Chapter 1

Protecting the Nation's Groundwater From Contamination: Findings

Contents

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CHAPTER OVERVIEW

Contamination of groundwater—by organic and inorganic chemicals, radionuclides, and/or micro-organisms—has occurred in every State and is being detected with increasing frequency. For a long time, the land surface and subsurface were considered safe and convenient depositories for many of society's wastes and non-waste products. Only recently has the limited capacity of natural soil processes to change contaminants into harmless substances, before they reach groundwater, become widely recognized.

Detailed quantitative estimates of the nationwide extent and effects of groundwater contamination are not now, and probably never will be, available. The time, costs, and technical requirements to develop nationwide estimates would be prohibitive. In addition, information necessary for predicting future contamination problems—about future uses of groundwater, potential sources, and types of contaminants—cannot be known with certainty.

Contaminants found in groundwater—particularly organic chemicals— are associated with adverse health, social, environmental, and economic impacts. Although only a small portion of the Nation's total groundwater resource is thought to be contaminated, the potential effects of this contamination are significant and warrant national attention.

Public health concerns arise because some contaminants are individually linked to cancers, liver and kidney damage, and damage to the central nervous system. They also arise because information is not available about the health impacts of many other individual contaminants, or of mixtures of contaminants as typically found in groundwater. Uncertainties about human health impacts are likely to persist because impacts are difficult to study; for example, impacts may not be observable until long after exposure.

Social impacts are often related to anxiety and fear about exposure to contaminants. Exposure can occur unknowingly because even if groundwater is contaminated, it may be odorless, colorless, and tasteless. Exposure can also occur over many years and in many ways—by drinking, eating, bathing, and breathing.

Environmental impacts include the quality degradation of not only soil, but also air and surface water because of interrelationships among environmental media (e. g., groundwater can provide base-flow to streams). Vegetation, fish, and wildlife can be affected adversely.

The economic costs of detecting, correcting, and preventing groundwater contamination at even a single site are high; for example, corrective action can be tens of millions of dollars or more. Economic losses that occur from impaired groundwater quality include decreases in agricultural and industrial productivity, lowered property values, the costs for repair or replacement of damaged equipment and materials, and the costs of developing alternative water supplies,

Adverse impacts from groundwater contamination are likely to increase. Contaminated groundwater is often located near industrialized, heavily populated areas, which increases the likelihood of human exposure. Groundwater is also increasingly relied on as a source of water for many uses; withdrawals for all uses increased from about 35 billion gallons per day in 1950 to almost 90 billion gallons per day in 1980. Groundwater is now a source of drinking water for approximately one-half the Nation's population. It also fills about 40 percent of the Nation's irrigation requirements, about 80 percent of rural requirements both in the home and for livestock, and about 25 percent of self-supplied industrial purposes (other than hydroelectric power).

Current information about the Nation's groundwater contamination problems may not describe the actual situation as much as it reflects the way in which investigations are conducted—which contaminants have been looked for, where they have been looked for, and where they have been found. Because substances found as contaminants in groundwater are used throughout society, more widespread detection of contamination can be expected as efforts increase to monitor known problems, locate as yet undetected problems, and monitor potential problems. Known sources of contamination include not only the commonly recognized point sources associated with hazardous wastes (as defined by Federal statutes) but also non-point sources and sources associated with non-hazardous wastes and non-waste products.

Examples that reflect the diversity of known sources of contamination include: injection wells and septic tanks, which are designed to discharge potential contaminants into the ground; storage tanks and landfills, which are designed to store, treat, and/or dispose of potential contaminants; pipelines and transfer operations, which transport potential contaminants; agricultural practices, which include pesticide and fertilizer applications; production wells, which provide a conduit for potential contaminants to enter groundwater; and salt-water intrusion, which can be induced or worsened by human activities.

