United States
Environmental Protection
Agency

Montana Office EPA
Region 8
Federal Building
Helena, Montana 59601

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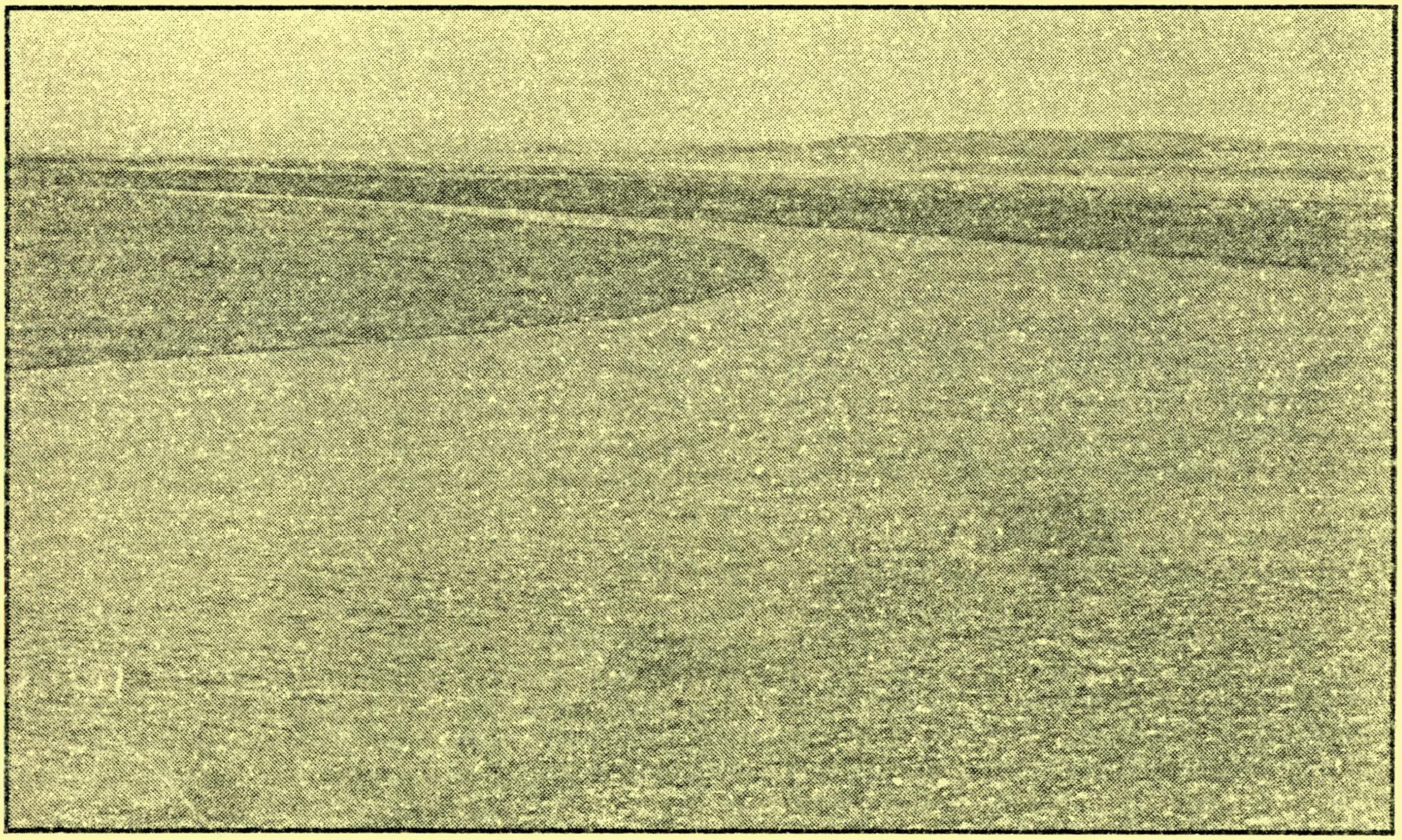
EPA

DRAFT ENVIRONMENTAL IMPACT STATEMENT



Impact of Canadian Power Plant Development and Flow Apportionment on the Poplar River Basin

APPENDIX

Prepared with the assistance of Tetra Tech Inc.

EPA 908/80-003

JULY 1980

DRAFT ENVIRONMENTAL IMPACT STATEMENT

IMPACT OF CANADIAN POWER PLANT DEVELOPMENT AND FLOW APPORTIONMENT ON THE POPLAR RIVER BASIN

APPENDICES A-I

U.S. Environmental Protection Agency
Montana Office Region 8
Helena, Montana

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Tetra Tech Report No. TC-3254

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APPENDIX A

DESCRIPTION OF POPLAR RIVER BASIN

Appendix A-1. Geology and Soils

A-1.1 GEOLOGY

A-1.1.1 Bedrock Formations

The stratigraphic section in northeastern Montana is given in Table A-1.1. The bedrock formations are exposed along the flanks of the terraces and in the southern part of the basin in the Poplar Dome (Anticline). The oldest formation exposed is the Bearpaw Shale of Upper Cretaceous age. The shale contains some marine fossils and may have sand layers in the upper strata. The Fox Hills Sandstone overlies the Bearpaw Shale. The Fox Hills Sandstone has a lower unit of marine shale and silt and an upper unit of sandstone which is partly eroded in many places. The Hell Creek Formation also consists of shales, siltstones, and sandstones with some dinosaur fossils. These two formations are difficult to distinguish in the Poplar River Basin and are therefore combined for classification (Feltis, 1978). The total thickness of both formations in the upper Poplar River Basin is 135 to 210 feet (Feltis, 1978).

In the Tertiary Age this area probably consisted of low marshes and forests sloping east from the ancestral Rocky Mountains (Howard, 1960). The Fort Union Formation is composed of stratified siltstones, clay, lignite beds, and sandstones. Plant and fresh-water fossils and limestone concretions can be found. The entire formation is up to 1,000 feet thick in the Poplar River Basin area. In some places the Fort Union can be divided into members including the Sentinel Butte, Tongue River, Lebo shale, and Tullock members. Only the Tullock member was identified separately on the geologic map (Figure A-1.1).

The Flaxville Formation of Miocene or Pliocene age rests unconformably on the Fort Union Formation. The formation consists of sands and gravels with some sandstone and conglomerate. The gravel is 80 to 90 percent quartzite pebbles; 10 to 15 percent chalcedony, petrified wood, and jasper; 1 to 3 percent Fort Union Formation fragments; 1 to 3 percent porphyry fragments; and minor amounts of vertebrate fossils (Feltis, 1978). The Flaxville Formation is found on the high plateaus and ridges and can be up to 65 feet thick.

A-1.1.2 Quaternary Deposits

The Wiota gravels of Holocene age are found on pediments and ridges below the higher plateaus and are up to 15 feet thick. The fluvial gravels are composed of 80 to 90 percent quartzites; 10 to 15 percent argillites; and 1 of 10 percent jasper, chalcedony, and petrified wood (Feltis, 1978).

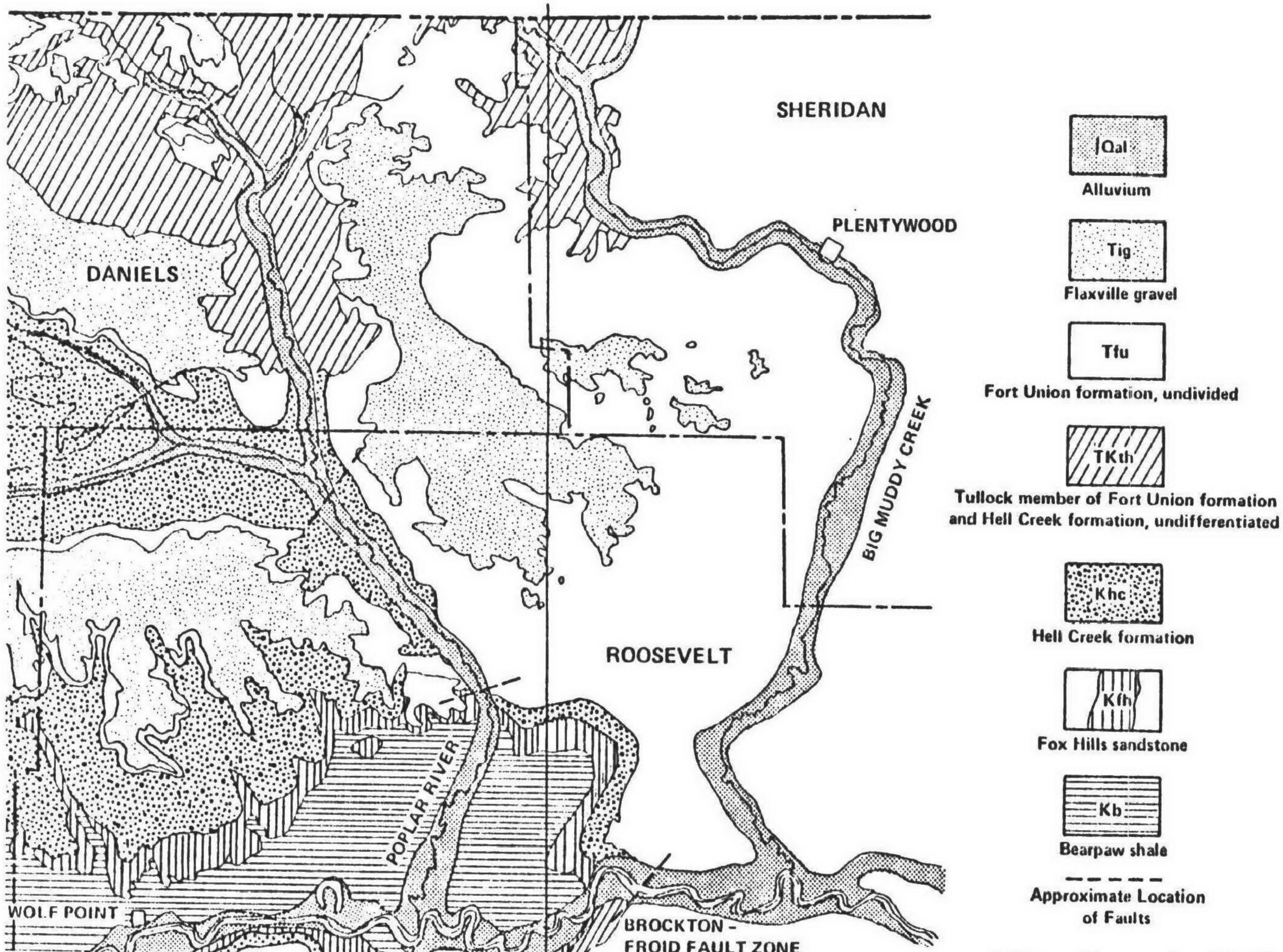
Table A-1.1

STRATIGRAPHY OF FORMATIONS IN NORTHEASTERN MONTANA

System	Series	Formation	Thickness (feet)	General Character
Quaternary	Holocene	Alluvium and colluvium	0-50	Fine to coarse flood-plain deposits of Poplar River valley and major tributaries, consist mostly of silt and sand with gravel lenses. Also include slope-wash deposits on hillsides and in valleys consisting chiefly of locally derived silt, sand, and gravel
	Pleistocene	Glacial and alluvial deposits	0-100	Unconsolidated glacial till, glacial lake deposits, and poorly to well-sorted silt, sand, and gravel in various types of glacio-fluvial deposits. Also include deposits of preglacial or interglacial periods which may be, in part, buried by till
		Wiota Gravels	0-10	Brown gravel containing sparse glacial erratics overlain, in places, by till. Consist of 95 percent brown quartzite pebbles derived from the Flaxville Formation, and less than 5 percent erratics consisting of limestone, dolomite, igneous, and metamorphic rocks from Canada. The erratics are generally absent in unglaciated areas.
Tertiary	Pliocene or Miocene	Flaxville Formation	0-100	Brown moderately well-sorted and well-stratified sand and sandy gravel deposits as much as 65 feet thick. Lithology 90 percent brown and red quartzite, remainder chalcedony and fragments from the Fort Union Formation. Locally contains large lenses of volcanic ash as much as 20 feet thick.
	Paleocene	Fort Union Formation	800±	Well-sorted and well-stratified gray clay, bentonitic gray clay, brown carbonaceous clay, lignite, buff silt, gray silty limestone concretions, olive-gray sand, and buff calcareous sandstone. Marked lateral variation in lithology. For distribution of lignite see Collier (1924).
Cretaceous	Upper Cretaceous	Hell Creek Formation	220-280[1]	Well-stratified sequence of shales, siltstones, sandstones, and carbonaceous shales. Overall appearance is somber greenish gray. Lower 50 to 100 feet is predominately medium-tan sand, locally cemented to sandstone. A few quartzite pebbles occur in basal 50 feet
		Montana Group: Fox Hills Sandstone	85-115[1]	Consists of upper sandstone unit 50 to 80 feet underlain by transitional marine shale unit 35 feet thick. Lower unit consists of thin-bedded well-laminated shale grading to silt toward top. Upper sandstone contains numerous concretions. Upper part of formation removed by erosion in many places before deposition of Hell Creek Formation
		Montana Group: Bearpaw Shale	1,100-1,200	Dark-olive-gray slightly fissile semiconsolidated jointed clayey shale. Contains hard elliposoidal concretions of several kinds, many containing marine fossils. A few sandy beds present in the upper part. Thin bentonite seams present and bentonite is also disseminated through some shale zones

[1]Total thickness of Fox Hills Sandstone and Hell Creek Formation in the upper Poplar River Basin ranges from about 135 to 210 feet

Source Feltis, 1978



After Howard, 1960

Figure A-1.1 BEDROCK GEOLOGIC MAP OF U.S. PART OF POPLAR RIVER BASIN

Till deposits are considered to be from two glaciations, both of Wisconsin age (Howard, 1960). The early Wisconsin till is more widespread than the Mankato drift, which is found in the East Fork valley of the Poplar River. Generally, the till deposits consist of unstratified clay, silt, sand, and gravel. Erratics (large boulders of glacial origin) may be from limestone, dolomite, igneous or metamorphic rocks. The average thickness is 10 feet, although in some places they may be 25 feet thick.

Other types of glacial deposits include eskers such as found north of Scobey which form when meltwater flows on or within glacial ice, and kame deposits which form when sand and gravel are deposited against ice or on the sides of meltwater channels within the ice. The thickness of esker and kame deposits may be up to 20 and 55 feet, respectively (Feltis, 1978). Glacial outwash is deposited by meltwater streams. The material is stratified silt, sand, and gravel with erratics and can be up to 35 feet thick. In many instances, lakes formed where drainage was blocked by glacial ice. Deposits associated with these glacial lakes include sediment brought in by streams, beach deposits, and fine-grained lake and pond deposits. These deposits are limited in areal extent and are between 7 and 20 feet thick.

A-1.1.3 Geology in Canadian Part of Basin

In the area of the Cookson Reservoir Dam the till is between 0 to 50 feet and includes a gravel zone. The till was not differentiated here although the till has been subdivided in other parts of southern Saskatchewan into the Saskatoon Group and the Sutherland Group (Whitaker, *et al.*, 1972).

The Empress Group is late Tertiary to early Quaternary in age (Whitaker, *et al.*, 1972). The strata are fluvial or lacustrine in origin and occur in preglacial valleys and on bedrock uplands. Some of the occurrences on these bedrock uplands have been given separate formation names--Cypress Hills, Wood Mountain, and Flaxville. The sediments are stratified sands, silts, and clay with a basal gravel unit. The upper sands are predominantly quartz and feldspar with chert, limestone, and dolomite fragments. The basal gravels include chert and quartzite pebbles and cobbles with quartzose sands (Whitaker, *et al.*, 1972).

The Ravenscrag Formation is of Tertiary origin. The sediments formed an alluvial plain sloping away from the ancestral Rocky Mountains. The Ravenscrag Formation includes sand, silt, and lignite coal beds. The major seam to be mined at the Poplar site is the Hart coal seam. Individual lenses are not widespread. The formation was 335 feet in a deep testhole located about 1.25 miles east of the dam.

The Frenchman Formation is a marine strata of Cretaceous age. The formation is of variable thickness and consists of fine sand, silt, and clay. The formation was 130 feet thick in the deep test-hole east of the dam. Some carbonaceous and calcareous zones are present which contribute to the generally poor water quality of this aquifer.

The Bearpaw Formation is late Cretaceous in age. The formation is predominantly noncalcareous shale and silty shale of marine origin. Beds of fine sand, silt, and bentonite also occur (Parizek, 1964).

A-1.1.2 Structure

Major geologic structures in the study area include the Poplar Dome (Anticline) in the southern part of the Poplar River Basin and the Opheim Syncline in the northwest part of the basin. The entire area is on the northern edge of the Williston basin which is a large structural syncline involving rocks of Cretaceous or older age. Underlying the Fort Union Formation are east-dipping strata of Cretaceous age including the Bearpaw Shale, Judith River Formation, and Dakota Sandstone; Jurassic sandstone and shales; the Madison Limestone of Mississippian age; and Devonian, Ordovician, and Cambrian rocks.

These structures have resulted in minor folding and faulting of the Fort Union Formation in the area. The Brockton-Froid Fault zone is a northeast-trending thrust fault near the southeast part of the Poplar River Basin. Several other faults with small displacements of the Fort Union Formation are found. These faults do not have a consistent trend. Approximate locations are shown on Figure A-1.1.

A-1.2 SOILS

The soils found in the Poplar River Basin are derived from the glacial till and outwash deposits and locally exposed bedrock formations. The soils in the Canadian part of the basin belong to the Brown and Chernozemic Brown groups. These groups are characterized by low organic content and light to gray brown color with a calcareous layer in the subsoil. The soils developed on the glacial till in areas of gently sloping topography are predominantly Fife Lake loam of the Orthic Brown soil subgroup with a minor component of Eluviated Brown soils. These soils are well-drained and moderately calcareous. In areas of level to undulating topography the soils developed from glacial outwash are predominantly Fife Lake sandy loam of the Rego Brown soil subgroup. These soils have either no B horizon or a very shallow one (less than two inches). The soils may contain gravel and have moderately calcareous zones. The drainage of these soils is usually good. Meadow sandy loam soils of the Orthic Humic Gleysol soil subgroup are found in kettle and slough areas in glacial outwash deposits. These soils are poor to very poorly drained and farming is therefore restricted in such areas.

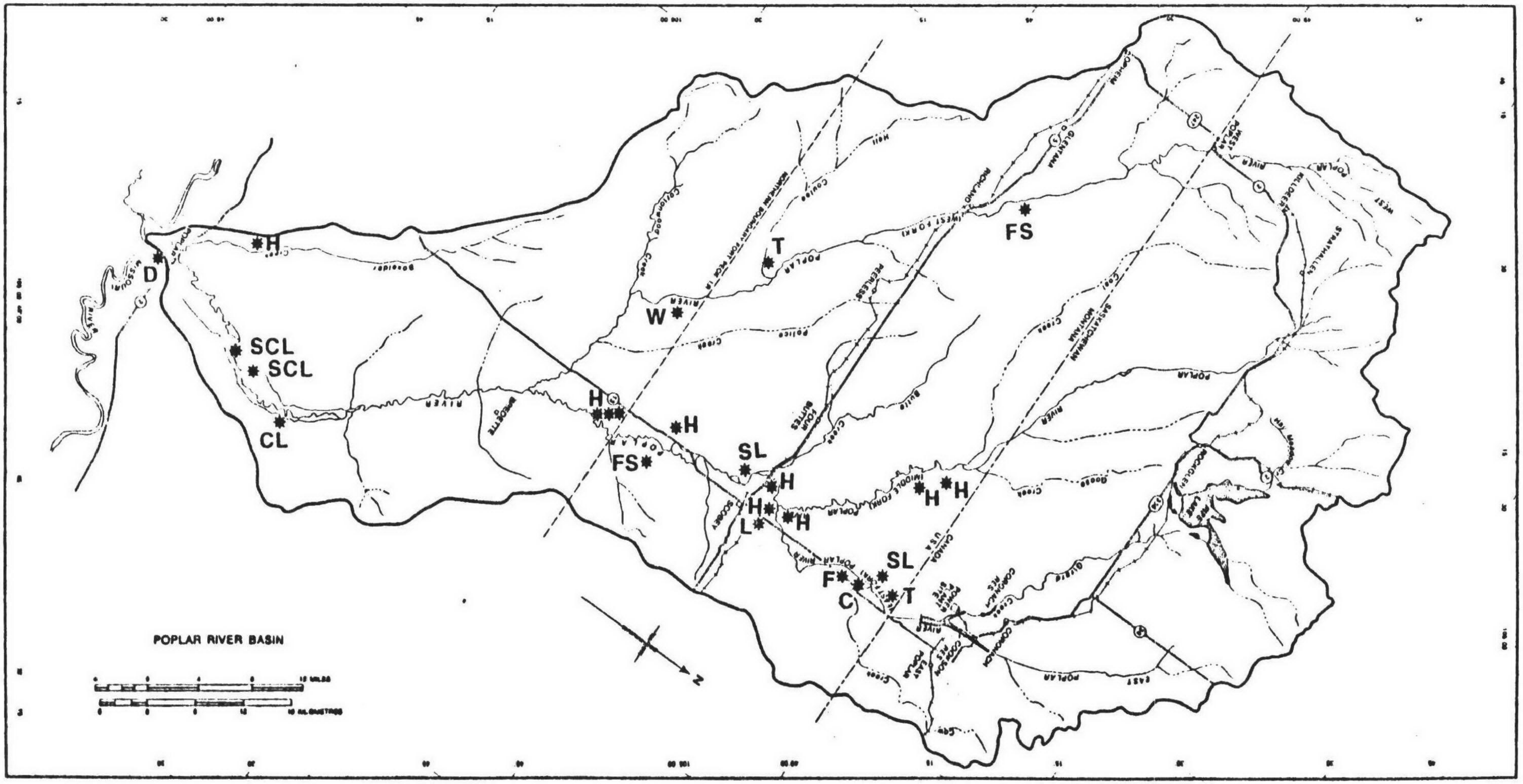
The soils developed on the Ravenscrag Formation range from gravelly sandy loam to clay loam. The soils may have quartzite pebbles and fragments of bedrock or coal which are brought to the surface when the soil is cultivated. The soil is moderately calcareous (6 to 15%) (Nelson, 1977) which would mediate some of the effects of using high sodium water for irrigation.

Soil surveys for Daniels and Roosevelt Counties are currently being made by the Soil Conservation Service. The detailed soil survey will not be completed for about two years (Smetana, 1979). Therefore, information from preliminary work was used. Figure A-1.2 shows the soil series for each of 24 locations sampled for the Montana Health and Environmental Sciences Department and a survey of bank materials along the Poplar River by the Montana DNRC.

Erosion hazard restricts the use of some land for agriculture and can indicate the amount of sediment which could wash off into the river. The soils on the upland areas underlain by glacial till have a moderate erosion hazard under good agricultural management practices. Soils developed on sands and gravels of the Flaxville Formation in some areas may have wind erosion problems if left fallow for long periods (Bloom and Botz, 1975). Soils developed on the Fort Union Formation where shale layers are close to the surface (usually less than 40 inches) have a moderate erosion hazard. At the edge of the terraces steep slope areas can occur which are referred to as "breaks." These areas have shallow, well-drained soils and have a severe erosion hazard. A badlands-type topography can develop in these areas which can result in high sediment loads to nearby streams.

The chemical properties of the soils influence the type of agriculture which can be practiced, the yield of crops, and the suitability of the soil for long-term irrigation. Measurements of pH, conductivity, calcium, sodium, magnesium, and boron were made on 13 soil samples from Daniels County (Horpestad, 1978). Analyses of the above parameters plus potassium content and cation exchange capacity (CEC) were made on a total of 20 samples at 11 sites on the Fort Peck Indian Reservation. Table A-1.2 is a summary of the chemical data for the soils. The low cation exchange capacities of most of the sites in the lower part of the basin suggest that the clay component of the soil is composed of more illite and kaolinite than smectite minerals. The moderate to low organic content of the soils is also reflected in the low CEC Values.

Two of the soils had high sodium adsorption ratios (ratio of Na to Ca & Mg) and conductivity. Soils at site 109 along the main stem of the Poplar River south of the northern boundary of the Fort Peck Indian Reservation would be classified as saline-alkali. The site has been irrigated for about 66 years. Soils at site 119 near the confluence of the East and Middle Forks were classified as saline



KEY:

✸ Soil Sampling Site

H	Havrelon Loam	T	Turner Loam
T	Trembles Fine Sandy Loam	D	Dooley Series
C	Cherry Silt Loam	SL	Silty Loam (soil series not given)
F	Farnuf Loam	SCL	Silty clay loam
FS	Farland Silt Loam	CL	Clay loam
W	Williams Loam		
L	Lohler Loam		

Figure A-1.2 SOIL SERIES IN THE U.S. PART OF THE POPLAR RIVER BASIN

Table A-1.2

CHEMICAL PROPERTIES OF SOILS IN U.S. PART OF BASIN

Site No	Soil Type	Parent Material	Boron (Total)*	K	Ca (Saturation Extract)	Mg (Saturation Extract)	Na (Saturation Extract)	CEC meq/100g	pH (Saturation Extract)	Cond (Saturation Extract)	Sodium Adsorption Ratio (SAR)
Upper Basin											
99	Loam	Alluvium	13	**	18	15	150	**	8 2	1780	6 2
100	Loam	Alluvium	10		35	17	41		8 3	1250	1 4
101	Sandy Loam	Alluvium	19		52	8 4	160		8 1	2260	5 5
102	Silt Loam	Alluvium	12		65	11	15		7 5	1340	0 45
103	Loam/ Clay Loam	Alluvium	10		120	26	92		7 6	2990	2 0
104	Loam	Glacial Till	10		26	14	86		8 4	1770	3 4
105	Silt Loam	Alluvium	8 8		22	8 4	66		7 7	1030	3 0
106	Silt Loam/ Silty Clay Loam	Alluvium	9 2		20	13	77		7 6	1140	3 3
107	Silt Loam	Alluvium	7 5		25	12	6 5		7 6	760	0 27
108	Sandy Loam	Alluvium	7 0		31	6 9	17		7 6	700	0 72
109	Loam	Alluvium	18		76	76	900		8 4	7820	[illegible]
118	Loam/Silty Clay Loam	Alluvium	13		21	14	91		8 3	1430	3 8
119	Silty Clay Loam	Alluvium	12		82	40	440		8 3	6210	10
Lower Basin											
FP-1	Silty Clay Loam	Alluvium	3 1	167	37	40	110	22	8 4-8 5	900	3
FP-2	Clay/Clay Loam	Alluvium	4 1	566	94	66	434	44	7 7-8 3	3380	8 3
FP-3	Clay Loam	Alluvium	3 3	180	166	178	761	22	8 7	600	9 7
FP-4	Clay Loam	Glacial Outwash	ND	143	33	33	127	20	8 2-9 0	1100	3 7
FP-5	Clay Loam	Glacial Outwash	ND	230	75	36	7	23	7 6-8 3	500	0 2
FP-6	Clay Loam/ Sandy Loam	Dune Sand Over Outwash	ND	87	63	140	264	16	8 7-9 3	1470	4 2
FP-7	Sandy Loam/ Sandy Clay Loam	Glacial Till	ND	115	53	31	126	21	7 9-8 5	500	3 4
FP-8	Clay Loam	Glacial Till	ND	173	57	180	279	17	8 2-8 6	2570	4 1
FP-9	Loam/Sandy Loam	Alluvium	ND	100	75	32	31	15	8 1-8 4	670	0 7
FP-10	Clay Loam	Colluvium	3 78	255	76	57	109	25	7 9-8 1	1580	0 4
FP-11	Clay Loam	Colluvium	3 13	248	63	46	32	25	7 8-8 0	1050	0 7

Note All values are in mg/ℓ except conductivity in umhos/cm and pH

Data from Horpestad, 1978

*Boron Data for the lower basin samples are "hot water soluble" fraction of Boron only

**Data not available for upper basin samples

ND = Not Determined

which is common for soils of the Lohler series (Horpestad, 1978). This site had been irrigated for about nine years which may have contributed to the salinity. Two other sites (103 and FP #2) were clasified as slightly saline.

These soils have slight to moderate alkalinities based on the pH range of 7.5 to 9.3 (Table A-1.2). Within this pH range several plant nutrients are less available to plants. These include phosphorus, boron, iron, manganese, zinc, copper, cobalt, and to a lesser extent calcium and magnesium (Brady, 1974).

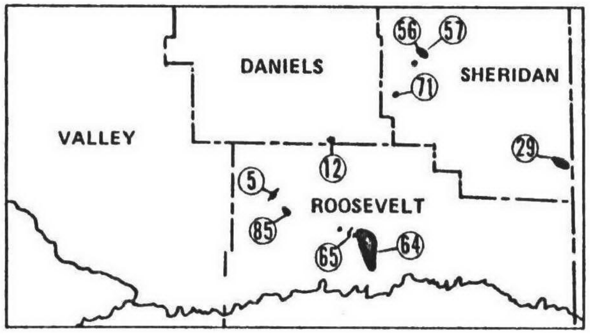
Boron is an essential micronutrient for plants, especially for alfalfa (Brady, 1974). At pH values greater than 7 the element is less available to plants. The high levels of boron in the Poplar River and Fife Lake are a concern as the element may be toxic at high concentrations. The study by Horpestad (1978) tested the correlation of boron soil concentrations with years of irrigation and with boron concentrations in adjoining stream reaches. There was a positive correlation between boron concentration in the stream and in the soil. Boron is attenuated by the soil depending on the type of soil, irrigation practices, and cation concentration of the irrigation water and soil. Thus, the soil concentration is not solely a linear function of stream concentration.

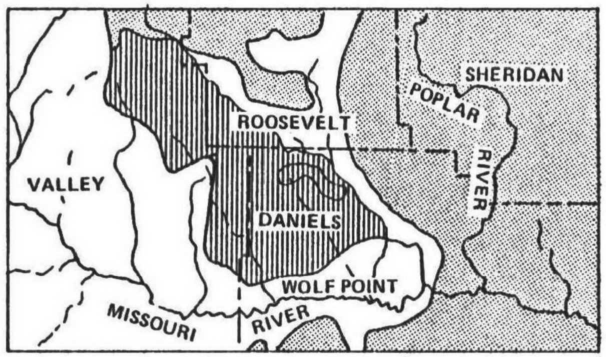
A-1.3 MINING AND MINERAL RESOURCES

A-1.3.1 Fuel Resources

Oil has been produced from the nine fields shown in Figure A-1.3 The Benrud and Tule Creek fields lie just to the west of the Poplar River Basin. The total estimated reserves in the Bredette-North, Poplar, and Poplar Northwest fields are 73,866,000 bbls (USGS, 1968). The producing zones are at an approximate depth of 5550 to 6260 feet. The two fields near Poplar were discovered in 1952 and produce at an average rate of 6,480 barrels of oil per day at the Poplar field and 58 barrels of oil per day at the Poplar Northwest field (USGS, 1968). The Bredette-North field was discovered in 1956 and produces 31 barrels of oil per day (USGS, 1968). Known reserves of oil in Montana could be depleted by 1980-1982 (Montana DNRC, 1975). Exploration for oil and gas is continuing in the Poplar River area.

Several lignite coal fields exist in the Poplar River area, although no coal is being mined in the U.S. part of the basin at present. The general location of the lignite fields and estimated thickness of the coal beds are shown in Figure A-1.3 for the U.S. part of the basin. The entire Poplar River Basin is underlain by the Fort Union or Ravenscrag Formations, both of which contain the coal seams except in the





64 Oil fields

No.	Field Name
5	Benrud
12	Bredette-North
29	Dwyer
56	Outlook (Sil-Dev.)
57	Outlook (Up. Ord.)
64	Poplar
65	Poplar Northwest
71	Redstone
85	Tule Creek

MILES
50 0

LIGNITE

MORE THAN 30 INCHES THICK

LESS THAN 30 INCHES THICK

Source: after USGS, 1968.

Figure A-1.3 FUEL RESOURCES OF THE U.S. POPLAR RIVER BASIN lower section of the basin. There are two fields in Roosevelt County--the Fort Kipp and Lanark deposits. The Fort Kipp field has estimated reserves of 331 million tons covering 14,500 acres (Montana HES, 1978). The average ash and sulfur content is 4.6 and 0.20 percent, respectively, with an average Btu content of 6,110. The Lanark field has estimated reserves of 100 million tons covering 3,531 acres. The average ash and sulfur content is 6.3 and 0.40 percent, respectively, with an average Btu content of 6,853. The Medicine Lake field (3,740 acres) and the Reserve field (18,231 acres) are between the Poplar River and Big Muddy Creek. The estimated reserves of the fields are 58 and 246 million tons (Montana HES, 1978). The average ash and sulfur content of the Medicine Lake field is 7.2 and 1.0 percent with an average Btu content of 6,870. The Reserve field has an average ash and sulfur content of 7.6 and 0.4 percent with an average Btu content of 6,599.

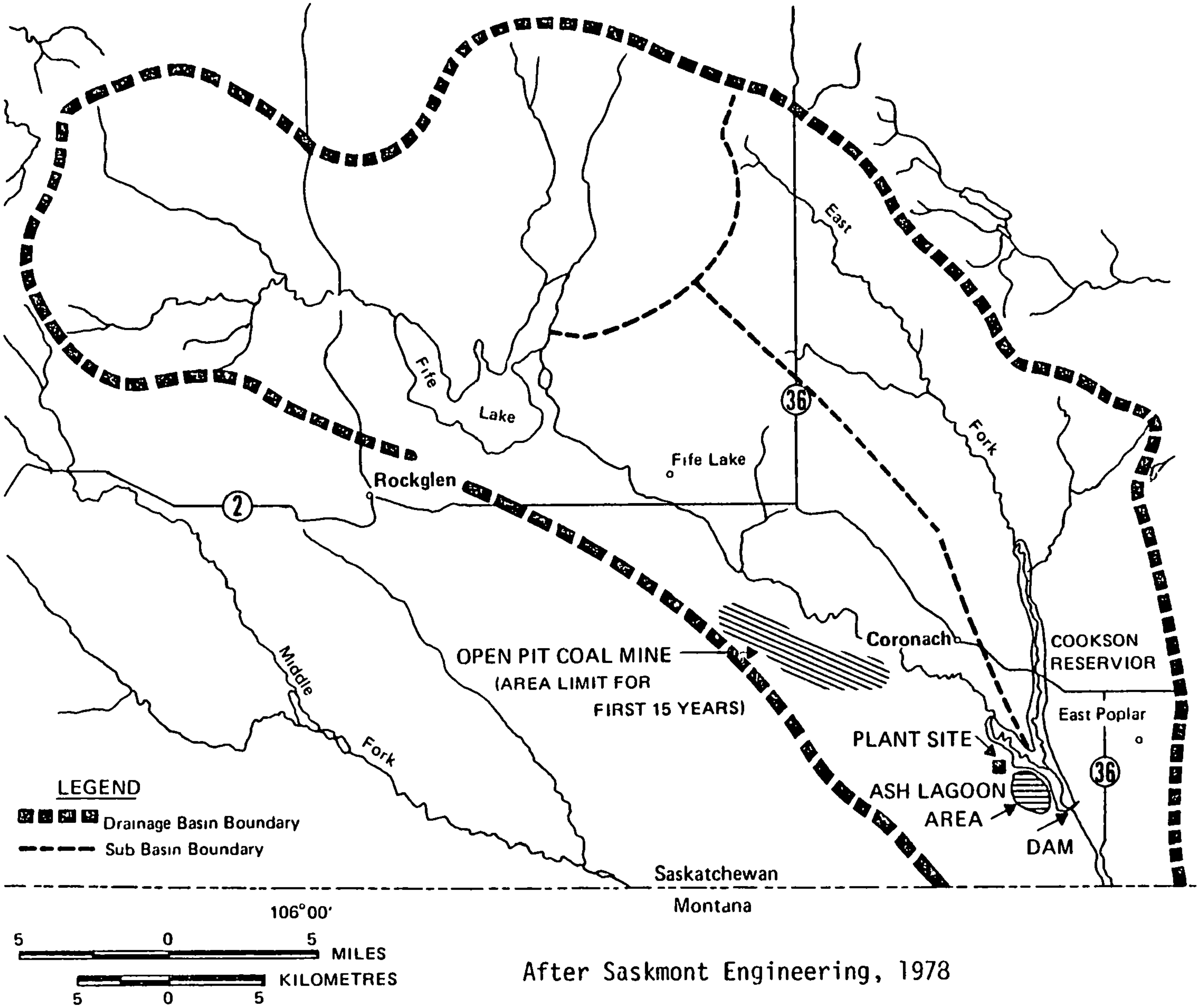
The Fort Kipp, Medicine Lake, and Reserve fields have been classified as strippable, although the thick glacial till hinders mining. The stripping ratio (net cubic yards overburden to tons lignite) for the Fort Kipp coal was 4.73:1 (Fort Peck Tribes, 1978). These areas have a low probability of development due to overburden and low Btu value (Montana Energy Advisory Council, 1976). Areas to the south and east will probably be developed first since these areas were not glaciated. No mining for coal took place in 1975 in the U.S. part of the basin.

There are six major and six minor coal fields in the Saskatchewan part of the Poplar River Basin. The breakdown by size of economically recoverable reserves is as follows (Poplar River Task Force, 1976):

Number of Fields	Reserve Size, Million Tons
1	500-600
4	200-350
1	100-200
6	less than 50

All the recoverable coal is at a depth of less than 150 feet. Seams with a thickness of 3 to 5 feet were included if the stripping ratio was less than ten to one.

The Hart coal seam will be mined to supply coal for the Saskatchewan Power Corporation's power plants near Coronach. The area to be mined and the site of the plant are shown in Figure A-1.4. The chemical characteristics of the coal are given in Table A-1.3 and indicate low sulfer content of 1.3 percent. The projected coal requirement



After Saskmont Engineering, 1978

Figure A-1.4 LOCATION OF MINE AREA, SPC POWER PLANT AND ASH LAGOONS

Table A-1.3

CHEMICAL CHARACTERISTICS OF POPLAR RIVER COAL

Coal Analysis (Dry Basis)

TEST	ASH	CARBON	HYDROGEN	NITROGEN	SULFER	OXYGEN
5 & 6	22.32	55.30	3.50	0.80	1.31	16.77

Ash Analysis

TEST	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	SO_3
B5	38.11	24.10	3.89	15.11	4.75	3.54	1.04	0.16	1.15
B6	38.08	21.04	4.12	14.28	2.50	1.87	1.27	0.14	0.84
F5	39.34	24.34	4.43	15.36	4.91	3.22	1.09	0.20	0.58
F6	37.78	18.77	4.47	14.22	4.61	1.31	1.31	0.72	0.48

NOTE: All values are expressed as percent. Data are from Saskatchewan Power Corporation Coal and Environmental Programs, 1976.

for the first 300 MWe power plant unit is 50 million tons over the life of the plant with an associated water requirement of 4,400 acre-feet per year. The projected coal and water requirements for four 300 MWe power plant units are 200 million tons and 10,200 acre-feet per year, respectively (Poplar River Task Force, 1976).

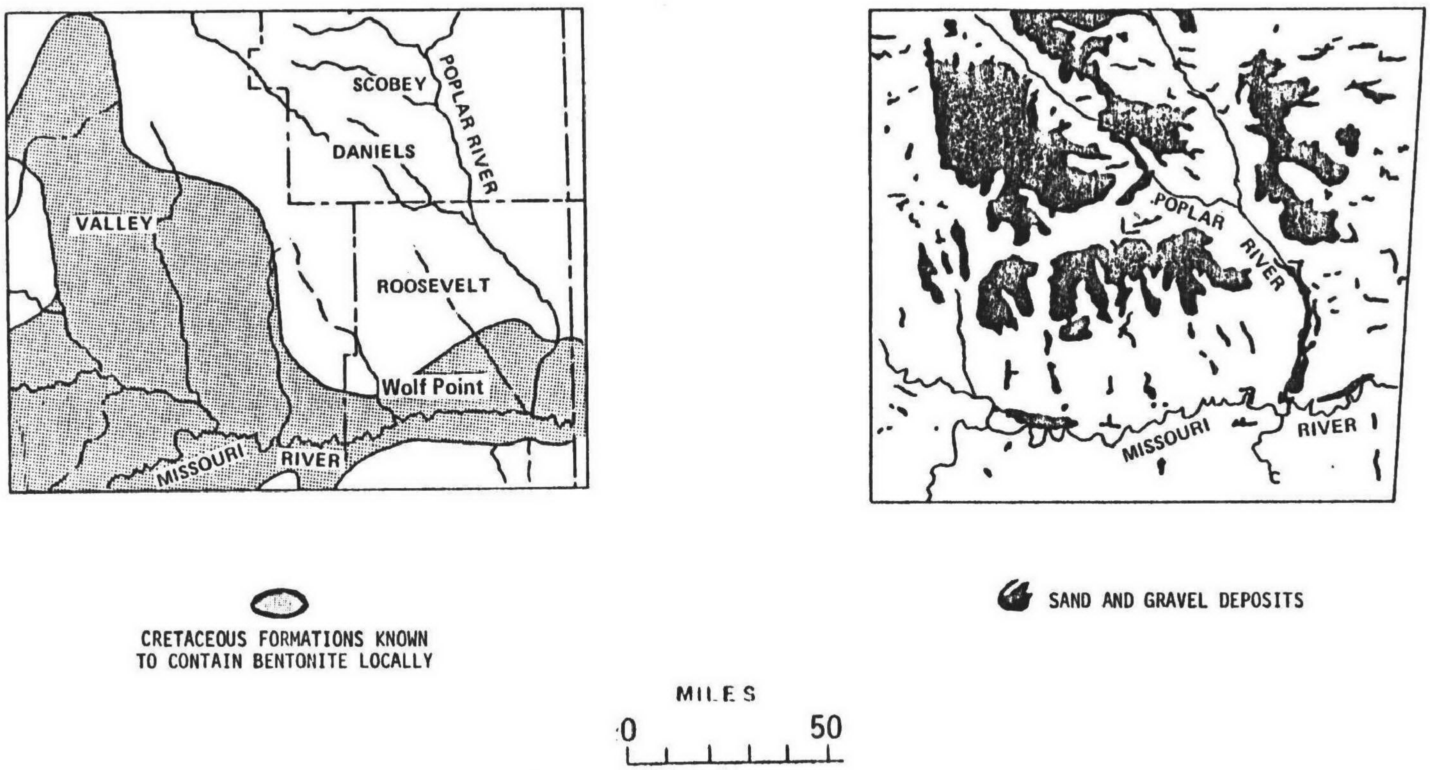
A-1.3.2 Non-fuel Resources

Potash is found in the bedded salt deposits of the Prairie Evaporite Formation of Devonian age which occurs throughout most of the basin in Saskatchewan and Montana at depths between 3,000 and 5,000 feet. The potash is recovered by solution mining to dissolve the mineral sylvite. Both water and coal are needed for the production of potash which is used for fertilizer. A plant producing about 3 million tons per year of potash requires approximately 5,000 acre-feet of water and 3,500 tons of lignite coal or 2,500 tons of subbituminous coal (Montana DNRC, 1978). The personnel requirements for the mining and processing plant after construction of the facilities are estimated to be 200 people.

No potash mines are presently operating in the U.S. part of the basin. Potash is being mined in Saskatchewan by the Pittsburgh Plate Glass Industries at a rate of 1.5 million tons per year. This company is also conducting exploratory work to determine the feasibility of mining in the Poplar River and neighboring Big Muddy Creek basins. Water for the mining and processing operation may be obtained from the deep Dakota Sandstone Formation.

The Farmer's Potash Company has plans for a potash mine near Scobey and a processing plant located one mile northeast of Scobey. The company applied for a beneficial water use permit in 1976 to construct two reservoirs for the solution mining operation. One reservoir would be built on the East Fork, about three miles west of Scobey, with a capacity of 7,000 acre-feet. The other reservoir would be built on Beaver Creek in Big Muddy Creek Basin with a capacity of 12,955 acre-feet. The maximum water requirement of 5,000 acre-feet per year would be met by the two reservoirs and possibly groundwater. The company is waiting to apply for a permit under the major Facilities Siting Act until economic and environmental studies are completed and rights to adequate water supplies have been obtained. The projected start date is currently 1985. The Montana DNRC is holding the water permit application until a decision on the apportionment plan for the Poplar River has been made.

Other resources include sand and gravel in the glacial till and outwash deposits and bentonite deposits in the U.S. part of the basin (Figure A-1.5). Small mining operations may be taking place for construction purposes within Montana, but no large mines are currently



after USGS, 1968.

Figure A-1.5 LOCATION OF BENTONITE, SAND, AND GRAVEL DEPOSITS IN THE U.S. PART OF THE POPLAR RIVER BASIN operating or planned. In the Saskatchewan part of the basin deposits of quartzite (a source of high grade silica), clays suitable for making stoneware and bricks, and marl for building stone are found. These deposits have not been developed and no development is anticipated prior to 1985 (Poplar River Task Force, 1976). Water requirements for these mining operations have not been included in the projected water uses for 1985 or 2000 due to the uncertain plans for development.

Table A-2.1

LAND USE OF INDIAN TRUST AND GOVERNMENT-OWNED LAND, ON AND NEAR FORT PECK RESERVATION--CALENDAR YEAR 1972

	Total Use	Open Grazing	Commercial Timber	Non-Commercial Timber	Dry Farm	Wild Lands Unused	Other Uses Non-Agricultural
Fort Peck							
TOTAL	965,868	653,139	3,000	3,759	283,156	0	5,009
Used by Indians	371,430	187,045	3,000	9,759	163,344	0	2,461
Used by non-Indians	583,143	457,987	0	0	116,870	0	2,548
Idle (unused)	11,295	8,107	0	0	2,942	0	0
Area-Wide							
TOTAL	5,278,174	3,612,674	574,177	234,192	688,566	45,020	26,813
Used by Indians	3,117,632	2,330,032	574,177	234,192	254,493	22,974	17,243
Idle (unused)	40,216	11,866	0	0	5,484	22,046	143

Note: Includes only government-owned land assigned to Indians.

Source: Bureau of Indian Affairs, Billings Area Office.

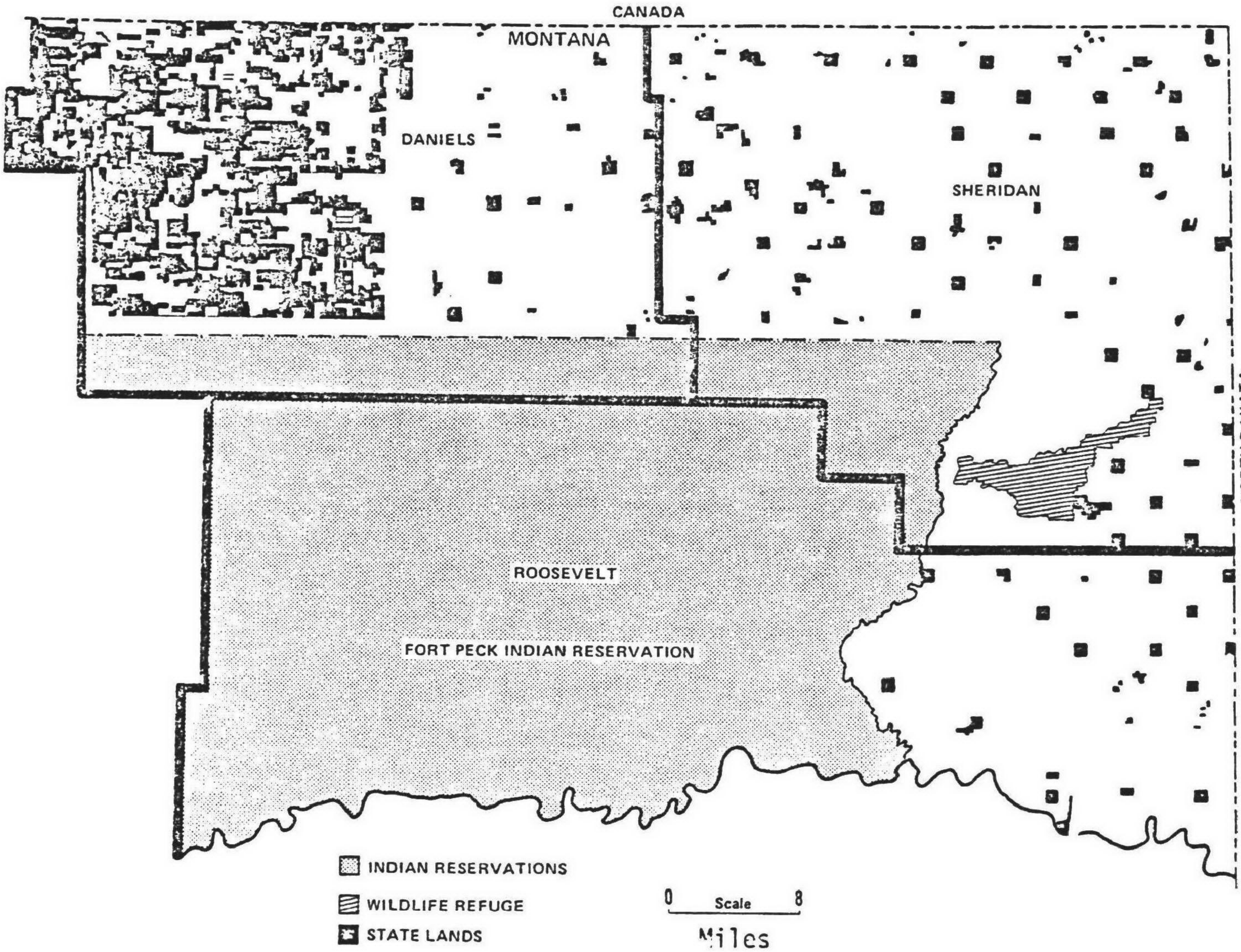


Figure A-2.1 MAJOR LAND OWNERSHIP CATEGORIES IN DANIELS, ROOSEVELT AND SHERIDAN COUNTIES

Table A-2.2

SURFACE LAND OWNERSHIP IN NORTHEASTERN MONTANA COUNTIES

County	Total Area	Federal	State	BIA Trust	Private, County and Municipal
Daniels					
Area (acres)	923,456	846	221,115	38,351	663,144
Percent of Total		0.09	23.9	4.1	71.8
Roosevelt					
Area (acres)	1,535,232	55,315	19,944	487,428	972,545
Percent of Total		3.6	1.3	31.7	63.3
Sheridan					
Area (acres)	1,100,736	27,252	45,847	51,704	975,933
Percent of Total		2.5	4.2	4.7	88.7

Source: Northern Great Plains Resources Program, 1974

Appendix A-3. Surface Hydrology

A-3.1 POPLAR RIVER FLOWS

Annual flow frequencies were compiled for the West, Middle, and East forks of the Poplar at the International Boundary and for the Poplar River at Poplar, Montana. Figures A-3.1 through A-3.4 show the histograms for total annual flow in acre-feet (ac-ft). Conversions to mean annual discharge in cfs are made by dividing the flow in acre-feet by 724. These figures can be used in several ways. First, the return interval for a given magnitude of flow can be obtained. The annual flow is located on the x-axis, and the value on the y-axis where the flow intersects the frequency curve is the chance that a flow of magnitude x will be equalled or exceeded. The reciprocal of this chance is the estimated return period in years. Secondly, the expected value of the distributions can be obtained. This value represents the 'normal' annual flow. The expected total annual runoff along with its associated return period is shown in Table A-3.1.

Generally for short records or for skewed data the expected value is more representative of 'normality' than the arithmetic mean. The mean of annual flows is consistently higher than the expected value at these stations. Given that the expected flow of the Poplar River at Poplar, Montana, is 83,860 ac-ft, it is evident that the 1975 flow of 323,000 ac-ft is a more extreme event. In fact, its return period is about one in 18 years.

If the precipitation and streamflows for an expected year (one in three year event) are investigated one can make the following observations. Annual precipitation would be approximately 10.9 inches or equivalently 1,930,512 ac-ft for the entire basin. Streamflow at the mouth is 83,860 ac-ft. Of that flow, 27,085 ac-ft comes from across the International Boundary (32.3%). This percentage corresponds very nearly to the area of the basin above the boundary. The increased contribution of the lower part of the basin may be due to increased groundwater seepage into the stream as the basin outlet is approached. The difference in annual precipitation and annual streamflow account for losses due to evapotranspiration and deep groundwater recharge. This volume is 1,846,652 ac-ft. Streamflow, therefore, accounts for only 4.3% of the total annual water input to the basin. The assumption that no significant subsurface basin inflow occurs has been made. Feltis (1978) has noted that groundwater recharge occurs almost exclusively from precipitation falling within the basin

In addition to the annual water balance, one can, with additional data, reconstruct the watershed hydrologic status on a seasonal basis. The period of least hydrologic activity is winter. The river freezes and groundwater seepage maintains a small flow amounting to about 5 cfs at the mouth of the Poplar. Approximately 36 inches of snow will

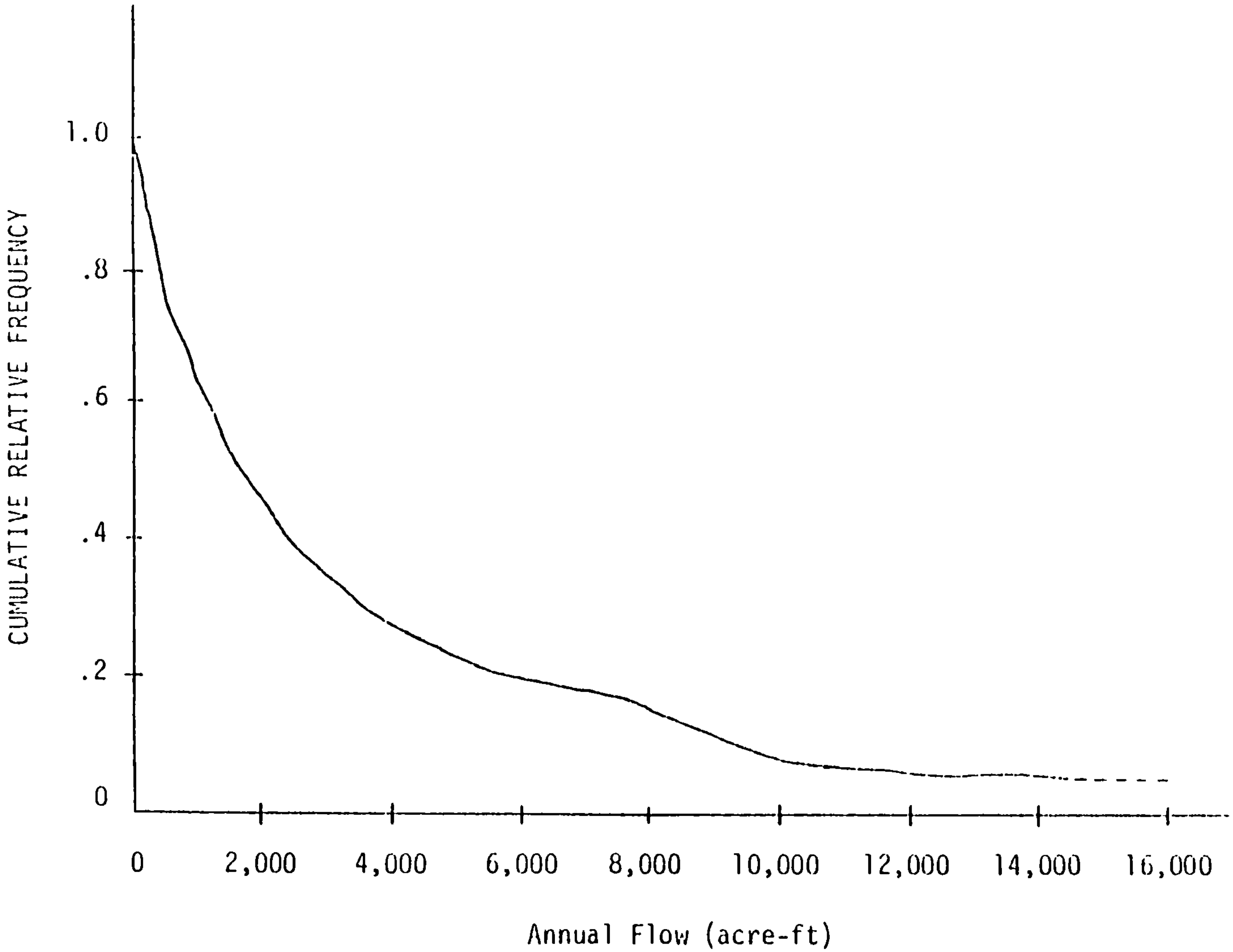


Figure A-3.1 FREQUENCY DISTRIBUTION OF TOTAL ANNUAL FLOW FOR WEST FORK POPLAR RIVER AT THE INTERNATIONAL BOUNDARY

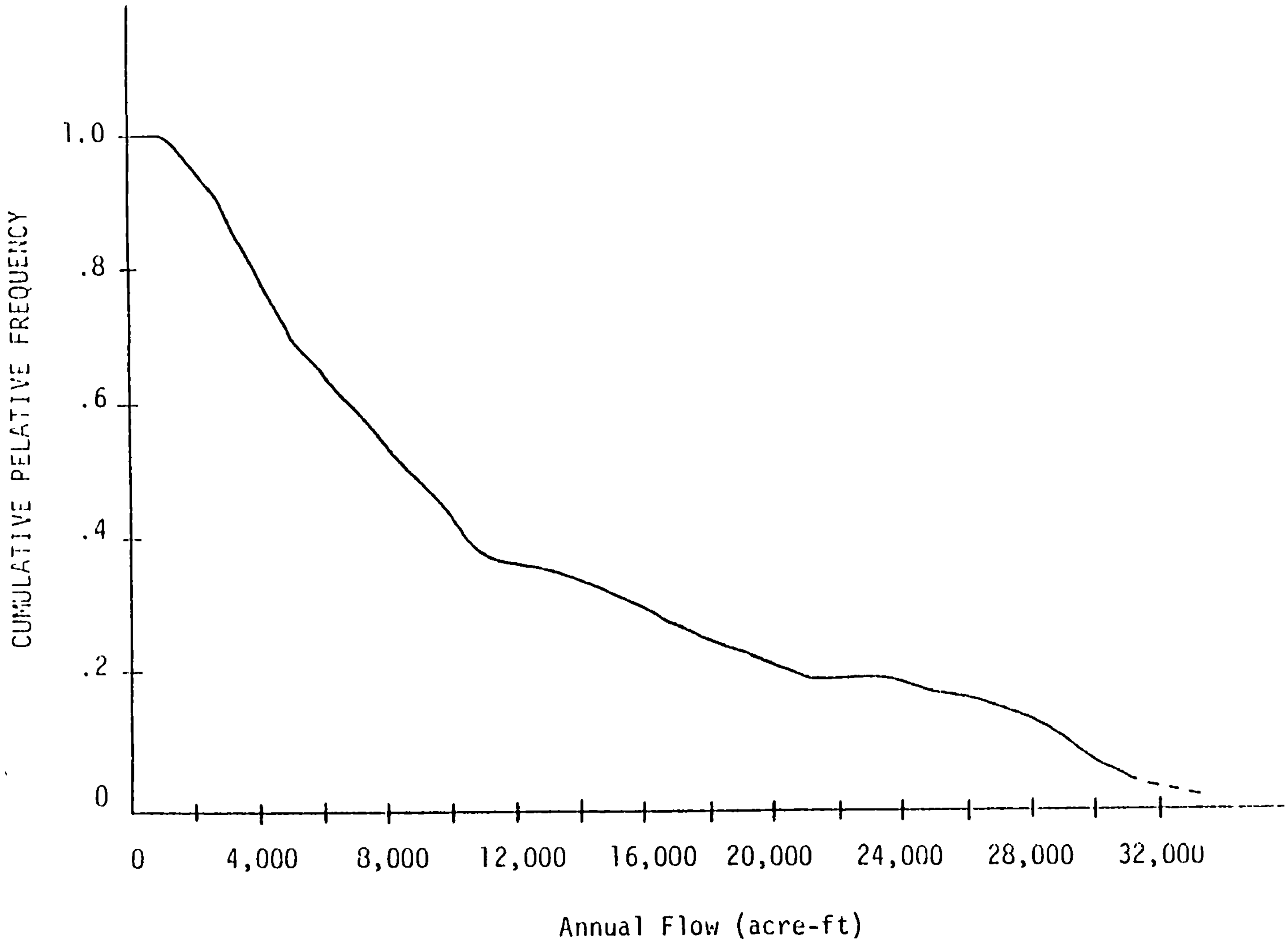


Figure A-3.2 FREQUENCY DISTRIBUTION OF TOTAL ANNUAL FLOW FOR MIDDLE FORK POPLAR RIVER AT INTERNATIONAL BOUNDARY

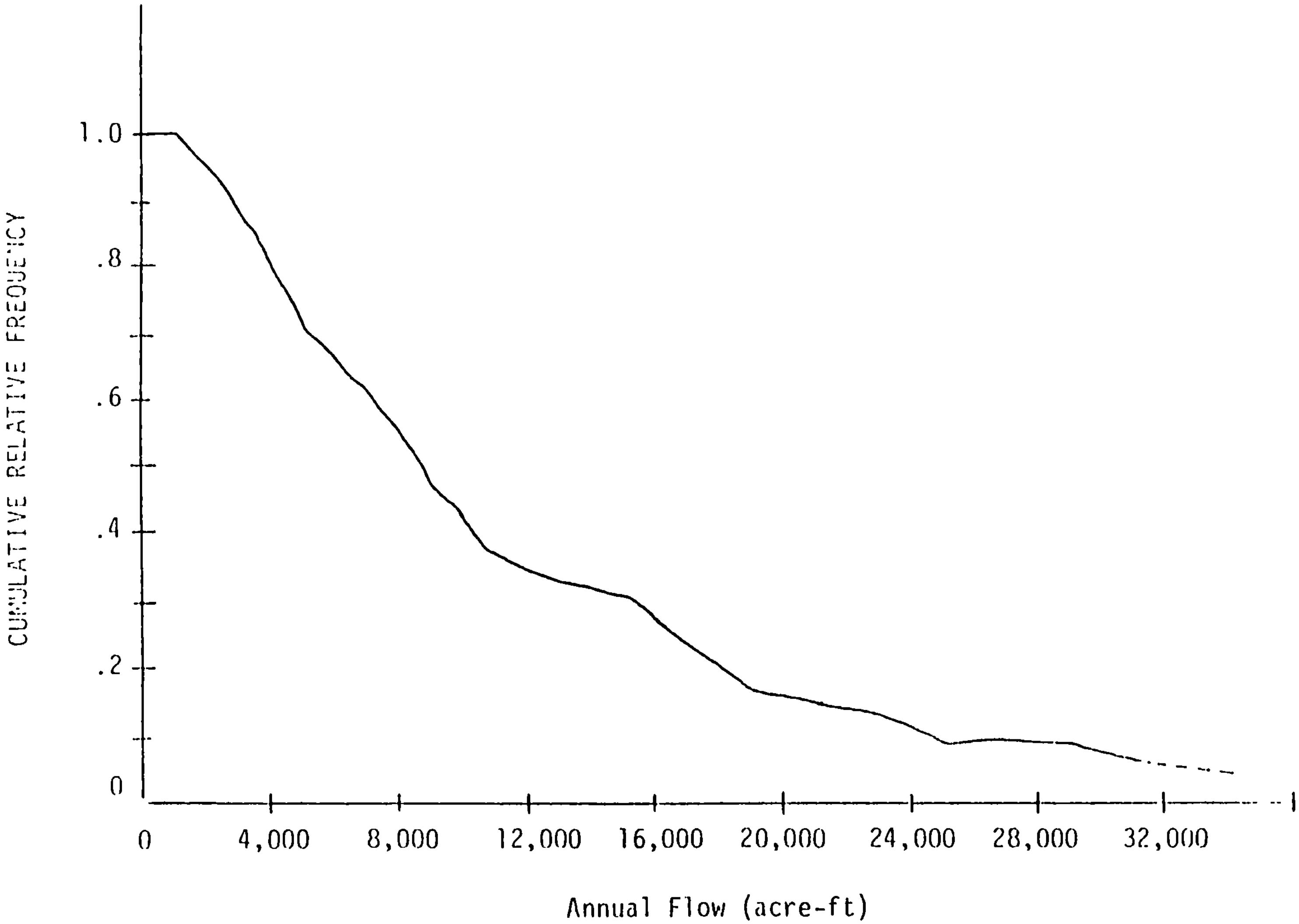


Figure A-3.3 FREQUENCY DISTRIBUTION OF TOTAL ANNUAL FLOW FOR EAST FORK POPLAR RIVER AT THE INTERNATIONAL BOUNDARY

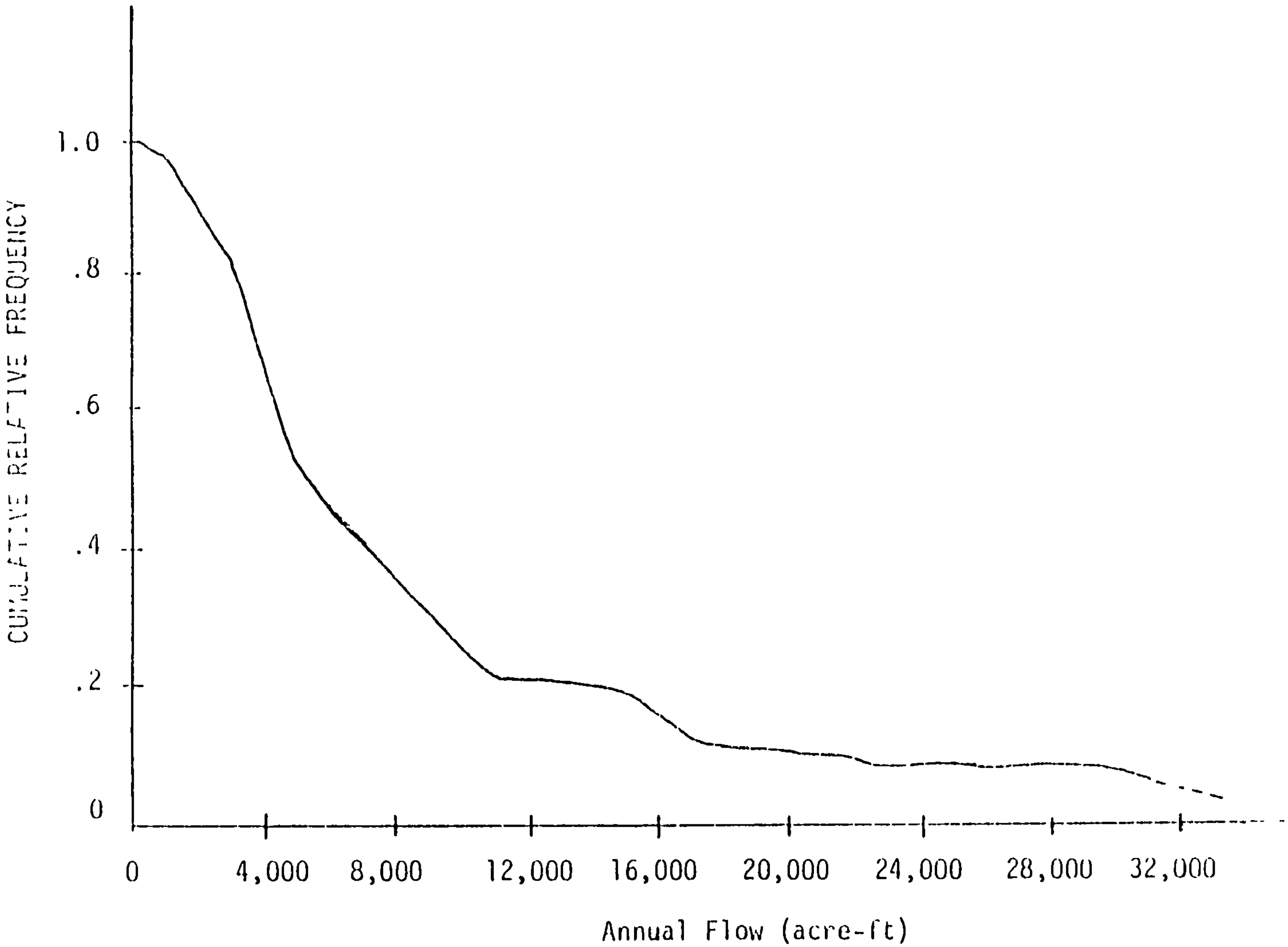


Figure A-3.4 FREQUENCY DISTRIBUTION OF TOTAL ANNUAL FLOW FOR POPLAR RIVER NEAR POPLAR, MONTANA

Table A-3.1

COMPARISON OF EXPECTED ANNUAL FLOWS, MEAN FLOWS AND THE 1975 FLOWS IN THE POPLAR RIVER

River Segment	Expected Annual Flow (ac-ft)	Return Period (yrs)	Mean Flow* (cfs)	1975 Flow (ac-ft)
West Fork @ I.B.	3,445	3.0	4.76	9,200
Middle Fork @ I.B.	11,790	2.7	16.28	34,040
East Fork @ I.B.	11,850	2.9	16.37	34,040
Poplar River @ Poplar, Montana	83,860	3.0	115.83	323,000

*Period of Record: 1933-1974.

fall in a normal year and frost will penetrate to nearly 50 inches. As spring approaches, snowmelt begins to produce runoff. This occurs in late March, April or early May. The drainage, occurring over frozen soil, produces an initially rapid hydrologic response. Within 10 days to 3 weeks the peak annual runoff occurs. Streamflow during this peak period accounts for roughly three-fourths of the total annual flow. This flow tapers off to 10-20 cfs at the basin outlet during the summer (International Joint Commission, 1978). During late spring, the bulk of the ground water recharge is thought to occur. Although precipitation peaks in June, the evaporative demand is so high that little of the rainfall is envisioned as migrating to ground water during this time. Summer rainfall is typically convective, characterized by short, intense bursts. Depending on antecedent moisture conditions and proximity of the storm cell path to the channel, these may or may not produce significant contributions to streamflow. As fall approaches, both rainfall quantities and evaporative demand decline rapidly and when winter returns, the system once again assumes hydrologic dormancy.

