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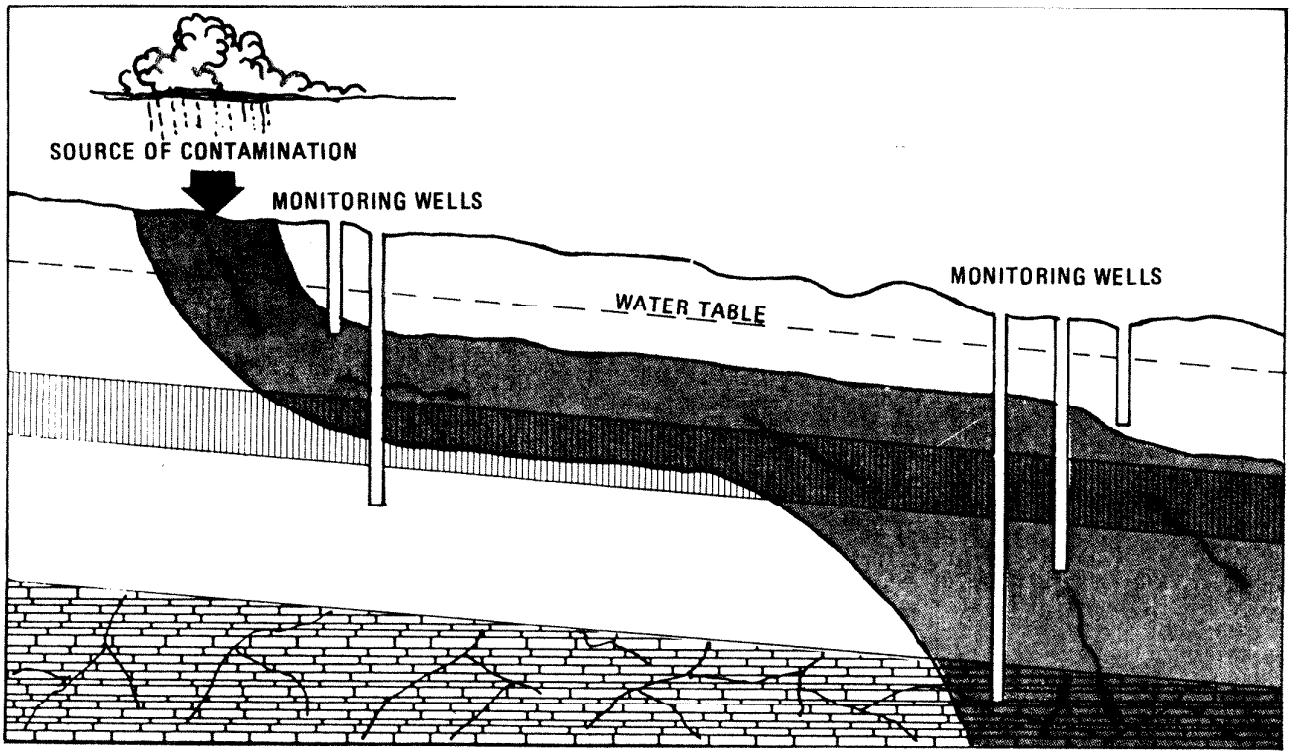
GROUND WATER MONITORING STRATEGY FOR WASHINGTON

III. Ground Water Monitoring Needs Evaluation

IV. Recommended Strategy for Addressing Monitoring Needs

JULY 1988



85-8C

WATER QUALITY INVESTIGATIONS SECTION
WASHINGTON STATE DEPARTMENT OF ECOLOGY

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EXECUTIVE SUMMARY

An integrated approach to ground water monitoring is needed to provide timely, relevant, and reliable information to protect and manage ground water resources in Washington. This is the third report in the Ground Water Monitoring Strategy series. The purpose of this report is to identify areas where improvements or additional effort are needed to ensure that the most urgent ground water data needs are effectively and efficiently met.

Two approaches are used to identify and evaluate deficiencies in the current range of ground water monitoring activities in the state. The first is to compare the objectives for ground water monitoring (Report 1: Objectives for Ground Water Monitoring) with ongoing and recent monitoring activities (Report 2: Summary of Ground Water Monitoring Activities). The second approach uses the responses to a "Ground Water Monitoring Needs Questionnaire;" a questionnaire that was sent to a wide range of professionals involved in ground water monitoring, management, and protection, both within and outside the Department of Ecology.

The primary objectives around which the ground water monitoring strategy is developed are:

1. Characterize the ground water resource

2. Promptly identify new ground water problems

3. Assess known problems to determine cause-and-effect relationships

4. Ensure compliance with regulations

5. Evaluate the effectiveness of ground water management programs

Comparison of the monitoring objectives with current and recent monitoring activities helped to identify the following gaps. These gaps hamper Ecology's ability to effectively manage ground water resources in the state.

- No coordinated monitoring effort exists to promptly identify ground water problems. Delays in problem identification increase risks to public health and often lead to major increases in costs required to resolve the problems.

- Comprehensive and detailed information and interpretation of the physical properties and interrelationships of ground waters in major aquifers areas of the state is often inadequate, incomplete, and/or unavailable. This hinders activities as diverse as locating new water supplies, classifying ground waters, and remediating contamination problems.

- No monitoring programs exist to track regional changes in ground water conditions (except in the Spokane Valley Aquifer and perhaps in designated Ground Water Management Areas).

- Few monitoring resources are assigned to determine the cause and extent of ground water contamination incidences that do not rank on the Hazardous Waste Cleanup list. Examples of this class of problem include those caused by non-point sources, by unknown sources, or by the cumulative effects of several sources (e.g., "grey-area sites").

- Inadequate resources (especially staff and test well drilling capability) to design, track, conduct, and inspect ground water compliance and enforcement monitoring. Examples include activities associated with solid waste sites, state waste discharge permits, and the Hanford Nuclear Reservation.

Responses to the monitoring questionnaire provided additional insight and details regarding gaps identified above. When asked to rate the importance of the five major objectives for monitoring, respondents from within Ecology rated "ensuring compliance with applicable regulations" somewhat higher than the other objectives. Those from outside Ecology rated "characterization of the ground water resources" most important. After combining all responses, the importance of all five objectives rated between "fairly high" and "very high" (the two highest ratings).

In addition to the five general objectives, a series of more specific sub-objectives were listed in the questionnaire so that respondents could flag more specific monitoring needs.

Questionnaire participants also rated the discrepancy between the need for monitoring data and the amount and quality of data currently being collected. Most respondents noted that the most pressing needs were related to the activities of the Solid Waste Section and the Water Quality Program.

Issues of monitoring design and execution were also addressed in the monitoring questionnaire. Respondents rated current monitoring activities positively in many aspects of design and execution, but identified four problem areas:

- data management

- quality assurance/quality control and statistical considerations

- intra- and interagency coordination

- cost effectiveness

These are concerns that affect all present and future monitoring efforts. There is an urgent need to evaluate the quality and usefulness of existing data; organize and

make more available the data that are judged to be adequate, useful, and reliable; and develop capabilities that will permit rapid retrieval and analysis of these data. The issues bulleted above need to be addressed and resolved in roughly the same time frame that the department begins to address the monitoring deficiencies highlighted in this report.

A ten-year plan for addressing the needs identified is also outlined in this report.

Specific monitoring-related activities recommended in order to meet the needs identified in this report are listed below.

- CHARACTERIZE THE GROUND WATER RESOURCE

  Establish a long-term program to characterize the ground water resources and hydrogeology of major aquifers in Washington. The detail of this characterization should be consistent with the management objectives for aquifers. The responsibility for this effort should be shared among state, federal, and local resource management agencies as this information is needed at all levels of government to make informed decisions that will serve to effectively protect and manage ground water sources.

- PROMPTLY IDENTIFY NEW PROBLEMS

  Establish long-term, regional ground water quality monitoring networks in vulnerable areas where ground water is or is likely to become a major water source. This effort should dovetail with local efforts (e.g., Ground Water Management Areas) and also address areas unlikely to soon undertake locally sponsored monitoring. These networks should be designed to detect ground water contamination in areas where it is suspected, and to a lesser extent track background water quality.

  - Follow up on preliminary agricultural chemical monitoring study conducted during 1988-90. Needs will include defining extent of problems discovered, defining the conditions under which chemicals reach potable drinking water, and looking at additional vulnerable areas.

  - Develop short-term, special-purpose monitoring networks to determine whether a suspected area-wide contamination problem exists (i.e., studies to determine if ground water in and near a heavily industrialized area is contaminated with volatile organic compounds).

- ASSESS KNOWN PROBLEMS TO DETERMINE CAUSE-AND-EFFECT RELATIONSHIPS

  - Begin to conduct cause-and-effect ground water monitoring studies at sites where the party or mechanism responsible for a known or suspected

problem is undetermined and/or the extent of the problem is unknown. A major output from this activity would be to assign "grey-area sites" to an Ecology program or regional office unit (i.e., Solid Waste, Hazardous Waste Cleanup, Water Quality) for their attention, tracking, and resolution.

A potential candidate for such a study is arsenic contamination of ground water in the Granite Falls area. The cause and extent of seriously elevated arsenic concentrations have not been determined.

- ENSURE COMPLIANCE WITH REGULATIONS

  - Begin filling the void in Ecology staff resources assigned to design and oversee compliance and enforcement ground water monitoring networks.

  - Conduct ground water compliance monitoring inspections at solid waste, industrial, and municipal facilities that discharge to ground water.

- EVALUATE PROGRAM EFFECTIVENESS

  - Conduct routine, follow-up ground water monitoring at hazardous waste sites after cleanups have been completed to determine the effectiveness of the cleanup.

Although protection of public water supplies is not a direct Ecology responsibility, there is a need for an early-warning monitoring capability that would identify the approach of contamination before major drinking water systems are compromised.

Although the activities recommended here are presented as distinct and separate efforts, it is important to recognize that the results of each are important to assure the success of the other efforts. An increasing recognition of ground water as a major, vulnerable, and often irreplaceable water source, makes clear the urgent need for adequate monitoring.

I. Introduction

Ground water monitoring is a principal component of the ground water management and protection process (Ecology, 1987a). As the importance of reliable, relevant information regarding ground water increases, the need for a coordinated, forward-looking approach for gathering and using data is becoming more urgent.

Parts three and four of the five-part strategy for ground water monitoring in Washington are contained in this report. Specific ground water monitoring needs are identified and evaluated. These needs are derived from a comparison of the objectives for ground water monitoring described in Volume I. Objectives for Ground Water Monitoring (Ecology, 1987b) and current activities in the state described in Volume II. Summary of Ground Water Monitoring Activities (Ecology, 1987c). Results of a questionnaire on ground water monitoring needs completed by 34 professionals in the ground water area were also incorporated into the report.

A long-term (ten-year) strategy is presented for meeting the major ground water monitoring needs identified.

II. Purpose and Scope

The purpose of this report is to describe the areas in which the five basic objectives presented in Volume I. are not adequately addressed by current ground water monitoring activities. These five objectives are:

1. Characterize the ground water resource

2. Promptly identify new problems

3. Assess known problems to determine cause-and-effect relationships

4. Ensure compliance with regulations

5. Evaluate program effectiveness

Each monitoring objective plays a part in meeting Ecology's mandate to protect the waters (including ground waters) of the state. This report evaluates ground water monitoring efforts in terms of these objectives. Activities are recommended for filling in data gaps. A guiding principle behind these recommendations is to maximize the usefulness of new and existing data while carefully prioritizing commitment of new resources.

