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Water

EPA

Improved Protection of Water Resources from Long-Term and Cumulative Pollution:

Prevention of Ground-Water Contamination in the United States

Prepared for the
Organization for Economic
Co-operation and Development

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IMPROVED PROTECTION OF WATER RESOURCES FROM LONG-TERM AND CUMULATIVE POLLUTION

PREVENTION OF GROUND-WATER CONTAMINATION
IN
THE UNITED STATES

Prepared for the
Organisation for Economic Co-operation and Development

OFFICE OF GROUND-WATER PROTECTION
OFFICE OF WATER
U.S. ENVIRONMENTAL PROTECTION AGENCY
APRIL 1987

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FOREWORD

In 1986 the Organisation for Economic Co-operation and Development (OECD) initiated a major "Project on Policies to Improve Surface and Ground-Water Management." OECD selected three problem areas for detailed investigation:

- Sub-Project One: Improved Integration of Water Resources With Other Government Policies
- Sub-Project Two: Improved Water Demand Management
- Sub-Project Three: Improved Protection of Water Resources from Long-term and Cumulative Pollution.

This report is the U.S. national report for sub-project three to be discussed at the May 1987 meeting of the Group on Natural Resource Management of OECD's Environment Directorate.

The Office of Ground-Water Protection, Office of Water, of the U.S. Environmental Protection Agency led the preparation of this report based on guidelines from OECD:

- Chapter I- Introduction provides an overview of U.S. ground-water resources, ground-water quality, and governmental responsibilities for ground-water protection
- Chapter II- Major Sources of Pollution discusses the contaminants and sources of concern in the U.S., with particular attention to regional trends
- Chapter III- Management Instruments describes the various policies, tools, practices, and measures currently used or being considered for ground-water protection in the U.S.
- Chapter IV- Management Problems identifies recent efforts to improve ground-water protection programs despite continued uncertainty due to the localized nature of the problem and the lack of complete information
- Chapter V- Case Studies briefly recommends several possible cases and the rationale for their selection
- Chapter VI- References cites all documents used to prepare the report, so that others may obtain copies.

Numerous individuals participated in the preparation of the report. EPA's Office of Ground-Water Protection circulated it to other offices within the Agency, to the U.S. Department of Interior and its U.S. Geological Survey, and to a representative of a private foundation and an academic institution. Booz, Allen & Hamilton Inc. assisted in assembling the report.

I. INTRODUCTION

I. INTRODUCTION

Ground water in the United States is a vital, economically important national resource. Over the past three decades, its value as a reliable source of clean water has become evident, and in some places it is the only source of water. As of 1985, ground water provided almost one-quarter of the fresh water used daily in the U.S., and every state used ground water to meet some of its water needs. Ground water is the source of drinking water for approximately one-half of the total population of the U.S. and for 97 percent of the residents of rural areas. Agricultural operations and industry also account for substantial uses of ground water in the U.S.

In addition to meeting the nation's demand for water, ground water plays an important environmental function. For example, ground water sustains many aquatic wetlands and terrestrial ecosystems. It also accounts for about one-third of the flow of all surface waters in the U.S. and provides 100 percent of the flow in some regions during periods of low flow.[1]

Most ground water in the U.S. is clean and available in sufficient quantities to meet future needs, but some local and regional problems have arisen. In a few areas, ground-water declines have been documented, with the rate of withdrawals exceeding the rate of replenishment.[2] Additionally, varying concentrations of a wide array of contaminants have appeared in a number of locales. Agricultural chemicals, such as fertilizers and pesticides, and industrial chemicals including heavy metals and solvents, have received the most attention in the press, but federal and state government surveys and investigations have found more than 200 separate substances in the nation's ground waters.[3]

Although only trace levels of these substances have been found in most areas tested, a number of communities have closed public wells serving millions after finding excessive concentrations of contaminants. Public officials are particularly concerned that ground-water contamination may be more widespread than reported to date and that it may steadily increase unless adequate control measures are adopted.

Scientific limitations preclude both a comprehensive identification of ground-water quality and assessment of the health effects of detected contaminants. The nature of ground water itself demands precision in selecting sampling locations. Moreover, analytic testing techniques are neither generally available nor affordable for unknown, unspecified substances. Further, contaminants are often present in minute concentrations, below the detection limits of many common technologies. Finally, there are limits in the ability to estimate both acute and chronic health effects of exposure to contaminants in ground water. Despite these limitations, it is important to proceed with the initiation and development of ground-water protection programs.

Development of effective programs is greatly challenging the ingenuity and institutional capacity of all levels of government in the U.S., because ground water for many reasons is substantially more difficult to address than other resources such as surface water and air. Protection of air quality, for example, involves the regulation of a small number of automobile manufacturers, a few thousand large industries, and a somewhat greater number of smaller industrial and commercial activities. Ground-water protection, by contrast, involves the control of tens of thousands of hazardous waste sites, millions of underground storage tanks, and billions of tons (billions of kilograms) of pesticide and fertilizer application. The potentially regulated community consists of not just a relatively few large industries but also countless small businesses, farmers, and individuals.

While prevention is a complex undertaking, cleanup is even more difficult. For surface water and air, merely halting the discharge of contaminants effectively dilutes them to safe ambient levels. Such measures are less effective for ground water, because ground water moves so slowly, natural attenuation processes are so limited, and contaminants adhere to the soils. Additional steps are necessary to prevent the contamination of drinking water supplies. Cleanup techniques involve extracting and treating the contaminated ground water before using it or reinjecting it into the aquifer. These methods can be enormously expensive and are not always very effective. Treatment at the tap also is possible in some cases but sometimes the only viable, though costly, solution is to abandon the contaminated ground-water supply and replace it with another source of water.

The diversity of institutional characteristics across the country also complicates ground-water protection efforts. No two regions, for example, have the same combination of ground-water uses, land uses, contaminants and sources, and ground-water management instruments. Superimposed on this regional diversity is a rapidly evolving federal government role.

In the late 1970s, the U.S. Environmental Protection Agency (EPA) recognized a need to better articulate its own approach to the growing problem of ground-water contamination. The Agency's <u>Ground-Water Protection Strategy</u>, issued in 1984, acknowledged the absence of overriding federal leglislation and recognized that states should have the principal responsibility for ground-water protection because of their legal and historical roles in land use, water allocation, and public health protection.[4] It also recognized that the federal government's roles were to control certain contaminants and sources, provide technical and financial assistance to the states, and to provide coordination for research, resource characterization, and information management.

Since the issuance of EPA's Ground-Water Protection Strategy, both the federal and state governments have continued to make substantial progress in strengthening protection of ground water. Programs to manage waste sources such as abandoned waste sites, landfills, land application of sludge and wastewater, injection wells, surface impoundments, and waste piles have received considerable attention in the past three years. New programs to address previously unregulated sources such as underground storage tanks are in the early stages of development, and existing programs governing pesticides and toxic substances are increasing their consideration of ground water. In addition to these source-specific activities, many initiatives focus on the overall protection of ground-water. At the federal level, some examples of these measures include EPA's establishment of a new Office of Ground-Water Protection, Congressional enactment of ground-water amendments to the Safe Drinking Water Act, and EPA ground-water grants to states to build their ground-water programs. Other federal activities include data collection and interpretation under the U.S. Geological Survey's (USGS) Federal-State Cooperative Program,[5] the Regional Aquifer System Analysis (RASA) Program,[6] and a wide array of research projects.

States, in turn, have realized significant achievements in the ground-water arena. By the end of 1986, close to forty states had either completed or initiated development of ground-water protection strategies that will guide their future policymaking and program development efforts. In addition, like the federal government, states have perceived the need for better interagency coordination and have established a variety of oversight committees, task forces, or working groups to address this need. Many states have reexamined their statutory and regulatory authorities, identified needed changes, and have developed new laws and regulations. Other significant activities have included mapping ground-water resources, developing ground-water classification systems and standards, sponsoring technical workshops and training, and upgrading the collection and management of ground-water data.

A. GROUND-WATER RESOURCES IN THE UNITED STATES

Every day approximately 4.2 trillion gallons (16 trillion liters) of precipitation fall on the continental United States. About two-thirds of that precipitation evaporates, about 61 billion gallons (232 billion liters) soak into aquifers, and the rest runs off directly to streams and rivers. Estimates of the ground-water resources of the U.S. found within one-half mile (0.8 kms) of the land surface range from 15 to 100 quadrillion gallons (57 to 380 quadrillion liters). These resources are 50 times greater in volume than all the nation's surface waters at any given point in time. Economically usable ground-water resources are 35 times the total annual surface runoff and 400 times the country's total water withdrawals.[7]

Major aquifers (Figure I-1) underlie most of the land area of the U.S.;[8] however, they vary significantly in size, yield, interconnectedness, permeability, and flow velocity. Some of these aquifers or aquifer systems cover small, localized areas, while others encompass thousands of square miles and cross the geopolitical boundaries of several states. Generally, the larger aquifers have greater geological and hydrological complexity and present correspondingly intricate management problems. Management of these large aquifers is even further complicated by diverse, sometimes incompatible state and local management instruments, and the lack of interjurisdictional coordination mechanisms.

The richest ground-water resources are found in the mid-Atlantic, the Gulf Coast, the Great Plains, and the Central Valley of California. These resources are estimated to yield hundreds to thousands of gallons (liters) of fresh water per minute. Less extensive aquifers that yield smaller quantities of water are found throughout the country. Because of the relative scarcity of surface water in the far West, however, that area depends heavily on ground water.

In order to broadly characterize ground-water conditions in the U.S., the USGS has identified 15 ground-water regions (Figure I-2)[9]. Within each of these regions, the composition, arrangement, and structure of rock units are more or less similar. Permeabilty and vulnerability may vary within and across these ground-water regions.

B. USE OF GROUND WATER

Although surface water still serves most of the daily water needs of the U.S., ground water is used increasingly to meet these needs. The USGS has published estimates of water use every five years from 1950 to 1980; the 1985 data presently are

Figure I-1
Productive Aquifers and Withdrawals from Wells in the U.S.

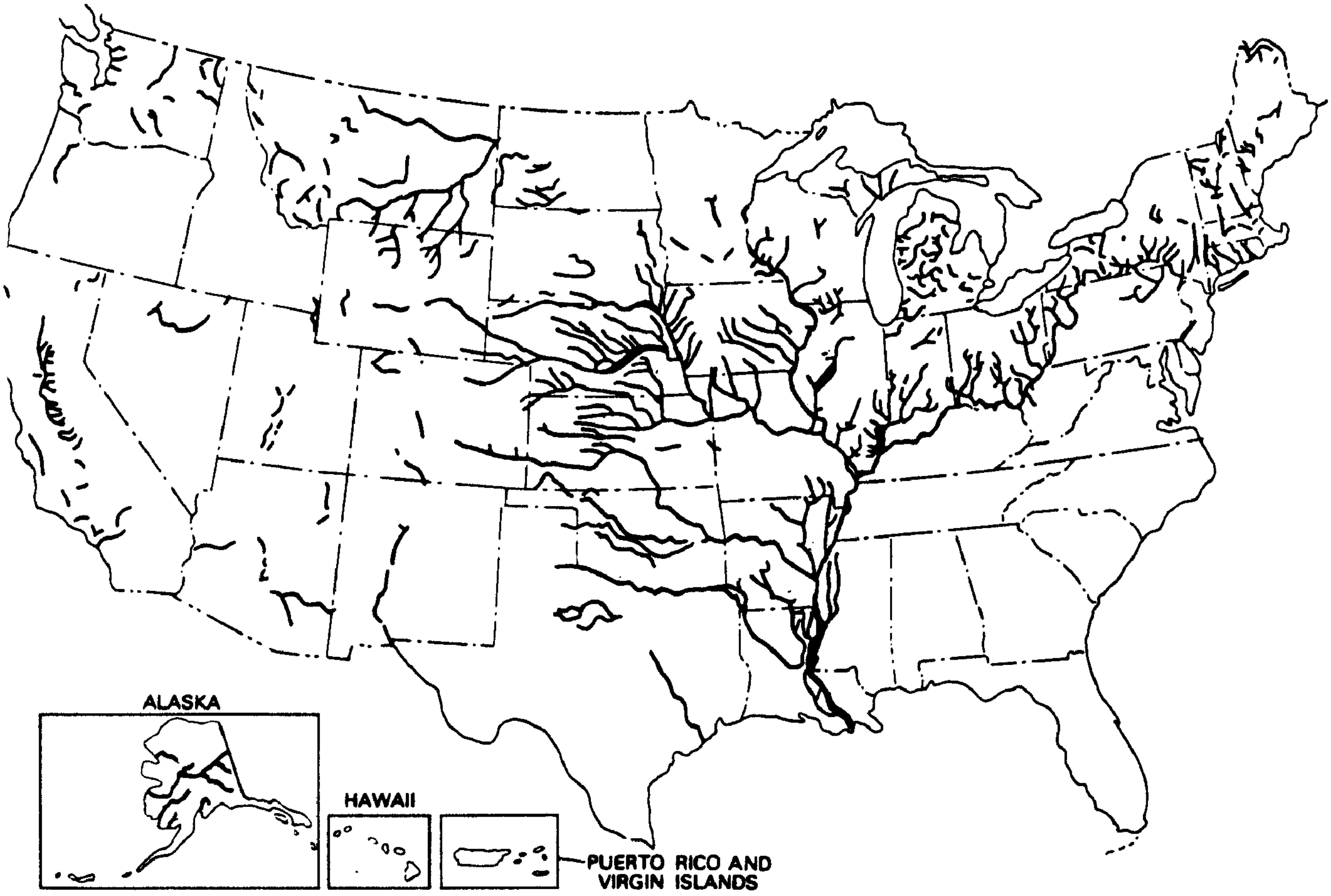
Source: U.S. Geological Survey, Synthetic Fuels Development, Earth Sciences Considerations (Denver, Colo.: U.S. Geological Survey, 1979), p. 24.

Figure I-2
Ground-Water Regions in the U.S.

Alluvial Valleys (Region 12) Ground-Water Region

Source: U.S. Geological Survey, <u>Ground-Water Regions of the United States</u>, Water-Supply Paper 2242 (Reston, Va.: U.S. Geological Survey, 1984), pp. 17-18.

Figure I-2
Ground-Water Regions in the U.S.
(Continued)



being compiled, and the data will be available in late 1987. Between 1950 and 1980, total fresh water withdrawals increased from 174 to 372 billion gallons per day. Nearly one-quarter of this fresh water (82 billion gallons per day/312 billion liters per day) was from ground-water sources, more than double the 1950 level of 34 billion gallons per day (129 billion liters per day).[10] Preliminary estimates for 1985 suggest that between 1980 and 1985, total fresh water withdrawals decreased by nine percent from 1980 and that ground-water withdrawals dropped by seven percent (Figure I-3).

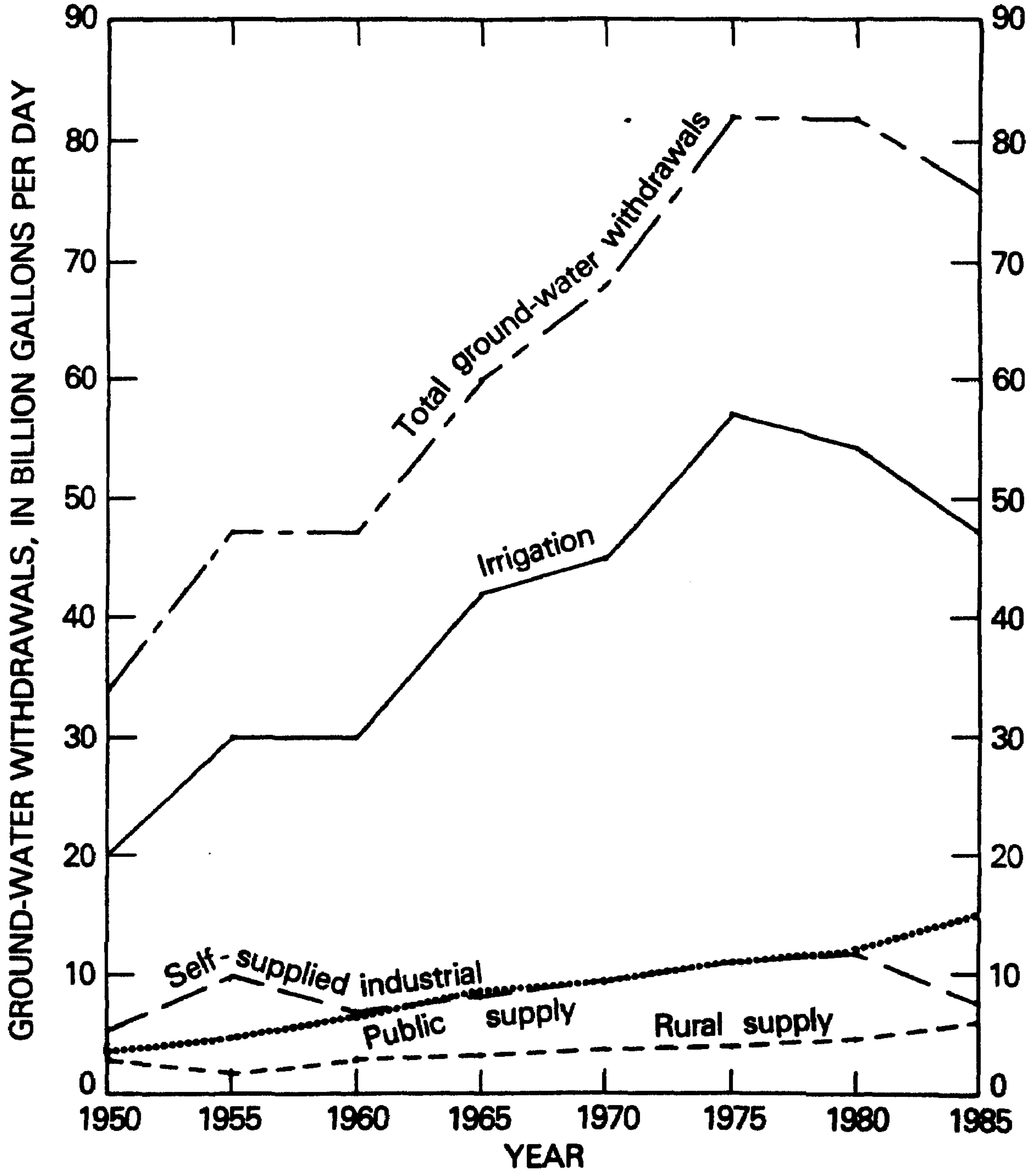
Off-stream water usage in the U.S. typically is described in terms of four sectors:

- Public water supplies are water withdrawals by public and private water suppliers, which are delivered to a variety of users for domestic, public, industrial, and commercial use
- Rural water supply consists of self-supplied domestic use, drinking water for livestock, and other uses such as dairy sanitation, evaporation from stock-watering ponds, cleaning, and waste disposal
- Irrigation is primarily the agricultural use of water to supplement natural rainfall and, to a lesser extent, water used to maintain park lands
- Self-supplied industrial water refers to water industry withdraws from sources other than public supplies. Industries that depend upon self-supply include, but are not limited to, steel, chemical and allied products, mining, petroleum refining, and thermo-electrical power.[11]

For all four sectors, the ground-water withdrawals were higher in 1985 than in 1950, but growth trends were distinctly different by sector.

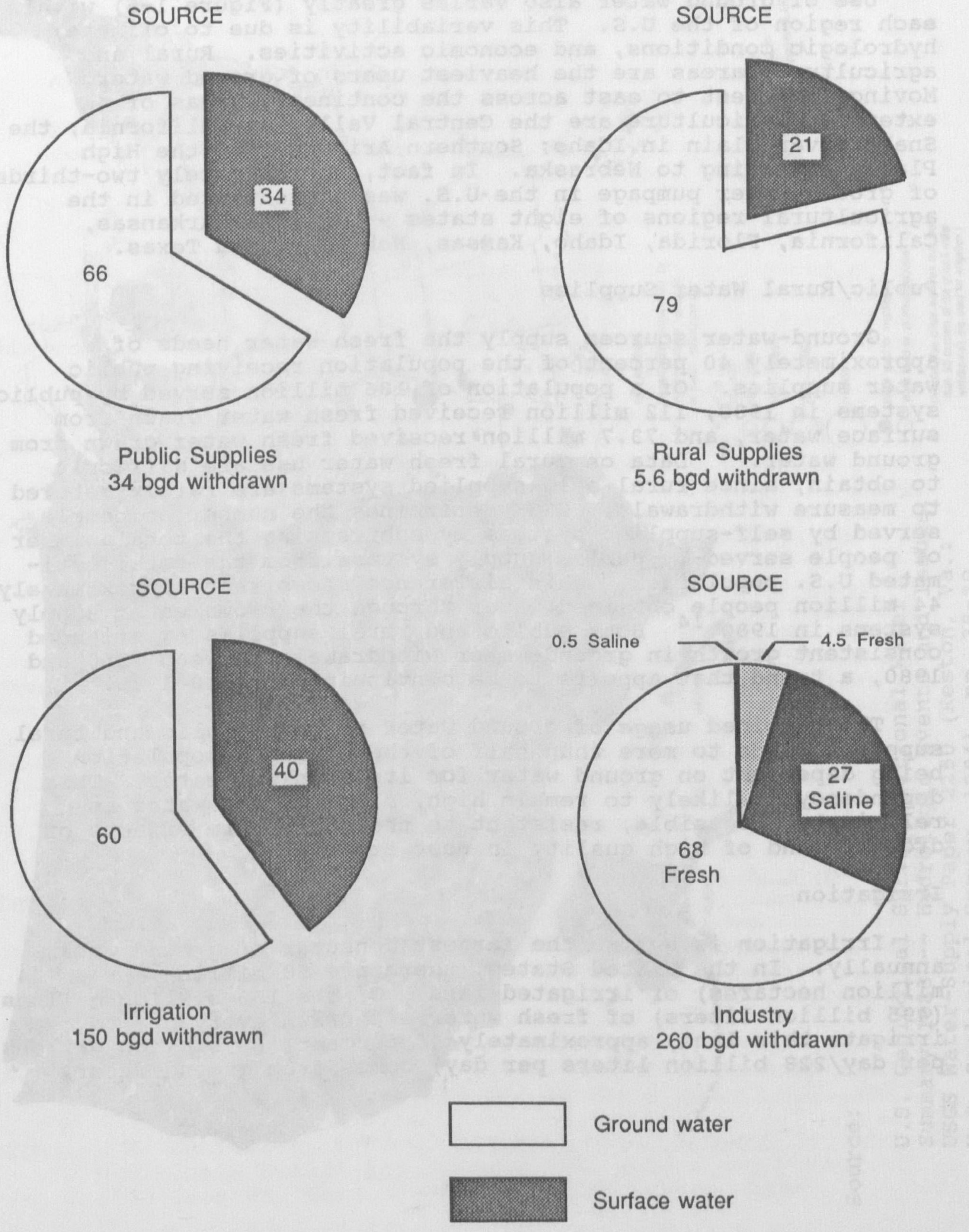
The most significant increases in ground-water usage occurred in the irrigation and public supply sectors, with only modest increases during those three decades in industrial self-supply and rural supply. Irrigation consistently has remained the largest user of ground water and rural supply the smallest user. Public supply has consistently increased. Within each sector, ground water also varies as a percentage of total water usage (Figure I-4). Rural supply depends upon ground water more than any other sector, receiving 79 percent of its total water from ground-water sources. By contrast, self-supplied industry is the least reliant on ground water, with fresh and saline ground-water withdrawals constituting only

Figure I-3
Trends in Ground-Water Withdrawals, 1950-1985



Source: Wayne B. Solley, U.S. Geological Survey, Written Communication, 1987.