A-3.2 STREAM HYDRAULICS AND SEDIMENT TRANSPORT

Hydraulically, the Poplar is similar to other alluvial channels. During most of the year, low flow conditions are prevalent. Velocities are extremely low in the pool sections and moderate over the riffle areas. At these low velocities, very little transport of alluvial materials or bedload takes place. What makes the low flow periods hydraulically critical is that the sandy banks in the bends may be undercut so that significant mass-wasting (sloughing) of banks may occur, tending to fill up the pools. This undercutting may be caused by velocity acceleration in the bends or by wave action induced by high winds. These deep pools are the refuge for many game fish species during low-flow periods so that keeping them scoured is important. Velocities are low enough in the pools during low-flow periods that very little material is envisioned as being transported to the riffle areas. The riffles are beds of gravel and cobbles which are important in providing a spawning habitat for game fish. Many of the riffle areas are above the water surface during these flow conditions.

Under high flow conditions the bulk of the bank erosion occurs. However, it is during this period that the scouring of pools and cleansing of riffles also occur. Velocities in the bends accelerate on the rising limb of the hydrograph during the spring high flow. This causes sediments to be transported out of the pools. Movement of fine particles causes shifting and migration of the larger gravel and cobbles, which in turn exposes more fine sediments making them available for transport.

During high flows, if velocities in the pools are high enough to move sediments out, the velocities over the riffle areas will be even higher (by the continuity equation) and, therefore, little deposition should take place in these areas. Although many fine sediments are transported long distances downstream during this time, the primary cleansing effect through sediment movement is most likely from the pools to the point bars or from riffle areas to point bars only short distances downstream.

As the hydrograph reaches a falling stage, velocities lessen and hydraulic sorting occurs in pool areas. The large particles drop out of suspension, first being deposited at the upper ends of the pools, and smaller particles are settled out farther into the pool. This produces a graded effect, large to small, as one moves from the upper to lower end of the pool areas. During the falling limb of the hydrograph, siltation of the riffle areas may occur.

Because of the paucity of precipitation in the area, flat slopes and vegetative cover on the watershed, there is most likely little sediment transport in overland flow from undisturbed areas. If the totality of streamflow during a normal year (83,860 ac-ft) came from sheet flow, the net depth over the basin would be .47 inches. It is known that approximately three-fourths of this streamflow comes from spring snowmelt, leaving only .11 inches of depth for the overland flow component which might occur in concert with erosive rainfall activity. In a more extreme year like 1975, as much as 1.8 inches might come from overland flow with .5 inches coming from a source other than snowmelt. Even this amount would probably not cause extreme losses from natural areas. The soils of the area are fairly erodable, however. Stewart (1975) points out that on 30 to 40 percent of the cropland in the basin, agricultural use is limited by erosion. As of 1975, he points out that 50 to 75 percent of the area was in use as croplands and 25 to 50 percent were in use as rangeland. Cropland was pointed out as having a moderate potential contribution to watershed sediment yield.

Using the Universal Soil Loss equation, the annual loss from cropland from the total basin area (assuming 50 percent is under cultivation) would be 213,120 tons. Taking the average drainage density for the entire basin as .36 mi^{-1}, the sediment delivery ratio can be found (Zison, et al., 1977). For this basin it is about 12 percent, giving the total annual loading to streams from overland flow as 25,574 tons. This corresponds to a mean annual concentration at the outlet (under normal flow) of 225 ppm, assuming that all is retained in suspension. This condition is approximated during extremely high flows.

From suspended sediment samples taken at the outlet the above analysis shows that sediment loss from agricultural activities has the potential for contributing a large portion of the total sediment load. The remainder of sediment loading would be due to bank erosion, mass wasting, and loading from undisturbed areas.

Appendix A-4. Ground Water Hydrology

A-4.1 AQUIFER CHARACTERISTICS

There are three major aquifers in the Canadian part of the basin: the glacial drift, the Ravenscrag Formation, and the Frenchman Formation. At higher elevations in the basin the Wood Mountain Formation occurs, although it is not used near the power plant or reservoir site. The Ravenscrag Formation can be subdivided into four aquifers.

The glacial drift aquifer is composed of sand and gravel layers and includes the Empress Formation, which is a gravel zone in the lower part of the geologic section. A well inventory by Saskmont Engineering (1978) in the vicinity of the power plant identified 31 wells completed in drift. Depths ranged from 13 to 110 feet with an average depth of 46 feet. Well yields averaged between 5 and 32 gpm. The maximum yield of 534 gpm was measured at the Coronach municipal well which was completed in a gravel zone. Most of the shallow wells were dug, and are therefore between 2 and 3 feet in diameter. Static water levels were between 5 and 97 feet below land surface in 1977. The glacial drift aquifer supplies water primarily for domestic and stock uses.

The Ravenscrag Formation is equivalent to the Fort Union Formation and is an important regional source of water. Of the wells inventoried, 45 were completed in this formation as listed below:

Coal above Hart coal seam	18
Sand above Hart coal seam	16
Hart coal seam	6
Sand below Hart coal seam	5

The wells tapping coal or sand above the Hart seam are 26 to 246 feet deep. The average depth is 79 feet. Available yield data were limited. The measurements from the well inventory (Saskmont Engineering, 1978) were from 1 to 60 gpm. The high yield well is used for irrigation. Other wells are used for domestic water supply and stock. The static water level varied between 8 and 89 feet below land surface in the coal above the Hart coal seam and 8 to 111 feet below land surface in the sand above the Hart coal seam. Wells completed in these zones may be dug or drilled wells with the diameter varying between 4 and 30 inches.

The Hart coal seam supplies six wells. The closest ones to the mine site where dewatering will occur are approximately one mile away. Twelve wells were installed to dewater the mine site and monitor the water level decline. The depths of the existing domestic and stock wells are between 49 and 164 feet with an average depth of 112 feet.

The static water level in these wells before dewatering was between 14 and 70 feet below land surface. The well yield depends on local fracturing and is quite variable with a transmissivity of 1.08 x 10^4 to 1.2 x 10^6 gpd/ft. The dewatering wells can produce between 300 and 360 gpm. The pumping rate needed to dewater the mine site is expected to decrease from 3.2 mgd to 1.4 mgd in wet years or to 0.68 mgd in dry years over an eight year period (Saskatchewan Power Corporation, 1977).

The sand below the Hart coal seam is tapped by only five wells. The depths range from 180 to 325 feet with an average depth of 230 feet. Yields were between 5 and 7 gpm. The static water levels were 9 to 63 feet below land surface in 1977.

The Frenchman Formation is equivalent to the Fox Hills-Hell Creek Formation in the U.S. part of the basin. The formation is composed of fine sand with silt and clay lenses. The transmissivity of the aquifer is estimated at about 6,000 gpd/ft. (Saskmont Engineering, 1978). The quality of water from this formation is less than that from the other aquifers. Only three wells in the inventory are completed in this zone. Well depths are 265, 266, and 455 feet. Static water levels were between 70 and 128 feet below land surface in the confined aquifer. The wells were rotary drilled with diameters between 4 and 8 inches. Two of the three wells were not considered potable by the owners. The deep well at the power plant site is to be used for nonpotable purposes. The other two wells are used for stock watering. Well yields for the stock wells were between 8 and 40 gpm.

In the U.S. part of the basin the major aquifers from oldest to youngest are the Fox Hills Sandstone, Hell Creek Formation, Fort Union Formation, Flaxville Formation, Wiota gravels, glacial deposits, and alluvium. The Fox Hills and Hell Creek are combined because the boundary is hard to distinguish in this area (Feltis, 1978). Groundwater is found under unconfined and confined conditions, depending on the presence of low permeability layers such as shale or impermeable glacial till. If a well taps a confined aquifer where the water level is above the land surface, the well flows. Flowing wells are found in the lower parts of the river valleys. Groundwater in the alluvium, Flaxville Formation, and Wiota Gravels is unconfined. The Fox Hills-Hell Creek Formation is confined. Groundwater in the Fort Union Formation is unconfined in the upper part but may be confined in deeper sections.

A study of the shallow aquifers in the East and Middle fork areas of the Poplar River Basin was conducted by the USGS. The area covered is shown in Figure A-4.1. As part of this study water levels in 176 wells completed in shallow aquifers were measured and 20 wells and one spring were sampled. Another USGS project is being conducted to inventory wells completed in deeper zones. At this time well data

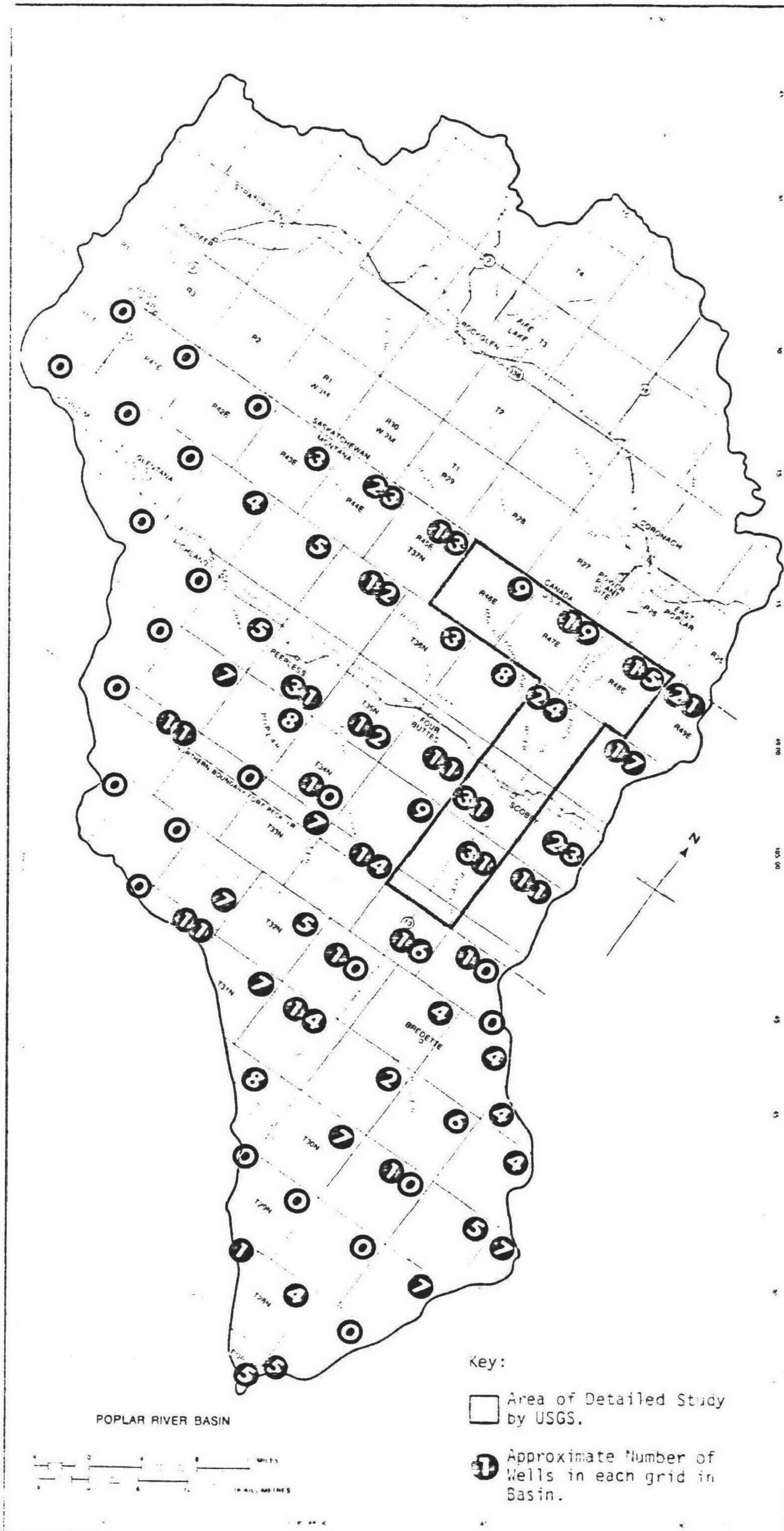


Figure A-4-1 LOCATION OF WELLS IN U.S. PART OF POPLAR RIVER BASIN in the area is limited. Well registration maintained by the Montana Bureau of Mines and Geology lists 506 wells in Daniels County and 717 wells in Roosevelt County. Well registration records may not list new wells and may include abandoned wells.

Wells with a known source were identified from the well listing to provide some data on well yields and water levels. Water levels were generally 9 to 20 feet below land surface at the time of well completion. Yields of the wells were between 2 and 550 gpm with an average yield of 152 gpm. Only two wells were completed in the glacial outwash deposits. The depths were 21 and 55 feet with a static water level of 12 and 43 feet, respectively. The yields were about 10 gpm. Data on the Flaxville Formation were incomplete. The average yield for three wells was 32 gpm with a maximum yield of 80 gpm.

There were 30 wells which listed the Fort Union Formation as a source. The depths ranged between 53 and 400 feet. The static water level at the time of well completion was from 2 to 340 feet below land surface. The yield averaged 9 gpm with a range of 3 to 20 gpm. Three wells were listed as completed in the Fox Hills-Hells Creek aquifer. The depths were between 160 and 348 feet with a static water level of 25 to 180 feet below land surface at the time of well completion. The yields were between 6 and 11 gpm. The Bearpaw Formation, underlying the Fox Hills-Hells Creek aquifer, was given as the completion zone for five wells. One of these wells listed a yield of 1100 gpm which is much greater than the other aquifers. The depths of the wells completed in the Bearpaw Formation were between 45 and 120 feet with static water levels between 18 and 90 feet. The yield data discussed above are only a small sampling of the total number of wells. The data does indicate that well yields are adequate for domestic and stock purposes but few wells have the high yields needed for large-scale irrigation projects.

Appendix A-5. Water Quality

A-5.1 SURFACE WATER

This section describes baseline surface water quality conditions within the Poplar River Basin and addresses water quality standards and criteria. Water quality data collected during the 1975 baseline year as specified by the EPA is the basis of the description; however, annual variations in several parameters during the period of 1973-77 are also considered.

For each sampling station (see Figure 4.5-1), and for water quality constituent values consistently reported, the number of observations and the minimum, mean, maximum, and standard deviation were computed. In addition, certain correlation statistics were also computed. The minimum, mean, and maximum values serve to establish baseline upper and lower limits for each water quality constituent, and the mean is a central (and probable) value. When considered together, the minimum, mean, and maximum also provide an indication of skewness of the data. The standard deviation is a measure of data dispersion.

There were several factors which make the 1975 data not a true baseline. While a substantial data base was available, in many cases, there were fewer than four observations per station. Consequently, the complete complement of statistics generated are probably of real value for relatively few stations (about six) where there were ten or more observations. Nonetheless, for completeness and purposes of comparison, all available statistics are presented for stations having at least three observations. System conditions changed in late 1975 so data after that time are not representative of pre-reservoir conditions. In addition, 1975 was an unusually wet year as discussed in the section on Surface Water Hydrology (Appendix A-3). It can only be a coarse comparison to use statistics from 1975 data to evaluate post-power plant operation data in terms of environmental impacts. Post reservoir (1976-77) data would be better.

Turning now to the question of concomitant variables, it is reasonable to assume that water quality data are relatively dependent upon such variables as temperature and flow. If we wish to use the standard deviation of, say, TDS (for 1975) to decide whether some TDS value in a later year is likely an outlier (i.e., represents true environmental changes in the prototype), and if flow and temperature change substantially over the period during which TDS was measured in 1975, then it must be known whether an unusual value observed in the later year is a true outlier or merely a manifestation of the effect of flow (seasonality, storm activity, diversions, discharges, waste sources) or temperature (seasonality, meteorological conditions, changes in vegetative canopy). To consider this question (albeit in an elementary fashion) correlations between water quality variables and flow and water temperature were examined. Presumably, where such correlations are low, the water quality variable can be supposed to be relatively unaffected by date of sampling, and if normality of deviations from the mean is assumed, then the standard deviation may be considered to have its usual distributional connotation. That is, that about 68 percent of all values should fall within ±1 standard deviation, 95 percent within ±2 standard deviations, and so on. Also, sample means can be compared in the usual way using the t statistic.

Where there are substantial correlations between a given water quality variable and flow or temperature, the following reason is suggested. First, there is an apparent seasonal, thermal, and/or hydrodynamic dependency in the water quality variable. This would be anticipated for D.O. (both flow and temperature dependency) and BOD (nonpoint flows, storms, seasonal dependency) for example, but perhaps less clearly so for constituents such as boron and fluoride, which may come in through accretion from ground water. The strength and sign of the dependency are suggested by the correlation coefficient, and the fitted linear relationship by the slope and intercept.

Second, where r (the linear correlation coefficient) is substantial, the standard deviation, as computed and reported in the tables presented later, is not a good statistic for evaluating later year observations since the normality assumption is probably not valid. Clearly, the distribution of sampling dates would determine, to a large extent, the data distribution for any water quality constituent which is strongly dependent upon flow and/or temperature.

Finally, as an elementary statistical approach, the relationships shown in the tables (the slope, m_Q and m_T, and intercept, b_Q and b_T) could be used to recompute standard deviations correcting for any correlation with flow or temperature. The assumption is that the fitted line represents a true relationship between the water quality parameter and flow or temperature and that if the data were normalized using the fitted equation, then these values would be normally distributed. As a first approximation, by computing the standard deviation of the residualized data and using this as the reference standard deviation, outliers (indicating environmental change) can be flagged by similarly residualizing new observations and determining the number of standard deviations away from zero they represent.

A-5.1.1 Reaches North of the International Boundary

Table A-5.1 shows water quality and statistics for sampling stations located north of the International Boundary. These stations are as shown in Figure A.5-1. As indicated in Table A-5.1, data from five sampling stations were available, with four having about 20 observations over the year. Sampling was done quite uniformly over time with one or two dates per month. This gives a good, uniform temporal distribution to the data, except at Fife Lake Outlet (C7), where flows are intermittent.

In general, water at station C1 is of fair quality, although sodium, hardness, and TDS levels are high (means of 123, 361, and 734 mg/ℓ,

Table A-5.1

WATER QUALITY STATISTICS FOR STREAM SAMPLING LOCATIONS IN CANADA

Station and its Location	Sampling Dates (mo/day 1975)	Statistics	pH	Carbonate Alkal mg/l $CaCO_3$	Total Alkal mg/l $CaCO_3$	Conductivity µmhos/cm	Turbidity JTU	Color APHA	TDS mg/l	Sulfate mg/l SO_4	Chloride mg/l	Silica mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Potassium mg/l	Total Hardness mg/l	O-PO_4 mg/l	Total P mg/l	Total Nitrate mg/l	Arsenic mg/l	Li µg/l
Sampling position C1, East Poplar River 5 km S E of Coronach on Highway #36	1/14 1/27 2/20 2/25 3/10 3/24 4/15 4/30 5/12, 5/27 6/10 6/17, 7/3 8/6 8/19 9/3 10/1 10/29 11/18 12/11	n	20		20	20	20	19	20	20	20	20	20	20	20	20	20	20	20	20	20	20
		Min	7 20		84 0	252	500	0 0	206	40 0	2 60	4 20	22 0	9 00	10 0	6 30	95 0	0 0	0 0	0 0	0 0	11 0
		Mean			452	990	10 2	16 3	734	191	5 43	10 6	71 8	43 3	123	14 7	361	0137	0315	187	461	21 1
		Max	8 02		596	1400	115	75 0	899	289	14 0	19 2	102	55 0	195	30 0	453	064	148	940	1 00	58 0
		S			134	309	25 6	21 4	193	63 2	2 74	3 97	19 7	12 7	45 6	7 42	95 4	0149	0358	296	284	11 1
		a_d			232	282	14 0	24 9	-257	60 4	1 86	-9 04	30 8	-18 3	-69 2	8 76	141	0029	0229	195	228	7 51
		b_d			608	1180	753	- 918	907	232	4 18	16 9	92 6	55 6	169	20 6	456	0118	0161	319	635	26 1
		r_d			610	- 268	160	339	392	281	200	669	- 460	423	- 447	- 348	435	0565	168	- 153	235	- 169
		n_d			20	20	20	19	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Sampling position C6, East Poplar River at International boundary	1/14 1/27 2/10 2/25 3/10 3/24 4/15 4/30 5/12, 5/27 6/10 6/17 7/3 7/21 8/6 8/15 9/3, 10/1 10/29 11/18 12/23	n	21	8	21	21	21	20	21	21	21	21	21	21	21	21	21	21	21	21	21	21
		Min	7 40	16 0	106	336	450	0 0	158	65 0	300	2 40	25 0	10 0	21 0	8 6	104	0 0	010	0 0	0 0	10 2
		Mean		35 4	537	1300	10 5	27 8	1010	321	8 25	9 66	51 5	46 2	241	22 0	318	0136	0542	157	543	32 0
		Max	8 92	66 0	731	2070	79 0	80 0	1720	660	20 8	21 0	98 0	63 0	513	64 0	438	253	292	1 28	1 20	64 0
		S		15 6	148	435	17 5	22 7	357	154	5 03	6 27	21 8	12 8	123	15 4	74 5	0542	0977	308	361	16 9
		a_d		149	84 3	296	15 0	57 7	314	235	8 63	16 4	46 8	4 13	146	13 3	137	0824	214	0016	619	24 5
		b_d		107	596	1100	203	13 0	796	160	1 61	21 0	85 1	49 1	141	12 8	413	0732	0535	158	970	15 2
		r_d		413	- 168	201	252	738	259	448	565	774	661	- 0954	350	255	- 542	449	683	0315	505	429
		n_d		8	21	21	21	20	21	21	21	21	21	21	21	21	21	21	21	21	21	21

Table A-5.1 (continued)

Station and its Location	Sampling Dates (mo/day, 1975)	Statistics	pH	Carbonate Alkal mg/ℓ $CaCO_3$	Total Alkal mg/ℓ $CaCO_3$	Conductivity µmhos/cm	Turbidity JTU	Color APHA	TDS mg/ℓ	Sulfate mg/ℓ SO_4	Chloride mg/ℓ	Silica mg/ℓ	Calcium mg/ℓ	Magnesium mg/ℓ	Sodium mg/ℓ	Potassium mg/ℓ	Total Hardness mg/ℓ	O PO_4 mg/ℓ	Total P mg/ℓ	Total Nitrate mg/ℓ	Ammonia mg/ℓ	COD mg/ℓ
Sampling position C2 Girard Creek feeding Coronach Reservoir, 1 6 km west of Coronach	1/14 1/27, 2/10, 2/25, 3/10, 3/24, 4/15 4/30 5/12, 5/27, 6/10 6/17, 7/3 7/21 8/6 8/19 9/3 10/1 10/29 11/18, 12/23	n	21		9	21	21	20	21	21	21	21	21	21	21	21	21	21	21	21	21	21
		Min	7 15		30 0	102	399	0 0	305	87 0	5 00	1 10	20 0	10 0	34 7	8 70	102	0 0	0 0	0 0	0 0	8 50
		Mean			70 2	578	1530	36 5	1230	414	12 9	8 16	53 1	52 9	283	31 9	350	0759	113	170	539	40 1
		Max	9 12		107 0	832	3000	75 0	1920	700	26 5	20 0	103	71 0	563	123	541	250	332	900	1 40	118
		S			27 2	175	589	26 4	421	170	6 71	6 58	27 4	16 0	145	28 2	93 9	0741	106	222	324	26 0
		a_d			167	47 1	685	78 2	589	254	16 7	-15 6	-72 3	-7 37	254	22 2	-211	189	265	- 163	- 153	12 1
		b_d			-85 6	545	1050	-18 7	822	240	1 43	18 9	103	58 0	108	16 6	495	0543	0694	283	644	31 7
		r_d			533	0795	343	863	413	439	733	- 702	- 778	- 136	518	232	- 663	752	738	- 217	- 140	1 36
		n_d			9	21	21	20	21	21	21	21	21	21	21	21	21	21	21	21	21	21
Sampling position C4	1/14 1/27, 2/10, 2/25, 3/10, 3/24, 4/15, 4/30, 5/12, 5/27 6/10 6/17, 7/3 7/21, 8/6 8/19 9/3 10/1 10/29 11/18, 12/23	n	21	13	21	21	21	20	21	21	21	21	21	21	21	21	21	21	21	21	21	21
		Min	6 85	14 0	79 0	200	1 20	5 00	70 0	38 0	1 70	800	11 0	7 00	12 8	3 50	62 0	0 0	040	0 0	0 0	11 0
		Mean		74 9	500	1360	10 8	39 5	1100	398	15 1	4 55	25 4	45 5	293	39 8	251	111	189	141	823	48 6
		Max	9 24	141	832	2220	54 0	70 0	1860	650	29 0	9 80	38 0	69 0	526	130 0	343	294	450	730	4 74	87 0
		S		37 9	265	718	14 8	20 9	659	231	9 02	3 25	7 51	20 8	186	39 1	90 6	093	127	184	970	21 5
		a_d		17 7	101	503	17 0	31 2	424	138	6 32	-3 62	9 88	-1 58	143	-10 5	-30 8	152	183	- 116	- 351	9 16
		b_d		61 3	431	1020	- 790	17 6	815	303	10 7	7 03	32 1	46 6	195	47 0	272	0067	064	221	1 06	42 4
		r_d		132	116	213	348	449	195	181	213	318	- 400	- 023	234	- 082	- 103	498	436	- 192	- 110	129
		n_d		13	21	21	21	20	21	21	21	21	21	21	21	21	21	21	21	21	21	21

Table A-5.1 (continued)

Station and Its Location	Sampling Dates (mo/day, 1975)	Statistics	pH	Carbonate Alkal mg/ℓ $CaCO_3$	Total Alkal mg/ℓ $CaCO_3$	Conductivity µmhos/cm	Turbidity JTU	Color APHA	TDS mg/ℓ	Sulfate mg/ℓ SO_4	Chloride mg/ℓ	Silica mg/ℓ	Calcium mg/ℓ	Magnesium mg/ℓ	Sodium mg/ℓ	Potassium mg/ℓ	Total Hardness mg/ℓ	O PO_4 mg/ℓ	Total P mg/ℓ	Total Nitrate mg/ℓ	Ammonia mg/ℓ	COD mg/ℓ
Sampling position C7, Fife Lake near outlet into Girard Creek	5/27 6/10 6/17, 7/1, 7/3, 8/6, 8/19, 10/1	n	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
		Min	8 90	24 0	577	1370	26 0	20 0	1420	456	8 00	2 80	15 9	56 0	325	17 0	270	100	250	0 0	150	12 1
		Mean		72 0	671	1870	41 1	41 3	1570	582	19 7	5 24	17 6	61 6	427	50 3	299	215	336	0437	400	39 3
		Max	9 00	127	751	2400	83 0	60 0	1700	690	28 0	6 80	21 0	67 0	526	125	328	342	480	190	850	51 0
		S		30 0	66 6	317	18 5	11 6	116	84 9	7 88	1 63	1 88	4 44	63 6	37 8	22 7	0762	0775	063	270	12 0
		m_d		-63 9	-418	-237	67 5	24 0	-571	135	-21 1	-7 07	-18 2	-28 0	44 8	-230	-156	- 555	- 139	- 0296	719	23 9
		b_d		132	1060	2090	-22 4	18 7	2100	454	39 6	11 9	34 7	88 0	385	267	446	738	467	0716	- 277	61 9
		r_d		- 193	- 567	068	329	187	- 445	144	- 242	- 393	- 874	- 571	0636	- 550	- 621	- 658	- 162	- 0424	240	- 181
		n_d		8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

Notes n represents the number of observations used in computing all statistics Min = minimum observed value, Mean = arithmetic mean of all n values, Max = maximum observed value, S = standard deviation defined by $S = \sqrt{\left(\Sigma X^2 - \frac{(\Sigma X)^2}{n}\right) / (n-1)}$, m_d is the slope of fitted line, b_d is the intercept of fitted line, and r_d is the linear correlation coefficient The independent variable is derived as X = COS ((| ((Month - 1) x 30 + day of month - 183) | x π)/366) which should correlate approximately with water temperature respectively). At station C6, below Cookson Reservoir, the same problems exist, with TDS and sodium levels roughly doubled relative to the value at C1. In addition, the water is fairly high in sulfate (mean of 321 mg/ℓ). Like the water at station C1, phosphate, and nitrogen are high (maxima of .253 and 1.28 mg/ℓ, respectively). This may account for eutrophication observed in the East Fork.

Water at station C2 (above Coronach Reservoir on Girard Creek) is commonly very turbid and high in dissolved solids, falling into the "brackish" category (1000 - 10,000 mg/ℓ). It is quite high in sulfate, the mean of 21 measurements in 1975 being 414 mg/ℓ, and is high in sodium, potassium, phosphorus, nitrogen, and total hardness (means of 283., 31.9, .113, .709, and 350 mg/ℓ, respectively). COD values are also high, with up to 118 ppm having been observed.

After passing through Coronach Reservoir, turbidity is greatly reduced and silica, calcium, and hardness are also reduced. Ammonia and total phosphorus appear to increase, while nitrate decreases, suggesting chemical reduction in the reservoir.

Water samples collected at Fife Lake outlet exhibit very substantial nutrient enrichment, with total phosphorus concentrations ranging from 0.25 to 0.48 ppm. Nitrogen is also high (maximum N due to nitrate and ammonia = 1.05 mg/ℓ). The water is consistently brackish, being very high in sulfate, sodium, and potassium (means of 582., 427., and 50.3 mg/ℓ, respectively), probably due to concentration by evaporation.

At all stations, except C2, the waters are high in alkalinity (up to 832 mg/ℓ at C4), and tend to be somewhat alkaline, with pH values commonly ranging up to 9.0 (except at C1 where the highest value was about 8.0).

As discussed earlier, in evaluating data from later years, the standard deviation can be used to flag altered conditions (unlikely data values). However, if the data are temperature dependent, then noramlity or non-normality of the data depends upon the temporal distribution of sampling, and the sampling distribution cannot be ignored or considered random. Further, assessing whether or not a value is unusual must take into account temperature, or entirely misleading results will be obtained. The values of r_d in the table provide guidance as to where temperature dependence is indicated and wnere it is not. As noted at the foot of the table, the date was used as a surrogate for temperature since the latter was not available. This means that r will tend to underestimate temperature dependency.

Critical values for r at the 95 percent confidence level are as follows:

n	$\pm r_{critical}$
21	.431
20	.441
19	.453
9	.650
8	.686

Using these values, one can decide whether to use the standard deviation or to consider temperature as a concomitant variable. This assumes, of course, that the α = .05 level is acceptable. Actually a higher value would represent a more conservative approach. As suggested in Table A-5.1, over distance, none of the water quality constituents is consistently correlated with day of the year. In general there appears to be no clear pattern in the correlations despite the relatively large number of observations available. This may well be due to the use of the date as a surrogate for temperature.

A-5.1.2 West Fork, South of the International Boundary

As shown in Table A-5.2, there are little data available for the West Fork of the Poplar River. In most cases, only three observations were made over a short span of time, making generalizations tenuous at best. In addition, since the data represent primarily May, July, August, and September conditions, data for later years can only be compared meaningfully if they, too, represent these months. Table A-5.2 includes the regression statistics for the linear correlation of each water quality constituent with temperature (T) and flow (Q). The results of West Fork data are presented here primarily for completeness and without discussion since little reliance can be placed on correlations based on only three or four observations.

A-5.1.3 Middle Fork, South of the International Boundary

Table A-5.3 shows summary water quality statistics for the Middle Fork of the Poplar River. Although data were available for more water quality constituents here than for the West Fork and for four rather than three sampling stations, there were similarly few observations over time at any station. Therefore, Table A-5.3 includes correlation statistics for water quality constituents versus temperature and flow for comparison purposes only. These will not be discussed here. Also

Table A-5.2

WATER QUALITY STATISTICS FOR THE WEST FORK OF THE POPLAR RIVER

Station	Location	Sampling Dates (mo/day, 1975)	Statistics	D O ppm	pH	Specific Conductivity µmhos	TSS ppm	TDS ppm	Na ppm	Al ppb	Fe ppb	Ca ppm	Mg ppm	B ppm	K ppm
WF-4	West Fork of the Poplar River about six miles southwest of Peerless, Montana	7/29/ 7/31, 8/05	n	3		3	3	3	3		3	3	3	3	
			Min	10 3		940	5 00	784	248		250	8 80	16 0	500	
			Mean	11 0		1084	7 66	800	269		250	9 80	17 0	1 02	
			Max	12 4		1275	10 0	830	289		250	11 6	19 0	1 35	
			S	1 18		172 2	2 52	26	20 5		0 0	1 73	1 73	453	
			a_Q / a_T	- / 342		- / -11 6	- / 583	- / 7 50	- / 083		- / 0 0	- / - 250	- / 500	- / 083	
			b_Q / b_T	- / 2 83		- / 1362	- / 6 33	- / 620	- / 267		- / 250	- / 15 8	- / 5 00	- / - 983	
			r_Q / r_T	- / 999		- / - 233	- / 803	- / 999	- / 014		- / 0 0	- / 50	- / 1 00	- / 636	
			n_Q / n_T	- / 3		- / 3	- / 3	- / 3	- / 3		- / 3	- / 3	- / 3	- / 3	
61802	Latitude 48° 37' 27"N Longitude 105° 39' 18"W SE¼ SE¼ sec 33, T 33N R 46E Daniels County	8/14, 9/17, 11/25	n					3	3			3	3	3	3
			Min					635	170			30 0	24 0	530	5 70
			Mean					671	187			32 3	24 7	550	5 87
			Max					708	200			36 0	25 0	560	6 00
			S					36 6	15 3			3 21	577	017	416
			a_Q / a_T					8 39 / -4 00	3 78 / 1 50			780 / - 373	- 135 / 066	- 004 / 002	- 105 / 048
			b_Q / b_T					632 / 710	171 / 201			29 0 / 36 0	25 2 / 24 0	567 / 530	6 10 / 5 18
			r_Q / r_T					998 / - 942	960 / - 843			963 / -1 0	- 909 / 989	- 909 / 989	- 982 / 995
			n_Q / n_T					3 / 3	3 / 3			3 / 3	3 / 3	3 / 3	3 / 3
WF-3	West Fork of the Poplar River at Highway 13 bridge	5/12, 5/18, 7/29, 7/31, 8/05	n	4		6	4	4	5	3	3	3	3	3	
			Min	6 6		805	8 00	406	139	300	250	11 8	16 0	1 00	
			Mean	8 05		1169	19 26	721	220	367	500	12 5	17 0	1 08	
			Max	8 60		1650	30 0	770	279	400	700	13 8	19 0	1 15	
			S						59 2	57 7	229	1 15	1 73	076	
			a_Q / a_T	- / 012		- / 13 1	- / 1 66	- / 9 02	- / 6 13	- / 2 58	- / 22 4	- / - 144	- / - 216	- / 007	
			b_Q / b_T	- / 7 81		- / 898	- / -14 6	- / 526	- / 93 6	- / 306	- / -30 7	- / 15 9	- / 22 1	906	
			r_Q / r_T	- / 092		- / 239	- / 812	- / 726	- / 594	- / 254	- / 556	- / - 711	- / - 711	- / 556	
			n_Q / n_T	- / 4		- / 6	- / 4	- / 4	- / 5	- / 3	- / 3	- / 3	- / 3	- / 2	

Table A-5.2 (continued)

Station	Statistics	HCO₃ ppm	SO₄ ppm	Cl ppm	F ppm	Ca, Mg Hardness ppm
WF-4	n					
	Min					
	Mean					
	Max					
	S					
	m_Q m_T					
	b_Q b_T					
	r_Q r_T					
	n_Q					
61802	n	3	3	3	3	3
	Min	544.	120.	5 10	500	180.
	Mean	580.	120	5.37	.500	183.
	Max	622	120.	5 90	.500	190.
	S	39.4	0.0	462	0 0	5.77
	m_Q m_T	10.1 | -4 46	0.0 | 0 0	.108 | - 053	0 0 | 0 0	1.35 | - 663
		538 | 624.	120 | 120	4 92 | 5 89	500 | 500	178. | 190
		999 | -.973	0.0 | 0.0	.909 | - 989	0 0 | 0.0	909 | - 989
		3 | 3	3 | 3	3 | 3	3 | 3	3 | 3
WF-1						

Note Statistics presented are the number of total observations ("n"), the minimum observed value ("Min"), the arithmetic mean ("Mean"), the maximum observed value ("Max"), the standard deviation ("S," see Table 1), the slope ("m) of the fitted line for temperature ("T" in degrees C) and flow ("Q," in cfs), the ordinate intercept of the line ("b"), the correlation coefficient ("r") and the number of observations used in the regression ("n_T" and "n_Q")

Table A-5.3

WATER QUALITY SUMMARY STATISTICS FOR THE MIDDLE FORK, POPLAR RIVER

Station	Location	Sampling Dates (mo/day, 1975)	Statistics	D O ppm	pH	Specific Conductivity µmhos	TSS ppm	TDS ppm	Na ppm	Al ppb	Fe ppb	Cu ppb	Ca ppb	Mg ppb	Zn ppb	B ppm
06176000	Latitude 48° 59' 30" N Longitude 105° 41' 40" W SE¼ sec 6, T 37N, R 46E, Daniels County	7/7, 8/02, 9/07	n	3		3		3	3		3		3	3		3
			Min	4 60		788		611	120		30 0		30 0	26 0		920
			Mean	8 70		1273		815	217		60 0		36 3	38 7		1 34
			Max	11 4		1670		1070	300		90 0		44 0	48 0		1 70
			s	3 42		447		283	90 7		36 1		7 09	11 4		393
			m_Q / m_T	- 094 / - 710		-12 7 / -69 9		-7 98 / -67 3	-2 53 / -18 8		732 / 8 10		- 167 / -1 58	- 329 / -1 19		- 011 / - 081
			b_Q / b_T	10 1 / 23 4		1523 / 1206		972 / 2048	287 / 617		44 4 / -114		38 6 / 70 3	45 2 / 64 2		1 56 / 3 07
			r_Q / r_T	- 917 / - 922		- 942 / - 893		- 936 / - 901	- 927 / - 811		.729 / 958		- 781 / - 991	- 961 / - 465		- 929 / - 909
			n_Q / n_T	3 / 3		3 / 3		3 / 3	3 / 3		3 / 3		3 / 3	3 / 3		3 / 3
MF-3	Middle Fork at the second county road crossing approximately five miles upstream from MF 2	7/29, 7/31, 8/05	n	3		3	3	3	3	3	3	3	3	3	3	3
			Min	6 00		1375	41 0	872	248	1100	1150	4 00	29 4	32 0	10 0	1 10
			Mean	6 77		1400	57 3	893	265	1667	1750	5 33	31 7	41 7	10 0	1 47
			Max	7 40		1450	76 0	916	279	2100	2600	6 00	33 4	48 0	10 0	1 90
			s	709		43 3	17 6	22 1	15 8	513	757	1 15	2 08	8 50	0 0	404
			m_Q / m_T	- / 002		- / 13 3	- / -4 9	- / -1 77	- / 4 05	- / -158	- / -166.	- / 129	- / - 597	- / 1 37	- / 0 0	- / 123
			b_Q / b_T	- / 6 73		- / 1103	- / 166	- / 932	- / 374	- / 5197	- / 5910	- / 2 45	- / 45 1	- / 11 0	- / 10 0	- / 1 27
			r_Q / r_T	- / 607		- / 988	- / - 884	- / - 258	- / - 986	- / - 990	- / - 391	- / 359	- / - 922	- / 518	- / 0 0	- / 975
			n_Q / n_T	- / 3		- / 3	- / 3	- / 3	- / 3	- / 3	- / 3	- / 3	- / 3	- / 3	- / 3	- / 3
MF 2	Middle Fork at the first road crossing upstream from the East Fork confluence	5/12, 5/18, 7/29, 7/31, 8/05	n	5		5	4	4	5	3	3		3	3		3
			Min	5 40		880	18 0	630	44 0	800	800		23 6	32 0		1 60
			Mean	7 04		1366	27 8	940	209 2	933	900		25 3	39 3		1 73
			Max	8 50		1700	36 0	1050	320	1100	1100		27 6	44 5		2 00
			s	1 21		356	8 26	207	124	153	173		2 08	6 63		231
			m_Q / m_T	- / - 243		- / 78 8	- / 1 94	- / 60 5	- / 24 7	- / -66 7	- / -50 0		- / - 833	- / 1 08		/ 133
			b_Q / b_T	- / 31 9		- / -203	- / -13 6	- / -134	- / -282	- / 2467	- / 2050		- / 44 4	- / 14 4		- / -1 33
			r_Q / r_T	- / - 896		- / 985	- / 890	- / 923	- / 889	- / - 756	- / - 500		- / - 693	- / 288		- / 1 00
			n_Q / n_T	- / 5		- / 6	- / 4	- / 4	- / 5	- / 3	- / 3		- / 3	- / 3		/ 3
P	P is Tetra Tech designation for Montana State Health Dept station at Latitude 48° 7' 4" N Longitude 105° 29' 58" W	4/19, 8/14, 9/17, 11/25	n			3		4	4		3		4	4		3
			Min			672		537	96 0		20 0		25 0	13 2		1 30
			Mean			1227		890	232		33 3		32 5	37 3		1 53
			Max			1570		1040	300		50 0		50 0	50 0		1 70
			s			526		237	96 2		15 3		11 8	16 6		208
			m_Q / m_T			-25 1 / 54 3		-13 5 / 16 8	-5 32 / 8 17		-5 36 / 1 34		056 / - 840	- 896 / 712		- 071 / 022
			b_Q / b_T			1626 / 629 5		1078 / 752	305 / 164		61 2 / 18 5		53 3 / 39 4	49 7 / 31 4		1 90 / 1 30
			r_Q / r_T			-1 00 / 917		-1 0 / 679	- 970 / 816		- 982 / 849		- 083 / - 684	- 948 / 412		- 961 / 996
			n_Q / n_T			3 / 3		4 / 4	4 / 4		3 / 3		4 / 4	4 / 4		3 / 3

Table A-5.3 (continued)

Station	Statistics	K ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	F ppm	Ca Mg Hardness ($CaCO_3$) ppm	TON ppm	Total NH_4 N ppm	Total Kjeldahl N ppm	Total $NO_2 + NO_3$ ppm	Total N ppm	Total P ppm
Del7aUUU	n	3	3	3	3	3	3	3	3	3	3	3	3
	Min	8 80	376	120	4 20	200	180	410	0 0	430	0 0	490	030
	Mean	9 93	526	207	7 60	433	250	807	01	817	023	840	067
	Max	11 0	607	300	11 0	600	290	1 10	02	1 10	060	1 10	110
	S	1 10	130	90 2	3 4	.208	60 8	.356	01	347	032	315	040
	m_Q	002	-3 90	-2 28	- 089	- 006	-1 82	008	- 0003	007	- 0006	007	001
	m_T	190	-18 8	19 7	- 732	- 039	-8 48	080	- 002	078	- 722	071	008
	b_Q	9 89	602	252	9 36	554	206	654	015	669	035	705	044
	b_T	5 85	930	631	23 3	1 28	432	- 918	056	- 860	178	- 681	- 110
	r_Q	064	- 998	- 839	- 872	- 974	- 996	721	- 872	716	- 638	724	933
	r_T	766	- 645	- 973	- 956	- 838	- 620	999	- 956	999	- 997	999	905
	n_Q	3	3	3	3	3	3	3	3	3	3	3	3
	n_T	3	3	3	3	3	3	3	3	3	3	3	3
MF 3	n												
	Min												
	Mean												
	Max												
	S												
	m_Q												
	m_T												
	b_Q												
	b_T												
	r_Q												
	r_T												
	n_Q												
	n_T												
MF 2	n												
	Min												
	Mean												
	Max												
	S												
	m_Q												
	m_T												
	b_Q												
	b_T												
	r_Q												
	r_T												
	n_Q												
	n_T												
P	n	4	4	4	4	4	3						
	Min	8 60	306	78 0	5 00	250	230						
	Mean	9 10	604	230	9 75	488	270						
	Max	9 70	728	300	12 0	600	330						
	S	469	199	102	3 20	365	52 9						
	m_Q	0004	-11 3	-5 77	- 182	- 009	14 3						
	m_T	028	12 1	7 11	214	013	-5 16						
	b_Q	9 09	760	310	12 3	616	196						
	b_T	8 87	503	171	7 98	377	327						
	r_Q	016	- 993	- 989	- 997	- 982	756						
	r_T	577	585	667	642	780	- 941						
	n_Q	4	4	4	4	4	3						
	n_T	4	4	4	4	4	3						

Note Statistics presented are the number of total observations ("n"), the minimum observed value ("Min"), the arithmetic mean ("Mean") the maximum observed value ("Max"), the standard deviation ("S," see Table 1) the slope ("m) of the fitted line for temperature ("T" in degrees C) and flow ("Q," in cfs), the ordinate intercept of the line ("b"), the correlation coefficient ("r") and the number of observations used in the regression ("n_T" and "n_Q")

like the data for the West Fork, data were collected primarily in the late spring and summer months, and the temporal distribution of data is therefore inadequate to describe a one-year baseline condition. Comparisons of later-year data with the baseline year can only be meaningful if the data represent conditions similar to those prevailing during these months.

Dissolved oxygen levels exhibit substantial variability in this branch of the Poplar River, and some relatively low values have occurred (minima are 4.6 and 5.4 mg/ℓ for stations USGS 06178000 and MF-2, respectively). Since there are relatively few observations available, and the variability of dissolved oxygen is so high (S = 3.42 mg/ℓ at USGS station 06178000) it is likely that dissolved oxygen drops well below minimum acceptable levels (3-4 mg/ℓ) for fish.

Nutrient data are available only for the USGS station (06178000). From the few values reported, it appears that the waters tend to be somewhat nutrient-enriched with the N to P ratio being about 10 to 1 (determined from raw data), and total P concentrations as high as 0.11 ppm. As noted above with regard to dissolved oxygen, total P and total N variability is high. Since there were few observations, concentrations of nutrients may, at times, be substantially higher than the available data suggest.

A-5.1.4 East Fork South of the International Boundary

Table A-5.4 shows summary water quality statistics for the East Fork of the Poplar River. In contrast to available data for the Middle and West Forks, there was one station (at the International Boundary) with 11 observations dates and a good temporal distribution (monthly, from March through December). Another sampling station, located just above the confluence with the Middle Fork, had five observations (Monthly from July to November) for several water quality constituents, providing fairly good additional data.

Available dissolved oxygen values suggest that concentrations may drop to levels unacceptable for fish under some conditions. At the USGS station, the minimum observed value is 4.4 mg/ℓ. Assuming the data are approximately normally distributed, and with a standard deviation of 2.86 mg/ℓ, it might be expected that dissolved oxygen levels will drop below 4 about seven to eight percent of the time. Clearly, however, this is only an approximation because dissolved oxygen levels can be normally distributed only over a narrow range of values near the mean, provided the mean is near the midpoint of the range of possible dissolved oxygen values. This is true because dissolved oxygen is bounded above by saturation and below at 0 mg/ℓ.

The East Fork had mean total dissolved solids concentrations in the 1050-1750 ppm range in 1975. TDS appears dependent upon season with higher values in the fall and winter. At station "G", which is just

Table A-5.4

WATER QUALITY SUMMARY STATISTICS FOR THE EAST FORK POPLAR RIVER

Station	Location	Sampling Dates (mo/day, 1975)	Statistics	D O ppm	pH	Specific Conductivity μmhos	TSS ppm	TDS ppm	Na ppm	Fe ppb	Cu ppb	Ca ppm	Mg ppm	Zn ppb	B ppm	K ppm
EF 6	East Fork, immediately downstream from the U S Canada border	5/12, 5/18, 7/29, 7/31, 8/5	n	5	5	5	4	4	4	3	3	3	3	3	3	
			Min	4 5	6 50	675	10 0	430	52 0	400	6 00	30 4	41 5	5 00	2 50	
			Mean	7 22		1685	14 8	1310	370	467	6 00	34 1	58 5	10 0	3 15	
			Max	10 5	9 00	2410	23 0	1650	486	550	6 00	38 4	67 0	15 0	3 70	
			S	2 65		832	5 74	590	212	76 4	0 0	4 04	14 7	5 00	606	
			m_Q / m_T	- / - 608		- / 216	- / 224	- / 145	- / 51 5	- / -12 5	- / 0 0	- / -.750	- / 6 38	- / 1 26	- / - 113	
			b_Q / b_T	- / 19 1		- / -2544	- / 10 2	- / -1637	- / -680	- / 742	- / 6 0	- / 50 6	- / -81 8	- / -17 5	- / 5 62	
			r_Q / r_T	- / - 825		- / 932	- / 142	- / 892	- / 884	- / - 327	- / 0 0	- / - 371	- / 866	- / 500	- / - 371	
			n_Q / n_T	- / 5		- / 5	- / 4	- / 4	- / 4	- / 3	- / 3	- / 3	- / 3	- / 3	- / 3	
06178500	Latitude 49° 0 0" N Longitude 105° 24 30"W SW¼ sec 3, T 1, R 26W	3/4, 4/18, 5/22, 6/13, 7/17 8/14, 9/16 10/2 10/6, 11/26, 12/19	n	10	10	11		10	11	10		10	10		10	10
			Min	4 40	7 50	1180		689	120	30 0		28 0	30 0		1 60	7 50
			Mean	8 38		1609		1058	266	98 0		55 5	50 3		1 95	16 1
			Max	12 0	9 10	2300		1480	390	240 0		91 0	63 0		3 10	34 0
			S	2 86		333		250	88 1	64 1		21 2	10 1		674	8 81
			m_Q / m_T	0 0 / 075		- 441 / 23 0		-1 69 / 14 0	- 162 / 5 65	2 02 / 1 04		- 494 / -2 11	- 168 / 503		- 005 / 038	157 / 845
			b_Q / b_T	8 38 / 7 59		1628 / 1366		1085 / 909	257 / 206	65 7 / 86 9		63 4 / 77 9	63 0 / 45 0		2 02 / 1 55	13 5 / 7 10
			r_Q / r_T	0 0 / 231		- 031 / 600		- 163 / 513	- 047 / 559	760 / 149		- 561 / - 911	- 404 / 459		- 167 / 520	430 / 680
			n_Q / n_T	10 / 10		10 / 11		10 / 10	10 / 11	10 / 10		10 / 10	10 / 10		10 / 10	10 / 10
6	G is Tetra Tech designation for Montana State Health Department sampling location Latitude 48° 51' 6" N Longitude 105° 25' 13"W TRS 36N 48E 27AB	7/9 8/14, 9/17, 10/2, 10/7, 11/25	n			3		5	4			5	5		5	5
			Min			1800		1100	260			20 0	57 0		1 50	15 0
			Mean			1960		1367	335			32 5	61 0		2 00	23 8
			Max			2250		1745	430			44 0	66 0		3 20	33 0
			S			252		268	73 3			8 80	3 67		689	7 85
			m_Q / m_T			- / 62 0		7 71 / 25 8	24 2 / 8 35			- 067 / - 567	- 075 / - 180		- 007 / 003	138 / 683
			b_Q / b_T			- / 1058		1240 / 1011	248 / 245			33 6 / 40 3	62 2 / 63 5		2 11 / 1 96	21 5 / 14 4
			r_Q / r_T			- / 741		830 / 918	895 / 876			- 219 / - 616	- 590 / - 469		- 280 / 044	504 / 832
			n_Q / n_Q			- / 3		5 / 5	4 / 4			5 / 5	5 / 5		5 / 5	5 / 5

Table A-5.4 (continued)

Station	Statistics	HCO_3 ppm	SO_4 ppm	Cl ppm	F ppm	Ca Mg Hardness ($CaCO_3$) ppm	Alkalinity mg/l ($CaCO_3$)	TON ppm	Total NH_4 N ppm	Total Kjeldahl N ppm	Total NO_2 + NO_3 ppm	Total N ppm	Total P ppm
EF 6	n												
	Min												
	Mean												
	Max												
	S												
	m_Q / m_T												
	b_Q / b_T												
	r_Q / r_T												
	n_Q / n_T												
06178500	n	10	10	10	10	10	7	10	11	10	11	10	11
	Min	394	170	4 10	100	220	326	0 30	0 0	1 00	0 0	1 10	020
	Mean	670	306	8 21	290	345	550	1 18	236	1 43	035	1 46	090
	Max	929	500	16 0	500	450	736	1 90	080	1 90	160	1 90	400
	S	155	95 9	3 74	110	63 3	138	522	357	337	054	313	110
	m_Q / m_T	-4 03 / -5 04	774 / 8 60	048 / 350	- 003 / - 004	-1 89 / -3 06	-2 26 / 8 53	005 / 042	- 006 / - 034	- 001 / 009	- 001 / - 004	- 002 / 005	001 / 009
	b_Q / b_T	735 / 723	294 / 216	7 45 / 4 50	339 / 330	376 / 377	609 / 446	1 10 / 726	355 / 593	1 45 / 1 34	049 / .076	1 49 / 1 41	072 / - 010
	r_Q / r_T	- 628 / - 299	195 / 813	307 / 859	- 667 / - 318	- 719 / - 444	- 432 / 677	232 / 746	- 392 / - 821	- 069 / 241	- 320 / - 621	- 121 / 143	305 / 762
	n_Q / n_T	10 / 10	10 / 10	10 / 10	10 / 10	10 / 10	7 / 7	10 / 10	10 / 11	10 / 10	10 / 11	10 / 10	10 / 11
6	n	5		6	5	6					6		
	Min	739		3 00	260	290					0 0		
	Mean	789		9 92	292	338					016		
	Max	933		16 0	300	370					050		
	S	81 6		4 77	018	35 9					021		
	m_Q / m_T	- 684 / 1 32		- 126 / - 161	- 001 / - 001	-1 72 / -2 44					0001 / 001		
	b_Q / b_T	800 / 771		12 0 / 12 1	302 / 311	344 / 364					014 / 0 0		
	r_Q / r_T	- 242 / 155		- 763 / - 323	- 997 / - 718	- 130 / - 522					176 / 631		
	n_Q / n_T	5 / 5		6 / 6	5 / 6	4 / 4					6 / 6		

Note. Statistics presented are the number of total observations ("n"), the minimum observed value ("Min"), the arithmetic mean ("Mean"), the maximum observed value ("Max"), the standard deviation ("S," see Table 1), the slope ("m") of the fitted line for temperature ("T" in degrees C) and flow ("Q," in cfs), the ordinate intercept of the line ("b"), the correlation coefficient ("r") and the number of observations used in the regression ("n_T" and "n_Q")

above the confluence with the Middle Fork, the dependence is very strong (r_T^2 = .84) and there is also a possible dependence upon flow (r^2 = .69), significant at the 90 percent confidence level). If dependence is conceded, then S as shown in Table A-5.4 should not be used to compare data from later years.

Sodium levels in the East Fork are fairly high as shown in Table A-5.4 (mean of up to 486 mg/ℓ), appear to be relatively uniform spatially, and are possibly dependent upon both season and flow. Boron levels are also high, sometimes exceeding 3 ppm. Boron levels appear to be independent of season and flow, and based upon computed S values, should generally (95 percent of all observations) fall into the range 1.94 <B <4.4, .602 <B <3.3, and .66 <B <3.38 at stations EF-6, USGS 06178500, and G, respectively.

A-5.1.5 Poplar River Main Stem

Data were available for statistical summarization at four locations on the main stem, and Table A-5.5 presents the statistics. Based upon the limited number of observations available, it appears that dissolved oxygen is generally above any critical level for fish, although values (mg/ℓ) as low as 5.1 (at PR-1) and 5.7 (at PR-2) have been observed. Oxygen concentrations may, at times, drop below the 4 mg/ℓ level based on S. This is especially true at stations PR-1 and PR-2.

Water in the main stem is borderline brackish, and occasionally TDS concentrations approach 1500 ppm at PR-4. Suspended solids concentrations are generally low, as they are in the other forks, but have been observed as high as 1280 ppm at USGS station 06181000. All other TSS maxima are 62 mg/ℓ or lower. Suspended solids appears to be correlated with both temperature and flow, suggesting seasonality and a real deficiency in the data since, with the exception of one observation (USGS station 0618100), all data were collected during warm periods.

Sodium concentrations are high (means of about 300 mg/ℓ), and like TDS, are probably seasonally dependent but relatively uniform spatially.

A-5.1 GROUND WATER QUALITY

A-5.2.1 General Quality

Average ground water quality by formation is shown for the U.S. and Canadian parts of the basin in Tables A-5.6 and A-5.7, respectively. Summary tables of the well data are included (Tables A-5.8 through A-5.10. Figure A-5.1 shows a detailed ground water contour map with the chemical composition for the upper part of the basin.

Table A-5.5

WATER QUALITY SUMMARY STATISTICS FOR THE POPLAR RIVER MAINSTEM

Station	Location	Sampling Dates (mo/day, 1975)	Statistics	D.O. ppm	pH	Specific Conductivity µmhos	TSS ppm	TDS ppm	Na ppm	As ppb	Al ppb	Fe ppb	Cu ppb	Ca ppm	Mg ppm	Zn ppb
PR 4	Poplar River at the Highway 13 bridge five miles downstream from Scobey	5/12, 5/18, 7/29, 7/31, 8/05	n	4		5	4	4	5		3	3	3	3	3	3
			Min	6.40		925	18.0	556	54.0		700	750	4.00	17.6	28.5	0.0
			Mean	7.75		1634	26.5	1224	290		833	800	5.33	23.9	46.7	5.00
			Max	9.00		2200	37.0	1460	444		1000	900	6.00	28.4	60.5	10.0
			S	1.09		642	8.66	446	194		153	86.6	1.15	5.60	16.4	5.00
			a_Q / a_T	- / -.109		- / 95.0	- / 1.49	- / 57.1	- / 27.3		- / 6.58	- / -1.97	- / -.211	- / -.079	- / -3.24	- / .592
			b_Q / b_T	- / 9.97		- / -256	- / -4.57	- / 31.7	- / -253		- / 684	- / 845	- / 10.1	- / 43.8	- / 120	- / -8.42
			r_Q / r_T	- / -.686		- / .769	- / .937	- / .698	- / .732		- / .217	- / -.115	- / -.918	- / -.789	- / -.993	- / .596
			n_Q / n_T	- / 4		- / 5	- / 4	- / 4	- / 5		- / 3	- / 3	- / 3	- / 3	- / 3	- / 3
PR 2	Poplar River at the first crossing upstream from the Long Creek confluence	5/12, 5/18, 7/29, 7/31, 8/05	n	5		5	4	4	5		3	3	3	3	3	
			Min	5.7		1020	12.0	684	63.0		700	850	4.00	23.6	41.5	
			Mean	7.34		1459	35.0	1056	243		1500	1050	6.00	24.3	43.7	
			Max	8.90		1800	62.0	1200	351		2500	1400	8.00	24.6	48.0	
			S	1.34		380	21.3	249	131		917	304	2.00	.577	3.75	
			a_Q / a_T	- / -.145		- / 70.0	- / 3.11	- / 42.4	- / 22.1		- / -105	- / 0.0	- / -.324	- / .135	- / -.878	
			b_Q / b_T	- / 10.2		- / 87.8	- / -28.3	- / 193	- / -191		- / 3854	- / 1050	- / 13.2	- / 21.2	- / 63.3	
			r_Q / r_T	- / -.494		- / .837	- / .707	- / .827	- / .771		- / -.404	- / 0.0	- / -.569	- / .822	- / -.822	
			n_Q / n_T	- / 5		- / 5	- / 4	- / 4	- / 5		- / 3	- / 3	- / 3	- / 3	- / 3	
61610	Latitude 48° 10' 15" N Longitude 105° 10' 42" W NE¼ NE¼ Sec 19, T 2UN, R 51E Roosevelt County	8/13, 9/15, 12/23,	n	3		3	3		3	3		3		3	3	3
			Min	8.40		1650	31.0		320	1.00		10.0		23.0	37.0	0.0
			Mean	8.93		1823	461		340	2.67		43.3		34.3	41.0	3.33
			Max	9.20		2150	1280		370	5.00		60.0		53.0	45.0	10.0
			S	.462		283	709		26.5	2.08		28.9		16.3	4.00	5.77
			a_Q / a_T	-.017 / -.022		-18.8 / -23.8	-46.9 / -59.3		-1.75 / 2.22	102 / 132		1.91 / 2.42		-1.08 / -1.37	-.221 / -.276	214 / 278
			b_Q / b_T	9.40 / 9.24		2337 / 2149	1744 / 1272		388 / 370	-.131 / 867		-9.00 / 10.2		63.9 / 53.1	47.0 / 44.8	-2.50 / -.461
			r_Q / r_T	-.556 / -.571		-1.00 / -1.00	-.995 / -.994		-.992 / -.994	740 / 752		1.00 / .996		-.998 / -.999	-.831 / -.821	556 / 571
			n_Q / n_T	3 / 3		3 / 3	3 / 3		3 / 3	3 / 3		3 / 3		3 / 3	3 / 3	3 / 3
PR 1	Poplar River at Poplar, Montana	5/12, 5/18, 7/29, 7/31, 8/05	n	3		4	3	3	3		3	3	3	3	3	3
			Min	5.10		1100	18.0	986	310		600	750	4.00	25.6	35.0	0.0
			Mean	7.20		1469	25.3	1032	324		1033	1100	5.33	27.2	39.3	8.33
			Max	8.50		1600	34.0	1080	331		1600	1450	6.00	28.4	44.5	15.0
			S	1.84		246	8.08	47.0	12.1		513	350	1.15	1.44	4.80	7.64
			a_Q / a_T	- / .028		- / 38.6	- / -1.00	- / -4.71	- / .429		- / -118	- / -85.7	- / -.265	- / -.282	- / -1.14	- / -1.89
			b_Q / b_T	- / 6.56		- / 619	- / 49.0	- / 1144	- / 314		- / 3835	- / 3129	- / 11.6	- / 33.9	- / 66.3	- / 53.0
			r_Q / r_T	- / .004		- / .736	- / -.500	- / -.405	- / .143		- / -.932	- / -.990	- / -.929	- / -.789	- / -.957	- / -.999
			n_Q / n_T	- / 3		- / 4	- / 3	- / 3	- / 3		- / 3	- / 3	- / 3	- / 3	- / 3	- / 3

Table A-5.5 (continued)

Station	Statistics	B ppb	K ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	Ca Mg Hardness ($CaCO_3$) ppm	Total $NO_2 + NO_3$ ppm	Total P ppm
PR-4	n	3							
	Min	2 50							
	Mean	2 97							
	Max	3 40							
	S	451							
	m_Q / m_T	- / 088							
	b_Q / b_T	- / 968							
	r_Q / r_T	- / 984							
	n_Q / n_T	- / 3							
PR 2	n	3							
	Min	1 70							
	Mean	2 03							
	Max	2 30							
	S	306							
	m_Q / m_T	- / 035							
	b_Q / b_T	- / 1 25							
	r_Q / r_T	- / 404							
	n_Q / n_T	- / 3							
61810	n	3	3	3	3	3	3	3	3
	Min	1 00	7 90	616	290	46 0	220	010	0 0
	Mean	1 27	11 3	674	293	86 0	257	037	027
	Max	1 60	14 0	772	300	120	320	080	050
	S	306	3 11	85 1	5 77	37 4	55 1	038	025
	m_Q / m_T	016 / 021	200 / 254	-5 57 / 7 03	214 / 278	-2 05 / -2 63	-3 62 / -4 57	002 / 002	001 / .002
	b_Q / b_T	824 / 983	5 84 / 7 83	827 / 770	287 / 290	142 / 122	355 / 319	- 009 / 007	- 014 / 001
	r_Q / r_T	798 / 808	966 / 971	- 984 / - 981	556 / 571	- 827 / - 837	- 988 / - 985	661 / 675	889 / 881
	n_Q / n_T	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3
PR-1	n	3							
	Min	1 40							
	Mean	1 60							
	Max	1 80							
	S	20							
	m_Q / m_T	/ 049							
	b_Q / b_T	/ 441							
	r_Q / r_T	/ 990							
	n_Q / n_T	/ 3							

Note Statistics presented are the number of total observations ("n"), the minimum observed value ("Min"), the arithmetic mean ("Mean"), the maximum observed value ("Max"), the standard deviation ("S," see Table I), the slope ("m) of the fitted line for temperature ("T" in degrees C) and flow ("Q," in cfs), the ordinate intercept of the line ("b"), the correlation coefficient ("r") and the number of observations used in the regression ("n_T" and "n_Q")

Table A-5.6

AVERAGE GROUNDWATER QUALITY ANALYSES IN U.S. PART OF BASIN

Parameter	Quaternary Alluvium	Glacial Outwash	Flaxville Formation*	Fort Union Formation	Fox Hills-Hell Creek Formation
Lab, pH	7.2-7.6	6.7-7.5	7.0	6.8-8.6	8.4-8.7
Field conductivity	1662	1064	710	1609	1726
TDS, mg/ℓ	1251	664	400	1040	1144
Alkalinity, mg/ℓ	556	370	410	550	728
Hardness, mg/ℓ	386	514	340	390	12
Color	8	6	27	-	-
NO_3-N + NO_2-N, mg/ℓ	5.2	8.9	2.5	-	0.02
NH_3-N, mg/ℓ	0.21	0.05	0.05	-	-
Total PO_4-P, mg/ℓ	0.03	0.03	0.0	-	-
SO_4, mg/ℓ	350	224	17	320	55
Cl, mg/ℓ	21.4	14	7.2	9.8	120
F, mg/ℓ	0.4	0.3	1.0	0.6	2.5
Ca, mg/ℓ	52	103	62	78	3.4
Mg, mg/ℓ	54	62	45	48	0.9
Na, mg/ℓ	273	39	21	188	430
K, mg/ℓ	8	4	3	5	1
Fe, μg/ℓ	598	90	170	2719	400
Mn, μg/ℓ	206	150	140	200	7
Cu, μg/ℓ	0	5	5	-	-
Zn, μg/ℓ	20	40	2	-	-
B, mg/ℓ	2.1	.25	.23	1.7	2.2
Pb, μg/ℓ	22	25	23	-	-
Hg, mg/ℓ	0.0	0.0	0.0	-	-
Co, μg/ℓ	0	3	1	-	-
Ni, μg/ℓ	5	6	5	-	-
Cd, μg/ℓ	2	1	2	-	-
HCO_3, mg/ℓ	672	408	450	669	644
CO_3, mg/ℓ	0	0	0	0	41

*Only one sample.

Table A-5.7

AVERAGE GROUNDWATER QUALITY ANALYSES IN CANADIAN PART OF THE BASIN

		RAVENSCRAG FORMATION				
Parameter	Glacial Drift	Sana Above Hart Coal Seam	Coal Above Hart Coal Seam	Hart Coal Seam	Sand Below Hart Coal Seam	Frenchman Formation
Lab, pH	7.46	7.42	7.27	7.5	8.37	8.29
Field conductivity	1130	1360	1519		1452	1327
TDS, mg/ℓ	1124	1398	1370	1233	1204	1175
Alkalinity mg/ℓ	462	265	548	604	698	692
Hardness, mg/ℓ	611	771	923	488	56.5	81.5
Color	5.8	23	7	7.75	84	295
NO_3-N, mg/ℓ	6.19	16	3.88	0.545	0.059	0.1
NH_3-N, mg/ℓ	0.55	0.5	0.643		0.167	
Total PO_4-P, mg/ℓ	0.063	0.06	0.05		0.164	
SO_4, mg/ℓ	317	458	485	320	94	127
Cl, mg/ℓ	29.6	21.3	14.6	7.5	109	48.3
F, mg/ℓ	0.26	0.296	0.439	0.31	1.17	
Ca, mg/ℓ	116.6	151.9	167	37.9	7.43	20
Mg, mg/ℓ	79 6	93.3	109	36.1	9.39	10.4
Na, mg/ℓ	119.8	151	95	200	409	363
K, mg/ℓ	13.3	8.76	8.9	9	3.25	4.8
Fe, mg/ℓ	1.26	1.51	5.32	2.38	0.44	6.1
Mn, mg/ℓ	0.204	0.81	0.176	0.267	0.025	0.09
Cu, mg/ℓ	0.018	0.019	0.017		0.128	
Zn, mg/ℓ	0 516	0.99	0.039		0.53	
B, mg/ℓ	0.722	0.94	1.02	1.87	2.09	
Pb, mg/ℓ	0.023	0.024	0.045		0.028	
Hg, mg/ℓ	0.127	0.07	0.11		0.18	
Co, mg/ℓ	0.011	0.013	0.009		0.007	
Ni, mg/ℓ	0.012	0.02	0.013		0.008	
Cd, mg/ℓ	0.004	0.009	0.004		0.003	

Data from Saskmont Engineering, 1978.

