					
Mine	10[d]	7	92	11	56
Plant	1,254	1,171	5,770	1,688	227
Uranium					
Underground Mine	0.16	0.36	5	0.5	3
Mill	40	1.03	0.3	0.05	U

SO_2 = sulfur dioxide
NO_x = oxides of nitrogen
HC = hydrocarbons
CO = carbon dioxide
N = negligible
U = unknown

[a]These levels of emissions would violate several New Mexico State New Source Performance Standards.

[b]The Lurgi and Synthane gasification plants are 250 million standard cubic feet per day facilities with three emissions stacks at each plant. The Synthoil plant produces 100,000 barrels per day and has 24 stacks. White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[c]Assuming 99 percent electrostatic precipitators efficiency and 80 percent SO_2 scrubber efficiency. The SO_2 scrubber is also assumed to remove 40 percent of NO_x.

[d]These particulate emissions do not include fugitive dust.

[e]Range represents emissions assuming 0 and 40 percent NO_x removal by scrubbers.

[f]These emissions do not include fugitive HC.

[g]Synthoil data have a high uncertainty because of the small capacity of bench scale test facilities built to date. The Solvent Refined Coal liquefaction process now appears likely to become commercial sooner, and more reliable pilot plant data are available. These data are reported in White et al. Energy From the West: ERDS Report, Chapter 3.

in this scenario, some additional particulates will come from blasting, coal piles, and blowing dust.[1]

The largest single contributor to total emissions is the power plant for all pollutants except HC, in which case the Synthoil plant has the largest emissions (Table 5-3). For all criteria pollutants except carbon monoxide (CO), the Lurgi plant has the smallest total emissions.

The hypothetical power plant, for which data in Table 5-3 were calculated, has four 750 megawatt-electric (MWe) boilers, each with its own stack.[2] The boiler is equipped with an electrostatic precipitator (ESP) which removes 99 percent of the particulates and a scrubber which removes 80 percent of the SO_2 and from 0 to 40 percent of the NO_x.[3] For a power plant operating under these conditions, Table 5-4 gives emissions on the basis of a million Btu's of coal burned and compares them to the New Source Performance Standards (NSPS). Emissions of SO_2 more than meet NSPS.[4] However, particulate emissions exceed these standards, and NO_x emissions (assuming 40 percent removal by the scrubber) just meet NSPS. In order to meet NSPS, 99.4 percent particulates, 20 percent SO_2, and 36 percent NO_x removal would be required.[5]

In addition to emissions from the power plant itself, two 75,000-barrel oil storage tanks at the plant, with standard floating roof construction, will each emit up to 0.7 pound of HC per hour.

Both the power plant and the three coal synthetic fuels facilities are cooled by wet forced-draft cooling towers. Each

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[1]The effectiveness of current dust suppression practices is uncertain. Research being conducted by the Environmental Protection Agency (EPA) is investigating this question. The problem of fugitive dust from mines is discussed qualitatively in Chapter 10.

[2]Stacks are 500 feet high, have an exit diameter of 30.3 feet, mass flow rates of 2.6×10^6 cubic feet per minute, an exit velocity of 60 feet per second, and an exit temperature of 180°F.

[3]These efficiencies were hypothesized as reasonable estimates of current industrial practices; exact percentages are uncertain.

[4]NSPS limit the amount of a given pollutant a stationary source may emit; the limit is expressed relative to the amount of energy in the fuel burned.

[5]Section 109 of the Clean Air Act Amendments of 1977, Pub. L. 95-95, 91 Stat. 685 requires both an emissions limitation and a percentage reduction of SO_2, particulates, and NO_x. Revised standards are to be established by the EPA.

TABLE 5-4: COMPARISON OF EMISSIONS FROM POWER PLANT WITH NEW SOURCE PERFORMANCE STANDARDS (pounds per million Btu)

POWER PLANT	EMISSION	NSPS
Particulates	0.17	0.1
SO_2[a]	0.33	1.2
NO_x[b]	0.65-1.08	0.7

NSPS = New Source Performance Standards
Btu = British thermal unit
SO_2 = sulfur dioxide
NO_x = oxides of nitrogen

[a]New Mexico standards require that 65 percent of the SO_2 be controlled. Data from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[b]Range of NO_x emissions assumes 0 and 40 percent NO_x removal by the scrubber.

cell in the tower circulates water at a rate of 15,330 gallons per minute (gpm) and emits 0.01 percent of its water as a mist. The circulating water has a total dissolved solids (TDS) content of 3,300 parts per million, which results in a salt emission rate of 21,200 pounds per year for each cell.[1]

Underground uranium mining operations produce dust in the mine tunnels and crosscuts. Radon gas (Rn-222) and its daughters are emitted from the exposed surfaces in the mine and are present in greater concentrations than dust. The dust and radionuclides generated by the mining process are emitted into the atmosphere through exhaust ventilation shafts. This air flow dilutes the pollutants to a concentration well within federal and state regulatory standards.[2] The air emerges from the vent

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[1]The power plant has 64 cells, the Lurgi plant has 11, the Synthane plant has 6, and the Synthoil plant has 16.

[2]White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

shafts at a high velocity causing the pollutants to be dispersed rapidly into the atmosphere. The maximum emission rate of Rn-222 from the mine vent exhausts is about 2.94 curies per day for a 1,200 tons per day (tpd) mine.[1] The primary radiological air emission from the 1,000 tpd uranium mill is also Rn-222; emissions have been estimated to be about 9,000 curies per year.[2]

5.2.3 Impacts

This section describes air quality impacts which result from each type of conversion facility[3] (Lurgi, Synthane, Synthoil, power plant, and a uranium mill) taken separately and from a scenario which includes construction of all facilities according to the hypothesized scenario schedule. For the power plant, the effect on air quality of hypothesized emission controls, alternative emission controls, alternative stack heights, and alternative plant sizes are discussed. The focus is on concentrations of criteria pollutants (particulates, SO_2, NO_x, HC, and CO). See Chapter 10 for a qualitative description of sulfates, other oxidants, fine particulates, long-range visibility, plume opacity, cooling tower salt deposition, and cooling tower fogging and icing.

A. Lurgi Impacts

Few air quality impacts are associated with the construction phase of a Lurgi plant, although construction processes may increase wind-blown dust which currently causes periodic violations of 24-hour ambient particulate standards.

Air quality impacts result primarily from the operation of the Lurgi facility. Table 5-5 summarizes the concentrations of four pollutants predicted to be produced by the Lurgi plant. These pollutants (particulates, SO_2, NO_x, and HC) are regulated by federal and New Mexico state ambient air quality standards (also shown in Table 5-5). Based on these data, the typical concentrations associated with the plant when added to existing

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[1]White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 5.

[2]Ibid.

[3]Air quality impacts caused by the mines are expected to be negligible in comparison with impacts caused by conversion facilities.

TABLE 5-5: POLLUTION CONCENTRATIONS FROM LURGI PLANT AT FARMINGTON (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]				STANDARDS[b]				
			PEAK		AMBIENT			PSD	
	BACKGROUND	TYPICAL	PLANT	FARMINGTON	PRIMARY	SECONDARY	NEW MEXICO	CLASS I	CLASS II
Particulate									
Annual	40	N	N	N	75	60	60	5	19
30-day	40	N	N	N			90		
7-day	40	N	N	N			110		
24-hour	40	N	N	N	260	150	150	10	37
SO_2									
Annual	20		0.3	0.3	80		60	2	20
24-hour	20	0.7	4.6	0.9	365		260	5	91
3-hour	20	3.4	44.0	0.9		1,300	1,300	25	512
NO_2[c]									
Annual	10		0.3		100	100	100	NA	NA
24-hour	10	0.9	5.9	0.4			200	NA	NA
HC[d]									
3-hour	unknown	3.1	57.0	0.6	160	160	160	NA	NA

PSD = prevention of significant deterioration
N = no increase above background
SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide
NA = not applicable
HC = hydrocarbons

[a]These are predicted ground-level concentrations from the hypothetical Lurgi gasification facility. Annual average background levels are considered to be the best estimates of short-term background levels.

[b]"Primary" and "secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. PSD standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national parks. These data from from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[c]It is assumed that all oxides of nitrogen from plant sources are converted to NO_2.

[d]The 3-hour standard is measured at 6-9 A.M.

background levels, will be well below federal and state ambient air standards.[1]

Table 5-5 also lists the prevention of significant deterioration (PSD) standards, which are the allowable increments of pollutants that can be added to areas of relatively clean air (i.e., areas with air quality better than that allowed by ambient air standards).[2] "Class I" is intended to designate the cleanest areas, such as national parks and forests.[3] Peak concentrations attributable to the Lurgi plant do not exceed Class II allowable increments. However, the Class I increment for 3-hour SO_2 emissions is exceeded.

Since the plant exceeds one Class I increment, it would have to be located a sufficient distance from any Class I area to allow dilution of emissions by atmospheric mixing to required levels prior to their reaching such areas. The distance required for this dilution (which varies by facility type, size, emission controls, and meteorological conditions) in effect establishes a "buffer zone" around Class I areas.[4] No proposed Class I areas are within 10 miles of the plant site, but Mesa Verde National Park and San Pedro Parks National Wilderness Area are mandatory Class I areas in the vicinity of the Navajo power plant. Chaco Canyon National Monument, about 20 miles to the southeast, is another potential Class I area (Figure 5-3).

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[1]Potential air impacts are subject to the New Mexico state permit review system, which does not allow any facility development that threatens applicable state standards. If the operation of a plant will violate state standards, construction can be halted, and/or the plant may be required to install additional pollution control equipment.

[2]PSD standards apply only to particulates and SO_2.

[3]The Environmental Protection Agency initially designated all PSD areas Class II and established a process requiring petitions and public hearings for redesignating areas Class I or Class III. A Class II designation is for areas which have moderate, well-controlled energy or industrial development and permits less deterioration than that allowed by federal secondary ambient standards. Class III allows deterioration to the level of secondary standards.

[4]Analysis of buffer zone requirements is based on the potential of many western areas to become Class I, either by redesignation or by Congressional requirement. Estimated sizes of buffer zones are not based on dispersion modeling. Note that the term buffer zone is in disfavor. We use it because we believe it accurately describes the effect of PSD requirements.

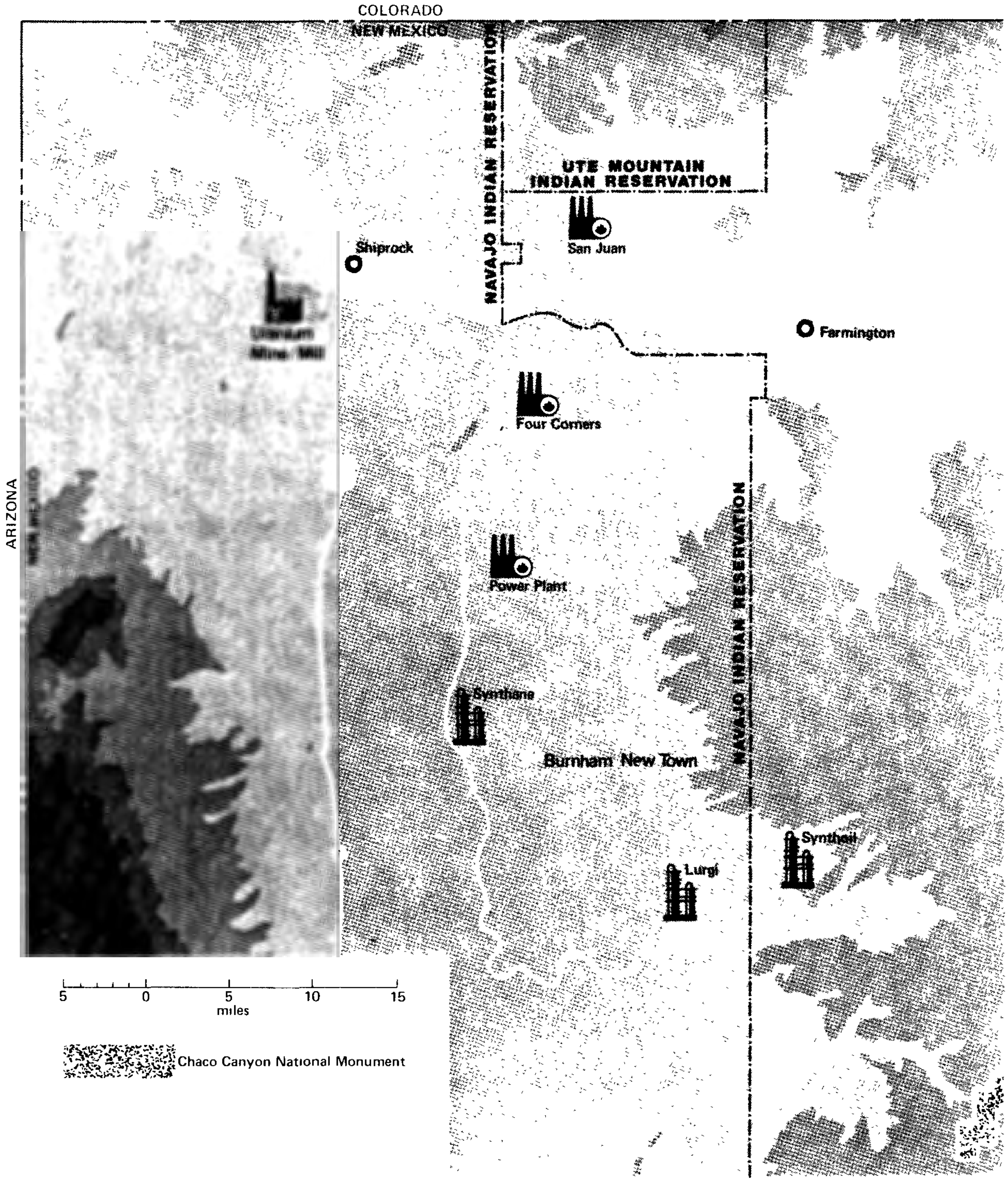

FIGURE 5-3: AIR IMPACTS OF ENERGY FACILITIES IN THE NAVAJO/FARMINGTON SCENARIO

In a worst-case situation, expected to occur infrequently, the interaction of pollutants from the Lurgi plant and its associated mine is expected to cause background visibility (presently about 60 miles) be reduced to between 25 and 40 miles, depending on the amount of SO_2 converted to sulfates in the atmosphere.[1]

B. Synthane Impacts

Typical and peak concentrations of four criteria pollutants from the proposed Synthane gasification plant are summarized in Table 5-6. No federal or state ambient standard will be violated by this facility.

The Synthane plant will exceed some of the allowable increments for PSD. Peak concentrations from the Synthane plant will violate Class I PSD standards for 24-hour and 3-hour SO_2. The PSD violation would require a buffer zone between the plant and any Class I area. Current Environmental Protection Agency (EPA) regulations would require a buffer zone of about 5 miles for the Synthane plant.

C. Synthoil Impacts

Table 5-7 lists typical plant concentrations, peak plant concentrations, and peak combined concentrations from the Synthoil liquefaction plant and surface mine. These data show that the only violation from the Synthoil facilities (plant or plant/ mine combination) will be HC emission levels, which violate both federal and state standards. They are more than 30 times greater than New Mexico's standard.

This facility will not violate any Class II PSD increments. Peak concentrations from the Synthoil plant will exceed Class I PSD increments for 24-hour particulate and SO_2 increments. In addition, typical concentrations from the plant will exceed the 24-hour SO_2 increment. These concentrations would require a 16-mile buffer zone between plant and any Class I area.

D. Power Plant Impacts

Because construction processes may increase windblown dust, periodic violations of 24-hour National Ambient Air Quality Standards (NAAQS) for particulates can be expected to increase during power plant construction. No other air quality impacts are associated with the construction of a power plant.

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[1]Short-term visibility impacts were investigated using a "box-type" dispersion model. This particular model assumes that all emissions occurring during a specified time interval are uniformly mixed and confined in a box that is capped by a lid or stable layer aloft. A lid of 500 meters was used. SO_2 to sulfate conversion rates of 10 percent and 1 percent were modeled.

TABLE 5-6: POLLUTION CONCENTRATIONS FROM SYNTHANE GASIFICATION PLANT AT FARMINGTON (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]				STANDARDS[b]				
			PEAK		AMBIENT			PSD	
	BACKGROUND	TYPICAL	PLANT	FARMINGTON	PRIMARY	SECONDARY	NEW MEXICO	CLASS I	CLASS II
Particulate									
Annual	40	N	N	N	75	60	60	5	19
30-day		N	N	N			60		
7-day		N	0.1	N			110		
24-hour		N	0.1	N	260	150	150	10	37
SO_2									
Annual	20	5.5	2.0	0.5	80		60	2	20
24-hour		32.0	32.0	3.0	365		260	5	91
3-hour			324.0	8.2		1,300	1,300	25	512
NO_2[c]									
Annual	10		2.8	0.7	100	100	100	NA	NA
24-hour		7.9	46.0	4.3			200	NA	NA
HC[d]									
3-hour	unknown	6.1	114.0	0.6	160	160	160	NA	NA

PSD = prevention of significant deterioration
N = no increase above background
SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide
NA = not applicable
HC = hydrocarbons

[a]These are predicted ground-level concentrations from the hypothetical Synthane gasification plant. Annual average background levels are considered to be the best estimates of short-term background levels.

[b]"Primary" and "secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. PSD standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national parks. These data are from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[c]It is assumed that all oxides of nitrogen from plant sources are converted to NO_2.

[d]The 3-hour standard is measured at 6-9 A.M.

TABLE 5-7: POLLUTION CONCENTRATIONS FROM SYNTHOIL LIQUEFACTION PLANT/MINE COMBINATION AT FARMINGTON
(micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]					STANDARDS[b]				
			PEAK			AMBIENT			PSD	
	BACKGROUND	TYPICAL	PLANT	PLANT AND MINE	FARMINGTON	PRIMARY	SECONDARY	NEW MEXICO	CLASS I	CLASS II
Particulate										
Annual	40		1.5	1.5	0.2	75	60	60	5	19
30-day			2.6	2.8	0.4			90		
7-day			8.8	9.4	1.4			110		
24-hour		8	16.0	17.0	1.4	260	150	150	10	37
SO_2										
Annual	20		3.2	3.3	0.3	80		60	2	20
24-hour		12	30.0	30.0	2.2	365		260	5	91
3-hour		51	136.0	136.0	2.6		1,300	1,300	25	512
NO_2[c]										
Annual	10		7.3	7.9	1.2	100	100	100	NA	NA
24-hour		52	85.0	124.0	10.0			200	NA	NA
HC[d]										
3-hour	unknown	326	21,500.0	21,500.0	7.5	160	160	160	NA	NA

PSD = prevention of significant deterioration
SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide
NA = not applicable
HC = hydrocarbons

[a]These are predicted ground-level concentrations from the hypothetical Synthoil liquefaction plant and mine. Annual average background levels are considered to be the best estimates of short-term background levels. Most of the peak concentrations from the plant and mine combination are attributable to the mine, with the exception of annual SO_2 levels. Concentrations over Farmington are largely attributable to the plant.

[b]"Primary" and "secondary" refer to federal ambient air quality standards designed to protect health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. PSD standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These data are from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[c]It is assumed that all oxides of nitrogen from plant sources are converted to NO_2.

[d]The 3-hour HC standard is measured at 6-9 A.M.

The majority of air quality impacts result from the operation of a power plant and depend on the degree of emission control imposed. Concentrations resulting from a base case, where control equipment is hypothesized to remove 80 percent of the SO_2 and 99 percent of all particulates, are discussed first, followed by a discussion of the effects on ambient air concentrations of alternative emission controls, alternative stack heights, and alternative plant sizes.

(1) Hypothesized Emission Control

Table 5-8 summarizes typical and peak concentrations of four criteria pollutants predicted to be produced by a power plant (3,000 MWe, 500-foot stack, 80 percent SO_2 removal, and 99 percent particulate removal). Peak concentrations from the plant will violate New Mexico's ambient air standard for 24-hour NO_2 levels. No other federal or state ambient standard will be violated by this facility and its associated mine. This facility does, however, exceed several allowable increments for PSD Class I. Class I 24-hour particulate increments and all SO_2 increments will be exceeded by plant peak concentrations. Class II increments for 24-hour particulates will just be met by the plant but exceeded by the the plant/mine combination.

These PSD violations would require buffer zones between the plant and any Class I area. Current EPA regulations would require a 58-mile buffer zone for the power plant. Nearby areas which have recently been designated Class I include Mesa Verde National Monument and San Pedro Parks National Wilderness Area.

(2) Alternative Emission Controls

The base case control for the Navajo power plant assumed an SO_2 scrubber efficiency of 80 percent and an ESP efficiency of 99 percent. The effect on ambient air concentrations of three additional emission control alternatives is shown in Table 5-9. These alternatives include a 95 percent efficient SO_2 scrubber with a 99 percent efficient ESP; an 80 percent efficient SO_2 scrubber with an ESP; an 80 percent efficient SO_2 scrubber with no ESP; and an alternative in which neither a scrubber nor an ESP are utilized.

An examination of Table 5-9 reveals violations of NAAQS and Class II increments occur only when controls are removed altogether for total suspended particulates (TSP), SO_2, or both. Removal of the SO_2 scrubber results in violations of NAAQS secondary standards for 3-hour SO_2, and all Class II PSD increments except annual SO_2. Removal of the ESP results in violations of all NAAQS and Class II PSD increments for TSP. The base case control meets all applicable standards for SO_2 and TSP emissions.

TABLE 5-8: POLLUTION CONCENTRATIONS FROM POWER PLANT/MINE COMBINATION AT FARMINGTON (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]					STANDARDS[b]				
			PEAK			AMBIENT			PSD	
	BACKGROUND	TYPICAL	PLANT	PLANT AND MINE	FARMINGTON	PRIMARY	SECONDARY	NEW MEXICO	CLASS I	CLASS II
Particulate										
Annual	40		1.8	1.8	0.2	75	60	60	5	19
30-day			3.2	3.2	0.4			90		
7-day			20.0	37.0	2.5			110		
24-hour		14	36.0	67.0	4.6	260	150	150	10	37
SO_2										
Annual	20		3.3	3.3	0.3	80		60	2	20
24-hour		9	65.0	84.0	8.3	365		260	5	91
3-hour		22	454.0	459.0	18.0		1,300	1,300	25	512
NO_2[c]										
Annual	10		6.5-11[d]	6.5-11[d]	0.6	100	100	100	NA	NA
24-hour		118	126-210[d]	388-472[d]	16.0			200	NA	NA
HC[e]										
3-hour	unknown		46.0	78.0		160	160	160	NA	NA

PSD = prevention of significant deterioration; NO_2 = nitrogen dioxide; HC = hydrocarbons
SO_2 = sulfur dioxide; NA = not applicable

[a]These are predicted ground-level concentrations from the hypothetical power plant and mine. Annual average background levels are considered to be the best estimates of short-term background levels. Concentrations over Farmington are largely attributable to the plant.

[b]"Primary" and "secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. PSD standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These data are from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[c]It is assumed that all oxides of nitrogen from plant sources are converted to NO_2.

[d]This range represents two assumptions about the removal of oxides of nitrogen by scrubbers. The first number assumes 40 percent is removed; the second number assumes none is removed.

[e]The 3-hour HC standard is measured at 6-9 A.M.

TABLE 5-9: AIR QUALITY IMPACTS RESULTING FROM ALTERNATIVE POWER PLANT EMISSION CONTROLS AT NAVAJO POWER PLANT

AMOUNT OF CONTROL (%)		MAXIMUM POLLUTANT CONCENTRATION ($\mu g/m^3$)				
SO_2	TSP	3-HR. SO_2	24-HR. SO_2	ANNUAL SO_2	24-HR. TSP	ANNUAL TSP
95	99	113	16	NC	36	1.8
80	99	454	65	3.3	36	1.8
80	0	454	65	3.3	3,600[a]	180.0
0	0	2,281	311	16.5	3,434[a]	180.0
APPLICABLE STANDARDS						
NAAQS						
(primary)		--	365	80.0	260	75.0
(secondary)		1,300	--	--	150	60.0
State standards		1,300	260	60.0	150	60.0
Class II PSD increments		512	91	20.0	37	19.0

$\mu g/m^3$ = micrograms per cubic meter
SO_2 = sulfur dioxide
TSP = total suspended particulates
HR. = hour
NC = not considered
NAAQS = National Ambient Air Quality Standards
PSD = prevention of significant deterioration

[a]Differences in 24-hour TSP concentrations for the two classes in which no electrostatic precipitator is used are attributable to the fact that the stack temperature rises when the SO_2 scrubber is turned off, which produces a small increase in the effectiveness of the smoke stack, and a slightly lower TSP concentration.

TABLE 5-10: AIR QUALITY IMPACTS RESULTING FROM ALTERNATIVE STACK HEIGHTS AT NAVAJO POWER PLANT

SELECTED STACK HEIGHTS (feet)	MAXIMUM POLLUTANT CONCENTRATION ($\mu g/m^3$) 3-HOUR SO_2	24-HOUR SO_2	24-HOUR TSP
300	497	72	40
500	454	65	36
1,000	365	26	14
APPLICABLE STANDARDS			
NAAQS			
(primary)	--	365	260
(secondary)	1,300	--	150
State standards	1,300	260	150
Class II PSD increments	512	91	37

$\mu g/m^3$ = micrograms per cubic meter
SO_2 = sulfur dioxide
TSP = total suspended particulates
NAAQS = National Ambient Air Quality Standards
PSD = prevention of significant deterioration

(3) Alternative Stack Heights

In order to examine the effects of alternative stack heights on air quality in the Navajo scenario, worst-case dispersion modeling was carried out for a 300-foot stack (lowest stack height consistent with good engineering practice), a 500-foot stack (an average or most frequently used height), and a 1,000-foot stack (a highest stack height). The results of this examination are shown in Table 5-10. Emissions from each stack are controlled by an 80 percent efficient SO_2 scrubber and a 99 percent efficient ESP. The 500-foot case was given previously as part of the base case.

A comparison of predicted emissions with applicable standards shows no NAAQS are violated with a 300-foot stack. However, Class II PSD increments for 24-hour TSP emissions are violated in the 300-foot stack height case.

(4) Alternative Plant Sizes

The base case 3,000 MWe power plant at Navajo (with 500-foot stack height, 80 percent SO_2 removal and 99 percent TSP removal) violates no NAAQS or Class II PSD increments. Any reduction in plant generating capacity would further reduce emissions of SO_2 and TSP. Results are shown in Table 5-11.

TABLE 5-11: AIR QUALITY IMPACTS RESULTING FROM ALTERNATIVE PLANT SIZES AT NAVAJO POWER PLANT

UNIT SIZE (MWe)	NUMBER OF UNITS	PLANT CAPACITY (MWe)	MAXIMUM POLLUTANT CONCENTRATION ($\mu g/m^3$)		
			3-HOUR SO_2	24-HOUR SO_2	24-HOUR TSP
750	1	750	114	16	9
	2	1,500	227	32	18
	3	2,250	340	49	27
	4	3,000	454	65	36
APPLICABLE STANDARDS					
NAAQS					
(primary)			--	365	260
(secondary)			1,300	--	150
State standards			1,300	260	150
Class II PSD increments			512	91	37

$\mu g/m^3$ = micrograms per cubic meter
MWe = megawatt-electric
SO_2 = sulfur dioxide
TSP = total suspended particulates
NAAQS = National Ambient Air Quality Standards
PSD = prevention of significant deterioration

(5) Summary of Power Plant Air Impacts

During the construction phase of the Navajo power plant, the frequency of violations of NAAQS particulate standards will probably increase. Once the 3,000 MWe hypothesized power plant and associated mine are in operation (80 percent SO_2 removal, 99 percent TSP removal, and 500-foot stack height), they are predicted to violate New Mexico's ambient air standard for NO_2 concentrations and the Class II PSD increment for 24-hour particulates. Removal of the SO_2 scrubbers or ESP would result in violations of several NAAQS and Class II PSD increments. Lowering the hypothesized stack height to 300 feet would result in violations of Class II PSD increments for 24-hour TSP emissions.

E. Uranium--Underground Mine and Mill Impacts

The primary radioactive isotope emitted from uranium milling is Rn-222. There is no federal standard for allowable Rn-222 air concentrations. A rule of thumb value commonly used as an acceptable level is one picocurie per liter of air (one picocurie is equal to 10^{-12} curies). In this study neither criteria pollutant nor radiological emissions from a uranium mine and mill were modeled. Thus, the concentrations that would result from the criteria pollutant emission rates given in Table 5-3 or from a 9,000 curie per year radiological emission rate are not known.

F. Scenario Impacts

(1) To 1980

Construction of the hypothetical Lurgi gasification plant will begin in 1977, and the plant will become operational in 1980. The population of Farmington is expected to increase from 27,900 (1975) to 34,800 by 1980.[1] This population increase will contribute to increases in pollution concentrations due solely to urban sources. Table 5-12 shows predicted 1980 concentrations of the five criteria pollutants in the center of Farmington and at a point 3 miles from the center of town.

When the Lurgi coal gasification plant becomes operational in 1980, visibility is expected to decrease from the current average of 60 miles to 59 miles.

When concentrations from urban sources are added to background levels and concentrations from the Lurgi plant (given in Table 5-5), annual particulate levels exceed the federal secondary standard, and 3-hour HC levels exceed the federal and New Mexico standards.[2] Moreover, concentrations of particulates (30-day, 7-day, and 24-hour), SO_2 (annual), and NO_2 (annual and 24-hour) approach the most restrictive federal or state standards.

(2) To 1990

Two new facilities are hypothesized to be constructed by 1990 in the Navajo/Farmington area. A power plant will become operational in 1986 and a Synthane gasification plant in 1990. Interactions of the pollutants from the power and Synthane plants are minimal because they have been (hypothetically) sited 6 miles apart. If the wind blows directly from one plant to the other, plumes will interact. The maximum pollutant concentration resulting from the interaction of Synthane plant with the power plant will just meet Class II PSD increments for 24-hour SO_2 emissions. The Class II PSD increment for 3-hour SO_2 emissions will be violated. The Lurgi plant is too far away to affect peak concentrations. If the plants were closer, the probability of interactions would increase.

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[1]See Section 5.4.3.

[2]HC standards are violated regularly in most urban areas.

TABLE 5-12: POLLUTION CONCENTRATIONS DUE TO URBAN SOURCES AT FARMINGTON

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]							STANDARDS[b]		
		MIDTOWN POINT			RURAL POINT					
	BACKGROUND	1980	1990	2000	1980	1990	2000	PRIMARY	SECONDARY	NEW MEXICO
Particulates										
Annual	40	27	30	32	4	6	6	75	60	60
30-day	40	42	46	50	42	46	50			90
7-day	40	62	69	74	62	69	74			110
24-hour	40	92	102	109	92	102	109	260	150	150
SO_2										
Annual	20	14	16	16	2	3	3	80		60
24-hour	20	48	54	54	48	54	54	365		260
3-hour	20	84	96	96	84	96	96		1,300	
NO_2[c]										
Annual	10	40	48	51	6	8	10	100	100	100
24-hour	10	136	163	173	136	163	173			200
HC[d]										
3-hour	unknown	750	871	900	750	871	900	160	160	160
CO										
8-hour	unknown	2,508	2,900	3,190	2,508	2,990	3,190	10,000	10,000	10,000
1-hour		4,110	4,990	5,730	4,110	4,900	5,730	40,000	40,000	15,000

SO_2 = sulfur dioxide HC = hydrocarbon
NO_2 = nitrogen dioxide CO = carbon monoxide

[a]These are predicted ground-level concentrations from urban sources. Background concentrations are taken from Table 5-5. "Rural points" are measurements taken 3 miles from the center of town.

[b]"Primary" and "secondary" are federal ambient air quality standards designed to protect public health and welfare, respectively. These data are from White, Irvin L., *et al*. *Energy From the West: Energy Resource Development Systems Report*. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[c]It is assumed that 50 percent of oxides of nitrogen from urban sources are converted to NO_2.

[d]The 3-hour HC standard is measured at 6-9 A.M.

When the power plant and Synthane plant come on-line with the Lurgi facility, visibility is expected to decrease from the current average of 60 miles in the Farmington region to 57 miles by 1990. In a worst-case situation, expected to occur about once a year, short-term visibilities could be reduced to between 3 and 9 miles, depending on the amount of SO_2 converted to particulates in the atmosphere.

Farmington's predicted population increase to 43,650 by 1990 will cause urban pollutant concentrations to reach the levels shown in Table 5-12. Combined with background levels, the 1990 concentrations will violate the federal secondary standards for annual particulate levels and New Mexico's 24-hour NO_2 and 3-hour HC standards. These concentrations also approach either a federal secondary or New Mexico standard for 30-day, 7-day, and 24-hour particulate levels and annual SO_2 levels. The HC violation, which will exceed New Mexico's standard by a factor of five, appears the most severe because it increases the likelihood of oxidant formation and photochemical smog.

(3) To 2000

One new facility, a Synthoil liquefaction plant, will become operational between 1990 and 2000. Interactions between the new Synthoil plant, the Lurgi, Synthane, and power plants will increase annual peak concentrations near the power plant. Interaction between the Synthoil and power plant plumes will result in maximum pollutant concentrations that just meet Class II PSD increments for 24-hour SO_2 levels. The Class II PSD increment for 24-hour TSP will be violated.

When all energy conversion facilities in the scenario come on-line in 2000, visibility is expected to decrease from the current average of 60 miles in the Farmington region to 56 miles. In a worst-case situation, expected to occur about once a year, short-term visibilities could be reduced to between 3 and 8 miles, depending on the amount of SO_2 converted to particulates in the atmosphere.

Farmington's population will increase to 49,600 by the year 2000, and increased pollution concentrations will be associated with this growth (Table 5-12). These increases will exceed two additional ambient standards beyond those violated by population increases in 1990 (New Mexico's 30-day and 7-day particulate standards). Further, 24-hour particulate levels will be virtually equal to federal secondary standards.

G. Other Air Impacts

Nine additional categories of potential air impacts have been examined; that is, an attempt has been made to identify sources of pollutants and how energy development may affect levels of these pollutants during the next 25 years. These categories include sulfates, oxidants, fine particulates, long-range visibility, plume opacity, cooling tower salt deposition, cooling tower fogging and icing, trace elements, and fugitive dust emissions.[1] Although there are likely to be local impacts as a consequence of these pollutants, both the available data and knowledge about impact mechanisms are insufficient to allow quantitative, site-specific analyses. Thus, these are discussed in a more general, qualitative manner in Chapter 10.

5.2.4 Summary of Air Impacts

Energy development hypothesized in the Navajo/Farmington region are: Lurgi and Synthane gasification facilities, a Synthoil liquefaction facility, a 3,000 MWe power plant, associated surface coal mines for the facilities, and a uranium mine (underground) and mill. Particulate standards are already periodically violated in the region due to blowing dust; mining and facility construction activities are likely to aggravate that problem.

Particulate emissions violate the federal NSPS for particulates, and the NSPS for NO_x may be violated (depending on the amount of NO_x removed by scrubbers which is highly uncertain).

Neither the Lurgi nor the Synthane facilities violate any federal ambient standards or Class II PSD increments. Buffer zones of 10 and 5 miles, respectively, would be required to meet Class I PSD increments. The Synthoil plant violates only the NAAQS for HC; a buffer zone of 16 miles would be required to meet Class I increments.

The power plant violates New Mexico's ambient NO_2 air standard but no federal ambient standards or Class II PSD increments. The combination of the power plant and mine violate the Class II increment for 24-hour particulates. Without the hypothesized 80 percent SO_2 and 99 percent TSP removal, the power plant would violate ambient air standards. Lowering the stack from the hypothesized height of 500 feet to 300 feet would cause the Class II PSD increment for 24-hour TSP to be violated.

The impact that population increases will have on air quality may be significant. Our results indicate that federal and New Mexico ambient standards for particulates and HC are likely to be violated. The HC problem may be severe due to its participation in the chemical reactions which produce smog.

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[1]No analytical information is currently available on the source and formation of nitrates. See Hazardous Materials Advisory Committee. Nitrogenous Compounds in the Environment, U.S. Environmental Protection Agency Report No. EPA-SAB-73-001. Washington, D.C.: Government Printing Office, 1973.

5.3 WATER IMPACTS

5.3.1 Introduction

Energy resource development facilities in the Navajo/ Farmington area are sited in the San Juan River Basin, a subbasin of the Colorado River. The major water source for this development is the San Juan River (see Figure 5-4). The New Mexico portion of the San Juan Basin is arid, and water supplies are limited. Within most of the basin, annual rainfall is generally 6 to 10 inches or less, and snowfall is approximately 24 inches.[1]

This section identifies the sources and uses of water required for energy development, the residuals that will be produced, and the water availability and quality impacts that are likely to result.

5.3.2 Existing Conditions

A. Groundwater

The aquifers of greatest significance to the Farmington area are:[2] an alluvial aquifer system along the San Juan River and Chaco Wash and their tributaries; a shallow bedrock sandstone aquifer in the Pictured Cliffs Formation; and a deep bedrock sandstone aquifer in the Morrison Formation.

Recharge of alluvial aquifers depends on stream flow; therefore, when associated with intermittent streams, alluvial aquifers are unreliable as supply sources. However, these aquifers are sometimes satisfactory as water sources for livestock and domestic purposes.

Water quality in the alluvial aquifer associated with Chaco Wash is relatively poor (contains up to 3,000 milligrams per liter [mg/ℓ] of TDS). Water quality in the alluvial aquifer of the San Juan River is probably somewhat better because the aquifer is recharged by a perennial rather than an intermittent stream.

The Pictured Cliffs sandstone aquifer is about 100 feet thick and lies about 30 feet below the deepest minable coal seam. Its yield is low (generally about 10 gpm), and the water is of poor

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[1]The moisture content of one inch of rain is equal to approximately 15 inches of snow.

[2]The entire New Mexico portion of the San Juan Basin was declared an underground basin in July 1976 by the State Engineer. Uses of the basin are subject to regulation as an aquifer of significance to water supply.

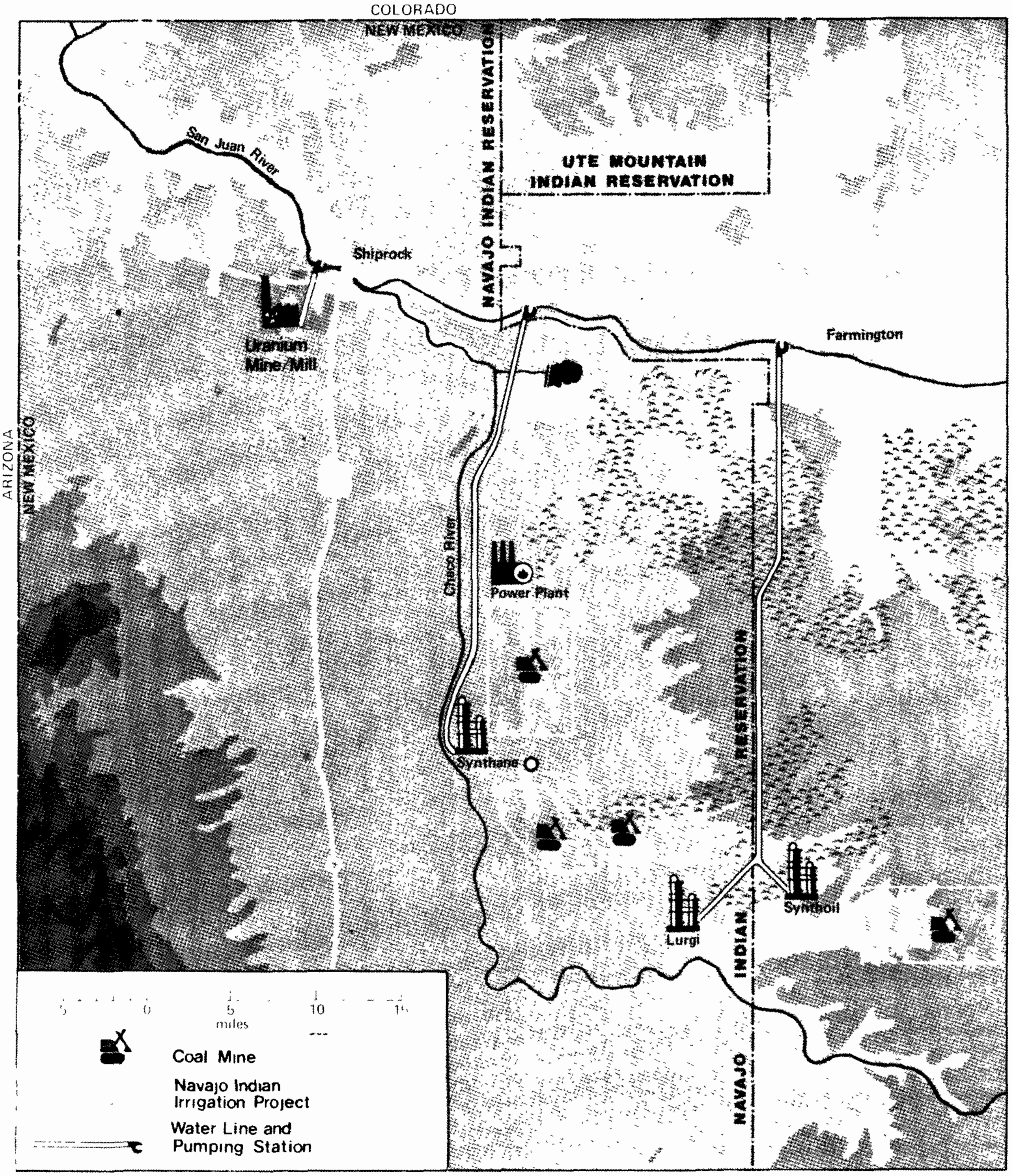

FIGURE 5-4: SURFACE WATER FEATURES AND WATER IMPACTS AT NAVAJO/FARMINGTON

quality. The TDS content is usually above 1,000 mg/ℓ and ranges as high as 75,000 mg/ℓ.[1] Recharge of the aquifer is estimated to be about 200 acre-feet per year (acre-ft/yr).

The Morrison sandstone aquifer is about 900 feet thick and, in the scenario area, occurs at a depth of about 5,000 feet. Little is known about the productivity and water quality of this aquifer.

B. Surface Water

All the southern tributaries of the San Juan River, including Chaco Wash and its tributaries, are ephemeral. Approximately 88 percent of the average annual water supply in the basin results from flow from the Colorado portion of the drainage basin.[2]

Allocation and control of water resources in the San Juan River currently involves a number of treaties and basinwide compacts which include state and federal jurisdictions. These are the: Colorado River Compact;[3] Upper Colorado River Basin Compact;[4] Mexico Treaty of 1944;[5] and the laws of the State of New Mexico.

Under the Upper Colorado River Basin Compact, New Mexico is entitled to 11.25 percent of the water in the Colorado River to

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[1]Forty-nine water samples from the Pictured Cliffs sandstone aquifer yielded an average TDS content of 25,442 mg/ℓ. U.S., Department of the Interior, Bureau of Reclamation. Western Gasification Project and Expansion of Navajo Mine by Utah International Inc., New Mexico: Final Environmental Statement, 2 vols. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1976, pp. 2-37 and 2-38.

[2]This inflow from Colorado helps to explain why New Mexico's entitlement is somewhat less than the total available water leaving the state. The San Juan actually contributes about 17 percent of the flow at Lee Ferry, the point at which Upper Basin flow is measured.

[3]Colorado River Compact of 1922, 42 Stat. 171, 45 Stat. 1064, declared effective by Presidential Proclamation, 46 Stat. 3000 (1928).

[4]Upper Colorado River Basin Compact of 1948, Pub. L. 81-37, 63 Stat. 31 (1949).

[5]Treaty between the United States of America and Mexico Respecting Utilization of Water of the Colorado and Tijuana Rivers and of the Rio Grande, February 3, 1944, 59 Stat. 1219 (1945), Treaty Series No. 994.

TABLE 5-13: FLOW CHARACTERISTICS OF THE SAN JUAN RIVER

LOCATION	DRAINAGE AREA (square miles)	20-YEAR AVERAGE FLOW (1955-75)	MAXIMUM FLOW (cfs)	MINIMUM FLOW (cfs)
Farmington	7,240	1,850 cfs 1,340,000 acre-ft/yr	68,000 (1927)[a]	14 (1939)[a]
Shiprock	12,900	1,848 cfs 1,339,000 acre-ft/yr	80,000 (1929)[a]	8 (1939)[a]

cfs = cubic feet per second   acre-ft/yr = acre-feet per year

Source: U.S., Department of the Interior, Geological Survey, Surface Water Supply of the U.S., 1961-65, Part 9, Colorado River Basin, Vol. 2, Water Supply Paper 1925. Washington, D.C.: Government Printing Office, 1970.

[a]The year of measurement.

which Upper Basin states are entitled. While estimates of the amount of water available to the Upper Basin states vary widely, our analysis is based on 5.8 million acre-ft/yr.[1] This would entitle New Mexico to 652,000 acre-ft/yr. However, the state of New Mexico bases its claim on an estimate of 6.3 million acre-ft/yr and, allowing for reuse of 24,000 acre-ft/yr, uses 727,000 acre-ft/yr for planning purposes.[2] At present, there is sufficient water available in the San Juan River to meet any of these estimates. However, the absence of impoundments below Navajo Reservoir reduces the practicability of diversions to Bloomfield and Aztec in spite of an apparently adequate total.

Baseline surface water flow in the Farmington area varies considerably. During low flow periods, withdrawals for energy use could be a substantial percentage of what is available. Flow characteristics of the San Juan River at Shiprock and Farmington are shown in Table 5-13. Since 1962, the flow in the San Juan

[1]These issues are elaborated in our regional analysis (Chapter 11). The 5.8 figure, one of the most common estimates, is from U.S., Department of the Interior, Water for Energy Management Team. Report on Water for Energy in the Upper Colorado River Basin. Denver, Colo.: Department of the Interior, 1974.

[2]Colorado River Compact of 1922, 42 Stat. 171, 45 Stat. 1064, declared effective by Presidential Proclamation, 46 Stat. 3000 (1928).

has been partially regulated by the Navajo Reservior, which was built to supply the Navajo Indian Irrigation Project (NIIP). The maximum and minimum flows of record at Farmington and Shiprock occurred before the construction of Navajo Reservoir. The reservoir operating conditions are shown in Table 5-14. To meet the NIIP water demand, it will be necessary to use the entire operating range and all of the active storage.

Not all of the water allocated to New Mexico in the Upper Colorado River Basin (UCRB) is currently being used. However, future developments may create a demand that exceeds that total available supply. Present and projected water allocations are shown in Table 5-15. This table is based on New Mexico's position that its share of available water is 703,000 acre-ft/yr. The largest future development is the NIIP, but water commitments for energy development are also substantial. If the water quantity from the Energy Management Team's estimate of 5.8 million

TABLE 5-14: OPERATING CONDITIONS FOR NAVAJO RESERVOIR

Maximum storage	6,085 feet above mean sea level 1,709,000 acre-feet
Minimum storage	5,990 feet above mean sea level 600,000 acre-feet
Normal operating range pre-NIIP[a]	6,025-6,050 feet above mean sea level
Minimum release September-April	450 cubic feet per second[b]
Minimum release May-August	700 cubic feet per second[b]

NIIP = Navajo Indian Irrigation Project

[a]The Navajo Indian Irrigation Project will require 330,000 acre-feet per year (acre-ft/yr) of which 226,000 acre-ft/yr will be consumed for irrigation and by evaporation and 104,000 acre-ft/yr will be returned.

[b]Model studies indicated that these minimum flows could not be met during 3 years using 1949-1965 flow data. Under these extreme events, discharges to the San Juan River may be less than 300 cubic feet per second to maintain minimum storage in the reservoir.

TABLE 5-15: NEW MEXICO'S PRESENT AND PROJECTED SAN JUAN RIVER WATER ALLOCATIONS

DEPLETIONS (nominal-at-site) (thousands of acre-feet per year)	1974	FUTURE
Irrigation (present)	83	83
Other[a] (present)	13	13
Hammond	8	10
San Juan-Chama	46	110
Navajo Reservoir Evaporation	24	26
Hogback Expansion	2	10
Utah International Incorporated (Four Corners)	25	39
Farmington M & I (increase)	0	5
Navajo Indian Irrigation	0	226
Navajo M & I Contracts		
New Mexico Public Service Company (San Juan)	5	16
Utah International Incorporated (WESCO)	0	35
El Paso Natural Gas Co.	0	28
Other (Gallup)	0	8
Animas-La Plata	0	34
Irrigation	0	14
M & I	0	20
Mainstream Reservoir Evaporation	58	58
Total depletions	264	735

M & I = Municipal and Industrial
WESCO = Western Gasification Company

Source: U.S., Department of the Interior, Bureau of Reclamation. <u>States' Comments, Westwide Study Report on Critical Water Problems Facing the Eleven Western States.</u> Denver, Colo.: Bureau of Reclamation, 1976.

[a]M & I, Fish and Wildlife (F & W), Recreation Mineral, etc.

acre-ft/yr is used to calculate New Mexico's portion of the Upper Colorado River water, only 652,000 acre-ft/yr would be available, in which case future depletions would exceed supply. This could lead to the reallocation of water currently allocated but not being used or the purchase of existing water rights for new uses.

The quality of water in the San Juan River, which will be the source of process water for the energy facilities in this area, is shown in Table 5-16 along with typical industrial boiler feed quality requirements and drinking water standards.

Two existing power plants are located in the San Juan Basin in the vicinity of the Navajo/Farmington area. The San Juan Power Plant has a closed-loop water system and does not return effluent to the San Juan. However, the Four Corners Power Plant discharges from Morgan Lake into Chaco Wash. This plant also uses Morgan Lake, a 1,200-acre lake, as a cooling pond. When evaporative losses from the lake increase water salinity to levels unacceptable for plant use, the lake is flushed into Chaco Wash and refilled from the San Juan River by pipeline. As reported by Arizona Public Service Company, the operator of the Four Corners plant, these intermittent discharges have an average TDS concentration of 3,000 mg/ℓ and are somewhat alkaline (acidity/alkalinity [pH] levels are often above 9.0).[1] In the future, the company may be required to reduce the TDS levels of water discharged to comply with state standards and regulations.

5.3.3 Factors Producing Impacts

The water requirements of and effluents from energy facilities cause water impacts. These requirements and effluents are identified in this section for each type of energy facility. Associated population increases also increase municipal water demand and sewage effluent; these are presented only for the scenario which includes facilities constructed according to the scenario schedule.

A. Water Requirements of Energy Facilities

The water requirements for energy facilities hypothesized for the Navajo/Farmington area are in Table 5-17. Two sets of data are presented. The Energy Resource Development System (ERDS) Report data are based on secondary sources, including impact statements, Federal Power Commission (FPC) docket filings, and

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[1]According to the New Mexico Water Quality Control Commission (San Juan River Basin Plan).

TABLE 5-16: WATER QUALITY IN SAN JUAN RIVER FOR 1973[a,b]

CONSTITUENT	FARMINGTON (mg/ℓ)		SHIPROCK (mg/ℓ)		DRINKING WATER STANDARDS[c]	TYPICAL BOILER FEEDWATER[d]
	MAXIMUM	TIME WEIGHTED AVERAGE	MAXIMUM	TIME WEIGHTED AVERAGE		
Calcium	71	55	78	60		0.10
Magnesium	13	8.9	17	11		0.03
Sodium	58	31	77	41		0.24
Potassium	3.2	2.3	3.1	2.5		
Bicarbonate	179	143	180	145		0.01
Sulfate	180	113	210	150	250[e]	0.14
Chloride	14	8.3	24	11	250[e]	0.96
Nitrate	0.50	0.25	0.64	0.33	10	
Total Dissolved Solids	411(1720)[f]	300(103)[g]	494(2,980)[f]	358(115)[g]	500[e]	10
Hardness (Ca, Mg)	230(820)[f]	174(65)[g]	260(1,100)[f]	199(70)[g]	6.5-8.5[e]	0.10
pH	8.1	7.8	8.5	8.0		8.8-10.8
Turbidity	2,000 JTU	10 JTU[h]	2,600 JTU	25 JTU[h]	5[i]	
Fecal Coliform	28,000/100 mℓ	10/100 mℓ	5,100/100 mℓ	220/100 mℓ[h]	1/100 mℓ[j]	
Dissolved Oxygen	11.6	8.4[i]	11.5	7.7[h]		
Sediment			21,800	278[f]		

mg/ℓ = milligrams per liter Mg = magnesium JTU = Jackson Turbidity Units
Ca = calcium pH = acidity/alkalinity mℓ = milliliters

[a]U.S., Department of the Interior, Geological Survey. 1973 Water Resources Data for New Mexico, Part 2: Water Quality Records. Albuquerque, N. Mex.: U.S. Geological Survey, 1975.

[b]Chemical analysis of composites or daily samples.

[c]U.S., Environmental Protection Agency. "National Interim Primary Drinking Water Regulations." 40 Fed. Reg. 59566-88 (December 24, 1975).

[d]Recommended by American Water Works Association, 1968.

[e]U.S., Environmental Protection Agency. "National Secondary Drinking Water Regulations," Proposed Regulations. 42 Fed. Reg. 17143-47 (March 31, 1977).

[f]Maximum of record.

[g]Minimum of record.

[h]Minimum measured 1973.

[i]Maximum turbidity units allowed on a monthly average. Jackson Turbidity Units are assumed to be equivalent to Turbidity Units in the standard using the Nephelometric Method.

[j]As the arithmetic mean of all samples examined per month using the membrane filter technique.

TABLE 5-17: WATER REQUIREMENTS FOR ENERGY FACILITIES AT FARMINGTON (acre-feet per year)[a]

TECHNOLOGY	ERDS REPORT[b] WET COOLING	WATER PURIFICATION ASSOCIATES[c] COMBINATION OF WET AND DRY COOLING[d]		
		HIGH WET	INTERMEDIATE WET	MINIMUM WET
Power Generation	29,400	29,206	9,089	NC
Gasification				
Lurgi	6,714	7,128	5,639	5,213
Synthane	9,090	8,670	6,694	6,289
Liquefaction				
Synthoil[e]	17,460	11,753	9,655	9,112
Uranium				
Underground Mine-Mill	1,350	NC	NC	NC
		Cost Range in Which Indicated Cooling Technology Is Most Economic (dollars per thousand gallons)		
Synthetic Fuels Facilities	NC	< 1.50	1.50-2.00	>2.00
Power Plant	NC	< 3.65-5.90	>3.65-5.90	NC

ERDS = Energy Resource Development Systems
NC = not considered

< = less than
> = greater than

[a]These values assume an annual load factor of 75 percent in the case of the 3,000 megawatt-electric power plant and 90 percent in the case of the 250 million cubic feet per day Lurgi and Synthane facilities and 100,000 barrel per day Synthoil facility.

[b]White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[c]Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

[d]Combinations of wet and wet dry cooling were obtained by examining the economics of cooling alternatives for the turbine condensers and gas compressor interstage coolers. In the high wet case, these are all wet cooled; in the intermediate case, wet cooling handles 10 percent of the load on the turbine condensers and all of the load in the interstage coolers; in the minimum practical wet case, wet cooling handles 10 percent of the cooling load on the turbine condensers and 50 percent of the load in the interstage coolers. For power plants, only variations on the steam turbine condenser load were considered practical; thus, only high wet and intermediate wet cases were examined.

[e]Synthoil data have a high uncertainty because of the small capacity of bench scale test facilities built to date. The Solvent Refined Coal liquefaction process now appears likely to become commercial sooner, and more reliable pilot plant data are available. These data are reported in White et al. Energy From the West: ERDS Report, Chapter 3.

recently published data accumulations,[1] and can be considered typical requirement levels. The Water Purification Associates' (WPA) data are from a study on minimum water-use requirements and take into account certain opportunities to recycle water on-site as well as the moisture content of the coal being used and local meteorological conditions.[2] As indicated in Table 5-17, the coal-fired power plant will have the largest water requirement of all hypothesized energy facilities in the Farmington scenario. The uranium mine and mill will have the least. More than 29,000 acre-ft/yr of water would be needed by the 3,000 MWe power plant if all wet cooling is used (the high wet case on Table 5-17). By using intermediate wet cooling (i.e., a combination of wet and dry cooling), water requirements could be reduced to slightly more than 9,000 acre-ft/yr, a savings of 69 percent. For synthetic fuels facilities, the intermediate wet cooling process could produce savings of from 18 (Synthoil) to 23 percent (Synthane). From an economic standpoint, the decision of which process to use often depends on the availability and price of water. In the case of the power plant, high wet cooling would be more attractive economically if water costs less than \$3.65 to \$5.90 per thousand gallons. If water costs more than \$3.65 to \$5.90 per thousand gallons, intermediate wet cooling would be the more attractive alternative. For synthetic fuel facilities, high wet cooling would be most attractive if water costs less than \$1.50 per thousand gallons. If water costs from \$1.50 to \$2.00 per thousand gallons, intermediate wet cooling would be the economical choice. Minimum wet cooling (i.e., maximum dry cooling) would save from 6 (Synthoil and Synthane) to 8 percent (Lurgi) more water than intermediate wet cooling. This process would become economically attractive if water costs more than \$2.00 per thousand gallons.

If water costs only \$0.25 per thousand gallons but intermediate wet cooling is utilized in order to conserve water, the increased cost of synthetic fuels would be about one cent per million Btu of fuel greater than if high wet cooling would have been used. In the case of a power plant, the increased cost of

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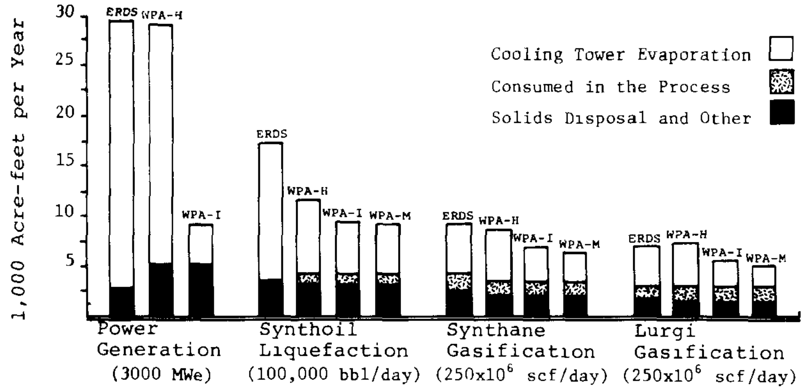
[1]ERDS is based on data drawn from University of Oklahoma, Science and Public Policy Program. Energy Alternatives: A Comparative Analysis. Washington, D.C.: Government Printing Office, 1975; and Radian Corporation. A Western Regional Energy Development Study, 3 vols. and Executive Summary. Austin, Tex.: Radian Corporation, 1975. These data are published in White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[2]Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.



ERDS = Energy Resource Development System
WPA-H = Water Purification Associates--High Wet Cooling
WPA-I = Water Purification Associates--Intermediate Wet Cooling
WPA-M = Water Purification Associates--Minimum Wet Cooling
MWe = megawatt-electric
bbl/day = barrel(s) per day
scf/day = standard cubic feet per day

Source: The ERDS data is from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming. The WPA data is from Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

FIGURE 5-5: WATER CONSUMPTION FOR ENERGY FACILITIES IN THE NAVAJO/FARMINGTON SCENARIO

intermediate wet cooling is about 0.1 to 0.2 cents per kilowatt-hour (kWh).

The use of the water required for energy facilities is shown in Figure 5-5. As indicated, the greatest water use for all energy technologies is for high wet cooling. Solids disposal consumes comparable quantities of water for all technologies, varying primarily as a function of the ash content of the feedstock coal.

In addition to the water requirements of the facilities, the coal mines that provide feedstock coal for the facilities will also require water. If reclamation of surface-mined lands includes irrigation, most of the water requirements for mining will be for reclamation (see Table 5-18). These quantities, which are regarded as maximum requirements, are 10 to 25 percent of the requirements for the conversion facility.

As mentioned previously, the San Juan River is the only reliable source of surface water in the area; thus, it is assumed to be the source of water for the energy facilities included in this area. As shown in Figure 5-3, pipelines will transport water from the San Juan River to the energy facilities. The rights to this water would have to be purchased from present holders. Groundwater supplies, the only alternative source, are not sufficient to support the postulated facilities.

TABLE 5-18: WATER REQUIREMENTS FOR RECLAMATION[a]

MINE	ACRES DISTURBED PER YEAR	MAXIMUM ACRES UNDER IRRIGATION	WATER REQUIREMENT (acre-ft/yr)
Power	830	4,150	3,110
Lurgi	360	1,825	1,370
Synthane	360	1,825	1,370
Synthoil	660	3,300	2,475
Total	2,210	11,100	8,325

acre-ft/yr = acre-feet per year

[a]Based on an irrigation rate of 9 inches per year for five years.

B. Effluents From Energy Facilities

(1) Coal Conversion Facilities

Table 5-19 lists expected amounts of solid effluents produced by coal conversion facilities in the Navajo scenario. The greatest amount of solid effluent will be produced by the Synthoil plant (more than 11,100 tpd), and the 3,000 MWe power plant is expected to produce more than 9,300 tons per day. The Synthane and Lurgi gasification plants are expected to produce the least amount of solid effluents (slightly less than 6,000 tpd). The power plant will have the highest volume of dissolved and dry solids (71 and 5,677 tpd), and the Synthoil plant is expected to produce the highest amount of wet solids (5,550 tpd).

Dissolved solids are present in the ash blowdown effluent, the demineralizer waste effluent, and the flue gas desulfurization (FGD) effluent. All coal conversion processes generate electricity on-site, thus flue gas cleaning, ash handling, and demineralization are generally required. One exception is the Synthoil process, which uses clean fuel gas for power generation; flue gas cleaning is not required for it. Demineralization is a method of preparing water for use in boilers, producing an effluent containing chemicals originally present in the source water. The bottom ash stream is the water used to remove bottom ash from the boiler. Bottom ash removal is done via a wet sluicing system using cooling tower blowdown water. Thus, the dissolved solids content of that stream is composed of chemicals from the ash and cooling water. The principal dissolved constituents of these wastewater streams are calcium, magnesium, sodium, sulfate, and chloride.

TABLE 5-19: EFFLUENTS FROM ENERGY CONVERSION FACILITIES AT FARMINGTON/NAVAJO

FACILITY TYPE	SOLIDS[a] (tons per day)				WATER IN EFFLUENT[b] (acre-feet per year)
	DISSOLVED	WET	DRY	TOTAL	
Coal[c]					
Lurgi (250 MMcfd)	24	5,284	667	5,115	575
Synthane (250 MMcfd)	22	1,540	4,417	5,979	1,328
Synthoil (100,000 bbl/day)	15	5,550	5,550	11,115	909
Electric Power (3,000 MWe)	71	3,582	5,677	9,330	2,290
Uranium[d]					
Underground Mine (1,100 mt/day)	0.13-0.31	0.04-0.48	0[e]	0.21-0.81[f]	53-81
Mill (1,000 mt/year)	[g]	6.46[g]	1,000	1,006	500

MMcfd = million cubic feet per day
bbl/day = barrels per day

MWe = megawatt-electric
mt = metric tons

[a]The values for solids are given for a day when the facility is operating at full load. In order to obtain yearly values, these numbers must be multiplied by 365 days and by the average load factor. Load factors are 90 percent for synthetic fuels facilities and 75 percent for power plants. The values given as solids do not include the weight of the water in which the solids are suspended or dissolved.

[b]The values for water discharged are annual and take into account the load factor.

[c]These data are from Radian Corporation. The Assessment of Residuals Disposal for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States, EPA Contract No. 68-01-1916. Austin, Tex.: Radian, 1978. The Radian Corporation report extends and is based on earlier analyses conducted by Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

[d]Calculated from data reported in the Corps of Engineers' Discharge Permit Applications.

[e]Mine wastes are generated as dry solids, but are generally put back into the mine.

[f]Dissolved and wet do not sum to total because the total includes some volatile solids.

[g]Dissolved and wet solids are given together in the wet column.

Wet solids from electric power and Lurgi or Synthane gasification facilities are in the form of flue gas sludge, bottom ash, and cooling water treatment waste sludge. Bottom ash is the primary constituent of wet solids produced by a Synthoil facility. Calcium carbonate ($CaCO_3$) and calcium sulfate ($CaSO_4$) are the primary constituents of flue gas sludge. The bottom ash is primarily oxides of aluminum and silicon. $CaCO_3$ is the principal constituent of the cooling water treatment waste sludge. In all cases the amount of cooling water treatment waste is very small, compared to the bottom ash and flue gas sludge.

Dry solids waste produced by coal conversion processes is primarily fly ash composed of oxides of aluminum, silicon, and iron. The water in the effluent stream accounts for between 5 (Synthoil) and 14 (Synthane) percent of the total water requirements of the individual energy facilities (data in Table 5-19 compared with that in Table 5-17).

Dissolved and wet solids are sent to evaporative holding ponds and later deposited in landfills. Dry solids are treated with water to prevent dusting and deposited in a landfill.[1]

(2) Underground Uranium Mine and Mill

Process effluents from the uranium underground mine and mill will contain significant quantities of suspended and dissolved solids and moderate levels of radioactive elements. Total quantities are given in Table 5-19. The major source of solids is the mill tailings, shown as dry solids on Table 5-19. Mill tailings will be ponded as a slurry and then landfilled. Dissolved and wet solids will be ponded separately from mill tailings. After settling, some of this pond water may be used for other purposes such as irrigation. It is expected that ponded effluent will have a solids content equal to or below that of the surface waters in the area. Radioactive solids (primarily as radium 226 [Ra-226]) will be precipitated in the pond and later landfilled with the mill tailings.

5.3.4 Impacts

This section describes water impacts which result from the mines and conversion facilities, and from a scenario which includes construction of all facilities according to the hypothesized scenario schedule. The water requirements and impacts associated with expected population increases are included in the scenario impact description.

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[1]The environmental problems associated with solid waste disposal in holding ponds and in landfills are discussed in Chapter 10.

A. Surface Coal Mines Impacts

As noted previously, the Pictured Cliffs sandstone aquifer is about 30 feet below the deepest minable coal seam and would probably be the only aquifer affected by mining. Flow patterns in the aquifer may be disturbed by the blasting required to fragment overburden and coal.

Surface water drainage patterns will be affected by mine excavations, some of which will trap runoff. Unless these ponds are pumped out regularly, the impounded water may eventually percolate into the groundwater system or evaporate, but this is not expected to produce a significant impact. Losses in runoff due to mine excavations are not expected to be significant locally because area streams are ephemeral and water would quickly dry up in any case. This loss of runoff into tributaries of the San Juan River would not reduce the flow in the river to a great extent.

B. Energy Conversion Facilities Impacts[1]

Water impacts may be divided into those occurring during construction and during operation and those occurring because of the water requirements of facilities and because of effluents from the facilities. These impacts are similar for each conversion facility except as they differ in degree.

Construction activities at the conversion facilities will remove vegetation and disturb the soil. These activities have an effect on surface water quality. The major effect will result from increases in the sediment load of local runoff. Maintenance areas and petroleum products storage facilities will also be needed to support construction equipment. Areas for the storage of other construction-related materials (such as aggregate for a concrete batch plant) may be required as well. All these facilities have the potential for contaminating runoff. Runoff control methods will be instituted at all of these potential sources of contaminants and will be channeled to a holding pond for settling, reuse, and evaporation. Because the supply of water to this pond is intermittent, evaporation may claim most of the water, although some of the water may be used for dust control.

Before the water supply pipeline from the San Juan River is completed, water for construction will be obtained temporarily from a well drilled into the Morrison sandstone aquifer. However, only about 400 acre-feet will be needed from the aquifer before

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[1]Discussion of potential effect of radioactive effluents and emmission of uranium mines and mills is provided in Chapter 10.

the pipeline is completed, a small part of the total water supply available from this aquifer.

Water requirements for operating a high wet-cooled power plant (average load factor of 75 percent) represent 11 percent of the 1974 depletions for the San Juan River (see Tables 5-15 and 5-17) and 4.5 percent of New Mexico's portion of Upper Colorado River water.[1] In contrast, an intermediate wet-cooled power plant would consume only 1.4 percent of New Mexico's portion of Upper Colorado River water. Each synthetic fuels plant will consume from 1.1 percent to 1.8 percent of New Mexico's UCRB allotment, if they are high wet cooled, and from 0.8 to 1.5 percent, if they are intermediate wet cooled.

Also, during operation, holding ponds and runoff retention facilities will decrease runoff from the plant sites below present levels. This loss may decrease flow in the San Juan River, but this effect by itself will be small and temporary. Also, this runoff reduction in combination with the water demand of any one facility could have a salt concentrating effect in the San Juan. That effect is likely to be small when considering one facility at a time.

C. Scenario Impacts

Water requirements for direct use by these hypothesized energy facilities increases from approximately 7,128 acre-ft/yr in 1980 when the Lurgi plant is operating to 46,354 acre-ft/yr by 1990 when the power plant, Synthane, and uranium facilities are also operating to 58,107 acre-ft/yr by the year 2000 when the Synthoil plant is added (high wet cooling is assumed in all cases from Table 5-17). If intermediate wet cooling is used, estimated water requirements would be reduced to 32,427 acre-ft/yr in the year 2000, a reduction of 45 percent. All of this water will be taken from the San Juan River. An irrigation program for reclamation of surface mined land would increase that requirement to 8,498 acre-ft/yr in 1980, 52,204 acre-ft/yr in 1990, and 66,432 acre-ft/yr in 2000.

The projected water needs of the expected increases in population are shown in Table 5-20.[2] This table is divided into reservation and nonreservation requirements; requirements are projected both with and without a new town. The water source for most towns is the San Juan River or its alluvial aquifer. These systems are expected to expand as the municipal demand increases. (A new town may have individual domestic wells or may pipe water

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[1]Assuming that portion is 652,000 acre-ft/yr.

[2]Population increases from secondary industries are not included in obtaining the estimates.

TABLE 5-20: EXPECTED WATER REQUIREMENTS FOR INCREASED POPULATION[a] (acre-feet per year)

YEAR	NONRESERVATION			RESERVATION		
	FARMINGTON[b]	AZTEC[c]	BLOOMFIELD[d]	SHIPROCK[e]	KIRTLAND-WATERFLOW[f]	BURNHAM AREA[g]
No New Town						
1980	2,519	900	70	465	150	616
1990	5,750	702	140	1,345	650	1,904
2000	7,925	965	190	2,250	860	1,883
New Town						
1980	1,440	180	35	440	150	560
1990	5,710	690	135	1,890	650	1,540
2000	8,840	1,080	210	2,540	860	1,820

[a]Per capita water consumption from: New Mexico, Interstate Stream Commission and State Engineer's Office. San Juan County Profile: Water Resources Assessment for Planning Purposes. Santa Fe, N.M.: New Mexico, Interstate Stream Commission, 1975, p. 22.

[b]326 gallons per capita per day (industrial included), 1972.

[c]196 gallons per capita per day, 1972. Water supplied from Animas River.

[d]100 gallons per capita per day, 1972.

[e]231 gallons per capita per day, 1972. Water supplied by City of Farmington.

[f]105 gallons per capita per day, 1973.

[g]125 gallons per capita per day, estimate.

from the San Juan River.) Aztec currently gets municipal water from the Animas River and is experiencing a severe water shortage.

Wastewater from the energy facilities, which will be impounded in evaporation ponds, will average 575 acre-ft/yr by 1980, 4,760 acre-ft/yr by 1990, and 5,665 acre-ft/yr by 2000.

Rural populations are assumed to use individual on-site waste disposal facilities (septic tanks and drain fields), and the urban population will require waste treatment facilities. Wastewater treatment capacity in the municipalities most affected by energy development activities are shown in Table 5-21. Wastewater increases resulting from development-induced population increases are apportioned as shown in Table 5-22. New wastewater treatment facilities adequate to meet the demands generated by these hypothetical developments and the associated population increases are being planned for all the impacted communities. These facilities will need to use the "best practicable" waste treatment technology to conform to 1983 standards and have allowance for recycling or zero discharge of pollutants to meet 1985 goals.[1] The 1985 goals could be met by using effluents for industrial process make-up water or for irrigating local farmland.

(1) To 1980

The Lurgi high-Btu gasification plant and its associated surface mine will be constructed and in operation by 1980. Its consumptive water demand (assuming high wet cooling) represents about 1.1 percent of New Mexico's portion of Upper Colorado River water. By itself, this does not represent a significant demand on surface water supplies; however, it does represent a large portion of water not already allocated.

From the present to 1980, most urban growth will be absorbed by existing communities, and local groundwater systems will not be significantly affected. Additional demands will be made on surface water supplies, but the overall increases should be small (see Table 5-20).

Municipalities must secure a permit to withdraw additional water from surface supplies in the area. As shown in Tables 5-21 and 5-22, wastewater treatment facilities will be operating at or exceeding design capacity in Aztec by 1980. Unless new facilities come on-line to meet these requirements, some surface water pollution may result from overloads and/or bypasses.

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[1]Federal Water Pollution Control Act Amendments of 1972, §§ 101, 301; 33 U.S.C.A. §§ 1251, 1311 (Supp. 1976).

TABLE 5-21: WASTEWATER TREATMENT CHARACTERISTICS FOR TOWNS AFFECTED BY THE NAVAJO SCENARIO[a]

TOWN	TYPE OF TREATMENT	DESIGN CAPACITY (MMgpd)	PRESENT FLOW (MMgpd)	PER CAPITA FLOW (gcd)
Farmington	2 bar screens, 2 grit chambers, 2 primary clarifiers, 2 trickling filters, 2 secondary clarifiers, 1 digester	7.5	4.5	140
Aztec	Bar screen, grit chamber, primary clarifer, digester, trickling filter, secondary clarifier	.6	.48	100
Bloomfield	Bar screen clarigester, trickling filter	1.5	0.6	91
Shiprock Area	Bar screen, primary clarifier, 2 trickling filters, secondary clarifier	1	.48	80
Kirtland-Waterflow-Fruitland	Septic field	--	--	--

MMgpd = million gallons per day
gcd = gallons per capita per day

[a]Data from the Director of Planning and Research, San Juan County, New Mexico.

TABLE 5-22: EXPECTED WASTEWATER FLOWS FROM INCREASED POPULATION[a]

YEAR	INCREASED FLOW ABOVE 1975 LEVEL (million gallons per day)					
	NONRESERVATION			RESERVATION		
	FARMINGTON[b]	AZTEC[c]	BLOOMFIELD[d]	SHIPROCK[e]	KIRTLAND-WATERFLOW[e]	BURNHAM AREA[e]
No New Town						
1980	1.02	0.41	0.05	0.14	0.10	0.35
1990	2.33	0.32	0.11	0.42	0.44	1.08
2000	3.21	0.44	0.15	0.70	0.58	1.07
New Town						
1980	0.58	0.08	0.03	0.14	0.10	0.32
1990	2.32	0.32	0.11	0.58	0.44	0.88
2000	3.58	0.49	0.17	0.78	0.58	1.04

[a]Per capita flow rates from personal communication, New Mexico Environmental Improvement Agency.

[b]148 gallons per capita per day

[c]100 gallons per capita per day

[d]91 gallons per capita per day

[e]80 gallons per capita per day

(2) To 1990

During the 1980-1990 period, the power plant, the Synthane high-Btu gasification facility, and the uranium mine and mill will be constructed and become operational. Since construction activities are greatest during this time period, the potential for surface water contamination by the sediment load as well as by other contaminants contained in the runoff is also greatest during this decade.

The three coal mines in operation by 1990 will affect the water quality of the Pictured Cliffs sandstone aquifer because, as indicated previously, it lies only about 30 feet below the lowest coal bed. Weathering and leaching of mine wastes and ash that are deposited in landfills will probably result in poor quality water filtering into the aquifer. However, the low annual precipitation of the area lessens the potential seriousness of this problem. In any case, water quality in the aquifer is already poor (TDS from 49 wells average about 25,500 mg/ℓ and range from 1,000 to 75,000 mg/ℓ). In addition, groundwater seepage or stormwater runoff will pool in operational areas of mines. The quality of water impounded in mined-out locations within the Navajo/Farmington area should be approximately the same as the quality of water in natural streams.[1] These impoundments will not result in a significant loss of water to the Colorado River System. The mines will have encompassed approximately 7,800 acres by 1990 (calculated from Table 5-18). If it is found that runoff retention facilities are required for this area, approximately 130 acre-ft/yr of water would be withheld from the local watersheds.

The four conversion facilities in operation by 1990 will probably not significantly affect the quantity of recharge water fed to the Pictured Cliffs aquifer. However, the failure or inadequacy of liners in on-site holding ponds may result in the leakage of pollutants into the Pictured Cliffs aquifer.

Changes in surface water quality will occur primarily as a result of the combined water demands of all the energy development facilities. The water supply system may eventually have a salt-concentrating effect because it will remove water with a relatively low TDS content from the river basin. Consequently, some increase in TDS may be noticed at both Lake Powell and Lake

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[1]U.S., Department of the Interior, Bureau of Reclamation. Western Gasification Company (WESCO) Coal Gasification Project and Expansion of Navajo Mine by Utah International Inc., New Mexico: Final Environmental Statement, 2 vols. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1976.

Mead.[1] The TDS concentrations at Shiprock and at Imperial Dam will increase by approximately 7.1 and 2.9 mg/ℓ respectively.[2] These increases are estimated averages and could be higher at Shiprock during low-flow periods. The increases would probably not vary seasonally at the major reservoirs because of their large buffer capacity. The Utah Water Research Laboratory of Utah State University estimates that the annual economic cost of salinity ranges from $45,900 to $230,000 for each mg/ℓ increase in TDS.[3]

In addition to salt concentration because of water withdrawals, some concentration of suspended solids (sediment) will occur downstream from the pipeline intakes if a gravel bed/perforated pipe intake filtration system is used. This system will remove relatively clear water, thus leaving most suspended particules in the San Juan River. At the plant sites, changes in surface water quality will be negligible because of the small amount of runoff (0.1-0.2 inch per year) and the runoff control systems provided. Similarly, plant effluents are not expected to significantly affect surface water qualities because of the use of discharge technology that meets the goals of the Federal Water Pollution Control Act Amendments of 1972.

Population increases resulting from these developments may be accommodated by existing communities or by a new town on reservation lands. Neither is expected to have much effect on groundwater quality or quantity. However, some increase in municipal and industrial needs must be met from surface water. As shown in Tables 5-21 and 5-22, the municipal wastewater loads will continue to stress the existing system. The 1976 design loads will be equalled or exceeded in Farmington, Aztec, Bloomfield, and Shiprock. Current expansion plans will provide adequate capacity in Farmington and Bloomfield if constructed on an appropriate schedule. Runoff will be increased by the expansion

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[1] U.S., Department of the Interior, Bureau of Reclamation. Western Gasification Company (WESCO) Coal Gasification Project and Expansion of Navajo Mine by Utah International Inc., New Mexico: Final Environmental Statement, 2 vols. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1976.

[2] Ibid. This statement calls for four 1,000 million standard cubic feet per day gasification plants to be in operation under 1981 conditions.

[3] Utah State University, Utah Water Research Laboratory. Colorado River Regional Assessment Study, Part 1, Executive Summary, Basin Profile and Report Digest, for National Commission on Water Quality. Logan, Utah: Utah Water Research Laboratory, 1975.

of existing towns. This runoff is generally routed directly into major streams and will eventually augment flow in the San Juan River.

(3) To 2000

The only major facilities to be added during the 1990-2000 decade are a Synthoil liquefaction plant and its associated coal mine. The mine will begin operation in 1999, and the plant will come on-line in 2000. Thus, the impacts associated with these facilities will be primarily related to construction during this decade.

The water impacts to 2000 are expected to be qualitatively about the same as to 1990. Quantitatively, the impacts will be somewhat higher because of the cumulative effect of the three existing plants and because of the addition of the Synthoil plant. Population growth will also continue during the decade, resulting in additional water demands and wastewater treatment requirements.

(4) After 2000

After the plants are decommissioned, the structures will remain. Although many areas will be reclaimed and revegetated, irrigation of the areas will ultimately cease. Subsequently, vegetation may be lost and erosion may increase. The berms around the ponds will also probably lose their protective vegetation and erode; the berms may breach as a result. If this happens, the materials within the pond site will erode and enter the surface water system. Although the salt materials from the evaporation ponds would be returning to their original source, the San Juan River, concentrations may be high enough to cause localized damage to aquatic ecosystems. Likewise, the addition of trace materials and solids from the ash disposal and tailing ponds may have an adverse effect. The low precipitation in the scenario area will retard the transport of these materials.

The towns associated with the energy development will likely remain but populations will decline. The effects of increased storm-water runoff from urban areas and the associated introduction of contaminants into surface water will also remain unless the water is treated.

5.3.5 Summary of Water Impacts

Water for energy development in the Navajo/Farmington area will be taken from the San Juan River Basin, a subbasin of the Colorado River. This water source is limited; estimates of the New Mexico allotment of UCRB water range from 652,000 acre-ft/yr to 703,000 acre-ft/yr. The power plant requires significantly more water (about 29,000 acre-ft/yr assuming high wet cooling and a 75 percent load factor) than the synthetic fuels plants, and all coal conversion facilities require significantly more than the uranium facilities. Of the coal conversion facilities, the Lurgi gasification plant requires the smallest water quantity (about 7,100 acre-ft/yr assuming high wet cooling and a 90 percent load factor). The greatest water use for all of the coal conversion facilities is for cooling. The use of intermediate cooling would reduce water requirements by 69 percent for the power plant, and between 18 and 23 percent for the synthetic fuels plants. The coal mines that provide feedstock coal for the facilities will require 10 to 25 percent of the amounts of water required for the conversion facilities.

Effluents from the energy facilities will be directed into clay-lined, on-site evaporative holding ponds. For the coal facilities, fly ash and bottom ash disposal generate the largest quantities of residuals primarily because the coal contains 19 percent ash. FGD also generates large quantities of residuals from power generation. Other residual quantities from coal conversion are insignificant. The only quantitatively significant residual from the uranium facility is the mill tailings, but these are up to 5 times less than residuals from coal plants.

If all the facilities are constructed, the total water requirement is as much as 81,750 acre-ft/yr[1] (about 12 percent of New Mexico's annual allotment), including water needs resulting from development-related population increases and the postulated new town development. Combined with other current and planned surface water usage in the area, this demand may exceed New Mexico's total allotment from the San Juan Basin, depending on the value used to represent the dependable flow in the Colorado River at Lees Ferry.

Wastewater from the energy facilities, which will be impounded in evaporation ponds, will average 575 acre-ft/yr by 1980 and increase to 5,665 acre-ft/yr by 2000. Wastewater increases will also result from population increases.

Water impacts will increase with the operation of the conversion facilities and their mines and with population increases. Poor quality water filtering from the mines to the Pictured Cliffs sandstone aquifer below the mines may affect the water quality of the aquifer which is already poor. Runoff from the plants and mines will be reduced by holding ponds and water retention facilities. Increased runoff from the expansion of towns will be directed to the San Juan River. Increased salt concentrations in the San Juan River will be caused by water removal.

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[1]Calculated from Tables 5-17, 5-18, and 5-20.

A potential long-term groundwater pollution problem is pond leakage. Pond liners should forestall this problem during the life of the plants, but the materials are likely to leach through the liners eventually and enter the groundwater system. Similarly, following the cessation of maintenance activities, berms containing salts, ash, trace materials, sanitary sludge, and scrubber sludge may be destroyed. If concentrations of these materials enter surface water systems, both local biota and downstream water users might be affected.

5.4 SOCIAL AND ECONOMIC IMPACTS

5.4.1 Introduction

San Juan County, the site of the hypothetical energy development proposed in the Navajo/Farmington scenario, is located in the extreme northwestern corner of New Mexico.

Understanding the many differences between Indians and non-Indians in the county is basic to an analysis of the social and economic effects of energy development within the Navajo/Farmington area. In the analyses which follow, Indian and non-Indian and reservation and nonreservation impacts generally are treated separately.

5.4.2 Existing Conditions

Less than 6 percent of the land in San Juan County is privately owned. The Navajo and the Ute Mountain Reservations occupy approximately 60 percent of the county; another 4.8 percent is owned by the state, and 29.5 percent is owned by the federal government.

San Juan County's 1974 population was 61,700, 56 percent of which was located in the three cities of Aztec, Bloomfield, and Farmington. Population density countywide was 11.2 persons per square mile; outside the three cities, it was 4.9. Approximately 35 percent of the county's 1970 population was Indian, 96 percent living on the Navajo Reservation. Thirteen percent of the population either had Spanish surnames or used Spanish as their primary language. Less than 1 percent was black. Except for a slight decline between 1960 and 1970, the county's population has been increasing over the past 35 years. Population in the three cities has also been increasing, and people have been somewhat more mobile than is generally the case in the western U.S.

Housing in the county is relatively new, four-fifths of it having been built since 1950. Between 1970 and 1973, 739 new homes were constructed; 551 in 1973 alone. Mobile homes comprised about 12 percent of all the houses in Farmington.[1]

The median value of a single-family dwelling in the county was about $13,000 in 1970 ($21,000 in 1975 dollars); the median rent was $80 ($130 in 1975 dollars). Both were somewhat higher in Farmington: the median house value there was about $18,000, and the median rent was about $165 per month.[2] In early 1976, the minimum price housing in Farmington was about $22,000, and the median was over $30,000. Rents ranged from $175 to about $260 per month.[3]

The county is governed by a board of commissioners. A substantial planning capacity has been developed within the County Planning and Research Department, which now has both a planner and assistant planner. Except for transportation and housing supply, the county seems to have an adequate infrastructure and service mix to accommodate additional population growth.[4] There is no countywide zoning ordinance at present. However, a land-use study is under way, the results of which are to be used by the commissioners to decide whether a zoning ordinance is needed.

Shiprock is the only urban center on the San Juan County portion of the Navajo Reservation.[5] It is unincorporated, has no established boundaries, and is governed by the Tribal Council. Public services are provided by the tribal, county, state, and

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[1]U.S., Department of Commerce, Bureau of the Census. County and City Data Book: A Statistical Abstract Supplement. Washington, D.C.: Government Printing Office, 1970; New Mexico, Bureau of Business and Economic Research. Community Profile: Farmington, 1974-75. Santa Fe, N. Mex.: New Mexico, Department of Development, 1974.

[2]Ibid.

[3]Farmington (New Mexico) Chamber of Commerce. General Information, January 15, 1976. Farmington, N. Mex.: Chamber of Commerce, 1976.

[4]See Zickefoose, Paul W. A Socioeconomic Analysis of the Impact of New Highway Construction in the Shiprock Growth Center Area. Las Cruces, N. Mex.: New Mexico State University, Center for Business Services, 1974; and Farmington. General Information.

[5]There are smaller, unincorporated communities in the Farmington/Shiprock corridor. These include Kirtland, Fruitland, and Waterflow.

federal governments. Water, sewer, and electrical services are provided generally only along the highway south from Shiprock. Health services are provided by the Public Health Service and the Bureau of Indian Affairs (BIA). Public safety is maintained by the Navajo and state police forces and the county sheriff. The BIA and the state of New Mexico construct and maintain the roads.

Farmington, the area's largest city, is governed by a four-member council, has a city manager, and has a professional planning capability. City services include water, sewers, electricity, police and fire protection, and recreation. There are no social assistance services apart from those provided jointly by the county and state.

According to the city planning department, most of the service delivery systems are currently operating at or near capacity. A recently completed status report identifies some $30 million worth of projects that are needed to absorb already anticipated population impacts.[1] In the view of both city and county officials, the primary need is construction and operating funds, not help in identifying and analyzing problems. The area is unusual in that relatively few studies have focused on energy development in San Juan County, in contrast to many other areas of the West.

The other off-reservation cities, Aztec and Bloomfield, have mayor-council governments and a city manager. Except for electricity, services in both are the same as those provided by Farmington.

Although a major portion of the reservation is within San Juan County, the Navajos retain a separate identity as the Navajo Nation. While the Navajos govern themselves, there are numerous unanswered questions in Indian law that can affect energy development in the area. For example, the water rights of Indians generally[2] are in question. The applicability of state laws intended to regulate energy development, particularly environmental laws, is also unresolved.[3]

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[1]Farmington, New Mexico, City of. Status Report, March 11, 1976. Farmington, N. Mex.: City of Farmington, 1976.

[2]Pelcyger, Robert S. "Indian Water Rights, Some Emerging Frontiers," in Rocky Mountain Mineral Law Foundation. Rocky Mountain Mineral Law Institute: Proceedings of the Twenty-First Annual Institute, July 17-19, 1975. New York, N.Y.: Matthew Bender, 1975, pp. 743-75.

[3]Will, J. Kemper. Questions and Answers on EPA's Authority Regarding Indian Tribes. Denver, Colo.: U.S., Environmental Protection Agency, Region VIII, 1976.

Concerning its ability to absorb and serve the anticipated population increases, the tribe has been increasing its professional staff, particularly its capacity to plan for economic development. The Tribal Council, the legislative arm of tribal government, has also created specialized commissions to deal with revenue needs and environmentally related challenges. For example, the Navajo Tax Commission is studying the potential for establishing property taxes within the reservation as a means of funding traditional services provided by the Council. In addition, this Commission is involved in efforts to renegotiate existing royalty rates for mining activity on Navajo land because the tribe believes it did not receive equitable treatment in the past. Another special commission, the Navajo Environmental Protection Commission, was created in response to the Navajo's need for an independent environmental assessment, regulatory, and enforcement organization. This five-member commission has the authority to implement the environmental policy of the tribe, serves as a forum for environmental information collection, and considers adverse environmental impacts associated with potential development on the reservation.[1]

The county's economy is characterized by diversity as illustrated by the 1973 distribution of employment shown in Table 5-23. However, the reservation economy is still predominantly agricultural, and the unemployment rate among Indians is well above the county average shown in Table 5-23. The traditional Navajo economy has centered around livestock grazing and near subsistence size irrigated plots. In recent years, subsistence agriculture has been supplemented by turquoise jewelry making and weaving. Employment off the reservation and some industrialization on the reservation have become necessary to provide employment on land already used beyond its capacity for subsistence agriculture.[2]

Farmington is the economic service center for northwestern New Mexico and thus contains a major portion of the available professional and supporting services for the various industrial

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[1]For a discussion of the development of the Navajo Environmental Protection Commission and problems related to the Commission's attempts to implement its regulatory and assessment potential, see Cortner, Hanna J. The Navajo Environmental Protection Commission and the Environmental Impact Statement, Lake Powell Research Project Bulletin 27. Los Angeles, Calif.: University of California, Institute of Geophysics and Planetary Physics, 1976.

[2]Austin, Lynn A., et al. Socio-Economic Impacts of Coal Mining on Communities in Northwestern New Mexico, Bulletin 652. Las Cruces, N. Mex.: New Mexico State University, 1977, p. 35.

TABLE 5-23: EMPLOYMENT DISTRIBUTION IN SAN JUAN COUNTY, 1973

INDUSTRY	EMPLOYEES	% OF EMPLOYED
Total Civilian Work Force	21,193	
Total Employed	19,371	100.0
Agriculture	1,597	8.2
Manufacturing	1,754	9.1
Mining	1,803	9.3
Contract Construction	1,943	10.0
Transportation, Communications, and Utilities	2,015	10.4
Wholesale and Retail Trade	3,596	18.6
Finance, Insurance, and Real Estate	438	2.3
Government	3,439	17.8
Services and Miscellaneous	2,787	14.4
Total Unemployed	1,822[a]	

Source: State of New Mexico Department of Development, Economic Development Division.

[a]8.2 percent of labor force.

and agricultural activities in the area. However, some supporting services are available in Aztec, Bloomfield, and Shiprock.

Per capita income in the county was $3,147 in 1972, which was below the average of $3,512 for the state as a whole.[1] For the Navajo Nation as a whole, the median individual income was $1,984 in 1969 and about $2,220 in 1972, well below the county and state averages.[2] Thus, relatively higher incomes off the reservation contrast sharply with low incomes among Navajos.

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[1]University of New Mexico, Bureau of Business and Economic Research. New Mexico Statistical Abstract, 1975. Albuquerque, N. Mex.: University of New Mexico, 1975.

[2]U.S., Department of Commerce, Bureau of the Census. Census of Population: 1970; Subject Reports: Final Report PC(2)-1F: American Indians. Washington, D.C.: Government Printing Office, 1973.

5.4.3 Factors Producing Impacts

Two factors associated with energy facilities dominate as the cause of social and economic impacts: manpower requirements and taxes levied on energy facilities. Tax rates are tied to capital costs, and/or the value of coal extracted, and/or the value of energy produced. Major taxes which apply to the scenario facilities (a power plant, Lurgi and Synthane gasification plants, Synthoil liquefaction plant, and uranium mill) and their associated mines are a sales tax, royalty payments on Indian-owned coal, and an energy conversion tax.

The manpower requirements for each scenario facility and its associated surface mine are given in Tables 5-24 through 5-28. For all mines, the manpower requirement for operation exceeds the peak construction requirement by at least two times. However, the reverse is true for the conversion facilities. The peak construction manpower requirement exceeds the operation requirement by 1.7 (Synthoil plant) to 7.0 times (Lurgi and Synthane plants). In combination, the total manpower requirement for each coal mine-conversion facility increases from the first year when construction begins, peaks, and then declines as construction activity ceases. The uranium mine-mill combination is characterized by a steady increase in manpower requirements. The peak total manpower requirement for each of the Lurgi, Synthane, and Synthoil mine-plant combinations is about 5,000 and, for the power plant, about 3,000. The fraction of the peak total manpower requirement needed for operation of the mine-plant combination ranges from 0.2 for the Lurgi and Synthane plants to 0.6 for the Synthoil plant. The total manpower required for operation of the Synthoil facility and its associated mine is more than three times that for each of the other plant-mine combinations.

A sales tax which is tied to the capital costs of the facilities, royalty payments which are tied to the value of the coal, and an energy conversion tax which is tied to the value of the energy produced generate revenue. The capital costs of the conversion facilities and mines hypothesized for the Farmington scenario are given in Table 5-29. For coal facilities, costs range from about $1,125 million (mine-gasification plant) to $2,170 million (mine-liquefaction plant) in 1975 dollars. Capital costs of the uranium mine-mill are considerably lower at $30 million.

Sales tax during the construction phase, most of which goes to the state government, is levied on materials and equipment only (Table 5-29). The current sales tax rate in New Mexico is 4 percent. Royalty payments are normally about 12.5 percent of the

TABLE 5-24: MANPOWER REQUIREMENTS FOR A 3,000 MEGAWATT POWER PLANT AND ASSOCIATED MINE[a]

YEAR FROM START	CONSTRUCTION WORK FORCE		OPERATION WORK FORCE		TOTAL IN ANY ONE YEAR
	MINE	POWER PLANT	MINE	POWER PLANT	
1		0			0
2		40			40
3		410			410
4	0	905			905
5	47	1,315			1,362
6	274	2,065		0	2,339
7	267	2,545	0	109	2,921
8	274	1,970	358	109	2,711
9	220	720	358	218	1,516
10	0	0	718	436	1,154
11			718	436	1,154

MWe = megawatt-electric

[a]Data are for a 3,000 MWe power plant and a surface coal mine large enough to supply that power plant (about 12.2 million tons per year) and are from Carasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975. Data uncertainty is -10 to +20 percent.

TABLE 5-25: MANPOWER REQUIREMENTS FOR A LURGI PLANT AND ASSOCIATED MINE[a]

YEAR FROM START	CONSTRUCTION WORK FORCE		OPERATION WORK FORCE		TOTAL IN ANY ONE YEAR
	MINE	LURGI PLANT	MINE	LURGI PLANT	
1	0				0
2	22				22
3	127				127
4	123		0		123
5	127	0	165		292
6	101	36	165		302
7	0	609	331		940
8		2,687	331		3,018
9		4,682	331		5,013
10		2,662	331	0	2,993
11		0	331	589	920
12			331	589	920

[a]Data are for a Lurgi plant and a surface coal mine large enough to supply that Lurgi plant (about 7.3 million tons per year) and are from Carasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975. Data uncertainty is -10 to +20 percent.

TABLE 5-26: MANPOWER REQUIREMENTS FOR A SYNTHANE PLANT AND ASSOCIATED MINE[a]

YEAR FROM START	CONSTRUCTION WORK FORCE		OPERATION WORK FORCE		TOTAL IN ANY ONE YEAR
	MINE	SYNTHANE PLANT	MINE	SYNTHANE PLANT	
1	0	0			0
2	22	36			58
3	127	609			736
4	123	2,687	0		2,810
5	127	4,682	165		4,974
6	101	2,662	165	0	2,928
7	0	0	331	589	920
8			331	589	920

[a]Data are for a Synthane plant and a surface coal mine large enough to supply that Synthane plant (about 6.6 million tons per year) and are from Carasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975. Data uncertainty is -10 to +20 percent.

TABLE 5-27: MANPOWER REQUIREMENTS FOR A SYNTHOIL PLANT AND ASSOCIATED MINE[a]

YEAR FROM START	CONSTRUCTION WORK FORCE		OPERATION WORK FORCE		TOTAL IN ANY ONE YEAR
	MINE	SYNTHOIL PLANT	MINE	SYNTHOIL PLANT	
1		0			0
2		62			62
3	0	598			598
4	36	2,247			2,283
5	211	4,283			4,494
6	205	5,003	0		5,208
7	211	3,503	275	0	3,989
8	169	1,081	275	1,467	2,992
9	0	0	552	2,935	3,487

[a]Data are for a Synthoil plant and a surface coal mine large enough to supply that Synthoil plant (about 12.2 million tons per year) and are from Carasso, M., <u>et al</u>. <u>The Energy Supply Planning Model</u>, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975. Data uncertainty is -10 to +20 percent. However, Synthoil data have an uncertainty because of the small capacity of the bench scale test facilities built to date. The Solvent Refined Coal liquefaction process now appears likely to become commercial sooner, and more reliable pilot plant data are available. These data are reported in White, Irvin L., <u>et al</u>. <u>Energy From the West: Energy Resource Development Systems Report</u>. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 3.

TABLE 5-28: MANPOWER REQUIREMENTS FOR AN UNDERGROUND URANIUM MINE AND PROCESSING MILL[a]

YEAR FROM START	CONSTRUCTION WORK FORCE		OPERATION WORK FORCE		TOTAL IN ANY ONE YEAR
	MINE	MILL	MINE	MILL	
1	80	150			230
2	80	150			230
3	80	150	250	80	560
4	80	150	250	80	560
5	80	150	500	80	810
6	80	150	500	80	810
7	80	75	750	160	1,065
8	80		750	160	990
9			930	160	1,090

[a]U.S., Department of the Interior, Bureau of Indian Affairs, Planning Support Group. Draft Environmental Impact Statement: Navajo-Exxon Uranium Development. Billings, Mont.: Bureau of Indian Affairs, 1976, Table 1.3, p. 1-36.

TABLE 5-29: CAPITAL RESOURCES REQUIRED FOR CONSTRUCTION OF FACILITIES
(in millions of 1975 dollars)[a]

FACILITIES	MATERIALS AND EQUIPMENT	LABOR AND OTHER	INTEREST DURING CONSTRUCTION[b]	TOTAL
Coal Conversion Facilities				
Power Plant 3,000 MWe	461	461	394	1,316
Lurgi or Synthane Gasification Plant (250 MMcfd)	469	369	219	1,057
Synthoil Liquefaction Plant (100,000 bbl/day)	689	832	649	2,170
Associated Surface Coal Mines				
For Power Plant (12.2 MMtpy)	66	36	31	133
For Lurgi Plant (7.3 MMtpy)	40	21	18	79
For Synthane Plant (6.6 MMtpy)	36	19	17	72
For Synthoil Plant (12.2 MMtpy)	66	36	31	133
Uranium Mine and Mill (1,000 mtpy)	8	16	6	30

MWe = megawatt-electric
MMcfd = million cubic feet per day
bbl/day = barrels per day
MMtpy = million tons per year
mtpy = metric tons per year

[a]Data are adjusted (assuming linearity) to correspond to the facility size hypothesized in this scenario and are from Carasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975.

[b]At 10 percent per year.

value of federally owned coal,[1] of which 50 percent is returned to state and local governments. However, all royalties for coal on Indian reservations are retained by the tribe. In New Mexico, an energy conversion tax is levied on the power plant at a rate of 0.4 mill per kWh.

5.4.4 Impacts

The nature and extent of the social and economic impacts depend on the size and character of the community or communities in which workers and their families live, on the state and local tax structure, and on many other social and economic factors. A scenario, which calls for the development of power, Lurgi, Synthane, Synthoil, and uranium facilities according to a specified time schedule (see Table 5-1), is used here as a vehicle through which the nature and extent of the impacts are explored. The discussion relates each impact type to the hypothetical scenario and includes population impacts, housing and school impacts, economic impacts, fiscal impacts, social and cultural impacts, and political and governmental impacts.

A. Population Impacts

Employment data for both energy development[2] and the NIIP[3] are listed in Table 5-30. Population impacts were determined using an economic base model, construction and operation employment data from Table 5-30, sets of secondary/basic employment multipliers which increase during the early years of energy development (Table 5-31), and population/employment multipliers which include wives

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[1] This is the federal government's target rate; actual rates will vary from mine to mine.

[2] Employment data for energy facilities are from Carasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975.

[3] For discussions of the NIIP, see Morrison-Knudsen Company. Navajo New Town Feasibility Overview. Boise, Idaho: Morrison-Knudsen, 1975. Morrison-Knudsen's population projections of the project are from Zickefoose, Paul W. A Socioeconomic Analysis of the Impact of New Highway Construction in the Shiprock Growth Center Area. Las Cruces, N. Mex.: New Mexico State University, Center for Business Services, 1974, p. 178.

TABLE 5-30: NEW EMPLOYMENT IN SAN JUAN COUNTY FROM ENERGY DEVELOPMENT AND NAVAJO INDIAN IRRIGATION PROJECT, 1975-2000

YEAR	ENERGY CONSTRUCTION	ENERGY OPERATION	NAVAJO INDIAN IRRIGATION PROJECT[a]	TOTAL
1975	0	0	0	0
1976	40	0	460	500
1977	250	0	570	820
1978	620	0	660	1,280
1979	1,120	270	810	2,200
1980	1,560	270	980	2,810
1981	2,890	550	1,190	4,630
1982	5,440	660	1,510	7,610
1983	6,880	940	1,600	9,420
1984	70	1,040	1,740	2,850
1985	820	2,130	1,780	4,730
1986	2,890	2,130	2,120	7,140
1987	4,890	2,400	2,140	9,430
1988	2,830	2,400	2,140	7,370
1989	0	3,270	2,140	5,410
1990	0	3,270	2,140	5,410
1991	0	3,270	2,140	5,410
1992	0	3,270	2,140	5,410
1993	30	3,270	2,140	5,440
1994	260	3,270	2,140	5,670
1995	1,010	3,270	2,140	6,420
1996	2,070	3,270	2,140	7,480
1997	2,380	3,270	2,140	7,790
1998	1,730	3,550	2,140	7,420
1999	640	4,180	2,140	6,960
2000	0	5,100	2,140	7,240

[a]Source: Zickefoose, Paul W. _A Socioeconomic Analysis of the Impact of New Highway Construction in the Shiprock Growth Center Area_. Las Cruces, N. Mex.: New Mexico State University, Center for Business Services, 1974, p. 178.

TABLE 5-31: ASSUMED SECONDARY/BASIC EMPLOYMENT MULTIPLIERS FOR NAVAJO/FARMINGTON SCENARIO, 1976-2000[a]

DATE	CONSTRUCTION PHASE MULTIPLIERS		OPERATION PHASE MULTIPLIERS	
	ANGLO	NAVAJO	ANGLO	NAVAJO
1976	0.5	0.1		
1977	0.5	0.1		
1978	0.5	0.1		
1979	0.5	0.1	1.0	0.20
1980	0.5	0.1	1.0	0.25
1981	0.5	0.1	1.1	0.30
1982	0.5	0.1	1.1	0.35
1983	0.5	0.1	1.2	0.40
1984	0.5	0.1	1.3	0.45
1985	0.5	0.1	1.4	0.50
1986	0.6	0.1	1.5	0.55
1987	0.6	0.1	1.6	0.60
1988	0.6	0.1	1.7	0.65
1989	0.6	0.1	1.8	0.70
1990	0.6	0.1	1.9	0.75
1991	0.6	0.1	2.0	0.80
1992	0.7	0.1	2.0	0.85
1993-2000	0.7	0.1	2.0	0.90

ASSUMED POPULATION/EMPLOYEE MULTIPLIERS[b]		
ACTIVITY	NON-NAVAJO	NAVAJO
Construction	2.05	5.0
Operation	2.30	5.0
Service	2.00	4.0

[a]These values were determined by synthesizing materials from several sources. See New Mexico State University, Department of Agricultural Economics and Agricultural Business. Socioeconomic Impact on Rural Communities of Developing New Mexico's Coal Resources. Las Cruces, N. Mex.: New Mexico State University, 1975, pp. 37-53; Morrison-Knudson Company. Navajo New Town Feasibility Overview. Boise, Idaho: Morrison-Knudsen, 1975; Robbins, Lynn A. The Impact of Power Development on the Navajo Nation, Lake Powell Research Project Bulletin 7. Los Angeles, Calif.: University of California, Institute of Geophysics and Planetary Physics, 1975; U.S., Department of the Interior, Bureau of Reclamation. El Paso Coal Gasification Project, New Mexico: Draft Environmental Statement. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1974; Zickefoose, Paul W. A Socioeconomic Analysis of the Impact of New Highway Construction in the Shiprock Growth Center Area. Las Cruces, N. Mex.: New Mexico State University Center for Business Services, 1974; U.S., Department of the Interior, Bureau of Reclamation. Western Gasification Company (WESCO) Coal Gasification Project and Expansion of Navajo Mine by Utah International Inc., New Mexico: Final Environmental Statement, 2 vols. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1976. Navajo household size was 5.1 persons per household in 1970 and the multipliers in the table may be large on average considering single workers.

[b]Non-Navajo (Anglo) population multipliers are adapted from Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976.

in service jobs (Table 5-31).[1] The resulting projected population increases are shown in Table 5-32, Figure 5-6, and Figure 5-7. In this analysis, population increases are assumed to be absorbed both by existing communities and by a new town to be built in the Burnham area by energy developers.[2] The populations for the new town in Table 5-32 are postulated as an example of the effect of the town. It would generally house less than 20 percent of the Navajo population in the county.

Because of the assumptions concerning Navajo employment, the Navajo population in San Juan County is expected to double by 1983 and to reach approximately 80,000 by 2000. (For example, if family members of Navajos remain in Arizona, then the estimates in Table 5-32 are high.) Farmington will grow to 50,000 by 1987, but after a construction phase will not reach that size again until 2000. Overall, the county population will more than double between 1975 and 2000 in the scenario.

The population of the county will increase about 33 percent by 1980 and 86 percent by 1990. The relative proportion of Navajos should increase from the present 40 to 50 percent. Some of the impetus for the increase in Navajo population will be the job opportunities afforded by the NIIP. Much of the increase is expected to occur in the vicinity of Shiprock, where housing with plumbing is being provided by the Navajo Tribe, but the new town would eventually be the largest urban area in the Navajo part of the county.

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[1]Population change also included natural increase which was assumed to be: 1.0 percent annually from 1975 to 1990 and 0.8 percent thereafter for the Anglo population; and 2.0 percent from 1975 to 1990, and 1.5 percent thereafter for the Navajo population. The Indian employment on energy projects was assumed to be one-half of the total through 1990 and 80 percent after 1990. All energy employees are assumed to come from outside of San Juan County. Ninety percent of NIIP employment is assumed to be Navajo, 10 percent of which is assumed to come from outside San Juan County. See U.S., Department of Interior, Bureau of Reclamation. _Western Gasification Company (WESCO) Coal Gasification Project and Expansion of Navajo Mine by Utah International Inc., New Mexico: Final Environmental Statement_, 2 vols. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1976, pp. 3-173 to 3-178.

[2]Morrison-Knudsen Company. _Navajo New Town Feasibility Overview_. Boise, Idaho: Morrison-Knudsen, 1975. Although the preliminary plans for the town suggest a fairly even Navajo-Anglo population, its location on the reservation and Farmington's proximity will probably eliminate its attraction to non-Indian families. WESCO's final environmental impact statement does not discuss a new town, stating that it is not a near-term possibility.

TABLE 5-32: POPULATION ESTIMATES FOR SAN JUAN COUNTY[a]

LOCATION	1975	1980	1983	1985	1987	1990	1995	2000
Reservation								
Shiprock	4,000	5,800	8,850	8,100	10,000	9,200	10,400	12,700
New Town	0	4,400	6,500	9,400	11,400	13,600	14,100	13,450
Other Navajo	21,000	25,800	39,900	33,000	41,500	34,600	40,300	53,450
Total	25,000	36,000	55,250	50,500	62,900	57,400	64,800	79,600
Nonreservation								
Farmington	27,900	34,800	48,200	40,500	50,100	43,650	47,500	49,600
Aztec	5,600	7,000	9,700	8,100	10,100	8,800	9,600	10,000
Bloomfield	2,100	2,700	3,700	3,100	3,800	3,350	3,600	3,800
Other	1,800	2,200	3,100	2,600	3,300	2,800	3,100	3,200
Total	37,400	46,700	64,700	54,400	67,300	58,600	63,800	66,600
County Total	62,400	82,700	119,950	104,900	130,200	116,000	128,600	146,200

[a]Given the assumptions of the scenario, these estimates have an error range of about ±30 percent, which is then incorporated in further projections below.

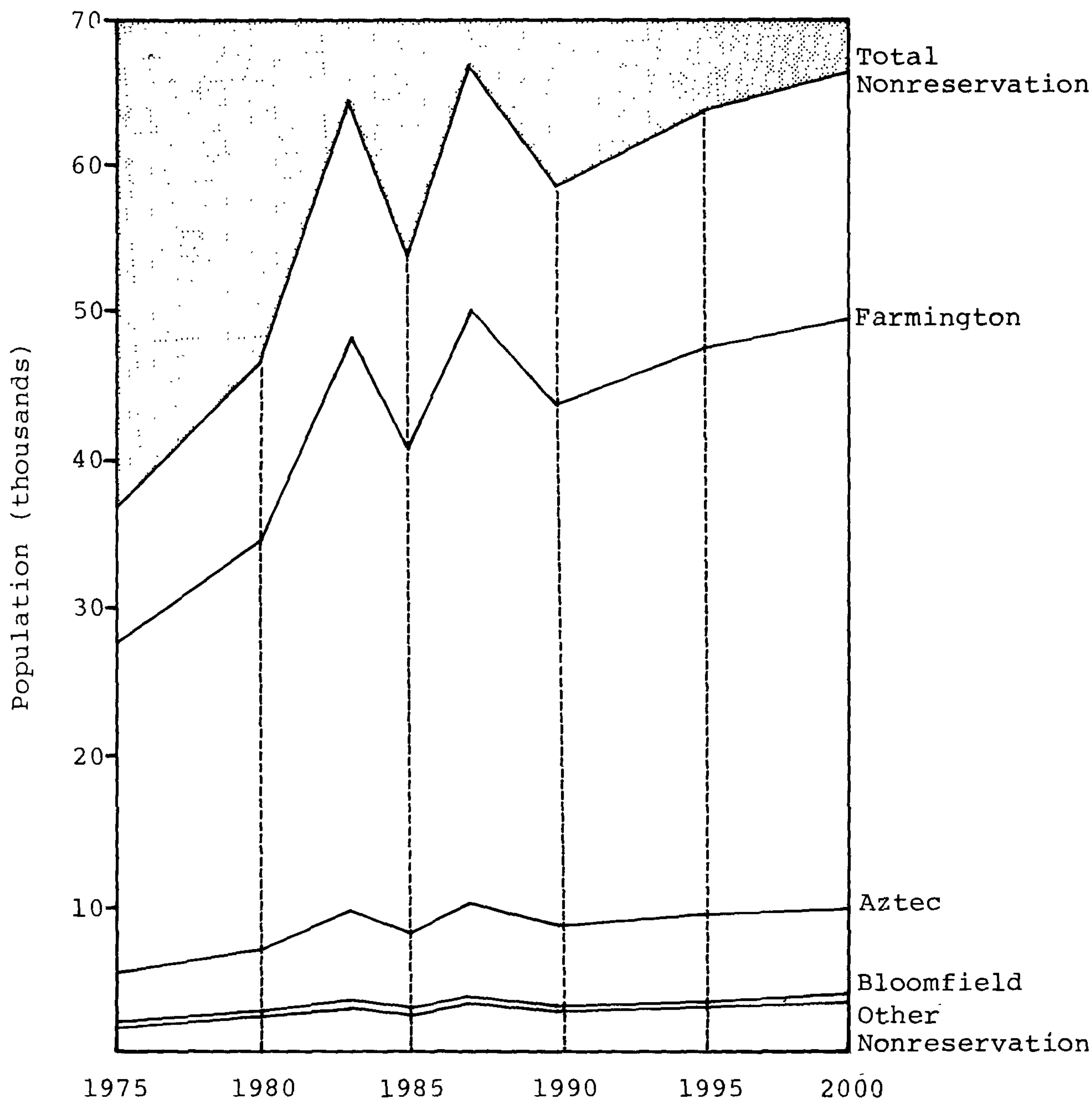

FIGURE 5-6: POPULATION ESTIMATES FOR NON-NAVAJO PORTION OF SAN JUAN COUNTY, 1980-2000

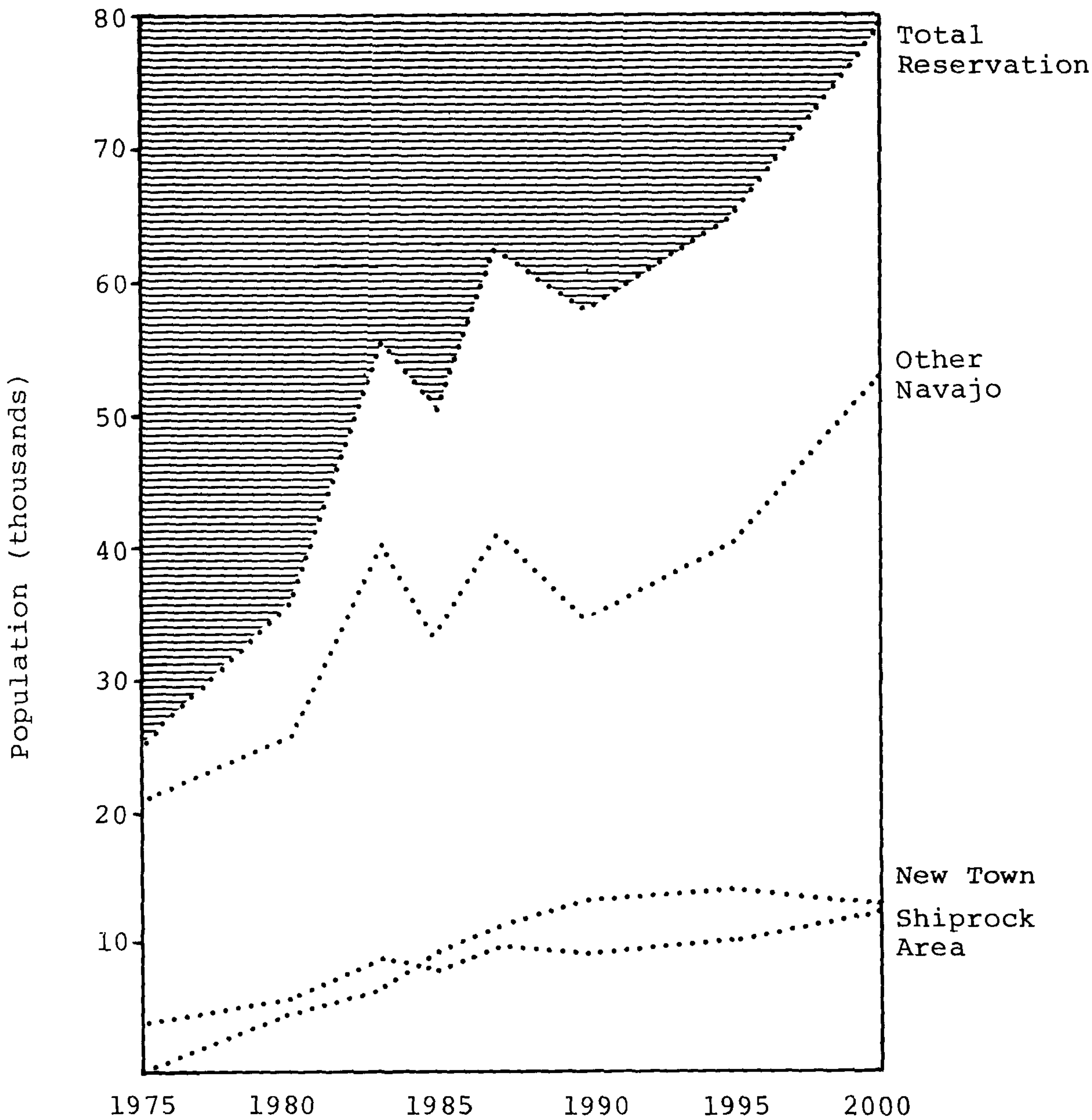

FIGURE 5-7: POPULATION ESTIMATES FOR NAVAJO RESERVATION PORTION OF SAN JUAN COUNTY, 1975-2000

B. Housing and School Impacts

(1) Housing

As shown in Table 5-33, the number of households in the county are projected to increase 145 percent by 2000. Navajo housing demand will double by 1983 and will be three times the 1975 level by the late 1990's.

Much of the required new housing could be supplied by continued expansion of the Navajo Tribal housing development at Shiprock, which has already provided several hundred one- and two-family homes with plumbing.[1] A shortfall in housing supply could result in a scattering of hogans, shanties, and mobile homes without running water in the vicinity of the irrigation and energy projects. If the new town is built, it could provide new employment opportunities and supply a significant proportion of the housing need for Navajo families. Water for the town could be drawn from the San Juan River along with water for the energy facilities. Finally, clusters of housing in the Farmington/Shiprock corridor are likely. Some Navajo homes in this area might be provided with running water by 1985.

By 2000, new off-reservation housing demands in Farmington, Aztec, and Bloomfield will be approximately 4,000, 800, and 300 homes, respectively. With few vacancies in the housing market, many of these may be mobile homes near existing developments or along the highway east and west of Farmington.[2] The spread of mobile homes outside urban areas will be constrained primarily by the availability of water but also by the availability of other utilities and the location of privately owned land in the county.

(2) Schools

As shown in Table 5-33, school enrollment can be expected to increase through 2000. These school enrollment changes also show distinctions between Indians and non-Indians. The Central Consolidated School District serving the reservation will be the most affected. The number of students will more than double by

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[1]Running water is unavailable except in the northern section of the county. Even there, it was unavailable until Shiprock was hooked up with the Farmington municipal system. In the central and southern parts of the county, poor quality groundwater is the only supply. See Section 5.3.

[2]U.S., Department of the Interior, Bureau of Reclamation. El Paso Coal Gasification Project, New Mexico: Draft Environmental Statement. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1974, pp. 2-123 to 2-130.

TABLE 5-33: ESTIMATED NUMBER OF HOUSEHOLDS AND SCHOOL ENROLLMENT IN SAN JUAN COUNTY, 1975-2000

CATEGORY	YEAR	NAVAJO RESERVATION PORTION[a]	NONRESERVATION PORTION[b]	TOTAL
Households	1975	5,000	11,350	16,350
	1980	7,200	14,150	21,350
	1983	11,000	19,600	30,600
	1985	10,100	16,500	26,600
	1987	12,600	20,300	32,900
	1990	14,350	17,750	32,100
	1995	16,200	19,350	35,550
	2000	19,900	20,200	40,100
Elementary Enrollment (20% of population)[c]	1975	5,000	7,500	12,500
	1980	7,200	9,350	16,550
	1983	11,000	12,950	23,950
	1985	10,100	10,900	21,000
	1987	12,600	13,450	26,050
	1990	11,500	11,700	23,200
	1995	12,950	12,750	25,700
	2000	15,900	13,300	29,200
Secondary Enrollment (10% of population)[c]	1975	2,500	3,750	6,250
	1980	3,600	4,650	8,250
	1983	5,500	6,500	12,000
	1985	5,050	5,450	10,500
	1987	6,300	6,700	13,000
	1990	5,750	5,850	11,600
	1995	6,500	6,400	12,900
	2000	7,950	6,650	14,600

[a]Based on five persons per household through 1985 and four persons per household after.

[b]Based on 3.3 persons per household. Both this and the above assumption give high estimates during construction.

[c]Overall averages, which may be high during construction.

1983 to 16,500 and then remain relatively constant until about 2000. Both elementary and secondary enrollment peak in 1987 and again in 2000, and a low point appears about 1985.

At 30 students per classroom, about 300 classrooms will be needed in the Central School District by 1983 and another 250 by the year 2000. Financing for school construction on the reservation could be gained from the proposed energy projects if property taxes are levied, as they can be used for this purpose.[1]

However, the revenues would lag behind the need by as much as 3 years. Some prepayment plan, or the proceeds from coal royalties, could provide the revenue for school construction with the necessary lead time.[2] New schools in the Burnham area, in particular, would help eliminate the present necessity for boarding schools.[3]

In the Farmington, Aztec, and Bloomfield School Districts, enrollment can be expected to increase somewhat during construction peaks.[4] The Farmington School District had excess classroom capacity in 1974[5] but will need about 265 classrooms by 1983. With expected enrollments, the need for additional classroom space will be minimal after the 1980's.

In higher education, the San Juan College campus of New Mexico University in Farmington (600-700 students) and the Shiprock Branch of Navajo Community College (more than 200 students)

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[1]Property taxes generally do not exist in the Navajo Nation. However, a large portion of school costs are provided from the state level.

[2]Some of the financial requirements will also be borne by the federal government, since currently about one-fourth of the Navajo children attend BIA schools.

[3]U.S., Department of the Interior, Bureau of Reclamation. El Paso Coal Gasification Project, New Mexico: Draft Environmental Statement. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1974, pp. 2-121, 3-72 to 3-73.

[4]No large increases are expected because of the declining birth rate of the white population. U.S., Department of Commerce, Bureau of the Census. "Projections of the Population of the United States, by Age and Sex: 1972-2000." Current Population Reports, Series P-25, No. 493 (1972).

[5]Real Estate Research Corporation. Excess Cost Burden, Problems and Future Development in Three Energy Impacted Communities of the West. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, p. IV-14.

will perhaps triple their current enrollments. As employment opportunities become available to more Navajos, vocational training at the Shiprock Branch may increase even more. Training facilities, such as the Navajo Engineering and Construction Authority, train workers in heavy construction trades; the demand for this training can be expected to increase as more energy development takes place on the reservation.[1]

C. Economic Impacts

One immediate change from energy development will be in local income distribution. In San Juan County, positive benefits will accrue to the Navajo population as new employment opportunities allow them to increase their incomes and improve their living standards.

Currently, two of the greatest disparities between Indians and non-Indians occur in income and housing conditions. The 1969 median income of white families in San Juan County was $9,343; the overall median in the county was $8,139. On the Navajo Reservation as a whole, a median individual income was $1,984;[2] comparable data on Navajo family income in the county are not available.

As shown in Table 5-34, the percentage of families with incomes in the $8,000-10,000 range increases through 1985 and then declines.[3] The median income and the proportion of households earning $15,000 and over fluctuates with the amount of construction activity (compare with Table 5-30). Overall, there will be relatively fewer low-income families, the result being a fairly constant median income. However, an overall increase in earnings for Navajos is expected, primarily because of a greater number of on-reservation job opportunities. The projected income distribution in Table 5-34 includes income increases for several hundred Navajo households currently in the area. Decreases in overall median income, when they occur, reflect a relative decrease in high-paying jobs in the oil and gas industries.

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[1]Zickefoose, Paul W. A Socioeconomic Analysis of the Impact of New Highway Construction in the Shiprock Growth Center Area. Las Cruces, N. Mex.: New Mexico State University, Center for Business Services, 1974, pp. 131, 148-49.

[2]U.S., Department of Commerce, Bureau of the Census. Census of Population: 1970; Subject Reports: Final Report PC(2)-1F: American Indians. Washington, D.C.: Government Printing Office, 1973.

[3]The income estimates here do not take into account national trends in income growth from productivity gains and other causes.

TABLE 5-34: PROJECTED INCOME DISTRIBUTION FOR SAN JUAN COUNTY, 1975-2000

YEAR	ANNUAL INCOME (1975 dollars)								
	LESS THAN $4,000	$4,000 TO $5,999	$6,000 TO $7,999	$8,000 TO $9,999	$10,000 TO $11,999	$12,000 TO $14,999	$15,000 TO $24,999	$25,000 AND OVER	MEDIAN HOUSEHOLD INCOME
1975	.184	.068	.065	.075	.080	.125	.291	.113	12,700
1980	.138	.056	.052	.130	.078	.120	.311	.115	13,150
1985	.137	.060	.078	.144	.080	.118	.286	.098	12,000
1990	.126	.058	.072	.134	.084	.120	.308	.097	12,650
1995	.120	.056	.069	.128	.085	.120	.321	.101	13,050
2000	.119	.058	.069	.126	.088	.122	.323	.096	13,000

Source: Data for 1975 are adapted from U.S., Department of Commerce, Bureau of the Census. Household Income in 1969 for States, SMSA's, Cities and Counties: 1970. Washington, D.C.: Government Printing Office, 1973, by inflating to 1975 dollars. Income distributions for energy project construction and operation workers and service employees are from Mountain West Research. Construction Worker Profile: Final Report. Washington, D.C.: Old West Regional Commission, December 1975, p. 50, assuming that "other newcomers" are operation employees and that new service workers earn between the U.S. average and the distribution for long-time residents. Navajo Indian Irrigation Project workers are assumed to earn $7,800; see Morrison-Knudsen, Company. Navajo New Town Feasibility Overview. Boise, Idaho: Morrison-Knudsen, 1975, p. III-10.

A second major economic effect will be the expansion of business activity, particularly on the Navajo Reservation where a number of new business establishments should be located. The potential of a concentrated market in the new town near Burnham would be attractive to businesses, but several bottlenecks to business development might occur. A major problem will be financing new enterprises since credit, even from the Small Business Administration, appears to be difficult to obtain.[1] Also, since reservation land is communally owned and may not be sold, a use-right must be obtained from both the tribal government and the area agency of the BIA before a business can be established. The application process involves some 20 steps and may take up to 5 years to complete.[2] This has discouraged business activity on the reservation, including those in the two largest expenditure categories for Navajos: automobile and truck sales and food purchases.[3] Most of the commercial benefits that will follow from an increase in the income of the San Juan County Navajos will go to businesses in Gallup and Farmington. It appears that business activity in these two communities will increase in any case, and that activity at Shiprock and the new town site could be encouraged by an easing of credit and tribal policies on land acquisition.

Additional industries which may locate in the county include cattle processing facilities (feedlots and slaughter operations) of the Navajo Agricultural Products Industry, on-site facilities to process by-products of gasification,[4] and a possible rail spur north from Gallup to Burnham or Shiprock.[5] There is considerable uncertainty regarding the latter two.

The extent to which usual boom effects will occur in San Juan County is not known. Local inflation in housing costs and wage rates for service workers is taking place, but public services and facilities are in much better shape than in more

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[1]U.S., Commission on Civil Rights. The Navajo Nation: An American Colony. Washington, D.C.: Commission on Civil Rights, 1975, pp. 31-39.

[2]Ibid., pp. 39-40.

[3]Morrison-Knudsen Company. Navajo New Town Feasibility Overview. Boise, Idaho: Morrison-Knudsen, 1975, p. II-2.

[4]Ibid., pp. III-1 to III-2.

[5]Zickefoose, Paul W. A Socioeconomic Analysis of the Impact of New Highway Construction in the Shiprock Growth Center Area. Las Cruces, N. Mex.: New Mexico State University, Center for Business Services, 1974, pp. 200-2.

isolated areas with no large towns. Price increases for retail goods and services will affect both Indians and non-Indians; the largest effect will be felt by those who do not benefit from wage inflation.

D. Fiscal Impacts

Public finance aspects are complicated by the location of facilities on an Indian reservation, as well as recent changes in federal mineral policies. The "dual entitlement" status of Indians means that the federal government provides many services (such as sanitation, health, and education), but local government must stand ready to provide services to Indians in their role as U.S. citizens.[1] The tribal council acts as another level of government in performing many traditional local government functions, such as police protection. Nevertheless, no public agency can levy property taxes within the reservation, except for a few limited items. As noted above, the Navajo Tax Commission is studying the potential for establishing property taxes. At rates comparable with Farmington's, some $57 million per year could be collected from the energy facilities in our scenario.[2]

The only substantial new revenue source available to the Tribal Council will be a royalty on coal. The amount of money involved is difficult to predict, because it depends on negotiation, but appears to be 12.5 percent.[3] That would generate $47.3 million annually for the Navajos by the end of the century.

For expenditures, the Tribal Council is assumed to provide all local government services for residents except education, health care, and construction of water and sewage facilities.[4]

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[1] U.S., Commission on Civil Rights. The Navajo Nation: An American Colony. Washington, D.C.: Commission on Civil Rights, 1975.

[2] Zickefoose, Paul W. A Socioeconomic Analysis of the Impact of New Highway Construction in the Shiprock Growth Center Area. Las Cruces, N. Mex.: New Mexico State University, Center for Business Services, 1974, p. 152.

[3] "Navajos Up Royalty Requirements for New Mexico Coal Gasification Project." Coal Industry News, Vol. 1, No. 5 (December 12, 1977), p. 9.

[4] In New Mexico, state and federal governments pay for most public school costs (79 percent in San Juan County), and more than one-fourth of the Navajo children attend federal (BIA) schools. The Indian Health Service handles the other functions named above. See Morrison-Knudsen Company. Navajo New Town Feasibility Overview. Boise, Idaho: Morrison-Knudsen, 1975, p. III-16.

The remaining functions should require $337 per capita for capital costs[1] and $129 per capita for annual operations.[2] Combining these data with the projected population increases, tribal finances would develop as shown in Table 5-35. The Tribe faces deficits at most times until 1983, when the second mine begins operations.[3] Thereafter, royalties are more than adequate, yielding surpluses of up to $10 million per year.

Off the reservation, local governments will likely rely primarily on residential and commercial property taxes, sales tax, and utility fees to obtain revenue from the energy developments. San Juan County's 1973 tax rolls showed noncorporate valuations of $3,030 per capita (1975 prices).[4] Applying this factor to the prevailing Farmington mill levies[5] and adding the current average utility bill ($216 per capita per year),[6] potential municipal revenues are shown in Table 5-36.

Sales and income taxes depend primarily on the aggregate of new income. Based on the projected distributions of household income and current New Mexico tax rates,[7] an average of 4.4 percent of new personal income will be due the state in income tax.

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[1] THK Associates, Inc. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, p. 30.

[2] U.S., Department of Commerce, Bureau of the Census. The Statistical Abstract of the United States. Washington, D.C.: Government Printing Office, 1975, Tables 429 and 432.

[3] Note that the population estimates include the irrigation project, but the revenue estimates do not.

[4] Zickefoose, Paul W. A Socioeconomic Analysis of the Impact of New Highway Construction in the Shiprock Growth Center Area. Las Cruces, N. Mex.: New Mexico State University, Center for Business Services, 1974, p. 28.

[5] New Mexico, Department of Development, Economic Development Division, and University of New Mexico, Bureau of Business and Economic Research. Community Profile: Farmington, 1974-75. Santa Fe, N. Mex.: New Mexico, Department of Development, 1974.

[6] Real Estate Research Corporation. Excess Cost Burden, Problems and Future Development in Three Energy Impacted Communities of the West. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, Table 17.

[7] Bureau of Census. The Statistical Abstract of the U.S. Table 435.

TABLE 5-35: FISCAL IMPACTS ON NAVAJO TRIBAL GOVERNMENT (millions of 1975 dollars)

YEAR	NEW CAPITAL INVESTMENT EACH YEAR	OPERATING COSTS ABOVE 1975 LEVELS[a]	NEW COAL ROYALTIES[b]	SURPLUS (deficit)
1976	0.77	(.29)0.29	0	(1.06)
1977	0.61	(.23)0.53	0	(1.14)
1978	0.55	(.21)0.74	1.98	.69
1979	1.02	(.39)1.13	1.98	(0.17)
1980	0.74	(.28)1.41	3.96	1.81
1981	1.96	(.75)2.16	3.96	(0.16)
1982	2.53	(.97)3.13	3.96	(1.70)
1983	2.01	(.77)3.90	8.26	2.35
1984	0	(-1.52)2.38	8.26	5.88
1985	0	(.90)3.28	12.54	9.26
1990	1.39	(.89)4.17	16.50	10.94
1995	2.48	(.95)5.12	16.50	8.90
2000	5.00	(1.91)7.03	23.09	11.06

[a]Numbers in parentheses show increases over the previous year. Numbers not in parentheses are the operating costs for that year.

[b]If the rate is 55 cents per ton.

TABLE 5-36: PROJECTED ADDITIONAL UTILITY FEES AND PROPERTY TAXES, NONRESERVATION COMMUNITIES (millions of 1975 dollars)

SOURCE	1980	1985	1990	1995	2000
Property tax, state	0.12	0.28	0.47	0.55	0.72
Property tax, local	0.46	1.10	1.85	2.17	2.85
Utility fees	1.13	2.72	4.55	5.36	7.03

TABLE 5-37: PROJECTED ADDITIONAL INCOME AND SALES TAXES (millions of 1975 dollars)

SOURCE	1980	1985	1990	1995	2000
Personal income	51.80	107.30	165.00	197.60	235.80
Taxable sales	18.10	37.50	57.70	69.20	82.50
State share, sales tax (4%)	0.72	1.50	2.31	2.77	3.30
Local share, sales tax (2%)	0.36	0.75	1.15	1.38	1.65
State income tax	2.28	4.76	7.18	8.75	10.48

Assuming further, that five-eighths of personal income will be spent off the reservation, and that 56 percent of that will be on items subject to sales tax, income-related taxes can be summarized as in Table 5-37.

Finally, the state of New Mexico taxes coal mining and electrical production directly. "Privilege" and "severance" taxes total 1.25 percent of the gross value of the coal (less some minor deductions). Electricity generation is taxed at a rate of 0.4 mill per kWh.[1] Based on scenario assumptions, these taxes should result in the revenues shown in Table 5-38.

The various revenues calculated above can be regrouped by level of government, as shown in Table 5-39, and then compared with new expenditures (Tables 5-35 and 5-40).

TABLE 5-38: PROJECTED TAX REVENUES, PRIVILEGE AND SEVERANCE TAXES (millions of 1975 dollars)

SOURCE	1980	1985	1990	1995	2000
Coal	0.8	2.9	4.2	4.7	7.3
Electricity	0.0	7.8	7.8	7.8	7.8

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[1]The current law has been challenged as an unconstitutional interference with interstate commerce. See Bronder, Leonard D. Taxation of Coal Mining: Review with Recommendations. Denver, Colo.: Western Governors' Regional Energy Policy Office, 1976.

TABLE 5-39: PROJECTED TOTAL REVENUES FROM ALL SOURCES (millions of 1975 dollars)

LOCATION	1980	1985	1990	1995	2000
Reservation	2.9	9.0	11.9	11.9	16.7
County, Municipal	2.0	4.6	7.6	8.9	11.5
State	3.9	17.2	22.0	24.6	29.6
Total: All state and local	8.8	30.8	41.4	45.4	57.8

The simplest comparison to be made involves state government. A realistic assumption is that the state's costs will rise in proportion to population. These costs amounted to $621 per capita in fiscal 1973.[1] Applying a scale-up for inflation and San Juan County population growth, the following cumulative cost increase is projected for the state: $12.6 million in 1980, $28.8 million in 1985, $43.3 million in 1990, $51.1 million in 1995, and $63.0 million in 2000.

These figures suggest that new state expenditures will be about twice as large as new revenues. However, not all of the county's new people will come from out of state.[2] People who move about within the state will not cause any appreciable change in state government requirements. Although very difficult to forecast, at least half the new people should come from instate. If this is the case, the state government will experience very little net fiscal effect from these developments. However, the state, and its government, would grow in absolute size about 3 percent.

Using basic data from a recent western planning study,[3] capital costs for local government are estimated to be $2,360 per capita for county and municipal governments off the

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[1]University of New Mexico, Bureau of Business and Economic Research. New Mexico Statistical Abstract, 1975. Albuquerque, N. Mex.: University of New Mexico, 1975, p. 61.

[2]This has been the case for workers on the San Juan Generating Plant project. See Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, December 1975, pp. 8-17.

[3]THK Associates, Inc. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, p. 30.

TABLE 5-40: SUMMARY OF ADDITIONAL LOCAL GOVERNMENTAL EXPENDITURES AND REVENUES, OFF-RESERVATION (millions of 1975 dollars)

LOCATION	1980	1985	1990	1995	2000
Expenditure					
Capital[a]	12.4	17.3	20.1	8.8	18.2
Operating	0.9	2.1	3.5	4.1	5.4
Annual expenditure, if no borrowing	3.4	5.6	7.5	5.9	9.0
Annual expenditure, with borrowing[b]	2.1	4.9	8.2	9.6	12.6
Revenue	2.0	4.6	7.6	8.9	11.5

[a]Total for 5-year period ending at specified date.

[b]Current operating costs paid "as you go" plus all previous capital costs amortized over 20 years at 7-percent interest.

reservation. Using New Mexico's average figures for local expenditures, these governments will also need $166 per person per year for operating costs. Combining these data with the projected population increases, additional local governmental expenditures are shown in Table 5-40. The previously tabulated revenue figures are included for comparison.

On a "pay as you go" basis of financing, local government faces a negative fiscal impact (new expenditures exceeding new revenues) until about 1990, after which the fiscal impact turns positive. In consideration of that long-term prospect, the municipalities may decide to borrow the portion for capital expenditures. After taking interest costs into account, that method is seen to result in slight but consistent deficits, growing to about $1.1 million per year by the end of the century.

Finally, the federal government is more involved fiscally in this scenario than in the others because of the large Indian population. Federal commitments undertake the expense and/or administration of sanitation, health, education, and other functions. Moreover, the Department of Interior has a responsibility to oversee mineral lease terms and other major action of the Tribal Council.

E. Social and Cultural Impacts

Changes in the Navajo culture and lifestyle may be considerable during the next 25 years because of increased agricultural activities as well as energy development. Navajos traditionally emphasize sharing and communal possession (as opposed to personal ownership of property) and harmony with nature and the land (as opposed to modern agricultural and industrial activities).[1] Development will result in challenges to these traditional attitudes and values, and conflicts will probably develop between the tribal government and locals.[2] The Burnham chapter's rejection of the proposed gasification-coal mining operations in the Burnham area is an example of this.[3]

Most Navajos seem to dislike urban living. For example, the growth of Shiprock as a relatively major settlement on the reservation occurred simultaneously with a large increase in drinking, automobile accidents, and child abuse.[4] Energy development is likely to bring even greater changes in family structures and daily schedules than urbanization. However, the availability of job opportunities on the reservation should be favored by most Navajos who prefer to work locally rather than off the reservation.[5]

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[1] Some practices of the Navajos seem to contradict this description; for example, overgrazing is common.

[2] New Mexico State University, Department of Agricultural Economics and Agricultural Business. Socioeconomic Impact on Rural Communities of Developing New Mexico's Coal Resources. Las Cruces, N. Mex.: New Mexico State University, 1975, pp. 217-22; and Goodman, James M. "Some Observations on the Navajo Sense of Place." Unpublished paper, University of Oklahoma, Department of Geography, 1975; and Zickefoose, Paul W. A Socioeconomic Analysis of the Impact of New Highway Construction in the Shiprock Growth Center Area. Las Cruces, N. Mex.: New Mexico State University, Center for Business Services, 1974, pp. 39-45.

[3] New Mexico State University, Socioeconomic Impact on Rural Communities, pp. 435-36. This was not a consensus decision. However, it is indicative of a tribal split.

[4] Zickefoose. Impact of Highway Construction in Shiprock Area.

[5] Ruffing, Lorraine T. "Navajo Economic Development Subject to Cultural Constraints." Economic Development and Cultural Change, Vol. 24 (April 1976), pp. 611-21.

Some benefits from development are certain, such as increases in income and purchasing power and the consequent capabilities of Navajos to buy or build modern homes. However, the increase in the Navajo population in San Juan County is certain to take place more rapidly than the provision of such things as medical care, housing, and other social services. The current gap between medical needs and available care, already a major problem for the Navajos, will probably widen as population increases. Roads, utilities, and retail establishments may also lag behind the population growth.

Quality-of-life effects on Farmington and the rest of the county are expected to be minor in comparison with those on the Navajo. During the oil and gas boom in the 1950's, Farmington's population grew more than 600 percent in 10 years. The expected rate of increase in coming years will be small by comparison. Although rapid growth has resulted in some service lags, notably in housing, Farmington's urban services and retail mix generally make it a better environment for its residents than smaller towns with the same problem but fewer amenities.

As for health services, the San Juan County Hospital is being expanded and remodeled to triple the 97-bed capacity (including specialized beds) of 1973. Consequently, health care should be less of a problem in the future. Among western cities, Farmington is well-equipped to handle the impacts of energy developments largely because of its size and infrastructure. Typical boomtown problems are not as likely to occur in Farmington as they are in smaller, less developed localities.

Increases in both Indian and non-Indian populations within the county will increase contact betewen the two groups. Relations are likely to become strained, with increased conflict between Indians and non-Indians and between the Tribal Council and other governments.

F. Political and Governmental Impacts

As noted earlier, disagreements between the Navajo Tribal Council, local chapters, and individuals regarding the level of economic activitiy already exist. These are likely to continue, and perhaps even to intensify, as energy development becomes more extensive. For example, a confrontation over Navajo negotiation rights may occur, although the Navajos should be able to resolve their differences with the federal government more easily than some other tribes.

Navajos will receive increased revenues from industrial operations on their land, but the specific quantities and sources of those revenues depend on the tribe's priorities and the extent of the projects it pursues. Existing royalty rates are to be renegotiated by the Navajo Tax Commission because the tribe now believes that it did not receive fair treatment in the past. New contracts negotiated with prospective developers will provide more benefits to the tribes, not only in increased royalty rates but in such areas as training and jobs for Navajos.

In some ways the tribe's income needs are greater than those of many local governments. For example, road-building presents a particular problem because the Tribal Council is not recognized as a local government for various federal cost-sharing programs.[1] On the other hand, the federal government directly provides some services, such as health care.

Participation in tribal affairs and government by local Navajo chapters and individuals has increased with increased mining and industrial development on the reservation. Opposition to Anglo developments on Navajo land and the Tribal Council's nontraditional policies on such issues could have serious effects on Navajo community spirit in the San Juan County area. Contrasts between the poor, traditional Burnham area and more modernized Shiprock are great. However, residents of both areas have opposed non-Navajo exploitation of Navajo lands.[2]

The increasing importance of Farmington as the center of economic and other activities can be expected to continue. Most of the city's revenue comes from city-operated utilities, including electricity, water, and solid waste treatment operations. The city also benefits from growth outside boundaries because it provides water to Shiprock and a number of unincorporated towns in the Farmington/Shiprock corridor. Property taxes are its smallest source of revenue. The sales tax and utility revenues are likely to increase as the county's population increases. However, major capital improvements will be needed for adequate development of water and sewage systems. Police and fire protection also need to be improved.[3]

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[1]U.S., Commission on Civil Rights. The Navajo Nation: An American Colony. Washington, D.C.: Commission on Civil Rights, 1975, p. 19.

[2]U.S., Department of the Interior, Bureau of Reclamation. Western Gasification Company (WESCO) Coal Gasification Project and Expansion of Navajo Mine by Utah International Inc., New Mexico: Final Environmental Statement, 2 vols. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1976.

[3]Real Estate Research Corporation. Excess Cost Burden, Problems and Future Development in Three Energy Impacted Communities of the West. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, pp. IV-4 to IV-13.

As noted in the population impact analysis, the demand for housing in San Juan County will more than double by 1985, with off-reservation needs greatest in Farmington and Aztec. Assistance for these and other communities, particularly during the short term, will necessarily have to come from other levels of government. Pressure will likely be exerted on the state to provide mechanisms which make more money available to traditional lending institutions for home mortgage loans. Although New Mexico presently does not have an administrative division of housing to administer fiscal programs to assist in the development of low or moderate income housing in rural areas, the state does provide limited aid through other state agencies.[1] Rapid energy development in the area may cause expansion of these administrative activities since eligibility for funds from the federal government's "Community Development Block Grant Program" requires that a housing plan for assisting low- or moderate-income persons must be implemented by states requesting such assistance. The state also has a housing finance agency, the Mortgage Finance Agency, whose purpose is to assist in securing mortgage funds for traditional lending institutions.

Due to the lack of a comprehensive countywide zoning plan, certain types of strip development in the San Juan Valley west of Farmington along U.S. 550 and on other limited private lands in the county are expected to continue.[2] Mobile homes, in particular, are likely to proliferate in the area, both on and off the reservation lands. Such development could result in undesirable impacts since the state does not now provide design criteria or standards for mobile home parks (except indirectly through health codes). Even if more effectively planned, the development of large parks for mobile homes (especially in remote areas) can lead to problems for local and county governments with regard to their ability to provide essential public services, regulate activities, control land use, and enforce regulations and standards. The state recently reported problems of enforcement of solid waste rules and regulations, indicating this was primarily because small communities lacked the necessary capital

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[1]Rapp, Donald A. Western Boomtowns, Part I, Amended: A Comparative Analysis of State Actions, Special Report to the Governors. Denver, Colo.: Western Governors' Regional Energy Policy Office, 1976, pp. 20-22.

[2]U.S., Department of the Interior, Bureau of Reclamation, Western Gasification Company (WESCO) Coal Gasification Project and Expansion of Navajo Mine by Utah International Inc., New Mexico: Final Environmental Statement, 2 vols. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1976, p. 3-84.

for implementing required technologies and because of a significant lack of funds at the state level.[1]

5.4.5 Summary of Social and Economic Impacts

Manpower requirements and the tax rates associated with energy facilities are major determinants of social and economic impacts. For the mines, manpower requirements for operation exceed peak construction manpower requirements. However, the reverse is true for the conversion facilities; i.e., more labor is required for construction than for operation. In combination, requirements for each coal mine-conversion facility increase from the first year when construction begins, peak, and then decline as construction activity ceases. Total manpower required for operation of the Synthoil facility and its associated mine is more than three times that of other coal mine-plant combinations.

A property tax, sales tax, royalty payments on Indian owned coal, and an energy conversion tax generate revenue for the local and state governments. Capital costs of the coal conversion facilities and mines hypothesized for the Farmington scenario range from about 1,125 (mine-gasification plant facility) to 2,100 (mine-Synthoil plant facility) millions of 1975 dollars. A sales tax of 4 percent is levied on the materials and equipment purchased in constructing each facility. However, no property tax is collected from facilities located on Indian reservations. Royalty payments are about 12.5 percent of the value of federally owned coal, of which 50 percent is returned to state and local government. However, all royalties for coal on Indian reservations are retained by the tribe. In New Mexico, an energy conversion tax is levied on the power plant at a rate of 0.4 mill per kWh.

If all of the energy facilities hypothesized are constructed, the 1975 population of San Juan County will more than double because of both the energy and agricultural development proposed in the Navajo/Farmington scenario. The largest increases are expected among the Navajo in the reservation portion of the county. The urban areas of the county (such as Farmington, Aztec, Shiprock, and a new town near Burnham) will attract much of the new population. Most of the secondary employment growth will be in Farmington, bringing its population to about 50,000 by the year 2000. The largest increases in the demand for housing and schools will also be on the Navajo Reservation.

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[1] Rapp, Donald A. <u>Western Boomtowns</u>, Part I, Amended: <u>A Comparative Analysis of State Actions</u>, Special Report to the Governors. Denver, Colo.: Western Governors' Regional Energy Policy Office, 1976, p. 28.

As employment opportunities and incomes improve, the lifestyle of many Navajos will generally change from a dispersed rural existence to a more settled and affluent one. The current rural distribution represents the highest rural population density in the nation. New provisions for modern housing with plumbing and kitchens will greatly affect the Navajo quality of life, and this is a major impetus for Navajo support of the concept of a new town in the Burnham area.[1]

Public services, especially health care, water, and sewers, will be among the greatest needs both on and off the reservation. Coordination between the tribe, local Anglo governments, and the federal government will become important within the county so that the quality of growth can be controlled. The tribe itself must derive virtually all its new revenues from coal royalties. The above analysis has shown that a royalty rate of 55 cents per ton would ultimately provide net surpluses of more than $10 million per year. However, deficits may be experienced as late as 1982. Local Anglo governments similarly can expect surpluses eventually (late 1980's) but deficits in the short run.

5.5 ECOLOGICAL IMPACTS

5.5.1 Introduction

The area considered for ecological impacts in the Navajo/Farmington scenario is bounded on the west by the Utah and Arizona borders and on the north by the San Juan National Forest. The study area extends eastward as far as the Chama River and southward to the Chaco Canyon.[3] Elevations range from 5,000 feet over much of the desert to 9,000 feet in the mountain areas.

Energy development at Navajo/Farmington will take place in a desert environment. As noted earlier, the average annual rainfall is 6-8 inches in most of the area and up to 10 inches at higher elevations. Limited precipitation, coupled with excessive grazing are the major factors controlling the composition and productivity of the terrestrial ecosystem.

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[1]Morrison-Knudsen Company. Navajo New Town Feasibility Overview. Boise, Idaho: Morrison-Knudsen, 1975.

[2]Some net income should be derived from the irrigation project, but this cannot be estimated at present.

[3]This area includes most of the present and potential influences of human populations living in the Farmington area and encompasses the ranges of migratory game animals.

5.5.2 Existing Biological Conditions

The coal fields being developed at Navajo/Farmington lie in a broad expanse of desert. Table 5-41 summarizes plants and animals characteristic of the biological communities found in the scenario area. Vegetation south of the San Juan River is very sparse desert grass and shrubland, with species composition reflecting the slight saltiness of much of the soil. Indian and non-Indian ranchers are a major influence of this ecosystem. For example, livestock grazing on the Navajo Reservation has removed most of the plant cover, and much of the topsoil has been carried away by erosion.

The scarcity of water in the area also limits animal population. The fauna is typified by a variety of desert-adapted rodents, lizards, and songbirds.[1] Several birds of prey are found in the area. Foxes, coyotes, and badgers constitute the bulk of the mammalian predators. Except for small numbers of antelope using the more productive grass and shrublands northeast of Farmington, there are few game animals in the area. Rare or endangered species include the peregrine falcon, bald eagle, and black-footed ferret.

The desert is bounded on the north by irrigated croplands, natural marshlands, and riparian woods found in the San Juan River floodplain. In addition to a relatively diverse and abundant assemblage of mammals and reptiles, this zone of well-watered vegetation supports a wide variety of birds, both resident and migratory. For example, the waterfowl habitat of the San Juan Valley is of regional significance.[2]

The foothills to the north and east are pinyon-juniper woodland with some scrub oak and a variety of grasses and forbs. Greater rainfall in these areas makes the foothills more productive than the desert grass and shrublands. Consequently, the fauna is more diverse and abundant there, especially the bird life, which finds a broad spectrum of food and habitats within this type of vegetation. These foothills are also important areas for deer, especially in winter.

Above the pinyon-juniper zone and more distant from Farmington lie coniferous forests consisting primarily of ponderosa pine

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[1]The San Juan Valley lies in the Central Flyway and provides habitat for winter migratory waterfowl and spring breeding populations.

[2]U.S., Department of the Interior, Southwest Energy Federal Task Force. Southwest Energy Study, Appendix H: Report of the Biota Work Group. Springfield, Va.: National Technical Information Service, 1972, PB-232 104, pp. 26-30.

TABLE 5-41: SELECTED COMPONENTS OF MAIN COMMUNITIES, NAVAJO/FARMINGTON SCENARIO

COMMUNITY TYPE	CHARACTERISTIC PLANTS	CHARACTERISTIC ANIMALS
Desert Grassland-Shrub	Blue grama Galleta grass Indian ricegrass Alkali scaton Russian thistle Shadscale Mormon tea	Ord's kangaroo rat Silky pocket mouse Spotted ground squirrel Whitetailed prairie dog Collared lizard Horned lark Coyote Antelope
Pinyon-Juniper Woodland	Pinyon pine Utah juniper Curl-leaf mountain mahogany Cliff rose Gambel oak	Barbary sheep Mule deer Cliff chipmunk Pinyon mouse Gambel's quail Pinyon jay
Riparian	Indian ricegrass Rabbitbrush Tamarisk Willows Cottonwood Elm	House mouse Western harvest mouse Porcupine Desert cottontail Red fox Great blue heron Mule deer
Midelevation Conifer Forests	Ponderosa pine Blue spruce Douglas fir Aspen Moutain maple Alder Oceanspray Gambel oak	Mule deer Elk Turkey Chickadee Cooper's hawk Band-tailed pigeon Pigmy nuthatch
Subalpine Conifer Forests	Corkbark fir Subalpine fir Engelmann spruce Aspen Mountain maple Box myrtle Snowberry	Mule deer Elk Mountain goat Bighorn sheep Beaver Marmot Marten Blue grouse Gray jay

and Douglas fir. This vegetation supports a diverse fauna distinct from that of the pinyon-juniper zone. For example, beaver inhabit most of the mountain streams, and bald eagles winter in this area. Game animals include turkey, as well as deer and elk during the winter.

The highest forest type is dominated by corkbark fir and Engelmann spruce. Alpine meadows occur above the timberline. Big game animals use these high forests and meadows as summer range.

The quality of the aquatic habitat in the San Juan River is influenced by the Navajo Reservoir, constructed in 1962, which is located about 45 miles upstream from Farmington. Cold water discharged from the lower layers of the reservoir controls stream conditions 15-18 miles below the dam.[1] Beyond this distance the river assumes a more typical desert character, becoming warmer and silty. The colder waters support a trout fishery, and a limited warm-water fishery is located near Farmington. Below Farmington, many nongame fish occur; however, the water is too turbid for game fish. Other streams in the area are primarily intermittent; and while they support short-lived invertebrate and plant populations, they probably do not contain fish.

The mineral cycles of arid desert land in San Juan County are "slowed down" relative to many temperate grasslands and forests. Nutrients such as nitrogen and phosphorus are confined to the upper soil layers, due to limited leaching, and this may separate them from the plant roots.[2] Also microbial decomposition of litter and wood is limited to the short periods of adequate soil moisture following rainstorms.[3] However, the principal factor

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[1]U.S., Department of the Interior, Bureau of Reclamation. El Paso Coal Gasification Project, New Mexico: Draft Environmental Statement. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1974, p. 2-84.

[2]See Jurinak, J.J., and R.A. Griffin. Factors Affecting the Movement and Distribution of Anions in Desert Soils, US/IBP Desert Biome Research Memo 72-38, 1972. Skujing, J. Nitrogen Dynamics in Desert Soils; I, Nitrification, US/IBP Desert Biome Research Memo 72-40, 1972.

[3]Tiedeman, A.R., and J.O. Klemmedson. "Nutrient Availability in Desert Grassland Soils Under Mesquite (Prosopis juliflora) Trees and Adjacent Open Areas." Soil Science Society of America Proceedings, Vol. 37 (January-February 1973), pp. 107-11.

limiting vegetative production is usually moisture rather than nutrients.[1]

5.5.3 Factors Producing Impacts

Four factors associated with construction and operation of the scenario facilities (a power plant, Lurgi plant, Synthane plant, Synthoil plant, uranium mill, and their associated mines) can cause ecological impacts: land use, population increases, water use and water pollution, and air quality changes. With the exception of land use, the quantities of each of these factors associated with each facility were given in previous sections of this chapter. Land-use quantities are given in this section, and the others are summarized.

Land use by each of the facilities proposed for the Farmington area is given in Table 5-42. Acres used during the lifetime (30 years) of each coal facility range from 11,605 (gasification plant-mine combination) to 27,300 (power plant-mine combination). By comparison, the uranium mine-mill requires only 350 acres. Land use by NIIP, a large nonenergy development which began operation in 1976, will affect the ecosystems in the scenario area.[2] Following the initial phase, the NIIP will add about 10,000 acres to the system each year until it reaches its planned limit of 96,630 acres in 1986.

Manpower required for construction and operation of the facilities is expected to cause an increase in urban population. Peak manpower required for construction of the facilities is

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[1]The production of vegetation is low. The gross primary productivity of the several vegetation types found in the area is estimated to be about 1.7×10^6 kilocalories per hectare per year, which is almost an order of magnitude less than productivity at the other scenario locations (except for Kaiparowits) of this study. Productivity is chiefly limited by rainfall, and coverage values for the sparse vegetation range from about 5 to 20 percent.

[2]The system will consist of a main open canal and three laterals, with water delivered to the fields by sprinkler systems. Possible crops are corn and sugar beets, and several crops a year are feasible. The Animas-La Plata Project, a Bureau of Reclamation program of reservoirs and irrigated agriculture in two river valleys, is roughly one-seventh the size of the NIIP and will use Animas River water, which will be returned to the San Juan through the La Plata River.

TABLE 5-42: LAND USE BY SCENARIO FACILITIES[a]

FACILITY	LAND USE	
	ACRES PER YEAR	ACRES PER 30 YEARS
Conversion Facilities		
Power Plant (3,000 MWe)		2,400
Lurgi or Synthane Gasification Plant (250 MMcfd)		805
Synthoil Plant (100,000 bbl/day)		2,060
Uranium Mill (1,000 mtpy)		280
Associated Mines		
For Power Plant (12.2 MMtpy)	830	24,900
For Lurgi Plant (7.3 MMtpy)	360	10,800
For Synthane Plant (6.6 MMtpy)	360	10,800
For Synthoil Plant (12.2 MMtpy)	660	19,800
Uranium Underground Mine (1,100 mtpd)	NA	70

MWe = megawatt-electric
MMcfd = million cubic feet per day
bbl/day = barrels per day
mtpy = metric tons per year
MMtpy = million tons per year
mtpd = metric tons per day
NA = not applicable

[a]The land used by the coal mines will increase every year by the amount given in the table for 30 years, the life-time of the facilities. However, the land occupied by a conversion facility or by the underground uranium mine will not vary after construction of the project.

about 2,800 for the power plant and mine, about 5,000 for each of the other coal facilities, and about 230 for the uranium facility. After the facilities are constructed, manpower required for operation of the power, Lurgi, and Synthane plant and mine combinations is about 1,000 each, for the Synthoil plant and mine, over 3,000, and for the uranium mine and mill, about 1,100.

The water requirement for the power plant (about 29,000 acre-ft/yr assuming high wet cooling and 75 percent load factor) is significantly greater than that required by the synthetic fuels plants or by the uranium facility. Of the coal facilities the Lurgi plant requires the smallest water quantity--about 7,128 acre-ft/yr (assuming high wet cooling and 90 percent load factor).

The uranium mine and mill will require about 1,350 acre-ft/yr. Water will be withdrawn from the San Juan River to meet the water requirements of the facilities. Wastewater from the facilities directed to ponds or treatment facilities will contribute contaminants to surface and groundwater only as evaporative ponds leak or erode.

The annual ambient air concentrations of SO_2 will range from 0.3 (Lurgi gasification plant-mine combinations) to 3.3 (Synthoil and power plant-mine combinations) $\mu g/m^3$. Peak concentrations from the Synthoil plant will violate New Mexico's ambient air standard for HC by more than 130 times.

5.5.4 Impacts

The nature of the ecological impacts caused by these factors depends on the plant and animal community type on which they are imposed. For example, the impact of land use depends on whether desert shrub, riparian, or pinyon-juniper communities are being used. Some of the land-use trends are now evident or could occur regardless of energy-related growth. A scenario, which calls for power, Lurgi, Synthane, and Synthoil plants, a uranium mill, and their associated mines to be developed according to a specified time schedule (see Table 5-1), is used here as the vehicle through which the extent of the impacts is explored. Impacts caused by land use, population increases, water use and water pollution, and by air quality changes are discussed for each time period.

A. To 1980

Most of the early impacts of the scenario will be a consequence of construction activities. At the same time, expansion of the NIIP will begin modifying the ecological baseline. Table 5-43 shows the expected land use by the proposed energy facilities, urban population, and NIIP in San Juan County. By 1980, the NIIP will use 30,000 acres (0.9 percent of the land in San Juan County); the urban population will require 5,142 acres (0.15 percent). The Lurgi facility will be the only facility operating by 1980 and will use 1,165 acres or 0.03 percent of the land in San Juan County. These lands are currently used for grazing, primarily by sheep. An average of 365 acres of forage is required to support one cow with calf or five sheep per year (based on the BIA's recommended stocking rates).[1] Table 5-44 gives the

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[1]U.S., Department of the Interior, Bureau of Reclamation. Western Gasification Company Coal Gasification Project and Expansion of Navajo Mine by Utah International Inc., New Mexico: Final Environmental Statement, 2 vols. Salt Lake City, Utah: Bureau of Reclamation, Upper Colorado Region, 1976, p. 2-131.

TABLE 5-43: LAND USE IN FARMINGTON SCENARIO AREA (in acres)[a]

	1975	1980	1990	2000
By Energy Facilities				
Conversion Facilities				
Power Plant (3,000 MWe)			2,400	2,400
Lurgi Plant (250 MMcfd)		805	805	805
Synthane Plant (250 MMcfd)			805	805
Synthoil Plant (100,000 bbl/day)				2,060
Uranium Mill (1,000 mtpy)			280	280
Mines				
Power Plant (12.2 MMtpy)			4,980	13,280
Lurgi Plant (7.3 MMtpy)		360	3,960	7,560
Synthane Plant (6.6 MMtpy)			360	3,960
Synthoil Plant (12.2 MMtpy)				660
Underground Uranium Mine (1,100 mtpd)			70	70
Subtotal		1,165	13,660	31,880
By Urban Population[b]				
Indian Reservations				
Residential	1,250	1,645	2,535	3,545
Streets	250	329	507	709
Commercial	30	40	61	85
Public and Community Facilities	78	102	157	220
Industry	125	164	254	354
Subtotal	1,733	2,280	3,513	4,913
Nonreservation				
Residential	1,835	2,065	2,495	2,725
Streets	367	413	499	545
Commercial	44	50	60	65
Public and Community Facilities	114	128	155	169
Industry	184	206	250	272
Subtotal	2,544	2,862	3,459	3,776
Subtotal	4,277	5,142	6,973	8,689
Total Land Use	4,277	6,307	20,633	40,564
Land Use for NIIP		30,000	96,630	96,630
Total Land in San Juan County	3,523,840			
Indian Reservations	2,114,304			
Nonreservation	1,409,536			

MWe = megawatt-electric
MMcfd = million cubic feet per day
bbl/day = barrels per day
mtpy = metric tons per year
MMtpy = million tons per year
mtpd = metric tons per day
NIIP = Navajo Indian Irrigation Project

[a]Values in each column are cumulative for year given.

[b]Acres used by the urban population were calculated using population estimates in Table 5-32 for San Juan County assuming: residential land = 50 acres per 1,000 population; streets = 10 acres per 1,000 population; commercial land = 1.2 acres per 1,000 population; public and community facilities = 3.1 acres per 1,000 population; and industry = 5 acres per 1,000 population. Adapted from THK Associates, Inc. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development Land Use Study. Denver, Colo.: THK Associates, 1974.

TABLE 5-44: POTENTIAL LIVESTOCK PRODUCTION FOREGONE IN THE NAVAJO/FARMINGTON SCENARIO AREA[a]

ACRES LOST		ANIMAL EQUIVALENTS			
		BIA RECOMMENDED STOCKING[b]		MAXIMUM ACTUAL STOCKING (1975)	
		COWS/CALVES	SHEEP	COWS/CALVES	SHEEP
1980	6,307[c]	14	24	42	72
1990	20,633[c]	45	79	135	237
2000	40,564[c]	88	156	264	468
Post-2000[d]	80,600[c]	178	315	534	945
1974 Inventory[e] San Juan County		23,805	42,692	23,805	42,692
Loss as % of 1974 Inventory		0.7%	0.7%	2.2%	2.2%
Loss to NIIP	96,630	212	375	939	1,125
Loss as % of 1974		0.9%	0.9%	2.7%	2.7%

BIA = Bureau of Indian Affairs NIIP = Navajo Indian Irrigation Project

[a]Included transmission, pipeline, and water line rights-of-way.

[b]Present 64:36 ratio of sheep to cattle in San Juan County used to estimate equivalents, assuming 365 acres is required to support one cow with calf or five sheep per year.

[c]Acres lost include land use by energy facilities and by the urban population; the percent of land used by the energy facilities is 18 percent in 1980, 66 percent in 1990, 78 percent in 2000, and 89 percent post-2000.

[d]Assumes failure of reclamation efforts.

[e]U.S., Department of Commerce, Bureau of the Census. 1974 Census of Agriculture; Preliminary Report, San Juan County, New Mexico. Washington, D.C.: Government Printing Office, 1976.

number of animals (using the present 64-36 ratio of sheep to cows in San Juan County[1]) foregone because of land used by the energy facilities and urban population. The acres lost by 1980 would support 14 cows with calves and 24 sheep (Table 5-44). Because actual Navajo stocking rates are often three times the recommended rate, the forage lost could support up to 42 cows with calves and 72 sheep.

Impacts on wildlife at the Lurgi construction site will be comparatively minor. The larger, more mobile animals, such as badgers and horned larks, will be driven away by the activity. Many of the smaller species with restricted movement patterns, such as the pocket mouse or kangaroo rat, will be killed directly. For the most part, the species affected are widespread throughout the entire desert, and the habitat affected by construction activity is neither unique nor distinctive. The cliffs along the Chaco River, however, constitute important nesting habitat for the area's birds of prey, particularly the golden eagle and red-tail hawk. The water line feeding the Lurgi plant will be constructed along the rim of the Chaco Wash, causing birds of prey to abandon their nests if the disturbance coincides with the nesting period. Once the water line is in place, some of the birds could be expected to return, but original nesting density would probably not be restored.

The population of San Juan County by 1980 is expected to be 82,700, up 30 percent. Increases in poaching of game animals and shooting of nongame species have been observed widely throughout the western states during periods of construction and mineral exploration. Poaching in northern New Mexico is already extensive, in some places equalling legal kill levels (according to a recent study in the Guadalupe Mountains by the New Mexico Department of Game and Fish).[2] Antelope and deer are the species most likely to suffer from extensive poaching. The nesting birds

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[1]U.S., Department of Commerce, Bureau of the Census. 1974 Census of Agriculture; Preliminary Report, San Juan County, New Mexico. Washington, D.C.: Government Printing Office, 1976.

[2]Poaching differs from legal hunting in its impact on game populations by being indiscriminate with respect to age, sex, and season. By removing pregnant females and nonbreeding young, it can exert a significant impact on the ability of the population to maintain an adequate base of breeding adults. Poaching not only harms game populations directly, it reduces the number of surplus animals which may be legally taken. Without license revenues, management and patrol programs designed to protect the herds are difficult to finance. The New Mexico Department of Game and Fish views poaching as one of their most significant problems.

of prey in the Chaco Wash are especially vulnerable to shooting as a consequence of waterline construction.

Water use, water pollution, and air quality changes associated with energy development will not cause significant impacts by 1980.

B. To 1990

The NIIP will be completed by 1986 and the power, Lurgi, and Synthane plants and associated mines will be in operation by 1990.

By 1990, land used by the NIIP will by 96,630 acres (2.7 percent of the land in San Juan County), by the energy facilities, 13,660 acres (0.4 percent), and by the urban population, 6,973 acres (0.2 percent). Loss of grazing lands will have agricultural impacts. The amount of land used by the energy facilities and urban population would support 45 cows with calves and 79 sheep according to the BIA recommended stocking rate. However, this is one-third of the actual stocking rate practiced (Table 5-44). Total acres used by the NIIP would support 212 cows with calves and 375 sheep (according to BIA stocking rates, Table 5-44). This total is 0.9 percent of the 1974 inventory of cows and sheep in San Juan County.[1]

The expansion of irrigated agriculture during this period will begin to establish a trend toward replacement of the desert fauna with species typical of agricultural areas. The limiting factors will become the availability of food and cover. Waterfowl may benefit from the habitat provided by surface canals adjacent to croplands, especially where grains are grown. Desert rodent species may be replaced by those commonly associated with croplands and which consequently have a higher probability of contact with man. Plague is endemic in northwest New Mexico, and as human and rodent populations grow, the probability of cases of human plague may increase.

Actual habitat disruption by the facilities is, as indicated above, of minimal ecological significance in San Juan County. However, the increased population, which will exceed 130,000 by 1990 (more than twice the 1975 population), will have significant ecological impacts. Game poaching and illegal shooting of nongame is expected to increase as population increases, which

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[1]U.S., Department of Commerce, Bureau of Census. 1974 Census of Agriculture; Preliminary Report, San Juan County, New Mexico. Washington, D.C.: Government Printing Office, 1976.

would cause noticeable declines in wildlife populations by 1990. The most vulnerable big game populations are the deer (Deer Management Area 10) and the antelope located in the foothills southeast of Farmington. The declining deer populations are nonmigratory and their range is particularly accessible by vehicle on oil and gas exploration trails. The antelope herd is already declining due to harrassment and illegal harvest, and could be virtually eliminated by 1990. Furthermore, the demand for legitimate hunting, especially for big game, will also increase as construction-related populations grow. Hunting pressure on deer is already high especially in the foothills near Farmington. Between 1970 and 1973, hunters using Deer Management Area 10 (which includes almost all the New Mexico deer habitat in this scenario) increased from 8,159 to 12,600. Concurrently, hunter success dropped from 24.9 percent to 11.4 percent.

Game animals on Navajo lands are subject to shooting that is controlled more by Indian social custom than by state laws and management. Game populations suffer from year-round or uncontrolled harvest, as well as from habitat destruction by heavy grazing from domestic animals. Changes in wildlife use on reservation lands from new Indian towns or changed population distributions are not expected.

The impact of the scenario in increased demand for backcountry types of recreation will begin to be felt by 1990. Initially, much of this demand will focus on the San Juan Mountains, particularly the newly designated San Juan Wilderness area and the adjacent Rio Grande Wilderness. The San Juan Forest staff has indicated that use permits may be used in order to limit access in 4-5 years. With demand for recreational areas, adjacent foothills and midelevation forests will be used to a greater degree.[1] Vegetation along stream banks, lakes, and in meadows at high altitudes may deteriorate due to the effects of camping, horses, and foot traffic.[2] Other impacts might include: the disturbance and

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[1]Foothill lands controlled by the Ute Mountain and Southern Ute Reservations are, however, essentially closed to dispersed recreation by tribal attitude and policy. Most of the recreational pressure from the Farmington area is likely to concentrate in the foothills of the San Juan National Forest in Colorado and in the highlands east of Farmington, including the Carson National Forest.

[2]For example, the San Juan National Forest presently has rules restricting camping within a specified distance of certain high-altitude lakes and streams. High meadows are summer range for both deer and elk, and support distinctive populations of small vertebrates and insects of both scientific and aesthetic interest. Delicate alpine flora can be greatly reduced in diversity or destroyed after a few years of trampling.

subsequent redistribution of elk, especially on calving grounds; fragmentation of key deer ranges by recreational development on private lands;[1] harrassment of deer and other wildlife by heavy off-road vehicle (ORV) use in the hills east of Farmington, especially in winter;[2] and local erosion.

Expanding urban development will also begin to produce noticeable impacts by 1990. Strip development along the San Juan River will fragment riparian habitat. While some species of ducks, shorebirds, and songbirds will lose some habitat due to this development, the loss will be compensated for, in part, by the NIIP. Species such as the great blue heron, which depend heavily on fish and other aquatic fauna, may decline. Wild dogs, already a problem, will increase in numbers and disturb deer wintering in the uplands adjacent to the San Juan River or in the valley itself. Finally, heavy ORV use within roughly 20 miles of concentrations of human populations will deteriorate some terrain. Even without development of a new town at Burnham, some clustering of dwellings in the area may be expected because of its location relative to the NIIP and the energy developments.

Water requirements for the scenario facilities and municipalities will be met with water from the San Juan River. Water withdrawals may result in high concentrations of salt and suspended solids in the river. During construction of the facilities, runoff may also contaminate surface water. Groundwater may be contaminated by weathering and leaching of mine wastes and ash deposited in mined-out areas.

Effluents from the facilities will be ponded and are not expected to contaminate water. However, the increased effluents from the municipalities will require updated sewage treatment facilities. Difficulties in procuring funds for adequately updating municipal sewage facilities may result in the direct discharge of most of the treated sewage generated by the growing urban populations by 1990. Especially during late-summer periods of low flow, the added nutrients and biochemical oxygen demand carried in sewage treatment effluent, coupled with agricultural runoff, could cause serious problems of algal growth and lowered dissolved oxygen

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[1]This could be particularly significant west of Durango, parallel to U.S. 160 from Durango to Cortez, and in the Animas River valley below the Purgatory ski area. However, Colorado's land-use laws provide for county approval of such development, which may afford a measure of control.

[2]Assuming a total of 28,000 new families by 1990 and one ORV for each four families yields an estimate of 7,000 such vehicles. By 2000, the total is 8,750. These could exert very significant impacts on nearby foothill habitats if uncontrolled.

in the river from Farmington to below Shiprock. If treatment facilities are improved during the second half of the decade these effects will diminish.

The four facilities operating by 1990 are sited far enough apart so that interaction of air pollutants from each will not be significant. Peak concentrations from the power plant-mine combination will violate New Mexico's 24-hour NO_2 ambient air standard. Pollution due to Farmington's predicted population increase will violate New Mexico's 3-hour HC standards. The HC violation, which will exceed New Mexico's standard by a factor of five, appears the most severe because it increases the likelihood of oxidant formation and photochemical smog. Although the uncertainty is high, expected ambient air concentrations of criteria pollutants are not expected to cause chronic or acute damage to ecological communities.

C. To 2000

By 2000, all five of the scenario facilities will be operating. Continued expansion of the coal mines from 1990-2000 plus construction of the Synthoil facility will use additional land. Land use by 2000 by the facilities and urban population will be 40,560 acres or 1.1 percent of the land in San Juan County (Table 5-43). The forage produced on this acreage would support 88 cows with calves and 156 sheep per year (according to the BIA stocking rate, which is one-third of the actual stocking rate, Table 5-44).

Population in San Juan County will increase to 146,300, a 134 percent increase over the 1975 population. The increased population will exacerbate the ecological impacts described above associated with game poaching, illegal and legal hunting, recreation activities, and urban development.

Local changes in the mineral cycles at Farmington are likely to occur in two major categories: physical changes in nutrient pools, and changes in the biological sector of the nutrient cycles. Physical changes will be due primarily to erosion (particularly from the wind) of surface soil and litter. These impacts will arise from construction, livestock overgrazing, recreational activities (especially ORV use), and surface mining. Another physical change will be the minimization of stream flow variations as a result of the operational practices of the Navajo Reservoir. This will reduce the deposition of soil in riparian habitats which now occurs following high-flow periods.

In general, water impacts associated with the scenario facilities and urban population by 2000 will be qualitatively similar to, but more intense than, 1990 impacts. The impact of biological changes in the mineral cycles though vegetation loss will be limited spatially because the desert is divided into "microwatersheds" with an individual shrub at the center of each small catchment area.[1] Changes from energy development will operate on the level of the individual microwatersheds rather than on some larger unit such as a stream watershed or plant community. By the year 2000, the withdrawal of water from the San Juan Basin will have risen to 226,000 acre-ft/yr for the NIIP, 66,400 acre-ft/yr for the new energy facilities,[2] and about 15,350 acre-ft/yr of additional water for the increased population. Most of this water will be diverted directly from the Navajo Reservoir.[3] By 2000, the Navajo Reservoir, which is currently drawn down about 45 feet per year, will be drawn down 95 feet per year to meet the water requirements for the NIIP, energy facilities, and increased urban population. The impacts of these water withdrawals on the reservoir will be minor. Game fish populations now in the reservoir are expected to continue to reproduce, although shallow water habitat important to spawning and juvenile survival will be seasonally reduced as the lake level drops. Algae and aquatic macrophytes, if fluctuating lake levels allow their growth, will be stranded along the shoreline as the water recedes. After they have decayed and the lake level again rises, a decrease in dissolved oxygen could occur in areas where vegetative growth is permitted.

The net effect of the withdrawals may be a decrease in flows of cold water downstream. Although the storage project maintains a minimum flow of 400 cubic feet per second (cfs) for downstream use, lowering of potential flows closer to this minimum will have few beneficial, and many adverse, consequences, including: limiting the already excellent cold water fishery for rainbow and brown trout below Navajo Reservoir; some deposition of silt and sand bars downstream which will reduce the stability of bottom habitats, including fish spawning and nesting sites; warming of waters and reduction of total amount of aquatic habitat in areas of depleted

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[1]See, for example, Stark, N. Distillation--Condensation of Water and Nutrient Movement in a Desert Ecosystem, US/IBP Desert Biome Research Memo 73-44, 1973; Charley, J.L. "The Role of Shrubs in Nutrient Cycling," in McKell, C.M., J.P. Blaisdell, and J.R. Goodin, eds. Wildland Shrubs--Their Biology and Utilization, USDA Forest Service General Technical Report INT-1. Ogden, Utah: U.S., Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1972; Garcia-Moya, E., and C.M. McKell. "Contribution of Shrubs to the Nitrogen Economy of a Desert-Wash Plant Community." Ecology, Vol. 51 (Winter 1970), pp. 81-87.

[2]Assuming high wet cooling for the scenario facilities operating at the expected load factor (Table 5-17) and including the water used for mine reclamation (Table 5-18).

[3]U.S., Department of the Interior, Bureau of Reclamation, Farmington, New Mexico. Personal Communication, January 1977.

flow (effects of flow reduction will be much more significant than increase in dissolved solids); and reduction in marsh vegetation within the floodplain, reducing waterfowl nesting habitat.

About 209 cfs will be annually returned to the San Juan River above Shiprock at Chaco Wash from seasonal irrigation runoff and artificial aquifers created by the NIIP. This return will contain high TDS concentrations and quantities of pesticides and fertilizers. Though base flows at Navajo Dam should maintain flow at Shiprock, the dilution of this irrigation return could become critical to water quality at and below Shiprock during periods of low flow.[1] The ability of the river to dilute the concentrated irrigation runoff could be enhanced by almost 20 percent through the use of once-through cooling processes at the energy facilities.[2]

Wastewater impounded at the four plant sites could attract desert animals and waterfowl. The impact of these wastewaters on wildlife is dependent on accessibility and their composition. The wastes of the coal conversion plants are of particular interest because they may contain various organic compounds known or suspected to be carcinogenic (see Chapter 10). Evaporation ponds are likely to contain high concentrations of chemicals and be unpalatable and odoriferous. In addition, sublethal or chronic effects would probably not affect a sufficient number of animals to be significant on a regional scale.

As reported previously in the air impact analysis, ground level SO_2 and NO_2 concentrations from the proposed facilities will generally be at least an order of magnitude below the federal standards even under the worst conditions. However, New Mexico's ambient air standard for 24-hour NO_2 will be violated by the power plant facility. The Synthoil facility will violate New Mexico's ambient HC air standard by more than 130 times. Concentrations of SO_2 and NO_2 over most croplands will be much lower than in the facility vicinity, on the order of 10 $\mu g/m^3$ or less. At this level, SO_2 has not been found to produce either acute or chronic damage to the type of crops to be grown in the irrigation project. The effects of air-dispersed trace elements, including large

[1]Low flow of record at Shiprock since the construction of Navajo Dam is 68 cfs (present management attempts to assure 400 cfs).

[2]About 75 percent of the total water required for energy production is lost to evaporation in forced-draft cooling towers. If once-through cooling is employed, this water can be returned to the San Juan above Chaco Wash and Shiprock. The increased dilution of 20 percent reflects changes in volume and disregards losses from the river due to evaporation or seepage; it similarly does not reflect periods of increased rainfall or other seasonal variation.

amounts of fluorine, cadmium, arsenic, and mercury, cannot be predicted. However, under similar circumstances, concentrations of these elements (with the exception of fluorine) were not predicted to reach toxic concentrations in terrestrial environments.[1] Fluoride concentrations, with all facilities on-line, may approach cumulative damage levels in sensitive plants of 1 part per billion over extended periods of time, depending on the stack gas scrubbing method.[2]

Other potential impacts on the biological portion of mineral cycling arise from SO_2 emissions. A considerable amount of sulfur will be emitted into the air and may eventually be deposited on land. The impact of this additional sulfur is not known, but it may be expected to accumulate in the ecosystem, eventually reacting with biological components and beginning to cycle within the systems.[3] However, given the anticipated level of scenario development, it is unlikely that sufficient sulfate will enter the soil to induce an overall acidification problem, especially since many soils are slightly alkaline.

D. After 2000

A total of 71,900 acres, which is 2.0 percent of the acres in San Juan County, will have been disturbed by the facilities during their 30-year lifetime (Table 5-42) and an additional 8,700 acres by the urban population (Table 5-43). This total acreage of 80,600 would support 178 cows with calves and 315 sheep (according to BIA recommended stocking rate, which is one-third of the actual 1975 stocking rate), which is 0.7 percent of such livestock in San Juan County in 1974 (Table 5-44). Attempts by ranchers to compensate for these forage losses by moving sheep or cows to other, unmined lands will probably be unsuccessful. Overgrazing on Navajo lands is already heavy, and increased grazing pressure on remaining rangelands may decrease forage production to the point where livestock carrying capacities are significantly lower than they were prior to energy development.

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[1]U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976, pp. III-60 to III-64.

[2]Ibid., p. III-65.

[3]See Tiedeman, A.R., and J.O. Klemmedson. "Nutrient Availability in Desert Grassland Soils Under Mesquite (Prosopis juliflora) Trees and Adjacent Open Areas." Soil Science Society of America Proceedings, Vol. 37 (January-February 1973), pp. 107-11; and Tucker, T.C., and R.L. Websterman. Gaseous Losses of Nitrogen from Soil of Semi-Arid Regions, US/IBP Desert Biome Research Memo 73-37, 1973.

The major cumulative habitat losses of the Navajo Scenario will take place in an area of desert bounded by the San Juan River, New Mexico Highway 44, and the Chaco Wash. Environmental factors which will limit the reestablishment of vegetation are: limited rainfall and high evaporation, erodibility and salinity of much of the overburden material, general absence of good topsoil, and uncontrolled grazing by large livestock populations on the Navajo Reservation.

Overgrazing by Navajo livestock is a critical factor. Reseeding efforts at Black Mesa on the Navajo Reservation have failed several times, largely because livestock destroyed the early growth.[1] Alternative techniques, such as planting seedlings, may substantially increase the success of revegetation, but at present no formal plans have been developed to initiate a seedling program. Current practices at two surface mines in the Four Corners area involve application of up to 12 inches of water for a period of 2 years in an effort to reestablish growth of both native and nonnative species. Invasion of nonpalatable species (Russian thistle) has occurred, and some species common to wetter locations have been established, but successful long-term maintenance of these species does not appear likely. Data for a period of longer than two years are not available.

Impacts after 2000 associated with population increases, water use and water pollution, and air quality changes are expected to be similar to those prior to 2000.

5.5.5 Summary of Ecological Impacts

Four factors associated with construction and operation of the scenario facilities can significantly affect the ecological impacts of energy development: land use, population increases, water use and water pollution, and air quality changes. Land use by urban population and energy facilities during their 30-year lifetime will be 80,600 acres, which is 2.3 percent of the land in San Juan County. Land use by a nonenergy development, the NIIP, which will use 96,630 acres between 1976 and 1986, will also cause ecological impacts. By 2000, the urban population in San Juan County will increase to 146,300, a 134 percent increase over the 1975 population. Water use by the year 2000 will be 226,000 acre-ft/yr for the NIIP, 66,400 acre-ft/yr for the energy

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[1]Thames, J.L., and T.R. Verma. "Coal Mine Reclamation in the Black Mesa and the Four Corners Areas of Northeastern Arizona," in Wali, M.K., ed. Practices and Problems of Land Reclamation in Western North America. Grand Forks, N. Dak.: University of North Dakota Press, 1975.

facilities, and 15,350 acre-ft/yr for the increased population. These water requirements will be met with water from the Navajo Reservoir which has a limited water supply. By 2000, the Navajo Reservoir, which is currently drawn down about 45 feet per year, will be drawn down 95 feet per year to meet the total water requirements. Effluents from the energy facilities will be ponded to prevent contamination of surface water and groundwater. Increased effluents from the urban population will require updated sewage treatment facilities to prevent water pollution.

Although ecological impacts will begin with the first year of the scenario, noticeable regional effects will probably not become evident until after 1985. The most important of these impacts--judged on the basis of geographic extent, potential for altering the size and/or stability of populations of important species, or likelihood of resulting in a change in the structure or function of a large portion of an ecosystem--are summarized below. Their expected cumulative impact on selected animals is presented in Table 5-45.

Major ecological impacts are ranked into classes in Table 5-46. These classes are based on the extent of habitat and number of species affected by a given action. Class A impacts such as habitat removal or fragmentation, the replacement of the desert ecosystem by cultivated croplands, and little or no revegetation on mined areas, affect several species over a wide area and are considered the most severe. Class B impacts locally affect fewer species and include illegal shooting and poaching as well as the potential loss of small herds of antelope. Impacts that are likely to affect the fewest animals and are extremely localized (such as the consumption of impounded wastewaters) are ranked as Class C.

Assuming that climatic factors, poor soils, and overgrazing will combine to preclude effective reclamation of strip mines, the combined effect of habitat loss from energy developments will be to cause an overall decline in the water- or food-limited desert fauna and to replace it by a cover-limited fauna typical of farmlands. Total animal abundance will probably increase due to the impact of the irrigation project, in spite of the opposite trend associated with energy development.

Two groups of species will serve as barometers or indicators of this change. Species adapted to the desert (which are expected to decline because of habitat loss) include Gunnison's prairie dog, Ord's kangaroo rat, the silky pocket mouse, and white-throated wood rat. Decline in these, particularly the prairie dog, will affect other species adapted to living among and preying on them. For example, the western burrowing owl, ferruginous hawk, and badger may be expected to exhibit sharp declines. In addition to a decrease in predators, fragmentation of open areas will contribute to the decline of gray and kit foxes. The NIIP will provide a food base for increased numbers of other rodents and birds, some of which may become pests (such as the pocket gopher, which

TABLE 5-45: FORECAST OF POPULATION STATUS OF SELECTED SPECIES FOR THE FARMINGTON SCENARIO

	1980	1990	2000
Big Game			
Deer	Little change from present trend.	Accelerated decline of herds east of Farmington; beginning of decline along river valleys, and along U.S. 160 in Colorado.	Continued decline of eastern herd, with moderate to serious loss of hunting potential. Moderate decrease in numbers of deer along the San Juan. Slight to moderate decline of populations wintering in hills along U.S. 160.
Elk	Little change.	Possible slight decline in overall numbers.	Possible decline in overall numbers. Redistribution away from areas of regular human use.
Antelope	Continued decline.	Probable extirpation around Farmington.	
Bighorn Sheep (Colorado)	Continued transplants by Colorado Division of Wildlife; numbers increase.	Numbers come under control of hunting and stabilize.	
Game Birds			
Waterfowl	Increase in breeding populations.	Increasing trend peaks and slows, shifts from San Juan, Animas, LaPlata Valley wetlands to irrigated areas.	Slight decline from preceding peak, but net increase over 1975 base levels.
Pheasant, Quail	Increase in numbers.	Increasing trend peaks and levels off.	Continued overall moderate population levels throughout irrigated areas.
Chukar	Little change.	Extirpation or severe reduction of population near Farmington; no major changes elsewhere.	
Turkey	Possible local increases in populations in San Juan National Forest.	Little change.	Little change.
Doves	Slight local increase around irrigation projects.	Moderate increase around irrigation projects.	
Rare, Endangered, or Threatened			
American Peregrine Falcon	Stable to slight decline.	Severe decline is likely; probable loss of nesting birds on the Colorado side.	Probable equilibration at low numbers of wintering birds.

TABLE 5-45: (Continued)

	1980	1990	2000
Rare, Endangered, or Threatened (Continued)			
Bald Eagle (subspecies undetermined)	Little change.	Possible loss of nesting birds in San Juan Valley north of reservoir.	Decline in numbers of wintering birds.
Black-Footed Ferret	Little change.	If present, likely to extirpated.	
Colorado Squawfish	Little change.	If present below Shiprock, likely to decline severely or become extinct.	
Spotted Bat	Little change.	If present, likely to be reduced or extirpated.	
Prairie Falcon	Decline.	Probable loss of nesting birds in coal area.	
Osprey	Little change.	Decline of nesting populations.	Continued decline, becoming locally infrequent.
Ferruginous Hawk	Slight decline.	Strong decline and possible local extirpation.	
Burrowing Owl	Slight decline.	Strong decline.	Probable equilibration at low numbers.
Humpback Sucker	Little change.	If present below Shiprock, likely to decline strongly or become extinct.	
Ecological Indicators			
Riparian Habitat			
Beaver	Stable or slight decline.	Moderate decline in number.	Continued decline in number.
Bald Eagle	Stable.	Moderate decline in nesting; wintering populations decline slightly.	Continued low nesting populations, and slight to moderate decline in wintering populations.
Irrigated Landscape Species	Moderate increase in population.	Continued increase, stabilized after 1986.	Stable overall trend.
Desert Grassland Species	Moderate decline in numbers.	Accelerated decline especially of breeding raptors.	Continued decline at lowered rate.

TABLE 5-46: SUMMARY OF MAJOR FACTORS AFFECTING ECOLOGICAL IMPACTS

IMPACT CATEGORY	1975-80	1980-90	1990-2000+
Class A	Direct habitat removal Habitat fragmentation by NIIP and development Shift in ecosystem: desert to cultivated cropland	Direct habitat removal Habitat fragmentation by NIIP and development Shift in ecosystem: desert to cultivated cropland Grazing losses (NIIP) Loss of endangered species	Direct habitat removal Unsuccessful revegetation of mine sites Grazing losses (NIIP and mines) Loss of endangered species
Class B	Poaching of big game Shooting of nongame species	Lowered flows in San Juan Illegal shooting and poaching Loss of antelope Increase in recreation demands; ORV's Feral dogs	Lowered flows in San Juan Intensified overgrazing by Navajo on remaining rangelands Increase in recreation demands; ORV's Feral dogs
Class C		Consumption of impounded wastewater by wildlife Increased incidence of plague	Consumption of impounded wastewater by wildlife Increased incidence of plague
Uncertain	Introduction of pesticides, fertilizers	Introduction of pesticides, fertilizers	Introduction of pesticides, fertilizers

NIIP = Navajo Indian Irrigation Project ORV = off-road vehicle may increase where root crops [such as sugar beets] are grown). Gophers, mice, and moles are now found in the area and are expected to become common as the expansion of agriculture proceeds. Some of these rodent populations could become reservoirs for plague. Swallows and various small farmland sparrows will also increase; although the horned lark will still be a common resident, it will no longer be the dominant species.

Coincident with this increase in smaller wildlife, there will probably be an expansion of the population of several predators or omnivores adapted to farmland situations. Many of the hawks already breeding in the area could increase in numbers as a result of the increased prey base in the irrigated lands, provided that adequate nesting sites are present. These include the marsh hawk, kestrel, redtail, and roughleg. Red fox and striped skunk will probably also increase.

Toxic substances discharged into on-site holding ponds cannot be ruled out as hazards to some wildlife, but the possibility of their constituting a threat on a region-wide scale appears to be small. The ecological impact of pesticide and fertilizer use by the NIIP cannot be predicted.

Withdrawals from the San Juan River for irrigation and energy use will reduce flow to minimum requirements during dry periods. This reduction will lower both abundance and diversity in the aquatic ecosystem. Floodplain marshes, important to waterfowl, may be reduced in extent.

The most widespread of the scenario's impacts, with the greatest potential for reducing the abundance and diversity of native plant and animal life, are those arising from the growth of San Juan County's population from 62,400 to 146,300 over the study period. These impacts include fragmentation of riparian foothill habitat by residential and commercial development, which will place additional stress on deer, waterfowl, and other water-related avifauna. In particular, antelope near Farmington are expected to be lost or decline to a few individuals. Vandalism will tend to reduce diversity and abundance of birds of prey near town and within the area of the energy developments. In additon, domestic and wild dogs may become a significant stress on both small and large animals adjacent to the San Juan Valley. A major impact of increased population will be to increase erosion losses and thus reduce vegetative cover.

Several endangered species may be affected by energy development. The Black-footed ferret is known to exist near the scenario area but not within it. If present, they will probably be eliminated. Three of seven active peregrine falcon nests in the Rockies are located near Durango close to an area receiving increasing use by campers and recreationists. The reason for their continued decline is uncertain; if they are disturbed by hikers, they may desert these nesting sites. At least one bald eagle nest is known in the San Juan Valley above the Navajo Reservoir; heavier recreational use of this area could result in its abandonment. The Colorado squawfish and the humpback sucker (recently removed from "threatened" status) have been reported from the San Juan River. If present below Shiprock, they could be eliminated locally by flow depletion.

Several of the significant impacts described above can be modified by changes in technologies. If mined areas are planted with native seedlings following a complete replacement of topsoils, reclamation will have a better chance to succeed, although long-term stability is still an issue. In addition, salt deposition from cooling tower drift would be eliminated by the use of a cooling lake (although such a lake would almost be as large as the area affected by cooling tower drift), by the use of dry cooling towers, or by once-through cooling processes. A decrease in water consumption would benefit the riparian habitats along the San Juan River. In addition, controls over access to remote habitats, especially by vehicle, would minimize the adverse effects to the ecosystem from the enlarged population. However, such restrictions on use would substantially reduce the aesthetic and recreational values of the ecosystem.

5.6 OVERALL SUMMARY OF IMPACTS AT NAVAJO/FARMINGTON

Major benefits resulting from the hypothetical developments in the Navajo/Farmington scenario will be the production of 500 million cubic feet of gas and 100,000 barrels of oil daily, 3,000 megawatts of electric power generating capacity, and annual production of 1,000 metric tons of yellowcake. These benefits accrue primarily to people outside the area, but locally substantial increases in per capita income, trade, and other economic development could take place, principally to the Navajo Nation.

Social, economic, and political impacts associated with energy development in the Navajo/Farmington area tend to be a function of the labor and capital intensity of facilities and, when multiple facilities are involved, of scheduling their construction. These factors determine the pace and extent of migration of people to the scenario area as well as the financial and managerial capability of local governments to provide services and facilities for the increased population. Labor forces increase the population directly and indirectly. More labor is required for construction of the facilities than for operation; thus suitable scheduling of facility construction can minimize population instability. Of the scenario facilities considered, the gasification-mine combinations are the least labor-intensive and the Synthoil facility is the most. Revenue for the local, state, and federal governments is generated mainly by sales taxes, royalty payments on federally owned coal, and an energy conversion tax levied on the energy produced. The fact that Farmington is a relatively large community now with extant planning capacity will mitigate negative social, economic, and political impacts. Farmington has a greater capacity to handle growth than do smaller communities. All communities regardless of size will encounter difficulty in obtaining funds for increased public facilities and services. Solutions to problems concerning who receives the benefits of revenue from the conversion technologies and who provides services needed involves all levels of government and their ability to relate to each other. There are currently no funding assistance programs in New Mexico for small communities.

If people who have migrated out of the area returned and were hired along with some local unemployed laborers (to meet the manpower requirements for energy facility construction and operation), then political and cultural impacts caused by a population increase of strangers would not be as great. In the Farmington area, lifestyle and cultural differences, especially concerning Indians and non-Indians, will influence the way in which impacts from energy development are perceived.

Air quality impacts associated with energy development are related primarily to quantities of pollutants emitted by the facilities and to those associated with population increases. Of the coal facilities, the greatest concentrations of particulates, NO_x, and SO_2 are emitted by the power plant and the least, by the gasification plant, but the Synthoil plant emits higher HC concentrations than the other plants. Uranium mine-mill emissions of criteria pollutants are negligible compared to coal plants. Diffuse population-related emissions would probably cause higher concentrations of particulates, NO_x, and HC than those produced by the facilities.

The sulfur content of Farmington coal is such that SO_2 emissions from a power plant with no emission controls would violate NSPS and ambient air standards. With 80 percent sulfur removal, neither would be violated. Dispersion potential in the scenario area is good, and plumes from the hypothesized facilities are rarely expected to interact. Thus, the presence of several facilities is not expected to create significant violations of ambient air quality standards.[1] Individually, only the Synthoil plant greatly exceeds standards due to the low-level fugitive HC emissions. In selected instances, the facilities exceed both Class I and Class II significant deterioration increments. The ambient air quality standards are currently exceeded for both particulates and HC at Farmington, and the new population and facilities can be expected to exacerbate this problem. In addition, the plumes of the plants will be visible from any part of the area and will

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[1]Exceptions may occur during downslope wind conditions. New Mexico Environmental Improvement Agency Staff, Personal Communication, November 23, 1976.

typically reduce visibility about 10 percent, with much greater reduction under adverse meteorological conditions.

Technological variables affecting impacts include improved emission controls or reduced plant size. Both these alternatives, if carried out at an adequate operational level, would reduce the number of potential standards violations. In addition, coal beneficiation steps that would remove inorganic sulfur would also reduce conflicts with sulfur standards.

Water impacts associated with energy development in the Navajo-Farmington area are a function of the water required for and effluents produced by facilities and associated populations. Of the coal facilities, a power plant requires the most water, a Lurgi plant, the least. The uranium facility uses five times less water than the Lurgi plant and 21 times less than the power plant. Water demand for the population is significant but less than that for the facilities. Effluents from the various types of conversion plants are similar in amount but different in composition. For example, effluents from coal gasification plants are primarily ash and from power plants are nearly equal amounts of ash and FGD sludge. Effluents from all facilities will be ponded to prevent contamination of surface water and groundwater.

Site-specific factors that affect water impacts in the Farmington area are: the limited supply of water in the San Juan Basin; the generally poor quality surface and groundwater; and the high ash content and low moisture content of Farmington coal. More ash-containing effluents will be produced by plants in this scenario area than in other scenario areas. and more water is required by a Lurgi facility using Farmington coal than for Lurgi facilities located elsewhere in the West, where coal contains more moisture.

If all the scenario energy facilities are built according to the hypothesized time schedule, conflicts over water use in the San Juan Basin will increase substantially, both among users in the basin and between users in the Farmington area and those presently using downstream flow. This use would significantly affect the quality of the surface water (especially in such characteristics as TDS, temperature, and the ability of water to transport sediment) and other features of stream hydrology. Groundwater quality could also be affected by leaching chemicals from the settling ponds, and erosion of the pond dikes could affect surface waters.

Dry or wet/dry cooling combinations significantly decrease water consumption especially for the power plant, but would both increase costs and decrease plant efficiency. Among other changes, this efficiency change would result in some expansion of mining, air emissions, and a slightly larger population. Changes in cooling methods could affect up to 13 percent of available water in the Basin. Other technological changes could be significant, including the use of treated sewage for plant cooling (as is done in some southwest areas). The use of combinations of cooling towers and evaporation ponds could also reduce some water use, especially during the winter.

Ecological impacts associated with energy development in the area depend on land use, population increases, water use and water pollution, and air quality changes. Land use by surface mining activities is greater than use by conversion facilities or than the amount of land required by expanded populations. However, mined lands can potentially be reclaimed, while land use by conversion facilities and populations is permanently lost. In the Farmington area, reclamation success is uncertain; the arid climate and poor soils will make it difficult. Impacts associated with increased populations will be significant, if recreational activities on public lands are allowed to fragment habitat and disrupt wildlife. Use of the limited water supply will decrease aquatic habitat availability, but water pollution is not expected to have significant impact on aquatic communities. The exception is possible leakage of effluent ponds which contain heavy metals, trace elements, and carcinogenic compounds. In the Farmington area, air emissions and ambient air concentrations are not expected to affect ecological communities.

If all the facilities hypothesized are constructed, several significant ecological effects are likely to occur from the combined impacts of surface mining, land use, new population, and the use of water. Water withdrawal from the San Juan will adversely affect the aquatic and riparian ecosystems. The new population will fragment habitat, damage vegetation, and contribute to the erosion of soils, as well as stress wildlife populations through intentional or inadvertent harrassment. Thus, certain species are likely to be eliminated or significantly reduced on a local basis. The combined impact of mining and desert irrigation will favor an animal community in the desert portion of the scenario area which is more typical of farmlands or grasslands than of the original arid desert shrub ecosystem.

Several of these impacts could be significantly modified by reclamation technologies or by extensive social controls. By using seedling transplants, adequate water, and fertilization, reclamation might have a better short-term chance of success. However, the costs of this practice would be significant and would divert water from other beneficial uses. Controls over human use of the area would require an extensive use of permits for recreational use and zoning. Provisions for habitat control in the river valley and habitat management programs on farmlands can also affect vegetation and animal abundance.

CHAPTER 6

THE IMPACTS OF ENERGY RESOURCE DEVELOPMENT AT THE RIFLE AREA

6.1 INTRODUCTION

Energy development in the Rifle area is located in Rio Blanco and Garfield counties in northwestern Colorado (Figure 6-1). As shown in Figure 6-2, the hypothetical developments include crude oil, coal, and oil shale extraction, conversion, and transportation. The TOSCO II (the Oil Shale Corporation) oil shale retorting facility is assumed to produce 50,000 barrels per day (bbl/day) with oil shale supplied by an underground mine. The modified *in situ* process (Occidental Oil Shale) oil shale facility is assumed to produce 57,000 bbl/day. Pipelines transport the upgraded oil from the TOSCO II and *in situ* facilities to refineries outside the region. In the modified *in situ* process, a portion of the shale is mined prior to establishing the *in situ* retort; that portion may simply be disposed of at the surface or retorted in a TOSCO II surface retort. A 3.4 million tons per year (MMtpy) room-and-pillar coal mine supplies a 1,000-megawatt electric (MWe) power plant that provides electricity to local users and the regional power grid via 500-kilovolt (kV) transmission lines. The 400-well field produces 50,000 bbl/day, which is transported via pipeline to refineries outside the region. These facilities will be constructed between 1977 and 2000. The construction schedules for the scenario and selected technical details of these facilities are presented in Table 6-1.[1]

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[1]While this hypothetical development may be similar to some developments proposed by Moon Lake Electric Company, Midland Coal Company, Blue Mountain Coal, Gulf Oil, Shell Oil, Superior Oil Shale, Paraho Oil Shale Demonstration, Consolidation Coal, W.R. Grace, Hanna Mining, Utah International, and others, it must be stressed that the development identified here is hypothetical. As with the others, this scenario was used to structure the assessment of a particular combination of technologies and existing conditions.