Figure I-4
Water Use By Sector, 1986, In Percent



Source: U.S. Geological Survey, Estimated Use of Water in the United States in 1980, U.S. Geological Survey Circular 1001 (Reston, Virginia, U.S. Geological Survey, 1983).

five percent of its total water withdrawals. Ground water provides 34 percent and 40 percent respectively of the total water used by the public supply and irrigation sectors.[12]

Use of ground water also varies greatly (Figure 1-5) within each region of the U.S. This variability is due to climate, hydrologic conditions, and economic activities. Rural and agricultural areas are the heaviest users of ground water. Moving from west to east across the continent, areas of extensive agriculture are the Central Valley in California; the Snake River Plain in Idaho; Southern Arizona; and the High Plains extending to Nebraska. In fact, approximately two-thirds of ground-water pumpage in the U.S. was concentrated in the agricultural regions of eight states -- Arizona, Arkansas, California, Florida, Idaho, Kansas, Nebraska, and Texas.

Public/Rural Water Supplies

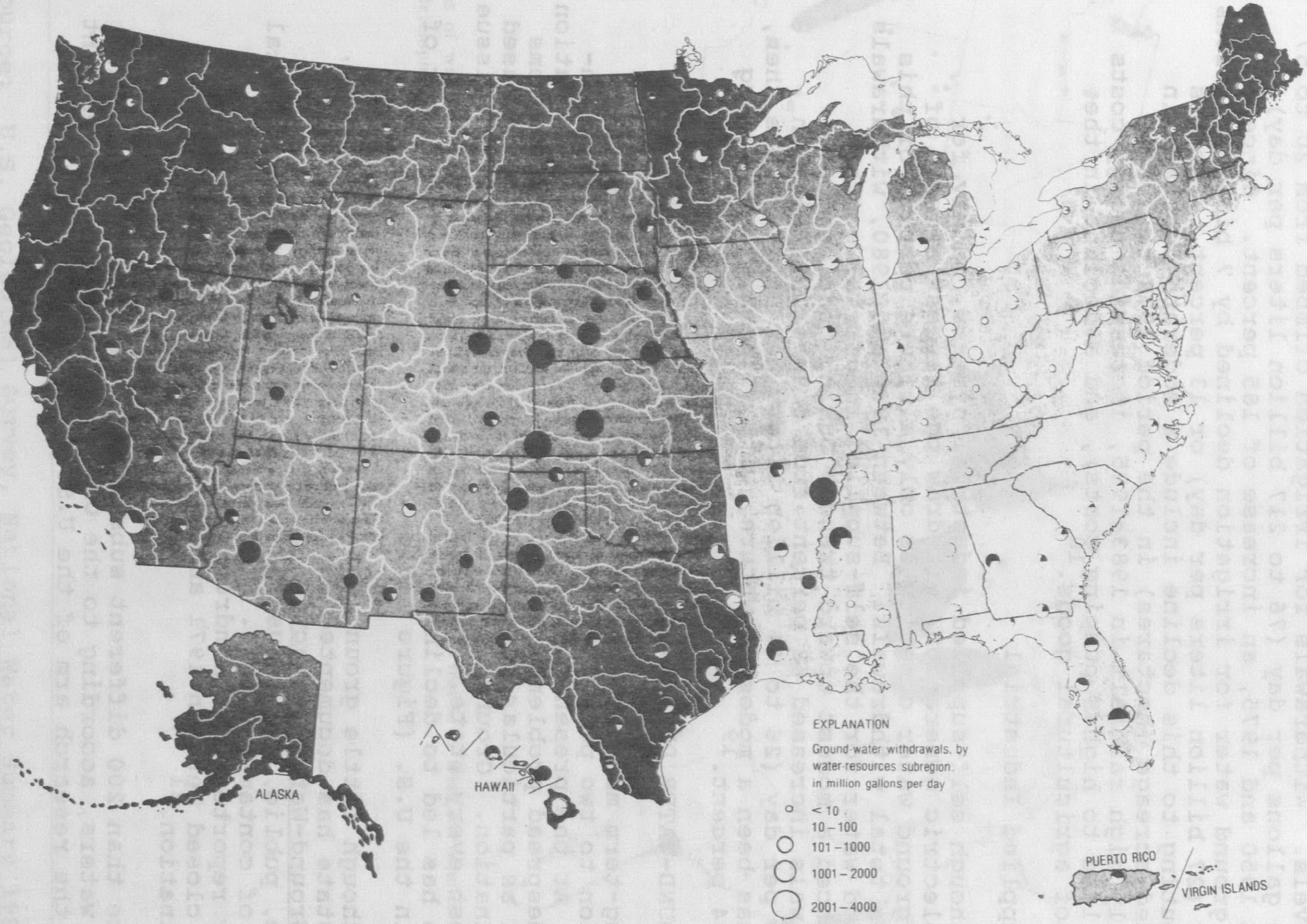
Ground-water sources supply the fresh water needs of approximately 40 percent of the population receiving public water supplies. Of a population of 186 million served by public systems in 1980, 112 million received fresh water drawn from surface water, and 73.7 million received fresh water drawn from ground water.[13] Data on rural fresh water use are difficult to obtain, since rural self-supplied systems are rarely metered to measure withdrawals. USGS determines the number of people served by self-supplied systems by subtracting the total number of people served by public supply systems from the total estimated U.S. population. This difference shows that approximately 44 million people obtained water through their own water supply systems in 1980.[14] Both public and rural supplies experienced consistent growth in ground-water withdrawals between 1950 and 1980, a trend that appears to be continuing in 1980-1985.[15]

The combined usage of ground water through public and rural supplies leads to more than half of the nation's population being dependent on ground water for its drinking water. This dependency is likely to remain high, since ground water is relatively accessible, resistant to the short-term effects of drought, and of high quality in most areas.[16]

Irrigation

Irrigation is by far the largest consumer of ground water annually. In the United States, there are 58 million acres (24 million hectares) of irrigated land. Of the 150 billion gallons (495 billion liters) of fresh water withdrawn every day to irrigate this land, approximately 40 percent (60 billion gallons per day/228 billion liters per day) comes from ground water.[17]

Figure I-5
Ground-Water Withdrawals
By Water-Resources Subregions, 1980



Source:

U.S. Geological Survey, National Water Summary 1983 -- Hydrologic Events and Issues, USGS Water-Supply Paper 2250 (Reston, Va.: U.S. Geological Survey, 1984), pp. 38-39.

After a 25-year period of growth in withdrawals for irrigation (1950-1975), withdrawals since 1975 have declined to 1970 levels. Withdrawals for irrigation climbed from 20 to 57 billion gallons per day (76 to 217 billion liters per day) between 1950 and 1975, an increase of 185 percent. Since 1980, use of ground water for irrigation declined by 7 billion gallons per day (27 billion liters per day) or 13 percent. Factors contributing to this decline include a moderate decrease in irrigated acreage (hectares) in the period 1978 to 1982, unusually high rainfall in 1983-1985, increasing energy costs (which lead to higher pumping costs), and a decline in the prices of agricultural goods.[18]

Self-Supplied Industrial

Although self-supplied industrial systems, mainly for thermoelectric generation, withdraw the largest amounts of water, ground water constitutes only a minute portion of this sector's total withdrawals. Between 1960 and 1980, withdrawals of ground water for the self-supplied industrial sector experienced a modest upward trend. During that period, withdrawals increased 68 percent from 6.9 to 11.6 billion gallons per day (26 to 44 billion liters per day). Since then, there has been a modest downturn, with withdrawals declining about 34 percent.[19]

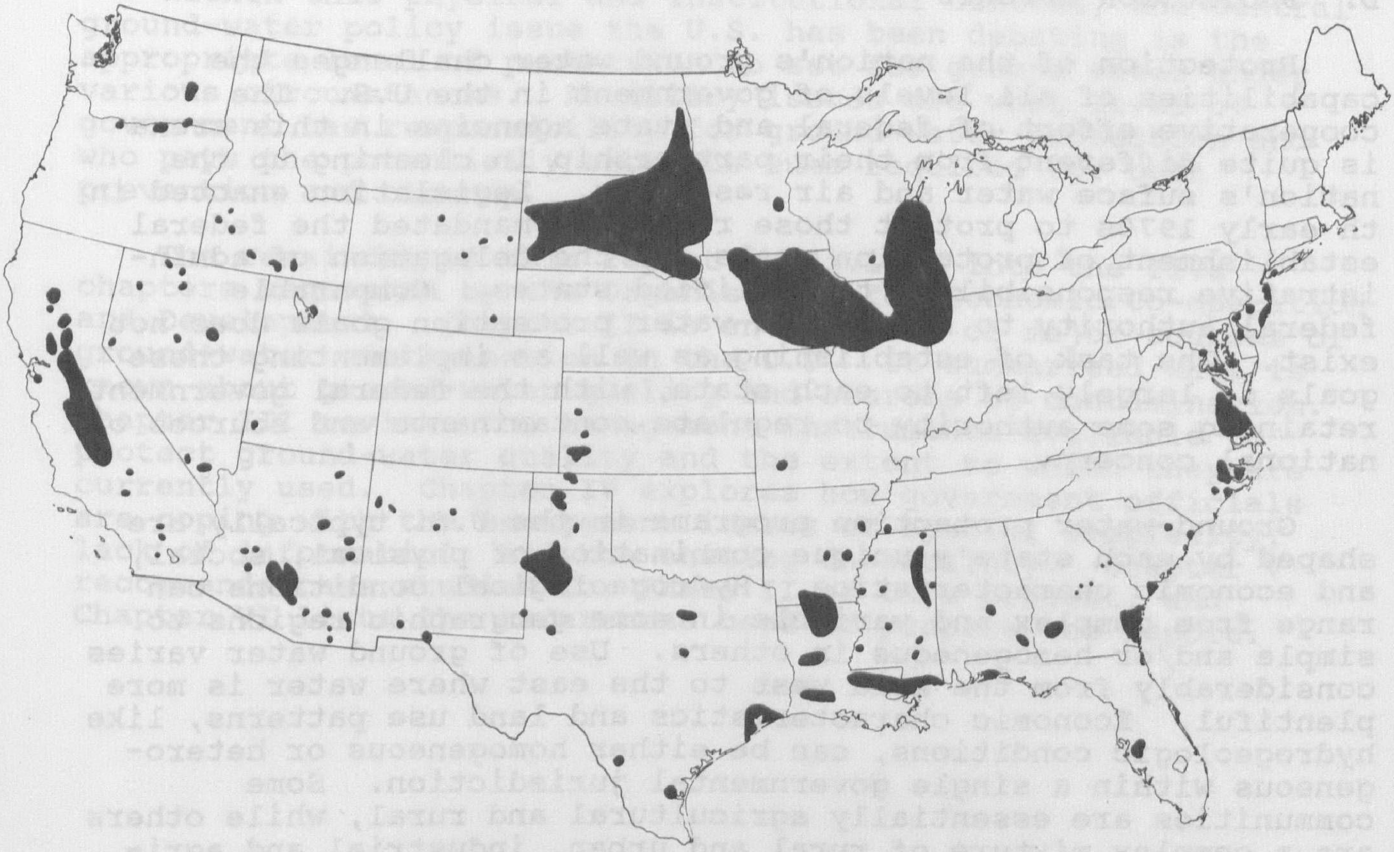
C. GROUND-WATER DEPLETION AND CONTAMINATION

Long-term management of ground-water resources requires attention to two potential problems: depletion and contamination. At the present time, neither depletion nor contamination are widespread problems, but there are some localized problems as well as particular concerns over the potential for increased contamination. Ground-water availability is a significant issue in almost every state. The development of ground-water resources has led to declining ground-water levels in a number of areas in the U.S. (Figure 1-6).

Although little ground water in the U.S. is contaminated, every state has documented some incidents of contamination. EPA's Ground-Water Protection Strategy reported that 8000 private, public, and industrial wells suffered from substantial levels of contamination[20]. The Council on Environmental Quality reported that hundreds of wells affecting millions of people closed between 1971 and 1978 because of excessive contamination.[21]

More than 200 different substances have been found in U.S. ground waters, according to the Office of Technology Assessment (OTA), the research arm of the U.S. Congress. Of these

Figure I-6
Relative Water Depletion



Areas of water-table decline or artesian water-level decline in excess of 40 feet in at least one aquifer since predevelopment.

Source: U.S. Geological Survey, National Water Summary 1983 -- Hydrologic Events and Issues, USGS Water-Supply Paper 2250 (Reston, Va.: U.S. Geological Survey, 1984), p. 40.

substances, approximately 175 were organic chemicals, and over 50 were inorganic chemicals, biological organisms, and radionuclides.[22] At certain levels of exposure, a number of these have tested positive in animal studies for reproductive and birth defects; impairment of the liver, kidneys, and central nervous system; and cancer.

D. PROTECTION EFFORTS

Protection of the nation's ground water challenges the capabilities of all levels of government in the U.S. The cooperative effort of federal and state agencies in this arena is quite different from their partnership in cleaning up the nation's suface water and air resources. Legislation enacted in th early 1970s to protect those resources mandated the federal establishment of protection goals and the delegation of administrative responsibility to qualified states. Comparable federal authority to set ground-water protection goals does not exist. The task of establishing as well as implementing these goals is largely left to each state, with the federal government retaining some authority to regulate contaminants and sources of national concern.

Ground-water protection programs in the U.S. typically are shaped by each state's unique combination of physical, social, and economic characteristics. Hydrogeological conditions can range from complex and variable in some geographic regions to simple and/or homogeneous in others. Use of ground water varies considerably from the arid west to the east where water is more plentiful. Economic characteristics and land use patterns, like hydrogeologic conditions, can be either homogeneous or heterogeneous within a single governmental jurisdiction. Some communities are essentially agricultural and rural, while others are a complex mixture of rural and urban, industrial and agricultural. Collectively, these factors determine the types and numbers of sources and contaminants in a given area, the likelihood of contaminants reaching the ground water, and the extent of human exposure to that contamination.

Institutional capabilities are as diverse as ground-water, land use, and economic characteristics. Federal agencies have responsibilities and authorities for information-gathering and control of some, but not all, contaminants and sources. A few states devised ground-water protection strategies several years ago, but most have adopted or begun preparing them within the past three years. Local units of government within these states have varying authority for independent action, and state and local ground-water protection programs across the country are at different stages of development and implementation. Some ground-water programs primarily borrow policies and management instruments from surface water, air quality, and waste management programs. A small number also have begun to adopt innovative approaches to ground-water protection centered on land use controls. All are grappling with the complex nature of ground-water protection, the lack of sufficient information about the problem, and the resulting uncertainties.

Within this physical and institutional context, the central ground-water policy issue the U.S. has been debating is the appropriate level of protection to set for ground water under various circumstances. Ancillary issues are what level of government has responsibility for ground-water protection and who pays the potentially enormous sums required for both prevention and cleanup.

The remainder of this report is divided into the five chapters requested by the Organisation for Economic Co-operation and Development. Chapter II is an overview of major sources of ground-water contamination in the U.S. It summarized what is known about ground-water quality and sources of contamination. Chapter III reviews the management instruments available to protect ground-water quality and the extent to which they are currently used. Chapter IV explores how government officials are coping with the management issues of spatial complexity, lack of information, and the ensuing uncertainty. Chapter V recommends case studies for Phase II of this project, and Chapter VI lists the references used to prepare the report.

II. MAJOR SOURCES OF POLLUTION

II. MAJOR SOURCES OF POLLUTION

Ground-water contamination has occurred in various locations throughout the U.S., and the discovery of more contamination is likely now that public and governmental attention is focused on the problem. The types of substances found in ground water range from conventional biological organisms to complex, highly toxic synthetic organic chemicals.

Many diverse sources are responsible for the presence of these substances in ground water. Some substances occur naturally, but many are the result of a wide variety of common agricultural, residential, commercial, and industrial activities. Sources can be stationary, with specific discharge points (i.e., point sources), or they can be broad geographic areas with undefined discharge points (i.e., non-point sources). Individual sources in the U.S. vary in size, from large waste management sites to small underground storage tanks or septic systems. Most types of sources are associated with more than one class of contaminant, and multiple sources often are responsible for a single type of contaminant. Contaminants from septic systems, for example, may include microorganisms, nitrates, and solvents. Nitrates in ground water, though, are attributable not only to septic systems but also to fertilizer application on farmlands, among other sources.

Both the types of contaminants and the sources of contamination vary from one region of the U.S. to another, and the actual threat an individual source poses to the ground water and ultimately to human health depends upon a complex set of factors. Local hydrogeology, for example, determines the ground water's general vulnerability to contamination and the extent of transport and attenuation of contaminants. The siting, design, and operation of the source determine whether contaminants will be released and, and if so, the types and amounts of the contaminants that may reach the ground water. If contaminants do reach the aquifer, their inherent toxicity, the existence of natural attenuation processes, and the extent of human exposure all determine the severity of the impact on human health.

The extent of contamination and number of individual sources of contamination are two perplexing questions that still must be addressed. A national inventory of contaminants and sources is not feasible, but several publications have compiled the available information. EPA's <u>Ground-Water Protection Strategy</u> summarized some of this information in order to provide a starting point for strengthening and broadening the Agency's efforts to address particularly troublesome or previously ignored sources. Shortly thereafter, the Office of Technology

Assessment published a major report summarizing available information on the quality of the nation's ground water and the known or suspected sources of contamination. This report linked the more than 200 substances found in ground water with 33 principal categories of sources (Figure II-1).

A. GROUND-WATER QUALITY

In the U.S., ground-water contaminants generally are addressed according to four categories: microbiological organisms, inorganic chemicals, organic chemicals, and radionuclides. EPA has established or proposed health-based drinking water standards for those substances most frequently found in public drinking water supplies. Under recent amendments to the Safe Drinking Water Act, EPA will expand its standard-setting efforts over the next few years to address 89 substances.

Biological Contaminants

Information about the incidence of pathogens in ground water within the U.S. is limited. There have been reports, however, of typhoid, tuberculosis, cholera, and hepatitis. During the past 10 years, ground water serving over 100 million people, or 10 percent of public water supplies from ground-water sources, reportedly exceeded EPA's drinking water standard for micro-microbiological contaminants. Small systems had the most prevalent violations.[1]

Data on the outbreaks of waterborne disease, including outbreaks from contaminated ground water, are maintained by the Centers for Disease Control and EPA's Health Effects Research Laboratory. These data are based on reports from states, and probably understate the situation.

According to EPA's data, 158 recorded outbreaks from bacterial, viral and parasitic contamination of ground water reported between 1945 and 1950 were responsible for 31,350 cases of illness (Figure II-2).[2] Between 1971 and 1982, contaminated ground-water was the cause of about one-half of all reported outbreaks of acute waterborne disease in the U.S.[3]

Inorganic Substances

Some 37 inorganic substances have been found in ground water in the U.S., including 27 metals (Figure II-3).[4] Between 1975-1985, about 1,500 to 3,000 public water supplies out of 40,000 using ground water exceeded EPA's national primary or secondary drinking water standards for inorganic substances.[5] The most common problems were fluoride and nitrates. A variety of inorganic substances also were found in rural residential wells (Figure II-4).[6]

Figure II-1
Sources of Ground-Water Contamination in the U.S.

	Organic chemicals				Inorganic chemicals			Biologicals	Radionuclides
	Aromatic hydrocarbons	Oxygenated hydrocarbons	Hydrocarbons with specific elements	Other hydrocarbons	Metals/ cations	Nonmetals/ anions	Inorganic acids		
Category I									
Subsurface percolation	▶	▶	▶	▶	▶	▶		▶	
Injection wells	◁	◁	▶	◁	▶	▶		▶	▶
Land application[b]									
a Wastewater				▶	▶	▶		▶	
b Wastewater byproducts				▶	▶	▶		▶	▶
c Hazardous waste	▶		▶		◁	◁			
Category II									
Landfills	▶	▶	▶	▶	▶	▶	▶	◁	▶
Open dumps	▶	▶	▶	▶	▶	▶	▶	▶	
Residential disposal	▶	▶	▶	▶	▶	▶	▶	▶	
Surface impoundments	▶	▶	▶	▶	▶	▶	▶	▶	▶
Waste tailings					▶	▶	▶		▶
Waste piles					▶	▶	▶		▶
Materials stockpiles					◁	◁			
Graveyards					▶	▶		▶	
Animal burial					◁	◁		◁	
Above-ground storage tanks	◁	◁	◁	▶	◁	◁	◁	◁	◁
Underground storage tanks	▶	▶	▶	▶	▶	◁	◁	◁	◁
Containers	◁	◁	◁	◁	◁	◁	◁	◁	◁
Open burning and detonation sites					◁	◁			
Radioactive disposal sites									▶

Key:
▶ Contaminant in class has been found in groundwater associated with source.
◁ Potential exists for contaminant in class to be found in groundwater associated with source.

Source: Office of Technology Assessment, U.S. Congress, <u>Protecting the Nation's Groundwater From Contamination</u>, (Washington, D.C.: Office of Technology Assessment, October 1984), pp. 48-49.

Figure II-1
Sources of Ground-Water Contamination in the U.S.
(Continued)

	Organic chemicals				Inorganic chemicals			Biologicals	Radionuclides
	Aromatic hydrocarbons	Oxygenated hydrocarbons	Hydrocarbons with specific elements	Other hydrocarbons	Metals/ cations	Nonmetals/ anions	Inorganic acids		
Category III									
Pipelines	◁	◁	◁	◀	◁	◁	◁	◁	
Materials transport and transfer operations	◁	◀	◀	◀	◁	◁	◁	◁	◁
Category IV									
Irrigation practices					◀	◀			
Pesticide applications			◀						
Fertilizer applications			◀		◀	◀		◁	
Animal feeding operations					◀	◀		◁	
De-icing salts applications					◁	◀			
Urban runoff	◁	◁	◀	◁	◀	◀	◁	◀	
Percolation of atmospheric pollutants					◀	◀			
Mining and mine drainage					◀	◀	◀		◀
Category V									
Production wells									
a. Oil	◁			◀	◀	◀			
b. Geothermal and heat recovery					◀	◀			◁
c. Water supply					◀	◀			
Other wells	◁	◁	◁	◁	◁	◁	◁	◁	◁
Construction excavation					◁	◁			
Category VI									
Groundwater-surface water interactions	◁	◁	◁	◁	◁	◁	◁	◁	◁
Natural leaching					◀	◀			◀
Salt-water intrusion					◀	◀			◀

[a] Based primarily on University of Oklahoma, 1983. Additional information from Colton, et. al., 1979; Metropolitan Area Planning Council, 1982; Ridgley, et. al., 1982; San Francisco Bay Regional Water Quality Control Board, 1983; and Kaplan, et. al., 1983.

[b] Documentation was not available on the land application of non-hazardous wastes

Figure II-2
Waterborne Disease in the U.S. Due to Bacterial, Viral, and Parasitic Contamination of Ground Water, 1945-1980

PATHOGEN	OUTBREAKS	CASES OF ILLNESS
Bacteria	94	26,041
Viruses	55	3,291
Parasites	9[(a)]	2,018
TOTAL	158	31,350

(a) = 1953-1980

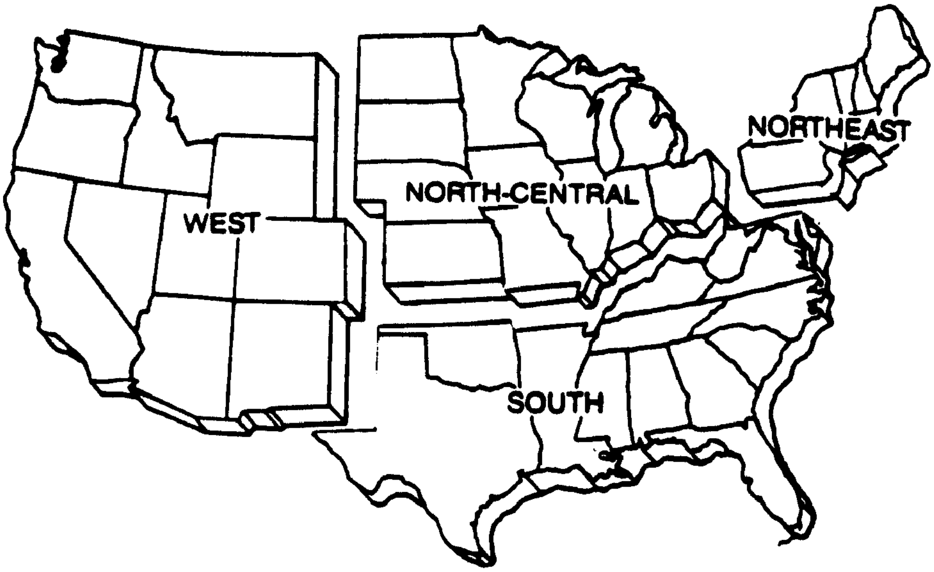
Source: U.S. Environmental Protection Agency, Health Effects Research Laboratory as reported in Patrick, Ruth et al., Groundwater Contamination in the United States (Philadelphia, Pennsylvania: University of Pennsylvania Press, 1983), pp. 91-96.