Table A-5.8

CHEMICAL ANALYSES (COMMON CONSTITUENTS) OF WATER FROM WELLS AND ONE SPRING[1,3]

Montana sampling site	Date Mo-Dy-Yr	Geologic source	Water source	Water depth	Specific conductance µmhos/cm at 25°C)	pH field (units)	Water temperature (°C)	Hardness (Ca,Mg)	Non-carbonate hardness	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Sodium adsorption ratio	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)
35N46E16CBCD	9-8-77	Qal	W	36	1,430	7.5	9.0	230	0	36	34	270	8	6	6?0	0
36N48E01BFCD	8-4-77	Tfu	W	60	2,160	7.2	9.0	230	0	51	24	450	13	4	760	0
09CDDC	8-3-77	Qal	W	42	1,320	7.5	7.0	380	0	66	52	180	4	6	560	6
11CCCA	8-4-77	Kfh	W	348	2,050	8.4	9.0	11	0	3.4	.6	510	67	1	98	23
16BBCA	8-4-77	Qal	W	16	1,900	7.4	11.0	310	0	54	42	340	8	8	690	0
27ABAB	8-9-77	Qal	W	20	1,430	7.6	10.0	330	0	50	50	240	6	12	680	0
32BCBA	8-6-77	Kfh	W	160	1,480	8.6	9.0	8	0	2.3	.4	380	61	1	750	21
33CCCA	8-9-77	Qal	W	16	2,230	7.7	8.0	450	0	52	90	360	7	10	790	0
37N46E01CDDC	8-2-77	Tfu	W	60	890	7.1	8.5	500	3	100	61	13	.3	5	610	0
08DDCA	8-2-77	Tfu	W	53	1,210	8.6	8.5	28	0	6.3	3.1	290	24	2	590	0
22ADCD	8-6-77	Qo	W	41	1,070	6.7	9.0	590	230	130	63	17	.3	5	430	0
27BCDC	8-2-77	Tfu	S	--	1,820	6.8	7.5	400	0	86	45	310	7	8	770	0
37N47E01CACA	9-16-75	Qo	W	55	1,190	7.5	8.5	520	210	100	65	37	.7	5	370	0
	10-8-76	Qo	W	55	1,260	--	8.0	630	310	140	67	40	.7	5	3?0	-
09CBBB2	8-5-77	Tf	W	80	710	7.0	10.0	340	0	62	45	21	.5	3	450	0
16ACCD	8-2-77	Tfu	W	400	1,270	6.9	7.0	570	0	110	74	95	2	8	710	0
22AAAA	8-4-77	Tfu	W	150	900	7.0	8.0	380	0	72	48	68	2	5	550	0
37N48E04BBBA	9-16-75	Kfh	W	227	1,670	8.7	--	11	0	2.9	1.0	430	56	2	610	120
	10-8-76	Kfh	W	227	1,710	--	10.0	8	0	2.3	.5	420	65	1	870	-
05AAAA	10-8-76	Kfh	W	218	1,720	8.4	8.5	23	0	6.1	2.0	410	37	2	860	0
15DDCC	8-4-77	Tfu	(?)	--	1,290	7.0	7.0	620	51	120	80	89	2	6	690	0
23CDDB	8-4-77	Qo	W	21	920	7.4	11.0	430	62	74	60	52	1	3	450	0
27BACA	8-5-77	Qo	W	24	880	7.3	7.0	400	67	69	54	48	1	3	400	0

Table A-5.8 (continued)

Montana sampling site	Date Mo-Dy-Yr	Geologic source	Alkalinity, total as $CaCO_3$	Sulfide, total as S	Sulfate SO_4	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)	Dissolved solids (Sum of constituents)	Nitrite plus nitrate (N)	Boron (B) (μg/L)	Iron, total (Fe) (μg/L)	Lithium (Li) (μg/L)	Manganese (Mn) (μg/L)	Analysis by
35N48E16CBCD	8-8-77	Qal	530	1.8	270	10	0.5	13	960	0.00	1,400	--	90	70	GS
36N48E01BBCD	8-4-77	Tfu	630	--	540	11	.5	15	1,470	.16	2,400	2,010	90	90	BM
09CDDC	8-3-77	Qal	460	--	280	6.5	.3	19	880	2.1	1,200	140	70	<10	BM
11DCCA	8-4-77	Kfh	850	--	220	38	1.7	14	1,300	.03	2,200	400	60	10	BM
18BDCA	8-4-77	Qal	570	--	430	25	.3	14	1,620	7.0	1,400	730	90	50	BM
27ABAB	8-9-77	Qal	560	--	270	8.6	.3	13	1,320	.02	1,900	970	100	150	BM
32[illegible]CBA	8-6-77	Kfh	670	--	35	93	3.3	9.9	940	.04	2,400	--	50	4	GS
33CCCA	8-9-77	Qal	660	--	500	57	.3	11	1,490	17	2,000	550	140	750	BM
37N46E01CDDC	8-2-77	Tfu	500	--	20	3.2	.5	20	520	.07	300	2,000	30	180	BM
06DDCA	8-2-77	Tfu	480	--	130	20	1.9	10	750	1.8	2,100	270	50	10	BM
22ADCD	8-6-77	Qo	350	1.4	240	20	.1	16	710	1.2	150	--	20	220	GS
27BC[illegible]C	8-2-77	Tfu	630	--	410	5.0	.2	16	1,260	.03	2,800	1,200	140	200	BM
37N47E01CABA	9-16-75	Qo	310	--	280	17	.3	14	700	17	110	--	--	--	GS
	10-8-76	Qo	320	.2	290	21	.4	13	770	21	120	--	--	--	GS
09CBBB2	8-5-77	Tf	370	.5	17	7.2	1.0	13	400	2.5	230	--	20	140	GS
16ACCD	8-2-77	Tfu	590	--	160	7.3	.2	17	820	.3	1,400	20	80	140	BM
22AAAA	8-4-77	Tfu	450	--	61	4.5	.2	15	550	.04	1,600	12,000	60	110	BM
37N48E04BBBA	9-16-75	Kfh	710	--	7.4	150	2.3	12	1,040	.03	2,000	--	--	--	GS
	10-8-76	Kfh	710	.2	5.8	160	2.5	12	1,030	0	2,100	--	--	--	GS
05AAAA	10-8-76	Kfh	700	.6	4.9	160	2.7	13	1,030	0	2,100	--	--	--	GS
19DDCC	8-4-77	Tfu	570	--	220	3.4	.2	15	870	.02	1,400	1,540	80	670	BM
23C[illegible]B	8-4-77	Qo	370	--	140	3.2	.3	14	570	5.1	570	90	40	10	BM
27BACA	8-5-77	Qo	330	1.5	170	7.0	.4	15	570	.02	320	--	60	220	GS

[1]See Table A-3 for chemical analyses showing nutrients and minor elements for wells 35N48E16CBCD, 36N48E32BCBA, 37N46E22ADCD, 37N47E01CABA, 37N47E09CBBB2, 37N48E04BBBA, 37N48E05AAAA, and 37N48E27BACA.

[2]Water flows from uncased hole, possibly from seismic survey.

[3]Constituents are dissolved and in milligrams per liter, except as indicated.

Geologic source: Kfh, Fox Hills-Hell Creek aquifer; Tfu, Fort Union Formation; Tf, Flaxville Formation, Qo, glacial outwash, Qal, alluvium.

Water source: W, water well, S, spring.

Analysis by: BM, Montana Bureau of Mines and Geology; GS, U.S. Geological Survey.

Table A-5.9

CHEMICAL ANALYSES (NUTRIENTS AND MINOR ELEMENTS) OF WATER FROM SELECTED WELLS[1]

Variable	Units	Data							
Sampling site (Montana)	--	35N48E16CBCD	36N48E32BCBA	37N46E22ADCD	37N47E01CABA	37N47E09CBCB2	37N48E04BBBA	37N48E05AAAA	37N48E27BACA
Date of collection	(Mo-Day-Yr)	8-8-77	8-6-77	8-6-77	10-8-76	8-5-77	10-6-76	10-8-76	8-5-77
Geologic source	--	Qal	Kfh	Qo	Qo	Tf	Kfh	Kfh	Qo
Well depth	feet	36	160	41	55	80	227	218	24
Color (platinum cobalt scale)	--	8	180	6	--	27	--	--	6
Bromide (Br)	mg/L	.1	.9	0.1	.0	.0	.0	.0	.1
Iodide (I)	mg/L	.02	.15	.00	.02	.01	.02	.02	.00
Nitrite plus nitrate, total as N	mg/L	.01	.03	1.0	21	3.0	.00	.00	.01
Nitrite plus nitrate, dissolved as N	mg/L	.00	.04	1.2	--	2.5	--	--	.02
Nitrogen, ammonia, total as N	mg/L	.19	.42	.04	.00	.05	.41	.61	.0[illegible]
Nitrogen, ammonia, dissolved as N	mg/L	.21	.43	.07	--	.08	--	--	.09
Nitrogen, ammonia, dissolved as NH_4	mg/L	.27	.55	.09	--	.10	--	--	.12
Nitrogen, total organic, as N	mg/L	1.0	.48	.91	.40	.39	.22	.13	2.2
Nitrogen, total kjeldahl, as N	mg/L	1.2	.90	.95	.40	.44	.63	.74	2.3
Nitrogen, total as N	mg/L	1.2	.93	2.0	21	3.4	.63	.74	2.3
Nitrogen, total as NO_3	mg/L	5.4	4.1	8.6	95	15	2.8	3.3	10
Phosphorus, total as P	mg/L	.03	.46	.02	.07	.00	.29	.32	.00
Phosphorus, total (PO_4)	mg/L	.09	1.4	.06	--	.00	--	--	.00
Aluminum, dissolved as Al	μg/L	0	20	0	20	10	30	20	0
Arsenic, dissolved as As	μg/L	8	1	0	0	0	2	1	0
Barium, dissolved as Ba	μg/L	100	300	400	10	200	20	60	200
Beryllium, dissolved as Be	μg/L	--	--	--	<7	--	<9	<9	--
Bismuth, dissolved as Bi	μg/L	--	--	--	<7	--	<9	<9	--
Cadmium, dissolved as Cd	μg/L	2	1	3	0	2	0	0	1
Chromium, dissolved as Cr	μg/L	8	8	8	<7	8	<9	<9	8

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Table A-5.9 (continued)

Variable	Units	Data							
Sampling site (Montana)	--	35N48E16CBCD	36N48E32BCBA	37N46E22ADCD	37N47E01CABA	37N47E09CBCB2	37N48E04BBBA	37N48E05AAAA	37N.8E27B.CA
Date of collection	(Mo-Day-Yr)	8-8-77	8-6-77	8-6-77	10-8-76	8-5-77	10-6-76	10-8-76	8-5-77
Geologic source	--	Qal	Kfh	Qo	Qo	Tf	Kfh	Kfh	Qo
Well depth	feet	36	160	41	55	80	227	218	24
Cobalt, dissolved as Co	µg/L	0	4	0	<7	1	<9	<9	0
Copper, dissolved as Cu	µg/L	0	0	1	10	5	0	0	0
Gallium, dissolved as Ga	µg/L	--	--	--	<7	--	<9	<9	--
Germanium, dissolved as Ge	µg/L	--	--	--	<20	--	<20	<20	--
Iron, dissolved as Fe	µg/L	1,600	590	250	20	170	340	660	390
Lead, dissolved as Pb	µg/L	22	10	49	14	23	<14	<14	11
Mercury, dissolved as Hg	µg/L	.0	.0	.0	.0	.0	.0	.0	.0
Molybdenum, dissolved as Mo	µg/L	4	4	0	<7	1	12	<9	0
Nickel, dissolved as Ni	µg/L	5	10	6	<7	5	<9	<9	5
Selenium, dissolved as Se	µg/L	0	0	2	27	5	0	0	0
Silver, dissolved as Ag	µg/L	--	--	--	<3	--	<5	<5	--
Strontium, dissolved as Sr	µg/L	540	100	1,000	480	390	50	170	610
Tin, dissolved as Sn	µg/L	--	--	--	<10	--	<14	<14	--
Titanium, dissolved as Ti	µg/L	--	--	--	<3	--	210	270	--
Vanadium, dissolved as V	µg/L	.0	9	0.0	<14	.0	<18	18	.0
Zinc, dissolved as Zn	µg/L	20	10	50	--	2	--	--	30
Zirconium, dissolved as Zr	µg/L	--	--	--	<10	--	<20	<20	--
Alpha, gross total as U natural	µg/L	15	40	15	19	23	41	25	14
Beta, gross total as CS-137	pCi/L	4.0	4.1	5.6	19	5.2	9.7	11	5.0
Beta, gross total as strontium/yttrium-90	pCi/L	5.0	5.1	6.8	18	6.5	8.2	9.2	6.2

[1]Analyses by U S. Geological Survey

Geologic source: Kfh, Fox Hills-Hell Creek aquifer; Tf, Flaxville Formation, Qo, glacial outwash, Qal, alluvium.

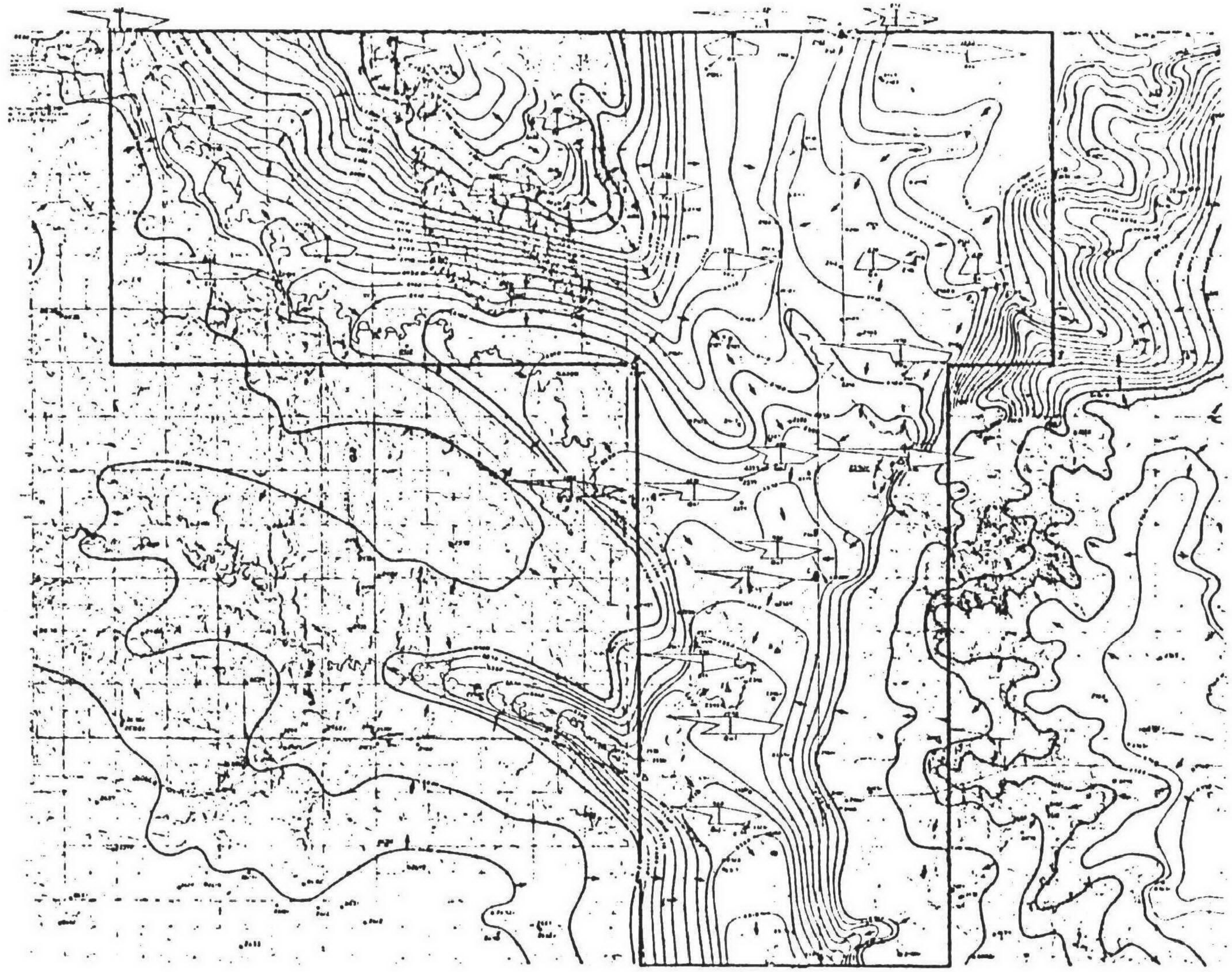
Table A-5.10

SUMMARY OF CHEMICAL ANALYSES OF WELLS IN CANADIAN PART OF POPLAR RIVER BASIN

AQUIFER	RANK	pH FIELD	pH LAB	CONDUCTIVITY 25°C UMHO CM FIELD	CONDUCTIVITY 25°C UMHO CM LAB	TOTAL DISSOLVED SOLIDS MG/L	ALKALINITY T (AS $CaCO_3$) MG/L	TOTAL HARDNESS (AS $CaCO_3$) MG/L	COLOUR APHA	NO_3 (NITRATE AS N) MG/L	NH_3 (AMMONIA AS N) MG/L	PO_4 (TOTAL PHOSPHATE AS P) MG/L
DRIFT	NUMBER OF ANALYSES		50	22	43	50	50	43	44	44	23	24
	MAXIMUM		8.65	1057	2800	2712	663	1576	15	85	2.1	0.087
	MINIMUM		6.94	490	373	198	103	105	<5	0.008	0.01	0.019
	MEAN		7.48	1130	1315	1124	462	611	5.8	6.19	0.55	0.063
	STANDARD DEVIATION		0.34	428	508	515	106	295	2.8	14.6	0.57	0.025
RAVENSCRAG	NUMBER OF ANALYSES		33	11	27	31	32	27	24	28	13	13
FORMATION	MAXIMUM		8.27	2940	2723	2863	803	1609	102	270	1.11	0.149
SAND ABOVE	MINIMUM		7.83	647	470	290	258	6.0	1	<0.01	0.09	0.036
HART COAL	MEAN		7.42	1160	1594	1398	265	771	23	16	0.5	0.06
SEAM	STANDARD DEVIATION		0.26	612	583	675	147	553	25	55.8	0.33	0.03
RAVENSCRAG	NUMBER OF ANALYSES		19	12	17	18	18	17	16	17	17	12
FORMATION	MAXIMUM		8.02	3059	3120	3387	664	2360	21	41	1.6	0.081
COAL ABOVE	MINIMUM		6.91	571	694	503	342	170	2	0.01	0.84	0.033
HART COAL	MEAN		7.27	1519	1572	1370	548	823	7	3.80	0.643	0.05
SEAM	STANDARD DEVIATION		0.32	666	560	673	89	517	5.2	10.4	0.521	0.017
RAVENSCRAG	NUMBER OF ANALYSES		15			15	15	8	8	10		
FORMATION	MAXIMUM		8			2058	744	587	10	1.35		
HART COAL	MINIMUM		7.1			843	314	396	5	0.06		
SEAM	MEAN		7.5			1233	604	488	7.75	0.545		
	STANDARD DEVIATION		0.30			319	103	59	2.12	0.51		
RAVENSCRAG	NUMBER OF ANALYSES		10	3	18	8	18	10	8	18	4	5
FORMATION	MAXIMUM		8.95	1547	2732	2348	788	240	150	0.18	1.58	0.339
SAND BELOW	MINIMUM		7.98	1338	1248	835	563	17	3	<0.01	0.09	0.048
HART COAL	MEAN		8.37	1452	1895	1284	658	56.5	84	0.058	0.187	0.164
SEAM	STANDARD DEVIATION		0.27	144	483	433	53.4	67.5	88	0.06	0.63	0.12
FRENCHMAN	NUMBER OF ANALYSES		8		4	4	6	4	2	4		
FORMATION	MAXIMUM		8.69		1760	1441	737	383	350	0.22		
	MINIMUM		7.65		818	894	653	7.6	240	0.03		
	MEAN		8.29		1327	1175	692	81.5	295	0.1		
	STANDARD DEVIATION		0.49		444	306	31.4	148	78	0.63		
C.D.W.S. (1968) MAXIMUM PERMISSIBLE LIMITS FOR TOXIC CHEMICALS										$NO_3 + NO_2$ > 10.0		
C.D.W.S. (1968) RECOMMENDED LIMITS		(8.5 8.3)				1000	30 500				0.05	0.005
SASKATCHEWAN ENVIRONMENT MUNICIPAL DRINKING WATER OBJECTIVES (MAXIMUM)		(7.0 8.5)				1500	500	800	15			
C.D.Q.G. (1975) PRIVATE WATER SUPPLIES SATISFACTORY QUALITY RANGES		(7.0 8.5)				100 500	50 500	50 500		UP TO 40		

AQUIFER	RANK	SO_4 MG/L	Cl MG/L	F MG/L	Ca MG/L	Mg MG/L	Na MG/L	K MG/L	Fe MG/L	Mn MG/L	Cu MG/L	Zn MG/L	B MG/L	Pb MG/L	Hg UG/L	Cd MG/L	Ni MG/L	Co MG/L
DRIFT	NUMBER OF ANALYSES	50	50	24	50	50	50	44	49	49	43	43	25	40	43	34	47	41
	MAXIMUM	1113	145	0.47	298	178	280	23	8.15	1.0	0.13	3.03	1.85	0.11	1.5	0.010	0.031	[illegible]
	MINIMUM	5	0.4	0.045	46	16	8.84	3.1	0.005	0.001	0.003	0.004	<0.01	0.001	<0.0[illegible]	0.002	0.004	0.001
	MEAN	317	28.6	0.26	116.6	78.8	119.8	13.3	1.26	0.204	0.018	0.516	0.727	0.023	0.127	0.011	0.012	0.014
	STANDARD DEVIATION	208	31.4	0.126	53.5	44.7	141.8	28.1	1.88	0.207	0.022	0.707	0.636	0.021	0.388	0.006	0.006	0.014
RAVENSCRAG	NUMBER OF ANALYSES	32	32	14	32	32	32	28	32	31	28	27	18	23	23	18	28	26
FORMATION	MAXIMUM	1106	188	0.70	188	344	825	25	14.3	2.73	0.034	0.50	1.65	0.06	0.37	0.04	6.07	0.11
SAND ABOVE	MINIMUM	12.7	0.3	0.11	0.3	0.5	4.5	2	0.03	0.001	0.004	0.008	0.03	0.008	<0.05	<0.002	0.004	<0.001
HART COAL	MEAN	458	21.3	0.286	151.8	93.3	151	8.76	1.51	0.81	0.018	0.89	0.84	0.024	0.07	0.013	0.07	0.085
SEAM	STANDARD DEVIATION	316	37.5	0.155	140.1	85.4	128	5.73	2.68	0.88	0.011	0.12	0.50	0.017	0.06	0.01	0.023	0.0[illegible]
RAVENSCRAG	NUMBER OF ANALYSES	18	18	12	18	18	18	18	19	18	17	17	14	17	13	16	16	11
FORMATION	MAXIMUM	1595	71	2.6	478	287	241	26	58	0.28	0.038	0.5	2.31	0.07	0.6	0.03	0.04	0.01
COAL ABOVE	MINIMUM	71	2	0.07	24	22	7	3	0.087	0.021	0.003	0.016	0.18	0.01	0.05	0.003	0.004	0.001
HART COAL	MEAN	485	14.8	0.438	167	109	85	8.0	5.32	0.176	0.017	0.039	1.02	0.045	0.11	0.009	0.013	0.004
SEAM	STANDARD DEVIATION	384	18	0.65	109	61	75	6.8	11.8	0.086	0.014	0.177	0.772	0.015	0.21	0.007	0.010	0.003
RAVENSCRAG	NUMBER OF ANALYSES	15	15	8	15	15	15	8	15	15			8					
FORMATION	MAXIMUM	1100	18	0.38	118	158	781	10	10.6	0.45			2.6					
HART COAL	MINIMUM	100	2	0.28	4.3	3.7	47	8	0.4	0.08			1.55					
SEAM	MEAN	320	7.5	0.31	37.8	36.1	200	9	2.38	0.267			1.87					
	STANDARD DEVIATION	230	5	0.044	40.3	43.3	69	2.12	2.62	0.123			0.34					
RAVENSCRAG	NUMBER OF ANALYSES	10	10	8	18	18	18	18	10	18	8	7	6	8	9	4	7	8
FORMATION	MAXIMUM	261	188	2.28	42	54	433	5	2.28	0.064	0.038	4.57	2.46	0.07	1.8	0.008	0.01	0.00[illegible]
SAND BELOW	MINIMUM	8.8	<1.0	0.26	2	1.2	359	1	0.068	0.005	0.004	0.007	1.74	0.009	<0.01	0.006	0.006	<0.001
HART COAL	MEAN	84	109	1.17	7.43	8.38	408	3.25	0.44	0.025	0.128	0.53	2.08	0.078	0.18	0.007	0.008	0.004
SEAM	STANDARD DEVIATION	120	88	0.84	7.8	16.1	27	1.4	0.8	0.021	0.012	1.5	0.24	0.0075	0.31	0.001	0.007	0.002
FRENCHMAN	NUMBER OF ANALYSES	6	6	2	6	6	6	4	4	6	2							
FORMATION	MAXIMUM	284	115		68	32	407	8	27.6	0.28								
	MINIMUM	3.8	4		2.3	8.4	303	3	0.22	0.01								
	MEAN	127	48.3		78	10.4	363	4.8	6.1	0.09								
	STANDARD DEVIATION	107	51.8		27.8	13.7	44	2.2	10.6	0.1								
C.D.W.S. (1968) MAXIMUM PERMISSIBLE LIMITS FOR TOXIC CHEMICALS													5.0	0.05				0.01
C.D.W.S. (1968) RECOMMENDED LIMITS		500	250		200	150			0.3	0.05	1.0	5.0						
SASKATCHEWAN ENVIRONMENT MUNICIPAL DRINKING WATER OBJECTIVES (MAXIMUM)		500	250	1.5		200	300		0.3	0.05	1.0	5.0						
C.D.Q.G. (1975) PRIVATE WATER SUPPLIES SATISFACTORY QUALITY RANGES		UP TO 400	UP TO 250				UP TO 300		UP TO 0.3	UP TO 0.05								

Source: Saskatchewan Power Corporation, 1977.



Key:

- • Well
- — 2800 Water Level Contour
- —▸ Flow Direction

Groundwater Concentration Diagram

Shows concentration of cations and anions, in milliequivalents per liter. Number above diagram is dissolved-solids concentration, in milligrams per liter. Letters below diagram are abbreviations for geologic source: Kfh, Fox-Hills-Hell Creek aquifer of Late Cretaceous age; Tfu, Fort Union Formation of Tertiary age; Tf, Flaxville Formation of Tertiary age; Qo, glacial outwash or Quaternary age; and Qal, alluvium of Quaternary age

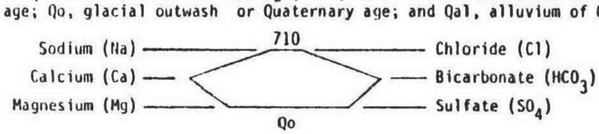


Figure A-5.1 GROUNDWATER CONTOUR MAP OF THE EAST FORK SUB-BASIN FROM THE INTERNATIONAL BORDER TO THE FORT PECK INDIAN RESERVATION

A-5.2.2 Comparison of Ground Water and Water Quality Standards

The parameters included in the U.S. primary drinking water quality standards (EPA, 1977b) will be discussed first. Arsenic, barium, cadmium, chromium, and mercury concentrations did not exceed the standards. One sample from a well completed in the glacial outwash deposits near the upper Middle Fork of the Poplar River had a lead concentration of 49 µg/ℓ close to the standard of 50 µg/ℓ. Reported values of nitrate plus nitrite in samples from three wells exceeded the standard for nitrate of 10 mg/ℓ. Two of the wells were completed in glacial outwash and the other was completed in the Quaternary alluvium. These two aquifers show higher nitrate + nitrite concentrations. Another sample from a well completed in the glacial outwash had a selenium concentration of 27 µg/ℓ which exceeded the standard of 10 µg/ℓ. The fluoride maximum standard of 2.4 mg/ℓ was exceeded in three out of five samples from the Fox Hills-Hell Creek aquifer. The available measurements of alpha radioactivity did not exceed the standard.

U.S. secondary standards are designed to protect aesthetic qualities including taste and odor and to minimize corrosion properties. Chloride, copper and zinc concentrations were below standards. Iron concentrations were high in samples from nine out of 13 wells. The highest concentrations were found for the Fort Union Formation. Manganese concentrations exceeded the standard in samples from 12 out of 18 wells. The pH of water from wells tapping the Fox Hills-Hell Creek Formation were just above the upper limit of 8.5. Sulfate concentrations in samples from the Quaternary alluvium were all above the standard of 250 mg/ℓ. Samples from three out of five wells were greater than 400 mg/ℓ which can cause laxative effects. One sample from a well completed in the Flaxville Formation had a TDS concentration below 500 mg/ℓ. Samples from all the other wells exceeded 500 mg/ℓ. There are no Federal standards for hardness but high levels can cause problems for households. Soft water (less than 75 mg/ℓ as $CaCo_3$) was found in samples from wells completed in the Fox Hills-Hell Creek Formation and in one well completed in the Fort Union Formation. Hard water was found in samples from a well tapping the Quaternary alluvium and a well tapping the Fort Union Formation. Samples from all the other wells had very hard water ranging from 310 to 630 mg/ℓ. The discussion above shows that most of the wells sampled exceeded one or more of the secondary standards.

The Canadian standards for direct health effects will be discussed first. The limit for nitrite plus nitrate (1968) is 10 mg/ℓ although for private water supplies (the 1975 guidelines would allow up to 40 mg/ℓ) was equalled or exceeded in samples from four out of 50 wells. The limit for cadmium of 0.01 mg/ℓ was exceeded in samples from two out of 25 wells. Standards for fluoride were not exceeded.

Other parameters affect taste, odor, and corrosion including TDS, iron, copper, zinc, and sulfate. Samples from only four out of 26 wells are within the Canadian 1975 TDS guidelines of 100-500 mg/ℓ.

The Saskatchewan Environment limit of 150 mg/ℓ for TDS is exceeded in samples from five out of 26 wells. The Saskatchewan Environment maximum limit for alkalinity of 500 mg/ℓ is exceeded in samples from nine out of 26 wells. As would be expected, the hardness limit of 800 mg/ℓ is also exceeded in several samples from the wells (four out of 25). Sulfate concentrations in water from eight out of 50 wells were above the Saskatchewan Environment limit of 500 mg/ℓ. Iron concentrations were high in some well samples (up to 8.15 mg/ℓ). The recommended limit to reduce staining and taste effects of 0.3 mg/ℓ was exceeded in samples from four out of 26 wells. Manganese concentrations were higher than the recommended limit of 0.05 mg/ℓ in samples from 15 out of 26 wells. Limits for magnesium, sodium, copper, zinc, and color were not exceeded as shown in Figure A-5.2.

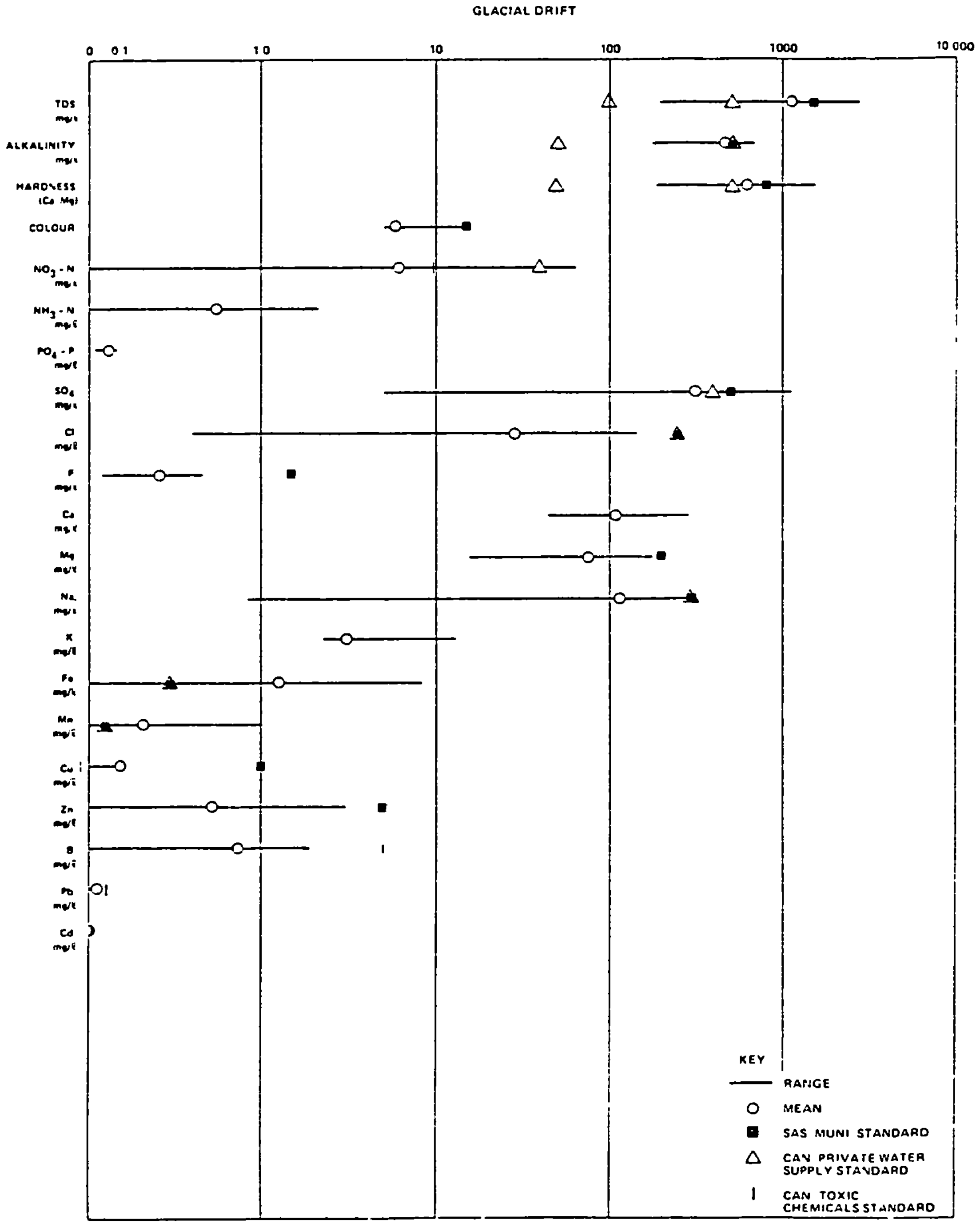
The four zones in the Ravenscrag Formation used for water supplies will be discussed together. Figures A-5.3 through A-5.6 show the ranges for selected chemical parameters and the drinking water standards. The nitrate concentrations exceeded the standard of 10 mg/ℓ in samples four out of 25 wells in the sand and coal above the Hart Seam but not in the Hart coal seam itself or the underlying sand. Samples from four out of 26 wells in the Ravenscrag Formations were above the standard for lead of 0.05 mg/ℓ. Two well water samples from the sand and coal above the Hart coal seam had cadmium analyses above the limit of 0.01 mg/ℓ, although the average for the formations was below the limit. Fluoride concentrations were below the standard of 1.5 mg/ℓ in samples from the upper sand and the Hart coal seam. One sample from the upper coal and one from the lower sand had fluoride concentrations above 1.5 mg/ℓ.

Some of the standards designed to protect aesthetic qualities were exceeded. Copper, zinc, and chloride limits were below standards. TDS concentrations increased in the deeper zones of the Ravenscrag Formation. The guideline of 1,500 mg/ℓ was exceeded in samples from 11 out of 40 wells. One sample from a well tapping the coal above the Hart coal seam had 3,302 mg/ℓ TDS which is above the maximum concentration suitable for drinking water. The limit for alkalinity of 500 mg/ℓ is exceeded in samples from eight out of 40 wells. Hardness is greater than 800 mg/ℓ in samples from eight out of 40 wells. Sulfate concentrations in the sand below the Hart coal seam are lower than the other zones. The limit of 500 mg/ℓ is exceeded in samples from seven out of 40 wells. Water from some of the wells has sulfate concentrations above 1,000 mg/ℓ which may cause health effects. In addition, some of the wells have H_2S odors. Magnesium and sodium concentrations in samples from three out of 40 wells exceeded the Saskatchewan limits of 200 and 300 mg/ℓ. Iron and manganese limits of 0.3 and 0.05 mg/ℓ were exceeded in 38 and 36 out of 40 wells, respectively.

The Frenchman Formation is the deepest aquifer used. Water from this aquifer has a high organic content, is strongly colored, and is considered unsuitable for drinking (Saskmont Engineering, 1978). The high color evident from Figure A-5.7 is partly from the high iron and manganese concentrations along with the organics. Analyses for sodium in three wells were all above the limit of 300 mg/ℓ.

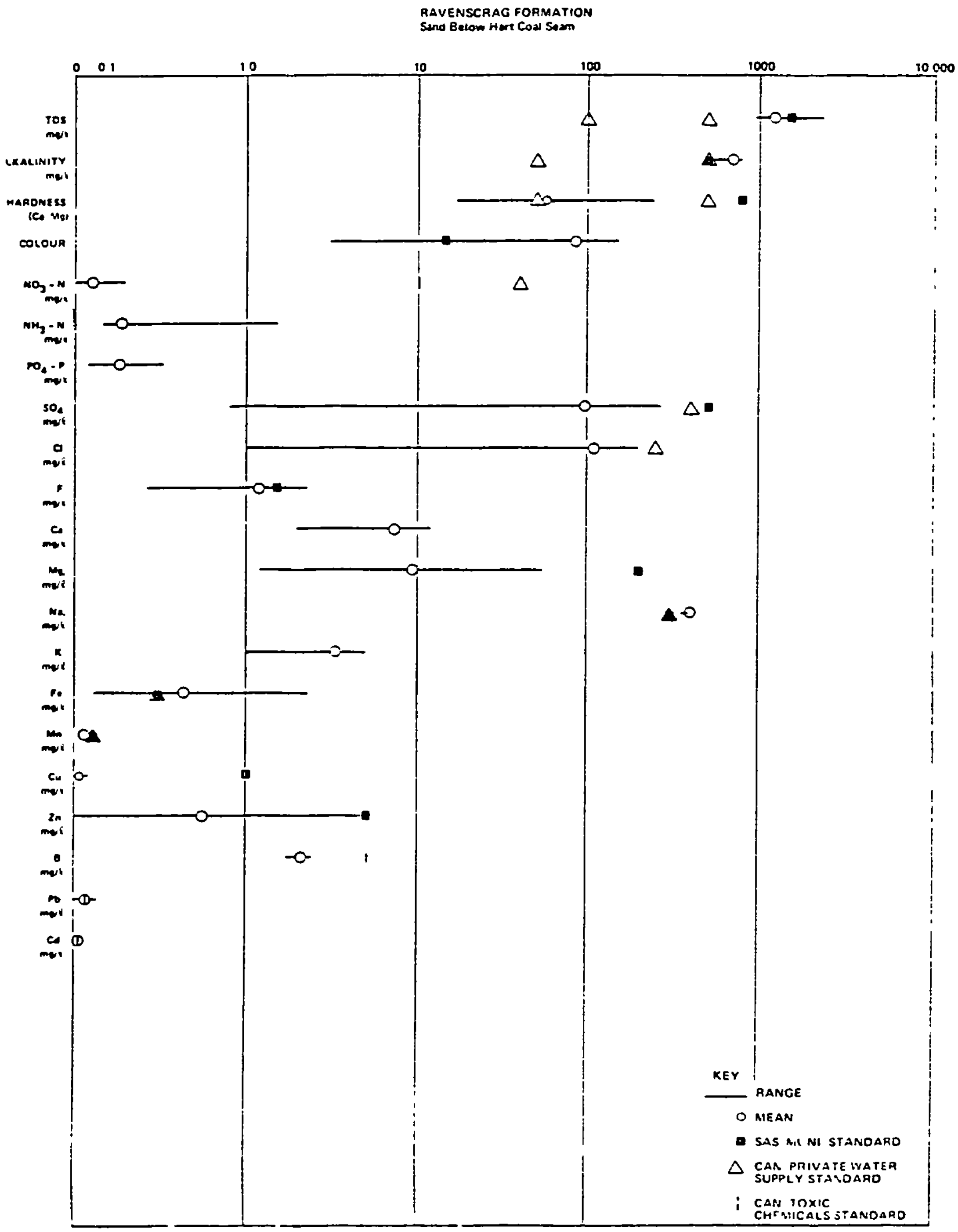
Water from all six aquifers is used for stock watering. The well water would be classified as good (less than 2,500 mg/ℓ) to fair (2,500-3,500 mg/ℓ) under the Montana water classification system. A comparison of the U.S. specific cation and anion guidelines and the water quality of the aquifers showed that sodium, calcium, chloride, boron, copper, lead, mercury, and cobalt guidelines were not exceeded in any of the aquifers. Concentrations of fluoride and magnesium in some well water from the Ravenscrag Formation were between the threshold and limiting values of 1-6 mg/ℓ and 250-500 mg/ℓ, respectively. The coal aquifers in the Ravenscrag Formation were also higher than the threshold limit of 500 mg/ℓ for sulfate and the limit of 0.05 mg/ℓ for cadmium. The glacial drift aquifer may have concentrations over the limit for sulfate of 1,000 mg/ℓ.

One well completed in the sand above the Hart coal seam was used for agricultural purposes. The Saskatchewan general guidelines for agriculture and irrigation were compared to the water quality analyses. The maximum limit for TDS of 3,100 mg/ℓ would be exceeded by water from the coal above the Hart coal seam. Water in the sand above the Hart coal seam can have sodium concentrations above 500 mg/ℓ. Some of the well samples had sulfate and hardness concentrations between the threshold and limiting values. The high conductance values of most samples would classify the water as medium to high salinity hazard (Class II) with some water from the coal above the Hart coal seam classified as very high salinity hazard (Class III). This classification gives only a general indication of the suitability of the water for irrigation since the type of soil and crop is also an important factor.



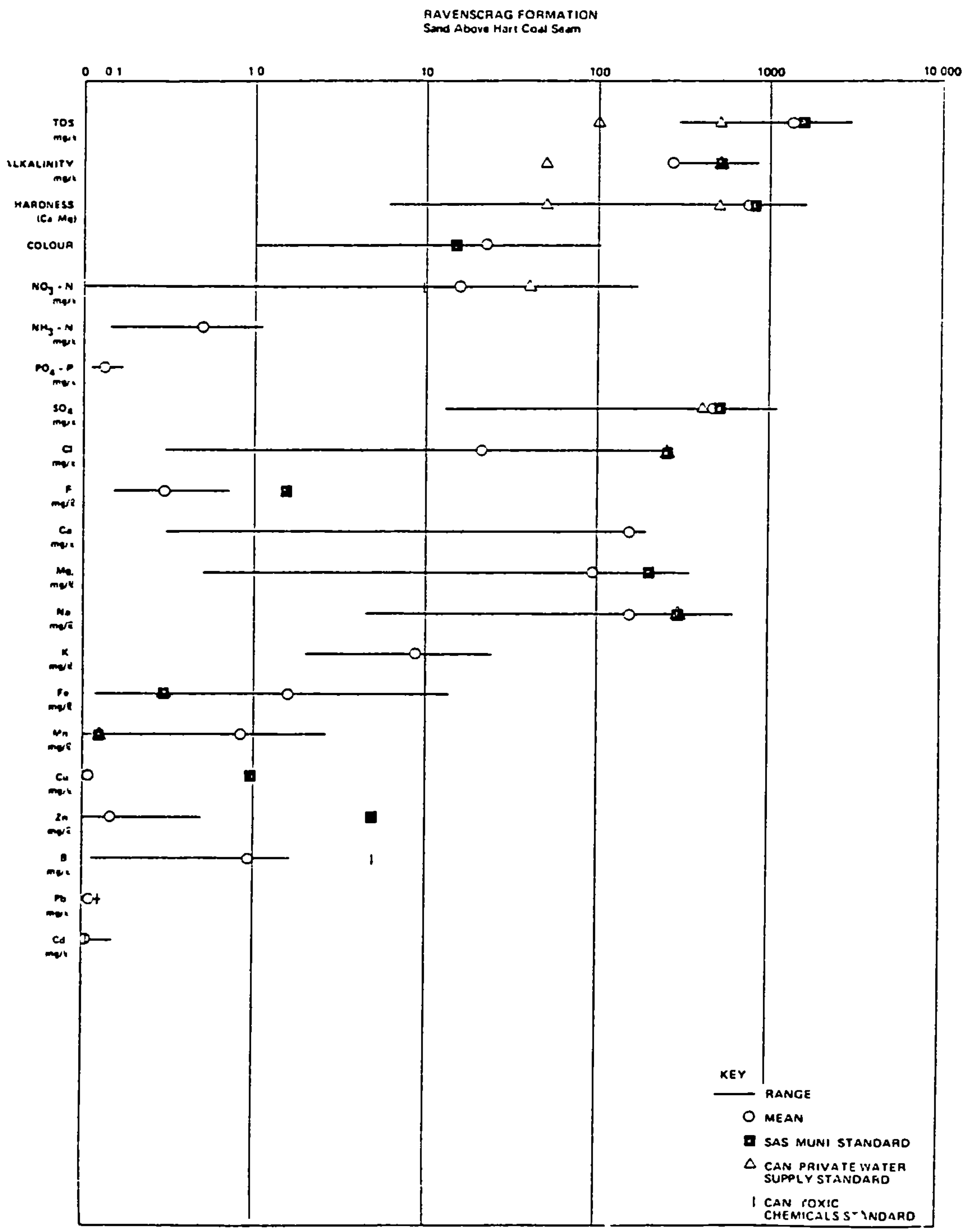
Data from Saskmont Engineering, 1978

Figure A-5.2 RANGES OF SELECTED CHEMICAL PARAMETERS IN WATER SAMPLES FROM THE GLACIAL DRIFT IN THE CANADIAN PART OF THE POPLAR RIVER BASIN



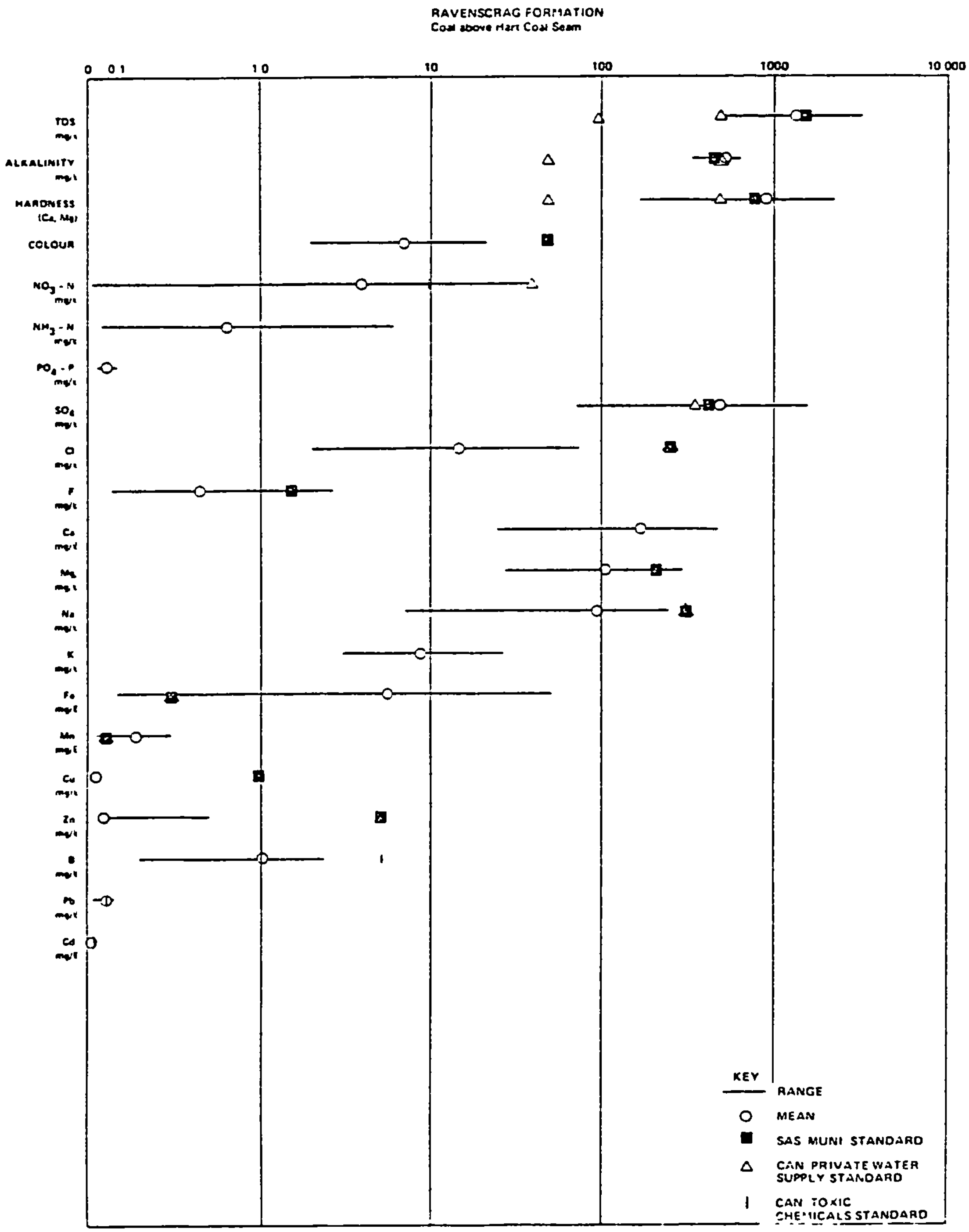
Data from Saskmont Engineering, 1978

Figure A-5.3 RANGES OF SELECTED CHEMICAL PARAMETERS IN WATER SAMPLES FROM THE SAND BELOW THE HART COAL SEAM IN THE CANADIAN PART OF THE POPLAR RIVER BASIN



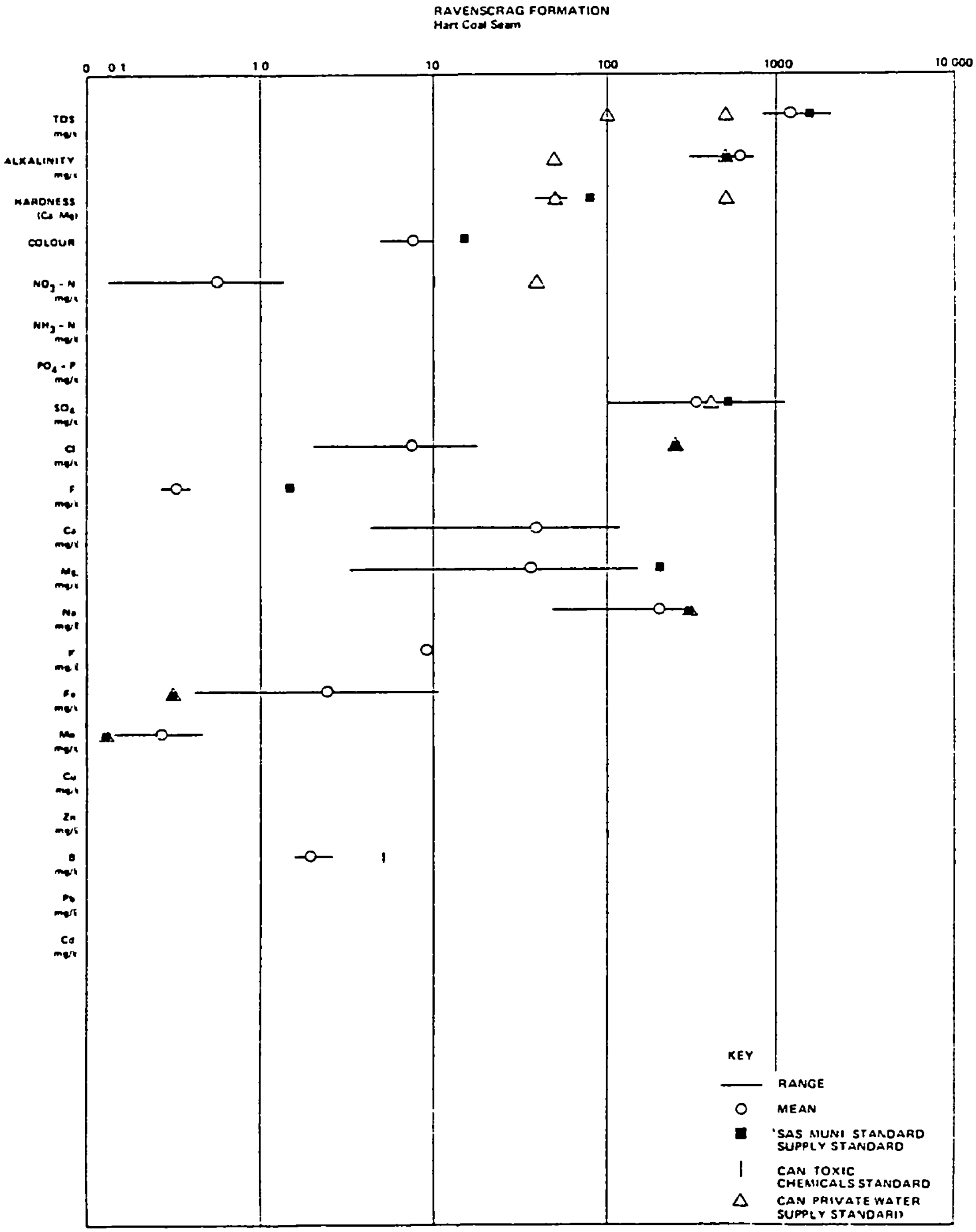
Data from Saskmont Engineering, 1978

Figure A-5.4 RANGES OF SELECTED CHEMICAL PARAMETERS FOR WATER SAMPLES IN THE SAND ABOVE THE HART COAL SEAM IN THE CANADIAN PART OF THE POPLAR RIVER BASIN



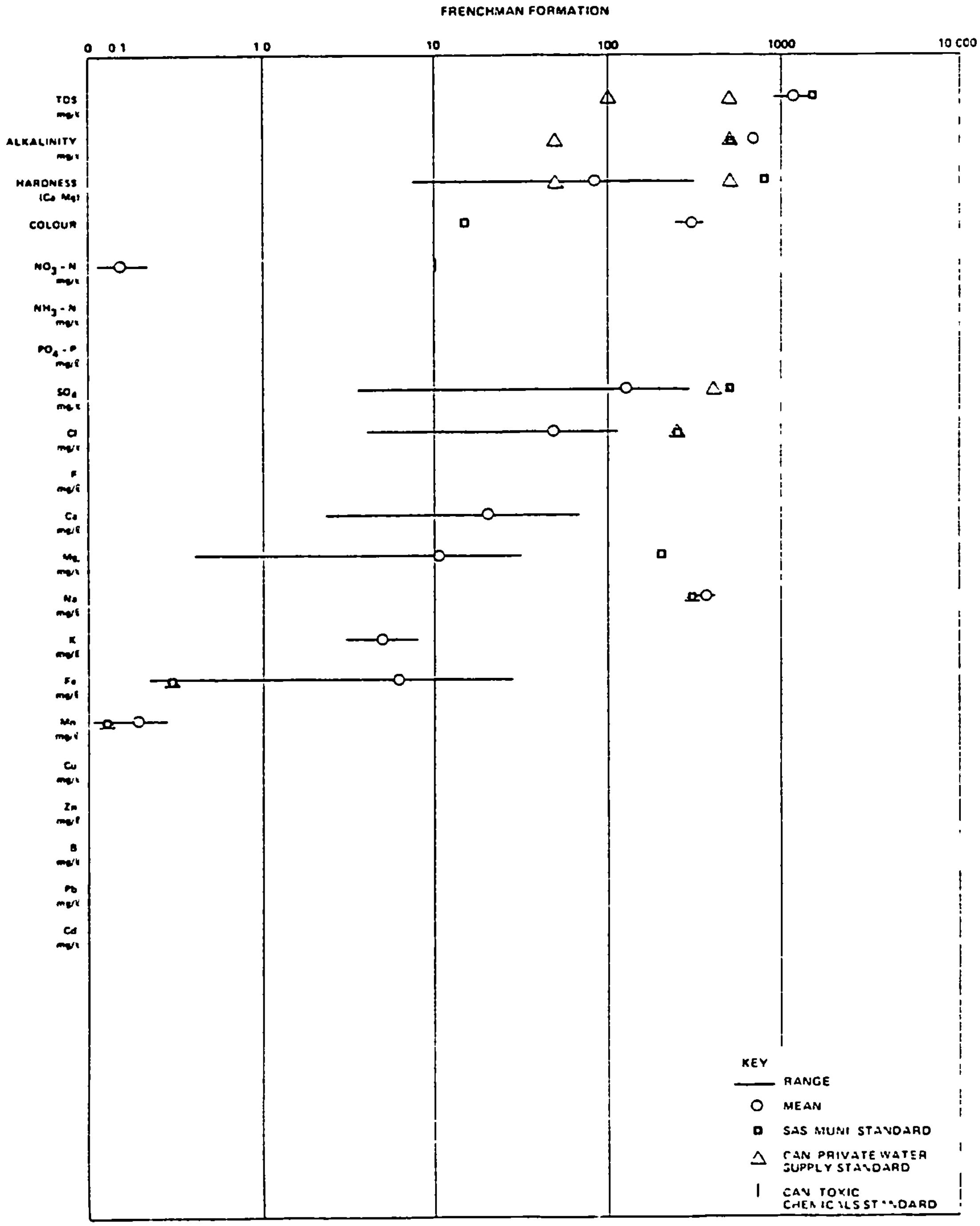
Data from Saskmont Engineering, 1978

Figure A-5.5 RANGES OF SELECTED CHEMICAL PARAMETERS FOR WATER SAMPLES IN THE RAVENSCRAG COAL ABOVE THE HART COAL SEAM IN THE CANADIAN PART OF THE POPLAR RIVER BASIN



Data from Saskmont Engineering, 1978

Figure A-5.6 RANGES OF SELECTED CHEMICAL PARAMETERS FOR WATER SAMPLES FROM THE HART COAL SEAM IN THE RAVENSCRAG FORMATION IN THE CANADIAN PART OF THE POPLAR RIVER BASIN



Data from Saskmont Engineering, 1978

Figure A-5.7 RANGES OF SELECTED CHEMICAL PARAMETERS FOR WATER SAMPLES FROM THE FRENCHMAN FORMATION IN THE CANADIAN PART OF THE POPLAR RIVER BASIN

Appendix A-6. Vegetation and Wildlife

A-6.1 VEGETATION

The Poplar River Basin lies within the Mixed Prairie grassland zone, which is characterized by native tracts of grasslands dominated by porcupine grass *(Stipa spartea)*, blue gamma *(Boutelova gracilis)* and northern wheatgrass *(Agropyron smithii)*. However, as indicated by the land use characteristics of the Poplar River drainage, greater than 50 percent of this region is utilized for agricultural purposes. Cereal grains including wheat, oats, barley as well as flax and hay constitute the major vegetation cover of the area. The most important of the cereal crops produced in the area is spring wheat. A total of 62 percent of the cropland planted in Daniels County in 1975, for example, was planted in this grain (Tanner, 1977).

The Poplar drainage is primarily a dryland farming region. Dryland farming techniques practiced in the area, which tend to maximize the effectiveness of light annual precipitation, consist of stripcropping in which crops are alternated with strips of fallow land. During successive growing seasons strips of cropland are alternately planted and fallowed. Less than one percent of the agricultural acreage of the basin was under irrigation during 1975 although a much greater area is considered to be irrigable (Bloom, et al., 1975).

Rangeland, which represents the next largest land use area, in the Poplar Basin is composed of a mixture of native and introduced grasses as well as various forbs. As previously noted, native or natural tracts of grassland are dominated by porcupine grass, blue gamma and northern wheatgrass. The introduced species and various forbs, however, are the most important components of grazed grasslands. Introduced grasses include green needlegrass *(Stipa viridula)*, bluegrasses *(Poa* spp.*)* and crested wheatgrass *(Agropyron cristatum)*. The main forbs associated with the rangeland include: fringed sage *(Artemisia frigida)*, yarrow *(Archillea* sp.*)*, bedstraw *(Galium borcale)*, white milkwort *(Polygala alba)*, and two-groove milvetch *(Astragalus bisulcatus)*.

The distribution of these grasses and forbs in the basin is determined primarily by such factors as topography, moisture availability and grazing pressure. Tracts of the native *Stipea - Boutelova - Agropyron* assemblage are found exclusively in ungrazed, dry upland areas. Dry upland areas which have not been recently grazed or are only lightly grazed, however, are dominated by porcupine grass *(Stipea spartea)*, but under heavy grazing pressure bluegrasses *(Poa* spp.*)*, June grass *(Koeleria cristata)* and forbes such as pasture sage *(Artemisa frigida)* dominate the rangeland. Upland grasslands which have undergone extreme grazing pressure are comprised almost exclusively of pasture sage. Uncultivated meadows occurring in the floodplains have been heavily grazed upon and are dominated by such species as bluegrasses *(Poa* spp.*)*, manna grass *(Glyceria grandis)* and reed grass *(Calamagrostis* sp.*)*.

Although the basin is dominated by cropland and grassland areas dense stands of shrubs occur along the lower Poplar River and other streams as well as in the coulees of the breaks and in isolated spots in the uplands. The major species in all areas include: rose *(Rosa woodsii)*, snowberry *(Symphoricarpos occidentalis)*, silver sage *(Artemisia cana)* and chokecherry *(Prunus virgianus)*. Less common shrubs include silverberry *(Elaeagnus commutata)*, serviceberry *(Amelanchier alnifolia)*, gooseberry *(Ripes* spp.*)*, red-osier dogwood *(Cornus stolonifera)*, horizontal juniper *(Juniperus horizontalis)*, shrubby cinquefoil *(Potentilla fructosa)* and Willow *(Salix* spp.*)* (Stoneberg, 1977).

Very few stands of native deciduous trees exist in the Poplar basin. Isolated stands of the aspen poplar *(Populus tremuloides)* and the green ash *(Fraxinus pennsylvanica)* are found in protected areas along the lower Poplar River and in breaks and coulees.

A-6.2 WILDLIFE

This section provides an overview of wildlife resources within the Poplar River drainage basin. Included in the following descriptions are the enumeration of abundant species, information concerning the distribution of wildlife within previously defined landforms and vegetative cover types, and documentation of the importance of specific habitats for the maintenance of existing wildlife populations.

The information assembled in this document was obtained primarily from interim reports on wildlife studies conducted by the Ecological Services Division of the Montana Department of Fish and Game (DeSimone, 1978a, 1978b, and 1978c, 1979; and Stoneberg, 1977, 1978). These wildlife investigations were conducted in that area of the Poplar River drainage within Daniels County, Montana.

Additionally, the wildlife resources within the area of the Coronach development site are catalogued in this section. Previous reports which documented the wildlife resources within a 178 square mile area surrounding the coal reserve area, reservoir and the power plant site were used for this purpose (Saskatchewan Power Corporation, 1977; Blood, et al., 1976).

A-6.2.1 Avifauna

A complete list of all birds identified in the Canadian study area which surrounds the Coronach Reservoir and the power generating station and in the Poplar River drainage area within Daniels County is presented in Table A-6.20 at the end of Appendix Section A-6. Abundance and density estimates for numerically important species of waterfowl, upland gamebirds and raptors are provided in subsequent sections. Additionally, descriptions of habitat requirements, specific breeding areas, and where available, production estimates are included in these sections.

A-6.2.2 Upland Gamebirds

Upland gamebird species found in the Poplar River Basin include the ring-necked pheasant *(Phasianus colchicus)*, the gray or Hungarian partridge *(Perdix perdix)*, the sharp-tailed grouse *(Pedioecetes phasianellus)* and the sage grouse *(Centrocercus urophasianus)*. Sage grouse were infrequently encountered in field studies conducted in the drainage basin and they most likely do not breed in this area (DeSimone, 1978a).

Although ring-necked pheasants are reportedly common in the Poplar River Valley in the vicinity of Fife Lake, only a minimal number are believed to occur in the 65 square mile development area in the vicinity of the site (Blood, et al., 1976). Several sources, however, indicate that ring-necked populations are widespread in that portion of the Poplar River Basin below the International Border. Field studies conducted in Daniels County (DeSimone, 1978a and 1978b) showed that pheasants were most frequently observed in and around shrubs associated with water courses. Data collected during these roadside crowing count studies indicated that there was an average of 13.3 male pheasant crows (calls) per 2-minute stop in streambottom habitats while only 3.3 crows per 2-minute stop were heard in upland or benchland habitats. The results of these studies conducted during two consecutive years are provided in Table A-6.1.

Sharp-tailed grouse were observed in both the development area and the study areas in Daniels County, Montana (Blood, et al., 1976; DeSimone, 1978b). In both areas, sharp-tails were most frequently observed in the grazed and ungrazed pastures. Moreover, the sharp-tail breeding (dancing) grounds were found more frequently in grassland habitats. A summary of observations of sharp-tailed grouse by land form and vegetational cover in Daniels County over the period April, 1977 through June, 1978 is provided in Table A-6.2. The location of dancing grounds observed during this study period is depicted in Figure A-6.1 and descriptive information concerning these areas is provided in Table A-6.3.

The Hungarian or gray partridge was found to be the most common upland gamebird in the vicinity of the Coronach development site (Blood, et al., 1976) The perferred habitat of this species was found to be woody brush areas associated with extensive tracts of grain. Likewise, 48 percent of the Hungarian partridge observations made in Daniels County (DeSimone, 1978a and 1978b) were in or near wheat fields which were in proximity to roadside cover, shelter belts or near farm buildings. A summary of observations of Hungarian partridge by land form and vegetational cover in the Poplar River drainage in Daniels County during studies spanning the period April, 1977--June, 1978, is presented in Tables A-6.4 and A-6.5.

