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Resource Document for the Ground-Water Monitoring Strategy Workshop

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I. INTRODUCTION

This document has been prepared as background material in support of a workshop sponsored by the Environmental Protection Agency to develop a ground-water monitoring strategy. It should serve as a useful reference on current activities in ground-water monitoring and as a guide to selected state and federal ground-water monitoring programs. The document has been organized to provide information on:

- The background of ground-water monitoring initiatives at EPA
- Existing ground-water monitoring activities at the federal and state level
- Case studies of notable monitoring programs and surveys
- Ground-water resources in the U.S.
- The cost of ground-water monitoring
- Technical monitoring issues likely to arise during this workshop

The reports contained in this document are by no means exhaustive. Rather, they are summaries of key ground-water monitoring activities and issues that have been selected to illustrate the development of a national ground-water monitoring strategy. As such, they should serve as useful background information on the subject. This document is current as of February 1985, and may contain information no longer applicable to particular ground-water monitoring initiatives and programs.

II. EPA GUIDANCE ON MONITORING

- Environmental Monitoring Policy Statement
- Guidance for Preparing Environmental Monitoring Strategies
- Ground-Water Protection Strategy: Executive Summary

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

DEC 23 1983

OFFICE OF
THE ADMINISTRATOR

12-29-83
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MEMORANDUM FOR: Assistant Administrators
General Counsel
Inspector General
Associate Administrators
Regional Administrators
Staff Office Directors

FROM: Alvin L. Alm
Deputy Administrator

SUBJECT: Environmental Protection Agency Environmental Monitoring Policy Statement

This memorandum transmits the Environmental Protection Agency's first environmental monitoring policy statement. Environmental monitoring, which we have defined as the broad set of activities providing chemical, physical, geological, biological, and other environmental data required by environmental managers, is an essential part of all our activities, including planning and research, rulemaking, compliance assessment, and program evaluation. A system of credible, accurate and correctly applied monitoring information is essential to our overall credibility as an Agency. While a number of activities we undertake compete for scarce resources, we must be sure to require an appropriate balance between those activities and adequate environmental monitoring.

The monitoring policy was prepared by the Agency's Task Force on Monitoring, which I convened, and which was comprised of EPA and State experts on all aspects of environmental monitoring. This policy crystallizes the considerable experience and expertise on environmental monitoring that has been gained over the past several years and organizes it into a set of coherent goals for our program offices to build on in constructing individual monitoring strategies.

I expect each of you to take an active role in your programs' planning for and management of monitoring activities. I also expect you to coordinate monitoring efforts in your program with those of other offices in the Agency and to make maximum use of environmental information in planning and managing your programs. The Task Force developed this monitoring policy so such consultations and cooperation could take place with reference to a shared set of Agency goals and objectives for environmental monitoring.

This policy is only the first step in our efforts to improve the status of environmental monitoring in the Agency. Subsequent efforts include the production of monitoring strategies by each EPA line program office in May, and a series of recommendations from the Task Force relative to sorting out roles, responsibilities and relationships among the various offices with responsibilities for monitoring activities at EPA. I know I can count on you to support these efforts, and particularly to involve yourselves personally in developing the monitoring strategies called for in this policy statement.

Attachment

ENVIRONMENTAL MONITORING POLICY STATEMENT
ENVIRONMENTAL PROTECTION AGENCY

PURPOSE

Environmental monitoring is an essential part of all Agency activities from planning and research, to rule-making, compliance and pollution control, and evaluating programs' effectiveness. Monitoring, while not an end in itself, is an integral part of a sound environmental program. In order to acquire and successfully use information on the broad range of public health and environmental problems, their causes, and potential for control, EPA, State, and local officials must systematically identify environmental data needs and collect and evaluate extensive chemical, physical, geological, biological, and other data related to pollution effects, sources, transport, and control. This task increasingly has become as complex as it is costly. Despite substantial progress by EPA and States, persistent problems of the past, if left uncorrected, will hinder our ability to meet the new challenges of the future, particularly those involving toxic chemical pollutants. Periodic criticism has focused on: limited coordination, control, or planning of Agency monitoring activities; uncertain quality of the data collected; the design of networks and studies that result in data of limited use; lack of data suitable for trend analyses; difficulty of accessing information; incompatibility of data bases; and the limited analysis and use of environmental data for EPA decision making. While these problems have not been universal, the critical nature of the Agency's monitoring efforts requires that EPA address even isolated incidents of these problems.

The purpose of this policy statement is to establish overall goals and objectives for Agency monitoring programs, which specifically are to:

1. Meet the full range of current and future Agency needs for environmental data.

2. Ensure monitoring is technically and scientifically sound.

3. Ensure environmental monitoring data are managed to facilitate both access and appropriate use in Agency decision making.

4. Ensure effective and coordinated Agency-wide processes for planning and execution of monitoring activities.

5. Ensure that roles and responsibilities are clear in regard to monitoring management and implementation by EPA and State officials.

SCOPE

For the purpose of this policy "environmental monitoring" is broadly defined as the set of activities which provides chemical, physical, geological, biological, and other environmental data required by environmental managers. Under this broad definition, "monitoring" includes: planning the collection of environmental data to meet specific program objectives and environmental information needs; designing monitoring systems and studies; selecting sampling sites; collecting and handling samples; lab analysis; reporting and storing the data; assuring the quality of the data; and analyzing, interpreting, and making the data available for use in decision making and reporting to the public. Thus, "monitoring" would include the data generated to support rule making, to develop control strategies, to determine compliance, to enforce regulations and standards, to assess exposure, to anticipate emerging problems, to plan and evaluate the effectiveness of national and State environmental strategies and program activities, and to establish national, Regional, and State baselines and trends, and to track environmental progress.

GOALS AND OBJECTIVES

The following sections describe in greater detail the specific objectives under each of the goals of the Agency's monitoring policy.

1. MEETING THE FULL RANGE OF NEEDS FOR ENVIRONMENTAL MONITORING DATA

- EPA national program managers should plan and develop their national environmental monitoring programs to meet the full range of present and projected future uses for which the data are needed. These should generally include uses to:

  - Identify present and future environmental and health problems through national, Regional, State, and local baseline and trend measurement. Such information is necessary to

    -- establish program priorities;
    -- provide regular reports to the public on the state of the environment, important trends over time, and Agency progress; and
    -- evaluate the progress and effectiveness of environmental programs, including delegated programs.

    Wherever appropriate, in addition to changes in environmental quality, these measurements should provide a basis for assessing or estimating exposure of and/or direct effects of pollutants on humans, animals, fish, and plants, and the risk of environmental damage. Impacts on both health and "welfare" -- that is, effects such as corrosion and changes in aesthetic quality, should be considered.

- Provide the underlying technical basis for environmental management activities in order to:

  -- set sound national, State, and site specific standards and rules;
  -- define effective control strategies and programs;
  -- establish site-specific controls and/or abatement programs;
  -- determine compliance with ambient and source standards;
  -- develop effective enforcement cases; and
  -- support research monitoring to develop environmental models.

- Develop, through research, new and improved monitoring techniques and methods, systems design, sample analysis, and collection methods to better address existing problems and to meet emerging problems.

- EPA managers should plan and design individual monitoring studies or networks to achieve a clearly defined objective and, wherever it is cost-effective to do so, design them to achieve multiple objectives.

- Monitoring networks and sampling surveys should be designed to anticipate future needs and uses of the data. For example,

  - Specimen banking should be considered to allow for retrospective analyses, long-term trend monitoring, and verifying the effectiveness of environmental controls.

  - Gas chromatograms, mass spectrograms, and sample extracts should be preserved in appropriate situations for retrospective analyses of chemicals that subsequently are suspected of having adverse effects.

- Agency managers should make optimum use of environmental monitoring data already collected by States and other Federal agencies.

2. ENSURING AGENCY MONITORING IS TECHNICALLY AND SCIENTIFICALLY SOUND

- Prior to monitoring, environmental managers should clearly identify the use for which the data will be collected. Provisions should exist for network or sampling design, sample handling, sample analysis, quality assurance, data handling, and data interpretation commensurate with the uses to which the data will be put.

- Networks and sampling studies should be designed so the resulting data are complete and valid relative to the objectives.

  - Prior to data collection the completeness of data (i.e., the amount of data needed to satisfy the objective) should be documented.

  - Sampling sites, sampling procedures, and sampling frequencies and parameter coverage should be selected to ensure that the resulting data accurately represent the medium sampled to meet the objectives.

  - EPA should assist States in design of systems and studies by providing guidance, technical assistance, and peer review.

- Monitoring required of States or the regulated community should meet all applicable Office of Management and Budget clearances.

- Environmental monitoring data should be quality assured at all phases of monitoring so that the data are of known quality and the quality is thoroughly documented. Historical data should be used with appropriate care and validation, recognizing the possible limitations of some data due to the lack of quality assurance or other information on potential sources of error.

  - All samples should be collected, handled, and analyzed in adherence with the Agency's mandatory quality assurance program.

  - The quality assurance/quality control program for each monitoring study or network should control and quantify, to the extent possible, the total method error. Potential sources of error include sampling, sample handling, laboratory measurements, calculations, and data processing.

- Monitoring networks and sampling surveys should be based to the extent possible and where appropriate on prototype or pilot studies to determine how monitoring would actually function in practice, to demonstrate by example the analyses to be made of the data, and to allow assessment of alternative monitoring approaches prior to large fixed commitments.

3. MANAGING ENVIRONMENTAL MONITORING DATA TO FACILITATE ACCESS AND APPROPRIATE USE IN DECISION MAKING AND AVAILABILITY TO THE PUBLIC

- Environmental data should be stored in automated data systems or filing systems for hard copy with the location, time of sample collection, relevant quality control data, and other required information so that other potential beneficiaries can easily obtain and use the data. Consultant contracts should provide for timely access to data.

- Data should be accompanied by documentation of quality assurance/quality control (QA/QC) procedures, including quantitative statements of precision and accuracy, where appropriate. The statements should pertain to the entire measurement system and at a minimum include sample collection, sample handling, and lab analysis.
  - The statements should be reported in hard copy reports; the long-term goal is to include statements in ADP systems.
- Data bases which include confidential data should be managed in a way that will permit use of and access to key non-confidential environmental data.
- Program offices, Regional offices, and the Office of Research and Development (ORD) should keep EPA's Information Clearinghouse updated.
  - Offices should submit information to the Clearinghouse at the start of each new monitoring initiative and at the completion of each monitoring initiative.
  - Offices should review and update their Clearinghouse information at regular intervals.
- Agency managers should use pertinent environmental data wherever possible in Agency decision processes, including setting EPA policies and priorities.
- Agency managers should report regularly to the Administrator environmental information and policy implications for their programs.
- Agency managers should routinely develop reports which interpret and make available to the public significant data and findings of monitoring programs, including those describing important national trends or emerging problems and the strategies in place or planned for addressing those problems.
- Agency managers should provide the Regions and States guidelines for interpreting and using environmental data. Section 1 of this policy has generally identified the uses of data and areas for which guidelines may be appropriate.

4. ENSURING EFFECTIVE AND COORDINATED AGENCY-WIDE PLANNING AND EXECUTION OF MONITORING ACTIVITIES

The basic planning, management, and implementation of monitoring programs resides with EPA's program offices, in some situations with the Office of Research and Development and with State and local governments. EPA's program offices attempt to ensure that EPA's and States' and local governments' monitoring is both effective, and where appropriate, coordinated with other programs, States and other Federal activities. Program offices and ORD establish requirements and provide guidance to State and local governments on monitoring, including network design, sampling and analysis, quality assurance, and reporting. They also have sponsored efforts to define more clearly monitoring needs and to integrate activities. Examples of some program office efforts to strengthen Agency monitoring are standing work groups on monitoring, priority workplans arranged around specific topic areas and coordinated through ad hoc committees, participation in the Clearinghouse, and regular meetings of quality assurance officers and of Regional coordinators.

To ensure maximum coordination and integration of efforts across the Agency as well as within programs, EPA also has in place several mechanisms to provide Agencywide management and coordination of monitoring efforts. The Office of Research and Development is responsible for coordinating and managing the Agency's quality assurance program, as well as developing new monitoring methods and operating research monitoring programs; the Office of Administration and Resources Management (OARM) is responsible for the management of Agency automated data systems, examining issues concerning laboratory facilities, and through the Office of the Comptroller, conducting budget analyses; the Office of Policy, Planning, and Evaluation (OPPE) is responsible for promoting the development of baselines and trends, evaluating existing monitoring systems (OPPE will develop criteria for how they will evaluate such systems), and coordinating Agency review of monitoring strategies and proposals. Also, OPPE is responsible for coordinating development of the Administrator's Guidance and is responsible for the Management Accountability System, both of which provide mechanisms for ensuring that priorities and tasks established and approved by the Administrator are accomplished.

To enhance these current efforts, the following changes are being introduced to strengthen coordination of monitoring activities across the Agency and to permit most effective use of our limited monitoring resources.

- Monitoring Strategies: Monitoring strategies will be prepared by each Headquarters Program Office, including the Office of Research and Development, and subsequently evaluated annually and updated as needed so that program offices and the Administrator and Deputy Administrator may use them in planning and managing environmental monitoring activities throughout the Agency. Every program's original monitoring strategy or significantly altered update will be reviewed by OPPE, by other programs and Regional reviewers, and by the States where appropriate. The States should be involved in the initial stages of the development of monitoring strategies for programs in which States will play a major role. An outline of the content of the strategies is given in the attachment and will be described more fully in separate guidance.

- Monitoring Budgets: Both to ensure that adequate resources are devoted to the collection, analysis and management of environmental data, and that Agency resources are used effectively and efficiently, OPPE will work with the Office of Administration and Resources Management to conduct an overall budget analysis of monitoring. Budget reviews will make use of the monitoring strategies.

- Laboratory Capability and Professional Training: To carry out Agency programs, Regional laboratories should maintain or have access to appropriate state-of-the-art field and analytical equipment and personnel with needed skills. Regional laboratories and other EPA laboratories, in conjunction with appropriate program offices, will prepare and update annually a three or more year plan for equipment purchases.

  Regional laboratories and other EPA laboratories should maintain accurate inventories of their scientific equipment in the Personal Property System managed by the Office of Administration and Resources Management.

  Program offices should, at the time of proposing regulations or environmental standards which require monitoring by EPA in the Federal Register, carefully consider the adequacy of monitoring capability, including laboratory equipment, needed to carry out the monitoring. Programs should also consider State and local needs.

- Technical Guidance: To enable the technical guidance the Agency produces to be coordinated, sampling and analytical methods should include a clear description of their official status and relationship to other Agency sampling and analytical methods.

  The Office of Research and Development is directed to develop an Agency-wide standard protocol for validating analytical methods. This protocol should be used by all programs whenever they validate methods.

  Performance data on lab analytical methods should be reported to ORD in the required format to keep current the document titled Compilation of Data Quality Information. This document provides environmental measurement method performance data for establishing achievable data quality goals.

5. ENSURING CLEAR ROLES AND RESPONSIBILITIES

As this document states, many offices and organizations in EPA as well as State and local government agencies are involved in the Agency's different monitoring efforts. Some have line responsibility for design and implementation of monitoring systems and for collecting, analyzing, and reporting data. Others are responsible for setting and overseeing policy and cross-program coordination. Because of the variety of monitoring that the Agency carries out or requires, environmental managers at all levels need to clearly understand these various roles and responsibilities. To ensure this, the Deputy Administrator will clearly delineate the roles and responsibilities of the various offices and agencies involved in monitoring activities.

ATTACHMENT

ENVIRONMENTAL MONITORING STRATEGIES

To implement monitoring programs that achieve the goals established in the Environmental Protection Agency's Monitoring Policy, each line program (Office of Air and Radiation, Office of Water, Office of Solid Waste and Emergency Response, Office of Pesticides and Toxic Substances, and Office of Research and Development) will develop program monitoring strategies. These strategies will be key documents for Agency-wide and program management of the Agency's monitoring activities.

Monitoring strategies will be prepared and subsequently updated as needed. The strategies, including existing strategies, should be evaluated annually by the program offices and updated as needed so that the program offices may use them in preparing their budgets. Drafts of new strategies or copies of existing strategies should be submitted to the Deputy Administrator (DA) by April 4. Following the submissions, the Assistant Administrators shall brief the DA on their monitoring strategies, including the use of the data, benefits of the data, and coordination with other programs and States and local agencies and other Federal agencies. The goal is to have complete and up-to-date strategies submitted by the Assistant Administrators by May 25 of each year.

Completing a new strategy or substantially revising an existing strategy may not be achievable by April and May of 1984. Most strategies will generally require considerable intra-EPA coordination among program offices and enforcement, research, and Regional Offices. Also coordination with the States, local agencies, and other Federal agencies will usually be necessary. Therefore, for the April and May 1984 dates, a program office should at least complete an interim document that provides the Administrator and Deputy Administrator with a description of the approach the program is taking to monitoring. The description should include the program's data needs, how the program will use the data in programmatic decisions, the approach to collecting the data, and the resource implications. Because not all aspects of the monitoring strategy may be completed, milestones for completing the full strategy, including adequate coordination, should be included. The milestones for completing a strategy should not extend beyond May 1985.

The final strategies, and interim documents to the extent possible, as a minimum should contain the elements listed below. Because every program's monitoring strategy will be reviewed by other programs, each program should try to adhere to the outline as closely as possible.

Outline for Monitoring Strategies

- Describe the goals and objectives of the monitoring program and identify the program's data needs (specify priorities).
- Describe the extent to which these needs are now being met.
- Outline the plan for program's monitoring to meet these needs.
- Describe how design, sample handling, chemical analysis, data analysis and data processing will be carried out to assure (1) representativeness and (2) quantification of overall error bounds.
- Describe linkages with other programs, including monitoring programs, criteria and standards and risk assessment; describe linkages with other Federal agencies.
- Identify technical barriers, issues, and opportunities.
- Clarify the respective responsibilities of various Headquarters offices, the Regions, and State and local programs.
- Identify data processing and data analysis tasks.
- Provide a schedule for implementation.
- In an appendix, describe costs and other relevant resource issues.
  - Evaluate alternative strategies under varying levels of resources.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

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MEMORANDUM FOR: Assistant Administrators
General Counsel
Inspector General
Associate Administrators
Regional Administrators
Staff Office Directors

FROM: Alvin L. Alm
Deputy Administrator

SUBJECT: Guidance for Preparing Environmental Monitoring Strategies

This memorandum provides guidance for preparing the monitoring strategies called for in the Environmental Monitoring Policy which I recently issued. The Office of Air and Radiation, Office of Water, Office of Solid Waste and Emergency Response, Office of Pesticides and Toxic Substances, and Office of Research and Development each will develop monitoring strategies. Draft strategies are due April 4, 1984; final strategies are due May 25, 1984.

The development of these strategies is an important step in ensuring that the Agency moves closer to the goals of the Policy -- conducting and managing monitoring activities so that programs:

1. Meet the full range of current and future Agency needs for environmental data.

2. Ensure monitoring is technically and scientifically sound.

3. Ensure environmental monitoring data are managed to facilitate both access and appropriate use in Agency decision making.

4. Ensure effective and coordinated Agency-wide processes for planning and execution of monitoring activities.

5. Ensure that roles and responsibilities are clear in regard to monitoring management and implementation by EPA and State officials.

The strategies will give us, for the first time, a comprehensive understanding of our needs for environmental information, the activities now under way and planned to meet those needs, and the interrelationships between programs' monitoring efforts. They will also give us the capability to more effectively plan for and manage monitoring activities across the Agency and to shift resources where necessary.

I recognize that, where programs are developing new monitoring strategies or substantially revising an existing strategy, it may not be possible to prepare the complete strategy by May of 1984, especially where strategies will require considerable coordination within EPA and with the States, local agencies, and other Federal agencies. Therefore, for the May 1984 deadline, a program office does not need to have final strategies for those new and substantially revised monitoring activities. Each program, though, should at least complete an interim document for those areas which provides a description of the approach the program is taking to monitoring. The description should include the program's data needs, how the program will use the data in programmatic decisions, the approach to collecting the data, current gaps that exist, and the resource implications of implementing the strategy. For those aspects of the monitoring strategy that are not completed, milestones for completing the strategy, including adequate coordination, must be included. No milestones for completing a strategy should extend beyond May 1985.

I have been pleased with the progress made by the Monitoring Task Force to date and look forward to the individual program monitoring strategies.

Attachment

GUIDANCE FOR PREPARING ENVIRONMENTAL MONITORING STRATEGIES

INTRODUCTION

This document is the companion piece to the Environmental Protection Agency's Monitoring Policy Statement and provides guidance to the program offices for preparing environmental monitoring strategies. Programs' draft strategies are due April 4, 1984; final strategies are due May 25, 1984.

PURPOSE OF STRATEGIES

Systematic and well thought out environmental monitoring that meets the Environmental Protection Agency's needs for a wide range of information is essential for the overall credibility of the Agency's programs.

The Monitoring Policy specifies that each line program (Office of Air and Radiation, Office of Water, Office of Solid Waste and Emergency Response, Office of Pesticides and Toxic Substances, and Office of Research and Development) will develop program monitoring strategies. Having written monitoring strategies for each program that address similar aspects of monitoring should give managers and staff throughout the Agency a better understanding of the many environmental monitoring efforts under way. It should also improve coordination of monitoring activities between programs, between Headquarters and the Regions, and between EPA and State and local agencies conducting environmental monitoring. Finally, preparing monitoring strategies will also be a way to identify where monitoring that is needed is not under way, problems with monitoring that need improvement, and activities that are duplicative of other programs' efforts or that are not effective and need to be corrected.

APPROACH

This guidance follows the outline for monitoring strategies included as an attachment to the Monitoring Policy. Each program's monitoring strategy should:

- define the full range of its environmental data needs,
- outline how those needs are being and will be met,
- identify problem areas and present specific actions that will be taken to address them, and
- provide schedules for achieving key interim and final monitoring milestones.

In preparing its strategy, each program office should consider each point of the Policy Statement to ensure that the strategy is consistent with the Policy. Specifically the goals and objectives for Agency monitoring activities stated in the Policy are to:

1. Meet the full range of current and future Agency needs for environmental data.

2. Ensure monitoring is technically and scientifically sound.

3. Ensure environmental monitoring data are managed to facilitate both access and appropriate use in Agency decision making.

4. Ensure effective and coordinated Agency-wide processes for planning and execution of monitoring activities.

5. Ensure that roles and responsibilities are clear in regard to monitoring management and implementation by EPA and State officials.

More than one strategy may be necessary for some offices. For example, a program might choose to develop one strategy to deal with compliance monitoring and data reported by sources and another strategy to deal with ambient and other types of monitoring. Also, some programs may already have existing strategies that fulfill most or all of the elements of a strategy as specified by the Policy. If so, programs may use existing strategies and supplement them as needed. Because many offices will be reviewing the strategies to ensure coordination, the strategies or supplemental material should adhere to the outline as closely as possible.

The strategies should be succinct, with the length of each strategy not expected to exceed 50 pages.

This guidance is not intended to be comprehensive for every aspect of a strategy, nor is it intended to inhibit a program office's creativity in preparing its strategy. Furthermore, not all elements of a strategy outlined in the guidance will be equally applicable to all monitoring activities. For example, some programs require much more coordination with States than other programs. Therefore, programs should try to cover the items in the guidance but should not be constrained to those items.

CONTENT OF STRATEGIES

SECTION 1: PROGRAM'S MONITORING GOALS AND OBJECTIVES AND ENVIRONMENTAL INFORMATION NEEDS

A clear statement of the program's monitoring goals, objectives and environmental information needs, including both narrow operational and broader long-term needs, is perhaps the most important section of the strategy. This section should answer why such information is needed, what questions are to be answered, what decisions will be based on the monitoring information, and what the relative priorities of these needs are.

Some statutes mandate certain monitoring, or specify activities that require monitoring, in order to carry out the activities. These legislated activities and related monitoring requirements should be identified in this section of the strategy.

In preparing this section of their strategies, programs should refer to the information needs that are listed in the Monitoring Policy. Examples of questions that a program should consider when developing its strategy are:

A. <u>What Data Will the Program Collect to Make Assessments of Status, Trends, and Emerging Problems?</u>

- For which chemicals, class of chemicals, or other parameters will national, Regional, State and local environmental baselines and measurement of trends be established? Some baselines and trends may have already been established by existing monitoring networks or programs, and these should be identified in the monitoring strategy.

- For which populations or species will monitoring data be collected to allow exposure and risks to be assessed? What environmental damage, such as corrosion and/or impairment of aesthetics, will be assessed?

- For what types of problems and for which chemicals or class of chemicals will monitoring be done to detect emerging problems?

B. <u>What Monitoring Will the Program Do to Support Operational Needs?</u>

- What rulemaking, including the chemicals, class of chemicals or industrial processes, will be supported by monitoring?

- For which sources or classes of sources is compliance to be determined? What are the relative priorities of these sources for compliance monitoring?

- For which ambient standards will compliance be determined?

- What is the anticipated level of enforcement monitoring that will be required?

- What specific control activities will be monitored to evaluate program effectiveness? In what terms will effectiveness be measured (e.g., environmental quality, exposure, and/or risk)?

C. <u>What Research is Planned for Developing New or Improving Existing Monitoring Methods Such as Instrumentation, Network Design, Sample Collection and/or Analysis?</u>

This list of questions is not intended to be an exhaustive list or apply equally to all programs. However, programs should define their monitoring data needs as precisely as possible.

Also, because some data often can be used for more than one purpose, programs may want to display their needs in a table or matrix.

SECTION 2: DESCRIBE THE EXTENT TO WHICH NEEDS ARE NOW BEING MET

This section of the strategy should describe the existing networks and/or other monitoring efforts. In addition, the strategy should describe which environmental information needs identified in Section 1 are being fulfilled by the current monitoring efforts and how they are being met.

This section should identify each monitoring program or individual project and describe for each:

1. the goals and objectives
2. the data needs that are being satisfied or will be satisfied.

This section also should identify the additional monitoring needed, beyond that which currently is conducted, to fulfill the environmental information needs identified in Section 1 of the strategy. This additional monitoring should be described in terms of the type and extent of the networks and/or other projects or special studies, or the source oriented monitoring efforts that are needed.

Limitations exist with any monitoring system; not all environmental information needs can be met by any one given monitoring effort. These limitations should be discussed. For example, if the network or monitoring system design is stratified to develop a national baseline but not to target on potential hot spots or localized concentrations, or if monitoring is for hot spots or priority areas and not for an overall baseline, this should be made clear. If exposure to pesticides is being monitored by an adipose network, it should be made clear what pesticides can be detected using that network and how or whether the program plans to track pesticides that would not show up using that method (e.g., plans to analyze for metabolites in body fluids).

SECTION 3: OUTLINE THE PROGRAM'S PLAN FOR MONITORING TO MEET THESE NEEDS

This section should clearly identify the program's priorities for the current and proposed monitoring activities described above. (Provide the relative priority and approximate costs of each program in terms of personnel and contract dollars.) Programs should indicate priorities in two ways: (1) assuming existing approved levels of program resources, including transfers of resources into or out of monitoring activities; and (2) assuming some additional resources. The strategies should clearly indicate alternatives regarding allocation of resources to monitoring.

The quality assurance project plans that are required and their status should be referenced. For each monitoring effort, the title and date of issuance of completed quality assurance project plans should be included. If quality assurance plans have not been prepared, the schedule for completion of the project plans should be included.

SECTION 4: DESCRIBE HOW DESIGN, SAMPLING HANDLING, CHEMICAL ANALYSIS, DATA ANALYSIS AND DATA PROCESSING WILL BE CARRIED OUT TO ASSURE (1) REPRESENTATIVENESS AND (2) QUANTIFICATION OF OVERALL ERROR BOUNDS

The strategy should include sufficient detail about how the monitoring will be conducted to give the reader a clear understanding of the data that will be produced by the effort.

It is important that the representativeness and the confidence one can expect in the data be as clear as possible.

SECTION 5: DESCRIBE LINKAGES WITH OTHER PROGRAMS, INCLUDING MONITORING PROGRAMS, CRITERIA AND STANDARDS, RISK ASSESSMENT AND ENFORCEMENT; DESCRIBE LINKAGES WITH OTHER FEDERAL AGENCIES

There are several areas where improved coordination would be very beneficial. Some linkages may have already been established between or among monitoring programs and need only be described in the strategy. Other coordination efforts need to be developed and clarified. The strategies should address the areas that generally need better coordination and provide specific plans for improving coordination. The areas to be covered are:

- Intra-Program Coordination. Monitoring activities within programs that potentially should be better coordinated include a program's monitoring to support criteria and standards, risk assessment and enforcement activities within a program or across programs.

- Inter-Program Coordination. Perhaps the greatest short-term opportunities for improved coordination are inter-program monitoring of ground water contaminants by the Drinking Water, RCRA, and Superfund programs, and coordination of toxic air pollutant monitoring and data reporting among the Air, RCRA, and Superfund programs.

- Coordination among Federal agencies. Some legislation is very specific about establishing coordination among different Federal agencies. The Clean Water Act and Federal Insecticide, Fungicide, and Rodenticide Act state this clearly. Other legislation, while not as specific, also requires coordination, such as between Superfund and the Centers for Disease Control. In general, Federal monitoring is not well coordinated despite significant potential benefits.

- o <u>Research and Development Support</u>. Each program office will need to identify the research support it will need from ORD. ORD should address analytical methods development, development and distribution of quality control samples, development of standard reference materials through the National Bureau of Standards, development of anticipatory monitoring networks, and monitoring for developing models as well as other areas.

- o <u>Technical assistance to the States</u>. What technical assistance is needed by the States in order to help ensure that programs can be carried out?

  - Lab support for the more difficult samples
  - Training
  - Quality control assistance

- o <u>EPA Regional labs and field support</u>. What lab and field support do the Regions need to provide to carry out the monitoring objectives? This support should be stated specifically enough to be used in planning equipment purchases and staffing.

- o <u>Contract support</u>. The contract support that is planned to support monitoring should be described, including the provisions for ensuring the quality control of the data.

SECTION 6: IDENTIFY TECHNICAL BARRIERS, ISSUES, AND OPPORTUNITIES

Many monitoring efforts can be envisioned that can not be readily implemented due to lack of appropriate analytical procedures or other technical limitations. Also, opportunities may exist for collecting data more directly related to a program's needs by developing or incorporating new techniques.

This section should clearly identify any barriers, issues, and opportunities so that they can be dealt with as systematically as possible.

SECTION 7: CLARIFY THE RESPECTIVE RESPONSIBILITIES OF VARIOUS HEADQUARTERS OFFICES, THE REGIONS, AND STATE AND INCLUDING LOCAL PROGRAMS

It will become increasingly important to clarify the respective roles and responsibilities of EPA Headquarters, Regional Offices, and State and local agencies. This will be particularly important for State and local agencies, since many States and communities have multiple agencies responsible for EPA monitoring, which can further complicate coordination.

SECTION 8: IDENTIFY DATA PROCESSING AND DATA ANALYSIS TASKS

In order to ensure that the monitoring data collected are used most effectively, programs should develop a strategy for using environmental data and explain how data will be stored and made accessible to users, and how such data will ultimately influence program management.

- Programs should describe existing and planned storage systems for environmental data, including current problems.
  - What system will be used to store data from each monitoring activity or network?
  - Who will input the data and how often will this be done?
  - What problems have there been?
- Programs should describe current and needed data processing and data analysis capability.
  - What types of analyses are and will be conducted with the data? Who will carry out the analyses and how often?
  - How will data be made accessible and to whom?
  - How compatible are systems within a program? With the systems of other programs?
- Programs should explain how the data supports program management.
  - How will the results of analyses be used?
  - What types of reports will result from the analyses? For whom are they prepared?
- Where programs have identified potential and existing multiprogram use of monitoring data, the strategy should describe how data storage, retrieval, and analysis will be coordinated to support multiprogram application.

SECTION 9: PROVIDE A SCHEDULE FOR IMPLEMENTATION

The strategy should be written specifically enough so that once Sections 1 through 4 have been completed, milestones can be identified and included in the Strategy. Some of the milestones may relate to developing networks, some to completing final products, and some to assessing compliance of a certain class of sources. Some of the final products may be more than a year in the future; interim milestones should be included.

APPENDIX: COST AND OTHER RELEVANT RESOURCE ISSUES

In order for information to be available in development of the FY 1986 Agency budget, programs should include in a separate section (not for Agency-wide distribution) a more detailed presentation of their resource needs. This section should elaborate on the costs described in Section 2, and discuss costs of monitoring activities and relative priorities. Ideally, costs should be described in terms of funding, positions, extramural funding, and State grant funding. The costs should be identified in terms of planning, field efforts and sampling, laboratory support, data handling, quality assurance, data analysis, and data interpretation. (Guidance for this appendix needs to be developed with the Comptroller's Office.)

A GROUND-WATER PROTECTION STRATEGY

FOR THE

ENVIRONMENTAL PROTECTION AGENCY

AUGUST 1984

EXECUTIVE SUMMARY

In the last decade the public has grown increasingly aware of the potential problem of ground-water contamination. Reports of chemicals threatening drinking water supplies have mobilized State, local and Federal governments to respond. But these responses suffer from a lack of coordination among responsible agencies, limited information about the health effects of exposure to some contaminants, and a limited scientific foundation on which to base policy decisions.

Officials at all levels of government have begun to look for a definable strategy to protect ground water. The strategy presented here will provide a common reference for responsible institutions as they work toward the shared goal of preserving, for current and future generations, clean ground water for drinking and other uses, while protecting the public health of citizens who may be exposed to the effects of past contamination.

EPA Administrator William D. Ruckelshaus recognized the need to protect ground-water quality as a national concern. In response, Deputy Administrator Alvin L. Alm formed a Ground-Water Task Force to: (1) identify areas of serious inconsistencies among programs and institutions at the State, local and Federal levels; (2) assess the need for greater program coordination within EPA; and (3) help strengthen States' capabilities to protect ground-water resources as they themselves define the need. In line with EPA's mission to preserve and enhance environmental quality, this strategy document focuses on issues of ground-water quality.

(Issues of water quantity and allocation are also important, but they are outside the province of EPA. Many ground-water quality issues (for example, salt-water intrusion) are closely related to issues of ground-water quantity and allocation. States will have to approach such issues through integrated policies; topics relating primarily to quantity and allocation are not addressed in this document. With respect to EPA activities the scope and intent of this document includes only EPA's statutory and regulatory authority.)

The Task Force was composed of staff from each affected EPA Program Office and two EPA regions. The Office of Water chaired the group. Beginning work in June 1983, the Task Force delivered a draft report to the Deputy Administrator on September 1, 1983. He sought the views of senior Agency policy-makers by meeting with the involved Assistant Administrators and their key staff on many occasions to discuss the report and its implications.

As options began to narrow, this senior policy group requested additional analyses from the Task Force, consulting with Regional Administrators as it proceeded. At length, after concerted debate and broad-scale Agency involvement, the main policy elements for an EPA Ground-Water Protection Strategy emerged. Draft conclusions were discussed with Congressional staff, State organizations, and environmental and industry organizations.

A draft strategy resulting from that decision process was then distributed to State officials and to select State, business and industry, and environmental organizations for comment. Approximately 150 organizations submitted comments. After receiving comments from these interested parties, EPA revised the draft strategy for final consideration by the Deputy Administrator and Assistant Administrators. This final Ground-Water Protection Strategy is the product of that deliberation process.

A Perspective on Ground Water

In the 1970's, national environmental concern focused mainly on natural resources and pollutants we could see or smell. Surface water and air quality, specific types of contaminants such as pesticides, or obvious sources of contamination such as uncontrolled hazardous waste sites, were of primary concern. People concerned themselves only rarely with ground water since, hidden from view as it is, few knew or really understood how seriously the resource was being compromised.

Today, ground-water contamination looms as a major environmental issue of the 1980's. The attention of agencies at all levels of government, as well as that of industry and environmentalists, is now focused on this vital resource. As contamination has appeared in well water and wells have been closed, the public has expressed growing concern about the health implications of inappropriate use and disposal of chemicals. As concern has increased, so have demands for expanded protection of the resource.

Our understanding of the sources and dimension of the threat is limited, but increasing. Scientists can now measure specific organic chemicals at the parts-per-billion or -trillion levels. As new health studies are completed and as we learn more about various sources of ground-water contamination, our capacity to deal with this problem increases. Scientists and engineers have also learned more about how contaminants move in the subsurface -- which ones bind to soils and which ones pass through to the water table beneath. They are now identifying technologies to prevent, control, and clean up ground-water contamination.

Major Authorities and Responsibilities

The Task Force reviewed EPA's statutory authority as it relates to ground water and examined the current scope and extent of State programs as well. While the nature and variability of ground water makes its management the primary responsibility of States, the Task Force found that a number of Federal authorities exist to support States in the effort.

Since these Federal statutes were enacted at various times for separate purposes, inconsistency developed in EPA's regulations and in the decisions made under them. While these differences are often necessary and reasonable, there are a number that appear to hinder a cohesive approach to ground-water protection. Improving harmony among EPA's program rules affecting ground-water protection is an important need, since inconsistency in such matters leads to confusion and less effective protection than if roles, requirements, and responsibilities are clear and consistent.

In addition to its own authorities, EPA found a variety of powerful State and local statutes available for use. A number of States have begun their own programs for ground-water protection, some built on permits supported by a system of aquifer classification. Continuing the development of State programs in this area is vital, as they have the basic responsibility for the protection of the ground-water resource.

Strategic Concerns

Given public concerns, EPA, as well as State and local governmental agencies, must decide how best to protect public health and critical environmental systems. It seems clear to many that we must direct our energies to minimize future contamination, even as we detect and manage contamination associated with past activities.

Protecting ground water will be difficult. Starting with limited knowledge of the resource and limited means to address existing or potential problems, we must expend our efforts where groundwater contamination would cause the greatest harm. Consequently, we assign highest priority to those ground waters that are currently used as sources of drinking water or that feed and replenish unique ecosystems.

Ground-water protection is a very complex and difficult issue. It will require sustained effort at all levels of government over a long period of time before this resource will be adequately protected. Within this context, EPA developed its Ground-Water Protection Strategy.

EPA's Ground-Water Protection Strategy

The EPA Strategy includes four major components that address critical needs. They are:

- Short-term build-up of institutions at the State level;
- Assessing the problems that may exist from unaddressed sources of contamination--in particular, leaking storage tanks, surface impoundments, and landfills;
- Issuing guidelines for EPA decisions affecting ground-water protection and cleanup; and
- Strengthening EPA's organization for ground-water management at the Headquarters and Regional levels, and strengthening EPA's cooperation with Federal and State agencies.

These components, described in detail in Chapter IV, are summarized below.

EPA will provide support to States for program development and institution building. EPA will encourage States to make use of certain existing grant programs to develop ground-water protection programs and strategies. These funds will support necessary program development and planning, the creation of needed data systems, assessment of legal and institutional impediments to comprehensive State management, and the development of State regulatory programs such as permitting and classification. Regional Administrators will work with Governors so that funds are directed to the State agency or programs with the most complete authority and capability to undertake or continue statewide program or strategy development. EPA will also provide State agencies with technical assistance in solving ground-water problems and will continue to support a strong research program in ground water.

EPA will address contamination from underground storage tanks. Because the evidence suggests that leaking storage tanks--particulary from gasoline--may represent a major, unaddressed source of ground-water contamination, the Deputy Administrator has directed the Office of Toxic Substances to design a study to identify the nature, extent, and severity of the problem. EPA is investigating the application of the Toxic Substances Control Act (TSCA), as well as other authorities, as a potential legal basis for applying appropriate requirements on design and operation of these tanks. In the meantime, the Agency will issue chemical advisories to alert owners and operators about the problem and work with States and industry to develop voluntary steps to reduce contamination. EPA is also planning direct regulation of underground storage of hazardous waste under the Resource Conservation and Recovery Act (RCRA).

EPA will study the need for further regulation of land disposal facilities, including surface impoundments and landfills. EPA, in cooperation with the States, will conduct studies of impoundments and landfills as to the degree of danger they present, set priorities for control, review the regulatory options available, and determine if additional Federal controls are needed.

EPA will adopt guidelines for consistency in its ground-water protection programs. The guidelines will be based on the policy that ground-water protection should consider the highest beneficial use to which ground water having significant water resources value can presently or potentially be put. Under this policy, the guidelines define protection policies for three classes of ground water, based on their respective value and their vulnerability to contamination. These guidelines are intended to provide a framework for the decisions that EPA and States will have to make in implementing EPA programs. The guidelines will be used by EPA and the States to make decisions on levels of protection and cleanup under existing regulations, to guide future regulations, and to establish enforcement priorities for the future. (These regulations will then provide the legal basis for the implementation of the guidelines. It is not intended that any substantive or procedural rights are provided by this Strategy.)

The classes of ground water are as follows:

Class I: Special Ground Waters are those that are highly vulnerable to contamination because of the hydrological characteristics of the areas under which they occur and that are also characterized by either of the following two factors:

a) Irreplaceable, in that no reasonable alternative source of drinking water is available to substantial populations; or

b) Ecologically vital, in that the aquifer provides the base flow for a particularly 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 system 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.

EPA will accord different levels of protection to each class as described in the examples below. Chapter IV describes in more detail the regulatory approaches EPA will take to protect these ground-water classes under each statute.

To prevent contamination of Class I ground waters EPA will initially discourage by guidance, and eventually ban by regulation, the siting of new hazardous waste land disposal facilities over Special Ground Waters. Some restrictions may also be applied to existing land disposal facilities. Further, Agency policy will be directed toward restricting or banning the use in these areas of those pesticides which are known to leach through soils and are a particular problem in ground water. EPA's general policy for cleanup of contamination will be the most stringent in these areas, involving cleanup to background or drinking water levels.

Ground waters that are current and potential sources of drinking water (Class II) will receive levels of protection consistent with those now provided for ground water under EPA's existing regulations. In addition, where ground waters are vulnerable to contamination and used as a current source of drinking water, EPA may ban the siting of new hazardous waste land disposal facilities, initially through guidance, and later through regulation. While EPA's cleanup policy will assure drinking water quality or levels that protect human health, exemptions will be available to allow a less stringent level under certain circumstances when protection of human health and the environment can be demonstrated. EPA may establish some differences in cleanup depending on whether the ground water is used as a current or potential source of drinking water or for other beneficial purposes.

Ground waters that are not considered potential sources of drinking water and have limited beneficial use (Class III) will receive less protection than Class I or II. Technology standards for hazardous waste facilities generally would be the same as for Class I and Class II. With respect to cleanup, should the hazardous waste facility leak, waivers establishing less stringent concentration limits would be considered on a case-by-case basis. Waivers would not be available, however, when a facility caused the contamination that precluded future use. EPA's Superfund program will not focus its activities on protecting or improving ground water that has no potential impact on human health and the environment.

To improve the consistency and effectiveness of EPA's current ground-water programs, the guidelines will be incorporated into each of the Agency's relevant program areas. Many of these programs are delegated to the States, and for most programs, States must demonstrate that their programs are "no less stringent" than the Federal program in order to qualify for authorization to implement the programs. However, in implementing these guidelines EPA will provide as much flexibility to the States as is possible under state delegation agreements.

Consequently, EPA will to the extent possible keep regulatory requirements based on EPA's ground-water protection guidelines general and performance-oriented. EPA will, in addition, develop guidance to accompany such regulations for use by EPA when EPA directly administers a program in a State (e.g., implementation in a non-delegated State or implementation of a program which cannot be delegated). Such accompanying guidance would not be binding on the States, but it could also be used by the States to assist them in developing their own regulatory requirements or guidelines. This guidance will, for example, define more precisely the meaning of the terms used in the Strategy, such as "vulnerable and unique habitat".

The task of actually determining whether the ground water in a particular location fits the criteria for Class I, II, or III will be a site-specific determination. In programs involving permits, such as RCRA and Underground Injection Control (UIC), for example, this determination will be made during the permitting process based on data supplied by the permit applicant. In cleanup actions under Comprehensive Environmental Response Compensation and Liability Act (CERCLA), the ground-water class will be determined in conjunction with the assessment of the extent of contamination. Where States have already mapped or designated ground water for that location, the State classification of the ground water will provide useful guidance.

EPA will improve its own institutional capability to protect ground water. EPA has assigned ground-water coordination and development responsibilities to the Assistant Administrator for Water and he has established an Office of Ground-Water Protection to oversee the implementation of this Strategy. The Director of that Office has already started to work with other EPA offices and Regions to institutionalize EPA and State ground-water roles, plan for correction of uncontrolled sources of contamination, identify and resolve inconsistencies among EPA programs, and learn more about the nature and extent of ground-water contamination.

EPA Regional offices are also in the process of establishing Regional ground-water units. They will coordinate Regional ground-water policy and program development and assist the States through grants and technical assistance designed to increase their institutional capabilities to manage ground water.

EPA will carry out this Strategy in partnership with other Federal agencies, especially the Department of Interior (DOI), to insure that the Strategy is implemented as effectively as possible.

The body of this report contains three chapters and an Appendix. Chapter II describes the nature and extent of ground-water contamination. Chapter III describes State and Federal programs for ground-water protection. Chapter IV describes EPA's strategy to protect ground water. The appendices include a matrix describing State, local, and Federal roles and a summary of the options considered by EPA in developing this Strategy.

* * * * * * *

III. FEDERAL GROUND-WATER MONITORING ACTIVITIES

- Summary of Federal Ground-Water Monitoring Provisions and Objectives
- Summary of EPA Ground-Water Monitoring Programs
- Description of EPA Ground-Water Monitoring Task Force
- Report on U.S.G.S. Federal-State Cooperative Water Resources Program

Office of Technology Assessment Summary of Federal Groundwater Monitoring Provisions and Objectives

Statutory authority	Monitoring provisions[a]	Monitoring objectives
Atomic Energy Act	Groundwater monitoring is specified in Federal regulations for low-level radioactive waste disposal sites. The facility license must specify the monitoring requirements for the source. The monitoring program must include: —Pre-operational monitoring program conducted over a 12-month period. Parameters not specified. —Monitoring during construction and operation to provide early warning of releases of radionuclides from the site. Parameters and sampling frequencies not specified. —Post-operational monitoring program to provide early warning of releases of radionuclides from the site. Parameters and sampling frequencies not specified. System design is based on operating history, closure, and stabilization of the site.	To obtain background water quality data and to evaluate whether groundwater is being contaminated.
	Groundwater monitoring related to the development of geologic repositories will be conducted. Measurements will include the rate and location of water inflow into subsurface areas and changes in groundwater conditions.	To confirm geotechnical and design parameters and to ensure that the design of the geologic repository accommodates actual field conditions.
	Groundwater monitoring may be conducted by DOE, as necessary, part of remedial action programs at storage and disposal facilities for radioactive substances.	To characterize a contamination problem and to select and evaluate the effectiveness of corrective measures.
Clean Water Act		
—Sections 201 and 405	Groundwater monitoring requirements are established on a case-by-case basis for the land application of wastewater and sludge from sewage treatment plants.	To evaluate whether groundwater is being contaminated.
—Section 208	No explicit requirements are established; however, groundwater monitoring studies are being conducted by SCS under the Rural Clean Water Program to evaluate the impacts of agricultural practices and to design and determine the effectiveness of Best Management Practices.	To characterize a contamination problem and to select and evaluate the effectiveness of corrective measures.
Coastal Zone Management Act	The statute does not authorize development of regulations for sources. Thus, any groundwater monitoring conducted would be the result of requirements established by a State plan (e.g., monitoring with respect to salt-water intrusion) authorized and funded by CZMA.	
Comprehensive Environmental Response, Compensation, and Liability Act	Groundwater monitoring may be conducted by EPA (or a State) as necessary to respond to releases of any hazardous substance, contaminant, or pollutant (as defined by CERCLA).	To characterize a contamination problem (e.g., to assess the impacts of the situation, to identify or verify the source(s), and to select and evaluate the effectiveness of corrective measures).
Federal Insecticide, Fungicide, and Rodenticide Act—Section 3	No monitoring requirements established for pesticide users. However, monitoring may be conducted by EPA in instances where certain pesticides are contaminating groundwater.[b]	To characterize a contamination problem.
Federal Land Policy and Management Act (and Associated Mining Laws)	Groundwater monitoring is specified in Federal regulations for geothermal recovery operations on Federal lands for a period of at least one year prior to production. Parameters and monitoring frequency are not specified.	To obtain background water quality data.
	Explicit groundwater monitoring requirements for mineral operations on Federal lands are not established in Federal regulations. Monitoring may be required (as a permit condition) by BLM.	
Hazardous Liquid Pipeline Safety Act	Although the statute authorizes development of regulations for certain pipelines for public safety purposes, the regulatory requirements focus on design and operation and do not provide for groundwater monitoring.	
Hazardous Materials Transportation Act	Although the statute authorizes development of regulations for transportation for public safety purposes, the regulatory requirements focus on design and operation and do not provide for groundwater monitoring.	
National Environmental Policy Act	The statute does not authorize development of regulations for sources.	
Reclamation Act	No explicit requirements established; however, monitoring may be conducted, as necessary, as part of water supply development projects.	
Resource Conservation and Recovery Act	Groundwater monitoring is specified in Federal regulations for all hazardous waste land disposal facilities (e.g., landfills, surface impoundments, waste piles, and land treatment units).	

Office of Technology Assessment Summary of Federal Groundwater Monitoring Provisions and Objectives-continued

Statutory authority	Monitoring provisions[a]	Monitoring objectives
Resource Conservation and Recovery Act (cont'd) —Subtitle C	*Interim Status* monitoring requirements must be met until a final permit is issued. These requirements specify the installation of at least one upgradient well and three downgradient wells. Samples must be taken quarterly during the first year and analyzed for the National Interim Drinking Water Regulations, water quality indicator parameters (chloride, iron, manganese, phenols, sodium, and sulfate), and indicator parameters (pH, specific conductance, TOC, and TOX). In subsequent years, each well is sampled and analyzed quarterly for the six background water quality indicator parameters and semiannually for the four indicator parameters. *Groundwater monitoring requirements can be waived* by an owner/operator if a written determination indicating that there is low potential for waste migration via the upper-most aquifer to water supply wells or surface water is made and certified by a qualified geologist or engineer. The determination is not submitted to EPA for verification or approval.	To obtain background water quality data and evaluate whether groundwater is being contaminated.
	The monitoring requirements for a *fully permitted* facility are comprised of a three-part program:	To obtain background water quality data or evaluate whether groundwater is being contaminated (detection monitoring), to determine whether groundwater quality standards are being met (compliance monitoring), and to evaluate the effectiveness of corrective action measures.
	—*Detection Monitoring* — Implemented when a permit is issued and there is no indication of leakage from a facility. Parameters are specified in the permit. Samples must be taken and analyzed at least semiannually. *Exemptions* from detection monitoring program may be granted by the regulatory authority for landfills, surface impoundments, and waste piles with double liners and leak detection systems.	
	—*Compliance Monitoring* — Implemented when groundwater contamination is detected. Monitoring is conducted to determine whether specified concentration levels for certain parameters are being exceeded (levels are based on background concentrations, maximum contaminant levels specified by the National Drinking Water Regulations [if higher than background], or an alternative concentration limit [established on a site-specific basis]). Samples must be taken and analyzed at least quarterly for parameters specified in the permit. Samples must also be analyzed for a specific list of 375 hazardous constituents (Appendix VIII, 40 CFR 261) at least annually.	
	—*Corrective Action Monitoring* — Implemented if compliance monitoring indicates that specified concentration levels for specified parameters are being exceeded (and corrective measures are required). Monitoring must continue until specified concentration levels are met. Parameters and monitoring frequency not specified.	
	—Exemption from groundwater monitoring requirements may be granted by the regulatory authority if there is no potential for migration of liquid to the uppermost aquifer during the active life and closure and post-closure periods.	
—Subtitle D	Groundwater monitoring may be required by State solid waste programs. Federal requirments for State programs *recommend* the establishment of monitoring requirements.	
Safe Drinking Water Act —Part C—Underground Injection Control Program	Groundwater monitoring requirements may be specified in a facility permit for injection wells used for in-situ or solution mining of minerals (Class III wells) where injection is into a formation containing less than 10,000 mg/l TDS. Parameters and monitoring frequency not specified except in areas subject to subsidence or collapse where monitoring is required on a quarterly basis. Groundwater monitoring may also be specified in a permit for wells which inject beneath the deepest underground source of drinking water (Class I wells). Parameters and monitoring frequency not specified in Federal regulations.	To evaluate whether groundwater is being contaminated.

Office of Technology Assessment Summary of Federal Groundwater Monitoring Provisions and Objectives—continued

Statutory authority	Monitoring provisions	Monitoring objectives
Surface Mining Control and Reclamation Act	Groundwater monitoring is specified in Federal regulations for surface and underground coal mining operations to determine the impacts on the hydrologic balance of the mining and adjacent areas. A groundwater monitoring plan must be developed for each mining operation (including reclamation). At a minimum, parameters must include total dissolved solids or specific conductance, pH, total iron, and total manganese. Samples must be taken and analyzed on a quarterly basis.	To obtain background water quality data and evaluate whether groundwater is being contaminated.
	Monitoring of a particular water-bearing stratum may be waived by the regulatory authority if it can be demonstrated that it is not a stratum which serves as an aquifer that significantly ensures the hydrologic balance of the cumulative impact area.	
Toxic Substance Control Act —Section 6	Groundwater monitoring specified in Federal regulations requires monitoring prior to commencement of disposal operations for PCBs. Only three wells are required if underlying earth materials are homogenous, impermeable and uniformly sloping in one direction. Parameters include (at a minimum) PCBs, pH, specific conductance, and chlorinated organics. Monitoring frequency not specified.	To obtain background water quality data.
	No requirements are established for active life or after closure.	
Uranium Mill Tailings Radiation Control Act	Federal regulatory requirements for active mill tailings sites are, for the most part, the same as those established under Subtitle C of RCRA.[c]	To obtain background water quality data, evaluate whether groundwater is being contaminated, determine whether groundwater quality standards are being met, and evaluate the effectiveness of corrective action measures.
	Groundwater monitoring for inactive sites may be conducted if necessary to determine the nature of the problem and for the selection of an appropriate remedial action.	To obtain background water quality data and to characterize a contamination problem.
Water Research and Development Act	The statute does not authorize the development of regulations for sources. Groundwater monitoring may be conducted as part of projects funded by the act.	

[a]The monitoring provisions presented in this table are either: those specified by regulations for existing and new sources, or for groundwater monitoring that may be conducted as part of an investigatory study or remedial action program.
[b]Pesticide manufacturers may be required by EPA to submit groundwater monitoring data as part of the registration requirements for a pesticide product to evaluate the potential for a pesticide to contaminate groundwater.
[c]See app. E.2 for a summary of the differences between UMTRCA and RCRA monitoring requirements.

SOURCE: Office of Technology Assessment.

SUMMARY OF EPA GROUND-WATER MONITORING PROGRAMS

SUBMITTED TO:

U.S. Environmental Protection Agency
Office of Drinking Water
Washington, D.C.

SUBMITTED BY:

Policy Planning and Evaluation, Inc.
McLean, VA

Contract Number 68-01-6827

Four EPA offices, the Office of Drinking Water, the Office of Pesticides, the Office of Emergency Response (Superfund), and the Office of Solid Waste have significant direct or indirect involvement in monitoring ground-water quality. The involvement of the Office of Drinking Water results primarily from its mandate to protect drinking water supplies, to establish drinking water standards, and to evaluate system compliance. Recently reported contamination of ground-water by pesticides in several areas has led to a change in its exposure assessment program. The participation of the Offices of Solid Waste and Emergency Response results from the need to monitor Superfund sites and hazardous waste and Subtitle D facilities. The prime interest of the Office of Toxic Substances is in assessing exposure of people and the environment to toxic chemicals. To date, ground-water monitoring by this office is not of high priority. This chapter discusses the ground-water monitoring programs of these EPA offices. The programs are also summarized in Figure 1.

A. OFFICE OF DRINKING WATER (ODW)

1. Introduction

The Safe Drinking Water Act provides for the safety of drinking water supplies by the establishment of national drinking water quality standards. Under the Act, EPA is responsible for establishing the national standards and the states are responsible for enforcing them. Major provisions of the Act include: the establishment of enforceable primary regulations for the protection of health; non-enforceable secondary regulations relating to taste, odor, and appearance of drinking water; and measures to protect underground drinking water sources and variances and exemptions.

FIGURE 1

SUMMARY OF EPA'S GROUND-WATER MONITORING PROGRAMS

Program	Purpose of Monitoring	Point of Monitoring	Frequency of Monitoring	Contaminants Monitored	Monitoring Responsibility	Coverage	QA/QC Guidance	Data Storage and Access	Remarks
1. **DRINKING WATER**									
a. Regulated Contaminants									
• Microbiological			1 to 500 samples per month depending on the system size and source.	Microbiological					Quarterly samples for systems of less than 3,000 people.
• Turbidity			None	Turbidity					--
• Inorganics			Analysis and sampling to be done every three years. Last done in 1983.	Arsenic, barium, cadmium, chromium, lead, etc.					Sampling and analysis to be repeated every three years.
• Organic Chemicals Other than THMs	Compliance with maximum contaminant levels (MCLs).	Representative of the distribution system.	Analysis to be done at the discretion of the State.	Certain pesticides and herbicides	Public water system	National	Yes	Original data reported to States. Data for systems not meeting an MCL reported to EPA and stored in FRDS.	Organochlorine pesticides and chlorophenoxy acid herbicides covered by the regulation.
• Radioactivity			Compliance based on quarterly samples. Analysis to be done every four years.	Gross Alpha and Beta; total radium; radium 226; strontium 89.90, etc.					Sampling and analysis to be repeated every four years.
• Trihalomethanes			One to four samples per year.	Trihalomethanes					Regulations applicable to systems serving more than 10,000 people.

(Continued)

SUMMARY OF EPA'S GROUND-WATER MONITORING PROGRAMS (Continued)

Program	Purpose of Monitoring	Point of Monitoring	Frequency of Monitoring	Contaminants Monitored	Monitoring Responsibility	Coverage	QA/QC Guidance	Data Storage and Access	Remarks
1. DRINKING WATER (Continued)									
b. Underground Injection Control Program	Monitoring of ambient quality of underground sources of water. In general, monitoring is required only if ground-water is or will be used for drinking water purposes.	In accordance with specific sampling plan for a site or an area.	Class I: Class II: Class V: determined by the state/regional directors. Class III: semi-monthly.	Injection fluids.	Operators of Class I, II, III, and V wells.	--	Yes	Data submitted at time of approval. Primacy States may have their own requirements.	Regulations became effective in May 1984. Data to be reported to States. Class V monitoring at the discretion of the directors.
c. Sole-Source Aquifer Program	To assess danger to public health as part of EIS, or individual project review.	Depends on the water quality problem faced.	Depends on the water quality problem faced.	Depends on the water quality problem faced.	Federal agency whose projects may affect the aquifer, or project applicant.	Federally financially-assisted projects that might impact recharge area of designated aquifers.	--	Reported in EIS, or project application.	EPA assesses the impact of a Federal project on a sole-source aquifer through the NEPA project, or individual project review.
d. Support for Standard Setting									
• Previous Surveys[a]									--
• National Inorganics and Radionuclides Survey	Determine whether a standard should be set.	Representative of the distribution system.	One-time surveys.	Specified in the surveys.	EPA/States	Sampled water systems. Representative of all water systems and problems.	Yes	Data available from the Office of Drinking Water.	Survey completed recently.
• Pesticides Survey									Survey in planning stages (see Pesticides Program).

(Continued)

SUMMARY OF EPA'S GROUNDWATER MONITORING PROGRAMS (Continued)

Program	Purpose of Monitoring	Point of Monitoring	Frequency of Monitoring	Contaminants Monitored	Monitoring Responsibility	Coverage	QA/QC Guidance	Data Storage and Access	Remarks
1. DRINKING WATER (Continued)									
e. Contamination Incidents	1) Define the scope and magnitude of contamination. 2) Assess future expansion.	--	Depends on the site requirements.	Those affecting public health.	State, generally	Specific incidents.	Yes	None	Regional drinking water offices help hazardous waste and superfund programs when public water systems have been contaminated.
2. PESTICIDES PROGRAM									
a. Nationwide Pesticide Groundwater Contamination Study	Detect problems of direct exposure.	← Study in the planning stages (10-50 pesticides). →			EPA. State and county governments will probably participate.	1,500 - 3,000 groundwater samples expected.	Yes	Will be stored in EPA computers.	Primary office responsible: ODW.
b. USGS Regional Assessment Program	Determine the nature and extent of contamination in agricultural areas.	← Study in the planning stages. →		Pesticides and organics.	USGS	Florida, Kansas, Nebraska, California, and Louisiana/Mississippi (tens to thousands of square miles for each assessment).	Yes	--	Will take four years to complete. Program supposed to cover organics and other pollutants.

(Continued)

SUMMARY OF EPA'S GROUND-WATER MONITORING PROGRAMS (Continued)

Program	Purpose of Monitoring	Point of Monitoring	Frequency of Monitoring	Contaminants Monitored	Monitoring Responsibility	Coverage	QA/QC Guidance	Data Storage and Access	Remarks
2. PESTICIDES PROGRAM (Continued)									
c. Single Chemical Leaching Studies	Registration of pesticides.	← Laboratory studies. →			Registrant	Local	Need for a monitoring guidance document.	--	--
d. Collaboration with States and/or Pesticide Hazard Assessment Projects	Assessment of ground-water contamination.	← Depends on local conditions. →			States and USGS	--	--	--	--
e. Dougherty Plains Field Validation Study	← Predict pesticide movement and fate. Project involves controlled application of two pesticides, aldicarb and metolachlor. Project initiated by ORD to validate a model. →								
3. SOLID WASTE PROGRAM									
a. Superfund Sites	Clean-up with superfund.	--	Depends on specific site requirements.	Those affecting public health/ environment.	State, generally	--	Yes	--	--
	Enforcement.	--	Depends on specific site requirements.	Those affecting public health/ environment.	Owner/ Operator	--	Yes	--	Monitoring requirements specified in the consent decree.

(Continued)

SUMMARY OF EPA'S GROUND-WATER MONITORING PROGRAMS (Continued)

Program	Purpose of Monitoring	Point of Monitoring	Frequency of Monitoring	Contaminants Monitored	Monitoring Responsibility	Coverage	QA/QC Guidance	Data Storage and Access	Remarks
3. SOLID WASTE PROGRAM (Continued)									
b. Active Hazardous Waste Facilities	Detect contamination.	Uppermost aquifer immediately beneath edge of waste.	Quarterly to establish background; semiannual for detection.	Specified indicator parameters (see reg.).		--	--	--	--
	Assess extent of contamination (assessment monitoring).	Uppermost aquifer immediately beneath edge of waste.	Specified in plan (minimum quarterly).	All Appendix VIII of 40 CFR 261.	Owner/ Operator	--	--	--	--
	Monitor compliance with ground-water protection standard or corrective action plan.	Uppermost aquifer immediately beneath edge of waste.	Specified in plan (minimum quarterly).	Specified Appendix VIII constituents quarterly, all constituents annually.		--	--	--	--
c. Non-Hazardous Waste Facilities (Subtitle D is a state program)	Ensure guidelines for Subtitle D facilities are not exceeded.	Specified by the State.	Specified by the State.	In general, contaminants regulated under the Safe Drinking Water Act.	Owner or operator	Facilities	No	None at the Federal level.	--

(Continued)

SUMMARY OF EPA'S GROUND-WATER MONITORING PROGRAMS (Continued)

Program	Purpose of Monitoring	Point of Monitoring	Frequency of Monitoring	Contaminants Monitored	Monitoring Responsibility	Coverage	QA/QC Guidance	Data Storage and Access	Remarks
4. TOXICS PROGRAM	No specific ground-water monitoring program mandate. Toxics program supposed to assess exposure to toxic substances; exposure through ground-water is not a major concern of the program.								