Figure II-3
Inorganic Substances Found in Ground Water

SUBSTANCE	CONCENTRATION (milligrams per liter)
Aluminum	0.1-1,200
Ammonia	1.0-900
Antimony	--
Arsenic	0.01-2,100
Barium	2.8-3.8
Beryllium	less than 0.01
Boron	--
Cadmium	0.01-180
Calcium	0.5-225
Chlorides	1.0-49,500
Chromium	0.06-2,740
Cobalt	0.01-0.18
Copper	0.01-2.8
Cyanides	1.05-14
Fluorides	0.1-250
Iron	0.04-6,200
Lead	0.01-56
Lithium	--
Magnesium	0.2-70
Manganese	0.1-110
Mercury	0.003-0.01
Molybdenum	0.4-40
Nickel	0.05-0.5
Nitrates	1.4-433
Nitrites	.
Palladium	.
Potassium	0.5-2.4
Phosphates	0.4-33
Selenuim	0.6-20
Silver	9.0-3330
Sodium	3.1-211
Sulfates	0.2-32,318
Sulfites	.
Thallium	.
Titanium	.
Vanadium	243.0
Zinc	0.1-240

Source: The Conservation Foundation, Groundwater Protection (Washington, D.C.: The Conservation Foundation, 1987), p. 69.

Figure II-4
Summary of Inorganic Elements in EPA Rural Water Survey



Element	Level Exceeded (mg/l)	Nationwide	West	North-Central	Northeast	South
		in % of Rural Households				
Mercury	0.002	24.1	10.4	31.8	22.0	25.0
Iron	0.3	18.7	70	28.2	16.0	17.0
Cadmium	0.01	16.8	27.1	20.7	1 6	17.3
Lead	0 05	16.6	16.9*	10.8*	9.6*	23.1*
Manganese	0.05	14.2	4.7	19.9	16.9	12.3
Sodium	100	14 2	15.0	19.2	6.0	14.1
Selenium	0 01	13.7	41 3	25.7	0.0	2.1
Silver	0 05	4 7	2.1	3.7	4 8	4 8
Sulfates	2500	4 0	11 7	7 4	0 5	0.7
Nitrate-N	100	2 7	4 0	5 8	0 3	1 3
Fluoride	1 4	2 5	6 2	1 8	0 0	2 7
Arsenic	0 05	0.8	2 1	1 8	0 0	0 0
Barium	1 0	0 3	0 0	0 0	0 0	0.7
Magnesium	1250	0 1	0 5	0 1	0.0	0 0
Chromium	0 05	**	0 0	0 0	0 0	0 0
Borpn	†					

* may be distorted upwards

** not detected

† not tested

Source: The Conservation Foundation, Groundwater Protection (Washington, D.C.: The Conservation Foundation, 1987), p. 70

Concern over the health effects of inorganics has focused on toxic metals, such as mercury and lead, although nitrates and other salts also have received some attention. The precise effects of these substances on human health has not been conclusively established. For example, some of these metals may be beneficial in trace amounts, but also may produce a range of both acute and chronic effects at various doses (Figure II-5)[7]. Even among the better understood toxic metals such as cadmium, lead, and mercury, the significance of ground water as an exposure pathway is not clear. There is some indication, in fact, that other exposure routes may be far more significant than ground water. For cadmium, the most significant pathways appear to be diet, smoking, and breathing air near industrial areas. By contrast, drinking water is emerging as a principal route of human exposure to lead, but that exposure is due to decomposing lead pipes in the delivery system rather than to contamination of the ground-water source.

Although deaths due to nitrate ingestion are rare, at least one infant death occurred in 1986 as a result of formula made with water from a nitrate-tainted well.[8] Other possible, but not conclusively documented, effects of some inorganics include impairment of the nervous system, risk of cancer, and birth defects.[9]

Organic Compounds

Within the U.S., a number of organic compounds are found in commonly used household products such as dyes, food additives, detergents and other cleansers, cosmetics, plastics, solvents, paint, and pesticides. Public officials are particularly concerned that the concentration of these synthetic organic contaminants in ground water substantially exceeds their concentrations in surface water (Figure II-6).[10]

Data compiled by the Council on Environmental Quality (CEQ) in 1981 illustrate the frequent occurence of contamination from organics. CEQ identified major problems from toxic organics in some wells in almost all states east of the Mississippi River as well as in some sparsely populated states in the West. Trichloroethylene was the contaminant most frequently found in 2,984 wells tested in 18 states, with a total of 33 contaminants detected.[11]

Five surveys EPA conducted over the past decade (Figure II-7)[12] examined 14 of the most common volatile organic compounds and have provided some insights into the national pattern of ground-water contamination from these substances.[13] All five surveys found at least some incidence of carbon tetra-

Figure II-5
Types of Adverse Health Effects Associated with Cadmium, Lead, and Mercury

	ENVIRONMENTAL AGENTS & SOURCES OF EXPOSURE		
TYPES OF HEALTH EFFECTS	CADMIUM	LEAD	MERCURY
Cancer	●	○	
Cardiovascular system	○	●	
Respiratory system	●		
Brain & nervous system		●	●
Gastrointestinal system		○	
Urinary system	●	●	●
Reproductive system		○	○
Skeletal system	○		
Circulatory System	○	●	
Eye System		●	●
Endocrine system		○	
Injury to embryo/fetus		●	●
Psychological (affective) disturbances		●	●

Notes: ● indicates the relationship is established in humans

○ indicates a weak or questionable association in humans

Source: The Conservation Foundation, Groundwater Protection (Washington, D.C.: The Conservation Foundation, 1987), p.93.

Figure II-6
Concentrations of Toxic Organic Compounds Found in Drinking Water Wells and Surface Water

CHEMICAL	GROUND-WATER CONCENTRATION (ppb)*	HIGHEST SURFACE WATER CONCENTRATION REPORTED (ppb)
Trichlorethylene (TCE)	900-27,300	160
Toluene	55-6,400	6.1
1,1,1-Trichloroethane	965-5,440	5.1
Acetone	3,000	NI
Methylene chloride	47-3,000	13
Dioxane	2,100	NI
Ethyl benzene	2,000	NI
Tetrachloroethylene	717-1,500	21
Cyclohexane	540	NI
Chloroform	67-490	700
Di-n-butyl-phthalate	470	NI
Carbon tetrachloride	135-400	30
Benzene	30-330	4.4
1,2-Dichloroethylene	91-323	9.8
Ethylene dibromide (EDB)	35-300	NI
Xylene	69-300	24
Isopropyl benzene	290	NI
1,1-Dichloroethylene	70-280	0.5
1,2-Dichloroethane	250	4.8
Bis (2-ethylhexyl) phthalate	170	NI
DBCP (1,2-dibromo-3-chloropropane)	68-137	NI
Trifluorotrichloroethane	35-135	NI
Dibromochloromethane	20-55	317
Vinyl chloride	50	9.8
Chloromethane	44	12
Butyl benzyl-phthalate	38	NI
Gamma-BHC (Lindane)	22	NI
1,1,2-Trichloroethane	20	NI
Bromoform	20	280
1,1-Dichloroethane	7	0.2
Alpha-BHC	6	NI
Parathion	4.6	0.4
Delta-BHC	3.8	NI

ppb = parts per billion, 1 ppb = 1/1000 ppm; 1 ppm - mg/l; NI = not investigatigated

Source: The Conservation Foundation, Groundwater Protection
(Washington, D.C.: The Conservation Foundation, 1987), p.83.

Figure II-7
Volatile Organic Compounds Examined in Five National Surveys

	NORS	NOMS	NSP	CWSS	GWSS
APPROXIMATE NUMBER OF GROUNDWATER SYSTEMS SAMPLED	16	18	12	330	945
Trichloroethylene		●	●	●	●
Tetrachloroethylene		●	●	●	●
Carbon Tetrachloride	●	●	●	●	●
1,1,1-Trichloroethane		●	●	●	●
1,2-Dichloroethane	●	●	●	●	●
Vinyl Chloride		●	●		
Dichloromethane		●	●		●
Benzene		●	●	●	●
Chlorobenzene			●	●	●
Dichlorobezene(s)		●	●		●
Trichlorobenzene(s)		●	●		●
1,1-Dichloroethylene			●		●
cis - or trans-1,2-Dichlorethylene			●	●	●

SOURCE: Adapted from Rip G. Rice, ed., Safe Drinking Water: The Impact of Chemicals on a Limited Resource (Alexandria, Virginia: Drinking Water Research Foundation, 1985) p. 164 in The Conservation Foundation, Groundwater Protection (Washington, D.C.: The Conservation Foundation, 1987).

chloride and 1,2 dichloroethane. The five most frequently detected compounds in the Ground Water Supply Survey were trichloroethylene; 1,1,1-trichloroethane; tetrachloroethylene; cis/trans-1,2-dichloroethylene; and 1-1-dichloroethane.[14] This same study showed that about 20 percent of all public water supply wells and 30 percent of wells in urban areas showed trace levels of at least one volatile organic.[15]

Recent state investigations demonstrate that toxic organic contamination of ground water is occurring in widely separated areas of the country. A 1985 California study, for example, detected trace levels of 33 organic chemicals in 18 percent of 3,000 drinking water wells surveyed, but only 165 of these wells had contaminant levels that exceeded state drinking water standards. In another study, conducted over a five-year period, Nebraska detected volatile organic compounds in 10 percent of its community water supplies.[16]

Public oficials also have been examining the extent of ground-water contamination from organic pesticides. A number of published studies conducted during the past five years reveal different facets of the extent of pesticide contamination. In a background document published in 1985, EPA confirmed that normal agricultural usage had contributed to contamination from at least 17 pesticides in at least 23 states (Figure II-8).[17] Although found only at trace levels, there was concern that these pesticides were present at all in ground water.

Some state investigations indicate that pesticide contamination may actually be higher when all sources of pesticides are taken into consideration. California reported in 1985 that 57 different pesticides detected in the state's ground waters were responsible for contaminating an estimated 2,887 wells. The study attributed the contamination not only to normal pesticide application but also to spills and leaks from a variety of sources.[18] In New York, over half of 8,404 wells tested on Long Island for aldicarb were found to have trace levels of the chemical. As a result, the pesticide manufacturer provided activated carbon filters to the owners of over 2,000 wells with concentrations of aldicarb in excess of state drinking water standards.[19]

In addition to aldicarb, DBCP and EDB are two of the most prevalent pesticides found in ground water. California found DBCP, a nematicide, in more than 8,000 wells tested between 1979 and 1982, and the pesticide also has been detected in the ground waters of Arizona, Hawaii, South Carolina, and Maryland.[20] EDB, another nematicide, has been found in the ground water of eight states, including nearly 11 percent of 8,000 wells tested in Florida as of 1984.[21]

Figure II-8
Pesticides Found In Ground Waters Of 23 States

PESTICIDE	USE*	STATE	TYPICAL POSITIVE, ppb**
Alachlor	H	MD, IA, NE, PA	0.1-10
Aldicarb (sulfoxide & sulfone)	I,N	AR, AZ, CA, FL, MA, ME, NC, NJ, NY, OR, RI, TX, VA, WA, WI	1-50
Atrazine	H	PA, IA, NE, WI, MD	0.3-3
Bromacil	H	FL	300
Carbofuran	I,N	NY, WI, MD	1-50
Cyanazine	H	IA, PA	0.1-1.0
DBCP	N	AZ, CA, HI, MD SC	0.02-20
DCPA (and acid products)	H	NY	50-700
1,2-Dichloropropane	N	CA, MD, NY, WA	1-50
Dinoseb	H	NY	1-5
Dyfonate	I	IA	0.1
EDB	N	CA, FL, GA, SC, WA, AZ, MA, CT	0.05-20
Metolachlor	H	IA, PA	0.1-0.4
Metribuzin	H	IA'	1.0-4.3
Oxamyl	I,N	NY, RI	5-65
Symazine	H	CA, PA, MD	0.2-3.0
1,2,3-Trichloropropane	N (impurity)	CA, HI	0.1-5.0

* H = herbicide; I = insecticide; N = nematicide

** ppb = parts per billion; 1 ppb = 1/1000 ppm; 1 ppm = 1 mg/l

Source: U.S. Environmental Protection Agency, Office of Ground-Water Protection, Pesticides In Ground Water: Background Document (Washington, D.C. U.S. Environmental Protection Agency, May 1986), p. 9.

EPA recognizes that available figures on pesticide contamination are somewhat outdated and is establishing a computerized bibiliography of pesticide monitoring studies so that both the Agency and the states can keep informed of expanding monitoring efforts. Even with this bibliography, it is clear that available data have not provided a national picture, so EPA currently is conducting a nationwide survey that will examine the occurrence of over 60 pesticides in ground water and the hydrogeologic characteristics and pesticide usage practices that promote or mitigate leaching to ground water.

At the present time, available data do not conclusively link pesticide contamination of ground water in the U.S. with specific incidents of illness or disease. To collect additional information on health effects of human exposure to pesticides in the U.S., EPA is using the provisions of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) to ask pesticide registrants for a full complement of environmental fate data on pesticides suspected of leaching to ground water.

Radionuclides

Approximately 20 different radionuclides have been detected in the nation's ground water (Figure II-9).[22] Most of these substances emit a combination of alpha and beta radiation, and generally are found in concentrations well below those likely to pose major health problems. Another problem emerging as a greater risk to human health is ground-water contamination from radon. Investigations are underway to examine the extent the radon exposure in the U.S. and the relative contribution of each pathway of exposure.

B. SOURCES OF CONTAMINATION

The 33 sources on OTA's list generally can be grouped into four basic categories:

- <u>Waste generation and management</u> generally refers to facilities, operations, or practices that create or generate waste (such as animal feedlots or burial sites) and treat, store, or dispose of waste

- <u>The commercial/production category</u> encompasses the storage, handling, transport, or development of resources, materials, and finished products

- <u>Chemical application</u> refers to the land application of substances for beneficial purposes (such as pesticides, fertilizers, and road deicing salts)

Figure II-9
Categorization of Known and Potential
Radionuclides in Ground Water by Mode of Decay

RADIONUCLIDE	a	b	b and g combined	g
Antimony-125			x	
Barium-140			x	
Cesium-134			x	
* Cesium-137			x	
* Chromium-51				x
* Cobalt-60			x	
Iodine-129			x	
* Iodine-131			x	
* Iron-59			x	
* Lead-210			x	
* Phosphorus-32		x		
* Plutonium-238	x			
* Plutonium-243			x	
* Radium-226	x			
* Radium-228		x		
Ruthenium-103			x	
* Ruthenium-106		x		
* Scandium-46			x	
Strontium-89		x		
* Strontium-90		x		
Strontium-131			x	
* Thorium-270	x			
* Tritium		x		
Uranium-230	x			
* Uranium-238	x			
* Zinc-65			x	
* Zirconium-95			x	

* Radionuclides marked with an asterisk are known to have contaminated groundwater

a = alpha radiation
b = beta radiation
g = gamma radiation

Source: The Conservation Foundation, Groundwater Protection (Washington, D.C.: The Conservation Foundation, 1987), p. 83.

A miscellaneous category covers other sources such as salt-water intrusion.

Some sources, such as underground storage tanks and injection wells, fit more than one category (Figure II-10).[23]

Waste Generation and Management

Waste generation and management historically have been regarded as the most significant long-term sources of ground-water contamination in the U.S., and these sources continue to receive the most attention at all levels of government. Landfills have been the most highly visible but are not the only waste sources of ground-water contamination. Of the 33 types of sources OTA listed, in fact, two-thirds (22) fall into this waste generation and management category.

The magnitude of the potential problem from these sources is apparent from a profile of their numbers, contaminants, and geographic distribution (Figure II-11). Collectively, these sources number in the millions: over 23 million septic systems, with one-half million new ones added annually; between three and 10 million steel and fiberglass tanks; about 281,000 active injection wells; nearly 200,000 surface impoundments; and about 17,000 landfills. Waste generation and management sources in the U.S.contribute to the presence of all four types of ground-water contaminants, and at least 16 of the sources are associated with at least three of the four contaminant categories. Some types of sources, such as road deicing salts or saltwater intrusion, are concentrated in just a few areas, but many other sources are distributed nationwide.[24]

The siting, design, construction, operation, and closure of waste generation sources are the key factors affecting the likelihood and severity of ground-water contamination. Many of the millions of waste generation and management sources already in operation were sited at a time when there was little concern over ground-water quality. Closure of these facilities will not entirely ameliorate the problem, because the wastes will remain in the ground for many years and continue to discharge leachate to the aquifer.

For these "existing" sources, EPA has taken special corrective steps, while concurrently initiating preventive programs to more effectively manage new sources. EPA has banned wells that inject hazardous wastes into shallow formations, for example, because mitigation measures would not sufficiently protect drinking water supplies. Surface impoundments have been of concern because many are located in hydrogeologically vulnerable areas and in proximity to current sources of drinking

Figure II-10
Contaminant Sources By Category

SOURCE	WASTE MANAGEMENT	COMMERCIAL/ PRODUCTION	CHEMICAL APPLICATION	OTHER
1. Subsurface percolation	√			
2. Injection wells	√	√		
3. Land application	√			
4. Landfills	√			
5. Open dumps	√			
6. Residential disposal	√			
7. Surface impoundments	√			
8. Waste tailings	√			
9. Waste piles	√			
10. Materials stockpiles	√	√		
11. Graveyards	√			
12. Animal burial	√			
13. Aboveground storage tanks	√	√		
14. Underground storage tanks	√	√		
15. Containers	√	√		
16. Open burning/detonation	√			
17. Radioactive disposal sites	√			
18. Pipelines	√	√		
19. Materials transport		√		
20. Irrigation				√
21. Pesticide application			√	
22. Fertilizer application			√	
23. Animal feedlots	√			
24. De-icing			√	
25. Urban runoff	√			
26. Perc. of atmospheric pollutants				√
27. Mining/mine drainage	√	√		
28. Production wells		√		
29. Other wells (monitoring & explor.)		√		
30. Construction excavation	√			
31. Ground/surface water interaction				√
32. Natural leaching				√
33. Salt water intrusion				√
34. Abandoned waste sites	√			
35. Nuclear facilities	√			

Figure II-11
Profile of Waste Generators and Management Sources

SOURCE	POTENTIAL CONTAMINANTS	NUMBER/VOLUME	GEOGRAPHIC DISTRIBUTION
Subsurface percolation	Organics, metals, nitrates, phosphates, micoorganisms	22 million domestic 25,000 industrial	Highest concentration in Eastern third of country and portions of West Coast
Injection wells	Organics, metals, inorganic acids, microorganisms, radinouclides	280,752 active	Varies by well type -- Class I (hazardous waste) - Gulf Coast and Great Lakes -- Class II (oil/gas) - throughout the U.S. -- Class III (mining) - Southwest -- Class V - agricultural wells in IA, ID, TX, CA; industrial wells in NY and NJ
Land Application	Nitrogen, phosphorous, metals organics, microorganisms	2,463 POTWs -- sludge application 1,000 POTWs -- land treatment 250 hazardous waste land treatment units 18,889 non-hazardous units	Unkown
Landfills	Organics, inorganics, micro-organisms, radinouclides	16,416 landfills 9,284 municipal 3,155 industrial	Urban locations nationwide
Open Dumps	Organics, inorganics, micro-organisms	1,856 - 2,396	55 states and territories
Residential Disposal	Organics, metals, other inorganics, microorganisms	Unkown	Nationwide

Figure II-11
Profile of Waste Generators and Management Sources
(Continued)

SOURCE	POTENTIAL CONTAMINANTS	NUMBER/VOLUME	GEOGRAPHIC DISTRIBUTION
Surface Impoundments	Organics, metals and other inorganics, microorganisms, radionuclides	191,822 surface impoundments -- 16,232 industrial -- 2,426 municipal -- 17,159 agricultural -- 19,813 mining -- 125,074 oil and gas -- 11,118 other	70% in hydrogeologically vulnerable areas 37% over current ground-water sources of drinking water Highest number of non-hazardous are in AR, KS, LA, MN, OH, OK, PA,TX, WV
Waste Tailings and Piles	Arsenic, sulfuric acid, copper, selenium, molybdenum, uranium, thorium, radium, lead, manganese, vanadium	Total mining - 2.3 billion tons/yr. -- Metal - 250 million tons/yr. -- Uranium - 215 million tons/yr. Hazardous waste - 0.39 billiion tons	Unknown
Material Stockpiles	Metals, inorganics, radionuclides	Annual materials production - 3.4 billion tons/yr. Stockpiles - 700 million tons/yr.	Nationwide
Graveyards	Metals, nonmetals, microorganisms	Unknown	Nationwide
Animal Burial		Unknown	Unknown
Aboveground Storage	Organics, inorganics, microorganisms, radionuclides	Unkown	Nationwide

Figure II-11
Profile of Waste Generators and Management Sources
(Continued)

SOURCE	POTENTIAL CONTAMINANTS	NUMBER/VOLUME	GEOGRAPHIC DISTRIBUTION
Underground Storage	Organics, inorganics, microorganisms, radionuclides	Steel - 2.4 - 4.8 million tanks Fiberglass - 0.1 million tanks Total capacity - 25 billion gallons Hazardous storage - 2,032 tanks	Nationwide

Source: U.S. Environmental Protection Agency, Office of Ground-Water Protection, <u>EPA Activities Related to Sources of Ground-Water Contamination</u> (Washington, D.C.: U.S. Environmental Protection Agency, 1987).

water. Septic systems have the potential to contaminate the ground water both because they often have been installed in unsuitable locations and are not always properly operated and maintained.

Commercial/Production Sources

Commercial/production sources have been of increasing concern in recent years, particularly since 70 percent of the sources in this category also fall into the waste generation and management category. The three sources unique to this category are materials transport, production wells, and other wells (e.g., monitoring and exploration wells).

These sources are receiving increased attention because of their large numbers, widespread geographic distribution, numerous contaminants, and large volumes of potential contaminant leaks and discharges (Figure II-12). Materials transport, for example, involves 10,000-16,000 spills per year, production wells number in the millions, billions of tons (kilograms) of materials are stockpiled, underground storage tanks also number in the millions, and there are hundreds of thousands of injection wells and miles of pipelines.[25]

Federal and state roles for managing each of these sources are quite different, with programs in varying stages of development and implementation. EPA, for example has regulated some types of injection wells for many years, but is only just beginning to consider developing regulations for others under the Underground Injection Control Program of the Safe Drinking Water Act. Until the amendments to the Resource Conservation and Recovery Act in 1984, underground storage tanks largely were neglected as a source of ground-water contamination, but under Subtitle I of the Act, EPA is proposing regulations, and states are readying to assume new program responsibilities. Implementation of EPA's authorities under Subtitle D of RCRA now covers waste storage containers at facilities that treat, store, or dispose of hazardous waste. States and their localities have the principal responsibility for cleaning up transportation leaks and spills not addressed by the responsible parties, but can receive federal Superfund assistance if the incidents exceed their technical and financial capabilities.