Table A-6.1

COMPARISON OF PHEASANT CROWING COUNT ROUTES CONDUCTED
IN THE POPLAR RIVER DRAINAGE IN
DANIELS COUNTY DURING 1977 AND 1978

	Upland Habitat			Riparian Habitat			
Date	No. Stops	No. Crows	Crows/ Stop	No. Stops	No. Crows	Crows/ Stop	Location[1]
4/13/77	4	13	3.6	3	16	5.3	1
5/5/78	4	11	2.8	3	14	4.7	
4/21/77	15	102	6.8	5	86	17.2	2
5/2/78	15	65	4.3	5	41	8.2	
4/22/77	14	45	3.2	2	28	14.0	2-3
4/30/78	14	32	2.3	2	16	8.0	
4/23/77	-	-	-	13	286	22.0	4
4/28/78	-	-	-	13	144	11.1	
4/25/77	10	2	0.2	-	-	-	5
5/1/78	9	3	0.3	-	-	-	
4/27/77	9	15	1.7	2	16	8.0	6
5/1/78	9	23	2.5	2	18	9.0	
5/3/77	15	95	6.3	2	29	14.5	7
4/29/78	8	37	4.6	2	14	7.0	
5/5/78	8	20	2.5	-	-	-	
Total 78	16	57	3.6				
5/14/77	7	20	2.9	3	18	6.0	8
5/4/78	7	35	5.0	3	15	5.0	
5/16/77	10	10	1.0	-	-	-	9
5/4/78	7	12	1.7	-	-	-	
5/17/77	10	22	2.2	-	-	-	10
5/3/78	11	11	1.0	-	-	-	
1977	94	324	3.4	30	479	16.0	
1978	92	249	2.7	30	262	8.7	

1. Route Locations are shown in Figure A-6-1.

Source: DeSimone, 1978b

Table A-6.2

OBSERVATIONS OF SHARP-TAILED GROUSE BY LAND FORM AND VEGETATIONAL COVER IN DANIELS COUNTY FROM APRIL THROUGH DECEMBER, 1977 AND JANUARY, 1978

Land Form	Vegetational Cover[1]	April-June		July-September		October-December		January		Total	
		No.	%	No.	%	No.	%	No.	%	No.	%
Uplands	a			5	4.9	17	14.7			22	5.8
Uplands	ai	6	4.9	26	25.2			6	15.4	38	10.0
Uplands	ak							22	56.4	22	5.8
Uplands	c	49	39.8	14	13.6	21	18.1	3	7.7	87	22.8
Uplands	ci	3	2.4	27	26.2	18	15.5			48	12.6
Uplands	ck					4	3.5	6	15.4	10	2.6
Uplands	d	11	8.9							11	2.9
Uplands	di	3	2.4	6	5.4					9	2.4
Uplands	c			12	10.3					12	3.1
Uplands	f	1	2.8			28	24.1	2	5.1	31	8.1
Subtotal		73	40.7	78	75.7	100	86.2	39	100	290	76.1
Riparian	ai	1	0.8							1	0.3
Riparian	c	41	33.3	11	10.7	16	13.8			68	17.8
Riparian	ci	7	5.7							7	1.8
Riparian	f	1	0.8	13	12.6					14	3.7
Riparian	fi			1	1.0					1	0.3
Subtotal		50	59.3	25	24.3	16	13.8			91	23.9
Total		123	100.0	103	100.0	116	100.0	39	100.0	381	100.0

[1] Vegetational Cover Types:
- a. Grain crops, stubble, summer fallow
- b. Hay crops
- c. Grazed grasslands
- d. Ungrazed grasslands
- f. Brush patches
- i. Road edge
- j. Homesteads
- k. Windbreaks and shelter belts

Source: DeSimone, 1978b

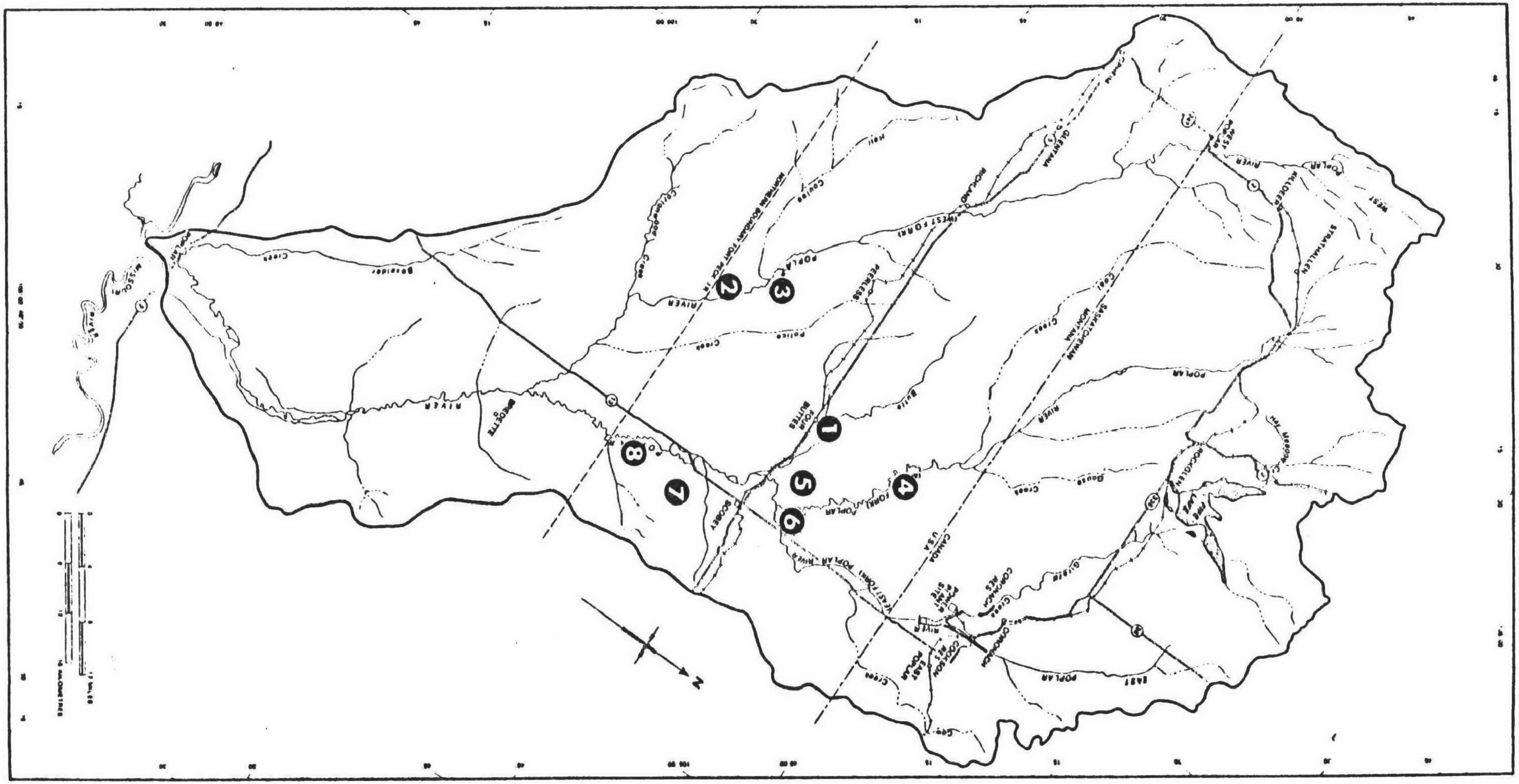


Figure 4.8-1 SHARP-TAILED GROUSE DANCING GROUNDS LOCATED DURING THE SPRING 1977 AND 1978

Table A-6.3

INFORMATION CONCERNING SHARP-TAILED GROUSE DANCING GROUNDS LOCATED IN DANIELS COUNTY DURING SPRING 1977 AND 1978

Ground No.[1]	No. Males 1977	No. Males 1978	Land Form	Vegetational Cover
1	31	24	Riparian	grazed grasslands
2	17	12	Uplands	grazed grasslands
3	9	8	Uplands	grazed grasslands
4	6	2	Riparian	grazed grasslands
5	11	5	Uplands	ungrazed grasslands
6	23	11	Uplands	grazed grasslands
7	-	17	Uplands	grazed grasslands
8	-	18	Riparian	grazed grasslands

[1] See Figure A-6.1 for location of dancing grounds.

Source: DeSimone, 1978b

Table A-6.4

OBSERVATIONS OF HUNGARIAN PARTRIDGE BY LAND FORM AND VEGETATIONAL COVER IN DANIELS COUNTY FROM APRIL THROUGH DECEMBER, 1977 AND JANUARY, 1978

Land Form	Vegetational Cover[1]	April-June		July-September		October-December		January		Total	
		No	%	No	%	No.	%	No.	%	No.	%
Uplands	a	6	6.6	60	15.8	5	6.1	24	8.4	95	11.4
Uplands	ai	45	49.4	136	35.9			71	24.9	252	30.1
Uplands	aj			4	1.1					4	0.5
Uplands	ak	4	4.4					46	16.1	50	6.0
Uplands	b							19	6.7	19	2.3
Uplands	bi			10	2.6			21	7.4	31	3.7
Uplands	c	6	6.6	38	10 0	42	51.2	27	9.5	113	13.5
Uplands	ci	6	6.6	22	5.8			21	7.4	49	5.9
Uplands	d					5	6.1			5	0.6
Uplands	di	2	2.2			4	4.9			6	0.7
Uplands	f					15	18.3			15	1.8
Uplands	fi			16	4.2					16	1.9
Uplands	j									2	0.2
Subtotal		71	78.0	286	75.5	71	86.6	229	80.4	657	78.6
Riparian	a	1	1.1					40	14.0	41	4.9
Riparian	ai	6	6.6	9	2.3					15	1.8
Riparian	ak			11	2.9					11	1.3
Riparian	c	6	6.6	56	14.8			10	3.5	72	8.6
Riparian	ci	3	3.3	3	0 8	11	13.4			17	2 0
Riparian	f	2	2.2	14	3.7			6	2.1	22	2.6
Riparian	fi	2	2.2							2	0.2
Subtotal		20	22.0	93	24.5	11	13.4	56	19.6	180	21.4
Total		91	100.0	379	100 0	82	100 0	285	100.0	837	100.0

[1]Vegetational Cover Types:
a. Grain crops, stubble, summer fallow
b. Hay crops
c. Grazed grasslands
d. Ungrazed grasslands
f. Brush patches
i. Road edge
j. Homesteads
k. Windbreaks and shelter belts

Source DeSimone, 1978a

Table A-6.5

OBSERVATIONS OF HUNGARIAN PARTRIDGE BY LAND FORM AND VEGETATIONAL COVER IN THE POPLAR RIVER DRAINAGE IN DANIELS COUNTY FROM MARCH THROUGH JUNE, 1978

Land Form	Vegetational Cover[1]	March		April		May		June		Total	
		No.	%	No.	%	No.	%	No.	%	No.	%
Uplands	a	9	4.3	2	7.4	8	24.2	-	-	19	6.3
Uplands	ai	39	18.4	15	55.5	6	18.2	1	4.5	61	20.3
Uplands	ak	88	41.5	-	-	-	-	-	-	88	29.2
Uplands	b	7	3.3	7	25.9	-	-	-	-	14	4.7
Uplands	bi	-	-	2	7.4	11	33.3	-	-	13	4.3
Uplands	ci	28	13.2	7	25.9	2	6.1	10	45.6	47	15.6
Uplands	ck	11	5.2	-	-	-	-	-	-	11	3.7
Uplands	d	20	9.4	-	-	-	-	-	-	20	6.6
Uplands	dk	-	-	1	3.7	-	-	-	-	1	0.3
Subtotal		202	95.3	34	100.0	27	81.8	11	50.0	274	91.0
Riparian	c	7	3.3	-	-	2	6.1	-	-	9	3.0
Riparian	ci	3	1.4	-	-	-	-	-	-	3	1.0
Riparian	d	-	-	-	-	2	6.1	11	50.0	13	4.3
Riparian	f	-	-	-	-	2	6.1	-	-	2	0.7
Subtotal		10	4.7	-	-	6	18.3	11	50.0	27	9.0
Total		212	100.0	34	100.0	33	100.1	22	100.0	301	100.0

[1]Vegetational Cover Types.
a. Grain crops, stubble, summer fallow
b. Hay crops
c. Grazed grasslands
d. Ungrazed grasslands
f. Brush patches
i. Road edge
j. Homesteads
k. Windbreaks and shelter belts

Source: DeSimone, 1978b

A-6.2.3 Raptors

A list of the raptorial birds observed in the area of the Coronach development site during 1975-1976 as well as information concerning the preferred habitat and seasonal abundance of these species is presented in Table A-6.6. A similar list of raptors observed in the Poplar River drainage in Daniels County from April, 1977 through June, 1978 is given in Table A-6.7.

The marsh hawk *(Circus cyaneus)* followed by the Swainson's hawk *(Butco swainsoni)*, the burrowing owl *(Speotyto cuniculavia)*, the golden eagle *(Aquila chrysaetos)* and the American kestrel *(Falco sparverius)* were the most common raptor species observed during the studies conducted in Daniels County. These species were generally found associated with the grasslands and grain fields, however, the nesting habitats required by these species are quite diverse. The marsh hawk, for example, nests primarily along creeks and in grasslands especially near brushy cover, while the Swainson's hawk and golden eagles are dependent on trees for nesting sites; the nests of these two species may be associated with shelter belts and windbreaks in the study area. Moreover, nests of burrowing owls are usually associated with grazed or ungrazed grasslands.

The above species as well as the ferruginous hawk *(Buteo regalis)* are of particular interest since they represent species observed in the area which are either currently or have previously been included on the American Endangered list.

A-6.2.4 Ungulates

Big game species observed in the Coronach development site area and the Daniels County study area of the Poplar River Basin include: the white-tailed deer *(Odocoileus virginianus)*, the pronghorn antelope *(Antilocapra americana)*, and the mule deer *(Odocoileus hemionus)*. These species are not considered common and their numbers are not significant in the area surrounding the Coronach Reservoir and power plant site (Blood, et al., 1976). Studies conducted in Daniels County (Stoneberg, 1978 and DeSimone, 1978a and 1978b), however, found that while only insignificant mule deer and limited pronghorn antelope populations existed in the Poplar River Basin, substantial numbers of white-tailed deer were present.

Population estimates based on aerial surveys indicated an average density of 1.10 deer/square mile within an area including Daniels County and portions of Sheridan County (Stoneberg, 1978).

The approximate winter distribution of white-tailed deer, based on aerial surveys conducted during the period November, 1977--February, 1978 (Stoneberg, 1978), is indicated in Figure A-6.2. Observations made during these surveys indicated that benchland, which represents the dominant

Table A-6.6

RAPTORIAL BIRDS OBSERVED IN THE AREA OF CORONACH DEVELOPMENT SITE IN 1975-1976

SPECIES	STATUS	ABUNDANCE	HABITAT
Sharp-skinned hawk	Migrant	Rare	Treed areas
Cooper's hawk	Migrant	Rare	Treed areas
Red-tailed hawk	Summer visitor Migrant	Rare Common	Unrestricted
Swainson's hawk	Summer resident	Fairly common	Grasslands, etc. Nests in trees
Ferruginous hawk	Summer resident	Uncommon in dev. area Common in adjacent	Native Grasslands
Rough-legged hawk	Migrant Winter visitor	Fairly common Rare	Unrestricted
Golden eagle	Permanent resident Winter resident	Uncommon Common	Hill and valley Less restricted in winter
Bald eagle	Migrant	Rare	Large water bodies
Marsh hawk	Summer resident	Common	Native prairie, hayfields, wet areas
Prairie falcon	Summer (non-breeding) Migrant	Uncommon Fairly common	Hill and valley Less restricted during migration
Richardson's merlin	Permanent resident (Non-breeding)	Very uncommon	Grasslands, trees
American kestrel	Summer resident Migrant	Very uncommon Common	Hill and valley, towns, unrestricted
Great horned owl	Permanent resident	Uncommon	Shelterbelts
Snowy owl	Winter visitor	Uncommon, fluctuates	Grainfields, etc.
Short-eared owl	Summer resident(?)	Rare	Creek borders, wet areas
Burrowing owl	Summer resident	Common	Native pastures

Source Blood, et al, 1976

Table A-6.7

OBSERVATIONS OF RAPTORS BY LAND FORM AND VEGETATIONAL COVER IN DANIELS COUNTY FROM APRIL, 1977 THROUGH JUNE, 1978

VEGETATIONAL COVER	UPLAND HABITAT: Grain Crops, Stubble, Summer Fallow	UPLAND HABITAT: Hay Crops	UPLAND HABITAT: Grazed Grasslands	UPLAND HABITAT: Ungrazed Grasslands	UPLAND HABITAT: Brush Patches	UPLAND HABITAT: Homesteads	RIPARIAN HABITAT: Grain Crops, Stubble, Summer Fallow	RIPARIAN HABITAT: Hay Crops	RIPARIAN HABITAT: Grazed Grasslands	RIPARIAN HABITAT: Ungrazed Grasslands	RIPARIAN HABITAT: Brush Patches	RIPARIAN HABITAT: Homesteads	TOTAL
April through June 1977													
Marsh hawk	13		6				1	1	12	1	3		37
Prairie falcon									1				1
American kestrel	1		1										2
Red-tailed hawk	2		1					1					4
Swainson's hawk	2		3	1	1				2				9
Ferruginous hawk			1										1
Rough-legged hawk	1		2										3
Golden eagle	1									1			2
Bald eagle									2				2
Great horned owl	2												2
Burrowing owl									1				1
July through September 1977													
Marsh hawk	50		18		2		3		7		3		93
Prairie falcon					1				1				2
American kestrel	7		3										10
Swainson's hawk	12	1	12	2			2		5				24
Ferruginous hawk			1										1
Rough-legged hawk	1												1
Golden eagle			3						2				5
Great horned owl	1												1
Burrowing owl			15						1				16
Short-eared owl					1				1				2
October through December 1977													
Marsh hawk			2				1		1		1		5
Prairie falcon			2						1				3
Swainson's hawk									1				1
Rough-legged hawk	1												1
January through June 1978													
Marsh hawk	37		15	1			3		13		6		75
Prairie falcon	1								3				4
American kestrel			1										1
Red-tailed hawk			1										1
Swainson's hawk	3		5						3				11
Ferruginous hawk			1						1				2
Rough-legged hawk			1										1
Golden eagle			3						4				7
Great horned owl					1				1				2
Burrowing owl			8										8
Short-eared owl	4		1										5
Snowy owl					1								1

Source DeSimone, 1978a and 1978b

landform in the study area, supported the largest number of deer. The sandhills, located in Sheridan County more than 50 miles east of the Poplar River, accounted for approximately 1 percent of the study area, supported 17 percent of the population. A list of vegetative cover types identified where deer were observed and an estimated percent utilization of these cover types by white-tailed deer is presented in Table A-6.8.

A-6.2.5 Furbearers, Predators and Other Small Mammals

A complete listing of furbearers, predators and other small mammals identified during surveys conducted both in the Coronach Reservoir and plant site development area and the Poplar River drainage basin is presented in Table A-6.9. During studies conducted in Daniels County (DeSimone, 1978a), the muskrat *(Ondatra zibethica)* was the most commonly observed furbearer, followed by the beaver *(Castor canadensis)*, and the mink *(Mustela vison)*. Additionally, a single river otter *(Lutra canadensis)* was observed on the East Fork Poplar River; however, this species is considered rare in the area.

Predators observed during these studies included the coyote *(Canis latvans)*, red fox *(Vulpes fulva)*, longtail weasel *(Mustula frenata)*, striped skunk *(Mephitis mephitis)* and the badger *(Taxidea taxus)*.

Small mammals which were observed include the Richardson's ground squirrel *(Spermophilus richardsoni)*, porcupine *(Erethizon dorsatum)*, white-tailed jackrabbit *(Lepus townsendi)*, mountain cottontail *(Sylvilagus nuttalli)*, field mice *(Peromyscus* spp.*)*. A summary of observations of furbearers, predators and other small mammals in the Poplar River drainage basin in Daniels County which also provides an indication of the relative abundance of the species, is presented in Table A-6.10.

A-6.2.5 Waterfowl

Observations of waterfowl during spring migration indicated the existence of major migratory corridors for numerous species along the East Fork Poplar River, Middle Fork Poplar River, Coal Creek, and the West Fork Poplar River (DeSimone, 1978). A summary of the waterfowl identified and the abundance of ducks and Canada geese within the Poplar River drainage during aerial surveys conducted in the spring of 1977 and 1978 is given in Tables A-6.11 through A-6.14. In addition to Canada geese *(Branta canadensis)* the most common waterfowl observed along these migration corridors during movement between breeding and winter areas include: mallards *(anas platyrhynchos)*, American wigeon *(A. americana)*, gadwalls *(A. strepera)*, and pintails *(A. acuta)*.

Extensive waterfowl inventories have been conducted in a 65 square mile area surrounding the Poplar River generating station in Saskatchewan, referred to here as the development area (Blood, *et al.*, 1976), and in

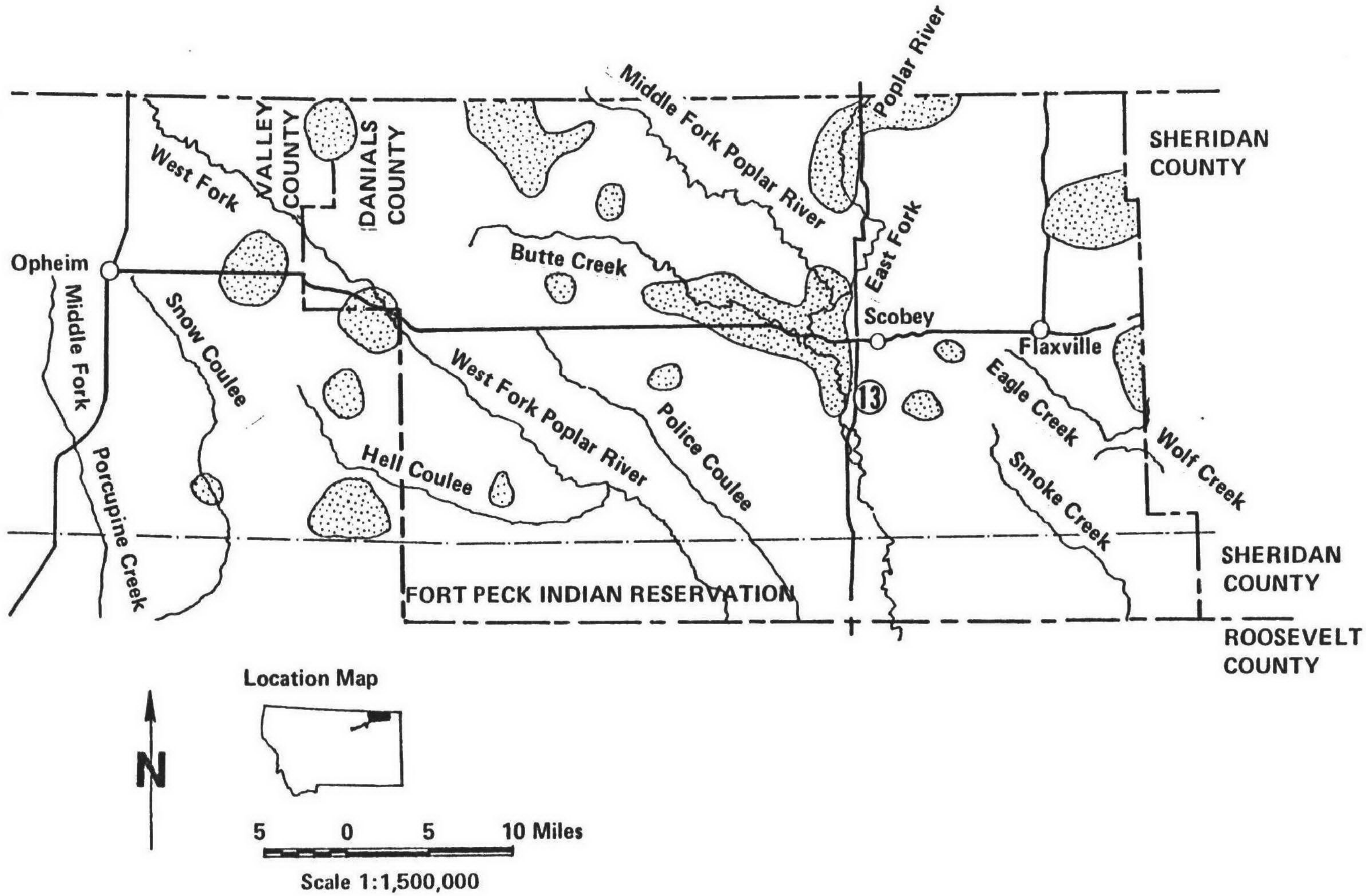


Figure A-6.2 THE APPROXIMATE WINTER DISTRIBUTION OF WHITE-TAILED DEER, BASED ON AERIAL SURVEYS CONDUCTED DURING THE PERIOD NOVEMBER, 1977 - FEBRUARY, 1978 (Stoneberg, 1978)

Table A-6.8

VEGETATIVE COVER TYPES ASSOCIATED WITH WHITE-TAILED DEER OBSERVATIONS AND AN ESTIMATE OF THE PERCENT UTILIZATION OF THESE COVER TYPES

Cover Type	Percent Use by Deer
Cropland	24
Cropland-shrubs	8
Cropland-hedgerows	9
Total Cropland	41
Grassland	2
Grassland-shrubs	26
Grassland-hedgerows	1
Total Grassland	29
Cropland-grassland	16
Cropland-grassland-shrubs	11
Cropland-grassland-hedgerows	1
Total Cropland-grassland	28
Shrubs	1

Source: Stoneberg, 1978

Table A-6.9

FURBEARERS, PREDATORS AND OTHER SMALL MAMMALS OBSERVED IN THE POPLAR RIVER BASIN AND THE CORONACH DEVELOPMENT SITE

Common Name	Scientific Name
Beaver	*Castor canadensis*
Muskrat	*Ondatra Zibethica*
Mink	*Mustela vison*
Raccoon	*Procyon lotor*
Coyote	*Canis latrans*
Red Fox	*Vulpes fulva*
Porcupine	*Erethizon dorsatum*
Badger	*Taxidea taxus*
Longtail weasel	*Mustela frenata*
Striped skunk	*Mephitis mephitis*
Richardson ground squirrel	*Spermophila richardsoni*
Thirteen-lined ground squirrel	*Citellus tridecemlineatus*
Whitetail jackrabbit	*Lepus townsendi*
Mountain cottontail	*Sylvilagus nuttali*
Snowshoe hare*	*Lepus americanus*
Olive-backed pocket mouse*	*Perognathus fasciatus*
Deer mouse	*Peromyscus maniculatus*
Northern grasshopper mouse	*Onychomys leucogaster*
Gapper's red-backed vole*	*Clethrionomys gapperi*
Meadow vole	*Microtus pennsylvanicus*
Sagebrush vole*	*Lagurus curtatus*
House mouse	*Mus musculus*
Masked shrew	*Sorex cinereus*
River otter	*Lutra canadensis*

Source: DeSimone, 1979; Blood, et al., 1976.

*Observed at development site only.

Table A-6.10

OBSERVATIONS OF FURBEARERS, PREDATORS AND OTHER SMALL MAMMALS IN THE POPLAR RIVER DRAINAGE IN DANIELS COUNTY OVER THE PERIOD APRIL, 1977 THROUGH JUNE, 1978

Common Name	Scientific Name	East Fork and Main Poplar River	Middle Fork Poplar River	Coal Creek	Butte Creek	West Fork Poplar River	Uplands	TOTAL
Beaver	*Castor canadensis*	30	2		2	1		35
Muskrat	*Ondatra zibethica*	58	4	1	3	2		68
Mink	*Mustela vison*	12	1			1		14
River Otter	*Lutra canadensis*	1						1
Raccoon	*Procyon lotor*	14	2	3	2	1		22
Coyote	*Canis latrans*	2			2	5		9
Red Fox	*Vulpes fulva*	4	1				1	6
Porcupine	*Erethizon dorsatum*	1					8	9
Badger	*Taxidea taxus*	2			1			3
Longtail weasel	*Mustela frenata*		2					2
Striped skunk	*Mephitis mephitis*	4		1	1	1	3	10
Richardson ground squirrel	*Spermophila richardsoni*						>10	>10
Thirteen-lined ground squirrel	*Citellus tridecemlineatus*	1						1
Whitetail jackrabbit	*Lepus townsendi*	3		1			6	10
Mountain cottontail	*Sylvilagus nuttali*	1						1

Source DeSimone, 1978a and 1978b

Table A-6.11

SPRING CENSUS OF MIGRATORY CANADA GEESE ON MAJOR WATERWAYS IN DANIELS COUNTY, 1977

		April 7	April 21	April 26	May 3
East Fork Poplar River	Singles				
	Pairs				
	Groups				
	Subtotal	0	0	0	0
Middle Fork Poplar River	Singles				
	Pairs	1		1	
	Groups	2(16)[1/]		1(4)	
	Subtotal	18	0	6	0
Coal Creek	Singles			1	1
	Pairs				
	Groups				
	Subtotal	0	0	1	1
Butte Creek	Singles	1			
	Pairs				
	Groups				
	Subtotal	1	0	0	0
West Fork Poplar River	Singles	1	1	4	5
	Pairs	2	1	3	5
	Groups	3(20)	1(3)	2(8)	1(9)
	Subtotal	25	6	18	24
	Total	44	6	25	25

[1/] Figures in brackets give exact number of grouped birds.

Source: DeSimone, 1978a

Table A-6.12

SPRING CENSUS OF DUCKS ON MAJOR WATERWAYS IN DANIELS COUNTY, 1977

		April 7	April 21	April 26	May 3	May 12	May 20	May 27	June 4	June 15
East Fork Poplar River	Singles	5	16	22	58	62	89	97	83	49
	Pairs	72	185	166	140	154	136	72	61	39
	Groups	10(157)	13(185)	21(376)	31(371)	48(166)	33(99)	35(97)	38(142)	36(384)
	Subtotal	306	571	730	709	536	460	338	347	511
Middle Fork Poplar River	Singles	2	2	15	29					
	Pairs	38	69	125	107					
	Groups	7(320)	8(404)	17(463)	19(247)					
	Subtotal	398	544	728	490					
Coal Creek	Singles	3	2	3	10					
	Pairs	8	17	32	29					
	Groups	2(9)	2(19)	4(20)	6(33)					
	Subtotal	28	55	87	101					
Butte Creek	Singles	12	8	7	15					
	Pairs	49	44	38	32					
	Groups	17(368)	7(188)	11(110)	9(64)					
	Subtotal	478	284	193	143					
West Fork Poplar River	Singles	6	11	18	46					
	Pairs	65	118	189	123					
	Groups	11(272)	20(357)	31(432)	54(518)					
	Subtotal	408	604	838	810					
	Total	1618	2058	2566	2253	536	460	338	347	511

Figures in brackets give exact number of grouped birds.

Source DeSimone, 1978a

Table A-6.13

CENSUS OF CANADA GEESE ON THE POPLAR RIVER IN DANIELS COUNTY DURING SPRING, 1978

Date	Location	Singles	Pairs	Young No. Broods/ No. Young	Total Adults/Young
April 14	West Fork	-	3	-	6/-
May 1	West Fork	2	3	-	8/-
May 11	West Fork	4	4	-	12/-
May 18	Main River	-	1	-	2/-
May 20	Main River	-	1	-	2/-
May 20	West Fork	2	4	2/5	10/5
May 27	West Fork	-	9	3/9	18/9
June 9	West Fork	-	3	2/5	6/5

Source: DeSimone, 1978b

Table A-6.14

AERIAL CENSUS OF DUCKS ON THE POPLAR RIVER IN DANIELS COUNTY DURING SPRING, 1978

		Mallards	American Wigeon	Pintails	Gadwalls	Blue-Winged Teal	Northern Shovelers	Lesser Scaup	Common Merganser	Coots	Other Ducks	Unidentified	TOTAL
April 14	East Fork	46	25	42	-	-	-	-	-	-	-	111	224
	Main River	77	19	31	2	-	1	-	-	-	-	394	524
	Middle Fork	107	33	30	1	-	1	-	-	-	-	264	436
	Coal Creek	7		4	-	-	-	-	-	-	-	26	37
	Butte Creek	21	20	11	-	-	-	-	-	-	-	76	128
	West Fork	63	20	51	5	-	2	-	-	-	-	714	855
	Total	321	117	169	8	-	4	-	-	-	-	1585	2204
May 1	East Fork	85	38	28	8	9	14	6	-	-	-	42	230
	Main River	81	60	18	11	1	-	-	-	-	-	-	171
	Middle Fork	142	39	19	16	4	1	-	-	-	-	21	242
	Coal Creek	14	-	-	-	-	-	-	-	-	-	-	14
	Butte Creek	46	17	4	3	4	2	-	-	-	-	3	79
	West Fork	97	30	40	10	6	2	2	15	-	-	101	303
	Total	465	184	109	48	24	19	8	15	-	-	167	1039
May 11	East Fork	74	54	38	45	21	8	5	-	1	-	6	252
	Main River	102	72	17	30	5	2	-	-	38	-	1	267
	Middle Fork	120	51	13	31	6	3	-	-	2	3	4	233
	Coal Creek	20	2	2	2	-	1	-	-	-	-	1	28
	Butte Creek	65	28	7	7	17	10	5	-	-	-	-	139
	West Fork	98	51	42	45	18	7	6	13	8	11	4	303
	Total	479	258	119	160	67	31	16	13	49	14	16	1222
May 20	East Fork	85	55	26	54	5	12	2	6	-	2	4	251
	Main River	101	46	11	33	13	3	-	-	-	-	-	207
	Middle Fork	144	64	24	53	8	18	1	-	-	2	16	330
	Coal Creek	36	9	6	3	3	-	-	-	-	-	3	60
	Butte Creek	71	21	5	21	3	6	-	1	-	-	-	128
	West Fork	98	44	36	42	6	3	-	14	-	-	5	248
	Total	535	239	108	206	38	42	3	21	0	4	28	1224

Table A-6.14 (continued)

		Mallards	American Wigeon	Pintails	Gadwalls	Blue-Winged Teal	Northern Shovelers	Lesser Scaup	Common Merganser	Coots	Other Ducks	Unidentified	TOTAL
May 27	East Fork	69	35	9	49	8	11	-	-	-	-	4	185
	Main River	121	44	9	33	6	10	-	-	-	-	2	225
	Middle Fork	168	59	12	44	10	13	2	4	-	-	4	316
	Coal Creek	18	7	-	3	-	-	-	-	-	-	3	31
	Butte Creek	88	23	12	18	3	6	-	-	-	6	15	171
	West Fork	141	58	16	44	8	12	3	2	-	4	57	345
	Total	605	226	58	191	35	52	5	6	-	10	85	1273
June 9	East Fork	89	50	1	44	4	2	-	2	-	-	9	201
	Main River	104	40	2	28	8	5	-	-	1	-	50	238
	Middle Fork	112	53	3	32	4	3	-	-	-	-	4	211
	Coal Creek	17	4	0	2	-	1	-	-	-	-	-	24
	Butte Creek	100	18	2	12	2	3	-	-	-	-	13	150
	West Fork	171	81	2	59	10	8	1	-	-	-	41	373
	Total	593	246	10	177	28	22	1	2	1	0	117	1197

Source: DeSimone, 1978b

Montana exclusive of the Fort Peck Indian Reservation (DeSimone, 1977 and 1978). The results of these studies have provided information concerning the utilization and importance of these areas as breeding areas for several species of ducks.

Breeding pairs of several species of dabbling ducks have been recorded along stream or river bottom areas within the Poplar River Basin, and waterfowl production in these areas is significant (Blood, et al., 1976; DeSimone, 1978). Mallards and American wigeon are the most abundant species found in the breeding areas, but nesting gadwalls, pintail, blue-winged teal *(Anas discors)*, northern shovelers *(A. Clypeata)*, green-winged teal *(A. crecca carolinensis)*, and canvasbacks *(Aytha valisineria)* have also been observed in the study area (Blood, et al., 1976; DeSimone, 1978a).

Characteristic differences exist in nesting habitat selection, as well as the behavior and the food preferences of the aforementioned species. The chronology of migration and breeding cycles are similar, however (Bellrose, 1976). Although yearling males are less likely to breed than older birds, most dabbling ducks breed as yearlings. In general, a loose pair bond is established in the wintering area, and a northward migration to nesting areas commences as early as February with most ducks arriving in the breeding area by mid-April. Upon arrival in the breeding area, each pair selects a waiting or resting site. A certain degree of spacing is maintained in these areas which effectively limits the number of pairs that a particular breeding ground can accommodate. Within a few days following the selection of a waiting site, the pair begins to fly over the adjacent area and subsequently selects the nesting site. A great deal of variation exists in the preferred vegetation cover for the nesting areas of these dabblings, but they are generally located in upland areas within a range of a few meters to 100 m of the water. Clutch size is variable and species specific, but generally these ducks lay from 5-15 eggs per nest. Nest success varies greatly with nest habitat and is influenced by predation and land-use practices. Ducklings pass through three distinct classes defined by stages in the appearance of a full complement of body feathers. The young are generally capable of flight after 50-60 days.

The pair bond between the drake and hen lasts until the initiation of incubation. At this time the drakes begin to leave the home ranges and collect in large numbers for their eclipse molt prior to the winter migration. During this period of time, usually 3-4 weeks, the drakes remain flightless. Hens with successful nests stay with the broods until the young can fly, then molt in the rearing area or move to areas occupied by molting drakes. By late August or early September, large groups of flying young, drakes and hens gather in feeding areas prior to the migration to wintering areas.

Waterfowl production on potholes in the development area and on the Coronach Reservoir is low, but production is considered significant in the wetland habitat along two streams (Blood, et al., 1976). Brood surveys conducted along the East Poplar River and Girard Creek during the period July-August, 1975, indicated the presence of eight species of brooding pairs along these watercourses. The most abundant species identified in these surveys was the mallard; breeding pair densities of 0.92 and 2.0 broods per river mile were reported on Girard Creek and East Poplar River, respectively. Other species observed in these surveys in order of decreasing abundances include: gadwall, blue-winged teal, American wigeon, pintail, northern shoveler, canvasbacks, and green-winged teal. The overall density of breeding waterfowl was estimated to be 4.3 broods per mile on the East Poplar River and 3.5 broods per mile on Girard Creek. A summary of the actual number of broods observed, breeding pair density and mean brood size of each species observed in the surveys conducted in the development area is provided in Table A-6.15.

Observations of waterfowl were made during spring migrations on four portions of the East Fork Poplar River in Daniels County, Montana in 1977 (DeSimone, 1978) and along the East Fork Poplar River as well as portions of the Middle Fork Poplar River, Coal Creek, Butte Creek, and West Fork Poplar River in Daniels County in 1978 (DeSimone, 1978). These observations included not only census information as noted above but also estimates of the breeding pair population, waterfowl production, and the hatching chronology of waterfowl broods.

Studies conducted during the period April-June, 1977, indicated mallards were the predominant breeding duck along the East Fork Poplar River; a total of 160 breeding pairs were counted along the 50.8 miles of the river studied. American wigeon were the next most common breeder followed by pintails, gadwalls, blue-winged teal, and northern shovelers. An average of five breeding pairs of ducks per mile was estimated in these areas. A summary of the breeding pair densities observed along the four sections of the river inventoried is provided in Table A-6.16.

In addition to those species of breeding pairs observed along the East Fork Poplar River during the previous year, the lesser scaup *(Aythya affinis)* and the common merganser *(Mergus merganser)* were observed in the area during the spring of 1978 and were considered probable breeders, but broods were not observed (DeSimone, 1978). The highest density of breeding pairs were observed on the East Fork Poplar River followed in order by those areas added during the 1978 breeding survey: the Middle Fork, Main Fork, West Fork, Butte Creek, and Coal Creek. An average of 3.7 breeding pairs per mile was estimated over the total 200.5 miles of the watercourses surveyed. The breeding pair densities of each species observed in the areas studied during 1978 and provided in Table A-6.17. Moreover, data concerning brood production and reproduction success on the East Poplar and main Poplar River during 1977 and 1978 are presented in Table A-6.18.

Table A-6.15

NUMBER OF BREEDING PAIRS (BROODS). BREEDING PAIR DENSITIES AND BROOD SIZES ON GIRARD CREEK AND THE EAST POPLAR RIVER IN THE DEVELOPMENT AREA BASED ON SURVEYS CONDUCTED IN 1975

Species	Number of Broods Counted in Survey Areas		Estimated Breeding Pair Density (Number of breeding pairs/mile of river)		Mean Brood Size
	Girard Creek	E. Poplar River	Girard Creek	E. Poplar River	
Mallard (*Anas platyrhynchos*)	13	7	0.92	2.00	7.4
Gadwall (*A. strepera*)	11	2	0.77	0.57	8.1
Blue-winged Teal (*A. discors*)	11	1	0.77	0.29	8.1
American Wigeon (*A. americana*)	5	0	0.35	0.00	8.2
Pintail (*A. acuta*)	5	0	0.35	0.00	8.3
Northern Shoveler (*A. clypeata*)	3	5	0.21	1.43	7.2
Canvasback (*A.*	1	0	0.07	0	7.0
Green-winged Teal (*A.*	1	0	0.07	0	4.0

Source. Blood, et al., 1976

Table A-6.16

BREEDING PAIR DENSITIES OBSERVED ALONG FOUR CONTIGUOUS SECTIONS OF THE EAST FORK POPLAR RIVER IN 1977*

Species	Densities (breeding pair/mile) in Designated Study Areas			
	1	2	3	4
Mallard (*A. platyrhynchos*)	3.23	2.94	3.03	3.57
American Wigeon (*A. americana*)	1.10	0.53	0.81	0.65
Pintail (*A. acuta*)	0.56	0.42	0.36	0.36
Blue-winged Teal (*A. clypeata*)	0.11	0.18	0.27	0.43
Gadwall (*A. strepera*)	0.44	0.18	0.49	0.43
Northern Shoveler (*A. clypeata*)	0.11	0.18	0.09	0.15
TOTAL (pairs/mile)	5.55	4.35	5.00	5.55

*Sections ran from Canadian boarder to the northern boundary of the Fort Peck Indian Reservation.

Source: DeSimone, 1978

Table A-6.17

BREEDING PAIR DENSITIES OBSERVED ON THE POPLAR RIVER SYSTEM IN DANIELS COUNTY DURING THE SPRING OF 1978

Species	Densities (breeding pair/mile) in Designated Study Areas					
	East Fork	Main River	Middle Fork	Coal Creek	Butte Creek	West Fork
Mallard (*A. platyrhynchos*)	2.86	2.44	2.77	1.33	1.49	1.12
American Wigeon (*A. americana*)	1.41	1.00	1.00	0.31	0.40	0.53
Pintails (*A. acuta*)	0.89	0.32	0.32	0.16	0.09	0.30
Gadwalls (*A. strepera*)	1.12	0.48	0.53	0.08	0.25	0.31
Blue-winged Teal (*A. clypeata*)	0.14	0.16	0.11	0.08	0.03	0.07
Northern Shoveler (*A. clypeata*)	0.14	0.10	0.13	-	0.09	0.04
Lesser Scaup (	0.05	-	0.03	-	-	0.01
Common Merganser (	0.05	-	-	-	-	0.03
MEAN (pairs/mile)	6.66	4.55	5.00	1.96	2.38	2.44

Source: DeSimone, 1978

Table A-6.18

NUMBER AND AVERAGE BROOD SIZE OF DUCK BROODS OBSERVED ON THE EAST POPLAR AND MAIN POPLAR RIVER DURING 1977 AND 1978

	Class I[1/]			Class II[2/]			Class III[3/]		
	No. Broods	No. Young	Average Brood Size	No Broods	No. Young	Average Brood Size	No. Broods	No. Young	Average Brood Size
Mallards									
1977	28	143	5.1	37	148	4.0	46	156	3.4
1978	14	97	6.9	34	167	4.9	12	85	7.1
American Wigeon									
1977	10	59	5.9	17	72	4.2	12	64	5.3
1978	12	85	7.1	25	164	6.6	4	17	4.3
Pintails									
1977	7	28	4.0	4	17	4.3	3	8	2.7
1978	1	9	9.0	5	29	5.8	1	8	8.0
Gadwall									
1977	11	70	6.4	6	30	5.0	10	48	4.8
1978	6	54	9.0	7	39	5.6	3	38	12.7
Blue-winged Teal									
1977	5	29	5.8	2	7	3.5	7	30	4.3
1978	10	70	7.0	9	66	7.3	4	24	6.0
Northern Shoveler									
1977	-	-	-	2	9	4.5	1	3	3.0
1978	1	7	7.0	2	16	8.0	1	5	5.0
Total									
1977	61	322	5.3	68	283	4.2	79	309	3.9
1978	44	322	7.3	82	481	5.9	25	177	7.1

[1/] Broods from 3 to 17 days old.

[2/] Broods from 18 to 40 days old.

[3/] Broods from 41 days old to flight.

Source DeSimone, 1978b

A-6.2.6 Rare and Endangered Species

Nongame species designated as being of special interest or concern in the area of Daniels County are given in Table A-6.19. This list was compiled by the Montana Department of Fish and Game (Flath, 1970). The species included are considered rare or sensitive to environmental changes. Four animals, the Black-footed ferret, Wolf, Bald eagle and Peregrine falcon, are also on the current Federal rare and endangered list. Any effects of the operation of the proposed facilities on the species listed would be of a secondary nature, i.e., changes in the terrestrial environment or habitat loss, but the previously presented impact assessments (Section 5.6) do not provide evidence that these species will be significantly affected by the Canadian power plants or flow apportionment.

Table A-6.19

LIST OF NONGAME SPECIES OF SPECIAL INTEREST OR CONCERN IN DANIELS COUNTY, MONTANA (Flath, 1978)

	Status			
	Known Occurrence	Suspected Occurrence	Potential Occurrence	Former Range
Mammals				
Pygmy shrew			X	
Preble shrew			X	
Black-footed ferret			X	X
Least Weasel		X		
Swift fox				X
Wolf			X	X
Black-tailed prairie dog			X	
Reptiles				
Snapping turtle			X	
Plains hognose		X		
Amphibians				
Dakota toad	X			
Birds				
Goshawk			X	X
Sharp-shinned hawk			X	
Cooper's hawk			X	
Ferruginous hawk			X	
Golden eagle			X	
Bald eagle	X			
Marsh hawk		X		
Osprey			X	
Gyrfalcon			X	X
Prairie falcon			X	X
Peregrine falcon			X	X
Pigeon hawk	X			
Mountain plover		X		
American golden plover			X	
Sanderling			X	
Snowy owl			X	X
Burrowing owl	X			
Great gray owl			X	
Long-eared owl			X	
Saw-whet owl			X	X
Eastern bluebird	X			
Dickcissel			X	

KEY

X indicates occurrence of species.

Underlined species are also on the Federal rare and endangered list.

Table A-6.20

OBSERVATIONS OF AVIFAUNA IN THE CORONACH STUDY AREA
AND IN THE DANIELS COUNTY STUDY AREA DURING
1977-1978

		Daniels Co.	Coronach
Red-throated Loon	*Gavia Stellata*		X
Horned grebe	*Podiceps auritus*	X	
Red-necked grebe	*Podiceps grisegena*		X
Western grebe	*Aechmophorns accidentalis*		X
Eared grebe	*Podiceps nigricollis*	X	
Pied-billed grebe	*Podilymbus podiceps*	X	X
White pelican	*Pelecanus erythrorhynchos*	X	X
Double-crested cormorant	*Phalacrocorax auritus*	X	X
Great blue heron	*Ardea herodias*	X	X
Black-crowned night heron	*Nycticorax nycticorax*	X	X
American bittern	*Botaurus lentiginosus*	X	X
Whistling swan	*Olor columbianus*	X	
Canada goose	*Branta canadensis*	X	
Snow goose	*Chen caerulescens*	X	
Mallard	*Anas platyrhynchos*	X	X
Gadwall	*Anas strepera*	X	X
Pintail	*Anas acuta*	X	X
Green-winged teal	*Anas crecca*	X	X
Blue-winged teal	*Anas discors*	X	X
American wigeon	*Anas americana*	X	X
Northern shoveler	*Anas clypeata*	X	X
Redhead	*Aythya americana*	X	
Ring-necked duck	*Aythya collaris*	X	
Canvasback	*Aythya valisineria*	X	X
Lesser scaup	*Aythya affinis*	X	
Common goldeneve	*Bucephala clangula*	X	
Bufflehead	*Bucephala albeola*	X	
Ruddy duck	*Oxyura jamaicensis*	X	
Common merganser	*Mergus merganser*	X	
Sharp-shinned hawk	*Accipiter striatus*		X
Cooper's hawk	*Accipiter cooperii*		X
Red-tailed hawk	*Buteo jamaicensis*	X	X
Swainson's hawk	*Buteo swainsoni*	X	X
Rough-legged hawk	*Buteo lagopus*	X	X
Ferruginous hawk	*Buteo regalis*	X	X
Golden eagle	*Aquila chrysaetos*	X	X
Bald eagle	*Haliaeetus leucocephalus*	X	X
Piping plover	*Charadrius melodus*		X

Table A-6.20 (continued)

		Daniels Co.	Coronach
Osprey	*Pandion haliaetus*		x
Marsh hawk	*Circus cyaneus*	x	x
Merlin	*Falco columbarius*		x
Merlin	*Falco Columbarius richardsonii*		x
Prairie falcon	*Falco mexicanus*	x	x
Whooping crane	*Grus americana*		x
American kestrel	*Falco sparverius*	x	x
Sharp-tailed grouse	*Pedioecetes phasianellus*	x	
Sage grouse	*Centrocercus urophasianus*	x	
Ring-necked pheasant	*Phasianus colchicus*	x	
Gray partridge	*Perdix perdix*	x	
Sandhill crane	*Grus canadensis*	x	x
Sora	*Porzana carolina*	x	
Virginia rail	*Rallus limicola*	x	
American coot	*Fulica americana*	x	
Killdeer	*Charadrius vociferus*	x	x
Black-bellied plover	*Squatarola squatarola*	x	
Common snipe	*Capella gallinago*	x	
Long-billed curlew	*Numenius americanus*	x	
Upland sandpiper	*Bartramia longicauda*	x	x
Spotted sandpiper	*Actitis macularia*	x	
Solitary sandpiper	*Tringa solitaria*	x	
Willet	*Catoptrophorus semipalmatus*	x	
Greater yellowlegs	*Tringa melanoleuca*	x	
Lesser yellowlegs	*Tringa flavipes*	x	
Pectoral sandpiper	*Calidris melanotos*	x	
Baird's sandpiper	*Calidris bairdii*	x	
Long-billed dowitcher	*Limnodromus scolopaceus*	x	
Marbled godwit	*Limosa fedoa*	x	x
American avocet	*Recurvirostra americana*	x	
Wilson's phalarope	*Steganopus tricolor*	x	
Northern phalarope	*Lobipes lobatus*	x	
California gull	*Larus californicus*	x	
Ring-necked gull	*Larus delawarensis*	x	
Franklin's gull	*Larus pipixcan*	x	
Common tern	*Sterna hirundo*	x	
Black tern	*Chlidonias niger*	x	
Rock dove	*Columbalivia*	x	
Mourning dove	*Zenaida macroura*	x	
Great horned owl	*Bubo virginianus*	x	x
Snowy owl	*Nyctea scandiaca*	x	x

Table A-6.20 (continued)

		Daniels Co.	Coronach
Burrowing owl	*Speotyto cunicularia*	x	x
Short-eared owl	*Asio flammeus*	x	x
Common nighthawk	*Chordeiles minor*	x	x
Belted kingfisher	*Megaceryle alcyon*	x	
Common flicker	*Colaptes auritus*	x	
Downey woodpecker	*Dendrocopos pubescens*	x	
Red-headed woodpecker	*Melanerpes erythrocephalus*	x	
Eastern kingbird	*Tyrannus tyrannus*	x	x
Western kingbird	*Tyrannus verticalis*	x	
Say's phoebe	*Sayornis saya*	x	
Horned lark	*Eremophila alpestris*	x	x
Tree swallow	*Iridoprocne bicolor*	x	
Bank swallow	*Riparia riparia*	x	x
Rough-winged swallow	*Stelgidopteryx ruficollis*	x	
Barn swallow	*Hirundo rustica*	x	x
Cliff swallow	*Petrochelidon pyrrhonota*	x	x
European starling	*Sturnus vulgaris*		x
Sprague's pipit	*Anthus spragueii*		x
Black-billed magpie	*Pica pica*	x	
Common crow	*Corvus brachyrhynchos*	x	
Red-breasted nuthatch	*Sitta canadensis*	x	
Brown creeper	*Certhia familiaris*	x	
House wren	*Troglodytes aedon*	x	
Gray catbird	*Dumetella carolinensis*	x	
Brown thrasher	*Toxostoma rufum*	x	
American robin	*Turdus migratorius*	x	
Swainson's thrush	*Hylocichla guttata*	x	
Mountain bluebird	*Sialia currucoides*	x	
Ruby-crowned kinglet	*Regulus calendula*	x	
Bohemian waxwing	*Bombycilla garrulus*	x	
Cedar waxwing	*Bombycilla cedrorum*	x	
Loggerhead shrike	*Lanius ludovicianus*	x	x
Starling	*Sturnus vulgaris*	x	
Black-and-white warbler	*Mniotilta varia*	x	
Tennessee warbler	*Vermivora peregrina*	x	
Yellow warbler	*Dendroica petechia*	x	
Magnolia warbler	*Dendroica magnolia*	x	
Blackpoll warbler	*Dendroica striata*	x	
Ovenbird	*Seiurns aurocapillus*	x	
Northern waterthrush	*Seiurus noveboracensis*	x	

Table A-6.20 (continued)

		Daniels Co.	Coronach
Common yellowthroat	*Geothlypis trichas*	x	
Yellow-brested chat	*Icteria virens*	x	
American redstart	*Setophaga ruticilla*	x	
Bobolink	*Dolichonx oryzivorus*	x	
Western meadowlark	*Sturnella neglecta*	x	x
Yellow-headed blackbird	*Xanthocephalux xanthocephalus*	x	
Red-winged blackbird	*Agelaius phoeniceus*	x	x
Brewer's blackbird	*Euphaga cyanocephalus*	x	x
Common grackle	*Quiscalus guiscula*	x	
Brown-headed cowbird	*Molothrus ater*	x	x
Common redpoll	*Acanthis flammea*		x
Rose-breasted grosbeak	*Pheucticus ludovicianus*	x	
American goldfinch	*Spinus tristis*	x	
Rufous-sided towhee	*Pipilo erythrophthalmus*	x	
Lark bunting	*Calamospiza melanocorys*	x	x
Savannah sparrow	*Passervulus sandwichensis*	x	x
Grasshopper sparrow	*Ammodramus savannarum*	x	x
Baird's sparrow	*Ammodramus bairdii*		x
Vesper sparrow	*Pooecetes gramineus*	x	
Dark-eyed junco	*Junco hyemalis*	x	
Tree sparrow	*Spizella arborea*	x	
Chipping sparrow	*Spizella passerina*	x	
Clay-colored sparrow	*Spizella pallida*	x	x
White-crowned sparrow	*Zonotrichia leucophrys*	x	
Song sparrow	*Melospiza melodia*	x	
Chestnut-collared longspur	*Calcarius ornatus*	x	x
McCown's Longspur	*Rhynchophanes mccownii*		x
Snow bunting	*Plectrophenax nivalis*	x	

Appendix A-7. Aquatic Biota

A-7.1 PHYCOPERIPHYTON

The phycoperiphyton of the Poplar River system were surveyed on three dates during 1975 and 1976 by Bahls (1977). The pooled data revealed that the Poplar River supports a diverse diatom periphyton community comprised of 189 diatom taxa comprising 34 genera. In addition, 31 genera of non-diatoms were also observed.

The 26 most abundant diatom taxa and their pooled percent relative abundance (PRA) values are presented in Table A-7.1. The two most abundant species were *Nitzschia frustulum* var. *Subsalina* and *Epithemia sorex*. *Nitzschia* and *Navicula* were the most common genera based on total number of observed species.

The non-diatom periphyton were dominated by members of the chlorophyta (green algae) and Cyanophyta (blue-green algae). The dominant chlorophyte species were *Cladophora* and *Stigeodonium*, which were observed to occur in all of the river segments. The blue-green alga *Rivularia* was also common in all river segments.

A comparison of the five river segments (East Fork, Middle Fork, West Fork, Poplar River prior to West Fork, and Poplar River below West Fork), which are ranked by percent similarity indices, is presented in Table A-7.2. The paired comparisons indicate that the East and West Forks are the most floristically dissimilar segments of the river. Moreover, both of these forks are quite dissimilar from the downstream segments. The Middle Fork displayed the highest similarity with the downstream segments of the main Poplar River.

The dissimilar floral nature of the West and East Forks is also indicated by their numbers of "exclusive" phycoperiphyton taxa, which were 16 and 26, respectively. The "exclusive" taxa of the main Poplar River segment and West Fork ranged from five to eight. The West and East Forks also had similarly low PRA *Nitzschia* species (34.1 and 32.2, respectively) when compared to the higher values reported for the Middle Fork and main stem Poplar River. The PRA *Nitzschia* value has been used as an indicator of the relative magnitude of nitrogenous pollution.

The mean diatom diversity indices (Margalef and Simpson) for the Poplar River were compared to those of other Montana streams by Bahls (1977). A comparison of the seven streams (Flathead River, East Gallatin River, North Fork Dry Creek, North Fork Fivemile Creek, Clarks Forks River, and Tongue River) indicated that the Poplar River displayed either the highest (Margalef's) or second highest (Simpson's) diversity. These results indicate that the Poplar River is a favorable environment for diatoms and no evidence of severe stress (as indicated by low diversity) was observed.

Table A-7.1

DIATOM TAXA IN THE POPLAR RIVER SAMPLES HAVING A POOLED PRA OF 1.0 OR GREATER

Taxa	Number of Samples	Pooled PRA
Achnanthes minutissima	14	1.3
Amphora ovalis var. *pediculus*	16	4.6
Caloneis bacillum	14	1.0
Cyclotella meneghiniana	18	1.6
Diatoma tenue (including var. *elongatum*)	16	3.7
Epithemia sorex	18	9.6
Epithemia turgida	18	1.4
Fragilaria construens var. *venter*	14	6.4
Fragilaria vaucheriae	15	1.3
Gomphonema angustatum	13	2.2
Gomphonema parvulum	13	1.2
Navicula atomus	9	1.1
Navicula cryptocephala var. *veneta*	18	2.4
Navicula secreta var. *apiculata*	17	1.4
Nitzschia acicularis	17	2.3
Nitzschia dissipata	17	6.0
Nitzschia epiphytica	13	1.5
Nitzschia filiformis	13	2.2
Nitzschia frustulum	17	2.1
Nitzschia frustulum var. *subsalina*	18	12.2
Nitzschia palea	18	5.0
Nitzschia paleacea	14	5.0
Rhopalodia gibba	17	1.1
Stephanodiscus minutus	16	5.2
Synedra radians	12	3.4
Synedra ulna	15	1.9

Source: Bahls, 1977

Table A-7.2

PAIRED COMPARISONS OF PERIPHYTON PERCENT SIMILARITY INDICES (PSI) FOR POPLAR RIVER SEGMENTS

Rank	Segment Pair[1]	PSI
1	EM, PR	78.50
2	EF, MF	61.00
3	MF, EM	60.10
4	MF, PR	59.70
5	EF, PR	54.30
6	MF, WF	52.35
7	EF, EM	51.05
8	WF, PR	50.15
9	EM, WF	47.25
10	EF, WF	46.60

[1]Segment identifications: Poplar River, PR: East Fork, EF; West Fork, WF; Middle Fork, MF; Poplar River above West For, EM.

Source: Bahls, 1977

A-7.2 MACROPHYTES

Limited information is available concerning the present submerged aquatic macrophyte distribution in the Poplar River Basin. A field survey conducted by the Biological Resources Committee of the International Poplar River Water Quality Board (IPRWQB, IJC, 1979) on 24 May 1978 indicated that the upper East Fork was dominated by the submerged macrophytes *Myriophyllum exalbescens* and *Potamogeton* sp. Other plants observed included emergent forms such as *Carex* sp., *Eleocharis* sp., *Scirpus* sp. and *Typha* sp. (rushes, sedges and cattails). Other sections of the Poplar River did not have the significant macrophyte growth observed in the East Fork.

An aerial infrared survey of emergent macrophytes was conducted over several segments of the Poplar River during July 1979 (DeSimone, 1980). Five river segments totalling 10.3 miles were surveyed: two segments on the upper East Fork, two segments on the lower East Fork and one segment on the main river below the confluence of the Middle Fork. Although emergent vegetation was observed in all river segments, the highest percent coverage (40%) occurred in the upper East Fork near the International Boundary. Emergent coverage in the other three East Fork sections ranged from 5.8 to 21.6 percent. Weighted average coverage (based on survey distance) for the East Fork was 13.8 percent. The main river had the lowest coverage at 2.3 percent.

A-7.3 BENTHIC MACROINVERTEBRATES

Only limited data are available on the benthic macroinvertebrates of the Poplar River Basin. Montana Department of Fish and Game (1978) reported riffle bottom faunal densities during two sampling dates in 1977 (22 March and 29 June). The bottom communities were dominated by three orders of aquatic insect larvae: Diptera, Ephemeroptera and Trichoptera (Table A-7.3). These three orders comprised over 96 percent of the organisms collected from most river segments. The upper East Fork (near the border) was quite different in that about 30 percent of the samples were comprised of gammaridean amphipods. Amphipods, decapods, annelids, molluscs and other insect larvae were observed infrequently in all other parts of the Poplar River Basin. The large freshwater clam, *Anodontis gradis*, was commonly observed throughout the Poplar River drainage.

The mean densities (per square foot) of total organisms during the March and June sampling periods were 616 and 804, respectively. Total densities were quite variable, both spatially and temporally, and ranged from five to over 6,000 per square foot.

In general, the highest densities of total macroinvertebrates occurred in the mainstem Poplar River and the lower reaches of the West and Middle Forks (Table A-7.4). Lowest total densities were measured in the Upper East Fork.

Table A-7.3

MEAN PERCENT COMPOSITION OF JUNE BENTHIC MACROINVERTEBRATE SAMPLES IN THE POPLAR RIVER DRAINAGE

	Ephemeroptera	Diptera	Trichoptera	Other
Upper East Fork	0.7	25.1	45.0	29.2
Lower East Fork	11.5	19.8	65.6	3.1
Lower Middle Fork	30.7	13.3	54.8	1.2
Lower West Fork	81.2	13.0	3.8	2.0
Mid-Poplar River (above West Fork)	20.0	0.5	79.4	0.1
Mainstem Poplar River	46.8	1.6	51.4	0.2

Source: Montana Department of Fish and Game, 1978

Table A-7.4

MEAN DENSITIES (NO./FT^2) OF TOTAL BENTHIC MACROINVERTEBRATES IN RIFFLE AREAS DURING 1977

River Segment	March	June
Upper East Fork	735	400
Lower East Fork	298	237
Upper Middle Fork	79	*
Lower Middle Fork	578	880
Mid-West Fork	718	595
Lower West Fork	170	1,042
Upper Poplar River (near Scobey)	2,595	974
Mid-Poplar River (above West Fork)	329	1,471
Mainstem Poplar River	37	827

*Insufficient flow for sample collection.

Source: Montana Department of Fish and Game, 1978

An unpublished benthic fauna survey conducted at eight Poplar River sites by the U.S. Environmental Protection Agency was cited in the Biological Resources Committee report (IPRWQB, IJC, 1979). Dominant taxa for the East Fork, West Fork and Main Poplar near Scobey are listed in Table A-7.5.

The average total macroinvertebrate densities in the river segments studied were remarkably similar at about 39,000 per m^2. However, the taxonomic composition was distinct among sampling sites. The East Fork was dominated by Diptera (83%) with a relatively low occurrence of Ephemeroptera (6%). The West Fork and upper Poplar River dominant macroinvertebrate assemblages were generally similar, being comprised of about 37-39 percent dipterans and 50-55 percent trichoptera. Of the dominant Trichoptera and Ephemeroptera taxa in the Poplar River, most are characteristic of lotic environments. Some taxa, such as *Caenis*, may be found in either lotic or lenthic habitats.

A-7.4 FISH

The earliest comprehensive survey of the fishes of the Poplar River Basin was conducted during 1975 by Montana Department of Fish and Game (1976). The game fish populations were comprised of three species: Walleye, *Stizostedion vitreum*; Northern Pike, *Esox lucius* and smallmouth bass, *Micropterus dolomieui*. Although it is not classified as a game fish in Montana, Goldeye *(Hiodon alosoides)* were also collected. The goldeye is occasionally utilized by anglers as sport fish in the basin.

A total of 28 species of fish was identified in the Poplar River Basin, belonging to ten families (Table A-7.6). Approximately half of the total species observed would be considered forage fish and are included in the families Cyprinidae and Catostomidae. White sucker, lake chub, shorthead redhorse, longnose dace and fathead minnow were commonly observed throughout the drainage area. Several species (e.g., freshwater drum, channel catfish and burbot) occurred only in the lower mainstem of the Poplar River near its confluence with the Missouri River.

Game fish were found to have a widespread distribution in the Poplar River Basin (Montana Fish and Game, 1978). The two major species, Walleye and Northern Pike, occurred in relatively high densities in all areas except the middle and upper reaches of the West Fork and in the Upper East Fork.

Numbers of walleye per river mile ranged from 23 to 276 (Figure A-7.1). Densities of walleye were highest in the Middle Fork and lowest in the upper West and East Forks.

Table A-7.5

DOMINANT MACROINVERTEBRATE TAXA COLLECTED IN THE POPLAR RIVER

Taxa	West Fork	East Fork	Upper Poplar
Epheneroptera			
Baetıs sp.	X*		X
Caerrıs sp.	X	X	
Pseudocloeon sp.	X		X
Paraleptophlebia sp.	X		
Heptagenia sp.	X		
Trichoptera			
Cheumatopsyche sp.	X	X	X
Hydropsyche sp.	X	X	X
Agraylea sp.	X	X	
Diptera			
Conchapelopia sp.	X	X	X
Thiemanniella sp.	X		
Rheotanytarsus sp.	X	X	X
Cricotopus sp.	X	X	X
Polypedilum sp.			X
Orthocladius sp.		X	X
Simuliidae		X	X
Aphıpoda		X	
Hydracarina	X		

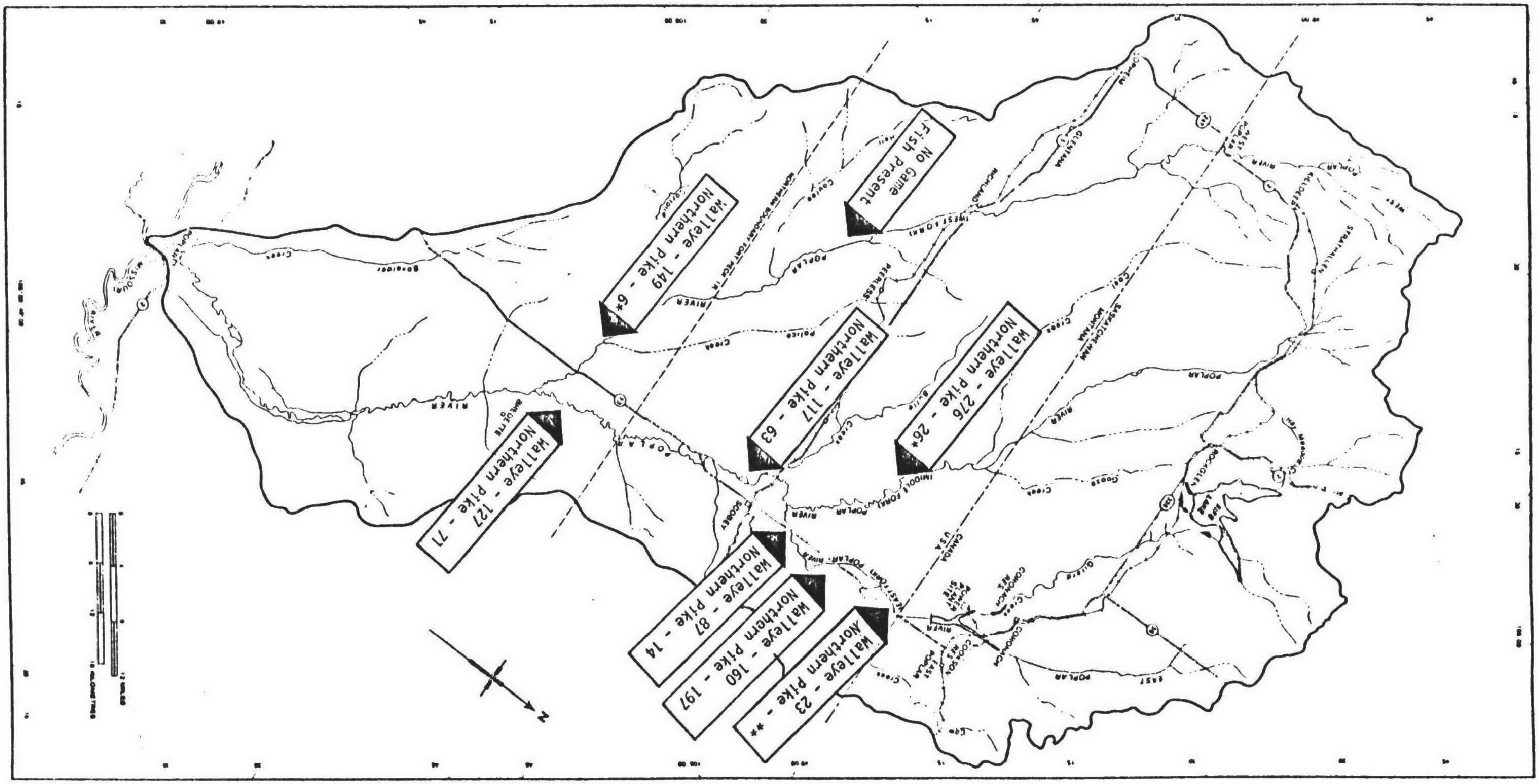
*"X" indicates presence of species.

Source: IPRWQB, IJC, 1979.

Table A-7.6

A SUMMARY OF FISHES OBSERVED IN THE POPLAR RIVER

Family	Common Name	Scientific Name
Hiodontidae	Goldeye	*Hiodon alosoides*
Esocidae	Northern pike	*Esox lucius*
Cyprinidae	Carp	*Cyprinus carpio*
	Pearl dace	*Semotilus margarita*
	Northern redbelly dace	*Chrosomus eos*
	Flathead chub	*Hybopsis gracilis*
	Lake chub	*Hybopsis plumbea*
	Emerald shiner	*Notropus atherinoides*
	Brassy minnow	*Hybognathus hankinsoni*
	Silvery minnow	*Hybognathus nuchalis*
	Fathead minnow	*Pimephales promelas*
	Longnose dace	*Rhinichthys cataractae*
Catostomidae	River carpsucker	*Carpiodes carpio*
	Bigmouth buffalo	*Ictiobus cyprinellus*
	Shorthead red horse	*Moxostoma breviceps*
	White sucker	*Catostomus commersoni*
	Longnose sucker	*Catostomus catostomus*
Ictaluridae	Channel catfish	*Ictalurus punctatus*
	Black bullhead	*Ictalurus melas*
	Stonecat	*Noturus flavus*
Gadidae	Burbot	*Lota lota*
Gasterosteidae	Brook stickleback	*Eucalia inconstans*
Centrarchidae	Smallmouth bass	*Micropterus dolomieui*
Percidae	Yellow perch	*Perca flavescens*
	Walleye	*Stizostedion vitreum*
	Sauger	*Stizostedion canadense*
	Iowa darter	*Etheostoma exile*
Sciaenidae	Freshwater drum	*Aplodinotus grunniens*



*approximate due to limited recapture
**insufficient sample

Figure A-7.1 WALLEYE AND NORTHERN PIKE POPULATION ESTIMATES (NUMBER PER MILE) FOR POPLAR RIVER SECTIONS IN 1977

(Data from Montana Fish and Game, 1978)

Northern pike occurred in lower numbers than walleye, and estimates ranged from six to 197 per mile when sufficient fish were collected for analysis. Northern pike were not collected in the mid-West Fork and were extremely rare in the upper East Fork. Tagging studies conducted by Stewart (1980) indicate that Poplar River walleye and northern pike are generally sedentary with little migration occurring among river segments.