Although individual ground water monitoring activities are usually designed to achieve one of the five basic objectives above, results of distinctly different studies are often beneficial or necessary for the success of others. For instance, a monitoring program designed to identify new ground water problems (Objective 2) depends on hydrogeologic characterization and background water quality information (Objective 1). In turn, problem assessment (Objective 3) depends on identification of problems (Objective 2) so that the most critical ones can be promptly prioritized and addressed. (See Volume I. Figure 1 for illustration of this relationship.)

Two methods are used in this report to identify and prioritize ground water monitoring needs:

1. Chapter III. presents an evaluation of existing ground water monitoring activities in terms of the five objectives listed above.

2. Chapter IV. presents results of the Ground Water Monitoring Needs survey completed by 34 people involved in ground water monitoring and/or management in Washington State.

Needs common to all five monitoring objectives are described in Chapter V. A ten-year goal for addressing these needs is presented in Chapter VI. Chapter VII. contains a schedule of activities recommended to implement this goal.

III. Ground Water Monitoring Data Needs

Effective ground water management and decision-making are hampered by several gaps in ground water data acquisition. These deficiencies can be identified by comparing the ground water monitoring activities described in Volume II. (Ecology, 1987c) with the objectives for ground water monitoring discussed in Volume I. (Ecology, 1987b). Limitations and strengths of existing efforts are described below, followed by a summary of unaddressed needs.

A. Evaluation of recent and current ground water activities.

Tables 1 and 2 outline the major strengths and weaknesses of the principal ground water monitoring efforts in the state as they relate to the five monitoring objectives. (See Volume II. [Ecology, 1987c] for more details on these monitoring activities.)

Many shortcomings in existing ground water data and monitoring efforts are evident when viewed collectively. The major unaddressed needs for addressing the five objectives are described below:

1. Characterize the ground water resource

Neither regional hydrogeology nor ground water quality characteristics are understood adequately to carry out Ecology's ground water protection and management responsibilities.

More than any other element, a basic understanding of the hydrogeologic properties of major aquifers is essential for success in designing monitoring programs to meet any of the five objectives. Most other ground water protection and management efforts likewise depend on knowledge of ground water movement and vulnerability; i.e., aquifer classification, non-point source evaluation, underground injection control, and Underground Storage Tank (UST) management. For the most part, broadscale, regional hydrogeological interpretations and maps of major aquifer areas are not available. Aquifer and hydrogeologic properties of some very local sites have been thoroughly described and mapped, mostly for hazardous waste sites. These interpretations are difficult to produce and are often incomplete due to the lack of regional hydrogeologic interpretation.

Data describing the quality of ground water unaffected by human activities is likewise scarce and is not being tracked over time. Some of the data collected by the USGS could be classified as typical of unaffected ground water. However, it is difficult to segregate existing data based on proximity to human influences.

Table 1. Summary of strengths and weaknesses of major ground water monitoring activities in meeting Objectives 1 and 2: Characterize the ground water resource and Promptly identify new problems.

CURRENT GW MONITORING ACTIVITY (Agency)	OBJECTIVES 1. Characterize the ground water resource	2. Promptly identify new problems
U.S. Geologic Survey	Hydrogeology of Spokane Aquifer, deep Columbia Basin aquifers, and several localized areas well-defined. (Figure 1 shows major aquifers in state.) Water quality data from specific study areas for 1960s and 1970s. Limited data back to 1930s. Early 1980s one-time sampling of 700 wells around state for inorganics. No on-going water quality data collection. Puget Lobe Regional Aquifer Systems Analysis (RASA study) 1988-1990s to describe and model regional ground water movement. All water quality data in computerized format accessible to Ecology (WATSTORE/STORET). Adequate Quality Assurance (QA).	Most wells sampled in USGS studies have been deep wells--either in non-surficial aquifers or deep areas of surficial aquifers. Likelihood of detecting emerging or existing contamination problems in these areas is low. Recent studies have focused on assessment of known problems. No on-going data collection to determine water quality changes over time. Few wells sampled more than once, preventing discovery of trends. Monitoring typically has not focused on areas most vulnerable to contamination or where land uses are most likely to degrade ground water.
DSHS--Public Water Supply (PWS) well sampling	Infrequent data collection (one well per system every three years) for primary and secondary drinking water constituents (Table 3) at larger systems (99 or more connections). Total of about 2,500 systems. Nitrate sampling required at smaller systems every three years but not enforced. Well screens often long and/or multiple screens at different depths. Samples from such wells a blend of water from different depths in aquifer or different aquifers. Data collected since 1978 on computer system, routinely transferred to Ecology PC-STORET data base. 50-60 organic compounds to be sampled in larger systems (Class 1 and 2). If none detected initially, on-going sampling to occur every 3-5 years. Figure 2 shows the number of Class 1 and 2 wells in each county.	Most wells screened in deeper or multiple depth zones. (Problems usually occur first in shallow aquifer zones.) PWS wells often fairly distant from potential contamination sources. By the time problems evident in PWS wells, often too late for cost-effective remedy. Purveyors collect samples. Sample location and field QA not always reliable. No PWS wells in many potential problem areas; e.g., suburban and rural areas.
Department of Natural Resources (DNR)	Mapping regional state geology at 1:250,000 scale. Data being complied from finer scaled maps. Began 1983--scheduled completion 1993. Primarily bedrock geology, but surficial deposits shown when they are principal unit; e.g., Puget Sound area. These maps would be useful for developing regional hydrogeologic maps.	Regional geology maps may be somewhat useful for identifying vulnerable ground water areas where problems more likely.

Table 1 - continued.

CURRENT GW MONITORING ACTIVITY (Agency)	OBJECTIVES 1. Characterize the ground water resource	2. Promptly identify new problems
Ecology GWMA Program	High quality hydrogeologic and water quality characterization for designated areas (1-2 yr characterization study). Extent of follow-up or long-term monitoring not yet determined. Standard guidelines for field and laboratory QA/QC. Standardized data management (STORET/WATSTORE). Not all areas with existing or emerging ground water problems becoming involved. Figure 3 shows GWMA locations.	One to two-year characterization studies do not necessarily focus on potential contamination problems, but on general baseline conditions. Hydrogeological interpretation useful for future problem identification monitoring. Specific follow-up ground water monitoring to determine program effectiveness not yet determined.
Ecology Hazardous Waste Cleanup (HWCU)/EPA CERCLA	Thorough characterization of hydrogeology in immediate area of cleanup site only. Hydrogeologic data may contribute to knowledge of regional conditions, but, in most areas, not significantly. Upgradient ground water quality data may be useful for regional characterization. Data from small monitoring wells not directly comparable to that from large PWS or irrigation wells. Until now, after a site is cleaned up, no follow-up or monitoring. Most monitoring wells are abandoned. High quality data, although QA/QC provisions differ from site to site. Data management neither standardized nor automated yet.	Site-specific ground water usually of limited use in identifying new problems. However, Preliminary Assessment information, including evaluation of existing information about a site, may be useful in identifying new problems. These efforts do not necessarily focus on the most vulnerable ground water areas, facilities, nor land uses.
Ecology Technical Services--WQIS	Current agricultural chemical study will provide some regional scale water quality information in three study areas. However, parameters restricted to those indicative of agricultural chemicals; e.g., pesticides, nitrate. Usually short-term studies using existing wells (monitoring wells, public or private wells). Samples collected near known or suspected problem sites usually not representative of regional conditions. Detailed QA/QC. Data collected prior to 1988 in paper files.	Two current problem identification studies: 1) agricultural chemical study aimed at identifying contamination in vulnerable ground waters. Existing wells to be sampled for chemicals used in specific areas. Data to be automated. Detailed QA/QC. 2) Long Beach Peninsula study to provide preliminary information to determine if septic systems degrading shallow ground water. Most other studies designed to describe known problems. Existing wells chosen to represent the known source.

Table 1 - continued.

CURRENT GW MONITORING ACTIVITY (Agency)	OBJECTIVES 1. Characterize the ground water resource	2. Promptly identify new problems
Hazardous Waste Management/RCRA Facilities	Thorough characterization of immediate site hydrogeology. A small portion of this information may be of use for regional hydrogeologic characterization. Water quality data from monitoring wells representative of ground water leaving the site, except upgradient wells. Data from upgradient monitoring wells not directly comparable with those from large diameter and/or long-screened wells.	Samples collected from monitoring wells at 36 facilities designed to represent ground water moving away from hazardous waste facilities. Detection stage monitoring useful in identifying problems due to the regulated facility. Data of limited use in discovering other problems. Apparently high quality data from monitoring wells although QA/QC procedures not always closely overseen or documented.
Solid Waste Landfills	About 30 of the 76 major landfills in the state conduct ground water monitoring. Monitoring wells used. Data representative of very localized site. Data from upgradient wells may be of use in regional characterization. Data not automated. QA/QC procedures not established.	Monitoring well samples represent ground water moving away from solid waste landfills in the uppermost aquifer. Data used to detect leachate leaving the site, usually too site-specific to be of use in identifying other problems.
State Waste Discharge Facilities	Site-specific monitoring using monitoring wells and/or existing nearby wells. Often no background wells. Data not automated. QA/QC procedures not established. Data from monitoring wells representative of small portion of the aquifer. Results not directly comparable with those from public water supply wells. Few facilities with ground water monitoring.	Samples represent ground water moving away from the discharge area. Data mainly useful for identifying problems due to the discharge, usually too site-specific for identifying other problems. Few facilities with ground water monitoring.