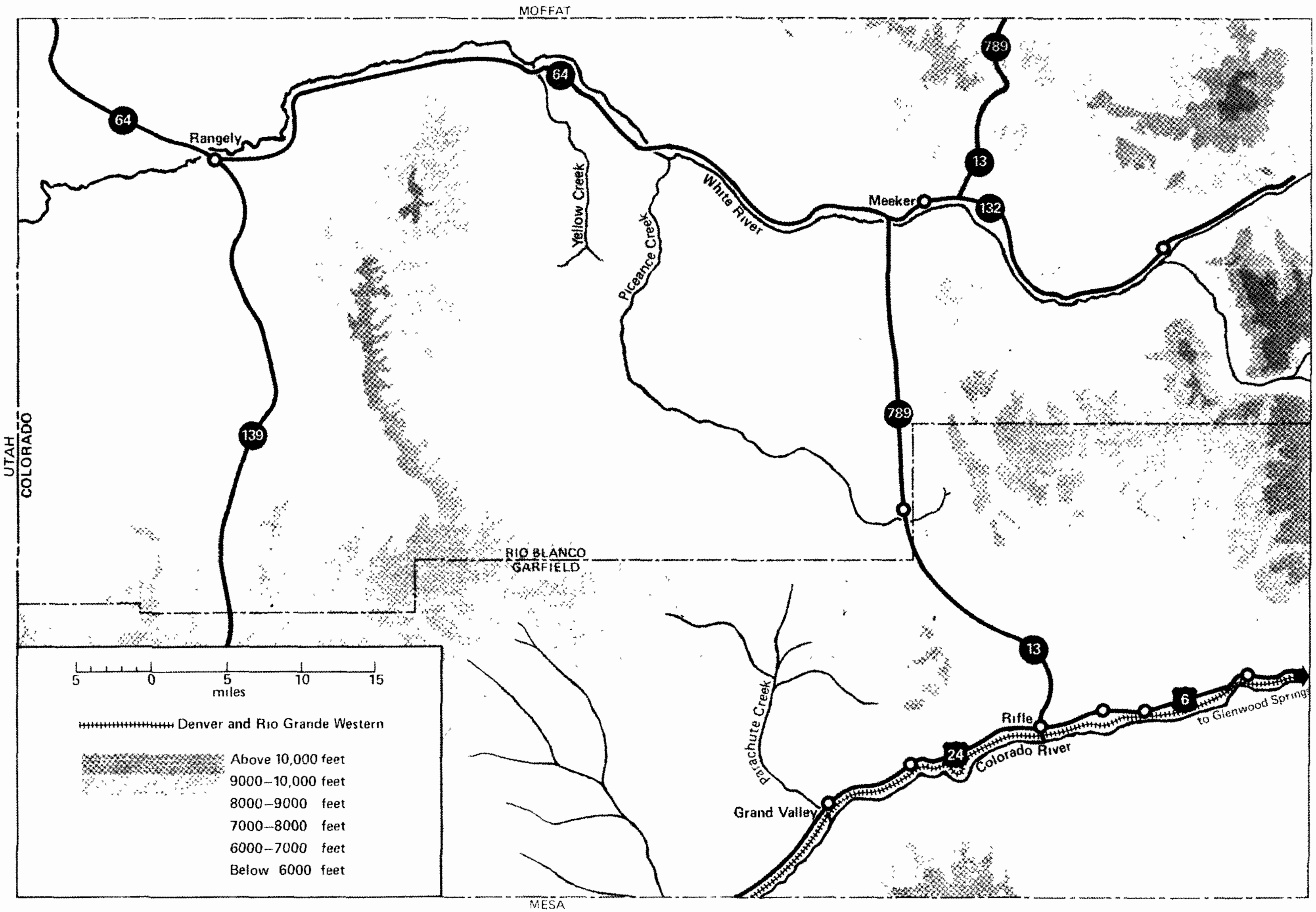

FIGURE 6-1: LOCATION OF THE RIFLE SCENARIO AREA

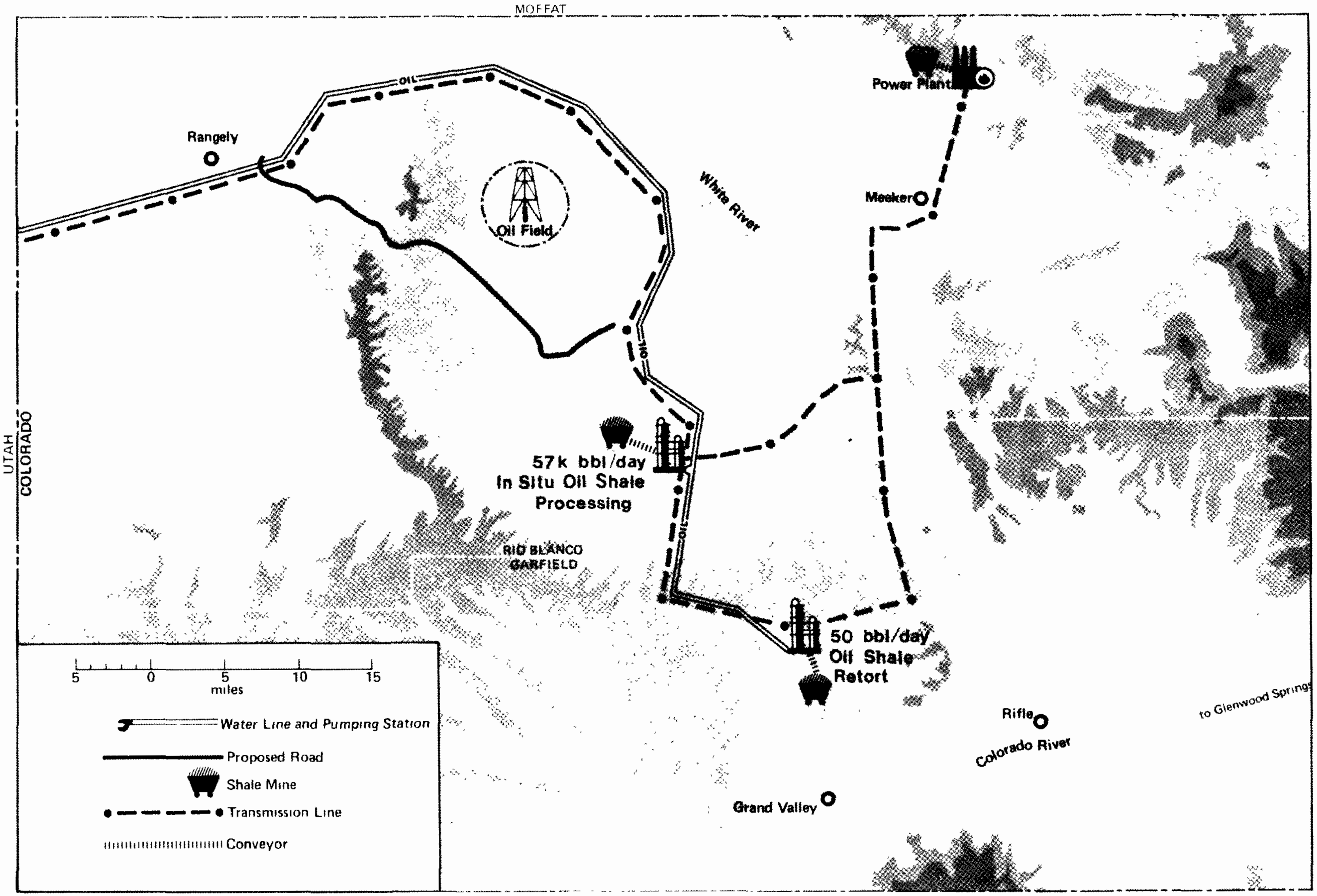

FIGURE 6-2: ENERGY FACILITIES IN THE RIFLE SCENARIO

TABLE 6-1: RESOURCES AND HYPOTHESIZED FACILITIES AT RIFLE

Resources	CHARACTERISTICS		
Coal[a] (billions of tons)	Coal		
Resources 8	Heat Content[d]	11,220 Btu's/lb	
Proved Reserves 4	Moisture	13 %	
	Volatile Matter	42 %	
Oil Shale[b] (billions of barrels)	Fixed Carbon	53 %	
Resources 117	Ash	5 %	
Proved Reserves 58	Sulfur	0.6 %	
Oil (billions of barrels)			
Resources[c] 10			
Technologies	**FACILITY SIZE**	**COMPLETION DATE**	**FACILITY SERVICED**
Resource Production			
Coal			
One underground room-and-pillar mine utilizing continuous miners	3.4 MMtpy	1980	Power plant
Oil Shale			
One underground room-and-pillar mine	26 MMtpy	1985	Oil shale retort
Oil			
400 wells drilled at the rate of 100 per year	12,500 bbl/day	1982	Pipeline
	12,500 bbl/day	1983	Pipeline
	12,500 bbl/day	1984	Pipeline
	12,500 bbl/day	1985	Pipeline
Conversion			
1,000-MWe power plant consisting of two 500-MWe turbine generators; 34% plant efficiency; 80% efficient limestone scrubbers; 99% efficient electrostatic precipitator; and wet forced-draft cooling towers[e]	500 MWe	1979	Power plant
	500 MWe	1980	Power plant
One 50,000 bbl/day TOSCO II oil shale facility with wet forced-draft cooling towers	50,000 bbl/day	1985	Oil shale
One modified in situ oil shale facility	57,000 bbl/day	1990	
Transportation			
Coal			
Two conveyor belts from the mine to the plant		1980	Power plant
Oil			
One 16-inch pipeline	50,000 bbl/day	1985	Oil well field
Oil Shale			
One conveyor belt	26 MMtpy	1985	Oil shale retort
Shale Oil			
One 20-inch pipeline	107,000 bbl/day	1985	Oil shale retort
Electricity			
One line (to regional power grid)	500 kV	1980	Power plant
One line (to local power grid)	265 kV	1980	Power plant

Btu's/lb = British thermal units per pound
MMtpy = million tons per year
bbl/day = barrels per day
MWe = megawatt-electric
kV = kilovolts

[a] 1974 Keystone Coal Industry Manual. New York, N.Y.: McGraw-Hill, 1974, p. 477. Proved reserves are calculated as 50 percent of the defined resources.

[b] National Petroleum Council, Committee on U.S. Energy Outlook. U.S. Energy Outlook. Washington, D.C.: National Petroleum Council, 1972, pp. 207-8. Proved reserves are calculated as 50 percent of the defined resources.

[c] National Petroleum Council, Committee on U.S. Energy Outlook, Oil and Gas Subcommittees, Oil and Gas Supply Task Groups. U.S. Energy Outlook: Oil and Gas Availability. Washington, D.C.. National Petroleum Council, 1973.

[d] Ctvrtnicek, T.E., S.J. Rusek, and C.W. Sandy. Evaluation of Low-Sulfur Western Coal Characteristics, Utilization, and Combustion Experience, EPA-650/2-75-046, Contract No. 68-02-1302. Dayton, Ohio: Monsanto Research Corporation, 1975.

[e] Due to format restrictions, this facility was defined as four 250-MWe units for the calculations of the social/economic impacts.

In all four impact sections of this chapter (air, water, social and economic, and ecological), the factors that produce impacts are identified and discussed separately for each energy facility type. In the air and water sections, the impacts caused by those factors are discussed separately for each facility type and, in combination, for a scenario in which all facilities are constructed according to the scenario schedule. In the social and economic and ecological sections, only the combined impacts of the scenario are discussed. This distinction is made because social, economic, and ecological effects are, for the most part, higher order impacts. Consequently, facility-by-facility impact discussions would have been repetitive in nearly every respect.

Land ownership in the area is predominantly federal, with state and private ownership clustered along streams in valleys. The area population has been increasing in the last decade, but unemployment is low. Employment is highest in the service industries, but construction and agriculture are also major employers. The area enjoys some tourist trade as it is on a commonly used route to Aspen and Vail. The quality of life in the area is considered excellent by the residents, and a larger than normal fraction of the population is of retirement age.

The terrain is rugged to mountainous, and climate varies with altitude. Annual precipitation is between 12 and 20 inches, and annual snowfall is between 60 and 100 inches. The climate is cool, with only 50 to 120 frost-free days per year. Due to the absence of pollution sources, air quality is good, although air stagnation occurs in the valleys.

Biological communities in the Rifle area also vary with altitude. Valley floors near streambeds are primarily croplands but contain elder, oak, and willow trees, and a large variety of birds and small mammals. As the elevation increases, plant and animal species become more characteristic of mountain areas, moving from pinyon-juniper to fir and pine at high altitudes with deer and elk, as well as some black bear. Hunting for deer and elk is a major activity in the area.

The White and Colorado Rivers and their tributaries are the principal surface water sources for the area, with numerous intermittent streams flowing into them. Water quality in the smaller streams is generally poor, primarily as a result of irrigation runoff. However, water quality is good in the major streams. Groundwater is located predominately in alluvial aquifers which are associated with the surface streams. Groundwater is also found in a bedrock aquifer associated with the Mahogany Zone, the richest source of oil shale. Additional site characteristics are shown in Table 6-2 and elaborated in greater detail as needed in the following sections.

TABLE 6-2: SELECTED CHARACTERISTICS OF THE RIFLE AREA

Environment	
Elevation	4,700-11,000 feet
Precipitation	12-20 inches average annually
Temperature	January mean daily minimum = 7.7°F July mean daily maximum = 89.4°F
Air Stability	Inversions more frequent in fall and winter months. Inversions and air stagnation common in valleys year-round. Dispersion conditions better on plateaus.
Vegetation	Elder, oak, and willow near valley floors. Juniper, fir, and pine at higher elevations.
Social and Economic[a]	
Land Ownership	
Federal	70 %
State and Private	30 %
Population Density	4.1 per square mile
Income	$4,000 per-capita annual (1974)

[a]Figures given are the Rio Blanco/Garfield County average.

6.2 AIR IMPACTS[1]

6.2.1 Existing Conditions

A. Background Pollutants

Air quality in the Rifle area is currently affected by a number of air emission sources, the most significant of which is the Mid-Continent Coal and Coke Company. Measurements of concentrations of criteria pollutants[2] taken through late 1975 in the Rifle area indicate that no federal or Colorado ambient air standards are violated.[3] Based on these measurements the annual average background levels for all six criteria pollutants chosen as inputs to the dispersion model are in micrograms per cubic meter; particulates, 12; sulfur dioxide (SO_2), 2; nitrogen oxides (NO_x), 5; hydrocarbons (HC), 130; carbon monoxide (CO), 1,000; and oxidants, 68.[4]

B. Meteorological Conditions

The worst dispersion conditions for the Rifle area are associated with stable air conditions, low wind speeds (less than 5-10 miles per hour), unchanging wind direction, and relatively low mixing depths.[5] These conditions are likely to increase concentrations

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[1]The federal standards referred to in this section are those promulgated prior to the revisions mandated by the Clean Air Act Amendments of 1977, Pub. L. 95-95, 91 Stat. 685.

[2]Criteria pollutants are those for which ambient air quality standards are in force: CO, HC, NO_x, oxidants, particulates, and SO_2. The term "hydrocarbons" is generally used to refer to nonmethane HC.

[3]Ashland Oil, Inc.; Shell Oil, Operator. Oil Shale Tract C-b Environmental and Exploration Program, Summary Reports 2, 3, 4 and 5. Denver, Colo.: C-b Oil Shale Project, Inc., October 1975.

[4]These estimates are based on the Radian Corporation's best professional judgment. They are used as the best estimates of the concentrations to be expected at any particular time. Measurements of HC and CO are not available in the rural areas. However, high-background HC levels have been measured at other rural locations in the West and may occur here. Measurements of long-range visibility in the area are not available, but the average is estimated to be 60 miles.

[5]Mixing depth is the distance from the ground to the upward boundary of pollution dispersion.

of pollutants from both ground-level and elevated sources.[1] Since worst-case conditions differ at each facility location (largely due to the wide variety of terrain in the Rifle area), predicted annual average pollutant levels will vary among locations even if pollutant sources are identical. Meteorological conditions in the area are generally unfavorable for pollution dispersion about 30 percent of the time. Hence, plume impaction[2] and limited mixing of plumes caused by temperature inversions at the plume height can be expected to occur regularly.[3] Good dispersion conditions associated with moderate winds and large mixing depths are expected to occur about 15 percent of the time.

As is the case at most western sites, the potential for dispersion of pollutants in the Rifle area varies considerably by season and time of day. Fall and winter mornings are most frequently associated with poor dispersion, due largely to more persistent high-pressure areas with lower wind speeds and mixing depths.

6.2.2 Factors Producing Impacts

The primary emission sources in the Rifle area are a power plant, oil shale processing and retorting facilities, supporting coal and oil shale mines, the oil well fields, and population increases. The focus of this section is on emissions of criteria pollutants from the facilities.[4] Table 6-3 lists the amounts of the five criteria pollutants emitted by each of the facilities. Oil well field emissions are negligible in comparison to the power plant and oil shale facility emissions. For all conversion processes, most emissions come from the plants, rather than the mines, since all mines are underground. Most underground coal and oil shale mine-related pollution originates from diesel engine combustion products, primarily NO_x, HC, and particulates. Although the mines are underground and dust suppression techniques are hypothesized in the scenario, some additional particulates will come

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[1]Ground-level sources include towns and strip mines that emit pollutants close to ground level. Elevated sources are stack emissions.

[2]Plume impaction occurs when stack plumes impinge on elevated terrain because of limited atmospheric mixing and stable air conditions.

[3]National Climatic Center. Wind Dispersion by Pasquill Stability Class, Star Program for Selected U.S. Cities. Asheville, N.C.: National Climatic Center, 1975.

[4]Air impacts associated with population increases are discussed below (Section 6.2.3) as they relate to the scenario, which includes all facilities constructed according to the hypothesized schedule.

TABLE 6-3: EMISSIONS FROM FACILITIES
(pounds per hour)

FACILITIES	PARTICULATES	SO_2	NO_x	HC	CO
Electrical Generation (1,000 MWe)	370	1,944	4,774-7,956[a]	132	444
Underground Coal Mine (3.4 MMtpy)	97	N	N	U	N
TOSCO II Plant (50,000 bbl/day)	860	350	1,900	1,020	80
Underground Oil Shale Mine (26 MMtpy)	125	N	270	54	480
Modified In Situ Oil Shale Processing (57,000 bbl/day)	74	174	588	120	84
Modified In Situ Oil Shale Processing with Surface Retort (57,000 bbl/day)	362	343	1,777	130	U
Mine for the Modified In Situ Process	286	N	225	9	195
Oil Wells (50,000 bbl/day)	0.3	21.7	17.6	4.3[b]	1.3

SO_2 = sulfur dioxide
NO_x = nitrogen oxide
HC = hydrocarbons
CO = carbon monoxide
MWe = megawatt-electric

MMtpy = million tons per year
N = negligible
U = unknown
bbl/day = barrels per day

[a]Range represents emission assuming 0 and 40 percent NO_x removal by the scrubber.

[b]This value is for total organics emissions.

from blasting, coal piles, oil shale crushing, and blowing dust.[1] The power plant emits more SO_2 than the oil shale facilities, but the TOSCO II facility emits more particulates than the power plant or the *in situ* oil shale process. Overall, the *in situ* facility without the surface retort emits the least amount of criteria pollutants (Table 6-3).

The hypothetical power plant, for which data in Table 6-3 were calculated, has two 500-MWe boilers each with its own stack.[2] The plant is equipped with an electrostatic precipitator (ESP) which removes 99 percent of the particulates and a scrubber which removes 80 percent of the SO_2 and from 0 to 40 percent of the NO_x.[3] For a power plant operating under these conditions, Table 6-4 lists the amounts of particulates, SO_2 and NO_x expected to be emitted per million Btu of coal burned and compares the amounts to the New Source Performance Standards (NSPS).[4] The amounts of particulates and SO_2 emitted are well below these standards. In order to just meet NSPS, the power plant would require 97.3 percent particulate removal, but no SO_2 removal.[5] If no NO_x is removed, NSPS will be exceeded. A minimum of 15 percent NO_x must be removed to meet NSPS.

In addition to emissions from the stacks, one 75,000-barrel oil storage tank at the plant, with standard floating roof construction, will emit up to 0.7 pound of HC per hour.

Both the power plant and the TOSCO II oil shale conversion facility are cooled by wet forced-draft cooling towers. Each cell in the tower circulates water at a rate of 15,330 gallons

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[1]The effectiveness of current dust suppression practices is uncertain. Research is being conducted by the Environmental Protection Agency. The problem is discussed qualitatively in Chapter 10.

[2]Stacks are 500 feet high, have an exit diameter of 23.6 feet, mass flow rates of 1.57×10^6 cubic feet per minute, an exit velocity of 60 feet per second, and an exit temperature of 180°F.

[3]Exact amount of removal of NO_x by scrubbers is uncertain. The maximum estimate is 40 percent; minimum is 0.

[4]NSPS limit the amount of a given pollutant a stationary source may emit; the limit is expressed relative to the amount of energy in the fuel burned.

[5]Clean Air Act Amendments of 1977, Pub. L. 95-95, 91 Stat. 685, § 109, require both an emissions limitation and a percentage reduction of SO_2, particulates, and NO_x. Revised standards have not yet been established by the Environmental Protection Agency.

TABLE 6-4: COMPARISON OF EMISSIONS FROM POWER PLANT WITH NEW SOURCE PERFORMANCE STANDARDS (pounds per million Btu)

POWER PLANT	EMISSION	NSPS
Particulates		0.1
SO_2[a]	.19	1.2
NO_x	.48-.80[b]	0.7

NSPS = New Source Performance Standards
Btu = British thermal unit
SO_2 = sulfur dioxide
NO_x = nitrogen oxide

[a]The Colorado State standard for SO_2 emissions is 0.4 pounds per million Btu. Data from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[b]Range represents 0 and 40 percent removal by SO_2 scrubbers.

per minute (gpm) and emits 0.01 percent of its water as a mist.[1] The circulating water has a total dissolved solids (TDS) content of 3,500 parts per million. This results in a salt emission rate of 21,500 pounds per year for each cell.[2]

6.2.3 Impacts

This section describes air quality impacts which result from each type of conversion facility (a power plant and oil shale

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[1]Efficiencies are Radian's estimates of current industrial practices.

[2]The power plant has 22 cells and the 50,000-bbl/day TOSCO II oil shale plant has 5.

plants) taken separately[1] and from a scenario which includes construction of all facilities according to the hypothesized scenario schedule.[2] For the power plant the effect on air quality of hypothesized emission control, alternative emission control, alternative stack heights, alternative plant sizes, and alternative plant locations are discussed. The focus is on concentrations of criteria pollutants (particulates, SO_2, NO_x, HC, and CO). See Chapter 10 for a qualitative description of sulfates, other oxidants, fine particulates, long range visibility, plume opacity, cooling tower salt deposition, and cooling tower fogging and icing.

In all cases, air quality impacts result primarily from the operation rather than the construction of these facilities. Construction impacts are limited to periodic increases in particulate concentrations due to windblown dust. These may cause periodic violations of 24-hour National Ambient Air Quality Standards (NAAQS) for particulates.

A. Power Plant Impacts

Air quality impacts result primarily from the operation of the power plant and depend largely on the degree of emission control imposed. Concentrations resulting from the hypothesized case where control equipment removes 80 percent of the SO_2 and 99 percent of particulates are discussed first, followed by a discussion of alternative emission controls, alternative stack heights, alternative plant sizes, and alternative plant locations.

(1) Hypothesized Emission Control

Table 6-5 summarizes the concentrations of four pollutants predicted to be produced by this hypothesized power plant (1,000 MWe, 80 percent SO_2 removal, and 99 percent particulate removal). These pollutants (particulates, SO_2, nitrogen dioxide [NO_2], and HC) are regulated by federal and Colorado state ambient air quality standards, which are also shown in Table 6-5. This information shows that the typical concentrations associated with the plant, when added to existing background levels, are below most federal and state ambient air standards. However, the peak concentrations produced by the plant do violate Colorado's 24-hour and 3-hour SO_2 standards.

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[1]Air quality impacts caused by the underground mines are expected to be negligible in comparison with impacts caused by conversion facilities.

[2]Because air emissions from the oil well field are small in comparison to those from the power plant and oil shale facilities, the impacts of those emissions are not considered in this section.

TABLE 6-5: POLLUTION CONCENTRATIONS FROM A 1,000 MEGAWATT POWER PLANT AT RIFLE (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]				STANDARDS[b]				
			PEAK		AMBIENT			PSD	
	BACKGROUND	TYPICAL	PLANT	MEEKER	PRIMARY	SECONDARY	COLORADO	CLASS I	CLASS II
Particulate									
Annual	12		0.4		75	60	45	5	19
24-hour		0.2	30.0	0.9	260	150	150	10	37
SO_2									
Annual	2		2.3	0.1	80		5[c]	2	20
24-hour		1.3	155	4.6	365		50[c]	5	91
3-hour		7	530	23		1,300	100[c]	25	512
NO_2[d]									
Annual	5		5.7-9.5	0.2-0.3	100	100	100		
HC[e]									
3-hour	130	0.4	33	1.2	160	160	160		

PSD = prevention of significant deterioration
SO_2 = sulfur dioxide
NO_2 = nitrogen oxide
HC = hydrocarbons

[a]These are predicted ground-level concentrations from the hypothetical 1,000 megawatt-electric power plant. Annual average background levels are considered to be the best estimate of short-term background levels.

[b]"Primary" and "secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. PSD standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These data are from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[c]This standard represents Colorado's Category II. Except for national parks and monuments, Colorado is designated Category II with provision for changing to Category III. If Rifle were designated Category III, the standards would allow higher concentrations of SO_2. Data from White, et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[d]This range represents two assumptions about the removal of oxides of nitrogen by scrubbers. The first number assumes 40 percent removed; the second number assumes none removed.

[e]The 3-hour standard is measured at 6-9 a.m.

Table 6-5 also lists Prevention of Significant Deterioration (PSD) standards, which are the allowable increments of pollutants that can be added to areas of relatively clean air (i.e., areas with air quality better than that allowed by ambient air standards).[1] Class I standards, intended to protect the cleanest areas such as national parks, are the most restrictive.[2] Peak concentration from the power plant exceeds Class II increments for 3-hour and 24-hour SO_2 and Class I increments for 24-hour particulates, annual, 24-hour, and 3-hour SO_2.

Since the plant exceeds Class I increments, it would have to be located far enough from any Class I areas to allow emissions to be diluted by atmospheric mixing prior to reaching such areas. The distance required for this dilution (which varies by facility type, size, emission controls, and meteorological conditions) in effect establishes a "buffer zone" around Class I areas. Current Environmental Protection Agency (EPA) regulations would require a minimum buffer zone of 13.6 miles between this hypothesized power plant and any Class I area's boundary.[3] Although no proposed Class I areas are within 15 miles of the plant site, the White River National Forest is less than 10 miles to the east. If this forest were designated a Class I area, the power plant would probably violate allowable increments (Figure 6-3). Maroon Bells-Snowmass National Wilderness Area and Mt. Zirkel National Wilderness Area have been designated Class I areas and are in the vicinity of the Rifle facility.

In a worse-case situation, expected to occur about once a year, the power plant may reduce background visibility (presently about 60 miles) to between 9 and 27 miles, depending on the amount

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[1]PSD standards apply only to particulates and SO_2.

[2]The Environmental Protection Agency initially designated all PSD areas Class II and established a process requiring petitions and public hearings for redesignating areas Class I or Class III. A Class II designation is for areas which have moderate, well-controlled energy or industrial development and permits less deterioration than that allowed by federal secondary ambient standards. Clean Air Act Amendments of 1977, Pub. L. 95-95, 91 Stat. 685.

[3]Note that buffer zones around energy facilities will not be symmetric circles. This lack of symmetry is clearly illustrated by area windroses which show wind direction patterns and strengths for various areas and seasons. Hence, the direction of prevention of significant deterioration areas from energy facilities will be critical to the size of the buffer zone required. Note also that the term buffer zone is in disfavor. We use it because we believe it accurately describes the effect of PSD requirements.

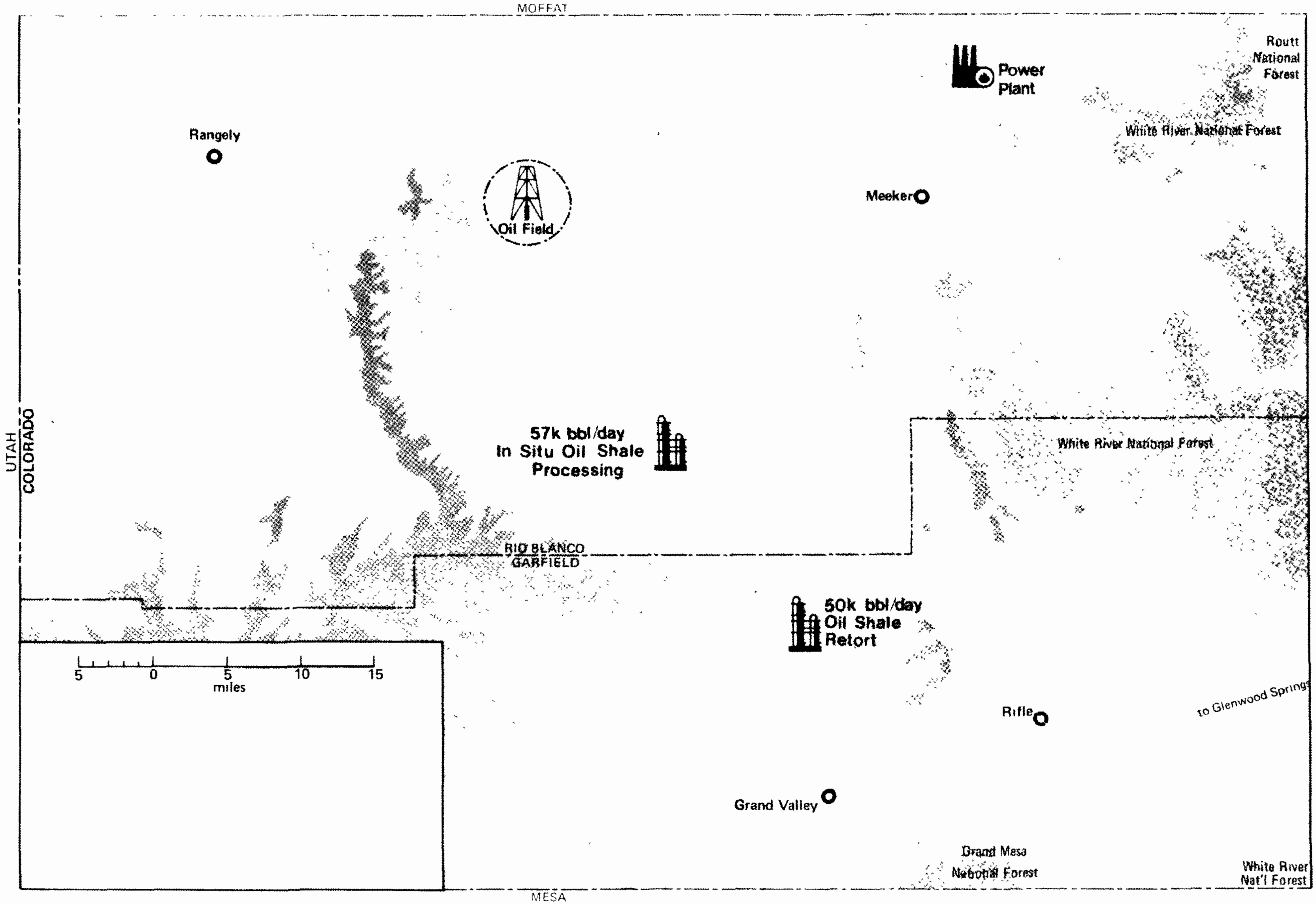

FIGURE 6-3: AIR IMPACTS OF ENERGY FACILITIES IN THE RIFLE SCENARIO

of SO_2 converted to particulates in the atmosphere.[1] On the average, visibility reductions are expected to be negligible.

(2) Alternative Emission Controls

The base case control for the Rifle power plant assumed an SO_2 scrubber efficiency of 80 percent and an ESP efficiency of 99 percent. The effect on ambient air concentrations of three additional emission control alternatives is illustrated in Table 6-6. These alternatives include a 95 percent efficient SO_2 scrubber; a scrubber without an ESP; and an alternative in which neither a scrubber nor an ESP are utilized.

An examination of Table 6-6 reveals violations of Class II PSD increments for 3-hour and 24-hour SO_2 emissions with the 80 percent efficient scrubber. Complete removal of the scrubber aggravates these violations and results in violations of the less stringent NAAQS for 3-hour and 24-hour SO_2 emissions. The use of 99 percent efficient ESP allows the plant to meet all applicable standards for total suspended particulates (TSP) emissions. Removal of the ESP results in violations of the NAAQS for 24-hour TSP emissions and Class II PSD increments for 24-hour and annual TSP. The utilization of a 95 percent efficient SO_2 scrubber with an ESP would violate the Colorado 3-hour SO_2 standard.

(3) Alternative Stack Heights

In order to examine the effects of alternative stack heights on air quality in the Rifle scenario, worst-case dispersion modeling was carried out for a 300-foot stack (lowest stack height consistent with good engineering practice), a 500-foot stack (an average or most frequently used height), and a 1000-foot stack (highest stack height). The results of this examination are shown in Table 6-7. Emissions from each stack are controlled by an 80 percent efficient SO_2 scrubber and a 99 percent efficient ESP. The 500-foot stack case was given previously as part of the base case control.

A comparison of predicted concentrations with applicable standards shows no violations of NAAQS with a 300-foot stack. However, Class II PSD increments for 3-hour SO_2, 24-hour SO_2, and 24-hour TSP are exceeded with this lowest stack height alternative. The base case control also violated Class II PSD increments for 3-hour and 24-hour SO_2 emissions. Colorado's 3-hour SO_2 standards are violated even with a 100-foot stack.

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[1]Short-term visibility impacts were investigated using a "box type" dispersion model. This particular model assumes that all emissions occurring during a specified time interval are uniformly mixed and confined in a box that is capped by a lid or stable layer aloft. A lid of 500 meters has been used through the analyses. SO_2 conversion rates of 10 percent and 1 percent per hour were modeled.

TABLE 6-6: AIR QUALITY IMPACTS RESULTING FROM ALTERNATIVE EMISSION CONTROLS AT RIFLE POWER PLANT

AMOUNT OF CONTROL (%)		MAXIMUM POLLUTANT CONCENTRATION ($\mu g/m^3$)				
SO_2	TSP	3-HR. SO_2	24-HR. SO_2	ANNUAL SO_2	24-HR. TSP	ANNUAL TSP
95	99	132	39	NC	29.5	0.4
80	99	530	155	2.3	29.5	0.4
80	0	530	155	2.3	2,950[a]	44
0	0	1,831	748	11.5	2,850[a]	44
APPLICABLE STANDARDS						
NAAQS						
(primary)		--	365	80	260	75
(secondary)		1,300	--	--	150	60
State standards		100	50	5	150	45
Class II PSD increments		512	91	20	37	19

$\mu g/m^3$ = micrograms per cubic meter
SO_2 = sulfur dioxide
TSP = total suspended particulates
HR. = hour
NC = not considered
NAAQS = National Ambient Air Quality Standards
PSD = prevention of significant deterioration

[a]Differences in 24-hour TSP concentrations for the two cases in which no electrostatic precipitator is used are attributable to the fact that the stack temperature rises when the SO_2 scrubber is turned off, which produces a small increase in the effectiveness of the smoke stack, and a slightly lower TSP concentration.

TABLE 6-7: AIR QUALITY IMPACTS RESULTING FROM ALTERNATIVE STACK HEIGHTS AT RIFLE POWER PLANT

SELECTED STACK HEIGHTS (feet)	MAXIMUM POLLUTANT CONCENTRATION ($\mu g/m^3$)		
	3-HR. SO_2	24-HR. SO_2	24-HR. TSP
300	861	298	57
500	530	155	30
1,000	204	30.8	5.9
APPLICABLE STANDARDS			
NAAQS			
(primary)	--	365	260
(secondary)	1,300	--	150
State standards	100	50	150
Class II PSD increments	512	91	37

$\mu g/m^3$ = micrograms per cubic meter
HR. = hour
SO_2 = sulfur dioxide
TSP = total suspended particulates
NAAQS = *National Ambient Air Quality Standards*
PSD = prevention of significant deterioration

(4) Alternative Plant Sizes

The results of an examination of the effects of alternative plant sizes on air quality in the Rifle scenario are given in Table 6-8. The hypothesized 1000 MWe power plant will violate Class II PSD increments for 3-hour and 24-hour SO_2 emissions. A reduction of the size of the power plant to 500 MWe would allow the unit to operate within applicable federal standards, but it would still violate the Colorado 3-hour SO_2 standard.

(5) Alternative Plant Locations

The complex terrain of the proposed Rifle power plant site aggravates violations of Class II PSD increments during periods of plume impaction on that terrain. Thus, the effect of relocating the plant to a site where the terrain at and around the plant is flat was examined. Sites along the ridge separating the Piceance Creek and Roan Creek watersheds (west-southwest of the original site of the Rifle power plant near Meeker) have a low potential for impaction with elevated terrain. Table 6-9 shows the results of this examination. Relocation of the Rifle power plant (1000 MWe, 80 percent SO_2 removal, 99 percent TSP removal) would allow the facility to operate well within all applicable standards.

TABLE 6-8: AIR QUALITY IMPACTS RESULTING FROM ALTERNATIVE POWER PLANT SIZES AT RIFLE

UNIT SIZE (MWe)	NUMBER OF UNITS	PLANT CAPACITY	MAXIMUM POLLUTANT CONCENTRATIONS ($\mu g/m^3$)		
			3-HR. SO_2	24-HR. SO_2	24-HR. TSP
500	1	500	265	77.5	15
	2	1,000	530	155	30
APPLICABLE STANDARDS					
NAAQS					
(primary)			--	365	260
(secondary)			1,300	--	150
State standards			100	50	150
Class II PSD increments			512	91	37

$\mu g/m^3$ = micrograms per cubic meter
MWe = megawatt-electric
HR. = hour
SO_2 = sulfur dioxide
TSP = total suspended particulates
NAAQS = National Ambient Air Quality Standards
PSD = prevention of significant deterioration

TABLE 6-9: AIR QUALITY IMPACTS RESULTING FROM RELOCATING THE RIFLE POWER PLANT FROM A COMPLEX TO A FLAT TERRAIN[a]

TERRAIN CASE	MAXIMUM POLLUTANT CONCENTRATION ($\mu g/m^3$)		
	3-HR. SO_2	24-HR. SO_2	24-HR. TSP
Complex	530.4	155.1	29.5
Flat	91.5	9.08	1.73
APPLICABLE STANDARDS			
NAAQS			
(primary)	--	365	260
(secondary)	1,300	--	150
State standards	100	50	150
Class II PSD increments	512	91	37

$\mu g/m^3$ = micrograms per cubic meter
HR. = hour
SO_2 = sulfur dioxide
TSP = total suspended particulates
NAAQS = National Ambient Air Quality Standards
PSD = prevention of significant deterioration

[a]Stack height is assumed to be 500 feet, 80 percent SO_2 removal, 99 percent TSP removal, 1,000 megawatts-electric.

(6) Summary of Power Plant Air Impacts

During the construction phase of the Rifle power plant, the frequency of current violations of NAAQS particulate standards will probably increase. Once the 1000 MWe power plant is in operation (80 percent SO_2 removal, 99 percent TSP removal, and 500-foot stack height), Class II PSD increments for 3-hour and 24-hour SO_2 emissions will be violated. If the plant were equipped with a 95 percent efficient SO_2 scrubber, all applicable federal standards could be met. With an 80 percent efficient SO_2 scrubber, Class II PSD increments could also be met by utilization of a 1000-foot stack, reducing power plant capacity to 500 MWe, or relocating the plant site to a location with flat terrain. However, the only alternative which would not violate Colorado's 3-hour SO_2 standard is relocating the plant site to flat terrain.

B. TOSCO II Shale Plant Impacts

Table 6-10 shows typical and peak concentrations of criteria pollutants from the proposed TOSCO II oil shale plant. Predicted hydrocarbon concentrations exceed the federal primary and state ambient air standards for HC. Class II PSD increments are exceeded for 24-hour TSP, and Class I PSD increments are exceeded for 3-hour and 24-hour SO_2. Colorado's 3-hour SO_2 standard is also violated by peak concentrations.

The effects of alternative stack heights for a 50,000 bbl/day TOSCO II plant on ambient air concentrations are shown in Table 6-11. All stack height alternatives meet applicable federal standards for SO_2 concentrations. Colorado's 3-hour SO_2 standards are violated by all but the 300 foot stack height. None of the three alternatives can meet the Class II PSD increments for 24-hour TSP emissions.

In a worse-case situation, expected to occur infrequently, the TOSCO II facility may reduce background visibility (presently about 60 miles) to between 7 and 10 miles, depending on the amount of SO_2 converted to particulates in the atmosphere.

C. _In Situ_ Oil Shale Processing With and Without Surface Retorting Impacts

Tables 6-12 and 6-13 show typical and peak concentrations of criteria pollutants from the proposed _in situ_ oil shale processing facility (Table 6-12), and from the proposed _in situ_ oil shale processing facility with a surface retort (Table 6-13). Concentrations resulting from the processing facility by itself or with a surface retort violate no NAAQS or Class II PSD increments. Peak concentrations do violate the Class I PSD increment for 24-hour particulates. The processing facility with a retort also violates Class I PSD increments for 24-hour and 3-hour SO_2.

TABLE 6-10: POLLUTANT CONCENTRATIONS FROM A 50,000 BARREL PER DAY TOSCO II OIL SHALE PROCESSING FACILITY AT PARACHUTE CREEK (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]				STANDARDS[b]				
			PEAK		AMBIENT			PSD	
	BACKGROUND	TYPICAL	PLANT	GRAND VALLEY	PRIMARY	SECONDARY	COLORADO	CLASS I	CLASS II
Particulate									
Annual	12		2.0		75	60	45	5	19
24-hour		6.6	83	6.0	260	150	150	10	37
SO_2[c]									
Annual	2		1.3		80	--	5[d]	2	20
24-hour		5.3	22	3.8	365	--	50[d]	5	91
3-hour		11.5	122	5.9	--	1,300	100[d]	25	512
NO_2[e]									
Annual	5		2.8	0.1	100	100	100	--	--
HC									
3-hour		1,100	38,540	837	160	160	160	--	--

PSD = prevention of significant deterioration
SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide
HC = hydrocarbons

[a]These are predicted ground-level concentrations from the hypothetical 50,000 barrels per day TOSCO II plant. Annual average background levels are considered to be the best estimate of short-term background levels.

[b]"Primary" and "secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. PSD standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These data are from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[c]It is assumed that all nitrogen oxide from plant sources is converted to NO_2.

[d]Allowable increments which cannot be exceeded in areas designated Category II by Colorado.

[e]The 3-hour HC standard is measured at 6-9 a.m.

TABLE 6-11: AIR QUALITY IMPACTS RESULTING FROM ALTERNATIVE STACK HEIGHTS AT RIFLE TOSCO II PLANT

SELECTED STACK HEIGHTS (feet)	MAXIMUM POLLUTANT CONCENTRATION ($\mu g/m^3$)		
	3-HR. SO_2	24-HR. SO_2	24-HR. TSP
100	378	47	85
200	122	22	83
300	93	15	81
APPLICABLE STANDARDS			
NAAQS			
(primary)	--	365	260
(secondary)	1,300	--	150
State standards	100	50	150
Class II PSD increments	512	91	37

$\mu g/m^3$ = micrograms per cubic meter
HR. = hour
SO_2 = sulfur dioxide
TSP = total suspended particulates

NAAQS = National Ambient Air Quality Standards
PSD = prevention of significant deterioration

TABLE 6-12: POLLUTANT CONCENTRATIONS FROM A 57,000 BARREL PER DAY IN SITU OIL SHALE PROCESSING FACILITY AT RIFLE (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS				STANDARDS[a]				
			PEAK		AMBIENT			PSD	
	BACKGROUND	TYPICAL	PLANT	RIO BLANCO	PRIMARY	SECONDARY	COLORADO	CLASS I	CLASS II
Particulate									
Annual	12	--	0.4	0.0	75	60	45	5	19
24-hour		8.2	19.4	1.0	260	150	150	10	37
SO_2									
Annual	2	--	0.1	0.0	80	--	5[b]	2	20
24-hour		1.1	3.2	0.3	365	--	50[b]	5	91
3-hour		10.1	17.4	2.7	--	1,300	100[b]	25	512
NO_2									
Annual	5	--	1.3	0.2	100	100	100	--	--
HC									
3-hour	--	29.4	100.2	3.7	160	160	160	--	--

PSD = prevention of significant deterioration
SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide
HC = hydrocarbons

[a]These data are from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[b]Allowable increments which cannot be exceeded in areas designated Category II by Colorado.

TABLE 6-13: POLLUTANT CONCENTRATIONS FROM A 57,000 BARREL PER DAY IN SITU OIL SHALE PROCESSING FACILITY WITH SURFACE RETORT AT RIFLE

POLLUTANT AVERAGING TIME	CONCENTRATIONS				STANDARDS[a]				
			PEAK		AMBIENT			PSD	
	BACKGROUND	TYPICAL	PLANT	RIO BLANCO	PRIMARY	SECONDARY	COLORADO	CLASS I	CLASS II
Particulate									
Annual	12	--	1.0	0.1	75	60	45	5	19
24-hour		13.8	32.6	3.3	260	150	150	10	37
SO_2									
Annual	2	--	0.3	0.1	80	--	5[b]	2	20
24-hour		2.0	5.8	1.4	365	--	50[b]	5	91
3-hour		26.5	37.7	5.9	--	1,300	100[b]	25	512
NO_2									
Annual	5	--	3.6	0.7	100	100	100	--	--
HC									
3-hour	--	57.6	128.0	1.2	160	160	160	--	--

PSD = prevention of significant deterioration
SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide
HC = hydrocarbons

[a]These data are from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[b]Allowable increments which cannot be exceeded in areas designated Category II by Colorado.

D. Scenario Impacts

(1) To 1980

Construction of the hypothetical power plant begins in 1977, and the plant becomes operational in 1980. Several small towns, such as Rifle and Grand Valley, are expected to increase their populations as a result of the energy development in this scenario.[1] By 1980, the population of Rifle should increase from 2,500 to 2,950, and Grand Valley should grow from 360 to 700. These increases will contribute to increases in pollution concentrations due solely to urban sources. Table 6-14 shows predicted concentrations of five criteria pollutants for Rifle in 1980. Concentrations are estimated at a point in the center of the town and at a point 3 miles from the center.

When concentrations from urban sources are added to background levels, the federal HC standard is exceeded.[2] No other federal or state standards are approached by the combination of background and urban sources by 1980.

(2) To 1990

Both the TOSCO II and in situ oil shale facilities are hypothesized to be constructed by 1990 in the Rifle area. A 50,000 bbl/day TOSCO II oil shale plant with an underground oil shale mine will become operational in 1985 and the 57,000 bbl/day in situ facilities will become operational in 1990.

If the wind blows directly from one plant to the other, plumes may interact. However, maximum concentrations of pollutants due to interactions of the plumes from the power plant and TOSCO II plant do not violate any applicable standards at a hypothetical separation distance of 5 miles. Concentrations which result from plume interaction are less than those produced by either plant under worst-case dispersion conditions. With the addition of the oil shale facilities, visibility is expected to decrease from the current average of 60 miles in the Rifle region to 58 miles by 1990. In a worst-case dispersion situation, expected to occur infrequently, short-term visibility may be reduced to between 7 and 10 miles.

Rifle's predicted population increase to 6,150 and Grand Valley's increase to 3,900 will cause concentrations of urban pollutants to reach the levels shown in Table 6-14 at Rifle, and Table 6-15 at Grand Valley. The Federal HC standard, which will be exceeded by a factor greater than three, continues to be the only

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[1]Refer to Section 6.4.3.

[2]HC standards are violated regularly in most urban areas.

TABLE 6-14: POLLUTION CONCENTRATIONS DUE TO URBAN SOURCES AT RIFLE (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]					STANDARDS[b]		
		MIDTOWN POINT		RURAL POINT				
	BACKGROUND	1980	1990[c]	1980	1990[c]	PRIMARY	SECONDARY	COLORADO
Particulates								
Annual	12	6	20	2	3	75	60	45
24-hour		9	68	19	68	260	150	150
SO_2								
Annual	2	3	10	1	2	80		5[d]
24-hour		9	34	9	34	365		50[d]
3-hour		10	60	16	60		1,300	100[d]
NO_2[e]								
Annual	5	9		4	8	100	100	100
HC[f]								
3-hour	130	102	571	102	571	160	160	160
CO								
8-hour	1,110	616	1,940	616	1,940	10,000	10,000	10,000
1-hour		1,010	3,170	1,010	3,170	40,000	40,000	40,000

SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide
HC = hydrocarbons
CO = carbon monoxide

[a]These are predicted ground-level concentrations from urban sources. Background concentrations are taken from Table 6-5. "Rural points" are measurements taken 3 miles from the center of town.

[b]"Primary" and "secondary" are federal ambient air quality standards designed to protect the public health and welfare, respectively.

[c]No additional plants after 1990. Air impacts are assumed to stay the same.

[d]Allowable increments which cannot be exceeded in areas designated Category II by Colorado. Data from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[e]It is assumed that 50 percent of oxides of nitrogen from urban sources is converted to NO_2.

[f]The 3-hour HC standard is measured at 6-9 a.m.

TABLE 6-15: POLLUTION CONCENTRATIONS DUE TO URBAN SOURCES AT GRAND VALLEY, 1990 (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]			STANDARDS[b]		
	BACKGROUND	MIDTOWN POINT	RURAL POINT	PRIMARY	SECONDARY	COLORADO
Particulates						
Annual	12	11	1	75	60	45
24-hour		37	37	260	150	150
SO_2						
Annual	2	6	1	80		5[c]
24-hour		20	20	365		50[c]
3-hour		36	36		1,300	100[c]
NO_2[d]						
Annual	5	17	2	100	100	100
HC						
3-hour	130	301	301	160	160	160
CO						
8-hour	1,000	1,140	1,140	10,000	10,000	10,000
3-hour		1,970	1,870	40,000	40,000	40,000

SO_2 = sulfur dioxide NO_2 = nitrogen dioxide HC = hydrocarbons CO = carbon monoxide

[a]These are predicted ground-level concentrations from urban sources. Background concentrations are taken from Table 6-5. "Rural points" are measurements taken 3 miles from the center of town.

[b]"Primary" and "secondary" are federal ambient air quality standards designed to protect the public health and welfare, respectively.

[c]Allowable increments which cannot be exceeded in areas designated Category II by Colorado. Data from White, Irvin L., _et al_. _Energy From the West: Energy Resource Development Systems Report_. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[d]It is assumed that 50 percent of oxides of nitrogen from urban sources is converted to NO_2.

ambient standard violated in Rifle by 1990. Concentrations over Grand Valley will violate federal and Colorado HC standards. Although the populations of Rifle and Grand Valley will grow somewhat by the year 2000, the resultant pollution concentrations are expected to increase less than 5 percent over 1990 values.

E. Other Air Impacts

Additional categories of potential air impacts have been examined; that is, an attempt has been made to identify sources of pollutants and how energy development may affect levels of these pollutants during the next 25 years. These include sulfates, oxidants, fine particulates, long-range visibility, plume opacity, cooling tower salt deposition, cooling tower fogging and icing, trace element emissions, and fugitive dust emissions.[1] Although there are likely to be local impacts as a consequence of these pollutants, both the available data and knowledge about impact mechanisms are insufficient to allow quantitative, site-specific analyses. Thus, these are discussed in a more general, qualitative manner in Chapter 10.

6.2.4 Summary of Air Impacts

A 1,000 MWe power plant, one 50,000 barrel per day TOSCO II oil shale plant with an underground mine, one 57,000 bbl/day *in situ* oil shale processing facility, and a 50,000 bbl/day oil field are projected for the Rifle area. To meet NSPS the power plant would require 97.3 percent particulate removal, no SO_2 removal, and 15 percent NO_x removal. However, with this level of control, the plant would violate federal ambient standards for 3-hour and 24-hour SO_2 as well as Colorado's 24-hour SO_2 standard.

With 80 percent SO_2 and 99 percent particulate removal, peak concentrations from the plant do not violate federal ambient standards, but 24-hour SO_2 concentrations still exceed the Colorado 24- and 3-hour standards. With the control, the plant also exceeds Class II PSD increments for 3-hour and 24-hour SO_2. Class II increments can be met by increasing the SO_2 scrubber efficiency to 95 percent, by increasing the stack height to 1,000 feet, by decreasing plant capacity to 500 MWe, or by relocating the plant to flat terrain. Of these alternatives, only the relocation results in no violation of Colorado's 3-hour SO_2 standard.

The 50,000 bbl/day TOSCO II plant exceeds the federal NAAQS for HC and the Class II PSD increments for 24-hour TSP, but the

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[1] Little analytical information is currently available on the source and formation of nitrates. See: Hazardous Materials Advisory Committee. Nitrogenous Compounds in the Environment, U.S., Environmental Protection Agency Report No. EPA-SAB-73-001. Washington, D.C.: Government Printing Office, 1973.

Class II PSD increments can be met through an increase in the stack height.

The *in situ* oil shale processing facilities (with or without a surface retort) do not violate any NAAQS or Class II PSD increments.

If all facilities are constructed according to the hypothesized schedule, population increases in Rifle and Grand Valley will add to and create pollution problems. By 1990, Colorado's annual SO_2 and federal and Colorado 3-hour HC standards will be violated.

6.3 WATER IMPACTS

6.3.1 Introduction

Energy resource development facilities in the Rifle area are sited in the Upper Colorado River Basin (UCRB). The major water sources will be the White and Colorado Rivers, but groundwater will also supply a significant part of the requirements (see Figure 6-4). In the scenario area, annual precipitation varies between 11 and 20 inches per year depending on elevation, with annual snowfall varying between 60 and 100 inches.[1]

This section identifies the sources and uses of water required for energy development, the residuals that will be produced, and the water availability and quality impacts that are likely to result.

6.3.2 Existing Conditions

A. Groundwater

The Rifle area contains both bedrock and alluvial aquifers. Bedrock aquifers are in the combined Uintah and Green River Formations and in the Mesa Verde Group. The Uintah and Green River aquifers are separated by the Mahogany Zone, the principal source of oil shale. Since leakage is common through the zone, the two aquifers behave as if they were parts of the same unit, although their water quality differs. The total volume of water stored in the Uintah and Green River aquifers has been estimated to be about 25 million acre-feet.[2] The flow through the aquifers in the Piceance Creek drainage basin is estimated to be about 36 cubic

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[1]The moisture content of one inch of rain is equal to approximately fifteen inches of snow.

[2]U.S., Department of the Interior. Final Environmental Statement for the Prototype Oil Shale Leasing Program, 2 vols. Washington, D.C.: Government Printing Office, 1973, Vol. I, p. 11-141.

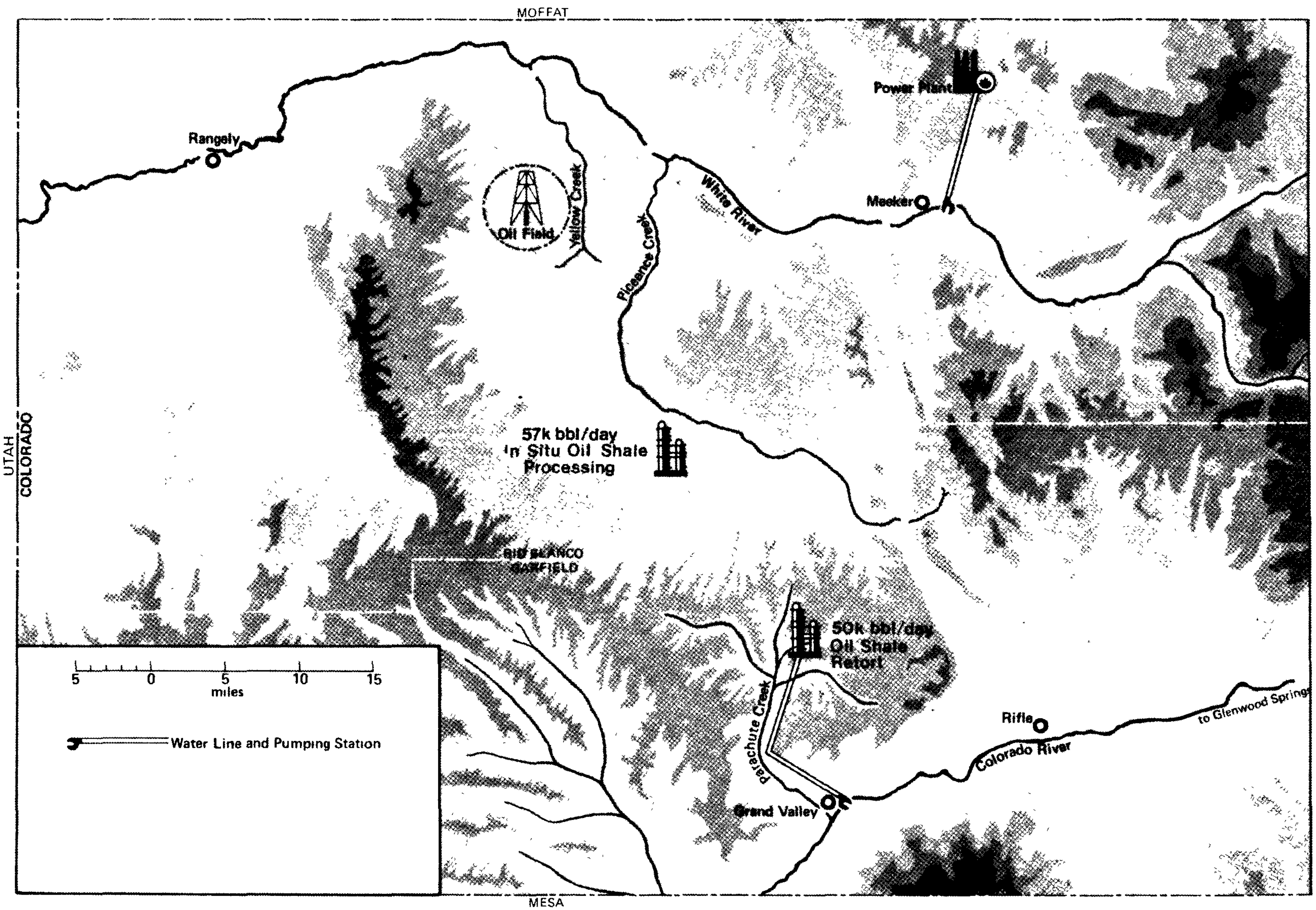

FIGURE 6-4: WATER PIPELINES FOR ENERGY FACILITIES IN THE RIFLE SCENARIO

feet per second (cfs).[1] Most of the recharge takes place in outcrops of the aquifers, and groundwater flow is toward the center of the Piceance Basin. Discharge is mostly from springs and into alluvial aquifers. Wells penetrating both aquifers should yield as much as 1,000 gallons per minute (gpm). The total dissolved solids (TDS) of water in the upper aquifer is generally less than 1,000 milligrams per liter (mg/ℓ), but the TDS of water in the lower aquifer is as high as 40,000 mg/ℓ.[2]

Aquifers in the Mesa Verde Group are important to the scenario area because this group is the projected source of coal for the power plant. Very little information is available on ground water in the Mesa Verde Group. These aquifers, many of which are perched, occur in discontinuous beds of sandstone that are interspersed in the shales of the formation. Records[3] indicate that wells in the Mesa Verde Group produce less than 50 gpm in the scenario region, but no data are available on water quality for the Mesa Verde aquifers.

The alluvial aquifers associated with the Colorado and White Rivers are recharged by their respective rivers and, therefore, are highly reliable and productive sources of water. The hydrology is much the same for the Parachute and Piceance Creek aquifers; however, their productivity is relatively low, and current use is limited to providing water for livestock. Water quality in the two creek aquifers is relatively good with TDS of less than 1,000 mg/ℓ in the upper reaches. Because of decreases in the quality of discharge from the bedrock aquifers, groundwater quality in the alluvium becomes progressively worse downstream, eventually reaching 3,000 mg/ℓ TDS.

B. Surface Water

As shown in Figure 6-4, the White and Colorado Rivers are the major surface-water supply sources for energy development in the Rifle scenario. Flow allocations in both of these rivers are governed by the Colorado River Compact,[4] the Upper Colorado River

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[1] Weeks, John B., _et al_. _Simulated Effects of Oil-Shale Development on the Hydrology of Piceance Basin, Colorado_, U.S., Geological Survey Professional Paper 908. Washington, D.C.: Government Printing Office, 1974, p. 40.

[2] _Ibid_., p. 40.

[3] Colorado Land Use Commission. _Colorado Land Use Map Folio_. Denver, Colo.: Colorado Land Use Commission, 1974.

[4] Colorado River Compact of 1922, 42 Stat. 171, 45 Stat. 1064, declared effective by Presidential Proclamation, 46 Stat. 3000 (1928).

Basin Compact,[1] and the Mexican Treaty of 1944,[2] as well as the laws of the State of Colorado. Colorado's share of the flow in the UCRB is determined with reference to the natural flow of the Colorado River at Lees Ferry, Arizona. This flow has been estimated to be from 5.25 to 6.3 million acre-feet per year (acre-ft/yr); the most widely accepted estimate is that made by the Department of Interior at 5.8 million acre-ft/yr.[3] Using that value, Colorado's share of the flow is about 3 million acre-ft/yr. Near Rifle, the Colorado River has an average flow of 2.8 million acre-ft/yr, and the White River averages 455,000 acre-ft/yr. However, not all of the flow in the Colorado River near Rifle or in the White River is available for future energy development. Considerable uncertainty exists over how demands for increased water allocations for agricultural irrigation, municipal needs, instream needs, and other legal commitments and uses will be handled.

Present uses of UCRB water in Colorado are shown in Table 6-16. The main use is for irrigation, but a significant portion is diverted to the San Juan River and to municipal use in the Denver area. Although about 745,000 acre-ft/yr from the Colorado River system are estimated to be available for the State of Colorado to develop[4] not all of this will be available for energy in the Rifle area.

Water quality in the White and Colorado Rivers is shown in Table 6-17. Also shown are water quality data for Piceance and Parachute Creeks, both of which may be impacted by energy development. Water quality is generally good in the White and Colorado Rivers and in Parachute Creek, but TDS and hardness levels are high in Piceance Creek, primarily due to bicarbonates and sodium.

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[1]Upper Colorado River Basin Compact of 1948, Pub. L. 81-37, 63 Stat. 31 (1949).

[2]Treaty between the United States of America and Mexico Respecting Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, February 3, 1944, 59 Stat. 1219 (1945), Treaty Series No. 994.

[3]U.S., Department of the Interior, Water for Energy Management Team. Report on Water for Energy in the Upper Colorado River Basin. Denver, Colo.: Department of the Interior, 1974, p. 11.

[4]U.S., Department of the Interior, Bureau of Reclamation. Westwide Study Report on Critical Water Problems Facing the Eleven Western States. Washington, D.C.: Government Printing Office, 1975, p. 261.

TABLE 6-16: WATER USE IN THE UPPER COLORADO RIVER BASIN PORTION OF THE STATE OF COLORADO (in thousands of acre-feet)[a]

	GREEN RIVER SUBBASIN	UPPER MAIN STEM SUBBASIN
Estimated 1974 Water Use		
Estimated exports	0	614[b]
Irrigation	89	779
Municipal and industrial including rural	2	14
Minerals	4	8
Thermal electric	10	4
Recreation fish and wildlife	3	8
Other	5	11
Consumptive conveyance losses	22	175
Reservoir evaporation	2	37
Total depletions[c]	137	1,650

[a]U.S., Department of the Interior, Bureau of Reclamation. Westwide Study Report on Critical Water Problems Facing the Eleven Western States. Washington, D.C.: Government Printing Office, 1975, p. 260-261.

[b]Includes intersubbasin transfer to San Juan River and interbasin transfer to the Denver, Colorado area.

[c]Includes Colorado's remaining share of mainstream reservoir evaporation.

6.3.3 Factors Producing Impacts

The water requirements of and effluents from energy facilities cause water impacts. These requirements and effluents are identified in this section for each type of energy facility. Associated population increases also increase municipal water demand and sewage effluent; these are presented in Section 6.3.4 for the scenario which includes all facilities constructed according to the scenario schedule.

TABLE 6-17: WATER QUALITY AND FLOW DATA FOR RIFLE VICINITY

	WHITE RIVER[a] NEAR MEEKER	COLORADO RIVER[b] ABOVE GRAND VALLEY	PICEANCE CREEK[c] AT WHITE RIVER	PARACHUTE CREEK[b] NEAR GRAND VALLEY	DRINKING WATER STANDARD	TYPICAL[d] BOILER FEEDWATER
Drainage Area (square miles)	762[e]	4,558[f]	629	141[g]		
Maximum Flow (cfs)	6,370[e]	30,100[f]	407	470[g]		
Minimum Flow (cfs)	173[e]	286[f]	0.50	0.0[g]		
Average Flow (cfs) (acre-ft/yr)	622 450,600	2,700 1,955,000[f]	19 13,980	19 13,770		
Dissolved Silica (mg/ℓ)	10.4	--	14	--		
Calcium (mg/ℓ)	40.7	64	49	86.3		0.10
Magnesium (mg/ℓ)	8.5	13	82	13.48		0.03
Sodium (mg/ℓ)	8.6	94	742	98.48		0.24
Chloride (mg/ℓ)	9.5	119	153	118.5	250[h]	0.96
Bicarbonate (mg/ℓ)	113	144	1,644	143.8		<0.01
Sulfate (mg/ℓ)	45.5	129	414	129.1	250[h]	0.14
Nitrate (mg/ℓ)	.13	1.8	.4	1.8	10[i]	
Total Dissolved Solids (mg/ℓ)	181	454	2,301	701	500[h]	<10
Hardness (mg/ℓ)	134	--	459	--	6.5-8.5	<0.10
Suspended Sediment	663	--	681	--		
pH Units	8	8	8.3	8	6.5-8.5[h]	8.8-10.8

cfs = cubic feet per second
acre-ft/yr = acre-feet per year
mg/ℓ = milligrams per liter

< = less than
pH = acidity/alkalinity

TABLE 6-17: (Continued)

[a]Water quality data are flow weighted averages computed from available data. U.S., Department of the Interior, Geological Survey. 1974 Water Resources Data for Colorado, Part 2: Water Quality Records. Washington, D.C.: Government Printing Office, 1975.

[b]Water quality data from Colony Development Operation; Atlantic Richfield Company, Operator. An Environmental Impact Analysis for a Shale Oil Complex at Parachute Creek, Colorado, Part I: Plant Complex and Service Corridor. Denver, Colo.: Atlantic Richfield, 1974, p. 43, Table 7.

[c]Water quality data are flow weighted averages computed from available data. Water quality and flow data from Fickle, John F., et al. Hydrologic Data from Piceance Basin, Colorado, Colorado Water Resources Basic-Data Release No. 31. Denver, Colo.: Colorado Department of Natural Resources, 1974.

[d]Recommended by American Water Works Association, Inc. Water Quality and Treatment, 3rd ed. New York, N.Y.: McGraw-Hill, 1971.

[e]Flow data from U.S., Department of the Interior, Geological Survey. 1974 Water Resources Data for Colorado, Part I: Surface Water Records. Washington, D.C.: Government Printing Office, 1975.

[f]Flow data for Colorado River at Glenwood Springs, Colorado, Station No. 09072500. Ibid.

[g]Flow data from Leavesley, George H., hydrologist, U.S. Geological Survey, Denver, Colorado. Personal communication.

[h]U.S., Environmental Protection Agency. "National Secondary Drinking Water Regulations." Proposed Regulations. 42 Fed. Reg. 17143-47 (March 31, 1977).

[i]U.S., Environmental Protection Agency. "National Interim Drinking Water Regulations." 40 Fed. Reg. 59,566-87 (December 24, 1975). These regulations include other standards not given here.

A. Water Requirements of Energy Facilities

The water requirements for energy facilities hypothesized in the Rifle area are shown in Table 6-18. Two sets of data are presented. The Energy Resource Development System (ERDS) data are based on secondary sources, including impact statements, Federal Power Commission docket filings, and recently published data accumulations,[1] and can be considered typical requirement levels. The Water Purification Associates data are from a study on minimum water use requirements and take into account opportunities to recycle water on site as well as the moisture content of the coal being used and local meteorological conditions.[2] The manner in which water is consumed by these facilities is shown in Figure 6-5. Cooling consumes the most water in power generation, while for oil shale processing, cooling, and solid waste disposal consume comparable amounts.

As indicated in Table 6-18, the 1,000 MWe coal-fired power plant at Rifle requires 9,400 acre-ft/yr of water, using a high wet cooling technology. The water requirements of the power plant equipped with an intermediate wet cooling system (i.e., combination of wet and dry towers) are 2,786 acre-ft/yr, a reduction in water use of some 71 percent. For the 50,000 barrel TOSCO II oil shale retort water requirements are 4,650 to 9,272 acre-ft/yr.[3] The water requirements of the _in situ_ oil shale facility are 4,360 acre-ft/yr without surface retort, and 5,663 acre-ft/yr with a surface retort.[4] The type of cooling chosen is often determined by

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[1]The ERDS is based on data drawn from University of Oklahoma, Science and Public Policy Program. _Energy Alternatives: A Comparative Analysis_. Washington, D.C.: Government Printing Office, 1975; and Radian Corporation. _A Western Regional Energy Development Study_, Final Report, 3 vols. and _Executive Summary_. Austin, Tex.: Radian Corporation, 1975. These data are published in White, Irvin L., _et al_. _Energy From the West: Energy Resource Development Systems Report_. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[2]Gold, Harris, _et al_. _Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States_. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

[3]The difference between these two values is the exclusion of mine dust control and spent shale reclamation water requirements in the low value and the inclusion of it in the high value. See footnote "e" of Table 6-18.

[4]Both of these values include water for mine dust control and the 5,663 value includes water for spent shale reclamation. See footnotes "f" and "g" of Table 6-18.

TABLE 6-18: WATER REQUIREMENTS FOR ENERGY FACILITIES AT RIFLE (acre-feet per year)

TECHNOLOGY[a]	ERDS[b] WET COOLING	WPA[c] COMBINATIONS OF WET AND DRY COOLING[d]	
		HIGH WET	INTERMEDIATE WET
Power Generation (1,000 MWe)	9,400	9,494	2,786
Oil Shale Retort TOSCO II (50,000 bbl/day)	9,272[e]	NC	6,468[i]
Modified *In Situ* Oil Shale (57,000 bbl/day)	4,360[f]	NC	NC
Modified *In Situ* Oil Shale With Surface Retort (57,000 bbl/day)	5,663[g]	NC	NC
Oil Well Field (50,000 bbl/day)	2,500-4,100[h]	NC	NC
	Cost range in which indicated cooling technology is most economic (dollars per thousand gallons)		
Power Plant	NC	<3.65-5.90	>3.65-5.90

ERDS = Energy Resource Development Systems Report
WPA = Water Purification Associates
MWe = megawatt-electric
NC = not considered
bbl/day = barrels per day
< = less than
> = greater than

[a]These values assume an annual load factor of 75 percent in the case of the power plant and 90 percent in the case of the oil shale facilities.

[b]White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[c]Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

[d]Combinations of wet and wet-dry cooling were obtained by examining the economics of cooling alternatives for the steam turbine condensors. In the high wet case, these are all wet cooled; in the intermediate case, wet cooling handles ten percent of the load on the turbine condensors.

[e]Of the total 9,272, 891 is for dust control in the mining operations; 7,301 is needed for the retort; and 1,100 is used for reclaiming and revegetating the spent shale.

[f]Of the total 4,360, 730 is used for dust control in the mining operations and 3,630 is needed for the *in situ* retort.

[g]Of the 5,663, 547 is for dust control in the mining operations; 2,722 is needed for the *in situ* retort and 2,081 for the surface retort; and 313 is used for reclaiming and revegetating the spent shale.

[h]This represents the water requirements of a water flood in the oil field.

[i]This value represents the water requirements for a TOSCO II retort (4,653 acre-ft) and water for spent shale disposal (1,815 acre-ft). The engineering design for that system calls for integration of some dry cooling, thus it is termed intermediate wet.

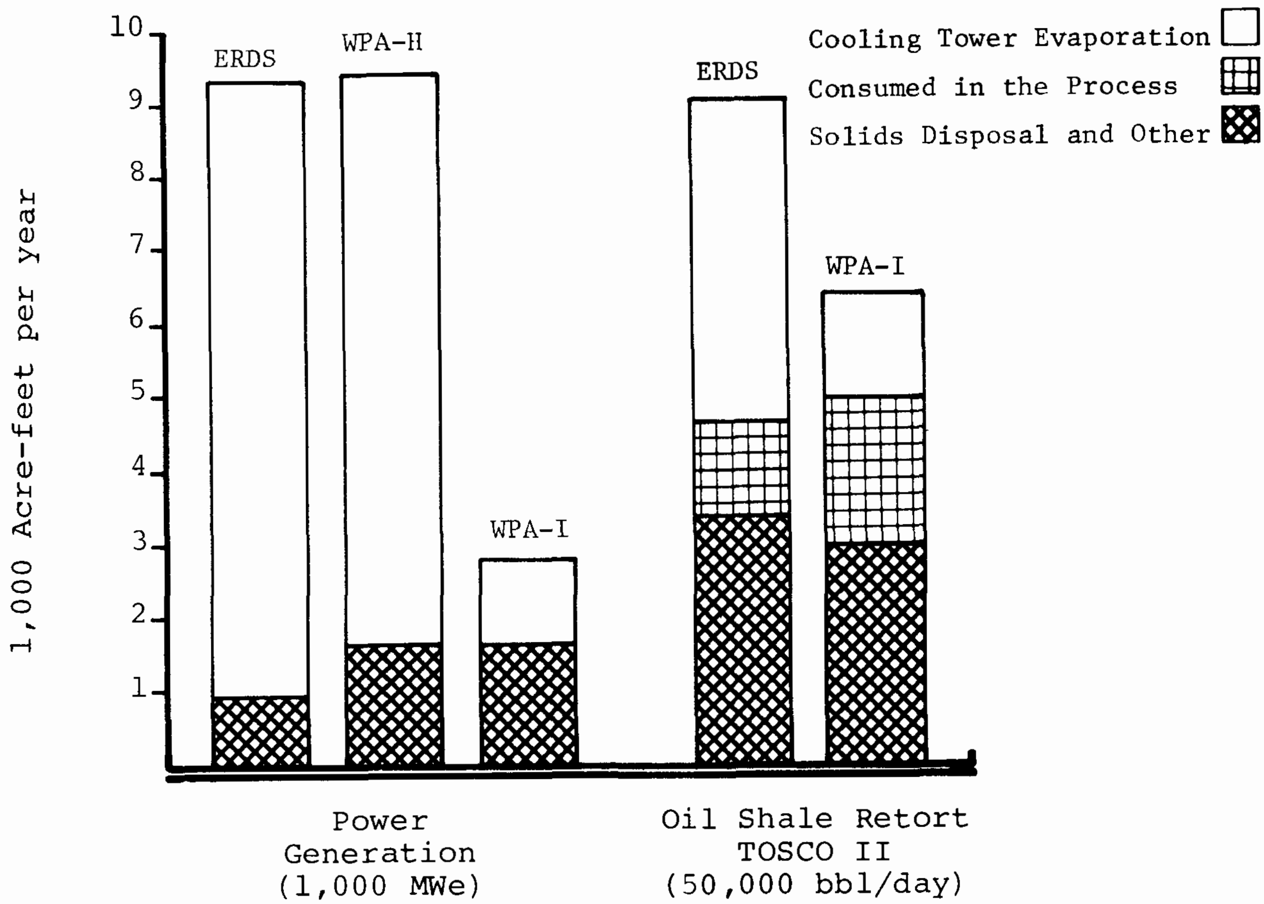

FIGURE 6-5: WATER CONSUMPTION FOR ENERGY FACILITIES IN THE RIFLE SCENARIO

ERDS = Energy Resource Development System
WPA-H = Water Purification Associates-High Wet Cooling
WPA-I = Water Purification Associates-Intermediate Wet Cooling
MWe = megawatt-electric
bbl/day = barrels per day

Source: The ERDS data is from White, Irvin L. et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming. The WPA data is from Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977. The oil shale retort includes water used for spent shale disposal.

water availability and price. The current price of water in the Southwest is 3 to 30¢ per thousand gallons. If water costs increase above a range of $3.60 to $5.90 per thousand gallons, it becomes more profitable to use less water by employing intermediate wet cooling for the power plant. However, which cooling system is chosen may depend on other factors in addition to economics. If intermediate wet cooling is used, even though water costs $0.25 per thousand gallons, the cost of electricity would increase 1 to 2 cents per kilowatt hour.

As shown in Figure 6-4, water for the power plant will be taken from the White River near Meeker. Water that has been released from a new upstream off-channel impoundment will be withdrawn from the Colorado River near Grand Valley to supply the 50,000 bbl/day oil shale plant. This new impoundment will be filled with flood flows from the Colorado River. The 57,000 bbl/day oil shale plant will use as process water groundwater from dewatering the oil shale mines.

B. Effluents from Energy Facilities

Table 6-19 lists expected amounts of solid effluents produced by energy facilities in the Rifle scenario. The greatest amount of solid effluents will be produced by the 50,000 bbl/day TOSCO II facility, more than 49,000 tons per day. The 1,000 MWe power plant is expected to produce less than 700 tons of solid effluents per day (assuming average load factors).[1] The TOSCO II plant will produce the highest volume of dry and wet solids, more than 48,000 tons of dry solids, primarily spent shale, and slightly less than 1,000 tons of wet solids per day. The power plant will have the highest volume of dissolved solids, 12 tons per day. Effluents from the modified _in situ_ process are essentially unknown. If the mined shale is retorted, the spent shale will be produced at a rate of 27,000 tons per day.

In the power plant and TOSCO II plant, dissolved solids are present in the ash blowdown effluent, the demineralized waste effluent, and the flue gas desulfurization effluent.[2] The principle constituents of wastewater which appear as dissolved solids are calcium, magnesium, sodium, sulfate, and chlorine.

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[1]The average load factor for the power plant is 75 percent and TOSCO II facility is 90 percent.

[2]Demineralization is a method of preparing water for use in boilers; it produces a waste stream composed of chemicals present in the source water. The ash blowdown stream is the water used to remove bottom ash from the boiler. Bottom ash removal is done via a wet sluicing system using cooling tower blowdown water. Thus, the dissolved solids content of that stream is composed of chemicals from the ash and cooling water.

TABLE 6-19: EFFLUENTS FROM COAL AND OIL SHALE CONVERSION PROCESSES AT RIFLE[a]

FACILITY TYPE	SOLIDS[b] (tons per day)				WATER IN EFFLUENT[c] (acre-feet per year)
	DISSOLVED	WET	DRY	TOTAL	
Electric Power (1,000 MW)	12	327	302	641	94
Oil Shale Tosco II (50,000 bbl/day)	9	968	48,300	49,277	2,010
Modified *In Situ* (57,000 bbl/day)	U	U	U	U	U
Modified *In Situ* with Surface Retort (57,000 bbl/day)	U	U	27,000	U	U
Oil Well Field[d] (50,000 bbl/day)	U	U	U	U	U

MW = megawatt bbl/day = barrels per day U = unknown

[a]These data are from Radian Corporation. *The Assessment of Residuals Disposal for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States*, EPA Contract No. 68-01-1916. Austin, Tex.: Radian Corporation, 1978. The Radian Coporation report extends and is based on earlier analyses conducted by Water Purification Associates and reported in Gold, Harris, et al. *Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States*. U.S., Environmental Protection Agency, 1977.

[b]These values are given for a day when the facility is operating at full load. In order to obtain yearly values, these numbers must be multiplied by 365 days and by the average load factor. Load factors are 90 percent for synthetic fuels facilities and 75 percent for power plants. The values given as solids do not include the weight of the water in which the solids are suspended or dissolved.

[c]The values for water discharged are annual and take into account the load factor.

[d]While oil field effluent data are not considered they are thought to be quite small in comparison to effluents from the power plant and oil shale facilities.

Wet solids from the electric power plant are in the form of flue gas sludge, bottom ash, and cooling water treatment waste sludge. Calcium carbonate ($CaCO_3$) and calcium sulfate ($CaSO_4$) are the primary constituents of flue gas sludge. The bottom ash is primarily oxides of aluminum and silicon. $CaCO_3$ is the principal constituent of cooling water treatment waste. In all cases, the amount of cooling water treatment waste is very small, compared to the bottom ash and flue gas sludge. The quantity of wet solids in the flue gas desulfurization sludge depends on the efficiency of the facility's scrubbers (80 percent removal has been assumed here), and on the SO_2 content of the flue gas. Dry solid waste produced by the power plant is primarily fly ash composed of oxides of aluminum, silicon, and iron.

The water content of the effluent stream accounts for one percent of the total water requirements of the power plant, and from 21 to 31 percent of the total water requirements of the TOSCO II oil shale retort. (Data in Table 6-19 compared with data in Table 6-18).

Dissolved and wet solids will be sent to evaporative holding ponds and later deposited in landfills. Dry solids are treated with water to prevent dusting and deposited in a landfill.[1] The spent shale is expected to be dumped into canyons, compacted, and revegetated.

6.3.4 Impacts

This section describes water impacts which result from the mines and conversion facilities individually, and from a scenario which includes construction of all facilities according to the hypothesized scenario schedule.[2] The water requirements and impacts associated with expected population increases are included in the scenario impact description.

A. Mine Impacts

(1) Underground Coal Mine

The coal mine for the power plant will use surface-water sources and should not result in the depletion of any regional groundwater aquifers. However, the mine openings will probably intercept some of the groundwater flow in the Mesa Verde Group,

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[1]The environmental problems of solid waste disposal in landfills are discussed in Chapter 10.

[2]Because the water requirements of and effluents from the oil well field are small in comparison to those of the power plant and oil shale facilities, water impacts of the oil well field are not considered in this section.

and any associated dewatering operations could also cause depletion of local aquifers, particularly if the aquifers are perched.

Since the coal mine will be located on a natural watershed divide, runoff affected by the mining process can be trapped without disturbing natural surface-water drainage. Also, because this is an underground mine, only a small area will be needed for surface facilities that cause changes in water quality. Water affected by these facilities will be trapped and introduced into the water treatment facilities at the power plant.

The extent of the impacts will increase as expanded mine openings intercept more aquifers and/or remove more of the original aquifer, resulting in greater interruption of groundwater flow. Also, mine subsidence may begin to set in and may lead to such effects as topographic and drainage pattern changes, disruption of groundwater flow in the overburden, and possibly mixing of fresh and saline aquifers.

(2) Underground Oil Shale Mines

The oil shale mine will have several impacts on the bedrock groundwater aquifers.[1] Interception of the flow will cause several springs and seeps to dry up, and the recharge to alluvial aquifers will also be reduced. Mining operations will deplete the bedrock aquifers by 420 acre-ft/yr (0.58 cfs), which will lower the local water table below the bed of Parachute Creek and thus eliminate its base flow.[2]

B. Energy Conversion Facilities Impacts

Water impacts may be divided into those occurring during construction and during operation, and those occurring because of the water requirements of facilities and because of effluents from the facilities.

Construction activities at the conversion facilities will remove vegetation and disturb the soil. These activities have an effect on surface-water quality. The major effect will be increases in the sediment load of local runoff. Maintenance areas and petroleum products storage facilities will also be needed to

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[1]Weeks, John B., et al. Simulated Effects of Oil-Shale Development on the Hydrology of Piceance Basin, Colorado, U.S. Geological Survey Professional Paper 908. Washington, D.C.: Government Printing Office, 1974, p. 4.

[2]U.S., Department of the Interior, Bureau of Land Management. Draft Environmental Impact Statement: Proposed Development of Oil Shale Resources by the Colony Development Operation in Colorado. Washington, D.C.: Bureau of Land Management, 1975, p. 34.

support construction equipment. Areas for the storage of other construction-related materials (such as aggregate for a concrete batch plant) may be required as well. All these facilities have the potential for contaminating runoff. Runoff control methods will be instituted at all the potential sources of contaminants. Runoff will be channeled to a holding pond for settling, reuse, and evaporation. Because the supply of water to this pond is intermittent, evaporation may claim most of the water, but some of the water may be used for dust control.

(1) Power Plant

The operation of a 1,000 MWe power plant facility will require from 2,800 to 9,500 acre-feet of surface water annually (see Table 6-18). This water will come from the White River near Meeker. A 28-acre surface reservoir to be constructed at the plant site will contain a 21-day supply of water. This water will be used during extremely low-flow periods in the White River, but the plant will generally not draw water solely from the reservoir for more than 14 consecutive days. At full load, the plant requires approximately 20 cubic feet of water per second and this is about 14 percent of the lowest recorded flow in the White River at Meeker.

Since water for the coal-fired power plant will be obtained from surface-water sources, excessive withdrawals and aquifer depletions are not expected to be major problems. In fact, leakage from fresh-water storage ponds should have the beneficial effect of recharging local perched aquifers with high quality water that will tend to dilute lower quality water. Lower quality recharge would be expected from cooling tower and sanitary effluent ponds and from scrubber sludge and ash disposal sites. This may result in contamination of local Mesa Verde aquifers.

Approximate quantities of effluents expected from the operation of the power plant are given in Table 6-19. These effluents will be discharged into clay-lined retention ponds to reduce the potential for pollution of local surface waters or groundwaters, although some leakage from these ponds could occur and pollute groundwater.

(2) 50,000 bbl/day Oil Shale Plant

Since water for operation of the 50,000 bbl/day oil shale plant will be taken from surface water, the water requirements of this plant will have minimal negative impact on groundwater supplies. Although water storage ponds at the site may provide beneficial recharge to the bedrock aquifers, leakage from effluent disposal ponds may lower groundwater quality. If the spent (processed) oil shale from the 50,000 bbl/day plant is deposited in gullies as planned, infiltrating precipitation and water added for revegetation may leach trace elements and dissolved salts into both bedrock and alluvial aquifers (the latter by pollution of streamflow which becomes recharge to the alluvial aquifers).

The water supply system envisioned for the 50,000 bbl/day oil shale plant on Parachute Creek will have little effect on surface flows. Water is postulated to be released from an upstream impoundment and removed near the confluence of the Colorado River and Parachute Creek. The impoundment will be offstream and will be filled with flood flows from the Colorado River. There should be no measurable adverse environmental impact from this water supply system provided the impoundment design is adequate to handle extreme low-flow periods. If the plant were to withdraw process water without a corresponding impoundment release, the plant requirement of 12.7 cfs is equivalent to 1.8 percent of the minimum low flow of record near Cameo, Colorado[1] (the closest gauging station with adequate records). Even during such an extreme event, changes caused by the process withdrawals would be small.

The large areas used for spent shale disposal will contribute to the increases in surface runoff as will the process facilities and roads. Also, the oil shale disposal piles may become semi-impermeable until vegetation has been established, which could increase runoff as much as 1.4 acre-feet per acre of disposal pile.[2] However, this increase in runoff will appear as a loss of flow in the local streams during the life of the plant because the water will be caught by retention facilities and treated for use as process make-up water. These facilities will cause a portion of the natural watershed to be effectively removed from the basin, thus causing the flow decrease in local streams. After vegetation is established and runoff quality has been shown to be acceptable, the retention facility will be deactivated and runoff will be returned to these streams.

(3) In Situ Oil Shale Facility

Potential sources of surface water impacts from the in situ oil shale operation in the Rifle scenario include sediment delivery, leaching of dissolved solids, and leaching of toxic substances into the Piceance Creek watershed. Runoff retention facilities will be used around shale piles, and dams in nearby gulches should be adequate to protect surface water systems from runoff. However,

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[1]U.S., Department of the Interior, Bureau of Land Management. Draft Environmental Impact Statement: Proposed Development of Oil Shale Resources by the Colony Development Operation in Colorado. Washington, D.C.: Bureau of Land Management, 1975, p. 34.

[2]Weeks, John B., et al. Simulated Effects of Oil Shale Development on the Hydrology of Piceance Basin, Colorado, U.S. Geological Survey Professional Paper 908. Washington, D.C.: Government Printing Office, 1974.

complete protection will not be possible during construction of these dams. After diversion and retention facilities are completed in 1982, pollution of the watershed will be markedly reduced. Water tapped by these facilities will be used for shale moisturization, treated and recycled in the retorting process, or evaporated in clay-lined pits. The result will be minimal quality and quantity impacts upon surface waters. There is a possibility of mine water defluoridation and discharge into Piceance Creek. Defluoridation would bring the mine water within EPA drinking water standards, and would augment the watershed in times of low flows, and reduce the fluoride concentrations in the creek slightly. Withdrawals of water from the Colorado River are expected to be minimal and will have a negligible impact on water quality and availability in that basin. Because of the mine dewatering operations, a reduction of groundwater discharge to streams will occur in the Piceance and Yellow Creek Basins.

The underground mine and associated surface facilities are likely to affect both upper and lower aquifers during construction, operation, and postoperation phases. During the construction phase, leaching of shale piles, and disposal of excess water from dewatering and irrigation of the shale piles could result in a groundwater contamination problem. During the operational phase, shale oil and related organic and inorganic compounds could all be considered contaminants that could enter the groundwater systems. If the mined oil shale is retorted at the surface, it will pose a potential threat to the groundwater system. Leaching and migration of leachate to groundwater systems are not likely to occur unless the piles become saturated or nearly saturated. The likelihood of spent shale leachate reaching groundwater systems will depend on whether excess mine water is disposed of by irrigation of the shale and, if so, the rate of application of this irrigation water. Petroleum-like products from the surface operations of the _in situ_ facility may also pose water quality problems for groundwater at the site due to leakage or spills. This problem can be minimized by proper operation and maintenance of equipment, and prompt cleanup of any spills or leaks.

After the operations cease, the _in situ_ retorts may become saturated by the water table, releasing contaminants into the water and lowering water quality. The higher permeability of the retort area can also be expected to affect the flow relationship of the upper and lower bedrock aquifers. The combustion of the oil shale in these retorts may mobilize trace elements, organic substances, or other potentially hazardous materials that could be subsequently leached by groundwater after operations cease and the water table reestablishes itself. Whether the high temperatures used in the retort will increase or decrease the availability of trace elements or other contaminants is unknown. The potential for groundwater contamination by trace elements is currently under investigation.

TABLE 6-20: EXPECTED MUNICIPAL WATER REQUIREMENTS FOR INCREASED POPULATION IN THE RIFLE REGION[a]
(acre-feet per year)

LOCATION	1975[b]	1980	1990	2000
Rifle	364	65	530	575
Grand Valley	29	30	280	290
Glenwood Springs	615	26	80	119
Rural	1,308	110	140	205
Meeker	374	800	880	950
Rangely	374	480	380	410
Grand Junction	8,386	782	2,665	3,898

[a]Based on 130 percent of reported wastewater flow. See Table 6-22.

[b]1975 data are estimated municipal water usage. Data for 1980, 1990, and 2000 represent increased water usage over the 1975 requirements.

C. Scenario Impacts

Water impacts resulting from interactions among the hypothesized facilities and water impacts resulting from associated population increases are discussed in this section.

Water requirements for direct use by these hypothesized energy facilities (assuming high wet cooling) increase from approximately 9,500 acre-ft/yr in 1980, when the power plant is operating, to 24,000 acre-ft/yr by 1990, when the power plant and both oil shale plants are in operation.

The increased population associated with energy development will require additional water supply facilities. An estimated total of 17,900 acre-ft/yr of water will be required by the year 2000. This requirement has been broken down by municipality in Table 6-20.[1] Water for municipal use will probably be withdrawn

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[1]Population estimates do not include increases caused by secondary industries.

from Colorado's allocation of the Colorado River either through a direct intake of river water or from wells in alluvial aquifers. In either case, permits must be obtained from the State of Colorado to withdraw this water.

Rural populations are assumed to use individual, on-site waste disposal facilities (septic tanks and drainfields). The urban population will require waste treatment facilities. The current status of wastewater treatment facilities in the municipalities most affected by energy development activities is indicated in Table 6-21. The wastewater generated by the population increases associated with energy development is shown in Table 6-22.

Based on current capacities of treatment facilities, all the communities impacted in this scenario, except Glenwood Springs and Grand Junction, will require new wastewater treatment facilities to accommodate new population due to energy developments. New facilities will need to use "best practicable" waste treatment technologies to conform to 1983 standards, and must make allowance for recycling or zero discharge of pollutants to meet 1985 standards.[1] The 1985 standards could be met by using effluents from the waste treatment facility for industrial process make-up water or for irrigating local farmland.

(1) To 1980

The only facilities to be in operation by 1980 are the 1,000 MWe power plant and its associated underground coal mine. The water requirement for the power plant will be approximately 9,500 acre-ft/yr, assuming high wet cooling and a 75 percent load factor (Table 6-18). This requirement is about 2 percent of the average flow and 8 percent of the minimum flow of the White River near Meeker.[2] Intermediate wet cooling could reduce water use by 71 percent.

The effects of energy development-related population growth on area municipal facilities in terms of increased water supply and wastewater treatment demand are shown in Tables 6-20 and 6-21.

Small communities will be significantly affected by large increases in water and wastewater service requirements. Updating treatment facilities to meet expected population demands may cost more per capita in a small municipality than in a large city. Under present law, pollutants from the sewage treatment plant may

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[1]Federal Water Pollution Control Act Amendments of 1972, §§ 101, 301; 33 U.S.C.A. §§ 1251, 1311 (Supp. 1976).

[2]Flow values obtained from Table 6-17; minimum flow values in cfs converted to acre-ft/yr by multiplying by 724.5 acre-ft/yr/cfs.

TABLE 6-21: WASTEWATER TREATMENT CHARACTERISTICS FOR TOWNS AFFECTED BY THE RIFLE SCENARIO[a]

TOWN	TYPE OF TREATMENT	DESIGN LOAD (MMgpd)	PRESENT FLOW (MMgpd)	FUTURE FACILITIES
Rifle	Aerated lagoon system	0.3	.218	Preparing 201[b] plan
Grand Valley	Extended aeration package plant	0.03	overloaded	Preparing 201 plan
Glenwood Springs	Trickling filter plant	1.3	0.5	Completed 201 plan
Grand Junction	Trickling filter plant	7.3	4.23	Completed 201 plan
Meeker	Extended aeration	0.2	0.24	Currently under expansion to 0.4 MMgpd activated sludge + tertiary treatment
Rangely	Aerated lagoon	0.16	0.13	Design phase for expansion to 1.0 MMgpd with aerated lagoons

MMgpd = million gallons per day

[a]Colorado Water Quality Control Commission, personal communication.

[b]Refers to the Federal Water Pollution Control Act Amendments of 1972, § 201, 33 U.S.C.A. § 1281 (Supp. 1976) wherein federal funds are available for the planning, design, and construction of wastewater treatment facilities.

TABLE 6-22: EXPECTED WASTEWATER FLOWS FROM INCREASED POPULATION IN THE RIFLE REGION[a]

LOCATION	GALLONS PER CAPITA PER DAY	1975	INCREASED FLOW ABOVE 1975 LEVEL (increased gallons per day)		
			1980	1990	2000
Rifle	100	0.25	0.04	0.36	0.39
Grand Valley	54	0.02	0.02	0.19	0.20
Glenwood Springs	91	0.42	0.018	0.055	0.082
Rural	100	0.89	0.026	0.12	0.18
Meeker	114	0.25	0.61	0.68	0.73
Rangely	65	0.12	0.33	0.26	0.28
Grand Junction	128	5.8	0.54	1.83	2.64

[a]Based on population estimates given below in Section 6.4.

discharge to surface waters until 1985. If a reliable treatment scheme can be devised, there should be no significant pollution from this practice. Where population growth occurs in rural areas having no centralized treatment facilities, groundwater quality may be decreased by septic tank and drainfield systems, but the substrate has a natural capacity for renovation if septic tank density becomes too great.

Other environmental effects to be expected as a result of population growth include a decrease in surface-water quality stemming from urban runoff. If contaminated runoff recharges aquifers, then groundwater quality may be affected as well. Leachates from additional municipal solid waste disposal sites can also contaminate both groundwater and surface water.

(2) To 1990

The 50,000 bbl/day TOSCO II oil shale plant will begin operations in 1985. Construction of the in situ oil shale facility will begin in 1984, and the plant will go on-line in 1990. The 1,000 MWe power plant will continue operation throughout this period.

By 1990, the mine for the TOSCO II plant will have disturbed 375 acres of land which will result in impoundment of runoff water. The water for the retort, 4,650 acre-ft/yr, will be taken from the Colorado River. This requirement is 0.2 percent of the average flow of the Colorado River above Grand Valley and 2.2 percent of the minimum flow.

Municipal water supply requirements will have to be met through increases in service systems and treatment facilities. The quantities of the increases in water supply and wastewater are shown in Table 6-20 and 6-22.

If municipalities install sewage treatment facilities that meet the goal of zero discharge of pollutants by 1985, the increased municipal effluent will have little effect on groundwater systems. A possible exception is excess leakage from municipal sewer lines that could contaminate shallow aquifers. Population growth in rural areas may also have an impact on aquifers. In areas of high population density where septic tank and drainfield disposal methods are used, the cumulative effect of the septic tanks may exceed the capacity of the soils to renovate the drainfield effluent. The result could be the direct infiltration of effluents into aquifers, thereby lowering groundwater quality. Other sources of contamination for both surface and groundwater are urban runoff and leachate from solid waste disposal sites.

(3) To 2000

The impacts of the in situ oil shale facility, TOSCO II oil shale plant, and the coal mine and power plant will continue as in the preceding decade. Continued operations at the coal mine, *in situ* oil shale mine, and the 50,000 bbl/day oil shale plant are expected to increase the effects on the depletion of bedrock aquifers. Water added to the spent shale during revegetation, as well as natural precipitation, will leach trace elements, dissolved salts, and other contaminants from the shale. This contaminated water may then recharge the lower Green River aquifer, which has low water quality (high TDS) even in natural conditions. As mining activities increase, recharge into Yellow and Piceance Creeks (Figure 6-1) will be further diminished, and water quality will be lowered in the groundwater recharge areas.

Because of Public Law 92-500, which has a goal of zero discharge of pollutants by 1985, the only surface-water effects associated with effluent disposal at the energy facilties will be the result of unplanned occurrences. Ponds used for the ultimate disposal of cooling-tower blowdown, sanitary effluent, and scrubber sludge will continue to fill. The associated water will be evaporated or may leak into the pond liner material, carrying some of the dissolved constituents with it. There will be the continuing possibility that some harmful constituents will reach the groundwater system and cause a degradation of both surface and groundwater supplies. Clay absorption in the pond liner or, where it occurs, in the clay substrate will reduce the TDS content.

Increased urban and rural population growth in the 1990-2000 decade will produce qualitatively similar but quantitatively greater effects as compared with the preceding decade. Municipal facilities will experience progressively increasing demands for water supply and wastewater treatment (see Tables 6-20 and 6-22). Water supplies will continue to be charged against Colorado's share of Upper Basin surface water, whether taken from streams or alluvial aquifers. Wastewater treatment facilities will be changed from discharging to local streams to recycling or land application of effluents. Recycled water may help diminish the water supply demands placed on local sources by hypothesized energy development facilities.

(4) After 2000

After operations cease, the oil shale and coal mines may subside over the long term, resulting in minor changes in topography and drainage patterns as well as changes in groundwater flow patterns in the overburden. In addition, the coal mine may produce acid water. However, insufficient groundwater data preclude the evaluation of this potential problem. The low-sulfur content of the coal may reduce this probability.

After the plants are decommissioned, the facilities will remain. Leakage from effluent disposal ponds may continue to recharge and contaminate groundwater systems long after operations cease unless the sites are properly maintained. Likewise, the dikes around the evaporative ponds may lose their protective vegetation and erode, and the dikes may be breached as a result. Subsequently, materials within the pond site will erode and enter the surface-water system.

As municipal wastewater plants are upgraded, the quality of effluents will improve and the impacts on groundwater will lessen. Further, as rural areas become more densely populated, more of these areas will switch from septic tanks to municipal wastewater treatment systems. The decreased septic tank load will alleviate the associated groundwater degradation problem. However, those areas remaining on septic tanks will pose a continued hazard to local groundwater systems.

6.3.5 Summary of Water Impacts

Water impacts are caused by: (1) the water requirements of and effluents from the energy facilities, (2) the water requirements of and wastewater generated by associated population increases, and (3) the coal and oil shale mining processes.

Water sources postulated for the Rifle scenario facilities are the White River near Meeker, the Colorado River near Grand Valley, and groundwater from mine dewatering. Depending on whether the energy facilities are high wet cooled, the water requirement in acre-ft/yr ranges from 2,786 to 9,494 for the power plant, 6,470 to 9,270 for the 50,000 bbl/day oil shale plant, and 4,360 to 5,660 acre-ft/yr for the *in situ* oil shale facility. Operation of all the facilities could require as much as 24,000 acre-ft/yr. The use of intermediate wet cooling at the expected load factors could reduce this demand by a total of 54 percent. Little water is saved by intermediate cooling of oil shale processes (29 percent), but savings are substantial (71 percent) when intermediate wet cooling is used on the power plant. The White River near Meeker, the hypothesized source of water for the power plant, has an average flow of 450,000 acre-ft/yr and a minimum flow of 173 cfs.[1] The Colorado River above Grand Valley, the hypothesized source of water for the 50,000 bbl/day oil shale plant, has an average flow of 1,955,000 acre-ft/yr and minimum flow of 286 cfs.[2] The impact of surface water withdrawal on water availability is not a major local issue, especially for the Colorado River. One of the most significant impacts will be the interception of groundwater flow in the Piceance Creek Basin by the *in situ* oil shale facility.

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[1]For perspective and comparison with the water requirements of energy facilities, 173 cfs is equivalent to 125,000 acre-ft/yr.

[2]Two-hundred and eight-six cfs is equivalent to 207,000 acre-ft/yr.

Effluents from the energy facilities, in tons per day, average 641 from the power plant, and 49,300 from the 50,000 bbl/day oil shale plant. Effluents from the oil shale retorts are primarily spent shale. Over the long term, spent shale deposits are likely to have an impact on both groundwater and surface water. The hydrology of the upper parts of the affected stream basins will be changed by filling gullies with spent shale. After revegetation, natural precipitation will continue to leach trace elements. Some of this leachate may recharge bedrock aquifers, and some will surface at the toe of the piles and enter surface-water systems. Runoff from spent shale piles will be trapped and cycled for process water, but only for the life of the plants. Waste disposal ponds at the various energy conversion plant sites will also pose a long-term pollution potential to both groundwater and surface water systems. The berms that impound the ponds may ultimately be destroyed by erosion, and the pond contents (soluble solids, ash, toxic metals, and other wastes) may be released to surface water. The pond liners are designed to be effective for the life of the plant, but they may not prevent escape of the pond contents over the long term. Leaching of pond contents would result in infiltration into the subsurface and recharge to local aquifers. If the vertical permeability is low, the leachate will migrate laterally, discharge into stream basins, and ultimately contaminate surface streams.

Municipal water use in the scenario area will increase to 17,900 acre-ft/yr by the year 2000, due to increased population associated with energy development. The additional water for municipal use will probably be withdrawn from the Colorado River. Increased population will also cause wastewater increases, totaling 4.51 million gallons per day by 2000. Scenario municipalities listed in Table 6-23, other than Glenwood Springs and Grand Junction, will require new wastewater treatment facilities for the increased wastewater generated.

The coal mine for the power plant will use surface-water sources and should not result in the depletion of any regional groundwater aquifers. However, the openings of the coal and oil shale mines and associated dewatering operations may cause aquifer depletion. Interception of the Parachute Creek and the Piceance Creek aquifers by the mine for the oil shale plant may result in the elimination of their base flows. Coal mine subsidence may occur and lead to such effects as topographic and drainage pattern changes, disruption of groundwater flow in the overburden, and possibly mixing of fresh and saline aquifers.

Finally, runoff will decrease during facility construction, and will remain measurably less than current levels after the facilities are completed due to trapping of this runoff to guard against water quality deterioration.

6.4 SOCIAL AND ECONOMIC IMPACTS

6.4.1 Introduction

The social and economic effects resulting from energy developments in the Rifle scenario will occur primarily in Garfield and Rio Blanco Counties and the city of Grand Junction. At present, the area population is concentrated in the eastern portion of the counties; the hypothetical energy developments will be located in the western portion of the counties. Most of the anticipated social and economic impacts will result either directly or indirectly from the population increase that will come with energy development. This section describes and analyzes existing conditions in the area and the changes likely to accompany energy development.

6.4.2 Existing Conditions[1]

Garfield and Rio Blanco Counties occupy 6,254 square miles and had a combined 1974 population of 21,700, giving the region a population density of 3.5 people per square mile. Colorado's overall density is 21.2 people per square mile. The population of the area increased in the 1960-70 decade, but not on a comparable level with the state (8.2 percent increase for the two counties as compared with 25.8 percent for the state). Speculation and anticipation concerning oil shale production in the area has been a major cause for this population growth. Further, Rio Blanco County's population declined by 6 percent during the decade, primarily due to net outmigration. About one-half of the residents in the two counties live in unincorporated areas. Populations and population changes for the area counties and towns are shown in Table 6-23.

Employment by industry in the two counties is shown in Table 6-24. Tourist-related employment is centered in Glenwood Springs, which is on the route to Aspen and Vail.

Garfield and Rio Blanco Counties are each governed by a board of county commissioners. Both counties have planning departments and countywide zoning regulations (see Table 6-25). Both also belong to a council of governments made up of elected officials from these counties and Moffat and Mesa Counties. This council of governments has focused much of its attention on oil shale development within the area. According to a survey of residents and officials,

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[1]For a detailed history and current description of the scenario area, see Ashland Oil, Inc.; Shell Oil Co., Operator. Oil Shale Tract C-b: Socio-economic Assessment, prepared in conjunction with the activities related to lease C-20341 issued under the Federal Prototype Oil Shale Leasing Program. n.p.: March 1976, Vol. I.

TABLE 6-23: POPULATIONS OF COUNTIES AND TOWNS IN THE RIFLE VICINITY

LOCATION	1974	1970	1960
Rio Blanco County	5,200	4,842	5,150
Meeker	2,000	1,579	1,655
Rangely	1,725	1,591	1,464
Garfield County	16,500	14,821	13,017
Glenwood Springs	4,646	4,106	3,637
Rifle	2,403	2,150	2,135
Carbondale	1,600	726	612
New Castle	618	499	447
Silt	720	434	384
Grand Valley	360	350	245
Mesa County	57,200	54,374	50,715
Grand Junction	26,400	20,170	18,900

Sources: U.S., Department of Commerce, Bureau of the Census. "Estimates of the Population of Colorado Counties and Metropolitan Areas: July 1, 1973 and July 1, 1974." Current Population Reports, Series P-26, No. 103 (April 1975); Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

TABLE 6-24: EMPLOYMENT DISTRIBUTION BY INDUSTRY, GARFIELD AND RIO BLANCO, 1970

INDUSTRY	GARFIELD	RIO BLANCO	TWO-COUNTY AREA (%)
Agriculture	558	306	11.0
Mining	395	208	8.6
Construction	678	152	10.6
Manufacturing	166[a]	42[b]	2.7
Transportation and Communication	214	32	3.1
Utilities	186	62	3.2
Wholesale Trade	153	53	2.6
Retail Trade	1,242	241	18.9
Finance, Insurance, and Real Estate	265	56	4.1
Services	1,236	603[c]	23.4
Government and Education	564	153	9.1
Not Reported	208	0	2.7
Total	5,865	1,980	100

Sources: U.S., Department of Commerce, Bureau of Economic Affairs and U.S., Department of the Interior, Bureau of Land Management.

[a]Mostly food processing.

[b]Mostly petroleum refining.

[c]Mostly professional services.

TABLE 6-25: LAND-USE REGULATIONS, GARFIELD AND RIO BLANCO COUNTIES AND LOCAL MUNICIPALITIES, 1975

LOCATION	PLANNING COMMISSION	ZONING ORDINANCE	MOBILE HOME REGULATIONS	SUBDIVISION REGULATIONS	BUILDING CODE
Garfield County	Y	Y	Y	Y	Y
Carbondale	Y	Y	N	Y	Y
Glenwood Springs	Y	Y	Y	Y	Y
Grand Valley	Imminent	N	N	N	N
New Castle	Y	Y	N	N	Y
Rifle	Y	Y	Y	Y	Y
Silt	Imminent	Y	N	N	Y
Rio Blanco County	Y	Y	Y	Y	Y (UBC)[a]
Meeker	Y	Y	Y	Y	County
Rangely	Y	Y	Y	Y	County

Y = county or community does have the commission or regulation
N = absence of commission or regulation

Source: THK Associates, Inc. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974; and Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

[a]Uniform Building Code

stringent land-use controls are favored in Garfield County and opposed in Rio Blanco County.[1]

Carbondale, Glenwood Springs, New Castle, Silt, Rifle, and Grand Valley are the incorporated cities in Garfield County. Carbondale, Grand Valley, and Rifle are governed by a mayor and council. All three also have a professional city manager, but only Carbondale has a professional planner. (Carbondale has recently grown because of energy development in nearby Pitkin County.) Public services include water, sewers, public safety, and fire protection.[2] Apparently, current services are operating at or near capacity; however, expansion is either under way or being discussed in all three cities.

Meeker and Rangely are incorporated cities in Rio Blanco County. Both are governed by a mayor and council. Meeker has a city manager and Rangely has a town administrator, but neither has a professional planner. Public services in Meeker include water, sewers (provided by a separate district), a volunteer fire department, and public safety. Rangely provides the same services except that it is just beginning to develop its sewer system.

Education for the counties and municipalities is provided by separate school districts. Other special districts provide for sanitation, fire protection, and hospital.

6.4.3 Factors Producing Impacts

Two factors associated with energy facilities dominate as the causes of social and economic impacts: manpower requirements and taxes levied on energy facilities. Tax rates are tied to capital costs, and/or the value of coal extracted, and/or the value of energy produced. Taxes which apply to the Rifle scenario facilities are a property tax, sales tax, severance tax, royalty payments for federally owned coal, and oil shale bonus bids.

The manpower requirements for each scenario facility are given in Tables 6-26 to 6-28. For the oil shale mines, the manpower requirement for operation exceeds the peak construction requirement by two times and, for the coal mine, by eight times. However, the reverse is true for the conversion facilities; peak construction manpower requirements exceed the operation requirement by six times for the power plant and four times for the TOSCO II plant *in situ*

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[1]VTN Colorado, Inc. Socioeconomic and Environmental Land-Use Survey: Moffat, Routt, and Rio Blanco Counties, Colorado, Summary Report. Denver, Colo.: VTN Colorado, 1975, p. 160.

[2]Sewer service in Carbondale and fire protection in Grand Valley are provided by separate districts. Rifle is now forming a separate fire protection district.

TABLE 6-26: MANPOWER REQUIREMENTS FOR A 1,000 MEGAWATT POWER PLANT AND ASSOCIATED MINE[a]

YEAR FROM START	CONSTRUCTION WORK FORCE		OPERATION WORK FORCE		TOTAL IN ANY ONE YEAR
	MINE	POWER PLANT	MINE	POWER PLANT	
1	0	0			0
2	31	126			157
3	71	394	0		465
4	101	619	150	0	870
5	163	763	300	33	1,259
6	115	597	600	65	1,377
7	21	216	1,200	121	1,568
8	0	0	1,200	131	1,331

[a]Data are for a 1,000 megawatt-electric power plant and an underground coal mine large enough to supply that power plant (about 3.4 million tons per year) and are from Carasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975; data uncertainty is -10 to +20 percent.

TABLE 6-27: MANPOWER REQUIREMENTS FOR A 50,000 BARREL PER DAY TOSCO II PLANT AND ASSOCIATED MINE[a]

YEAR FROM START	CONSTRUCTION WORK FORCE		OPERATION WORK FORCE		TOTAL IN ANY ONE YEAR
	MINE	TOSCO II PLANT	MINE	TOSCO II PLANT	
1		0			0
2		43			43
3	0	311			311
4	115	824			939
5	313	1,342			1,655
6	356	1,322			1,678
7	157	778	0	0	935
8	0	0	591	327	918
9			591	327	918

[a]Data are for a 50,000 barrel per day TOSCO II oil shale plant and an underground oil shale mine large enough to supply that plant (about 26 million tons per year) and are from Carasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975; data uncertainty is -10 to +20 percent.

TABLE 6-28: MANPOWER REQUIREMENTS FOR A 57,000 BARREL PER DAY IN SITU OIL SHALE PLANT AND ASSOCIATED MINE

YEAR FROM START	CONSTRUCTION WORK FORCE		OPERATION WORK FORCE		TOTAL IN ANY ONE YEAR
	MINE	IN SITU PLANT	MINE	IN SITU PLANT	
1		250			250
2		400			400
3	140	960		50	1,150
4	260	1,040		50	1,350
5	550	1,950	270	130	2,900
6	200	1,000	530	270	2,000
7			1,090	510	1,600
8			1,090	510	1,600
9			1,090	510	1,600

[a]Calculated from data on maximum manpower needs given in Ashland Oil, Inc. and Occidental Oil Shale, Inc. Supplemental Material to Modifications to Detailed Development Plans for Oil Shale Tract C-b, prepared for Area Oil Shale Supervisor, July 21, 1977.

oil shale facilities. In combination, the total manpower requirement for each oil shale mine-conversion facility combination increases from the first year when construction begins, peaks, and then declines as construction activity ceases. There is almost no peak for the coal mine-power plant combination. Peak total manpower is about 1,570 for the power plant, 1,680 for the 50,000 bbl/day TOSCO II plant, and 2,900 for the 57,000 bbl/day Occidental modified in situ plant. For the oil shale facilities, total labor required for operation is about half that required during peak construction. The 50,000 bbl/day oil shale plant and mine require the least labor, 920, for operation and the 57,000 bbl/day plant and mine require the most, 1,600.

The property tax and sales tax, which are tied to capital costs of the conversion facilities, and royalty payments and the severance tax which are tied to the value of the coal, and oil shale bonus bids, generate revenue for the local and state government. The capital costs of the conversion facilities and mines hypothesized for the Rifle scenario are given in Table 6-29. Costs range from about 515 (mine-power plant facility) to 556 million 1975 dollars (50,000 bbl/day oil shale plant and mine). The property tax, most of which goes to local government, is levied on the cash value of the facility (approximately the total capital cost given in Table 6-29) after construction of the facility is

TABLE 6-29: CAPITAL RESOURCES REQUIRED FOR CONSTRUCTION OF FACILITIES (in millions of 1975 dollars)[a]

FACILITIES	MATERIALS AND EQUIPMENT	LABOR AND MISCELLANEOUS	INTEREST DURING CONSTRUCTION[b]	TOTAL
Power Plant, 1,000 MWe	154	154	131	439
Associated underground coal mine 3.4 MMtpy	35	21	20	76
In Situ Oil Shale, 57,000 bbl/day[c]	315	127	111	553
TOSCO II Oil Shale, 50,000 bbl/day[c]	217	191	148	556

MWe = megawatt-electric
MMtpy = million tons per year
bbl/day = barrels per day

[a]Data are adjusted (assuming linearity) to correspond to the facility size hypothesized in the scenario and are from Carasso, M., et al. *The Energy Supply Planning Model*, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975; and Ashland Oil, Inc., and Occidental Oil Shale, Inc. *Oil Shale Tract C-b Modifications to Detailed Development Plan*. Ashland, Ky.: Ashland Oil, Inc., 1977.

[b]At ten percent per year.

[c]Cost includes those for the mine and retort.

completed. The sales tax, most of which goes to the state government, is levied on materials and equipment only (Table 6-29) as these materials and equipment are purchased during construction. The current sales tax rate in Colorado is 3.5 percent and the property tax rate in Rio Blanco and Garfield Counties is about 1.37 percent.[1] In Colorado, there is also a 5 percent severance

[1]This is the effective, average property tax rate. The actual rate is computed using a number of assessment ratios, since certain kinds of equipment (e.g., pollution control equipment) are taxed at different rates or may be exempt.

tax, most of which goes to the state government, levied on the value of the coal that is mined. Royalty payments for federally owned coal are about 12.5 percent of the coal value,[1] of which 50 percent is returned to local and state government. A royalty rate of $1.12 per ton[2] is collected on oil shale and bonus bids may be as high as $48 million for a mine supplying a 57,000 bbl/day facility. Half of the royalty and bonus bid payments are designated to go to the state.

6.4.4 Impacts

The nature and extent of the social and economic impacts caused by these factors depend on the size and character of the community or communities in which workers and their families live, on the state and local tax structure, and on many other social and economic factors. A scenario, which calls for the development of a power plant and two oil shale plants according to a specified time schedule (see Table 6-1), is used here as a vehicle through which the nature and extent of the impacts are explored. The discussion relates each impact type to the hypothetical scenario and includes population impacts, housing and school impacts, economic impacts, fiscal impacts, social and cultural impacts, and political and governmental impacts.

A. Population Impacts

The first major energy-related impact on western Colorado will be from construction workers associated with the coal mine and power plant complex, followed in 1978 by oil well drilling personnel. All construction in this scenario will be completed before 1990. Population changes were estimated by means of an economic base model, the employment data from the Bechtel Corporation[3] in Table 6-30, and a set of multipliers for construction and for operation phases. Construction-phase multipliers increase from 0.3 in 1975 to 0.7 in 1982 and remain constant thereafter; operation-phase multipliers begin at 0.4 in 1977 and rise to 1.2 by 1986.[4] Low multiplier effects are the rule rather than the

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[1]This is the federal government's target rate; actual rates will vary from mine to mine.

[2]For 30 gallons per ton oil shale, 1974 dollars.

[3]Carasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975.

[4]These values were adapted from Crawford, A.B., H.H. Fullerton, and W.C. Lewis. Socio-Economic Impact Study at Oil Shale Development in the Uintah Basin, for White River Shale Project. Providence, Utah: Western Environmental Associates, 1975, pp. 156-58.

TABLE 6-30: CONSTRUCTION AND OPERATION EMPLOYMENT FOR RIFLE ENERGY DEVELOPMENT SCENARIO, 1975-2000

YEAR	CONSTRUCTION	OPERATION	TOTAL
1975	157		157
1976	465		465
1877	720	150	870
1978	1,360	330	1,690
1979	2,930	665	3,595
1980	4,465	1,330	5,795
1981	4,860	1,740	6,600
1982	5,570	2,150	7,720
1983	5,160	2,560	7,720
1984	3,015	2,970	5,985
1985	940	4,300	5,240
1986	2,350	4,350	6,700
1987	2,730	4,350	7,080
1988	2,500	4,700	7,200
1989	1,200	5,100	6,300
1990	0	5,900	5,900
1990-2000	0	5,900	5,900

Source: Carasso, M., et al. The Energy Supply Planning Model. 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975; and Ashland Oil, Inc., and Occidental Oil Shale, Inc. Oil Shale Tract C-b Modifications to Detailed Development Plan. Ashland, Ky.: Ashland Oil, Inc., 1977.

exception in rural areas.[1] Further, the overall population estimates were distributed spatially among the urban centers in and around Garfield County (Table 6-31 and Figures 6-6 and 6-7). The Grand Valley vicinity at the mouth of Parachute Creek is expected to receive a large amount of the increase in population. A new

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[1]See Summers, Gene F., et al. Industrial Invasion of Nonmetropolitan America. New York, N.Y.: Praeger, 1976, pp. 54-59. Population employee multipliers used were 2.05 for construction workers, 2.50 for operation workers, and 2.0 for service workers (all of which take into account two-worker households). They were adapted from Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976.

TABLE 6-31: POPULATION ESTIMATES FOR GARFIELD AND RIO BLANCO COUNTIES AND GRAND JUNCTION, 1975-2000[a]

LOCATION	1975	1980	1985	1990	1995	2000
Rio Blanco						
Meeker	2,200	7,000	6,950	7,500	7,700	7,900
Rangely	1,800	6,850	5,600	5,800	5,950	6,100
Rural	1,200	2,050	2,050	2,250	2,300	2,350
Total	5,200	15,900	14,600	15,500	15,950	16,350
Garfield						
Rifle	2,500	2,950	5,000	6,500	6,700	6,800
Grand Valley	360	700	2,470	4,200	4,300	4,400
Glenwood Springs	4,650	4,850	5,050	5,250	5,400	5,550
Rural	8,990	9,750	10,680	10,300	10,500	10,750
Total	16,500	18,250	23,200	26,250	26,900	27,500
Grand Junction Area	45,000	49,200	54,200	59,500	62,700	65,800

[a]Estimates incorporate an annual natural increase of 0.8 percent through 1990, and 0.5 percent thereafter, except in Grand Junction where the rates used were 1.5 percent and 1.0 percent to include urban agglomeration effects. In general, given the conditions assumed in this scenario, the estimates should have a maximum error range of ±25 percent. This range carries through the subsequent analyses based on population estimates.

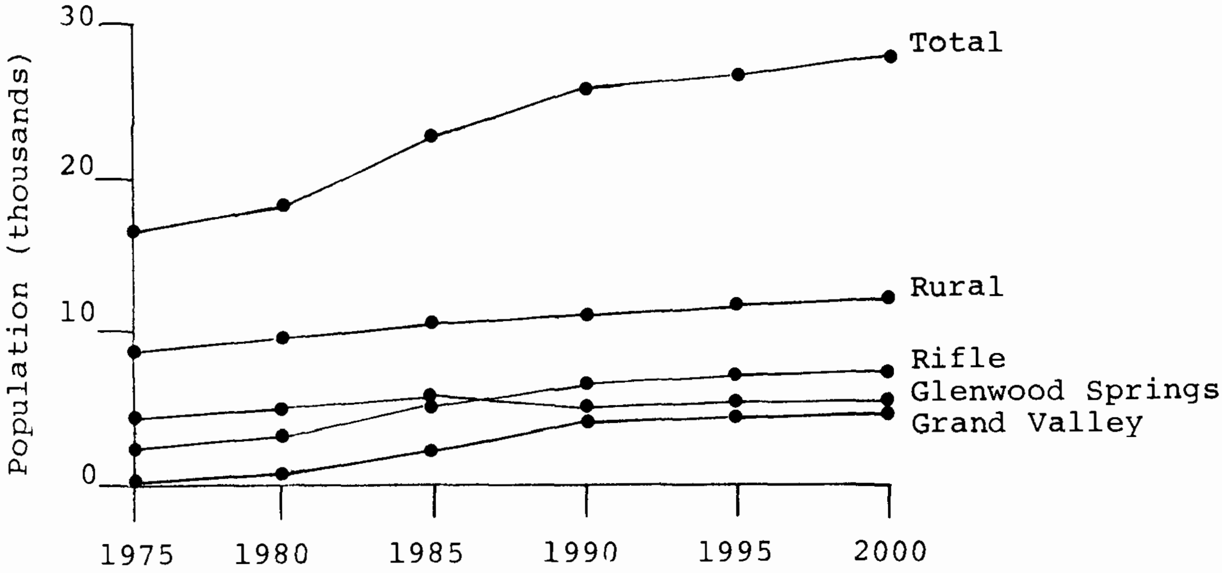

FIGURE 6-6: POPULATION ESTIMATES FOR GARFIELD COUNTY, 1980-2000

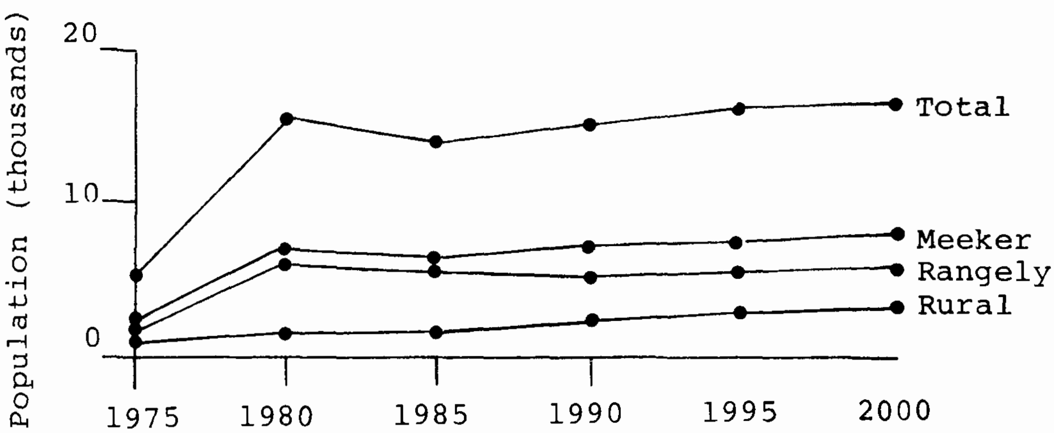

FIGURE 6-7: POPULATION ESTIMATES FOR RIO BLANCO COUNTY, 1980-2000

town development discussed in some reports is not anticipated in this scenario.[1]

The population of Garfield County is expected to increase more than 65 percent to almost 28,000 people by 2000. Rifle should grow three-fold to 6,800, becoming larger than Glenwood Springs by 1990. Grand Valley is expected to increase from 360 to 4,400, a twelve-fold increase. Rio Blanco County is expected to grow 200 percent by 1990, with much of the growth taking place in Rangely and Meeker (Figure 6-6). Meeker is projected to increase to 7,900 people by 2000. For the two-county area, the 22,150 population increase from 1975 to 2000 represents a doubling of the population.[2]

In general, the population increase in the scenario is expected to take place primarily in and near the established towns. Outside the two-county area, service employment will increase in Grand Junction, the major service center in western Colorado. A 46 percent population increase is expected in the Grand Junction area as a result of the energy development hypothesized in this scenario (Table 6-31).

Age-sex breakdowns of the projected populations in Garfield and Rio Blanco Counties help in predicting changes in the housing and educational needs of the area. The new employment was assumed to be distributed by age as found in recent surveys in the West.[3]

The resulting age-sex distribution in Table 6-32 shows an increase in the 25-34 age group and, through 1990, the 0-5 age group. The 35-54 age group increases after 1990. In addition, the relative proportion of males to females is high during the 1980-1995 period because of single males associated with energy development.

B. Housing and School Impacts

Housing demand and school enrollment can be estimated by employing the information in Tables 6-31 and 6-32, and assuming that children in the 6-13 age group are in elementary school, and those in the 14-16 age group are in secondary school (see Table 6-33 and

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[1]See the uncontrolled urban development pattern in THK Associates. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, pp. 74-75.

[2]For a scenario which projects greater population growth, see Ibid., pp. 75-77.

[3]Data adapted from Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 38.

TABLE 6-32: PROJECTED AGE-SEX DISTRIBUTION FOR GARFIELD AND RIO BLANCO COUNTIES, 1975-2000[a]

AGE	1975	1980	1985	1990	1995	2000
Female						
65-over	.055	.031	.028	.024	.024	.028
55-64	.051	.032	.029	.026	.032	.041
35-54	.113	.091	.085	.082	.104	.116
25-34	.059	.097	.096	.107	.087	.093
20-24	.033	.037	.036	.038	.049	.053
17-19	.030	.027	.033	.033	.033	.036
14-16	.031	.024	.028	.027	.030	.031
6-13	.078	.067	.080	.077	.077	.067
0- 5	.046	.052	.057	.060	.046	.025
Total	.496	.458	.472	.474	.482	.490
Male						
65-over	.050	.029	.026	.022	.024	.028
55-64	.049	.038	.031	.027	.033	.044
35-54	.116	.117	.100	.098	.120	.120
25-34	.058	.123	.123	.134	.101	.101
20-24	.031	.052	.044	.044	.051	.054
17-19	.032	.033	.035	.035	.034	.036
14-16	.034	.026	.029	.028	.030	.031
6-13	.084	.070	.082	.079	.078	.067
0- 5	.047	.053	.058	.060	.046	.025
Total	.501	.541	.528	.527	.517	.506

Source: Table 6-31 and data from Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 38.

[a]Totals do not always sum to 1.0 because of rounding.

TABLE 6-33: ESTIMATED NUMBER OF HOUSEHOLDS AND SCHOOL ENROLLEMNT IN GARFIELD AND RIO BLANCO COUNTIES, 1975-2000[a]

YEAR	NUMBER OF HOUSEHOLDS	NUMBER OF ELEMENTARY SCHOOL CHILDREN[b]	NUMBER OF SECONDARY SCHOOL CHILDREN[c]
1975	6,600	3,500	1,410
1980	12,300	4,630	1,690
1985	11,900	5,960	2,100
1990	13,300	6,370	2,200
1995	13,800	6,490	2,500
2000	14,900	5,740	2,700

Source: Tables 6-31 and 6-32.

[a]Debeque and Roaring Fork school districts were excluded from calculations.

[b]Ages 6-13.

[c]Ages 14-16. These age group assumptions result in a possible underestimate of at most 25 percent (current enrollment is just over 6,700), but relative sizes are indicative of impacts.

Figure 6-8). Based on these projections, expected housing demand nearly doubles almost immediately, indicating that about 5,700 new units will be needed in the Garfield-Rio Blanco County area by 1980. Growth in demand is somewhat slower thereafter, but 2,600 additional new homes will be needed between 1980 and 2000.

The distribution of housing estimated in Table 6-33 largely reflects temporary construction worker households living in mobile homes through 1990, particularly between 1975 and 1980. Even more families are likely to live in mobile homes if local housing construction cannot keep up.[1] Given existing infrastructure, the

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[1]Housing construction in western Colorado is not keeping up with demand. See Bolt, Ross M., Dan Luna, and Lynda A. Watkins. <u>Boom Town Financing Study</u>, 2 vols. Denver, Colo.: Colorado Department of Local Affairs, 1976.

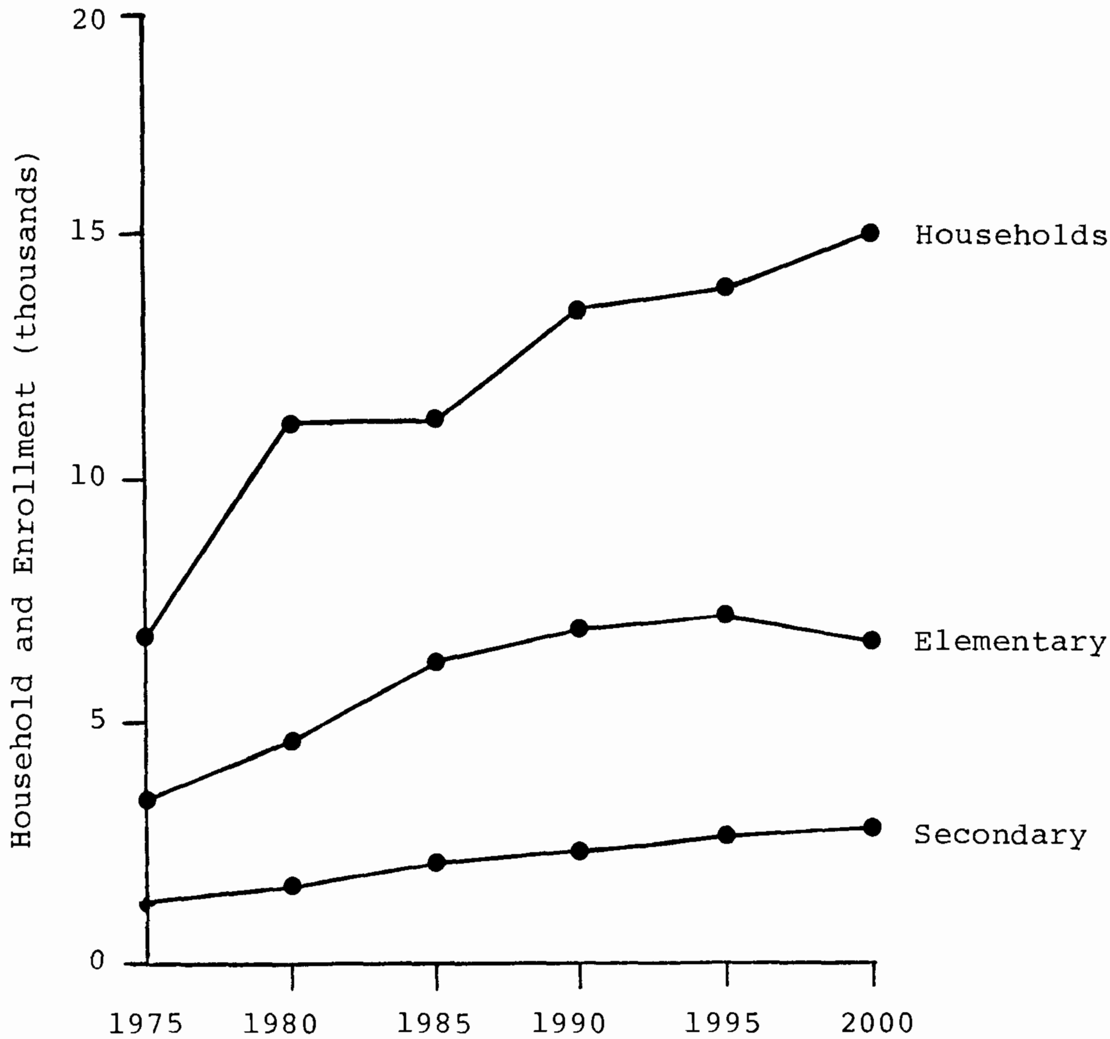

FIGURE 6-8: ESTIMATED NUMBER OF HOUSEHOLDS AND SCHOOL ENROLLMENT IN GARFIELD AND RIO BLANCO COUNTIES, 1980-2000

majority of mobile homes will be concentrated in the Grand Valley area, where 63 of the present 87 dwellings are mobile homes. Rifle, where mobile homes currently account for less than 10 percent of available housing, is expected to maintain a relatively low percentage if the local building industry attempts to meet demands there.[1]

School enrollment impacts will vary between elementary and high school over time. Elementary enrollment is expected to peak at 6,500 in 1995 (85 percent more than the 1975 level). The 380 classrooms suggests that some excess capacity is available[2] (Table 6-34). A 29 percent rise in enrollment between 1975 and 1980 can be absorbed on an overall classroom basis, but impacts will be greater at some locations than at others. For example, nearly one-half of all new enrollment by 1980 is expected in Rangely, which in 1974 had an average of just over six students in each of its 67 classrooms. To maintain an average of 21 pupils per classroom, 10 new classrooms will be needed by 1980, 60 percent of them in elementary schools. However, by 1985, Rangely will not need any of the 25 additional classrooms. In the other districts, enrollment and classroom needs increase steadily, creating a $7 million increase in operating expenditures by 2000. Teachers, bus drivers, maintenance, and supplies, as well as the purchase of new school buses, will be in addition to the construction costs. The estimates in Table 6-34 suggest that the additional enrollment during the 1980's and early 1990's may well be accommodated by split sessions or temporary facilities, keeping capital expenditures for permanent facilities to a minimum. However, this may be difficult in Rangely, where the peak enrollment in 1980 will be 23 percent above the 2000 peak.

C. Economic Impacts

Agriculture now dominates the economy of Rio Blanco County (35 percent of all 1972 earnings).[3] However, as energy development proceeds, the economy will shift to mining and extraction. In Garfield County, the mixed tourism-related local economy will shift to mining and service and local government employment

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[1]Data on December, 1974 housing are taken from Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

[2]Ibid.

[3]U.S., Department of Commerce, Bureau of Economic Analysis. "Local Area Personal Income." Survey of Current Business, Vol. 54 (May 1974, Part II), pp. 1-75.

TABLE 6-34: SCHOOL DISTRICT FINANCE PROSPECTS, GARFIELD AND RIO BLANCO COUNTY DISTRICTS, 1975-2000 (in 1975 dollars)

LOCATION	YEAR[a]	ENROLLMENT		CLASSROOMS NEEDED AT 21 PER ROOM		CAPITAL EXPENDITURE[b] (millions of dollars)		OPERATIONAL EXPENDITURES (millions of dollars)	
		New	Total	New	Total	New	Total	New	Total
Rifle	1975	-	1580	-	75				2.07
	1980	155	1735	7	82	.37	.40	.30	2.40
	1985	550	2285	26	108	1.37	1.80	1.10	3.50
	1990	280	2565	13	121	.68	2.50	.56	4.10
	1995	115	1680	6	127	.32	2.80	.23	4.30
	2000	45	2725	2	129	.11	2.90	.10	4.40
Grand Valley	1975	-	190	-	20			-	.44
	1980	75	265	0	20[c]	0	0[c]	.15	.60
	1985	400	665	12	32	.63	.63	.80	1.40
	1990	360	1025	17	49	.90	1.5	.72	2.10
	1995	30	1055	2	51	.11	1.6	.06	2.15
	2000	25	1080	1	52	.05	1.6	.05	2.20
Meeker	1975	-	700	-	44			-	1.05
	1980	975	1675	36	80	1.89	1.90	1.95	3.00
	1985	-10	1665	-	80	0	0	-.02	3.00
	1990	150	1815	7	87	.37	2.30	.30	3.30
	1995	50	1865	3	90	.16	2.45	.10	3.40
	2000	45	1910	3	93	.16	2.60	.09	3.50
Rangely	1975	-	600	-	67			-	1.10
	1980	1025	1625	10	77[c]	.53	.53[c]	2.05	2.15
	1985	-430	1195	-	-	0	0	-.86	1.30
	1990	50	1245	-	-	0	0	.10	1.40
	1995	40	1290	-	-	0	0	.08	1.50
	2000	35	1325	-	-	0	0	.07	1.55

[a]Current data are from U.S., Federal Energy Administration, Region VIII, Socioeconomic Program Data Collection Office. Regional Profile: Energy Impacted Communities. Lakewood, Colo.: Federal Energy Administration, 1977.

[b]An average of $2,500 per pupil space was obtained from Froomkin, Joseph, J.R. Endriss, and R.W. Stump. Population, Enrollment and Costs of Elementary and Secondary Education 1975-76 and 1980-81, Report to the President's Commission on School Finance. Washington, D.C.: Government Printing Office, 1971, by inflating to 1975 dollars.

[c]Excess capacity of class rooms in 1975 will be filled before others are needed.

related to population growth. Major economic benefits will result from employment and income in the energy industries and from tax revenues of various types (Table 6-35, Figures 6-9 and 6-10). The scenario development should result in a 13 percent higher median household income, while during construction the median is 28 percent above the 1975 level[1] (see Figure 6-9). The principal change in the overall income distribution is an increase in the relative number of households earning $15,000 to $25,000 (Figure 6-10).

The general increase in business activity should be roughly proportional to the population gains in each locality. The temporary benefits from construction workers and their somewhat higher incomes will accrue primarily to the nearby towns of Rifle, Meeker, Rangely, and Grand Valley. Some commercial growth should occur in Grand Junction as a result of the Rifle-Meeker area development, but other development in western Colorado is likely to be a bigger source of growth in that city.

Local governments will receive tax benefits, although municipal services will experience shortfalls early in the period. School districts will have little difficulty after the early rush of new residents, partly because their taxing areas include the energy facilities with their relatively large valuations. Based on an enrollment increase of 4,000 students in all districts within two counties by 1995, nearly $10 million in new school construction will be required in the area. Property tax receipts should keep up with this need. In municipalities, where energy facilities do not add directly to tax revenues, meeting needs for public facilities may be more difficult.

Water and sewage treatment facilities are among the primary problems faced by any small community experiencing a significant population influx. In terms of capital expenditures, these two items will account for 75 percent of all nonschool expenditures needed to serve additional population in the scenario area.[2] Within the area, excess capacity exists only in Grand Junction's

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[1]These income impacts will be in addition to national trends in income growth from productivity gains and other causes.

[2]THK Associates. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, p. 30; see also Lindauer, R.L. Solutions to Economic Impacts on Boomtowns Caused by Large Energy Development. Denver, Colo.: Exxon Co., USA, 1975. pp. 43-44.

TABLE 6-35: PROJECTED INCOME DISTRIBUTION FOR GARFIELD AND RIO BLANCO COUNTIES, 1975-2000

	ANNUAL INCOME (1975 dollars)								
YEAR	LESS THAN 4,000	4,000 TO 6,000	6,000 TO 8,000	8,000 TO 10,000	10,000 TO 12,000	12,000 TO 15,000	15,000 TO 25,000	25,000 AND OVER	**MEDIAN HOUSEHOLD INCOME**
1975	.139	.078	.083	.089	.093	.119	.285	.114	12,450
1980	.090	.055	.055	.072	.074	.119	.388	.128	15,900
1985	.105	.066	.066	.091	.089	.131	.365	.096	13,900
1990	.100	.065	.063	.091	.094	.132	.372	.091	13,980
1995	.098	.065	.061	.089	.096	.132	.375	.092	14,070
2000	.098	.065	.061	.089	.096	.132	.375	.092	14,070

Source: Data for 1975 are taken from U.S., Department of Commerce, Bureau of the Census. Household Income in 1969 for States, SMSA's, Cities and Counties: 1970. Washington, D.C.: Government Printing Office, 1973, p. 22, and inflated to 1975 dollars. Income distribution for construction workers, operation workers, and service workers are from Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 50, assuming that new service workers households have the same income distribution as long time residents and the "other newcomers" are operation employees.

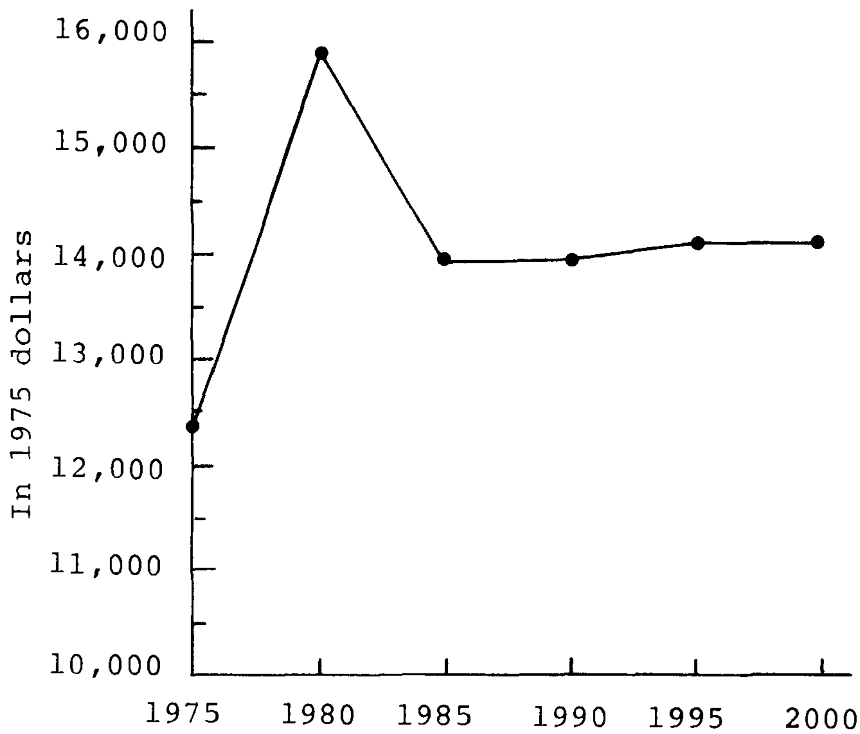

FIGURE 6-9: MEDIAN FAMILY INCOME, GARFIELD AND RIO BLANCO COUNTIES, 1970-2000

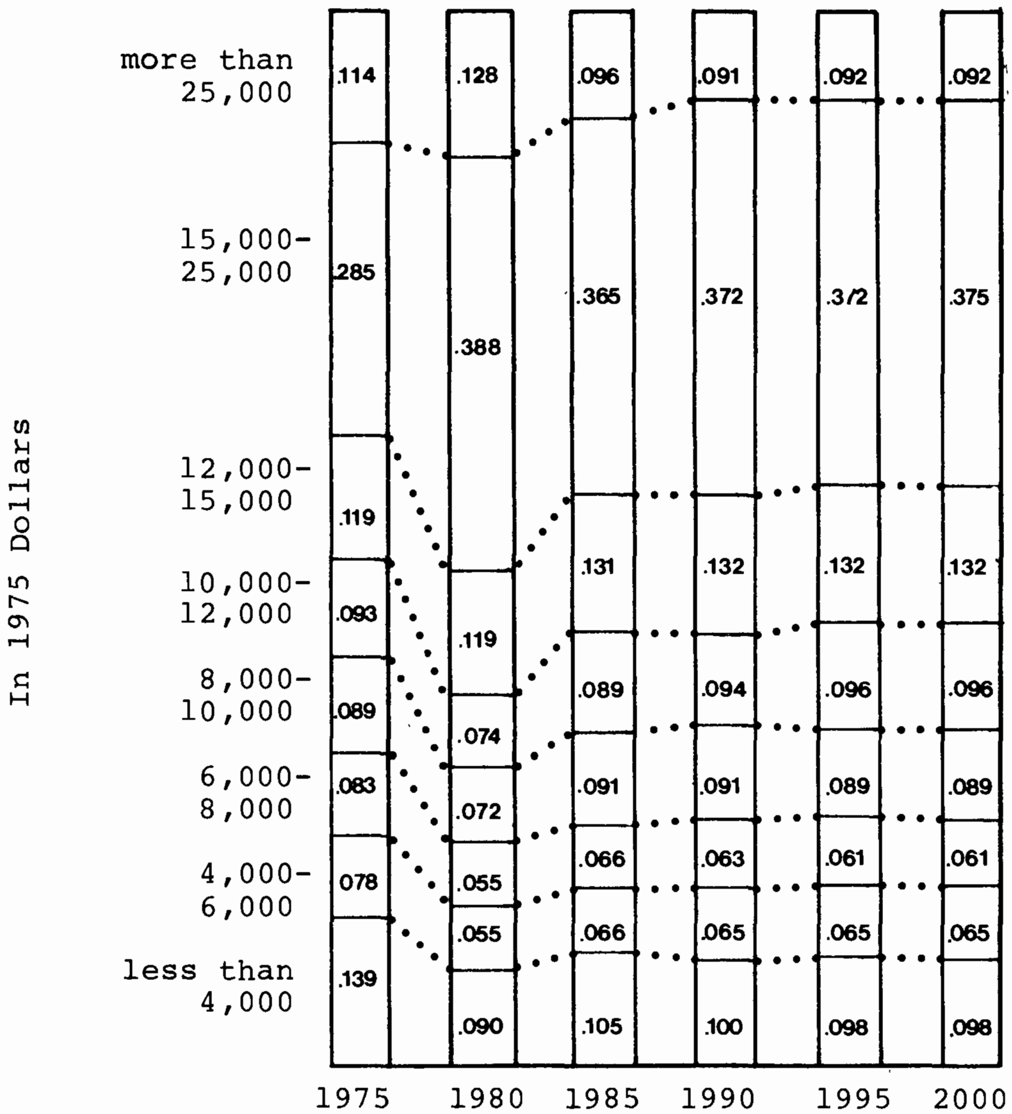

FIGURE 6-10: PROJECTED ANNUAL INCOME DISTRIBUTION FOR GARFIELD AND RIO BLANCO COUNTIES, 1975-2000 (in 1975 dollars)

water and sewage treatment facilities,[1] suggesting that the communities in Garfield and Rio Blanco Counties will be forced to expand their systems before the population arrives (1975-1980, Table 6-36), or have insufficient capacities during construction booms. Other capital needs, especially health care, will demand sizable capital outlays by 1980. Only Rangely's population will decline in the postconstruction phase after 1980.

In terms of overall expenditures, per capita costs tend to rise as a town's population increases because more services are provided; however, much of the increase is normally for capital expenditures and debt service.[2] Based on an average of $120 per capita, the additional operating expenditures required of municipal governments in the scenario area are shown in Table 6-37. Meeker and Grand Valley will need 4 and 12 times, respectively, their 1975 annual budgets by 1990. Particular needs likely to be generated by population growth are full-time fire protection to assist existing volunteer departments and an expansion of county sheriff and municipal police forces and vehicles.[3]

D. Fiscal Impacts

The major source of revenue from energy development will be the property tax on energy facilities. Over $1.6 billion (Table 6-29) will be invested in energy facilities by 1990.[4] Assuming that current mill levies are maintained, the property tax on these facilities will generate nearly $36 million in new revenues annually by 1990. Table 6-38 details these levies, and Table 6-39 shows the resulting property tax revenues by jurisdiction. Valuations are based on investment costs in the Bechtel Energy Supply Planning Model.[5]

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[1]Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

[2]THK Associates. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, p. 41.

[3]Ashland Oil, Inc.; Shell Oil Co., Operator. Oil Shale Tract C-b: Socio-Economic Assessment, prepared in conjunction with the activities related to lease C-20341 issued under the Federal Prototype Oil Shale Leasing Program. n.p.: March 1976, Vol. I, pp. VIII-34 to VIII-35.

[4]All figures are in 1975 dollars.

[5]Carasso, M., et al. The Energy Supply Planning Model, 2 vol. San Francisco, Calif.: Bechtel Corporation, 1975.

TABLE 6-36: PROJECTED NEW CAPITAL EXPENDITURE REQUIRED FOR PUBLIC SERVICES IN GARFIELD AND RIO BLANCO COUNTY COMMUNITIES, 1975-2000 (in thousands of 1975 dollars)

LOCATION	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000	TOTAL
Rifle						
Water and sewage[a]	792	3,608	2,640	352	176	7,568
Other[b]	266	1,211	887	118	59	2,541
Grand Valley						
Water and sewage[a]	598	3,115	3,045	176	176	7,110
Other[b]	201	1,046	1,042	59	59	2,407
Glenwood Springs						
Water and sewage[a]	352	352	352	264	264	1,584
Other[b]	118	118	118	89	89	532
Meeker						
Water and sewage[a]	8,448	-88	968	352	352	10,048
Other[b]	2,837	-30	325	118	118	3,368
Rangely						
Water and sewage[a]	8,888	-2,200	352	264	264	7,568
Other[b]	2,985	-739	118	89	89	2,442

[a]Water and sewage treatment plant requirements amount to $1,760,000 for each 1,000 additional population; an additional $591,000 goes to other physical needs. See THK Associates, Inc. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, p. 30. All figures from that source are inflated to 1975 dollars.

[b]Other includes parks and recreation (32 percent), hospitals (45 percent), libraries (5 percent), fire protection (5 percent), police (3 percent), administration (3 percent), and public works (7 percent). Streets and roads are not included.

TABLE 6-37: ADDITIONAL OPERATING EXPENDITURES FOR MUNICIPAL GOVERNMENT IN GARFIELD AND RIO BLANCO COUNTIES, 1980-2000 (above 1975 levels in thousands of 1975 dollars)[a]

YEAR	RIFLE	GRAND VALLEY	GLENWOOD SPRINGS	MEEKER	RANGELY
Current Base Budget, 1975[b]	690	38	927	132	462
1980	54	41	24	576	606
1985	300	253	48	570	456
1990	480	461	72	636	480
1995	504	473	90	660	498
2000	516	485	108	684	516

[a] Based on an average of $120 per capita (1975 dollars) broken down as follows: highways (25 percent), health and hospitals (14 percent), police (7 percent), fire protection (12 percent), parks and recreation (6 percent), libraries (4 percent), and administration (10 percent). See THK Associates, Inc. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, p. 41.

[b] Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Compilation of Raw Data on Energy Impacted Communities Including Characteristics, Conditions, Resources, and Structures. Denver, Colo.: Mountain Plains Federal Regional Council, 1976.

TABLE 6-38: MILL LEVIES AND PER CAPITA TAXES FOR JURISDICTIONS IN THE RIFLE AREA

JURISDICTION	RIO BLANCO COUNTY[a]	GARFIELD COUNTY[b]	GRAND JUNCTION (Mesa County)
County assessed value for residential and commercial property per capita	$4,260.	$4,410.	$3,090.
School mill levy	29.07	54.98	70.93
General fund mill levy	11.88	22.83	29.88
School tax per capita	124.	242.	219.
General fund tax per capita	51.	101.	92.

[a]1974 tax inflated to 1975. Source: VTN Colorado, Inc. *Environmental Impact Assessment for the Proposed Colowyo Mine, Colowyo Coal Company*. Denver, Colo.: VTN Colorado, 1975, p. IV, 91-93.

[b]1972 tax inflated to 1975. Source: Bassett, F.B. *Upper Colorado Mainstem Region, Social-Economic Profile; Grand Junction District (Colorado)*. Boulder, Colo.: Western Interstate Commission for Higher Education, 1973.

TABLE 6-39: PROPERTY TAX REVENUES FROM ENERGY FACILITIES (in millions of 1975 dollars)

JURISDICTION	1978	1980	1983	1985	1990
Rio Blanco Schools	2.4	5.0	14. 0	18.2	18.2
Rio Blanco General	1.0	2.0	5.7	7.5	7.5
Garfield Schools	0	0	0	.3	7.2
Garfield General	0	0	0	.1	3.0
Total	3.4	7.0	19.7	26.1	35.9

Source: Tables 6-29 and 6-38.

In comparison to the industrial plants, valuations of related residential and commercial property are negligible, adding only about one percent to the above figures. However, for some jurisdictions (such as Grand Junction), residential and commercial development will be the only source of new property taxes.

The average tax rates in Table 6-38 can be applied to population increments in the impacted areas. At the same time, it is convenient to add another population-related source: fees for services such as water and sewer. If Grand Junction data are indicative of the entire area, $61.60 per year per capita in fees may be added to the tax revenues. Applying these rates to the anticipated population increases, revenues may be estimated for the jurisdictions in the region (Table 6-40).

Next to the property tax, the biggest local revenue will come from sharing federal mineral revenues, because the hypothetical oil shale mine is located on leased federal land. The royalty rate is 12¢ per ton (1974 dollars) for shale containing 30 gallons of shale oil per ton and may be adjusted to reflect changes in the price of crude.[1] For a 50,000 bbl/day facility, annual payments would be $3,120,000. If royalty rates are applied at the same rate to the shale oil recovered from the <u>in situ</u> facility, an additional $3,550,000 per year would be collected. Also, the bonus bid

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[1]"Fact Sheet" accompanying Department of the Interior news release, November 29, 1973.

TABLE 6-40: REVENUES FROM RESIDENTIAL AND COMMERCIAL PROPERTY TAXES AND MUNICIPAL UTILITY FEES, SELECTED JURISDICTIONS (above 1975 levels in millions of 1975 dollars)

JURISDICTION	1980	1985	1990
Rio Blanco Schools	1.33	1.17	1.28
Rio Blanco General	1.21	1.07	1.17
Garfield Schools	.36	1.62	2.36
Garfield General	.24	1.09	1.59
Grand Junction Schools	.92	1.99	3.18
Grand Junction General	.65	1.40	2.23

Source: Based on population increase data from Table 6-32, and per capita school and general fund tax given on Table 6-38, and a water and sewer fee of $61.60 per capita.

payment will add a much larger amount to this. The highest bonus bid so far received is the $41,300 per acre offer obtained from the Standard Oil of Indiana/Gulf venture in 1974.[1] Assuming this to be indicative of what could be collected from a commercially viable project, and applying it to both oil shale facilities,[2] the projected bonus bid is $53 million, which is payable in five annual installments starting with the bid date. (The following allocations assume a bid date of 1979 for the 50,000 bbl/day mine and 1984 for the 57,000 bbl/day facility.) Recently passed legislation allocates one-half of federal mineral revenues to the state of origin, with one-fourth of that amount intended for mitigating local impacts. Altogether, the state share of oil shale bonus bids would be $2.5 million per year during 1979-1983, and $2.8 million during 1984-1988. The state and local share of royalty payments

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[1]U.S., Federal Energy Administration. Project Independence Blueprint Final Task Force Report--Potential Future Role of Oil Shale: Prospects and Constraints. Washington, D.C.: Government Printing Office, 1974, Appendix B, p. 17.

[2]The mine-site for the 50,000 bbl/day TOSCO II plant is 606 acres. For the 57,000 bbl/day *in situ* process, only a portion of the shale that is retorted is mined. Since the nature of the bonus bid in that case has not been established, this calculation scales the bonus bid to the 50,000 bbl/day plant and sums the two.

TABLE 6-41: NEW SALES TAX REVENUES[a]
(millions of 1975 dollars)

JURISDICTION[b]	1980	1985	1990
State of Colorado (3%)	1.99	1.83	2.57
Rio Blanco County (0.5%)	.21	.12	.14
City of Grand Junction (0.5%)	.08	.11	.16
Total	2.28	2.06	2.87

[a]Assuming 56 percent of income goes to retail sales. Revenues geographically distributed proportionally to population.

[b]These are the only jurisdictions in the region which currently levy a sales tax.

would be about $3 million per year beginning in 1983 for the TOSCO II facility and continuing for the mine life. For the *in situ* facility, a comparable royalty rate would be $3.5 million per year beginning in 1990.

State income and sales taxes are the major sources of revenue tied to personal income. Colorado's income tax, which reaches 8 percent of taxable income for incomes above $10,000,[1] implies collections of $848 per household based on the projected 1980 income distribution, and $794 per household based on the steady-state distributions. Expected income tax revenues are $1.9 million in 1978, $5.4 million in 1980, $6.6 million in 1983, $5.9 million in 1985, and $8.9 million in 1990. Sales taxes are detailed in Table 6-41. Some undetermined portion of this additional revenue is overestimated because some of the immigrating workers will leave other parts of Colorado to work on these energy projects.

Finally, all state and local revenues can be summarized by jurisdiction. These are shown in Table 6-42 and can be compared with anticipated expenditures for these jurisdictions. It is

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[1]U.S., Department of Commerce, Bureau of the Census. *The Statistical Abstract of the United States*. Washington, D.C.: Government Printing Office, 1975, Table 435. We assume a standard deduction of $4,000 per household.

TABLE 6-42: SUMMARY OF REVENUES DUE TO ENERGY FACILITIES (millions of 1975 dollars)

JURISDICTION	1980	1985	1990
State of Colorado[a]	9.9	13.3	14.9
School Districts			
Rio Blanco	6.3	19.4	19.5
Garfield	.36	1.9	9.6
Grand Junction	.92	2.0	3.2
County and Municipal			
Rio Blanco	3.4	8.7	8.8
Garfield	.24	1.2	4.6
Grand Junction	.72	1.5	2.4

[a]Including portions of royalties earmarked for local assistance.

immediately apparent that school districts in Rio Blanco County will derive substantial fiscal advantages from the projected developments.[1] For example, in 1990, new operating expenditures in Meeker and Rangely will be at a rate of $4.7 million per year (the sum of expenses for Meeker and Rangely from Table 6-34), while new revenues for these districts total $19.5 million (Table 6-42). Mill levies could be reduced and capital requirements still be met on a pay-as-you-go basis. Garfield County districts will also enjoy surpluses eventually but may face deficits before the *in situ* oil shale facility comes on-line in 1990. For example, in 1985 the Rifle and Grand Valley districts will need an additional $4.9 million (the sum of expenses for Rifle and Grand Valley from Table 6-34) over current operating budgets, while new revenues only reach $1.9 million (Table 6-42). Further, $2 million in new facilities will be needed by that date. The prospect of $9.6 million per year in new revenues for Garfield County schools after 1990 may provide a basis for borrowing in the interim.[2] County and municipal governments in these counties show short-falls for capital

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[1]Compare Table 6-42 with Table 6-34.

[2]Note that some of the state government's royalty share is earmarked for local impact mitigation.

expenditures until 1990. Grand Junction (in Mesa County) occupies an intermediate position, with moderate revenue increases ($1.5 million by 1985, $2.4 million by 1990).

If Colorado state government maintains its current rate of expenditures ($1,125 per capita), and if no more than one-fourth of the people new to this area come from out of state, then the state government will experience positive fiscal benefits. Any immigration rate much greater than 25 percent would lead to new expenses exceeding new revenues.

E. Social and Cultural Impacts

The primary societal effects of energy resource development in western Colorado should be related to the economic changes in the area. Shifts from an agricultural and tourism base to a resource-extraction base will alter the political base and social relations of the population over the long term. Social conflict between newcomers and long-time residents is most likely in Rio Blanco County where newcomers will outnumber oldtimers before 1980. Other conflicts between these groups of residents are likely, at least in the short term, because of the strain put on local services by the population increase.[1] A large cluster of mobile homes may prove to be undesirable to both inhabitants and close neighbors. Finally, the cost of living generally rises faster than the incomes of long-time residents; this is especially true for persons on fixed incomes who compose a significant proportion of the present population. However, in general, social impacts in the Rifle area will probably be less severe than was thought a few years ago.[2]

The quality of life as perceived by people in the Rifle area would undergo some changes because of energy development. The present residents like the small community size and environmental quality of the area but some are dissatisfied with the range of

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[1]A particular problem in rapid growth communities is a degeneration of telephone service, suggesting that private industry also has a lead time problem in coping with new demands from growth. See U.S., Federal Energy Administration. Project Independence Blueprint Final Task Force Report--Potential Future Role of Oil Shale: Prospects and Constraints. Washington, D.C.: Government Printing Office, 1974, p. 246.

[2]Compare Ibid., pp. 238-58; and University of Denver, Research Institute; Resource Planning Associates; and Socioeconomic Associates. Socioeconomic and Secondary Environmental Impacts of Western Energy Resource Development, Working Paper, for the Council on Environmental Quality. Denver, Colo.: University of Denver Research Institute, 1976, pp. VII-1 through VII-11.

shopping and entertainment facilities.[1] Thus, the population growth expected with energy development, especially during the construction phase, will have a negative effect on the area's quality of life for some residents, but others will welcome the accompanying increase in the number and range of goods and services available locally. For example, educational services for adults are likely to be expanded by Colorado Northwestern Community College in Rangely. Rangely and Meeker will be most impacted by 1980 (in this scenario), after which a new stability will be difficult to achieve until after 1990. The shift in the economic base from agriculture and tourism will be indicative of the shifts in lifestyles for people in the area as more seasonally stable industries replace the dependence on the traditional lines of work.

F. Political and Governmental Impacts

As shown in the preceding analysis, energy development in Garfield and Rio Blanco Counties will lead to demands for new public facilities and services. Communities in the two counties will be forced to expand their water and sewer systems before the population arrives; capital will be needed for health care facilities; and fire and police protection will have to expand. Each of these demands requires increasing government activity and expenditures at the local level. However, a major problem for the communities is their lack of planning resources and infrastructure to prepare for and manage rapid population growth. This lack, together with the anticipated expenditure needs discussed above, suggests that fiscal and planning shortfalls are likely.

Although school districts and the two counties will enjoy long-term revenue benefits from the projected development, the Garfield County districts will face deficits before the energy facilities are assessed and placed on the tax rolls. That is, front-end financial problems and the manner in which revenues are distributed from both the state and the counties will greatly influence the net fiscal status of the localities and districts during the short-term construction period, especially those outside the immediate vicinity of a mining activity. The creation of a new town or planned subdivisions financed largely by industry near Grand Valley could alleviate many of the problems anticipated for that community. Rifle and Meeker will be able to handle the impact to a greater extent primarily because of their expected growth as service centers. The service-related growth of these two municipalities will help to balance the population pressure in western Colorado and will provide the towns additional tax revenues to finance capital improvements and public services.

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[1]Bickert, Carl E. von. Attitudes and Opinions Related to the Development of an Oil Shale Industry, for the Oil Shale Regional Planning Commission and the Colorado West Area Council of Governments. Denver, Colo.: Bickert, Browne and Coddington and Associates, Inc., 1973.

Another impact category which may involve government is the demand for housing and mobile homes subdivisions to accommodate temporary and longer term workers. Colorado provides minimum standards for subdivision design, platting, provision of utilities, open space, and similar control criteria. The Department of Local Affairs within the state's Division of Housing serves as the administrative organization to assist in the establishment and financing of needed housing.[1] In addition, Colorado's Housing Finance Corporation can help alleviate low and middle income housing needs by securing home mortgage money for traditional lending institutions in rural areas. Since a number of the energy-impacted communities must rely on mobile homes to meet temporary population growth, it is significant that Colorado has adopted mobile home construction standards for all mobile homes sold in the state. Of more critical concern, however, is the need to assure adequate enforcement of construction standards and the provision of now nonexistent mobile home park codes of design.[2]

The most important political impacts are related to land use in the area and the effect of energy development on ranchers. Politically, the rancher-dominated system will be strained by newcomers almost from the beginning of construction. As development progresses, urban centers will acquire a larger proportion of voters and, hence, political influence in the counties. This shift can begin as early as 1980 in Rio Blanco County when a large number of new permanent workers and their families are present.

6.4.5 Summary of Social and Economic Impacts

Manpower requirements and the capital cost of the energy facilities are major causes of social and economic impacts. The manpower requirements for operation of the underground mines exceed peak construction manpower requirements, particularly in the case of the coal mine. However, the reverse is true for the conversion facilities. The peak construction manpower requirement for the power plant exceeds the operation requirement by about six times. In combination, the total manpower requirement for each oil shale mine-conversion facility increases from the first year when construction begins, peaks, and then declines as construction activity ceases. After all the facilities and their associated mines are

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[1]Bolt, Ross M., Dan Luna, and Lynda A. Watkins. Boom Town Financing Study, 2 vols. Denver, Colo.: Colorado Department of Local Affairs, 1976.

[2]See the Policy Analysis of Planning and Growth Management in White, Irvin L., et al. Energy From the West: Policy Analysis Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

constructed, operation of the 50,000 bbl/day *TOSCO II* plant will require the least labor and the 57,000 bbl/day in situ oil shale facility, the most.

Property tax, sales tax, severance tax, royalty payments, and oil shale bonus bids generate revenue for local and state government. Capital costs of the conversion facilities and mines hypothesized for the Rifle area range from about $515 million (mine-power plant facility) to $556 million (1975 dollars) for the 50,000 bbl/day oil shale plant and mine combination. The property tax is levied at a rate of about 1.37 percent on the cash value of each facility and the sales tax is levied at a rate of 3.5 percent on the materials and equipment purchased. Royalty payments are about 12.5 percent of the value of federally owned coal and 12¢ per ton of oil shale mined. Oil shale bonus bids are expected to be about $25 million for a 50,000 bbl/day facility. About half of all mineral revenues will go to the state government.

If all facilities are constructed according to the hypothesized schedule, the Rifle scenario energy development will increase the population of western Colorado by 43,000 people, 16,000 of whom will be in the area by 1980. This early increase, consisting largely of construction workers, will require 5,700 homes, at least 40 percent of which may be mobile homes. As construction workers are replaced by operational employees, the proportion of mobile homes may be able to decline to about 20 percent of total housing. School enrollment will increase through 1995 and subside after that. The long-term capital need for education will be about $6 million by 1990; operating expenditures will more than triple for the school districts serving Rifle and Grand Valley. The towns of Meeker, Rangely, Rifle, and Grand Valley likewise will receive the bulk of the population impact from development.

The long-term income benefit to Rifle area residents is estimated to be about a 13 percent increase; during construction the increase will be up to 28 percent. Some local inflation will reduce the latter to the long-term level. Grand Junction, the economic service center for the area, also will receive some commercial benefits from these energy developments.

Local governments will require greatly expanded facilities to serve the larger local populations, especially in water and sewage treatment. In fact, about $20 million will be needed primarily by Meeker and Rangely by 1980; an additional $12 million will be needed by Rifle and Grand Valley by 1990.

The change from an agricultural and tourism base to an energy development base will have social as well as economic effects. Population concentrations and conflicts over agricultural land in population expansion areas will require adjustments within the local area. The overall planning capacity of local governments appears to be inadequate to manage growth in the area.

6.5 ECOLOGICAL IMPACTS

6.5.1 Introduction

The area considered for ecological impacts in the Rifle scenario extends from the Colorado-Utah state line eastward to the middle of the White River National Forest, and from Grand Mesa on the south to the northern Moffat County line.[1]

The complex topography of the area varies from river valleys at 4,700 feet to mountains higher than 11,000 feet. Both rainfall and temperature vary with topography; conditions are relatively drier and warmer at lower altitudes than at higher altitudes. The structures of the area's varied soils reflect the combined influence of biological conditions, weather, and topography. In the study area, the principal influences controlling the development of biological communities are slope, elevation, and exposure. Forestry, agriculture, and grazing have a locally important influence.

6.5.2 Existing Biological Conditions

Vegetation types correspond approximately to altitude and exposure. The major types in order of elevation are: riparian (streamside) and agricultural bottomlands; salt desert shrub; sagebrush communities; pinyon-juniper woodland; mixed mountain brush areas; midelevation coniferous forest; and subalpine coniferous forest. Mixtures of types are often found together in patches. The dominant species characteristic of these biological communities are summarized in Table 6-43.

Although widely distributed, most smaller animals generally live within a single community. However, some birds and most big game species range more widely. The larger mammals (such as deer, elk, bear, and mountain lions) generally move freely between zones but use them selectively and during different seasons. Fifty-four species of mammals, 260 species of birds, and 13 species of reptiles and amphibians have been reported for the area. Rare or endangered terrestrial species include the bald eagle and peregrine falcon; the black-footed ferret may also be present.

Aquatic habitats vary from temporary creeks and small permament streams such as Parachute and Piceance Creeks to the area's two major rivers, the Colorado and the White. Both cold-water and warm-water fish inhabit these streams, including trout, mountain whitefish, bluehead sucker, channel catfish, Colorado squawfish, and carp.

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[1]A large area was considered due to the extensive influence of increased human populations.

TABLE 6-43: SELECTED CHARACTERISTIC SPECIES OF MAIN COMMUNITIES, RIFLE SCENARIO

COMMUNITY TYPE	CHARACTERISTIC PLANTS	CHARACTERISTIC ANIMALS
Riparian (bottomlands)	Crops Cottonwood Box elder Willow species Green ash	Muskrat Raccoon Snakes (e.g., common garter) Amphibians (e.g., tiger salamander) Songbirds (e.g., yellow-throat)
Salt desert shrub	Cropland (some irrigated) Shadscale Greasewood Fourwing saltbush Nuttall saltbush	Lizards (e.g., short-horned) Kangaroo rat Jackrabbit Gray fox
Sagebrush	Big sage Silver sage Rabbitbrush Bitterbrush	Antelope Mule deer (winter) Blue and sage grouse Sagebrush lizard Brewers blackbird Sage sparrow
Pinyon-juniper	Pinyon pine Utah juniper Bitterbrush Mountain mahogany Rabbitbrush	Blue and sage grouse Mountain cottontail Scrub jay Least chipmunk Mule deer Elk (winter)
Mountain brush	Serviceberry Mountain mahogany Chokecherry Snowberry Gambel oak	Deer (migratory or winter) Chickadees Kinglets Gray jay, Steller's jay
Midelevation	Ponderosa pine Douglas fir Snowberry Mountain maple Serviceberry	Mule deer (summer) Elk (summer) Red squirrel Lewis' woodpecker Snowshoe hare Hawks and owls
Subalpine forest	Engelmann spruce Lodgepole pine Aspen Fescut species Needle grass	Mule deer (summer) Elk (summer) Mountain goat Bighorn sheep Red fox Hawks and owls Clark's nutcracker

6.5.3 Factors Producing Impacts

Four factors associated with construction and operation of the scenario facilities can cause ecological impacts: land use, population increases, water use and pollution, and air pollution. With the exception of land use, the quantities of each of these factors associated with the scenario facilities were given in previous sections of this chapter. Land-use quantities are given in this section and the others are summarized.

Land use by each of the facilities proposed for the Rifle area is given in Table 6-44. The amount of land used during the lifetime of each facility (30 years) ranges from 180 acres (the *in situ* oil shale process) to 2,650 acres (the 50,000 bbl/day TOSCO II facility and mine). In the two cases where spent shale disposal is required (TOSCO II and *in situ* with a surface retort), land use is high.

The manpower required for construction and operation of the facilities is expected to cause an increase in urban population. Peak manpower requirement for the scenario facilities is about 1,570 for the power plant and mine, 1,680 for the 50,000 bbl/day plant and mine, and 2,900 for the 57,000 bbl/day *in situ* plant and mine. After construction is completed, manpower requirement for operation is 1,330 for the power plant and mine, 920 for the 50,000 bbl/day TOSCO II plant and mine, and 1,600 for the 57,000 bbl/day *in situ* plant and mine. Assuming the power plant is wet cooled, its water requirement is 9,400 acre-ft/yr. The TOSCO II facility will require 9,300 acre-ft/yr and the *in situ* facility from 4,360 to 5,660 acre-ft/yr. Water sources postulated to meet these requirements are the White River near Meeker, the Colorado River near Grand Valley and groundwater from mine dewatering. Effluent streams from the facilities directed to ponds or treatment facilities will contribute contaminants to surface and groundwater only if evaporative ponds leak or erode. The annual ambient air concentrations of SO_2 will range from 0.1 (*in situ* shale) to 2.3 micrograms per cubic meter ($\mu g/m^3$) (power plant). Peak concentrations from the power plant will violate Colorado's 24-hour and 3-hour SO_2 ambient air standard. Typical and peak concentrations from the TOSCO II oil shale plant will greatly exceed federal ambient air standards for HC.

6.5.4 Impacts

The nature of the ecological impacts caused by these factors depends on the plant and animal community type on which they are imposed. For example, the impact of land use depends on whether desert shrub, riparian, or pinyon-juniper communities are used. Some of the land-use trends are now evident or could occur regardless of energy related growth. A scenario, which calls for the development of a power plant, 50,000 bbl/day oil shale plant, and 57,000 bbl/day *in situ* oil shale plant and associated mines, to be

TABLE 6-44: LAND USE BY SCENARIO FACILITIES

FACILITY	LAND USE (acres/30 years)
Coal	
Underground Mine (3.4 MMtpy)	500[a]
Power Plant (1,000 MWe)	800
Oil Shale	
Underground Oil Shale Mine (26 MMtpy)	500[a]
TOSCO II Retort (50,000 bbl/day)	2,150[b]
In Situ Processing (57,000 bbl/day)	180[c]
In Situ Processing with Surface Retort (57,000 bbl/day)	1,240[d]
Oil Well Field (50,000 bbl/day)	1,000[e]

MMtpy = million tons per year   bbl/day = barrels per day
MWe = megawatt-electric

[a]Includes only that portion of the mine site to be occupied by surface structures.

[b]Includes 650 acres for the retort site and 1,500 acres for spent shale disposal over 30 years.

[c]Includes land for surface structures associated with the mine (100 acres) and *in situ* process (80 acres).

[d]Includes land for surface structures associated with the mine (100 acres), surface retorting (240 acres), and spent shale disposal over 30 years (900 acres).

[e]This assumes a figure of five acres per well for cleared area around producing wells, pipeline right-of-way, separation facilities, and roads.

developed according to a specified time schedule (see Table 6-1), is used here as the vehicle through which the extent of the impacts are explored. Impacts caused by land use, population increases, water use and pollution, and by air pollution are discussed.

A. To 1980

The power plant and its associated underground coal mine will begin operation in 1980. Table 6-45 shows the expected land use by the energy facilities and urban population in the scenario area which includes Rio Blanco and Garfield Counties. By 1980, 3,061 acres will be used by the power plant and its associated mine and by the urban population; this is about 0.1 percent of the land in these counties (Table 6-45). Table 6-46 gives the community types lost due to land use by energy facilities and urban population. Habitat losses by 1980 will be primarily mountain brush and sagebrush. Land in the scenario area which is managed by the Bureau of Land Management (BLM) is presently grazed in spring and fall by cattle and sheep and is stocked below its carrying capacity (based on forage production alone) to preserve wildlife and watershed values. The forage which could be produced on the 3,061 acres used by 1980 is roughly equivalent to the food consumed by 43-86 cows with calves or 215-432 sheep using the area as seasonal pasture.[1] Temporary land use of about 750 acres during construction of transmission line rights-of-way is not included in acres lost (Tables 6-45 and 6-46) because grazing values can be restored with proper reclamation practice to a level similar to that which existed before the line was built.

The impacts of habitat removal on small nongame species that do not occupy large ranges will probably be localized, not affecting populations on adjacent undisturbed areas. These local losses will not adversely affect predators that use them as food.

The power plant site is located within a large elk winter range. The total area affected is small--less than five percent of the total winter range unit--but human activity may cause elk to stay as much as a half mile from the construction site. The impact of these factors alone, in terms of elk populations, cannot

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[1]Based on the carrying capacity of the land in acres per animal unit month (AUM), as furnished by the BLM (White River Resource Area personnel, personal communication, 1976). An AUM, a unit of forage production, is the amount of food consumed by a cow with calf, or five sheep in a month. Because of differences in food habits, the unit cannot generally be extended to wild grazing animals. Potential forage losses calculated in AUM's are independent of season. Acres of forage required per animal unit assuming seaonal pasturing (six-month) is 35.4 to 70.8. Twelve-month pasturing would require twice as many acres.

TABLE 6-45: LAND USE IN RIFLE SCENARIO AREA (in acres)[a]

		1975	1980	1990	2000
By Energy Facilities					
Conversion Facilities					
Power Plant (1,000 MWe)			800	800	800
Oil Shale *In Situ* (57,000 bbl/day)				180	180
Oil Shale *Retort* (50,000 bbl/day)				2,150	2,150
Associated Mines					
Underground Coal Mine (3.4 MMtpy)			500	500	500
Underground Oil Shale (26 MMtpy)				500	500
Subtotal			1,300	4,130	4,130
By Urban Population[b]					
Rio Blanco County					
Residential		260	795	870	915
Streets		52	159	174	183
Commercial		6	19	21	22
Public and Community Facilities		16	49	54	57
Industry		26	80	87	92
Subtotal		360	1,102	1,206	1,269
Garfield County					
Residential		445	475	570	600
Streets		89	95	114	120
Commercial		11	11	14	14
Public and Community Facilities		28	30	35	37
Industry		44	48	57	60
Subtotal		617	659	790	831
Subtotal		977	1,761	1,996	2,100
Total Land Use		977	3,061	6,126	6,230
Total Land in Rifle Scenario	4,005,760				
Land in Rio Blanco County	2,088,320				
Land in Garfield County	1,917,440				

MWe = megawatt-electric
MMtpy = million tons per year
bbl/day = barrels per day

[a]Values in each column are cumulative for year given.

[b]Acres used by the urban population were calculated using population estimates in Table 6-32 for Rio Blanco and Garfield Counties assuming: residential land = 50 acres per 1,000 population; streets = 10 acres per 1,000 population; commercial land = 1.2 acres per 1,000 population; public and community facilities = 3.1 acres per 1,000 population; and industry = 5 acres per 1,000 population. Adapted from THK Associates. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land-Use Study. Denver, Colo.: THK Associates, 1974.

TABLE 6-46: VEGETATION LOSSES OVER TIME IN THE RIFLE SCENARIO AREA (acres)[a]

COMMUNITY TYPE	1980	1990	2000
Mountain brush	2,755	3,939	3,644
Sagebrush	214	238	263
Pinyon-juniper	92	1,949	2,323
Total	3,061	6,126	6,230

[a]The data in the table include land use by energy facilities and urban population. The following land-use categories are not included in the table: product pipelines will remove roughly 70 acres of mountain brush, 170 acres of sage, 70 acres of pinyon-juniper. New roads will occupy a total of approximately 710 acres in the riparian/agricultural zone but will remove substantially less than that amount of vegetation (probably only about 360 acres) because the widths of the existing roads are already cleared. A new road connecting the town of Rangely to the Piceance Creek site will remove 240 acres of mixed pinyon-juniper and upland sagebrush. The oil field development around Rangely will disturb a total of 850 acres, divided between the oil wells themselves and the gathering pipelines connecting them.

be quantified with available data but would probably be small compared to overall herd size.

While the activities of construction workers will have negligible impacts on most nongame species outside the immediate plant site, several-fold increases in big game poaching are typically observed around large construction projects in the West.[1] For these species, the impact of illegal kills will probably be more significant with respect to areawide populations than will habitat loss. Other than big game animals, the only other species which are

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[1]Grand Junction Field Office Staff, Colorado Division of Wildlife. Personal Communication, 1976.

subject to local reductions by illegal shooting are large birds of prey, including hawks and eagles.[1]

Manpower associated with energy development is expected to cause a 57 percent increase over the 1975 urban population in Rio Blanco and Garfield Counties by 1980. Urban population increase, together with growing use by out-of-state visitors, will place additional demands on mountain habitats for dispersed backcountry recreational activities. Designated wilderness areas will receive especially heavy demand.[2] Recreational activities with a potential for altering wildlife distribution patterns include: camping and fishing, which tend to cause selective deterioration of delicate riparian and lakeshore habitats; off-road-vehicle (ORV) use; and hiking and backpacking. Certain heavily used areas are already beginning to show visible signs of deterioration.[3]

Recreational opportunities offered by the White River and Grand Mesa National Forests tend to draw visitors from all over the nation. As a regional recreational focus, the area receives a strong impact from the metropolitan centers along Colorado's Front Range as well as from the Western Slope. The population change is likely to have a disproportionately large impact on National Forest use because residents will use the forests repeatedly, rather than once or twice yearly. Also, persons visiting new residents may help to swell the number of forest visitors.

Increased human presence in mountainous backcountry tends to lead to withdrawal of sensitive species away from areas of activity.

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[1]Poaching has a much more severe impact than legitimate hunting in that it affects game of both sexes and occurs throughout the year. Removal of pregnant females and nonbreeding young can affect the ability of the population to maintain adequate breeding stock. Legitimate hunting is regulated so as to assure the presence of enough breeding adults to regenerate the herd year after year.

[2]Two areas certain to be used more intensely are Snowmass/Maroon Bells and Flat Tops--the Elk Creek and Canyon Creek drainages. Three areas adjacent to Snowmass/Maroon Bells are also likely to be used extensively, particularly if they are designated as wilderness areas (a possibility which is currently being considered). Another area not classified as wilderness but also susceptible to heavy recreational use is the Grand Mesa National Forest immediately south of Rifle.

[3]For example, along the Canyon del Diablo portion of Main Elk Creek which lies in the scenario area, excessive use since 1972 has led to serious erosion problems along roads and trails. Increased fishing in Main Elk Creek has already reduced the quality of the trout fishery. Todd, J. "We're Losing the Wild in the Wilderness." Colorado Outdoors, Vol. 25 (March/April 1976), pp. 10-11.

Species considered sensitive to this type of disturbance include mountain lion, pine marten, bear, and elk. The diversity and abundance of small mammals and birds may be decreased on a local scale around heavily used areas. Snowmobile use, although usually concentrated in areas of deep snow avoided by migratory wildlife in winter, can be particularly stressful to big game animals.

Deer and elk normally winter at different elevations, which permits them to share the available winter habitat. Depending on the degree to which elk are disturbed in wintering areas, movement of these animals to lower elevations could bring them into direct competition with deer, which may suffer as a result. There is also some circumstantial evidence that displacement of elk by heavy recreational activity in their high-elevation summer range and calving ground may be associated with declines in overall numbers.[1] With existing controls on use, continued deterioration in habitat quality may be expected in wilderness areas.[2]

Recreational vehicle use of the rugged lands of the Roan Plateau and adjacent uplands may increase. Much of this region is presently accessible by road or trail, and most of this land is under BLM control which has limited personnel for adequate enforcement. Besides supporting a diverse small-vertebrate fauna, these lands constitute a major mule deer winter range; inadvertent or intentional harassment by ORV users could result indirectly in the loss of an unquantifiable number of animals.[3]

The water requirement of the power plant will be about 8 percent of the average flow and 21 percent of the minimum flow of the White River near Meeker, its water source. The increased water demand for the 1980 urban population will probably be met with water from the Colorado River. Effluents from the energy facility will be ponded. Increased wastewater from urban population will require updated treatment facilities. Contaminated urban runoff and leachates from additional municipal solid waste disposal sites could contaminate groundwater and surface water.

Air quality changes due to emissions of criteria pollutants from the power plant are not expected to cause significant ecological impacts by 1980.

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[1]San Juan National Forest Staff. Personal Communication, 1976.

[2]The White River National Forest has no current plans to institute a backcountry permit system. Colorado Division of Wildlife Staff. Personal Communication, 1976.

[3]During the late winter months, deer are usually in their poorest condition. Avoiding ORV pursuit, especially by snowmobiles, may debilitate weakened individuals sufficiently to reduce their resistance to disease.

B. To 1990

All the scenario facilities will be operating by 1990. By this time, 6,126 acres of land, about 0.15 percent of the total acres in Rio Blanco and Garfield Counties, will have been used by the energy facilities and urban population. Forage which could be produced on the land used would support 78-155 cows with calves or 388-777 sheep assuming they are seasonally pastured. Land use by 1990 will affect local populations of small vertebrates and predators, but area-wide populations will probably remain stable.

Increases in manpower requirements for construction and operation of the facilities is expected to cause a 92 percent increase over the 1975 urban population in Rio Blanco and Garfield Counties, which will total 41,800 by 1990. Population of elk, deer, antelope, hawks, and bald eagles could decline by 1990 as a result of increased poaching associated with increasing construction forces and urban population.

The additional vehicular traffic in and out of the two oil shale plant/mine complexes will also have an additional adverse influence on wildlife, particularly on mule deer which concentrate in the Parachute Creek Valley during the winter. Initially, road kills of wildlife will increase sharply. As many as 100 deer may be killed in the first year or two of heavy traffic in Parachute Creek.[1] Subsequently, deer may begin to avoid their old winter concentration areas and attempt to winter in adjacent habitats.

The bulk of the human population influx into the scenario area is expected by 1990. Most changes associated with urban growth should be apparent by 1985, although they intensify somewhat later. In addition to urban growth, increased population will add to existing demands for recreational and second home sites. Areas most affected by this kind of growth will include the White River Valley east of Meeker, the Glenwood Springs area, and the Rifle area.

The major impacts of urban and residential growth on animals arise through fragmentation of habitat; for example, where foothills used as winter deer range are subdivided for recreational homesites, and where there is local intensification of such activities as ORV and trail bike use and similar miscellaneous disturbances. Valley and foothill habitats, which contain the most developable lands, are most vulnerable to this type of deterioration.

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[1]Colony Development Operation; Atlantic Richfield Company, Operator. An Environmental Impact Analysis for a Shale Oil Complex at Parachute Creek, Colorado, Part I: Plant Complex and Service Corridor. Denver, Colo.: Atlantic Richfield, 1974; and U.S., Department of the Interior. Final Environmental Impact Statement for the Prototype Oil Shale Leasing Program, 2 vols. Washington, D.C.: Government Printing Office, 1973.

Fragmentation of biological communities is likely to have the greatest impact in the White River valley east of Meeker, and species with large ranges will be most affected. For example, according to the Colorado Division of Wildlife personnel, 30-50 percent of the elk herd in the White River National Forest winter on private lands, and available winter range is thought to limit the size of this herd. Elk are sensitive to human disturbance and tend to move completely away from areas with increased levels of activity.[1] Therefore, the impact of energy-related habitat fragmentation and clearing will be greater than the proportion of acreage involved. The mule deer winter range will also be affected. Deer are less liable to wholesale emigration in response to habitat fragmentation, but some measurable reduction in numbers is probably inevitable.

Urban development will occur primarily in the major river valleys, and fragmentation will probably affect species typical of the cultivated valley lands. However, these species are adapted to fragmented habitat. The chukar partridge, a bird with narrow habitat requirements, is likely to be eliminated locally near Grand Junction. This could reduce the total breeding population slightly. Beaver remaining in the valley might also suffer from clearing of riparian vegetation, which is their primary food source.

Urban water demands and generation of wastewater are expected to increase as the population increases. However, water withdrawals for municipalities and the energy facilities are not expected to have a significant impact on the aquatic ecology of the Colorado River, which has an average flow of 1,955,000 acre-ft/yr.

The effect of dewatering on vegetation will be confined primarily to the riparian and agricultural areas. Deteriorated water quality could curtail irrigation in the remainder of the drainage. This will probably result in a shift in vegetation from cultivated grasses to one of the two major native valley floor associations; sagebrush and saltbush-greasewood. Accumulation of salts in irrigated soils may favor the latter.

Some species of terrestrial animals will be affected directly by the loss of these valley vegetation types. These include muskrat, raccoon, other stream-side mammals of medium size, and the characteristic small bird species of riparian woodlands. Small mammals, which are abundant in irrigated haylands, will be reduced in numbers, which may in turn lead to locally reduced numbers of predators and wintering birds of prey.

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[1]This statement represents the current conventional wisdom; recent observations at Glenwood Springs and Steamboat Springs have indicated that elk may return to such ranges after a few years (Colorado Division of Wildlife, Grand Junction, Colorado. Personal Communication, 1976).

While the upland vegetation may persist without change, the loss of accessible water from springs and streams will probably alter the composition and perhaps the abundance of their animal communities. For example, sage grouse and blue grouse require moist areas with plentiful succulent vegetation and accessible water during the brood-rearing phase of their life cycle. A sage grouse brood-rearing area lying along the southern edge of the Piceance basin will probably be abandoned if its springs are lost. In winter, mule deer can probably obtain their water needs from snow or meltwater; thus, the large populations wintering there might not be seriously affected by groundwater depletion. However, deer may cease to use some of the area in summer.

Interception of groundwater flow in the Parachute Creek Basin by the 50,000 bbl/day oil shale plant is not expected to result in a significant loss of base flow in the Colorado River. Reduced flows may result in slight increases in salinity downstream. Due to dewatering, the sport fishery in the Piceance Creek, which includes brown, rainbow, and brook trout and mountain whitefish, will probably be lost or degraded. More adaptable nongame species may remain.

The potential ecological impact of flow reduction in the White River is impossible to quantify with available data. Flow-reduction sufficient to result in ecological stress is not likely to occur every year. Instream flow needs for maintaining the aquatic community have not been established for the White River. Lowered current velocity will reduce populations of organisms living on sediment-free stream bottoms fed on by fish and limit fish spawning or nesting habitat.

The oil shale complex will dispose of spent shale in on-site impoundments; catastrophic failures of these impoundments are unlikely during the 30 years of plant operation.[1] However, should such an event occur (most probably as a result of a flash flood), spent shale from the Parachute Creek disposal pile could be carried as far as the Colorado River. The fine-grained shale could physically obliterate existing bottom communities in Parachute Creek, rendering them unstable and reducing productivity for several years. Heavy metals in the shale could be slowly released into the aquatic environment, possibly contaminating the food chain if present in sufficient quantities. Also, there is evidence that carbonaceous spent shales of the type produced by the TOSCO II process contain at least moderately carcinogenic substances which are

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[1] U.S., Department of the Interior, Bureau of Land Management. Draft Environmental Impact Statement: Proposed Development of Oil Shale Resources by the Colony Development Operation in Colorado. Washington, D.C.: Bureau of Land Management, 1975.

water soluble and subject to leaching.[1] The spent shale piles containing salts, trace elements, and potentially carcinogenic compounds will be treated to prevent the occurrence of significant ecological impacts.[2]

Accidental rupture of product pipelines could release quantities of oil or ammonia into the Parachute Creek drainage area. The effects of such a spill could be both acute (from introducing water-soluble toxins into the aquatic ecosystem) and chronic (from fouling of the bottom by oil). Relatively small spills might result in possible fish kills.[3] Following a spill which entered one of the flowing rivers or streams in the scenario area, oil would tend to collect in the quiet backwaters used by young fish and could foul productive riffle areas.

Alkaline shale dusts and salts carried in cooling tower drift also damage vegetation. Processed shale resembling cement-kiln dust, which is thought to cause premature needle-drop in conifers,[4] would be confined to the immediate plant and spent shale disposal areas. The effect of salt deposition around cooling towers would also be confined to an area within a few hundred yards in the direction of prevailing winds. The highest salt deposition rates will be associated with the power plant; and the lowest level will occur at the Parachute Creek oil shale plant.

The projected emissions of SO_2 result in periodic high ground-level concentrations when plumes impact on adjacent high terrain. High SO_2 concentrations have caused acute damage in experiments with ponderosa pine. The sensitivities of other woody plants in the area are either lower or have not been tested. The area of

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[1]Schmidt-Collerus, Josef J. The Disposal and Environmental Effects of Carbonaceous Solid Wastes from Commercial Oil Shale Operations. Denver, Colo.: University of Denver, Research Institute, 1974.

[2]Pfeffer, Fred M. Pollutional Problems and Research Needs for an Oil Shale Industry, EPA-660/2-74-067. Ada, Okla.: Robert S. Kerr Environmental Research Laboratory, 1974.

[3]U.S., Department of the Interior, Bureau of Land Management. Draft Environmental Impact Statement: Proposed Development of Oil Shale Resources by the Colony Development Operation in Colorado. Washington, D.C.: Bureau of Land Management, 1975.

[4]U.S., Department of Health, Education and Welfare, Public Health Service. Air Quality Criteria for Particulate Matter, National Air Pollution Control Administration Publication No. AP-49. Springfield, Va.: National Technical Information Service, 1969.

vegetation damage would probably be less than one to two square miles. Ground-level concentrations near the smaller plant are not high enough to suggest such acute damage, although chronic impacts (resulting in reduced growth, vigor, and resistance to disease) cannot be ruled out. Slight to negligible soil acidification[1] could also result from a combination of dry deposition of particulate sulfates and SO_2. Total scenario SO_2 emissions are probably not high enough to result in acid rain problems, although acid mists could form locally under certain conditions.

C. To 2000

Although construction of all the scenario facilities will be completed by 1990, land use will continue to increase due to disposal of spent shale and urban growth. By 2000, about 6,230 acres, (about 0.16 percent of the total acres in Rio Blanco and Garfield Counties) will be used by the energy facilities and urban population (Table 6-45). Forage which could be produced on the land used would support 111-222 cows with calves or 555-1,110 sheep, assuming they are seasonally pastured. Other ecological impacts associated with land use by 1990 will be more intense by 2000.

In 2000, the urban population will have doubled its 1975 level in Rio Blanco and Garfield Counties. Ecological impacts associated with urban population increase, water use and pollution, and air pollution will be qualitatively similar to those described by 1990.

D. After 2000

About 7,000 acres of land, 0.18 percent of the total area in Rio Blanco and Garfield Counties, will be used by the energy facilities (Figure 6-2). If the facilities are located totally or primarily on land suitable for other development (which is only a small fraction of the total area), the effect will be much greater than implied by the total area occupied. The population-related land requirements shown in Table 6-45 must use the developable land in the river valleys, which constitutes only about 393,600 acres in the two counties.[2] The requirements for most population-related land needs amount to only 2,100 acres (0.54 percent of the

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[1]Acidifying the soil with sulfates is thought to increase the rate at which nutrients are lost from the soil by leaching.

[2]THK Associates, Inc. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, pp. 61-70; see also Ashland Oil, Inc., Shell Oil Co., Operator. Oil Shale Tract C-b: Socio-Economic Assessment, prepared in conjunction with the activities related to lease C-20341 issued under the Federal Prototype Oil Shale Leasing Program, 2 vols. n.p.: March 1976.

developable land and 1.41 percent of the "most suitable" developable land) in Garfield and Rio Blanco Counties.[1]

Ecological impacts after 2000 associated with population increase, water use and pollution, and air pollution are expected to be similar to those prior to 2000.

6.5.5 Summary of Ecological Impacts

Four factors associated with construction and operation of the scenario facilities can significantly affect the ecological impacts of energy development: land use, population increases, water use and pollution, and air pollution. About 7,000 acres of land, 0.16 percent of the total area in Rio Blanco and Garfield Counties, will be used by the energy facilities and urban population during the thirty-year lifetime of the facilities. By 2000, urban population in Rio Blanco and Garfield Counties will be 43,850, an increase of 100 percent over the 1975 population. The water requirement of the power plant (operating at the expected load factor and assuming high wet cooling is used) will be 2 percent of the average flow and 8 percent of the minimum flow of its water source, the White River. The base flow of the White River may be reduced during periods of low flow due to water withdrawal for the power plant. Water withdrawn for an oil shale plant and municipalities from the Colorado River, which has an average flow of 1,955,000 acre-ft/yr, is not expected to have a significant impact. Colorado's 24-hour and 3-hour SO_2 ambient air standards will be violated by emissions from the power plant.

Major ecological impacts caused by these factors are ranked into categories in Table 6-47. These categories are based upon the extent of community change and number of species affected. Class A impacts such as habitat removal or fragmentation or changes caused by the failure of shale piles or pipelines are the most severe. Class B impacts locally affect fewer species and include stream flow depletion and illegal shooting. Impacts which are likely to affect the fewest animals and are extremely localized such as the localized plant damage from plume impaction, are ranked as Class C.

A fourth category includes impacts that cannot be evaluated with certainty because adequate understanding of their mechanisms is not available. The complex processes that govern the movement of toxic metal ions and organic substances, such as may be contained in spent shale piles, are not well enough known to determine

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[1] Ratings according to THK Associates, Inc. Impacted Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, p. 70. The development ratings therein unfortunately include currently irrigated lands as favorable for development, a conflict in use which will have to be resolved.

TABLE 6-47: SUMMARY OF MAJOR ECOLOGICAL IMPACTS, RANKED BY SIGNIFICANCE

IMPACT CATEGORY	1975-1980	1980-1990	1990-2000
Class A		Pipeline rupture Retention dam failure Habitat fragmentation	Pipeline rupture Retention dam failure Habitat fragmentation
Class B	Illegal shooting	Flow depletion in White River Illegal shooting Increased recreational use of backcountry areas	Flow depletion in White River Groundwater depletion Illegal shooting Increased recreational use of backcountry areas
Class C	Grazing losses	Grazing losses Localized SO_2 plant damage	Grazing losses Loss of irrigation water, Piceance Creek
Uncertain		Leaching of toxins from spent shale	Leaching of toxins from spent shale Subacute SO_2 injury to vegetation

SO_2 = sulfur dioxide

whether normal operation will involve a risk of contaminating Parachute Creek. Similarly, ignorance of the quantitative dynamics of acid rain formation and of the entry of atmospheric sulfates into forest soils means that the risk of subacute damage to vegetation from SO_2 emissions cannot be assessed when only the amounts of SO_2 emitted are known.

Table 6-48 summarizes the ecological impacts on several selected animal species. Their cumulative effects on several species of interest to people will be as follows.

(1) Game Species

While not significantly affected by any of the direct impacts of energy facilities, elk may experience range displacement, and possible direct reduction in numbers, as a result of population growth. Mule deer populations have been low and decreasing in recent years, but the reasons for this are not known with certainty. It appears reasonable to expect an accelerated decline throughout the study period. Antelope habitat in Grand Valley, already substantially fragmented by agriculture, will be further affected by urban and residential growth and probably by the use of ORV's near population centers. Coupled with poaching pressure, these influences will probably contribute to an overall decline in the antelope population throughout the scenario time frame.[1]

(2) Rare and Endangered Species

Bald eagles within the scenario area have habitat classified as critical along the White River between Piceance Creek and Meeker and three small areas south of Rangley. These areas are all easily accessible from human population centers, and shooting will probably reduce the number of eagles using these areas. Slight to marked declines may be expected from about 1978 through the scenario time frame.

6.6 OVERALL SUMMARY OF IMPACTS FOR THE RIFLE SCENARIO

The developments hypothesized for the Rifle area could produce benefits of 157,000 bbl/day of oil and 1,000 megawatts of electricity. Most of this energy would be transported out of the Rifle area and the western region. Average incomes would increase about 13 percent over present levels, and economic service activities would be increased. As a result of increased urbanization, residents in the area could enjoy more services and amenities, and several existing communities could either acquire or improve water and sewage treatment facilities, health services, parks, and recreational areas. Communities will also be able to professionalize their staff, particularly in planning. Improved roads, largely in the river and creek valleys, will make access to recreational areas easier for hunters, hikers, ORV enthusiasts, and other potential users.

Social, economic, and political impacts associated with energy development in the Rifle area tend to be a function of the labor and capital intensity of facilities and, when multiple facilities

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[1]Selected additional game species are mentioned in Table 6-48.

TABLE 6-48: FORECAST OF POPULATION STATUS OF SELECT SPECIES

	1980	1990	2000
GAME SPECIES			
Elk	Possible redistribution around Meeker due to habitat fragmentation, poaching. Continued regional increase.	Continued displacement extending between Grand Junction and Glenwood Springs. Possible competition with deer at lower elevations. Continued increase or stable population numbers.	No further major impacts. Population trends continue to be governed by natural factors.
Mule deer (White River herd unit)	Decline in wintering populations in upper White River, due to habitat fragmentation, poaching.	Small declines in summer populations in Piceance Creek due to dewatering; continued declines of Upper White River. Possible additional decline due to competition with elk.	No further major impacts. Continued slight decline or restoration of natural factors as population controls.
Antelope	Slight decline in Grand Valley from habitat fragmentation, poaching.	Continued slight decline.	Continued slight decline.
Bighorn sheep	Little change.	Little change.	Little change.
Mountain lion	Little change.	Slight decline related to reduction in deer numbers.	Continued stable or slight decline.
Waterfowl	Slight decline in wintering goose populations near Meeker.	Continued slight to moderate decline near Meeker.	Continued stable or slight decline.
Upland game birds (Sage and Blue grouse, pheasant, Gambel's quail, chukar)	Slight reductions from overshooting or poaching near Meeker.	Moderate reduction of grouse populations in Piceance Creek due to dewatering. Poaching losses near Rangely and Meeker. Decline in quail and chukar from habitat loss in Grand Valley.	Continued declines from habitat loss due to progressive urbanization, dewatering.
RARE OR ENDANGERED SPECIES			
Bald eagle[a]	Little change.	Slight to moderate decline in White River Valley and near Meeker.	Continued slight decline or possible stabilization.
Black-footed ferret[a]	Little change, if present.	Little change, if present.	Little change, if present.
Peregrine falcon[a]	Little change.	Possible loss from disturbance of Peregrines on east fork of Parachute Creek, if nesting.	
Colorado squawfish,[a] Humpback chub	Little change.	Little change.	Little change.
Humpback sucker[b]	Little change.	Little change.	Little change.
OTHER UNCOMMON SPECIES			
Colorado cutthroat trout	Little change.	Little change.	Little change.
Prairie falcon, Ferruginous hawk	Slight local declines around Meeker, if present, by illegal shooting.	Slight declines in birds wintering in the Piceance Creek Valley because of decline in prey base.	Continued slight declines in birds in Piceance Creek Valley from decline in prey base.

[a]Listed by U.S. Fish and Wildlife Service.

[b]Listed by the State of Colorado.

are involved, of scheduling their construction. These factors determine the pace and extent of migration of people to the scenario area, as well as the financial and managerial capability of local governments to provide services and facilities for the increased population. Labor forces increase the population directly and indirectly. For most facility types, more manpower is required for construction of the facility than for operation; thus, where multiple facilities are involved, construction can be scheduled so that population increases and instability are minimized. Revenue for the local, state, and federal governments is derived from property taxes and sales taxes, both of which are tied to the capital intensity of the facility, and from royalty payments on federally owned coal and oil shale. Acquiring funds for the expansion of public services and public facilities will be difficult. The fact that communities are small with undeveloped planning capacity will make that acquisition more difficult. Colorado has no funding assistance programs which would aid in financing increased public costs associated with increased population; but, in Colorado, districts rather than individual communities provide public services and facilities. In general, solutions to problems of who receives the revenue and who provides the services will involve all levels of government and their abilities to relate to each other. Lifestyle and cultural differences among residents and newcomers influence the way in which impacts from energy development are perceived. However, some of the impacts related to an influx of "strangers" can be alleviated if labor forces include people who had previously migrated out of the area and local unemployed laborers.

Air impacts associated with energy development in the Rifle area are related primarily to quantities of pollutants emitted by the energy facilities and quantities associated with activities of the increased population. A power plant emits more SO_2, NO_2, and CO than an oil shale plant, but the TOSCO II oil shale plant emits more HC and particulates than a power plant. Pollutant concentrations of HC associated with the population could be greater than those from the facilities. The complex terrain and poor dispersion conditions in the Rifle area exacerbate air pollution problems. For example, ambient air concentrations will exceed Colorado or federal standards in at least two categories. Colorado SO_2 standards are exceeded by a factor of 5 by the 1,000 MWe power plant. The federal primary standard for HC is greatly exceeded, as fugitive emissions from the 50,000 bbl/day facility produce ambient concentrations that are 240 times the standard. There may also be an oxidant problem at Rifle and Grand Valley, visibility in the area will be reduced, and some Class II significant deterioration increments are exceeded.

Water impacts associated with energy development in the Rifle area depend primarily on the water requirements of and effluents produced by the facilities. Water required for a power plant (which is primarily for cooling purposes), is more than that for oil shale plants, but the use of wet/dry cooling can significantly reduce the water required for a power plant. Water demand by the population is significant but less than that for the energy facilities. Effluents from the oil shale plants, most of which are spent shale, exceed those from the power plant. With the exception of spent shale, all effluents will be ponded to prevent groundwater and surface water contamination. Mining activities intercept aquifers, affecting base flows of groundwater and surface water. Water availability will probably not pose a problem for energy development in the Rifle area and water quality is generally good in the White and Colorado Rivers and Parachute Creek. It is poor in Piceance Creek.

Mine dewatering will lower groundwater tables so that after several decades, seeps and springs within several miles of the mine along Piceance Creek may diminish or run dry, which may affect vegetation and animal populations. In the long term, processed shale, whether stored on the surface or underground, will potentially have an impact on groundwater and surface water. Leachate from both will enter bedrock aquifers and local streams. It is also likely that, over the long term, the waste disposal ponds at the oil shale plants and the power plant will become sources of contaminants which will infiltrate local aquifers and possibly migrate into surface streams.

Ecological impacts associated with energy development in the Rifle area depend on land use, population increases, water use and pollution, and air pollution. Habitat removal by the new population and the energy facilities will adversely affect both large and small animals, but changes in animal population will not be large. Larger stresses to animal life are more likely from additional hunting and from reduction in stream flow, which may eliminate some aquatic species and reduce riparian habitat. Plume impaction from the power plant and oil shale facilities is likely to produce damage to vegetation in an area up to several square miles. Process engineering changes and the imposition of additional environmental control technologies, such as increased efficiency of SO_2 scrubbers, would lessen air impacts. Some air, water, and land impacts can be mitigated by in situ oil shale retorting.