Groundwater contamination problems will continue, and probably increase, as long as there are sources, contaminants, and users not being addressed. Despite the paucity of quantitative details, sufficient information is available about the nature of groundwater contamination to justify national action to protect groundwater quality—described in this study as involving choices among activities to detect, ***correct,*** and prevent contamination—in order to minimize associated adverse impacts. Policy options generally relate to the development and implementation of Federal and State protection programs and include a broadening of programs to those sources, contaminants, and users not now covered and the provision of adequate and sustained Federal support to the States. Unfortunately, the costs and technical uncertainties associated with detection and correction activities effectively preclude the investigation and correction of all known and/or suspected contamination problems. Therefore, prevention is central to any long-term approach to groundwater quality protection. In general, selection among detection, correction, and prevention activities—given limited funds and technical capabilities—will depend on policy decisions regarding which and to what extent groundwater resources will be protected.

FEDERAL AND STATE APPROACH TO GROUNDWATER PROTECTION

Numerous Federal and State programs for protecting groundwater quality-for detecting, correcting, and preventing contamination-have been established and expanded in recent years. These efforts have made a significant contribution to the protection of groundwater. For example, sources of contamination have been identified, inventories of selected sources have been conducted, numerous incidents have been documented, and scientific advances have been made in understanding groundwater flow.

At the Federal level, at least 16 statutes authorize programs relevant to groundwater protection, and more than two dozen agencies and offices are involved in groundwater-related activities. All 50 States are concerned about contamination and have programs, at varying stages of development, to protect groundwater. As many as seven agencies with groundwater responsibilities have been identified in a single State.

Despite growing Federal and State efforts, programs are still limited in their ability to protect against contamination. For example, there is no explicit national legislative mandate to protect groundwater quality; and although the groundwater protection strategy of the U.S. Environmental Protection Agency acknowledges the need for comprehensive resource management, the details of the strategy do not fully provide for it. Most authorized programs are in their early stages, and some are at least 10 years from being fully in place. Groundwater quality-related programs among, and within, institutions are often not coordinated, nor are they coordinated with programs for groundwater quantity or surface water even though groundwater and surface water quality and quantity are interconnected.

From a groundwater protection viewpoint, existing Federal and State programs also generally have a narrow focus with respect to sources, contaminants, and users. Essentially, the programs are concerned with managing selected sources of contamination, selected contaminants, and the users of public drinking water supplies.

Narrow Focus on Sources. —Federal and State programs generally focus on managing only selected point sources of contamination, particularly point sources associated with hazardous wastes. The programs vary in their approaches to protection of groundwater quality and generally do not take into account the potential of the sources to contribute to groundwater contamination. Further, the non-hazardous waste, non-waste, and non-point sources that are known to contaminate groundwater are usually not covered.

Narrow Focus on Contaminants. —This study has documented the detection of over 200 substances—both natural and synthetic—in groundwater. Yet the Federal Government has established only 22 mandatory water quality standards, 18 of which are for specific chemicals. These Federal standards, developed under the National Interim Primary Drinking Water Regulations of the Safe Drinking Water Act, are inadequate, as substantiated by State responses to the OTA State survey. As a result, many States have set their own standards for drinking water and groundwater quality; both the types of contaminants addressed and the stringency of standards vary from State to State.

Narrow Focus on Users. —Federal and State programs are directed primarily at the protection of public drinking water supplies. Yet as much as 20 percent of the Nation's population may rely on private wells for drinking water. The extent to which people relying on private wells are being exposed to groundwater contaminants is unknown, and data are generally not being collected to find out. Data are also unavailable about the impacts of groundwater contamination on non-drinking water uses.

As a result of the narrow focus of Federal and State programs with respect to groundwater protection in terms of sources, contaminants, and

