Ground-Water Contamination—No "Quick Fix" in Sight
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No “Quick Fix” in Sight

by Gerald Meyer

The Problem in Perspective

The full magnitude of ground-water contamination in the United States is not known, and Federal and State efforts to assess and address the problem more fully are being mobilized. Health concerns aroused by the large number of contamination cases discovered in recent years and the specter of a more widespread problem likely to be revealed by systematic areal inventory have accelerated policy, management, regulatory, investigative, and public information initiatives.

Additionally, the local and aggregate impacts of these unsettling underground discoveries have evoked greater recognition of the important role of ground water in the national water supply. Contamination events, which commonly lead to closure of supply wells and attendant hardships to users, are unhappy but vivid reminders that half the population of the Nation is served by ground water and 41 percent of agricultural irrigation water is pumped from ground-water reservoirs and that in many localities ground water is the only economical source of high-quality water. Contaminated ground water has limited utility, and, practically speaking, deterioration in quality constitutes a permanent loss of water resource because treatment of the water or rehabilitation of the aquifers is presently generally impractical.

The contamination situation has also brought under scrutiny the role of the land and underlying aquifers in the growing national waste-management predicament. Land-use practices have placed ground-water quality in jeopardy on a wider front than earlier perceived as the result of both deliberate and unintentional release of waste liquids into soils and
rocks and subsequently into ground water (fig. 1). Several decades of vigorous and generally successful reduction in waste discharge into the atmosphere and into surface bodies of water have stimulated land disposal as an economically attractive and readily accessible alternative practice, which is sanctioned and encouraged by the Government with suitable precautions. However, as threats to water, environment, and health are recognized, stricter requirements are being imposed, and the door to the remaining waste-disposal domain—the land and the subsurface—is closing. The land has always been an inadvertent or deliberate recipient of human and animal wastes, and likely it always will be. Complete control of all sources of groundwater contamination will never be economically or physically possible. It is the levels of protection that must be decided.

In attempts to characterize the seriousness of the situation for legislators and the public, the known cases of underground hazardous waste contamination have been described collectively as "the tip of the iceberg," with the prediction that "this will become the environmental issue of the 1980's," or, more direly, "the environmental horror story of the eighties." And, indeed, the list of contaminated sites is lengthening as the intensity of search mounts.

What, then, can the earth scientist contribute to rational perspective and practicable solutions for this unwieldy public problem?

Earth scientists have a record of contributions and governmental understanding of natural resources and management issues. Much of the earth science information produced by the U.S. Geological Survey is directly usable for the management of America's minerals, water, and environment. Also, the need for supporting programmatic research to rest on demonstrable, the Geological Survey's hydrological and resources contributions, are commonly proceeding problem-oriented or problem-resulting, stemming from the intimate relationship of water with human endeavors, the local and areal studies and the understanding of the processes of water and water resources. A cooperative water-resources program with State agencies is"grass roots" investigational, especially compatible with the localized nature of water contamination of ground water.

The ground-water contamination problem is rooted in our agroindustrial society, the accompanying population growth and urbanization, and increased pressure on land and water. In most affected areas are a multitude of zoned and overlapping problems similarly distributed throughout the country, for which future actions are much more than remedial reclamation efforts. New legal, institutional, technical ground will need to be broken.
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What, then, can the earth scientist contribute to rational perspective and practicable solutions for this unwieldy perplexing public problem?

Earth scientists have established a record of contribution to public and governmental understanding of natural-resources and land-management issues. Much of the earth science information now produced by the U.S. Geological Survey is directly usable in planning for the management of the Nation's minerals, water, land, and environment. Also, the relevance of supporting programs of fundamental research to resource and environmental concerns is readily demonstrable. The Geological Survey's hydrological and water-resources contributions, particularly, are commonly problem oriented or problem related, stemming from the intimate relations of water with human endeavors and the local and areal studies engendered by the long-standing cooperative water-resources program with State agencies. These "grass roots" investigations are especially compatible with the localized nature of waste-disposal contamination of ground water.

The ground-water contamination problem is rooted in our vigorous agroindustrial society, with accompanying population growth, urbanization, and increasing stress on land and water. In reality, at issue are a multitude of distinctive and overlapping problems, irregularly distributed throughout the country, for which future preventive actions are much more promising than remedial reclamation measures. New legal, institutional, and technical ground will need to be paved. Viewed by the scientist, then, ground-water contamination is deep seated and not amenable to "quick fixes" or nostrums. Instead, long-term, expensive, and complex protective, preventive, and corrective measures lie ahead which, to be effective and affordable, must be designed around a working knowledge of controlling field conditions—socioeconomic, hydrogeologic, and geographic.