CHAPTER 7

THE IMPACTS OF ENERGY RESOURCE DEVELOPMENT AT THE GILLETTE AREA

7.1 INTRODUCTION

Energy development proposed for the Gillette area will take place in Campbell County, Wyoming (Figure 7-1). This development consists of six surface coal mines, a mine-mouth electric generation plant, two coal gasification plants, a coal liquefaction plant, coal export via both rail and slurry pipeline, natural gas production, two uranium mines (surface and solutional), and a uranium mill. As shown in Figure 7-2, all these facilities are located within 40 miles of Gillette. Although some of the electricity is to be distributed within Wyoming, most of the energy is to be transported to demand centers in the Midwest. Construction of these facilities was to have begun in 1975, and all the facilities included in the scenario are to be in operation by the year 2000. Table 7-1 identifies the technologies to be used and gives the timetable for their deployment.[1]

In all four impact sections of this chapter (air, water, social and economic, and ecological), the factors that produce impacts are identified and discussed separately for each energy facility type. In the air and water sections, the impacts caused by those factors are also discussed separately for each facility type and, in combination, for a scenario in which all facilities are constructed according to the scenario schedule. In the social and economic and ecological sections, only the combined impacts of the scenario are discussed. This distinction is made because

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[1]While this hypothetical development may parallel actual development proposed by Carter Oil Company, Northern Natural Gas, Black Hills Power and Light, Carter Mining, Atlantic Richfield, Wyodak Resources Development, Kerr-McGee, Sunoco Energy Development, AMAX Coal, El Paso Natural Gas, Falcon Coal, Shell Oil, and others, the development identified here is hypothetical. As with others, this scenario was used to structure the assessment of a particular combination of technologies and existing conditions.

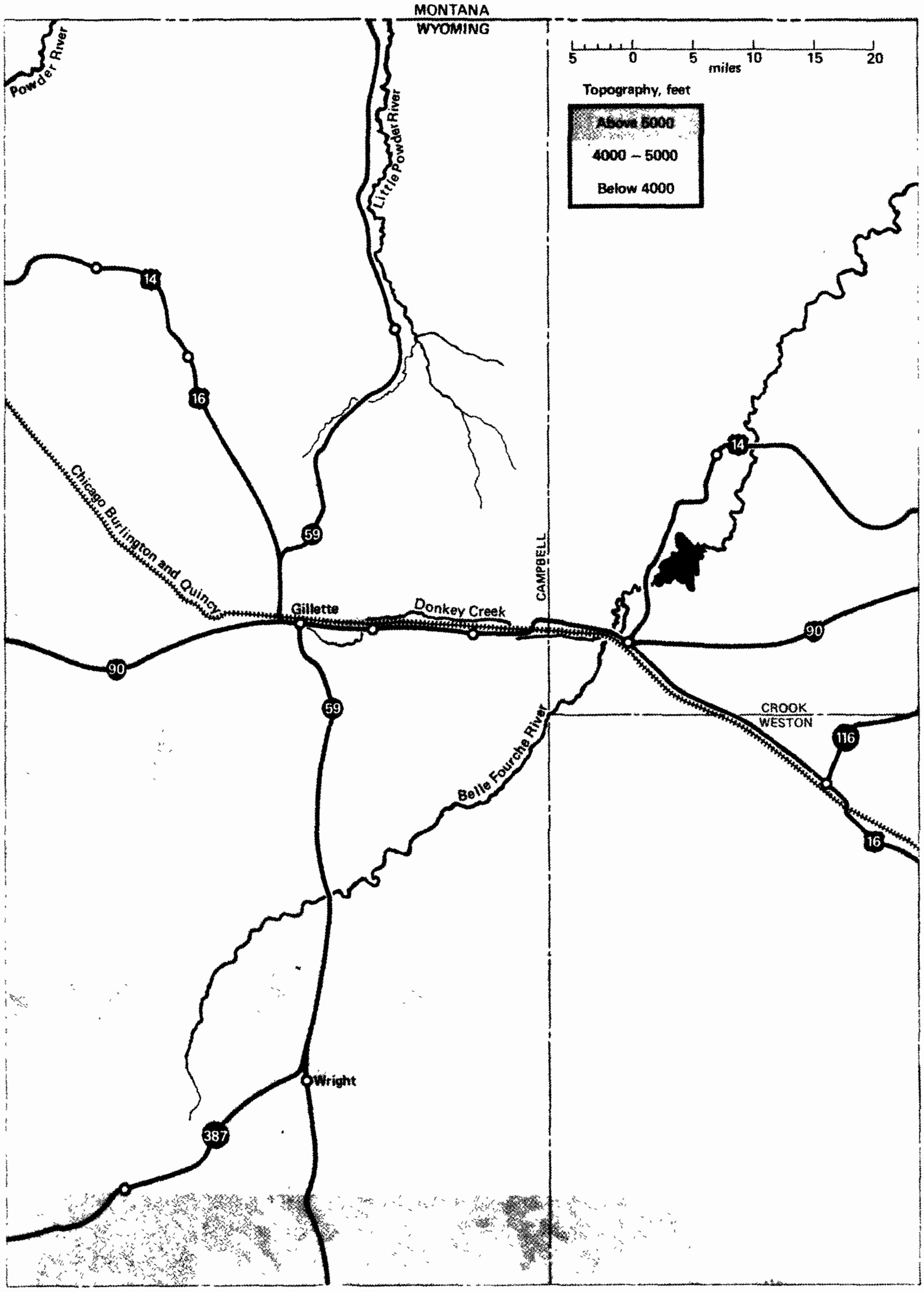

FIGURE 7-1: MAP OF THE GILLETTE SCENARIO AREA

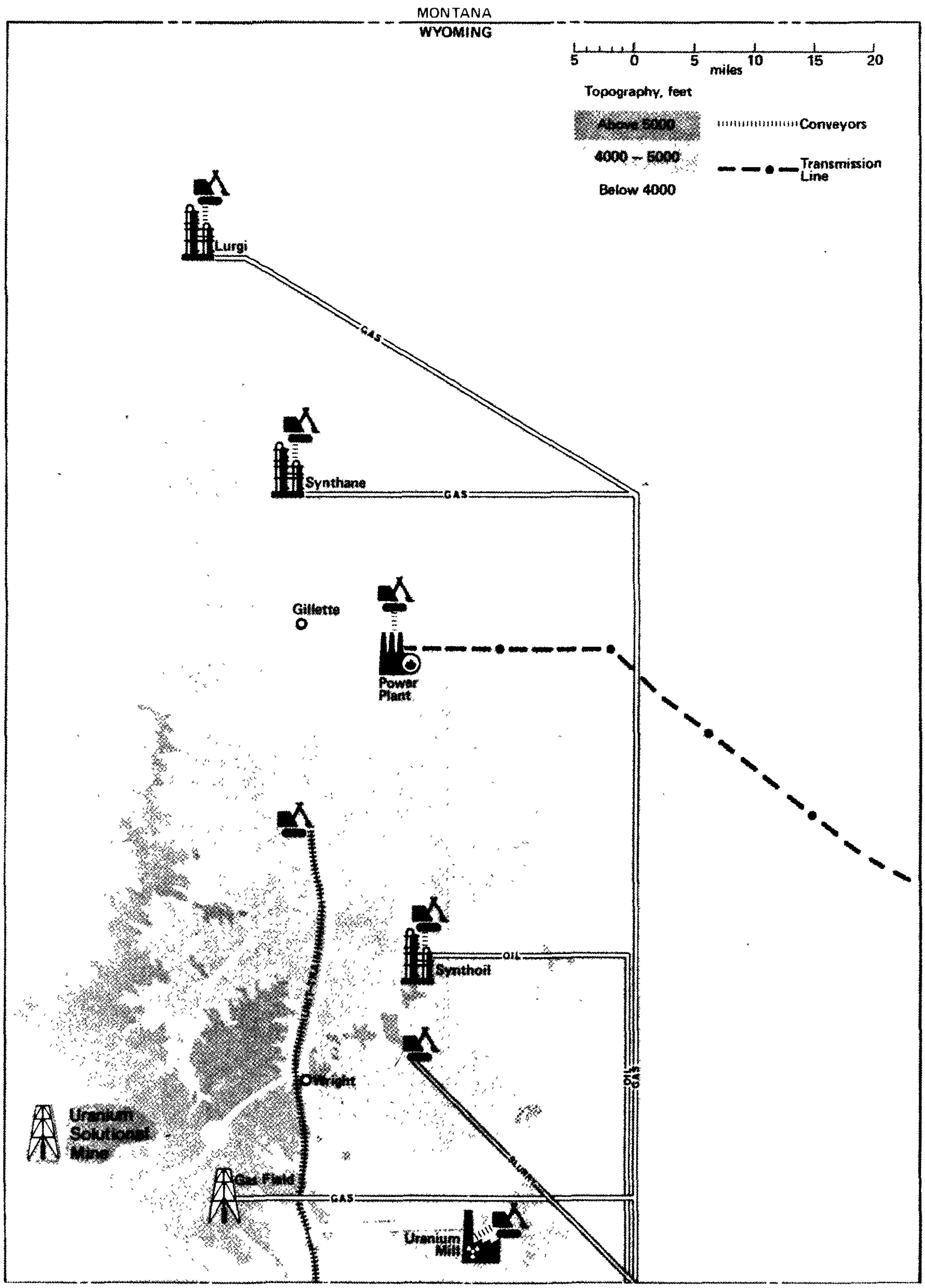

FIGURE 7-2: ENERGY FACILITIES IN THE GILLETTE SCENARIO

TABLE 7-1: RESOURCES AND HYPOTHESIZED FACILITIES AT GILLETTE

Resources	CHARACTERISTICS		
Coal[a] (billions of tons)	Coal[b]		
Resources 16	Heat Content 7,980 Btu's/lb		
Proved Reserves 13	Moisture 32 %		
Natural Gas[c] (trillion standard cubic feet)	Volatile Matter 43 %		
Reserves 3.2	Fixed Carbon 42 %		
Uranium[d] (million of tons of ore)	Ash 8 %		
Reserves 353	Sulfur 0.6 %		
	Uranium		
	U_3O_8 Content 0.07%		

Technologies	FACILITY SIZE	COMPLETION DATE	FACILITY SERVICED
Extraction			
Coal			
Six surface mines of varying capacity using draglines	25.0 MMtpy	1980	Rail Export
	25.0 MMtpy	1985	Slurry Export
	9.4 MMtpy	1985	Lurgi Plant
	12.8 MMtpy	1985	Power Plant
	8.1 MMtpy	1995	Synthane
	12.1 MMtpy	2000	Synthoil
Uranium			
One surface mine using dozers for ore removal	1,100.0 mtpd	1985	Uranium
Gas			
Completion of 83 wells with a combined production of 250 MMscfd	6	1977	Natural Gas
	27	1978	Natural Gas
	50	1979	Natural Gas
Conversion			
One natural gas processing plant for the removal of H_2S and natural gas liquids	250 MMscfd	1979	
One Lurgi coal gasification plant operating at 73 percent thermal efficiency; nickel-catalyzed methanation process; Claus plant H_2S removal; and wet forced-draft cooling towers	250 MMscfd	1985	
One 3,000 MWe power plant consisting of four 750 MWe turbine generators; 34 percent plant efficiency; 80 percent efficient limestone scrubbers; 99 percent efficient electrostatic precipitator; and wet forced-draft cooling towers	750 MWe	1982	
	750 MWe	1984	
	1,500 MWe	1985	
One uranium ore processing plant using acid leaching of ore and ammonia precipitation to product 1,000 metric tons of U_3O_8 per year	1,000 mtpy	1985	

TABLE 7-1: (Continued)

	FACILITY SIZE	COMPLETION DATE	FACILITY SERVICED
Conversion (Continued)			
One solutional mine-mill producing 250 tons of U^3O^8 per year	250 tpy	1985	
One Synthane coal gasification plant operating at 80 percent thermal efficiency; nickel-catalyzed methanation process; Claus plant H_2S removal; and wet forced-draft cooling towers	250 MMscfd	1995	
One coal liquefaction plant operating at 92 percent efficiency; nickel-catalyzed methanation process; Claus plant H_2S removal; and wet forced-draft cooling towers	100,000 bbl/day	2000	
Transportation			
Coal			
Conveyors from mines to facilities			
Railroad	25 MMtpy	1980	Coal
Slurry Pipeline	25 MMtpy	1985	Coal
Gas			
One 36-inch pipeline	250 MMscfd	1979	Gas
Oil			
One 16-inch pipeline	100,000 bbl/day	2000	Oil
Electricity			
Four lines	500 kV	1982	Power Plant
	500 kV	1984	Power Plant
	500 kV (2)	1985	Power Plant

Btu's/lb = British thermal units per pound
U_3O_8 = uranium oxide
MMtpy = million tons per year
mtpd = metric tons per day
MMscfd = million standard cubic feet per day
H_2S = hydrogen sulfide
MWe = megawatt-electric
mtpy = metric tons per year
tpy = tons per year
bbl/day = barrels per day
kV = kilovolts

[a]Wyoming, Department of Economic Planning and Development. Coal and Uranium Development of the Powder River Basin--An Impact Analysis. Cheyenne, Wyo.: Wyoming, Department of Economic Planning and Development, 1974.

[b]Ctvrtnicek, T.E., S.J. Rusek, and C.W. Sandy. Evaluation of Low-Sulfur Western Coal Characteristics, Utilization, and Combustion Experience, EPA-650/2-75-046. Dayton, Ohio: Monsanto Research Corporation, 1975. Estimates are for the Powder River Basin.

[c]American Petroleum Institute. Petroleum Facts and Figures, 1971 Edition. Washington, D.C.: American Petroleum Institute, 1971, p. 114. The value cited is for the state of Wyoming.

[d]U.S., Energy Research and Development Administration. Statistical Data of the Uranium Industry, January 1, 1976. Grand Junction, Colo.: Energy Research and Development Administration, 1976, p. 49. Value cited is for \$30/lb U_3O_8 reserves for the state of Wyoming.

social, economic, and ecological effects are, for the most part, higher order impacts. Consequently, facility-by-facility impact discussions would have been repetitive in nearly every respect.

In 1975, Campbell County had a population of 17,000--more than double its 1960 total. This population influx resulted primarily from the large number of energy-related employment opportunities in the area. The county's 1970 median income was $11,300, which was higher than both the Wyoming and national medians. Assessed 1975 valuation was in excess of $32 million, which was the highest in the state. At current tax rates, this valuation constitutes a tax base adequate to provide county social services for an increasing population. The county is governed by a three-member board of commissioners. Currently, all three commissioners are either ranchers or local businessmen; newcomers have not yet displaced locals to the extent that might have been expected. Although countywide zoning regulation is not practiced, development in an area around Gillette is controlled. The county and the city fund the City of Gillette-Campbell County Department of Planning and Development, which is responsible for all facets of municipal and countywide planning.

Gillette, the county seat and the only incorporated town in Campbell County, had a population of 14,000 in 1975. It is governed by a mayor and city council. While there is no city manager, there is a part-time city administrator. The city provides public safety, water, sewer, sanitation, and electrical services. Schools are operated by a countywide system, and the city cooperates with the county to provide animal control, fire protection, an airport, and snow removal. Both the water and sewer systems are operating at capacity, and efforts are under way to expand both.

Most of the area around Gillette is still rural, and ranching is a major activity. At higher elevations, ponderosa pine and juniper woodlands predominate. At lower elevations there are deciduous woodlands along streambeds; however, most of the area is rangeland. The 4-percent decline in farmland in Campbell County from 1969 to 1974 is part of a 3-percent decline throughout Wyoming. This has occurred in part because several ranches in the area have been sold or leased to coal mine developers. Six large surface mines were in operation or under construction in 1977, the largest being the AMAX Belle Ayre Mine, which was the third largest producing mine in the U.S. in 1976, with production of 7.4 million tons.

Runoff from the limited rainfall drains northward into the watersheds of the Powder and Belle Fourche Rivers, both of which are within the Upper Missouri River Basin (UMRB). These surface waters have intermittent flow and are not a reliable and adequate source of water.

Air quality in the region is good, although winter inversions offer the potential for periods of pollutant accumulation. The principal existing source of industrial emissions is the Wyodak power plant, a 330 megawatt (MW) dry-cooled electric plant located 5 miles east of Gillette. Selected characteristics of the area are summarized in Table 7-2.

7.2 AIR IMPACTS[1]

7.2.1 Existing Conditions

A. Background Pollutants

Measurements of criteria pollutant[2] concentrations taken at Rapid City, South Dakota,[3] indicate that no federal or Wyoming standards are currently exceeded. Based on these measurements, annual average background levels chosen as inputs to the air dispersion models are (in micrograms per cubic meter): sulfur dioxide (SO_2), 18; particulates, 17; and nitrogen dioxide (NO_2), 4.[4]

B. Meteorological Conditions

Worst-case dispersion conditions can be associated with stable air conditions, low wind speeds (less than 5-10 miles per hour), persistent wind direction, and relatively low mixing depths.[5]

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[1]The federal standards referred to in this section are those promulgated prior to the revisions mandated by the Clean Air Act Amendments of 1977, Pub. L. 95-95, 91 Stat. 685.

[2]Criteria pollutants are those for which ambient air quality standards are in force: carbon monoxide (CO), nonmethane hydrocarbons (HC), NO_2, oxidants, particulates, and SO_2. The term "hydrocarbons" is used to refer to nonmethane HC.

[3]U.S., Environmental Protection Agency, Region VIII Energy Office, Surveillance Analysis Division. Ambient Air Quality Monitoring Network--EPA Region VIII Energy Areas, EPA 908/4-77-011. Denver, Colo.: Environmental Protection Agency, 1977.

[4]These estimates are based on the Radian Corporation's best professional judgment. They are used as the best estimates of the concentrations to be expected at any particular time. Background concentrations of HC and CO are unknown, but high background HC levels have been measured at other rural locations in the West and may occur here. Background CO levels are assumed to be relatively low.

[5]Mixing depth is the distance from the ground to the upward boundary of pollution dispersion.

TABLE 7-2: SELECTED CHARACTERISTICS OF THE GILLETTE AREA

CHARACTERISTIC	VALUE
Environment	
Elevation	4,000-5,000 feet
Precipitation	14 inches average annually
Temperature	
Winter Daily Low (January)	11° F
Summer Daily High (July)	87° F
Air Stability	Stable 31 percent of the time
Soils	Sandy to sandy loam, variable
Biota	
Vegetation	Grasslands (plus coniferous and deciduous)
Croplands	92-percent rangeland, 4-percent croplands (forage)
Dominant Animals	Cattle, rabbits, antelope
Major Limiting Factors	Droughts, grazing
Social and Economic[a]	
Mineral Ownership (%)	
Federal	46.8 %
State	7.1 %
Local Government and Private	46.1 %
Land Ownership	
Federal	12.6 %
State	6.5 %
Local Government and Private	80.8 %
Population (County)	17,000
Population Density	3.8 per square mile
Unemployment	2.6 % (1970)
Income (per family)	$18,500
Poverty Level (less than $3,000)	4.8 %
Government	
County	Board of County Commissioners
City (Gillette)	Mayor-Council
Taxation	Primarily property tax
Public Department Expenditures	$1.4 million (1972 Campbell County)

Source: U.S., Department of Commerce, Bureau of the Census, County and City Data Book: A Statistical Abstract Supplement. Washington, D.C.: Government Printing Office, 1972, pp. 534-545.

[a]Campbell County, 1975 dollars.

Under these conditions, increases in pollutant concentrations from both ground-level sources such as towns and strip mines and elevated sources such as tall scrubber stacks are likely. These worst-case dispersion conditions differ at each facility location and are reflected in the predicted annual average pollutant levels among locations. Prolonged periods of air stagnation are uncommon in the Gillette area. However, meteorological conditions unfavorable for pollution dispersion occur approximately 30 percent of the time. Thus, plume impaction[1] and limited plume mixing due to temperature inversions at plume height can be expected with some regularity.[2]

The pollution dispersion potential for the Gillette area will also vary considerably with the season and time of day. Pollution problems are most likely during fall and winter mornings when mixing depths and wind speeds are lowest. Dispersion potential is generally greatest during the spring.

7.2.2 Factors Producing Impacts

The primary sources of air emissions in the Gillette scenario are: a power plant; three coal synthetic fuel facilities (Lurgi, Synthane, and Synthoil); a natural gas plant; a uranium mill; supporting gas wells; surface coal mines; surface and solutional uranium mines; and emission sources associated with population increases such as vehicles and residential and commercial heating and cooling. The focus of this section is on emissions of criteria pollutants from the energy facilities.[3] Table 7-3 lists the amounts (in pounds per hour) of the five criteria pollutants emitted by each of the eight facilities. For the coal facilities, most of the emissions come from the plants rather than the mines. Most mine-related pollution will originate from diesel engine combustion products, primarily nitrogen oxides (NO_x), HC, and

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[1]Plume impaction occurs when stack plumes impinge on elevated terrain because of limited atmospheric mixing and stable air conditions.

[2]See National Climatic Center. Wind Dispersion by Pasquill Stability Classes, Star Program for Selected U.S. Cities. Ashville, N.C.: National Climatic Center, 1975.

[3]Air impacts associated with population increases are discussed in Section 7.2.3 as they relate to the scenario (which includes all facilities constructed according to the hypothesized schedule).

particulates. Although water spray will be used to suppress dust, some additional particulates will occur from blasting, coal piles, and blowing dust.[1]

Except for HC the power plant is the greatest contributor of pollutants in all cases. Both the Synthoil plant and the natural gas wells exceed the power plant in HC emissions (Table 7-3). The largest of the primary emission sources, the power plant, will have four 750 megawatt-electric (MWe) boilers, each with its own stack.[2] The plant will be equipped with an electrostatic precipitator (ESP) which will remove 99 percent of particulates and a scrubber which will remove 80 percent of the SO_2.[3] Scrubbers are thought to remove some of the NO_x generated in the boiler, but the amount removed is uncertain. These data represent a range of 0 to 40 percent NO_x removal. The plant's two 75,000 barrel oil storage tanks (standard floating roof construction) will each emit up to 0.7 pound of HC per hour.

Table 7-4 lists the amounts of particulates, SO_2, and NO_x expected to be emitted (per million British thermal units [Btu's]) from a power plant operating under the previously described conditions. When compared with federal New Source Performance Standards (NSPS), the particulates and SO_2 emitted more than meet these standards.[4] Whether or not NO_x emissions will meet standards depends on the quantity of NO_x removed by scrubbers. At least 22 percent of the total will have to be removed to meet the standard. To meet federal NSPS for particulates and SO_2, the 3,000 MWe power plant would require 97.5 percent particulate removal; no SO_2 removal would be required.[5]

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[1]The effectiveness of current dust suppression practices is uncertain. Research being conducted by the Environmental Protection Agency (EPA) is investigating this question. The issue of fugitive dust is discussed qualitatively in Chapter 10.

[2]Stacks are 500 feet high, have an exit diameter of 30.0 feet, mass flow rates of 2.56×10^6 cubic feet per minute, an exit velocity of 60 feet per second, and an exit temperature of 180° Fahrenheit.

[3]These efficiencies were hypothesized as reasonable estimates of current industrial practices.

[4]NSPS limit the amount of a given pollutant a stationary source may emit; the limit is expressed relative to the amount of energy in the fuel burned.

[5]Section 109 of the Clean Air Act Amendments of 1977, Pub. L. 95-95, 91 Stat. 685, requires both an emissions limitation and a percentage reduction of SO_2, particulates, and NO_x. Revised standards have not yet been established by the EPA.

TABLE 7-3: EMISSIONS FROM FACILITIES
(pounds per hour)

FACILITIES	PARTICULATES	SO_2	NO_x	HC	CO
3,000 MWe Power Plant					
Mine[a]	12.6[b]	8.3	0.5	69	13.1
Plant	1,196	6,440	15,812–26,353[c]	440	1,464
Lurgi					
Mine	7[b]	4.6	62	39	7.3
Plant	N	516	649	47[d]	N
Synthane					
Mine	6[b]	4	54	33	6.3
Plant	8	3,524	5,052	94[d]	176
Synthoil[a]					
Mine	10[b]	6.8	92	56	11
Plant	482	936.7	4,616	1,350	181
25 MMtpy Export Coal Mine (rail)	13[b]	8.3	113	69	13
25 MMtpy Coal Mine (slurry)	13[b]	8.3	113	69	13
Natural Gas Production/Processing	2	468	655	1,000	2
Uranium					
Surface Mine (open pit)	361[b]	8.9	123	U	93.4
Mill	40	1.03	0.3	0.05	U
Solutional Mine-Mill	N	N	N	U	N

SO_2 = sulfur dioxide
NO_x = oxides of nitrogen
HC = hydrocarbons
CO = carbon monoxide
MWe = megawatt-electric
N = negligible
MMtpy = million tons per year
U = unknown

[a]Synthoil data have a high uncertainty because of the small capacity of bench scale test facilities built to date. The Solvent Refined Coal liquefaction process now appears likely to become commercial sooner, and more reliable pilot plant data are available. These data are reported in White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 3.

[b]These particulate emissions do not include fugitive dust.

[c]Range represents NO_x removal of 0 to 40 percent.

[d]These emissions do not include fugitive hydrocarbons.

TABLE 7-4: COMPARISON OF EMISSIONS FROM POWER PLANT WITH NEW SOURCE PERFORMANCE STANDARDS (pounds per million Btu)

POWER PLANT	EMISSION	NSPS
Particulates	0.04	0.1
SO_2 [a]	0.22	1.2
NO_x [b]	0.54-0.90	0.7

NSPS = New Source Performance Standards
Btu = British thermal unit
SO_2 = sulfur dioxide
NO_x = oxides of nitrogen

[a]The Wyoming State standard for SO_2 emissions is 0.2 pounds per million Btu. Data from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[b]Range represents 0 to 40 percent NO_x removal by the scrubber.

All the coal conversion facilities and the power plant will be cooled by wet forced-draft cooling towers. Each of the various cells in the cooling towers circulates water at a rate of 15,330 gallons per minute (gpm) and emits 0.01 percent of its water as a mist. The circulating water has a total dissolved solids (TDS) content of 3,870 parts per million (ppm). This resuilts in a salt emission rate of 24,600 pounds per year for each cell.[1]

Emissions of criteria pollutants from uranium surface and solutional mines and milling technologies are negligible (Table 7-3). Radioactive emissions from uranium surface mining include primarily radon gas (Rn-222) and its daughters. The amount of Rn-222 released into the atmosphere is a function of the amount of overburden and mine surface and varies with mining rates. For a 1,200 ton per day (tpd) mine,[2] Rn-222 gas release would be about 33.2 curies per year.[3]

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[1]In the scenario, the power plant has 64 cells, the Lurgi plant has 11, the Synthane plant has 6, and the Synthoil plant has 16.

[2]One thousand two hundred short tons is about equivalent to 1,100 metric tons.

[3]White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 5.

Because uranium solutional mining techniques are still in the research and development stage, data on this process are not complete. Information available on the air emissions of a solutional uranium mine is qualitative and represents gaseous emissions for alkaline leach, solutional uranium mining. The primary gaseous emissions are likely to be carbon dioxide (CO_2), ammonia (NH_3), ammonium chloride (NH_4Cl), and uranium oxide (U_3O_8).[1] The primary radioactive air emissions from the 1,000 tpd uranium mill are Rn-222, estimated to be about 9,000 curies per year.[2]

7.2.3 Impacts

This section describes air quality impacts which result from each type of energy facility (Lurgi, Synthane, Synthoil, power plant, natural gas plant, uranium facilities, and coal transport by rail and slurry pipeline) taken separately[3] and from a scenario which includes construction of all facilities according to the scenario schedule. For the power plant the effect on air quality of the hypothesized emission control, alternative emission controls, and alternative stack heights are discussed. Interactions among facilities and impacts caused by the expected population increase are included in the scenario impact discussion. The focus is on concentrations of criteria pollutants (particulates, SO_2, NO_x, HC, and CO). See Chapter 10 for a qualitative description of sulfates, other oxidants, fine particulates, long-range visibility, plume opacity, cooling tower salt deposition, and cooling tower fogging and icing.

In all cases, air quality impacts result primarily from the operation rather than the construction of these facilities. Construction impacts are limited to periodic increases in particulate concentrations due to windblown dust. However, since the highest particulate measurements do not exceed either federal or Wyoming standards, blowing dust should not cause particulate problems.

A. Power Plant Impacts

For power plants, concentrations of criteria pollutants depend greatly on the degree of emission control imposed. Concentrations resulting from the hypothesized case in which control

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[1]White, Irvin L., _et al_. _Energy From the West: Energy Resource Development Systems Report_. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 5.

[2]_Ibid_.

[3]Air quality impacts caused by the surface coal mines are expected to be negligible in comparison with impacts caused by the conversion facilities. However, the impact of fugitive dust originating from mines is uncertain and is discussed qualitatively in Chapter 10.

equipment removes 80 percent of the SO_2 and 99 percent of the particulates are discussed first followed by a discussion of the effect of alternative emission controls and alternative stack heights.

(1) Hypothesized Emission Control

Table 7-5 summarizes the typical and peak concentrations of four pollutants predicted to be produced by the power plant (3,000 MWe, 500 foot stack, 80 percent SO_2 removal, and 99 percent particulate removal). These pollutants (particulates, SO_2, NO_x, and HC) are regulated by federal and Wyoming state standards (Table 7-5). Peak concentrations from the power plant and its mine are not expected to violate any federal or Wyoming ambient air standards.

Table 7-5 also lists prevention of significant deterioration (PSD) standards, which are the allowable increments of pollutants that can be added to areas of relatively clean air (i.e., areas with air quality better than that allowed by ambient air standards).[1] "Class I" designation is intended to protect air quality in the cleanest areas, such as national parks and forests, and Class III allows deterioration to the level of national ambient secondary standards.

No Class II increments are violated by the power plant. However, several Class I increments are exceeded. When combined with its associated mine, peak concentrations from the plant exceed all short-term (24-hour or less) Class I increments. In addition, typical 3-hour SO_2 levels from the power plant equal the allowable Class I increment.

Since Class I increments are violated by this facility, it would have to be located a sufficient distance from any designated Class I areas to allow dilution of emissions by atmospheric mixing to allowable concentrations prior to their reaching that area. The distance required for this dilution, which varies by facility type, size, emission controls, and meteorological conditions, establishes what is in effect a "buffer zone" around Class I areas. Current EPA regulations would require a buffer zone of about 44 miles between the power plant and a Class I boundary.[2] Currently, there is no designated Class I area within this buffer zone.

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[1]PSD standards apply only to particulates and SO_2.

[2]Buffer zones around energy facilities will not be symmetrical because wind direction and strength vary by area and season. Hence, the direction of Class I areas from energy facilities will be critical to the size of the buffer zone required. Note also that the term buffer zone is in disfavor. We use it because we believe it accurately describes the effect of PSD requirements.

TABLE 7-5: POLLUTION CONCENTRATIONS FROM POWER PLANT/MINE COMBINATION (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATION[a]					STANDARDS[b]				
			PEAK			AMBIENT			PSD	
	BACKGROUND	TYPICAL	PLANT	PLANT AND MINE	GILLETTE	PRIMARY	SECONDARY	WYOMING	CLASS I	CLASS II
Particulate										
Annual	17		0.4	0.4	0.2	75	60	60	5	19
24-hour		1.2	8.7	19	13	260	150	150	10	37
SO_2										
Annual	18		1.6	1.6	0.6	80		60	2	20
24-hour		3.9	47	51	48	365		260	5	91
3-hour		25	323	323	117		1,300	1,300	25	512
NO_2[c]										
Annual	4[c]		4.6-7.7[d]	4.6-7.7[d]		100	100	100		
HC[e]										
3-hour		2.0	43	78	30	160	160	160		

PSD = prevention of significant deterioration
SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide
HC = hydrocarbons

[a]These are predicted ground-level concentrations from the hypothetical power plant/mine combination. Annual average background levels are considered to be the best estimates of short-term background levels. Concentrations over Gillette are largely attributable to the plant.

[b]"Primary" and "secondary" refer to federal ambient air quality standards designed to protect health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. PSD standards are the allowable increments which can be added to areas of relatively clean air, such as national forests. These data are from White, Irvin L., _et al_. _Energy From the West: Energy Resource Development Systems Report_. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[c]It is assumed that all oxides of nitrogen from plant sources are converted to NO_2.

[d]This range represents two assumptions about the removal of oxides of nitrogen by scrubbers. The first number assumes 40 percent is removed; the second number assumes none is removed.

[e]The 3-hour HC standard is measured at 6-9 a.m.

Reductions in background visibility (currently, about 70 miles) may occur infrequently on a short-term basis to between 3 and 10 miles, depending on the amount of SO_2 converted to particulates in the atmosphere.[1]

(2) Alternative Emission Controls

The base case control for the Gillette power plant assumed an SO_2 scrubber efficiency of 80 percent and an ESP efficiency of 99 percent. The effect on ambient air concentrations of three additional emission control alternatives is illustrated in Table 7-6. These alternatives include a 95 percent efficient SO_2 scrubber in conjunction with a 99 percent efficient ESP, an 80 percent efficient SO_2 scrubber without an ESP, and an alternative in which neither a scrubber nor an ESP is utilized.

An examination of Table 7-6 reveals that removal of particulate control results in violations of Class II PSD increments for 24-hour and annual total suspended particulates (TSP) and and National Ambient Air Quality Standards (NAAQS) 24-hour TSP standards. If no scrubber is utilized, violations of Class II PSD increments for 3-hour and 24-hour SO_2 emissions and NAAQS for 3-hour SO_2 emissions result. No violations result from the base case of 80 percent SO_2 efficient scrubber and an ESP.

(3) Alternative Stack Heights

In order to examine the effects of alternative stack heights on ambient air quality in the Gillette scenario, worst-case dispersion modeling was carried out for a 300-foot stack (lowest stack height consistent with good engineering practice), a 500-foot stack (an average or most frequently used height), and a 1,000-foot stack (a highest stack height). The results of this examination are shown in Table 7-7. Using a 300-foot stack, the Gillette power plant can operate within all applicable standards.

(4) Summary of Power Plant Air Impacts

A 3,000 MWe power plant with a 500 foot stack, 80 percent SO_2 removal, and 99 percent particulate removal can meet all applicable standards (NAAQS, Wyoming, and Class II PSD increments). The same plant with a 300 foot stack will also meet applicable standards. Without a scrubber or particulate control, the plant would violate all Class II PSD increments (except that for annual SO_2) and several NAAQS.

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[1]Short-term visibility impacts were investigated using a "box-type" dispersion model. This particular model assumes all emissions occurring during a specified time interval are uniformly mixed and confined in a box capped by a lid or stable layer aloft. A lid of 500 meters was used. SO_2 to sulfate conversion rates of 10 percent and 1 percent were modeled.

TABLE 7-6: AIR QUALITY IMPACTS RESULTING FROM ALTERNATIVE EMISSION CONTROLS AT GILLETTE POWER PLANT

AMOUNT OF CONTROL (%)		MAXIMUM POLLUTANT CONCENTRATION ($\mu g/m^3$)				
SO_2	TSP	3-HR. SO_2	24-HR. SO_2	ANNUAL SO_2	24-HR. TSP	ANNUAL TSP
95	99	81	12	NC	8.7	0.4
80	99	323	47	1.6	8.7	0.4
80	0	323	47	1.6	870[a]	40
0	0	1,610	229	8.0	850[a]	40
APPLICABLE STANDARDS						
NAAQS						
(primary)		--	365	80	260	75
(secondary)		1,300	--	--	150	60
State standards		1,300	260	60	150	60
Class II PSD Increments		512	91	20	37	19

$\mu g/m^3$ = micrograms per cubic meter
SO_2 = sulfur dioxide
TSP = total suspended particulates
HR. = hour
NC = not considered

NAAQS = National Ambient Air Quality Standards
PSD = prevention of significant deterioration

[a]Differences in 24-hour TSP concentrations for the two cases in which no electrostatic precipitator is used are attributable to the fact that the stack temperature rises when the SO_2 scrubber is turned off, which produces a small increase in the effectiveness of the smoke stack and a slightly lower TSP concentration.

TABLE 7-7: AIR QUALITY IMPACTS RESULTING FROM ALTERNATIVE STACK HEIGHTS AT GILLETTE POWER PLANT

SELECTED STACK HEIGHTS (feet)	MAXIMUM POLLUTANT CONCENTRATION ($\mu g/m^3$)		
	3-HR. SO_2	24-HR. SO_2	24-HR. TSP
300	342	55	10
500	323	47	8.7
1,000	290	31	5.7
APPLICABLE STANDARDS			
NAAQS			
(primary)	--	365	260
(secondary)	1,300	--	150
State standards	1,300	260	150
Class II PSD Increments	512	91	37

$\mu g/m^3$ = micrograms per cubic meter
HR. = hour
SO_2 = sulfur dioxide
TSP = total suspended particulates
NAAQS = National Ambient Air Quality Standards
PSD = prevention of significant deterioration

B. Lurgi Impacts

Typical and peak concentrations from the operation of a Lurgi gasification plant are summarized in Table 7-8. Peak concentrations are not expected to violate any federal or Wyoming ambient air standards nor any Class II PSD increments. However, peak SO_2 concentrations from the Lurgi plant exceed the 3-hour Class I PSD increment. These PSD violations will require a buffer zone of 7.4 miles for the plant. Currently there is no designated Class I area within this buffer zone.

The effects of alternative stack heights for a Lurgi gasification plant on ambient air concentrations are shown in Table 7-9. No violations of applicable standards will occur with any of the boiler/dryer stack height combination alternatives.

A reduction in short-term visibility from current background visibility of 70 miles to between 17 and 60 miles may occur infrequently, depending on the amount of SO_2 converted to particulates in the atmosphere.

TABLE 7-8: POLLUTION CONCENTRATIONS FROM LURGI GASIFICATION PLANT AT GILLETTE (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]				STANDARDS[b]				
			PEAK		AMBIENT			PSD	
	BACKGROUND	TYPICAL	PLANT	GILLETTE	PRIMARY	SECONDARY	WYOMING	CLASS I	CLASS II
Particulate									
Annual	17		N	N	75	60	60	5	19
24-hour			N	N	260	150	150	10	37
SO_2									
Annual	18	0.7	0.3	0.1	80		60	2	20
24-hour		3.4	4.6	0.4	365		260	5	91
3-hour			44.0	1.0		1,300	1,300	25	512
NO_2[c]									
Annual	4		0.3	0.1	100	100	100	NA	NA
HC[d]									
3-hour		3.1	57.0	0.1	160	160	160	NA	NA

PSD = prevention of significant deterioration
N = no change over background concentrations
SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide
NA = not applicable
HC = hydrocarbons

[a]These are predicted ground-level concentrations from the hypothetical Lurgi gasification plant. Annual background levels are considered to be the best estimates of short-term background levels.

[b]"Primary" and "secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. PSD standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national parks. These data are from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[c]It is assumed that all oxides of nitrogen from plant sources are converted to NO_2.

[d]The 3-hour HC standard is measured at 6-9 a.m.

TABLE 7-9: AIR QUALITY IMPACTS RESULTING FROM ALTERNATIVE STACK HEIGHTS AT GILLETTE LURGI FACILITY

SELECTED STACK HEIGHTS (feet)	MAXIMUM POLLUTANT CONCENTRATION ($\mu g/m^3$)		
	3-HR. SO_2	24-HR. SO_2	24-HR. TSP
150 (dryers) 400 (boilers)	47	4.9	N
300 (dryers) 500 (boilers)	44	4.6	N
450 (dryers) 700 (boilers)	43	2.8	N
APPLICABLE STANDARDS			
NAAQS			
(primary)	--	365.0	260
(secondary)	1,300	--	150
State standards	1,300	260.0	150
Class II PSD Increments	512	91.0	37

$\mu g/m^3$ = micrograms per cubic meter
HR. = hour
SO_2 = sulfur dioxide
TSP = total suspended particulates
N = no change over background concentrations
NAAQS = National Ambient Air Quality Standards
PSD = prevention of significant deterioration

C. Synthane Impacts

Table 7-10 summarizes typical and peak concentrations from the Synthane gasification plant. The plant does not violate any federal or Wyoming ambient air standards nor any Class II PSD increments. However, the peak plant concentrations violate Class I increments for annual, 24-hour, and 3-hour SO_2. These pollutant concentrations would require a buffer zone of less than 5 miles.

Short-term visibility may be reduced from current background visibility of 70 miles to between 2 and 11 miles, depending on the amount of SO_2 converted to particulates in the atmosphere.

TABLE 7-10: POLLUTION CONCENTRATIONS FROM SYNTHANE GASIFICATION PLANT/MINE COMBINATION AT GILLETTE (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]				STANDARDS[b]				
			PEAK		AMBIENT			PSD	
	BACKGROUND	TYPICAL	PLANT	GILLETTE	PRIMARY	SECONDARY	WYOMING	CLASS I	CLASS II
Particulate									
Annual	17	N	N	N	75	60	60	5	19
24-hour		N	0.1	N	260	150	150	10	37
SO_2									
Annual	18	N	2.3	1.5	80		60	2	20
24-hour		5.5	32	4.6	365		260	5	91
3-hour		32	324	17.3		1,300	1,300	25	512
NO_2[c]									
Annual	4	N	3.3	2.2	100	100	100		
HC[d]									
3-hour		6.1	114	0.2	160	160	160		

PSD = prevention of significant deterioration
N = no change above background concentration
SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide
HC = hydrocarbons

[a]These are predicted ground-level concentrations from the hypothetical Synthane gas plant. Annual average background levels are considered to be the best estimates of short-term background levels.

[b]"Primary" and "secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. PSD standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national parks. These data are from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[c]It is assumed that all oxides of nitrogen from plant sources are converted to NO_2.

[d]The 3-hour HC standard is measured at 6-9 a.m.

D. Synthoil Impacts

Table 7-11 lists typical concentrations from the Synthoil plant, peak concentrations from the plant, and peak concentrations from the plant and mine combination. These data show that the only federal and state ambient air quality violation will be the 3-hour HC ambient standard. HC concentrations resulting from the Synthoil plant greatly exceed those allowed.

The Synthoil plant does not violate any Class II PSD increments, but the plant and mine combination violates all Class I increments for SO_2. These pollutant concentrations would require a buffer zone of 13 miles for the Synthoil plant.

The effects of alternative stack heights for a Synthoil plant on ambient air concentrations are shown in Table 7-12. With a 100-foot stack (the lowest alternative stack height), no applicable standards would be violated.

Worst-case impacts on short-term visibility, expected to occur infrequently, may reduce background visibility of 70 miles to between 10 and 28 miles, depending on the amount of SO_2 converted to particulates in the atmosphere.

E. Coal Rail Transport Impacts

Table 7-13 summarizes the concentrations of four pollutants predicted to be produced by the strip mine for coal rail transport. The data indicate that the strip mine will not violate any federal or state ambient standards.

Peak concentrations attributable to the strip mine for coal rail transport do not exceed allowable Class II increments. However, the Class I increments for 24-hour and 3-hour SO_2 and 24-hour particulates are violated. Current EPA regulations would require a buffer zone of less than 5 miles between this facility and a Class I area boundary.

F. Coal Slurry Pipeline Impacts

Typical and peak concentrations from the operation of the strip mine supporting the coal slurry pipeline are summarized in Table 7-14. Air impacts from this strip mine are expected to be similar to those produced by the strip mine for coal rail transport shown in Table 7-13. Peak concentrations are not expected to violate any federal or Wyoming ambient air standards.

No Class II increments are violated by the strip mine. However, several Class I increments are exceeded by this facility. Peak concentrations exceed all short-term (24-hour or less) Class I increments. These PSD violations will require a buffer zone of less than 5 miles for the strip mine, according to current EPA regulations.

TABLE 7-11: POLLUTION CONCENTRATIONS FROM SYNTHOIL LIQUEFACTION PLANT/MINE COMBINATION AT GILLETTE (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]					STANDARDS[b]				
			PEAK			AMBIENT			PSD	
	BACKGROUND	TYPICAL	PLANT	PLANT AND MINE	GILLETTE	PRIMARY	SECONDARY	WYOMING	CLASS I	CLASS II
Particulate										
Annual	18		0.7	0.7	0.1	75	60	60	5	19
24-hour		1.3	6	6	0.5	260	150	150	10	37
SO_2										
Annual	17		3.6	3.6	0.4	80		60	2	20
24-hour		5.9	31	31	1.7	365		260	5	91
3-hour		23	109	109	5.9		1,300	1,300	25	512
NO_2[c]										
Annual	4		4.4	6	2	100	100	100		
HC[d]										
3-hour	unknown	503	25,100	25,100	5.9	160	160	160		

PSD = prevention of significant deterioration
SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide
HC = hydrocarbons

[a]These are predicted ground-level concentrations from the hypothetical Synthane gas plant/mine combination. Annual average background levels are considered to be the best estimates of short-term background levels. Concentrations over Gillette are largely attributable to the plant.

[b]"Primary" and "secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. PSD standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These data are from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[c]It is assumed that all oxides of nitrogen from plant sources are converted to NO_2.

[d]The 3-hour HC standard is measured at 6-9 a.m.

TABLE 7-12: AIR QUALITY IMPACTS RESULTING FROM ALTERNATIVE STACK HEIGHTS AT GILLETTE SYNTHOIL PLANT

SELECTED STACK HEIGHTS (feet)	MAXIMUM POLLUTANT CONCENTRATION ($\mu g/m^3$)		
	3-HR. SO_2	24-HR. SO_2	24-HR. TSP
100	140	49	10
200	109	31	6
300	83	21	4.2
APPLICABLE STANDARDS			
NAAQS			
(primary)	--	365	260
(secondary)	1,300	--	150
State standards	1,300	260	150
Class II PSD increments	512	91	37

$\mu g/m^3$ = micrograms per cubic meter
HR. = hour
SO_2 = sulfur dioxide
TSP = total suspended particulates
NAAQS = National Ambient Air Quality Standards
PSD = prevention of significant deterioration

G. Natural Gas Impacts

Table 7-15 summarizes the concentrations of four pollutants predicted to be produced by the natural gas wells. These pollutants (SO_2, particulates, NO_2, and HC) are regulated by federal and Wyoming state standards. The data show that, while typical concentrations from the natural gas wells do not violate ambient standards, peak concentrations may exceed both the federal and state HC standards by a factor of more than six.

Peak concentrations from the natural gas wells do not exceed allowable Class II increments. However, the Class I standards for 3-hour and 24-hour SO_2 are exceeded. This PSD violation would require a buffer zone of less than 5 miles between this facility and a Class I area boundary according to current EPA regulations.

TABLE 7-13: POLLUTION CONCENTRATIONS FROM STRIP MINE FOR COAL RAIL TRANSPORT AT GILLETTE (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]				STANDARDS[b]				
			PEAK		AMBIENT			PSD	
	BACKGROUND	TYPICAL	MINE	GILLETTE	PRIMARY	SECONDARY	WYOMING	CLASS I	CLASS II
Particulate									
Annual	17	6.8	0.3	0	75	60	60	5	19
24-hour			12	0	260	150	150	10	37
SO_2									
Annual	18		0.2	0	80		60	2	20
24-hour		3.5	8	0	365		260	5	91
3-hour		10	48	0.1		1,300	1,300	25	512
NO_2[c]									
Annual	4			0.2	100	100	100		
HC[d]									
3-hour	unknown	5.5		0.1	160	160	160		

PSD = prevention of significant deterioration
SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide
HC = hydrocarbons

[a]These are predicted ground-level concentrations from the hypothetical 25 million tons per year strip mine. Annual average background levels are considered to be the best estimates of short-term background levels.

[b]"Primary" and "secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. PSD standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These data are from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[c]It is assumed that all oxides of nitrogen from plant sources are converted to NO_2.

[d]The 3-hour HC standard is measured at 6-9 a.m.

TABLE 7-14: POLLUTION CONCENTRATIONS FROM STRIP MINE FOR COAL SLURRY LINE AT GILLETTE (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]				STANDARDS[b]				
			PEAK		AMBIENT			PSD	
	BACKGROUND	TYPICAL	MINE	GILLETTE	PRIMARY	SECONDARY	WYOMING	CLASS I	CLASS II
Particulate									
Annual	17		0.3	0	75	60	60	5	19
24-hour		6.8	12	0	260	150	150	10	37
SO_2									
Annual	18		0.2	0	80		60	2	20
24-hour		3.5	8	0	365		260	5	91
3-hour		10	48	0.1		1,300	1,300	25	512
NO_2[c]									
Annual	4		2.9	0.1	100	100	100		
HC[d]									
3-hour		5.5	49	0.1	160	160	160		

PSD = prevention of significant deterioration
SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide
HC = hydrocarbons

[a]These are predicted ground-level concentrations from the hypothetical 25 million tons per year strip mine/coal slurry line. Annual average background levels are considered to be the best estimates of short-term background levels.

[b]"Primary" and "secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. PSD standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These data are from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[c]It is assumed that all oxides of nitrogen from plant sources are converted to NO_2.

[d]The 3-hour HC standard is measured at 6-9 a.m.

TABLE 7-15: POLLUTION CONCENTRATIONS FROM NATURAL GAS PRODUCTION AT GILLETTE
(micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]				STANDARDS[b]				
			PEAK		AMBIENT			PSD	
	BACKGROUND	TYPICAL	PLANT	GILLETTE	PRIMARY	SECONDARY	WYOMING	CLASS I	CLASS II
Particulate									
Annual	17		0	0	75	60	60	5	19
24-hour		0	0	0	260	150	150	10	37
SO_2									
Annual	18		0.6	0	80		60	2	20
24-hour		3.2	14.0	0	365		260	5	91
3-hour		14	55.0	0		1,300	1,300	25	512
NO_2[c]									
Annual	4		0	0	100	100	100		
HC[d]									
3-hour		56	1,087	0	160	160	160		

PSD = prevention of significant deterioration
SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide
HC = hydrocarbons

[a]These are predicted ground-level concentrations from natural gas production. Annual average background levels are considered to be the best estimates of short-term background levels.

[b]"Primary" and "secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. PSD standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These data are from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[c]It is assumed that all oxides of nitrogen from plant sources are converted to NO_2.

[d]The 3-hour HC standard is measured at 6-9 a.m.

H. Uranium Surface and Solutional Mines and Mill Impacts

Since emissions of criteria pollutants from uranium facilities are negligible in comparison to those from coal facilities, uranium facility emissions were not modeled. The primary radioactive isotope emitted from uranium milling is Rn-222. There is no federal standard for allowable Rn-222 air concentrations. A rule of thumb value commonly used as an acceptable level is one picocurie per liter (pCi/ℓ) of air (1 picocurie is equal to 10^{-12} curies). Thus, the ambient air concentrations that would result from a 9,000 curie per year emission rate are not known.

I. Scenario Impacts

(1) To 1980

The hypothetical strip mine for coal rail transport and the natural gas wells will become operational in 1980, and the town of Gillette is expected to increase its population from 14,000 to 26,650 by 1980.[1] This increase will contribute to increases in pollution concentrations from urban sources. Pollution from energy-related population increases will result largely from additional automobile traffic. Concentrations have been estimated from available data on average emissions per person in several western cities. Table 7-16 shows predicted concentrations of five criteria pollutants measured at the center of the town and at a point 3 miles from the center of town.[2] The calculations indicate that pollution from urban sources will only exceed standards from HC. It should be noted that HC standards are violated regularly in most urban areas.

(2) To 1990

By 1990, the power plant, coal slurry pipeline, Lurgi gasification plant, all associated coal mines, and the uranium facilities will become operational. Interactions of the pollutants from the plants are minimal due to the assumed distances between them. If the wind blows directly from one plant to another, plumes may interact. However, concentrations which result are less than those produced by either plant and mine combination when the wind blows from the plant to the mine (peak plant/mine concentration). The maximum pollutant concentrations resulting from the interaction of the power plant and Lurgi gasification

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[1]See Section 7.4.3.

[2]Pollution concentrations from population increases were computed under the assumption that urban emissions are directly proportional to population.

TABLE 7-16: POLLUTION CONCENTRATIONS DUE TO URBAN SOURCES AT GILLETTE (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]							STANDARDS[b]		
	BACKGROUND	MIDTOWN POINT			RURAL POINT					
		1980	1990	2000	1980	1990	2000	PRIMARY	SECONDARY	WYOMING
Particulate										
Annual	17	22	27	30	5	7	10	75	60	60
24-hour		75	92	102	75	92	102	260	150	150
SO_2										
Annual	18	12	14	16	3	4	5	80		60
24-hour		41	48	54	41	48	54	365		260
3-hour		72	84	96	72	84	96		1,300	1,300
NO_2[c]										
Annual	4	35	41	45	8	12	17	100	100	100
HC[d]										
3-hour	unknown	660	780	871	660	780	871	160	160	160
CO										
8-hour	unknown	2,200	2,550	2,970	2,200	2,550	2,970	10,000	10,000	10,000
1-hour		3,600	4,180	4,870	3,600	4,180	4,870	40,000	40,000	40,000

SO_2 = sulfur dioxide HC = hydrocarbons
NO_2 = nitrogen dioxide CO = carbon monoxide

[a]These are predicted ground-level concentrations from urban sources. Background concentrations are taken from Table 7-4. "Rural points" are measurements taken 3 miles from the center of town.

[b]"Primary" and "secondary" are federal ambient air quality standards designed to protect the public health and welfare, respectively.

[c]It is assumed that 50 percent of oxides of nitrogen from urban sources are converted to NO_2.

[d]The 3-hour HC standard is measured at 6-9 a.m.

facilities (when they are separated by 5 miles) will not violate applicable standards. The plants could have been sited such that short-term concentrations were highest for the case of plant interaction.

Gillette's population increase to 44,500 by 1990 will cause urban pollutant concentrations to increase to the levels shown in Table 7-16. As in the 1980 case, the only federal or state ambient standard violated is that for HC.

(3) To 2000

Two new facilities, a Synthane gasification plant and a Synthoil liquefaction plant, will become operational between 1990 and 2000. Maximum pollutant concentrations resulting from interactions of the Synthane and Synthoil plants with the power plant do not violate federal or Wyoming ambient standards.

Gillette's population will increase to 69,200 by the year 2000, and increased pollution concentrations will be associated with growth (Table 7-16). Still, only the HC ambient standard will be exceeded by this source; no other standard will even be approached.

J. Other Air Impacts

Nine additional categories of potential air impacts have been examined: that is, an attempt has been made to identify sources of pollutants and how energy development may affect levels of these pollutants during the next 25 years, including sulfates, oxidants, fine particulates, long-range visibility, plume opacity, cooling tower salt deposition, cooling tower fogging and icing, trace element emissions, and fugitive dust emissions.[1] Although there are likely to be local impacts as a consequence of these pollutants, both the available data and knowledge about impact mechanisms are insufficient to allow quantitative, site-specific analyses. Thus, these are discussed in a more general, qualitative manner in Chapter 10.

7.2.4 *Summary of Air Impacts*

Eight facilities (a power plant, Lurgi and Synthane gasification plants, a Synthoil liquefaction plant, coal rail transport, coal slurry pipeline, natural gas wells, a uranium mill, and both a surface and solutional uranium mine) are projected for the

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[1]No analytical information is currently available on the source and formation of nitrates. See Hazardous Materials Advisory Committee. Nitrogenous Compounds in the Environment, EPA-SAB-73-001. Washington, D.C.: Government Printing Office, 1973.

Gillette area. To meet NSPS, the 3,000 MWe power plant would require 97.5 percent particulate removal, no SO_2 removal, and 22 percent NO_x removal. However, at this level of control, several federal ambient air standards and Class II PSD increments would be violated.

With 80 percent SO_2 and 99 percent particulate removal and either a 500 or 300 foot stack height, neither ambient air standards nor Class II PSD increments will be exceeded. When combined with its associated mine, peak concentrations from the power plant will exceed short-term Class I increments. A buffer zone of 44 miles between the plant and Class I area would be required.

Typical and peak concentrations from both the Lurgi and Synthane gasification plants will not violate any federal or Wyoming ambient air standards or Class II PSD increments. Since Class I PSD increments will be violated by both plants, buffer zones of 7.4 miles (Lurgi) and 5 miles (Sythane) would be required.

The 3-hour peak HC concentrations which result from the Synthoil plant will greatly exceed the federal and Wyoming ambient air standards. No other ambient air standards or Class II PSD increments will be violated. The violations of Class I PSD increments would require a buffer zone of 13 miles between the Synthoil plant and any area designated Class I.

Typical and peak concentrations from the operation of the strip mines for coal rail transport and coal slurry pipeline are not expected to violate any federal or Wyoming ambient air standards or Class II PSD increments. However, some Class I PSD increments will be exceeded and would require buffer zones of less than 5 miles between the mines and an area designated Class I.

Peak concentrations from the natural gas wells may exceed both the federal and Wyoming ambient air standards for HC by a factor of more than six. No other ambient air standards or Class II PSD increments will be violated. The Class I increment for 3-hour SO_2 is exceeded and would require a buffer zone of less than 5 miles.

Impacts from the uranium mill and its associated surface mine are expected to be negligible. Those from a solutional mine are uncertain.

If all eight facilities are constructed according to the hypothesized schedule, population increases in Gillette will add to existing pollution problems. Current violations of HC standards will continue to increase through the year 2000, but no other violations of ambient standards due to urban sources are expected in Gillette.

7.3 WATER IMPACTS

7.3.1 Introduction

As shown in Figure 7-3, Gillette, Wyoming, is located in a water-poor area of the relatively water-rich UMRB. Surface water sources that could supply the needs of energy development at Gillette are all a considerable distance away; these include the Yellowstone River, its tributaries, and the Belle Fourche, Green, and North Platte Rivers. In this area, annual rainfall is about 14 inches, and annual snowfall is about 48 inches, the equivalent of an additional 3.2 inches of rainfall.[1]

This section identifies the sources and uses of water required for energy development, the residuals that will be produced, and water availability and quality impacts that are likely to result.

7.3.2 Existing Conditions

A. Groundwater

The most productive aquifer systems in the Gillette area are the deeply buried Madison Limestone aquifer (mostly over 5,000 feet deep), shallow aquifer systems in the Fort Union and Wasatch Formations (mostly less than 300 feet deep), and alluvial aquifer systems associated with the surface drainage. Although no estimate is available on the quantity of water stored in these aquifers (information is especially inadequate for the Madison), the total volume of groundwater available in the northeast Wyoming region without exceeding recharge rates is estimated at 15,000 acre-feet per year (acre-ft/yr).[2]

The quality of water in the Madison aquifer, as measured by TDS concentrations, ranges from less than 500 milligrams per liter (mg/ℓ) near recharge areas in the Powder River Basin to more than 4,000 mg/ℓ near the Montana-North Dakota line.[3]

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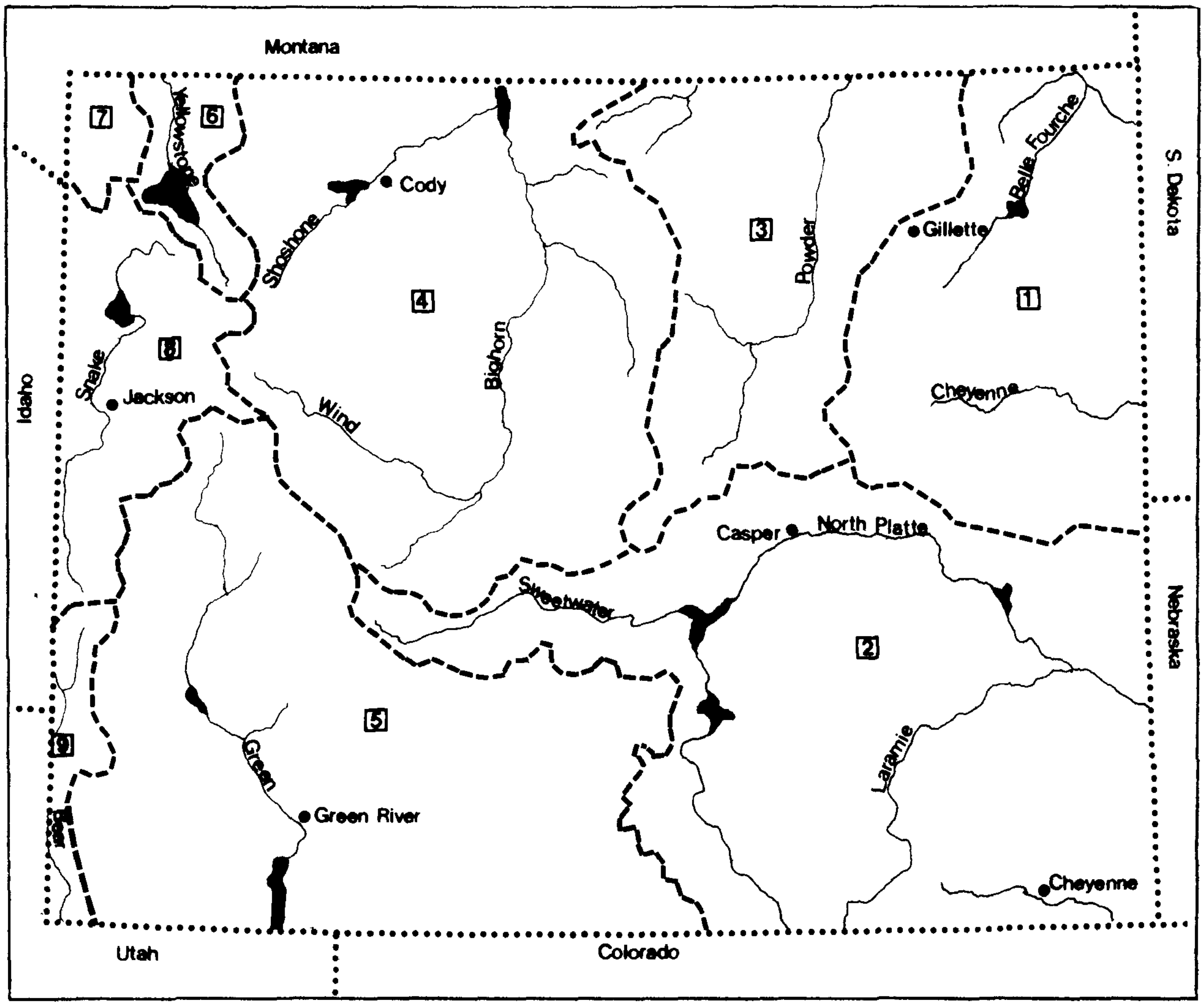
[1]The moisture content of 1 inch of rain is equal to approximately 15 inches of snow.

[2]U.S., Department of the Interior, Bureau of Land Management, et al. Final Environmental Impact Statement for the Proposed Development of Coal Resources in the Eastern Powder River Coal Basin of Wyoming, 6 vols. Cheyenne, Wyo.: Bureau of Land Management, 1974.

[3]Swenson, Frank A. Possible Development of Water from Madison Group and Associated Rock in Powder River Basin, Montana-Wyoming. Denver, Colo.: Northern Great Plains Resources Program, 1974, p. 3.



SUBBASINS

1. Western Dakota Tributaries
2. Platte-Niobrara Rivers
3. Powder River
4. Bighorn River
5. Green River
6. Yellowstone
7. Upper Missouri River Tributaries
8. Snake River
9. Bear River

FIGURE 7-3: SURFACE WATER SOURCES IN THE VICINITY OF GILLETTE

Water from the Madison has municipal, industrial, domestic, and livestock uses in the Wyoming region. Because the Madison is a limestone aquifer with irregular caverns storing the water, the productivity of a particular well depends on the number or size of caverns encountered by the well borehole. Wells producing several hundred gpm are common.

Several alluvial aquifers are present along the streams in the scenario area. The aquifer along Donkey Creek, about 5 miles east of Gillette, is the most productive, having wells that yield from only a few to as much as several hundred gpm[1] at a depth of from 3 to 20 feet.[2] Water quality of these alluvial aquifers is generally only fair,[3] and the water is presently used only for livestock and domestic purposes.

The most important aquifers in the Gillette area are in the shallow bedrock Fort Union and Wasatch Formations. These aquifers are in coal beds and lens-like sandstone bodies interbedded with shales. Wells yield up to 100 gpm in the Fort Union Formation and up to 500 gpm in the Wasatch Formation.[4] Water taken from these formations is used for livestock and domestic purposes as well for 95 percent of Gillette's municipal water supply.[5] Water quality is variable, with a generally lower concentration of TDS than the alluvial aquifers.[6]

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[1]Wyoming, State Engineer's Office. A Report from the Wyoming Water Planning Program. Cheyenne, Wyo.: Wyoming, State Engineer's Office, 1972, p. 61.

[2]U.S., Department of the Interior, Bureau of Land Management, et al. Final Environmental Impact Statement for the Proposed Development of Coal Resources in the Eastern Powder River Coal Basin of Wyoming, 6 vols. Cheyenne, Wyo.: Bureau of Land Management, 1974, p. I-95.

[3]TDS range from about 500 to more than 2,000 mg/ℓ, but most water ranges from 1,000 to 1,500 mg/ℓ. Ibid., p. I-199.

[4]Wyoming, State Engineer's Office. Water Planning Program.

[5]Northern Great Plains Resources Program, Water Work Group, Ground Water Subgroup. Shallow Ground Water in Selected Areas in the Fort Union Coal Region, Open File Report 74-48. Helena, Mont.: U.S., Department of the Interior, Geological Survey, 1974, p. 35.

[6]The TDS content ranges from 300 to more than 2,000 mg/ℓ, but the range of most bedrock aquifer water in the Powder River Basin is limited to 500-1,500 mg/ℓ dissolved solids. BLM. FEIS: Eastern Powder River Coal Basin, p. I-130.

B. Surface Water

As shown in Figure 7-3, Gillette, Wyoming is located approximately on the divides of several major watersheds: The Belle Fourche, Little Powder, Cheyenne, and Powder River Basins. Therefore, as energy development takes place around Gillette, the water needs could be met from several of these sources.

The water supply situation is complicated by the Yellowstone and the Belle Fourche Compacts.[1] The Yellowstone Compact was negotiated between Wyoming, Montana, and North Dakota to control water allocations in the Yellowstone River Basin. The compact recognizes all water rights existing in the basin as of January 1, 1950, and provides for the division of all remaining (unallocated) flow. Flow in the tributaries to the Yellowstone is divided as shown in Table 7-17.

However, an important provision within the compact states that no water will be diverted out of the basin without the consent of the signatory states. As Gillette is outside the Yellowstone Basin, this provision will directly affect the availability of water to energy development.

Water appropriations in the Belle Fourche River are governed by a compact between Wyoming and South Dakota. This compact states that all water unappropriated as of February 1944 is allocated 10 percent to Wyoming and 90 percent to South Dakota. There are several intermittent streams in the scenario area. Although there are no data on these streams, it is doubtful that they have enough flow to supply water for energy development. For example, Gillette is located on Donkey Creek, an ephemeral tributary of the Bell Fourche River, but the drainage area of the creek above Gillette is only 0.28 square mile.

The availability of water to meet energy development demands is shown in Table 7-18. Surface water would be available from several distant sources, including the Yellowstone River and its tributaries, the Belle Fourche, Cheyenne, Little Missouri, Green, and North Platte Rivers, and Lake Oahe (on the Upper Missouri in South Dakota).

7.3.3 Factors Producing Impacts

The water requirements of and effluents from energy facilities cause water impacts. These requirements and effluents are identified in this section for each type of energy facility. Associated population increases also increase municipal water demand and sewage effluent; these are presented in Section 7.3.4

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[1]Yellowstone River Compact of 1950, Pub. L. 82-231, 65 Stat. 663 (1951); and Belle Fourche River Compact of 1943, Pub. L. 78-236, 58 Stat. 94 (1944).

TABLE 7-17: LEGAL DIVISION OF FLOW: YELLOWSTONE RIVER TRIBUTARIES

TRIBUTARY	WYOMING (percent)	MONTANA (percent)
Clarks Fork	60	40
Bighorn	80	20
Tongue	40	60
Powder	42	58

for the scenario which includes all facilities constructed according to the scenario schedule.

A. Water Requirements of Energy Facilities

The water requirements of energy facilities included in the Gillette scenario are shown in Table 7-19. Two sets of data are presented. The Energy Resource Development System (ERDS) Report data are based on secondary sources, including impact statements, Federal Power Commission docket filings, and recent published data accumulations,[1] and can be considered typical requirement levels. The Water Purification Associates data are from a study on minimum water-use requirements and take into account certain opportunities to recycle water on site as well as the moisture content of the coal being used and local meteorological data.[2]

As indicated in Table 7-19, the power plant requires more water than the other facilities if wet cooling is used (the high wet case in Table 7-19 or 25,842 acre-ft/yr). By using a combination of wet and dry cooling (i.e., intermediate wet cooling), water requirements can be reduced by 75 percent to 6,465

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[1]The ERDS Report is based on data drawn from: University of Oklahoma, Science and Public Policy Program. Energy Alternatives: A Comparative Analysis. Washington, D.C.: Government Printing Office, 1975; and Radian Corporation. A Western Regional Energy Development Study, Final Report, 4 vols. Austin, Tex.: Radian Corporation, 1975. These data are published in White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[2]Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

TABLE 7-18: WATER USE AND AVAILABILITY FOR TRANSPORT FOR ENERGY DEVELOPMENT IN GILLETTE[a] (in acre-feet per year)

ESTIMATED DEPLETIONS OF STREAM FLOW								
STREAM	FLOW LEAVING NORTHEASTERN WYOMING	IRRIGATION	MUNICIPAL, DOMESTIC, & STOCK	INDUSTRIAL	RESERVOIR EVAPORATION	TOTAL	WATER YIELD FROM NORTHEASTERN WYOMING	WYOMING'S[b] LEGAL SHARE
Tongue River	302,700	77,100	2,400	1,000	3,100	83,600	386,300	96,000
Powder River	322,600	66,100	2,100	700	27,600	96,500	419,100	121,000
Little Missouri River	31,400	1,800	100	--	2,100	4,000	35,400	--
Bell Fourche River	76,400	1,500	1,000	1,000	16,800	20,300	96,700	7,000
Cheyenne River	64,800	4,500	600	1,700	14,100	20,900	85,700	15,000[c]
Bighorn River								1,800,000
Total	797,900	151,000	6,200	4,400	63,700	225,300	1,023,200	2,039,000

[a]U.S., Department of the Interior, Bureau of Land Management, et al. Final Environmental Impact Statement for the Proposed Development of Coal Resources in the Eastern Powder River Coal Basin of Wyoming, 6 vols. Cheyenne, Wyo.: Bureau of Land Management, 1974.

[b]Wyoming, State Engineer's Office, Water Planning Program. The Wyoming Framework Water Plan. Cheyenne, Wyo.: Wyoming, State Engineer's Office, 1973.

[c]No legal restriction.

TABLE 7-19: WATER REQUIREMENTS FOR ENERGY FACILITIES AT GILLETTE (acre-feet per year)

TECHNOLOGY[a]	ERDS[b] WET COOLING	WPA[c] COMBINATION OF WET AND DRY COOLING[d] HIGH WET	INTERMEDIATE WET	MININUM WET
Power Generation	29,400	25,842	6,465	NC
Gasfication				
Lurgi	6,714	5,823	4,206	3,721
Synthane	9,090	7,776	5,875	5,484
Liquefaction				
Synthoil[e]	17,460	9,227	7,539	7,026
Coal Slurry	18,390	NC	NC	NC
Gas Wells	380	NC	NC	NC
Uranium				
Solutional Uranium Mine	200	NC	NC	NC
Surface Mine-Mill	1,350	NC	NC	NC
	Cost Range in Which Indicated Cooling Technology Is Most Economic (dollars per thousand gallons)			
Synthetic Fuels Facilities	NC	< 1.50	2.00	>2.00
Power Plant	NC	<3.65-5.90	>3.65-5.90	NC

ERDS = Energy Resource Development System
WPA = Water Purification Associates
NC = not considered
< = less than
> = greater than

[a]These values assume an annual load factor of 75 percent in the case of the 3,000 megawatt-electric power plant and 90 percent in the case of a 250 million cubic feet per day Lurgi and Synthane facilities and 100,000 barrel per day Synthoil facility.

[b]White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[c]Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

[d]Combinations of wet and wet/dry cooling were obtained by examining the economics of cooling alternatives for the turbine condensers and gas compressor interstage coolers. In the high wet case, these are all wet cooled; in the intermediate case, wet cooling handles 10 percent of the load on the turbine condensers and all of the load in the interstage coolers; in the minimum practical wet case, wet cooling handles 10 percent of the cooling load on the turbine condensers and 50 percent of the load in the interstage coolers. For power plants, only variations on the steam turbine condenser load were considered practical; thus, only high wet and intermediate wet cases are examined.

[e]Synthoil data have a high uncertainty because of the small capacity of bench scale test facilities built to date. The Solvent Refined Coal liquefaction process now appears likely to become commercial sooner, and more reliable pilot plant data are available. These data are reported in White et al. Energy From the West: ERDS Report, Chapter 3.

acre-ft/yr. For synthetic fuels facilities the intermediate wet cooling system could save between 19 (Synthoil) and 28 percent (Lurgi) of the water required for a high wet (i.e., all wet) system. From an economic standpoint, the decision as to which process to use will depend on the availability and price of water. In the case of the power plant, high wet cooling is economically attractive if water costs less than $3.65 to $5.90 per thousand gallons. If water costs more than $3.65 to $5.90 per thousand gallons, intermediate wet cooling would be the most attractive alternative. For synthetic fuels facilities, high wet cooling would be most attractive if water costs less than $1.50 per thousand gallons. If water costs increase to about $1.50 per thousand gallons, intermediate wet cooling would be the economical choice. Minimum wet cooling (i.e., maximum dry cooling) would save from 6 (Synthoil) to 8 percent (Lurgi) more water than intermediate wet cooling and would become economically attractive if water costs more than $2.00 per thousand gallons.

If water costs only $0.25 per thousand gallons but intermediate wet cooling is utilized in order to conserve water, the increased cost of synthetic fuels would be about one cent per million Btu of fuel produced more than if high wet cooling were used. If water costs $0.25 per thousand gallons and intermediate wet cooling rather than high wet cooling is chosen for the power plant, the economic penalty is 0.1 to 0.2 cents per kilowatt hour.

About 200 acre-feet of water per year will be used to leach the yellowcake at the solutional uranium facility. The water will be pumped into the uranium ore deposits as a leaching solution through insertion wells. The leaching solution and dissolved uranium is then pumped to a processing mill via production wells. More than half of the total water requirement is for postleaching aquifer restoration. Techniques for restoration of the aquifer include: total water removal; water removal, clean-up, and recycle; and solutional restoration. In the case of water removal, clean-up, and recycle, contaminated water is pumped from the aquifer, treated above ground, and then reinjected into the aquifer where it originated. The scenario reported here assumes this option for aquifer restoration. Most of the water needed for the solutional uranium mine will be generated as a part of the solutional leaching and aquifer restoration operations. Additional wells may be drilled on-site.[1]

Figure 7-4 indicates the manner in which water is consumed by the hypothesized energy facilities. As indicated, more water is used for cooling than for processing and solids disposal combined. Solids disposal consumes comparable quantities of water

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[1]See White, Irvin L., _et al_. _Energy From the West: Energy Resource Development Systems Report_. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 5.

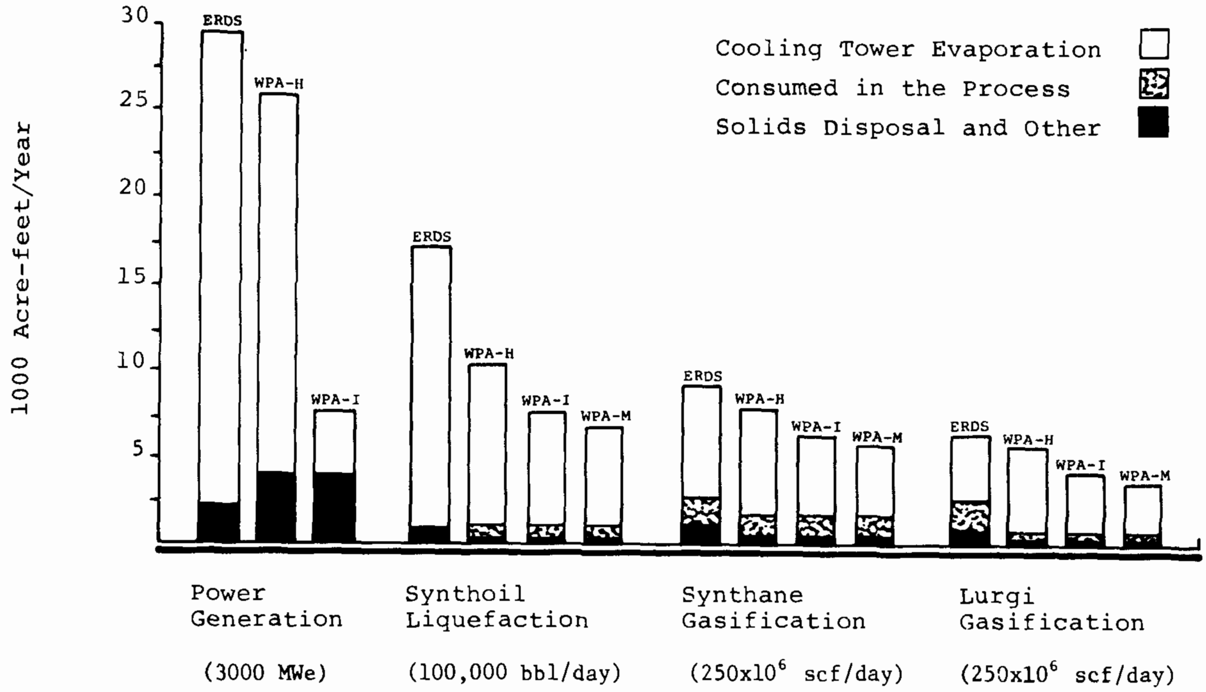

FIGURE 7-4: WATER CONSUMPTION FOR ENERGY FACILITIES IN THE GILLETTE SCENARIO

ERDS = Energy Resource Development System
WPA-H = Water Purification Associates - High Wet Cooling
WPA-I = Water Purification Associates - Intermediate Wet Cooling
WPA-M = Water Purification Associates - Minimum Wet Cooling
MWe = megawatt-electric
bbl/day = barrels per day
scf/day = standard cubic feet per day

Source: The ERDS data is from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming. The WPA data is from Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

TABLE 7-20: WATER REQUIREMENTS FOR RECLAMATION[a]

MINE	ACRES DISTURBED/YEAR	MAXIMUM ACRES UNDER IRRIGATION	WATER REQUIREMENTS (acre-ft/yr)
Power Plant	110	550	415
Lurgi	85	425	320
Synthane	85	425	415
Sythoil	110	550	415
Rail Transport	220	1,110	825
Slurry Pipeline	220	1,110	825
Total	830	4,170	3,215

acre-ft/yr = acre-feet per year

[a]Based on an irrigation rate of 9 inches per year for 5 years, which is the difference between water demand of native grasses and average precipitation. See U.S., Department of the Interior, Bureau of Land Management. Resource and Reclamation Evaluation: Otter Creek Study Site, EMRIA Report No. 1. Billings, Mont.: Bureau of Land Management, 1975.

for all technologies, varying primarily as a function of the ash content of the feedstock coal.

In addition to the energy facility water requirements, the associated mines that provide feedstock coal will also require water. If reclamation of surface mined lands includes irrigation, most of the water requirements for mining will be for reclamation (see Table 7-20).

Assuming the legal restraints of the various compacts can be favorably resolved, several pipeline or aqueduct schemes for supplying Gillette with water have been evaluated by industry and government agencies. Figure 7-5 shows some of these schemes. Table 7-21 presents representative flow data at possible diversion points from these rivers and some water quality parameters of interest.

The cost of transporting water to the energy development will depend on several factors, including the route selected and the volume of flow. Cost figures for some of those diversions are shown in Table 7-22.

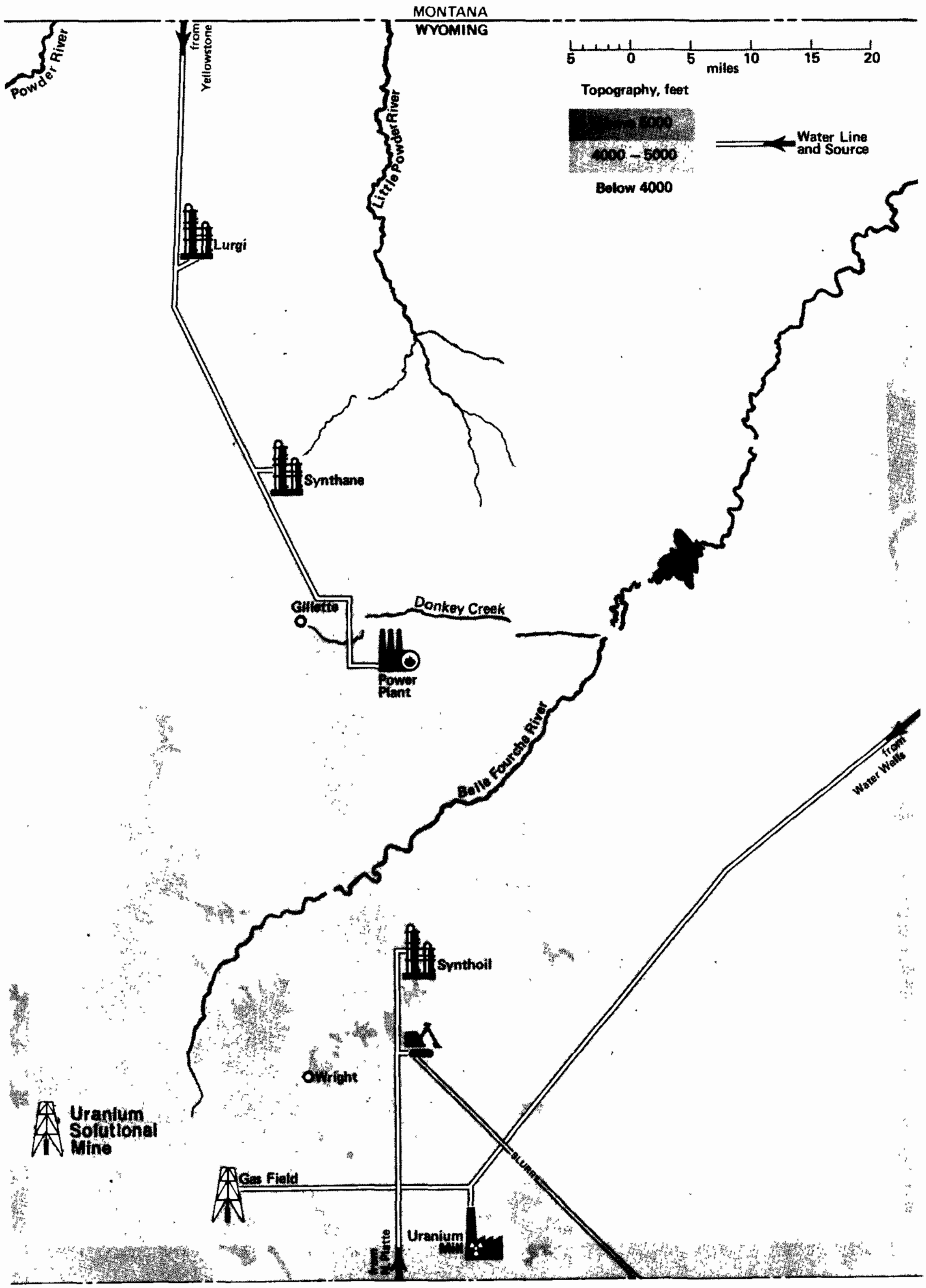

FIGURE 7-5: WATER PIPELINES FOR ENERGY FACILITIES IN THE GILLETTE SCENARIO

TABLE 7-21: STORAGE, FLOW, AND QUALITY DATA FOR POSSIBLE WATER DIVERSION POINTS TO SUPPLY DEVELOPMENT AT GILLETTE

RIVER	LOCATION	DRAINAGE AREA (square miles)	MINIMUM FLOW (cfs)	MAXIMUM FLOW (cfs)	AVERAGE FLOW (acre-ft/yr)
Green River	Green River, Wyoming	≈ 9,700[a]	170	16,500	1,249,000
North Platte	Near Glenrock, Wyoming	12,365[a]	176	16,000	
Bighorn	Hardin, Montana	1,101	0.2	4,520	205,970
Yellowstone	Miles City, Montana	10,600	5,135	96,300	8,166,510
Nowood	Tensleep, Wyoming	803	0.7	3,330	76,800
RESERVOIR	**RIVER BASIN**	**INACTIVE AND DEAD STORAGE (acre-feet)**	**ACTIVE STORAGE (acre-feet)**	**FLOOD STORAGE (acre-feet)**	**TOTAL STORAGE (acre-feet)**
Boysen	Bighorn	252,100	549,900	150,400	952,400
Bighorn	Bighorn	502,300	613,700	259,000	1,375,000
RIVER	**LOCATION**	**DISSOLVED OXYGEN (mg/ℓ)**	**TDS (mg/ℓ)**	**pH**	**TOTAL HARDNESS (mg/ℓ as $CaCO_3$)**
Green River	Green River, Wyoming		181-762[b]	7.4-8.7[c]	160-260[c]
North Platte	Near Glenrock, Wyoming		181-1,002[b]		
Bighorn	Hardin, Montana	7.5-22	370-1,160	7.5-9.3	100-540
Yellowstone	Miles City, Montana		150-624	6.9-8.5	86-204
Nowood	Tensleep, Wyoming		507-889[c]	8.0-8.3	180-600[c]

cfs = cubic feet per second
acre-ft/yr = acre-feet per year
≈ = approximate
TDS = total dissolved solids

pH = acidity
mg/ℓ = milligrams per liter
mg/ℓ as $CaCO_3$ = milligrams per liter as calcium carbonate

[a]Contributed at diversion point.

[b]Calculated from specific conductance.

[c]1973-1974.

TABLE 7-22: ALTERNATIVE WATER SUPPLY COSTS FOR GILLETTE[a]

SERVICE AREA	WATER SOURCES	DIVERSON POINT	COST PER ACRE-FOOT (dollars)
Gillette, Wyoming vicinity and south	Bighorn River	Bighorn Lake	270
	Bighorn River	Hardin, Montana	250
	Yellowstone River	Miles City, Montana	220
	Missouri River	Oahe Reservoir, South Dakota	294
	Green River	Rock Springs, Wyoming	235

Source: Gibbs, Phil Q. "Availability of Water for Coal Conversion," Preprint No. 2561. Paper presented at the American Society of Civil Engineers National Convention, Denver, Colorado, November 1975.

[a]Assumptions - 8 percent interest
8 mills/kilowatt hour for pumping
40 year repayment of capital costs
Flow 300,000-600,000 acre-feet per year

The cost required to bring large quantities of water into Gillette may be such that only a federal organization, such as the Bureau of Reclamation, would be able to finance the construction. However, a consortium of private companies might fund a water system for all the developments and thus be able to take advantage of economies of scale. In effect, this could mean that the timing of facility completions and subsequent start-ups would be at more defined intervals. Several facilities might come on line at the same time to match the completion of an increment of the water supply system. Although the costs shown in Table 7-22 are for a 300,000-600,000 acre-ft/yr delivery rate, this volume may not be provided in one step. Alternatively, individual industries may provide their own water supply systems. The cost of individual systems would be higher but might still be within the economic limits of project feasibility.

In the immediate vicinity of Gillette, the Madison aquifer is too deep (10,000-14,000 feet)[1] for economical use, but about 50 miles to the east the aquifer is only about 1,500 feet from the surface and thus could be economically tapped and pumped by pipeline to the Gillette area. Such a system could be used to supply some of the water needs for energy development.

The water supply system postulated for this scenario assumes that, rather than a single water-supply pipeline, the industries will use various surface and groundwater sources, and water will be pumped to the industrial site. The Lurgi and Synthane gasification plants and the power plant will draw water from the Yellowstone River at Miles City. The Synthoil liquefaction plant and coal slurry facility will take water from the North Platte River near Douglas. Water for the rail transport facility will be taken from local, shallow aquifers in the Fort Union Formation. This water will be obtained from mine dewatering operations. Water for the uranium mill and the natural gas plant will be withdrawn from the Madison limestone aquifer in the vicinity of Sundance.

B. Effluents from Energy Facilities

(1) Coal conversion facilities

The expected amounts of solid effluents produced by coal conversion facilities in the Gillette scenario are shown in Table 7-23. The greatest amount of solid effluents will be produced by the Synthoil plant (more than 2,500 tpd). The 3,000 MWe power plant will produce more than 2,300 tpd of solid effluents, and Synthane and Lurgi plants are each expected to produce more than 1,350 tons of solid effluents per day. The power plant will produce the largest total quantity of dissolved and dry solids (50 and 1,303 tpd), and the Synthoil plant will produce the most wet solids (1,250 tpd).

Dissolved solids are present in the ash blowdown effluent, the demineralizer waste effluent, and the flue gas desulfurization

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[1]Swenson, Frank A. <u>Possible Development of Water from Madison Group and Associated Rock in Powder River Basin, Montana-Wyoming</u>. Denver, Colo.: Northern Great Plains Resources Program, 1974.

TABLE 7-23: EFFLUENTS FROM ENERGY CONVERSION FACILITIES AT GILLETTE[a]

FACILITY TYPE	SOLIDS[a] (tons per day)				WATER IN EFFLUENT[b] (acre-feet per year)
	DISSOLVED	WET	DRY	TOTAL	
Coal[c]					
Lurgi (250 MMcfd)	25	1,186	154	1,365	681
Synthane (250 MMcfd)	25	321	1,014	1,360	924
Synthoil (100,000 bbl/day)	20	1,250	1,249	2,519	864
Electric Power (3,000 MW)	50	958	1,303	2,311	1,827
Uranium[d]					
Surface Mine (1,100 mtpd)	0.8-3.8	0.3	0[e]	1.2-5.1[f]	500-1,600
Mill (1,000 mtpy)	[g]	6[g]	1,000	1,006	500
Solutional Mine-Mill (250 tpy)	7.0	2.2	0.7-1.4[h]	9.8-10.5	125
Natural Gas (250 MMcfd)	0	0	0	0	0

MMcfd = million cubic feet per day
bbl/day = barrels per day
MW = megawatt
mtpd = metric tons per day
mtpy = metric tons per year
tpy = tons per year

[a]These values are given for a day when the facility is operating at full load. In order to obtain yearly values, these numbers must be multiplied by 365 days and by the average load factor. Load factors are 90 percent for synthetic fuels facilities and 70 percent for power plants. The values given as solids do not include the weight of the water in which the solids are suspended or dissolved.

[b]The values for water discharged are annual and take into account the load factor.

[c]These data are from Radian Corporation. The Assessment of Residuals Disposal for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Austin, Tex.: Radian Corporation, 1978. The Radian Corporation report extends and is based on earlier analyses conducted by Water Purification Associates and reported in Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

[d]Calculated from data reported in the Corps of Engineers Discharge Permit Applications.

[e]Overburden could be considered a dry solid effluent. Since it is placed back in the mine, it is not included here.

[f]Total is not the sum of dissolved and wet because it includes volatile solids.

[g]Dissolved and wet solids are included in wet column.

[h]Tailings calculated as 1-2 pounds of dry waste per pound of yellowcake where 250 tons of yellowcake per year is 1,370 pounds per day.

effluent.[1] The principal constitutents of wastewater (which appear as dissolved solids) are calcium, magnesium, sodium, sulfate, and chlorine.

Wet solids from electric power and Lurgi or Synthane gasification facilities are in the form of flue gas sludge, bottom ash, and cooling tower treatment waste sludge. Bottom ash is the primary constituent of wet solids produced by a Synthoil facility. Calcium carbonate ($CaCO_3$) and calcium sulfate ($CaSO_4$) are the primary constituents of flue gas sludge. Bottom ash is primarily oxides of aluminum and silicon. $CaCO_3$ is the principal constituent of the cooling water treatment waste sludge. In all cases, the amount of cooling water treatment waste is very small, compared to the amount of bottom ash and flue gas sludge.

Dry solids produced by coal conversion processes are primarily fly ash composed of oxides of aluminum, silicon, and iron.

Dissolved and wet solids are transported to evaporative holding ponds and later deposited in a landfill. Dry solids are treated with water to prevent dusting and deposited in a landfill.[2]

The water in the effluent stream accounts for between 5 (Synthoil) and 10 percent (Lurgi and Synthane) of the total water requirements of the individual coal conversion facilities (water effluent given in Table 7-23 compared to water requirements in Table 7-19).

(2) Uranium Facilities

Only the uranium mill produces a significant quantity of solids in the form of mill tailings (Table 7-23), but these are still less than solids from coal plants. Water effluent from the surface mine will be ponded. Mill tailings will be disposed of in a landfill. Ponded water has a radium-226 (Ra-226) content of about 100 pCi/ℓ, whereas groundwater is generally about 3.3

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[1]Note that all coal conversion processes generate electicity on-site, thus flue gas cleaning, ash handling, and demineralization are required for all. One exception is the Synthoil proess which uses clean fuel gas for power generation; flue gas cleaning is not required for it. Demineralization is a method of preparing water for use in boilers; it produces an effluent composed of chemicals present in the source water. The ash blowdown stream is the water used to remove bottom ash from the boiler. Bottom ash removal is done via a wet sluicing system using cooling tower blowdown water. Thus, the dissolved solids content of the stream is composed of chemicals from the ash and cooling water.

[2]The environment problems associated with solid waste disposal in holding ponds and landfills are discussed in Chapter 10.

pCi/ℓ. In order to prevent groundwater contaminants, the radium is treated in the pond, precipitated, and later transferred to a landfill along with the mill tailings.

Effluents from the solutional uranium leaching operation are similar to those from the mill, except that mill tailings are reduced significantly (Table 7-23). A solutional facility produces 1 to 2 pounds of tailings per pound of yellowcake, whereas a normal milling operation produces 300 pounds of tailings per pound of yellowcake.

7.3.4 Impacts

This section describes water impacts which result from the coal surface mines, gas wells, conversion facilities, coal rail transport, coal slurry pipeline, and uranium facilities and from the combination of facilities in the Gillette scenario. The water requirements and impacts associated with expected population increases are included in the scenario impact description.

A. Coal, Uranium, and Gas Extraction Impacts

The surface coal mines may have several disturbing effects on the local Fort Union Formation aquifers. The coal mines will probably intersect either perched or water-table aquifers and disrupt aquifer flow patterns. If the mine is below the water table (the coal seams are aquifers in parts of the Fort Union Formation), mine dewatering will be necessary, and depletion of the aquifers will result. Discharges from mine dewatering probably will not exceed 500 gpm. Local springs and seeps on hillsides may dry up, and water levels in local wells may be lowered. Additionally, the base flow of streams in the area may be reduced. To comply with the zero-discharge provisions of current legislation, water from dewatering will be used for dust control and washing or will be reinjected in Fort Union aquifers far enough down-gradient to prevent recycling of water to the mine. Thus, the only loss to the aquifers will be local. After the coal slurry pipeline begins operation in 1985, reinjection can be discontinued, and the water from dewatering can be piped to the slurry preparation plant for use as process water.

Depending on the composition of the overburden, weathering and oxidation of the spoil material may result in the release of contaminants. Both natural precipitation and water added for revegetation may pick up the contaminants and transport them into local aquifers. Aquifers in the immediate mine area will be affected the most. Aquifers in coal beds that are mined will be destroyed, and aquifers in the overburden will experience large changes in such properties as porosity and permeability. No alluvial aquifers are close enough to the mine to be affected by mining operations.

Surface water drainage patterns will be affected by mine excavations, some of which will trap runoff. Unless these mines are pumped out regularly, some of the impounded water may eventually percolate into the groundwater system but should not produce any significant impacts. Losses in runoff due to mine excavation are not expected to be significant locally because area streams are ephemeral and runoff flow would quickly dry up in any case.

As the mines continue to operate, reclamation efforts will increase and larger water requirements must be satisfied. This could be accomplished by the use of water from mine dewatering and from wastewater treatment plant effluent at Gillette (see Table 7-22).

Solutional uranium leaching operations will produce impacts on both surface and groundwater systems. Construction activities will remove vegetation and disturb soils over a small area. Drilling activities will cause intermittent disturbances of surface water. The potential exists for excessive sediment delivery during storms to Willow Creek and the Powder River. However, due to the present sparse vegetation and current high rate of sediment delivery during storms, significant impacts from the facility's construction are not anticipated.

Wastes from the solutional uranium mining facility will be stored in plastic-lined, temporary retention ponds on the site. The liquid will be allowed to evaporate, and no effluent will be discharged to surface waters. Another disposal alternative would be to use the liquid wastes for irrigation. The possibility of mineralogical and radiological pollution of the Powder River makes this an unlikely alternative.

Impacts on the groundwater system can occur from the subsurface solutional leaching process or from the leaching of residuals generated from the processing of the ore at a disposal site. The most significant potential impacts relate to reductions in the water quality of the Wasatch aquifer.

The gas wells will have little or no impact on local surface water or groundwater systems, provided that proper well drilling and completion practices are used.

B. Energy Conversion Facilities and Coal Export Impacts

Annual average water requirements (assuming expected load factors and high wet cooling, see Table 7-19) range from a low for Lurgi gasification of 5,823 acre-ft/yr to a high for a power plant of 25,842 acre-ft/yr. Any one facility, then, would withdraw a small percentage of the Yellowstone River's average annual flow of 8,200,000 acre-ft/yr. On the other hand, worst case conditions, when a facility is operating at the expected load factor on a day when its water source was at low flow, could be significant. Low flow on the Yellowstone is 5,135 cubic feet per second (cfs) and on the North Platte is 176 cfs (Table 7-21).[1] Withdrawals by any one energy facility operating at the expected load factor range from 0.1 to 0.7 percent of the Yellowstone's low flow and from 4.8 to 21.3 percent of the North Platte's low flow (Lurgi and a power plant respectively). Since each of the facilities will have on-site reservoirs, withdrawals could be reduced during low-flow periods when the plants would draw from the reservoirs.

The situation in the North Platte could be further ameliorated if water were released into it from upstream reservoirs (such as the Pathfinder Reservoir or Seminole Reservoir). Alternatively, water could be conveyed from the Green River to the North Platte to augment flows or to supply water to the facilities (see Figure 7-6). The impact of these withdrawals on the North Platte River during low-flow periods could be significant both in terms of flow depletion and from salt-concentrating effects. Alternate surface sources (such as a pipeline from Lake Oahe on the Upper Missouri River in South Dakota) or the use of groundwater to meet part of the needs may be necessary. Since the Gillette coal slurry and Synthoil facilities are outside the Yellowstone River Basin, Wyoming cannot transfer Yellowstone River water to the facilities without the consent of Montana and North Dakota. In any case, Wyoming can only use water that has been allocated to it by the Yellowstone Compact. Agreements will have to be made for Wyoming to remove water from the Yellowstone River in Montana.

The uranium mine and facilities will use local groundwater, i.e., the Madison aquifer in the vicinity of Sundance, and are therefore not expected to have a significant impact on surface water. The mill's withdrawal of 1,350 acre-ft/yr of water (Table 7-19) may contribute to the depletion of the Madison aquifer. About 1,000 tpd of solid wastes in the form of processing tailings will be produced by the uranium mill (Table 7-23). These tailings will be disposed of in tailings ponds that will also be used for the disposal of liquid and solid chemical and radiological wastes.[2] These wastes may pose a particularly large hazard to local aquifers should the tailings ponds leak. The degree of the hazard depends on the chemistry and radiology of the tailings and other wastes deposited in the ponds. The effectiveness of any pond liners provided will also strongly influence the degree of hazard.

No significant impact on surface water is expected from other plant effluents because discharge technology that meets the goals of the Federal Water Pollution Control Act Amendments of 1972

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[1]For comparison with withdrawals given in Table 7-19, 5,135 cfs converts to 3,720,000 acre-ft/yr and 176 cfs converts to 127,512 acre-ft/yr; in general, 724.5 acre-ft/yr equals 1.0 cfs.

will be used. Pollution prevention systems include the discharge of all effluents into clay-lined, on-site evaporative holding ponds to prevent contamination of local surface water or groundwater systems, although pond liners may leak pollutants to local aquifers.[1] Runoff retention facilities will also be used.

C. Scenario Impacts

Water impacts resulting from interactions among the hypothesized facilities and their associated mines and water impacts resulting from associated population increases are discussed in this section.

Water requirements for direct use by these hypothesized energy facilities (assuming high wet cooling) will be at least 56,400 acre-ft/yr in 1990 when the power plant, Lurgi plant, coal slurry pipeline, uranium mine and mill, solutional uranium mine-mill, and natural gas production are operating, and 82,900 acre-ft/yr in 2000 when all hypothesized scenario facilities are operating. Additional water (about 5 percent of the water requirement for the facilities in 2000) may be required for mine reclamation purposes.

Most of the municipal water supply will probably be taken from groundwater supplies. Although the water supply for Gillette is presently derived from a local well field, water probably will be pumped in the future from the Madison aquifer in the vicinity of Sundance. Additional water for Casper will be obtained by increased development of existing sources. Water requirements for increased population growth are shown in Table 7-24.

Wastewater from the energy facilities which will be impounded in evaporation ponds will average 4,100 acre-ft/yr by 1990 and 5,900 acre-ft/yr by 2000.[2]

Rural populations are assumed to use individual, on-site waste disposal facilities (septic tanks and drainfields), and the urban population will require waste treatment facilities. The current status of wastewater treatment facilities in the municipalities most affected by energy development activities is indicated in Table 7-25. Increases in wastewater resulting from energy development-induced population increases are portioned as shown in Table 7-26.

New wastewater treatment facilities adequate to meet the demands generated by these hypothetical developments and the

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[1]See Chapter 10 for a discussion of the environmental problems associated with evaporative holding ponds.

[2]Values from Table 7-23.

TABLE 7-24: EXPECTED WATER REQUIREMENTS FOR INCREASED POPULATION (acre-feet per year)[a]

YEAR	RURAL[b] CAMPBELL COUNTY	GILLETTE[c]	CASPER[d]	TOTAL
1980	85	3,400	490	3,975
1990	170	8,198	1,510	9,878
2000	286	14,873	2,370	17,529

[a]Above 1975 level.

[b]Based on 80 gallons per capita per day.

[c]Based on 240 gallons per capita per day.

[d]Based on 200 gallons per capita per day. U.S., Department of the Interior, Geological Survey. Estimated Use of Water in the United States in 1970, Circular 676. Washington, D.C.: Government Printing Office, 1972.

associated population increases should be planned for Gillette by 1980. These facilities must use the "best practicable" waste treatment technology to conform to 1983 standards and must allow for recycling or zero discharge of pollutants (ZDP) to meet 1985 goals.[1] The 1985 goal could be met by using effluents from the waste treatment facility for industrial process make-up water or for irrigating local farmland. The energy development postulated in this scenario should not require any increase in wastewater treatment capacity for Casper.

(1) To 1980

The gas wells and the coal mine for rail transport will be constructed and in operation by 1980. The mine which will disturb about 200 acres per year will trap runoff and thus affect the local ephemeral stream drainage pattern. Prior to 1980, revegetation will not have been initiated, and water will be required only for dust suppression. Trapped runoff in conjunction with water from dewatering operations will be used for dust suppression. By 1980, natural gas production will require 380 acre-ft/yr of water (Table 7-19); this quantity is assumed to be withdrawn from the Madison aquifer.

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[1]Federal Water Pollution Control Act Amendments of 1972, §§ 101, 301, 33 U.S.C.A. §§ 1251, 1311 (Supp. 1976).

TABLE 7-25: WASTEWATER TREATMENT CHARACTERISTICS OF COMMUNITIES AFFECTED BY ENERGY DEVELOPMENT AT GILLETTE[a]

	GILLETTE	CASPER
Type of Treatment	Extended Aeration	Adding secondary treatment to existing facility
Design Load	1.2 MMgpd (1.6 with modification)	10 MMgpd
Current Load	1.3 MMgpd	7 MMgpd
Future Plans	Powder River Areawide Planning Organization in Sheridan doing 208[b] planning; Step 1 of 201 is being done[c]	None at present

MMgpd = million gallons per day

[a]Water Quality Division of Department of Environmental Quality.

[b]Refers to Federal Water Pollution Control Act Amendments of 1972, Pub. L. 92-500, § 208, 33 U.S.C.A. § 1288 (Supp. 1976), which encourages areawide waste treatment management.

[c]*Ibid.*, § 201, 33 U.S.C.A. § 1281 (Supp. 1976), which provides grants for construction of treatment works.

TABLE 7-26: EXPECTED WASTEWATER FLOWS FROM INCREASED POPULATION

INCREASED FLOW ABOVE 1975 LEVEL (million gallons per day)		
YEAR	GILLETTE[a]	CASPER[b]
1980	1.01	0.20
1990	2.44	0.61
2000	4.42	0.95

[a]80 gallons per capita per day.

[b]90 gallons per capita per day.

The increase in population associated with the Gillette scenario will require an additional 4,000 acre-ft/yr of water by 1980 (see Table 7-24).[1] This additional water will be taken either from local aquifers in the Fort Union Formation or from the Madison aquifer in the vicinity of Sundance. A well or well field capable of producing about 870 gpm will be required. This well represents a significant withdrawal, especially from the local Fort Union aquifers. Some of the population increase will take place in rural areas, rather than in Gillette. The increased withdrawal of groundwater at individual homesites is not expected to be significant.

Contamination of local bedrock aquifers from septic tank systems associated with rural homesites may pose a significant water quality problem where the housing and septic tank densities become great enough to exceed the natural renovation capacity of the substrata. The Gillette area has an expansive clay soil that is not especially desirable for septic tank drainage fields and may become clogged or overloaded.

The increased capacity requirement for wastewater treatment will be about one million gallons per day (MMgpd). This will necessitate construction of a new treatment facility at Gillette or expansion of the existing facility. Unless new facilities come on-line to meet these requirements, some surface water pollution may result from overloads and/or bypasses.

(2) To 1990

The coal mines and energy conversion and transportation facilities for the slurry pipeline, the 3,000 MWe power plant, the Lurgi high-Btu gasification plant, the uranium mine and processing mill, and the solutional uranium facility will be in operation by 1985.

By 1990, the coal mines for the facilities in operation will have disturbed a total of 4,275 acres (calculated from Table 7-20). Total annual water consumption will be 56,400 acre-ft/yr of which 36,100 will be withdrawn from the Yellowstone River (for the power plant and Lurgi facility), 18,390 will be withdrawn from the North Platte River (for the slurry pipeline), and 1,900 from the Madison aquifer (for uranium processing and solutional uranium mine and natural gas production).[2] Total withdrawal from the Yellowstone

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[1]Population increases induced by secondary industries are not included in this estimate.

[2]All numbers assume expected average load factors and wet coolers. Power plant and Lurgi data are Water Purification Associates high wet cooling; others, Energy Research and Development Systems wet cooling.

River represents 0.8 percent of its low flow, and total withdrawal from the North Platte River represents 14.4 percent of its low flow.

During the 1980-1990 period, the municipal requirements for water at Gillette will increase to 8,200 acre-ft/yr. This increased withdrawal, which is equivalent to about 5,020 gpm, presents a significant possibility for aquifer depletion from either the local well field or the Madison aquifer near Sundance. Because both Gillette and Casper are projected to use groundwater as a source for municipal needs, there will be no major impacts on local surface water hydrology as a result of withdrawals.

Increased capacity requirements for both water supply and wastewater capacities will be needed. Both cities may be able to sell effluents for reclamation or irrigation and thus satisfy the requirements for ZDP.

Runoff will be increased by the expansion of existing towns, and some lowering of the water quality in nearby streams is expected from this.

The potential for aquifer pollution from increased septic tank use in rural areas will be similar to that described for the preceding decade but will be larger in magnitude.

(3) To 2000

The coal mine and conversion facility for the Synthane plant will be operating by 1995. The Synthoil operation will be in production by 2000. The other energy conversion facilities, their associated mines, and the gas wells will continue operation during this decade, so that all hypothesized facilities will be in operation in 2000.

By 2000, a total of 11,050 acres will have been disturbed by the coal mines (calculated from Table 7-20). Disturbed land will impound runoff water and thus reduce the amount of water available to local streams. Total annual water consumption is about 82,900 acre-ft/yr of which 45,200 acre-ft/yr will be withdrawn from the Yellowstone River (for the power, Lurgi, and Synthane plants), 35,800 acre-ft/yr will be withdrawn from the North Platte River (for the Synthoil plant and coal slurry pipeline), and 1,900 acre-ft/yr will be withdrawn from the Madison aquifer (for uranium operations and natural gas production).

Total withdrawal from the Yellowstone River represents 1.0 percent of its low flow, and total withdrawal from the North Platte River represents 22.5 percent of its low flow. In addition, reclamation of coal mines may require 3,200 acre-ft/yr.

Municipal requirements for water will increase to 14,900 acre-ft/yr at Gillette and 2,400 acre-ft/yr at Casper (Table 7-24) due to the population increases from the energy conversion facilities. This increased withdrawal will lower groundwater levels, especially in the shallow aquifers in the Gillette area and the Madison aquifer near Sundance. To meet these water needs, either the well field in the vicinity of Sundance could be expanded or surface water pipelines could be used to import water.

Wastewater treatment facilities at Gillette must be expanded to accommodate the additional needs (see Table 7-25). Effluents will continue to be used for reclamation or irrigation and thereby satisfy the requirements for ZDP by 1985.

Runoff from urban expansion will continue to increase resulting in further lowering of the water quality in nearby streams. The potential for aquifer pollution from increased use of septic tanks by rural populations will increase as in previous decades.

(4) After 2000

The mines will continue to operate with the same impacts as stated in the 1990-2000 decade until they are exhausted. Although many areas will be reclaimed and revegetated after the mines and their associated energy conversion facilities are decommissioned, irrigation of the areas will cease, some vegetation will be lost, and erosion will increase. After the mines shut down and are recontoured and revegetated, disruption of shallow aquifer systems will continue, and surface flows will continue to be modified both in volume and quality.

After the energy conversion facilities are shut down, the berms around the ponds will probably lose their protective vegetation and erode, eventually resulting in breaches in the berms. When this happens, the materials within the pond site will erode and enter the surface water system or percolate into the groundwater aquifers. The low precipitation in the scenario area will be a retarding factor in the transport of these materials.

Population levels will remain stable at least until the mines and associated energy conversion technologies are decommissioned. Thus, groundwater depletions will continue, and there will be a reduction in the quality of surface water resources in the vicinity of Gillette and Casper due to runoff from the population increases. The amount of water in any surface water sources used to supply municipal needs will also be reduced.

7.3.5 Summary of Water Impacts

Water impacts are caused by (1) the water requirements of and effluents from the energy facilities, (2) the water requirements of and wastewater generated by associated population increases, and (3) the coal and uranium mining processes.

The impacts of the water requirements of the energy facilities depend largely on the source of that water. In the immediate vicinity of Gillette, supplies of groundwater and surface water are insufficient; and water must be imported by pipeline from such sources as the Yellowstone River and its tributaries (Clarks Fork, Bighorn, Tongue, and Powder), Belle Fourche River, Green River, North Platte River, and Lake Oahe on the Upper Missouri River in South Dakota. The cost for this water will vary with the distance from the facility site. However, before these sources can be used for energy development, legal restrictions from several compacts need to be lifted.

This analysis hypothesized that water for energy development would be withdrawn from several sources including the Yellowstone River, the North Platte River, the Madison limestone aquifer, and shallow aquifers in the Fort Union Formation. Under a worst-case condition, when any one facility was operating at the expected load factor on the day when the river was at low flow, the facility would withdraw from 4.8 to 21.3 percent (Lurgi-power plant) of the North Platte and 0.1 to 0.7 percent of the Yellowstone River. Average withdrawals are considerably lower percentages of the annual average flow rates on the rivers. The average flow rate on the Yellowstone is 8,200,000 acre-ft/yr. Annual average withdrawals by energy facilities (assuming they are high wet cooled and operating at expected annual average load factors) are: for Lurgi-5,823 acre-ft/yr; for Synthane-7,776 acre-ft/yr; for Synthoil-9,227 acre-ft/yr; for the power plant-25,842 acre-ft/yr; for the slurry pipeline-18,390 acre-ft/yr; for uranium production-1,350 acre-ft/yr; solutional uranium facility-200 acre-ft/yr; and for natural gas production-380 acre-ft/yr. The use of intermediate wet cooling by these facilities operating at expected load factors can reduce these requirements by 19 to 75 percent. The energy development hypothesized in this scenario analysis which calls for the power, Lurgi, and Synthane plants to obtain water from the Yellowstone River and the Synthoil plant and slurry pipeline to obtain water from the North Platte River would require 1.1 percent of the Yellowstone River flow and 21.6 percent of the North Platte under worst-case conditions (expected load factors and low flow on the rivers). The impact of these withdrawals on the North Platte River during low-flow periods could be significant in terms of flow depletion and salt-concentrating effects. Alternate surface sources or the use of groundwater to meet part of the needs may be necessary. Similarly, the water requirement of the uranium mill is expected to contribute to the depletion of its water source, the Madison aquifer.

Solid effluents from the following energy facilities in tpd average 2,300 from the power plant, 2,500 from the Synthoil plant, slightly less than 1,400 from the Synthane plant and Lurgi plant, 1,000 from the uranium mill, and 10 from the solutional uranium facility. The objective of ZDP set forth in the Federal Water Pollution Control Act[1] will necessitate on-site entrapment and disposal of effluents. Therefore effluents will be discharged into clay-lined, on-site evaporative holding ponds. Furthermore, runoff prevention systems will be installed to direct runoff to a holding pond or to a water treatment facility. These methods protect the quality of surface water systems (at least for the life of the plants), but groundwater quality may be reduced by leakage and leaching from the disposal ponds and pits. Similarly, dry solid wastes such as the tailings produced by the uranium mill will be disposed of in tailing ponds which may pose a particularly large hazard to local aquifers should the tailing pond leak.

By the year 2000, municipal water use will total 17,493 acre-ft/yr in the scenario area due to energy-related increases in population. Most of the municipal water supply will be taken from groundwater supplies. The population increase in Gillette will increase the water requirement significantly (by 14,837 acre-ft/yr) and may contribute to depletion of local aquifers and the Madison aquifer. Also, Gillette will need new wastewater treatment facilities (4.4 MMgpd) by the year 2000.

The surface coal mines may have several disturbing effects on the local Fort Union Formation and Wasatch aquifers. The coal mines will probably intersect aquifers and disrupt their flow patterns. If mine dewatering is necessary, aquifer depletion may result. Local springs and seeps on hillsides may dry up, water levels in local wells may be lowered, and the base flow of streams in the area may be reduced. Moreover, natural precipitation and water added for revegetation may pick up contaminants from mining activities and transport them to local aquifers.

By the year 2000, about 11,050 acres will have been disturbed by the coal mines. Disturbed land will impound runoff water and thus reduce the amount of water available to local, ephemeral streams. The change in local stream flow patterns will, in turn, affect wildlife habits.

7.4 SOCIAL AND ECONOMIC IMPACTS

7.4.1 Introduction

All the hypothetical developments in the Gillette scenario will occur in Campbell County in northeast Wyoming. This area experienced an oil and gas boom in the 1960's, followed by a population decline in the latter part of that decade. The current coal boom began in the early 1970's, and the area's

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[1]Federal Water Pollution Control Act Amendments of 1972, Pub. L. 92-500, §§ 101, 301, 33 U.S.C.A. §§ 1251, 1311 (Supp. 1976).

population was twice that of 1960. With the hypothetical development included in this scenario, the population will continue to increase but at an accelerated rate. Most of the social and economic impacts in the area will be related to population growth.

7.4.2 Existing Conditions

Campbell County has an area of 3 million acres. In 1974, its population was 12,000 by U.S. Census Bureau estimates, giving it a population density of 2.7 persons per square mile. Local estimates run as high as 17,000 for 1975. More than 80 percent of the population is centered in the only incorporated city, Gillette, which is the county seat. Since much of the population growth has occurred as a consequence of energy development, the population is disproportionately young and male.

Table 7-27 gives the employment distributions in Gillette during 1970 and in Campbell County during 1970 and 1975. As shown, construction, mining, and services are the major employers. Gillette also receives some economic benefit from hunters and tourists en route to Devil's Tower National Monument, the Black Hills, and Bighorn National Forest. Due to its location on Interstate 90, Gillette also serves some visitors to Yellowstone and Grand Teton National Parks.

Campbell County is governed by a board of three county commissioners elected at large for 4-year terms. The incumbents currently are all ranchers, indicating that long-time residents of the area have not been displaced by newcomers as quickly as might be expected with a rapid influx of new population.

The county provides few services by itself, in part because they are provided by the state (social and health services) or by the city and county jointly under the Wyoming Joint Powers Act.[1] The school system is countywide, and fire protection and airport services are provided cooperatively by the city and county. The city and county also cooperate in planning, animal control, park maintenance, and snow removal. As noted earlier, Campbell County now provides about one-third of the support for the city of Gillette Department of Planning and Development, which is responsible for planning, zoning administration, city engineering, and building inspection. The staff consists of a planner, assistant planner, planning intern, city engineer, and several building inspectors.

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[1]This act gives county and/or city governments the powers of both governments when they work together. For a description of this legislation, see Hayen, Roger L., and Gary L. Watts. A Description of Potential Socioeconomic Impacts from Coal-Related Developments in Campbell County, Wyoming. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, pp. 70-71.

TABLE 7-27: EMPLOYMENT DISTRIBUTION BY INDUSTRY FOR 1970 AND 1975

INDUSTRY	CAMPBELL COUNTY 1970		CAMPBELL COUNTY 1975	
	NUMBER	PERCENT	NUMBER	PERCENT
Agriculture	601	12.5	579	8.4
Mining	1,323	27.5	1,406	20.3
Construction	268	5.6	1,604	23.1
Manufacturing	156	3.2	168[a]	2.4
Transportation	359	7.5	457	6.6
Communication and Utilities	96	2.0	175	2.5
Wholesale Trade	129	2.7	164	2.4
Retail Trade	706	14.4	898[b]	12.9
Finance, Insurance, and Real Estate	162	3.4	206	3.0
Services	907	18.9	1,154[c]	16.6
Public Administration	96	2.0	122	1.8
Total	4,803	99.7	6,933	100.0

Source: 1970 - U.S., Department of Commerce, Bureau of the Census. Census of Population: 1970 General Social and Economic Characteristics. Washington, D.C.: Government Printing Office, 1971.

1975 - Estimated from Matson, Roger A., and Jeanette B. Studer. Energy Resources Development in Wyoming Powder River Basin: An Assessment of Potential Social and Economic Impacts, prepared for Northern Great Plains Resources Program. Cheyenne, Wyo.: University of Wyoming, Water Resources Research Institute, 1974, p. 80.

[a]Mostly nonelectric machinery.

[b]Mostly motor vehicles and service stations.

[c]To a large extent in public schools.

Gillette is governed by a part-time mayor and six councilmen who are elected for 4-year terms. The city also has a full-time city administrator. In addition to those services provided jointly with the county, the city provides its residents sewer, garbage, and electrical services. The electrical utility was recently expanded, but the city's application to the Economic Development Administration (EDA) for $2 million to fund the extension and improvement of its sewage treatment facilities has been denied. The sewer system has recently been expanded through loans from the Wyoming Farm Loan Board.

The single countywide school district has met the needs of a growing population. In Gillette, two new elementary schools and a junior high school have been built, and two existing elementary schools have been enlarged. In large part, education problems have been minimal because the rate of population growth has been relatively steady and because the county's tax base has expanded with energy development.

In addition to the help provided by the state under the programs mentioned above, Gillette receives assistance from the Gillette Human Services Project, staffed by recent graduates of the University of Wyoming. This program (funded by EDA, state revenue sharing funds, the Campbell County Children's Center, and some energy developers) provides research assistance for finding solutions to growth-related problems and also provides extra manpower to human service agencies in impacted communities.[1]

7.4.3 Factors Producing Impacts

Two factors associated with energy facilities dominate as the cause of social and economic impacts: manpower requirements and taxes levied on energy facilities. Tax rates are tied to capital costs, and/or the value of the coal extracted, and/or the value of energy produced. Taxes which apply to the Gillette scenario facilities (power plant, Lurgi plant, Synthane plant, Synthoil plant, coal rail transport, coal slurry pipline, gas wells, and a uranium mill) and their associated mines are: a property tax, sales tax, severance tax, and royalty payments on federally owned coal.

The manpower requirements for each scenario facility and its associated mine are given in Tables 7-28 to 7-35. For the coal mines and the uranium mines, manpower requirements for operation exceed peak construction manpower requirements by two times. However, the reverse is true for the power, Lurgi, Synthane, and

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[1]See Uhlmann, Julie M. Gillette Human Services Project, Annual Report, August 31, 1976. Laramie, Wyo.: University of Wyoming, Wyoming Human Services Project, 1976.

TABLE 7-28: MANPOWER REQUIREMENTS FOR A 3,000 MEGAWATT POWER PLANT AND ASSOCIATED MINE[a]

YEAR FROM START	CONSTRUCTION WORK FORCE		OPERATION WORK FORCE		TOTAL IN ANY ONE YEAR
	MINE	POWER PLANT	MINE	POWER PLANT	
1		0			0
2		40			40
3	0	420			420
4	36	905			941
5	211	1,315		0	1,526
6	205	2,265	0	109	2,579
7	211	2,545	275	109	3,140
8	169	1,990	275	218	2,652
9	0	720	552	436	1,708
10	0	0	552	436	988

MWe = megawatt-electric

[a]Data are for a 3,000 MWe power plant and a surface coal mine large enough to supply that power plant (about 12.8 million tons per year) and are from Carasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975; data uncertainty is -10 to +20 percent.

Synthoil plants and the gas wells. The peak construction manpower requirements for these facilities exceed the operation requirements by 1.7 (Synthoil plant) to 7 times (Lurgi and Synthane plants). In combination, the total manpower requirement for each coal mine-conversion facility increases from the first year when construction begins, peaks, and then declines as construction activity ceases. Peak total manpower requirements for the Lurgi, Synthane, and Synthoil mine-plant combinations are about 5,000, and, for the power plant, about 3,100. The fraction of the peak total manpower requirement needed for operation of the mine-plant combination ranges from 0.2 for the Lurgi and Synthane plants to 0.6 for the Synthoil plant. The total manpower required for operation of the Synthoil facility and its associated mine is more than three times that of the other plant-mine combinations.

Property and sales taxes, which are tied to capital costs of the facilities, and a severance tax and royalty payments, which are tied to the value of coal, generate revenue for the state and local governments.

TABLE 7-29: MANPOWER REQUIREMENTS FOR A LURGI PLANT AND ASSOCIATED MINE[a]

YEAR FROM START	CONSTRUCTION WORK FORCE		OPERATION WORK FORCE		TOTAL IN ANY ONE YEAR
	MINE	LURGI PLANT	MINE	LURGI PLANT	
1	0	0			0
2	29	36			65
3	169	609			778
4	164	2,687	0		2,851
5	169	4,682	220	0	5,071
6	135	2,662	220	589	3,606
7	0	0	442	589	1,031
8			442	589	1,031

[a]Data are for a Lurgi plant and a coal mine large enough to supply that plant (about 9.4 million tons per year) and are from Carasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975; data uncertainty is -10 to +20 percent.

TABLE 7-30: MANPOWER REQUIREMENTS FOR A SYNTHANE PLANT AND ASSOCIATED MINE[a]

YEAR FROM START	CONSTRUCTION WORK FORCE		OPERATION WORK FORCE		TOTAL IN ANY ONE YEAR
	MINE	SYNTHANE PLANT	MINE	SYNTHANE PLANT	
1	0	0			0
2	25	36			61
3	148	609			757
4	144	2,687	0		2,831
5	148	4,682	192	0	5,022
6	118	2,662	192	589	3,561
7	0	0	386	589	975
8			386	589	975

[a]Data are for a Synthane plant and a surface coal mine large enough to supply that Synthane plant (about 8.1 million tons per year) and are from Carasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975; data uncertainty is -10 to +20 percent.

TABLE 7-31: MANPOWER REQUIREMENTS FOR A SYNTHOIL PLANT AND ASSOCIATED MINE[a]

YEAR FROM START	CONSTRUCTION WORK FORCE		OPERATION WORK FORCE		TOTAL IN ANY ONE YEAR
	MINE	SYNTHOIL PLANT	MINE	SYNTHOIL PLANT	
1		0			0
2		62			62
3	0	598			598
4	36	2,247			2,283
5	211	4,283			4,494
6	205	5,003	0		5,208
7	211	3,503	275	0	3,989
8	169	1,081	275	1,467	2,992
9	0	0	552	2,935	3,487

[a]Data are for a Synthoil plant and a surface coal mine large enough to supply that Synthoil plant (about 12.1 million tons per year) and are from Carasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975; data uncertainty is -10 to +20 percent. Synthoil data have a high uncertainty because of the small capacity of the bench scale test facilities built to date. The Solvent Refined Coal Liquefaction process now appears likely to become commercial sooner, and more reliable pilot plant data are available. These data are reported in White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 3.

TABLE 7-32: MANPOWER REQUIREMENTS FOR A SURFACE COAL MINE FOR RAIL TRANSPORT OR SLURRY PIPELINE[a]

YEAR FROM START	CONSTRUCTION WORK FORCE[b]	OPERATION WORK FORCE[b]	TOTAL IN ANY ONE YEAR
1	0		0
2	72-108		72-108
3	422-633		422-633
4	410-615	0	410-615
5	422-633	550-825	972-1,458
6	338-507	550-825	888-1,332
7	0	1,104-1,656	1,104-1,656
8		1,104-1,656	1,104-1,656

[a]Data are for a large surface coal mine for coal export (about 25 million tons per year) via rail transport or slurry pipeline and are from Carasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975; data uncertainty -10 to +20 percent.

[b]Manpower required for construction or operation of the surface coal mine is given as a range since it depends on seam thickness, which is highly variable at Gillette.

TABLE 7-33: MANPOWER REQUIREMENTS FOR GAS WELLS[a]

YEAR FROM START	CONSTRUCTION WORK FORCE[b]	OPERATION WORK FORCE[b]	TOTAL IN ANY ONE YEAR
1	0		0
2	144		144
3	729	0	729
4	1,695	58	1,753
5	1,488	314	1,802
6	0	790	790
7		790	790

[a]Data are for 83 gas wells with a combined production of 250 million standard cubic feet per day and are from Carasso, M., et al. The Energy Supply Planning Model. San Francisco, Calif.: Bechtel Corporation, 1975; data uncertainty is -10 to +20 percent.

TABLE 7-34: MANPOWER REQUIREMENTS FOR A URANIUM MILL AND ASSOCIATED MINE[a]

YEAR FROM START	CONSTRUCTION WORK FORCE		OPERATION WORK FORCE		TOTAL IN ANY ONE YEAR
	MINE	URANIUM MILL	MINE	URANIUM MILL	
1	0				0
2	57				57
3	65	0	178	111	354
4	81	22	178	111	392
5	70	117	178	111	477
6	5	10	178	111	304
7	0	0	178	111	289

[a]Data are for a uranium mill and a surface uranium mine large enough to supply that mill (about 1,000 metric tons per year) and are from Carasso, M., *et al*. *The Energy Supply Planning Model*. San Francisco, Calif.: Bechtel Corporation, 1975; data uncertainty is -10 to +20 percent.

TABLE 7-35: MANPOWER REQUIREMENTS FOR A SOLUTIONAL URANIUM MINE[a]

YEAR FROM START	CONSTRUCTION WORK FORCE	OPERATION WORK FORCE	TOTAL IN ANY ONE YEAR
1	50	0	50
2	20	60	70
3	0	60	60
4	0	60	60

[a]Data are for a 250 ton per year *in situ* solutional mining operation and are from Larson, W.C., Geologist, Twin Cities Mining Research Centers, U.S. Bureau of Mines. Personal communication, November 23, 1977.

The capital costs of the conversion facilities and mines hypothesized for the Gillette scenario are given in Table 7-36. Costs range from 8 to 30 (uranium facilities) to 2,170 million 1975 dollars (mine-Synthoil plant facility). Property tax, most of which goes to local government, is levied on the cash value of the facility (approximately the total capital cost given in Table 7-36) after construction of the facility is completed. Sales tax, most of which goes to the state government, is levied on materials and equipment only (Table 7-36) as these materials and equipment are purchased during construction. The current sales tax rate in Wyoming is 4 percent, and the property tax rate in Campbell County is about 2.52 percent.[1] In addition, there is a severance tax levied at a rate of 3.5 percent on the value of the coal mined. This revenue will be used for loans to the local government with interest going to the state government. Royalty payments are about 12.5 percent of the value of federally owned coal,[2] of which 50 percent is returned to state and local government.

7.4.4 Impacts

The nature and extent of the social and economic impacts caused by these factors depend on the size and character of the community or communities in which workers and their families live, on the state and local tax structure, and on many other social and economic factors. A scenario, which calls for the development of power, Lurgi, Synthane, and Synthoil plants, coal rail transport, coal slurry pipeline, gas wells, uranium mines, and a mill according to a specified time schedule (see Table 7-1), is used here as a vehicle through which the nature and extent of the impacts are explored. The discussion relates each impact type to the hypothetical scenario and includes population impacts, housing and school impacts, economic impacts, fiscal impacts, social and cultural impacts, and political and governmental impacts.

A. Population Impacts

In this scenario, the principal initial impact of energy development on Gillette and northern Wyoming was from the workers associated with the construction of an export surface coal mine in 1975 and with gas drilling activities in 1976. The employment related to the eight scenario developments is summarized in Table 7-37. The cyclincal nature of the construction activity is

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[1]This is the effective, average property tax rate. The actual tax rate is computed using a number of assessment ratios, since certain kinds of equipment (e.g., pollution control equipment) are taxed at different rates or may be exempt.

[2]This is the federal government target rate; actual rates will vary from mine to mine.

TABLE 7-36: CAPITAL RESOURCES REQUIRED FOR CONSTRUCTION OF FACILITIES (in millions of 1975 dollars)[a]

FACILITIES	MATERIALS AND EQUIPMENT	LABOR AND OTHER	INTEREST DURING CONSTRUCTION	TOTAL
Coal Conversion Facilities				
Power Plant (3,000 MWe)	461	461	394	1,316
Lurgi or Synthane Gasification Plant (250 MMcfd)	469	369	219	1,057
Synthoil Plant (100,000 bbl/day)	689	832	649	2,170
Associated Surface Coal Mines				
For Power Plant (12.8 MMtpy)	72	39	33	144
For Lurgi Plant (9.4 MMtpy)	52	28	24	104
For Synthane Plant (8.1 MMtpy)	46	26	21	93
For Synthoil Plant (12.1 MMtpy)	65	35	30	130
Surface Coal Mine for Coal Export via rail transport or slurry pipeline (25 MMtpy)	137	74	63	274
Uranium Mine and Mill (1,000 mtpy)	8	16	6	30
Uranium Mine (Solutional, 250 mtpy)	2	4	2	8

MWe = megawatt-electric
MMcfd = million cubic feet per day
bbl/day = barrels per day
MMtpy = million tons per year
mtpy = metric tons per year

[a]Data are adjusted (assuming linearity) to correspond to the facility size hypothesized in this scenario and are from Carasso, M., et al. The Energy Supply Planning Model. San Francisco, Calif.: Betchel Corporation, 1975; and Larson, W.C., Geologist, Twin Cities Mining Research Centers, U.S. Bureau of Mines. Personal communication, 1977.

[b]At 10 percent per year.

TABLE 7-37: NEW EMPLOYMENT IN ENERGY DEVELOPMENT IN CAMPBELL COUNTY, 1975-2000 (person years)

YEAR	CONSTRUCTION	OPERATION	TOTAL
1975	110	0	110
1976	780	0	780
1977	1,340	0	1,340
1978	2,370	880	3,250
1979	2,420	1,140	3,560
1980	1,080	2,450	3,530
1981	2,780	2,450	5,230
1982	5,800	2,680	8,480
1983	8,130	3,890	12,020
1984	5,530	5,080	10,610
1985	760	5,920	6,680
1986	0	5,920	5,920
1987	0	5,920	5,920
1988	0	5,920	5,920
1989	0	5,920	5,920
1990	60	5,920	5,980
1991	760	5,920	6,980
1992	2,830	5,920	8,750
1993	4,890	6,110	11,000
1994	3,380	6,700	10,080
1995	2,280	6,890	9,170
1996	4,490	6,890	11,380
1997	5,210	6,890	12,100
1998	3,710	7,170	10,880
1999	1,250	8,640	9,890
2000	0	10,380	10,380

Source: Carasso, M., _et al_. _The Energy Supply Planning Model_. San Francisco, Calif.: Bechtel Corporation, 1975; and Larson, W.C., Geologist, Twin Cities Mining Research Centers, U.S. Bureau of Mines. Personal communication, 1977.

evident, but a long-term new energy work force of over 10,000 persons is expected by 2000.[1] Overall population changes are based on the annual energy employment (for both construction and operation) and are estimated by means of an economic base model, the employment data in Table 7-37, and two sets of time-dependent multipliers (Table 7-38). The population estimates, shown in Table 7-39 and Figure 7-6, were distributed among Gillette, the remainder of Campbell County, and Casper. No new population clusters in Campbell County are explicitly considered here, although scattered settlement is becoming more common. For example, Atlantic Richfield is providing housing at the town of Wright (near Reno Junction), about 40 miles south of Gillette.[2] Note that the population impacts would differ significantly for a construction schedule different from that analyzed here.

The population of Campbell County will increase over fourfold to 75,400 by the year 2000 given the energy development proposed in the Gillette scenario. Most of this growth will occur in and near Gillette, where the area will attain a population of about 69,000 by 2000. Casper will achieve a population of over 50,000 as a result of the scenario development and will grow even larger if other extensive developments take place in eastern and central Wyoming. The size of the facilities in this scenario result in somewhat larger population estimates for Campbell County than previous studies have found; thus, the population discussed in this section may overestimate future conditions.[3]

Age-sex distributions of the projected population in Campbell County provide an indication of housing and educational needs in the area. Using 1970 age distributions, new employment in the

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[1]Based on projections using Bechtel's energy supply planning model. See Carasso, M., _et al_. _The Energy Supply Planning Model_. San Francisco, Calif.: Bechtel Corporation, 1975.

[2]"Town Revived in Coal Boom." _Denver Post_, July 13, 1976.

[3]See, for example, U.S., Department of the Interior, Bureau of Reclamation and Center for Interdisciplinary Studies. _Anticipated Effects of Major Coal Development on Public Services, Costs, and Revenues in Six Selected Counties_. Denver, Colo.: Northern Great Plains Resources Program, 1974, pp. 149-75; and Wyoming, Department of Economic Planning and Development. _Coal and Uranium Development of the Powder River Basin--An Impact Analysis_. Cheyenne, Wyo.: Wyoming, Department of Economic Planning and Development, 1974, pp. 51-75.

TABLE 7-38: EMPLOYMENT AND POPULATION MULTIPLIERS FOR GILLETTE SCENARIO POPULATION ESTIMATES

SERVICE/BASIC MULTIPLIERS[a]		
YEAR	CONSTRUCTION	OPERATION
1975	0.4	
1976	0.4	
1977	0.5	
1978	0.5	0.8
1979	0.6	0.9
1980	0.6	0.9
1981	0.7	1.0
1982	0.7	1.0
1983	0.7	1.1
1984	0.7	1.2
and after	0.7	1.2
POPULATION/EMPLOYEE MULTIPLIERS[b]		
Construction	2.05	
Operation	2.30	
Services	2.00	

[a]These values were selected after examining several studies of the northeastern Wyoming area, including Hayen, Roger L., and Gary L. Watts. A Description of Potential Socioeconomic Impacts from Coal-Related Developments on Campbell County, Wyoming. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975; Northern Great Plains Resources Program, Socioeconomic and Cultural Aspects Work Group. Socioeconomic and Cultural Aspects of Potential Coal Development in the Northern Great Plains, Discussion Draft. Denver, Colo.: Northern Great Plains Resources Program, 1974; U.S., Department of the Interior, Bureau of Land Management, et al. Final Environmental Impact Statement for the Proposed Development of Coal Resources in the Eastern Powder River Coal Basin of Wyoming, 6 vols. Cheyenne, Wyo.: Bureau of Land Management, 1974; Wyoming, Department of Economic Planning and Development. Coal and Uranium Development of the Powder River Basin--An Impact Analysis. Cheyenne, Wyo.: Wyoming, Department of Economic Planning and Development, 1974; U.S., Department of the Interior, Bureau of Reclamation and Center for Interdisciplinary Studies. Anticipated Effects of Major Coal Development on Public Services, Costs, and Revenues in Six Selected Counties. Denver, Colo.: Northern Great Plains Resources Program, 1974; Matson, Roger A., and Jeanette B. Studer. Energy Resources Development in Wyoming's Powder River Basin: An Assessment of Potential Social and Economic Impacts. Denver, Colo.: Northern Great Plains Resources Program, 1974.

[b]Adapted from Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976.

TABLE 7-39: POPULATION ESTIMATES FOR CAMPBELL COUNTY, GILLETTE, AND CASPER, 1975-2000[a]

YEAR	CAMPBELL COUNTY[b]	GILLETTE	CASPER
1975	17,000[c]	14,000[c]	40,000
1980	30,600	26,650	42,200
1985	49,700	44,800	45,000
1990	49,400	44,500	46,750
1995	63,450	57,700	48,650
2000	75,400	69,200	50,600

[a]Estimates incorporate an annual natural increase of 0.8 percent through 1990 and 0.5 percent from 1991-2000. Some yearly peaks, caused by the employment needs in Table 7-38, are missed in the above presentation. Given the assumptions of the scenario, the estimates of population increase should be considered to have a ±20 percent range associated with them.

[b]Campbell County was assumed to be the location for 100 percent of all energy development employment in the scenario, with 90 percent occurring in or near Gillette and the remaining 10 percent at Casper.

[c]Source: Local estimates (Enzi, Mike, Mayor of Gillette, Wyoming. Personal communication). U.S. Census estimates are closer to 12,000 and 10,000 for the county and city, respectively.

county was assumed to correspond to data reported in the Construction Worker Profile.[1]

The marital status of construction workers and age distribution of their children were also assumed to be distributed according to recent survey findings in the West. The resulting age-sex distributions (Table 7-40) show increases in the 25-34 age group through 1985 and in the 35-64 age groups after 1985. During intensive construction periods, the relative proportion of males to females is especially high, although males compose at least 51.5 percent of the population throughout the 25-year period.

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[1]See Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 38.

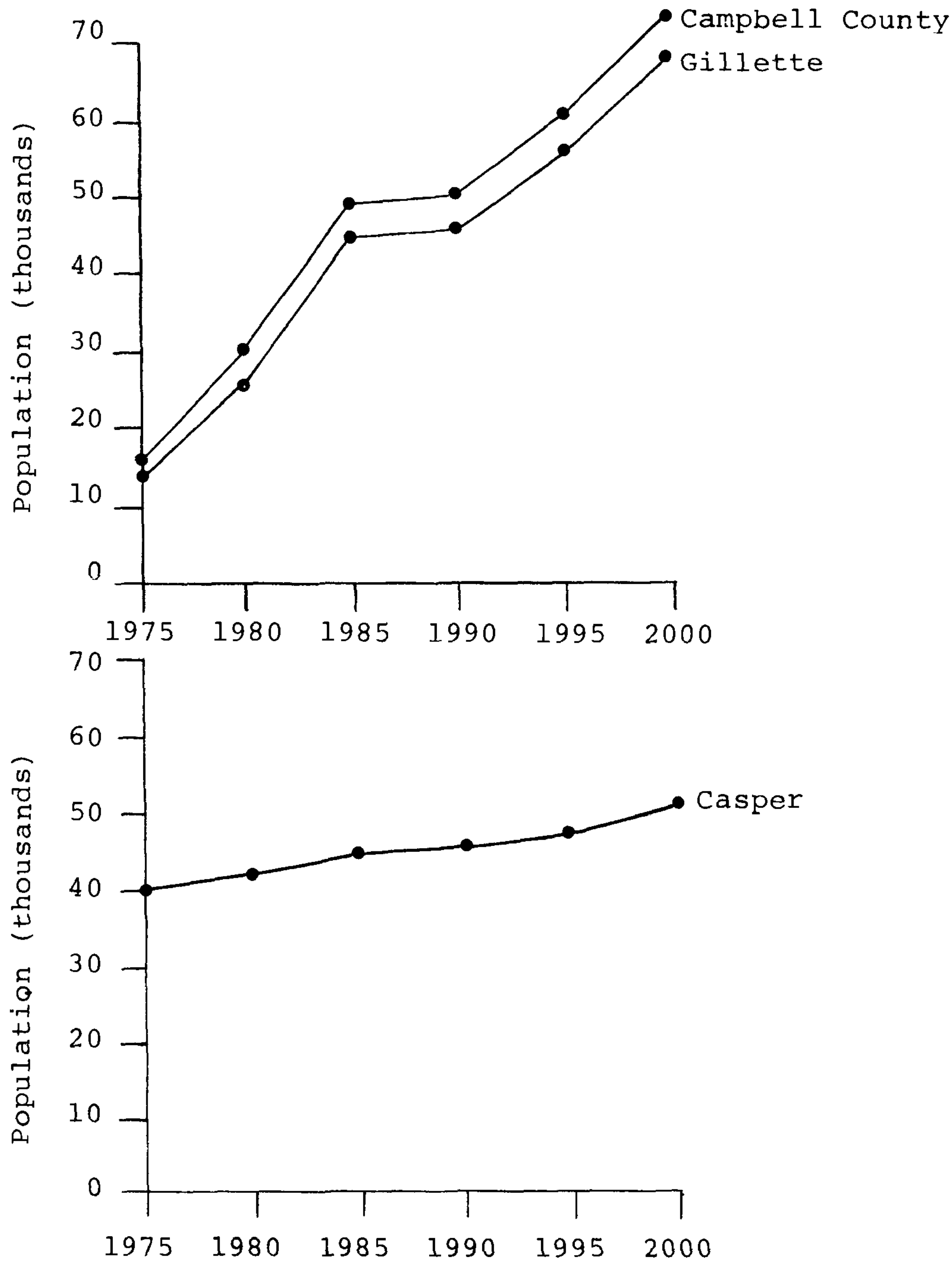

FIGURE 7-6: POPULATION ESTIMATES FOR CAMPBELL COUNTY, GILLETTE, AND CASPER, 1975-2000

TABLE 7-40: PROJECTED AGE-SEX DISTRIBUTIONS OF CAMPBELL COUNTY, 1975-2000[a]

AGE	1975	1980	1985	1990	1995	2000
Female						
65-over	.025	.013	.009	.010	.011	.015
55-64	.024	.018	.014	.019	.126	.139
35-54	.090	.083	.075	.125	.125	.129
25-34	.076	.118	.132	.114	.106	.116
20-24	.046	.048	.048	.041	.051	.043
17-19	.025	.024	.023	.032	.031	.025
14-16	.031	.024	.028	.034	.025	.027
6-13	.094	.076	.082	.071	.065	.063
0-5	.071	.074	.074	.039	.040	.026
Total	.482	.478	.485	.485	.480	.483
Male						
65-over	.022	.012	.008	.011	.013	.017
55-64	.029	.021	.016	.023	.030	.042
35-54	.120	.104	.088	.142	.143	.146
25-34	.085	.136	.145	.122	.118	.126
20-24	.041	.050	.050	.041	.054	.044
17-19	.022	.024	.024	.032	.031	.025
14-16	.032	.025	.028	.034	.025	.027
6-13	.097	.077	.083	.071	.065	.063
0-5	.069	.073	.074	.039	.040	.026
Total	.517	.522	.516	.515	.519	.516

[a]Total may not sum to 1.0 because of rounding.

B. Housing and School Impacts

Housing demand and school enrollment can be estimated from the data in Tables 7-39 and 7-40.[1] The resulting projections are shown in Table 7-41. The level of energy development in this scenario results in nearly triple the number of households by 1985, rising to a total of over 28,000 households by the year 2000. Except for 1985-1990, the average annual rate of growth is over 5 percent.

In 1975, approximately one-third of Gillette's residences were mobile homes.[2] By 1977 nearly 40 percent were mobile homes[3] because of constraints in the local housing market. To keep mobile homes at that proportion would require over 400 single-family homes and about 200 multifamily units to be built annually through 1985 and from 1990-2000 (Table 7-42). Some energy developers are currently providing housing for their employees because of the tight housing market, but other residents find housing difficult to purchase.[4]

School enrollment impacts will vary over time (Table 7-41 and Figure 7-7). Overall school enrollment in the scenario is expected to increase over 150 percent by 1985 and to reach 13,550 by 2000. The upward trend in elementary enrollment is broken only by a slight decline between 1985 and 1990, which reflects the absence of energy construction activity. High school enrollment shows a similar trend five years later; enrollment increases except for a slight drop between 1990 and 1995. At an average class size of 25 students and an estimated $2,500 per student space, 192 new classrooms will be needed by 1985 at a cost of approximately $12 million (Table 7-43). The school district's

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[1]Housing demand can be estimated by assuming the number of males aged 50 years and older approximates the number of households in the area. School enrollment can be estimated by assuming that the 6-13 age group constitutes elementary school enrollment and the 14-16 age group is the enrollment in secondary schools.

[2]Mountain Plains Federal Regional Council. Compilation of Raw Data on Energy Impacted Communities Including Characteristics, Conditions, Resources and Structures. Denver, Colo.: Mountain Plains Federal Regional Council, 1976.

[3]U.S., Federal Energy Administration, Region VIII, Socioeconomic Program Data Collection Office. Regional Profile: Energy Impacted Communities. Lakewood, Colo.: Federal Energy Administration, 1977.

[4]"Wyoming Grassland Transformed to Coal Mining Center." Civil Engineering--ASCE, Vol. 47 (September 1977), pp. 50-56.

TABLE 7-41: ESTIMATED NUMBER OF HOUSEHOLDS AND SCHOOL ENROLLMENT IN CAMPBELL COUNTY, 1975-2000

YEAR	NUMBER OF HOUSEHOLDS	NUMBER OF ELEMENTARY SCHOOL CHILDREN[a]	NUMBER OF SECONDARY SCHOOL CHILDREN[b]	TOTAL SCHOOL ENROLLMENT
1975[c]	5,000	3,250	1,050	4,300
1980	9,900	4,700	1,500	6,200
1985	15,250	8,200	2,800	11,000
1990	16,250	7,000	3,350	10,350
1995	22,700	8,250	3,200	11,450
2000	28,300	9,500	4,050	13,550

[a]Ages 6-13.

[b]Ages 14-16.

[c]Estimates.

TABLE 7-42: DISTRIBUTION OF NEW HOUSING BY TYPE OF DWELLING[a]

PERIOD	MOBILE HOME	SINGLE-FAMILY	MULTI-FAMILY AND OTHER
1975-1980	2,000	2,000	900
1980-1985	2,150	2,150	1,050
1985-1990	400	400	200
1990-1995	2,600	2,600	1,250
1995-2000	2,250	2,250	1,100

[a]Assumes 40 percent of new homes will be mobile homes, 40 percent will be single-family, and 20 percent multi-family dwellings or other types (campers or recreational vehicles). These percentages are approximately those found in Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 103.

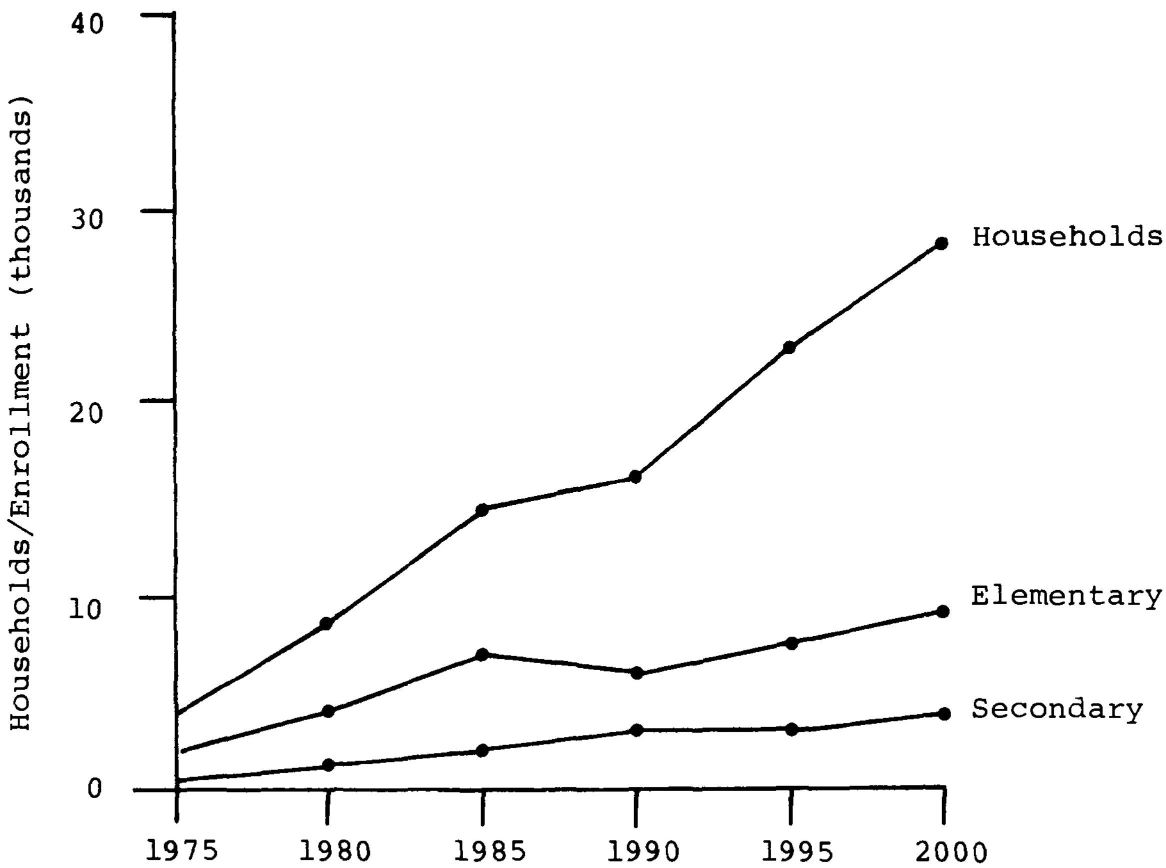

FIGURE 7-7: PROJECTED NUMBER OF HOUSEHOLDS, ELEMENTARY AND SECONDARY SCHOOL CHILDREN IN CAMPBELL COUNTY, 1975-2000

financial needs would triple by the end of the century in this scenario, although there will be a brief period of overcapacity in the late 1980's.

C. Economic Impacts

The economy of Campbell County is now dominated by mining, agriculture, and construction (totaling 48 percent of total personal income). Conversely, services, local government, finance, insurance, and real estate employ less than state and national averages.[1] Gillette's economy also receives a significant contribution from out-of-state hunters. This mix should become somewhat less concentrated in energy-related sectors

[1]U.S., Department of Commerce, Bureau of Economic Analysis. "Local Area Personal Income." Survey of Current Business, Vol. 54 (May 1974, Part II), pp. 1-75.

TABLE 7-43: SCHOOL DISTRICT FINANCE NEEDS FOR CAMPBELL COUNTY, 1975-2000[a]

TIME PERIOD	ENROLLMENT INCREASE	NEW CLASSROOMS NEEDED (at 25 students per classroom)[b]	CAPITAL EXPENDITURES FOR CLASSROOM CONSTRUCTION (millions of dollars)[c]	OPERATING EXPENDITURES (millions of dollars)[d]	
				INCREASE	TOTAL[e]
1975-1980	1,900	76	4.75	3.80	12.40
1980-1985	4,800	192	12.00	9.60	22.00
1985-1990	-650	-96	-1.63	-1.30	20.70
1990-1995	1,100	44	2.75	2.20	22.90
1995-2000	2,100	84	5.25	4.20	27.10

[a]These figures may be compared with Hayen, Roger L., and Gary L. Watts. A Description of Potential Socioeconomic Impacts from Coal-Related Developments on Campbell County, Wyoming. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, pp. 24, 78, 87.

[b]Enrollment in 1976 was 4,054 students in 161 classrooms, an average of 25 students per room. See U.S., Federal Energy Administration, Region VIII, Socio-economic Program Data Collection Office. Regional Profile: Energy Impacted Communities. Lakewood, Colo.: Federal Energy Administration, 1977.

[c]An average of $2,500 per pupil space was obtained from Froomkin, Joseph, J.R. Endriss, and R.W. Stump. Population, Enrollment and Costs of Elementary and Secondary Education 1975-76 and 1980-81, A Report to the President's Commission on School Finance. Washington, D.C.: Government Printing Office, 1971, inflated to 1975 dollars.

[d]An overall average of $2,000 per pupil was assumed, exclusive of debt service.

[e]Total includes estimated 1975 operating expenditures of $8.6 million.

during the next 25 years as service-sector employment gradually increases to a more average level compared to state and national employment.

Primarily because of the change in industry mix as construction declines in importance, the county-wide income distribution should gradually decline to $16,100 (1975 dollars) during the 1975-2000 period.[1] However, despite this 11.5-percent decline, the county-wide average will still be above the current national average (Table 7-44 and Figure 7-8). The proportion of households in income categories between $8,000 and $15,000 will increase, while the proportion in the over $25,000 category will decrease. High school age boys are being attracted to high-wage energy-related employment, and, as a consequence, high school girls are being employed in gas stations and other services. This pattern is likely to continue for some time.

The expected increase in the service sector will actually be caused by an anticipated expansion in local business activity. The rapid increase in the number of businesses in Gillette, which has tripled since 1968, should continue. Even if the rural population growth is greater than expected, Gillette will still benefit from retail activity because it is the only market center in the county. Casper, the nearest city larger in size than Gillette, also will receive additional retail activity because of Campbell County's energy development.

To the extent that export mines are developed, rather than mines directly attached to conversion facilities, the local economy would experience less direct benefit. On the other hand, the smaller population would place smaller demands on public services.[2]

Tourism is not likely to be greatly affected because, unlike many parts of the West, Gillette is not a particularly attractive place for tourism. Some traffic occurs because of Devil's Tower National Monument 60 miles east of town, but the area does not compare with the major national parks in the region as a tourist attraction. However, hunting of the large antelope, deer, and other animal populations is likely to increase substantially (within state licensing limits) as a result of the increased population (see Section 7.5).

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[1]This projection does not include national trends, such as technological change, productivity gains, etc.

[2]See White, Irvin L., <u>et al</u>. <u>Energy From the West: Energy Resource Development Systems Report</u>. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

TABLE 7-44: PROJECTED INCOME DISTRIBUTION FOR CAMPBELL COUNTY, 1975-2000 (in 1975 dollars)[a]

YEAR	LESS THAN 4,000	4,000 TO 5,999	6,000 TO 7,999	8,000 TO 9,999	10,000 TO 11,999	12,000 TO 14,999	15,000 TO 24,999	25,000 AND OVER	MEDIAN HOUSEHOLD INCOME
1975	.061	.039	.039	.059	.066	.113	.377	.246	18,200
1980	.048	.035	.036	.063	.084	.120	.442	.171	17,580
1985	.051	.040	.037	.070	.094	.125	.446	.136	16,390
1990	.058	.045	.040	.073	.097	.127	.432	.128	16,390
1995	.055	.044	.038	.069	.097	.126	.445	.128	16,600
2000	.059	.047	.041	.075	.102	.129	.434	.113	16,100

[a]Data for 1975 are adapted from U.S., Department of Commerce, Bureau of the Census. Household Income in 1979 for States, SMSA's, Cities and Counties: 1970. Washington, D.C.: Government Printing Office, 1973, p. 57, and inflated to 1975 dollars. Income distributions for construction, operation, and service workers are from Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 50, assuming that new service workers' households have the same income distribution as long-time residents and that "other newcomers" are operation employees.

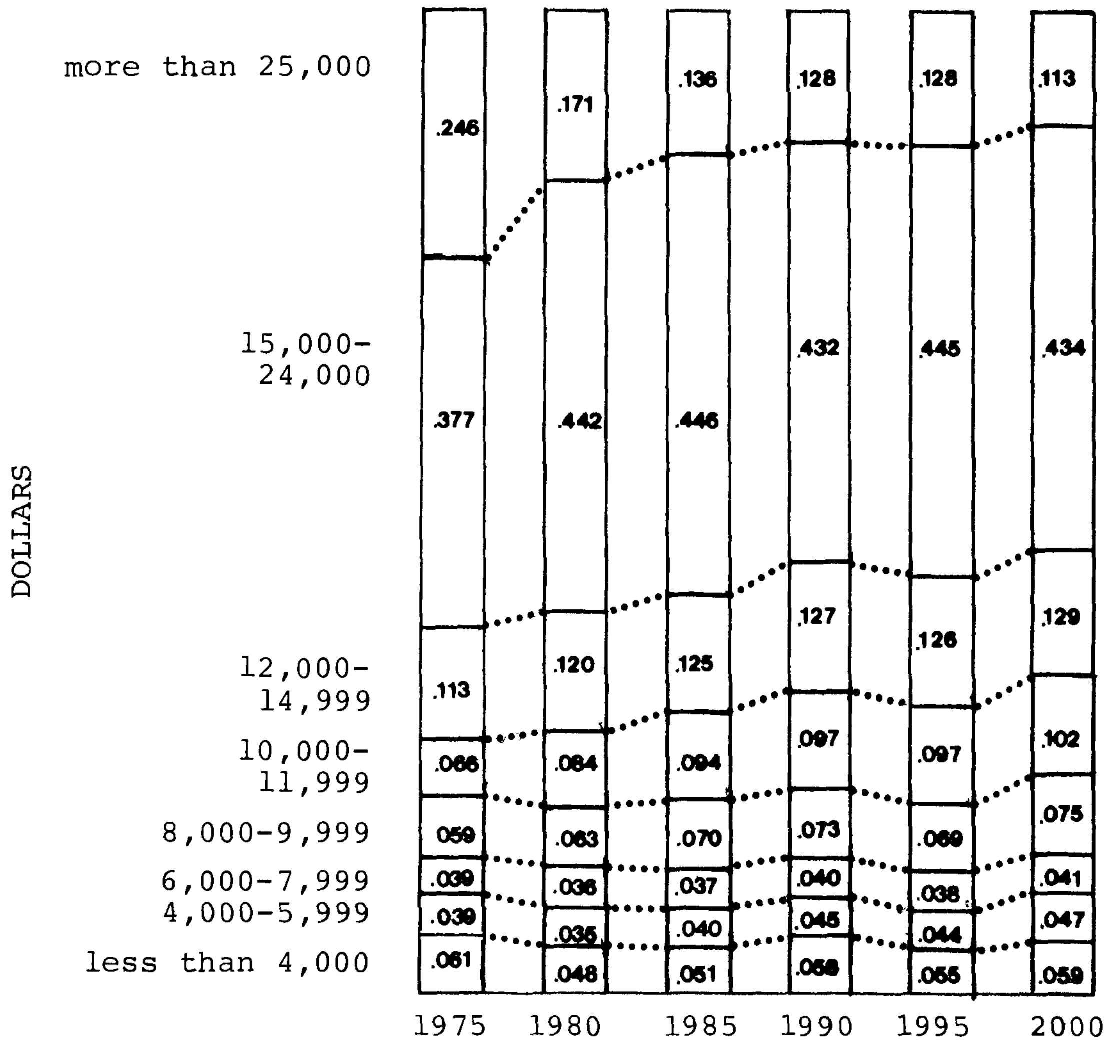

FIGURE 7-8: PROJECTED ANNUAL INCOME DISTRIBUTION FOR CAMPBELL COUNTY, 1975-2000 (in 1975 dollars)

D. Fiscal Impacts

Municipal services will be severely strained, especially early in the population expansion period.[1] An estimate of capital expenditure needs for Gillette emphasizes the importance of water and sewage facilities in rapid population growth areas (Table 7-45). In overall operating expenditures, per capita costs tend to rise as a town's population increases; however, much of the increase can be attributed to capital expenditures and debt service.[2] Employing an average of $120 per capita, the additional operating expenditures required of Gillette as a result of the scenario increase an average of 5.3 percent per year (compound) through 2000 (Table 7-46). The estimated operating expenditures are probably low (perhaps as much as 20 percent), but they indicate the increase in financial needs with a population increase. Adding these operating expenditures to the capital needs in Table 7-45 shows that Gillette will have problems in meeting population-related needs through 1985 and again after 1990. A major cause of these problems will be that energy development taking place outside Gillette's city limits will not provide the city with the tax revenues needed to fund the required municipal services.[3]

The largest portion of new taxes will come from levies directly on the facilities, and the largest of these items will be the property tax. By the end of the century, the energy developments in our scenario will carry an assessed value of about $6 billion, or almost 20 times the total 1975 assessment in Campbell County. Until the last few years of the scenario, the new values consist of roughly equal portions of facilities (assessed at 24 percent of invested value) and coal production (assessed at 100 percent of each year's extracted value). The final facility to be added, a 100,000 barrels per day liquefaction plant, is very capital-intensive, bringing $2.1 billion of new property to the county or some 18 times as much as the value of

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[1]See Gillette, Wyoming, City of. Catalog of Public Investment Projects, 1976 to 1986. Gillette, Wyo.: City of Gillette, 1976; and Campbell County Chamber of Commerce. Economic Impact of Anticipated Growth: City of Gillette and Campbell County, Wyoming. Gillette, Wyo.: Campbell County Chamber of Commerce, 1976.

[2]THK Associates, Inc. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974.

[3]Campbell County Chamber of Commerce. Economic Impact of Anticipated Growth: City of Gillette and Campbell County, Wyoming. Gillette, Wyo.: Campbell County Chamber of Commerce, 1976.

TABLE 7-45: PROJECTED NEW CAPITAL EXPENDITURES REQUIRED FOR PUBLIC SERVICES IN GILLETTE, 1975-2000 (millions of dollars)

PERIOD[a]	WATER AND SEWAGE[b]	HOSPITAL[c]	AIRPORT[c]	OTHER[d]	TOTAL
1975-1980	22.3	11		7.5	40.8
1980-1985	31.9		7	10.7	49.6
1990-1995	23.2	10		7.8	41.0
1995-2000	20.2	5		6.8	32.0

[a]1985-1990 is omitted because a slight decline in population (and therefore, in-service demands) occurs during that period.

[b]Based on $1.76 million for each 1,000 additional population; see THK Associates, Inc. *Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study*. Denver, Colo.: THK Associates, 1974, p. 30; and Lindauer, R.L. *Solutions to Economic Impacts on Boomtowns Caused by Large Energy Developments*. Denver, Colo.: Exxon Co., USA, 1975, pp. 43-44.

[c]From Gillette, Wyoming, City of. *Catalog of Public Investment Projects, 1976 to 1986*. Gillette, Wyo.: City of Gillette, 1976.

[d]Based on $591,000 for each 1,000 additional population. Category includes parks and recreation, city-owned utilities, libraries, police and fire protection, administration, public works, and street and road maintenance. See THK Associates. *Impact Analysis and Development Patterns*, p. 30.

TABLE 7-46: NECESSARY OPERATING EXPENDITURES OF GILLETTE, 1975-2000

YEAR	OPERATING EXPENDITURE NEEDS[a] (Thousands of 1975 dollars)
1975[b]	2,514
1980	4,032
1985	6,210
1990	6,174
1995	7,758
2000	9,018

[a]Based on $120 per capita (1975 dollars) added to the 1975 figure of $2,514 million. The needs can be broken down as follows: roads and streets (25 percent), health and hospitals (14 percent), police (7 percent), fire protection (12 percent), parks and recreation (6 percent), libraries (4 percent), administration (10 percent), and other (12 percent). See THK Associates, Inc. Impacts Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, Inc., 1975, p. 41. The $120 average is probably low for Gillette.

[b]Source: Hayen, Roger L., and Gary L. Watts. A Description of Potential Socioeconomic Impacts from Coal-Related Developments on Campbell County, Wyoming. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, p. 30. This source is particularly useful for detailed projections of short-term needs (through 1985).

the coal which annually supplies it (and two-thirds of the value of all other facilities in the scenario combined).

When the current mill levies--48.98 mills for schools (local and state programs) and 11.99 mills for other county purposes[1]--are applied to the assessed values of the energy facilities, new revenues would be generated as in Table 7-47. The major beneficiary of new property tax revenues would be education. In 2000, nearly $140 million would be added annually to school budgets if the current rates were maintained. However, as indicated in

[1]U.S., Department of the Interior, Bureau of Reclamation and Center for Interdisciplinary Studies. Anticipated Effects of Major Coal Development on Public Services, Costs, and Revenues in Six Selected Counties. Denver, Colo.: Northern Great Plains Resources Program, 1974, p. 341.

TABLE 7-47: NEW PROPERTY TAX REVENUES, CAMPBELL COUNTY
(millions of 1975 dollars)

SOURCE	1980	1985	1990	1995	2000
Values of facilities[a]	633.0	2,856.0	2,856.0	3,763.0	6,179.0
Value of coal production[b]	216.0	698.0	790.0	981.0	1,234.0
Value of residential development[c]	0.78	188.0	187.0	268.0	337
School revenue, Campbell[d]	18.9	70.0	74.5	95.4	137.0
Other revenue, Campbell[d]	4.6	17.1	18.2	23.4	33.6
Municipal revenue, Gillette[e]	0.58	1.42	1.41	2.01	2.54

[a]Carasso, M., et al. The Energy Supply Planning Model. San Francisco, Calif.: Bechtel Corporation, 1975. See Table 7-37.

[b]Scenario definition combined with Stanford Research Institute projections of price. See Cazalet, Edward, et al. A Western Regional Energy Development Study: Economics, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

[c]Population projections in Table 7-40 combined with assumption of $5,762 per capita (market value) for residential and commercial development. See Hayen, Roger L., and Gary L. Watts. A Description of Potential Socio-economic Impacts from Coal-Related Developments on Campbell County, Wyoming. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, p. 108.

[d]At current rates (see text).

[e]At assumed mill levy of 8 applied to residential and commercial development.

Table 7-43, the school will need only $27 million per year in additional operating expenditures to maintain current standards. Clearly, there would be considerable leeway for lowering the school mill levy.

Other revenues derived directly from energy facilities include severance taxes and royalties. The Impact Assistance Act,[1] will collect 2 percent of the value of coal extracted until $160 million has been accumulated. The mines in our scenario will produce that much coal by 1990, so that tax collected statewide will probably terminate in the 1980's. Proceeds will be allocated by the Wyoming Farm Loan Board to impacted areas for building infrastructure, especially roads. Another tax of 1.5 percent will not terminate and will be collected to establish the Mineral Trust Fund.[2] Income from the fund will go to the state's general fund, but the principal will be used for loans to localities. Finally, the state will receive 50 percent of federal coal royalties. Under recent legislation, royalties have been targeted at one-eighth of the coal value. (Approximately 45 percent of the coal in the scenario area is owned by the federal government.) The various mineral taxes and royalties are summarized in Table 7-48.

The other public revenue impacts in this scenario, sales taxes and utility fees, are population-related. New sales tax revenues can be estimated on the basis of the incomes already projected. At each point in time, all the following factors are multiplied together: number of new households (since 1975), average income per household,[3] average propensity to buy taxable goods,[4] the sales tax rate,[5] and the split between levels of government.[6] These factors are brought together in Table 7-49 along with an estimate of municipal utility fees.

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[1]The act provides funds to mitigate impacts related to the development of coal, gas, shale oil, and other minerals.

[2]See Hayen, Roger L., and Gary L. Watts. <u>A Description of Potential Socioeconomic Impacts from Coal-Related Developments on Campbell County, Wyoming</u>. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, pp. 69-70.

[3]$17,600 in 1980, $16,910 in 1985 and thereafter were used.

[4]The average for the mountain states is 56 percent of income.

[5]Three percent by the state, another one percent optional by county.

[6]Two-thirds to the state, roughly one-sixth each to county and city.

TABLE 7-48: SEVERANCE TAXES AND PUBLIC ROYALTIES
(millions of 1975 dollars)

SOURCE	1980	1985	1990	1995	2000
Impact Assistance Act[a]	4.3	12.0	0.0	0.0	0.0
Mineral Trust Fund[b]	14.0	61.0	132.0	216.0	319.0
Interest on Mineral Trust Fund[a,c]	0.7	3.0	6.6	10.8	16.0
State Share of Federal Royalties[a,d]	6.1	19.6	22.2	27.6	34.7

[a]Annual rate.

[b]Accumulation.

[c]At 5 percent.

[d]Assuming 45 percent of coal under federal lease.

TABLE 7-49: ADDITIONAL POPULATION-RELATED TAXES AND FEES
(millions of 1975 dollars)

SOURCE	1980	1985	1990	1995	2000
Retail sales, Campbell	48.3	97.1	106.5	167.6	220.6
Retail sales, Casper	8.2	15.9	25.1	33.4	41.7
Sales Tax Shares					
State	1.29	0.31	3.51	5.36	6.99
Campbell County	0.32	0.65	0.71	1.12	1.47
Gillette City	0.32	0.65	0.71	1.12	1.47
Casper and Natrona	0.08	0.16	0.25	0.33	0.42
Total	2.01	1.17	5.18	7.93	10.35
Utility fees, Gillette[a]	1.98	4.84	4.79	6.86	8.67
Utility fees, Casper[a]	0.35	0.79	1.06	1.36	1.66

[a]At $157 per capita. See Hayen, Roger L., and Gary L. Watts. A Description of Potential Socioeconomic Impacts from Coal-Related Developments on Campbell County, Wyoming. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, p. 118.

All the revenue sources identified above for the state and Campbell County can be regrouped by level of government, as in Table 7-50. Comparisons can then be readily made with the demands for new public expenditures (Table 7-45 and 7-46). Under current conditions, Gillette will always be short of revenues for necessary expenditures. For Gillette to meet its expenditures, it must share costs with Campbell County or annex county land to add to the city tax base.[1]

E. Social and Cultural Impacts

Several major groups of people live in and around Gillette: ranchers, oil company employees, coal mining and related construction employees, and businessmen. The managerial-level oil company employees, some of them Gillette residents for 10 years, are able to take part in local affairs, while more recent newcomers related to coal development largely are not.[2]

The social segregation has geographical manifestations particularly noticeable in the predominance of mobile home living among new workers and their families. One effect of a large increase in coal-related population is likely to be yet more mobile home neighborhoods spatially distinct from existing housing. Gillette residents strongly dislike the appearance and quality of living of mobile home parks, and that condition will probably only increase as a result of the scenario analyzed here.[3] Further, child neglect and abuse, to the extent it actually occurs, appears to be a consequence of the migrant nature of construction families around Gillette.[4]

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[1]See Campbell County Chamber of Commerce. Economic Impact of Anticipated Growth: City of Gillette and Campbell County, Wyoming. Gillette, Wyo.: Campbell County Chamber of Commerce, 1976.

[2]University of Montana, Institute for Social Science Research. A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming. Missoula, Mont.: Institute for Social Science Research, 1974, pp. 49-52, 75.

[3]Ibid; Pernula, D. City of Gillette/Campbell County: 1977 Citizen Policy Survey. Gillette, Wyo.: Gillette/Campbell County Department of Planning and Development, 1977.

[4]Richards, Bill. "Western Energy Rush Taking Toll Among Boom Area Children." Washington Post, December 13, 1976, pp. 1, 4. Gillette officials say that this is not a problem and that Richards is guilty of hyperbole in most of his stories about Gillette and Campbell County.

TABLE 7-50: NEW REVENUE FROM ENERGY DEVELOPMENT BY LEVEL OF GOVERNMENT (millions of 1975 dollars)

JURISDICTION	1980	1985	1990	1995	2000
Wyoming (state revenues)[a]	12.4	39.6	32.3	43.8	57.7
Campbell County	4.9	17.6	18.9	24.5	35.1
City of Gillette	2.9	6.9	6.9	10.0	12.7
Campbell County School District	18.0	70.0	74.5	95.4	137.0

Source: Tables 7-47, 7-48, and 7-49.

[a]Includes amounts to be allocated to impact areas.

Another type of separation results from the coal trains which roll slowly through Gillette several hours each day, cutting the town into two sections. Like many western towns, Gillette grew up on both sides of the railroad tracks that run through town. As coal traffic has increased (and continues to increase), vehicles, including emergency vehicles, are forced to wait for trains to pass. An overpass or underpass would solve this problem but would create others. Congestion would occur at the single access point, and weather would have effects on usefulness. Underpasses are subject to temporary flooding, and overpasses become icy in winter. These conditions would be preferable to the daily interruption of all cross-town interaction.

In public and private services, medical care is in particularly short supply. Only eight physicians served Gillette and Campbell County in 1974, a ratio of about one physician to 1,500 people. By 1977, the town had 10 physicians, but the population also had grown; making the ratio one physician to about 1,700 people.[1] Gillette has had trouble attracting and keeping doctors, and as a consequence, many residents drive long distances for

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[1]By comparison, Sheridan has 17 doctors, a ratio of one per 675 people; the national average is about one per 660 people. See Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975; and U.S., Federal Energy Administration, Region VIII, Socioeconomic Program Data Collection Office. Regional Profile: Energy Impacted Communities. Lakewood, Colo.: Federal Energy Administration, 1977.

TABLE 7-51: PHYSICIAN NEEDS IN CAMPBELL COUNTY, 1975-2000

YEAR	POPULATION	AT RATIO OF ONE DOCTOR PER 1,000 PEOPLE	AT RATIO OF ONE DOCTOR PER 700 PEOPLE
1975	17,000	17	24
1980	30,600	31	44
1985	49,700	50	71
1990	49,400	49	71
1995	53,450	63	91
2000	75,400	75	108

medical care. This is a matter of great concern.[1] The need for new physicians (Table 7-51) will be as acute as the need for additional water and sewage treatment but is less likely to be ameliorated by local government policy. Physicians are highly mobile and attracted by both large urban areas (and their well-equipped hospitals) and pleasant outdoor amenities. For the latter reason, Sheridan seems to do better than Gillette and other similar-size towns at attracting physicians.[2] Company-supported health maintenance organizations or other group medical practice may be necessary to meet medical needs in Campbell County. In addition, the current trend toward family practice, rather than medical specialization, may help small cities such as Gillette.[3]

The social unrest among the various groups in Gillette will exist until some stable pattern of social interaction takes precedence over the constant conflict between oldtimers and newcomers.[4]

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[1]Pernula, D. City of Gillette/Campbell County 1977 Citizen Policy Survey. Gillette, Wyo.: Gillette/Campbell County Department of Planning and Development, 1977, pp. 4-5 and pp. 23-39.

[2]University of Montana, Institute for Social Science Research. A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming. Missoula, Mont.: University of Montana, Institute for Social Science Research, 1974.

[3]Loan forgiveness programs also appear to be an important influence on rural and small-town location of physicians. See Coleman, Sinclair. Physician Distribution and Rural Access to Medical Services, R-1887-HEW. Santa Monica, Calif.: Rand Corporation, 1976.

[4]University of Montana. Impact of Coal Development.

On a county wide scale, ranchers now dominate most local positions of power. This control is most threatened by the growth of urban Gillette, not by the mining and energy-related activity. The urbanization issue in Wyoming and much of the West is particularly contentious because of the desire to keep the small-town atmosphere, which is declining.[1]

The quality of life in Gillette will not be judged favorably by many residents during the course of this development. Water supply problems, medical service shortages, and the lack of street maintenance are only a few of Gillette's negative attributes that largely can be expected to continue.[2] On the positive side, employment opportunities are abundant in Gillette, the number and mix of retail goods and commercial services is expanding steadily, and a number of high-quality recreational areas are available within a few hours of the town.

The negative aspects of living in Gillette will not be reduced or eliminated easily. Financial strain on the community appears to be a major source of unfavorable opinion about life there. In addition, the integration of new residents into social groups and their participation in local affairs may be difficult and constitutes an important consideration for individuals.

F. Political and Governmental Impacts

Some of the social effects of energy development will be reflected in the political affairs and governmental administration of both Gillette and Campbell County. Immediate impacts on governmental administration will occur as localities demand expanded public services and as the sphere of public purpose is extended into quasi-public areas such as the provision of private housing and health care. Providing these services will require a concerted planning, coordination, and implementation effort on the part of all the parties-at-interest in the Gillette energy development area. Further, the changing nature of the population

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[1]University of Montana, Institute for Social Science Research. A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming. Missoula, Mont.: University of Montana, Institute for Social Science Research, 1974; and Northern Great Plains Resources Program, Socioeconomic and Cultural Aspects Work Group. Socioeconomic and Cultural Aspects of Potential Coal Development in the Northern Great Plains, Discussion Draft. Denver, Colo.: Northern Great Plains Resources Program, 1974, pp. 37-73.

[2]Pernula, Dale. City of Gillette/Campbell County 1977 Citizen Policy Survey. Gillette, Wyo.: Gillette/Campbell County Department of Planning and Development, 1977.

will strain the existing political balance, forcing accommodation of new attitudes and values in local decisions.

Wyoming, through the state legislature, has implemented a number of measures to reduce local fiscal impacts caused by energy-related growth.[1] The Wyoming Community Development Authority was created and authorized to provide loans to communities and to provide additional financing capacity to traditional lending institutions for low-interest housing loans. Severance tax revenues were to be used to back the Development Authority, thus providing a better bond rating for municipal loans by guaranteeing repayment. This Wyoming finance agency is unique because it was given the power to make loans to both the public and private sectors to raise additional mortgage money. Although the non-housing provisions of the Authority have been declared unconstitutional by the state supreme court, the Authority is expected to provide substantial assistance to mitigate housing shortages associated with energy development.

Legislative provisions for distribution the coal tax allow the Wyoming Farm Loan Board to disperse funds collected from the state severance tax. Grants are made to communities which have exhausted other reasonable means of financing sewer and water systems, streets, and road projects. Gillette received over $900,000 in 1975-76 for its water and sewer system from coal tax grants.[2] As a condition for issuing development permits for large energy facilities, the Wyoming Industrial Development Information and Siting Act of 1975 provides authority to require an applicant to share in the financing of needed public facilities and services, including schools. Coal mines valued at less than $50 million are excluded from these requirements, but coal conversion facilities and large uranium mills are subject to the Act.[3]

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[1]For a detailed review of Wyoming's legislative package dealing with the fiscal impacts of energy development, see Hayen, Roger L., and Gary L. Watts. A Description of Potential Socioeconomic Impacts from Coal-Related Developments on Campbell County, Wyoming. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, pp. 57-74.

[2]Bronder, L.D., N. Carlisle, and M.D. Savage. Financial Strategies for Alleviation of Socioeconomic Impacts in Seven Western States. Denver, Colo.: Western Governors' Regional Energy Policy Office, 1977, p. 391.

[3]Wyoming Industrial Development Information and Siting Act, Wyoming Statutes, 35-502.75 through 35-502.94. For more information, see Chapter 8, Housing, in White, Irvin L., et al. Energy From the West: Policy Analysis Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

Energy development in the area will also lead to changes in Gillette's relationship with Campbell County. Public services, such as law enforcement, fire protection, and water supply, will require a concerted effort on the part of the city and Campbell County to upgrade and maintain adequate levels of performance. Although, as shown in the previous fiscal analysis, expenditures and revenues will be fairly equal between 1975 and 1990, Gillette will experience a deficit until 1983. This deficit will be at its largest, $1.2 million, in 1980. When compared to Gillette's 1975 budget of about $2.5 million, these data indicate the city will be faced with a deficit approximately 50 percent as large as current revenues. If capital costs are included, the deficit in 1980 would be about $2.5 million instead of $1.2 million. A factor mitigating this fiscal imbalance could be redistribution of tax revenues from the county since its revenues are expected to expand dramatically after 1980, nearly tripling Gillette's expenditures by 1985. With redistribution to Gillette, the total operating and capital expenditures required in this scenario could easily be met after 1980, but such action requires uncommon fiscal cooperation between both jurisdictions.[1]

As noted earlier, the city and county cooperate on planning, as personified by a city-county planner on the county payroll.[2] Along with Wyoming's Joint Powers Act, which authorizes counties to join with other local governments in financing facilities, planning for future growth of Gillette appears to be reasonably possible. However, there is no means for requiring that the Joint Powers Act be involved, leaving the vast majority of Gillette's financing problems to the city. In addition, the city-county planner's recommendations need not be, and often are not, approved by the Board of County Commissioners. Another complication to planning results from the fact that the Industrial Development Information and Siting Act applies to facilities with construction costs greater than $50 million. Several of the currently planned operations were valued slightly below that limit[3] in what was perhaps an attempt to avoid the effects of the law. These and

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[1]See Campbell County Chamber of Commerce. Economic Impact of Anticipated Growth: City of Gillette and Campbell County, Wyoming. Gillette, Wyo.: Campbell County Chamber of Commerce, 1976.

[2]During the fiscal year 1975, the total county contribution was $55,000 of the $150,000 budget of the Department of Planning and Development. Wyoming, Department of Planning and Development. Personal communication, 1976.

[3]Gillette, Wyoming, City of. Statement of Planning Considerations, February 13, 1976. Gillette, Wyo.: City of Gillette, 1976.

similar specific problems greatly limit Gillette's efforts to plan adequately for future growth.[1]

Finally, energy development at Gillette will result in changes for traditional organized interests and, over the long term, will likely affect the power base that has prevailed in Gillette-Campbell County relations. That is, the control of county affairs by the ranchers will decline to allow representation of Gillette in county government affairs. Like many parts of the West, town and county affairs have been kept distinct; in fact, the population of the town is typically less than that of the remainder of the county. The reverse situation now exists with regard to the city of Gillette and Campbell County, but political power in the county government still is held by the ranchers. It is not clear at what point, in the course of future development, the political balance will shift to meet the population balance. Whenever it does, the changeover will be difficult for long-time residents.[2]

7.4.5 Summary of Social and Economic Impacts

Manpower requirements and the tax rates levied on the energy facilities are major causes of social and economic impacts. For the mines, manpower requirements for operation exceed peak construction manpower requirements. However, the reverse is true for the coal conversion facilities and gas wells, i.e., more labor is required for construction than for operation. In combination, total manpower requirement for each coal mine-conversion facility combination increases from the first year when construction begins, peaks, and then declines. Total manpower required for operation of the Synthoil facility and its associated mine is more than three times that of other coal mine-plant combinations.

Property tax and sales tax, which are tied to the capital costs of the facilities, and a severance tax and royalty payments,

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[1]A further example is the inability of Gillette to expand in preferred directions because of land ownership by parties, including energy developers, who are unwilling to give up their land to urban expansion.

[2]University of Montana, Institute for Social Science Research. A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming. Missoula, Mont.: University of Montana, Institute for Social Science Research, 1974; and Northern Great Plains Resources Program, Socioeconomic and Cultural Aspects Work Group. Socioeconomic and Cultural Aspects of Potential Coal Development in the Northern Great Plains, Discussion Draft. Denver, Colo.: Northern Great Plains Resources Program, 1974, pp. 37-73.

which are tied to the value of coal, generate revenue for the state and local government.

Capital costs of the hypothesized conversion facilities and mines in the Gillette area range from about $8 million for a solutional uranium mine to $2.17 billion (1975 dollars) for a mine-Synthoil plant facility. A property tax is levied at a rate of about 1.52 percent on the cash value of each facility, and a sales tax is levied at a rate of 4 percent on materials and equipment purchased during construction. In addition to these taxes related to capital costs, there is a severance tax levied at a rate of 3.5 percent on the value of the coal mined. State and local government also received 50 percent of the royalty payments which are about 12.5 percent of the value of federally owned coal.

Of all locations in the western U.S., the Gillette, Wyoming, area is expected to be one of the areas most intensively impacted by energy development. The scenario analyzed here indicates that the county population will grow over four-fold by the year 2000, with a large part of the growth taking place in or near Gillette. Housing needs and school enrollments will expand similarly. Most new housing units will be mobile homes, reflecting the reluctance of builders, finance firms, and residents to expect anything but short-term growth.

Campbell County's economy has already been largely energy-impacted, although primarily by oil and gas production. Through 1985, this concentration in energy should continue, slowly giving way to greater representation of service employment related to population. The energy and service sectors will exceed agriculture in the county in terms of income and employment. A gradual decline in household median income will occur over the 25-year period as a result of the change in industry mix and the growth of relatively lower paying service jobs.

Municipal expenditures for capital facilities and operating budgets are expected to be quite large, particularly in the capital expenditures area where $163 million will be needed over the 25-year period. For 1980 to 1985, because of the increasing tax base, the county will have a financial surplus, whereas Gillette will show a deficit. Consequently, a concerted effort on the part of both jurisdictions will be needed to meet the demands for public facilities and services.

Social problems resulting from, for example, the large number of mobile homes and the lack of sufficient medical care will make life especially difficult for newcomers to Gillette. The newcomer/oldtimer disparity is also manifested in political control, which presently remains in the hands of ranchers countywide. Planning for the future growth of Gillette within the county is thwarted by both these political considerations and the growing power of energy developers in the county.

The major technological choices affecting social and economic impacts in Campbell County are essentially the alternatives between exporting coal or converting it within the local area. The greatest impacts will occur during construction of a conversion facility, which requires 20 to 30 times the labor force for construction of a mine alone. Thus, construction of mines would not produce so great a fluctuation in the work force as that which takes place in the scenario during the mid-1980's. Importantly, however, differences in operation of the facilities are not as great as construction, and half the work force (and attendant population) would not be required if the coal were shipped from the region. However, without the plants, the tax base for Campbell County would significantly diminish.

Other technological choices would produce some change in social impacts. For example, if plant efficiency decreases, due to such factors as dry-cooling towers, mining might require 5 percent more labor; if the plants were located at more distant locations, some shifts in population location of commuters might take place. If extensive export mining called for additions to rail service rather than slurry lines, impacts would be difficult to predict and would depend on the extent of new rail access to the region and the degree to which rail lines would be monopolized by coal cars.

Prediction of many of the social and economic impacts depends largely on assumptions in the economic base model and, for example, of taxation rates. Improvements in knowledge of the current situation probably would not result in significant improvements in the ability to predict impacts in this area. However, important changes in quality-of-life and political impacts are more difficult to predict and can only be approached by means of local data, such as surveys of attitudes and aspirations of people within the region or a greater understanding of the underlying political structure of Gillette and Campbell County.

7.5 ECOLOGICAL IMPACTS

7.5.1 Introduction

The area considered in evaluating the Gillette scenario extends from the Bighorn Mountains eastward to the Black Hills and northward from the North Platte River to the Montana border. Most of this land is rolling prairie of 4,600 to 5,000 feet in elevation, relieved by stream valleys and buttes and ridges rising a few hundred feet from the surrounding landscape. The climate is semiarid, with extreme annual variations in temperature which, together with soil moisture and topography, are the major factors affecting the distribution of plant and animal species.[1]

7.5.2 Existing Biological Conditions

There are two major biological communities present in the prairie portion of the study area: sagebrush-grasslands and Ponderosa pine woodlands. The sagebrush-grasslands are of several subtypes, a shrubby salt-tolerant greasewood type along streamcourses and silver sage or big sage dominant in well-drained upland sites. Most of the area is big sage grassland used for grazing cattle. There are also a few pure grassland areas largely devoid of shrubs.

Antelope and sage grouse, two species which depend heavily on large expanses of sage, are exceptionally abundant in the Gillette area. Wyoming also has almost half the world's population of pronghorn antelope, and most of these inhabit the study area. Other typical animal species are shown in Table 7-52. Rare or endangered species include the peregrine falcon, bald eagle, black-footed ferret, and northern kit fox; and possibly other species threatened with extinction also occur in or migrate through the area.[2]

Ponderosa pine woodlands are found largely in rough topography to the north of Gillette and in a small range of hills to the southeast. The widely spaced trees provide a variety of food plants, cover, and nesting sites for a distinctive bird fauna and a variety of small mammals (Table 7-52).[3]

A small amount of riparian habitat is found in the prairie portion of the scenario area, principally along the Powder,

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[1]Packer, Paul E. Rehabilitation Potentials and Limitations of Surface-Mined Land in the Northern Great Plains, General Technical Report INT-14. Ogden, Utah: U.S., Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1974, p. 4.

[2]Northern Great Plains Resources Program. Effects of Coal Development in the Northern Great Plains: A Review of Major Issues and Consequences at Different Rates of Development. Denver, Colo.: Northern Great Plains Resources Program, 1975, p. 46.

[3]Most of the area's birds of prey hunt over both communities; species include: Swainson's, red-tailed, and ferruginous hawks; golden eagle; marsh hawk; prairie falcon; kestrel; and great horned owl. Other ubiquitous predators include the coyote, bobcat, and red fox.

TABLE 7-52: SELECTED CHARACTERISTIC SPECIES OF MAIN COMMUNITIES, GILLETTE SCENARIO

COMMUNITY TYPE	CHARACTERISTIC PLANTS	CHARACTERISTIC ANIMALS
Sagebrush Grassland	Big Sagebrush Silver Sagebrush Greasewood Gardner Saltbush Alkali Sacaton Bluegrass Needle and Thread Grass Western Wheat Grass	Antelope Coyote Richardson's Ground Squirrel Black Tailed Prairie Dog Western Harvest Mouse Sage Grouse Golden Eagle
Ponderosa Pine Woodlands	Ponderosa Pine Rocky Mountain Juniper Skunkbush Sumac Western Snowberry Stoneyhills Muhly Green Needlegrass Sideoats Grama	Mule Deer Elk Porcupine Wild Turkey Bushytail Woodrat Least Chipmunk Bobcat
Riparian	Plains Cottonwood Sanbar Willow Boxelder Wild Rose Rubber Rabbitbrush Wildrye Wheatgrass Needlegrass	Mule Deer Whitetail Deer Red Fox Meadowvole Mallard Western Kingbird Skunk Bobcat Raccoon

Little Powder, Belle Fourche, and Cheyenne Rivers, and Black Thunder and Lightning Creeks. Composition of this vegetation type ranges from narrow rows of cottonwoods with a shrubby understory to a relatively well-developed floodplain forest. Whitetail deer and a number of other mammals are found principally in these bottom woodlands.

Aquatic habitat is limited in extent in the prairie portion of the scenario area. Flows in the area's major streams--North Platte, Cheyenne, Belle Fourche, and Powder Rivers--vary considerably from both natural runoff and irrigation withdrawals. Warm-water fish species predominate, except below the discharges of several reservoirs in the North Platte. Fish habitat in the

Powder, Belle Fourche, and Cheyenne Rivers is limited because extreme summer flow reductions leave only a series of deep holes and pools with little water flowing between them. Species tolerant of these conditions include burbot, carp, white sucker, and fathead minnow. Stock ponds and small irrigation reservoirs usually support largemouth bass and panfish, while larger reservoirs support both warm- and cold-water species. Mountain lakes and streams in the Black Hills and Bighorn Mountains are stocked with trout.

7.5.3 Factors Producing Impacts

Four factors associated with construction and operation of the scenario facilities (electric power, Lurgi, Synthane, and Synthoil plants and their associated surface coal mines, surface coal mines for rail and slurry export, surface and solutional uranium mines and mills, and gas wells) can cause ecological impacts: land use, population increases, water use and water pollution, and air quality changes. With the exception of land use, the quantities of each of these factors associated with the scenario facilities were given in previous sections of this chapter. Land-use quantities are given in this section (Table 7-53), and the others are summarized. As indicated in Table 7-53, the solutional uranium facility and natural gas production and processing system require the least amount of land overall (200 and 1,080 acres over 30 years respectively). For coal plant-mine combinations, land use ranges from a low of 3,550 acres (gasification plant and mine) to a high of 5,770 acres (power plant and mine) during the 30-year facilities' lifetime. Land use for the surface uranium mine and mill (3,730 acres/30 years) is similar in magnitude to that for the coal plant-mine combinations. The surface coal mines for coal export will use the most land overall, 6,600 acres.

As described in Section 7.4, manpower required for construction and operation of the scenario facilities is expected to cause an increase in urban population in Campbell County. Peak manpower required during construction of the facilities is about 2,750 for the power plant-mine combination, about 5,000 for the Lurgi, Synthane, and Synthoil plant-mine combinations, 1,700 for the gas wells, 200 for the uranium mine and mill, and 50 for the solutional uranium mine. After construction is completed, manpower required for operation is about 1,000 for the power, Lurgi, and Synthane plant-mine combinations, about 3,400 for the Synthoil plant-mine combination, 800 for the gas wells, 300 for the uranium mine and mill, and 60 for the solutional mine.

Water required for the plants operating at the expected load factor ranges from about 5,825 (Lurgi plant) to 25,800 acre-ft/yr (power plant) assuming high wet cooling is used (Table 7-19). Water for the power, Lurgi, and Synthane plants will be withdrawn from the Yellowstone River; water for the Synthoil plant and coal

TABLE 7-53: LAND USE BY SCENARIO FACILITIES

FACILITY	LAND USE[a]	
	ACRES PER YEAR	ACRES PER 30 YEARS
Coal Conversion		
Power Plant (3,000 MWe)		2,400
Lurgi or Synthane Gasification Plant (250 MMcfd)		805
Synthoil Plant (100,000 bbl/day)		2,060
Surface Coal Mines		
For Power Plant (12.8 MMtpy)	100	3,300
For Lurgi Plant (9.4 MMtpy)	85	2,550
For Synthane Plant (8.1 MMtpy)	85	2,550
For Synthoil Plant (12.1 MMtpy)	110	3,300
For Rail Transport (25 MMtpy)	220	6,600
For Slurry Pipeline (25 MMtpy)	220	6,600
Natural Gas Production/Processing (250 MMcfd)		1,080
Uranium		
Surface Mine (1,100 mtpd)	115	3,450
Mill (1,000 mtpy)		280
Solutional Mine-Mill (250 tpy)		200

MWe = megawatt-electric
MMcfd = million cubic feet per day
bbl/day = barrels per day
MMtpy = million tons per year
mtpd = metric tons per day
mtpy = metric tons per year
tpy = tons per year

[a]The land used by the mines will increase every year by the amounts given in the table for 30 years, the lifetime of the facilities. However, land occupied by the plants will not vary after construction is completed.

slurry facility, from the North Platte River; water for rail transport facility, from local shallow aquifers; water for the uranium mill and gas liquefaction plant, from the Madison limestone aquifer. Wastewater from the facilities directed to ponds or treatment facilities will contribute contaminants to surface and groundwater only as ponds leak or erode.

The annual ambient air concentrations of SO_2 from the scenario facilities will range from 0.2 (coal mines for coal export) to 3.6 micrograms per cubic meter ($\mu g/m^3$) (Synthoil plant). Typical and peak concentrations of criteria pollutants from the facilities for coal export, power plant, Lurgi plant, Synthane plant, and uranium mill are not expected to violate any federal or Wyoming ambient air standards. Peak concentrations from both the gas wells and Synthoil plant will violate the federal and Wyoming 3-hour HC ambient air standard.

7.5.4 Impacts

The nature of the ecological impacts caused by these factors depends on the plant and animal community type on which they are imposed. For example, the impact of land use depends on whether shrub grassland, pine woodland, or riparian woodland is being used. Some of the land-use trends are now evident or could occur regardless of energy-related growth. A scenario which calls for power, Lurgi, Synthane, and Synthoil plants and their associated mines, surface coal mines for rail export and slurry export, uranium surface mine and mill and solutional mine, and gas wells to be developed according to a specified time schedule (see Table 7-1), is used here as the vehicle through which the extent of the impacts are explored. Impacts caused by land use, population increases, water use and water pollution, and air quality changes are discussed for each time period.

A. To 1980

Most of the early impacts of the scenario will be a consequence of construction activities. Expected land use by the urban population and the scenario facilities from 1975-2000 are given in Table 7-54. By 1980, about 2,840 acres, 0.09 percent of the land in Campbell County, will be used by the urban population by the one energy facility which is on-line. Table 7-55 shows that shurb grassland will be the community type primarily used by the urban population and energy facilities. Forage which could be produced on the 2,840 acres would support 30-53 cows with calves and 41-74 sheep in a year (Table 7-56).[1] For purposes of comparison, a 1974 Census of Agriculture Preliminary Report for Campbell County indicates a total inventory of 91,893 cows with calves and 126,890 sheep (including lambs).

The expected impact during the first 5 years is relatively minor in this scenario, primarily due to the limited extent of development. The amount of habitat removed by constructing the

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[1]Livestock carrying capacities are expressed as Animal Unit Months (AUM's). An animal unit is one cow and her calf or five sheep. An AUM refers to the amount of forage required to support one animal unit for 1 month. AUM's do not refer to wildlife. Estimated current forage requirements are 3.5-6 acres of forage for one AUM for grasslands and sagebrush grasslands, and 3.5-4.0 acres for pine and riparian lands. Private lands are now overstocked, and 3-4 acres are used to feed one cow with calf per month.

TABLE 7-54: LAND USE IN GILLETTE SCENARIO AREA (in acres)[a]

	1975	1980	1990	2000
By Energy Facilities				
Coal Conversion Facilities				
Power Plant (3,000 MWe)			2,400	2,400
Lurgi Plant (250 MMcfd)			805	805
Synthane Plant (250 MMcfd)				805
Synthoil Plant (100,000 bbl/day)				2,060
Surface Coal Mines				
For Power Plant (12.8 MMtpy)			550	1,650
For Lurgi Plant (9.4 MMtpy)			425	1,275
For Synthane Plant (8.1 MMtpy)				425
For Synthoil Plant (12.1 MMtpy)				
For Rail Export (25 MMtpy)			2,200	4,400
For Slurry Export (25 MMtpy)			1,100	3,300
Uranium Facilities				
Surface Mine (1,100 mtpd)			575	1,725
Mill (1,000 mtpy)			280	280
Solutional Mine-Mill (250 tpy)			200	200
Natural Gas Production/Processing (250 MMcfd)		1,080	1,080	1,080
Subtotal		1,080	9,615	20,405
By Urban Population in Campbell County[b]				
Residential	600	1,270	2,185	3,505
Streets	120	254	437	701
Commercial	14	30	52	84
Public and Community Facilities	37	79	136	217
Industry	60	127	218	350
Subtotal	831	1,760	3,028	4,857
Total Land Use	831	2,840	12,643	25,262
Total Land In Campbell County 3,043,840				

MWe = megawatt-electric
MMcfd = million cubic feet per day
bbl/day = barrels per day
MMtpy = millions tons per year
mtpd = metric tons per day
mtpy = metric tons per year
tpy = tons per year

[a]Values in each column are cumulative for year given.

[b]Acres used by the urban population were calculated using population estimates in Table 7-39 for Campbell County assuming: residential land = 50 acres per 1,000 population; streets = 10 acres per 1,000 population; commercial land = 1.2 acres per 1,000 population; public and community facilities = 3.1 acres per 1,000 population; and industry = 5 acres per 1,000 population. Adapted from THK Associates, Inc. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974.

TABLE 7-55: LAND CONSUMPTION: GILLETTE SCENARIO (acres)

COMMUNITY TYPE	PERMANENT LOSS		
	1980	1990	2000
Grassland[b]	930	1,330	1,920
Shrub grassland[a]	2,840	12,643	25,262
Pine Woodland[b]	550	780	930
Riparian Woodland[b]	130	190	250

[a]Assumes land use by energy facilities and urban population given in Table 7-54 will be on shrub grassland areas.

[b]These community types will be affected by land use for rail spur from Gillette area to Douglas which supports the export mines, a trunk line which supports the gas wells, and transmission and pipeline rights-of-way; these land uses are temporary and are not included in Table 7-54.

rail line, opening the first export mine, and developing the gas field with its system of gathering and transmission pipelines will be negligible compared to the total amount of sagebrush-grassland habitat available. Smaller vertebrates will be lost during construction, but many will tend to recolonize the pipeline rights-of-way after reseeding.[1] Although local impacts in affected areas will eliminate some species,[2] the net impact on areawide populations will be negligible.

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[1]Species recolonizing rights-of-way may not be the same as those initially found there, owing to change in vegetation cover.

[2]U.S., Department of the Interior, Bureau of Land Management, et al. Final Environmental Impact Statement for the Proposed Development of Coal Resources in the Eastern Powder River Coal Basin of Wyoming, 6 vols. Cheyenne, Wyo.: Bureau of Land Management, 1974, p. IV-115.

TABLE 7-56: POTENTIAL LIVESTOCK PRODUCTION FOREGONE: GILLETTE SCENARIO

ACRES LOST[a]		ANIMAL EQUIVALENT[b]	
		COWS WITH CALF	SHEEP
1980	2,840	30-53	41-74
1990	12,643	137-234	193-330
2000	25,262	274-469	386-661
Post-2000[c]	39,112	423-725	597-1,022
1974 Inventory,[d] Campbell County		91,893	126,890[e]
Loss as percent of 1974 Inventory (Post-2000)		0.5-0.8	0.5-0.8

[a]Includes cumulative land use by energy facilities and urban population given in Table 7-55.

[b]Carrying capacity of 3.5-6.0 acres of forage per Animal Unit Month (AUM) assumed for calculations. Actual capacity on private lands which are now overstocked are 3-4 acres per AUM.

[c]Includes total land use during 30 year lifetime of facilities.

[d]U.S., Department of Commerce, Bureau of the Census. 1974 Census of Agriculture; Preliminary Report, Campbell County, Wyoming. Washington, D.C.: Government Printing Office, 1976.

[e]Includes lambs.

The introduction of the rail line, which will carry seven unit trains daily, will interfere with the movements of larger, wide-ranging species such as deer and antelope. Seasonal movements between areas of winter browse and summer feeding and watering will be disrupted. The rail line also bisects two large winter concentration areas. If prevented from movement between winter and summer areas, antelope could decline in abundance, particularly during periods of drought-induced stress. This area is also subject to extensive habitat fragmentation[1] by energy development during subsequent years, which could accentuate this population trend.

Livestock production on either side of the railroad right-of-way will also require that it be fenced on both sides. These fences will prevent crossing of the rail line by antelope and will cause occasional, temporary entrapment of deer and antelope within the right-of-way.[2]

Manpower required for construction will cause the urban population in Campbell County to increase by 80 percent over the 1975 population, which will total 30,600 by 1980 (Table 7-39). Ecological impacts associated with population increases, water use and water pollution, and air quality changes will not be significant by 1980.

B. To 1990

By 1990, the gas wells, uranium surface and solutional mines and mill, surface mines for coal export, and power and Lurgi plants and their associated mines will be on-line. Land use by the urban population and by the energy facilities given in Table 7-54 is expected to be 12,640 acres, 0.41 percent of the land in Campbell County. Forage which could be produced on this land area, (primarily shrub grassland and small amounts of streamside vegetation, Table 7-55) would support 137-234 cows with calves and 193-330 sheep for a year (Table 7-56).

While the proportion of the total extent of habitat lost to facility siting is negligible, the addition of new sites will tend to fragment habitat used by the widest ranging of the area's wildlife: the pronghorn antelope. Fragmentation will increase in the subsequent decade; together with the impact of the railroad, this splitting of the species' range could result in changes

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[1]Habitat fragmentation occurs when the continuous mosaic of habitat types available to area wildlife becomes a discontinuous patchwork because of artificial barriers such as fences, irrigation canals, rail lines, or large barren expanses of mined areas. Wildlife species travel among different habitats daily, and often seasonally, to fulfill food, water, and cover requirements. Barriers which fragment habitat stress wildlife because they limit or prohibit access to these important needs.

[2]There has been some question about the impact of fencing the railroad right-of-way. Though deer can either jump or crawl through/under fences, antelope crawl under them and only rarely attempt to jump.

in seasonal movements and distribution.[1] Increased traffic on the highway parallel to the rail line will constitute a wildlife hazard. The impact of highway kills on areawide populations of smaller wildlife will be negligibly small, but the increased amount of carrion available may, in turn, attract birds of prey and some mammalian predators, which will be vulnerable to road-kill. Because of their low numbers, the threat to bald eagles, which feed on both carrion and live prey, warrants concern, although areawide populations of most other predators are high enough to absorb occasional deaths without decline.

It has been relatively common practice for large energy developers to purchase irrigation water rights as a stop-gap measure to ensure a water supply.[2] If this happened in this hypothetical scenario, conversion of these rights to industrial use could eliminate a portion of the wildlife habitat provided by irrigated crop and pasture land. Although restricted in extent, this habitat type may be important to a number of wildlife species, including ring-necked pheasant and water fowl as well as a variety of small mammals and birds.

A potential physical hazard is presented by the extra-high voltage power transmission line. Migrating birds may occasionally fly into the wires or suffer electrocution because of corona discharge. However, appropriate design can reduce the problem of electrocuting large birds perching on the towers. The corona discharge from the line could cause wildlife and livestock to avoid the general area.[3]

Increases in the population of the Gillette area over the second decade will induce continuing changes in land-use patterns. The effect of town growth on wildlife populations is irregular and is related to topography and the movements of people, but it probably extends no farther than 20 miles from the outskirts of town into the plains. For most species, a smaller radius (perhaps

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[1]Current fencing practices on public lands in the study area are antelope-oriented; that is, bottom fence strands are 14-16 inches above the ground, and Bureau of Land Management-designed "antelope guards" are provided. Fencing on private lands does not usually incorporate such designs and has likely produced some changes in distribution already.

[2]Industry has already purchased some 12,000 acres of irrigated cropland to obtain the associated water rights. However, as described in Part III, it is not clear that agricultural water rights can be converted for use in energy development.