Chemical Application Sources

Chemical application sources are emerging as a ground-water protection priority in many locales. Both the public and government officials gradually have realized that the normal, beneficial application of pesticides, fertilizers, and deicing salts may have adverse consequences for ground water (Figure II-13). In 1982, 552 million pounds (248 million kilograms) of

FIGURE II-12

Profile of Commercial/Production Sources

SOURCE	POTENTIAL CONTAMINANTS	NUMBER/VOLUME	GEOGRAPHIC DISTRIBUTION
Injection Wells	Organics, metals, inorganic acids, microorganisms, radionuclides	Active - 280, 752 active	--Varies by well type --Class II (oil/gas) - throughout U.S. --Class III (mining) - southwest --Class V - agricultural wells in IA, ID, TX, CA; industrial wells in NY, NJ
Materials Stockpiles	Metals, inorganics, radionuclides	Annual materials production - 3.4 billions tons Stockpiles (?) - 700 million tons	Nationwide
Aboveground Storage Tanks	Organics, inorganics, microorganisms, radionuclides	Unknown	Nationwide
Underground Storage Tanks	Organics, inorganics, microorganisms,		Nationwide
Containers	Organics, inorganics, microorganisms, radionuclides	3,577 facilities used containers to store 0.16 billion gallons of hazardous waste	Unknown

Source: U.S. Environmental Protection Agency, Office of Ground-Water Protection. EPA Activities Related to Ground-Water Contamination, February 1987.

FIGURE II-12
Profile of Commercial/Production Sources
(continued)

SOURCE	POTENTIAL CONTAMINANTS	NUMBER/VOLUME	GEOGRAPHIC DISTRIBUTION
Pipelines	Microorganisms , organics, inorganics	175,000 miles of petroleum product pipelines (1976) carrying 9.63 billion bbls 700,000 miles of sewer pipeline (1976) carrying 5.6 trillion gallons	Nationwide
Materials Transport	Organics, inorganics, microorganisms	10,000-16,000 spills per year spills account for approximately 0.35 percent of 4 billions tons shipped annually (1984)	Nationwide
Mining/Mine Drainage	Acids, metals, radionuclides	15,000 active coal mines (1986) 67,000 inactive coal mines phospate mines Metalic ore mines	Varies by mining type
Production Wells	Organics, inorganics, microorganisms	548,000 oil wells produced approximately 3.1 billion bbls crude oil (1980) Up to 1.2 million abandoned wells 376,000 irrigation wells for 126,000 farms	Oil Wells - nationwide Geothermal wells - primarily CA, NV, ID Water wells - mostly in the Southwest, Central Plains, Idaho, and Florida
Other wells (monitoring and exploration)	Organics, inorganics, microorganisms radionuclides	Unknown	Unknown

Source: U.S. Environmental Protection Agency, Office of Ground-Water Protection.
EPA Activities Related to Ground-Water Contamination, February 1987.

FIGURE II-13

Profile of Chemical Application Sources

SOURCE	POTENTIAL CONTAMINANTS	NUMBER/VOLUME	GEOGRAPHIC DISTRIBUTION
Pesticide Application	Organics - 1,200-1,400 active ingredients Approximately 280 million acre-treatments annually	552 million pounds of active ingredients applied to crops in 1982	17 pesticides confirmed in 23 states (1986) due to normal agricultural application
Fertilizer Applications	Nitrates, phosphates	Fertilizer use has declined from 54 million tons to 42.3 million tons (1980-1983);	Highest fertilizer use in 1981-1982 - CA, IL, IN, IO, TX
Fertilizers in 1981-		1982 contained 11 million tons of nitrogen, 4.8 million tons of phosphates, 5.6 million tons of potash	
Deicing	Salts	9.35 million tons dry salts, and abrasives; 1.78 million gallons liquid salts applied to U.S. highways (1982-1983)	Northeast, Mid-Atlantic, Midwest

Source: U.S. Environmental Protection Agency, Office of Ground-Water Protection.
EPA Activities Related to Ground-Water Contamination, February 1987.

active pesticide ingredients were used on major U.S. crops alone; additional amounts were used in forest lands, recreational settings, and home gardens. Fertilizer usage in the U.S. in 1983 was 42.3 million tons (38 billion kilograms), down from 54 million tons (49 billion kilograms) in 1980, but still a substantial amount. During the 1982-1983 winter, at least 9.35 million tons (8.5 billion kilograms) of dry salts and abrasives and 1.78 million gallons (6.8 million liters) of liquid salts were applied to U.S. highways.[26]

Sources in this category are subject to varying amounts of governmental regulation. The federal government historically has regulated pesticides, but not deicing salts or fertilizers. Under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), EPA must register pesticide products. This authority allows EPA to prohibit pesticides outright or to restrict their use in a number of ways. EPA's restrictions in the past principally were designed to prevent unacceptable levels of dietary exposure. In its registration decisions, EPA increasingly is considering the potential for these pesticides to leach to ground water. The Agency also has been developing an Agricultural Chemicals in Ground-Water Strategy to more effectively use existing statutory authorities to manage both fertilizers and pesticides. State and local authority over these chemical applications in theory is much broader, through land use planning and control. Zoning, for example, can limit the areas approved for agriculture and thus at least partially influence the use of fertilizers and pesticides. Building codes, in turn, can encourage methods of storing road deicing salts that mitigate leaching to the ground water. Few localities in practice utilize their land use authorities for these purposes.

Miscellaneous Sources

Five sources currently fall into this category: irrigation, percolation of atmospheric pollution, ground/surface water interaction, natural leaching, and salt water intrusion (Figure II-14).[27] Information on the geographic distribution of these sources and the potential extent of their impact on ground-water quality is less complete than for the other categories of sources.

Irrigation is probably the most widely studied of the five sources. About 14 percent of all cropland in the U.S. is irrigated, most commonly in the West, Central, and Southern Plains. Common contaminants from irrigation are fertilizers, pesticides, naturally occurring substances (e.g., selenium) and sediment.[28]

FIGURE II-14
Profile of Other Sources

SOURCE	POTENTIAL CONTAMINANTS	NUMBER/VOLUME	GEOGRAPHIC DISTRIBUTION
Irrigation Practices	Fertilizers, pesticides, naturally occurring contaminants (e.g., selenium), sediment	14 percent of cropland is irrigated	West, Central, and South Plains, Arkansas, Florida
Percolation of Atmospheric Pollutants	Sulphur and nitrogen compounds, asbestos, heavy metals	Unknown	Acid rain around Great Lakes, Northeast Distribution of other pollutants varies
Ground Water/Surface Water Interaction	Organics, inorganics, microorganisms, radionculides	Unknown	Unknown
Natural Leaching	Inorganics, radionuclides	Unknown	Unknown, very localized
Salt Water Intrusion	Inorganics, radionuclides	Unknown	Predominantly coastal areas -- CA, TX, LA, FL, NY, Southwest, Central Plains

Source: U.S. Environmental Protection Agency, Office of Ground-Water Protection. EPA Activities Related to Ground-Water Contamination, February 1987.

A less well-studied source is salt-water intrusion which is the migration of saline water into fresh water aquifers. Known to occur predominantly in the coastal areas of the U.S., salt-water intrusion raises the salinity of and introduces inorganics and radionuclides to fresh water aquifers.[29]

Very little is known about the remaining three sources. OTA reports that all four classes of contaminants potentially are associated with ground water/surface water interactions, but provided no information on the extent of the problem or its geographic distribution. Similarly, natural leaching is known to result in levels of radionuclides and inorganics, but based on incomplete information the problem appears to be very localized. Percolation of atmospheric pollutants (i.e., acid rain) as a source of ground-water contamination is virtually unstudied.[30]

This group of sources currently appears to be the least addressed by any level of government. EPA has sponsored some special studies of these sources, but has no regulatory authority. At the state and local level, control of these sources is often closely linked to management of withdrawals.

C. REGIONAL TRENDS

The best indicator of source control priorities in the U.S. is information from the states. In 1986, 52 states and territories submitted data on their ground-water problems and programs as required by section 305(b) of the Clean Water Act.

These reports illustrate some common trends nationwide and also highlight the regional diversity characteristic of the U.S. Collectively, the states and territories identified 16 major sources of ground-water contamination (Figure II-15).[31] Seven of these -- septic systems, underground storage tanks, agricultural activities, on-site landfills, surface impoundments, municipal lagoons, and abandoned waste sites -- were major sources in more than one-half of the states and territories. Twelve of the 16 also were cited as the primary source in one or more states, but none was the leading source in more than approximately one-quarter of the states. The most frequently cited primary source was underground storage tanks.[32]

A closer look at each of these types of sources illustrates the magnitude, diversity, and complexity of ground-water protection in the U.S.

Figure II-15
Major Sources of Ground-Water Contamination Reported by States

SOURCE TYPE	MAJOR SOURCE		PRIMARY SOURCE
	No. States	% States	No. States
SEPTIC TANKS	46	89%	9
UNDERGROUND STORAGE TANKS	43	83%	13
AGRICULTURAL ACTIVITIES	41	79%	6
ON-SITE LANDFILLS	34	65%	5
SURFACE IMPOUNDMENTS	33	64%	2
MUNICIPAL LANDFILLS	32	62%	1
ABANDONED WASTE SITES	29	56%	3
OIL AND GAS BRINE PITS	22	42%	2
SALT WATER INTRUSION	19	37%	4
OTHER LANDFILLS	18	35%	0
ROAD SALTING	16	31%	1
LAND APPLICATION	12	23%	0
REGULATED WASTE SITES	12	23%	1
MINING ACTIVITIES	11	21%	1
UNDERGROUND INJECTION WELLS	9	17%	0
CONSTRUCTION ACTIVITIES	2	4%	0

NOTES

* Four States did not report ground-water contamination sources in their 305(b) submittals.

** Based on a total of 52 States and Territories which reported ground-water contamination sources in thier 305(b) submittals.

*** Five States did not indicate a primary source.

Source: U.S. Environmental Protection Agency, Office of Ground-Water Protection, Ground-Water Quality Chapter of *Section 305(b) Report* , p. 7.

Septic Systems

As of 1980, approximately 23 million domestic septic systems were in operation in the U.S., discharging about 820-1,460 million gallons (3.1-5.6 trillion liters) of wastewater annually.[33] One-half million new systems are installed each year,[34] with 64,000 new ones in Florida alone in 1984.[35] In addition to the domestic systems, approximately 25,000 commercial and industrial ones discharge an estimated 1.2-1.9 billion gallons (4.6-7.2 billion liters) per year.[36]

Several areas of the country, including California, Connecticut, Delaware, Florida, Massachusetts, and New York have attributed their ground-water contamination at least in part to failing septic systems.[37] Among the seven sources of ground-water contamination most frequently reported by the states and territories, septic tanks seem to be of greatest concern. In 1986, 89 percent (46) identified failing septic systems as a major source of contamination.[38] Nine states also reported septic systems as their primary source of ground-water contamination.

Carefully managed systems can be highly beneficial without harming the ground water. Septic systems are relatively low in cost, require minimal maintenance, can recharge the aquifer, and are especially effective in low density areas where public sewers are neither available nor feasible.

The degree of potential risk depends upon local hydrogeology and the size, design, installation, operation, and maintenance of the system. Septic systems also raise issues of cumulative pollution; effluent resulting from system densities of more than 40 per square mile (15 per square kilometer), for instance, have the potential to overload the carrying capacity of the soils. Infrequent inspections and pumping of the tanks can clog the tank and interfere with both the decomposition of wastes and the discharge of the effluent to the drainfield. A special problem is the use of cleaning solvents which not only have been shown to be ineffective but also are harmful to the tank and cause toxic organics to seep into the ground water. A 1980 estimate indicates that up to one-third of the nation's septic systems may be operating improperly.[39]

Underground Storage Tanks

Underground storage tanks have received much attention in the past few years, with Subtitle I of the Resource Conservation and Recovery Act focusing the energies of all levels of government to address the problem. In 1986, 83 percent of the states and territories identified this source as one of their major sources of concern, making it the second most frequently cited source. In addition, about 25 percent reported underground storage tanks to be the primary source of concern.[40]

Underground storage tanks are buried steel or fiberglass tanks and associated piping systems used primarily for fuel storage, but industry in the U.S. also uses them to store a wide range of feedstock materials and other substances such as acids, metals, solvents, chemicals, and wastes. The estimated cumulative capacity of all non-waste tanks in the U.S. is 25 billion gallons (95 billion liters), but the extent to which that capacity is used is unknown.[41] Estimates of the number of steel tanks in the U.S. range from as low as three million to as high as 10 million.[42] Approximately 1.3 million of these are newly regulated and are used to store motor fuels at service stations and non-retail businesses.[43] The remainder are used in a wide variety of other economic activities, including farming operations, trucking operations, and government. About 100,000 fiberglass tanks are also used to store both petroleum and non-petroleum products.[44]

In addition to these non-waste tanks, approximately 2,031 tanks regulated under Subtitle C of the Resource Conservation and Recovery Act are used for the storage and treatment of hazardous wastes.[45] Figures are not available for other tanks operating under surface water discharge permits.

Underground storage tanks, like septic systems, have several benefits. They typically are used for safety reasons, to minimize worker exposure to chemicals, to reduce clutter at the work site, and to limit the potential for fire hazards.

Despite these benefits, underground storage tanks are potentially harmful to ground water. The leading problem is leaks, which may result from corrosion of the tank, improper installation of or damage to the tank, and faulty piping.

Corrosion is thought to be the most significant one. The life expectancy of a steel tank is 15-20 years. About 21 percent (1.0 million of 4.8 million) of the tanks in the U.S. are over 16 years old,[46] suggesting that without corrective action many new incidents of contamination can be expected as the remainder of the tank population ages.

Though a large number of tanks now are leaking and many more have the potential to leak without remedial action, the effects on ground water do not yet seem to be significant. As the result of early detection, an estimated 85 percent of the documented leaks at service stations have not gone beyond the boundaries of the stations. Of the remaining 15 percent, about 10 percent did not substantially affect the underlying aquifer.[47]

Management of underground storage tanks requires a dual approach: one set of measures for existing tanks and another set for newly installed ones. For the former, typical control measures consist of protecting the tank from corrosion, corrective action for detected leaks, and backup containment such as natural or synthetic liners, concrete vaults, or double walls. Even with these measures it may be impossible to prevent leakage. Measures for new tanks include design, construction, and installation standards. In both cases, monitoring is essential for the early detection and abatement of leaks.

Agricultural Activities

Agricultural activities ranked third among the states and territories as a major source of ground-water contamination, with 79 percent (41) identifying it as a major source and six states (Arizona, Arkansas, Connecticut, Hawaii, and Iowa) citing it as a primary source.[48]

Common sources of ground-water contamination associated with agricultural activities include infiltration and runoff from pesticide and fertilizer application to croplands, irrigation, return flows, and infiltration of runoff from animal feedlots and burial sites. These sources are particularly difficult to control because they often are dispersed geographically and represent widely accepted farming practices.

In 1982, the U.S. had approximately 383 million acres (155 million hectares) devoted to crop production, with some crop-growing in all 50 states.[49] This agricultural acreage is heavily dependent upon pesticides and fertilizers and requires significant irrigation as well.

About 50,000 pesticide products encompassing 600 different active ingredients are available for agricultural use in the U.S. Between 1966 and 1986, use of these products increased substantially. Estimated 1984 usage of pesticides to major crops was 1.08 billion pounds (0.5 billion kilograms).[50] While some pesticides were applied to forest lands, recreational areas, and home gardens, about 69-72 percent of the pesticides were used in agriculture.[51]

Fertilizer usage also increased substantially (300 percent) between 1960 and 1980.[52] Since then it has declined 22 percent from 54 million tons (49 billion kilograms) to 42.3 million tons (38 billion kilograms) in 1982-1983.[53] The five states with the highest fertilizer use in 1981-1982 were California, Illinois, Indiana, Iowa, and Texas.[54] Fertilizer application has become a major concern because farmers often apply two or three times the amount crops require, a practice that allows the level of nitrates in the soil to build up and then leach into the ground water.

Irrigation practices intensify the problems associated with pesticide and fertilizer application and also introduce the added problem of salinity. An estimated 14 percent of all cropland in the U.S. is irrigated.[55] Irrigation return flows tend to concentrate salts, fertilizers, and pesticides. Salinity of ground water can increase as a result of evaporation, transpiration, and leaching of saline soils.

Municipal and On-site Landfills

On-site and municipal landfills were reported as major sources of ground-water contamination by 65 percent and 62 percent respectively of the states and territories. Five states identified on-site landfills as their leading ground-water contamination source, and one state identified municipal landfills as the primary source.[56]

Landfills historically have been the most common method for disposing of hazardous and non-hazardous solid waste in the U.S. These land disposal facilities are either municipal or industrial, and industrial landfills can be either at the waste generation site or off site. Municipal landfills handle solid waste products that generally, but not always, are non-hazardous, while industrial facilities typically receive hazardous wastes.

EPA estimated in 1986 that the U.S. has a total of 16,416 off-site landfills, including 9,284 municipal landfills and 3,511 industrial landfills. Included in this total are about 700 hazardous landfills at 136 facilities.[57] In addition to the off-site facilities, there are an estimated 75,000 industrial on-site landfills that may contain hazardous wastes.[58] About 96 percent of all hazardous waste generated in the U.S. is treated and disposed of in these on-site facilities, but EPA estimates that thousands of municipal landfills also may contain hazardous wastes.[59]

Surface Impoundments

In 1986, states and territories reported surface impoundments to be the fifth most significant major source of ground-water contamination. Approximately 64 percent of the states and territories identified surface impoundments as a major source, with two states citing surface impoundments as their primary ground-water contamination source.[60] States with the highest number of non-hazardous surface impoundments are Arkansas, Kansas, Louisianna, New Mexico, Ohio, Oklahoma, Pennsylvania, Texas, and West Virginia.[61]

Surface impoundments are natural depressions or manmade holding areas such as excavations, lagoons, or dikes. Small impoundments, commonly referred to as "pits" are used by industries, municipalities, agricultural operations, and households for special purposes such as waste storage or sludge disposal. Wastewater in impoundments is treated in several ways: chemical coagulation and precipitation, pit adjustment, biological oxidation, separation of susupended solids from liquids, and temperature reductions. Some impoundments lose liquid through evaporation and/or seepage into the soil. Other impoundments discharge their liquid periodically or continuously into streams, lakes, bays, or the ocean.

A 1986 EPA study reported that there are 191,822 surface impoundments in the U.S. Types of impoundments include: 16,232 (8 percent) industrial, 2,426 (1.2 percent) municipal, 17,159 (9 percent) agricultural, 19,813 (10 percent) mining, 125,074 (65 percent) oil and gas and 11,118 (6 percent) other. In addition, there are 3,184 known hazardous waste treatment, storage, or disposal impoundments located at approximately 400 facilities.[62] Four industries -- paper and allied products, chemicals and allied products, petroleum and coal products, and primary metals -- are the major users of impoundments.[63] As the numbers show, however, other widespread uses of impoundments are storage and disposal of municipal sewage sludge, animal feedlot and other farm wastes, oil and gas extraction wastes, utility industry wastes, and cooling water.

Surface impoundments in theory can be managed in a way that is protective of ground water, but in practice they often are not. About 70 percent are located in hydrogeologically vulnerable areas, and approximately one-third are located over aquifers currently serving as sources of drinking water.[64] Liners, which can significantly lower the potential for contamination, historically have been used at relatively few impoundments. Even where liners are in place, leaks can occur from rips, deterioration, or cracks. Assuming a leakage rate of six percent, OTA has estimated that impoundments release approxiimately 1,800 billion gallons (6.8 trillion liters) of liquid wastes each year.[65]

Abandoned Waste Sites

Over one-half of the states and territories identified abandoned waste sites as a major source of ground-water contamination, making it the seventh most frequently cited major source. Three states cited abandoned waste sites as their primary source of ground-water contamination.[66]

Under its Superfund program to cleanup contamination that threatens the public health and the environment, EPA has identified nearly 20,000 sites potentially requiring some corrective action.[67] Based on preliminary investigations and inspections of these sites, close to 900 have been placed on the National Priorities List (NPL) for consideration for cleanup using federal funds.[68] Nearly all states have at least one site on the list with the highest number of sites in NJ (91), NY (57) and Michigan (56).[69] Approximately 75 percent of the sites on the NPL have documented ground-water contamination.[70]

The large numbers of many different types of sources and the varying geographic distribution of these sources means that ground-water contamination problems often are highly localized and require solutions tailored to local hydrogeologic, economic, and institutional characteristics. In theory, numerous management instruments are available to all levels of government for preventing, detecting, and mitigating ground-water contamination. Many of these measures were established for other purposes, however, and government officials gradually are adapting them to the issue of ground-water protection.

III. MANAGEMENT INSTRUMENTS

III. MANAGEMENT INSTRUMENTS

Protection of ground-water resources for future generations requires attention to both ground-water allocation and quality. In the U.S., the approaches to these dual management issues have evolved quite differently. States traditionally have had primary authority in governing ground-water allocation and usage. The federal government manages ground-water supplies and usage for about one-third of U.S. lands, which are publicly owned; and must meet trust responsibilities for appoximately 50 million acres, which are mostly Indian reservations. In the area of protecting ground-water quality, the federal government has begun to take the initiative in forging an intergovernmental partnership.

Most of the policies and programs that specifically address ground-water quality are relatively new and are undergoing considerable change. Existing programs control some but not all of the 33 types of sources identified by OTA. For many of these regulated sources, however, requirements often are not fully protective of ground water since few of the environmental statutes adopted over the past 15 years had ground-water protection as their principal objective.

Escalating public concern over ground-water contamination prompted environmental and health officials to apply existing authorities more explicity for ground-water protection. At the same time, the continuing national debate questioned the adequacy of a rigid application of separate traditional regulatory approaches such as ambient standards and discharge permits given the locally unique combinations of hydrogeological conditions, sources, land use patterns, and institutional capabilities across the country. Concerns have also been voiced that an expanded federal role might erode traditional state and local control over water allocation and land use.

There was a gradual recognition that regardless of the respective roles of each level of government, the U.S. needed to move away from its focus on sources and towards protection of the ground water itself. A first step in this direction was EPA's publication in 1984 of its Ground-Water Protection Strategy. Under that strategy, EPA has strengthened its internal organization for protecting ground water, has promoted the use of a consistent policy for the prevention and cleanup of ground-water contamination, and has begun to address a broader range of sources. At the same time, the Department of Interior (DOI) has continued its efforts to map and characterize the nation's principal aquifers and has stepped up its efforts to help states by providing baseline information needed to create ground-water programs. In many states, ground-water protection for the first time captured the attention of state legislatures and governors, resulting in the adoption of state ground-water protection strategies, enactment of new laws, promulgation of new regulations, and establishment of new ground-water agencies or the reorganization of existing agencies to highlight their new ground-water protection functions.

A second result has been the Congressional enactment of the 1986 amendments to the Safe Drinking Water Act which encourage states to adopt Wellhead Protection Programs. Under these programs, states will delineate wellhead protection areas (WHPAs) around their public water supply wells and adopt whatever combination of financial, regulatory, technical assistance, or educational measures are necessary to prevent and mitigate contamination that may adversely affect human health.

This chapter portrays the range of management instruments currently used or under consideration for ground-water protection in the U.S. These instruments fall into five categories: institutional, legal, regulatory, economic, and other.

A. INSTITUTIONAL INSTRUMENTS

The most common types of institutional instruments include the administrative structure for ground-water protection, the mechanisms for policymaking and coordination, and the participation of the public in decisionmaking. In the U.S., federal, state, and local governments share responsibility for the development and utilization of these instruments.

Administrative Organization

A complex network of federal, state, and local agencies engage in a wide variety of activities designed to promote the protection of ground-water quality. Some of these agencies have had a role in ground-water allocation or protection issues for many years. In other cases, existing agencies only recently have added ground-water protection to their other responsibilities. At the state level, some new agencies have been established to handle the protection of ground water.

States and their localities have the lead responsibility and authority for protecting ground water, a role that reflects historical legal doctrines, land use practices, authorities for the protection of public health, and the lack of overriding federal legislation. Specific functions of the states and localities typically include mapping their ground-water resources, inventorying sources, monitoring ground-water quality, and formulating management strategies to protect drinking water supplies.

The new Wellhead Protection and Sole Source Aquifer Demonstration Programs under the SDWA will provide additional opportunities for states and localities to strengthen their capabilities in these areas.

The federal government will continue to establish health-based standards and formulate control programs for certain contaminants and sources, such as pesticides and landfills, that are of national concern. Other federal functions include research, data collection, and technical and financial assistance to the states in their efforts to build institutional capability and formulate management strategies.