Contamination of ground water by land practices and malpractices is not a new phenomenon in the United States. Events in the 1800's are on record. Two centuries of development undoubtedly invoked a significant cumulative toll on the quality of shallow ground water even before the advent of the exotic pernicious chemicals ushered into the environment in the post World War II period. Despite the resource's history of chemical and hydraulic stress, the volume of ground water significantly degraded can still be assumed to be extremely small compared to the enormous volumes of unaffected water in storage nationally. Intensified inventory may allow an estimate of the portion degraded, but it seems apparent that the resource historically has demonstrated resiliency except under the harshest treatment. Without minimizing the seriousness of cases of contamination recorded to date, these events have served to sound the alert at a relatively early stage that finds the overall safety and usefulness of the Nation's ground-water resources largely undiminished.
For much of the country, then, there is time for informed planning and program design. The following sections of this paper chronicle governmental programs, authorized, legislated, and implemented, including a comprehensive national strategy for ground-water protection now in preparation under the leadership of the U.S. Environmental Protection Agency that will set forth an organized nationwide rationale for systematic attention to ground-water quality.

Federal and State Programs

The Nation has made advances in the reduction of some sources of ground-water contamination, but the bulk of the effort lies ahead. Comprehensive management of the Nation's ground water is a pioneer enterprise. Policy, managerial, regulatory, and technical precedents are rare. Local and State management is uneven—effective in some States and in various stages of evolution in others. The States now have environmental protection laws and water-quality legislation generally suitable at least for exercise of protective measures for ground-water quality, if not for more comprehensive management. Organizational and program improvements are in evidence; although similar to the Federal record, ground-water quality protection and management has been given second-class priority compared to surface water.

Recent State initiatives are identical to those spurring Federal efforts, concern for loss of usable water, endangerment of health and environment, and the compelling incentives imparted by publicized "horror stories." Specific "point sources" that lead to localized cases of ground-water contamination are receiving more attention initially than "nonpoint" areal and regional contamination originating from more widespread activities, including the collective diffused effects of large clusters of point-source contamination events. Nonpoint problems pose the greater managerial and technical challenge. By virtue of the localized occurrence of many ground-water quality problems, it can be anticipated that the national ground-water protection strategy now under development by the Environmental Protection Agency will install a prominent frontline role for the States.

Existing Federal water-quality legislation pertains primarily to the Nation’s surface water; ground water is addressed rarely. A few statutes pertain specifically to ground water, and interpretative ingenuity has yielded others that, by intent or phraseology, are concluded to embrace the ground-water resource. The record of Federal legislation concerning water quality provides a chronicle of evolving programs that consider the ground-water resource and its protection.

The Refuse Act, one section of the River and Harbor Act of 1899, has been employed with success during the past decades to regulate discharges to navigable streams and, primarily focused on provisions of the act and management as an environmental and, therefore, having quality significance toward national management is reflected in the passage of the Water Pollution Control Act of 1948. Here, the emphasis is on stream improvement, but, in reference to ground water, it was a precursor of amended legislation over several decades.

The Nuclear Regulatory Commission, the Energy Research and Development Administration, the U.S. Department of Defense, and the Environmental Protection Agency share responsibility to collaborate in the control of radioactive materials and in other actions to protect the public environment from hazardous activity. The Atomic Energy Act of 1954 assigns primary responsibility to the Nuclear Regulatory Commission (NRC). The Environmental Protection Agency establishes standards for protection of the general public from radioactivity. The NRC is the primary agent for the control of nuclear contamination on the land. Disposal of active waste materials is serious jeopardy to public health and water resources, societal and technical
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The Refuse Act, one section of the River and Harbor Act of 1899, has been employed with success during the past decade as authority to regulate discharge of wastes to navigable streams. Though primarily focused on rivers, provisions of the act address land management as an influence on environmental and water quality and, therefore, have ground-water quality significance. Further progress toward national water-quality management is reflected in passage of the Water Pollution Control Act of 1948. Here, too, the primary emphasis is on stream-quality improvement, but, by a passing reference to ground water, the act was a precursor of broader amended legislation to follow in several decades.