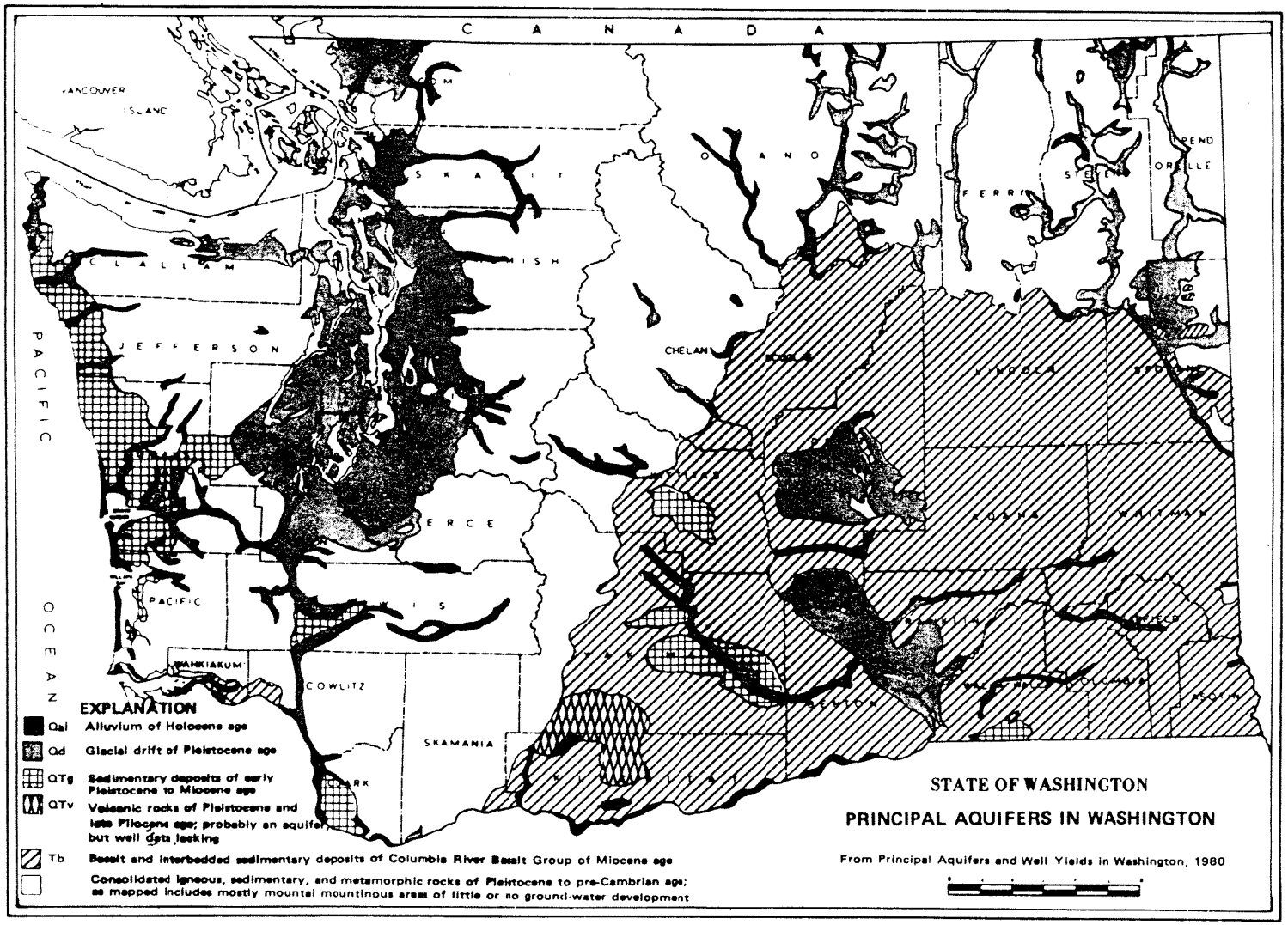

Figure 1. Principal aquifers in Washington.

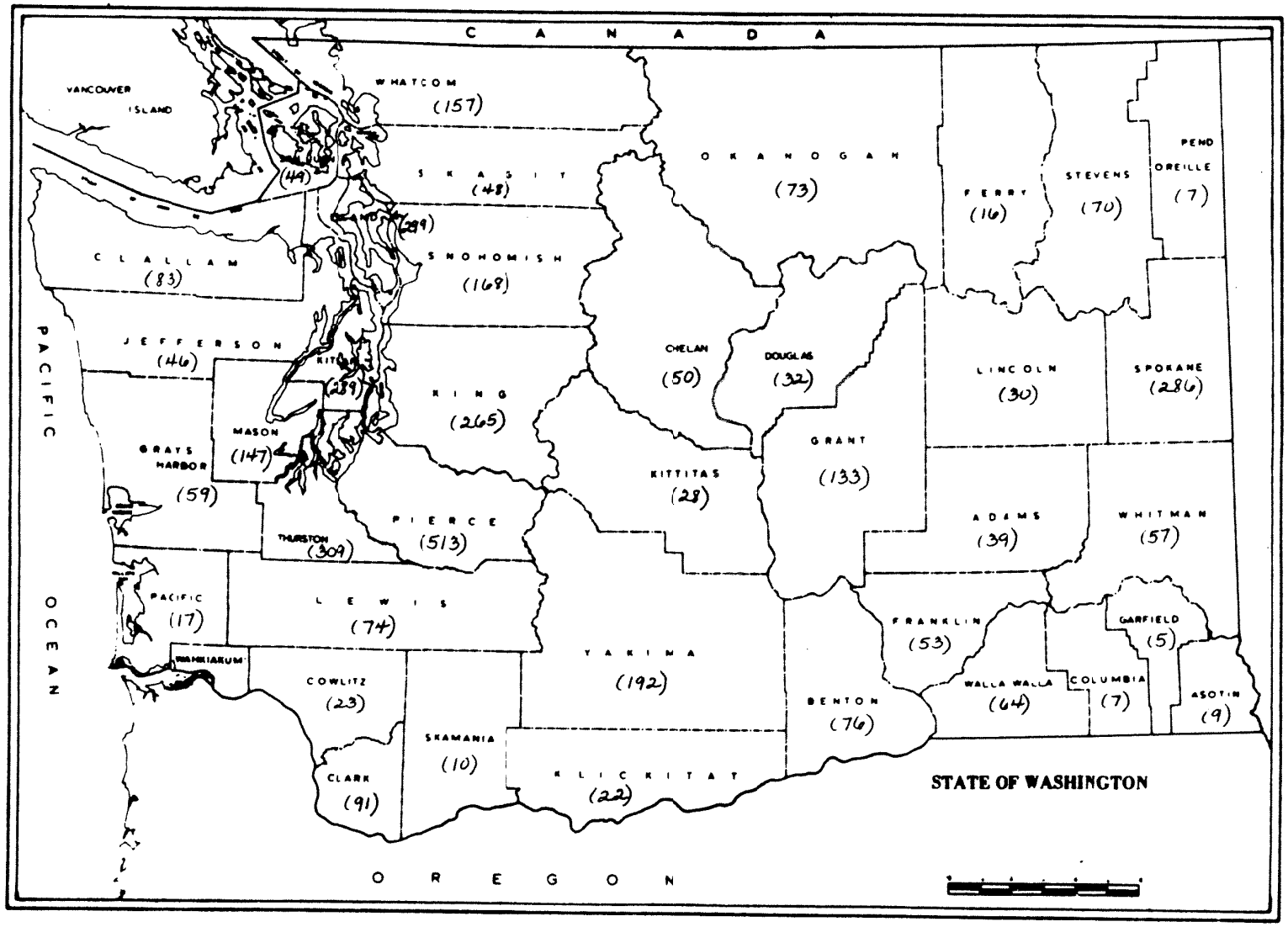

Figure 2. Number of public supply wells in each county that are part of Class I and II systems.

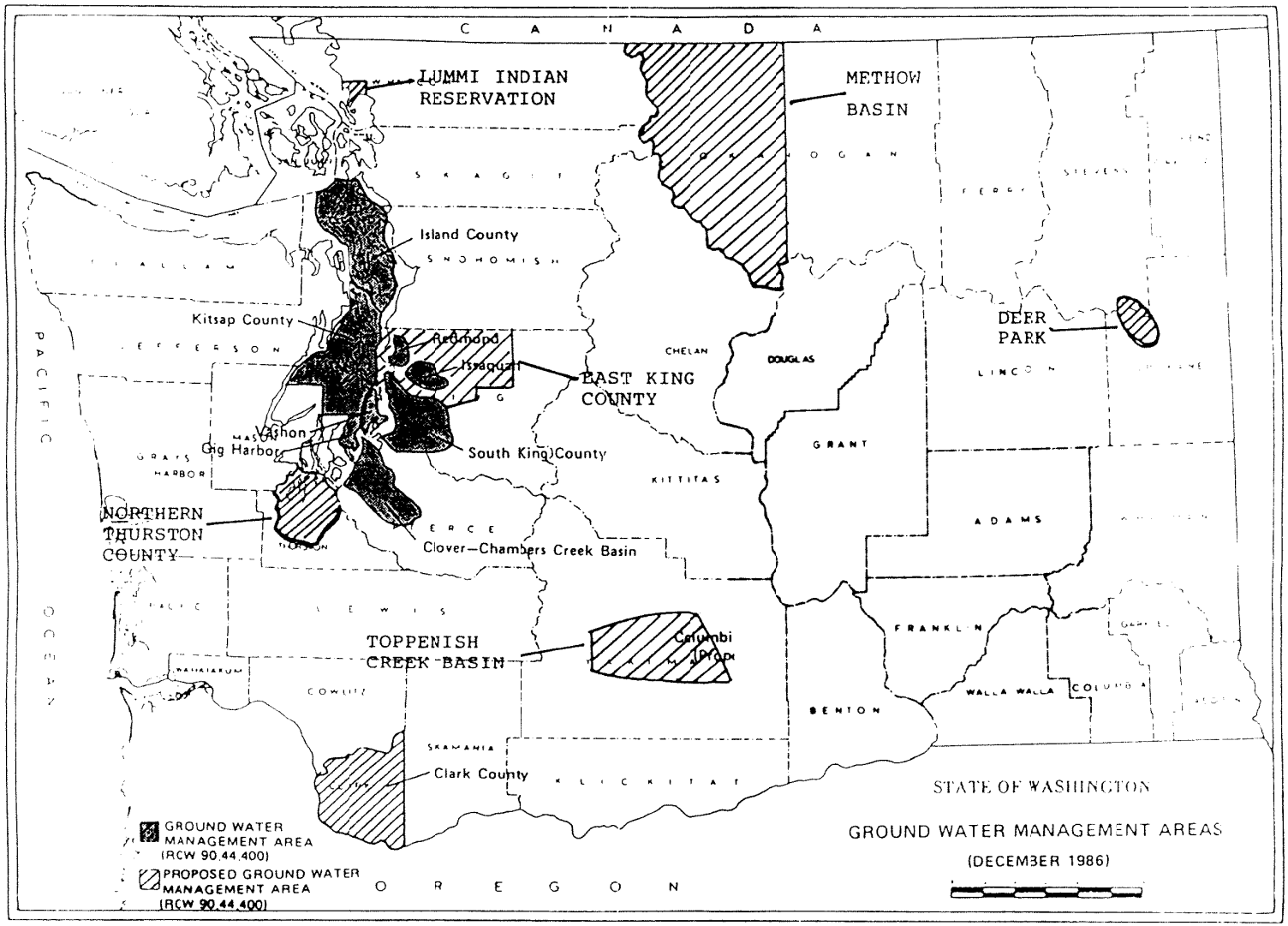

Figure 3. Location of designated and proposed Ground Water Management Areas. North Thurston County, Clark County, and Deer Park Basin are now designated rather than proposed.

Table 2. Summary of strengths and weaknesses of ground water monitoring activities in meeting Objectives 3, 4, and 5: Assess known problems to determine cause-and-effect relationships, ensure compliance with regulations, and evaluate program effectiveness.