[3]Research under the sponsorship of the Electric Power Research Institute is intended to reveal the extent to which large power lines can influence wildlife.

10 miles) would include most concentrated day-to-day human activity, the presence of domestic dogs and cats, traffic, noise, and suburban habitat fragmentation that would noticeably reduce the abundance and diversity of terrestrial wildlife. If, however, growth is scattered into small subdivisions along the north-south axis of the coal field, the combined effect on wildlife habitat of both industrial and residential land use would be more extensive than around a single town. This pattern could result if Gillette is unable to finance sewage treatment facilities meeting EPA standards, thus favoring scattered small developments.

By 1990, the urban population in Campbell County will be about 49,400, almost triple the 1975 population. Larger concentrations of people may bring increases in hunting and poaching, primarily of deer, elk, antelope, and sage grouse. Poaching typically reaches high levels around large construction projects and will have begun to occur in the previous scenario decade. Illegal kills of nongame animals are likely to follow a similar pattern. Birds of prey are usually prime targets, especially those which frequent roadsides such as bald and golden eagles and Swainson's hawks. The peregrine falcon, occasionally seen in the area, and the prairie falcon, a resident, can probably tolerate less of this kind of stress than the more abundant species. Varmint hunting is popular in the area, concentrating mainly on fox, coyote, and bobcat. A major increase in trapping and hunting, due to the increased human population and rising fur prices, could reduce the bobcat and possibly the fox populations. Since coyotes typically do not decline unless concerted efforts are made against them, their numbers could increase slightly as a result of lowered competition with other predators.

Patterns of recreational land use could shift if private lands are closed to hunting and other recreational uses. This trend is already in evidence around Gillette. Ranchers who close their lands will probably keep them closed even after the first population influx has passed. Such actions could reduce illegal game kill on large areas of sage-grassland. This trend would also force outdoor recreationists to almost exclusive use of the area's public lands, particularly the Black Hills and Bighorn National Forests.[1]

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[1]Lands to the northwest and southeast of Gillette that are under the administration of the Bureau of Land Management (BLM) and Basin National Grasslands or are administered by the Forest Service will be affected to a smaller degree. The BLM lands are important deer and elk habitat; unrestricted use of off-road vehicles in these areas could be particularly harmful to elk, which occupy very restricted ranges.

Wildlife populatons in the Black Hills will probably be affected more severely than those in the Bighorn Mountains due to the proximity of Gillette. While large parts of the Bighorn National Forest are administered as primitive areas and proposed for wilderness classification, the Black Hills National Forest is so well supplied with roads that the Forest Service plans to close some of them to reduce traffic in potential "backcountry" areas.[1] Further, about 20 percent of the area within the Black Hills National Forest boundary is not owned by the federal government. This land consists of scattered, small, privately held parcels whose subdivision could affect many kinds of wildlife through habitat fragmentation.[2] The net effect of developing recreational forested lands would be to protect, to some extent, animals typical of the well-developed sagebrush grasslands (where energy facilities occur) at the expense of forest ecosystems.

Water withdrawals from the North Platte and Yellowstone Rivers for energy development are not expected to cause significant ecological impacts. Localized adverse impacts may arise from dewatering the surface mines and from contamination of groundwater percolating through these mines after backfilling and revegetation. Mine dewatering may affect the water table as much as 2 miles away.[3] Springs or surface discharges within that distance might become unpalatable to wildlife from contamination by leached salts after flow is resumed.

Although the discharge of municipal sewage into area streams is to be controlled during this decade, Gillette will probably continue current discharge practices until about 1985 (Section 7.3). Such discharge could contain harmful amounts of nutrients and perhaps some organic material. Gillette presently discharges its sewage effluent into Donkey Creek, an intermittent stream. Assuming that this practice continues, the added flow could help stabilize the aquatic ecosystem. However, nutrients carried by the wastewater could cause algal blooms in pool habitats, lowering dissolved oxygen levels and causing odor problems as they

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[1]U.S., Department of Agriculture, Forest Service, Rocky Mountain Region. Draft Environmental Statement for the Timber Management Plan for the Black Hills National Forest. Denver, Colo.: Forest Service, 1976.

[2]Particularly vulnerable are whitetail deer, which winter at lower elevations, largely outside the forest boundary.

[3]U.S., Department of the Interior, Geological Survey. Final Environmental Impact Statement: Proposed Plan of Mining and Reclamation, Belle Ayr South Mine, Amax Coal Company, Coal Lease W-0317682, Campbell County, Wyoming, 2 vols. Reston, Va.: Geological Survey, 1975.

decay. Further, the Belle Fourche River, about 23 miles downstream, might receive nutrient-laden water from Donkey Creek, although the effects would be significantly diminished.

Typical and peak concentrations of criteria pollutants from the scenario facilities are not expected to cause significant ecological impacts.

C. By 2000

All the scenario facilities will be on-line by 2000. Land use by 2000 by urban population and energy facilities given in Table 7-54 will total 25,262 acres, 0.8 percent of the acres in Campbell County. Forage which could be produced on this land area, which is primarily shrub grassland (Table 7-55), would support 274-469 cows with calves and 386-661 sheep in a year (Table 7-56).

Recreational and land-use changes along with illegal harvest may adversely affect the twc small elk herds in the area (50 in the Rochelle Hills and a larger herd, about 200, along the badlands of the Little Powder River). These herds are too small to sustain continued loss of breeding animals of both sexes. Another factor affecting the vulnerability of elk is the large proportion of their range that lies on public lands. The area's other game species are likely to be protected somewhat by the closure of private lands.

Ecological impacts associated with land use and population increases will be similar to, but more intense than, impacts described for 1990. By 2000, the urban population in Campbell County will be 75,400, 4.4 times the 1975 population.

The removal of water from the North Platte River (Section 7.3) will equal 22 percent of low flow by 2000. Periodic stress in the aquatic community is likely to occur, at least in years of low flow. Lowered stream flows affect aquatic ecosystems by changing fish distributions and behavior, reducing the productivity of plants and invertebrates, reducing the total bottom area, changing overall water quality, and lowering the rate of food transfer from riffle to pool areas.

Flows in the North Platte are affected by reservoir operation. Reduced flow effects will be greatest in the periods of lowest river discharge, principally in winter. At other times, flow is great enough so that water withdrawal in the anticipated amounts will be only a very small portion of the total discharge. Thus, spring or fall fish spawning is not likely to be influenced.

In the drier months, increasing stress to game might conceivably bring about species shifts favoring nongame fishes.[1]

Dewatering will also reduce the extent of habitat available to wintering waterfowl. Large numbers of mallards, green-winged teal, golden-eye, and merganser, together with some geese, winter on the North Platte below Glenrock.

Both airborne and waterborne industrial wastes can introduce hazardous substances into the environment. Under most conditions, combined plant emissions should not add significantly to ground-level pollutant concentrations. Consequently, acute air pollution damage to vegetation or animals does not seem likely. Since the total land area exposed to airborne pollutants does reflect the number of emission sources, low-level exposure to SO_2 will cover a broad area downwind of the line of developments. Peak ground-level concentrations will be highest--323 milligrams per cubic meter (0.13 ppm) 3-hour average--downwind of the plant. These concentrations are below those generally thought to cause acute vegetation damage.

Some evidence suggests that fine particulate matter originating in the Great Plains is reduced over the Black Hills by the scavenging effects of precipitation and by the ability of vegetation to act as a filter.[2] The latter mechanism may account for as much as a two-fold reduction in particulate concentration. Thus, much of the sulfates and sulfites emitted as fine particulates or forming subsequently in the atmosphere may be deposited in the Black Hills. This phenomenon would carry with it the possibility of slight soil acidification, but total emissions are far below levels which have been associated with locally acid rainfall or chronic damage to plants. The tendency toward soil acidification will probably also be small. Other influences in the same time frame may have a greater affect on overall vegetation productivity and influence the ecosystems at large. Grazing and drought will remain the principal factors limiting the productivity of prairie vegetation, while the intent of the Forest Service to manage the Black Hills National Forest intensively

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[1]These nongame fishes have more flexible habitat requirements and include carp, white sucker, river carpsucker, buffalos, and bullheads. Nongame species which may be adversely affected include the stonecat and shorthead redhorse.

[2]Davis, B.L., et al. The Black Hills as a "Green Area" Sink for Atmospheric Pollutants, First Annual Report, prepared for the USDA Rocky Mountain Forest and Range Experiment Station, Report 75-8. Rapid City, S. Dak.: South Dakota School of Mines and Technology, Institute of Atmospheric Sciences, 1975.

as a system of small, even-aged stands[1] overrides the influence of long-distance transport of air pollutants from Gillette as an overall habitat influence.

D. After 2000

Land use by urban population and energy facilities (in Table 7-56) during the 30-year lifetime of the facilities will total 39,112 acres, 1.3 percent of the acres of land in Campbell County. Very little of the land in the county is cropland (about 4 percent); most of the land on and near the resource sites is currently used to graze cattle and sheep.[2] Little of this activity would be affected by mining, although 10 percent of the county will be within 0.5 mile of some transportation right-of-way, including rail, extra-high voltage transmission lines, and slurry pipelines. Forage which could be produced on the 39,112 acres, which are primarily shrub grassland, would support 423-725 cows with calves and 597-1,022 sheep (including lambs) in a year, which represents 0.5-0.8 percent of the 1974 inventory of cows with calves and sheep in Campbell County.

Of the 39,112 acres used during the 30-year scenario time period, about 11,200 acres will be permanently lost to urban expansion and facility structures and 27,900 acres will be used by mining. Experimental work in the Gillette area has shown that a cover of range grasses can be established on regraded mine spoils. Opinions differ on the length of time required to establish self-sustaining vegetation, but this technology assessment assumes that 5 years will be sufficient, after which there will be no further manipulation of the revegetated area. However, since spoil material lacks the structure of soils developed over longer periods, moisture in the revegetated mine spoils will probably not be as good (nor natural nutrient cycles as effective) as those in native soils. Further, since soil moisture availability and fertility are usually the major factors limiting plant growth on spoils from this part of the Fort Union Formation, revegetated areas may have less dense plant cover, lower productivity, and exhibit less stability in the face of such stresses as grazing or the region's periodic droughts than adjacent undisturbed vegetation. In consequence, the net effect of mining will probably be to convert shrubland used to a less productive, probably less stable early-successional type of grassland.

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[1] U.S., Department of Agriculture, Forest Service, Rocky Mountain Region. Draft Environmental Statement for the Timber Management Plan for the Black Hills National Forest. Denver, Colo.: Forest Service, 1976.

[2] U.S., Department of Commerce, Bureau of the Census. 1974 Census of Agriculture; Preliminary Report, Campbell County, Wyoming. Washington, D.C.: Government Printing Office, 1976.

The ecological impact of reclamation changes can be qualitatively described, based on successional patterns observed on abandoned farmland in the area.[1] Table 7-57 is a classification of area animals according to their preference for different vegetation types. (Figure 7-9 shows the expected changes in area animal populations on lands reclaimed with varying success.) This diagram shows that, during the 1980-2000 time period, most of the mined lands will be in an early stage of succession (modified by early introduction of perennial grasses). For example, ground squirrels, pocket gophers, and kangaroo rats will be abundant if spoil conditions permit burrowing, although on some mines, spoil textures may limit their occurrence. However, total numbers or biomass of these small vertebrates may be less than the original population, especially if grazing is permitted or plant cover is low. In contrast, those Group 1 species that depend on mature sage stands will be found in very small numbers. The resulting local change in prey species composition will probably not cause a change in the relative abundance of different predators. Potential exceptions are the golden and wintering bald eagles and the larger buzzard hawks, which prey heavily and sometimes almost exclusively on rabbits. The overall impact of hunting, trapping, and illegal shooting will probably have a more important effect on predator numbers than mining.

Other ecological impacts associated with land use, population increases, water use and water pollution, and air quality changes as described for 1990 and for 2000 will continue during the 30-year lifetime of the facilities.

7.5.5 Summary of Ecological Impacts

Four factors associated with construction and operation of the scenario facilities can significantly affect the ecological impacts of energy development: land use, population increases, water use and water pollution, and air quality changes. Land use by urban population and energy facilities during the 30-year lifetime of the facilities will total 39,112 acres, 1.3 percent of the acres of land in Campbell County. By 2000, urban population in Campbell County will be 75,400, an increase of 4.4 times the 1975 population. Water withdrawal for energy development from the Yellowstone River will represent 1 percent of its low flow and from the North Platte River, 22 percent of its low flow. Increased municipal water demands will be met with groundwater

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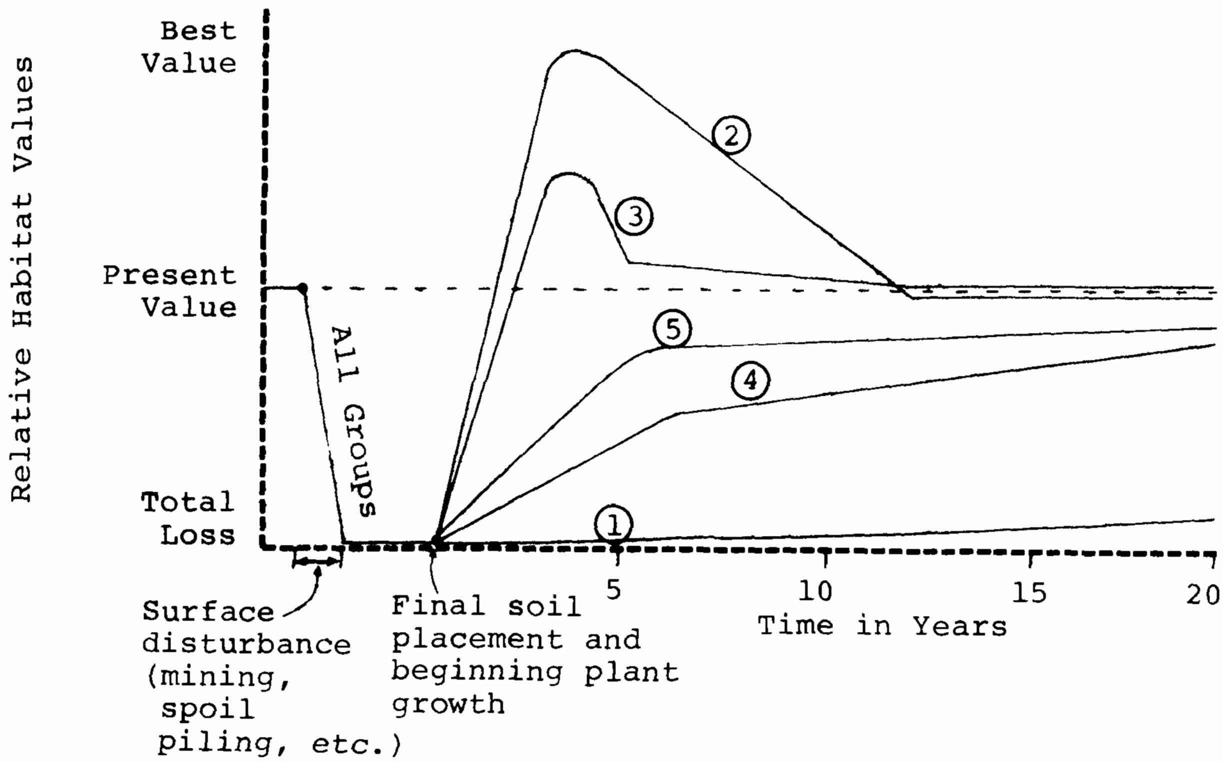
[1] U.S., Department of the Interior, Bureau of Land Management, et al. Final Environmental Impact Statement for the Proposed Development of Coal Resources in the Eastern Powder River Coal Basin of Wyoming, 6 vols. Cheyenne, Wyo.: Bureau of Land Management, 1974; and Lang, R.L. "Vegetation Changes Between 1943 and 1965 on the Shortgrass Plains of Wyoming." Journal of Range Management, Vol. 26 (November 1973), pp. 407-9.

TABLE 7-57: HABITAT GROUPS OF SELECTED ANIMALS REPRESENTATIVE OF THE STUDY AREA

Group I Animals heavily dependent on sagebrush for food or cover or nesting sites or combination thereof and/or other upland shrubs such as greasewood, saltbrush, and rabbitbrush, especially for winter feed	Pronghorn Antelope Mule Deer White-tailed Deer Sagebrush Vole Deer Mouse Least Chipmunk White-tailed Prairie Dog White-tailed Jackrabbit
Group II Animals feeding heavily on seeds and/or foliage or roots of weedy species of forb or annual grasses and/or nesting on ground in open grasslands	Thirteen-lined Ground Squirrel Richardson's Ground Squirrel Northern Pocket Gopher Wyoming Pocket Gopher Ord's Kangaroo Rat Western Harvest Mouse
Group III Animals nesting on the ground in open grasslands and/or feeding primarily on perennial grass seeds or foliage	Black-tailed Prairie Dog Prairie Vole Chestnut Collared Longspur McCown's Longspur
Group IV Animals that depend primarily on the riparian (stream-side) plant associations and/or marshy or moist meadow areas around lakes or ponds to directly or indirectly provide food or cover or nesting or breeding sites	Raccoon Mink Striped Skunk Beaver Muskrat Long-tailed Vole Black-billed Magpie Red-shafted Flicker
Group V Animals requiring the open pine timber, juniper breaks, or rough, rocky topography for cover or food or nesting sites	Elk Bushytail Wood Rat Porcupine Pygmy Nuthatch Cassins Kingbird White-winged Junco Pinon Jay

Source: U.S., Department of the Interior, Bureau of Land Management, _et al._ _Final Environmental Impact Statement for the Proposed Development of Coal Resources in the Eastern Powder River Coal Basin of Wyoming_, 6 vols. Cheyenne, Wyo.: Bureau of Land Management, 1974.



CURVE NUMBER	LEGEND ANIMAL GROUP (list of animals in each group is found in Table 7-57)
1	Group I
2	Group II (projected rehabilitation unsuccessful)
3	Group III (projected rehabilitation successful)
4	Group IV (projected rehabilitation unsuccessful)
5	Group V (projected rehabilitation successful)

Source: U.S., Department of the Interior, Bureau of Land Management, et al. Final Environmental Impact Statement for the Proposed Development of Coal Resources in the Eastern Powder River Coal Basin of Wyoming, 6 vols. Cheyenne, Wyo.: Bureau of Land Management, 1974.

FIGURE 7-9: EXPECTED HABITAT VALUE TRENDS FOR PARTICULAR ANIMAL GROUPS AFTER DISTURBANCE WITH ATTEMPTED REHABILITATION TO PERENNIAL GRASSLANDS from local aquifers. Effluents from the plants will be ponded to prevent water pollution. Increased wastewater from the urban population will require updated sewage treatment facilities. Typical and peak concentrations of criteria pollutants from the facilities for coal export, power plant, Lurgi plant, Synthane plant, and uranium mill are not expected to violate any federal or Wyoming ambient air standards. Peak concentrations from both the gas wells and Synthoil plant will violate the federal and Wyoming 3-hour HC ambient air standard.

The sources and expected period of major ecological impacts are shown in Table 7-58. Major impacts of the Gillette scenario are ranked according to the total area and number of species which they affect in Table 7-59. Class A impacts are considered most severe because they affect the largest number of species over an extensive area. In this scenario, habitat fragmentation takes place in a large area important to antelope. Poaching and illegal shooting affect both game and nongame species and are often widespread.

Another direct impact of the scenario is the low-flow reduction in the North Platte River from cumulative water withdrawals. Although uncertain due to lack of knowledge about the river channel in the scenario area, some detectable changes in the productivity of the ecosystem may result, at least during years of below-average flow.

Finally, the greatest potential impact arises from the indirect land-use pressures of a large increase in population. Especially significant is game poaching during construction peaks, which may decimate the area's small elk herds.

Suburban habitat fragmentation, concentrated human activity, and similar localized impacts associated with growth of an urban center such as Gillette are ranked as Class B impacts. Though they may affect several species, the geographic area in which the impacts are realized is relatively small.

Because the geographic area affected by facilities siting is small compared to the total amount of similar available habitat, grazing losses are given the most minor of rankings: Class C.

The cumulative impact of facility siting on habitat quantity and quality will principally reflect the success of reclamation and the degree to which habitat is fragmented and the movements of wide-ranging species are disrupted by the new rail line and its parallel high-traffic highway. Antelope will probably be most sensitive to this impact because of the large range they normally occupy.

TABLE 7-58: FORECAST OF POPULATION STATUS OF SELECTED SPECIES FOR THE GILLETTE SCENARIO[a]

	1980	1990	2000
Game Species Mule and Whitetail Deer	Moderate decline of prairie populations from heavy poaching pressure, loss of habitat, and redistribution.	Some decline in Black Hills deer populations, especially in whitetails, from fragmentation of winter range.	Probably stabilization or increase of Black Hills herds, owing to the implementation of even-aged stand management. Partial recovery of prairie populations following termination of construction activity and reduction of poaching pressure.
Antelope	Moderate decline owing to habitat fragmentation, restriction of movement patterns, heavy poaching pressure.	Continued low population levels, relative to 1975, compensated to a degree by closure of private lands to hunting.	Partial recovery if poaching pressure goes down. Trend toward willingness to jump fences could conceivably restore wider movement patterns by this time, alleviating effects of habitat fragmentation.
Elk	Moderate to serious decline of Fortification and Rochelle populations from poaching.	Accelerated decline because of added stress of harrassment by recreational vehicles.	Probably extirpation of Rochelle Hills population. Severe reduction or loss of Fortification Creek herd.
Sage Grouse	Slight decline in numbers from increased shooting, loss of habitat.	Possible compensation for increased legal and illegal harvest owing to private land closure.	
Turkey (Black Hills)	Little change.	Possible decline in numbers from illegal shooting, frequently on private lands dispersed throughout the forest.	Probable stabilization owing to implementation of even-aged stand management.
Pheasant	Little change.	Moderate to (potentially) serious decline because of downtrend in irrigated agriculture.	Continued downtrend.
Waterfowl	Little change.	Possible slight decline region-wide because of reduction in irrigated agriculture.	Persistence of slight downtrend because of dewatering in the North Platte River.
Mourning Dove	Little change.	Little change.	Little change.
Rare or Endangered Species[b] National Level Peregrine Falcon	Probable loss of wintering individuals from illegal shooting.	Continued low numbers.	Continued low numbers.
Bald Eagle	Probable loss of wintering individuals from auto collision, illegal shooting.	Increased risk to nesting birds on North Platte River from harrassment or illegal shooting. Continued losses of wintering birds.	Possible loss of some nesting pairs on the North Platte owing to disturbance; continued losses of wintering birds.

TABLE 7-58: (Continued)

	1980	1990	2000
Rare or Endangered Species (Continued) Black-Footed Ferret	Little change (if present) unless habitat is disturbed directly.	Potential decline through overshooting prairie dog towns, harrassment.	Continued potential for decline through disturbance of prairie dog towns.
Ecological Indicators Early Succession (reclamation) Richardson's Ground Squirrel[b]	Little change.	Potential local increase on reclaimed mines and where spoil texture permits burrowing.	Potentially increased presence on mined lands, especially if older spoils develop a texture favorable for burrowing.
Western Harvest Mouse, Horned Lark	Little change.	Potential local increases in response to availability of food on reclaimed mine lands.	Potential continued response to mine reclamation.
Mature Sage Grasslands (habitat loss) Cottontail, Jackrabbit, Lark Sparrow, Sagebrush Lizard	Little change.	Slight decline in local populations due to habitat loss.	Continued slight decline.
Streamflow in North Platte River Rainbow, Brown Trout	Little change.	Possible decline in numbers due to dewatering, possibly also from increased fishing pressure. Can be remedied by stocking.	Continued decline, reflecting further dewatering. Perhaps less effectively remedied by stocking.
Stonecat	Little change.	Decline in numbers because dewatering.	Possibly sharp decline, from further dewatering; potential for loss of the species in some areas of the river.
Carp, White Sucker, Buffalo	Little change.	Slight tendency to increase as a result of dewatering.	Possibly marked increase in importance, reflecting habitat changes brought on by further dewatering.

[a]This table is intended to show population trends from energy development alone; it assumes that all other factors remain constant.

[b]Endangered species indentified for Wyoming include Shovelnose Sturgeon, Goldeye, Silvery Minnow, Sturgeon Chub, W. Smooth Green Snake, and Northern Kit (Swift) Fox. The scenario possesses little changes for these, except the Northern Kit Fox which may experience possible loss of individuals through predator, trapping, and hunting.

[c]Although these species favor early successional vegetation and may be locally dominant or characteristic on reclaimed mines, their acutal density may be quite low if the vegetation is of low productivity.

TABLE 7-59: SUMMARY OF MAJOR FACTORS AFFECTING ECOLOGICAL IMPACTS

IMPACT CATEGORY	1975-1980	1980-1990	1990-2000
Class A	Habitat fragmentation Increased recreational use of public lands	Habitat fragmentation Poaching and illegal shooting Stream flow reductions Increased recreational use of public lands	Habitat fragmentation Poaching and illegal shooting Stream flow reductions Increased recreational use of public lands
Class B	Growth of Gillette	Growth of Gillette	Growth of Gillette
Class C	Grazing losses (facilities siting)	Grazing losses (facilities siting)	Grazing losses (facilities siting)
Uncertain		Irrigated agricultural losses	Sulfate fallout in Black Hills Irrigated agricultural losses

7.6 OVERALL SUMMARY OF IMPACTS AT GILLETTE

The intended energy benefit from the hypothetical developments in the Gillette area will be the production and shipment of 50 million tons of coal per year, 100,000 barrels of synthetic oil, 750 million standard cubic feet per day of synthetic and natural gas, and 3,000 MW of electricity. In addition, 1,250 metric tons per year of U_3O_8 will be produced for enrichment for nuclear reactors. Locally, the benefits include increased income to the city and county, increased retail and wholesale trade, and secondary economic development. Campbell County will also receive increased tax revenues as will the state of Wyoming.

Social, economic, and political impacts associated with energy development in the Gillette area tend to be a function of the labor and capital-intensity of development and, when multiple facilities are involved, of scheduling their construction. These factors determine the pace and extent of migration of people to the scenario area as well as the financial and managerial capability of local governments to provide services and facilities for the increased population. Labor forces increase the population directly and indirectly. More manpower is required for the operation of the uranium mine and coal mines than for construction, but conversion facilities require more manpower for construction (at its peak) than for operation. Of the scenario facilities, the Synthoil facility is the most labor-intensive. Suitable scheduling of facility construction can minimize population instability usually associated with construction forces. Revenue for local, state, and federal governments is generated by property taxes, sales taxes, a severance tax, and royalty payments on federally owned coal. Although Gillette is a relatively large community, it may have difficulty in meeting the demands associated with the expected population increase. Wyoming offers funding assistance for communities needing expanded public services and facilities to meet demands of new residents. Lifestyle and cultural differences among residents and newcomers influence the way in which impacts from energy development are perceived. As a result, if people who have migrated out of the area returned and were hired along with some local unemployed laborers to meet the manpower requirements for energy facility construction and operation, then the impacts caused by a population of strangers would not be as great.

If all facilities are constructed according to the hypothesized schedule, social, economic, and political changes in Campbell County will stem primarily from a four- to fivefold growth in population. Housing demands will be largely met by mobile homes. Nearly 1.3 percent of Campbell County will undergo changes in land use adding significantly to the assessed valuation. However, the tax base for Gillette will not increase enough to meet new demands placed on public services, and the political strength within the county may shift from ranchers and businessmen to energy developers.

Technological variables affecting these impacts are primarily alternatives between exporting coal or converting it within Campbell County. Construction of conversion facilities requires 20 to 30 times the labor of a mine alone and would not produce great fluctuations in the work force. However, if the coal were shipped from the region, the tax base for Campbell County would significantly diminish. If export mining resulted in increased rail service rather than slurry lines, impacts would depend on the extent of new rail access to the region and the degree to which rail lines would be monopolized by coal cars.

Air quality impacts associated with energy development are related primarily to quantities of pollutants emitted by the energy facilities and to diffuse emissions associated with the population. The power plant emits higher concentrations of all criteria pollutants other than HC than the other conversion facilities. The sulfur content of coal in the scenario area is low enough that a power plant with no emission controls could meet the SO_2 NSPS but not the ambient air standards.

Both the Synthoil plant and natural gas production facilities emit HC in amounts that will result in ambient air concentrations in excess of both Wyoming and federal standards. In addition, current levels of HC in the city of Gillette are estimated to be in excess of standards, and any addition from the plants and additional urban growth will exacerbate this problem. If the Black Hills National Forest to the east is reclassified as a Class I area, significant deterioration increments for SO_2 will be exceeded. In addition, the plumes of the plants will be visible from many locations in the area, and average long-range visibility will be reduced by up to 8 percent when all the facilities are operating. Under adverse meteorological conditions, visibility will be reduced to an even greater extent.

Several potential air controls could ameliorate the extent of the air impacts, although the HC problem cannot be solved short of enclosing the entire plant or making major improvements in valve and flange design. Either a reduction in plant size, improved scrubbers, or coal washing to remove inorganic sulfur would reduce sulfur emissions to minimize potential conflicts with significant deterioration standards. Increasing precipitator efficiency to 99.5 percent would result in less reduction in visibility and reduce emissions of most trace elements by 50 percent.

Water impacts associated with energy development in the Gillette area depend on the water requirements of and effluents produced by the facilities. Of the coal conversion facilities, the power plant has the largest water requirement and the Lurgi plant, the smallest. Water consumed by the energy facilities (if all those hypothesized are constructed) will significantly affect the streams used as water sources, especially the North Platte River where the low flow will be reduced by about 22 percent. This reduction in flow would also increase in-stream salinity and affect downstream agricultural users as well as the quality of water for aquatic life. Groundwater quality may also be affected by leaching chemicals from settling ponds and by the erosion of storage ponds. Surface water quality in the immediate vicinity of Gillette is also threatened by inadequate sewage treatment facilities.

Technological changes could significantly affect the consumptive use of water. One small power plant in the Gillette region is currently using dry cooling, and the potential exists for using dry-cooling towers or wet/dry cooling for the hypothetical conversion facilities in this scenario. This would significantly affect the potential conflicts that might arise from using the waters of the North Platte or in transporting water from the Yellowstone River in Montana to Wyoming.

Ecological impacts associated with energy development in the Gillette area are a function of land use, population increases, water use and water pollution, and air quality changes. Most of the land use will be due to mining activities. However, it is expected that much of the mined land will be returned to grassland following reclamation. This change, together with habitat fragmentation, will likely decrease productivity of selected species. Combined with habitat attrition and poaching from the increased population, some species of game will be adversely affected unless positive steps are initiated in protection and game management. Consumptive use of water for plant cooling and slurry transport will reduce the extent of riparian habitat and the quality of the aquatic ecosystem, and the new rail line will limit movement of antelope, reducing population size. The principal technological variables affecting ecological impacts include population size and water consumption addressed above and alternative methods for transporting energy resources.

CHAPTER 8

THE IMPACTS OF ENERGY RESOURCE DEVELOPMENT AT THE COLSTRIP AREA

8.1 INTRODUCTION

The Colstrip area of Rosebud County in southeastern Montana is shown in Figure 8-1. The energy developments proposed for this area consist of surface coal mining, an electric power generating plant, Lurgi and Synthane high British thermal unit (Btu) gasification plants, and a Synthoil coal liquefaction plant (Figure 8-2). Extra-high voltage transmission lines transport electricity from the power plant to demand centers in the midwestern U.S. These facilities are to be constructed between 1977 and 2000. Coal characteristics, technological alternatives, and the scenario's development schedule are summarized in Table 8-1.[1]

In all four impact sections of this chapter (air, water, social and economic, and ecological), the factors that produce impacts are identified and discussed separately for each energy facility type. In the air and water sections, the impacts caused by those factors are also discussed separately for each facility type and, in combination, for a scenario in which all facilities are constructed according to the scenario schedule. In the section on social and economic impacts (8.4) and on ecological impacts (8.5), only the combined impacts of the scenario are discussed. This distinction is made because social, economic, and ecological effects are, for the most part, higher order impacts. Consequently, facility by facility impact discussions would have been repetitive in nearly every respect.

Rosebud County's 1975 population was about 8,600, with agriculture the major source of earned income (33 percent in 1972). Other major sectors of economic activity are government, wholesale and retail trade, and construction. Construction activity has

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[1]While this hypothetical development may parallel developments proposed by Northern Natural Gas, Western Energy, Westmoreland Resources, AMAX Coal, Montana Power, and others, the development identified here is completely hypothetical. As with the others, this scenario was used to structure the assessment of a particular combination of technologies and existing conditions.

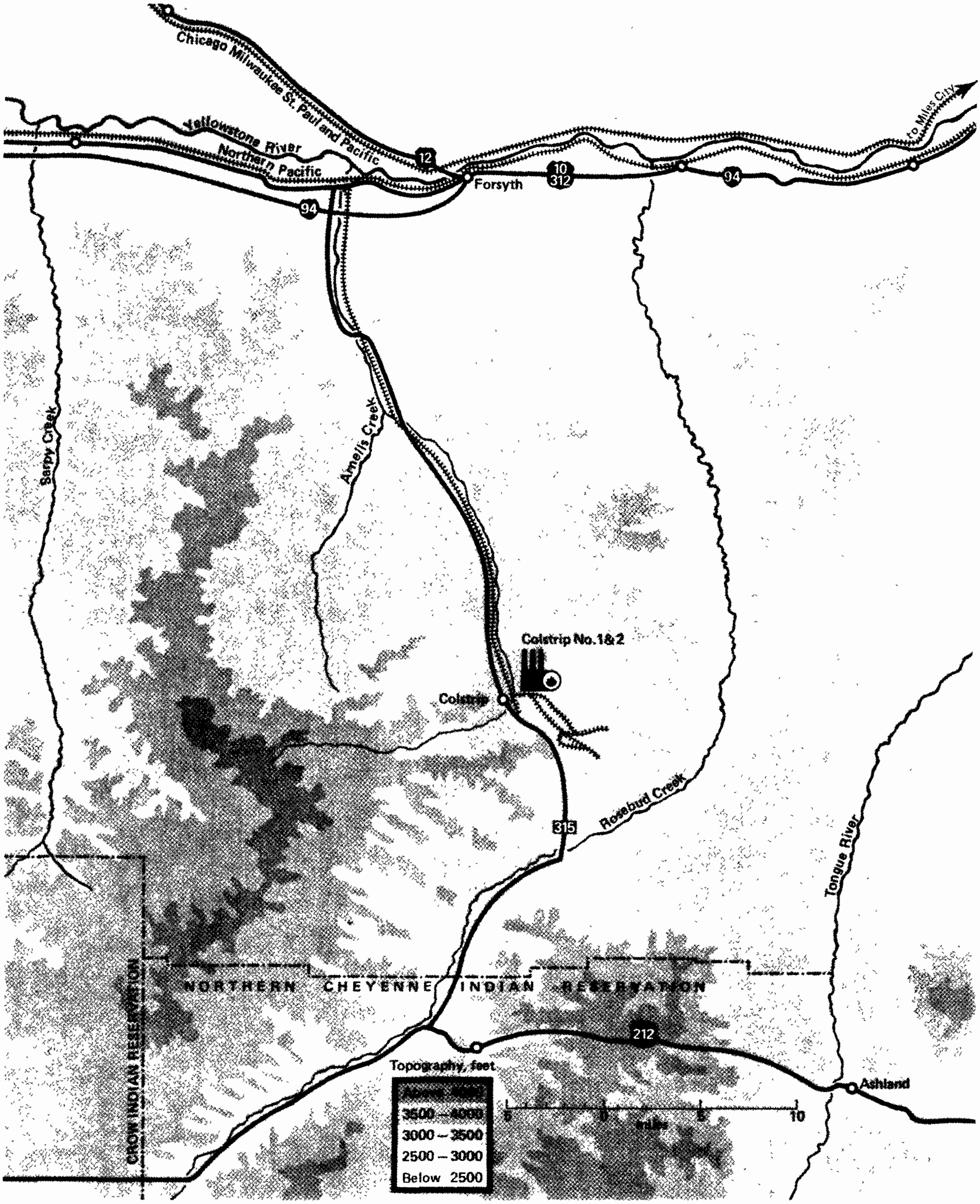

FIGURE 8-1: THE COLSTRIP SCENARIO AREA

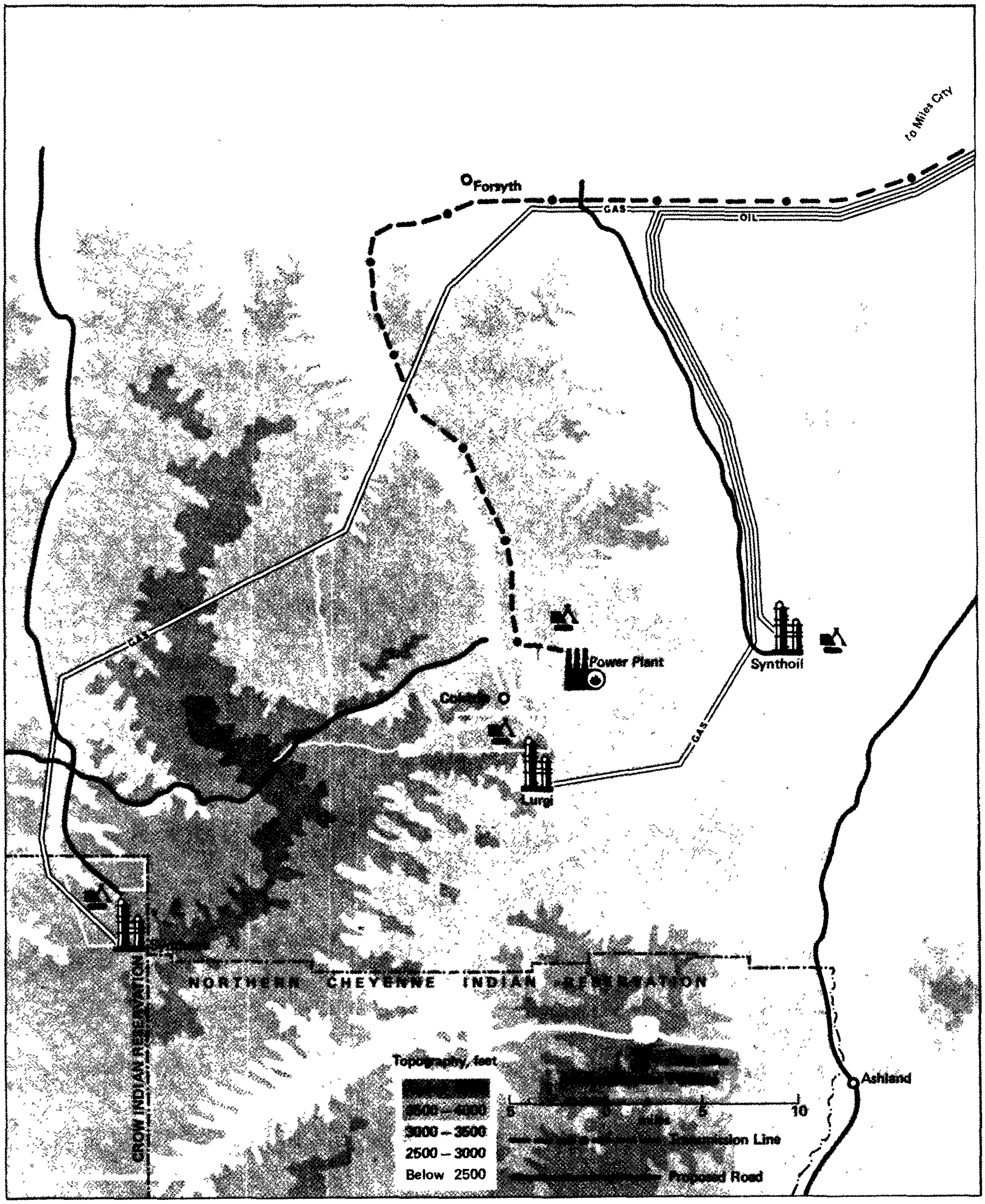

FIGURE 8-2: THE LOCATION OF ENERGY DEVELOPMENT FACILITIES AT COLSTRIP

TABLE 8-1: RESOURCES AND HYPOTHESIZED FACILITIES AT COLSTRIP

Resources		CHARACTERISTICS	
Coal[a] (billions of tons)		Coal[b]	
Resources	1.4	Heat Content	8,870 Btu's/lb
Proved Reserves	1.1	Moisture	24 %
		Volatile Matter	39 %
		Fixed Carbon	51 %
		Ash	10 %
		Sulfur	1 %

Technologies	FACILITY SIZE	COMPLETION DATE	FACILITY SERVICED
Extraction			
Coal			
Four surface area mines of varying capacity using draglines	16.8 MMtpy 9.6 MMtpy 8.4 MMtpy 12.0 MMtpy	1984 1989 1994 1999	Power Plant Lurgi Synthane Synthoil
Conversion			
One 3,000 MWe power plant consisting of four 750 MWe turbine generators; 34% plant efficiency; 80% efficient limestone scrubbers; 99% efficient electrostatic precipitator; and wet forced-draft cooling towers	750 MWe 750 MWe 1,500 MWe	1982 1984 1985	
One Lurgi Coal Gasification plant operating at 73% thermal efficiency; nickel-catalyzed methanation process; Claus plant H_2S removal; and wet forced-draft cooling towers	250 MMscfd	1990	
One Synthane Coal Gasification plant operating at 80% thermal efficiency; nickel-catalyzed methanation process; Claus plant H_2S removal; and wet forced-draft cooling towers	250 MMscfd	1995	
One Synthoil Coal Liquefaction plant operating at 92% thermal efficiency; Claus plant H_2S removal; and wet forced-draft cooling towers	100,000 bbl/day	2000	
Transportation			
Coal			
Transportation from the mines to facilities provided by trucks			
Gas			
One 30-inch pipeline	250 MMscfd	1990	Lurgi Plant
Oil			
One 16-inch pipeline	100,000 bbl/day	2000	Synthoil Plant
Electricity			
Four 500 kV lines	500 kV 500 kV 500 kV (2)	1982 1984 1985	Power Plant Power Plant Power Plant

Btu's/lb = British thermal units per pound
MMtpy = million tons per year
MWe = megawatt-electric
MMscfd = million standard cubic feet per day
H_2S = hydrogen sulfide
bbl/day = barrels per day
kV = kilovolts

[a]Montana Energy Advisory Council. Coal Development Information Packet. Helena, Mont.: State of Montana, 1974.

[b]Ctvrtnicek, T.E., S.J. Rusek, and C.W. Sandy. Evaluation of Low-Sulfur Western Coal Characteristics, Utilization, and Combustion Experience, EPA-650/2-75-046, Contract No. 68-02-1302. Dayton, Ohio: Monsanto Research Corporation, 1975.

TABLE 8-2: SELECTED CHARACTERISTICS OF THE COLSTRIP AREA

Environment	
Elevation	3,000-4,000 feet
Precipitation	12-16 inches average annually
Air Stability	Air stagnation most frequent during fall and winter
Vegetation	Ponderosa pines at higher elevations; rolling grasslands at lower elevations
Social and Economic[a]	
Landownership	
Federal	4.7 %
State	5.1 %
Private	90.2 %
Population Density	1.69 per square mile
Unemployment[b]	6.4 %
Income[c]	$3,751 per capita annual

[a]Rosebud County.

[b]June 1978 (Source: Montana State Government, Office of Research Analysis, Helena, Montana).

[c]1972 Data.

increased substantially as a result of recent energy development in the area. Per capita income in Rosebud County has been slightly lower than the Montana average, averaging out the prosperous ranching activity and the relative poverty of the Northern Cheyenne Indians, who comprised 28 percent of the population in 1970.

The area around Colstrip is generally a semiarid plateau, dissected by several tributaries of the Yellowstone River. The topography ranges from gently rolling basins to rugged uplands and eroded buttes. Rangeland accounts for 77 percent of the county. Although most land in Rosebud County is privately owned, the federal government owns much of the mineral rights.

Both groundwater and surface water are available in the area, the latter primarily from the Yellowstone and Tongue Rivers and Rosebud Creek. Air quality in the area is good, with the major present pollutant being blowing dust. Selected characteristics of the area are summarized in Table 8-2.

8.2 AIR IMPACTS[1]

8.2.1 Existing Conditions

A. Background Pollutants

Air quality in the Colstrip area is currently affected by several sources of air emissions, the largest of which are the Colstrip 1 and 2 generating facilities and the Ashland Timber Company. Coal strip mines in the area may also cause some localized increases in pollutant concentrations. Measurements of concentrations of criteria pollutants[2] taken in the Colstrip area do not violate any federal or Montana Standards.[3] Based on these measurements, the annual average background levels chosen as inputs to the air dispersion model are (in micrograms per cubic meter [$\mu g/m^3$]): sulfur dioxide (SO_2), 6; particulates, 15; and nitrogen dioxide (NO_2), 10.[4]

B. Meteorological Conditions

The worst dispersion conditions for the Colstrip area are associated with stable air conditions, low wind speeds (less than 5-10 miles per hour), unchanging wind direction, and relatively

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[1]The federal standards referred to in this section are those promulgated prior to the revisions mandated by the Clean Air Act Amendments of 1977, Pub. L. 95-95, 91 Stat. 685.

[2]Criteria pollutants are those for which ambient air quality standards are in force: carbon monoxide (CO), nonmethane hydrocarbons (HC), NO_2 , oxidants, particulates, and SO_2. The term "hydrocarbons" is generally used to refer to nonmethane HC. The HC standard serves as a guideline for achieving oxidant standards.

[3]U.S., Environmental Protection Agency, Region VIII Energy Office, Surveillance Analysis Division. Ambient Air Quality Monitoring Network--EPA Region VIII Energy Areas, Report No. 908/4-77-011. Denver, Colo.: Environmental Protection Agency, October 1977.

[4]These estimates are based on the Radian Corporation's best professional judgment. They are used as the best estimates of the concentrations to be expected at any particular time. Measurements of HC and CO are not available in the rural areas. However, high-background HC levels have been measured at other rural locations in the West and may occur here. Background CO levels are now assumed to be relatively low. Measurements of long-range visibility in the area are not available, but the average is estimated to be 60 miles.

low mixing depths.[1] These conditions are likely to increase concentrations of pollutants from both ground-level and elevated sources.[2] Since worst-case conditions differ at each facility, annual average pollutant levels vary among locations even if pollutant sources are identical. Meteorological conditions in the area are generally unfavorable for pollution dispersion more than 27 percent of the time. Hence, plume impaction[3] and limited plume mixing caused by temperature inversions at stack height can be expected to occur regularly.[4] Favorable dispersion conditions associated with moderate winds and large mixing depths are expected to occur about 14 percent of the time.

The pollution dispersion potential for the Colstrip area varies considerably with the season and time of day. Fall and winter mornings are most frequently associated with poor dispersion due largely to low wind speeds, low mixing depths, and the prevalence of high-pressure systems during these seasons. The highest potential for dispersion occurs during the spring when low-level winds are strongest.

8.2.2 Factors Producing Impacts

The primary air emission sources in the Colstrip scenario are a power plant, three coal conversion facilities (Lurgi, Synthane, and Synthoil), supporting surface coal mines, and those sources associated with population increases. The focus of this section is on emissions of criteria pollutants from the energy facilities.[5] Table 8-3 lists the amounts of the five criteria pollutants emitted by each of the four facilities. In all four cases, most emissions come from the plants rather than the mines. Most mine-related pollution will originate from diesel engine combustion products,

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[1]Mixing depth is the distance from the ground to the upward boundary of pollution dispersion.

[2]Ground-level sources include towns and strip mines that emit pollutants close to ground level. Elevated sources are stack emittors.

[3]Plume impaction occurs when stack plumes impinge on elevated terrain because of limited atmospheric mixing and stable air conditions.

[4]See National Climatic Center. Wind Dispersion by Pasquill Stability Classes, Star Program for Selected U.S. Cities. Ashville, N.C.: National Climatic Center, 1975.

[5]Air impacts associated with population increase are discussed below (Section 8.2.3) as those impacts relate to the scenario, which includes all facilities constructed according to the hypothesized schedule.

TABLE 8-3: EMISSIONS FROM FACILITIES
(pounds per hour)

FACILITIES[a]	PARTICULATES	SO_2	NO_x	HC	CO
3,000 MWe Power Plant					
Mine	14[b]	9.2	126	76	15
Plant	2,792	14,000	18,900-31,500[c]	524	1,752
Lurgi					
Mine	7.7[b]	5	69	8	42
Plant	N	516	649	47[d]	N
Synthane					
Mine	6.9[b]	4.6	62	7.2	38
Plant	8	3,524	5,052	94	176
Synthoil[e]					
Mine	10	6.7	92	11	56
Plant	482.4	936.7	4,616	1,350	181

SO_2 = sulfur dioxide
NO_x = oxides of nitrogen
HC = hydrocarbons
CO = carbon monoxide
MWe = megawatt-electric
N = negligible

[a]A detailed description of each plant is contained in White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming. Stack parameters, heights, and pollutant emission rates are described in detail.

[b]These particulate emissions do not include fugitive dust.

[c]Range indicates NO_x removal efficiencies of 0 and 40 percent.

[d]These emissions do not include fugitive HC.

[e]Synthoil data have a high uncertainty because only bench scale test facilities have been built to date. The Solvent Refined Coal liquefaction process now appears likely to become commercial sooner, and more reliable pilot data are available. These data are reported in White et al. Energy From the West: ERDS Report, Chapter 3.

primarily nitrogen oxides (NO_x), hydrocarbons (HC), and particulates. Although water spray will be used to suppress dust in this scenario, some additional particulates will occur from blasting, coal piles, and blowing dust.[1]

The largest of these sources, the power plant, has four 750-megawatt-electric (MWe) boilers, each with its own stack.[2] The plant is equipped with electrostatic precipitators (ESP) which remove 99 percent of particulates and scrubbers which remove 80 per cent of the SO_2 and from 0 to 40 percent of the NO_x.[3] The plant has two 75,000-barrel oil storage tanks, with standard floating roof construction, each of which will emit about 0.7 pound of HC per hour. Table 8-4 lists the amounts of particulates, SO_2, and NO_x expected to be emitted (in pounds per million Btu) from the power plant operating under the conditions described above and compares emissions to the New Source Performance Standards (NSPS).[4] Particulate and NO_x emissions just meet NSPS with 99 percent total suspended particulate (TSP) removal and 40 percent scrubber removal of NO_x. If the scrubbers remove none of the NO_x emissions, the NSPS will be violated. In order to just meet NSPS, a minimum of 20 percent of SO_2 emissions and 36 percent of NO_x emissions removal would be required.[5]

The power plant and the three coal conversion facilities are cooled by wet forced-draft cooling towers. Each cell circulates water at a rate of 15,330 gallons per minute (gpm) and emits 0.01 percent of its water as a mist. The circulating water has a total dissolved solids (TDS) content of 3,200 parts per million (ppm), which results in a salt emission rate of 21,200 pounds per year for each cell.[6]

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[1]The effectiveness of current dust suppression practices is uncertain. Research being conducted by the Environmental Protection Agency (EPA) is investigating this question. The issue of fugitive dust is discussed qualitatively in Chapter 10.

[2]Each stack is 500 feet high.

[3]Efficiency of NO_x removal may vary from 0 to 40 percent.

[4]NSPS limit the amount of a given pollutant a stationary source may emit; the limit expressed relative to the amount of energy in the fuel burned.

[5]The Clean Air Act Amendments of 1977, Pub. L. 95-95, 91 Stat. 697 § 109, requires both an emissions limitation and a percentage reduction of SO_2, particulates, and NO_x. Revised standards have not yet been established by the EPA.

[6]The power plant has 64 cells, the Lurgi plant has 11, the Synthane plant has 6, and the Synthoil plant has 16.

TABLE 8-4: COMPARISON OF EMISSIONS FROM POWER PLANT WITH NEW SOURCE PERFORMANCE STANDARD (pounds per million Btu)

POWER PLANT	EMISSION	NSPS[a]
Particulates	0.10	0.1
SO_2	0.48	1.2
NO_x[b]	0.65-1.08	0.7

NSPS = New Source Performance Standards
Btu = British thermal unit
SO_2 = sulfur dioxide
NO_x = oxides of nitrogen

[a]The Montana state standard for SO_2 emissions is one pound per million Btu plus the maximum control capability which is technically practicable and economically feasible as determined by the Air Quality Bureau. Data from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[b]Range indicates NO_x removal by scrubber of 0 and 40 percent.

8.2.3 Impacts

This section describes air quality impacts which result from each type of coal conversion facility (Lurgi, Synthane, Synthoil, and power plant) taken separately[1] and from a scenario which includes construction of all facilities according to the hypothesized scenario schedule. For the power plant the effect on air quality of hypothesized emission controls, alternative emission controls, and alternative stack heights are discussed. The focus is on concentrations of criteria pollutants (particulates, SO_2, NO_2, HC, and carbon monoxide [CO]).

See Chapter 10 for a qualitative description of sulfates, other oxidants, fine particulates, long-range visibility, plume opacity, cooling tower salt deposition, and cooling tower fogging and icing.

In all cases, air quality impacts result primarily from the operation rather than the construction of these facilities. Construction impacts are limited to periodic increases in particulate concentrations due to windblown dust, which may cause periodic violations of 24-hour ambient particulate standards.

[1]Air quality impacts caused by the surface mines are expected to be negligible in comparison with impacts caused by conversion facilities.

A. Power Plant Impacts

Concentrations of criteria pollutants resulting from power plant emissions depend largely on the extent of emission control imposed. Concentrations resulting from the hypothesized case where control equipment removes 80 percent of the SO_2 and 99 percent of the particulates are discussed first followed by a discussion of alternative emission controls and alternative stack heights.

(1) Hypothesized Emission Control

Table 8-5 summarizes the typical and peak concentration of four criteria pollutants predicted to be produced by a power plant (3,000 MWe, 80 percent SO_2 removal, 99 percent TSP removal). These pollutants (particulates, SO_2, NO_2, and HC) are regulated by the federal and Montana state ambient air quality standards, which are shown in Table 8-5. Peak concentrations from the plant will not violate ambient air standards but will exceed the Class II prevention of significant deterioration (PSD) increment for 3-hour SO_2.[1] Peak concentrations from the power plant will exceed all Class I increments except that for annual particulates, with typical concentrations violating the 24-hour and 3-hour SO_2 increment.

Since the plant exceeds Class I increments, it would have to be located a sufficient distance from any Class I area so that emissions will be diluted by atmospheric mixing to acceptable concentrations prior to reaching such areas. The distance required for this dilution (which varies by facility type, size, emission controls, and meteorological conditions) in effect establishes a "buffer zone" around Class I areas. Current Environmental Protection Agency (EPA) regulations require a minimum buffer zone of 75 miles between the power plant and any Class I area boundary.[2]

(2) Alternative Emission Controls

The base case control for the Colstrip power plant assumed an SO_2 scrubber efficiency of 80 percent and an ESP efficiency of 99 percent. The effect on ambient air quality of three additional

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[1]PSD standards apply only to particulates and SO_2.

[2]Note that buffer zones around energy facilities will not be symmetric circles. This lack of symmetry is clearly illustrated by area "wind roses," which show wind direction and strength patterns for various areas and seasons. Hence, the direction of PSD areas from energy facilities will be critical to the size of the buffer zone required. Note also that the term "buffer zone" is in disfavor. We use it because we believe it accurately describes the effect of PSD requirements.

TABLE 8-5: POLLUTION CONCENTRATIONS FROM POWER PLANT/MINE COMBINATION AT COLSTRIP (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]					STANDARDS[b]				
			PEAK			AMBIENT			PSD	
	BACKGROUND	TYPICAL	PLANT	PLANT AND MINE	COLSTRIP	PRIMARY	SECONDARY	MONTANA	CLASS I	CLASS II
Particulate										
Annual	15		0.5	0.5	0.3	75	60	75	5	19
24-hour		5.6	17	23	19	260	150	200	10	37
SO_2										
Annual	6		2.7	2.7	0.5	80		23	2	20
24-hour		16	87	90	57	365		115	5	91
3-hour		31	657	657	341		1,300		25	512
NO_2[c]										
Annual	10		3.6-6.0[d]	3.6-6.0[d]	2.3	100	100	100		
HC[e]										
3-hour		4.7	43	69	45	160	160	160		

PSD = Prevention of Significant Deterioration SO_2 = sulfur dioxide NO_2 = nitrogen dioxide HC = hydrocarbons

[a]These are predicted ground-level concentrations from the hypothetical power plant/mine combination. Annual average background levels are considered the best estimates of short-term background levels. Concentrations over Colstrip are largely attributable to the plant.

[b]"Primary" and "secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. PSD standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These data are from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[c]It is assumed that all oxides of nitrogen from plant sources are converted to NO_2.

[d]This range represents two assumptions about the removal of oxides of nitrogen by scrubbers. The first number assumes 40 percent is removed; the second number assumes that none is removed.

[e]The 3-hour HC standard is measured at 6-9 a.m.

emission control alternatives is illustrated in Table 8-6. These alternatives include a 95 percent efficient SO_2 scrubber used in conjunction with a 99 percent efficient ESP; an 80 percent efficient SO_2 scrubber without an ESP; and an alternative in which neither a scrubber nor an ESP are utilized. In each case, plant capacity is assumed to be 3,000 MWe with 500-foot stack heights.

An examination of Table 8-6 reveals that by using a 95 percent efficient SO_2 scrubber with an ESP, the power plant can meet all applicable standards. The base case violates 3-hour Class II PSD increments for SO_2 emissions. Removal of the ESP results in violations of National Ambient Air Quality Standards (NAAQS) for 24-hour TSP emissions and Class II PSD increments for 24-hour and annual TSP emissions.

(3) Alternative Stack Heights

In order to examine the effects of alternative stack heights on ambient air quality in the Colstrip scenario, worst-case dispersion modeling was carried out for a 300-foot stack (a lowest stack height consistent with good engineering practice), a 500-foot stack (an average or most frequently used stack height), and a 1,000-foot stack height (a highest stack height). Emissions from each stack are controlled by an 80 percent efficient SO_2 scrubber and a 99 percent efficient ESP. The 500-foot stack height was given previously as part of the base case. Table 8-7 illustrates the results of this analysis.

A comparison of predicted emissions with applicable standards in Table 8-7 shows violations of the Class II PSD increments for 3-hour SO_2 emissions with both a 300- and a 500-foot stack height. The 300-foot case also violates the Class II PSD increment for 24-hour SO_2 emissions. The only case which violates no applicable standards is the 1,000-foot stack height.

(4) Summary of Air Impacts of Power Plant

The frequency of current violations of the NAAQS particulate standards at the Colstrip power plant site will probably increase during the construction phase of the power plant due to blowing dust. Once the plant is in operation, the 3,000 MWe plant at Colstrip (80 percent SO_2 removal, 99 percent TSP removal, 500-foot stack height) is expected to violate Class II PSD increments for 3-hour SO_2 emissions. No other applicable standards should be violated by this facility. If the plant were equipped with a 95 percent efficient SO_2 scrubber or if stack heights were increased to 1,000 feet, all applicable standards would be met.

B. Lurgi Impacts

Typical and peak pollutant concentrations from the Lurgi plant are summarized in Table 8-8. Peak concentrations from the plant

TABLE 8-6: AIR QUALITY IMPACTS RESULTING FROM ALTERNATIVE EMISSIONS CONTROLS AT COLSTRIP POWER PLANT

AMOUNT OF CONTROL (%)		MAXIMUM POLLUTANT CONCENTRATION ($\mu g/m^3$)				
SO_2	TSP	3-HR. SO_2	24-HR. SO_2	ANNUAL SO_2	24-HR. TSP	ANNUAL TSP
95	99	164	22	NC	17.3	0.5
80	99	657	87	2.7	17.3	0.5
80	0	657	87	2.7	1,730.0[a]	50.0
0	0	3,284	416	13.5	1,690.0[a]	50.0
APPLICABLE STANDARDS						
NAAQS						
(primary)		--	365	80	260	75
(secondary)		1,300	--	--	150	60
State standards		750	115	23	200	75
Class II PSD increments		512	91	20	37	19

$\mu g/m^3$ = micrograms per cubic meter
SO = sulfur dioxide
TSP = total suspended particulates
HR. = hour
NC = not considered
NAAQS = National Ambient Air Quality Standards
PSD = Prevention of Significant Deterioration

[a]Differences in 24-HR. TSP concentrations for the two cases in which no electrostatic precipitator is used are attributable to the fact that the stack temperature rises when the SO_2 scrubber is turned off, which produces a small increase in the effectiveness of the smoke stack, and a slightly lower TSP concentration.

TABLE 8-7: AIR QUALITY IMPACTS RESULTING FROM ALTERNATIVE STACK HEIGHTS AT COLSTRIP POWER PLANT

SELECTED STACK HEIGHTS (feet)	MAXIMUM POLLUTANT CONCENTRATION ($\mu g/m^3$)		
	3-HR. SO_2	24-HR. SO_2	24-HR. TSP
300	728	96.1	18.2
500	657	87	17.3
1,000	252	62.6	16.0
APPLICABLE STANDARDS			
NAAQS			
(primary)	--	365	260
(secondary)	1,300	--	150
State standards	750	115	200
Class II PSD increments	512	91	37

$\mu g/m^3$ = micrograms per cubic meter
HR. = hour
SO_2 = sulfur dioxide
TSP = total suspended particulates
NAAQS = National Ambient Air Quality Standards
PSD = Prevention of Significant Deterioration

TABLE 8-8: POLLUTION CONCENTRATIONS FROM LURGI PLANT AT COLSTRIP (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]				STANDARDS[b]				
			PEAK		AMBIENT			PSD	
	BACKGROUND	TYPICAL	PLANT	COLSTRIP	PRIMARY	SECONDARY	MONTANA	CLASS I	CLASS II
Particulate									
Annual	15	N	N	N	75	60	75	5	19
24-hour		N	N	N	260	150	200	10	37
SO_2									
Annual	6	N	0.2	0.1	80		23	2	20
24-hour		0.7	4.6	4.4	365		115	5	91
3-hour		3.4	44	19		1,300		25	512
NO_2[c]									
Annual	10	N	0.2	0.2	100	100	100		
HC[d]									
3-hour		3.1	57	0.6	160	160	100		

PSD = Prevention of Significant Deterioration
N = no change over background conditions
SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide
HC = hydrocarbons

[a]These are predicted ground-level concentrations from the hypothetical Lurgi plant. Annual average background levels are considered the best estimates of short-term background levels.

[b]"Primary" and "secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. PSD standards are the allowable increments of pollutions which can be added to areas of relatively clean air, such as national parks. These data are from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[c]It is assumed that all oxides of nitrogen from plant sources are converted to NO_2.

[d]The 3-hour HC standard is measured at 6-9 a.m.

will not violate any federal or Montana ambient air standards, nor will they exceed Class II PSD increments. However, the plant exceeds Class I increments for the 3-hour SO_2 averaging time. This PSD violation would require a buffer zone of 7.8 miles between this plant and any Class I area boundary in order to comply with current EPA regulations.

C. Synthane Impacts

Typical and peak concentrations from the Synthane gasification plant are summarized in Table 8-9. These data show that no ambient standards will be violated and no Class II PSD increments will be exceeded. However, the Synthane plant will violate Class I increments for 24-hour and 3-hour SO_2. These emission levels would require a buffer zone of 7.1 miles. The plant-mine combination may reduce visibility over short time periods in a worst-case situation (expected to occur infrequently) to between 2 and 11 miles, depending on the amount of SO_2 converted to particulates in the atmosphere.[1]

D. Synthoil Impacts

Table 8-10 lists typical concentrations from the Synthoil liquefaction plant and peak concentrations from the plant. The Synthoil plant will exceed only the 3-hour HC standard, but will do so by a factor of more than 100. It will not exceed any Class II PSD increments. However, it will violate the Class I increments for annual and 24-hour SO_2. These potential Class I violations would require a buffer zone of 13.4 miles.

E. Scenario Impacts

(1) To 1980

Construction of the hypothetical power plant will begin in the 1975-1980 period, but the plant will not become operational until after 1980. The population of Colstrip should increase from the 1975 level of 3,000 to 4,080 by 1980.[2] This increase will contribute to increases in pollution concentrations due solely to urban sources. Pollution from energy-related population increases will be mainly due to additional automobile traffic. Concentrations

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[1]Short-term visibility impacts were investigated using a "box-type" dispersion model. This particular model assumes that all emissions occurring during a specified time interval are uniformly mixed and confined in a box that is capped by a lid or stable layer aloft. A lid of 500 meters has been used through the analyses. SO_2 to sulfate conversion rates of ten percent and one percent were modeled.

[2]Refer to Section 8.4.3.

TABLE 8-9: POLLUTION CONCENTRATIONS FROM SYNTHANE PLANT AT COLSTRIP (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]				STANDARDS[b]				
			PEAK		AMBIENT			PSD	
	BACKGROUND	TYPICAL	PLANT	COLSTRIP	PRIMARY	SECONDARY	MONTANA	CLASS I	CLASS II
Particulate									
Annual	15	N	N	N	75	60	75	5	19
24-hour		N	0.1	0.1	260	150	200	10	37
SO_2									
Annual	6	N	1.5	0.3	80		23	2	20
24-hour		5.5	32	3.7	365		115	5	91
3-hour		32	324	12		1,300		25	512
NO_2[c]									
Annual	10	N	2.2	0.4	100	100	100		
HC[d]									
3-hour		6.1	114	0.4	160	160	160		

PSD = Prevention of Significant Deterioration
NO_2 = nitrogen dioxide
N = no change over background conditions
SO_2 = sulfur dioxide
HC = hydrocarbons

[a]These are predicted ground-level concentrations from the hypothetical Synthane plant. Annual average background levels are considered the best estimates of short-term background levels.

[b]"Primary" and "secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. PSD standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national parks. These data are from White, Irvin L., _et al._ _Energy From the West: Energy Resource Development Systems Report_. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[c]It is assumed that all oxides of nitrogen from plant sources are converted to NO_2.

[d]The 3-hour HC standard is measured at 6-9 a.m.

TABLE 8-10: POLLUTION CONCENTRATIONS FROM SYNTHOIL PLANT AT COLSTRIP (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]				STANDARDS[b]				
			PEAK		AMBIENT			PSD	
	BACKGROUND	TYPICAL	PLANT	COLSTRIP	PRIMARY	SECONDARY	MONTANA	CLASS I	CLASS II
Particulates									
Annual	15		0.6		75	60	75	5	19
24-hour		3	9	0.6	260	150	200	10	37
SO_2									
Annual	6		2.4	0.1	80		23	2	20
24-hour		7.2	17	1.9	365		115	5	91
3-hour		23	92	3.0		1,300		25	512
NO_2[c]									
Annual	10		4	0.5	100	100	100		
HC[d]									
3-hour		428	17,200	9.3	160	160	160		

PSD = Prevention of Significant Deterioration
SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide
HC = hydrocarbons

[a]These are predicted ground-level concentrations from the hypothetical Synthoil plant. Annual average background levels are considered the best estimates of short-term background levels. Concentrations over Colstrip are largely attributable to the plant.

[b]"Primary" and "secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once a year. PSD standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These data are from White, Irvin L., *et al.* *Energy From the West: Energy Resource Development Systems Report*. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[c]It is assumed that all oxides of nitrogen from plant sources are converted to NO_2.

[d]The 3-hour HC standard is measured at 6-9 a.m.

have been estimated from available data on average emission per person in several western cities. Table 8-11 lists predicted concentrations of the five criteria pollutants measured in the center of town and at a point 3 miles from the center of town. This information shows that the only ambient standard violated in Colstrip due to urban sources is that for HC.[1]

(2) To 1990

The power plant will become operational in 1985, and a Lurgi gasification plant will become operational in 1989. Interactions of the pollutants from the plants are minimal because they have been (hypothetically) sited 6 miles apart. If the wind blows directly from one plant to the other, plumes will interact. However, the resulting concentrations would be less than those produced by either plant and mine combination when the wind blows from the plant to the mine (peak plant/mine concentration). The predicted maximum pollutant concentration resulting from interactions of the power plant and Lurgi facilities at a 6-mile separation distance just meet the Class II PSD increment for 24-hour SO_2 emissions; but the Class II PSD increment for 3-hour SO_2 is violated. Had the plants been sited closer together, the probability of the interactions would increase.

When the power plant and Lurgi facility are both operating, visibility is expected to decrease from the current average of 60 miles in the region near Miles City, Montana to 58 miles. In a worst-case situation, expected to occur infrequently, short-term visibilities could be reduced to between 3 and 9 miles depending on the amount of SO_2 converted to particulates in the atmosphere.

Colstrip's projected population increase to 5,250 will cause some increases in urban pollutants (Table 8-11). As in the 1980 case, the HC standard will be the only one violated. All other pollutant concentrations remain well within federal and state standards.

(3) To 2000

Two new facilities, a Synthoil liquefaction plant and a Synthane gasification plant, will become operational between 1990 and 2000. Interactions between the new Synthoil and Synthane plants and the Lurgi and electrical generation plants will increase annual peak concentrations. Interaction of the Synthane and Synthoil plants with the power plant will violate Class II PSD increments for 24-hour and 3-hour SO_2 emissions.

When all four of these coal conversion facilities come online in the Colstrip region, visibility is expected to decrease

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[1]HC standards are violated regularly in most urban areas.

TABLE 8-11: POLLUTION CONCENTRATIONS DUE TO URBAN SOURCES AT COLSTRIP (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]							STANDARDS[b]		
		MIDTOWN POINT			RURAL POINT					
	BACKGROUND	1980	1990	2000	1980	1990	2000	PRIMARY	SECONDARY	MONTANA
Particulates										
Annual	15	8	10	13	1	1	2	75	60	75
24-hour		27	34	44	27	34	44	260	150	200
SO_2										
Annual	6	4.5	5	7	0	0	1	80		23
24-hour		15	17	24	15	17	24	365		115
3-hour		27	30	42	27	30	42		1,300	
NO_2[c]										
Annual	10	13	16	21	1	2	3	100	100	100
HC[d]										
3-hour		210	270	351	210	270	361	160	160	160
CO										
8-hour		902	1,056	1,320	907	1,056	1,320	10,000	10,000	10,000
1-hour		1,478	1,730	2,163		1,730	2,163	40,000	40,000	40,000

SO_2 = sulfur dioxide NO_2 = nitrogen dioxide HC = hydrocarbons CO = carbon monoxide

[a]These are predicted ground-level concentrations for urban sources. Background concentrations are taken from Table 8-5. "Rural points" are measurements taken three miles from the center of town.

[b]"Primary" and "secondary" are federal ambient air quality standards designed to protect the public health and welfare, respectively.

[c]It is assumed that 50 percent of oxides of nitrogen from urban sources are converted to NO_2.

[d]The 3-hour HC standard is measured at 6-9 a.m.

from the current average of 60 miles to 56 miles by the year 2000. In a worst-case situation, expected to occur infrequently, short-term visibilities could be reduced to between 3 and 9 miles.

Colstrip's population will increase to 7,910 by the year 2000, and some increase in pollution concentrations will be associated with this growth (Table 8-11). Although the ambient standard for 3-hour HC is exceeded, no other ambient standards are approached.

F. Other Air Impacts

Nine additional categories of potential air impacts have received preliminary attention; that is, an attempt has been made to identify sources of pollutants and how energy development may effect levels of these pollutants during the next 25 years. These include sulfates, oxidants, fine particulates, long-range visibility, plume opacity, cooling tower salt deposition, cooling tower fogging and icing, fugitive dust, and trace element emissions. Although there are likely to be local impacts as a consequence of these pollutants, both the available data and knowledge about impact mechanisms are insufficient to allow quantitative, site-specific analyses. Thus, these are discussed in a more general, qualitative manner in Chapter 10.

8.2.4 Summary of Air Impacts

Four new facilities (a power plant, Lurgi and Synthane gasification plants, and a Synthoil liquefaction plant) are projected for the Colstrip area. To just meet NSPS, the 3,000 MWe power plant would require 99 percent particulate, 20 percent SO_2, and 36 percent NO_x removal. However, at this level of control, ambient air standards would be violated. With 80 percent SO_2 and 99 percent particulate removal, no federal or Montana ambient air standards will be violated, but the Class II PSD increment for 3-hour SO_2 will be exceeded. In order to meet this Class II increment, the power plant would have to be equipped with a scrubber which removed 95 percent of the SO_2 or with 1,000-foot (rather than 500-foot) stacks.

Peak concentrations from the power plant will exceed Class I increments except that for annual particulates. Typical concentrations will violate the 24-hour and 3-hour SO_2 increments. These PSD violations would require a buffer zone of 75 miles.

Typical and peak pollutant concentrations from the Lurgi and Synthane gasification plants will not violate any federal or Montana ambient air standards, nor will they exceed any Class II PSD increments. However, both plants will exceed Class I increments; buffer zones of 7.8 miles for the Lurgi plant and 7.1 for the Synthane plant would be required.

The only federal or Montana ambient air standard that the Synthoil plant violates is the 3-hour HC standard, but it does so by a factor of more than 100. No Class II PSD increments will be exceeded. However, the Class I increments for 24-hour SO_2, 3-hour SO_2, and annual SO_2 will be exceeded. These PSD violations would require a buffer zone of 13.4 miles.

If all four facilities are constructed according to the hypothesized schedule, population increases in Colstrip will add to existing pollutant levels. Violations of HC standards will be exacerbated by concentrations due solely to urban sources.

8.3 WATER IMPACTS

8.3.1 Introduction

Energy resource development facilities in the Colstrip scenario are sited in the Yellowstone River Basin, a subbasin of the Upper Missouri River Basin (UMRB). Although several large tributaries could be used (see Figure 8-3), the major water source for this development is the Yellowstone River. Annual precipitation in the area is about 14 inches, 3-4 inches of which fall as snow.[1] Thus, the area receives adequate precipitation to sustain local water demands by irrigation, municipal, and industrial users.

8.3.2 Existing Conditions

A. Groundwater

The largest aquifer systems in the Colstrip area are the Madison aquifer, aquifer systems in the coal and sandstone beds of the Tongue River Member of the Fort Union Formation, and alluvial aquifers. Although the Madison aquifer is quite deep in the Colstrip area (about 7,500 feet),[2] it is considered here as a potential water source because of its high pressure (water will rise in a well to within a few hundred feet of the ground surface). The closest recharge area of the Madison is along the Bighorn Mountains several miles southwest of Colstrip. Discharge is primarily by upward leakage into overlying strata.

Although large quantities of water are available from the Madison aquifer in the southeastern Montana region, its productivity in the Colstrip area has not been fully evaluated. A test well drilled through this aquifer near Colstrip indicates well

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[1]The moisture content of one inch of rain is equal to approximately 15 inches of snow.

[2]Swenson, Frank A. Possible Development of Water From Madison Group and Associated Rock in Powder River Basin, Montana-Wyoming. Denver, Colo.: Northern Great Plains Resources Program, 1974.

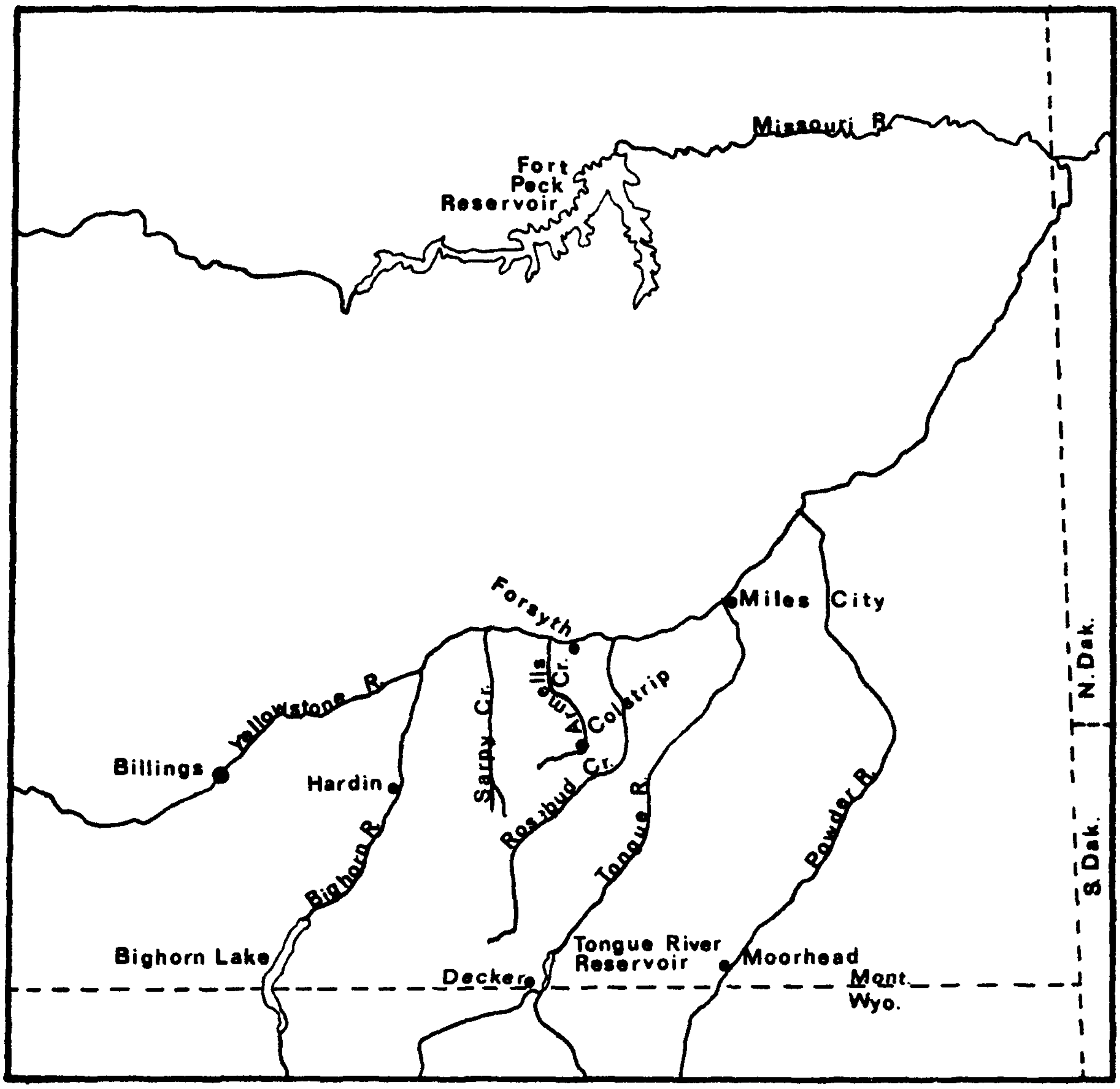

FIGURE 8-3: IMPORTANT HYDROLOGIC FEATURES OF THE COLSTRIP SCENARIO AREA

productivity may be between 200 and 300 gpm.[1] The TDS content of the aquifer in the scenario area is about 2,000 milligrams per liter (mg/ℓ). Although deep wells into the Madison aquifer could provide a significant fraction of the water required by energy facilities in the Colstrip area, surface water and shallow groundwater sources can possibly be developed at less expense.

Aquifers in the Tongue River Member are in sandstone and coal beds that are deposited in alternate layers with shales. The main coal bed aquifer is the Rosebud coal seam, which is the primary source of coal at Colstrip. The water table depth varies but is usually less than 50 feet. Yields of individual wells are usually less than 100 gpm. Recharge is from rainfall and surface streams. Discharge is to seeps and springs on hillsides and as baseflow to the larger streams.

Water quality in the Tongue River aquifer system is highly variable, differing with each sandstone body and coal seam. The median TDS content of 49 water samples from the Tongue River Member was about 900 mg/ℓ,[2] and fresh water is generally less than 1,000 mg/ℓ (1,000-3,000 mg/ℓ is considered slightly saline by the United States Geological Survey [USGS] standards).[3] The hardness of Tongue River aquifer water decreases with depth.[4] At present, this groundwater is used only for domestic purposes and livestock watering. Although the aquifer system of the Tongue River Member could not support the energy facilities of the scenario, it could provide water for associated municipal growth.

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[1]Montana, Department of Natural Resources and Conservation, Energy Planning Division. Draft Environmental Impact Statement on Colstrip Electric Generating Units 3 and 4, 500 Kilovolt Transmission Lines and Associated Facilities. Helena, Mont.: Montana, Department of Natural Resources and Conservation, 1974, V. 3-A, p. 359.

[2]Hopkins, William B. Water Resources of the Northern Cheyenne Indian Reservation and Adjacent Area, Southeastern Montana, U.S. Geological Survey Hydrologic Investigations Atlas HA-468. Washington, D.C.: Government Printing Office, 1973.

[3]U.S., Department of the Interior, Geological Survey. Study and Interpretation of the Chemical Characteristics of Natural Water, Water Supply Paper 1473. Washington, D.C.: Government Printing Office, 1970, p. 219.

[4]Ibid.; and Renick, B. Coleman. Geology and Groundwater Resources of Central and Southern Rosebud County, Montana, U.S. Geological Survey Water Supply Paper 600. Washington, D.C.: Government Printing Office, 1929, p. 40.

The alluvial aquifers are along the Yellowstone River and its tributaries, Rosebud Creek and the Tongue River. The alluvium along these rivers is up to 100 feet thick; as much as 60 of that 100 feet are saturated.[1] Wells may yield up to 700 gpm for short periods. Most recharge to and discharge from these aquifers is by interflow with the associated streams, with additional water lost to vegetation and wells. Water quality in the alluvial aquifers depends on the quality of the river water and the groundwater received from the bedrock formation. The median TDS content of 16 samples taken from alluvial aquifers was about 1,100 mg/ℓ.[2] Present uses of water from alluvial aquifers are limited to supplying domestic and livestock needs. Alluvial aquifers such as those along the Tongue River could provide part of the water for municipal growth, but could not support energy facilities.

B. Surface Water

The Colstrip scenario lies within the Yellowstone River Subbasin of the UMRB. The Yellowstone and Missouri Rivers contribute comparable flows at their confluence on the Montana-North Dakota border. The main tributaries of the Yellowstone flowing through the Fort Union coal region are the Powder, Tongue, and Bighorn Rivers (see Figure 8-3). Flows for these rivers are shown in Table 8-12. The largest reservoir in this part of the Yellowstone Basin is Bighorn Lake, which is located on the Bighorn River about 75 miles southwest of Colstrip and has a total storage of 1.3 million acre-feet (acre-ft). The only other storage facility of significance is the 74,000 acre-ft Tongue River Reservoir about 50 miles south of Colstrip.[3]

Flows in lower elevation tributaries to the Yellowstone River peak between March and early May. The larger rivers, which depend on the higher-elevation snowpack for their spring runoff flows, peak between mid-June and mid-July. Many of the small streams have significant discharges from midwinter to early spring as a result of snowmelt caused by chinook winds or by local thunderstorms in the summer. The soils in the area have relatively low permeability, resulting in low infiltration rates. Runoff averages 0.2-0.5 inch per year.

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[1]Hopkins, William B. Water Resources of the Northern Cheyenne Indian Reservation and Adjacent Area, Southeastern Montana, U.S. Geological Survey Hydrologic Investigations Atlas HA-468. Washington, D.C.: Government Printing Office, 1973.

[2]Ibid.

[3]Northern Great Plains Resources Program. Water Work Group Report. Billings, Mont.: U.S., Department of the Interior, Bureau of Reclamation, 1974.

TABLE 8-12: SELECTED FLOW DATA FOR THE UPPER MISSOURI AND YELLOWSTONE RIVERS (Flows adjusted to the 1970 level of water resources development)[a]

SUBBASIN OR TRIBUTARY	DRAINAGE AREA (sq. mi.)	ANNUAL FLOW		
		MAXIMUM (acre-feet)	MINIMUM (acre-feet)	AVERAGE (acre-feet)
Upper Missouri River (At Sioux City, Iowa)	314,600	-	-	21,821,000
Upper Missouri River (At Oahe Dam)	243,500	-	-	18,525,000
Yellowstone River	70,115	12,690,000	3,720,000	8,800,000
Powder River	13,415	1,154,000	43,000	416,000
Tongue River	5,400	569,000	32,000	304,000
Bighorn River	22,885	-	-	2,550,000
Clarks Fork	2,783	1,124,000	538,000	767,000
Upper Missouri Tributaries (upstream from confluence with the Yellowstone River)	91,557	-	-	7,276,000

sq. mi. = square mile

[a]U.S., Department of the Interior, Water for Energy Management Team. Report on Water for Energy in the Northern Great Plains Area with Emphasis on the Yellowstone River Basin. Denver, Colo.: Department of the Interior, 1975.

The Yellowstone River is free-flowing to its confluence with the Bighorn River. Because the flows in the Bighorn are about the same as those of the Yellowstone, and because the Bighorn River is regulated by Bighorn Lake, the flows in the Yellowstone near Forsyth (where the energy facilities will draw water) are regulated for most of the year (see Figure 8-3).

Water supply and use in Montana is shown in Table 8-13. About 70 percent of total water use is for irrigation. The majority of this water is supplied through state and federal projects, but a portion has been developed privately. Groundwater also is used for irrigation but in negligible amounts compared to surface-water usage.

With the exception of Glendive, municipalities downstream of Miles City use groundwater as a public supply; towns upstream from Miles City use surface water.[1]

The water quality of the Yellowstone Basin rivers is generally good, with the possible exception of the Powder River. Both the Tongue and Bighorn are considered of national importance as sport fishing areas. The Powder River characteristically has high TDS concentrations (3,000-10,000 mg/ℓ), which is considered moderately saline by USGS standards. Combined with its tendency to dry up in some stretches in late summer, these TDS levels reduce the Powder River's potential for use as boiler make-up or drinking water. The major source of pollution in all three rivers is agricultural. The representative values of water quality parameters given in Table 8-14 can help individuals evaluate water quality acceptability for specific uses. Although not reported in this table, iron and manganese concentrations in Armells Creek at Colstrip commonly exceed EPA's Proposed National Secondary Drinking Water Regulations.[2]

8.3.3 Factors Producing Impacts

The water requirements of and effluents from energy facilities cause water impacts. These requirements and effluents are identified in this section for each type of energy facility. Associated population increases also increase municipal water demand and sewage effluent; these are presented in Section 8.3.4 for the scenario which includes all facilities constructed according to the scenario schedule.

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[1]Montana, Department of Natural Resources and Conservation, Energy Planning Division. Draft Environmental Impact Statement on Colstrip Electric Generating Units 3 and 4, 500 Kilovolt Transmission Lines and Associated Facilities. Helena, Mont.: Montana, Department of Natural Resources and Conservation, 1974.

[2]U.S., Environmental Protection Agency. "National Secondary Drinking Water Regulations," Proposed Regulations. 42 Fed. Reg. 17,143-47 (March 31, 1977).

TABLE 8-13: ESTIMATED 1975 SURFACE-WATER SITUATION FOR SELECTED AREAS IN MONTANA[a]
(1,000 acre-feet)

SUPPLY OR USE	YELLOWSTONE RIVER	UPPER MISSOURI RIVER
Average Annual Water Supply		
Modified Inflow to Region[b]	6,305	847
Undepleted Water Yield	4,239	8,398
Estimated 1975 Imports	0	140
Total Water Supply	10,544	9,385
Estimated 1975 Water Use[c]		
Irrigation	776	1,480
M & I Including Rural	43	56
Minerals	10	0
Thermal Electric	1	0
Other[d]	49	155
Reservoir Evaporation	234	369
Total Depletions	1,113	2,060
Estimated Future Water Supply		
Modified 1975 Water Supply[e]	9,431	7,325
Estimated Legal or Instream Commitments	0	0
Net Water Supply[f]	9,431	7,325

M & I = municipal and industrial

[a]U.S., Department of the Interior, Bureau of Reclamation. West-wide Study Report on Critical Water Problems Facing the Eleven Western States. Washington, D.C.: Government Printing Office, 1975.

[b]Inflow reflects the effects of depletions upstream of state lines.

[c]Includes surface water, surface-related groundwater, and mined groundwater.

[d]No depletions are attributed to thermal electric, recreation, and consumptive conveyance losses.

[e]Modified 1975 supply is determined by subtracting estimated total water use from total supply.

[f]Available for future instream uses such as for fish, wildlife, recreation, power, or navigation or for consumtive use. Physical or economic constraints could preclude full development.

TABLE 8-14: SELECTED WATER QUALITY PARAMETERS FOR MAJOR SOUTHEASTERN RIVERS[a] (parts per million by weight)

PARAMETER	YELLOWSTONE AT FORSYTH[a]	POWDER AT MOORHEAD[a]	BIGHORN AT HARDEN[a]	TONGUE NEAR DECKER[b]	SARPY CREEK[c]	ROSEBUD NEAR COLSTRIP[c]	ARMELLS FORSYTH[c]	DRINKING WATER STANDARD[d]	TYPICAL BOILER FEED WATER[e]
Calcium	23[f]-74	65-159	48-81	31-83	18-130	29-93	24-170		0.10
Magnesium	4-29[f]	24-132	19-46	16-67	8-190	19-110	12-210		0.03
Sodium	17-81	48-121	13-78	7-59	14-600	13-100	35-1,000		0.24
Potassium	1.7[f]-4.8[f]		1.5-3		7.4-11	74-12	6.5-12		
Bicarbonate	87[f]-203[f]	140-212	212-307	128-306	89-853	132-606	89-913		<0.01
Sulfate	44-268	283-740	61-285	53-330	40-1,400	54-420	110-2,400	250[g]	<0.14
Chloride	3.2[c]-12[f]	6-33	1.0-4.4	0-2	3.1-16	1.1-7	4.7-29	250[g]	0.96
Nitrate	0.06-0.8	0.2-8.7	0.1-0.4	0-1.6	0.00-0.46	0-0.42	0-0.23	10[d]	
TDS	151[f]-660	510-4,080[h]	256-952[h]	145[h]-853	100-2,610	198-1,000	245-4,030	500[g]	<10.0
Hardness (Ca, Mg)	84[f]-300[f]	0[h]-1,220[h]	140[h]-381	108[h]-580[h]	78-1,100	150-670	110-1,300	6.5-8.5[g]	<0.10
pH	7.6[f]-8.5[f]	6.8-8.5	7.5[h]-8.7[h]	7.0[h]-8.6[h]	7.6-8.5	7.5-8.9	7.4-8.6	5[d]	8.8-10.8
Turbidity	4-300		24-51	6-35	30-100	5-200	1-400		
BOD	2.1-3.6	0.6[h]-10[h]	0.7[h]-3.5	3.2-3.4					
Fecal Coliform (counts/100 mg/ℓ)	0-130	24-2,400	25-70	2.0					
Dissolved Oxygen	7.3[c]-12.8	5.2[h]-12.4[h]	8.4-15[h]	9.1-13.3	7.8-11	7.2-12.6	7-13.2	1/100mℓ[d]	
Sediment (SS)	9-992		87-123	10-110					

< = less than
TDS = total dissolved solids
Ca = Calcium
Mg = Magnesium
pH = acidity
BOD = biochemical oxygen demand
mg/ℓ = milligrams per liter
mℓ = milliliters
SS = suspended solids

[a]Montana, Department of Natural Resources and Conservation, Energy Planning Division. Draft Environmental Impact Statement on Colstrip Electric Generating Units 3 and 4, 500 Kilovolt Transmission Lines and Associated Facilities. Helena, Mont.: Montana, Department of Natural Resources and Conservation, 1974.

[b]Based on only three measurements.

[c]From unpublished and provisional U.S. Geological Survey data.

[d]U.S., Environmental Protection Agency. "National Interim Primary Drinking Water Regulations," effective June 24, 1977, Fed. Reg. (December 24, 1975), Vol. 40, No. 248, pp. 59566-87. These regulations include other standards not given here.

[e]American Water Works Association, Inc. Water Quality and Treatment, 3rd ed. New York, N.Y.: McGraw-Hill, 1971, p. 510, Table 16-1. Some numbers derived from Table 16-1 assuming concentrating factor - 100, high pressure drum type boiler.

[f]Scan of recent U.S. Geological Survey yearly Water Resources Data - Water Quality Records.

[g]U.S., Environmental Protection Agency. "National Secondary Drinking Water Regulations," Proposed Regulations. 42 Fed. Reg. 17143-47 (March 31, 1977).

[h]Northern Great Plains Resources Program, Water Work Group. Water Quality Subgroup Report, discussion draft. Denver, Colo.: U.S., Environmental Protection Agency, Region VIII, 1974.

A. Water Requirements of Energy Facilities

The water requirements of energy facilities hypothesized for the Colstrip area are shown in Table 8-15. Two sets of data are presented. The Energy Resource Development System (ERDS) data are based on secondary sources (including impact statements, Federal Power Commission docket filings, and recently published data accumulations[1]) and can be considered typical consumptions. The Water Purification Associates data are from a study on minimum water-use requirements for the Colstrip area and take into account opportunities to recycle water on site as well as the moisture content of the coal being used and local meteorological data.[2] As indicated in Table 8-15, the power plant requires more water (26,659 acre-feet per year [acre-ft/yr] assuming high wet cooling) then the other coal conversion facilities. The Synthoil liquefaction facility will require more than 10,000 acre-ft/yr, the Lurgi gasification facility will require more than 6,250 acre-ft/yr, and the Synthane gasification facility will require more than 7,800 acre-ft/yr (all cases assuming high wet cooling). If intermediate wet cooling (a combination of wet and dry cooling) is used, water requirements for energy facilities could be reduced from 73 percent (power plant) to 16 percent (Synthoil). If intermediate wet cooling is used for all facilities, the Synthoil plant will require the most water, 8,481 acre-ft/yr. From an economic standpoint, availability and cost of water often determine which cooling technology would be the most profitable to use. For synthetic fuel facilities, intermediate wet cooling technology would save money if water costs more than $1.50 per thousand gallons. High wet cooling would be the economic choice for power plants if water costs less than $3.65 to $5.90 per thousand gallons. Minimum wet cooling (i.e., maximum dry cooling), not considered for the power plant, would result in economic savings at the synthetic fuel facilities if water costs more than $2.00 per thousand gallons. Minimum wet cooling would save an additional 9 (Synthoil and Synthane) to 10 percent (Lurgi) more water than intermediate wet cooling. If water costs only $0.25 per thousand gallons and intermediate

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[1]The ERDS is based on data drawn from University of Oklahoma, Science and Public Policy Program. Energy Alternatives: A Comparative Analysis. Washington, D.C.: Government Printing Office, 1975; and Radian Corporation. A Western Regional Energy Development Study, Final Report, 3 vols. and Executive Summary. Austin, Tex.: Radian Corporation, 1975. These data are published in White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[2]Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

TABLE 8-15: WATER REQUIREMENTS FOR ENERGY FACILITIES AT COLSTRIP (acre-feet per year)

TECHNOLOGY[a]	ERDS REPORT[b] WET COOLING	WATER PURIFICATION ASSOCIATES[c] COMBINATIONS OF WET AND DRY COOLING[d] HIGH WET	INTERMEDIATE WET	MINIMUM WET
Power Generation	29,400	26,659	7,336	NC
Gasification				
Lurgi	6,354	6,283	4,618	4,142
Synthane	9,090	7,808	5,923	5,536
Liquefaction				
Synthoil[e]	17,460	10,296	8,481	7,904
	Cost range in which indicated cooling technology is most economic (dollars per thousand gallons)			
Synthetic Fuels Facilities	NC	<1.50	1.50-2.00	>2.00
Power Plant	NC	<3.65-5.90	>3.65-5.90	NC

ERDS = Energy Resource Development Systems
NC = not considered
< = less than
> = greater than

[a]These values assume an annual load factor of 75 percent in the case of the 3,000 megawatt-electric power plant and 90 percent in the case of a 250 million cubic feet per day Lurgi and Synthane facilities and 100,000 barrel per day Synthoil facility.

[b]White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[c]Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

[d]Combinations of wet and wet/dry cooling were obtained by examining the economics of cooling alternatives for the turbine condensors and gas compressor interstage coolers. In the high wet case, these are all wet cooled; in the intermediate case, wet cooling handles 10 percent of the load on the turbine condensors and all of the load in the interstage coolers; in the minimum practical wet cases, wet cooling handles 10 percent of the cooling load in the turbine condensors and 50 percent of the load in the interstage coolers. For power plants, only variations on the steam turbine condensor load were considered practical; thus, only high wet and intermediate wet cases were examined.

[e]Synthoil data have a high uncertainty because of the small capacity of bench scale test facilities built to date. The Solvent Refined Coal liquefaction process now appears likely to become commercial sooner, and more reliable pilot plant data are available. These data are reported in White et al. ERDS Report. Chapter 3.

wet cooling is utilized in order to conserve water, the increased cost of synthetic fuels would be about one cent per million Btu of fuel more than if high wet cooling had been used. In the case of a power plant, the added cost of intermediate wet cooling is 0.1 to 0.2 cents per kilowatt hour of electricity.

Figure 8-4 indicates the manner in which water is consumed by the hypothesized energy facilities. As indicated, more water is used for cooling than processing and solids disposal combined. Solids disposal consumes comparable quantities of water for all technologies, varying primarily as a function of the ash content of the feedstock coal.

Additional water requirements are associated with the coal mines that will support these facilities. Reclamation efforts (see Table 8-16) will use the majority of the mine water required; dust control, handling, crushing, and service water requirements are estimated to be approximately 1,240 acre-ft/yr[1] for all four mines, or 25 percent of that required for reclamation. However, the reclamation water requirements are not clearly defined for this specific coal spoil waste under area climatic conditions. Table 8-16 estimates were based on an irrigation rate of 9 inches per year over a 5-year period.[2]

Water for the various scenario energy conversion facilities in the Colstrip area will be imported by individual pipelines from the Yellowstone River as shown in Figure 8-5. The Yellowstone River is the most likely source of water because of its proximity, high flow, and good quality. However, there has been a 3-year moratorium on new diversions from the Yellowstone in excess of 20 cubic feet per second (cfs) (14,000 acre-ft/yr).[3] This moratorium, which was to end in 1977, was put into effect to allow Montana time to clear up water rights questions raised by a change in procedures. Since the Montana Water Use Act of 1973, the state has administered all surface water and groundwater rights through a permit system. Montana is now in the process of determining valid appropriations under the old "right of use" system before approving new rights

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[1]Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

[2]Differences between water demand of native grasses and average precipitation. See U.S., Department of the Interior, Bureau of Land Management. Resource and Reclamation Evaluation: Otter Creek Study Site, EMIRA Report No. 1. Billings, Mont.: Bureau of Land Management, 1975.

[3]Montana Revised Codes Annotated § 89-8-105 (Cumulative Supplement 1975).

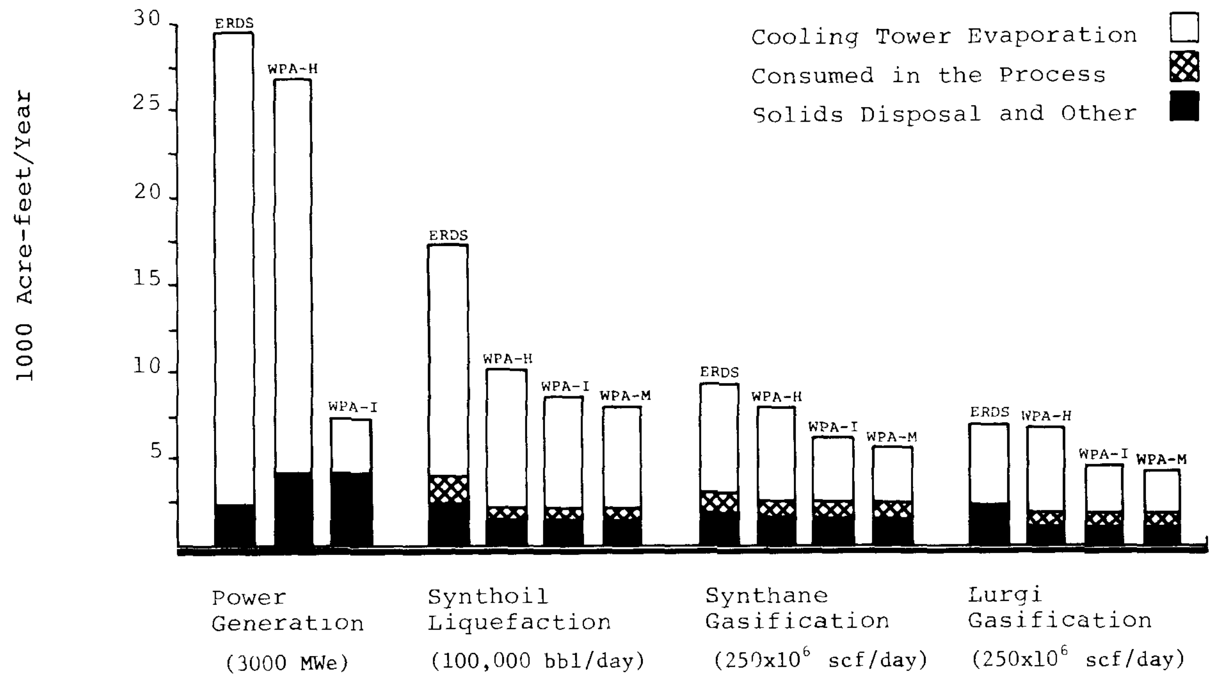

FIGURE 8-4: WATER CONSUMPTION FOR ENERGY FACILITIES IN THE COLSTRIP SCENARIO

ERDS = Energy Resource Development Systems
WPA-H = Water Purification Associates - High Wet Cooling
WPA-I = Water Purification Associates - Intermediate Wet Cooling
WPA-M = Water Purification Associates - Minimum Wet Cooling
MWe = megawatt-electric
bbl/day = barrels per day
scf/day = standard cubic feet per day

Source: The ERDS data is from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming. The WPA data is from Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

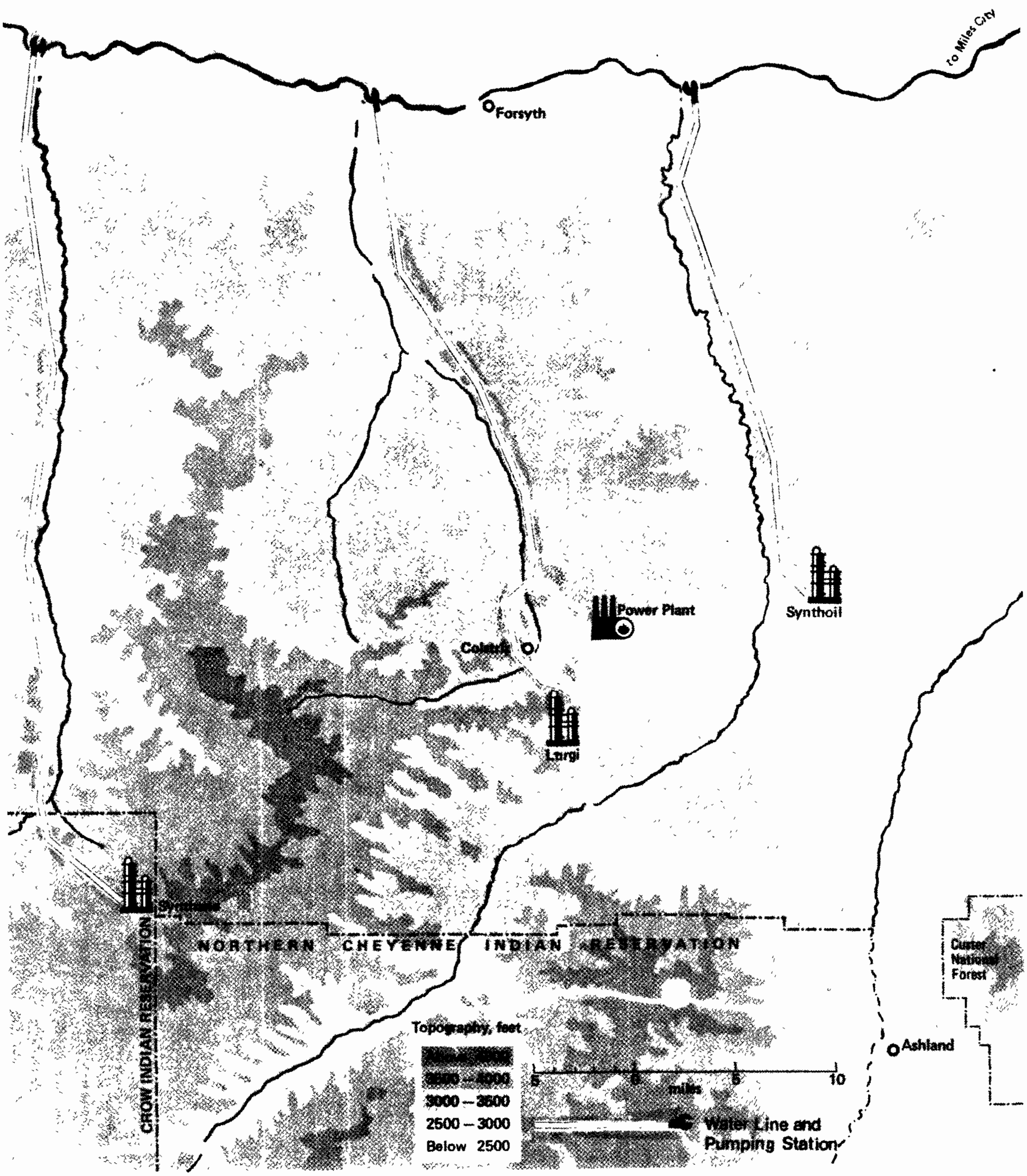

FIGURE 8-5: WATER PIPELINES FOR ENERGY FACILITIES IN THE COLSTRIP SCENARIO

TABLE 8-16: WATER REQUIREMENTS FOR RECLAMATION[a]

MINE	ACRES DISTURBED PER YEAR	MAXIMUM ACRES UNDER IRRIGATION	WATER REQUIREMENT (acre-ft/yr)
Power Plant	340	1,720	1,290
Lurgi	240	1,180	890
Synthane	240	1,180	890
Synthoil	250	1,250	940
Total	1,070	5,330	4,010

acre-ft/yr = acre-feet per year

[a]Assuming an irrigation rate of 9 inches per year over a 5-year period.

that might overallocate Yellowstone River water. When this situation has stabilized, a developer will be able to apply for a new right. Although an old right could be transferred, it might not be recognized or given the same priority under the new system.

B. Effluents from Energy Facilities

Table 8-17 lists expected amounts of solid effluents to be produced by energy facilities in the Colstrip scenario. Solid effluents will be produced by Lurgi, Synthane, Synthoil, and the 3,000 MWe power plant. The Synthoil facility is expected to produce more than 4,300 tons of total solid effluents per day when operating at full capacity. The power plant will produce more than 4,100 tons of solid effluents per day. Solid wastes from the Lurgi plant are expected to be slightly less than 2,400 tons per day (tpd), and Synthane solid waste production is expected to total more than 2,200 tpd. The Synthoil plant is expected to have the highest rate of wet solid production (over 2,100 tpd); and the power plant is expected to produce the most dissolved and dry solids (60 and 2,222 tpd). The total daily solid waste production from all facilities hypothesized in the Colstrip scenario will be slightly less than 13,000 tpd.

Dissolved solids are present in the ash blowdown stream, the demineralizer waste stream, and the flue gas desulfurization (FGD)

TABLE 8-17: EFFLUENTS FROM COAL CONVERSION PROCESSES AT COLSTRIP[a]

FACILITY TYPE	SOLIDS[b] (tons per day)				WATER IN EFFLUENT[c] (acre-feet per year)
	DISSOLVED	WET	DRY	TOTAL	
Lurgi (250 MMcfd)	22	2,057	262	2,341	580
Synthane (250 MMcfd)	21	500	1,728	2,249	915
Synthoil (100,000 bbl/day)	25	2,129	2,129	4,283	871
Electric Power (3,000 MWe)	60	1,822	2,222	4,104	2,107

MMcfd = million cubic feet per day
bbl/day = barrels per day
MWe = megawatt-electric

[a]These data are from Radian Corporation. The Assessment of Residuals Disposal for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Austin, Tex.: Radian Corporation, 1978. The Radian Corporation report extends and is based on earlier analyses conducted by Water Purification Associates and reported in Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

[b]Facility sizes are those assumed throughout the report. These values are given for a day when the facility is operating at full load. In order to obtain yearly values, these numbers must be multiplied by 365 days and by the average load factor. Load factors are 90 percent for synthetic fuel facilities and 75 percent for power plants. The values given as solids do not include the weight of the water in which the solids are suspended or dissolved.

[c]The values for water discharged are annual and take into account the load factor.

stream.[1] The principal constituents of wastewater which appear as dissolved solids are calcium, magnesium, sodium, sulfate, and chlorine.

Wet solids from the electric power plant and Lurgi or Synthane gasification facilities are in the form of flue gas sludge, bottom ash, and cooling wastewater treatment sludge. Calcium carbonate ($CaCO_3$) and calcium sulfate ($CaSO_4$) are the primary constituents of flue gas sludge. Bottom ash is the primary constituent of wet solids produced by a Synthoil facility. The bottom ash is primarily made up of oxides of aluminum and silicon. $CaCO_3$ is the principal constituent of the cooling water treatment waste sludge. In all cases the amount of cooling water treatment waste is very small compared to the bottom ash and flue gas sludge.

Dry solids waste produced by coal conversion processes is primarily fly ash composed of oxides of aluminum, silicon, and iron. The water in the effluent stream (Table 8-17) accounts for between 8 (power plant) and 12 (Synthane) percent of the total water requirements of coal conversion facilities (data in Table 8-17 compared to that in Table 8-15). Dissolved and wet solids are sent to evaporative holding ponds and later deposited in landfills. Dry solids are treated with water to prevent dusting and deposited in a landfill.[2]

8.3.4 Impacts

This section describes water impacts which result from the mines, conversion facilities (a power plant, Lurgi plant, Synthane plant, and Synthoil plant), and from a scenario which includes construction of all facilities according to the hypothesized scenario schedule. The water requirements and impacts associated with expected population increases are included in the scenario impact description.

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[1]Note that all coal conversion processes generate electricity on-site, thus flue gas cleaning, ash handling, and demineralization are required for all. One exception is the Synthoil process which uses clean fuel gas for power generation; fuel gas cleaning is not required for it. Demineralization is a method of preparing water for use in boilers; it produces a waste stream composed of chemicals present in the source water. The ash blowdown stream is the water used to remove bottom ash from the boiler. Bottom ash removal is done via a wet sluicing system using cooling tower blowdown water. Thus, the dissolved solids content of that stream is composed of chemicals from the ash and cooling water.

[2]The environmental problems associated with solid waste disposal in holding ponds and landfills are discussed in Chapter 10.

A. Surface Mine Impacts

The opening of the surface coal mines for the conversion facilities will cause disturbances of aquifer systems in the Tongue River Member of the Fort Union Formation. Since the source of the coal, the Rosebud seam, is a large aquifer in the Tongue River Member, mine dewatering will probably be required in most areas. This dewatering may lead to local aquifer depletion and a resultant lowering of water levels in nearby wells. Springs and seeps on hillsides may dry up, and there may be a significant loss to the base flow of Rosebud Creek. The water from mine dewatering operations will be pumped to the facilities and used as make-up water for cooling towers or will be used for mine operations and for revegetation of spoil material. Shallow bedrock aquifers in the coal and overburden will be lost in the mine area. Replacing the overburden will not necessarily reestablish aquifers because homogenization of the overburden will change its porosity and permeability. If acid and trace element contaminants are present, they could move laterally and appear as part of the discharge of springs and seeps, thus contaminating these important sources of water for wildlife. Alluvial aquifers along Rosebud Creek may also be contaminated by water from the strip mine, either by water recharging directly from polluted bedrock aquifers or by surface water from contaminated seeps and springs. There is a significant possibility that contaminated groundwater from the mine areas will begin flowing into Armells, Sarpy, and Rosebud Creeks (see Figure 8-3 for stream locations).

The opening of the coal mines will also have some impact on the local surface water. Since vegetation will be removed and soil disturbed, the silt load will be increased in local streams until runoff can be controlled by ponding and settling. Until other uses develop, ponded runoff will be used for dust control and revegetation, with the excess being evaporated. Ponding the runoff decreases surface water flows which could affect the flow patterns of intermittent streams in the mine areas. There may also be fugitive spills of lubricants and fuels either in bulk from a storage site or from machine maintenance. These petroleum products will not readily degrade and will contaminate runoff.

B. Energy Conversion Facilities Impacts

Water impacts may be divided into those occurring during construction and operation, and those occurring because of the water requirements of and the effluents from the facilities.

Although the construction activities associated with the facilities are not expected to have an appreciable impact on any groundwater system in the scenario area, they will remove vegetation and disturb the soil. Thus, construction activities will affect surface water quality, primarily in the form of sediment load increases. Additionally, the equipment used during construction will require petroleum storage and maintenance facilities. Other areas will be required for storage of materials for the concrete batch plant and other construction-related activities. All these facilities will contaminate runoff. Runoff control techniques will be instituted at all the potential contaminant locations. Runoff will be gathered in a common pond for settling, reuse, and evaporation. As the supply of water to this pond is very intermittent, evaporation may claim most of the water, although some may be used for dust control at aggregate storage sites.

Assuming the facilities are high wet cooled, Table 8-15 shows the energy conversion plants will consume about 26,659 acre-ft/yr (power plant), 6,283 acre-ft/yr (Lurgi plant), 7,808 acre-ft/yr (Synthane plant), and 10,296 acre-ft/yr (Synthoil plant). For perspective, the water source, the Yellowstone River at Miles City, has an average flow of 8,800,000 acre-ft/yr and minimum flow of 3,720,000 acre-ft/yr (Table 8-12).[1] Under worst-case conditions, when a facility is operating at 100 percent load factor on a day when the river was at low flow, withdrawals would range from 0.14 to 1.2 percent of the river flow depending on the type of facility.

The disposal sites for effluents from the plants will pose a water quality hazard for shallow aquifer systems. Fluids from liquid waste disposal ponds (sanitary effluent, cooling tower blowdown, etc.) may infiltrate through leaky or ineffective pond liners and enter groundwater systems, thus lowering the quality of the water.

C. Scenario Impacts

Water impacts resulting from interactions among the hypothesized facilities and their associated mines and water impacts resulting from associated population increases are discussed in this section.

Water requirements for direct use by these hypothesized energy facilities (assuming high wet cooling and operation at the expected load factor, Table 8-15) increase from approximately 26,700 acre-ft/yr in 1990 when the power plant is operating to 50,600 acre-ft/yr in 2000 when all the facilities are operating. Additional water, about 8 percent of the water requirement for the facilities in 2000, may be required for mine reclamation purposes.

Assuming that the towns on the Yellowstone River (including Miles City) will continue to use surface water for municipal needs, the projected increases in water supply requirements as a result

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[1]Minimum flow is 5,135 cfs and is converted to acre-ft/yr only so that withdrawals by the energy facilities given in acre-ft/yr can be compared.

TABLE 8-18: EXPECTED WATER REQUIREMENTS FOR INCREASED POPULATION[a] (acre-feet per year)

LOCATION	1980	1990	2000
Forsyth[b]	1,120	4,256	12,320
Colstrip	245	420	784
Miles City[c]	35	91	322
Billings[c]	56	154	504

[a]Above the 1975 base level; based on 125 gallons per capita per day.

[b]Based on 1,000 gallons per capita per day (present consumption during the summer - Montana Water Quality Bureau).

[c]Only growth caused by energy development included.

of energy development (based on population predictions from Section (8.4) are shown in Table 8-18.[1] Rural population growth generally is not expected because of county zoning and land-use practices. The only municipality shown in Table 8-18 that will use groundwater as a supply source is Colstrip, where a well field will be developed that will tap aquifers in the Tongue River member. Since only about 500 gpm will be needed by the year 2000, the well field should not be extensive.

Wastewater from the energy facilities (Table 8-17), which will be impounded in evaporation ponds, will average 2,837 acre-ft/yr by 1990, and 4,623 acre-ft/yr by 2000. The wastewater generated by the population increases associated with energy development is shown in Table 8-19. Rural populations are assumed to use individual, on-site waste facilities (septic tanks and drain fields), and the urban population will require waste treatment facilities. Current treatment practices in affected communities are shown in Table 8-20.

Based on current treatment facility capacities, new facilities will be required in Colstrip before 1980, in Forsyth around 1990, and in Miles City before 2000. These facilities must use the "best practicable" waste treatment technology to conform to

[1]Increases from secondary industry are not included in obtaining population estimates.

TABLE 8-19: EXPECTED WASTEWATER FLOWS FROM INCREASED POPULATION[a]

LOCATION	1980	1990	2000
Forsyth	0.1	0.38	0.1
Colstrip	0.175	0.30	0.56
Miles City	0.025	0.065	0.23
Billings	0.04	0.11	0.36

[a]Above the 1975 base level, based on 100 gallons per capita per day. Rural population is assumed to use septic tanks, so no wastewater is present. Only growth caused by energy development considered.

1983 standards.[1] The 1985 goal (zero discharge of pollutants) could be met by using effluents for industrial process make-up water of for irrigating local farmland.

(1) To 1980

Between the present and 1980, the only activity scheduled is the beginning of the construction of the 3,000 MWe power plant and the opening of the associated coal mine. Therefore, prior to 1980 there will be little land disturbance by mines (and therefore only minor reductions in the amount of runoff which no longer reaches streams) and no water required by the conversion facilities.

Of the 1,456 acre-ft/yr of water required by the population increases associated with the Colstrip scenario, 245 acre-ft/yr for the town of Colstrip will come from the Tongue River Member aquifer. The remainder will come from the Yellowstone River to satisfy needs in Forsyth, Miles City, and Billings (see Table 8-18).

The municipal growth at the Colstrip scenario will be restricted to expansion of existing communities, most of which have municipal sewage treatment facilities. Septic tanks may pose a significant hazard to groundwater quality in local Tongue River Member aquifers. The projected population increase at Colstrip for the scenario will increase the magnitude of the hazard to groundwater quality.

Miles City, Forsyth, and Billings must increase their wastewater treatment facility capacities to meet the expected needs.

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[1]Federal Water Pollution Control Act Amendments of 1972, Pub. L. 92-500, 86 Stat. 816, and 844 §§ 101, 301; 33 U.S.C.A. §§ 1251, 1311 (Supp. 1976).

TABLE 8-20: WASTEWATER TREATMENT CHARACTERISTICS FOR THE COLSTRIP SCENARIO[a]

TOWN	TYPE OF TREATMENT	DESIGN CAPACITY (MMgpd)	PRESENT FLOW (MMgpd)	PER CAPITA FLOW	FUTURE PLANS
Forsyth	2-cell stabilization 8.18 acres	0.54	0.27	100	Abandon present facility--use oxidation ditch and digestion
Miles City	3-cell stabilization	1.18	1.02	106	Upgrade operation of existing system
Colstrip	3-cell stabilization	0.09	0.09	90	None
Billings	New secondary treatment plant September 1976				

MMgpd = million gallons per day

[a]Letter from Department of Health and Environmental Services, State of Montana, 1976.

As shown in Tables 8-19 and 8-20, wastewater treatment requirements will exceed capacity at Colstrip. Facilities must be expanded or treatment levels must be upgraded to meet the requirements of the Federal Water Pollution Control Act (FWPCA) guidelines. This combined effect will be felt most acutely within the smaller communities, and some financial hardship may result.

(2) To 1990

Construction of the 3,000 MWe, coal-fired power plant will continue, and its associated coal mine will be opened during the 1980-1985 period. The power plant will go on-line in 1985. In addition, construction will begin on the Lurgi high-Btu gasification plant and its associated coal mine after 1985 so that this plant can begin operation by 1990.

By 1990, the mine for the power plant will have disturbed 1,700 acres of land (Table 8-16) resulting in runoff impoundment of about 140 acre-ft/yr.[1] Water consumption for the operation of the power plant (26,660 acre-ft/yr) will be about 0.3 percent of the average flow and 0.72 percent of the minimum flow of the Yellowstone River at Miles City.

About 4,920 acre-ft/yr of additional water will be required by population increases caused by the scenario at Colstrip (Table 8-18). Of this amount, 420 acre-ft/yr will be withdrawn from groundwater sources in the town of Colstrip. This quantity of water, which is equivalent to about 260 gpm, may begin to deplete the local shallow aquifers. Several wells will be required, and local water levels may be lowered.

This scenario assumes that the town of Colstrip will build a municipal sewage treatment plant between 1985 and 1990. Until then, the septic tank and drainfield systems will continue to degrade the water quality of local shallow aquifers. The population influx during the 1980-1990 decade will add considerably to the groundwater quality problems. Much of the water taken from local groundwater supplies will be returned to the shallow aquifers through the septic tanks, but such recycling may have serious public health implications. The natural renovating capacity (primarily filtration by sands and absorption by clays) of the Tongue River Member may be exceeded with increased septic tank use.

Although the water usage of the municipalities relying on surface water will increase, the amount demanded will still be small compared to the total flow of the Yellowstone. Water requirements for municipalities will increase as more construction workers migrate into the area. Forsyth will have the greatest increase, about 4,250 acre-ft/yr above the 1975 level. Municipalities must

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[1]Assuming one inch of runoff per year.

also treat an increased wastewater load as shown in Table 8-19. Forsyth will have the greatest increase and will exceed the capacity of its current facilities. Because provisions of the FWPCA restrict pollutant discharge after 1983, the communities affected by growth have the additional problem of effluent disposal. Alternate disposal methods, such as selling the effluent to the energy conversion facilities for use as irrigation water for mine reclamation, will be sought. Therefore, no appreciable impact is likely in local surface waters.

(3) To 2000

The Lurgi high-Btu gasification plant will go into operation in 1990. Construction of the Synthane high-Btu gasification plant and associated coal mine will begin shortly after 1990, and the plant will begin operating in 1995. Finally, construction will begin after 1995 on the Synthoil coal liquefaction plant and its associated coal mine, and the plant will begin operation in 2000.

By 2000, a total of 8,700 acres of land will have been disturbed by the coal mines for the facilities (Table 8-16), reducing runoff to surface streams (via impoundment) by about 700 acre-ft/yr. This reduction is likely to affect the flow patterns of local streams. The water requirement for the operation of all the scenario facilities (at the expected load factor and assuming high wet cooling, see Table 8-15) will total about 0.6 percent of the average flow and 1.3 percent of the minimum flow of the Yellowstone River at Miles City.

By the year 2000, the town of Colstrip will withdraw about 780 acre-ft/yr (480 gpm) from local groundwater resources. After 1990, the town will be using a municipal sewage treatment facility; thus, none of this water will be returned to shallow aquifers through septic tank systems. The result will likely be depletion of local shallow aquifers as described for the preceding decade.

A total of 13,930 acre-ft/yr of surface water above the 1975 level will be required by Forsyth, Miles City, and Billings. This amount of water should not significantly affect flow in the Yellowstone River. Wastewater treatment plant capacity must be expanded from the 1975 base level by a factor of 10 for Miles City and Forsyth, and the capacity at Colstrip must be tripled. Thus, the communities will probably have substantial problems in funding and constructing new treatment plants on an appropriate schedule, and package treatment will probably be used as a stopgap measure. Because pollutants from municipal facilities will not be discharged into surface streams, there will not be any significant impacts on local watersheds.

(4) After 2000

All four coal conversion facilities will continue to operate after 2000, and their impacts will be much the same as those described for earlier decades.

The mines will continue to have long-range impacts on groundwater systems after mine operations cease, despite the reclamation measures that will be undertaken for restoration of surface uses of the land. The overburden that is returned to the mine will have aquifer characteristics quite different from the original, undisturbed overburden.

The evaporative pond dikes which have been maintained during plant operation will receive no maintenance after shutdown. These dikes could lose their protective vegetation, erode, and eventually be breached. Subsequently, the materials within the pond site will erode and enter the surface water system. The salt concentrations may be high enough to cause damage to local streams.

8.3.5 Summary of Water Impacts

Water impacts are caused by (1) the water requirements of and effluents from the energy facilities, (2) the water requirements of and wastewater generated by associated population increases, and (3) the coal mining process itself.

Assuming the energy facilities hypothesized for the Colstrip area are high wet cooled, the water requirements in acre-ft/yr are 26,659 for the power plant, 6,283 for the Lurgi plant, 7,808 for the Synthane plant, and 10,296 for the Synthoil plant. Operation of all the facilities could require as much as 50,600 acre-ft/yr from the Yellowstone River. The use of intermediate wet cooling for the facilities operating at the expected load factor could reduce this amount by 48 percent. The Yellowstone River, the water source for the hypothesized energy conversion facilities, has an average annual flow at Miles City of 8,800,000 acre-ft/yr and minimum flow of 3,720,000 acre-ft/yr. Thus, all facilities operating at the expected load factor during a low flow period (a worst-case) would consume only 1.4 percent of the river flow.

Wastewater from the energy facilities (in acre-ft/yr) average 2,107 from the power plant, 580 from the Lurgi plant, 915 from the Synthane plant, and 871 from the Synthoil plant. The objective of zero discharge of pollutants set forth in the FWPCA[1] will necessitate on-site entrapment and disposal of all these effluents. Therefore, effluents will be discharged into clay-lined, on-site evaporative holding ponds. Furthermore, runoff prevention systems will

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[1]Federal Water Pollution Control Act Amendments of 1972, Pub. L. 92-500, 86 Stat. 816, and 844, §§ 101, 301; 33 U.S.C.A. §§ 1251, 1311 (Supp. 1976).

be installed to direct runoff to a holding pond or to a water treatment facility. These methods protect the quality of surface water systems (at least for the life of the plants), but groundwater quality may be reduced by leakage and leaching from the disposal ponds and pits.

Municipal water use in the scenario area will be 13,390 acre-ft/yr by the year 2000. If the towns in the area continue to use surface water, most of the water demand will be met with water from the Yellowstone River.[1] However, surface water resources are not expected to be greatly affected by the municipal water requirements. Increased population will also cause wastewater increases totalling 1,25 million gallons per day by 2000. New sewage treatment plants in several towns, particularly in Colstrip, will be required.

The coal mines for the energy facilities will have impacts on both groundwater and surface water. Mine dewatering, which will probably be required in most areas, may lead to local aquifer depletion and a resultant lowering of water levels in nearby wells. Springs and seeps on hillsides may dry up, and there may be a significant loss to the base flow of Rosebud Creek. Shallow bedrock aquifers in the coal and overburden will be lost in the mine area, and replacing the overburden will not necessarily reestablish aquifers. Furthermore, contaminants from the mines may contaminate springs, seeps, alluvial aquifers, and creeks in the area.

By 2000, nearly 9,000 acres of land will have been disturbed by the coal mines. Silt loading in local streams will occur until runoff is controlled by ponding. Ponding the runoff will decrease surface water flow and alter flow patterns in local, intermittent streams.

8.4 SOCIAL AND ECONOMIC IMPACTS

8.4.1 Introduction

The primary area of social and economic effects in the Colstrip scenario will be Rosebud County, Montana and, to a lesser extent, the cities of Billings and Miles City. Most of the effects anticipated will result either directly or indirectly from population changes.

8.4.2 Existing Conditions

Rosebud County covers 5,037 square miles and had a 1975 population of approximately 8,600 people. The resulting population density of 1.69 persons per square miles is low in comparison with the 1970 Montana average of 4.77 persons per square mile. The

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[1]Colstrip will be the only scenario municipality using ground water.

county's population has increased since 1970 after a period of relative stability with most of the growth occurring in Colstrip and Forsyth (see Table 8-21). In 1970, the Northern Cheyenne Indian Reservation in the southern portion of Rosebud County accounted for 1,700 people, or about 28 percent of the county's population.

Agriculture dominates the Rosebud County economy, accounting for 33 percent of all earned income in 1972 (the average for Montana was 19.7 percent). The average size ranch or farm was 2,665 acres in 1974. The proportion of farm income from ranching (livestock income) is higher than the state average: 75.9 percent compared to 63.6 percent. (The distribution of employment by industry in 1970 is shown in Table 8-22.) However, recent development related to power plant construction has altered this pattern by adding substantially to the construction employment proportion.

As shown in Figure 8-6, the county's road network is more developed in an east-west direction, focusing on Billings 100 miles to the west and Miles City to the east. Both the Burlington Northern (formerly Northern Pacific) and the Chicago, Milwaukee, St. Paul, and Pacific Railroads cross the county from east to west, running through Forsyth. A spur line runs south through Colstrip.

Rosebud County is governed by a board of three elected county commissioners. There is currently no county charter, but one is being developed by a study commission elected in 1975. A county planning board was created in January 1974, and a master plan was to be completed by late 1976. Law enforcement consists of one sheriff with deputies in Forsyth (the county seat), Colstrip, Ashland, and Birney.

Colstrip is an unincorporated community owned by Western Energy Company, a subsidiary of Montana Power Company.[1] Most basic municipal services, such as streets, water, and sewer facilities, have been provided by the company.[2] The planning board has taken an active role to assure that the town of Colstrip meets all county zoning and building requirements. A town council has been formed to provide resident input to Western Energy Company planners. There were no full-time physicians or dentists in Colstrip in 1975; since then, a clinic facility has been opened with a full-time staff.

Forsyth, the county seat and only incorporated town in Rosebud County, is governed by a mayor and four councilmen. There is

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[1]Colstrip has been a company-owned town since it was founded by Northern Pacific Railroad in 1923. It was sold to Montana Power in 1959.

[2]Current sewage treatment facilities consist of septic tanks and drainage systems.

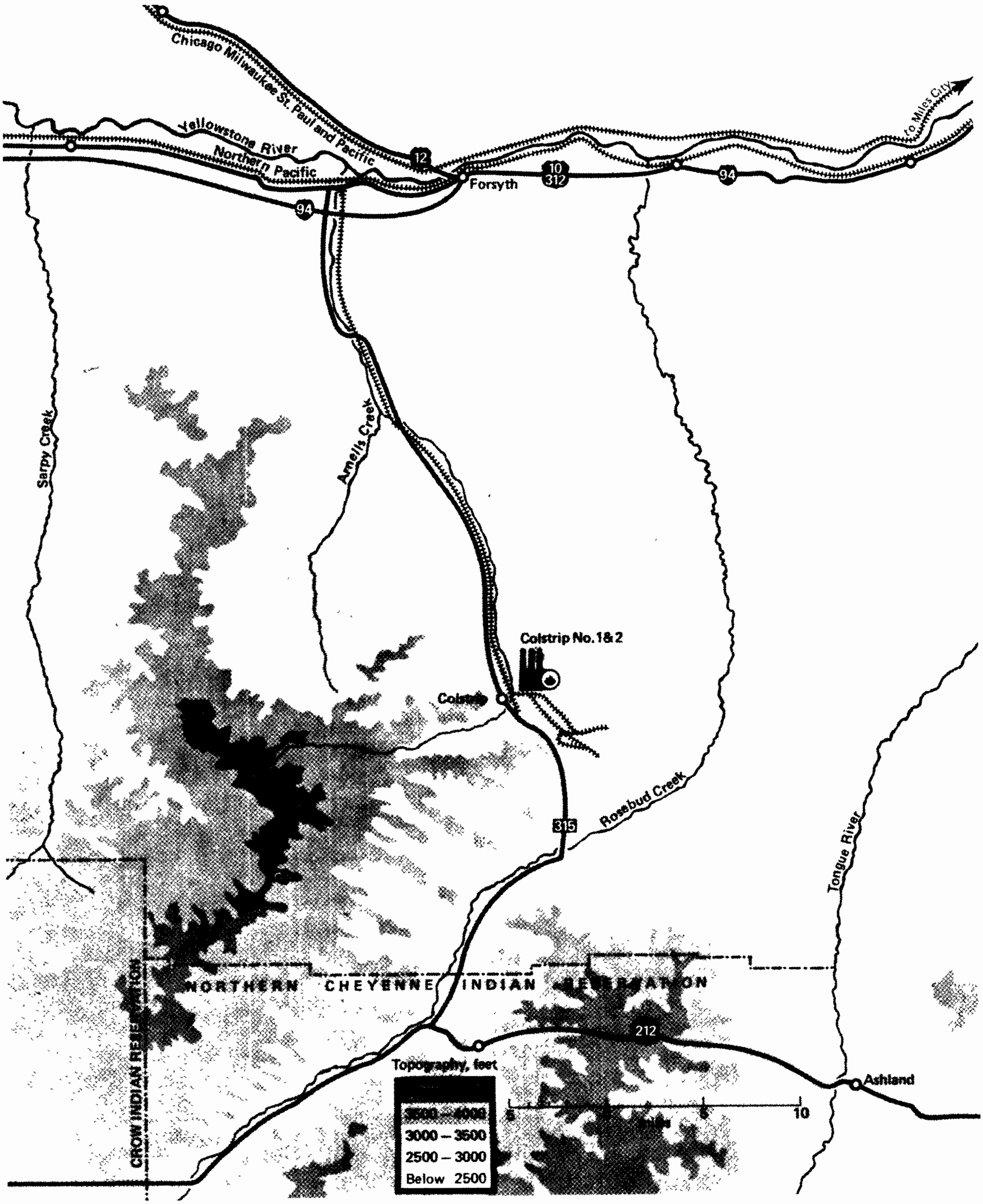

FIGURE 8-6: TRANSPORTATION FACILITIES IN THE ROSEBUD COUNTY AREA

TABLE 8-21: POPULATION OF ROSEBUD COUNTY, COLSTRIP AND FORSYTH, 1940-1975[a]

YEAR	ROSEBUD COUNTY	COLSTRIP	FORSYTH
1975[b]	8,500	3,000	2,500
1974		2,650	2,950
1973	6,959	1,800	2,700
1970	6,032	422	1,873
1960	6,187	439	2,032
1950	6,570	553	1,906
1940	6,477		1,696

[a]U.S., Department of Commerce, Bureau of the Census. County and City Data Book: A Statistical Abstract Supplement. Washington, D.C.: Government Printing Office, 1972; University of Montana, Institute for Social Science Research. A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming. Missoula, Mont.: Institute for Social Science Research, 1974; Westinghouse Electric Corporation, Environmental Systems Department. Colstrip Generation and Transmission Project: Applicant's Environmental Analysis. Pittsburgh, Pa.: Westinghouse Electric Corporation, 1973; Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

[b]Estimated.

no planning department, and most of the planning is done by the city through the use of consultants. Forsyth has both city-owned and operated water and sewage treatment systems, and expansion of the water system is now underway.

8.4.3 Factors Producing Impacts

Two factors associated with energy facilities dominate as the cause of social and economic impacts: manpower requirements and taxes levied on the energy facilities. Tax rates are tied to capital costs, and/or the value of coal extracted, and/or the value of energy produced. Taxes which apply to the Colstrip scenario facilities (power plant, Lurgi and Synthane gasification plants, and Synthoil liquefaction plant) and their associated mines are

TABLE 8-22: EMPLOYMENT DISTRIBUTION IN ROSEBUD COUNTY, 1970

INDUSTRY	NUMBER	PERCENTAGE
Total Civilian Labor Force	2,346	100
Total Employed	2,238	95.4
Agriculture	497	22.2
Contract Construction	116	5.2
Manufacturing	175	7.8
Wholesale and Retail Trade	316	14.1
Services	81	3.6
Education	257	11.5
Government	553	24.7
Other	243	10.9
Total Unemployed (1970)[a]	108	4.6

Source: U.S., Department of Commerce, Bureau of the Census. County and City Data Book: A Statistical Abstract Supplement. Washington, D.C.: Government Printing Office, 1972, p. 294.

[a]June 1978 unemployment is 6.4 percent (Montana State Government Office of Research Analysis, 1978).

property tax, a severance tax, and royalty payments on federally owned coal.

The manpower requirements for each scenario facility and its associated surface coal mine are given in Tables 8-23 to 8-26. For the mines, the manpower requirement for operation exceeds the peak construction manpower requirement by two times. However, the reverse is true for the conversion facilities; the peak construction manpower requirement exceeds the operation requirement by 1.7 (Synthoil plant) to 7.0 times (Lurgi and Synthane plants). The peak total manpower requirements for each mine-conversion facility increases from the first year when construction begins, peaks, and then declines as construction activity ceases. The peak total manpower requirement for the Lurgi, Synthane, and Synthoil mine-plant combination is about 5,000 and for the power plant, about 3,000. The fraction of the peak total manpower requirement needed for operation of the mine and plant combination ranges from 0.2 for the Lurgi and Synthane plants to 0.6 for the Synthoil plant. The total manpower required for operation of the Synthoil facility and its associated mine is more than three times that for each of the other plant-mine combinations.

TABLE 8-23: MANPOWER REQUIREMENTS FOR A 3,000 MEGAWATT POWER PLANT AND ASSOCIATED MINE[a]

YEAR FROM START	CONSTRUCTION WORK FORCE		OPERATION WORK FORCE		TOTAL IN ANY ONE YEAR
	MINE	POWER PLANT	MINE	POWER PLANT	
1		0			0
2		40			40
3		420			420
4	0	905			905
5	36	1,315			1,351
6	211	2,065		0	2,276
7	205	2,545	0	109	2,859
8	211	1,990	275	109	2,585
9	169	720	275	218	1,382
10	0	0	552	436	988
11			552	436	988

MWe = megawatt-electric

[a]Data are for a power plant and a surface coal mine large enough to supply that power plant (about 16.8 million tons per year) and are from Carasso, M. et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975; data uncertainty is -10 to +20 percent.

TABLE 8-24: MANPOWER REQUIREMENTS FOR A LURGI PLANT AND ASSOCIATED MINE[a]

YEAR FROM START	CONSTRUCTION WORK FORCE		OPERATION WORK FORCE		TOTAL IN ANY ONE YEAR
	MINE	LURGI PLANT	MINE	LURGI PLANT	
1	0	0			0
2	36	36			72
3	211	609			820
4	205	2,687	0		2,892
5	211	4,682	275		5,168
6	169	2,662	275	0	3,106
7	0	0	552	589	1,141
8			552	589	1,141

[a]Data are for a Lurgi plant and a surface coal mine large enough to supply that Lurgi plant (about 9.6 million tons per year) and are from Carasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975; data uncertainty is -10 to +20 percent.

TABLE 8-25: MANPOWER REQUIREMENTS FOR A SYNTHANE PLANT AND ASSOCIATED MINE[a]

YEAR FROM START	CONSTRUCTION WORK FORCE		OPERATION WORK FORCE		TOTAL IN ANY ONE YEAR
	MINE	SYNTHANE PLANT	MINE	SYNTHANE PLANT	
1	0	0			0
2	36	36			72
3	211	609			820
4	205	2,687	0		2,892
5	211	4,682	275		5,168
6	169	2,662	275	0	3,106
7	0	0	552	589	1,141
8			552	589	1,141

[a]Data are for a Synthane plant and a surface coal mine large enough to supply that Synthane plant (about 8.4 million tons per year) and are from Carasso, M., *et al*. *The Energy Supply Planning Model*, 2 vols. San Francisco, *Calif.*: Bechtel Corporation, 1975; data uncertainty is -10 to +20 percent.

TABLE 8-26: MANPOWER REQUIREMENTS FOR A SYNTHOIL PLANT AND ASSOCIATED MINE[a]

YEAR FROM START	CONSTRUCTION WORK FORCE		OPERATION WORK FORCE		TOTAL IN ANY ONE YEAR
	MINE	SYNTHOIL PLANT	MINE	SYNTHOIL PLANT	
1		0			0
2		62			62
3	0	598			598
4	36	2,247			2,283
5	211	4,283			4,494
6	205	5,003	0		5,208
7	211	3,503	275	0	3,989
8	169	1,081	275	1,467	2,992
9	0	0	552	2,935	3,487

[a]Data are for a Synthoil plant and a surface coal mine large enough to supply that Synthoil plant (about 12.0 million tons per year) and are from Carasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975; data uncertainty is -10 to +20 percent. Synthoil data have a high uncertainty because of the small capacity of bench scale test facilities built to date. The Solvent Refined Coal liquefaction process now appears likely to become commercial sooner, and more reliable pilot plant data are available. These data are reported in White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 3.

A property tax which is tied to capital costs of the facilities and a severance tax and royalty payments which are tied to the value of coal generate revenue for the state and local governments. The capital costs of the conversion facilities and mines hypothesized for the Colstrip scenario are given in Table 8-27. Costs range (in millions of 1975 dollars) from about 1,150 (mine-gasification plant facility) to 2,170 (mine-Synthoil plant facility). The property tax, most of which goes to local governments, is levied on the cash value of the facility (approximately the total capital cost given in Table 8-27) after construction of the facility is completed, but no property tax is collected when a facility is located on an Indian reservation. The property tax in Rosebud County, Montana is about 1.19 percent.[1] Currently, there is no sales tax, but a severance tax of 30.5 percent is levied on the coal extracted. Revenue obtained from the severance tax is divided between the state government and local government (52.3 and 47.7 respectively). State and local government also receive 50 percent of royalty payments which are about 12.5 percent of the value of federally owned coal.[2] However, all royalties are retained by Indian tribes when the coal is on Indian reservations.

8.4.4 Impacts

The nature and extent of the social and economic impacts caused by this factor depend on the size and character of the community or communities in which workers and their families live, on the state and local tax structure, and on many other social and economic factors. A scenario, which calls for the development of power, Lurgi, Synthane, and Synthoil facilities according to a specified time schedule (see Table 8-1), is used here as a vehicle through which the nature and extent of the impacts are explored. The discussion relates each impact type to the hypothetical scenario and includes population impacts, housing and school impacts, economic impacts, fiscal impacts, social and cultural impacts, and political and governmental impacts.

A. Population Impacts

The first major impact on the Rosebud County area from the scenario will be from construction workers associated with the power plant complex beginning in 1977 (Table 8-28). Construction activity in the scenario is scheduled to end in 2000, although

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[1] This is the effective, average property tax rate. The actual rate is computed using a number of assessment ratios, since certain kinds of equipment (e.g., pollution control equipment) are taxed at different rates or may be exempt.

[2] This is the federal government's target rate; actual rates will vary from mine to mine.

TABLE 8-27: CAPITAL RESOURCES REQUIRED FOR CONSTRUCTION OF FACILITIES (in millions of 1975 dollars)[a]

FACILITIES	MATERIALS AND EQUIPMENT	LABOR AND MISCELLANEOUS	INTEREST DURING CONSTRUCTION[b]	TOTAL
Conversion Facilities				
Power Plant (3,000 MWe)	461	461	394	1,316
Gasification Plant (250 MMcfd)	469	369	219	1,057
Synthoil Plant (100,000 bbl/day)	689	832	649	2,170
Associated Surface Coal Mines				
For Power Plant (16.8 MMtpy)	91	49	42	182
For Lurgi Plant (9.6 MMtpy)	52	28	24	104
For Synthane Plant (8.4 MMtpy)	46	26	21	93
For Synthoil Plant (12.0 MMtpy)	65	35	30	130

MWe = megawatt-electric
MMcfd = million cubic feet per day
bbl/day = barrels per day
MMtpy = million tons per year

[a]Data are adjusted (assuming linearity) to correspond to the facility size hypothesized in the scenario and are from Carasso, M., *et al*. *The Energy Supply Planning Model*, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975.

[b]At 10 percent per year.

TABLE 8-28: CONSTRUCTION AND OPERATION EMPLOYMENT FOR COLSTRIP SCENARIO, 1975-2000 (person years)

YEAR	CONSTRUCTION	OPERATION	TOTAL
1975			
1976			
1977	40	0	40
1978	420	0	420
1979	900	0	900
1980	1,350	0	1,350
1981	2,280	0	2,280
1982	2,750	110	2,860
1983	2,200	380	2,580
1984	890	490	1,380
1985	70	990	1,060
1986	820	990	1,810
1987	2,890	990	3,880
1988	4,890	1,260	6,150
1989	2,830	1,260	4,090
1990	70	2,130	2,200
1991	820	2,130	2,950
1992	2,890	2,130	5,020
1993	4,920	2,400	7,320
1994	3,090	2,400	5,490
1995	1,010	3,270	4,280
1996	2,070	3,270	5,340
1997	2,380	3,270	5,650
1998	1,730	3,540	5,270
1999	640	4,180	4,820
2000	0	5,100	5,100

Source: Carasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975.

employment in construction is minimal in 1985 and 1990.[1] The population estimates explicitly take into account the major market centers of Eastern Montana, Billings, and Miles City, as well as settlements in Rosebud County (Figure 8-7).

[1]Population changes were estimated by means of an economic base model, the employment data from Table 8-28, and the multipliers in Tables 8-29 and 8-30.

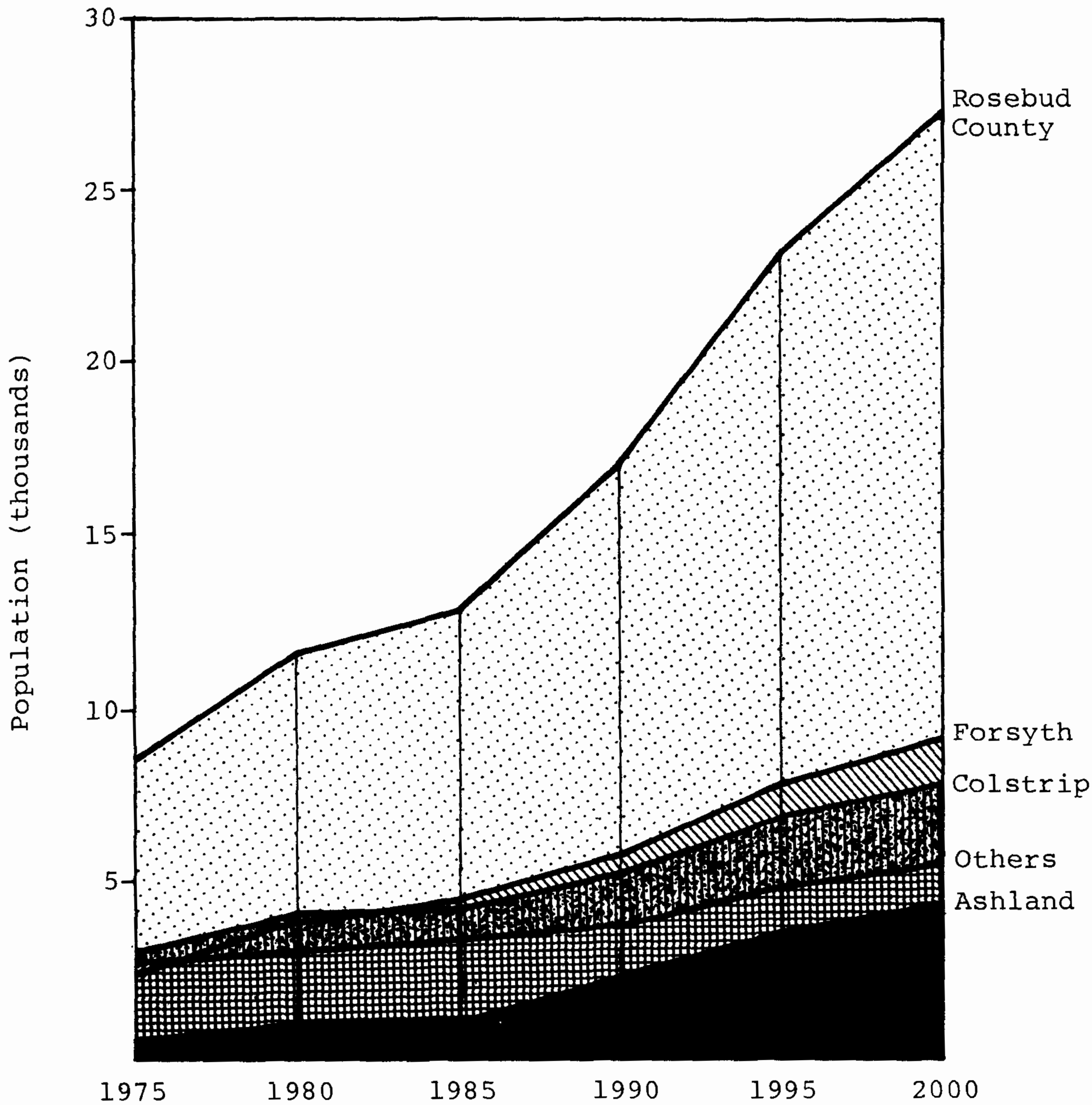

FIGURE 8-7: POPULATION ESTIMATES FOR ROSEBUD COUNTY, 1975-2000

TABLE 8-29: EMPLOYMENT AND POPULATION MULTIPLIERS FOR COLSTRIP SCENARIO POPULATION ESTIMATES

SERVICE/BASIC EMPLOYMENT MULTIPLIERS[a]		
LOCATION	CONSTRUCTION	OPERATION
Rosebud County	0.2	0.5
Miles City	0.1	0.15
Billings	0.15	0.25
(Regional Total)	(0.45)	(0.90)

POPULATION/EMPLOYEE MULTIPLIERS[b]	
Construction	2.05
Operation	2.3
Service	2.0

[a]These values were chosen after examining several studies concerned with population impacts in the Northern Great Plains including Polzin, Paul E. Water Use and Coal Development in Eastern Montana. Bozeman, Mont.: Montana State University, Joint Water Resources Research Center, 1974; White, Randle V. The Decker-Birney-Ashland Area and Coal Development: An Economic Study. Missoula, Mont.: University of Montana, Bureau of Business and Economic Research, 1975; Montana, Department of Natural Resources and Conservation, Energy Planning Division. Final Environmental Impact Statement on Colstrip Electric Generating Units 3 and 4, 500 Kilovolt Transmission Lines and Associated Facilities. Helena, Mont.: Montana, Department of Natural Resources and Conservation, 1974, pp. 120-131; U.S., Department of the Interior, Bureau of Reclamation and Center for Interdisciplinary Studies. Anticipated Effects of Major Coal Development on Public Services, Costs, and Revenues in Six Selected Counties. Denver, Colo.: Northern Great Plains Resources Program, 1974; University of Denver, Research Institute. The Social, Economic and Land Use Impacts of a Fort Union Coal Processing Complex, Final Report, for U.S., Energy Research and Development Administration. Springfield, Va.: National Technical Information Service, 1975. FE-1526, pp. 29-49; Erickson, Ronald E. "Social Impacts of Coal Gasification or a Practical Joke," in Clark, Wilson F., ed. Proceedings of the Fort Union Coal Field Symposium, Vol. 4: Social Impact Section. Billings, Mont.: Eastern Montana College, 1975, pp. 451-53; Johnson, Maxine C., and Randle V. White. Colstrip, Montana: The Fiscal Effects of Recent Coal Development and an Evaluation of the Community's Ability to Handle Further Expansion. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975.

[b]Adapted from Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976. These multipliers are aggregates which balance such factors as single-person households, large families, and working spouses.

TABLE 8-30: ASSUMED POPULATION ATTRACTION OR CAPTURE RATES USED TO ALLOCATE POPULATION WITHIN ROSEBUD COUNTY

	FORSYTH	COLSTRIP	ASHLAND	OTHER
Energy Population				
1975-1985	.40	.40	.10	.10
1986-1990	.20	.20	.40	.20
1991-2000	.30	.30	.20	.20
Service Population				
1975-1985	.75	.15	.10	
1986-1990	.40	.20	.30	.10
1991-2000	.40	.20	.20	.20

The projected population of Rosebud County is expected to increase more than three-fold to over 27,000 by 2000 (Table 8-31).[1] The peak population occurs in 1993 in all parts of the county, with a slightly smaller short-term peak in 1988. Ashland will receive the most severe impact because of its current small size; its 1988 peak is nearly 10 times its present size of 500. Forsyth and Colstrip remain over 5,000 population after 1986 with occasional peaks during construction activity. The projections reported here effectively consider Colstrip as more similar to other towns. However, its past and present ownership by Western Energy Company could preclude additional population from settling there. If Colstrip is incorporated by the mid-1980's, the populations in Table 8-31 are more realistic.

Outside Rosebud County, Miles City and Billings will receive a noticeable amount of service industry growth stemming from

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[1]Because the Northern Cheyenne Reservation is not the site of coal development in this scenario, estimates of Indian employment are difficult to make. About 200-300 Indians may be directly employed, and out-migration is likely to be slowed. The Northern Cheyenne population is included in the "other" category in Table 8-31.

TABLE 8-31: POPULATION ESTIMATES FOR ROSEBUD COUNTY, 1975-2000[a]

YEAR	ROSEBUD COUNTY	FORSYTH	COLSTRIP	ASHLAND	OTHER[b]
1975	8,600	2,500	3,000	500	2,600
1980	11,620	3,820	4,080	790	2,930
1981	13,350	4,690	4,770	980	3,090
1982	14,850	5,290	5,230	1,100	3,230
1983	14,700	5,270	5,130	1,090	3,210
1984	12,740	4,440	4,380	890	3,030
1985	12,690	4,510	4,280	880	3,020
1986	14,260	4,880	4,610	1,450	3,320
1987	18,430	5,870	5,460	3,020	4,080
1988	23.200	7.010	6,430	4,810	4,950
1989	19,680	6,260	5,740	3,400	4,280
1990	17,160	5,830	5,250	2,340	3,740
1991	18,710	6,320	5,690	2,640	4,060
1992	22,860	7,640	6,870	3,470	4,880
1993	27,660	9,170	8,220	4,420	5,850
1994	24,500	8,200	7,310	3,790	5,200
1995	23,350	7,900	6,910	3,550	4,990
1996	25,540	8,600	7,530	3,990	5,420
1997	26,270	8,840	7,740	4,130	5,560
1998	25,910	8,750	7,630	4,050	5,480
1999	25,770	8,750	7,550	4,020	5,450
2000	27,170	9,240	7,910	4,350	5,670

[a]Given the development in this scenario, the population increases are within a ±25 percent range of expected conditions. For example, Rosebud County's population in 2000 should be between 22,500 and 31,800.

[b]Other includes a rural population of about 1,800 throughout the period, as well as townsites such as Rosebud, Lame Deer, and Birney.

wholesale and retail sales to Rosebud County residents.[1] Miles City, east of Forsyth, should grow in population by 5,800, or 62

[1]University of Montana, Institute for Social Science Research. A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming. Missoula, Mont.: University of Montana, Institute for Social Science Research, 1974, pp. 61-69; and Polzin, Paul E. Water Use and Coal Development in Eastern Montana. Bozeman, Mont.: Montana State University, Joint Water Resources Research Center, 1974.

percent, by the year 2000. Expected growth in the Billings area of 17,800 is only about 27 percent of its current population. The bulk of the overall population increase from the scenario is expected to take place within Rosebud County, where nearly all of the cyclincal impacts occur.[1]

Age-sex breakdowns of the projected population of Rosebud County help to indicate the housing and educational needs of the area. From the county's 1970 age-sex distributions, new immigrants were assumed to fall into categories derived from studies of energy-impacted communities.[2] The resulting age-sex distribution (Table 8-32) shows particular increases in the 25-34 age groups and a high proportion of school-age children through 1985. The disparity between males and females should diminish throughout the energy development period.

B. Housing and School Impacts

Housing demand and school enrollment can be estimated by employing the information in Tables 8-31 and 8-32 and by assuming that the 6-13 age group is elementary school enrollment and the 14-16 age group comprises secondary school enrollment (Table 8-33, Figure 8-8). The demand for housing is twice the 1975 level by the mid-1980's, then doubles again during the peak construction activity around 1993 (Table 8-33). At least 600 extra homes would be needed for peak population before the year 2000.

In accordance with the experience of other energy-impacted areas, much of the housing for development workers will be provided by mobile homes. About 39 percent of Rosebud County's housing in 1974 was made up of mobile homes, up from about 9.5 percent in 1970.[3] More than 50 percent of the newcomers will be forced to live in mobile homes, with the percentage being higher at Colstrip than at Forsyth.[4] These trends were begun in connection with

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[1]When construction employment does not carry over from year to year, the employees, their families, and one-half of the associated service population is assumed to leave the area. Given the large amount of energy construction activity which might occur in the West, this assumption is as reasonable as its alternatives.

[2]Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, pp. 33-38.

[3]U.S., Department of Agriculture, Committee for Rural Development. 1975 Situation Statement: Rosebud-Treasure Counties. Forsyth, Mont.: Department of Agriculture, 1975, pp. 65-74.

[4]Mountain West Research. Construction Worker Profile, Community Report: Forsyth and Colstrip, Montana. Washington, D.C.: Old West Regional Commission, 1976.

TABLE 8-32: PROJECTED AGE-SEX DISTRIBUTION FOR ROSEBUD COUNTY, 1975-2000

CATEGORY	1975	1980	1985	1990	1995	2000
Females						
65 and over	.051	.037	.033	.024	.018	.016
55-64	.039	.035	.031	.026	.024	.022
35-54	.102	.102	.098	.095	.094	.094
25-34	.057	.090	.113	.143	.158	.172
20-24	.035	.043	.042	.045	.048	.048
17-19	.025	.027	.027	.028	.029	.030
14-16	.029	.023	.023	.020	.018	.017
6-13	.092	.072	.075	.066	.059	.056
0-5	.064	.051	.055	.050	.046	.045
Total	.494	.480	.496	.498	.494	.499
Males						
65 and over	.050	.036	.033	.023	.017	.015
55-64	.043	.041	.033	.028	.026	.027
35-54	.113	.118	.105	.100	.100	.096
25-34	.059	.104	.115	.144	.163	.172
20-24	.027	.042	.037	.042	.047	.047
17-19	.020	.026	.024	.026	.029	.028
14-16	.038	.029	.029	.024	.020	.019
6-13	.095	.074	.076	.067	.059	.057
0-5	.060	.049	.052	.049	.045	.044
Total	.516	.520	.504	.502	.506	.501

Source: Table 8-31 and data adapted from Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, pp. 33-38.

construction activity on Colstrip power plant Units 1 and 2, and would continue in the scenario development here. Any single- and multifamily units are likely to be located primarily at town sites within the county. Since only Forsyth and Colstrip currently provide municipal water service, development in the Ashland vicinity must rely on septic tanks.

School enrollment impacts will be relatively minor through 1983, with a 43 percent elementary increase and a 49 percent secondary increase over 1975 levels (Table 8-33). From 1983 to 1993,

TABLE 8-33: ESTIMATED NUMBER OF HOUSEHOLDS AND SCHOOL ENROLLMENT IN ROSEBUD COUNTY, 1975-2000

YEAR	HOUSEHOLDS[a]	ELEMENTARY[b]	SECONDARY[c]
1975	2,510	1,560	510
1980	3,960	1,700	600
1983	4,470	2,220	760
1988	7,330	3,090	1,020
1993	8,900	3,480	1,130
1995	7,680	2,760	890
2000	8,300	3,070	980

[a]Estimated from number of males aged 22 and over, representing an aggregate of single-person households and families. Estimates should be seen as medians in a 25-percent error range.

[b]Ages 6-13, resulting in somewhat low estimates; the upper end of the range should be 20-25 percent above these figures.

[c]Ages 14-16, resulting in somewhat low estimates; see "b" above.

enrollments will nearly double at both school levels. The enrollments peak in 1993, and the 2000 enrollments are very close to the 1988 levels. This suggests that temporary facilities could accommodate the 1990's construction bulge at much less expense than permanent structures. About 200 new classrooms will be needed for the 1993 peak, which is about 25 more than will be needed for the 2000 enrollment (Table 8-34). Capital expenditures for new schools should be below $6.5 million, especially if modular-type classrooms are used for peak enrollments; annual operating expenditures should double (in constant dollars) by 1993.[1] The distribution of these needs within the county is suggested by the population distribution in Table 8-31.

[1]These estimates may be compared with U.S., Department of the Interior, Bureau of Reclamation and Center for Interdisciplinary Studies. Anticipated Effects of Major Coal Development on Public Services, Costs, and Revenues in Six Selected Counties. Denver, Colo.: Northern Great Plains Resources Program, 1974, pp. 230-52.

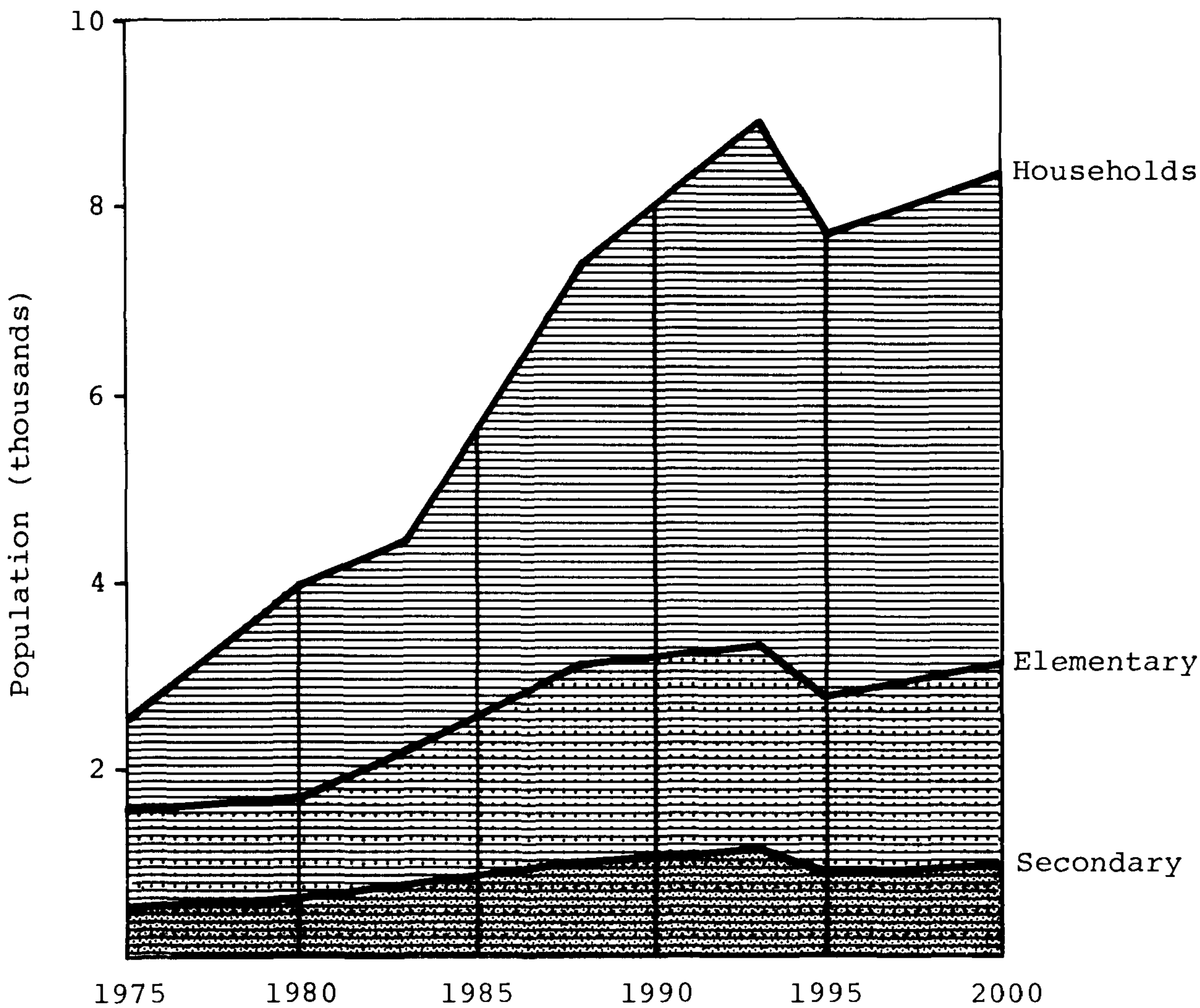

FIGURE 8-8: PROJECTED NUMBER OF HOUSEHOLDS, ELEMENTARY AND SECONDARY SCHOOL CHILDREN IN ROSEBUD COUNTY, 1975-2000

TABLE 8-34: SCHOOL FINANCE CONDITIONS FOR ROSEBUD COUNTY DISTRICTS, 1975-2000

	1975	1980	1983	1988	1993	1995	2000
Enrollment Increase over 1975	2,070	2,300	2,980	4,110	4,610	3,650	4,050
Classrooms (at 21 per room)	96	110	142	196	220	174	193
Capital Expenditure Increase over 1975 (millions of 1975 dollars)[a]		0.58	2.28	5.10	6.35	3.95	4.95
Annual Operating Expenditure Increase (millions of 1975 dollars)[b]		2.88	3.73	5.14	5.76	4.56	5.06

[a]An average of $2,500 per putil space was obtained from Froomkin, Joseph, J.R. Endriss, and R.W. Stump. Population, Enrollment and Costs of Elementary and Secondary Education 1975-76 and 1980-81, Report to the President's Commission on School Finance. Washington, D.C.: Government Printing Office, 1971. This figure is a high estimate where modular or other inexpensive construction is used.

[b]Based on an average of $1,250 per pupil per year. See Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

C. Economic Impacts

Rosebud County's economy currently is dominated by agriculture, especially ranching, which accounted for 33 percent of all 1972 earnings.[1] Coal mining and conversion activities will undoubtedly shift the major portion of income to the extraction and utilities sectors, although most of the land will remain agricultural. Local service and government employment will also expand, especially at Forsyth, the county seat. Based on new employment opportunities in Rosebud County, the overall income distribution will change considerably over the course of the scenario (Table 8-35; Figure 8-9). Largely because of the higher paying jobs in energy industries, the $15,000-20,000 category should expand considerably. However, both the distribution and the median income are strongly influenced by construction activity, as evidenced by the up-and-down effect during the 1980-1990 period. In addition, short-term inflation will reduce purchasing power at times, a fact disguised by the constant dollar computation.

The scenario energy developments will result in local business increases similar to but substantially greater than the increases resulting from the recent construction of Colstrip Units 1 and 2. However, Billings and Miles City should receive much of the wholesale and retail expansion from Rosebud County population growth[2] (Table 8-36, Figure 8-10). Since Montana has no sales taxes, the economic benefits to these market centers will be primarily indirect, coming in the form of increased employment and new businesses.

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[1]U.S., Department of Commerce, Bureau of Economic Analysis. "Local Area Personal Income." Survey of Current Business, Vol. 54 (May 1974, Part II), pp. 1-75.

[2]University of Montana, Institute for Social Science Research. A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming. Missoula, Mont.: University of Montana, Institute for Social Science Research, 1974, p. 69; Johnson, Maxine C., and Randle V. White. Colstrip, Montana: The Fiscal Effects of Recent Coal Development and an Evaluation of the Community's Ability to Handle Further Expansion. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, p. 56; and Polzin, Paul E. Water Use and Coal Development in Eastern Montana. Bozeman, Mont.: Montana State University, Joint Water Resources Research Center, 1974.

TABLE 8-35: PROJECTED INCOME DISTRIBUTION FOR ROSEBUD COUNTY, 1975-2000 (proportion of 1975 dollars)

INCOME	1975	1980	1985	1990	1995	2000
Less than 4,000	.202	.130	.148	.117	.090	.086
4,000-5,999	.117	.078	.090	.074	.059	.058
6,000-7,999	.084	.055	.066	.062	.050	.050
8,000-9,999	.107	.080	.095	.090	.081	.086
10,000-11,999	.166	.101	.133	.110	.105	.109
12,000-14,999	.113	.112	.120	.123	.124	.128
15,000-24,999	.196	.334	.290	.342	.396	.399
25,000-over	.066	.109	.079	.082	.096	.085
Median Household Income (dollar)	9,840	13,490	11,790	13,150	14,780	14,600

Source: Data for 1975 are taken from U.S., Department of Commerce, Bureau of the Census. Household Income in 1969 for States, SMSA's, Cities, and Counties: 1970. Washington, D.C.: Government Printing Office, 1973, p. 39, and inflated to 1975 dollars. Income distributions for construction worker, operation worker, and service worker households are from Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 50, assuming that "other newcomers" are operation employees and that new service worker households have the same income distribution as long-time residents. The income data on Colstrip and Forsyth combined closely follow the data for currently affected communities in the West. Colstrip residents tend to have higher incomes than Forsyth residents, largely because the former are nearly all employed by Western Energy Company, whereas Forsyth has a mix of employers.

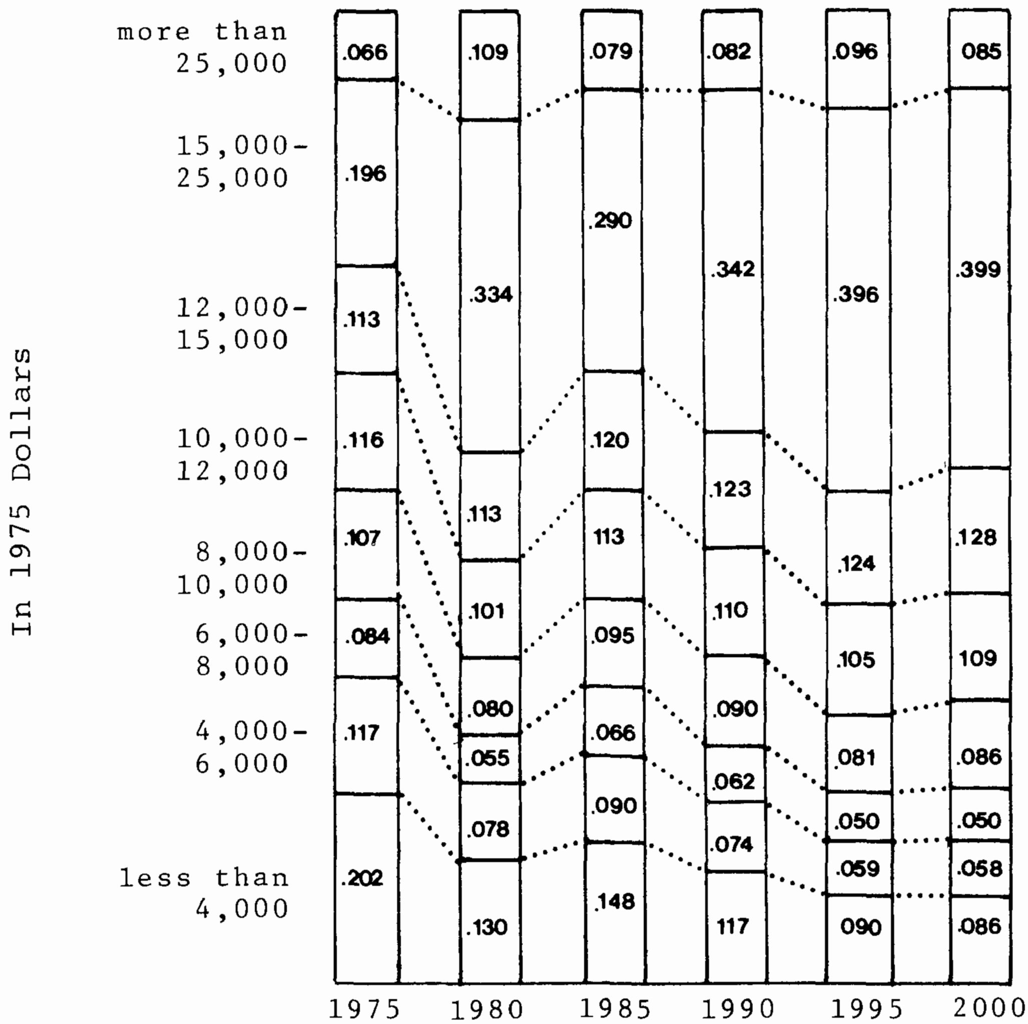

FIGURE 8-9: PROJECTED ANNUAL INCOME DISTRIBUTION FOR ROSEBUD COUNTY, 1975-2000

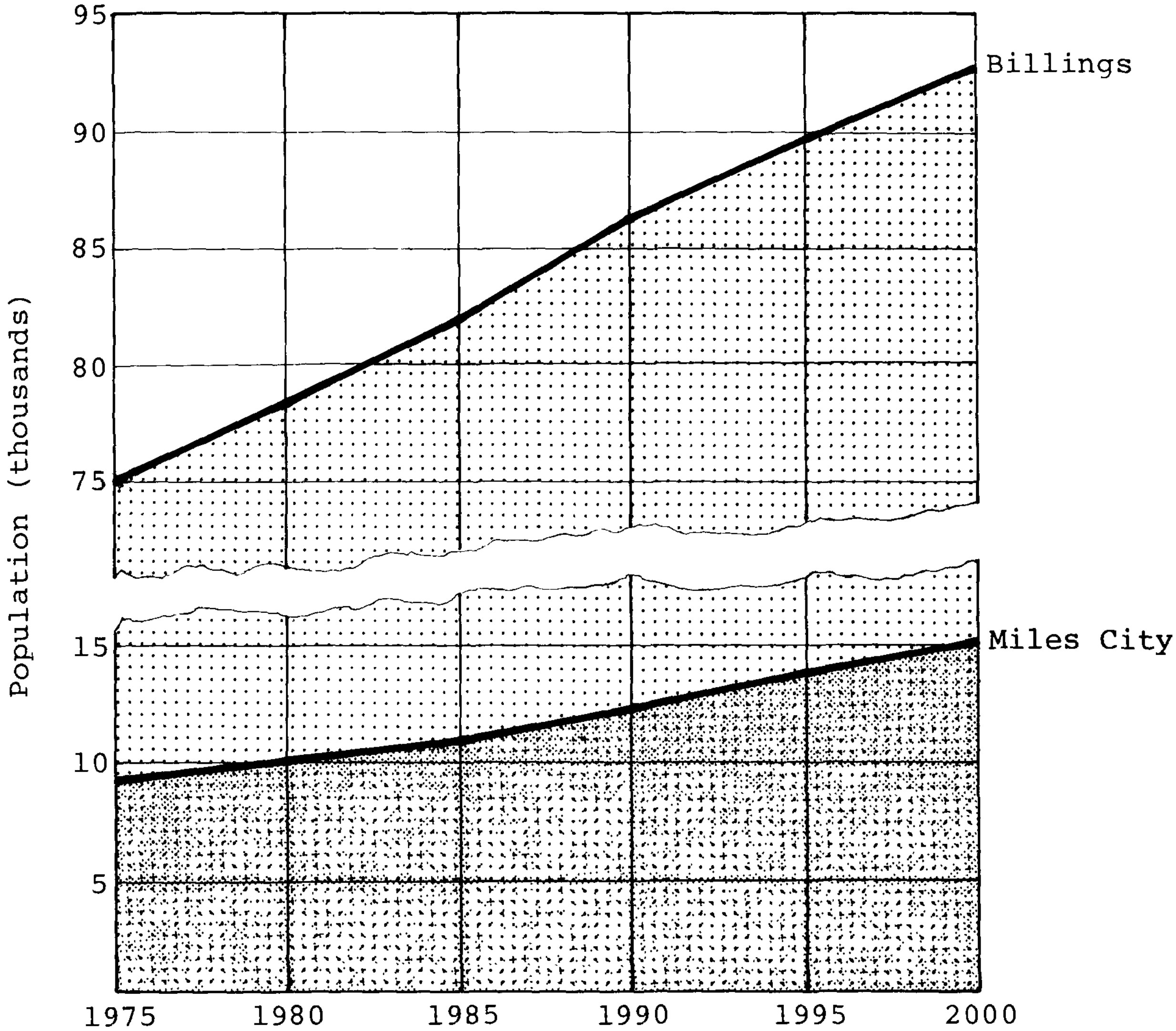

FIGURE 8-10: POPULATION ESTIMATES FOR BILLINGS AND MILES CITY, 1975-2000

TABLE 8-36: PROJECTED POPULATION FOR BILLINGS AREA AND MILES CITY, 1975-2000

YEAR	BILLINGS	MILES CITY
1975	75,000	9,200
1980	78,400	9,900
1985	82,000	10,700
1990	86,400	12,200
1995	89,800	13,800
2000	92,800	15,000

Rosebud County finances have been studied extensively,[1] and an analysis specific to this scenario follows in the section on fiscal impacts. The Forsyth water and sewage treatment facilities are currently used to capacity (only primary sewage treatment is available), and an expansion of the system is being studied.[2] As is common for small communities, the expenditure for such facilities is the largest single category of capital requirements (Table 8-37). The major period of expenditure need in Forsyth occurs after 1985, and especially in the early 1990's. Ashland, which currently has no water system, will require about $8 million to meet demands in the 1988-1993 period. However, temporary facilities might be used at some savings.

To meet projected needs, municipal operating expenditures in Forsyth and Ashland must increase five-fold by 2000, the larger increases occurring in the late 1980's and early 1990's (Table 8-38).

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[1]U.S., Department of the Interior, Bureau of Reclamation and Center for Interdisciplinary Studies. Anticipated Effects of Major Coal Development on Public Services, Costs, and Revenues in Six Selected Counties. Denver, Colo.: Northern Great Plains Resources Program, 1974; and Johnson, Maxine C., and Randle V. White. Colstrip, Montana: The Fiscal Effects of Recent Coal Development and an Evaluation of the Community's Ability to Handle Further Expansion. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975.

[2]Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975; and U.S., Department of Agriculture, Committee for Rural Development. 1975 Situation Statement: Rosebud-Treasure Counties. Forsyth, Mont.: Department of Agriculture, 1975, p. 84.

TABLE 8-37: PROJECTED NEW CAPITAL EXPENDITURES REQUIRED IN FORSYTH AND ASHLAND, 1975-2000 (in thousands of 1975 dollars)

USE CATEGORY	1975-1980	1980-1983	1983-1988	1988-1993	1993-2000
Forsyth					
Water and Sewage[a]	2,320	2,550	3,060	3,800	120
Other[b]	780	860	1,030	1,280	40
Ashland					
Water and Sewage[a]	510	530	6,550[c]	0	0
Other[b]	170	180	2,200[c]	0	0

[a]Water and sewage plant requirements are assumed to be $1,760,000 for each additional 1,000 population, and an additional $591,000 per 1,000 population goes to other physical plant needs. See THK Associates, Inc. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, p. 30. All figures from that source are inflated to 1975 dollars. See also Lindauer, R.L. Solutions to Economic Impacts on Boomtowns Caused by Large Energy Developments. Denver, Colo.: Exxon Co., USA, 1975, pp. 43-44.

[b]Other includes parks and recreation (32 percent), hospitals (45 percent), libraries (5 percent), fire protection (5 percent), police protection (3 percent), administration (3 percent), and public works (7 percent). Some of these are not applicable to Forsyth.

[c]1988 is the expected year of peak population in Ashland.

TABLE 8-38: PROJECTED OPERATING EXPENDITURES OF FORSYTH AND ASHLAND, 1980-2000 (in dollars above 1975 level)[a]

YEAR	FORSYTH	ASHLAND
1980	458,000	95,000
1983	632,000	131,000
1988	841,000	577,000
1993	1,100,000	530,000
1995	948,000	426,000
2000	1,109,000	522,000
1974 Budget	214,353	Unknown[b]

[a]Based on a figure of $120 per capita (1975 dollars) broken down as follows: streets and roads (25 percent), health and hospitals (14 percent), police (7 percent), fire protection (12 percent), parks and recreation (6 percent), libraries (4 percent), administration (10 percent), sanitation and sewage (10 percent), and other (12 percent). See THK Associates, Inc. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, p. 30. All figures from that source are inflated to 1975 dollars. These figures will be high estimates for Forsyth because some of these services are provided by county funds.

[b]Not known. Ashland is an unincorporated community.

The provision of necessary services for construction-related populations will be a major problem because property taxes will not provide revenue until the construction is completed. This has been the case in Rosebud County recently.[1]

The large revenue benefits from energy development discussed in other studies[2] have only begun to be felt in the towns; they

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[1]U.S., Department of Agriculture, Committee for Rural Development. 1975 Situation Statement: Rosebud-Treasure Counties. Forsyth, Mont.: Department of Agriculture, 1975, p. 63.

[2]Johnson, Maxine C., and Randle V. White. Colstrip, Montana: The Fiscal Effects of Recent Coal Development and an Evaluation of the Community's Ability to Handle Further Expansion. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975.

may only partially compensate local municipalities which are forced to absorb large population increases but do not include the energy facilities within their area of taxation. This is likely to be the case for Forsyth, Ashland, and other Rosebud County towns, where newcomers employed in energy development must live.[1] What little land ranchers and other landowners make available for housing will continue to escalate in price, and general inflation for goods and services will be felt. These problems will be worse during intensive construction periods when greater demands will be placed on local markets.[2]

D. Fiscal Impacts

In this section, the tax rates currently in effect in Rosebud County are applied to project incremental revenues likely to arise from energy development. Some taxes, such as severance taxes, apply directly to the energy developments; others, such as personal income taxes, derive indirectly. Some taxes are local, some are state, and some are collected by the state for local distribution.

(1) Coal Mines License Tax[3]

This excise tax will probably capture more revenue from energy development than any other tax. The rate will depend on heat content and contract price, but it will generally be 30 percent of sales price at the mine.[4] The Resource Indemnity Trust Tax is also based on the value of minerals extracted, in this case at a 0.5 percent rate.[5] Receipts are placed in a trust which will accumulate to

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[1]If Colstrip remains a company town, then the company could directly provide many facilities from internal funds, without having to go through the tax system. See Section 8.4.8 below.

[2]A description of recent experience in the area is found in the University of Montana, Institute for Social Science Research. A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming. Missoula, Mont.: University of Montana, Institute for Social Science Research, 1974.

[3]Montana Revised Codes Annotated, Title 84, Chapter 13 (Cumulative Supplement 1976); Johnson, Maxine C., and Randle V. White. Colstrip, Montana: The Fiscal Effects of Recent Coal Development and an Evaluation of the Community's Ability to Handle Further Expansion. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975, pp. 43-46.

[4]For heat content greater than 7,000 Btu's per pound and prices greater than $1.40 per ton.

[5]Montana Revised Codes Annotated, Title 84, Chapter 70 (Cumulative Supplement 1976).

TABLE 8-39: SEVERANCE TAX REVENUES FROM COLSTRIP SCENARIO ENERGY DEVELOPMENT[a] (millions of 1975 dollars)

YEAR	GROSS RECEIPTS	TAX REVENUES
1978	0	0
1980	0	0
1983	80	24.4
1985	171	52.2
1988	239	72.9
1990	292	89.1
1995	438	133.6
2000	652	198.9

[a]The Coal Mines License Tax accounts for 98.4 percent of the tax revenues in the table, at 30 percent of the mine revenues. The remainder is the Resource Indemnity Trust Tax, at 0.5 percent of mine revenues.

$100 million with certain restrictions. This scenario simply credits the funds to the state legislature's discretion.

Projected prices for western coal indicate a rise from $9.52 per ton in 1983 to $13.94 by 2001 (all figures in 1975 currency).[1] The Colstrip scenario calls for new coal production to reach 47 million tons per year by 2000. Multiplying these quantities together and then by 30.5 percent, annual mine and tax revenues are projected (Table 8-39).

(2) Property Taxes

Several forms of property are taxed by a host of governmental units. This analysis concentrates on the energy facilities, associated municipal construction, and "gross proceeds" of mines. It is assumed that energy facilities in the scenario will be taxed during construction in proportion to the resources invested as of each date. The actual value of facilities subject to property tax would thus grow continuously (Table 8-40). It can be seen in the table that the energy developments, rather than the resulting residential and commercial growth, will dominate the tax assessment rolls.

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[1]Cazalet, Edward, et al. A Western Regional Energy Development Study, Economics, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

TABLE 8-40: PROJECTED PROPERTY VALUATION IN ROSEBUD COUNTY (millions of 1975 dollars)

YEAR	FACILITIES	MINERALS	RESIDENTIAL AND COMMERCIAL[a]
1978	55	0	4
1980	276	0	11
1983	998	80	23
1985	1,135	171	15
1988	1,831	239	54
1990	2,051	292	31
1995	3,605	438	79
2000	4,862	642	96

[a]Based on $3,800 per capita and population growth in Rosebud County. See Polzin, Paul E. Water Use and Coal Development in Eastern Montana. Bozeman, Mont.: Montana State University, Joint Water Resources Research Center, 1974, p. 142.

Taxable values are derived from these actual values by a series of statutorially defined ratios. Most property receives a multiplier of 0.12, so that the recent mill levy of 94.42 is equivalent to a rate of 1.133 percent of full market value.[1] Applying the tax rates to the taxable values, and using the current formulas for apportionment, likely property tax receipts are summarized in Table 8-41.

These revenues far exceed previous annual receipts in Rosebud County. At the current time (after some energy-related development has already been felt), the county's total of nonutility property has a taxable value of $15.3 million. By contrast, energy facilities will grow to a taxable value of $584 million by 2000, and gross proceeds will reach $117 million. Clearly, these facilities

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[1]Pollution control equipment has a multiplier of 0.028, and gross proceeds from strip mining have a multiplier of 18. We do not make separate provisions for control equipment in these estimates, however. See Johnson, Maxine C., and Randle V. White. Colstrip, Montana: The Fiscal Effects of Recent Coal Development and an Evaluation of the Community's Ability to Handle Further Expansion. Washington, D.C.: U.S., Department of the Interior, Office of Minerals Policy Development, 1975.

TABLE 8-41: PROJECTED PROPERTY TAX RECEIPTS IN ROSEBUD COUNTY (millions of 1975 dollars)

CATEGORY	1978	1980	1983	1985	1988	1990	1995	2000
State	0	0.2	0.8	0.9	1.5	1.7	2.9	3.9
County General Purposes	0.2	0.8	3.3	4.1	6.5	7.4	12.5	16.6
County for Schools	0.3	1.9	6.3	7.9	12.6	14.4	24.3	32.3
School District 19	0.1	0.7	2.5	3.1	4.9	5.6	9.5	12.6
Total Levy	0.6	3.6	12.9	16.0	25.5	29.1	49.2	65.4

will become the mainstay of local public finances, especially for the school district which depends almost entirely on property taxes. A comparison with Table 8-34 shows that the school districts in Rosebud County can enjoy substantial surpluses if current tax rates are maintained.

The valuation of facilities will probably take on political overtones, considering its crucial role in determining local budgets. The tax assessment process, conducted at the state level, may enjoy some insulation from local political pressures, but these facilities are so capital-intensive as to have a noticeable impact even on the state's tax rolls.

Also, there is a distinct possibility that rates may be reduced, especially those of the property tax and coal mines severance tax. Otherwise (if no major spending programs were introduced), large surpluses would build up in state and county treasuries. Moreover, the 30 percent rate of the license tax far exceeds rates in neighboring states (about 6 percent in North Dakota and 3.5 percent in Wyoming). Thus, this high rate might eventually cause a loss of some development to other states.

(3) State Income Tax[1]

The state income tax in Montana is a graduated tax and therefore depends on the income distribution (Table 8-35; Figure 8-9). Including $3,600 in exemptions and deductions for a family of four, the average tax collected per household will be in the range of

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[1]See Montana Revised Codes Annotated, Title 84, Chapter 49 (1947).

TABLE 8-42: NEW STATE INCOME TAX RECEIPTS FROM ENERGY DEVELOPMENT
(millions of 1975 dollars)

YEAR	NEW HOUSEHOLDS IN ROSEBUD COUNTY	TOTAL NEW PERSONAL INCOME	NEW TAX RECEIPTS[a]
1978	425	5.7	0.4
1980	1,230	16.6	1.1
1983	1,955	23.0	1.5
1985	1,305	15.4	1.0
1988	5,460	71.8	4.7
1990	3,090	40.6	2.6
1995	7,680	113.5	7.4
2000	9,660	141.0	9.2

[a]At 6.5 percent of new personal income.

6.5-6.6 percent of household income. Taking into account the income distribution in Table 8-35, the total new income tax revenue is shown in Table 8-42.

(4) Distribution

The state receives all funds generated by electrical producers' and income taxes, and a portion of the mill levy, as detailed previously (Table 8-41). The county government will receive new funds from the coal tax and the mill levy. All new funds for schools will come from mill levies (by the county and by the districts). Further, the Coal Mines License Tax and the Resource Indemnity Trust Tax are distributed as follows beginning in 1979: 41 percent goes to the state general fund; 34.5 percent goes to local impact and education trust funds (of which 3/7 may be disbursed in grants); 21.1 percent goes to state-earmarked purposes (public schools equalization receives 46.5 percent of that portion, park acquisition receives 23.2 percent, energy research receives 18.6 percent, and resource development bonds support receives 11.6 percent); and 3.4 percent goes to the originating county.[1] The distribution of new revenues from all taxes is summarized in Table 8-43.

The property valuation data presented in Table 8-40 showed that less than 2 percent of new *ad valorem* revenues will come from residential and commercial development. Since the energy facilities will be located in unincorporated areas, municipalities will

[1]These figures differ from language in RCM 84-1309.1 because the License Tax and Resource Indemnity Trust Tax have been combined for ease of calculation.

TABLE 8-43: DISTRIBUTION OF NEW TAX REVENUES FROM COLSTRIP SCENARIO DEVELOPMENT (millions of 1975 dollars)

YEAR	STATE GENERAL PURPOSE	STATE EARMARKED FUNDS	STATE GRANTS TO LOCAL	COUNTY GENERAL PURPOSES	SCHOOLS (county and district)
1978	0.4	0	0	0.2	0.4
1980	1.3	0	0	1	2.6
1983	14.3	5.1	3.6	4.1	8.8
1985	31.1	11	7.7	5.9	11
1988	43.9	15.4	10.8	9	17.5
1990	48.6	18.8	13.2	10.4	21
1995	72.9	28.2	19.8	17	33.8
2000	102.5	42	29.4	23.4	44.9

be excluded from the larger part of new property taxes. Combined with the fact that there is no sales tax in Montana, this means that towns such as Forsyth must depend to a great extent on allocations from higher levels of government.

But if all the state impact aid funds are channeled back to their county of origin, then all local needs can be met, with surpluses, after 1981. In the first few years, the fiscal balance will be as shown in Table 8-44.

E. Social and Cultural Impacts

A distinctive aspect of the Rosebud County area is the continued opposition of many area ranchers to strip mining and other energy development. The arguments are largely economic, since the land and water supplies are crucial to ranching operations, but also include aesthetics (focusing on transmission lines) and combinations of the two (including air pollution effects on visibility and on vegetation).[1]

[1] "Colstrip Testimony." The Plains Truth, Vol. 5 (February/ March 1976), pp. 11-16; see also Montana, Department of Natural Resources and Conservation, Energy Planning Division. Draft Environmental Impact Statement on Colstrip Electric Generating Units 3 and 4, 500 Kilovolt Transmission Lines and Associated Facilities. Helena, Mont.: Montana, Department of Natural Resources and Conservation, 1974, Vol. 3-B, pp. 789-825; University of Montana, Institute for Social Science Research. A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming. Missoula, Mont.: University of Montana, Institute for Social Science Research, 1974, pp. 27-35.

TABLE 8-44: CONSOLIDATED FISCAL BALANCE, TOWN OF FORSYTH AND ROSEBUD COUNTY, 1976-1985 (millions of 1975 dollars)

CATEGORY	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
New Expenditures										
Capital	0.05	0.11	0.67	0.85	0.80	1.59	1.22	0.09	0	0.36
Operating	0	0.01	0.04	0.09	0.13	0.21	0.27	0.27	0.19	0.21
New Revenues										
State Aid	0[a]	0	0	0	0	0	0	3.61	3.61	7.73
County	0	0	0.16	0.44	0.83	1.57	2.33	4.09	4.46	5.83
Surplus (deficit)	(.05)	(.12)	(.55)	(.50)	(.10)	(.23)	.84	7.34	7.88	12.99

[a]The zeros indicate that no such revenues are generated in the county (in our scenario) until 1983. Aid may still be provided by the state with funds generated in other areas. See Section 8.4.8.

Newcomers to the Rosebud County area have not been uniformly impressed with living conditions in the area. Land for housing subdivisions is not available, even in small lots, and mobile home living is the primary alternative. Even in the company-owned town of Colstrip, few families actually own their homes.[1] More unsettling to many families is the separation within Colstrip between construction workers, nonadministrative operation workers, and administrators and supervisors; there is no evidence that this will be eliminated in the future. As a result, a number of workers, especially those with families, have chosen to live in Forsyth,[2] and this can be expected to continue.

The major social impacts on long-time residents will be on the ranchers, who perceive their way of life and values threatened by coal development. For all, local inflation will be a problem when limited competition allows rising prices to take advantage of high incomes.

The quality of life in Rosebud County varies with residential location. Dissatisfaction with medical services, housing availability, and streets and roads is common in both Colstrip and Forsyth. Residents of Colstrip have been quite dissatisfied with entertainment and shopping facilities, resulting in an overall characterization of the town as "isolated" and "dull." In Forsyth, these services are more readily available, and dissatisfactions are more regularly expressed regarding housing quality. People recently living in Forsyth tend to have positive descriptions about the town, characterizing it as "friendly" and "happy." Forsyth's established town atmosphere appears to be much preferred over other locations in Rosebud County.[3]

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[1]For descriptions of Colstrip, see Myhra, David. "Colstrip, Montana--the Modern Company Town." Coal Age, Vol. 80 (May 1975), pp. 54-57; Schmechel, W.P. "Developments at Western Energy Company's Rosebud Mine," in Clark, Wilson F., ed. Proceedings of the Fort Union Coal Field Symposium, Vol. 1. Billings, Mont.: Eastern Montana College, Montana Academy of Sciences, 1975, pp. 60-66.

[2]University of Montana, Institute for Social Science Research. A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming. Missoula, Mont.: University of Montana, Institute for Social Science Research, 1974, pp. 16-18, 43-45.

[3]Mountain West Research. Construction Worker Profile, Community Report: Forsyth and Colstrip, Montana. Washington, D.C.: Old West Regional Commission, 1976, pp. 28-32, 56-61.

Medical care will continue to be a pressing need in the county, as in most of nonmetropolitan America. At least 16 more physicians will be needed by 2000 just to maintain the current average of one physician per 1,500 people. Twice that number would be needed to meet national averages. As elsewhere in the West and in rural areas, attracting physicians will be difficult if not impossible. A subsidized group practice with guaranteed working hours would be a possible inducement for practicing physicians. New doctors could also be influenced to locate in small towns through loan forgiveness programs.[1]

F. Political and Governmental Impacts

As noted in the preceding fiscal analysis, the state and the school districts generally will have sufficient revenues to respond to energy-related impacts. However, the net fiscal status of local units of government will depend largely on administrative and policy decisions made at the state and county levels of government and by the private owners of Colstrip. For example, Forsyth, which will probably be the major recipient of newcomers, must depend on state-level impact aid and county revenues because the energy facilities in this scenario are located in unincorporated areas. Distribution decisions of this nature become even more critical because Montana has no sales tax.

Funding decisions about facilities and services at Colstrip will be up to the discretion of its administrators, as is the case for any company town. Administrators will have wide latitude in the way they provide services or amenities. In addition, workers on energy developments not participated in by the Western Energy Company may not be allowed to live in Colstrip as long as the company owns the town. Colstrip's ultimate incorporation is not scheduled, and even if it should occur early enough for the town to absorb new residents, the usual strains caused by service demands associated with rapid growth would arise. Decisions in both regards will also influence the number of people locating in other communities.

Actions by the Montana Coal Board clearly will be instrumental in determining whether financial problems in communities outside the immediate area of the mines will be handled adequately. If all Montana state impact funds are channeled back to their county of origin, then fiscal demands for the town of Forsyth can be met, with surpluses, after 1981. During 1976-1981, deficits will be experienced, most notably in 1978 ($550,000) and 1979 ($500,000). Besides funneling state revenues back to Forsyth, two additional factors can be brought to bear on the "lead time" problem experienced

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[1]Coleman, Sinclair. Physician Distribution and Rural Access to Medical Services, R-1887-HEW. Santa Monica, Calif.: Rand Corporation, 1976.

in the short term. First, according to state law, county commissioners can request prepayment of taxes on a new industrial facility, not to exceed three times the estimated property tax due the year the facility is completed.[1] These advance funds would provide immediate local impact assistance. Second, the state can use severance tax revenues generated in other parts of the state, just as Rosebud's revenues can later be sent to areas beginning their growth in the 1980's. In fact, Montana already has distributed $3.96 million in such revenues to Rosebud and Big Horn Counties as of mid-1976. This aid is presently helping to reduce financial hardship in Forsyth, Colstrip, and Ashland.[2]

Another government impact category where money appears to be one of the principal problems is law enforcement. Funds are needed for manpower and equipment to adequately handle the large projected influx of people, especially during the construction phase of development. At present, the counties are levying all they can (at least all that is politically feasible) to assist in meeting the needs of their localities. Local revenues are being supplemented by revenue sharing grants and other federal sources. Police protection in both Rosebud and Treasure Counties is a consolidated city-county effort and, in each, is administered by the Sheriff's office. Officers have jurisdiction over their entire county, including rural areas, city properties, and unincorporated towns. In the near future, inadequate protection for Colstrip and Ashland may force incorporation of these towns and formation of their own police departments.[3]

The most important political impacts appear to be related to decisions concerning land use in the area. Local governing bodies in Montana are required by law to adopt subdivision regulations which conform to minimum standards, including: a requirement for environmental assessments; analysis of possible social and economic impacts; and dedication of land for open space (parks) or payment of cash in lieu of land.[4] In addition, a 1975 amendment to the Montana Subdivision and Platting Act establishes specific "public interest" criteria which county commissioners must consider and respond to before taking action on a subdivision application,

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[1] Montana Revised Codes Annotated § 84-41-105 (Cumulative Supplement 1975).

[2] Old West Regional Commission Bulletin, Vol. 3 (September 1, 1976), p. 4.

[3] U.S., Department of Agriculture, Committee for Rural Development. 1975 Situation Statement: Rosebud-Treasure Counties. Forsyth, Mont.: Department of Agriculture, 1975, pp. 83-84.

[4] Montana Revised Codes Annotated §§ 11-3859 through 11-3876 (Cumulative Supplement 1975).

including expressed public opinion and potential social and environmental effects.[1]

The majority of the people in Rosebud County are very concerned about the balance between social costs of industrial growth and related economic gains, and they want to play a role in the planning and decisionmaking process for further development.[2] Controversy over planning and zoning decisions may become more pronounced as the area population increases. This is particularly significant since Rosebud County's zoning laws and regulations constrain the availability of land for subdivision purposes, forcing most new residents to locate in existing towns. The resultant expansion of the towns to a more urban character will be difficult for some long-time residents to accept.[3] Others will enjoy the greater range of goods and services available. The county, which as already noted receives much of the taxation benefit from energy development, will continue its adaptation to more populated conditions by expanding roads and cooperating with the local communities. These decisions do not always rest well with the landowners, nearly all of whom are ranchers.[4]

8.4.5 Summary of Social and Economic Impacts

Manpower requirements and the taxes levied on the energy facilities are major causes of social and economic impacts. For the mines, manpower requirements for operation exceed peak construction manpower requirements. However, the reverse is true for the conversion facilities, i.e., more labor is required for construction than for operation. In combination, total manpower requirements for each mine-conversion facility combination increase from the first year when construction begins, peaks, and then declines as

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[1]This amendment should provide a forum for the public in important growth-related decisions; however, it also raises the potential for political conflict.

[2]U.S., Department of Agriculture, Committee for Rural Development. 1975 Situation Statement: Rosebud-Treasure Counties. Forsyth, Mont.: Department of Agriculture, 1975, p. 59.

[3]*Ibid.*, pp. 57-59.

[4]For example, the decision to build a new road between Colstrip and Forsyth was opposed by area ranchers, who reportedly prefer unpaved roads because they "discourage nosey tourists and cattle thieves." See University of Montana, Institute for Social Science Research. A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming. Missoula, Mont.: University of Montana, Institute for Social Science Research, 1974, p. 74.

construction activity ceases. Total manpower required for operation of the Synthoil facility and its associated mine is more than three times that of other mine-plant combinations.

A property tax, which is tied to capital costs, and a severance tax and royalty payments, which are tied to the value of the coal, generate revenue for the state and local government. Capital costs of the conversion facilities and mines hypothesized for the Colstrip scenario range (in millions of 1975 dollars) from about 1,150 (mine-gasification plant facility) to 2,170 (mine-Synthoil plant facility). The property tax rate in Montana is about 1.19 percent but is not collected when a facility is located on an Indian reservation. Currently, there is no sales tax in Montana, but a severance tax on coal of 30.5 percent is divided between the state and local governments. State and local governments also receive 50 percent of the royalty payments which are 12.5 percent of the value of federally owned coal. However, all royalties are retained by Indian tribes when coal is on Indian reservations.

If all facilities hypothesized in the Colstrip scenario are built, the Rosebud County population will increase by about 25,000 people by the year 2000. The largest population increases are expected in Forsyth, which will grow six-fold during the scenario period to 13,500. Mobile homes will be the major housing type throughout the period, reflecting the unavailability of land for home construction. School enrollments will grow slowly until about 1990 when rapid growth will take place. The expenditure requirements for school districts follow the same pattern, suggesting that lead times may be easier to deal with in Rosebud County.

Local area incomes will change along with the shift in economic activity. Greater reliance on energy sectors will raise median incomes 48 percent by 2000 and even more during construction booms. These incomes will likely induce local inflation, especially in housing. Miles City and Billings will receive a significant amount of the wholesale and retail activity from Rosebud County development.

Population-related government expenditures follow the trend of population growth, with the greatest need occurring in the early 1990's. Of particular importance will be the water and sewage treatment facilities, which will require over $19 million in capital expenditures by 2000. Although the state and the school districts will generally have sufficient funds to respond to impacts, the municipalities are dependent on coal tax funds and actions by the state Coal Board for adequate revenues for local services.

Rancher opposition to coal development in Rosebud County will probably grow as additional grazing land is strip-mined. The company-owned town of Colstrip provides an uncertain governmental problem through potential prohibitions on living within the town while working nearby. Rosebud County's planning capacity and regulatory ability appear able to constrain the type of unplanned sprawl occurring in some areas in the West.

8.5 ECOLOGICAL IMPACTS

8.5.1 Introduction

The area considered for ecological impacts in the Colstrip scenario extends from the Bighorn Mountains in the southwest, eastward to the Tongue River, and north to the Yellowstone River. Most of the landscape consists of rolling hills broken by more rugged uplands and dissected by several tributaries to the Yellowstone. Elevations range from 2,700 feet at Forsyth to 5,200 feet in the Little Wolf Mountains. The climate is semiarid with extreme annual variations in temperature and occasional violent storms which, together with soil moisture and topography, largely determine the abundance and distribution of the biota.[1] Agricultural practices, particularly livestock grazing and sagebrush eradication programs, are important influences on the ecosystem.

8.5.2 Existing Biological Conditions

The terrestrial ecosystem is characterized by two major biological communities: ponderosa pine and juniper woodlands; and the more gently rolling sagebrush grasslands of lower elevations. In addition to these, floodplains and streambanks support a distinctive riparian vegetation. Table 8-45 lists species characteristic of these community types. Although vertebrate wildlife range across all three of these vegetational types, unifying them into a single ecosystem, many species have seasonal preferences, moving in response to the availability of shelter and forage in winter and succulent vegetation in summer.[2] Rare and endangered species include the peregrine falcon and bald eagle; the black-footed ferret may also be present.

The diversity of vegetation is related to small-scale topographic variabilities, such as rock outcrops where fissures hold pockets of soil and water for trees. The mixture of vegetation in turn supports a variety of wildlife. The least abundant riparian

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[1]Packer, Paul E. Rehabilitation Potentials and Limitations of Surface-Mined Land in the Northern Great Plains, General Technical Report INT-14. Ogden, Utah: U.S., Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1974.

[2]For example, mule deer and antelope tend to use all three types of vegetation, although exhibiting a preference for woodland and sagebrush respectively. The coyote, a major predator, and the deer mouse, an important prey species, are also found in all types of habitats.

TABLE 8-45: SELECTED CHARACTERISTIC SPECIES OF MAIN COMMUNITIES, COLSTRIP SCENARIO

COMMUNITY	CHARACTERISTIC PLANTS	CHARACTERISTIC ANIMALS
Sagebrush Grassland	Green needlegrass Needle-and-thread grass Western wheatgrass Blue grass Big sage Silver sage	Pronghorn antelope Whitetailed jack-rabbit Badger Western meadowlark Sage grouse Short-horned lizard
Pine Woodland	Ponderosa pine Rocky mountain juniper Bluebunch wheatgrass Sideoats grass Snowberry Goldenrod	Mule deer Porcupine Bobcat Ground squirrel species Great horned owl Red-shafted flicker Turkey Sharptail grouse
Streamsides (Riparian)	Plains cottonwood Green ash Willow Wild currant Bluegrass Foxtail Dock	Whitetail deer Raccoon Little brown bat Red fox Shorebirds (e.g., killdeer) Yellowthroat Ringneck pheasant Leopard frog

habitat is probably the most critical to the maintenance of overall ecosystem diversity, as this type is used (at least seasonally) by most of the area's vertebrate species. Its extent has been reduced by irrigated agriculture, especially in the large floodplains of the Yellowstone, Bighorn, and Tongue Rivers.