The Nuclear Regulatory Commission, the Energy Research and Development Administration of the U.S. Department of Energy, and the Environmental Protection Agency share responsibilities and collaborate in the control of radioactive materials and emissions and in other actions necessary to protect the public health and environment from harmful radioactivity. The Atomic Energy Act of 1954 assigns principal regulatory responsibility to the Nuclear Regulatory Commission. The Environmental Protection Agency establishes standards for protection of the general environment from radioactivity. Water is the primary agent for transport of nuclear contaminants disposed of on the land. Disposal of radioactive waste materials without serious jeopardy to the environment and water resources is a societal and technical challenge.

Environmental impact analyses and statements required before initiation of certain Federal activities or construction under the National Environmental Policy Act of 1969 have drawn attention to the functions of water in the biosphere and to the susceptibility of the water resources to contamination. Water concerns and hydrologic investigations precipitated by the act undoubtedly have served to raise consciousness of the existence of the ground-water resource and its significant role in land and water management.

The Federal Water Pollution Control Act, which was amended in 1972 and which established a major nationwide program of waste management, pointed to surface-water quality improvement and protection. Ground-water relevance is left to inference in most of the act, but several sections clearly apply to that resource, and implementing programs are evolving. Section 208 is the most pertinent. It supports and encourages state-wide and areal planning for waste management for the purposes of environmental and water quality protection. The broad planning promoted by the act is especially appropriate to the solution of areally extensive ground-water contamination problems of non-point origin.

Two other sections of the amended act clearly apply to ground water. Section 304(e) requires that the Environmental Protection Agency issue guidelines to State and Federal agencies on how to deal with both nonpoint
contamination and a long list of specific potential sources, including waste-disposal wells, surface impoundments, landfills, septic waste systems, saltwater intrusion, and the degradation of water quality attributable to pumping water from wells. Section 402 makes provision for issuance of permits by the States to regulate disposal of wastes in wells. However, the requirement is limited in both interpretation and application to deep waste-injection wells only.

The goal of the Safe Drinking Water Act of 1974 is evident in its name; it is intended to assure safe drinking water for all persons supplied by public water systems. It includes provisions intended specifically to protect aquifers utilized as sources of drinking water and to control and protect them from subsurface waste discharge (underground injection). Special protection is afforded to "sole-source" or "principal drinking-water-source" aquifers. Requirements of the act apply only to Federal and federally supported activities that endanger drinking-water sources, but it serves as a base or model for parallel State controls. As of now, sole-source aquifers have been designated for the following localities: Fresno, Calif., Miami, Fla. (Biscayne aquifer), San Antonio, Tex. (Edwards Limestone), Spokane-Rathdrum Prairie, Wash.-Idaho, Passaic River Basin, N.J. (buried valley), Long Island, N.Y., and Ten Mile Creek, Md. Four others are being initiated: southwestern Missouri, karst aquifer system, Cape Cod, Mass., New Jersey coastal plain, and Scott Valley, Calif. A number of additional localities have been proposed.

The Resources Conservation and Recovery Act of 1976 regulates the management, storage, transportation, and disposal of hazardous wastes. The main thrust is improved land-disposal practices, which would have obvious potential benefits to ground-water quality protection.

These legislated programs do not constitute an exhaustive listing of Federal actions benefiting ground-water quality. The Environmental Protection Agency administers the Toxic Substances Control Act of 1975 and the Insecticide, Fungicide, and Rodenticide Act of 1972 as well as other programs whose broad purpose is to limit release of harmful chemicals to the environment, though they may not address the ground-water domain directly. And many Federal Departments carry mission-oriented responsibilities for land and resource management and environmental protection that include water-resources concerns. The Surface Mining Control and Reclamation Act of 1977 administered by the Department of the Interior is one example, and innumerable relevant activities can be identified in programs of the Department of Agriculture, the Army Corps of Engineers, and the Department of Commerce.

Thus, the array of Federal and State programs that deal with the environment and water contains some measure of ground-water quality protection, and these programs constitute a foundation for expanding this broad complex. However, it should be recognized that fundamental policies on how the Nation should address this broad complex will have to be formulated. The Federal Protection Agency is engaged in developing a national ground-water strategy to define priorities for a national program geared towards the far-reaching effects of contamination, the strategy devised with State and public participation.
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Thus, the array of Federal and State programs that deal with the environment and water contains some measure of ground-water quality protection, and, collectively, these programs constitute the foundation for expanded effort. However, it should be noted that fundamental policies concerning how the Nation should address this broad complex issue are yet to be formulated. The Environmental Protection Agency is engaged in development of a national ground-water protection strategy to define policies and national program goals. Because of the far-reaching effects of contamination, the strategy is being devised with State and broad public participation.