[a] Six surveys have been conducted in the past:

(1) National Organic Reconnaissance Survey (1975);
(2) National Organic Monitoring Survey (1976-1977);
(3) National Screening Program for Organics in Drinking Water (done by SRI International between 1976 and 1981);
(4) Community Water Supply Survey (1978, . . .);
(5) The Rural Water Survey (1978); and
(6) The Ground-water Supply Survey (1980-1981).

Section 1445 of the Act explicitly authorizes the Administrator to require monitoring for a wide variety of purposes, namely: to establish and determine compliance with regulations; to administer financial assistance; to evaluate health risks of unregulated contaminants; and to advise the public of such risks. Monitoring authorization is also implied in Section 1450(a)(1), which grants to the Administrator broad authority to prescribe such regulations as are necessary or appropriate to carry out his functions. In general, monitoring is designed to collect data that is representative of the quality of water in the distribution system. Monitoring activities pursuant to these authorities may be grouped into five broad categories:

- support for standard setting;
- evaluation of system compliance with drinking water standards;
- monitoring associated with contamination incidents;
- underground injection control program monitoring; and
- other monitoring activities.

The categories are discussed below.

2. <u>Support for Standard Setting -- Public Water Supply Systems</u>

The goal of this activity is to provide occurrence data on contaminants under consideration for standard-setting for the Public Water Supply Program. The data are used to help determine whether the contaminant occurs sufficiently frequently and at high enough levels that setting a standard is warranted; to estimate national economic impact of prospective regulations; and to estimate the reduction in exposure that would result from regulation. In the case of carcinogens, the data enable EPA to project the reduction in excess cancer deaths.

The Phase I revision to the National Interim Primary Drinking Water Regulations addresses the volatile synthetic organic chemicals most commonly found in drinking water. The Phase II and III revisions and future changes will be supported by the National Inorganics and Radionuclides Survey (NIRS) and by the National Pesticides Survey.

Several surveys, of differing scope and with a wide range of goals, have been supported by ODW over recent years.[1] Other surveys, now in the planning stage, will support EPA's regulatory activities in the future. In addition to these efforts, the National Inorganics Survey, started in the summer of 1984, will cover a wide range of unregulated inorganic contaminants, in addition to a number of inorganics and radionuclides. The National Pesticides Survey will come too late for Phase II, but it will provide a systematic database on drinking water contamination with pesticides for use in future standard-setting activities.

3. Evaluation of System Compliance with Drinking Water Standards

The goal of this program is to provide data and information on the extent to which systems are meeting the requirements of the Safe Drinking Water Act. As part of the Public Water System Program, EPA develops standards, called Maximum Contaminant Levels (MCLs), for contaminants which may have an adverse effect on health. Should a state show that it has standards and enforcement authorities that are at least as stringent as those promulgated by EPA, primary enforcement responsibility ("primacy") may be delegated to the state. The state then accepts day-to-day responsibility for assuring that monitoring is conducted and that standards are met.

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[1]National Organics Reconnaissance Survey; National Organics Monitoring Survey; SRI-Pesticides Survey; Rural Water Survey; Community Water Supply Surveys (2); and National Screening Program for Organics in Drinking Water; Groundwater Supplies.

The monitoring data are of limited usefulness to the Ground-water Office for the following reasons:

- The data collected by public water systems must be "representative of the distribution system;" hence, if water obtained from ground-water sources is treated, the monitoring data will not be representative of the quality of ground-water. In addition, if taken from multiple wells at multiple depths, the data will not be exactly representative of ground-water.
- Only when water systems violate the drinking water standards are they required to report to EPA. (These data are stored in the FRDS database.) The "raw" data are kept by owners and operators of the water systems; states get only the summary data.
- Only for trihalomethanes and microbiological contaminants, the data are collected on a continuous basis. The data measuring inorganics and radioactivity levels are collected, in general, every three and four years, respectively.

4. Contamination Incidents

Ordinarily, state and local governments (frequently supported by EPA grant funds) are the primary agencies to deal with incidents of contamination. The Regional Offices are involved directly in non-primacy states and in a technical assistance mode in primacy states. A number of problems exist in this approach to contamination incidents: (1) levels of concern vary between states, resulting in non-uniform and often inconsistent monitoring approaches; (2) due to the short time required to respond to an emergency, inadequate attention is often paid to quality assurance (QA); (3) inadequate analytical methodology often exists; and (4) monitoring data which are generated are stored at the state and local level, and cannot be easily accessed.

5. Underground Injection Control Program

The Underground Injection Control program is a Federal/state program designed to control the subsurface emplacement of fluids by well injection in a way which will prevent the endangerment of underground sources of drinking water. The program was established by the Safe

Drinking Water Act of 1974 and provides for authorization of well injection by either permit or rule. Persons operating injection wells under either scheme are required by regulation to conduct certain monitoring and report the results to either the state or EPA.

Injection wells have been segregated in the regulations into five classes, as follows:

Class I: hazardous waste and other industrial or municipal wells injecting below the deepest underground source of drinking water (USDW);

Class II: injection wells associated with oil and gas production or storage;

Class III: mineral extraction wells;

Class IV: hazardous waste or radioactive waste disposal wells injecting into or above a USDW; and

Class V: injection wells not included in Classes I-IV.

The UIC regulations became effective in May 1984. Because of a lack of experience with the program, the quality and quantity of groundwater data that can be collected cannot be predicted accurately. However, the following problems will limit the data available:

- most operators will submit monitoring data only when they obtain their permits;
- only Class III well operators are required to monitor groundwater quality on a continuous basis; monitoring by other operators is generally at the discretion of state authorities; and
- primacy states are not required to submit even summary groundwater quality data to EPA.

6. Monitoring in Support of the Sole Source Aquifer (SSA) Program

The SSA program applies to areas where one aquifer is the principal source of drinking water which, if contaminated, would create a significant hazard to public health. Once designated a sole source aquifer, no commitment of Federal financial assistance may be made for a project which may contaminate the aquifer through the recharge zone. In order to effectively manage the program, monitoring of ground-water quality is conducted, the nature of which depends on the ground-water quality problems faced. The monitoring is generally conducted by other Federal agencies as part of the NEPA process, with limited direct participation by EPA.

7. Special Surveys

a. The Surface Impoundment Assessment (SIA)

The original SIA was intended to provide a preliminary approximation of the contamination potential of surface impoundments -- pits, ponds, and lagoons used for waste treatment, storage or disposal by industry and municipalities. This study revealed that there are more than 180,000 impoundments, almost half of which are located over thin or permeable unsaturated zones which are vulnerable to contamination. Most of these impoundments are unlined, and about one-third of the industrial sites contain wastes which may be hazardous. At the direction of the Administrator, EPA is now designing a follow-on SIA which will include ground-water monitoring, which the original survey was not designed to do. It will include impoundments not covered by the Hazardous Waste program. (Those that do contain hazardous wastes are required to monitor under the hazardous waste regulations.) In view of the expense of drilling ground-water monitoring wells, it is likely that monitoring will be conducted at selected sites where monitoring or drinking water wells already exist.

b. The Rural Water Survey

The Rural Water Survey, mandated by Congress, focused on individual and small cluster systems serving rural areas. It was intended to shed light on matters such as the number of rural residents inadequately served by a public or private water system; the number exposed to health risks due to inadequate supplies; and the number which actually contracted illnesses which could be attributed to such supplies. The survey, which provides the first comprehensive, statistically valid picture of rural water systems, showed, among other things, that approximately 25% of the surveyed households exhibited some evidence of bacterial contamination. It also confirmed the widely held view that contamination rates were lowest in public water supplies and highest in individual systems not meeting current construction standards, e.g., cisterns and dug wells. Properly constructed wells had lower rates of contamination in their water supplies than improperly constructed ones, but higher rates than public water systems.

B. OFFICE OF PESTICIDES

1. EPA's Mandate in Registering Pesticides

Under the amended Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), EPA may register and continue in effect the registrations of pesticide products that do not pose the risk of unreasonable adverse effects to man, other non-target species, or the environment. In making this statutory finding, EPA is to consider both the potential risks and benefits of each pesticide use. In those instances where risks resulting from use exceed the benefits obtained, EPA may restrict or cancel the registered uses.

Exposure information is needed by EPA:

- to predict resulting risks from use when granting a registration for a pesticide product containing new active ingredients;
- to predict the resulting incremental risk expected from a new use of an existing pesticide product;

- after registration, to ensure that unreasonable adverse effects from the product's use do not occur from unexpected accumulations of pesticides in humans or the environment or by unexpected or unanticipated routes of exposure. Exposure information is critical to decisions to remove pesticides from the market or otherwise restrict their use; and

- to determine baseline concentrations and trends over time to support the Agency's overall mission to protect public health and the environment, to detect emerging pesticide problems, and to assist in determining the impact of program policy decisions.

2. FIFRA Monitoring Mandate

Sections 20(b) and (c) of the amended FIFRA require the EPA Administrator to formulate a national plan for monitoring pesticides and to conduct any pesticide monitoring activities necessary to complement the FIFRA and the national monitoring plan. Specifically, the FIFRA states:

> "20(b) NATIONAL MONITORING PLAN. - The Administrator shall formulate and periodically revise, in cooperation with other Federal, State, or local agencies, a national plan for monitoring pesticides.
>
> "20(c) MONITORING. The Administrator shall undertake such monitoring activities, including, but not limited to, monitoring in air, soil, water, man, plants, and animals, as may be necessary for the implementation of this Act and of the national pesticide monitoring plan. The Administrator shall establish procedures for the monitoring of man and animals and their environment for incidental pesticide exposure, including, but not limited to, the quantification of incidental human and environmental pesticide pollution and the secular trends thereof, and identification of the sources of contamination and their relationship to human and environmental effects. Such activities shall be carried out in cooperation with other Federal, State, and local agencies."

In addition to the above guidance, Congress has more recently expressed interest in pesticide monitoring and completion of a monitoring plan, as reflected in the House Committee on Agriculture

Report No. 98-104.[2] As part of that committee report, the committee urged "EPA to develop a meaningful national monitoring plan, which shall include provisions for the collection, storage, interpretation, and dissemination of data on the quantities of pesticides used, by active ingredient, by crop, and by geographical area. In addition, the plan should address measures to collect data on human exposure to pesticides. Likewise, the plan should include provisions to monitor indirect exposure to pesticide residues in the environment. This data should be collected and stored in a fashion which maximizes the ability of the agency to appraise trends in relevant indicators of pesticides use and the levels of pesticides in man, on food, or in the environment."

3. Ground-water Monitoring Activities

The Office of Pesticide Programs (OPP) has been involved in a number of studies to monitor pesticide contamination of ground-water. These studies can be categorized by the number of pesticides monitored and the geographical extent of the study. The first category involves studies which were conducted by OPP because of findings of specific pesticide contamination in a single area, such as aldicarb on Long Island; ethylene dibromide (EDB) in Seminole County, Georgia; and EDB and dibromochloropropane (DBCP) in a well at Kunia, Hawaii. Also included in this type of study are several projects being conducted by the Office of Research and Development (ORD) to gather field data for model validation and risk assessment, such as the Dougherty Plains Field Validation Study and the Congressionally-mandated study of Temik (aldicarb) in Florida.

In a second category of study, state agencies have conducted monitoring surveys to assess water quality for a number of pesticides in

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[2] U.S. Congress. 1983. House of Representatives Committee on Agriculture Consideration of H.R. 2785, 98th Cong., 1st Sess., 11 May, 1983, P. 6-7.

a limited geographical area and have contacted OPP for technical guidance or analytical support. Examples of this type are the Central Sands survey in Wisconsin for multiple chemicals; the California study for DBCP, carbofuran, EDB, and simazine in four aquifers; and the U.S. Geological Survey (USGS) study in southwestern Georgia for a number of pesticides.

A third category of study has involved the assessment of a single chemical in ground-water in multiple locations, such as the DBCP survey in the southeastern United States and the survey for aldicarb in drinking water in selected areas of the United States.

A fourth category of study involves evaluating the extent of ground-water contamination by multiple chemicals in multiple locations, such as the nationwide drinking water survey, being developed jointly by the Office of Drinking Water and OPP, and the USGS Regional Water Quality Assessments currently in progress.

a. OPP/ODW Nationwide Pesticide Ground-water Contamination Study

This study is in its earliest planning stages. The two goals of the survey are: (1) to identify pesticide contaminants and determine their approximate concentrations and frequencies in water supplies, and (2) to relate findings of pesticide contaminants in underground water supplies to agricultural use patterns for these chemicals. We estimate that 1,500-3,000 ground-water samples will be collected. Approximately one year will be required to design this statistical survey. Analyses for 10-50 pesticides will be undertaken.

b. USGS Regional Assessment Program

The regional assessments will determine the nature and extent of the ground-water contamination problem in agricultural areas (in part) in Florida, Kansas, Nebraska, California, and Louisiana/ Mississippi. The study areas in the regional assessments may vary in size from a few tens to a few thousand square miles, and will be chosen for their representative climatic and geohydrologic environments.

c. Single Chemical Ground-water/Leaching Studies

These are required in two types of situations -- during the routine registration review process and for potential high hazard, special review situations.

d. Collaborative Projects and Technical Assistance

Much of what OPP has done in the last few years falls under this heading. This area can run the gamut from basic processes research to emergency response situations.

e. Dougherty Plains Field Validation Study

One of OPP's highest priorities for pesticide research is the field validation of mathematical models used to predict pesticide movement and fate. The Dougherty Plains study involves the controlled application of two pesticides -- aldicarb, a mobile pesticide, and metolachlor, a relatively non-mobile pesticide -- and the subsequent monitoring for residues in the soil column and ground-water. The field data of this five-year project (1983-1987) will be used to validate the leaching predictions of the Pesticide Root Zone Model (PRZM).

4. Data Processing and Data Analysis Tasks

Ground-water monitoring generates quantitative measurement data through studies conducted by the registrants, OPP, states, and other organizations.

Field monitoring data generally are not input to an automated system for storage and retrieval, but are retained in paper form as reports of studies. All registrant-submitted studies are stored as part of the total database in support of each registration. A single study may support more than one registration. A complete, automated inventory of all submitted studies, which includes ground-water monitoring studies, is maintained for all registration data. A cross referencing system by chemical, registration number, registrant, pesticide use, etc., is maintained in automated and microfiche form. The automated system allows access both to hard copy summaries in the form of reviewer reports and to the locations within OPP files where the actual studies may be found. Studies submitted by registrants are generally protected as confidential business information and may not be released. The existing system does not maintain any inventory of studies which were not submitted by registrants, even if such studies are used in evaluating ground-water contamination potential.

Several systems of numeric identification for pesticides are used within OPP. The primary chemical numbering systems in OPP predate the Chemical Abstract Service (CAS) system which is used practically universally elsewhere. CAS numbers have been assigned to a majority of the registered pesticides but the task has not been completed. Once all pesticides have been assigned numbers, interaction between OPP data systems and outside data systems will be possible.

The data from the ODW, USGS, and state compliance monitoring activities will be managed using the existing capabilities of the EPA STORET system operated by the Office of Water. STORET is an automated database which provides the technology to store, retrieve, and sort large bodies of data and perform complex analyses using mapping capabilities and a number of ancillary databases.

The uses of ground-water monitoring data in evaluating pésticides have been discussed before. Once program improvements have been completed, information from ground-water studies will be used (1) to develop information on regional and nationwide trends, (2) to identify needs for more intensive enforcement, (3) to support regulatory actions, and (4) to measure program performance.

C. OFFICE OF EMERGENCY RESPONSE (SUPERFUND)

1. Introduction

The Superfund program's primary responsibility is to protect public health and welfare and the environment by responding to actual or threatened releases of hazardous substances or contaminants. Although the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) does not mandate environmental monitoring, the program requires extensive environmental data in order to fulfill its response mission.

The magnitude of the resultant need for monitoring over the next several years is driven by the size of the universe of uncontrolled hazardous waste sites and other releases. At the present time, EPA's Emergency and Remedial Response Information System has an inventory of about 16,500 sites which may need Superfund action. Each site may undergo a preliminary assessment and site inspection to determine the extent of endangerment to the public health and the environment and appropriate response actions.

By February 1984, 7,300 of approximately 15,000 preliminary assessments had been completed, with the remainder scheduled for completion by FY 1986. Work had been completed on 2,200 site inspections, with another 6,000-8,300 scheduled for completion by FY 1987. The results of these site inspections will determine the number of remedial investigations and feasibility studies to be undertaken.

The Superfund monitoring efforts not only are extensive in scope but also complex because of the numerous governmental entities involved under CERCLA and the National Oil and Hazardous Substances Contingency Plan (NCP, 40 CFR 300). For example, EPA Headquarters, as the national Superfund manager, works with all 10 regions and the states to establish program policies and priorities and to ensure coordination with other

EPA programs such as RCRA and the development of a ground-water protection strategy.

Regional offices always have played a major role in Superfund's environmental monitoring. For instance, in many regions, the Environmental Services Division is heavily involved in both Superfund field and laboratory activities. This effort involves site screening/inspection efforts, enforcement sampling, and quick turnaround laboratory analyses. With expanded delegations, regions now will have the primary responsibility for making response decisions.

States have been key participants in the program since its inception. This state participation may occur on an individual basis or through the Regional Response Team (RRT). At the present time, states may conduct the preliminary assessments and site inspections using RCRA 3012 funds transferred to the Superfund program. States additionally may lead all other phases of response, from remedial investigation to implementation of the remedial action. Moreover, states must assume responsibility for post-response monitoring, where required, within one year of the completion of the remedial response. Some regional offices currently are providing the states with training on QA/QC procedures. In addition, EPA's goal is to have in place, by FY 1986, a system for ensuring emergency response preparedness at both the state and local level.

2. Description of Data Needs

Regional and Headquarters Superfund personnel need sufficient, reliable data on which to base the following types of site-specific response decisions:

- determination of whether an endangerment to public health or the environment exists from a hazardous substance release or threat of release and determination of the appropriate type of response (i.e., removal or remedial action);
- selection of appropriate cleanup methods;

- establishment of post-response monitoring requirements;
- determination that the response has been appropriate, the endangerment mitigated; and
- determination that the response is effective in the long term.

Data collection in the Superfund program, therefore, is primarily site-specific, covering both sampling of media and sources of contamination (e.g., drums, storage tanks) as well as measurement of the physical, biological, geological, hydrological, and chemical characteristics of the site and its environs.

a. Monitoring During Removal Response, Remedial Design, and Remedial Action

Environmental sampling and testing is an important part of the actual removal or remedial action because conditions at the site may change. For example, contaminants have the potential to migrate within the site and off-site because of weather conditions or even the cleanup activities themselves. Thus, for both types of responses, monitoring of the environmental conditions throughout the cleanup may be necessary to confirm or change the scope of the activities depending on site conditions. For removals, monitoring data may be especially helpful to the OSC in determining whether the endangerment has been mitigated and termination of the response is appropriate.

Under the direction of the lead Federal or state agency, monitoring during response may be conducted either by the government or its contractors. For example, the ERT, a component of the Superfund program office, can activate the Environmental Emergency Response Unit (EERU) -- a cooperative effort between ERT and the Oil and Hazardous Materials Spills Branch of the Office of Research and Development -- to deploy a mobile analytical laboratory to ensure that any discharge of treated effluent from a hazardous waste lagoon meets state water quality standards.

b. Establishment of Post-Response Monitoring Requirements

Both removal and remedial responses may require post-cleanup operation and maintenance (O&M) that may include long-term monitoring of site conditions to determine the effectiveness of the cleanup. The OSC or RSPO, in consultation with RRT members, sets the requirements on the basis of the conditions specific to each site.

All O&M requirements for fund-financed responses should be identified in the respective removal (action memorandum) and remedial (record of decision) approval documents. For removals, the state must assume responsibility for O&M no later than six months after the removal begins. For remedial responses, EPA will share the costs of O&M with the state for one year following completion of response, after which the state assumes full responsibility. O&M requirements for a private party cleanup taken under enforcement procedures are incorporated into a consent order or decree.

c. Monitoring for Enforcement Actions

In addition to providing for direct Federal or state fund-financed responses, CERCLA authorizes EPA to take enforcement actions to obtain private responses and/or to recover the costs of fund-financed responses. Both types of enforcement activities either require new environmental monitoring or utilize the data from the monitoring efforts already described.

For example, EPA may either issue a unilateral administrative order or enter into a court-approved consent decree for a private party to conduct a preliminary assessment, site inspection, remedial investigation, or post-response monitoring. The private party must prepare and submit to EPA for approval a sampling plan that is consistent with EPA's QA/QC guidelines. If EPA or the state conducts a fund-financed response and then seeks cost recovery, all of the data collected during the response phases may be used in the case.

3. Design of Data Collection Effort

As noted previously, the Superfund program collects and uses site-specific environmental data to support response decisions and activities. A well-designed plan for conducting sampling and environmental measurement is the first step in promoting reliable site-specific data; hence many sampling plans are site-specific.

While neither CERCLA nor the National Oil and Hazardous Substances Contingency Plan prescribe specific requirements for sampling or other environmental testing and measurement, section 300.66(c) of the NCP establishes some general guidelines. Under these guidelines, the collection of samples should be minimized during inspection activities to evaluate the site and determine appropriate response.

4. Data Storage and Handling

The Superfund program compiles and generates a vast array of site-specific data, which is collected and stored in a variety of paper files and automated systems in both regional and Headquarters offices.

a. Paper Files

All of Superfund's environmental monitoring data are located in hard copy reports which are stored in files in the ten regions and EPA Headquarters. Each region has complete files (administrative and environmental data) for each response activity undertaken in the region. Key administrative documents such as action memoranda, cooperative agreements, or pollution reports (POLREPS) are also stored in site files at EPA Headquarters.

b. Automated and Manual Systems/Databases

Two automated databases are the Emergency and Remedial Response Information System (ERRIS) and the National Priority List Technical Database.

ERRIS is a computerized inventory of all sites which have come to Superfund's attention and may require remedial response. It contains descriptive and location information about the site, information on administrative incidents, and Hazard Ranking Scores (HRS). Responsibility for data entry rests with the regional offices. An improved ERRIS (ERRIS II) will update the current inventory when it becomes available.

The National Priority List Database currently contains HRS data for 691 sites and resides and is maintained on Mitre Corporation's IBM 4341. Access currently is limited to Mitre staff under contract to OERR, but OERR will have direct access once it completes copying of the data onto EPA's IBM computer.

Additional systems are the automated Project Tracking System (PTS) for remedial response, and the manual Removal Tracking System (RTS) for removal actions. PTS contains program management data, such as obligations, estimated costs, and actual/planned start and completion dates. RTS has similar program management data as well as descriptive data about the site and its environs, the release, the threats, and response progress.

c. Future Needs

At the present time, OSWER/OERR is undertaking a needs survey to assess the future configuration and contents of Superfund databases and systems. This survey will identify both regional and EPA Headquarters needs for data and the status of current methods for managing that data. Based on the recommendations in the needs survey, OSWER/OERR will identify some additional projects.

D. OFFICE OF SOLID WASTE (RCRA)

1. Regulation of Hazardous Waste Facilities

a. Background

Environmental monitoring activities in support of EPA's program for the management and control of hazardous waste are twofold in purpose. Environmental monitoring data are required to establish and refine the national hazardous waste regulatory program. Such data are also required to measure compliance with the regulatory program, and thereby measure the effectiveness of the program in achieving protection of human health and the environment.

Performance monitoring activities help to verify whether or not a waste management facility or technology operates as it should. These activities include:

- characterizing the amounts, types, and hazards of residuals left after waste treatment/destruction (e.g., incinerator trial burns);
- detecting facility/technology failures and the nature/hazard of contaminants released (e.g., soil pore and ground-water monitoring at land treatment and land disposal facilities); and
- monitoring the effectiveness of corrective measures instituted in response to facility/technology failures (e.g., ground-water monitoring).

b. Status of Monitoring

While activities related to the assessment of the RCRA regulatory program's effectiveness are limited, in comparison to OSWER's "identification/characterization" activities, they are extremely important in fulfilling EPA's responsibilities under RCRA.

This enforcement responsibility is accomplished, to a large extent, through the gathering and analysis of environmental monitoring data. Some of these data are collected directly by the Agency, while other data are provided to the Agency and authorized states by the regulated community (which includes approximately 50,000 generators, 12,000 transporters, and 7,500 management facilities), in accordance with promulgated regulations and facility permit conditions.

To date, OSWER has directed little of its limited resources (and those of authorized state hazardous waste management agencies) to assessments of the RCRA program's effectiveness in terms of trend analyses of ambient environmental quality.

For landfills, surface impoundments, and land treatment facilities, the major performance monitoring activity is ground-water monitoring. There are two distinct sets of ground-water monitoring requirements. The first are those requirements set out under the interim status facility standards (40 CFR Part 265, Subpart F). These regulations establish minimum requirements on the number of wells required, their positioning relative to the waste disposal area, the frequency of sampling required, and test procedures to be followed. The regulations also specify the constituents for which analysis must be performed. Ground-water monitoring is required to establish background and subsequent levels of specified parameters, and downgradient water quality. The monitoring must continue for the operating life of the facility and, for disposal facilities, the 30-year post-closure period. Additional monitoring is required if downgradient contamination is detected. No corrective action is required under interim status. Data reporting requirements are also established.

The second set of requirements pertain to fully permitted facilities. 40 CFR Part 264, Subpart F specifies ground-water monitoring requirements for permitted facilities analogous to interim status monitoring. Specific parameters subject to data reporting requirements can be found in these regulations. Permitted facilities are required, however, to implement corrective actions if monitoring detects contamination in excess of the facility's ground-water protection standard.

c. Extent Monitoring Strategy Needs Are Being Met

How well and to what extent OSW's RCRA monitoring program is proceeding is a mixed picture. For example, ground-water monitoring requirements have been developed, but some data, yet unconfirmed, suggest that full compliance with these requirements has not occurred at all facilities. In addition, some data submitted have been found to be incomplete or are of insufficient quality and accuracy. Other problems include a continuing need to ascertain appropriate testing methods, the lack of methods for some parameters, and the need to ensure the proper analysis and use of these data.

Problems with sampling and testing methods limit the analysis. While many methods exist, missing methods, non-standardized methods, and methods that are too costly to run are sometimes encountered in both waste characterization and technology performance monitoring. Addressing as many of these issues as possible needs to be and is an important future monitoring strategy activity. Most of the EPA's QA/QC activities are, in fact, directed to this end.

d. Responsibility for Monitoring

Technology performance monitoring is principally the facility owners/operators' responsibility. Largest of these are the ground-water monitoring requirements. These requirements specify the minimum number of wells required, their location relative to the facility, the frequency of sampling needed, and what constituents must be sampled. Ground-water monitoring records must be kept at the facility for a period of six years. Under the interim status standards, selected data must also be reported to the EPA or authorized state. Permitted facilities need not routinely report their data to the EPA or the state (unless the permit so requires), but the data may be requested and must be provided.

e. RCRA Monitoring Data Storage Needs

For ground-water monitoring data, the Agency, as yet, has no centralized storage system for these data. This information is usually kept by the permittee and only sent to the EPA or the state when requested, or when required in the facility's permit. OSW is currently examining its needs (and states' needs) and options for automated storage and manipulation of these parametric data. No decision has been made to date.

f. Enforcement

There has been some evidence to suggest that facility owner/operator noncompliance with ground-water monitoring requirements may be quite significant. This problem is compounded by the fact that Agency-approved methods are not required to be used, resulting in inconsistent application of standards and action limits. Also, action thresholds have not been established for all parameters. These enforcement-related issues are important priorities within the RCRA monitoring strategy.

2. Regulation of Subtitle D Facilities

In general, Subtitle D establishes provisions for state regulation of all types of non-hazardous solid wastes, including municipal and industrial landfills, municipal and industrial surface impoundments, sewage sludge landspreading facilities, industrial land treatment facilities, and others. Other facilities, including ocean dumping sites and facilities for disposal of oil and gas brines and dredging fill material, are not covered by Subtitle D, but may be related to state solid waste regulatory programs.

The criteria developed by EPA under Subtitle D allow facilities to be classified as acceptable or unacceptable. The classification is based on the extent to which the facilities have characteristics that abate health and environmental effects relating to the following criteria:

- floodplains;
- endangered species;
- surface water;
- ground-water;
- food-chain cropland;
- disease;
- air; and
- safety (including gases, fire, bird hazard to aircraft, and public access).

According to the available data, the following conclusions can be drawn about state regulation of these facilities:

- State agencies have evaluated facilities using the Subtitle D ground-water criterion to varying degrees. According to the available data, evaluation of surface impoundments and landspreading facilities using the ground-water criterion may be generally poor; and
- State agencies appear to be aware of the presence of ground-water protection factors (monitoring and leachate control) at solid waste landfills, but the percentage of such facilities is very low for some states. State agencies appear to have less knowledge on the presence of monitoring and leachate control at surface impoundments and sludge facilities. Where state agencies have information, they have reported a very low use of monitoring and leachate control at these facilities.

In general, states do not have ground-water monitoring data for most Subtitle D facilities. Indeed, very few states have evaluated these data.

E. OFFICE OF TOXIC SUBSTANCES (OTS)

1. Current Status

Monitoring is one of the four major elements in the OTS approach to integrated, multimedia exposure assessments. Exposure assessments can be conducted during early problem definition for potential problems or during intensive investigations for regulatory action. The other three elements are identification of sources or release, identification of populations at risk, and characterization of the properties and fate of a chemical. A variety of literature resources, databases, and models on release and transport are used to examine systematically the likelihood of exposure through any of seven routes (occupational, consumer, transportation, disposal, food, drinking water, and ambient media).

During the OTS exposure/risk assessment process, a chemical is examined to determine whether it poses a risk to the public health or the environment and should be regulated. Even if the chemical in question meets or exceeds some criteria for unreasonable risk, information on the manner and extent of use, and the cumulative exposure likely to occur, is also needed. These two separate pieces of information are then pulled together into one package called a risk assessment. If a chemical is determined to be a risk, regulatory or non-regulatory actions are selected and implemented to limit exposure to the public and the environment. Such action by the EPA is called a control action. The Agency then tries to measure compliance with the resulting control action by means of compliance monitoring.

In practice, the process has a severe limitation. The available data for assessment of the risk posed by a chemical often consist exclusively of toxicological data. Reliable exposure data are often not available and surrogate information such as production data are inadequate or misleading. Very little, if any, ground-water data are collected by OTS.

2. Statutory Basis

The Toxic Substances Control Act (TSCA) holds chemical producers responsible for generating adequate data to assess the risk potential of their own chemicals (Section 2). Congress acknowledged that industrial chemicals are made for an enormous and ever-changing variety of uses. For this reason there is no straightforward process of registration and no concomitant requirement for risk assessment information. Congress also assumed that only a few of the thousands of general industrial chemicals might possibly present an unreasonable risk and that the risk should be defined by responsible producers and the EPA acting in concert through public sharing of risk information.

All of the sections requiring submission to EPA/OTS of hazard and exposure information (Section 5 for new chemicals, Section 8 reporting on existing chemicals, and Section 4 testing by industry) provide that a public record be maintained and available. Section 14 specifically mandates that health and safety data be disclosed.

TSCA requires that submitted data be demonstrably "reliable and adequate" for the purpose of risk assessment (Section 3(12)). To ensure reliable and adequate data, the Act requires OTS to specify or develop the methods and techniques for data generation under Section 4 test rules. Under Section 4(b), a process of generic standard-setting for test methods to be used by industry has been established, which now can be applied to exposure studies. Under Section 10, the EPA is enjoined to develop monitoring data, techniques, and instruments which may be used in the detection of toxic chemical substances (Sections 10(a) and (d)). It was assumed that EPA, under TSCA, would have to deal with a wide variety of chemicals, conditions of usage or exposure, and receptor media, human and environmental. For this reason, dissemination of methods and techniques of testing, analysis and quality assurance are as important to prevention of risk as are the data results themselves.

January 9, 1985

Ground Water Monitoring Task Force
Mission Statement

Although the basic ground water monitoring requirements have been in place since 1980, EPA has experienced significant difficulty in gaining compliance with these rules by the regulated community. Compliance is important because without adequate monitoring, it is not possible to determine whether facilities are leaking sufficiently to pose a threat to human health and the environment. Secondly, wastes from CERCLA clean-up activities are going to these facilities. Unless the Agency knows through ground water monitoring whether these facilities are adequately protective, it may be necessary at a later time to move these wastes yet again at significant added cost.

As a result, the Administrator has established a Task Force to evaluate the level of compliance and deal with the causes of poor compliance. There are two parts to this effort.

I. Evaluate the status of ground-water monitoring at existing commercial hazardous waste land disposal facilities to determine the following:

   a. compliance with the regulations,

   b. level of contamination in the ground water, if any, and

   c. compliance with the ground water aspects of the Superfund off-site policy.

The effort will include review of existing documents and field inspections and sampling. Decisions will be reached by consensus between teams of experts from the State and region involved and a core team that will be involved in all evaluations. The core team will include members from States and regions as well as from Headquarters. This work is expected to take about one year.

II. Produce strategies covering the following:

a. Evaluate existing and planned guidance documents around EPA, determine consistency with the regulations and with each other, evaluate strengths and weaknesses, determine gaps, propose programs to optimize and provide expanded guidance where called for.

b. Determine audiences in EPA and States that require training and the content of the training needed, evaluate existing and planned training programs, determine shortcomings and gaps, and propose programs to optimize training.

c. Identify knowledge gaps that inhibit adequate implementation of the rules, and working with the Hazardous Waste Research Committee develop a program to address these needs.

d. Identify problems with the regulations that inhibit implementation or do not adequately protect human health or the environment, estimate relative importance of these problems vis a vis other activities on the regulatory development agenda so that decisions can be made on the level of resources to apply to fixing them.

This work will be conducted at Headquarters by a dedicated team with input from the facility assessment core team, regional and State officials, and other EPA offices. It is expected to take four to six months to conclude this work

The Chairman of the Task Force is Fred Lindsey, telephone 202-382-4756, who reports directly to the Assistant Administrator for Solid Waste and Emergency Response. Questions and comments are welcome.

THE U.S. GEOLOGICAL SURVEY FEDERAL - STATE COOPERATIVE WATER RESOURCES PROGRAM IN FISCAL YEAR 1984

by Bruce K. Gilbert

U.S. GEOLOGICAL SURVEY
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1984

The U.S. Geological Survey Federal-State Cooperative Water Resources Program in Fiscal Year (FY) 1984

By Bruce K. Gilbert

ABSTRACT

The U.S. Geological Survey's Federal-State Cooperative Program for water-resources data collection, investigations, and research was carried out with some 800 State, regional, and local agencies in fiscal year (FY) 1984. Total funding in this 50-50 matching program amounted to about $100 million and included work underway in every State, Guam, Puerto Rico, and several U.S. territories.

The Geological Survey and its cooperating agencies mutually identify key issues and problems to determine which activities will be included. For 1984, the principal concerns included ground-water contamination, water supply and demand, stream quality, hydrologic hazards, and acid precipitation.

This report provides some perspective on program development and describes a few of the year's highlights.

INTRODUCTION

The Federal-State Cooperative Water Resources Program continues to be the largest component of the U.S. Geological Survey's water resources activity. This program was carried out in working partnership with more than 800 State, regional, and local agencies during FY 1984. Joint funding in the 50-50 matching Cooperative Program totaled about $100 million, and comprised almost half the total program of the Water Resources Division (WRD). The Cooperative Program began in Kansas in 1895, and has grown and changed with time (Gilbert and Buchanan, 1981). Hydrologic data collection and interpretive investigations were underway in every State, Puerto Rico, and several United States territories in 1984.

Perhaps the most important characteristic of the program throughout is that it has been and is "policy relevant." That is, most investigations are responding to a recognized or potential problem and provide hydrologic information and analyses needed for making decisions or for formulating plans. The program also contributes to the advancement of hydrologic science and provides a major part of the Geological Survey's water information base. Table 1 shows selected national water issues and examples of where and when they were first identified as part of Cooperative Program activities.

Table 1.--National water issues identified as part of water-resource investigations supported by the Cooperative Program

National Water Issues	Issue Identified in the Federal-State Cooperative Program
Acid Precipitation	New York 1965 North Carolina 1962
Oil Shale Development	Colorado 1962
Coal Hydrology (Acid Mine Drainage)	Kentucky 1955 Pennsylvania 1964
Solid Waste Disposal	Florida 1970
Hazardous Waste Disposal	Georgia 1963
Radioactive Waste Disposal	New York 1961
Indian Water Rights	North Dakota 1949 Arizona 1962
Urban Hydrologic Planning	California 1961
Ground-Water Mining	New Mexico 1926 Utah 1950 Colorado 1960
Streamflow Depletion by Wells	New Mexico 1941 Colorado 1963
Design of Interstate Highway System Bridges	New York 1963 Wisconsin 1971
Reservoir Planning and Design	Connecticut 1925
Saltwater Encroachment	New Jersey 1923 California 1940 Florida 1945
Land Subsidence	California 1940
Flood Plain Management	Pennsylvania 1961 North Carolina 1968
Deep Well Injection	Florida 1966
Lake Eutrophication	Florida 1971 Pennsylvania 1972
Streamflow Quality	Minnesota 1907 Illinois 1907
Water Use	Wyoming 1923
Water Rights	Wyoming 1899
Ground-Water Quality	New Jersey 1923
Surface-Water Quality	South Carolina 1956
Quality of Public Water Supplies	North Carolina 1961

HYDROLOGIC DATA COLLECTION

Practically all of the Geological Survey's data collection stations, funded in large part by this Cooperative Program, serve several purposes. In addition to providing information responsive to State or local needs, the Federal-State Cooperative Program stations (see table 2) provide information that satisfies the needs of many Federal agencies--for example: flood prediction, land use planning, streamflow regulation, hydroelectric power production, waste disposal standards, pollution regulation, mined-land reclamation, and energy development. Table 2 shows that in FY 1984 the Federal-State Cooperative Program provided sole support for nearly half the continuous streamflow discharge stations in the total Geological Survey network; and, in combination with other funding sources, provided partial support for another 18 percent of the total network of these stations.

The operation of data-collection network stations is a continuing activity. Although many data-collection stations are operated on a long-term basis as components of national networks, some are discontinued each year when their purpose has been served; new stations are installed as demanded by changing needs and priorities. The Geological Survey's entire stream gaging program, which includes gaging stations funded by the Federal Program, the Federal-State Cooperative Program, and the other Federal agency reimbursable program, is being systemically analyzed to improve its effectiveness. This nationwide analysis includes the identification of alternate methods, such as flow routing and statistical regression models, of providing streamflow data and information.

HYDROLOGIC INVESTIGATIONS AND RESEARCH

In addition to the data-collection activities, approximately 550 hydrologic investigations and water-resources research projects funded by the Federal-State Cooperative Program were underway in FY 1984. These included areal appraisals and special studies conducted throughout the Nation. Areal water-resources appraisals (which range from small basin or county to statewide or regional in size) define, characterize, and evaluate the extent, quality, and availability of the water resource. During the past decade or so, increasing emphasis has been given to water-quality issues, including aquifer contamination, acid precipitation, river quality assessments, and storm runoff.

Special analytical and interpretive studies address existing and foreseeable hydrologic conditions and problems, are somewhat more specific in nature and smaller in size than areal appraisals, and sometimes involve applied research. They may require from a few months to 2 to 3 years to complete, and result in analytical, interpretive, and predictive reports, data, and information leading to the solution of problems or more complete utilization and protection of the Nation's water resources.

Table 2.--Water data collection activities of the U.S. Geological Survey, FY 1984.

Types of Stations	Number of Stations				
	A. Federal Program	B. Federal-State Cooperative Program	C. Other Federal Agencies	D. Combined Support	Total
SURFACE WATER					
Discharge					
Continuous Record	567	3567	1629	1389	7152
Partial Record	79	2860	394	591	3924
Stage only--Streams					
Continuous Record	4	122	193	100	419
Partial Record	9	374	50	38	471
Stage only--Lakes and Reservoirs					
Continuous Record	10	467	258	111	846
Partial Record	11	283	57	49	400
Quality					
Continuous Record	157	294	211	122	784
Scheduled, long-term	540	1629	470	267	2906
Short-term or project	122	382	294	122	920
GROUND WATER					
Water Levels					
Continuous Record	101	1313	117	451	1982
Scheduled, long-term	830	17297	950	4970	24047
Short-term or project	1719	6183	607	1083	9592
Quality					
Scheduled, long-term	15	2251	219	586	3071
Short-term or project	547	2182	288	1560	4577

Explanation

Types of Stations

Continuous record: The station is instrumented to continuously monitor hydrologic conditions and, in some instances, transmit data in real time.

Partial record: Hydrologic information is collected only during selected periods, for example, during floods or droughts, or annual low flow.

Scheduled, long-term operation: Hydrologic information is collected on a fixed schedule for a long period to detect trends.

Short term or project stations: Hydrologic information is collected to meet the needs of a specific study. Data supplement those available from scheduled long-term continuous record, and partial-record stations.

Number of Stations

Column A: Those stations totally supported by funds appropriated to the Geological Survey Federal Program subactivity.

Column B: Those stations supported by funds appropriated to the Geological Survey Federal-State Cooperative Program subactivity.

Column C: Those stations totally supported by reimbursement from other Federal agencies.

Column D: Those stations supported by a combination of two or more of the above.

The Nation's rivers have historically been used for water supplies, dilution of waste, recreation, commerce, and for production of fish and other aquatic crops. These uses are not all compatible, and over time many problems have surfaced, which managers are attempting to solve. Deterioration in the quality of water supplies for domestic, municipal, industrial, and agricultural uses is a growing problem, which can affect human health as well as the economy. In spite of considerable progress in solving complex water problems, stresses impacting the quality of the surface and ground waters are multiplying. Ground water supplies drinking water for at least half of the Nation's population. In some places, especially in densely populated and industrialized areas, disposal of toxic wastes has made ground water unsafe for use. For an isolated point source of contamination, such as an industrial disposal pond, the consequences may be severe in magnitude but only local in extent. In some places, however, many separate industries located over a large area and some agricultural practices are contributing to widespread contamination.

PROGRAM PRIORITIES

Each year, cooperator proposals typically exceed Federal funds available for matching by several million dollars. Priorities for data collection and hydrologic investigations and research are based on a continuing, detailed analysis of water problems and issues. The Geological Survey and its cooperating agencies work together in a continuing process that leads to adjustments in each year's program. The process is guided by a determination of the key hydrologic problems and issues requiring priority consideration in the selection of new, or the retention of ongoing projects in the overall program. This is carried out through discussions with State and local cooperators, Federal agency officials, and through awareness of concerns of the general public. For 1984, most new cooperative investigations addressed the principal concerns derived from this national perspective--ground-water contamination, water supply and demand, stream quality, hydrologic hazards, and acid precipitation. These and other studies respond to the increasing need for information at local, State, regional, and national levels. The final selection of new projects is timed to coincide with critical points in the budgetary cycles of the Federal Government and the numerous State and local cooperating governments. With respect to the Federal government's budgeting cycle, specific negotiations for the upcoming fiscal year regarding individual projects are initiated with cooperators in January through March, are based on the provisions of the President's Budget submission to Congress, and may be subsequently modified based on appropriations actions taken by Congress.

MERIT PROPOSAL PROCESS

Most of the Federal matching funds are allocated to highest priority activities by the Division's four Regional offices after ranking the work proposed in their respective geographical areas of responsibility. However, the Geological Survey has instituted a new process for evaluating and funding selected proposals for water-resources investigations as part of the Federal-State Cooperative Program. The Federal matching fund support for merit proposals was $1 million in FY 1983 and about $1 million in FY 1984. Thus, with the cooperators providing an equal amount of funds, a total of about $2 million was allocated each year. In 1983, 16 investigations were selected of the 33 proposed, and in 1984, 15 of 44 proposals were selected. Plans are to identify $1 million of U.S. Geological Survey matching funds for investigations to be chosen through this process in FY 1985.

The new system formalizes existing procedures that have been used for the past 10-15 years to rank candidate proposals for allocation of funds. Each merit proposal is reviewed and evaluated separately by five members of the Geological Survey's senior staff. The group then meets as a panel to consolidate rankings and arbitrate differences, and funds are allocated to the investigations in priority order. Additional effort is applied, however, to ensure that the highest priority work is undertaken with the merit funds and that the anticipated technical contributions to the science of hydrology will be of top quality. Figure 1 shows how merit proposal funds were allocated to selected topical areas in FY 1984.

Although it is highly probable that all the merit investigations would have been funded under traditional procedures, the system has produced worthwhile results. The program development process has been strengthened because of the increased deliberation within WRD during the merit ranking. Incentive has been added for the planning and development of high quality proposals, and technology transfer has been enhanced through closer interaction of operational and research programs.

WATER-QUALITY ACTIVITIES

Ground-water contamination headed the 1984 list of priority issues for the Cooperative Program. This continued the trend from 1982 and 1983, and is expected to be repeated in 1985. The National Water Summary--1983 (U.S. Geological Survey, 1984) reports that contamination from hazardous wastes, point and nonpoint sources of pollution, saline water intrusion, eutrophication, acid precipitation, and other water-quality issues are of concern throughout the Nation (table 3).

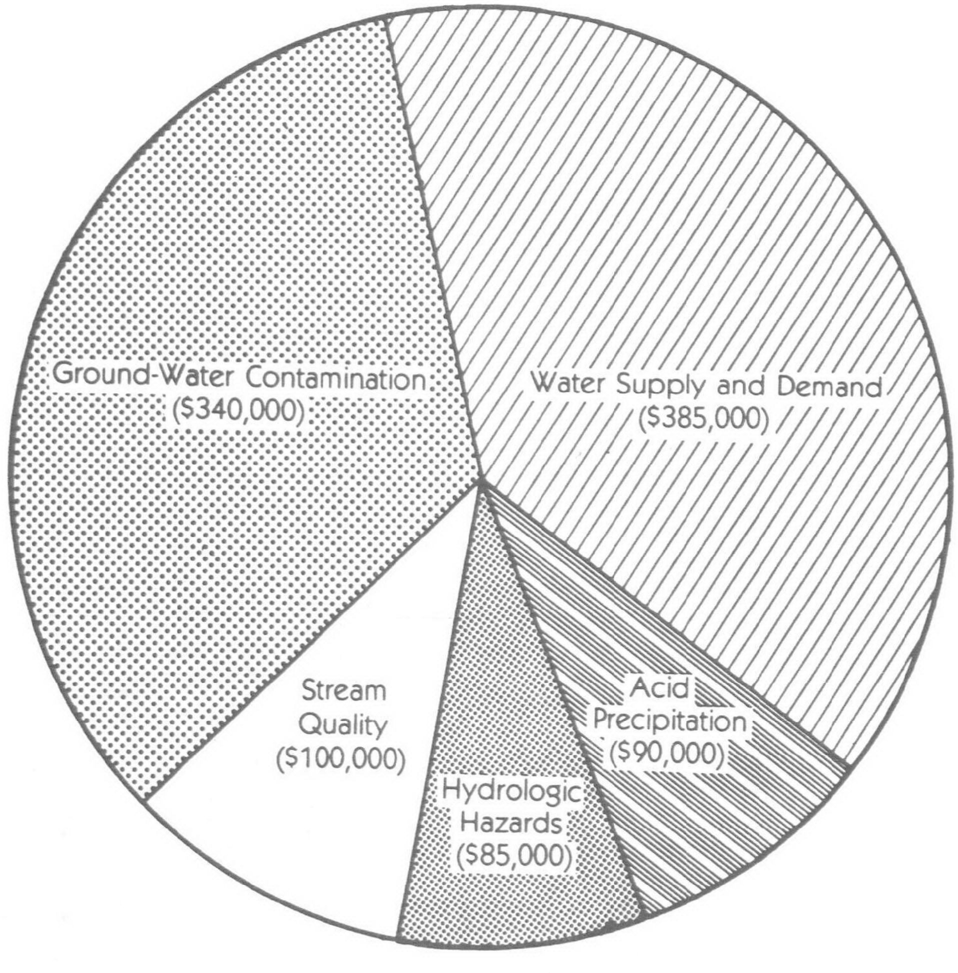

Figure 1.–The merit proposal process in fiscal year 1984 focused $1 million of Federal matching funds, as part of the Cooperative Program, on high priority water-resources issues.

Table 3. -- Index to State water issues as compiled from *The National Water Summary - 1983.*

WATER ISSUE / STATE	ALABAMA	ALASKA	ARIZONA	ARKANSAS	CALIFORNIA	COLORADO	CONNECTICUT	DELAWARE	FLORIDA	GEORGIA	HAWAII	OTHER PACIFIC ISLANDS	IDAHO	ILLINOIS	INDIANA	IOWA	KANSAS	KENTUCKY	LOUISIANA	MAINE	MARYLAND AND D.C.	MASSACHUSETTS	MICHIGAN	MINNESOTA	MISSISSIPPI	MISSOURI	MONTANA	NEBRASKA	NEVADA	NEW HAMPSHIRE	NEW JERSEY	NEW MEXICO	NEW YORK	NORTH CAROLINA	NORTH DAKOTA	OHIO	OKLAHOMA	OREGON	PENNSYLVANIA	RHODE ISLAND	SOUTH CAROLINA	SOUTH DAKOTA	TENNESSEE	TEXAS	UTAH	VERMONT	VIRGINIA	WASHINGTON	WEST VIRGINIA	WISCONSIN	WYOMING	PUERTO RICO	VIRGIN ISLANDS
WATER AVAILABILITY ISSUES																																																						
Surface water		●	●	●	●		●		●	●	●	●	●	●	●	●	●	●	●	●		●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●		●	●	●		●	●	●
Ground water	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●		●	●		●	●		●		●	●
WATER QUALITY ISSUES																																																					
Surface water																																																					
General quality							●							●			●				●										●						●	●								●	●		●				
Point sources	●	●		●			●		●	●	●		●	●	●			●	●		●	●	●	●		●			●	●	●		●	●	●	●	●			●	●	●	●	●	●				●	●		●	●
Nonpoint sources	●	●	●	●	●		●		●	●	●		●	●		●	●	●	●		●	●	●			●			●	●	●		●	●		●	●	●	●	●	●	●	●	●	●				●	●		●	●
Hazardous wastes	●					●										●	●			●		●	●			●				●	●									●	●		●			●	●		●				
Saline water			●			●			●								●		●							●									●		●							●	●						●	●	
Ground water																																																					
General quality		●	●				●			●				●		●		●		●						●				●					●						●	●				●	●						
Point sources		●	●	●		●	●	●	●		●	●	●	●		●				●	●	●	●	●	●		●	●					●	●		●		●	●	●	●	●		●		●		●		●	●	●	●
Nonpoint sources		●	●		●			●	●	●	●	●	●	●		●				●	●	●	●	●	●	●		●				●	●			●		●	●	●	●			●				●		●	●		
Hazardous wastes	●		●	●	●	●		●	●				●	●	●	●	●	●	●	●	●	●		●		●	●			●	●	●	●	●		●	●	●	●	●			●	●	●	●	●	●	●	●			
Radioactive wastes																		●	●						●				●			●	●								●		●					●					
Saline water	●			●	●			●	●	●	●	●					●		●			●		●	●	●					●		●	●	●			●			●			●				●				●	
Eutrophication		●				●	●	●		●					●								●	●									●	●	●							●	●	●		●	●	●			●		
Bottom sediment contamination										●												●	●																					●			●	●					
Precipitation		●					●		●						●			●		●	●	●		●	●					●	●		●	●	●	●		●	●			●			●	●		●	●	●	●		
HYDROLOGIC HAZARDS AND LAND ISSUES																																																					
Flooding		●	●	●	●	●	●	●		●			●	●	●		●	●	●	●			●	●	●	●		●	●		●		●	●	●	●	●	●	●			●	●	●	●	●	●	●	●	●	●	●	●
Subsidence			●		●																								●															●									
Sinkholes	●								●	●								●								●															●		●									●	
Erosion and sedimentation		●								●		●		●			●		●	●	●		●	●		●	●	●						●		●						●								●		●	●
Wetlands, wetsoils, and drainage				●					●				●	●				●				●					●	●					●		●							●								●	●	●	
Resource development		●	●	●		●			●						●		●	●	●	●	●			●		●	●			●			●	●	●	●	●		●		●	●	●	●	●	●	●	●	●		●		
INSTITUTIONAL AND MANAGEMENT ISSUES																																																					
Water allocation		●	●			●				●						●	●								●		●	●	●	●	●	●	●		●							●		●	●	●	●				●	●	
Water laws		●	●	●	●			●		●	●		●	●	●	●				●	●	●			●			●			●										●	●		●						●		●	
Indian water rights			●																													●																			●		
Interbasin transfer					●		●			●												●												●			●														●		
Treaties and compacts			●		●	●											●		●								●		●			●	●		●									●	●			●			●		
Financing the infrastructure																	●														●		●				●															●	●
Water resources management			●				●		●	●		●	●	●		●	●		●		●	●		●	●	●	●				●								●	●		●		●			●	●	●	●	●	●	●

About 800 Cooperative Program investigations were active in 1984. Of these, some 200 were operated for collection of hydrologic data--surface water, ground water, water quality, sediment, and precipitation--and 48 were identified as part of the water-use activity. The balance of approximately 550 were hydrologic investigations, research, and special studies of which a minimum of 400 included some water-quality aspects. About 100 of these were principally concerned with investigations of contamination of surface or ground water. Table 4 shows the distribution of funding, by discipline, for hydrologic investigations and research from 1979 to 1984. The numbers were derived from estimates of the effort, in percent, that would be expended by the various disciplines in each project. For investigative and research activities, the amount of effort in water-quality work has increased from 20.1 percent in 1979, to 22.4 percent in 1984.

EXAMPLES OF CURRENT INVESTIGATIONS

In FY 1984, the Federal-State Cooperative Program continued to focus on water-resources investigations of highest priority to the Nation. Examples of these activities are furnished below.

WASHINGTON STATE: Hazardous Waste Investigations

In the State of Washington more than 200 hazardous-waste sites are located where there is a high probability of leachate impacting the surface and ground water. The State is developing a major program to deal with this problem and has asked the Geological Survey for technical assistance. The resulting investigation consists of four phases: (1) hydrogeologic characterization of existing hazardous-waste sites, (2) research on how the pollutants are moving through the water system and on the reaction processes that are involved, (3) broad characterization of the most and least suitable areas for land disposal of hazardous waste within the State, and (4) technical assistance in the evaluation of the hydrogeological aspects of proposals and reports being considered by the State.

SOUTHWEST LOUISIANA: Organic Waste Containment in the Mississippi Embayment

An investigation is underway to document current and past hydrodynamic and geochemical characteristics at a waste site located in Calcasieu Parish of southwestern Louisiana. Contaminant migration and the transport rates of various pollutants will be analyzed by use of a ground-water flow model. The objective is to define the clay mineralogy and the hydraulic processes related to the presence and movement of organic solutes in geologic materials having low hydraulic conductivities.

Table 4.--Distribution of funding (Federal side), by discipline, for hydrologic investigations and research, from FY 1979-1984, Federal-State Cooperative Program. (Does not include data-collection activities.)

Dollars, in thousands, and (percent)					
Fiscal Year	General Hydrology	Ground Water	Quality of Water	Surface Water	Total
1979	$4,146 (21.6)	$7,081 (36.9)	$3,861 (20.1)	$4,108 (21.4)	$19,196 (100)
1980	$4,744 (23.5)	$7,100 (35.1)	$4,157 (20.6)	$4,200 (20.8)	$20,201 (100)
1981	$4,758 (23.3)	$7,492 (36.7)	$4,183 (20.5)	$3,972 (19.5)	$20,405 (100)
1982	$5,050 (23.6)	$7,226 (33.8)	$4,593 (21.5)	$4,500 (21.1)	$21,369 (100)
1983	$4,924 (23.0)	$7,051 (33.0)	$4,723 (22.1)	$4,683 (21.9)	$21,381 (100)
1984	$3,860 (17.3)	$8,179 (36.6)	$5,007 (22.4)	$5,297 (23.7)	$22,343 (100)

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U.S. Geological Survey, 1984, National Water Summary 1983--Hydrologic Events and Issues, Water-Supply Paper 2250, 243p.

IV. STATE GROUND-WATER MONITORING ACTIVITIES

- Summary of Illinois Ground-Water Programs and Comparison with Other State Monitoring Programs
- Summary of Wisconsin Ground-Water Monitoring Activities
- Summary of Arizona Ground-Water Monitoring Activities
- Report on New Jersey Ground-Water Monitoring Strategy and Activities

Design of a Statewide Ground-Water Monitoring Network

for

Illinois

Michael O'Hearn
Susan Schock
Illinois State Water
Survey Division
Illinois Department of Energy
and Natural Resources
December 1984

GROUND WATER MONITORING PROGRAM REVIEW OF SELECTED STATES

A preliminary review of ground-water monitoring programs and plans in selected states was undertaken to determine where the State of Illinois stands with respect to their programs and to benefit from their experiences in designing and operating statewide monitoring programs. Letters were sent to water-resource management agencies in twenty-six states known to have programs or plans for programs, in all areas of the country, asking the recipients to briefly describe their existing or proposed statewide ground-water monitoring programs. All but four states responded to this initial inquiry. Four states were selected for further discussion, because at the time of the inquiry their respective programs or plans appeared to be more advanced than Illinois'. Although this evaluation was necessarily subjective, it helped put the problem in perspective and suggested some possible solutions which were extremely useful in the design of the monitoring network described in this report.

Table 1 is a brief comparison of some of the features of the ground water monitoring programs of the states visited during the review process. All entries have been listed in rought order of importance to the specific program.

The program in Georgia is the best example of a cooperative effort with the USGS, and one agency organization reviewed. The Mighican program is in its early stages and striving to be an organized effort beneficial to all involved. The Texas program is probably the most sophisticated and best developed in terms of data reporting and management. The New Jersey program is unique in that it is being created from its inception and is emphatically interested in contamination problems. In general, the efforts of the State

Table 1. Comparison of Monitoring Program from Selected States***

	ILLINOIS**	GEORGIA	MICHIGAN	NEW JERSEY	TEXAS
Square miles	56,400	58,876	58,216	7,836	267,338
Population*	11,418,461	5,464,265	9,258,340	7,364,158	14,228,383
No. of counties	102	159	68	21	254
Monitoring Program Elements:	ground water quality, water levels (water use--separate program)	water use, water levels, water quality	water levels, water quality	water quality, water level, water use	water levels, water quality (water use--separate program
Cooperating Agencies:	ISWS, IEPA, USGS, ISGS, IDPH	GDNR, USGS	MDNR, USGS, MDH, MDPH	NJSGS, USGS, USEPA-REGII	TWRB, USGS, TDPH
Objectives:	overview conditions, document significant changes	overview conditions, aquifer mapping, detect changes in quantity and quality	establish base line quality	ambient quality and quantity, detect contamination	overview levels, quantities, and qualities, detect changes in above
Well Types Monitored:	PWS wells (future installations for monitoring?)	PWS-finished water samples, dedicated monitoring installations	"semi-public" wells (i.e. parks, restaurants, etc.)	special installations for monitoring	private, public, industrial, and agricultural
Number of Wells Monitored:	1306 potential: 962 primary, 344 alternates (potential?)	125 at present, several underway (1000 potential) PWS wells for regulated analyses	117 levels 100-150 quality,	100 for quality 600-700 levels,	600-700/yr quality and and level (6000 potential)

Table 1. Concluded

	ILLINOIS**	GEORGIA	MICHIGAN	NEW JERSEY	TEXAS
Sampling Frequency:	level 1, 3.5 yr cycle; level 2, 5 yr cycle; level 3 as needed	water levels--semi-annual, some continuous recorders, qualities 3-5 yr cycle	levels done daily to monthly	1-4 times anually (based on ground water flow velocity) intensive studies 2-3 times per month	water levels semi-annually, quality 5-6 yr cycle
Number of Parameters:	levels 1, SDWA and organic scan; level 2, SDWA and priority pollutants; level 3 as needed	1st yr SDWA and organic scan, subsequent as indicated by water quality	83-84 inorganics	1st yr wide spectrum, inorganics and organic scan, 2nd yr "indicators"	16-18 inorganics and physical
Cost:	$700,000/yr for complete program	$100,000/yr operation only, system in place	$36,000/yr for sampling and analysis program	$165,000/yr operation only with system in place	$800,000-$1 M/ annually for sampling and analysis program, complete highly sophisiticated program
Features:	cooperative, comprehensive monitoring, analysis, and reporting; tripwire for special studies	(water use mainly) sophisticated program with graphics; all water divisions housed in one agency	storage system being developed on cooperative basis	data entry from paper underway	sophisticated, highly developed geographic information system and reporting system; tripwire for special studies

*** information from interview and overviews
** proposed program
* 1980 census

of Illinois appear to be about average compared with the progress toward statewide monitoring programs in other states. Further discussions took place during on-site visits with representatives of water-resource agencies in the states of Georgia, Michigan, New Jersey, and Texas.

As a result, the following general observations are offered:

1) Statewide ground-water monitoring programs are often developed in response to a legislative mandate.

2) Programs are often developed as only one component of an overall ground-water management plan (for example, to provide information in support of the well drilling permitting process).

3) Programs are often operated by the "information" arm of the state with the resulting information most often used by the "regulatory" arm.

4) Most state programs are operated in cooperation with the USGS on a cost-sharing basis.

5) Most programs share the same basic objectives; characterizing ground-water conditions in time and space and detecting significant changes in these conditions in support of resource-management activities.

6) Statistical concepts are not usually a major factor in the design of the monitoring network. Instead, a balance is struck between what is ideal and what is practically attainable given each state's resources and individual situation.

7) Priority areas are usually determined on the basis of existing or potential use for water supply and general aquifer susceptibility.

8) An assessment of existing data is often performed to identify information gaps and to help set priorities for monitoring.

9) Identification of historical data which are most reliable and useful for monitoring purposes is seen as an important component of monitoring network design.

10) The available historical data (especially older data and data from private wells) are usually incomplete and of questionable reliability which greatly reduces its value for statewide monitoring purposes.

11) Many existing programs are limited to the occasional sampling of public water wells under the SDWA or to site-specific monitoring of potential point sources under the Resource Conservation and Recovery Act (RCRA).

12) Some programs emphasize the collection of baseline data in unaffected areas (as a standard against which to measure future changes), while others target areas at high risk because of the presence of known potential contamination sources.