During 1977, walleye and northern pike in spawning condition occurred at almost all sampling locations in the basin. The distribution of walleye eggs indicates that spawning is restricted to shallow (<2 ft deep) riffle areas with a clean gravel substrate (Montana Fish and Game, 1978). A typical riffle area providing optimal spawning habitat for walleye is indicated in Figure A-7.2.

Northern pike normally spawn among submerged flood plain vegetation shortly after ice breakup in the spring (Breeder and Rosen, 1966). Although a considerable number of samples was collected throughout the Poplar River Basin, no pike eggs were observed. There were also no larval pike collected in 195 samples containing over 3,600 larvae of other fish species. The failure of pike reproduction during 1977 was also indicated by the lack of 0+ individuals in the fish samples obtained during the summer and fall.

Both larval surveys and fall young-of-the-year surveys indicated that, during 1977, there was a very low reproductive success of walleye in the East Fork. Larval walleye were collected in other portions of the drainage and the occurrences of 0+ walleye in the Middle Fork and main river were relatively high when compared with the East Fork.

The spring runoff during 1977 was low and, in combination with the reduced flows caused by the Cookson Reservoir Dam, probably resulted in the low reproduction of walleye in the East Fork. The runoff in 1976 was about average, and in that year a large year class was formed in the East Fork. No data are available, however, to document the reproductive patterns of Poplar River fishes prior to impoundment of the upper East Fork.

The magnitude of winter ice coverage appears to be a critical factor in the survival of Poplar River gamefish. Winter kill of fishes during 1977-78 and 1978-79 was evidenced by the observation of dead fish after thawing and a decline in the abundance of older fish in the 1977 to 1979 sampling period (Stewart, 1979 and 1980). During the two severe winters, ice thickness reached 4 feet with severe oxygen depletion occurring in the remaining water.

The aquatic biota of the Canadian portion of the Poplar River Basin has been summarized by Saskmont Engineering (1978). The following sections provide a brief description of the aquatic biota in Cookson Reservoir and the East Fork between the dam and the international boundary. The biota of upstream areas (e.g., Fife Lake, Girard Creek) are

Figure A-7.2 RIFFLE AREA ON THE MIDDLE FORK OF THE POPLAR RIVER also described by Saskmont Engineering (1978); however, these descriptions are not included since they would not exert as direct an influence on U.S. portions of the basin as the East Fork and Cookson Reservoir.

Plankton samples collected from Cookson Reservoir during April and June, 1977, indicated that the phytoplankton communities are comprised of approximately equal abundances of green algae, blue-green algae and diatoms. The maximum chlorophyll-a concentration recorded was 24.5 mg/ℓ, while Secchi depths ranged from 0.3 to 0.9 m.

The fishes of Cookson Reservoir are representative of the species occurring in the upper East Fork prior to impoundment. The major species observed during 1976 and 1977 gill-net surveys were Walleye *(Stizostedion vitreum)*, carp *(Cyprinus carpio)*, white sucker *(Catostomus commersoni)* and lake chub *(Couesus plumbeus)*. Seine collections (i.e., smaller, littoral-zone fishes) were dominated by fathead minnows *(Pimephales promelas)* and brook sticklebacks *(Culaea inconstans)*.

The East Fork below the dam site has a fish community similar to that observed in the lower portions of the river. Gill net catches in 1976 and 1977 were dominated by walleye, northern pike and suckers. Carp and goldeye were observed at lower frequencies.

A distinctive characteristic of the 1976 collections was the occurrence of rainbow trout *(Salmo gairdneri)* at a relatively low frequency of 1.4 percent.

Appendix A-8. Meteorology and Air Quality

A-8.1 WIND

Wind plays an important role in the dispersion and dilution of pollutants emitted into the atmosphere. Pollutant concentrations are inversely proportional to wind speeds, i.e., the stronger the wind the lower the pollutant concentrations. Wind data have been measured at several stations at and near Scobey since March, 1977. Data available to data were from March, 1977 through February, 1979 (Gelhaus, et al., 1979). There were two periods of missing data due to equipment malfunctions between May 4, 1977, and September 7, 1977, and all of September, 1978. Wind speed, direction and other climatological data are now being measured continuously at Scobey, Montana. These hourly data will be available for use in running the CRSTER air quality model.

The wind pattern at both Scobey and Glasgow is bipolar with the wind coming from the northwest or southeast quadrants in all months. The least common wind direction for both places was from the northeast quadrant.

The frequency distribution of transboundary wind directions, which consists of the wind sectors from west-northwest through north to east-northeast, at Scobey and Glasgow is given below for 1978.

Month	Scobey	Glasgow
Jan	45.5	35.6
Feb	44.6	35.6
Mar	44.6	39.2
Apr	34.2	31.2
May	45.7	44.4
Jun	27.5	36.2
Jul	49.7	47.9
Aug	44.7	45.9
Sep (1977)	39.3	35.7
Oct	38.1	50.3
Nov	39.8	45.2
Dec	35.4	49.9

The value for September, 1977 was used since data were not available for Scobey in 1978. The average frequency that winds came across the border was 41 percent for both Scobey and Glasgow although the monthly distribution differed somewhat. Wind rose plots for Scobey and Glasgow are included in Appendix B.

Calm winds in April through September of 1978 occurred about 1.9 percent of the time at Scobey and 1.0 percent of the time at Glasgow. During the rest of the year calm winds occurred in 1978 2.6 percent of the time at Scobey and 4.0 percent of the time at Glasgow. Wind speeds at Scobey averaged 2.5 m/sec in the mornings and 5 m/sec in the afternoons. The wind speeds are generally lower in the summer months, although the prevailing winds are more likely to be from the southeast quadrant (Gelhaus, et al., 1979).

A-8.2. TEMPERATURE

The typical range during April to September is 29°F to 85°F with an average temperature of 59°F. The extreme temperatures for these months for the period 1940-1978 are -13°F and 106°F. Temperature during the winter (December through February) typically varies between -3.3 and 26.9°F with an average temperature of 12.6°F.

Upper air temperature measurements were made at Scobey since March 1977. Plots of the data are given in Gelhaus, et al., 1979.

A-8.3 INVERSIONS

The vertical dispersion of air pollutants over a region may be hampered by the presence of a temperature inversion in the layers of the atmosphere near the surface of the earth. Normally in the atmosphere, the temperature decreases with height. The rate of temperature decrease is called the lapse rate. A reversal of the normal lapse rate, wherein temperature increases with altitude, is termed an inversion. Physical and dynamic atmospheric processes can create inversions at the surface or at any height above the ground. Surface and elevated inversions are illustrated in Figure A-8.1. The height of the base of the inversion at any given time is known as the "mixing height".

Usually inversions are lower before sunrise than during daylight hours. After sunrise the mixing height normally increases as the day progresses, because the sun warms the ground, which in turn warms the surface air layer. As this heating continues, the temperature of the surface layer approaches the potential temperature of the base of the inversion layer. When this temperature becomes equal, the inversion layer begins to erode at its lower edge. If enough warming takes place, the inversion layer becomes thinner and thinner and finally "breaks" (when its base reaches its top); and the surface layers can then mix upward without limit. This phenomenon is frequently observed in the middle to late afternoon on summer days when visibilities improve or cumulus clouds form if sufficient moisture is present.

A study of mixing height frequencies throughout the contiguous U.S. was made by Holzworth (1972). The study centered on two times of the day, morning and afternoon. The details of the calculations employed in obtaining the mixing heights are present in Holzworth's 1972 report. The results were presented on an annual and seasonal basis. Wind speeds

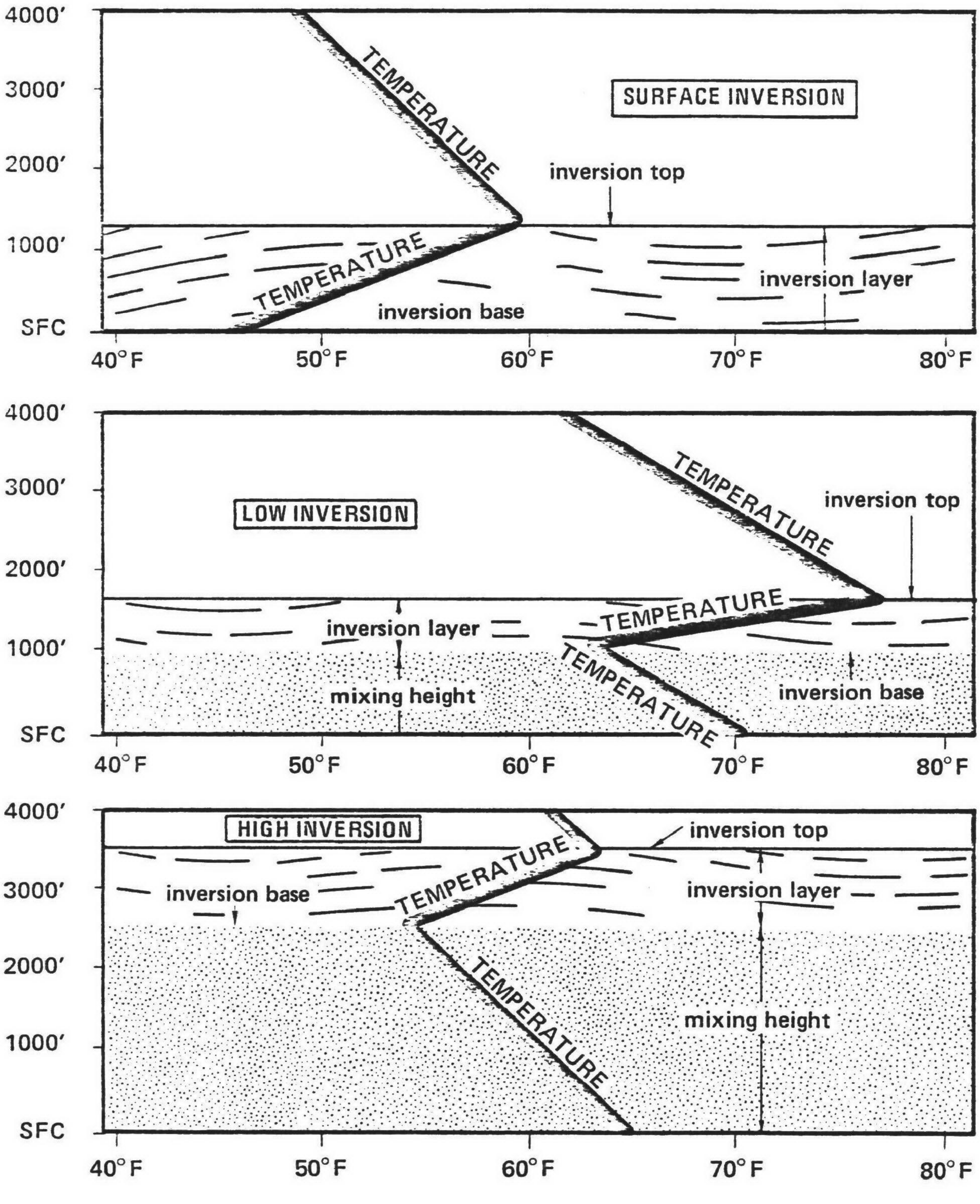


Figure A-8.1 THESE GRAPHS OF AIR TEMPERATURE VERSUS ALTITUDE ABOVE GROUND LEVEL SHOW TYPICAL INVERSIONS, RESPECTIVELY: SURFACE-BASED, LOW, AND HIGH INVERSIONS. POLLUTANTS ARE CONFINED TO THE AIR VOLUME BELOW THE BASE OF ANY INVERSION, OR IN A VERY SHALLOW LAYER NEAR THE GROUND IN THE CASE OF A SURFACE INVERSION.

for both morning and afternoon were also obtained as arithmetic averages of speeds observed at the surface and aloft within the mixing layer. Spatial analyses of mixing height and wind speeds were presented. These analyses indicated that mixing height values obtained at Glasgow are representative of the study area and may be employed for air quality modeling. Holzworth's results for Glasgow are summarized in Table A-8.1.

Portelli (1975) in a study of mixing heights for the period 1965-1969 found an annual average afternoon mixing height of 3494 feet. This is somewhat lower than the 5131 height obtained by Holzworth (1972).

The upper air temperature data from Scobey (Gelhaus, et al., 1979) were used to compute mixing heights at Scobey. These results are given along with mixing heights computed at Glasgow by Gelhaus and Machler (1978) in Table A-8.2. Holzworth's values for morning heights are generally higher than those of Gelhaus and Machler for Glasgow partly because different values were added to the minimum temperature. Holzworth (1972) used 5°C while Gelhaus and Machler (1978) used 2.5°C. Gelhaus, et al. (1979) used 3°C for the morning temperatures and 2°C for the afternoon temperatures at Scobey.

The frequency of low level inversions is of interest as it is related to the phenomenon known as "fumigation". This phenomenon occurs as a result of a plume from a stack emitting into a low level stable layer (a-a′ in Figure A-8.2) during the night. Because of the stable conditions, little or none of the effluent reaches the ground level. However, after sunrise, solar heating causes the daytime mixed layer to form next to the surface and grow thicker with time. As the top of the mixed layer envelopes the plume (b-b′ in Figure A-8.2), it is diffused downward and may produce high ground-level concentration in the narrow region below the original stable plume. This occurs for short periods generally less than an hour.

A study of low level inversions (below 500 feet above station) was made by Hosler (1961). His results for Glasgow are shown in Table A-8.3. The results indicate that early morning inversions (0500 MST) occur during all seasons of the year with percentage frequencies ranging from 72 percent in the spring to 84 percent in the summer. Daytime inversion (1700 MST) frequencies are the highest in the winter, with values near 56 percent and lowest in the summer with values near four percent. From these results, it may be concluded that trapping of pollutants may occur throughout the year, but the highest potential for air pollution is in the winter season.

The new data for Scobey show that inversions with tops below 200 m occur between zero and 27 percent of the time in the morning and zero to 17 percent of the time in the afternoon. Inversions with tops between 200 and 500 m could occur between 60 and 100 percent of the time in the morning and zero to 92 percent in the afternoons. Inversions up to these heights were less common in the summer months with the exception of inversions between 200 and 500 m in the mornings. A summary of the first inversion base, thickness, and frequency by time of day is shown in Table A-8.4. The data show that inversions are common throughout the year although morning inversions occur more in the summer and winter months.

Table A-8.1

MEAN SEASONAL AND ANNUAL MORNING AND AFTERNOON MIXING HEIGHTS (FEET), AND WIND SPEEDS (KNOTS) FOR GLASGOW, MONTANA (1960-1964)

	Morning		Afternoon	
Period	Height (ft)	Speed (kts)	Height (ft)	Speed (kts)
Winter	928	10.6	1719	13.4
Spring	1282	12.2	6466	15.7
Summer	997	11.1	8051	14.0
Autumn	859	10.3	4288	15.0
Annual	1017	11.1	5131	14.6

Table A-8.2

MEAN SEASONAL AND ANNUAL MORNING AND AFTERNOON MIXING HEIGHTS (FEET)

	Morning Height		Afternoon Height	
Period	Glasgow*	Scobey**	Glasgow	Scobey†
Winter	551	418	3602	886
Spring	436	629	1000	2469
Summer	666	293	5007	4560
Autumn	761	415	6545	2433
Annual	603	506††	4038	2587

*Period of Record 1971-1975 (Holzworth, 1972)

**Period of Record April, 1977 - March, 1979 (Gelhaus, *et al*., 1979)

†Based on limited data

††For 1978 only.

Table A-8.3

PERCENT FREQUENCY OF INVERSIONS BASED BELOW 500 FEET ABOVE SURFACE AT GLASGOW, MONTANA

	Time (MST)			
Season	2000	0800	1700	0500
Winter	75	75	56	76
Spring	68	38	7	72
Summer	50	14	4	84
Autumn	79	53	17	83

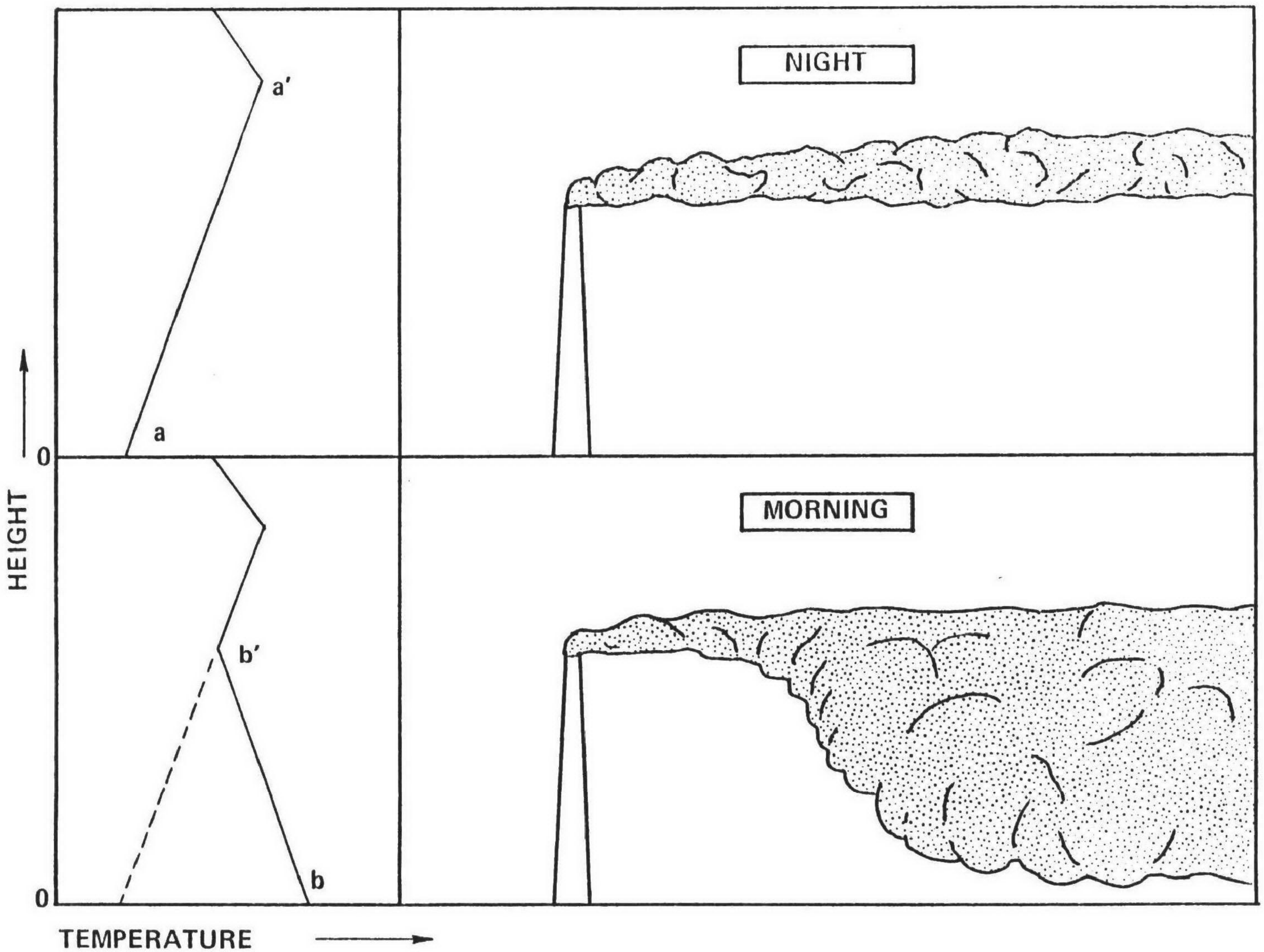


Figure A-8.2 SCHEMATIC OF LOW-LEVEL INVERSION BREAKUP RESULTING IN FUMIGATION

Table A-8.4

MOST COMMON CHARACTERISTICS OF FIRST INVERSIONS AT SCOBEY

Time of Day

Month	0001-0600 MST			0601-1200 MST			1201-1800 MST			1801-2400 MST		
	Base*	Thickness*	Frequency**	Base	Thickness	Frequency	Base	Thickness	Frequency	Base	Thickness	Frequency
1978 Apr	sfc	101-300	66 7	200	101-300	16.7	200	1-100	16 7	sfc	101-300	83 3
May	sfc	101-300	90.0	100	101-300	68.8	sfc	101-300	7.4	sfc	101-300	86.7
Jun	sfc	101-300	100.0	200	101-300	96.7	100	1-100	13 3	sfc	101-300	100 0
Jul	sfc	101-300	96.8	100	101-300	93.5	200	101-300	9 7	sfc	101-300	100.0
Aug	sfc	101-300	100.0	200	1-100	96 8	sfc	1-100	6.7	sfc	101-300	100 0
Sep	sfc	301-500	83.3	200	101-300	76.7	sfc	1-100	50 0	sfc	101-300	86 7
Oct	sfc	101-300	90.3	200	101-300	90.3	sfc	101-300	87.1	sfc	101-300	96 7
Nov	sfc	101-300	86.7	sfc	101-300	80.0	sfc	301-500	83.3	sfc	101-300	83 3
Dec	sfc	301-500	100 0	sfc	301-500	89.7	sfc	301-500	93.3	sfc	301-500	96.8
1979 Jan	sfc	301-500	96.7	sfc	301-500	87.1	sfc	301-500	100.0	sfc	301-500	100.0
Feb	sfc	301-500	96.4	sfc	301-500	92.9	200	101-300	88.5	sfc	301-500	100.0
Mar	sfc	301-500	87.1	sfc	301-500	87.1	sfc	301-500	77.4	sfc	301-500	83 9

*Units for base and thickness are meters.

**Percent frequency of occurrence of period with first inversion present.

Note. All data are based on acoustic radar measurements.

A-8.4 AIR QUALITY

The governments of the U.S. and Montana have established air quality standards to protect public health and welfare. The Federal Clean Air Act Amendments of 1977 require that national primary air quality standards be attained by 1982 (with extensions to 1987 in certain instances). Montana standards cover some additional pollutants not included in the national standards.

The national standards are divided into two categories: Primary and secondary. Primary standards are set at the levels of air quality necessary, with an adequate margin of safety, to protect the public health. Secondary standards are set to protect the public welfare, including plant and animal life, visibility, buildings and materials. The Federal Environmental Protection Agency (EPA) has set both primary and secondary standards for six contaminants.

- Sulfur Dioxide (SO_2)
- Total Suspended Particulate (TSP)
- Nitrogen Dioxide (NO_2)
- Carbon Monoxide (CO)
- Hydrocarbons (HC), corrected for methane
- Ozone (O_3)

The existing air quality in the study and impact area is very good. Recent measurements taken by the Montana Air Quality Bureau 1977-1978, in Northeastern Montana have shown very low concentrations of SO_2, NO_2 and particulates (Gelhaus, et al., 1979). Since there are no major sources of pollutant emission in Northeastern Montana, these results might have been anticipated. Sulfur dioxide concentrations at the border station for 1977 and 1978 and at the Fort Peck station for 1977 were below the minimum detection limit of 0.01 ppm. The maximum concentrations of nitrogen dioxide measured were 0.01 at the border station and 0.011 at the Fort Peck station. The averages for both stations were below the minimum detection limit of 0.005 ppm. The maximum total suspended particulate concentration at the border station was 107 $\mu g/m^3$ while the average concentration was 21.9 $\mu g/m^3$. Concentrations at the Richardson and Engberg stations were 129 and 109 $\mu g/m^3$ for the maximum value and 24.3 and 27.6 $\mu g/m^3$ for the average, respectively. A comparison of these values with the National and Montana ambient air quality standards shows that SO_2, NO_2 and suspended particlates concentrations are well below standard.

Although air quality measurements were not taken in this area during the baseline year, 1975, it may be concluded that the air quality was as good or better than measured in 1977-1978. This conclusion is based on the fact that there was little or no change in emission sources during this time period.

Appendix A-9. Social and Economic Profile

A-9.1 AGE PROFILE

The number and percent of total population by age group for Daniels and Roosevelt counties in 1970, the latest year available, are shown in Tables A-9.1 and A-9.2. In Daniels County between 1960 and 1970, the proportion of people 65 years and older increased. The greatest declines were in the age groups of people under 5 and 18 years old. These trends probably will continue into the future in view of the national trend toward lower birth rates and the lack of local employment opportunities, which forces younger people to leave the area.

In contrast, in Roosevelt County between 1960 and 1970, the number of 18 year olds increased. The number of persons under 5 years did decline, however, because of the lower birth rates.

A-9.2 RACE PROFILE

Race breakdowns for Daniels and Roosevelt counties for 1970, the lastest year available, are shown in Tables A-9.3 and A-9.4.

In Daniels County between 1960 and 1970 there was a large decrease in the number of whites, and a large percentage (but small absolute) increase in the nonwhite population, due to an increased number of native Americans.

Roosevelt County showed the same trends between 1960 and 1970. Here there was a large percentage and absolute increase in the number of nonwhites, which may be due to the high birthrate on the reservation.

A-9.3 SEX PROFILE

Table A-9.5 gives a breakdown by sex for the two counties for 1970, the latest year available.

A-9.4 URBAN AND RURAL PROFILE

Daniels and Roosevelt counties have very few cities. All the cities that exist in Daniels County have fewer than 2,500 inhabitants. Roosevelt County, however, has a few cities that exceed 2,500 (see Table A-9.6).

Table A-9.1

TOTAL POPULATION BY AGE GROUP - DANIELS COUNTY

Age/Sex Group	1960 Number	1960 Percent of Total	1970 Number	1970 Percent of Total	Percent Change 1960-1970
Total, all ages	3,755	100.0	3,083	100.0	-17.9
Under 5	486	11.6	190	6.2	-56.4
5-17	1,024	27.3	885	28.7	-13.6
18-59	1,697	45.2	1,422	46.1	-16.2
60-64	167	4.4	136	4.4	-18.6
65 and over	431	11.5	450	14.6	4.4
Median age			33.9	--	

Table A-9.2

TOTAL POPULATION BY AGE GROUP - ROOSEVELT COUNTY

Age/Sex Group	1960 Number	1960 Percent of Total	1970 Number	1970 Percent of Total	Percent Change 1960-1970
Total, all ages	11,731	100.0	10,365	100.0	-11.6
Under 5	1,667	14.2	939	9.1	-4.7
5-17	3,586	30.6	3,389	32.7	-5.5
18-59	5,061	43.1	4,672	45.1	-7.0
60-64	316	2.7	373	3.6	18.0
65 and over	1,101	9.4	992	9.6	-9.9
Median age			24.9	--	

Source: Montana Department of Community Affairs, Division of Research and Information Systems, County Profiles, March, 1978.

Table A-9.3

POPULATION BY RACIAL GROUP - DANIELS COUNTY

Racial Group	1960 Number	1960 Percent of Total	1970 Number	1970 Percent of Total
Total population	3,755	100.0	3,083	100.0
White	3,750	99.9	3,065	99.4
Nonwhite	5	0.1	18	0.6
Indian	3	0.05	16	0.5
Other	2	0.05	2	0.1

Table A-9.4

POPULATION BY RACIAL GROUP - ROOSEVELT COUNTY

Racial Group	1960 Number	1960 Percent of Total	1970 Number	1970 Percent of Total
Total population	11,731	100.0	10,365	100.0
White	8,958	76.4	7,201	69.5
Nonwhite	2,773	23.6	3,164	30.5
Indian	2,733	23.3	3,110	30.0
Other	40	0.3	54	0.5

Source: Montana Department of Community Affairs, Division of Research and Information Systems, County Profiles, March, 1978.

Table A-9.5

POPULATION BY SEX GROUP

Sex Group	Daniels County Number	Daniels County 1970 Percent of Total	Roosevelt County Number	Roosevelt County 1970 Percent of Total
Male, all ages	1,568	100.0	5,156	100.0
Under 5	100	6.4	468	9.1
5-17	446	28.4	1,728	33.5
18-59	738	47.1	2,290	44.4
60-64	63	4.0	190	3.7
65 and over	221	14.1	480	9.3
Median age	33.5	--	24.6	--
Female, all ages	1,515	100.0	5,209	100.0
Under 5	90	5.9	471	9.0
5-17	439	29.0	1,661	31.9
18-59	684	45.1	2,382	45.7
60-64	73	4.8	183	3.5
65 and over	229	15.1	512	9.8
Median age	34.2	--	25.1	--

Source: Montana Department of Community Affairs, Division of Research and Information Systems, County Profiles, March, 1978.

Table A-9.6

POPULATION BY RURAL OR URBAN LOCATION

Residence	Daniels County Number	Daniels County 1970 Percent of Total	Roosevelt County Number	Roosevelt County 1970 Percent of Total
Population	3,083	100.0	10,365	100.0
Urban	0	0.0	3,095	29.9
Rural	3,083	100.0	7,270	70.1
Places 1,000 to 2,500	1,486	48.2	1,389	13.4
Other rural	1,597	51.8	5,881	56.7

Source: Montana Department of Community Affairs, Division of Research and Information Systems, County Profiles, March, 1978.

A-9.5 INDIAN RESERVATION AND COMMUNITIES

A-9.5.1 Age Distribution

In 1970, a larger percentage of Fort Peck Indians were under 15, 46 percent, as compared to the State of Montana as a whole, 30 percent. There was also a smaller percentage of Indians 55 years and older (see Table A-9.7.

A-9.5.2 Employment

Fifty-one percent of the Indian labor force was employed in 1970. About 30 percent of these Indians are employed as service workers. Most of the others are either professional, clerical, or craftsmen. There were two industries employing a total of 44 persons (1973). The Fort Peck Tribal industry reconditioned rifles, and Multiplex West, Inc., produced teletype equipment. Less than half (47 percent or 337) of all the agricultural operators on the reservation are Indians.

Table A-9.7

AGE OF INDIAN POPULATION ON FORT PECK RESERVATION

	All Races Number	All Races Percent	Under 5 Percent	5-14 Percent	15-24 Percent	25-34 Percent	35-44 Percent	45-54 Percent	55-64 Percent	65 & Over Percent	Median Age
Fort Peck	3,441	100 0	13.7	32 5	17.6	9.6	9.4	7.3	4.8	5.1	N/A
Total Indian	26,385	100.0	13.2	31.0	18.6	11.7	9.3	6.7	4.8	4.8	17.2
Urban	5,070	19.2	15.6	27 0	22.2	12.3	9.0	6.5	3.6	3.8	18.6
Rural	21,315	80.8	12.6	31.9	17.7	11.5	9.3	6.8	5.0	5.1	N/A
Total Montana Polulation	694,409	100.0	8.2	21.7	17.5	11.5	10 8	11.2	9.1	9.9	27.1

Note. Median age not reported for counties and reservations.

Source. 1970 U.S. Census

A-9.5.3 Unemployment

At 49 percent, the unemployment rate is extremely high on the Fort Peck Indian Reservation. The average unemployment rate for all reservations in Montana is 38 percent. (Bureau of Indian Affairs, Profile of the Montana Native American, August, 1974.)

A-9.5.4 Income

Approximately 49 percent of individuals were below the poverty level in 1969, as compared to 13.5 percent of all individuals in the State of Montana. An even higher percentage of Indian families, 67 percent, were below the poverty level compared to 37 percent for the state as a whole.

A-9.5.5 Education

Almost 20 percent of the Indian population over 25 years of age were high school graduates in 1970. However, in the State of Montana as a whole, almost 60 percent of the population over 25 had graduated from high school.

A-9.5.6 Housing

Almost half of the housing on the reservation was built in 1939 or earlier. Less than 10 percent has been built since 1969. In addition, almost 40 percent of the structures are in substandard condition. (Montana Department of Community Affairs, Division of Research and Information Systems, County Profiles, March, 1978.)

- Condition of Existing Housing Units, June 30, 1973
  - 516 Standard condition
  - 316 Substandard condition

    219 need replacement, 97 need renovation.

The demand for housing on the reservation exceeded the supply in 1973. There was a need for about 300 more housing units, which would amount to about a 40 percent increase in the housing supply.

A-9.6 HOUSING AND PUBLIC SERVICES

The vacancy rate in Daniels County in 1970 was twice as high as in the State of Montana as a whole. The rate had increased for both owner and renter by 11.4 percent since 1960. Interestingly, the vacancy rates in Daniels County vary greatly. Flaxville has a 5 percent vacancy rate, compared to 13 percent in Scobey. Sixty-five percent of the housing in the county was constructed in 1939 or earlier. Only 10 percent of the housing (117 units) were built between 1960 and 1970. The majority of the houses (87%) have some or all plumbing facilities (hot and cold water, flush toilet, and a bathtub or shower).

The vacancy rate within Roosevelt County dropped by 14.6 percent between 1960 and 1970. The vacancy rate for owner-occupied housing was less than 1 percent with the rental vacancy rate 10.1 in 1970. Roosevelt County had a very high rate of crowding that was directly attributed to the housing conditions on Fort Peck Indian Reservation.

Substandard housing is another major problem in Roosevelt County. There are two contributing factors, the high number of units that lack plumbing, and the fact that the majority (65%) of the housing was built in 1939 or earlier. The condition of the housing is also reflected in the rental rates. Over 60 percent of the rental units in 1970 were renting for $100 or less. The median gross rent was about $85.

A-9.7 HEALTH, EDUCATION AND WELFARE

A-9.7.1 Health

There are three hospitals located in Roosevelt County: Roosevelt Memorial Hospital with 19 beds in the town of Culbertson, Community Hospital with 22 beds in Poplar, and Trinity Hospital with 44 beds in Wolf Point. (American Hospital Association Guide to the Health Care Field, 1977 edition.) Occupancy rates for these hospitals was 36.8 percent, 40.9 percent, and 50.0 percent, respectively. Data used in making these statistics was collected by the American Hospital Association during a 12-month period ending September 30, 1976.

According to the American Medical Association's "Physician Distribution and Medical Licensure in the U.S., 1976," there were a total of three nonfederal physicians in Roosevelt County as of December 31, 1975. Of these three, two were general practicioners and the third was a surgeon. By 1978, the number of doctors had increased in Roosevelt County to about nine, and doctors were considered in short supply (Nordwick, 1979). The number of doctors should continue to increase along with the population.

In addition to the hospitals, there are two nursing homes in Roosevelt County, one in Wolf Point, and a second in Poplar. Both homes have 22 beds (Nordwick, 1979).

Daniels County has one hospital in the town of Scobey: the Daniels Memorial Hospital with 11 beds and an occupancy rate of 38.5 percent. The county had two general practitioners in 1975. There is one nursing home in the county with a total of 55 beds. (Sources and date of data same as for Roosevelt County.) Following the trend in population, it is expected that health care facilities and practitioners will remain relatively stable in Daniels County (Nordwick and Bourassa, 1979).

Further health statistics for both counties are as shown in Tables A-9.8 and A-9.9. Roosevelt County has a somewhat higher birth and death rate per 1,000 population than Daniels County. The four leading causes of death in Daniels County are: heart disease, cancer, stroke, and accident. Disease rates for Daniels County are higher than the state average in two cases and lower in two cases. Roosevelt County also ranks higher than the state average in two cases and lower in two others, but for different diseases (Table A-9.9).

A-9.7.2 Education

The only schools in Daniels County are located in Flaxville and Scobey. There is an elementary school and a high school in each city. Total enrollment declined from 756 in the 1974-75 school year to 737 in the 1975-76 school year, a drop of 2.5 percent.

There are six elementary and six high schools located in Roosevelt County. Schools are located in the town of Brockton, Culbertson, Froid, Poplar, and Wolf Point. Enrollment in the public schools declined from 2,805 in 1974-75 to 2,741 in 1975-76, a decrease of 2.3 percent. Declining enrollment in both counties is probably due to the declining birth rate. Daniels County had a slightly lower pupil-teacher ratio (14.2) than Roosevelt County (14.4) in 1975-76, although the ratio declined in each county between 1974-75 and 1975-76 due to lower enrollments and a greater number of teachers.

The median number of school years completed by persons 25 years and older, as of 1970, in Daniels County was 12.1 compared to Roosevelt County, in which the median number of years completed was 11.6 (Montana Department of Community Affairs, Division of Research and Information Systems, County Profiles, March, 1978). As would be expected, Daniels County has a slightly higher percentage of high school graduates than Roosevelt (52 versus 48). Finally, budget figures for both school districts are shown in Table A-9.10. Daniels County shows a higher budgeted expenditure per pupil than Roosevelt County.

Table A-9.8

LIVE BIRTHS AND DEATHS, 1975

	Births	Deaths		Rate per 1,000 Population	
		Total	Infant	Births	Deaths
Daniels County	59	24	0	19.7	8.0
Roosevent County	239	105	4	23.9	10.5

Source: Montana Department of Community Affairs, Division of Research and Information Systems, County Profiles, March, 1978.

Table A-9.9

RATES PER 100,000 POPULATION FOR THE FOUR LEADING CAUSES OF DEATH: 1975*

Item	State		Daniels County		Roosevelt County	
	Number	Rate	Number	Rate	Number	Rate
Heart Disease	2,178	291.2	9	300.0	29	290.0
Cancer	1,105	147.7	4	133.3	13	130.0
Cerebrovascular Disease (stroke)	660	88.2	3	100.0	10	100.0
Accidents	584	78.1	2	66.7	17	170.0

*Four leading causes shown represent the experience of the entire state; an individual county may have other causes of death that should appear among the top four.

Source: Montana Department of Community Affairs, Division of Research and Information Systems, County Profiles, March, 1978.

Table A-9.10

GENERAL FUND REVENUE FOR BUDGET SUPPORT OF PUBLIC SCHOOLS AND BUDGETED EXPENDITURE PER PUPIL, ALL DISTRICTS: 1976-77

Item	Daniels County School Year 1976-77	Roosevelt County School Year 1976-77
Anticipated General Fund Revenue	$1,316,714	$4,106,989
Foundation Program	720,599	2,405,635
Schedule	677,701	2,185,500
Special Education	42,898	220,135
Permissive Levy	180,150	601,409
District	104,624	318,775
State	75,526	282,634
Voted Levy	415,965	1,099,945
ANB* (Pupils)	756	2,832
Budgeted Expenditure per Pupil	1,742	1,450

*Average Number Belonging in public school the previous year.

Source: Montana Department of Community Affairs, Division of Research and Information Systems, County Profiles, March, 1978.

A-9.7.3 Welfare

There were more people receiving some kind of assistance in Daniels County than Roosevelt. Programs included are Aid to Dependent Children, Medicaid, food stamps, Social Security, and the Supplemental Security Income Program (SSI), formerly known as old-age assistance.

A large number of eligible low-income people in Daniels and Roosevelt Counties are not taking advantage of available welfare programs. One study showed that in 1974 eight percent and 16 percent of those eligible were receiving food stamps in Daniels and Roosevelt Counties, respectively, compared to a state figure of 22.5 percent. Only six percent and seven percent of those eligible in Daniels and Roosevelt Counties were using medical assistance during 1974, as opposed to a participation rate of 11 percent statewide. (Human Resources Situation Report, 1974.)

A-9.8 LEISURE AND RECREATION

Recreation opportunities in Daniels County include hunting, fishing, camping, picnicking, skiing, snowmobiling, golf, swimming, curling, independent baseball, softball, basketball, and bowling. The Daniels County Fair is probably the highlight of the summer and provides entertainment for many residents of the county. Rodeos, night shows, auto-daredevil shows, and livestock shows have been entertainment features at the fairs.

There is a sports club known as the 750 Club in Flaxville. This club holds an annual celebration during the summer. The main activities are racing events including novelty horse races, foot races, and bicycle races.

Legion baseball provides recreation for many boys and entertainment for many fans. The team is based in Scobey, but boys from the entire county are on the team. High school sports also play a big role as recreational activities in Daniels County.

Snowmobiling has become a rapidly-increasing family sport during the past years. There are quite a few snowmobiles in the county. Snowmobiling has been a good recreational sport for men, women, and children. The "Can-Am" (Canadian-American) Snowmobile Racing Association was formed in order to organize the racing events. This association includes members from Canada and towns in Daniels County as well as Sheridan County.

Calf-roping and steer wrestling have also become popular in the county over the past few years. There is an organized Roping Club in Scobey that included members from the surrounding communities. There is a lot of competition among the ropers, and the breeding of fine horses for the activity is growing.

The Wolf Point Historical Society has established a museum at Wolf Point. The site of Fort Kipp is on the Missouri River between Poplar and Culbertson. No restoration of the fort has taken place, but the Fort Peck tribes hold an annual dance at the site. An historic fur trading post, Fort Union, and a military post, Fort Buford, are on the Missouri River just east of the Montana-North Dakota state line. These posts have been and are being partially restored. There is a museum at Fort Buford in one of the original buildings.

A-9.9 ECONOMIC PROFILE

A-9.9.1 Employment and Unemployment

The size of the Daniels County labor force has been steadily increasing since 1972 after a decline between 1960 and 1970. During the 10-year period 1960 to 1970 there was a decrease of 23.2 percent in the number of males 14 years and older, and only a 16.3 percent increase in the number of females 14 years and older working in Daniels County. The occupation groups that experienced the largest declines in male employees were farmers and farm managers and clerical and kindred workers. The increases in females in employment were largely in the categories of sales work and farmers and farm managers (Table A-9.11).

There were 1,205 persons in the Daniels County labor force in 1972 (Table A-9.12). Between 1972 to 1975, there was a small increase in total employment within the county. There were increases in government, construction, and trade, along with a decrease in farm employment (Table A-9.13). An estimate for 1977 employment was 1,489, or an increase of 284 people (20%) since 1972. The unemployment rate also dropped dramatically between 1972 (5.6%) and 1974 (2.2%) and increased slowly to 2.9% in 1977.

The size of the Roosevelt County labor force declined between 1960 and 1970 from 3,461 to 3,278. The decline was due to a 20.5 percent (517 persons) decline in male employment that was not offset by an increase in female employment of 35.6 percent (334 persons) (Table A-9.14). The largest declines in male employment occurred in two industries: agriculture, forestry, and fisheries (47.8%), and transportation, communication, and other utilities (42.0%).

The size of the labor force has been increasing since 1970 in Roosevelt County. The projected labor force for 1975 was 4,628, or almost a 40 percent increase since 1970. The government sector experienced some of the largest growth (24%). Agriculture and military were the only areas that declined in employment (Table A-9.15).

The Roosevelt County unemployment rate in 1975 was 6.9 percent, down from 8.9 percent in 1970. The preliminary estimate for 1977 was 5.1 percent, illustrating that employment opportunities were expected to continue to improve (Table A-9.16).

Table A-9.11

OCCUPATION OF EMPLOYED PERSONS IN DANIELS COUNTY BY SEX (1960 AND 1970)

Occupation Group	1960	1970	Percent Change 1960 to 1970
Male employed, 14 years old and over	1,003	770	-23.2
Professional, technical, and kindred workers	48	50	4.2
Managers and administrators (nonfarm)	102	100	-2.0
Sales workers	25	23	-8.0
Clerical and kindred workers	22	10	-54.5
Craftsmen, foremen, and kindred workers	76	86	13.2
Operatives and kindred workers	65	38	-41.5
Laborers (nonfarm)	4	21	425.0
Farmers and farm managers	453	321	-29.1
Farm laborers and foremen	80	84	5.0
Service workers, except private household	42	29	-31.0
Private household workers	0	0	-
Occupation not reported	86	8	-90.7
Female employed, 14 years old and over	282	328	16.3
Professional, technical and kindred workers	47	26	-44.7
Managers and administrators (nonfarm)	26	12	-53.8
Sales workers	5	18	260.0
Clerical and kindred workers	60	90	50.0
Craftsmen, foremen, and kindred workers	0	0	-
Operatives and kindred workers	12	17	41.7
Laborers (nonfarm)	0	0	-
Farmers and farm managers	4	41	925.0
Farm laborers and foremen	9	7	-22.2
Service workers, except private household	69	109	58.0
Private household workers	18	16	-11.1
Occupation not reported	32	4	-87.5

Source: U.S. Bureau of the Census, U.S. Census of Population: 1960, V. 1, PT. 28; 1970, Fourth Count Summary Tape.

Table A-9.12

ESTIMATES OF THE LABOR FORCE AND AVERAGE UNEMPLOYMENT RATES FOR DANIELS COUNTY: 1960 TO 1977

Year	Labor Force*	Unemployed	Unemployment Rate**
1960	1,335	50	5.6
1970	1,102	4	0.4
1972	1,205	67	5.6
1973	1,297	54	4.2
1974	1,354	30	2.2
1975	1,351	34	2.5
1976	1,422	40	2.8
1977***	1,489	43	2.9

*Persons 16 years and older, defined as employed or unemployed, excluding members of the armed forces, including self-employed, unpaid family workers, and domestic workers.

**Unemployed expressed as percentage of the labor force.

***Preliminary.

Source: Montana Department of Labor and Industry, Employment Security Division, Montana Employment and Labor Force, V. 7, No. 7, July, 1977; V. 8, No. 3, March, 1978.

Table A-9.13

EMPLOYMENT BY TYPE AND BROAD INDUSTRIAL SOURCES FOR DANIELS COUNTY
1971 TO 1975

Item	1971	1972	1973	1974	1975	Percent Change 1971-1975
Total employment	1,592	1,551	1,622	1,648	1,638	2.9
Number of proprietors	849	853	844	835	815	-4.0
Farm proprietors	533	523	515	505	484	-9.2
Nonfarm proprietors	316	330	329	330	331	4.7
Wage and salary employment	743	698	778	813	823	10.8
Farm	140	141	141	154	130	-7.1
Nonfarm	603	557	637	659	693	14.9
Government	208	206	232	230	240	15.4
Federal	22	21	24	22	25	13.6
Federal civilian	22	21	24	22	25	13.6
Military	0	0	0	0	0	-
State and local	186	185	208	208	215	15.6
Private nonfarm	395	351	405	429	453	14.7
Manufacturing	(D)	(D)	(D)	(D)	(D)	(D)
Mining	0	3	4	3	0	-
Construction	15	17	20	19	21	40.0
Transportation, communications, and public utilities	56	50	53	65	57	1.8
Trade	191	184	177	182	227	18.8
Finance, insurance, and real estate	(D)	(D)	(D)	(D)	24	(D)
Services	110	70	121	127	(D)	-
Other	0	0	(D)	(D)	(D)	(D)

*Full-and part-time wage and salary employment plus number of proprietors.

(D) Not shown to avoid disclosure of confidential information. Data are, however, included in totals.

Source: Bureau of Economic Analysis, U.S. Department of Commerce, Regional Economic Information System (magnetic tape).

Table A-9.14

OCCUPATION OF EMPLOYED PERSONS FOR ROOSEVELT COUNTY BE SEX (1960 AND 1970)

Occupation Group	1960	1970	Percent Change 1960 to 1970
Male employed, 14 years old and over	2,523	2,006	-20.5
Agriculture, forestry, and fisheries	1,085	566	-47.8
Mining and construction	275	227	-17.5
Manufacturing	106	87	-17.9
Transportation, communication, and other utilities	174	101	-42.0
Wholesale and retail trade	423	433	2.4
Finance, insurance, and real estate	23	51	121.7
Business and repair services	61	93	52.5
Personal services	39	37	-5.1
Entertainment and recreation services	9	9	-
Professional and related services	151	153	1.3
Public administration	148	157	6.1
Industry not reported	29	92	217.2
Female employed, 14 years old and over	938	1,272	35.6
Agriculture, forestry, and fisheries	17	54	217.6
Mining and construction	4	0	-100.0
Manufacturing	36	31	-13.9
Transportation, communication, and other utilities	59	22	-62.7
Wholesale and retail trade	194	306	57.7
Finance, insurance, and real estate	20	42	110.0
Business and repair services	4	40	900.0
Personal services	166	104	-37.3
Entertainment and recreation services	22	9	-59.1
Professional and related services	315	437	38.7
Public administration	78	137	75.6
Industry not reported	23	90	291.3

Source: U.S. Bureau of the Census, U.S. Census of Population: 1960, V. 1, PT. 28; 1970, Fourth Count Summary Tape.

Table A-9.15

EMPLOYMENT BY TYPE AND BROAD INDUSTRIAL SOURCES FOR ROOSEVELT COUNTY, 1971 TO 1975*

Item	1971	1972	1973	1974	1975	Percent Change 1971-1975
Total employment	4,252	4,398	4,477	4,602	4,811	13.1
Number of proprietors	1,344	1,352	1,338	1,326	1,295	-3.6
Farm proprietors	797	782	770	756	724	-9.2
Nonfarm proprietors	547	570	568	570	571	4.4
Wage and salary employment	2,908	3,046	3,139	3,275	2,516	20.9
Farm	245	246	246	269	227	-7.3
Nonfarm	2,663	2,800	2,893	3,006	3,289	23.5
Government	864	863	921	918	960	11.1
Federal	202	209	205	210	229	13.4
Federal civilian	194	202	198	204	224	15.5
Military	8	7	7	6	5	-37.5
State and local	662	654	716	708	731	10.4
Private nonfarm	1,799	1,937	1,972	2,088	2,329	29.5
Manufacturing	70	77	93	70	180	157.1
Mining	(D)	(D)	(D)	81	98	(D)
Construction	20	22	24	61	60	200.0
Transportation, communications, and public utilities	113	117	122	127	144	27.4
Trade	593	573	586	627	686	15.7
Finance, insurance, and real estate	74	77	79	86	82	10.8
Services	864	1,018	1,005	1,023	1,062	22.9
Other	(D)	(D)	(D)	13	17	(D)

*Full- and part-time wage and salary employment plus number of proprietors.

(D) Not shown to avoid disclosure of confidential information. Data are included, however, in totals.

Source: Bureau of Economic Analysis, U.S. Department of Commerce, Regional Economic Information System (magnetic tape).

Table A-9.16

ESTIMATES OF THE LABOR FORCE AND AVERAGE UNEMPLOYMENT RATES FOR ROOSEVELT COUNTY: 1960 TO 1977

Year	Labor Force*	Unemployed	Unemployment Rate**
1960	3,793	332	8.8
1970	3,599	321	8.9
1972	3,895	229	5.9
1973	4,040	333	8.2
1974	4,228	284	6.7
1975	4,628	319	6.9
1976	5,057	320	6.3
1977***	5,813	298	5.1

*Persons 16 years and older, defined as employed or unemployed, excluding members of the armed forces, including self-employed, unpaid family workers, and domestic workers.

**Unemployed expressed as percentage of the labor force.

***Preliminary.

Source: Montana Department of Labor and Industry, Employment Security Division, Montana Employment and Labor Force, V. 7, No. 7, July, 1977; V. 8, No. 3, March, 1978.

A-9.9.2 Income

The median family income in Daniels County increased by 72.8 percent from $4,488 in 1959 to $7,754 in 1969. Per capita income increased by 98 percent from $4,637 in 1970 to $9,185 in 1975. Total personal income within Daniels County increased by 101 percent between 1970 and 1975. All major sources contributed to the increase (Table A-9.17). Farming, however, remains the major source of income within the county, followed by wholesale and retail trade.

In Roosevelt County the median family income increased by 74.4 percent from $4,562 in 1959 to $7,955 in 1969. Per capita income within the county rose by 111 percent from $3,132 in 1970 to $6,609 in 1975. Total personal income within the county increased by 114 percent. All major sources contributed to this substantial change in income (Table A-9.18) but the three industries with largest income growth occurred were agriculture, manufacturing, and contract construction.

A-9.9.4 Industrial and Business Activities

In 1975, there were a total of 84 industrial and business establishments in Daniels County. There are no major industries in the county. The small industries that do exist serve only the county area. The industrial opportunities are small due to the lack of raw materials, the local market, and the cost and availability of transportation.

Most of the industrial business employment (53%) is in the retail and service sectors. A majority of these establishments are small and have no more than four employees (Table A-9.19). Since 1972, almost a third of the retail trade establishments have closed. Four out of seven of the automotive dealers and gasoline service stations also went out of business between 1972-1975.

In 1975, there were a total of 240 industrial and business establishments in Roosevelt County, which employed a total of 1,677 persons. The annual payroll was $10,140,000 (Table A-9.30). Most of the county businesses are small and employed fewer than four persons.

There are over 140 establishments within the retail trade and service sector employing almost 70 percent of the people. The number of retail establishments has declined since 1972 from 148 to 93. Eating and drinking places declined from 39 to 22. Automotive dealers and service stations decreased from 29 to 22.

Table A-9.17

PERSONAL INCOME BY MAJOR SOURCES FOR DANIELS COUNTY 1970 TO 1975*

Item	1970	1971	1972	1973	1974	1975	Percent Change 1970 to 1975
Total Labor and Proprietors Income by Place of Work	11,011	9,654	16,614	24,478	22,541	22,116	100 9
By Type							
Wage and salary disbursements	3,053	3,355	3,501	4,092	4,849	5,538	81 4
Other labor income	141	176	191	217	260	310	119 9
Proprietors income	7,817	6,123	12,922	20,169	17,432	16,268	108 1
Farm	6,741	5,012	12,008	18,711	15,710	14,399	113.6
Nonfarm	1,076	1,111	914	1,458	1,722	1,869	73.7
By Industry							
Farm	7,234	5,555	12,604	19,369	16,518	15,133	109.2
Nonfarm	3,777	4,099	4,010	5,109	6,023	6,983	84.9
Private	2,748	2,954	2,778	3,714	4,463	5,185	88.7
Manufacturing	(D)	(D)	(D)	(D)	(D)	(D)	(D)
Mining	(L)	(L)	(L)	(L)	(L)	(L)	(D)
Contract construction	85	110	121	150	170	200	135.3
Wholesale & retail trade	1,112	1,373	1,313	1,573	1,876	2,430	118.5
Finance, insurance, and real estate	(D)	(D)	(D)	(D)	(D)	276	(D)
Transportation, communications, and public utilities	(D)	476	479	552	687	712	(D)
Services	902	732	576	1,101	1,332	(D)	(D)
Other industries	52	55	(L)	(D)	(D)	(D)	(D)
Government	1,029	1,145	1,232	1,395	1,560	1,798	74.7
Federal, civilian	196	210	208	277	270	329	67.9
Federal, military	43	48	56	59	65	78	58.1
State and local	790	887	968	1,059	1,225	1,401	77.3
Per capita income (dollars)	4,637	4,450	6,517	9,299	8,911	9,185	

*Current income from all sources, measured after deduction of personal contributions to social security, government, retirement, and other social insurance programs but before deduction of income and other personal taxes (in $1,000's).

(D) Not shown to avoid disclosure of confidential information. Data are included in totals.

(L) Less than $50,000. Data included in Totals.

Source: Bureau of Economic Analysis, U.S Department of Commerce, Regional Economic Information System (Magnetic Tape).

Table A-9.18

PERSONAL INCOME BY MAJOR SOURCES FOR ROOSEVELT COUNTY 1970 TO 1975*

Item	1970	1971	1972	1973	1974	1975	Percent Change 1970 to 1975
Total Labor and Proprietors Income by Place of Work	25,072	23,759	33,778	52,143	51,376	53,728	114.3
By Type							
Wage and salary disbursements	14,133	14,952	16,782	18,148	20,645	24,530	73.6
Other labor income	672	811	950	977	1,076	1,345	100.1
Proprietors income	10,267	7,996	16,046	33,018	29,655	27,853	171.3
Farm	7,636	5,152	13,505	29,661	25,599	23,361	205.9
Nonfarm	2,631	2,844	2,541	3,357	4,056	4,492	70 7
By Industry							
Farm	8,472	6,070	14,508	30,773	26,966	24,605	190 4
Nonfarm	16,600	17,689	19,270	21,410	24,410	29,123	75.4
Private	11,599	12,065	13,135	14,736	17,071	20,684	78.3
Manufacturing	297	533	610	736	528	1,181	297.6
Mining	(D)	(D)	(D)	(D)	997	1,540	(D)
Contract construction	292	268	249	260	642	773	164.7
Wholesale & retail trade	3,639	3,832	3,823	4,513	5,311	6,380	75.3
Finance, insurance, and real estate	673	804	814	839	946	1,061	57.7
Transportation, communications, and public utilities	1,052	1,118	1,202	1,336	1,530	1,825	73.5
Services	5,068	4,930	5,855	6,349	6,879	7,657	51.1
Other industries	(D)	(D)	(D)	(D)	238	267	(D)
Government	5,001	5,624	6,135	6,634	7,339	8,439	68.7
Federal, civilian	1,661	1,913	2,109	2,310	2,409	2,842	71.1
Federal, military	223	226	253	265	278	282	26.5
State and local	3,117	3,485	3,773	4,059	4,652	5,315	70.5

*Current income from all sources; measured after deduction of personal contributions to social security, government, retirement, and other social insurance programs but before deduction of income and other personal taxes (in $1,000's).

(D) Not shown to avoid disclosure of confidential information. Data are included in totals.

Source. Bureau of Economic Analysis, U.S. Department of Commerce, Regional Economic Information System (Magnetic Tape)

Table A-9.19

BUSINESS ENTERPRISE, TRADE, AND SERVICES,
DANIELS COUNTY, 1975

Selected Industry Group	Employees,* Week Including March 12	Annual Payroll ($1,000)	Establishments by Employment-size Class				
			Total	1-4	5-19	20-99	100+
Total	376	2,603	84	62	19	3	0
Agricultural services, forestry, fisheries	(A)	(D)	1	1	0	0	0
Mining	(A)	(D)	1	1	0	0	0
Contract Construction	2	42	4	4	0	0	0
General contractors & operative builders	(A)	(D)	2	2	0	0	0
Special trade contractors	(A)	(D)	2	2	0	0	0
Manufacturing	(A)	(D)	1	1	0	0	0
Printing and publishing	(A)	(D)	1	1	0	0	0
Transportation & other public utilities	57	471	3	1	1	1	0
Trucking and warehousing	(A)	(D)	0	0	0	0	0
Communication	(B)	(D)	3	1	1	1	0
Wholesale trade	83	843	16	8	8	0	0
Wholesale trade-durable goods	33	357	4	0	4	0	0
Retail trade	102	520	32	25	6	1	0
Building materials & garden supplies	4	72	3	3	0	0	0
Food stores	(A)	(D)	3	2	1	0	0
Automotive	(A)	(D)	3	1	2	0	0
Apparel and accessory stores	11	45	4	3	1	0	0
Eating and drinking places	51	149	12	9	2	1	0
Finance, insurance, and real estate	22	224	4	3	1	0	0
Real estate	(A)	(D)	1	1	0	0	0
Services	99	419	17	13	3	1	0
Hotels and other lodging places	(A)	(D)	1	0	1	0	0
Personal services	(A)	(D)	3	3	0	0	0
Auto repair, services, and garages	6	33	1	0	1	0	0
Amusement and recreation services	(A)	(D)	4	2	1	1	0
Health services	(B)	(D)	4	2	1	1	0
Nonclassifiable establishments	2	23	5	5	0	0	0

*Excludes government employees, railroad employees, self-employed persons, farm workers, and domestic service workers

(D) Figures withheld to avoid disclosure of operations of individual establishments, other alphabetics indicate employment-size class: (A) 0-19, (B) 20-99, (C) 100-249, (E) 250-499, (F) 500-999, (G) 1,000-2,499, (H) 2,500-4,999

Source. U.S. Bureau of the Census, County Business Patterns, 1975 (Magnetic Tape).

Table A-9.20

BUSINESS ENTERPRISE, TRADE, AND SERVICES, ROOSEVELT COUNTY, 1975

Selected Industry Group	Employees,* Week Including March 12	Annual Payroll ($1,000)	Establishments by Employment-size Class				
			Total	1-4	5-19	20-99	100+
Total	1,677	10,140	240	170	56	13	1
Agricultural services, forestry, fisheries	(A)	(D)	3	3	0	0	0
Mining	35	478	4	1	3	0	0
Contract Construction	27	175	13	12	1	0	0
General contractors & operative builders	13	86	4	3	1	0	0
Special trade contractors	14	89	9	9	0	0	0
Manufacturing	140	1,367	10	5	2	3	0
Food and kindred products	(B)	(D)	3	2	0	1	0
Transportation & other public utilities	70	782	13	10	2	1	0
Trucking and warehousing	11	88	8	8	0	0	0
Communication	(A)	(D)	4	2	2	0	0
Wholesale trade	143	1,448	30	21	9	0	0
Wholesale trade-durable goods	40	430	6	3	3	0	0
Retail trade	424	2,199	93	67	25	1	0
Building materials & garden supplies	(B)	(D)	9	9	0	0	0
General merchandise stores	31	172	4	2	2	0	0
Food stores	78	469	16	10	5	1	0
Automotive dealers & service stations	106	749	20	13	7	0	0
Apparel and accessory stores	26	134	6	3	3	0	0
Eating and drinking places	113	345	27	22	5	0	0
Finance, insurance, and real estate	80	762	12	6	5	1	0
Real estate	(A)	(D)	1	1	0	0	0
Services	718	2,699	49	34	7	7	1
Hotels and other lodging places	(B)	(D)	5	4	0	1	0
Personal services	18	83	7	6	1	0	0
Business Services	(A)	(D)	2	1	1	0	0
Auto repair, services, and garages	(A)	(D)	2	2	0	0	0
Amusement and recreation services	(A)	(D)	2	2	0	0	0
Health services	162	877	12	8	1	3	0
Nonclassifiable establishments	(B)	(D)	13	11	2	0	0

*Excludes government employees, railroad employees, self-employed persons, farm workers, and domestic service workers.

(D) Figures withheld to avoid disclosure of operations of individual establishments, other alphabetics indicate employment-size class (A) 0-19, (B) 20-99, (C) 100-249, (E) 250-499, (F) 500-999, (G) 1,000-2,499, (H) 2,500-4,999

Source U.S. Bureau of the Census, County Business Patterns, 1975 (Magnetic Tape).

APPENDIX B

METEOROLOGY

B-1. SUMMARY WIND DATA

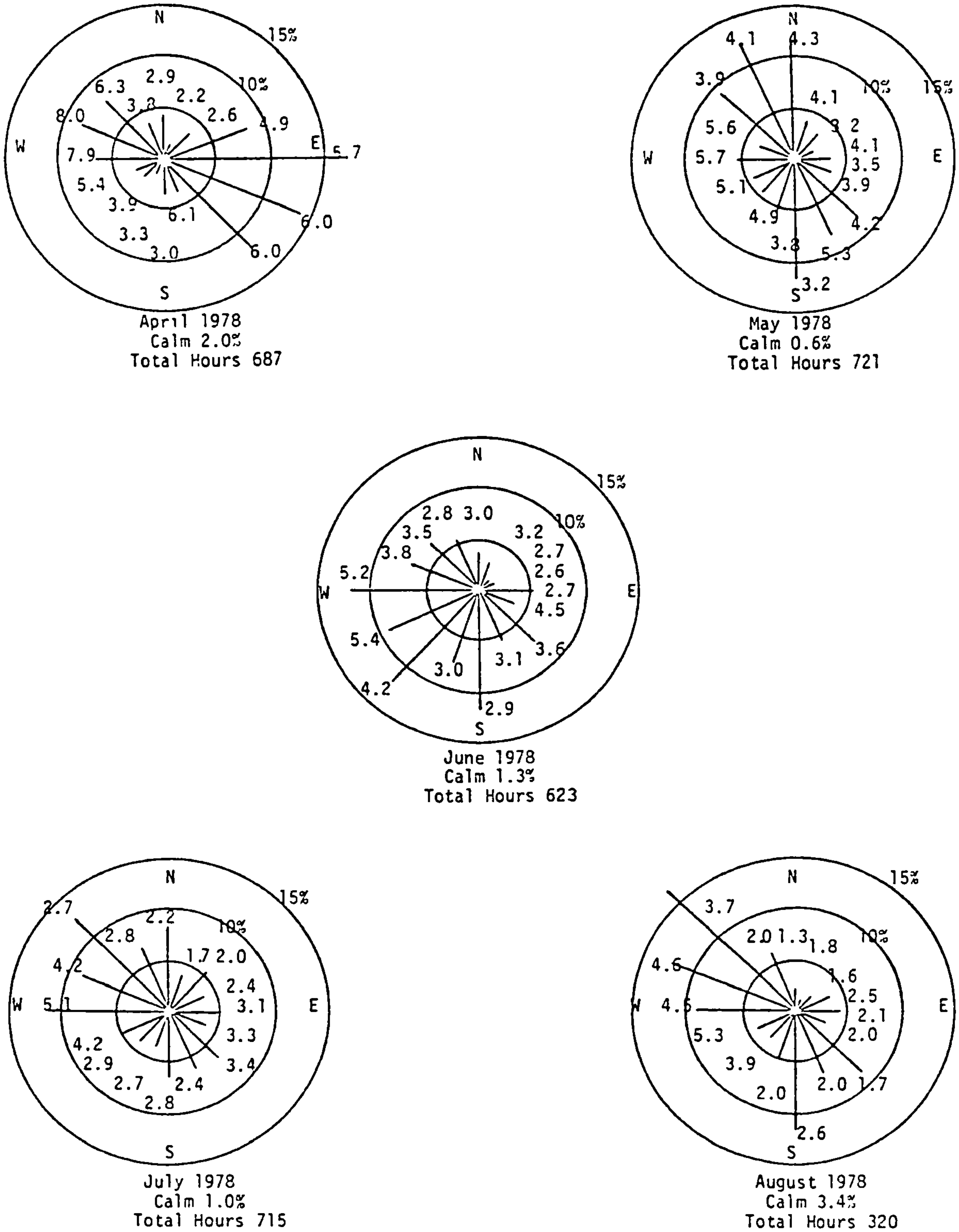
Wind rose plots are included for the growing season months of April through September for Scobey (Figure B-1) and Glasgow, Montana (Figure B-2) and for the other months in Figures B-3 and B-4, respectively. Similar plots and wind rose frequency tables for Scobey and Glasgow from March, 1977 through March, 1979 were included in the report on the background air quality done by the Montana Air Quality Bureau (Gelhaus, *et al.*, 1979). The report also included a frequency summary of the upper level winds at Scobey.

B-2. CLIMATOLOGICAL DATA

Summary tables for Scobey and Glasgow, Montana show temperature, precipitation, and wind speed (Tables B-1 through B-3).

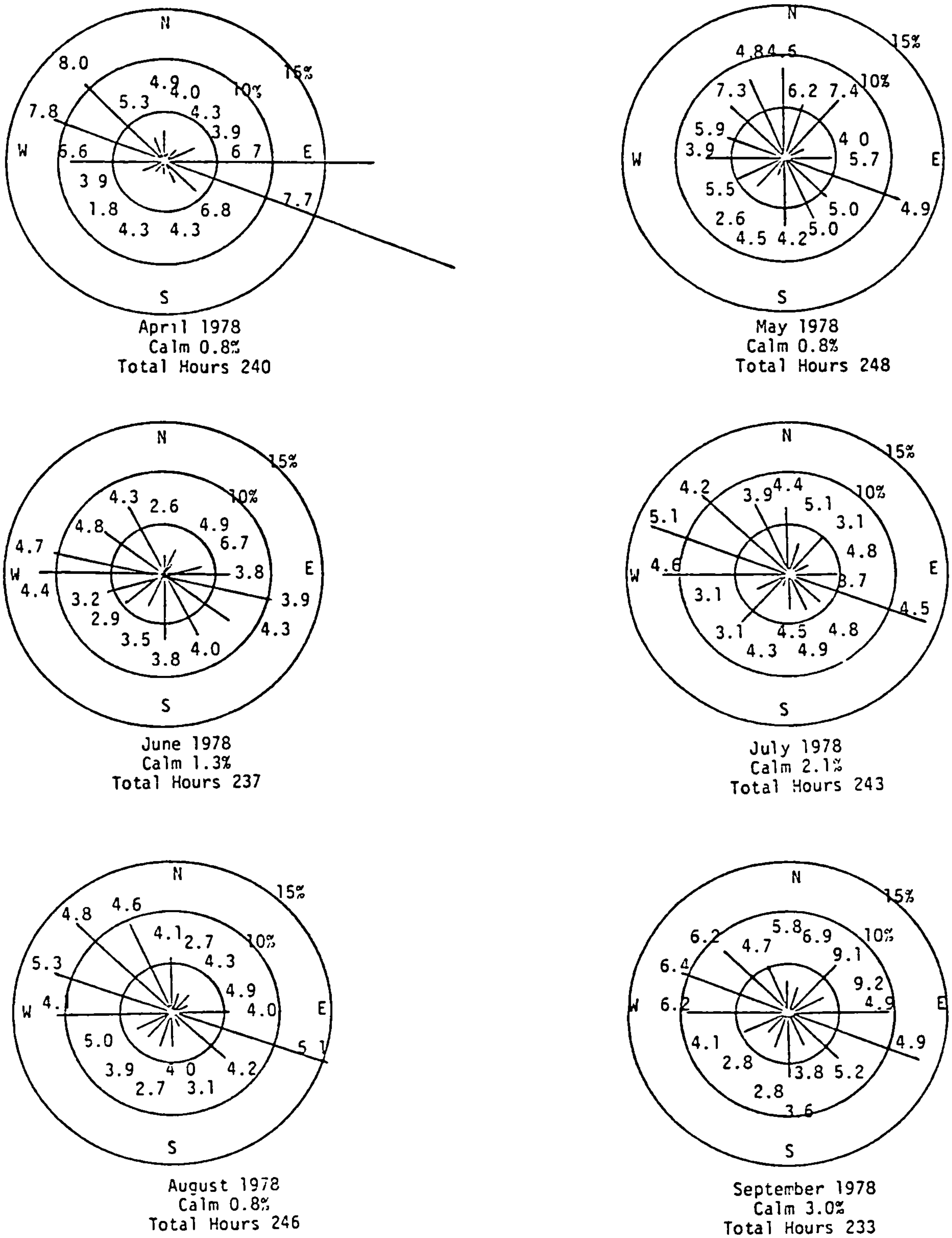
B-3. AIR QUALITY STANDARDS

National Ambient Air Quality Standards and Montana AAQS are given in Tables B-4 and B-5, respectively.