Rivers support a varied and diverse aquatic fauna and supply important breeding and migration habitat for waterfowl. Fish populations are generally dominated by nongame species such as bullheads, goldeye, carp, suckers, shubs, minnows, and dace. Game fishes in the area include sauger and channel catfish; trout and bass have been introduced. Three native game species of particular importance in the Yellowstone and Tongue River are the paddlefish, shovelnose sturgeon, and pallid sturgeon, which enter the rivers in the spring to spawn. A total of 49 species of fish have been recorded in the Yellowstone in Montana.[1]

The Bighorn Mountains are covered with a variety of coniferous forests, zoned by altitude and topography. Alpine meadows are scattered over the highest elevations. The animal life of the Bighorns is accordingly diverse; game animals include elk, mule deer, black bear, mountain lion, bighorn sheep, antelope, white-tailed deer, and moose. Most of the big game animals are limited by winter range. Several uncommon species requiring special management practices include the wolverine, pine marten, and spotted bat.[2]

8.5.3 Factors Producing Impacts

Four factors associated with construction and operation of the scenario facilities (power plant, Lurgi plant, Synthane plant, Synthoil plant, and their associated mines) can cause ecological impacts: land use, population increases, water use and water pollution, and air quality changes. With the exception of land use, the quantities of each of these factors associated with the scenario facilities were given in previous sections of this chapter. Land-use quantities are given in this section, and the others are summarized. Land use by each of the facilities proposed for the Colstrip scenario is given in Table 8-46. The amount of land used during the lifetime of each facility (30 years) ranges from about 8,000 (gasification plant-mine combination) to 12,600 (power plant-mine combination) acres.

Manpower requirements associated with construction and operation of the scenario energy facilities will cause an increase in the urban population in the scenario area. Peak manpower requirements for the facilities range from 2,859 for the power plant and mine to about 5,200 for each of the other facilities. After construction is completed, manpower required for operation is about 1,000 for the power, Lurgi, and Synthane plants and mines and 3,487 for the Synthoil plant and mine.

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[1]Peterman, Larry G., and Michael H. Haddix. "Preliminary Fishery Investigations on the Lower Yellowstone River," in Clark, Wilson F., ed. Proceedings of the Fort Union Coal Field Symposium, Vol. 2: Aquatic Ecosystems Section. Billings, Mont.: Eastern Montana College, 1975, p. 99.

[2]In addition, the flammulated owl, American osprey, prairie falcon, grayling, greater sandhill crane, and gyrfalcon have also been described as requiring special management by the U.S. Fish and Wildlife Service.

TABLE 8-46: LAND USE BY SCENARIO FACILITIES

FACILITY	LAND USE[a]	
	ACRES/YEAR	ACRES/30 YEARS
Conversion Facilities		
Power Plant (3,000 MWe)		2,400
Lurgi or Synthane Gasification Plant (250 MMcfd)		805
Synthoil Plant (100,000 bbl/day)		2,060
Associated Surface Coal Mines		
For Power Plant (16.8 MMtpy)	340	10,200
For Lurgi Plant (9.6 MMtpy)	240	7,200
For Synthane Plant (8.4 MMtpy)	240	7,200
For Synthoil Plant (12.0 MMtpy)	250	2,500

MWe = megawatt-electric; bbl/day = barrels per day
MMcfd = million cubic feet per day; MMtpy = million tons per year

[a]The land used by the surface coal mines will increase every year by the amounts given in the table for 30 years, the lifetime of the facilities. However, the land occupied by the plants will not vary after construction is completed.

Water requirements for the scenario facilities operating at the expected load factor range from about 6,283 acre-ft/yr (Lurgi plant) to 26,600 acre-ft/yr (power plant) assuming the facilities are high wet cooled. The water source will be the Yellowstone River which has an average flow of 8,800,000 acre-ft/yr and minimum flow of 3,720,000 acre-ft/yr[1] at Miles City (Table 8-13). Effluents from the energy facilities will be ponded and will contaminate surface water or groundwater only if pond liners leak or erode. Typical and peak concentrations of criteria pollutants from the power, Lurgi, and Synthane plants will not violate any federal or Montana ambient air standards. Annual concentrations of SO_2 in the plant vicinity ranges from 0.2 (Lurgi plant) to 2.7 $\mu g/m^3$ (power plant and mine). Peak concentrations of pollutants from the Synthoil plant will only exceed the 3-hour federal ambient air standard for HC but will do so by a factor of more than 100.

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[1]Minimum flow is 5,135 cfs and is converted to acre-ft/yr here only so that withdrawals by the energy facilities given in acre-ft/yr can be compared.

8.5.4 Impacts

The nature of the ecological impacts caused by these factors depends on the plant and animal community type on which they are imposed. For example, the impact of land use depends on whether sagebrush grassland or pine woodland communities are being used. Some of the land-use trends are now evident or could occur regardless of energy-related growth. A scenario, which calls for power, Lurgi, Synthane, and Synthoil plants and their associated mines to be developed according to a specified time schedule (see Table 8-1), is used here as the vehicle through which the extent of the impacts are explored. Impacts caused by land use, population increases, water use and water pollution, and air quality changes are discussed.

A. To 1980

During the 1975-1980 period, construction will start on the power plant and mine scheduled to come on-line in 1985. Land use by the energy facilities and urban population is given in Table 8-47. Land use by 1980 by the urban population only totals about 800 acres, about 0.03 percent of the total amount of land in Rosebud County. Forage which could be produced on this acreage would support 9-18 cows with calves and 1-3 sheep in a year depending on what type of habitat is disturbed by the urban population (Table 8-48).[1] For purposes of comparison, a 1974 Census of Agriculture Preliminary Report for Rosebud County indicates a total inventory of 94,500 cattle and calves and 15,245 sheep (including lambs).

At the power plant site, direct habitat removal affects most small vertebrate species locally and is not expected to reduce regional populations. However, the site area is a wintering area for mule deer and antelope, and the disturbance from construction activity may cause big game species to disperse into adjacent areas. Sharptail and sage grouse courtship and brood-rearing activities could be disturbed or displaced as far as 2 miles from the site.

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[1]This estimate is derived from the carrying capacity of the different vegetation types in acres per Animal Unit Month (AUM). An AUM is a measure of forage production and represents the amount of forage required to sustain a cow with calf, or five sheep, for a month. Because food habits differ, the unit cannot generally be applied to wildlife. Since the unit has no time dimension, its interpretation in terms of total numbers of livestock depends on whether the range is used seasonally or all year. Carrying capacities are: 3.5-7.0 acres/AUM in sagebrush grassland; 3.5-4.0 acres/AUM in pine woodland; and 5.5 acres/AUM in other grassland types. Carrying capacity of 3.5-7.0 acres/AUM was used for this calculation. Payne, G.F. Vegetation Rangeland Types in Montana, Bulletin 671. Bozeman, Mont.: Montana State University, Montana Agricultural Experiment Station, 1973.

TABLE 8-47: LAND USE (in acres)[a]

	1975	1980	1990	2000
By Energy Facilities				
Conversion Facilities				
Power Plant (3,000 MWe)			2,400	2,400
Lurgi Plant (250 MMcfd)			805	805
Synthane Plant (250 MMcfd)				805
Synthoil Plant (100,000 bbl/day)				2,060
Associated Surface Coal Mines				
For Power Plant (16,8 MMtpy)			2,040	5,440
For Lurgi Plant (9.6 MMtpy)			240	2,640
For Synthane Plant (8.4 MMtpy)				1,440
For Synthoil Plant (12.0 MMtpy)				250
Subtotal			5,485	15,840
By Urban Population in Rosebud County[b]				
Residential	430	580	860	1,360
Streets	86	116	172	272
Commercial	10	14	21	33
Public and Community Facilities	27	36	53	84
Industry	43	58	86	136
Subtotal	596	804	1,192	1,885
Total Land Use	596	804	6,677	17,725
Total Land in Rosebud County 3,223,680				

MWe = megawatt-electric
MMcfd = million cubic feet per day
bbl/day = barrels per day
MMtpy = million tons per year

[a]Values in each column are cumulative for year given.

[b]Acres used by the urban population were calculated using population estimates in Table 8-31 for Rosebud County assuming: residential land = 50 acres per 1,000 population; streets = 10 acres per 1,000 population; commercial land = 1.2 acres per 1,000 population; public and community facilities = 3.1 acres per 1,000 population; and industry = 5 acres per 1,000 population. Adapted from THK Associates. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974.

TABLE 8-48: POTENTIAL LIVESTOCK PRODUCTION FOREGONE: COLSTRIP SCENARIO[a]

	ACRES LOST	ANIMAL EQUIVALENTS[b] COW/CALVES	SHEEP
1980	804	9- 18	1- 3
1990	6,667	77-154	12- 24
2000	17,725	205-410	32- 64
Past-2000[c]	40,005	462-925	72-143
1974 Inventory Rosebud County[d]		94,499	15,245[e]
Loss (% of 1974 Inventory)		0.5-1.0	0.5-0.9

[a]Includes land used by plants, associated mines, and urban population. Acres lost does not include land disturbed by: transmission, gas, and water lines to the plants; two new roads to the Synthane and Synthoil facility sites; improved highways connecting major new population centers.

[b]Assuming carrying capacity is 3.5-7.0 acres on range used all year.

[c]Total land use during 30-year facility lifetime.

[d]U.S., Department of Commerce, Bureau of the Census. 1974 Census of Agriculture; Preliminary Report, Rosebud County, Montana. Washington, D.C.: Government Printing Office, 1976.

[e]Includes lambs.

Increases in both legal and illegal hunting are typically associated with large construction projects in the West. Poaching will probably center near Colstrip and the construction site, especially since both mule deer and antelope now concentrate there in winter.[1] Private landowners have already begun to close their

[1]Unlike legitimate hunting, poaching can reduce the breeding stock by taking females and young, which can affect the ability of the population to replace harvested individuals by reproduction. As populations decline, the number of individuals which may be safely harvested by legal hunters is reduced, and legal hunts may be curtailed or even discontinued.

lands to hunters and other outdoor recreationists; with the first construction peak, land closure will probably become common. While this action may reduce poaching, it will also focus legitimate big hunting pressure on the nearby Custer and Bighorn National Forests, where hunter success may decline. Manpower required for construction will cause the urban population in Rosebud County to increase by 35 percent over the 1975 population, which will total 11,620 by 1980 (Table 8-31). Ecological impacts associated with population increase, water use and water pollution, and air quality changes associated with energy development will not be significant by 1980.

B. To 1990

By 1990, the power and Lurgi plants and their associated surface coal mines will be on-line. Land use by 1990 by these energy facilities and the urban population will be about 6,680 acres or about 0.2 percent of the land in Rosebud County (Table 8-47). Forage which could be produced on this land would support 77-154 cows with calves and 12-24 sheep in a year (Table 8-48). Land use by the power plant and mine combination will primarily be sagebrush grassland and pine woodland, and by the Lurgi plant and mine combination (sited east of Colstrip), sagebrush, woodland, and pure grassland. The Lurgi plant will not occupy portions of key wildlife ranges.

By 1990, major improvement in vehicular access will occur throughout the scenario area. Highway rights-of-way will generally follow the major stream courses in the area and will constitute a major adverse influence on these restricted habitat zones. By 1990, the volume of traffic along large portions of Armells and Rosebud Creeks and the Tongue River will have increased several-fold. Habitat removal will affect a variety of small birds, mammals, and amphibians, among them the sharptail grouse and ring-necked pheasant. Whitetail deer, largely restricted to valley bottoms, are likely to decline. In particular, the highway following the Tongue River would bisect two mule deer winter concentration areas and an antelope concentration area, increasing road kills and resulting in a slight reduction of the deer and antelope populations.

The urban population in Rosebud County will be about 17,160 by 1990, an increase of 100 percent over the 1975 population. This growth in areawide human populations, especially at Colstrip and Forsyth, will contribute to illegal shooting of nongame animals, off-road vehicle (ORV) use, and habitat fragmentation from subdivision and strip development. Birds of prey, such as Swainson's hawk and the golden eagle, which frequent roadsides and perch on power or telephone poles, are most vulnerable to shooting. Varmint hunting can indirectly affect the probability of the survival of black-footed ferrets in the area (if they are present), especially if prairie dog populations are reduced.[1] Other nontarget species, particularly the Northern kit fox and other beneficial small predators, may also show noticeable declines by 1990.

Some local disturbance of big game animals and interference with the breeding and nesting of sharptail and sage grouse may occur. Feral dogs (dogs allowed to run loose and become wild) may threaten local wildlife near population centers. Because the town of Colstrip lies within an area of winter deer and antelope concentrations, there is a potential for harassment by dogs to develop into a sufficiently important stress to effect a reduction in numbers,[2] beginning as early as 1980, in the absence of additional controls.

Water use and water pollution associated with the energy facilities are not expected to cause significant ecological impacts. Growing municipalities in the area may discharge increasing amounts of sewage effluent into surface waters, at least until new systems can be built. Although discharge from Forsyth would flow into the Yellowstone, the amount will be negligible, even in comparison to the historical low-flow in the Yellowstone. Dilution will reduce nutrient concentrations well below levels that might affect aquatic production. However, continued use of septic systems around Colstrip could contaminate groundwater and transfer nutrients into Armells Creek. Although the stream is intermittent, nutrient enrichment could cause algal blooms that reduce the quality of the aquatic environment for fish.

Air quality changes associated with energy development are not expected to cause significant ecological impacts.

C. To 2000

Construction of the Synthane and Synthoil facilities in the sagebrush grassland of Sarpy Creek Valley occurs between 1990-2000. By 2000 all the scenario facilities will be in operation. Land use by the facilities and the urban population will total 17,725

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[1]A survey conducted by a consulting firm from 1972 to 1975 in a 10x20-mile rectangle bracketing Colstrip did not detect ferrets. Schwarzkoph, William F., and Raymond R. Austin. "Monitoring Wildlife Parameters Prior to Extensive Strip Mining and Operation of Coal-Fired Steam Generating Plants at Colstrip, Montana," in Clark, Wilson F., ed. Proceedings of the Fort Union Coal Field Symposium, Vol. 5: Terrestrial Ecosystems Section. Billings, Mont.: Eastern Montana College, 1975, p. 668.

[2]The net impact of such growth-related stresses is not always to reduce the stability of the population but to lower the proportion of the total ("surplus") that can safely be removed by hunting without threatening the balance.

acres or about 0.6 percent of the land in Rosebud County (Table 8-47). Forage on this acreage would support 205-410 cows with calves and 32-64 sheep in a year (Table 8-48). These facilities will further fragment wildlife habitat around Colstrip and the Sarpy Creek Valley. The greatest impacts on wildlife will probably be associated with the loss of thickets and woodlands along valleys affected by road construction. Poaching will probably continue to be associated with peaks in construction activity. The combined effects of habitat loss, vehicular traffic, and increased legal and illegal hunting will probably result in at least moderate reductions in populations of white-tailed deer and pheasant. A zone of urban influence extending several miles around Colstrip may result in which wildlife will be generally less abundant and diverse, and game species will be uncommon. Although the Synthoil plant on Sarpy Creek will be a more isolated influence, it is sited in an antelope winter concentration area and will probably cause some relocation. However, areawide populations of nongame species with small ranges are not likely to be affected as strongly.

Energy-related population increases and resultant urban development will require a relatively negligible portion of land (about 1,885 acres, Table 8-47) and will be located almost entirely at existing towns. Zoning and subdivision regulations in the county will prevent the rural settlement scatter that is occurring elsewhere in the West.

By 2000, the urban population in Rosebud County will be about 27,170, about a 215 percent increase over the 1975 population. An increase in recreational activities is expected due to this increased population. An important feature of the Colstrip scenario is the limited availability of public land open to or suitable for camping, hiking, hunting, fishing, and snowmobile and ORV use. The closest public lands are the two National Forests, Custer in Montana and Bighorn in Wyoming.

The greatest potential for damage exists in the Bighorn National Forest. The forest will probably be a regional focus for recreation for increased populations throughout the entire Powder River resource region. Large areas of the forest are closed to vehicular traffic, or otherwise restricted, in the winter months, which will tend to concentrate ORV and snowmobile use on the remaining open areas. Wilderness areas will receive heavy foot and horse traffic in the summer months, unless restrictions are placed on the number of visitor days permitted. Although numerous forest species are tolerant of human activity, some species (including elk, pine marten, and bighorn sheep) avoid areas of heavy human activity. Disturbance of these animals may result in a complex pattern of redistribution which could increase competition with other species. For example, if elk are displaced onto lower elevation in winter, they may compete with deer. Deer usually decline under these circumstances unless the winter range is underutilized. In addition, subdivision of private lands along the boundaries of the national forest can fragment deer winter range.

As fishing increases in the high mountain lakes, the quality of the sport fisheries will decrease, although more intensive stocking programs can help maintain fish populations. However, without careful management of use, relatively fragile vegetation around these lakes may be severely damaged by campers and pack trains, especially above timberline. Smaller wildlife (such as pikas, ground squirrels, and marmots) could also decline in numbers around heavily used areas, especially if dogs are permitted in the high country.

Beginning with the opening of the power plant in 1985, the scenario's water demands will be capable of reducing low-flow in the summer months in the Yellowstone River during dry years to a point where some short-term ecological response may become noticeable. The magnitude of such flow reductions would be greater downstream of the scenario area near the Yellowstone-Missouri confluence than in the withdrawal area. Between Miles City and Sidney, large irrigation withdrawals currently reduce summer low-flows by an amount equivalent to roughly 50 percent of the low-flow of record. Outside the growing season, including the spring runoff period critical to migratory spawners such as the paddlefish and sturgeon, flow near Sidney is appreciably greater than at Miles City. For this reason, even though the impact on summer low-flow could be significant in the lower Yellowstone, no interference with the reproductive patterns of either spring or fall spawning fishes are expected to result from the Colstrip scenario alone.

Water removal by the scenario developments for energy facilities peaks at 51,000 acre-ft/yr by the end of the scenario time frame. The impact of this use depends on the ecosystem dynamics of the Yellowstone River. Key ecosystem components are presently under intensive study but are not yet sufficiently well known to permit establishment of instream flow requirements.[1] Consequently, it is not possible to predict the magnitudes of the ecological consequences of reduced summer low-flows. However, possible effects include additional sedimentation to a limited degree during summer, reducing the productive riffle areas crucial to the food supply of most game fishes, and reducing the area of quiet backwaters, island edges, and vegetated banks important for the growth and survival of many juvenile fish.[2] These impacts would be temporary, and a

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[1]Performed by the Montana Department of Natural Resources for the Old West Regional Commission, Dr. Kenneth Blackburn, Project Coordinator.

[2]Peterman, Larry G., and Michael H. Haddix. "Preliminary Fishery Investigations on the Lower Yellowstone River," in Clark, Wilson F., ed. Proceedings of the Fort Union Coal Field Symposium, Vol. 2: Aquatic Ecosystems Section. Billings, Mont.: Eastern Montana College, 1975, p. 99.

return to normal flow conditions will permit the ecosystem to restore its balance in subsequent years.[1]

Dewatering of active mines can affect discharge in springs and seeps, with consequent reduction in the base flow of springs. The severity of the resultant ecological consequences will depend on the scale of the impact and cannot be predicted with certainty. However, the following kinds of impacts could occur if discharge were eliminated over a large portion (for example, 25 percent) of the Rosebud Creek Basin throughout the entire time frame:

Reduction in diversity and biomass of the Rosebud Creek ecosystem. The stream is not important as a fishery, but loss of ecosystem productivity would affect terrestrial species such as the raccoon, shorebirds, and waterfowl.

Reduction in extent and vigor of riparian vegetation dependent on stream underflow. Losses of this type of vegetation, if extensive, would reduce carrying capacity for all species listed as characteristic of this vegetation type, including white-tailed deer, sharptail grouse, pheasant, muskrat, and mink. Sage grouse brood-rearing areas could also be affected.

Reduction in density of smaller wildlife dependent on springs and seeps for watering, including mourning dove and several species of rodents. More drought-resistant forms, such as Ord's kangaroo rat and woodrats, may replace the species lost.

Reduction of runoff, due to impoundment of mine and plant site drainage, affects 6,400 acre-feet of runoff lost to the Sarpy, Armells, and Rosebud Creek drainages. This will combine with that of reduced groundwater discharge to produce the impacts discussed above.

By the year 2000, all the scenario facilities will accumulate impounded wastewaters on site. All these waste ponds will contain considerable amounts of carbonate and sulfate salts, together with various trace metals and chemical wastes from demineralizing operations. In addition, wastewaters from coal conversion may contain a variety of toxic organic compounds, especially phenols (a number of organic agents known or thought to be carcinogenic), as well as

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[1]The Yellowstone is expected to supply water not just for the development of the immediately adjacent coal deposits but for industry as far away as Gillette. Therefore, although the Colstrip scenario in itself is not expected to result in major ecological damage from dewatering, regional water demands could occasion serious stress. The ecological impacts of withdrawls at this scale are discussed in Chapter 12.

dissolved hydrogen sulfide and ammonia. These materials could pose a threat to wildlife if they were repeatedly consumed or contacted.[1] Impoundments made of reclaimed mine spoils and ash might leach heavy metals in waters or be incorporated into aquatic and terrestrial food chains, depending on concentration and food chain links with the terrestrial ecosystem. Even with these conditions met, the resulting ecological impacts would be local.

All the scenario facilities emit air pollutants into the atmosphere, the greatest quantities coming from the power plant. SO_2 concentrations may affect vegetation. Acute injury normally results from exposures of a few hours to high levels of SO_2. Short-term field fumigation studies have revealed threshold sensitivities of 1.0-1.5 ppm for range grasses[2] and between 1 and 6 ppm for sagebrush and associated shrubs.[3] SO_2 damage to white and jack pine has been observed in the field with continous exposure to between 0.13 and 0.5 ppm ambient concentrations.[4] Laboratory and field fumigation tests have produced injury in ponderosa

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[1]Wildlife will probably not drink from these impoundments even though conventional fencing would deter few species. The extreme saltiness and probably unpleasant odors will render these waters unpalatable, especially with clean water available nearby in the water reservoirs at each site. Waterfowl may occasionally land on these ponds, especially during migration, but in the absence of aquatic vegetation or animal life, would not remain long enough for repeated contact with carcinogens to increase the risk of tumor formation. Thus, the toxic and carcinogenic compounds retained in impoundments will probably not constitute an actual hazard to wildlife.

[2]Tingey, D.T., R.W. Field, and L. Bard. "Physiological Responses of Vegetation to Coal-Fired Power Plant Emissions," in Lewis, R.A., N.R. Glass, and A.S. Lefohn, eds. The Bioenvironmental Impact of Coal-Fired Power Plant, 2nd Interim Report: Colstrip, Montana, EPA-600/3-76-013. Corvallis, Oreg.: Corvallis Environmental Research Laboratory, 1976.

[3]Hill, A.C., et al. "Sensitivity of Native Desert Vegetation to SO_2 and to SO_2 and NO_2 Combined." Journal of the Air Pollution Control Association, Vol. 24 (February 1974), pp. 153-57.

[4]Dreisinger, B.R. "Monitoring Atmospheric Sulfur Dioxide and Correlating Its Effects on Crops and Forests in the Sudbury Area," in Conference on the Impact of Air Pollution on Vegetation: Proceedings. Toronto, Canada: Ontario Department of Energy and Resources Management, 1970; and Linzon, S.N. "Damage to Eastern White Pine by Sulfur Dioxide, Semimature-Tissue Needle Blight, and Ozone." Journal of the Air Pollution Control Association, Vol. 16 (March 1966), pp. 140-44.

pine between 0.4 and 10.0 ppm, depending on the investigator.[1] Crops grown in the Colstrip area are largely alfalfa and winter wheat, both of which are sensitive to SO_2. Acute damage has occurred in wheat at concentrations of 0.20-0.40 ppm[2] and in alfalfa at 0.5 ppm.[3]

Dispersion modeling indicates that the highest short-term ground-level concentrations experienced, with all facilities on-line, will be 0.26 ppm (3-hour average) downwind of the power plant. Under most circumstances, concentrations will be at least an order of magnitude less. This maximum level could damage wheat crops, and dispersion conditions producing these high concentrations occur mainly in the winter. Spring brings the most favorable conditions for ventilation.

Chronic damage typically occurs when SO_2 levels are much lower than those required to induce direct injury. Chronic SO_2 pollution damage of alfalfa and wheat may be possible downwind of the power plant. Judging from the relatively higher tolerances of native plants to acute SO_2, these species may be less likely to develop chronic injury symptoms. However, in the absence of appropriate data, the possibility cannot be ruled out.

D. After 2000

Land use by the urban population and energy facilities during their 30-year lifetime will total 40,055 acres, about 1.2 percent of the land in Rosebud County (Table 8-47 and 8-48). Over 92 percent of Rosebud County is cropland, grazing land, or woodland, and any land use would necessarily reduce the agricultural acreage. The amount of forage which could be produced on 40,055 acres would support 462-925 cows with calves and 72-143 sheep per year, about 0.5-1.0 percent of the 1974 inventory of cows with calves and sheep in Rosebud County (Table 8-48). Additional land bordering on coal

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[1]Hill, A.C., et al. "Sensitivity of Native Desert Vegetation to SO_2 and to SO_2 and NO_2 Combined." Journal of the Air Pollution Control Association, Vol. 24 (February 1974), pp. 153-57.

[2]Guderian, R., and H. Van Haut. "Detection of SO_2 Effects Upon Plants." Staub-Reinhaltung der Luft, Vol. 30 (1970), pp. 22-35.

[3]Tingey, D.T., et al. "Vegetation Injury from Interaction of Nitrogen Dioxide and Sulfur Dioxide." Phytopathology, Vol. 61 (December 1971), pp. 1506-11.

mining areas may be rendered unsuitable for grazing as a result of odors, pollution, dust, and noise.[1]

Land leased for coal as of July 1974 covers 3.86 percent of the county (about 129,000 acres), indicating a potentially greater number of surface mines.[2] The ultimate impact of mining, which will use 32,100 acres primarily consisting of sagebrush/grasslands, pine forest, and savanna, will depend on the success with which they are reclaimed. Although variable, the overall climate around Colstrip favors reclamation. However, during periods of drought, moisture stress will reduce the success of new plantings and alter the species composition of existing stands.[3]

Overburden characteristics vary widely among the coal fields of southeastern Montana. While spoils from the existing mine at Colstrip are not excessively saline, overburden at the nearby Decker mine and in the neighboring Otter Creek coal field contains layers which are salty enough to cause problems with the initial establishment of vegetation. At Decker, it has been shown that salinity of the surface spoil is acceptably reduced after the first one or two years, especially if irrigated.[4]

Although with proper fertilization and surface treatment spoils can be returned to a productive cover of grasses, it has proven more difficult to reestablish woody vegetation equivalent to the preexisting biological community. Ponderosa pine, important over almost half the total mine areas, will be particularly difficult to restore, both because it requires a long time to mature and because its need for water is generally greater than that of the grasses.

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[1]Montana, Department of Natural Resources and Conservation, Energy Planning Division. Draft Environmental Impact Statement on Colstrip Electric Generating Units 3 and 4, 500 Kilovolt Transmission Lines and Associated Facilities. Helena, Mont.: Montana Department of Natural Resources and Conservation, 1974, pp. 767-70.

[2]U.S., Department of Agriculture, Committee for Rural Development. 1975 Situation Statement: Rosebud-Treasure Counties. Forsyth, Mont.: Department of Agriculture, 1975, pp. 46-47.

[3]Short-term climatic fluctuations in the Colstrip area result in severe droughts lasting two years or more, recurring at one-or-two-decade intervals. Drought cycles of 15-20 years are characteristic of this area, with drier than normal years occurring more frequently than years with above-average precipitation.

[4]Farmer, E.E., et al. Revegetation Research on the Decker Coal Mine in Southeastern Montana, Research Paper INT-162. Ogden, Utah: U.S., Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1974.

The foregoing factors suggest that reclamation efforts may partially or completely restore grazing values in most years barring problems with excess salts in the soil, but will not restore the original native cover.[1] Thus, the original ecosystem of mined areas will probably not be restored, since both topographic and vegetational diversity are critical factors. The degree to which this grazing value is restored will depend on climatic patterns, spoil characteristics, and grazing management. Therefore, the 32,100 acres mined in the scenario should be considered a long-term loss to wildlife such as antelope, sage grouse, and a large number of songbirds which depend on shrubby cover at some critical point in their life cycle.

Small amounts of cropland in the Armells Creek Valley will be removed by strip mining and community expansion; some agricultural land will also be preempted by the construction of new roads in the Tongue River and Rosebud Creek valleys. While exact acreage figures are not known, the total will be well below one percent of Rosebud County's 1974 cropland total of 157,400 acres. Toward the end of the scenario, and after 2000, salinity increases brought on by contamination of groundwater by mine leaching could reduce the extent of irrigated agriculture locally near the mines. However, salinities would have to rise between 10- and 100-fold to enter the range toxic to crops; this is unlikely even in the immediate vicinity of the contamination source.

Ecological impacts after 2000 caused by urban population, water use and water pollution, and air quality changes will be similar to those described prior to 2000.

8.5.5 Summary of Ecological Impacts

Four factors associated with construction and operation of the scenario facilities can significantly affect the ecological impacts of energy development: land use, population increases, water use and water pollution, and air quality changes. Land use by the urban population and energy facilities during the thirty-year lifetime of the facilities will total 40,055 acres, 1.2 percent of the land in Rosebud County. By 2000, the urban population in Rosebud County will be about 27,120, a 215 percent increase over the 1975 population. Water requirements for the energy facilities operating at the expected load factor (assuming high wet cooling) will be

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[1]The largely discounted agricultural practice of repeated summer fallowing has resulted in the loss of some 380,000 acres of cropland in Montana because of the deposition of salts in the surface soil. Salts dissolved from the lower layers are carried upward through evaporation into the surface. A similar problem could arise in irrigated or fallowed spoil material. Mine reclamation experience in this region has not covered a time span long enough for such a phenomenon to be observed.

51,000 acre-ft/yr which represents 0.6 percent of the average flow and 1.4 percent of the minimum flow of their water source, the Yellowstone River. This river is also the water source for municipalities in the scenario area (except for Colstrip which uses groundwater). Effluents from the energy facilities will be ponded to prevent water contamination. Increased wastewater from the increased population will require new sewage treatment facilities. The SO_2 level due to plant emissions may cause acute damage to wheat crops and/or chronic damage to wheat and alfalfa crops. Table 8-49 summarizes expected population trends in selected animal species over the scenario period. However, climatic fluctuations characteristic of southeastern Montana can, and probably will, modify these predictions considerably either by imposing ecosystem-wide stress (drought, winter conditions) or especially benign conditions (abundant spring and summer rainfall, easy winters).

Noticeable impacts on game animal populations arising from scenario activities will not develop until the first construction peak in the 1980-1990 decade. Recent wildlife population trends of the Colstrip area have been downward since 1971, and these trends have been projected arbitrarily over the remainder of the 1975-1980 period.

The greatest local impact on mule deer populations will arise from the encroachment of mining and residential-urban growth on wintering habitat near Colstrip. In addition, poaching may be expected to have moderate to serious consequences. By the 1990-2000 decade, only scattered groups of deer may continue to winter there. Roads passing directly through wintering areas may also result in increases in road kills, possibly followed by changed distribution patterns. The cumulative impact of all these influences is expected to be a moderate decline in deer numbers throughout the scenario area, especially around Colstrip.

Antelope around Colstrip will be affected by the same stresses as mule deer but to a somewhat greater degree because more wintering habitat is affected. The continued presence of large expanses of superior antelope habitat north of the Yellowstone will tend to reduce the regional significance of this loss. However, by 1995, antelope may decline to very low levels in Rosebud County.

Of the three major game birds in the Colstrip area, pheasants will suffer most from the loss of habitat and sage grouse least. Loss of springs and seeps and reduced stream flow due to mine dewatering and runoff interception may also eliminate some brood-rearing habitat for these species. However, closure of private lands to hunting may counteract these trends to the extent that,

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[1]The following discussion does not include the Bighorn Mountains.

TABLE 8-49: FORECASTS OF POPULATION STATUS OF SELECTED MAJOR SPECIES FOR THE COLSTRIP SCENARIO

	1980	1990	2000
Game Animals			
Mule Deer	Continuation of present downtrend, independent of scenario activity.	Aggravation of downtrend through combined influence of poaching and facility siting in wintering areas near Colstrip.	Possibly increased downtrend as population growth, further construction, increase in poaching, and additional urban and industrial growth at Colstrip displace wintering deer concentrations.
Whitetail Deer	Continuation of present uptrend, independent of scenario.	Stabilization and possible downtrend through poaching, habitat loss from road construction.	Definite downtrend due to increased poaching and construction of heavily used roads in all major drainage bottoms.
Antelope	Continuation of recent downtrend, independent of scenario activity.	Aggravation of downtrend due to poaching and facility siting in winter concentration area near Colstrip.	Probable increase in downtrend due to additional facility siting in winter concentration areas, especially around Colstrip, as well as increased poaching.
Sage Grouse	Continuation of recent downtrend, independent of scenario activity.	Slight local decline around Colstrip.	Definite decline around Colstrip, due to mining activities and urban influence. Effects of mine dewatering may be locally significant.
Pheasant	Continuation of recent downtrend, independent of scenario activity.	Decline around Colstrip, Rosebud, and Armells Creek drainage from habitat loss.	Continued decline, spreading to Sharpy Creek drainage.
Turkey	Little change due to scenario activity.	Little change due to scenario activity.	Possible slight downtrend if poaching pressure is heavy.
Waterfowl	Little change.	Little change.	Little change.

TABLE 8-49: (Continued)

	1980	1990	2000
Rare Species National Level Peregrine Falcon	Little change.	Possible loss of individuals from illegal shooting.	Increased probability of loss of individuals from shooting.
Bald Eagle	Little change.	Possible loss of individuals from illegal shooting or automobile collision.	Probable loss of individuals from shooting, collision.
Black-Footed Ferret	Little change, if present.	Little change.	Little change, unless inhabited prairie dog colonies are subjected to heavy shooting pressure.
Indicators of Ecological Change Mining and Reclamation Prairie Vole, Cottontail	Little change.	Elimination on mined land, newly reclaimed areas. Vole may recolonize well-grown stands of grasses.	Both species begin returning to old reclaimed areas.
Richardson's Ground Squirrel	Little change.	Elimination on newly mined land. If spoil texture permits burrowing, may come to be a dominant rodent on newly reclaimed areas.	Increasing importance on reclaimed areas of "middle age," especially if weathering improves suitability of spoil for burrowing. Decline on old reclaimed areas, with dense grass stands.
Dewatering of the Yellowstone River Stonecat	No change.	Probably no noticeable change.	Possible restriction of distribution between Miles City and the Missouri confluence.
Carp, Sucker, Burbot	No change.	Probably no noticeable change.	Possible slight increase in dominance in the overall fish fauna below Miles City.

while local declines may be observed in the immediate vicinity of the plant sites and Colstrip, overall county populations may remain largely unaffected.

Three species currently listed as threatened by the Fish and Wildlife Service may be found in the Colstrip area. The bald eagle and peregrine falcon are seasonal visitors; both are susceptible to illegal shooting, but the impact of such individual losses on overall population levels is probably outweighed by influences on breeding habitat elsewhere.

Although apparently absent from the immediate Colstrip vicinity, the black-footed ferret has been confirmed in Rosebud County as late as 1972. The main threat to these animals from the scenario developments will probably be through destruction of prairie dog towns utilized by ferrets. Intensive study in the areas where most of the scenario facilities will be sited has so far failed to discover the animals.

The prairie falcon, recently removed from the Fish and Wildlife Service list, is an uncommon resident which may breed in the scenario area. These birds are also subject to illegal shooting; if they breed in the area, they could, unlike the other two raptor species, decline because of shooting losses.

Several species of mammals and fish can be considered as indicators of ecological change. Reclaimed mine areas may, for a time, take on the character of early successional communities and support a fauna dominated by rodents. Richardson's ground squirrel, which feeds to a large extent on weedy forbs, may be an indicator of the formation of this kind of community, provided that the texture of the soil permits burrowing. Species characteristic of mature vegetation include the prairie vole and cottontail rabbit; the first requires relatively dense stands of grasses, while the second prefers brushy areas. Their absence is an indication of the degree to which the vegetation has been modified from its original structure, and their return will signal at least partial success in restoring wildlife values. Dewatering in the Yellowstone is expected to result in only minor and temporary changes in the ecosystem. Such change as may be observed would probably first be indicated by a restriction in the distribution of the stonecat, a species especially sensitive to flow conditions, below Miles City. The somewhat more pervasive ecological change which might result from cumulative water withdrawals for industry outside the immediate scenario area would be signaled by an increase in the dominance of such generalist fish species as carp, catfish, and suckers.

Table 8-50 ranks the major impacts on the ecosystem into three classes, based on their severity and extent. Class C includes impacts which are expected to be very localized (within a few square miles) and thus will not create measurable changes in the stability of areawide animal populations. Thus, direct habitat removal is

TABLE 8-50: SUMMARY OF MAJOR FACTORS AFFECTING ECOLOGICAL IMPACTS

IMPACT CATEGORY	1975-1980	1980-2000
Class A	Fragmentation of deer and antelope wintering areas by facility, town siting, mining	Continued fragmentation of sagebrush/grassland habitat Fragmentation of riparian habitats
Class B	Illegal shooting	Illegal shooting Increased recreational pressure on national forests
Class C	Grazing losses Loss of irrigated cropland	Grazing losses Loss of irrigated cropland Water withdrawal from Yellowstone River Acute SO_2 damage to crops
Uncertain	Contamination of Armells Creek by sewage from septic systems	Contamination of Armells Creek by sewage from septic systems Chronic SO_2 damage to sensitive vegetation Local flow depletions of springs and seeps from mine dewatering Contamination of groundwater from mine spoil leaching

SO_2 = sulfur dioxide

included until 1980, as are alterations in groundwater discharge. Water withdrawals from the Yellowstone (for this section) are also placed in Class C because of the infrequency with which they would occasion adverse impacts and because the natural adaptive characteristics of the ecosystem are considered capable of compensating for such infrequent disturbances.

Class B impacts include those that affect animal populations which range over larger areas (the size of national forests or counties). This class includes game poaching and illegal shooting of nongame species, such as raptors, and growing demands on the recreational resources of the two nearby national forests.

Class A impacts include those which are considered to be the key factors involved in the projected declines of animal populations discussed above. Habitat loss and fragmentation, particularly in limited streamside habitats and winter concentration areas, are key aspects of the scenario that cannot be materially reduced. Because critical wildlife habitats are affected, the severity of the impact cannot be much lessened by management of remaining lands, as can be done with livestock grazing. The limitations of geology and climate on reclamation also curtail the potential restoration of wildlife values on mined lands.

8.6 OVERALL SUMMARY OF IMPACTS AT COLSTRIP

The primary benefits of the hypothetical energy developments in the Colstrip area will be the production and shipment of 500 million cubic feet of synthetic natural gas per day, 100,000 barrels per day of synthetic crude oil, and 3,000 megawatts of electricity. However, these benefits clearly will accrue primarily to people outside the area. Local benefits are principally economic and include increased tax revenues for state as well as county and local governments, increased retail and wholesale trade, and secondary economic development. New revenues will provide for expansion of municipal services, such as water distribution and treatment systems, police and fire protection services, and improved health care facilities. Local governments will generally be hard-pressed initially to provide the services for the increased population. Existing school, housing, health, and public safety services will be overwhelmed at the outset by the influx of workers and their families. For example, in Rosebud County a fourfold increase in population by 2000 will result in increases in both the demand for housing and for educational facilities. Revenues produced by the development will be adequate to pay for the education demands, but municipal services in the 1975-1980 time frame will be inadequate for the construction population as revenues do not improve until the operation phase in the mid-1980's.

Social and economic impacts associated with energy development in the Colstrip area tend to be a function of the labor and capital intensity of development and, when multiple facilities are involved, of scheduling their construction. These factors determine the pace and extent of migration of people to the scenario area as well as the financial and managerial capability of local governments to provide services and facilities for the increased population. Labor forces increase the population directly and indirectly. More labor is required for construction of the facilities than for operation; thus suitable scheduling of facility construction can minimize population instability. Of the facilities hypothesized for the Colstrip scenario, the power plant-mine combination is the least labor-intensive and the Synthoil facility is the most. Property taxes which are tied to the capital cost of the energy facilities and a severance tax and royalty payments which are tied to the value of the coal will generate revenue for local, state, and federal governments. Solutions to problems concerning who gets the benefits of revenue from the energy facilities and who provides services needed by the increased population in the scenario area involves all levels of government and their ability to relate to each other. Montana's state government provides financial assistance to communities for the expansion of public services and public facilities. The state gives the communities a portion of the state revenue obtained from mineral leases and severance taxes. The fact that communities in the scenario area are small and do not have well developed planning capabilities will make social and economic impacts difficult to handle. These impacts would be mitigated if people who have migrated out of the area returned and were hired along with some local unemployed laborers to meet the manpower requirements for energy facility construction and operation.

Many of the negative impacts associated with increased population could be minimized if coal rather than electricity and synthetic oil and gas was exported from the Colstrip area. Construction impacts would be reduced while revenue benefits to the state from producing the resource would continue. However, elimination of the conversion facilities would substantially decrease both capital investment and additions to the property tax base which provide for expanded local public services. Alternative rates of development or scheduling affect the social impacts from construction phases of the energy developments. If the construction phases of the different facilities were coordinated, the minor boom and bust cycles could be avoided. This would be a significant advantage for planning housing and educational facilities.

Air quality impacts associated with energy development are related primarily to quantities of pollutants emitted by the facilities and to diffuse emissions associated with population increases. The greatest concentrations of particulates, NO_x, and SO_2 are emitted by the power plant and the least by the gasification plant; but, the Synthoil plant produces higher HC concentrations than the other conversion facilities. Air quality impacts will be limited to the violation of the federal ambient HC standard. The violation will occur in connection with the Synthoil facility and the increased urban growth at Colstrip. All other federal standards, as well as EPA's PSD increments, will be met. Control of fugitive HC at Colstrip from the Synthoil facility is difficult to achieve short of locating the plant elsewhere.

Water impacts associated with energy development in the Colstrip area are a function of the water required and effluents produced by energy facilities and associated population. The power plant requires the most; the Lurgi requires the least. Water demand for the population is significant but less than that for the facilities. Effluents from synthetic fuels plants are similar in amounts but different in composition. Effluents from coal gasification plants are primarily ash, and from power plants are nearly equal amounts of ash and FGD sludge. Effluents from all the facilities will be ponded to prevent contamination of surface water and groundwater in the scenario area.

Water quality impacts may be minimized by achieving FWPCA zero discharge goals. The most significant water quality impact will be associated with municipal water treatment facilities. It is doubtful that Forsyth, the only community in Rosebud County which currently has a wastewater treatment facility, will be able to expand its facility at the rate necessary to match the projected population growth. The other communities rely on septic tanks, which will pose a hazard to groundwater quality. This may ultimately pose a special hazard to the Colstrip residents because they will be relying on groundwater resources for their municipal water needs.

Meeting the water requirements of energy development will take a small fraction of the average flow of the Yellowstone River, but this may be significant during periods of low flow. Groundwater aquifer systems in the Colstrip area may be depleted as a result of Colstrip's increasing municipal requirements, coal mine dewatering practices, and decreased surface runoff, which will increase the infiltration rate.

Flow reduction in the Yellowstone can be reduced by wet/dry or dry cooling of the power plants at greater economic costs but with savings of up to 64 percent of the water demand for the energy facilities. A minimum of water from the Yellowstone would be used if the coal were shipped out of the region before conversion.

Ecological impacts associated with energy development in the Colstrip area are a function of land use, population increases, water use and water pollution, and air quality changes. Land use by surface mining activities will be greater than that by energy facility structures and by the population. However, much of the land used by mining can be reclaimed. The average rainfall (10-20 inches annually) and well-developed soil in the scenario area makes revegetation likely. However, when and if the original plant community will be reestablished is highly uncertain. Habitat fragmentation and stress induced by increased recreational activities will adversely affect wildlife and some species of game animals. Ecological impacts associated with water use and water pollution, and air quality changes are not expected to be significant in the Colstrip area.

CHAPTER 9

THE IMPACTS OF ENERGY RESOURCE DEVELOPMENT AT THE BEULAH AREA

9.1 INTRODUCTION

Although energy development proposed for the Beulah area will take place in Mercer, Oliver, and McLean Counties in west-central North Dakota, most development is centered around Beulah in Mercer County (Figure 9-1). This development consists of five surface coal mines that will produce from 10-20 million tons per year, a 3,000 megawatt-electric (MWe) mine-mouth electric generation plant, and four coal gasification plants, each capable of producing 250 million standard cubic feet per day. The location of these facilities is shown in Figure 9-2. Although some of the electricity and gas will be distributed within North Dakota, most of the energy will be shipped to demand centers farther eastward via gas pipelines and electrical transmission lines. Construction of these facilities began in 1975, and all the facilities will be fully operational by 2000. The technologies to be deployed and the timetable for their deployment are presented in Table 9-1.[1]

In all four impact sections of this chapter (air, water, social and economic, and ecological), the factors that produce impacts are identified and discussed separately for each facility type. In the air and water sections, the impacts caused by those factors are also discussed separately for each facility type and, in combination, for a scenario in which all facilities are constructed according to the scenario schedule. In the social and economic and ecological sections, only the combined impacts of the scenario are discussed. This distinction is made because social, economic, and ecological effects are, for the most part, higher order impacts. Consequently, facility-by-facility impact discussions would have been repetitive in nearly every respect.

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[1]While this hypothetical development may parallel development proposed by Baukol-Noonan, Minnkota Power Cooperative, Knife River Coal Mining, Consolidation Coal, Montana-Dakota Utilities, Coteau Properties, American Natural Gas, Basin Electric Power Cooperative, United Power Association, Falkirk Mining, and others, the development identified here is hypothetical. As with the others, this scenario was used to structure the assessment of a particular combination of technologies and existing conditions.

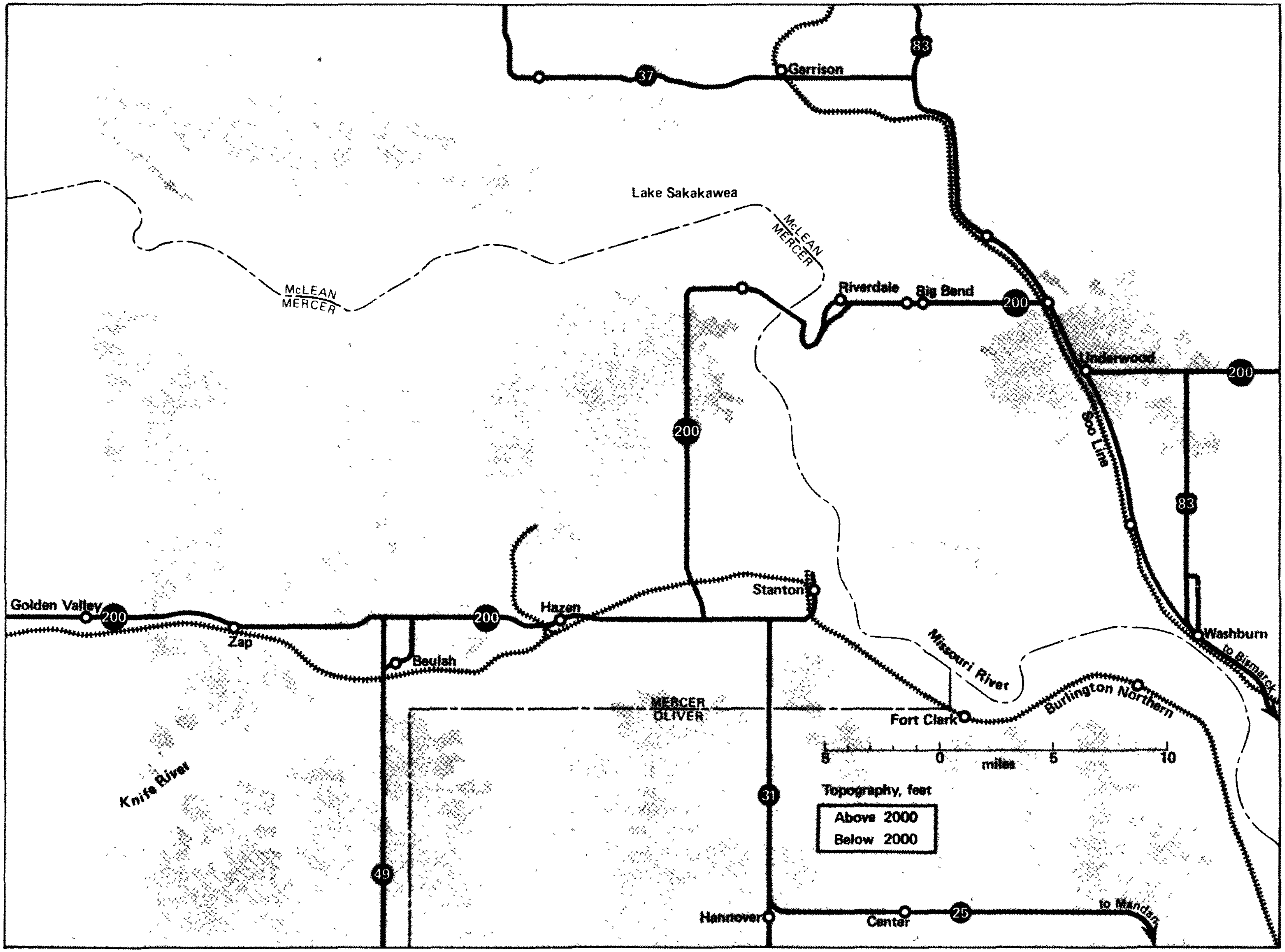

FIGURE 9-1: THE BEULAH SCENARIO AREA

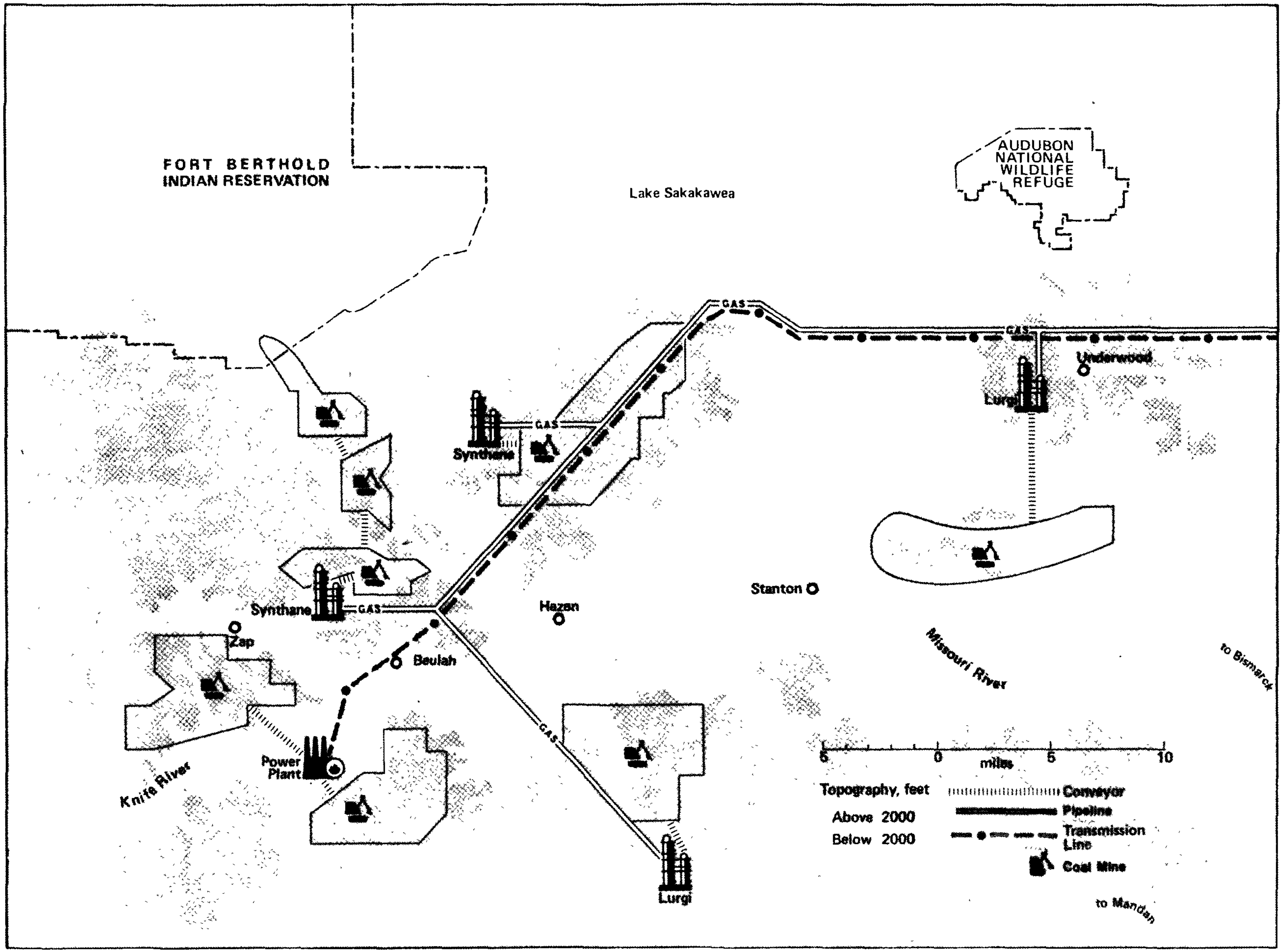

FIGURE 9-2: ENERGY FACILITIES IN THE BEULAH SCENARIO

TABLE 9-1: RESOURCE AND HYPOTHESIZED FACILITIES AT BEULAH

Resources	CHARACTERISTICS	
Coal[a] (billions of tons)	Coal[b]	
Resources 2	Heat Content	7,070 Btu's/lb
Proved Reserves 1.6	Moisture	36 %
	Volatile Matter	40 %
	Fixed Carbon	32 %
	Ash	6 %
	Sulfur	0.8%

Technologies	FACILITY SIZE	COMPLETION DATA	FACILITY SERVICED
Extraction			
Coal			
Five surface mines of varying capacity using draglines	19.2 MMtpy	1980	Power Plant
	10.8 MMtpy	1982	Lurgi
	10.8 MMtpy	1987	Lurgi
	9.6 MMtpy	1995	Synthane
	9.6 MMtpy	2000	Synthane
Conversion			
One 3,000 MWe power plant consisting of four 750 MWe turbine generators; 34% plant efficiency; 80% efficient limestone scrubbers; 99% efficient electrostatic precipitator, and wet forced-draft cooling towers	750 MWe	1977	Power Plant
	750 MWe	1979	Power Plant
	1,500 MWe	1980	Power Plant
Two Lurgi coal gasification plants operating at 73% thermal efficiency; nickel-catalyzed methanation process; Claus plant H_2S removal; and wet forced-draft cooling towers	250 MMscfd	1982	Lurgi
	250 MMscfd	1987	Lurgi
Two Synthane coal gasification plants operating at 80% efficiency; nickel-catalyzed methanation process; Claus plant H_2S removal; wet forced-draft cooling towers	250 MMscfd	1995	Synthane
	250 MMscfd	2000	Synthane
Transportation			
Gas			
Two 30-inch pipelines		1982	Lurgi
		1995	Synthane
Electricity			
Four 500 kV lines	500 kV	1977	Power Plant
	500 kV	1979	Power Plant
	500 kV (2 lines)	1980	Power Plant

Btu's/lb = British thermal units per pound
MMtpy = million tons per year
MWe = megawatt-electric
MMscfd = million standard cubic feet per day
H_2S = hydrogen sulfide
kV = kilovolts

[a]Anderson, Donald L. Regional Analysis of the U.S. Electric Power Industry, Vol.4A: Coal Resources in the United States, for U.S. Energy Research and Development Administration. Springfield, Va.: National Technical Information Service, 1975.

[b]Ctvrtnicek, T.E., S.J. Rusek, and C.W. Sandy. Evaluation of Low-Sulfur Western Coal Characteristics, Utilization, and Combustion Experience, EPA-650/2-75-046, Contract No. 68-02-1302. Dayton, Ohio: Monsanto Research Corporation, 1975.

The three-county area is generally characterized by low unemployment, farming, and privately owned lands. Aside from agriculture, the remainder of the labor force is distributed mostly in the service and trade industries and government services. Manufacturing has been extremely limited. The reliance on agriculture has resulted in a steadily shrinking population (30 percent smaller in 1970 than in 1950).

The topography is primarily gently rolling prairies; the climate is semiarid with extreme seasonal variations in temperature. Much of the past ecological diversity has recently given way to intensive livestock grazing and cultivation, and aquatic habitats have been modified by reservoirs. Groundwater and surface water are available in the area, the latter primarily from the Missouri River and the Garrison Reservoir. Air quality is generally good with good dispersion conditions prevailing throughout the year. Selected characteristics of the area are summarized in Table 9-2. Elaborations of these characteristics are introduced as required to explain the impact analyses reported in this chapter.

9.2 AIR IMPACTS[1]

9.2.1 Existing Conditions

A. Background Pollutants

Air quality in the Beulah area is currently affected by four lignite-fired power plants ranging from 13.5 MWe to 23.5 MWe. Measurements of criteria pollutant[2] concentrations taken at Bismarck, North Dakota,[3] do not indicate violations of any federal or state standards for particulates, sulfur dioxide (SO_2), or nitrogen oxides (NO_x). Based on these measurements, annual average background levels chosen as inputs to the air

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[1]The federal standards referred to in this section are those promulgated prior to the revisions mandated by the Clean Air Act Amendments of 1977, Pub. L. 95-95, 91 Stat. 685.

[2]Criteria pollutants are those for which ambient air quality standards are in force: carbon monoxide, hydrocarbons, NO_x, oxidants, particulates, and SO_2.

[3]U.S., Department of the Interior, Bureau of Reclamation, Upper Missouri Region. ANG Coal Gasification Company: North Dakota Project: Draft Environmental Statement. Billings, Mont.: Bureau of Reclamation, 1977.

TABLE 9-2: SELECTED CHARACTERISTICS OF THE BEULAH AREA

Environment	
Elevation	1,700-2,200 feet
Precipitation (annual)	17 inches average annually
Temperatures	
January minimum	-1°F
July maximum	86°F
Vegetation	Mixed-grass prairie with stream-side woodlands
Social and Economic[a]	
Land Ownership	Private ownership in excess of 90%
Land Use	97% agriculture
Population Density	5.9 per square mile
Unemployment	3.6%
Income	$11,270 per capita annual
County Government	Board of Commissioners
City (Beulah) Government	Mayor-Council
Taxation	Primarily property tax
County Revenues (1972)	$750,000

[a]Characteristics for Mercer County, 1975 dollars.

dispersion models are: particulates, 39; SO_2, 14; and nitrogen dioxide (NO_2), 4.[1]

B. Meteorological Conditions

The worst dispersion conditions for the Beulah area are associated with stable air conditions, low wind speeds (less

[1]These estimates are based on the Radian Corporation's best professional judgement. They are used as the best estimates of the concentrations to be expected at any particular time. Measurements of hydrocarbons (HC) and carbon monoxide (CO) are not available in the rural areas. However, high-background HC levels have been measured at other rural locations in the West and may occur here. Background CO levels are assumed relatively low. Measurements of long-range visibility in the area are not available, but the average is estimated to be 60 miles.

than 5-10 miles per hour), persistent wind direction, and relatively low mixing depths.[1] These conditions are likely to increase concentrations of pollutants from both ground level and elevated sources.[2] Since worst-case conditions differ at each facility location, predicted annual average pollutant levels vary among locations even if pollutant sources are identical. Prolonged periods of air stagnation are uncommon in the Beulah area because of moderate to strong winds, relatively high mixing depths, and a general lack of stagnating high-pressure systems. Meteorological conditions in the area are generally unfavorable for pollution dispersion about 30 percent of the time. Hence, plume impaction[3] and limited mixing of plumes caused by air inversions at plume height can be expected with some regularity.[4] Favorable dispersion conditions associated with moderate winds and large mixing depths are expected less than 15 percent of the time.

The pollution dispersion potential for the Beulah area may be expected to vary considerably with the season and time of day. Fall and winter mornings are most frequently associated with poor dispersion due largely to lower wind speeds and mixing depths.

9.2.2 Factors Producing Impacts

The emission sources in the Beulah scenario which will produce air impacts are a power plant, four gasification facilities (two Lurgi and two Synthane), supporting surface mines, and those sources associated with population increases. The focus of this section is on emissions of criteria pollutants from the energy facilities.[5] Table 9-3 lists the amounts of the five criteria pollutants emitted by each of the three types of facilities. In

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[1]Mixing depth is the distance from the ground to the upward boundary of pollution dispersion.

[2]Ground-level sources include towns and strip mines that emit pollutants close to ground level. Elevated sources are stack emissions.

[3]Plume impaction occurs when stack plumes impinge on elevated terrain because of limited atmospheric mixing and stable air conditions.

[4]See National Climatic Center. Wind Dispersion by Pasquill Stability Classes, Star Program for Selected U.S. Cities. Ashville, N.C.: National Climatic Center, 1975.

[5]Air impacts associated with population increases are discussed below (Section 9.2.3) since those impacts relate to the scenario, which includes all facilities constructed according to the hypothesized schedule.

TABLE 9-3: EMISSIONS FROM FACILITIES
(pounds per hour)

FACILITY[a]	PARTICULATES	SO_2	NO_x	HC	CO
Power Plant					
Mine	24[b]	16	215	180	25
Plant	3,012	13,848	21,084-35,140[c]	652	2,176
Lurgi					
Mine	7[b]	5	66	8	40
Plant	N	516	649	47[d]	N
Synthane					
Mine	8[b]	5	69	8	42
Plant	8	3,524	5,052	94[d]	176

SO_2 = sulfur dioxide
NO_x = oxides of nitrogen
HC = hydrocarbons
CO = carbon monoxide
N = negligible

[a]The Lurgi and Synthane gasification facilities each produce 250 million standard cubic feet per day, and each plant has three stacks.

[b]These particulate emissions do not include fugitive dust.

[c]Range represents 0 and 40 percent NO_x removal by scrubbers.

[d]These emissions do not include fugitive HC.

all three cases, most emissions come from the plants rather than the mines. Most mine-related pollution originates from diesel engine combustion products, primarily NO_x, hydrocarbons (HC), and particulates. Although dust suppression techniques are hypothesized in the scenario, some additional particulates will come from blasting, coal piles, and blowing dust.[1]

The largest single contributor to total emissions for all pollutants is the power plant. The hypothetical power plant in the Beulah area has four 750-MWe boilers, each with its own

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[1]The effectiveness of current dust suppression practices is uncertain. Separate research being conducted by the Environmental Protection Agency is investigating this question. The problem of fugitive dust is discussed briefly in Chapter 10.

stack.[1] The plant is equipped with an electrostatic precipitator (ESP) which removes 99 percent of the particulates and a scrubber which removes 80 percent of the SO_2. Scrubber removal of NO_x is uncertain and is thought to vary from none to 40 percent. The plant has two 75,000-barrel oil storage tanks, with standard floating roof construction, each of which will emit up to 0.7 pound of HC per hour. Table 9-4 lists the amounts of particulates, SO_2, and NO_x emitted (per million British thermal units [Btu] of coal burned) from a power plant operating under the conditions described above and compares those emissions to the New Source Performance Standards (NSPS).[2] SO_2 emissions are well below the standard, but particulate emissions just meet the standard; NO_x emissions violate it. NO_x removal of 38 percent is required to just meet NSPS. In order for the power plant to just meet the NSPS for SO_2, 48 percent efficient SO_2 scrubbers (as opposed to the 80 percent hypothesized) removal would be required.[3]

The power plant and the two coal conversion facilities are cooled by wet forced-draft cooling towers. Each of the cells in the cooling towers circulates water at a rate of 15,330 gallons per minute (gpm) and emits 0.01 percent of its water as a mist. The circulating water has a total dissolved solids (TDS) content of 4,580 parts per million. This results in a salt emission rate of 29,100 pounds per year for each cell.[4]

9.2.3 Impacts

This section describes air quality impacts which result from each type of conversion facility (power plant, Lurgi, and Synthane)

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[1]Stacks are 500 feet high, have an exit diameter of 33.1 feet, mass flow rates of 3.10 x 10^6 cubic feet per minute, an exit velocity of 60 feet per second, and an exit temperature of 180° Farenheit.

[2]NSPS limit the amount of a given pollutant a stationary source may emit; the limit is expressed relative to the amount of energy in the fuel burned.

[3]The Clean Air Act Amendments of 1977, Pub. L. 95-95, 91 Stat. 685, § 109, requires both an emissions limitation and a percentage reduction of SO_2, particulates, and NO_x. Revised standards have not yet been established by the Environmental Protection Agency.

[4]The power plant has 64 cells, the Lurgi plant has 11, and the Synthane plant has 6.

TABLE 9-4: COMPARISON OF EMISSIONS FROM POWER PLANT WITH NEW SOURCE PERFORMANCE STANDARDS
(pounds per million Btu)

POWER PLANT	EMISSION	NSPS[a]
Particulates	0.10	1.10
SO_2	0.47	1.2
NO_x[b]	0.72-1.2	0.7

NSPS = New Source Performance Standards
Btu = British thermal unit
SO_2 = sulfur dioxide
NO_x = oxides of nitrogen

[a]The North Dakota state SO_2 emission standards are the same as federal. Data from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[b]Range represents 0 and 40 percent NO_x removal by scrubbers.

taken separately[1] and from a scenario which includes construction of all facilities according to the hypothesized scenario schedule. For the power plant the effect on air quality of hypothesized emission control, alternative emission control, alternative stack heights, and alternative plant sizes are discussed. The focus is on concentrations of criteria pollutants (particulates, SO_2, NO_2, HC, and carbon monoxide [CO]). See Chapter 10 for a qualitative description of sulfates, other oxidants, fine particulates, long-range visibility, plume opacity, cooling tower salt deposition, and cooling tower fogging and icing.

In all cases, air quality impacts result primarily from the operation rather than the construction of these facilities. Construction impacts are limited to periodic increases in particulate

[1]Air quality impacts caused by the surface mines are expected to be negligible in comparison with impacts caused by conversion facilities.

concentrations due to windblown dust. These may cause periodic violations of 24-hour ambient particulate standards.

A. Power Plant Impacts

Concentrations of criteria pollutants resulting from power plant emissions depend largely on the extent of emission control imposed. Concentrations resulting from the hypothesized case where control equipment removes 80 percent of the SO_2 and 99 percent of the particulates are discussed first followed by a discussion of the effect of alternative emission controls, alternative stack heights, and alternative plant sizes.

(1) Hypothesized Emission Control

Table 9-5 summarizes the concentrations of four criteria pollutants predicted to be produced by the power plant (3,000 MWe, 80 percent SO_2 removal, and 99 percent particulate removal) and its supporting surface mines. These pollutants (particulates, SO_2, NO_x, and HC) are regulated by federal and North Dakota state ambient air quality standards (also shown in Table 9-5). This information shows that the typical and peak concentrations associated with the plant and with the plant and mine combination will be well below federal ambient standards. However, the North Dakota 1-hour SO_2 standard will be violated, and the 1-hour NO_2 standard will be exceeded by a factor of 7.

Table 9-5 also lists Prevention of Significant Deterioration (PSD) standards, which are the allowable increments of pollutants that can be added to areas of relatively clean air (i.e., areas with air quality better than that allowed by ambient air standards).[1] "Class I" is intended to designate the cleanest areas, such as national parks and forests. Typical concentrations of the short-term (less than 24-hour) averaging time for SO_2 from the power plant and mine combination will exceed allowable Class I increments. In addition, peak concentrations attributable to the power plant and the plant and mine combination will far exceed the 24-hour and 3-hour Class I increments for SO_2 (24-hour and 3-hour averaging times). They will be exceeded by a factor greater than 20. The peak SO_2 concentration for the power plant and the plant and mine combination will also cause the Class II 24-hour and 3-hour increments to be exceeded.

Since the plant exceeds some Class I increments, it would have to be located far enough away from any such areas so that emissions will be diluted by atmospheric mixing to allowable concentrations prior to reaching any Class I area. The distance required for this dilution (which varies by facility type, size, emissions controls, and meteorological conditions) in effect

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[1]PSD standards apply only to particulates and SO_2.

TABLE 9-5: POLLUTION CONCENTRATIONS FROM POWER PLANT/MINE COMBINATION AT BEULAH (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]					STANDARDS[b]				
			PEAK			AMBIENT			PSD	
	BACKGROUND	TYPICAL	PLANT	PLANT AND MINE	BEULAH	PRIMARY	SECONDARY	NORTH DAKOTA	CLASS I	CLASS II
Particulate										
Annual	39		0.3	1.4	0.4	75	60	60	5	19
24-hour		3.7	26	26	20	260	150	150	10	37
SO_2										
Annual	14		1.3	1.8	0.6	80		60	2	20
24-hour		6.2	112	112	81	365		260	5	91
3-hour		31	692	692	396		1,300	1,300	25	521
1-hour			863	863				715		
NO_2[c]										
Annual	4	94	2.3-3.8[d]	12-14[d]	3	100	100	100		
1-hour			1,456-2,427[d]	1,456-2,427[d]				200		
HC[e]										
3-hour		6.9	41	50	26	160	160	160		

PSD = prevention of significant deterioration
SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide
HC = hydrocarbons

[a]These are predicted ground-level concentrations from the hypothetical power plant/mine combination. Annual average background levels are considered to be the best estimates of short-term background levels. Concentrations over Beulah are largely attributable to the plant.

[b]"Primary" and "secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. PSD standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national forests. These data are from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2.

[c]It is assumed that all oxides of nitrogen from plant sources are converted to NO_2.

[d]This range represents two assumptions about the removal of oxides of nitrogen by scrubbers. The first number assumes 40 percent is removed; the second number assumes none is removed.

[e]The 3-hour HC standard is measured at 6-9 a.m.

establishes a "buffer zone" around Class I areas. Current Environmental Protection Agency (EPA) regulations would require a 75-mile buffer zone between the power plant and a Class I area boundary.[1] Since there are no current or potential Class I areas within the power plant's "buffer zone," no Class I standards are expected to be violated.

In a worst-case situation, expected to occur infrequently, short-term visibility may be reduced from the current background visibility of 60 miles to between 2 and 5 miles, depending on the amount of SO_2 converted to particulates in the atmosphere.[2]

(2) Alternative Emission Controls

The base case control for the Beulah power plant assumed a SO_2 scrubber efficiency of 80 percent and an ESP efficiency of 99 percent. The effect on ambient air concentrations of three additional emission control alternatives is illustrated in Table 9-6. These alternatives include a 95 percent efficient SO_2 scrubber in conjunction with a 99 percent efficient ESP; an 80 percent efficient SO_2 scrubber without an ESP; and an alternative in which neither a scrubber nor an ESP are utilized.

An examination of Table 9-6 reveals the utilization of 95 percent efficient SO_2 scrubber allows the plant to operate within the Class I PSD increments for SO_2 emissions. Removal of the scrubber results in violations of both National Ambient Air Quality Standards (NAAQS) and Class II PSD increments for SO_2. Removal of the ESP also results in violations of NAAQS and Class II PSD increments for particulates.

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[1]Note that buffer zones around energy facilities will not be symmetric circles. This lack of symmetry is clearly illustrated by area "wind roses," which show wind direction patterns and strengths for various areas and seasons. Hence, the direction of PSD areas from energy facilities will be critical to the size of the buffer zone required. Note also that the term buffer zone is in disfavor. We use it because we believe it accurately describes the effect of PSD requirements.

[2]Short-term visibility impacts were investigated using a "box-type" dispersion model. This particular model assumes that all emissions occurring during a specified time interval are uniformly mixed and confined in a box that is capped by a lid or stable layer aloft. A lid of 500 meters has been used through the analyses. SO_2 to sulfate conversion rates of 10 percent and 1 percent were modeled.

TABLE 9-6: AIR QUALITY IMPACTS RESULTING FROM ALTERNATIVE EMISSION CONTROLS AT BEULAH POWER PLANT

AMOUNT OF CONTROL (%)		MAXIMUM POLLUTANT CONCENTRATION ($\mu g/m^3$)				
SO_2	TSP	3-HR. SO_2	24-HR. SO_2	ANNUAL SO_2	24-HR. TSP	ANNUAL TSP
95	99	173	28	NC	26	.3
80	99	692	112	1.3	26	.3
80	0	692	112	1.3	2,600[a]	30.
0	0	3,247	559	6.5	2,430[a]	30.
APPLICABLE STANDARDS						
NAAQS						
(primary)		--	365	80	260	75
(secondary)		1,300	--	--	150	60
State Standards		1,300	260	60	150	60
Class II PSD Increments		512	91	20	37	19

$\mu g/m^3$ = micrograms per cubic meter
SO_2 = sulfur dioxide
TSP = total suspended particulates
HR. = hour
NC = not considered

NAAQS = National Ambient Air Quality Standards
PSD = prevention of significant deterioration

[a]Differences in 24-HR. TSP concentrations for the two cases in which no electrostatic precipitator is used are attributable to the fact that the stack temperature rises when the SO_2 scrubber is turned off, which produces a small increase in the effectiveness of the smoke stack, and a slightly lower TSP concentration.

(3) Alternative Stack Heights

In order to examine the effects of alternative stack heights on ambient air quality in the Beulah scenario, worst-case dispersion modeling was carried out for a 300-foot stack (lowest stack height consistent with good engineering practice), a 500-foot stack (an average or most frequently used height), and a 1,000-foot stack (a highest stack height). The results of this examination are shown in Table 9-7. Emissions from each stack are controlled by an 80 percent efficient SO_2 scrubber and a 99 percent efficient ESP. The 500-foot case was given previously as part of the base case. A comparison of predicted emissions from the Beulah power plant with applicable standards shows no violations of Class II PSD increments for SO_2 if a 1,000-foot stack is used.

(4) Alternative Plant Sizes

The base case 3,000 MWe power plant at Beulah (500-foot stack height, 80 percent SO_2 removal, and 99 percent total suspended particulates [TSP] removal) violates Class II PSD increments for 3-hour and 24-hour SO_2 emissions. As shown in Table 9-8, a reduction in plant capacity to 2,250 MWe allows the plant to meet the Class II PSD increment for 24-hour SO_2 emissions, but a further reduction to 1,500 MWe is required to meet the Class II PSD 3-hour SO_2 emission increment.

(5) Summary of Power Plant Air Impacts

During the construction phase of the Beulah power plant, the frequency of current violations of NAAQS particulate standards will probably increase. Once the 3,000 MWe power plant is in operation (80 percent SO_2 removal, 99 percent TSP removal, and 500-foot stack height), Class II PSD increments for 3-hour and 24-hour SO_2 emissions will be violated. If the plant were equipped with a 95 percent efficient SO_2 scrubber or if capacity were reduced to 1,500 MWe, all applicable standards could be met.

B. Lurgi Impacts

Typical and peak pollution concentrations are summarized for the two Lurgi plants in Table 9-9. Peak concentrations from these new plants are not expected to cause violations of federal or North Dakota state ambient air standards, and these facilities will easily meet all Class II PSD increments. The Class I increment for 3-hour SO_2 concentrations will be exceeded. In accordance with EPA regulations, this Class I PSD violation would require a maximum Class I buffer zone of about 13.1 miles for each plant. Since there are no current or proposed Class I areas within these buffer zones, no significant deterioration problems are anticipated.

TABLE 9-7: AIR QUALITY IMPACTS RESULTING FROM ALTERNATIVE STACK HEIGHTS AT BEULAH POWER PLANT

SELECTED STACK HEIGHTS (feet)	MAXIMUM POLLUTANT CONCENTRATION ($\mu g/m^3$)		
	3-HR. SO_2	24-HR. SO_2	24-HR. TSP
300	745	125	29
500	692	112	26
1,000	261	13	3
APPLICABLE STANDARDS			
NAAQS			
(primary)	--	365	260
(secondary)	1,300	--	150
State Standards	1,300	260	150
Class II PSD Increments	512	91	37

$\mu g/m^3$ = micrograms per cubic meter
HR. = hour
SO_2 = sulfur dioxide
TSP = total suspended particulates
NAAQS = National Ambient Air Quality Standards
PSD = prevention of significant deterioration

In a worst-case situation, expected infrequently, short-term reductions in visibility (background visibility is about 60 miles) to between 15 and 52 miles may occur, depending on the amount of SO_2 converted to particulates in the atmosphere.

C. Synthane Impacts

Table 9-10 gives typical and peak concentrations from the Synthane gasification plant. These data show violations of North Dakota ambient air standards for 1-hour NO_2 concentrations. Peak concentrations from the Synthane plants will exceed Class I PSD increments for 24-hour and 3-hour SO_2 levels. These violations will require an 18.6-mile buffer zone between each plant and any designated Class I area.

In a worst-case situation, which is expected to occur infrequently, the background visibility of 60 miles may be reduced to between 2 and 11 miles, depending on the amount of SO_2 converted to particulates in the atmosphere.

TABLE 9-8: AIR QUALITY IMPACTS RESULTING FROM ALTERNATIVE PLANT SIZES AT BEULAH POWER PLANT

UNIT SIZE (MWe)	NUMBER OF UNITS	PLANT CAPACITY (MWe)	MAXIMUM POLLUTANT CONCENTRATION ($\mu g/m^3$)		
			3-HR. SO_2	24-HR. SO_2	24-HR. TSP
750	1	750	173	28	6.5
	2	1,500	346	56	13.0
	3	2,250	519	84	19.5
	4	3,000	692	112	26.0
APPLICABLE STANDARDS					
NAAQS					
(primary)			--	365	260
(secondary)			1,300	--	150
State Standards			1,300	260	150
Class II PSD Increments			512	91	37

$\mu g/m^3$ = micrograms per cubic meter
MWe = megawatt-electric
HR. = hour
SO_2 = sulfur dioxide
TSP = total suspended particulates
NAAQS = National Ambient Air Quality Standards
PSD = prevention of significant deterioration

D. Scenario Impacts

(1) To 1980

Construction of the hypothetical power plant and Lurgi gasification plant will begin in this period, with the power plant becoming fully operational by 1980. A slight reduction in long-range visibility from the current average of 60 miles at Bismarck, North Dakota, is expected once the power plant becomes operational. The town of Beulah is projected to grow from a 1975 population of 1,350 to 2,300 by 1980. This increase will contribute to increases in pollution concentrations from urban sources. Table 9-11 shows predicted concentrations of the five criteria pollutants measured at the center of the town and at a "rural" point, 3 miles from the center of the town. When concentrations from urban sources only are added to background levels, no federal or North Dakota state ambient standards will be exceeded.

TABLE 9-9: POLLUTION CONCENTRATIONS FROM LURGI PLANT AT BEULAH (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]					STANDARDS[b]				
			PEAK			AMBIENT			PSD	
				BEULAH						
	BACKGROUND	TYPICAL	PLANT	LURGI 1	LURGI 2	PRIMARY	SECONDARY	NORTH DAKOTA	CLASS I	CLASS II
Particulate										
Annual	39	N	N	N	N	75	70	60	5	19
24-hour		N	N	N	N	260	150	150	10	37
SO_2										
Annual	14	N	0.7	0.1	0.1	80		60	2	20
24-hour		0.7	3.6	0.4	2.9	365		260	5	91
3-hour		3.4	44	1.1	7.8		1,300	1,300	25	512
1-hour		4.3	55	1.3	9.7			715		
NO_2[c]										
Annual	4	N	0.2	0.1	0.1	100	100	100		
1-hour		6.2	69	1.6	12.2			200		
HC[d]										
3-hour		3.1	57	0.1	4.0	160	160	160		

PSD = prevention of significant deterioration SO_2 = sulfur dioxide HC = hydrocarbons
N = no change over background concentrations NO_2 = nitrogen dioxide

[a]These are predicted ground-level concentrations from the hypothetical Lurgi plant. Annual average background levels are considered to be the best estimates of short-term background levels.

[b]"Primary" and "secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. PSD standards are the allowable increments of pollutants which can be added to areas of relatively clean air, such as national parks. These data are from White, Irvin L., *et al*. *Energy From the West: Energy Resource Development Systems Report*. Washington, D.C.: Environmental Protection Agency, forthcoming, Chapter 2.

[c]It is assumed that all oxides of nitrogen from plant sources are converted to NO_2.

[d]The 3-hour HC standard is measured at 6-9 a.m.

TABLE 9-10: POLLUTION CONCENTRATIONS FROM SYNTHANE PLANT AT BEULAH
(micrograms per cubic meter)

	CONCENTRATIONS[a]					STANDARDS[b]				
			PEAK			AMBIENT			PSD	
				BEULAH						
POLLUTANT AVERAGING TIME	BACKGROUND	TYPICAL	PLANT	SYNTHANE 1	SYNTHANE 2	PRIMARY	SECONDARY	NORTH DAKOTA	CLASS I	CLASS II
Particulate										
Annual	39	N	N	N		75	60	60	5	19
24-hour		N	0.1	0.1		260	150	150	10	37
SO_2										
Annual	14	N	1.4	1.2	0.5	80		60	2	20
24-hour		5.5	25	19	24	365		260	5	91
3-hour		32	324	200	63		1,300	1,300	25	512
1-hour		40	404	250	79			715		
NO_2[c]										
Annual	4	N	1.9	1.7	0.8	100	100	100		
1-hour		50	579	367	116			200		
HC[d]										
3-hour		6.1	114	4.4	0.3	160	160	160		

PSD = prevention of significant deterioration
N = no change over background concentrations
SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide
HC = hydrocarbons

[a]These are predicted ground-level concentrations from the hypothetical Synthane gasification facility. Annual average background levels are considered to be the best estimates of short-term background levels.

[b]"Primary" and "secondary" refer to federal ambient air quality standards designed to protect public health and welfare, respectively. All standards for averaging times other than the annual average are not to be exceeded more than once per year. PSD standards are the allowable increments of pollution which can be added to areas of relatively clean air, such as national parks. These data are from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report, Washington D.C.: Environmental Protection Agency, forthcoming, Chapter 2.

[c]It is assumed that all oxides of nitrogen from plant sources are converted to NO_2.

[d]The 3-hour HC standard is measured at 6-9 a.m.

TABLE 9-11: POLLUTION CONCENTRATIONS DUE TO URBAN SOURCES AT BEULAH (micrograms per cubic meter)

POLLUTANT AVERAGING TIME	CONCENTRATIONS[a]							STANDARDS[b]		
	BACKGROUND	MIDTOWN POINT			RURAL POINT			PRIMARY	SECONDARY	NORTH DAKOTA
		1980	1985	1995	1980	1985	1995			
Particulates										
Annual	39	5	7	8	1	1	2	75	60	60
24-hour		17	24	27	17	24	27	260	150	150
SO_2										
Annual	14	3	4	5	0	0	1	80		60
24-hour		9	14	15	9	14	15	365		260
3-hour		15	24	27	15	24	27		1,300	1,300
1-hour		18	29	32	18	29	32			715
NO_2[c]										
Annual	4	8	11	14	1	1	2	100	100	100
1-hour		54	79	97	54	79	97			200
HC										
3-hour		120	180	210	120	180	210	160	160	160
CO										
8-hour		506	792	924	506	792	924	10,000	10,000	10,000
1-hour		829	1,298	1,514	829	1,298	1,514	40,000	40,000	40,000

SO_2 = sulfur dioxide NO_2 = nitrogen dioxide HC = hydrocarbons CO = carbon monoxide

[a] These are predicted ground-level concentrations from urban sources. Background concentrations are taken from Table 9-5. "Rural points" are measurements taken 3 miles from the center of town.

[b] "Primary" and "secondary" are federal ambient air quality standards designed to protect the public health and welfare, respectively.

[c] It is assumed that 50 percent of oxides of nitrogen from urban sources are converted to NO_2.

(2) To 1990

One Lurgi gasification plant will become operational in 1982. A second Lurgi plant will be constructed and become operational in 1987. Maximum pollutant concentrations resulting from the interaction of power plant and Lurgi plumes at a 5-mile separation distance violate Class II PSD increments for 24-hour and 3-hour SO_2 emissions. If the wind blows directly from one plant to the other, plumes will interact. However, resulting concentrations would be less than those produced by either plant and mine combination (which are located much closer together) when the wind blows from the plant to the mine (peak plant/mine concentration). Had the plants been sited closer together, the probability of interactions would increase. A slight reduction in long-range visibility from the current average of 60 miles at Bismarck, North Dakota, is expected.

Beulah's population is predicted to grow to 4,000 by 1985, then to decline to 2,200 by 1990. The concentrations of urban pollutants for 1985 are shown in Table 9-11. The 3-hour HC concentrations predicted for 1985 will violate federal primary and secondary standards as well as North Dakota air quality standards.[1] All other criteria pollutant concentrations are expected to be well within established standards.

(3) To 2000

Two Synthane gasification plants will become operational between 1990 and 2000. Interactions between the Synthane plants, power plant, and Lurgi plants will cause increases in annual peak concentrations. However, these increases are expected to be relatively small (less than 3 micrograms per cubic meter [$\mu g/m^3$] for particulates and SO_2 and less than 15 $\mu g/m^3$ for NO_2) and should not violate any standards.

When all of these facilities come on line, visibility is expected to decrease from the current average of 60 miles in the Beulah region to 54 miles. At a hypothetical 5-mile separation distance, maximum pollutant concentrations resulting from interaction of power plant and Synthane plant plumes will violate Class II PSD increments for 24-hour and 3-hour SO_2 emissions.

During the 1990-2000 decade, the town of Beulah will again record an increase and then a decrease in population. The maximum population will reach 4,800 in 1995, and increased pollution concentrations will be associated with this growth (Table 9-11). As was the case in 1985, only 3-hour HC levels will exceed any

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[1]Ambient HC standards are violated regularly in most urban areas.

federal or state ambient air standards. All other pollutant concentrations fall well within existing air quality standards.

E. Other Air Impacts

Additional categories of potential air impacts have been qualitatively examined; that is, an attempt has been made to identify sources of pollutants and how energy development may affect levels of these pollutants during the next 25 years. These categories are sulfates, oxidants, fine particulates, long-range visibility, plume opacity, cooling tower salt deposition, cooling tower fogging and icing, trace element emissions, and fugitive dust emissions.[1] Although there are likely to be local impacts as a consequence of these pollutants, both the available data and knowledge of impact mechanisms are insufficient to allow quantitative, site-specific analyses. Thus, these are discussed in a more general, qualitative manner in Chapter 10.

9.2.4 Summary of Air impacts

Five new facilities (a power plant, two Lurgi, and two Synthane gasification plants) are projected for the Beulah area. To just meet NSPS, the 3,000 MWe power plant would require 99 percent particulate, 48 percent SO_2, and 38 percent NO_x removal. However, at this level of control, ambient air standards for SO_2 would be violated. With 80 percent SO_2 and 99 percent particulate removal, Class II PSD increments for 3- and 24-hour SO_2 would be exceeded, and North Dakota's 1-hour ambient standards for NO_x and SO_2 would be violated. In order to meet these Class II increments and North Dakota standards, the plant would have to be equipped with a 95 percent efficient scrubber or plant capacity would have to be reduced to 1,500 MWe.

Typical and peak pollutant concentrations from the Lurgi and Synthane gasification plants and their associated mines will not violate any federal ambient standards or any Class II PSD increments. The Lurgi plants meet North Dakota ambient air standards, but the Synthane plants are likely to violate North Dakota's 1-hour NO_2 standard.

If all five facilities are constructed according to the hypothesized schedule, population increases in Beulah will add to existing pollutant levels. Violations of HC standards may occur by 1990 due solely to urban sources.

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[1]No analytical information is currently available on the source and formation of nitrates. See Hazardous Materials Advisory Committee. Nitrogenous Compounds in the Environment, EPA-SAB-73-001. Washington, D.C.: Government Printing Office, 1973.

9.3 WATER IMPACTS

9.3.1 Introduction

The main source of water in the Beulah area is the Upper Missouri River (see Figure 9-3). Water is available either from the rivers in the area or from Lake Sakakawea. Although of lesser importance, the Knife River is also capable of supplying water to some energy developments. Annual rainfall averages about 15 inches, and annual snowfall averages about 36 inches.[1]

This section identifies the sources and uses of water required for energy development, the residuals that will be generated, and the water availability and quality impacts that are likely to result.

9.3.2 Existing Conditions

A. Groundwater

The Beulah area is located on the southeastern edge of the Williston Basin, a large sedimentary basin encompassing much of western North Dakota and eastern Montana. Groundwater is available from deep bedrock aquifers, shallow sandstone aquifers, lignite aquifers, and alluvial aquifers in the area.[2] Deeper, potentially highly productive aquifers, such as the Dakota or the Madison, are important regionally but apparently do not contain potable water in the Beulah area.

Deep bedrock aquifers include the Fox Hills and basal Hell Creek aquifer and the upper Hell Creek and lower Cannonball-Ludlow aquifer, with the former being deeper. Wells in the lower aquifers are as much as 1,500 feet deep and yield up to 150 gpm, while the upper aquifer wells are about 500-800 feet deep with maximum yields of 100 gpm. The water quality of the two aquifers is quite similar; both contain predominately sodium bicarbonate with a TDS content of about 1,500 milligrams per liter (mg/ℓ). (The U.S. Geological Survey defines 1,000-3,000 mg/ℓ as slightly saline.) Both aquifers are currently tapped for domestic livestock uses, with the lower aquifer also being used for municipal supplies.

The lower Tongue River Formation aquifer is in shallow sandstone and is separated from the deeper Hell Creek-Cannonball-Ludlow aquifer by a considerable thickness of relatively

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[1]The moisture content of one inch of rain is equal to approximately 15 inches of snow.

[2]Croft, M.G. Ground-Water Resources, Mercer and Oliver Counties, North Dakota, North Dakota Geological Survey Bulletin 56, Part III. Grand Forks, N.D.: North Dakota Geological Survey, 1974.

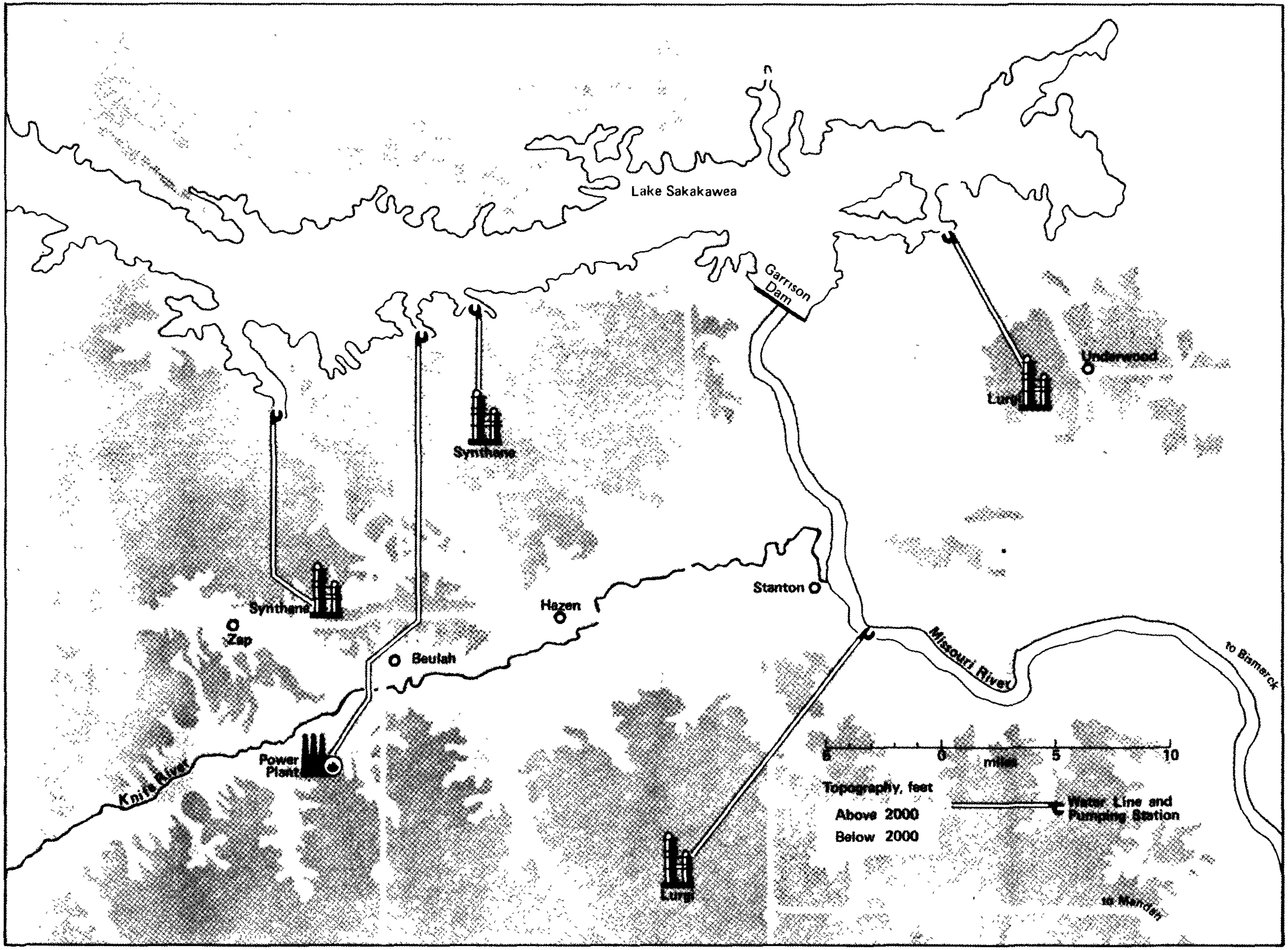

FIGURE 9-3: WATER PIPELINES FOR ENERGY FACILITIES IN THE RIFLE SCENARIO

impermeable siltstone and claystone beds. The formation is only about 150 feet thick, and well yields are only about 5 gpm. The water contains sodium bicarbonate with a TDS of 1,400-1,700 mg/ℓ. The aquifer is tapped by wells for domestic and stock purposes.

Lignite bed aquifers are also used for domestic and stock purposes. Well yields are generally less than 10 gpm, and TDS concentration is generally over 1,000 mg/ℓ.

Alluvial aquifers are present along the intermittent and perennial streams in the Beulah area. The most important of these are the Knife River and Missouri River aquifers and those along Goodman, Antelope, Elm, and Square Butte Creeks. Thicknesses range generally from 100 to 200 feet. The alluvial aquifers are the most productive in the Oliver County area, generally yielding more than 500 gpm.[1] Also, water quality is generally better than in the bedrock aquifers. TDS concentration ranges from about 500 to about 1,700 mg/ℓ. Water from alluvial aquifers is used for a wide variety of purposes.

B. Surface Water

The illustrative energy facilities in the Beulah area are located generally south of the eastern portion of Lake Sakakawea in the Upper Missouri drainage basin. Garrison Dam, which is near Riverdale, impounds the Missouri River to form Lake Sakakawea. The lake is used for flood control, irrigation, power, recreation, navigation, and as a water supply source for municipal and industrial users. Reservoir characteristics are shown in Table 9-12.

Flows in the Missouri River are greatly affected by conditions in the Yellowstone River Basin, which supplies about one-half of the average annual flow at Garrison Dam. Pertinent data for flow at Bismarck are shown in Table 9-13.

Another significant perennial river in the Beulah area is the Knife River, which runs east through Beulah and Hazen to its confluence with the Missouri River below Garrison Dam. The Knife River is part of the Western Dakota Subbasin. Stream flow and other characteristics of the Knife River are shown in Table 9-13. Available data on local creeks are also shown in Table 9-13. The consumptive water uses reported for this area in 1975 are shown in Table 9-14. The Corps of Engineers has estimated that water will be available to supply both irrigation and energy users

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[1]Croft, M.G. Ground-Water Resources, Mercer and Oliver Counties, North Dakota, North Dakota Geological Survey Bulletin 56, Part III. Grand Forks, N.D.: North Dakota Geological Survey, 1974.

TABLE 9-12: RESERVOIR CHARACTERISTICS--LAKE SAKAKAWEA[a]

Location of Garrison Dam •	Near Riverdale, North Dakota at river mile 1,389.9	
Contributing drainage area	180,050	square miles
Approximate length	178	miles
Maximum width	14	miles
Average width	3	miles[b]
Maximum operating pool elevation and area	1,775 129,000	feet above mean sea level; acres
Inactive storage between 1,775 and 1,673 feet above mean sea level	5	million acre-feet
Total gross storage between 1,854 and 1,673 feet above mean sea level	24.4	million acre-feet
Maximum discharge	348,000	cubic feet per second
Minimum discharge[c]	1,320	cubic feet per second
Average discharge	21,500	cubic feet per second
Power production plant capacity	500	megawatt-electric
dependable capacity	302	megawatt-electric
Surface fluctuation[b]	15 30	feet average feet maximum in recent years

[a]Missouri Basin Inter-Agency Committee. The Missouri River Basin Comprehensive Framework Study. Denver, Colo.: U.S., Department of the Interior, Bureau of Land Management, 1971.

[b]Northern Great Plains Resources Program, Water Work Group. Water Quality Subgroup Report, Discussion Draft. Denver, Colo.: U.S., Environmental Protection Agency, Region VIII, 1974.

[c]U.S., Department of the Interior, Bureau of Reclamation, Upper Missouri Region. Final Environmental Statement: Initial Stage, Garrison Diversion Unit, Pick-Sloan Missouri Basin Program, North Dakota. Billings, Mont.: Bureau of Reclamation, 1975.

TABLE 9-13: STREAM FLOW DATA IN THE BEULAH SCENARIO AREA

RIVER AND LOCATION	YEARS OF RECORD	DRAINAGE AREA (sq. mi.)	MINIMUM FLOW (cfs)	MAXIMUM FLOW (cfs)	AVERAGE FLOW	
					(cfs)	(acre-ft/yr)
Missouri River at Bismarck	45	186,400	1,800	500,000	21,720	15,740,000
Knife River at Hazen	40	2,240	0	35,300	181	131,100
Square Butte Creek Below Center	8	146	0	9,700	14.2	10,290
Spring Creek at Zap	28	549	0	6,130	43.8	31,730
West Branch Otter Creek near Beulah	8	26.5	0	23,700	4.1	2,960

sq. mi. = square miles
cfs = cubic feet per second
acre-ft/yr = acre-feet per year

TABLE 9-14: CONSUMPTIVE WATER USES IN THE WESTERN DAKOTAS SUBBASIN

USE	WATER REQUIREMENT (acre-ft/yr)
Irrigation	555,000
Livestock	68,000
Municipal and Industrial	28,000
Mining	23,000
Rural Domestic	16,000
Steam Electric	9,000
Manufacturing	4,000
Total	703,000

acre-ft/yr = acre-feet per year

Source: Missouri River Basin Commission. The Missouri River Basin Water Resources Plan, Final Draft Report. Omaha, Nebr.: Missouri River Basin Commission, 1977, p. 151.

through the year 2020.[1] However, releases to sustain navigation may be curtailed under some conditions.

Water quality in Lake Sakakawea is relatively good. Measurements have been made both in the lake and downstream of Garrison Dam. Some of these data are reported in Table 9-15 so that a specific water user can make an evaluation of the suitability of local water quality as it pertains to a particular use. Water quality data for the Knife River is scarce, although there are known high silt and nutrient loads. The nutrients that accompany the silt are related to agricultural fertilizer uses. These nutrients increase aquatic plant growth which reduces fish populations. Because of these conditions, there is almost no sport fishing in the upper Knife River Basin, although the lower river is a good sport fishery. Water quality parameters have been compiled for area streams from several locations and are shown in Table 9-15.

[1]U.S., Army, Corps of Engineers, Missouri River Division, Reservoir Control Center. Missouri River Main Stem Reservoirs Long Range Regulation Studies, Series 1-74. Omaha, Nebr.: Corps of Engineers, 1974.

TABLE 9-15: WATER QUALITY DATA FOR THE BEULAH SCENARIO (milligrams per liter)

LOCATION	Ca	Mg	Na	K	Cl	HCO_3	SO_4	NO_3	TDS	HARDNESS	pH	FLOW (cfs)
Missouri River[a] at Garrison Dam	49	19	59	4.4	9	180	170	.16	428	199	8.1	21,600
Lake Sakakawea[b]												
Red Butte Bay								4	345[c]	216	8	NA
Beaver Bay								5.5	350[c]	220	8	NA
Wolf Creek Bay								6.5	325[c]	220	7.9	NA
Knife River[b] Maximum								.54[d]	1510	530	8.3	5,930
At Hazen Minimum								0.00[d]	204	81	7	13
Mean								.26[d]	1004	320	7.9	392
Spring Creek[a,e] Maximum									1110			4.2
At Zap Minimum									108			1,120
West Branch[a,e] Maximum									1290			.10
Otter Creek Minimum									432			10
Square Butte[a,e] Maximum					1.5[f]		72[f]		588	100[f]	7.5[f]	1.2
Creek Below Center Minimum									318			370
Drinking Water Standard[g]					250[g]		250[g]	10[h]	500[g]		6.5-8.5[g]	
Typical Boiler[i] Feed Water	.10	.03	.24	.01	.96	.01			10	.01	8.8-10.8	

Ca = calcium
Mg = magnesium
Na = sodium
K = potassium
Cl = chloride
HCO_3 = bicarbonate
SO_4 = sulfates
NO_3 = nitrates
TDS = total dissolved solids
PH = acidity/alkalinity
cfs = cubic feet per second
NA = not applicable

[a]U.S., Department of the Interior, Geological Survey. 1973 Water Resources Data for North Dakota, Part 2: Water Quality Records. Washington, D.C.: Government Printing Office, 1974, Time-Weighted Average Values.

[b]Northern Great Plains Resources Program, Water Work Group. Water Quality Subgroup Report, Discussion Draft. Denver, Colo.: U.S., Environmental Protection Agency, Region VIII, 1974.

[c]Conductivity was reported; as no units were shown, the values were not converted to TDS.

[d]As nitrogen.

[e]Miscellaneous surface-water quality sites, values for 1973 water year only.

[f]Average values from: EBASCO Services, Inc. Environmental Impact Analysis: Milton R. Young Steam Electric Station Center Unit 2 for Minnkota Power Cooperative, Inc., and Square Butte Electric Cooperative, Inc. New York, N.Y.: EBASCO Services, Inc., 1973.

[g]U.S., Environmental Protection Agency. "National Secondary Drinking Water Regulations," Proposed Regulations. 42 Fed. Reg. 17,143-47 (March 31, 1977).

[h]U.S., Environmental Protection Agency. "National Interim Primary Drinking Water Regulations." 40 Fed. Reg. 59,566-88 (December 24, 1975). These regulations include other standards not given here.

[i]From a variety of sources, see American Water Works Association, Inc. Water Quality and Treatment, 3rd ed. New York, N.Y.: McGraw-Hill, 1971, p. 510, Table 16-1. Some numbers derived from Table 16-1 assuming concentrating factor = 100, high pressure, drum-type boiler.

The availability of water to all the illustrative energy facilities is largely controlled by interstate compacts that govern water use in areas above Lake Sakakawea.[1] Since no provision has generally been made in these compacts to govern the location of the withdrawal of water by the owner, allotments can be accounted for at downstream locations. For instance, Yellowstone River water currently allotted to Wyoming but not being used within that state could be withdrawn as far downstream as, for example, Lake Oahe and pumped back to Wyoming. Yet assuming that some allocated water must be passed through, there should be sufficient water available in Lake Sakakawea to supply the scenario energy developments.

A permit for withdrawal of water from Lake Sakakawea must be obtained from the North Dakota State Water Commission. There has been a moratorium on the issuing of permits from Lake Sakakawea that was in effect until July 1977. This moratorium was instituted to allow the legislature to restructure the water allocation program. The availability of water will be decided by the state after allowing for currently allocated water, including the rights of the Bureau of Reclamation to water for the Garrison Diversion Unit.

9.3.3 Factors Producing Impacts

The water requirements of and effluents from energy facilities cause water impacts. These requirements and effluents are identified in this section for each type of energy facility. Associated population increases also increase municipal water demand and sewage effluent; these are presented in Section 9.3.4 for the scenario which includes all facilities constructed according to the scenario schedule.

A. Water Requirements of Energy Facilities

The water requirements for energy facilities hypothesized in the Beulah area are shown in Table 9-16. Two sets of data are presented. The Energy Resource Development System (ERDS) data are based on secondary sources including impact statements, Federal Power Commission docket filings, and recently published

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[1]Belle Fourche River Compact of 1943, 58 Stat. 94 (1944); Yellowstone River Compact of 1950, 65 Stat. 663 (1951).

TABLE 9-16: WATER REQUIREMENTS FOR ENERGY FACILITIES AT BEULAH (acre-feet per year)

TECHNOLOGY[a]	ERDS[b] WET COOLING	WPA[c] COMBINATION OF WET AND DRY COOLING[d]		
		HIGH WET	INTERMEDIATE WET	MINIMUM WET
Power Generation	29,400	23,884	5,494	NC
Gasification				
Lurgi	6,705	4,891	3,307	2,853
Synthane	9,090	7,671	5,878	5,520
	Cost range in which indicated cooling technology is most economic (dollars per thousand gallons)			
Gasification Facilities	NC	<1.50	1.50-2.00	>2.00
Power Plant	NC	<3.65-5.90	>3.65-5.90	NC

ERDS = Energy Resource Development System
WPA = Water Purification Associates
NC = not considered
< = less than
> = greater than

[a]These values assume an annual load factor of 75 percent in the case of the 3,000 megawatt-electric power plant and 90 percent in the case of a 250 million cubic feet per day Lurgi and Synthane facilities.

[b]White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[c]Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

[d]Combinations of wet and wet/dry cooling were obtained by examining the economics of cooling alternatives for the turbine condensers and gas compressor interstage coolers. In the high wet case, these are all wet cooled; in the intermediate case, wet cooling handles 10 percent of the load on the turbine condensers and all of the load in the interstage coolers; in the minimum practical wet case, wet cooling handles 10 percent of the cooling load on the turbine condensers and 50 percent of the load in the interstage coolers. For power plants, only variations on the steam turbine condenser load were considered practical, thus, only high wet and intermediate wet cases were examined.

data accumulations.[1] The Water Purification Associates data are from a study on minimum water use requirements and take into account opportunities to recycle water on-site as well as the moisture content of the coal being used and local meteorological conditions.[2] As indicated in Table 9-16, the 3,000 MWe coal-fired power plant is expected to require the most water of all hypothesized energy facilities in the Beulah scenario (23,884 acre-feet per year [acre-ft/yr], assuming high wet cooling). The Lurgi and Synthane gasification facilities will require 4,891 and 7,671 acre-feet per day (assuming high wet cooling at the expected load factor of 90 percent). If intermediate wet cooling technology is used (a combination of wet and dry cooling), water requirements for energy facilities could be reduced by 77 percent for the power plant, 30 percent for the Lurgi facility, and 23 percent for the Synthane facility. From an economic viewpoint, the decision of which cooling technology to use often depends on the availability and price of water. For the power plant, high wet cooling is most economical if water costs less than $3.65 to $5.90 per thousand gallons. Intermediate wet cooling would save money if water costs rise above the $3.65 to $5.90 range. For synthetic fuel facilities, when water costs rise above $1.50 per thousand gallons, the intermediate wet cooling technology saves money. Additional water savings of from 7 to 14 percent could be realized for synthetic fuel facilities if minimum wet cooling is utilized. This technology would be economically advantageous if water costs more than $2.00 per thousand gallons. If water costs only $0.25 per thousand gallons and intermediate wet cooling is used in order to conserve water, the increased cost of synthetic fuels produced in the Beulah scenario would be about 1 cent per million Btu of fuel produced. However, in the case of electricity, the added cost of intermediate wet cooling would be 0.1 to 0.2 cent per kilowatt-hour (kWh).

The manner in which water is used by the energy facilities is shown in Figure 9-4. As indicated there, the greatest use for all energy conversion technologies is for cooling. Solids disposal

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[1]The ERDS Report is based on data drawn from: University of Oklahoma, Science and Public Policy Program. Energy Alternatives: A Comparative Analysis. Washington, D.C.: Government Printing Office, 1975; and Radian Corporation. A Western Regional Energy Development Study, 3 vols. and Executive Summary. Austin, Tex.: Radian Corporation, 1975. These data are published in White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[2]Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, April 1977. See Appendix B.

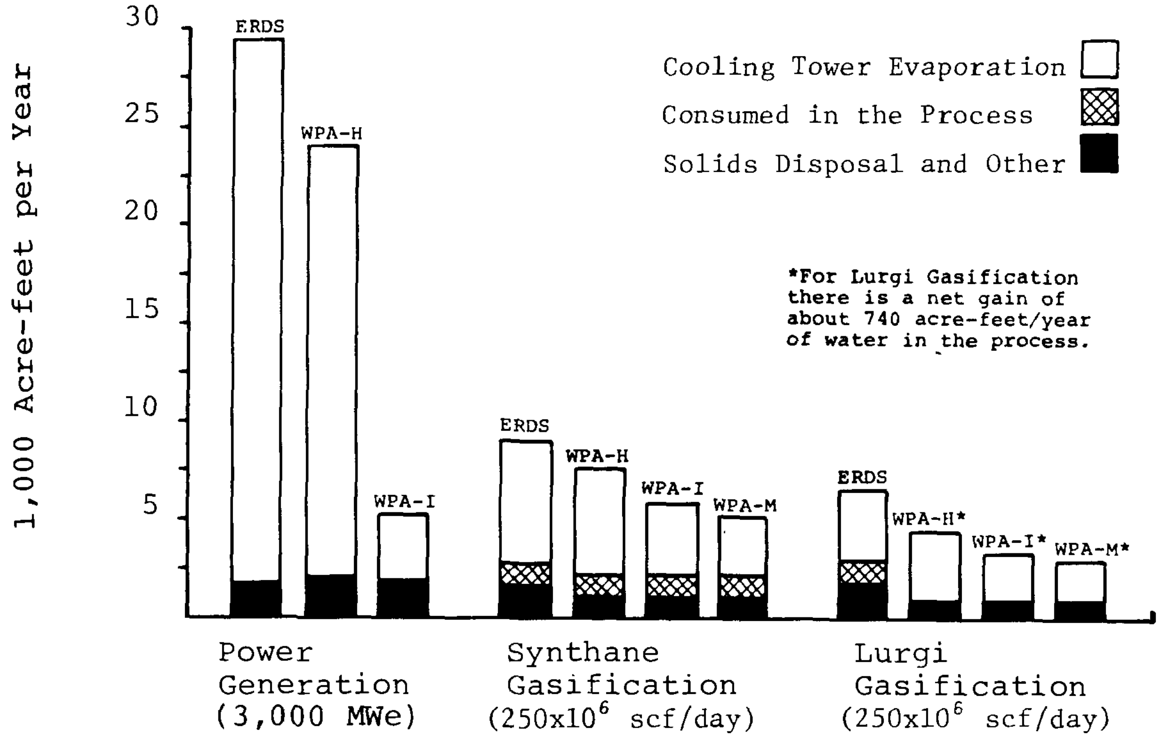

FIGURE 9-4: WATER CONSUMPTION FOR ENERGY FACILITIES IN THE BEULAH SCENARIO

ERDS = Energy Resource Development System
WPA-H = Water Purification Associates--High Wet Cooling
WPA-I = Water Purification Associates--Intermediate Wet Cooling
WPA-M = Water Purification Associates--Minimum Wet Cooling
MWe = megawatt-electric
scf/day = standard cubic feet per day

Source: The ERDS data is from White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming. The WPA data is from Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

consumes comparable quantities of water for all technologies, varying primarily as a function of the ash content of the feedstock coal.

The water requirement associated with mining includes dust control, handling, crushing, and service as well as reclamation. Reclamation requirements have been calculated, assuming 5 years of irrigation at a rate of 9 inches per year, and are given in Table 9-17. Water requirements for dust control are expected to range from 240 acre-ft/yr at the mine for the Lurgi plant to 400 acre-ft/yr at the mine for the power plant. Water to meet reclamation and dust control demands will come from mine dewatering activities whenever possible and will be supplemented with surface water if needed.

The first Lurgi facility, the power plant, and the two Synthane facilities will obtain their water through a pipeline from Lake Sakakawea because it is the largest, most reliable local source. Water will be withdrawn from an intake system below the minimum operating level of the lake and pumped to on-site reservoirs. The second Lurgi facility will use water released from Lake Sakakawea and withdrawn from its intake on the Missouri River downstream from Garrison Dam. As with the other facilities, the water will be pumped from the river to an on-site reservoir. Alternatively, the second Lurgi facility could use an upstream reservoir on the Knife River, such as the proposed Bronco Reservoir,[1] as a water source.

B. Effluents from Energy Facilities

The quantities of solid effluents from the energy facilities hypothesized for the Beulah area are shown in Table 9-18. The largest effluent quantities are from flue gas desulfurization (FGD) and ash disposal. Since the lignite in this area has only 6 percent ash, disposal requires less water than for coals with higher ash contents. The quantity of FGD effluent depends mainly on the sulfur content of the coal (0.8 percent by weight on a dry basis) and the scrubber efficiency (80 percent removal assumed).

As indicated in Table 9-18, the synthetic fuels facilities (Lurgi and Synthane) and the 3,000 MWe coal-fired power plant will produce solid effluents in the Beulah scenario. The highest volume of solid waste will come from the power plant (more than 3,800 tons of solid wastes per day). The Lurgi and Synthane plants each will generate about 2,200 tons of solid wastes per day. The combined total of solid wastes from all facilities will

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[1]Northern Great Plains Resources Program. Water Work Group Report. Billings, Mont.: U.S., Department of the Interior, Bureau of Reclamation, 1974.

TABLE 9-17: WATER REQUIREMENTS FOR RECLAMATION[a]

MINE	ACRES DISTURBED PER YEAR	MAXIMUM ACRES UNDER IRRIGATION	WATER REQUIREMENT (acre-ft/yr)
Power Plant	840	4,200	3,150
Lurgi (2)	1,000	5,000	3,750
Synthane (2)	1,000	5,000	3,750
Total			10,650

acre-ft/yr = acre-feet per year

[a]Assumes 9 inches per year for 5 years.

be more than 12,600 tons per day (tpd). The largest amount of dissolved and dry solids is expected to come from the power plant (74 and 2,138 tpd). The Lurgi plants each will produce about 2,000 tpd of wet solids.

Dissolved solids are present in the ash blowdown stream, the demineralizer waste stream, and the FGD stream.[1] The principal constituents of wastewater which appear as dissolved solids are calcium, magnesium, sodium, sulfate, and chlorine.

Wet solids from the electric power and Lurgi or Synthane gasification facilities are in the form of flue gas sludge, bottom ash, and cooling water treatment waste sludge. Calcium carbonate ($CaCO_3$) and calcium sulfate ($CaSO_4$) are the primary constituents of flue gas sludge. The bottom ash is primarily oxides of aluminum and silicon. $CaCO_3$ is the principal constituent of the cooling water treatment waste sludge. In all cases, the amount of cooling water treatment waste is very small, compared to the bottom ash and flue gas sludge.

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[1]Note that all coal conversion processes generate electricity on-site, thus flue gas cleaning, ash handling, and demineralization are required for all. Demineralization is a method of preparing water for use in boilers; it produces a waste stream composed of chemicals present in the source water. The ash blowdown stream is the water used to remove bottom ash from the boiler. Bottom ash removal is done via a wet sluicing system using cooling tower blowdown water. Thus, the dissolved solids content of that stream is composed of chemicals from the ash and cooling water.

TABLE 9-18: EFFLUENTS FROM COAL CONVERSION PROCESSES AT BEULAH[a]

FACILITY TYPE	SOLIDS[b] (tpd) DISSOLVED	WET	DRY	TOTAL	WATER IN EFFLUENT[c] (acre-ft/yr)
Lurgi (250 MMcfd)	32	1,986	251	2,269	807
Synthane (250 MMcfd)	29	484	1,663	2,176	975
Electric Power (3,000 MWe)	74	1,634	2,138	3,846	1,978

tpd = tons per day
acre-ft/yr = acre-feet per year
MMcfd = million cubic feet per day
MWe = megawatt-electric

[a]These data are from Radian Corporation. The Assessment of Residual Disposal for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. EPA Contract No. 68-01-1916. Austin, Tex.: Radian Corporation, 1978. The Radian Corporation report extends and is based on earlier analyses conducted by Water Purification Associates and reported in Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

[b]These values are given for a day when the facility is operating at full load. In order to obtain yearly values, these numbers must be multiplied by 365 days and by the average load factor. Load factors are 90 percent for synthetic fuels facilities and 75 percent for power plants. The values given as solids do not include the weight of the water in which the solids are suspended or dissolved.

[c]The values of water discharged are annual and take into account the load factor.

Dry solid waste produced by the coal conversion processes is primarily fly ash composed of oxides of aluminum, silicon, and iron. The water in the effluent stream (Table 9-18) accounts for between 9 (power plant) and 16 (Lurgi) percent of the total water requirements of the individual energy facilities (data in Table 9-18 compared with that in Table 9-16). Dissolved and wet solids are sent to evaporative holding ponds and later deposited in landfills. Dry solids are treated with water to prevent dusting and deposited in a landfill.[1]

9.3.4 Impacts

This section describes water impacts which result from the mines, conversion facilities (a power plant, two Lurgi plants, and two Synthane plants), and from a scenario which includes construction of all facilities according to the hypothesized scenario schedule. The water requirements and impacts associated with expected population increases are included in the scenario impact description.

A. Surface Mine Impacts

Surface mining will affect the quantity and quality of both groundwater and surface water. The chief groundwater effect of opening the mines will be the disruption of shallow bedrock aquifers in the Tongue River formation. Both sandstone aquifers and lignite beds will be destroyed by the removal of the lignite. Excavation will disrupt the flow patterns of aquifers encountered, requiring mine dewatering which may lead to excessive drawdowns and aquifer depletion. Aquifers in the overburden cannot be restored to premining conditions by replacement of the overburden during reclamation.

Mining operations may result in oxidation which could cause the generation of acid waters and the release of dissolved contaminants which would infiltrate the substrata below and adjacent to the mines. The infiltrating contaminated water could in turn pollute local shallow bedrock aquifers.

These groundwater depletion and contamination problems will be manifested in local wells, springs, and seeps. Aquifer depletion will lower water levels in wells, and some wells may dry up or have to be deepened. Depletion may also cause flow reductions in springs, and some springs may dry up. Groundwater contamination from leaching of the overburden could ruin wells and/or springs. Most of the impacts will be in consolidated bedrock aquifers, but nearby alluvial aquifers could also be affected.

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[1]The environmental problems associated with solid waste disposal in holding ponds and in landfills are discussed in Chapter 10.

These effects would be most pronounced where alluvial aquifers are recharged by base flow from bedrock aquifers. The streams associated with the alluvial aquifers may also receive contaminated water as base flow from bedrock or alluvial aquifers.

Runoff from the mine area will be high in suspended solids from erosion of open banks, spoil piles, and the mine floor and will contain higher than ambient concentrations of the trace metals associated with the coal. The greater part of the contaminated runoff will remain in or enter the mine area either by natural flow or through runoff retention structures. No contaminated runoff will be allowed to directly enter a natural stream. About 83 acre-ft/yr of runoff could be trapped by each 1,000 acres of active mine or reclamation area.[1] If there is a large excess of water from mine dewatering and runoff, it will be treated and used as make-up for process water at the associated energy conversion facility.

B. Energy Conversion Facilities Impacts

Water impacts may be divided into those occurring during construction and during operation and those occurring because of the water requirements of facilities and because of effluents from the facilities.

Construction activities at the facilities will remove vegetation and disturb the soil, affecting surface-water quality by increasing the sediment load of local runoff. Additionally, the equipment used during construction will require maintenance areas and petroleum products storage facilities. Areas for the storage of other construction-related materials, such as aggregate for a concrete batch plant, will be required as well. All these facilities have the potential for contaminating runoff. Runoff control methods will be instituted at all these potential sources. Runoff will be channeled to a holding pond for settling, reuse, and evaporation. Because the supply of water to this pond is intermittent, evaporation may claim most of the water. Some of the water may be used for dust control.

Power plant construction will cause additional environmental effects where the water supply pipeline crosses the Knife River; construction activities will require that parts of the river be dammed temporarily. Increased silt loads and possible erosion of

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[1]This estimate corresponds to 1 inch per year of runoff.

stream banks due to increased velocities at the dam site may result.[1]

Operation of the facilities may have some impact on local groundwater systems. However, it will not contribute to local aquifer depletion because process and cooling water for these facilities will be provided by Lake Sakakawea. The range of water requirements for the facilities, if high wet cooling is used, is 23,884 acre-ft/yr for the power plant, 4,891 acre-ft/yr for each Lurgi plant, and 7,671 acre-ft/yr for each Synthane plant (Table 9-16). These ranges in water requirements represent 0.5 to 2.4 percent of the minimum discharge from Lake Sakakawea (956,340 acre-ft/yr)[2] and 0.03 to 0.2 percent of the annual average discharge (15,576,750 acre-ft/yr).

The effluents from the energy conversion facilities likely to have the greatest impact on local groundwater supplies are those that will be ponded on the facility sites. Pond liners for the effluent storage ponds are designed to prevent leakage during the lifetime of the energy conversion facility, but they may leak because of failure, inadequate design, or improper maintenance. In the event of pond liner leakage, contaminants could enter the substrata either by direct infiltration of contaminated liquids or by leaching of solids or semisolids by natural precipitation. Local groundwater contamination may or may not occur, depending on the composition of the fluids or leachate and on the renovative capacity (filtration and absorption) of the substrata. This capacity will vary according to local geologic conditions.

The Lurgi and Synthane facilities will produce solid wastes which will be trucked to disposal sites located in mined-out areas. Decomposition and leaching of these wastes could accentuate the contamination problems described earlier for the mines. In addition, there will be on-site ponds similar to those at the power plant for toxic, nontoxic, and sanitary wastes. Because of the provisions of Public Law 92-500, there will be no planned continuous or intermittent discharge of pollutants to surface waters.

C. Scenario Impacts

Water impacts resulting from interactions among the hypothesized facilities and their associated mines and water impacts

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[1]Alternatively, the pipeline may be attached to the Highway 49 Bridge that crosses the Knife River south of Beulah. Reconnaissance of the area would be necessary to determine if this alternative is viable.

[2]Value obtained from Table 9-12 using the conversion factor of 1 cubic foot per second equals 724.5 acre-ft/yr.

resulting from associated population increases are discussed in this section.

Water requirements for direct use by these hypothesized energy facilities (assuming high wet cooling) increase from approximately 24,000 acre-ft/yr in 1980 when the power plant is operating to 33,665 acre-ft/yr in 1990 when the power plant and Lurgi plants are operating and to 49,008 acre-ft/yr in 2000 when all the plants are operating. Additional water, about 23 percent of the water requirement for the facilities, in 2000 may be required for reclamation purposes.

As shown in Table 9-19, population increases associated with energy development will also require additional water supplies.[1] In the scenario area, municipal water use will total 4,645 acre-ft/yr by the year 2000, with intermediate demands related to labor-intensive construction as high as 4,000 acre-ft/yr. Currently, water demands are being met with groundwater at all municipalities except Bismarck and Mandan, which use surface water from the Missouri River. Permits are required from the North Dakota State Water Commission to withdraw any additional municipal water.

Wastewater from the energy facilities which will be impounded in evaporation ponds will average 2,000 acre-ft/yr by 1980, 3,600 acre-ft/yr by 1990, and 5,500 acre-ft/yr by 2000 (Table 9-18).

Rural populations are assumed to use individual, on-site waste disposal facilities (septic tanks and drain fields), and urban populations will require waste treatment facilities. The wastewater generated by the population increases associated with energy development will amount to 1.25 million gallons per day (MMgpd) by 1980, 1.56 MMgpd by 1990, and 3.30 MMgpd by 2000 as shown in Table 9-20. During most of that time, the Bismarck-Mandan area will account for about 80 percent of the totals, but construction demand peaks will cause some fluctuations. Beulah will require increased capacity of 0.34 MMgpd by 1995, more than double its average over the 25-year period under consideration. Similary, Zap peaks in 1985 and Hazen in 1995. Current wastewater treatment practices in these communities are shown in Table 9-21.

Based on the current treatment facilities capacities, all the communities in the scenario will require new facilities to accommodate new population due to energy developments. In Bismarck-Mandan, facilities will not have to expand immediately but will be needed before 2000. New facilities must use "best practicable" waste treatment technologies to conform to 1983

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[1]Estimates do not include population increases caused by secondary industries.

TABLE 9-19: EXPECTED WATER REQUIREMENTS FOR INCREASED POPULATION[a]
(acre-feet per year)

TOWN	1980	1985	1990	1995	2000
Beulah	133	371	119	483	147
Golden Valley	6	14	8	17	15
Hazen	78	162	106	400	190
Stanton	34	39	35	81	85
Zap	25	74	13	46	32
Center	53	39	39	60	81
Fort Clark	4	7	6	13	15
Hannover	15	3	3	7	8
Bismarck-Mandan	1,344	1,708	1,834	2,842	4,032
Mercer County/ Rural[b]	11	3	16	21	25
Oliver County/ Rural[b]	20	24	29	33	38

[a]Above 1975 base level; based on 125 gallons per capita per day.

[b]Based on 80 gallons per capita per day.

TABLE 9-20: EXPECTED WASTEWATER FLOWS FROM INCREASED POPULATION[a]
(million gallons per day)

TOWN	1980	1985	1990	1995	2000
Beulah	0.10	0.27	0.09	0.34	0.11
Golden Valley	0	0.01	0.01	0.01	0.01
Hazen	0.06	0.12	0.08	0.29	0.14
Stanton	0.02	0.03	0.03	0.06	0.06
Zap	0.02	0.05	0.01	0.03	0.02
Center	0.04	0.03	0.03	0.04	0.06
Fort Clark	0	0.01	0	0.01	0.01
Hannover	0.01	0	0	0.01	0.01
Bismarck-Mandan	1	1.22	1.31	2.03	2.88

[a]Above 1975 base level; based on 100 gallons per capita per day.

TABLE 9-21: WASTEWATER TREATMENT CHARACTERISTICS OF COMMUNITIES AFFECTED BY BEULAH SCENARIO

TOWN	TYPE OF TREATMENT	HYDRAULIC LOADING
Beulah	2-cell waste stabilization pond, 15 acres	At capacity
Golden Valley	3-cell waste stabilization pond, 5 acres	Can expand by about 100-200 people
Hazen	2-cell waste stabilization pond, 18 acres	At capacity
Stanton	2-cell waste stabilization pond, 5.2 acres	At capacity
Zap	2-cell waste stabilization pond, 2.75 acres	At capacity
Center	Waste stabilization, with new but presently inoperable system, 6.5 acres	Old system--overloaded; new plus old system--at capacity
Fort Clark	No system	
Hannover	No system	
Bismarck	Expanding to extended aeration, secondary clarifier, sand filtration, chlorination	Designed for 55,000
Mandan	Extended aeration, filtration, chlorination	Designed for 20,000

Source: North Dakota Health Department. Personal communication.

standards and must allow for recycling or zero discharge of pollutants to meet 1985 goals. The 1985 standard could be met by using effluents for industrial process makeup water or for irrigating local farmland.[1]

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[1]Federal Water Pollution Control Act Amendments of 1972, Pub. L. 92-500, §§ 101, 301; 33 U.S.C.A. §§ 1251, 1311 (Supp. 1976).

(1) To 1980

The only activity scheduled before 1980 is the construction of the power plant, the first Lurgi gasification plant, and the openings of their respective lignite surface mines. The power plant will go on-line in 1980, but the Lurgi plant will not go into operation until 1982. Therefore, prior to 1980 there will be little land disturbance by mines (and therefore only minor reductions in the amount of runoff which no longer reaches streams) and no water required by the conversion facilities.

This analysis assumes that the additional water requirements for communities in the scenario now using groundwater sources will also be met from groundwater which will be withdrawn by well fields in nearby alluvial aquifers. The productivity of the aquifers supplying each town should be sufficient to meet the needs without significant aquifer depletion. A possible exception is Hannover, which may have to be provided with supplemental water from surface sources or by a pipeline from a well or well field in the Square Creek aquifer. Increased surface water withdrawals by Bismarck-Mandan to meet projected population needs are not expected to have an appreciable effect on the flow of the Missouri River.

As noted in Table 9-21, all the small towns in the scenario area, with the exception of Fort Clark and Hannover, presently use waste stabilization ponds for sewage treatment. Residences in Fort Clark and Hannover use individual septic tank and drainfield systems. Bismarck and Mandan have municipal sewage treatment plants. Both the stabilization ponds (because of leakage) and the septic tank systems may pose a water quality hazard to local shallow aquifer systems in both the bedrock and the alluvium. This hazard will be magnified by the population increases associated with the energy development projected for the scenario area.

(2) To 1990

During the 1980-1990 interval, three of the energy facilities will begin operation. The power plant will go on-line in 1980, and the Lurgi plants will start operation in 1982 and 1987. The associated coal mines will begin operation concurrent with their plants.

By 1990, the mines for the facilities in operation will have disturbed a total of 13,900 acres (calculated from Table 9-17) resulting in a loss of runoff (since this runoff is impounded) of 1,160 acre-ft/yr. Water requirements will total about 33,600 acre-ft/yr by 1990 or 3.5 percent of the minimum discharge of Lake Sakakawea and about 0.2 percent of the lake's average annual discharge.

As a result of population growth, municipal water requirements will increase dramatically about the mid-1980's and then will decrease to near the 1980 levels by the end of the decade. The alluvial aquifers or surface-water systems that supply the various communities should be able to meet these additional needs without aquifer depletion. Excessive groundwater withdrawals may occur at Beulah and Zap during the population peak, but the losses will be made up by recharge in later years.

(3) To 2000

The two Synthane plants of the scenario will be constructed between 1990 and 2000. Both plants will be in operation by 2000. By 2000, surface mining for all facilities will have disturbed 34,800 acres of land (calculated from Table 9-17). Due to runoff impoundment, this will result in a loss of water to local streams of about 2,900 acre-ft/yr. The combined effect of runoff loss, disrupted land, and mine dewatering could significantly affect base flows of streams and aquifers.

After conversion facilities are operating, the total water requirement assuming high wet cooling and the expected load factors (Table 9-16) will be 49,000 acre-ft/yr. This requirement is 5 percent of Lake Sakakawea's minimum discharge and 0.3 percent of its average annual discharge. These withdrawals should not have a significant effect on water supplies. However, they may cause some increase in downstream pollutant concentrations because of the loss of higher quality water. This effect--mainly an increase in total dissolved solids--is difficult to evaluate quantitatively.

As in the previous decade, population levels in the communities of the scenario area during the 1990-2000 decade will increase to a high level in the mid-1990's, then decrease toward the end of the decade. The aquifers and rivers used by all the communities except Beulah should be able to meet the increased water needs without significant aquifer depletion. At Beulah, the groundwater withdrawals may exceed the recharge to the Knife River aquifer temporarily, but the losses would be made up after the population declines.

The middecade population peak will again increase the stress on the quality of water in local shallow aquifers because of excess septic tank usage and leakage from waste stabilization ponds. The renovative capacity of the substrata is not unlimited, and continued introduction of septic tank and stabilization pond effluent will probably lead eventually to aquifer contamination.

(4) After 2000

The second Synthane plant will begin operating in 2000, but most of the impacts after 2000 will occur after the various energy facilities shut down.

The mines associated with the five energy conversion facilities will continue to produce the same impacts described for earlier decades as long as the plants operate. After the plants are shut down, the total mine area will be reclaimed and mine dewatering will cease. Although aquifer depletion will no longer be a concern, groundwater quality impacts will continue after the mine areas are reclaimed. However, over the long term, the oxidation and release of contaminants in the overburden will be completed, and the rate of release will taper off.

After the facilities are decommissioned, the runoff control systems will no longer be operating. The amount of runoff contamination will be the result of erosion of the berms and leakage in the pond liners from lack of maintenance.

Some of the people who migrate into the area because of energy development are likely to remain after the plants are shut down. If so, water supply demands on the alluvial aquifers and the Missouri River will continue. These sources should be able to meet the needs without significant depletion.

Communities that have not built municipal sewage treatment plants will continue to present a water quality hazard to local aquifers through the use of septic tanks and waste stabilization ponds. As noted earlier, this hazard is cumulative in that the renovative capacity of the substrata will eventually be exhausted.

By the end of the decade, wastewater treatment demands in communities with severe treatment problems should have decreased to levels within the plant capacities of the various communities.

9.3.5 Summary of Water Impacts

Water impacts are caused by: (1) the water requirements of and effluents from the energy facilities, (2) the water requirements of and wastewater generated by associated population increases, and (3) the coal mining process itself.

Assuming the energy facilities hypothesized for the Beulah area are high wet cooled, the water requirements in acre-ft/yr are 23,884 for the power plant, 9,782 for the two Lurgi plants, and 15,342 for the two Synthane plants. Operation of all the facilities could require as much as 49,000 acre-ft/yr from Lake Sakakawea which is 0.3 percent of its average annual discharge and 5 percent of its minimum discharge. The use of intermediate wet cooling for the facilities operating at the expected load factor could reduce this demand by 72 percent. The water requirements at the mines will generally be met from dewatering operations.

Wastewater from the energy facilities, in acre-ft/yr, average 2,119 from the power plant, 807 from each Lurgi facility, and 975 from each Synthane plant. The objective of zero discharge of pollutants set forth in the Federal Water Pollution Control Act (FWPCA)[1] will necessitate on-site entrapment and disposal of all of these effluents. As a result, effluents will be discharged into clay-lined, on-site evaporative holding ponds, and runoff prevention systems will be installed to direct runoff[2] to a holding pond or to a water treatment facility. These methods protect the quality of surface water systems (at least for the life of the plants), but groundwater quality may be reduced by leakage and leaching from the disposal ponds and pits.

Municipal water use in the scenario area will total 4,645 acre-ft/yr by 2000 with intermittent demands related to labor-intensive construction as high as 4,000 acre-ft/yr. Most of this municipal water demand is expected to be in Bismarck-Mandan where the source is the Missouri River. Small quantities for other towns will be taken from groundwater. Increased population will also cause wastewater increases, totaling 3.4 MMgpd by 2000. Disposal of urban sanitary wastes may pose several hazards to groundwater quality, and overloaded waste stabilization ponds may lower the quality of surface water. Two cycles of rapid population increases followed by rapid decreases, coupled with the requirements of the FWPCA, will tax the ability of the communities to provide adequate municipal treatment. Special measures may have to be instituted, such as using the municipal effluent as process water at one or more of the energy conversion facilities, to prevent the municipal effluents from degrading surface-water quality. The alternative is building expensive treatment plants that will not be used efficiently over the long term.

The coal mines for the hypothesized energy facilities will also have several indirect impacts on both groundwater and surface water. If mine dewatering is necessary, local shallow bedrock aquifers in the Tongue River formation may be depleted. The result would be a lowering of water levels in wells or the drying up of wells, seeps, and springs. Additionally, bedrock recharge to alluvial aquifers and base flow to streams may be greatly

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[1]Federal Water Pollution Control Act Amendments of 1972, Pub. L. 92-500, §§ 101, 301; 33 U.S.C.A. §§ 1251, 1311 (Supp. 1976).

[2]Runoff will average 83 acre-ft/yr for each 1,000 acres of land disturbed by a mine or facility, totalling 5,800 acre-ft/yr by the year 2000.

reduced or eliminated. Returning overburden to the mines during reclamation may change aquifer characteristics and infiltration rates. A total of 33,000 acres will be mined by 2000 and 84,400 acres over the life of all facilities. Overturning the overburden will also bring to the surface materials that were formerly deeply buried. Oxidation and release of these materials (acid waters) could lower the quality of surface water and groundwater sources. Infiltrating precipitation may leach these materials and carry them directly as recharge to aquifers or indirectly to surface water sources either as springs or as base flow to streams. The potential pollution problem associated with the overburden will continue for several years after plant shutdown and will diminish slowly as oxidation and other reactions in the overburden go to completion.

Finally, during construction, the energy facilities may lower the quality (turbidity and dissolved solids content) of surface water because of soil disturbance. Accidental spills of fuels and lubricants may also enter the surface water system and infiltrate to groundwater systems.

9.4 SOCIAL AND ECONOMIC IMPACTS

9.4.1 Introduction

The hypothesized developments in the Beulah scenario will occur in three counties of west-central North Dakota: Mercer, Oliver, and McLean. Of the five facilities, three will be in Mercer County; Oliver and McLean Counties will contain one facility each. Most of the anticipated social and economic impacts can be attributed either directly or indirectly to the attendant population increases. This analysis focuses on Mercer County because the facilities are centrally located around Beulah and because the county has several other small towns which will be affected by the hypothetical developments.

9.4.2 Existing Conditions

Together, the three counties cover 3,828 square miles and had a 1974 population of 19,757 (a population density of 5.2 persons per square mile). Mercer County alone encompasses 1,042 square miles and had a 1974 population of 6,400 (about six persons per square mile). The area is served by several state highways and two railroads: the Burlington Northern running east and west, and the Milwaukee, St. Paul, and Sault Ste. Marie (Soo Line) running north and south.

Between 1950 and 1970, Mercer County's population decreased by 29 percent. The state's population also decreased over this period, but its 1 percent change was minor compared to the loss in Mercer County (Table 9-22). This decline continued at a

TABLE 9-22: POPULATION, MERCER COUNTY AND NORTH DAKOTA, 1950-1970

	POPULATION			PERCENT POPULATION CHANGE		
	1950	1960	1970	1950-60	1960-70	1950-70
Mercer County	8,686	6,805	6,175	-21.7	-10	-29
North Dakota	619,636	632,446	617,761	+2.1	-2.3	- 1

Source: U.S., Department of Commerce, Bureau of the Census. 1950 Census of Population; 1960 Census of Population; and 1970 Census of Population. Washington, D.C.: Government Printing Office, various dates.

slower pace into the early 1970's; the county population decreased 6.5 percent (from 6,600 to 6,175) between 1967 and 1972.

There are six population centers in Mercer County, ranging from 100 to 1,200 people each. In addition to Beulah, incorporated towns in the county are: Stanton (the county seat), Golden Valley, Hazen, Pick City, and Zap. Unlike the county trend, population in the three largest towns (Beulah, Stanton, and Hazen) has remained fairly stable over the past 20 years. The major loss has been from the unincorporated rural areas.

Agriculture dominates the economy of Mercer County. In 1970, 33 percent of the labor force was employed in agriculture, (more than 10 times the national average) as compared to 21 percent statewide. The rest of the labor force was scattered throughout industry, with no other predominating sector (Table 9-23). However, the dominance of agriculture is on the decline in Mercer County, reflecting a statewide trend. Total cropland, land in farms, and the number of farms have all declined from 1969 to 1974 in both Mercer and Oliver Counties.[1] Mining and utilities sectors now generate more income than any other sector except

[1]U.S., Department of Commerce, Bureau of the Census. 1974 Census of Agriculture; Preliminary Reports, Mercer County and Oliver County, North Dakota. Washington, D.C.: Government Printing Office, 1976.

TABLE 9-23: EMPLOYMENT BY INDUSTRY GROUP IN MERCER COUNTY, 1970

INDUSTRY GROUP	NUMBER EMPLOYED	PERCENT OF TOTAL
Agriculture, forest, and fisheries	713	33.4
Mining	115	5.9
Construction and manufacturing (Total)	151	7.1
Food and kindred products	6	0.3
Printing, publishing, and products	3	0.1
Transportation, communication	70	3.3
Utilities and sanitary sewers	175	8.2
Retail trade	210	10.5
Food and dairy products store	69	3.4
Restaurants	49	2.4
Trade	210	9.8
Finance, insurance, and real estate	71	3.3
Miscellaneous services	388	18.2
Public administration	91	4.3
Total Employment	2,321	100

Source: U.S., Department of Commerce, Bureau of the Census. Census of Population: 1970; General Social and Economic Characteristics. Washington, D.C.: Government Printing Office, 1971.

agriculture.[1] Both trends largely reflect the coal resource developments already under way in the area.

Both legislative and administrative functions in Mercer County are exercised by the Board of County Commissioners which is composed of three members serving 4-year terms. The Mercer County Planning Commission, consisting of nine members, serves under the County Board. The Commission's primary responsibilities consist of planning and zoning activities in all unincorporated areas of the county. Decisions of the Planning Commission are subject to approval by the County Commissioners.

In 1967, the majority of local government expenditures (60.3 percent) in the county went into education. Other major

[1]U.S., Department of Commerce, Bureau of Economic Analysis. "Local Area Personal Income." Survey of Current Business, Vol. 54 (May 1974, Part II), pp. 1-75.

expenditures included: highways, 19.4 percent; public welfare, 3.8 percent; and health and hospitals, 0.4 percent. The total local expenditure for that year was $1.8 million. Law enforcement in Mercer County is handled by a sheriff and five deputies. The county is served by one hospital, located in Hazen, which has 39 beds and two full-time doctors. The county also provides a public health nurse who travels throughout the county.

Although Stanton is the county seat, almost all the retail and professional services are provided by the two largest towns, Beulah and Hazen.

Beulah is governed by a six-member city council and a mayor. There is no full-time planner; the city engineer performs planning services for the town when necessary. However, there is a planning commission which meets once a month, and the town has a master plan and a zoning code. Medical services consist of a clinic staffed by one doctor and one dentist, an eye clinic, and an ambulance service. Law enforcement is provided by one policeman and one county sheriff's deputy. The fire department consists of a 58-man volunteer force and two fire trucks. In addition, the city owns and operates its own water and sewage treatment system.

Hazen is governed by a mayor and four councilmen. The new position of city planner was created to deal with growth from energy development. It is now filled on a part-time basis by the city manager, but there are plans to fund it on a full-time basis starting in 1977. There is also a voluntary planning commission composed of nine members who meet twice a month. Law enforcement is provided by one policeman and one county sheriff's deputy. Fire protection is provided by a volunteer fire department. The city owns and operates its own water and sewer systems, which are presently operating at full capacity.

Both Beulah and Hazen appear to have adequate physical capacity in their public service institutions to provide for the needs of their current residents. Further, both cities showed budget surpluses in fiscal 1973.[1] However, the pressures created by rapid growth could require rapid expansion of facilities and services in these communities, and thus a sudden increase in their public service employment. Under existing legislation, the cities are not prepared to do this; the maximum indebtedness of North Dakota cities cannot, by law, exceed 5 percent of their total assessed valuations. Thus, Beulah and Hazen are authorized debts of only $87,600 and $56,400, respectively. Given today's costs, such sums will not allow much expansion of public services in

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[1]This is typical of North Dakota's recent experience. The state general fund has a surplus equal to almost a full year's budget, and voters recently approved a reduction in sales tax rates. See the Denver Post, November 6, 1976.

these communities. Further, even if a referendum should pass by a vote of two-thirds of the local residents, this limit can only be raised an additional 3 percent.

9.4.3 Factors Producing Impacts

Two factors associated with energy facilities dominate as the cause of social and economic impacts: manpower requirements and taxes levied on the energy facilities. Tax rates are tied to capital costs, and/or the value of coal extracted, and/or the value of energy produced. Taxes which apply to the Beulah scenario facilities (a power plant, two Lurgi, and two Synthane gasification plants and their associated mines) are: property tax, sales tax, severance tax, royalty payments for federally owned coal, and an energy conversion tax.

The manpower requirements for each type of scenario facility and its associated surface coal mine are given in Table 9-24 and 9-25. For the mines, manpower requirement for operation exceeds peak construction manpower requirement by 2.5 times. However, the reverse is true for the conversion facilities; peak construction manpower requirement exceeds the operation requirement by 5 (power plant) to 7 times (Lurgi and Synthane plants). In combination, the total manpower requirement for each mine-conversion facility increases from the first year when construction begins, peaks, and then declines as construction activity ceases. Peak total manpower requirement is about 5,600 for each gasification plant and 3,200 for the power plant. The fraction of peak total manpower requirement needed for operation of the mine and plant combination is about 0.2 for the gasification plants and 0.4 for the power plant. The total manpower required for operation of the plant-mine combination is about the same for each scenario facility and its associated mine.

A property tax and sales tax which are tied to capital costs, a severance tax and royalty payments which are tied to coal value, and an energy conversion tax which is tied to energy produced generate revenue for the state and local governments. The capital costs of the conversion facilities and mines hypothesized for the Beulah scenario are given in Table 9-26. Costs are about 1,160 millions of 1975 dollars for each mine-gasification plant and 1,525 for the mine-power plant. The property tax, most of which goes to local government, is levied on the cash value of the mines only (approximately the total capital cost given in Table 9-26) after the construction of the mine is completed. Sales tax, most of which goes to the state government, is levied on materials and equipment only (Table 9-26) as the materials and equipment are purchased during construction. The current sales tax rate in North Dakota is 4 percent, and the property tax rate in Mercer,

TABLE 9-24: MANPOWER REQUIREMENTS FOR A 3,000 MEGAWATT POWER PLANT AND ASSOCIATED MINE[a]

YEAR FROM START	CONSTRUCTION WORK FORCE		OPERATION WORK FORCE		TOTAL IN ANY ONE YEAR
	MINE	POWER PLANT	MINE	POWER PLANT	
1	0	0			0
2	58	460			518
3	338	2,220		0	2,558
4	328	2,265	0	109	2,702
5	338	2,345	440	109	3,232
6	270	1,990	440	218	2,918
7	0	720	883	436	2,039
8		0	883	436	1,319

MWe = megawatt-electric

[a]Data are for a 3,000 MWe power plant and a surface coal mine large enough to supply that power plant (about 19.2 million tons per year) and are from Carasso, M., _et al._ _The Energy Supply Planning Model_, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975; data uncertainty is -10 to +20 percent.

Oliver, and McLean counties is about 1.48 percent.[1] The severance tax (of which 40 percent goes to local government, 30 percent to state government, and 30 percent is saved) is levied at a rate of 5 percent on the value of the coal mined. Royalty payments, of which 50 percent is returned to state and local government, are about 12.5 percent of the value of federally owned coal.[2] However, all royalties are retained by Indian tribes when the coal is on the reservation. The energy conversion tax, most of which goes to state government, is levied at a rate of 0.25 mill per kWh on the power plant and $0.10 per thousand cubic feet (Mcf) on the gasification plants. No energy conversion tax is collected on conversion facilities located on Indian reservations.

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[1]This is the effective, average property tax rate. The actual rate is computed using a number of assessment ratios, since certain kinds of equipment (e.g., pollution control equipment) are taxed at different rates or may be exempt.

[2]This is the federal government's target rate; actual rates will vary from facility to facility.

TABLE 9-25: MANPOWER REQUIREMENTS FOR A LURGI OR SYNTHANE PLANT AND ASSOCIATED MINE[a]

YEAR FROM START	CONSTRUCTION WORK FORCE		OPERATION WORK FORCE		TOTAL IN ANY ONE YEAR
	MINE	GASIFICATION PLANT	MINE	GASIFICATION PLANT	
1	0				0
2	32				32
3	190	0			190
4	185	609	0		794
5	190	2,687	248	0	3,125
6	152	4,682	248	589	5,671
7	0	2,662	497	589	3,748
8		0	497	589	1,086

[a]Data are for a gasification plant and a surface coal mine large enough to supply that plant (about 10.8 million tons per year [MMtpy] for the Lurgi plant and about 9.6 MMtpy for the Synthane plant) and are from Carasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975; data uncertainty is -10 to +20 percent.

TABLE 9-26: CAPITAL RESOURCES REQUIRED FOR CONSTRUCTION OF FACILITIES (in millions of 1975 dollars)[a]

FACILITIES	MATERIALS AND EQUIPMENT	LABOR AND MISCELLANEOUS	INTEREST DURING CONSTRUCTION[b]	TOTAL
Conversion Facilities				
Power Plant (3,000 MWe)	461	461	394	1,316
Lurgi or Synthane Gasification[c] Plant (250 MMcfd)	469	369	219	1,057
Associated Surface Coal Mines				
For Power Plant (19.2 MMtpy)	104	56	48	208
For Lurgi Plant (10.8 MMtpy)	59	32	29	118
For Synthane Plane (9.6 MMtpy)	52	28	24	104

MWe = megawatt-electric
MMcfd = million cubic feet per day
MMtpy = million tons per year

[a]Data are adjusted (assuming linearity) to correspond to the facility size hypothesized in this scenario and are from Carasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975.

[b]At 10 percent per year.

[c]Two Lurgi and two Synthane facilities are hypothesized for the Beulah area, but data are for one plant and its associated mine.

9.4.4 Impacts

The nature and extent of the social and economic impacts caused by these factors depends on the size and character of the community or communities in which workers and their families live, on the state and local tax structure, and on many other social and economic factors. A scenario, which calls for the development of a power plant, two Lurgi and two Synthane gasification plants, and their associated mines according to a specified time schedule (see Table 9-1), is used here as a vehicle through which the nature and extent of the impacts are explored. The discussion relates each impact type to the hypothetical scenario and includes population impacts, housing and school impacts, economic impacts, fiscal impacts, social and cultural impacts, and political and governmental impacts.

A. Population Impacts

Most of the social and economic impacts in the Beulah scenario will result from population increases, initially during construction and later during operation of the facilities.

The initial major effect on the Beulah area will be caused by construction of the electric generating plant beginning in 1975, followed in 1977 by work on the first Lurgi gasification plant. The construction employment results in the sharply cyclical employment pattern of Table 9-27 (based on the employment multipliers in Table 9-28). Construction work in this scenario extends throughout the 1975-2000 time period, with the brief exception of 1988 and 1989. The entire employment-induced population change is assumed to occur within the existing towns and is allocated among those in Mercer, Oliver, and McLean Counties as well as the Bismarck-Mandan area.[1] The population estimates are shown in Table 9-29 and Figures 9-5 and 9-6.

Because of construction period peaks and the location of the plants in this scenario, Mercer County is expected to nearly double in population by 1985, fall to around 8,600 in 1990, rise to 14,000 in the mid-1990's, then level off at just over 10,000 by the end of the century. Beulah and Hazen, the largest towns in the county, will closely reflect this trend. The early scenario activity will take place in Oliver County, where the total population will increase rapidly until 1980, then gradually

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[1]Population changes were estimated by means of the economic base model (See Part II, Introduction) and the multipliers in Table 11-28. The overall estimates were allocated among those towns in the Beulah area within an hour's drive of each facility. The allocation model assumes that larger towns and closer towns should attract a greater proportion of new residents and balances the effects of population and commuting distance.

TABLE 9-27: CONSTRUCTION AND OPERATION EMPLOYMENT IN ENERGY DEVELOPMENT SCENARIO, 1975-2000 (person-years)

YEAR	CONSTRUCTION	OPERATION	TOTAL
1975	520	0	520
1976	2,560	0	2,560
1977	2,630	110	2,740
1978	2,870	630	3,500
1979	3,050	660	3,710
1980	3,600	1,570	5,170
1981	4,830	2,160	6,990
1982	2,690	2,410	5,100
1983	190	2,410	2,600
1984	790	2,400	3,190
1985	2,880	2,650	5,530
1986	4,830	3,240	8,070
1987	2,660	3,490	6,150
1988	0	3,490	3,490
1989	0	3,490	3,490
1990	30	3,490	3,520
1991	190	3,490	3,680
1992	790	3,490	4,280
1993	2,880	3,740	6,620
1994	4,830	4,330	9,160
1995	2,660	4,580	7,240
1996	190	4,580	4,770
1997	790	4,580	5,370
1998	2,880	4,830	7,710
1999	4,830	5,410	10,240
2000	2,600	5,660	8,260

Source: Carasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975.

TABLE 9-28: EMPLOYMENT AND POPULATION MULTIPLIERS

ENARIO

YEAR	SERVICE/BASIC EMPLOYMENT MULTIPLIERS[a]	
	OPERATION	CONSTRUCTION
1975 - 1979	0.5	0.3
1980 - 1984	0.7	0.5
1985 - 1989	1.0	0.7
1990 - 2000	1.2	0.7
ACTIVITY	**POPULATION/EMPLOYEE MULTIPLIERS[b]**	
Construction	2.05	
Operation	2.5	
Service	2.3	

[a]These values were selected after examining several studies concerning energy development in North Dakota and the Northern Great Plains, including Leholm, A., F.L. Leistritz, and J.S. Wieland. Profile of North Dakota's Coal Mine and Electric Power Plant Operating Work Force, Agricultural Economics Report No. 100. Fargo, N.D.: North Dakota State University, Department of Agricultural Economics, 1975; U.S., Department of the Interior, Bureau of Reclamation and Center for Interdisciplinary Studies. Anticipated Effects of Major Coal Development on Public Services, Costs, and Revenues in Six Selected Counties. Denver, Colo.: Northern Great Plains Resources Program, 1974; University of Denver, Research Institute. The Social, Economic, and Land Use Impacts of a Fort Union Coal Processing Complex, Final Report, for U.S., Energy Research and Development Administration. Springfield, Va.: National Technical Information Service, 1975. FE-1526; Luken, Ralph A. Economic and Social Impacts of Coal Development in the 1970's for Mercer County, North Dakota. Washington, D.C.: Old West Regional Commission, 1974; Dalsted, Norman L., et al. Economic Impact of Alternative Energy Development Patterns in North Dakota, for Northern Great Plains Resources Program. Fargo, N.D.: North Dakota State University, Department of Agricultural Economics, 1974; Argonne National Laboratory, Energy and Environmental Systems Division. Mercer County Case Study: The Economic Impacts, Draft Report. Argonne, Ill.: Argonne National Laboratory, 1976; See Summers, Gene F., et al. Industrial Invasion of Nonmetropolitan America. New York, N.Y.: Praeger, 1976, pp. 54-59 for a discussion of low multiplier effects in rural areas.

[b]Adapted from Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, December 1975. These multipliers represent aggregates of married couples with children, working wives, and single employees, not simply family sizes.

H

Valley

BEULAH SCENARIO AREA, 1975-2000[a]

		30	1985	1990	1995	2000
	40	2,300	4,000	2,200	4,800	2,400
	520	140	200	160	220	210
	270	1,600	2,400	1,000	4,100	2,600
	2,920	760	900	770	1,100	1,130
		450	800	360	600	500
		2,900	3,950	3,100	3,150	3,200
	6,400	8,150	11,250	8,600	14,000	10,050
	620	1,000	900	900	1,050	1,200
	100	130	150	140	190	210
	100	210	120	120	150	160
	1,380	1,600	1,650	1,700	1,750	1,800
	2,200	2,950	2,800	2,850	3,150	3,350
ean County						
Big Bend	100	125	140	140	170	240
Riverdale	700	900	1,000	1,000	950	1,300
Underwood	780	975	1,000	1,050	1,200	3,500
Washburn	800	1,100	1,100	1,100	1,350	1,900
Other	9,120	9,300	9,700	10,100	10,300	10,600
TOTAL	11,500	12,400	13,000	13,300	14,000	17,500
Bismarck-Mandan County						
TOTAL	46,900	56,500	59,100	60,000	67,200	75,700

[a]Natural increases of 0.8 percent through 1990 and 0.5 percent thereafter are included. Estimated population declines in this table assume that construction workers and their families will leave the area when construction employment does not carry over from year to year. Given the large amount of energy construction activity which might occur in the West, this assumption is as reasonable as its alternatives. Totals are rounded.

TABLE 9-27: CONSTRUCTION AND OPERATION EMPLOYMENT IN BEULAH ENERGY DEVELOPMENT SCENARIO, 1975-2000 (person-years)

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1981	4,830	2,160	6,990
1982	2,690	2,410	5,100
1983	190	2,410	2,600
1984	790	2,400	3,190
1985	2,880	2,650	5,530
1986	4,830	3,240	8,070
1987	2,660	3,490	6,150
1988	0	3,490	3,490
1989	0	3,490	3,490
1990	30	3,490	3,520
1991	190	3,490	3,680
1992	790	3,490	4,280
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1994	4,830	4,330	9,160
1995	2,660	4,580	7,240
1996	190	4,580	4,770
1997	790	4,580	5,370
1998	2,880	4,830	7,710
1999	4,830	5,410	10,240
2000	2,600	5,660	8,260

Source: Carasso, M., *et al.* *The Energy Supply Planning Model*, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975.

TABLE 9-28: EMPLOYMENT AND POPULATION MULTIPLIERS IN THE BEULAH SCENARIO

YEAR	SERVICE/BASIC EMPLOYMENT MULTIPLIERS[a]	
	OPERATION	CONSTRUCTION
1975 - 1979	0.5	0.3
1980 - 1984	0.7	0.5
1985 - 1989	1.0	0.7
1990 - 2000	1.2	0.7
ACTIVITY	POPULATION/EMPLOYEE MULTIPLIERS[b]	
Construction	2.05	
Operation	2.5	
Service	2.3	

[a]These values were selected after examining several studies concerning energy development in North Dakota and the Northern Great Plains, including Leholm, A., F.L. Leistritz, and J.S. Wieland. Profile of North Dakota's Coal Mine and Electric Power Plant Operating Work Force, Agricultural Economics Report No. 100. Fargo, N.D.: North Dakota State University, Department of Agricultural Economics, 1975; U.S., Department of the Interior, Bureau of Reclamation and Center for Interdisciplinary Studies. Anticipated Effects of Major Coal Development on Public Services, Costs, and Revenues in Six Selected Counties. Denver, Colo.: Northern Great Plains Resources Program, 1974; University of Denver, Research Institute. The Social, Economic, and Land Use Impacts of a Fort Union Coal Processing Complex, Final Report, for U.S., Energy Research and Development Administration. Springfield, Va.: National Technical Information Service, 1975. FE-1526; Luken, Ralph A. Economic and Social Impacts of Coal Development in the 1970's for Mercer County, North Dakota. Washington, D.C.: Old West Regional Commission, 1974; Dalsted, Norman L., et al. Economic Impact of Alternative Energy Development Patterns in North Dakota, for Northern Great Plains Resources Program. Fargo, N.D.: North Dakota State University, Department of Agricultural Economics, 1974; Argonne National Laboratory, Energy and Environmental Systems Division. Mercer County Case Study: The Economic Impacts, Draft Report. Argonne, Ill.: Argonne National Laboratory, 1976; See Summers, Gene F., et al. Industrial Invasion of Nonmetropolitan America. New York, N.Y.: Praeger, 1976, pp. 54-59 for a discussion of low multiplier effects in rural areas.

[b]Adapted from Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, December 1975. These multipliers represent aggregates of married couples with children, working wives, and single employees, not simply family sizes.

TABLE 9-29: POPULATION ESTIMATES FOR THE BEULAH SCENARIO AREA, 1975-2000[a]

LOCATION	1975	1980	1985	1990	1995	2000
Mercer County						
Beulah	1,350	2,300	4,000	2,200	4,800	2,400
Gold Valley	100	140	200	160	220	210
Hazen	1,240	1,600	2,400	1,000	4,100	2,600
Stanton	520	760	900	770	1,100	1,130
Zap	270	450	800	360	600	500
Rural	2,920	2,900	3,950	3,100	3,150	3,200
TOTAL	6,400	8,150	11,250	8,600	14,000	10,050
Oliver County						
Center	620	1,000	900	900	1,050	1,200
Ft. Clark	100	130	150	140	190	210
Hannover	100	210	120	120	150	160
Rural	1,380	1,600	1,650	1,700	1, 750	1,800
TOTAL	2,200	2,950	2,800	2,850	3,150	3,350
McLean County						
Big Bend	100	125	140	140	170	240
Riverdale	700	900	1,000	1,000	950	1,300
Underwood	780	975	1,000	1,050	1,200	3,500
Washburn	800	1,100	1,100	1,100	1,350	1,900
Other	9,120	9,300	9,700	10,100	10,300	10,600
TOTAL	11,500	12,400	13,000	13,300	14,000	17,500
Bismarck-Mandan County						
TOTAL	46,900	56,500	59,100	60,000	67,200	75,700

[a]Natural increases of 0.8 percent through 1990 and 0.5 percent thereafter are included. Estimated population declines in this table assume that construction workers and their families will leave the area when construction employment does not carry over from year to year. Given the large amount of energy construction activity which might occur in the West, this assumption is as reasonable as its alternatives. Totals are rounded.

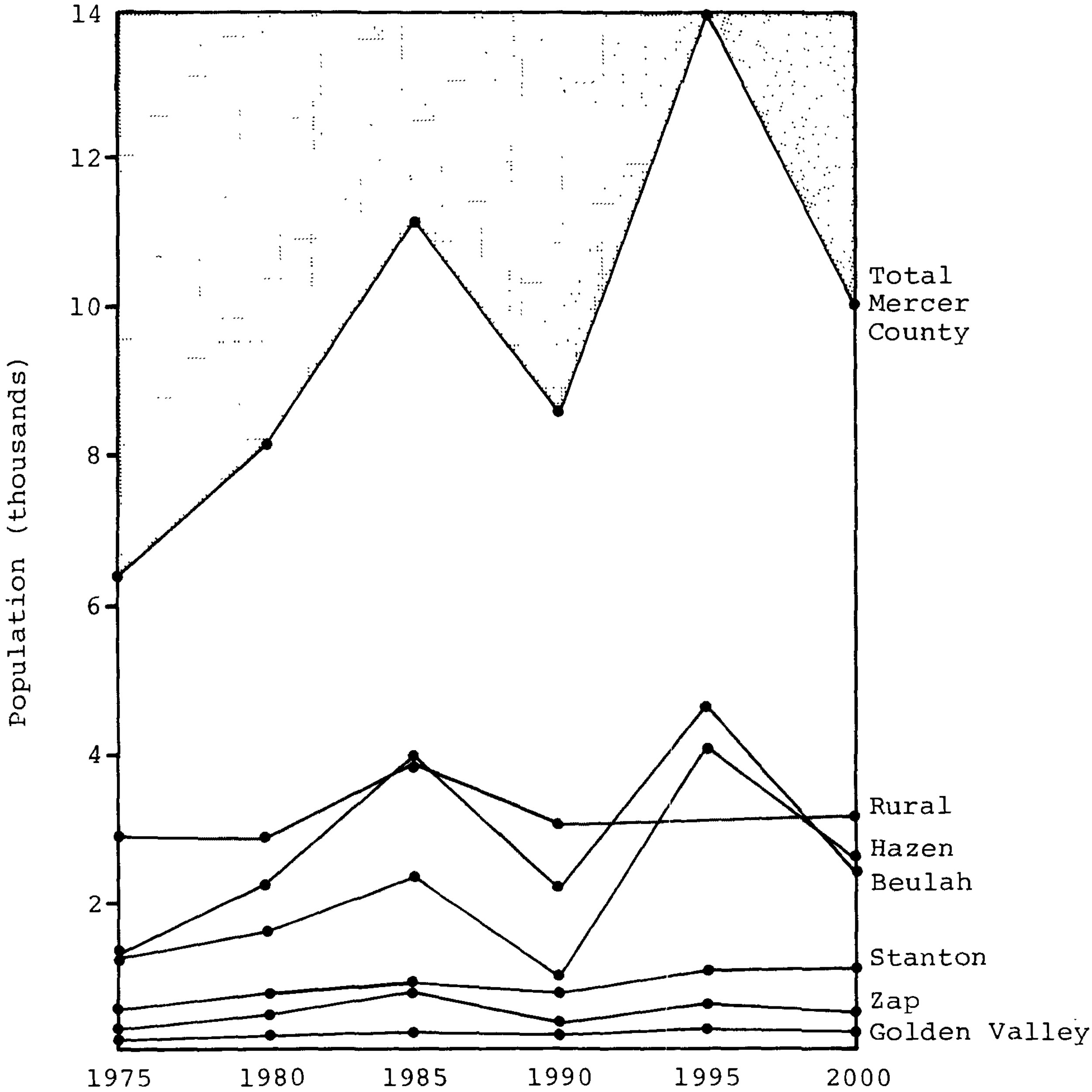

FIGURE 9-5: POPULATION ESTIMATES FOR BEULAH SCENARIO AREA, 1975-2000

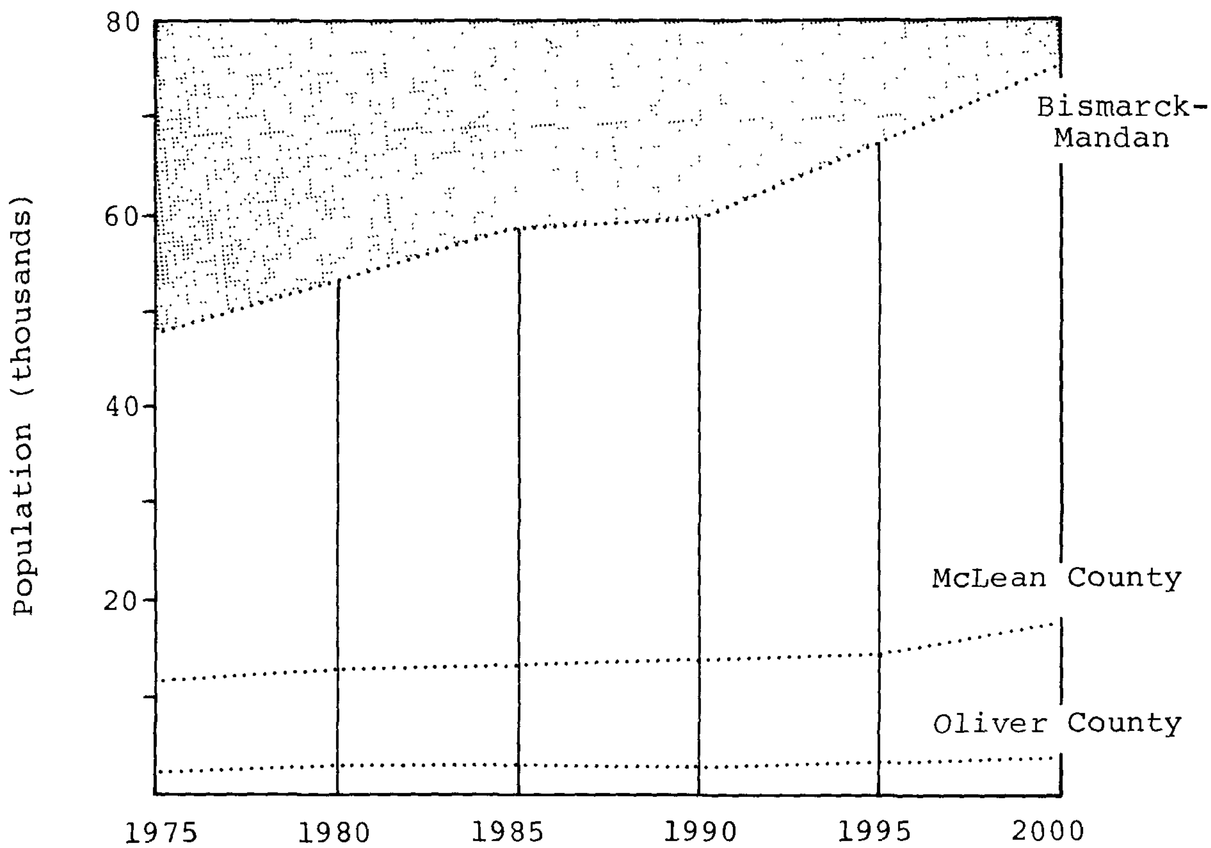

FIGURE 9-6: POPULATION ESTIMATES FOR OLIVER AND McLEAN COUNTIES, AND BISMARCK-MANDAN, 1975-2000

ch a population of about 3,350 by 2000. Much
ending lopment activity in Oliver County will focus on
decrease, energy d, which is expected to double in population to
of the Cation of McLean County, the site of the last
the town of ation facility, will increase by nearly 3,000
1,200. The 95. This increase will be concentrated in the
scenario good, which will grow by nearly a factor of 5 be-
people and 2000. Finally, the Bismarck-Mandan urban area
town of east should grow steadily to 75,700 (a 61-percent
tween ver the period. The largest absolute population growth
to t scenario is expected to occur in Bismarck and Mandan.

in-sex breakdowns of the projected population in Mercer allow estimates of housing and educational needs. Since the Beulah scenario developments will be located in County, the effects of the construction population booms at county are of particular interest. The 1970 age-sex ributions and data from community surveys in the West were d to estimate age-sex distributions for new employees and eir families.[1] The resulting distribution for Mercer County hows the effects of construction activity. During heavy construction periods (e.g., 1985 and 1995 in Table 9-30), the 20-34 age groups, particularly males, are predominant. However, other age groups also appear to vary in relation to the amount of energy construction.

B. Housing and School Impacts

Housing demand in the Mercer County area will be highly dependent on construction activity. The number of households in the county will reach a peak of 5,700 in 1995 but will level off to 4,200 in 2000; this compares to a 1975 level of 1,950 households (Figure 9-7, Table 9-31). The peak housing demands will be met largely by mobile homes, as is common in short-term situations. These homes will be located mainly in and around Beulah, the town most affected by the cyclical changes in population. If housing construction in the county keeps up with the projected needs, over 1,200 single-family and 500 multifamily units will be built by the year 2000 (Table 9-32). Currently, about 12 percent of the county's housing consists of mobile homes,[2] a proportion

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[1]Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, December 1975.

[2]Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

TABLE 9-30: PROJECTED AGE-SEX DISTRIBUTION FOR MERCER COUNTY, 1975, 2000[a]

AGE	1975	1980	1985	1990	1995	2000
Female						
65-Over	.057	.032	.020	.036	.018	.024
55-64	.061	.040	.033	.059	.035	.068
35-54	.115	.105	.121	.180	.133	.204
25-34	.051	.110	.130	.072	.131	.066
20-24	.027	.042	.047	.018	.041	.015
17-19	.020	.022	.023	.012	.019	.012
14-16	.035	.024	.019	.031	.020	.025
6-13	.091	.067	.055	.061	.050	.050
0-5	.050	.044	.026	.016	.025	.017
TOTAL	.507	.486	.474	.485	.472	.481
Male						
65-Over	.051	.029	.021	.038	.020	.027
55-64	.065	.044	.037	.067	.041	.079
35-54	.118	.116	.140	.206	.155	.235
25-34	.054	.128	.152	.077	.153	.067
20-24	.019	.044	.054	.011	.044	.009
17-19	.023	.025	.023	.008	.019	.010
14-16	.030	.021	.019	.032	.020	.025
6-13	.083	.063	.054	.061	.050	.050
0-5	.050	.044	.026	.016	.025	.017
TOTAL	.493	.514	.526	.516	.527	.519

Source: Table 9-29 and Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1975.

Totals do not always sum to 1.0 because of rounding.

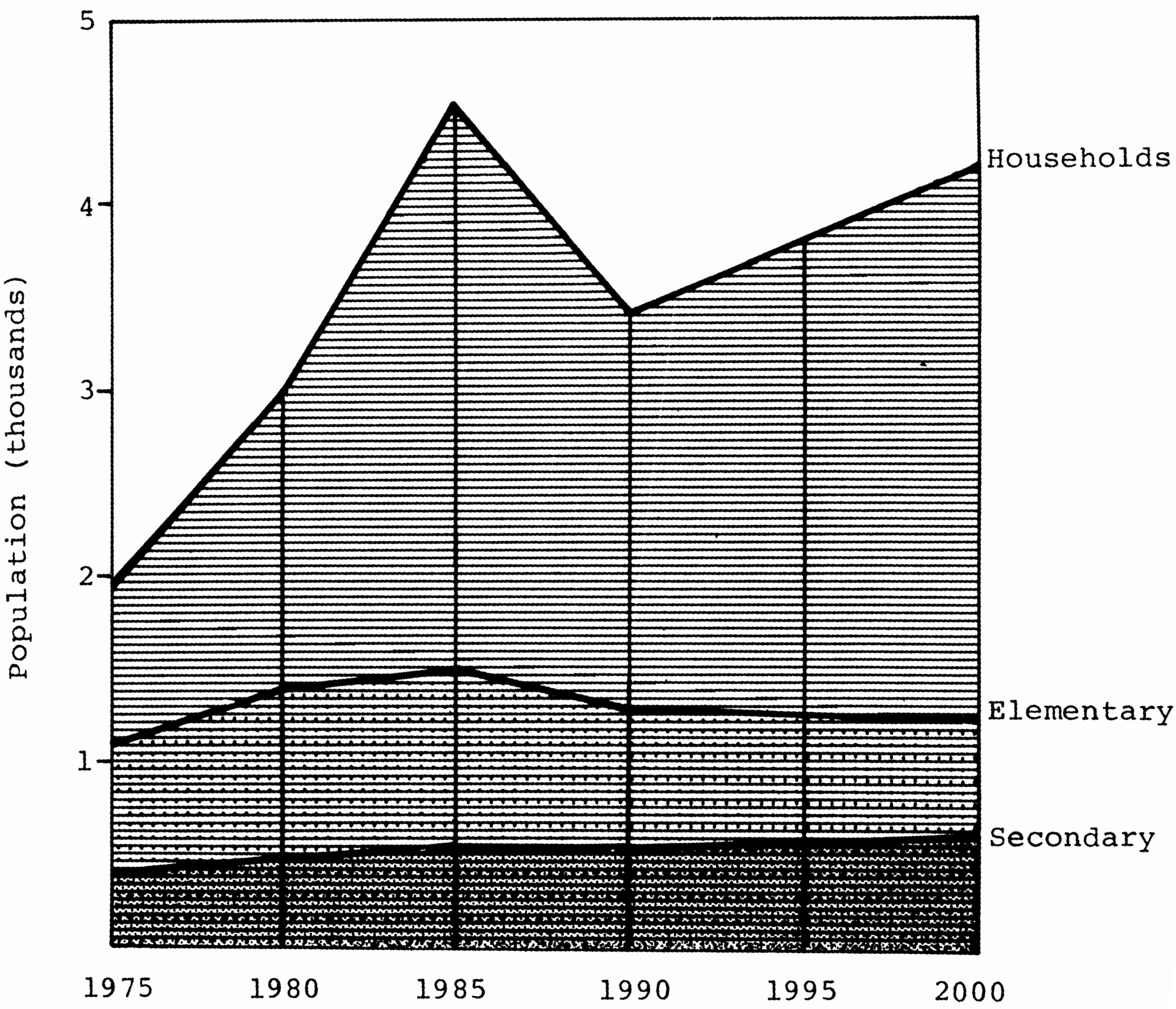

FIGURE 9-7: PROJECTED NUMBER OF HOUSEHOLDS, ELEMENTARY, AND SECONDARY SCHOOL CHILDREN IN MERCER COUNTY, 1975-2000

TABLE 9-31: NUMBER OF HOUSEHOLDS AND SCHOOL ENROLLMENT IN MERCER COUNTY, 1975-2000

YEAR	NUMBER OF HOUSEHOLDS[a]	NUMBER OF ELEMENTARY SCHOOL CHILDREN[b]	NUMBER OF SECONDARY SCHOOL CHILDREN[c]
1975	1,950[d]	1,100[d]	400[d]
1980	3,000	1,400	480
1985	4,500	1,500	540
1990	3,400	1,300	540
1995	5,700	1,750	690
2000	4,200	1,250	620

[a]Includes single-person households, which are about 20 percent of the total.

[b]Ages 6-13 plus 25 percent adjustment to improve estimates.

[c]Ages 14-16 plus 25 percent adjustment to improve estimates.

[d]Estimated.

TABLE 9-32: DISTRIBUTION OF NEW HOUSING NEEDS BY TYPE OF DWELLING[a]

PERIOD	MOBILE HOME	SINGLE-FAMILY	MULTI-FAMILY	OTHER[b]
1975-1980	420	410	130	90
1980-1985	580	610	180	120
1985-1990[c]	-890	0	0	-210
1990-1995	850	190	360	300
1995-2000[c]	-860	0	-140	-300

[a]Compiled from Table 9-31 and data adapted from Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1975, p. 103.

[b]For example, campers and recreational vehicles.

[c]Negative values indicate dwelling removal, under the assumption that mobile homes will be the first to be removed during periods of population decline.

that would more than triple in such peak construction years as 1985 and 1995.

School enrollment impacts show another trend, with differences in timing between elementary and high schools (Table 9-31). The overall peak will be reached in 1995, when over 2,400 students will be enrolled (72 percent in elementary schools). In terms of the school financial situation, the current surplus of 30 classrooms would allow any need through 1990 to be met with current facilities (Table 9-33). A short-term need for 15 additional classrooms in 1986 and in the 1990's suggests that low-cost temporary classrooms or double sessions could largely solve the demand problem without building any new, permanent schools. Annual operating expenditures for schools in Mercer County should be almost double the present $1.5 million level during the 1990's; however, the average annual budget during the scenario period should be less than 50 percent above current expenditures. The Bismarck-Mandan school districts will have to build over 200 classrooms at a cost of over $14 million because those districts are already operating near their capacities.

C. Economic Impacts

The economy of the Beulah area is still predominantly agricultural, particularly Oliver County where 58.8 percent of 1972 personal income was derived from agriculture. The 1972 levels for McLean and Mercer Counties were 42.0 percent and 27.2 percent, respectively. In that year, the mining, construction, and utility industries were already important to Mercer County, providing 38 percent of personal income for its inhabitants.[1] As energy developments increase in the area, additional lands will be taken out of agricultural production, but employment opportunities in energy-related sectors will expand. Consequently, the Mercer County economy should become even more energy dependent, and the other counties will also see a percentage decline in their reliance on agriculture.

Largely because of the change in industry mix areawide, the income distribution will rise to reflect the higher paying employment[2] opportunities for both local residents and newcomers. For example, in Mercer County the highest incomes will occur during the 1986 and 1995 construction booms, when nonlocals will be a

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[1]U.S., Department of Commerce, Bureau of Economic Analysis. "Local Area Personal Income." Survey of Current Business, Vol. 54 (May 1974, Part II), pp. 1-75.

[2]In recent years, high agricultural prices have resulted in high farm incomes, often exceeding the projected energy operation salaries. Over the long term, however, energy occupations will be higher paying.

TABLE 9-33: SCHOOL FINANCE NEEDS FOR MERCER COUNTY AND BISMARCK-MANDAN, 1975-2000

COUNTY	YEAR	ENROLLMENT INCREASE OVER 1975	CLASSROOMS AT 21 STUDENTS PER ROOM[a]	NEW CAPITAL EXPENDITURES (millions of dollars)[b]	NEW OPERATING EXPENDITURES (millions of dollars)[c]
Mercer	1975	1,500	101[d] (71)		
	1980	380	101 (89)	0.0	0.49
	1985	540	101 (97)	0.0	0.70
	1990	340	101 (87)	0.0	0.44
	1995	940	116	0.84	1.22
	2000	370	101 (89)	0.0	0.48
Bismarck-Mandan	1975	12,300	407[d]		
	1980	2,100	507	5.25	2.73
	1985	2,600	531	6.50	2.38
	1990	2,800	540	7.00	2.64
	1995	4,100	600	10.25	4.35
	2000	5,700	676	14.25	6.43

[a]Numbers in parentheses are classroom needs, which are at times less than the 101 currently available.

[b]Assuming an average of $2,500 per pupil space. See Froomkin, Joseph, J.R. Endriss, and R.W. Stump. Population, Enrollment and Costs of Elementary and Secondary Education 1975-76 and 1980-81, Report to the President's Commission on School Finance. Washington, D.C.: Government Printing Office, 1971. Data from that source were inflated to 1975 dollars.

[c]Assuming $1,300 per pupil; see Argonne National Laboratory, Energy and Environmental Systems Division. Mercer County Case Study: The Economic Impacts, Draft Report. Argonne, Ill.: Argonne National Laboratory, 1976, Appendix A. An overall average of about $1,000 per pupil was inflated to 1975 dollars.

[d]Actual number in 1974 from Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

TABLE 9-34: PROJECTED INCOME DISTRIBUTION FOR MERCER COUNTY, 1975-2000
(in 1975 dollars)

INCOME	1975[a]	1980	1985	1990	1995	2000
Less than $4,000	.188	.105	.074	.097	.066	.082
4,000- 5,999	.122	.071	.053	.067	.049	.058
6,000- 7,999	.114	.065	.045	.061	.042	.052
8,000- 9,999	.087	.072	.063	.075	.066	.075
10,000-11,999	.084	.089	.092	.094	.095	.097
12,000-14,999	.110	.117	.119	.140	.130	.136
15,000-24,999	.234	.381	.434	.389	.439	.407
25,000-over	.061	.100	.119	.094	.112	.093
Median Household	9,700	14,500	16,200	14,300	16,200	15,000

Source: Tables 9-24, 9-25, and 9-26 and Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, December 1975.

[a]U.S., Department of Commerce, Bureau of the Census. Household Income in 1969 for States, SMSA's, Cities, and Counties: 1970. Washington, D.C.: Government Printing Office, 1973.

large part of the labor force (Table 9-34). A projected overall rise of over 50 percent in median income by 2000 includes the expansion of the local economy and employment of local people as well as immigrants to the area.

The increases in the service sector will be concentrated in local retailing activities, particularly in Beulah. Beulah, Hazen, Underwood, and Washburn currently serve as local trade centers, whereas Mandan and Bismarck are the regional centers for wholesale and retail activity.[1] The primary change expected from energy development is a growing predominance of Beulah in the Mercer-Oliver-McLean county area. Because of the attraction of Bismarck and Mandan, no major secondary industries are expected to locate near Beulah.

Mercer County communities must provide public services for the increased population. Beulah and Hazen, in particular, will require extensive additions to their water and sewage treatment

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[1]Owens, Wayne W., and Elmer C. Vangsness. Trade Areas in North Dakota, Extension Bulletin No. 20. Fargo, N.D.: North Dakota State University, Cooperative Extension Service, 1973.

facilities through 1985 (Table 9-35).[1] Facilities capable of meeting the 1985 demands should be adequate through 2000, except for the 1995 construction boom. The Bismarck-Mandan area also will have an early capital need (before 1980) for over $22 million, which will become somewhat more gradual for the rest of the period. Other capital needs, especially for health care facilities, will demand considerable expenditures, as indicated in Table 9-35.

In terms of operating expenditures, Beulah's municipal budget should triple to nearly $600,000 during the peak construction years. Hazen will be affected much the same as Beulah in absolute terms, which means a much greater proportional growth (Table 9-36). Since energy developments will be located in rural areas and the associated population will settle in the towns, some revenues will not add directly to the tax base of impacted towns.

The temporary removal of land from agriculture, the availability of well-paying jobs, and the expansion of towns in the Beulah area will combine to change the region into a more diverse economy. The early boom will cause planning and budgetary difficulties for the towns nearby, although revenues should be sufficient for needs.[2] Most long-term benefits will accrue to the Bismarck-Mandan area, where wholesale and retail activity will expand to serve the increased population.

D. Fiscal Impacts

North Dakota has recently enacted significant changes in the collection and disbursement of taxes on energy facilities. The new severance tax applies to the mining of coal, while the new privilege tax applies to the conversion of coal to other energy forms. (Thus, operators will have some incentive to "strip and ship" and avoid the privilege tax, rather than process or use the coal at the mine site.)

The Beulah scenario envisions an annual production of 60.3 million tons of coal by the end of the century, a 3,000 MWe power plant (full production by 1980), and four assorted gasification

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[1]Actually both towns have some unused capacity, so that early needs will be somewhat less. See Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

[2]Leistritz, L., A.G. Leholm, and T.A. Hertsgaard. "Public Sector Implications of a Coal Gasification Plant in Western North Dakota," in Clark, Wilson F., ed. Proceedings of the Fort Union Coal Field Symposium, Vol. 4: Social Impacts Section. Billings, Mont.: Eastern Montana College, 1975, pp. 429-42.

TABLE 9-35: PROJECTED NEW CAPITAL EXPENDITURE REQUIRED FOR PUBLIC SERVICES IN SELECTED NORTH DAKOTA COMMUNITIES, 1975-2000 (in thousands of 1975 dollars)

PUBLIC SERVICES	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000
Beulah					
Water and Sewage	1,670	2,990	0	1,408	0
Law Enforcement	17	30	0	14	0
Other	544	974	0	458	0
Hazen					
Water and Sewage	986	1,056	0	2,992	0
Law Enforcement	10	11	0	30	0
Other	321	344	0	974	0
Bismarck-Mandan					
Water and Sewage	16,900	4,580	1,584	12,670	14,960
Law Enforcement	170	46	16	128	150
Other	5,500	1,490	516	4,126	4,870

Source: Water and sewage plant requirements amount to $1,760,000 for each additional 1,000 population; $17,730 is required for law enforcement capital costs; and $573,000 goes for other physical plant needs, broken down as follows: parks and recreation (33 percent); hospital (46 percent); libraries (5 percent); fire protection (5 percent); administration (3 percent); and public works (8 percent). Streets and roads are not included as municipal capital costs. See THK Associates, Inc. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1975, p. 30. All data from that source are inflated to 1975 dollars. See also Lindauer, R.L. Solutions to Economic Impacts on Boomtowns Caused by Large Energy Developments. Denver, Colo.: Exxon Co., USA, 1975, pp. 43-44.

TABLE 9-36: NECESSARY OPERATING EXPENDITURES OF MUNICIPAL GOVERNMENTS IN SELECTED COMMUNITIES, 1980-2000[a] (dollars)

YEAR	BEULAH	HAZEN	BISMARCK-MANDAN
1980	114,000	67,000	1,152,000
1985	318,000	139,000	1,464,000
1990	102,000	91,000	1,572,000
1995	414,000	343,000	2,436,000
2000	126,000	163,000	3,456,000
Current (1974) Budget[b]	143,850	10,950	12,417,206

[a]Above 1975 base level, based on population given in Table 9-29 and a figure of $120 per capita, broken down as follows: highways (25 percent); health and hospitals (14 percent); police (7 percent); fire protection (12 percent); parks and recreation (6 percent); libraries (4 percent); administration (10 percent); sanitation and sewage (10 percent); and other (12 percent). See THK Associates, Inc. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974.

[b]Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

plants to come on-line between 1982 and 2000. Applying current tax rates to the projected incremental increases, revenues likely to arise from these energy developments are:

- Coal Mining. The severance tax is $0.50 per ton.[1] The authorizing legislation makes explicit provision for keeping up with inflation; thus, the $0.50 figure can be used throughout, in terms of 1975 currency. With the production levels of this scenario, the severance tax yields the following revenues:[2]

1980	1985	1990	1995	2000	
$12.3	$17.8	$20.5	$25.3	$30.1	(millions)

- Electrical Generation. The tax rate is one-fourth mill per kWh. For a 3,000 MWe plant at 70 percent load factor, the tax would amount to $4.6 million per year. The assumptions are that one-fourth of this rate will be achieved in 1977-1978, one-half in 1979, and the full rate thereafter.

- Gasification. Conversion facilities pay either 2.5 percent of gross receipts or $0.10 per Mcf, whichever is greater. Taking the $0.10 rate, each gasification facility will generate revenues of $8.2 million per year.

- Property Taxes. Although the privilege tax stands in lieu of ad valorem taxes on conversion facilities, coal mines are still subject to property taxes. In North Dakota, the average current assessment ratio is 17 percent, the legal taxable value ratio is 50 percent, and the average mill levy is 174 (17.4 percent).[3] All these factors are effectively multiplied together to yield a true tax rate of 1.48 percent of market value. During the scenario time frame, five surface mines will be inaugurated at a total development cost of $493 million. Applying the 1.48 percent rate to these facilities, property tax revenues will grow as follows:

1980	1985	1990	1995	2000	
$3.03	$4.38	$4.99	$6.14	$7.30	(millions)

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[1]Bronder, Leonard D. Taxation of Coal Mining: Review with Recommendations. Denver, Colo.: Western Governors' Regional Energy Policy Office, 1976; and Stenehjem, Erik. Intra-Laboratory Memo. Argonne National Laboratory, February 9, 1976.

[2]Distribution will be considered after all revenues are listed.

[3]Stenehjem. Intra-Laboratory Memo.

- Distribution. The new tax laws take cognizance of those jurisdictional problems occurring in other energy-rich areas. In most of the other scenarios, the county in which facilities are located has reaped the most significant portion of the revenues, while other jurisdictions have had to provide extra services without the benefit of new taxes. North Dakota has, instead, largely supplanted the property tax with new formulas designed to spread revenues over a variety of governmental units.

  The severance tax is distributed into the following shares:

  - 35 percent of the Coal Development Impact Office (see Section F. Political and Governmental Impacts).

  - 30 percent to the state general fund.

  - 5 percent to the county of origin.

  - 30 percent to the state trust fund.

After legislative appropriation, the impact development office has wide latitude in disbursing these funds to any local units impacted by coal development. The trust fund, administered by the board of university and school lands, is to be held in perpetuity. However, income from this fund can be paid to the state general fund. The Beulah scenario should result in an accumulation of $133 million by the end of the century. An income of 5 percent, then, would make another $6.6 million available to the state beyond its 30-percent share.

The coal conversion tax is distributed as follows:

- 90 percent to the state general fund.

- 4.5 percent to the schools in originating county.

- 4.0 percent to the county general fund.

- 1.5 percent to the towns in the originating county.

School and town allocations must be prorated on the basis of attendance and population, respectively.

In recent years, Mercer County has been allocating 51 percent of tax revenues to the general fund, 48 percent to schools, and 1 percent to a state medical fund.[1] This is assumed to continue.

These various taxes will be applied to the full complement of energy facilities (five mines, an electric station, and four gasification plants), and the revenues will be distributed by formula. The net result, by jurisdiction, is given in Table 9-37.

These revenues appear adequate to yield an overall net surplus. However, the state government will capture most of this new revenue and will also benefit from income and sales taxes (not calculated here). In addition, the towns are only guaranteed $560,000 per year by the end of the century; their solvency depends on allocations from the Coal Development Impact Office (which operates within the office of the governor).[2] That source can cover all municipal fiscal impacts if allocated with that goal in mind. Local property taxes might even be reduced with no real decline in the ability to provide government services in the long term.

E. Social and Cultural Impacts

The removal of land from agricultural production for strip mining will be difficult for some farmers, but the compensation from the mining activity, as well as the jobs made available, will be welcomed by many. The steady out-migration from the Beulah area in recent years would be turned around, an event that would also be favored by most residents.[3] Judging from recent experiences, a large part of the labor force for energy development

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[1]U.S., Department of the Interior, Bureau of Reclamation and Center for Interdisciplinary Studies. Anticipated Effects of Major Coal Development on Public Services, Costs, and Revenues in Six Selected Counties. Denver, Colo.: Northern Great Plains Resources Program, 1974.

[2]They may also benefit from commercial and residential property taxes and utility fees not calculated here.

[3]Bickel, D., and C. Markell. "Problems and Solutions Related to Measuring Regional Attitudes Toward Coal Development and Life Styles in the Eastern Williston Basin," in Clark, Wilson F., ed. Proceedings of the Fort Union Coal Field Symposium, Vol. 4: Social Impacts Section. Billings, Mont.: Eastern Montana College, 1975, pp. 421-28.

TABLE 9-37: ALLOCATION OF TAXES LEVIED DIRECTLY ON ENERGY FACILITIES, MERCER COUNTY (millions of 1975 dollars)

JURISDICTION	1980	1985	1990	1995	2000
State General Fund[a]	8.1	18.2	28.1	38.6	49.4
Impact Development Office	4.3	6.2	7.2	8.9	10.5
County General Office	2.3	3.6	4.3	5.6	6.7
School Districts	1.6	2.7	3.3	4.2	5.2
Towns	0.1	0.2	0.3	0.4	0.6
Total	16.4	30.9	43.2	57.7	72.4

[a]Including medical fund and income from trust fund (at 5 percent).

will be made up of local people.[1] Many other workers are likely to be North Dakotans, and at least one-third of all employees will be from outside the Northern Great Plains. Nonlocal employment of such skilled workers as pipefitters and electricians is even more likely, up to levels of 70 percent and higher.[2]

Major uncertainty exists concerning the extent to which the local housing construction industries will be able to supply single-family and multifamily homes. A shortage of homes and subsequent reliance on mobile homes would be unpleasant to many families arriving in the Beulah area. Medical care will also be a problem for the scenario area, where only four doctors are available between Mandan and Dickinson (70 miles southwest of Beulah), two of whom are affiliated with a 39-bed hospital at Hazen.[3] Government policy is generally unable to induce doctors

[1]Leholm, A., F.L. Leistritz, and J.S. Wieland. Profile of North Dakota's Coal Mine and Electric Power Plant Operating Work Force, Agricultural Economics Report No. 100. Fargo, N.D.: North Dakota State University, Department of Agricultural Economics, 1975.

[2]Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, December 1975, pp. 14-19.

[3]Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

to settle in small communities when there are ample opportunities in more attractive places,[1] although loan forgiveness programs have had some success.[2] For example, Underwood, Stanton, and Center currently have no doctors, and projected population growth will create the need for physicians in these towns. The Bismarck-Mandan area currently has 91 doctors but could need as many as 50 more by 2000. The urban areas clearly will have much less difficulty attracting physicians than the rural towns.

F. Political and Governmental Impacts

The population increases expected in the Beulah scenario will create a general need for more local government resources. None of the towns in the area has a full-time mayor or city manager,[3] but the planning needs during the energy boom may provide sufficient impetus to change that. Zoning and subdivision regulations, building codes, and mobile home park design standards already exist to guide local expansion and permanent construction in municipalities.

A major uncertainty in the scenario area is the extent to which the local housing construction industry will be able to cope with increasing demand for single-family and multifamily homes. At present, North Dakota does not have an administrative organization at the state level to assist in the establishment and financing of necessary housing in rural areas; the state also does not have a housing financing agency or corporation whose specific purpose is to assist in securing mortgage money for traditional lending institutions. A program designed to administer bonds and related fiscal mechanisms could be made operational through the Bank of North Dakota, but the statutory authority usually granted to state housing finance corporations is lacking. Consequently, growth communities are unable to use many national

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[1]Lankford, Phillip L. "Physician Location Factors and Public Policy." Economic Geography, Vol. 50 (July 1974), pp. 244-55.

[2]Coleman, Sinclair. Physician Distribution and Rural Access To Medical Services, R-1887-HEW. Santa Monica, Calif.: Rand Corporation, 1976.

[3]Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. Socioeconomic Impacts and Federal Assistance in Energy Development Impacted Communities in Federal Region VIII. Denver, Colo.: Mountain Plains Federal Regional Council, 1975.

and federal financial sources for housing that are available to other states.[1]

Besides problems of housing, county and local governments will be hard-pressed to provide the range of services that traditionally falls within the scope of their responsibilities. Mitigation of negative impacts in facilities and services categories will depend largely on the availability of front-end capital and the ability of government to plan for such impacts. As noted in the fiscal analysis, existing debt ceilings in Beulah and Hazen are not adequate if these localities are to cope with projected demands. Consequently, the fiscal solvency of these two communities, as well as others in the scenario area, depends largely on the distribution of funds from the recently created Coal Development Impact Office. The Office administers the revenues collected from the state severance tax on coal. By statute, the Coal Development Impact Office has the authority to formulate a plan to provide financial aid to local governments in coal development areas and to make grants to counties, cities, school districts, and other taxing districts. Decisions regarding the amount of an impact grant awarded to an eligible political subdivision must consider the amount of revenues which the local governments will gain from other tax sources.[2] Clearly, the office will play an important role in facilitating responses to service demands within the state's energy-impacted communities because it has responsibility for determining not only which community will receive aid but also how much assistance each will receive. As presently organized, the program leaves local administrators and officials in a state of uncertainty as to whether they should prepare proposals and whether they will indeed receive funds for projects they propose. Also uncertain is the Office's budget, at least in the long-term.[3]

As well as affecting the governmental institutions and processes in the scenario area, energy development can be expected to affect the political activity and attitudes of the residents. Although little information exists concerning the effects on local government of population influences associated specifically with energy development, conflicts between newcomers and area natives may produce noticeable effects on a community. Energy development workers are a potential political force because their

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[1]Rapp, Donald A. Western Boomtowns, Part I, Amended: A Comparative Analysis of State Actions, Special Report to the Governors. Denver, Colo.: Western Governors' Regional Energy Policy Office, 1976.

[2]North Dakota Century Code §§ 57-62-04 (Cumulative Supp. 1975).

[3]The Coal Development Impact Program was scheduled to last until June 30, 1977 unless renewed by the state legislature.

socioeconomic characteristics are generally associated with higher than average involvement in politics.[1] Also, they generally have urban viewpoints that conflict with the rural viewpoints of the local government personnel. (In this scenario area, as in most of the West, the present county governments are controlled by agricultural interests.) If long-time residents are willing to compromise with new interests (e.g., by channeling the increased revenues toward support of increased local services and amenities), then conflicts between the two groups may be minimized.

9.4.5 Summary of Social and Economic Impacts

Manpower requirements and taxes levied on the energy facilities are major causes of social and economic impacts. For the mines, manpower requirements for operation exceed peak construction manpower requirements. However the reverse is true for the conversion facilities; peak construction manpower requirement exceeds the operation requirement by 5 to 7 times. In combination, total manpower requirement for each mine-conversion facility increases from the first year when construction begins, peaks, and then declines as construction activity ceases. Total manpower required for operation of the plant-mine combination is about the same for each scenario facility and its associated mine.

A property tax and sales tax which are tied to capital costs, severance tax and royalty payments which are tied to the value of coal, and an energy conversion tax which is tied to the energy produced generate revenue for the state and local government. Capital costs of the conversion facilities and mines hypothesized for the Beulah scenario in millions of 1975 dollars are about 1,200 for each of the mine-gasification facilities and 1,500 for the mine-power plant facility. The property tax is levied at a rate of about 1.48 percent on total capital costs, and the sales tax is levied at a rate of 4 percent on materials and equipment. In addition, the severance tax is levied at a rate of 5 percent on the value of the coal mined. Royalty payments for federally owned coal are about 12.5 percent. All royalties are retained by Indian tribes for coal on the reservation. The energy conversion tax is levied at a rate of 0.25 mill per kWh on the power plant and $0.10 per Mcf on the gasification plants. No energy conversion tax is collected from facilities on Indian reservations.

Energy development in the Beulah area, especially strip mining and coal gasification, will cause population shifts over a three-county area focusing on Beulah and greater expansion in

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[1]For a discussion of the characteristics that are usually associated with a high level of involvement in political affairs, see Flanigan, William H. Political Behavior of the American Electorate, 2nd ed. Boston, Mass.: Allyn and Bacon, 1972.

the Bismarck area. The greater population influxes will accompany facilities construction in 1985 and 1995-2000. If facilities are constructed according to the hypothesized schedule, an overall increase of 40,000 people in the area is expected by 2000, nearly 30,000 of which will probably live in the Bismarck-Mandan area. Temporary housing, particularly mobile homes, will have to provide shelter for construction boom periods. Mobile homes could become more permanent fixtures if the local homebuilding industry cannot provide the single-family and multifamily units that could be demanded by the year 2000.

School enrollment in Mercer County will be greatest in 1995 but will remain at least 50 percent above 1975 levels through the rest of the century. This indicates an average annual budget increase for schools in the county of about $2 million over current levels. New classroom needs will be small in comparison with other scenarios studies; the Bismarck-Mandan urban area will receive the greatest long-term impact, requiring 270 classrooms and $14 million in capital expenditures.

Agriculture's dominant position in the economy of the Beulah area will be replaced by coal-related sectors. New job opportunities will allow many local people and former North Dakotans to take energy development positions. As a result, median income in the area will rise about 50 percent over the 1975 level, although short-term peaks will occur during construction periods. In wholesale and retail services, Bismarck-Mandan will see increases in activity, while Beulah and Hazen may expand as local retail centers. Combined with increases in population, these economic changes may result in new political alignments and leadership.

Municipal services and related expenditures must increase substantially to provide the necessary services, which will be concentrated exclusively in the towns. Medical care is a particular problem area, especially since it is difficult to attract doctors to nonmetropolitan locations. For example, the need for doctors by 2000 in the Beulah area will be difficult to meet under current trends. Planning for and managing energy development-related impacts may require full-time professional personnel in local governments, rather than the current part-time nonprofessionals.

9.5 ECOLOGICAL IMPACTS

9.5.1 Introduction

The area evaluated in the Beulah scenario extends southward to the Heart River, eastward past the Missouri River, northward 10 miles beyond Lake Sakakawea (Garrison Reservoir), and westward to the Badlands of the Little Missouri. Most of the land is gently rolling prairie, crossed by a few streams. The climate is semiarid, with extreme annual variations in temperature.

Climate (especially winter weather), topography, and soil types largely determine the nature of the native biota and its productivity. Agriculture has markedly altered the natural grassland ecosystem, reducing both the diversity and abundance of wildlife.

9.5.2 Existing Biological Conditions

Two major native biological communities are found in the area, each with characteristic animal and plant species indicated in Table 9-38. The more extensive is the mixed mid- and short-grass prairie that forms a nearly complete ground cover in upland areas.[1] More than half of this area is under cultivation, principally for wheat or forage crops, and the remainder is grazed. Antelope are important game species in the area. Black-footed ferrets are thought to be present but have not been confirmed. Both small birds and larger birds of prey are numerous.[2] The peregrine falcon formerly bred on buttes and escarpments in the prairie habitat type but is now thought to be extinct as a breeding bird in North Dakota. Thousands of water-fowl nest and stop during migration on the many small lakes and marshes (an important duck production area).

The second major community is a variable woodland with its major development along the Missouri River Floodplain and tributaries.[3] The complex physical structure of these woodland areas, which provide a wide variety of nesting or denning sites and food sources, promotes a diversity of animal life, including a

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[1]Characteristic grassland herbs such as lupine, goldenrod species, and blazing-star, as well as silver sage, rabbitbrush, and other shrubs, lend diversity to the vegetation but do not contribute significantly to overall productivity or cover.

[2]Bird faunas include a number of typical prairie species, including western meadowlark, horned lark and lark bunting, golden eagle, Swainson's hawk, marsh hawk, red tailed hawk, kestrel, merlin, prairie falcon, and burrowing owl. Upland game birds include sharptail grouse and Hungarian partridge. The ring-necked pheasant is particularly characteristic of agricultural areas.

[3]The bottomland forest consists of climax stands of green ash, American elm, box elder, and burr oak, with successional stands dominated by willow and cottonwood.

TABLE 9-38: SELECTED CHARACTERISTIC SPECIES OF MAJOR BEULAH SCENARIO BIOLOGICAL COMMUNITIES

COMMUNITY	CHARACTERISTIC PLANTS	CHARACTERISTIC ANIMALS
Grassland/cropland mosiac	Needle and thread grass Western wheatgrass Blue grama Little bluestem Silver sage Blazing-star	Pronghorn antelope Jackrabbit species Ground squirrel species Badger Meadowlark Golden eagle Marsh hawk Short-horned lizard
Riparian woodlands	Cottonwood Green ash American elm Burr oak Willow species Buffaloberry	Whitetail deer Porcupine Tree squirrel Skunk Mink Flycatchers Leopard frog Garter snake

wide variety of birds.[1] Typical mammals of woodlands habitats include porcupine, shrews, and whitefooted mice. Many predators and omnivores, including the red fox, mink, weasel, striped skunk, and raccoon, prefer the wooded floodplain or ravine habitats where there is both cover and a variety of prey. Game animals include wild turkey, cottontail rabbit, tree squirrels, and whitetailed deer, which also range into the prairies adjacent to the major stream courses. To the west, along the course of the Little Missouri River, lies an area of eroded badland topography.

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[1]Birds include large numbers of insect eaters such as the vireos, wrens, and flycatchers. The bald eagle once nested along the Missouri River, and an active nest was reported in 1975 for McLean County, within the study area, although it subsequently failed.

Although beyond the immediate scenario area, these badlands may potentially have high recreational use.[1]

Aquatic communities in the scenario area vary from small lakes in the glaciated prairie to the large impoundments on the Missouri River and its tributaries. Fisheries are principally of the warm-water type, except within and below reservoirs, where both warm-water and cold-water species occur. The Missouri River between Lakes Oahe and Sakakawea is considered to be one of the outstanding sport fisheries of the Great Plains.

The biota described above is subject to several man-made stresses which may intensify throughout the study period. Chief among these influences is the expansion of cultivated land since the early 1960's. Substantial reductions have occurred in the floodplain forest of the Missouri between Lake Sakakawea and Lake Oahe. Draining wetlands and eliminating fencerow vegetation has reduced cover for small animals and water fowl. Agriculture also contributes sediment, pesticides, and nutrients from fertilizers, through runoff, and most impoundments in the western part of the state (except main stem reservoirs) are now heavily contaminated with nutrients (eutrophic).[2] Damming the Missouri River has reduced flooding and meandering. This change has apparently reduced productivity in the floodplain forest and promotes the replacement of successional cottonwood and willow stands by hardwoods.[3]

9.5.3 Factors Producing Impacts

Four factors associated with construction and operation of the scenario facilities (a power plant, two Lurgi and two Synthane gasification plants, and their associated mines) can cause ecological impacts: land use, population increases, water use and

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[1]Despite the harshness of the environment, wildlife is diverse within the badlands. Species for which these areas constitute especially high-quality habitat include mule deer, cottontail rabbit, and bighorn sheep (introduced in the 1950's and now present in huntable numbers). Many hawk and falcon species find good nesting habitat in the rugged terrain, as does the golden eagle. Prairie dog distribution follows the grassland portions of the badlands, and a black-footed ferret was sighted near Medora in 1973.