U.S. Geological Survey Investigations

Knowledge of the makeup and workings of the Earth is a basic requirement for the design of technically sound economic measures for the management of ground-water quality. Land usage determines the nature, source, and severity of contamination events in the subsurface, and management of the Nation's ground-water quality is tied to land-use practices. Figure 2 illustrates the hydrologic connection diagrammatically. Ground-water quality cannot be addressed in isolation.

The Water Resources Division of the Geological Survey addresses water-information requirements of the Nation through comprehensive programs of investigation, data collection, and research. Collaboration with the States and with a number of Federal agencies enables local, State, regional, and national levels of work. Multidiscipline technical teams pursue

hydrologic, chemical quality, and geochemical investigations in tandem or integrally, and groundwater is infused among these programs. The work of the Water Resources Division cannot be separated clearly into surface-
and groundwater components, but groundwater is estimated to constitute about 40 percent of the organization's total program.

The "grass roots" Cooperative Program with State geological and water agencies is particularly conducive to groundwater investigation because a large share of the problems is of localized areal extent. These jointly funded investigations deal with an array of general and specific water concerns. The increasing number of investigations concerned specifically with groundwater contamination is a measure of the Cooperative Program's response to that growing problem. During the 1950's, 6 contamination reports were published; during the 1960's, there were 42 reports; and during the 1970's, 121.

Broader programs of national scope, funded solely with Federal funds, include investigations of regional and national scale, systematic hydrologic observations, and research. "Thrust" programs address critical national water problems. In 1978, the Geological Survey initiated the major Regional Aquifer-System Analysis Program for the purpose of providing regional hydrologic descriptions for the 28 principal aquifer systems of the country. These regional studies complement the State cooperative investigations; together, they provide a foundation of technical information on flow systems and quality of water to aid all levels of planning and management. With regard to contamination problems, an effort is being made in the Regional Aquifer-System Analysis Program to interpret water-quality and geochemical information integrally with knowledge of the flow systems to predict large-area water-quality problems of the future and to aid in the design of preventive, management, and, where practicable, corrective measures.

A number of other national Geological Survey programs deal with critical water- and waste-management problems involving groundwater quality and contamination. The decade-old Subsurface Waste Storage Program addresses hydrologic principles and terrane suitability associated with practices of subsurface waste disposal, contamination, and groundwater-quality management. A major program concerned with nuclear energy hydrology is yielding scientific information required to manage, store, and dispose of radioactive waste materials. These programs represent efforts of substantial proportions but are only a small version of the investegative and research effort likely to be required to provide adequate earth science information for management of groundwater quality.

The immensity of the Nation, the chemical and physical diversity of its terrane, and intensity of land usage pose major challenges to the study of ground-water quality, and much remains to be done.

Special challenges are posed by the chemical hydrology of groundwaters, including methodologies. Sodium adsorption methods have become standard for the evaluation of ground-water hydrochemistry. Not only hydraulic flow characteristics are well established and used nationally, but solute transport processes that aid prediction of the movement of inorganic contaminants in groundwater are in need of additional field testing and refinement. Monitoring sites utilized in the development of models for organic solute evaluation are limited to a number of comprehensive field study.

The Outlook

Ground-water contamination problems now attract broad governmental and public attention. In this country are numerous and water-management solutions rest largely on the decisions of these practices to take into account the susceptibility of ground-water resources. Federal and State agencies are now in evidence, and comprehensive policy programs are being developed to support the restoration of contaminated groundwater resources generally.
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The immensity of the Nation, the chemical and physical diversity of its terrane, and intensity of land usage pose major challenges for ground-water quality management, and much remains to be learned. Special challenges rest with geochemical hydrology and predictive methodologies. Simulation methods have become basic tools of ground-water hydrology, but only hydraulic flow models are well established and fully operational. Solute transport models that aid prediction of the movement of inorganic constituents in ground water are in hand, but additional field testing and verification are needed. Accuracy and reliability are dependent on improved methods for acquiring the physical and chemical data from study sites utilized in the mass transport equations. Transport models for organic solutes pose still additional difficulties that will entail more extensive laboratory and field study.

The Outlook

Ground-water contamination problems now attracting wide governmental and public concern in this country are rooted in land- and water-management practices. Solutions rest largely in changing these practices to take into account the susceptibility of the ground-water resources to degradation. Federal and State actions are now in evidence, and more comprehensive policies and programs are being devised. Although restoration of contaminated ground water is generally imprac-
As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.