Eleven separate Federal agencies, and often multiple offices within these agencies, have some jurisdiction over ground water (Figure III-1).[1] Each agency has a distinct and separate ground-water role (Figure III-2). Of these agencies, the U.S. Environmental Protection Agency (EPA) has lead responsibility for the quality of the ground water and implements regulatory and research programs designed to protect ground water. Among its various responsibilities, the U.S. Geological Survey (USGS), an agency within the Department of Interior (DOI), has a principal role in providing baseline data on the nation's aquifers and ground-water usage. Other agencies within DOI, as well as the U.S. Department of Agriculture (USDA), have responsibility for protecting land and other natural resources (including ground water) under their domain, and the Department of Defense controls and mitigates potential sources of pollution at defense installations.

Within EPA, ground-water protection has become an integral part of many programs (Figure III-3) originally established to meet other objectives (Figure III-4). For the most part, these programs address one or more discrete sources of ground-water contamination.[2] The Office of Pesticide Programs, for example, is now including ground-water quality considerations into its decisions on old and new pesticide registrations and label requirements. Programs originally established to promote waste recycling and recovery, in order to reduce health risk from dumps, municipal landfills, lagoons, and other wasterepositories, now have a predominant ground-water protection orientation.

The creation of the EPA's Office of Ground-Water Protection (OGWP) in 1984 provided a focal point within the Agency for the many separate, evolving ground-water programs. For the past three years, OGWP has concentrated on providing leadership for the formulation of EPA ground-water policy, for fostering operational coordination within the Agency's regional offices, and for launching programs that address ground water as a resource.[3]

Figure III-1
Federal Agencies with Ground-Water Protection Roles

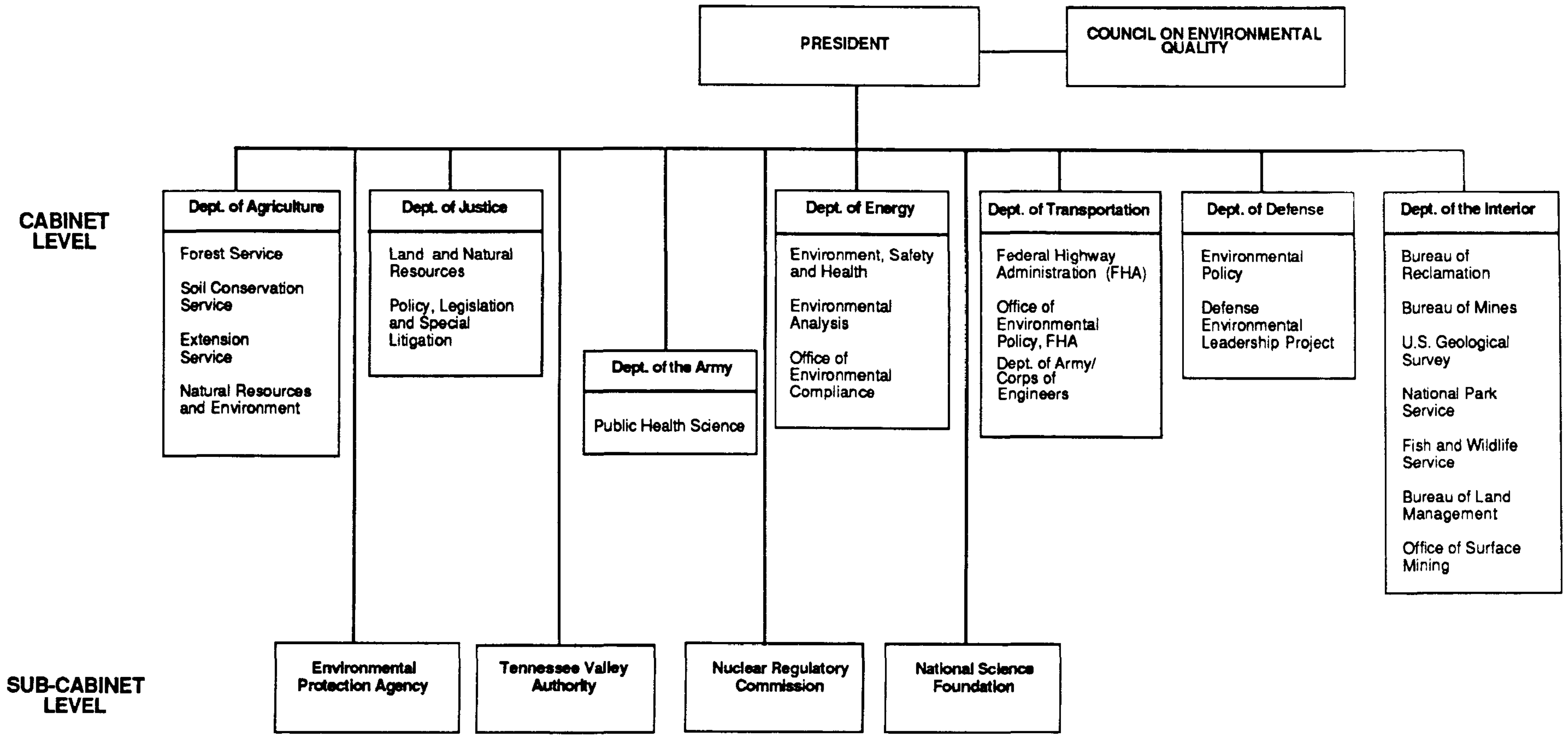


FIGURE III-2
Ground-Water Roles of Selected Federal Agencies

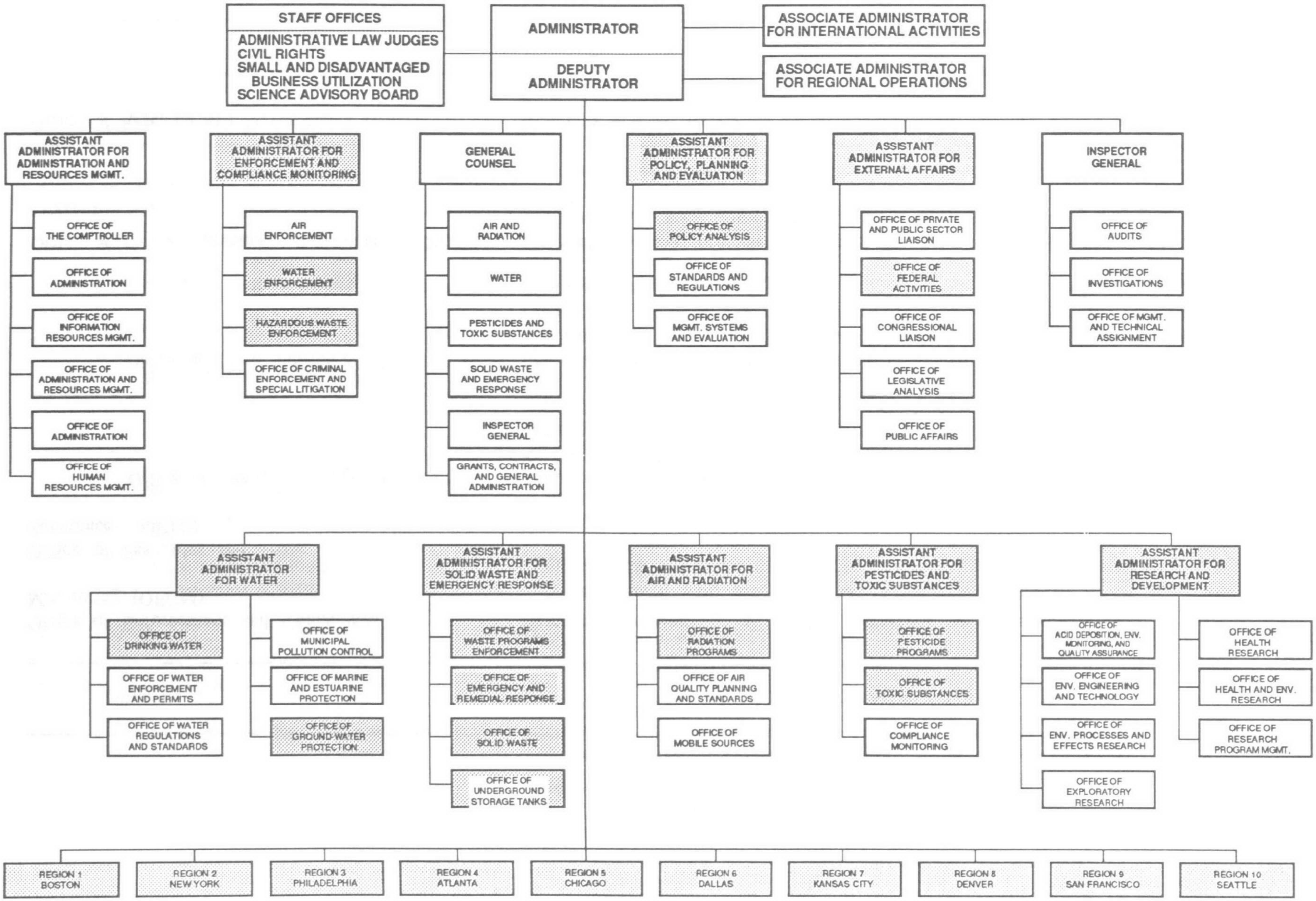
AGENCY	DESCRIPTION OF ACTIVITIES
Department of Agriculture (USDA)	
- Agriculture Research Service	Conducts limited number of research projects related to (1) ground-water recharge, (2) impacts of agricultural activities on ground-water quality.
- Forest Service	Conducts research projects on fate and transport of pesticides (under the National Agricultural Pesticide Impact Assessment Program).
Department of Commerce (DOC) - National Bureau of Standards	Responsible for projects on quality assurance standards used by other federal agencies to monitor analytical performance of laboratories.
Department of Defense (DOD)	Participates in program to identify and evaluate hazardous waste disposal sites on military installations, undertake remedial action (Installation Restoration Program). Provides technical support in certain branches for the Installation Restoration Program, conducts program related research. Develops water quality criteria for certain munitions compounds. With EPA, is working on design, construction, research for CERCLA-designated sites.
Environmental Protection Agency (EPA)	Develops and implements a wide range of source control programs, assesses the quality of drinking water and sets national drinking water standards, conducts research on contaminant movement and health effects as well as treatment technologies.

FIGURE III-2
Ground-Water Roles of Selected Federal Agencies
(Continued)

AGENCY	DESCRIPTION OF ACTIVITIES
Department of Energy (DOE)	Operates programs for identifying and decommissioning contaminated nuclear materials storage and processing facilities, conducting site-specific hydrogeologic investigations.
Department of Housing and Urban Development (HUD)	Conducts environmental assessments for housing projects, takes ground water into account.
Department of the Interior (DOI)	
- Bureau of Land Management	Inventories hazardous waste sites on public lands and manages ground-water resources under these lands.
- National Park Service	Conducts ground-water monitoring studies at national parks.
- U.S. Geological Survey	Collects and analyzes hydrogeologic information, conducts research on hydrogeology, and coordinates federal activities on data gathering.
- Fish and Wildlife Service	Inventories hazardous waste sites for all FWS lands and facilities.
- Bureau of Indian Affairs	Inventories hazardous waste sites on or near Indian reservations.
National Science Foundation (NSF)	Supports research projects and diverse hydrogeology projects. Conducts policy-related research.
Nuclear Regulatory Commission (NRC)	Researches fate and transport of radioactive substances.

Source: Office of Technology Assessment, Protecting the Nation's Groundwater from Contamination (Washington, D.C.: U.S. Congress, Office of Technology Assessment, 1984), p. 72.

Figure III-3
Organization Of U.S. EPA



▨ EPA Offices with Ground-Water Responsibilities

Source: U.S. Environmental Protection Agency

FIGURE III-4
Ground-Water Activities of EPA Offices

OFFICE	DESCRIPTION OF ACTIVITIES
Office of Enforcement and Compliance Monitoring (OECM)	Enforces provisions of all EPA-administered laws.
Office of Pesticides and Toxic Substances (OPTS)	
- Office of Pesticides Programs (OPP)	Regulates the use of pesticides to protect the environment and human health. Restricts use of pesticides that have significant potential to leach to ground water. Participates in special surveys such as the one on pesticides in drinking water and leads the development of the agricultural chemicals in the ground-water strategy.
- Office of Toxic Substances (OTS)	Regulates the use in commerce of toxic chemicals. Examines ways to more effectively use provisions of TSCA to protect ground water from toxic substances. Participates, for instance, in the development of the agricultural chemicals in the ground-water strategy.
Office of Policy, Planning and Evaluation (OPPE)	Undertakes special projects to support EPA's policymaking. For example, it looks at comparative risk from various sources of ground-water contamination, attempts to delineate the dimension of the problem from some unaddressed sources, and provides policy and economic expertise to other offices.
Office of Research and Development (ORD)	Conducts a wide variety of research projects to enhance EPA's understanding of the movement of ground water and contaminants, to improve source/contaminant detection, and to improve source controls.

FIGURE III-4
Ground-Water Activities of EPA Offices
(Continued)

OFFICE	DESCRIPTION OF ACTIVITIES
Office of Solid Waste and Emergency Response (OSWER)	
- Office of Emergency and Remedial Response (OERR)	Implements the Superfund program which encompasses both emergency response and longer term remedial action to releases or threatened releases of hazardous substances that pose an actual or potential threat to human health or the environment, including ground water.
- Office of Solid Waste (OSW)	Regulates a variety of waste management sources of contamination such as landfills, surface impoundments, land application, waste piles under the RCRA. Sets requirements for transporters, generators and treatment, storage and disposal facilities, including ground-water monitoring requirements for facilities.
- Office of Underground Storage Tanks (OUST)	Conducts the new program to prevent ground-water contamination from leaky underground storage tanks.
- Office of Waste Programs Enforcement (OWPE)	Enforces the Superfund and RCRA programs. Inspects RCRA-regulated facilities for compliance with regulatory requirements including those for ground-water monitoring. Ascertains that private parties are fulfilling administrative orders for Superfund-mandated cleanups.
Office of Water (OW)	
- Office of Drinking Water (ODW)	Administers the Underground Injection Control Program, which is designed to protect underground sources of drinking water from contamination from unsound injection wells.

FIGURE III-4
Ground-Water Activities of EPA Offices
(Continued)

OFFICE	DESCRIPTION OF ACTIVITIES
- Office of Drinking Water (ODW) (continued)	Implements the public water supply program under the SDWA, setting and enforcing primary and secondary drinking water standards and water supply monitoring requirements.
- Office of Ground-Water Protection (OGWP)	Carries out the goals of the Ground-Water Protection Strategy, which are: • Building ground-water institutions at the state level • Assessing the problems from unaddressed sources of contamination • Issuing guidelines for EPA decisions affecting ground-water protection and cleanup • Strengthening EPA's organization for ground-water management at the Headquarters and Regional levels and strengthing EPA's cooperation with federal and state governments. Implements two state grant ground-water protection programs established by the SDWAA. These are the Sole Source Aquifer Demonstration Program and the Wellhead Protection Program. Implements grants to states under the Clean Water Act to develop state ground-water protection strategies and adopt measures to control nonpoint sources.
Office of Air and Radiation (OAR)	
- Office of Radiation Programs (ORP)	Participates in investigations of radionuclides and radon in the nation's ground waters and in standard-setting to protect health.

All 50 states have been quite active during the past two years in instituting administrative structures that have explicit responsibility for ground-water protection. A few states, like Arizona, Maine, Georgia, and Oklahoma, have centralized all surface and ground-water quality issues in a single state agency.[4] Others, such as Kansas, concentrate responsibility at the state level, but divide functions among several agencies. Some states have delegated many of their responsibilities to local agencies.[5] Only a small number of states closely coordinate ground-water quantity and quality issues, even when a single agency administers both allocation and protection programs. One exception is Georgia, where functions previously split among the Departments of Mining and Health and the State Water Quality Board are now concentrated in the Environmental Protection Division of the Department of Environmental Protection.[6]

The U.S. has more than 91,000 units of local government, including cities, counties, townships, and special districts. Local governments, by and large, are creatures of the state and have no power in their own right. The extent of state control over localities varies from state to state and even within states acccording to the different forms of local governmental units. Home rule amendments to state constitutions or home rule legislation has authorized some local governments to operate independently to address issues not expressly preempted by state law.

Local governments typically can influence ground-water use and quality through their responsibility for public water supply and their land use and zoning powers. Local government administrative arrangements for managing ground water vary according to the traditional distribution of authority, responsibility, and resources within each state.

Policymaking and Coordination

In the U.S. power and responsibility are shared among the legislative, executive, and judicial branches of government. The President, as chief executive, and the Congress cooperate and compete in the making of national policy. Congress shapes policy in exercising its authorities for adopting laws and marshalling resources through the annual appropriation process. Executive agencies propose policy positions, prepare budgets for Congressional consideration and approval, and interpret and carry out legislation enacted by Congress. The evolution of national policies for ground water has followed this pattern.

Policymaking for ground-water protection in the U.S. is in a period of transition, with Congress and federal agencies examining the issue more closely. Throughout the late 1970s and early

1980s, Congressional hearings and a number of special federal studies, surveys, and investigations attempted to begin to answer basic questions about the extent and causes of contamination and the consequences for human health. During this period, the federal government sought ways to broaden its use of existing legislative authorities and acquired some new ones.

To the unitiated observer, the process of change in the U.S. may seem confusing, and even chaotic, but in fact some consensus is emerging on the key policy issues. Debate continues, of course, on how to solve those issues, but a number of coordinating mechanisms at and between each level of government are providing a forum within which to examine the issues.

Memoranda of Understanding (MOUs) and Interagency Agreements (IAGS) are the principal formal mechanisms available to federal agencies to coordinate policymaking and other activities of mutual interest. In 1985, the EPA and DOI negotiated a two-part MOU establishing areas of cooperation on ground-water protection. One part of the MOU addresses the respective roles of EPA and the USGS in ground-water research and developement, monitoring, and technical assistance. The second part focuses on the responsibilities of EPA and the Bureau of Reclamation in the High Plains Recharge Demonstration Program. EPA and several other agencies also have entered into MOUs to implement provisions of some of EPA's many ground-water related programs. In the Superfund program, for example, EPA has entered into MOUs with the Coast Guard, the Department of Health and Human Services, and the Federal Emergency Management Agency. While these MOUs are not specific to ground-water protection, they cover areas of responsibility that often involve the cleanup of abandoned waste sites that have created a ground-water contamination problem.

Interagency committees and work groups offer another avenue for coordination of policy, research, and other activities. The Federal Interagency Ground-Water Protection Committee is an informal committee comprised of representatives of 11 different departments and agencies with some role in ground-water management and protection. Chaired by EPA's Assistant Administrator for Water, the committee serves as a forum for exchanging information on many ground-water issues.

States in which multiple agencies still have overlapping ground-water protection roles also have instituted coordination mechanisms such as councils, committees, task forces, and working groups. Some of these coordinating entities have been transient, while others have long-term, ongoing functions. In Maryland, for example, a committee with long-term responsibility for implementing the state's completed ground-water protection strategy replaced the temporary task force that developed the strategy. California has established three permanent committees to promote coordination among federal, state, and local agencies; and in Wisconsin, a permanent advisory committee composed of representatives of the Governor's office and several state agencies has far-reaching advisory powers that include budgets, ground-water monitoring, data management, research, and laboratory analysis.[7]

Public Participation

Public involvement in environmental decisionmaking is an important institutional concept in the U.S. Many environmental statutes, including those which address ground-water protection, usually contain provisions for public participation. The Administrative Procedures Act also specifies substantive and procedural requirements for the public's participation in regulatory development. Formal, statutory requirements include governmental notification to the public of pending actions, opportunity for public comment on regulatory or other actions, and public hearings or community meetings. Informal approaches consist of public workshops, community relations or public information programs, and a variety of other communication techniques.

Over the past decade, the public has become increasingly sophisticated in its demand for participation in environmental decisionmaking. EPA's hearings in January 1981 on its ground-water strategy, for instance, attracted almost 900 attendees, 172 witnesses who offered testimony, and written comments from 390 additional individuals and organizations.[8] Implementation of the Safe Drinking Water Act Amendments already has included two major EPA-sponsored workshops; moreover, the legislation itself requires states to adopt a public participation process in planning their new ground-water protection programs.

B. LEGAL INSTRUMENTS

A number of legal instruments play a role in regulating ground-water ownership and usage, as well as the diverse activities that may affect ground-water quality. These include constitutional law, statutes, regulations, executive orders, and enforcement tools such as permits, administrative orders, judicial orders, and citizen suits. In addition to the instruments associated with environmental laws, there are also the common law doctrines of nuisance and torts.

Ownership and Allocation of Ground Water

Two distinct legal doctrines govern water ownership, withdrawal, and usage. The first, found primarily in the 31 eastern states, is based on various interpretations of the rule of reasonable use. This rule basically assumes that the ground water is owned by the owner of the overlying property. One interpretation of "reasonable use" is that this owner may withdraw water for the benefit of the land immediately overlying the aquifer, but not for some distant land. A second variation of "reasonable use" is the correlative rights rule, under which the landowner is entitled to a portion of the ground water that reflects the size of the property in relation to the total land area overlying the aquifer.

The 17 contiguous western states and Alaska, by contrast, operate under the doctrine of prior appropriation. In these states, all natural waters belong to the public or to the state, not to the overlying landowners. States may grant private individuals the right to appropriate water for their own beneficial use. Typically, appropriation is accomplished through permitting. Permit reviewers ascertain that the proposed source of water is unappropriated and that the requested appropriation will not infringe on other water rights or be contrary to the public interest. The withdrawal permit specifies the place and purpose of the ground-water use, the point of diversion, and the facility to be constructed, but does not guarantee the availability of sufficient water. Priorities among competing uses for the same source of water generally are resolved in favor of the user with the earliest appropriation, but a prior appropriation can be set aside when a new proposed use is socially preferred. State statutes typically give preference to domestic and municipal uses, followed by agricultural and industrial use.

Constitutional Framework

In the U.S., constitutions at both the national and state level serve as the fundamental legal instruments, establishing the division of powers among the federal, state, and local levels of government. The U.S. Constitution delegates certain specifically enumerated legislative, executive, and judicial powers to the federal government. In addition, the federal government holds various implied powers, i.e., those powers that may be reasonably inferred from expressly delegated powers. States are given all powers that are not delegated to the national government, except those expressly denied to them. These constitutional principles have had important implications for the management and protection of the nation's ground-water resources.

Although the U.S. Constitution does not explicitly address protection of the environment, it indirectly authorizes the federal government to act in this arena under the constitutional authority Congress has to regulate interstate commerce. Expansively interpreted by the Supreme Court, the federal "commerce clause" has provided the constitutional basis for federal measures to protect the quality of the nation's air and surface water resources. A 1982 Supreme Court decision (Sporhase v. Nebraska, 458 U.S. 941) extended this authority to ground water by confirming that ground water is an article of interstate commerce subject to regulation by Congress.[9]

The authority reserved to the states under the federal constitution is itself governed by state constitutions. Most state constitutions are similar to the U.S. Constitution and do not contain specific provisions for safeguarding the environment in general or ground water in particular. Although a few state constitutions include provisions granting citizens a general right to a healthy environment, the majority of state measures for environmental protection have been based generally on inherent state police powers. That is, the state constitutions confer to the states authority to take actions necessary to protect the public health, safety, and general welfare of its citizens. This broad authority enables states and their political subdivisions (i.e., municipalities and counties) not only to establish police and fire departments but also to enact legislation and create agencies to administer ground-water and other environmental protection programs.

Statutory Instruments

Legislation that protects ground water is found at all three levels of government. At the federal level, there is no single, overriding ground-water statute. Rather, sixteen separate laws address ground water in some way (Figure III-5).[10] Many were not originally written for ground-water protection but over time have been broadly interpreted and expanded to cover this issue.

A number of these federal statutes control specific contaminants and sources of ground-water contamination, while others establish programs to preserve or restore the ground water. In order to implement this legislation, federal agencies develop and promulgate regulations, setting forth their interpretation of the requirements and obligations imposed under each statute. These regulations have the full force and effect of law and are important legal instruments which establish the specific requirements involving the control of private and public activities affecting ground-water quality.