[2]Henegar, D.L. "Fisheries Division, Western District and Statewide Research Report." North Dakota Outdoors, Vol. 38 (No. 7, 1976), pp. 18-20.

[3]Johnson, W.C., R. L. Burgess, and W.R. Kaemmerer. "Forest Overstory Vegetation and Environment on the Missouri River Floodplain in North Dakota." Ecological Monographs, Vol. 46 (Winter 1976), pp. 59-84.

water pollution, and air quality changes. With the exception of land use, the quantities of each of these factors associated with the scenario facilities were given in previous sections of this chapter. Land-use quantities are given in this section, and the others are summarized. Land use by each type of facility proposed for the Beulah area is given in Table 9-39. During the 30-year facility lifetime, 15,000 acres are used by a gasification plant-mine combination. Energy developers have already leased existing farmland to be used for surface coal mining.[1]

Manpower requirements associated with construction and operation of the scenario energy facilities will cause an increase in the urban population in the scenario area. Peak total manpower requirement is about 5,600 for each gasification plant-mine combination and 3,200 for the power plant-mine combination. After facility construction is completed, manpower required for operation of each facility is about 1,100.

Water for the scenario facilities operating at the expected load factor range from 4,891 (Lurgi plant) to 23,884 acre-ft/yr (power plant) assuming high wet cooling (Table 9-16). The water source for the facilities, Lake Sakakawea, has an average annual discharge of 15,576,750 acre-ft/yr and minimum discharge of 956,340 acre-ft/yr (Table 9-12). Effluents from the energy facilities will be ponded and will contaminate surface water or groundwater only if pond liners leak or erode. The annual concentration of SO_2 in the plant vicinity will range from 0.7 (Lurgi plant) to 1.8 $\mu g/m^3$ (power plant and mine). Typical and peak concentrations of criteria pollutants from the power plant-mine combination will be well below all federal and most state ambient standards. Only the North Dakota 1-hour SO_2 and NO_2 standards will be violated; however, the NO_2 standard will be exceeded by a factor of 7. Typical and peak concentrations of criteria pollutants from the Lurgi and Synthane facilities are not expected to exceed any federal ambient air standards, although the state 1-hour NO_2 standard may be exceeded by the Synthane plants.

9.5.4 Impacts

The nature of the ecological impacts caused by these factors depends on the plant and animal community type on which they are imposed. For example, the impact of land use depends on whether grassland or shrubland communities are being used. Some of the land-use trends are now evident or could occur regardless of energy-related growth. A scenario, which calls for power, Lurgi, and Synthane plants and their associated mines to be developed

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[1]Johnson, Jerome E., Robert E. Beck, and Cameron D. Sillers. The North Dakota Farmer/Rancher Looks at Severed Mineral Rights, Agricultural Economics Miscellaneous Report No. 18. Fargo, N.D.: North Dakota State University, Department of Agricultural Economics, 1975.

TABLE 9-39: LAND USE BY SCENARIO FACILITIES AT BEULAH

FACILITY	LAND USE[a]	
	ACRES/YEAR	ACRES/30 YEARS
Conversion Facilities		
Power Plant (3,000 MWe)		2,400
Lurgi or Synthane Gasification Plant (250 MMcfd)[b]		805
Associated Surface Coal Mine		
For Power Plant (19.2 MMtpy)	840	25,200
For Lurgi Plant (10.8 MMtpy)	500	15,000
For Synthane Plant (9.6 MMtpy)	500	15,000

MWe = megawatt-electric
MMcfd = million cubic feet per day
MMtpy = million tons per year

[a]The land used by the mines will increase every year by the amounts given in the table for 30 years, the lifetime of the facilities. However, the land occupied by the plants will not vary after construction is completed.

[b]Two Lurgi and two Synthane plants are hypothesized for the Beulah area, but data is given for one Lurgi or one Synthane plant and its associated mine.

according to a specified time schedule (see Table 9-1) is used here as the vehicle through which the extent of the impacts are explored. Impacts caused by land use, population increases, water use and water pollution, and air quality changes are discussed.

A. To 1980

Most of the early ecological impacts will be due to construction activities. By 1980, land use by the urban population and the power plant (the only plant on-line by 1980) will be 4,035 acres, which is 0.2 percent of the total acres in Mercer, Oliver, and McLean Counties (Table 9-40). Table 9-41 shows that energy facilities and urban population are expected to use grassland/cropland habitat. Nearly 50 percent of the land in Mercer, Oliver, and McLean Counties is cropland and about 50 percent is grassland used for grazing. Based on this 1.1 ratio of cropland (for cultivation) to grassland (for grazing), it is assumed in Table 9-41 that one-half of land use associated with energy development (Table 9-39) will be cropland and one-half will be grassland. If so, forage which could be produced on 2,018 acres (50 percent of land used by 1980) would support 55 cows with calves and 3 sheep

TABLE 9-40: LAND USE IN THE BEULAH SCENARIO AREA (in acres)[a]

		1975	1980	1990	2000
By Energy Facilities					
Conversion Facilities					
Power Plant (3,000 MWe)			2,400	2,400	2,400
1st Lurgi Plant (250 MMcfd)				805	805
2nd Lurgi Plant (250 MMcfd)				805	805
1st Synthane Plant (250 MMcfd)					805
2nd Synthane Plant (250 MMcfd)					805
Associated Surface Coal Mines					
For Power Plant (19.2 MMtpy)				8,400	16,800
For 1st Lurgi Plant (10.8 MMtpy)				4,000	9,000
For 2nd Lurgi Plant (10.8 MMtpy)				1,500	6,500
For 1st Synthane Plant (9.6 MMtpy)					2,500
For 2nd Synthane Plant (9.6 MMtpy)					
Subtotal			2,400	17,910	40,420
By Urban Population[b]					
Mercer County					
Residential		320	410	430	500
Streets		64	82	86	100
Commercial		8	10	10	12
Public and Community Facilities		20	25	27	31
Industry		32	41	43	50
Subtotal		444	568	596	693
Oliver County					
Residential		110	150	140	170
Streets		22	30	28	34
Commercial		3	4	3	4
Public and Community Facilities		7	9	9	10
Industry		11	15	14	17
Subtotal		153	208	194	235
McLean County					
Residential		575	620	665	875
Streets		115	124	133	175
Commercial		14	15	16	21
Public and Community Facilities		36	38	41	54
Industry		58	62	66	88
Subtotal		798	859	921	1,213
Subtotal		1,395	1,635	1,711	2,141
Total Land Use		1,395	4,035	19,621	42,561
Total Land In Beulah Scenario Area	2,449,920				
Mercer County	666,880				
Oliver County	1,321,600				
McLean County	461,440				

MWe = megawatt-electric MMcfd = million cubic feet per day MMtpy = million tons per year

[a]Values in each column are cumulative for year given.

[b]Acres used by the urban population were calculated using population estimates in Table 9-29 for Mercer, Oliver, and McLean Counties assuming: residential land = 50 acres per 1,000 population; streets = 10 acres per 1,000 population; commercial land = 1.2 acres per 1,000 population; public and community facilities = 3.1 acres per 1,000 population; and industry = 5 acres per 1,000 population. Adapted from THK Associates. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974.

TABLE 9-41: HABITAT LOSS OVER TIME IN THE BEULAH SCENARIO AREA[a]
(acres)

HABITAT	1980	1990	2000	POST 2000[a]
Grassland/ Cropland	4,035	19,621	42,561	92,961
Valley Shrublands and Forests	160	260	290	2,080

[a]Assumes that land use by urban population and scenario facilities given in Table 9-39 will primarily occur on grassland or cropland in Mercer, Oliver, and McLean counties. Land use by transmission lines and water supply lines (not included in Table 9-39) are included in this table.

in a year (Table 9-42).[1] By comparison, Mercer County had an inventory of 53,125 cattle and calves and 2,192 sheep and lambs in 1974.[2] The impact of lost cropland on yield will vary with weather conditions and with potential improvements in cultivation practices or plant varieties.[3] Using the current figure of 25 bushels per acre, the loss of 2,018 acres of cropland would reduce yield by a maximum of 50,450 bushels, assuming all cropland was in

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[1]Grazing value of land is usually estimated in terms of acres per Animal Unit Month (AUM). An AUM is defined as the amount of forage required to support one cow and calf, or five sheep, for a month. AUM's relate only to production of forage used by sheep and cattle; differences in food habits make the unit inappropriate for wildlife. An average of 3 acres per AUM was assumed for calculations.

[2]U.S., Department of Commerce, Bureau of the Census, 1974 Census of Agriculture; Preliminary Report, Mercer County, North Dakota. Washington, D.C.: Government Printing Office, 1976.

[3]It has been suggested that North Dakota wheat yields could rise from 25 to 112 bushels per acre through such improvements. Stewart, Robert E., Jr., Alan Golbert, and Jerome Johnson, eds. Conference on the Future of Agriculture in Southwestern North Dakota, Held at Dickenson State College, Dickenson, May 1973, Little Missouri Grassland Study, Interim Report No. 3. Fargo, N.D.: Little Missouri Grassland Study, 1973.

TABLE 9-42: AGRICULTURAL PRODUCTION FOREGONE

PERIOD	ACRES LOST[a]	YIELD FOREGONE[b] (bushels)	ANIMAL EQUIVALENTS[c]	
			COWS/CALVES	SHEEP
1980	4,035	50,450	55	3
1990	19,621	245,275	270	14
2000	42,561	532,025	585	30
Post-2000	92,961	1,162,025	1,278	65
Mercer-Oliver county production 1974[d]		2,086,300	90,922	1,359
Cululative loss as percent of county production		56%	1%	2%

[a]Acres lost are cumulative for each year given until the energy facilities stop operation (after their 30-year lifetime). Since 50 percent of the land in Mercer, Oliver, and McLean counties is cropland and 50 percent is grassland, it is assumed that acres lost will be 50 percent cropland and 50 percent grassland.

[b]Assuming all cropland is in wheat.

[c]Assuming 99 percent of all animal units are cattle, 1 percent sheep. Carrying capacity of 3 acres of forage per Animal Unit Month (for one cow with calf or five sheep) assumed for calculations.

[d]Livestock inventory and wheat figures from U.S., Department of Commerce, Bureau of the Census. <u>1974 Census of Agriculture; Preliminary Report, Mercer County, North Dakota</u>. Washington, D.C.: Government Printing Office, 1976.

wheat (Table 9-42). By contrast, 1,361,547 bushels of wheat were harvested in Mercer County in 1974.[1]

The relatively small amount of habitat removed directly in this part of the scenario time frame is expected to have only locally adverse impacts on wildlife, mostly small species. A possible exception is the pronghorn antelope. Beulah lies in the center of an area of high-quality habitat, and the disturbance resulting from the construction of the power plant may cause some animals to avoid the area.

The presence of large construction forces has been correlated with increases in illegal big game hunting. However, in the Beulah area, almost all land is owned privately, and most landowners will probably post their lands as the first construction forces move into the area. While a certain amount of trespassing will probably occur, poaching is not expected to reduce the reproductive capacity of game populations. In this respect, the Beulah scenario differs from other scenarios where large amounts of unpatrolled public lands exist.

Construction populations will also increase the demand for legal hunting and fishing. While upland game (sharptail grouse, pheasant, Hungarian partridge, and cottontail) populations will probably be able to withstand this, increased use of the publicly owned game management areas may call for additional controls. The supply of deer, antelope, and turkey may not be sufficient to meet potential hunting demand.

By 1980, manpower required for construction of facilities will have caused an increase in the population in Mercer, Oliver, and McLean Counties to 23,500, a 19 percent increase over the 1975 population. Population increases are expected to occur primarily in Beulah and the small nearby towns. Ecological impacts associated with population increases will not be significant by 1980.

Fisheries in the area are maintained by stocking, and the hatcheries presently supplying this area of North Dakota have slack capacity. Thus, existing fisheries are probably adequate to supply the increased demand of the 1975-1980 period.

If a reservoir of 11,000 acre-feet capacity is constructed on the Knife River to supply the Lurgi plant, the area's fishery potential will be changed. Situated upstream of the industrial sites, the reservoir would not be subject to siltation problems resulting from construction. The reservoir would trap sediment

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[1]U.S., Department of Commerce, Bureau of the Census. 1974 Census of Agriculture; Preliminary Report, Mercer County, North Dakota. Washington, D.C.: Government Printing Office, 1976.

from the upper portion of the Knife River drainage which, in conjunction with controlled releases downstream, could help alleviate sedimentation problems in the lower Knife caused by either industry or agriculture. The lake itself would probably support a warm-water sport fishery. The river's present populations of sauger, walleye, pike, and channel cat would benefit from stabilization of downstream flows.

Population growth in the Beulah area may result in discharges of municipal sewage effluent, at least temporarily, into the Knife River and Heart Butte Creek. Such discharges typically have large concentrations of dissolved oxygen. Depending on the quantities discharged and the base flow in the stream, these pollutants could cause serious problems for several miles downstream. Nuisance blooms of algae and lowered dissolved oxygen levels could result. If all of the towns affected by population booms were to discharge into the Knife or its tributary, Spring Creek, pollutants might have a localized impact on the Missouri River.

Ecological impacts associated with water use and pollution (from the facilities) and air quality changes will not be significant by 1980.

B. To 1990

By 1990, the power and two Lurgi plants will be on-line. Land use by the urban population and energy facilities will total 19,621 acres, 0.8 percent of the land in Mercer, Oliver, and McLean Counties (Table 9-40). Forage which could be produced on grassland used (assuming 50 percent of land used by 1990 is grassland) would support 270 cows with calves and 14 sheep (Table 9-42). The cropland foregone (assuming 50 percent of land used by 1990 is cropland and assuming wheat is planted on all cropland used) would support 245,275 bushels of wheat (Table 9-42).

Habitat fragmentation due to urban and industrial growth around Beulah will probably begin by the end of the second scenario decade, affecting, for example, more than half of the high-quality antelope habitat around Beulah. The number of antelope using this area will decline, and the regional populations will reflect the loss of this key area. Deer using this same area will probably also show local declines because the Knife River Valley and Spring Creek are key habitats, providing food and protection from severe winter weather. The cyclical nature of unemployment could induce some workers to remain in the Beulah area between construction peaks, and ready access to deer populations, especially in winter, could make game poaching attractive. Antelope might also suffer, although their wideranging habits make access more difficult. If poaching becomes widespread, the number of deer and antelope that could safely be harvested by legitimate hunters would decrease.[1]

Demand for hunting and fishing will continue to increase over the 1980-1990 decade. Fishing pressure could exceed the capacity of existing hatcheries, but the two large reservoirs on the Missouri will probably continue to meet demands for fishing, expecially if recent introduction of such open-water fish as coho, lake trout, and lake whitefish are successful. Upland gamebirds could become somewhat scarcer around Beulah and Bismarck-Mandan. Continued expansion of cropland and reduction of fencerow and roadside cover will also lower production of small game during the 1980-1990 time frame (particularly ring-necked pheasant, Hungarian partridge, and sharptail grouse). Demand for big game hunting will exceed supply by a growing margin.

Human population size will fluctuate markedly between 1980 and 1990, exhibiting two distinct peaks: one around 1981 and one around 1986. By 1990, urban population in Mercer, Oliver, and McLean Counties will be 24,750, a 23 percent increase over 1975 population. Increased populations will place greater demands on the more accessible outdoor recreational resources of the area. On or adjacent to the two mainstem Missouri reservoirs, most continuing human activity will be confined to specific public access areas, although displacement of game onto private land during hunting seasons is likely. Deterioration of plant communities due to recreational use is more likely to occur in the Little Missouri Badlands. Depending on the access and use restrictions placed on these lands by the Forest Service, there is a potential for serious erosion problems arising from vehicle use. Even with stringent regulations, a certain amount of illegal use of off-road vehicles is likely to occur due to the difficulty of enforcing regulations over such an extensive area. Presently, the Little Missouri channel is used in winter as a snowmobile course. Additional use, proportional to population increases, could place a potential stress on deer.[2]

Population peaks of the early and middle 1980's could result in temporary discharges of municipal sewage effluents into the Knife River and Spring Creek. Impacts of such discharge could be exacerbated in the 1980-1990 time frame if mine dewatering and runoff control results in lowered base flow in these two streams.

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[1]Because illegal hunting takes pregnant females and non-breeding young, it can reduce the number of breeding adults.

[2]A recently published study on white-tailed deer suggests that increased movement such as may be caused by harassment could occasion substantial increases in energy expenditures. Moen, A.N. "Energy Conservation of White-Tailed Deer in the Winter." Ecology, Vol. 57 (Winter 1976), pp. 192-98.

The extent and seriousness of nutrient enrichment problems depend both on the amount and character of effluents discharged and on the base flows of affected streams.

Water use and air quality changes associated with energy development are not expected to cause significant ecological impacts by 1990.

C. To 2000

By 2000, all of the scenario facilities hypothesized for the Beulah area will be on-line. Land use by urban population and energy facilities will be 42,561 acres, 1.7 percent of total acres in Mercer, Oliver, and McLean Counties (Table 9-40). Forage which could be produced on grassland used would support 585 cows with calves and 30 sheep; cropland used could be cultivated to yield 532,025 bushels of wheat (Table 9-42).

Ecological impacts associated with land use and population increase by 2000 will be similar to those described for 1990. Beulah and Hazen will be centers of the high construction population in 1995. By 2000, the urban population in Mercer, Oliver, and McLean Counties is expected to be 30,900, a 54 percent increase over 1975 population (Table 9-29).

Ecological impacts caused by water use and water pollution associated with energy development will be similar to those described by 1990.

Emissions of criteria air pollutants under most conditions will not result in ground-level concentrations likely to produce chronic damage to range or cropland vegetation. SO_2 concentrations similar to those causing chronic damage to wheat under experimental conditions may occur for brief periods. Therefore, SO_2 emissions are not likely to significantly limit crop or forage yields. The addition of sulfur to mineral cycles as particulate fallout or rain washout might be beneficial in sulfur-deficient soils of the area.[1]

Trace elements, including mercury, fluorine, lead, arsenic, zinc, copper, and uranium, will be emitted chiefly from the power

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[1]Painter, E.P. "Sulfur in Forages." North Dakota Agricultural Experiment Station Bimonthly Bulletin, Vol. 5 (No. 5, 1943), pp. 20-22.

plants.[1] These elements will eventually enter the crop and grassland mineral cycles, but their pathways through the ecosystem are not well known. Therefore, the exact impact of their introduction cannot be predicted. Trace element buildup in both soils and vegetation has been recorded downwind of several power plants, but consequent toxic effects have not been documented.

D. After 2000

During the 30-year lifetime of the energy facilities, land use by the urban population and energy facilities will total 92,961 acres, 4 percent of the land in Mercer, Oliver, and McLean counties. Forage which could be produced on grassland used would support 1,278 cows with calves and 65 sheep in a year, which is 1 percent of cows with calves and 2 percent of sheep in the 1974 inventory of Mercer and Oliver counties (Table 9-42). Wheat which could be cultivated on cropland used would be 1,162,025 bushels, 56 percent of the wheat harvest in Mercer and Oliver counties in 1974 (Table 9-42).

Of the 92,961 acres used, 7,761 acres will be permanently lost to urban population and facility structures and 85,200 will be used by mining. The long-term ecological impact of mining will depend on the success with which these lands are reclaimed. The climate of North Dakota is generally favorable for reclamation, and several land-use options are possible.[2] Restoration of mined areas for use as cropland is typically attractive because of its relatively low cost. It is also possible to restore these mined areas to a mixed-grass prairie, consisting (at least in part) of native species, and suitable for grazing. Normal succession to a mature grassland in similar areas takes 15-20 years after

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[1]Some North and South Dakota lignites have locally high concentrations of uranium, in excess of 0.1 percent. Swanson, Vernon F., et al. Composition and Trace Element Content of Coal, Northern Great Plains Area, U.S., Department of the Interior Report 52-83. Washington, D.C.: Government Printing Office, 1974, p. 7.

[2]Sandoval, F.M., et al. "Lignite Mine Spoils in the Northern Great Plains: Characteristics and Potential for Reclamation." Paper presented before the Research and Applied Technology Symposium on Mined Land Reclamation. Pittsburgh, Pa.: Bituminous Coal Research, Inc., 1973.

disturbance.[1] Wildlife habitat values can be restored for many upland game species by the use of woody plantings for food and cover.[2]

The resemblance between reclaimed mined areas and early stages of grassland development may result in colonization by species which typically characterize early stages of grassland development, such as various ground squirrels, the western harvest mouse, and horned lark. In mature grasslands and successful reclaimed areas, antelope, sharptail grouse, jack-rabbits, and a variety of small birds (typified by the chestnut-collared longspur) are characteristically predominant. However, species adapted to croplands will differ little from those which may be expected to colonize newly reclaimed areas.

Certain overburden characteristics could potentially limit the success of reclamation, at least locally. High sodium levels occur in some of the strata overlying several existing mines in western North Dakota, and the problem appears to be widespread over the lignite fields of the Fort Union Formation.[3] Unless carefully buried, these layers could inhibit plant growth and prove highly susceptible to erosion. Further, even if buried, increased infiltration of water leaching through the unconsolidated spoil material could bring salts from these layers to the surface.

Ecological impacts after 2000 associated with population increases, water use and water pollution, and air quality changes will be similar for those prior to 2000.

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[1]Aikman, J.M. "Secondary Plant Succession on Muscatine Island, Iowa." Ecology, Vol. 11 (June 1930), pp. 577-88; Tolstead, W.L. "Plant Communities and Secondary Succession in South-Central South Dakota." Ecology, Vol. 22 (July 1941), pp. 322-28.

[2]Early experience at the Knife River Coal Company's Beulah mine has shown that upgraded spoil piles, planted with a mixture of wildlife food plants, are abundant in upland species such as grouse, pheasant, and rabbits, which typically suffer heavy losses because of winter storms. Large numbers of white-tailed deer from the adjacent Knife River Valley also shelter in the area intermittently. Legal provisions requiring that spoils be graded to resemble the original topography under these circumstances reduces potential value for wildlife.

[3]Packer, Paul E. Rehabilitation Potentials and Limitations of Surface-Mined Land in the Northern Great Plains, General Technical Report INT-14. Ogden, Utah: U.S., Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1974.

9.5.5 Summary of Ecological Impacts

Four factors associated with construction and operation of the scenario facilities can significantly affect the ecological impacts of energy development: land use, population increases, water use and water pollution, and air quality changes. Land use by the urban population and energy facilities during the 30-year lifetime of the facilities will total 92,961 acres, 4 percent of the total acres in Mercer, Oliver, and McLean counties. By 2000, urban population in these counties is expected to be 30,900, a 54 percent increase over the 1975 population. Water required for the scenario facilities (operating at the expected load factor and assuming high wet cooling) will be 46,000 acre-ft/yr which represents 5 percent of the minimum discharge and 0.3 percent of the average annual discharge of the water source, Lake Sakakawea. Effluents from the energy facilities will be ponded to prevent water pollution. Typical and peak concentrations of criteria pollutants from the plants are not expected to cause significant ecological impacts.

Table 9-43 summarizes the effects of the ecological impacts on the area's game species, rare or endangered species, and selected indicators of ecological change.

The major scenario influences on deer and antelope populations in the area are expected to be localized habitat fragmentation and, possibly, illegal harvest. This will probably be more important for area-wide antelope population because changes will occur to the less plentiful quality habitat.

Upland game is expected to begin a localized decline in the early 1980's. Wild turkey, with harvests carefully controlled by the state of North Dakota, will probably not show major declines attributable to the scenario. However, many species are likely to experience regionwide reductions in numbers as a result of clearing grasslands, wetlands, and river bottoms for agriculture.

Endangered species, including bald eagles and peregrine falcons that are occasionally seen in the area, may be adversely affected by the scenario. Both species are subject to illegal shooting. Bald eagles also tend to be sensitive to human disturbance within 1 or 2 miles of a nest; increased human population and activity along the Missouri could therefore reduce the likelihood of restoring a breeding population of eagles. The number of peregrines visiting the area is probably controlled by conditions in their breeding range; consequently, the potential impact of illegal shooting in the Beulah area on the number of birds seen there from year to year is difficult to specify.

The black-footed ferret is known to be in the area from a recent sighting near Medora but has not been located in the Beulah vicinity. The major threat to this species, aside from

TABLE 9-43: FORECAST OF POPULATION STATUS OF SELECTED SPECIES FOR THE BEULAH SCENARIO[a]

	1980	1990	2000
Game Animals			
Antelope	Slight to moderate decline in density in Beulah area	Moderate decline throughout Beulah area, possible reduction in huntable populations	Marked decline throughout Beulah area, definite reduction in huntable populations
White-tailed deer	Little change or slight decline in density in Beulah area	Slight decline in areawide populations, if illegal kills are high around Beulah. Possible slight decline in the Little Missouri Badlands if heavy recreational use	Areawide numbers continued slightly below 1975 levels from habitat fragmentation, poaching, and recreational use in the Badlands. If mined lands reclaimed for wildlife, some deer may winter there
Sharptail Grouse, Hungarian Partridge, Pheasant	Little change	Slight declines in density around Beulah	Continued slight to moderate decline in areawide numbers unless mined lands are extensively reclaimed for wildlife values
Cottontail Rabbit	Little change	Little change areawide, local declines where strip mining eliminates habitat	Little change areawide, local declines from mining, count balanced by reclamation if adequate cover is provided
Rare or Endangered Species			
National Level			
Peregrine Falcon	Little change	Possible loss of individuals due to illegal shooting	Possible loss of individuals due to illegal shooting
Black-footed Ferret	Little change, unless directly displaced by mining or facilities siting[a]		
Bald Eagle	Little change	Likelihood of reestablishing nesting pair along the Missouri River may be reduced	Likelihood of reestablishing nesting pair along the Missouri River may be reduced
Other Uncommon Species			
Northern Kit Fox (swift fox)	Little change	Possible loss of individuals through trapping and hunting for predators	Possible loss of individuals through trapping and hunting for predators

TABLE 9-43: (Continued)

	1980	1990	2000
Prairie Falcon, Ferruginous Hawk, Prairie Merlin	Possible loss of breeding individuals due to illegal shooting		
Burrowing Owl	Possible localized losses due to habitat loss, probably not of a regional significance[a]		
American Osprey	Little change[a]		
Indicators of Ecological Change			
Mining and Reclamation			
Jackrabbit, Chestnut-collared Longspur, Ferruginous Hawk	Little change	Local losses where strip mining eliminates habitat, continued low numbers on lands reclaimed for cropland	Continued local losses from mining. Return (in later stages of succession) to areas reclaimed to grazing land.
Horned Lark	Little change	May become the dominant bird on reclaimed lands in early stages of succession, and lands reclaimed for crops	Continued dominance on early succession reclamation landscapes, lowered dominance on late succession grasslands and areas reclaimed for wildlife
Thirteen-lined Ground Squirrel	Little change	If conditions favor burrowing may become abundant on reclaimed lands in early stages of succession	Continued abundance on successional lands, increasing as soil structure develops and improves conditions for burrowing
Eutrophication			
Largemouth Bass	If dissolved oxygen concentrations fall below 4 milligrams per liter, bass will either avoid polluted waters, or will be smaller in size		

[a]This chart reflects the influence of the energy developments only. Continued expansion of cultivation under present U.S. Department of Agriculture policy will occasion additional impacts.

direct destruction of habitat, would be through reduction of prairie dog numbers by varmint hunters.

The endangered Northern Kit (swift) Fox is susceptible to traps set for other species and is mistaken for a young coyote by hunters. With increased numbers of people participating in these activities, this species could be reduced in numbers or lost altogether.

Table 9-44 summarizes the major factors producing ecological impacts in the Beulah scenario area. These have been grouped into three classes, based on their geographic extent and the number of species they affect.

SO_2 pollution is given a Class C rating because its impact on vegetation, measured as productivity, will be at least an order of magnitude less than the effects of normal year-to-year variations in climatic factors and grazing pressure. The impact of land-use changes on agricultural production will likewise be small, usually less than 0.1 percent of county totals.

Most of the impacts of rising human populations fall into Class B, namely: illegal shooting, increased use of delicate badlands areas, and discharge of sewage treatment plant effluents into surface waters. Conversion of native rangeland to cropland as mining and reclamation proceed is also included. These impacts rate higher in severity because they can potentially alter the size of areawide populations of some animals or bring about shifts in community composition in habitats of restricted occurrence.

Class A impacts are considered to be the pivotal problems responsible for the projected animal population impacts discussed above. In the Beulah scenario, habitat removal, fragmentation, and the incidental disturbances coincident with urban growth cluster within an area of high-quality wildlife habitat. Most critically, these impacts are difficult to manage.

9.6 OVERALL SUMMARY OF IMPACTS AT BEULAH

The intended energy benefit from the hypothetical developments in the Beulah area will be production and export of 3,000 MWe of electricity and 1 billion cubic feet per day of synthetic natural gas by the year 2000. Locally, the benefits include increases in retail trade, income to residents, state and local governments, and secondary economic development.

Social and economic impacts associated with energy development in the Beulah area tend to be a function of the labor and capital intensity of developments and, when multiple facilities are involved, of scheduling their construction. These factors determine the pace and extent of migration of people to the

TABLE 9-44: SUMMARY OF MAJOR FACTORS AFFECTING ECOLOGICAL IMPACTS

IMPACT CATEGORY	1975-1980	1980-1990	1990-2000
Class A	Direct removal and fragmentation of habitat Zones of urban activity	Direct removal and fragmentation of habitat Zones of urban activity	Direct removal and fragmentation of habitat Zones of urban activity
Class B	Illegal shooting Discharge of municipal sewage effluents	Illegal shooting Discharge of municipal sewage effluents Excessive recreational use of badlands Conversion of native range to cropland via reclamation	Illegal shooting Excessive recreational use of badlands Conversion of native range to cropland via reclamation
Class C	Grazing, crop losses	SO_2 emissions Grazing, crop losses	SO_2 emissions Grazing, crop losses
Enhancing some species	Reservoir on the Knife River	Reservoir on the Knife River	Reservoir on the Knife River

scenario area as well as the financial and managerial capability of local governments to provide services and facilities for the increased population. Labor forces increase the population directly and indirectly. More labor is required for construction of the facilities than for operation; thus suitable scheduling can minimize population instability. The power plant-mine combination is less labor intensive than the gasification facilities. Taxes which apply to the energy facilities (a property tax, sales tax, severance tax, royalty payments, and energy conversion tax) will generate revenue for local, state, and federal governments. Solutions to problems concerning who gets the revenue benefits and who provides public services and facilities needed by the increased population in the scenario area involve all levels of government and their ability to relate to each other. North Dakota's state government will financially assist growing communities by giving them a portion of revenue obtained from mineral leasing and severance taxes. Impacts will be difficult to handle in small communities which do not have sufficient planning capacities to manage growth. Many of these impacts would be mitigated if people who have migrated out of the area returned and were hired along with some local unemployed laborers (to meet the manpower requirements for energy facility construction and operation).

If all of the facilities hypothesized are constructed, social, economic, and political changes in the 3-county area will stem primarily from the overall 40 percent growth in population. The distribution of this growth will determine the severity of the impacts. The new jobs are expected to raise the median income in the area about 50 percent above the 1975 level. The increased demand for housing will be largely met by mobile homes. Medical care and other professional services are expected to be seriously lacking throughout the 3-county area. As a result of the development, agriculture's dominant position in the economy will be replaced by coal-related sectors. Exporting coal would significantly reduce both the adverse and beneficial effects of much of the population growth, as well as lower property tax benefits to local governments.

Air quality impacts associated with energy development at Beulah are related primarily to quantities of pollutants emitted by the facilities and to diffuse emissions associated with population increases. The power plant emits greater pollutant concentrations than the gasification plant, but ambient air concentrations associated with the expanded population may be higher than those resulting from conversion facility emissions.

As presently configured, the planned facilities will have a minimal effect on the local air quality. The four gasification plants do not cause any North Dakota (except the 1-hour NO_x standard in the case of Synthane) or federal ambient standards to be exceeded. However, although power plant emissions meet federal ambient standards, they exceed the North Dakota 1-hour SO_2 and NO_2 ambient standards. In addition, general urban development at Beulah will cause both the federal and state 3-hour hydrocarbons standards to be exceeded by 1985. Also, the plumes of the plants will be visible from many locations in the area, and the average long-range visibility will be reduced about 10 percent when all the facilities are operating and to a greater extent during periods of air stagnation.

The SO_2 emissions could be decreased through an improvement in scrubber efficiency, the precombustion washing of the coal, or through a reduction in plant operating capacity. Although scrubbers for NO_2 are still in the experimental stage, these emissions can be controlled, to a limited extent, by boiler firing modifications such as staged firing, low excess air, and reduction of plant capacity, or by exporting coal.

Water impacts associated with energy development in the Beulah area are a function of the water required and effluents produced by energy facilities and the associated population. The power plant requires the most water, the Lurgi, the least. Effluents from all energy facilities will be ponded to prevent contamination of surface water and groundwater in the scenario area.

The water consumption attributed to the energy facilities and their associated development is not expected to significantly deplete groundwater or surface-water resources. Although there will be no intentional discharges of pollutants to groundwaters or surface waters, deterioration of local water quality may result from the failure of settling and holding ponds and the improper disposal of urban sanitary wastes. The integrity of the storage ponds may be breached via the leaching of chemicals through the pond liners or from the erosion of pond dikes; both possibilities will become more likely as the facilities age. Sewage disposal, although not presently a problem in the area, is expected to become serious as the urban growth out-paces the ability of municipalities to respond. This problem will be most evident during periods of peak growth which, for this hypothesized development, occur in the mid-1980's and mid-1990's.

Although surface waters are most abundant in this scenario, technological changes could further reduce depletions. The potential exists for using wet-dry cooling towers for the hypothetical conversion facilities in this scenario but at considerable expense. Local water quality could be mitigated through the installation of recyclable waste disposal systems or packaged systems for mobile home parks (which compose a large portion of the new housing).

Ecological impacts associated with energy development in the Beulah area depend on land use, population increases, water use and water pollution, and air quality changes. Land use by surface mining activities will be greater than that by energy facility structures and population needs. However, much of the land used by mining can be reclaimed. The average rainfall of 10-20 inches annually and well-developed soil in the scenario area will make revegetation likely. However, when and if the original plant communities will be reestablished is uncertain.

Ecological impacts will stem largely from the population increases. Therefore, the area surrounding Beulah will probably be the most severely impacted. As a result of habitat fragmentation, the productivity of selected species will likely decrease. Poaching is also expected to be a serious problem unless positive steps are initiated in game protection and management. Other impacts of human activities will include simplification of ecosystem structure (with increases in relative abundance of fewer species) and loss of soil nutrients due to erosion.

Controls over human use of the area, such as permits for recreational use and zoning, would minimize attrition of habitat. Provisions for habitat control in the river valley and habitat management programs on farmlands can also affect changes to vegetation and animal abundance.

Ecological impacts associated with water use and water pollution and air quality changes are not expected to be significant.

CHAPTER 10

LOCALIZED IMPACTS

10.1 INTRODUCTION

In addition to potential site-specific impacts of energy development reported in the preceding six chapters, a number of other impacts may be experienced in the vicinity of energy extraction and conversion facilities. This chapter discusses these "localized" impacts. These are discussed here rather than in the six site-specific chapters either because they do not differ significantly from site to site or because too little is known about them to treat them on a site-specific basis. Included are several air impacts categories, impacts from trace element emissions, problems associated with solid waste treatment and disposal, noise impacts, aesthetic impacts, public health impacts, and occupational health and safety impacts.

10.2 AIR IMPACTS

Ten categories of potential local air impacts are discussed; sulfates, oxidants, fine particulates, long-range visibility, plume opacity, cooling tower salt deposition, cooling tower fogging and icing, fugitive dust, startup and shutdown of conversion facilities, and air impacts of geothermal development.

10.2.1 Sulfates

Sulfates result from the oxidation of sulfur dioxide as stack gas plumes mix with air. Because of the complexity of the chemical reactions forming sulfates and the very small particle size of sulfate aerosols (in the submicron range), predicting atmospheric distribution of sulfates is very difficult. For example, sulfuric acid (a sulfate) is formed from the oxidation of sulfur dioxide (SO_2), and then reacts with other components in the atmosphere to produce salts such as ammonium sulfate. A summary of measured atmospheric sulfate concentrations in selected western locations in 1974 is provided in Table 10-1. In most locations average sulfate concentrations are highest in the winter and fall.

TABLE 10-1: SELECTED QUARTERLY AVERAGE SULFATE CONCENTRATIONS FOR 1974[a] (24-hour samples)

LOCATION	SULFATE CONCENTRATIONS ($\mu g/m^3$)					
					MAXIMUM	
	WINTER	SPRING	SUMMER	FALL	MONTH	CONCENTRATION
Phoenix (City), Arizona	9.8	4.9	3.6	8.6	November	11.0
Phoenix Area, Arizona Sun City/Mesa Paradise/Maricopa	6.5	3.6	3.7	8.1	November	12.0
Grand Canyon, Arizona	2.5	1.8	2.3	2.1	December	4.1
Nogales/Tucson, Arizona	7.5	5.0	3.6	6.8	March	9.9
Denver (City), Colorado	6.9	5.5	5.0	4.7	December	8.5
Mesa Verde National Park, Colorado	0.7	1.7	2.7	3.1	October	3.3
Albuquerque, New Mexico	3.5	2.9	4.4	4.8	November	4.9
Salt Lake/Ogden (City), Utah	8.8	4.3	4.8	5.9	December	14.3
Cheyenne (City), Wyoming	1.9	2.5	3.4	2.7	August	3.7
Casper (City), Wyoming	5.0	4.2	4.1	5.7	November	7.3
Yellowstone/Grand Teton Parks, Wyoming	1.0	1.8	1.4	1.4	March	2.5

$\mu g/m^3$ = micrograms per cubic meter

[a]Teknekron, Inc., Energy and Environmental Engineering Division. An Integrated Technology Assessment of Electric Utility Energy Systems, Briefing Materials: Air Quality Impact Methodology and Results--Regional Study and Subregional Problem Areas: Southwest, Rocky Mountains, Northern Great Plains. Berkeley, Calif.: Teknekron, 1978, pp. 84-85.

Whether energy development will significantly increase these sulfate concentrations generally depends on SO_2 emission levels and the rate at which SO_2 is converted to sulfates in the atmosphere. One study suggests the peak conversion rate of SO_2 to sulfates in plumes is less than 1 percent each hour.[1] Although conversion rate estimates vary from 1 to 20 percent per hour,[2] 20 percent rates have only been associated with oil-fired power plants,[3] probably due to finer particle size found in oil-fired plant emissions. Rates for coal-fired power plants have been reported at 1 to 3 percent per hour. Ground-level sulfate concentrations which would result from the energy development scenarios at each of the six sites are given in Table 10-2 for SO_2 to sulfate conversion rates of 1 to 10 percent per hour. Conversion rates greater than 5 percent per hour could result in 24-hour ambient sulfate levels large enough to produce increases in mortality (discussed in the public health impacts Section 10.7).[4] There are currently no federal standards for ambient concentrations of sulfates, but Montana and North Dakota have established 24-hour sulfates standards of 12 micrograms per cubic meter ($\mu g/m^3$) not to be exceeded more than once per year.[5] Facilities modeled at Colstrip, Montana, and Beulah, North Dakota, would not exceed this standard at 10 percent conversion rates (Table 10-2). Sulfate aerosols also affect visibility, as described in Section 10.2.4 below.

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[1]Nordsieck, R., et al. Impact of Energy Resource Development on Reactive Air Pollutants in the Western United States, Draft Report to U.S. Environmental Protection Agency, Contract No. 68-01-2801. Westlake Village, Calif.: Environmental Research and Technology, Western Technical Center, 1975.

[2]U.S., Congress, House of Representatives, Committee on Science and Technology, Subcommittee on Environment and the Atmosphere. Review of Research Related to Sulfates in the Atmosphere, Committee Print. Washington, D.C.: Government Printing Office, 1976.

[3]Ibid.

[4]U.S., Environmental Protection Agency. Position Paper on Regulation of Atmospheric Sulfates, EPA 450/2-75-007. Research Triangle Park, N.C.: National Environmental Research Center, 1975.

[5]Teknekron, Inc., Energy and Environmental Engineering Division. An Integrated Technology Assessment of Electric Utility Energy Systems, Briefing Materials: Air Quality Impact Methodology and Results--Regional Study and Subregional Problem Areas: Southwest, Rocky Mountains, Northern Great Plains. Berkeley, Calif.: Teknekron, 1978, p. 7.

TABLE 10-2: GROUND-LEVEL SULFATE CONCENTRATIONS FOR POWER PLANTS

POWER PLANT SCENARIO SITE	PEAK SULFATE CONCENTRATION ($\mu g/m^3$) CONVERSION RATE			
	ONE PERCENT	TWO PERCENT	FIVE PERCENT	TEN PERCENT
Kaiparowits/Escalante	2.2	4.4	11	22
Navajo/Farmington	0.8	1.6	4	8
Rifle	1.5	3.0	7.5	15
Gillette	0.5	1.0	2.5	5
Colstrip	0.9	1.8	4.5	9
Beulah	1.1	2.2	5.5	11

$\mu g/m^3$ = micrograms per cubic meter

10.2.2 Oxidants

Oxidants (including such compounds as ozone, aldehydes, peroxides, peroxyacly nitrates, chlorine, and bromine) are a criteria pollutant which either can be emitted from sources or formed in the atmosphere. For example, oxidants can be formed when hydrocarbons (HC) combine with oxides of nitrogen (NO_x). Measured average levels of oxidants varies widely throughout the study area as indicated in Figure 10-1. Peak oxidant values typically occur during summer, with some variation based on location.[1] Daily maxima occur during late afternoon, and have been documented at 0.08 to 0.09 parts per million (ppm) in the Northern Great Plains sites and from 0.03 to 0.04 ppm in the Central Rockies.[2] Thus, measurements found in the Northern Great Plains indicate that

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[1]Teknekron, Inc., Energy and Environmental Engineering Division. An Integrated Technology Assessment of Electric Utility Energy Systems, Briefing Materials: Air Quality Impact Methodology and Results--Regional Study and Subregional Problem Areas: Southwest, Rocky Mountains, Northern Great Plains. Berkeley, Calif.: Teknekron, 1978, pp. 88-89.

[2]Ibid.

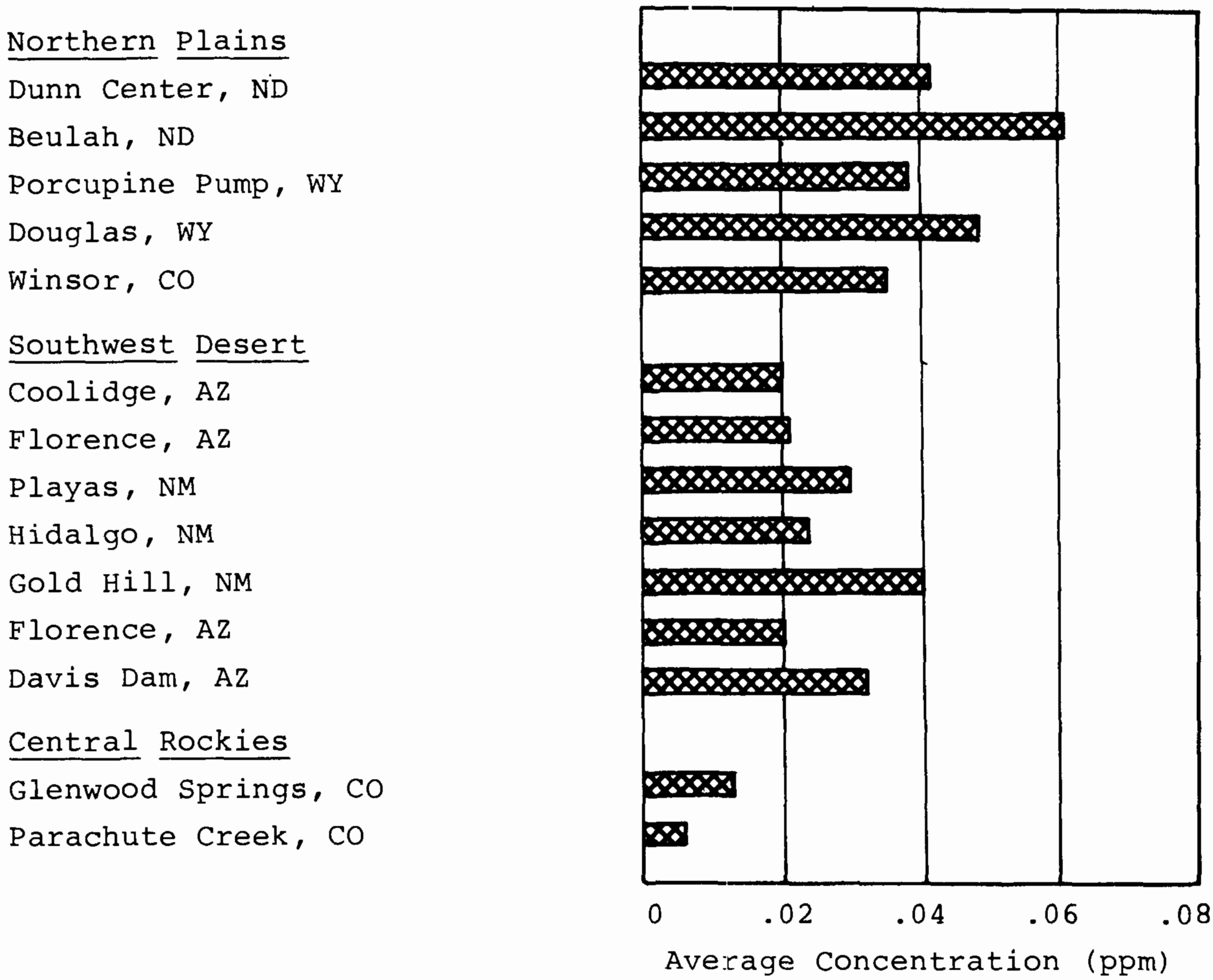

FIGURE 10-1: OXIDANT CONCENTRATION BY SITE

Source: Teknekron, Inc., Energy and Environmental Engineering Division. An Integrated Technology Assessment of Electric Utility Energy Systems, Briefing Materials: Air Quality Impact Methodology and Results--Regional Study and Subregional Problem Areas: Southwest, Rocky Mountains, Northern Great Plains. Berkeley, Calif.: Teknekron, 1978, pp. 88-89.

existing conditions could exceed the standard of 0.08 maximum 1-hour concentration.[1]

Present knowledge of the conversion processes forming oxidants is insufficient to predict concentrations based on residual emissions. However, the relatively low peak HC concentrations from a power plant and associated mine suggest that oxidant problems will not be greatly exacerbated by power plant HC emissions alone. However, oxidant problems could result from background HC with the high levels of NO_x emitted in power plant plumes. The extent of this problem has not been predicted.

Oxidant problems are not expected from Lurgi or Synthane conversion facilities. However Synthoil plants, TOSCO II oil shale facilities, and natural gas production facilities all produce peak HC levels many times greater than federal standards.[2] For example, a 100,000 barrels per day (bbl/day) Synthoil plant produces peak HC concentrations about 150 times greater than the federal standard and emits NO_x in the plume. As a result, facilities of this size may have difficulty obtaining a construction permit because they could cause oxidant standards to be violated. This may create special problems in North Dakota and other locations where synthetic fuel facilities are planned, and where current levels of oxidants already exceed or approach federal primary standards.

10.2.3 Fine Particulates

Fine particulates are primarily ash and coal particles emitted by the conversion facilities which are less than 3 microns (three one-millionth of an inch) in diameter.[3] Current information suggests that particulate emissions controlled by electrostatic precipatators (ESP) have a mean diameter of less than 5 microns, while uncontrolled power plant emissions have a mean

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[1]40 C.F.R. 50.9 (Standard Promulgated February 18, 1975). Environmental Protection Agency Administrator Douglas M. Costle has proposed relaxation of the primary photochemical oxidant ambient standard from 0.08 ppm to 0.1 ppm. The effect would be to reduce restrictions on industrial growth in some western locations. O'Donnel, Francis J. "Washington Report." Journal of the Air Pollution Control Association, Vol. 28 (July 1978), p. 660.

[2]See the various site-specific analyses, Chapters 4 through 9.

[3]Some fine particulates are also produced by atmospheric chemical reactions. These fine particulates appear at long distances from the plants because of the length of time required for these chemical reactions to occur.

diameter of about 10 microns.[1] In general, the higher the efficiency of the ESP, the smaller the mean diameter of the particles emitted by the plant stacks. The high efficiency ESP's (99 percent removal by weight) selectively remove coarse particulates to the point that an estimated 50 percent (by weight) of the total particulate emissions are fine particulates. This percentage applies to power plants and Lurgi and Synthane gasification processes. However, since only half of the particulate emissions from the Synthoil plant are controlled, only about 25 percent of its emissions will be fine particulates. Even when high degrees of particulate controls are used and ambient particulate standards are met, there may still be cause for concern due to small particulates. These fine particulates are not efficiently filtered out by the body's respiratory system and thus they may have serious health effects. The effect of fine particulates on respiratory problems is discussed in Section 10.7 (public health impacts). Fine particulates can also adversely affect visability as discussed in the following sections.

10.2.4 Long-Range Visibility

Fine particulates, including aerosols, reduce long-range visibility. Particulates suspended in the atmosphere scatter light, which reduces the contrast between an object and its background. As distance increases, the contrast level eventually falls below that required by the human eye to distinguish the object from the background. Estimates of the effect on visibility of energy facilities hypothesized for this study are based on empirical relationships between visual distance and fine particulate concentrations. Visibility in the West generally averages about 60 to 70 miles.[2] As shown in Table 10-3, in many western locations average (long-term) visibility has been decreasing since the 1950's (except in Pueblo, Colorado). As facilities in this study become operational, average visibility will further decrease by about 12 percent.[3] Episodes of air stagnation will cause substantially greater reductions of visibility on a short-term basis.

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[1]Fifty percent of the mass is contained in particles less than this diameter. Eppright, B.R., et al. A Program to Model the Plume Opacity for the Kaiparowits Steam Electric Generating Station, Final Report, Radian Project No. 200-066 for Southern California Edison Company. Austin, Tex.: Radian Corporation, 1974.

[2]The measurement of visibility is not an exact science. In the West visibility measurements have been taken at few locations and have generally not been recorded over the last several decades.

[3]An average value from site-specific analyses, Chapters 4-9.

TABLE 10-3: 1953-1970 VISIBILITY TRENDS IN SELECTED LOCATIONS

LOCATION	PERCENT CHANGE IN VISIBILITY DISTANCE FROM 50th PERCENTILE[a]	COMMENTS
Phoenix, Arizona	-12 percent	trend from 1960-1972
Prescott, Arizona	-27 percent	75th percentile used
Winslow, Arizona	- 7 percent	80th percentile used
Colorado Springs, Colorado	-10 percent	trend from 1953-1966
Denver, Colorado	- 9 percent	trend from 1955-1967
Grand Junction, Colorado	0 percent	
Pueblo, Colorado	+25 percent	trend from 1955-1967
Salt Lake City, Utah	-23 percent	
Cheyenne, Wyoming	-14 percent	trend from 1959-1972

Source: Trijonis, J., and Yuan, K. "Visibility in the Southwest. An Exploration of the Historical Data Base." Technology Service Corporation, Environmental Protection Agency, December 1977 from Teknekron, Inc., Energy and Environmental Engineering Division. An Integrated Technology Assessment of Electric Utility Energy Systems, Briefing Materials: Air Quality Impact Methodology and Results--Regional Study and Subregional Problem Areas: Southwest, Rocky Mountains, Northern Great Plains. Berkeley, Calif.: Teknekron, 1978, p. 21.

[a]50th percentile = distance (miles) of visibility occurring 50 percent of the time.

Since the sulfates produced from conversion of SO_2 are a major portion of aerosols from energy facilities such as power plants, they can affect visibility. Impacts of sulfates alone on visibility were evaluated using conversion rates of 1 and 10 percent SO_2 to sulfates per hour and these were reported in the six site-specific chapters (Chapters 4-9). A conversion rate of 1 percent could cause visibility during a worst-case episode to be reduced from its present value of 60 to 70 miles to 8 to 60 miles as shown in Table 10-4. A 10 percent conversion rate could cause visibility to be reduced to 4 to 50 miles. The greatest visibility reduction is associated with power plants and the associated mines. These estimates are for worst-case periods, occurring once to several times per year during air stagnations.

In order to provide better information on visibility, a view monitoring network was established in the spring of 1978 at seven locations in Utah and Arizona. The objective is to provide baseline long-range visibility data and document the effects of new energy facilities.[1]

10.2.5 Plume Opacity

Fine particulates in plumes increase opacity in the same way they limit long-range visibility and subsequently obscure the view of an object or scenery in the background.[2] Reduced light transmission through energy facility plumes is principally due to the amount of particulates and nitrogen dioxide (NO_2).[3] The particulates are typically from sources described earlier, including fly ash, sulfates, and nitrates from conversion of NO_x.[4]

In the scenarios included in this study, ESP's will remove enough particulates to meet emission standards, but stack plumes would probably exceed the 20 percent opacity new source performance standard (NSPS) for power plants, (40 percent opacity is

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[1] Pitchford, Marc L. "Visibility Investigative Experiment in the West." Communique (Las Vegas, Nev.: U.S., Environmental Protection Agency), Vol. 10 (January 2, 1978), pp. 1-2.

[2] Opacity is the degree to which emissions reduce transmission of light and obscure the view of an object in the background. 40 C.F.R. 60.2(j).

[3] Williams, M.D., and E.G. Walther. Theoretical Analysis of Air Quality: Impacts on the Lake Powell Region, Lake Powell Research Project Bulletin 8. Los Angeles, Calif.: University of California, Institute of Geophysics and Planetary Physics, 1975, p. 19.

[4] Ibid.

TABLE 10-4: WORST-CASE VISIBILITY REDUCTIONS AT ONE PERCENT SULFATE CONVERSION RATE

FACILITY[a]	SITE	BACKGROUND VISIBILITY (miles)	WORST-CASE SHORT-TERM VISIBILITY[b] (miles)	PERCENT VISIBILITY REDUCTION
Coal-fired power plant	Kaiparowits Rifle[c]	70 60	8.6 43.6	87.7 27.3
Coal-fired power plant and mine	Gillette Beulah	70 60	9.6 4.8	86.3 92.0
Lurgi gasification and mine	Farmington Gillette	60 70	41.6 48.4	30.7 30.9
Synthane gasification and mine	Gillette Colstrip	70 60	59.5 48.9	15.0 18.5
Synthoil liquefaction and mine	Gillette	70	48.8	30.3
TOSCO II oil shale	Rifle	60	44.4	26.0
Lurgi and Synthane gasification, coal-fired power plants, and mines	Farmington Colstrip	60 60	9.3 8.1	84.5 86.5
Coal-fired power plants Lurgi gasification, and mines	Colstrip	60	8.7	85.5
Lurgi and Synthane gasification, Synthoil liquefaction, coal-fired power plant and mines	Farmington	60	8.2	86.3
Lurgi gasification and mine (2 plants)	Beulah	60	37.4	37.7
Synthane gasification and mine (2 plants)	Beulah	60	29.4	51.0

[a]Facilities modeled are 3,000 megawatt-electric coal-fired power plant, 250 million cubic feet per day (MMcfd) Lurgi gasification, 250 MMcfd Synthane gasification, 100,000 barrels per day (bbl/day) Synthoil liquefaction, 50,000 bbl/day TOSCO II oil shale and the associated mines. The power plants were modeled with 99 percent removal of particulates and 80 percent removal of sulfur dioxide.

[b]Short-term visibility impacts were investigated using a "box-type" dispersion model. This particular model assumes all emissions occurring during a specified time interval are uniformly mixed and confined in a box capped by a lid or stable layer aloft. A lid of 500 meters has been used through the analyses. The conversion rate of sulfur dioxide to sulfates was assumed to be one percent per hour.

[c]The power plant at Rifle was 1,000 megawatts-electric.

permissible for up to 2 minutes during any one hour).[1] Although it is difficult to determine violations of this standard, if it were close to stacks, additional particulate removal capabilities would probably be required (up to approximately 99.9 percent of all plume particulates on some energy facilities). Analysis of air quality impacts in the Lake Powell region due to the Navajo power plant has indicated that under stable atmospheric conditions and low wind speed, significant plume opacity would occur further than 25 miles downwind from the plant.[2] Although difficult to predict, similar impacts could result from power plants modeled in this study.

10.2.6 Cooling Tower Salt Deposition

Cooling tower "drift" (i.e., emissions from wet-cooling towers) contains primarily calcium, magnesium, and sodium salts as well as other chemcials contained in the cooling water. The quantity of these salts emitted depends on the amount of cooling water required for the facility and the content of dissolved solids in the water source.

Depending on the site, drift from a Lurgi facility is estimated to range from 400 to 600 pounds of dissolved solids per day; from a Synthane facility, 700 to 1,000 pounds per day; from a Synthoil facility, 1,000 to 1,700 pounds per day; and from a 3,000 megawatt-electric (MWe) power plant, 3,000 to 6,400 pounds per day.[3]

The salts are entrained in mist of varying particle size and are deposited over a large area. As shown in Table 10-5, deposition rates are much higher in close proximity to facilities than

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[1] 40 C.F.R. 60.42(a)(2).

[2] Williams, M.D., and E.G. Walther. Theoretical Analysis of Air Quality: Impacts on the Lake Powell Region, Lake Powell Research Project Bulletin 8. Los Angeles, Calif.: University of California, Institute of Geophysics and Planetary Physics, 1975, pp. 20-22.

[3] The quantity of salt in cooling tower drift depends not only on the size and operation of the facility but also on the total dissolved solids (TDS) content of the cooling water. The TDS in the source water for the six sites analyzed is (in ppm): Kaiparowits, 7,120; Farmington, 3,330; Rifle, 3,500; Gillette, 3,870; Colstrip, 3,200; and Beulah, 4,580. Each cell in a cooling tower circulates water at a rate of 15,300 gallons per minute and emits about 1.53 gallons per minute as a mist. A 3,000 MWe power plant has 64 cooling tower cells; a Lurgi plant, 11; a Synthane plant, 6; and a Synthoil plant, 16. Load factors are 70 percent for the power plant and 90 percent for the synthetic fuel facilities.

TABLE 10-5: COOLING TOWER SALT DEPOSITS FOR SITE-SPECIFIC SCENARIOS[a] (pounds per acre per year)

SCENARIO	DISTANCE FROM COOLING TOWERS[b]		
	TO 1 MILE	1 TO 8 MILES	8 TO 23 MILES
Kaiparowits	80	7	0.6
Navajo/Farmington	5-23	0.5-4.9	0.1-0.9
Rifle	5-23	0.4-1.6	0.03-0.10
Gillette	7-70	0.7-3.4	0.02-0.2
Colstrip	8.5-91	0.6-5.8	0.02-0.2
Beulah	8.5-91	0.6-5.8	0.02-0.2

[a]For specific data on deposition from facilities refer to site-specific Chapters 4 through 9.

[b]Ranges are due to different types of facilities.

at a distance. Some interaction of salt deposition from among the various plants also occurs, although at rates significantly below maximum deposition rates that occur near the cooling towers. For example, the area midway between the power plant and Synthane plant in the Gillette scenario will receive an average of 3.7 pounds of salt per acre per year.

Effects of cooling tower drift are briefly summarized in the ecological impact sections of the site-specific Chapters 4 through 9. Generally, surveys of the effect of cooling tower drift have not shown alterations in plant or animal populatons outside facility boundaries, even for facilities using brackish or saline cooling water.[1] Local effects include corrosion of equipment within facility boundaries.[2] Whether salt deposition influences

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[1]U.S., Environmental Protection Agency. Development Document for Effluent Limitation Guidelines and New Source Performance Standards for the Steam Electric Power Generating Point Source Category. Washington, D.C.: Environmental Protection Agency, 1974, p. 642.

[2]Ibid., p. 641.

such factors as vegetation productivity, and ground or surface water salinity is dependent on natural rates of salt deposition and removal. Adverse effects on the environment (such as reduced vegetation) have only been documented within several hundred yards of cooling towers.[1]

10.2.7 Cooling Tower Fogging and Icing

Fogging and icing can be two of the more noticeable effects of wet cooling towers. Fog is produced when warm humid air from the towers mixes with cold ambient air.[2] When this occurs, the cooling tower vapor condenses into a fog or into ice if the temperature is below freezing. The development of fog depends largely on local conditions; the areas normally susceptable are those where natural fogs frequently occur.[3] The sites in the eight-state study area typically have about 10 foggy days per year. Northern Great Plains locations have a greater tendency to develop cooling tower fogs than do southwestern sites since their climates are cooler. According to criteria developed through Environmental Protection Agency (EPA) sponsored studies, most of the western region has a "low" potential for cooling tower fogging.[4] Portions of North Dakota, South Dakota, eastern Wyoming, and southeastern Montana have a "moderate" potential.[5]

The fog plume of mechanical draft cooling towers is emitted close to the ground, and its principal adverse effect is impaired vehicle travel, especially when icing occurs (approximately 100 days in most sites). Other types of adverse environmental effects may occur, such as impaired scenic vistas close to facilities. The potential for modification of regional or local weather patterns also constitutes a possible impact, but this has not been verified.[6]

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[1]U.S., Environmental Protection Agency. Development Document for Effluent Limitation Guidelines and New Source Performance Standards for the Steam Electric Power Generating Point Source Category. Washington, D.C.: Environmental Protection Agency, 1974, p. 643.

[2]*Ibid*.

[3]*Ibid*.

[4]*Ibid*.

[5]*Ibid*., p. 645.

[6]*Ibid*., p. 648.

10.2.8 Fugitive Dust

Fugitive dust emissions from surface coal mining operations are produced by the removal, loading, and dumping of overburden (material overlaying the coal) and by blasting, drilling, loading, transporting, and dumping the coal. Heavy machinery (loaders, scrapers, graders, tractors) traveling on the haul roads also produce dust. The entire exposed surface area of the mine can contribute to wind blown dust.

The quantity of fugitive dust produced is determined by the amount of material available for entrainment which is induced by wind action. Blasting, loading, and dumping will typically produce higher concentrations of particulate emissions than drilling, transporting, or exposed storage piles. As would be expected, wind velocity strongly affects the quantity of emissions of fugitive dust.[1] Higher concentrations of dust tend to occur closer to the ground, but levels are highly erratic.[2] Particulate concentrations often increase with downwind sampling distances (10 to 50 meters).

Variations in emissions among mines are attributable to differences in soil type, equipment used, climate, and dust suppression methods employed. Particulate emissions (in pounds per ton [lbs/ton] of coal mined) were estimated for five coal mines in the West. The five sites and estimated emission were: northeast Colorado (1.5 lbs/ton); southwest Wyoming (2.9 lbs/ton); southeast Montana (0.6 lbs/ton); central North Dakota (1.2 lbs/ton); and northern Wyoming (1.0 lbs/ton coal).[3] This range represents 0.03 to 0.09 pounds per million British thermal unit (Btu) of coal mined.

10.2.9 Startup and Shutdown

When a coal-fired power generation unit is started up (either after being shut down for maintenance or in order to meet peak demands) air emissions are sometimes completely uncontrolled for an interim time period. During this startup period emissions are exempt from NSPS. The period of controlled emissions during startup (upset conditions) depends on the kind of emission control equipment used. For example, if control devices are integrated into the plant design for operation prior to firing the

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[1] PEDCo-Environmental, Inc. Survey of Fugitive Dust, EPA Contract No. 68-01-4489. Kansas City, Mo.: PEDCo-Environmental, n.d., p. 54.

[2] Ibid.

[3] Ibid., p. 63.

boiler, no warm-up period may be needed. However, some ESP's and scrubber units only control emissions when flue gas streams are appropriately heated and the units are electrically energized.

For example, one of the Four Corners power plants in northwestern New Mexico has an ESP system that requires a warm-up period. Data on that plant from the New Mexico Health and Social Services Department indicates that the shortest startup time (warm-up period) during the last 5 years was 7 minutes and the longest was 1 week.[1] The mean time of operation with uncontrolled emissions was 16.86 hours and most startups lasted longer than 12 hours. When data over the last 5 years was averaged, the plant operated, on the average, 2 hours per day with uncontrolled emissions.[2] The main causes of breakdowns during this 5 year period were problems with the boiler, power distribution and generation, and the ESP.

10.2.10 Air Impacts of Geothermal Development

For the case of hot water geothermal development, hydrogen sulfite (H_2S) air emissions, considered a potential problem, were modeled in order to predict air concentrations under worst case meteorological conditions. The results of that modeling are given in Table 10-6 along with the state standards for H_2S. These data indicate that no standards will be violated if 99 to 99.9 percent emission control is achieved. Violations could occur with only 90 percent control. The Stretford process has been used in industrial applications for H_2S removal achieving 99.99 percent removal. Thus, the technology required for H_2S control is thought to be available and feasible for geothermal applications.

10.3 TRACE ELEMENTS[3]

Trace elements are those elements present in the earth's crust at concentrations of 0.1 percent (1,000 ppm) or less. The

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[1] New Mexico, Health and Social Services Department. "Upset Analysis of the Four Corners Power Plant." March 7, 1978.

[2] Ibid.

[3] Sources of information for this discussion are Kash, Don E., et al. The Impact of Accelerated Coal Utilization, Contract No. OTA-C-182. Norman, Okla.: University of Oklahoma, Science and Public Policy Program, 1977; and Radian Corporation. The Assessment of Residuals Disposal for Steam Electric Power Generation and Synthetic Fuel Plants in the Western United States, EPA Contract No. 68-01-1916. Austin, Tex.: Radian Corporation, 1978, pp. 92-110. The latter source also contains information on the organic compounds that are formed during conversion and can be emitted.

TABLE 10-6: WORST-CASE HYDROGEN SULFIDE IMPACTS FROM A 100 MEGAWATT GEOTHERMAL POWER PLANT (micrograms per cubic meter)[a]

	CONCENTRATION AND STANDARDS (ONE-HALF HOUR AVERAGING TIME)	
	FLASHED STEAM POWER GENERATION[b]	BINARY PROCESS POWER GENERATION[c]
Control (H_2S Removal)		
90 %	133	NC
99 %	13.3	46.2 - 59.3
99.9%	NC	4.6 - 5.9
Standards[d]		
New Mexico	46 - 152	
Wyoming	40 - 70	
Montana	42 - 70	
North Dakota	45 - 75	

H_2S = hydrogen sulfide
NC = not considered

[a]Assuming worst case meteorology

[b]Stack parameters for flashed steam include 60 feet stack height, 85°F temperature, 30 feet per second flow velocity and a volumetric flow rate of 2.8×10^3 cubic feet per minute.

[c]Stack parameters for binary fluid process include 130 feet stack height, 125°F temperature, 30 feet per second flow velocity, and a volumetric flow rate ranging from 3.62×10^4 cubic feet per minute to 3.62×10^3 cubic feet per minute.

[d]From White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 2. In New Mexico, the lower standard applies statewide except in the Pecos Permian Basin industrial area where the high standard applies. In Wyoming, Montana, and North Dakota, the lower standard may not be violated more than two times in five consecutive days and the higher standard may not be violated more than two times a year.

quantity and kinds of trace elements in coal vary with location (Table 10-7). Each coal has a unique composition, and methods used to predict exactly what happens to the trace elements in coal during energy conversion processes have not been fully developed. As a result, data on trace element emissions and discharges from coal conversion technologies are quite preliminary. Estimated amounts of trace elements are also present in the source water used for plant cooling (Table 10-8). The fate of these elements is also difficult to predict. However, they can be emitted to the atmopshere in a gaseous form or as a mist in the cooling tower drift or they may be discharged in some liquid or solid form in the wastewater effluents from the conversion technology.

The total amount of trace elements introduced into the environment become quite large when the amount of coal processed is considered. For example, for a 3,000 MWe coal fired electric power plant at Gillette, the quantity of a single trace element (arsenic) processed would range from 12.8 to 51.2 tons per year (tpy) (assuming a range of 1-4 ppm concentration of arsenic in Gillette coal as shown in Table 10-7). As a point of comparison with the amounts of this element occurring naturally in surface waters, the arsenic in power plant cooling water supply for Gillette would be 0.04 to 0.02 tpy depending on local concentrations. At Colstrip, 80 tpy of lead will be contained within the coal for two 3,000 MWe power plants; about 500 to 2,000 times as much as present in the cooling water. If a billion tons of coal were processed, a single trace element with a concentration of 10 ppm would account for 10,000 tons of residual waste in a single year.

These trace elements may be emitted into the atmopshere via the stack, into holding ponds via wastewater discharge, or into groundwater via leaching of solid wastes. The amount of trace elements produced as residuals from coal conversion depends primarily on the amount of trace elements in the raw coal, but the emission or effluent streams in which they are found and the chemical forms that occur depends on the temperature at which each trace elements volatizes and on the operation of the coal conversion technology.

Trace elements will appear in the bottom ash, fly ash, flue gas desulfurization (FGD) sludge, and other residual streams (e.g., wastewater from water treatment and cooling tower blowdown). In the case of synthetic fuels facilities, some trace elements may also be present in the product gas and oil. Combustion of coal is thought to cause most trace elements to occur in the fly ash and scrubber sludge and a reduced concentration of volatile trace elements in the bottom ash. Only volatile elements are thought to be present in the synthetic gas and oil. Under the high temperature processing conditions for coal in synthetic fuel

TABLE 10-7: TRACE ELEMENTS IN SELECTED WESTERN COALS[a]

ELEMENT	GILLETTE (ppm)	NAVAJO/FARMINGTON (ppm)	KAIPAROWITS/ESCALANTE (ppm)
Antimony	.1 - .7	.3 - 1.2	0.6 - .2
Arsenic	1 - 4	.1 - 3	.02 - 1.6
Beryllium	.2 - .7	NA	.3 - .7
Cadmium	.1 - .2	.2 - .4	.06 - 1.6
Chromium	NA	NA	1.3 - 5.9
Flourine	30 - 200	200 - 780	8 - 96
Lead	1.5 - 40	1.4 - 4.0	NA
Manganese	NA	NA	4 - 8
Mercury	.1 - .28	.2 - .3	.03 - .05
Nickel	NA	3 - 30	4 - 6
Selenium	.2 - 3.2	.1 - .2	0 - 8
Uranium	.3 - 3.2	NA	.3 - 1
Vanadium	NA	NA	7 - 9
Zinc	2.1 - 25	1.1 - 27	NA

ppm = parts per million by weight   NA = not available

[a]Sinor, J.E. Evaluation of Background Data Relating to New Source Performance Standards for Lurgi Gasification, Final Report, EPA 600/7-77-057, EPA Contract No. 68-02-2152, Task 11. Denver, Colo.: Cameron Engineers, Inc., 1977 (source for Navajo/Farmington, New Mexico data). U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976 (source for Kaiparowits/Escalante data).

TABLE 10-8: CONCENTRATIONS OF TRACE ELEMENTS IN SELECTED SOURCE WATER[a] (parts per million by weight)

ELEMENT	BEULAH, LAKE SAKAKAWEA	COLSTRIP, YELLOWSTONE RIVER	GILLETTE, YELLOWSTONE RIVER	GILLETTE, NORTH PLATTE RIVER
Arsenic	0-0.004	0.004-0.007	0.001-0.005	0.002-0.005
Barium	0-0.200	NA	NA	0.056-0.062
Beryllium	0	0-0.010	0-<0.010	0-<0.001
Cadmium	0-0.001	0-<0.010	0	<0.002-0.003
Chromium	0-<0.010	0	0-0.010	<0.003
Cobalt	0-0.001	NA	NA	<0.002-0.003
Copper	0-0.002	0.001-0.002	0.002	0.002-0.004
Lead	0-0.002	0.001-0.004	0.001-0.002	<0.003-0.006
Manganese	0-0.002	0-0.010	0-0.005	0.018-0.022
Mercury	0-<0.0005	0-0.0002	0-0.0002	NA
Molybdenum	0.002-0.003	0.001-0.002	0.001-0.003	0.003
Nickel	0.003-0.004	0.002-0.005	0.002-0.003	<0.002-0.003
Radon	NA	NA	NA	0.0001
Selenium	0-0.001	0.001-0.002	0.001-0.002	0.005-0.007
Strontium	0.470-0.530	NA	NA	0.500-0.600
Uranium	NA	NA	NA	0.010
Vanadium	NA	0-00016	0.001-0.0012	<0.002-0.003
Zinc	0.005-0.020	0-0.010	0	0-0.010

NA = not available

[a]Radian Corporation. The Assessment of Residuals Disposal for Steam Electric Power Generation and Synthetic Fuel Plants in the Western United States. Austin, Tex.: Radian Corporation, 1978, p. 79.

production volatile trace elements that may occur in the product gas or oil include mercury, antimony, fluoride, selenium, vanadium, lead, molybedenum, nickel, boron, zinc, cadmium, chromium, copper, cobalt, uranium, arsenic, and silver. These are expected to occur in greatest concentration in the FGD sludge and occur in very low concentrations in the bottom ash. Nonvolatile elements (e.g., beryllium, barium, iron, and manganese) will be present in the bottom ash and fly ash in similar proportions.

Gaseous emissions of trace elements are difficult to control. Current air pollution control technologies are largely ineffective in controlling gaseous emissions of rare elements. However, when trace elements are part of liquid or solid waste streams, they can be more easily controlled by discharging them to holding ponds or landfills. But the potential for contamination of surface or groundwater still exists from seepage, leaks, or failures of the liquid waste holding ponds or solid waste landfill.

Very little is known about the seriousness of emissions to the atmosphere of trace elements from coal, although the problem is now receiving increased research attention. Similarly, the effects of trace elements on human health are not well understood; however, a summary of known or anticipated effects is presented in Section 10.7 (public health impacts).

10.4 SOLID WASTE TREATMENT AND DISPOSAL

By 1980, nationwide wastes from coal-fired power plants are estimated to be 70 million tpy from SO_2 (FGD) scrubbers and 60 million tpy of fly ash from the ESP and bottom ash collection systems.[1] A single 1,000 MWe power plant is estimated to produce 44 million tons of waste in a 30-year period.[2] The quantities and composition of solid wastes produced from each type of energy conversion facility at each site are given in the water sections of Chapters 4 through 9. This section deals with the overall problem of treatment and disposal of these wastes.

10.4.1 Application of Holding Ponds

Holding ponds are large, man-made basins widely used for retaining liquid effluents from coal conversion facilities in the West while allowing the water to be evaporated. However, wastes can leave the holding pond and become environmental problems through evaporation, wind erosion, leaching, accidental berm

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[1] Gavande, S.A., W.F. Holland, and C.S. Collins. Survey of Technological and Environmental Aspects of Wet-Residue Disposal in Evaporative Holding Ponds, Final Report. Austin, Tex.: Radian Corporation, 1978.

[2] Ibid.

failures, and pond overflow.[1] Some waste pollutants from holding ponds are released to the air along with evaporated water. These include H_2S, methane, ammonia, and other nitrogen gases which are contained in the sludge. Thus, contamination of areas immediately adjacent to the holding pond can occur by evaporation and wind-whipped spray if the wastes are in liquid form, or by wind erosion of dried wastes in the holding pond. Seepage from the holding pond is likely to leach out nitrates, chlorides, sulfates, boron, and cyanide through the soil to adjacent groundwater systems.[2] If the holding pond leaks, the more soluble elements in the effluent may leach into the underground water system. Heavy rains or a period of decreased evaporation rate coupled with a heavy rate of effluent inflow into the holding pond can cause pond overflow and subsequent pollution of surface or groundwaters. Good pond design and use of natural or synthetic liners can be used to reduce the chance of overflow and leaching. Groundwater monitoring can be used to assess the extent of leaching.

Liquid or solid residuals usually consist of fly ash from the ESP, bottom ash, FGD sludge, and demineralizer and cooling tower blowdown liquids. Although many disposal configurations are possible, some facility configurations include three types of disposal ponds and at least one landfill.[3] Fly ash is dry and is usually deposited directly in a landfill. Bottom ash is usually sluiced to an ash pond, allowed to settle, and the water sent to an evaporation pond along with water from the demineralizer. FGD sludge is usually routed along with cooling tower wastewater to a sludge pond. Solids from the ash and sludge ponds are periodically removed by dredging or other dewatering techniques and deposited in a landfill. Fly ash, bottom ash, and FGD sludge may be mixed together before land filling to enhance compaction and stabilization. Disposal of these solid wastes can require a large amount of land for interim storage ponds and for final disposal in landfills.

A. Pond Design

Evaporative holding ponds located over thick, impermeable clay deposits reduce the chance of groundwater contamination in

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[1] Gavande, S.A., W.F. Holland, and C.S. Collins. Survey of Technological and Environmental Aspects of Wet-Residue Disposal in Evaporative Holding Ponds, Final Report. Austin, Tex.: Radian Corporation, 1978.

[2] Ibid.

[3] Radian Corporation. The Assessment of Residuals Disposal for Steam Electric Power Generation and Synthetic Fuel Plants in the Western United States. Austin, Tex.: Radian Corporation, 1978.

the event of accidental overflow or seepage. If a suitable clay is located with 30 miles of the power plant, it may be economically and technically feasible to transport the clay to the pond site. The pond consists of an excavated area (usually rectangular to accommodate large earth-moving equipment) with the excavated material used to construct an embankment (berm) on the sides. Currently, most holding ponds are unlined since unlined ponds are easier and more economical to construct. However, unlined ponds pose the greatest potential for groundwater contamination. This potential danger has led to the recent development of various pond lining methods to prevent seepage. Alternative pond linings include clay, synthetic membranes, and cement or asphaltic coatings of the pond bottom and sides.

The environmental impact of evaporative holding ponds depends primarily on the pond's capacity to contain the accumulation of wastes from an energy facility and on the ability of operators to retire the site safely and to a productive use. Very little data are available regarding the performance of holding ponds after construction. Ultimately, the capacity for ground and surface water contamination depends on the nature of the local geologic, climatic and hydrologic conditions, and the integrity of the holding pond system, including human management capability.

B. Disposal of Ponded Wastes

Fly ash, bottom ash, and FGD sludge are eventually deposited in landfills or holding ponds and stabilized by chemical addition or evaporation to dryness. Some portions of all three solid waste streams may be mixed together prior to this final deposition. Because very few regulations cover FGD sludge, disposal procedures are uncertain. In addition, the design of a holding pond must take into account local weather extremes and hydrogeologic conditions which vary greatly from north to south in the West. Optimum design and operation of holding ponds has not been determined for most areas in the eight-state study area.

There is very limited published information on the use of liners for holding ponds. In one system, a polyvinyl chloride (synthetic) liner covered with one foot of soil was first used but was later found inadequate because heavy equipment could not enter the pond for cleaning. Soil cement was later used but was found to deteriorate severely. Finally, ashpaltic concrete was used to line five of six ponds at the site and was found satisfactory.[1]

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[1]Gavande, S.A., W.F. Holland, and C.S. Collins. Survey of Technological and Environmental Aspects of Wet-Residue Disposal in Evaporative Holding Ponds, Final Report. Austin, Tex.: Radian Corporation, 1978, pp. 68-69.

Studies of the physical properties of FGD system wastes indicate that the material cannot usually be placed in a landfill without the aid of a chemical stabilization agent. Usually 35 to 55 percent of the water may be removed from the sludge in the holding pond prior to disposal. The sludge can be mixed with fly ash and lime or with cement fixatives and transported to a landfill. Although chemical fixation of power plant wastes is expensive, it would substantially reduce the risks of solid wastes leaching into ground or surface water after disposal.[1] After deposition in a landfill, wastes could be compacted and covered with several feet of compacted soil. The site may then be revegetated to prevent erosion of the soil cover. In arid and semiarid regions of the West, supplementary irrigation will probably be needed if a soil stabilization plant cover is to be established over disposed wastes.

Although the potential toxicity of power plant waste leachates has not been established at this time, there are numerous potentially toxic elements produced in the coal conversion process discussed in the following sections. For example, arsenic, selenium, boron, chloride, mercury, and sulfates can produce detrimental impacts on the environment, and, if not properly disposed of, may eventually pose a major threat to human health (see Section 10.7).

10.4.2 Effects of Ponds or Landfills on Groundwater

The impact of solid waste disposal on groundwater quality depends on the toxicity of chemicals present. For coal-fired power plants the major sources of the chemicals are soluble species in the ash and in the scrubber liquor blowdown.

The scrubber liquor is the most important factor affecting the leachate quality during initial leaching of the disposed solids into the soil.[2] After that, the solubility of the ash and scrubber solids is most important.

Table 10-9 illustrates average chemical composition of FGD sludge liquors from four power plants. Several chemical species have average (mean) concentrations above the EPA drinking water standards. These elements include arsenic, boron, total chromium, iron, lead, manganese, mercury, selenium, chloride, fluoride, and sulfates. Particular consideration should be given to mercury

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[1] Jones, Julian W. "Disposal of Flue-Gas Cleaning Wastes." Chemical Engineering, Vol. 84 (February 14, 1977), pp. 79-85.

[2] Rossoff, J., et al. Disposal of By-Products from Non-Regenerable Flue Gas Desulfurization Systems, Second Progress Report, EPA-600/7-77-052. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

TABLE 10-9: RANGE OF CONCENTRATION OF SELECTED CONSTITUENTS IN SCRUBBER LIQUORS

CONSTITUENTS	RANGE OF CONSTITUENT CONCENTRATIONS[a] (micrograms per liter)	EPA DRINKING WATER STANDARDS DECEMBER 1976
Arsenic	<0.004-0.3	0.05[b]
Beryllium	<0.002-.14	-
Boron	8.0-46	1.0[b]
Cadmium	0.004-.11	0.01[b]
Calcium	520-3,000	-
Chromium (total)	.01-.5	0.05[b]
Cobalt	.10-.7	-
Copper	<0.002-.2	1.0
Iron	.02-8.1	0.3[b]
Lead	.01-.4	0.05[b]
Magnesium	3-2,750	-
Manganese	.09-2.5	0.05[b]
Mercury	.003-.07	0.002[b]
Molybdenum	.91-6.3	-
Nickel	.05-1.5	-
Potassium	5.9-32	-
Selenium	<0.001-2.2	0.01[b]
Silver	0.005-.6	0.05[b]
Sodium	14-2,400	no limit[c]
Tin	3.1-3.5	-
Vanadium	<0.001-.67	-
Zinc	.01-.35	5.0
Chloride	420-4,800	250.0[b]
Fluoride	.07-10	0.7-1.2[b,d]
Sulfite	.8-3,500	-
Sulfate	720-10,000	250.0[b,d]
Phosphate	.03-.41	no limit[c]
Chemical Oxygen Demand	60-390	-
Total Dissolved Solids	3,200-150,000	no limit[c]
Total Alkalinity (as $CaCO_3$)	41-150	no limit[c]
Acidity/Alkalinity	3.04-10.7	5-9[b]

EPA = Environmental Protection Agency $CaCO_3$ = calcium carbonate

Source: Rossoff, J., et al. Disposal of By-Products from Non-Regenerable Flue Gas Desulfurization Systems, Second Progress Report, EPA-600/7-77-052. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

[a]Samples obtained from: EPA/Tennessee Valley Authority (TVA), Shawnee, Steam Plant - venturi and spray tower; EPA/TVA Shawnee Steam Plant - turbulent contact absorber; Arizona Public Service Cholla Station - flooded disk scrubber and absorption tower; and Duquesne Light Phillips Station - single - and dual-stage venturi.

[b]Scrubber liquor effluent from one or more power plants exceeds water criteria.

[c]"No limit" indicates that insufficient data existed for prescribing limits.

[d]U.S., Department of Health, Education and Welfare, Public Health Service. USPHS Drinking Water Standards 1962, USPHS Publication No. 956. Washington, D.C.: Public Health Service, 1962.

because of its high toxicity in very low concentrations. The chloride and sulfate levels are also high.

The leachate produced from holding ponds has been characterized by several laboratory pond simulation studies and from actual operating ponds.[1] Results from leaching studies of three sludges are summarized in Table 10-10. The values indicate averages from the Tennessee Valley Authority (TVA) Shawnee limestone sludge, Arizona Public Service Cholla limestone sludge, and the Southern California Edison, Mohave limestone sludge. The concentration of major components (sulfate, chloride) decreased rapidly during the first few displacements of water through the sludge. Some trace elements are more difficult to flush from the system. However, some trace elements will continue to be flushed from fine particulate matter and subsequently enter soils in small quantities.

In 1974, EPA began a field evaluation of the disposal of untreated and treated flue gas cleaning wastes.[2] The disposal evaluation site was located near the Shawnee coal-fired power plant (Paducah, Kentucky). In the clay lined ponds with low permeability, the groundwaters show no evidence of altered quality.[3] However, leachate studies showed that the concentrations of major dissolved solids, i.e., chlorides, sulfates, and total dissolved solids (TDS), progressively increase in the leachate during the first year. The data also indicate that the concentrations may level off at approximately those measured between the second and fifth year. The concentrations of heavy metals in the leachate and the liquor show trends similar to those of the major species. However, it is not possible to project exact concentrations because of the relatively small amounts present and the complex chemistry involved.

Other studies at fly ash disposal sites indicate that trace metals are released from the pond to the groundwater at generally

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[1] Rossoff, J., et al. Disposal of By-Products from Non-Regenerable Flue Gas Desulfurization Systems, Second Progress Report, EPA-600/7-77-052. Washington, D.C.: U.S., Environmental Protection Agency, 1977; and Holland, W.F., et al. Environmental Effects of Trace Elements from Ponded Ash and Scrubber Sludge. Austin, Tex.: Radian Corporation, 1975.

[2] Leo, P.P., and J. Rossoff. Control of Waste and Water Pollution from Power Plant Flue Gas Cleaning Systems, First Annual R&D Report, EPA 600/7-76-018. Research Triangle Park, N.C.: U.S., Environmental Protection Agency, 1976.

[3] Ibid.

TABLE 10-10: SELECTED COMPOSITION OF SLUDGE LIQUORS AND LEACHATES

CONSTITUENT	SLUDGE LIQUOR COMPOSITION[a] (mg/ℓ)	LEACHATES COMPOSITION[a] (mg/ℓ)	
		FIRST LEACHING[b]	FIFTIETH LEACHING[c]
Arsenic	<0.004-0.14	<0.004-0.06	<0.004
Cadmium	0.003-0.05	0.001-0.05	<.001-0.003
Chromium	0.09-0.25	0.019-0.05	0.002-0.015
Copper	0.01-0.56	0.007-0.11	0.01-0.03
Lead	0.01-0.25	0.016-1.7	<0.001-0.08
Mercury	<.005-0.13	0.00008-0.05	<.00005-0.004
Selenium	0.12-2.5	0.03-0.2	0.004-0.01
Zinc	0.07-0.18	0.06-2.7	0.01-0.045
Chloride	1,430-2,225	900-7,700	65-130
Floride	0.7-30	2.4-10.8	<0.2-6.1
Sulfate	4,400-25,000	3,500-9,000	1,000-1,300
Acidity/Alkalinity	4.3-8.3	4.6-8.5	4.5-7.45
Total Dissolved Solids	9,100-92,500	6,500-24,300	1,600-2,400

mg/ℓ = micrograms per liter   < = less than

[a]Based on data from Southern California Edison Mohave limestone sludge, Arizona Public Service Cholla limestone sludge and Tennessee Valley Authority Shawnee limestone sludge (aerobic and anaerobic conditions).

[b]Leachate produced from first displacement of pore space by infiltrating water.

[c]The Leachate produced after the 50th displacement of the pore space by infiltrating water.

low levels.[1] Increased concentrations of several times the normal levels occur when ponds are first filled and again when maintenance results in a large fly ash loading. Once trace metals are released, their behavior in groundwater depends upon the site-specific chemical and hydrologic characteristics. Metals were found to accumulate in the soils at the point where pond seepage water and natural groundwater meet, probably due to chemical precipitation and absorption onto soils. Arsenic in particular has displayed high increases over background levels. Potential toxicity of leachates has not been extensively established at this time. Information on general leachate quality, however, indicates a potential pollution problem and a need for careful site selection, monitoring, installation of liners, and other management practices.

10.5 NOISE IMPACTS

10.5.1 Introduction

Noise can be defined as any sound that may produce an undesired physiological or psychological effect in an individual or animal or that may interfere with the behavior of an individual or group.[2] Noise can temporarily or permanently damage hearing, interfere with speech communications and the perception of auditory signals, disturb sleep, and interfere with the performance of complicated tasks. More intangibly, it can be a source of annoyance and adversely affect mood.[3] Within recent years, recognition and quantification of these effects have resulted in the identification of noise as an environmental pollutant that raises both social and health concerns.[4]

The following analysis of noise impacts focuses on cases representative of conditions encountered in the mining, construction, and operation activities of energy development. Noise levels for three activities are estimated: surface strip mining, constructing a 3,000 MWe power plant, and operating a 3,000 MWe power plant. These cases were analyzed to determine whether the

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[1]Theis, J.L., et al. Field Investigations of Trace Metals in Ground Water from Fly Ash Disposal, Draft. South Bend, Ind.: University of Notre Dame, Department of Civil Engineering, 1977.

[2]Kerbec, Matthew J. "Noise and Hearing," Preprint from 1972 edition of Your Government and the Environment. Arlington, Va.: Output Systems Corporation, 1971.

[3]Miller, James D. Effects of Noise on People. St. Louis, Mo.: Central Institute for the Deaf, 1971.

[4]White, Frederick. Our Acoustic Environment. New York, N.Y.: Wiley, 1975.

noise they produce would be a source of concern for nearby populations. Evaluations were based on the equivalent sound level averaged over 24 hours and historical data on the response of humans to these average levels. Transportation noise impacts are discussed in Chapter 11.6.

10.5.2 Criteria for Noise Impacts

In evaluations of the impact of environmental noise, EPA criteria were used as the basis for estimating effects from construction, operation, and mining.[1] The noise level limits considered by EPA to be essential to protect public welfare and safety are presented in Table 10-11. Additional criteria may be developed based on the efforts required to communicate in the presence of ambient sound levels. These efforts are shown in Table 10-12 and indicate, for example, that for an ambient sound level of 78 decibels (dB) a very loud voice must be used to communicate with someone only 1 foot away. These criteria are consistent with the effect of noise on telephone communication, where a background noise level above 75 decibels A-weighted (dBA) makes telephone conversation difficult (Table 10-13).

The change in sound level is an important factor in assessing the impact from added noise sources. It is just possible to detect a change in noise level of 2-3 dBA, while a 5 dBA change is readily apparent. An increase in noise level of 10 dBA is equivalent to a doubling of the loudness of the sound.

The effects of noise on wildlife and domestic animals are less well understood. Studies of animals subjected to varying noise exposures in laboratories have demonstrated physiological and behavioral changes, and these reactions are assumed applicable to wildlife. However, no scientific evidence currently correlates the two. Large animals adapt quite readily to high sound levels. Conversely, loud noise disrupts brooding in poultry and consequently can decrease egg production.[2]

The major effect of noise on wildlife is related to the use of auditory signals. Acoustic signals are important for survival in some wildlife species. Probably the most important effect is related to the prey-predator situation. An animal that relies on its ears to locate prey and an animal that relies on its ears to detect

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[1]EPA recommends use of a measure which accounts for greater impact than noise makes at night compared to the day, or the "day-night average sound level." This measure is called decibels A-weighted, or dBA.

[2]Memphis State University. Effects of Noise on Wildlife and Other Animals. Springfield, Va.: National Technical Information Service, 1971.

TABLE 10-11: SOUND LEVELS REQUIRED TO PROTECT PUBLIC HEALTH AND WELFARE[a]

EFFECT	LEVEL[b]		AREA
Hearing loss[c]	$L_{eq}(24)$	70 dB	All areas
Outdoor activity interference and annoyance	L_{dn}	55 dB	Outdoors in residential areas and farms and other outdoor areas where people spend widely varying amounts of time and other places in which quiet is a basis for use.
	$L_{eq}(24)$	55 dB	Outdoor areas where people spend limited amounts of time, such as school yards, playgrounds, etc.
Indoor activity interference and annoyance	L_{dn}	54 dB	Indoor residential areas.
	$L_{eq}(24)$	45 dB	Other indoor areas with human activities such as schools, etc.

dB = decibel(s)
L_{eq} = the sound level averaged over a 24-hour period.
L_{dn} = the sound level L_{eq} weighted with a 10 dB larger impact for nighttime sounds.

[a]U.S., Environmental Protection Agency, Office of Noise Abatement and Control. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety. Arlington, Va.: Environmental Protection Agency, 1974, p. 3.

[b]Table to be read as follows: To protect from a hearing loss, the sound level $L_{eq}(24)$ must be less than 70 dB in all areas, both indoor and outdoor.

[c]Hearing loss level represents annual averages of daily sound level over a period of 40 years that produces impairment to hearing.

TABLE 10-12: SOUND LEVELS PERMITTING SPEECH COMMUNICATION

LISTENER DISTANCE (feet)	AMBIENT SOUND LEVEL FOR SPEECH COMMUNICATION (dBA)			
	LOW VOICE	NORMAL VOICE	RAISED VOICE	VERY LOUD VOICE
1	60	66	72	78
2	54	60	66	72
3	50	56	62	68
4	48	54	60	66
5	46	52	58	64
6	44	50	56	62
12	38	44	50	56

dBA = decibels A-weighted

Source: Tracor, Inc. Guidelines on Noise. Washington, D.C.: American Petroleum Institute, 1973.

TABLE 10-13: QUALITY OF TELEPHONE USAGE IN THE PRESENCE OF STEADY-STATE MASKING NOISE

NOISE LEVEL (dBA)[a]	TELEPHONE USAGE
30-50	Satisfactory
50-65	Slightly Difficult
65-75	Difficult
Above 75	Unsatisfactory

dBA = decibels A-weighted

Source: Tracor, Inc. Guidelines on Noise. Washington, D.C.: American Petroleum Institute, 1973.

predators are both impaired by intruding noise.[1] The reception of auditory mating signals could also be limited and therefore affect reproduction. Distress or warning signals from mother animals to infants (or vice versa) or within groups of social animals could be masked and possibly lead to increased mortality. There are clues that short-term high noise levels may startle wild game birds and stop the brooding cycle for an entire season.[2]

In the following analysis, noise levels were predicted from a model incorporating information on ambient air and topographic conditions and the properties of energy dispersion (sound energy) in air under these conditions. The results of this model predict energy levels at selected distances from single or multiple sources. The results are presented in terms of day-night equivalent sound levels (L_{dn}).

10.5.3 Surface Strip Mining

The principal noise sources during typical strip-mining operations will be bulldozers, the dragline, rock drills, blasting, and coal haulers.[3] A typical mining operation is shown in Figure 10-2, emphasizing the topographic barriers to noise from surface mining.

Sound levels for each of the above sources are given in Table 10-14. The 50-foot high piles of overburden will effectively block most sound radiation. For the typical mining geometry shown in Figure 10-2, the spoil piles will weaken radiated levels by about 15 dBA in the northern and southern quadrants. Predicted radiation noise levels, in the form of L_{dn} contours, are shown in Figure 10-3 for the typical surface mining operation.

Haulers will be the principal noise source in mining. However, their L_{dn} will be less than 55 dBA in all directions for distances greater than 2,000 feet and will have less impact than the noise levels predicted for power plant construction and operation.

10.5.4 Plant Construction

Facility construction noise will be caused primarily by heavy construction equipment. Plant construction noise is usually

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[1]Memphis State University. Effects of Noise on Wildlife and Other Animals. Springfield, Va.: National Technical Information Service, 1971.

[2]Ibid.

[3]The noise impact of blasting depends on size and depth of charge, acoustic properties of soil, and presence of sound attenuating barriers, thus is highly variable.

TABLE 10-14: REPRESENTATIVE SOUND LEVEL FOR MINING NOISE SOURCES

EQUIPMENT	SOUND LEVEL PER UNIT (dBA/vehicle)
Dragline	68
Bulldozer	82
Rock Drill	72
Loader	72
Coal Haulers	7

dBA = decibels A-weighted

Source: Battelle Memorial Institute, Columbus Laboratories. Detailed Environmental Analysis Concerning a Proposed Coal Gasification Plant for Transwestern Coal Gasification Co., Pacific Coal Gasification Co., and Western Gasification Co., and the Expansion of a Strip Mine Operation Near Burnham, N.M. Owned and Operated by Utah International, Inc. Columbus, Ohio: Battelle Columbus Laboratories, 1973.

concentrated in four areas: reservoir, ash disposal area, evaporative ponds, and cooling tower and power block construction. The equipment assumed to be operating in each area was:

Reservoir:	1 crane, 3 bulldozers, 6 dump trucks;
Ash disposal area:	1 crane, 2 bulldozers, 4 dump trucks;
Evaporative ponds:	1 grader, 2 bulldozers; and
Cooling tower and power block construction:	2 cranes, 6 air compressors, 4 rock drills, 10 pneumatic wrenches, 6 welding generators, 2 graders, 6 dump trucks.

The sound levels for each of these pieces of equipment are listed in Table 10-15.

Total sound level of the equipment in each of the four areas will be: reservoir, 92.3 dBA; ash disposal, 91.3 dBA; evaporative ponds, 88.5 dBA; and power block and cooling tower, 109.9 dBA.

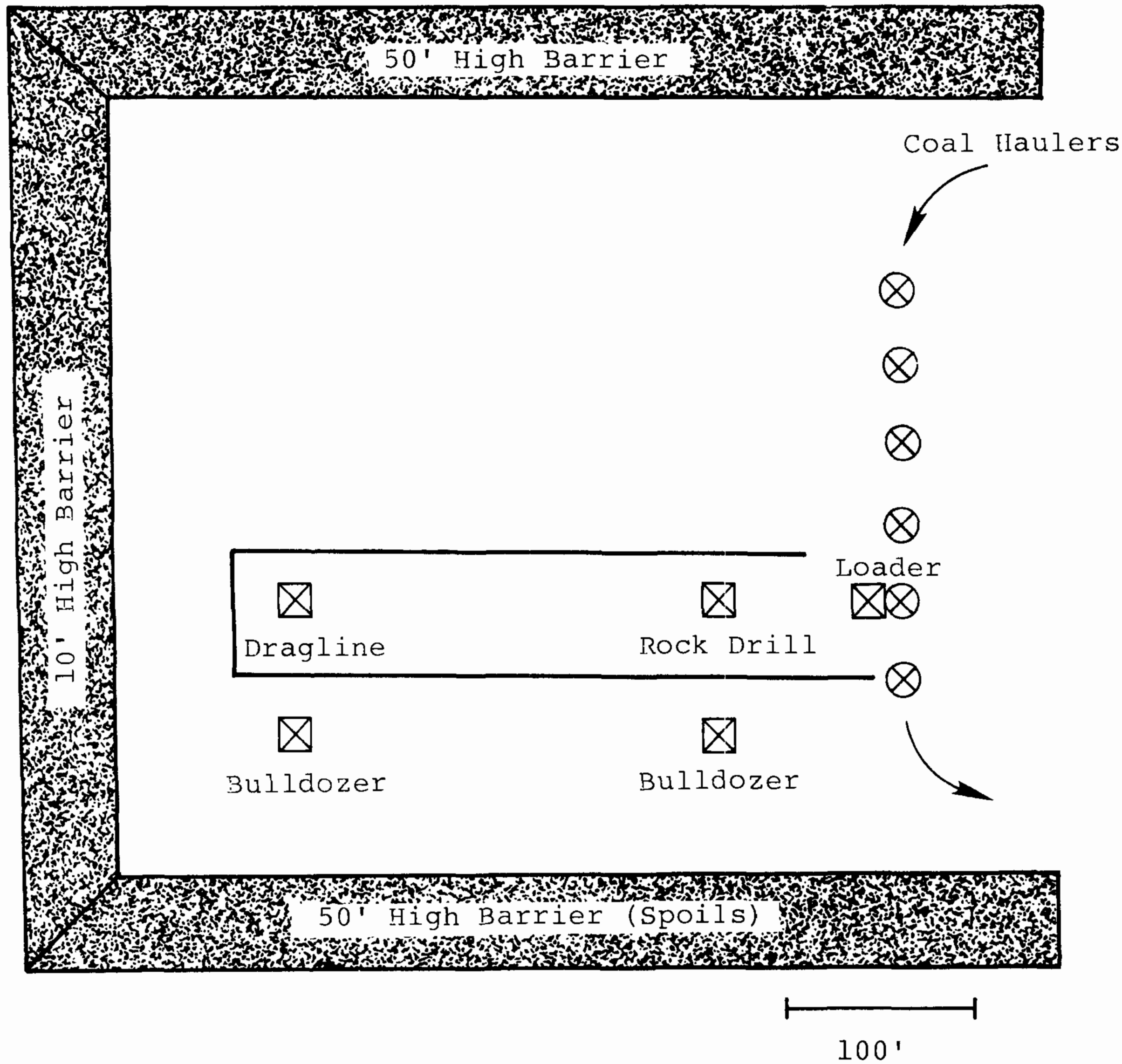

FIGURE 10-2: TYPICAL SURFACE COAL MINE CONFIGURATION

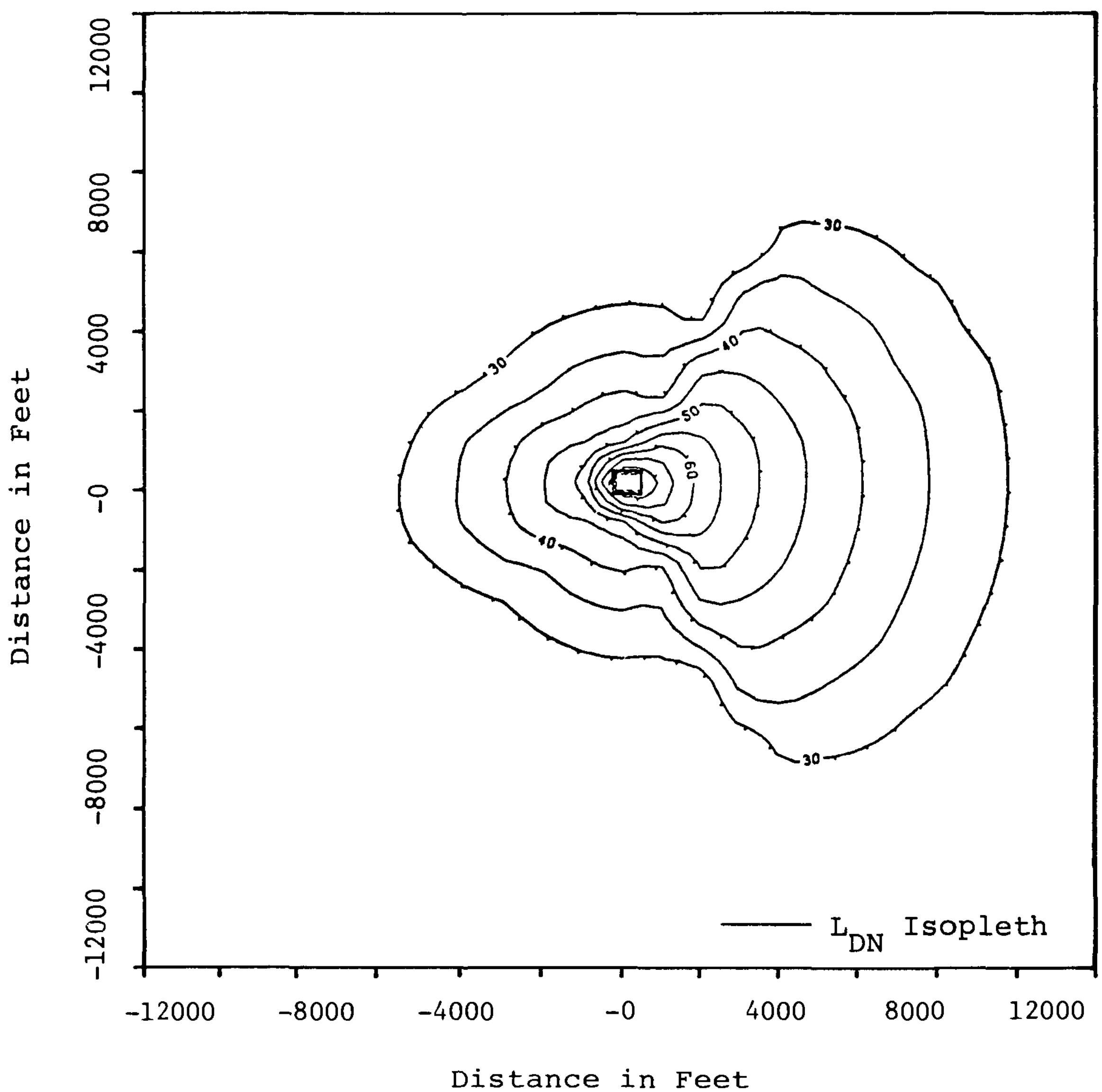

FIGURE 10-3: RADIATED NOISE FOR TYPICAL COAL MINING OPERATION

TABLE 10-15: SOUND LEVELS FOR CONSTRUCTION NOISE SOURCES

EQUIPMENT	SOUND LEVEL PER UNIT (dBA/item)
Bulldozer	80
Air Compressor	86
Welding Generator	83
Rock Drill	99
Pneumatic Drill	98
Crane	88
Grader	86
Dump Truck	81

dBA = decibels A-weighted

Source: Bolt, Beranek, and Newman. Noise from Construction Equipment and Operations, Building Equipment, and Home Appliances. Cambridge, Mass.: Bolt, Beranek, and Newman, 1971.

The principal contributors to cooling tower and power block construction will be pneumatic wrenches and rock drills. Trucks will also be significant noise sources, since there are so many.

Expected noise radiation during plant construction is shown in Figure 10-4. Contours of constant sound level (L_{dn} isopleths) are shown in 5-dB increments from 30 to 70 dBA. The results show that L_{dn} will be greater than 55 dBA within a range of approximately 4,000 feet (over three-quarters of a mile) of the construction areas. This will probably annoy people residing near construction sites.

10.5.5 Plant Operation

Principal noise sources for a typical coal-fired power plant will include the cooling towers, pulverizer, bulldozers on the coal pile, coal car shakers, and railroad car switching. Representative data for these pieces of equipment are listed in Table 10-16. The effect of the power block and the coal pile in weakening the noise levels were included in these predictions.

The predicted radiated noise levels for plant operation are shown in Figure 10-5. L_{dn} levels of 55 dBA will extend to about one mile from the plant. Thus, some community annoyance should be expected out to this distance. L_{dn} levels of 45 dBA will extend to about 1.7 miles from the plant. The plant noise will be noticeable to about this range.

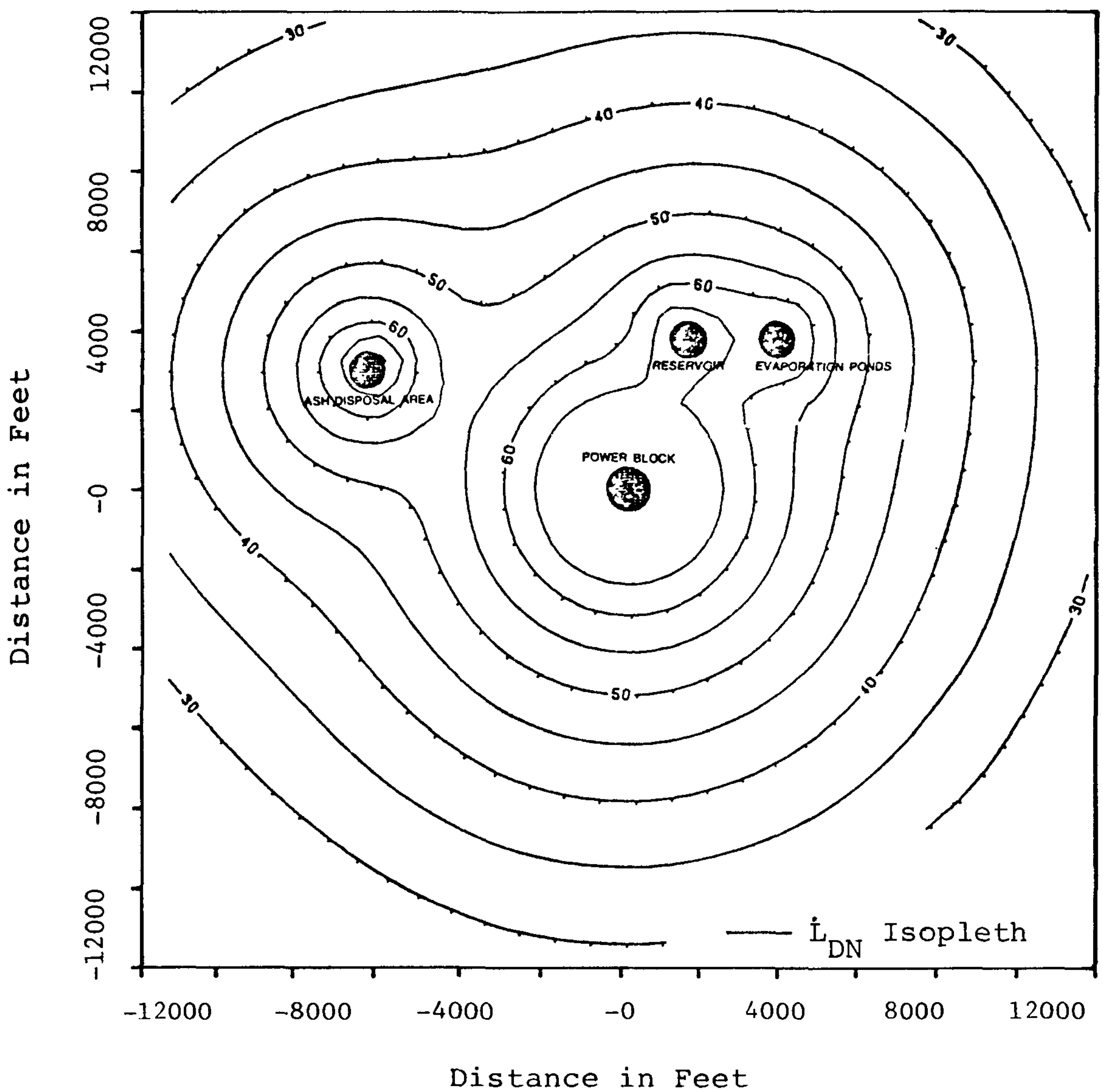

FIGURE 10-4: RADIATED NOISE FOR TYPICAL POWER PLANT CONSTRUCTION

TABLE 10-16: REPRESENTATIVE SOUND LEVEL FOR COAL-FIRED POWER PLANT NOISE SOURCES

EQUIPMENT	SOUND LEVEL PER UNIT (dBA/item)
Cooling Towers[a]	104
Pulverizer	104
Bulldozers[b] (270 horsepower)	80
Car Switching[c] (50% duty)	82
Coal Car Shakers	101

dBA = decibels A-weighted

[a]Tracor, Inc. Guidelines on Noise. Washington, D.C.: American Petroleum Institute, 1973.

[b]Bolt, Beranek, and Newman. Noise from Construction Equipment and Operations, Building Equipment, and Home Appliances. Cambridge, Mass.: Bolt, Beranek, and Newman, 1971.

[c]Swing, Jack W., and Donald B. Pies. Assessment of Noise Environments Around Railroad Operations, Report No. WCR 73-5. El Segundo, Calif.: Wyle Laboratories, 1973.

10.6 AESTHETIC IMPACTS

10.6.1 Introduction

Aesthetic impacts will depend on the personal experiences, priorities, and values that different people place on visual qualities. Aesthetic characteristics are one aspect of quality-of-life considerations, along with social and economic aspects of life such as satisfaction with personal income, housing, and employment. Since these kinds of concerns are measured most accurately through personal responses, this analysis of aesthetic impacts is intended only to identify potential areas of concern associated with western energy resource development. Our categories of aesthetic impacts include land, air, noise, water, biota, and man-made objects (Table 10-17); the overall aesthetic quality of an area probably depends on all these factors.

10.6.2 Land

Strip mining will be the source of many of the aesthetic land impacts in the West. The texture of overburden piles is usually coarse but not distinctive, and uniform from pile to pile.

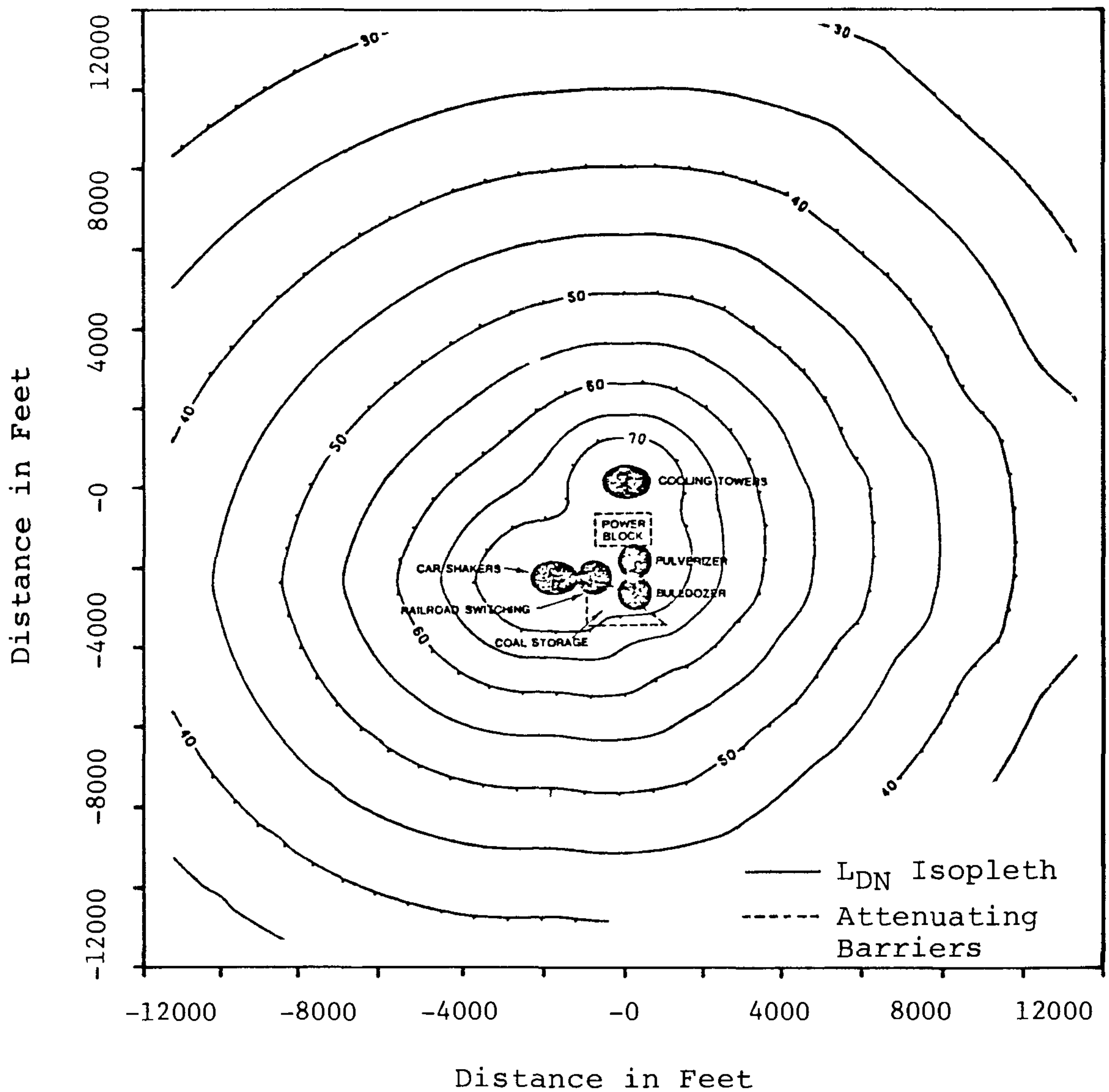

FIGURE 10-5: RADIATED NOISE FOR TYPICAL POWER PLANT OPERATION

TABLE 10-17: CATEGORIES OF AESTHETIC IMPACTS

CATEGORY	CONTRIBUTING FACTORS
Land	Surface Texture and Color Relief and Topographic Character
Air	Odor Visibility
Noise	Background Intermittent
Water	Clarity and Rate of Movemnet Shoreline Appearance Odor and Floating Material
Biota	Domestic Animals, Kind and Quantity Wild Animals Diversity and Density of Vegetation Unique Species
Man-made Objects	Density Skyline Alteration Conspicuousness Overall Impression Isolation Unique Composition

Source: Adapted from Battelle Memorial Institute, Columbus Laboratories. Final Environmental Evaluation System for Water Resource Planing, Contract No. 14-06-D-7182. Washington, D.C.: U.S., Department of the Interior, Bureau of Reclamation, 1972, pp. 59-86; Brossman, Martin W. Quality of Life Indicators: A Review of State-of-the-Art and Guidelines Derived to Assist in Developing Environmental Indicators. Springfield, Va.: National Technical Information Service, 1972; Water Resources Research Center of the Thirteen Western States, Technical Committee. Water Resources Planning, Social Goals and Indicators: Methodological Development and Empirical Test. Logan, Utah: Utah University, Utah Water Research Laboratory, 1974.

The color varies depending on the location but is most often a uniform gray, a color that quite often contrasts with the surrounding surface. Long ridges without variation are the major relief and topographic characteristics of overburden spoils.

The aesthetic impact of this modified topography is often dependent on the scenic properties of a region. In the southwest, for example, limited vegetation of "badlands" areas and their heterogenous topography reduce the extent and contrast of strip-mine spoils. In the Rocky Mountain areas, the impact of modified topography may be significant, but in many instances this can only be viewed from a restricted vantage point. In the Northern Great Plains, mine spoils contrast with the surrounding topography, however, restoration to grasslands or crops occurs more rapidly than in other areas.

Requirements for reclamation of strip-mined land include provisions that land be returned to its original grade. In some cases, aesthetics might be improved by regrading efforts that add distinctive new contours to the land or allow the development of vegetation which was not natural to the area before mining. For additional discussion of reclamation impacts see Chapter 11.

10.6.3 Air

Aesthetic impacts related to air quality are likely no matter where conversion facilities are located in the West. Long-range visibility as a physical air impact has been discussed in Chapter 11.2. The long-range visibility and clean air now enjoyed in most areas of the western states is a valued resource, and the deterioration of visibility is often considered a significant aesthetic impact.[1] A single visible plume in an otherwise clear sky can result in a negative response from some people.

Odors are frequently associated with air pollutants, such as SO_2 and NO_x. However, there are other causes of odors such as trace pollutants and various HC's. Such odors can also detract from aesthetic quality.

10.6.4 Noise

Noise impacts are discussed in Section 10.5. Since noise criteria have been set for occupational hazards but not for public nuisance, most authors place noise in the overall category of aesthetic impacts. Noises which will not damage hearing can still be aesthetically displeasing and negatively affect quality of life. As indicated in Chapter 11.6 (transportation), people living near busy rail lines in the West will be increasingly impacted by noise.

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[1]Josephy, Alvin M. "Kaiparowits: The Ultimate Obscenity." Audubon, Vol. 78 (Spring 1976), pp. 64-90.

10.6.5 Water

The clarity and rate of movement of water are valued aesthetic qualities. Water consumption for energy development will probably increase turbidity and lower flow rates, thereby reducing the turbulence of water movement in many streams. Some ecological impacts of this have been noted as secondary impacts in the local scenarios (Chapters 4-9).

Shoreline appearance can be affected by increased nutrient levels in streams which generate shoreline algae, by reduced stream flows or lake levels which expose previously submerged areas, or by increased turbidity which may settle out to change the color of shore areas. Odors in streams can be caused by increased biological or chemical oxygen demand, excess chlorine or fluorine, and/or various trace materials and pollutants. Odors can be perceived as aesthetically unpleasant even if levels are well within water quality standards. Floating material is almost always considered to be aesthetically displeasing. Garbage, beverage cans, sewage, and oil slicks are usually associated with increased local populations.

10.6.6 Biota

Wild or domestic animals may be perceived favorably and considered to be an aesthetic asset to an area. A negative impact of energy facilities will occur when a development reduces the number of animals either due to disturbance to grazing land or the presence of an increased human population. A valued feature of most public parks is the diversity and well-being of both vegetation and wildlife.

Increased vegetation is almost always a welcome aesthetic addition in and near urban areas. Reclamation efforts at strip mines near towns are critical in this regard. The presence of unique species of plants or animals is a valued aesthetic benefit and reductions in endangered species due to energy development are possible (see Chapter 11).

10.6.7 Man-Made Objects

The density of buildings or other man-made objects can be aesthetically important, and a vast expanse of buildings, railroad cars, drill holes, or other evidence of human presence is aesthetically objectionable to many people. Skyline alteration can be an important impact because of the long distance from which a structure on the skyline can be observed. Tall smokestacks and transmission lines are often the most objectionable of these features, especially in the rural West where man-made features are relatively few. However, even right-of-way clearings for buried pipelines may produce an objectionable skyline alteration.

Conspicuousness is related to skyline alteration, but a facility may be conspicuous without altering the skyline. Color, architectural design, and location relative to tall natural features are important. Facilities designed to conform to the surroundings wherever possible are often aesthetic benefits rather than costs.

In contrast, some individuals also perceive man-made structures or engineering activities as aesthetically pleasing. For example, the sweeping lines of large cooling towers or tall stacks can be viewed as a positive contribution to an apparently barren or desolate landscape. The range of these individual perceptions highlights the difficulty in generalizing about the aesthetic costs and benefits of energy resource development.

10.7 PUBLIC HEALTH IMPACTS

10.7.1 Introduction

As indicated in Sections 10.2, 10.3, and 10.4, energy development exposes people to pollutants such as sulfur oxides, particulates, trace elements, radioactive substances, and organic chemicals such as HC. Each of these can adversely affect public health. Some of these chemicals are released in very large quantities, while others are emitted in small amounts. In addition, some of these substances may change in the environment to form compounds with different chemical properties (e.g., sulfates, nitrates, photochemical oxidants).

The impact of many of these substances on humans is still uncertain; however, a number of studies indicate that public health may be endangered by: (1) inhalation of substances emitted from energy facilities; (2) ingestion of substances from water contaminated either directly by effluents or by leaching from waste disposal areas; or (3) ingestion of animal or plant foods, such as milk, that have picked up hazardous substances (e.g., arsenic) released by energy conversion processes. Also, energy development activities may cause increased accident rates for the general public.[1]

Health effects can be as clear-cut as increased mortality (death) from a train accident or as difficult to ascertain as small increases in birth defects or in the incidence of cancer. The most pervasive uncertainty is that associated with dose-response relationships where understanding is incomplete at best. Human responses to pollutant doses are influenced by a host of factors, such as: the individual's age and general health, the presence or absence of other pollutants, general environmental

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[1]For a description of accidents associated with transportation facilities, see Chapter 11.

conditions, and the constancy or variation of the pollutant concentration. The level of ill health that is serious varies according to age, sex, race, and occupation. For example, respiratory irritation caused by elevated SO_2 levels may be a minor problem to teenagers but a major concern to the elderly.[1] Types of responses are identified and summarized in Table 10-18.

Because dose-response relationships are uncertain, there is little agreement on defining appropriate "zero-effect" exposure levels for the pollutants produced by energy facilities. Some pollutants can be tolerated without adverse effects as long as exposure is below some threshold level; other pollutants, however, will cause adverse effects at any level of exposure (no threshold). Unless these threshold determinations can be made, the only way to avoid health impacts is to avoid exposure entirely, which is usually expensive and often unattainable. Determination of "zero-effect" exposure levels for human beings may, in fact, be impossible because of limitations in experimental research (e.g., clinical investigation requires the deliberate exposure of human subjects to health hazards). Consequently, determination of dose-response is generally limited to extrapolations from toxicological studies of animals or historical studies of human events. Thus, adverse health effects from western energy development are difficult to determine at the current time.

This section identifies adverse health effects to the general population outside the "fence-line" of energy facilities,[2] addressing several categories of death and illness (Table 10-18). Data on the pollutants from energy facilities that could cause health impacts are identified and discussed by disease category.

10.7.2 Residuals from Energy Development

Table 10-19 lists some of the residuals introduced by energy development and the type of health impact which can be associated with each. Quantities of most of these pollutants emitted by energy facilities were given in Chapters 4-9 and summarized in Chapter 3. Selected data on the relationship of these pollutants to disease are described for three specific disease categories: respiratory disease, cancer, and systemic illnesses.

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[1]Argonne National Laboratory, Energy and Environmental Systems Division, Environmental Impact Studies Division, and Biological and Medical Research Division. <u>A Preliminary Assessment of the Health and Environmental Effects of Coal Utilization in the Midwest, Vol. I: Energy Scenarios, Technology Characterizations, Air and Water Resource Impacts, and Health Effects</u>, Draft. Argonne, Ill.: Argonne National Laboratory, 1977, pp. 169-80.

[2]Occupational health and safety problems (inside the fence-line) are discussed in Section 10.8.

TABLE 10-18: SELECTED TYPES OF HEALTH RESPONSES[a]

TYPE	DESCRIPTION
Irritation	Organs or tissues are inflamed as a reaction against foreign materials. Widespread inflamation may increase susceptibility to disease.
Coirritant effect	Stimulation or irritation when exposures with other substances result in irritation. For example, simultaneous exposure to both ozone and oxides of nitrogen can result in additive or multiplicative responses.
Aggravation of pre-existing conditions	Exposure to some pollutants may have acute or fatal results if a preexisting heart or lung ailment exists.
Direct toxicity	Cellular damage from agents that disrupt cell function. Key enzymes may be inactivated resulting in local or widespread loss of organ or tissue function.
Physical synergisms or blocking	Loss of ciliary activity, for example, or thickening of tissues that interferes with removal of foreign materials.
Carcinogenesis (Cancer)	Pollutants or metabolic byproducts may stimulate uncontrolled growth of tissue that results from an accumulation of genetic mutations, chromosome aberration, biochemical changes or viral infection.
Cocarcinogenic effects	A factor that facilitates the induction of cancer by another substance, (e.g., exposure to sulfur dioxide increases cancer rate from Benzapyrene aerosol).
Birth defect or Teratogenesis	Abnormal birth or stillbirth resulting from genetic, maternal, or other causes.
Mutagenesis	Chromosome or gene damage that may be expressed as cancer or birth defects or disease.
Protective effects	Some exposures result in the development of cross tolerances. For example prior exposure to ozone reduces the irritant effect of a subsequent exposure to other oxidants.

[a]Modified from Argonne National Laboratory, Energy and Environmental Systems Division, Environmental Impact Studies Division, and Biological and Medical Research Division. A Preliminary Assessment of the Health and Environmental Effects of Coal Utilization in the Midwest, Vol. I: Energy Scenarios, Technology Characterizations, Air and Water Resource Impacts, and Health Effects, Draft. Argonne, Ill.: Argonne National Laboratory, 1977, pp. 169-80.

TABLE 10-19: SELECTED RESIDUALS FROM ENERGY DEVELOPMENT AND TYPES OF HEALTH EFFECTS

RESIDUAL	TYPE OF EFFECT
Air	
Sulfur dioxide (and sulfates)	Respiratory disorders
Fine particulates	Respiratory disorders
Hydrocarbons	Cancer
Trace elements	Circulatory and respiratory disorders
Radioactive particles	Cancer
Water	
Hydrocarbons	Cancer
Trace elements	Circulatory and systemic disorders
Bacteria (sewage)	Infectious disease
Radioactive particles	Cancer
Land and Transportation	
Trains	Accident (collisions)
Trucks	Accident (collisions)
Extra-high voltage lines	Nervous system disorders
Pipelines	Accidents (explosion and fire)
Construction and Operation Employees	Accidents and disease transmission

10.7.3 Respiratory Problems

Accelerated fossil fuel utilization results in increased emissions of SO_2, NO_x, particulates, and many other air pollutants. As shown in Table 10-20, human illness and death from respiratory diseases have been related to these air pollutants. Possible effects include increases in new cases and/or aggravation of existing cases of bronchitis, emphysema, pneumonia, and asthma. There could also be other respiratory and cardiovascular symptoms, together with secondary effects on other parts of the body (such as the heart) that would be strained because of coughing or breathing difficulties. These effects are especially likely during prolonged periods of atmospheric inversion when ambient concentrations peak.

Although these effects have been studied intensively, dose-response relationships are still ambiguous. Most research has concentrated on particulates and SO_2 (with the 1952 air pollution disaster in London being a major source of data). Adverse health effects appear to result from a complex of emitted pollutants rather than from any single pollutant.[1] Research also indiates that the risk of health impacts is especially high for children, asthmatics, the elderly, and individuals who already suffer from cardio-respiratory disease.[2] For example, epidemiological studies in Great Britain have demonstrated a relationship between particulate and SO_2 pollution and the incidence of bronchitis, chronic cough, and reduced lung function in children. While SO_2 is associated with lower respiratory tract bacterial illness, NO_x seems to be associated with increased susceptibility to upper respiratory tract viral infections, especially in children. There is considerable evidence that symptoms of emphysema and other chronic pulmonary diseases are worsened by high short-term levels of air pollution.[3] Effects of specific pollutants are discussed below.

A. Sulfur Dioxide

Present SO_2 levels are low (2 to 20 $\mu g/m^3$) in most rural locations where energy development will occur. Installation of energy facilities, particularly power plants, will contribute to higher SO_2 levels as summarized in Chapters 3 and 11. If scrubbers are used, the increase in SO_2 caused by energy facilities

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[1]Goldstein, B.D. Health Effects of Gas-Aerosol Complex, Report to the Special Committee on Health and Biological Effects of Increased Coal Utilization. New York, N.Y.: New York University Medical Center, 1977, p. 1.

[2]Ibid., p. 14.

[3]Ibid., p. 1.

TABLE 10-20: AIR POLLUTANTS AND ASSOCIATED RESPIRATORY HEALTH EFFECTS[a]

MAJOR POLLUTANTS	PRINCIPAL RESPIRATORY EFFECT OF INHALATION (known or suspected)
Total Suspended Particulates	Directly toxic effects or aggravation of the effects of gaseous pollutants, especially SO_x; aggravation of asthma or other respiratory or cardiorespiratory symptoms; increased cough and chest discomfort; increased mortality
Oxides of Sulfur	Aggravation of respiratory diseases, including asthma, chronic bronchitis, and emphysema; reduced lung function: irritation of respiratory tract; increased mortality
Photochemical Oxidants	Aggravation of respiratory and cardiovascular illness, irritation of respiratory tract, impairment of cardiopulmonary function
Oxides of Nitrogen	Aggravation of respiratory and cardiovascular illness; increased respiratory inhibition; cause of pneumonia
Arsenic	Bronchitis and other respiratory illnesses
Barium	Nose and throat irritation
Beryllium	Acute and chronic respiratory disorder from short term exposure
Chromium	Lesions of respiratory mucous membranes
Fluorides	Irritation of respiratory tract and respiratory impairment
Manganese	Pneumonia in high doses
Nickel Carbonyl	Possible cause of asthma
Phenols and Cresols	Corrosion of mucous membranes of nasal and respiratory tract
Selenium	Respiratory irritation
Vanadium	Acute respiratory irritation

SO_x = oxides of sulfur

[a]Kash, Don E., et al. Impacts of Accelerated Coal Utilization, Report submitted to the Office of Technology Assessment. Norman, Okla.: University of Oklahoma, Science and Public Policy Program, 1977, p. 8-1. Adapted from U.S., Council on Environmental Quality. Environmental Quality, Sixth Annual Report. Washington, D.C.: Government Printing Office, 1975.

and urban activities will be below primary and secondary standards for all averaging times. One exception is western Colorado, where plume impaction on elevated terrain will cause primary standards to be violated.[1] If scrubbers are not used, facilities in areas of relatively flat terrain could result in SO_2 concentrations which exceed the ambient standards designed to protect human health.

Even with 80 percent sulfur removal, a potential health problem could result from exposure to sulfate. Whether this is a problem depends on the conversion rates of SO_2 to sulfate. As discussed previously in this chapter, rate estimates vary from 1 to 20 percent conversion of SO_2 to sulfate per hour, although conversion rates for the facilities studied here appear to range from 1 to 3 percent.[2] If conversion rates are 10 percent per hour, 24-hour ambient sulfate levels are as much as two times greater than those projected to produce increases in mortality according to EPA studies (Table 10-21).[3]

These data can be extended to compare the health risk of these levels of atmospheric sulfate against baselines of health disorders of average U.S. populations (Table 1-22).[4] These data indicate that energy facilities emissions may cause an aggravation of asthma, and heart and lung disease in the elderly.

B. Oxidants

Oxidants in the atmosphere are a product of the photochemical reactions of HC and NO_2 (among other compounds). The process is augmented in situations where pollutants accumulate by virtue of topographic and/or meteorological factors. Although oxidants could become a problem in the oil shale region (see Rifle scenario) due

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[1]In western Colorado, values may exceed standards in some areas during conditions which do not favor dispersal. On a regional scale of development, additional areas of plume impaction may occur.

[2]U.S., Congress, House of Representatives, Committee on Science and Technology, Subcommittee on Environment and the Atmosphere. Review of Research Related to Sulfates in the Atmosphere, Committee Print. Washington, D.C.: Government Printing Office, 1976.

[3]U.S., Environmental Protection Agency. Position Paper on Regulation of Atmospheric Sulfates, EPA 450/2-75-077. Research Triangle Park, N.C.: National Environmental Research Center, 1975.

[4]Data on disease incidence in populations at risk within the eight state study area are not available.

TABLE 10-21: LOCAL SCENARIO SULFATE CONCENTRATIONS AND THEIR HEALTH EFFECTS

SCENARIO	PEAK SULFATE CONCENTRATION (micrograms per cubic meter) CONVERSION RATE[a] ONE PERCENT	TEN PERCENT
Kaiparowits/Escalante	2.2	22
Navajo/Farmington	0.8	8
Rifle	1.5	15
Gillette	.5	5
Colstrip	.9	9
Beulah	1.1	11
HEALTH EFFECTS[b]	**LEVELS PRODUCING HEATLH EFFECTS**	
Aggravation of asthma	6-10	
Increased chronic bronchitis	14	
Increased acute respiratory disease	10-25[c]	

[a]Conversion rates vary for different technologies and are dependent on particle size and other factors. Rates for coal-fired power plants have been reported at 1-3 percent per hour, and rates for oil-fired power plants are as much as 20 percent per hour.

[b]U.S., Environmental Protection Agency. Position Paper on Regulation of Atmospheric Sulfates, EPA 450/2-75/007. Research Triangle Park, N.C.: National Environmental Research Center, 1975.

[c]U.S., Council on Environmental Quality. Environmental Quality, Sixth Annual Report. Washington, D.C.: Government Printing Office, 1975.

TABLE 10-22: HEALTH IMPACTS OF SULFATE AEROSOL[a]

HEALTH EFFECT	POPULATION AT RISK	ASSUMED BASELINE FREQUENCY OF DISORDER WITHIN POPULATION AT RISK	POLLUTANT CONCENTRATION THRESHOLD FOR EFFECT	EFFECT OF INCREASE AS PERCENT OF BASELINE PER POLLUTANT UNIT ABOVE THRESHOLD
Mortality	Total population	Daily death rate of 2.6 per 100,000	25 $\mu g/m^3$ for one day or more	2.5% per 10 $\mu g/m^3$
Aggravation of heart and lung disease in elderly	Chronic heart and lung disease among population older than 65 years is 27%	One out of five of population at risk complain of symptom aggravation on any given day	9 $\mu g/m^3$ for one day or more	14% per 10 $\mu g/m^3$
Aggravation of asthma	Asthma in the general population is 3%	One out of 50 asthmatics experiences an attack each day	6 $\mu g/m^3$ for one day or more	34% per 10 $\mu g/m^3$
Lower respiratory disease in children	All children	50% of children have one attack per year	13 $\mu g/m^3$ for several years	77% per 10 $\mu g/m^3$

$\mu g/m^3$ = micrograms per cubic meter

[a]Argonne National Laboratory, Energy and Environmental Systems Division, Environmental Impact Studies Division, and Biological and Medical Research Division. A Preliminary Assessment of the Health and Environmental Effects of Coal Utilization in the Midwest, Vol. I: Energy Scenarios, Technology Characterizations, Air and Water Resource Impacts and Health Effects, Draft. Argonne, Ill.: Argonne National Laboratory, 1977.

to HC emissions, the photochemical process is so complex that predictions of levels or locations where oxidants may be a health problem are not possible.

C. Nitrogen Dioxide and Other Oxides of Nitrogen

Two important forms of NO_x are nitric oxide (NO) and NO_2. NO_2 is more stable and is a lung irritant in short-term exposures (4-6 hours) at levels as low as 0.5 ppm (1,000 $\mu g/m^3$).[1] Some studies have indicated diminished lung function and possible cancer-producing effects from NO_x. Tables 10-23 and 10-24 show projected NO_x concentrations in our scenarios and potential health effects at various concentrations.[2] Acute effects are possible at NO_2 concentrations of 1,000 $\mu g/m^3$ (Table 10-23) while respiratory illness rates increase at 24-hour concentrations above about 150 $\mu g/m^3$. Concentrations predicted to occur around urban areas as a result of energy development (Table 10-23) are below 100 $\mu g/m^3$ except at Farmington and Gillette. However, peak 24-hour concentrations in the vicinity of power plants are all above 100 $\mu g/m^3$ and range as high as 1,200 $\mu g/m^3$ where plumes impact on rugged terrain. While these extremely high values due to plume impaction probably do not present a major health problem (since few people generally reside where the plumes impact), some increase in respiratory illness rates in the vicinity of power plants is possible.

D. Particulates

Although much of the research focus on health effects has been on total suspended particulates (TSP), it now appears that fine particulates may be a more important contributor to health

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[1]Argonne National Laboratory, Energy and Environment Systems Division, Environmental Impact Studies Division, and Biological and Medical Research Division. A Preliminary Assessment of the Health and Environmental Effects of Coal Utilization in the Midwest, Vol. I: Energy Scenarios, Technology Characterizations, Air and Water Resource Impacts and Health Effects, Draft. Argonne, Ill.: Argonne National Laboratory, 1977, p. 171.

[2]See Chapman, R.S., et al. "Chronic Respiratory Disease." Archives of Environmental Health, Vol. 27 (September 1973), pp. 138-42; U.S., Department of Health, Education and Welfare, Public Health Service, National Air Pollution Control Administration. Chattanooga, Tennessee-Rossville, Georgia Interstate Air Quality Study, 1967-68, Publication No. APTD-0583. Durham, N.C.: National Air Pollution Control Administration, n.d.; and Shy, C.M., et al. "The Chattanooga School Children Study: Effects of Community Exposure to Nitrogen Dioxide; Incidence of Acute Respiratory Illness." Journal of the Air Pollution Control Association, Vol. 20 (September 1970), pp. 582-88.

TABLE 10-23: PEAK NITROGEN DIOXIDE CONCENTRATION FOR SCENARIO LOCATIONS (24-hour average measured in micrograms per cubic meter)

LOCATION	SOURCE: URBAN (1990)	SOURCE: POWER PLANT
Kaiparowits	88	130 - 220
Escalante	-	760 - 1,260
Farmington	163	125 - 210
Rifle (Grand Valley)	57	380 - 630
Gillette	140	115 - 190
Colstrip	54	120 - 200
Beulah[a]	42	170 - 280
Acute Biological Effects	1,000	(4-6 hours)

[a]Urban value is for 1995, not 1990.

impacts.[1] Particulate scrubbers can remove approximately 99 percent (by weight) of the particulates in power plant emissions; however, this efficiency varies as a function of particle size. Fine particulates are not trapped as efficiently as larger particulates by current particulate removal systems. These fine particulates may pose serious health hazards because they can absorb sulfates, heavy metals, and nitrogen compounds and carry them into respiratory systems.[2] While larger particulates also possess this property, smaller particulates are especially amenable to absorption of toxic materials, including trace metals.[3] In combination with gaseous air pollutants, such as SO_2, particulates

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[1]Fine particulates are those less than 3 microns in size.

[2]Electric Power Research Institute. "Coordinating the Attack on Particulates." EPRI Journal, Vol. 2 (September 1977), pp. 16-18.

[3]Glass, Norman R., ed. "Environmental Effects of Increased Coal Utilization: Ecological Effects of Gaseous Emissions from Coal Combustion." Washington, D.C.: U.S., Environmental Protection Agency, Office of Research and Development, Office of Health and Ecological Effects, November 4, 1977.

TABLE 10-24: AVERAGE BIWEEKLY RESPIRATORY ILLNESS RATES PER 1,000 FAMILIES ACCORDING TO EXPOSURE TO NITROGEN DIOXIDE

NO_2 EXPOSURE LEVEL (Average 24-hour)		ILLNESS RATE FOR ALL FAMILY MEMBERS
PARTS PER MILLION	MICROGRAMS PER CUBIC METER	
0.109	200	17.7
0.078	150	17.5
0.062	117	16.3
0.043	90	15.0

NO_2 = nitrogen dioxide

[a]Modified from Braustein, H.S., E.D. Copenhaver, and H.A. Pfuderer. Environmental, Health and Control Aspects of Coal Conversion: An Information Overview. Oak Ridge, Tenn.: Oak Ridge National Laboratory, 1977, Vol. 2, p. 10-79; and Shy, C.M., et al. "The Chattanooga School Children Study: Effects of Community Exposure to Nitrogen Dioxide; Incidence of Acute Respiratory Illness." Journal of the Air Pollution Control Association, Vol. 20 (September 1970), pp. 582-88.

may worsen the toxic effects.[1] Furthermore, the smaller size of fine particulates allows them to be inhaled deeper into the lungs (Figure 10-6).

There is a significant natural background level of airborne particulates in all areas, especially in arid environments. Very wide variations occur; the range is 1-600 $\mu g/m^3$ or more and is a function of the arid conditions and occasional dust storms. Thus, the 24-hour federal primary standard of 260 $\mu g/m^3$ is probably exceeded frequently throughout a year.

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[1]Argonne National Laboratory, Energy and Environmental Systems Division, Environmental Impact Studies Division, and Biological and Medical Research Division. A Preliminary Assessment of the Health and Environmental Effects of Coal Utilization in the Midwest, Vol. I: Energy Scenarios, Technology Characterizations, Air and Water Resource Impacts and Health Effects, Draft. Argonne, Ill.: Argonne National Laboratory, 1977.

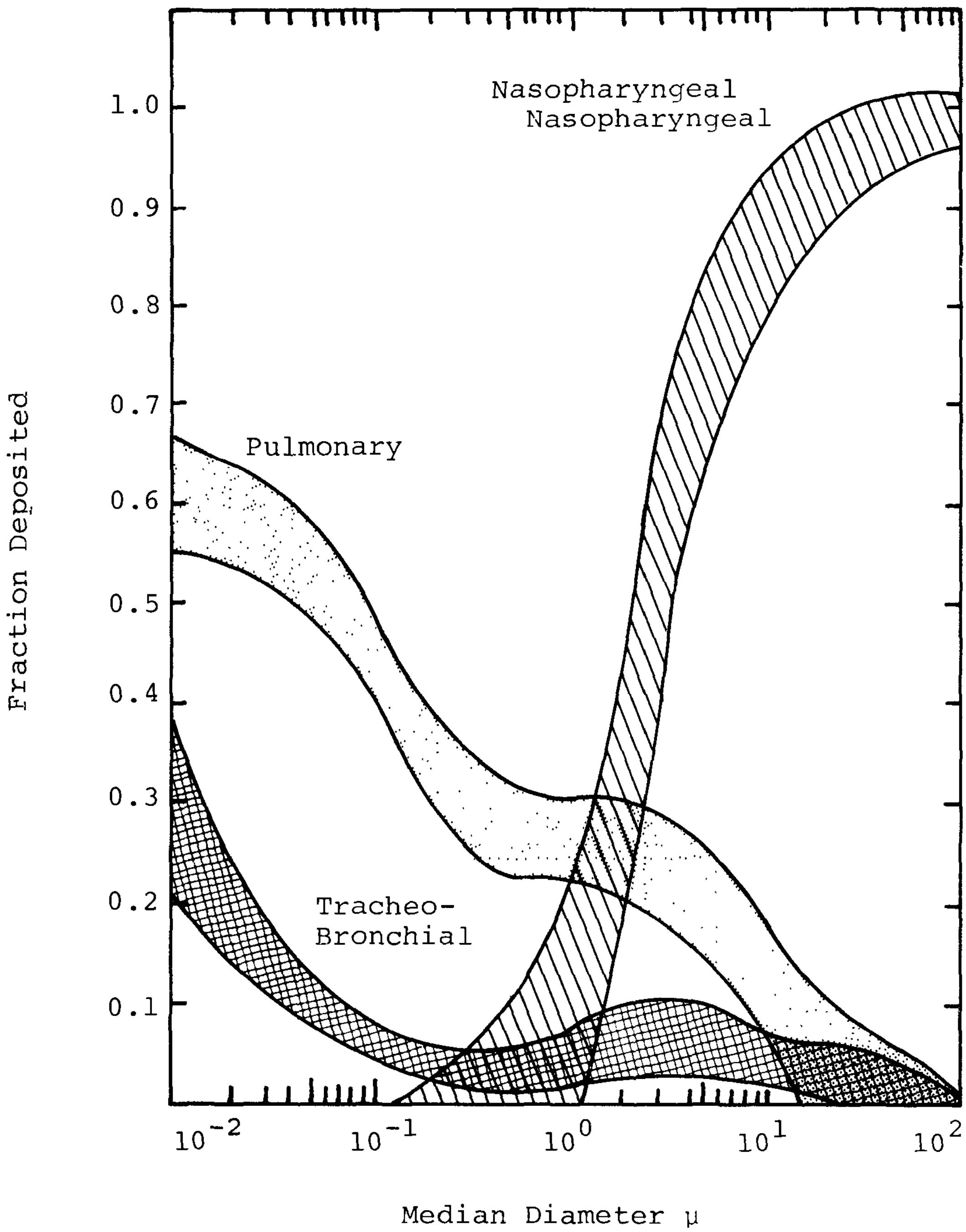

FIGURE 10-6: FRACTION INHALED PARTICLES DEPOSITED IN THE THREE RESPIRATORY TRACT COMPARTMENTS AS A FUNCTION OF MASS MEDIAN DIAMETER

Source: Braumstein, H.M., E.D. Coperhaven and H.A. Pfudever. Environmental, Health and Control Aspects of Coal Conversion: An Information Overview. Vol. 2, p. 10-24. Oak Ridge National Laboratory, April 1977.

Over the six scenarios, energy facilities will contribute 18-152 $\mu g/m^3$ to ambient air particulate loading, and urban expansion will contribute about 30-100 $\mu g/m^3$. Because ambient concentrations periodically exceed standards, emissions from facilities and urban expansion may aggravate health problems. The particles emitted from energy facilities will be small (half of the particles, by weight, have a diameter below 1-3 microns) and will remain suspended in the atmosphere over long distances (hundreds of miles).

10.7.4 Cancer

The pollutants of primary concern as to the incidence of cancer from increased combustion or conversion of fossil are HC and radioactivity. HC compounds such as benzo(a)pyrene, a polynuclear aromatic hydrocarbon (PAH), as well as air and waterborne radioactive elements are known to cause cancer in experimental animals and are considered responsible for certain kinds of cancer in people. Although the clearest danger of such impacts is in connection with occupational health (discussed in Section 10.8), there are some risks to public health as well. Some carcinogenic substances and their effects are summarized in Table 10-25. HC and radioactive emissions and effects are discussed in more detail.

A. Hydrocarbons

Fossil fuel combustion or conversion (e.g., synthetic fuel processes) create HC compounds that do not exist naturally. For instance, the pyrolysis of organic materials often leads to carcinogenic tars, including condensed PAH, due to incomplete combustion.[1] Generally, the hotter the temperature at which fuels are carbonized, the greater the production of carcinogenic agents. Some HC are carcinogenic on their own. Others are cocarcinogenic: that is, in combination with a "promoter," they change from being inactive to being carcinogenic. For example, either SO_2 or particulates when in combination with benzo(a)pyrene have been shown to be associated with lung tumor formation.[2] Still other HC appear to be anticarcinogenic, at least under certain conditions. One research conclusion to date is that the combination

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[1] Kennaway, E.C. "Experiments on Cancer-Producing Substances." British Medical Journal, Vol. 2 (1925), pp. 1-4, as cited in Falk, Hans L. Health Effects of Coal Mining and Combustion, No. 7: Carcinogens and Cofactors. Oak Ridge, Tenn.: Oak Ridge National Laboratory, Information Center Complex, Environmental Reponse Center, 1977, p. 27.

[2] Much of this research has been conducted on laboratory animals and the effects on humans are less certain.

TABLE 10-25: CARCINOGENS AND THEIR EFFECTS

SUBSTANCE	PRINCIPAL CARCINOGENIC EFFECT OF INHALATION, INGESTION, AND CONTACT
Arsenic	Skin cancer
Benzene	Suspected cause of leukemia
Beryllium	Suspected cause of bone and lung cancer
Cadmium	Possible relation to prostate cancer
Chromium	Suspected cause of lung cancer
Hydrocarbons	Suspected contribution to cancer
Lead	Suspected occupational carcinogen
Nickel	Occupational cancer incidence
Nickel Carbonyl	Cause of lung cancer
Phenols and Cresols	Occupational carcinogen (skin)
Polycyclic Aromatic Hydrocarbons	Carcinogen
Some Radioactive Substances (Compositions vary with different types of coal)	Linkage with a few certain types of cancer
Zinc Chloride	Possible carcinogen

Source: U.S., Council on Environmental Quality. Environmental Quality, Sixth Annual Report. Washington, D.C.: Government Printing Office, 1975; U.S., Council on Environmental Quality. Environmental Quality, Seventh Annual Report. Washington, D.C.: Government Printing Office, 1976.

of cigarette smoking and urban air pollution is clearly associated with a high incidence of lung cancer.[1] Investigators in Britain have also found a relationship between air pollution and stomach cancer,[2] and the same effect has been observed in the U.S.[3] One study estimated that a 1,000 MWe coal-fired plant, located in an area where a population of 1.5 million lived within an 80 kilometer radius, would result in 1-6 deaths a year due to PAH emissions.[4]

Measurements of HC are not available in most rural areas included in these scenarios but high background HC levels (130 $\mu g/m^3$) have been measured in the oil shale area of northwestern Colorado. Sources of HC include vegetation, evaporation from subsurface petroleum deposits,[5] and present urban/industrial activity. However, these naturally occurring HC have low PAH content.

In many urban areas the current federal 3-hour ambient air quality standard for HC is already exceeded largely due to automotive emissions. Data from our site-specific analyses (summarized in Section 3.2) indicate that the HC standard will be violated as a result of urban expansion induced by energy development at most such sites in the West. In addition to cars, the major sources of HC are fugitive losses from synthetic fuels plants and fuel storage facilities. Power plant operations are

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[1]Falk, Hans L. Health Effects of Coal Mining and Combustion, No. 7: Carcinogens and Cofactors. Oak Ridge, Tenn.: Oak Ridge National Laboratory, Information Center Complex, Environmental Response Center, 1977.

[2]Ibid.; Goldstein, B.D. Health Effects of Gas-Aerosol Complex, Report to the Special Committee on Health and Biological Effects of Increased Coal Utilization. New York, N.Y.: New York University Medical Center, 1977, p. 1.

[3]Falk. Health Effects of Coal Mining, No.7.

[4]Argonne National Laboratory. An Assessment of the Health and Environmental Impacts of Fluidized Bed Combustion of Coal Applied to Electric Utility Systems, Draft. Argonne, Ill.: Argonne National Laboratory, 1977, as cited in Baser, M.E., and S.C. Morris. Assessment of the Potential Role of Trace Metal Health Effects in Limiting the Use of Coal Fired Electric Power, informal report. Upton, N.Y.: Brookhaven National Laboratory, National Center for Analysis of Energy Systems, Biomedical and Environmental Assessment Division, 1977, p. 11; and Lundy, R., as cited in Ibid.

[5]See Section 10.8 for a description of cancer related to crude oil extraction and refining.

generally a minor contributor. These new sources of PAH compounds will be introduced into areas that have been relatively free of such contamination. Although stack gas cleaning systems remove most of the PAH, removal may only imply transferral to sludge materials. These solid wastes and others from new coal conversion technologies may pose new health dangers since carcinogenic compounds could escape from the solid waste disposal areas and enter water supply systems. Very little is known about the potential seriousness of water contamination.

B. Radioactive Materials

Exposure to radiation is possible from coal, uranium, and oil shale resource systems. Very little is known about the fate of radioactive materials from oil shale processing and it is not considered further here. Current information on exposure to radioactive materials from coal and uranium facilities is discussed below.

(1) Coal Facilities

Radioactivity in coal is highly variable, as shown in Table 10-26. Reported values for Radium 226 (Ra-226), a major source of this radioactivity, generally range from 1 to 4 picocuries[1] per gram (pCi/g) of coal in the U.S.[2] When coal is burned, most of the radium remains with the ash and is therefore concentrated. Ra-226 concentrations have been reported in various coal ashes, ranging from 2.1 to 5.0 pCi/g with a mean of 3.8 pCi/g;[3] other investigators have reported up to 8.0 pCi/g. This may be compared with a typical value of 1.0 pCi/g for ordinary soils.

Depending on the disposition of the ash retained by the collectors, opportunities exist for radioactivity to enter the environment. If the ash is simply accumulated in piles, radioactive material may be resuspended with dust or leached from the piles to local surface waters. Radon-222 (Rn-222) (a product of

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[1]Picocuries, a standard measurement of radioactivity, indicate the disintegration of 0.037 nuclei per second.

[2]Jaworowski, A., et al. "Artificial Sources of Natural Radionuclides in the Environment," in Adams, J., W.M. Lowder, and T.F. Gesell, eds. Natural Radiation Environment, CONF 720805-P2. Washington, D.C.: U.S., Energy Reserach and Development Administration, 1972, pp. 809-18.

[3]Eisenbud, M., and H.G. Petrow. "Radioactivity in the Atmospheric Effluents of Power Plants That Use Fossil Fuels." Science, Vol. 144 (April 17, 1964), pp. 288-89.

TABLE 10-26: RADIOACTIVITY IN SELECTED COALS[a]
(picocuries per gram)

COAL SAMPLE LOCATION	Ra-226	Ra-228	Th-220	Th-232
Western U.S.				
Utah	1.3	0.8	1.0	-
Wyoming	-	1.3	1.6	-
Montana	2.9[b]	0.8	0.8	0.8
Other U.S.				
Widow's Creek	1.6	2.7	2.8	2.7
Appalachian	3.8	2.4	2.6	-
Bartsville	2.3	3.1	-	3.1
Alabama	2.3	2.2	2.3	-
Tennessee Valley Authority	4.25	2.85	2.85	2.85
Colbert	3.1	6.9	1.6	6.9
Foreign				
Japan	-	1.5	1.6	-
Australia	7.98	-	-	-
Poland	2.0[b]	-	-	-

Ra = radium — = unknown
Th = thorium

[a]Eisenbud, M., and H.G. Petrow. "Radioactivity in the Atmospheric Effluents of Power Plants That Use Fossil Fuels." Science, Vol. 144 (April 17, 1964), pp. 288-89; Martin, J.E., E.D. Harward, and D.T. Oakley. "Radiation Doses from Fossil Fuel and Nuclear Power Plants," in International Atomic Energy Agency Symposium, New York, 1970, Report SM-146/19. Vienna, Austria: International Atomic Energy Agency, 1971, pp. 107-25; Jaworowski, A., et al. "Artificial Sources of Natural Radionuclides in the Environment," in Adams, J., W.M. Lowder, and T.F. Gesell, eds. Natural Radiation Environment, CONF 172805-P2. Washington, D.C.: U.S., Energy Research and Development Administration, 1972, pp. 809-18; Bedrosian, P.H., D.G. Easterly, and S.L. Cummings. Radiological Survey Around Power Plants Using Fossil Fuel, Report #EERL 71-3. Washington, D.C.: U.S., Environmental Protection Agency, 1971.

[b]Assuming 15 percent ash content.

the radioactive decay of thorium and radium) emanates as a gas from these piles.[1]

Concentrations of radioactivity in the air due to coal combustion may be estimated by multiplying the radioactivity in the fly ash by the airborne concentration of the fly ash. For example, for the Kaiparowits scenario, Table 10-27 gives airborne radioactivity concentrations in three towns for the years 1990 and 2000. Lung doses can be calculated[2] from these and are given in Table 10-28 for the seven most important radioisotopes found in coal. Several studies carried out at higher dose rates than these found a risk rate of 1.2 cases of lung cancer per year per million exposed persons at one rem[3] exposures.[4] For the doses calculated in Table 10-28, this translates into an individual risk of one chance in 30 billion of contracting cancer in any one year. Thus, cancer risks due to airborne radioactivity from coal combustion are negligible.

(2) Uranium Mining and Milling

One serious radioactivity problem in uranium development is tailing piles from uranium milling operations that contain several thousand times as much radium as ordinary soils. According to

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[1]Martin, J.E. "Comparative Population Radiation Dose Commitments of Nuclear and Fossil Fuel Electric Power Cycles," in Proceedings of the Eighth Midyear Topical Symposium of the Health Physics Society: Population Exposure, CONF-741018. Washington, D.C.: U.S., Atomic Energy Commission, 1974.

[2]International Commission on Radiological Protection. Recommendation of the International Commission on Radiological Protection on Permissible Dose for Internal Radiation, Report No. 2. New York, N.Y.: Pergamon, 1959.

[3]A rem is a unit of radiation received by an organism (as particles or rays) proportional to the amount of potential biological damage. Natural background dosage levels are approximately 0.125 rem.

[4]Assuming an average exposure period of 30 years, this translates to a risk of 36 lung cancer cases per million persons at one rem exposure. National Academy of Sciences/National Research Council, Advisory Committee on the Biological Effects of Ionizing Radiation. The Effects on Populations of Exposure to Low Levels of Ionizing Radiation. Washington, D.C.: National Academy of Sciences, 1972.

TABLE 10-27: ESTIMATED ANNUAL AVERAGE AIRBORNE RADIOACTIVITY DUE TO COAL COMBUSTION IN 1990 AND 2000

TOWN	RADIOACTIVITY CONCENTRATION (picomicrocuries per cubic meter)[a]						
	U^{238}	U^{234}	Th^{230}	Ra^{226}	Th^{232}	Ra^{228}	Th^{228}
Page	0.6	0.6	0.6	0.6	0.7	0.5	0.4
Escalante	0.6	0.6	0.6	0.5	0.7	0.5	0.4
Glen Canyon	0.6	0.6	0.6	0.6	0.7	0.5	0.4

U = uranium Th = thorium Ra = radium

[a]10^{-18} curie per cubic meter.

TABLE 10-28: ESTIMATED INDIVIDUAL LUNG DOSES IN VICINITY OF PAGE, ESCALANTE, AND GLEN CANYON DUE TO ATMOSPHERIC RADIOACTIVITY PRODUCED BY COAL COMBUSTION

ISOTOPE	ESTIMATED DOSE (μrem per year)[a]
U^{238}	0.2
U^{234}	0.2
Th^{230}	3.0
Ra^{226}	0.5
Th^{232}	2.6
Ra^{228}	0.8
Th^{228}	3.0

μrem = 10^{-6} rem Th = thorium
U = uranium Ra = radium

[a]Note that natural background radiation = 0.125 rem = 125,000 μrem.

one study, exposures from uranium tailings piles pose a significant health risk at distances up to 1 kilometer.[1]

The uranium mill is also the energy facility releasing the greatest quantity of uranium particulates to the atmosphere and the source of the major uranium population exposure dose.[2] Most of the atmospheric uranium releases are from the drying process.[3] Although the amount of uranium radioactivity released is substantially lower than that of radon, the dose of radioactivity from uranium which actually reaches human tissues is over two orders of magnitude higher;[4] this results in the relatively high population exposure doses due to uranium.[5]

Estimates of the radiation doses to individuals through the air pathway in the vicinity of a mill from routine plant emissions (not tailings piles) are shown in Table 10-29. They include estimated "collective" lung doses to the population in the vicinity. The average "collective" lung dose is determined by summing the individual radiation doses to individuals living throughout an 80 kilometer radius of the mill.[6]

Potential health effects to members of the general population in the vicinity of a model mill are estimated to be 0.0002 lung cancers per year of operation of 0.005 lung cancers for 30 years

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[1]Swift, Jerry J., James M. Hardin, and Harry W. Calley. Potential Radiological Impact of Airborne Releases and Direct Gamma Radiation to Individuals Living Near Inactive Uranium Mill Tailings Piles. Washington, D.C.: U.S., Environmental Protection Agency, Office of Radiation Programs, 1976.

[2]Hong, Lee, et al. Potential Radioactive Pollutants Resulting from Expanded Energy Programs. Las Vegas, Nev.: U.S., Environmental Protection Agency, August 1977, p. 125.

[3]Ibid.

[4]Rn-222 is a radioactive isotope produced from the decay of thorium and radium. It is emitted as a gas and rises in the atmosphere; thus, less of it is available to be respired by the population. Uranium is emitted as a dust from low level sources and remains at low levels, making it more available to be respired by humans.

[5]Hong, et al. Potential Radioactive Pollutants.

[6]U.S., Environmental Protection Agency, Office of Radiation Programs. Environmental Analysis of the Uranium Fuel Cycle, Part IV: Supplementary Analysis. Washington, D.C.: Environmental Protection Agency, July 1976, p. 23.

TABLE 10-29: RADIATION DOSES TO INDIVIDUALS DUE TO INHALATION IN THE VICINITY OF A MODEL MILL

RADIONUCLIDE	RADIATION FROM SOURCE[a] (mCi/y)	DOSE EQUIVALENT TO CRITICAL ORGAN (LUNG): INDIVIDUAL AT PLANT BOUNDARY (mrem/y)	DOSE EQUIVALENT TO CRITICAL ORGAN (LUNG): AVERAGE INDIVIDUAL WITHIN 80 km (mrem/y)	COLLECTIVE CRITICAL ORGAN DOSE[b] WITHIN 80 km (person rem/yr)
Uranium-234 and 238	180	170	3.9×10^{-2}	2.2
Thorium-230	15	15	3.4×10^{-3}	0.2
Radium-226	10	15	2.2×10^{-3}	0.1
Total	205	200	4.5×10^{-2}	2.5

mCi/y = millicuries per year   mrem/y = millirems per year   km = kilometers

Source: U.S., Environmental Protection Agency, Office of Radiation Programs. Environmental Analysis of the Uranium Fuel Cycle, Part IV: Supplementary Analysis. Washington, D.C.: Environmental Protection Agency, July 1976, pp. 24-25.

[a]Releases to water pathways assumed equal to zero, and doses from Radon-222 are not included.

[b]The population model for the model mills assumes that 5.5×10^4 persons are exposed within 80 km of the mill site.

[c]Note that natural background is equivalent to 125 mrem/y.

of operation.[1] This calculation assumed that food consumed by individuals living near the mill is not produced locally so that exposure through food chains is not significant compared to lung exposures resulting from the direct inhalation of radioactive particulate matter. The radon exposure pathway was excluded. Significant radon exposure is also likely.[2]

In the vicinity of uranium mills and tailing piles in the Grants Mineral Belt area, New Mexico, radon levels are up to 10 times the accepted standards.[3] Studies have indicated that a significant risk to health may result to workers and residents of the area from these doses to lung tissues. Apparent sources of this elevated readiation level have been particles and gases from mines and tailings piles.[4] Currently the New Mexico state government is conducting a more detailed study to evaluate this health risk. Programs to minimize exposure to workers and the general public from uranium mill tailings are being conducted in Colorado.[5]

10.7.5 Systemic Illness

Western energy development results in releases of small amounts of many toxic substances, including CO, cadmium, arsenic,

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[1]U.S., Environmental Protection Agency, Office of Radiation Programs. Environmental Analysis of the Uranium Fuel Cycle, Part IV: Supplementary Analysis. Washington, D.C.: Environmental Protection Agency, July 1976, p. 26.

[2]Radon is the major residual radiation source in a uranium mill. See U.S., Atomic Energy Commission, Directorate of Licensing, Fuels and Materials. Environmental Survey of the Uranium Fuel Cycle, WASH-1248. Washington, D.C.: Atomic Energy Commission, 1972, p. S-19.

[3]New Mexico Environmental Improvement Agency. Personal Communication, November 1977.

[4]Ibid.

[5]Mesa County Department of Health. "Fact Sheet: Uranium Mill Tailings Remedial Action Program." Grand Junction, Colo.: Mesa County Department of Health, February 1973, p. 4; and Mesa County Department of Health. "Colorado's Involvement with Uranium Mill Tailings." Grand Junction, Colo.: Mesa County Department of Health, August 9, 1976, pp. 1-17; and Parmenter, Cindy. "U.S. May Foot 90% of Bill to Clean Up Uranium Tailings." Denver Post, July 22, 1978, p. 16.

and vanadium. There is a risk that (in spite of careful controls) some of these substances will be inhaled or ingested by people, causing problems that vary in seriousness from irritation to death. Many toxic substances appear to be threats mainly to occupational health, but public health could be affected as well.

Although trace elements are present in very small quantities in fuels, they can be concentrated in waste streams, enter the ecological system and tend to accumulate in organisms. Potential emission rates for trace elements were discussed earlier in this chapter. The most immediate health concern is that dietary intake levels for some trace metals are already approaching what have been defined by World Health Organization/Food and Agriculture Organization as tolerable limits. Cadmium intake, for example, is estimated at 75 percent of the limit, and increases of cadmium concentrations in soil are reflected widely in foodstuffs.[1] Mercury and lead are also close to tolerable levels. Thus, relatively small additions from individual energy facilities might lead to serious long-term health effects if a large number of new facilities are involved. The effects of selected trace elements are discussed below.

A. Lead

Lead is present as a natural substance in airborne particulates, coal, and oil shale, but it is essentially absent from petroleum. The average adult has a daily intake of 300 micrograms (μg) of lead, with about 90 percent via ingestion and 10 percent via respiration. However, absorption of lead via the gastrointestinal system is only about 10 percent, whereas absorption via the pulmonary route is 30-50 percent.[2] Thus, airborne lead could account for up to half the total lead absorbed.[3] In view of the steadily increasing pollution of air and soils with lead from motor vehicle exhausts, accumulation and toxicity in exposed human beings may occur.[4] Chronic lead poisoning requires months

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[1] Mahaffey, K.R., et al. "Heavy Metal Exposure from Foods." Environmental Health Perspective, Vol. 12 (1975), pp. 63-69.

[2] Schroeder, H.A., and I.H. Tipton. "The Human Body Burden of Lead." Archives of Environmental Health, Vol. 17 (December 1968), pp. 965-78.

[3] Goldsmith, J.R., and A.C. Hexter. "Respiratory Exposure to Lead: Epidemiological and Experimental Dose Response Relationships." Science, Vol. 158 (October 6, 1967), pp. 132-34.

[4] Ibid.

or years to develop. At present, there is concern that exposure to even very low levels of lead will produce subtle central nervous system pathologies, especially in children.

Increased emissions of lead from energy facilities can be significant both in terms of direct exposure to humans and because airborne lead will settle to the ground and enter the food web. However, the lead emitted from energy facilities will probably be minute as compared to that resulting from the expanded population's use of motor vehicles burning leaded gasolines. As lead compounds are removed from gasoline, the overall risk would be reduced.

B. Mercury

Mercury occurs in coal, petroleum, and probably in oil shale. Depending on the combustion system and ancillary air pollution control devices, 10-90 percent of the contained mercury can be emitted to the atmosphere. This mercury emitted can be converted to the more toxic organic form by microorganisms, and then concentrated in food webs. Exposure to elevated mercury levels in foods produces nervous system disorders and death.[1] The Food and Drug Administration (FDA) has established a 500 parts per billion (ppb) standard for mercury levels in food.

The level of mercury emitted to the atmosphere by energy facilities is unlikely to constitute a hazard from direct exposure or ingestion. However, intrusion of mercury into the aquatic food web raises possibilities of contamination of fish used as human food. For example, in the Kaiparowits scenario (Chapter 4), mercury can reach Lake Powell from the facilities by direct fallout from emissions and by runoff. Mercury deposition from the hypothetical Kaiparowits power plant alone ranges from 16 to 480 pounds of mercury entering the lake each year, or 1-27 percent of the present estimated rate of addition from natural sources.[2] Levels in some predatory fish in Lake Powell currently exceed the standard of 500 ppb, and energy facility emissions have been estimated to cause increases of 10-50 percent above this value,

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[1] Pettyjohn, Wayne A. "Trace Elements and Health," in Pettyjohn, Wayne A., ed. Water Quality in a Stressed Environment: Readings in Environmental Hydrology. Minneapolis, Minn.: Burgess, 1972, pp. 245-246.

[2] U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976.

depending on the number of plants, locations, and coal characteristics.[1]

C. Cadmium

Cadmium is found in coal and oil shale but is absent from petroleum. Cadmium is known to be highly toxic as particulates or fumes; it accumulates in the human kidney and liver, acts on the circulatory system,[2] irritates the lung (producing emphysema),[3] and at higher exposures causes damage to the excretory system.[4] Some of these effects occur at atmospheric concentrations of 500-2,500 $\mu g/m^3$ over as little as 3 days.[5] Lower levels may be associated with high blood pressure or stomach and intestinal disorders. Between 4 and 41 percent of the cadmium in coal is emitted as flue gas in three power plants recently studied.[6] Thus, because of potential emission of between 60 and 2,000 pounds/year[7] (from a 3,000 megawatts [MW] power plant) and the possible role of cadmium in producing hypertension, a health hazard may exist from its accumulation in humans.

D. Arsenic

The toxicity of arsenic depends on its chemical form. Metallic arsenic is thought to be nontoxic, while arsine (AsH_3, a

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[1] Standiford, D.R., L.D. Potter, and D.E. Kidd. Mercury in the Lake Powell Ecosystem, Lake Powell Research Project Bulletin No. 1. Los Angeles, Calif.: University of California, Institute of Geophysics nad Planetary Physics, 1973, p. 16.

[2] Schroeder, H.A. "Cadmium, Chromium, and Cardiovascular Disease." Circulation, Vol. 35 (March 1967), pp. 570-82.

[3] Bouhoys, A., and J.M. Peters. "Control of Environmental Lung Disease." New England Journal of Medicine, Vol. 283 (September 10, 1970), pp. 573-82.

[4] Piscator, M., K.L. Beckmans, and A.B. Tryckerier, eds. Proteninuria in Chronic Cadmium Poisoning. Stockholm, Sweden: n.p., 1966.

[5] Schroeder, H.A. Cadmium, Zinc, and Mercury, Air Quality Monograph No. 70-16. Washington, D.C.: American Petroleum Institute, n.d.

[6] Radian Corporation. Coal Fired Power Plant Trace Element Study, Vol. 1: A Three Station Comparison. Austin, Tex.: Radian Corporation, 1975, p. 36.

[7] Ibid., p. 31.

colorless gas) is extremely toxic.[1] Because arsenic is suspected of being a carcinogen, exposure from coal combustion or conversion facilities increases the possibility of cancer. Arsenic deposited in the aquatic environment may undergo microbiological transformation similar to what has been observed with mercury.

E. Vanadium

Vanadium is present in coal, petroleum, and oil shale. The production of residual petroleum fuels results in a concentration of the vanadium compounds which then are released during combustion. Vanadium has low toxicity in most forms, although there are some associations between airborne vanadium and respiratory disease. Vanadium dioxide acts as an acid in aqueous solution and when inhaled contributes to respiratory irritation.[2] Most cases of respiratory effects have resulted from exposures of 1-50 $\mu g/m^3$ in dusty air.[3] In 1967, the annual average concentration of airborne vanadium in nonurban western locations was approximately 0.003 $\mu g/m^3$,[4] making the dose of 1-50 $\mu g/m^3$ many thousand times greater than ambient concentrations. This element is potentially harmful because of its involvement in respiratory disease and bcause it is a "new" or introduced element in the local environment.

10.7.6 Population-Related Health Problems

Some of the greatest potential impacts on health are indirectly attributed to energy development because they result from rapid population growth.[5] Population growth can cause impacts of two general types: (1) impacts dependent on public services, including inadequate water supplies, sewage treatment, solid waste management, and health care services; and (2) disease

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[1]U.S., Department of Health, Education, and Welfare, Public Health Service. Preliminary Air Pollution Survey of Arsenic and Its Compounds. Raleigh, N.C.: Public Health Service, 1969.

[2]Stokinger, H.E. "Vanadium," in Patty F.A., ed. Industrial Hygiene and Toxicology, Vol. 2. New York, N.Y.: Wiley Interscience, 1963, pp. 1171-82.

[3]Lewis, C.E. "The Biological Actions of Vanadium, II." Archives of Industrial Health, Vol. 19 (1959), p. 497.

[4]Athanassiadis, Y.C. Air Pollution Aspects of Vanadium and Its Compounds, National Air Pollution Control Administration. Bethesda, Md.: Litton Systems, Inc., 1969.

[5]Copley International Corporation. Health Impacts of Environmental Pollution in Energy-Development Impacted Communities, Executive Summary for the Environmental Protection Agency. La Jolla, Calif.: Copley International, 1977, pp. 29-30.

transmission and increases in accident rates associated with crowding.[1] These two categories are closely linked; for example, improved public services can reduce accidents and adequate health services can minimize the incidence of disease.

Increases in community size shown in Table 10-30 are a function of employment in energy facilities and population multipliers for secondary services (see sections on social and economic impacts in Chapters 4-9). For some communities, existing facilities are adequate; in others, such as Farmington, sewage treatment is inadequate or, as in Gillette, water supplies are limited. When community environmental services become overloaded, contamination of the environment may occur. In Fruitland, New Mexico, for example, population growth associated with two large power plants and surface coal mines has resulted in a proliferation of mobile homes and septic tanks that leak sewage.[2] In many rural locations, inadequate water supply affects personal hygiene which in turn is conducive to the transfer of pathogens among people.[3]

A variety of criteria can be applied to assess the significance of health problems caused by inadequate environmental services, including rate of population growth, number of persons per dwelling unit, capacity of water treatment and sewage treatment systems relative to demand, distance to a physician or hospital, and the presence of community health plans.[4] Based on these criteria, a recent study indicated that energy development significantly affected 60 communities, 38 are moderately affected, (Table 10-31), and another 114 would be potentially affected adversely[5] if population continues to grow without added services.

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[1]Copley International Corporation. Health Impacts of Environmental Pollution in Energy-Development Impacted Communities, Executive Summary for the Environmental Protection Agency. La Jolla, Calif.: Copley International, 1977, pp. 29-30. For a description of accidents associated with transportation facilities, see Chapter 11.

[2]New Mexico, Environmental Improvement Agency, Staff. Personal Communication, June 1977.

[3]Copley. Health Impacts of Environmental Pollution.

[4]Ibid., pp. 13-16.

[5]States included in the study are in EPA Region VIII (Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming). States not included but a part of this technology assessment are Arizona and New Mexico. Ibid.

TABLE 10-30: INCREASE IN COMMUNITY POPULATIONS DUE TO ENERGY DEVELOPMENT HYPOTHESIZED FOR THE SIX SITE-SPECIFIC SECNARIOS

COMMUNITY	CURRENT POPULATION 1975	POPULATION PROJECTED		
		1980	1990	2000
Kaiparowits (Kane County, Utah)	3,300	7,460	11,480	12,060
Farmington (San Juan County)	62,400	82,700	116,000	146,200
Rifle (Grand Junction Area; Rio Blanco and Garfield Counties)	45,000	49,200	59,500	65,800
Gillette (city alone)	14,000	26,650	44,500	69,200
Colstrip (Rosebud County)	8,600	11,620	17,160	27,170
Beulah (Mercer County)	6,400	8,150	8,600	10,050

TABLE 10-31: NUMBER OF COMMUNITIES IDENTIFIED AS HAVING HEALTH IMPACTS AS A RESULT OF ENERGY DEVELOPMENT[a]

STATES	SIGNIFICANTLY IMPACTED			MODERATELY IMPACTED		
	ALL FACTORS	POPULATION, WATER, SEWAGE	POPULATION	ALL FACTORS	POPULATION, WATER, SEWAGE	POPULATION
Colorado	9	9	8	2	3	0
Montana	1	0	2	2	2	1
North Dakota	0	0	0	3	1	1
South Dakota	1	0	1	2	1	1
Utah	0	8	1	0	0	7
Wyoming	11	6	3	4	3	5
Total	22	23	15	13	10	15
All combination of factors	60			38		

[a]Copley International Corporation. Health Impacts of Environmental Pollution in Energy-Development Impacted Communities, Executive Summary for the Environmental Protection Agency. La Jolla, Calif.: Copley International, 1977.

Diseases and increases in accident rates associated with crowding are also likely to increase in energy impacted communities. Crowding, for example, favors the spread of airborne pathogens such as influenza, the common cold, as well as childhood and other contagious diseases. In addition, crowding produces stress that can result in mental illness, child abuse, alcoholism, and other behavioral disorders.[1] In some locations, an increased rural population will be exposed to diseases only infrequently encountered. For example, in the northwestern quadrant of New Mexico where extensive coal, uranium, and petroleum deposits are found, more than 50 cases of plague have occurred since 1949.[2] This area has a population of less than 100,000 yet it has half the plague cases occurring in the U.S. and the rate of incidence has been continually increasing in recent decades. In 1975, more than 15 cases of plague were reported in New Mexico.[3] One of the more substantiated hypotheses is that the encroachment of human population into areas that were once wilderness is responsible for these outbreaks of plague.[4] Without disease control or public education programs, the population growth associated with energy development in areas with endemic parasitic or contagious diseases is likely to intensify the incidence of those diseases.

10.8 IMPACTS ON OCCUPATIONAL HEALTH AND SAFETY

10.8.1 Introduction

Most of the factors associated with energy development that can affect public health (discussed in Section 10.7) can also affect workers in energy facilities. They include fugitive dust, gaseous emissions, and radioactive substances as well as the more toxic liquid and solid waste by-products handled by the workers. In addition, workers will be subject to the risk of injuries resulting from falls, fires, contact with machinery, and being struck by objects. The combination of health and safety risks

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[1]Copley International Corporation. Health Impacts of Environmental Pollution in Energy-Development Impacted Communities, Executive Summary for the Environmental Protection Agency. La Jolla, Calif.: Copley International, 1977, pp. 29-30.

[2]Weber, Neil S. "Plague in New Mexico." Albuquerque, N. Mex.: State of New Mexico, Environmental Improvement Agency, Vector Control Program, January 1977, p. 26.

[3]Ibid., p. 27.

[4]Ibid., pp. 8-9. Plague is transmitted primarily through contact with fleas that have been associated with wild rodent populations.

has been a focus of increasing legislative attention in recent years.[1] The remainder of this section summarizes safety risks and then discusses these safety hazards in more detail in the development of coal, crude oil and natural gas, geothermal power, oil shale, and uranium.

10.8.2 Summary of Safety Risks

Table 10-32 summarizes accident rate information for facilities considered in this study. The data are based on industry averages or, in some cases, projections from related industries, and should be interpreted with caution. They are accident-related and do not include deaths or lost time due to chronic health problems related to pollutants in the working environment. Using information on the operational work force for each facility, these data were converted to indicate the frequency of accidents per worker per year. As shown in Table 10-33, underground mining is the most risky occupation as measured by the probability of death due to on-the-job injuries. Uranium mill workers have the highest probability of injury.

Compared to other industries, as shown in Table 10-34 the risk of injury in most energy facilities appears to be similar. The exception, again, is underground mining, which has a higher risk than other industries.

10.8.3 Coal Development

A. Accidents

As suggested above, underground mining is the most hazardous technology in the coal fuel cycle. The contrast between underground and surface mine safety is distinctive when compared on an equivalent energy basis, since the more hazardous underground mines yield less coal per worker per day. As shown in Table 10-35, deaths from underground mining are about five times higher per

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[1] Specific coal-focused legislation includes the Federal Coal Mine Health and Safety Act of 1969, Pub. L. 91-173, 83 Stat. 742; the Federal Mine Safety and Health Amendments Act of 1977, Pub. L. 95-164, 91 Stat. 1290; and the Black Lung Benefits Act of 1972, improved safety is assigned to the Mine Enforcement and Safety Administration. The Occupational Safety and Health Act, Pub. L. 91-596, 84 Stat. 150, seeks to improve the health and safety of all workers including those in energy facilities, creating the National Institute for Occupational Safety and Health for research, and the Occupational Safety and Health Administration for standards setting and enforcement.

TABLE 10-32: SUMMARY OF OCCUPATIONAL ACCIDENT DATA FOR TYPICAL SIZE FACILITIES

RESOURCE AND FACILITY	DEATHS PER YEAR	INJURIES PER YEAR	WORKER DAYS LOST PER YEAR
Coal			
Surface Mining (12 MMtpy)	0.60	19	1,300
Underground Mining (12 MMtpy)[a]	5.00	260	14,000
Coal Beneficiation	0.56	11	4,900
Gasification (250 MMsfd)	0.45	15	4,200
Liquefaction (30,000 bbl/day)	0.32	6.2	1,494
Power Plant (3,000 MWe)	0.77	3.2	1,200
Oil (100,000 bbl/day)	0.45	43	7,154
Gas (250 MMcfd field)	0.20	19	3,200
Geothermal	NA	NA	NA
Oil shale			
Underground mine (66,000 tpd crushed shale)	0.80	34	NA
Surface mine (66,000 tpd crushed shale)	0.20	10	NA
Modified in situ (41,000 tpd oil shale) mining	0.10	5	NA
Surface retorting	0.15	15	NA
Modified in situ including processing	NA	NA	NA
Uranium			
Mine	NA	NA	NA
Mill (1,200 Mtpy)	0.046	14.1	873

MMtpy = million tons per year
MMsfd = million standard feet per day
bbl/day = barrels per day
MWe = megawatts-electric
MMcfd = million cubic feet per day
NA = not available
tpd = tons per day
Mtpy = metric tons per year

Sources: White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 3; and Hittman Associates, Inc. Environmental Impacts, Efficiency and Cost of Energy Supplied by Emerging Technologies, Draft Report on Tasks 7 and 8, HIT-582. Columbia, Md.: Hittman Associates, May 1974.

[a]Data on coal mining from Bliss, C., et al. Accidents and Unscheduled Events Associated with Non-Nuclear Energy Resources and Technology. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

TABLE 10-33: SAFETY RISKS ASSOCIATED WITH ENERGY FACILITIES EXPRESSED PER INDIVIDUAL

FACILITY	FREQUENCY PER WORKER PER YEAR[a] OF:	
	DEATH	INJURY
Coal		
Surface mining (12 MMtpy)	0.0011	0.034
Underground mining (12 MMtpy)	0.0024	0.090
Gasification (250 MMsfd)	0.0008	0.002
Liquefaction (30,000 gpd)	0.0004	0.007
Power plant (3,000 MW)	0.0017	0.007
Oil (100,000 bbl/day)	0.0002	0.021
Gas (250 MMcfd field)	0.0003	0.024
Oil Shale		
Underground mine (66,000 tpd crushed shale)	0.0014	0.062
Surface retorting	0.0004	0.045
Uranium		
Mill (1,200 Mtpy)	0.0003	0.104

MMtpy = million tons per year
MMsfd = million standard feet per day
gpd = gallons per day
MW = megawatt
bbl/day = barrels per day
MMcfd = million cubic feet per day
tpd = tons per day
Mtpy = metric tons per year

[a]Data from Table 10-32 divided by operational work force for each facility (given in Chapters 4-9 and summarized in Chapter 3).

TABLE 10-34: INJURY RATES IN SELECTED INDUSTRIES, 1973

INDUSTRY	FREQUENCY OF INJURY PER WORKER[a] PER YEAR
Automobile	.0032
Chemical	.0085
Petroleum	.0135
Shipbuilding	.0142
Nonferrous metals and products	.0186
Surface mining, all types[b]	.0195
Construction	.0272
Railroad equipment	.0285
Quarry[b]	.0353
Underground mining, except coal[b]	.0505
Underground coal mining[b]	.0709
All industries[c]	.0211

Source: Bliss, C., et al. Accidents and Unscheduled Events Associated with Non-Nuclear Energy Resources and Technology. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

[a]These values were calculated from the above source. Injury rates in the source were given as injuries per million man hours. We assumed that one million man hours was equivalent to 500 man years (i.e., an average worker works 2,000 hours per year).

[b]Based on data for 1972.

[c]Rates not fully comparable from year to year due to reporting inconsistencies.

TABLE 10-35: ANNUAL DEATHS, INJURIES, AND WORK DAYS LOST FOR COAL-FIRED ELECTRICITY SYSTEMS[a] (1,000 megawatt power plant with a load factor of 0.75)

OCCUPATIONAL HEALTH	EXTRACTION UNDERGROUND	EXTRACTION SURFACE	PROCESSING	TRANSPORT[b]	CONVERSION[c]	TRANSMISSION
Deaths	1.67	0.308	0.0238	2.30	0.012	NA
Injuries	85	13.9	2.56	23.40	1.38	NA
Workdays lost[d]	4,678	499	99.50	2,340	152.9	NA

NA = not available

[a]Bliss, C., et al. Accidents and Unscheduled Events Associated with Non-Nuclear Energy Resources and Technology. Washington, D.C.: U.S., Environmental Protection Agency, 1977, p. 51.

[b]Impacts of coal based on coal transport exclusively by rail (average distance 300 miles); annual coal supply for a 1,000 megawatts-electric plant is 0.1 percent of total national ton-mileage. Assumed that average injury leads to loss of 100 workdays.

[c]Assumes one-half the combined deaths and permanent injuries to be fatal injuries. Permanent total disabilities are considered to represent 6,000 workdays lost, and other disabilities are estimated at 100 days lost.

[d]Excluding workdays lost attributed to complicated pneumoconiosis.

than for surface mining, injuries are about six times higher, and work days lost are about nine times higher. The frequency of injuries in underground coal mines is also higher than for underground mining of other materials.[1]

Underground mine accidents have become much less frequent since the passage of the Mine Health and Safety Act of 1969. However, mine safety varies with the geological characteristics of the site and the specific technology being used. For example, in 1975 not a single lost-time accident at the working face occurred in all shortwall mining.[2] Increased coal production, however, is likely to require the use of inexperienced miners and accident rates are likely to increase unless effective training programs are instituted for new miners (Mining Enforcement and Safety Administration [MESA] now requires miners to be trained).[3]

As Table 10-35 indicates, coal processing (e.g., cleaning, sizing, and drying operations) and coal conversion to electric power are considerably less hazardous than mining and coal transport. The accident potential of synthetic fuels production from coal is not known. However, since most liquefaction and gasification processes operate at high temperature and pressure, accidents involving pressure vessel rupture may be expected.[4]

Transmission and distribution accidents involve downed power lines and accidents involved in construction, operation, and repair. A National Safety Council study in 1972 showed that the accident frequency rate for the electric utility industry was less than the average for all reporting industries with 6.42 injuries

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[1]The frequency of injuries in underground coal mines is more than three times the average for selected industries and about one and a half times the average for underground mining of other materials. The severity of underground coal mining injuries was almost eight times the all-industry average and about 25 percent higher than noncoal underground mining. Bliss, C., et al. Accidents and Unscheduled Events Associated with Non-Nuclear Energy Resources and Technology. Washington, D.C.: U.S., Environmental Protection Agency, 1977, p. 30.

[2]Kash, Don E., et al. The Impacts of Accelerated Coal Utilization, Draft Report, Contract No. OTA-C-182. Norman, Okla.: University of Oklahoma, Science and Public Policy Program, 1977, pp. 8-19.

[3]Ibid.

[4]Bliss et al. Accidents and Unscheduled Events, p. 30.

million worker-hours exposure. However, the severity rate was higher with 1,003 total days charged for injuries per million worker-hours exposure compared to 655 per million worker-hours exposure for all reporting industries for the period 1970-1972.[1]

B. Respiratory Disease

Respiratory illness caused from working in underground coal mines is perhaps the best known occupational health impact. "Black lung disease" (pneumoconiosis), chronic bronchitis, emphysema, and airways obstruction currently affect more than one-third of the underground coal miners in the U.S.[2] The death rate from respiratory disease among workers in deep mines has been five times the heavy industrial average.[3] In 1973 the federal government paid about $1 billion to coal miners and their dependents as compensation for black lung disease, and the total compensation level may rise to $8 billion by 1980.[4] It is expected that under MESA regulation, future mining operations will cause less black lung disease among new employees, but new cases are almost certain to occur.

C. Cancer

Workers in coal mines and in some conversion facilities are subject to increased incidence of cancer. The cancer hazard due to the combustion products of coal have been observed in related industries. For example, cancer death rates over 300 times higher than the general population have been reported for workers

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[1]Bliss, C., <u>et al</u>. <u>Accidents and Unscheduled Events Associated with Non-Nuclear Energy Resources and Technology</u>. Washington, D.C.: U.S., Environmental Protection Agency, 1977, p. 30.

[2]U.S., Department of Health, Education, and Welfare, National Institute for Occupational Safety and Health. <u>Occuaptional Safety and Health Implications of Increased Coal Utilization</u>, Draft. Rockville, Md.: National Institute for Occupational Safety and Health, 1977, lines 88-92.

[3]U.S., Department of the Interior, Bureau of Land Management, <u>et al</u>. <u>Final Environmental Impact Statement for the Proposed Development of Coal Resources in the Eastern Powder River Coal Basin of Wyoming</u>, 6 vols. Cheyenne, Wyo.: Bureau of Land Management, 1974.

[4]Edwards, P.E. <u>The Washington Post</u>, May 29, 1973, as cited in National Academy of Sciences, National Research Council, Commission on Natural Resources, Committee on Mineral Resources and the Environment. <u>Mineral Resources and the Environment</u>. Washington, D.C.: National Academy of Sciences, 1975, p. 213.

on the top of coke ovens.[1] Experience in the 1950's with a coal liquefaction plant operated by Union Carbide in Institute, West Virginia showed that, despite efforts to educate workers to the hazards of unnecessary contact with oils and instruction in decontamination practices, skin cancer during 7 years of operation occurred at 16-37 times the rate normally reported.[2] Air samples showed benzo(a)pyrene concentrations (see Section 10.7) as high as 18.70 micrograms per 100 cubic meters on plant premises. This is about 30 times higher than an urban environment with heavy automobile traffic.[3] In Japan, Britain, and Sweden, excess cancers of various organs have been noted in workers producing gas from coal in various processes.[4]

These observations suggest but do not causally establish increased cancer risks associated with coal-conversion processes, and it is not possible to generalize from these cases to the facilities planned for the western U.S. because both the specific processes and their scale of operation differ. In addition, recent federal requirements for maintaining worker safety have changed working conditions.

The raw materials for coal conversion generally contain very small quantities of cancer-causing substances. Further, the processes of gasification and liquefaction result in the formation of complex organic molecules, some of which may cause cancer. Synthetic gas prior to upgrading to pipeline quality contains

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[1]Lloyd, J.W. "Long-Term Mortality Study of Steelworkers: V. Respiratory Cancer in Coal Plant Workers." Journal of Occupational Medicine, Vol. 13 (February 1971), pp. 53-68.

[2]Sexton, R.J. "The Hazards to Health in the Hydrogenation of Coal: I. An Introductory Statement on General Information Process Description, and a Definition of the Problem," Archives of Environmental Health, Vol. 1 (September 1960), pp. 181-86; and Sexton, R.J. "The Hazards to Health in the Hydrogenation of Coal: IV. The Control Program and the Clinical Effects." Archives of Environmental Health, Vol. 1 (September 1960), pp. 208-31.

[3]Ketcham, N.H., and B.S. Norton. "The Hazards to Health in the Hydrogenation of Coal: III. The Industrial Hygiene Studies." Archives of Environmental Health, Vol. 1 (September 1960), pp. 194-207.

[4]Kauai, M., et al. "Epidemiologic Study of Occupational Lung Cancer." Archives of Environmental Health, Vol. 14 (1967), pp. 859-64; and Doll, R., et al. "Mortality of Gas Workers with Special Reference to Cancers of the Lung and Bladder, Chronic Bronchitis, and Pneumoconiosis." British Journal of Industrial Medicine, Vol. 22 (January 1965), pp. 1-12.

more hazardous substances than the final product.[1] Therefore, the greatest plant hazards will be from fugitive losses of raw synthetic gas and from the cleanup procedures (sulfur recovery, tar separation, etc.) designed to remove harmful substances. To a lesser extent, fugitive emissions from storage and blending of the final product may constitute a hazard.[2] Workers stationed in these areas would receive regular exposure to fugitive emissions in amounts largely determined by standards of controls and cleanliness.

Solid wastes from coal conversion include an ash discharged into a settling pond as a wet-solid. If process wastewaters are used to slurry the ash, workers may be in contact with a number of toxic compounds. The solid wastes potentially most hazardous are the chars and tars produced as process residues. In many instances, these could be burned in utility boilers. However, even then, care in preventing contact with these materials when transferred from reactor to boiler would be required.

D. Stress Effects

The rapid development and use of coal is likely to increase overtime hours worked, employee fatigue, and hence accident rates.[3] Moreover, these factors can contribute to physical and mental health problems related to job stress and strain, such as heart disorders and neuroses. The impact may be especially serious on coal miners, who have been reported by National Institute of Occupation Safety and Health (NIOSH) to have unusally high levels of psychological distress and a high incidence of morbidity and mortality from stress-related disorders.[4]

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[1] Of the major gasification processes, the highest risk of occupationally related cancer is thought to be associated with high-pressure, fixed-bed processes. Freudenthal, R.I., G.A. Lutz, and R.I. Mitchell. Carcinogenic Potential of Coal and Coal Conversion Products, Battelle Energy Program Report. Columbus, Ohio: Battelle Memorial Institute, Columbus Laboratories, 1975.

[2] Cavanaugh, E.C., et al. Potentially Hazardous Emissions from the Extraction and Processing of Coal and Oil, EPA-650/2-76-038. Austin, Tex.: Radian Corporation, 1975.

[3] U.S., Department of Health, Education, and Welfare, National Institute for Occupational Safety and Health. Occupational Safety and Health Implications of Increased Coal Utilization, Draft. Rockville, Md.: National Institute for Occupational Safety and Health, 1977, lines 830-32.

[4] Ibid., lines 820-29.

10.8.4 Crude Oil and Natural Gas Development

Although less severe than in coal development, occupational accidents in the crude oil resource system are frequent and costly in terms of numbers of injuries, work days lost, and damage to equipment.[1] Major accidents involve spillage, blowouts, fire, explosion, and entanglement in machinery. These accidents occur at each stage in the energy cycle. Hazardous explosive conditions are associated with well blowouts, pipeline ruptures and leaks, other transportation accidents, and storage tank accidents.[2] Major losses of life and property from such events occur in refineries and tank farms.[3]

In the natural gas system, blowouts during drilling of exploratory and production wells, release of sulfur compounds during processing, and failures of pipelines account for the largest number of accidents.[4] Sudden uncontrolled release of natural gas may result in explosions and fires causing damage to equipment and loss of life or injury to persons in the vicinity. In addition, the general public is exposed to pipeline hazards because they traverse populated residential and commercial areas.[5]

Pipeline distribution accounts for the largest number of injuries and workdays lost in the natural gas system: about 0.0138 injuries/10^{12} Btu's of gas produced and 0.324 worker days lost/10^{12} Btu's, respectively.[6] Most pipeline failures can be attributed to corrosion and damage by outside forces. Other possible sources of natural gas accidents are the failure of aboveground storage tanks.

Higher rates of cancers of the lung, nasal cavities, and sinus have been observed in counties where petroleum industries are most heavily concentrated,[7] including four counties in

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[1] Bliss, C., _et al._ _Accidents and Unscheduled Events Associated with Non-Nuclear Energy Resources and Technology_, Washington, D.C.: U.S., Environmental Protection Agency, February 1977, p. 30.

[2] _Ibid._

[3] _Ibid._, p. 31

[4] _Ibid._

[5] _Ibid._

[6] _Ibid._

[7] Mortality is 1.15 to 1.48 as great as expected. Plot, William J., _et al._ "Cancer Mortality in U.S. Counties with Petroleum Industries." _Science_, Vol. 198 (October 7, 1977), pp. 51-53.

Wyoming.[1] But this incidence is thought to be related to refining or petrochemical industries, rather than to the extraction and transportation phases included in this technology assessment. Table 10-36 summarizes the results of a study on safety risks for oil and gas field development workers.[2] On an equivalent energy basis, the risk of death to workers in oil and gas fields is about the same, risk of injury is higher in oil fields than in gas fields and risk of work days lost is higher in gas fields than in oil fields.

10.8.5 Geothermal Resource Development

Only limited working experience is available in geothermal resources development. Accidents reported include transportation accidents associated with exploration, blowouts, leaks, explosions during extraction, and mechanical accidents associated with the electric power generation step. The most severe anticipated accident would be a well blowout releasing hot fluids and steam to the surface.[3] A blowout can cause injuries as well as damage to equipment. Early development at both the Cerro Prieto field in Mexico and at the Geysers in California has resulted in blowouts.[4] If natural gas is present, a fire could also result.[5] A less severe accident would be a pipeline leak or rupture caused by an earthquake, mechanical failure, human error, or pressure buildup due to mineral deposition.[6] Geothermal resource development can also cause subsidence resulting in damage to buildings and equipment. A summary of accident types associated with geothermal resource development is given in Table 10-37.

Health hazards in geothermal development may also result from exposure to hydrogen sulfide and ammonia. Depending on the type of accident or condition, these gases may be released to the atmosphere in toxic concentrations along with certain trace gases

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[1] "Using Cancer's Rates to Track Its Cause." Business Week, November 14, 1977, p. 69. Counties included: Carbon, Laramie, Natrona and Park.

[2] Battelle Columbus and Pacific Northwest Laboratories. Environmental Considerations in Future Energy Growth. Columbus, Ohio: Battelle Columbus Laboratories, 1973.

[3] Bliss, C., et al. Accidents and Unscheduled Events Associated with Non-Nuclear Energy Resources and Technology. Washington, D.C.: U.S., Environmental Protection Agency, 1977, p. 32.

[4] Ibid., p. 193.

[5] Ibid., p. 33.

[6] Ibid.

TABLE 10-36: OCCUPATIONAL SAFETY RISKS IN OIL AND GAS DEVELOPMENT OPERATIONS[a]

SAFETY RISK	TYPICAL SIZE FIELD		EQUIVALENT ENERGY (10^{12} Btu/year)	
	OIL (100,000 bbl/day)	GAS (250 MMcfd)	OIL	GAS
Deaths per year	0.45	0.2	0.002	0.002
Injuries per year	43.0	10.0	0.20	0.11
Man Days Lost per year	2,200.0	3,200.0	10.39	35.07

Btu = British thermal unit
bbl/day = barrels per day at 5.8 x 10^6 Btu's per barrel
MMcfd = million cubic feet per day at 1,000 Btu's per cubic foot

[a]Battelle Columbus and Pacific Northwest Laboratories. Environmental Considerations in Future Energy Growth. Columbus, Ohio: Battelle Columbus Laboratories, 1973.

TABLE 10-37: TYPE OF ACCIDENT OCCURRENCE BY GEOTHERMAL RESOURCE[a]

ACCIDENT	VAPOR-DOMINATED HYDROTHERMAL	LIQUID-DOMINATED HYDROTHERMAL	GEOPRESSURED	HOT, DRY ROCK
Exploration				
Blowouts	×	×	×	×
Subsidence		×	×	
Rig accidents	×	×	×	×
Extraction				
Blowouts	×	×	×	×
Induced seismicity and seismic induced failures	×	×	×	×
Landslides	×	×	×	×
Erosion	×	×	×	×
Rig failure	×	×	×	×
Production				
Organic fluid explosion or spillage		×		
Subsidence		×	×	
Clogging and sealing		×		

[a]Bliss, C., et al. Accidents and Unscheduled Events Associated with Non-Nuclear Resources and Technology. Washington, D.C.: U.S., Environmental Protection Agency, 1977, p. 194.

such as mercury which are toxic at lower concentrations.[1] Actual worker exposure has not been determined.

Many geothermal waters contain concentrations of radium above drinking water standards.[2] These waters also contain radon daughters. According to one study, radiation risk from occupational exposures is not likely if water streams are contained and adequate ventilation exists. However, possible impacts depend on the size of development and type of technology used.[3]

10.8.6 Oil Shale Development

Occupational exposure to health and safety risks in oil shale development occur both in the mining and conversion phases. Safety hazards are summarized in Table 10-38. These data are based on projections from related industrial activities, not on actual experience with oil shale development. Thus, they must be interpreted cautiously.

As indicated in Table 10-38, conventional oil shale development (mining followed by surface retort) exposes more workers to the hazards of a mine environment and process phases, which produce more HC, than does modified *in situ* development. The data in Table 10-38 also indicate that mining oil shale will be less hazardous than mining coal.[4] Roof collapse is less likely for an equivalent sized room because of the hardness of the shale. However, larger rooms are likely to be used in oil shale mining. Explosions in the mine due to buildup of flammable gases probably will not occur, although explosive mixtures of dust may form.[5] Explosions and fires may also occur in shale processing. The incidence of severe accidents is likely to be similar to that observed for other processes involving use of hydrogen under high pressure.[6]

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[1] Resource Planning Associates, Inc. *Western Energy Resources and the Environment: Geothermal Energy*. Washington, D.C.: U.S., Environmental Protection Agency, Office of Energy, Minerals, and Industry, 1977, pp. 67-68.

[2] O'Connell, M.F., and R.F. Kartmann. *Radioactivity Associated with Geothermal Waters in the Western United States*. Las Vegas, Nev.: U.S., Environmental Protection Agency, n.d., p. 21.

[3] *Ibid.*, p. 22.

[4] Bliss, C., *et al*. *Accidents and Unscheduled Events Associated with Non-Nuclear Energy Resources and Technology*. Washington, D.C.: U.S., Environmental Protection Agency, February 1977, p. 33.

[5] *Ibid.*

[6] *Ibid.*

TABLE 10-38: SUMMARY OF SAFETY HAZARDS IN OIL-SHALE DEVELOPMENT

TECHNOLOGY	DEATHS PER YEAR	INJURIES PER YEAR	WORKER DAYS LOST PER YEAR
Underground Mine (66,000 tpd)	0.8	34	NA
Surface Mine (66,000 tpd)	0.2	10	NA
Modified In Situ (mine only)[a] (41,000 tpd processed)	0.1	15	NA
Surface Retorting (50,000 bbl/day)	0.15	15	NA
Modified In Situ - Processing Stage (50,000 bbl/day)	NA	NA	NA

tpd = tons per day
bbl/day = barrels per day
NA = not available

Source: Hittman Associates, Inc. *Environmental Impacts, Efficiency and Cost of Energy Supplied by Emerging Technologies*, Draft Report on Tasks 7 and 8, HIT-582. Columbia, Md.: Hittman Associates, 1974.

[a]Assume accident rate equivalent to underground mine, with 25 percent removal of oil shale rock.

Health hazards in underground mines also include exposure to shale dust that contains silica, inorganic salts, toxic metals, and organics. Free silica can cause silicosis.[1] Some studies indicate that shale consists of 10 percent silica although other analyses found no free silica in respirable size ranges.[2]

Oil shale itself is not generally thought to be cancer producing; the organic portion of the shale rock is mainly low-molecular-weight organic material with little aromatic HC content. However, retorting produces such HC as PAH's suspected of producing cancer. Tests on Colorado oil shale gave a distillate containing 2 percent PAH's.[3] Upgrading shale oil reduces its carcinogenicity by breaking down these components. However, the residues may contain relatively high concentrations of PAH's.[4]

British workers regularly exposed to raw shale oil and to lubricating oil made from shale have showed a high incidence of scrotal and skin cancer.[5] Skin cancers have also been found in workers exposed to shale-derived tars, light oil, waxes, and cutting oils.[6] However, in contrast with the British experience, oil shale industries in Estonia, Brazil, and Sweden have not reported increased incidences of cancer among workers. No skin cancers were detected in the small-scale Bureau of Mines shale oil demonstration plant near Rifle, Colorado although there was a high incidence of benign skin lesions.

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[1]White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapter 4.

[2]Ashland Oil, Inc.; Shell Oil Col. Operator. Oil Shale Tract C-b: Detailed Development Plan and Related Materials, prepared for submittal to the Area Oil Shale Supervisor pursuant to Lease C-20341 issued under the Federal Prototype Oil Shale Leasing Program, February 1976, Vol. 1, p. V-77.