CURRENT GW MONITORING ACTIVITY	OBJECTIVES		
Agency	3. Assess known problems to determine cause-and-effect relationships	4. Ensure compliance with regulations	5. Evaluate program effectiveness
USGS	Two major on-going efforts: 1)Pasco Basin study on effect of agricultural activities on ground water quality and quantity. 2)Yakima petroleum spill study. Because Pasco study is more broad-scale than Yakima study, it may require more monitoring to determine direct cause-effect relationships. High quality data for both studies, especially Yakima spill study. Data automated (WATSTORE/ STORET).	Interpretations of existing hydrogeology and ground water quality data have been published for three landfills in the state. Studies do not directly address regulatory compliance.	Together with additional data, USGS data would be very useful for evaluating effectiveness of ground water protection programs.
DSHS	Data from Class 1 and 2 PWS's (sampled once every three years) may be useful in preliminary scoping for a problem assessment study. PWS usually not optimally located for determining the source and extent of problems. Drinking water parameters often not relevant to the type of problem under investigation. QA limited. Data automated (STORET), accessible.	Data collected by purveyors to meet DSHS regulations for drinking water quality.	Together with additional data, DSHS data could be very useful for evaluating effectiveness of ground water protection programs.
DNR Geologic Mapping	Geologic maps may be somewhat useful for assessing problems.	Geologic maps may be somewhat useful for designing compliance monitoring networks.	Geologic maps will be somewhat useful for evaluating some ground water management and protection programs. However, hydrogeological maps of similar scale would be more relevant.
Ecology-GWMA Program	Hydrogeologic and ground water quality data will be useful in scoping and planning problem assessment studies in GWMA's. On-going monitoring should be useful. Characterization effort alone will not provide sufficient information to assess the cause, effect, nor extent of problems discovered. Presumably good QA. Data computer accessible (STORET/WATSTORE).	Broad scale baseline data from this effort will be of limited use for this purpose. Data may be of slight use for comparison with data from regulated facilities.	Continued ground water monitoring needed after GWMA programs are adopted to evaluate effectiveness of the GWMA programs as well as other activities.

Table 2 - continued.

CURRENT GW MONITORING ACTIVITY	OBJECTIVES		
Agency	3. Assess known problems to determine cause-and-effect relationships	4. Ensure compliance with regulations	5. Evaluate program effectiveness
Ecology HWCU/EPA CERCLA	Monitoring at HWCU sites aimed at assessing cause, effect, and extent of the problem. Sites that meet specific criteria are put on either the national or state priority list. Intensive, site-specific studies thoroughly characterize hydrogeology, ground water flow, and water quality in immediate problem area. Ground water sampling is from monitoring wells. High quality data, although QA procedures vary among sites. Data management not yet standardized nor automated.	HWCU investigations usually carried out at sites where regulations have already been violated. Follow-up monitoring after clean-up is completed would address compliance with regulations, but has not been carried out at sites where clean-up is complete.	Ground water monitoring needed following clean-up to determine if remediation measures taken are effective.
Ecology Technical Services, WQIS	Problem identification studies (agricultural chemicals and Long Beach septic system studies) useful in determining if problems are significant, and if necessary, in scoping detailed assessments. Other studies aimed directly at assessing documented problems to determine cause, effects, extent. Detailed quality assurance, especially for organics and pesticides. Data collected prior to 1988 in paper files.	Small portion of studies have addressed regulated facilities where spills or leakage to ground water suspected. Constituents in addition to those required in the permit are usually sampled. (Often permits do not require monitoring at all.) Detailed Quality Assurance. Data not automated.	Together with additional data, Technical Services data could be useful in evaluating effectiveness of ground water protection programs.
Hazardous Waste Management/ RCRA Facilities	Assessment stage monitoring conducted if contamination is discovered via Detection Level monitoring. Frequent data collection (quarterly; each site has approved sampling plan. Ecology inspectors check field QA/QC procedures, split samples. Annual sampling for Appendix VIII constituents at Assessment stage sites. Data not automated.	Detection level monitoring: frequent; many monitoring wells at each facility; few parameters measured. Assessment level monitoring: frequent; many monitoring wells; more parameters measured than for detection level (site-specific parameters, and annually for Appendix VIII constituents). Both Detection and Assessment: inadequate resources for data interpretation in Ecology. Data not automated. QA/QC over-sight improving. EPA's TEGD used as QA/QC reference (U.S. EPA, 1986)	Data useful for evaluating hazardous waste management, facility operation, and siting efforts. Possibly a portion of data also useful for evaluating other ground water programs and activities.

Table 2 - continued.

CURRENT GW MONITORING ACTIVITY	OBJECTIVES		
Agency	3. Assess known problems to determine cause-and-effect relationships	4. Ensure compliance with regulations	5. Evaluate program effectiveness
Solid Waste Landfills	Monitoring at solid waste landfills to allow early leachate detection. Data analysis not yet conducted regularly by Ecology to determine if contamination occurring. Therefore problem often not detected if one exists. Some problems detected and assessed under HWCU.	Regulated by local health departments (often conflict of interest). Ecology has limited authority to ensure that monitoring is conducted properly. Only about 30 of the 76 major land fills conduct ground water monitoring. Ecology staff resources for reviewing oversight are low. 450 landfills total (Betts, 1987). Data are not automated. QA/QC has not been specifically addressed.	Data could be useful for evaluating landfill siting and management activities. Such problems as lack of data, data of unverified quality, and lack of an automated data management system prevent use for this purpose.
State Waste Discharge Compliance data	Monitoring designed to detect problems caused by discharge. Theoretically, if a problem is detected, a detailed assessment study of the extent and severity would be required. However, this has not occurred yet.	Self-monitoring carried out at only about 25 percent of industrial and municipal facilities with definite or potential discharges to ground water (Ecology, 1986a). Specialized expertise in writing ground water monitoring permit requirements and interpreting data are limited. No written guidance for developing ground water monitoring requirements for waste discharge permits, nor for QA/QC. Consistency among regional offices lacking.	These data could be useful in evaluating effectiveness of waste discharge facilities and procedures. Currently only Eastern Regional Office has automated data management system. Data from other regions are not accessible, nor of reliable quality. A number of discharges to ground water are not required to monitor ground water.

Data from public water supply (PWS) wells are restricted to the primary and secondary drinking water standards which do not include the majority of constituents for which background information is needed (see Table 3).

Table 3. Primary and secondary drinking water contaminants.

Primary	Secondary
Arsenic	Color
Barium	Iron
Cadmium	Manganese
Chromium	Total dissolved solids
Fluoride	Chloride*
Lead	Sulfate*
Mercury	Copper**
Nitrate	Odor**
Selenium	Zinc**
Silver	

*Analysis is required only when total dissolved solids concentration exceeds 500 mg/L.
**Analysis is required only when determined necessary by the Department of Social and Health Services.

It is also difficult to determine from available documentation which data from PWS wells are representative of background conditions. In multi-source public well systems, samples collected every three years for primary drinking water parameters may be taken from a different well each time. These wells may be screened in totally different aquifers and/or far apart, making relevant comparisons over time impossible. Information on location of sampled public supply wells is also not always reliable or precise. The usefulness of these data for determining background conditions in major aquifers is limited and in many cases, of questionable validity.

GWMA ground water and hydrogeologic characterization studies should provide useful data for the participating areas. However, not all major ground water districts in the state that need such characterization and resulting management activities are likely to be included in a GWMA.

The Spokane Aquifer, although not a GWMA, is an Aquifer Protection District. Hydrogeologic studies and mapping have been done and ongoing ground water background quality monitoring has been conducted there for over ten years.

2. Promptly identify new problems

A preliminary ground water monitoring needs assessment (Ecology, 1986a) pointed out a number of activities in the state with a potential to contaminate ground water that are not addressed by current monitoring efforts. These activities include:

- Agricultural practices
- Commercial, municipal, and industrial facilities (including light industry)
- Storm- and wastewater injection wells
- Densely populated, unsewered areas
- Gasoline and chemical underground tanks, pipes, and storage areas
- Large-volume spills
- Cumulative point and non-point sources

A portion of data from recent ground water quality monitoring activities may be useful as a first step in discovering emerging or existing problems from the above sources. However, these small data sets of variable reliability can only provide a basis for more directed problem-discovery monitoring.

Lack of a hydrogeologic basis for determining regional ground water flow paths and vulnerability relative to potentially contaminating land uses makes data analysis to detect problems difficult. Information on locations of potentially contaminating land uses and corresponding maps are keys to deciding where to focus problem-detection monitoring efforts. A compilation and interpretation of information on physical hydrological properties of aquifers, as well as overlying soils and land uses are needed.

Most of the USGS and DSHS ground water data are from samples of large-diameter, long-screened, deep wells, often screened at more than one depth. Contamination generally occurs first and in highest concentrations at the top of shallow aquifers. Even severe contamination in a shallow aquifer may be diluted to below problem levels in samples from large-diameter wells with long or multiple screens.

Wells sampled by the USGS and purveyors of PWS's are usually somewhat removed from potential contamination sources. Data from

them therefore do not generally provide timely warning of contamination problems. The infrequent sampling at PWS's and limited parameters sampled also limit the use of these data for use in discovering problems.

Ground water characterization monitoring at GWMA's may help identify ground water quality problems. However, monitoring plans at GWMA's are designed mainly to determine baseline and unaffected conditions. The level and intent of ongoing monitoring following completion of initial characterization studies has not been determined.

None of the existing ground water quality monitoring efforts focus on long-term analysis of regional ground water quality. Detection of problems at a stage where they can be readily corrected or mitigated is therefore currently unlikely. Additional monitoring is needed, especially in areas where human activities are most likely to contaminate high-priority ground water. Information on background conditions is also necessary for comparison with suspected problem areas and to detect unsuspected problems.

3. Assess known problems to determine cause-and-effect relationships

There is currently no system for evaluating and prioritizing contamination problems that do not fit into the regulated and/or hazardous categories. Local governmental entities typically have neither the funding nor the technical expertise necessary for designing and carrying out investigations to address such incidents. Additional monitoring capability is therefore needed at the state level to pursue the most critical non-standard ground water contamination problems. Ground water quality problems that are inadvertently identified, or those discovered through monitoring efforts such as PWS drinking water monitoring or GWMA investigations should be ranked according to specified criteria so that those posing the greatest immediate threat are promptly investigated. This prioritization system should take into account human and environmental health risks and include information on soils, hydrogeology, water quality, and other pertinent factors.

A hazard ranking system for state hazardous waste sites will be developed by July 1988, according to the Hazardous Waste Cleanup Law (Ch. 70.105B WAC). Non-standard contamination sites that do not rank on this list should be included in the generic prioritization list.

Follow-up monitoring at sites where cleanup of hazardous wastes has been completed is also a need that falls into this category. This type of monitoring to evaluate the effectiveness of a program is also included in III.A.5., below.

4. Ensure compliance with regulations

The basic needs common to all compliance monitoring efforts, including hazardous waste management facilities/RCRA, solid waste sites, and permitted waste discharges are:

- Computerized data base(s) to store data and to alert Ecology staff to problems; standardized system for ensuring data meet permit requirements.

- Quality assurance provisions included in permits.

- Periodic data analysis and interpretation to detect problems in time to minimize contamination.

- Additional technically trained staff to design, review, and oversee compliance ground water monitoring and interpret data.

Most of the individual compliance monitoring efforts have additional specific areas where improvements are needed. These needs are listed below.

a. Solid waste sites

Ground water monitoring is being conducted at only about half of the 76 major landfills in the state (Betts, 1987). Many of these landfills have received hazardous waste. Some have become Hazardous Waste Cleanup sites. Monitoring at most landfills where monitoring is being conducted does not meet the required State Minimum Functional Standards (Ch. 173-304 WAC). Ecology needs additional staff experienced in the fields of hydrogeology, water quality/chemistry, and toxicology to provide adequate oversight and technical guidance to the likewise understaffed local health departments that issue permits.

The effects on state ground waters of other solid waste activities is not well-known. Ground water monitoring at sludge disposal facilities and solid waste surface impoundments is not usually required by local health departments. Although the severity of potential contamination from these activities is usually considered less than that from landfills, ground water monitoring may be needed in certain cases, especially in hydrogeologically sensitive areas.