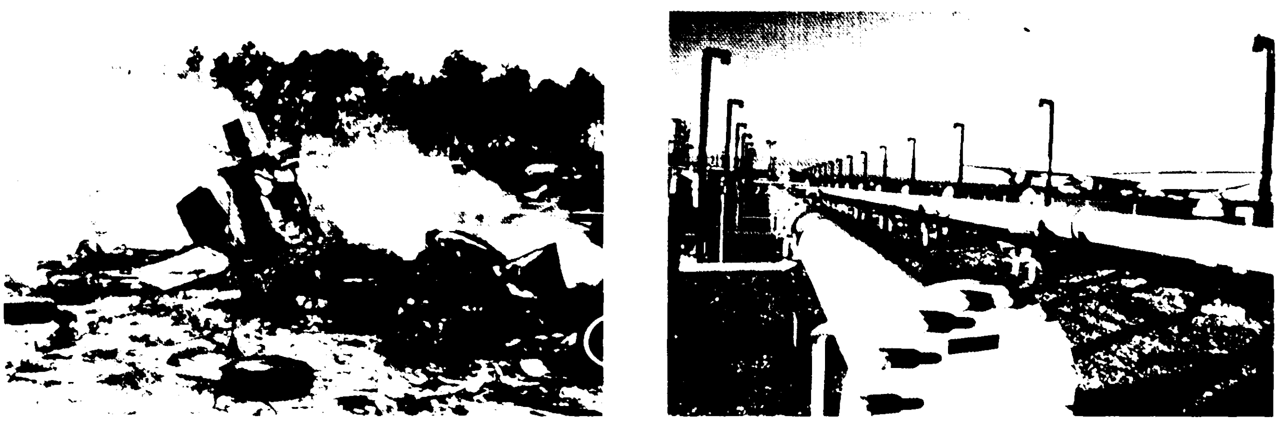

Photo credits: State of Florida Department of Environmental Regulation (left) and Office of Technology Assessment (right)

Sources of potential groundwater contamination are diverse and include the most commonly addressed point sources associated with hazardous wastes as well as sources associated with non-hazardous wastes (e.g., open dumps, which are usually point in nature and may also contain hazardous wastes) and non-wastes (e.g., product pipelines, which are non-point).

users, related activities to protect against contamination are also narrow in focus. Examples are described below.

Detection Programs

The focus of both inventorying and monitoring efforts is on selected point sources of contamination, primarily on sources of hazardous wastes. Federal inventories of specific sources are limited to surface water impoundments under the Safe Drinking Water Act and to hazardous waste sites and open dumps under the Resource Conservation and Recovery Act. State inventories are directed primarily at sources designed to store, treat, and/or dispose of wastes (e. g., landfills) and at sources designed to discharge potential contaminants into the subsurface (e. g., injection wells). In general, only recently has groundwater monitoring begun to include organic chemicals and trace metals. Routine monitoring is required only for public drinking water supplies, as opposed to private drinking water supplies and supplies for non-drinking water purposes.

Corrective Action Programs

Few corrective actions have been undertaken to date relative to the number of sites identified as requiring such action. For example, although federally funded corrective actions authorized by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also known as "Superfund") could potentially address a broad range of sources and contaminants, actions thus far have been restricted to primarily hazardous waste sites; in addition, such corrective actions have generally not involved the cleanup of contaminated groundwater. Overall, the provisions of Federal programs for corrective action vary. Two programs establish standards for cleanup (the Resource Conservation and Recovery Act and the Uranium Mill Tailings Radiation Control Act); other programs (e. g., CERCLA) establish cleanup standards on a case-by-case basis.

State corrective action programs are similarly at an early stage of development. The greatest number of State programs relate to spills and accidents and to leaks from storage; other activities tend to be associated with point sources that are designed either to retain (e. g., in landfills) or to discharge (e. g., via injection wells) potential contaminants into the subsurface. Many State corrective actions result from complaints rather than systematic efforts to identify contaminated sites.

Prevention Programs

A limited number of potential sources are addressed in Federal and State programs to prevent groundwater contamination. The programs focus primarily on sources associated with hazardous wastes and other toxic materials. Implementation and enforcement of most program requirements are still in their early stages. Differences among programs have little relationship to the potential for different sources to cause contamination. Current approaches to preventing contamination include provisions for the design, operation, siting, restricted use, and closing of sources. The approaches may be either mandatory or voluntary. Additional approaches to the prevention of groundwater contamination from specific sources include use of alternatives to the contaminating activity (e. g., to land disposal), process or product changes for reduction of waste hazard levels and volumes, and waste recycling and recovery.