13) The storage of potentially valuable data in paper files limits the states' ability to apply these data to large-scale monitoring objectives. Carefully planned data entry programs are a necessary first step.

14) The size of the area requiring monitoring determines, to a large extent, the degree of detail to which the area can be monitored. Given the same level of funding, smaller states (e.g., New Jersey) are able to obtain more detailed information than larger states (e.g., Texas). This requires larger states to place greater emphasis on the setting of priorities for data collection.

15) Program evaluation is usually incorporated in the network design so the program is responsive to changing needs or monitoring objectives.

16) The skill and dedication of the personnel responsible for the monitoring program are critical factors in the successful operation of a high quality monitoring program.

Description of Wisconsin's Ground-Water Monitoring Program

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DESCRIPTION OF WISCONSIN'S GROUNDWATER MONITORING PROGRAM

Wisconsin's groundwater monitoring effort includes two distinct approaches. Most of the monitoring done in the state can be characterized as monitoring done to determine impacts of contamination on the groundwater resources. This monitoring is carried out at the state level primarily by the Wisconsin Department of Natural Resources and consists of four separate functions which are named in Wisconsin's groundwater legislation. These functions are problem assessment monitoring, regulatory monitoring, at risk well monitoring and management practice monitoring. The other area of monitoring, to which far fewer resources are devoted, is called resource definition monitoring. Activities conducted in this area are aimed at determining the native or natural characteristics of groundwater without any human induced changes.

Below is listed the type of monitoring done and the principal state and federal agencies active in conducting that type of monitoring in Wisconsin.

I. Contamination Monitoring

A. Problem Assessment Monitoring

Problem assessment monitoring is done to determine and to assess the extent to which substances are in the groundwater. Included in this category are Wisconsin's monitoring programs for pesticide sampling of private wells and volatile organic chemical monitoring of public and private wells. The Wisconsin Department of Natural Resources is the agency with responsibility for conducting this monitoring. The monitoring is not ambient monitoring in that it is directed toward areas that are identified as being susceptible to contamination and particular chemicals that are identified as being of concern. The areas and wells selected for sampling are selected for the particular contaminant being monitored for.

B. Regulatory Monitoring

Regulatory monitoring is to determine the extent to which groundwater is contaminated and meets or exceeds state groundwater standards. Regulatory monitoring is that monitoring which is required as part of a regulation around a regulated facility. Examples of regulatory monitoring in Wisconsin are monitoring systems around landfills and monitoring systems around wastewater disposal facilities such as seepage lagoons or ridge and furrow systems. The monitoring is conducted by the owner or operator of the facility and the reports are submitted to the Wisconsin's Department of Natural Resources usually on a monthly or quarterly basis. The contaminants which must be monitored for are specified in an administrative rule or in the individual approval or permit for that facility. The Department of Natural Resources staff reviews the monitoring results which are submitted. State personnel may also visit the facility and collect their own samples to cross-check the data which is being submitted. Groundwater monitoring systems always consist of a well or wells upgradient from the facility and a series of wells downgradient from the facility. Only about 1/5 of the landfills in

Wisconsin presently have groundwater monitoring systems. All landfills approved in recent years, however, do have groundwater monitoring systems associated with them. In addition Wisconsin recently passed legislation authorizing the Wisconsin DNR to require monitoring where necessary upon the relicensing of existing landfills where no monitoring was previously required. Wisconsin's wastewater program regulates municipal wastewater seepage lagoons as well as a variety of industrial wastewater disposal facilities. All municipal wastewater seepage lagoons have groundwater monitoring systems and routinely report their data. Only a fraction of industrial wastewater facilities have groundwater monitoring systems because most of those facilities are very small. Ridge and furrow systems for diary plant wastes are a primary example.

C. At Risk Well Monitoring

At risk well monitoring is done where substances have been identified in groundwater and where groundwater standards have been exceeded. This monitoring consists largely of follow-up or investigatory monitoring in areas of known problems to better identify the nature and extent of the contamination. At risk well monitoring is monitoring of existing drinking water wells in an area where groundwater is known to be contaminated. This type of monitoring was included in Wisconsin's groundwater legislation in response to demands by citizens and environmental groups that the State has an obligation for providing analysis of people's wells known to be at risk.

D. Management Practice Monitoring

Management practice monitoring could be called applied research. It is done to determine the practices necessary to meet state groundwater standards. It is also done to judge the adequacy of existing designs or existing regulations covering various sources of contamination. For example, groundwater monitoring cannot be required in every farmer's field where pesticides are being applied. However, Wisconsin has a number of projects underway judging the potential for leaching of pesticides to groundwater under various conditions. There are many small wastewater disposal systems where regulatory monitoring of every facility would not be feasible. Wisconsin is studying, however, a number of small seepage cell systems and ridge and furrow systems to judge the adequacy of their performance and apply those determinations to judging the performance of many similar systems. Another example of management practice monitoring is the study of the performance of various septic system designs. Management practice monitoring can be used for either judging performance or for developing new best management practices.

The following is an estimate for the biennial totals for contracts for contamination monitoring in Wisconsin. These totals include the costs for laboratory analysis and the cost for studies which are contracted for. They do not include the cost for WDNR staff.

Problem Assessment Monitoring	$568,000
Regulatory Monitoring	720,000
At Risk Well Monitoring	452,000
Management Practice Monitoring	100,000

II. Resource Definition Monitoring

Resource definition monitoring is done to determine background or natural groundwater quality in the state. This monitoring is done by the United Geologic Survey, The Wisconsin Geological and Natural History Survey and the Wisconsin Department of Natural Resources. This data is entered on the U.S.G.S. WATSTORE System. These analysis are primarily for inorganic chemicals. These include dissolved solids, hardness, alkalinity, calcium, magnesium, sodium, iron magnesium sulfate, chloride, fluoride, and nitrate. There is presently data from approximately 2,500 wells on the WATSTORE System. No estimate for the annual cost for this type of monitoring is available. WDNR collects a one-time sample for inorganic chemical analysis from every new municipal well upon its completion as part of this effort.

Summary of Ground-Water Monitoring

in

Arizona

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1/23/85

SUMMARY OF GROUNDWATER MONITORING CONDUCTED UNDER THE AUSPICES OF THE ARIZONA DEPARTMENT OF HEALTH SERVICES

TYPE	PURPOSE	CONSTITUENT(S)	AREA(S)
Regional (ambient) monitoring	To assess regional water quality and/or impact of large-scale land use on groundwater quality	1. EDB, DBCP	1. Irrigated agriculture in Maricopa County and Yuma area.
		2. Aldicarb	2. Pecan-growing area, Green Valley
		3. Major ions and trace metals	3a. Mining areas south of Tucson and in Globe-Miami b. Cortaro area--NW of Tucson c. Green Valley
		4. Nitrates	4. St. David
		5. Volatile organic chemicals (VOC) and DBCP	5. Mesa Tri-cities area; Yuma area
		6. Radiochemicals	6. Rio Puerco
		7. Microorganisms	7. Pinetop-Lakeside

COMMENTS: Most monitoring uses existing production wells. Items 3-5 undertaken by Councils of Governments with Federal 205(j) or 208 funding.

TYPE	PURPOSE	CONSTITUENT(S)	AREA(S)
Site-specific contamination investigations			
A. 3012 program	A. Federal program to assess uncontrolled hazardous waste sites	A. Priority pollutants	A. Ten sites
B. State-funded targeted studies	B. To assess public health hazard and extent of contamination at known or suspected contaminated sites through sampling of nearby production wells	B. Primarily TCE and other VOCs	B. Most sites have been in the Phoenix and Tucson metropolitan areas
C. Emergency/complaint response	C. Same as B	C. Constituents are specific to the emergency event or complaint	C. Wherever emergency/complaint occurs
D. Superfund Remedial activities	D. To provide data necessary to undertake Superfund activities	D. Primarily VOCs	D. Tucson Superfund site
E. Non-superfund Remedial activities	E. To assess nature and extent of contamination and public health hazard at known spill-leak sites; facility assumes responsibility for installation and sampling of monitoring wells. ADHS collects split samples.	E. Constituents are specific to problem. Currently most remedial activities involve TCE and other volatiles and, in the case of gasoline storage tank leaks, benzene, toluene and the zylenes.	E. Most sites are in Phoenix and Yuma areas.

TYPE	PURPOSE	CONSTITUENT(S)	AREA(S)
Regulatory Compliance Monitoring			
A. Safe Drinking Water Act	A. To insure that people serviced by water systems receive water that meets certain standards	A. Constituents specified in primary drinking water standards plus the unregulated organic chemicals of concern to ADHS (such as TCE, EDB, DBCP)	A. All over the State
B. Groundwater Permits Program	B. To insure that discharges do not cause a violation of groundwater quality standards.	B. Constituents are specific to the waste discharged.	B. Where necessary
C. Resource Conservation and Recovery Act (RCRA)/Arizona State Hazardous Waste Management Act	C. To provide early warning of migration of hazardous wastes to groundwater; to develop proper remedial action response to protect groundwater.	C. Primary Drinking Water Standards; indicator parameters pH, EC, TOX, TOC; major ions; specific hazardous waste constituents as needed.	C. Most hazardous waste sites are in Phoenix-Tucson corridor.

COMMENT: Responsibility for this type of monitoring is borne by the Facility being regulated. Role of ADHS is to insure that monitoring programs are sufficient to meet ADHS expectations; and to collect split samples to document the quality of data.

GROUNDWATER SAMPLING AREAS SINCE 1979

DEVELOPING AN INTEGRATED FEDERAL, STATE AND COUNTY GROUND WATER MONITORING STRATEGY

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Introduction

A dramatic increase in the value of ground water resources and concern for its protection has occurred in the past decade. The first section of this paper presents a brief summary of the conditions which caused New Jersey to develop an integrated ground water monitoring program. The second section describes in detail the cooperative strategy developed to utilize all resources, at the federal, state and county level, to achieve a technically adequate system for the protection of our ground waters.

History of Conditions

In the early seventies it was a common misconception, among health officials as well as the general public, that ground water supplies were inherently 'protected' by their subsurface nature. Aside from the two obvious problems of salt water intrusion and supply depletion, the subtle long term contamination problems went unrecognized for years.

At the federal level, the United States Geological Survey's (USGS) Water Resources Division (WRD) in cooperation with the New Jersey Department of Environmental Protection was conducting two excellent monitoring networks - the Water Level Monitoring Network and the Salinity Network. Both networks addressed long recognized ground water problems. However, these two long term basic data gathering programs did not address ground water contamination from man-made sources.

At the state level, when the New Jersey Department of Environmental Protection (NJDEP), Division of Water Resources, was created in 1971 most of the technical and budgetary resources were devoted to surface water. But in a state where sixty percent of the potable water supply comes from ground water and public supply wells exist in almost every area of the state, new ground water problems were being identified almost daily. By 1975, the ever increasing number of ground water problem areas prompted NJDEP to create a 'special services' unit and to increase the staff of full time ground water geologists from one to five.

However, the extent of New Jersey's ground water problems demanded that the special services unit act almost exclusively as an emergency response group. Most of their efforts were spent on major existing pollution problems.

As the major causes of ground water pollution were identified, isolated attempts were made to monitor for potential ground water contamination. At the state level, registered landfills were required to install monitoring wells and to submit quarterly compliance water analyses. However, ground water quality standards did not exist and the sampling and analytical methodologies required to obtain representative aquifer analyses were just being developed. This was especially true for low level organic contamination.

At the county level, local health departments were instituting inspection and testing of domestic well supplies. But tests for bacteria, hardness, pH, nitrogen and chlorides were insufficient in a state as densely populated and as heavily industrialized as New Jersey. There was clearly no concerted or technically adequate program to monitor the state's ground water resources.

By 1979 the magnitude of the ground water contamination problem necessitated the creation of the NJDEP, Bureau of Ground Water Management and to more than double existing geological staff. Still, Bureau geologists were hard-pressed to locate the reliable, up-to-date ground water information needed to evaluate the existing problems. Only the USGS data on coastal plain salinity and water levels were both reliable and available. Six areas were isolated as the major impediments to the preservation and protection of existing ground water supplies:

1. Lack of ground water quality standards;
2. Lack of monitoring requirements for all dischargers to ground water;
3. Lack of adequate sampling and analytical quality controls;
4. Unavailability of ground water data for the northern New Jersey highlands and lowlands regions;
5. Unaccessibility of exisiting data, and;
6. A total lack of monitoring program coordination.

Therefore, in 1979 a strategy was designed, which resulted in two 208 Ground Water Grants and a set of Laboratory Certification Regulations which in combination allowed New Jersey to address the preceeding six issues. The first grant provided the funds necessary to allow New Jersey to assume primacy of the federal pollution discharge permit program, (NPDES). The New Jersey program (NJPDES) includes regulations governing dischargers to ground water as well as the federally regulated dischargers to surface water. In addition, ground water quality standards were promulgated and the laboratory certification program, necessary to insure that compliance monitoring submitted by dischargers is technically adequate, was established. Until that time, only potable water supply analyses required certifiable sampling and analytical quality control. Finally, the Integrated Ground Water Monitoring Strategy (IGWMS) was designed to coordinate the monitoring program being developed with the various existing programs. The focus of this paper is the framework established, under the IGWMS, to provide comprehensive ground water monitoring program coordination.

The Integrated Ground Water Monitoring Strategy

Originally, the two main objectives of the Integrated Ground Water Monitoring Strategy were:

1. To identify all existing ground water monitoring programs, at all levels of government, and;
2. To identify any monitoring information gaps.

However, the policy and budget changes which developed in the 1980's resulted in an increased scope for this grant. Three additional project goals were stressed;

1. To eliminate program duplication by coordinating the various monitoring programs;
2. To enhance the accessibility of information between programs by developing a centralized data pool, and;

3. To bring all monitoring programs up to a minimum, standard level of quality control.

To identify and characterize existing ground water monitoring programs a detailed survey questionnaire was sent to 90 agencies. The 90 agencies were selected on the basis of their likelihood to collect or have interest in ground water monitoring information. Also each agency conducting a ground water monitoring program was interviewed. Evaluation of the information collected showed that 85 percent of the ground water monitoring conducted in New Jersey was performed by the United States Geological Survey, the United States Environmental Protection Agency, the Delaware River Basin Commission and the New Jersey Department of Environmental Protection.

Additional analysis of existing federal, interstate and state programs showed that the vast majority of the resources devoted to ground water monitoring focused on pollution or quantity analysis. The critical monitoring gap identified was the lack of ambient ground water quality data.

Data Base Coordination

Having identified both existing programs and the major monitoring gap, efforts were initiated to establish links between the existing federal, interstate and state programs. A Water Monitoring Work Group was created in 1981. This group met bi-monthly and included 17 federal, interstate and state agencies conducting water monitoring programs, as well as agencies interested in using water monitoring data. These meetings provided a forum to discuss monitoring problems and to coordinate program planning among all of the agencies involved.

Two major issues were clarified during the Water Monitoring Work Group meetings:

1. A very wide range of quality assurance techniques were employed by the various programs. This made individual agencies reluctant to exchange or rely upon much of the existing data, and;
2. The inaccessibility of the monitoring information, especially at the state level, made such exchanges impossible.

All of the state's ground water data was stored in paper files at that time.

To eliminate program duplication agencies must be able to rely on the information collected by other sources and to gain access to the needed data. Thus, the computerization of the state's historical and incoming ground water data, in a manner compatible with the existing federal and interstate data bases, was initiated. This task was closely coordinated with the state's laboratory quality assurance unit.

The overall data storage strategy was considered a crucial step in the creation of a centralized data pool. Three separate data bases were being used for ground water data storage. The USGS ground water data resides in the federal WATSTORE data base in the Ground Water Site Inventory (GWSI) file. This file is specifically designed to store and manipulate water data parameters of a physical nature. Unfortunately, WATSTORE does not accomodate chemical water quality data, which is vital to the state's monitoring programs. The Delaware River Basin Commission's (DRBC) data resides in the

System 2000, a privately developed data base. This data base is also designed specifically for water quantity data and is unsuitable for New Jersey's more demanding needs. The United States Environmental Protection Agency's (USEPA) data resides in STORET, the federal water quality data base. STORET was chosen to be the repository for NJDEP's ground water monitoring data for five reasons:

1. STORET is designed to store and manipulate water quality data;
2. Some NJDEP surface water data is already stored in STORET and ground water data management personnel could work in-house with surface water personnel to develop computer usage capabilities;
3. STORET is a 'user friendly' system and can be efficiently used by scientists without an extreme amount of programming experience;
4. A wide variety of accessory packages, including analytical, statistical and graphical programs, are compatible with STORET, and;
5. The WATSTORE federal data base periodically updates its files into STORET.

Three long term state level monitoring programs exist which collect ground water quality information which required computerization:

1. The landfill compliance monitoring files, which contain ten years of historical water data;
2. The Bureau of Ground Water Management's case files, which also contain ten years of historical water data, and;

3. The recently promulgated New Jersey Pollutant Discharge Elimination System program (NJPDES), which is now beginning to collect tremendous amounts of ground water data.

Once data encoding had begun it was realized that a state level data storage strategy was necessary in order to separate each file from the other two. This was necessary for reasons of scientific reliability of the data. The historical water quality data in the landfill and pollution case files was collected in the period prior to the passage of the laboratory quality assurance regulations which govern non-potable supply water analyses and certify water quality laboratories. Indiscriminate combination of the historical data with the NJPDES file information, which would be collected after the laboratory regulations would become effective, would result in a 'contaminated' data base. Such a move would effectively nullify the quality assurance controls recently instituted. To avoid this problem and to lessen future user costs a separate agency code was established for the landfill file, for each individual pollution case and for the NJPDES computer files being designed.

By specifying agency codes in programs, data may be retrieved by its source file. Conversely, by specifying a New Jersey code or a geographic code the data from all files will be grouped before being printed out. Individual pollution cases were given separate agency codes in order to reduce the cost of retrieving frequently analyzed and graphed data sets.

The next task, after computerization of the state's files, was to establish linkages between the USGS Ground Water Site Inventory files on WATSTORE, the DRBC System 2000 files and STORET. Direct linkage was attempted; however, hardware incompatabilities prevented direct access from one system into another. The only alternative, at that point, was to achieve computer system coordination by developing a retrieval linkage. This concept calls for an identification system to be developed which would provide each individual well in the state with a unique i.d. number. These unique i.d. numbers would then be input into all New Jersey ground water files, in WATSTORE, System 2000 and STORET, as a sorting key word. Once this has been completed, information cross referencing will be established.

To increase the usefulness of the well identifier, instead of developing an arbitrary numbering system, the agencies agreed on using the identification system employed by the NJDEP Well Permits Section. The Well Permits Section of NJDEP maintains the well permit, well record and geologic log on many of the wells drilled in the state since 1947. The numbering system is based upon the New Jersey Atlas Sheet Series and incorporates a general location of each well in the i.d. number. Once all wells in each computer base receive their i.d. number, agencies can easily provide one another with needed, specific well information. In addition, the general location of any well is immediately recognizable and the drilling or geologic information , which is maintained on microfiche, can be quickly accessed. At this time, the USGS and NJDEP are entering the well i.d. numbers and the DRBC is preparing to do the same.

County Level Ground Water Monitoring

After developing the mechanisms to coordinate federal, interstate and state level ground water monitoring programs, the Bureau of Ground Water Management staff approached the 21 county governments in New Jersey. It was hoped to coordinate IGWMS efforts with the recently passed County Environmental Health Act. This act requires all New Jersey counties to monitor and enforce environmental health standards for water, air, solid waste and noise pollution in a manner consistent with the performance standards promulgated by the NJDEP.

Ocean County, in the eastern coastal plain of New Jersey, expressed a serious commitment of county staff and resources, partially utilizing funding from a federal 208 grant, to this project and proposed that the county level ground water monitoring pilot program begin there. A cooperative sampling program was designed based on the major concern of Ocean County, the protection of its vulnerable water table aquifers, and the need for ambient ground water quality information. After examination of land use patterns and field location of accessible wells, 270 wells were selected for the first sampling year. Sampling began in October of 1981.

Eighty percent of the selected wells were water table wells. These 216 wells were distributed in areas of county concern which fell outside of the areas covered by the state regulatory programs, or in pristine areas suitable for the acquisition of ambient background quality data. The remaining twenty percent of the wells were screened in the deeper artesian aquifers important to the current and future potable supply of the county. Each well was sampled once and analyzed for seven common dissolved ions, fourteen trace metals, six nutrients and four selected volatile organic compounds.

To develop county level abilities, USGS personnel trained Ocean County staff in standardized sampling protocol; including well evacuation, sampling, sample preservation and storage techniques. Ocean County health laboratory personnel and equipment were also tested for quality control. The county laboratory received blind samples, split samples, instructions in instrument control methodologies and suggestions on record keeping throughout the project.

The monitoring results were stored in WATSTORE and will be updated into STORET by 1983. Currently, the monitoring results are being evaluated to determine which well stations and chemical parameters should be included in next years monitoring program. Also, several shallow wells will be drilled by the Bureau of Ground Water Management in areas where wells are unavailable.

This project is geared to developing county level ground water monitoring and laboratory capabilities. Once the basic monitoring framework has been established and the county has demonstrated sufficient quality controls, USGS and NJDEP will drop out of the project. It has not been determined where the next county level monitoring project will be located.

Ambient Ground Water Quality Network

The final step in developing the Integrated Ground Water Monitoring Strategy was to include ambient ground water quality monitoring in the USGS/NJDEP Water Quality Surveillance Network. Until FY'82 this network only monitored surface water quality on a regular basis. However, the inability to immediately develop county level monitoring capabilities and the real need for reliable ambient ground water quality data resulted in a shift of program priorities and resources. Many surface water stations have been dropped from the network and about 100 wells will be added in FY'83. These wells have been selected and will be sampled yearly to collect long term ambient ground water quality data. Well stations were selected by their accessibility, distance from point sources of contamination, by land use patterns, their relation to base flow and the minimum number of wells needed to statistically define regional aquifer quality. One hundred surface water stations will continue to be sampled six times each year.

The minimum chemical parameter list for ground water data consists of 31 indicator substances from 8 chemical groups. The chemical groups include base neutrals, acid extractables, nutrients, major ions, trace metals and other organic compounds. Seventy-three additional chemical parameters will be examined in certain wells. The information collected in this program will be stored in WATSTORE and updated into STORET.

Conclusion

Although the goal of the Integrated Ground Water Monitoring Strategy is to coordinate existing ground water monitoring programs and to develop a centralized data pool, these steps are only one facet of a much larger effort. To develop a truly integrated ground water monitoring strategy all levels of government must combine resources and share areas of expertise. Legislation must be passed where necessary, and a real commitment to protect and preserve ground water resources must be made. The following six steps summarize New Jersey's activities in developing an effective ground water monitoring strategy:

1. Existing programs were identified and characterized;
2. Monitoring gaps were identified;
3. Legislation to protect our ground water resources was passed and programs funded;
4. Quality control standards were instituted;
5. Monitoring information was made accessible and coordinated with the existing programs, and;
6. Programs to fill existing monitoring gaps were developed.

Overview of Ground-Water Monitoring Activities

in

New Jersey

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February, 1985

Overview of Ground-Water Monitoring Activities in New Jersey

In 1982, a survey was made of all ground-water monitoring programs conducted in New Jersey. Seventeen groups were involved in collecting and analyzing, to one degree or another, ground-water quality and water use data. Six data base management systems were in use by various state, interstate and federal agencies. Since that time, there has been a substantial expansion of ground-water monitoring activities fueled by implementation of new laws and public awareness of ground water pollution.

At present, most ground-water monitoring activities in New Jersey are managed directly or indirectly by the Division of Water Resources (DWR), an agency of the New Jersey Department of Environmental Protection (DEP). DWR has lead responsibility for: 1) the Safe Drinking Water Act, 2) permits for ground-water allocation and well construction; 3) permits for pollutant discharges to ground water (including the UIC program), 4) ground-water pollution and ground-water monitoring aspects of RCRA; 5) evaluation and investigation of cases of ground-water pollution discovered by agency enforcement activities or Superfund studies; and 6) cooperative programs with the USGS for base-line monitoring.

In 1983, 2,052 wells were drilled solely for the purpose of monitoring ground-water quality (data from well construction permits issued). The vast majority of these wells were constructed to evaluate cases of ground-water pollution reported to the DEP or discovered by this agency. In addition, large numbers of existing wells are tested by state and local agencies. Little documentation is available as to the exact number of wells sampled; however, the order of magnitude is believed to be a few thousand per year.

The following New Jersey legislation is having a major impact on ground water monitoring:

1) New Jersey Water Pollution Control Act of 1976 which is commonly referred to as NJPDES or the New Jersey Pollutant Discharge Elimination System.

    First implemented in 1982, this law requires permits for all pollutant discharges to ground and surface water in the state. The definition of discharge specifically includes all activities which may cause pollutants to seep or drain to the land or ground waters. Thus, landfills, surface impoundments, spray irrigation of wastewater, land application of municipal and industrial sludges, waste piles, injection wells, and multi-unit septic systems require state discharge permits. It is estimated that over 2,000 facilities will require ground-water discharge permits in New Jersey. To date, about 15 percent of these have been permitted. All permits issued require substantial ground-water monitoring and installation of monitoring wells.

2) Environmental Cleanup and Responsibility Act of 1983 or "ECRA".

This act requires approval by the state environmental agency (DEP) before most industrial establishments can sell or transfer property. A state certification that the soil, ground water and surface water are not contaminated with hazardous substances is required. About 1,000 facilities per year are expected to be evaluated under this law. It is anticipated that 20 to 30 percent of these will require substantial ground-water monitoring.

3) 1984 Amendments to the New Jersey Safe Drinking Water Act.

This law requires that the state establish contaminant levels (MCL) for twenty-two organic chemicals (mostly volatile organics) within 18 months of the effective date of the act and, within two years, establish MCLs for other chemicals which pose a cancer risk of one in one million. All public water supplies are then to be tested for these substances. In New Jersey, ground water provides about one half of the total water supply (excluding power-plant cooling water).

Because of this rapidly growing ground-water monitoring activity, basic regulatory requirements have been established as follows:

1) All monitoring wells require a well construction permit (application and well completion report) and must be drilled by a licensed well driller.

2) Water samples (both surface water and ground water) must be collected in accordance with a "Field Procedures Manual".

3) Laboratories analyzing water samples collected for all programs (i.e. safe drinking water, discharge permit monitoring) must be certified by the state for proficiency in each parameter analyzed.

4) Specific requirements in regulations and permits for accurate monitoring--well locations, type of well construction, "as-built" certification of construction, and submitting monitoring data on standardized reporting forms--have also been written.

Obviously, the large amount of ground water data being collected presents a data management problem. Currently, only data from the base-line monitoring programs managed by the USGS and state regulatory programs (monitoring required by state discharge permits and the state/federal Safe Drinking Water Act) are routinely entered into computer data bases.

V. CASE STUDY: GROUND-WATER MONITORING IN FLORIDA

INTRODUCTION

The following pages describe the Ground-Water Monitoring Program in Florida. This information was obtained from Dr. Rodney DeHan of the Ground-Water Section of the Florida Department of Environmental Regulation for use in this document. The section on monitoring strategies is taken from a questionnaire prepared by EPA Region IV.

The material is organized as follows:

- Florida's Ground-Water Monitoring Plan
- Status Report, February 1984, on Implementation of Water Quality Assurance Act
- Monitoring Strategies:
    1) Ambient
    2) Compliance
    3) Pesticides
    4) Emergency Responses
    5) Special Studies
    6) Unaddressed Federal Sources
- Ground-Water Monitoring Costs

Florida

GROUND WATER MONITORING PLAN

FLORIDA DEPARTMENT OF ENVIRONMENTAL REGULATION

Introduction

Historically, ground water has been a high quality, inexpensive and readily available source of potable water in Florida. This state is one of few in the nation that depends almost totally on ground water for drinking, and ground water supplies half the water used for agriculture, industry and electric power generation. Florida's dependence on ground water will increase along with increases in population and industrial development.

The expected increase in the demand for ground water will aggravate the susceptibility of the resource to pollution unless measures are taken to better manage and protect the aquifers.

Because of Florida's hydrogeology, ground water aquifers are highly susceptible to pollution by man's activities on the land surface. Detection of ground water pollution and subsequent clean up (if possible at all) is very difficult — and extremely costly.

The discovery of large-scale pollution of Florida ground water by the pesticide Ethylene Dibromide, and threats from hazardous and non-hazardous waste sites, are samples of the seriousness of the problem.

The Florida Legislature recognized these issues and began major steps to address them when it passed the Water Quality Assurance Act of 1983.

Ground Water Quality to be Monitored

Among many other things, the Act requires the Department of Environmental Regulation (DER) to cooperate with other state and federal agencies, water management districts, and local governments to establish a "a ground water quality monitoring network designed to detect or predict contamination of the state's ground water resources."

The Act instructs the DER to make information generated by the network available to state and federal agencies and local governments to help with their regulatory and land use planning decisions. This publication is to inform state legislators, local governments and the general public of the DER's plans and actions to establish the ground water quality monitoring network.

The DER expects the network to provide information in three major areas:

- Determination of the quality of water provided to the public by major well fields in the state.
- Determination of the ambient or unaffected ground water quality.
- Determination of the quality of ground water affected by sources of pollution.

Results from the network will help state, local and federal agencies make regulatory, water and land use decisions that are founded on technical and scientific bases. The ultimate benefit of this approach will be improved management and protection of ground water.

The Ground Water Quality Monitoring Program

Following is a brief description of the status of the program developed by the DER to evaluate ground water quality and assure that drinking water is free of contamination.

GOAL I

To Ensure that the Majority of Floridians are Consuming Uncontaminated Drinking Water

The federal and the state Safe Drinking Water Acts require public water suppliers to analyze their treated water for certain chemical, physical and bacteriological parameters known as "primary" and "secondary" drinking water criteria. While these criteria are useful in detecting pollution from domestic sources and some industrial and agricultural sources, they are inadequate to detect toxic and carcinogenic organic chemicals, including many pesticides.

To fill this gap, the DER contracted with the U.S. Geological Survey (USGS) to collect and analyze samples from 96 major Florida public water supply well fields for additional parameters. The parameters were selected as indicators of the presence of toxic and carcinogenic organics and pesticides.

The 96 well fields serve some three million Floridians. In all, there are some 7,000 public water supply wells in the state. The department has asked community public water supply systems which were not sampled by USGS to conduct similar analyses on a voluntary basis. Because of the importance of these tests, the department plans to require the analyses by administrative rule in the future.

GOAL II

To Determine the Quality of Ground Water Affected by Sources of Pollution

This goal, and to some extent the first goal, are being accomplished in three phases. The DER has developed agreements with each of the five water management districts to carry out the program tasks.

Phase I

Compilation of Existing Data and Generation of New Data

A large volume of data must be collected before actual ground water monitoring can begin, either through existing or new wells. The necessary data includes:

- **Location of point and nonpoint source pollution.**

Point sources include landfills (active or abandoned), percolation ponds, industrial septic tanks, land application sites, buried tanks, drum recycling operations, mining waste discharge (and gypsum stacks) and drainage wells.

- **Delineation of the depth, areal extent and continuity of impermeable zones.**

This information is essential to determine aquifer zones to be monitored and the depth and location of monitoring wells.

- **Location and delineation of cones of depression around well fields.**

Withdrawal of water from wells creates a situation (around the wells) of increased percolation rates from the surface and thus a higher potential for pollution of the aquifer and subsequent withdrawal of pollutants through the supply well. It is essential that cones of depression be delineated, and proper monitoring wells drilled to predict or detect contamination before any contaminated water is withdrawn through the supply wells.

- **Location and delineation of the outcrop areas for the Floridan Aquifer.**

The Floridan aquifer is the major drinking water aquifer in the state. In general, it is protected from surface pollution by confining beds of low permeability clay, by overlaying surficial aquifers, and by its location at great depths underground. In a number of areas of the state, however, the Floridan comes close to the surface (outcrops) and becomes the surficial aquifer. In these cases, the aquifer is highly susceptible to pollution. Development and location of waste disposal facilities in these areas must be viewed with great caution and closely monitored.

• Location and delineation of wetlands, springs, sinkholes and other direct or indirect recharge areas.

Surface water in wetlands is interconnected with ground water. The quality of water in a wetland is a critical factor which affects the quality of ground water. Other recharge areas are of similar significance to the Floridan outcrop areas. Protection is necessary through prudent management and monitoring of these areas.

• Location of agricultural and other areas where pesticides, herbicides and fertilizers are heavily used.

The highly publicized Aldicarb (Temik) and Ethylene Dibromide (EDB) issues are two painful examples of the significance of the pesticide problem. The application of toxic chemicals in agriculture and other activities has traditionally been accompanied by limited understanding of the effect of these chemicals on ground and surface water quality.

Widespread contamination of ground water by EDB has focused attention on the need for close monitoring of ground water in areas where pesticides and other chemicals are applied. This problem is extremely difficult to address because the areas affected are extremely large, the pollution is dispersed, and few accurate records of application areas and rates are available. Cooperation between the DER, the Department of Health and Rehabilitative Services, the Department of Agriculture and Consumer Services, and the Department of Community Affairs is essential in locating pesticide application areas and designing monitoring wells to predict and detect ground water contamination before it happens.

• Identification of saltwater intrusion boundaries.

The problem is limited primarily to coastal areas where extreme withdrawal of fresh water has caused the seawater to move into coastal aquifers. This is being adequately addressed by the water management districts. Continued attention to saltwater intrusion is essential in designing a statewide monitoring network to ensure that the saltwater boundaries are stabilized and — when possible pushed back.

• Location and plugging of free-flowing artesian wells.

Oil and gas exploration activities have resulted in the existence of a large number of free-flowing wells. The wells have great potential for wasting precious fresh water and they can become contaminated with salt or lower quality water from deeper aquifers.

Thousands of these wells have been located and plugged by the water management districts. However, thousands of others remain unplugged and thousands more remain unidentified.

Although the Act identifies this problem as a separate issue, it is part of the monitoring network effort since free-flowing wells are possible sources of pollution. The Act also identifies data collation as a separate function, but data collection also is an integral part of the establishment of a ground water monitoring network. Both data collection and the free-flowing well problem are being coordinated by the Groundwater Program in DER.

Phase II

Determination of the Number and Location of Monitoring Wells

Federal, regional, state and local agencies have, for various reasons, drilled and used monitoring wells in the state, and records with varying degrees of completeness and accuracy from these wells are already in existence. Many of these wells may be used as part of the monitoring network. The DER has conducted a search for such wells (in cooperation with the USGS and the University of Florida) and has located 1,800 wells which may be suitable. Additional research must be conducted to locate more wells for ground water monitoring. The location of existing wells will save a great deal of money that would otherwise be spent on drilling new wells.

Some new wells will be drilled in areas where no existing wells can be found, or where the existing wells are not suitably located to serve as monitoring points. The location of the monitoring wells (both new and existing) will be in relation to sources of pollution, and to evaluate ambient ground water quality.

Phase III

Collection and Analysis of Water Samples and Establishment of Water Quality Trends.

Specific monitoring parameters have been established to allow the DER to determine the effect of sources of pollution. The number and type of parameters vary according to the type of waste discharged. The sampling project is designed to provide baseline water quality data for subsequent monitoring of water quality trends. For evaluation of ambient water quality, only indicator parameters will be sampled for and analyzed less frequently than for aquifers affected by pollutants.

Data will be entered into DER computer systems. Computerized graphic systems will express data in a clear, easily understandable format suitable for decision making. Data analysis will be closely coordinated with the data collection effort and the information will be included in an annual bibliography. Reports and bibliographies will be made available to the Legislature and local, state and regional agencies to help them in their decision making.

Phase III will continue for the foreseeable future with necessary modifications for development, growth, economics and water quality changes.

Summary and Recommendations

In planning the network tasks, many factors were taken into consideration. Protection of the state's environment and the public health were the two main goals. However, economic factors and the availability of funds and manpower are important factors which significantly shape the level of effort possible in the time allotted.

It is evident that all three phases cannot be completed under the available time and funding level. Accordingly, the plan is designed to complete Phase I and a significant part of Phase II in fiscal year 1983-84. During this fiscal year, each water management district is to select a pilot area where all three phases will be carried out. Such areas will be selected on the basis of environmental sensitivity and high potential impact on public health. This approach will enable the DER and the water management districts to establish methods to carry out all three phases statewide when funds become available.

While exact levels of needed funding are not available, at least the current $2 million appropriation should be continued for the next three fiscal years for the network to be fully operative.

DEPARTMENT OF ENVIRONMENTAL REGULATION

FEBRUARY 1984

STATUS

REPORT ON IMPLEMENTATION

OF THE

WATER QUALITY ASSURANCE ACT

STATE OF FLORIDA

DEPARTMENT OF ENVIRONMENTAL REGULATION

TWIN TOWERS OFFICE BUILDING
2600 BLAIR STONE ROAD
TALLAHASSEE, FLORIDA 32301-8241

BOB GRAHAM
GOVERNOR

VICTORIA J. TSCHINKEL
SECRETARY

February 29, 1984

Honorable N. Curtis Peterson, Jr.
Florida Senate President
Suite 409
The Capitol
Tallahassee, Florida 32301

Honorable H. Lee Moffitt
Speaker
Florida House of Representatives
Suite 420
The Capitol
Tallahassee, Florida 32301

Dear President Peterson and Speaker Moffitt:

I am very pleased to enclose a report on our implementation of the Water Quality Assurance Act of 1983.

While much remains to be done, I believe you will be as satisfied as I am over the progress we have made in the implementation of this complex and most important legislation. Several key areas are worth noting:

*Sewage Treatment Grant rules for the state priority systems are adopted. We are working actively with communities throughout the state -- particularly the small communities -- to make sure that those who most need help are ready when funds are available in November.

*We and the water management districts are well along in the groundwater monitoring program so desperately needed to produce the information we need to fully protect our underground drinking water supplies.

*The Pesticide Review Council is fully operational, has met several times and is providing valuable assistance to the Department of Agriculture and Consumer Services in its pesticides program.

President Peterson,
Speaker Moffitt
February 29, 1984
Page two

*The Local Government Hazardous Waste Assessments are well underway in the most populated areas of the state -- working under guidelines prepared by the department. The next group of counties are preparing to begin their work.

*Amnesty Days -- which will allow homeowners and small businesses to dispose of small amounts of hazardous waste at no charge -- is about to begin on schedule.

*Nearly $1 million were spent from the Water Quality Assurance Trust Fund for state clean up activities at the City Chemical site in Orlando.

*The department and other agencies have sampled 3,345 private and public potable water wells for possible contamination by the pesticide EDB and have found the pesticide in some 541 wells. Some $1.2 million have been spent or obligated from the Water Quality Assurance Trust Fund for the sampling and anaysis of well water, for providing alternate supplies of drinking water, and for research into filters which can remove the contamination.

More detailed summaries of each of these programs, and of the others required under the Water Quality Assurance Act, are in the report. Each summary report describes the requirements to be met and our progress, and outlines the schedule for the months ahead.

It is not unusual for legislation which is as wide ranging and complex as the Water Quality Assurance Act to contain oversights and omissions. While the Water Quality Assurance Act is no exception, we are amazed at how few there are; another example of a tremendous amount of painstaking work by the Senate, the House of Representatives, and their respective staffs. We have submitted corrective legislation to the appropriate committees in both Houses of the Legislature. It will receive its first subcommittee hearings in both Houses in early March, and department staff will work closely with your committees as this legislation progresses.

While we are pleased with our progress so far, we realize there is much much more to do; in fact, most of the work lies ahead. Preventing further contamination of groundwater; cleaning up hazardous waste sites, and ensuring that the mistakes of the past do not become the habits of the future are not short-term tasks. Your successors as President of the Senate and Speaker of the House of Representatives, and my successors as Secretary of the Department of Environmental Regulation, all will find themselves fully occupied in the years ahead.

PART I - SECTION 2

DATA COLLECTION

Task Description:

Establish central repository for all scientific and factual information relating to water resources generated by local governments, water management districts and state agencies. Collect, maintain and make available such information to public and private users within the state.

Status:

Most sources of water quality data have been identified. State agencies, water management districts, local programs and several private agencies have been contacted through a questionaire or phone survey. Meetings have also been held with several agencies including most DER district offices. OPS personnel have copied data at agencies which have non-automated water quality information. Copies are being systematically transferred to Tallahassee. Agencies with automated data files will have their tapes transferred by the Data Management Staff. Draft computer formats for monitoring well inventory information and test results have been sent out for comments. Agencies have also been asked to comment on their potential use and needs of the DER data base system.

Schedule:

OPS will complete the bulk of data aquisition from agencies with non-automated files by the end of February. They will transcribe data to format sheets in March. Tapes will be required from agencies with automated files in February, March and April. A method of continually updating the data base will be developed in February.

PART I - SECTION 2

BIBLIOGRAPHY

Task Description:

Computerized Bibliography of Existing Water Resources Information: The Bureau of Water Analysis and the Groundwater Section are to prepare and distribute a bibliography of all documents related to state water resources. The bibliography will be updated and reissued on an annual basis to make new sources of information available to interested persons.

Status:

A project plan defining all tasks necessary to develop the bibliography has been prepared. The bibliography is being built upon an existing 6,000-reference computerized information file related to the Florida Gulf Coast developed by the FDER under a grant from the U.S. Fish and Wildlife Service. The file is maintained on the Northeast Regional Data Center (NERDC) IBM Computer at the University of Florida. A substantial amount of data from computer science, assembled bibliographies, and current library holdings has been entered onto the Lanier word processor to be merged into the bibliographic file at NERDC. All reference entries have been assigned key words to allow retrieval of specific information. In addition, a letter has been prepared for distribution to local agencies requesting any bibliographic items that they feel should be included on our master file.

Schedule:

First Draft - April 1, 1984
Final Draft - July 1, 1984

PART II - SECTION 3

GROUND WATER QUALITY MONITORING

Task Description:

Establish a ground water monitoring network designed to detect or predict contamination of the state's ground-water resources.

Status:

With the exception of Southwest Florida Water Management District (SWFWMD), contracts with the other four districts have been finalized and their work is progressing satisfactorily. Although SWFWMD has not signed a contract yet, it has been working on compiling data that will satisfy some of the requirements of phase I. The other districts have followed the plan of study as outlined by the Department of Environmental Regulation. Briefly, they are finishing phase I (data compilation) and working on phase II (location of existing wells). In certain selected pilot areas within each district, they are trying to implement all three phases (phase III is sampling existing wells and drilling new wells). Northwest Florida Water Management District NWFWMD) is the most advanced in the pilot study. It has drilled over 20 wells so far and is preparing a sample them.

The USGS monitoring of 96 wellfields for drinking water and organic parameters is nearing completion. All wells have been sampled, positive detections are being repeated for confirmation.

Schedule:

USGS study should be completed by late March. Contract with SWFWMD will be signed in March. The bulk of phase I tasks will be finished by March for the four districts. Pilot area studies for the districts (other than NWFWMD) will be initiated by late February.

PART III- SECTION 5

WELL FIELD CONTAMINATION

Task Description:

Establish a program to prevent or minimize the danger of contamination to potable water supplies; Contract for clinical testing.

Status:

There are four items associated with the task:

a) Inventory or private and public wells - Wells fields for major cities are presently being sampled under a contract agreement with the Department. We also asked that community systems serving 1,000 or more persons submit analyses of their water, including the priority pollutants as well as analysis for EDB, Temik and certain other pesticides. This analysis is due by June, 1984. Bill in the House and Senate would require this analysis. However, the Drinking Water Section is developing rules to require this monitoring. The section is also proceeding with setting maximum contaminant levels for certain volatile organic compound and is cooperating with EPA in an analysis of South Florida Wells contaminated with vinyl chloride. The Superfund staff has asked that we assist in inventorying wells in the danger zone of the Biscayne Aquifer sites. This would be carried out jointly with DHRS. Further statewide inventories of private wells must await legislative funding. Staff is also involved in the EDB contamination inventory and in developing carbon filter specifications for private and public wells.

b) Contract for Clinical Testing - A generalized MOU has been signed with DHRS to utilize WQAA Trust Fund monies for investigations or testing in areas where drinking water has become contaminated. DHRS did propose an effort in Polk County to try to relate EDB contamination to cancer occurrences. The proposal was not acceptable to DER and is being re-drafted to meet agency suggestions. A funding ceiling has been identified to carry out this effort. A second draft of the proposal is now due.

c) Review of Drinking Water Interagency Agreement - The agreement was reviewed during December and January. No significant comments were offered on proposed changes. We are now preparing clarifying language changes. General coordination with DHRS is continuing, with monthly meetings at the Tallahassee level. DER District Offices also regularly coordinate with County health units. We are reviewing a proposal to designate Martin County as an Approval County health unit.

d) Well Field Siting - We are continuing the evaluation of Chaper 17-22 and reviewing other local agency rules regarding cone of influence models, etc. for possible incorporation in DER's rules.

Schedule:

a) The rules requiring water system testing for the priority pollutants is scheduled for the April ERC as are the MCL's for the volatile organics. The results of th USGS sampling programs are due in late March. The inventory effort for the Biscayne Aquifer Superfund Site will be discussed at the February meeting with DHRS and further schedules developed following that. The specifications for home carbon filter units are developed and available.

b) A review of current rules on well field siting is on-going, and changes of 17-22 should be ready for initiating the rule making process in June 1984.

c) The generalized MOU with DHRS is complete and signed. A draft proposal for specific studies/testing in Polk County is due from DHRS.

d) The review of the drinking water interagency agreement is complete. Clarifying language changes are being made and should be completed in February. Another review is scheduled for June, 1984.

PART V - SECTIONS 9 and 10

PESTICIDES

Task Description:

Develop a pesticide review program.

Status:

The following elements of the department's pesticide review program have been completed:

A DER scientist, Mr. Gregory Parker, Chief, Bureau of Groundwater Protection and Waste Management, has been appointed as the department's representative on the Pesticide Review Council.

Recommendations were made for the Governor's appointees to the Pesticide Review Council and all members have been appointed. Dr. Aloysius Wood has served as Chairman since January, Dr. Stephen King is Vice-Chairman, and Gregory Parker is Secretary. There have been two significant meetings of the Council. At the December 2, 1983 meeting, a subcommittee was appointed to review restricted-use pesticides to recommend study priorities. Also, Commissioner Doyle Conner asked the Council to review Telone II as a replacement for EDB in the DACS buffer zone and push-andtreat nematode control programs.

At the January 20, 1984 meeting, the Council deferred action on Telone II and passed several resolutions; one in support of Commissioner Conner's Stop Sale of EDB-contaminated food products, and the second to request that the Bureau of Product and Data Evaluation (DACS) report on the feasibility of developing a comprehensive pesticide-use reporting system. A third resolution supported development of a list of pesticides that should be monitored in groundwater.

Recruitment is complete for the five positions in the Pesticide Review Section. Current work elements of the department's pesticide program include:

- Developing test criteria for the impact of pestides on water resources.
- Evaluation of DACS/EPA pesticide registration programs under FIFRA.
- Interagency EDB Task Free support.
- Evaluation of other state pesticide programs.

- Development of a pesticide use data base.

- Integrated Pest Management and alternatives to chemical control.

Schedule:

The administrative framework for the department's pesticide review program is complete.

PART X SECTION 77

ENVIRONMENTAL REORGANIZATION

Task Description:

Delegation of Water Well Contractor Licensing to the Water Management Districts.

Status:

The Department of Environmental Regulation, and the Water Well Contractor Association have met and discussed proposed changes to Chapter 17-20, FAC. A draft of these proposed changes and a draft delegation order is expected by March 1, 1984. We do not anticipate any legislative changes will be required.

Schedule:

Delegation of Chapter 17-20, FAC to the WMDs and the accompanying changes to Chapter 17-1, FAC are on schedule for adoption by October 1984.

PART XI - SECTION 84

POLLUTANT SPILL PREVENTION AND CONTROL

Task Description:

Develop a program for the cleanup and restoration of sites contaminated with hazardous substances and other contaminants using state funds and matching federal Superfund dollars.

Status:

Federal Sites - EPA funding for Superfund activities continued to be slow during the quarter. Three new applications were submitted to EPA for funding for four Superfund sites during the quarter; but it appears that money will not be approved until next quarter. The resulting Cooperative Agreements will allow studies to begin for the first phase of Superfund program activities. Actual clean-up will begin, at best, 12 to 15 months after first phase funding is received.

Responsible parties are progressing with preliminary studies, clean-up, or contamination control measures on six Superfund sites. These actions will eliminate the need for state or federal dollars to be spent for these activities.

Negotiations are underway for responsible party actions on three additional Superfund sites.

Feasibility studies have been started during the quarter; two under state leads with federal funding, and one large study under EPA lead covering three sites in Dade County. EPA has plans to begin EPA lead studies for three additional sites in the next quarter. These studies are aimed at supporting enforcement actions or Superfund financed clean-ups.

State sites - Contractor selection for necessary study phases of projects dominated activity during the quarter. Site screening and selection was also a major task accomplished during the period. Studies will begin on nine state sites during the next quarter. Two state funded immediate removals are planned for next quarter. We are presently seeking legal access to these sites to allow the clean-up contractor to do the work.

Negotiations or legal actions have resulted in responsible party actions on six sites originally planned for state funded activities.

Schedule:

Ongoing activity.

PART XI - SECTION 84

POLLUTANT SPILL PREVENTION AND CONTROL

Task Description:

Undertake the removal of prohibited pollutant discharges (spills) if the responsible party fails to act immediately. Prepare a statewide list of leaking pollutant storage tanks.

Status:

$300,000 out of the WQATF has been earmarked for pollutant spills and the removal of abandoned drums containing unknown hazardous waste. The list of leaking tanks has been completed. Field response procedures for gasoline/petroleum contamination incidents have been developed. Contamination log sheets have been drafted for district use.

Schedule:

Ongoing activity.

PART XI - SECTION 84

POLLUTANT SPILL PREVENTION AND CONTROL

Task Description:

The department is to establish regulations governing standards for construction, installation, maintenance, permitting, removal, and disposal of storage tanks. Facilities to be regulated contain tanks with greater than 550 gallons of pollutants and are located in nonresidential areas. Pollutants were defined as oil, petroleum products, pesticides, ammonia, chlorine and derivatives thereof, excluding liquefied petroleum gases.

Status:

Two public workshops and several presentations have been held and a third is scheduled on the proposed rule. The rule will be phased with first priority being given to above- and belowground storage tanks storing gasoline and other petroleum products used for transportation fuels. Tallahassee and district staff have been hired to implement the program.

Schedule:

The first phase of the rule will be presented for adoption to the ERC at its April 11 meeting.

"Environmental Monitoring Strategy for Groundwater"
Ambient

I. Goals and Objectives

The goals of the ambient ground water monitoring network are essentially threefold. First, establishing the background water quality for ground water found within the three aquifer systems in the state is necessary before it is possible to accomplish the second major goal of the network, to detect and predict changes in ground water quality resulting from point and nonpoint sources of pollution and other human activities. The third objective is to monitor the quality of public drinking water that is supplied by major wellfields.

II. Extent Data Needs are Being Met

To accomplish these goals it is necessary to establish a network that adequately monitors all three aquifer systems (the surficial aquifer, intermediate Aquifer System, Floridan Aquifer) in three dimensions. The following types of data have been (and are being) generated or compiled prior to drilling new wells for use in the Network.

- Locations of point sources of pollution
- Land use patterns indicative of areas where nonpoint pollution may pose a threat.
- Hydrogeological information such as:

  1) Thickness and extent of surficial aquifers and areas of significant use.
  2) Thickness and extent of the Intermediate Aquifer System.
  3) Thickness and extent of the Floridan aquifer.
  4) Areas where the Floridan Aquifer hydraulically exists as seperate water bearing zones.
  5) Areas where the Floridan is at or near land surface.
  6) Areas where the Floridan is under water table condition.
  7) Locations of major well fields.
  8) Flow directions within the three aquifer systems.
  9) Areas of saltwater intrusion.
  10) Areas of karst development (fractures, sinkholes, etc.).

III. Programs Plan to Meet Needs

The above mentioned data is being compiled by the five Water Management districts under the supervision of DER ambient staff at the present time and this phase is nearing completion. With this information available it will be possible to choose wells in the proper location and of the correct depth. For instance, landuse patterns and density of point sources of pollution will be used in conjunction with hydrogeologic data to determine the density and location of monitor wells needed in a particular area.

After this initial compilation of hydrogeologic data, another major data collection effort will occur. A comprehensive set of chemical analyses will be performed on the first set of samples collected from all wells in the network. The results of these analyses will be used to classify wells in the network as to quality of water being monitored at each site:

I. Pollution Source Monitonig Well
   A. Point Source Monitoring Well
   B. Nonpoint Source Monitoring Well

II. Background Monitoring Well
   A. Nonpristine Background Monitoring Well
   B. Pristine Background Monitoring Well

By classifying the wells it will be possible to establish a sampling frequency and scheme compatible with the site. For instance a well in proximity to a point source of pollution would need to be monitored more frequently and for more specific chemical parameters than a pristine background well, which may be monitored only for indicator parameters on infrequent basis.

Once the network is operating, data needs will include chemical data tailored to fit the nature of the site, locations of additional areas or sites that are found to require monitoring, more site specific geological information for areas discovered to have problems, information pertaining to the materials used and activities at point and nonpoint sites.

IV. Data Verification

A. Point of Sample Requirements

1. Premonitoring Activities

a. Safety considerations will vary depending on the type of well being sampled. The vast majority of wells will be monitoring ground water of background quality.

b. Extensive data compilation outlined in I (above) will provide general information. At specific sites where problems are detected, a more detailed study will be necessary.

c. See I above

d. See 1 above

e. Modeling is not required by law. However, presently plans exist that have the ambient staff modeling major pollution sites. Data needed for modeling will be site specific. A more intensive monitoring frequency (than required for the general Network) will be required for those sites designated for modeling.

f. Each well in the Ambient Network will initially be tested for a series of parameters listed on the included list (attachment "A"). If there is significant indications of organic or organohalide contamination through TOC or TOX, then further specific organic parameters will be tested.

After the first testing, each well will subsequently be tested for parameters chosen on a case by case basis dependent on what contamination is considered likely. Surrogates parameters such as TOC or TOX or Specific conductance will be used to indicate the presence of organic and inorganics respectively.

g. All ambient monitoring is intended to be in the saturated zone at this time. Also, at this time the number, density and depths of wells in the network has not been established.

h. See I and IV A.1.b. above

i. See IV A.1.g. above

j. Laboratories to be used will be either the DER laboratory or a DER approved commercial lab.

2. a. - c. See attachment "B"

3. a. See IV A.1.a above
   b. See attached general sampling recommendations
   c. See I
   d. See IV A.3.b. above
   e. Follow EPA and DER SOP

B. 1.-4. Laboratories must be listed in "FDER Statewide Environmental Chemistry Laboratory Quality Assurance Program" report. FDER's Q/A bureau monitors these labs. A program for environmental laboratory certification is currently being considered by the Department.

C. Much of the data analysis will be done using standard commercial software packages (SPSS, BMDP, SYSTAT, Minitab, etc.). Any in-house produced programs will be thoroughly tested before use. Quality assurance on all data generated or accepted by the Department is performed by the newly formed Quality Assurance Section located in the Bureau of Water Analysis.

V. Linkage With Other Programs

It is anticipated that the five Water Management Districts, the DER Division of Permitting, counties, cities, other state agencies, the federal government and the private sector will use data collected by the ambient program. The data should be ideal for determining (1) background and (2) nonpoint ground water quality data. Most data transfer (80%) via computer linkage should be sent from "ambient" to the other agencies; not vice versa, unless more than one agency happen to collect data from the same well. In such cases data sharing and exchange would be desirable provided proper quality assurance is implemented.

The applicable MCL's are used as standards when available. When MCL's are not available the 1:1000,000.0 risk assessment or the nondetection limits are used for man-made contaminants judged to be toxic or carcinogenic.

VI. Technical Barriers

The following are technical barriers encountered in all ground water monitoring activities.

a. The availability of indicator parameters that can be used in Lieu of analysis of full suite of chemical parameters.

b. The availability of good relatively simple mathematical models that can be used in predicting contaminant movement and fate of toxic chemicals in the ground water.

c. Basic data on movement of organics through confining beds and the potential for chemical or microbiological degradation in the ground water.

d. The lack of scientifically based numerical values for what i.e. a safe level of toxic and carcinogenic chemicals in the ground water i.e. the issue of "how clean is clean".

e. Lack of technical data on the reaction of chemicals with various types of monitor well casings.

f. Shortage of technically qualified professionals, affordable by the State, in the fields of hydrology, toxicology, soil science, chemistry and mathematical modelling.

g. Better (more precise) geophysical instrumentation that can determine the existance and dimensions of leachate plumes from the land surface.

h. Less cumbersome field safety equipment that can be utilized in hazardous sites investigations.

VII. Percived Roles of EPA Headquarters

The state is in full agreement with the EPA's Ground Water Strategy which states that the management and protection of ground water is primarily a state responsibility. EPA's role is perceived as involving the following:

a. Financial assistance. A dependable and independent source of funding approved by Congress should be established to help the states develop (or implement) ground water programs.

b. Research and Development. The EPA is the logical agency where research needs in the following areas should be satisfied:

- Toxicological studies on chemicals of the priority pollutants list and other chemicals judged to be toxic or carcinogenics.

- Based on toxicology, behavior and fate of contaminants in the ground water, geochemical and geophysical properties of contaminants, the EPA should endeavor to develop criteria for how clean is clean and Maximum Contaminant Levels for various types of aquifer and for drinking water supplies.

- Development of methods for waste volume reduction for the industries involved in discharge to ground water.

- Development of better technology for recycling of waste.

- Development of better technology for disposal and/or storage of hazardous waste.

c. Assist the states in areas involving interstate aquifers contamination.

d. Assist in controversial enforcement cases where local political or other constraints may hamper the states effort.

e. Develop programs in cooperation with the universities to train professionals to be ground water specialists.

VIII. Data Processing and Analytical Tasks

A. 1-4. Data Bases

Data will be stored in a central repository that is accessible through a telecommunications link. These data will be in a form compatible with graphical display using an Intergraph graphics system. Data will be coming directly from a DER approved lab, so there should be no problem with data quality assurance.

B. Uses

1. Administrative

Data generated will be forwarded to lcoal programs, water management districts and counties to help in their decision making process involving land use or water allocation.

2. Trend analyses

   Statistical analyses will be conducted on the acquired data. The results will be supplied to all interested parties or will be published. The primary user, in addition to 1. above, is the DER. Data establishing trends will be used in rule development, permitting of waste disposal and management facilities and in consumptive use permits by the Water Management Districts.

3. Rulemaking legislation

   Background data will be ideal for legislation that declares aquifer segments "sole source", exempted aquifers or single source aquifers. Certain aquifers may, on the basis of trends be condemned as sources of drinking water supplies.

4. Modeling

   Data collected by the Network may be used for modelling of aquifers or aquifer segments on regional basis. Data collected for the compliance program are better suited for site specific modelling of plume behavior.

5. Measuring effectiveness.

   The data maybe used to measure the effectiveness of the various states' program in a general long term fashion. The Network data is not expected to be used for measuring the effectiveness of specific programs.

6. Health and Environmental impact

   Data will be shared with the State's Department of Health or the Federal CDC for use as the basis for potential epidemiological or health survey studies.

7. Fate and Movements of pollutants See IV 1.e.

C. Problems

The major problem is developing a statewide network that is uniform. Since each of the five water management districts is developing a network for its area, there is a tendency toward the development of five seperate networks. The FDER ambient staff is working hard to avert this problem and provide a verifying role.

D. Analytical Software

See IV C.

E. Roles of EPA

See item VII.

IX. Training and Technical Assistance

See VIII. E.; Drillers are licenced (state law) but they are not certified. They should be certified.

X. Implementation Schedule

Monitoring should begin in late 1985.

Environmental Monitoring Strategy for Ground Water

Compliance

1. Goals and Objectives:

Compliance with the ground water criteria is assured through the point source facilities permitting mechanism. This mechanism requires that any direct or indirect discharge to ground water must be monitored for compliance with specific ground water standards and criteria. These criteria are detailed in Chapters 17-3 and 17-4, FAC. The general goal of this effort is to insure that the state's ground water quality is protected for the most beneficial uses.

A. Drinking Water

The State of Florida has assumed Primary Enforcement Responsibility (Primacy) for the Safe Drinking Water Act. The Acts requirements for compliance with the Primary and Secondary Drinking Water Standards are enforced through monitoring of the finished water for these standards. These standards are enforced for the community and noncommunity public water supplies by both the DER and the Florida Department of Health and Rehabilitative Services (HRS). The Florida Administrative Code Chapter 17-22 is used for this purpose.

B. Underground Injection Control (UIC)

The State of Florida has also assumed Primacy for the UIC Program from EPA. Th- Florida Administrative Code Chapter 17-28 was developed and adopted for the purpose of enforcing the UIC criteria to projects discharging into the underground environment. This chapter is more stringent, in several aspects, than the EPA guidelines. The DER is responsible for Classes I, III, IV and V while The Department of Natural Resources (DNR) is responsible for Class II oil and gas wells. Injection of hazardous waste through Class IV is prohibited in Florida. Florida also just recently prohibited injection of hazardous waste through Class I. Injection of effluents or stormwater runoff into Class V wells is allowed provided such effluents meet the ground water criteria which are identical to the drinking water standards.

C. CERCLA

The DER is deeply involved in investigation of and cleanup of Superfund sites. The state has also established its own "mini superfund" for cleanup of sites that do not qualify for CERCLA funding. Monitoring criteria for cleanup are developed on a case-by-case basis following both Chapter 17-3 and Chapter 17-3/17-4, FAC, criteria.

E. Pesticides

The primary responsibility for regulation of pesticides use is with the State Department of Agriculture. The DER, however, has in the last two years begun an active program designed to guard against environmental damage due to pesticide use. A detailed discussion of this effort will be forwarded to EPA under a separate cover.

F. Sole Source Aquifer

The Biscayne Aquifer has been designated as a Sole Source Aquifer. This designation has not yet been put to the test very effectively in Florida. Certain segments of the Floridan aquifer in Volusia County is also being considered by EPA for designation as a Sole Source Aquifer.

II. Extent Data Needs Are Being Met:

The compliance program and monitoring (if properly enforced) should meet the data needs for evaluating point source impact on the ground water. Current level of enforcement staff, however, falls drastically short of adequate. The result is that monitoring data are generated by permittes and accepted by the department with little attention paid to quality assurance and even less to data analysis.

III. Program's Plan to Meet the Data Needs:

A. Development of the Ambient Ground Water Monitoring Network (see Ambient).

B. The Department has submitted a request to the Florida Legislature for an increase in enforcement personnel.

C. The Water Quality Assurance A^t of 1983 established a Data Collection Program for both surface and ground water data. The Groundwater Section is responsible for implementing the gathering, quality assurance and dissimination of available data in the state, regional and local agencies. This computerized data repository along with the data generated by the network is expected to fulfill many of the states ground water data needs.