In order to ensure that reliable self-monitoring data are being collected, periodic ground water monitoring inspections are needed at regulated solid waste sites, particularly major landfills. In addition

to sampling constituents and wells required to be sampled under permits, other relevant constituents and wells can be sampled during inspections to evaluate the effectiveness of permit monitoring provisions. This type of system has been successfully used by the New Jersey Department of Environmental Protection at landfills (Carter, 1983).

b. Waste discharges to ground

State permits for waste discharges to ground require significantly more staff resources and increased priority. Roughly two-thirds of the state waste discharge permits that involve discharges to ground do not require ground water monitoring (Ecology, 1986a). An unknown but potentially large number of facilities with potential discharge to ground exist without permits. Staff involved in developing and overseeing ground water monitoring permit activities should include specialists in hydrogeology, water quality analysis, and toxicology.

Consistency among the four Ecology regional offices in terms of waste discharge permit ground water monitoring provisions is currently lacking. Written guidance on monitoring network design, sample collection, sample analysis, quality assurance/quality control, data analysis, and data management are needed.

Inspection sampling similar to that described for solid waste sites is needed, especially at sites located in hydrogeologically sensitive areas where the effects of ground water contamination pose the greatest risks to the public and the environment.

c. Hanford Nuclear Reservation

A variety of facilities that discharge hazardous and nuclear waste to ground water are distributed over the hundreds of square miles at the Hanford Nuclear Reservation. The degree of ground water contamination on the reservation is a matter of conjecture, since toxic and nuclear wastes have been handled and disposed of there for over 40 years with little documentation or monitoring. Hundreds of sites require monitoring under federal RCRA regulations. Current Ecology staff resources are not adequate to review proposed monitoring plans needed at these sites. Likewise, as contamination is found in the areas where reliable monitoring is being done, staff resources are not sufficient to work on more intensive monitoring and cleanup plans.

d. Unaddressed point sources

Several types of facilities with a substantial potential to contaminate ground water are not specifically addressed by existing regulatory programs. These include underground storage tanks, Class V storm- and wastewater disposal wells, improperly abandoned wells, and light industrial activities. Ground water monitoring at some of these sites may be warranted, especially in areas with highly vulnerable ground water that is a major source of drinking water or other beneficial use.

5. Evaluate program effectiveness

Unless ground water protection and management programs are reviewed and evaluated, we cannot justify continued management efforts or improve upon those efforts. An essential criterion for judging the effectiveness of these programs is through analysis of a reliable, on-going record of ground water data collected in areas where management efforts are being conducted (and, for comparison, others where not conducted). An example would be the GWMA Program as a whole.

This periodic evaluation of ground water management and protection efforts should include both mid-level decision-makers and technically specialized staff involved in ground water monitoring (Rajagopal, 1986). Discussions should include an evaluation of how well data collected meet management needs and how data are being used for management decisions. Several areas of current ground water management attention that will require evaluation of ground water monitoring data includes:

- Best Management Practice implementation for non-point pollution sources.
- Underground Injection Control.
- Management of unregulated facilities with potential to contaminate ground water (i.e., commercial septic systems, underground storage tanks and piping, and light industries).
- GWMA Program effectiveness.
- Waste Discharge Permit efforts for discharges to ground.

In order to evaluate the comprehensive effectiveness of all ground water protection and management efforts, a regional, broad-scale monitoring network is needed that incorporates relevant available data and adds monitoring sites as necessary. Regional hydrogeologic interpretation and mapping efforts are related needs.

IV. Ground Water Monitoring Needs Survey

A questionnaire was developed to solicit the perspective of state ground water investigators, managers, and regulators on ground water monitoring needs.

The questionnaire developed in July 1987 was distributed to Ecology Regional and Program Managers, members of Ecology's Ground-Water Technology and Techniques Group, Washington DSHS Drinking Water Unit, EPA Region 10, USGS Tacoma District Office, state universities, local agencies involved in ground water management, and environmental groups.

A copy of the questionnaire is provided in Appendix A. The survey system was roughly patterned after that used by Mar, *et al.* (1985) for surface water monitoring evaluation.

The questionnaire sought opinions on the importance of both general and specific ground water monitoring activities in the state. Respondents were also asked to evaluate specific ground water data from major data collection efforts in the state with which they were familiar.

Thirty-four individuals responded to the 65 questionnaires distributed. Numerical responses for the four sections were tallied and mean values used for analysis. A summary of the results is provided in Appendix B.

The need for monitoring to address each of the five objectives was rated almost equally high (between fairly high and very high). Objective 5, Evaluating program effectiveness, was viewed as a less immediate, long-term need.

Responses indicated that a few of Ecology's ground water monitoring activities are perceived to generally meet their objectives; i.e., Hazardous Waste Cleanup, RCRA/Dangerous Waste, Water Resources, and Technical Services monitoring efforts. However, the Water Quality Program and Solid Waste Section ground water monitoring efforts were seen as falling far short of the level needed.

The areas where responses indicated the most severe lack of monitoring effort were:

1. Discharges to ground that operate without permits.

2. Agricultural chemicals and chemigation.

3. Identification of ground water problems.

4. Evaluation of effectiveness of ground water quality protection efforts.

V. Agency-Wide Needs

Although fulfillment of each monitoring objective requires specific activities and resources, several areas of common need exist. These needs involve integrated operation of the various monitoring activities to provide the information necessary to make sound management decisions in an efficient manner.

1. Data management

   Intra-agency ground water data management is an area of immediate, urgent need as indicated in the overall low score in the questionnaire for how well various efforts address this. The level of discussions within Ecology on data management also indicates this is a high-priority need. The next report in this Ground Water Monitoring Strategy series will focus on data management. Therefore, the following is merely a preliminary discussion.

   Ground water data for Washington are stored in a number of locations and formats. Assembly of data for a particular area in the state or parameter of interest is currently difficult and time-consuming. Federal, state, and local agencies each have data that could be of great value to other agencies. However, different data storage systems, sample location references, and lack of communication that data exist, often prevents efficient data use. A centralized data base where all significant, adequately reliable data are stored and accessible would be useful. A more reasonable goal, however, is a linkage system that allows various users to access and use data collected by other agencies and organizational units within Ecology.

   A list of needs identified by questionnaire respondents included:

   - Integrate and coordinate ground water data management (e.g., regional offices and various programs).

   - Establish common data descriptors, definitions, units of measurement, and location identifiers.

   - Develop Geographic Information System (GIS) for overlaying, displaying, and interpreting complex data.

   - Develop ground water compliance monitoring data management capabilities.

   These items will be briefly discussed below.

   A preliminary step toward improving data accessibility and usefulness is to inventory the major data sources that Ecology uses or would like to use relevant to ground water. Factors such as information contained in each

data base, the format in which the data are stored, data collection methods, etc. could then be used to determine ways of making data more available and usable to those who need them around the agency and in the public sector. Common descriptors for the same type of data are crucial for data sharing.

A unified well identification system would eliminate confusion in one area due to the various numbering systems currently used by different agencies or parts of agencies. For instance, a public drinking water well may have several different identifiers--one for DSHS, one for USGS, and more than one for Ecology. A single identifier for each well in the state should be established. A similar effort has been conducted as a basis for an Ecology GIS that includes all geographically related data. Results of the GIS study provide the basis for an inventory specifically designed for ground water-related information.

The effectiveness of most ground water monitoring and protection efforts would be greatly improved by development of a GIS system. Information such as soil type, geology, water table elevations, land use, etc. displayed on a map can be a time-saving tool for prioritizing areas or sites for monitoring or other management needs. This tech-nique also simplifies interpretation and presentation of results that are difficult to explain; e.g., three-dimensional ground water movement.

Ground water monitoring efforts designed for different purposes have different data management requirements. Therefore, each major monitoring activity must either adapt an existing data base to its needs or develop a new system. Most of Ecology's ground water compliance monitoring efforts have not had sufficient resources to enter data submitted from compliance facilities into a data base. A computerized data base would allow compliance monitoring data to be submitted in an electronic format. Simplified data entry procedures would minimize data entry time. Techniques for automated data verification and interpretation to enable quick data evaluation and prepa-ration for other users should also be implemented.

2. Coordination

Improved coordination among various organizational units within Ecology that collect or use ground water data is urgently needed. One way to improve in-house and external coordination is through the Ground Water Coordination Committee. The Technical Subcommittee is composed of staff involved in ground water management, monitoring, and cleanup activities. The Management Subcommittee, comprised of program and regional managers, has not yet convened. One of the duties of the committee will be to establish mechanisms for improved coordination. As

ground water monitoring activities continue to develop, new technical and policy questions arise which may best be resolved in a group that includes representatives from various branches of the department. Recommendations based on such discussions would provide executive managers with a strong base for making effective decisions regarding monitoring and management of ground water. In addition, these recommendations would help to improve technical soundness and consistency to Ecology monitoring and protection efforts.

Increased cooperation between Ecology and other agencies involved in ground water monitoring is an on-going need. The division of responsibilities among the agencies should be reviewed and clarified as new activities develop and current activities evolve.

Another way to increase information exchange within Ecology and with external organizations is to develop a comprehensive bibliographic data base of Washington ground water and hydrogeologic information sources. An annotated bibliography or data base with titles, authors, and subjects of publications relevant to ground water, such as the one Ecology's Water Resources and Water Quality Programs have begun, could be made available to PC users in Ecology and around the state.

Written reports should follow all significant investigative efforts, including those recommended by this report. This will benefit others working in the area and prevent duplication of effort.

A newsletter that focuses on ground water monitoring activities in the state would also provide a mechanism for improved communication among various agencies and the public.

3. Quality assurance/quality control and statistical considerations

Monitoring efforts carried out under the Hazardous Waste Cleanup, Hazardous Waste Management/RCRA, and Ground Water Management Area programs require written quality assurance plans (e.g., Ecology, 1986b; U.S. EPA, 1986). These programs also have written guidelines for development of individual quality assurance plans. Some of the other monitoring efforts sponsored or required by Ecology may include quality assurance provisions, although these are less specific and consistent.

Written guidance for developing and overseeing quality assurance sampling, analysis, and data reporting provisions is needed for other ground water monitoring efforts (especially regulatory self-monitoring). Provisions for quality assurance should also be included in state permit waste discharge monitoring requirements. Oversight of quality assurance activities is also

necessary to ensure that established requirements are carried out and that data submitted meets data quality objectives.

The development of department-wide protocols for ground water sampling and analysis would provide a solid base for data continuity among various programs and functions at both the state and local levels. These protocols would be analogous to the Puget Sound Protocols and address issues such as sampling well construction, vertical and horizontal positioning accuracy, well development and sampling techniques, analytical techniques, statistical considerations, and quality assurance/quality control guidelines for all of these issues.

The statistical aspect of ground water monitoring network designs for Ecology-sponsored activities requires more attention. Depending on the purpose and scope of monitoring efforts, estimates of confidence in the data as well as techniques for measuring differences over time and space, should be addressed prior to sample collection. These estimates and techniques may change depending on results obtained during the study.

Statistical reliability of data is translated into study conclusions and thereby determines the the role these conclusions play in decision-making. Therefore, it is critical that adequate communication occur between those who intend to use the results of ground water monitoring studies and those conducting the studies.