FIGURE III-5
Federal Laws Related to the
Protection of Ground-Water Quality

STATUTES
Atomic Energy Act
Clean Water Act
Coastal Zone Management Act
Comprehensive Environmental Response, Compensation, and Liability Act
Federal Insecticide, Fungicide, and Rodenticide Act
Federal Land Policy and Management Act (and associated mining laws)
Hazardous Materials Transportation Act
National Environmental Policy Act
Reclamation Act
Resource Conservation and Recovery Act
Safe Drinking Water Act
Surface Mining Control and Reclamation Act
Toxic Substances Control Act
Uranium Mill Tailings Radiation Control Act
Water Research and Development Act

Source: Office of Technology Assessment, Protecting the Nation's Groundwater from Contamination (Washington, D.C.: U.S. Congress, Office of Technology Assessment, 1984), p. 65.

In many respects, state legal instruments parallel federal ones in that state laws and regulations provide the primary legal basis for state protection of ground-water resources. Under federalism, though, diversity is the hallmark of state approaches to ground-water protection. Many states have specific legislation that establishes water ownership principles and the attendant rights, obligations, and limitations; and several states have legislation that sets goals for protecting the states' ground waters.

Additionally, like the federal government, states have enacted their own statutes designed to address specific sources of ground-water contamination. For sources that also are regulated under federal law, states typically enact laws that are at least as stringent as federal ones, in order to receive authority from EPA to administer the programs and to qualify for federal financial assistance. When not preempted by federal law, some states have adopted requirements that exceed federal statutory requirements or which address sources that are unregulated by the federal government. These federal and state laws may also be supplemented by local ordinances.

Judicial Instruments

Most federal and state environmental statutes, as well as local ordinances, contain enforcement provisions. These may consist of either or both administrative and judicial remedies. Several of the statutes EPA administers grant the Agency the authority to issue administrative orders requiring compliance, imposing penalties for noncompliance, or specifying remedial measures. If these administrative measures are not effective, or if the violation is sufficiently severe in the first place, EPA also has the option of seeking judicial relief through civil or criminal actions. The outcome of these actions may include judicial orders, under which a court mandates a violator to take specific corrective actions within a specified time frame, pay financial penalties, or even face a jail term.

Yet another judicial instrument authorized by many federal environmental statutes is the citizen suit. Established as a backup for federal enforcement authority, the "citizen enforcement" provisions empower private citizens, environmental groups, and others to bring suit in federal court against alleged violators of federal environmental requirements or even against the governmental agencies administering the laws for failure to carry out their legal responsibilities.

The states have authority under their own constitutions to enforce their own statutes and regulations for ground-water protection, but they often employ a more limited range of administrative and judicial remedies for enforcement. In the past, for example, many state laws did not authorize the use of administrative orders or civil penalties in environmental enforcement cases. During the last decade, a number of states have expanded their enforcement instruments to reflect more closely the federal range of administrative and judicial tools, including recourse to "citizen suits."

In addition to these judicial instruments authorized by statutes, judicial remedies based on traditional principles of American common law are available to both public and private parties. The most common ones are the doctrines of public and private nuisance and the emerging area of toxic tort litigation.

C. REGULATORY INSTRUMENTS

The use of regulatory instruments to protect the quality of ground water is evolving. Most of the instruments used to date were established for other purposes and have been adapted to ground-water protection. They largely deal with the control of specific contaminants or types of sources, although a few are beginning to focus on the overall protection of the ground-water resource. Types of regulatory instruments that are in use or under consideration include standard-setting, source controls, product controls, and land use controls. At the present time, not all of these instruments are used uniformly to address the types of sources described in Chapter II (Figure III-6).

Standard-Setting

Standards either limit the permissible concentrations of a substance in ground water or limit the permissible amount or concentration of a substance to be discharged from a particular source. There are two variations on the first type: a single concentration limit for all ground waters, or variable concentration limits based on the type of water use (e.g., drinking, agricultural, industrial). Most standards are numerical, expressed as parts per million or billion, but sometimes standards are qualitative such as "adequate to support aquatic life."

None of the federal laws described above establish national ground-water quality standards. Under the Safe Drinking Water Act (SDWA), though, EPA establishes standards for public drinking water supplies. As national concern with ground-water contamination has mounted, these drinking water standards have become a surrogate for ground-water standards.

The SDWA establishes two types of national drinking water standards. Primary standards, known as Maximum Contaminant

Figure III-6
Regulatory Instruments

	SOURCE CONTROLS				PRODUCT CONTROLS	LAND USE CONTROLS
SOURCES	PERFORMANCE STANDARDS	TECHNICAL STANDARDS	BEST MANAGEMENT PRACTICES	PROJECT REVIEW		
Category I						
Subsurface percolation	√	√	√	√	√	√
Injection wells (waste)		√				
Injection wells (non-waste)		√				
Land application	√	√	√	√		√
Category II						
Landfills		√		√		√
Open dumps (including illegal dumping)	√					
Residential (or local) disposal	√					
Surface impoundments	√	√		√		√
Waste tailings	√	√		√		√
Waste piles	√	√		√		√
Materials stockpiles			√			√
Graveyards						√
Animal burial						√
Aboveground storage tanks		√				√
Underground storage tanks	√	√				√
Containers		√	√			√
Open burning/detonation sites		√				√
Radioactive disposal sites	√	√		√		√
Category III						
Pipelines		√				√
Materials transport/transfer operations		√	√			√
Category IV						
Irrigation practices			√			
Pesticide applications			√		√	
Fertilizer applications			√			
Animal feeding operations	√		√			√
Deicing salts applications			√			√
Urban runoff			√			
Percolation of atmospheric pollutants						
Mining and mine drainage	√	√	√	√		
Category V						
Production wells		√		√		√
Other wells (non-waste)				√		√
Construction excavation			√	√		√
Category VI						
Ground water-surface water interactions			√			
Natural leaching						
Salt-water intrusion/brackish water upconing			√			

Levels (MCLs), are health amd technology based, include monitoring requirements, and are enforceable. Secondary standards protect the public welfare by providing guidelines on the water's taste, odor, color, and other non-aesthetic characteristics. EPA also issues Health Advisories, which identify potentially hazardous contaminants and contain information on the health effects of those contaminants as well as analytical measurement techniques and control technologies. These Health Advisories are designed to help state officials administer their drinking water programs before MCLs are formally adopted.

For each regulated pollutant, MCLs establish the maximum concentration allowed in tap water provided by public water supply systems. These MCLs are based on ideal health goals, previously described as Recommended Maximum Contaminant Levels (RMCLs), and now called Maximum Contaminant Level Goals (MCLGs). MCLGs are set at levels that present no known or anticipated health effect, with a margin for safety. The purpose of MCLGs is to set a target for revising existing and establishing new MCLs. MCLs are supposed to be set as close as is "feasible" to MCLGs. Factors affecting feasibility include the availability and cost of treatment technology.

Under the SDWA of 1974, EPA was required to issue its MCLs on an interim basis and to revise them periodically. To date, EPA has set interim MCLs for 26 contaminants and a final MCL for one contaminant. EPA also has proposed MCLGs for 31 contaminants, put final MCLGs in place for seven, and has proposed MCLs for eight contaminants. EPA also is considering setting MCLS for radon and uranium and revising its interim MCLs for other radionuclides.[11] Figure III-7 summarizes the status of existing and proposed national drinking water standards. EPA's standard-setting efforts will encompass these as well as additional efforts in order to implement the requirement under the SDWA Amendments to set standards for 83 specified contaminants within three years. The limitation on drinking water standards is that they apply only to public supplies that serve 25 or more individuals and not to supplies from private, residential wells.

At the state level, there has been diverse but not widespread activity in setting ground-water quality goals and standards. This activity generally has taken four forms: establishing narrative ground-water standards, adapting state surface water quality criteria and/or standards to ground water, adopting federal drinking water standards, and adopting drinking water standards for contaminants not yet covered by federal regulations. States that have established standards for ground water have taken different approaches. Some states, such as

FIGURE III-7
Existing and Proposed National Drinking Water Standards

CONTAMINANT CATEGORY	INTERIM MCLS	FINAL MCLS	PROPOSED		FINAL MCLGs
			MCLGs	MCLs	
MICROBIOLOGICAL	Total Coliform		Giardia lamblia		
INORGANICS	Arsenic	Fluoride	Arsenic		
	Barium		Asbestos		
	Cadmium		Barium		
	Chromium		Cadmium		
	Lead		Chromium		
	Mercury		Copper		
	Nitrate/Nitrite		Lead		
	Selenium		Nitrate		
	Silver		Nitrite		
			Selenium		
ORGANICS (SYNTHETIC)	Endrin		Acrylamide		
	Lindane		Alachlor		
	Methoxychlor		Aldicarb, aldicarb sulfoxide, aldicarb sulfone		
	2,4-D		Chlordane		
	2,4,5-TP Silvex		Carbofuran		
	Toxaphene		Dibromochloropropane (DBCP)		
			1,2-Dichloropropane		
			Epichlorhydrin		
			Ethyl Benzene		
			Heptachlor		
			Heptachlorepoxide		
			Pentachlorophenol		
			Polychlorinated Biphenyls (PCBs)		

FIGURE III-7
Existing and Proposed National Drinking Water Standards
(Continued)

CONTAMINANT CATEGORY	INTERIM MCLS	FINAL MCLS	PROPOSED		FINAL MCLGs
			MCLGs	MCLs	
ORGANICS (SYNTHETIC) (Continued)			Styrene Toluene Xylene		
ORGANICS (VOCs)			Chlorobenzene Trans-1,2-dichloro ethylene Cis-1,2-dichloro ethylene	Benzene Carbon Tetrachloride p-Dichlorobenzene 1,2-Dichloroethane 1,1-Dichloroethylene 1,1,1-Tricholoroethane Trichloroethylene Vinyl Chloride	Benzene Carbon Tetrachloride 1,1-Dichloroethylene 1,2-Dichloroethane Trichloroethylene 1,1,1-Trichloroethane Vinyl Cloride
ORGANICS (Other)	4 types of Trihalomethanes				
RADIONUCLIDES	Gross alpha particle activity Beta particle and photon radioactivity from man-made radionuclides Radium-226 Radium-228			EPA is considering MCLS for radon and uranium	

FIGURE III-7
Existing and Proposed National Drinking Water Standards
(Continued)

CONTAMINANT CATEGORY	INTERIM MCLS	FINAL MCLS	PROPOSED		FINAL MCLGs
			MCLGs	MCLs	
Miscellaneous	Sodium monitoring and reporting				
	Monitoring of distribution systems for corrosion and other problems				
Secondary	pH, Chloride, Copper, Foaming Agents, Sulfate, Total Dissolved Solids (Hardness), Zinc, Color, Corrosivity, Iron, Manganese, Odor				

Source: U.S. Environmental Protection Agency, "Protecting Our Drinking Water", EPA Journal, September 1986 (Washington, D.C.: U.S. Environmental Protecion Agency, 1986), pp. 27-28.

Connecticut, have adopted a differential protection policy which establishes variable standards according to the use classification of the ground water. Other states have a policy of either uniformly protecting all ground waters or allowing limited degradation (Figure III-8).[12] Wisconsin has adopted the distinctive but increasingly popular approach of taking enforcement action against sources when ambient monitoring detects contamination at a specified fraction, called a "preventive action level," of the health-based ground-water standard. The intent is to prevent contaminant concentrations from reaching the point at which public health or the environment are threatened.

Discharge standards for the 33 principal types of sources of ground-water contamination are not widely used either.

Most of the standards that do exist are surface water standards limiting the contaminants in effluent from sources in the waste management and commercial/production categories. In addition, some states and localities limit dicharges from large residential or industrial septic systems.

Source Controls

Three types of controls generally are available to limit the contamination a source releases and the potential for that contamination to reach the ground water:

- Technical standards specify design and construction techniques as well as pollution control technologies (i.e., best available control technology)
- Best management practices (BMPs) include the management, operation, and maintenance of a source or facility. Some examples include restrictions on operating hours, limitations on process materials, or requirements for inspection and maintenance
- Project review examines the impacts proposed projects may have on the environment.

The first two types of controls typically are established and enforced through a permitting process.

Technical standards seem to be the most commonly used approach to controlling major sources of ground-water contamination regulated under existing federal and state laws. Federal statutes and regulations govern the siting, design, construction, and closure of underground injection wells, landfills, surface impoundments, and waste piles, while state

FIGURE III-8

State Ground-Water Classification Systems and Standards

STATES	GROUND-WATER CLASSIFICATION SYSTEM Number of Classes	Criteria for Classification	SAMPLE OF GROUND-WATER QUALITY STANDARDS
ALASKA	-	-	13 contaminants
ARIZONA	-	-	Any contaminant that would interfere with current or future uses of ground water
CALIFORNIA	N/A	N/A	Inorganic salts
CONNECTICUT	4	Based on use, quality, land use, and flow system	EPA drinking water standards; include taste, odor, and color
FLORIDA	4	Highest protection for single-source and potable aquifers	Primary and secondary drinking water constituents, MCLs for 8 other organics, and natural background levels for other constituents
HAWAII	2	Fresh water and saline water	N/A
IDAHO	2	Special-resource water--protection against degradation, unless social or economic factors override; potable-water supplies--protection as drinking water without treatment	Primary and secondary drinking water standards

FIGURE III-8
State Ground-Water Classification Systems and Standards
(Continued)

STATES	GROUND-WATER CLASSIFICATION SYSTEM Number of Classes	Criteria for Classification	SAMPLE OF GROUND-WATER QUALITY STANDARDS
ILLINOIS	4	Domestic use, limited use, or general non-domestic use or limited use	N/A
IOWA	5	Based on vulnerability to contamination by considering hydrogeologic characteristics	N/A
KANSAS	3	Fresh, usable, and brine water	Federal drinking water standards, inorganic chemicals
MAINE	2	Suitable for drinking water supplies; suitable for everything else	N/A
MARYLAND	3	N/A	Federal drinking water standards
MASSACHUSETTS	3	Drinking water quality, saline, below drinking-water quality	N/A

FIGURE III-8
State Ground-Water Classification Systems and Standards
(Continued)

STATES	GROUND-WATER CLASSIFICATION SYSTEM Number of Classes	 Criteria for Classification	SAMPLE OF GROUND-WATER QUALITY STANDARDS
MINNESOTA	-	-	National primary and secondary drinking water standards.
MONTANA	4	Based on present and potential beneficial uses	All drinking-water parameters and all substances deleterious to beneficial uses
NEBRASKA	-	-	Federal primary drinking water standards and most of the secondary drinking water standards
NEW JERSEY	4	Total dissolved solids (TDS)	Nutrients, metals, and organics
NEW MEXICO	2	Full protection of ground water with less than 10,000 mg/1 TDS; ground water with more than 10,000 mg/1 TDS not covered by standards	35 numerical standards, plus a generic "toxic pollutant" standard defining acceptable levels of protection for human and animal health
NEW YORK	3	Fresh ground water; saline ground water with chloride concentrations in excess of 1,000 mg/1 or TDS greater than 2,000 mg/1	83 contaminants

FIGURE III-8
State Ground-Water Classification Systems and Standards
(Continued)

STATES	GROUND-WATER CLASSIFICATION SYSTEM Number of Classes	 Criteria for Classification	SAMPLE OF GROUND-WATER QUALITY STANDARDS
NORTH CAROLINA	5	Fresh ground water used as the primary source of drinking water (GA); brackish waters at depths greater than 20 feet below the land surface that recharge surface and ground water (GSA); fresh water at depths less than 20 feet that recharge surface and ground water (GB); brackish waters at less than 20 feet (GSB); contaminated water technically or economically infeasible for upgrading to a higher class (GC)	19 contaminants
OKLAHOMA	N/A	Beneficial uses have been designated for 21 ground-water basins and formations, but standards being developed for each beneficial use	Primary standards, including 10 inorganic chemicals and 5 radiological contaminants and secondary standards

FIGURE III-8
State Ground-Water Classification Systems and Standards
(Continued)

STATES	GROUND-WATER CLASSIFICATION SYSTEM Number of Classes	Criteria for Classification	SAMPLE OF GROUND-WATER QUALITY STANDARDS
TEXAS	N/A	N/A	N/A
UTAH	-	-	Regulations from SDWA.
VERMONT	2	Ground waters that supply or could supply community water	Less stringent than federal drinking-water standards
VIRGIN ISLANDS	4	Ranked categories of use	N/A
WEST VIRGINIA	N/A	N/A	
WYOMING	7	Domestic; agricultural; livestock; aquatic life; life; industry; hydrocarbon and mineral deposits; unsuitable for any use	Maximum 26 contaminants, depending on class, pH, and TDS

Source: The Conservation Foundation, Groundwater Protection (Washington, D.C.: The Conservation Foundation, 1987), pp. 174-175, 180.

and local laws are beginning to establish similar requirements for septic systems and a variety of other sources not yet addressed by federal law. BMPs are less frequently used, partly because they are the hardest to enforce due to the extensive monitoring required.

Project review is limited at the federal and state level, but is the principal tool for source control at the local level. At the federal level, the preparation of Environmental Impact Statemements under the National Environmental Policy Act (NEPA), as well as the review of certain projects under the Sole Source Aquifer program of the Safe Drinking Water Act provide government officials with the opportunity to review the environmental impacts of federally-assisted projects. At the state level, the extent of project review typically depends upon the existence of state environmental impact laws comparable to the federal NEPA. Review at the local level is fairly extensive, largely in connection with the evaluation of site and subdivision plans. Historically, these reviews have focused more on transportation, public safety, air, surface water, and wetlands issues than on ground-water protection.

Product Controls

Product controls are slowly beginning to emerge as a means of protecting ground water. In recent years, for example, a few states and localities have banned or limited the sale and use of septic system cleaning solvents because these products are known to be ineffective, as well as harmful to ground water. At the federal level, EPA is taking a number of steps to restrict chemicals and pesticide products that have significant potential to leach to the ground water.

One step is EPA's development of an Agricultural Chemicals in Ground Water Strategy, establishing a long-term framework for the control of fertilizers and pesticides. As part of its strategy development, EPA is examining how to better employ its current statutory authorities under the Federal Insecticide, Fungicide, and Rodenticide Act, the Toxic Substances Control Act, Superfund, and the Safe Drinking Water Act to protect the quality of ground water. At the same time, both the pesticide and toxic substance control programs have begun to incorporate ground-water considerations into their decisions on registering chemical and pesticide products. Other controls include improved pesticide product labels, providing users with more explicit directions on how to safeguard the ground water, and limiting use to certified applicators.

Land Use Controls

Patterns of land use have significant implications for the long-term use of ground water. New growth and development increase the rate of ground-water withdrawals and the likelihood of substances leaching into the ground water. State and local governments are beginning to more fully appreciate the relationships between land use and ground-water quality, but to date only a few have adapted traditional land use instruments for ground-water protection.

Typical land use instruments are eminent domain, comprehensive planning, zoning, land acquisition, easements, and subdivision regulations. Eminent domain is the governmental power to acquire land needed for public purposes upon payment of reasonable compensation to the owner. Comprehensive planning is a process local governments use to direct future growth in an orderly fashion, and zoning establishes districts in which specified land uses are permitted, subject to various conditions. Land acquisition is the purchase of fee simple title to a legally delineated parcel of land, and easements are legal agreements between property owners or between a property owner and a public agency. An easement may grant access to someone other than the property owner or may restrict the use of the property. Subdivision regulations complement zoning ordinances by specifying requirements that developers must meet in order to utilize their land. These requirements may include proper arrangment of streets, adequate open space, and control of population densities.

In combination, these instruments can promote ground-water protection by restricting activities within sensitive areas. Of these techniques, zoning is probably the one most easily adapted to, although still rarely used for, ground-water protection. Zoning techniques may include reducing development densities to prevent intensive use over recharge areas, thereby indirectly limiting the density of septic system discharges in a given area and employing zoning overlay districts to establish protective zones around recharge areas and well heads[13]. Presently 12 states and localities have adopted protective zones around well heads (Figure III-9),[13] and many more are likely to establish them under EPA's new Wellhead Protection Program. The various methods that can be used to delineate these protective zones largely reflect each area's unique combination of hydrogeological characteristics, potential sources of contamination, and the institutional capabilities to manage such sources.

There are a small but growing number of examples of the use of other land use tools for ground-water protection (Figure III-10).[14] One that is particularly innovative is

FIGURE III-9
Examples of Land Use Controls
for Ground-Water Protection

LOCALE	INSTRUMENT	DESCRIPTION
Southampton Township, Long Island, New York	Required minimum lot size	Five-acre lots are required for development on 25,000 acres of the Pine Barrens to protect ground-water quality.
Brookhaven, Long Island, New York	Rezoning	Large portion of industrial land rezoned to residential use, which is less intense, to protect ground-water quality.
Pinelands, New Jersey	Restrictions on density of septic systems	Septic drain fields must meet certain specifications so as to limit nitrogen loadings.
Barnstable, Massachusetts	Zoning overlay district	District consists of zones of contribution to existing and future supply wells because the area relies solely on ground water to meet its needs.
Austin, Texas	Protective zones around recharge areas	Separate ordinances created three zones: the critical water quality zone, the buffer zone, and the upland zone to protect the watersheds in the Edwards Aquifer recharge area.

Source: U.S. Environmental Protection Agency, Office of Ground-Water Protection, Background Information on Sole Source Aquifer and Wellhead Protection Program Development (Washington, D.C.: U.S. Environmental Protection Agency, 1986), pp. 2-30, 2-39, 2-47. Frank DiNovo and Martin Jaffe, Local Ground-Water Proteciton Midwest Region (Chicago: American Planning Association, 1984), p.110.

FIGURE III-10
Protective Ground-Water Zones

STATE/LOCALITY	ZONING FOR GROUND-WATER PROTECTION
CONNECTICUT	Geologic/geomorphic mapping
FLORIDA	Calculated fixed radii
- Dade County	10, 30, and 210 day travel times or a 1-foot drawdown
- Broward County	10, 30, and 210 day travel times or a 1-foot drawdown
- Palm Beach County	30, 210, and 500 day travel times or a 1-foot drawdown
ILLINOIS	1000 feet fixed ring
MASSACHUSETTS	Geologic/geomorphic mapping
- Cape Cod	Uniform flow approach and subregional flow system
- Duxbury	Uniform flow approach and aquifer boundaries
- Edgartown	Uniform flow approach and aquifer boundaries
NEBRASKA	Arbitrary fixed radii
VERMONT	Geologic/geomorphic mapping

Source: U.S. Environmental Protection Agency, Office of Ground-Water Protection, Workshop on Guidance for the Wellhead Protection and Sole Source Aquifer Demonstration Programs: Hydrogeologic Criteria (Washington, D.C.: U.S. Environmental Protection Agency, 1987), p. IV-2.

Massachusett's Aquifer Land Aquisition program, in which the state established a fund to assist localities in the purchase of land to protect aquifers. Massachusetts requires localities to establish ground-water protection zones and submit applications to obtain grants for land purchase funds. The State establishes funding priorities according to the value and use of the resource, cost-effectiveness of the proposed project, and degree of resource protection proposed by an applicant.

D. ECONOMIC INSTRUMENTS

Economic instruments have the potential to protect ground water in three ways. They can provide disincentives for noncompliance with source-specific controls. Conversely, they can serve as incentives for completely replacing or at least minimizing the controlled activity. Finally, economic instruments can help finance ground-water protection programs.

Examples of common economic instruments include financial penalties, disposal fees or taxes, financial responsibility requirements, special taxes, and grants. Economic instruments largely are used as part of the overall regulatory scheme for controlling major sources of contamination, such as injection wells, landfills, lagoons, and abandoned waste sites. Originally established to achieve objectives other than ground-water protection, they are slowly being adapted for this new purpose.

Financial Penalties

All major federal and state environmental statutes set financial penalties for failure to comply with specified statutory requirements. These fines typically are intended to discourage the lack of compliance with source or contaminant controls or to compel corrective action. Although the specific penalties vary from statute to statute, there are some common characteristics. Typically, fines are assessed for each day of each violation. The statute may establish a specific amount or a range of the fine, with some laws establishing administrative or judicial discretion in tailoring the penalty according to the seriousness of the violation and the extent of good faith efforts to comply with regulatory requirements.