A focus on sources is one approach to prevent contamination; other types of approaches have not been widely applied to groundwater. For example, few efforts have been made to control activities located in recharge areas (i. e., portions of a drainage basin that replenish an aquifer). Approaches that are not source-specific are most suitable when there is no single identifiable source or when high volumes of groundwater or large areas are involved (e. g., non- point sources or a clustering of point sources). The Federal Government does provide some support for the protection of selected recharge areas through the Sole Source Aquifer Program under the Safe Drinking Water Act; selected recharge areas are also being protected by some States and local governments through land use controls and land acquisition.

Another approach to prevent groundwater contamination is through restrictions on the manufacture or generation, distribution, and use of the contaminating substances themselves. This approach recognizes the fact that any one substance can be released into groundwater from many different sources. To illustrate, pesticides may be introduced from non-point sources such as land application, non-waste sources such as storage tanks, hazardous waste sources such as landfills, and non-hazardous waste sources such as residential disposal. Although both the Toxic Substances Control Act and the Federal Insecticide, Fungicide, and Rodenticide Act authorize regulation of potential groundwater contaminants, application of associated programs to groundwater has been limited.

TECHNICAL AND NON-TECHNICAL CONSTRAINTS

The effectiveness of Federal and State programs to protect groundwater from contamination has been limited not only by their narrow focus but also by technical and non-technical factors.

Underlying all groundwater protection activities is the hydrogeologic investigation which is used, for example, to detect existing problems, monitor the performance of corrective actions, and monitor the effectiveness of preventive activities. In general, the technologies for obtaining hydrogeologic information are available. Nevertheless, there will always be some degree of uncertainty about contamination because of inherent difficulties in dealing with a phenomenon that is inaccessible to direct observation. Many advances have been made to improve the reliability of results (i. e., to reduce uncertainty), but they often increase the costs and time required to conduct the investigation.

There are major constraints on hydrogeologic investigations in some situations. For example, the technology for conducting reliable investigations in certain geologic environments such as fractured rock, which occurs throughout the United States, is lacking. Investigations can also be very costly and time-consuming depending on site conditions and the level of detail required by the investigation objectives (e. g., investigations just to define a contamination problem could cost anywhere from $25,000 to $500,000 and take many months to complete). In addition, the reliability of a hydrogeologic investigation depends on highly skilled personnel because investigations must be tailored to the site-specific nature of any groundwater contamination problem. Adequately trained personnel are generally in short supply.

Many of the constraints associated with hydrogeologic investigations—costs, time, inadequate supply of trained personnel, and technical uncertainties—also apply to detection, correction, and prevention activities. The importance of the constraints to these activities varies, however, and additional constraints also become relevant.