[3]Not all PAH's are carcinogens, but most organic carcinogens found in shale oil are PAH's.

[4]Schmidt-Collerus, Josef J. Disposal and Environmental Effects of Carbonaceous Solid Wastes from Commercial Oil Shale Operations. Denver, Colo.: University of Denver, Research Institute, 1974.

[5]Commoner, B. "From Percival Pott to Henry Kissinger." Hospital Practice, Vol. (1975), pp. 138-41.

[6]Auld, S.J.M. "Environmental Cancer and Petroleum." Journal of the Institute of Petroleum, Vol. 36 (April 1950), pp. 235-53.

Some carcinogens will be emitted in the stack gas from the boilers and retort;[1] these will be dispersed into the atmosphere around the plant. While a continuing pattern of exposure would occur in areas affected by poor dispersion, there is no direct evidence to suggest that the concentration resulting would constitute a significant health hazard.

Spent shale disposal could also expose populations to cancer-causing chemicals. In Estonian spent shale dumps, small unsaturated HC molecules (with less than 25 carbon atoms), some of which could be carcinogenic, are believed to be formed.[2] Carbonaceous spent shale produced by retorting Colorado oil shale has been shown to contain carcinogens.[3] Workers compacting the spent shale or maintaining the containment dikes, could be exposed to these substances regularly by inhalation.

Process waters and various aqueous plant wastes will be contaminated with PAH's and other HC. These wastes may be used to slurry or "wet down" the spent shale, and workers involved may be exposed to the carcinogens through contact or inhalation.

10.8.7 Uranium Development

Workers are exposed to potentially hazardous conditions in both uranium mines and mills. Underground metals mining is safer than underground coal mining, but exposure to radioactive materials is greater. Milling requires exposure to several risks, including exposure to radiation.

A. Mining

The two principle hazards from uranium mining are accidents within the mine and exposure to disease producing residuals. Accident data are not avilable for uranium mines apart from other underground metal mines. These industry data indicate that hard

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[1]These include the polynuclear aromatic carcinogens 7,12-dimethylbenz(a)anthracene, dibonz(a,j)anthracene, 3-methylcholanthrene, benz(c)phenanthrene, benzpyrenes, benzanthracenes, chrysene, and carbazoles, among others. Barrett, R.E., et al. Assessment of Industrial Boiler Toxic and Hazardous Emissions Control Needs, Final Report, Cotract No. 68-02-1232, Task 8. Columbus, Ohio: Battelle Memorial Institute, Columbus Laboratories, 1974

[2]Schmidt-Collerus, Josef J. Disposal and Environmental Effects of Carbonaceous Solid Wastes from Commercial Oil Shale Operations. Denver, Colo.: University of Denver, Research Institute, 1974.

[3]Ibid.

rock mining is a hazardous activity, although less hazardous than coal mining (see Table 10-34). Because conditions vary significantly among mines, average data should be interpreted with caution for assessing the risk at specific locations. Like coal, surface uranium mining is less hazardous than underground mining.

The incidence of lung cancer in uranium miners has been of special concern, and during the last 10 years exposure levels have been reduced in an attempt to lower the incidence of disease. In a study of 4,180 uranium miners from 1950 to 1973, approximately 180 excess respiratory malignancies have been reported (1 out of every 23 miners).[1] Among this group, some 600 to 1,000 may eventually die prematurely due to lung cancer.[2] Other studies indicate that one out of every six of these miners may die of lung cancer within 10 years following 1976.[3] Of 100 Navajo miners who worked on one Southwest mine, 18 have died of lung cancer and radiation induced illnesses.[4] Although average doses have been reduced, some scientists believe that present standards expose miners to levels that would create lung cancer at double the average rate of the population.[5]

B. Milling

The most likely types of accidents associated with uranium mill operations are inadvertent discharges of tailings to nearby rivers or streams or a major fire in a solvent extraction circuit.[6] Tailings dams could fail because of flooding, equipment failure,

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[1]Schurgin, Arell A., and Thomas C. Hollocher. "Radiation-Induced Lung Cancers Among Uranium Miners," in Union of Concerned Scientists, ed. The Nuclear Fuel Cycle: A Survey of the Public Health, Environmental, and National Security Effects of Nuclear Power, rev. ed. Cambridge, Mass.: MIT Press, 1975, p. 9.

[2]Ibid.

[3]Nafziger, Rich. Indian Uranium: Profits and Perils, AIO Red Paper. Albuquerque, N. Mex.: Americans for Indian Opportunity, 1976.

[4]Ibid., as cited in Schurgin and Hollocher. "Radiation-Induced Lung Cancers."

[5]Schurgin and Hollocher. "Radiation-Induced Lung Cancers," p. 30.

[6]U.S., Atomic Energy Commission, Directorate of Licensing, Fuels and Materials. Environmental Survey of the Uranium Fuel Cycle, WASH-1248. Washington, D.C.: Atomic Energy Commission, 1972, p. B-22.

or operating errors such as inattention.[1] One reported incident involved the release of about 2,000 gallons of tailings liquid due to a break in a secondary tailings dike; the break was caused by unusually high runoff from melting snow.[2]

In the solvent extraction process of a mill,[3] several thousand gallons of solvent (mostly kerosene), containing as much as several thousand pounds of natural uranium, are present and used in the refining process. This solvent represents a potential for a serious fire and release of uranium. Explosions and fires with a large volume of intense smoke, such as those characteristic of petroleum fires, are possible. Both fires and tailings releases have occurred in a number of uranium mills. However, two large fires in two separate mills involving solvent extraction circuits, in which 2 to 3 thousand pounds of uranium were present in the circuits at the time, caused no appreciable release of uranium.[4] Additional incidents occur in the uranium mill's drying and packaging area. Fires have been caused by the improper use of an open flame or welding.[5] Other accidents include overflows from process tanks, failure of process lines, or leaks and spills of sulfuric acid or kerosene.[6] Health risk from exposure to radiation in the vicinity of uranium mills is discussed in Section 10.7.

A five year study of the safety of nuclear facilities provides a summary of the occupational health hazards from uranium mills. For a 1,200 ton per day uranium mill, the following results were reported per year: 0.046 deaths, 17.1 injuries, and

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[1]U.S., Atomic Energy Commission, Directorate of Licensing, Fuels and Materials. Environmental Survey of the Uranium Fuel Cycle, WASH-1248. Washington, D.C.: Atomic Energy Commission, 1972, p. B-22.

[2]Ibid., p. B-23.

[3]For a detailed description of a uranium mill, see White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[4]AEC. Uranium Fuel Cycle. Accident data are not available.

[5]Ibid.

[6]Ibid., p. B-27.

73 man days lost.[1] With changes in the design of facilities and possible improvements in worker safety programs, these statistics are likely to change.

10.8.7 Summary of Occupational Health and Safety

Of the energy technologies considered in this study, underground mining of coal presents the greatest occupational safety risks--significantly more risky than underground mining of other ores. When considered on the basis of equivalent amounts of coal produced, underground coal mining compared with surface coal mining results in at least five times more deaths, injuries, and work days lost. However, recent legislation is expected to lower the occupational safety risks associated with underground coal mining. The most severe accidents in oil, gas, and geothermal fields are due to blowouts and leaks which can cause explosions.

The best known and best documented occupational health risks are respiratory disorders (black lung disease) in underground coal miners and lung cancer in underground uranium miners. Black lung disease affects more than one-third of underground coal miners and lung cancer (from radiation exposure) is expected in one out of every six uranium miners within 10 years after prolonged exposure. Both of these occupational health risks are expected to decline with new, tighter standards.

Other occupational health risks are less certain; some are cancer related. Synthetic fuels production produces known carcinogens and concentrates them as chars and tars in process residues. Carcinogens are present in raw shale oil and raw synthesis gas. Workers will be exposed to these and can assimilate them through inhalation or skin contact. Exposure levels are highly uncertain and safe exposure levels have not been determined.

Consistent data useful for comparisons among technologies are generally not available. Some data vary on an annual basis due to major accidents. Data are also difficult to interpret on a risk per individual or per Btu basis. A major problem that emerges has been obtaining comparable data on death and accident risks useful for alerting policymakers to critical phases in western energy fuel cycles.

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[1] U.S., Atomic Energy Commission. The Safety of Nuclear Power Reactors (Light Water-Cooled) and Related Facilities, Final Draft, WASH-1250. Springfield, Va.: National Technical Information Service, 1973.

CHAPTER 11

REGIONAL IMPACTS

11.1 INTRODUCTION

This chapter reports the results of analyses of the aggregate impacts of western energy development. That is, whereas Chapters 4 through 9 discussed the impacts of hypothetical developments at six specific sites and Chapter 10 discussed impacts that are likely in the area surrounding a particular energy facility, this chapter assesses the effects of energy development on the entire eight-state study area. Impact categories include regional air impacts, water impacts on river basins, social and economic impacts on states or the entire region, ecological impacts of a regional nature, and impacts of energy transportation systems. The chapter begins with a discussion of the assumptions on the extent of energy development that provides a basis for the impact analyses.

11.1.1 Location of Development

Regional impacts result from the overall levels and rates of development likely for the entire eight-state region. Impacts also depend upon the distribution of the different energy resources in the region. Coal is found in all eight states as shown in Figure 11-1. The largest concentrations are found in the Northern Great Plains. Oil shale deposits are concentrated in the Green River Formation in Colorado, Utah, and Wyoming. These are shown in Figure 11-2. The largest deposits of uranium are found in New Mexico and Wyoming, although some uranium may be found in each of the eight states, as shown in Figure 11-3. Crude oil and natural gas reserves are largest in New Mexico and Wyoming, although both of these resources are also found in Colorado, Utah, and North and South Dakota. Areas of geothermal resources are still being discovered, but resources have been primarily identified in the western half of the region. High temperature geothermal resource areas are shown in Figure 11-4. These general patterns of resource distribution and more detailed patterns described in subsequent sections provide a mechanism for locating impacts within the region.

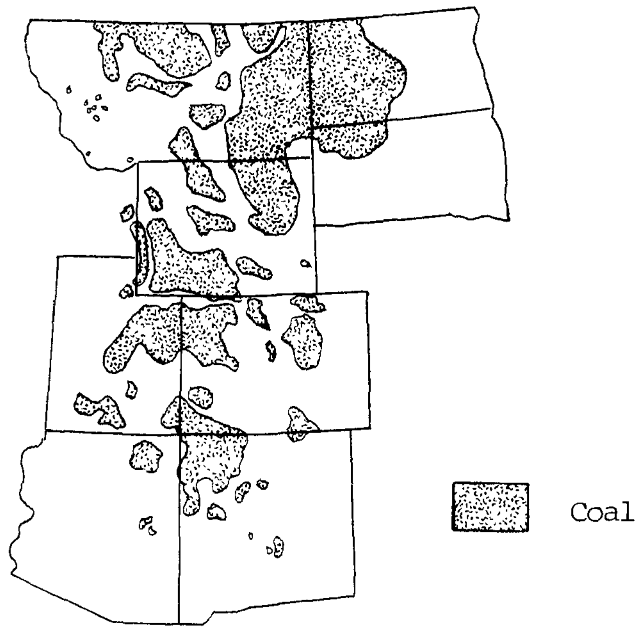

FIGURE 11-1: GENERAL DISTRIBUTION OF COAL RESOURCES IN EIGHT WESTERN STATES

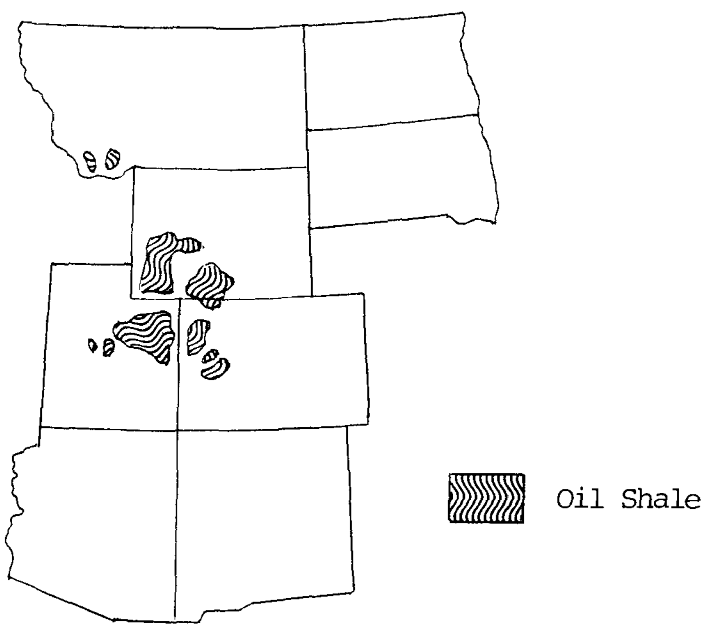

FIGURE 11-2: GENERAL DISTRIBUTION OF OIL SHALE RESOURCES IN EIGHT WESTERN STATES

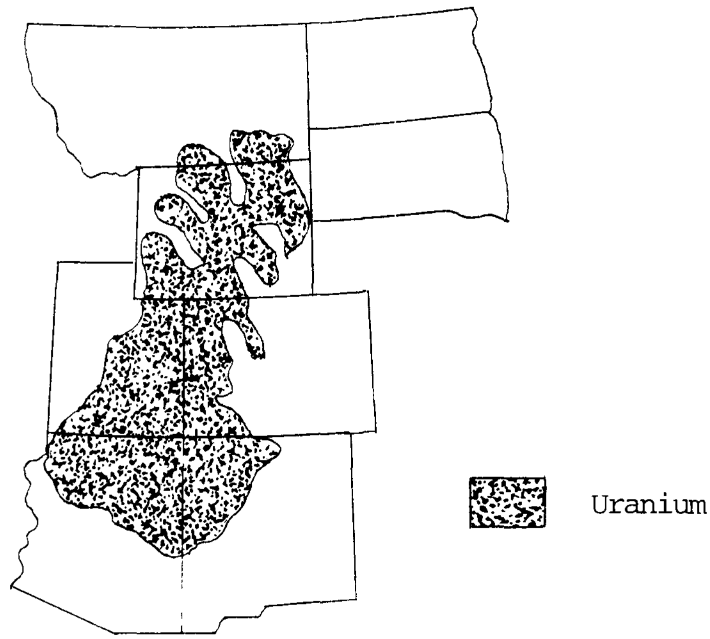

FIGURE 11-3: GENERAL DISTRIBUTION OF URANIUM RESOURCES IN EIGHT WESTERN STATES

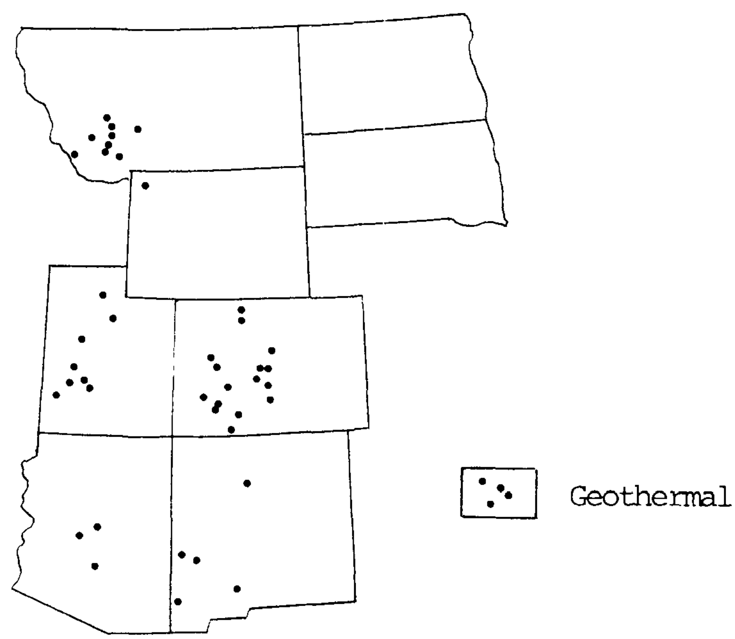

FIGURE 11-4: GENERAL DISTRIBUTION OF GEOTHERMAL RESOURCES IN EIGHT WESTERN STATES

11.1.2 Levels of Development

Stanford Research Institute's (SRI) interfuel competition model was used to construct two energy resource development scenarios for the eight states corresponding to two projections of national energy demands between the present and 2000.[1] These projections of energy supply from the West are used in this report as a vehicle for assessing impacts. A representative range of energy supplies provides the basis for anticipating the potential extent and magnitude of impacts. Although based on informed interfuel competition modeling, the levels of energy production in these scenarios should not be interpreted as predictions of what is likely to occur.

The SRI model considers various combinations of energy resources that could supply energy demands at a particular location at a particular time. Estimates are made of the costs of delivered energy in different fuel forms from various sources, and an economic analysis is used to determine the quantity provided by each source. For example, demand for distillate fuel oil in Chicago could be supplied from: crude oil produced in Wyoming and piped to Chicago for refining; oil shale mined, retorted, and upgraded to synthetic crude oil in Colorado, then piped to Chicago for refining; or coal mined and converted to synthetic crude oil in Colorado, then piped to Chicago for refining. Each of these "paths" as well as others, must be analyzed as part of the entire U.S. energy system to determine the fraction of demand to be met by each resource at each location.

The two demand levels assumed to create the two supply scenarios were SRI's Nominal and Low Demand cases. The Nominal case assumed a demand 30 percent higher than the Ford Foundation Technical Fix case.[2] (The Ford Foundation's Technical Fix case was an attempt to anticipate the results of a variety of voluntary and mandatory energy conservation measures.) The Nominal Demand case scenario results in an energy supply of 156.9 quads (Q) and an end use demand of 79.98 Q for the year 2000. The Low Demand case corresponds to the Ford Foundation's Technical Fix Scenario. It results in an annual growth rate of approximately 2.1 percent,

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[1] Cazalet, Edward, _et al_. _A Western Regional Energy Development Study: Economics_, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

[2] Ford Foundation, Energy Policy Project. _A Time to Choose: America's Energy Future_. Cambridge, Mass.: Ballinger, 1974.

with an energy supply of 129.5 Q and an end use demand of 67.97 Q for the year 2000.[1]

The SRI model was used at the time the impact scenarios were being formulated (1975) because the SRI model was the most readily available and well documented, it projected energy demands to the year 2000, it analyzed multiple demand scenarios, and it disaggregated geographically to the area of interest in this study. The model did, however, have limitations which included the following:

- The contribution predicted from oil shale grows very rapidly in the 1990-2000 decade (from five to forty-two 100,000 barrels per day (bbl/day) plants in the Nominal case) although it now seems unlikely that development at that rate could be accomplished.

- Oil shale was considered to be produced solely from surface mines, and *in situ* oil shale retorting was not considered.

- Contributions from geothermal resources were not included.

- Western coal was assumed to be of one composition and heating value throughout the West. Actually, wide variations exist, such as between North Dakota lignite and Kaiparowits bituminous.

- Only limited account was taken of the availability of equipment and personnel to accomplish the development indicated. As noted later in this chapter, both could tend to constrain developments to levels below those indicated.

- Installation of flue gas desulfurization (FGD) control equipment (stack gas scrubbers) was not considered on electrical power generating plants using western coal, and all coal was considered to be produced from surface mines.

These assumptions and omissions constrain the utility of the model, and modifications discussed below will attempt to deal with them.

The oil shale levels of development forecast appear too high because the commercial oil shale developments that were expected in the mid-1970's have failed to materialize. The only

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[1]Cazalet, Edward, *et al.* *A Western Regional Energy Development Study: Economics*, *Final Report*, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976. Losses within the system account for the difference between the supply and end use demand numbers.

oil shale development plan that has been approved by the Secretary of the Interior is Occidental and Ashland's in situ development of Colorado Tract B. This development is predicted to produce 57,000 bbl/day of shale oil by 1983. Development plans for Colorado Tract A call for in situ retorting, and a federally sponsored 100,000 bbl/day surface retort facility may be built, but the construction times for these facilities make it unlikely that the levels of development will exceed the following:

1990--2 levels: one and five 100,000 bbl/day facilities

2000--2 levels: 10 and 25 100,000 bbl/day facilities

Thus, the SRI scenarios are modified to include these levels of oil shale development.

Levels of geothermal development are likely to remain small in comparison to total electric power production until the year 2000. Assuming a national production level of geothermal-based electric power of between 2,500 and 5,000 megawatts-electric (MWe) in 1985 and between 7,000 and 50,000 MWe in 2000,[1] it seems reasonable to forecast the development of 100 to 200 MWe by 1985 and 700 to 5,000 by 2000 in the eight-state study area. The 100 to 200 MWe are based on planned developments in the Jemez Mountains in New Mexico and in the vicinity of Roosevelt, Utah. The 700 to 5,000 MWe are 10 percent of the level of national production estimated for 2000. This is approximately the percentage of U.S. geothermal resources located in the eight-state area. Thus, the SRI scenarios are adjusted for these levels of geothermal development in the eight-state study area.

Dealing with the assumptions concerning the coal characteristics and levels of emission controls made in the SRI model requires consideration of recent changes in emission control

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[1]These are consensus estimates from Loveland, Walter D., Bernard I. Spinrad, and C.H. Wang, eds. Magnitude and Deployment Schedule of Energy Resources; Proceedings of a Conference Held on July 21-23, 1975, in Portland, Oregon, under the Sponsorship of the Energy Research and Development Administration, Pacific Northwest Regional Commission, and Oregon State University Office of Energy Research and Development. Corvallis, Oreg.: Oregon State University, 1975; and U.S., Energy Research and Development Administration, Division of Geothermal Energy. Definition Report: Geothermal Energy Research, Development and Demonstration Program. Springfield, Va.: National Technical Information Service, 1975. These estimates do not include direct thermal uses such as space heating and crop drying.

regulations as a result of the Clean Air Act (CAA) Amendments of 1977. The Low Demand and Nominal cases in the SRI model call, respectively, for 970 million and 1,150 million tons of coal to be produced nationally in 1985. Without a change in current policies, the National Energy Plan[1] would require production of approximately 1,080 million tons of coal annually in 1985. However, the plan proposes policy changes which would have the net effect of boosting national coal production in 1985 to about 1,280 million tons per year (MMtpy).

The inclusion in the 1977 CAA Amendments of a "best available control technology" (BACT) requirement for new, large coal burning facilities complicates matters further because the requirement can be expected to shift some coal production away from the West after 1985. The requirement that all coal-fired power plants be equipped with scrubbers would largely eliminate the advantage of using low sulfur western coal in most regions of the country. Demand through 1985 is not likely to be significantly affected because of existing long-term contracts but demand for western coal after 1985 would be strongly affected. One study performed at Argonne National Laboratory estimated the effect that alternative BACT definitions will have on regional coal markets.[2] In that study all alternative BACT scenarios are projected to have substantial effects on western coal production; especially affected were Northern Great Plains coal shipments to the middle regions of the nation. In 1990 the production of Northern Great Plains coal ranged from 202 to 239 MMtpy for alternative BACT definitions compared to a base case (which assumed a continuation of New Source Performance Standards [NSPS]) production of 388 MMtpy. These compare with 1976 production levels of 46 million tons. Production of "other western" coal was largely unaffected by BACT according to the Argonne study. On the basis of these results, it appears that even SRI's Low Demand case will be too high for western coal production after 1985 if BACT is implemented. The Nominal case probably represents a reasonable upper bound on development if less stringent sulfur controls are imposed and if the Administration's proposal requiring utilities to shift from oil and natural gas to coal is adopted.

The projections for the two cases are given in Table 11-1 and 11-2, and include the modifications indicated above for oil

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[1]U.S., Executive Office of the President, Energy Policy and Planning. The National Energy Plan. Washington, D.C.: Government Printing Office, 1977.

[2]Krohm, G.C., C.D. Dux, and J.S. Van Kuiken. Effects on Regional Coal Markets of the "Best Available Control Technology" Policy for Sulfur Emissions, National Coal Utilization Assessment. Argonne, Ill.: Argonne National Laboratory, 1977.

TABLE 11-1: PROJECTION OF WESTERN ENERGY RESOURCE PRODUCTION NOMINAL DEMAND CASE[a]

ENERGY TYPE	TOTAL U.S. PRODUCTION (Q)[b]					FRACTION OF U.S. PRODUCTION FROM WEST (%)					NUMBER OF FACILITIES REQUIRED IN WESTERN REGION[c]				
	1975	1980	1985	1990	2000	1975	1980	1985	1990	2000	1975	1980	1985	1990	2000
Coal[d]															
Mines	10.26	15.12	21.17	25.12	50.99	15.3	33.3	46.2	50.2	58.7	19	60	116	149	351
Powder River						8.0	25.2	38.3	42.9	53.2	10	45	95	127	319
Rocky Mountain						7.2	8.2	7.9	7.4	5.4	9	15	21	22	32
Direct Use	8.61	11.98	15.61	17.05	23.98	17.4	31.1	43.4	48.7	61.8					
Unit Train	8.61	10.46	11.06	11.06	11.93	17.4	30.6	43.3	48.2	59.3	4	8	12	13	17
Powder River						9.7	23.9	37.0	42.0	53.9	2	6	10	11	15
Rocky Mountain						7.8	6.7	6.3	6.1	5.4	2	2	2	2	2
Slurry Pipeline	0	1.52	4.55	5.99	12.05		34.2	43.7	49.6	64.3	0	1	5	7	18
Powder River							30.3	39.6	45.2	59.5	0	1	4	6	17
Rocky Mountain							3.9	4.2	4.3	4.8	0	0	1	1	1
Gasification	0	0	0.02	0.61	7.80			20.0	37.7	49.1	0	0	0	3	47
Powder River								20.0	36.1	47.1	0	0	0	3	45
Rocky Mountain								0	1.6	2.1	0	0	0	0	2
Liquefaction	0	0	0.02	0.20	1.84				0.5	16.6	0	0	0	0	2
Powder River									0.5	16.4	0	0	0	0	2
Rocky Mountain									0	0.2	0	0	0	0	0
Electrical Generation	3.04	4.35	5.14	5.59	6.66	1	11.0	18.1	19.3	21.5	1	8	15	18	23
Powder River						0	7.1	13.0	14.3	17.3	0	5	11	13	18
Rocky Mountain						1	3.9	5.1	5.0	4.2	1	3	4	5	5

TABLE 11-1: (Continued)

ENERGY TYPE	TOTAL U.S. PRODUCTION (Q)[b] 1975	1980	1985	1990	2000	FRACTION OF U.S. PRODUCTION FROM WEST (%) 1975	1980	1985	1990	2000	NUMBER OF FACILITIES REQUIRED IN WESTERN REGION[c] 1975	1980	1985	1990	2000
Oil Shale	0	0.001	0	0.95	4.76		100	100	100	100	0	0	0	5	25
Powder River							0	0	0	0	0	0	0	0	0
Rocky Mountain							100	100	100	100	0	0	0	5	25
Uranium Fuel	2.19	5.34	10.77	13.90	26.10	89.0	89.3	91.0	91.1	91.0	7	16	33	42	79
Powder River						34.2	34.6	35.2	35.3	35.2	3	6	13	16	31
Rocky Mountain						54.8	54.7	55.8	55.8	55.8	4	10	20	26	48
Gas (Methane)	19.71	23.73	26.40	26.02	18.34	8.7	8.3	8.1	8.0	5.8	19	22	23	23	12
Powder River						0	0	0	0	0	0	0	0	0	0
Rocky Mountain						8.7	8.3	8.1	8.0	5.8	19	22	23	23	12
Domestic Crude Oil	16.61	21.10	24.75	25.96	22.79	8.6	8.0	6.3	5.1	4.5	7	8	8	6	5
Powder River						0	0	0	0	0	0	0	0	0	0
Rocky Mountain						8.6	8.0	6.3	5.1	4.5	7	8	8	6	5
Geothermal	-	-	.15	-	1.49	-	-	8.0	-	10.0	0	0	2		71
Powder River						-	-	0	-	0	0	0	0		0
Rocky Mountain						-	-	8.0	-	10.0	0	0	2		71

Q = 10^{15} British thermal unit(s). One Q equals approximately 172 million barrles of oil, 60 million tons of western coal, or one trillion cubic feet of natural gas.

[a]Based on Stanford Research Institute Nominal case and Ford Foundation data.

[b]Input values for coal direct use; output values for others.

[c]Facility sizes and load factors assumed are: mines, 5 million tons per year (MMtpy) (100 percent); unit trains and slurry pipelines, 25 MMtpy (100 percent); gasification, 250 million standard cubic feet per day (90 percent); liquefaction, 100,000 barrels per day (bbl/day) (90 percent); electrical generation, 3,000 megawatts-electric (MWe) (70 percent); oil shale, 100,000 bbl/day (90 percent); uranium fuel, 1,000 tons per year of yellowcake (90 percent); gas (methane), 250 million cubic feet per day (100 percent); domestic crude oil, 100,000 bbl/day (100 percent); geothermal, 100 MWe (70 percent).

[d]Coal subcategories do not add to total because of other usage; for example, hydrogen from coal.

TABLE 11-2: PROJECTION OF WESTERN ENERGY RESOURCE PRODUCTION LOW DEMAND CASE[a]

ENERGY TYPE	TOTAL U.S. PRODUCTION (Q)[b]					FRACTION OF U.S. PRODUCTION FROM WEST (%)					NUMBER OF FACILITIES REQUIRED IN WESTERN REGION[c]				
	1975	1980	1985	1990	2000	1975	1980	1985	1990	2000	1975	1980	1985	1990	2000
Coal[d]															
Mines	10.26	13.36	17.40	20.24	38.65	15.3	32.0	44.1	48.4	57.2	19	51	91	116	260
Powder River						8.0	24.2	36.6	41.4	52.1	10	38	75	99	237
Rocky Mountains						7.2	7.9	7.5	7.1	5.1	9	13	16	17	23
Direct Use	8.61	10.65	12.88	13.82	18.75	17.4	29.4	41.0	46.2	59.0					
Unit Train	8.61	9.34	9.17	9.02	9.35	17.4	29.0	40.8	45.8	56.5	4	7	9	10	12
Powder River						9.7	22.6	34.8	39.9	51.4	2	5	8	9	11
Rocky Mountains						7.8	6.4	6.0	5.9	5.0	2	2	1	1	1
Slurry Pipeline	0	1.31	3.71	4.80	9.40		32.1	41.5	47.1	61.6	0	1	4	6	14
Powder River							29.0	37.5	42.9	57.2	0	1	3	5	13
Rocky Mountains							3.1	4.0	4.2	4.4	0	0	1	1	1
Gasification	0	0	0.01	0.37	4.90			10.0	40.5	46.9	0	0	0	2	28
Powder River								10.0	40.5	45.1	0	0	0	2	27
Rocky Mountains								0	0	1.8	0	0	0	0	1
Liquefaction	0	0	0	0.05	0.79				2	47.5	0	0	0	0	2
Powder River									2	46.7	0	0	0	0	2
Rocky Mountains									0	0.8	0	0	0	0	0
Electrical Generation	3.04	3.40	3.85	4.01	4.53	1.0	12.0	19.0	20.9	23.8	1	6	12	13	17
Powder River						0	7.9	13.8	15.7	19.4	0	4	9	10	14
Rocky Mountains						1.0	4.1	5.2	5.2	4.4	1	2	3	3	3

TABLE 11-2: *(Continued)*

ENERGY TYPE	TOTAL U.S. PRODUCTION (Q)[b]					FRACTION OF U.S. PRODUCTION FROM WEST (%)					NUMBER OF FACILITIES REQUIRED IN WESTERN REGION[c]				
	1975	1980	1985	1990	2000	1975	1980	1985	1990	2000	1975	1980	1985	1990	2000
Oil shale	0	0.001	0.001	0.19	0.95		100	100	100	100	0	0	0	1	5
Powder River							0	0	0	0	0	0	0	0	0
Rocky Mountains							100	100	100	100	0	0	0	1	5
Uranium Fuel	2.19	4.56	8.28	10.40	18.80	89.0	91.0	91.1	91.0	91.0	7	14	25	32	57
Powder River						34.2	35.3	35.2	35.2	35.2	3	5	10	12	22
Rocky Mountains						54.8	55.7	55.8	55.8	55.8	4	9	15	20	35
Gas (Methane)	19.71	23.12	25.21	24.61	17.69	8.7	8.6	7.9	7.7	6.7	19	22	22	21	13
Powder River						0	0	0	0	0	0	0	0	0	0
Rocky Mountains						8.7	8.6	7.9	7.7	6.7	19	22	22	21	13
Domestic Crude Oil	16.61	21.16	24.46	25.37	22.62	8.6	8.2	6.5	5.3	4.0	7	8	8	6	5
Powder River						0	0	0	0	0	0	0	0	0	0
Rocky Mountains						8.6	8.2	6.5	5.3	4.0	7	8	8	6	5
Geothermal	-	-	.07	-	.21	-	-	8.0	-	10.0	0	0	1	1	10
Powder River						-	-	0	-	0	0	0	0	0	0
Rocky Mountains						-	-	8.0	-	10.0	0	0	1	1	10

Q = 10^{15} British thermal unit(s). One Q equals approximately 172 million barrels of oil, 60 million tons of western coal, or one trillion cubic feet of natural gas.

[a]Based on Stanford Research Institute Low Demand case and Ford Foundation data.

[b]Input values for coal direct use; output values for others.

[c]Facility sizes and load factors assumed are: mines, 5 million tons per year (MMtpy) (100 percent); unit trains and slurry pipelines, 25 MMtpy (100 percent); gasification, 250 million standard cubic feet per day (90 percent); liquefaction, 100,000 barrels per day (bbl/day) (90 percent); electrical generation, 3,000 megawatts-electric (MWe) (70 percent); oil shale, 100,000 bbl/day (90 percent); uranium fuel, 1,000 tons per year of yellowcake (90 percent); gas (methane), 250 million cubic feet per day (100 percent); domestic crude oil, 100,000 bbl/day (100 percent); geothermal-electric, 100 MWe (70 percent).

[d]Coal subcategories do not add to total because of other usage; for example, hydrogen from coal.

shale and geothermal development. As used in the SRI model, the "Powder River Region" refers to the states of Montana, Wyoming, and North and South Dakota;[1] the "Rocky Mountain Region" includes New Mexico, Arizona, Utah, and Colorado. Allocations of national nuclear production were based on present production rates. The number of facilities required was calculated by assuming the facility sizes and capacity factors shown in Tables 11-1 and 11-2 and determining how many facilities of this size will be needed for the total production indicated. Adjusting total energy supply for the reduction in number of oil shale facilities and the addition of geothermal, the supply for the Nominal Demand case is reduced to 155.1 Q and for Low Demand to 124.0 Q.

In the SRI model, the geographical distribution of development was carried out dividing the western states into only two subregions, the Powder River and the Rocky Mountain areas. For some of our impact analyses, it was necessary to disaggregate further to a state. The number of facilities by state used in the analysis is given in Table 11-3. For the near future (to 1985), disaggregation was done on the basis of the locations of announced energy facility developments.[2] For later times (1990 and 2000), development was assumed to be proportional to the proved reserves in each state. Disaggregation based on resource levels was done only to provide a basis for impact analyses. Actual siting of facilities depends upon a number of other factors, including site characteristics, land availability and several legal and institutional factors.

11.1.3 Development Options

Although energy resources are located in the West, options exist for where these resources are converted to end use forms. Options will depend upon the resource being handled. Oil shale must be retorted very near the mine mouth because the yield of the ore is small (high quality oil shale yields about 30 gallons per ton of ore) and transportation costs per unit of energy are consequently high. Subsequent processing of the shale oil

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[1] In the SRI model, the Powder River region includes the Powder River Basin and the Fort Union Basin. With several smaller geologic basins, this area may be considered equivalent to the Northern Great Plains region.

[2] Denver Federal Executive Board, Committee on Energy and Environment, Subcommittee to Expedite Energy Development; and Mountain Plains Federal Regional Council, Socioeconomic Impacts of Natural Resource Development Committee. A Listing of Proposed, Planned or Under Construction Energy Projects in Federal Region VIII: A Joint Report. August 1975. (Unpublished report.)

TABLE 11-3: NUMBER OF FACILITIES BY STATE IN THE LOW AND NOMINAL DEMAND SCENARIOS

STATE	1975	1980 LOW	1980 NOMINAL	1990 LOW	1990 NOMINAL	2000 LOW	2000 NOMINAL
Colorado							
Power plants		1	1	1	2	1	2
Modified *in situ*		0	0	1	3	3	13
Uranium		0	0	1	2	2	3
Natural gas		0	0	0	8	4	4
TOSCO II		0	0	0	2	2	10
New Mexico							
Natural gas	19	22	22	21	15	9	8
Crude oil	7	8	8	6	6	5	5
Uranium	4	9	10	19	22	31	42
Power plants		0	1	1	1	1	1
Geothermal		0	0	1	10	10	71
Gasification		0	0	0	0	1	2
Utah							
Power plants	1	1	1	1	2	1	2
Uranium		0	0	0	2	2	3
TOSCO II oil shale		0	0	0	0	0	2
Montana							
Power plants		1	2	3	5	5	6
Gasification		0	0	0	1	9	15
Liquefaction		0	0	0	0	1	1
Wyoming							
Power plants	3	1	1	3	2	3	3
Uranium		5	6	12	16	22	31
Gasification		0	0	0	0	5	9
Liquefaction		0	0	0	0	1	1
North Dakota							
Power plants		2	2	4	6	6	9
Gasification		0	0	2	2	13	21

produced in the retort may be at a distant site because the characteristics of the shale oil are comparable to crude oil, and pipeline transportation is economical.

Geothermal energy conversion to electricity must be done near the wellhead because of heat transfer losses in transportation. As a consequence, geothermal power plants tend to be smaller than fossil fuel plants because of the areal extent of well fields.

Uranium ore is also low quality, so that the first step in conversion, milling to yellowcake, is done in the vicinity of the mine. Other steps in the nuclear fuel cycle were not considered in this study.

Oil and gas are both easily and economically transported by pipeline in virtually the form in which they come out of the ground. At the present time, most crude oil refining is carried on outside of the eight states considered in our study. Since the oil and gas resources in the region are limited, we assume that this continues to be the case.

Coal, then, is the only resource considered in the study which may be converted or processed at the mine mouth, a demand center, or at some other intermediate location at which other required resources (such as water or labor) are available or regulations are attractive. As discussed in Chapter 1, site specific analyses of the impacts of coal conversion facilities were carried out only for locations in the vicinity of mines. Although most of the utilization of western coal is likely to be outside the eight-state region, analysis of impacts at these demand center sites was not carried out. Siting at intermediate locations was also not analyzed, although sites in South Dakota near the Missouri River appear to be under consideration for western coal processing.[1]

In addition to locational options, different rates of development of western energy resources can be considered. Rates of development at a specific location make a substantial difference in the social, economic, and political impacts at that location, but do not substantially change air and water impacts. Regionally, social and economic impacts are also heavily affected by rate of development, and in addition, impacts may arise because

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[1]Corsentino, J.S. Projects to Expand Fuel Sources in Western States: Survey of Planned or Proposed Coal, Oil Shale, Tar Sands, Uranium, and Geothermal Supply Expansion Projects, and Related Infrastructure, in States West of the Mississippi River (as of May 1976), Bureau of Mines Information Circular 8719. Washington, D.C.: Government Printing Office, 1976, p. 144.

of bottlenecks in the provision of materials and equipment required for facility construction or operation. There may also be ecological impacts which are dependent on the rate of development; for example, plant and animal species may respond differently depending on the time allowed to adapt to changed surroundings resulting from new facilities.

Chapters 4-9 in this report presented the results of site specific impact analyses and include the residuals and resource requirements data needed to perform the impact analysis for each facility (i.e., data on emissions, effluents, water requirements, land use, labor requirements, and capital cost). These same data are used in this chapter, aggregated at the regional level. Neither geothermal development nor enhanced recovery of oil were considered in the site specific analyses, but residuals data for them are given in Chapter 3 and these technologies are included in the scenarios in this chapter.

11.2 AIR IMPACTS

11.2.1 Introduction

This section estimates regional air impacts which may result from energy developments in the eight western states. The analysis is carried out for the two development scenarios (Low and Nominal case) described in the previous section. Regional impacts discussed include effects of total emissions and possible inadvertent weather modification, with the focus on total emissions.

11.2.2 Existing Conditions

A. Air Quality

Table 11-4 gives national ambient air quality standards for the six criteria pollutants[1] and estimates of average background levels for these pollutants in the West. Based on the limited data available, ambient air quality in the eight-state study area appears good when considered in the context of annual average concentrations of criteria pollutants. However, short-term (24-hour) particulate concentrations periodically exceed the federal primary standard in some areas. This violation occurs because of windblown dust. This is generally considered to be a natural condition resulting from the arid climate, but

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[1]Criteria pollutants are those for which federal ambient air quality standards have been established. They include particulates, sulfur dioxide, nitrogen dioxide, photochemical oxidants, hydrocarbons, and carbon monoxide.

TABLE 11-4: REGIONAL AIR QUALITY AND NATIONAL STANDARDS[a] (micrograms per cubic meter)

POLLUTANT	BACKGROUND LEVEL[b]	AMBIENT STANDARDS	
		PRIMARY	SECONDARY
Particulates			
Annual geometric mean	12 - 40	75	60
Maximum 24-hour	600	260[c]	150[c]
Sulfur Dioxide			
Annual geometric mean	10 - 20	80	NA
Maximum 24-hour		365[c]	NA
Maximum 3-hour		NA	1,300[c]
Nitrogen Dioxide			
Annual geometric mean	10	100	100
Photochemical Oxidants			
Maximum 1-hour	60 - 180[d]	160[c]	160[c]
Hydrocarbons[e]			
Maximum 3-hour (6-9 a.m.)	130[f]	160[c]	160[c]

NA = not applicable

[a]40 C.F.R. 50 (1976).

[b]These levels represent the range of measurements available across the eight-state study area.

[c]Not to be exceeded more than once a year.

[d]Oxidant concentrations vary greatly by location. Peak oxidant values typically occur during the summer and daily maxima occur during late afternoon. Daily maxima in the Northern Great Plains have been documented at 160 to 180 micrograms per cubic meter ($\mu g/m^3$) and in the Central Rockies at 60 to 80 $\mu g/m^3$. See Teknekron, Inc., Energy and Environmental Engineering Division. An Integrated Technology Assessment of Electric Utility Energy Systems, Briefing Materials: Air Quality Impact Methodology and Results--Regional Study and Subregional Problem Areas: Southwest, Rocky Mountains, Northern Great Plains. Berkeley, Calif.: Teknekron, 1978, pp. 88-89.

[e]The HC standard is not a strict standard as is the case with the other criteria pollutants; rather, it primarily serves as a guideline for achieving oxidant standards.

[f]Annual average. No short-term measurements are available for HC; annual concentrations are considered good indicators of baseline concentrations.

it has been suggested that human activity has destabilized the ground surface so that dust is more easily released.[1]

In addition, oxidant background levels (short-term) in the Northern Great Plains have been documented at 160 to 180 micrograms per cubic meter ($\mu g/m^3$) (Table 11-4), values which equal or exceed the 1-hour federal standard (160 $\mu g/m^3$). Short-term measurements of background hydrocarbon (HC) concentrations are not available, but longer term averages approach the standard (Table 11-4). The extent to which high background oxidant and HC levels are caused by human activity or natural conditions is uncertain. The fact that high HC concentrations have been recorded in sparsely populated areas of Colorado[2] indicates that natural sources of HC may be important.[3] In northwestern Colorado, natural sources include vegetation (significant emissions have been measured for some vegetation indigenous to the area[4]) and evaporation from subsurface petroleum deposits.

B. Meteorology

The meteorological conditions which govern dispersion of pollutants and long range transport of pollutants are especially important in an assessment of likely air quality impacts due to resource development. Dispersion potential improves with larger mixing depths[5] and wind speeds. It is generally best during spring and summer because of high mixing depths and poorest during the winter due to low mixing depths. Geographically, the southeastern part of the region has the best

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[1] U.S., Department of the Interior, National Park Service, Denver Service Center. Analysis of Kaiparowits: Power Plant Impact on National Recreation Resources. Denver, Colo.: Denver Service Center, 1976, p. 44.

[2] Palomba, Joseph, Jr., comments in the "Report on the Fifth APCA Government Affairs Seminar, A New Look at the Old Clean Air Act." Journal of the Air Pollution Control Association, Vol. 27 (June 1977), p. 529.

[3] Fosdick, George E., and Spencer A. Bullard. Air Quality Control for Oil Shale Tract C-b. Denver, Colo.: C-b Shale Oil Project, 1976, p. 6.

[4] Rasmussen, Reinhold A. "What Do the Hydrocarbons from Trees Contribute to Air Pollution?" Journal of the Air Pollution Control Association, Vol. 22 (July 1972), pp. 537-43.

[5] Mixing depth is the height from the ground to the upward boundary of pollutant dispersion.

dispersion potential because of typically high mixing depths and high wind speeds. Mixing depths in the northern part of the region tend to be lower, while wind speeds tend to be higher in the eastern part than in the western part of the region.

Air stagnation can cause serious dispersion problems in the Upper Colorado River Basin (UCRB) during the winter because large masses of dense, cold air may be trapped between the Rocky and Sierra Nevada Mountains. Sharp terrain differences on the western slope of the Rockies exacerbate this problem by trapping air in deep valleys. In contrast to the UCRB, the Upper Missouri River Basin (UMRB) has much less air stagnation because of stronger winds and less rugged terrain.

Long range transport of certain pollutants (e.g., sulfates and fine particulates) can create problems considerable distances from energy facilities. The areas impacted by this long range transport depend upon the trajectories of air masses which contain the sulfate or fine particulate pollutant. Current knowledge of air mass trajectories suggests that, during summer, trajectories of air masses following fronts may carry air from the Powder River Basin to the Denver area; trajectories of masses that precede fronts may carry air to Denver from the Four Corners area. The air from the Four Corners area, however, is likely to lose much of its pollutant load over the Rockies because of rainout.

11.2.3 Emissions

Two separate analyses of air emissions from energy development in the eight-state area have been carried out. In the first analysis, the emissions which result from the energy facilities, as projected through the year 2000 in the Low and Nominal Demand scenarios, are evaluated. These emission levels include those associated with energy related population increases. In the second analysis, growth in air emissions in the West through the year 2000 are examined where other economic sectors (in addition to energy facilities) are accounted for.

A. Emissions From Energy Facilities

Aggregate emissions from the energy facilities depend on the mix of technologies and the composition of the coal used at the various coal facilities. Table 11-5 gives emissions for each technology, given the coal compositions assumed for each area. These are aggregated for two subregions in accordance with the number of facilities projected in the Low and Nominal Demand scenarios (the number of each kind of facility in each subregion is given in Table 11-1 and 11-2). Population related air emissions are estimated using coefficients for each criteria

TABLE 11-5: EMISSIONS FROM ENERGY FACILITIES[a]
(thousands of tons per year)

FACILITY	STATE	PARTICULATES	SO_2	NO_x	HC
3000 MWe Power Plant[b] 75 percent load factor	Utah	6.90	19.05	49.27 - 82.12	1.38
	New Mexico	16.49	32.06	62.09 - 103.48	1.72
	Colorado	3.65	19.16	47.05 - 78.41	1.30
	Wyoming	3.93	21.15	51.94 - 86.57	1.44
	Montana	9.17	45.99	62.09 - 103.48	1.72
	North Dakota	9.89	45.49	69.26 - 115.43	2.14
250 MMscfd Lurgi Gasification plant 90 percent load factor	New Mexico	N	2.03	2.56	0.18
	Wyoming	N	2.03	2.56	0.18
	Montana	N	2.03	2.56	0.18
	North Dakota	N	2.03	2.56	0.18
250 MMscfd Synthane Gasification Plant 90 percent load factor	New Mexico	0.03	13.89	19.91	0.37
	Wyoming	0.03	13.89	19.91	0.37
	Montana	0.03	13.89	19.91	0.37
	North Dakota	0.03	13.89	19.91	0.37
100,000 bbl/day Synthoil Liquefaction Plant 90 percent load factor	New Mexico	4.94	4.62	22.74	6.65
	Wyoming	1.90	3.69	18.20	5.32
	Montana	1.90	3.69	18.20	5.32
100,000 bbl/day TOSCO II Oil Shale Retort 90 percent load factor	Colorado	6.78	2.76	14.98	8.04
100,000 bbl/day Modified *In Situ* Oil Shale Processing 90 percent load factor	Colorado	0.51 - 2.50	1.20-2.37	4.07 - 12.29	0.83-0.90
1000 mtpy Uranium Mill	New Mexico	0.17	0.004	0.001	N
	Wyoming	0.17	0.004	0.001	N
100,000 bbl/day Oil Extraction 90 percent load factor	Colorado	0.002	0.17	0.14	0.03
250 MMscfd Natural Gas 90 percent load factor	Wyoming	0.008	1.84	2.58	3.94
100 MWe Geothermal 75 percent load factor		NA	0.69[c]	NA	NA

SO_2 = sulfur dioxide
NO_x = oxides of nitrogen
HC = hydrocarbons
MWe = megawatt-electric
MMscfd = million standard cubic feet per day

N = negligible
bbl/day = barrels per day
mtpy = metric tons per year
NA = not available

[a]These data are from chapters 4-9 where pounds per hour were converted to tons per year using the load factor.

[b]Assuming 80 percent SO_2 scrubber efficiency, 99 percent particulate removal efficiency, and from 0 to 40 percent NO_x removal.

[c]Hydrogen sulfide, assuming 90 percent removal efficiency.

pollutant.[1] Emissions from the energy facilities, those associated with the population, and the totals are given in Tables 11-6 and 11-7 for the Northern Great Plains (North Dakota, Montana, and Wyoming) and in Tables 11-8 and 11-9 for the Rocky Mountain States (Colorado, Utah, and New Mexico). Figure 11-5 summarizes these data by indicating the increases (or decreases) relative to 1975 emission levels that projected emissions represent.

Note from Table 11-6 through 11-9 that, except in the case of HC, emissions from energy related population increases are only a small fraction (0.04 to 6.5 percent) of those from the energy facilities. In fact, the site specific analyses (Chapters 4-9) indicated that HC air concentrations which result from emissions associated with the population (from automobile and space heating systems) are likely to violate the federal ambient air quality HC standard. In the Northern Great Plains (Tables 11-6 and 11-7) HC emissions from the population exceed those from energy facilities by the year 2000. This is not the case in the Rocky Mountain States (Table 11-9: Nominal) because the oil shale facilities are located there and emit relatively large quantities of HC.

Figure 11-5 shows that for the Low Demand case in 2000 the largest increases above 1975 levels for sulfur dioxide (SO_2) and oxides of nitrogen (NO_x) occur in the Northern Great Plains subregion (1.71 times greater than 1975 levels for SO_2 and on the order of 5.6 times greater than 1975 levels for NO_x). The largest increase by the year 2000 in the Rocky Mountain region (Low Demand case) is for NO_x (1.36-1.51 times greater than 1975 levels. NO_x emission levels are highly uncertain since the quantity of NO_x that scrubbers will remove has been estimated to range from none to 40 percent. The data in Tables 11-6 through 11-9 reflect that range. In the Rocky Mountain States, Figure 11-5 shows that HC emission levels for the Low Demand case increase only slightly, but for the Nominal Demand case they increase to a level 1.27 times larger than the 1975 level due to sharply increased levels of oil shale production. Overall, emissions due to energy facilities are projected to be lower in the Rocky Mountain States than in the Northern Great Plains. This is a consequence of the projections which indicate that larger numbers of coal fired power plants will be built in the Northern Great Plains than in the Rocky Mountain States; power plants emit greater quantities of criteria pollutants (except HC) than other energy facilities.

Emissions by state are given in Table 11-10 for the Low and Nominal Demand scenarios in 1990 and 2000. The increases

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[1]These coefficients are given in footnote c of Tables 11-6 through 11-9.

TABLE 11-6: PROJECTED EMISSIONS FOR THE NORTHERN GREAT PLAINS: LOW DEMAND SCENARIO
(thousands of tons per year)

	PARTICULATES	SO_2	NO_x	HC
Emissions in 1975[a]	471	1123	338	438
Emissions Projected: 1980				
Energy facilities[b]	33.28	174.05	260.68 - 419.48	7.15
Population[c]	0.08	0.43	3.26	3.99
Total and increase above 1975[d]	504.36 (1.07)	1297.48 (1.15)	601.94 - 760.74 (1.78 - 2.25)	449.15 (1.03)
Emissions Projected: 1990				
Energy facilities[b]	80.45	399.34	641.61 - 1054.35	18.58
Population[c]	0.25	1.32	10.01	12.24
Total and increase above 1975[d]	551.70 (1.17)	1523.66 (1.36)	989.62 - 1402.36 (2.93 - 4.15)	468.82 (1.07)
Emissions Projected: 2000				
Energy facilities[b]	124.85	788.72	1221.46 - 1809.32	43.82
Population[c]	0.98	5.16	39.22	47.99
Total and increase above 1975[d]	596.83 (1.27)	1916.88 (1.71)	1598.68 - 2186.54 (4.73 - 6.47)	529.81 (1.21)

SO_2 = sulfur dioxide NO_x = oxides of nitrogen HC = hydrocarbons

[a]1975 emissions levels indicated in Tables 11-6 through 11-10 come from U.S., Environmental Protection Agency. National Emissions Data System (NEDS) Annual Report. Research Triangle Park, N.C.: National Environmental Research Center, 1975.

[b]Obtained by multiplying emission factors given in Table 11-5 by the number of each type of facility at each level of development (Tables 11-1 and 11-2) and summing for the three time periods.

[c]Obtained by multiplying the population projections from Table 11-34 by emission coefficients. In tons per year per 1,000 people, emission coefficients are: particulates, 1.9; SO_2, 10; NO_x, 76; and HC, 93.

[d]Total is the sum of 1975 emissions plus those from the energy facilities plus those from the population. Increase above 1975 level is obtained by dividing total by the 1975 level.

TABLE 11-7: PROJECTED EMISSIONS FOR THE NORTHERN GREAT PLAINS: NOMINAL DEMAND SCENARIO (thousands of tons per year)

	PARTICULATES	SO_2	NO_x	HC
Emissions in 1975[a]	471	1123	338	438
Emissions Projected: 1980				
Energy facilities[b]	42.62	220.04	322.77 - 522.96	8.87
Population[c]	0.10	0.55	4.19	5.13
Total and increase above 1975[d]	513.72 (1.09)	1343.59 (1.20)	664.96 - 865.15 (1.97 - 2.56)	452.00 (1.03)
Emissions Projected: 1990				
Energy facilities[b]	115.35	569.12	863.60 - 1416.83	25.14
Population[c]	0.34	1.80	13.66	16.71
Total and increase above 1975[d]	586.69 (1.25)	1693.92 (1.51)	1215.26 - 1768.49 (3.59 - 5.23)	479.85 (1.09)
Emissions Projected: 2000				
Energy facilities[b]	165.77	1114.49	1693.48 - 2461.24	56.90
Population[c]	1.42	7.49	56.94	69.67
Total and increase above 1975[d]	638.19 (1.35)	2244.98 (2.00)	2088.42 - 2856.18 (6.18 - 8.45)	564.57 (1.29)

SO_2 = sulfur dioxide NO_x = oxides of nitrogen HC = hydrocarbons

[a]1975 emissions levels indicated in Tables 11-6 through 11-10 come from U.S., Environmental Protection Agency. National Emissions Data System (NEDS) Annual Report. Research Triangle Park, N.C.: National Environmental Research Center, 1975.

[b]Obtained by multiplying emission factors given in Table 11-5 by the number of each type of facility at each level of development (Tables 11-1 and 11-2) and summing for the three time periods.

[c]Obtained by multiplying the population projections from Table 11-34 by emissions coefficients. In tons per year per 1,000 people, emission coefficients are: particulates, 1.9; SO_2, 10; NO_x, 76; and HC, 93.

[d]Total is the sum of 1975 emissions plus those from the energy facilities plus those from the population. Increase above 1975 level is obtained by dividing total by the 1975 level.

TABLE 11-8: PROJECTED EMISSIONS FOR THE ROCKY MOUNTAIN STATES: LOW DEMAND SCENARIO (thousands of tons per year)

	PARTICULATES	SO_2	NO_x	HC
Emissions in 1975[a]	414	712	472	489
Emissions Projected: 1980				
Energy facilities[b]	0.88	24.87	54.93 - 86.29	13.28
Population[c]	0.06	0.34	2.56	3.13
Total and increase above 1975[d]	414.94 (1.00)	737.21 (1.04)	529.49 - 560.85 (1.12 - 1.19)	505.41 (1.03)
Emissions Projected: 1990				
Energy facilities[b]	24.37	57.32	122.35 - 195.10	11.74
Population[c]	0.09	0.46	3.53	4.32
Total and increase above 1975[d]	438.46 (1.06)	769.78 (1.08)	597.88 - 670.63 (1.27 - 1.42)	505.06 (1.03)
Emissions Projected: 2000				
Energy facilities[b]	43.44	65.70	159.14 - 231.66	-1.72[e]
Population[c]	0.28	1.46	11.08	13.56
Total and increase above 1975[d]	457.72 (1.11)	779.16 (1.09)	642.22 - 714.74 (1.36 - 1.51)	500.84 (1.02)

SO_2 = sulfur dioxide NO_x = oxides of nitrogen HC = hydrocarbons

[a]1975 emissions levels indicated in Tables 11-6 through 11-10 come from U.S., Environmental Protection Agency. National Emissions Data System (NEDS) Annual Report. Research Triangle Park, N.C.: National Environmental Research Center, 1975.

[b]Obtained by multiplying emission factors given in Table 11-5 by the number of each type of facility at each level of development and summing for the three time periods. The number of facilities represents the increase above 1975.

[c]Obtained by multiplying the population projections from Table 11-34 by emission coefficients. In tons per year per 1,000 people, emission coefficients are: particulates, 1.9; SO_2, 10; NO_x, 76; and HC, 93.

[d]Total is the sum of 1975 emissions plus those from the energy facilities plus those from the population. Increase above 1975 level is obtained by dividing total by the 1975 level.

[e]This is a negative number because oil and gas production declines through 2000; HC emissions from oil and gas facilities decrease more than those from additional synthetic fuels facilities and power plants increase.

TABLE 11-9: PROJECTED EMISSIONS FOR THE ROCKY MOUNTAIN STATES: NOMINAL DEMAND SCENARIO (thousands of tons per year)

	PARTICULATES	SO_2	NO_x	HC
Emissions in 1975[a]	414	712	472	489
Emissions Projected: 1980				
Energy facilities[b]	21.19	56.93	117.03 - 189.78	15.00
Population[c]	0.08	0.43	3.29	4.03
Total and increase above 1975[d]	435.27 (1.05)	769.36 (1.08)	592.32 - 665.07 (1.25 - 1.41)	508.03 (1.04)
Emissions Projected: 1990				
Energy facilities[b]	52.54	114.48	270.16 - 407.12	38.36
Population[c]	0.19	1.01	7.69	9.41
Total and increase above 1975[d]	466.73 (1.13)	827.49 (1.16)	749.85 - 886.81 (1.59 - 1.88)	536.77 (1.10)
Emissions Projected: 2000				
Energy facilities[b]	138.89	197.12	495.72 - 632.68	86.26
Population[c]	0.95	4.99	37.90	46.38
Total and increase above 1975[d]	553.84 (1.34)	914.11 (1.28)	1005.62 - 1142.58 (2.13 - 2.42)	621.64 (1.27)

SO_2 = sulfur dioxide NO_x = oxides of nitrogen   HC = hydrocarbons

[a] 1975 emissions levels indicated in Tables 11-6 through 11-10 come from U.S., Environmental Protection Agency. National Emissions Data System (NEDS) Annual Report. Research Triangle Park, N.C.: National Environmental Research Center, 1975.

[b] Obtained by multiplying emission factors given in Table 11-5 by the number of each type of facility at each level of development and summing for the three time periods. The number of facilities represents the increase above 1975.

[c] Obtained by multiplying the population projections from Table 11-34 by emission coefficients. In tons per year per 1,000 people, emission coefficients are: particulates, 1.9; SO_2, 10; NO_x, 76; and HC, 93.

[d] Total is the sum of 1975 emissions plus those from the energy facilities plus those from the population. Increase above 1975 level is obtained by dividing total by the 1975 level.

TABLE 11-10: PROJECTED EMISSIONS IN SIX WESTERN STATES: LOW AND NOMINAL DEMAND SCENARIOS[a] (thousands of tons per year)

		PARTICULATES	SO_2	NO_x	HC
Colorado:	1975[b]	222	54.2	163	213
Increase[c]	1990	5.32 - 25.78	20.94 - 63.92	70.91 - 200.50	2.17 - 51.05
	2000	22.08 - 95.00	37.39 - 96.00	127.45 - 391.65	35.70 - 109.94
Total:	2000	244.08 - 317.00	91.59 - 150.20	290.45 - 554.65	248.70 - 322.94
New Mexico:	1975[b]	113	490	220	168
Increase[c]	1990	19.05 - 19.52	36.32 - 31.50	87.81 - 72.34	9.57 - -14.07[d]
	2000	21.01 - 22.92	28.29 - 76.54	67.96 - 76.62	-37.47[d] - -41.14[d]
Total:	2000	134.01 - 135.92	518.29 - 566.54	287.96 - 296.62	130.53 - 126.86
Utah:	1975[b]	79	168	89	108
Increase[c]	1990	0.00 - 7.24	0.00 - 19.06	0.00 - 65.69	0.00 - 1.38
	2000	0.34 - 20.97	0.01 - 24.58	N - 95.66	N - 17.46
Total:	2000	79.34 - 99.97	168.01 - 192.58	89.00 - 184.66	108.00 - 125.46
Wyoming:	1975[b]	83.1	76.5	80	61
Increase[c]	1990	13.32 - 10.07	63.49 - 42.35	207.77 - 138.53	4.32 - 2.88
	2000	17.58 - 19.24	107.03 - 138.52	282.13 - 327.06	11.01 - 12.11
Total:	2000	100.68 - 102.34	183.53 - 215.02	362.13 - 407.06	72.01 - 73.11
Montana:	1975[b]	301	960	164	300
Increase[c]	1990	27.51 - 45.88	137.97 - 237.91	248.34 - 425.15	5.15 - 8.87
	2000	48.04 - 57.38	305.28 - 399.03	533.19 - 683.36	16.39 - 19.76
Total:	2000	349.04 - 358.38	1265.28 - 1359.03	697.19 - 847.36	316.39 - 319.76
North Dakota:	1975[b]	87.1	86.6	94.5	77.5
Increase[c]	1990	39.62 - 59.40	197.88 - 288.86	391.85 - 576.54	9.11 - 13.39
	2000	59.74 - 89.66	376.42 - 576.17	700.06 - 1067.00	16.42 - 25.03
Total:	2000	146.84 - 176.76	463.02 - 663.17	794.56 - 1161.43	93.92 - 102.53

SO_2 = sulfur dioxide
NO_x = oxides of nitrogen
HC = hydrocarbons
N = negligible

[a]For 1990 and 2000 the Low Demand projection is given first, followed by the Nominal Demand projections.

[b]The 1975 emission levels indicated in Tables 11-6 through 11-10 come from U.S., Environmental Protection Agency. National Emissions Data System (NEDS) Annual Report. Research Triangle Park, N.C.: National Environmental Research Center, 1975.

[c]Contribution projected to come from energy facilities.

[d]This is a negative number because oil and gas production declines through 2000; HC emissions from oil and gas facilities decrease more than those from additional synthetic fuels facilities and power plants increase.

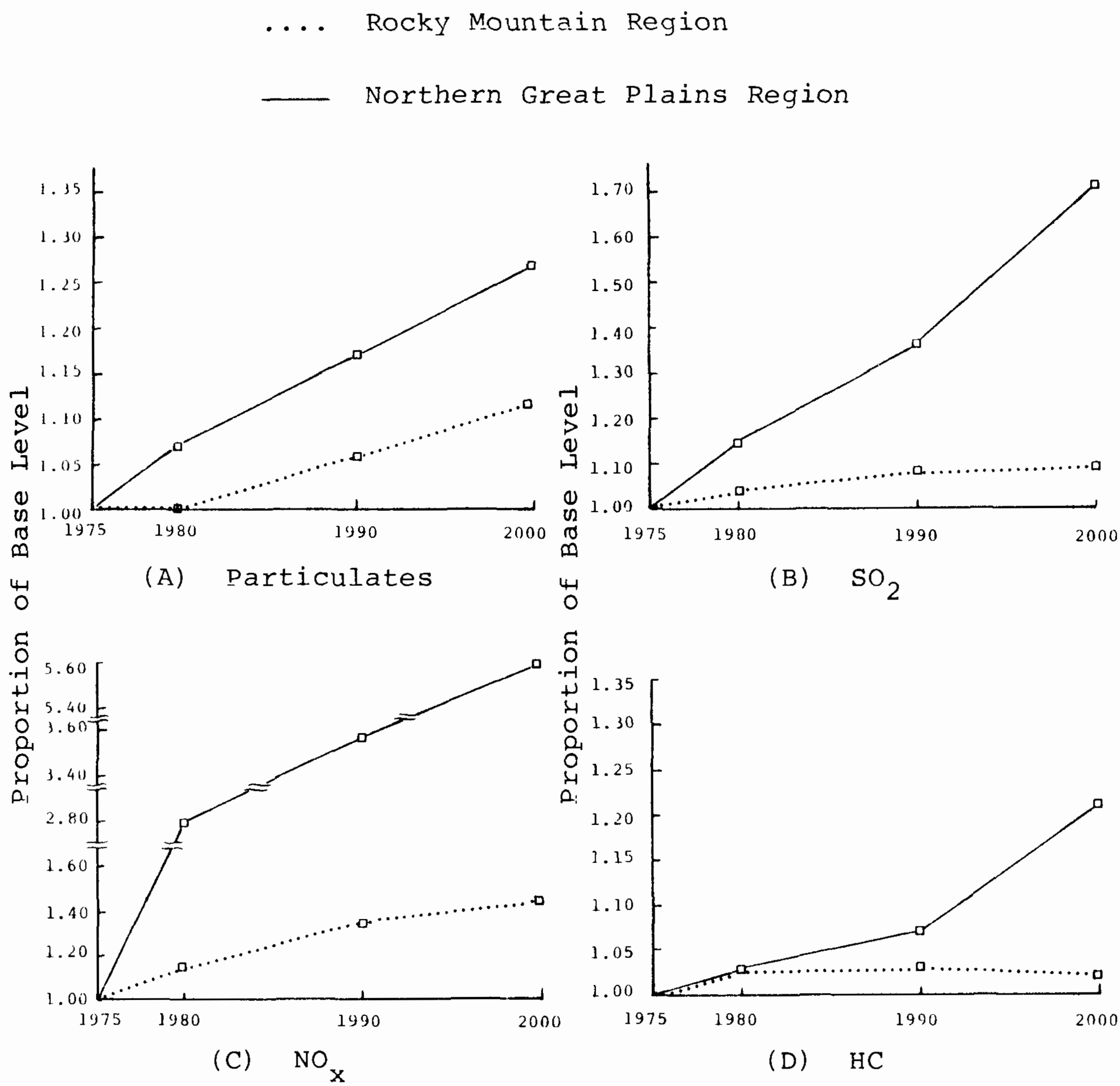

FIGURE 11-5: PROJECTED INCREASE ABOVE 1975 LEVELS OF EMISSIONS IN TWO SUBREGIONS, LOW DEMAND SCENARIO

in emissions by state follow the same general trends found in the resource subareas. In the Low Demand case, Montana is projected to have the highest emissions of particulates, SO_2 and HC by 2000, while North Dakota is projected to have the highest NO_x emissions. In the six states listed, NO_x emissions generally would increase more than the other criteria pollutant emissions, with increases by 2000 ranging up to 700,000 tons per year (Low Demand) for North Dakota. SO_2 emissions are also expected to show large increases by 2000, while particulate emissions are expected to be only slightly higher than 1975 levels. In New Mexico, very little change in emissions between 1990 and 2000 and between the Low and Nominal cases is projected. This is because, although synthetic fuel and geothermal energy are increasing, oil and gas production is decreasing between 1990 and 2000.

Table 11-11 lists emissions in selected states (outside the western region) which are thought to be representative of low or moderately industrialized states (such as Iowa and Georgia) and of highly industrialized states (such as Ohio and California). By comparison, the 1975 emissions and projected emissions in the six western states are relatively low[1] with the exception of projected SO_2 emissions. For example, 1975 particulate levels in the six states listed in Table 11-10 ranged from 79,000 to 301,000 tons. These can be compared with 1972 levels in Iowa (239,000 tons), California (1,100,000 tons) and Ohio (1,947,999 tons). In 2000, particulate emissions in the six states are projected to range from 79,300 tons to 349,000 tons (Low Demand). The highest value is for Montana, which is similar to 1972 emissions in Iowa. Projected emissions of NO_x and HC in the six western states are generally lower than emissions in the states outside the region (Table 11-10 compared with Table 11-11). By 2000, however, SO_2 emissions (Low Demand) in Montana exceed those in all states shown in Table 11-11 except Ohio. In New Mexico and North Dakota, projected SO_2 emissions in 2000 (Low Demand) are similar to 1975 emissions in California and Georgia.

Emissions densities (calculated as the facility emissions divided by the area of the region in which production occurs) also give some indication of likely regional air quality problems such as reductions in visibility and sulfate formation. For SO_2, a density of 14 tons per year per square mile (500 kg/km^2) has been identified in the Ohio River Basin as a level above

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[1]This finding is stated for the purpose of comparison only. We do not intend to imply that the degradation that would be experienced would be either acceptable or unacceptable.

TABLE 11-11: EMISSIONS IN SELECTED STATES IN 1972[a]
(thousands of tons per year)

STATE	PARTICULATES	SO_2	NO_x	HC
Ohio	1,947	3,290	1,210	1,272
California	1,110	434	1,830	2,380
Georgia	446	521	408	505
Washington	179	301	207	380
Texas	606	830	1,440	2,450
Iowa	239	312	267	349

SO_2 = sulfur dioxide
NO_x = oxides of nitrogen
HC = hydrocarbons

[a]U.S., Environmental Protection Agency. National Emissions Report, EN-226. Research Triangle Park, N.C.: National Environmental Research Center, 1974.

which air pollution problems may arise.[1] Table 11-12 gives emission densities for SO_2 using two regional areas. In one case, the state area is divided into total SO_2 emissions for that state (from Table 11-10). In the other case, the area of all counties in which energy facilities are projected to be sited is divided into total SO_2 emissions. This county level emission density calculation is done for two subregions, Northern Great Plains and Rocky Mountains. As indicated in Table 11-12, in the year 2000 the 14 tons per year per square mile index is exceeded for the counties in the Northern Great Plains in both the Low and Nominal cases; it is slightly exceeded in the Rocky Mountains in the Nominal case. While this index of 14 tons per square mile was calculated for the Ohio River Basin and thus may not apply to the West, these calculations do suggest that the magnitude of emissions is of concern.

B. Emissions From All Economic Sectors

The second air emission analysis was carried out using the Environmental Protection Agency's (EPA's) Strategic Environmental

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[1]Smith, Lowell F., and Brand L. Niemann, "The Ohio River Basin Energy Study: The Future of Air Resources and Other Factors Affecting Energy Development." Paper presented at the Third International Conference on Environmental Problems of the Extractive Industries, Dayton, Ohio, November 29-December 1, 1977, p. 22.

TABLE 11-12: EMISSION DENSITIES FOR SULFUR DIOXIDE (tons per square mile per year)

	1975	2000 LOW	2000 NOMINAL
By state[a]			
New Mexico	4.02	4.25	4.65
Colorado	0.52	0.88	1.44
Utah	1.98	1.98	2.27
Montana	6.52	8.57	9.21
Wyoming	0.78	1.88	2.20
North Dakota	1.22	6.54	9.36
By counties aggregated to subregions[b]			
Rocky Mountain States	5.40	8.04	13.38
Northern Great Plains	1.35	20.43	28.32

[a]Calculated by dividing total sulfur dioxide (SO_2) emissions by state from Table 11-10 by the area of each state in square miles.

[b]Calculated by dividing total SO_2 emissions from all energy facilities in a subregion by the total area of all counties in which energy facilities are located. Total SO_2 emissions are obtained from Tables 11-6 through 11-9; 1975 emissions for the subregion must be subtracted from that total and 1975 emissions for the counties added. County areas are 25,308 square miles in the Rocky Mountain States and 41,608 square miles in the Northern Great Plains. 1975 SO_2 emissions for the counties total 136,400 tons per year (Rocky Mountains) and 56,300 tons per year (Northern Great Plains).

Assessment System (SEAS) model[1] which examined growth in air emissions for all economic sectors due to a "Nominal Dirty"

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[1]U.S., Environmental Protection Agency, Technology Assessment Model Project (TAMP). A Description of the SEAS Model, Project Officer Dr. Richard Ball. Washington, D.C.: Environmental Protection Agency, 1977. (Unpublished report.)

(155 Q) demand scenario. The "Nominal Dirty" scenario assumed 4.2 million bbl/day of shale oil by the year 2000 rather than the 2.5 million bbl/day assumed in the SRI Nominal scenario. Emission assumptions were based on emissions data collected for SEAS. Emissions control assumptions correspond to pre-1977 State Implementation Plans, with NSPS becoming effective in 1979, except in Arizona, Colorado, New Mexico, Utah, and Wyoming, where stricter state standards are assumed to apply after 1979.

Disaggregation of emissions was to three subregions: I - North and South Dakota and Montana; II - Colorado and Wyoming; and III - New Mexico, Arizona, and Utah.

Emissions of criteria pollutants for these subregions are shown in Figures 11-6 through 11-10. The greatest increases in emissions are projected to occur in Colorado and Wyoming with a 900 percent increase in SO_2, 677 percent increase in NO_x, and 248 percent increase in particulates by the year 2000. Emissions of HC and carbon monoxide (CO) decline until 1990 in the eight-state area, and increase only modestly after that. The sources of these emissions are primarily automobiles rather than industry. The decline is caused by the SEAS model assumption that emission control on automobiles will gradually tighten through the 1980's. The effect of that tightening, if it occurs, apparently more than offsets the population growth and associated increased numbers of automobiles.

As shown in Figure 11-6, projected SO_2 emissions decrease in New Mexico, Arizona, and Utah. Sources of emissions explain this trend. The sources of SO_2 emissions for Colorado and Arizona are shown in Figure 11-11 for 1980, 1990, and 2000. In Colorado, production of electricity and industrial use of coal, along with oil shale development are the sources of increasing SO_2 emissions. In Arizona, production of electricity from coal accounts for an increased level of SO_2 emissions, but this is more than offset by tightened emission standards on copper smelting, the source of 92.6 percent of 1980 SO_2 emissions.

11.2.4 Inadvertent Weather Modification[1]

Since coal combustion and synthetic fuel production add heat, water vapor, and various air pollutants to the atmosphere, they have the potential to affect weather patterns. Effects can include changes in precipitation (particularly cloudiness,

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[1] As indicated in the introduction to this chapter, the so-called greenhouse effect will not be considered here.

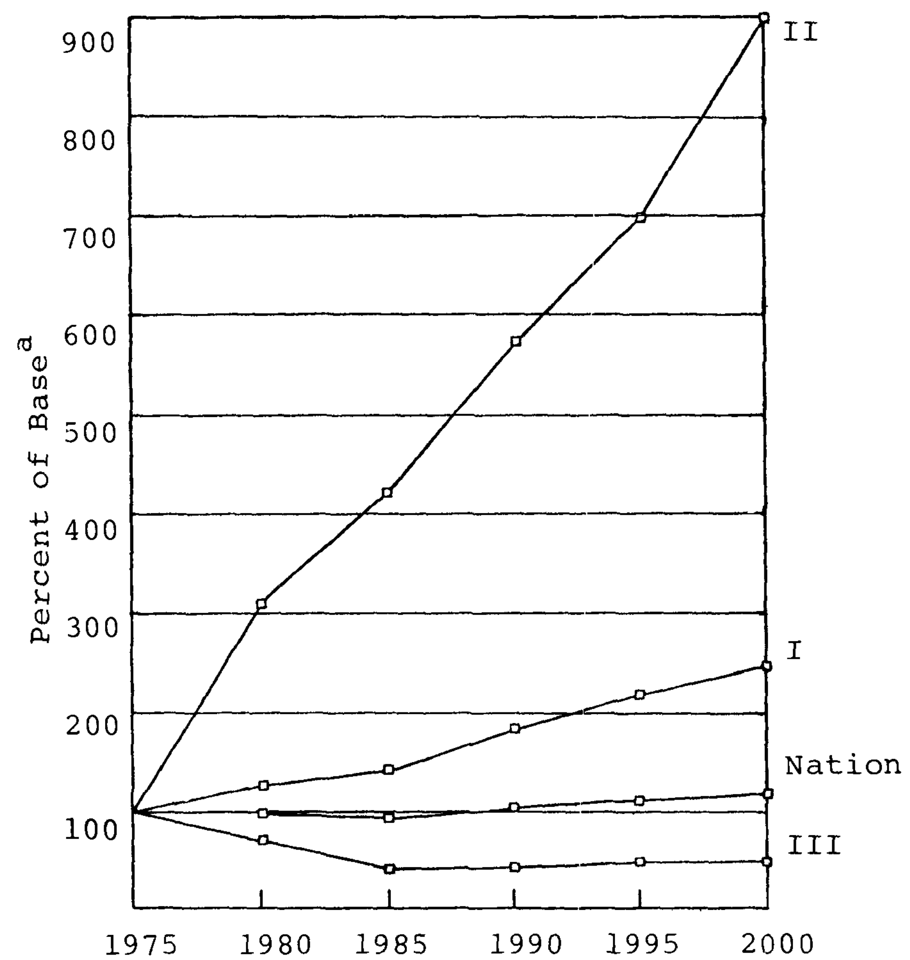

FIGURE 11-6: GROWTH OF SULFUR DIOXIDE EMISSIONS IN THE NOMINAL DIRTY SCENARIO

[a]1975 base sulfur dioxides were as follows: Nation, 28.17 million tons per year; Subregion I (Montana, North Dakota, and South Dakota), 379.7 thousand tons per year (Mtpy); Subregion II (Colorado and Wyoming), 154.1 Mtpy; and Subregion III (New Mexico, Arizona, and Utah), 2883.0 Mtpy.

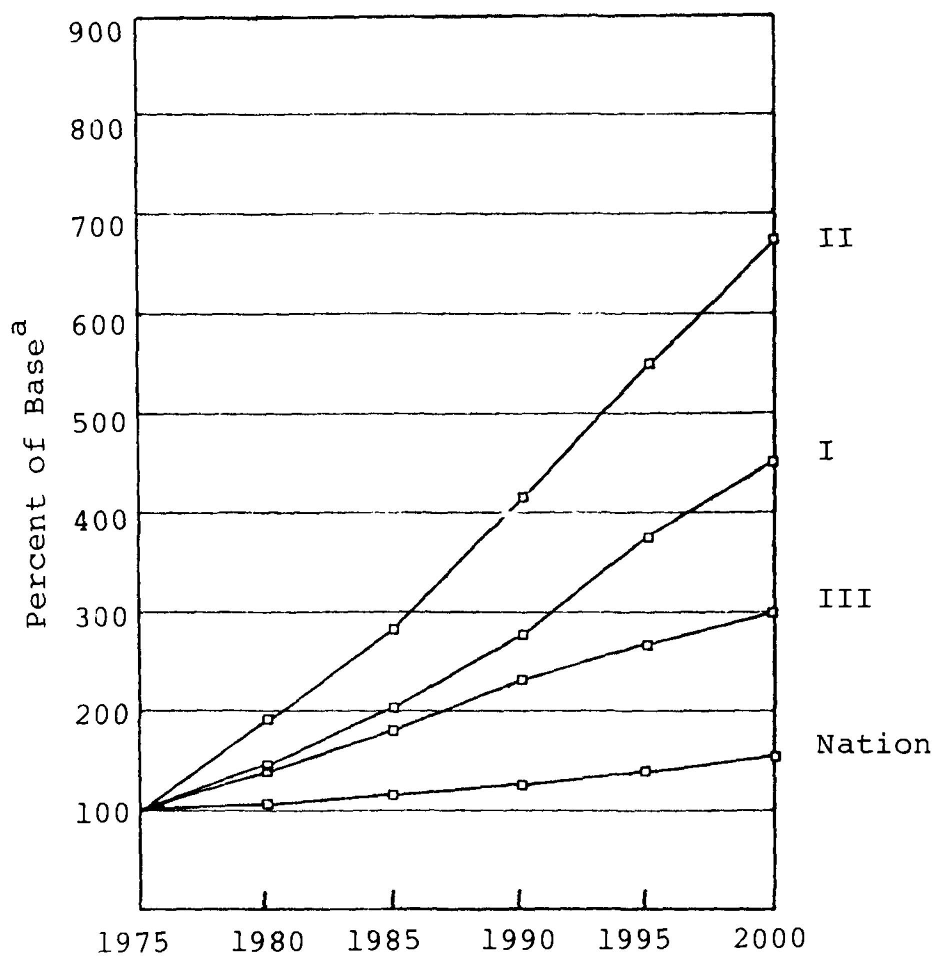

FIGURE 11-7: GROWTH OF OXIDES OF NITROGEN EMISSIONS IN THE NOMINAL DIRTY SCENARIO

[a]1975 base oxides of nitrogen were as follows: Nation, 17.55 million tons per year; Subregion I (Montana, North Dakota, and South Dakota), 169.5 thousand tons per year (Mtpy); Subregion II (Colorado and Wyoming), 237.7 Mtpy; and Subregion III (New Mexico, Arizona, and Utah), 379.4 Mtpy.

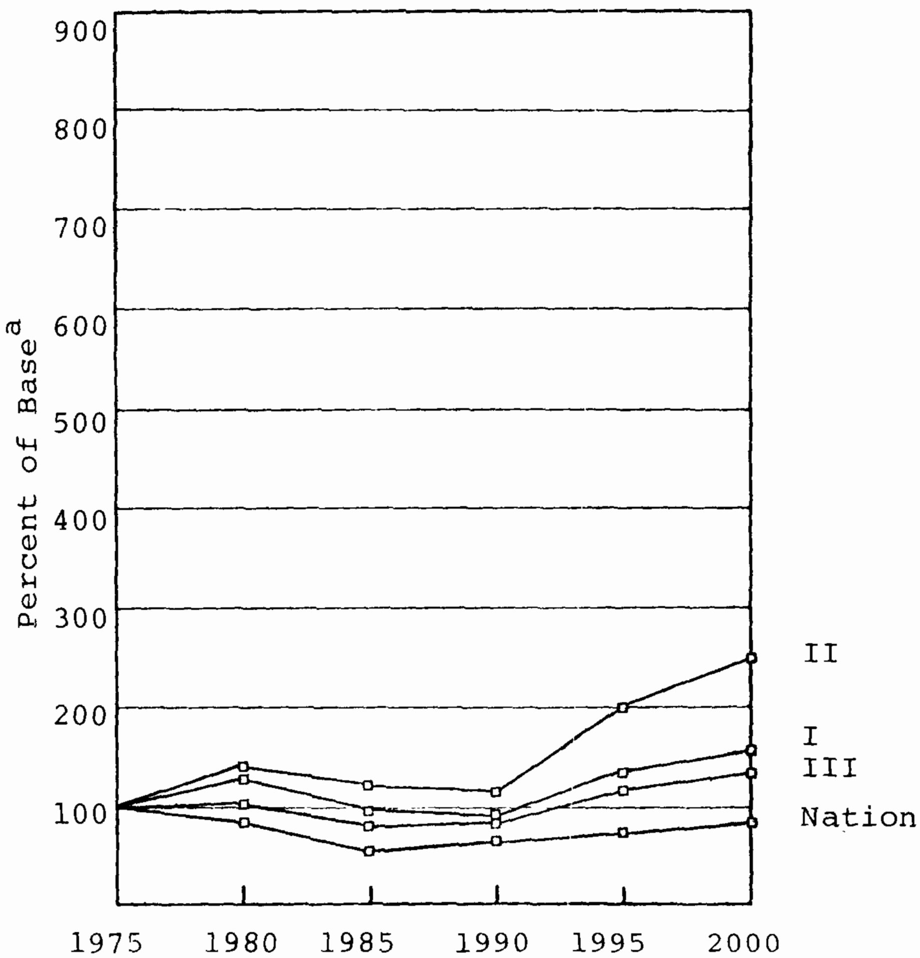

FIGURE 11-8: GROWTH OF PARTICULATE EMISSIONS IN THE NOMINAL DIRTY SCENARIO

[a]1975 base particulates were as follows: Nation, 20.19 million tons per year; Subregion I (Montana, North Dakota, and South Dakota), 160.4 thousand tons per year (Mtpy); Subregion II (Colorado and Wyoming), 228.0 Mtpy; and Subregion III (New Mexico, Arizona, and Utah), 335.8 Mtpy.

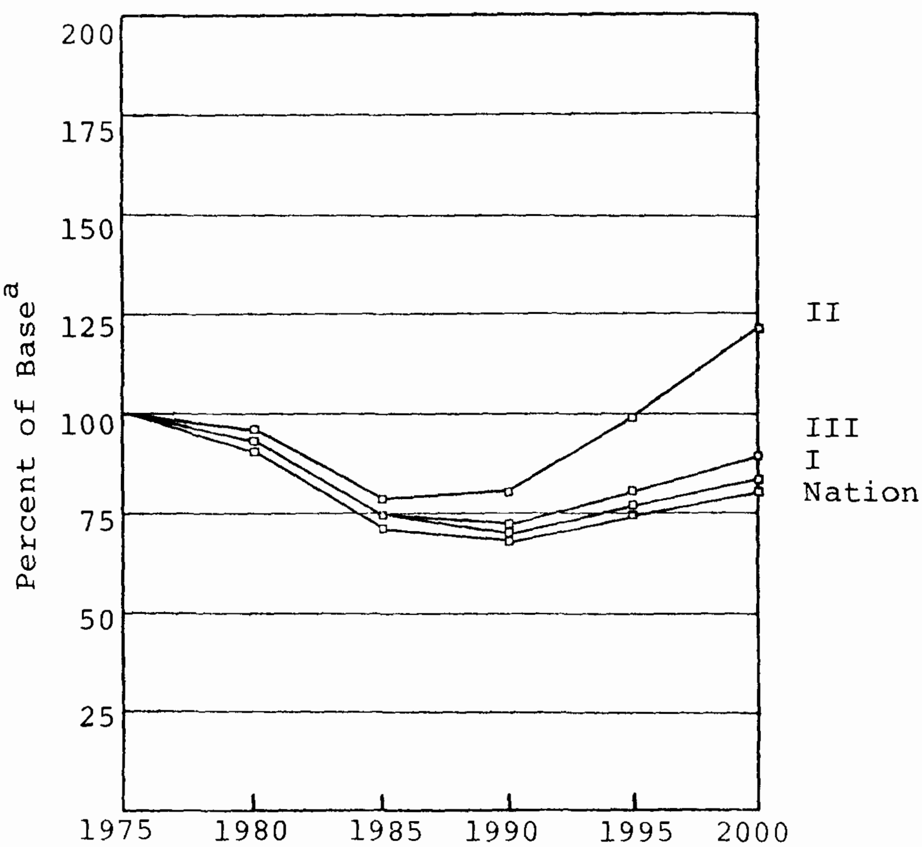

FIGURE 11-9: GROWTH OF HYDROCARBON EMISSIONS IN THE NOMINAL DIRTY SCENARIO

[a]1975 base hydrocarbons were as follows: Nation, 14.87 million tons per year; Subregion I (Montana, North Dakota, and South Dakota), 216.9 thousand tons per year (Mtpy); Subregion II (Colorado and Wyoming), 216.9 Mtpy); Subregion III (New Mexico, Arizona, and Utah), 368.3 Mtpy.

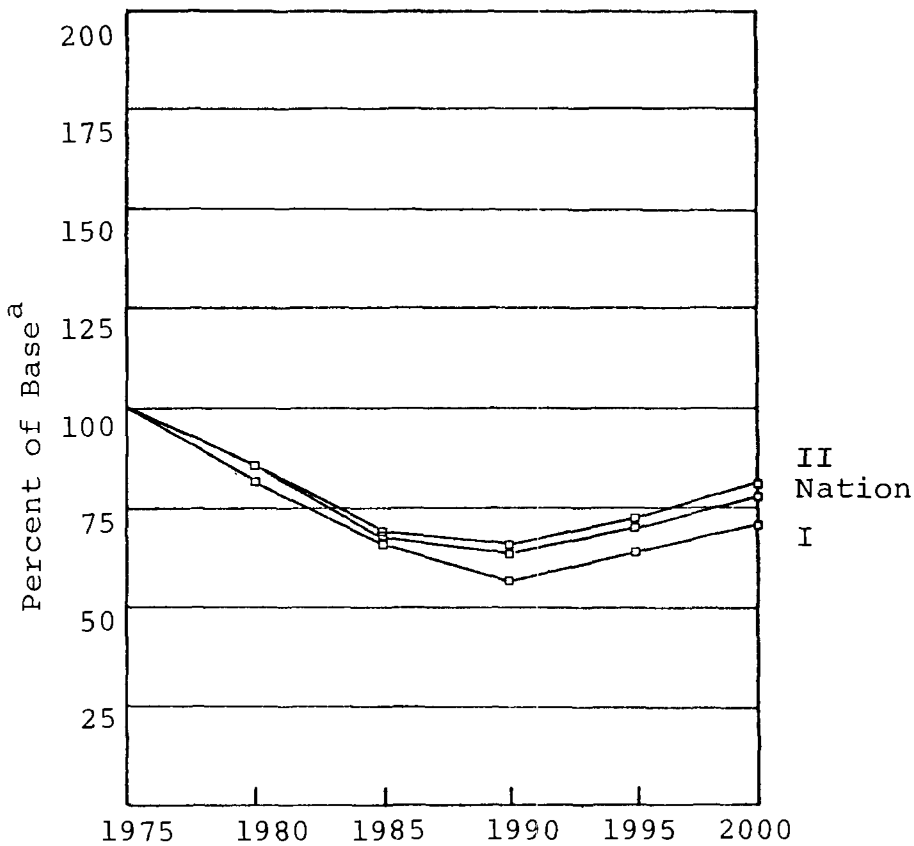

FIGURE 11-10: DECLINE OF CARBON MONOXIDE EMISSIONS IN THE NOMINAL DIRTY SCENARIO

[a]1975 base carbon monoxides were as follows: Nation, 103.3 million tons per year; Subregion I (Montana, North Dakota, and South Dakota), 1127.0 thousand tons per year (Mtpy); Subregion II (Colorado and Wyoming), 1592.0 Mtpy; and Subregion III (New Mexico, Arizona, and Utah), 2672.0 Mtpy.

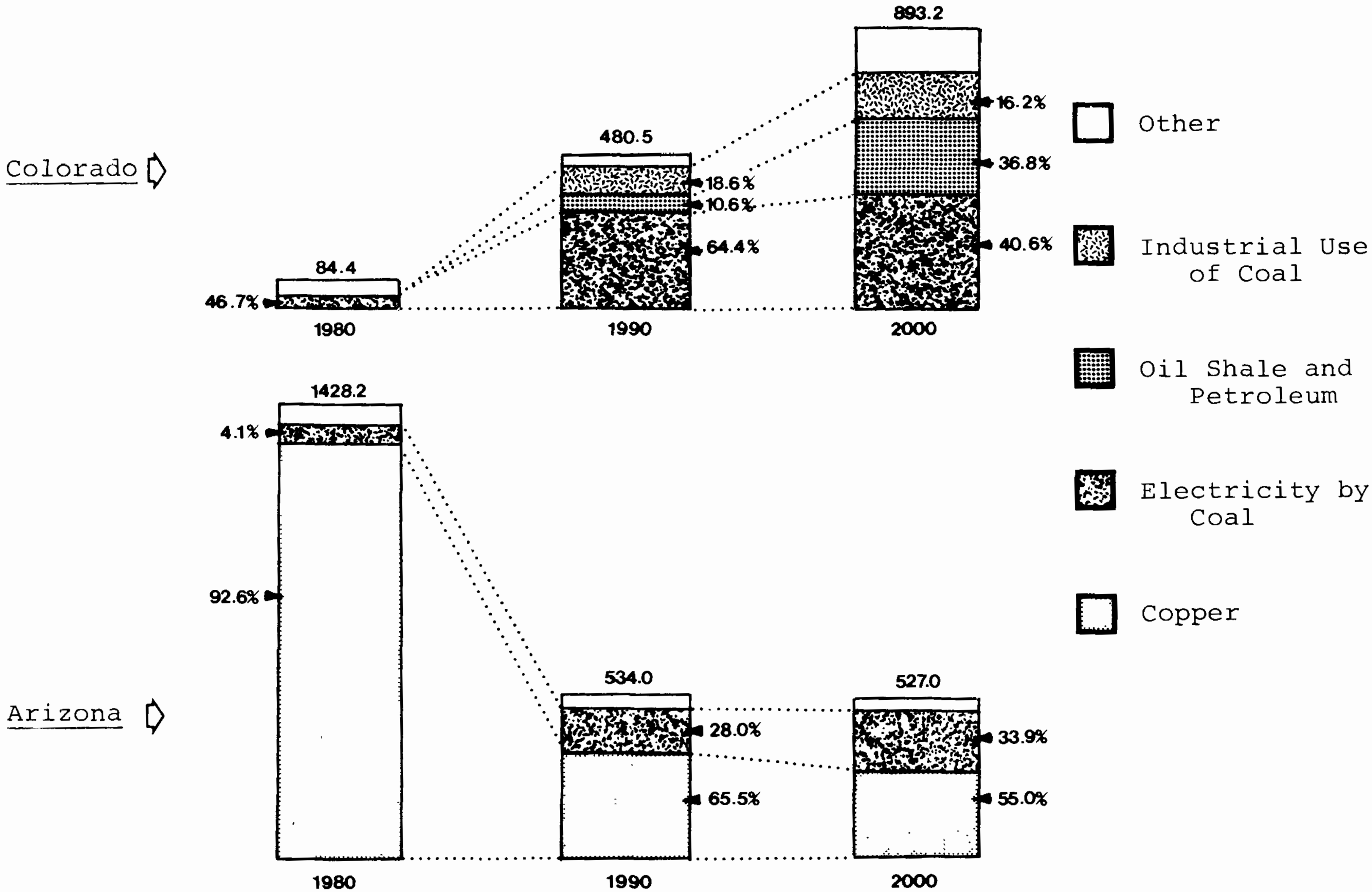

FIGURE 11-11: SOURCES OF SULFUR DIOXIDE EMISSIONS IN COLORADO AND ARIZONA, 1980-2000, NOMINAL DIRTY SCENARIO (thousands of tons per year)

fogginess, humidity levels, rain and snowfall amounts), changes in temperature, wind velocity reductions, and production of severe weather.

Most of the research in inadvertent weather modification has been concerned with precipitation effects. Because cloud droplets form around small particles, the addition of small particulate matter (smaller than that normally perceived to affect air quality) is thought to have the most impact. But whether these particulate additions cause precipitation to increase or decrease is uncertain. In general, adding small particulates to the air leads to clouds consisting of many small droplets which are slow in coalescing into rain.[1] On the other hand, formation of snow in winter clouds and in the upper, cold portions of summer clouds depends on the presence of insoluble particles;[2] their presence tends to increase precipitation but it is not known whether particulates from coal facilities will cause this effect.

One research project in the Midwest section of the country recognized both increases and decreases in rainfall, depending on the details of the weather situation.[3] Another study indicated an increase in rainfall due to the presence of large particles in pulp mill plumes.[4] In nearly all cases, where an increase in precipitation due to pollution was observed, the location already had plentiful moisture. In arid and semiarid regions, there is concern that air pollution may decrease precipitation. One very preliminary study of the Northern Great Plains indicates that a decrease in precipitation would be likely with significant levels of coal development because of the increase in cloud "stability" due to large numbers of small particulates that would be introduced.[5] Clearly, even minor changes in rainfall in the western states would have a major impact on ecosystems and crop production. In short, particulates

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[1]Dennis, Arnett S., and Briant L. Davis. Statement in Support of a National Energy Research and Development Plan (presented at ERDA Public Meeting, Denver, Colorado, May 17-18, 1976), Bulletin 76-2. Rapid City, S.D.: South Dakota School of Mines and Technology, Institute of Atmospheric Sciences, 1976.

[2]Cloud seeding procedures generally involve the introduction of insoluble particles into cold clouds.

[3]Project METROMEX. "A Review of Results Summarized by the National Science Foundation and Other Groups." Bulletin of the American Meteorological Society, Vol. 55 (1974), pp. 86-121.

[4]Dennis and Davis. Support of National R&D Plan.

[5]Ibid.

added by activities such as coal-fired power plants may travel hundreds of miles downwind. While the effects of those particulates on precipitation amounts may be significant, the nature of the effect is largely unknown.

11.3 WATER IMPACTS

11.3.1 Introduction

Water impacts have been evaluated for the UCRB and UMRB. Impacts are assessed for two levels of development (Low and Nominal Demand cases) and for the time period 1980 to 2000. Water requirements and water effluents of mining, conversion facilities, energy transportation modes, and associated population increases are identified and resulting water impacts are analyzed for each basin.

11.3.2 Impacts in the Upper Colorado River Basin

The UCRB includes parts of Wyoming, Utah, Colorado, Arizona, and New Mexico. It can be divided into three subregions associated with the Green River, the Upper Main Stem of the Colorado River, and the San Juan River as shown in Figure 11-12.

A. Existing Conditions

(1) Surface Water

The magnitude of water availability impacts associated with energy development in the UCRB depends in part on the quantity of surface water available in the basin. Estimates of this supply vary widely, but three references are most commonly used:

1. The Department of the Interior's Water for Energy Management Team[1] estimates that at least 5.8 million acre-feet per year (acre-ft/yr) are available for consumptive use in the UCRB. Their estimate is based on releasing 8.25 million acre-ft/yr to the Lower Basin and allowing for shortages to irrigation users during subnormal years.

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[1] U.S., Department of the Interior, Water for Energy Management Team. Report on Water for Energy in the Upper Colorado River Basin. Denver, Colo.: Department of the Interior, 1974.

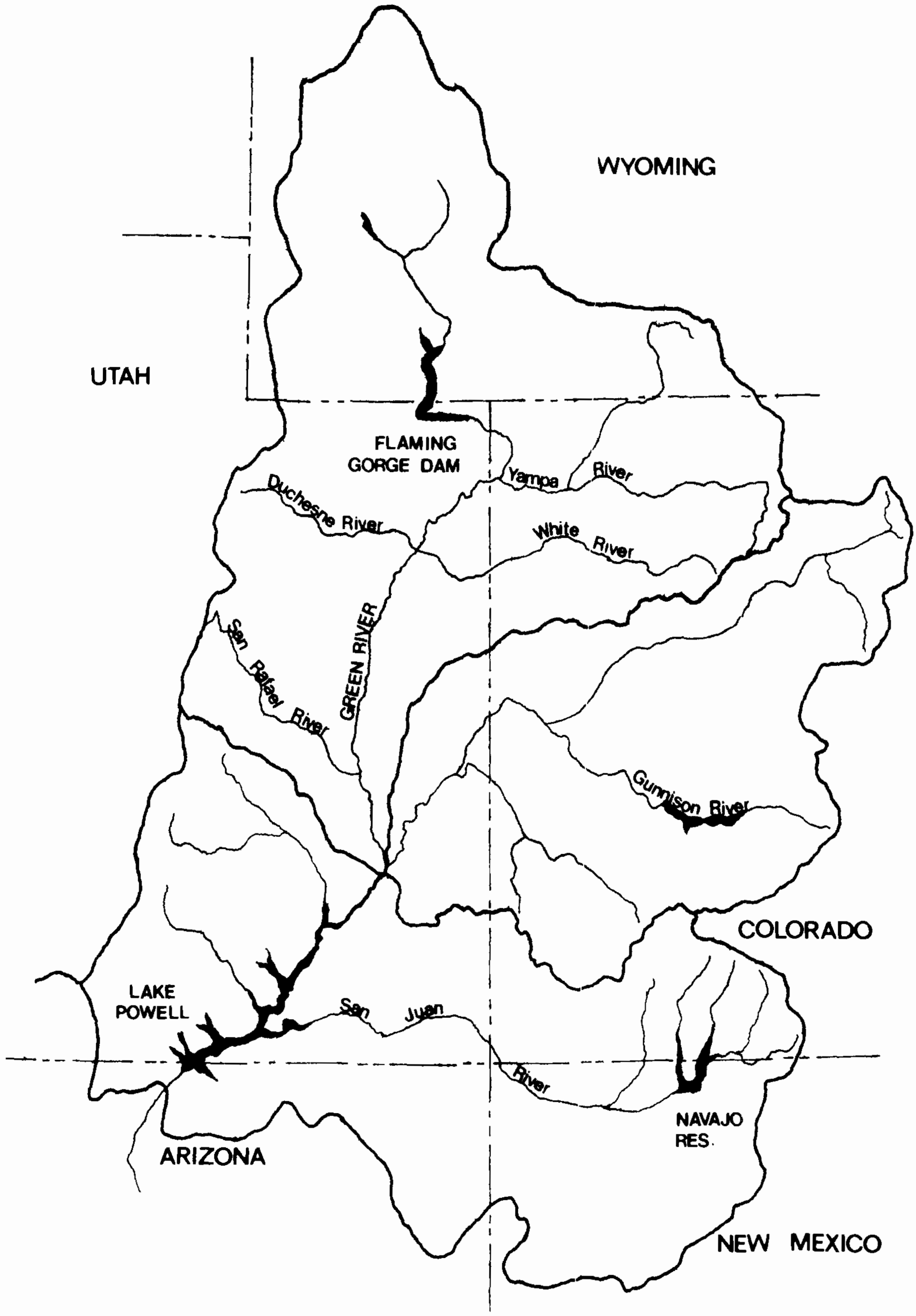

FIGURE 11-12: UPPER COLORADO RIVER BASIN

2. Tipton and Kalmbach[1] estimated that 6.3 million acre-ft/yr would be available for consumptive use if 7.5 million acre-ft/yr[2] were delivered to the Lower Basin and Upper Basin users did not have to experience any shortages.

3. Weatherford and Jacoby estimated that 5.25 million acre-ft/yr are available for consumptive use if 8.25 million acre-ft/yr are delivered to the Lower Basin.[3]

In our analysis, 5.8 million acre-ft/yr was used, although for impacts which are particularly dependent on flow rate, the effects of using other values are noted.[4]

Estimates of the quantities of water currently being consumed in the UCRB also vary, primarily because of the inconsistent

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[1]Tipton and Kalmbach, Inc. Water Supplies of the Colorado River, in U.S., Congress, House of Representatives, Committee on Interior and Insular Affairs. Lower Colorado River Basin Project. Hearings before the Subcommittee on Irrigation and Reclamation, 89th Cong., 1st sess., 1965, p. 467.

[2]The difference between the Department of Interior's estimate of 8.25 million acre-ft/yr and this estimate of 7.5 million acre-ft/yr which must be released to the Lower Basin is due to assumptions about where the water that is guaranteed to Mexico will come from. In the Mexican Water Treaty of 1944 (Treaty between the United States of America and Mexico Respecting Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, February 3, 1944, 59 Stat. 1219 [1945], Treaty Series No. 994), the U.S. agreed to guarantee Mexico 1.5 million acre-ft/yr; the Department of Interior's estimate assumes that the Upper Basin states are responsible for supplying one half of the amount or 0.75 million acre-ft/yr. The Upper Basin states evidently do not assume delivery of 0.75, thus their estimate is 7.5 rather than 8.25 million acre-ft/yr.

[3]Weatherford, Gary D., and Gordon C. Jacoby. "Impact of Energy Development on the Law of the Colorado River." Natural Resources Journal, Vol. 15 (January 1975), pp. 171-213.

[4]Estimates of water available for consumptive use generally assume an average flow rate for the Colorado River. The most common estimate of average flow rate is 13.5 million acre-ft/yr. However, the standard deviation of these estimates is 3.4 million, meaning that in 67 percent of the years, flow would be between 10.1 and 16.9 million acre-ft. In drought years, flow could be much less; flow for 1977 has been estimated at 5.3 million acre-feet.

depletion categories used by various studies. Table 11-13 gives values for 1974 depletions totaling 3.7 million acre-ft/yr.[1] Using different assumptions, another study estimated 1975 depletions to be 3.2 million acre-ft/yr.[2]

Irrigation of agriculture accounted for 58 percent of the 1974 depletion. Interbasin transfers, the largest of which was to the Denver area, consumed 20 percent, and evaporation losses accounted for 14 percent. Other uses were negligible compared to these.

Water quality in the UCRB has been studied extensively. The principal water quality problem is salinity. The average annual salt flow at Lee Ferry has been estimated at 8.6 million tons, of which 4.3 million tons are from natural sources, 1.5 million tons from agriculture and 2.8 million tons from other manmade sources.[3] A detailed description of the natural sources of salinity is included in several reports.[4] According to the classification system used by the U.S. Geological Survey (USGS), water with a salt or total dissolved solids (TDS) content of up to 1,000 milligrams per liter (mg/ℓ) is considered fresh. The EPA Interim Primary Drinking Water Standard has no TDS limit;[5] however, the EPA

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[1]U.S., Department of the Interior, Water for Energy Management Team. Report on Water for Energy in the Upper Colorado River Basin. Denver, Colo.: Department of the Interior, 1974, p. 13.

[2]U.S., Department of the Interior, Bureau of Reclamation. Westwide Study Report on Water Problems Facing the Eleven Western States. Washington, D.C.: Government Printing Office, 1975.

[3]Hyatt, M. Leon, et al. Computer Simulation of the Hydrologic-Salinity Flow System Within the Upper Colorado River Basin. Logan, Utah: Utah State University, Utah Water Research Laboratory, 1970. Other studies differ in their breakdown of sources but appear to agree on total load in the river.

[4]Williams, J. Stewart. The Natural Salinity of the Colorado River, Occasional Paper 7. Logan, Utah: Utah State University, Utah Water Research Laboratory, 1975; and U.S., Department of the Interior, Bureau of Reclamation, Water Quality Office. Quality of Water--Colorado River Basin, Progress Report No. 7. Denver, Colo.: Bureau of Reclamation, 1975.

[5]U.S., Environmental Protection Agency. "National Interim Primary Drinking Water Regulations." 40 Fed. Reg. 59,566-88 (December 24, 1975).

TABLE 11-13: ESTIMATED 1974 DEPLETIONS IN THE UPPER COLORADO RIVER BASIN
(thousands of acre-feet per year)

USE	ARIZONA	COLORADO	UTAH	WYOMING	NEW MEXICO	TOTAL	PERCENT OF TOTAL DEPLETION
Thermal power plants	[a]	9	1	3	25	38	1.0
Food and fiber (irrigation)	10	1,255	529	258	102	2,153	58.1
Fish, wildlife, and recreation[b]	3	31	24	16	6	30	2.1
Minerals and mining		17	9	18	4	48	1.3
Livestock ponds and evaporation		21	6	21[c]	31[d]	79	2.1
Municipal and industrial		18	6	3	8	35	1.0
Exports		504	130	10	110	754	20.3
Subtotal	13	1,855	705	329	286	3,137	
Main stem reservoir losses	0	269	120	73	58	520	14.0
Total depletion	13	2,124	825	402	344	3,657	

Source: U.S., Department of the Interior, Water for Energy Management Team. Report on Water for Energy in the Upper Colorado River Basin. Denver, Colo.: Department of the Interior, 1974, p. 130.

[a]First unit of Navajo Power Plant went on line in May of 1974. Actual depletion amount not available.

[b]Natural historic wildlife consumption not included.

[c]Includes evaporation from Fontenelle Reservoir.

[d]Includes evaporation from Navajo Reservoir.

proposed secondary standard recommends that TDS be limited to 500 mg/ℓ.[1] For livestock, water is rated good up to a TDS of 2,500 mg/ℓ.[2]

The more saline the water, the less desirable it is for agricultural purposes as well as for drinking. Concentrations of TDS at various points in the UCRB are shown in Table 11-14. All the streams are fresh according to the USGS classification system, except for the San Rafael River which flows through extensive salt and potash deposits in Utah.

The allocation of water rights and legal/political problems surrounding them will be important in determining whether a portion of the unused water in the UCRB can be used for energy developments. The legal structure governing the Colorado River has a long history of development.[3] Major compacts include the Colorado River Compact, which apportioned the flow between the Upper and Lower Basins and guaranteed 7.5 million acre-ft/yr to the Lower Basin. The UCRB Compact[4] divided the flow available to the Upper Basin, giving 50,000 acre-ft/yr to Arizona and apportioning 51.75 percent of the remainder to Colorado, 11.25 percent to New Mexico, 23 percent to Utah, and 14 percent to Wyoming.

The Mexican Water Treaty of 1944 guarantees Mexico 1.5 million acre-ft/yr from the Colorado River[5] but does not specify whether this amount should come equally from the Upper and Lower Basin apportionments or all from the Lower Basin. In addition,

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[1]U.S., Environmental Protection Agency. "National Secondary Drinking Water Regulations," Proposed Regulations. 42 Fed. Reg. 17,143-47 (March 31, 1977).

[2]U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976, p. II-152.

[3]The appropriation system dates to the 1800's, and the Colorado River Compact was enacted in 1922 (42 Stat. 171) and declared effective by Presidential Proclamation in 1928 (46 Stat. 3000).

[4]Upper Colorado River Basin Compact of 1948, Pub. L. 81-37, 63 Stat. 31 (1949).

[5]Treaty between the United States of America and Mexico Respecting Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, February 3, 1944, 59 Stat. 1219 (1945), Treaty Series No. 994.

TABLE 11-14: AVERAGE TOTAL DISSOLVED SOLIDS CONCENTRATIONS IN STREAMS OF THE UPPER COLORADO REGION, 1941-1972

STATION LOCATION	TOTAL DISSOLVED SOLIDS (mg/ℓ)
Green River Subregion	
Green River at Green River, Wyoming	307
Green River near Greendale, Utah	421
Green River at Green River, Utah	456
Duchesne River near Randlett, Utah	680
San Rafael River near Green River, Utah	1,688
Upper Main Stem Subregion	
Colorado River near Glenwood Springs, Colorado	270
Colorado River near Cameo, Colorado	405
Colorado River near Cisco, Utah	612
Gunnison River near Grand Junction, Colorado	621
San Juan-Colorado Subregion	
San Juan River near Archuleta, New Mexico	159
San Juan River near Bluff, Utah	447
Upper Colorado Region Outlet	
Colorado River at Lee Ferry, Arizona	558

mg/ℓ = milligrams per liter

Source: Abstracted from U.S., Department of the Interior, Bureau of Reclamation, Water Quality Office. Quality of Water--Colorado River Basin, Progress Report No. 7. Denver, Colo.: Bureau of Reclamation, 1975.

an agreement with Mexico in 1973[1] and the Colorado River Basin Salinity Control Act of 1974[2] address salinity problems in the basin. Water quality standards for the Colorado River have been set by the states of the basin at 723 mg/ℓ below Hoover Dam, 747

[1] International Boundary and Water Commission. "Permanent and Definitive Solution to the International Problem of the Salinity of the Colorado River," Minute No. 242. Department of State Bulletin, Vol. 69 (September 24, 1973), pp. 395-96.

[2] Colorado River Basin Salinity Control Act of 1974, Pub. L. 93-320, 88 Stat. 266 (codified at 43 U.S.C.A. §§ 1571 et seq. [Supp. 1976]).

mg/ℓ below Parker Dam, and 879 mg/ℓ at Imperial Dam.[1] Adding to the complexity are the uncertainties associated with quantification of federal and Indian water rights and any allocation of flows to instream use. The federal government owns about 70 percent of the land in the Colorado River Basin and Indians have claimed rights to as much water as needed on the reservation. Federal and Indian rights under the Winters Doctrine reserve a sufficient quantity of unappropriated water to accomplish the purposes for which land was reserved. The Winters Doctrine has been affirmed in the courts to hold that reserved rights are not subject to state appropriation laws and that those rights are not lost if they are not used. These water problems and issues are elaborated in the Policy Analysis Report.[2]

(2) Groundwater

Large quantities of groundwater are present in the UCRB. Although its distribution and quality are largely a function of geology and topography, UCRB groundwater is generally more evenly distributed than surface water and has a higher TDS. The most important groundwater aquifers are in sedimentary bedrock and in sand and gravel alluvium along rivers and streams. An estimated 115 million acre-ft/yr of water is stored in these aquifers at a depth of less than 100 feet,[3] with substantially greater quantities in deeper reservoirs. This quantity is almost four times the storage capacity of all surface water reservoirs in the basin. The rate of recharge is about 4 million acre-ft/yr, but because many groundwater aquifers are isolated, the rate of withdrawal locally without mining must be determined from local recharge rates. Wells capable of yielding as much as 1,000 gallons per minute (gpm) can be drilled in much of the basin.[4]

Flow into groundwater aquifers usually takes place at high elevations where precipitation and flow in surface streams is

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[1] 41 Fed. Reg. 13,656-57 (March 31, 1976). Colorado agreed to the standards at a later date.

[2] White, Irvin L., et al. Energy From the West: Policy Analysis Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[3] Price, Don, and Ted Arnow. Summary Appraisals of the Nation's Ground-Water Resources--Upper Colorado Region, U.S. Geological Survey Professional Paper 813-C. Washington, D.C.: Government Printing Office, 1974.

[4] U.S., Department of the Interior, Bureau of Reclamation. Westwide Study Report on Water Problems Facing the Eleven Western States. Washington, D.C.: Government Printing Office, 1975, p. 35.

greatest and where the layers of rock making up the aquifer crop out at the surface. Discharge from the aquifers occurs at lower elevations in springs, seeps, and back into surface streams. Because of the slow movement of water in the aquifer, its behavior is much like that of a surface impoundment. With a continuous discharge, this can be beneficial to maintaining flow in surface streams during periods of normal low flow.

Water quality in aquifers in the UCRB varies widely but in general is a function of the mineral composition of the aquifer and the length of time the water has been stored there. Thus, water close to the recharge area (at higher elevations) has the best quality, and quality decreases at lower elevations. Water in aquifers above 7,000 feet elevation generally has a TDS of less than 1,000 mg/ℓ.[1] This is fresh water according to the USGS classification system.

About 133,000 acre-ft/yr of groundwater are currently used in the UCRB.[2] In the basin, this is 2 percent of the total water used[3] and about 3 percent of the annual recharge rate for groundwater. Groundwater use is limited by inadequate knowledge of its location and quality, and because the slow movement of water in aquifers requires a large number of wells over a wide area to withdraw at a substantial rate. (For perspective, if a sufficiently large groundwater aquifer could be found, 25 wells would be required, each producing 1,000 gpm, to supply water to a 3,000 megawatt-electric [MWe] power plant.) In addition, obtaining rights to groundwater can be difficult because of the inconsistencies and uncertainties associated with its administration. Groundwater has been administered locally rather than on a statewide or regional basis, but this situation is changing as demand for water increases.

B. Water Requirements

The water requirements for energy development in the UCRB have been calculated for the two levels of energy development

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[1]Price, Don, and Ted Arnow. Summary Appraisals of the Nation's Ground-Water Resources--Upper Colorado Region, U.S. Geological Survey Professional Paper 813-C. Washington, D.C.: Government Printing Office, 1974.

[2]U.S., Department of the Interior, Bureau of Reclamation. Westwide Study Report on Water Problems Facing the Eleven Western States. Washington, D.C.: Government Printing Office, 1975, p. 35.

[3]Price and Arnow. Ground-Water Resources--Upper Colorado Region.

postulated in Section 11.1.[1] These requirements are shown in Table 11-15. Assuming high wet cooling, the largest requirements are for power plants. If intermediate cooling is used, regional water demands for energy would be reduced by about 60,000 acre-ft by the year 2000, assuming the Low Demand case. This represents about a 20 percent decrease in total basin water requirements.[2]

Projected water requirements resulting from the increases in population associated with the three levels of development are shown in Table 11-16. Assuming a daily consumption of 150 gallons per person, these water requirements will be less than 85,000 acre-ft/yr. This is approximately the amount of water required for three steam-electrical power plants. Thus, population water requirements will be small compared to those for the facilities themselves, and will remain small, even if the per capita consumption doubles from the 150 gallons assumed.

Total increased water requirements for the UCRB in the year 2000 for the two levels of energy development assumed in Section 11.1 are: Low Demand case, 311,500 acre-ft/yr and Nominal Demand case, 1,338,000 acre-ft/yr with wet cooling. If wet/dry cooling is used, water requirements are reduced to 251,500 acre-ft/yr in the Low Demand case and 1,246,800 acre-ft/yr in the Nominal Demand case.

C. Water Effluents

Solid effluents and the quantity of wastewater produced by the energy facilities are given in Table 11-17 for the three time periods and two demand cases. Oil shale development (both TOSCO II and modified *in situ*) contributes nearly 85 percent of the total solids produced by energy development in the Basin. Overall, solid effluents in the Nominal case are more than four times those in the Low Demand case.

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[1] The location of energy facilities will be critical in determining total demand on the water system. In this report, the regional demands are not addressed with respect to a specific site but rather with respect to the basin as a whole.

[2] Gold, Harris, *et al*. *Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States*. Washington, D.C.: U.S., Environmental Protection Agency, 1977. For an elaboration of these potential savings, including savings associated with minimal wet cooling, see Chapter 4, "Water Policy Analysis," of White, Irvin L., *et al*. *Energy From the West: Policy Analysis Report*. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

TABLE 11-15: WATER REQUIRED FOR ENERGY FACILITIES IN UPPER COLORADO RIVER BASIN FOR YEAR 2000
(thousand acre-feet per year)

FACILITY	WATER REQUIRED PER FACILITY[a]		TOTAL PROJECTED REQUIREMENTS--YEAR 2000					
			LOW DEMAND			NOMINAL DEMAND		
	HIGH WET COOLING[b]	INTERMEDIATE WET COOLING[b]	NUMBER OF FACILITIES	HIGH WET COOLING	INTERMEDIATE WET COOLING	NUMBER OF FACILITIES	HIGH WET COOLING	INTERMEDIATE WET COOLING
Power Plant (3,000 MWe)	28.5 - 29.8	9.1 - 9.5	3	85.5 - 89.4	27.3 - 28.5	5	142.5 - 149	45.5 - 47.5
Gasification (250 MMscfd)	7.3 - 8.1[c]	5.9 - 7.7	1	7.3 - 8.1	5.9 - 7.7	2	14.6 - 16.2	11.8 - 15.4
Liquefaction (100,000 bbl/day)	6.7 - 7.5	5.8 - 6.8	0	0	0	0	0	0
TOSCO II Oil Shale (100,000 bbl/day)	9.3	NC	2	18.6	NC	12	111.6	NC
Modified In Situ Oil Shale (100,000 bbl/day)	3.5	NC	3	10.5	NC	13	45.5	NC
Uranium Mills-Mines (1,000 mtpy)	0.32 - 0.35[d]	NC	35	11.2 - 13.0	NC	48	15.4 - 17.8	NC
Slurry Pipelines (25 MMtpy)	19.2	NA	1	19.2	NA	1	19.2	NA
Coal Mines (25 MMtpy)	0.12	NA	23	2.8	NA	32	3.8	NA
Geothermal (100 MWe)	12.7	NC	10	127.0	NC	71	902.0	NC
Total	-	-	78	282 - 287	223 - 227[e]	184	1255 - 1265	1163 - 1169

MWe = megawatt-electric
MMscfd = million standard cubic feet per day
bbl/day = barrels per day
NC = not considered
mtpy = metric tons per year
MMtpy = million tons per year
NA = not available

[a]These data are the range of water requirements found in chapters 4-9 for the standard size facilities and standard load factors assumed throughout this report and summarized in Table 11-1.

[b]High wet cooling is defined as all wet cooling; intermediate wet cooling combines wet and dry cooling by dry cooling some of the load on turbine condensors.

[c]This range incorporates water requirements for both Synthane Gasification (7.3) and Lurgi Gasification (7.8 to 8.1) found in our site-specific analyses.

[d]This range reflects the different water requirements for underground mines (0.02) and surface mines (0.05), added to water required by the mill (0.3).

[e]Totals for the intermediate case add intermediate requirements for power plants and gasification to the high wet cooling requirements for the other facilities.

TABLE 11-16: WATER REQUIREMENTS FOR POPULATION INCREASES IN THE UPPER COLORADO RIVER BASIN (thousand acre-feet per year)[a]

STATE	LOW DEMAND[b]				NOMINAL DEMAND[b]			
	1980	1985	1990	2000	1980	1985	1990	2000
Colorado	0.6	1.6	3.8	16.3	0.3	7.1	9.6	63.1
New Mexico	4.1	4.2	3.5	6.6	5.3	4.8	4.8	11.4
Utah	0.8	0.5	0.5	1.5	1.6	2.0	2.5	9.2
Total	5.7	6.4	7.8	24.5	7.3	14.0	17.0	83.8

[a]Above the water consumed in 1975. Numbers may not total due to rounding.

[b]Assuming 150 gallons per capita per day and using population estimates from Section 11.4, "Social and Economic Impacts."

TABLE 11-17: WATER EFFLUENTS FROM ENERGY DEVELOPMENTS IN THE UPPER COLORADO RIVER BASIN[a]

DEMAND LEVEL AND EFFLUENT SOURCE	SOLIDS (MMtpy)			WASTEWATER (thousand acre-ft/yr)		
	1980	1990	2000	1980	1990	2000
Low Demand						
Energy Facility						
Power Plant	3.19	4.78	4.78	2.57	3.86	3.86
Gasification	0	0	1.82	0	0	0.95
Liquefaction	0	0	0	0	0	0
TOSCO II Oil Shale	0	0	64.75	0	0	8.04
Modified *In Situ* with Surface Retort	0	15.56	46.68	0	U	U
Uranium Mill	3.30	7.34	12.84	4.50	10.00	17.50
Population[b]	NC	NC	0.01	NC	NC	16.33
Total	6.49	27.68	130.88	7.07	13.86	46.68
Nominal Demand						
Energy Facility						
Power Plant	4.78	7.96	7.96	3.86	6.43	6.43
Gasification	0	0	3.64	0	0	1.90
Liquefaction	0	0	0	0	0	0
TOSCO II Oil Shale	0	67.75	258.99	0	8.04	32.16
Modified *In Situ* with Surface Retort	0	46.68	264.54	0	U	U
Uranium Mill	3.67	9.54	17.62	5.00	13.00	24.00
Population	NC	NC	0.04	NC	NC	55.85
Total	8.45	131.93	552.79	8.86	27.47	120.34

MMtpy = million tons per year
acre-ft/yr = acre feet per year

U = unknown
NC = not calculated

[a]These data are from chapters 4-9 for the standard size facilities and load factors assumed throughout the report and summarized in Section 11.1.

[b]Wastewater at 100 gallons per person per day, and 500 milligrams per liter solids. Population increases are 145,840 (Low Demand), and 498,700 (Nominal) by the year 2000. See Section 11.4.

D. Water-Related Impacts of Energy Development in the UCRB

(1) Surface Water

The most obvious impact of energy development in the UCRB will be the withdrawal of water to supply the energy conversion facilities. As noted above, basinwide water requirements for the two levels of development could range from 248,000 to 1,338,000 acre-ft/yr by 2000 depending on the level of development and cooling technology. Using 1974 depletion levels, and assuming the Water for Energy Management Team's estimate of 5.8 million acre-ft/yr available to the Upper Basin is correct, the Upper Basin states are entitled to approximately 2.1 million acre-ft/yr of surface water which is not now being used in the Upper Basin.[1] The energy developments postulated in our scenarios would require between 15 and 64 percent of this water.[2] In addition, water will be required for secondary industrial and agricultural uses occurring as a direct result of the energy developments, as well as for growth occurring independent of energy development.[3]

Depending on how the demands for water are divided among the rivers in the UCRB and how reservoirs are used to regulate flow, flow depletion could become a problem as a result of energy withdrawals. Table 11-18 shows requirements disaggregated to various river basins for the year 2000. In all cases, the total energy-related demand is well below the average flow. However, the demands are a large fraction of typical low flows and equal or exceed record low flows in the Four Corners Area. These water requirements and the resulting flow reductions which could occur during low flow periods could threaten fish and waterfowl species. (These impacts are discussed in Section 11.5.)

The water requirements for energy development described above will also affect water quality. Unless desalination is carried out, current TDS values could increase significantly as a result of energy development in the UCRB. Even assuming no return flows from energy facilities, salt concentration will increase because of the withdrawal of water upstream of the principal

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[1] U.S., Department of the Interior, Water for Energy Management Team. Report on Water for Energy in the Upper Colorado River Basin. Denver, Colo.: Department of the Interior, 1974.

[2] This assumes wet cooling is used. From 13 to 50 percent is required if wet/dry cooling is used. Alternatives for dealing with water availability problems are discussed in: White, Irvin L., et al. Energy From the West: Policy Analysis Report. U.S., Environmental Protection Agency, Washington, D.C.: forthcoming, Chapter 4.

[3] Water for Energy Management Team. Upper Colorado River Basin.

TABLE 11-18: ENERGY FACILITY WATER DEMAND VERSUS SUPPLY FOR SELECTED RIVER BASINS[a]

SUBAREA	LOW DEMABD CASE FOR SUBAREA (year 2000)[b]	MAJOR SURFACE WATER SOURCE	AVERAGE FLOW	LOW FLOW OF RECORD	MINIMUM FLOW[c]
Four Corners	174,280-177,310 acre-ft/yr (241-245 cfs)	San Juan River at Farmington	1,810,000 acre-ft/yr (2,500 cfs)	14 cfs	100-300 cfs
		San Juan River at Shiprock	1,664,000 acre-ft/yr (2,300 cfs)	8 cfs	40-200 cfs
West Colorado	49,180- 50,540 acre-ft/yr (68-70 cfs)	Colorado River near Cameo	2,821,000 acre-ft/yr (3,900 cfs)	700 cfs	800-1300 cfs
	29,100 acre-ft/yr (40 cfs)	White River near Meeker	455,400 acre-ft/yr (630 cfs)	112 cfs	170-210 cfs
East Utah	29,500- 30,860 acre-ft/yr (41-43 cfs)	Green River near Jensen	3,106,000 acre-ft/yr (4,290 cfs)	102 cfs	250-800 cfs

acre-ft/yr = acre-feet per year   cfs = cubic feet per second

[a]Data from U.S., Department of the Interior, Geological Survey. Surface Water Supply of the U.S., 1961-65, Part 9, Colorado River Basin, Vols. 1 and 2, Water Supply Papers 1924 and 1925. Washington, D.C.: Government Printing Office, 1970; and U.S., Department of the Interior, Geological Survey. Surface Water Supply of the U.S., 1966-70, Part 6, Missouri River Basin, Vol. 1, Water Supply Paper 2116. Washington, D.C.: Government Printing Office, 1974.

[b]Demand assuming the Low Demand case for the year 2000 (see Section 11.1); water requirements for the technologies from the Energy Resource Development System descriptions and attributed to the nearest surface water supply to the resource location. White, Irvin L., et al. Energy From the West: Energy Resource Development Systems Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[c]The range represents the minimum flows that occurred during 1961-65.

sources of salt loadings. For example, salinity increases of 2 mg/ℓ at Imperial Dam were projected to result from the Kaiparowits project alone.[1] If desalination projects are not carried out, increases in salinity at Imperial Dam are projected to increase from the present level of 879 mg/ℓ to as high as 1,250 mg/ℓ in the year 2000.[2] This will be in violation of the limit established by the states in response to requirements of the Federal Water Pollution Control Act (FWPCA); hence, additional salinity control measures, such as those authorized by the Salinity Control Act of 1974,[3] will be required. The economic costs of damages due to increases in salinity at Imperial Dam have been estimated at $230,000 per mg/ℓ of TDS increase,[4] primarily because of decreased crop production from lands irrigated with this water. Control of salt loadings through irrigation management and other on-farm measures has been estimated at between $7,000 and $750,000 per mg/ℓ, and desalination plants would cost between $100,000 and $4,000,000 per mg/ℓ at Imperial Dam.[5]

Although the most significant water-related impacts in the UCRB will be due to water depletions and increases in salinity, several other impacts will also be important. These include municipal and industrial water supply and wastewater treatment problems, in-stream water needs to support fish and wildlife, and disposal of effluents from energy facilities. Most of these impacts are discussed in the site-specific chapters and Chapter 10.

(2) Groundwater

The quantity and quality of groundwater in the UCRB should decrease as a consequence of energy development. Both types of impacts will result from withdrawals from and additions to water in aquifer systems.

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[1]U.S., Department of the Interior, Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976, p. III-157.

[2]Utah State University, Utah Water Research Laboratory. Colorado River Regional Assessment Study, Part 1: Executive Summary, Basin Profile and Report Digest, for National Commission on Water Quality. Logan, Utah: Utah Water Research Laboratory, 1975, p. 26.

[3]Colorado River Basin Salinity Control Act of 1974, Pub. L. 93-320, 88 Stat. 266 (codified at 43 U.S.C.A. §§ 1571 et seq. [Supp. 1976]).

[4]Utah Water Research Laboratory. Colorado River Regional Assessment Study, Part 1, p. 2.

[5]Ibid., Part 1, p. 5.

Groundwater withdrawals from aquifer systems could increase significantly if energy resources are developed close to the levels projected by our Low Demand scenario. While some groundwater withdrawals may be needed to dewater mines, most groundwater will be used for supplying municipal and rural population needs. Groundwater is especially attractive as a water source for domestic supplies in a water-short area like the UCRB. At present, about 31,000 acre-ft/yr are withdrawn for municipal supplies and about 14,000 acre-ft/yr are used for domestic supplies in rural areas.[1] About 4,000 acre-ft/yr of groundwater are currently used for cooling in power plants.

Large-scale groundwater withdrawals could lead to both local and regional lowering of the aquifer water levels in the immediate vicinity of wells. Lowered water levels could cause wells, springs, and seeps to go dry and could result in lower base flows in streams and rivers. The close interrelationship between groundwater and surface water could result in disputes over water rights stemming from groundwater withdrawals.

Mining may affect local groundwater systems in several ways. Both underground and surface mines can interrupt aquifer flow, making dewatering operations necessary. As much as 765 square miles (about one-quarter percent) of the total surface area of the UCRB may be subjected to surface mining.[2] Depending on the composition of the overburden, oxidation may release contaminants to local shallow groundwater systems. In areas where the energy resource is also an aquifer, as coal strata sometimes are, the aquifer will be destroyed when the resource is mined. If the overburden is an aquifer, the aquifer properties may be greatly altered when the overburden is removed and then replaced. Reclaiming surface mined lands will not generally restore the aquifer properties. Mixing materials may reduce porosity and permeability, but this tendency may be offset by the disaggregation and loosening of materials during removal and replacement. The net effect will vary according to the geologic conditions and will have to be evaluated on a case-by-case basis.

Most of the groundwater quality degradation that will result from energy development will be caused by chemical additions or disturbance to the natural aquifer systems. Shallow aquifers may

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[1]U.S., Department of the Interior, Bureau of Reclamation. Westwide Study Report on Water Problems Facing the Eleven Western States. Washington, D.C.: Government Printing Office, 1975, p. 51.

[2]Land use for surface mining is discussed in detail in Section 11.5 of this chapter and Chapter 7 of White, Irvin L., et al. Energy From the West: Policy Analysis Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

be polluted locally by mines, by energy conversion facilities, and by facilities associated with population growth. Deep aquifers would generally be polluted only where deep-well injection is used as a means of liquid waste disposal.

Contaminated water from energy conversion facilities may enter groundwater systems directly as a result of seepage of liquid wastes and indirectly from leaching of solid waste from disposal sites. The types of pollutants will vary from facility to facility, depending on the type of conversion process and the composition and quantity of waste generated. Estimates of the amount of waste generated for the conversion processes considered are presented in Table 11-17.

In most places in the UCRB, the bedrock between the surface and the water table is mostly sandstone and shales which can filter and absorb contaminated seepage. In addition, the water table in bedrock aquifers is quite deep, which also reduces the chances for contamination. In alluvial aquifers, the unconsolidated sand, gravel, and clay can similarly filter and absorb contaminants.

Population growth associated with the projected energy development of the scenario will have two principal impacts on groundwater systems: the withdrawals required for municipal and domestic supplies, and the liquid and solid waste disposal methods used. If large towns develop over small or low-permeability aquifers, water levels may decline as a result of excessive withdrawal. Since the soils in much of the UCRB are thin, the effluent from septic tank drainfields (where used) may not be fully renovated, and partially-treated effluent may seep into local groundwater. Pollutants leached from municipal solid waste disposal sites could also contaminate shallow aquifers, but the arid climate over most of the basin lessens the potential seriousness of this problem.

11.3.3 Impacts in the Upper Missouri River Basin

A. Existing Conditions

(1) Surface Water

Surface water is available from several sources in the UMRB. As shown in Figure 11-13, the major subbasins are the Upper Missouri, Yellowstone, Western Dakota Tributaries, and Eastern Dakota Tributaries. The major tributaries to the Missouri are the Yellowstone, Powder, Little Missouri, Cheyenne, Belle Fourche, and James Rivers. Flows are generally highest in the western part of

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[1]Problems and issues related to holding ponds disposal of effluents are discussed in Chapter 5 of White, Irvin L., et al. Energy From the West: Policy Analysis Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

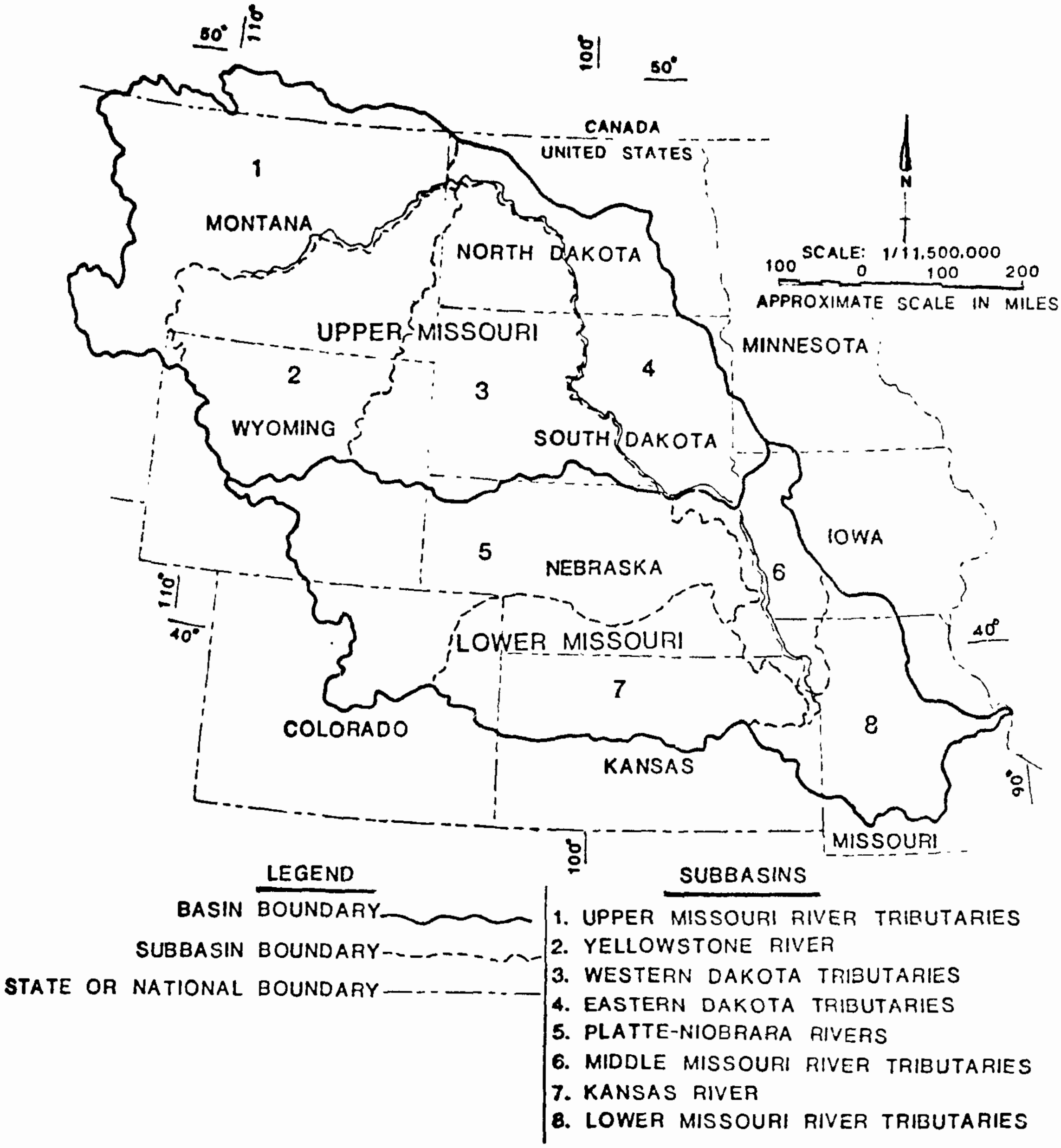

FIGURE 11-13: SUBBASINS OF THE MISSOURI RIVER BASIN

the basin as a result of melting snow and ice in the spring, and can also be periodically high in any part of the basin as a result of prolonged rainfall or thunderstorms.

Major river flows in the Fort Union Coal Region of the UMRB are shown in Table 11-19. The 8.8 million acre-ft/yr in the Yellowstone contributes about half the total flow into the Missouri above Lake Sakakawea. Water supply and use in the Montana and Wyoming portions of the UMRB are shown in Table 11-20 for 1975. Total depletions are only 16 percent of the 20 million acre-ft/yr available in Montana and 19 percent of the nearly 8 million acre-ft/yr available in Wyoming. Data on categories of depletions for the Fort Union region of the UMRB in North Dakota are not available.

The total average depletion in the UMRB is about 6.5 million acre-ft/yr including reservoir evaporation above Sioux City, Iowa.[1] The undepleted flow at that point is approximately 28.3 million acre-ft/yr of which 19 million acre-ft/yr are estimated to be the practical limit for depletions.[2] Hence, at present, an additional 12.5 million acre-ft/yr are apparently available for use.

Water quality in the UMRB is generally good. Table 11-21 gives concentrations of TDS at selected locations in the Fort Union Coal Region. The Missouri River at Bismarck and the Yellowstone River at its mouth both have TDS concentrations of less than 450 mg/ℓ, and only the Powder River has a TDS concentration much greater than that considered fresh by the USGS classification system.

The allocation of water rights and the legal political problems surrounding them are important in determining whether a portion of the unused water of the Yellowstone and other rivers in the UMRB can be used for energy purposes.[3]

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[1]Northern Great Plains Resources Program. Water Work Group Report. Billings, Mont.: U.S., Department of the Interior, Bureau of Reclamation, 1974, p. 16.

[2]U.S., Department of the Interior, Water for Energy Management Team. Report on Water for Energy in the Northern Great Plains Area with Emphasis on the Yellowstone River Basin. Denver, Colo.: Department of the Interior, 1975, p. VII-6.

[3]These problems and associated issues are discussed in Chapter 4 of White, Irvin L., et al. Energy From the West: Policy Analysis Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

TABLE 11-19: FLOW IN MAJOR STREAMS IN THE FORT UNION COAL REGION OF THE UPPER MISSOURI RIVER BASIN[a]

RIVER AND LOCATION	MAXIMUM ANNUAL FLOW (acre-feet)	MINIMUM ANNUAL FLOW (acre-feet)	AVERAGE ANNUAL FLOW (acre-feet)
Yellowstone Basin			
Clarks Fork Yellowstone	1,124,000	538,000	767,000
Wind-Bighorn near mouth	3,607,000	1,429,000	2,550,000
Tongue near mouth	569,000	32,000	304,000
Powder near mouth	1,154,000	43,000	416,000
Yellowstone near Sidney	12,690,000	3,720,000	8,800,000
Western Dakota Tributaries			
Little Missouri near mouth	1,294,000	34,000	390,000
Knife near mouth	315,000	3,000	118,000
Heart near mouth	515,000	17,000	154,000
Cannonball near mouth	711,000	1,000	149,000
Grand near mouth	712,000	9,000	156,000
Missouri River at Lake Sakakawea	-	-	16,952,000
Missouri River at Oahe Reservoir	-	-	18,525,000
Missouri River at Sioux City, Iowa	-	-	23,300,000[b]

[a]Northern Great Plains Resources Program. Water Work Group Report. Department of the Interior, Bureau of Reclamation, 1974, p. 13.

[b]U.S., Department of the Interior, Water for Energy Management Team. Report on Water for Energy in the Northern Great Plains Area with Emphasis on the Yellowstone River Basin. Denver, Colo.: Department of the Interior, 1975, p. VII-6.

TABLE 11-20: WATER SUPPLY AND USE IN THE UPPER MISSOURI RIVER BASIN (1,000 acre-feet per year)

	MONTANA	WYOMING
TOTAL WATER SUPPLY [a]	20,141	7,884
Estimated depletions[a]		
Irrigation	2,280	1,245
Municipal and industrial	99	29
Minerals and mining	10	55
Thermal electric	1	3
Other	204	
Reservoir evaporation	603	172
Total depletions	3,197	1,504

Source: U.S., Department of the Interior, Bureau of Reclamation. Westwide Study Report on Water Problems Facing the Eleven Western States. Washington, D.C.: Government Printing Office, 1975, pp. 229, 300, 411, 412.

[a]Water supply and depletion estimates are only for the Upper Missouri portion of the states. The states include portions of other river basins as well.

Interstate compacts exist for two rivers in the UMRB important for energy resource development: the Yellowstone and the Belle Fourche. The Belle Fourche River Compact[1] apportions 90 percent of the unappropriated water of the river to South Dakota and 10 percent to Wyoming. The Yellowstone River Compact[2] apportions the waters of the Yellowstone and its tributaries between Montana and Wyoming as follows:

TRIBUTARY	PERCENT TO: WYOMING	MONTANA
Clarks Fork	60	40
Bighorn	80	20
Tongue	40	60
Powder	42	58

[1]Belle Fourche River Compact of 1943, 58 Stat. 94 (1944).

[2]Yellowstone River Compact of 1960, 65 Stat. 663 (1951).

TABLE 11-21: WATER QUALITY OF SELECTED RIVERS IN THE FORT UNION COAL AREA OF THE UPPER MISSOURI RIVER BASIN[a]

RIVER	TDS (mg/ℓ)
Bighorn River at Bighorn, Montana	613
Tongue River at Miles City, Montana	496
Powder River at Moorhead, Montana	1,226
Yellowstone River at Miles City, Montana	396
Missouri River at Bismarck, North Dakota	441

TDS = total dissolved solids   mg/ℓ = milligrams per liter

[a]Northern Great Plains Resources Program. Water Work Group Report. Billings, Mont.: U.S., Department of the Interior, Bureau of Reclamation, 1974, p. 62.

Based on these allocations and estimates of annual flow and present consumption on the Belle Fourche and Yellowstone, estimates have been made of unappropriated flow available to the states involved. These are shown in Table 11-22. The flow in the Yellowstone basin available to Wyoming is estimated at 2.44 million acre-ft/yr; that available to Montana is estimated at 1 million acre-ft/yr.

(2) Groundwater

Aquifers in the UMRB include both deep and shallow aquifers in the bedrock as well as shallow aquifers in the alluvium above the bedrock. A total of about 860 million acre-ft of water is stored in these aquifers at a depth of less than 1,000 feet.[1] The aquifers most likely to affect or be affected by our hypothesized energy developments are the Madison (which extends to several thousand feet in depth), several aquifers in the Fort Union Coal formation (which are less than a hundred feet deep), and alluvial aquifers associated with the major rivers and streams. The shallow bedrock and alluvial aquifers are not productive enough to be considered as potential sources of water for energy facilities,[2] but they will probably be used extensively to supply water for the associated population growth. If groundwater is used to help meet the demands of the energy conversion facilities, the Madison aquifer is the most likely source.

The Madison aquifer is presently being studied as a possible water source for energy developments, although its hydrogeology is not completely understood.[3] Some wells into the aquifer yield

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[1]Missouri Basin Inter-Agency Committee. The Missouri River Basin Comprehensive Framework Study. Denver, Colo.: U.S., Department of the Interior, Bureau of Land Management, 1971, Vol. 1, p. 63.

[2]Swenson, Frank A. "Potential of Madison Group and Associated Rocks to Supply Industrial Water Needs, Powder River Basin, Wyoming and Montana," in Hadley, R.F., and David T. Snow, eds. Water Resources Problems Related to Mining. American Water Resources Association Proceedings, Vol. 18 (1974), p. 212.

[3]Swenson, Frank A. Possible Development of Water from Madison Group and Associated Rock in Powder River Basin, Montana-Wyoming. Denver, Colo.: Northern Great Plains Resources Program, 1974.

TABLE 11-22: ALLOCATION OF FLOWS BY INTERSTATE WATER COMPACTS FOR STREAMS WITHIN THE FORT UNION COAL REGION[a]

COMPACT	STREAM	AVERAGE ANNUAL FLOW[b] (acre-ft/yr)	UNAPPROPRIATED FLOW[c] (acre-ft/yr)	UNAPPROPRIATED FLOW AVAILABLE TO STATES[c] (acre-ft/yr)		
				WYOMING	MONTANA	SOUTH DAKOTA
Yellowstone River	Powder River	416,000	287,300	120,000	166,600	-
	Tongue River	304,000	241,000	96,400	144,700	-
	Bighorn River	2,500,000	2,200,000	1,800,000	400,000	-
	Clarks Fork	767,000	714,000	429,000	285,000	-
Belle Fourche	Belle Fourche River	184,000	87,000	7,300	-	79,700

acre-ft/yr = acre-feet per year

[a]Taken from U.S., Department of the Interior, Water for Energy Management Team. Report on Water for Energy in the Northern Great Plains Area with Emphasis on the Yellowstone River Basin. Denver, Colo.: Department of the Interior, 1975, p. II-5.

[b]Historic average annual flow adjusted to the 1970 level of development.

[c]Wyoming, State Engineer's Office, Water Planning Program. Water and Related Land Resources of Northeastern Wyoming, Report No. 10. Cheyenne, Wyo.: Wyoming Water Planning Program, 1972.

more than 10,000 gpm, but most yield less than 1,000 gpm.[1] The Madison is recharged at high elevations where the limestone forming the aquifer crops out. High elevation rainfall and snowmelt are the primary sources of the water. Discharge from the Madison is to wells and, via leakage, into shallower aquifers. The quality of water in the Madison, as measured by TDS, ranges from less than 500 mg/ℓ near the recharge areas in the Powder River Basin to more than 4,000 mg/ℓ near the Montana-North Dakota line.[2] In the Williston Basin area, where the water has been in the aquifer much longer, it is moderately to very saline according to the USGS classification system (3,000-10,000 mg/ℓ), and therefore not as likely to be used for energy facilities in the lignite fields of western North Dakota. Existing uses of Madison groundwater are for municipal, industrial, domestic, stock, and oil field waterflood purposes.[3]

Aquifers in the Fort Union Formation occur in both sandstone beds and coal seams. They are recharged from precipitation in high elevation areas and from surface streams. Most of these aquifers are at or near the water table depth. Water quality in Fort Union aquifers varies depending on rock composition and how long the water has been in the aquifer. Existing uses are primarily for rural domestic supplies and stock watering.

Alluvial aquifers are located below major rivers and streams in the basin. The total amount of water stored in these aquifers is not known, but the productivity of some is sufficient to supply irrigation wells that produce over 1,000 gpm. Water quality in alluvial aquifers is usually good unless recharge is from lower bedrock aquifers. Existing uses include supplying water for municipal, domestic, stock, and irrigation needs.

Groundwater use in the UMRB is limited by the large number of wells usually needed to produce high yields, the low permeability of the aquifers which limits the flow per well, and the lack of sufficient knowledge on the occurrence, location, and properties of the aquifers.

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[1]U.S., Department of the Interior, Geological Survey. Plan of Study of the Hydrology of the Madison Limestone and Associated Rocks in Parts of Montana, Nebraska, North Dakota, South Dakota, and Wyoming, Open-File Report 75-631. Denver, Colo.: Geological Survey, 1975, p. 3.

[2]Swenson, Frank A. Possible Development of Water from Madison Group and Associated Rock in Powder River Basin, Montana-Wyoming. Denver, Colo.: Northern Great Plains Resources Program, 1974, p. 3.

[3]U.S. Geological Survey. Hydrology of Madison Limestone.

B. Water Requirements

The water requirements for energy development in the UMRB have been calculated for the two levels of energy development postulated in Section 11.1. These requirements are shown in Table 11-23. Assuming high wet cooling, requirements for power plants and slurry pipelines are at least twice those of any other facility. For the Low Demand case, total basinwide requirements by the year 2000 could reach almost 900,000 acre-ft/yr, assuming high wet cooling. If intermediate wet cooling is used by all conversion facilities, regional consumption in the UMRB for the Low Demand case in the year 2000 could be reduced by about 320,000 to 375,000 acre-ft.[1] This is about a 40 percent reduction in water demand. Using minimal wet cooling could reduce requirements even further but at a higher economic cost.[2]

Water requirements resulting from the increases in population associated with the three levels of development are shown in Table 11-24. Assuming a daily consumption of 150 gallons per person, these water requirements do not exceed 87,000 acre-ft/yr in the Low Demand case, which is about 10 percent of that required for energy facilities.

Total increased water requirements for energy development and related population increases in the UMRB in the year 2000 for the two levels of development are: Low Demand case, 969,000 acre-ft/yr and Nominal Demand case, 1,344,000 acre-ft/yr with high wet cooling. If intermediate wet cooling is used, water requirements could be reduced to 594,000 acre-ft/yr in the Low Demand case and 878,000 acre-ft/yr in the Nominal Demand case.

C. Water Effluents

Solid effluents and the quantity of wastewater produced by the energy facilities are given in Table 11-25 for the three time periods and two demand cases. For the Low Demand case, solid effluents range from 5 (in 1980) to 39 (in 2000) million tons per year (MMtpy). The quantity of wastewater generated ranges from 10 (in 1980) to 61 (in 2000) thousand acre-ft/yr; this represents less than 10 percent of the water requirements.

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[1]Gold, Harris, et al. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

[2]Analyses of the reduced water requirements of minimum wet cooling are presented in the site-specific chapters (7,8, and 9). These chapters should be referred to for additional details for facilities in the UMRB.

TABLE 11-23: WATER REQUIRED FOR ENERGY FACILITIES IN THE UPPER MISSOURI RIVER BASIN (thousands acre-feet per year)

FACILITY	WATER REQUIRED PER FACILITY[a]		TOTAL PROJECTED REQUIREMENTS--YEAR 2000					
			LOW DEMAND			NOMINAL DEMAND		
	HIGH WET COOLING[b]	INTERMEDIATE WET COOLING[b]	NUMBER OF FACILITIES	HIGH WET COOLING	INTERMEDIATE WET COOLING	NUMBER OF FACILITIES	HIGH WET COOLING	INTERMEDIATE WET COOLING
Power Plant (3000 MWe)	23.9 - 26.7	5.5 - 6.1	14	334.6 - 373.8	77.0 - 85.4	18	430.2-480.6	99.0 - 109.9
Gasification (250 MMscfd)	5.9 - 7.7[c]	3.7 - 5.7	27	159.3 - 207.9	99.9 - 125.4	45	265.5-346.5	166.5 - 256.5
Liquefaction (100,000 bbl/day)	5.8 - 6.8	3.7 - 4.8	2	11.6 - 13.6	7.4 - 9.6	2	11.6-13.6	7.4 - 9.6
Uranium Mills-Mines (1000 mtpy)	0.32 - 0.35[d]	NA	22	7.04 - 7.7	NA	31	9.9-10.9	NA
Coal Mines (25 MMtpy)	0.124	NA	237	29.4	NA	319	39.6	NA
Slurry Pipelines (25 MMtpy)	19.2	NA	13	249.6	NA	17	326.4	NA
Total			315	791.5 - 882.0	470.3-507.1[e]	432	1,083.2-1,217.6	648.8-752.9[e]

MWe = megawatt-electric
MMscfd = million standard cubic feet per day
bbl/day = barrels per day
mtpy = metric tons per year
NA = not available
MMtpy = million tons per year

[a]These data are the range of water requirements found in Chapters 4-9 for the standard size facilities and standard load factors assumed throughout this report and summarized in Table 11-1.

[b]High wet cooling as defined in all wet cooling. Intermediate wet cooling combines wet and dry cooling by dry cooling some of the load on the turbine condensors.

[c]This range incorporates water requirements for both Synthane Gasification (6.4-7.2) and Lurgi Gasification (5.9-7.7).

[d]This range reflects the different water requirements for underground mines (0.02) and surface mines (0.05).

[e]Totals for the intermediate case are derived by adding intermediate requirements for power plants, gasification, and liquefaction to the high wet cooling requirements of the other facilities.

TABLE 11-24: WATER REQUIREMENTS FOR POPULATION INCREASES IN THE UPPER MISSOURI RIVER BASIN (thousand acre-feet per year)[a]

STATE	LOW DEMAND[b]				NOMINAL DEMAND[b]			
	1980	1985	1990	2000	1980	1985	1990	2000
Montana	2.5	8.0	8.6	34.7	3.2	11.0	14.3	49.7
North Dakota	2.2	4.2	6.7	29.4	2.2	5.3	8.0	41.8
Wyoming	2.4	5.3	6.8	22.5	3.8	6.6	7.9	34.3
Total	7.2	17.6	22.1	86.7	9.3	23.0	30.2	125.9

[a]Above the water consumed in 1975. Numbers may not total due to rounding.

[b]Assuming 150 gallons per capita per day and using population estimates from Section 11.4, "Social and Economic Impacts."

TABLE 11-25: WATER EFFLUENTS FROM ENERGY DEVELOPMENT IN THE UPPER MISSOURI RIVER BASIN[a]

DEMAND LEVEL AND FACILITY TYPE	SOLIDS (million tons per year)			WASTEWATER (thousand acre-feet per year)		
	1980	1990	2000	1980	1990	2000
Low Demand						
Power Plant	3.51	8.78	12.30	7.87	19.67	27.54
Gasification	0.00	0.00	16.42	0.00	0.00	20.99
Liquefaction	0.00	0.00	2.23	0.00	0.00	1.73
Uranium Mills	1.83	4.40	8.07	2.50	6.00	11.00
Population[b]	NC	NC	0.04	NC	NC	57.80
Total	5.34	13.18	39.06	10.37	25.67	119.06
Nominal Demand						
Power Plant	4.39	11.42	15.81	9.83	25.57	35.41
Gasification	0.00	1.82	27.36	0.00	2.33	34.99
Liquefaction	0.00	0.00	2.23	0.00	0.00	1.73
Uranium Mills	2.20	5.87	11.38	3.00	8.00	15.50
Population[b]	NC	NC	0.06	NC	NC	83.91
Total	6.59	19.11	56.91	12.83	35.90	171.54

NC = not calculated

[a]These data are from chapters 4-9 for the standard size facilities and load factors assumed throughout the report and summarized in Section 11.1.

[b]Wastewater at 100 gallons per person per day, and 500 milligrams per liter solids. Population increases are 516,050 (Low Demand) and 749,200 (Nominal) by the year 2000. Refer to Section 11.4.

D. Water Related Impacts of Energy Development in the Upper Missouri River Basin

(1) Surface Water

The water requirements for energy development through the year 2000, identified above, are 5 to 10 percent of the 12.5 million acre-ft estimated to be available for use in the UMRB. Because of the limited data on water availability and energy requirements for individual rivers in the UMRB, estimates cannot be made of the impacts that energy development might have on particular rivers, although demands on the Yellowstone from Powder River coal development probably will be substantial. However, the overall impact on the basin from energy developments is not expected to be as serious as in the UCRB.

However, water depletions in the UMRB may reduce the length of the navigation season in the Lower Missouri. One study has estimated that if an additional 10 million acre-ft/yr were withdrawn from UMRB, this season would drop from a nominal 8 months to zero for 11 of the next 75 years.[1] If an additional 600,000 acre-ft/yr are withdrawn (approximately the amount required in our Low Demand, intermediate wet cooling case), the season would drop to zero for only one of the next 75 years.[2]

Much of the Fort Union Coal Region is in areas not served by nearby large streams; thus, a regional water system may be required to service a large part of the proposed development.[3] If a regional water supply system is developed, there will be an effect on the river as well as on the land area disturbed by the construction. The magnitude of the effect will be related to intake design considerations and the amount of water withdrawn.

Water quality impacts due to energy development in the UMRB have been estimated in other studies for levels of development similar to those assumed here and found to be small. TDS concentration increases in the Missouri River at Bismarck were estimated

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[1]U.S., Army, Corps of Engineers, Missouri River Division, Reservoir Control Center. Missouri River Main Stem Reservoirs Long Range Regulation Studies, Series 1-74. Omaha, Nebr.: Corps of Engineers, 1974, p. 23.

[2]U.S., Department of the Interior, Water for Energy Management Team. Report on Water for Energy in the Northern Great Plains Area with Emphasis on the Yellowstone River Basin. Denver, Colo.: Department of the Interior, 1975, p. V-21.

[3]U.S., Department of the Interior, Bureau of Reclamation. Appraisal Report on Montana-Wyoming Aqueduct. Billings, Mont.: Bureau of Reclamation, 1974.

to be from 13 mg/ℓ to 454 mg/ℓ.[1] Changes in TDS concentrations in tributaries were highly variable, with increases predicted in some and decreases in others. Both the amount of change and direction depend on assumptions concerning level and type of development and the amount and quality of return flows to the streams.

Although the most significant water-related impacts in the UMRB will be due to water depletions and changes in water quality, a number of additional impacts may also be important. These include municipal and industrial water supply and wastewater treatment problems, in-stream water needs to support fish and wildlife, and disposal of effluents from energy facilities. Most of these impacts are discussed in the site-specific chapters and Chapter 10.

(2) Groundwater

Groundwater withdrawals could be increased by the projected energy resource development scenario. Some withdrawals will be for mine dewatering operations, but most withdrawals will be for consumption. Yield from shallow aquifers is not sufficient to meet the water needs of the energy conversion facilities.[2] However, groundwater will probably make significant contributions to water supply for the associated population growth. Large-scale withdrawals could result in lowering of the aquifers' water levels in the vicinity of wells, which if large relative to the recharge rate, could cause wells, springs, and seeps to go dry, and lower base flows in streams and rivers.

The Madison aquifer will probably be used if groundwater is needed for energy facilities. The Madison may be able to supply a significant fraction of the water required by some facilities, but groundwater mining may occur as a result.[3] This has occurred

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[1] Northern Great Plains Resources Program. Water Work Group Report. Billings, Mont.: U.S., Department of the Interior, Bureau of Reclamation, 1974, p. 66.

[2] Swenson, Frank A. "Potential of Madison Group and Associated Rocks to Supply Industrial Water Needs, Powder River Basin, Wyoming and Montana," in Hadley, R.F., and David T. Snow, eds. Water Resources Problems Related to Mining. American Water Resources Association Proceedings, Vol. 18 (1974), p. 212.

[3] Swenson, Frank A. Possible Development of Water from Madison Group and Associated Rock in Powder River Basin, Montana-Wyoming. Denver, Colo.: Northern Great Plains Resources Program, 1974; U.S., Department of the Interior, Geological Survey. Plan of Study of the Hydrology of the Madison Limestone and Associated Rocks in Parts of Montana, Nebraska, North Dakota, South Dakota, and Wyoming, Open-File Report 75-631. Denver, Colo.: Geological Survey, 1975.

in the vicinity of Midwest, Wyoming, where about 12-14 wells were drilled for waterflood supplies for oil field secondary recovery. This development caused a decline of 3,000 feet in the water levels in wells, with an area of influence extending under six townships.[1] Mining also may affect local groundwater systems by interrupting or changing aquifer flow and by introducing effluents into groundwater aquifers.

Mining and energy conversion facility effects on groundwater systems in the UMRB will be similar to those described earlier for the UCRB. However, a number of possible impacts cannot be adequately assessed because of a lack of detailed knowledge about UMRB groundwater. Data on both the rate of movement of groundwater and the fate and effects of pollutants in groundwater systems are needed.[2] Estimates of the amount of waste generated for the conversion processes have been summarized in Table 11-25. Most of the residuals will be produced by the power plants and gasification facilities.[3]

11.3.4 Summary of Regional Water Impacts

A. Upper Colorado River Basin

In the UCRB, water demands for energy uses for the year 2000 will be 15 to 64 percent of presently unallocated water for the two levels of energy development being considered. If intermediate wet cooling is used for power plants and coal synfuel facilities, this demand can be reduced by about 60,000 acre-ft (20 percent reduction) in the Low Demand case and about 91,000 acre-ft (about 7 percent) in the Nominal case.

Meeting these water requirements will increase the salinity of the Colorado even if no pollutants are discharged from the

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[1]Swenson, Frank A. "Potential of Madison Group and Associated Rocks to Supply Industrial Water Needs, Powder River Basin, Wyoming and Montana," in Hadley, R.F., and David T. Snow, eds. Water Resources Problems Related to Mining. American Water Resources Association Proceedings, Vol. 18, (1974), p. 217.

[2]Northern Great Plains Resources Program, Water Work Group, Groundwater Subgroup. Shallow Ground Water in Selected Areas in the Fort Union Coal Region, Open-File Report 74-48. Helena, Mont.: U.S., Department of the Interior, Geological Survey, 1974, p. 13.

[3]Problems and issues related to holding ponds disposal of effluents are discussed in Chapter 5 of White, Irvin L., et al. Energy From the West: Policy Analysis Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

facilities. This will occur because water consumption by energy resource facilities will concentrate salt levels.

Groundwater and surface water must be considered parts of a single resource system if water management is to be well-informed. Groundwater resources will be used primarily for municipalities, and both municipal withdrawals and possible groundwater pollution from sewage disposal will affect the resource. An additional groundwater impact may occur as a result of mine dewatering.

B. Upper Missouri River Basin

Impacts on the UMRB due to energy development will not be as serious as those in the UCRB, primarily because considerably more water is available in the Missouri. Based on regionwide figures, energy facilities will require 8 to 11 percent of the water available in the year 2000 for the two demand scenarios considered. If intermediate wet cooling is used, demand could be reduced about 375,000 acre-ft (about 40 percent reduction) for the Low Demand case in the year 2000. In the Nominal case, demands could be reduced about 465,000 acre-ft (35 percent) by the year 2000.

The navigation season on the Lower Missouri will be reduced as a result of depletions for energy facilities in the Upper Basin. Depletions of 600,000 acre-ft/yr would result in one of the next 75 years having no navigation season; depletions of 10 million acre-ft/yr would result in 11 of the next 75 years having no navigation season.

Groundwater from the Madison aquifer may be used to supplement surface water for energy facilities in the UMRB. Because of low porosity in the aquifer, municipal users of this groundwater source may be affected. Drilling deeper wells or finding supplemental municipal sources may be necessary. However, these assessments are tentative because of insufficient information about groundwater resources in the basin.

11.4 SOCIAL AND ECONOMIC IMPACTS

11.4.1 Introduction

In this section, social and economic impacts of western energy development are analyzed and discussed for the western region and, in some aspects, for the nation as a whole. Population impacts are considered first, primarily in terms of net population changes expected in the West as a result of each of the two levels of energy resource development being examined. Following is an economic and fiscal analysis which estimates changes in personal income, public services, and economic structure in the western region. Social and cultural effects and political and governmental impacts are discussed next, followed by an analysis of impacts on the availability of personnel, materials and equipment, and capital.

11.4.2 Population Impacts

This section analyzes the large-scale, regionwide population changes due to western energy developments in contrast to the site-specific analyses reported in Chapters 4-9. For both the Nominal case and Low Demand case of the SRI model described in Section 1 of this chapter, manpower requirements for construction and operation were obtained from the Bechtel Energy Supply Planning Model.[1] Average (rather than peak) construction employment was used for each of the energy facilities that are projected to be built in the various time periods. The population changes are discussed first for the entire eight-state area and then for selected subregions where energy development is expected to be concentrated.

A. Regionwide

One of the most important factors that will influence population change is the number and location of the necessary personnel. These can be considered as two specific questions: how many of the required workers will be available locally, and where will the others come from? A greater availability of local workers will decrease the need for in-migration.

Limited information on the West indicates that about 46 percent of the energy construction workforce is found locally in the Four Corners states (Arizona, Colorado, New Mexico, and Utah), and about 34 percent locally in the Northern Great Plains states (Montana, North Dakota, South Dakota, and Wyoming).[2] In the future, as energy development increases, more workers are likely to move into the area from outside the West, and proportionately fewer workers will probably be available from within the region. In the absence of other data, the available estimate of 66 percent net in-migration to Northern Great Plains localities and 54 percent to local areas in the Four Corners states are used here.[3]

Employment in energy development of in-migrants to an area generally induces secondary employment in other industries and, therefore, additional population in families. Table 11-26 lists the employment multiplier for operation, which represents the number of new jobs in other industries induced by one energy job, and the population multiplier, which represents family size or

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[1] Carrasso, M., _et al_. _The Energy Supply Planning Model_. San Francisco, Calif.: Bechtel Corporation, 1975.

[2] Mountain West Research. _Construction Worker Profile_, Final Report. Washington, D.C.: Old West Regional Commission, 1976, pp. 14-17.

[3] _Ibid_. These figures appear to balance future in-migration to the region with movements within and among the western states.

TABLE 11-26: EMPLOYMENT AND POPULATION MULTIPLIERS FOR OPERATION PHASE

YEAR	EMPLOYMENT MULTIPLIER	POPULATION MULTIPLIER
1980	0.4	3
1985	0.8	3
1990	0.8	3
2000	1.0	3

the number of people per employee. The employment and population multipliers for the construction phase of a facility were combined for simplicity into a single figure Of 2.0, which may underestimate the population impacts of construction in some areas.

Population impacts of energy facility construction and operation for the SRI Nominal and Low Demand cases were estimated with an economic base model methodology, using the multipliers above.[1] Construction-related, operation-related, and overall population increases for the eight-state region are included in Table 11-27. The estimated trend shows that in both the Nominal and Low Demand cases, the greatest population gains will occur during the 1990's. An overall regional addition of about 660,000 people is likely by 2000 in the Low Demand scenario. Construction employment is relatively more important during the late 1970's and the 1990's when the rate of energy development is projected to be the greatest. Although the population increases are not large on a regionwide scale (less than a seven percent increase over the 1975 population of 9,551,000 for the Low Demand case in 2000), the impacts will not be evenly distributed. In fact, the parts of the West likely to receive the greatest energy-related population increases are those with the smallest current populations, not the metropolitan areas which account for about half of the region's present population.

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[1]This methodology is commonly used to assess energy development impacts. See Crawford, A.B., H.H. Fullerton, and W.C. Lewis. Socio-Economic Impact Study of Oil Shale Development in the Uintah Basin, for White River Shale Project. Providence, Utah: Western Environmental Associates, 1975, pp. 147-58; Stenehjem, Erik J. Forecasting the Local Economic Impacts of Energy Resource Development: A Methodological Approach, ANL/AA-3. Argonne, Ill.: Argonne National Laboratory, 1975.

TABLE 11-27: POPULATION INCREASES IN WESTERN STATES AFTER 1975 DUE TO ENERGY DEVELOPMENT

YEAR	SRI CASE	CONSTRUCTION-RELATED[a]	OPERATION-RELATED	OVERALL INCREASE
1980	Nominal	38,900	59,600	98,500
	Low Demand	31,600	45,000	76,700
1985	Nominal	38,900	179,400	218,300
	Low Demand	32,400	118,200	150,600
1990	Nominal	39,500	241,400	280,900
	Low Demand	20,900	157,200	178,100
2000	Nominal	386,500	861,100	1,247,600
	Low Demand	187,300	474,600	661,900

SRI = Stanford Research Institute

[a]Based on the average annual construction employment for the construction period of each facility and the projected number of facilities.

B. Subregional

Disaggregation of the energy supply areas provides an analysis of subregional impacts on state and substate areas (Table 11-28). Considerable error is potentially built into this procedure, even on the state level; for example, potential development in South Dakota and Arizona is approximated as zero. County-level projections appear to include many reasonable locations within states but occasionally concentrate resource development in too few areas. The substate areas where populations vary most between the two levels of development are those where oil shale resources are located.

Aggregating the data in Table 11-28 by state, and separating construction and operation-based population, illustrates the distribution of impacts among the western states (Table 11-29). Overall, the Low Demand case would result in a population increase 47 percent below that of the Nominal case, with the greatest difference in Utah (89 percent lower) and in Colorado (73 percent lower) because of differences in oil shale production between the two cases. The largest absolute and relative growth is expected in the coal areas of the Northern Great Plains states of Montana, North Dakota, and Wyoming, where operation-related population increases of 19.8 percent, 17.9 percent, and 27.4 percent, respectively, are projected due to Low Demand levels of energy development

TABLE 11-28: PERMANENT POPULATION ADDITIONS AFTER 1975 FOR ENERGY AREAS OF SIX WESTERN STATES

COLORADO				
	GARFIELD, MESA, AND RIO BLANCO COUNTIES AREA		HUERFANO COUNTY AREA	
YEAR	NOMINAL CASE	LOW DEMAND CASE	NOMINAL CASE	LOW DEMAND CASE
1980	1,800	0	0	3,600
1985	17,300	0	11,600	9,300
1990	34,600	7,500	11,600	11,200
2000	240,800	55,100	12,700	12,700
UTAH				
	KANE AND GARFIELD COUNTIES AREA		UINTAH AND GRAND COUNTIES AREA	
YEAR	NOMINAL CASE	LOW DEMAND CASE	NOMINAL CASE	LOW DEMAND CASE
1980	6,400	2,200	0	0
1985	10,800	2,900	600	0
1990	12,200	2,900	500	0
2000	12,800	3,100	27,000	2,100
NEW MEXICO				
	NORTHWESTERN AREA (SAN JUAN, MCKINLEY, AND VALENCIA COUNTIES)		SOUTHEASTERN AREA (LEA, EDDY, ROOSEVELT, AND CHAVES COUNTIES)	
YEAR	NOMINAL CASE	LOW DEMAND CASE	NOMINAL CASE	LOW DEMAND CASE
1980	6,300	3,700	9,900	8,200
1985	14,600	11,400	12,900	10,500
1990	20,600	15,200	6,900	4,800
2000	54,200	35,700	0	0
MONTANA				
	BIG HORN, ROSEBUD, AND POWDER RIVER COUNTIES AREA			
YEAR	NOMINAL CASE	LOW DEMAND CASE		
1980	11,600	10,400		
1985	53,400	38,100		
1990	74,800	48,900		
2000	215,100	149,400		
WYOMING				
	CAMPBELL COUNTY AREA		CENTRAL AND SOUTHERN WYOMING (JOHNSON, SHERIDAN, CONVERSE, NATRONA, CARBON, FREMONT, AND SWEETWATER COUNTIES)	
YEAR	NOMINAL CASE	LOW DEMAND CASE	NOMINAL CASE	LOW DEMAND CASE
1980	14,200	8,800	2,400	900
1985	25,000	19,800	10,000	7,200
1990	32,200	26,300	12,800	10,200
2000	81,100	52,300	68,900	50,300
NORTH DAKOTA				
	WEST CENTRAL AREA (DUNN, MCLEAN, MERCER, AND OLIVER COUNTIES)		SOUTHWESTERN AREA (BILLINGS, BOWMAN, HETHINGER, MCKENZIE, SLOPE, STARK, AND WILLIAMS COUNTIES)	
YEAR	NOMINAL CASE	LOW DEMAND CASE	NOMINAL CASE	LOW DEMAND CASE
1980	7,000	7,000	0	0
1985	14,000	14,500	4,500	4,600
1990	21,400	25,600	13,800	4,600
2000	84,600	52,400	61,700	61,500

TABLE 11-29: POPULATION INCREASES IN WESTERN STATES AFTER 1975 DUE TO ENERGY DEVELOPMENT

STATE	1975 POPULATION (million)	YEAR	NOMINAL CASE		LOW DEMAND CASE	
			CONSTRUCTION	OPERATION	CONSTRUCTION	OPERATION
Colorado	2.534	1980	200	1,800	400	3,600
		1985	13,100	29,500	600	9,300
		1990	11,100	46,200	3,800	18,700
		2000	122,200	253,500	29,600	67,800
New Mexico	1.147	1980	15,600	16,200	12,700	12,100
		1985	1,300	27,600	3,500	21,900
		1990	1,200	27,500	800	20,100
		2000	13,800	54,300	3,400	35,700
Utah	1.206	1980	3,100	6,400	2,700	2,200
		1985	400	11,400	0	2,900
		1990	2,500	12,700	0	2,900
		2000	15,000	39,800	4,100	5,200
Montana	.748	1980	7,400	11,600	4,900	10,400
		1985	12,200	53,400	9,400	38,100
		1990	10,400	74,800	2,200	48,900
		2000	80,800	215,100	57,500	149,400
North Dakota	.635	1980	6,200	7,000	6,200	7,000
		1985	9,300	22,500	6,400	19,000
		1990	12,400	35,200	9,900	30,100
		2000	100,700	148,300	61,400	113,900
Wyoming	.374	1980	6,400	16,600	4,700	9,700
		1985	4,600	35,000	4,900	27,000
		1990	1,900	45,000	4,000	36,500
		2000	54,300	150,000	31,300	102,600

A comparison of the energy-related population growth projected here with a set of projections for the same period based on long-term trends made by the Department of Commerce's Office of Business Economics (now the Bureau of Economic Analysis) and the Department of Agriculture's Economic Research Service (OBERS projections) gives an indication of the relative magnitude of energy-related impacts (Table 11-30).[1] The OBERS projections merely extend past trends into the future, with the result that: the out-migration in the Northern Great Plains is expected to continue; such rapidly growing metropolitan areas as Denver, Phoenix, Salt Lake City, and Albuquerque are projected to continue growing; and mining activity in the West is expected to continue the trend experienced through about 1970. This involves very slow growth when compared with current activity. Because of recent events, which have broken some seemingly long-term trends, the actual population and economic activity levels in the West through 1975 show the OBERS projections to be large underestimates.[2] Since energy development is the major impetus for reversal of the trends in the Northern Great Plains states, and is a considerable stimulus in the Four Corners states, the OBERS projections can be assumed to be the likely state of the western region in the absence of energy development. Thus, the greatest impact from energy development will be in those states which were expected to continue to lose population (generally the Northern Great Plains), whereas the smallest impact will be in those states where other growth was projected (the Four Corners states).

To summarize, the population impacts from western energy developments will not be large regionwide (at most a 13 percent increase in the Nominal case through 2000). However, these developments will largely take place far from the metropolitan areas and will impact small towns and rural areas most. In some areas, a 10-fold population increase by 2000 is possible under conditions similar to the levels of development considered here. Examples of effects in these areas are included in the site-specific analyses of chapters 4-9.

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[1]U.S., Department of Commerce, Bureau of Economic Analysis and Department of Agriculture, Economic Research Service. 1972 OBERS Projections: Economic Activity in the U.S., Vol. 4: States, for the U.S. Water Resources Council. Washington, D.C.: Government Printing Office, 1974.

[2]U.S., Department of Commerce, Bureau of Economic Analysis, Regional Economic Analysis Division. "Tracking the BEA State Economic Projections." Survey of Current Business, Vol. 56 (April 1976), pp. 22-29. For example, Montana, North Dakota, South Dakota, and Wyoming have grown in population in contrast to projected steady declines. New Mexico is nearing its projected population for the year 2000; all other states in the region also are well above the estimates.

TABLE 11-30: COMPARISON OF POPULATION INCREASES FOR LOW DEMAND CASE ENERGY DEVELOPMENT WITH OBERS POPULATION PROJECTIONS, 1980-2000

STATE	YEAR	ENERGY-RELATED POPULATION INCREASE[a]	OBERS PROJECTION[b]	ENERGY-RELATED INCREASE AS A PERCENTAGE OF OBERS PROJECTION	ACTUAL 1975 POPULATION
Colorado	1980	4,000	2,586,100	0.2	2,534,000
	1990	22,600	2,889,900	0.8	
	2000	97,400	3,134,100	3.1	
New Mexico	1980	24,800	1,054,900	2.4	1,147,000
	1990	20,900	1,131,200	1.8	
	2000	39,100	1,180,400	3.3	
Utah	1980	4,900	1,160,100	0.4	
	1990	2,900	1,309,600	0.2	
	2000	9,300	1,412,100	0.6	1,206,000
Montana	1980	15,300	669,700	2.3	748,000
	1990	51,100	664,500	7.6	
	2000	206,900	656,400	30.1	
North Dakota	1980	13,200	578,700	2.3	635,000
	1990	40,000	563,400	7.0	
	2000	175,300	545,200	32.1	
Wyoming	1980	14,400	330,900	4.3	374,000
	1990	40,500	334,000	12.1	
	2000	133,800	333,400	40.1	
Arizona[c]	1980		2,225,900		2,224,000
	1990		2,700,900		
	2000		3,065,500		
South Dakota[c]	1980		654,500		683,000
	1990		647,500		
	2000		637,000		

[a]Operation plus construction phases; from Table 11-29.

[b]Source: U.S., Department of Commerce, Bureau of Economic Analysis and Department of Agriculture, Economic Research Service. 1972 OBERS Projections: Economic Activity in the U.S., Vol. 4: States, for the U.S. Water Resources Council. Washington, D.C.: Government Printing Office, 1974.

[c]Arizona and South Dakota were not expected to be significantly impacted directly by the levels of energy development analyzed. See Section 11.1.

11.4.3 Economic Impacts

A. Personal Income

New income will be generated in the region because of job opportunities for both newcomers and current residents. Based on the population increases shown in Table 11-30 and income data for workers in communities with energy development,[1] changes to states' aggregate personal incomes and per capita income for the Low Demand case energy development can be estimated (Table 11-31).

According to these projections, energy development is expected to increase total income in the six-state area by about 16 percent[2] over the 25-year period, an absolute increase from $35.8 to $41.4 billion per year.[3] Further, most of the increase would occur during the 1990's, corresponding to the most intensive energy development. Thus, energy development alone would induce an annual growth rate of income of 1.06 percent during that decade.

On the state level, Wyoming would experience the greatest relative gain in aggregate personal income (+51.9 percent over the quarter-century), and Utah would experience the least (+1.4 percent). By the per capita measure, Montana would make the greatest absolute gain ($630 per year), and Utah would have the least ($30 per year).[4] The only change in rank order on the basis of per capita incomes will occur in the 1990's when Wyoming is expected to surpass Colorado.

These increases in per capita income would be due in large part to construction because construction labor generally is paid more than operational labor. In fact, in three states (North Dakota, Wyoming, and Colorado) current per capita incomes are higher than the average assumed for new operation workers and their families ($5,660). This is because of current construction and other high-wage occupations. High agricultural income in 1969,

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[1]Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 50.

[2]An annual growth rate of 0.5 percent (compound). This is in addition to income growth from other sources, such as productivity gains and national trends.

[3]The 1975 aggregate income value of $35.8 billion per year plus $5.6 billion expected increase by 2000 from Table 11-31 gives the total of $41.4 billion per year.

[4]Although not calculated here, South Dakota and Arizona will experience the least new energy development of the eight states studied and the smallest income gains from new energy developments.

TABLE 11-31: CHANGES IN ANNUAL PERSONAL INCOME, SIX WESTERN STATES, LOW DEMAND CASE ENERGY DEVELOPMENT[a]

STATE	ADDITIONS TO AGGREGATE INCOME ABOVE 1975 LEVELS (millions of 1975 dollars)				STATEWIDE PER CAPITA INCOMES[b] (constant 1975 dollars)				
	1980	1985	1990	2000	1974	1980	1985	1990	2000
Colorado	32	88	186	888	5,970	5,970	5,980	5,990	6,090
New Mexico	248	191	157	326	4,620	4,730	4,680	4,670	4,740
Utah	45	22	24	82	4,970	4,990	4,980	4,980	5,000
Montana	133	358	371	1,709	5,330	5,400	5,460	5,460	5,960
North Dakota	119	206	318	1,516	6,200	6,260	6,270	6,300	6,730
Wyoming	115	232	276	1,077	5,760	5,840	5,880	5,860	6,360
Six State Total	692	1,097	1,332	5,598					
Six State Average					5,475	5,530	5,540	5,540	5,810

[a]With the population projections as a base, our estimated error range for the income changes is an additional ±20 percent. National trends or competition for labor within the region could cause these income increases to be greater.

[b]These are per capita incomes; family or household incomes would be about three times these figures.

the year of census data collection, caused some problems with income comparisons. Thus, incomes in some areas may slip to about current levels when energy-related construction diminishes.

B. Current Economic Structure

The economic structures of the eight states vary considerably, with agriculture dominating in the Northern Great Plains and tourist-related service activities dominating in the Four Corners states (Table 11-32). Manufacturing activities are less important in the region than nationally, and federal government employment is greater. Although accounting for only a small proportion of income compared to other sectors, mining and energy development income is particularly important in Wyoming, New Mexico, Arizona, and Utah.

The energy resource areas within the region are also the areas with the greatest current agricultural activities.[1] This suggests that the land-use, water-use, employment, and income impacts of energy resource development will fall disproportionately on agriculture. However, employment impacts are difficult to predict since employment in agriculture has been declining. Furthermore, energy development may hold and/or bring back young people who have been moving out of the region, in addition to bringing new in-migration. Agricultural income has been increasing, although employment on farms is declining. The relative economic importance of agriculture is better indicated by total farm income (as shown in Table 11-32) than by employment trends.

C. Secondary Industrial Impacts[2]

There are two general types of secondary industrial effects from energy development: (1) the attraction of large industries directly linked to energy facilities, such as plants to process by-products of coal gasification plants; and (2) local and regional service industries that respond to population growth to serve residential and business customers.

Linked industries may be classified as upstream (or supplier firms) and downstream (or user firms). Upstream industries are those that supply inputs to an industry, such as equipment

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[1]Detailed breakdowns of income by industry and local area can be found in U.S., Department of Commerce, Bureau of Economic Analysis. "Local Area Personal Income." Survey of Current Business, Vol. 54 (May 1974, Part II), pp. 1-75.

[2]This discussion is taken in part from University of Denver Research Institute, Industrial Economics Division. Methodology Papers: Linked Industry. Denver, Colo.: University of Denver Research Institute, 1977.

TABLE 11-32: PERCENTAGE OF INCOME DERIVED FROM ECONOMIC SECTORS IN THE WESTERN REGION, 1972

SECTOR	U.S. AVERAGE	U.S. NONMETROPOLITAN AVERAGE	COLORADO	NEW MEXICO	UTAH	ARIZONA	MONTANA	NORTH DAKOTA	WYOMING	SOUTH DAKOTA
Farm	3.3	12.4	4.2	5.5	2.7	3.5	19.7	28.6	10.4	29.6
Federal Government Civilian	4.5	3.5	6.3	10.2	12.9	5.0	5.8	4.7	5.7	5.4
Federal Military	2.5	3.1	5.2	5.5	1.9	4.5	2.9	6.1	3.8	3.5
State and Local Government	11.0	12.4	11.0	15.7	12.0	12.3	11.9	11.0	14.4	12.1
Manufacturing	26.9	26.0	15.9	6.4	15.9	15.1	9.9	4.5	6.5	7.7
Mining	1.0	2.6	1.8	5.4	3.9	4.2	2.9	0.8	11.1	1.1
Contract Construction	6.3	5.7	8.7	7.7	7.2	4.6	6.8	7.3	9.6	10.7
Transportation, Communication, and Utilities	7.3	5.7	7.7	7.4	8.2	6.1	8.9	6.6	10.4	5.8
Wholesale and Retail	16.4	14.1	17.9	15.2	17.2	16.4	15.4	16.7	13.7	15.5
Finance, Insurance, and Real Estate	5.4	2.8	5.9	4.4	4.4	5.9	3.7	3.4	3.3	3.5
Services	15.1	11.2	14.9	16.3	13.3	16.0	11.7	9.9	10.5	10.6
Other	0.3	0.6	0.3	0.3	0.2	0.4	0.3	0.4	0.3	0.4

Source: U.S., Department of Commerce, Bureau of Economic Analysis. "Local Area Personal Income." Survey of Current Business, Vol. 54 (May 1974, Part II), pp. 1-75; and U.S., Department of Commerce, Bureau of Economic Analysis. "Personal Income by Major Sources, 1971-73." Survey of Current Business, Vol. 55 (August 1974), pp. 38-41.

uppliers and manufacturers, machine shops, and electric power suppliers.[1] Downstream industries include intermediate processors (such as producers of intermediate petrochemical products and electrolytically processed metals) and end producers, such as plastic products.

(1) Supplier or Upstream Industries

Supplier industries are easily identified on an aggregate national basis in input-output tables, such as those published by the U.S. Department of Commerce[2] and the data embodied in the SEAS.[3] However, both of these provide only national perspectives, not regional ones. The national data reflect aggregate linkages among industries, and effects on particular industries will be felt only in locations where those industries are present. Available models include only current or historical data, which emphasize large industrial cities and deemphasize the potential effects on western urban areas. Where a wide industry mix already exists, it is more likely that industries will see an increase in production from major needs, such as steel, arising from anywhere in the country. This is why Birmingham, Pittsburgh, and Duluth are the three metropolitan areas projected to be most affected by increased western energy development.[4] In general, urban areas in the West (including Albuquerque, Billings, Denver, and Salt Lake City) receive a much smaller effect of secondary industrial development than do urban areas in the northeast or West Coast (e.g., Chicago, Detroit, Pittsburgh, Cleveland, and Los Angeles).[5] Although past trends cannot be expected to continue completely, it is still certain that the bulk of industrial expansion attributable to energy development will take place in existing or growing industrial complexes. Of western cities, the Salt Lake City area

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[1] Some projections of input needs and impacts on producing industries and regions are included in Section 11.4.8.

[2] U.S., Department of Commerce. Input/Output Structure of the U.S. Economy, 1967. Washington, D.C.: Government Printing Office, 1973.

[3] SEAS is summarized and applied to the western energy context in White, Irvin L., et al. Energy From the West: A Progress Report of a Technology Assessment of Western Energy Resource Development. Washington, D.C.: U.S., Environmental Protection Agency, 1977, Vol. II, pp. 828-38 and in Section 11.4.8 below.

[4] Ibid., Vol. II, p. 837.

[5] Control Data Corporation and International Research and Technology Corporation. Scenario Run Analysis: Western Energy Development. Washington, D.C.: U.S., Environmental Protection Agency, Technical Information Division, 1977.

contains the industry mix in steel and nonferrous metals most likely to be affected.[1]

(2) User or Downstream Industries

User industries are rarely, if ever, included in development plans for energy facilities, and information for an adequate impact analysis is virtually nonexistent. One reason for this may be the uncertainty associated with the magnitude, duration, and timing of linked industry development. Downstream industries may not have an adequate market even though their potential inputs may be assured by energy facility by-products. Trade-off decisions must be made between transport costs and relocation costs by linked industry firms established in other locations. In addition, the life of the energy resource at a location or within an area may be difficult to predict.[2]

For some energy projects, the by-products from processing an energy resource, and other minerals occurring in a resource area, are easily identified. Coal gasification by the Lurgi process produces six major by-products in substantial quantities (Table 11-33). These by-products can be processed near the plant site if the volume produced provides a sufficiently reliable source of raw material to processing industries. A minimum of three to four Lurgi plants is currently considered adequate to attract firms that would use the by-products. Otherwise, the by-products would be transported out of the area to purchasing firms.[3]

Oil shale development involves by-products both from mining and from retorting. Other minerals such as dawsonite and nahcolite occur interspersed with oil shale and can be extracted from lateral shafts. Dawsonite is a source of alumina that can compete with foreign bauxite for the aluminum industry. Nahcolite is naturally occurring sodium bicarbonate (baking soda), which has several commercial uses including use as an FGD agent. The baking soda alternative for FGD is not feasible without a nahcolite source because industrially refined baking soda is prohibitively expensive. The possibilities of multimineral mining, including other minerals along with oil shale in western Colorado, improve the economic

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[1]Control Data Corporation and International Research and Technology Corporation. Scenario Run Analysis: Western Energy Development. Washington, D.C.: U.S., Environmental Protection Agency, Technical Information Division, 1977.

[2]University of Denver Research Institute, Industrial Economics Division. Methodology Papers: Linked Industry. Denver, Colo.: University of Denver Research Institute, 1977, pp. 2-3.

[3]Morrison-Knudsen Company. Navajo New Town Feasibility Overview. Boise, Idaho: Morrison-Knudsen, 1975.

TABLE 11-33: SALABLE BY-PRODUCTS FROM LURGI COAL GASIFICATION (tons per year)[a]

BY-PRODUCT	QUANTITY PRODUCED
Sulfur	67,230
Crude Phenols	33,870
Naphtha	104,940
Tar Oils[b]	176,290
Tar	246,680
Anhydrous Ammonia	68,410

Source: U.S., Department of the Interior, Bureau of Reclamation. Western Gasification Company (WESCO) Coal Gasification Project and Expansion of Navajo Mine by Utah International Inc., San Juan County, New Mexico: Final Environmental Impact Statement, 2 vols. Salt Lake City, Utah: Bureau of Reclamation, 1976.

[a]Based on 7,970 hours/year of a 250 million standard cubic feet per day plant.

[b]Does not include in-plant usage.

viability of oil shale.[1] Flue gas cleaning using baking soda may also allow sulfur to be produced as a by-product from power plants at a cost much lower than current sulfur production.[2]

Oil shale surface retorting produces coke, low British thermal unit (Btu) gas, ammonia, and sulfur. The low-Btu gas can be expected to be used in the oil shale facilities.[3] The remaining by-products could be sold to firms that need them as inputs, although the products are likely to be transported out of the region to existing processing plants until supplies become great enough in an area to attract investment in a plant there. The value of

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[1]Strabala, Bill. "Colorado Nahcolite Venture Planned." Denver Post, October 10, 1976; Strabala, Bill. "Oil Shale Mine to Test Multimineral Leasing Plan." Denver Post, July 3, 1977.

[2]"A Growing Squeeze on Sulfur." Business Week, August 22, 1977, pp. 64-65.

[3]Just, J., et al. New Energy Technology Coefficients and Dynamic Energy Models. McLean, Va.: MITRE Corporation, 1975, Vol. 1, p. 57.

these products from a 50,000 bbl/day plant annually is about $5.6 million (1975 dollars).[1]

(3) Service Industries

More local secondary effects are virtually impossible to predict with locational and temporal accuracy. These industries include machine shops, supply houses, machinery parts dealers, accounting firms, and other businesses that are needed to serve some needs of energy developers. A major difficulty in projections is the trend among many developers and construction contractors to provide most or all of these services for themselves. It is extremely difficult to predict when enough firms would be present in an area to create the need for a single, lower-cost, specialized entrepreneur in these businesses. This is most probable in larger cities, such as Casper and Grand Junction, where the business market in the area is larger.

A second type of service industry is wholesale and retail trade, which is related to population growth but has strong tendencies to concentrate in large cities. Although the retail sector grows along with population in any small town, a significant fraction of retail expansion takes place in larger cities, and nearly all wholesale activities are located there. Large cities serve as market centers for large regions, and are less affected by the cyclical population changes in any small town. As a town grows, it adds new businesses of a higher-order nature, but a larger city acquires more businesses from growth anywhere in an extended market area. There is a fairly consistent progression of businesses related to population size that could be expected to be replicated in the West.[2] These range, for example, from service stations to drugstores to furniture stores and reflect the available population in the town's market area.

Some market center relationships in the West will probably change as a result of energy development, such as Gillette becoming more important than Sheridan as a retail center in northern Wyoming. However, the largest absolute service growth will tend to concentrate in existing large centers. This growth is of a cumulative nature and merely causes more growth as a result.[3]

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[1]Just, J., et al. New Energy Technology Coefficients and Dynamic Energy Models. McLean, Va.: MITRE Corporation, 1975, Vol. 2, p. 139, updated to 1975 dollars.

[2]Berry, B.J.L. The Geography of Market Centers and Retail Distribution. Englewood Cliffs, N.J.: Prentice-Hall, 1967.

[3]Pred, A.R. City-Systems in Advanced Economies. New York, N.Y.: Wiley, 1977.

D. Local Inflation

Price levels have always been somewhat higher in sparsely settled areas for two primary reasons: transportation costs from places of manufacture, and lack of competition in small towns. The only items with consistently lower prices tend to be those produced locally, such as meat in most western locations.

When isolated towns "boom", the demand for goods and services increases, and prices rise, and/or shortages occur. In recent western boomtowns, residents have expressed dissatisfaction with the availability of certain items more often than others; especially housing, land, and professional and retail services.[1] Employers have also experienced a general shortage of labor. However, the retailing sector tends to respond quickly and, in fact, local consumers eventually have access to a greater variety of goods when larger, more specialized stores are built.

Boomtown inflation affects different people in various ways. Generally, inflation will benefit sellers and increase costs for buyers. For example, landowners will benefit if they sell, but renters will suffer from higher rents. Depending on methods of property taxation, landowners must pay taxes with higher assessed valuations on their holdings. In the local labor market, employers will suffer from increased wages while workers will benefit. Increased wages will usually more than compensate for increased prices, but some people, especially retirees, may not be in a position to take advantage of the improved employment conditions. Retirees also are adversely affected by property tax increases, and in some areas many have been forced to sell their homes.

Local government also acts as a participant in the local economy. As a buyer, it mainly purchases labor and must compete with the energy developers. Since most taxes are based on property assessments, revenues will eventually rise with the general pace of inflation. However, assessments are often out of date; thus, revenues may lag behind local governmental expenditures.[2] Permanent increases in tax rates should not be necessary. In fact, rates can be expected to decline for some county governments after tax revenues begin to outpace needs.

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[1]Moutain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976.

[2]Fiscal impacts on local government are considered in more detail in the social and economic section of Chapters 4-9.

11.4.4 Public Services

A. Expenditures

Much of the development of energy resources in the West will occur in sparsely populated areas. Some communities of less than 5,000 people will increase their populations many times over. Thus, large investments in public facilities will be required, and operating expenses will be much higher than before the boom. Public investments at the local level will be devoted largely to water supply, sewage treatment, and school buildings (Table 11-34).[1] Altogether the Low Demand case level of development would necessitate local capital expenditures of about $1.35 billion by the end of the century, most of this between 1990 and 2000, when the annual rate of new investment is expected to reach $90 million (almost 4 times the 1975-1980 annual requirement). This pattern is expected to hold for all the states in the study area but is most extreme in Montana and North Dakota. Although Table 11-34 shows expenditure needs only for operation-phase population, the additional amounts for construction employees and their families can be seen in the relative sizes of the populations in Table 11-30. Full cost figures were not calculated because temporary facilities for construction are often chosen at a lower cost to communities.

Local governments will also have to increase their operating budgets by a total of $344 million annually by the year 2000 (Table 11-35), with school districts accounting for about 75 percent of the increase. As with capital costs, the operating costs in the 1990's will mushroom the most in energy areas of Montana, North Dakota, and Wyoming.

State government expenditures will also increase as populations rise (Table 11-36). Again, the greatest increases will be in the Northern Great Plains states, which account for 78 percent of the estimated expenditures for the region by the year 2000. By the year 2000, annual local operating expenditures are expected to be $344.2 million; new state annual expenditures will be $571.3 million; and the total capital expenses for the 25-year period are $1,353.2 million.

B. Revenues

If state governments tax individuals at current rates and also incur current per capita costs, new energy developments can always be expected to provide a net surplus. This is because new revenue from conventional sources (mainly income and excise taxes)

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[1] To facilitate comparisons among the states, consistent per capita figures were used in the calculations, even though expenditure levels actually vary from state to state and community to community.

TABLE 11-34: LOCAL CAPITAL EXPENDITURE NEEDS FOR LOW DEMAND CASE ENERGY DEVELOPMENT, 1975-2000 (in millions of 1975 dollars)

STATE	PERIOD	WATER AND SEWER	SCHOOLS	OTHER	TOTAL
Colorado	1975-1980	6.3	1.8	2.1	10.2
	1980-1985	10.0	2.8	3.4	16.2
	1985-1990	16.5	4.7	5.6	26.8
	1990-2000	86.4	24.6	29.0	140.0
	1975-2000	119.2	33.9	40.1	193.2
New Mexico	1975-1980	21.3	6.1	7.1	34.5
	1980-1985	17.2	4.9	5.8	27.9
	1985-1990	0	0	0	0
	1990-2000	24.3	6.9	8.2	39.4
	1975-2000	62.8	17.9	21.1	101.8
Utah	1975-1980	3.9	1.1	1.3	6.3
	1980-1985	1.2	0.4	0.4	2.0
	1985-1990	0	0	0	0
	1990-2000	4.0	1.2	1.4	6.6
	1975-2000	9.1	2.7	3.1	14.9
Montana	1975-1980	18.3	5.2	6.1	29.6
	1980-1985	48.8	13.9	16.4	79.1
	1985-1990	19.0	5.4	6.4	30.8
	1990-2000	176.9	50.2	59.4	286.5
	1975-2000	263.0	74.7	88.3	426.0
North Dakota	1975-1980	12.3	3.5	4.1	19.9
	1980-1985	21.1	6.0	7.1	34.2
	1985-1990	19.5	5.6	6.6	31.7
	1990-2000	147.5	41.9	49.5	238.9
	1975-2000	200.4	57.0	67.3	324.7
Wyoming	1975-1980	17.1	4.9	5.7	27.7
	1980-1985	30.4	8.7	10.2	49.3
	1985-1990	16.7	4.8	5.6	27.1
	1990-2000	116.3	33.1	39.1	118.5
	1975-2000	180.5	51.5	60.6	292.6
Six State Total	1975-1980	79.2	22.6	26.4	128.2
	1980-1985	128.7	36.7	43.3	208.7
	1985-1990	71.7	20.5	24.2	116.4
	1990-2000	555.4	157.9	186.6	899.9
	1975-2000	835.0	237.7	280.5	1353.2

Source: Based on energy operation population increases in Table 11-34 and data in THK Associates, Inc. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, p. 30, inflated to 1975 dollars. Water and sewage plant expenditures are \$1.76 million per 1,000 additional population. School capital costs are \$2500 per pupil, where school enrollment is assumed to be 20 percent of the new population. Other costs amount to \$591,000 per 1,000 population. School capital costs are taken from Froomkin, Joseph, J.R. Endriss, and R.W. Stump. Population, Enrollment and Costs of Elementary and Secondary Education 1975-76 and 1980-81, Report to the President's Commission on School Finance. Washington, D.C.: Government Printing Office, 1971.

TABLE 11-35: ANNUAL ADDITIONAL OPERATING EXPENDITURES OF LOCAL GOVERNMENTS IN SIX WESTERN STATES, 1980-2000, FOR LOW DEMAND ENERGY DEVELOPMENT
(in millions of 1975 dollars)

STATE	YEAR	COUNTY AND MUNICIPAL	SCHOOL	TOTAL
Colorado	1980	0.5	1.6	2.1
	1985	1.2	4.0	5.2
	1990	2.7	9.0	11.7
	2000	11.7	39.0	50.7
New Mexico	1980	3.0	9.9	12.9
	1985	3.0	10.0	13.0
	1990	2.5	8.4	10.9
	2000	4.7	15.6	20.3
Utah	1980	0.6	2.0	2.6
	1985	0.3	1.2	1.5
	1990	0.3	1.2	1.5
	2000	1.1	3.7	4.8
Montana	1980	1.8	6.1	7.9
	1985	5.7	19.0	24.7
	1990	6.1	20.4	26.5
	2000	24.8	82.8	107.6
North Dakota	1980	1.6	5.3	6.9
	1985	3.0	10.2	13.2
	1990	4.8	16.0	20.8
	2000	21.0	70.1	91.1
Wyoming	1980	1.7	5.8	7.5
	1985	3.8	12.8	16.6
	1990	4.9	16.2	21.1
	2000	16.1	53.6	69.7
Six State Total	1980	9.2	30.7	39.9
	1985	17.0	57.2	74.2
	1990	21.3	71.2	92.5
	2000	79.4	264.8	344.2

Source: Based on energy construction and operation population increases in Table 11-29 and data in THK Associates, Inc. Impact Analysis and Development Patterns Related to an Oil Shale Industry: Regional Development and Land Use Study. Denver, Colo.: THK Associates, 1974, p. 30. The per capita figure used is $120 (1975 dollars). School operating costs used are $2,000 per pupil (which is an average figure that varies considerably among school districts). School enrollment is assumed to be 20 percent of the new population.

TABLE 11-36: NEW ANNUAL EXPENDITURES, CAPITAL AND OPERATING, OF STATE GOVERNMENTS, 1980-2000, LOW DEMAND ENERGY DEVELOPMENT
(millions of 1975 dollars)

STATE	1980		1985		1990		2000	
	TOTAL	CONSTRUCTION RELATED	TOTAL	CONSTRUCTION RELATED	TOTAL	CONSTRUCTION RELATED	TOTAL	CONSTRUCTION RELATED
Colorado	3.5	3.1	8.5	0.5	19.5	3.4	84.1	25.5
New Mexico	21.4	11.0	21.9	3.0	18.0	0.7	33.7	2.9
Utah	4.2	2.3	2.5	0	2.5	0	8.0	3.5
Montana	13.2	4.2	41.0	8.1	44.1	1.9	178.6	49.6
North Dakota	11.4	5.4	21.9	5.5	34.5	8.5	151.3	53.0
Wyoming	14.4	4.1	27.5	4.2	35.0	3.5	115.6	27.0
Six State Total	68.1	30.1	123.3	21.3	153.6	18.0	571.3	161.5

Source: Based on population increases in Table 11-29 and average expenditure level of $863 per capita, as reported in U.S., Department of Commerce, Bureau of the Census. The Statistical Abstract of the United States. Washington, D.C.: Government Printing Office, 1976, Table 429.

approximately balance new costs, while additional revenues will be available from special energy taxes.

The principal taxes currently levied on energy production and conversion are summarized in Table 11-37, along with current (1975) property tax rates. Applying these rates to the projected numbers of facilities in each state in the Low Demand case gives an estimate of energy-derived revenues (not counting conventional sources such as personal income taxes) for the years 1980, 1990, and 2000 (Table 11-38).

In the long run, most state and local governments can be expected to derive more funds from new revenues than they expend on new costs. The problem is one of timing and distribution, as emphasized throughout the reports of this project.[1] If states do not distribute revenues to local governments, or if impacted localities do not receive property tax benefits, then the overall surplus of funds becomes meaningless at the local level.

Finally, Montana stands out from the other states in having a particularly large surplus. In fact, of the $2.95 billion likely to be collected in the six-state region, fully $1.32 billion is expected to be generated within Montana. Most of this will come from the 30 percent coal mine severance tax, which is much higher than rates in any other state.

11.4.5 Social and Cultural Effects

Agriculture and agricultural interests presently dominate much of the eight-state area. The setting in the resource-rich parts of the region is primarily rural, with any urban population being limited to small towns. Local lifestyles and cultures associated with this western setting are likely to be changed by circumstances related to energy development, particularly where oldtimers (i.e., native westerners) perceive themselves as being outnumbered by newcomers who hold different values and have different interests.[2] Over time, the values and attitudes of the newcomers to the area could become dominant. The impact of projected large population shifts is especially acute when distinctive

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[1]White, Irvin L., et al. Energy From the West: Policy Analysis Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming, Chapters 8 and 9; White, Irvin L., et al. Energy From the West: A Progress Report of a Technology Assessment of Western Energy Resource Development. Washington, D.C.: U.S., Environmental Protection Agency, 1977, Chapter 3.

[2]Corless, C.F., and B. Jones. "The Sociological Analysis of Boom Towns." Western Sociological Review, Vol. 8 (1977), pp. 76-90.

TABLE 11-37: STATE MINERAL SEVERANCE TAXES, PROPERTY TAXES, AND ENERGY CONVERSION TAXES (percentages)

	COAL[a]	GAS AND OIL	URANIUM	SHALE OIL	EFFECTIVE PROPERTY TAX RATE	ENERGY CONVERSION TAX
Colorado	7.2[b]	5.0[c]	2.5[c]	4.0	1.37	0
Montana	30.0[b]	2.65[b,e]	–[d]		1.19	0
New Mexico	4.6[b]	4.9[c]	5.0[b]		1.21	$.0004[f]
North Dakota	11.3[b]	5.0	–[d]		1.48	$.00025; $.10[g]
Utah	0.0	2.0	1.0		1.82	
Wyoming	10.5[h]	4.0	5.5		1.52	

Source: Bronder, Leonard D. Severance Tax Comparisons Among WGREPO States, Staff Analysis No. 77-28. Denver, Colo.: Western Governors' Regional Energy Policy Office, June 1977.