Penalities can be civil or criminal. Criminal penalties are far more strigent than civil fines. Under the Resource Conservation and Recovery Act (RCRA), for example, an administrative compliance order may set a civil penalty of $25,000 per violation, per day. Failure to comply with the terms of the administrative order can result in an additional

$25,000 fine. Criminal penalties, on the other hand, are up to $50,000 per day for knowingly violating the law and $250,000 for knowingly endangering public health and the environment.

State Disposal Taxes

As of 1984, at least 11 states required direct taxes or fees on hazardous wastes either at the point of generation or disposal (Figure III-11). Commonly referred to as waste-end taxes, a principal objective is to provide industry with an economic incentive to use waste management practices such as recycling and incineration that are more environmentally desirable than land disposal, which has a high potential for contaminating the ground water.[15]

Financial Responsibility

Some federal environmental laws require owners and operators of certain regulated facilities to demonstrate that they have sufficient financial resources to operate their facilities properly and to pay for the costs of proper closure and post-closure maintenance. Provisions requiring financial responsibility are in the SDWA, RCRA, and the Surface Mining and Reclamation Act.

Although these requirements vary somewhat among statutes, generally the regulated entity has a number of options for demonstrating financial responsibility. Owners and operators of active hazardous waste managment facilities regulated under RCRA must have sufficient insurance to cover both sudden and non-sudden releases of contaminants. Closure and post-closure requirements can be met through letters of credit, escrow accounts, surety bonds, and financial worth tests.

Trust Fund Taxation

Both the Superfund and UST programs utilize special taxes to finance trust funds that are used to prevent or mitigate releases of hazardous substances that threaten the environment or public health. The original Superfund law established a $1.6 billion trust fund financed largely through a tax on petroleum and 42 chemicals used commercially. Reauthorization of the fund through the Superfund Amendments and Reauthorization Act (SARA) of 1986 expands the trust fund to $8.5 billion and restructures the taxation scheme. In addition to taxes on chemical feedstocks, a new broad-based environmental tax on corporations and an increased tax on petroleum help finance the trust fund. Additional sources of funds are Congressional appropriations, interest, and the federal government's recovery of cleanup costs from private responsible parties.

FIGURE III-11
Sample of State Waste-End Tax Systems

STATE	TAX DESCRIPTION	PURPOSE OF TAX
CONNECTICUT	Tax on waste generators.	Raise revenue for the Superfund match and hazardous waste cleanup.
OHIO	Tax on commercial disposal facilities. Only land disposal is taxed.	Fund the state's hazardous waste regulatory program.
ILLINOIS	Tax on commercial disposal facilities. Specified hazardous wastes are exempt.	Raise revenue to fund the cleanup of hazardous waste sites.
FLORIDA	Tax on offsite disposing generators. Disposal facilities, government facilities, and recyclers are exempt.	Match federal Superfund.
KENTUCKY	Tax on generators shifted in 1984 to a tax on disposal facilities.	Raise revenue for hazardous waste cleanup.
SOUTH CAROLINA	Tax on generators who dispose of waste by land disposal.	Raise revenue for cleanup of uncontrolled hazardous waste sites.
MINNESOTA	Tax on generators. Small quantity generators can be exempted.	Raise revenue to operate the state's hazardous waste regulatory program.

FIGURE III-11
Sample of State Waste-End Tax Systems
(Continued)

STATE	TAX DESCRIPTION	PURPOSE OF TAX
MISSOURI	Four separate taxes on:	
	- Generators producing more than 10 tons of hazardous waste a year	Fund administrative costs of the state's hazardous waste program.
	- The state's only commercial landfill	Same as above.
	- Landfill wastes over 10 tons	Raise revenue to clean up inactive hazardous waste sites.
	- Each person employed by a generator.	Same as above.

Source: U.S. General Accounting Office, State Experience with Taxes on Generators or Disposers of Hazardous Waste (Washington, D.C.: U.S. General Accounting Office, 1984), pp. 47-49.

Financing of the Leaking Underground Storage Tank Trust Fund under Subtitle I of RCRA is completely different. The $500-millon UST Trust Fund will rely on a tax of 1/10 of one cent on certain petroleum products, primarily motor fuels.

Federal Grants

Many of the major environmental laws EPA administers have contained provisions for federal grants to states. Typically, these grants have been designed to assist states in financing new treatment facilities, such as sewage treatment plants, or new environmental programs. At the present time, federal laws provide authorization for three different and distinct ground-water grant programs. Under section 106 of the Clean Water Act, EPA has awarded nearly $20 million to states and territories to assist them in devising ground-water protection straegies that would guide all future ground-water protection efforts. The 1987 amendments to the Clean Water Act also establish ground-water grants for non-point sources. Two grant programs under the Safe Drinking Water Act are specifically oriented toward comprehensive protection of ground-water resources. Under the first, EPA will share with states the cost of developing and implementing programs to establish and manage wellhead protection areas. The second will share with eligible applicants the financing of demonstration projects to protect the ground-water resources of Critical Aquifer Protection Areas (CAPAs) within approved Sole Source Aquifers.

E. OTHER INSTRUMENTS

A variety of other instruments are used by federal and state governments to protect ground water. These instruments include ground-water classification, data collection and management, monitoring, and research and development.

Ground-Water Classification

In 1984, EPA issued the Ground-Water Protection Strategy, setting out the Agency's plans for enhancing ground-water protection efforts. A central feature of the strategy is a policy framework for Agency programs which accords differing levels of protection to ground water based on its use, value to society, and vulnerability to contamination. The strategy divides ground water into three classes:

- Class I: Special Ground Waters are those that are highly vulnerable to contamination because of the hydrogeological characteristics of the areas under which they occur and are also characterized by either of the following two factors: irreplaceable, in that no reasonable alternative of drinking water is available to substantial populations; or ecologically vital, in that the aquifer provides the base flow for a particularily sensitive ecological system that, if polluted, would destroy a unique habitat.

- Class II: Current and Potential Sources of Drinking Water and Waters Having Other Beneficial Uses are all other ground waters that are currently used or are potentially available for drinking water or other beneficial use.

- Class III: Ground Waters Not Considered Potential Sources of Drinking Water and of Limited Beneficial Use are ground waters that are heavily saline, with Total Dissolved Solids (TDS) levels over 10,000 mg/L, or are otherwise contaminated beyond levels that allow cleanup using methods reasonably employed in public water treatment. These ground waters also must not migrate to Class I or II ground waters or have a discharge to surface water that could cause degradation.[16]

In December 1986, EPA issued Draft Guidelines for Ground-Water Classification Under the EPA Ground-Water Protection Strategy to implement its differential protection policy[17]. These draft Guidelines further define the classes, concepts, and key terms related to the classification system outlined in the strategy and describe the procedures and information needs for classifying ground water. The guidelines are intended for use by EPA in its national programs. Over the next six months specific implementation policies will evolve, but some programs already have adopted classification. Under Superfund, for example, classification contributes to the designation of sites for the National Priorities List for site cleanup and the formulation of cleanup policies.

Monitoring and Data Management

Several federal and state agencies monitor ground water. The monitoring may include sampling of the ground water, tap water, or releases from a source. Supplemental data often include information about the number, types, and location of sources.

USGS has the primary responsibility for collecting data about the quality of water. The major part of this work is carried out by ground-water investigations in the Federal-State Cooperative Program. In 1982, USGS also began a national program to study toxic wastes and their behavior and fate in aquifer systems. The data collection carried out for this program is designed to examine the relationship between ground-water quality and land use.

Other federal efforts have consisted of national surveys of contaminants drinking water supplies or sources. These surveys help EPA decide what regulations to develop and what specific measures to adopt. To support the adoption of national drinking water standards, for example, EPA has conducted five surveys on the quality of drinking water supplies that use ground-water sources. At the present time, surveys on radionuclides and pesticides are still in progress. Under RCRA and Superfund, EPA together with the states have identified the number, location, and contamination potential of open dumps, surface impoundments, and hazardous waste sites.

At least eight separate federal statutes require ground-water monitoring for specific sources (Figure III-12).[18] Thirty-eight states monitor ground-water quality or are developing monitoring programs. Some localities, too, are sponsoring or undertaking monitoring with the help of USGS. States are required to monitor public drinking water supplies under the SDWA so that drinking water standards are met. Forty-six states conduct inventories of potential sources of contaminants, and forty-nine states monitor sources for potential contamination.

In 1985, EPA formulated a national <u>Ground-Water Monitoring Strategy</u> designed to coordinate many of these disparate monitoring efforts. It supports the goals of the Agency's <u>Ground-Water Protection Stragety</u> and contains seven monitoring objectives and an implementation plan.[19]

Research and Development

At least 26 federal offices are involved in research and development (R&D) on ground water (Figure III-13).[20] The most extensive R&D activity is undertaken by EPA's Office of Research and Development (ORD). In a 1986 survey of EPA ground-water activities, ORD reported projects that addressed specific types of contaminant sources as well as general scientific support. Examples of projects include the application of geophysical and remote sensing methods to detect sources of contamination, assessment and development of improved techniques for prevention and cleanup of contamination, and development of models to predict movement of ground water and contaminants.

Resource Characterization

Aquifer mapping and assessment are two well-established activities. For many years, the primary objective of these

FIGURE III-12
Ground-Water Monitoring Provisions of Federal Statutes

STATUTE	MONITORING OBJECTIVES	GROUND -WATER MONITORING PROVISIONS
Atomic Energy Act (AEA)	Obtain background water quality data and evaluate ground-water contamination.	Monitoring for low-level radioactive disposal sites. Facility licenses must specify monitoring requirements for the source.
	Confirm geotechnical and design parameters and ensure that design of geologic repositories accommodates actual field conditions.	Conduct monitoring related to development of geologic repositories.
	Characterize contamination and select and review corrective measures.	DOE may conduct monitoring on remedial actions at storage and disposal facilities for radioactive substances.
Clean Water Act (CWA)		
- Sections 201 and 405	Evaluate ground-water contamination. plant by products.	Monitoring for land application of sewage treatment
- Section 208	Characterize contamination and select and review corrective measures.	No requirements established. Some ongoing monitoring of agricultural practices.
Coastal Zone Management Act (CZMA)		No source regulations authorized

FIGURE III-12
Ground-Water Monitoring Provisions of Federal Statutes
(Continued)

STATUTE	MONITORING OBJECTIVES	GROUND-WATER MONITORING PROVISIONS
Comprehensive Environmental Response, Compensation, and Liability Act	Characterize a contamination problem.	Monitoring by EPA and States as necessary for responding to hazardous substances releases.
Federal Insecticide, Fungicide, and Rodenticide Act - Section 3	Characterize a contamination problem.	No monitoring required for pesticide users. EPA may monitor contamination.
Federal Land Policy and Management Act (and Associated Mining Laws)	Obtain background water quality data.	Monitoring for geothermal recovery operations on federal lands at least one year prior to production. Monitoring for mineral operations on federal lands not specified. Bureau of Land Management may require monitoring.
Hazardous Liquid Pipeline Safety Act		No monitoring provisions.
Hazardous Materials Transportation Act		No monitoring provisions.
National Environmental Policy Act (NEPA)		No provisions for development of source regulations.

FIGURE III-12
Ground-Water Monitoring Provisions of Federal Statutes
(Continued)

STATUTE	MONITORING OBJECTIVES	GROUND-WATER MONITORING PROVISIONS
Reclamation Act		No explicit requirements; monitoring may be conducted as part of water supply development projects.
Resource Conservation and Recovery Act (RCRA)		Monitoring specified for all hazardous wastes land disposal facilities.
- Subtitle C	Obtain background water quality data and evaluate ground-water contamination.	_Interim Status_ monitoring required until receipt of final permit. Owner/ operator can waive monitoring requirements if a qualified geologist/engineer determines low potential for waste migration.
	Obtain background water quality data, determine ground-water contamination, determine compliance with standards, evaluate corrective action measures.	Fully permitted facilities must have a program for: - detection monitoring - compliance monitoring - corrective action monitoring. Exemptions may be granted in low-risk situations.
- Subtitle D		State solid waste programs may require monitoring. Federal govt. recommends State programs require monitoring.

FIGURE III-12
Ground-Water Monitoring Provisions of Federal Statutes
(Continued)

STATUTE	MONITORING OBJECTIVES	GROUND-WATER MONITORING PROVISIONS
Safe Drinking Water Act (SDWA) - Part C (Underground Injection Control)	Evaluate ground-water contamination.	Monitoring may be specified for - injection wells used for in-situ or solution mineral mining where injection is into a formation containing < 10,000 mg/1 TDS. - wells injecting beneath the deepest underground sources of drinking water.
Surface Mining Control and Reclamation Act (SMCRA)	Obtain background water quality data and evaluate ground-water contamination.	Monitoring is specified for surface and underground coal mining operations. Monitoring of a particular water-bearing stratum may be waived if it is determined that the stratum is not part of the project's cumulative impact area.
Toxic Substance Control Act (TSCA) - Section 6	Obtain background water quality data.	Monitoring is required prior to commencement of disposal operations for PCBs.

FIGURE III-12
Ground-Water Monitoring Provisions of Federal Statutes
(Continued)

STATUTE	MONITORING OBJECTIVES	GROUND-WATER MONITORING PROVISIONS
Uranium Mill Tailings Radiation Control Act (UMTRCA)	Obtain background water quality data, evaluate ground-water contamination, determine compliance, evaluate corrective action measures.	Requirements, for the most part, are similar to RCRA Subtitle C.
Water Research and Development Act	Obtain background water quality data, characterize contamination.	Optional monitoring of inactive sites to determine contamination problems and select remedial actions. No provisions for development of source regulations.

Source: Office of Technology Assessment, Protecting the Nation's Groundwater From Contamination (Washington, D.C.: U.S. Congress, Office of Technology Assessment, 1984), pp. 156-158.

FIGURE III-13
Federal Ground-Water Quality Research and Development[a]

	Categories of groundwater quality R&D[b]									
Federal organization	1	2	3	4	5	6	7	8	9	10
National Science Foundation			X		X				X	
Department of Agriculture										
Agricultural Research Services			X			X				
Forest Service			X							
Soil Conservation Service					X	X			X	
Department of Commerce										
National Bureau of Standards	X									
Department of Defense										
Army Corps of Engineers		X			X	X			X	X
Army Medical Bioengineering R&D Laboratory	X									
Army Toxic and Hazardous Materials Agency	X								X	
Department of Energy		X								
Department of Interior										
Bureau of Indian Affairs					X					
Bureau of Land Management					X					
Bureau of Reclamation					X	X				
Fish and Wildlife Service					X					
Geological Survey		X	X	X	X	X	X			
National Park Service				X	X					
Office of Surface Mining					X		X			
Office of Water Policy		X	X					X	X	
Environmental Protection Agency										
Environmental Monitoring Systems Laboratory	X		X							
R.S. Kerr Environmental Research Laboratory			X							
Environmental Research Laboratory			X							
Office of Pesticide Programs			X							
Office of Radiation Programs	X				X					
Office of Research and Development		X	X		X				X	X
Office of Solid Waste					X					
Office of Water								X		
Nuclear Regulatory Commission		X	X							

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[a] The listing is not exhaustive but covers principal programs and activities related to groundwater quality R&D. Examples of other Federal R&D activities omitted here address quantity estimates, use patterns, source inventories, recharge information exchange, socioeconomic effects of alternavie supples, and environmental effect of contamination.

[b] Key for categories of groundwater research and development:

1 - Standards certification, quality assurance, and water quality criteria.
2 - Hydrogeologic investigations and dynamics of groundwater flow.
3 - Subsurface fate and transport of contaminants.
4 - Background monitoring of groundwater quality.
5 - Detection of groundwater contamination from various sources.
6 - Salt-water intrusion and salinity problems.
7 - Surface water-groundwater interactions.
8 - Control of groundwater contamination from various sources.
9 - Treatment technologies.
10 - Evaluation of alternatives.

Source: Office of Technology Assessment, Protecting the Nation's Groundwater from Contamination (Washington, D.C.: U.S. Congress, Office of Technology Assessment, 1984), p. 85.

efforts was to characterize the quantity of ground water available nationwide as well as in particular regions. Recently, ground-water characterization activities have emphasized the definition of regional ground-water systems.

The USGS has lead responsibility for characterizing all of the nation's surface and ground-water resources. These studies range from broad regional studies and national overviews to site-specific investigations. In addition to the national scale efforts of USGS, there are special federal programs and projects to conduct region or site-specific assessments of ground-water resources. One example is the effort to characterize the Ogallala aquifer that underlies eight states in the High Plains region. Other efforts include site-specific ground-water assessments under the RCRA and Superfund programs.

The states, too, have undertaken some resource characterization activity. A recent EPA analysis of state progress in building ground-water programs shows that most of the states and territories have undertaken a variety of activities related to resource characterization. These activities have included mapping aquifers and their recharge areas, preparing detailed reports of state ground-water resources, and conducting detailed site assessments.

The U.S. clearly has an extensive array of management measures it can bring to bear on the complicated task of ground-water protection, although many of these measures were not developed for that purpose. Consequently, policymakers and other government officials face a major challenge in adapting these instruments and weaving them together in a way that promotes some national consistency while accommodating the vastly different needs of the 50 states and their local governments.

IV. MANAGEMENT PROBLEMS

IV. MANAGEMENT PROBLEMS

Ground-water protection is an exceptionally complex and challenging environmental issue in the U.S. The diversity of hydrogeologic settings, land uses, and institutional capabilities nationwide complicates efforts to ascertain the extent and severity of ground-water contamination. Varying institutional capabilities makes it difficult to fashion effective ground-water protection measures. The fact that ground-water policies have been shaped by different levels of government based on statutes not necessarily passed with ground water in mind further complicates the picture.

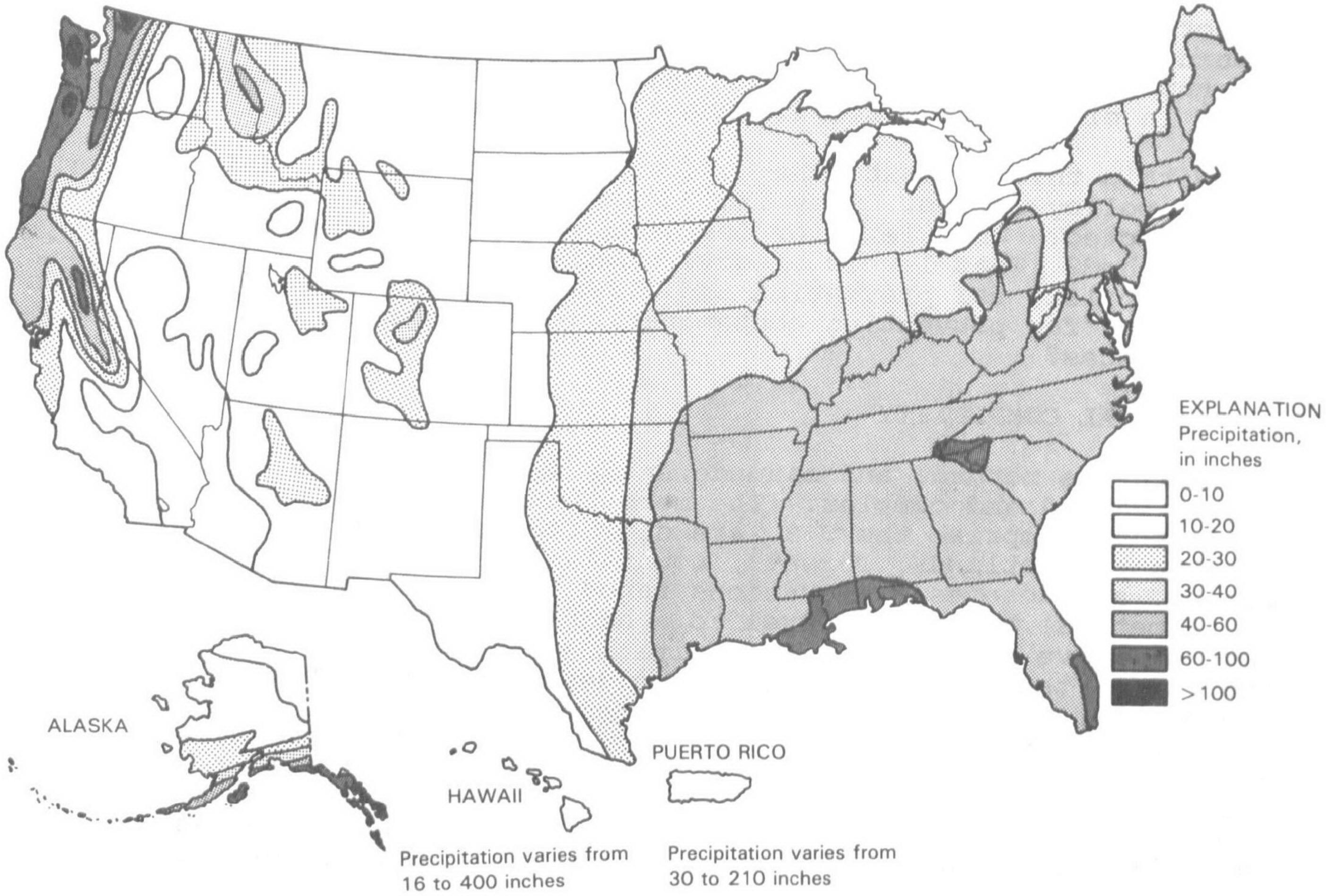
Within this context, the U.S. is debating several basic public policy issues. They include: what ground water should be protected? What level or levels of protection should be established? What levels of government should assume responsibility for prevention and cleanup, and finally, who should pay for preventing contamination or mitigating its consequences?

A. SPATIAL COMPLEXITY

Both the natural and manmade environments in the U.S. are highly varied and complex. The more than three million square miles that comprise the U.S. are characterized by coastal and non-coastal wetlands, forests, mountains and river valleys, plains, and deserts. Elevations range from a low of 281.9 feet (85.9 meters) below sea level to a high of 20,320 feet (6,193.5 meters) above sea level. Precipitation varies annually, ranging from a few tenths of an inch in the desert areas in the southwest to 400 inches (1016 centimeters) per year in some locations in Hawaii (Figure IV-1).[1] Accompanying this varied topography and climate are diverse and abundant natural resources. Timber, fertile soil, water, and a wide array of minerals have shaped a complex economic system that encompasses agriculture, mining, manufacturing, and a variety of services.

Ground-water resources and land use patterns are highly variable and closely linked. While most of the U.S. population resides in metropolitan areas, most of the nation's land area remains rural in nature, with some areas of the country comprising an intricate web of urban and non-urban land uses. These use patterns determine the types and numbers of potential sources of contamination and the population at risk from incidents of ground-water contamination. Hydrogeologic characteristics in turn determine the likelihood of source discharges contaminating an aquifer. The greater the complexity and variability of ground-water characteristics and land use

FIGURE IV-1
Average Annual Precipitation in the
United States and Puerto Rico



Precipitation varies from 16 to 400 inches

Precipitation varies from 30 to 210 inches

Source: U.S. Geological Survey, National Water Summary 1983--Hydrologic Events and Issues, USGS Water-Supply Paper 2250 (Reston, Va.: U.S. Geological Survey, 1984), p. 14.

activities in a given jurisdiction, the more difficult it is to develop effective protection programs. Shaping a national public policy or approach that is suitable in all or even the great majority of situations is even more difficult.

B. LACK OF INFORMATION

Relatively little is known about ground-water properties, since ground-water has only recently emerged as a major environmental issue in the eyes of the public, legislators, and governmental officials and therefore lacks the considerably longer history and experience of the surface water and air programs. Although substantial information exists for some sources of contamination and for some contaminants, the level of knowledge is not uniform for all potential problems either from a national or local perspective.