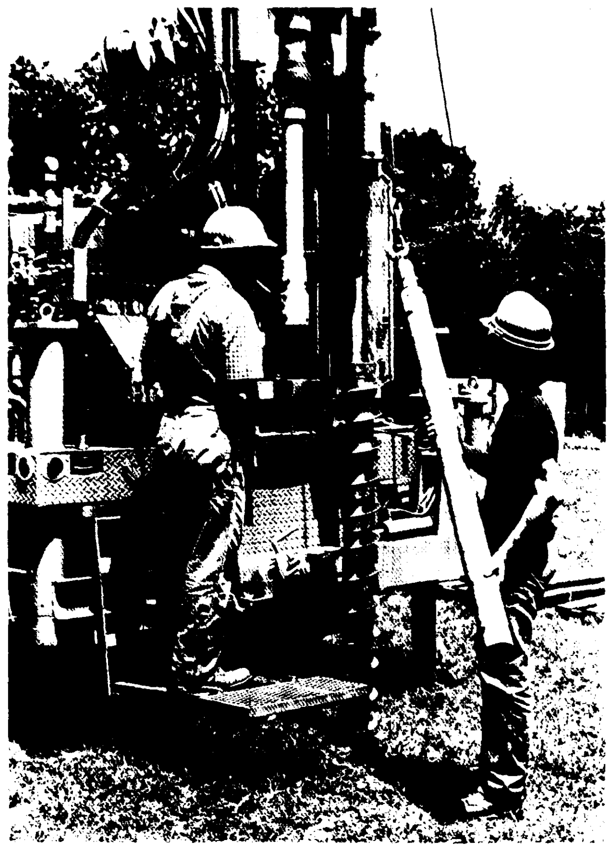

Photo credit: U.S. Environmental Protection Agency

In general, techniques for conducting hydrogeologic investigations are available for most environments. Here a drilling rig provides access to undisturbed, uncontaminated samples of a deep aquifer; a hollow-stem auger holds the drilling hole open while a sampling tube is lowered inside and pushed into undisturbed aquifer material.

Detection activities are primarily constrained by the high costs of monitoring. For example, the annual collection and analysis of groundwater quality samples from the 12-14 million private wells in the United States could cost $7 billion or more depending on the techniques used; and such a sampling program would still provide only a snapshot of data, at discrete places and for one point in time, that conveys little information about the sources of any existing contamination or the potential for further or future contamination. One institutional constraint on some States is their lack of authority to obtain data about particular sources of contamination.

Techniques for analyzing groundwater quality samples are biased in terms of which of the contaminants present they detect, and some contaminants cannot be readily measured at low but potentially harmful levels using routinely available methods. Water quality data can also be difficult to analyze and interpret, especially if trace levels or mixtures of contaminants are present or if contaminants have changed chemically and biologically into substances different than those expected.

Major constraints on alternatives for corrective action include: uncertainty about the effectiveness of various techniques to improve groundwater quality; the dependence of technology performance on the amounts of both money and time available; the high costs of taking corrective action of any sort; the need for suitably trained professionals to design and implement measures appropriate for site-specific conditions; and the lack of experience, especially with the large areas or large volumes of contaminated groundwater that are typical of non-point sources. The nature of the contaminants is another constraint; for example, treatment techniques can be costly depending on the contaminants present, and their performance is uncertain when there is a complex mixture of contaminants and/or concentrations change rapidly. Based on experience-to-date, correction alternatives-containment, withdrawal, treatment, in-situ rehabilitation, and management options— appear to be selected according to how rapidly they can be implemented, how rapidly they become effective, the extent to which the uncertainties inherent in their performance can be reduced, and whether there is clear authority to implement the selected strategy.

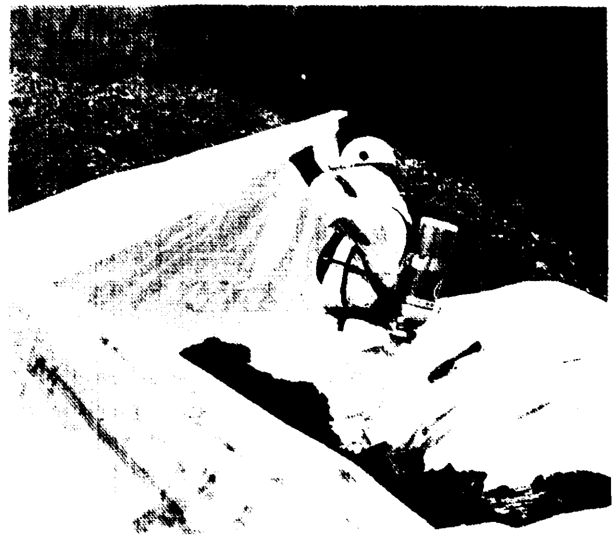

Photo credit: U.S. Environmental Protection Agency

Protective clothing is worn to prevent exposure to contaminants while undertaking corrective measures.

Institutional constraints on corrective actions relate to ease of access to the site, availability of alternatives for disposal of any contaminants withdrawn or excavated, and ability to implement some correction activities (e. g., withdrawal via pumping) given established water rights. Corrective action can also have environmental side-effects. For example, the management option of closing wells results in the continued presence of and potential for further migration of contaminants, and excavation may transfer contaminants to another site or other environmental media (e. g., surface water and air).