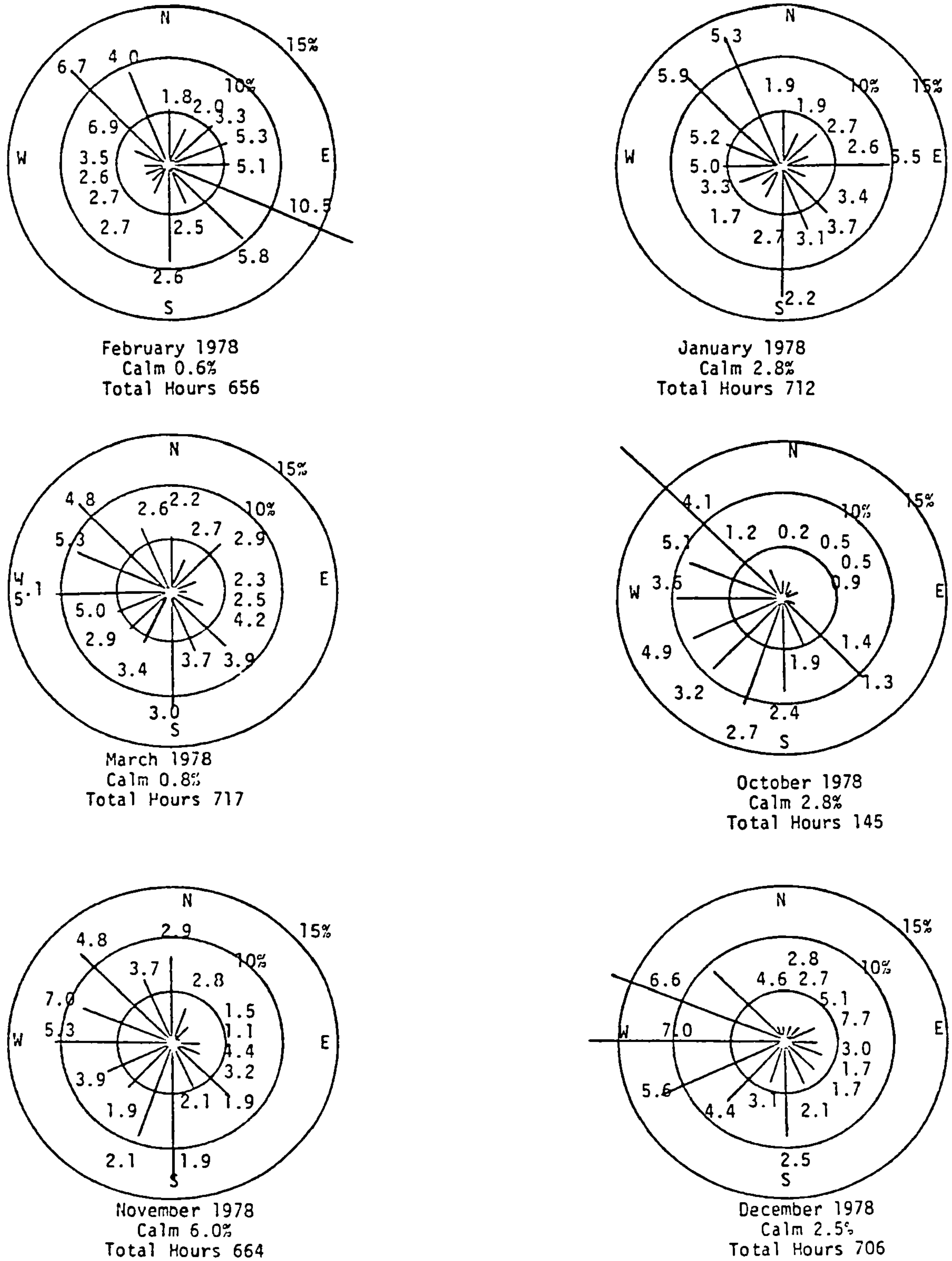
Note: Wind speeds shown are average speeds in miles per hour. September data were not available.

Figure B-1 APRIL TO AUGUST WIND ROSES AT SCOBEY, MONTANA (Gelhaus, et al., 1979)



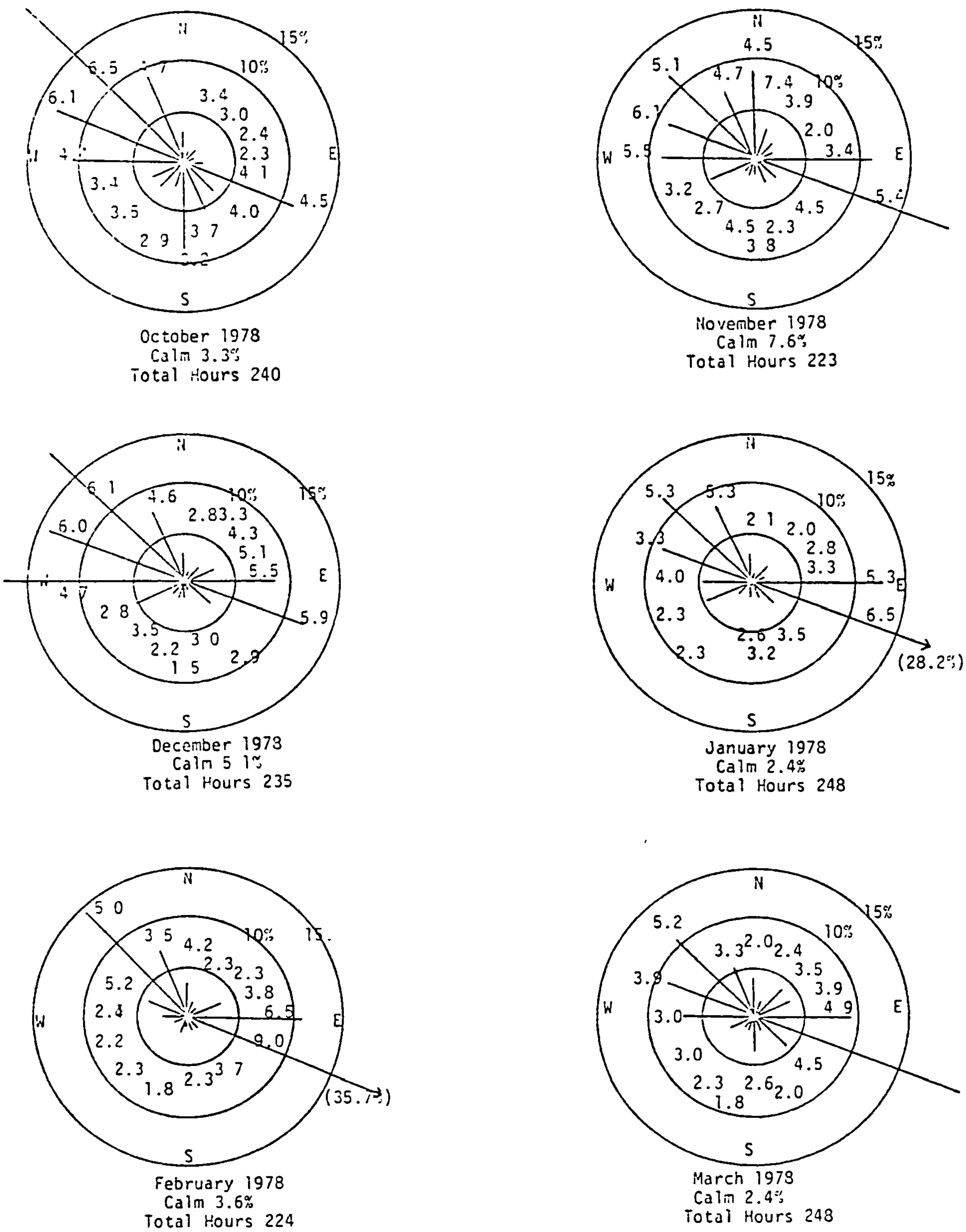
Note: Wind speeds shown are average speeds in miles per hour.

Figure B-2 MONTHLY WIND ROSES AT GLASGOW, MONTANA (Gelhaus, et al., 1979)



Note: Wind speeds shown are average speed in miles per hour.

Figure B-3 OCTOBER TO MARCH WIND ROSES AT GLASGOW, MONTANA (Gelhaus, et al., 1979)



Note: Wind speeds shown are average speed in miles per hour.

Figure B-4 OCTOBER TO MARCH WIND ROSES AT GLASGOW, MONTANA (Gelhaus, et al., 1979)

Table B-1

1975 METEOROLOGICAL DATA FOR GLASGOW, MONTANA

Month	Temperature (°F) Average Monthly	Temperature (°F) Extreme Highest	Temperature (°F) Extreme Lowest	Precipitation (in) Water Equivalent	Precipitation (in) Snow, Ice	Wind (mph) Average Speed	Number of Days Clear	Number of Days Partly Cloudy	Number of Days Cloudy	Number of Days Precipitation ≥0.01 in	Number of Days Heavy Fog
January	18 5	47	-17	0.11	1.5	10.7	7	13	11	5	0
February	12 6	49	-21	0 23	3.5	11 8	12	2	14	8	0
March	24 7	60	2	0 61	7.4	12 8	5	12	14	15	0
April	35 9	66	-3	1.30	4 0	12.0	4	3	23	13	4
May	52 8	84	32	1.93	T	12.8	3	11	17	11	1
June	62 4	91	40	1.20	0 0	11.0	8	10	12	15	0
July	73.1	103	50	4.18	0 0	9.5	12	13	6	11	0
August	64 9	96	42	1.37	0.0	10.9	13	10	8	13	1
September	56 3	86	32	0.42	0.0	10.5	15	9	6	4	0
October	45 0	85	20	1.77	7.0	9.8	5	7	19	5	0
November	30.1	75	-15	0.40	5.5	8.7	7	4	19	9	1
December	18.5	50	-22	0.38	4.7	8.8	6	7	18	8	2
Year	41 2	103	-22	13 9	33 6	10.8	97	101	167	117	9

Table B-2

NORMAL, MEAN AND EXTREME METEOROLOGICAL DATA FOR GLASGOW, MONTANA

	Temperature (°F)			Precipitation (inches)					Wind (mph)	Mean Number of Days				
					Water Equivalent			Snow, Ice						
Month	Average Monthly	Record Highest	Record Lowest	Normal	Maximum Monthly	Minimum Monthly	Maximum in 24 hrs	Maximum Monthly	Average Speed	Clear	Partly Cloudy	Cloudy	Precipitation >0 01 in	Heavy Fog
January	9 2	55	-47	0.39	1.24	T	0.37	24.2	10.8	5	7	19	9	1
February	15.2	57	-32	0.32	0.59	0 05	0.27	10.6	10 6	5	7	16	7	2
March	25.2	75	-19	0 37	0 93	0.05	0.40	14.8	11 7	5	10	16	7	2
April	42.8	88	-3	0.71	1.99	0.07	1.16	13.7	12.9	5	8	17	7	1
May	54 2	91	24	1.31	3.27	0.03	2.07	5.2	12.1	5	11	15	9	*
June	62.0	98	33	2.72	5 36	0.89	2.47	0.0	11.2	7	11	12	11	*
July	70.5	103	41	1.43	5.17	0.12	3.98	0.0	10.4	13	12	6	8	*
August	69.0	106	39	1.51	3.65	0.04	2.45	0.0	11.1	13	10	8	7	*
September	57 2	97	23	0.85	2.20	0.04	1.00	1.1	11.0	9	9	12	6	*
October	46.4	88	5	0.56	1.77	T	1.07	7.0	10.7	8	8	15	5	1
November	29.0	75	-18	0 39	1.26	T	0.37	17.2	9.7	6	6	18	6	2
December	17 1	54	-37	0.31	0.78	0 03	0.31	13 9	9.7	5	8	18	8	3
Annual	41.5	106	-47	10 87	5.36	T	3.98	24.2	11.0	86	107	172	89	12

*Less than one half day.

Table B-3

NORMAL, MEAN AND EXTREME METEOROLOGICAL DATA FOR SCOBEY, MONTANA

Month	Temperature (°F)			Precipitation (inches)					Wind
	Average Monthly (1949-78)	Record Highest (1940-78)	Record Lowest (1940-78)	Normal (1941-70)	Maximum Monthly (1940-78)	Minimum Monthly (1940-78)	Maximum in 24 hrs	Snow, Ice Maximum Monthly	Average Monthly Wind Speed* (mph)
Jan	7.2	55	-43	0 58	1.93	T	0.88	22 0	1.9
Feb	15.8	59	-40	0.50	2.61	0 0	0.79	35.4	2 9
Mar	25 4	77	-32	0.60	2 94	T	1 67	25 6	3 0
Apr	42 1	90	-13	0.99	2.81	0 02	1.63	19.0	2 7
May	54 2	97	7	1 67	5.47	0.12	1.75	1 0	4 0
Jun	63 2	100	23	3.04	8 18	0 92	2 90	T	3.0**
Jul	69 7	106	34	1 72	9.10	0 34	6.90		1 7**
Aug	68 1	105	26	1 76	4.69	0 11	2 05		1 3**
Sep	56 8	101	10	1.22	4.63	0.05	1 99	T	1 2**
Oct	45 7	90	- 4	0 62	1.71	0.00	1.30	5 7	0 7
Nov	28 5	75	-28	0.42	1 61	0.00	0 74	18.4	1 9
Dec	14 9	60	-37	0.50	1.64	0 00	0.83	16.5	2 3
Annual	41.0	106	-43	13.62	21.90	6.98	6.90	35.4	2 2

*Period of record is March, 1977 through March, 1979.

**Values available only for one month in above period.

T = trace of precipitation

after Gelhaus, *et al*., 1979.

Table B-4

NATIONAL AMBIENT AIR QUALITY STANDARDS[1]

Pollutant	Averaging Time	Primary[2,3]	Secondary[2,4]
Ozone	1 hour	240 $\mu g/m^3$	Same as primary standards
		(0.12 ppm)	Same as primary standards
	12 hours	-	Same as primary standàrds
	8 hours	10 mg/m^3	Same as primary standards
		(9 ppm)	Same as primary standards
	1 hour	40 mg/m^3	Same as primary standards
		(35 ppm)	Same as primary standards
Nitrogen dioxide	Annual average	100 $\mu g/m^3$	Same as primary standards
		(0.05 ppm)	Same as primary standards
	1 hour	-	Same as primary standards
Sulfur dioxide	Annual average	80 $\mu g/m^3$	-
		(0.03 ppm)	-
	24 hour	365 $\mu g/m^3$	-
		(0.14 ppm)	-
	3 hour	-	1300 $\mu g/m^3$
			(0.5 ppm)
	1 hour	-	-

Table B-4 (continued)

Pollutant	Averaging Time	Primary[2,3]	Secondary[2,4]
Suspended Particulate Matter	Annual geometric mean	75 $\mu g/m^3$	60 $\mu g/m^3$
	24 hour	260 $\mu g/m^3$	150 $\mu g/m^3$
Hydrocarbons (Corrected for methane)	3 hour (6-9 A.M.)	(0.24 ppm)	Same as primary standards Same as primary standards

[1]National standards, other than those based on annual average or annual geometric means, are not to be exceeded more than once per year.

[2]Concentration expressed first in units in which it was promulgated. Equivalent units given in parentheses are based upon a reference temperature of 25°C and a reference pressure of 760 mm of mercury. All measurements of air quality are to be corrected to a reference temperature of 25°C and a reference pressure of 760 mm of Hg (1,013.2 millibar); ppm in this table refers to ppm by volume, or micromoles of pollutant per mole of gas.

[3]National primary standards: The levels of air quality necessary, with an adequate margin of safety, to protect the public health. Each state must attain with primary standards no later than three years after that state's implementation plan is approved by the Environmental Protection Agency (EPA).

[4]National secondary standards: The levels of air quality necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant. Each state must attain the secondary standards within a "reasonable time" after implementation plan is approved by the EPA.

Source: Code of Federal Regulations Title 40, subchapter C, Part 50.

Table B-5

MONTANA AMBIENT AIR QUALITY STANDARDS

Pollutants	Standards (Maximum permissible concentrations)
Sulfur dioxide	0.02 ppm, maximum annual average
	0.10 ppm, 24-hour average, not to be exceeded over one percent of the days in any three month period
	0.25 ppm not to be exceeded for more than one hour in any four consecutive days
Reactive sulfur (sulfation)	0.25 milligrams sulfur trioxide per 100 square centimeters per day, maximum annual average
	0.50 milligrams sulfur trioxide per 100 square centimerers per day, maximum for any one month period
Suspended sulfate	4 micrograms per cubic meter of air, maximum allowable annual average
	12 micrograms per cubic meter of air, not to be exceeded over one percent of the time
Sulfuric acid mist	4 micrograms per cubic meter of air, maximum allowable annual average
	12 micrograms per cubic meter of air, not to be exceeded over one percent of the time
	30 micrograms per cubic meter of air, hourly average, not to be exceeded over one percent of the time
Hydrogen sulfide	0.03 ppm, one-half-hour average, not to be exceeded more than twice in any five consecutive days
	0.05 ppm, one-half-hour average, not be exceeded over twice a year

Table B-5 (continued)

Pollutants	Standards (Maximum permissible concentrations)
Total suspended particulate	75 micrograms per cubic meter of air, annual geometric mean 200 micrograms per cubic meter of air, not to be exceeded more than one percent of days a year
Settled particulate (Dustfall)	15 tons per square mile per month, three month average in residential areas 30 tons per square mile per month, three month average in heavy industrial areas
Lead	5.0 micrograms per cubic meter of air, 30 day average
Berryllium	0.01 micrograms per cubic meter of air, 30 day average
Fluorides, total (as HP) in air	1 part per billion parts of air, 24 hour average
Fluorides (as F) in forage for animal consumption - dry weight basis	35 parts per million
Fluorides (gaseous)	0.3 micrograms per square centimeter per 28 days

Source: Montana Administrative Code, Chapter 14, Environmental Sciences Division, Subchapter 1, Air Quality Bureau.

APPENDIX C

CRSTER AIR QUALITY MODEL

C-1. SINGLE SOURCE (CRSTER) MODEL

The Single Source (CRSTER) Model is a steady-state, Gaussian plume dispersion model designed for point-source applications. It calculates pollutant concentrations for each hour of a year at 180 receptor sites on a radial grid. The hourly concentrations are averaged to obtain concentration estimates for time increments of specified length, such as 3-hour, 8-hour, 24-hour, and annual. The model contains the concentration equations, the Pasquill-Gifford dispersion coefficients, and the Pasquill stability classes, as given by Turner (1970). Plume rise is calculated according to Briggs (1972). No depletion of the pollutant is considered. (Abstract from User's Manual (EPA, 1977)).

The Single Source (CRSTER) Model has two sections, one that estimates the effective height of the pollutant plume from a point source, and another that models the downwind section of the plume. In both parts assumptions about atmospheric air flow are made to assure a reasonable computer program but still depict most of the atmospheric processes.

The plume rise in this model is based on equations developed by Briggs (1972) where it is assumed that the plume rise depends on the inverse of the mean wind speed and is proportional to the 2/3 power of the downwind distance from the source.

$$\Delta h = (X_f)^{2/3} u^{-1}$$

Some modifications are made to account for windy and near calm conditions. The final plume rise only is used and does not take into effect negative buoyancy of relatively cold plumes nor flow changes caused by buildings and other tall structures near the source stack.

Briggs final plume rises are shown in the following equations:

- For unstable or neutral atmospheric conditions, the downwind distance of the final plume rise is $X_f = 3.5 X^*$, which results in

$$\Delta h = 1.6 F^{1/3} (3.5 X^*)^{2/3} u^{-1}$$

where, depending on buoyancy

$$X^* = 14 F^{5/8}, \qquad F < 55 \ m^4/s^3$$

$$X^* = 34 F^{2/5}, \qquad F \geq 55 \ m^4/s^3$$

-For stable atmospheric conditions, the downwind distance of the final plume rise is $X_f = \pi u s^{-1/2}$, which results in

$$\Delta h = 2.5\ [F/(\mu s)]^{1/3}, \text{ windy conditions}$$

$$\Delta h = 5\ F^{1/4}\ s^{3/8}, \text{ for near calm conditions}$$

See Table C-1 for symbol definitions.

It is assumed that the plume cross-section expands in a Gaussian manner caused by eddy diffusion as it is transported downwind by the mean wind. Empirical dispersion coefficients, σy, σz, determined by Pasquill (1974), Gifford (1961) and Turner (1970) are used to determine the surface concentrations, as shown in the following equation.

$$X\ (x,y) = \frac{Q}{\pi \sigma_y \sigma_z u} \exp\left[-.5\ (y/\sigma y)^2\right] \exp\left[-.5\ (H/\sigma z)^2\right]$$

u is the wind speed that is advecting the plume along the X - axis. The pollutant emission is given as a uniform rate Q and H is the cross-sectional center of the plume and is defined as

$$H = h_s + \Delta h$$

where h_s is the stack height.

The Single Source (CRSTER) Model modifies this plume concept by trapping between the mixing layer top and ground, uniform mixing in the mixing layer beyond a critical distance, and exclusion of plumes released above the mixing layer.

This model treats the top of the mixing layer as a boundary similar to that of the ground. Mixing caused by this trapping is modeled by reflections of plume at the mixing height and ground. These reflections can then be represented by the convergent infinite series of Gaussian plume terms.

$$X = \frac{Q}{\pi \sigma_y \sigma_z u} \exp\left[-.5\ (y/\sigma_y)^2\right] \sum_{N=-\infty}^{N=+\infty} \exp\left[-.5\ \left(\frac{H+2LN}{\sigma_z}\right)^2\right],$$

where L is the mixing height. For economic reasons a limit of summation iterations is 45 instead of infinity. Beyond a certain distance determined by this series it can be safely assumed that there is homogeneous vertical mixing.

Table C-1

DEFINITION OF SYMBOLS USED IN BRIGGS' PLUME RISE EQUATIONS

Symbol	Definition	Units
g	gravitational acceleration	9.8 $^{m}/s^{2}$
d	inside stack diameter	m
F	buoyancy flux parameter $[g\ V_s\ (d/2)^2\ (T_s - T/T_s)]$	m^{4}/s^{3}
X*	distance at which atmospheric turbulance dominates entrainment	m
Δh	plume rise above stack top	m
T	ambient air temperature	°K
Tx	stack gas temperature	°K
u	mean wind speed	m/s
V_s	stack gas exit velocity	m/s
s	restoring acceleration per unit vertical displacement for adiabatic motion in the atmosphere $g\ ^{\partial\theta}/_{\partial z}\ T^{-1}$	s^{-1}
$\partial\theta/_{\partial z}$	vertical potential temperature gradient of the atmosphere between stack top and plume top	°K/m

Other assumptions employed by the Single Source (CRSTER) Model are; the atmosphere is an ideal gas, there is a continuous uniform emission rate of pollutants, a homogeneous wind within the mixing layer, and a steady-state condition. The steady-state condition does not allow any effects of plume history. It is also assumed that the pollutant emitted is a stable gas or aerosol that remains suspended in the air. There is no removal or addition by chemical means downwind.

In order to counter the bias of the wind data supplied by the National Weather Service where wind directions were reported to the nearest 10°, the Single Source (CRSTER) Model superimposed a random variation from -4° to +5°.

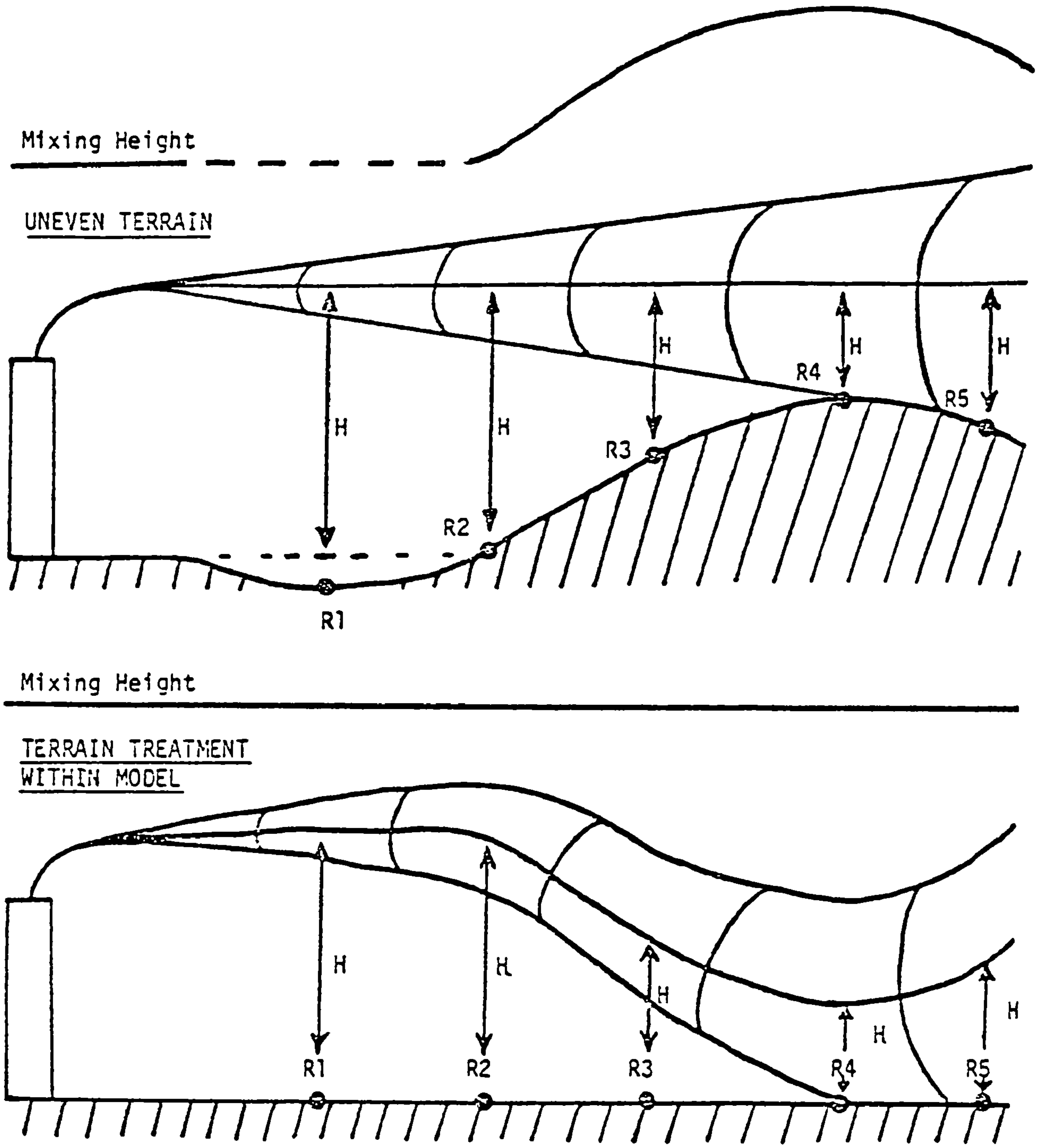
The Single Source (CRSTER) Model functions on the prepared hourly observations created by the Preprocessor program. This program accepts the hourly surface observations and the twice-daily mixing heights based on upper air observations obtained from the National Climatic Center. To produce the hourly mixing heights needed by the Single Source (CRSTER) Model, the Preprocessor uses two interpolation schemes depending if the plume is over an urban area or rural area. In both the urban and rural environments when conditions are neutrally stable the hourly mixing heights are interpolated on the maximum from the previous day, computation day and following day which were based on the 1400 LST upper air sounding. For stable conditions in the urban environment interpolation would be made between the maximum mixing height at 1400 LST and the minimum heights are assumed constant during darkness and then variations are made between sunrise and sunset. The rural scheme is different in that in the stable conditions the mixing height is interpolated between zero at sunrise and the maximum mixing height at 1400. After 1400 it is interpolated with next days maximum mixing height.

The Preprocessor determines the stability by knowing sunrise and sunset, solar elevation, ceiling height and cloud cover. From this net radiation indices can be calculated. In conjunction with surface wind speeds the stability classification can be made.

Uneven terrain is considered by the Single Source (CRSTER) Model by assuming the plume's height is unaffected but the mixing height remains at a constant height over the changing terrain. This situation is changed to flat terrain where the plume altitude is altered accordingly but the plume height, H, remains unchanged (as shown in Figure C-1).

Ground elevation below the ground elevation of the plant is considered at plant elevation and any terrain higher than stack altitude terminates processing after printing out an error message.

From all the input meteorological variables and emission source paramaters the Single Source (CRSTER) Model can produce, for each hour in a given time period, surface pollutant concentrations surrounding the



Note: R1-R5 are receptor points at 5 ring distances.

Figure C-1 ILLUSTRATION OF THE METHOD FOR TERRAIN ADJUSTMENT IN THE SINGLE SOURCE (CRSTER) MODEL source. These values are given for receptor points along 36 radials, spaced at 10° intervals, where the ring distances are determined by the user. However, it is more important to the user if over a years time the maximum concentrations for each receptor point are recorded. Also, printed out are the second highest concentrations. This model is set up to record the highest and second highest concentrations of 1 hourly computations, 3-hour averaged sections, and daily averaged sections. An annual overall average is also produced. For completeness the model can be set up for 2, 4, 6, 8, or 12 hour average periods.

LIMITATIONS OF THE SINGLE SOURCE (CRSTER) MODEL

One of the biggest sources of error for this model is when emissions, wind speeds, directions, local turbulence, and atmospheric stability are changing rapidly in time and/or distance. Thus, the passage of fronts, onsets of sea breezes, and other rapid events will introduce large errors, since this program is very sensitive to changes in wind direction. Since a homogeneous air flow is assumed, the existence and variations of vertical shears cannot be accounted for. Directional variation of vertical shear would allow clockwise or counterclockwise plume patterns, increasing the error as radial distance is increased. Dispersion coefficients (σy and σz) can vary in the downwind direction only. In reality vertical variations may also exist. Thus, the coefficients provide only an estimate of dispersion.

As mentioned earlier, the terrain is only allowed to vary between the stack top and ground elevation of the plant and should be less. This restriction limits this model to flat plains. Omission of local aerodynamic effects that interact with the plume may make the model less real. Obviously, downwash cannot be incorporated even though it can be important. Other aerodynamic obstacles could impede the plume and allow for greater surface concentrations near the plant.

Near-calm conditions cause the Gaussian plume equation used to develop unrealistically large surface concentrations. For this reason, when winds are below 1.0 m/sec but greater than calm, the values are increased to 1.0 m/sec. In a calm condition, this model uses the wind direction from the previous non-calm hour. If a series of consecutive calm hours occur pollutant concentrations are overestimated.

The Single Source (CRSTER) Model considers only hot buoyant plumes. There are some cases where emitted plume temperatures are very similar to the ambient temperature. This would not allow for the resulting increase of surface concentrations near the stack and lesser concentrations further away.

Table C-2

SULFUR DIOXIDE CONCENTRATIONS ($\mu G/M^3$) OBTAINED FROM MODEL CALCULATIONS AT RECEPTORS ALONG SPECIFIED AZIMUTHS FOR ZERO PERCENT CONTROL AT THE 600 MW POPLAR RIVER PLANT

ZERO PERCENT CONTROL

Receptor	1 Hour Average			3 Hour Average			24 Hour Average			Annual Average		
Distance	Highest/2nd Highest			Highest/2nd Highest			Highest/2nd Highest			1964		
(Km)	120°	170°	260°	120°	170°	260°	120°	170°	260°	120°	170°	260°
6	213/175	145/137	170.113	78.1/76.0	48.4/45.6	56.9/37.5	24.1/13.8	6.4/6.1	7.1/6.8	1.5	0.22	0.21
8	202/158	143/106	198/98.2	72.7/72.5	47.6/47.0	66.6/32.7	21.6/19.2	7.7/6.0	9.4/8.3	1.9	0.27	0.29
10	172/133	126/91.5	183/87.1	63.8/63.8	55.3/42.1	62.6/41.2	21.5/18.7	9.6/6.1	10.3/7.8	2.1	0.31	0.34
12	147/122	109/97.6	161/74.1	58.4/55.8	57.1/36.5	56.1/45.5	21.7/19.6	10.3/7.9	10.2/8.1	2.1	0.33	0.38
14	128/112	95.6/94.5	141/76.4	55.3/52.6	56.2/31.9	50.3/47.0	21.0/19.9	10.5/9.1	9.7/8.9	2.1	0.35	0.41
16	113/101	87.7/84.8	125/75.9	53.6/48.3	54.0/29.2	46.8/45.7	19.9/19.4	10.2/9.9	9.3/9.1	2.1	0.35	0.43
18	102/91.5	80.1/76.2	113/73.7	51.2/46.8	51.2/26.7	45.5/42.1	18.7/18.7	10.4/9.9	9.4/8.5	2.0	0.35	0.44
20	92.5/83.6	72.9/69.3	102/70.8	48.7/44.8	48.2/25.4	43.7/39.1	17.8/17.4	10.6/9.5	9.2/7.9	2.0	0.35	0.44
22	84.9/84.1	66.7/63.6	93.9/67.4	46.1/42.8	45.2/25.8	41.7/36.4	16.9/16.6	10.6/9.0	9.2/7.3	1.9	0.34	0.44
24	83.5/78.4	61.3/58.7	86.8/64.0	43.6/41.2	42.4/25.9	39.6/34.1	16.1/15.4	10.5/8.5	8.7/6.8	1.8	0.33	0.43
30	78.1/72.3	49.2/48.0	70.9/54.4	37.0/36.1	35.0/24.9	33.8/28.9	14.6/13.3	9.8/7.2	7.8/6.3	1.6	0.30	0.40
35	71.9/66.6	48.5/44.8	61.7/52.3	32.5/32.1	30.2/23.3	29.7/26.8	13.5/11.5	9.0/6.2	7.0/6.3	1.4	0.28	0.38
40	66.0/64.9	48.3/44.8	54.6/53.2	28.9/28.7	26.4/21.6	26.5/26.4	12.6/10.4	8.3/5.5	6.3/6.2	1.3	0.25	0.35
45	64.4/60.7	46.7/43.4	52.2/50.5	26.0/25.8	23.3/20.0	25.5/25.3	11.6/9.5	7.6/4.8	6.0/5.8	1.2	0.23	0.32
50	63.6/61.9	45.1/41.9	51.0/49.3	23.6/23.3	20.8/18.4	24.4/24.3	10.8/8.6	7.0/4.3	5.8/5.3	1.1	0.21	0.30

Note: Dashed line indicates location of International Boundary.

Table C-3

SULFUR DIOXIDE CONCENTRATIONS ($\mu G/M^3$) OBTAINED FROM MODEL CALCULATIONS AT RECEPTORS ALONG SPECIFIED AZIMUTHS FOR SIXTY PERCENT CONTROL AT THE 600 MW POPLAR RIVER PLANT

SIXTY PERCENT CONTROL

Receptor	1 Hour Average			3 Hour Average			24 Hour Average			Annual Average		
Distance	Highest/2nd Highest			Highest/2nd Highest			Highest/2nd Highest			1964		
(Km)	120°	170°	260°	120°	170°	260°	120°	170°	260°	120°	170°	260°
6	85.2/70.0	58.0/54.8	68.0/45.2	31.2/30.4	19.4/18.2	22.8/15.0	9.6/5.5	2.6/2.4	2.8/2.7	0.60	0.09	0.08
8	80.8/63.2	57.2/42.4	79.2/39.3	29.1/29.0	19.0/18.8	26.6/13.1	8.6/7.7	3.1/2.4	3.8/3.3	0.76	0.11	0.12
10	68.8/53.2	50.4/36.6	73.2/34.8	25.5/25.5	22.1/16.8	25.0/16.5	8.6/7.5	3.8/2.4	4.1/3.1	0.84	0.12	0.14
12	58.8/48.8	43.6/39.0	64.4/29.6	23.4/22.3	22.8/14.6	22.4/18.2	8.7/7.8	4.1/3.2	4.1/3.2	0.84	0.13	0.15
14	51.2/44.8	38.2/37.8	56.4/30.6	22.1/21.0	22.5/12.8	20.1/18.8	8.4/8.0	4.2/3.6	3.9/3.6	0.84	0.14	0.16
16	45.2/40.4	35.1/33.9	50.0/30.4	21.4/19.3	21.6/11.7	18.7/18.3	8.0/7.8	4.1/4.0	3.7/3.7	0.84	0.14	0.17
18	40.8/36.6	32.0/30.5	45.2/29.5	20.5/18.7	20.5/10.7	18.2/16.8	7.5/7.5	4.2/4.0	3.8/3.8	0.80	0.14	0.18
20	37.0/33.4	29.2/27.7	40.8/28.3	19.5/17.9	19.3/10.2	17.5/15.6	7.1/7.0	4.2/3.8	3.7/3.2	0.80	0.14	0.18
22	34.0/33.6	26.7/25.4	37.6/27.0	18.4/17.1	18.1/10.3	16.7/14.6	6.8/6.6	4.2/3.6	3.7/2.9	0.76	0.14	0.18
24	33.4/31.4	24.5/23.5	34.7/25.6	17.4/16.5	17.0/10.4	15.8/13.6	6.4/6.2	4.2/3.4	3.5/2.7	0.72	0.13	0.17
30	31.2/28.9	19.7/19.2	28.4/21.8	14.8/14.4	14.0/10.0	13.5/11.6	5.8/5.3	3.9/2.9	3.1/2.5	0.64	0.12	0.16
35	28.8/26.6	19.4/17.9	24.7/20.9	13.0/12.8	12.1/9.3	11.9/10.7	5.4/4.6	3.6/2.5	2.8/2.5	0.56	0.11	0.15
40	26.4/26.0	19.3/17.9	21.8/21.3	11.6/11.5	10.6/8.6	10.6/10.6	5.0/4.2	3.3/2.2	2.5/2.5	0.52	0.10	0.14
45	25.8/24.3	18.7/17.4	20.9/20.2	10.4/10.3	9.3/8.0	10.2/10.1	4.6/3.8	3.0/1.9	2.4/2.3	0.48	0.09	0.13
50	25.4/24.8	18.0/16.8	20.4/19.7	9.4/9.3	8.3/7.4	9.8/9.7	4.3/3.4	2.8/1.7	2.3/2.1	0.44	0.08	0.12

Note: Dashed line indicates location of International Boundary.

Table C-4

SULFUR DIOXIDE CONCENTRATIONS ($\mu G/M^3$) OBTAINED FROM MODEL CALCULATIONS AT RECEPTORS ALONG SPECIFIED AZIMUTHS FOR NINETY PERCENT CONTROL AT THE 600 MW POPLAR RIVER PLANT

NINETY PERCENT CONTROL

Receptor	1 Hour Average			3 Hour Average			24 Hour Average			Annual Average		
Distance	Highest/2nd Highest			Highest/2nd Highest			Highest/2nd Highest			1964		
(Km)	120°	170°	260°	120°	170°	260°	120°	170°	260°	120°	170°	260°
6	21 3/17 5	14 5/13.7	17 0/11 3	7.8/7 6	4 8/4.6	5 7/3 7	2.4/1 4	0 64/0 61	0.71/0.68	0.15	0 02	0.02
8	20 2/15 8	14 3/10 6	19 8/9 8	7 3/7 3	4 8/4 7	6.7/3.3	2 2/1.9	0 77/0 60	0.94/0.93	0.19	0 03	0.03
10	17 2/13 3	12 6/9 2	18 3/8 7	6 4/6.4	5 5/4.2	6 3/4.1	2 2/1 8	0 96/0.61	1.0/0.78	0 21	0.03	0 03
12	14 7/12 2	10 9/9 8	16 1/7 4	5 8/5 6	5.7/3 7	5.6/4 6	2 2/2.0	1 0/0 79	1 0/0.81	0.21	0 03	0.04
14	12 8/11 2	9 6/9 5	14 1/7 6	5 5/5.3	5 6/3.2	5 0/4.7	2 1/2.0	1 1/0.91	0.97/0 89	0.21	0 04	0.04
16	11 3/10 1	8 8/8 5	12 5/7 6	5 4/4.8	5 4/2 9	4 7/4 6	2 0/1.9	1.0/0.99	0.93/0.91	0.21	0 04	0.04
18	10 2/9 2	8 0/7 6	11.3/7 4	5.1/4 7	5 1/2 7	4.6/4 2	1.9/1.9	1 0/0.99	0.94/0.85	0.20	0 04	0 04
20	9 3/8 4	7 3/6 9	10 2/7 1	4 9/4.5	4 8/2 5	4 4/3 9	1 8/1 7	1.1/0.95	0.92/0.79	0.20	0.04	0 04
22	8 5/8 4	6 7/6 4	9 4/6 7	4.6/4.3	4 5/2 6	4 2/3.6	1.7/1.7	1.1/0.90	0.92/0.73	0.19	0.03	0.04
24	8 4/7 8	6 1/5 9	8.7/6 4	4 4/4.1	4 2/2 6	4 0/3 4	1 6/1.5	1.1/0 85	0.87/0.68	0.18	0 03	0.04
30	7 8/7 2	4 9/4.8	7 1/5 4	3 7/3 6	3.5/2 5	3.4/2.9	1 5/1 3	0.98/0.72	0.78/0 63	0.16	0.03	0.04
35	7 2/6 7	4 9/4 5	6 2/5 2	3 3/3 2	3 0/2 3	3.0/2.7	1.4/1.2	0 90/0.62	0.70/0.63	0.14	0.03	0.04
40	6 6/6 5	4 8/4 5	5 5/5 3	2 9/2 9	2.6/2 2	2.7/2.6	1.3/1.0	0 83/0 55	0 63/0 62	0.13	0.03	0.04
45	6 4/6 1	4 7/4 3	5 2/5 1	2 6/2 6	2.3/2.0	2.6/2.5	1 2/1 0	0 76/0.48	0.60/0.58	0.12	0.02	0 03
50	6 4/6 2	4 5/4 2	5 1/4 9	2 4/2 3	2.1/1 8	2 4/2.4	1.1/0 9	0 70/0 43	0.58/0 53	0 11	0 02	0.03

Note: Dashed line indicates locations of International Boundary.

Table C-5

SULFUR DIOXIDE CONCENTRATIONS ($\mu G/M^3$) OBTAINED FROM MODEL CALCULATIONS AT RECEPTORS ALONG SPECIFIED AZIMUTHS FOR ZERO PERCENT CONTROL AT A 1200 MW POPLAR RIVER PLANT

ZERO PERCENT CONTROL

Receptor	1 Hour Average			3 Hour Average			24 Hour Average			Annual Average		
Distance	Highest/2nd Highest			Highest/2nd Highest			Highest/2nd Highest			1964		
(Km)	120°	170°	260°	120°	170°	260°	120°	170°	260°	120°	170°	260°
6	426/350	290/274	340/226	156/152	96.8/91.2	114/75.0	48.2/27.6	12.8/12.2	14.2/13.6	3.0	0.44	0.42
8	404/316	286/212	396/196	145/145	95.2/94.0	133/65.4	43.2/38.4	15.4/12.0	19.6/16.6	3.8	0.54	0.58
10	344/266	252/183	366/174	128/128	111/84.2	125/82.4	43.0/37.4	19.2/12.2	20.6/15.6	4.2	0.62	0.68
12	294/244	218/195	322/148	116/112	114/73.0	112/91.0	43.4/39.2	20.6/15.8	20.4/16.2	4.2	0.66	0.76
14	256/224	191/189	282/153	111/105	112/63.8	101/94.0	42.0/39.8	21.0/18.2	19.4/17.8	4.2	0.70	0.82
16	226/202	175/170	250/152	107/96.6	108/58.4	93.6/91.4	39.8/38.8	20.4/19.8	18.6/18.4	4.2	0.70	0.86
18	204/183	160/152	226/147	102/93.6	102/53.4	91.0/84.2	37.4/37.4	20.8/19.8	18.8/17.0	4.0	0.70	0.88
20	185/167	146/139	204/142	97.4/89.6	96.4/50.8	87.4/78.2	35.6/34.8	21.2/19.0	18.4/15.8	4.0	0.70	0.88
22	170/168	133/127	188/135	92.2/85.6	90.4/51.6	83.4/72.8	33.8/33.2	21.2/18.0	18.4/14.6	3.8	0.68	0.88
24	167/157	123/117	174/128	87.2/82.4	84.8/51.8	79.2/68.2	32.2/30.8	21.0/17.0	17.4/13.6	3.6	0.66	0.86
30	156/145	98.4/96.0	142/109	74.0/72.2	70.0/49.8	67.6/57.8	29.2/26.6	19.6/14.4	15.6/12.6	3.2	0.60	0.80
35	144/133	97.0/89.6	123/105	65.0/64.2	60.4/46.6	59.4/53.6	27.0/23.0	18.0/12.4	14.0/12.6	2.8	0.56	0.76
40	132/130	96.6/89.6	109/106	57.8/57.4	52.8/43.2	53.0/52.8	25.2/20.8	16.6/11.0	12.6/12.4	2.6	0.50	0.70
45	129/121	93.4/86.8	104/101	52.0/51.6	46.6/40.0	51.0/50.6	23.2/19.0	15.2/9.6	12.0/11.6	2.4	0.46	0.64
50	127/124	90.2/83.8	102/98.6	47.2/46.6	41.6/36.8	48.8/48.6	21.6/17.2	14.0/8.6	11.6/10.6	2.2	0.42	0.60

Note: Dashed line indicates location of International Boundary.

Table C-6

SULFUR DIOXIDE CONCENTRATIONS (μG/M^3) OBTAINED FROM MODEL CALCULATIONS AT RECEPTORS ALONG SPECIFIED AZIMUTHS FOR SIXTY PERCENT CONTROL AT A 1200 MW POPLAR RIVER PLANT

SIXTY PERCENT CONTROL

Receptor	1 Hour Average			3 Hour Average			24 Hour Average			Annual Average		
Distance	Highest/2nd Highest			Highest/2nd Highest			Highest/2nd Highest			1964		
(Km)	120°	170°	260°	120°	170°	260°	120°	170°	260°	120°	170°	260°
6	170/140	116/110	136/90.4	62.5/60.8	38.7/36.5	45.5/30.0	19.3/11.0	5.1/4.9	5.7/5.4	1.2	0.18	0.17
8	162/126	114/84.8	158/78.6	58.2/58.0	38.1/37.6	53.3/26.2	17.3/15.4	6.2/4.8	7.8/6.6	1.5	0.22	0.23
10	138/106	101/73.2	146/69.7	51.0/51.0	44.2/33.7	50.1/33.0	17.2/15.0	7.7/4.9	8.2/6.2	1.7	0.25	0.27
12	118/97.6	87.2/78.1	129/59.3	46.7/44.6	45.7/29.2	44.9/36.4	17.4/15.7	8.2/6.3	8.2/6.5	1.7	0.26	0.30
14	103/89.6	76.5/75.6	113/61.1	44 2/42.1	45.0/25.5	40.2/37.6	16.8/15.9	8.4/7.3	7.8/7.1	1.7	0.28	0.33
16	90.4/80.8	70.2/67.8	100/60.7	42.9/38.6	43.2/23.4	37.4/36.6	15.9/15.5	8.2/7.9	7.4/7.4	1.7	0.28	0.34
18	81 6/73 2	64.1/61.0	90.4/59.0	41.0/37.4	41.0/21.4	36.4/33.7	15.0/15.0	8.3/7.9	7.5/6.8	1.6	0.28	0.35
20	74 0/66.9	58.3/55.4	81.6/56.6	39.0/35.8	38.6/20.3	35.0/31.3	14.2/13.9	8.5/7.6	7.4/6.3	1.6	0.28	0.35
22	67.9/67.3	53.4/50.9	75.1/53.9	36.9/34.2	36.2/20.6	33.4/29.1	13.5/13.3	8.5/7.2	7.4/5.8	1.5	0.27	0.35
24	66.8/62.7	49.0/47.0	69.4/51.2	34 9/33.0	33.9/20.7	31.7/27.3	12.9/12.3	8.4/6.8	7.0/5.4	1.4	0.26	0.34
30	62 5/57 8	39 4/38.4	56.7/43.5	29 6/28.9	28.0/19.9	27.0/23.1	11.7/10.6	7.8/5.8	6.2/5.0	1.3	0.24	0.32
35	57 5/53.3	38.8/35.8	49.4/41.8	26.0/25.7	24.2/18 6	23.8/21.4	10.8/9.2	7.2/5.0	5.6/5.0	1.1	0.22	0.30
40	52 8/51 9	38.6/35.8	43.7/42.6	23.1/23.0	21.1/17 3	21.2/21.2	10.1/8.3	6.6/4.4	5.0/5.0	1.0	0.20	0.28
45	51.5/48.6	37.4/34.7	41.8/40.4	20.8/20.6	18 6/16.0	20.4/20.2	9.3/7.6	6.1/3.8	4.8/4.6	0.96	0.18	0.26
50	50 9/49.5	36.1/33.5	40.8/39.4	18.9/18.6	16.6/14.7	19.5/19.4	8.6/6.9	5.6/3.4	4.6/4.2	0.88	0.17	0.24

Note: Dashed line indicates location of International Boundary.

Table C-7

SULFUR DIOXIDE CONCENTRATIONS (µG/M^3) OBTAINED FROM MODEL CALCULATIONS AT RECEPTORS ALONG SPECIFIED AZIMUTHS FOR NINETY PERCENT CONTROL AT A 1200 MW POPLAR RIVER PLANT

NINETY PERCENT CONTROL

Receptor	1 Hour Average			3 Hour Average			24 Hour Average			Annual Average		
Distance	Highest/2nd Highest			Highest/2nd Highest			Highest/2nd Highest			1964		
(km)	120°	170°	260°	120°	170°	260°	120°	170°	260°	120°	170°	260°
6	42.6/35.0	29.0/27.4	34.0/22.6	15.6/15.2	9.7/9.1	11.4/7.5	4.8/2.8	1.3/1.2	1.4/1.4	0.30	0.04	0.04
8	40.4/31.6	28.6/21.2	39.6/19.6	14.5/14.5	9.5/9.4	13.3/6.5	4.3/3.8	1.5/1.2	2.0/1.7	0.38	0.05	0.06
10	34.4/26.6	25.2/18.3	36.6/17.4	12.8/12.8	11.1/8.4	12.5/8.2	4.3/3.7	1.9/1.2	2.1/1.6	0.42	0.06	0.07
12	29.4/24.4	21.8/19.5	32.2/14.8	11.6/11.2	11.4/7.3	11.2/9.1	4.3/3.9	2.1/1.6	2.0/1.6	0.42	0.07	0.08
14	25.6/22.4	19.1/18.9	28.2/15.3	11.1/10.5	11.2/6.4	10.1/9.4	4.2/4.0	2.1/1.8	1.9/1.8	0.42	0.07	0.08
16	22.6/20.2	17.5/17.0	25.0/15.2	10.7/9.7	10.8/5.8	9.4/9.1	4.0/3.9	2.0/2.0	1.9/1.8	0.42	0.07	0.09
18	20.4/18.3	16.0/15.2	22.6/14.7	10.2/9.4	10.2/5.3	9.1/8.4	3.7/3.7	2.1/2.0	1.9/1.7	0.40	0.07	0.09
20	18.5/16.7	14.6/13.9	20.4/14.2	9.7/9.0	9.6/5.1	8.7/7.8	3.6/3.5	2.1/1.9	1.8/1.6	0.40	0.07	0.09
22	17.0/16.8	13.3/12.7	18.8/13.5	9.2/8.6	9.0/5.2	8.3/7.3	3.4/3.3	2.1/1.8	1.8/1.5	0.38	0.07	0.09
24	16.7/15.7	12.3/11.7	17.4/12.8	8.7/8.2	8.5/5.2	7.9/6.8	3.2/3.1	2.1/1.7	1.7/1.4	0.36	0.07	0.09
30	15.6/14.5	9.8/9.6	14.2/10.9	7.4/7.2	7.0/5.0	6.8/5.8	2.9/2.7	2.0/1.4	1.6/1.3	0.32	0.06	0.08
35	14.4/13.3	9.7/9.0	12.3/10.5	6.5/6.4	6.0/4.7	5.9/5.4	2.7/2.3	1.8/1.2	1.4/1.3	0.28	0.06	0.08
40	13.2/13.0	9.7/9.0	10.9/10.6	5.8/5.7	5.3/4.3	5.3/5.3	2.5/2.1	1.7/1.1	1.3/1.2	0.26	0.05	0.07
45	12.9/12.1	9.3/8.7	10.4/10.1	5.2/5.2	4.7/4.0	5.1/5.1	2.3/1.9	1.5/1.0	1.2/1.2	0.24	0.05	0.06
50	12.7/12.4	9.0/8.4	10.2/9.9	4.7/4.7	4.2/3.7	4.9/4.9	2.2/1.7	1.4/0.86	1.2/1.1	0.22	0.04	0.06

Note: Dashed line indicates location of International Boundary.

Table C-8

OXIDES OF NITROGEN CONCENTRATIONS ($\mu G/M^3$) OBTAINED FROM MODEL CALCULATIONS AT RECEPTORS ALONG SPECIFIED AZIMUTHS FOR 600 AND 1200 MW POPLAR RIVER POWER PLANTS

	600 MW PLANT						1200 MW PLANT					
Receptor Distance	1 Hour Average Highest/2nd Highest			Annual Average 1964			1 Hour Average Highest/2nd Highest			Annual Average 1964		
(Km)	120°	170°	260°	120°	170°	260°	120°	170°	260°	120°	170°	260°
6	71.5/58.7	48.7/45.9	57.1/37.8	0.51	0.07	0.07	143/117	97.4/91.8	114/75.6	1.0	0.14	0.14
8	67 7/52.9	47.9/35.6	66.4/32.9	0.63	0.09	0.10	135/106	95.8/71.2	132/65.8	1.3	0.18	0.20
10	57.7/44.4	42.4/30.7	61.6/29.2	0.70	0.11	0.12	115/88.8	84.8/61.4	123/58.4	1.4	0.22	0.24
12	49.2/41.1	36.7/32.8	54.0/24.9	0.72	0.11	0.13	98.4/82.2	73.4/65.6	108/49.8	1.4	0.22	0.26
14	42.9/37.5	32.0/31.7	47.4/25.6	0.72	0.12	0.14	85.8/75.0	64.0/63.4	94.8/51.2	1.4	0.24	0.28
16	38.0/33.8	29.4/28.4	42.0/25.5	0.70	0.12	0.14	76.0/67.6	58.8/56.8	84.0/51.0	1.4	0.24	0.28
18	34 1/30.7	26.9/25.6	37.8/24.7	0.68	0.12	0.15	68.2/61.4	53.8/51.2	75.6/49.4	1.4	0.24	0.30
20	31 0/28.1	24 5/23.2	34.3/23.7	0.66	0.12	0.15	62.0/56.2	49.0/46.4	68.6/47.4	1.3	0.24	0.30
22	28 4/28.2	22.4/21.3	31.5/22.6	0.63	0.11	0.15	56.8/56.4	44.8/42.6	63.0/45.2	1.3	0.22	0.30
24	28 0/26.3	20.6/19.7	29.1/21.5	0.61	0.11	0.14	56.0/52.6	41.2/39.4	58.2/43.0	1.2	0.22	0.28
30	26.2/24.2	16.5/16.1	23.8/18.3	0.53	0.10	0.14	52.4/48.4	33.0/32.2	47.6/36.6	1.1	0.20	0.28
35	24.1/22.3	16.3/15.0	20.7/17.5	0.47	0.09	0.13	48.2/44.6	32.6/30.0	41.4/35.0	0.94	0.18	0.26
40	22.1/21.8	16.2/15.0	18.3/17.9	0.43	0.09	0.12	44.2/43.6	32.4/30.0	36.6/35.8	0.86	0.18	0.24
45	21.6/20.3	15.6/14.6	17.5/16.9	0.39	0.08	0.11	43.2/40.6	31.2/29.2	35.0/33.8	0.78	0.16	0.22
50	21.3/20.8	15.1/14.0	17.1/16.5	0.35	0.07	0.10	42.6/41.6	30.2/28.0	34.2/33.0	0.70	0.14	0.20

Note: Dashed line indicates location of International Boundary.

APPENDIX D

FLOW AND QUALITY MODELS

D-1. WATER QUANTITY MODEL

The Karp II Model is described in Appendix A Surface Water Quality of the IJC Report on the Poplar River (IJC, 1979) and is not repeated here. There are several assumptions used in the model which will be described since they are important to an understanding of the quantity impacts. These assumptions relating to flow apportionment are listed below:

1. Monthly flow balancing is assumed since this is necessary for modeling purposes.

2. The apportionment requires delivery of at least 50 percent of the natural flow to the U.S. on the West Poplar and 50 percent of the combined flows of the East Poplar and Poplar Rivers. In the model, this requirement is checked at the end of each month. If this condition has not been met for a given month, the deficit amount is obtained through an unscheduled release from Canadian storage during the following month. The release is made from the Poplar River reservoir if it is available, otherwise it is made from Cookson Reservoir on the East Poplar River.

3. Canadian usage was limited to a maximum of 50 percent of natural flows in the West Poplar River and its tributary, 40 percent in the Poplar River, limited on the East Poplar River. These limitations were applied on monthly flow volumes. For the "full apportionment" scenarios Canadian usage was allowed to increase to the following percentages of the median of the natural flows for each month of the year for the period 1931-1974: 50 percent for the West Poplar River and its tributary, 40 percent for the Poplar River, and 60 percent for Cow Creek and Coal Creek. In addition, the above mentioned constraint of limiting Canadian usage to a percentage of the natural flow on a month by month basis was still maintained.

4. The demand releases specified for the East Poplar were made during the months of June through September and May of the following year in proportion to the irrigation requirement in these months.

5. Flows to the U.S. in excess of 50 percent of 1-month's natural flow were not credited to succeeding monthly releases due the U.S.

D-2. WATER QUALITY MODEL (KARP III)

The KARP III Model is also described in Appendix A Surface Water Quality (IJC, 1979). The description of the model is not repeated here but important data relating to the water quality impacts are given.

The initial water quality of the hypothetical reservoir on the Middle Fork of the Poplar River and the Cookson Reservoir are as follows:

Parameter	Hypothetical Reservoir	Cookson Reservoir
TDS	884 mg/ℓ	1200 mg/ℓ
Na	166 mg/ℓ	297 mg/ℓ
Hardness	292 mg/ℓ	119 mg/ℓ
SO_4	169 mg/ℓ	336 mg/ℓ
B	1.05 mg/ℓ	2.6 mg/ℓ

The accretion is calculated as the sum of the outflows from the downstream station and the diversions in a given reach minus the total inflow to the reach and total return flows to the reach. The quality of the outflow is determined from the mass balance equation. The quality of surface irrigation return flows were assumed to have a concentration 10 percent higher than the diverted water due to the effects of evaporation and salt pickup. The concentration of subsurface irrigation return flows was assumed equal to the concentration of the ground water. Ground water quality was estimated to be the quality measured in the stream at the downstream station during the low flow period. In the Poplar River Basin where the low flow period is December to February, the median historical quality was used (Table D-1). If a loss of flow occurred in a reach, the quality of the seepage was set equal to the outflow. If a gain of flow occurred, which was equal to or less than the estimated ground water accretion rate (Table D-2), the quality of the accretion was set equal to the ground water quality from Table D-1. If the accretion was greater than the estimated ground water accretion, then the flow was considered to be surface runoff and the quality set equal to the historical quality based on the regression equations.

The calculations for all conservative parameters were bypassed if the monthly flow was below about 30 ac-ft, or 0.5 cubic feet per second, because these low flows were not adequately represented by historical data and were outside the range of the model. The total amount of salt contained in these low flows is small, but concentrations could be high. Inclusion of these data would tend to raise the median concentrations. Tabulated model outputs reflect only those months in which the flow exceeded 30 ac-ft.

D-3. MODIFIED MONTREAL ENGINEERING MODEL (MME)

The MME Model simulates the Cookson Reservoir including the mine and power plant discharges. This model was used only for scenarios 4A

Table D-1

ESTIMATED CONCENTRATIONS OF CONSERVATIVE PARAMETERS IN GROUNDWATER

Station	TDS mg/ℓ	Sodium mg/ℓ	Hardness mg/ℓ	Sulfate mg/ℓ	Boron mg/ℓ
3	1280	320	420	390	1.7
6	1240	315	370	320	1.6
7	1240	315	370	320	1.6
8	1250	330	370	370	1.7
11	800	260	140	150	.5
12	1360	375	350	290	1.0

Table D-2

ESTIMATED GROUNDWATER ACCRETION

Station	GW Accretion Acre-Feet/Month
3	36
6	18
7	6
8	327
11	137
12	553

8A. Since the time that the modeling work was done Saskatchewan Power Corporation has proposed to recirculate the ash lagoon decant rather than discharge the decant to the reservoir. Therefore, scenarios 4A with one power plant and 8A with two power plants represent the "worst case".

A description of the model is included in Appendix A Surface Water Quality (IJC, 1979). Other reports describing the model are Saskmont Engineering (1978) and Swales (1978).

Power plant related inputs to the reservoir included sulfuric acid for treatment of the boiler feedwater (3,000 to 35,000 kg/unit depending on reservoir quality), 30.2 kg/unit day of Na+K and 47.7 kg/day of SO_4 from the demineralization process, decreased alkalinity of 70 to 105 kg/unit day and increased chloride of 49 to 74 kg/unit day. The ash lagoon decant was assumed to add 171 mg/ℓ TDS, 35 mg/ℓ Na, 180 mg/ℓ SO_4, and 10 mg/ℓ boron per month. The amount of the ash discharge could vary from zero to 3,000,000 cubic meters per month depending on the number of units operating.

Other inputs to the reservoir included Fife Lake overflows (Table D-3) and ground water from mine dewatering. The mine discharge of 1 to 2 cfs was assumed to have the following quality:

TDS	1070 mg/ℓ
Ca	104 mg/ℓ
Mg	52 mg/ℓ
Na	227 mg/ℓ
SO_4	301 mg/ℓ
B	1.7 mg/ℓ

Ash lagoon seepage was assumed to enter the East Poplar River between Morrison Dam and the International Boundary up to a maximum of 30 ac-ft/month. Seepage from the reservoir to the East Poplar River was assumed to be 70 ac-ft/month.

Table D-3

ESTIMATED CONCENTRATIONS OF MODELLED PARAMETERS IN FIFE LAKE OVERFLOWS

Month/Year	TDS	Ca	Mg	Na	SO_4	B
	mg/ℓ					
1952, 1975						
March	385	23	25	105	131	1.72
April	131	19	8	23	42	1.75
May	559	26	26	161	226	1.91
June	1251	29	51	407	516	1.5
July	1523	20	58	509	662	2.72
August	1576	26	66	530	619	1.92
September	1536	20	64	525	604	1.98
October	1451	18	61	492	567	1.71
1953						
March	880	70	51	235	304	1.72
April	842	55	54	224	294	1.75
May	872	39	56	250	313	1.91
June	863	34	51	248	333	1.5
July	874	23	51	252	345	2.72
August	890	27	54	273	322	1.92
September	940	29	60	286	338	1.98
October	897	31	58	265	328	1.71
1954, 1976						
March	334	20	17	91	122	1.72
April	801	17	36	265	319	1.75
May	1368	24	61	434	564	1.91
June	1324	25	60	419	541	1.5
July	820	25	38	259	315	2.72
August	1294	24	71	464	519	1.92
September	1298	28	73	425	554	1.98
October	1332	30	73	434	495	1.71

Source: Saskmont Engineering, 1978.

APPENDIX E

U.S. AND CANADIAN WATER USE

Table E-1

MONTHLY SCHEDULES OF DEMANDS FOR WATER

Schedule Number	Monthly Fraction of Annual Water Demand											
	October	November	December	January	February	March	April	May	June	July	August	September
1	-	-	-	-	-	.40	.30	.10	.05	.05	.05	.05
2	.09	.05	.04	.04	.02	.01	-	.05	.00	.19	.23	.17
3	-	-	-	-	-	1.0	-	-	-	-	-	-
4	-	-	-	-	-	-	-	.12	.18	.32	.27	.11
5	.07	.05	.04	.04	.04	.05	.06	.10	.14	.16	.15	.10
6	.02	-	-	-	-	.60	.22	.07	.04	.02	.01	.02
7	.02	.02	.01	-	-	.38	.36	.11	.08	.02	-	-
8	.04	-	-	-	-	.39	.47	.06	.04	-	-	-
9	.02	.01	-	-	-	.54	.35	.04	.02	.01	.01	-
10	.03	-	-	-	-	.30	.61	.03	.03	-	-	-
11	.01	.01	-	-	-	.62	.29	.03	.02	.01	.01	-
12	1.0	-	-	-	-	-	-	-	-	-	-	-
13	0.9	.03	-	-	-	.01	.05	.09	.10	.22	.24	.17

Table E-2

ESTIMATED UNITED STATES DEMAND FOR WATER IN ACRE-FEET PER YEAR

Level of Development	Station	Irrigation: Stock and Domestic Demand	Irrigation: Sprinkler Demand	Irrigation: Sprinkler RF	Irrigation: Spreader Demand	Irrigation: Spreader RF	Irrigation: Flood Demand	Irrigation: Flood RF[1]	Municipal Demand	Total Demand	Total RF[1]
	3	105	-	-	850	153	200	40	350	1505	193
	7	122	1090	196	70	12	1027	205	-	2309	413
1975	8	334	550	99	310	56	2733	547	-	3927	702
	11	469	810	146	369	71	120	24	-	1768	241
	12	802	-	-	260	78	470	77	-	1532	155
	3	135	-	-	950	171	320	64	400	1805	235
	7	145	1430	257	180	32	1130	226	-	2885	515
1985	8	370	870	157	540	97	2830	566	-	4610	820
	11	498	1130	203	619	116	470	94	-	2717	413
	12	5726	27658	-	260	78	470	77	-	34114	155
	3	215	-	-	1090	196	750	150	600	2655	346
	7	207	2560	461	310	56	1560	312	-	4635	829
2000	8	465	2020	364	880	158	3270	654	-	6635	1176
	11	563	2470	445	959	178	1010	202	-	5002	825
	12	5726	55316	-	260	78	470	77	-	61772	155
Schedule No.[2]		3[3]	4[3]	2	3	1	4	2	5		

[1]Return flows (RF) in the table are considered to be subsurface. In addition to these, there is a surface return flow calculated as 24 percent of the water diverted for flood irrigation in any given month.

[2]The schedules are listed in Table E-4; they give the fraction of the annual water demand for each month of the year.

[3]The 1985 and 2000 demands at station 12 for stock, domestic, and sprinkler irrigation were done according to schedule 12.

Table E-3

ACREAGES UNDER INDICATED IRRIGATION PRACTICE,
PRESENT AND FUTURE

Sub-basin	1975	1985	2000
		Spreader	
East Poplar	1023	1140	1308
Middle Poplar	88	215	373
Main Poplar (above Fort Peck)	367	650	1057
West Poplar	397(47)*	700(47)	1102(47)
Main Poplar (inside Fort Peck)	(312)	(312)	(312)
		Sprinkler	
East Poplar	0	0	0
Middle Poplar	474	620	1114
Main Poplar (above Fort Peck)	240	380	880
West Poplar	353(0)	493(0)	1073(0)
Main Poplar (inside Fort Peck)	(470)	(10,000)	(20,000)
		Flood	
East Poplar	65	95	225
Middle Poplar	310	340	470
Main Poplar (above Fort Peck)	823	850	983
West Poplar	75(0)	140(0)	305(0)
Main Poplar (inside Fort Peck)	(470)	(470)	(470)

* ( ) indicates Indian acreages in addition to non-Indian acreage shown.

Table E-4

SUMMARY OF CANADIAN WATER USES*

Use	1985 East	1985 Middle	1985 West	2000+ East	2000+ Middle	2000+ West
Irrigation	311	73	135	311	73	135
Reservoir Evaporation	3600	-	230	3600	4960	230
Municipal	150	-	-	317	333**	-
Domestic	477	173	58	477	173	58
Wildlife	150	150	-	150	150	-
Power Plant	2180	-	-	2180	1181	1827++
TOTAL	6868	396	423	7035	6870	2250
		7687			16155	

*All values are in ac-ft.

**Diversion to Coronach Reservoir for water supply purposes.

+Model runs do not include power plant on the Middle Fork or the West Fork diversions.

++Diversion to the Middle Fork for power plant.

Source: Department of Environment, Province of Saskatchewan, 1978.

Table E-5

SUMMARY OF UNITED STATES WATER USES*

Use	1985 East	1985 Middle	1985 West	1985 Main	2000 East	2000 Middle	2000 West	2000 Main
Irrigation Sprinkler	-	1430	1130	28528	-	2560	2470	57336
Spreader	950	180	619	800	1090	310	959	1140
Flood	320	1130	470	3300	750	1560	1010	3740
Municipal	400	-	-	-	600	-	-	-
Domestic and Stock	135	145	498	6096	215	205	563	6191
TOTAL	1805	2885	2717	38724	2655	4635	5002	68407
		46131 ac-ft				80699 ac-ft		

*All values in acre-feet.