IV. Data Verification:

A. Point of Sample Requirements.

1. Premonitoring Activities.

As discussed above, monitoring for the purpose of compliance is generally conducted by the permittee. The department has the authority to exercise "spot checking" and "sample splitting" if deemed necesary. In such cases the following general criteria are adhered to:

a. Safety Considerations

The DER has a "safety officer who supervises the personnel medical check up program to insure that field personnel are not exposed to hazardous substances. The officer is also responsible for insuring the use and maintenance of field safety equipment. Sites to be visited for field investigation are evaluated and ranked as (A), level (B), (C) or (D) level and special precautions are prescribed for each according to the enclosed plan.

b. Initial Site Survey

This would vary with each site but generally involves obtaining legal site access (if site is an unpermitted facility), obtaining topographical and geohydrological data from the USGS or the Bureau of Geology files, and ranking of site for level protection as described under (a) above. In case of the existence of volatile substances on site a portable gas chromatograph is used for a preliminary evaluation of the gases existence and concentration.

c. Monitoring Needed

This too is site specific. The state has the capability of conducting the needed monitoring (by three Operation Response Teams in the Groundwater Section, each of which is capable of full site investigation, coring, well drilling, sample collection and analysis). The state also has retained three private consulting firms to asist in site investigation when the operation response teams are too occupied.

d. Monitoring Objectives

To insure that the ground water is not contaminated beyond the established standards (if any) or beyond the ambient natural background.

e. Models

Models are not required legally, but the Groundwater Section is planning to develop and use such models (see ambient).

f. Contaminants to be Monitored

Chapter 17-3 and 17-4, FAC, require that the ground water receiving direct or indirect discharge be monitored for three groups of parameters:

1. The Primary Drinking Water Standards

2. The Secondary Drinking Water STandards

3. The Minimum Criteria (Those are the chemical or microbiological and physical agents that are considered toxic, carcinogenic, mutagenic or teratogenic and for which no MCL's are in existence. For practical purposes the EPA Priority Pollutants List is used to represent this category of criteria. Surrogate parameters such as coliform bacteria, specific conductance and Total Organic Carbon (TOC) are used whenever feasible to detect the existence of pathogens, inorganics and organics respectively).

g. Vadose zone monitoring is not required unless the soil is contaminated with hazardous materials.

The number of samples required for compliance purposes and frequency of reporting, etc., are detailed in Chapters 17-3/17-4 (enclosed).

h. Requirements are detailed in Chapters 17-3/17-4.

i. Requirements are detailed in Chapters 17-3/17-4.

j. Requirements are detailed in Chapters 17-3/17-4.

2. Well Design, Construction and Development

This information is detailed in Chapter 17-21 and Chapter 17-22, FAC (enclosed).

3. Site Sampling Requirements

B. Laboratory Requirements

C. Data A~alysis and Processing

See discussion under Ambient.

V. Linkage, etc...

See discussion under Ambient.

VI. Technical Barriers

See discussion under Ambient.

VII. EPA Role

See discussion under Ambient.

VIII. Data Processing and Analytical Tasks

A. See discussion under Ambient.

B. Uses.

1. Administrative

Data collected are used to bring permittees found in violation of the rules to compliance. If negotiations fail, notices of violations are issued and may be followed by enforcement through administrative hearings or litigation through the courts.

2. Trend Analysis

See discussion under Ambient.

3. Rulemaking

See discussion under Ambient.

4. Modeling

See discussion under Ambient.

5. Program Effectiveness

See discussion under Ambient.

6. Health Effects

See discussion under Ambient.

C. Problems

Mainly the lack of quality assurance and enforcement personnel shortage.

D. Analytical Software

See discussion under Ambient.

E. EPA Headquarters, etc.

See discussion under Ambient.

XI. Training and Technical Assistance

See discussion under Ambient.

X. Implementation Schedule

This program has been in effect since the late seventies and is ongoing for the foreseeable future.

INTRODUCTION

The Special Studies Category was selected for documenting the pesticide groundwater monitoring efforts of the Florida Department of Environmental Regulation (DER). Since the department has programs which can be documented by other categories, it was felt that this was a best fit.

Special Studies

Pesticide Review Section

I. Goals, Objectives and Environmental Data Needs

The goal of the Pesticide Review Section (PRS) is the development of a departmental pesticide review program that will ensure state actions relative to pesticides are only taken following a thorough review of all environmental impacts. This includes the development of a groundwater monitoring program capable of determining the level of safety necessary for applications of pesticides used under Florida's unique environmental conditions.

An environmental fate data base is available; however, many pesticides have little, if any, information. Therefore, Florida's data needs are enormous. These needs include, but are not limited to:

A. Physical and chemical nature of pesticides;
B. Determination and environmental nature of metabolites and degradates;
C. Saturated and unsaturated media mass transport factors;
D. Analytical methods;
E. Complete use information; and
F. Appropriate computer models.

II. Extent Data Needs are Being Met

Presently, the Florida regulatory framework for pesticides is permissive, and consequently, environmental data on most pesticides is lacking. The Water Quality Assurance Act of 1983 created the PRS within DER. This Section works closely with the Bureau of Product Data Evaluation (BPDE) organized within the auspices of the Department of Agriculture and Consumer Services (DACS) and other agencies to close these gaps.

Both the PRS and BPDE feel the most appropriate way to meet data needs is through the manufacturer. Although these units of government offer technical assistance to producers for product groundwater research in Florida-specific hydrogeology, most manufacturers are reluctant to carry out pesticide fate studies. Since the largest user of pesticides, the citrus industry, is located on the state's most permeable soils and over the most transmissive surficial aquifers, manufacturers of water soluble products may view Florida-specific studies as a liability.

Therefore, the most cost-effective manner to acquire necessary data on the environmental fate of pesticides is through the registration process. For this reason the PRS and BPDE are working to develop the regulatory framework of that process in order to meet data needs.

III. Describe Program Plan to Meet These Needs

The Pesticide Review Section work plan is based upon the following three major work elements:

A. Preregistration Review. Since pesticides cannot be used in Florida unless they are registered by DACS for specific applications, the registration process is a critical environmental review point. DER is currently formally involved in Section 24(c) Special Local Needs, Section 18, Emergency Exemption, and Experimental Use reviews. Additional rules for pesticide registration procedures have been developed by DACS, and are now being implemented.

B. Pesticide Contamination Response. The history of pesticide regulation and use in the state indicates that situations linked to previous practices will continue to surface. As is currently the case with EDB and Temik, the PRS is projecting that, for the forseeable future, a large portion of the resources of the section will be devoted to responding to pesticide contamination problems. This will occur through support for the Florida Groundwater Task Force.

C. Field Studies and Monitoring. Studies surveying levels of pesticides in defined areas, or monitoring at specific applications sites are important to environmental review of pesticide use and regulatory decisions. The PRS has developed a field capability to support these activities. Examples of this type of work are pesticide sampling criteria lists; studies of pesticide contamination in Highlands and Palm Beach Counties; and site specific monitoring for Temik, Lorsban, Nemacur, and Diquat.

The following support work elements are associated, to varying degrees, with each of the major elements above.

1. Evaluation of other state pesticide programs.

2. Development of pesticide transport and fate modelling capability.

3. Review Existing Pesticide Data. Data exists, primarily from the EPA and other states, linking certain pesticides to groundwater contamination. This data is being correlated with Florida pesticide use patterns to develop region-specific test criteria for water resources. This information will be used in field study applications and, ultimately, in regulatory decisions.

4. Development of strong liaison with EPA on pesticide issues. EPA regional pesticide programs are primarily aimed at enforcement. Learning the operation of the EPA pesticide program at the Washington level is an ongoing process. The state goal, shared with DACS, is to develop a program so that EPA will consider Florida-specific data early in the federal registration process. We intend to participate, to the fullest extent possible, in the proposed national EPA study of pesticides and groundwater.

5. Development of a pesticide use data base. A critical need for the state is the development of a pesticide application and tracking system. Ongoing work with industry, DACS, and the Pesticide Reveiw Council to implement these procedures will continue. The Pesticide Contamination Monitoring data base, designed for use in the EDB program, will be expanded to include sampling for other pesticides. Discussions have been held with DACS, with the objective of eventually computer linking directly the pesticide files and data bases of both agencies.

6. Development of a strong program for alternatives to the use of chemicals. Alternatives to chemicals, particularly in the area of biological controls, are more cost-effective than chemicals and are under-utilized in Florida. Our program will work with DACS, IFAS, the Pesticide Review Council, and within the department to develop awareness of these needs, and to identify research priorities and funding sources. Department support for such programs should be a high priority.

7. Developing programs with other state agencies involved in pesticide issues.

8. Soil Fumigant Sampling. Prior to use of EDB, the state conducted similar programs using other soil fumigants. The applications ended several years ago as the popularity of EDB increased. We are proposing a limited survey effort for other fumigants of about 200 samples, with the level of future effort to be determined based upon initial survey results.

IV. Data Verification

Since pesticides are registered for use under specific label requirements and permits are not generally required for agricultural fields, the regulatory framework for pesticide data verification essentially does not exist. Therefore, answering the segments that follow is an attempt to illustrate the type of technical assistance offered to Florida pesticide fate researchers.

A. Point of Sample Requirements

1. Premonitoring Activities

a. Safety Considerations

Each site is evaluated for safety. If safe site entry is an issue the appropriate safety level (A,B,C, or D) will be implemented. Safety with regards to physical barriers, such a terrain, is also considered. However, most sites which require evaluation would at most require Level D, because only trace amounts of chemicals are in question.

b. Initial Site Survey

The initial site survey generally consists of a literature review, site visit and gathering of site information. Other tasks may also be required if groundwater rules (described under separate category) are violated. The PRS, BPDE and manufacturer will generally determine what initial site information is necessary.

c. Monitoring Needed? Contractor or state?

If groundwater contamination seems to be an issue, then monitoring could be required. This monitoring may be carried out by the state, manufacturer, or agent of either. The determination of monitoring requirements is usually made based upon water solubility, partition coefficients, quantities used and susceptability of groundwater and porous media to contamination.

d. Define Monitoring Objectives

Monitoring objectives are to determine if pesticides or pesticide degradates are contaminating groundwater. These objectives are defined by the specific nature of the pesticide and hydrogeology of the application area.

e. Models, If Required, and Data Needs.

Models are predictive tools and are used only in concert with hard data. Of the current models used to identify mass transport issues, PRZM (Pesticide Root Zone Model) has been the accepted tool in well drained soils. Neither modelling nor verification of model parameters with actual field data are regulatory requirements; however, for a model to be acceptable it must have verifiable parameters. PESTAN and SUMATRA I offer alternatives to PRZM.

f. Contaminants to be Monitored and Analyzed.

i. Parameter Selection

Parameter selection is almost always determined from literature reviews or manufacturer disclosure. The parameters considered are the pesticides, metabolites, degradates and/or reaction products. Additionally, pH, conductance, temperature, oxidation-reduction potential and dissolved oxygen are usually always selected parameters.

ii. Use of Surrogates

Research using surrogates and/or tracers instead of the pesticide is usually not performed. Sometimes nitrogen fertilizers are used in a manner similar to a surrogate, but it could not take the place of the chemicals of interest. Surrogates for pesticides, et. al., with low solubilities, high partition coefficients or untraceable in porous media would also be inappropriate.

g. Vadose and/or Saturated Zone Monitoring

i. Initial Number of Samples Areally

The areal distribution of sampling points is directly related to site-specific and suspected mass transport factors. Each sampling scenario is selected using "worst case" conditions.

ii. Initial Number of Samples over Thickness

The number and depths of lysimeters, cluster wells and cores (or sediments) is site and chemical-specific. Again, "worst case" conditions will be selected.

h. Geohydrological/Geophysical Studies

Generally, each study undertaken examines literature and field hydraulics for data to determine the nature of the porous media. Sometimes single well and multiple well tests may be required. Down hole and surface geophysical surveys are employed for sites that may require this technology.

i. Well Location and Depths

In unconfined aquifers permanent monitor wells have open hole or screened intervals which are placed below the lowest recorded water level. Temporary monitor wells may only penetrate the top of the water table. Screened intervals are generally 5 to 10 feet, but may range from one foot to the entire thickness of the permeable strata.

In confined carbonate aquifers wells are usually completed just below the bottom of the confining bed and to an open hole depth which approximates the potentiometric surface for water levels in the vicinity.

j. Laboratory Selection

Selection criteria include:

- lab capabilities,
- methods developed, and
- costs.

In many cases a manufacturer will do their own analyses. these manufacturers may also split samples with responsible state agencies for quality assurance purposes. Contract labs performing specialized analytical services are used. State labs generally perform analysis for state data collection efforts.

2. Well Design, Construction and Development

a. Type of drilling equipment.

The type drilling equipment depends on the nature of the investigation. Hand augers are used in many cases for shallow wells tapping the top of the surficial aquifers. For permanent monitor wells, the most popular drilling technique is a rotary method using water circulation instead of drillers mud.

b. Materials Used in Borehole

i. Drillers mud: In most cases drillers mud will consist of a clay material used only to keep the hole open or prevent loss of circulation. Where possible the use of water as the sole drilling fluid is desirable. Degradable drilling fluids are usually avoided. Holes should be conditioned after drilling to remove mud cake and debris.

ii. Casing and screen materials: Materials used for casing and screen should be inert to sample parameters.

Usually PVC, FRP or stainless steel are acceptable. Threaded, instead of glued couplings, are preferable.

iii. Cements and cement additives: Grouting materials should also be non-reactive to sample parameters. ASTM Type II moderate sulfate resistance (Florida Class H or API Class B) with varying amounts of bentonite is useful for most applications.

c. Well Development

The method used for well development should assure production without cross contamination. Pumping and compressed air are the cleanest. Surge block methods provide better production.

3. Site Sampling Requirements

a. Safety Considerations

See A.1.a.

b. Protocol

The prescribed method of sampling depends on the chemical to be monitored and the hydraulics of the porous media.

c. Frequency

Each chemical has to be evaluated for its persistence and mass transport in each environment so that the appropriate sample frequency can be established.

d. Borehole Samplers

Several factors determine the type and nature of sampling devices used in a well. In every case, the sampler should not be a source of contamination.

e. Handling, Preservation, Transportation

The proper way to handle, preserve and transport samples depends upon the fraction collected. Samples are delivered to the lab in a manner which satisfies laboratory QA/QC.

B. Laboratory Requirements

1. QA/QC

Each lab must use methods which assure reproducability and a contaminant-free environment. Therefore, a strong quality assurance/control program is a requirement. QA/QC using manufacturers' labs is generally accomplished by split or duplicate samples collected for random analysis by a state or contract lab.

2. Protocol

Since only a few pesticides and degradates have EPA approved analytical techniques, some analyses require that the best technique available be used.

3. Certification

All labs providing analyses are certified to be capable of the service.

4. Turnaround Time/Backlog

This is a major problem. Since the analysis of many pesticides in water borders on research, the development of a technique usually increases turnaround time. State labs are more willing to provide analyses, but they are slower than contract labs.

C. Data Analysis and Data Processing

1. Quality Assurance

QA on all data from analysis of samples is performed by the lab performing analytical services. In many cases the QA is approved by DER's Bureau of Water Quality Management prior to analysis occurring. Agency labs follow QA procedures determined by the agency.

2. Software Packages

In-house data can be managed on several data processing packages. Data for DER use is usually stored in STORET if STORET numbers exist. Statistical packages amenable to personal computers are available.

V. Linkages with Other Programs

Almost all pesticide work done by this agency, with the exception of verifiable groundwater contamination issues, is done in close cooperation with other agencies. The Department of Health and Rehabilitative Services and DACS assist with both analytical and administrative services. HRS laboratory facilities provide analysis for pesticides and other chemicals of interest if techniques can be found in literature or appropriately modified.

If EPA approved methods exist, then HRS, DER, and DACS labs can, and do, provide analytical services.

DACS is the lead agency for pesticide registration functions. DER has provided assistance in the registration process by reviewing available data and commenting to DACS. Additionally, for reregistration and special review process, DER has assisted agencies and manufacturers with plans of study, data collection, quality control and recommendations.

DACS, DER and the Department of Community Affairs (DCA) cooperate to provide a data base and mitigating measures for the state EDB program. The university system has analytical functions in this and the Temik Studies.

The Department of Natural Resources (DNR), DACS, DER, as well as the university system cooperate to discover management techniques for aquatic weed control, biocontrol and other research programs.

VI. Technical Barriers, Issues and Opportunities

EPA approved analytical techniques for pesticidal contaminants provides a formidable barrier to mass transport studies. The lack of information on analytical techniques makes fate research projects nearly impossible. Without an EPA-approved technique for the analysis of a compound, few labs desire the analytical work. Commercial laboratories are generally eliminated from bidding on projects because technique development costs outweigh reasonable per sample service costs. Many state labs are currently overwhelmed with analytical tasks for other proejcts which do not alow them the convenience of taking time to develop techniques. Universities require funding which is only limited and usually very specific to certain compounds. Sometimes institutional labs have available resources to provide services from techniques which do appear from time to time in literature.

The lack of data on the physical characteristics of pesticide and pesticide degradates complicates mass transport predictions. Without such information (vapor pressure, solubility, partitioning, half-lives and others), computer modelling, sampling protocols for site investigations and numerous management processes are speculative.

VII. Perceived Roles of EPA Headquarters, EPA Regions, State and Local Agencies

EPA should establish a funding mechanism to carry out pesticide research on the state level. Research would include biocontrol as well as environmental fate projects. EPA should also require use studies on highly transmissive sediments as part of the registration process. Included in these use studies should be the complete chemistry through the degradation map of each pesticide. There should also be a reduction in the type of information which may be considered "confidential corporate secrets," especially when this information is useful in registration reviews.

Research on pesticides should be carried out on a state level. Site investigations for groundwater contamination issues should also be state and local program responsibilities.

VIII. Data Processing and Analytical Tasks

A. Data Bases

Data bases are in the developmental stages. The expansion of the EDB program to incorporate other pesticides and the linkage of DACS and DER computers are planned (see II).

B. Administrative Uses

1. DACS, HRS, DCA, DER, Water Management Districts, and local programs will have access to data generated. It is anticipated that data will be used as a management and predictive tool.

2. Trend Analysis

See II.

3. Rule Making

Data which formalizes fate and mass transport characteristics is currently being requested from the manufacturers. Soon it may be come a regulatory requirement for state registration of any pesticide.

4. Modelling

If model assumptions do not limit environmental data inputs and if physical traits of compounds of interest are amenable to the model, modelling can be useful. However, few decisions can be based on models developed under lab conditions or used without verified field data.

5. Measuring Effectiveness

Program effectiveness could be measured by numbers of Florida-specific studies being undertaken, number of reregistration reviews, and reduction of groundwater contamination complaints.

6. Health and Environmental Impact

HRS, DCA, DACS, and other agencies participate in programs which have health and environmental impacts. The state EDB program is one example. Although little human health information exists, this information should be generated for pesticide use in Florida.

7. Fate and Movement of Pollutants

There are numerous uses for this information, see VIII.B.3.

C. Problems

Problems with finding good, reliable information on pesticides are enormous. Manufacturers, wanting to put their best foot forward, will usually provide favorable research data, but they are reluctant to carry out Florida Studies (see II). Universities do not have the funds to do independent research.

D. Analytical Software

Analytical software varies from lab to lab (see Section IV.C.2).

E. EPA Headquarters, EPA Region, State, Local Agency Roles

See VII.

XI. Training and Technical Assistance

A. Training - Existing, Needed

1. State Personnel

Existing training includes several site safety and sampling short courses offered by EPA, NWWA, and others. Scholarships for research work should be offered as should pesticide sampling protocol, mass transport, and modelling training.

2. Certification

Lab certification is required but drillers are registered. The registration process for drillers is minimal and does not adquately determine a driller's qualification. Training for drillers on monitor wells would be desirable.

B. Technical Assistance

1. State Provided

The state should provide technical assistance to federal and local programs. The special review process on the federal level is an ideal target. Local program could be assisted by state research.

2. Needed by State

See VII.

C. EPA Headquarters, EPA Region, State and Local Roles

Section VII and Section IX.A.1.

X. Implementation Schedule

Programs within the state agency are currently being implemented. Registration requirements are under adminstrative review and should be cleared this year. A Special Review report on environmental levels of DDT resulting from the use of Dicofol was sent to EPA last year. Temik and EDB programs are continually generating data on those pesticides. Reports on EDB levels in diquat dibromide and the fate of methyl bromide and chloropicrin are completed. Studies of pesticide mass transport in porous media are currently "in the works" and will be completed. Many of the pesticides under special review are to be included in the latter studies (see Section III).

Environmental Monitoring Strategy for Ground Water
Emergency Response

In 1983 the Florida Legislature enacted and funded the "Water Quality Assurance Act of 1983". This Act established many programs designed to deal with the problems of grrund water pollution (see Act copy and associated task delineation document).

The programs most closely associated with monitoring are briefly described below:

The Department used its existing files, local program files, citizen notification and normal field investigation to compile a list of sites that are deemed potentially contaminating the ground water with potentially hazardous pollutants. This list forms the backbone of the monitoring effort being done in addition to the monitoring done under ambient and compliance.

The list is prioritized by ranking according to the procedure explained in the attached document.

A lead unit is assigned the responsibility of investigating each of these sites and generating the needed data for eventual cleanup by the responsible party, the local government, the state government or through the CERCCA program.

Investigation maybe conducted in-house by the OR teams (discussed under compliance) or by contracting it out. Cleanup on the other hand is always contracted out. Currently there are over 400 sites on this list. Addition of sites to the list or deletion from it is done on routine basis through a committee established for this purpose.

A second list for leaky gasoline tank, with potential for contaminating the ground water has also been established and is being used in the same fashion as the first list.

Emergency Response in the strict sense of dealing with spills, accidents, derailings or covert dumping is dealt with through an Emergency Response group located in the Bureau of Operation. This group involve representation of the DER, the Sheriff Department, the fire marshal and other concerned agencies who collectively take the necessary measures to deal with such emergencies. These measures vary with each case and can not be discussed in a meaningful way in this paper.

Any ground water monitoring data generated through the Emergency Response Program is handled in the same fashion and has the same user discussed under ambient or compliance. The obvious differences is that monitoring is of a short term duration if the source is immediately removed.

This now is a continuous program provided the funding is continued.

Environmental Monitoring Strategy for Ground Water
Special Studies

A large number of studies, research projects and surveys have been conducted or are planned on being conducted by the Groundwater Section. The purpose of all them studies is essentially the same; i.e.; to provide the necessary tools, data, and procedures to help the state in establishing a program for managing and protecting the quality of the ground water.

Below is a list of current studies and surveys being conducted and a budget estimate and source of funding.

Contracts update

Previous studies included the following:

- Impact of phosphate industries activities on the ground water.
- Impact of industrial impoundments on the Biscayne, sand and gravel and the Floridan aquifers.
- The Florida Surface Impoundment Assessment
- Degradation of trichloroethylene in the ground water
- The Florida Open Dump Inventory
- Inventory of Class V UIC Wells in Florida
- Development of a mechanism for grouping organic chemicals to reduce the cost of analysis of full suites of chemicals.
- Toxicological evaluation of chemicals on the priority pollutants list for the purpose of developing ranges of "safe" numerical values, and for how clean is clean.
- Delineation of near surface low permeability beds in Florida.
- Delineation of areas suitable for deep well injection in Florida.
- Delineation of the principal potable water aquifers in Florida.
- Survey of Public Water Supply Wells and Systems serving over 10,000 people for toxic chemicals not on the primary drinking water standards list.
- Organics in domestic sewage effluents used in spray irrigation and their impact on ground water quality.

Data collected through the above studies are handled in the same fashion planned for the ambient network data.

Environmental Monitoring Strategy for Ground Water
Unaddressed Federal Sources

With the exception of the Superfund sites (over 30 in Florida) all other sites, sources activities are unaddressed by the Federal government. The discussion under Emergency Response and to certain extenct Ambient and Compliance should provide a good idea of the State's activities in this regard.

Response to the questionaire items would therefore be identical. Once again this is a continuous program for the foreseeable future; until all sources of containation have been dealt with.

GROUND-WATER MONITORING COSTS

OPERATIONS RESPONSE ACTIVITIES

1 Driller Supervisor / 2 Drillers / 2 Driller Helpers / 10 Operations Response Positions

Salaries/Benefits/etc. 15 x 30,000	$450,000.00
Travel	
In-State	55,000.00
Out-of-State (Training)	15,000.00
Equipment (includes cost of two drill rigs*)	
FY'84 Field Equipment	478,225.00*
Office Furniture	15,200.00
FY'85 Field Equipment	94,000.00
Office Furniture	23,000.00
Maintenance & Repairs	2,600.00
Rental of Special Equipment	1,250.00
Books	1,000.00
Supplies	
Field	45,000.00
Lab	5,000.00
Office	1,000.00
Printing Costs	1,000.00
Vehicles: 2 Drill Rigs, 2 Water Trucks, 3 Field Trucks, 1 Mobile Lab	
Vehicles	
Operation Costs	18,000.00
Maintenance & Repairs	6,000.00

OTHER GROUND WATER ACTIVITIES

District Personnel		6 x 30,000	180,000.00
**Tallahasee Personnel		19 x 30,000	570,000.00
State Cleanup Fund			10,000,000.00
Hazaradous Waste Program			1,051.236.00
State Share	(40.39%)	424,594	
Federal Share	(59.61%)	626,642	
205(j)			
FY'85 Monies			135,000.00
FY'84 Monies (studies in progress)			71,294.00
FY'83 Monies (studies in progress)			174,638.00
Ambient Ground Water Program			1,790,000.00
Support Services Contracts			550,000.00

**Excludes drilling and field operations

VI. CASE STUDY: EPA OFFICE OF DRINKING WATER SURVEY

(Reprinted with permission from American Water Well Association Journal, *May 1984.)*

The Groundwater Supply Survey

James J. Westrick, J. Wayne Mello, and Robert F. Thomas

The results of the US Environmental Protection Agency, Office of Drinking Water, sampling and analysis of volatile organic compounds (VOCs) in finished water supplies that use groundwater sources are discussed. Concentrations of 29 VOCs in addition to five trihalomethanes and total organic carbon from 945 water supplies were measured. The five most frequently found compounds other than trihalomethanes were trichloroethylene, 1,1,1-trichloroethane, tetrachloroethylene, cis- and/or trans-1,2-dichloroethylene, and 1,1-dichloroethane. Approximately half of the samples were taken from a random list of water systems, which were subdivided into two sets of systems—those serving fewer than 10 000 persons and those serving more than 10 000 persons. The nonrandom samples were taken from systems selected by the states, using groundwater sources that were likely to show VOCs in drinking water. Large systems in the random sample had a significantly higher frequency of occurrence of VOC contamination than small systems and were also more likely to have higher levels of contamination.

Volatile organic compounds (VOCs) are a general category of synthetic organic chemicals that include low-molecular-weight, volatile aliphatic and aromatic hydrocarbons, many of which are halogenated. Their presence in groundwater supplies has been reported with increasing frequency. To supplement existing data on the occurrence of VOCs in drinking water for purposes of developing regulatory alternatives,[1] the US Environmental Protection Agency (USEPA), Office of Drinking Water (ODW), Technical Support Division (TSD), Cincinnati, Ohio, conducted a sampling and analysis program in 1981 and 1982. The objectives were: (1) to provide additional data for estimating the nationwide occurrence of VOCs in drinking water supplied from underground sources, and (2) to collect information about the physical characteristics of the well fields and the surrounding areas to develop a predictive capability for locating contaminated groundwater. Only the occurrence data are discussed here.

The survey consisted of two parts. Half of the sampling and analytical program developed data from a random sample of groundwater supplies obtained from the inventory of public water systems maintained in the Federal Reporting Data System (FRDS), from which 500 supplies were selected. Two subsets were developed: 300 of the systems serve fewer than 10 000 persons and 200 of the systems serve more than 10 000 persons. A second randomly selected two-part list provided replacement sampling sites for cases in which the supplies on the primary list of 500 were inappropriate or nonexistent. This occurred if, for example, a utility had recently begun to purchase its water from another utility that uses a surface water source.

Prior data on the occurrence of VOCs were gathered from samples collected from groundwater systems during the Community Water Supply Survey (CWSS) of 1978.[2] These data were used to estimate the necessary sizes of the samples. During the 1978 survey, the frequency of occurrence of the 10 VOCs for which analyses were conducted among the 300 groundwater systems serving fewer than 10 000 persons was 12 percent of the systems. Of the 29 groundwater systems that serve more than 10 000 persons, 45 percent contained at least one VOC. Using these occurrence frequencies as estimates of what might be found in the new survey, it was determined that sampling 300 small systems and 200 large systems would provide 95 percent confidence limits of ±30 percent and ±15 percent for the estimates of frequencies of occurrence for the small systems and large systems, respectively

The second part of the survey was used to encourage state agencies to try to identify problem supplies. The purpose of this portion of the survey was not only to expand state involvement but also to provide ODW with some information on the frequency and extent of serious problems, based on the state agency's knowledge of local conditions. Each state was assigned a number of sampling sites roughly proportional to its fraction of the total number of groundwater systems nationwide; this was designated the nonrandom sample. The target number of nonrandom sites was also 500. The state agencies were encouraged to select supplies that might be contaminated by VOCs because of the proximity of the well field to industries, landfills, or other potential sources of contamination. The state agencies were also encouraged to choose water supplies for which no VOC data were available in an effort to discover previously unknown instances of contamination.

General procedures

To obtain information from a maximum number of systems that use groundwater sources, one sample of finished water from each utility was collected at a point near the entrance to the distribution system. The VOC concentrations in water supplied from a single well that is not pumped continuously can vary depending on the pumping rate, the schedule, and the hydrodynamics of the plume of contamination. If multiple wells supply a system at a single entry point and some wells are contaminated whereas others are not, the VOC concentrations in the sample at the entry point could vary greatly, depending on which wells were in operation at the time of sampling. In systems with more than one entry point, a single sample would obviously represent only those wells contributing to that entry point. With these limitations in mind, the sample of finished water taken at or near a point of entry would provide a reasonable compromise between information obtained from a sample taken from a single well and that from multiple samples taken throughout the system.

State drinking water agencies played a major role in the planning and execution of this survey. Each state with primary public water system enforcement responsibility (primacy) was contacted through the regional USEPA drinking water offices. Most of the states indicated a willingness to assist in the project. State involvement consisted of reviewing the primary random list for errors or for inappropriate or nonexistent systems, filling in missing information on the randomly selected systems, selecting systems for inclusion in the nonrandom portion of the survey, and providing scheduling information to the TSD project engineer. In most cases, state personnel traveled to the sampling sites, collected the samples and site information, and shipped the samples in ice to the TSD laboratory in Cincinnati, Ohio, using sampling supplies provided by TSD. In nonprimacy states and states that were unable to assist in the planning or the sampling because of budgetary or other constraints, regional USEPA personnel provided the necessary assistance. Personnel from the TSD collected some samples that were obtainable within reasonable driving distance from Cincinnati or if it was not possible for either state or regional USEPA personnel to travel to the sampling locations.

Logistics

A sampling kit was prepared at TSD for each sampling location. Amber bottles of 60-mL and 250-mL capacity were dosed with a preservative (10 mg mercuric chloride/L), capped with PTFE fluorocarbon-faced septa and screw caps, affixed with preprinted labels that had been stamped with the sample identification numbers, and secured in expanded polystyrene boxes. A shipping blank (a 250-mL bottle containing organic-free water and preservative) was also included with the sampling kit. The shipping blanks were to remain with the sampling kit through all stages of transportation and storage so that the possibility of contamination from the surroundings could be investigated by analyzing the shipping blank.

Samples were received at TSD the day after they were collected. They were unpacked and logged in, and any unusual circumstances were noted. The sample bottles were then placed in storage in a cold room, free of organic vapor contamination, until they were repacked for shipment to the chemical analysis contract laboratory.* Since replicate samples were collected at each site, half the bottles were shipped to the contract laboratory and half were held in cold storage at TSD. This was necessary for quality assurance analysis of duplicates by TSD chemists or for quick-response, in-house verification of the contract laboratory's results.

When the samples were shipped to the contract laboratory, the information was entered into the TSD data system for tracking purposes. Primary analysis of the samples was completed by the contractor within 30 days of collection. The contract laboratory had access to the TSD data system, so upon completion of the analyses for a sample, the data were entered at the contractor's terminal and retrieved by the TSD project engineer in Cincinnati. The results for each sample were examined by the TSD project officer and verified by agreement between the project officer and the contract laboratory project leader after review of quality assurance information. The verified data were then entered into a confirmed data file. Reports of verified data for each USEPA region were periodically distributed to the appropriate USEPA regional office. The regional office then distributed two copies of the data to each state, one of which was forwarded by the state to the utility.

Figure 1. Random sampling sites

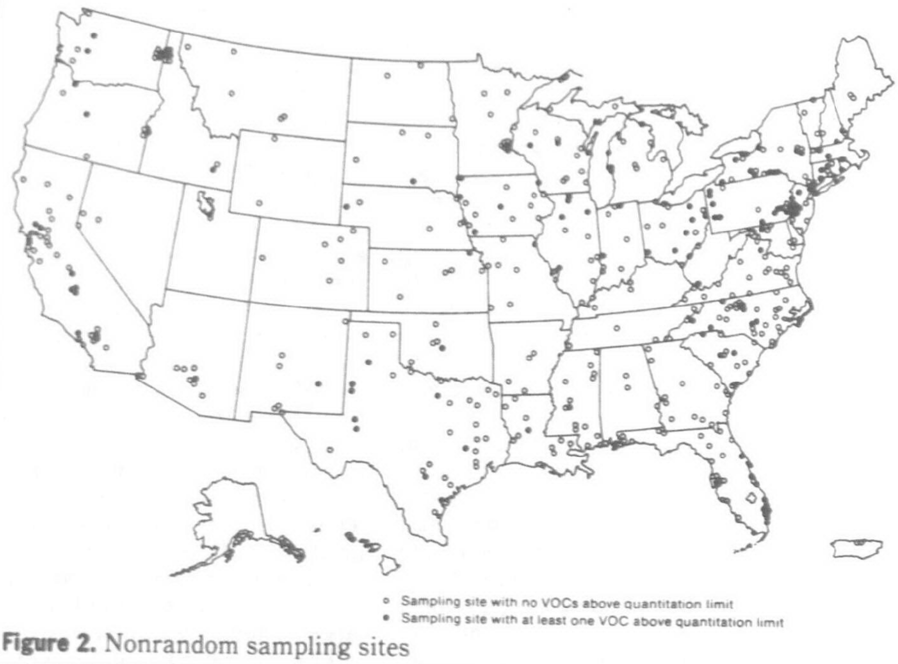

Figure 2. Nonrandom sampling sites

Analytical considerations

A total of 34 parameters were selected for analysis by purge-and-trap gas chromatographic methods (Table 1). However, the emphasis in this article is on the 29 VOCs other than the five trihalomethanes (THMs)—chloroform, bromodichloromethane, dibromochloromethane, dichloroiodomethane, and bromoform. The samples were not dosed with a reducing agent, so the THM formation reaction continued until the time of analysis or until the depletion of either residual chlorine or precursor material.

The two isomers of 1,2-dichloroethylene could not be separately determined by the analysis and thus are considered one parameter. The same is true for ortho- and paraxylenes. Methylene chloride originally was to be determined, but this compound is a widely used laboratory solvent and appears frequently as a laboratory contaminant. Because it was found in all the analyzed shipping blanks, it was impossible to ascertain whether the methylene chloride was originally present in a sample or had come from the surrounding atmosphere. Therefore, results for methylene chloride could not be validated.

The purge-and-trap gas chromatography (GC) analyses were conducted according to USEPA methods 502.1[4] and 503.1[5] with a significant modification. The nondestructive photoionization detector for analysis of aromatics and the

*SRI International, Inc., Menlo Park, Calif.

electrolytic conductivity detector for the analysis of halocarbons were coupled in series, allowing analysis for the complete list of 34 compounds with one sample purge. A comparability study conducted prior to the survey showed that serial analysis gave results equivalent to separate analyses for the two types of compounds. This technique proved beneficial in terms of the time and cost required for analysis. An additional benefit resulted from the acquisition of further information by using the two detectors in series. The photoionization detector can assist in identifying and quantifying compounds that coelute from the primary GC column or that have poor responses with the detector.

Quality assurance

When the contract for analytical services was written, a detailed quality assurance protocol was included for monitoring and maintaining the quality of data. This protocol was followed throughout the survey, and the validating data were continually scrutinized by the TSD project officer. Table 2 lists the quality assurances used.

USEPA reference samples. The precision and accuracy of analyses of the halocarbon and aromatic reference samples, which were analyzed weekly, met the quality assurance specifications. This was true for both the primary and confirmatory analytical schemes. The USEPA reference samples contained known concentrations of compounds, including the four common trihalomethanes and nine frequently found VOCs. The precision measure used was the coefficient of variation, the standard deviation of approximately 50 analyses divided by the mean of those values. The precision of the primary analysis of reference samples at levels below 5 $\mu g/L$ averaged ±13 percent with a range of ±8 percent for tetrachloroethylene to ±22 percent for 1,1,1-trichloroethane. For reference samples containing levels of more than 5 $\mu g/L$, the precision ranged from ±6 percent for trichloroethylene to ±20 percent for 1,1,1-trichloroethane. There was an average precision of ±11 percent. Accuracy is indicated by the percent error, that is, the difference between the mean of the measured values and the expected (true) value divided by the expected value. This parameter ranged from 0 percent for tetrachloroethylene at 5.9 $\mu g/L$ to −19 percent for dibromochloromethane at 2.1 $\mu g/L$, with averages of −9 percent below 5 $\mu g/L$ and −4 percent above 5 $\mu g/L$. Negative error indicates that the mean of the measured values was less than the expected value.

Duplicate analyses. As another gauge of precision, the contract called for duplicate analyses to be performed on a minimum of 10 percent of the samples. The duplicates were to agree within 40 percent for compounds present at concentrations of less than 5 $\mu g/L$ and within 20 percent at concentrations in excess of 5 $\mu g/L$. The precision measure used is the percent difference, i.e., 100 times the absolute difference in the duplicate values divided by the mean of the two values. Data were gathered on 16 individual compounds that were present collectively in the duplicate analyses. A total of 84 quantifiable results in concentrations of less than 5 $\mu g/L$ were duplicated. All but five met the precision criterion. The average percent difference for the quantifiable low-level duplicate results was 17 percent. Eighteen quantifiable pairs of duplicate results in concentrations in excess of 5 $\mu g/L$ were reported, with four of the 18 falling outside the precision limits. The average precision of the 18 pairs of samples with higher concentrations was 13 percent.

Confirmatory analyses. All samples found or suspected to contain VOCs other than THMs were reanalyzed by using different chromatographic columns that elute the compounds in different orders. In addition, samples containing chloroform at concentrations in excess of 40 $\mu g/L$ were reanalyzed by using the confirmatory column since chloroform at this level of concentration could mask small quantities of 1,2-dichloroethane. Approximately 33 percent of all samples were reanalyzed by second column chromatography for halocarbons and 6 percent for aromatics. Precision and accuracy of the analyses of the 19 USEPA reference samples for halocarbons and 11 USEPA reference samples for aromatics were documented. All accuracy values were within the contract limits for the primary analyses, and the precision values for all but two of the compounds fell within the error limits of the primary analysis. In addition, approximately 5 percent of all the samples were reanalyzed by gas chromatography-mass spectrometry for additional confirmation and tentative identification of unknown peaks.

Blind samples. Five blind samples were prepared by TSD in the initial phase of the survey to ascertain the contractor's ability to identify particular compounds qualitatively and to measure them quantitatively. The blinds consisted of five different mixtures of compounds, spiked into organic-free distilled water. These were periodically sent to the contractor early in the survey period disguised as survey samples. The mixtures were designed to pose selected anomalies in the analytical system, such as interferences or compounds with similar gas chromatographic retention times. Prior to shipment, the blinds were analyzed by TSD, and these results were compared with those subsequently reported by the contractor. In every case, the contractor correctly identified the spiked compounds. Although no quantitative criteria were established for the blind samples, the percent differences between the contractor's results and TSD-determined concentrations were within the error limits for duplicates for 27 of 32 pairs of values.

TSD analysis of duplicate samples. Replicate samples were collected in separate bottles and stored at TSD so they could be analyzed as an additional check on the contractor's laboratory results. The check samples to be analyzed by TSD were chosen from those that the contractor had reported to contain one or more of the VOCs. The percent differences between the contractor's results and those of TSD were within the error limits for 48 of the 64 pairs of values in excess of the quantitation limits. The error limits used are those established for a single laboratory conducting duplicate analyses of the same sample. Larger percent differences were expected for this comparison since the analyses were done on duplicate samples and analyzed by independent systems. Also, the duplicate samples often contained several compounds at widely varying concentrations, from less than 1 $\mu g/L$ to more than 100 $\mu g/L$.

The quality assurance program was a critical part of the analysis. It consumed a significant portion of the analytical resources and required considerable time and effort from TSD personnel. Careful attention to the monitoring, control, and documentation of the quality of the data resulted in a high degree of confidence that the identification and quantitation of compounds were accurate.

An in-depth description of the analytical quality assurance program for this survey can be found elsewhere.[6,7]

Results

The distribution of all samples is shown in Table 3 and Figures 1 and 2. The final number of random systems was 280 from systems serving fewer than 10 000 persons and 186 from systems serving more than 10 000 persons. The final tally for state-selected sites was 479. The number of random-sample sites in each state was roughly proportional to the number of groundwater systems in that state. The number of nonrandom samples allocated to a state was also based approximately on its number of groundwater systems. Figures 1 and 2 show all sampling locations.

The quantitation limits are not the same for all compounds. In most cases, the quantitation limit is either 0.2 $\mu g/L$ or 0.5 $\mu g/L$. This difference in quantitation limits can confuse the interpretation of the data somewhat, so the results of the survey should be viewed with the differing quantitation limits in mind. Unless otherwise stated, an "occurrence" is any specific organic parameter that was found at, or in excess of, the quantitation limit.

Random sample occurrences. Tables 4 and 5 summarize occurrences from the random sample for each of the 34 parameters. Table 4 contains data from the random sample of systems serving fewer than 10 000 persons, and Table 5 contains the results for systems serving more than 10 000 persons. These tables list the quantitation limit, the frequency of occurrence, the median concentration of the positive values of each compound, and the highest concentration for each parameter.

Because the two subsets of the random sample were selected independently and because a much higher percentage of large systems than small systems were included (15 percent of roughly 1200 systems serving more than 10 000 and 0.6 percent of nearly 48 000 systems serving fewer than 10 000 persons), the data from the large systems and the small systems were not combined. The normal curve approximation to the binomial distribution for large samples was used to conduct tests of the significance of the difference in frequency of occurrence of compounds in the two subsets of the random sample.[3] The large systems' frequency of occurrence was greater than the small systems' frequency of occurrence for trichloroethylene, cis- and/or trans-1,2-dichloroethylene, and tetrachloroethylene at the 0.01 significance level and for 1,2-dichloropropane, carbon tetrachloride, and 1,1,1-trichloroethane at the 0.05 significance level. No other significant differences in the occurrence of specific parameters could be discerned between the samples from large systems and those from small systems.

Though the data indicate that the frequency of occurrence of several of the compounds is higher among the larger communities, a similar inference cannot be drawn regarding the severity of contamination from a casual observation of Tables 3 and 4. The highest concentrations of 1,2-dichloropropane, trichloroethylene, and benzene were found in samples from the larger communities, whereas samples from small systems contained the highest levels of 1,1,1-trichloroethane, carbon tetrachloride, and tetrachloroethylene.

Trihalomethanes occurred more frequently in the samples from larger systems, but this could be because a higher percentage of large systems chlorinate their water supplies (85 percent of the large systems versus 56 percent of the smaller systems). The THM concentrations were generally low, although some groundwaters can produce high concentrations of THMs. Again, the different quantitation limits must be considered when the frequency of occurrences and the median of the positive values for THMs are evaluated. Since the samples were normally analyzed after one to four weeks of low-temperature storage, the THM concentrations reported are undoubtedly higher than they would have been had the THM formation reaction been stopped by a reducing agent at the time of sampling. Therefore, the concentrations reported may not be representative of concentrations in the distribution systems. However, the data provide an indication of the tendency for THMs to form in groundwater supplies.

There is no evidence in the literature that chlorination of drinking water

TABLE 1

Specific organic parameters

Contaminant	
Vinyl chloride	1,1,2-Trichloroethane
1,1-Dichloroethylene	1,1,1,2-Tetrachloroethane
1,1-Dichloroethane	1,1,2,2-Tetrachloroethane
cis- and/or trans-1,2-Dichloroethylene	Chlorobenzene
1,2-Dichloroethane	1,2-Dibromo-3-chloropropane
1,1,1-Trichloroethane	*n*-Propylbenzene
Carbon tetrachloride	*o*-Chlorotoluene
1,2-Dichloropropane	*p*-Chlorotoluene
Trichloroethylene	*m*-Dichlorobenzene
Tetrachloroethylene	*o*-Dichlorobenzene
Benzene	Styrene
Toluene	Isopropylbenzene
Ethylbenzene	Chloroform
Bromobenzene	Bromodichloromethane
m-Xylene	Dibromochloromethane
o + *p*-Xylene	Dichloroiodomethane
p-Dichlorobenzene	Bromoform

TABLE 2

Quality assurance protocol for the analysis of VOCs

Quality Assurance Analysis	Frequency or Amount	Specified Limits			Source of Sample
		Parameter	<5 μg/L *percent*	>5 μg/L *percent*	
USEPA reference samples	1 per week for each instrument	Precision Accuracy	±40 ±40	±20 ±20	Environmental Monitoring Support Laboratory, Cincinnati
Duplicate analyses	10 percent of samples	Agreement	40	20	Survey samples
Confirmatory analyses	100 percent of positives	Qualitative agreement			Survey samples
Blind samples	Variable	None specified			TSD
TSD analysis of duplicate samples	10 percent of positives	None specified			Survey samples

TABLE 3

Number of supplies sampled by state

State	Random	Nonrandom	State	Random	Nonrandom
Alabama	7	5	Nebraska	8	6
Alaska	4	4	Nevada	2	3
Arizona	8	9	New Hampshire	2	4
Arkansas	3	4	New Jersey	17	5
California	34	30	New Mexico	1	6
Colorado	2	6	New York	22	25
Connecticut	8	7	North Carolina	13	31
Delaware	1	1	North Dakota	0	3
Florida	44	31	Ohio	14	15
Georgia	14	13	Oklahoma	4	5
Hawaii	0	2	Oregon	7	7
Idaho	6	8	Pennsylvania	16	26
Illinois	15	12	Rhode Island	1	2
Indiana	8	8	South Carolina	5	11
Iowa	12	13	South Dakota	4	4
Kansas	11	6	Tennessee	6	4
Kentucky	4	3	Texas	41	33
Louisiana	14	10	Utah	8	2
Maine	0	2	Vermont	2	3
Maryland	4	6	Virginia	9	18
Massachusetts	11	4	Washington	19	10
Michigan	8	12	West Virginia	4	5
Minnesota	10	9	Wisconsin	7	13
Mississippi	14	14	Wyoming	0	2
Missouri	6	10	Puerto Rico	2	2
Montana	4	5			

TABLE 4

Summary of occurrences from 280 random sample sites serving fewer than 10 000 persons

Parameter	Quantitation Limit µg/L	Occurrences Number	Occurrences Percent	Median of Positives µg/L	Maximum Value µg/L
Vinyl chloride	1.0	0	0		
1,1-Dichloroethylene	0.2	4	1.4	1.2	6.3
1,1-Dichloroethane	0.2	10	3.6	0.51	3.2
cis- and/or trans-1,2-Dichloroethylene	0.2	3	1.1	0.23	1.7
1,2-Dichloroethane	0.5	0	0		
1,1,1-Trichloroethane	0.2	12	4.3	0.32	18
Carbon tetrachloride	0.2	5	1.8	0.37	16
1,2-Dichloropropane	0.2	1	0.4	0.75	0.75
Trichloroethylene	0.2	9	3.2	0.88	40
Tetrachloroethylene	0.2	13	4.6	0.35	23
Benzene	0.5	1	0.4	0.61	0.61
Toluene	0.5	4	1.4	0.62	0.85
Ethylbenzene	0.5	2	0.7	0.94	1.1
Bromobenzene	0.5	3	1.1	1.9	5.8
m-Xylene	0.2	6	2.1	0.32	1.5
o + *p*-Xylene	0.2	6	2.1	0.34	0.59
p-Dichlorobenzene	0.5	2	0.7	0.60	0.68
1,1,2-Trichloroethane	0.5	0	0		
1,1,1,2-Tetrachloroethane	0.2	0	0		
1,1,2,2-Tetrachloroethane	0.5	0	0		
Chlorobenzene	0.5	0	0		
1,2-Dibromo-3-chloropropane	5.0	1	0.4	5.5	5.5
n-Propylbenzene	0.5	0	0		
o-Chlorotoluene	0.5	0	0		
p-Chlorotoluene	0.5	0	0		
m-Dichlorobenzene	0.5	0	0		
o-Dichlorobenzene	0.5	0	0		
Styrene	0.5	0	0		
Isopropylbenzene	0.5	0	0		
Chloroform	0.2	104	37.1	1.4	140
Bromodichloromethane	0.2	100	35.1	1.4	60
Dibromochloromethane	0.5	87	31.1	2.1	52
Dichloroiodomethane	1.0	2	0.7	2.8	4.1
Bromoform	1.0	44	15.7	2.4	54

TABLE 5

Summary of occurrences from 186 random sample sites serving more than 10 000 persons

Parameter	Quantitation Limit µg/L	Occurrences Number	Occurrences Percent	Median of Positives µg/L	Maximum Value µg/L
Vinyl chloride	1.0	1	0.5	1.1	1.1
1,1-Dichloroethylene	0.2	5	2.7	0.28	2.2
1,1-Dichloroethane	0.2	8	4.3	0.54	1.2
cis- and/or trans-1,2-Dichloroethylene	0.2	13	7.0	1.1	2.0
1,2-Dichloroethane	0.5	3	1.6	0.57	0.95
1,1,1-Trichloroethane	0.2	15	8.1	1.0	3.1
Carbon tetrachloride	0.2	10	5.4	0.32	2.8
1,2-Dichloropropane	0.2	5	2.7	0.96	21
Trichloroethylene	0.2	21	11.3	1.0	78
Tetrachloroethylene	0.2	21	11.3	0.52	5.9
Benzene	0.5	2	1.1	9.0	15
Toluene	0.5	2	1.1	2.6	2.9
Ethylbenzene	0.5	1	0.5	0.74	0.74
Bromobenzene	0.5	1	0.5	1.7	1.7
m-Xylene	0.2	2	1.1	0.46	0.61
o + *p*-Xylene	0.2	2	1.1	0.59	0.91
p-Dichlorobenzene	0.5	3	1.6	0.66	1.3
1,1,2-Trichloroethane	0.5	0	0		
1,1,1,2-Tetrachloroethane	0.2	0	0		
1,1,2,2-Tetrachloroethane	0.5	0	0		
Chlorobenzene	0.5	0	0		
1,2-Dibromo-3-chloropropane	5.0	0	0		
n-Propylbenzene	0.5	0	0		
o-Chlorotoluene	0.5	0	0		
p-Chlorotoluene	0.5	0	0		
m-Dichlorobenzene	0.5	0	0		
o-Dichlorobenzene	0.5	0	0		
Styrene	0.5	0	0		
Isopropylbenzene	0.5	0	0		
Chloroform	0.2	106	57.0	1.6	300
Bromodichloromethane	0.2	101	54.3	1.6	71
Dibromochloromethane	0.5	96	51.6	2.9	59
Dichloroiodomethane	1.0	3	1.6	1.8	4.1
Bromoform	1.0	57	30.6	3.8	50

causes the formation of any of the VOCs other than THMs. There have been reports that commercial chlorine can contain traces of carbon tetrachloride, thereby contaminating chlorinated drinking water. Therefore, the carbon tetrachloride occurrence data should be qualified by the possibility that the cause of some occurrences of carbon tetrachloride could be contaminated chlorine.

The data from the random sample of systems serving fewer than 10 000 persons were examined for any other possible effects of chlorination. There was no significant difference in the frequency of occurrences of any VOCs between small systems that chlorinate and those that do not. The larger systems that do not chlorinate are too few in number to provide a valid comparison with larger systems that do chlorinate.

The number and percentage of contaminated supplies in each part of the random sample are listed in Table 6. Of 280 small systems, 47 contained one or more of the 29 VOCs included in the analysis. Of those 47 supplies, 19 had multiple contaminants above the quantitation limit. Of the 186 larger systems, 52 contained at least one contaminant. Of those, 25 supplies contained more than one VOC.

Water samples from 16.8 percent of the systems serving fewer than 10 000 persons and 28 percent of the larger systems' supplies contained at least one VOC. Confidence limits, based on the binomial distribution,[3] were constructed around the point estimates (16.8 and 28 percent) of the probability of VOC occurrences in systems in the two size categories. The confidence interval is simply a function of the observed frequency and the sample size and does not account for uncertainty owing to analytical variability or variation in water quality. The frequency of occurrence in all systems serving fewer than 10 000 persons can be estimated with 95 percent confidence to lie in the range of 12.9–21.7 percent. The large systems' frequency of occurrence can be estimated with 95 percent confidence to lie in the range of 22.1–35 percent. The frequency of occurrence for the large systems was greater than that for the small systems at the 0.01 significance level.

Table 7 shows the supplies by population category with summed VOC concentrations in various ranges of concentrations. For example, there were 88 supplies in the population category of 101–500 persons. Of those 88 supplies, 77 contained no VOC above the quantitation limit, 9 contained one or more of the contaminants with sums of concentrations less than 5.0 µg/L, and 2 had a summed VOC concentration in the range of 11–50 µg/L.

The number and percentage of supplies containing various levels of summed

VOC concentrations are shown in Table 8. The point estimate of the probability that a system serving more than 10 000 persons contains a summed VOC concentration greater than 5.0 μg/L was 6.5 percent (12 of 186), with a 95 percent confidence interval of 3.8–11 percent. Eight of 280 small systems (2.9 percent) contained a summed VOC concentration greater than 5.0 μg/L, resulting in a 95 percent confidence interval for the estimate of 1.5–5.6 percent. The frequency of occurrence of summed VOC concentrations greater than 5.0 μg/L was higher in large systems than in small systems at the 0.05 significance level.

Nonrandom sample occurrences. The nonrandom sample data are given in Tables 9 through 13. Obviously, higher frequencies and concentrations were found in this sample set than in the random sample. Nearly 25 percent of the large systems and 7 percent of the small systems selected were contaminated with trichloroethylene. Other compounds that appeared frequently included cis- and/or trans-1,2-dichloroethylene, 1,1,1-trichloroethane, tetrachloroethylene, and 1,1-dichloroethane. Of the 131 systems found to be contaminated with VOCs, more than half showed the presence of multiple contaminants; the water from one smaller community contained eight VOCs. Trichloroethylene, tetrachloroethylene, and cis- and/or trans-1,2-dichloroethylene were found 18, 11, and 10 times, respectively, in concentrations greater than 5.0 μg/L. Trichloroethylene occurred three times in concentrations greater than 50 μg/L and tetrachloroethylene and cis- and/or trans-1,2-dichloroethylene once each in concentrations greater than 50 ug/L. All xylene occurrences were in supplies serving fewer than 10 000 persons; in fact, only six occurrences of aromatic compounds were found in the larger supplies. Although 1,1,1-trichloroethane was the second most frequently found compound, it was found only four times in concentrations greater than 5.0 μg/L. Of the larger supplies selected, 37 percent had at least one measurable VOC and 18 percent had a summed VOC concentration greater than 5.0 μg/L. Of the smaller systems, 22 percent showed some contamination. The summed VOC concentration exceeded 5.0 μg/L in 5 percent of the samples.

TABLE 6

Summary of random-sample multiple occurrences of contaminants

Number of Contaminants	Population Category			
	≤10 000 Persons		>10 000 Persons	
	Number	*Percent*	*Number*	*Percent*
0	233	83.2	134	72.1
1	28	10.0	27	14.5
2	10	3.5	8	4.3
3	6	2.1	6	3.2
4	1	0.4	5	2.7
5	1	0.4	3	1.6
6	0	0	2	1.1
7	1	0.4	1	0.5
Total	280		186	

TABLE 7

Summed concentrations of VOCs in random samples*

Population	Number of Supplies With Summed Concentrations of VOCs					
	Below Quantitation Limit	Quantitation Limit				
		5.0 μg/L	*5.1-10 μg/L*	*11-50 μg/L*	*51-100 μg/L*	*>100 μg/L*
<100	70	9	0	1	0	0
101-500	77	9	0	2	0	0
501-1000	24	2	2	0	0	0
1001-2500	26	4	0	1	0	0
2501-5000	26	8	1	0	1	0
5001-10 000	10	7	0	0	0	0
10 001-100 000	123	38	5	6	1	0
>100 000	11	2	0	0	0	0

*Summed concentrations = summation of all VOCs exclusive of THMs.

TABLE 8

Summed concentrations in random samples

Summed Concentrations of VOCs—μg/L	Supplies with Summed Concentrations of VOCs Greater Than Value Shown			
	Population Category			
	≤10 000 Persons		>10 000 Persons	
	Number	*Percent*	*Number*	*Percent*
>Quantitation limit	47	16.8	52	28.0
>1.0	20	7.1	26	14.0
>5.0	8	2.9	12	6.5
>10	5	1.8	7	3.8
>50	1	0.4	1	0.5
>100	0	0	0	0

Resampling of contaminated supplies

Approximately 100 contaminated supplies were resampled. The states were asked to resample the finished water and were also given the opportunity to collect several raw water samples of their choosing. In many cases, the original sample point was not resampled or the sampling points were not described well enough to enable comparison of the original sample with the resample.

An example of data from resampled finished water illustrates some aspects of the groundwater VOC data. Table 14 shows the concentrations of VOCs in two samples of finished water, collected nine months apart, from a single well owned by a small town (city A).

These two samples show much the same pattern of contamination, with a possible slight decrease in concentrations in the second sample. Trichloroethylene, which was counted as an occurrence in the original sample, was not found above the quantification limit in the resample. When the original sample and the resample were from a single well, both usually contained nearly identical patterns of contamination. This increases confidence that the original results were accurate and reinforces the belief that levels of groundwater contamination usually change slowly.

The occurrence of a compound at or near the quantitation limit was often not repeated in the resample. For example, in the 37 supplies resampled from the original point, 25 occurrences in the original sample did not recur in the resample. (Many of the supplies resampled had multiple occurrences.) There were also 16 instances, however, in which a compound that was not found in the original sample was quantified in the resampled finished water. This nonrepeatability occasionally occurred in well samples, such as those shown in Table 14, with low levels of contaminants. This situation could result from either normal analytical variability or from actual changes in concentration at the well. This phenomenon was more common in larger systems in which the finished water was a blend of water from multiple wells with various levels of contamination. In these cases, changes in the concentrations of contaminants could result from changes in the relative contributions of the various wells as

TABLE 9

Summary of occurrences from 321 nonrandom sample sites serving fewer than 10 000 persons

Parameter	Quantitation Limit µg/L	Occurrences Number	Occurrences Percent	Median of Positives µg/L	Maximum Value µg/L
Vinyl chloride	1.0	0	0		
1,1-Dichloroethylene	0.2	5	1.6	0.35	3.0
1,1-Dichloroethane	0.2	6	1.9	0.62	1.2
cis- and/or trans-1,2-Dichloroethylene	0.2	11	3.4	1.3	17
1,2-Dichloroethane	0.5	3	0.9	2.9	3.4
1,1,1-Trichloroethane	0.2	25	7.8	1.2	8.2
Carbon tetrachloride	0.2	9	2.8	0.44	15
1,2-Dichloropropane	0.2	3	0.9	1.2	1.4
Trichloroethylene	0.2	23	7.2	1.2	29
Tetrachloroethylene	0.2	27	8.4	0.79	21
Benzene	0.5	5	1.6	1.6	12
Toluene	0.5	4	1.2	0.67	0.79
Ethylbenzene	0.5	3	0.9	0.87	0.95
Bromobenzene	0.5	2	0.6	0.97	1.2
m-Xylene	0.2	8	2.5	0.38	0.83
o + *p*-Xylene	0.2	10	3.1	0.44	2.5
p-Dichlorobenzene	0.5	4	1.2	0.74	0.90
1,1,2-Trichloroethane	0.5	0	0		
1,1,1,2-Tetrachloroethane	0.2	0	0		
1,1,2,2-Tetrachloroethane	0.5	0	0		
Chlorobenzene	0.5	1	0.3	2.7	2.7
1,2-Dibromo-3-chloropropane	5.0	0	0		
n-Propylbenzene	0.5	1	0.3	0.98	0.98
o-Chlorotoluene	0.5	0	0		
p-Chlorotoluene	0.5	0	0		
m-Dichlorobenzene	0.5	0	0		
o-Dichlorobenzene	0.5	1	0.3	2.2	2.2
Styrene	0.5	0	0		
Isopropylbenzene	0.5	0	0		
Chloroform	0.2	155	48.3	1.6	100
Bromodichloromethane	0.2	144	44.9	2.0	49
Dibromochloromethane	0.5	135	42.1	3.5	63
Dichloroiodomethane	1.0	5	1.6	1.4	4.2
Bromoform	1.0	88	27.4	3.7	110

TABLE 10

Summary of occurrences from 158 nonrandom sample sites serving more than 10 000 persons

Parameter	Quantitation Limit µg/L	Occurrences Number	Occurrences Percent	Median of Positives µg/L	Maximum Value µg/L
Vinyl chloride	1.0	6	3.8	2.7	8.4
1,1-Dichloroethylene	0.2	10	6.3	0.34	0.64
1,1-Dichloroethane	0.2	17	10.8	0.87	4.2
cis- and/or trans-1,2-Dichloroethylene	0.2	27	17.1	2.7	120
1,2-Dichloroethane	0.5	4	2.5	1.8	9.8
1,1,1-Trichloroethane	0.2	26	16.5	0.93	21
Carbon tetrachloride	0.2	6	3.8	0.70	9.4
1,2-Dichloropropane	0.2	4	2.5	0.70	18
Trichloroethylene	0.2	38	24.1	1.5	130
Tetrachloroethylene	0.2	18	11.4	0.66	69
Benzene	0.5	3	1.9	2.7	12
Toluene	0.5	1	0.6	1.5	1.5
Ethylbenzene	0.5	0	0		
Bromobenzene	0.5	0	0		
m-Xylene	0.2	0	0		
o + *p*-Xylene	0.2	0	0		
p-Dichlorobenzene	0.5	0	0		
1,1,2-Trichloroethane	0.5	0	0		
1,1,1,2-Tetrachloroethane	0.2	0	0		
1,1,2,2-Tetrachloroethane	0.5	0	0		
Chlorobenzene	0.5	0	0		
1,2-Dibromo-3-chloropropane	5.0	0	0		
n-Propylbenzene	0.5	0	0		
o-Chlorotoluene	0.5	1	0.6	2.4	2.4
p-Chlorotoluene	0.5	0	0		
m-Dichlorobenzene	0.5	0	0		
o-Dichlorobenzene	0.5	1	0.6	2.7	2.7
Styrene	0.5	0	0		
Isopropylbenzene	0.5	0	0		
Chloroform	0.2	100	63.3	2.1	430
Bromodichloromethane	0.2	100	63.3	2.2	110
Dibromochloromethane	0.5	87	55.1	4.6	51
Dichloroiodomethane	1.0	8	5.1	1.2	4.1
Bromoform	1.0	60	38.0	5.1	68

determined by their pumping rates. Temporal changes in concentrations could also result from a relatively rapid movement of the plume of contamination, which could occur during recharge and withdrawal in a highly permeable aquifer.