4. Cost effectiveness

Ground water monitoring can be very expensive and time-consuming. Increased emphasis should be placed on ensuring that monitoring efforts are designed to maximize benefits for individual projects and as much as possible for the Ecology information base as a whole. Costs can thereby be minimized and duplication of effort prevented.

Table 4. Ten-year ground water quality monitoring goal.

- CHARACTERIZE THE GROUND WATER RESOURCE

  Hydrogeology of major aquifers of the state will be characterized adequately to make decisions faced by Ecology and local entities. Background ground water quality will be tracked on a relatively infrequent basis to discern natural trends. Monitoring will be responsive to changing conditions. Information will be digitized for computer mapping or in a form available for such mapping.

- PROMPTLY IDENTIFY NEW PROBLEMS

  On-going, evolving water quality/water level monitoring program(s) will provide early detection of significant changes in major aquifer areas from point and non-point sources. This coordinated effort (using data from all available sources) will focus on high-risk land use/hydrogeologic/water dependence types. (These types will be determined from hydrogeology, land use, soils, and to some extent water use information.)

- ASSESS KNOWN PROBLEMS TO DETERMINE CAUSE-AND-EFFECT RELATIONSHIPS

  Ecology will have adequate resources (technical staff, laboratory resources, access to consultants) to assess the cause, extent, and implications of high priority ground water problems in order to efficiently resolve or mitigate these problems. This includes both site-specific and regional ground water quality problems.

- ENSURE COMPLIANCE WITH REGULATIONS

  Compliance monitoring will be conducted periodically at all major landfills and other potentially contaminating solid, hazardous, radioactive waste sites and waste discharge sites. Technical oversight will be sufficient to assess and assure compliance. Data will be managed electronically and will be accessible to those who need them. Compliance inspection monitoring capabilities will be adequate to ensure accuracy and sufficiency of self-monitoring data; and adequate to provide permit writers with information to write sound permits.

- EVALUATE PROGRAM EFFECTIVENESS

  Data from above monitoring activities will be used to evaluate major ground water protection and management programs; e.g., GWMA Program, state waste discharge permit efforts, UIC Program, ground water classification and standards development, Solid and Hazardous Waste Program, etc.

Areas of coordinated agency-wide effort:

- DATA MANAGEMENT

  Coordinated agency-wide data base(s) will be developed and maintained to store and analyze all reliable, priority data related to ground water (well location, well construction, water levels, water quality, hydrogeologic characteristics, land use, facilities with potential to contaminate GW). The data management system should have mapping and data analysis capabilities (e.g., statistics, contouring, modelling) for large and small data sets. Ties will be established with other data bases managed by such agencies as USGS, EPA, DNR, and DSHS.

- COORDINATION

  Ecology activities that involve ground water monitoring will be integrated as much as possible. Routine exchange of information and assistance will be facilitated through annual work plans and Ground Water Coordination Committee.

- QUALITY ASSURANCE/QUALITY CONTROL AND STATISTICAL CONSIDERATIONS

  Agency-wide monitoring protocols should be developed for ground water data collection activities. These protocols should establish minimum standards for data collection and analysis. Water Quality Program protocols will be developed early in the process for use in state waste discharge permit monitoring, etc.

  Statistical interpretation of data will become a major consideration in ground water monitoring network designs and data interpretation.

- COST EFFECTIVENESS

  The goal of meeting monitoring objectives and optimizing resource expenditure will be addressed and considered when planning and evaluating ground water monitoring activities.

VII. Implementation of the Ten-year Ground Water Quality Monitoring System Goal

The strategy for attaining the ten-year goal is to improve current data collection efforts, make efficient use of available data, gradually add monitoring efforts where most needed, and adapt efforts to meet ground water protection and management needs.

A series of coordinated, phased activities is needed to put this strategy into place. Table 5 outlines the recommended short-term (FY 89-91) and long-term (FY 92-98) activities (and associated FTEs) designed to implement the ten-year strategy. Some of the short-term activities are also divided into subtasks. Estimates for long-term FTE needs are less exact and would be based to a large extent on the outcome of short-term activities. Emphasis for recommendations was placed on Water Quality Program-related efforts that would likely be carried out by Technical Services' Water Quality Investigations Section or the Water Quality Management and Evaluation Section.

Although the items listed may appear to be distinct units, one should keep in mind that the effectiveness of each activity depends on implementation of at least one of the other activities listed, and in most cases, several of the others.

Table 5. Recommended activities (FY 1989-1991) designed to build the foundation for the 10-year ground water monitoring goal.

Activities (short-term: FY 199-91)	Dates	FTEs Needed (E=Existing; N=New)	Activities (long-term: FY 199?-1998)
Water Quality Program-related Activities			
1. Improve ground water data management capabilities.			1. Provide continued and additional data management staff resources needed. (2 FTEs/yr)
a. Determine data base management needs for Water Quality Program-related activities. Recommended approach for meeting these needs.	Nov 88-Apr 89 (6 months)	0.5 N 0.1 E (WQIS)	
b. Develop recommended data management system.	May 89-Jan 90 (9 months)	0.7 N 0.2 E (WQIS)	
c. Provide adequate staff for on-going data management.	Feb 90-June 91 (on-going)	1.5 N 0.2 E (WQIS)	
2. Develop strategy for regional hydrogeologic characterization mapping/interpretation.			2. Take part in hydrogeologic characterization/mapping effort according to plan. (0.5-3.0 FTEs/yr)
a. Convene inter-agency group to determine outputs, methodology, schedule, funding, etc.	July 89-Dec 89 (6 months)	0.5 N 0.1 E (WQIS)	
b. Take steps to implement hydrogeologic mapping plan designed above.	Jan 90-June 91 (1.5 years)	0.5-1.5 N 0.25 E (WQMES)	
3. Develop a broadscale ground water monitoring effort to detect problems due to point and especially non-point sources.			3. Gradually enlarge ground water monitoring in areas where most needed to detect and evaluate problems. Evaluate and adapt based on results. (2-3 FTEs/yr)
a. Analyze and interpret available ground water data to determine emerging or existing trends and areas where data lacking.	Jan 89-June 89 (6 months)	0.6 E (WQIS)	
b. Design and implement pilot study to detect regional or non-point ground water contamination and background trends in a high-priority area where contamination is known or suspected.	July 89-June 91 (on-going)	2.0 N 1.0 E (WQIS)	
4. Improve waste discharge permit monitoring.			4. Use written guidance; adapt over time. Guidance from HQ for regional consistency. Develop and implement ground water compliance inspections at permitted facilities. (5-10 FTEs/yr)
a. Add technical staff resources in regional offices for designing and overseeing ground water monitoring at regulated facilities.	July 89-June 91 (on-going)	8.0 N 1.0 E (SWRO, ERO: 0.25 each; WWRO: 1.0)	
b. Develop written guidance for designing monitoring networks, QA/QC, etc. for waste discharge permits to ground. Provide on-going technical assistance to regional offices.	July 89-June 91 (on-going)	2.0 N	
c. Develop ground water monitoring data management capabilities (coordinated with #1, above).	July 89-June 91 (on-going)	2.0 N	
5. Continue to develop agricultural chemical monitoring effort based on FY 88-89 study.			5. Evaluate and continue at level needed. (2-3 FTEs/yr)
a. Conduct follow-up monitoring in areas where agricultural chemical problems are identified.	July 90-June 91 (1 year)	0.5 E (WQIS)	
b. Conduct problem-identification monitoring for agricultural chemicals in other high-risk areas.	July 90-June 91 (on-going)	2.0 N	

Table 5 - continued.

Activities (short-term: FY 199-91)	Dates	FTEs Needed (E=Existing; N=New)	Activities (long-term: FY 1992-1998)
Water Quality Program-related Activities - continued			
6. Develop prioritization system for problem assessment monitoring at non-standard contamination (grey-area) sites (Water Quality-related).	July 90-Dec 90 (6 months)	0.1 N 0.3 E (WQMES)	
7. Expand capabilities for non-standard contamination (grey-area) assessment monitoring at high-priority sites.	July 90-June 91 (on-going)	2.0 N	7. Evaluate and adapt non-standard contamination assessment monitoring. (2-4 FTEs/yr)
8. Develop ground water monitoring procedures to evaluate effectiveness of GWMA programs.	July 90-March 91 (9 months)	0.70 N 0.25 E (WQMES)	8. Analyze GWMA data for effectiveness of programs. Adapt monitoring as necessary. (1.0 FTE/yr)
9. Enter or import computer information on land use, soils, hydrogeology, well locations, etc. to determine highest risk areas for ground water contamination.	July 89-June 91 (on-going)	1.0 N	9. Use and develop capabilities for manipulating this information (GIS) for such activities as #3, above. (0.5-1.0 FTE/yr)
10. Develop and implement ground water monitoring procedures and capabilities for evaluating major BMPs.	July 89-June 91 (on-going)	1.0 N 0.4 E (WQMES)	10. Analyze data for effectiveness of BMPs. Develop and adapt as needed. (1-3 FTE/yr).
11. Begin limited water quality monitoring through water level observation networks: CRO and ERO.	July 89-June 91 (on-going)	0.8 N	11. Increase water quality sampling in selected water level observation wells based on available data. Adapt as needed. (1-2 FTEs/yr)
			12. Based on #3 through 11, above, develop short-term, special-purpose monitoring study(ies) at selected areas. Evaluate and adapt over ti (2-4 FTEs/yr)
			13. Develop and implement ground water monitoring to evaluate effectiven of Well Had Protection Program as needed.
Non-Water Quality Program-Related Activities			
1. Continue follow-up ground water monitoring at Hazardous Waste Cleanup sites where cleanup is complete.	July 88-June 91 (on-going)	2.0 N 2.0 E (WQIS)	1. Increase follow-up ground water monitoring at HWCU sites. (2-4 FTEs/
2. Improve ground water monitoring at permitted solid waste sites (especially landfills).			2. Continue adequate oversight at solid waste facilities. Develop and implement ground water compliance inspections at solid waste (landfi and waste discharge permitted facilities. Evaluate and adapt over ti (2-7 FTEs/yr)
a. Add technical staff resources in regional offices for designing and overseeing ground water monitoring.	July 88-June 91 (on-going)	? N ? E	
b. Develop written guidance for reviewing monitoring networks, QA/QC, etc. Provide on-going technical assistance to regional offices.	July 89-June 91	? N	
c. Develop ground water monitoring data management capabilities (coordinated with #1, above).	July 89-June 91 (on-going)	? N	

VIII. Conclusions

A summary of Washington's major ground water monitoring needs and a recommended strategy for meeting them are presented in this report. The underlying philosophy of the strategy is to supplement available information with the most necessary additional monitoring or data collection efforts.

New or additional efforts are needed in all five objective areas. Major needs include:

1. Regional hydrogeologic mapping/interpretation effort for principal aquifers.

2. Regional problem identification/background monitoring to detect point and non-point pollution sources.

3. Ground water monitoring to investigate non-standard ground water contami nation sites (grey-area sites).

4. Improved ground water compliance monitoring and sampling inspections, especially at solid waste facilities and permitted facilities with discharges to ground.

5. Capability to assess ground water vulnerability via mapping of soils, land use, hydrogeology, etc.

6. Ground water monitoring to evaluate effectiveness of GWMA's, Best Management Practices, Hazardous Waste cleanups, and eventually Well Head Protection Areas.