Gaps in information are likely to continue, because of the difficulty and cost in obtaining data about ground-water properties, sources, contaminants, exposure, and health effects. For example, even establishing a monitoring network to obtain baseline data may be difficult. Identifying appropriate monitoring points is tricky because the pattern and rate of ground-water flows often are not clearly known. Installation of monitoring wells is expensive; and investigations undertaken just to define the dimensions of an existing contamination problem at a single site range from as little as $25,000 to in excess of $500,000, depending upon the complexity of conditions at the site. Laboratory analysis of a single sample from a single well costs about $500, and with approximately 12,000,000 private wells in the U.S., the total cost of a one-time survey of all of those wells can be close to six billion dollars. It is important, therefore, to identify the most critical information needs so that any investment in improving baseline information is well spent. As a result, decisionmakers are relying and will continue to rely heavily on anecdotal data about the extent of contamination, how to establish priorities, and how to carry out management and control strategies.

C. COPING WITH UNCERTAINTY

Major aspects of uncertainty relate to spatial complexity and lack of knowledge. Like all new programs, it takes time to accumulate knowledge and experience. For ground water, accumulating this knowledge is particularly difficult because ground water is a more complex medium, is highly variable from place to place, and is inaccessible.

Another major uncertainty is the future direction of public policies in the U.S. for the protection of ground-water resources. Central questions are the resource to be protected, the appropriate level of protection, the role of government, and the financing of the prevention and remediation of ground-water contamination. The accepted approach to answering these questions has been very different for ground water than for surface water and air quality. For example, the surface water and air programs classify media, yet this is a controversial approach for ground-water protection. Under the air program, the federal government sets ambient air quality standards, but no comparable authority exists for ground water. Finally, on these other programs, the federal government has played the lead role for establishing programs which it then delegates back to the states. In contrast, that federal role has not been accepted for ground-water protection because of the close link between protection and ground-water allocation and land use, which are areas of strong state responsibility.

What Is The Resource To Be Protected?

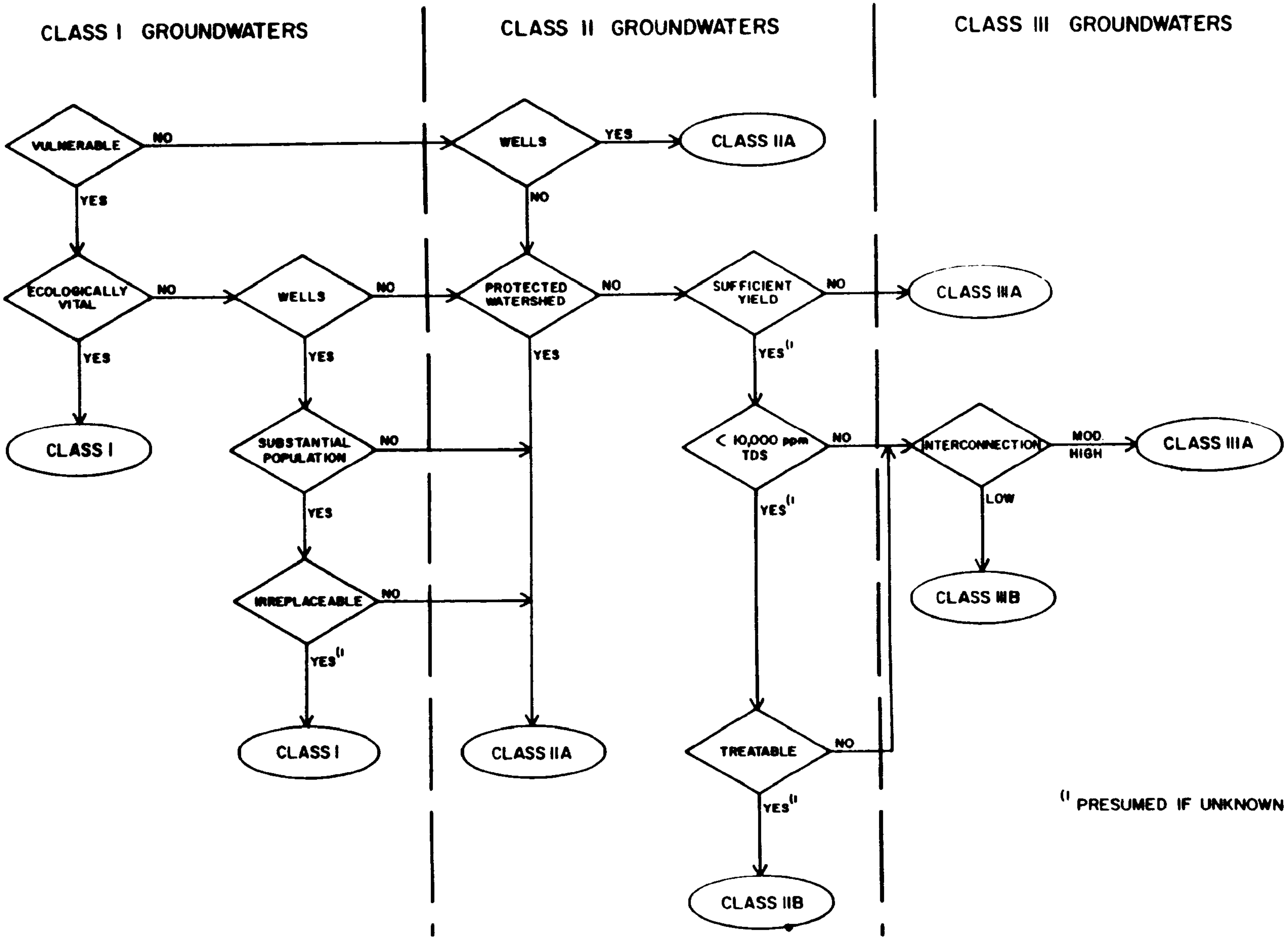
Various statutes in the U.S. imply different definitions of the ground water to be protected. The Safe Drinking Water Act, for instance, is designed to protect Underground Sources of Drinking Water, while other statutes include all ground waters whether or not they are potable. EPA's Ground-Water Protection Strategy addresses all ground water but recognizes that not all ground waters are identical. The strategy distinguishes sources of drinking water from other drinking water and further delineates current from potential sources yet affords some protection for all classes of ground water.

What Is The Appropriate Level of Protection?

Since ground water varies by use, value, and vulnerability, the levels of protection needed for different ground waters are not necessarily the same. EPA accordingly delineated the three classes of ground water summarized in the previous chapter, and in draft guidelines released for public comment in December 1986 provided detailed information on the procedures and data needs for arriving at a classification decision (Figure IV-2).[2] The classification is designed specifically to respond to the dual needs to accommodate widely varying local conditions while establishing a consistent technical approach to devising management strategies for sources regulated under EPA-administered programs.

The <u>Ground-Water Protection Strategy</u> further established the MCL, that is, the drinking water standard applied at the tap, as the basic protection level for both current and potentially available ground-water sources of drinking water, with

FIGURE IV-2
Classification Decision Process



Source: U.S. Environmental Protection Agency, Office of Ground-Water Protection, Guidelines for Ground-Water Classification Under the EPA Ground-Water Protection Strategy (Washington, D.C.: U.S. EPA, 1986), prepared by Geraghty & Miller, Inc., p. 19.

variations above and below those standards based on risk, i.e., ground-water class. The extent to which EPA's proposed classification system shapes ground-water decisions remains to be seen. In recent legislation, Congress has taken a different approach, establishing MCLGs as the basic goal for cleanup under Superfund, where such goals are relevant and appropriate to the circumstances of the release. At the same time Superfund is using classification to designate sites that will be eligible for the federal cleanup fund, programs addressing underground storage tanks and high level radioactive waste have taken the first steps to use the classification system set forth in the guidelines.

What Level of Government Should Manage Ground-Water Protection Efforts?

Historically, states have had the principal ground-water protection responsibility. Although federal source-related statutes have been passed, no overriding federal legislation like that for surface water or air exists for ground water. While some groups are calling for omnibus legislation, EPA has taken a position that states should retain the primary responsibility.

A major goal in EPA's Ground-Water Protection Strategy was to support state efforts to create and strengthen their own institutions to protect ground water. Over the past two and one-half years, EPA has provided the states with technical and financial assistance to accomplish this institution-building objective. With this enhanced capability, states are better equipped to tackle the new Wellhead Protection Program under the Safe Drinking Water Act.

Further, this program represents an appropriate and innovative way of dealing with the 50 states to achieve a national purpose. Unlike the other federal environmental programs, this one will not set requirements the states must meet. Rather, EPA will provide leadership in setting some broad goals and in helping states meet those goals.

Who Should Pay?

Prevention, detection, and treatment of ground-water contamination are all expensive. Unresolved policy questions are how the public and private sectors should share the costs of those efforts and how costs assumed by the public sector should be divided among federal, state, and local governments. Should a farmer, for example, be held financially responsible for ground-water contamination from the normal, agricultural use of a pesticide, or should the manufacturer be responsible? What role should federal, state, and local agencies play in requiring and financing the testing of all community water supply wells? Two approaches to financing cleanup are already in place under Superfund. One is to establish a special federal trust fund, financed by taxes on industry and by general revenues, to cleanup environmental contamination that other private and public entities are not capable of or willing to handle. At issue is the scope and number of ground-water contamination cases that the fund should address, and how the states should finance cleanup they undertake themselves. The second is to use administrative procedures and the courts to compel the responsible parties to pay directly or reimburse the federal government for cleanup.

While the question of "who pays?" is not a new issue, it is particularly difficult to address for ground water. Determining the responsible party often has proven to be lengthy and costly, because there may be multiple contributors to the contamination which may have been discharged quite some time ago. Moreover, once responsibility is assigned, it becomes difficult to decide how to apportion the sizeable costs among the various parties.

Despite the lingering questions over the standard of protection, the delineation of governmental roles, and the financing of ground-water protection efforts, government officials all recognize the importance of proceeding with the development of protection programs. Some areas of the country clearly need immediate attention, because public and private wells already have closed due to contamination. These areas do not have the luxury of waiting the several years it may take to substantially expand our knowledge or refine a public policy. The basic work of ground-water protection is proceeding.

V. CASE STUDIES

CHAPTER V: CASE STUDIES

Through case studies OECD members can share information about ground-water protection measures that have been effective and have the potential to transfer from one setting to another. In deciding how to select its case studies, the U.S. considered a number of approaches. Two options involved the conduct of national case studies, for either a select group of ground-water contamination sources or a set of ground-water management instruments and policies. While both approaches would have expanded baseline knowledge, neither would have adequately portrayed to member nations how hydrogeologic characteristics, land use patterns, and insitutional capabilities in the U.S. combine uniquely to shape the public agenda for ground-water protection in each state and its localities. The third alternative, therefore, was to select a set of states and localities in which to study how public officials tailored ground-water protection programs to regional and local conditions and in that context to analyze important public policy issues.

A. CONSIDERATIONS FOR CASE SELECTION

Five principal considerations in selecting cases are:

- Water use
- Geologic, hydrologic, and topographic conditions
- Types and numbers of sources and contaminants
- Institutional capabilities
- Legal instruments

Collectively, these factors are likely to ensure the selection of cases that capture the widest range of ground-water protection issues and approaches in the U.S.

Ground-Water Use

The ability of ground-water resources to meet a community's needs for water is an important determinant of public policies and programs for protecting ground-water resources. Changes in water use over time need to be considered in selecting cases. Some areas of the country have stable or declining populations, while other areas are experiencing and projecting considerable growth. Fluctuations in birth rates and economic conditions also occur over time. These changes affect water use, land use, the potential nature and extent of ground-water contamination, and the policies selected by state and local governments.

Legal Instruments

Legal instruments have a special importance, because they provide government officials with the needed authorities to manage both ground-water allocation and ground-water quality. Historically, the availability of water relative to the population's needs has shaped the doctrines governing ownership, allocation, and usage of water. The relative abundance of water in the eastern half of the country, for instance, is generally considered to be the factor that led to institutionalization of the doctrine of riparian rights in that part of the country. In the western half of the country, where arid conditions make fresh water a scarce resource, water is treated as a commodity that is distributed according to the doctrine of prior appropriation. Ground-water protection policies insitututed in areas that use one legal doctrine may not be easily transferable to settings which rely on the other doctrine.

Geologic, Hydrologic, and Topographic Characteristics

In the U.S., ground-water protection problems vary in their complexity and severity in large part because of the wide variations in physical characteristics of regional environments. These characteristics affect the potential range of economic activities and land use patterns in a given geographic area, the susceptibility of the ground water to contamination, and the effectiveness of alternative approaches to prevention and mitigation of ground-water contamination.

Sources and Contaminants

Case studies can help illuminate the current and the likely future extent of ground-water contamination by examining states and localities known to have different sets of sources and contaminants. Some communities, for example, have only a few different types of sources within their jurisdiction, while others have a complex array. In addition, the geographic distribution of sources and contaminants changes over time, in response to fluctuating demographic patterns and economic conditions. To capture this diversity of sources and contaminants, the cases selected will need to encompass ground-water protection programs of varying complexities.

Management Instruments for Ground-Water Protection

State and local ground-water protection programs, though relatively new, employ a wide array of the management instruments discussed in Chapter III. No two programs are alike, however.

The cases selected need to reflect the widely differing stages of development of these programs, the different types of ground-water standards they use or are considering, the extent of coverage of the 33 different types of sources, and the range of source and land use controls being adopted for ground-water protection.

B. CASE STUDY RECOMMENDATIONS

Based on the five important variables that account for the differences in ground-water protection programs, six different types of case studies appear to best represent the range of situations encountered in the U.S. These are:

Case 1: Complex and Highly Variable Hydrogeologic Setting

Case 2: Homogeneous Hydrogeologic Conditions

Case 3: Predominantly Agricultural Region

Case 4: Urban/Suburban Region

Case 5: Riparian Rights

Case 6: Prior Allocation

These cases demonstrate the important public policy issues ground-water protection programs in the U.S. will address in the coming decade.

Case 1: Complex and Highly Variable Hydrogeologic Setting

Highly diverse hydrogeologic conditions are common along the eastern coast of the U.S., particularly in the Mid-Atlantic region (New Jersey, Delaware, Maryland, Virginia, North Carolina), and in the western U.S. In these areas of the country, a state or county may find that completely different policies and practices are required to effectively protect ground-water in different parts of its jurisdiction. California Colorado, and Maryland may serve as good representatives for this type of case.

The State of California characteristically has an arid to semiarid climate and is known for serious water shortages. It is one of the most geologically diverse regions of the U.S. encompassing coastal and interior valleys and mountain ranges, volcanic terrains, deserts, fertile farmlands, and wastelands. Since the 1940s, California has experienced steady depletion of its ground-water resources and significant land subsidence has occurred in some areas of the state. More than 10 million people, or 46 percent of the state's population are served by ground-water supplies. The state has numerous sources of ground-water contamination and was one of the first regions of the county to experience salt-water intrusion.[1]

The State of Colorado uses ground-water sources to meet 18 percent of its total water needs. The state has a highly varying topography and geology. Its principal regions include the South Platte River Basin (unconsolidated alluvial aquifer), the Arkansas River Basin (unconsolidated alluvial aquifer), the High Plains (poor to moderately consolidated; gravel/sand/silt/clay aquifer; generally unconfined), the Rocky Mountain Region (unconfined aquifer, clay/silt/sand/gravel, unconsolidated; underlaid by a very deep, confined, unconsolidated aquifer), and the Western Plateau Region (confined, sandstone, and other materials). Each has characteristically different geologies that cause wide variations in ground-water availability and vulnerability.[2]

The State of Maryland, located on the eastern seaboard, has three different geologic regions. The eastern third of the state is located in the Coastal Plain and includes the Chesapeake Bay. This region's aquifers consist principally of unconsolidated sand and clay. Ground water is generally plentiful and accessible but is more vulnerable to contamination than elsewhere in the state. Salt-water intrusion has also been a problem. The region has deep artesian aquifers that are among the most productive in the Mid-Atlantic. Just west of the Coastal Plain is the Piedmont Province, where well yields are generally good. The far west corner of the state is located in The Blue Ridge Province. This region is characterized by metamorphosed sedimentary and igneous rock. Well yields are somewhat higher in this region than in the Piedmont Province.[3]

Case 2: Homogeneous Hydrogeologic Conditions

Regions of relatively little hydrogeologic diversity contend with far fewer complexities when setting land use and ground-water protection priorities. Dade County (Florida) and San Antonio (Texas) are candidates for this case study.

Dade County, Florida, in the southern portion of the state, is heavily dependent on the underlying Biscayne Aquifer as a source of drinking water. Nearly three million people who live in the county (which includes the city of Miami) rely on ground water for drinking. The aquifer is unconfined, close to the surface, and consists of limestone, sand, and sandstone. It is highly vulnerable to contamination, and the county has had numerous problems with contaminated wells. Salt-water intrusion has also been a problem.[4]

San Antonio, Texas is a rapidly growing city that relies solely on the underlying Edwards Aquifer for drinking water. The aquifer occupies an area of approximately 2,500 square miles (6,470 square kilometers). It is comprised of extensively faulted limestone and dolomite, about 500 feet (152 meters) thick. Because water is in short supply in the region, the State of Texas has designated the area as an underground water conservation district.[5]

Case 3: Predominantly Agricultural Region

The types of contaminants associated with agricultural activities include pesticides and nitrates. Regions dominated by agricultural land use are generally characterized by low density populations that rely on septic systems for domestic waste disposal and these can also be an important source of ground-water contamination. Kansas, Wisconsin, and Idaho are potential case study candidates.

The State of Kansas, located in the mid-western Great Plains region, is heavily reliant on ground water for its rural population and for irrigation purposes. Contamination from non-point agricultural runoff and chemigation are important ground-water problems in the state. Kansas also has an extensive oil and gas industry that is responsible for considerable potential ground-water contamination caused by deposited brine muds (from drilling), abandoned wells, and inadequately plugged wells. The state is divided into five Ground-Water Management Districts, which were created in the early 1970s in an effort to increase local involvement in ground-water resource management.

The State of Wisconsin, located on the western edge of the Great Lakes Basin, is heavily dependent on ground water for rural and municipal domestic supplies, livestock use, and irrigation. The state has experienced serious contamination problems from agricultural pesticides and fertilizer use. In 1984, Wisconsin legislated a new ground-water protection and remedial program. Unique aspects of the program include establishment of a two-tiered approach to setting ground-water quality standards (a health-based standard for protection and an enforcement standard for remediation), the formation of a Ground-Water Coordinating Council consisting of representatives from all of the State's agencies that have an interest or involvement in ground-water protection, an aggressive public information and education program, and a no-fault financing program that pays for replacement of contaminated wells.

The Idaho Panhandle Region, located in the Pacific Northwest, is solely reliant on the underlying Spokane Aquifer as a drinking water source. The region is sparsely populated, and widespread use of septic systems is one of the principal causes of ground-water contamination in the region. The State of Idaho has recently implemented ground-water protection policies that are designed to induce local governments to decrease reliance on septic systems in favor of other more centralized waste management practices.[6]

Case 4: Urban/Suburban Region

Urban and suburban regions are characterized by relatively dense populations and diverse industrial and commercial sources of ground-water contamination. Ground-water management strategies for these regions must consider a diverse array of potential sources and contaminants, many of which have been present for a long time. In these settings, prohibitions or restrictions on certain sources represent only a small step in the process of protecting ground-water quality, because of the likelihood that contaminants of longstanding already may have entered the soils and traveled toward the underlying aquifers. Recommended case study candidates include New Jersey and Massachusetts.

The State of New Jersey is located on the eastern seaboard of the U.S. in a region characterized by high population density and heavy industrial activity. Important sources of ground-water contamination in the state include: septic systems, municipal landfills, industrial landfills, underground storage tanks, salt-water intrusion, agricultural runoff, pesticides, illegal dumping of hazardous waste, leaky sanitary sewer lines, and abandoned wells. In 1985, the state reported that it was investigating over 400 cases of ground-water contamination. New Jersey maintains a Water Supply Master Plan for planning future supplies, has designated Water Supply Critical Areas to protect against serious drawdown and salt-water intrusion problems, and has a ground-water discharge permit program.[7]

The Commonwealth of Massachusetts, also located on the eastern seaboard, has many of the ground-water pollution problems typical of the industrialized eastern U.S. Significant sources of contamination include underground storage tanks, landfills, surface impoundments, road salt, agricultural chemicals, accidental chemical spills, industrial discharges, household chemicals, discharges from sewer systems, and salt-water intrusion. Massachusetts coordinates the activities of numerous state agencies and organizations and has an innovative program to provide local communities with financial assistance to acquire land for local ground-water protection purposes.[8]

Case 5: Riparian Rights

Water law, civil suits, torts, and water supply and protection decisions in the eastern U.S. are governed by policies consistent with the riparian rights concept. Institutional settings in the east are often further complicated in regions where numerous jurisdictions rely on a single aquifer as a water source. Long Island and Connecticut are two possible case studies offering the opportunity to examine different public policies and management approaches for ground-water protection.

Long Island, New York, an area that encompasses two counties and part of New York City, relies on its underlying aquifer as a primary water source for three million people. Local conditions make the aquifer particularly vulnerable; and a high level of industrial, commercial, and agricultural activity on the island have caused serious concern. Between 1976 and 1981, public and private wells in the region were closed due to contamination thought to originate with such sources as industrial activities, leaking underground storage tanks, use of household and agricultural chemicals, and septic systems. The region also experiences significant problems with recharge because a considerable quantity of water is discharged through sewer systems to the ocean. In areas near the shore, salt-water intrusion has also been a problem. To address these problems, a ground-water protection program involving more than 20 federal, state, regional and local government organizations has been initiated. These include the U.S. EPA, the New York State Department of Environmental Conservation, and county and city health departments.[9]

The State of Connecticut has adopted a comprehensive ground-water protection program that is considered to be one of the most advanced in the U.S. Administered by the State's Department of Environmental Protection, the program integrates a ground-water classification system, water quality standards, land use policies, and ground-water discharge permits. The state's program also is a good example of integrated environmental management because it recognizes the connection between surface and ground waters. The Department of Environmental Protection has also implemented an intensive data collection effort, in cooperation with the U.S. Geological Survey, to provide the technical data needed to implement the program.[10]

Case 6: Prior Allocation

In the western U.S., the water rights doctrine of prior appropriations dominates. Further complications are introduced where treaties with Indian Nations and agreements with Mexico affect water availability and use. Arizona and the multi-state region served by the Ogallala Aquifer are two possible cases.

Arizona has an arid climate, making fresh water a scarce resource in the state. In recent years, ground-water resources have become a major source for irrigation, municipal, and industrial use; and overdrafting is a significant problem in the state. Both the Arizona Department of Water Resources and the Arizona Department of Health Services have programs for protecting ground-water resources. The state has enacted the Arizona Ground-Water Management Act, passed in 1980, which created the Department of Water Resources. The Act also established four Active Management Areas where intensive management is needed to protect the ground water from overdrafting.[11]

The Ogallala Aquifer supplies water to portions of several states in the southwest including Texas, New Mexico, Oklahoma, Colorado, Kansas, and Nebraska. Because of arid conditions, the region's agricultural activities rely heavily on irrigation. As irrigation has risen steadily along with increases in agricultural production levels in the past three decades, substantial ground-water mining has occurred in the Ogallala. Each of the states drawing water from the Ogallala operates in different legal and institutional settings. Some cooperative programs are now emerging in recognition of the need to conserve water and increase recharge.

C. RECOMMENDATIONS

In identifying possible cases for the Organization for Economic Co-operation and Development to study, the U.S. has attempted to include state and local programs that are representative of the diversity of source types, hydrogeological characteristics, contaminant problems, insititutional chacteristics, and protection strategies. It is likely that not all of these cases can be conducted. Ones that offer the most interesting perspective on future public policy trends are:

- Wisconsin for its innovative standard-setting
- Connecticut which uses ground-water classification as a basis for a comprehensive ground-water management program
- Florida for its extensive use of land use controls
- Massachusetts which has a complex array of sources also offers some unique use of land use controls

- California for its geological diversity, multiple sources, and highly localized approach to ground-water protection

- Arizona where use of ground water is the overriding issue because of the scarcity of all water resources.

The OECD meeting in May provides a forum in which the U.S. can discuss these cases in more detail with other nations and gain insights into the case studies that could be most useful to them.

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