The data from resampling of finished water from individual wells reinforce confidence that the identification and quantitation of compounds in the samples were accurate. The data from larger, multiple-well systems show that concentrations of compounds in a finished water can vary considerably over time. Therefore, sampling a large number of supplies, as in this survey, provides an accurate representation of the percentage of systems with water containing VOCs and an indication of the magnitude of the levels of concentrations.

The variability of the quality of finished water from groundwater supplies is site-specific and not amenable to definition by a national survey such as this. In the face of this variability, the sampling approach was a compromise between providing broad national coverage and obtaining representative samples at each site.

Conclusion

The groundwater supply survey was undertaken primarily to strengthen the body of data on the occurrence of VOCs in groundwater supplies. Careful attention was paid to quality assurance so that a reliable representation of the occurrence of VOCs in US groundwater supplies would result. The frequencies of occurrence of 29 volatile compounds were documented in samples collected from 466 randomly selected communities and from 479 communities selected by the state agencies. The three most frequently detected compounds were trichloroethylene, tetrachloroethylene, and 1,1,1-trichloroethane. The percentages of supplies containing at least one VOC above the quantitation limit in the subsets of the survey were: random sample of systems serving fewer than 10 000 persons, 16.8 percent; random sample of systems serving more than 10 000 persons, 28 percent; nonrandom sample of systems serving fewer than 10 000 persons, 22.4 percent; and nonrandom sample of systems serving more than 10 000 persons, 37.3 percent. The percentages of supplies containing summed VOC concentrations in finished water greater than 5 µg/L were: random sample of systems serving fewer than 10 000 persons, 2.9 percent; random sample of systems serving more than 10 000 persons, 6.5 percent; nonrandom sample of systems serving fewer than 10 000 persons, 4.7 percent; and nonrandom sample of systems serving more than 10 000 persons, 17.7 percent.

Simple statistical tests, based on ran-

TABLE 11
Summary of nonrandom-sample multiple occurrences of contaminants

Number of Contaminants	Population Category			
	≤10 000 Persons		>10 000 Persons	
	Number	*Percent*	*Number*	*Percent*
0	249	77.6	99	62.7
1	35	10.9	19	12.0
2	15	4.7	14	8.9
3	11	3.4	7	4.4
4	7	2.2	7	4.4
5	2	0.6	7	4.4
6	0	0	4	2.6
7	1	0.3	1	0.6
8	1	0.3	0	0
Total	321		158	

TABLE 12
Summed concentrations of VOCs in nonrandom samples*

Population	Number of Supplies With Summed Concentrations of VOCs					
	Below Quantitation Limit	Quantitation Limit				
		5.0 µg/L	*5.1-10 µg/L*	*11-50 µg/L*	*51-100 µg/L*	*>100 µg/L*
<100	24	10	1	0	0	0
101-500	38	4	0	1	0	0
501-1000	27	5	0	2	0	0
1001-2500	62	8	0	1	0	0
2501-5000	43	18	0	2	0	0
5001-10 000	55	12	4	4	0	0
10 001-100 000	85	29	6	13	3	2
>100 000	14	2	0	3	0	1

*Summed concentrations = summation of all VOCs exclusive of THMs.

TABLE 13
Summed concentration levels in nonrandom samples

Summed Concentrations of VOCs—µg/L	Supplies with Summed Concentrations of VOCs Greater Than Value Shown			
	Population Category			
	≤10 000 Persons		>10 000 Persons	
	Number	*Percent*	*Number*	*Percent*
>Quantitation limit	72	22.4	59	37.3
>1.0	41	12.8	43	27.2
>5.0	15	4.7	28	17.7
>10	10	3.1	22	13.9
>50	0	0	6	3.8
>100	0	0	3	1.9

TABLE 14
VOCs found in original sample and resample in city A

Parameter	June 1981 µg/L	March 1982 µg/L
1,1-Dichloroethane	0.62	0.51
1,1,1-Trichloroethane	1.9	1.4
Trichloroethylene	0.21	<0.2
Tetrachloroethylene	1.3	0.94

dom sampling, showed significant differences in the frequency of occurrences of VOCs in the larger and smaller community subsets. The results of the random sample were also used to construct statistical confidence limits of estimates of the probabilities of occurrence.

The nonrandom portion of the sample provided additional data on the high side of the occurrence curve, since the sites were selected in hopes of finding a greater frequency of higher levels of contamination. For example, six of the eight supplies with summed VOC concentrations greater than 50 µg/L were from the nonrandom sample, including all three of the supplies with summed VOC concentrations greater than 100 µg/L.

Resampling of contaminated supplies strengthened confidence in the quality of the analytical data. It also showed that finished water quality, with respect to VOCs, can vary over time, especially in systems supplied by multiple wells.

Additional analysis of the data generated by this survey will appear in documents prepared by the USEPA in support of VOC regulatory recommendations.

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VII. GROUND-WATER RESOURCES IN THE UNITED STATES

- Summary of Ground-Water Resources in Geologic Regions*
- Summary of Ground-Water Production*
- Summary of Ground-Water Use*
- Report on Estimated Use of Water in the United States

**Selections from* Ground Water Issues and Answers, *American Institute of Professional Geologists, 1984.*

Ground Water Resources in Geologic Regions

1. **Western Mountains** – Underlain by hard, dense rocks; weathered rock locally yields modest supplies, as does alluvium in intermontane valleys. Large supplies are rare.

2. **Alluvial Basins** — Large depressed areas flanked by highlands and filled with erosional debris. Alluvial fill functions as an ideal aquifer, absorbing water readily from streams issuing from highlands and yielding large supplies to wells. Supports large-scale irrigated agriculture and provides municipal water for many cities.

3. **Columbia Lava Plateau** — Underlain by thousands of feet of basaltic lava flows, interbedded with alluvial and lake sediments. Lava rocks are highly permeable because of lava tubes, shrinkage cracks, and interflow rubble zones. Yields large supplies of water for irrigation and municipal use.

4. **Colorado Plateaus and Wyoming Basins** — Underlain by gently dipping sediments, mainly poorly-permeable sandstone and shale. Most productive aquifers are sandstone, furnishing small supplies for stock and domestic use. Prospects poor for large-scale ground-water developments, but such supplies are found at a few favorable localities.

5. **High Plains** — Underlain by alluvium of the Ogallala Formation, as much as 450 feet thick, which yields large supplies to wells, mainly for irrigation. Opportunity for recharge from streams is small, due to low rainfall and because large streams have cut below the base of alluvium. Water table is gradually declining in much of the area due to overdraft.

6. **Unglaciated Central Region** — Complex area of plains and plateaus, underlain by consolidated sedimentary rocks. Alluvium of stream valleys provides large supplies for industry and cities. Most productive aquifers in much of the region are dolomitic limestones and sandstones of low-to-moderate yield.

7. **Glaciated Central Region** — Similar to Unglaciated Central Region, except that area is mantled by glacial deposits as much as 900 feet thick. These contain lenses and beds of well-sorted sand and gravel, which yield large supplies of water for industrial and municipal use.

8. **Unglaciated Appalachians** — Mountainous area underlain mainly by consolidated sedimentary rocks of small-to-moderate water yield. Locally, limestones yield large supplies of water.

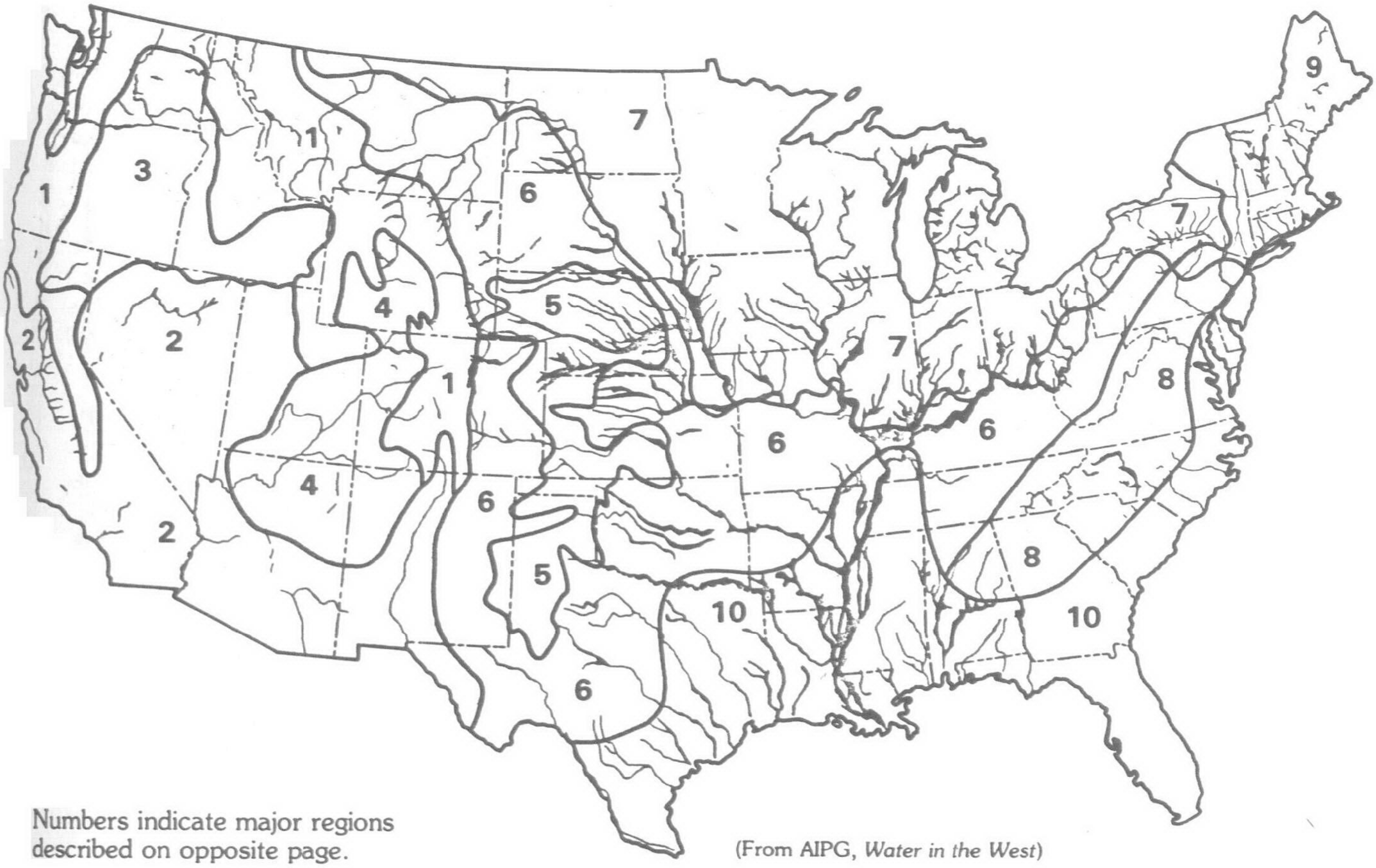
9. **Glaciated Appalachians** – Glacial deposits mantle steep areas and underlie valleys and lowlands. Yields from bedrocks are generally small to moderate. Principal ground-water sources are sand and gravel of glacial outwash plains, or channel fillings in stratified drift.

10. **Atlantic and Gulf Coastal Plains** — A huge, seaward-thickening wedge of sedimentary rocks consisting mainly of clay, sand, marl, and limestone. Thickness along coast increases southward from 300 to 30,000 feet. Large supplies of ground water can be obtained almost anywhere, although salt-water encroachment is a problem locally.

Alaska — Most has been glaciated, and large supplies of ground water can be obtained from glacial sand and gravel. Permafrost is present in northern Alaska, restricting the availability of ground water.

Hawaii — Entire island chain is composed of basaltic lava flows, which are highly permeable and yield water readily to wells and tunnels. Fresh-water body forms a lens floating upon sea water, so extraction must be carefully managed to avoid sea-water intrusion.

GROUND-WATER RESOURCES



Numbers indicate major regions described on opposite page.

(From AIPG, *Water in the West*)

Watercourses related to aquifers

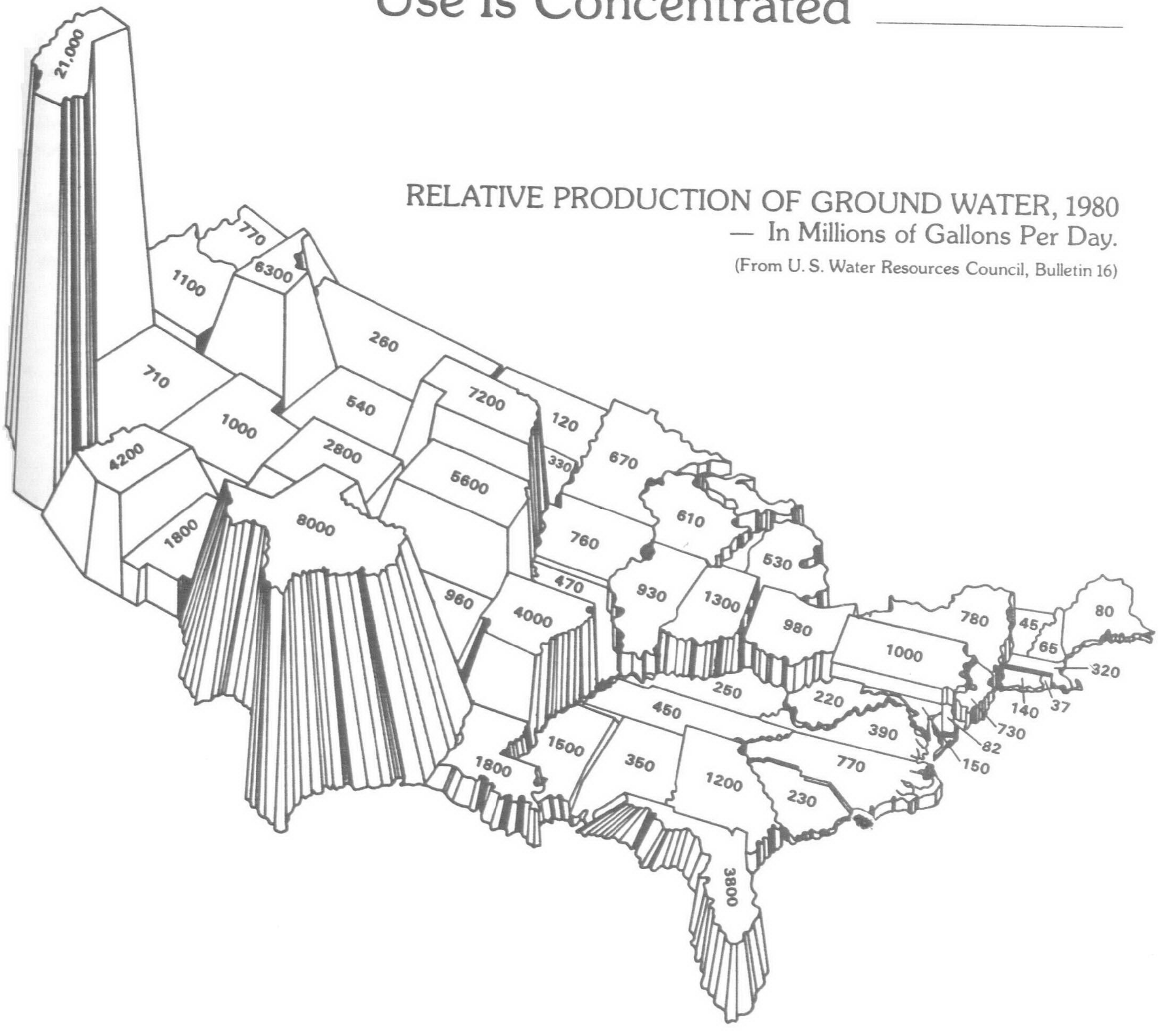
Areas of extensive aquifers that yield more than 50 gallons per minute of fresh water

Areas of less-extensive aquifers having smaller yields

Ground water sufficient for domestic and livestock supplies can be found throughout the country.

Larger ground-water supplies for industry, municipal use, and irrigation are obtained from high-permeability rocks and river deposits (alluvium).

Where Ground-Water Use Is Concentrated



RELATIVE PRODUCTION OF GROUND WATER, 1980
— In Millions of Gallons Per Day.
(From U. S. Water Resources Council, Bulletin 16)

- ☐ Although ground water is the main source of rural water supplies, and is the source for many cities, those uses are relatively small compared to irrigation demand. *Irrigation accounted for about 70% of the ground-water production in 1980.*

- ☐ Ground-water production for irrigation *tripled* between 1950 and 1980, increasing from 20 to 60 billion gallons per day.

- ☐ Irrigation demand, and thus the largest ground-water production, is concentrated in the semi-arid western states and in Florida.

- ☐ The four leading ground-water pumping states — California, Texas, Nebraska, and Idaho — account for almost *half* the total national production of ground water.

Ground Water Serves Many Users

Ground water provides 23% of the fresh water used in the United States. In the 17 semi-arid western states, it provides 38% of the fresh-water supply. It is the chief supply for rural domestic and stock use, and for small community supplies throughout the Nation.

Although not generally considered a "use," ground water serves another vital function: it sustains stream flows in dry weather. In highly permeable areas, ground water is the main source of stream flow at all times.

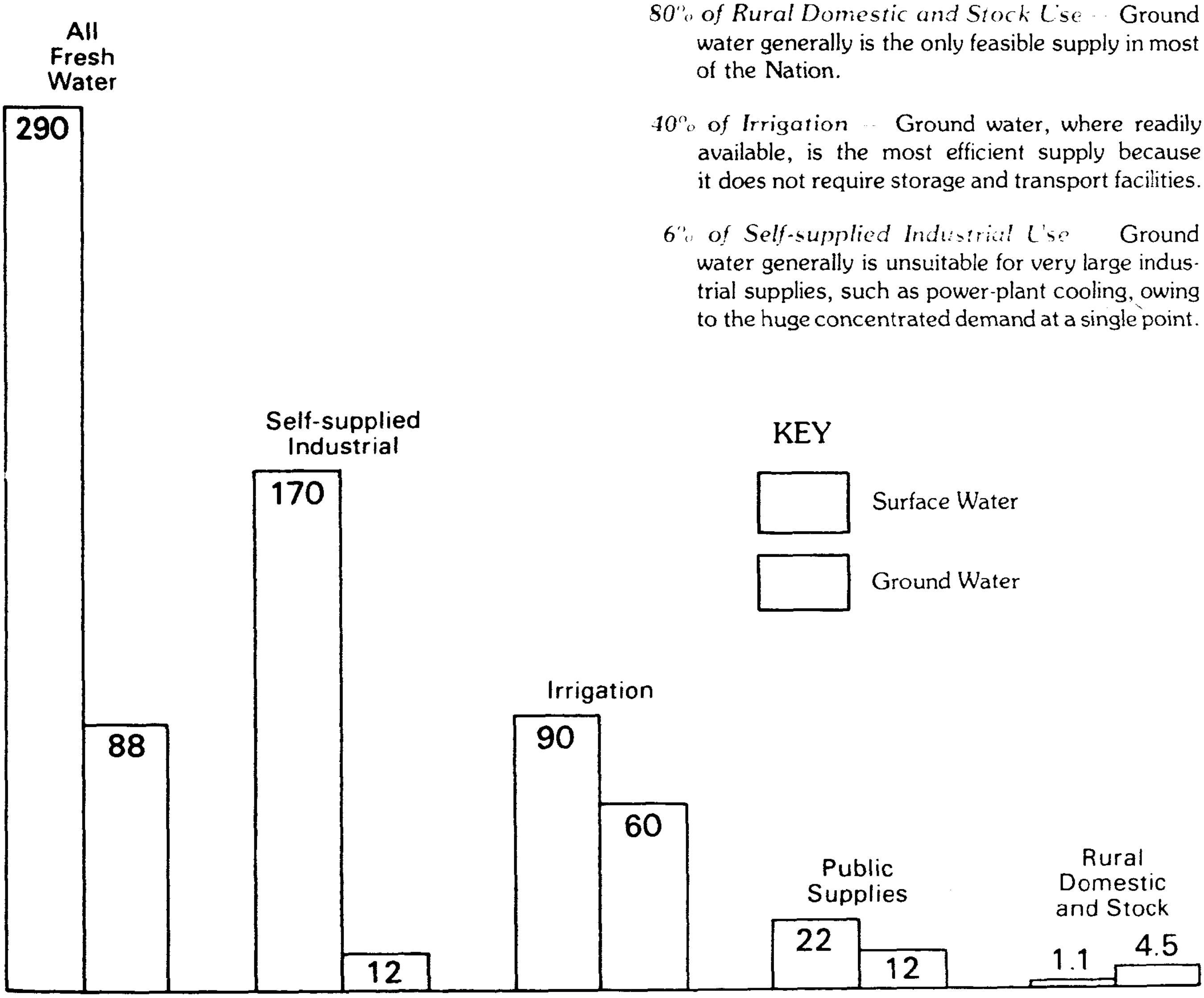
Water Uses Supplied by Ground Water

35% of Public Supply — Ground water is the most efficient supply for medium-sized cities and small communities because it does not require costly reservoirs and aqueducts. Of the 100 largest U.S. cities, 34 depend wholly or partly on ground water. The largest populations (1980) served entirely by ground water include Nassau-Suffolk Counties of Long Island, N.Y. (2.6 million), Miami (1.6), San Antonio (1.1), Memphis (0.9), Dayton (0.8), Honolulu (0.7), and Tucson (0.5).

80% of Rural Domestic and Stock Use — Ground water generally is the only feasible supply in most of the Nation.

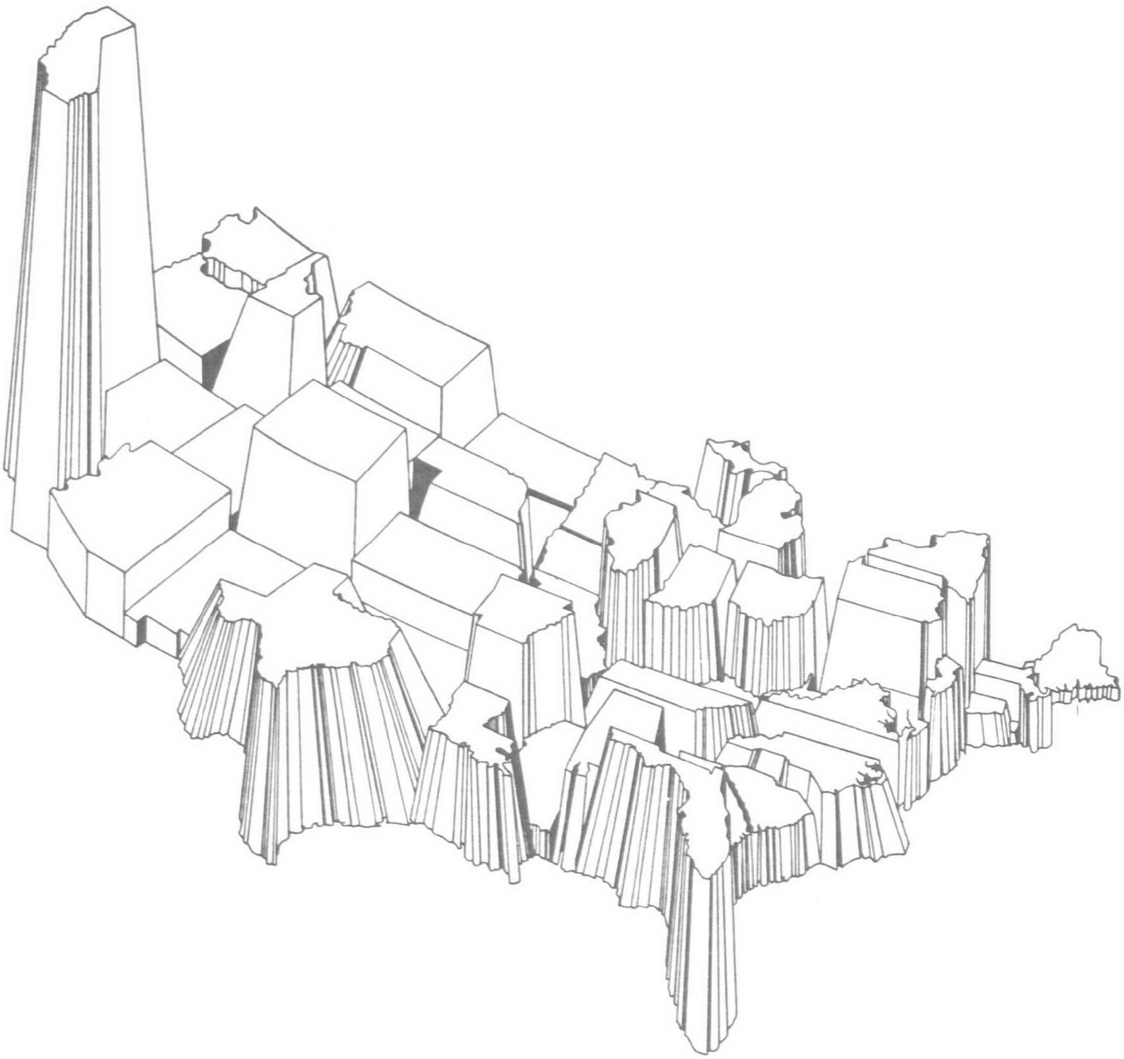
40% of Irrigation — Ground water, where readily available, is the most efficient supply because it does not require storage and transport facilities.

6% of Self-supplied Industrial Use — Ground water generally is unsuitable for very large industrial supplies, such as power-plant cooling, owing to the huge concentrated demand at a single point.

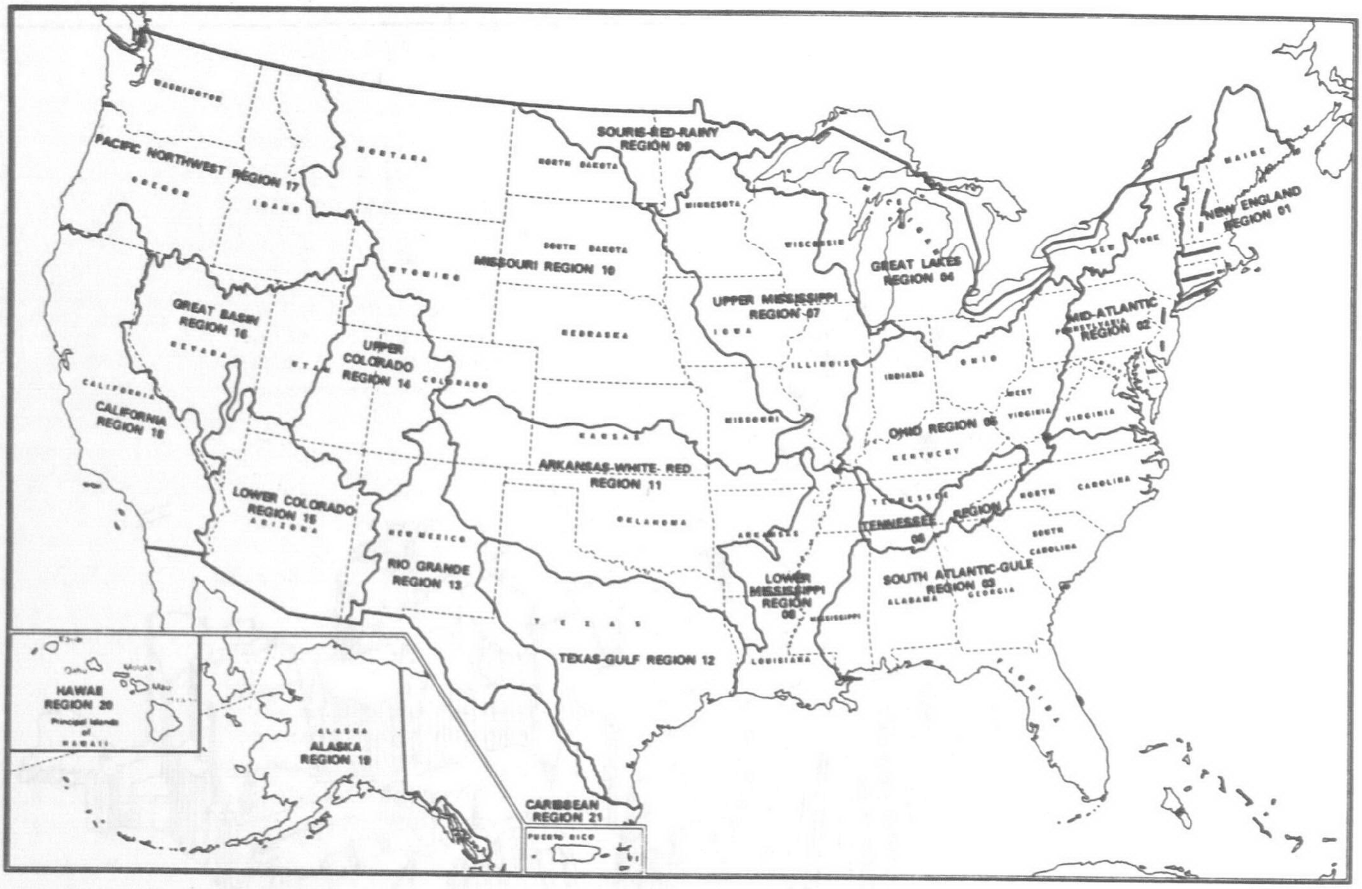


Fresh-Water Withdrawals in the United States, 1980, in billions of gallons per day.

ESTIMATED USE OF WATER IN THE UNITED STATES IN 1980



GEOLOGICAL SURVEY CIRCULAR 1001



Water-resources regions of the United States as established by the U.S. Water Resources Council in 1970. This map shows the relationship of the regions to the States. (See glossary in this report for definition of water-resources region.)

ABOUT THE COVER

Comparison of water withdrawals, by States, in 1980.

The total national rate of withdrawal of ground and surface water was 450 billion gallons per day. See table 14 for each State total.

ESTIMATED USE OF WATER IN THE UNITED STATES IN 1980

By Wayne B. Solley, Edith B. Chase, and William B. Mann IV

ABSTRACT

Water use in the United States in 1980 was estimated to be an average of 450 bgd (billion gallons per day) of fresh and saline water for offstream uses—an 8-percent increase from the 1975 estimate and a 22-percent increase from the 1970 estimate. Average per capita use for all offstream uses was 2,000 gpd (gallons per day) of fresh and saline water, and 1,600 gpd of fresh water; this represents a slight increase since 1975.

Offstream uses include (1) public supply (domestic, public, commercial, and industrial uses), (2) rural (domestic and livestock uses), (3) irrigation, and (4) self-supplied industrial uses (including thermoelectric power). From 1975 to 1980, public-supply use increased 15 percent to 34 bgd, rural use increased 14 percent to 5.6 bgd, irrigation use increased 7 percent to 150 bgd, and self-supplied industrial use increased 8 percent to 260 bgd. Within the industrial category, thermoelectric power generation increased 9 percent to 210 bgd, whereas other self-supplied industrial uses remained approximately constant at 45 bgd.

Total fresh water consumed—that part of water withdrawn that is no longer available for subsequent use—by these offstream uses increased 7 percent to 100 bgd, with irrigation accounting for the largest part of water consumed, estimated at 83 bgd.

Estimates of withdrawals by source indicate that from 1975 to 1980, total ground-water withdrawals increased 7 percent to 89 bgd, and total surface-water withdrawals increased 9 percent to 360 bgd. Total saline-water withdrawals increased by about 2 bgd to 72 bgd, of which 71 bgd was saline surface water. Reclaimed sewage amounted to about 0.5 bgd in 1980, an 11-percent decrease from 1975.

A comparison of withdrawals by States indicates that California withdrew the most water for offstream use, 54 bgd, more than double the amounts withdrawn by Florida and Texas, the next largest users. A similar comparison by water-resources regions indicates that the California and Mid-Atlantic regions accounted for nearly one quarter of the total water withdrawn in the United States. Total withdrawals for offstream use in the eastern water-resources regions, which include the Mississippi and Souris Rivers, accounted for 55 percent of the Nation's total withdrawals. Fresh-water consumptive use in the East was 8 percent of the total eastern withdrawals and accounted for only 19 percent of the national total consumptive use of 100 bgd. By comparison, consumptive use in the western water-resources regions accounted for 41 percent of the withdrawals in the West. The higher consumptive use in the West can be attributed to the fact that 91 percent of the total water withdrawn for irrigation occurred in the West and irrigation accounts for the largest part of water consumed.

Water used for hydroelectric power generation, an instream use, remained unchanged from 1975 at 3,300 bgd. This is in contrast to the increasing trend from 1950 to 1975.

Although 1980 estimates of water use were higher than the 1975 estimates for all offstream categories, trends established during the periods 1970 to 1975 and 1975 to 1980 indicate a general slackening in the rate of increase of total withdrawals in comparison to the period 1965 to 1970.

Public Supply

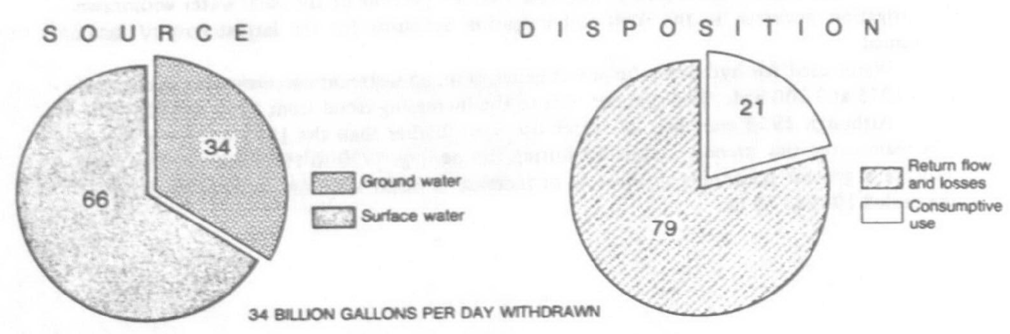
Public supply refers to water withdrawn by public and private water suppliers and delivered to a variety of users for domestic or household use, public use, industrial use, and commercial use. Public suppliers served about 186 million people in 1980, about 81 percent of the total population, a slight increase in percentage since 1975. Domestic use includes such activities as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, and watering lawns and gardens. Public use includes water for firefighting, street washing, and municipal parks and swimming pools. Many industrial and commercial establishments use public supplies, especially where the volume of water required is small and the quality of water must be high. However, some industries that require large amounts of water also use public supply for principal or auxiliary water. Among commercial users are hotels, restaurants, laundry services, office facilities, and institutions, both civilian and military. Data on population served by public supply and public-supply withdrawals and deliveries usually are reliable because local government agencies generally maintain relatively complete files.

Total water withdrawn for public supply in 1980 was estimated as 34 bgd, or an average of 183 gpd for each individual served (see tables 1 and 2). This amount represents a 15-percent increase from 1975 when 29 bgd of water was withdrawn for public supply or a per capita use of 168 gpd. (See "Methodology" section for how percentages were derived.) Part of this increase is due to the fact that nearly 2 bgd of water erroneously identified in previous reports as self-supplied industrial withdrawals is now included in the public-supply category. Another factor in the increase in this category is a 6-percent increase from 1975 in population served by public supplies along with higher per capita use. Combined daily average for domestic and public uses accounted for almost two-thirds of the public-supply withdrawals and was estimated at 22 bgd, or an average of 120 gpd for each individual served, compared to a per capita use of 117 gpd in 1975. Included in the 22 bgd is water lost in the distribution system. Industrial and commercial users received the other third of the public-supply withdrawals, about the same distribution as in 1975.

Water consumed by public-supply users increased 6 percent to 7.1 bgd in 1980, and accounted for about 21 percent of the public-supply withdrawals, approximately the same proportion as in 1965, 1970, and 1975. The larger cities were supplied principally by surface-water sources, which furnished about two-thirds of the public-supplied water.

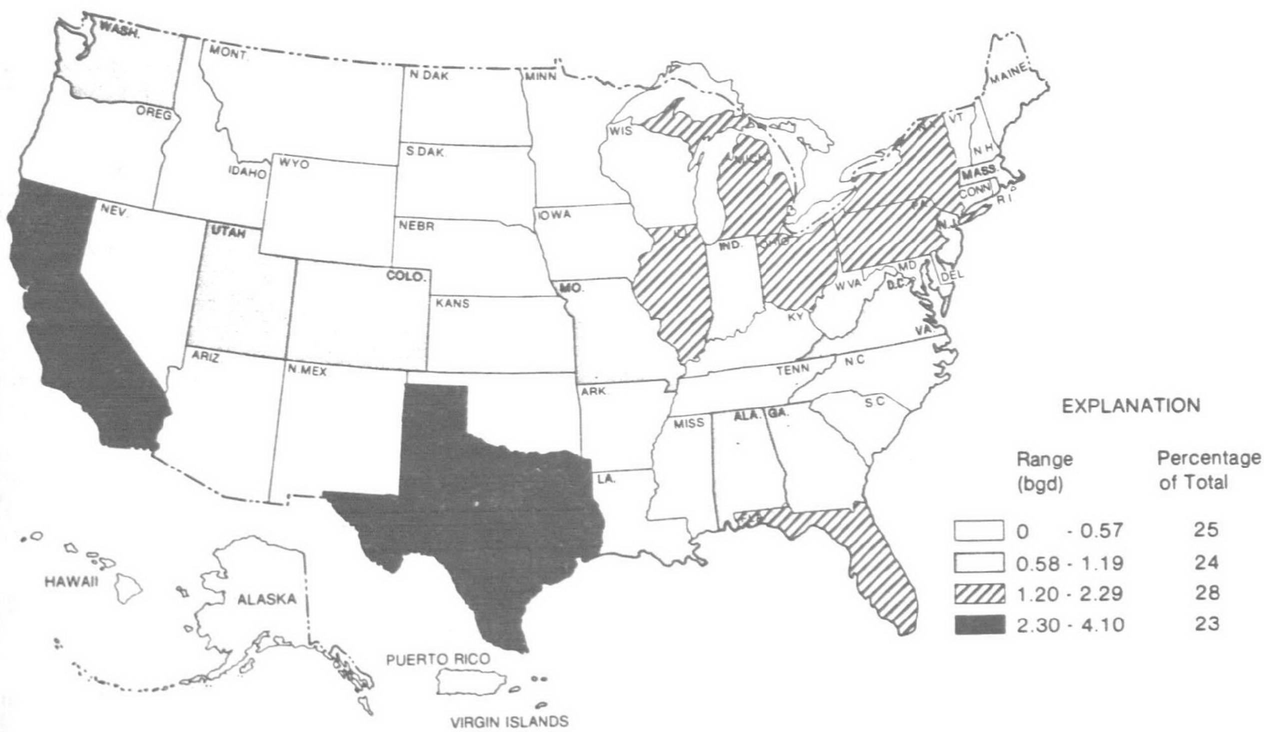
California, New York, and Texas, the three most populated States, withdrew the most water for public supplies, and accounted for about 30 percent of the Nation's total withdrawal by public suppliers. Per capita domestic use from public supplies averaged 100 gpd for the Eastern States and 150 gpd for the western States (see table 13). The two most populated water-resources regions, California and Mid-Atlantic, withdrew the most water for public supplies, and accounted for about 28 percent of the total withdrawal by public suppliers.

The range in public-supply fresh-water withdrawals by States and water-resources regions is shown in figure 1. Public-supply water-use data by States are given in table 1, and the same data by water-resources regions are given in table 2. The source of and disposition of withdrawals for public supply are shown in the chart below.



WATER WITHDRAWN FOR PUBLIC SUPPLY BY SOURCE AND DISPOSITION, 1980, IN PERCENT.

A. States



B. Water-resources regions

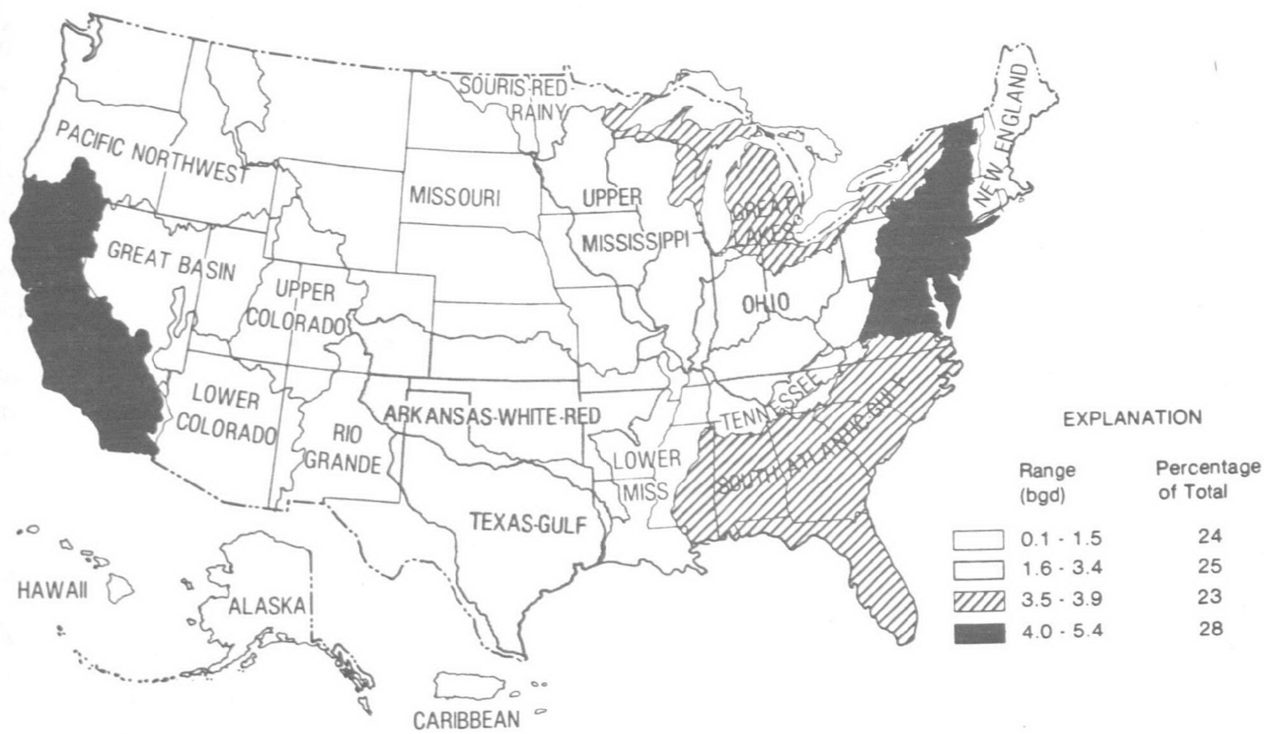


Figure 1. Public supply fresh-water withdrawals, by States and water-resources regions, 1980.

Table 1.—*PUBLIC SUPPLIED FRESH-WATER USE, BY STATES, 1980*

[Water-use data generally are rounded to two significant figures, population data and per capita data are rounded to three significant figures; figures may not add to totals because of independent rounding. mgd = million gallons per day; gpd = gallons per day]

STATE	POPULATION SERVED, in thousands			PER CAPITA USE, in gpd	WATER WITHDRAWALS, in mgd			WATER DELIVERED, BY TYPE OF USE, in mgd		CONSUMPTIVE USE, in mgd
	Source		Total		Source		Total			
	Ground water	Surface water			Ground water	Surface water		Industrial and commercial	Domestic and public[1]	
Alabama	1200	1740	2950	210	160	460	620	230	390	44
Alaska	172	113	286	187	23	30	53	14	40	33
Arizona	1490	945	2440	230	300	260	560	180	380	340
Arkansas	880	816	1700	155	110	150	260	77	190	64
California	9580	12700	22300	183	1900	2200	4100	800	3300	1700
Colorado	320	2220	2540	233	48	540	590	80	510	160
Connecticut	521	1980	2500	143	55	300	360	140	220	89
Delaware	254	240	494	158	30	48	78	8.6	69	0
D.C.	0	638	638	326	0	210	210	62	150	21
Florida	6800	991	7790	175	1200	180	1400	240	1100	330
Georgia	1320	2860	4180	185	230	540	770	360	410	180
Hawaii	914	51	965	207	180	15	200	64	140	60
Idaho	592	117	709	231	150	16	160	15	150	51
Illinois	4050	6690	10700	170	480	1300	1800	1000	790	18
Indiana	1920	1430	3350	172	300	280	580	270	300	79
Iowa	1600	528	2120	146	230	84	310	92	220	47
Kansas	903	832	1740	168	140	150	290	71	220	83
Kentucky	375	2080	2450	145	47	310	350	72	280	23
Louisiana	1850	1310	3160	192	270	340	610	91	510	350
Maine	101	372	473	221	20	85	100	34	70	10
Maryland	417	3040	3460	141	48	440	490	87	400	24
Massachusetts	1550	3850	5400	149	190	610	800	240	560	41
Michigan	1310	5280	6590	190	220	1000	1300	670	580	100
Minnesota	1910	1010	2920	150	230	210	440	130	300	44
Mississippi	1800	182	1980	147	250	42	290	80	210	100
Missouri	1520	3160	4690	156	160	570	730	300	440	150
Montana	184	339	524	273	50	93	140	54	89	53
Nebraska	961	276	1240	213	210	56	260	69	190	53
Nevada	329	392	721	322	93	140	230	80	150	69
New Hampshire	392	366	758	117	43	46	89	25	64	4.9
New Jersey	3420	3940	7360	145	450	620	1100	250	820	200
New Mexico	798	82	880	240	190	21	210	12	200	99
New York	3510	12100	15700	143	350	1900	2200	950	1300	380
North Carolina	474	2640	3110	184	70	500	570	230	340	110
North Dakota	258	247	505	116	26	33	59	5.6	53	34
Ohio	2950	6040	8990	160	380	1100	1400	630	800	180
Oklahoma	662	1670	2330	130	86	220	300	100	200	120
Oregon	344	851	1200	193	66	160	230	90	140	47
Pennsylvania	2180	6620	8800	172	240	1300	1500	350	1200	160
Rhode Island	142	723	864	147	19	110	130	50	77	6.3
South Carolina	541	1780	2320	152	78	270	350	130	230	53
South Dakota	321	134	455	167	52	24	76	21	55	15
Tennessee	1450	2270	3720	137	200	310	510	140	370	55
Texas	5030	6360	11400	335	930	2900	3800	2000	1800	640
Utah	662	634	1300	575	380	370	750	140	610	300
Vermont	113	207	320	149	17	31	48	15	33	5.8
Virginia	707	3160	3860	154	120	480	600	150	450	32
Washington	2100	1200	3300	246	300	510	810	370	440	170
West Virginia	411	921	1330	134	49	130	180	61	120	0.6
Wisconsin	1620	1420	3040	188	290	280	570	250	320	57
Wyoming	122	200	322	256	27	55	82	15	68	48
Puerto Rico	669	2530	3200	109	73	280	350	88	260	74
Virgin Islands	32	32	64	63	2.0	2.0	4.0	0.2	3.8	0.8
Total	73,700	112,000	186,000	183	12,000	22,000	34,000	12,000	22,000	7,100

[1]Includes losses in the distribution system.

Table 2.—*PUBLIC SUPPLIED FRESH-WATER USE, BY REGIONS, 1980*

[Water-use data generally are rounded to two significant figures, population data and per capita data are rounded to three significant figures; figures may not add to totals because of independent rounding. mgd = million gallons per day; gpd = gallons per day]

WATER-RESOURCES REGION	POPULATION SERVED, in thousands			PER CAPITA USE, in gpd	WATER WITHDRAWALS, in mgd			WATER DELIVERED, BY TYPE OF USE, in mgd		CONSUMPTIVE USE, in mgd
	Source		Total		Source		Total	Industrial and commercial	Domestic and public[1]	
	Ground water	Surface water			Ground water	Surface water				
New England	2730	7310	10000	148	330	1200	1500	490	1000	150
Mid-Atlantic	9440	24600	34100	159	1100	4300	5400	1500	3900	710
South Atlantic-Gulf	11400	10000	21400	177	1900	1900	3800	1200	2600	780
Great Lakes	2970	18600	21500	182	440	3500	3900	2100	1800	310
Ohio	5600	9710	15300	144	730	1500	2200	790	1400	240
Tennessee	727	1950	2680	153	89	320	410	95	310	44
Upper Mississippi	8330	4240	12600	155	1100	820	1900	860	1100	180
Lower Mississippi	4170	1170	5330	172	610	310	920	210	710	400
Souris-Red-Rainy	253	241	494	116	27	30	57	11	46	22
Missouri Basin	3360	4730	8090	171	530	850	1400	320	1100	360
Arkansas-White-Red	2280	3810	6090	255	320	1200	1600	790	760	310
Texas-Gulf	4330	5810	10100	298	800	2200	3000	1400	1600	550
Rio Grande	1100	268	1370	232	240	74	320	21	300	140
Upper Colorado	91	266	357	347	23	100	120	18	110	41
Lower Colorado	1710	1200	2910	248	370	350	720	230	490	390
Great Basin	800	769	1570	514	400	410	810	160	650	310
Pacific Northwest	3050	2260	5320	237	530	730	1300	500	770	290
California	9610	12700	22300	183	1900	2200	4100	800	3300	1700
Alaska	172	113	286	187	23	30	53	14	40	33
Hawaii	914	51	965	207	180	15	200	64	140	60
Caribbean	701	2560	3260	108	75	280	350	88	270	75
Total	73,700	112,000	186,000	183	12,000	22,000	34,000	12,000	22,000	7,100

[1]Includes losses in the distribution system.

Rural Use

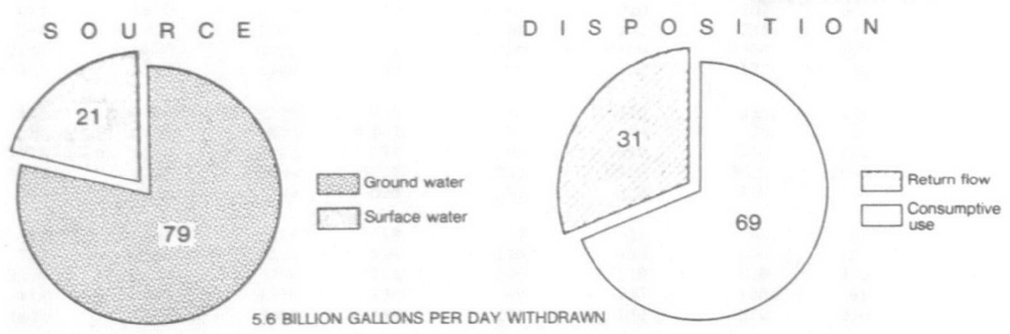
Water for rural use includes self-supplied domestic use, drinking water for livestock, and other uses such as dairy sanitation, evaporation from stock-watering ponds, and cleaning and waste disposal. The number of people served by self-supplied systems was determined by subtracting the total number of people served by public-supply systems from the total population, as derived from the U.S. Bureau of Census advance population data for 1980. The difference between these totals showed that 44 million people were served by their own water-supply systems in 1980, compared to 41 million people in 1975. Rural self-supplied systems rarely are metered and few "hard" data exist. Therefore, water for rural use can only be estimated.

The quantity of fresh water withdrawn for rural domestic and livestock use in 1980 was 5.6 bgd, a 14-percent increase from 1975. Rural domestic withdrawals were 3.4 bgd, a 23-percent increase from 1975. This large increase is the result of the increased population being served by self-supplied systems and an increase in the per capita use, which was about 79 gpd compared to about 68 gpd in 1975. The increase in per capita use reflects the application of more realistic estimating techniques, which also indicate that previous estimates were probably too low. The quantity of water used by livestock increased slightly from 2.1 bgd in 1975 to nearly 2.2 bgd in 1980.

The consumptive use of fresh water for rural domestic use and livestock use in 1980 was about 2.0 bgd and 1.9 bgd, or 57 and 88 percent of withdrawals, respectively. Total consumptive use was 69 percent of total rural withdrawals. Only about 5 percent of the rural domestic water was surface water, but some 45 percent of the water used for livestock was surface water.

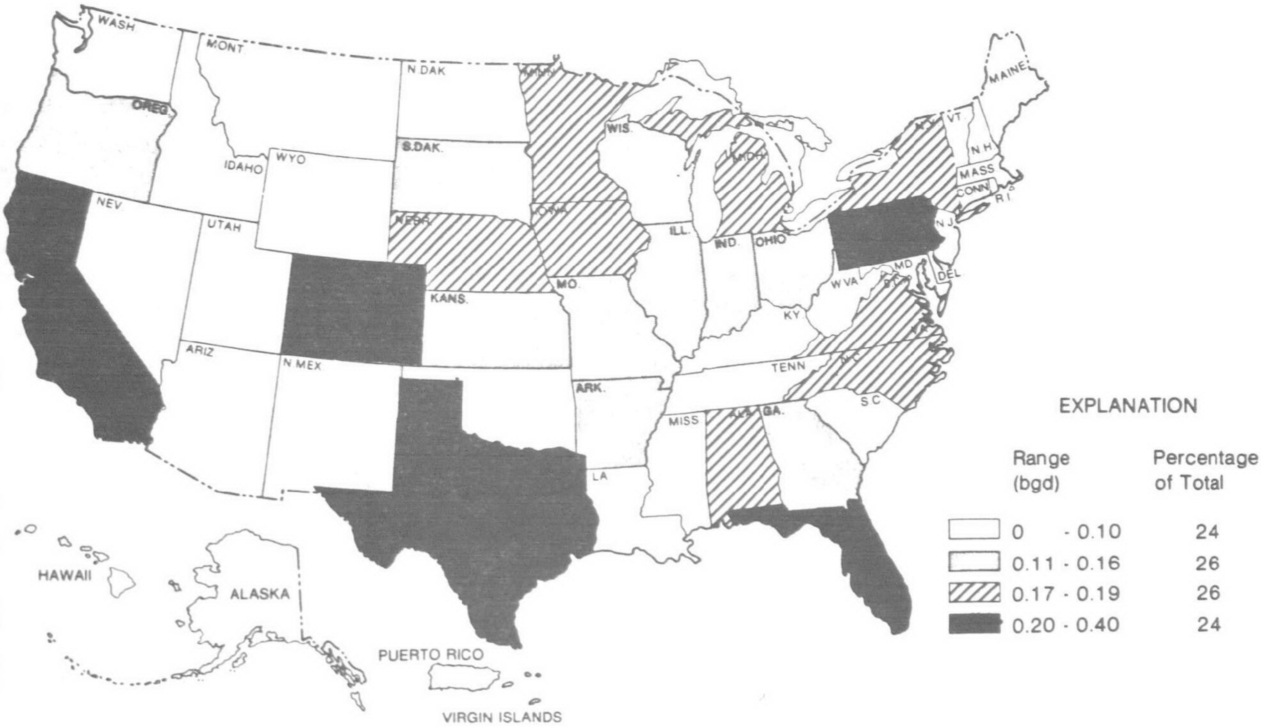
Rural domestic and livestock water use is fairly evenly distributed among the States with Texas and Florida the major users accounting for 7 percent and 6 percent, respectively. The South Atlantic-Gulf water-resources region withdrew the most water for total rural use, and it also experienced the largest volume increase in rural domestic withdrawals. The Missouri Basin region withdrew the most water for rural livestock use and accounted for about 18 percent of the total withdrawals for livestock use.

The range in rural fresh-water withdrawals by States and water-resources regions is shown in figure 2. Rural water-use data by States are given in table 3, and the same data by water-resources regions are given in table 4. The source of and disposition of withdrawals for rural use are shown in the chart below.



WATER WITHDRAWN FOR RURAL DOMESTIC AND LIVESTOCK USE BY SOURCE AND DISPOSITION, 1980, IN PERCENT.

A. States



B. Water-resources regions

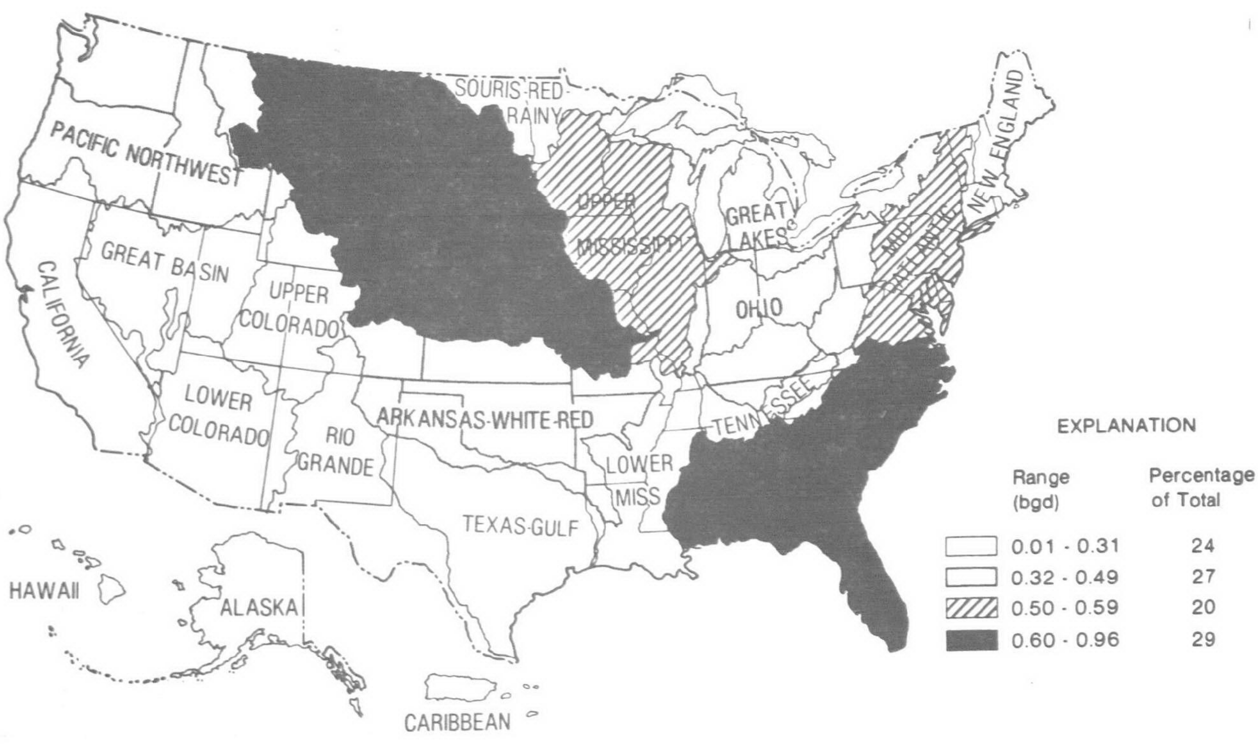


Figure 2. Rural fresh-water withdrawals, by States and water-resources regions, 1980.