APPENDIX F

WATER QUANTITY IMPACTS

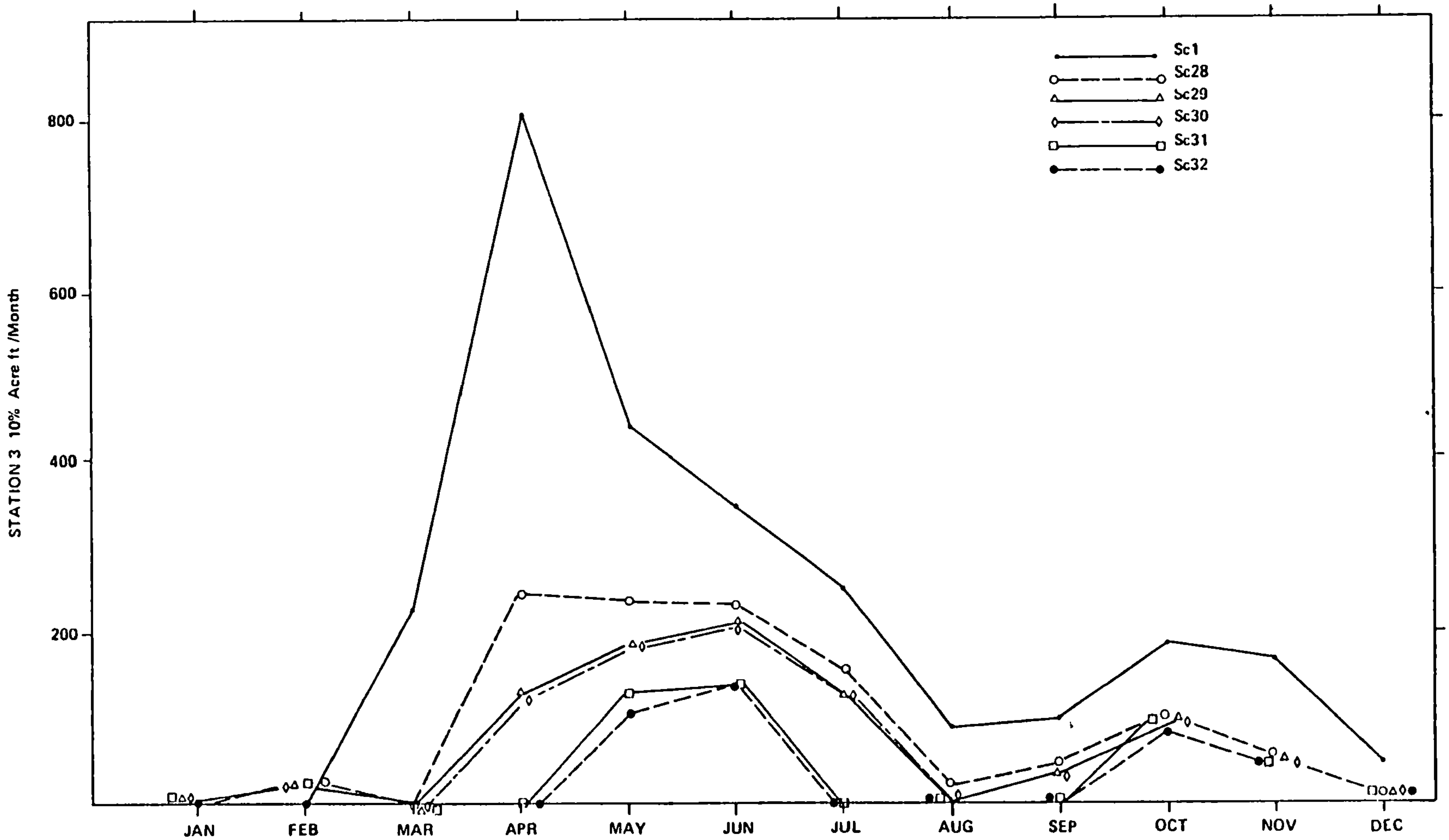


Figure F-1 FLOWS ON EAST FORK AT SCOBEY

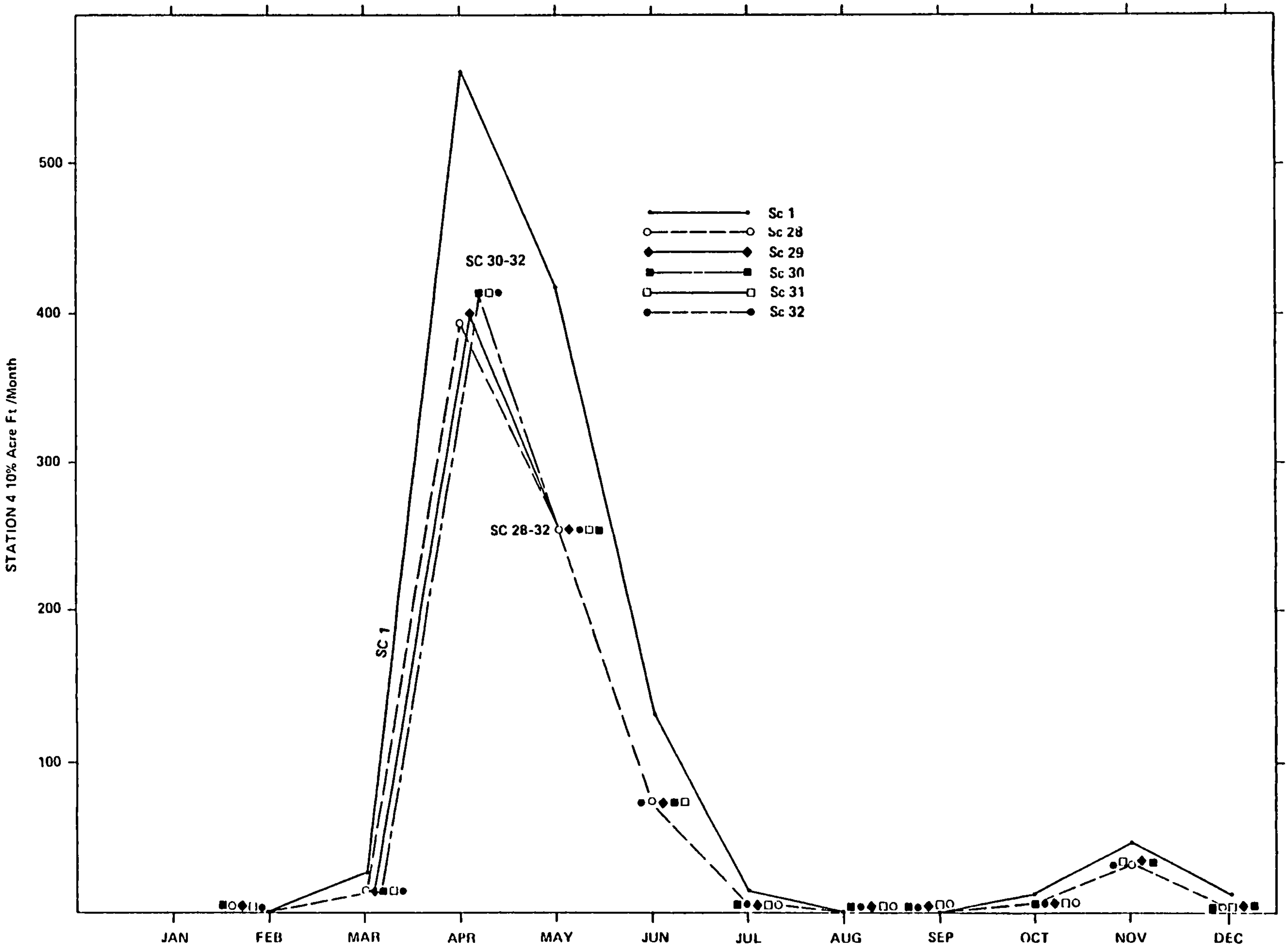


Figure F-2   FLOWS AT MIDDLE FORK AT INTERNATIONAL BORDER

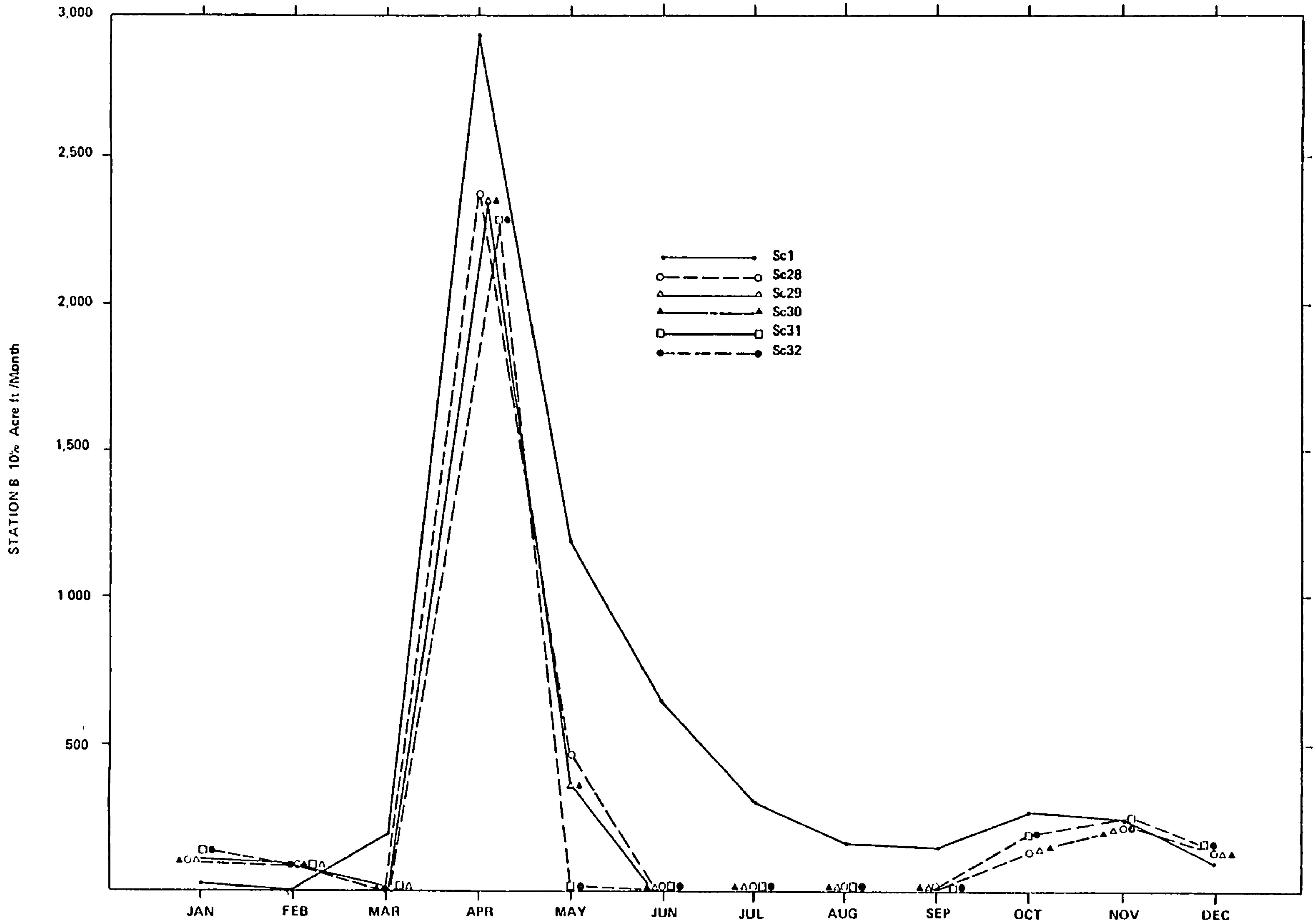


Figure F-3 FLOWS ON MAIN POPLAR AT BOUNDARY OF FORT PECK INDIAN RESERVATION

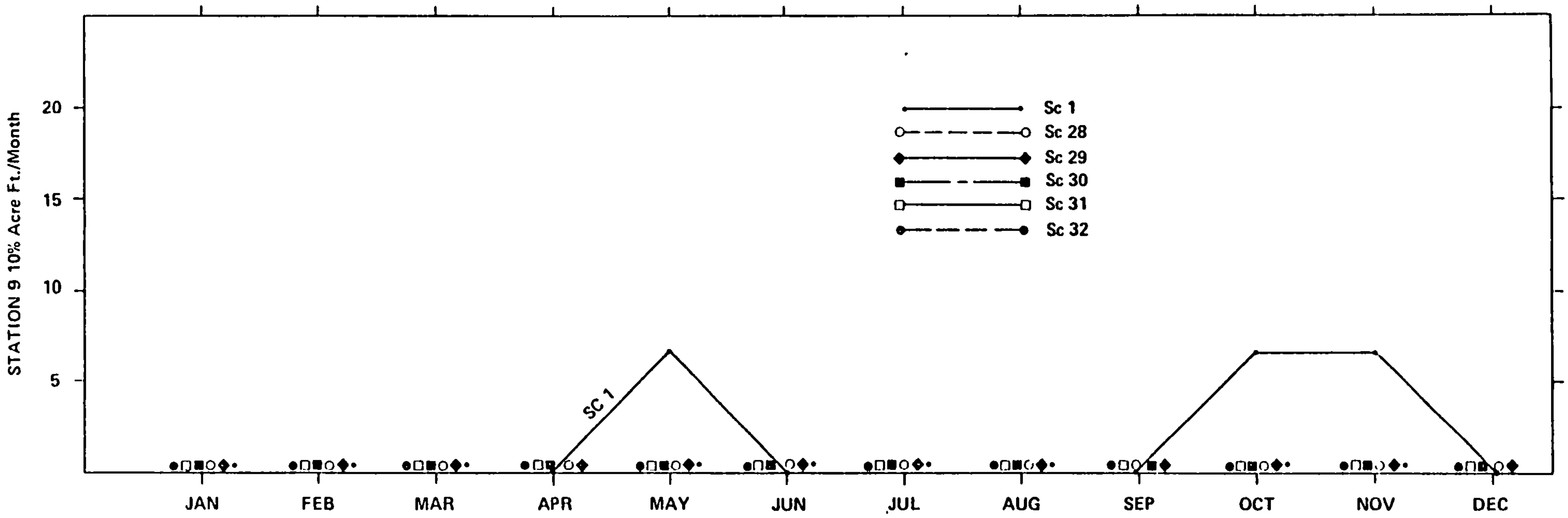


Figure F-4   FLOWS ON WEST FORK AT INTERNATIONAL BORDER

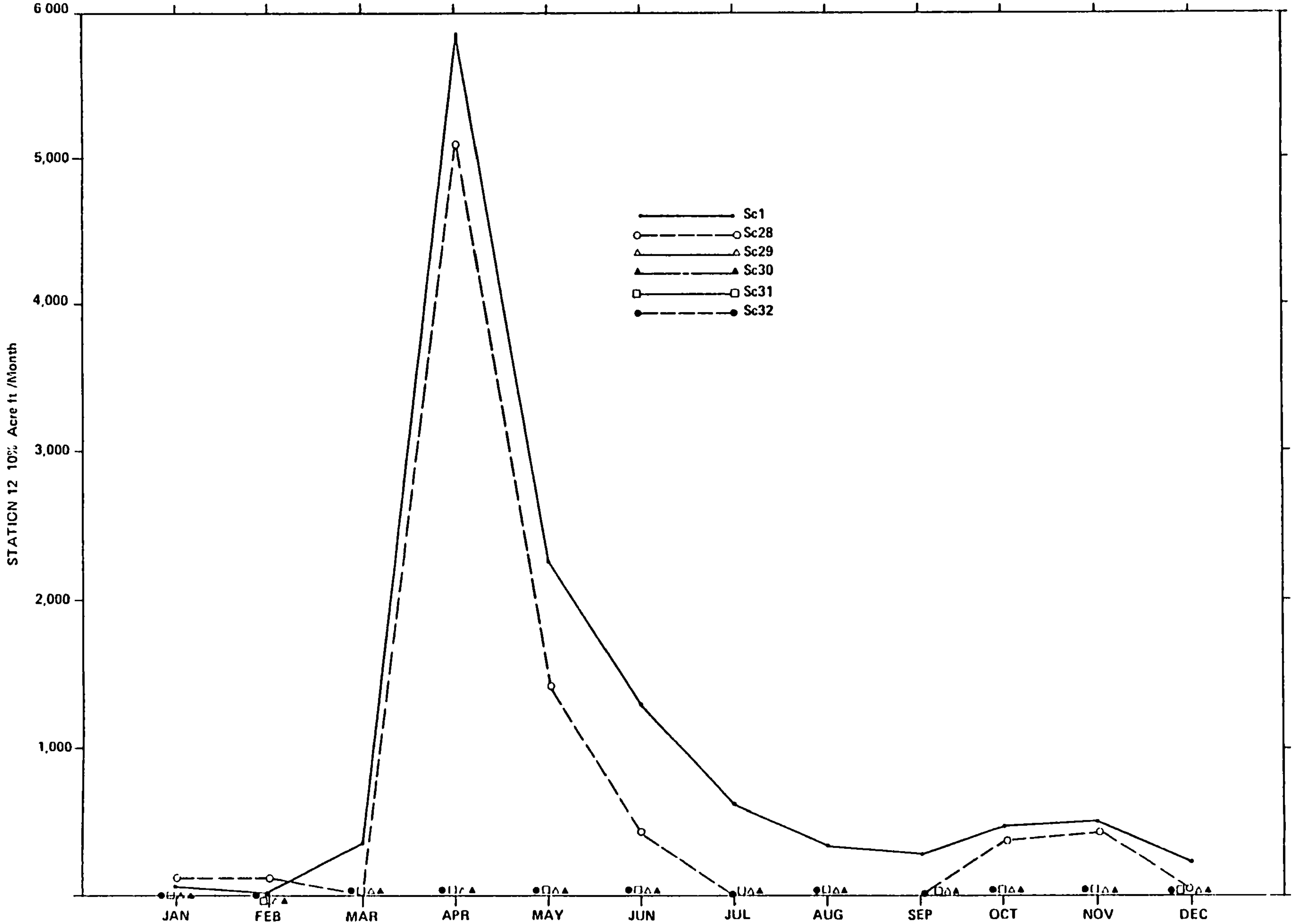


Figure F-5 FLOWS ON MAIN POPLAR AT POPLAR

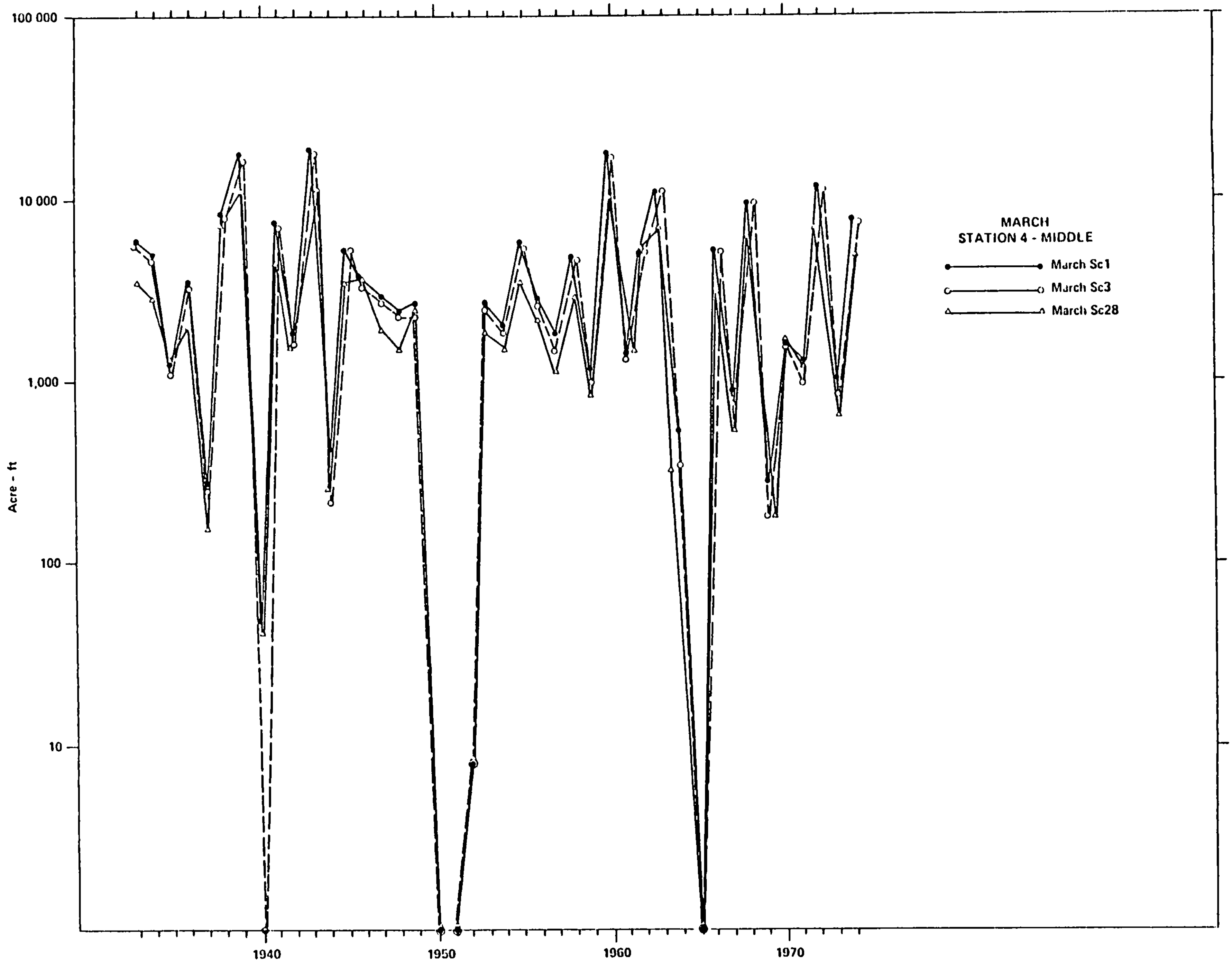


Figure F-6 MARCH FLOWS ON MIDDLE FORK AT INTERNATIONAL BORDER 1933-1974

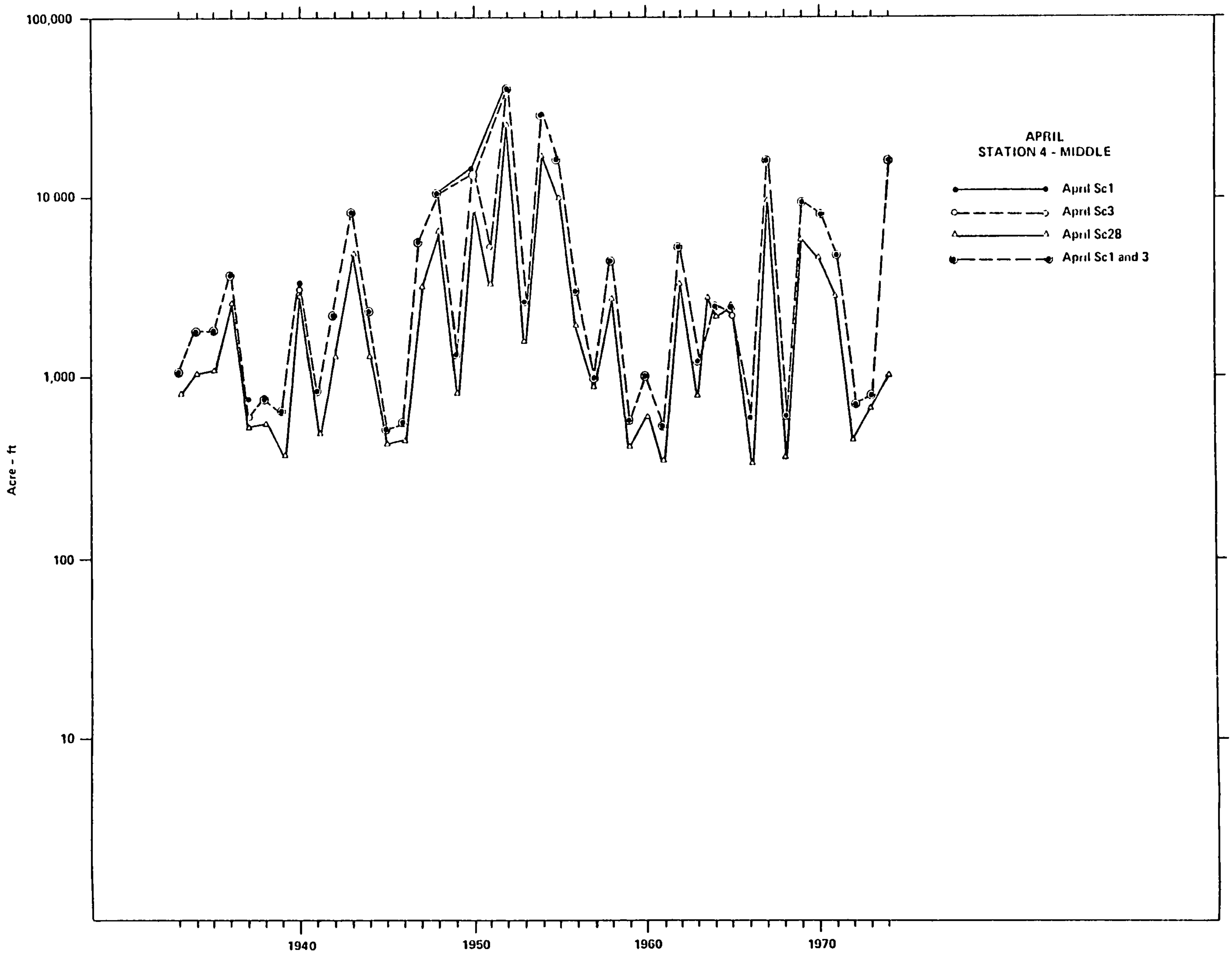


Figure F-7 APRIL FLOWS ON MIDDLE FORK AT INTERNATIONAL BORDER 1933-1974

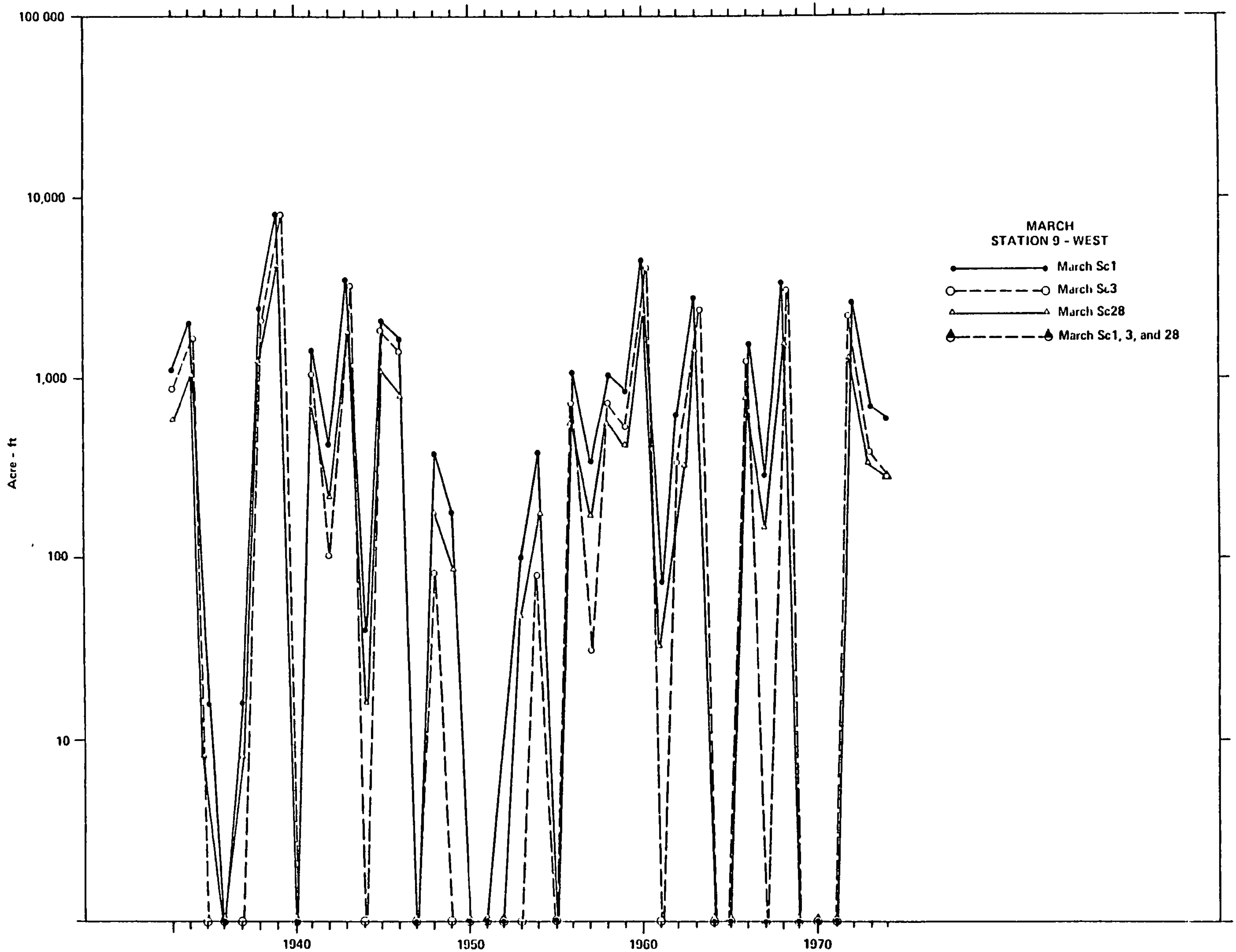


Figure F-8 MARCH FLOWS ON WEST FORK AT INTERNATIONAL BORDER 1933-1974

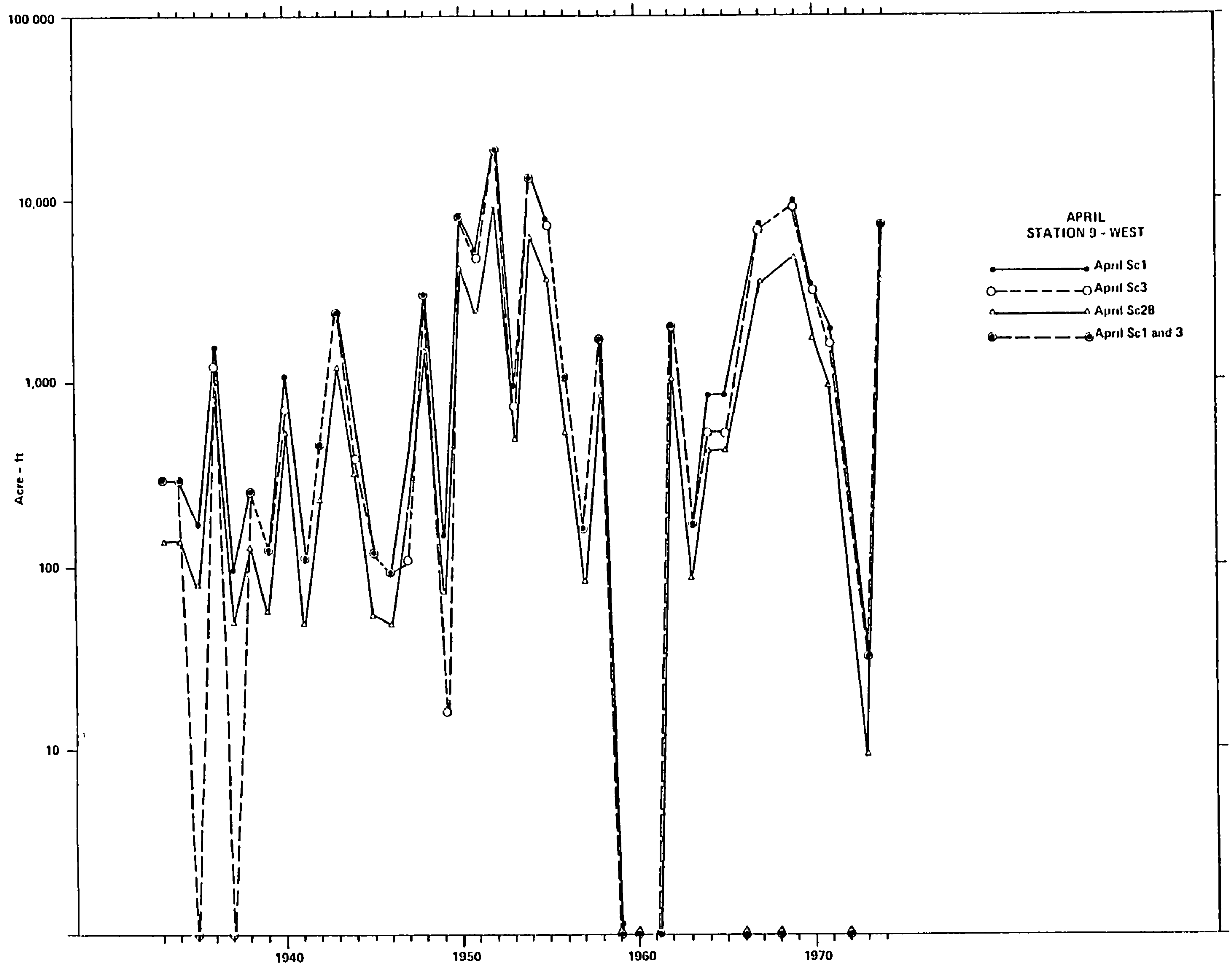


Figure F-9 APRIL FLOWS AT WEST FORK AT INTERNATIONAL BORDER 1933-1974

Table F-1

IRRIGABLE ACREAGE BASED ON WATER AVAILABILITY

Irrigable Acres with Water Available 90 Percent of the Time

Station	Estimated & Projected Irrigable Acres 1975	1985	2000	Irrigable Acres, June 1975	1985	2000	Maximum	Irrigable Acres, July 1975	1985	2000	Maximum	Irrigable Acres, August 1975	1985	2000	Maximum	Irrigable Acres, September 1975	1985	2000	Maximum
3	1,088	1,235	1,533	1,088	1,235	1,533	1,080(75)	1,088	1,235	1,533	376(75)	1,088	1,235	188	296(75)	1,088	1,235	188	344(75)
7	872	1,175	1,957	408	916	1,548	588	344	344	344	64	36	36	36	24	0	0	0	24
8	1,430	1,880	2,920	708	528	440	1,936	492	392	24	956	100	24	0	516	172	148	0	504
11	833	1,380	2,527	833	1,333	0	808	833	0	0	1,052	0	0	0	564	0	0	0	172
12	618	10,618	20,618	618	450	319	3,848	296	450	319	1,912	0	450	319	1,104	618	458	319	884
Totals	4,841	16,288	29,555	3,655	4,462	3,840	8,260	3,053	2,421	1,922	4,360	1,224	1,745	543	2,504	1,883	1,833	507	1,928

Irrigable Acres with Water Available 50 Percent of the Time

Station		Irrigable Acres, June 1975	1985	2000	Maximum	Irrigable Acres, July 1975	1985	2000	Maximum	Irrigable Acres, August 1975	1985	2000	Maximum	Irrigable Acres, September 1975	1985	2000	Maximum
3		1,088	1,235	1,533	1,716	1,088	1,235	1,533	1,440	1,088	1,235	1,533	1,080	1,088	1,235	1,533	1,276
7		872	1,175	1,957	2,308	440	440	440	676	72	72	72	84	72	72	72	84
8	Same as Above	1,430	1,880	2,920	1,648	1,188	1,080	708	2,920	508	516	220	1,716	1,716	508	440	1,568
11		833	1,380	2,527	1,788	833	24	0	1,152	833	0	0	660	833	0	0	244
12		618	10,618	4,186	3,302	618	10,618	4,186	7,104	618	10,618	4,186	3,944	618	10,618	4,186	3,064
Totals		4,841	16,288	13,123	10,762	4,167	13,397	6,867	13,292	3,119	12,441	6,011	7,484	3,119	12,489	6,231	6,236

Irrigable Acres with Water Available 10 Percent of the Time

Station		Irrigable Acres, June 1975	1985	2000	Maximum	Irrigable Acres, July 1975	1985	2000	Maximum	Irrigable Acres, August 1975	1985	2000	Maximum	Irrigable Acres, September 1975	1985	2000	Maximum
3		1,088	1,235	1,533	1,533(75)	1,088	1,235	1,535	1,535(75)	1,088	1,235	1,535	1,484(75)	1,088	1,235	1,533	1,540
7		872	1,175	1,957	1,957	872	1,175	1,957	1,957	872	1,175	1,396	1,957	720	720	720	1,372
8	Same as Above	1,430	1,880	2,920	2,920	1,430	1,880	2,920	2,920	1,430	1,880	908	2,920	1,430	1,880	1,248	3,356
11		833	1,380	2,527	2,527	833	1,380	2,527	1,592	833	1,380	2,527	932	833	1,380	48	956
12		618	10,618	15,331+	20,618	618	10,618	15,331+	20,618	618	10,618	15,331	8,256	618	10,618	15,331+	1,678
Totals		4,841	16,288	24,268	27,055	4,841	12,239	24,270	28,622	4,841	13,065	21,016	15,549	4,689	15,833	19,006	8,902

Data from Model Output by Montana Health and Environmental Sciences, 1979.

+This is acres which can be irrigated with sprinklers, if only 10 inches per year is applied then full demand could be met.

Table F-2

JUNE FLOWS UNDER ALTERNATIVE APPORTIONMENTS

Station 7 (Middle Fork)

Frequency	1975(1)* Ap IVa	Ap IVb	Ap V	Ap VI	2000(4) Ap IVa	Ap IVb	Ap V	Ap VI
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50	380.7	267.3	210.6	372.6	81.0	24.3	0.0	81.0
90	2681.1	2235.6	2016.9	2608.2	2381.4	1944.0	1717.2	2308.5

Station 11 (West Fork)

Frequency	1975(1) Ap IVa	Ap IVb	Ap V	Ap VI	2000(4) Ap IVa	Ap IVb	Ap V	Ap VI
10	129.6	129.6	129.6	129.6	0.0	0.0	0.0	0.0
50	421.2	437.4	421.2	429.3	64.8	97.2	64.8	72.9
90	2875.5	3045.6	2818.8	2924.1	2511.0	2721.6	2462.4	2559.6

*Number in parentheses indicates the number of power plants operating.

Data are from Karp II model output from Montana Health and Environmental Sciences

Table F-3

COMPARISON OF FLOWS FOR WORST NO-ACTION AND HISTORICAL CASES

March, Acre-Feet/Month

	1975 (4)*			1985 (5)			2000 (6)			Historical (2)		
Stations	10 Percent	50 Percent	90 Percent	10 Percent	50 Percent	90 Percent	10 Percent	50 Percent	90 Percent	10 Percent	50 Percent	90 Percent
7	16 2	2,154 6	8,910.0	8.1	2,154.6	8,966 7	0.0	2,170 8	8,901 9	16.2	3,693 6	18,014 4
11	1,166.4	2,648.7	18,273.6	907 2	2,389.5	18,014.4	558 9	2,041.2	17,641.8	1,190 7	2,988 9	20,841 3
3	0 0	226.8	3,426.3	0.0	121 5	3,296 7	0 0	24.3	3,069.9	0.0	2,130 3	14,320 8
8	0.0	0.0	11,372.4	0.0	0 0	10,910.7	0.0	0.0	10,165.5	0.0	4,122 9	29,273.4
12	0.0	5,637.6	33,939.0	0.0	0.0	3,078 0	0 0	0 0	0.0	0.0	8,456.4	57,728.7

June, Acre-Feet/Month

	1975 (4)			1985 (5)			2000 (6)			Historical (2)		
Stations	10 Percent	50 Percent	90 Percent	10 Percent	50 Percent	90 Percent	10 Percent	50 Percent	90 Percent	10 Percent	50 Percent	90 Percent
7	0.0	105 3	1,215 0	0.0	129.6	1,150.2	0 0	0 0	923 4	0.0	591.3	3,572.1
11	129 6	413.1	2,681 1	40 5	324 0	2,592.0	0.0	48 6	2,316.6	129 6	429 3	3,167.1
3	0.0	89 1	388.8	0.0	72.9	372 6	0.0	0 0	299.7	291 6	494.1	1,441 8
8	0 0	486.0	2,373.3	0.0	356.4	2,235 6	0.0	0.0	1,717 2	0 0	1,417.5	5,953.5
12	437 4	2,308 5	7,152.3	0 0	348 3	4,989 6	0.0	0.0	2,988 9	445.5	3,402.0	12,044.7

July, Acre-Feet/Month

	1975 (4)			1985 (5)			2000 (6)			Historical (2)		
Stations	10 Percent	50 Percent	90 Percent	10 Percent	50 Percent	90 Percent	10 Percent	50 Percent	90 Percent	10 Percent	50 Percent	90 Percent
7	0.0	0 0	534 6	0.0	0 0	453.6	0.0	0.0	137.7	0.0	0.0	1,579.5
11	89 1	113 4	162 0	0.0	0 0	113.4	0 0	0 0	32.4	97 2	137 7	275.4
3	0 0	48 6	178 2	0.0	16.2	137.7	0.0	0.0	16.2	162 0	380.7	810.0
8	0 0	0.0	2,527 2	0 0	0.0	2,154.6	0.0	0.0	1,425.6	0.0	137 7	5,038.2
12	0.0	842.4	8,100 0	0.0	137.7	5,265 0	0.0	0.0	1,895 4	0 0	955 8	11,801 7

August, Acre-Feet/Month

	1975 (4)			1985 (5)			2000 (6)			Historical (2)		
Stations	10 Percent	50 Percent	90 Percent	10 Percent	50 Percent	90 Percent	10 Percent	50 Percent	90 Percent	10 Percent	50 Percent	90 Percent
7	0 0	0.0	32 4	0.0	0 0	24.3	0.0	0.0	0 0	0.0	0 0	0 0
11	0.0	8.1	64 8	0 0	0 0	32.4	0.0	0.0	32 4	0 0	32 4	105 3
3	0.0	16 2	72 9	0 0	0.0	48 6	0 0	0.0	0.0	8 1	275 4	461.7
8	0 0	0 0	89 1	0 0	0.0	8.1	0.0	0.0	0.0	0 0	0 0	445.5
12	0 0	283 5	1,077 3	0 0	81.0	834 3	0.0	0 0	591.3	0 0	372 6	1,304.1

September, Acre-Feet/Month

	1975 (4)			1985 (5)			2000 (6)			Historical (2)		
Stations	10 Percent	50 Percent	90 Percent	10 Percent	50 Percent	90 Percent	10 Percent	50 Percent	90 Percent	10 Percent	50 Percent	90 Percent
7	0.0	0 0	40 5	0 0	0 0	89.1	0 0	0.0	40 5	0.0	0 0	0.0
11	0 0	16 2	202 5	0 0	0 0	48.6	0.0	0 0	0.0	0.0	16 2	251.1
3	0.0	64 8	129 6	0.0	40.5	121 5	0 0	0 0	0.0	56.7	380.7	583 2
8	0.0	0.0	89 1	0 0	0 0	8.1	0 0	0.0	0.0	0 0	121 5	696 6
12	16 2	372 6	1,142 1	0 0	178 2	826 2	0 0	0.0	469 8	16 2	477 9	1,652 4

*Numbers in parentheses are the scenario number for the Karp II model output of Montana Health and Environmental Sciences

Table F-4

PROJECTIONS OF PERSONAL INCOME IN DANIELS AND ROOSEVELT COUNTIES
(1975 Dollars)

A. Wage and Salary Income

	Daniels County		Roosevelt County	
	1985	2000	1985	2000
Employment	780	1,010	3,500	3,800
Average wage	$ 6,835	$ 6,835	$ 7,120	$ 7,120
Projected income (millions)	$5.3	$6.9	$25.3	$27.1

B. Nonfarm Proprietors' Income

	Daniels County		Roosevelt County	
	1985	2000	1985	2000
Employment	140	140	350	350
Average income	$13,400	$13,400	$11,300	$11,300
Projected income (millions)	$1.9	$1.9	$4.0	$4.0

C. Farm Proprietors' Income

		Daniels County	Roosevelt County	Total
Projected irrigated land (acres)	1975	3,480	554	4,034
	1985	4,686	8,887	13,573
	2000	7,408	17,221	24,629
Change in irrigated acreage*	1975-1985	1,206	8,333	9,539
	1985-2000	3,928	16,667	20,595
Additional income (millions) (at $50/acre)	1985	$0.1	$0.4	$0.5
	2000	0.2	0.8	1.0
Income of farm proprietors (millions)	1975	$11.9	$13.6	$25.5
	1985	12.0	14.0	26.0
	2000	12.1	14.4	26.5
Total wage, salary, and proprietors' income (millions)	1975	$19.8	$42.9	$62.7
	1985	19.2	43.3	62.5
	2000	20.9	45.5	66.4
Total personal income (millions)	1975	$25.5	$55.6	$81.1
	1985	24.7	56.1	80.8
	2000	26.8	59.0	85.8

*Based on water quantities available under the recommended apportionment.

APPENDIX G

WATER QUALITY IMPACTS

G-1. METHODOLOGY FOR PREDICTING IMPACTS ON CROPS

G-1.1 Boron Adsorption by Soils

The major characteristics of boron and its toxic effect at low concentrations were recognized in the 1930's. Eaton and Wilcox (1939) investigated the adsorption of boron by various soil components and noted that adsorption was highest in the pH range of 6.0 to 9.0. Other investigators studied the effects of other cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) on boron adsorption (Whetstone, *et al*., 1942; Olson and Berger, 1946, and Colwell and Cummings, 1944).

Boron adsorption/desorption was first described using the Langmuir isotherm by Hatcher and Bower (1958). This approach was later used by Biggar and Fireman (1960), Singh (1964), Bingham, *et al*. (1971), and Hadus and Hagin (1972). A two site analog version of the Langmuir expression was proposed by Griffin and Burau (1974) to better account for the desorption of native boron in soils which is not adequately described by the one site expression (Rhoades, et al., 1970).

From the reviewed literature it seems that the Langmuir isotherm is the best presently available tool for estimating boron adsorption/desorption phenomena. Although the more recent studies have shown that the theory may be inappropriate for native boron, the paucity of soil chemical and physical data for Poplar River basin soils preclude a complex site-specific approach.

Since no Langmuir constants have been determined for the Poplar River basin soils a method was sought that would relate the constants from other studies to chemical or physical properties of the soils. The measured soil parameter which was most highly correlated with K and Q of the Langmuir isotherm overall in the above studies was the soil cation exchange capacity (CEC). The data relating K and Q to CEC in all the above studies was tabulated. Since B adsorption is strongly pH dependent, only those soils having pH >7.0 were used in the subsequent analysis.

Regression of K and Q on CEC was performed but it was subsequently found that regression of CEC versus the slope and intercept of the linear Langmuir plot provided a better fit. (Q = 1/Slope and K = Slope/Intercept). The regression produced the following power curves:

$$\text{Intercept} = 2.92\ \text{CEC}^{-0.39} \quad r^{*} = -0.45$$

and

$$\text{Slope} = 239.85\ \text{CEC}^{-0.53} \quad r = -0.62$$

---

*Correlation coefficients were computed in the logarithmic domain.

where

the units of CEC are meq/100 g and the units of the intercept and slope are gm/mℓ and gm/mg, respectively.

Using these relationships, the K and Q for soils in the East Fork and those in the Fort Peck Reservation were estimated (Table G-1.1).

Table G-1.1

ESTIMATED LANGMUIR CONSTANTS FOR POPLAR RIVER SOILS

Sub-Basin	CEC	$K(\frac{mg}{ml})$	$Q(\frac{mg}{gn})$
East Fork	∿15	55.1	0.0187
Fort Peck Reservation	∿29	51.5	0.0249

These K and Q values were substituted into the equation for the Langmuir isotherm given by:

$$B_{ads} = \frac{KQB_e}{1+KB_e} \quad (1)$$

where B_{ads} = the adsorbed quantity of boron

K = the equilibrium constant

Q = the maximum adsorptive capacity of the soil

B_e = the equilibrium solution concentration of boron.

From a mass balance the adsorbed boron must be equal to that in the irrigation water minus that remaining in the equilibrium solution. Thus

$$B_{ads} = B_{iw} - B_e \quad (2)$$

where B_{iw} is the irrigation water concentration.

Substituting Eq. (2) into Eq. (1) results in the following equation:

$$B_{iw} - B_e = \frac{KQB_e}{1+KB_e} \quad (3)$$

This gives rise to a quadratic expression for B_e in terms of B_{iw} and the Langmuir constants K and Q. An adjustment must be made before proceeding. B_{ads} has units of $mg\text{-}B/gm_{soil}$ while B_{iw} and B_e are in mg-B/ℓ. Multiplying B_{ads} by the soil particle density, dividing by the volumetric saturation percentage of the soil and multiplying by the leaching efficiency factor gives an approximate value for the amount of solution each gram of soil encounters. Therefore Eq. (3) becomes

$$SP \frac{(B_{iw} - B_e)}{\rho_s f} = \frac{KQB_e}{1+KB_e}$$

where SP = the saturation percentage

ρ_s = the soil particle density (∿1.33 g/cm³).

Rearranging Eq. (3) into quadratic form gives

$$B_e^2 + B_e \left(Qf \frac{\rho_s}{SP} + \frac{1}{K} - B_{iw}\right) - B_{iw} = 0 \qquad (4)$$

which can be solved by the quadratic formula

$$B_e = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

where a = 1

$$b = Qf \frac{\rho_s}{SP} + \frac{1}{K} - B_{iw}$$

$$c = \frac{B_{iw}}{K}$$

and units of Q = $mg\text{-}B/gm_{soil}$

K = ml/mg-B

B_{iw} = mg-B/ml

G-1.2 Estimation of EC_{se} and SAR_{se}

The average values for TDS and SAR for the growing season (April to September) were obtained from the water quality model (see tables in Appendix G-2). TDS (mg/ℓ) were converted to conductivities (mmho/cm) by the use of the constant 2.08/1000. The constant 2.08 is the average of the conductivity factors given in Standard Methods (APHA, 1976) for all ions shown. The constant 1000 converts from μmho/cm to mmho/cm.

The steady-state values of SAR_{se} and EC_{se} were computed using an equation from Kamphorst and Bolt (1976). They present an equation for computing the leaching requirement of a soil such that

$$LF \simeq \frac{EC_{iw}}{f\left(\frac{SP}{FC}\right) EC_e + (1-f)\ EC_{iw}} \quad (5)$$

where LF = the leaching fraction

EC_{iw} = the conductivity of the irrigation water

f = a leaching efficiency factor (f = 0.6 for flood irrigation, and f up to 1 for sprinkler irrigation)

SP = the water content (volumetric) of the soil at saturation

FC = the water content of the soil at field capacity

EC_e = the steady-state salinity value of the saturation extract.

Rearranging this expression algebraically an expression for the steady-state salinity results:

$$EC_e = \frac{EC_{iw} - LF(1-f)EC_{iw}}{LF(f)\ \frac{SP}{FC}} \quad (6)$$

where all the terms are as previously defined.

The expression $f(SP/FC)\,EC_e + (1-f)\ EC_{iw}$ is an expression for the EC of the water draining from the root zone (EC_{dw}); thus, Eq. (5) arises from the expression

$$LF = \frac{EC_{iw}}{EC_{dw}} \quad (7)$$

(Bernstein and Francois, 1973). Similarly the relationship between leaching fraction and SAR is

$$\sqrt{LF} = \frac{SAR_{iw}}{SAR_{dw}} \quad (8)$$

(Bower, et al., 1968) assuming no precipitation of or dissolution of salts occurs during irrigation. It can be shown then that

$$SAR_e = \frac{SAR_{iw} - \sqrt{LF}(1-F)SAR_{iw}}{\sqrt{LF}(f)\ \frac{SP}{FC}} \quad (9)$$

Thus, the equilibrium saturation extract concentration that the plant responds to can be calculated by knowing the SAR and EC of the irrigation water.

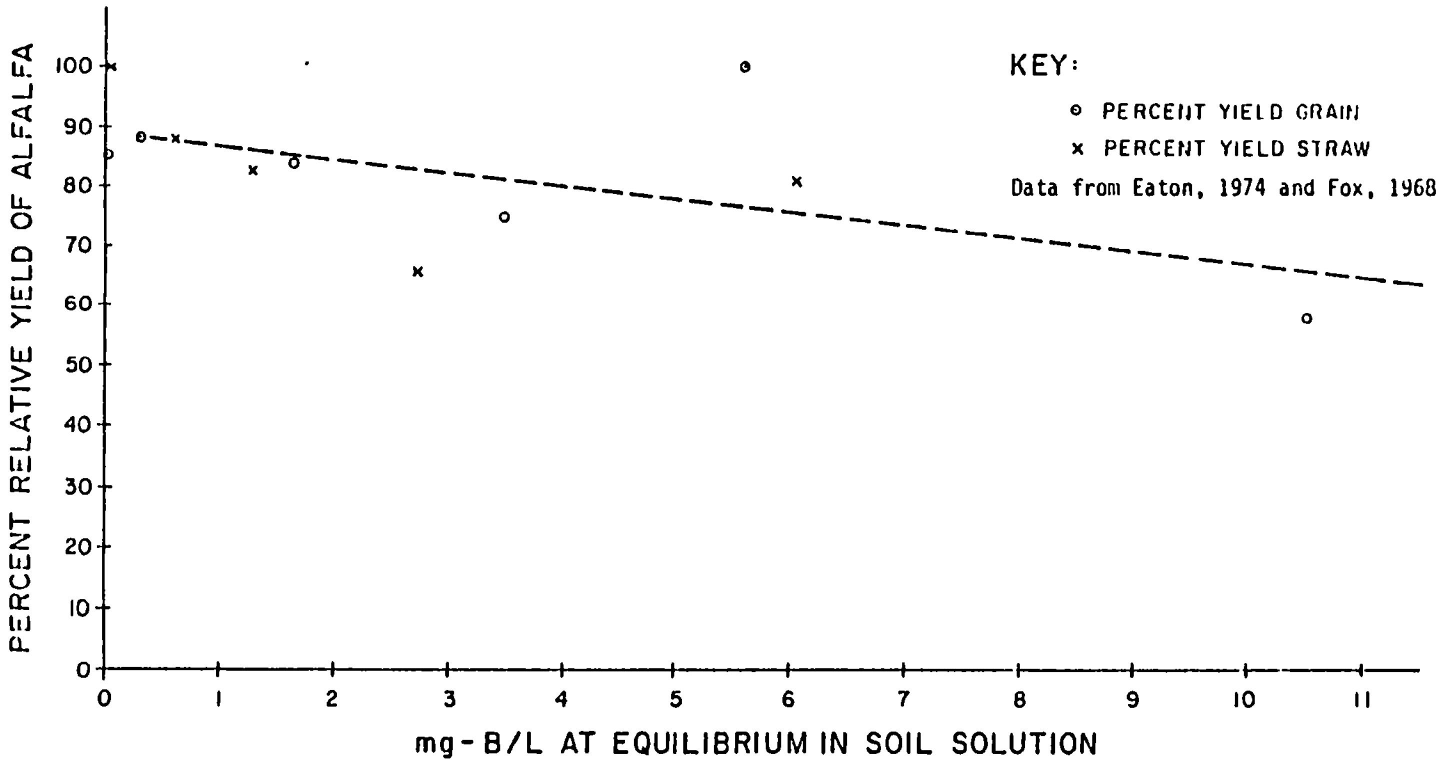
G-1.3 Predicted Crop Yields

Regression equations were developed between boron concentrations in the soil solution and the relative yields of alfalfa, wheat, barley, and oats. These relationships are shown in Figures G-1.1 through G-1.4. Regression equations were also developed between EC of the soil solution and crop yields. These relationships are shown in Figures G-5 through G-8.

The change in relative crop yields from present yields due to the combined effects of boron, salinity, and sodicity are tabulated for alfalfa, wheat, barley, and oats for the East Fork sub-basin and the Fort Peck Indian Reservation (Tables G-1.2 through G-1.5).

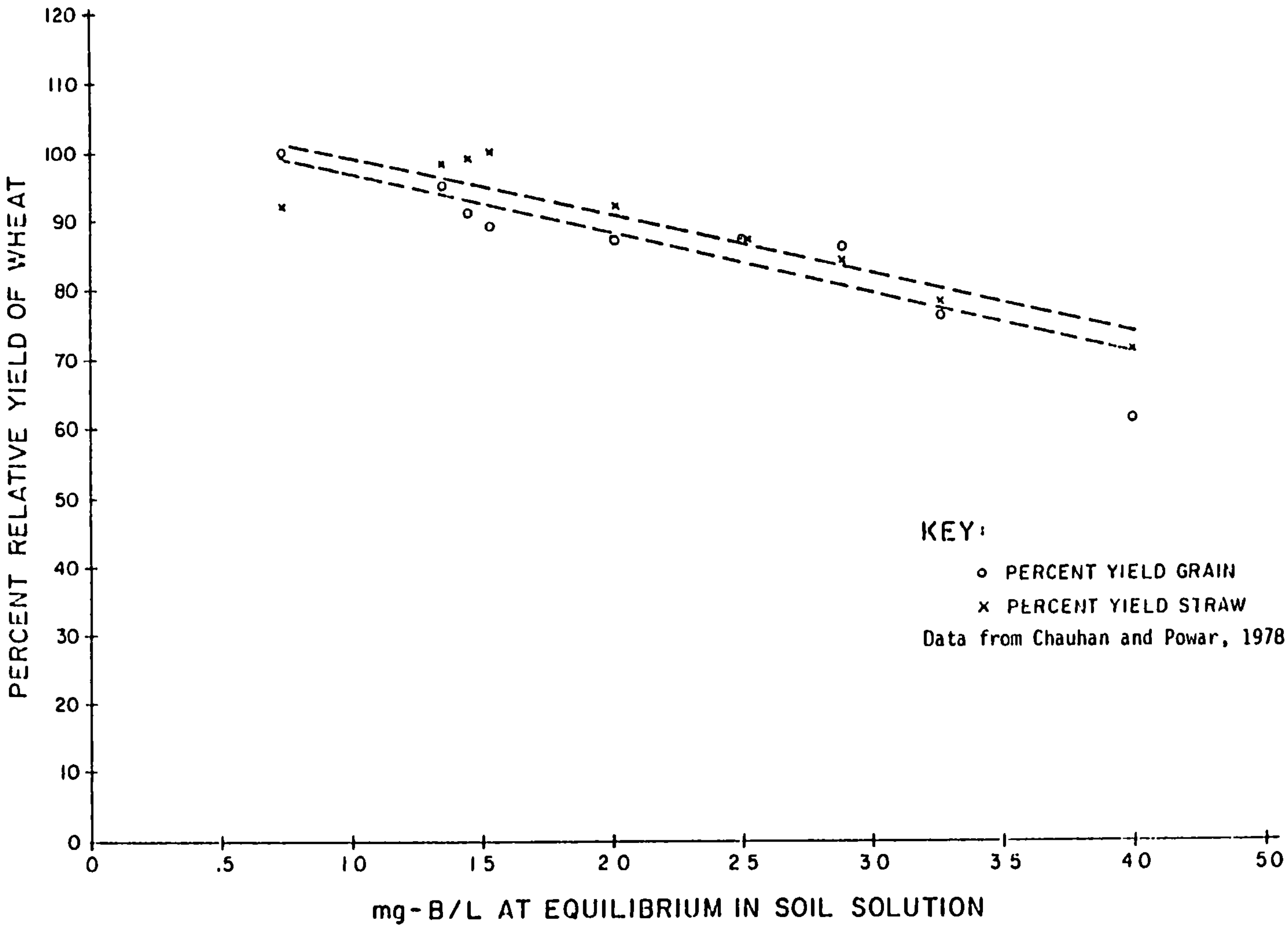
G-2. WATER QUALITY RESULTS

Tabular results are given for boron, TDS, SAR, and SO_4 concentrations at stations 1, 3, 8, and 12 for scenarios 2, 3, 28 through 32, 4A, and 8A.



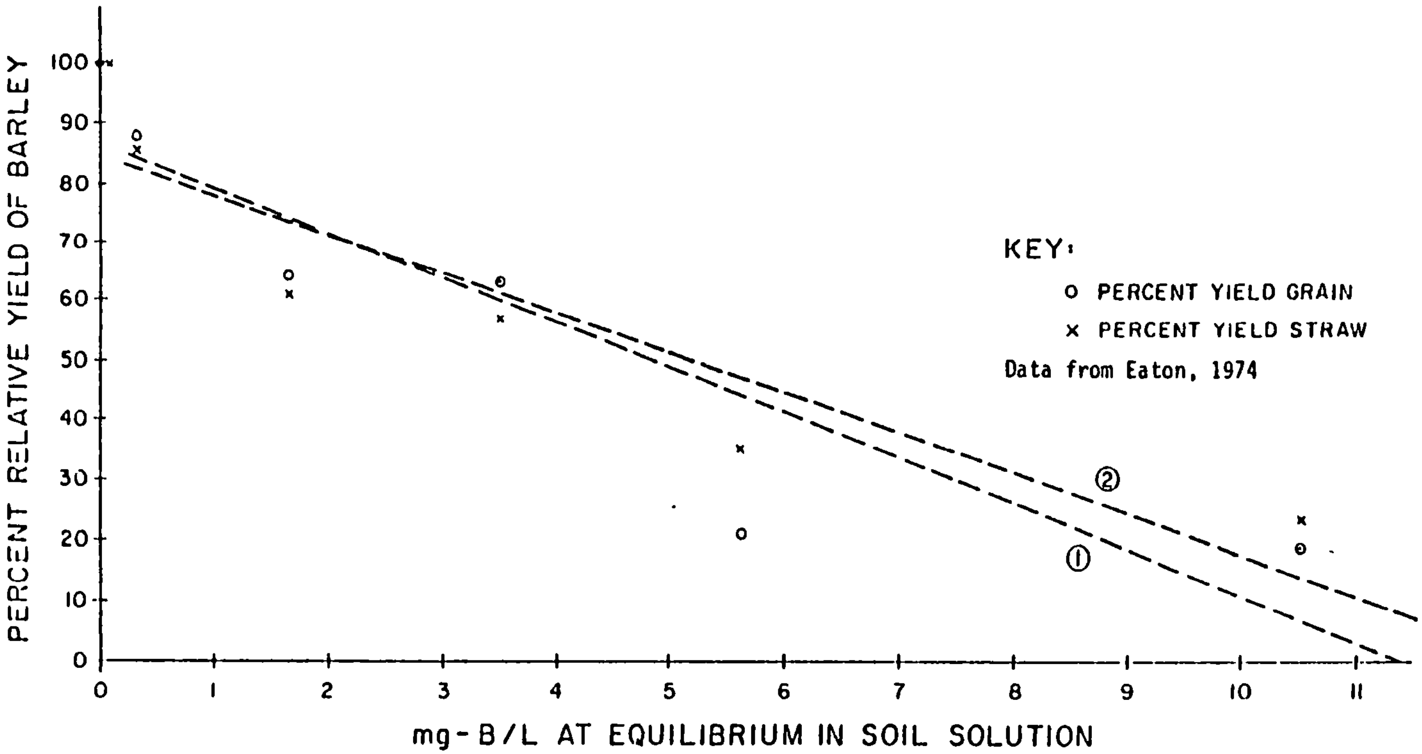
Note: Trace amounts of boron are required so maximum yield does not occur at zero boron concentration.

Figure G-1.1 EFFECT OF BORON CONCENTRATION ON ALFALFA YIELD



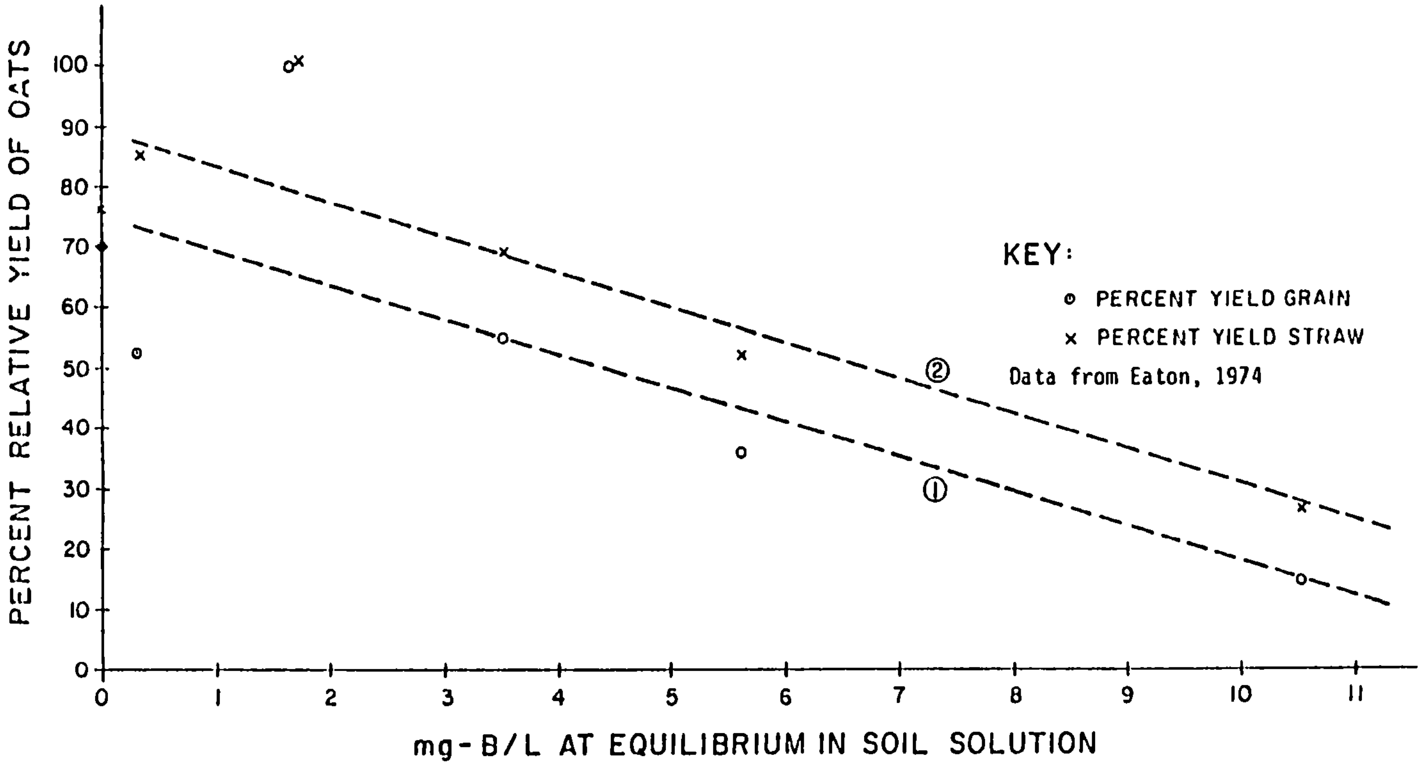
Note: Trace amounts of boron are required so maximum yield does not occur at zero boron concentrations.

Figure G-1.2 EFFECT OF BORON CONCENTRATION ON WHEAT YIELD



Note: Trace amounts of boron are required so maximum yield does not occur at zero boron concentration.

Figure G-1.3 EFFECT OF BORON CONCENTRATION ON BARLEY YIELD



Note: Trace amounts of boron are required so maximum yield does not occur at zero boron concentrations.