7. Ground water monitoring upgradient of major public water supply wells to detect contamination in time to take corrective action.

Improvements that are needed in all existing and future ground water monitoring activities are also addressed. These include:

- Data management.

- Coordination (intra- and inter-agency).

- Quality assurance/quality control and statistical considerations.

- Cost effectiveness considerations.

A time frame for a step-wise implementation of recommended activities is also presented. An iterative process of evaluating data and adapting monitoring efforts is recommended to promote optimal allocation of limited resources.

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APPENDICES

Appendix A. GROUND-WATER MONITORING NEEDS QUESTIONNAIRE

Name:_____
Affiliation:_____
Address:_____
_____

As you are probably aware, the Water Quality Investigations Section of Ecology is in the process of developing a Ground Water Monitoring Strategy. The first two portions of the process have been completed:

1) Outlining objectives for ground-water monitoring, and
2) Summarizing major monitoring efforts to date.

Volumes I. and II. of the Ground Water Monitoring Strategy cover these topics and are available (Ecology 1987a, 1987b). If you do not have copies, please call Barb Carey at 753-9163.

The third step in developing the monitoring strategy is to assess ground-water data needs relative to Ecology's responsibilities. The purpose of this effort is to obtain as comprehensive a view of ground-water monitoring needs as possible from the many perspectives of Ecology staff and managers around the state. We are extremely interested in your ideas about both present ground-water monitoring activities and future needs to enable the department to most effectively carry out it's mandates.

We are asking that you take some time to think about the items on this questionnaire, fill in your responses, and return the form to Barb Carey at the Southwest Regional Office.

The questionnaire is divided into four sections:

Section 1: The first section asks you to rate a number of objectives for which ground-water monitoring data can be used. First, we would like to know what priority you place on each of these objectives from the perspective of Ecology as a whole with its mission as you understand it. Second, we would like to know how important you think reliable ground-water monitoring data are in accomplishing each objective.

You will therefore have two ratings for each objective-- one for the relative importance of the objective to the department, the other for the importance of ground-water data to meet the objective. The first blank after each objective is for rating the objective (Column A), and the second blank is for rating the importance of monitoring data to accomplish that objective (Column B).

The objectives for ground-water monitoring listed below are organized according to the five broad-scale objectives described in Volume I. of the Ground Water Monitoring Strategy (Ecology, 1987a). If you wish to add any objectives or comments please do. We are very interested in

your ideas and suggestions.

Section 2: After you have rated the specific objectives we would like you to evaluate the importance of the five broad-scale objectives, assuming that they include most of the specific objectives that you just rated. The five broad-scale objectives are listed in Section 2 of this questionnaire. This information will help determine where the department's priorities for ground-water monitoring should lie. Again we would like your evaluation of the objective itself in the first column and the need for reliable ground-water monitoring data in the second column.

Section 3: The third section is a table showing major ground-water monitoring efforts in Ecology and DSHS (columns) and the five broad-scale monitoring objectives (rows). The purpose of this section is to get your view of the existing ground-water monitoring efforts. We would like to know how you think these efforts relate to the general ground-water monitoring objectives and to what extent these objectives are being met.

We would like you to direct your attention to the columns of the table in Section 3. that descibe monitoring activities that you are familiar with. We ask that you rate the ground-water monitoring efforts you know about in terms of their importance in meeting each broad-scale objective and then in terms of data quality and availability.

Section 4: The fourth section deals with the questions of why existing ground-water monitoring data are satisfactory or unsatisfactory in order to rectify current problems and prevent problems in the future.

Further instructions will be given with each section.

Thank you very much for your time and assistance. We hope you will benefit from thinking about these issues too. We will send you a summary of the questionnaire results when they are processed. We may be faced with further questions resulting from this questionnaire and may develop a short follow-up questionnaire or meeting. If you are interested in taking part in follow-up activities related to the assessment of ground-water monitoring needs please check here: _____

SECTION 1.

Please rate the following specific ground-water monitoring OBJECTIVES first in terms of RELATIVE NEED OR IMPORTANCE for Ecology as you see its mission (Column A). Then rate the need for ground-water monitoring data to accomplish that objective (Column B). Please rate the objectives as one of the following:

Very High	4
Fairly High	3
Medium	2
Low	1
Not Important	0

	Rating A	Rating B
1. Characterize the Ground-Water Resource		
a) Distinguish trends in ground water quality with an adequate level of confidence.	_____	_____
b) Determine baseline conditions for future comparison with nearby areas where land use may affect ground-water quality.	_____	_____
c) Distinguish between natural ground-water quality trends and those caused by human activities.	_____	_____
d) Provide a statewide perspective on ground-water quality.	_____	_____
e) Implement and refine the Ground Water Quality Protection Strategy.	_____	_____
f) Provide information for classifying aquifers and determining if aquifers are meeting their classification. (The Water Quality Program is developing an aquifer classification system.)	_____	_____
g) Provide information to be used for designation and development of Ground Water Management Area (GWMA) Programs (Chapter 173-100 WAC).	_____	_____
h) Provide preliminary data for local land use planning, facility site investigations (regulated and unregulated), in EIS processes, and/or initial contamination assessments.	_____	_____
i) Provide data for regional model development and verification.	_____	_____
Others:		

	Rating A	Rating B
2. Promptly Identify New Problems		
a) Discover new incidences of known types of ground-water problems, e.g.:		

	Rating A	Rating B
1) Agricultural chemical contamination (pesticides, fertilizers).	_____	_____
2) Contamination from solid waste facilities (landfills, sludge disposal, waste piles, surface impoundments, ect.).	_____	_____
3) Underground storage tanks and pipes leaking petroleum products or other contaminants.	_____	_____
4) Wastewater contamination from lagoons, spray irrigation systems, leaking sewers.	_____	_____
5) Chemical spills.	_____	_____
6) Hazardous waste storage and disposal.	_____	_____
7) Underground wastewater injection (e.g., stormwater disposal wells).	_____	_____
8) Inadequate septic system wastewater treatment.	_____	_____
9) Mining activities.	_____	_____
10) Improper well construction and/or abandonment.	_____	_____
11) Seawater intrusion.	_____	_____
12) Cumulative impact of several or many sources.	_____	_____
b) Discover or anticipate new types of problems: (hypothetical examples)		
1) Effects of acid rain percolation on ground-water contamination.		
2) Virus contamination from septic systems.	_____	____
c) Prioritize identified ground water contamination sites for further study and action.	_____	_____

Others:

	Rating A	Rating B
3. Assess Known Problems by Determining Cause and Effect Relationships		
a) Provide detailed information on the mechanisms of similar ground-water contamination incidences that can be used to establish Best Management Practices (BMP's) or to enable effective regulatory actions.	_____	_____
b) Provide sufficiently detailed information on similar ground-water contamination problems to develop reliable, standardized compliance monitoring procedures specific to hydrogeologic conditions found in Washington.	_____	_____
c) Evaluate behavior of toxic chemicals that leach into ground water and limit their use as necessary.	_____	_____

	Rating A	Rating B
d) Determine source, extent, and severity of documented ground-water contamination problems at specific sites (problems such as those listed in 2. above).	_____	_____
e) Characterize and prioritize waste sites (e. g., solid waste sites, UST's, pesticide contamination sites, ect.) that are known threats to ground water.	_____	_____
f) Determine appropriate corrective action and/or enforcement at contamination sites.	_____	_____
g) Determine effectiveness of corrective action and BMP's related to ground-water contamination.	_____	_____
h) Verify and calibrate ground-water flow and contaminant transport models in major geologic areas of the state.	_____	_____
i) Refine Ground Water Management Area boundaries	_____	_____
j) Refine aquifer classifications.	_____	_____

Others:

4. Ensure Compliance with Regulations	Rating A	Rating B
a) Issue or deny a discharge permit to ground water.	_____	_____
b) Assure that ground-water discharge permit conditions are being met (monitoring data is of adequate quality, submitted and analyzed in a timely manner and in a usable format).	_____	_____
c) Take action based on a violation of permit requirements.	_____	_____
d) Modify the conditions of a permit with a discharge to ground water.	_____	_____
e) Conduct facility inspections (e.g., audit sampling activities, split samples and analyze in Ecology laboratory, collect samples for additional constituents not required under the permit).	_____	_____
f) Develop or amend regulations related to specific facilities or activies that may affect ground water.	_____	_____

Others:

	Rating A	Rating B
5. Evaluate Program Effectiveness		
a) Determine whether regulatory goals are being met; whether goals are appropriate; if regulatory or management goals should be changed.	_____	_____
b) Determine whether ground-water monitoring and sampling programs are cost-effective.	_____	_____
c) Determine the effectiveness of implemented control measures to prevent or minimize ground-water contamination (or effectiveness of control measures for other purposes).	_____	_____
d) Determine whether federal and state laws are effective in preventing or minimizing ground-water contamination.	_____	_____
e) Determine whether ground-water quality problems are being detected under existing programs.	_____	_____
f) Determine whether documented ground-water quality problems are being prioritized and the source(s) and extent of the problems promptly investigated.	_____	_____
g) Determine the portion of ground-water quality problems that have been identified that are being investigated or have been investigated.	_____	_____
g) Determine whether intensive investigations to identify the source(s) and extent of ground water contamination have been done so.	_____	_____
h) Determine whether monitoring data collected to characterize ground-water conditions have been used to: - Identify new problems, - As baseline data for intensive surveys, or - As baseline data for compliance monitoring.	_____	_____
i) Determine whether Ground Water Management Area (GWMA) Programs are adequately protecting ground-water resources (both quality and quantity).	_____	_____
j) Determine whether there are ground-water areas in		

the state not designated as GWMA's where ground-water problems or potential problems are apparent. _____ _____

k) Determine whether ground-water monitoring data collected by Ecology, its grantees, and the regulated community are of adequate quality for the purposes that they are collected. _____ _____

l) Determine whether Ecology's ground-water monitoring data are managed such that full use can be made of them by others (in and outside Ecology). _____ _____

Others:

COMMENTS:

SECTION 2.

Please rate the following broad-scale ground-water monitoring objectives for their importance from your perspective in your section (Rating A) and then rate them for their importance from a departmental perspective (Rating B). The rating options are:

Very High	4
Fairly High	3
Medium	2
Low	1
Not Important	0

	Rating A	Rating B
1. Characterize the ground-water resource.	_____	_____
2. Promptly identify new problems.	_____	_____
3. Assess known problems by determining cause and effect relationships.	_____	_____
4. Ensure compliance with regulations.	_____	_____
5. Evaluate program effectiveness.	_____	_____

COMMENTS (on SECTION 2.):

SECTION 3.

Please look over the following table and decide which of the ground-water monitoring activities you are familiar with (organized by program across the top). For each monitoring activity you are familiar with, we would appreciate if you would give your assessment of the SEVERITY of the NEED for that activity if one wishes to accomplish each of the major objectives on the left side of the table. Please fill in your rating for this item in the TOP space in each box using the following rating system:

4: Data absolutely necessary
3: Data not absolutely necessary but of great use
2: Data not necessary but of some use
1: Data not necessary and may be of no use

After rating the need for the data for each objective in the program elements that you are familiar with, we would like to know what you feel t! quantity and quality of the data NOW being collected in terms of each objective is. Using the following rating system, we ask that you place your rating of the QUANTITY AND QUALITY of existing data beneath the number rating you chose for the data NEED of each objective. Please fill in your rating for this item in the lower space in each box using the following rating system:

4: Large amount of data, fairly good quality
3: Small amount of data, fairly good quality
2: Large amount of data, quality lacking
1: Small amount of data, quality lacking
0: Data not being collected
*: Data not yet collected, but will be.