Major constraints on prevention efforts include the lack of funds to implement existing programs, uncertainty about the technical adequacy of available methods and ongoing efforts, and incomplete understanding about the relationship between land use and groundwater quality. Some techniques used to prevent contamination are the same as those used for correction (e. g., containment measures such as liners), so that the same uncertainties about performance are pertinent.

NATIONAL POLICY IMPLICATIONS

National policy options generally relate to the development and implementation of Federal and State groundwater quality protection programs.

The existing Federal statutory framework appears to have the potential to protect the Nation's groundwater from further contamination. However, the realization of this potential will depend on broadening the coverage of authorized programs to those sources, contaminants, and users not presently included and on effectively implementing programs. Many approaches for broadening and implementing programs are possible, such as mandatory requirements, voluntary procedures, and/or incentives and disincentives. Effective implementation will also require the coordination of activities among and within agencies (e. g., health departments, State geological surveys, and departments of environmental protection) for both groundwater and surface water quality and quantity. Ultimately, groundwater quality protection will also depend on political judgments about both the appropriate role of the Federal Government and the importance of all States making comparable progress in their abilities to detect, correct, and/or prevent groundwater contamination.

Fundamental to the development of any national policy related to the protection of groundwater from contamination is recognition of the site-specific nature of the problems. Efforts to detect, correct, and prevent contamination must be tailored to the full range of conditions found at any site, including sources, contaminants, and users. National policy must be flexible in its ability to respond to and accommodate different groundwater quality problems characterized by varying site conditions. For example, the choice of appropriate monitoring parameters, locations, and frequencies cannot be rigidly specified apart from site conditions; however, the factors that need to be considered in making this choice could be specified. A major function of the Federal Government would be to provide adequate and sustained support to the States for detecting, correcting, and preventing groundwater contamination. The principal areas for Federal support to the States that would be the most helpful in achieving groundwater quality protection are funding, technical assistance, and research and development.

The need for flexibility in national policy is underscored by the vast differences among State approaches to protecting groundwater. States vary in their perception about their contamination problems, priorities among sources and users, capabilities, stages of program development and implementation, and institutional arrangements. Land use considerations, essential for preventing contamination from non-point sources or from clusters of point sources, have traditionally been addressed at the State and local levels.

Current Federal laws and programs have generally helped the States with their groundwater contamination problems. However, based on responses to the OTA State survey, the level of Federal support to the States is not adequate; nor is it directed at all of the States' problems. In some cases, current Federal laws and programs have created problems: surface water quality problems have been reduced at the expense of groundwater quality because Federal programs fail to recognize the interrelationships among environmental media; Federal programs fail to accommodate variations in State conditions; and the lack of an explicit national legislative goal to protect groundwater quality has led to uncoordinated Federal programs and has handicapped the States in obtaining authority to address certain problems.

Funding

Currently no Federal program has earmarked funds specifically for the protection of groundwater quality. In addition, funding for programs that have supported groundwater-related activities has been reduced or eliminated (e. g., funding under Section 208 of the Clean Water Act, for State solid waste programs under Subtitle D of the Resource Conservation and Recovery Act, and for the Rural Abandoned Mine Program under the Surface Mining Control and Reclamation Act). As a result,

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groundwater and other water quality programs are competing for limited State grants (e. g., under Sections 106 and 205(j) of the Clean Water Act). Because of the high costs associated with groundwater protection, Federal funding assistance is desired by the States for both the development and implementation of State initiatives.

Technical Assistance

Technical assistance to the States can include training programs, the development of criteria and/or guidelines, and information exchange.

Qualified personnel are essential for protection activities because activities need to be tailored to site conditions. The supply of qualified technical personnel appears to be limited and to be an important constraint on the Nation's ability to protect groundwater quality. Federal support for training and education is required for a *rapid* increase in the Nation's technical capabilities. The States have been assisted by the Cooperative Program of the U.S. Geological Survey, and they would like to see it and other technical assistance programs continued. Establishment of professional certification programs or other criteria (e. g., by the Federal Government, the States, or professional societies) for ensuring that personnel possess minimum technical qualifications would also help to develop—and to provide a check in the hiring of—qualified technical manpower.