Table 3.—*RURAL FRESH-WATER USE, BY STATES, IN MILLION GALLONS PER DAY, 1980*

[Data generally are rounded to two significant figures; figures may not add to totals because of independent rounding]

STATE	DOMESTIC USE				LIVESTOCK USE				TOTAL DOMESTIC AND LIVESTOCK USE			
	Withdrawals			Consumptive use	Withdrawals			Consumptive use	Withdrawals			Consumptive use
	By source		Total		By source		Total		By source		Total	
	Ground water	Surface water			Ground water	Surface water			Ground water	Surface water		
Alabama	100	0	100	100	25	63	88	88	130	63	190	190
Alaska	11	0.1	11	0.1	0	0.1	0.2	0.2	11	0.3	11	0.3
Arizona	32	0	32	24	9.8	1.8	12	8.1	42	1.8	43	32
Arkansas	57	0	57	51	22	39	61	61	78	39	120	110
California	130	9.5	140	82	36	51	87	46	160	60	220	130
Colorado	35	62	98	24	19	86	110	35	54	150	200	59
Connecticut	53	0	53	32	0.4	1.8	2.2	2.2	54	1.8	56	34
Delaware	25	0	25	0	2.0	0	2.0	2.0	27	0	27	2.0
D.C.	0	0	0	0	0	0	0	0	0	0	0	0
Florida	250	0.1	250	42	39	20	59	59	290	20	310	100
Georgia	140	0	140	85	17	11	28	28	150	11	160	110
Hawaii	3.5	0.4	3.9	3.4	5.3	0.2	5.5	4.8	8.8	0.6	9.4	8.2
Idaho	44	2.0	46	11	9.3	13	22	19	53	15	68	30
Illinois	79	3.6	82	58	49	16	65	65	130	20	150	120
Indiana	110	5.6	120	120	24	19	42	42	130	24	160	160
Iowa	55	0.2	55	22	100	25	130	130	160	25	180	150
Kansas	58	4.3	63	59	35	46	81	79	93	50	140	140
Kentucky	54	6.3	61	48	1.9	37	39	39	56	43	99	87
Louisiana	54	0	54	39	12	5.2	18	18	67	5.2	72	57
Maine	26	0.5	26	26	1.0	0.7	1.7	1.7	27	1.2	28	28
Maryland	49	0	49	32	10	0.5	11	11	59	0.5	60	43
Massachusetts	32	0	32	3.9	0.7	0.5	1.2	1.2	32	0.5	33	5.1
Michigan	160	0	160	27	17	5.0	22	19	180	5.0	180	46
Minnesota	120	0	120	120	58	10	68	68	180	10	190	190
Mississippi	27	0	27	24	9.7	12	21	21	37	12	49	45
Missouri	68	24	92	39	17	48	65	58	85	72	160	98
Montana	60	0	60	60	14	14	28	28	74	14	88	88
Nebraska	49	0	49	49	93	23	120	110	140	23	170	160
Nevada	11	0.7	11	6.6	3.7	8.5	12	8.9	14	9.2	24	15
New Hampshire	9.1	0.2	9.3	0.5	0.2	0.5	0.8	0.7	9.3	0.8	10	1.2
New Jersey	75	0	75	15	2.0	1.0	3.0	2.5	77	1.0	78	17
New Mexico	32	1.1	33	15	9.6	9.6	19	9.6	42	11	52	25
New York	130	0	130	13	37	20	58	52	170	20	190	65
North Carolina	140	0	140	140	33	5.6	39	39	170	5.6	170	170
North Dakota	11	0.2	11	11	13	8.2	21	21	24	8.4	32	32
Ohio	80	8.8	89	62	24	16	40	36	100	25	130	98
Oklahoma	29	5.2	35	31	8.2	50	58	58	38	55	93	89
Oregon	130	19	150	150	7.1	19	26	26	140	38	170	170
Pennsylvania	150	0	150	15	54	7.0	61	41	200	7.0	210	56
Rhode Island	4.9	0	4.9	0.8	0.1	0.1	0.2	0.2	5.0	0.1	5.1	1.0
South Carolina	65	0.2	65	65	12	10	22	22	77	10	87	87
South Dakota	21	1.4	22	16	81	11	92	85	100	12	110	100
Tennessee	43	0	43	12	7.0	35	42	42	50	35	85	54
Texas	130	0	130	130	120	150	270	270	250	150	400	400
Utah	26	3.3	29	10	31	9.0	40	11	57	12	69	21
Vermont	17	2.6	20	1.0	5.7	3.5	9.2	9.2	23	6.1	29	10
Virginia	150	0.1	150	74	2.3	26	28	17	150	26	180	91
Washington	40	11	52	18	4.1	2.0	6.1	3.0	44	13	58	21
West Virginia	18	1.3	19	0.2	1.0	6.6	7.6	6.7	19	7.9	27	6.9
Wisconsin	72	0	72	7.0	72	3.0	75	75	140	3.0	150	82
Wyoming	8.8	0.8	9.6	6.7	3.1	12	15	15	12	13	25	21
Puerto Rico	3.0	3.0	6.0	1.0	15	15	30	7.0	18	18	36	8.0
Virgin Islands	2.0	0.1	2.1	1.0	0	0.1	0.1	0.1	2.0	0.2	2.2	1.1
Total	3,300	180	3,400	2,000	1,200	980	2,200	1,900	4,400	1,200	5,600	3,900

Table 4.—*RURAL FRESH-WATER USE, BY REGIONS, IN MILLION GALLONS PER DAY, 1980*

[Data generally are rounded to two significant figures; figures may not add to totals because of independent rounding]

WATER-RESOURCES REGION	DOMESTIC USE				LIVESTOCK USE				TOTAL DOMESTIC AND LIVESTOCK USE			
	Withdrawals			Consumptive use	Withdrawals			Consumptive use	Withdrawals			Consumptive use
	By source		Total		By source		Total		By source		Total	
	Ground water	Surface water			Ground water	Surface water			Ground water	Surface water		
New England..........	130	1.1	130	63	4.5	4.7	9.2	9.2	140	5.8	140	73
Mid-Atlantic.........	430	2.4	430	110	79	32	110	86	510	35	550	190
South Atlantic-Gulf..	720	0.4	720	440	130	110	240	240	850	110	960	670
Great Lakes..........	270	2.9	270	74	64	20	84	77	330	23	350	150
Ohio.................	290	21	310	200	63	90	150	140	360	110	470	350
Tennessee............	61	0	61	39	12	29	41	40	73	29	100	79
Upper Mississippi....	290	10	300	190	220	51	270	270	510	61	570	460
Lower Mississippi....	94	0.5	94	67	17	25	42	41	110	25	140	110
Souris-Red-Rainy.....	23	0	23	23	9.8	3.8	14	14	33	3.8	37	37
Missouri Basin.......	210	22	230	170	270	120	390	380	480	150	630	550
Arkansas-White-Red...	130	25	160	120	85	150	240	230	210	180	390	350
Texas-Gulf...........	120	0	120	120	78	120	190	190	200	120	310	310
Rio Grande...........	33	0.7	33	18	26	6.0	32	26	58	6.7	65	44
Upper Colorado.......	15	43	58	17	2.4	91	94	22	18	130	150	39
Lower Colorado.......	37	0.1	37	27	12	5.2	17	11	48	5.4	54	38
Great Basin..........	32	3.8	36	14	34	12	46	17	66	16	82	30
Pacific Northwest....	230	32	270	200	21	34	55	49	250	66	320	250
California...........	130	9.4	140	84	36	50	86	47	170	60	220	130
Alaska...............	11	0.1	11	0.1	0	0.1	0.2	0.2	11	0.3	11	0.3
Hawaii...............	3.5	0.4	3.9	3.4	5.3	0.2	5.5	4.8	8.8	0.6	9.4	8.2
Caribbean............	5.0	3.1	8.1	2.0	15	15	30	7.1	20	18	38	9.1
Total............	3,300	180	3,400	2,000	1,200	980	2,200	1,900	4,400	1,200	5,600	3,900

Irrigation

Irrigation of crops developed along with the settlement of the arid West because most years farmers needed to irrigate to raise any crops. In the humid eastern States, irrigation has been used to supplement natural rainfall in order to increase the number of plantings per year and yield of crops per acre, and to reduce the risk of crop failures during drought periods. Irrigation also is used to maintain recreational lands such as parks and golf courses. Estimates of withdrawals for irrigation vary greatly. In some instances, they are based on subjective amounts of water required to raise an acre of a given crop. In other instances, accurate records of water application rates are available. Reliable estimates of water withdrawn for irrigation can be made if the number of acres irrigated and the water application rates are known. It usually is difficult to obtain reliable estimates for consumptive use and for conveyance loss. Thus, some of the estimates of consumptive use and conveyance loss may be only rough approximations of actual conditions. Nevertheless, it is likely that better estimates were made of water used per acre in 1980 than in 1975, and in particular, the values given for conveyance loss for 1980 are more realistic because of progressively better records being kept by the water users.

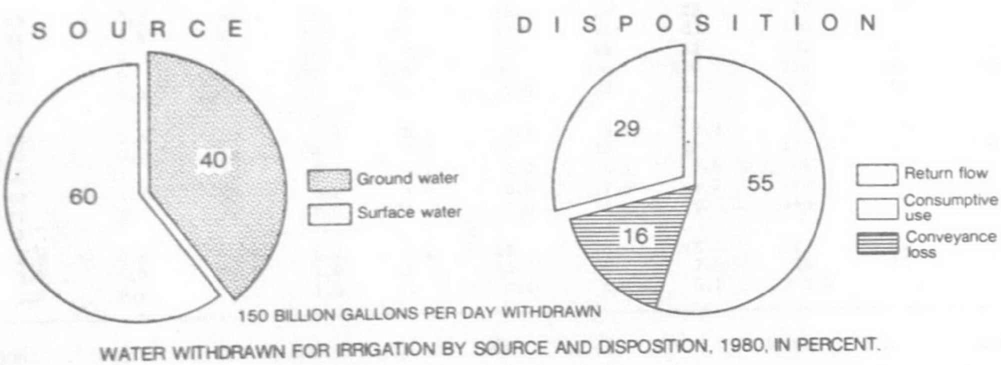
The quantity of water withdrawn for irrigation in 1980 was estimated at about 170 million acre-feet or 150 bgd. (See tables 5 and 6.) The water was used on approximately 58 million acres of farmland. This represents an increase in both water use and irrigated acreage of about 7 percent from the 1975 estimate. Where irrigation is used primarily to supplement natural rainfall, it is to be expected that there normally will be large differences in irrigation withdrawals from year to year.

The consumptive use of irrigation water was estimated to be 93 million acre-feet or 83 bgd in 1980. This was 55 percent of the irrigation water withdrawn, and accounted for about 81 percent of the total consumptive use by the Nation. Conveyance loss was estimated at about 26 million acre-feet (24 bgd) or 16 percent of 1980 irrigation withdrawals. Consumptive use and conveyance losses in 1980 were slightly higher than in 1975 but were essentially in the same proportion to irrigation water withdrawn as they were in 1975.

Surface water was the source of about 60 percent of the irrigation water (the same as 1975) and, except for a small fraction of 1 percent that was reclaimed sewage, ground water furnished the remainder.

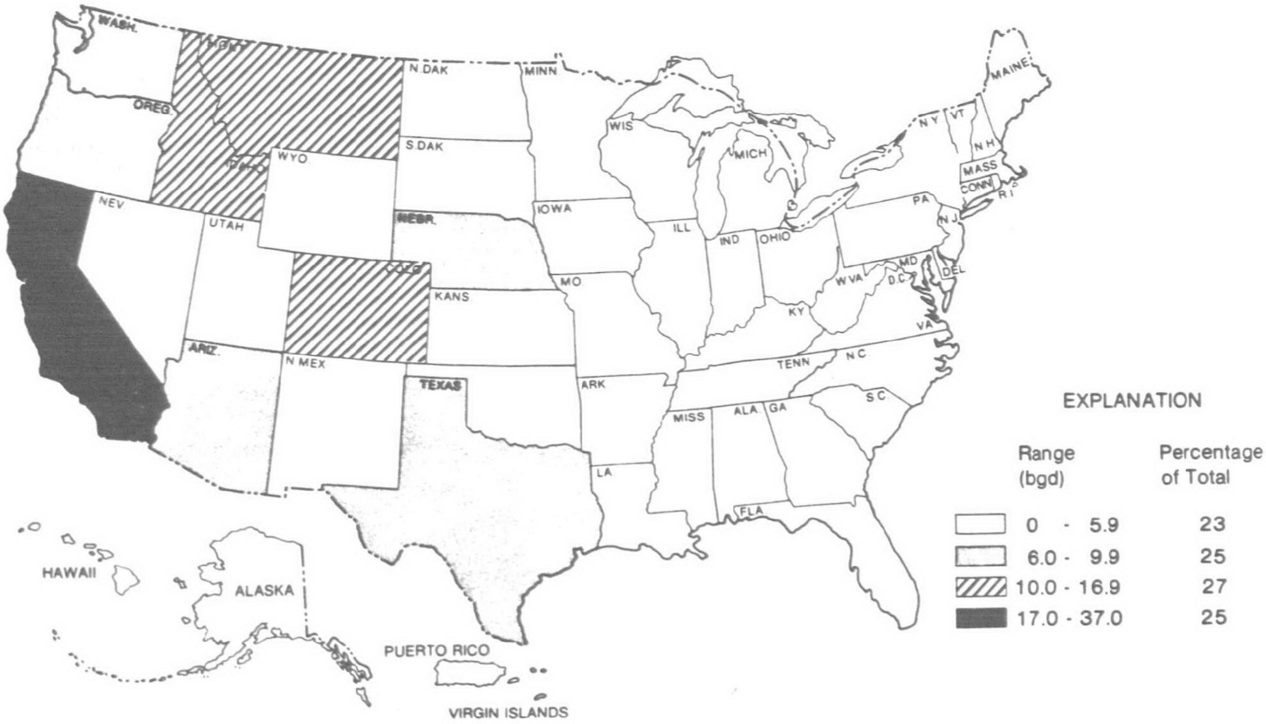
The nine western water-resources regions (regions 10–18), led by the California region, accounted for 91 percent of the total water withdrawn for irrigation in 1980, compared to 93 percent in 1975. In the eastern regions, most of the water used for irrigation was in the South Atlantic-Gulf and Lower Mississippi regions, which together withdrew over 3 bgd more water in 1980 than in 1975. The State of California was by far the largest user of irrigation water, withdrawing about 37 bgd, 25 percent of the national total, which is more than the next two largest users, Idaho and Colorado, combined. Nebraska and Georgia showed the largest increase in number of acres irrigated from 1975 to 1980.

The range in irrigation water withdrawals, by States and water-resources regions is shown in figure 3. A comparison of withdrawals for self-supplied industrial use and irrigation use by both States and water-resources regions is shown in figure 10. Irrigation water-use data by States are given in table 5 and the same data by water-resources regions are given in table 6. The source of and disposition of withdrawals for irrigation use are shown in the chart below.



WATER WITHDRAWN FOR IRRIGATION BY SOURCE AND DISPOSITION, 1980, IN PERCENT.

A. States



B. Water-resources regions

Figure 3. Irrigation water withdrawals, by States and water-resources regions, 1980.

Table 5.—*IRRIGATION WATER USE, BY STATES, IN THOUSAND ACRE-FEET PER YEAR AND MILLION GALLONS PER DAY, 1980*

[Data generally are rounded to two significant figures; figures may not add to totals because of independent rounding]

STATE	IRRIGATED LAND, in thousand acres	THOUSAND ACRE-FEET PER YEAR: Withdrawals: By source: Fresh water: Ground	Surface	Re-claimed sewage	Total	Convey-ance losses	Consump-tive use, fresh water	MILLION GALLONS PER DAY: Withdrawals: By source: Fresh water: Ground	Surface	Re-claimed sewage	Total	Convey-ance losses	Consump-tive use, fresh water
Alabama...........	75	11	27	0	37	0	37	9.4	24	0	33	0	33
Alaska............	0	0	0	0	0	0	0	0	0	0	0	0	0
Arizona...........	1300	4100	3800	3.9	8000	1000	4400	3700	3400	3.4	7100	900	4000
Arkansas..........	1800	3900	1800	0	5700	310	3500	3500	1600	0	5100	270	3100
California........	9700	20000	22000	170	42000	6300	25000	18000	19000	150	37000	5600	23000
Colorado..........	2700	3000	12000	0	16000	1800	4100	2700	11000	0	14000	1600	3600
Connecticut.......	17	1.8	21	0	23	0	23	1.6	19	0	21	0	21
Delaware..........	10	4.6	2.7	0	7.3	0	7.3	4.1	2.4	0	6.5	0	6.5
D.C...............	0	0	0	0	0	0	0	0	0	0	0	0	0
Florida...........	2000	1800	1600	0	3400	40	1700	1600	1400	0	3000	35	1500
Georgia...........	1000	420	230	0	650	0	650	380	200	0	580	0	580
Hawaii............	140	520	500	0	1000	340	680	460	450	0	910	300	610
Idaho.............	4000	4500	13000	15	18000	4000	6300	4100	12000	13	16000	3600	5600
Illinois..........	150	110	5.9	0	120	0	120	100	5.3	0	110	0	110
Indiana...........	65	240	24	0	260	0	260	210	21	0	230	0	230
Iowa..............	150	55	7.5	0	62	0	62	49	6.7	0	56	0	56
Kansas............	3400	5800	490	0	6300	160	4900	5200	440	0	5600	150	4300
Kentucky..........	14	0.3	5.2	0	5.5	0	5.5	0.2	4.7	0	4.9	0	4.9
Louisiana.........	740	1100	1400	0	2500	690	1800	990	1300	0	2200	610	1600
Maine.............	11	0.2	6.6	0	6.8	0	6.5	0.2	5.9	0	6.1	0	5.8
Maryland..........	33	11	11	0.1	22	0	22	10	9.4	0.1	20	0	19
Massachusetts.....	45	6.1	15	0	21	0	21	5.4	14	0	19	0	19
Michigan..........	320	86	120	33	240	0	240	77	110	30	210	0	210
Minnesota.........	460	160	20	0	180	0	180	140	18	0	160	0	160
Mississippi.......	480	950	150	0	1100	110	560	840	130	0	980	99	500
Missouri..........	240	110	33	0	140	0	120	98	30	0	130	0	100
Montana...........	2600	120	12000	0	12000	2700	2900	110	10000	0	11000	2400	2600
Nebraska..........	7100	7500	2900	0	10000	2100	8300	6700	2600	0	9300	1900	7400
Nevada............	850	590	2900	3.7	3500	800	1700	530	2600	3.3	3100	720	1500
New Hampshire.....	1.8	0	1.8	0	1.8	0	1.5	0	1.6	0	1.6	0	1.3
New Jersey........	75	45	17	0	62	0	50	40	15	0	55	0	45
New Mexico........	1400	1800	2200	0	4000	35	1900	1600	2000	0	3600	31	1700
New York..........	56	24	28	0	51	0	51	21	25	0	46	0	46
North Carolina....	150	44	100	0	150	0	150	39	93	0	130	0	130
North Dakota......	180	73	240	0.4	310	34	280	65	210	0.4	280	30	250
Ohio..............	48	2.1	3.8	0	5.9	0	5.4	1.9	3.4	0	5.3	0	4.8
Oklahoma..........	900	820	160	0	980	59	690	730	140	0	870	53	610
Oregon............	2100	950	5700	4.0	6600	1900	3300	850	5000	3.6	5900	1700	3000
Pennsylvania......	63	25	160	0	180	0	180	22	140	0	160	0	160
Rhode Island......	4.0	0.6	5.1	0	5.6	0.6	5.0	0.5	4.5	0	5.0	0.5	4.5
South Carolina....	73	19	42	0	61	0	61	17	37	0	54	0	54
South Dakota......	390	170	340	1.7	510	47	380	150	310	1.5	460	42	340
Tennessee.........	21	7.2	6.8	0	14	0.7	10	6.4	6.1	0	12	0.6	9.2
Texas.............	7700	7300	2100	78	9500	230	9000	6500	1900	70	8400	200	8000
Utah..............	1200	600	3000	0	3600	360	2700	530	2700	0	3200	320	2400
Vermont...........	1.6	0.3	1.3	0	1.6	0	1.2	0.3	1.2	0	1.4	0	1.0
Virginia..........	41	9.4	22	0	31	4.3	19	8.4	19	0	28	3.9	17
Washington........	1600	300	6900	0	7200	1300	2900	260	6100	0	6400	1200	2600
West Virginia.....	2.4	0.1	1.4	0	1.5	0	1.5	0.1	1.2	0	1.3	0	1.3
Wisconsin.........	240	92	3.4	0	95	0	86	82	3.0	0	85	0	77
Wyoming...........	1800	420	5000	0	5400	1800	2800	370	4500	0	4900	1600	2500
Puerto Rico.......	75	150	200	0	350	34	220	140	180	0	310	30	200
Virgin Islands....	0.5	0	0	0	0	0	0	0	0	0	0	0	0
Total..........	58,000	68,000	100,000	310	170,000	26,000	93,000	60,000	90,000	280	150,000	24,000	83,000

Table 6.—*IRRIGATION WATER USE, BY REGIONS, IN THOUSAND ACRE-FEET PER YEAR AND MILLION GALLONS PER DAY, 1980*

[Data generally are rounded to two significant figures; figures may not add to totals because of independent rounding]

WATER-RESOURCES REGION	IRRIGATED LAND, in thousand acres	THOUSAND ACRE-FEET PER YEAR						MILLION GALLONS PER DAY					
		Withdrawals				Convey-ance losses	Consump-tive use, fresh water	Withdrawals				Convey-ance losses	Consump-tive use, fresh water
		By source			Total			By source			Total		
		Fresh water		Re-claimed sewage				Fresh water		Re-claimed sewage			
		Ground	Surface					Ground	Surface				
New England..........	79	8.7	50	0	59	0.6	58	7.8	45	0	53	0.5	52
Mid-Atlantic.........	230	110	170	0.1	280	1.9	260	97	150	0.1	250	1.7	240
South Atlantic-Gulf..	3400	2300	2000	0	4300	42	2600	2000	1800	0	3800	38	2300
Great Lakes..........	450	200	140	33	380	0	370	180	120	30	340	0	330
Ohio.................	84	99	68	0	170	0.1	160	88	60	0	150	0.1	150
Tennessee............	14	3.0	4.7	0	7.6	0.2	7.4	2.7	4.1	0	6.8	0.2	6.4
Upper Mississippi....	820	390	32	0	420	0	410	350	29	0	380	0	370
Lower Mississippi....	2900	5400	3200	0	8700	1100	5400	4800	2900	0	7700	960	4800
Souris-Red-Rainy.....	120	52	20	0.2	72	4.4	67	46	18	0.2	64	3.9	60
Missouri Basin.......	14000	12000	20000	1.9	32000	6600	16000	11000	18000	1.7	28000	5900	15000
Arkansas-White-Red...	7000	9500	2700	17	12000	400	9100	8400	2400	15	11000	360	8200
Texas-Gulf...........	5200	4300	1800	62	6200	160	5500	3900	1600	55	5500	140	4900
Rio Grande...........	1400	1800	3000	0	4800	330	2400	1600	2700	0	4300	290	2100
Upper Colorado.......	1300	90	8300	0.1	8400	930	2200	81	7400	0.1	7500	830	2000
Lower Colorado.......	1400	4400	4200	7.0	8500	1100	4800	3900	3700	6.2	7600	950	4300
Great Basin..........	1900	1100	5500	4.1	6600	1100	3900	1000	4900	3.7	5900	1000	3500
Pacific Northwest....	7700	5700	27000	19	33000	7600	12000	5100	24000	17	29000	6800	11000
California...........	10000	20000	22000	170	42000	6500	26000	18000	20000	150	38000	5800	23000
Alaska.........	0	0	0	0	0	0	0	0	0	0	0	0	0
Hawaii...............	140	520	500	0	1000	340	680	460	450	0	910	300	610
Caribbean............	76	150	200	0	350	34	220	140	180	0	310	30	200
Total............	58,000	68,000	100,000	310	170,000	26,000	93,000	60,000	90,000	280	150,000	24,000	83,000

Self-Supplied Industrial

All Self-Supplied Industrial Use (Thermoelectric Power and Other Industries)

Self-supplied industrial water use is categorized in this report as thermoelectric power (electric utility) and "other" self-supplied water-using industries (see tables 7 and 8). "Other" self-supplied water-using industries include, but are not limited to, steel, chemical and allied products, paper and allied products, mining, and petroleum refining. Thermoelectric power plants can be powered by fossil-fuel, geothermal, or nuclear energy, and account for the largest quantity of water withdrawn for offstream use. (See table 22.) Because of the magnitude of water required for thermoelectric power generation, the estimates of use are discussed here as part of the total self-supplied industrial use and in more detail in a separate section (see page 25 and tables 9 and 10). Self-supplied industrial water systems often are metered and estimates of water withdrawn and consumed generally are reliable. It is likely that better estimates were made in 1980 than in 1975 because more comprehensive inventories were obtained and more accurate and complete records were available from the users.

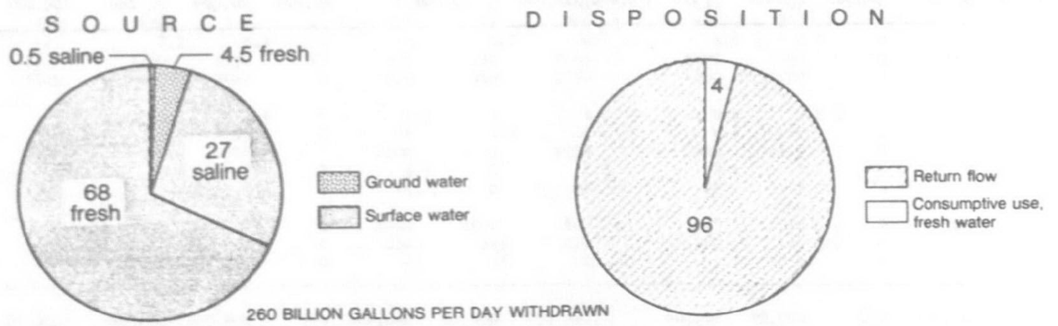
More water continues to be withdrawn for industrial use than for any other category. In 1980, the amount of self-supplied industrial water withdrawn was estimated at 260 bgd of which about 72 bgd was saline (see tables 7 and 8), this is an increase of 8 percent from the 1975 estimate. Of the 260 bgd, about 210 bgd or 83 percent of all industrial withdrawals was withdrawn by thermoelectric power plants (see tables 9 and 10). Withdrawals for thermoelectric power plants showed a 9-percent increase from 1975, and withdrawals for "other" industrial uses (about 45 bgd) remained about the same as in 1975. Saline water constituted about 28 percent of the total self-supplied industrial withdrawals, approximately the same proportion as in 1965, 1970, and 1975. Public-supply systems delivered about 2 bgd for thermoelectric power generation and about 10 bgd for other industrial and commercial uses. The withdrawal estimates for thermoelectric power plants (see tables 9 and 10) include the water from public supplies; however, public supplies are not included in the estimate for total self-supplied industrial use (tables 7 and 8) but are summarized in the public-supply category (see tables 1 and 2).

Consumptive use of fresh water by thermoelectric plants was about 2 percent and for other self-supplied industrial uses about 13 percent, giving a combined consumptive use of about 4 percent for all types of self-supplied industries. Saline water consumed by thermoelectric plants also was about 2 percent of the saline withdrawals, and about 15 percent for other industrial uses. These consumptive use figures are higher than in previous years and indicate an increased reuse of water.

The relative proportion of source of supply has remained constant since 1965—ground water still supplied nearly 5 percent, surface water about 95 percent, and reclaimed sewage only a fraction of 1 percent.

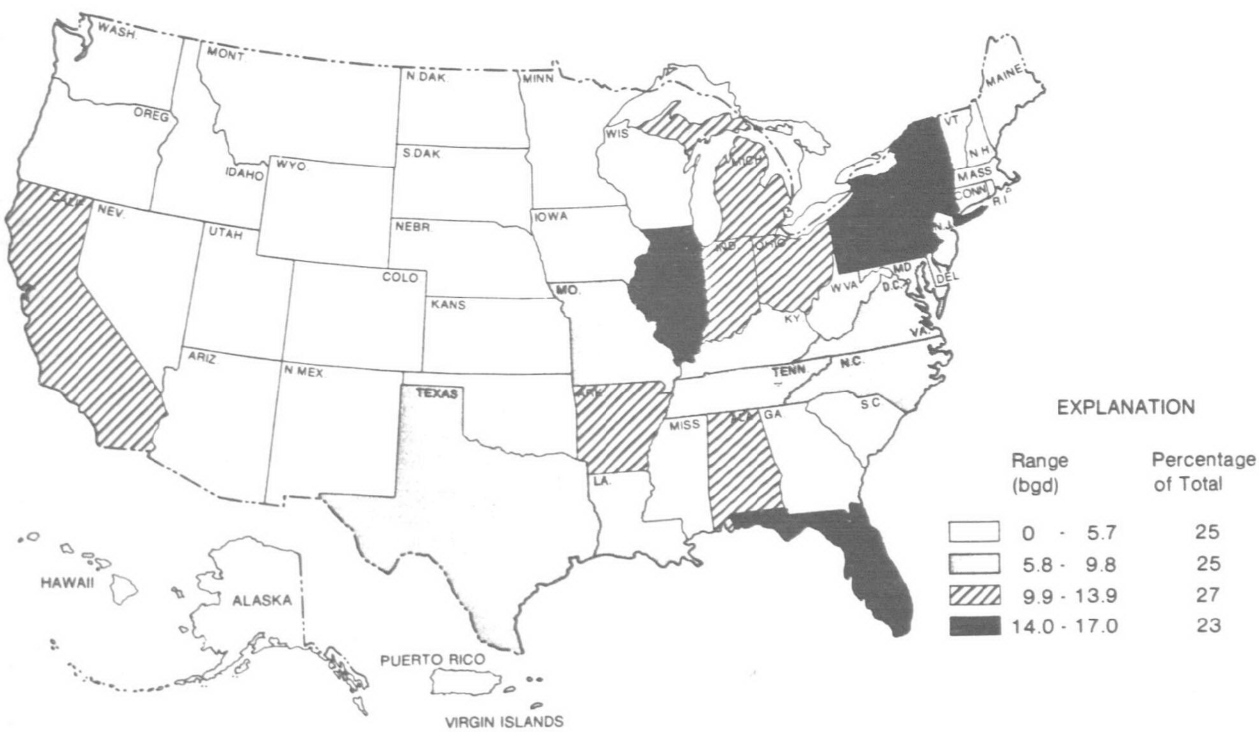
The Mid-Atlantic water-resources region withdrew slightly more water for industrial use in 1980 than in 1975 and withdrew the most saline water and total water (fresh and saline). The Ohio region withdrew about 6 percent more water for industrial use in 1980 than in 1975 and accounted for the most fresh-water withdrawals. Withdrawals in the State of Illinois for self-supplied industrial use increased 50 percent from 1975 to 1980, based on a more complete inventory of industrial users, making Illinois the second largest user of self-supplied industrial water behind Florida.

The range in self-supplied industrial water withdrawals by States and water-resources regions is shown in figure 4. A comparison of withdrawals for self-supplied industrial use and irrigation use by both States and water-resources regions is shown in figure 10. Self-supplied industrial water-use data by States are given in table 7, and the same data by water-resources regions are given in table 8. The source of and disposition of withdrawals for self-supplied industrial use are shown in the chart below.



WATER WITHDRAWN FOR ALL SELF-SUPPLIED INDUSTRIAL USE BY SOURCE AND DISPOSITION, 1980, IN PERCENT.

A. States



B. Water-resources regions

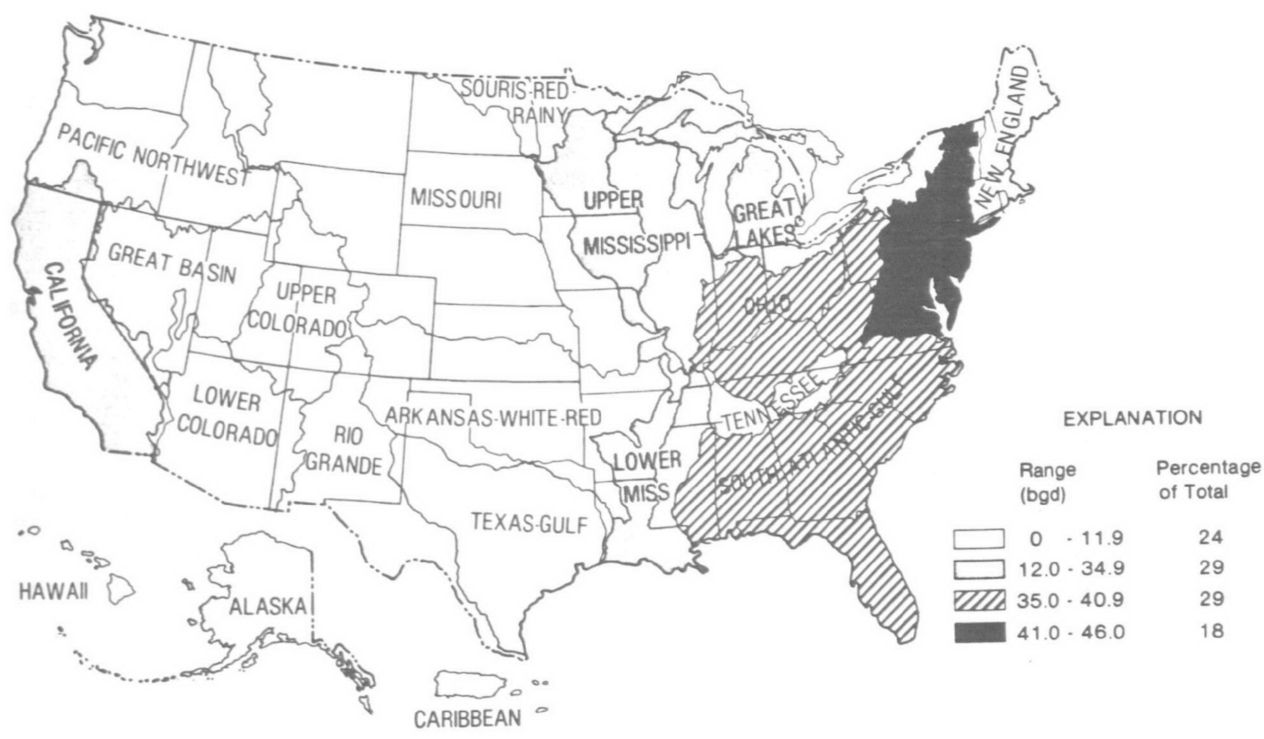


Figure 4. Self-supplied industrial water withdrawals, by States and water-resources regions, 1980.

Table 7.—*SELF-SUPPLIED INDUSTRIAL WATER USE, BY STATES, IN MILLION GALLONS PER DAY, 1980*

[Data generally are rounded to two significant figures; figures may not add to totals because of independent rounding]

STATE	ALL SELF-SUPPLIED INDUSTRIAL USE												
	Withdrawals										Consumptive use		
	By source and type							Total, excluding reclaimed sewage					
	Ground water			Surface water			Re-claimed sewage						
	Fresh	Saline	Total	Fresh	Saline	Total		Fresh	Saline	Total	Fresh	Saline	Total
Alabama	53	1.4	54	9700	73	9800	0	9800	75	9900	300	1.3	300
Alaska	14	0	14	140	0	140	0	160	0	160	1.5	0	1.5
Arizona	180	0	180	69	0	69	1.8	250	0	250	170	.8	170
Arkansas	320	0	320	9900	0	9900	0	10000	0	10000	300	0	300
California	1300	250	1600	1100	9800	11000	8.9	2400	10000	12000	230	100	330
Colorado	16	0	16	890	0	890	0	910	0	910	170	0	170
Connecticut	27	1.0	28	860	2400	3200	0	880	2400	3300	21	0	21
Delaware	21	.3	21	6.2	1100	1100	0	27	1100	1100	2.6	110	110
D.C.	0.8	0	0.8	130	0	130	0	130	0	130	2.3	0	2.3
Florida	710	42	750	1900	14000	16000	0	2600	14000	17000	500	55	550
Georgia	400	0	400	4700	200	4900	0	5100	200	5300	180	2.0	180
Hawaii	140	0	140	45	1200	1300	10	190	1200	1400	0	0	0
Idaho	2100	0	2100	120	0	120	0	2200	0	2200	180	0	180
Illinois	220	38	260	16000	0	16000	0	16000	38	16000	350	0	350
Indiana	640	0	640	12000	0	12000	0	13000	0	13000	220	0	220
Iowa	320	0	320	3400	0	3400	0	3800	0	3800	31	0	31
Kansas	190	0	190	340	0	340	0	530	0	530	110	0	110
Kentucky	150	0	150	4200	0	4200	0	4400	0	4400	180	0	180
Louisiana	440	19	460	8900	390	9300	0	9400	410	9800	870	38	910
Maine	34	0	34	670	710	1400	0	710	710	1400	8.9	0	8.9
Maryland	37	0	37	520	6600	7100	160	560	6600	7100	17	22	39
Massachusetts	93	0	93	1500	3500	5000	0	1600	3500	5100	25	5	30
Michigan	62	420	480	13000	0	13000	0	13000	420	14000	99	120	220
Minnesota	120	0	120	2200	0	2200	0	2300	0	2300	65	0	65
Mississippi	370	0	370	1200	660	1900	0	1600	660	2200	69	20	89
Missouri	130	0	130	5700	0	5700	0	5800	0	5800	320	0	320
Montana	32	2.1	34	250	0	250	0	280	2.1	280	28	.8	29
Nebraska	89	0	89	2200	0	2200	0	2300	0	2300	25	0	25
Nevada	71	9.0	80	160	0	160	11	230	9.0	240	79	7.6	86
New Hampshire	13	0	13	270	620	900	0	280	620	910	10	0	10
New Jersey	160	0	160	1500	7500	9000	0	1700	7500	9200	120	570	690
New Mexico	18	.9	18	54	0	54	0	71	.9	72	59	.4	59
New York	250	12	260	5300	8600	14000	0	5500	8600	14000	100	46	150
North Carolina	490	0	490	6700	42	6700	0	7200	42	7200	340	11	350
North Dakota	3.4	.2	3.6	930	0	930	0	930	.2	930	18	.1	18
Ohio	500	0	500	11000	0	11000	0	12000	0	12000	270	0	270
Oklahoma	100	95	200	350	0	350	0	450	95	540	220	95	320
Oregon	80	0	80	440	0	440	0	520	0	520	20	0	20
Pennsylvania	560	0	560	13000	93	13000	0	14000	93	14000	550	1.0	550
Rhode Island	13	0	13	23	330	350	0	35	330	360	2.9	0	2.9
South Carolina	58	0	58	5600	38	5700	0	5700	38	5700	83	.1	83
South Dakota	26	3.4	29	21	0	21	0	47	3.4	50	5.5	3.4	8.9
Tennessee	190	0	190	9300	0	9300	0	9500	0	9500	150	0	150
Texas	360	0	360	1400	6600	8000	0	1700	6600	8300	980	920	1900
Utah	68	4.0	72	460	56	510	0	520	60	580	90	45	130
Vermont	5.2	0	5.2	260	0	260	0	260	0	260	24	0	24
Virginia	110	.2	110	4700	4100	8800	0	4800	4100	8900	90	48	140
Washington	150	0	150	830	42	880	0	990	42	1000	150	6.3	150
West Virginia	150	0	150	5300	0	5300	0	5400	0	5400	190	0	190
Wisconsin	97	0	97	4900	0	4900	0	5000	0	5000	91	0	91
Wyoming	130	24	150	270	0	270	0	390	24	420	71	0	71
Puerto Rico	88	5.0	93	30	2400	2400	0	120	2400	2500	26	0	26
Virgin Islands	0	0	0	0	32	32	0	0	32	32	.2	4.0	4.2
Total	12,000	930	13,000	180,000	71,000	250,000	190	190,000	72,000	260,000	8,200	2,200	10,000

Table 7.—*SELF-SUPPLIED INDUSTRIAL WATER USE, BY STATES, IN MILLION GALLONS PER DAY, 1980*—Continued

[Data generally are rounded to two significant figures; figures may not add to totals because of independent rounding]

STATE	Thermoelectric power (electric utility)[1]: Withdrawals, by source: Fresh ground water	Withdrawals: Surface water: Fresh	Withdrawals: Surface water: Saline	Total fresh water	Consumptive use: Fresh	Consumptive use: Saline	Other industries: Withdrawals, by source: Ground water: Fresh	Ground water: Saline	Surface water: Fresh	Surface water: Saline	Reclaimed sewage	Total, excluding reclaimed sewage: Fresh	Total, excluding reclaimed sewage: Saline	Consumptive use: Fresh	Consumptive use: Saline
Alabama	1.5	8500	73	8500	29	0.1	51	1.4	1200	0.2	0	1300	1.6	270	1.2
Alaska	8.4	22	0	30	0.3	0	6.1	0	120	0	0	130	0	1.2	0
Arizona	40	49	0	89	51	0.8	140	0	20	0	1.8	160	0	120	0
Arkansas	3.1	9700	0	9700	100	0	320	0	190	0	0	510	0	200	0
California	890	1100	9200	2000	41	60	420	250	45	560	8.9	470	820	190	41
Colorado	9.4	160	0	170	97	0	7.1	0	730	0	0	730	0	73	0
Connecticut	0.2	610	2400	610	1.9	0	26	1.0	250	1.0	0	270	2.0	19	0
Delaware	5.4	0	670	5.4	0.5	67	15	0.3	6.2	390	0	22	390	2.1	39
D.C.	0	130	0	130	2.0	0	0.8	0	0.6	0	0	1.4	0	0.3	0
Florida	70	1800	14000	1900	32	48	640	42	140	15	0	780	57	470	6.4
Georgia	4.1	4400	160	4400	120	0	400	0	380	42	0	780	42	59	2.0
Hawaii	130	9.0	1200	140	0	0	9.1	0	36	7.0	10	45	7.0	0	0
Idaho	5.3	0	0	5.3	1.3	0	2100	0	120	0	0	2200	0	170	0
Illinois	8.4	14000	0	14000	260	0	210	38	1600	0	0	1800	38	88	0
Indiana	5.0	9700	0	9700	65	0	640	0	2500	0	0	3100	0	160	0
Iowa	4.0	3200	0	3200	20	0	320	0	230	0	0	550	0	11	0
Kansas	46	300	0	350	39	0	140	0	41	0	0	180	0	66	0
Kentucky	15	4000	0	4100	140	0	130	0	190	0	0	320	0	33	0
Louisiana	46	5800	180	5900	320	9.1	390	19	3100	210	0	3500	230	550	29
Maine	1.0	55	700	56	0	0	33	0	620	11	0	650	11	8.9	0
Maryland	3.0	400	6100	410	2.0	17	34	0	120	500	160	150	500	15	5.0
Massachusetts	0	1300	3400	1300	0	0	93	0	220	64	0	310	64	25	5.1
Michigan	0	12000	0	12000	0	0	62	420	1600	0	0	1700	420	99	120
Minnesota	2.2	1700	0	1700	7.2	0	120	0	470	0	0	590	0	58	0
Mississippi	17	1100	500	1100	33	3.5	360	0	97	160	0	450	160	36	16
Missouri	16	5500	0	5500	300	0	120	0	190	0	0	300	0	24	0
Montana	0	180	0	180	12	0	32	2.1	76	0	0	110	2.1	15	0.8
Nebraska	31	2200	0	2200	22	0	58	0	6.3	0	0	64	0	3.1	0
Nevada	8.1	86	0	94	20	0	63	9.0	74	0	11	140	9.0	58	7.6
New Hampshire	0	74	620	74	0	0	13	0	200	0	0	210	0	10	0
New Jersey	5.0	910	6500	910	70	500	150	0	600	1000	0	750	1000	50	65
New Mexico	11	54	0	65	55	0	6.6	0.9	0.1	0	0	6.6	0.9	4.2	0.4
New York	130	4300	8500	4400	4.6	34	120	12	980	120	0	1100	130	96	11
North Carolina	0	4300	6.4	4300	67	7.8	490	0	2400	36	0	2900	36	270	3.5
North Dakota	1.2	920	0	930	14	0	2.2	0.2	4.7	0	0	7.0	0.2	4.3	0.1
Ohio	21	10000	0	10000	93	0	470	0	1500	0	0	2000	0	180	0
Oklahoma	7.7	170	0	180	110	0	95	95	170	0	0	270	95	120	95
Oregon	0	22	0	22	0	0	80	0	420	0	0	500	0	20	0
Pennsylvania	6.8	10000	93	10000	290	1.0	550	0	3100	0	0	3600	0	260	0
Rhode Island	0	0.1	330	0.1	0	0	13	0	23	0.6	0	35	0.6	2.9	0
South Carolina	0.5	5200	7.7	5200	35	0.1	57	0	400	30	0	460	30	47	0
South Dakota	2.4	2.5	0	4.9	3.2	0	23	3.4	19	0	0	42	3.4	2.3	3.4
Tennessee	0	7800	0	7800	1.0	0	190	0	1500	0	0	1700	0	150	0
Texas	38	960	5500	990	500	470	320	0	410	1100	0	730	1100	490	450
Utah	0.2	64	5.9	64	9.9	4.6	68	4.0	390	50	0	460	54	80	40
Vermont	0	250	0	250	22	0	5.2	0	9.6	0	0	15	0	2.3	0
Virginia	1.2	4300	4000	4300	43	40	110	0.2	360	81	0	470	81	47	8.1
Washington	0	1.3	0	1.3	1.1	0	150	0	830	42	0	990	42	150	6.3
West Virginia	0	4600	0	4600	110	0	150	0	680	0	0	830	0	82	0
Wisconsin	1.2	4500	0	4500	46	0	96	0	350	0	0	450	0	45	0
Wyoming	1.1	220	0	220	45	0	130	24	44	0	0	170	24	25	0
Puerto Rico	3.0	0	1500	3.0	6.0	0	85	5.0	30	920	0	120	930	20	0
Virgin Islands	0	0	32	0	0.2	4.0	0	0	0	0	0	0	0	0	0
Total	1,600	150,000	65,000	150,000	3,200	1,300	10,000	930	29,000	5,400	190	39,000	6,300	5,000	970

[1]See Table 9 for additional information.

Table 8.—*SELF-SUPPLIED INDUSTRIAL WATER USE, BY REGIONS, IN MILLION GALLONS PER DAY, 1980*

[Data generally are rounded to two significant figures; figures may not add to totals because of independent rounding]

WATER-RESOURCES REGION	ALL SELF-SUPPLIED INDUSTRIAL USE — Withdrawals — By source and type — Ground water: Fresh	Ground water: Saline	Ground water: Total	Surface water: Fresh	Surface water: Saline	Surface water: Total	Reclaimed sewage	Total, excluding reclaimed sewage: Fresh	Saline	Total	Consumptive use: Fresh	Saline	Total
New England	180	1.0	180	3600	7500	11000	0	3700	7500	11000	87	5.1	92
Mid-Atlantic	690	12	700	18000	28000	45000	160	18000	28000	46000	540	780	1300
South Atlantic-Gulf	1800	44	1900	23000	15000	38000	0	25000	15000	40000	1300	92	1400
Great Lakes	660	420	1100	32000	0	32000	0	33000	420	33000	470	120	590
Ohio	1300	24	1300	34000	0	34000	0	35000	24	35000	930	0	930
Tennessee	97	0	97	11000	0	11000	0	11000	0	11000	240	0	240
Upper Mississippi	660	15	670	19000	0	19000	0	20000	15	20000	470	0	470
Lower Mississippi	1100	19	1100	11000	390	11000	0	12000	410	12000	1100	38	1200
Souris-Red-Rainy	5.1	0	5.1	59	0	59	0	64	0	64	6.6	0	6.6
Missouri Basin	430	26	450	8400	0	8400	0	8800	26	8900	420	4.5	430
Arkansas-White-Red	390	95	480	10000	2.0	10000	0	11000	97	11000	740	96	840
Texas-Gulf	270	0	270	1200	6600	7800	0	1500	6600	8100	710	920	1600
Rio Grande	30	.9	31	3.0	0	3.0	0	33	.9	34	24	.4	25
Upper Colorado	23	3.5	26	700	.7	700	0	730	4.2	730	190	.1	190
Lower Colorado	200	.2	200	130	0	130	12	340	.2	340	200	.2	200
Great Basin	130	13	140	500	55	550	1.1	630	68	700	110	52	160
Pacific Northwest	2300	0	2300	1400	42	1500	0	3700	42	3800	350	6.3	360
California	1300	250	1600	1100	9800	11000	8.7	2500	10000	12000	230	100	330
Alaska	14	0	14	140	0	140	0	160	0	160	1.5	0	1.5
Hawaii	140	0	140	45	1200	1300	10	190	1200	1400	0	0	0
Caribbean	88	5.0	93	30	2500	2500	0	120	2500	2600	26	4.0	30
Total	12,000	930	13,000	180,000	71,000	250,000	190	190,000	72,000	260,000	8,200	2,200	10,000

Table 8.—*SELF-SUPPLIED INDUSTRIAL WATER USE, BY REGIONS, IN MILLION GALLONS PER DAY, 1980*—Continued

[Data generally are rounded to two significant figures; figures may not add to totals because of independent rounding]

WATER-RESOURCES REGION	TYPE OF SELF-SUPPLIED INDUSTRIAL USE — Thermoelectric power (electric utility)[1] — Withdrawals, by source: Fresh ground water	Surface water: Fresh	Surface water: Saline	Total fresh water	Consumptive use: Fresh	Consumptive use: Saline	Other industries — Withdrawals, by source — Ground water: Fresh	Ground water: Saline	Surface water: Fresh	Surface water: Saline	Reclaimed sewage	Total, excluding reclaimed sewage: Fresh	Saline	Consumptive use: Fresh	Saline
New England	1.2	2300	7400	2300	21	0	180	1.0	1300	77	0	1500	78	66	5.1
Mid-Atlantic	110	15000	25000	15000	260	660	580	12	2900	2100	160	3400	2100	280	130
South Atlantic-Gulf	88	19000	15000	19000	270	63	1800	44	4100	280	0	5900	330	1100	29
Great Lakes	30	27000	0	27000	93	0	630	420	5100	0	0	5700	420	370	120
Ohio	52	30000	0	30000	520	0	1300	24	3700	0	0	5000	24	420	0
Tennessee	0	9300	0	9300	20	0	97	0	2000	0	0	2000	0	220	0
Upper Mississippi	13	16000	0	16000	290	0	650	15	2600	0	0	3300	15	170	0
Lower Mississippi	54	7700	180	7700	400	9.1	1000	19	3200	210	0	4300	230	740	29
Souris-Red-Rainy	0.9	53	0	54	1.0	0	4.2	0	5.1	0	0	9.3	0	5.6	0
Missouri Basin	48	8100	0	8200	350	0	380	26	300	0	0	680	26	77	4.5
Arkansas-White-Red	70	9900	0	10000	410	0	320	95	530	2.0	0	840	97	330	96
Texas-Gulf	30	950	5500	980	360	470	240	0	280	1100	0	520	1100	350	450
Rio Grande	15	2.5	0	17	11	0	16	0.9	0.5	0	0	16	0.9	13	0.4
Upper Colorado	0	140	0.7	140	130	0.1	23	3.5	560	0	0	590	3.5	63	0
Lower Colorado	45	45	0	90	49	0.8	160	0.2	86	0	12	250	0.2	150	0
Great Basin	4.5	120	5.2	130	5.9	4.5	130	13	370	50	1.1	500	63	100	48
Pacific Northwest	5.3	23	0	29	2.4	0	2300	0	1400	42	0	3700	42	350	6.3
California	890	1100	9200	2000	41	60	430	250	58	560	8.7	480	820	190	41
Alaska	8.4	22	0	30	0.3	0	6.1	0	120	0	0	130	0	1.2	0
Hawaii	130	9.0	1200	140	0	0	9.1	0	36	7.0	10	45	7.0	0	0
Caribbean	3.0	0	1500	3.0	6.2	4.0	85	5.0	30	920	0	120	930	20	0
Total	1,600	150,000	65,000	150,000	3,200	1,300	10,000	930	29,000	5,400	190	39,000	6,300	5,000	970

[1]See Table 10 for additional information.

Summary of Offstream and Instream Uses

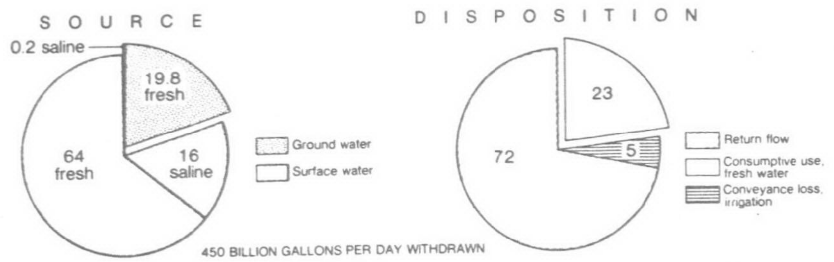
The estimated withdrawal of 450 bgd for all offstream uses (public supply, rural, irrigation, and self-supplied industrial use) in 1980 was about 8 percent greater than the withdrawals estimated for 1975. Ground-water withdrawals accounted for 89 bgd, a 7-percent increase over 1975; of this amount, 88 bgd was fresh water. Surface-water withdrawals accounted for 360 bgd, a 9-percent increase from 1975, of which 71 bgd was saline water. Reclaimed sewage amounted to 0.5 bgd in 1980, an 11-percent decrease from 1975.

Fresh-water consumptive use in 1980 was estimated at 100 bgd, a 7-percent increase from 1975. The percentages of water consumed by the various use categories were nearly the same as in 1970 and 1975. Irrigation water accounted for the largest amount of water consumed, 83 bgd. In addition, conveyance losses associated with irrigation were estimated at 24 bgd. Geographically, 80 percent of the consumptive use was in the Western States, a decrease of 4 percent since 1975 and 6 percent since 1970, whereas, the 20 percent consumed in the Eastern States reflects an increase of 6 percent since 1970. The range in fresh-water consumptive use by States and water-resources regions is shown in figure 8.

Several tables and illustrations are included in this section to summarize the vast amount of data given in this report. The percentages of water withdrawn and consumed by the four offstream water-use categories are shown in figure 6. The ranges in total offstream withdrawals by States and water-resources regions are shown in figure 7, and the ranges in comsumptive use are shown in figure 8. A comparison of withdrawals from ground- and surface-water sources for both States and water-resources regions is shown in figure 9. The withdrawals of the two largest offstream users, self-supplied industrial and irrigation use, are compared in figure 10.

The per capita withdrawals and consumptive use for the United States and for the eastern and western water-resources regions are given in table 13. The total offstream water use (withdrawals, conveyance losses, and consumptive use) is given by States in table 14 and by water-resources regions in table 15. A summary of withdrawals for the offstream water-use categories is given by States in table 16 and by water-resources regions in table 17. Ground- and surface-water withdrawals are summarized in tables 18 through 21 and also in figure 9.

Total offstream withdrawals by source and disposition are shown in the chart below.



TOTAL OFFSTREAM WATER WITHDRAWALS BY SOURCE AND DISPOSITION, 1980, IN PERCENT.

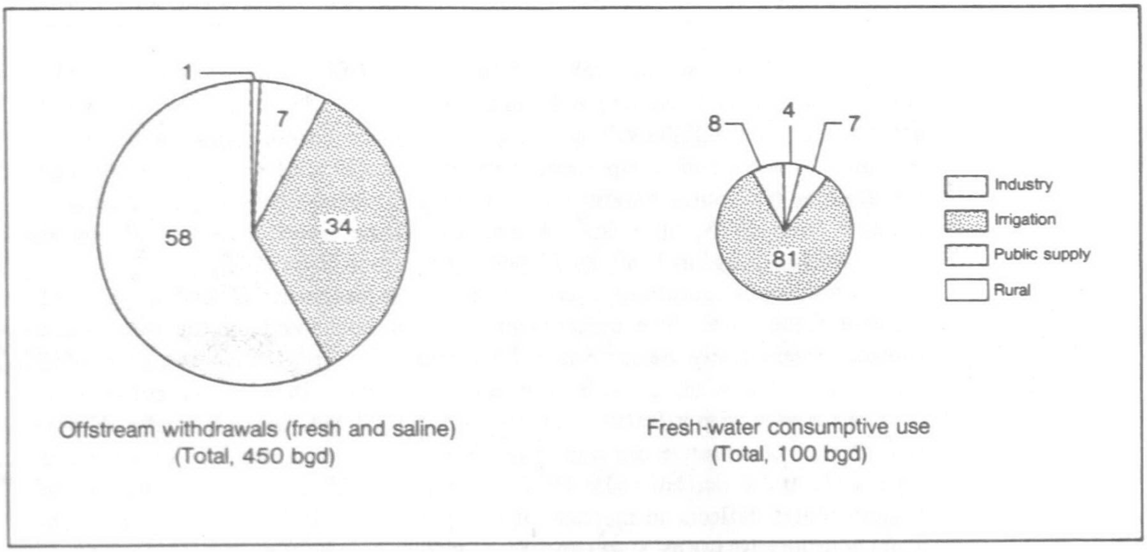


Figure 6. Percentage of total offstream withdrawals and fresh-water consumptive use, by categories of use, 1980.

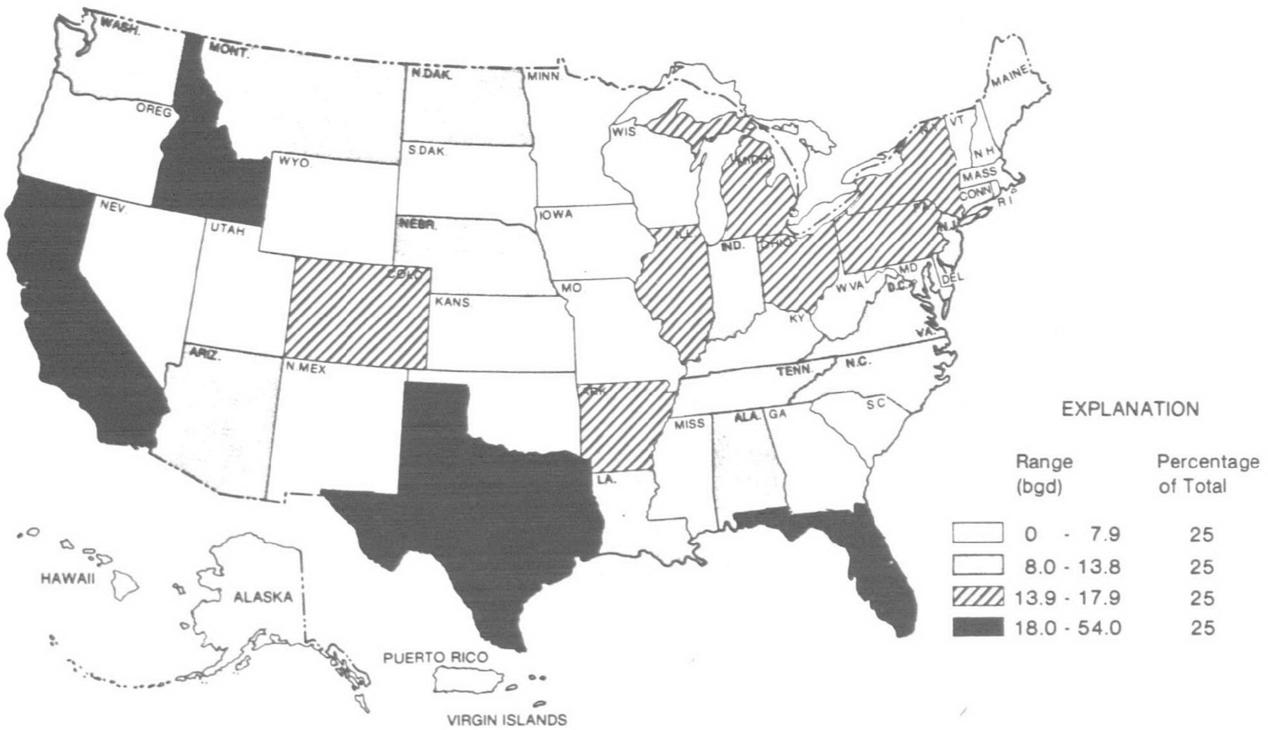
Table 13.—*PER CAPITA WATER WITHDRAWALS AND CONSUMPTIVE USE*
Eastern and western water-resources regions and United States, 1980

[Note: All per capita data calculated from unrounded figures and rounded to two significant figures]

	Conterminous United States water-resources regions		United States (50 States, District of Columbia, Puerto Rico, and Virgin Islands)
	Eastern (9 regions = 31 States)[1]	Western (9 regions = 17 States)[1]	
Population, in millions:			
Total	155.7	69.1	229.6
Served by public supplies	123.5	58.1	186.1
Self supplied (rural)	32.2	11.0	43.5
Per capita water use, in gallons per day:			
Offstream use:			
Total withdrawals[2]	1,600	2,900	2,000
Public supplies:			
All uses[3]	160	230	180
Domestic and public uses and losses[3]	100	150	120
Rural domestic use[4]	73	98	79
Irrigation[2]	82	2,000	660
Self-supplied industrial[2]	1,300	660	1,100
Consumptive fresh-water use[2]	120	1,200	450
Instream use:			
Hydroelectric power[2]	8,900	27,000	14,000
Total offstream and instream use[2]	10,000	30,000	16,000

[1] Approximate boundaries.
[2] Based on total population.
[3] Based on population served by public supplies.
[4] Based on rural population.

A. States



B. Water-resources regions

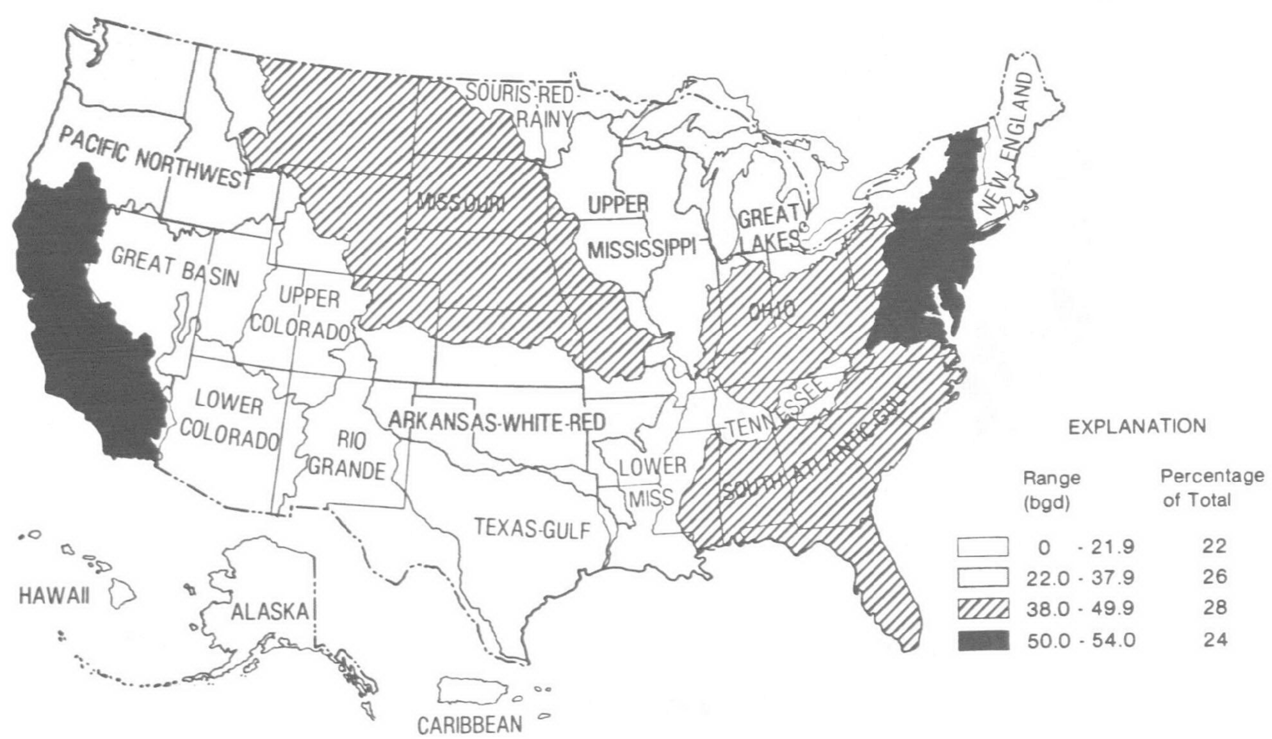


Figure 7. Total offstream water withdrawals, by States and water-resources regions, 1980.

A. States

B. Water-resources regions

Figure 8. Fresh-water consumptive use, by State and water-resources regions, 1980.