Figure G-1.4 EFFECT OF BORON CONCENTRATION ON OAT YIELD

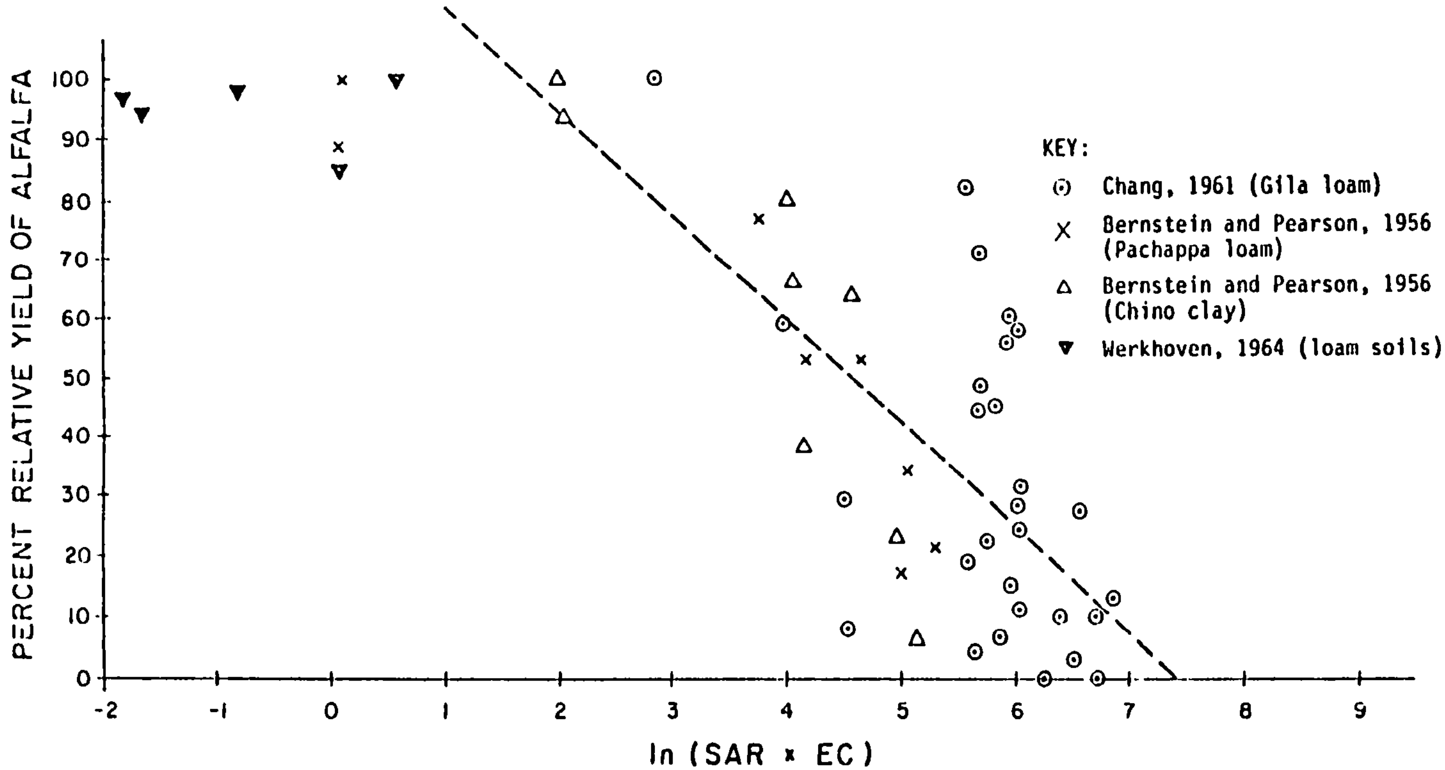


Figure G-1.5 PERCENT ALFALFA YIELD VERSUS f(EC,SAR) IN SATURATION EXTRACT

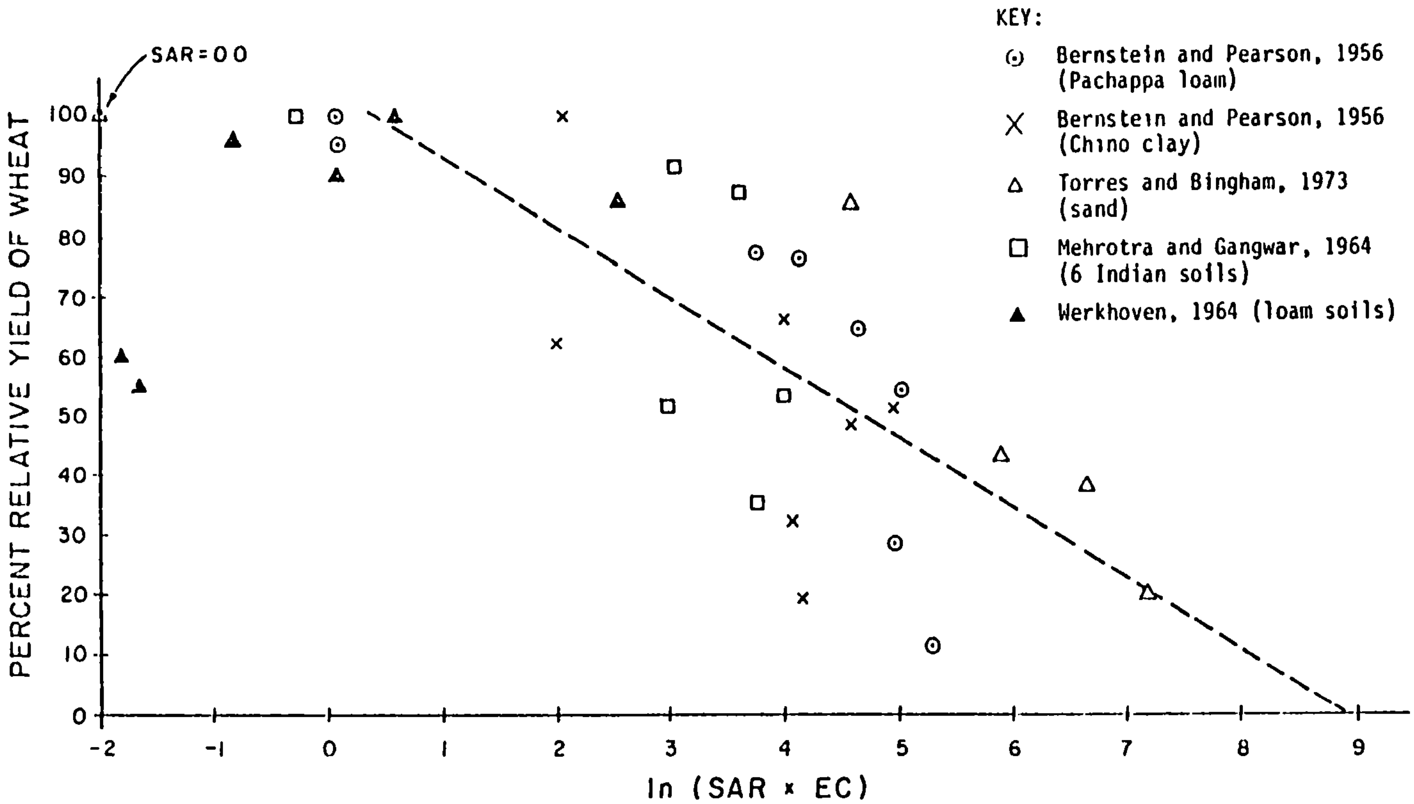


Figure G-1.6 PERCENT WHEAT YIELD VERSUS f(EC,SAR) IN SATURATION EXTRACT

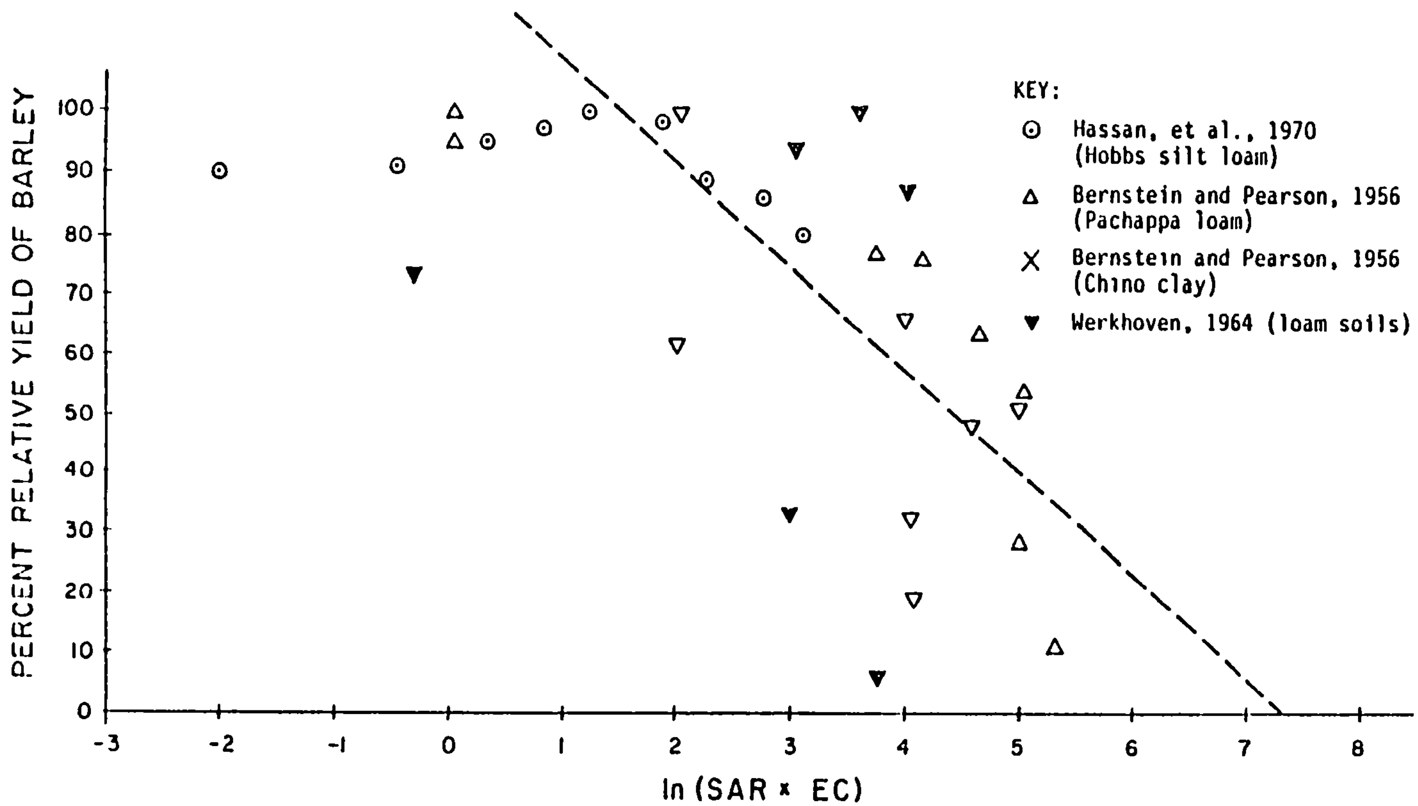


Figure G-1.7 PERCENT BARLEY YIELDS VERSUS f(EC,SAR) IN SATURATION EXTRACT

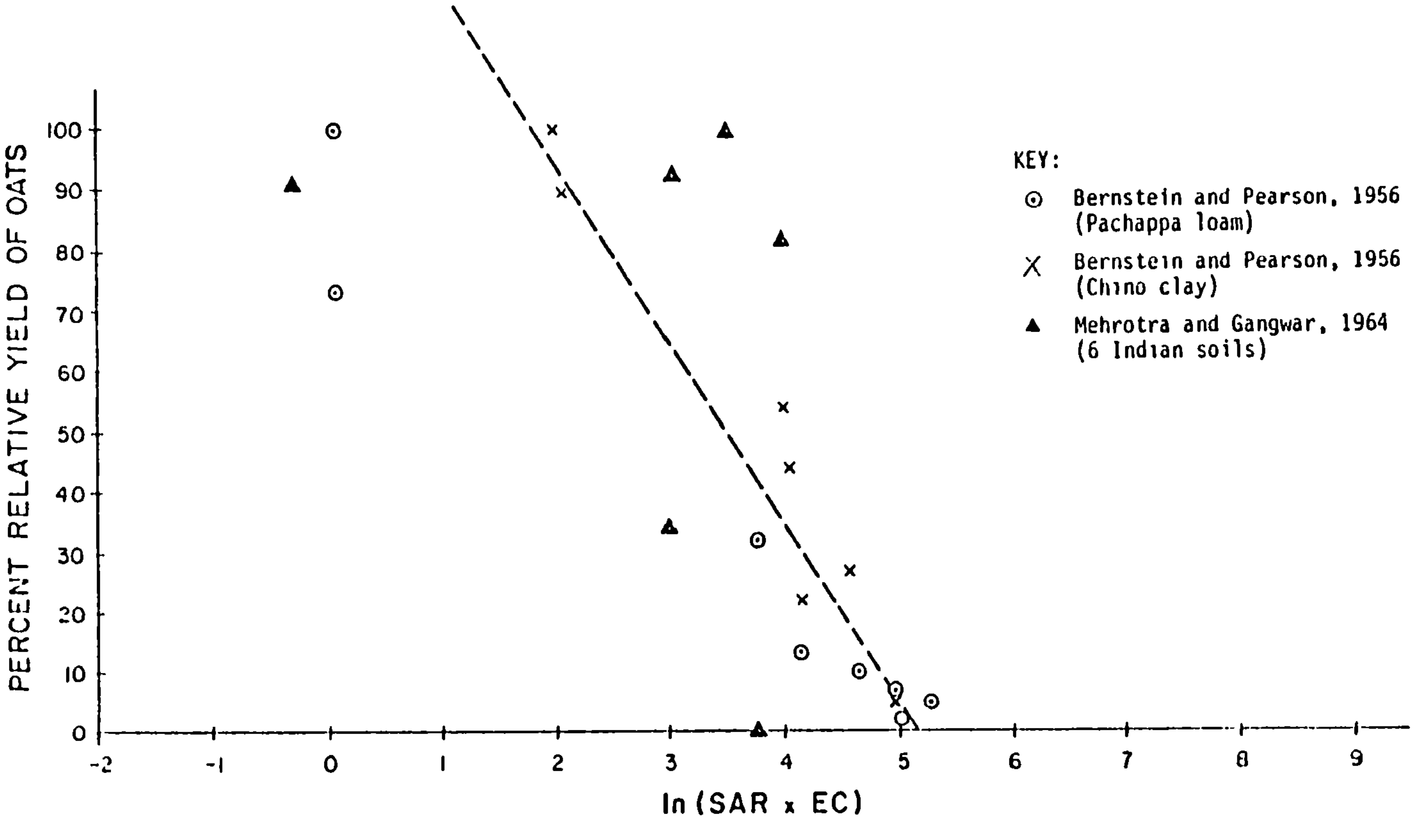


Figure G-1.8 PERCENT OAT YIELD VERSUS f(EC, SAR) IN SATURATION EXTRACT

Table G-1.2

CHANGES IN ALFALFA YIELD DUE TO COMBINED EFFECTS OF BORON, SALINITY AND SODICITY

			Relative Change in Yield, Percent								
	Rainfall Probability		90%			50%			10%		
	Leaching Fraction		.1	.2	.3	.1	.2	.3	.1	.2	.3
	WQ Prob.	Scenario									
East Fork Sub-basin	90%	28	0	*	*	-24	-4	+8	-35	-15	-1
		29	-4	*	*	-28	-5	+5	-38	-15	-6
		4A	-18	+2	*	-38	-18	-5	-46	-26	-14
		8A	-22	-3	+8	-44	-24	-11	-54	-11	-2
	50%	28	*	*	*	-9	*	*	-20	0	*
		29	*	*	*	-13	+8	*	-24	-3	*
		4A	-10	*	*	-29	-9	+4	-38	-17	-5
		8A	-13	+7	*	-32	-12	0	-41	-22	-9
	10%	28	*	*	*	+6	*	*	-6	*	*
		29	*	*	*	+6	*	*	-7	*	*
		4A	-2	*	*	-20	0	*	-29	-10	+3
		8A	-4	*	*	-22	-2	*	-31	-12	+1
Fork Peck Indian Reservation	90%	28	+6	*	*	-21	0	*	-32	-11	+1
		29	+5	*	*	-20	0	*	-30	-10	+2
		4A	-8	*	*	-27	-7	+5	-35	-15	-3
		8A	-8	*	*	-27	-7	+5	-35	-15	-3
	50%	28	+7	*	*	-15	+5	*	-25	-5	+7
		29	*	*	*	-15	+5	*	-25	-5	+7
		4A	-2	*	*	-21	-1	*	-29	-9	+1
		8A	-2	*	*	-21	-1	*	-29	-9	+1
	10%	28	*	*	*	-3	*	*	-15	+5	*
		29	*	*	*	-2	*	*	-14	+6	*
		4A	+7	*	*	-11	+8	*	-20	-1	*
		8A	+7	*	*	-11	+9	*	-20	0	*

* = Optimum Yield

WQ = Water Quality

Table G-1.3

CHANGES IN WHEAT YIELD DUE TO COMBINED EFFECTS OF BORON, SALINITY AND SODICITY

			Relative Change in Yield, Percent								
	Rainfall Probability		90%			50%			10%		
	Leaching Fraction		.1	.2	.3	.1	.2	.3	.1	.2	.3
	WQ Prob.	Scenario									
East Fork Sub-basin	90%	28	-13	+1	*	-20	-6	+2	-25	-11	-3
		29	-15	0	*	-22	-7	0	-28	-13	-6
		4A	-26	-12	-4	-35	-21	-11	-43	-29	-2
		8A	-39	-25	-17	-51	-37	-29	-62	-48	-4
	50%	28	-3	*	*	-10	*	*	-15	-1	*
		29	-5	*	*	-12	+2	*	-16	-3	*
		4A	-17	-4	+5	-24	-11	-3	-31	-18	-9
		8A	-24	-10	-2	-33	-20	-11	-50	-36	-28
	10%	28	*	*	*	0	*	*	-5	*	*
		29	*	*	*	-1	*	*	-6	*	*
		4A	+5	+3	+11	-17	-3	+5	-22	-9	-1
		8A	0	0	+8	-20	-7	+1	-27	-14	-5
Fork Peck Indian Reservation	90%	28	+1	+14	*	-7	+7	*	-12	+2	+10
		29	+1	+14	*	-6	+7	*	-11	+2	+10
		4A	-5	+11	*	-10	+4	+8	-14	0	+8
		8A	-5	+11	*	-10	+4	+8	-14	0	+8
	50%	28	+4	*	*	-3	+11	*	-8	+5	+14
		29	+4	*	*	-3	+11	*	-8	+5	+13
		4A	-1	+13	+21	-6	+8	+16	-10	+4	+12
		8A	-1	+13	+21	-6	+8	+16	-10	+4	+12
	10%	28	+7	*	*	+4	*	*	-1	+12	*
		29	*	*	*	+5	*	*	0	+13	*
		4A	+6	+18	*	0	+13	+18	-4	+9	+18
		8A	+6	+19	*	0	+14	+18	-4	+10	+18

* = Optimum Yield

WQ = Water Quality

Table G-1.4

CHANGES IN BARLEY YIELD DUE TO COMBINED EFFECTS OF BORON, SALINITY AND SODICITY

			Relative Change in Yield, Percent								
	Rainfall Probability		90%			50%			10%		
	Leaching Fraction		.1	.2	.3	.1	.2	.3	.1	.2	.3
	WQ Prob.	Scenario									
East Fork Sub-basin	90%	28	-18	+2	*	-29	-9	+3	-38	-18	-5
		29	-22	0	+9	-34	-11	+8	-42	-20	-12
		4A	-38	-17	-5	-47	-28	-16	-57	-16	-25
		8A	-49	-29	-17	-62	-43	-31	-75	-31	-4
	50%	28	-4	*	*	-14	+7	*	-21	-1	+11
		29	-6	*	*	-18	-3	*	-23	-5	+7
		4A	-26	-6	+6	-36	-16	-3	-43	-24	-11
		8A	-32	-12	0	-44	-24	-12	-61	-42	-3
	10%	28	*	*	*	+1	*	*	-6	*	*
		29	+10	*	*	0	*	*	-8	*	*
		4A	-17	+3	+15	-26	-7	-13	-33	+5	-1
		8A	-20	0	+12	-29	-10	+2	-37	-18	-5
Fork Peck Indian Reservation	90%	28	-6	*	*	-17	+3	*	-26	-5	+1
		29	-4	*	*	-16	+4	*	-22	-5	+2
		4A	-13	+7	*	-21	-1	+11	-27	-8	+4
		8A	-13	+6	*	-21	-1	+11	-27	-8	+4
	50%	28	0	*	*	-11	+9	*	-18	+2	+12
		29	0	*	*	-11	+9	*	-19	+1	+9
		4A	-7	+11	*	-15	+6	*	-21	-1	+11
		8A	-7	+11	*	-15	+6	*	-21	-2	+10
	10%	28	+11	*	*	-4	*	*	-8	+11	*
		29	*	*	*	+2	*	*	-7	*	*
		4A	+2	*	*	-5	+13	*	-11	+8	+2
		8A	+2	*	*	-5	*	*	-11	+9	+2

* = Optimum Yield

WQ = Water Quality

Table G-1.5

CHANGES IN OAT YIELD DUE TO COMBINED EFFECTS
OF BORON, SALINITY AND SODICITY

			Relative Change in Yield, Percent								
	Rainfall Probability		90%			50%			10%		
	Leaching Fraction		.1	.2	.3	.1	.2	.3	.1	.2	.3
	WQ Prob.	Scenario									
East Fork Sub-basin	90%	28	-37	-2	*	-55	-21	-1	-69	-35	-14
		29	-42	-4	*	-61	-23	-6	-74	-37	-24
		4A	-63	-28	-7	-78	-44	-24	N	-24	-3
		8A	-74	-40	-20	N	-58	-38	N	-72	-5
	50%	28	-11	*	*	-28	+6	*	-42	-8	*
		29	-17	*	*	-35	0	*	-44	-12	+7
		4A	-45	-13	+8	-32	-28	-7	-82	-39	-2
		8A	-53	-19	+1	-34	-36	-15	N	-53	-4
	10%	28	+14	*	*	-5	*	*	-17	*	*
		29	*	*	*	-7	*	*	-20	*	*
		4A	-32	+2	+13	-47	-14	+6	-58	-24	-3
		8A	-36	-3	+11	-50	-17	+4	-62	-28	-7
Fork Peck Indian Reservation	90%	28	-26	+9	*	-45	-10	+11	-57	-23	+6
		29	-23	+9	*	-42	-9	+12	-45	-22	+6
		4A	-38	-4	*	-31	-18	+2	-62	-28	-7
		8A	-38	-4	*	-32	-18	+2	-62	-28	-7
	50%	28	-16	*	*	-34	0	*	-37	-13	+10
		29	-16	*	*	-34	0	*	-47	-13	+9
		4A	-47	+5	*	-41	-8	+13	-51	-17	+3
		8A	-47	+5	*	-41	-8	+13	-51	-17	+3
	10%	28	+2	*	*	-23	*	*	-28	+5	*
		29	+13	*	*	-14	*	*	-26	+8	*
		4A	-12	+5	*	-25	+6	*	-35	-3	+1
		8A	-12	+5	*	-25	+8	*	-35	-3	+1

* = Optimum Yield

WQ = Water Quality

N = No Crop

Table G-2.1

PROJECTED BORON CONCENTRATIONS (PPM) FOR STATION 1

Scenario	Percent Probability Level	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		Month											
2	90	3.6	3 2	1.1	1.1	1.3	1.4	1.8	2.1	1.9	1.9	1.8	2.7
	50	2.9	2 5	0.3	0.5	1.0	1.2	1.3	1.4	1.3	1.3	1.6	2.1
	10	2.3	1.4	0.1	0.1	0.1	0.5	0.7	1.2	1.1	1 1	1.3	1.6
3	90	1.8	1.8	1.7	1.6	1.6	1.7	1.7	1.7	1.8	1.8	1.8	1.8
	50	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8
	10	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4
4A	90	8.9	9.3	5.1	5.2	4.9	5.6	6.6	7.5	7.2	7.8	6.8	7.0
	50	6.5	6.1	4.2	3.8	4.1	4.2	4.9	5.0	4.7	4.6	4.9	5.4
	10	3.6	3.9	3.0	2.7	3.0	3.1	3.2	3.3	3.4	3.4	3.3	3.6
8A	90	19.7	20.0	10.0	9.2	10.1	12.4	12.8	13.9	13.7	11.3	12.1	14.0
	50	12.0	11.1	6.4	5.5	6.8	7.5	8.1	8.7	8.2	7.8	8.0	9.7
	10	6.2	6.2	4.2	3.6	4.2	4.6	4.9	5.6	4.9	4.4	4.7	5.2
28	90	2.1	2.1	1.9	1.8	1.9	1.9	1.9	2.0	2 0	2.1	2.1	2.1
	50	1.0	1.0	0.9	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.0	1.0
	10	0.5	0.5	0.5	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0 4
29	90	2.7	2.7	2.4	2.2	2.2	2.2	2.3	2.4	2.5	2.6	2.6	2.7
	50	1.3	1.3	1.2	1.0	1.0	1.0	1.0	1.1	1.2	1.2	1.2	1 2
	10	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5
30	90	4.0	4.1	3.7	2.9	2.9	3.0	3.1	3.3	3.6	3.8	3.9	4.0
	50	1.7	1.7	1.6	1.3	.3	1.3	1.3	1.5	1.6	1.7	1.7	1.7
	10	0.6	0.6	0.6	0.5	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0 6
31	90	4.0	4.1	3.7	2.9	2.9	3.0	3.1	3.3	3.6	3.8	3.9	4 0
	50	1.7	1 7	1.6	1.3	1.3	1.3	1.4	1.5	1.6	1.7	1.7	1.7
	10	0.6	0.6	0.6	0.5	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6
32	90	7.5	7.8	8.0	4.8	3.8	4.1	4.7	5.5	6.5	7.2	7.6	7.6
	50	2.5	2.6	2.2	1.5	1.3	1.3	1.5	1.6	1.8	2.2	2.4	2.4
	10	0.7	0.8	0 8	0.6	0.5	0.4	0.5	0.6	0.6	0.7	0.7	0 7

Table G-2.2

PROJECTED BORON CONCENTRATIONS (PPM) FOR STATION 3

Scenario	Percent Probability Level	Month: Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	90	2.8	2.9	1.8	1.3	1.4	1.5	1.6	1.8	1.8	1.7	1.8	2.7
	50	2.5	2.2	0.7	0.8	1.2	1.3	1.4	1.5	1.4	1.4	1.6	2.0
	10	1.9	1.2	0.5	0.4	0.8	1.0	1.2	1.4	1.3	1.2	1.4	1.6
3	90	1.8	1.7	1.4	1.6	1.4	1.4	1.7	1.5	1.7	1.8	1.8	1.9
	50	0.8	0.9	1.2	1.1	1.2	1.1	1.1	1.2	1.3	1.4	1.1	0.9
	10	0.4	0.4	0.8	0.8	0.9	0.8	0.8	0.8	0.8	1.2	0.8	0.4
4A	90	8.6	8.6	3.2	3.0	4.2	4.7	5.5	6.5	6.5	5.7	6.2	7.0
	50	6.4	6.0	1.5	2.3	3.0	3.2	3.9	4.1	3.7	3.2	4.3	5.2
	10	3.5	3.7	1.1	1.5	2.3	2.4	2.5	2.9	2.7	2.6	3.0	3.5
8A	90	18.5	18.7	5.0	4.4	7.0	9.6	9.2	11.4	9.6	8.5	10.9	13.7
	50	11.8	10.7	1.5	2.7	4.6	5.3	6.3	6.7	6.0	4.9	6.9	9.1
	10	6.1	5.4	1.0	1.5	2.8	3.1	3.3	4.5	3.7	3.2	4.0	5.1
28	90	2.1	1.9	1.5	1.6	1.7	1.6	1.8	1.6	1.8	1.9	2.0	2.1
	50	1.0	1.0	1.2	1.2	1.2	1.2	1.2	1.2	1.4	1.5	1.2	1.0
	10	0.4	0.4	0.9	0.8	0.9	0.9	0.8	0.9	0.9	1.2	0.8	0.5
29	90	2.6	2.3	1.5	1.6	1.9	1.8	1.8	1.8	1.9	2.1	2.4	2.6
	50	1.2	1.3	1.2	1.2	1.3	1.3	1.3	1.3	1.5	1.6	1.4	1.3
	10	0.5	0.5	1.0	0.9	1.0	0.9	0.8	0.9	1.0	1.3	0.9	0.5
30	90	4.3	3.4	1.7	1.7	2.2	2.1	2.0	2.0	2.1	2.4	3.2	3.9
	50	1.7	1.7	1.2	1.3	1.5	1.5	1.5	1.6	1.7	1.7	1.7	1.7
	10	0.5	0.6	1.0	1.0	1.0	1.0	0.9	1.0	1.2	1.3	1.1	0.6
31	90	4.2	4.5	1.6	1.7	2.3	2.1	2.0	2.0	2.1	2.4	3.1	3.8
	50	1.7	1.6	1.1	1.3	1.5	1.5	1.5	1.5	1.6	1.7	1.7	1.7
	10	0.6	0.6	1.0	1.0	1.0	1.0	0.9	0.9	1.1	1.3	1.1	0.7
32	90	6.3	3.9	1.9	1.7	3.2	3.2	2.4	2.2	2.4	3.3	4.9	6.2
	50	2.0	1.8	1.2	1.3	1.5	1.5	1.5	1.6	1.7	1.9	2.1	2.0
	10	0.6	0.6	1.0	1.0	1.0	1.0	0.9	0.9	1.1	1.4	1.2	0.8

Table G-2.3

PROJECTED BORON CONCENTRATIONS (PPM) FOR STATION 8

Scenario	Percent Probability Level	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		Month											
2	90	2.8	2.9	1.8	1.3	1.4	1.5	1.6	1.8	1.8	1.7	1.8	2.7
	50	2.5	2.2	0.7	0.8	1.2	1.3	1.4	1.5	1.4	1.4	1.6	2.0
	10	1.9	1.2	0.5	0.4	0.8	1.0	1.2	1.4	1.3	1.2	1.4	1.6
3	90	1 8	1.7	1.4	1.6	1.5	1.5	1.7	1.5	1.7	1.8	1.8	1.9
	50	0.8	0.9	1.2	1.1	1.2	1.1	1.1	1.2	1.3	1.4	1.1	0.9
	10	0.4	0.4	0.8	0.8	0.9	0.8	0.8	0.8	0.8	1.2	0.8	0.4
4A	90	8.6	8.6	3.2	3.0	4.2	4.7	5.5	6.5	6.5	5.7	6.2	7.0
	50	6.4	6 0	1.5	2.3	3.0	3.2	3.9	4.1	3.7	3.2	4.3	5.2
	10	3.5	3.7	1.1	1.5	2.3	2.4	2.5	2.9	2.7	2.6	3.0	3.5
8A	90	18.5	18.7	5.0	4.4	7.0	9.6	9.2	11.4	9.6	8.5	10.9	13.7
	50	11.8	10.7	1.5	2.7	4.6	5.3	6.3	6.7	6.0	4.9	6.9	9.1
	10	6.1	5.4	1.0	1.5	2.8	3.1	3.3	4.5	3.7	3.2	4.0	5.1
28	90	2.1	1.9	1.5	1.6	1.7	1.6	1.8	1.6	1.8	1.9	2.0	2.1
	50	1.0	1.0	1.2	1.2	1.2	1.2	1.2	1 2	1 4	1.5	1.2	1.0
	10	0.4	0.4	0.9	0.8	0.9	0 9	0.8	0.9	0 9	1.2	0.8	0.5
29	90	2.6	2.3	1.5	1.6	1.9	1.8	1.8	1.8	1.9	2.1	2.4	2 6
	50	1.2	1.3	1.2	1.2	1.3	1.3	1.3	1.3	1 5	1.6	1.4	1.3
	10	0.5	0.5	1.0	0.9	1.0	0.9	0.8	0.9	1.0	1.3	0.9	0.5
30	90	4 3	3.4	1.7	1.7	2.2	2.1	2.0	2.0	2.1	2.4	3 2	3.9
	50	1.7	1.7	1.2	1.3	1.5	1.5	1.5	1.6	1.7	1.7	1.7	1.7
	10	0.5	0.6	1.0	1.0	1.0	1.0	0.9	1.0	1.2	1.3	1.1	0 6
31	90	4.2	4.5	1.6	1.7	2.3	2.1	2.0	2.0	2.1	2.4	3 1	3.8
	50	1.7	1.6	1.1	1.3	1.5	1.5	1.5	1.5	1.6	1.7	1.7	1 7
	10	0.6	0.6	1 0	1.0	1.0	1.0	0.9	0.9	1.1	1.3	1.1	0.7
32	90	6.3	3.9	1 9	1.7	3.2	3 2	2.4	2.2	2.4	3.3	4.9	6 2
	50	2.0	1.8	1.2	1.3	1 5	1.5	1.5	1.6	1.7	1.9	2.1	2.0
	10	0 6	0.6	1 0	1.0	1.0	1.0	0 9	0.9	1.1	1.4	1.2	0 8

Table G-2.4

PROJECTED BORON CONCENTRATIONS (PPM) FOR STATION 12

Scenario	Percent Probability Level	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		Month											
2	90	1.4	1.5	0.8	0.8	1.0	1.1	1.0	1.1	1.2	1.3	1.3	1.5
	50	1.3	1.3	0.5	0.6	0.9	0.9	0.9	1.0	1.0	1.2	1.2	1 3
	10	1.2	1.0	0 3	0.4	0.6	0.7	0.8	0.9	1.0	1.0	1.1	1 2
3	90	1.4	1.3	0.8	0.8	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1 3
	50	1.2	1.2	0.6	0.7	0.9	0.9	0.9	1.0	1.0	1.1	1.1	1.2
	10	1.0	0.9	0.2	0.4	0.6	0.7	0.8	0.9	0.9	1.0	1.0	1.0
4A	90	3.7	4.1	0.9	1.1	1.4	1.4	1.4	1 5	1 9	2.0	2.3	2.6
	50	2.5	2.6	0.6	0.8	1.1	1.1	1.0	1.2	1.4	1.5	1.6	1.7
	10	1.5	1.4	0.2	0.6	0.8	0.8	0.8	1.0	1.0	1 2	1.3	1 4
8A	90	-	-	-	1.0	1.9	1.9	1.7	1.7	2.2	-	-	-
	50	-	-	0.5	0.8	1.2	1.3	1.1	1.0	1.7	-	-	-
	10	-	-	-	0.5	0.8	0.5	0.9	1.0	1 0	-	-	-
28	90	1.4	1.4	0.8	0.8	1 0	1.0	1.0	1.1	1.1	1.3	1.3	1 3
	50	1 2	1.2	0.6	0 7	0.9	0.9	0.9	1.0	1.0	1.1	1.1	1.2
	10	1.1	0.9	0.2	0.4	0.6	0.7	0.8	0 9	0.9	1.0	1.0	1.1
29	90	-	-	-	0.8	1.0	1.1	1.0	1.1	1.2	-	-	-
	50	-	-	0.5	0 6	0.9	0.9	1.0	1.0	1.0	-	-	-
	10	-	-	-	0.4	0 6	0.4	0.9	1.0	0.9	-	-	-
30	90	-	-	-	0 8	1.1	1.1	1.1	1.1	1.2	-	-	-
	50	-	-	0.5	0 7	0 9	0.9	1.0	1 0	1.0	-	-	-
	10	-	-	-	0.4	0.6	0.4	0.9	1.0	0 9	-	-	-
31	90	-	-	-	0.8	1.0	1.1	1.1	1.0	1.0	-	-	-
	50	-	-	0 4	0.5	0.8	0 9	1 0	1.0	1.0	-	-	-
	10	-	-	-	0.4	0.6	0.5	0.8	1.0	1.0	-	-	-
32	90	-	-	-	0.8	1.0	1.1	1.0	1 0	1.0	-	-	-
	50	-	-	0.4	0.5	0.8	0.9	1.0	1.0	1.0	-	-	-
	10	-	-	-	0.4	0.6	0.5	0.8	1.0	1.0	-	-	-

Table G-2.5

PROJECTED TDS CONCENTRATIONS (PPM) FOR STATION 1

Scenario	Percent Probability Level	Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	90	1784	1622	681	613	692	730	925	1034	1005	974	942	1370
	50	1472	1288	252	339	563	639	681	769	716	703	834	1070
	10	1163	733	153	310	334	430	549	663	615	586	711	855
3	90	920	916	865	834	837	844	855	883	907	920	925	923
	50	535	534	500	454	443	456	475	494	512	531	536	535
	10	305	307	308	266	243	250	259	272	284	294	300	303
4A	90	1275	1234	1086	1044	1088	1099	1208	1294	1285	1261	1279	1255
	50	979	974	929	883	917	912	921	948	956	992	955	973
	10	719	735	770	588	658	766	718	756	793	861	846	799
8A	90	1591	1575	1194	1132	1220	1455	1367	1365	1376	1371	1431	1501
	50	1101	1072	988	938	956	984	991	1022	1054	1089	1055	1079
	10	816	810	842	644	727	786	765	769	830	886	881	848
28	90	1061	1058	984	930	935	946	958	992	1028	1053	1064	1063
	50	626	625	583	530	507	522	547	573	596	621	628	628
	10	331	334	335	291	260	268	278	293	307	319	326	329
29	90	1345	1344	1249	1107	1110	1131	1154	1208	1268	1313	1336	1342
	50	792	793	747	653	634	653	678	711	744	779	790	791
	10	376	379	380	334	288	297	308	327	344	358	368	372
30	90	2037	2079	1967	1459	1462	1506	1559	1668	1793	1898	1963	1058
	50	1070	1075	1003	859	816	842	885	936	991	1030	1047	1058
	10	446	452	453	398	330	341	355	378	400	420	432	439
31	90	2037	1074	1967	1459	1462	1506	1559	1668	1793	1898	1963	1999
	50	1070	1075	1003	859	816	842	885	936	991	1030	1047	1058
	10	446	452	453	398	330	341	355	378	400	420	432	439
32	90	4289	4689	4796	2551	2381	2546	2867	3358	3978	4129	4139	4131
	50	1492	1530	1347	999	847	884	965	1068	1146	1254	1358	1455
	10	546	559	561	438	381	396	413	443	474	520	520	532

Table G-2.6

PROJECTED TDS CONCENTRATIONS (PPM) FOR STATION 3

Scenario	Percent Probability Level	Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	90	1448	1470	1074	770	790	817	861	1009	1002	933	984	1368
	50	1255	1174	412	494	680	751	788	853	798	789	877	1073
	10	1019	674	301	274	467	562	660	769	712	686	763	866
3	90	989	880	920	889	858	827	885	911	950	1000	1006	978
	50	541	551	656	629	700	664	684	715	805	836	730	544
	10	293	303	504	458	518	501	480	529	528	716	523	323
4A	90	1267	1234	993	966	1059	1095	1101	1275	1277	1219	1218	1205
	50	983	980	629	781	897	896	927	970	965	971	1023	995
	10	727	739	550	550	667	748	758	810	843	902	882	821
8A	90	1582	1571	1054	1001	1113	1262	1255	1346	1238	1209	1392	1422
	50	1105	1050	643	819	938	948	975	1024	1006	1010	1072	1082
	10	826	816	516	527	703	780	817	829	886	904	915	868
28	90	1139	974	948	917	924	884	962	947	988	1058	1093	1106
	50	627	651	681	676	731	717	733	770	844	864	794	638
	10	314	329	549	498	556	566	498	569	571	723	563	347
29	90	1424	1256	1008	951	1024	1004	1039	1028	1102	1141	1262	1357
	50	784	800	679	729	800	794	789	841	916	936	899	795
	10	353	375	586	564	612	585	534	617	636	766	615	396
30	90	2308	1895	1085	991	1178	1164	1222	1206	1230	1324	1748	2010
	50	1060	1065	660	764	868	872	910	966	1031	1025	1118	1048
	10	402	442	561	586	635	599	575	645	749	796	689	452
31	90	2287	2469	1016	989	1195	1172	1209	1148	1211	1322	1724	1985
	50	1071	998	654	762	875	879	896	925	1003	1033	1126	1060
	10	426	417	552	565	641	608	586	594	687	808	704	489
32	90	3666	2416	1246	1006	1545	1708	1466	1346	1461	1791	3027	3151
	50	1293	1215	678	772	919	935	973	1009	1058	1140	1327	1253
	10	479	480	557	553	634	624	625	617	696	835	761	570

Table G-2.7

PROJECTED TDS CONCENTRATIONS (PPM) FOR STATION 8

Scenario	Percent Probability Level	Month Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	90	1288	1293	743	716	789	890	984	1080	1129	1049	1083	1298
	50	1254	1254	481	512	689	752	781	958	929	896	962	1151
	10	1104	916	367	328	493	554	543	727	797	770	834	950
3	90	1254	1207	765	743	832	918	917	1046	1087	1117	1106	1251
	50	1056	972	549	580	744	758	811	907	875	970	987	1057
	10	740	643	465	395	522	566	562	798	636	841	898	895
4A	90	1260	1244	786	765	882	974	1024	1177	1189	1187	1165	1288
	50	1123	1093	532	582	744	817	844	1014	1058	999	1046	1097
	10	964	907	443	442	565	568	578	894	890	860	895	980
8A	90	1400	1418	812	766	922	1111	1020	1141	1199	1215	1233	1354
	50	1177	1143	529	585	758	828	885	986	1087	1018	1053	1111
	10	1004	949	418	441	563	569	589	864	908	896	913	988
28	90	1254	1240	776	759	840	935	957	1047	1087	1127	1132	1269
	50	1089	995	543	580	754	768	821	927	901	986	1002	1076
	10	815	686	464	407	535	574	566	803	644	845	901	911
29	90	1345	1254	802	768	881	989	1008	-	1133	1179	1234	1330
	50	1151	1053	529	605	774	797	843	966	961	1018	1030	1096
	10	890	768	451	429	555	588	579	-	747	860	911	957
30	90	1544	1382	802	771	943	1050	1024	-	1171	1249	1229	1467
	50	1223	1124	520	589	789	829	872	978	1018	1048	1090	1138
	10	963	906	449	450	562	603	594	-	750	902	920	996
31	90	1484	1359	706	774	968	967	932	-	-	1253	1287	1423
	50	1223	1131	517	591	801	840	741	927	1039	1069	1105	1166
	10	1007	946	439	450	562	594	498	-	-	932	937	1017
32	90	1537	1698	711	788	1040	1010	956	-	-	1379	1462	1618
	50	1250	1229	519	602	810	869	739	933	1066	1118	1122	1226
	10	1037	1063	429	440	568	592	496	-	-	940	940	1033

Table G-2.8

PROJECTED TDS CONCENTRATIONS (PPM) FOR STATION 12

Scenario	Percent Probability Level	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		Month											
2	90	1305	1323	705	660	881	1130	1216	1382	1369	1136	1156	1253
	50	1236	1278	474	507	701	788	1018	1276	1246	1005	1011	1189
	10	1126	934	344	307	493	524	589	990	858	800	863	973
3	90	1308	1236	731	667	936	1147	1220	1383	1367	1188	1190	1229
	50	1127	1130	498	541	745	826	1008	1314	1207	1084	1044	1139
	10	857	777	380	338	506	537	614	1016	914	819	911	941
4A	90	1287	1279	710	684	916	1135	1216	1382	1364	1159	1207	1271
	50	1173	1188	495	524	729	812	1021	1246	1232	1072	1034	1156
	10	1029	920	370	359	524	538	607	1007	882	827	886	987
8A	90	-	-	-	667	904	1133	1376	1383	1364	-	-	-
	50	-	-	376	442	690	766	996	1325	1246	-	-	-
	10	-	-	-	315	506	473	611	1014	1043	-	-	-
28	90	1308	1251	731	674	939	1147	1220	1383	1367	1192	1207	1261
	50	1144	1149	498	541	749	838	1008	1314	1207	1087	1045	1144
	10	890	809	382	345	508	539	616	1018	914	820	913	948
29	90	-	-	-	669	956	1187	1376	1381	1369	-	-	-
	50	-	-	421	446	692	778	1049	1353	1304	-	-	-
	10	-	-	-	325	495	485	621	1093	1032	-	-	-
30	90	-	-	-	672	962	1214	1377	1377	1370	-	-	-
	50	-	-	388	461	697	776	1041	1341	1312	-	-	-
	10	-	-	-	330	509	481	626	1092	1036	-	-	-
31	90	-	-	-	644	881	1059	1331	1381	1365	-	-	-
	50	-	-	352	379	615	810	1073	1359	1360	-	-	-
	10	-	-	-	320	485	513	519	1198	1039	-	-	-
32	90	-	-	-	635	869	1060	1331	1381	1365	-	-	-
	50	-	-	345	363	618	815	1073	1359	1360	-	-	-
	10	-	-	-	324	489	512	512	1198	1039	-	-	-

Table G-2.9

PROJECTED SO_4 CONCENTRATIONS (PPM) FOR STATION 1

Scenario	Percent Probability Level	Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	90	465	421	143	147	168	178	231	274	253	245	236	353
	50	380	330	44	71	133	154	165	189	175	171	207	271
	10	296	179	20	15	71	97	129	160	147	139	173	212
3	90	294	248	240	227	228	229	230	236	244	249	250	250
	50	113	113	105	94	92	95	99	103	107	111	113	113
	10	57	58	59	49	43	45	47	50	52	54	56	57
4A	90	432	412	335	318	324	354	382	420	439	413	406	416
	50	320	309	271	259	265	272	283	298	290	296	299	299
	10	243	247	230	191	215	224	230	225	232	248	247	241
8A	90	666	689	420	409	437	557	529	541	526	493	545	584
	50	433	427	320	288	319	337	347	365	364	364	356	397
	10	309	294	272	242	253	258	258	280	274	279	287	294
28	90	291	290	269	255	256	260	264	275	284	290	292	292
	50	132	132	127	110	107	110	115	120	125	130	132	132
	10	62	63	64	54	46	48	50	53	56	59	61	62
29	90	368	370	332	303	306	311	317	331	348	360	366	368
	50	169	169	164	136	131	135	141	148	157	165	168	168
	10	71	72	73	62	51	53	56	60	63	67	69	70
30	90	557	569	508	396	402	414	428	457	491	520	537	547
	50	233	236	214	178	176	181	187	199	210	223	228	231
	10	84	86	87	75	59	62	65	69	74	78	81	83
31	90	557	569	508	396	402	414	428	457	491	520	537	547
	50	233	236	214	178	176	181	187	199	210	223	228	231
	10	84	86	87	75	59	62	65	69	74	78	81	83
32	90	1024	1054	1083	655	516	561	634	748	882	978	1024	1033
	50	342	350	293	204	170	182	200	218	244	298	328	335
	10	102	105	106	83	68	71	75	81	87	93	97	100

Table G-2.10

PROJECTED SO_4 CONCENTRATIONS (PPM) FOR STATION 3

Scenario	Percent Probability Level	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	90	386	380	307	204	206	213	224	267	266	244	255	353
	50	332	305	97	122	174	195	204	222	207	205	222	273
	10	258	164	66	59	114	138	167	200	183	175	193	216
3	90	266	241	259	249	232	226	247	251	268	283	286	269
	50	116	121	174	155	179	173	171	182	212	227	183	119
	10	57	58	120	106	126	127	117	127	127	192	124	64
4A	90	429	412	293	279	313	336	341	407	415	376	384	387
	50	321	313	175	218	257	260	277	292	287	280	303	303
	10	245	247	149	160	200	222	225	242	245	258	258	253
8A	90	660	665	339	326	358	447	430	488	455	413	499	573
	50	432	417	177	233	293	306	331	340	335	323	354	396
	10	310	287	133	160	218	242	251	285	272	269	287	300
28	90	313	268	265	254	253	240	264	260	279	298	307	302
	50	134	140	175	180	191	184	184	197	222	231	199	137
	10	61	63	132	114	135	140	121	136	137	193	133	69
29	90	383	320	280	266	284	266	271	280	298	320	351	374
	50	175	175	174	193	205	199	147	212	243	244	225	175
	10	69	72	143	128	149	150	128	153	156	197	147	80
30	90	607	466	295	273	324	314	297	309	325	370	480	554
	50	229	238	175	204	224	221	221	242	261	268	264	231
	10	78	85	145	148	163	153	137	163	172	209	163	91
31	90	602	629	272	272	333	317	298	309	325	370	475	549
	50	233	227	174	197	226	224	224	234	257	271	268	238
	10	87	82	143	139	165	156	145	151	174	214	169	104
32	90	857	560	325	277	381	453	347	332	369	495	689	873
	50	275	271	178	203	237	230	232	248	269	298	339	273
	10	96	93	145	138	166	158	152	146	165	219	183	119

Table G-2.11

PROJECTED SO_4 CONCENTRATIONS (PPM) FOR STATION 8

Scenario	Percent Probability Level	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	90	370	370	188	190	204	248	283	312	324	290	301	367
	50	370	370	103	122	178	193	213	279	254	237	266	325
	10	321	255	71	64	107	219	134	191	212	198	228	269
3	90	370	343	196	201	224	259	262	308	321	314	314	367
	50	299	272	127	141	195	204	229	253	246	265	283	301
	10	216	162	93	85	119	141	132	219	170	230	244	241
4A	90	397	392	194	204	237	275	310	354	367	349	347	386
	50	347	338	122	136	198	224	247	300	312	281	301	329
	10	294	273	84	102	137	142	138	256	261	243	253	282
8A	90	506	541	227	211	267	346	326	362	388	376	409	436
	50	390	373	125	136	208	231	270	304	333	294	317	348
	10	315	297	83	95	140	143	139	260	270	249	265	288
28	90	370	357	199	206	226	264	273	308	321	317	320	370
	50	306	279	122	139	198	210	231	258	251	268	286	306
	10	222	171	95	88	119	143	132	225	172	232	250	244
29	90	377	370	213	209	235	274	288	-	329	325	347	384
	50	324	295	123	140	204	215	238	284	265	276	291	318
	10	238	194	91	93	127	147	132	-	201	237	256	260
30	90	442	375	213	210	247	286	290	-	333	340	359	418
	50	337	308	118	140	209	220	244	284	275	281	296	323
	10	254	218	87	97	129	151	133	-	204	239	259	276
31	90	419	370	182	211	258	277	269	-	-	343	359	404
	50	337	318	112	141	216	231	209	270	298	288	301	326
	10	265	233	86	98	130	154	137	-	-	274	263	284
32	90	402	432	185	214	279	289	265	-	-	379	398	454
	50	352	328	112	140	218	237	208	271	304	301	313	333
	10	286	266	84	87	132	154	137	-	-	249	265	293

Table G-2.13

PROJECTED SO_4 CONCENTRATIONS (PPM) FOR STATION 12

Scenario	Percent Probability Level	Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	90	340	333	159	164	205	242	260	295	297	270	280	312
	50	308	315	109	121	174	186	232	271	284	237	247	287
	10	284	223	66	72	111	133	156	225	219	207	218	246
3	90	328	306	164	167	213	242	258	296	293	271	289	303
	50	281	271	118	128	183	200	232	274	267	251	254	276
	10	215	196	72	79	117	137	172	240	226	212	222	241
4A	90	348	362	162	171	219	242	260	296	306	295	308	325
	50	309	309	120	130	182	203	237	280	291	256	263	295
	10	286	229	66	87	131	144	167	235	231	220	226	255
8A	90	-	-	-	168	231	267	294	296	310	-	-	-
	50	-	-	96	109	184	204	245	281	292	-	-	-
	10	-	-	-	77	127	95	164	238	254	-	-	-
28	90	328	311	164	168	214	242	258	296	243	273	293	307
	50	282	278	118	130	183	200	232	274	271	251	254	278
	10	221	201	69	81	119	139	172	241	226	213	222	242
29	90	-	-	-	168	225	261	294	295	295	-	-	-
	50	-	-	98	116	180	192	238	283	285	-	-	-
	10	-	-	-	75	119	100	172	246	244	-	-	-
30	90	-	-	-	169	226	265	294	294	296	-	-	-
	50	-	-	83	117	182	194	237	274	287	-	-	-
	10	-	-	-	77	122	99	172	246	240	-	-	-
31	90	-	-	-	166	208	243	280	295	292	-	-	-
	50	-	-	77	93	156	197	237	283	291	-	-	-
	10	-	-	-	72	118	117	158	254	233	-	-	-
32	90	-	-	-	164	204	243	280	295	292	-	-	-
	50	-	-	75	88	156	197	237	283	291	-	-	-
	10	-	-	-	68	118	117	157	254	233	-	-	-

Table G-2.14

PROJECTED SAR VALUES FOR STATION 1

Scenario	Percent Probability Level	Month: Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3	90	4.7	4.7	4.6	4.5	4.5	4.5	4.5	4.5	4.6	4.7	4.7	4.7
	50	2 1	2.1	2.0	1.9	1.9	1.9	1.9	2 0	2.0	2.1	2 1	2 1
	10	1.2	1.3	1.3	1.1	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1.2
28	90	5.1	5.1	5.0	4.8	4.8	4.8	4.8	4.9	4.9	5.0	5.1	5.1
	50	2.3	2.3	2.2	2.0	2.0	2.0	2.1	2.1	2.2	2.3	2.3	2.3
	10	1.3	1.3	1.3	1.2	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.3
29	90	5.6	5.6	5.4	5.1	5.1	5.2	5.2	5.3	5.4	5.5	5.6	5.6
	50	2.6	2.6	2.5	2.3	2.2	2.3	2.3	2.4	2.4	2.5	2.6	2.6
	10	1.4	1.4	1.4	1.3	1.1	1.1	1.2	1.2	1.3	1.3	1.3	1.4
30	90	7.0	7.0	6.3	5.6	5.7	5.8	6 0	6.2	6.5	6.7	6.8	6 9
	50	3.0	3.0	2.9	2.6	2.5	2.6	2.6	2.7	2.8	2.9	3.0	3.0
	10	1.5	1.5	1.6	1.4	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5
31	90	7.0	7.0	6.3	5.6	5.7	5.8	6.0	6.2	6.5	6.7	6.8	6.9
	50	3.0	3.0	2.9	2.6	2.5	2.6	2.6	2.7	2.8	2.9	3.0	3.0
	10	1.5	1.5	1.6	1.4	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5
32	90	8.3	8.4	6.9	6.4	6.4	6.6	6.9	7.3	7.6	8.0	8.2	8.3
	50	3.6	3.7	3.3	2.7	2.5	2.6	2.8	2.9	3.1	3.4	3.5	3.5
	10	1.7	1 7	1.7	1.5	1.2	1.3	1.3	1.4	1.5	1.5	1.6	1.6
4A	90	6.1	5.9	5.0	4.9	5.1	5.3	5.4	5.9	5.6	5 6	5.7	5 7
	50	4.1	4.1	4 2	4.2	4.1	4.1	4.0	4.0	4.1	4.3	4.3	4.1
	10	3 2	3.3	3.8	2.7	2.9	3.6	3.4	3.4	3.6	3.9	3.8	3.6
8A	90	6.6	6.6	5.3	5 2	5 6	5.8	6.1	6 3	6.2	5.9	6.1	6.5
	50	4.5	4.5	4.4	4.3	4.4	4.4	4.3	4.4	4.5	4.6	4.5	4.5
	10	3.4	3.5	4.0	3.0	3.3	3.7	3.5	3.5	3.7	4.0	4.0	3.8

Table G-2.15

PROJECTED SAR VALUES AT STATION 3

Scenario	Percent Probability Level	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		Month											
3	90	4.9	4.7	5.6	5.7	5.2	5.0	5.0	5.3	5.7	6.1	5.6	5.0
	50	2.2	2.2	4.1	3.6	4.2	4.0	3.9	4.1	4.9	5.0	3.6	2.2
	10	1.3	1.3	3.2	2.9	3.3	3.1	3.0	2.9	3.0	4.6	2.6	1.4
28	90	5.2	5.0	5.6	5.8	5.3	5.1	5.2	5.4	5.8	6.2	5.7	5.3
	50	2.4	2.5	4.7	3.9	4.3	4.1	3.9	4.1	4.8	5.1	3.6	2.4
	10	1.3	1.3	3.4	2.9	3.5	3.3	3.1	3.0	3.1	4.6	2.7	1.5
29	90	5.9	5.6	5.6	5.0	5.5	5.2	5.6	5.5	5.9	6.4	5.9	5.9
	50	2.7	2.8	4.9	5.0	4.4	4.2	4.0	4.2	4.9	5.2	3.9	2.7
	10	1.5	1.4	3.7	3.0	3.8	3.5	3.2	3.1	3.2	4.6	3.0	1.6
30	90	7.0	6.1	5.6	5.8	5.7	5.6	5.9	5.5	5.8	6.7	6.8	6.9
	50	3.1	3.1	4.9	5 1	4.4	4.3	4.0	4.2	4.9	5.1	4.0	3.1
	10	1.5	1.6	3.8	3.3	3.8	3.5	3.3	3.2	3.3	4.6	3.1	1.7
31	90	7.0	6.9	5 4	5.8	5.8	5.6	5.9	5.6	5.8	6.7	6.8	6.9
	50	3.2	3.1	4.9	5.1	4.5	4.3	4.1	4.1	4.8	5.2	4.1	3.2
	10	1.7	1.6	3.7	3.1	3.9	3.6	3.4	3.3	3.3	4.7	3.3	2.0
32	90	6.6	5.8	5.6	5.6	5.8	5.6	5.5	5.3	5.7	7.4	7.3	8.7
	50	3.3	3.3	4.9	5.1	4.4	4.2	3.9	4.1	4.8	5.0	4.4	3.3
	10	1.8	1.7	4.4	3.6	3.5	3.5	3.4	3.0	3.0	4.6	3.3	2.1
4A	90	6.1	5.9	5.3	5.3	5.3	5.4	5.7	5.9	5.8	5.8	5.9	5 8
	50	4.1	4.3	4.8	4.9	4.9	4.9	4.7	4.7	5.0	5.2	4.7	4.3
	10	3.3	3.3	3.8	3.5	3.6	4.4	4.1	4.1	4.5	5.0	4.3	3.7
8A	90	6.7	6.6	5.3	5 5	5.6	6.0	6.0	6.4	6.2	6.1	6.2	6.5
	50	4.6	4.6	4.8	5.0	5.0	5.0	4.9	5.0	5.2	5.3	4.9	4.7
	10	3.5	3.5	4.3	3.9	4.0	4.5	4.2	4.1	4.6	5.0	4.5	3.9

Table G-2.16

PROJECTED SAR VALUES AT STATION 8

Scenario	Percent Probability Level	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		Month											
3	90	7.5	7.3	5.3	5.4	5.8	6.1	6.2	7.1	7.1	6.8	6.7	7 4
	50	6.2	5.9	3.7	4.0	5.2	5.5	5.7	6.1	5.4	6.2	6.3	6.5
	10	4.6	3.5	2.9	2.8	3.6	4.2	4.4	5.2	4.3	5.9	5.7	5.8
28	90	7.5	7.3	5.3	5.6	5.8	6.1	6.2	7.1	7.1	6.8	6.7	7.4
	50	6.3	5.9	3.8	4.1	5.1	5.5	5.7	6.1	5.4	6.2	6.3	6.5
	10	4.6	3.5	3.0	2.9	3.7	4.3	4.4	5.2	4.3	5.9	5.7	5.8
29	90	7.5	7.4	5.5	5.7	5.8	6.2	6.3	-	7.2	6.9	6.8	7.4
	50	6.4	6.0	3.7	4.2	5.2	5.6	5.8	6.5	5.5	6.2	6.3	6.6
	10	4.8	3.6	2.9	3.0	3.7	4.4	4.5	-	4.5	5.9	5.7	5.9
30	90	7.5	7.5	5.5	5.7	5.8	6.2	6.2	-	7.2	7.0	6.8	7.5
	50	6.5	6.0	3.7	4.3	5.2	5.5	5 7	6.4	5.4	6.1	6.3	6.5
	10	4.8	3.7	2.9	3.1	3.7	4.4	4.5	-	4.5	5.8	5.7	5.9
31	90	7.4	7.5	5.2	5.7	6.0	6.4	6.5	-	-	7.0	6.8	7.5
	50	6.5	6.2	3.5	4.3	5.3	5.7	5.7	6.6	6.5	6.3	6.4	6.7
	10	5.1	4.1	2.9	3.1	3.7	4.5	4.8	-	-	6.0	5.9	6.1
32	90	7.4	7.5	5.2	5.7	6.0	6.3	6.5	-	-	7.1	7.0	7.8
	50	6.4	6.0	3.5	4.3	5.3	5.6	5.7	6.6	6.5	6.2	6.3	6.6
	10	5.1	4.2	2.9	3.1	3.9	4.6	4.8	-	-	5.9	5.8	6.0
4A	90	6.9	6.7	5.2	5.4	5.5	6.0	6.2	6.7	6.6	6.6	6.5	7.0
	50	6.3	6.1	3.7	4.1	5.1	5.4	5.5	5.9	5.8	5.9	6.1	6.4
	10	5.2	4.5	2.7	3.0	3.6	4.3	4.2	5.2	5.3	5.7	5.5	5.7
8A	90	7.2	7.0	5.6	5.4	5.5	6.1	6.2	7.0	6.6	6.6	6.5	7 2
	50	6.4	6.2	3.7	4.1	5.1	5.5	5.7	6.0	6.1	6.0	6.2	6.5
	10	5.4	4.7	2.8	3.1	3.7	4.3	4.2	5.4	5.5	5.8	5.6	5.9

Table G-2.17

PROJECTED SAR VALUES AT STATION 12

Scenario	Percent Probability Level	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		Month											
3	90	8.1	8.0	8.0	6.4	7.8	8.7	9.6	9.9	9.5	8.0	7.8	8.1
	50	7.4	7.3	5.5	5.4	6.4	7.1	8.6	8.8	8.7	7.6	7.6	7.7
	10	5.4	5.7	4.1	3.6	5.1	5.4	5.2	8.0	7.2	6.7	7.3	6.7
28	90	8.1	8.0	8.5	6.5	7.8	8.7	9.6	9.9	9.4	8.0	7.8	8.1
	50	7.4	7.2	5.8	5.4	6.3	7.0	8.6	8.8	8.7	7.6	7.6	7.7
	10	5.4	5.7	4.2	3.6	5.1	5.5	5.2	8.0	7.2	6.7	7.3	6.7
29	90	-	-	-	6.3	7.7	8.6	9.6	10.4	10.1	-	-	-
	50	-	-	4.3	4.7	6.0	6.8	8.7	8.8	8.7	-	-	-
	10	-	-	-	3.4	4.9	5.5	5.2	8.3	7.5	-	-	-
30	90	-	-	-	6.3	7.6	8.6	9.6	10.4	10.1	-	-	-
	50	-	-	4.4	4.7	6.0	6.8	8.6	8.8	8.6	-	-	-
	10	-	-	-	3.5	4.9	5.5	5.2	8.2	7.4	-	-	-
31	90	-	-	-	6.1	7.3	8.4	10.1	10.5	9.4	-	-	-
	50	-	-	4.3	3.9	5.5	6.7	8.7	9 2	8.7	-	-	-
	10	-	-	-	3.2	4.5	5.2	4.6	8.7	8.6	-	-	-
32	90	-	-	-	6.1	7.3	8.4	10.1	10.5	9.4	-	-	-
	50	-	-	4.3	4.1	5.5	6.7	8.7	9.2	8.7	-	-	-
	10	-	-	-	3.2	4.5	5.2	4.6	8.7	8.6	-	-	-
4A	90	7.7	7.7	8.3	6.2	7.3	8.7	8.9	9.2	8.8	7.7	7.5	7.8
	50	7.2	7.2	5.4	5.3	6.0	6.5	8.0	8.6	8.0	7.4	7.3	7.5
	10	6.0	5.9	4.0	3.7	4.8	5.4	5.0	7.5	7.4	6.5	6.9	6.9
8A	90	-	-	-	6 1	7.0	8.4	8.9	9.6	8.8	-	-	-
	50	-	-	4.3	4.6	5.8	6.3	7.8	8.8	8.0	-	-	-
	10	-	-	-	3.5	4.8	5.4	5.0	7.6	7.4	-	-	-

APPENDIX H

IMPACTS UNDER ALTERNATIVE APPORTIONMENTS

Table H-1

PROJECTED BORON CONCENTRATIONS (MG/ℓ) AT STATION 3

Scenario	Percent Probability Level	Month: March	April	May	June	July	August	September
4	90	1.8	1.8	1.9	1.9	1.9	2.0	2.0
	50	1.5	1.6	1.8	1.9	1.9	1.9	1.9
5	90	1.8	1.8	1.9	1.9	1.9	-	2.0
	50	1.4	1.5	1.8	1.9	1.9	1.9	1.9
6	90	1.8	1.8	1.9	1.9	-	-	-
	50	1.4	1.5	1.8	1.8	1.6	1.8	1.8
23	90	1.5	1.5	1.6	1.6	1.8	1.6	1.8
	50	1.2	1.1	1.2	1.2	1.2	1.3	1.4
24	90	1.6	1.6	1.9	1.8	1.8	1.8	1.9
	50	1.2	1.2	1.3	1.3	1.3	1.3	1.5
25	90	1.8	1.7	2.2	2.1	2.0	2.0	2.1
	50	1.2	1.3	1.4	1.4	1.5	1.6	1.7
26	90	1.8	1.7	2.3	2.1	2.0	2.0	2.1
	50	1.2	1.3	1.4	1.4	1.5	1.6	1.7
27	90	2.5	1.7	2.5	3.2	2.3	2.2	2.4
	50	1.2	1.3	1.5	1.5	1.5	1.6	1.7

Table H-2

PROJECTED BORON CONCENTRATIONS (MG/ℓ) AT STATION 8

Scenario	Percent Probability Level	Month: March	April	May	June	July	August	September
4	90	1.4	1.3	1.6	1.5	1.5	-	-
	50	0.9	1.1	1.3	1.4	1.3	1.4	1.6
5	90	1.3	1.3	1.5	1.5	1.4	-	-
	50	0.9	1.1	1.3	1.4	1.2	1.4	1.5
6	90	1.3	1.3	1.4	1.5	-	-	-
	50	0.9	1.1	1.3	1.3	1.3	-	1.3
23	90	1.2	1.2	1.4	1.4	1.4	-	1.6
	50	0.8	0.9	1.2	1.2	1.3	1.4	1.3
24	90	1.2	1.2	1.5	1.5	1.5	-	1.6
	50	0.8	0.9	1.2	1.3	1.3	1.4	1.4
25	90	1.2	1.2	1.5	1.6	1.5	-	1.8
	50	0.8	0.9	1.2	1.3	1.4	1.4	1.5
26	90	1.1	1.2	1.5	1.5	1.5	-	-
	50	0.8	0.9	1.3	1.3	1.1	1.3	1.5
27	90	1.1	1.2	1.8	1.5	1.6	-	-
	50	0.8	0.9	1.3	1.3	1.1	1.4	1.6

Table H-3

PROJECTED SODIUM ABSORPTION RATIOS AT STATION 3

Scenario	Percent Probability Level	March	April	May	June	July	August	September
		Month						
4	90	6.9	6.8	7.0	7.1	7.1	7.1	7.2
	50	6.2	6.4	6.8	7.0	7.0	7.1	7.1
5	90	6.9	6.8	7.0	7.1	7.0	-	7.1
	50	6.1	6.3	6.8	7.0	7.0	7.0	7.1
6	90	6.9	6.8	7.0	7.0	-	-	-
	50	6.1	6.3	6.8	6.8	6.5	6.8	6.8
23	90	6.5	6.4	7.4	7.1	7.5	7.1	7.7
	50	5.3	5.0	5.4	5.3	5.2	5.5	5.9
24	90	6.6	6.4	8.3	7.8	8.0	7.9	8.2
	50	5.2	5.4	5.6	5.5	5.6	5.8	6.1
25	90	7.3	6.5	8.5	8.2	8.2	7.7	7.6
	50	5.2	5.5	6.0	5.9	6.2	6.3	6.5
26	90	7.5	6.5	8.5	8.1	8.0	7.4	7.5
	50	5.2	5.4	6.0	5.9	6.0	6.0	6.4
27	90	9.1	6.6	8.5	10.0	8.1	7.5	7.9
	50	5.2	5.4	5.9	6.1	6.1	6.0	6.2

Table H-4

PROJECTED SODIUM ABSORPTION RATIOS AT STATION 8

Scenario	Percent Probability Level	Month						
		March	April	May	June	July	August	September
4	90	6.7	6.3	7.0	7.2	7.1	-	-
	50	4.9	5.4	6.3	6.6	6.1	7.0	7.3
5	90	6.4	6.4	6.9	7.1	6.7	-	-
	50	4.7	5.3	6.3	6.6	6.1	6.9	7.3
6	90	6.2	6.3	6.9	6.9	-	-	-
	50	4.6	5.5	6.3	6.5	6.5	-	6.6
23	90	5.8	6.0	6.4	6.6	6.9	-	7.3
	50	4.2	4.8	5.8	5.9	6.1	6.6	6.1
24	90	6.0	6.0	6.5	6.8	7.0	-	7.4
	50	4.2	4.6	5.9	6.1	6.3	6.6	6.5
25	90	6.0	6.0	6.6	7.1	7.0	-	7.4
	50	4.0	4.6	6.0	6.2	6.4	6.8	6.5
26	90	5.6	6.1	6.7	6.9	6.7	-	-
	50	3.9	4.6	6.1	6.2	5.9	6.7	6.9
27	90	5.6	6.1	7.1	7.0	6.6	-	-
	50	3.9	4.7	6.1	6.3	5.9	6.7	6.9

Table H-5

PROJECTED TDS CONCENTRATIONS (MG/ℓ) AT STATION 3

Scenario	Percent Probability Level	Month: March	April	May	June	July	August	September
4	90	1102	1068	1115	1136	1144	1163	1194
	50	823	883	1042	1096	1100	1140	1142
5	90	1149	1073	1108	1140	1122	-	1174
	50	814	873	1036	1096	1095	1114	1152
6	90	1167	1077	1110	1095	-	-	-
	50	806	858	1050	1028	939	1042	1031
23	90	961	902	924	884	960	947	988
	50	674	642	726	715	717	773	844
24	90	1033	951	1024	1002	1037	1028	1102
	50	679	720	783	768	786	841	916
25	90	1128	982	1174	1160	1216	1206	1230
	50	673	759	865	855	910	966	1031
26	90	1132	990	1193	1169	1203	1148	1211
	50	662	740	865	865	893	926	1003
27	90	1687	1010	1541	1707	1437	1342	1461
	50	682	761	894	929	964	1008	1058

Table H-6

PROJECTED TDS CONCENTRATIONS (MG/ℓ) AT STATION 8

Scenario	Percent Probability Level	March	April	May	June	July	August	September
4	90	910	857	1071	1052	1055	-	-
	50	587	699	861	931	803	1014	1137
5	90	903	861	997	1053	925	-	-
	50	582	698	865	933	780	966	1091
6	90	806	844	980	1020	-	-	-
	50	585	706	847	883	863	-	887
23	90	809	789	884	942	957	-	1094
	50	549	618	785	803	830	931	901
24	90	834	800	930	1013	1007	-	1140
	50	547	624	798	825	843	966	960
25	90	834	803	991	1089	1022	-	1171
	50	543	630	819	861	874	977	1017
26	90	772	808	986	1000	932	-	-
	50	540	634	834	849	751	927	1039
27	90	772	817	1141	1029	954	-	-
	50	540	642	843	869	753	933	1066

APPENDIX I

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APPENDIX REFERENCES

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