Although contamination problems require site-specific judgments, they nevertheless have common features that are amenable to the development of Federal criteria and/or guidelines. From a national perspective, the goal of these criteria and/or guidelines would be to ensure that *at least* a minimum set of considerations is being taken into account for protection of groundwater quality. Further, they would also be an efficient means of providing information required by all States in handling their groundwater contamination problems; for example, general guidelines could be developed for assisting the States in setting priorities for allocating scarce resources among alternative protection activities. In addition to criteria and guidelines, the Federal Government could provide direct assistance to States in specified situations.

Technical assistance could include:

- With respect to detection:
  - — Criteria and/or guidelines to assist the States in conducting reliable hydrogeologic investigations under different site conditions and in addressing, for example, monitoring of the flow system, sampling and analysis, and data interpretation.
  - — Criteria and/or guidelines for addressing contaminants for which there are no Federal standards, including for mixtures. Standards development for these contaminants is also needed (see Research and Development, below),
  - — Criteria and/or guidelines to assist the States in setting priorities among sources and in determining which sources they will monitor and inventory.
- With respect to correction:
  - Criteria and/or guidelines to assist the States in selecting and implementing corrective action under various conditions.
  - Criteria and/or guidelines for setting cleanup standards on a site-specific basis, incorporating such factors as the limitations and likely performance of technology and current and/or potential users.
- With respect to prevention:
  - — Criteria and/or guidelines for preventing contamination from all potential contaminating sources; for a given source, performance criteria and/or guidelines for addressing its siting, design and operation during its active life, and closure. Alternatives for reducing the wastes generated by a source, and for waste recycling, also need to be considered as part of preventing contaminant ion from sources.
  - — Criteria and/or guidelines for considering prevention alternatives apart from those related to specific sources, e.g., for the protection of aquifer recharge areas and for establishing an institutional memory for the locations of sources, contaminants, and land uses.

Because of the complexities of groundwater contamination problems and because efforts to protect groundwater are generally in their early stages, there are several important opportunities for the Federal Government to facilitate information exchange among the States. Information exchange would not necessarily include the details of site-specific case studies; rather, programmatic information about State approaches to protection would assist the States in learning from the successes, and failures, of each other.

Photo credit; John Gilbert, EPA Environmental Response Team

Training of staff is required for dealing safely and effectively with site-specific groundwater contamination problems.

Research and Development

Some research and development activities can provide timely information that would support all of the States in their groundwater protection efforts. Key activities include:

- With respect to detection:
  - Research on toxicology and the adverse health effects of contaminants that are being found in groundwater, with particular emphasis on the synergistic effects of mixtures of contaminants.
  - Development of water quality standards for substances known to occur in ground-

water that are not now covered; these standards could be applied in State drinking water and groundwater quality programs.
- — Research on assessment of the environmental and economic impacts of contamination.
- — Research on less costly techniques for hydrogeologic investigations in general and development of reliable techniques for conditions that cannot now be addressed adequately (e. g., fractured rock).

- With respect to correction:
  - — Research on the behavior of individual contaminants in groundwater and, in particular, on the potential for the chemical and biological transformation of organic chemicals.
  - — Research on chemical and biological reactions in fluids that would be necessary, for example, for the development of techniques for treating water with multiple contaminants.
- With respect to prevention:
  - — Opportunities and mechanisms for preventing contamination, including ways of reducing the generation (e. g., by process or product changes) and disposal (e. g., through resource recovery and recycling) of potential contaminants.

Ultimately, the protection of groundwater from contamination will also depend on raising the consciousness of the public as has been done for littering and air and surface water pollution. All segments of society need to understand how their activities affect groundwater quality and, in turn, how they may be affected. Public confidence will grow only as the Nation makes timely efforts to detect, correct, and prevent groundwater contamination from all sources and contaminants, to protect all of the public's interests.

Illustration credit: Sacramento County, CA

Some communities have implemented household hazardous waste collection programs as part of their efforts to protect groundwater quality.

Background