[a] Surface-mined.

[b] Law written in cents per unit. Values of resources assumed here of: $8.33/ton for coal in Four Corners States; $5.73/ton for coal in Northern Great Plains; $1.45/thousand cubic feet for gas; $9.15/barrel for oil; $40/lb. for uranium (yellowcake).

[c] Before property tax credits.

[d] No taxable production in 1977.

[e] 3.4 percent effective rate for gas.

[f] 0.4 mills per kilowatt hour (kWh) of electricity generated.

[g] 0.25 mills per kWh of electricity; $.10 per thousand cubic feet of synthetic gas.

[h] Reverts to 8.5 percent after the 2 percent special levy has accumulated to $160 million (probably around 1993).

TABLE 11-38: ANNUAL ENERGY TAX AND PROPERTY TAX REVENUES IN SIX WESTERN STATES, 1980-2000 (millions of 1975 dollars)

STATE	YEAR	SEVERANCE TAXES	PROPERTY TAXES[a]	ENERGY CONVERSION TAXES[b]	COAL ROYALTIES[b]	TOTAL
Colorado	1980	6.0	3.1		5.2	14.3
	1990	38.6	23.3		12.9	74.8
	2000	127.0	85.0		12.9	224.9
New Mexico	1980	264.6	4.9			269.5
	1990	269.8	10.0	7.4		287.2
	2000	241.0	50.7	7.4		299.1
Utah	1980	0	23.3		3.5	26.8
	1990	0	23.3		3.5	26.8
	2000	3.2	23.8		3.5	30.5
Montana	1980	103.1	32.3		21.1	156.5
	1990	386.8	110.8		79.3	576.9
	2000	902.5	230.8		185.0	1318.3
North Dakota	1980	19.4	11.5	9.2		40.1
	1990	64.7	38.2	36.4		138.3
	2000	216.9	127.9	144.6		489.4
Wyoming	1980	52.1	39.7		17.6	109.4
	1990	125.0	105.9		31.7	262.6
	2000	262.3	288.0		42.3	592.6
Six State Total	1980	455.2	114.8	9.2	47.4	616.6
	1990	884.9	311.5	43.8	127.4	1367.6
	2000	1752.9	806.2	152.0	243.7	2954.8

[a]Most property taxes go to local governments.

[b]Indian nations will also receive revenues from any energy conversion taxes they have imposed and for any minerals mined within their boundaries.

ethnic and/or religious groups are involved, such as Indians, Mexican-Americans, and Mormons.

Many of these impacts can be discussed within the context of social and cultural effects, or what is generally termed the "quality of life" under the more general rubric of the "human environment." Many of the attributes commonly included under quality of life reflect the adequacy of public and private services. In the area of public services, the ability of local governments to manage population growth and its effects is a critical element. Federal, regional, and state action will be necessary in most parts of the West to reduce or prevent adverse effects on people's lives. Private services, including housing, medical care, and retail goods and services, also tend to be in short supply during rapid population growth. Some towns in the West will experience inadequacies in these areas as energy development proceeds.[1]

Medical care is an area of particular concern in the rural West, which, like most rural areas in the U.S., is chronically short of physicians. The permanent population increases expected in the West (those associated with energy facility operation) will require a total of 678 doctors by 2000 (Table 11-39). Construction-related population could add 268 doctors to this need, or a total of 946. It has tended to be difficult to attract doctors to small towns and rural areas such as those which will be affected by energy resource development in the West. In most energy areas, active policies will be needed to attract doctors away from metropolitan centers to small western towns.[2]

Since a substantial number of energy development-related impacts on individuals' lives are viewed as being negative, such developments can ultimately lead to a lowering of the overall quality of life.[3] For instance, in many areas of the West, about half the current housing consists of mobile homes, and this trend will probably continue. Indications are that dissatisfaction with mobile home living will increase in conjunction with feelings of social segregation experienced by some construction workers and their families. The tension and stress precipitated by value and

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[1]For an elaboration of these issues, see Chapter 8 "Housing," and Chapter 9 "Growth Management," in White, Irvin L., et al. Energy From the West: Policy Analysis Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[2]On this point, see Ibid., Chapter 9; and Coleman, Sinclair. Physician Distribution and Rural Access to Medical Services, R-1887-HEW. Santa Monica, Calif.: Rand Corporation, 1976.

[3]Gilmore, John S. "Boom Towns May Hinder Energy Resource Development." Science, Vol. 191 (February 13, 1976), pp. 535-40.

TABLE 11-39: INCREASED NUMBER OF DOCTORS NEEDED IN WESTERN STATES BY YEAR 2000, LOW DEMAND CASE[a]

STATE	NUMBER OF DOCTORS NEEDED
Colorado	97
New Mexico	51
Utah	7
Montana	213
North Dakota	163
Wyoming	147
Total	678

Source: Based on operation-related population increases (Table 11-29) and an average ratio of one doctor per 700 people, which is approximately the U.S. average.

lifestyle conflicts between long-time residents and newcomers must also be taken into account.[1]

The quality of life depends on the reactions of people to their problems as well as on the problems themselves. Thus, more than any other factor in western energy development, quality of life is largely unaffected by mitigating measures from outside sources. Local activity, planning, and cooperation are among the most influential factors that can improve the quality of life in energy-impact areas.

11.4.6 Political Impacts

Although the relative population increases projected for the region are not large (approximately 7 percent by 2000 in the Low Demand case), population growth in some states is substantial and will probably result in political changes. The populations of Montana, North Dakota, and Wyoming particularly will increase from 20 to 27 percent (Table 11-29). If the partisan preferences of newcomers to the region differ substantially from those of the

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[1]These conflicts are elaborated in University of Montana, Institute for Social Science Research. A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming. Missoula, Mont.: Institute for Social Science Research, 1974.

natives, the partisan character of the entire region may shift.[1] Similarly, if the influx of newcomers changes the demographic composition of the region, the level of political participation may change as well.

The impact of construction workers on the region will differ substantially from that of operation and maintenance personnel. Construction workers will have the most immediate effect on the region. They will strain the medical, housing, recreation, and service facilities of the individual communities in the site area, which may call on the state and federal government for assistance. However, since the majority of construction workers are temporary residents and many currently live in the region,[2] they will probably not have any lasting political impact.

Operation and maintenance personnel will follow the construction workers and will have a more definite political impact because they will reside in the region on a long-term basis. Selected characteristics of the operation and maintenance workers can be summarized from the reports on individual energy production/conversion sites as follows: they are highly skilled in the technical and managerial fields needed to operate the energy production facilities; their income is above the median level for all individuals; and they are mostly between 30 and 60 years of age. These characteristics are important in assessing the political impact of energy development because they are generally associated with a high level of involvement in politics.[3] Thus, operation workers are more likely to become involved in community affairs than other groups. They will seek offices in the local government and in school, church, and civic groups. If successful, these individuals are likely to use their leadership roles to guide the community's development according to their own values and priorities.

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[1] Bone, Hugh A., and Austin Ranney. Politics and Voters. New York, N.Y.: McGraw-Hill, 1976; Campbell, Angus, et al. The American Voter. New York, N.Y.: Wiley, 1960, pp. 37-38. Historically, interregional migration has shifted the partisan loyalties of the western United States from heavily Democratic to bipartisan.

[2] Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976.

[3] Lipset, Seymour Martin. Political Man. Garden City, N.Y.: Doubleday, 1960, p. 184; see also Pomper, Gerald. Voters' Choice. New York, N.Y.: Dodd Mead, 1975, Chapter 3; Flanigan, William H. Political Behavior of the American Electorate, 2nd ed. Boston, Mass.: Allyn and Bacon, 1972.

11.4.7 Energy-Related Economic Growth Impacts

The SEAS[1] model was used to analyze some of the macroeconomic impacts of expanded energy development. The SEAS model includes a Nominal Clean, Nominal Dirty, and Low Growth scenario. Energy production projected in the SEAS Nominal scenarios and in the Low Growth scenario is similar to that projected by the SRI model and used throughout most of this chapter. The principal difference is in oil shale projections which are 4.2 million bbl/day by 2000 in the SEAS Nominal cases but only 2.5 million bbl/day in the SRI Nominal case. The difference between the SEAS Nominal Clean and Nominal Dirty scenarios is in compliance dates for pollution control. These differences are given as needed in this section in order to interpret the information generated by the SEAS model.

Using these scenarios, the industries which are expected to be affected the most by western energy development were identified, and their projected growth rates were compared to those projected for nonenergy related industries. In addition, the macroeconomic impacts of two levels of environmental control were analyzed by comparing growth rates projected by the Nominal Clean and Nominal Dirty scenarios.

A. Growth in Industries Related to Energy Development

SEAS disaggregates the national economy into 176 industrial sectors. Industries related to western energy development were identified using an empirical criterion: those industries in which the output for the Nominal Growth case was at least 1 percent greater than the Low Growth case as of 1995 were assumed to be western energy related; that is, they sell a significant portion of their output to firms involved in western energy development. Based on this empirical criterion, of the 176 industrial sectors considered, 76, or 43 percent were identified as western energy related.

Using the Nominal Clean scenario, the nation's 25 fastest growing industries (including both energy and nonenergy related industries) were analyzed in order to identify whether or not their growth was due to or accelerated by western energy development. Table 11-40 lists the 25 fastest growing industries for three time frames. In the 1975 to 1980 period, 8 of the 25 are western energy related and 17 are unrelated to western energy; in the 1980 to 1990 and 1990 to 2000 time frames, 9 are western energy related and 16 are not.

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[1]U.S., Environmental Protection Agency, Technology Assessment Modeling Project (TAMP). <u>A Description of the SEAS Model</u>, Project Officer Dr. Richard Ball. Washington, D.C.: Environmental Protection Agency, 1977. (Unpublished report.)

TABLE 11-40: THE TWENTY-FIVE FASTEST GROWING INDUSTRIAL SECTORS IN THREE TIME FRAMES: COMPARISON OF GROWTH FOR ENERGY-RELATED AND NONENERGY RELATED SECTORS[a]

WESTERN ENERGY RELATED	PERCENT GROWTH			NOT WESTERN ENERGY RELATED	PERCENT GROWTH		
	1975-1980	1980-1990	1990-2000		1975-1980	1980-1990	1990-2000
Plastics	87.0	97.4		Jewelry and Silverware	86.9		50.5
Electrical Measuring Instruments	84.7	110.1	84.7	Agricultural Services	74.5	70.5	
Computers	62.1		67.7	Medical Instruments	72.9	82.1	54.7
Pulp Mills	61.2	97.6		Knitting	70.1		
Electronic Components	55.2	79.4	68.2	Drugs	70.1	113.2	52.9
Industrial Chemicals	51.6			Photographic Equipment	65.1	96.5	56.6
Other Metal Working	50.9			Floor Coverings	62.9		
Chemical Fertilizer Mining	49.6			Paper Mills	59.9	71.7	
Aircraft		74.6		Timepieces	57.3		51.2
Service Industry Machinery		73.0		Miscellaneous Plastic Products	52.0	82.6	
Aluminum		71.6		Noncellulosic Fibers	51.5		
Pipelines		71.4		Finance	51.4	72.3	
Machine Shops		69.7		Paperboard Containers	48.2		
Coal Mining			112.2	Telephone Services	46.8	91.1	63.1
Nonferrous Forging			71.3	Household Furniture	46.4		
Lead			70.4	Cement, Concrete, Gypsum	45.9		
Other Electrical Equipment			56.1	Cellulosic Fibers	45.7		
Engines and Turbines			52.8	Phonograph Records		115.1	51.7
Motors and Generators			51.6	Batteries		99.1	131.3
				Other Transportation Equipment		86.7	50.3
				Medical Services		79.2	52.4
				Business Forms		77.6	51.1
				Trailer Coaches		74.5	
				Hotels		74.3	
				Airlines		72.0	
				Communication Equipment			60.3
				Canned and Frozen Foods			54.5
				Business and Local Transit			53.6
				Other Leather Products			53.1
				Engine Electrical Equipment			50.1
Number of Industries	8	9	9		17	17	16

[a]From Strategic Environmental Assessment System: Nominal Clean Scenario.

Growth rates between energy related and nonenergy related sectors are not significantly different. In none of the three time frames are the energy-related sectors overrepresented among the fastest growing sectors. Random distribution would have put an average of 10 energy-related sectors in the fastest growing group in each time frame. It thus seems that other influences (such as demographic change) will have stronger effects on the economy than does western energy development.

However, some other trends indicated by the data on Table 11-40 do suggest that energy development eventually becomes a significant growth stimulus. For example, four of the five fastest growing industries by 2000 are energy related (electrical measuring instruments, coal mining, nonferrous forging, and lead). Moreover, batteries, the one nonenergy related industry that is part of the five fastest growing industries, is indirectly energy-related. That is, electrification is expected to be the major mode of utilizing coal resources, at least until such time as synthetic fuel industries mature. Growth of the battery and lead industries reflects, in particular, a projected penetration of 7.5 percent of the national auto fleet by electric cars by 2000.

B. Impacts of Environmental Controls

Given any particular level of energy development, alternative levels of pollution abatement expenditures can affect the growth rates of various industries. The SEAS model was used to compare economic growth rates projected for two versions of the Nominal growth scenario: one with strict environmental controls ("Nominal Clean") and one with lax controls ("Nominal Dirty"). The environmental compliance dates assumed in the SEAS scenarios are given in Figure 11-14. Some economic trends at the national level are given first, followed by trends in the eight-state study area.[1]

(1) Impacts at the National Level

In most respects the economy shows a greater pace of activity in the Nominal Clean scenario than in the Nominal Dirty scenario. Among macroeconomic variables, this is most evident in capital equipment investment which is 3.6 percent greater in 1990 in the Clean scenario than in the Dirty scenario. However, after 1990 the situation reverses and total investment becomes less in the Clean scenario than in the Dirty scenario. Industries which were induced to build new plants before 1990 in order to meet (or beat) tight regulations then reduce their rate of investment.

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[1] The SEAS model cannot precisely be disaggregated to the eight-state region but because the nature of existing industries in that region is known, the impacts on those industries can be estimated.

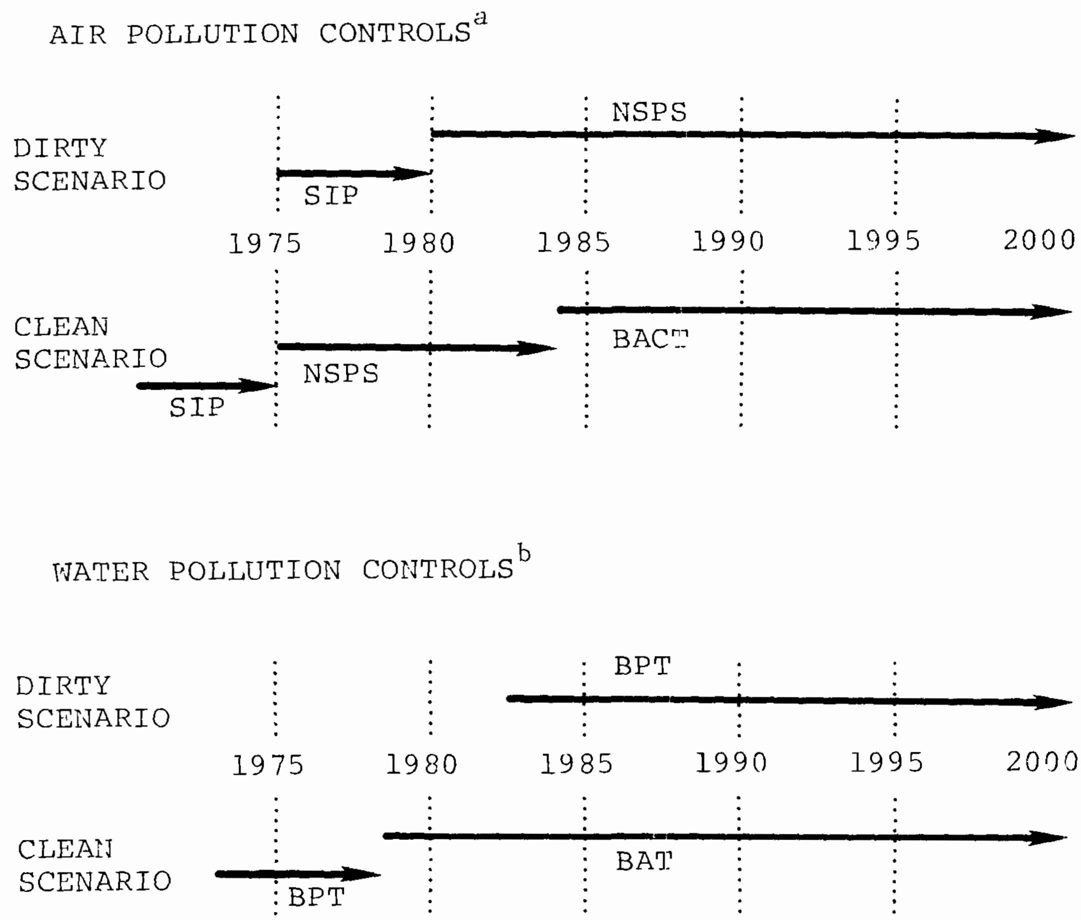

FIGURE 11-14: ENVIRONMENTAL COMPLIANCE DATES ASSUMED IN STRATEGIC ENVIRONMENTAL ASSESSMENT SYSTEMS SCENARIOS

NSPS = New Source Performance Standards
SIP = state implementation plans
BACT = best available control technology
BPT = best practicable technology
BAT = best available technology

[a] Refers to plants in operation as of 1975; newly built plants must meet BAT standards under both scenarios.

[b] Refers to plants beginning construction as of given date.

In addition, a significant difference between expenditures in the Nominal Clean and Nominal Dirty scenarios occurs in the late 1970's due to expenditures for water treatment. Investments in the 1970's are quite sensitive to compliance dates for Best Practicable Treatment (BPT) of water and to the preparation of industry and municipalities for Best Available Technology (BAT). BAT is assumed in the Nominal Clean scenario but not in the Nominal Dirty scenario (Figure 11-14). The 1980's bulge in water treatment expenditures is shown in Figure 11-15. Expenditures for water systems are $7.1 billion (1971 dollars) in the Nominal Clean scenario and $4.7 billion in the Nominal Dirty scenario in 1980, while by 1990, expenditures under both scenarios are $4.0 billion. In the case of sewer systems, expenditures in 1975 were estimated at $5 billion (Nominal Dirty) and 7.4 billion (Nominal Clean), increase to about $7.7 billion in 1980, and subsequently decrease to $4.3 billion by 1985 under both scenarios.

For 1980, the industrial sectors which show the largest difference in output between the Nominal Clean and Nominal Dirty scenarios are listed in Table 11-41. These include equipment manufacturing industries and industries which supply them with materials and services. While total output for all industrial sectors is only 0.65 percent greater in the Clean scenario than in the Dirty scenario, output for the auto manufacturing and repair industries is 6.82 percent and 4.94 percent greater (respectively) in the Clean than in the Dirty scenario (Table 11-41). This indicates that auto emission standards[1] will probably have greater economic impacts than will controls on stationary air pollution sources. Other strongly affected sectors shown in Table 11-41 include chemicals, reflecting their use for industrial pollution control, and steel, reflecting its use in equipment manufacturing.

As of 1990, the list of most strongly affected sectors (i.e., most strongly affected by the Clean as opposed to the Dirty Scenario) remains substantially the same. It shows some shift towards sectors related to electrical power, including special industrial machinery, lighting and wiring equipment, and aluminum.

(2) Impacts at the Regional Level

The western regional economy is largely oriented toward extractive rather than manufacturing industries.[2] In some cases,

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[1]Expenditures on such devices as catalytic converters are considered part of the auto industry's output. The difference between the scenarios reflects primarily the 1977 CAA Amendments.

[2]Federal Region VIII produces 8.7 percent of the nation's farm output, but only 1.4 percent of the value added by manufactures, while its population is 2.9 percent of the nation's.

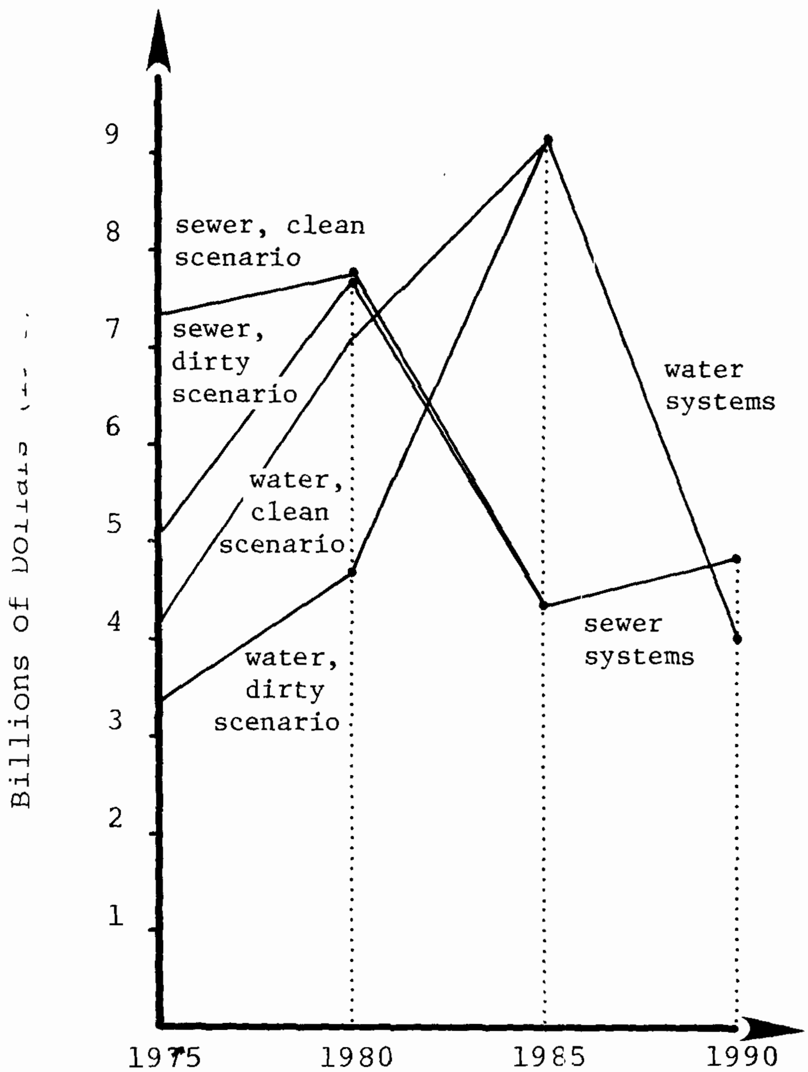

FIGURE 11-15: ANNUAL CONSTRUCTION EXPENDITURES ON WATER AND SEWER SYSTEMS

TABLE 11-41: SECTORS WITH LARGEST DIFFERENCES IN OUTPUT BETWEEN CLEAN AND DIRTY SCENARIOS, AS OF 1980

LARGEST PROPORTIONAL DIFFERENCES (percent)[a]		LARGEST ABSOLUTE DIFFERENCES (millions of 1971 dollars)	
Motor vehicles	6.82	Motor vehicles	5,705
Auto repair	4.94	Auto repair	1,210
Metal stamping	4.61	Industrial chemicals	1,029
Miscellaneous chemicals[b]	3.55	Steel	932
Engine electrical equipment	3.42	Petroleum refining	744
Industrial chemicals[c]	3.05	Wholesale trade	589
Pipes, valves, fittings	2.88	Business services	526
All sectors	0.65	All sectors	17,144

[a]All percent differences are positive.

[b]Miscellaneous chemicals subsectors which show the largest differences in the physical quantities produced include sodium chloride, ethylene, and propylene.

[c]Industrial chemicals subsectors which show the largest differences in physical quantities produced include sulfuric acid, chlorine, and sodium carbonate.

such as the extraction of molybdenum, virtually the entire national supply of the resource may come from one or two western states. Thus, national economic trends cause substantial variation in economic activity in localized areas. This is the case for several materials used in pollution abatement which, in accord with the SEAS assumptions of nationally stricter controls in the Clean scenario, will experience increased national demand.

Table 11-42 shows the 20 state/industry combinations (out of a total of 1,408 combinations considered) which experience the largest differences in demand between the Nominal Clean and Nominal Dirty scenarios. Several types of regional impacts can be observed: (1) demand for certain key materials is increased (e.g., copper, wood, aluminum, steel); (2) demand for certain manufactured items increases (e.g., computers, machinery); (3) the control of mobile sources of air pollution strongly affects the automobile industry and, due to decreased gasoline mileage, the oil industry; and (4) increased expenditure on pollution control "crowds out" other types of spending, hence decreases retail trade in some states.

Overall, economic impacts on the western region of pollution control expenditures reflect national demands for certain materials

TABLE 11-42: INDUSTRIES SHOWING THE LARGEST STATE-LEVEL DIFFERENCES IN OUTPUT, NOMINAL CLEAN VERSUS NOMINAL DIRTY SCENARIOS, 1990
(millions of 1971 dollars)

	DIFFERENCE IN OUTPUT[a]
Arizona	
Copper (refining and fabricating)	+31.30
Copper (mining)	+21.84
Motor vehicles (repair)	+15.19
Computers	+ 9.98
Aluminum	+ 8.74
Colorado	
Motor vehicles (repair)	+17.73
Oil and gas	+14.83
Retail trade	- 7.23
Special machinery	+ 6.13
Motor vehicles (mfg.)	+ 5.76
Wood products	+ 5.14
Steel	+ 5.13
Montana	
Wood products	+13.83
Copper (refining and fabricating)	+ 9.36
Petroleum refining	+ 6.55
New Mexico	
Oil and gas	+10.10
Metal ores (except iron or copper)	+ 5.63
Utah	
Motor vehicles (repair)	+ 8.36
Wyoming	
Petroleum refining	+ 8.99
Oil and gas	+ 7.40

[a]Differences expressed as output in Nominal Clean minus the output in Nominal Dirty scenario.

(such as copper, oil, and wood) which already play a major role in the region's economy.

11.4.8 Personnel Resources Availability

The question of personnel availability is addressed primarily on the regional and national levels because it is unlikely that local communities in the West will be able to fill the skilled positions required by the energy technologies.[1] The unskilled positions could largely be met locally but these would hardly lead to bottlenecks in any case. From the manpower supply point of view, the critical question is whether rapid energy development could be delayed by a nationwide shortage of key skilled personnel.

A. Levels of Development

As with the analysis of material and equipment resources, the overall pace of development is considered first. Manpower needs are based on the SRI Low Demand case projection and on the technical and skilled manpower resources for standard-size facilities as detailed in the Bechtel Energy Supply Planning Model.[2] Taking a 3,000-MWe mine-mouth power plant as an example, operation and maintenance will require a work force of: 24 engineers (16 electrical, 8 mechanical), 4 draftsmen, 56 supervisors, 240 skilled tradesmen (80 equipment operators, 80 welders, 48 electricians, and 32 pipefitters), and 112 relatively unskilled workers.

B. Operations

The total number of workers required for operating the number of plants in the Low Demand case, detailed by skill category, is about 144,000 as listed in Table 11-43. In terms of supply, the most readily available source of labor would be those workers filling similar positions in similar industries. If this source is orders of magnitude greater than western energy requirements, then western development should have relatively little impact in the labor market. On the other hand, if needs are large in comparison to supply, then other industries must be raided, workers upgraded, wages boosted, and/or standards lowered.

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[1] In one survey, 73.9 percent of the professional, technical, and supervisory workers were found to be of nonlocal origin. See Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 19.

[2] Cazalet, Edward, et al. A Western Regional Energy Development Study: Economics, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976; Carasso, M., et al. The Energy Supply Planning Model. San Francisco, Calif.: Bechtel Corporation, 1975.

TABLE 11-43: DEMAND FOR SKILLED AND PROFESSIONAL PERSONNEL, WESTERN REGION, POST-1975 FACILITIES, LOW DEMAND CASE (operational and maintenance)

OCCUPATION	1980	1985	1990	2000
Engineers				
Chemical		20	160	1,200
Civil		0	20	250
Electrical	120	220	310	650
Mechanical	70	140	260	700
Mining	70	170	300	700
Geological	10	20	60	150
Other	50	130	220	600
Total	320	700	1,430	4,250
Draftsmen	100	230	390	1,000
Supervisors	1,350	2,700	4,550	9,800
Other Technical	700	1,550	2,800	7,000
Total Managerial and Technical	2,150	4,480	7,740	17,800
Pipefitters	210	420	820	3,100
Electricians	990	2,000	3,350	7,500
Boilermakers	0	50	100	800
Carpenters	0	1,100	20	1,100
Welders	560	6,900	1,670	3,900
Operatives	2,900	3,950	13,100	40,000
Underground Miners	2,100	3,950	7,600	7,900
Other Skills and Crafts	3,500	8,500	16,400	48,500
Total Skills and Crafts	10,260	22,940	43,060	122,800
All Technical, Managerial, and Skilled	12,730	28,120	52,230	144,850

Source: Carasso, M., et al. The Energy Supply Planning Model. San Francisco, Calif.: Bechtel Corporation, 1975; and Cazalet, Edward, et al. A Western Regional Energy Development Study: Economics, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

This analysis is focused on the next decade because almost any degree of demand could be met by specific training, within 10 years.[1] Although special provisions might be required for schools or apprenticeship programs, supply would not be absolutely constrained by the current skill distribution beyond about 1985.

The 1970 data on occupations by industry were consulted to determine the characteristics of the labor force in the mining and utility industries. The 1985 personnel requirements, expressed as a percentage of this readily available pool, are indicated in Table 11-44. As shown in the table, labor requirements for developing western energy resources could range up to about 10 percent in some of the occupational categories, but for most occupations the demand would be less than 5 percent of available supply. The 9.5 percent indicated for operatives may actually be less because some 100,000 workers were deducted from this category and classified as "underground miners."

Western energy development may tighten the markets for technicians, mining engineers, and welders, with 1985 demand exceeding 6 percent of the readily available labor pool in each case. The technician category consists mainly of surveyors, instrumentation people, and chemical laboratory people.

Western development also may noticeably raise salaries, perhaps by as much as 20 percent. It may also provide the opportunity for further unionization in the West. Some skilled technicians (such as welders) can be easily transferred from other industries, while those such as mining engineers must take college courses and gain specific job experience over several years. Some increase in mining engineering education can already be detected.[2]

As noted previously, the major long-term limitation is not the current shape of the labor force but the training programs which are or are not instituted. In particular, the 1985-2000 period will bring very rapid increases in the demand for chemical and civil engineers, boilermakers, and carpenters. Clearly, new engineers must, at some point, go through a college curriculum, with some receiving advanced degrees. Conversely, skilled manual

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[1] One recent environmental impact statement which detailed the qualifications of the labor force indicated no more than 10 years experience is required for any of the positions. See U.S., Department of the Interior, Bureau of Land Management. Draft Environmental Impact Statement: Kaiparowits Project, 6 vols. Salt Lake City, Utah: Bureau of Land Management, 1976.

[2] The Bureau of Mines reports that college enrollments in that field have risen 22 percent in a single year. Poe, Edgar. "In Washington." Coal Mining and Processing, Vol. 13 (April 1976), pp. 39-42.

TABLE 11-44: 1985 WESTERN ENERGY DEMAND FOR OPERATIONAL LABOR AS A PERCENTAGE OF 1970 NATIONAL MARKET, LOW DEMAND CASE

OCCUPATION	1985 WESTERN DEMAND[a]	1970 SUPPLY[b]	PERCENTAGE
Engineers			
Chemical	20	5,800	0.3
Civil	0	1,300	0
Electrical	220	18,600	1.2
Geological[c]	20	2,100	1.0
Mechanical	140	4,400	3.2
Mining	170	2,500	6.8
Other	130	4,100	3.2
Total Engineers	700	38,800	1.8
Draftsmen	230	3,200	2.8
Supervisors	2,700	48,100	5.6
Other Technical	1,550	18,400	8.4
Total Managerial and Technical	4,480	74,700	6.0
Pipefitters[d]	420	10,500	4.0
Electricians[e]	2,000	100,200	2.0
Boilermakers	20	1,400	1.4
Carpenters	50	8,000	0.6
Welders[f]	1,100	16,400	6.7
Underground Miners[g]	3,950	112,100	3.5
Operatives[h]	6,900	72,300	9.5
Other Skills and Crafts	8,500	226,700	3.7
Total Skills and Crafts	22,940	547,600	4.2

[a]Taken from Table 11-43.

[b]Source: U.S., Department of Commerce, Bureau of the Census. Occupation by Industry, Subject Report PC(2)-7C. Washington, D.C.: Government Printing Office, 1973, Table 8. Workers were counted from the census industry categories of mining, excluding oil and gas production; privately-owned electric utilities; and petroleum refining.

[c]Census category: geologists.

[d]Census category: plumbers and pipefitters.

[e]Census category: electricians and linemen.

[f]Census category: welders and flamecutters.

[g]Census categories: blasters and powdermen, bolting operatives, earth drillers, mine operatives N.E.C., motormen.

[h]Nontransport operatives, excluding distinctly mining categories.

trades are learned primarily by "hands-on" experience. Therefore, the supply of engineers can be promoted through student scholarships and grants to colleges, and some skills can be learned in simulated mines and other such specially designed facilities.[1] In short, foreseeable labor requirements can be met, but some will require expanded training programs, union cooperation, and other actions.

C. Construction

The same basic methodology was used in the analysis of construction requirements. The census categories of "general contractors except buildings" and "special trades contractors, salaried employees" were used because they correspond roughly to what is generally known as "heavy construction." On the demand side, the Bechtel data base indicates the number of construction workers needed in each year leading up to the completion of each energy facility. For simplicity, the average number of workers in each year of major construction activity was multiplied by the number of plants in that phase at any given time. Estimates of the total numbers employed in selected years are given in Table 11-45. A maximum of 94,800 construction personnel will be needed in the late 1990's.

When 1985 demands are compared with the size of the construction labor force (Table 11-46), potential shortages of mining engineers, boilermakers, and chemical engineers are greater than the projected problems with operation and maintenance personnel. If the demands and supplies for these occupations are combined for a slightly wider group of industries (construction, mining, petroleum refining and electric utilities), the results are as shown in Table 11-47.

It appears that the supply of chemical engineers would not be a problem but that availability of boilermakers could constitute a significant bottleneck. Additional workers could be recruited from manufacturing industries, but ultimately apprenticeship programs must be expanded. Even if the 1985 demand is met from the current labor pool, a more than threefold increase beyond the 1985 demand is anticipated by 2000 (4,500 in construction versus 1,300 at the earlier date).

Beyond 1985, labor requirements would be greatly increased by gasification and shale oil plants. Particularly sharp growth in demand (sevenfold or more) would be felt for chemical and mechanical engineers, pipefitters, welders, and carpenters. As noted previously in the case of operations personnel, a long lead time

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[1] For example, Tillman, David A. "Peabody Training Center Simulates Real Underground Conditions." Coal Mining and Processing, Vol. 12 (December 1975), pp. 62-67.

TABLE 11-45: DEMAND FOR CONSTRUCTION WORKERS, SKILLED AND PROFESSIONAL, WESTERN REGION, LOW DEMAND CASE

OCCUPATION	1980	1985	1990	2000
Engineers				
Chemical	20	220	400	1,600
Civil	600	800	820	2,600
Electrical	360	480	540	1,700
Mechanical	330	570	720	2,500
Mining	80	160	140	400
Geological	30	70	60	200
Other	60	160	230	800
Total Engineers	1,480	2,460	2,910	9,800
Technicians				
Draftsmen	720	1,410	1,870	4,500
Supervisors	340	580	670	2,300
Other Technical	1,500	2,440	2,900	9,900
Total Managerial and Technical	2,560	4,430	5,440	16,700
Skilled Trades				
Pipefitters	2,100	4,640	6,650	25,400
Electricians	1,420	2,050	2,400	8,400
Boilermakers	1,300	1,300	1,240	3,800
Ironworkers	900	1,170	1,230	3,800
Carpenters	850	1,440	1,750	6,400
Operating Engineers	1,430	2,350	2,470	8,000
Welders	1,300	2,030	2,600	9,300
Other Skills and Crafts	920	1,180	1,140	3,200
Total Skills and Crafts	10,220	16,160	19,480	68,300
All Technical, Managerial, and Skilled	14,260	23,050	27,830	94,800

Source: Carasso, M., _et al_. _The Energy Supply Planning Model_. San Francisco, Calif.: Bechtel Corporation, 1975; and Cazalet, Edward, _et al_. _A Western Regional Energy Development Study: Economics_, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

TABLE 11-46: 1985 WESTERN ENERGY DEMAND FOR CONSTRUCTION LABOR AS PERCENTAGE OF 1970 NATIONAL MARKET, LOW DEMAND CASE

OCCUPATION	1985 WESTERN DEMAND	1970 SUPPLY	PERCENTAGE
Engineers			
Chemical	220	900	24.4
Civil	800	54,800	1.5
Electrical	480	4,800	10.0
Mechanical	570	4,300	13.3
Mining	160	100	160.0
Geological	70	500	14.0
Other	160	6,900	2.3
Total Engineers	2,460	72,300	3.4
Technicians			
Draftsmen	1,410	16,000	8.8
Supervisors	580	158,500	0.4
Other Technical	2,440	23,000	10.6
Total Technicians	4,430	197,500	2.2
Skilled Trades			
Pipefitters	4,640	174,100	2.7
Electricians	2,050	182,700	1.1
Boilermakers	1,300	2,600	50.0
Ironworkers[a]	1,170	44,800	2.6
Carpenters	1,440	133,000	1.1
Operating Engineers[b]	2,350	22,800	10.3
Welders	2,030	38,100	5.3
Other Skills and Crafts	1,180	822,100	0.1
Total Skills and Crafts	16,160	1,420,200	1.1

Source: Table 11-45 and U.S., Department of Commerce, Bureau of the Census. Occupation by Industry, Subject Report PC(2)-7C. Washington, D.C.: Government Printing Office, 1973, Table 8.

[a]Census categories of cranemen and hoistmen and structural metal craftsmen.

[b]Census categories of earth drillers, miscellaneous machine operatives, and fork lift operatives.

TABLE 11-47: 1985 WESTERN ENERGY DEMAND FOR SELECTED OCCUPATIONS IN CONSTRUCTION, MINING, PETROLEUM REFINING, AND ELECTRIC UTILITIES: LOW DEMAND CASE

OCCUPATION	1985 DEMAND	LABOR POOL	PERCENTAGE
Mining engineers	300	3,100	10.6
Boilermakers	1,320	6,600	20.0
Chemical engineers	240	8,200	2.9

Source: Tables 11-44 and 11-46 and U.S., Department of Commerce, Bureau of the Census. Occupation by Industry, Subject Report PC(2)-7C. Washington, D.C.: Government Printing Office, 1973, Table 8.

would allow these requirements to be met but would necessitate expansion of formal schooling and/or apprenticeship programs.

Western energy is still an emerging industry; thus, the future course of industrial relations has not yet been established. As the industry grows, it will obviously provide a major opportunity for union organization. What is considerably less clear is how far labor organization will go and what forms it might take. For example, the historical patterns of Appalachian mining probably will not be repeated. Almost all western mining is done by surface methods, which call for a smaller, more educated work force. There is more capital per worker than in underground mines, and the work is safer. All these features have a bearing on the pace and form of unionization. Moreover, the energy conversion facilities have small, highly specialized work forces. In short, western energy does not seem easily organizable into the type of industrial unions seen in the East. It is perhaps indicative that in the most recent coal strike, most western mines continued production.[1] Nevertheless, a number of labor organizations are trying to establish themselves.[2] The results cannot be predicted with any reliability.

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[1]Troelstrup, Glenn. "16,000 Tons of Coal a Day Shipped by Rail to Midwest Utilities." Denver Post, Feb. 26, 1978.

[2]Recent western organizing efforts of the United Mine Workers are described in "The UMW Is Learning How to Lose the West." Business Week, April 18, 1977, pp. 128, 130.

11.4.9 Capital Availability

A. Capital Requirements

Large investments would be required to develop western energy resources at either of the two levels being considered. Nationwide, investments would be even larger and questions have been raised about the ability and willingness of financial institutions to undertake such extensive commitments.

In this subsection, an attempt is made to answer several of these questions, specifically: (1) How large are the demands for capital implied by western energy development? What is the time distribution of these demands? (2) Is this demand for capital large compared to national markets, in the sense of raising interest rates or diverting substantial funds from other sectors? (3) Are the individual projects large compared to the credit limits of firms in the industry? Will western energy development alter current patterns of industrial organization? (4) How sensitive are these forecasts to changes in market conditions?

The capital resources required for the construction of several energy facilities are listed in Table 11-48. Conversion facilities account for over $1 billion each, and are responsible for the largest drain on the capital markets. Coal mining is a significant contributor, since the 100 surface mines projected in the Low Demand case account for nearly $13 billion in total investment by 2000.

The four energy technologies which contribute most to capital demands during the time frame of this study are surface coal mining, mine-mouth power generation, coal gasification, and oil shale processing. Financial data for these industries are summarized by periods in Table 11-49. The patterns of development are quite diverse. Whereas oil shale and gasification are young and growing industries, mining is characterized by a steady (almost linear) growth of output; and mine-mouth power plants will have achieved a "mature" industry status by the late 1980's with only slight growth afterwards. Oil shale and gasification, once begun in the West, will require steadily growing inputs of capital, while mining requires a fairly constant $250-500 million in new money per year. Also, with a number of new plants coming on-stream in the opening years of the study period, mine-mouth power will actually become a net supplier of funds by 1985.

These diverse trends add up to a very stable $1 billion rate of investment for the first 8 years,[1] not counting transportation.

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[1]Table 11-49 shows a total of 13.26 billion dollars over the 10 year period of 1976 through 1985; roughly 8 billion dollars of this is required in the first 8 years and 5 billion dollars in the last two years.

TABLE 11-48: CAPITAL RESOURCES REQUIRED FOR CONSTRUCTION OF FACILITIES (millions of 1975 dollars)

FACILITY	SIZE	MATERIALS AND EQUIPMENT	LABOR AND MISCELLANEOUS	INTEREST DURING CONSTRUCTION[a]	TOTAL
Mines					
Surface coal	12 MMtpy	64	35	30	129
Underground coal	3.4 MMtpy	35	21	20	76
Uranium[b]	1,000 MTpy	8	16	6	30
Conversion					
Power	3,000 MWe	459	459	351	1,169
Gasification	250 MMcfd	469	369	219	1,057
Synthoil	100,000 bbl/day	1,065	649	695	2,409
Shale Oil[c]	100,000 bbl/day	434	381	296	1,111

MMtpy = million tons per year
mtpy = metric tons per year
MWe = megawatt-electric
MMcfd = million cubic feet per day
bbl/day = barrels per day

Source: Linearly scaled from data in Carasso, M., et al. The Energy Supply Planning Model, 2 vols. San Francisco, Calif.: Bechtel Corporation, 1975.

[a]At 10 percent per year.

[b]Mining and milling to yield U_3O_8 (yellowcake).

[c]Mining, retorting, and upgrading.

TABLE 11-49: CASH FLOW, 1976-2000, FOUR MAJOR ENERGY SYSTEMS IN WESTERN STATES, LOW DEMAND CASE (billions of 1975 dollars)

INVESTMENT	1976-1980	1981-1985	1986-1990	1991-2000	TOTAL
Gross Investment					
Oil Shale	0	0	1.56	3.75	5.31
Gasification	0	0.80	5.40	35.81	42.01
Surface Mining	1.30	1.41	1.88	5.43	10.02
Mine-Mouth Power	5.42	4.33	1.04	2.70	13.49
Gross, Four Systems	6.72	6.54	9.88	47.69	70.83
Return Cash Flow	1.25	4.63	4.68	20.40	30.96
Net Investment	5.47	1.91	5.20	27.29	39.87

Source: Carasso, M., *et al*. *The Energy Supply Planning Model*. San Francisco, Calif.: Bechtel Corporation, 1975; and Cazalet, Edward, *et al*. *A Western Regional Energy Development Study: Economics*, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

During that period mine-mouth power would take the major portion of funds. By 1985, 36,000-MWe would be on-line. These power plants would contribute a return cash flow of almost $800 million per year, an amount equivalent to around 35 percent of the requirements for all new construction. However, in the mid-1980's, fundamental changes would begin to occur. First oil shale and then gasification will be absorbing funds as fast as the previous peak of mine-mouth power. Oil shale, though lagging during most of the time frame, will begin consuming funds in the late 1980's.

In short, energy development would require about $1 billion per year in new funds for quite a while, but after 1988 investment dwarfs anything previously encountered, reaching a $5 billion annual rate by the end of the century and still accelerating.

In terms of a regional disaggregation, the largest investments would be required in Montana and North Dakota in both the Nominal and Low Demand cases and in Colorado in the Nominal case (Table 11-50).[1] In Montana and North Dakota, investments would be needed primarily for coal development; in Colorado, they would be needed for oil shale development. Gasification would represent a sizable share of investment in the Northern Great Plains states after 1990.

New transportation facilities compose an important link in the western energy system and could boost total investment costs of the four resource technologies by $41 billion. This estimate is based on assumptions stated in Table 11-51 where the substantial costs of transporting coal, compared to the synthetic energy forms, can also be seen. In fact, the low-cost transport of synthetic fuels is one of the prime incentives for adopting them. (Transportation costs and capacities are described further in Section 11.6.)

The other energy systems in the aggregated scenario have negligible capital requirements. For example, although each underground mine requires more capital than a surface mine of similar size, surface mines will far outnumber underground mines in the West. As another example, uranium mining and milling have very low capital requirements per Btu.

Nevertheless, the Low Demand case estimates a western uranium output of 17.11 Q's (10^{15} Btu's) per year by the end of the century, which would require substantial investment in both enrichment and reactor facilities. In fact, if all the uranium output went to light water reactor plants, an investment of some $143 billion

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[1]This table differs from the previous tabulation in that only completed facilities are counted and interest costs are included. These alterations bring the results closer to figures that would be used in tax assessment.

TABLE 11-50: VALUES OF FACILITIES PLACED IN OPERATION, BY STATE, 1975-1990 AND 1990-2000 (billions of 1975 dollars)[a]

STATE	1975-1990 NOMINAL	1975-1990 LOW DEMAND	1990-2000 NOMINAL	1990-2000 LOW DEMAND
Colorado	8.22	2.54	19.54	4.06
New Mexico	1.54	1.38	2.86	1.38
Utah	2.55	1.28	2.22	0
Montana	10.45	5.93	23.05	14.27
North Dakota	10.31	7.87	26.28	16.49
Wyoming	3.90	4.80	12.15	9.36
Total (six states)	36.97	23.80	86.10	45.54

Source: Cazalet, Edward, et al. A Western Regional Energy Development Study: Economics, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

[a]Four energy systems are considered: gasification, oil shale, mine-mouth electricity, and coal mining. Figures include interest cost during construction.

would be required by the year 2000. Enrichment and other fuel processing facilities could require an additional $11.5 billion. These costs are noted in passing but are not among the prime concerns of this study because the facilities would be located outside the region.

Another category of costs not analyzed in detail is pollution control. Little hard information is available in this area. Nevertheless, electrical power plants will probably have to invest at least $100 per kilowatt (kW) (and perhaps twice that) for control of sulfur emissions.[1] Control devices will also entail increased operating costs, and reduced overall electric generating plant efficiency. Other pollutants will also require control devices, such as electrostatic precipitators (ESP) for fly ash. (The costs of sulfur control are considered here simply to

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[1]Ottmers, D.M., et al. Evaluation of Regenerable Flue Gas Desulfurization Processes, 2 vols. Austin, Tex.: Radian Corporation, 1976, Vol. 1, p. 20.

TABLE 11-51: INVESTMENT COSTS FOR ENERGY TRANSPORT, 1975-2000 (in 1975 dollars)

TRANSPORT MODE	RESOURCE	THROUGHPUT, YEAR 2000 (Quadrillion Btu-miles per year)[a]	CAPITAL COST (millions of dollars per Quadrillion Btu-miles per year)	INVESTMENT BY 2000 (billions of dollars)
Slurry pipeline	Coal	8,212	2.437[b]	20.01
Unit train	Coal	7,356	1.737[b]	12.78
Gas pipeline	Gas from coal	3,514	1.248[a]	4.40
Direct current transmission	Electricity	837	3.499[b]	2.93
Oil pipeline	Shale syncrude	3,496	.250[a]	0.88
		23,400		41.00

Btu = British thermal unit

[a]Cazalet, Edward, et al. A Western Regional Energy Development Study: Economics, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

[b]Deduced from Rieber, Michael, and Snao Lee Soo. "Route Specific Cost Comparisons: Unit Trains, Coal Slurry Pipelines and Extra High Voltage Transmission," Appendix B in White, Irvin L., et al. Energy From the West: A Progress Report of a Technology Assessment of Western Energy Resource Development. Washington, D.C.: U.S., Environmental Protection Agency, 1977. Routes of approximately 650 miles were taken as the norm.

indicate the orders of magnitude involved.) The $100 per kW figure implies additional capital costs of $540 million during 1976-1980, $570 million in the 1980's, and $270 million in the 1990's. Since the synthetic fuels systems are still being developed, it is difficult to estimate pollution control costs associated with them.

B. Impact on Capital Markets and Energy Companies[1]

The financial demands described above can be compared with the overall size of U.S. financial markets and the energy industries' historical share of those markets (Table 11-52). Equipment expenditures over the decade ending in 1975 averaged 7.9 percent of the gross national product (GNP).[2] An average of 7.8 percent up to 2000 and a compound GNP growth rate of 3.5 percent per year are assumed in the following comparisons. This is a bit high, but is consistent with the energy growth rate implicit in the SRI Nominal Demand case.[3] The proposed investments would not severely strain national capacity to build industrial structures and durable equipment, at least from this highly aggregated perspective. Even during the projected gasification and oil shale development boom during the 1990's, western energy development will constitute no more than 4 percent of the nation's new plants and equipment.

The share of investment traditionally taken by the energy industries provides another yardstick of impact. The U.S. Department of Commerce categories of electric and gas utilities, petroleum companies (domestic operations only), and mining companies together have usually accounted for approximately 30 percent of all new plant and equipment expenditures. In the last 5 years, these industries have been investing at a rate of $36 billion per year (1975 currency). Allowing a 3.5 percent annual growth rate, western energy projects would take only 2.8 to 3.5 percent of the sector's investments through 1990, but would account for 12 percent during the 1991-2000 period. By the 1990's, western development will begin taking a noticeable share of energy investment, but it will be replacing other investments, such as conventional oil and gas drilling. Thus, the energy sector should maintain its

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[1] This set of impacts and resulting issues is discussed in much greater detail in Chapter 10, "Capital Availability" in White, Irvin L., et al. Energy From the West: Policy Analysis Report. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[2] As reported in the "New Plant and Equipment Expenditures" series in the Survey of Current Business; published monthly by the U.S. Department of Commerce.

[3] Together the two assumptions allow for gradual implementation of energy conservation; for the average industry, Btu's per dollar output will decrease by 0.7 percent per year.

TABLE 11-52: INVESTMENTS FOR WESTERN ENERGY COMPARED TO NATIONAL NEW PLANT INVESTMENTS (in billions of 1975 dollars)

TIME PERIOD	INVESTMENT IN WESTERN ENERGY (FOUR SYSTEMS)[a]	NEW PLANT, ALL INDUSTRIES	PERCENTAGE
1976 - 1980	6.72	648	1.04
1981 - 1985	6.54	770	0.85
1986 - 1990	9.88	914	1.08
1991 - 2000	47.69	1,289	3.70
1976 - 2000	70.83	4,707	1.50

[a]Oil shale, coal gasification, surface mining, and mine-mouth power generation.

historic share of investment activity, even as it shifts to new technological systems.

Although western energy development is not large when compared either to the economy as a whole or to the energy industries, the projects envisioned in the scenarios could challenge the capacity of even the largest individual firms. The overall capital requirement would not be intolerably large, but the expenditures must be made in major segments. Some trends that appear likely for companies involved in western energy development include: increased diversification by oil companies into other energy resources; continued growth by mining firms; increasing use of consortium arrangements for financing large projects; and project financing for individual energy facility investments.[1]

According to the SRI model, if oil prices continue to rise, synthetic fuels systems would become attractive investments without governmental subsidies by 1990. This scenario assumes that world oil prices will advance from the 1975 price of $11 per barrel to $16 per barrel by the end of the century (1975 prices). In such a case, interfuel competition, with each technology receiving its minimum acceptable price, would drive imported oil out of the market. Shale syncrude, Lurgi gas, and other synthetic fuels could be produced for a total cost less than $16 per barrel equivalent according to SRI assumptions.

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[1]Vickers, Edward L. "Comments on Project Financing," in U.S., Department of the Interior, Bureau of Land Management. Southwest Energy-Minerals Conference Proceedings. Santa Fe, N. Mex.: Bureau of Land Management, 1977, Vol. II, pp. 209-39.

However, if the international oil cartel cannot (or will not) maintain prices, their oil will supply an increasingly large share of the U.S. energy market. SRI has run a sensitivity analysis in which world oil prices first fall, then rebound to $10 by the end of the century. Under such circumstances, oil shale development and other synthetic fuel projects would be almost forestalled. Such uncertainties, combined with the large capital cost of synfuels facilities, result in financial risks which may keep potential investors from participating in western energy development.

11.4.10 Summary of Regional Social, Economic, and Political Impacts

As a result of energy developments likely for the western U.S. between the present and 2000, the study area population can be expected to increase by 662,000-1,248,000 people. This population increase would generate most of the impacts discussed in this section. Relative increases projected are modest for Colorado, New Mexico, and Utah, but they may be as great as 20-27 percent in Montana, North Dakota, and Wyoming. Increases as great as 400 percent through the year 2000 will occur in some local areas in the West.

As a result of the new employment in the energy industry, regional income can be expected to increase by nearly 16 percent (in constant dollars) by 2000. The relative importance of economic sectors will change as well, with significant shifts from agriculture to energy in the Northern Great Plains states. Despite higher overall income, inflation can be expected to occur in some localities because of increased demands and inadequate supply of goods and services. This will adversely affect the elderly, those on fixed incomes, and small businessmen.

Local cultures and lifestyles will be affected, particularly those of ranchers, farmers, and Indians. Political affiliations may also change as a result of the influx of new residents. However, quality-of-life impacts will depend mostly on local conditions, and especially on how local governments and communities are able to respond to stresses induced by the new population. Their success will largely depend on their ability to plan and manage growth.

Capital expenditures for local government services in the region will approach $90 million per year between 1990 and 2000. Overall, a total of $1.35 billion will be needed for these purposes in the West from 1975 to 2000. In the aggregate, tax revenues should be adequate to cover these expenditures. However, jurisdictional barriers can lead to problems when revenues accrue in a jurisdiction other than the one most severely impacted. State distribution of revenues to local areas is a critical determinant of revenue adequacy or shortage at the local level.

Equipment, capital, and personnel availability constraints can also be expected to occur. Capital requirements for energy facilities will not, on the aggregate, be a large fraction of total capital required nationally for plants and equipment. However, the size of individual facilities will be so large that single companies are unlikely to have adequate capital or take the risks of borrowing for them. As a result, more joint ventures and outside financing will be required. On the whole, energy development would require about $71 billion in new funds from 1975 to 2000, but after 1988 investment would grow to a $5 billion annual rate by the end of the century.

Personnel resources will, for the most part, be adequate, but there will be substantial demands for chemical and mining engineers as well as a particularly high demand for boilermakers. These demands can probably be met only by establishing or enlarging training programs for these occupations.

11.5 ECOLOGICAL IMPACTS

11.5.1 Introduction

A diversity of plant and animal communities occur in the eight-state study area. Consequently the effects on ecosystems from energy development will vary widely over the region depending on the particular stresses within an area and the biological communities present. The ecological impacts sections in Chapters 4-9 identify and describe the kinds of impacts that can be anticipated given various local conditions. In assessing the ecological consequences of energy development over the region, it is clear that many of the effects will be qualitatively similar to those identified in the local scenarios; they will simply occur in more locations. In addition, regional development can pose cumulative stresses that will have ecological significance. Three of these cumulative stresses are discussed here: the impacts of consumptive water use on aquatic habitats; the loss and degradation of terrestrial communities through large-scale changes in land-use patterns; and the emissions of large quantities of SO_2 into the atmosphere. These stresses may act independently and synergistically to produce changes in plant and animal populations in the study area.

Each section identifies the types of impacts energy development may have on the area's biological communities and gives examples of ecological changes that result from altering factors which determine the abundance and distribution of plant and animal populations.[1] Throughout the eight-state area, the man-made and natural factors that act as stresses to ecosystems and their component populations vary in different areas. Consequently, these ecosystems differ in both their ability to sustain new stresses without deterioration and their resiliency or ability to recover from the changes induced by new stresses. These locational differences are highlighted in the following discussion.

11.5.2 Impacts from Water Consumption

Of all the habitats found in the study area, aquatic habitat is by far the most limited in extent. Further reduction in this habitat will have more widespread effects to both aquatic and terrestrial species than changes to large areas of terrestrial habitat. Development of the water resources needed for the regional scenario will result in three principal changes to aquatic habitats: decreased stream flow, changes in water quality, and construction of water supply reservoirs.

A. Flow Reduction

As indicated in Chapters 4-9, stream-flow depletion arises from different removal and consumption of water, aquifer depletion, and runoff control. Anticipated water demands from regional development for the Low and Nominal case are included in Section 11.3. The total energy-related demand by 2000 will be well below the average flow of many rivers in the region, but will represent a large proportion of typical low flows and, in some cases, will equal or exceed the low flow record. The physical impact of flow reduction will be most noticeable in the summer and late winter months when flow is normally at its lowest. Depending on the ultimate distribution and use of water rights, water withdrawals could reduce flow in some rivers to zero or nearly zero. Zero flow does not necessarily mean that there is no water in a stream bed but merely that it is not moving and therefore does not constitute a flow.

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[1]For example, factors that often limit the size and well-being of animal populations are the amount and condition of the ecosystem types that are available. Because many species require different kinds of habitat, the loss of only a small part of a population's total range may have a disproportionately large effect. Riparian (stream-side) habitat may be especially important for food gathering or water supply to some species. Other species may require lower elevation habitat for winter forage. These habitats may be a small portion of either the total range or habitat available, but they are critical to maintaining a population.

The water required by energy development would not all be withdrawn from existing low flows but, in part, would come from water released from storage in upstream reservoirs. In most parts of the eight-state region, large main-stem reservoirs on the Colorado and Missouri Rivers afford a source of stored water both for industrial use and maintenance of base flow. In other locations, new reservoirs would be needed to sustain flow during periods of low snowmelt and limited rainfall.

The greatest impacts on aquatic ecosystems could occur in the San Juan Basin and western Colorado. Increased irrigation such as the Navajo Indian Irrigation Project (NIIP), will consume additional water and add significant amounts of nutrient-, pesticide-, and silt-laden runoff to the San Juan; flow depletion could seriously reduce the dilution capacity of the river. Together, these factors may alter the extent and quality of the aquatic habitat in the San Juan River and in the San Juan arm of Lake Powell.

In western Colorado, heavy water demands could deplete flows in the White, Green, and Colorado Rivers. Even if as little as a quarter of the total water requirement for the area is apportioned to the White, demand would exceed typical minimum daily flows. The Colorado, measured near Rifle, commonly experiences minimum daily flows which will fall short of the total demand projected for the year 2000. Problems arising from excessive demand could be mitigated by using water from the Green River, although this river also experiences relatively small minimum flows. Severe flow depletion could reduce aquatic habitat and the ability to sustain threatened or endangered species.[1]

The Yellowstone River and its tributaries could experience withdrawals from 25 to 100 percent of typical low flows, depending on the use of reservoirs to regulate discharge. The portion of the Yellowstone from Billings, Montana to the Missouri confluence is free-flowing, and there is considerable public pressure to keep it so. However, the river is 20-100 miles away from many of the coal deposits; thus a long-distance delivery system typically involving reservoirs would be required. Irrigation demands on the Yellowstone are already high and could increase, further reducing dilution capacity and increasing nutrient and pesticide concentrations brought in by agricultural runoff. Expanded crop production,

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[1]A number of techniques for determining in-stream flow needs for biological resources have been reviewed. One simplified generalization suggests that flows be maintained at 25-30 percent of the average daily flow as much as 55 percent of the time. However, such measures tend to be quite unreliable when applied to specific situations. Bovee, K.D. The Determination, Assessment, and Design of "In-Stream Value" Studies for the Northern Great Plains Region. Denver, Colo.: Northern Great Plains Resources Program, 1975.

even on nonirrigated acreage, will add to the pollutant load entering the river through runoff.

The two main-stem rivers in the study area will reflect the cumulative influence of upstream and tributary withdrawals. As discussed in Section 11.3, the water required from the Upper Colorado for energy development by the year 2000 amounts to 16-55 percent of the unused water in the river. The degree to which flow in the Lower Colorado may be reduced by this demand depends on the extent of actual use of presently allocated water and on use of reservoir discharge to maintain base flows. Depending on the magnitude of flow reductions, marshlands in the lower valley could very likely be affected both in extent and species composition. Loss of these habitats could prove critical to the officially "threatened" Yuma clapper rail, as well as the black rail and a large number of waterfowl and shorebirds that find other suitable wetlands habitat scarce in the area.

In addition to affecting the aquatic community directly, reduced river flow will exert an influence on terrestrial vegetation (if floodplain water tables are lowered due to insufficient recharge from the stream). Riparian and floodplain habitats are perhaps the most important individual habitat types in the Great Plains and Southwestern deserts. They are used seasonally by many upland species as wintering habitat or as hunting range, and they support a distinctive and diverse animal community. They are among the most limited in extent of the major habitat types throughout the eight-state region and are rapidly being fragmented by urban and agricultural expansion. Riparian marshes important to waterfowl would be narrowed in some areas and perhaps lost, although in others, shoaling and reduced current velocity could induce a cycle of sedimentation and growth of emergent plants.

B. Water Quality Changes

Water consumption in the upper parts of the main river basins of the study area will reduce both volume and dilution potential downstream. In addition, the effect of evaporation on this reduced volume will further increase salinity, particularly in the LCRB. Without salinity control, salinity levels may increase to 1,100-1,400 mg/ℓ.[1] With successful operation of the Colorado

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[1]U.S., Environmental Protection Agency, Regions VIII and IX. The Mineral Quality Problem in the Colorado River Basin, Summary Report and Appendices. Denver, Colo.: Environmental Protection Agency, 1971; Colorado River Board of California. Need for Controlling Salinity of the Colorado River. Sacramento, Calif.: State of California, 1970; and U.S., Department of the Interior, Bureau of Reclamation, Office of Saline Water. Colorado River International Salinity Control Project, Special Report. N.p.: Bureau of Reclamation, 1973.

salinity control projects, salinities at or above Imperial Dam should range between 730 and 1,000 mg/ℓ.[1] A number of researchers have found that freshwater fish can generally live in water with TDS as high as 7,000 mg/ℓ, and some salt-tolerant freshwater species are found in natural waters with concentrations as high as 20,000 mg/ℓ. On the basis of a broad literature survey, some state agencies apply a 2,000 mg/ℓ limit as a water quality criterion for maintenance of freshwater fish and aquatic life.[2]

The salinities expected to develop in the LCRB appear too low to cause redistribution or mortality in fishes. However, there is very little information available for evaluating the possibility of subacute effects of salinity changes on fish or other aspects of the aquatic ecosystem. In-flowing pollutants from energy facilities, energy conversion waste disposal sites, and municipal sewage treatment effluent will add stresses, but their magnitude and effects are not possible to predict given the current state of knowledge.

C. Reservoir Construction

Additional impoundments will be required in the study area to insure a reliable source of water for energy development. For example, in the Yellowstone River Basin new impoundments would be needed to insure supply during late summer, fall, and winter.[3]

The reservoirs needed for energy developments offer a very different kind of habitat than that of the original river. Impoundments may reduce turbidity, trap sediment, and stabilize chemical variations. A large reservoir stratifies seasonally into a warm, productive upper layer and a colder lower layer in which the dissolved oxygen content may be lowered. Nongame fish may be able to compete with game fish more successfully, or game fish may simply lose much of their suitable spawning areas (as happened recently in North Dakota's Lake Sakakawea).

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[1]Maletic, J.T. "Salinity Control Planning in the Colorado River System," in Flack, J.E., and C.W. Howe, eds. Salinity in Water Resources: Proceedings of the 15th Annual Western Resource Conference, University of Colorado, July 1973. Boulder, Colo.: Merriam Publishing, 1974.

[2]McKee, Jack Edward, and Harold W. Wolf. Water Quality Criteria, 2nd ed. Sacramento, Calif.: Resources Agency of California, State Water Quality Control Board, 1963.

[3]Montana, Department of Natural Resources and Conservation, Water Resources Division. Which Way? The Future of Yellowstone Water, Draft. Helena, Mont.: Montana, Department of Natural Resources and Conservation, 1976, pp. 25-34.

Some reservoirs can develop highly productive, diverse ecosystems if they combine good water quality with a variety of habitats, especially shoreline spawning and nursery areas. If reservoirs experience large water-level fluctuations to maintain flow to energy facilities, then shoreline habitat cannot be maintained. Generally, reservoir in-flows are contaminated by pollutants and sediment. The reservoir sites most vulnerable to this pollution would be on major rivers in the Great Plains.[1] Mountain reservoirs would generally be less likely to become enriched (eutrophic).

To date, most of the large impoundments in the study area have been on main-stem rivers. However, concern about protecting the remaining free-flowing river habitats, as well as the cost of building large dams, may induce a trend toward off-stream impoundments. By trapping sediment and releasing steady flows of cool water, they could improve both the baseline quality of the remaining aquatic habitat and the stream's ability to assimilate municipal wastes.

In general, reservoirs increase the supply of some species, such as sport fish, both within the impoundment and frequently below it. Although the quality of sport fisheries may improve, the overall diversity of species could be reduced in areas where warm-water fishes predominate. Aquatic habitat will also be fragmented by reservoir construction, which will introduce effective barriers to movement of biota upstream and downstream. Finally, reservoir construction and operation will eliminate valuable floodplain vegetation or lower its productivity.[2] In sum, reservoirs built to supply water to energy developments (and other users) will have a mixture of effects that will increase the abundance of some species and stress or eliminate populations of others.

11.5.3 Terrestrial Habitat Degradation by Changing Land Use

As stated in the site-specific impact analyses in Chapters 4-9, the greatest stress to terrestrial ecosystems usually stems from the loss or degradation of habitat. Direct consumption of land for energy facilities can have an adverse influence if the amount of land required is large (as in the western North Dakota lignite fields) or if it overlaps areas of critical importance to animals, such as migratory routes or breeding areas. When both industrial and urban land disturbance is scattered through a

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[1] Most of the lakes and large impoundments in North Dakota have become highly eutrophic from nutrients and sediment brought in by agricultural runoff.

[2] Johnson, W.C., R.L. Burgess, and W.R. Kaemmerer. "Forest Overstory Vegetation and Environment on the Missouri River Floodplain in North Dakota." Ecological Monographs, Vol. 46 (Winter 1976), pp. 59-84.

vegetational type, the resulting fragmentation compounds the effects. A relatively small amount of the total plant community is eliminated but leaves no large areas without some degree of disturbance, and thus reduces the value of the remaining habitat. Finally, people exert a disturbing influence that typically thins out animals wary of human settlements.[1] We have concluded that the three major causes of habitat deterioration are: direct land use by energy conversion facilities and for urban expansion; dispersed recreation in wilderness and backcountry areas; and changes in land use due to mining and reclamation. Each is discussed below.

A. Land Use by Energy Conversion Facilities and for Urban Expansion

Table 11-53 presents land-use projections for the Low Demand case; it includes land use by the energy conversion facilities (not for coal mines) and for urban areas. For 53 sample counties in the U.S., new urban land use ranged from 0.097 to 0.481 acres per capita from 1961 to 1970, with an average of 0.173 acre.[2] The estimates in Table 11-53 were made using the average. The same data, by region, for both the Low and Nominal demand cases is given in Table 11-54. As Table 11-54 indicates, the energy facilities will use more land than the population expansion they produce. In all cases, total land use is less than 1 percent of the land in each group of counties. In 1980 and 1990, total land use by energy facilities and the urban population is highest in New Mexico, but by 2000 it is highest in Montana. As a percentage of the land in counties in which energy development is projected to occur, North Dakota, Montana, and Colorado show the highest land-use rates (0.42, 0.55, and 0.43 percent). In the Nominal Demand case, total land use in 2000 is 2.7 times than in Low Demand case for the Rocky Mountains and 1.4 times the Low Demand case for the Northern Great Plains (Table 11-54).

The most critical factor related to the effect of land use is the spatial pattern in which development occurs. In the case of urban land, scattered trailer parks, subdivisions, and individual dwellings built on small parcels of land (e.g., less than 5

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[1] For example, as indicated in chapters 4-9, outdoor recreational activities, particularly use of snowmobiles and other off-road vehicles, brings this disturbance into backcounty areas that have not been previously disturbed. Disturbances in winter can be important to some animals due to additional metabolic demands during periods of high physiological stress.

[2] Zeimetz, Kathryn A., et al. Dynamics of Land Use in Fast Growth Areas, Agricultural Economic Report No. 325. Washington, D.C.: U.S., Department of Agriculture, Economic Research Service, 1976.

TABLE 11-53: NEW LAND REQUIREMENTS FOR ENERGY FACILITIES AND URBAN LAND FOR LOW DEMAND CASE, 1980-2000 (in acres and percent of land in affected counties)

YEAR	ENERGY FACILITIES	URBAN LAND	TOTAL
COLORADO Garfield, Mesa, Rio Blanco, and Huerfano Counties (7,125,760 acres)			
1980	2,400 (0.03%)	623 (0.01%)	3,023 (0.04%)
1990	4,855 (0.07%)	5,173 (0.07%)	10,028 (0.14%)
2000	18,680 (0.27%)	11,729 (0.16%)	30,409 (0.43%)
UTAH Kane, Garfield, Uintah, and Grand Counties (11,027,840 acres)			
1980	2,400 (0.02%)	381 (0.003%)	2,781 (0.02%)
1990	2,400 (0.02%)	502 (0.004%)	2,902 (0.03%)
2000	2,960 (0.02%)	900 (0.01%)	3,860 (0.03%)
NEW MEXICO San Juan, McKinley, Valencia, Lea, Eddy, Roosevelt, and Chavez Counties (21,573,120 acres)			
1980	37,220 (0.17%)	2,059 (0.01%)	39,279 (0.18%)
1990	37,570 (0.17%)	3,460 (0.02%)	41,030 (0.19%)
2000	29,535 (0.14%)	6,176 (0.03%)	35,711 (0.17%)
MONTANA Big Horn, Powder River, and Rosebud Counties (8,542,770 acres)			
1980	2,400 (0.03%)	1,799 (0.02%)	4,199 (0.05%)
1990	7,200 (0.08%)	8,460 (0.10%)	15,660 (0.18%)
2000	21,305 (0.25%)	25,846 (0.30%)	47,151 (0.55%)
WYOMING Campbell, Johnson, Sheridan, Converse, Natrona, Carbon, Freément, and Sweetwater Counties (31,114,240 acres)			
1980	3,800 (0.01%)	1,678 (0.01%)	5,478 (0.02%)
1990	10,560 (0.03%)	6,314 (0.02%)	16,874 (0.05%)
2000	19,445 (0.06%)	17,750 (0.06%)	37,195 (0.12%)
NORTH DAKOTA Dunn, Mercer, McLean, Oliver, Billings, Bowman, Hettinger, McKenzie, Slop, Stark, and Williams Counties (10,625,920 acres)			
1980	4,800 (0.05%)	1,211 (0.01%)	6,011 (0.06%)
1990	11,210 (0.10%)	5,225 (0.05%)	16,435 (0.15%)
2000	24,865 (0.24%)	19,705 (0.18%)	44,570 (0.42%)

TABLE 11-54: LAND USE BY REGION, LOW AND NOMINAL DEMAND CASES (acres and percent of land in affected counties)

REGION	YEAR	ENERGY FACILITIES (excluding mines)	URBAN LAND	TOTAL
Rocky Mountain[a] (39,726,720 acres)				
Low	1980	42,020 (0.09%)	3,063 (0.01%)	45,083 (0.11%)
	1990	44,825 (0.11%)	9,135 (0.02%)	53,960 (0.13%)
	2000	51,175 (0.13%)	18,805 (0.05%)	69,980 (0.18%)
Nominal	1980	44,700 (0.11%)	4,221 (0.01%)	48,921 (0.12%)
	1990	65,955 (0.16%)	14,947 (0.04%)	80,092 (0.20%)
	2000	127,125 (0.32%)	60,117 (0.15%)	187,242 (0.47%)
Northern Great Plains[b] (50,282,880 acres)				
Low	1980	11,000 (0.02%)	4,688 (0.01%)	15,688 (0.03%)
	1990	28,970 (0.06%)	19,999 (0.04%)	48,969 (0.10%)
	2000	65,615 (0.13%)	63,301 (0.13%)	128,916 (0.26%)
Nominal	1980	13,680 (0.03%)	6,090 (0.01%)	19,770 (0.04%)
	1990	38,095 (0.08%)	26,815 (0.05%)	64,910 (0.13%)
	2000	92,225 (0.19%)	88,472 (0.17%)	180,697 (0.36%)

[a]Area includes the counties listed in Table 11-60 in Utah, New Mexico, and Colorado.

[b]Area includes the counties listed in Table 11-60 in North Dakota, Montana, and Wyoming.

acres) usually exert a much larger overall affect on habitat than an equivalent total land use concentrated around a few urban foci.

Certain habitats are likely to be more vulnerable than others to fragmentation and disturbance due to residential expansion. Especially in western Colorado and Utah, rough terrain often limits feasible residential sites to river and stream valleys, habitats which are both limited in extent and important to maintaining overall ecological diversity. The growing demand for recreational second homes in scenic mountain areas will also put pressure on foothill habitats, which are more feasible for home sites than higher elevations.[1] This kind of land use may be expected to develop particularly in the southern foothills of the Rockies bordering the desert of the Colorado Plateau,[2] in western Colorado's oil shale areas, and the Black Hills. The biological implications of the development in foothill winter ranges may be greater for some species than others. For example, these areas are typically the limiting factor controlling big game herds of the area.[3]

B. Impacts of Increased Outdoor Recreational Pressure

Regional ecological stresses brought on by energy development are closely related to the size of human populations in the study area. (Anticipated growth in regional human populations is detailed in Section 11.4.2.) As shown in Table 11-55, the cumulative percent increase of population projected over the entire eight-state region (Nominal Demand case) will be more than 10 percent by 2000, and a disproportionate share of this growth will occur near areas with high value for backcountry recreation. As a new energy impact, the baseline against which this growth in resident demand should be measured is the projected growth in tourists (nonresidents). Estimates made for the UCRB and Missouri River Basin Comprehensive Framework Studies indicate that it is reasonable to expect this demand to double or triple by the year 2000. Since the early 1970's, backcountry activities such as hiking, snowmobiling, jeeping, and backpacking or packing with horses have been rising in popularity, accounting for 5 to 15 percent of the total use in individual national forests.

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[1] For example, these patterns of land development are described in Montana State University, Gallatin Canyon Study Team. The Gallatin Area: A Summary Report, Bulletin 344. Bozeman, Mont.: Montana State University, Cooperative Extension Service, 1974, pp. 9-13.

[2] Including the deserts of southern Utah across the Navajo Reservation to central northern New Mexico.

[3] Montana State U., Gallatin Canyon Study Team. Gallatin Area, pp. 20-21.

TABLE 11-55: EXPECTED POPULATION INCREASES DUE TO NOMINAL CASE DEVELOPMENT IN SELECTED STATES AND THE EIGHT-STATE REGION

YEAR	COLORADO	NEW MEXICO	WYOMING	TOTAL EIGHT-STATE REGION
1975	2,534,000	1,147,000	374,000	9,551,000
1980	1,800	16,200	16,600	95,500
1990	46,200	27,500	45,000	280,900
2000	253,500	54,200	150,000	1,229,600

Residents and nonresidents generally have different backcountry use patterns. Residents are more often responsible for off-road vehicle use, including snowmobiles. Backpacking, hiking, and camping may be more evenly divided, while ski developments generally draw recreationists from long distances. An important limitation in projecting recreational demands is the difficulty of anticipating trends in recreational styles. For example, such technological innovations as snowmobiling are recent phenomena. Hydrofoil and shallow-draft boats make many western rivers available for recreational use. Similar uncertainty exists in land management practices. Current trends are to increase restrictions on wilderness and backcountry areas, but economics encourages the Forest Service to promote dispersed recreational activities by building trails and improving access.

Although the intensity of use is uncertain, the locations of recreational activities generally fall into three categories: major established tourist attractions (e.g., Yellowstone and Grand Teton National Parks); areas near population centers (e.g., Grand Mesa National Forest, near Grand Junction); and recreational areas with otherwise limited recreational opportunities (e.g., Black Hills National Forest in Wyoming and South Dakota). Table 11-56 lists some major areas which are likely to experience increased use because of regionwide energy development. If access to these areas is limited or controlled, the bulk of the growing demand will fall on adjacent nondesignated areas which still have a strong aesthetic appeal.

Energy-related population growth will probably result in potential damage to vegetation, and animal communities in four areas: western Colorado, the Powder River coal region, the Four Corners area, and the lignite fields of western North Dakota. In western Colorado, the large population influx is expected to locate in the midst of prime outdoor recreation areas; consequently, this area is likely to experience the greatest adverse ecological impacts. The Powder River and North Dakota areas will

TABLE 11-56: MAJOR BACKCOUNTRY AREAS LIKELY TO RECEIVE INCREASED PRESSURE DUE TO ENERGY DEVELOPMENT

STATE	NATIONAL FORESTS, PARKS, MONUMENTS, AND RECREATION AREAS	INCLUDED WILDERNESS AND PRIMITIVE AREAS
Colorado	Grand Mesa (NF)	
	Rio Grande (NF)	La Garita (WA), Upper Rio Grande (PA)
	Routt (NF)	Rawah (WA), Mt. Zirkel (WA)
	White River (NF)	Maroon Bells/Snowmass (WA), Gore Range/Eagle's Nest (WA), Flat Tops (WA)
	San Juan (NF)	San Juan (WA)
	Black Canyon of the Gunnison (NM)	
	Mesa Verde (NP)	
	Theodore Roosevelt (NP)	
New Mexico	Carson (NF)	Wheeler Peak (WA)
	Sante Fe (NF)	San Pedro Parks (WA)
	Chaco Canyon (NM)	
South Dakota	Black Hills (NF)	
Utah	Ashley (NF)	High Uintas (PA)
	Dixie (NF)	
	Fishlake (NF)	
	Arches (NP)	
	Dinosaur (NM)	
	Zion (NP)	
	Glen Canyon (RA)	
	Cedar Breaks (NM)	
	Capital Reef (NP)	
	Canyonlands (NP)	
	Bryce Canyon (NP)	
	Hovenweep (NM)	
Wyoming	Bighorn (NF)	Cloud Peak (PA)
	Bridger-Teton (NF)	Teton (WA), Bridger (WA)
	Medicine Bow (NF)	
	Shoshone (NF)	North Absaroka (WA), Popo Agie (PA), Washakie (WA), Glacier (PA)
	Yellowstone (NP)	
	Grand Teton (NP)	
	Bighorn Canyon (RA)	
	Flaming Gorge (RA)	

NF = National Forest
WA = Wilderness Area
PA = Primitive Area
NM = National Monument
NP = National Park
RA = Recreation Area

also experience substantial population increases; however, in these areas, outdoor recreationists will be limited in their choice of wilderness or backcountry areas. The three closest such areas (the Theodore Roosevelt National Memorial Park, the Black Hills National Forest, and the Bighorn National Forest) will receive concentrated use. The Custer National Forest, with few developed trails, campgrounds, or other facilities, may remain comparatively unused. The energy-related population growth in Utah and New Mexico (Four Corners) is expected to be comparatively small. Thus, although high quality wilderness and backcountry areas surround the area, these areas should not experience significant usage increases resulting from regional energy development. Some local impacts will occur, as discussed in Chapters 4 and 5.

C. Surface Mining and Reclamation

The impact of surface mining depends on the extent of mining, the reclamation practices employed, the existing conditions of soil and climate, and the objectives of the reclamation activity. Important variables of reclamation are practices in separation of topsoil and subsoil from the overburden, adjustments to topography, mulching, seeding, fertilization, and irrigation. The variety of existing conditions ranges from the rich soils of the Northern Great Plains with their low to moderate rainfall to the poor soils and arid climate of the desert southwest. The objectives of reclamation can vary from restoring natural conditions to establishing range grasses, providing of cover and forage for wildlife, and production of crops. Restoration of mined lands for productive use have also included proposals for commercial or recreational activities such as lakes, golf courses, or race tracks in locations near urban areas.[1] This section primarily addresses the process of reclamation for the establishment of biological resources, which can include native species, game animals, or croplands. Following a discussion of the extent of mining as projected by the regional scenario for the eight-state study area, this section identifies some of the major factors that affect reclamation, and describes the potential for success and the problems in reestablishing vegetation.

Since the early 1970's, a great deal of laboratory and field research has been performed to determine whether, and by what means, mine spoils can be reclaimed in the major western coal fields. Some critics express uncertainty about the soundness of long-range predictions based on the results of these short-term

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[1]For examples of economically successful projects, see: Ozarks Regional Commission. Mined-Land Redevelopment: Kansas, Missouri, Oklahoma. Wichita, Kans.: Wichita State University, 1973, pp. 6-8.

tests. Their reservations largely arise because of the inevitable lack of data concerning the long-term success of reclamation.

The total acreage disturbed through the year 2000 by surface mining under the two demand cases postulated for the eight-state scenario is summarized by subarea in Table 11-57. These subareas reflect both the geographic distribution of major coal resource areas and natural groupings of biotic communities. The Northern Great Plains includes the coals of eastern Montana and northern Wyoming and North Dakota's lignite, all part of the Fort Union Formation; the Intermountain subarea includes coal deposits in western Colorado and western Wyoming; and, the Southwest Deserts include the coals of northern New Mexico, Arizona, and southern Utah. It is possible to generalize about the conditions that influence the success of reclamation in these three major subareas within the eight-state study area, as summarized below.

(1) Existing Conditions Affecting Success of Reclamation

The climate, soils, and overburden characteristics are the most important locational factors determining the success of reclamation. Precipitation is an important component of climate. As indicated in the following section, approximately 6-10 inches of precipitation are generally considered to be the lower limit for successful revegetation, although the frequency and timing of this precipitation may be more important than the total amount.[1]

Surface soils within the eight-state study area vary greatly in sand content, organic content, and depth; and, a single mine often contains several soil types which differ in their suitability for use in reclamation. Thus, the following general observations are regional trends rather than uniformly occurring conditions. Rock strata overlaying coal deposits (overburden) also vary greatly. However, throughout the three subareas, certain characteristics typify the major geological formations where coal is found.

(a) Northern Great Plains

Most precipitation in the Northern Great Plains falls in spring and as summer showers,[2] and averages between 12 and 16 inches annually on most coal lands in the area. The timing of

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[1]Davis, Grant. U.S., Department of Agriculture, Forest Service, SEAM Program. Personal Communication, November 3, 1976.

[2]Cook, C.W., R.M. Hyde, and P.L. Sims. Guidelines for Revegetation and Stabilization of Surface Mined Areas in the States, Range Science Series No. 16. Fort Collins, Colo.: Colorado State University, Range Science Department, 1974.

TABLE 11-57: SURFACE ACREAGE ULTIMATELY DISTURBED BY SURFACE COAL MINING THROUGH THE YEAR 2000

	LOW DEMAND CASE	NOMINAL DEMAND CASE
Northern Great Plains[a]	622,350	861,600
Intermountain[b]	13,860	27,730
Southwest Deserts[c]	43,860	62,800

[a]Seam thickness assumed is that for site specific scenarios, Chapters 7, 8, and 9.

[b]One-third of the projected mines are underground and are not included; seam thickness assumed for surface mines is 7 feet.

[c]All projected mines in New Mexico are surface with seam thickness given in Chapter 5. Half of the projected mines in Utah are underground and not included; seam thickness for Utah surface mines is assumed to be 10 feet.

this rainfall is offset somewhat by the drying effects of the prevailing northwesterly winds,[1] especially in the western part of this subarea. As much as 20 percent of the rain that falls during the growing season may evaporate without penetrating to plant roots.[2] In addition, the climate is erratic,[3] and while the overall climate favors revegetation, periods of lowered moisture will reduce the success of seedlings or alter the composition of vegetation.

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[1]Packer, Paul E. Rehabilitation Potentials and Limitations of Surface-Mined Land in the Northern Great Plains, General Technical Report INT-14. Ogden, Utah: U.S., Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1974; and Wali, M.K., and F.M. Sandoval. "Regional Site Factors and Revegetation Studies in Western North Dakota," in Wali, M.K., ed. Practices and Problems of Land Reclamation in Western North America. Grand Forks, N.D.: University of North Dakota Press, 1975.

[2]Curry, R.R. "Biogeochemical Limitations on Western Reclamation," in Wali. Land Reclamation in Western North America.

[3]Thornthwaite, C.W. "Climate and Settlement on the Great Plains," in U.S., Department of Agriculture. Yearbook of Agriculture. Washington, D.C.: Government Printing Office, 1941.

Soils in the area generally have adequate nutrient and organic matter content to support plant growth. Topsoils may be 6-30 inches in depth, and weathered subsoil extends as deep as 20 feet in western North Dakota.[1] Topsoil varies with topography, and soils on steep slopes erode so that deep soils do not develop. Soils on level terrain are much deeper.

High salt content is a problem in some Northern Great Plains soils.[2] These soils are poorly drained, minimally permeable with a dry to a hard crust. Runoff from such soils is high, and they tend to erode. Soils in Wyoming and Montana tend to be deficient in phosphorus, while North Dakota soils may have insufficient nitrogen.[3]

Material below the soil and above the coal (overburden) in the Fort Union Formation is typically high enough in sodium to limit or prevent plant growth.[4] Overburden above lignite is more likely to present sodium problems than is the overburden overlying the subbituminous coal of the Fort Union Formation.[5] These spoils are also susceptible to erosion, especially under the relatively high rainfall of North Dakota. Overburden generally contains low or marginally adequate amounts of mineral nutrients; plant cover almost always responds to nitrogen and phosphorus

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[1]Wali, M.K., and F.M. Sandoval. "Regional Site Factors and Revegetation Studies in Western North Dakota," in Wali, M.K., ed. Practices and Problems of Land Reclamation in Western North America. Grand Forks, N. Dak.: University of North Dakota Press, 1975.

[2]Sandoval, F.M., et al. "Lignite Mine Spoils in the Northern Great Plains: Characteristics and Potential for Reclamation." Paper presented before the Research and Applied Technology Symposium on Mined Land Reclamation. Pittsburgh, Pa.: Bituminous Coal Research, 1973; and Packer, Paul E. Rehabilitation Potentials and Limitations of Surface-Mined Land in the Northern Great Plains, General Technical Report INT-14. Ogden, Utah: U.S., Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1974.

[3]Packer. Rehabilitation of Surface-Mined Land.

[4]Sandoval. "Lignite Mine Spoils."

[5]Packer. Rehabilitation of Surface-Mined Land.

fertilizers.[1] Potassium is sometimes adequate,[2] but calcium may be needed.[3]

(b) Intermountain Subarea

The varied topography and climate of the Intermountain subarea are the major determinants of the distribution of the three major vegetation types found over coal lands: foothill shrubland, pinyon-juniper woodland, and mountain shrub communities. The foothill shrublands generally receive from 9 to more than 15 inches of rainfall annually. Most precipitation falls as snow, with erratic showers of rain in spring and early summer. July and August tend to be dry, and native plants are often dormant during this period. Year-to-year variation is wide, and in drought years only 6-7 inches of rainfall may occur.[4] Pinyon-juniper woodlands at 4,000-7,000 feet receive 12-15 inches of rainfall annually.[5] Mountain shrub communities above this zone receive 15-30 inches of rainfall each year, about half of it as snow. Generally, precipitation is more favorable to revegetation at these altitudes than at other elevations in the Intermountain region.

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[1]Meyn, R.L., J. Holechek, and E. Sundberg. "Short and Long Term Fertilizer Requirements for Reclamation of Mine Spoils at Colstrip, Montana," in Clark, W.F., ed. Proceedings of the Fort Union Coal Field Symposium, Vol. 3: Reclamation Section. Billings, Mont.: Eastern Montana College, 1975, pp. 266-79; and Power, J.F., et al. "Factors Restricting Revegetation of Strip-Mine Spoils," in Clark. Fort Union Coal Field Symposium, Vol. 3, pp. 336-46.

[2]Sindelar, B.W., R.L. Hodder, and M. Majorous. Surface Mined Reclamation Research in Montana, Research Report No. 40. Bozeman, Mont.: Montana Agricultural Experiment Station, 1972.

[3]Power et al. "Factors Restricting Revegetation."

[4]National Academy of Sciences. Rehabilitation Potential of Western Coal Lands, a report to the Energy Policy Project of the Ford Foundation. Cambridge, Mass.: Ballinger, 1974.

[5]Plummer, A.P., D.R. Christenson, and S.B. Hansen. Restoring Big Game Range in Utah, Publication No. 68-3. Salt Lake City, Utah: Utah, Department of Natural Resources, Division of Fish and Game, 1968; and Water Resources Council, Upper Colorado Region State-Federal Inter-Agency Group. Upper Colorado Region Comprehensive Framework Study. Denver, Colo.: Water Resources Council, 1971.

Soils in the Intermountain subarea vary greatly, having developed over a wide variety of original rock. Three major types are found in the coal-producing regions.[1] Soils of dry sagebrush plateaus, mesas, and foothills in Utah are generally loamy but poor in organic matter and range from 20 to 60 inches in depth. Soils of sagebrush and juniper canyonlands, lower mountain slopes, and barren areas are less than 20 inches deep and subject to water erosion. Soils on western Colorado coal lands are loamy, rich in organic matter, and contain a variety of vegetation types; subsoils may contain clay and may have permeability problems. These soils are typically deep and are often farmed for dryland crops. All three of these soil types may require irrigation.

Because of the area's variable geology, generalizations about overburden characteristics cannot be made. For example, in western Colorado, mine spoils from the Mesa Verde formation are predominately fragmented hard rock and have low water holding capacity compared to finer materials. Therefore, vegetation is difficult to establish and maintain. These spoils are low in both available phosphorus and nitrogen needed for plant growth.[2]

Although part of the Mesa Verde formation, overburden in the western Wyoming Kemmerer coal fields varies considerably. Acid-producing iron pyrite is present in some strata, while others are alkaline. The salinity, ease of erosion, high aluminum content, and low pH (acidity/alkalinity) of some overburden materials make plant growth difficult. The overburden in this area generally contains enough mineral nutrients to accommodate the growth of plants in a greenhouse, although additional nitrogen helps.[3]

(c) Southwestern Deserts

Precipitation in this area is usually insufficient for satisfactory revegetation of mine spoils without supplemental irrigation. Annual rainfall averages 5-8 inches, but in

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[1]Water Resources Council, Upper Colorado Region State-Federal Inter-Agency Group. Upper Colorado Region Comprehensive Framework Study. Denver, Colo.: Water Resources Council, 1971.

[2]Berg, W.A. "Revegetation of Land Disturbed by Surface Mining in Colorado," in Wali, M.K., ed. Practices and Problems of Land Reclamation in Western North America. Grand Forks, N. Dak.: University of North Dakota Press, 1975.

[3]Lang, R.L. "Reclamation of Strip Mine Spoil Banks in Wyoming." University of Wyoming Agricultural Experiment Station Research Journal, Vol. 51 (1971).

exceptional years may range from 3 to 12 inches.[1] Rain falls largely in late summer (July through September); spring and fall seasons are generally dry.[2] Rainfall is often very irregular,[3] and conditions favorable for seeding and establishing plants may occur naturally only 1 in 10 years.[4] The timing of rainfall is particularly critical; experimental work with one native grass on wild lands in New Mexico showed that it could be planted with 80 percent success during only 2 weeks in the year; success fell rapidly to zero both before and after this period.[5] In areas such as Arizona's Black Mesa, high, gusty winds occur throughout the year. This enhances evaporation and thus results in inadequate soil moisture, even though rainfall may reach 12 inches annually.[6]

Soils in the arid coal regions of Arizona and New Mexico are generally poorly developed, hold little moisture, and are high in salt content. Moreover, these soils are often sandy, and the loss of vegetation through overgrazing leads to erosion. Drifting

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[1]National Academy of Sciences. Rehabilitation Potential of Western Coal Lands, a report to the Energy Policy Project of the Ford Foundation. Cambridge, Mass.: Ballinger, 1974.

[2]Aldon, E.R., and H.W. Springfield. "Problems and Techniques in Revegetating Coal Mine Spoils in New Mexico," in Wali, M.K., ed. Practices and Problems of Land Reclamation in Western North America. Grand Forks, N. Dak.: University of North Dakota Press, 1975.

[3]Gould, W.L., D. Rai, and P.L. Wierenga. "Problems in Reclamation of Coal Mine Spoils in New Mexico," in Wali. Land Reclamation in Western North America.

[4]Aldon and Springfield. "Revegetating Coal Mine Spoils."

[5]Aldon, E.F. "Establishing Alkali Sacaton on Harsh Sites in the Southwest." Journal of Range Management, Vol. 28 (March 1975), pp. 129-92.

[6]Thames, J.L., and T.R. Verma. "Coal Mine Reclamation in the Black Mesa and the Four Corners Areas of Northeastern Arizona," in Wali. Land Reclamation in Western North America.

and blowing soils can easily bury seedlings or reduce plant cover by abrasion.[1]

Mine spoils in the Southwest may also pose problems. For example, in the Fruitland Formation in the San Juan Basin, the sandstones and shales generally contain excessive amounts of sodium, low quantities of phosphorus, and variable amounts of nitrogen.[2] The development of soil-based mineral cycling systems takes place slowly. Centuries might be required before vegetation stabilizes,[3] and 10-30 years may be required for natural revegetation.[4]

(2) Probable Success of Revegetation

The success of a reclamation effort and the techniques needed to achieve it are very much influenced by the objectives of a reclamation program and local features. The differences in soil and overburden characteristics described above may require slightly different treatments between areas within a single mine, and soils and underlying strata can vary markedly in their suitability for reclamation within a few miles.[5] However, it is difficult to predict the success of revegetation in many western locations on the basis of available experimental results and

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[1]National Academy of Sciences. Rehabilitation Potential of Western Coal Lands, a report to the Energy Policy Project of the Ford Foundation. Cambridge, Mass.: Ballinger, 1974; Thames, J.L., and T.R. Verma. "Coal Mine Reclamation in the Black Mesa and the Four Corners Areas of Northeastern Arizona," in Wali, M.K., ed. Practices and Problems of Land Reclamation in Western North America. Grand Forks, N. Dak.: University of North Dakota Press, 1975; Gould, W.L., D. Rai, and P.L. Wierenga. "Problems in Reclamation of Coal Mine Spoils in New Mexico," in Wali. Land Reclamation in Western North America; and Aldon, E.F., and H.W. Springfield. "Problems and Techniques in Revegetating Coal Mine Spoils in New Mexico," in Wali. Land Reclamation in Western North America.

[2]Gould, Rai, and Wierenga. "Problems in Reclamation."

[3]NAS. Rehabilitation Potential of Western Coal Lands.

[4]Cook, C.W., R.M. Hyde, and P.L. Sims. Guidelines for Revegetation and Stabilization of Surface Mined Areas in the Western States, Range Science Series No. 16. Fort Collins, Colo.: Colorado State University, Range Science Department, 1974.

[5]For example, soils of poor texture and low organic content can be improved by mulching. Soils of low nutrient content can be fertilized with nitrogen, phosphorus, or other limiting elements.

field observations. As indicated above, local climatic conditions and the unreliability of rainfall over most of the area can potentially make the difference between success and failure in revegetation efforts. Further, in most areas, current experience covers a period of 6 years or less, which is not sufficient for the long-term stability of revegetated areas to be assessed.[1]

Reclamation efforts in the western U.S. will be limited most consistently by the timing and quantity of moisture available to plants.[2] The amount of precipitation and its seasonal distribution largely determine the likelihood of successful revegetation, even though soils vary in their ability to retain the amount that falls in a manner which makes it available to plants.

As indicated in the previous descriptions, areas generally receiving an average of 10 or more inches of rainfall per year can be made to support some plant growth without supplemental irrigation.[3] When mined lands have been graded with care and planted properly with suitable species, some areas with as little as 6 inches of rain have been revegetated.[4] In most of the semi-arid West, however, rainfall varies widely from year to year. Under these circumstances, periodic dry years or droughts lasting several years must be expected, and the success of revegetation at such times will be curtailed, especially in marginal areas.[5] The timing of rainfall is crucial to the establishment of plant

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[1]Farmer, E.E., et al. Revegetation Research on the Decker Coal Mine in Southeastern Montana, Research Paper INT-162. Ogden, Utah: U.S., Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1974.

[2]See for example: National Academy of Sciences. Rehabilitation Potential of Western Coal Lands, a report to the Energy Policy Project of the Ford Foundation, Cambridge, Mass.: Ballinger, 1974; Cook, C.W., R.M. Hyde, and P.L. Sims. Guidelines for Revegetation and Stabilization of Surface Mined Areas in the Western States, Range Science Series No. 16. Fort Collins, Colo.: Colorado State University, Range Science Department, 1974; Packer, Paul E. Rehabilitation Potentials and Limitations of Surface-Mined Land in the Northern Great Plains, General Technical Report INT-14. Ogden, Utah: U.S., Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1974.

[3]NAS. Rehabilitation Potential of Western Coal Lands.

[4]Davis, Grant. U.S., Department of Agriculture, Forest Service, SEAM Program. Personal Communication, November 3, 1976.

[5]NAS. Rehabilitation Potential of Western Coal Lands; and Packer. Rehabilitation of Surface-Mined Land.

cover. A lack of precipitation shortly after planting can reduce seedling success, and a difference of only 1-2 inches over the entire growing season may have significant consequences depending on its timing. Because of this, there will be a significant number of cases where reclamation efforts will either fail or be only marginally successful, especially where poor soil or topsoil characteristics are combined with an arid climate. Erratic rainfall patterns over the lifetime of a given mine may also be expected in years when seedling failure is unavoidable.

Over the long term, it will probably be possible to establish a cover of range grasses capable of containing erosion on most sites in the Northern Great Plains and in the higher foothill coal fields receiving adequate rainfall. However, this long-term trend may be punctuated by setbacks from periods of drought; provision for irrigation would mitigate this. During these periods, intensive management will be required for both seeded and established vegetation. Revegetation of some of the drier foothill sites will have a lesser chance for success, depending primarily on stresses over and above those arising from climate (such as those resulting from soil salinity and provisions for irrigation). Finally, in view of experience and the many adverse influences arrayed against desert sites, revegetation will be difficult unless the sites are prepared carefully and seedlings are planted, intensively managed, and irrigated, with grazing and public access strictly controlled.

(3) Reclamation for Specific Biological Objectives

Four biological objectives for reclamation are restoring natural vegetation, providing wildlife habitat, establishing livestock forage, and establishing croplands. Reestablishing native vegetation is difficult, and in some instances the original vegetation has not been present for decades or longer. Reclamation for wildlife is a more complicated process than restoration for livestock forage or cropland use. In contrast to grazing or farming, wildlife restoration must meet the needs of a relatively large number of animal species, which in turn requires a greater variety of plant species. Site characteristics, such as diverse topography and exposure, also play a large part in determining both the variety of vegetation that becomes established and the value of the habitat to wildlife. One example of the beneficial effects of diverse topography on wildlife values is the Knife River Coal Company's Beulah mine, which has helped maintain or increase the area's populations of grouse, pheasant, deer, and other small vertebrates. Prior to the establishment of state requirements for grading to a gently rolling contour, the spoils were left standing with only the ridgetops flattened. Planted shrub, grass, and forb species, selected for their food and cover value, have established thick stands in the valleys between the close-set spoil ridges where runoff provides high soil moisture content. Wildlife finds both food and shelter from winter storms, which typically cause large losses of upland wildlife. Federal Reclamation Standards and the western states now require mined lands to be regraded to some extent.

In addition to topographical variability, wildlife diversity and abundance are related to the spatial patterning of vegetation. A mosaic of grasses, low shrubs and thickets, and taller trees, combined with available free water, are necessary for many western species such as sharptail and sage grouse, jackrabbits and cottontails, and many birds of prey. A combination of nutritive food plants adequate to meet the varied needs of grazers, browsers, and seed and fruit eaters is necessary to reestablish the full complement of native fauna, including insects that are important food sources.

Several factors limit the success of woody plants. First, these plants grow slower than grasses and forbs. To speed the process, nursery stock may be planted, but this is expensive. Second, once planted, young shrubs and trees need protection from wildlife and livestock for 10-15 years before they can tolerate browsing. Third, natural rainfall may be insufficient or competition from other plants for the limited moisture on mine spoils may inhibit success.

Reclamation may attempt to restore grazing alone, and in the Northern Great Plains, particularly North Dakota, mined land may be planted to crops. This would favor animal species characteristic of early grassland succession rather than woody vegetation. In these "replacement" or successional communities in the Northern Great Plains, antelope, deer, grouse, jackrabbits, and a variety of small vertebrates will be infrequent on mined lands restored for grazing. Burrowing animals will be limited by the texture of the spoils themselves; black-footed ferrets and burrowing owls, normally associated closely with prairie dog colonies will also be affected. Intermountain cool areas are less homogeneous, and thus it is more difficult to specify what changes in wildlife communities may take place. Unless shrub cover is restored on foothill areas, however, deer and elk will be unable to use mined lands for winter range, and many western slope coals now underlie present big game winter ranges. As discussed in Chapter 5, strip mine areas in the desert southwest have already experienced stress from overgrazing, with an attendant loss of soil that will make restoration of rangelands more difficult. Also, even if successfully restored, these lands will likely be of low productivity.

Croplands may also be established in reclaimed areas and will likely expand in the eight-state region. The growth of agriculture may occur in the same time frame as the energy development scenario. A recent study[1] reports that new cropland is currently added at a nationwide rate of 1.25 million acres per year. At this rate, some 31 million acres will be brought under cultivation by the year 2000. However, a rapidly growing world food demand may result in the acceleration of agricultural expansion. Presently, only 81 percent (380 million acres) of the arable land in the U.S. is cropped. Thus, a theoretical maximum of 90 million acres could be added by 2000, not counting marginal lands requiring drainage or irrigation. In addition to new cropland being brought under cultivation, existing cropland is currently being lost at a national rate of 2.5 million acres per year to highways and urbanization. Since 1935, 100 million acres have been lost because of soil erosion. Most of these represent lost native ecosystems and wildlife habitat (although farms abandoned due to erosion eventually regain their value as habitat, at least for successional species). Thus, between 1975 and 2000 the nation may lose between 93 and 152 million acres of rangeland and native ecosystems from activities other than energy development, and reclamation for agricultural purposes may have a high priority according to agricultural interests. By comparison, land-use estimates for mining (Nominal case, Table 11-57) presented in this section with the potential for reclamation total only 0.95 million acres, much of which may utlimately be used for crops.[2]

11.5.4 Ecological Impacts of Sulfur Pollution

A great deal of concern exists concerning the potential damage of widespread SO_2 emissions on vegetation in the western energy resource states.[3] For example, livestock grazing is a major economic activity, and the potential threat of energy development to rangeland productivity can become a major issue in the eight-state area. Forests and other vegetation are also regarded as important resources. In view of projected increases

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[1]Pimentel, D., et al. "Land Degradation: Effects on Food and Energy Resources." Science, Vol. 194 (October 8, 1976), pp. 149-55.

[2]Highest land demands occur in the Northern Great Plains where reclamation for cropland is most feasible.

[3]Gordon, C.C., and P.C. Tourangeau. "Biological Effects of Coal-Fired Power Plants," in Clark, W.F., ed. Proceedings of the Fort Union Coal Field Symposium, Vol. 5: Terrestrial Ecosystems Section. Billings, Mont.: Eastern Montana College, 1975, pp. 509-30.

in livestock grazing of up to 80 percent by the year 2000,[1] even small, chronic declines in productivity over large areas of the West could have measurable economic impacts.

The impacts of SO_2 emissions, both directly and through the formation of sulfates, including acid rain, have received much attention, and adverse effects on vegetation have been widely documented. However, two major knowledge gaps prevent investigators from using regional SO_2 emission figures to predict the possibility of chronic SO_2 damage or acid rainfall: insufficient knowledge of the mechanisms by which SO_2 emissions may be translated into particulate sulfate fallout rates or low pH rainfall, and inadequate sophistication of dispersion models at a regional level.[2]

According to the air impact analysis in Section 11.2, SO_2 emissions in 2000 (Nominal case) would reach 663,000 tons per year (tpy) in North Dakota and 1,360,000 tpy in Montana with scrubbers removing 80 percent of the SO_2. Impacts in the oil shale development region, especially in Rio Blanco County, Colorado, are further complicated by the irregularity of the surrounding terrain, which can permit pollutants to be trapped in low-lying areas or cause plumes to impact on prominent ridges or mountainsides. Although it is not possible to make definitive statements about the likelihood of either particulate sulfate fallout or acid rain in these areas, the question may be approached by analogy with experiments or case histories as described below.

The effects of air pollution on the structure and function of plant communities can be separated into three classes:[3] undetectable or potentially beneficial effects; chronic harmful effects; and acute harmful effects. The term "harmful" effects here refers to reduction in plant growth or productivity. Undetectable or potentially beneficial impacts are associated with

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[1]Northern Great Plains Resources Program. Effects of Coal Development in the Northern Great Plains: A Review of Major Issues and Consequences at Different Rates of Development. Denver, Colo.: Northern Great Plains Resources Program, 1975.

[2]Ground-level concentrations used in this section are derived from dispersion models which may have an error range of up to 50 percent. However, conservative assumptions built into the models are thought to result in predicted levels high enough to compensate for this error. The net result is a figure which may exceed, but probably does not underestimate, actual field conditions.

[3]Smith, W.H. "Air Pollution--Effects on the Structure and Function of the Temperate Forest Ecosystem." Environmental Pollution, Vol. 6 (February 1974), pp. 111-29.

low pollution loads. Although there may be no detectable impact on individual plants, pollutants enter the mineral cycle of the ecosystem via normal pathways. This effect may not be harmful and may improve productivity if a particular mineral (such as sulfur) is in short supply.

Chronic harmful effects arise from intermediate pollution loads that result in damage to susceptible plant species, such as pines, typically over periods of months or a few years. Such effects may include lowered productivity, reduced reproduction, or increased susceptibility to disease or insect infestation. Where species are affected differently, competitive relationships may be altered and the composition of species in a community changed. Acid rain can be placed in this category. In addition to its direct impacts on plants, acid rain is believed to cause increased leaching of nutrients from soils. The net effect on the entire plant community may be to reduce biomass and productivity. This loss of mineral nutrients may be reversible only after very long periods of time, if at all. Also, ecosystem impacts may not be simply additive because changed competitive relationships can bring about the dominance of new species able to tolerate pollution stress better than competitors.

Acute impacts occur when ambient pollutant concentrations are high enough to cause acute damage to plants. If sufficiently severe, this impact can eliminate species from the affected community. Since woody plants are often more susceptible to acute damage than are herbaceous species, loss of dominants may change the physical structure of the vegetation. Extensive vegetation loss results in erosion and affects mineral cycling through direct soil loss. In most ecosystems, these effects will combine to reduce the amount of primary plant production available to the animal community; further ecosystem simplification can take place as a result of reduced energy flow through the food web.

Acute and chronic impacts lessen the economic value of the vegetation and reduce its complexity and, perhaps, its ability to respond adaptively to other stresses such as drought. Low-level impacts may actually increase productivity in some circumstances. The following discussion covers acute impacts first, followed by chronic and low-level effects.

A. Acute Impacts

Leaf injury (damage) from short-term exposure generally requires very high levels of SO_2. Concentrations of SO_2 which experimentally produce acute damage in 2-7 hours for a number of common western range grasses, important wildlife browse plants, trees, and crops are tabulated in Table 11-58; these experiments indicate that damage occurs between 0.4 and 10 parts per million (ppm). Results were selected to show the effects of exposures

TABLE 11-58: SELECTED SULFUR DIOXIDE CONCENTRATIONS WHICH EXPERIMENTALLY PRODUCED ACUTE INJURY IN WESTERN PLANT SPECIES

SPECIES	SULFUR DIOXIDE CONCENTRATION (ppm)	DURATION (hours)	TYPE OF OBSERVATION CONDITIONS
Grasses			
Western wheatgrass[a]	1.0-1.5	4	Laboratory, greenhouse-grown plants
Crested wheatgrass[b]	6	2	Field fumigation
Needle-and-thread-grass[a]	1.0-1.5	4	Laboratory, greenhouse-grown plants
Blue grama[b]	6	2	Field fumigation
Galleta[b]	10	2	Field fumigation
Indian ricegrass[b]	0.5	2	Field fumigation
Shrubs			
Big sage[b]	4	2	Field fumigation
Rubber rabbitbrush[b]	6	2	Field fumigation
Mormon tea[b]	6	2	Field fumigation
Snowberry[b]	1	2	Field fumigation
Curl-leaf mountain mahogany[b]	6	2	Field fumigation
Gambel oak[b]	10	2	Field fumigation
Fringed sagewort[a]	1	4	Laboratory, greenhouse-grown plants
Trees			
Subalpine fir[b]	10	2	Field fumigation
Utah juniper and Rocky Mountain juniper[b]	10	2	Field fumigation
Pinyon[b]	6	2	Field fumigation
Ponderosa pine	10	2	Field fumigation[b]
	0.5	7	Laboratory transplanted stock[c]
	1	6-7	Laboratory transplanted stock[c]
	0.39	6.2	Laboratory[c]
Crops			
Alfalfa	0.5	4	Laboratory[d]
	0.5	4-8	Field and greenhouse fumigation[c]
	0.4	7	Laboratory, greenhouse-grown plants[e]
Winter wheat	2	3	Field fumigation[c]
	1.35	1-2	Laboratory, greenhouse plants[c]

ppm = parts per million

TABLE 11-58: (Continued)

[a]Tingey, D.T., R.W. Field, and L. Bard. "Physiological Responses of Vegetation to Coal-Fired Power Plant Emissions," in Lewis, R.A., N.R. Glass, and A.S. Lefohn, eds. The Bioenvironmental Impact of a Coal-Fired Power Plant, 2nd Interim Report: Colstrip, Montana, EPA-600/3-76-013. Corvallis, Oreg.: Corvallis Environmental Research Laboratory, 1976.

[b]Bill, A.C., et al. "Sensitivity of Native Desert Vegetation to SO_2 and to SO_2 and NO_2 Combined." Journal of the Air Pollution Control Association, Vol. 24 (February 1974), pp. 153-57.

[c]Altman, Philip L., and Dorothy S. Dittmer, eds. Biology Data Book, 2nd ed. Bethesda, Md.: Federation of American Societies for Experimental Biology, 1973, Vol. 2.

[d]Tingey, D.T., et al. "Foliar Injury Responses of Eleven Plant Species to Ozone/Sulfur Dioxide Mixtures." Atmospheric Environment, Vol. 7 (February 1973), pp. 201-8.

[e]Zimmerman, P.W. In Proceedings of the United States Technical Conference on Air Pollution, Washington, D.C., 1950. New York, N.Y.: McGraw-Hill, 1952, p. 127.

corresponding roughly to the shortest averaging times (3-hour and 24-hour averages) used to calculate maximum ground-level SO_2 concentrations for the six site-specific scenarios. Extreme high values, resulting from plume impaction on high terrain, may be as much as 0.43 ppm,[1] while in the ventilated areas with flat terrain and lower sulfur coal highest 3-hour maxima are only to 0.13 ppm.[2] Power plants, Synthoil plants, and TOSCO II (the Oil Shale Company) plants create the highest 3-hour average concentrations. These maxima approach concentrations that have produced experimental injury in ponderosa pine and alfalfa. More typical 3-hour periods produce ground-level concentrations one-tenth to one-hundredth as high.

However, large areas of vegetation would not be expected to experience acute toxicity under the worst dispersion conditions considered. High ground-level concentrations result from direct impaction of a plume on high terrain. The highest modeled 3-hour concentration, 0.43 ppm from the Escalante power plant, occurs under these circumstances. Here, concentrations remain consistently high throughout the averaging period, but the affected area is quite small (roughly 1 or 2 square miles).

For most scenarios, ground-level concentrations will be 3-10 times lower than concentrations known to cause acute injury in fumigation experiments. In some scenarios, however, irregular terrain may result in infrequent plume impaction that could raise ground concentrations to levels which may cause acute damage to sensitive species. Some visible damage to ponderosa pine could occur within limited areas, especially in southern Utah and western Colorado. Elsewhere, sensitive species may be exposed to SO_2 levels near, but below, known damage levels. Evergreens are susceptible year-round, but the worst dispersion conditions over most of the eight-state region occur in the winter when most vegetation species are in a seasonal minimum of activity.

B. Chronic Impacts

Chronic damage to plants typically occurs at much lower concentrations than does acute damage. The premature loss of needles observed near the Mount Storm power plant in West Virginia[3] was associated with average SO_2 concentrations of 0.01

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[1]For the Escalante Power Plant, see Chapter 4.

[2]For the Gillette scenario, see Chapter 7.

[3]U.S., Environmental Protection Agency, Air Pollution Control Office. Mount Storm, West Virginia/German, Maryland and Luke, Maryland/Kaiser, West Virginia: Air Pollution Abatement Activity, APTD-0656. Research Triangle Park, N.C.: Environmental Protection Agency, 1971.

ppm, although 1-hour maxima as high as 0.36 ppm were recorded. Reductions of 15 percent in the yield weights of grain have been reported for winter wheat under chronic SO_2 levels averaging 0.015-0.05 ppm.[1] Chronic damage to alfalfa has been observed at concentrations between 0.024 and 0.051 ppm.[2] All these species are especially sensitive to SO_2.

Analysis of air impacts in the site-specific scenarios showed that multiple plume interactions seldom occur, and when they do, their cumulative effect on ground-level concentrations is less than the peak levels modeled for the individual plants. Consequently, in this regional discussion where the exact locations of the emission sources are not known, it is assumed that maximum ground-level concentrations can still be estimated in terms of individual plants, with the understanding that these impacts may be felt in many locations in the region as a whole.[3]

Using 24-hour averaging times, worst-case concentrations range between 0.001 ppm (modified *in situ* shale processing, Rifle) and 0.12 ppm (power plant, Escalante). Assuming the cut-off point for chronic damage is 0.01 ppm, an examination of the peak 24-hour averages predicted for the local scenarios shows that concentrations exceeding this level can generally be expected downwind of power plants, at least at some time. However, these are infrequent peaks and cover shorter periods than those usually associated with observed chronic SO_2 damage to plants in the field.

Ecological damage thought to result from acid rainfall has been documented in Scandinavia from long-distance transport of sulfates from England and in Germany's industrialized Ruhr

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[1]Guderian, R., and H. Stratmann. *Forschungsberichte des Landes Nordrhein-Westfalen No. 1118*. Koln: Westdeutscher Verlag, 1968, p. 5; and Guderian, R., and H. Stratmann. *Forschungsberichte des Landes Nordrhein-Westfalen No. 1920*. Koln: Westdeutscher Verlag, 1968, p. 3.

[2]Guderian, R., and H. Van Haut. "Detection of SO_2 Effects Upon Plants." *Staub-Reinhaltung der Luft*, Vol. 30 (1970), pp. 22-35.

[3]Background SO_2 data are scarce in the western states. However, existing figures indicate that typical levels are only a few $\mu g/m^3$, too small to make a difference significant to plants when added to calculated ground-level concentrations arising from energy facilities.

district.[1] In New Hampshire, rainfall acidification due to emissions from the urban industrial complexes of New England has also been documented.[2] From these and other studies, the following points emerge:

- Mechanisms of Acidification. The mechanisms by which rainfall is acidified are just now beginning to be understood qualitatively, and quantitative predictions of the effects on rainfall pH of given SO_2 emissions cannot yet be made. While some investigators have concluded that rainfall pH is governed by strong acids (such as sulfuric acid), others have presented evidence that weak acids may also be involved.[3] In spite of this lack of agreement, it is apparent that other ions besides sulfates are involved in determining the pH of rain. The major species appear to be sulfates, nitrates, and chlorides.[4] In addition to industrial sources, large amounts of nitrogen apparently enter the atmosphere because of the use of ammonia and nitrate fertilizers.[5] Atmospheric chloride ions, contributing to the formation of hydrochloric acid, also originate from the sea.

- Pathways into Terrestrial Ecosystems. Much of the sulfur reaching Sweden has been shown to be in the form of neutral ammonium sulfate compounds. These particles, which are thought to form catalytically or photochemically

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[1]Bolin, B., Chairman. Sweden's Case Study Contributions to the United Nations Conference on the Human Environment--Air Pollution Across International Boundaries: The Impact on the Environment of Sulfur in Air and Precipitation. Stockholm: Royal Ministry for Foreign Affairs, Kingl. Boktrychereit, P.A. Norsledt et Soner, 1971.

[2]Whittaker, R.H., et al. "The Hubbard Brook Ecosystem Study: Forest Biomass and Production." Ecological Monographs, Vol. 44 (Spring 1974), pp. 233-54.

[3]Frohliger, J.O., and R. Kane. "Precipitation: Its Acidic Nature." Science, Vol. 189 (August 8, 1975), pp. 455-57.

[4]Likens, G.E., and F.H. Bormann. "Acid Rain: A Serious Regional Environmental Problem." Science, Vol. 184 (June 14, 1974), pp. 1176-79.

[5]Tabatabai, M.S., and J.M. Laflen. "Nutrient Content of Precipitation Over Iowa," abstract in First International Symposium on Acid Precipitation and the Forest Ecosystem, Program and Abstracts. Columbus, Ohio: Ohio State University, Atmospheric Sciences Program, 1975.

in the air, enter the ecosystem as dry fallout. However, when the ammonia is absorbed by plants, both the remaining ammonia and the released sulfate ions tend to acidify soils.[1] Forest vegetation tends to filter out such particulates.[2] This may expose forests differentially to acidification problems. However, airborne alkaline or calcareous dust may increase the pH of rainfall and thereby counteract the effect of acid-forming substances in the air.[3] It has been suggested that the pH of rainfall depends jointly on atmospheric sulfur loading, the amount of dense forest vegetation in the area, and the extent of calcareous or limestone soils.[4]

- Geographic Variation. Observations of chronic damage from acid rainfall are not always consistent geographically. Recent efforts to use tree-ring data to document the impacts of region-wide reductions in rainfall pH in New England and Tennessee failed to reveal a statistically significant trend on a regional level, despite the evidence of the Hubbard Brook Study in New Hampshire.[5] Similarly, using the same method, no consistent trend in forest productivity has been

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[1]Dochinger, L.S., and T.A. Seliga. "Acid Precipitation and the Forest Ecosystem: A Report from the First International Symposium on Acid Precipitation and the Forest Ecosystem." Journal of the Air Pollution Control Association, Vol. 25 (November 1975), pp. 1103-5; Brosset, C. "The Role of Acid Particles in Acidification," abstract in First International Symposium on Acid Precipitation and the Forest Ecosystem, Program and Abstracts. Columbus, Ohio: Ohio State University, Atmospheric Sciences Programs, 1975.

[2]Davis, B.L., et al. The Black Hills as a "Green Area" Sink for Atmospheric Pollutants, First Annual Report, prepared for the USDA Rocky Mountain Forest and Range Experiment Station, Report 75-8. Rapid City, S.Dak.: South Dakota School of Mines and Technology, Institute of Atmospheric Sciences, 1975.

[3]Cooper, H.B.H., et al. "Chemical Composition Affecting the Formation of Acid Precipitation," abstract in Symposium on Acid Precipitation and the Forest Ecosystem.

[4]Winkler, E.M. "Natural Dust and Acid Rain," abstract in Symposium on Acid Precipitation and the Forest Ecosystem.

[5]Cogbill, C.V. "The Effect of Acid Precipitation on Tree Growth in Eastern North America," abstract in Symposium on Acid Precipitation and the Forest Ecosystem.

discovered in Norway.[1] In the northeastern U.S., a recent investigation found that the rate of nutrient loss from upland forest watersheds is still quite low, in spite of the rising acidity of rainfall.[2]

Acid rain has also been associated with single large sources, including large power generation complexes. In studies of the effects of multiple-plant generation complexes in West Virginia and Tennessee, premature pine needle drop, damage to crops, and reduced soil fertility were correlated with acid rain. In these cases, SO_2 emissions were generally greater than individual plant projections in this technology assessment.[3] SO_2 emissions densities at levels projected for the Nominal case for the Powder River Region in the year 2000 (see Section 11.2) are about one-third the SO_2 emissions densities of the highest industrialized states (e.g., Ohio) in the East, assuming 80 percent SO_2 removal from power plants. However, in eastern locations, rainfall is four to six times greater than in the eight-state study area. Acid rainfall due to lower emissions densities and rainfall seems less likely to become a regional problem in the eastern U.S.

C. Low-Level Effects

Atmospheric dispersion alone will likely result in low-level effects around most or all of the large facilities sited in the eight-state study area. In some areas, especially where dispersion is rapid (as in Wyoming), sulfur additions may be so small as to exert no detectable influence on either soil sulfur levels or plant productivity. Slightly larger sulfur inputs may enter the sulfur cycle through direct absorption by plants as SO_2, dry fallout, or rain scavenging.

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[1]Abrahamsen, G., and B. Tveite. "Impacts of Acid Precipitation on Coniferous Forest Ecosystems," abstract in First International Symposium on Acid Precipitation and the Forest Ecosystem, Program and Abstracts. Columbus, Ohio: Ohio State University, Atmospheric Sciences Program, 1975.

[2]Johnson, N.M., R.C. Reynolds, and G.E. Likens. "Atmospheric Sulfur: Its Effect on the Chemical Weathering of New England." Science, Vol. 177 (August 11, 1972), pp. 514-16.

[3]There are four plants in the Mount Storm area, totaling 3,400 MWe and emitting 788,000 tons of SO_2 in 1973. These plants burn high-sulfur coal without scrubbers. The Shawnee plant in Tennessee is rated at 1,750 MWe and emits 228,600 tons per year (1973). By contrast, the hypothetical Colstrip power plant will generate 3,000 MWe but will burn low-sulfur or medium-sulfur coal with scrubbers; its yearly emissions will be 14,000 tons.

11.5.5 Summary of Regional Ecological Impacts

The effects described above will change some existing pattern of stresses to aquatic and terrestrial ecosystems. Consumptive water use will result in flow depletion on some rivers. Especially vulnerable are the San Juan, the White, the Upper Colorado, and the Yellowstone. Cumulative impacts will also have adverse effects on the lower Colorado and Missouri. In-stream flow needs to protect aquatic ecosystems have not been established for most of these rivers, but it is expected that withdrawals could produce adverse impacts in several drainages. In addition to the physical impact of flow reduction, loss of dilution capacity increases the risk of harmful impacts due to the discharge of municipal effluents, agricultural runoff, and contaminated groundwater discharge. However, increased salinity does not appear to be a serious ecological problem. Construction of water supply systems may involve placing reservoirs on smaller tributary rivers and streams. These reservoirs can be beneficial in that they will trap sediment, provide fishery habitat, and can be used to regulate downstream flows. However, they also may interfere with spawning runs, destroy valuable riparian habitat, and build up excessive nutrient enrichment from agricultural runoff.

Increased backcountry recreational pressure may become a serious problem to some terrestrial ecosystems, especially high alpine areas, high- and mid-elevation mountain valleys, and adjacent desert watercourses. These habitats are critical to maintaining present levels of ecological diversity and are limited in extent. The heaviest population-related impacts will occur in the Black Hills, the Bighorn Mountains, and the mountainous areas surrounding the Colorado oil shale deposits.

Because of the extensive land use for strip mining in the Northern Great Plains, reclamation will be important. Reclamation success depends primarily on the extent and timing of rainfall, soil type and overburden characteristics, and the resiliency of plant and animal communities in restoration. The Southwestern deserts will be most difficult to reclaim because of low rainfall, poor soil characteristics, and overgrazing. Revegetation will probably be successful in the remainder of the eight-state region, but wildlife abundance and diversity will be reduced if grazing or crop production are the major reclamation objectives.

Development of large numbers of SO_2 emission sources over the western region is not expected to result in widespread damage to vegetation. Although the fate of sulfates in the air is poorly understood, comparison with recorded cases suggests that acid rainfall is unlikely to become a widespread problem. Acute damage to vegetation is expected only where rough terrain causes plume impaction. The oil shale area of western Colorado is the only region in which multiple sources are expected to result in cumulative impacts which could be chronically damaging to vegetation over areas of more than 1 or 2 square miles.

11.6 TRANSPORTATION IMPACTS

11.6.1 Introduction

Development of energy resources in the eight-state study area will produce solids, liquids, gases, and electricity as energy forms, with a different set of transportation modes available for each form (see Figure 11-16). In this analysis of energy transportation impacts, particular attention is paid to coal because (1) there are a wide variety of transportation options in the coal resource development system,[1] (2) a substantial investment is required (perhaps 75 percent of total western energy transportation investment) to develop the coal transportation system, and (3) there is substantial controversy surrounding the relative merits of rail and slurry pipeline systems.

In this section, the expected increase in the overall magnitude of western energy transportation is assessed, with some detail on modes and routes. The characteristics of the modes are then discussed, both in terms of their resource requirements (such as water) and in terms of their impacts (such as noise).

11.6.2 Magnitude of Transportation Activity

A. Coal

Figure 11-17 presents projections of the major movements of western coal used by electric utilities in the year 2000. It is based on a scenario of high coal use (western production for utilities of 788 million tons per year) and minimal environmental protection.[2] It should be borne in mind that the flows depend critically on such factors as air pollution policy. One study has projected, for example, that a uniformly applied 90 percent sulfur removal standard could reduce flows from the Northern

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[1]In addition to the modes shown in Figure 11-16, barges, trucks, and conveyors play a significant role in the eastern half of the country and localized areas in the West.

[2]Teknekron Inc., "Projections of Utility Coal Movement Patterns: 1980-2000," in U.S., Congress, Office of Technology Assessment. Task Reports: Slurry Coal Pipelines, Vol. II, Part 1. Washington, D.C.: Office of Technology Assessment, 1978. The 788 million tons per year exported from the West for use by utilities is equivalent to about 68 percent of all western coal production projected in the SRI Low Demand case and 50 percent of production projected in the SRI Nominal Demand case for 2000.

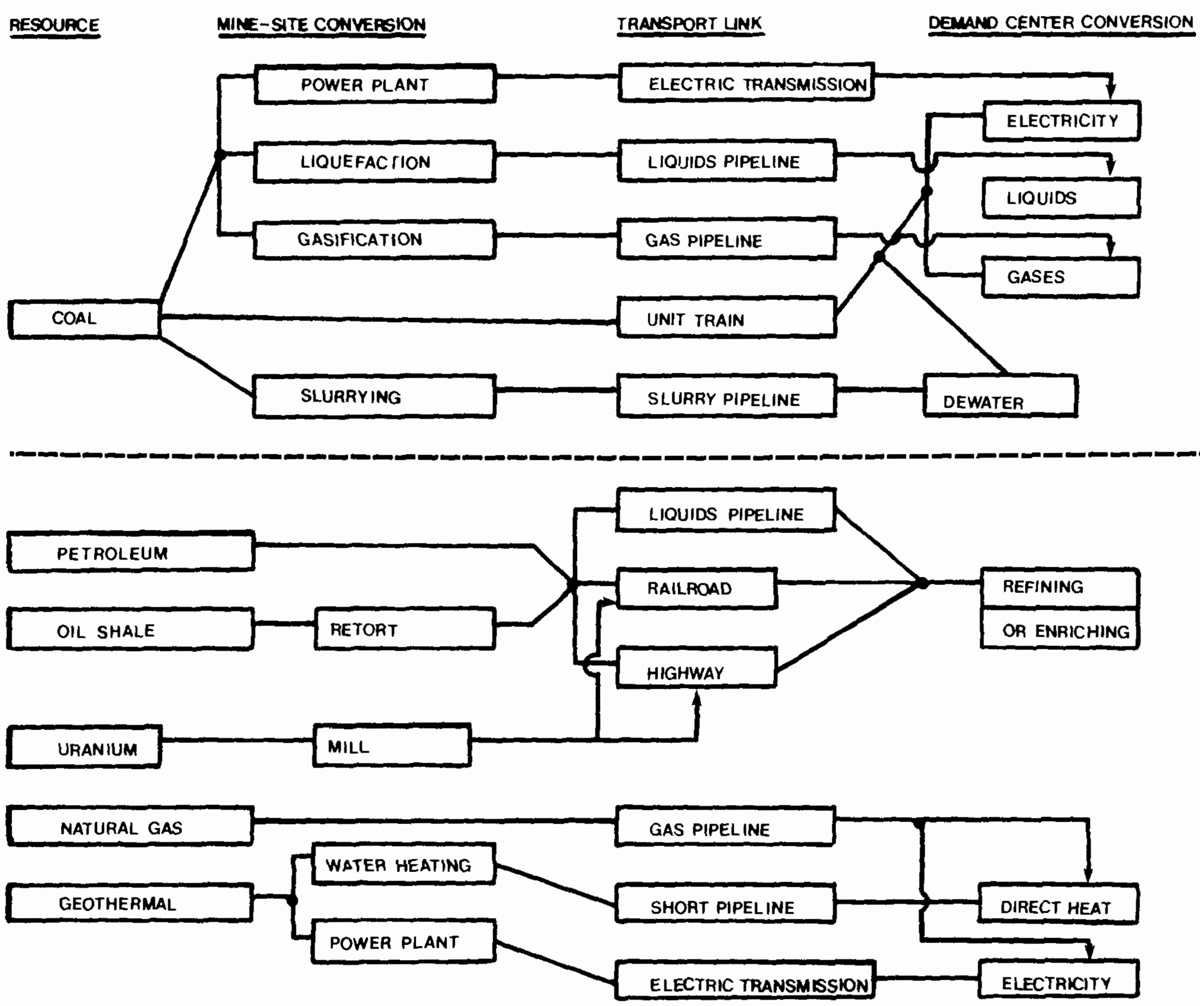

FIGURE 11-16: CONVERSION/TRANSPORT CONFIGURATIONS

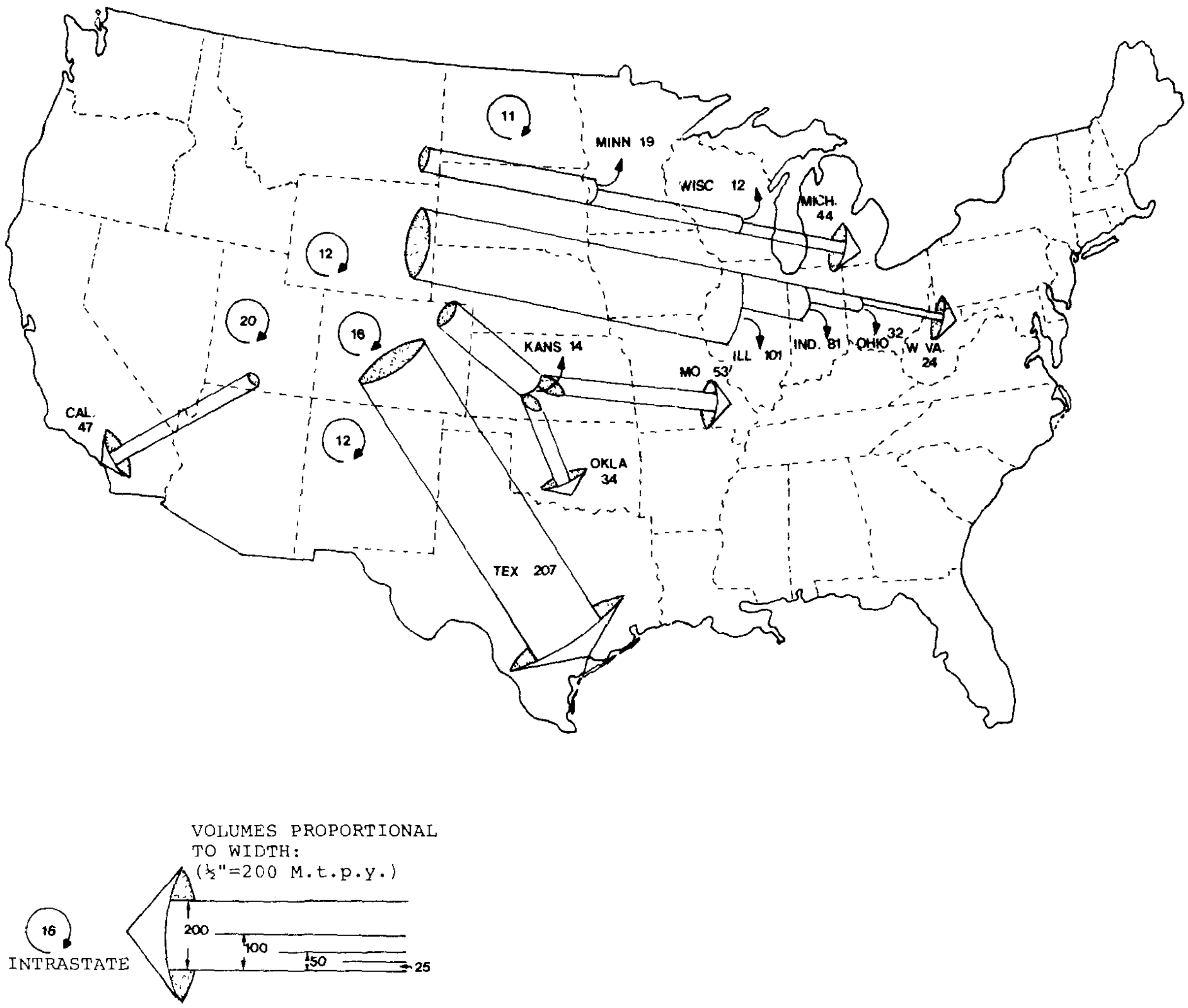

FIGURE 11-17: UTILITY COAL TRANSPORTATION FROM WESTERN SOURCES, YEAR 2000

Great Plains to the Midwest by a factor of four or more.[1] Nevertheless, the major movement of western coal will probably be from the Northern Great Plains eastward and southward. The largest single direction of movement will be from Wyoming to Texas, caused by extensive replacement of gas-fired power plants with coal-fired power plants.[2]

There is considerable uncertainty about the split of coal transportation between railroad and slurry modes. It is generally agreed that slurry pipelines are most economical when transporting large volumes over long distances, but investigators differ widely in quantifying these cost parameters. A rough estimate has been obtained by assuming that rail is more economical for all movements under 400 miles or 4 MMtpy and that pipeline is more economical for all movements over both 950 miles and 18 million tons.[3] These economic criteria imply that 48 percent of coal produced in the West would be transported by pipeline. This is equivalent to 62 percent of the coal which leaves the eight-state study area. Routes involved would be from Wyoming and Colorado to Texas, Kansas, Missouri, and Indiana.

B. Gases, Liquids, and Electricity

The magnitude of transportation of gases, liquids, and electricity was traced in the process of implementing the Stanford Research Institute interfuel competition model.[4] The model divides the U.S. into geographic regions, with resources, demands, and costs specified on a regional basis. On the basis of delivered costs, the model determines the quantity of energy which will be transported by each alternative among the supply and demand centers. The transportation links in the model extend from

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[1]Krohm, G.C., C.D. Dux, and J.C. Van Kuiken. Effect on Regional Coal Markets of the "Best Available Control Technology" Policy for Sulfur Emissions, National Coal Utilization Assessment. Argonne, Ill.: Argonne National Laboratory, 1977.

[2]However, the potential use by Texas utilities of Texas lignite makes this Wyoming to Texas projection quite uncertain.

[3]Intermediate situations can be allocated on the basis of some site-specific analysis. See General Research Corporation and International Research and Technology. "A Study of the Competitive and Economic Impact Associated with Coal Slurry Pipeline Implementation," in U.S., Congress, Office of Technology Assessment. Task Reports: Coal Slurry Pipelines, Vol. II, Part 1. Washington, D.C.: Office of Technology Assessment, 1978.

[4]Cazalet, Edward, et al. A Western Regional Energy Development Study: Economics, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

the energy resource areas to the centroids[1] of the energy demand regions. No attempt was made to simulate the complex network of links among numerous cities and towns. Results are displayed in Figures 11-18, 11-19, and 11-20.

Based on the Nominal Demand case, nine gas pipelines, each with a capacity of 1 billion cubic feet (bcf) per day, will originate in the Northern Great Plains, while four gas pipelines will be required in the Four Corners area in the year 2000 to transport both natural and synthetic gas. Data filed with the Federal Energy Regulatory Commission (FERC) show that two major interstate gas pipeline companies have lines currently transversing the Four Corners states with a total yearly capacity of 2,341 bcf, exclusive of added compression or looping which would increase the capacity. Therefore, except for short gathering lines to tie in with these existing trunk lines, it is anticipated that no new pipelines will be required to transport the gas projected to be produced in the Rocky Mountain region for the Nominal case. Existing lines will progressively transport less natural gas and more synthetic gas.

Based on the same Federal Power Commission (FPC) data, one major gas pipeline with a capacity of 56 bcf per year currently traverses the Northern Great Plains. In addition, a leg of the proposed Alcan gas pipeline will pass through part of the region.[2]

The Nominal case will require that 4 bcf, 201 bcf, and 3.43 trillion cubic feet (tcf) of gas per year be produced in the Northern Great Plains in 1985, 1990, and 2000, respectively. In this case, current lines will be adequate until the late 1980's, but new pipelines with a capacity of 3.37 tcf per year will be required by 2000 to meet the projected flows.

Liquid fuel flows from the western region will consist of shale oil, conventionally produced crude oil, and coal syncrude. Existing trunkline capacity from the Northern Great Plains has been estimated as 620,000 bbl/day.[3] In the Nominal case, 142,000 bbl/day will be produced in the year 2000 in the area. Therefore, except for tie-in lines, existing crude oil trunkline

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[1]A centroid of a region is calculated as the point which minimizes the average distance to all other points in the region.

[2]"President Chooses Alcan to Move Prudhoe Gas." Oil and Gas Journal, Vol. 75 (September 12, 1977), p. 73.

[3]U.S., Department of the Interior, Office of Coal Research. Prospective Regional Markets of Coal Conversion Plant Products Projected to 1980 and 1985. Washington, D.C.: Government Printing Office, 1974.

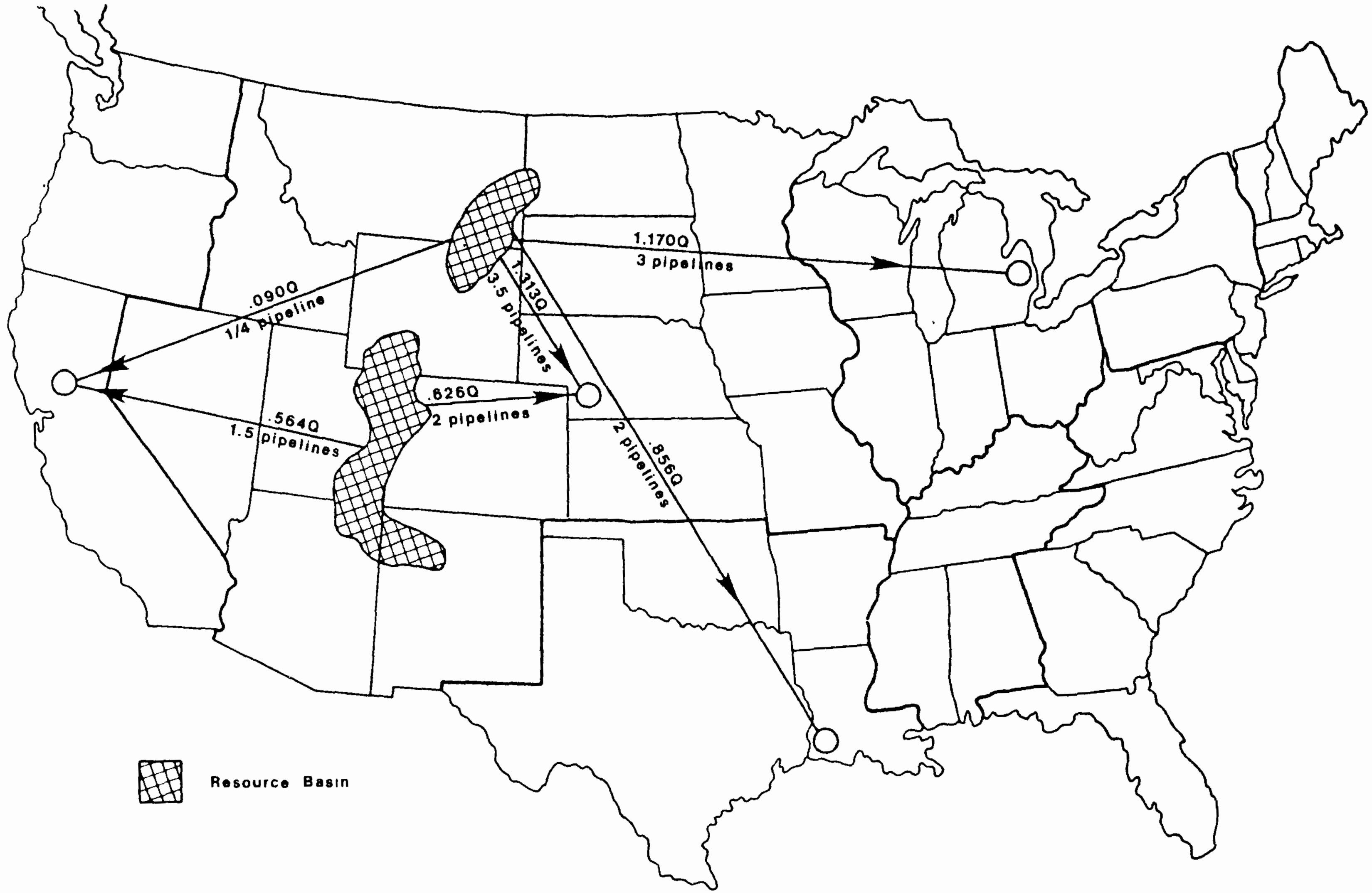

FIGURE 11-18: HIGH BTU GAS TRANSMISSION FROM WESTERN REGION, NOMINAL DEMAND CASE, YEAR 2000
(Capacity of each pipeline is one billion cubic feet per day)

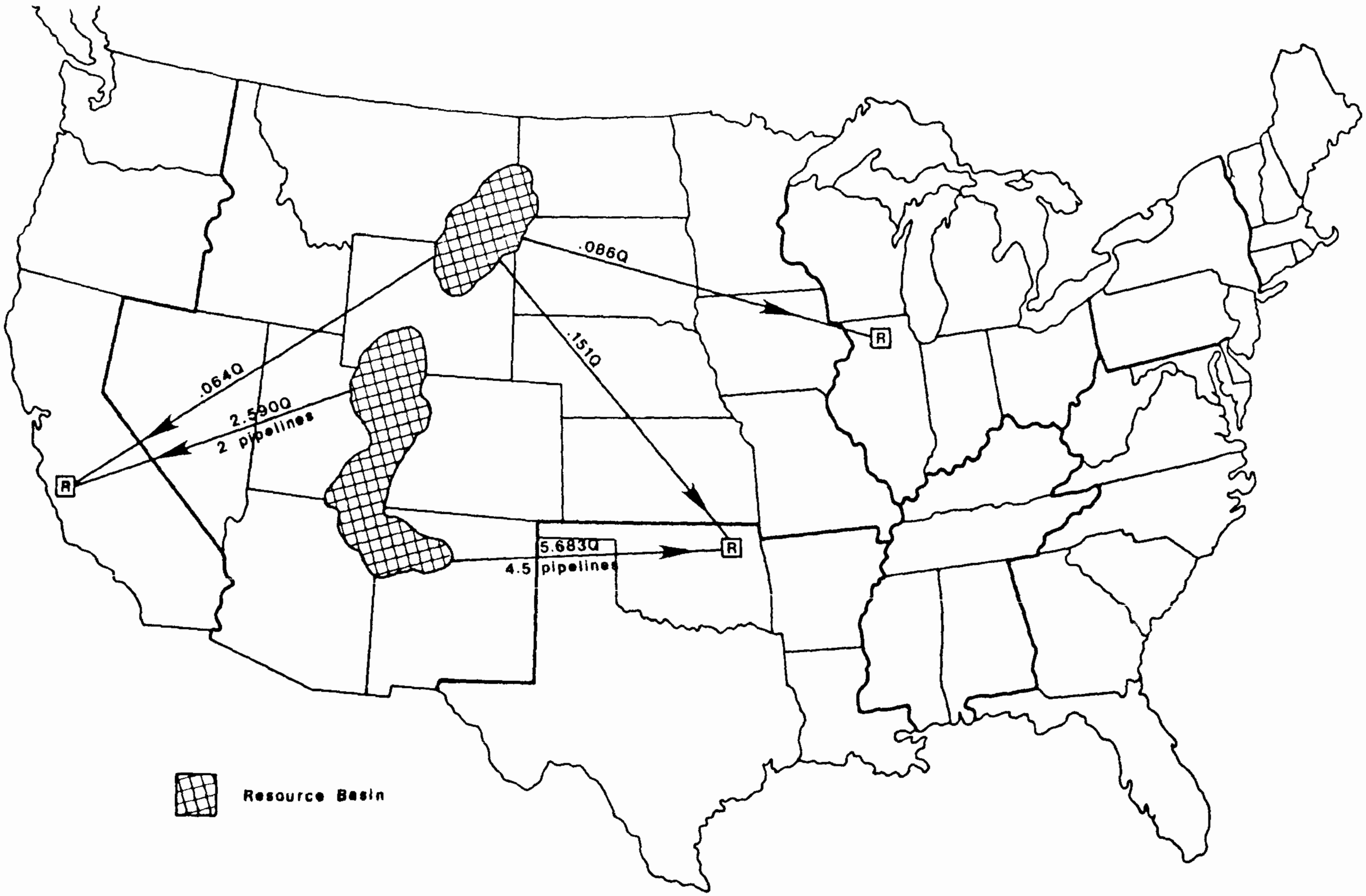

FIGURE 11-19: LIQUID PIPELINE (CRUDE OIL, SHALE OIL, COAL SYNCRUDE) ENERGY TRANSPORTED FROM WESTERN REGION NOMINAL DEMAND CASE, YEAR 2000

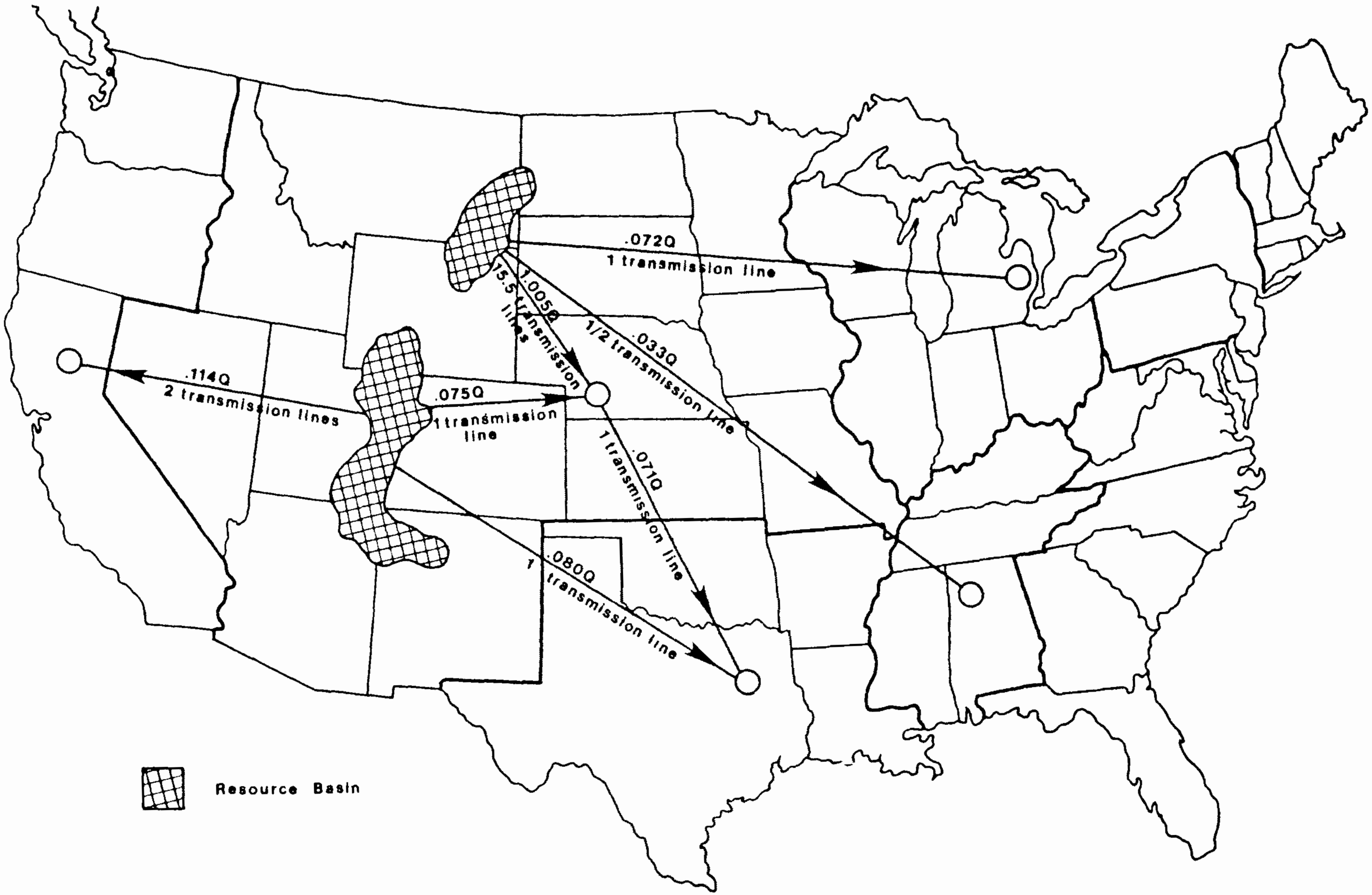

FIGURE 11-20: ELECTRICITY TRANSMITTED FROM WESTERN REGION, NOMINAL DEMAND CASE, YEAR 2000

capacity should be capable of transporting the projected production of liquid fossil fuels from the Northern Great Plains to refinery centers.

In the Nominal case, the Four Corners area will produce 3.91 million bbl/day of liquid fossil fuels in the year 2000. However, the Interstate Commerce Commission estimates the available crude oil trunkline capacity out of the area as only 260,000 bbl/day.[1] As a result, almost all the approximately 2,400 miles of 36-inch pipelines projected to be required must be newly constructed.

Most of the new electric power plants in the West are assumed to be located at the mine-mouth. This will entail new transmission facilities to tie into existing grid systems because few of the hypothesized mines are located near metropolitan demand centers. For the Nominal case in 2000, approximately 13,000 miles of new lines will be required.

The choice between alternating current (AC) and direct current (DC) will involve detailed consideration of the advantages and disadvantages of each system on a case by case basis. However, DC transmission at 600 kilovolts(kV) was assumed in performing this regional scenario analysis because it has potential for lower power losses and reduced environmental impact in the high-volume, long-distance applications considered in this study. It must be recognized, however, that technology of transmitting electricity via high-voltage direct current (HVDC) lines is still in its early development stages as compared to AC transmission, and the use of HVDC has been fairly limited. Of the 39,502 circuit miles of overhead extra-high voltage transmission lines operational in 1974, only 865 miles were DC lines operating at ±400 kV.[2]

11.6.3 Input Requirements

A. Economic Costs

Table 11-59 summarizes information on the costs of energy transportation on a unit basis and Table 11-60 summarizes costs for the entire region.

The front-end costs of unit train systems will consist of hopper cars, locomotives, new track, and upgrading of existing

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[1]U.S., Department of the Interior, Office of Coal Research. Prospective Regional Markets of Coal Conversion Plant Products Projected to 1980 and 1985. Washington, D.C.: Government Printing Office, 1974.

[2]"The Electric Century, 1874-1974." Electrical World, Vol. 181 (June 1, 1974), p. 431.

TABLE 11-59: SUMMARY ESTIMATES OF THE ECONOMIC CHARACTERISTICS OF TRANSPORT MODES

MODE	UNIT COST[a]	FIXED PORTION OF COST[b] (percent)	ENERGY CONSUMPTION[c] (percent)
DC Transmission	$2.78	84.6	11.0
Unit Trains	0.60	12.2	2.5
Pipelines			
Slurry	0.75	79.3	2.9
Gas	0.56	50.9	9.6
Oil	0.078	73.1	1.1

DC = direct current

[a]Except for electricity, the costs are 1975 dollars per million British thermal units (Btu) of energy flow over routes of 1,000 miles. In order to make the costs roughly comparable, the unit costs of electricity are expressed in terms of 1975 dollars per million Btu of electric energy, which assuming a 35 percent conversion efficiency requires three million Btu heat input at the power plant.

[b]Percent of annualized cost accounted for by amortization of initial investment. Assumed annual carrying charge of 22.8 percent.

[c]Percent of energy input which is lost or consumed over a 1,000 mile route.

track. All of these costs will vary depending on the characteristics of the particular route being considered, such as the physical condition of the roadbed, signalling systems, and other traffic. These factors also play a role in determining the average speed of the trains and hence how much rolling stock is needed to deliver coal at a given rate.

Railroads have been spending less and less on track maintenance over the last two decades. Results of a study for the Federal Energy Administration indicated that to restore 71 percent of the national rail lines (rails and ties) to normal condition will require $4.1 billion. A total expenditure of

TABLE 11-60: WESTERN ENERGY TRANSPORT, YEAR 2000
INCREASE OVER YEAR 1975

		LOW DEMAND CASE		NOMINAL DEMAND CASE	
MODE	ENERGY FORM	THROUGHPUT[a]	CAPITAL COSTS (billions of 1975 dollars)	THROUGHPUT[a]	CAPITAL COSTS (billions of 1975 dollars)
Slurry	Coal	375 MMtpy	14.2	483 MMtpy	20.1
Unit Train	Coal	306 MMtpy	9.9	433 MMtpy	12.78
Gas Pipeline	Gas from Coal	9.56 bcfd	3.93	10.70 bcfd	4.40
DC Transmission	Electricity	29,600 MWe	2.17	40,000 MWe	2.93
Oil Pipeline	Shale Syncrude	1.79 MMbbld	.86	1.83 MMbbld	.88
			31.00		41.00

MMtpy = million tons per year
bcfd = billion cubic feet per day
DC = direct current
MWe = megawatt-electric
MMbbld = million barrels per day

[a]In both Low and Nominal Demand Cases, quantities are adjusted to reflect equivalent throughputs over a standardized distance of 1,000 miles.

$12 billion has been estimated for complete restoration.[1] It was not determined whether this restoration process would enable existing lines to carry the increased tonnage required for coal unit trains. Existing rail lines might not be able to accommodate the tonnage and speed of projected coal unit train traffic. Some lines have been constructed specifically for unit trains,[2] but for many lines, new ballast, ties, and heavier rails will probably be required. Assuming that 33,000 miles of western track will require upgrading at a cost of $100,000 per mile, total upgrading cost would come to some $3.3 billion.

There is considerable disagreement as to how many trains can be run on a given route. Various investigators have used figures in their studies ranging from 25[3] to 230[4] MMtpy on a double track line. Assuming a saturation point of 70 MMtpy, 6,600 miles of new lines would be needed for moving western coal, at a cost of almost $2.0 billion.[5]

In any case, the larger portion of cost in a unit train system comes in the form of operating costs, as can be seen in Table 11-59,

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[1]U.S., Federal Energy Administration. Project Independence Blueprint, Final Task Force Report, Analysis of Requirements and Constraints on the Transport of Energy Materials, Vol. 1. Washington, D.C.: Government Printing Office, 1974.

[2]Doran, Richard K., Mary K. Duff, and John S. Gilmore. Socio-Economic Impacts of Proposed Burlington-Northern and Chicago & North Western Rail Line in Campbell-Converse Counties, Wyoming. Denver, Colo.: University of Denver, Research Institute, 1974.

[3]This lower limit makes allowance for other classes of traffic and assumes relatively poor track conditions. See Rieber, Michael, and Shao Lee Soo. "Route Specific Cost Comparisons: Unit Trains, Coal Slurry Pipelines and Extra High Voltage Transmission," Appendix B in White, Irvin L., et al. Energy From the West: A Progress Report of a Technology Assessment of Western Energy Resource Development. Washington, D.C.: U.S., Environmental Protection Agency, 1977.

[4]Desai, Samir, and James Anderson. Rail Transportation Requirements for Coal Movement in 1980. Cambridge, Mass.: Input Output Computer Services Inc., 1976, p. 2-32.

[5]U.S., Congress, Senate, Committee on Commerce. To Alleviate Freight Car Shortage, Senate Report 92-982 on S. 1729, 92d Cong., 2d sess., 1972.

and the largest single item in operating costs is labor. Approximately 43 railroad workers will be needed to transport each million annual tons of coal over a 1,000 mile route.[1]

In contrast with railroads, a large portion of the costs of slurry pipelines are front-ended. Estimates of front-end costs for a 25 MMtpy line range from $800 thousand[2] to $2 million[3] per mile. Interest charges and inflation rates are critical in converting these fixed costs into a per-ton equivalent. If a nominal cost of capital of 13 percent per annum must be borne at a time when 7 percent inflation is occurring, then the real cost of capital is approximately 6 percent. If, on the other hand, long term financing commitments are made at 13 percent and inflation subsequently moderates to 4 percent, then the real rate will have risen to approximately 9 percent. Using these two cases as examples of possible real interest rates, adding 2.5 percent to each for insurance and property taxes, and assuming a facility life of 30 years; each million dollars of initial investment would entail an annualized real[4] cost of from $89,800 to $116,400. Combining these rates with the range of construction cost estimates given above, the per ton capital cost (per 1000 miles) could vary from $2.87 to $9.31. As noted, operating costs are relatively small in a slurry system.

The economic characteristics of power transmission will depend on whether the AC or DC mode is utilized. DC is more stable, has smaller energy losses, and--at any power level--requires smaller lines, less insulation, and less right-of-way.[5] Nevertheless, until recently AC has been used almost exclusively in transmission. The major obstacle to DC has been the cost of terminal conversion facilities. Although these costs are coming down, the major applications of DC will continue to be primarily long distance and single source, such as with remote mine-mouth generating plants.

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[1]Freudenthal, David, et al. Coal Development Alternatives. Cheyenne, Wyo.: Wyoming Department of Economic Planning and Development, 1974, Table 2.3.

[2]Cazalet, Edward, et al. A Western Regional Energy Development Study: Economics, Final Report, 2 vols. Menlo Park, Calif.: Stanford Research Institute, 1976.

[3]Freudenthal, et al. Coal Development Alternatives, p. 34.

[4]In terms of the currency value prevailing at the time of the initial investment.

[5]Hingorani, Narain. "The Reemergence of DC in Modern Power Systems." EPRI Journal, Vol. 3 (June 1978), pp. 6-13.

B. Physical Input Requirements

Attention has been paid in a number of studies to the requirements for steel, land, and water which may be consumed or changed in energy transportation. Summary estimates are presented in Table 11-61. Unit trains and slurry pipelines are roughly comparable in total steel requirements, though the types of steel differ. Each system requires about 380 tons per mile for fixed structures (assuming 25 MMtpy capacity). In addition, railroads have to provide a fleet of locomotives and hopper cars. Some 500 unit trains, each consisting of 4 locomotives and 100 coal carrying cars,[1] would be needed by the year 2000 in the Nominal case. Approximately 2 million tons of steel would be needed to manufacture this fleet. On the other hand, most of the needed track has already been installed, whereas only one major slurry pipeline is currently in operation. Finally, it should be noted that the steel requirements for electric transmission lines are considerably less than for either trains or slurry lines.[2]

The slurry pipeline water estimates are based on an assumption of 740 acre-feet per million tons of coal, approximately a 50-50 mixture by weight. By comparison, the other energy transport systems use almost no water. However, transmission of electricity (or other converted energy forms) implies within-region use of water in the conversion process. In the case of electrical generation, about 2600 acre-feet would be needed for each million tons of coal burned, or more than 3 times as much water as would go into an equivalent amount of slurry.[3]

11.6.4 Impacts

A. Employment

Construction and permanent employment are directly influenced by the distribution of costs between construction and operational categories. As shown in Table 11-59, unit trains have the lowest ratio of construction to operating costs of the transportation systems considered. Correspondingly, there is less of a construction boom-bust cycle associated with railroads than with the other systems, especially where roadbeds are already in place. For each MMtpy of capacity, slurry pipelines employ 383 construction workers for two years, railroads employ 44 workers for three

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[1]Buck, P., and N. Savage. "Determine Unit-Train Requirements." Power, Vol. 118 (Jan. 1974), pp. 90-91.

[2]However, on the order of 65,000 tons of aluminum will be used in electrical transmission.

[3]Further details on water use can be found in section 11.3 of this chapter.

TABLE 11-61: NOMINAL AND LOW DEMAND CASE INPUT REQUIREMENTS, 1975 THROUGH 2000, FOR COAL AND ELECTRICITY TRANSPORTATION SYSTEMS

MODE	STEEL (millions of tons)		WATER (thousands of acre-feet/year)		LAND (thousands of acres)	
	NOMINAL	LOW	NOMINAL	LOW	NOMINAL	LOW
Unit Train	9.5	7.1	N	N	90	67
Coal Slurry Pipeline	7.8	5.9	341	258	244	184
DC Transmission	0.57	0.13	N	N	252	205

N = negligible
DC = direct current

years. In the operational phase, slurries employ 25 permanent workers, railroads 43.[1] Long distance transmission employs fewer operational workers than either of these, but just as in the case of water use, electric transmission implies within-region energy conversion, hence within-region conversion employment.

B. Health and Safety

Each transportation mode produces a different array of health impacts, some of which are indicated in Table 11-62. Due to longer experience with trains, the hazards of this mode have been quantified more precisely than for the other modes. It has been calculated, for example, that a flow of 20 unit trains per day over typical routes from the West averaging 1100 miles would cause 3.4 deaths and 14 injuries per year at grade crossings.[2] It has also been found that railroads caused 7.4 percent of the wildfire property losses in Nebraska in 1972-1976,[3] a figure which may be expected to increase with increasing coal traffic.

"Plugging" of slurry lines presents problems unique to this transport system. If a plug (or a break) occurs anywhere along the line, all of the slurry must be dumped or the coal will rapidly settle out. Therefore, a holding pond of 100 acre-feet capacity must be available at each pumping station.[4] The dumped slurry cannot be reinjected at these intermediate points, hence must be trucked to the origin or destination or otherwise disposed of on-site.

Routine disposal of coal fines at the destination presents similar problems. Due to incomplete separation of coal and water,

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[1]Freudenthal, David, et al. Coal Development Alternatives. Cheyenne, Wyo.: Wyoming Department of Economic Planning and Development, 1974, Chapter IV.

[2]Science Applications, Inc. "Environmental Impacts of Coal Slurry Pipelines and Unit Trains," in U.S., Congress, Office of Technology Assessment. Task Reports: Slurry Coal Pipelines, Vol. II, Part 2. Washington, D.C.: Office of Technology Assessment, 1978, p. 73.

[3]Ibid., p. 74.

[4]Rieber, Michael, and Shao Lee Soo. "Route Specific Cost Comparisons: Unit Trains, Coal Slurry Pipelines and Extra High Voltage Transmission," Appendix B in White, Irvin L., et al. Energy From the West: A Progress Report of a Technology Assessment of Western Energy Resource Development. Washington, D.C.: U.S., Environmental Protection Agency, 1977, pp. 79-80.

TABLE 11-62: HEALTH AND SAFETY IMPACTS

MODE	IMPACTS
Railroads	Derailments Traffic collisions Fires
Slurry Pipelines	Line breaks Forced dumping of slurry if pumps fail Disposal of coal fines at receiving end
High Voltage Electric	Shock Microsparking Behavioral disorders
Oil and Gas Pipelines	Explosions Fires
Trucks	Collisions

as much as 5.9 percent of the coal may have to be dumped in a sludge pond.[1]

High voltage (greater than 500 kV) electric transmission may cause biological effects which are qualitatively different from those of electricity in more familiar voltage ranges. Behavioral disturbances such as loss of appetite and listlessness have been reported among switchyard workers in isolated cases in the Soviet Union and Spain.[2] However, the extent of such impacts and the mechanisms involved have not been established.[3] Of course, lower voltages could be used to avoid potential problems, but the advantages of lower construction costs, narrower rights-of-way, and smaller power losses would be lost.

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[1]Calculated from data in Science Applications, Inc. "Environmental Impacts of Coal Slurry Pipelines and Unit Trains," in U.S., Congress, Office of Technology Assessment. Task Reports: Slurry Coal Pipelines, Vol. II, Part 2. Washington, D.C.: Office of Technology Assessment, 1978, pp. 44, 50.

[2]Kornberg, Harry. "Concern Overhead." EPRI Journal, Vol. 2 (June/July 1977), p. 9.

[3]For a review of the literature, see Miller, Morton, and Gary Kaufman. "High Voltage Overhead." Environment, Vol. 20 (January 1978), pp. 6-15, 32-36.

C. Barriers to Mobility

Since they are configured in long, continuous strips, transportation corridors tend to restrict the mobility of humans and animals. Animals will probably be most affected by railroads and powerlines, inasmuch as these will often be fenced off for safety reasons. Pipelines, on the other hand, will usually be placed underground. Mobility may be crucial to the survival of some species, especially where seasonal migration is involved.

Human mobility will be most disrupted where trains pass through towns. Passage time for a 100-car train traveling at 20 miles per hour is approximately 3 minutes. Under the Nominal case scenario, 43 round trips per day could be expected between the Powder River Basin and the industrial Midwest by the year 2000. To illustrate the possible effects of this level of coal traffic, suppose half of these unit trains (i.e., 22 per day) used a single section of track between these two regions. If this were the case, each crossing along the track would be blocked on the average 9 percent of the time. While it is not possible to accurately predict how much traffic will increase along any particular route, these calculations show that significantly increased train traffic could be very disruptive locally. One detailed study of Colorado traced a rail transportation scenario of about 90 million tons/year passing along the Front Range in 1985, and estimated the value of traffic delay time at $9.9 million annually in that state.[1]

D. Air Pollution

The most significant air quality impact anticipated from energy transportation will arise from the diesel emissions of unit trains. Emissions of particulates, HC, and CO from a rail route handling 65 MMtpy are equivalent to those of the average rural, federal, or state highway, i.e., on the order of 100 vehicles/hour. Sulfur oxide and NO_x emissions, however, would resemble more closely the emissions from an urban street.[2] In terms of concentrations, diesel locomotive emissions are not likely, by themselves, to cause ambient air quality standards to be violated.[3]

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[1]URS Company. Coal Train Assessment, Final Report for Colorado Department of Highways. Denver, Colo.: URS, 1976, Table C-1.

[2]Science Applications, Inc. "Environmental Impacts of Coal Slurry Pipelines and Unit Trains," in U.S., Congress, Office of Technology Assessment. Task Reports: Slurry Coal Pipelines, Vol. II, Part 2. Washington, D.C.: Office of Technology Assessment, 1978.

[3]*Ibid.*, p. 82.

Highly uncertain is the impact of ozone generated by high voltage transmission lines. Available studies indicate that concentrations generated by corona discharges on present extra-high voltage (EHV) transmission lines are too low to be deleterious to the environment.[1]

E. Noise

Residents along railroad rights-of-way will certainly notice the noise of passing coal trains. As noted above, many western towns were built around the tracks; moreover, short, widely spaced buildings will not block sound transmission effectively. At low levels, noise constitutes primarily an aesthetic detriment; at higher levels it can cause health and behavioral problems.

Noise characteristics of unit trains have been determined by calculating the noise radiated and its attenuation for each of the engines and cars, then summing the total for various locations away from the track.[2] The noise as a function of time is shown in Figure 11-21 for three observer distances from the tracks: 100 feet, 1,000 feet, and 3,000 feet. The calculations assume that there are few buildings to block or attenuate sound transmission.

At 100 feet, the separate contributions of the locomotive and the coal cars will stand out clearly. Engine noise will dominate for about a minute, and the peak value will be more than 100 decibels A-weighted (dBA). This noise level will require shouting to communicate with another person at a distance of 1 foot. (Occupational Safety and Health Administration regulations limit exposure to 100 dBA noise to no more than two hours per day).

At 1,000 feet, the noise level will not vary as widely over time, and the separate contributions of engine and coal car noise will not be so clearly defined. The noise level will be above 55 dBA for about 8 minutes. This is the level specified by the EPA as the "outdoor activity interference and annoyance" threshold. At 3,000 feet, the noise level will still be above 55 dBA for about 6 minutes, but the observed peak level will be reduced to 61 dBA.

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[1]Frydman, M., and C.H. Shih. "Effects of the Environment on Oxidants Production in AC Corona." <u>IEEE Transactions on Power Apparatus and Systems</u>, Vol. PAS-93 (January/February 1974), pp. 436-43; and Roach, J.F., V.L. Chartier, and F.M. Dietrich. "Experimental Oxidant Production Rates for EHV Transmission Lines and Theoretical Estimates of Ozone Concentrations Near Operating Lines." <u>IEEE Transactions on Power Apparatus and Systems</u>, Vol. PAS-93 (March/April 1974), pp. 647-57.

[2]Swing, Jack W., and Donald B. Pies. <u>Assessment of Noise Environments Around Railroad Operations</u>, Report No. WRC 73-5. El Segundo, Calif.: Wyle Laboratories, 1973.

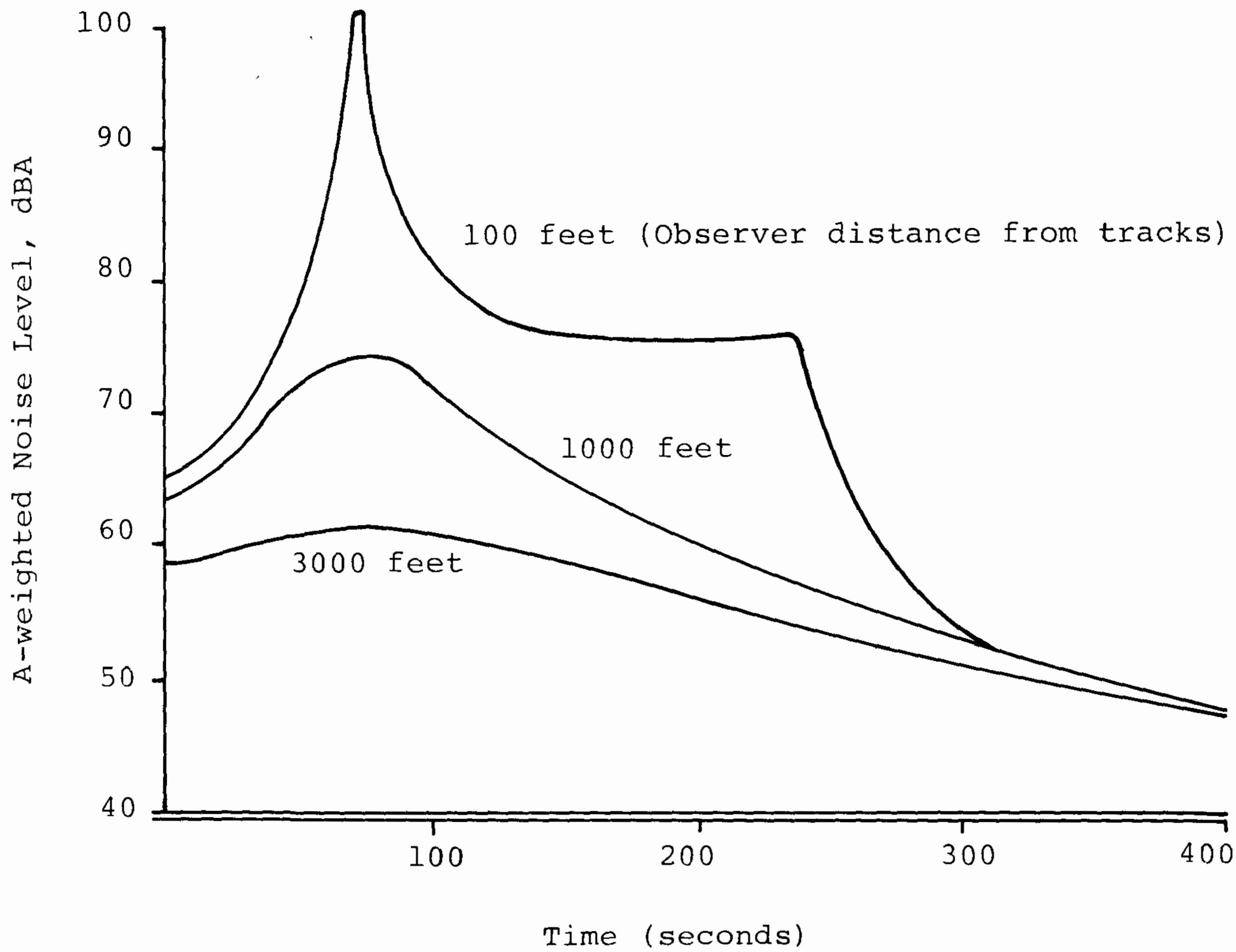

FIGURE 11-21: NOISE LEVEL OF PASSING COAL TRAIN

Source: Swing, Jack W., and Donald B. Pies. Assessment of Noise Environments Around Railroad Operations, Report No. WCR 73-5. El Secundo, Calif.: Wyle Laboratories, 1973.

In order to assess the aggregate effect of a series of noise disturbances over time, the day-night equivalent sound level (L_{dn}) measure has been developed. This averages the noise impacts over time to form a long-term equivalent sound level, including an adjustment to account for the greater subjective impact of noise at night compared to daytime.[1] Figure 11-22 shows calculated L_{dn} values at 100 and 1,000 feet from a railroad track as a function of the frequency of trains. If the L_{dn} value exceeds 65 decibels in a community, widespread complaints about noise can be expected. The graph indicates that 50 trains per day would be required to create such a noise level at a distance of 1,000 feet from the track, but only a few trains per day would be required to generate this noise level within a few hundred feet of the tract.

Route-specific analysis of the mainline from Colstrip, Montana to Chicago indicates that 1,134,000 people live within one mile on either side of that route. This gives a rough measure of how many people might be impacted by train noise.

F. Aesthetics

Aside from noise, the major aesthetic impacts of energy transportation will probably be experienced visually. The visual evidence of human presence in itself may be aesthetically objectionable, especially in primitive areas. The long, straight lines characteristic of transportation corridors can contrast markedly with natural landscapes. Among transportation facilities, transmission lines will have the greatest skyline alteration impacts because of their height and hence the long distances from which they can be seen. However, even right-of-way clearings for buried pipelines may produce an objectionable skyline alteration.

Facilities may also be conspicuous without altering the skyline. Color, design, and location relative to natural features are important variables.[2] Facilities designed with these elements in mind can even yield some aesthetic benefits.

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[1]See U.S., Environmental Protection Agency, Office of Noise Abatement and Control. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety. Arlington, Va.: Environmental Protection Agency, 1974.

[2]For a description of these aspects with regard to a railroad line, see U.S., Department of the Interior, Bureau of Land Management, et al. Final Environmental Impact Statement for the Proposed Development of Coal Resources in the Eastern Powder River Coal Basin of Wyoming. Cheyenne, Wyo.: Bureau of Land Management, 1974, Vol. III, pp. II-104 through II-105.

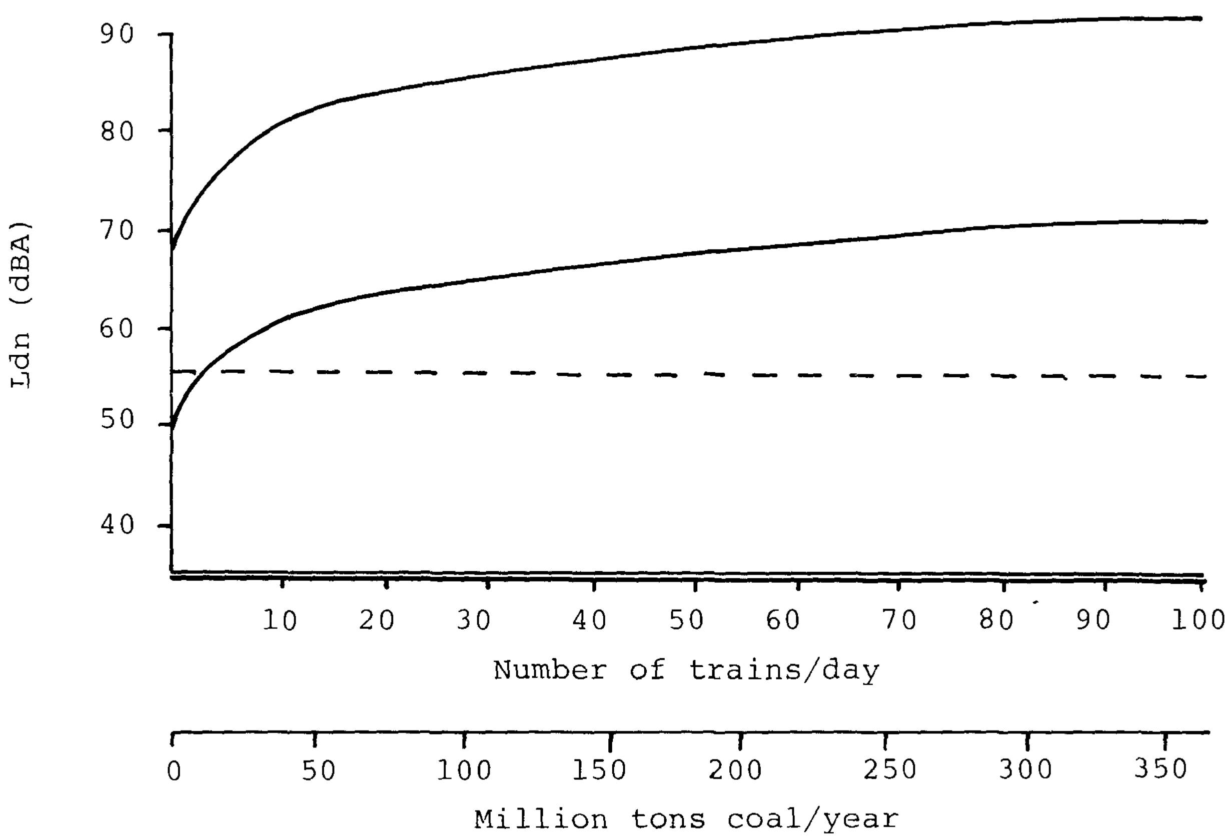

FIGURE 11-22: DAY-NIGHT AVERAGE SOUND LEVEL (Ldn) AS A FUNCTION OF COAL TRAIN FREQUENCY AND COAL TONNAGE

Source: Swing, Jack W., and Donald B. Pies. Assessment of Noise Environments Around Railroad Operations, Report No. WCR 73-5. El Secundo, Calif.: Wyle Laboratories, 1973.

GLOSSARY

AD VALOREM TAX--A tax imposed at a fixed percentage of the value of a commodity.

ALLUVIAL--Associated with materials (sand, gravel, etc.) transported by and laid down by flowing water.

ALTERNATING CURRENT (AC)--An electric current that reverses its direction at regularly recurring intervals.

AMBIENT AIR QUALITY STANDARDS--According to the Clean Air Act of 1970, the air quality level which must be met to protect the public health (primary) and welfare (secondary). Secondary standards are more stringent than Primary Ambient Air Quality Standards.

AMBIENT STANDARDS--Standards for the conditions in the vicinity of a reference point, usually describing the physical environment (the ambient temperature is the outdoor temperature, and ambient air refers to the normal air-quality conditions).

AMORTIZATION--The gradual reduction of an obligation, such as a mortgage, by periodically paying a part of the principal as well as the interest.

AQUIFER--A subsurface zone that yields economically important amounts of water to wells; a water-bearing stratum of permeable rock, sand, or gravel.

AQUATIC HABITAT--A type of site in, on, or near water where certain types of plants and/or animals naturally or normally live and grow.

AREA COUNCILS OF GOVERNMENT--Regional voluntary intergovernmental organizations. They serve the function of allowing greater cooperation and planning among local governments in solving problems that overlap more than one local jurisdiction. They also serve as a means to direct federal aid to cities.

AUGMENTATION--Increasing existing (water) supplies by adding to the quantities naturally available.

AVOIDANCE AREAS--Areas that are not to be utilized as sites for energy conversion facilities unless there are no acceptable alternatives.

BACKFILLING--A reclamation technique which returns the spoils to mined cuts or pits. This levels the land in a configuration similar to the original form.

BACKGROUND LEVELS--Ambient concentrations of hydrocarbons and particulates from natural sources, e.g., blowing dust.

BENEFICIAL USE--A doctrine derived from the appropriation system stipulating that water use must be made in accordance with the public interest of the best utilization of the water resource.

BERM--A shelf or wall built to contain spills around a fuel storage tank or to retain other liquids or semisolid materials as in waste stabilization ponds.

BEST AVAILABLE CONTROL TECHNOLOGY (BACT) REQUIREMENT--The part of the Clean Air Act which requires that a facility be equipped with the most up-to-date antipollution device. Example--coal-fired power plants equipped with scrubbers.

BREEDER REACTOR--A nuclear reactor that produces more fissile material than it consumes. This reactor is sometimes called the fast breeder because high energy (fast) neutrons produce most of the fissions in current designs.

BROWSE--Twigs, shoots, and leaves eaten by livestock and other grazing animals.

COMMODITIES CLAUSE--Section of the Interstate Commerce Act of 1887 which prevents railroads from transporting freight which they manufacture, mine, produce, own, or have an interest in. It has not been applied to any other transportation mode.

COMMON CARRIER--A transportation company which is licensed to provide its services at nondiscriminatory rates to all shippers who apply.

CONSTRUCTION/OPERATION EMPLOYMENT RATIO--The difference between the number of employees needed for the construction phase of a large project and the number needed for operation of the facility. Construction results in large employment increases, while employment declines are experienced during actual operation, resulting in the boom-bust cycle associated with large construction projects. The larger the ratio, the greater the employment decline when construction is completed.

CONVERSION FACILITY--Plant used to convert energy raw materials into usable energy forms.

CORONA DISCHARGE--A discharge of electricity appearing as a bluish-purple glow on the surface of and adjacent to a conductor when the voltage gradient exceeds a certain critical value; due to ionization of the surrounding air by the high voltage.

COST--The value of the best alternative which is foregone when an alternative is chosen.

CRITERIA POLLUTANTS--Six pollutants identified prior to passage of the Clean Air Act Amendments which now have established Ambient Air Quality Standards, i.e., sulfur dioxide, particulate matter, carbon monoxide, photochemical oxidants, nonmethane hydrocarbons, and nitrogen oxides.

CRITICAL AREAS--Land in energy development areas in which energy and recreational development should be restricted.

DEPLOYMENT--Strategic or wider utilization, in this case of energy resources.

DEREGULATION--The act or process of removing restrictions and regulations.

DESALINATION--Removal of salt, as from water or soil. Also known as desalting.

DIRECT CURRENT (DC)--An electric current flowing in one direction only and substantially constant in value.

DIVERTING--Turning the course of water from one direction to another.

DRY COOLING--A method used for dissipating waste heat whereby water is circulated in a closed system and cooled by air flow similar to a car radiator.

EASEMENT--The right held by one person or body to make use of the land of another for limited purposes.

ECOSYSTEM--The interacting members of the biological community and physical components that occur in a given area.

EFFECTIVENESS--The degree to which objectives are achieved.

EFFICIENCY--The degree to which a possible course of action minimizes costs and risks while maximizing beneficial impacts.

EFFLUENT--Any water flowing out of an enclosure or source to a surface water or groundwater flow network.

ELECTRIC POWER GENERATION--The large-scale production of electric power for industrial, residential, and rural use, generally in stationary plants designed for the purpose.

ELECTROSTATIC PRECIPITATORS--Devices that use an electric field to remove solid particles or droplets of liquid from plant exhaust stack gases.

EMINENT DOMAIN--The right of a government to take private property for public use by virtue of the superior dominion of the sovereign power over all lands within its jurisdiction.

ENHANCED RECOVERY--The increased recovery from a pool achieved by artificial means or by the application of energy extrinsic to the pool, which artificial means or application includes pressuring, cycling, pressure maintenance or injection to the pool of a substance or form of energy but does not include the injection into a well of a substance or form of energy for the sole purpose of (i) aiding in the lifting of fluids in the wells, or (ii) stimulation of the reservoir at or near the well by mechanical, chemical, thermal, or explosive means.

ENVIRONMENTAL IMPACT STATEMENT (EIS)--The National Environmental Policy Act requires that an EIS be filed with any proposed federal action that will affect the environment. The EIS is to contain: a description of the proposed action; the relationship of the action to plans for the affected area; the probable impact (both favorable and adverse); alternatives to the proposed action; unavoidable adverse environmental effects; and the relationship between short-term uses and long-term productivity.

EQUITY--A risk interest or ownership right in property.

EQUIVALENCY STANDARDS--Proposal to allow farmers and ranchers in arid regions to irrigate more land with water from federal water projects than those in more humid regions. Current standards restrict irrigation to 160 acres or 320 acres if both husband and wife are owners.

EVAPORATIVE HOLDING PONDS--Holding areas into which treated water effluents are discharged (rather than into navigable waters), where solid wastes accumulate and create potentially significant surface and groundwater quality problems.

EVAPOTRANSPIRATION--Loss of water from the soil both by evaporation and by transpiration from the plants growing thereon.

EXCLUSION AREAS--Areas designated by the federal government where energy development or conversion facilities cannot be sited.

FEASIBILITY--The degree to which a possible course of action is capable of being accomplished, particularly from a technological standpoint.

FLUE GAS DESULFURIZATION (FGD)--Removal of sulfur oxide pollutants from stack gas emissions by one of several possible methods.

FORB--An herb other than grass.

FRONT-ENDED COSTS--Costs which are incurred before or at the beginning of a project.

4-R ACT--Railroad Revitilization and Regulatory Reform Act of 1976, Pub. L. 94-201, 90 Stat. 31.

GASIFICATION--The conversion of coal or organic waste to a gaseous fuel.

GAUSS--The centimeter-gram-second unit of magnetic induction equal to the magnetic flux density that will induce an electromotive force of one one-hundred millionth of a volt in each linear centimeter of a wire moving laterally with a speed of one centimeter per second at right angle to a magnetic flux.

GAUSSIAN DISPERSION MODEL--The most commonly occurring probability distributions have the form:

$$(1/\sigma\sqrt{2\pi})\int_{-\infty}^{u} \exp(-u^2/2)\,du, \quad u = (x-e)/\sigma$$

where e is the mean and σ is the variance. Also known as Gauss' error curve or Gaussian distribution. A model used to measure or predict the normal distribution of air pollution.

GONDOLA CAR--Railroad car for carrying bulk materials such as coal and grain, with an open top and sealed bottom, so that emptying is usually achieved by rotating the car.

GROUNDWATER--Subsurface water occupying the saturation zone from which wells and springs are fed; in a strict sense, this term applies only to water below the water table.

"HARD ROCK" MINERALS--Solid minerals, as distinguished from oil and gas, especially those solid minerals found in hard rocks.

HIGH VOLTAGE TRANSMISSION LINE (HVTL)--An alternative method of coal transportation involving the production of mine-mouth electric power with subsequent transmission of large blocks of power on a point-to-point basis.

HIGH WET COOLING--A method used for dissipating waste heat whereby water is circulated between a condenser where it absorbs heat and a tower where the warm water is cooled by evaporation.

HOPPER CAR--Railroad car for carrying bulk materials such as coal and grain, with doors on the bottom for emptying.

HORIZONTAL DIVESTITURE--Disposal of a portion of a business which produces products which are somewhat substitutable for other products of the firm, e.g., coal produced by an oil company.

HORIZONTAL INTEGRATION--Ownership by one company of competing energy resources--coal, petroleum, uranium, etc.

HYDROLOGY--A science dealing with the properties, distribution, and circulation of water on the surface of the land, in the soil and underlying rocks, and in the atmosphere.

IMPLEMENTABILITY--(1) The ability to carry out or put into practical effect; (2) the ability to have uniform standards incorporated in legislation and regulations.

IMPOUNDMENT--Collection of water for irrigation, flood control, or similar purpose.

IN SITU--In the natural or original position; applied to energy resources when they are processed or converted in the geologic strata where they were originally deposited.

INFILTRATION--Permeation of water through the land surface into the groundwater system.

INSTREAM FLOW--Water flowing in a stream, typically with reference to a water requirement for fish and other biota.

INTERMEDIATE WET COOLING--The use of a mixture of high and minimum wet cooling technologies in power plants in order to conserve water resources. Also referred to as wet/dry cooling.

INTERMODEL COMPETITION--Competition between companies providing dissimilar modes of transportation, e.g., railroads versus trucks.

INTERMODEL UMBRELLA RATES--Protective rates allowed to be changed by companies providing the same mode of transportation.

INTRAMODEL COMPETITION--Competition between companies which are providing the same form of transportation, e.g., rail.

ISSUES--Impacts, problems, or consequences of energy resource development which generate conflict among parties-at-interest.

ISSUE SYSTEM--Conceptual framework which identifies the issue being considered, the parties involved, the area in which the dispute occurs, and the decisionmaking agencies with jurisdiction.

JOINT USE CORRIDOR--A narrow strip of land with restricted boundaries in which facilities of the same or different system are placed adjacent to each other in as close proximity as practical and feasible.

LEAD TIME--The time needed for planning, financing, and construction of required facilities before they are ready for use.

LEGUME--A dry, dehiscent fruit derived from a single simple pistil; common examples are alfalfa, beans, peanuts, and vetch.

LIGNITE--The lowest-rank coal, with low heat content, fixed carbon, and high percentages of volatile matter and moisture; early stage in the formation of coal.

LINK--A connection between two points, as in a transportation system (rail, pipeline) between a supply center and a demand center.

LIQUEFACTION--The conversion of a solid fuel, such as coal or organic waste, into liquid hydrocarbons and related compounds.

LIQUEFIED NATURAL GAS (LNG)--A clean, flammable liquid existing under very cold conditions that is almost pure methane.

METHACOAL--A coal slurry using methyl alcohol instead of water.

METHYL FUEL--An alkyl radical CH_3 fuel derived from methane by removal of one hydrogen atom.

MILLING--A process in the uranium fuel cycle by which ore containing only 2 percent uranium oxide is converted into a compound called yellowcake which contains 80 to 83 percent uranium oxide.

MINE DEWATERING--Pumping unwanted groundwater from a mine in order to achieve adequate mining conditions.

MINE-MOUTH SITING--Location of a facility in the vicinity or area of a mine, usually within several miles.

MINIMUM WET COOLING--A method used for dissipating waste heat whereby water is circulated in a closed system and cooled by air flow similar to a car radiator. Also known as dry cooling.

MIXING AND DILUTION--The dispersion of pollutants into the atmosphere resulting in a reduction in the level of concentration.

MOBILE SOURCES--Nonstationary sources of air pollution such as automobiles, trucks and buses; as defined by the Clean Air Act Amendments of 1977.

NATIONAL AMBIENT AIR QUALITY STANDARDS--Pollution standards established by the Clean Air Act Amendments of 1970 requiring a 90-percent reduction of automotive hydrocarbon and carbon monoxide emissions from 1970 levels by the 1975 model year and a 90-percent reduction in nitrogen oxide emissions from 1971 levels by the 1976 model year.

NEW SOURCE PERFORMANCE STANDARDS--Standards set for new industries to ensure that ambient standards are met and to limit the amount of a given pollutant a stationary source may emit over a given time. "New" in this context applies to facilities built since August 17, 1971.

NOMINAL CASE--One of the three levels of energy development used to make projections based on the energy model developed for Gulf Oil Corporation by Stanford Research Institute.

NONATTAINMENT AREAS--(1) Areas, typically urban with heavy automobile-related pollutants, in which "all available measures" will not attain ambient air quality standards by 1982. States must submit new implementation plans and must reduce emissions in the area each year to ensure that the ambient standard is attained by 1987; (2) areas where national air quality standards have not been met.

NONMETHANE HYDROCARBONS--An organic compound (as acetylene or benzene) containing only carbon and hydrogen and often occurring in petroleum, natural gas, and coal, other than the colorless, odorless, flammable, gaseous hydrocarbon CH_4.

NONPOINT SOURCES OF POLLUTION--Areawide water wastes, essentially those which are transported to surface and groundwaters from sources other than pipes and ditches. These include pesticides, fertilizers, sediments, natural salts, animal wastes, plant residues, and minerals.

OMB A-95 REVIEW PROCESS--Requirement that states provide the opportunity for governors and local officials to comment on application for federal funds to undertake a variety of catagorical programs, and that agencies of the federal government consider the comments of the general public in approving specific applications for funds.

OCEAN THERMAL GRADIENTS--Differences in temperature of the ocean water at various depths.

OFF-ROAD VEHICLES--Motor vehicles such as motorcycles, snowmobiles, and four-wheel drive vehicles that can operate over natural terrain without the need for roads.

OFFSET PLAN--EPA policy which permits new facilities to be sited in nonattainment areas where concentrations of criteria pollutants exceed air quality standards.

ONE-STOP SITING--Centralized decisionmaking alternative where one commission would handle all siting decisions and seek input from all concerned parties.

ORGANIZATION OF PETROLEUM EXPORTING COUNTRIES (OPEC)--A group of nations controlling over 75 percent of free-world petroleum reserves; includes Algeria, Indonesia, Iran, Libya, Nigeria, Saudi Arabia, United Arab Emirates, Venezuela, and others.

OXIDES OF NITROGEN--A class of air pollutants which includes several forms of the compound (NO, NO_2, NO_3 as well as others). Oxides of nitrogen are produced during combustion and constitute some of the reactants involved in the formation of photochemical smog.

OXIDES OF SULFUR--A class of air pollutants which includes several forms of the compound (SO_2 and SO_3).

OZONE--An oxidant formed in atmospheric photochemical reactions.

PARTICULATES--Microscopic solids that emanate from a range of sources and are widespread air pollutants. Those between 1 and 10 microns in size are most numerous in the atmosphere; they stem from mechanical processes and include industrial dusts, ash, etc.

PARTIES-AT-INTEREST--Individuals, groups, or organizations (such as local residents, Indian tribes, industry, labor, or various levels of government) whose interests or values are likely to be affected by the development of western energy resources.

PEAK GROUND LEVEL CONCENTRATION--The highest air pollutant density measured or predicted that is a result of human activity on the ground, e.g., automobile use. Always cited with respect to an averaging time.

PERCOLATION--Downward movement of water through soils.

PHOTOCHEMICAL OXIDANTS--Any of the chemicals which enter into oxidation reactions in the presence of light or other radiant energy.

PHREATOPHYTE--A deep-rooted plant that obtains its water from the water table or the layer of soil just above it. These plants are characteristically nonproductive vegetation, such as saltcedar, growing in stream beds, ditch canals, etc. which consume large quantities of water.

PLANNING CORRIDOR--A broad linear strip of land of variable width reserved between two geographic points which has ecological, technical, and/or economic advantages over adjacent areas for the location of transportation and/or utility systems.

PLUME IMPACTION--The point of contact between stack emissions and elevated terrain that results in high pollution concentration levels at that point.

POINT SOURCES OF POLLUTION--Those sources of water pollution which are discrete conveyances (pipes, channels, etc.) and are controlled by the effluent standards of the Federal Water Pollution Control Act Amendments of 1972. These include effluents from municipal sewage systems, storm water runoff, industrial wastes, and animal wastes from commercial feedlots.

POND LINER--The bottom of a pond, typically a specially prepared layer of clay, less permeable solids, or manmade materials.

POPULATION/EMPLOYMENT MULTIPLIER--A numerical multiplier applied to the number of workers needed to construct or operate a new facility that is used to project total population levels or increases.

POWER POOLING--The transfer of electricity among utilities in regional electrical service.

PREVENTION OF SIGNIFICANT DETERIORATION (PSD)--Pollution standards that have been set to protect air quality in regions that are already cleaner than the Ambient Air Quality Standards. Areas are divided into three categories determining the degree to which deterioration in the area will be allowed.

PRIME FARMLANDS--Land defined by the Agriculture Department's Soil Conservation Service based on soil quality, growing season, and moisture supply needed to produce sustained high crop yields using modern farm methods.

PRIMITIVE AREAS--Scenic and wild areas in the national forests that were set aside and preserved from timber cutting, mineral operations, etc., from 1930-1939 by act of Congress; these areas can be added to the National Wilderness Preservation System established in 1964.

PROBLEMS AND ISSUES--The two terms are not synonyms. The term "problems" is used when conflict among competing interests and values is not involved or is not being emphasized, "issues" when it is.

PROJECT FINANCING--Lending which is predicated more on the cash-generation capacity of a specific project than on the general credit-worthiness of the developer. Usually also involves long-term sales contracts and specific obligations with respect to completion and operation of the project.

PROJECT INDEPENDENCE--A program initiated in March 1974 designed to improve the energy position of the United States and perhaps to gain independence from foreign energy sources by 1985.

PUBLIC DOMAIN--Original public lands which have never left federal ownership; also, lands in federal ownership which were obtained by the government in exchange for public lands or for timber on such lands; also, original public domain lands which have reverted to federal ownership through operation of the public land laws.

RECLAMATION--Restoring mined land to productive use; includes replacement of topsoil, restoration of surface topography, waste disposal, and fertilization and revegetation.

REGRADING--The movement of earth over a depression to change the shape of the land surface; a finer form of backfilling.

RESERVES--Resources of known location, quantity, and quality which are economically recoverable using currently available technologies.

RESOURCES--Mineral or ore estimates that include reserves, identified deposits that cannot presently be extracted due to economical or technological reasons, and other deposits that have not been discovered but whose existence is inferred.

RETORTING--The decomposition within a closed heating facility (retort) of the solid hydrocarbon kerogen in oil shale to produce a variety of gases and a liquid hydrocarbon which can be upgraded to produce a synthetic crude oil.

RIGHT-OF-WAY--The legal right for use, occupancy, or access across land or water areas for a specified purpose or purposes, such as the construction of gas or oil pipelines. Such use on federal land is authorized by permit, lease, easement, or license. On patented lands, it is acquired by easement or purchase.

ROLLING STOCK--Railroad cars.

RUSSIAN THISTLE--A prickly European herb (Salsola kali tenuifolia) that is a serious pest in North America; also called Russian tumbleweed.

SALVAGED WATER--Water saved from current use which can be applied to another use.

SCIENCE COURT--A proposed "court" of scientific experts who will identify the significant science and technology questions related to public policy decisions, conduct adversary proceedings over the issues, and issue a judgment pertaining to the disputed technical questions.

SEAM--A bed of coal or other valuable mineral of any thickness.

SEEP--A spot where fluid (as water, oil, or gas) contained in the ground oozes slowly to the surface and often forms a pool.

SEDIMENTATION--The action or process of forming or depositing sediment (material deposited by water, wind, or glaciers).

701 PROGRAM--A federal program to provide financial assistance to local governments for county-wide land-use programs.

SEVERANCE TAX--A tax on the removal of minerals from the ground, usually levied as so many cents per barrel of oil or per thousand cubic feet of gas. The tax is sometimes levied as a percentage of the gross value of the minerals removed.

SITE SCREENING--A method which eliminates areas as possible sites for energy facilities on the basis of several criteria. Each stage of the process eliminates those locations that are unacceptable for a particular criterion. When all the unacceptable locations for each criterion are identified, the remaining sites are theoretically favorable for all criteria.

SLURRY PIPELINE--A pipeline through which coal (in the form of a mixture of water and coal) is transported.

SNOWPACK--The amount of annual accumulation of snow at higher elevations in the western United States, usually expressed in terms of average water equivalent.

SOFT MINERALS--Minerals such as oil and gas.

SOIL PERMEABILITY--The ability of an area of land to conduct fluids.

SOLUTIONAL MINING--The extraction of soluble minerals from subsurface strata by injection of fluids and the controlled removal of mineral-laden solutions.

SPENT SHALE--The material remaining after the kerogen is removed from oil shale by retorting. Its volume is greater than that of the original oil shale.

SPOIL PROPERTIES--Physical and chemical characteristics of refuse resulting from mining and processing operations, e.g., coal mining operations.

STAKEHOLDERS--Individuals who have a vested interest in decisions affecting development of western energy resources.

STATE IMPLEMENTATION PLAN (SIP)--Required by the Clean Air Act of 1970, SIP's outline state procedures for enforcing national ambient air standards and for monitoring the performance of local programs.

STRIP AND SHIP SITING--Determining the transport corridor through which it is possible to ship coal as coal instead of converted energy forms.

STRIP MINING--A mining method that entails the complete removal of all material from over the resource to be mined in a series of rows or strips; also referred to as surface mining.

STRIPPABLE RESERVES--Resources of known location, quantity, and quality, which are economically recoverable using currently available stripmining techniques.

SUBSIDENCE--The sinking, descending, or lowering of the land surface; the surface depression over an underground mine that has been created by subsurface caving.

SULFATES--A class of secondary pollutants that includes acid-sulfates and neutral metallic sulfates.

SULFUR DIOXIDE (SO_2) SCRUBBERS--Equipment used to remove sulfur dioxide pollutants from stack gas emissions, usually by means of a liquid sorbent.

SURFACE MINING--Mining method whereby the overlying materials are removed to expose the mineral for extraction.

SYNTHETIC FUELS--Artificially produced fuels.

SYNTHETIC NATURAL GAS (SNG)--Gas produced from a fossil fuel such as coal, oil shale, or organic material and having a heat content of about 1,000 Btu's per cubic foot.

TECHNOLOGICAL FIX--The application of technology to resolve social problems rather than seeking resolutions through behavioral or attitudinal change.

TECHNOLOGY ASSESSMENT--An examination (generally based on previously completed research rather than initiating new primary research) of the second and higher order consequences of technological innovation. TA attempts to balance these consequences against first-order benefits by identifying and analyzing alternative policies and implementation strategies so that the process of coping with scientific invention can occur in conjunction with, rather than after such invention.

THERMAL DISCHARGE--High temperature point source water pollutants that could prove hazardous to indigenous shellfish, fish, and wildlife in and on the body of water into which the discharge is made.

THROUGHPUT--The volume of feedstock charged to a process equipment unit during a specified time; the quantity of ore or other material passed through a mill or a section of a mill in a given time or at a given rate.

TRACE ELEMENT--A nonessential element found in small quantities (usually less than 1.0%) in a mineral. Also known as accessory element; quest element.

"208" PROGRAM--Federal Water Grant Program to make funds available to local jurisdictions for waste treatment facilities.

UNIT TRAIN--A system for delivering coal in which a string of cars, with distinctive markings and loaded to full visible capacity, is operated without service frills or stops along the way for cars to be cut in and out.

URANIUM TAILINGS--Uranium refuse material separated as residue in the preparation of various products such as ores.

VARIANCE POLICY--The procedure whereby a facility may receive a variance from the sulfur dioxide limits allowed for Class I areas whose air quality is cleaner than the Ambient Air Quality Standards.

VERTICAL INTEGRATION--Participation by one company in more than one level of an energy resource system; such participation may range from exploration for a resource through the distribution of the resource to consumers.

VOLATILE MATTER--Matter that can easily be vaporized at relatively low temperatures or exploded.

WATER INTENSIVE FORAGE CROPS--Crops such as alfalfa which consume relatively large quantities of water through evapotranspiration.

WATERSHED--Total land area above a given point on a stream or waterway that contributes runoff to that point.

WILDERNESS AREAS--Federal lands placed under the National Wilderness Preservation System by the Wilderness Act of 1964. Subject to existing uses and rights, commercial enterprises, permanent roads, buildings, motorboats, airplanes, etc., are forbidden in any land designated as part of the wilderness system.

WINDFALL PROFITS--Profits which occur because of a one-time, unexpected event, e.g., profits in the coal industry occasioned by a sudden increase in the price of oil.

YELLOWCAKE--The product of the milling process in uranium fuel cycle. It contains 80 to 83 percent uranium oxide (U_3O_8).

ZERO DISCHARGE--A goal of the Federal Water Pollution Control Act Amendments of 1972 to eliminate all point-source pollution of navigable water by 1985.

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