Table 14.—*TOTAL OFFSTREAM WATER USE, BY STATES, IN MILLION GALLONS PER DAY (except as noted), 1980*

[Water-use data generally are rounded to two significant figures; figures may not add to totals because of independent rounding]

STATE	POPULATION, in thousands	PER CAPITA USE, fresh water in gpd	WITHDRAWALS (includes irrigation conveyance losses): By source and type: Ground water: Fresh	Ground water: Saline	Ground water: Total	Surface water: Fresh	Surface water: Saline	Surface water: Total	Reclaimed sewage	Total, excluding reclaimed sewage: Fresh	Total, excluding reclaimed sewage: Saline	Total, excluding reclaimed sewage: Total	CONVEYANCE LOSSES	CONSUMPTIVE USE, fresh water
Alabama	3890	2700	350	1.4	350	10000	73	10000	0	11000	75	11000	0	570
Alaska	403	550	49	0	49	170	0	170	0	220	0	220	0	35
Arizona	2718	2900	4200	0	4200	3700	0	3700	5.3	8000	0	8000	900	4500
Arkansas	2290	6800	4000	0	4000	12000	0	12000	0	16000	0	16000	270	3600
California	23669	1900	21000	250	21000	23000	9800	33000	160	44000	10000	54000	5600	25000
Colorado	2889	5400	2800	0	2800	13000	0	13000	0	16000	0	16000	1600	4000
Connecticut	3108	420	140	1.0	140	1200	2400	3600	0	1300	2400	3700	0	160
Delaware	595	230	82	0.3	82	57	1100	1100	0	140	1100	1200	0	11
D.C.	638	530	0.8	0	0.8	340	0	340	0	340	0	340	0	23
Florida	9740	750	3800	42	3800	3600	14000	17000	0	7300	14000	21000	35	2400
Georgia	5464	1200	1200	0	1200	5500	200	5700	0	6700	200	6900	0	1000
Hawaii	965	1400	800	0	800	510	1200	1700	10	1300	1200	2500	300	680
Idaho	944	19000	6300	0	6300	12000	0	12000	13	18000	0	18000	3600	5900
Illinois	11418	1600	930	38	970	17000	0	17000	0	18000	38	18000	0	590
Indiana	5396	2600	1300	0	1300	13000	0	13000	0	14000	0	14000	0	690
Iowa	2913	1500	760	0	760	3500	0	3500	0	4300	0	4300	0	290
Kansas	2363	2800	5600	0	5600	980	0	980	0	6600	0	6600	150	4700
Kentucky	3661	1300	250	0	250	4600	0	4600	0	4800	0	4800	0	290
Louisiana	4199	2900	1800	19	1800	11000	390	11000	0	12000	410	13000	610	3500
Maine	1125	750	80	0	80	770	710	1500	0	850	710	1600	0	53
Maryland	4216	270	150	0	150	970	6600	7600	160	1100	6600	7700	0	100
Massachusetts	5737	430	320	0	320	2100	3500	5600	0	2500	3500	5900	0	90
Michigan	9258	1600	530	420	950	14000	0	14000	30	15000	420	15000	0	460
Minnesota	4061	760	670	0	670	2400	0	2400	0	3100	0	3100	0	450
Mississippi	2521	1100	1500	0	1500	1400	660	2000	0	2900	660	3500	99	710
Missouri	4888	1400	470	0	470	6400	0	6400	0	6900	0	6900	0	670
Montana	786	14000	260	2.1	260	11000	0	11000	0	11000	2.1	11000	2400	2700
Nebraska	1570	7700	7200	0	7200	4900	0	4900	0	12000	0	12000	1900	7600
Nevada	799	4500	710	9.0	720	2900	0	2900	14	3600	9.0	3600	720	1700
New Hampshire	921	420	65	0	65	320	620	940	0	380	620	1000	0	17
New Jersey	7360	390	730	0	730	2100	7500	9600	0	2900	7500	10000	0	380
New Mexico	1300	3000	1800	0.9	1800	2100	0	2100	0	3900	0.9	3900	31	1900
New York	17557	450	780	12	800	7200	8600	16000	0	8000	8600	17000	0	590
North Carolina	5874	1400	770	0	770	7300	42	7300	0	8100	42	8100	0	760
North Dakota	652	2000	120	0.2	120	1200	0	1200	0.4	1300	0.2	1300	120	330
Ohio	10797	1300	980	0	980	13000	0	13000	0	14000	0	14000	0	550
Oklahoma	3025	570	960	95	1100	760	0	760	0	1700	95	1800	53	1000
Oregon	2614	2600	1100	0	1100	5700	0	5700	3.6	6800	0	6800	1700	3200
Pennsylvania	11824	1300	1000	0	1000	15000	93	15000	0	16000	93	16000	0	920
Rhode Island	947	180	37	0	37	140	330	460	0	170	330	500	0.5	15
South Carolina	3119	2000	230	0	230	5900	38	6000	0	6200	38	6200	0	280
South Dakota	695	990	330	3.4	330	360	0	360	1.5	690	3.4	690	42	460
Tennessee	4591	2200	450	0	450	9600	0	9600	0	10000	0	10000	0.6	270
Texas	14013	1000	8000	0	8000	6300	6600	13000	70	14000	6600	21000	200	10000
Utah	1462	3100	1000	4.0	1000	3500	56	3600	0	4500	60	4600	320	2900
Vermont	511	660	45	0	45	290	0	290	0	340	0	340	0	41
Virginia	5346	1000	390	0.2	390	5200	4100	9300	0	5600	4100	9700	3.9	230
Washington	4127	2000	770	0	770	7500	42	7500	0	8200	42	8300	1200	2900
West Virginia	1950	2900	220	0	220	5400	0	5400	0	5600	0	5600	0	200
Wisconsin	4710	1200	610	0	610	5200	0	5200	0	5800	0	5800	0	310
Wyoming	471	11000	540	24	560	4800	0	4800	0	5300	24	5400	1600	2600
Puerto Rico	3400	240	310	5.0	320	500	2400	2900	0	810	2400	3200	30	300
Virgin Islands	100	63	4.0	0	4.0	2.2	32	34	0	6.3	32	38	0	2.1
Total	229,592	1,600	88,000	930	89,000	290,000	71,000	360,000	470	380,000	72,000	450,000	24,000	100,000

Table 15.—*TOTAL OFFSTREAM WATER USE, BY REGIONS, IN MILLION GALLONS PER DAY (except as noted) 1980*

[Water-use data generally are rounded to two significant figures; figures may not add to totals because of independent rounding]

WATER-RESOURCES REGION	POPULATION, in thousands	PER CAPITA USE, fresh water in gpd	WITHDRAWALS (includes irrigation conveyance losses) — By source and type — Ground water — Fresh	Ground water — Saline	Ground water — Total	Surface water — Fresh	Surface water — Saline	Surface water — Total	Reclaimed sewage	Total, excluding reclaimed sewage — Fresh	Total, excluding reclaimed sewage — Saline	Total, excluding reclaimed sewage — Total	CONVEYANCE LOSSES	CONSUMPTIVE USE, fresh water
New England..........	11941	450	650	1.0	650	4800	7500	12000	0	5400	7500	13000	0.5	360
Mid-Atlantic.........	38881	630	2400	12	2400	22000	28000	50000	160	24000	28000	52000	1.7	1700
South Atlantic-Gulf..	29449	1100	6600	44	6600	27000	15000	42000	0	34000	15000	49000	38	5100
Great Lakes..........	21489	1700	1600	420	2000	36000	0	36000	30	37000	420	38000	0	1300
Ohio.................	21461	1800	2500	24	2500	35000	0	35000	0	38000	24	38000	0.1	1700
Tennessee............	3677	3200	260	0	260	12000	0	12000	0	12000	0	12000	0.2	370
Upper Mississippi....	21083	1100	2600	15	2600	20000	0	20000	0	23000	15	23000	0	1500
Lower Mississippi....	6874	3000	6700	19	6700	14000	390	15000	0	21000	410	21000	960	7100
Souris-Red-Rainy.....	796	280	110	0	110	110	0	110	0.2	220	0	220	5.9	130
Missouri Basin.......	9761	4000	12000	26	12000	27000	0	27000	1.7	39000	26	39000	6000	16000
Arkansas-White-Red...	7900	3000	9400	95	9500	14000	2.0	14000	15	24000	97	24000	360	9600
Texas-Gulf...........	12524	820	5100	0	5100	5200	6600	12000	55	10000	6600	17000	140	6500
Rio Grande...........	1775	2700	1900	0.9	1900	2800	0	2800	0	4700	0.9	4700	290	2400
Upper Colorado.......	548	16000	140	3.5	150	8400	0.7	8400	0.1	8500	4.2	8500	830	2300
Lower Colorado.......	3241	2700	4500	0.2	4500	4200	0	4200	18	8700	0.2	8700	950	4900
Great Basin..........	1782	4200	1600	13	1600	5800	55	5900	4.8	7400	68	7500	1000	3900
Pacific Northwest....	7870	4400	8200	0	8200	26000	42	26000	17	34000	42	34000	6800	12000
California...........	23671	1900	21000	250	21000	23000	9800	33000	160	44000	10000	54000	5800	25000
Alaska...............	403	550	49	0	49	170	0	170	0	220	0	220	0	35
Hawaii...............	965	1400	800	0	800	510	1200	1700	10	1300	1200	2500	300	680
Caribbean............	3500	230	320	5.0	320	500	2500	3000	0	820	2500	3300	30	310
Total.............	229,592	1,600	88,000	930	89,000	290,000	71,000	360,000	470	380,000	72,000	450,000	24,000	100,000

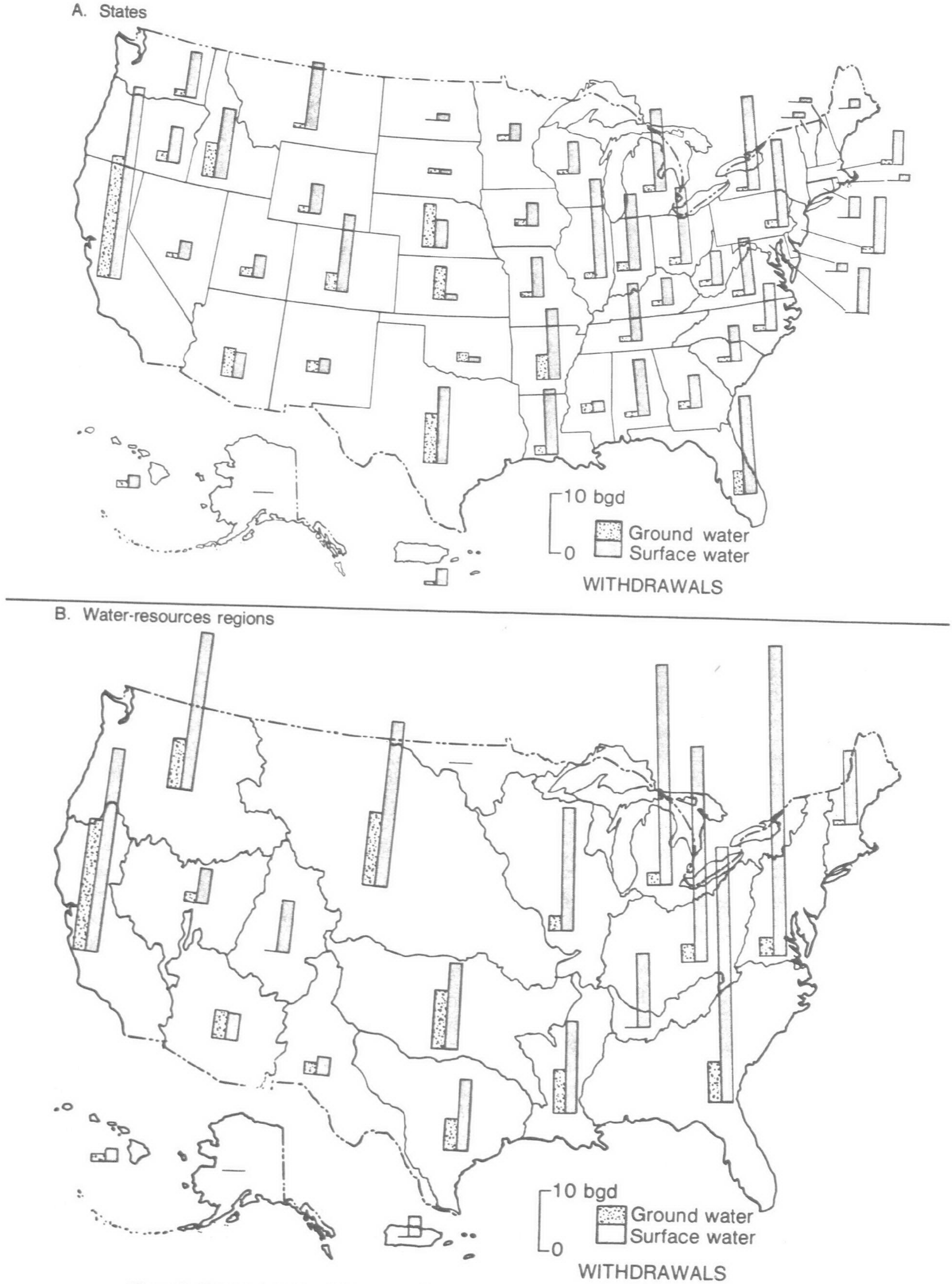


Figure 9. Withdrawals for offstream use from ground- and surface-water sources, by States and water-resources regions, 1980.

TRENDS IN WATER USE, 1950-1980

Water use for public supply, rural needs, irrigation, industry, and hydroelectric power generation has increased steadily from 1950 to 1980. This trend is shown graphically in figures 11 through 13. Data in table 22, which is a summary of estimated water use—offstream withdrawals, source of withdrawals, consumptive use, and instream use (hydroelectric power)—at 5-year intervals for the period 1950–1980, also confirm this trend. Table 22 also shows the percentage increase or decrease for the various categories of water use and sources of supply for the periods 1970–1975 and 1975–1980.

Trends established over the period 1950 to 1975 did not change significantly during the 1975–1980 period. For most categories of use, the general slackening in the rate of increase that was observed from 1970 to 1975 is again detectable for the 1975 to 1980 period. There are two exception to this trend: public supply and rural withdrawals increased 15 and 14 percent, respectively, compared to corresponding increases of 8 and 10 percent from 1970 to 1975. Part of the increase for public supply is due to the fact that nearly 2 bgd of water previously identified as self-supplied industrial withdrawals was actually public-supplied water, and it is now identified in the public-supply category. The increase in rural withdrawals resulted from an increase in the population being served by self-supplied systems and an increase in per capita use. This per-capita-use increase reflects the application of more realistic estimating techniques, which indicate that previous estimates were probably too low.

Irrigation water use declined from 1955 to 1960, when there was a decrease in the amount of surface water used, but irrigation water use has continued to increase since 1960. The amount of surface water used for irrigation increased 7.1 percent from 1975 to 1980—nearly double the 3.7 percent increase from 1970 to 1975. In contrast, the amount of ground water used for irrigation has increased steadily since 1950; however, the increase from 1975 to 1980 was only 5 percent compared to 27 percent from 1970 to 1975. The average amount of water required per acre for irrigation in 1980 (2.9 acre-ft per acre) was the same as in 1975. Although the acreage irrigated in 1980 was about 7 percent greater than in 1975, it was less than the 9-percent increase that took place from 1970 to 1975 and the 13-percent increase that took place from 1960 to 1965 and from 1965 to 1970.

More water continues to be withdrawn for industrial use than for any other category even though the rate of increase in water withdrawals for thermoelectric power continued to decline—a 33-percent increase from 1965 to 1970, an 18-percent increase from 1970 to 1975, and a 9-percent increase from 1975 to 1980. Withdrawals for other industrial uses remained about the same in 1970, 1975, and 1980.

Water used for hydroelectric power generation had been increasing steadily from 1950 to 1975, but in 1980 hydroelectric power water use was approximately the same as in 1975, compared to a 21-percent increase between 1970 and 1975.

A shift in the source of total withdrawals also is shown by table 22, which indicates that the withdrawal of fresh surface water increased by 10 percent between 1975 and 1980, compared to a 5-percent increase between 1970 and 1975. Fresh ground water and saline surface water, which showed substantial increases from 1970 to 1975 (22 and 31 percent respectively) only increased 7 and 2 percent, respectively, from 1975 to 1980. The slowdown in the rate of increase in total withdrawals, 8-percent increase between 1975 and 1980, more closely follows the rate of increase in total population of 6 percent during the same period. This is in contrast to the rate of increase in total withdrawals during the period 1970–1975, which was more than double the rate of population

Table 22.—*SUMMARY OF ESTIMATED WATER USE IN THE UNITED STATES, IN BILLION GALLONS PER DAY, AT 5-YEAR INTERVALS, 1950–80*

[Data for 1950–75 adapted from MacKichan (1951, 1957), MacKichan and Kammerer (1961), Murray (1968), and Murray and Reeves (1972, 1977). The data generally are rounded to two significant figures; however, the percentage changes are calculated from unrounded numbers]

	Estimated water use in billion gallons per day							Percentage increase (+) or decrease (–)	
	1950[1]	1955[1]	1960[2]	1965[2]	1970[3]	1975[4]	1980[4]	1970–75	1975–80
Population, in millions	150.7	164.0	179.3	193.8	205.9	[5]216.4	229.6	+5	+6
Offstream use:									
Total withdrawals	[5]180	240	270	310	370	420	450	+12	+8
Public supply	14	17	21	24	27	29	34	+8	+15
Rural domestic and livestock	3.6	3.6	3.6	4.0	4.5	4.9	5.6	+10	+14
Irrigation	[5]89	110	110	120	130	140	150	+11	+7
Self-supplied industrial:									
Thermoelectric power use	40	72	100	130	170	200	210	+18	+9
Other industrial uses	37	39	38	46	47	45	45	–6	+1
Source of withdrawals:									
Ground water:									
Fresh	34	47	50	60	68	82	88	+22	+7
Saline	([6])	.6	.4	.5	1	1	.9	–6	–5
Surface water:									
Fresh	[5]140	180	190	210	250	260	290	+5	+10
Saline	10	18	31	43	53	69	71	+31	+2
Reclaimed sewage	([6])	.2	[5].6	.7	.5	.5	.5	+2	–11
Consumptive use	([6])	([6])	61	77	[7]87	[7]96	[7]100	+10	+7
Instream use:									
Hydroelectric power	1,100	1,500	2,000	2,300	2,800	3,300	3,300	+21	–2

[1] 48 States and District of Columbia.
[2] 50 States and District of Columbia.
[3] 50 States, District of Columbia, and Puerto Rico.
[4] 50 States, District of Columbia, Puerto Rico, and Virgin Islands.
[5] Corrected from published report.
[6] Data not available.
[7] Fresh water only.

growth. The rate of increase in consumptive use of fresh water has steadily decreased from 13 percent for the period 1965–1970 to 7 percent for the period 1975–1980. The changes shown in table 22 and figures 11–13 can be attributed to several important factors:

1. Demands on the ground-water system influence the pumping lift, flow rate, or quality of the water supply. Each of these factors also influences the cost of water, and make users, especially irrigators, more selective and efficient with their use of ground water.
2. The price of water influences the volume used and encourages efficient use and may determine when the use of reclaimed water and increased reuse are viable alternatives.
3. Availability of water in a particular year, especially streamflow, strongly affects the quantity of water used for irrigation and hydroelectric power development.

Although 1980 estimates of water use were higher than the 1975 estimates for all offstream categories, trends established during the periods 1970 to 1975 and 1975 to 1980 indicate a general slackening in the rate of total withdrawals in comparison to the period 1965 to 1970. Even with the slackening of the rates of water withdrawal and consumptive use, major attention must be given to water-management problems, because in addition to the need for an adequate water supply, water-quality conditions must be suitable if supply and demand are to be in balance. The degree to which the different uses of water degrade the supply vary widely and affect the potential reuse of the return flows.

Projections of future water use are beyond the scope of this report, although the trends established over the past 30 years provide some basis for estimating future water demands. Many other agencies and commissions have made projections of national water use to the year 2000. Notable examples are studies by the Senate Select Committee on National Water Resources (U.S. Congress, 1961), Resources for the Future, Inc. (Wollman and Bonem, 1971), the National Water Commission (1973), and the U.S. Water Resources Council (1968 and 1978). Summaries of these national projections and projections for individual States to the year 2000 are included in a report prepared by the Congressional Research Service (Viessman and DeMoncoda, 1980). The projections vary greatly based on availability of reliable data and different assumptions of future population growth, economic conditions, environmental regulations and energy-resources development. Regardless of which projection proves correct, major attention must be given to water-management problems to ensure that maximum benefits will be obtained from use of the Nation's water resources.

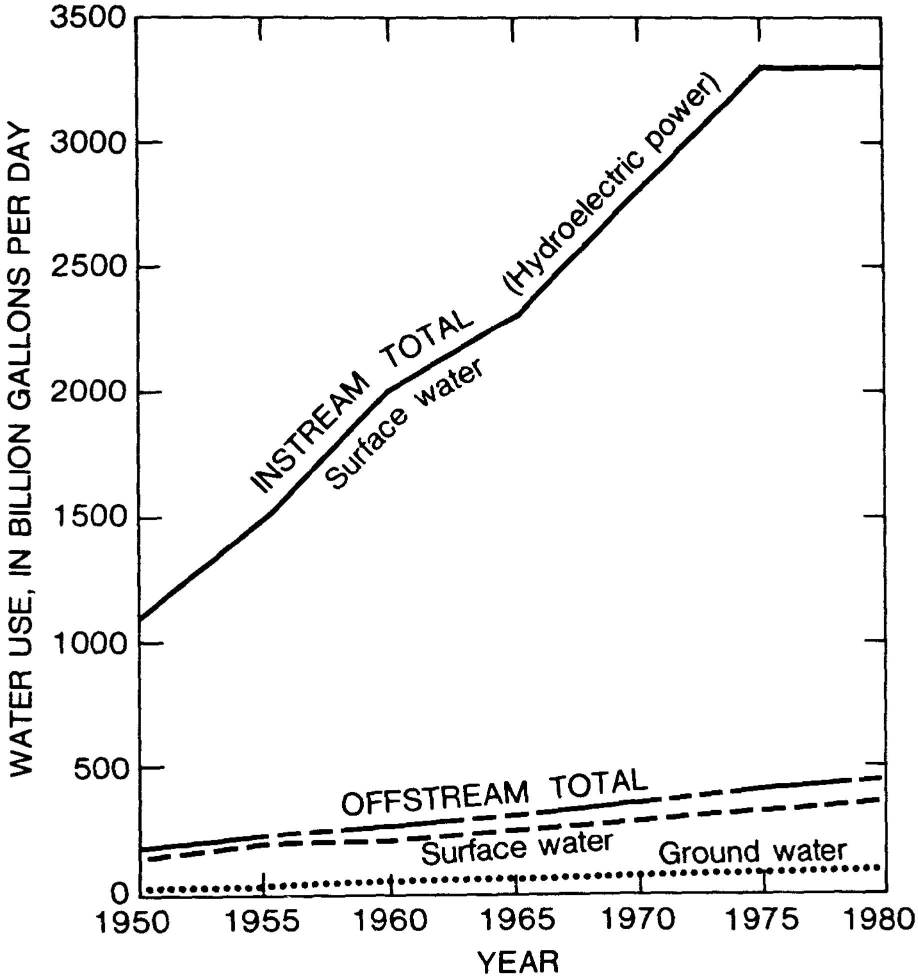


Figure 11. Trends in offstream and instream water use, 1950–80.

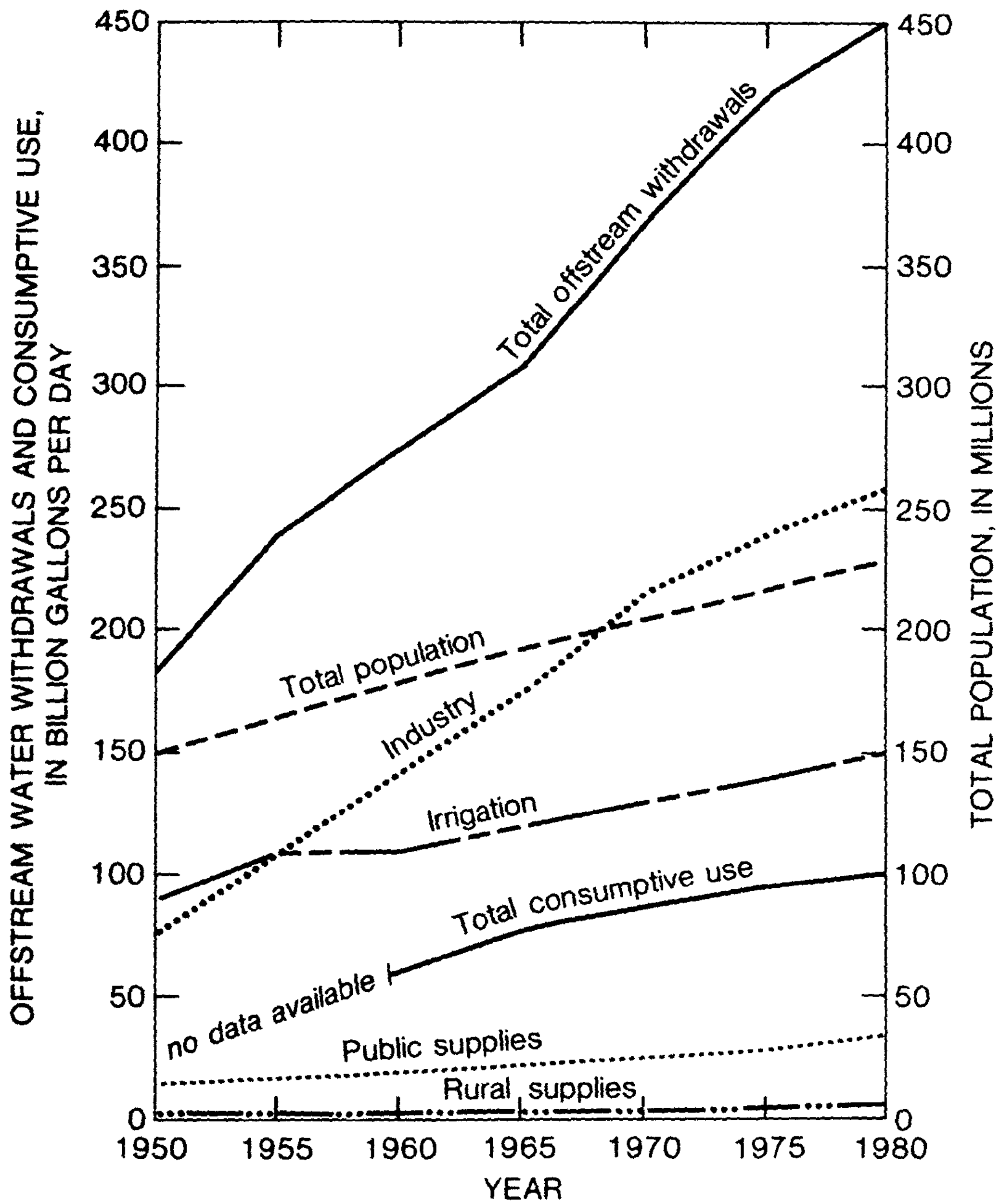


Figure 12. Trends in withdrawals, consumptive use, and population, 1950–80.

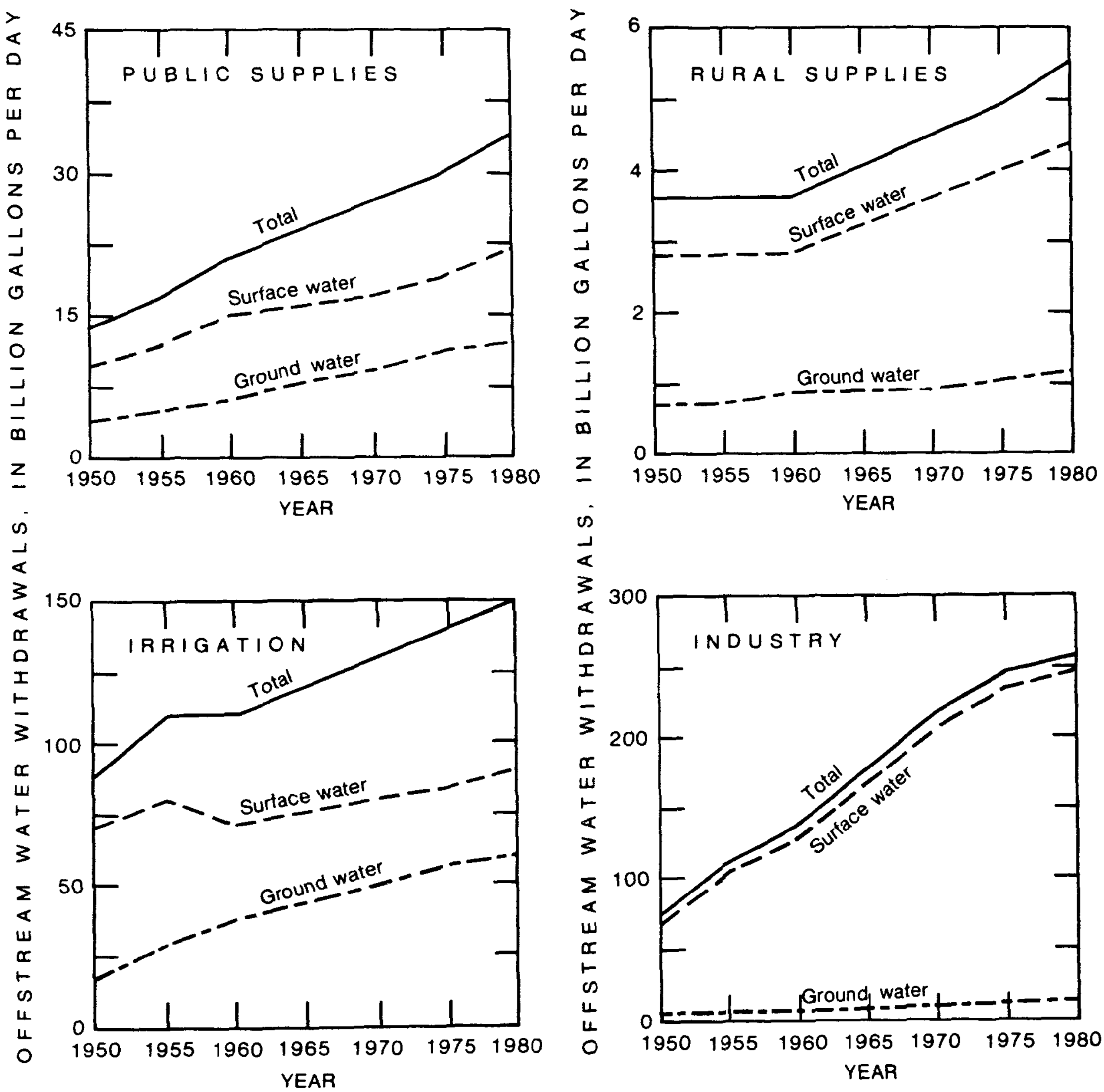


Figure 13. Trends in water withdrawals for public supplies, rural supplies, irrigation, and self-supplied industry, 1950–80.

VIII. COSTS OF GROUND-WATER MONITORING

Office of Ground-Water Protection
Cost of Ground-Water Monitoring

Introduction

Ground-water monitoring is currently being done at all levels of government and by the regulated community in conjunction with a variety of regulatory and research programs. The cost of existing ground-water monitoring is an important consideration in understanding the current monitoring efforts and the emphasis placed on monitoring by the various programs. In addition, the cost information is important in the development of realistic approaches for ground-water monitoring in the Ground-Water Monitoring Strategy.

General or "level of magnitude" cost information would seem to meet these needs rather than detailed data requiring elaborate study. Therefore, a study was designed that would use existing data that could be readily provided by the EPA programs, the other Federal agencies, and selected States. No attempt was made to survey all agencies nor integrate these diverse cost elements into a rigorous cost study, and therefore the results must be used with caution. The results do, however, provide a general perspective on where the "action" has been in ground-water monitoring.

Three types of cost data are provided in this report.

1) Selected program costs of EPA and other Federal agencies

2) Unit costs for ground-water sampling and laboratory analysis

3) Selected State expenditures

Study Assumptions

The data provided in this study does not necessarily represent the actual costs incurred by the various EPA and other government programs in performing ground-water monitoring nor do they represent a complete listing of all the ground-water monitoring costs incurred in the United States. The limitations of this cost data result from the following problems identified during the data gathering process:

- o Most agencies and programs do not include ground-water monitoring costs as a separate line item in their budgets. Consequently, they had to extrapolate a cost from their total budget.

- o The monitoring costs incurred by the regulated community are not easily accessible to EPA especially in the time-frame of a short study.

- o Monitoring is defined differently by the various programs/agencies and therefore there is limited consistency across the individual cost elements.

- o One factor in ground-water monitoring costs is well installation. In some cases, these monitoring costs may not include both capital and operation costs.

- o Only selected agencies/programs were included in the study and some agencies/programs were unable to provide data within the time-frame of this study.

TABLE 1 Selected Federal Ground Water Quality Monitoring Programs (Costs Year in Million dollars)

I. EPA*	
A. Safe Drinking Water Act	18
B. RCRA (Interim Status)	17-54
C. CERCLA	38-50
D. Federal Insecticide Fungicide Rodenticide Act	2-3
II. Other Federal	
A. Department of the Interior	
1. United States Geological Survey	9
2. Bureau of Land Management	0.4
B. Department of Energy	5-10
C. Department of Defense	245-290
D. Department of Agriculture	0.2 - 0.3

*Figures include both government and some private sector costs

TABLE 2 Selected Unit Costs
For Various Ground-Water Monitoring Elements
(Costs in Dollars)

I. Installation (Depends on depth & construction)

A. Drilling/well installation (USGS) Test Wells — $2.60 - $48.00/foot; Average 8.83/foot

B. Drilling/well installation (State of Illinois) Monitoring Wells — $50 - $100/foot

II. Sampling Costs (Interim Status RCRA) Average $200/well

III. Analytical Costs

A. CONTRACT LAB PROGRAM FOR CERCLA ANALYSIS -

Average 1984 sample price

1. Organic Routine Analytical Service	550
2. Inorganic Routine Analytical Service	68
3. Dioxin Routine Analytical Service	304
4. Special Analytical Service (SAS)	282

Table 2 - Continued

B. Prices of Ground-Water Analysis required under the Interim Status Subpart F Regulations of RCRA.

1. Parameters required by §265.92(b)(1)

	Price Range	Mean Price
a. Arsenic	8-50	22
b. Barium	5-35	14
c. Cadmium	5-43	14
d. Lead	5-43	14
e. Mercury	8-55	24
f. Selenium	8-66	23
g. Silver	7-40	14
h. Fluoride	5-39	15
i. Nitrate	7-50	15
j. Turbidity	1-35	8
k. Coliforms	6-75	18
l. Radium	13-187	70
m. Gross Alpha	8-66	31
n. Gross Beta	8-66	33
o. Endrin	11-69	29
p. Lindane	11-69	29
q. Methoxychlor	11-69	29
r. Toxaphene	11-69	29

Table 2 - Continued

s. 2,4 - D	13-200	49
t. 2,4, 5 -T P Silvex	13-200	49
u. Chromium		15

2. Parameters required by §265.92(b)(2)

a. Iron	5-35	12
b. Manganese	5-35	12
c. Phenols	13-130	27
d. Chloride	5-35	10
e. Sodium	5-35	12
f. Sulfate	4-35	13

3. Parameters required by §265,92(b)(3)

	Price Range	Mean Price
a. pH	0-15[1]	4
b. Specific Conductance	2-25[1]	6
c. TOX	9-200[1]	67
d. TOC	8-80[1]	26

[1]These prices account for only one sample; the regulations require that four samples be analyzed.

4. Prices of Ground-Water Analyses not currently required under the Interim Status Subpart F regulations.

	Price Range	Mean Price
a. Volatile Organic Scan	50-1,500	208
b. Extractables (base/neutral)	40-1,500	307

C. RCRA Annual Costs (Average) For Intermin Status Wells

Baseline Monitoring	$4100/Well/Yr
Assessment Monitoring	$2000/Well/Yr
Detection Monitoring	$ 740/Well/Yr

TABLE 3* Selected Ground-Water Monitoring Expenditures in Illinois for 1984 - 1985 (Costs in 1000 dollars)

I.	Illinois EPA		
	A. Division of Drinking Water		400 - 581
	B. Division of Land Pollution Control		3,500 - 8,600
	1. RCRA	75 - 85	
	2. CERCLA	3,400 - 8,500	
	3. Non Hazardous Waste Program	20	
II.	Illinois State Geological Survey		70-90
III.	Illinois State Water Survey		400
IV.	Illinois Department of Health		130
	A. Non-Community Water Supplies	54	
	B. Private Well Analysis	76	
V.	Metropolitan Sanitary District		450
VI.	Private Well Monitoring Program		350-360
VII.	Industry		
	A. RCRA		400 - 1,200

*These costs estimates were provided by the State of Illinois. Individuals from the programs listed provided the line item cost estimates.

TABLE 4* Selected Ground-Water Monitoring Expenditures in Mississippi For FY 1984 (Costs in $1000)

I.	Ambient Monitoring Network	25
II.	Mississippi Board of Health	50
III.	Bureau of Geology	380
IV.	Bureau of Land Resources	112
V.	Bureau of Pollution Control	100-150

*These costs were provided by the State of Mississippi. Individuals from the programs listed provided the line item cost estimates.

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IX. TECHNICAL GROUND-WATER MONITORING ISSUES

- EPA Office of Research and Development Report on Monitoring Research
- Report on Storage and Retrieval of Ground-Water Data at the U.S. Geological Survey
- Report on Storage and Retrieval of Water-Resources Data at the U.S. Geological Survey
- Survey of the Water Well Industry*

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GROUND WATER MONITORING RESEARCH

The Environmental Protection Agency, Office of Research and Development, is performing monitoring research in three program areas to meet the needs of Drinking Water Monitoring (Clean Water Act), Active Hazardous Waste Site Monitoring (Resource Conservation and Recovery Act-RCRA), and abandoned hazardous waste sites monitoring (Comprehensive Environmental Response Compensation and Liability Act, Superfund, CERCLA). Each program is carrying out research according to its mandate. However, close coordination in all phases of planning and management is performed to insure that duplication of effort is avoided and that the results of investigations in one program can be utilized in other programs.

The research carried on under the CWA in fiscal year 1985 has a goal to provide a scientific data base on methods for regulatory, enforcement and management decisions concerning the protection of groundwater resources, especially sources of drinking water. Specific programs included research into: (1) fluid movement resulting from injection well use. The program includes developing techniques for locating abandoned wells and mapping plume movement from the wells; (2) evaluation and development of laser-induced fluorscence for monitoring specific pollutants using fiber optics. This program will provide a technique for remotely measuring contaminate concentrations at relatively low costs; and (3) evaluation of hollow stem auger drilling methods to determine if sampling wells completed by this method contribute to the verical movement of contaminants outside the well casing.

In FY '86, the program will increase its efforts to include technical support to EPA Regional Offices for analyzing underground injection permits and locating abandoned wells. In addition, a program to determine the effects of seasonal variation and sampling frequency on the accuracy and confidence of data derived from groundwater monitoring will be implemented.

The RCRA program for groundwater monitoring is focused on developing and evaluating methods for monitoring operating hazardous waste sites and for monitoring sites closed by RCRA and Superfund actions. The program includes development of techniques to monitor vapors in the soil column to determine leaks and map resultant contaminate plumes. Biomonitoring screening techniques and the use of indicator parameters as guides for chemical testing are also being investigated.

Remote sensing applications such as photography, multi-spectral scanners and thermal sensors are being investigated for site characteriztion and post-closure monitoring. Fiber optic uses are also being investigated for monitoring in the vadose as well as in the saturated zone. The use of the optics are being evaluated for leak detection as well as plume definition and mapping.

The leaking of contaminants from underground storage has been raised as a major ground water problem with the signing of the new RCRA Act. How to determine through monitoring of soil, surface water, ground water and air that a tank is leaking is a major task in the Office of Research and Development. At present there are a number of monitoring methods that have been developed for RCRA and Superfund that may be applicable.

The major applications that will be investigated in FY 1985 and FY 1986 include:

- Passive activated charcoal soil gas monitoring for hydrocarbons;
- Continuous gasoline monitors using fiber optics;

- Long-term monitoring with electrical resistivity;
- Pulse impedance monitoring; and
- Geophysical monitoring for hydrocarbon contamination.

In FY 1986, the fiber optic program will investigate sensors which will be compound specific. The tests will include ruggedness and durabilty and the requirements to make them a long term monitoring tool. A number of methods for monitoring the unsaturated zone will be investigated in the field in order to determine the most variable methods. In addition, programs in the use of geostatistical analysis and geophysical monitoring of plume definition will continue.

The Superfund program is in the process of applying what has been learned in the RCRA and CWA research programs. Specifically, the research in geopyhsical methods to map leachates is being applied to abandoned waste sites. In the past, investigations of subsurface conditions at waste sites has depended upon drilling to obtain information on the geologic setting, upon monitoring wells for samples of ground water and upon laboratory analyses to establish the presence of contaminants. During the past decade, extensive development in geophysical equipment, field methods, analytical techniques and associated computer processing has greatly improved the capability to characterize site conditions, locate buried drums and contaminate plumes and measure ground water flow, speed, and direction.

Under the Superfund program the ORD is providing technical support to EPA Regions and States to characterize the extend of problems at and around hazardous waste sites. In addition, the program is undertaking an extensive technology transfer program to pass on ORD experience and research outputs to the user community. Through, the use of formal short term seminars and extensive publication in professional journals the ORD hopes to reach EPA regional and program office staff, CERCLA contractor personnel and state agency managers. It is expected that the program will continue in FY 1986. As new techniques are developed the program will continue its program to apply them.

Outputs:

Drinking Water

Monitoring Ground Water with Fiber Optics	12/85
Mapping Fluid Movement from Injection Wells	12/85
Sources of Variability Affecting Ground Water Monitoring Data	12/85
Methods of Construction for Monitoring Wells	6/86

RCRA

Interim Report on Selection of Indicator Parameters	1/85
Interim Report on Soil Gas Column Monitoring	12/85
Interim Report on Fiber Optics Sensing	12/85
Interim Report on Monitoring in the Vadose Zone	12/85
Interim Report on Evaluation of Geophysical Methods for Lechate Detection	12/85

Superfund

Annual Report on Sub-surface Geophysical Site Investigations	11/85
Management Plan for FY 1986 Geophysical Monitoring	9/85

Storage and Retrieval of Ground-Water Data at the U.S. Geological Survey

By Maria W. Mercer and Charles O. Morgan

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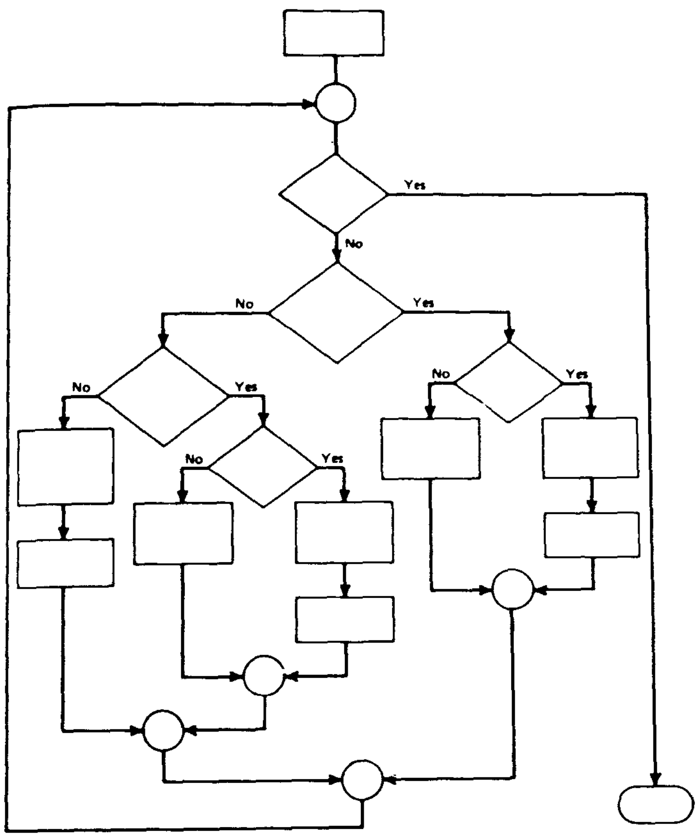

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Storage and Retrieval of Ground-Water Data at the U.S. Geological Survey

By Maria W. Mercer and Charles O. Morgan

ABSTRACT

The U.S. Geological Survey maintains a computerized Ground-Water Site-Inventory (GWSI) file that contains information about wells and springs at sites from all States of the United States. This file contains data collected by U.S. Geological Survey personnel and personnel of cooperating State, local, and Federal agencies. The file is easily accessible to members or users of the National Water Data Exchange (NAWDEX). Since the establishment of the GWSI file in 1974, the data base has grown 19 percent per year and contains information on about 770,000 sites as of February 1981.

INTRODUCTION

In the mid-1960's, ever-increasing amounts of data and a need for timely access to these data necessitated computerized data banks for the storage of information such as personnel records, daily business and financial records, and, in the case of the U.S. Geological Survey, hydrologic records. In keeping with one of the Survey's missions, that of collecting and publishing information about the Nation's natural resources (U.S. Geological Survey, 1981), the Survey created and maintains a central storage facility for water resources data known as the National Water Data Storage and Retrieval System (WATSTORE), at its National Headquarters in Reston, Va. Included in this computerized storage facility are representative ground-water data collected throughout the United States. This ground-water information resides in an online computer data file, which is maintained by a Data Base Management System (DBMS) called SYSTEM 2000[1] (MRI Systems Corp., 1974a). The name and acronym given this data base is the *G*round-*W*ater *S*ite-*I*nventory (GWSI) file.

[1]The use of brand or company names in this report is for identification purposes and does not constitute endorsement by the U.S. Geological Survey.

PURPOSE

As demand for ground water increases, the availability of site-specific ground-water data becomes very important in solving such problems as those involving water-supply and waste-disposal operations. To make competent management decisions concerning these problems, all available ground-water data in the vicinity of a site should be scrutinized as part of the evaluation process. This paper describes the various ground-water data elements that reside in the GWSI and explains how these data are entered and retrieved.

HISTORY OF THE GWSI

Twenty years ago, ground-water data collected in field offices by Survey hydrologists were stored in filing cabinets, many times on locally devised nonstandard inventory forms. During the 1960's, an attempt was made within the Survey to establish a standard approach to the storage of ground-water data in a national computer file (Lang and Leonard, 1967). Because of the specialized needs of hydrologists in diverse climatic and geologic areas of the country and the limitations of the data system, the national computer file was not used widely.

Because of the increasing demand for timely ground-water data, a need arose to redesign the structure of the data system to satisfy more fully the requirements of hydrologists and to establish a centrally controlled computer file that could be easily accessed by all users. A decision was reached in the early 1970's to obtain a commercially developed computerized DBMS to organize and maintain this file of raw ground-water data. The GWSI was designed and implemented in 1974, as documented in the "WATSTORE User's Guide, Volume 2" (U.S. Geological Survey, 1975), using the newly acquired

DBMS, SYSTEM 2000. The chief purposes of the GWSI are (1) to meet the need for storage of nationally standardized ground-water data and (2) to provide nationwide computer access to these data.

Because nationwide ground-water data are stored in one easily accessible computer file, the GWSI is a very useful tool for interpreting the hydrogeology of an area. An organization using the GWSI to work on projects throughout the Nation needs to learn only one retrieval technique to obtain the output in a standard format; this allows more time for the analysis of the findings. The tedious computer programing required for adjusting to different data sources is eliminated by using the standardized GWSI data base.

STRUCTURE OF GWSI

The structure of a SYSTEM 2000 data base is *hierarchical*, sometimes called a *tree structure* (see fig. 1). The top node (box) of this treelike structure is, in fact, the root, and, if turned upside down, the structure resembles a tree with its limbs branching upward. The top node, called ENTRY, which contains a unique identification number and location information for a ground-water site, can have many descendants (branches downward). However, no descendants may have more than one parent (branches upward). Figure 1 illustrates these relations. ENTRY, the top node, has descendants, including LIFT, CONSTRUCTION, and GEOLOGY data. However, LIFT has only one parent, ENTRY. Each of these nodes, called schema records, contains up to 46 components of site information leading to 270 possible data items per site. Not all 270 possible data items are coded for any one site. Some items are unique to specific site types; for example, springs. If a ground-water site contains only the data listed in the top node (ENTRY (location data)) then only these data are in the file. The other schema records are not established until pertinent data are entered into the GWSI and, thus, do not occupy valuable computer disk file space. The SYSTEM 2000 DBMS uses indexing techniques to keep track of the locations of data items that are stored randomly in an online computer disk file. This indexing feature simplifies the addition of data to the GWSI file and makes retrievals more efficient.

COLLECTION OF DATA FOR GWSI

The bulk of the data in the GWSI file is collected by Survey personnel as part of water-resources investigations and water-level monitoring programs, in cooperation with State and local governments and other Federal agencies. Typically, data are collected by a hydrologist who inventories wells or springs by

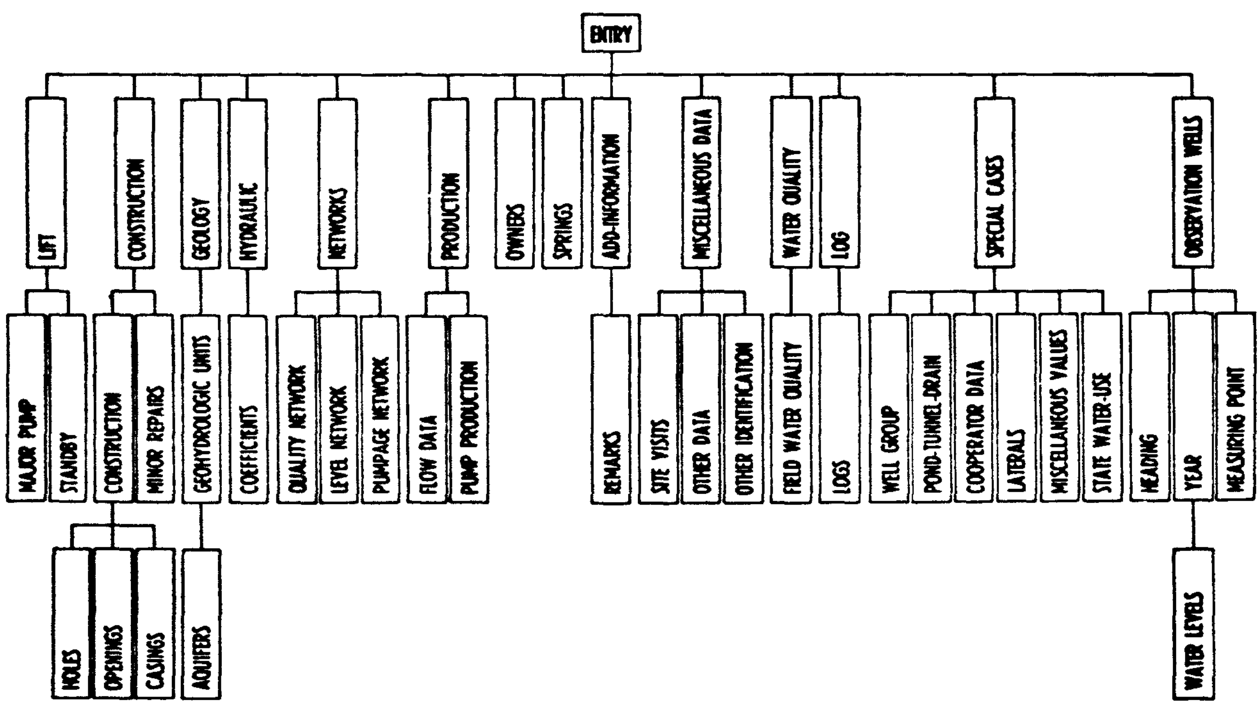

FIGURE 1.—Hierarchical structure of GWSI data base.

examining them in the field. The information obtained is transcribed onto standard forms designed for the recording of data for input to the computer file.

Most data in the GWSI file are raw ground-water data entered by the inputting agency. Few statistical items are stored because these values can be readily calculated from raw data residing in the data base. Some of the categories of data that can be stored in schema records for each site in the GWSI are listed in table 1. Table 1 describes the schema records in figure 1 starting with the top node ENTRY, proceeding down each branch, then left to right.

TABLE 1.—*Description of GWSI schema records*

[For a detailed explanation of all components within each schema record available in the GWSI see "WATSTORE User's Guide, Volume 2," Chapter II, Section B]

Schema record	Description of information
ENTRY	Site identifiers such as latitude and longitude, altitude, State, county, and so forth.
LIFT	Type, such as pump or bucket; includes horsepower, intake setting, and so forth.
MAJOR PUMP	Manufacturer, serial number, energy consumption, capacity, and so forth.
STANDBY	Alternative power types.
CONSTRUCTION	
CONSTRUCTION	Date of completion, contractor, seal type, finish, and seal bottom.
HOLES	Type of well and dimensions, including diameter of top and bottom of hole.
OPENINGS	Depth intervals of perforated zones, size and shape, and screen material.
CASINGS	Type and material, top in reference to land surface, depth to bottom, and diameter of each string.
MINOR REPAIRS	Repair information.
GEOLOGY	
GEOHYDROLOGIC UNITS	Name of formation, including unit identifier and its depth.
AQUIFERS	Includes static water level in aquifer.
HYDRAULIC	Includes the unit identifier.
COEFFICIENTS	Includes conductivity, diffusivity, and leakance.
NETWORKS	
QUALITY NETWORK	Water-quality network, including name of agency that gathers samples at site.
LEVEL NETWORK	Water-level network, including name of agency that collects water-level measurements at site.
PUMPAGE NETWORK	Pumpage network, including name of agency that monitors water withdrawal at site.
PRODUCTION	
FLOW DATA	Information about springs, including flow period and discharge.
PUMP PRODUCTION	Production of the well, including production date and method.
OWNERS	The site's owner, name, and ownership date.
SPRINGS	Spring data; for example, name and number of openings.
ADDITIONAL INFORMATION	
REMARKS	Additional remarks about the site.
MISCELLANEOUS DATA	Other references and sources of data.
SITE VISITS	Visits to the site, such as the inventory person and date of visit.
OTHER DATA	Location and formats of other data available about the site.
OTHER IDENTIFICATION	Other site identifiers.

TABLE 1.—*Description of GWSI schema records*—Continued

Schema record	Description of information
ENTRY—Continued	
WATER QUALITY	
FIELD WATER QUALITY[1]	Field water-quality data, such as the sample date, the constituent, its measurement, and source (aquifer name).
LOG	
LOGS	Type of geophysical or other logs available for the well, including type and source.
SPECIAL CASES	
WELL GROUP	Multiple wells that are manifolded to a single discharge pipe, including the number of wells and the deepest and shallowest wells in the group.
POND, TUNNEL, DRAIN	The length, width, and depth of a pond, tunnel, or drain.
COOPERATOR DATA	Data that cooperating local agencies need, such as cooperator's site identifier, registration number, and so forth.
LATERALS	Information about Ranney wells, including the depth, length, and diameter of the laterals that drain to the central well.
MISCELLANEOUS VALUES	Data for which no other schema record has been established.
STATE WATER USE	The State's use of water, including water type and the amount of water.
OBSERVATION WELLS	
HEADING	Textual information about the site.
YEAR	Specific year for data in the lower level schema record(s).
WATER LEVELS	Includes water-level measurements and respective dates.
MEASURING POINT	Includes the measuring point height and the date when the measurement was made.

[1]Although several field collected parameters of water-quality data (including temperature, conductance, and pH) are stored in the GWSI, the bulk of water-quality data reside in a nationwide file called *Storage* and *Retrieval* (STORET), a file maintained by the U.S. Environmental Protection Agency (1973). The *National Water Data Exchange* (NAWDEX) Local Assistance Centers provided in table 2 are authorized users of the STORET file and may retrieve ground-water-quality data for its subscribers.

QUALITY CONTROL AND ENTRY OF GWSI DATA

All ground-water data input to the GWSI data base should be reviewed for accuracy. The primary quality control measures are the responsibility of the inputting office. Once that office is satisfied that the data on field forms are correct, these data are transcribed to the format required for entry into the computer; for example, punched cards. Before entry into the GWSI file, the data are checked for logic and syntax errors by the inputting office by using a computerized verification system. This series of computer programs provides several types of error checks, such as (1) *syntax check,* which ensures valid input data (for example, correct codes are used and alphabetic characters are not entered where numeric data belong); (2) *compatibility check,* which ensures compatibility between data elements that are being entered or between input values and those that already reside in the data base (the depth to water, for example, cannot exceed the depth of the well); and (3) *out-of-range check,* which indicates whether input data fall within the bounds of certain parameters provided in tables in the computer programs (for example, maximum and minimum values of latitude, longitude, and altitude reside in the tables for each State).

Input data will be entered into the GWSI file by the GWSI Data Base Manager (DBM) at the Survey's National Headquarters when all data have passed the error checks. All reports concerning final verification of the update process to the GWSI are sent to the originating office.

The inputting office may not directly update the GWSI data base. Only the DBM may update. Once the data are in the GWSI file, the inputting office must verify these data and correct any errors, such as transposition of numbers or misspelling of names that were not detected earlier in the proofing process. Erroneous data can be modified easily by the inputting office.

Non-Survey organizations that wish to enter data into GWSI must establish access to the data base by registering with the NAWDEX Program Manager. Detailed information about accessing the GWSI is discussed in a subsequent section entitled "Users and Use of the GWSI." Non-Survey organizations may obtain standard forms for encoding input information in the GWSI format by contacting GWSI personnel of the Survey at the National Headquarters.

Since the inception of the GWSI file, the data base has grown at an average of 19 percent per year and contains information related to about 770,000 sites, as of February 1981. Figure 2 indicates the growth pattern for the past 3 years. The number of ground-water sites for which data have been entered into the GWSI file for each State, including Puerto Rico, is shown in figure 3.

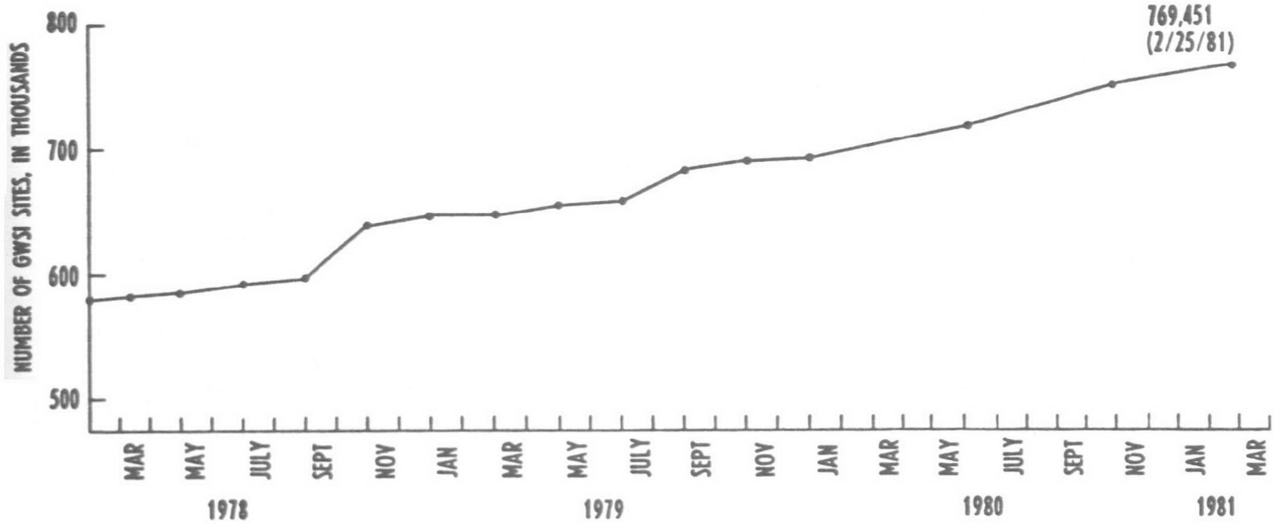

FIGURE 2.—Increase in the number of sites in the GWSI data base.

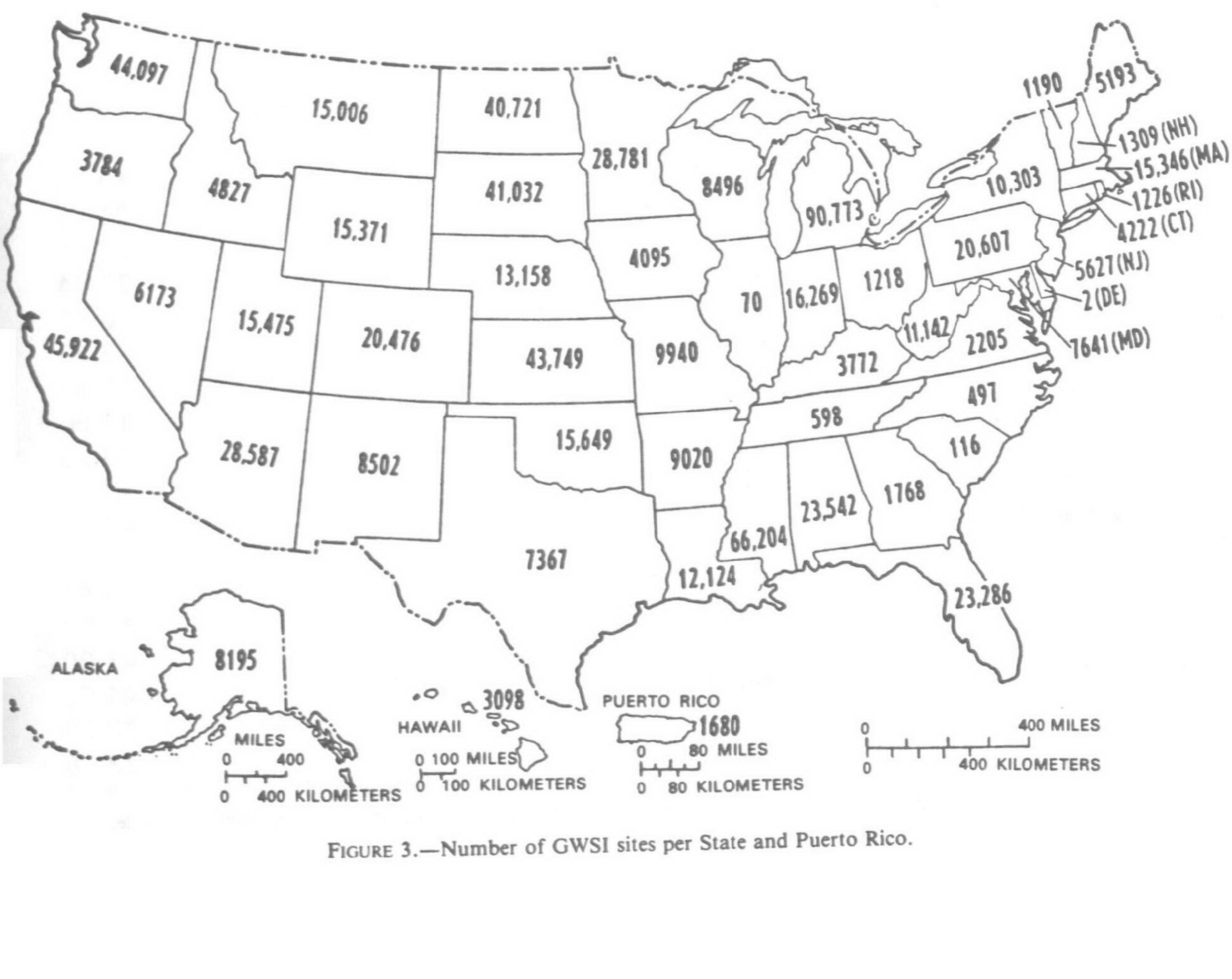

FIGURE 3.—Number of GWSI sites per State and Puerto Rico.

RETRIEVAL OF DATA FROM GWSI

Once data reside in the GWSI, their retrieval is relatively simple. This capacity for quick, efficient retrieval is the primary purpose for choosing a DBMS for storage of ground-water data. The SYSTEM 2000 DBMS "Natural Language" (MRI Systems Corp., 1974b) computer program allows persons not trained in computer languages to use brief, English-like commands to retrieve simple printouts of data. A water-level table produced by using this program is shown in figure 4. For more elaborate presentation of data, a feature called "Report Writer" (MRI Systems Corp., 1974c) is available as part of the DBMS.

If the "Natural Language" and "Report Writer" facilities are insufficient for retrieving data in a prescribed format, SYSTEM 2000 has an additional feature, "Programing Language Extension" (PLEX) (MRI Systems Corp., 1979) that can include prescribed SYSTEM 2000 statements in the code of a higher level programing language, such as COBOL, FORTRAN, and PL/I. With PLEX, any GWSI data item can be manipulated at the user's discretion. The user may produce specialized reports, use statistical or graphical routines, and pass data to or merge with other computer files. The Survey has several PLEX computer programs that produce report tables, X-Y plots, and map plots for many of the data in the GWSI (see figures 5, 6, and 7).