COMMENTS:

SECTION 4.

For each program in Ecology that you are familiar with that collects ground-water data please indicate how well you feel the elements listed are addressed on a scale of 1 to 5 (5 being very satisfactory and 1 being very unsatisfactory). (This section after University of Washington, 1985

Program Name:_____

	Rating
a) Establishment of relevant, meaningful goals and objectives.	_____
b) Scientifically sound study design tied directly to established goals and objectives.	_____
c) Regulatory guidance or requirements.	_____
d) Statistical considerations including estimate of allowable error, confidence level adequate sampling of control sites).	_____
e) Execution of study design.	_____
f) Use of appropriate sampling equipment.	_____
g) Ability to distinguish real change from other sources of variation (e.g. natural variation, other contaminant sources).	_____
h) Level of expertise of study designers, samplers, or data interpreters.	_____
i) Consistency in sample design methodology among studies.	_____
j) Consistency in sampling and analytical methodology among studies.	_____
j) Data management and potential for use by others.	_____
k) Usefulness and timliness of reports.	_____
l) Consideration of similar studies.	_____
m) Coordination with related programs.	_____
n) Coordination with other agencies in areas of common interest.	_____
o) Cost effectiveness.	_____

Others:

COMMENTS: (Continue on attached sheet if needed.)

Reference

Ecology, Washington State Department of, 1987a. Ground Water Monitoring Strategy for Washington. I. Objectives for ground water monitoring. Report 85-8A, 24pp.

Ecology, Washington State Department of, 1985b. Ground Water Monitoring Strategy for Washington. II. Summary of ground water monitoring activities. Report 85-8B, 51pp.

University of Washington Department of Civil Engineering, 1985. Sampling design for aquatic ecological monitoring, Vol. 5, Delphi Supplement. Prepared for the Electric Power Research Institute, Publication No. EA-4302, Palo Alto, CA.

Appendix B. Summary of Ground Water Monitoring Needs Questionnaire Results

Section 1 of the Questionnaire

The first section dealt with prioritizing a number of possible sub-objectives for each of the five major objectives discussed in Chapter III and in Volumes I and II of the Ground Water Monitoring Strategy. Below is a list of the sub-objectives for which the mean ratings indicated fairly high to very high importance.

Objective 1. Characterize the ground water resource

a) Distinguish trends in ground water quality/quantity with an adequate level of confidence.

b) Determine baseline conditions for future comparison with nearby areas where land use may affect ground water quality.

c) Distinguish between natural ground water quality/quantity trends and those caused by human activities.

Objective 2. Promptly identify new problems

a) Discover new incidences of known types of problems; e.g.:

1) Agricultural chemical contamination
2) Contamination from solid waste facilities
3) Underground storage tanks, leaking petroleum delivery pipes
5) Chemical spills
6) Hazardous waste storage and disposal
7) Underground wastewater injection (e.g., stormwater wells)
12) Cumulative impact of several or many sources

b) Prioritize identified ground water contamination sites for further study and action (initial prioritization based on minimal data).

Objective 3. Assess known problems by determining cause-and-effect relationships

a) Provide information on mechanisms of similar ground water contamination incidences that can be used to establish Best Management Practices (BMPs).

d) Determine source, extent, and severity of documented ground-water (contamination) problems at specific sites.

e) Characterize and prioritize waste sites that are known ground water threats.

f) Determine appropriate corrective action and/or enforcement action at contamination sites (next step after 3.d. above).

g) Determine effectiveness of corrective action and BMPs related to ground water contamination (next step after 3.f. above, also fits under Objective 5, Evaluate program effectiveness).

Objective 4. Ensure compliance with regulations

a) Issue or deny a discharge permit to ground water.

b) Assure that ground water discharge permit conditions are being met (monitoring data are of adequate quality, submitted and analyzed in a timely manner and in a usable format).

c) Take action based on violation of permit requirements.

d) Modify the conditions of a permit with a discharge to ground water.

f) Develop or amend regulations related to specific facilities or activities that may affect ground water.

Objective 5. Evaluate program effectiveness

a) Determine whether regulatory goals are being met; whether goals are appropriate; if regulatory or management goals should be changed.

c) Determine the effectiveness of implemented control measures to prevent or minimize ground water contamination.

d) Determine whether federal and state laws are effective in preventing or minimizing ground water contamination.

f) Determine whether documented ground water quality problems are being prioritized and the source(s) and extent of the problems promptly investigated.

k) Determine whether ground water monitoring data collected by Ecology, its grantees, and the regulated community are of adequate quality for the purposes that they are intended.

1) Determine whether Ecology's ground water monitoring data are managed such that full use can be made of them by others (in and outside Ecology).

The following additional sub-objectives were suggested for Section 1:

- Before the above objectives can be prioritized, it is necessary to define the physical hydrogeology of the state's aquifer systems. This would require definition of the recharge and discharge areas, ground water flow paths, interrelationships of the aquifer systems in three dimensions, etc.; i.e., a comprehensive approach to define the ground water resource.

- Identify radionuclide/chemical contamination on/adjacent to the Hanford Reservation. Develop a time series of plume movements using 3H, 14C, 129I as indicators (Ecology's responsibility under RCRA/CERCLA).

- Develop more in-house experience and capability for ground water studies.

Comments on Objective 2 (Promptly identify new problems) focused on adding problem activities to the list such as the Hanford Reservation, raw material and product storage, agricultural return flows (including chemigation), service station bays, septic systems receiving hazardous material, coal piles, wood chips, and road salt.

Two comments on Objective 4 (Ensure compliance with regulations) conveyed the opinion that state wastewater treatment regulations should be updated to require ground water monitoring for lagoons and land application sites. Two responses advocated increased emphasis on ensuring that regulated facilities meet ground water monitoring permit provisions.

A general comment on this section was that resources are simply not available to do most of the monitoring needed to meet the sub-objectives. Public and legislative support is needed to obtain more resources to meet the most vital needs. Effort is needed to make this a priority and to create visibility.

Section 2 of the Questionnaire

The second part of the questionnaire asked respondents to rate the five objectives for ground water monitoring from 0 (unimportant) to 4 (very important).

The mean ratings for Section 2 are shown below. Values for Ecology respondents were calculated separately from those submitted by other entities. Means for the combined responses are presented as well.

Objective	Rating A		
	Ecology (n=22)	Outside (n=9)	Combined (n=31)
1. Characterize the resource	3.4	3.7	3.4
2. Promptly identify new problems	3.4	3.3	3.4
3. Assess known problems	3.5	2.9	3.4
4. Ensure compliance with regulations	3.7	3.2	3.5
5. Evaluate program effectiveness	3.0	3.1	3.0

Objective	Rating B		
	Ecology (n=21)	Outside (n=8)	Combined (n=29)
1. Characterize the resource	3.2	3.6	3.3
2. Promptly identify new problems	3.3	3.1	3.2
3. Assess known problems	3.5	3.5	3.5
4. Ensure compliance with regulations	3.7	3.8	3.7
5. Evaluate program effectiveness	3.5	2.8	3.3

Another respondent wrote that physical hydrogeology and aquifer mapping are absolutely necessary prior to assigning priorities among basic objectives. Another comment was: if the objectives refer to ground water quantity as well as quality issues, then they are all high priorities. Another respondent suggested that Objectives 4 and 5 (Ensure compliance with regulations and Evaluate program effectiveness) should be considered in a longer time frame than the others.

Section 3 of the Questionnaire

The third section of the questionnaire asked respondents to rate the contribution of the major routine ground water monitoring efforts carried out by Ecology and DSHS in meeting each objective as shown in Table 2. The scale used for rating was:

4 Data absolutely necessary
3 Data not absolutely necessary but of great use
2 Data not necessary but of some use
1 Data not necessary and may be of no use

The top blank in each box was for this rating. The bottom blank was for rating the quantity and quality of data from each effort. The rating scale below was used:

4 Large amount of data, fairly good quality
3 Small amount of data, fairly good quality
2 Large amount of data, quality lacking
1 Small amount of data, quality lacking
0 Data not being collected
* Data not yet collected, but will be

For each objective, mean values were calculated for the data need and data quality ratings (horizontally) as well as for each individual effort (vertically). Mean values for the monitoring effort ratings are shown at the bottom of each column. The number of responses for each effort is also shown (n = 4-11). Most people only rated the monitoring efforts with which they were directly involved, although some rated programs that they evidently were not familiar with. For example, some respondents rated the quantity and quality of data that do not exist or have not yet been collected (the second part of each box in the table). Such erroneous data ratings, where evident, were not included in calculations. Combined mean rating values for data need and data quality for each objective are shown in the right-hand column.

The horizontal ratings for the five objectives in Table 2 represent the mean ratings of the severity of the need for the individual monitoring efforts in order to meet the objective. For instance, a low value indicates little perceived contribution toward the objective; a high value indicates a greater perceived contribution. (The amount and quality of data are not included in this rating.) All five objectives rated fairly to very important, although Promptly identifying problems, Assessing known problems to determine cause-and-effect relationships, and Ensuring compliance with regulations, rated somewhat higher.

A rough measure of the relative effectiveness of individual monitoring efforts was evaluated by the ratio of the mean rating of the need for the effort to the mean data quality/ quantity rating. A ratio of 1 indicates that data closely meet the level of need; greater than 1 that the data do not meet the need; and less than 1 that the need is more than met by data currently collected.

Hazardous Waste Cleanup and RCRA/Dangerous Waste Monitoring data were judged closest to meeting their established needs. Monitoring activities under the Solid Waste Section and Water Quality Program were furthest from meeting their respective needs.

Section 4 of the Questionnaire

About half of the respondents critiqued one or more of Ecology's ground water monitoring activities for the elements shown in Table 3. Monitoring activities in the following programs were evaluated: Hazardous Waste Cleanup, Solid Waste, Hazardous Waste Management (RCRA), Water Resources Investigations, Water Quality Investigations, Nuclear Waste Management, and Waste Discharge Permits.

Table 3. Mean rating values for all monitoring efforts evaluated in Section 4 of the questionnaire. (taken from questionnaire)

Element	Mean Rating (n=15)
a) Level of expertise of study designers, samplers, or data interpreters.	3.6
b) Establishment of relevant, meaningful goals and objectives.	3.5
c) Scientifically sound study design tied directly to established goals and objectives.	3.3
d) Use of appropriate sampling equipment.	3.3
e) Ability to distinguish real change from other sources of variation (e.g. natural variation, other contaminant sources).	3.3
f) Consistency in sampling and analytical methodology among studies.	3.3
g) Consideration of similar studies.	3.3
h) Usefulness and timeliness of reports.	3.2
i) Execution of study design.	3.1
j) Consistency in sample design methodology among studies.	3.1
k) Regulatory guidance or requirements.	3.0
l) Statistical considerations (including estimate of allowable error, confidence level, adequate sampling of control sites).	2.9
m) Cost effectiveness.	2.9
n) Coordination with other agencies in areas of common interest.	2.8
o) Coordination with related programs.	2.7
p) Data management and potential for use by others.	2.4