USERS AND USE OF THE GWSI

The principal contributors to, and users of, the GWSI are personnel of the Survey. However, many engineering and environmental consultants retrieve data from the GWSI file, as do university researchers and State and local governmental agencies. Individuals also request ground-water information for their own use.

An evaluation of the ground-water resources of an area generally begins with a perusal of the existing data. For many areas, GWSI provides this starting point by supplying information about many of the

```
LIST/REPEAT SUPPRESS/ C1,C235,C237
----
 WH C1 EQ 392854106024501 OR
----
C1 EQ 393439106055901 OR
----
C1 EQ 393633105580601:
* SITE-ID                  WL-MEAS-DATE        WL-MEASUREMENT
***
* 392854106024501           08/10/1976                  19.73
*                           09/13/1973                  21.00
*                           09/17/1975                  20.31
*                           10/14/1974                  25.44
* 393439106055901           08/09/1977                  18.91
*                           08/10/1976                  12.40
*                           09/14/1973                  11.88
*                           09/17/1975                  11.96
*                           08/09/1978                  13.23
*                           08/22/1979                  11.89
* 393633105580601           08/10/1976                  40.66
*                           09/23/1977                  42.27
*                           09/13/1973                  43.41
*                           09/17/1975                  41.89
*                           10/14/1974                  43.90
*                           08/09/1978                  41.62
*                           08/22/1979                  43.39
*                           08/07/1980                  43.58
```

FIGURE 4.—Water-level table produced by using a "Natural Language" retrieval command, which is listed above the table.

LOCAL NUMBER	ALTITUDE OF LAND SURFACE (FEET)	USE OF SITE	USE OF WATER	OWNER	PRINCIPAL AQUIFER	TEMPERATURE (DEGREES C)	SPECIFIC CONDUCTANCE (UMHOS/CM AT 25 C)
SC01604632DDAC1 0	75	W	H	HAZENBERG, HANK	110QRNR	--	--
SC01604634BCBC1 0	50	W	H	ERICKSON, ARNE	--	--	--
SC01604634BCDD1 0	55	W	H	COOK, TIM	110QRNR	--	--
SC01604634BCDD2 0	55	W	H	BLUSH, ROBERT	110QRNR	--	--
SC01604634CBAD1 0	35	W	H	HILL, FRANK	110QRNR	3.0	70
SC01704429CBDC1 0	90	U	U	USAF KGSLM, 3RD RADIO	110QRNR	--	--
SC01704510DCCC1 0	60	W	H	ANGASAN, RALPH	110QRNR	--	--
SC01704514BDDD1 0	80	W	C	RCA WH ALC, KING SLM	110QRNR	--	--
SC01704522BBBC1 0	50	W	H	WILLIAMS, BERTHA	110QRNR	--	--
SC01704522CCAB1 0	25	W	P	FAA, KING SLM	110QRNR	5.0	1100
SC01704523ABAC1 0	75	W	--	USAF, KING SLM	110QRNR	--	--
SC01704523ACCB1 0	50	U	U	USAF, KING SLM	110QRNR	--	--
SC01704523ADCC1 0	75	Z	U	USAF, KING SLM	110QRNR	--	--
SC01704523BACD1 0	75	W	P	USAF, KING SLM	110QRNR	5.0	280
SC01704523BACD2 0	75	W	P	USAF, KING SLMN	110QRNR	--	--
SC01704523BBAB1 0	75	W	P	USAF, KING SLM	110QRNR	--	--
SC01704523CDCB1 0	35	U	U	WOOD Z, LODGE	--	--	--
SC01704523CDCB2 0	35	W	C	WOOD Z, LODGE	--	--	--
SC01704523CDCB3 0	35	W	C	EDDIES, FRPLC IN	--	--	--
SC01704523CDCD1 0	35	W	Z	ADF & G, KING SLM	--	--	--

Explanation of codes:

(1) Use of Water
- W Withdrawal of Water
- U Unused
- Z Destroyed

(2) Use of Water
- H Domestic
- U Unused
- C Commercial
- P Public Supply
- Z Other

(3) Principal Aquifer
Quaternary System

FIGURE 5.—Report table of GWSI data produced by PLEX program.

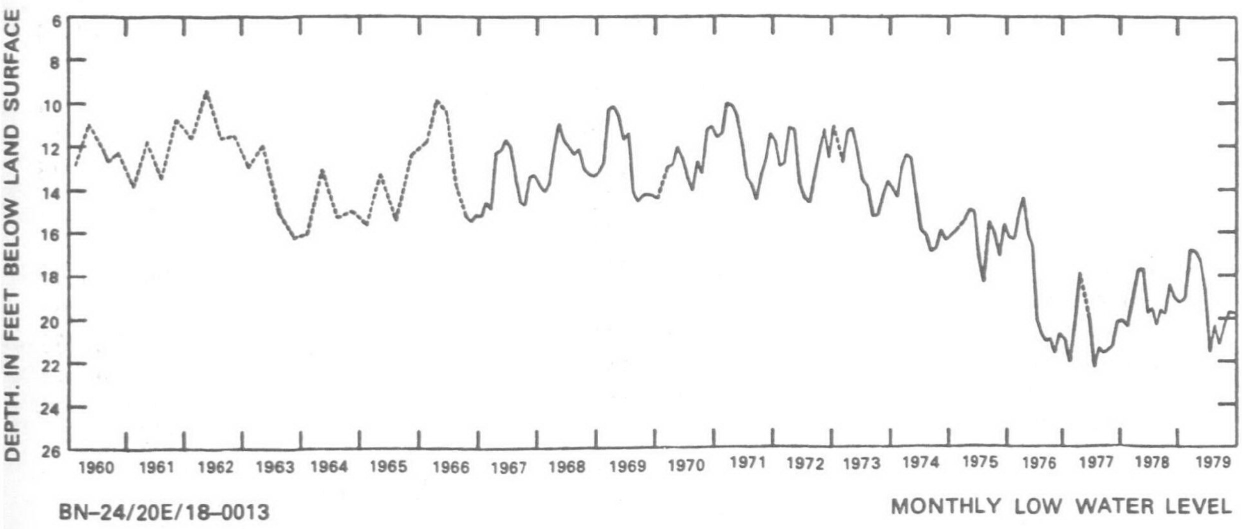

FIGURE 6.—Hydrograph showing water levels in a typical well during a 20-year period of record. Dashed line indicates period of intermittent record.

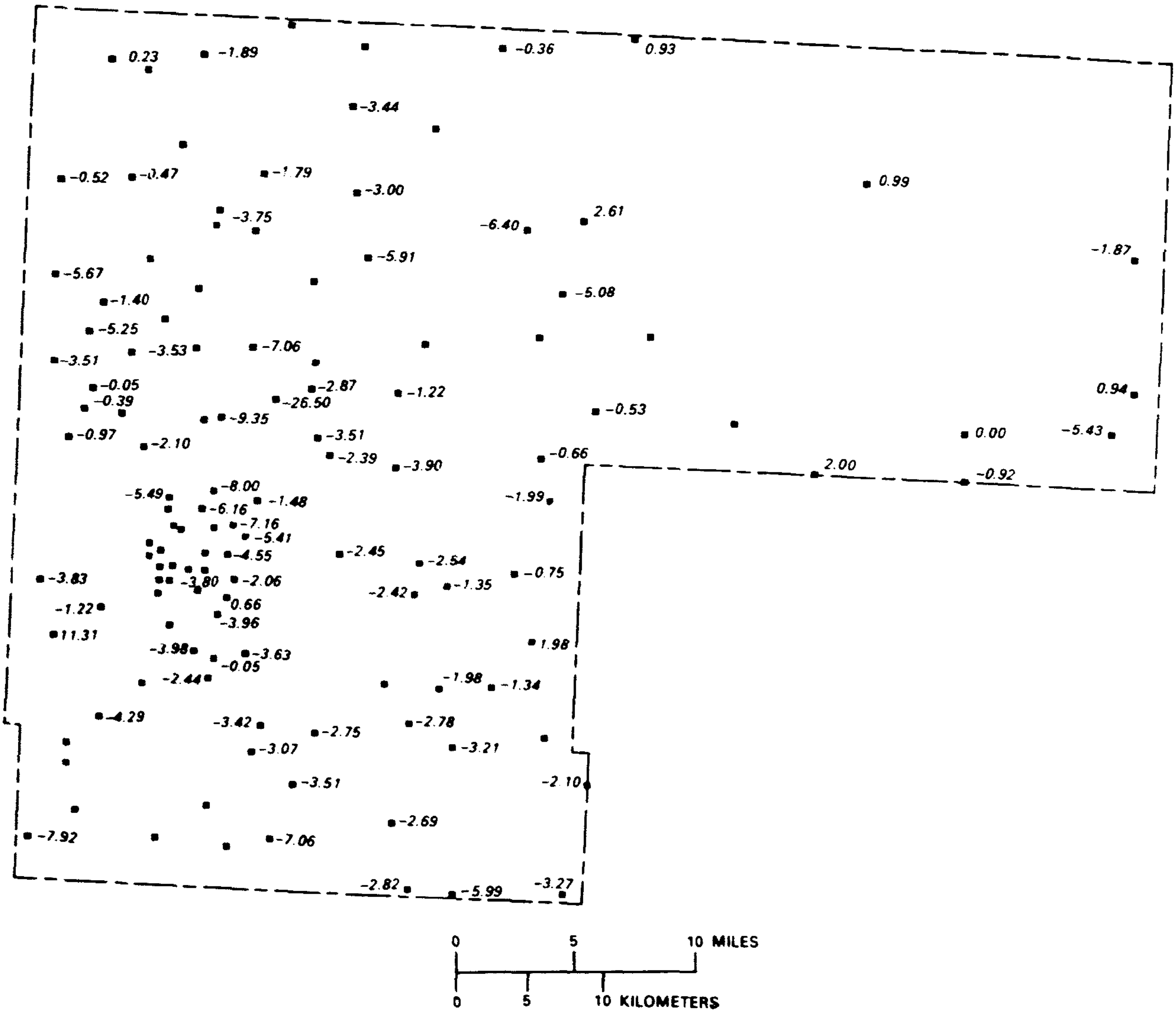

FIGURE 7.—Example of computerized map plot from the GWSI data base, on a Kansas county outline. Water level changes, in feet, are indicated at many sites.

existing wells and springs. Historical water-level data, from which hydrographs and maps of potentiometric surfaces may be constructed, are particularly helpful. These data also may aid in interpreting the effects of climate fluctuations and resource development in the area under study.

Data may be obtained from the GWSI either by submitting a request to NAWDEX (Edwards, 1978) or by establishing direct, online access to the data bases. NAWDEX services are available through a nationwide network of Assistance Centers (Edwards, 1980) located in 45 States and Puerto Rico. The locations of these centers are given in table 2, and a free directory of all Assistance Centers may be obtained from NAWDEX (see the address given below). Charges for retrieving data are assessed at the rate of the actual cost of retrieval of the requested data from the GWSI. Those users desiring direct, online access to the GWSI must sign a Memorandum of Agreement with the Survey for this purpose and must assume full financial responsibility for their use of the Survey's computer system. This agreement authorizes users to input data to the GWSI, as well as make retrievals from it. Requests for direct access to the data base must be submitted in writing to the Program Manager, National Water Data Exchange, U.S. Geological Survey, 421 National Center, Reston, VA 22092.

TABLE 2.—*Locations of NAWDEX Assistance Centers*

ALABAMA	Tuscaloosa.
ALASKA	Anchorage.
ARIZONA	Tucson.
ARKANSAS	Little Rock.
CALIFORNIA	Menlo Park.
COLORADO	Lakewood (Denver) and Ft. Collins.
CONNECTICUT	Hartford.
FLORIDA	Tallahassee, Miami, Orlando, and Tampa.
GEORGIA	Doraville (Atlanta).
HAWAII	Honolulu (also serves American Samoa and Guam).
IDAHO	Boise.
ILLINOIS	Champaign.
INDIANA	Indianapolis.
IOWA	Iowa City (2 locations).
KANSAS	Lawrence.
KENTUCKY	Louisville.
LOUISIANA	Baton Rouge.
MARYLAND	Towson (also serves Delaware and District of Columbia).
MASSACHUSETTS	Boston (also serves Maine, New Hampshire, Rhode Island, and Vermont).
MICHIGAN	Okemos (Lansing) and Ann Arbor.
MINNESOTA	St. Paul.
MISSISSIPPI	Jackson.
MISSOURI	Rolla.
MONTANA	Helena.
NEBRASKA	Lincoln (2 locations).
NEVADA	Carson City.
NEW JERSEY	Trenton.
NEW MEXICO	Albuquerque.
NEW YORK	Albany and Syosset.
NORTH CAROLINA	Raleigh.
NORTH DAKOTA	Bismarck.
OHIO	Columbus.
OKLAHOMA	Oklahoma City.
OREGON	Portland and Salem.
PENNSYLVANIA	Harrisburg and Philadelphia.
PUERTO RICO	Ft. Buchanan (San Juan) (also serves Virgin Islands).
SOUTH CAROLINA	Columbia.
SOUTH DAKOTA	Huron.
TENNESSEE	Nashville.
TEXAS	Austin.
UTAH	Salt Lake City (2 locations) and Logan.
VIRGINIA	Richmond, Blacksburg, and Reston.
WASHINGTON	Tacoma.
WEST VIRGINIA	Charleston.
WISCONSIN	Madison.
WYOMING	Cheyenne.

CONCLUSIONS

Solution of today's complex hydrologic problems requires the timely availability of reliable ground-water data. The GWSI data base, in conjunction with the SYSTEM 2000 data base management system, provides these reliable and unbiased ground-water data for the hydrologist or planner who requires quick and easy access to them.

Standardization of input-retrieval procedures and data formats exists in the GWSI for all data, and the techniques of manipulating the ground-water data are the same throughout the United States. The goals of the Survey in establishing a nationwide ground-water data base, thus, have been accomplished.

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Collection, Storage, Retrieval, and Publication of Water-Resources Data

Standardization of Hydrologic Measurements
By G. F. Smoot

Use of Earth Satellites for Automation of Hydrologic Data Collection
By R. W. Paulson

Operational Hydrometeorological Data-Collection System for the Columbia River
By N. A. Kallio

Storage and Retrieval of Water-Resources Data
By C. R. Showen

Publication of Water-Resources Data
By S. M. Lang and C. B. Ham

GEOLOGICAL SURVEY CIRCULAR 756

1978

STORAGE AND RETRIEVAL OF WATER-RESOURCES DATA

By Charles R. Showen

ABSTRACT

The U.S. Geological Survey investigates the occurrence, quantity, quality, distribution, and movement of the surface and underground waters that comprise the water resources of the United States. It is the principal Federal water-data agency and, as such, collects and disseminates about 70 percent of the water data currently being used by numerous State, local, private, and other Federal agencies to develop and manage the Nation's water resources. As part of the Geological Survey's program of releasing water data to the public, a large-scale computerized system has been developed for the processing, storage, and retrieval of water data collected through its activities.

The U.S. Geological Survey's National Water Data Storage and Retrieval System (WATSTORE) was established in November 1971 to modernize water-data processing procedures and techniques and to provide for more effective and efficient management of data-releasing activites. The system is operated and maintained on the central computer facilities of the Survey at its National Center in Reston, Va.

INTRODUCTION

The Geological Survey currently (1976) collects data at approximately 10,000 stream-gaging stations, 1,300 lakes and reservoirs, 4,300 surface water-quality stations, 4,100 water-temperature stations, 880 sediment stations, 2,500 water-level observation wells, and 5,800 ground-water-quality wells. Each year, many water-data collection sites are added and others are discontinued; thus, large amounts of diversified data, both current and historical, are amassed by the Survey's data collection activities. A large-scale computerized storage and retrieval system is used by the Geological Survey to store and disseminate water data acquired through its many activities.

The National Water Data Storage and Retrieval System (WATSTORE) was established in November 1971 to provide for more effective and efficient management of the Survey's data-releasing activities. The WATSTORE system provides for the processing, storage, and retrieval of water data pertaining to surface water, quality of water, and ground water. At present, there are 50 Geological Survey remote job-entry sites (fig. 5), located in various offices throughout the country, that are equipped with high-speed computer terminals for remote access to the system.

GENERAL SYSTEM DESCRIPTION

The WATSTORE system consists of several files (fig. 6) in which data are grouped and stored by common characteristics and data collection frequencies. The system is also designed to allow for the inclusion of additional data files if the need should arise in future years. Currently, the following files are maintained: (1) Daily Values File, which is composed of surface-water, quality-of-water, and ground-water data measured on a daily or continuous basis; (2) Peak Flow File, which is composed of annual peak values for streamflow stations; (3) Water-Quality File, which is composed of chemical and biological analyses for surface- and ground-water sites; and (4) Ground-Water Site-Inventory File, which is composed of hydrologic, geologic, and well-inventory data for ground-water sites. In addition, a Station Header File, an index file of sites for which data are stored in the system, is also maintained.

Most of the computer programs used in the system are written in Programming Language 1 (PL/1) for the IBM 360 or 370 series computers[2] and were developed internally to satisfy the data-processing requirements of the Geological Survey. The WATSTORE system is directly accessible by computer terminals which are maintained by the Geological Survey and other Federal and State agencies.

DETAILED SYSTEM DESCRIPTION

The WATSTORE system is designed to use magnetic disk to store current data and magnetic tape to store historical data. This technique is used because of the high cost involved in maintaining online disk files. Approximately 15 per-

[2]The use of trade names does not constitute endorsement by the U.S. Geological Survey.

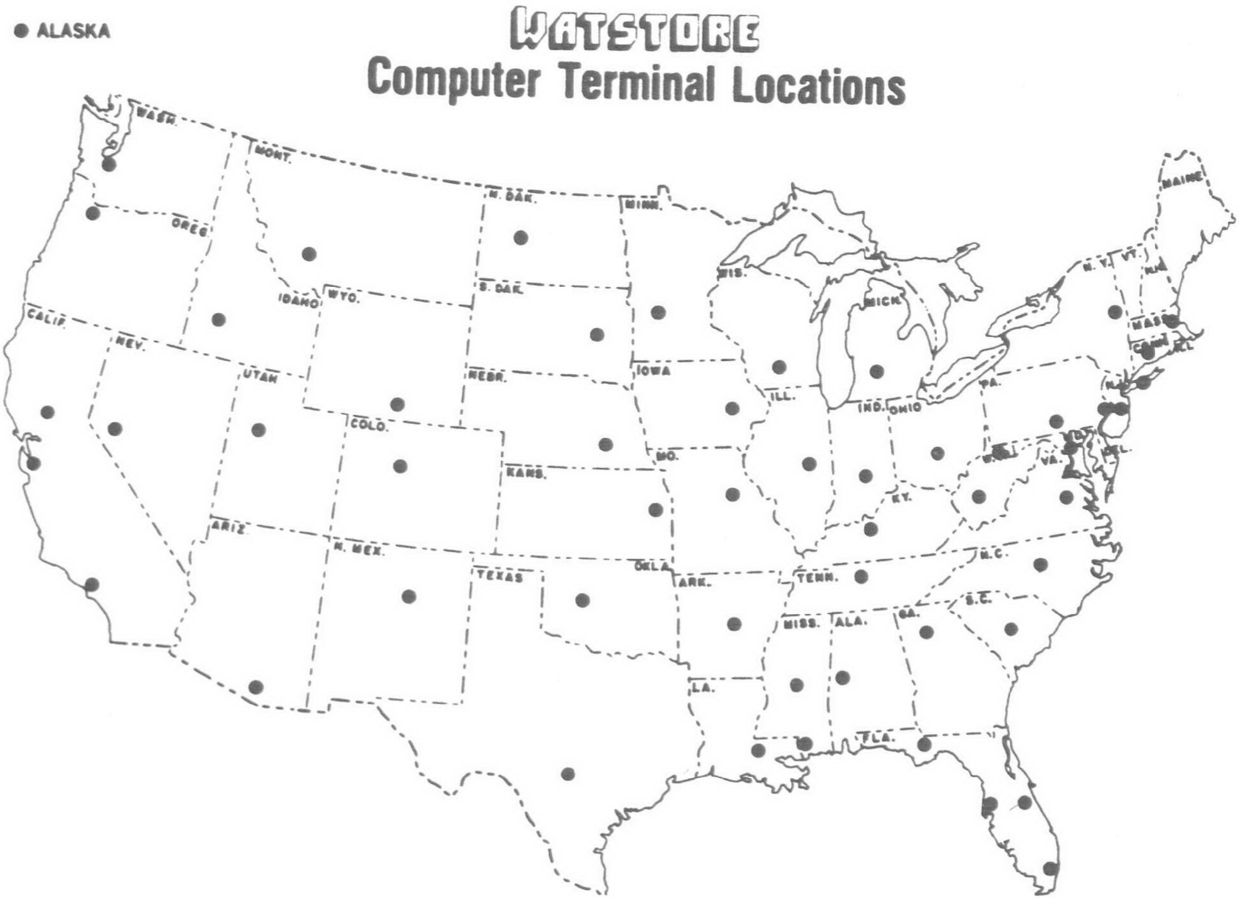


FIGURE 5.—Map indicating location of WATSTORE computer terminals.

cent of the data is stored on magnetic disk and the remainder on magnetic tape. "Current data" is defined as data for the current year and the year immediately preceding. Data failing to meet this criterion are removed periodically from disk and merged with data in the historical file, which is maintained in a sequential manner on magnetic tape by station identification number and date. The retrieval computer programs permit data to be retrieved from the current file, the historical file, or both files.

The Station Header File and the Daily Values File have the option to "password" protect data stored in these files for one or more specified sites. The use of password protection prohibits unauthorized updates and (or) retrieval from the files. These files also provide for the identification of data by an agency code which permits data to be stored for agencies outside the Geological Survey.

A brief description of each of the WATSTORE files is given below:

STATION HEADER FILE

The Station Header File contains information pertinent to the identification, location, and physical description of over 130,000 sites for which data are stored in the WATSTORE files. The file serves as an automated index from which a retrieval list of stations may be obtained without searching massive data files. The information items stored in this file are listed below:

- Agency code
- Station identification number
- Station locator (latitude–longitude)
- State code
- District code
- County code
- Drainage area
- Contributing drainage area
- Site code
- Station name
- Hydrologic unit code

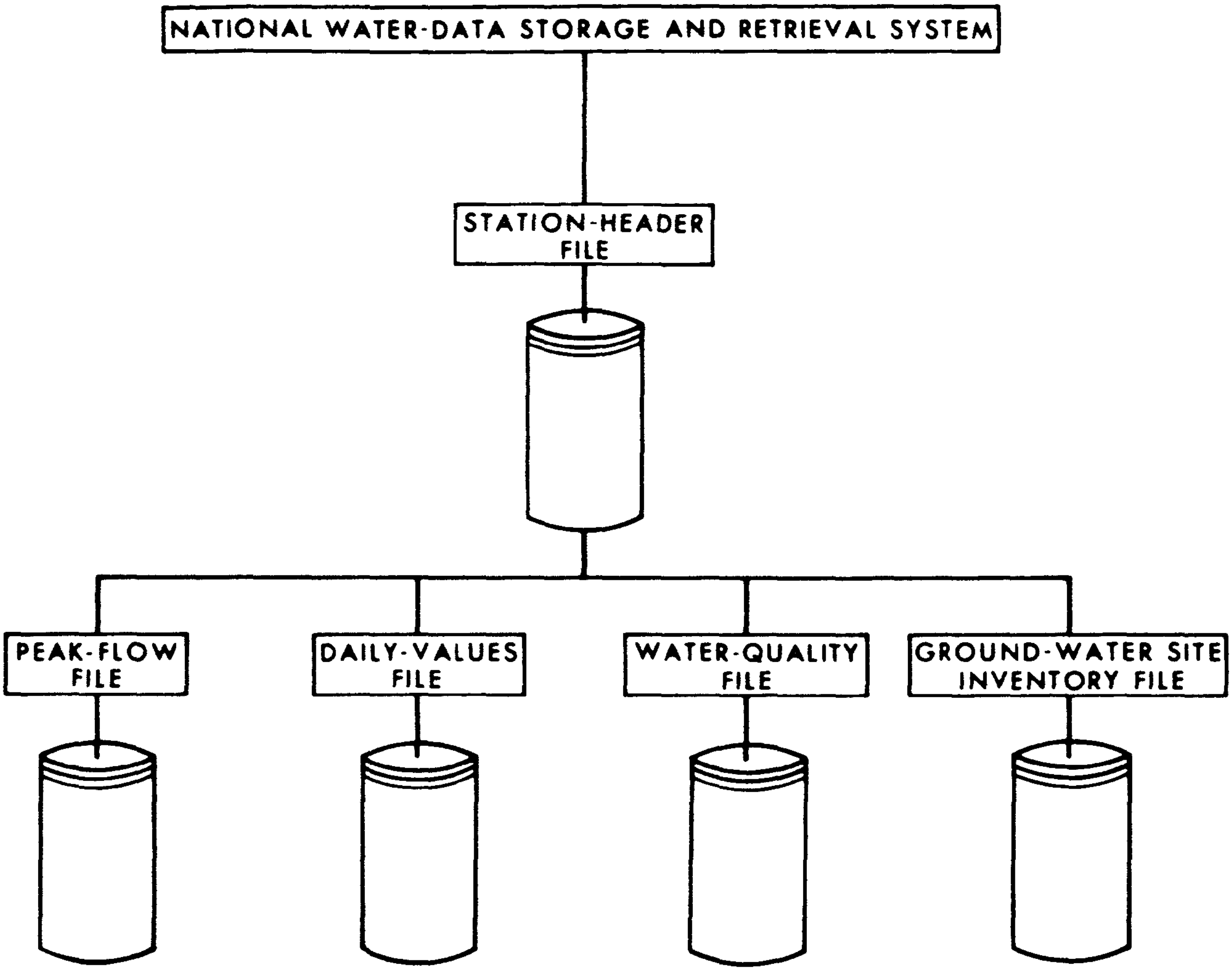


FIGURE 6.—Schematic representation of WATSTORE files.

- Gage or land surface datum
- Geologic unit code
- Well depth
- Aquifer type
- Password

The eight underlined items are mandatory items for each station, and data are not permitted to be stored in the data files without this information. The mandatory fields were so designated because of retrieval purposes, for example, the capability of being able to retrieve all stations in a particular county in a particular State.

A typical example of the use of this file would be to select a group of data satisfying a defined set of criteria, such as to provide a list of stations that have surface-water data in the files and are located in Fairfax County, State of Virginia, that have a drainage area of less than 20 square miles. Computer programs are available that will permit the retrieval stations to be plotted on a line printer using various scales suitable for use as a map overlay, as well as to print selected data only for the retrieval stations. The retrieval stations list also may be used as input to retrieval programs for other WATSTORE files.

DAILY VALUES FILE

The Daily Values File contains water-data parameters measured or observed either on a daily or on a continuous basis and numerically reduced to daily values. Instantaneous measurements at fixed-time intervals, daily mean values, and statistics such as daily maximum and minimum values also may be stored. This file currently contains over 120 million daily values including data for streamflow values, river stages, reservoir contents, water temperatures, specific conductance values, sediment concentrations, sediment discharges, and ground water levels.

The data in this file are identified in the following manner:

- State code
- Agency code
- Station identification number
- Cross section locator (Distance in feet from left bank)
- Sampling depth (Depth at which observation was made)
- Parameter code (Five-digit numeric code to identify the parameter measured)
- Water year (The 12-month period, October 1 through September 30)
- Statistic code (Five-digit numeric code to identify the frequency of measurement or numeric reduction of the data)

Each record in this file contains daily values for a water year (October 1 through September 30). Since most retrievals from the file are made on a State basis, the records in storage are grouped by States to minimize retrieval costs.

Data may be retrieved from the Daily Values File in the following formats: (1) in the form of a computer printout (listing), (2) in punched card form, (3) in a monthly character format on a magnetic device (usable on almost any type computer), and (4) in the standard daily values record format on a magnetic device.

This file also has password protection to protect records against unauthorized updating and (or) retrieval.

A generalized retrieval program retrieves records from this file in machine-readable form and passes the retrieved records to computer application programs. Examples of the application programs are:

- Publication tables
- Data inventory of selected portions of the file
- Preparation of X–Y plots on the Calcomp plotter
- Preparation of monthly and annual statistics
- Preparation of duration tables, low- and high-value sequence summaries, and log-Pearson frequency distributions

WATER-QUALITY FILE

The Water-Quality File contains information pertaining to the chemical, physical, biological, and radiochemical composition of both surface and ground water. The data stored in this file are primarily obtained through the analytical techniques performed by the three central water-quality laboratories operated by the Geological Survey. At present, this file contains the results of over 850,000 analyses of water samples, and the analyses may contain data for more than 570 different constituents.

The data in this file are identified as follows:

- Station identification number
- Collection date
- Time of collection
- Parameter code (Five-digit numeric code to identify the parameter measured)

Data may be retrieved from the Water-Quality File in the form of a computer printout (listing), in punch-card form or as punch-card images on a magnetic device, and in the standard water-quality record format on a magnetic device.

A generalized retrieval program retrieves records from this file in machine-readable form and passes the retrieved records to computer application programs. Examples of the application programs are:

- Publication tables
- Frequency analyses
- Stiff diagrams
- Piper diagrams
- Collins diagrams
- Ropes diagrams
- Irrigation classification
- Ratio tables
- Map plots
- Interface with statistical programs for plotting and contouring on Calcomp plotters

PEAK FLOW FILE

The Peak Flow File contains the annual maximum (peak) streamflow (discharge) and the annual maximum gage height (stage) values obtained at surface-water sites. It currently contains more than 350,000 annual maximum observations.

Data may be retrieved from the file in the form of tables, card images, or records on a magnetic device. The primary application program for this file is a program that computes log-Pearson Type III frequency distribution. This program produces a table of basic statistics, theoretical values, and a frequency distribution plot of both actual and theoretical values.

GROUND-WATER SITE-INVENTORY FILE

The Ground-Water Site-Inventory File contains inventory data about wells, springs, and other sources of ground water. The data included are site location and identification, geohydrologic characteristics, well-construction history, and one-time field measurements such as water temperature.

The Ground-Water Site-Inventory File is managed and maintained through a generalized Data-Base Management System called SYSTEM 2000. This system is marketed by MRI Systems Corp., Austin, Tex. SYSTEM 2000 is oriented to the collection, maintenance, and manipulation of data en masse, and it provides a report-generation capability, a data-base loading facility, a teleprocessing interface, and a query language. The Ground-Water Site-Inventory File is designed to accommodate 209 data elements. At present, the file contains data for 140,000 sites. This file is currently being built and the number of sites is anticipated to increase to 1 million within a year.

Using the retrieval language which is available as a part of SYSTEM 2000, data can be retrieved selectively and listed in a variety of ways. A program to retrieve selected data and prepare publication tables has been written, and programs to interface the file with plotter and statistical routines are under development.

SYSTEM OPERATION

All data files of the WATSTORE system are maintained and managed on the central computer facilities of the Geological Survey at its National Center in Reston, Va. However, data may be entered into or retrieved from WATSTORE through a number of locations that are part of a nationwide telecommunication network.

At present, there are 50 Geological Survey remote job-entry sites, located in various offices throughout the country, that are equipped with high-speed computer terminals for remote access to the WATSTORE system. These terminals provide rapid and efficient access to the system and allow each site to enter data or retrieve data from the system within several minutes to overnight, depending upon the priority placed on the request.

The Geological Survey operates more than 9,000 data collection stations that remotely collect water data on punched-paper tape. To provide for current and timely processing and reporting of these data, a transmission network provides for the local translation of data to a computer-compatible form and transmits the translated data over telephone circuits to the central computer facility. These data are then processed by the central computer via a computer terminal located at the transmission site. The results obtained by this procedure are simultaneously stored in the WATSTORE files and printed at the transmission site.

Data are also entered into the files which are obtained from the LANDSAT and GOES (Geostationary Operational Environmental Satellite) satellite systems. At present data from 150 sites are being collected in this manner.

Three central water-quality laboratories that analyze more than 60,000 water samples per year also contribute data to the system. The laboratories are highly automated and perform chemical analyses that range from determinations of simple inorganic compounds such as chlorides to complex organic compounds such as pesticides. As each analysis is completed, the results are verified by laboratory personnel and then transmitted via a computer terminal and stored in the WATSTORE system.

SYSTEM PRODUCTS

Water data compiled by the Geological Survey are used in many ways by decision makers for the management, development, and monitoring of water resources. Thus, in addition to its data processing, storage, and retrieval capabilities, WATSTORE can provide a variety of useful products to meet diverse needs. These products range from simple retrieval of data in tabular form to complex statistical analyses. A wide variety of retrieval options for the system are available, such as,

- Individual station
- Polygon of latitude–longitude
- State
- County
- Aquifer code (for ground-water sites)

- Dates
- Individual parameters
- Greater than or less than specified parameter values

A typical retrieval request might be for a list of all the dissolved-oxygen values of less than 5.0 mg/l (milligrams per liter) for a particular county in a particular State.

A summary of the products available is as follows:

1. Computer-Printed Tables: Users most often request data from WATSTORE in the form of tables printed by the computer. These tables may contain lists of actual data or condensed indexes that indicate the availability of data stored in the files. A variety of formats is available to display the many types of data.
2. Computer-Printed Graphs: Another capability of WATSTORE is to computer-print graphs for the rapid analysis or display of data. Computer programs are available to produce bar graphs (histograms), line graphs, frequency-distribution curves, X–Y point plots, site-location map plots, and similar items by means of line printers.
3. Statistical Analyses: WATSTORE uses the Geological Survey's collection of computer programs known as STATPAC (Statistical Package) to provide extensive analyses of data such as regression analyses, the analysis of variance, transformations, and correlations.
4. Digital Plotting: WATSTORE also makes use of software systems that prepare data for digital plotting on peripheral, offline Calcomp plotters available at the central computer site. Plots that can be obtained include hydrographs, frequency-distribution curves, X–Y point plots, contour plots, and three-dimensional plots.
5. Data in Machine-Readable Form: Data stored in WATSTORE also can be obtained in machine-readable form for use on other computers or for use as input to user-written computer programs. These data are available in the standard storage formats of the WATSTORE system or in the form of punch cards or punch-card images on magnetic tape.

FEATURE

A Survey of the Water Well Industry

A recent *Water Well Journal* survey of water well contractors and pump installers from around the United States describes a typical contractor as a sole proprietor, most likely living in the midcontinent area, engaged in both drilling and pump work who has been in business for almost 20 years.

Marketing Advancements, a national market research and consulting firm specializing in the water well and shallow oil and gas well industries, was commissioned by the *Water Well Journal* to conduct the survey during August and September of 1984.

The *Journal*'s objectives were:

- To develop a profile of contractor demographic characteristics
- To determine the scope of the industry
- To determine how contractors purchase pumps and construction equipment.

From a sampling universe of 10,866 contractor readers of *Water Well Journal*, Marketing Advancements selected randomly, on an "nth" name basis, 1,440 names to receive a direct mail questionnaire. An excellent 40.7 percent return rate was achieved for a study sample of 587 respondents.

Firms of those surveyed typically installed about 50 submersible pumps in 1983, of which 45 were in private home wells. More than half of these installations were for new wells. Contractors expect the submersible or jet pump to have a lifetime of about 10 years. The most common types of installations cited were ½ horsepower submersible pumps and 2¼-to 6-inch well diameters.

The typical contractor primarily installed PVC casing and homemade punched or slotted screen. Total costs charged by contractors for private home/domestic wells in 1983 were about $2,600.

The typical contractor owned one of each drilling rig type, one pump hoist, one pipe/water truck and two pickup trucks. A high percentage of these units were more than six years old in 1983, leading a high percentage of contractors to intend to purchase or lease additional equipment before 1986.

Less than one-third of all water well contractors were involved in any new ground water heat pump installations. Those that were most typical constructed the heat pump well.

Comments included by respondents reflect a contractor body interested and appreciative of the survey—and to *Water Well Journal*—for their potential benefits to the industry. Other frequent comments included mention of declining business due to the economy, government regulations or advancing personal age or retirement. Hopes for improvement in the coming years were also expressed.

As one would expect, the survey sample was located predominantly in the midcontinent region, with respondents here comprising more than two-fifths of the total.

State Where Firm Is Located:

43.1%	Midcontinent (Ill., Ind., Mich., Ohio, Wis., Iowa, Kan., Minn., Mo., Neb., N.D., S.D.)
22.6	South (Del., Fla., Ga., Md., N.C., S.C., Va., W.Va., Ala., Ky., Miss., Tenn., Ark., La., Okla., Texas)
18.1	West (Ariz., Colo., Mont., Idaho, Nev., N.M., Utah, Wyo., Alaska, Calif., Hawaii, Ore., Wash.)
16.2	Northeast (Conn., Maine, Mass., N.H., R.I., Vt., N.J., N.Y., Pa.)

Sole proprietorships continued to dominate the water well industry, although more than one-third of the respondents classified themselves as corporations.

Business Is A:

53.8%	Sole proprietorship
36.8	Corporation
9.4	Partnership

The vast majority of contractors were engaged in both drilling and pump work.

Business' Work Is:

61.1%	Both drilling and pump work
19.2	Only pump work
11.3	Only drilling
8.4	Other

Contractors were somewhat more likely not to be members of state water well associations than members. Membership in the National Water Well Association was at a lower rate.

State Association?		NWWA Member?	
47.2%	Yes	28.3%	Yes
52.8	No	71.7	No

The ages of contractors' businesses ranged from less than one to 184 years, with the average (mean) age at 24 years (year of establishment being 1960). However, the median year (same number of businesses older as younger) was 1965, with 1978 and 1981 being the most frequent years.

Firm Began Business In:

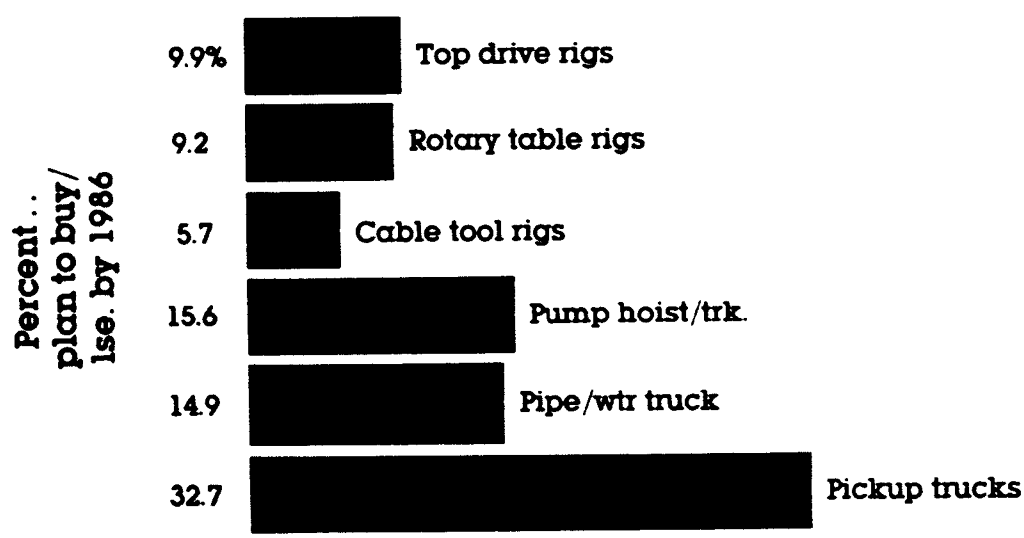
1950 or earlier	25.3%
1951-1960	15.4%
1961-1970	20.1%
1971-1980	28.8%
1981-1984	10.4%
Mean (average)	1960
Median (middle)	1965
Mode (most frequent)	1978, 1981

Submersible pumps dominated water well installation activity, with the average contractor installing 51 in 1983.

Number Installed in 1983

Mean	Median	
51	26	Submersible pumps
15	5	Jet pumps
5	0	Line-shaft turbine pumps
6	0	Other pump types

Purchase or Lease Plans (Before December 31, 1985), By Equipment Type



Most water well pump installation activity took place in the private home sector.

Number Installed in Private Homes (1983)

Mean	Median	
45	24	Submersible pumps
13	5	Jet pumps
3	0	Other pump types

Pump installations for irrigation purposes were much less frequent.

Number Installed in Irrigation Wells (1983)

Mean	Median	
3	0	Submersible pumps
2	0	Line-shaft turbine pumps
1	0	Other pump types

The majority of private home submersible pump installations were for new wells, while jets and other pumps were much less dominant.

Percentage of Pumps Installed in Private Homes for New Wells

53%	of submersible pumps
2	of jet pumps
8	of other pumps

The average pump in private home use is perceived to require replacement after about 10 to 13 years of operation.

Years Before Replacement

Mean Years	
10.4	Submersible pumps
12.9	Jet pumps
12.0	Other pump types

The majority of submersible pumps installed were in the ½ to 1 horsepower range.

Number of Pumps Installed in Each Horsepower Range (1983)

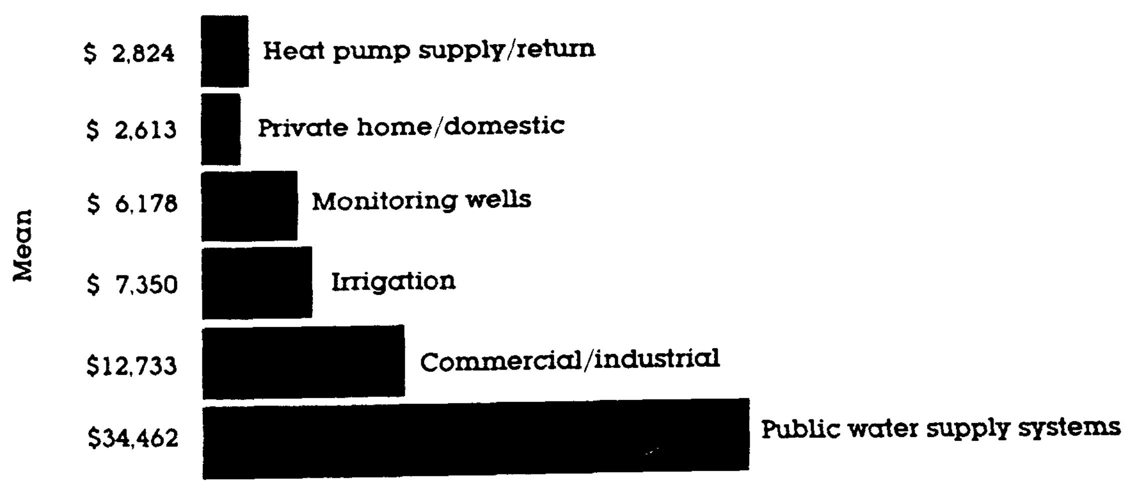
Mean Submersibles	Mean Jets	
6.2	2.1	Less than or 1/3 horsepower
28.8	10.3	1/2 horsepower
14.1	3.1	3/4 horsepower
10.3	5.4	1 horsepower
5.2	.7	1½ horsepower
2.4	<1.0	2 horsepower
2.1	<1.0	3 horsepower
2.8	.0	5 horsepower
<1.0	.0	7½ horsepower
1.0	.0	10 horsepower
3.5	.0	Higher than 10 horsepowers

By far the greatest activity of water well construction was in the private home area.

Number of Water Wells Constructed in Each Type (1983)

Mean	
50.6	Private home/domestic
4.9	Monitoring
4.6	Commercial/industrial
3.8	Irrigation
2.4	Heat pump supply/return
1.8	Public water supply system
9.4	Other types

Total Costs Charged Typical Customer (1983)



Water wells were most commonly installed with diameters listed in the 2¼- to 6-inch category.

Number of Water Wells with Each Diameter (1983)

Mean	
4.5	1- to 2-inch well points
5.8	2-inch or less (not well points)
46.6	2¼ to 6 inches
15.9	6½ to 12 inches
5.2	Larger than 12 inches

PVC and steel casing dominated the amount of casing footage installed by water well contractors in 1983.

Total Feet of Casing Type Installed (1983)

Mean Feet	
3,780	PVC
3,966	Steel
1,411	Galvanized steel
474	Others

Screens used in well construction were dominated by homemade punched or slotted types, although the commercial varieties found widespread use as well.

Total Feet of Screen Type Installed (1983)

Mean Feet	
3.65.0	Homemade punched or slotted
210.0	Commercial punched or slotted
136.0	Continuous slot (wire-wound)
134.5	Commercial plastic
131.7	Others

Water well contractors tended to own/lease only one drilling rig of each type they used. Ownership/leasing of multiple trucks was more prevalent.

Number of Equipment/Trucks Owned/Leased (1983)

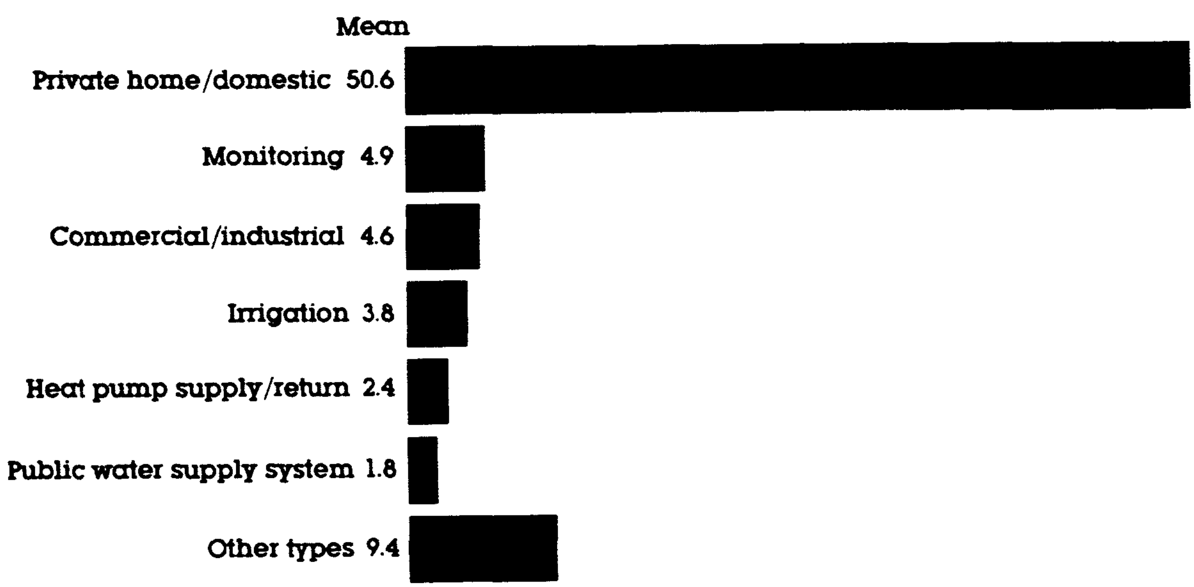
Mean	
.5	Top drive drilling rigs
.9	Rotary table drilling rigs
1.0	Cable tool drilling rigs
1.0	Pump hoists mounted on trucks
1.4	Pipe/water trucks
2.6	Pickup trucks

Equipment owned/leased ranged widely in age, with many older than six years. As would be expected, there is a very strong intent for additional equipment purchase/lease within the next year.

Number of Equipment Units in Each Age Category/Purchase or Leasing Plans (Before December 31, 1985)

	% of units owned				% plan to
	under 1 year	1-3 years	4-6 years	more than 6 years	buy/lse. by 1986
Top drive rigs	7.0	16.2	26.8	50.0%	9.9%
Rotary table rigs	2.4	11.5	13.0	73.1%	9.2
Cable tool rigs	.7	1.6	4.2	93.5%	5.7
Pump hoist/trk	5.0	13.6	29.4	52.0%	15.6
Pipe/wtr truck	2.7	10.1	22.0	65.2%	14.9
Pickup trucks	9.3	34.4	25.2	31.1%	32.7

Number of Water Wells Constructed in Each Type (1983)



There was a very low degree of involvement in 1983 with new ground water heat pump installations or new earth-coupled loop-type heat pump systems.

Water Well Contractor Involvement in Ground Water Heat Pumps Installations (1983)

Percent not involved with any new ground water heat pump installations	69.8%
Percent involved in complete installation	6.6%
Number installed (mean)	19.4
Percent doing partial (shared with contractors in other trades)	7.8%
Well contractor share of work (mean)	48.0%
Number installed (mean)	9.8
Percent only constructing well/pump (other contractors installing pump)	14.0%
Number installed (mean)	10.6
Percent involved in new earth-coupled loop-type heat pump systems	2.7%
Number installed (mean)	73

Water well installation costs averaged around $2,600 for private applications, and more than double that amount for the commercial sector.

Total Costs Charged Typical Customer (1983)

Mean	
$ 2,824	Heat pump supply/return
$ 2,613	Private home/domestic
$ 6,178	Monitoring wells
$ 7,350	Irrigation
$12,733	Commercial/industrial
$34,462	Public water supply systems

Why We Ask You — And a Thank You

Many of the 587 questionnaires returned to Marketing Advancements carried comments from the participants. Many were helpful notes of explanation and suggestions as how to better approach a subject. But we also received several remarks such as, "You are getting as bad as the government with all of these forms." We suspect that because 853 of the 1,440 mailed questionnaires never came back that many other members of the industry were also tired of answering questions.

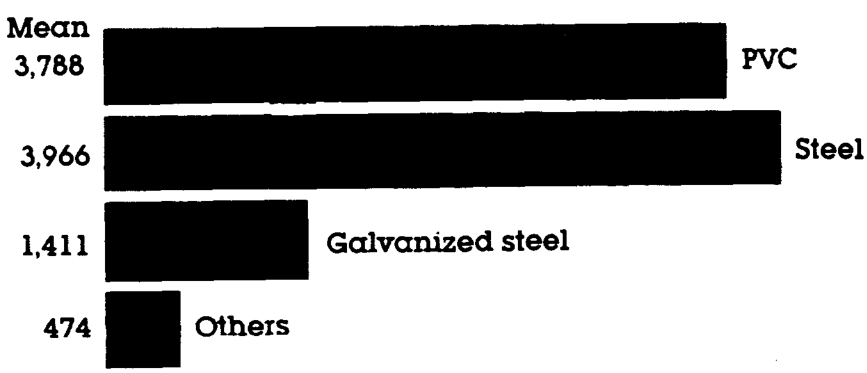
So why does the *Water Well Journal* persist in asking questions of members of the U.S. water well industry?

For several reasons.

For 39 years the *Water Well Journal* has been the recognized voice of the ground water industry. Obviously, we wish to maintain that position and perhaps even to build upon it. The best way for us to achieve that goal is to learn more about our industry and our readers—you. While we would enjoy meeting and talking with each of you personally—which we make a significant effort to do at the trade shows we attend and by the numbers we interview for each issue of the *Water Well Journal*—clearly, it would be an impossible task. Our best alternative, which we recognize and regret as being highly impersonal, is the mail survey.

Through the mail survey we can ask you to help us, to explain to us things we have wondered about, or have been asked questions about by the manufacturers of our industry—the people who are interested in providing more and better products to you so that you can better serve your customers and make a greater profit.

Total Feet of Casing Type Installed (1983)



We think you also benefit from the knowledge we gain and use to report stories that your answers have told us that you want to read. The *WWJ* editorial staff has already met and reviewed the results of this most recent survey and has started to plan where we can better serve you.

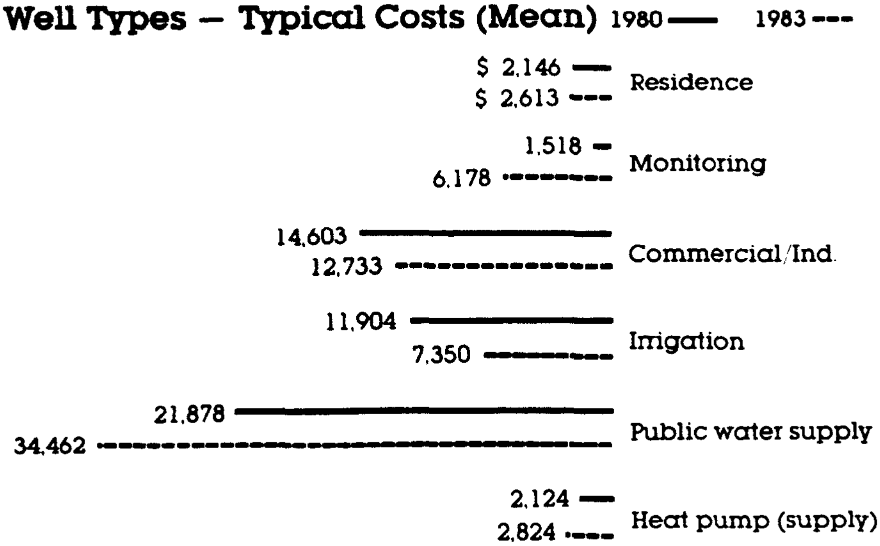
Of course, *WWJ* also benefits from your answers because we can show our advertisers more information about our industry. They in turn utilize this information to showcase in the *Water Well Journal* the products and services that they can offer you.

We suspect that the information we publish is also used by trade associations, scientists, government agencies and by our competitors. We're happy to share it with anyone.

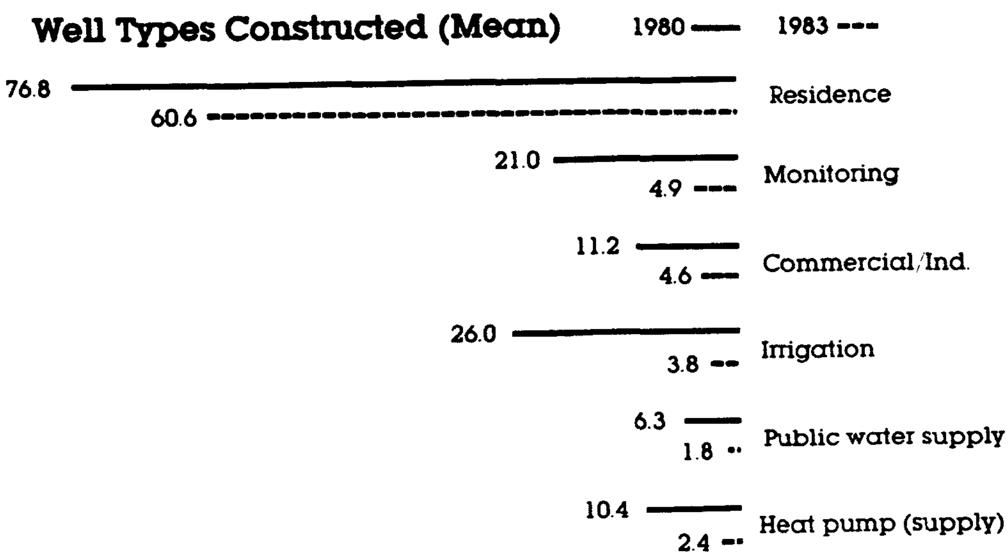
We think you also find our survey reports interesting. Time and again we are told by drillers and pump installers how much they enjoy reading about their industry peers from around the nation and even the world. We see our surveys as just another look at you, your competitors and your livelihood.

The *Water Well Journal* thanks all of the busy companies that answered our detailed questionnaire. Your help is immensely valuable. For those who couldn't help us on this most recent occasion, perhaps you'll be able to assist us if we should call upon you again. We hope so. ■

Well Types – Typical Costs (Mean)



Well Types Constructed (Mean)



X. OFFICE OF TECHNOLOGY ASSESSMENT: FINDINGS ON GROUND-WATER CONTAMINATION

Protecting the Nation's Groundwater From Contamination

OTA Reports are the principal documentation of formal assessment projects. These projects are approved in advance by the Technology Assessment Board. At the conclusion of a project, the Board has the opportunity to review the report, but its release does not necessarily imply endorsement of the results by the Board or its individual members.

CONGRESS OF THE UNITED STATES
Office of Technology Assessment
Washington D C 20510

Chapter 1

Protecting the Nation's Groundwater From Contamination: Findings

CHAPTER OVERVIEW

Contamination of groundwater—by organic and inorganic chemicals, radionuclides, and/or microorganisms—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 baseflow 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

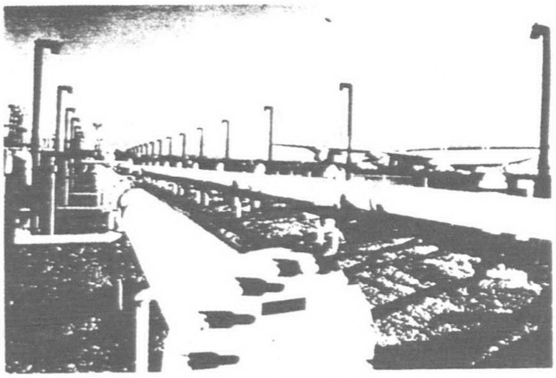


Photo credits: State of Florida Department of Environmental Regulation (left) and Office of Technology Assessment (right)

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.

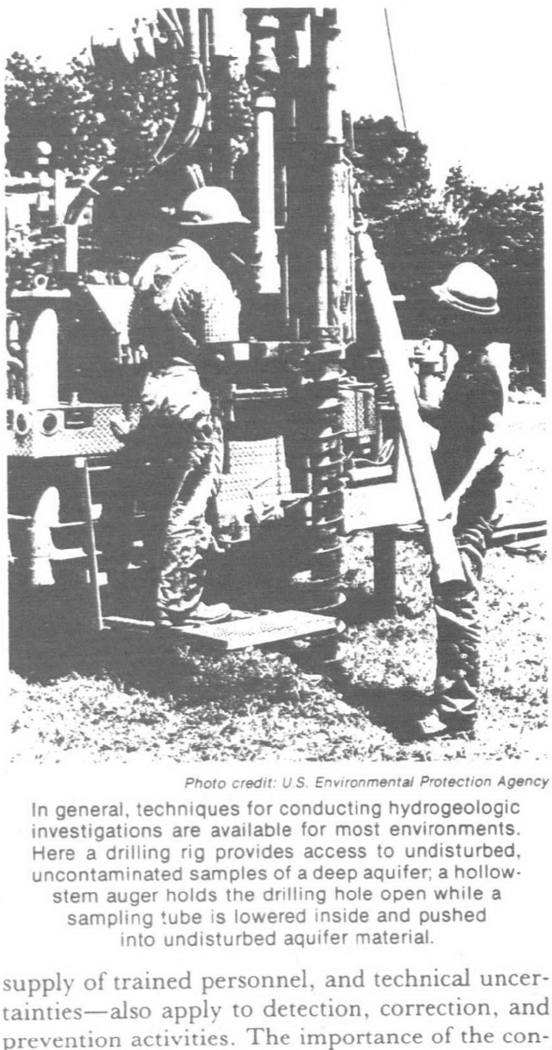


Photo credit: U.S. Environmental Protection Agency

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.

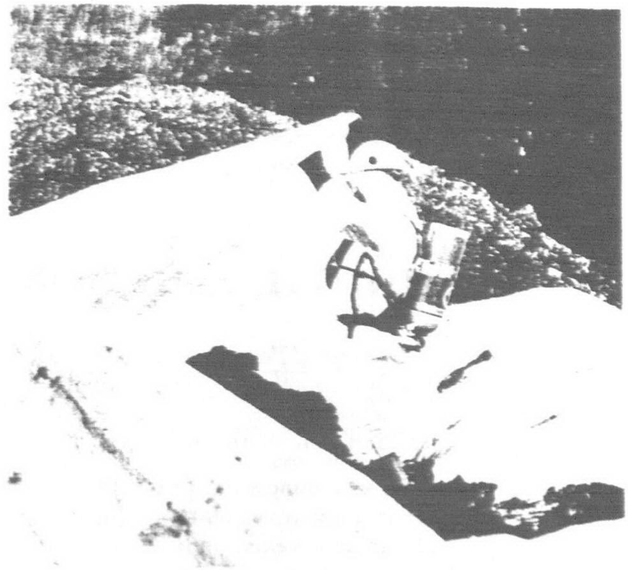


Photo credit: U.S. Environmental Protection Agency

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,

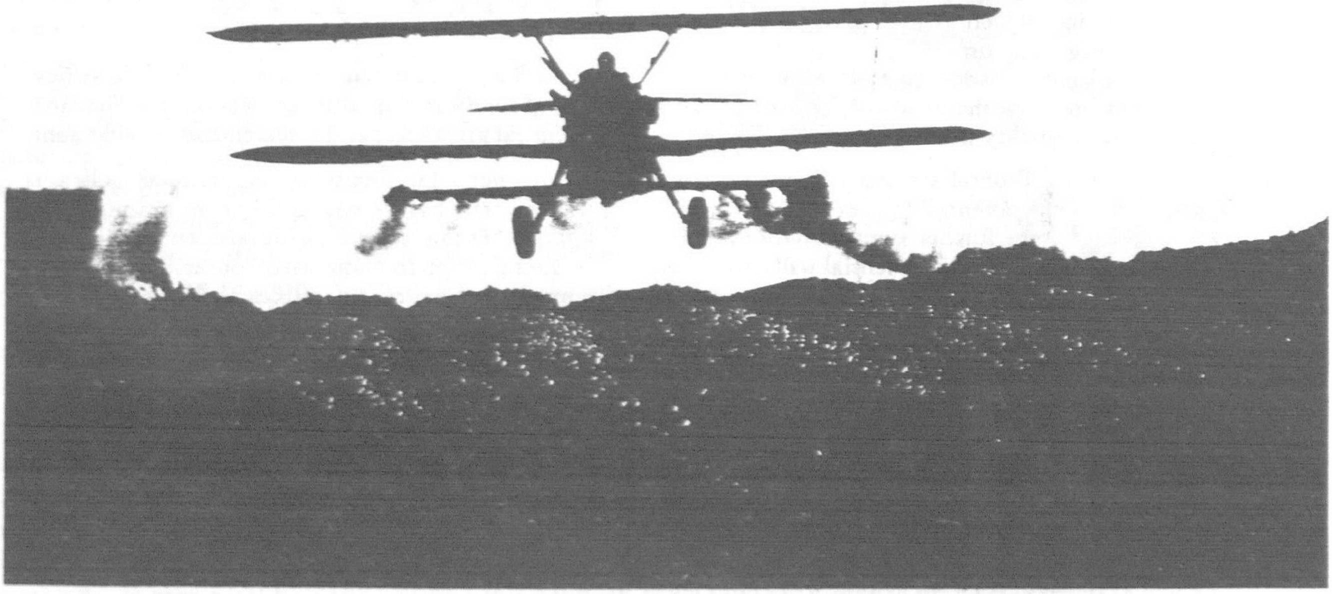


Photo credit: Charles O'Rear, U.S. Environmental Protection Agency

Many States lack adequate authority to deal with agriculturally related sources of groundwater contamination including pesticide and fertilizer applications and agricultural wastes.

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 contamination 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

Photo credit: John Gilbert, EPA Environmental Response Team

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

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.

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.

XI. SELECTED BIBLIOGRAPHY

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