M E M O R A N D U M

COMMONWEALTH OF VIRGINIA

DEPARTMENT OF ENVIRONMENTAL QUALITY

DIVISION OF WATER PROGRAM COORDINATION

SUBJECT: Guidance Memorandum No. 98 - 2010
VPDES Permit and VPA Permit Ground Water Monitoring Plans

TO: Regional Directors

FROM: Larry Lawson, P.E., Division Director

DATE: September 30, 1998

COPIES: Regional Permit Managers, Regional Water Permit Managers, Regional Remediation Program Managers, Regional Compliance and Enforcement Managers, Martin Ferguson, Alan Anthony, Andy Hagelin, Hassan Vakili, Terry Wagner (without attachment)

The Department of Environmental Quality is charged with the protection of state waters and the issuance of VPDES and VPA permits is one way of accomplishing that goal. The State Water Control Law (62.1-44.3) provides a definition of state waters which is inclusive of ground water. The ground water standards (9 VAC 25-260-190) sets forth the approach that DEQ should take in considering potential permits and it states as follows:

> "In order to prevent the entry of pollutants into groundwater occurring in any aquifer, a soil zone or alternate protective measure or device sufficient to preserve and protect present and anticipated uses of ground water shall be maintained at all times. Zones for mixing wastes with ground water may be allowed, upon request, but shall be determined on a case-by-case basis and shall be kept as small as possible."

Ground water monitoring has been addressed in both VPDES and VPA permits for many years; however, the various approaches from region to region may not have been consistent. Thus, in early August 1997, a ground water committee was established for the purpose of developing a guidance document on ground water monitoring, with specific emphasis on VPDES and VPA permitting. This guidance, which is attached, is to assist the regional offices in making consistent decisions on various ground water issues given fairly similar situations. In addition, it addresses issues as 1) when to require ground water monitoring, 2) monitoring well installation, 3) parameters to consider for monitoring, 4) proper sampling and analytical methods, 5) review of the submitted data, 6) risk assessment and 7) remediation. The guidance is based on existing ground water standards, and other existing procedures and it represents a consensus by both the Regional and Central Offices on ground water monitoring.

In support of this document, are the following: 1) one copy of the user's manual for GRITS/STAT; 2) four diskettes containing the GRITS/STAT program; and, 3) a diskette containing a Lotus spreadsheet with the student's t-test. These three items have been previously provided to each region. The ground water guidance document (less the attachments) will also be placed on K:\Agency\OWPS with the other OWPP guidance documents. The document is in WordPerfect 5.1 and formatted for printing on an HP LaserJet 4si.

DISCLAIMER

This provides procedural guidance to the staff. This document is guidance only. It does not establish legal rights or obligations. It does not establish a binding norm and is not finally determinative of the issues addressed. Agency decisions in any particular case will be made by applying the State Water Control Law and the implementation regulations on the basis of the site specific facts.

GUIDANCE FOR VPDES AND VPA PERMIT GROUND WATER MONITORING PLANS

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LIST OF ATTACHMENTS

LIST OF ATTACHMENTS (continued)

LIST OF REFERENCES

1. Davis, Stanley N. and DeWiest, Roger J. M., Hydrogeology, 1966 [Attachments I-3 & 4 and VII-4 were copied from this reference.]

2. Driscoll, Fletcher G., Groundwater and Wells, second edition, 1995 [Attachments IV-3 and VIII-4 were copied from this reference.]

3. Department of Environmental Quality, Office of Waste Management, Virginia Solid Waste Management Regulations (9 VAC 20-80 et seq.), Amendment 1, March 15, 1993 [Attachment VI-1 was copied from this reference.]

4. Department of Environmental Quality, Office of Waste Management, Statistical Compliance with the Solid and Hazardous Waste Regulations, A Training Course, January 18-20, 1994

5. Frye, Keith, "Roadside Geology of Virginia", Mountain Press Publishing Company, 1991 [Attachment IV-2 was copied from this reference.]

6. Nielsen, David M., Practical Handbook of Ground-Water Monitoring, 1991

7. Old Dominion University Research Foundation, Applied Marine Research Laboratory, "Guidance for Development of Health-Based Cleanup Goals Using the Decision Tree/REAMS Program", July 1994

8. U.S. Environmental Protection Agency, Office of Research and Development, EPA Handbook Ground Water Volume II: Methodology (EPA/625/6-90/016b) July 1991 [Attachments VII-2 and VIII-3, 5 & 8 were copied from this reference.]

9. U.S. Environmental Protection Agency, Office of Research and Development, EPA Ground Water Handbook January 1989 [Attachments I-1, IV-5 and VII-1 & 3 were copied from this reference.]

10. U.S. Environmental Protection Agency, Office of Research and Development, A GRound Water Information Tracking System with STATistical Analysis Capability, GRITS/STAT, v 5.0, User Documentation (draft), April 1997 [Attachment VI-2 contains example printout results from this program.]

11. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, "RCRA Ground Water Monitoring Technical Enforcement Guidance Document", September 1986 [Attachment IV-4 was copied from this reference and modified.]

LIST OF REFERENCES (continued)

12. U.S. Environmental Protection Agency, Technology Transfer, EPA Seminar Publication, Corrective Action: Technologies and Applications (EPA/625/4-89/020) September 1989 [Attachments VIII-1, 2, 6 & 7 were copied from this reference.]

13. U.S. Geological Survey, U.S. Geological Survey Water Resources Investigations Report 88-4059, Adopted from "Ground-Water Resources of the York-James Peninsula of Virginia" [Attachment I-5 was copied from this reference.]

14. Virginia Groundwater Protection Steering Committee, A Groundwater Protection Strategy for Virginia, May 1987 [Attachments I-2 and IV-1 were copied from this reference.]

15. VPDES Permit Technical Manual [Attachment IV-6 was copied from this reference.]

I. INTRODUCTION

OUT OF SIGHT, OUT OF MIND. That is what can happen with the protection of ground water; however, it is of vital importance and must be continuously thought about in both the Virginia Pollutant Discharge Elimination System (VPDES) and Virginia Pollution Abatement (VPA) permitting processes. In addition to maintaining the State's ground water standards, it is important to protect ground water for existing and potential users.

The Department of Environmental Quality (DEQ) has various purposes, including the protection of the atmosphere, land and waters of the Commonwealth from pollution (Section 10.1-1183, DEQ Statutes). In addition, the State Water Control Board has been charged with various powers and duties which are delineated in the State Water Control Law (SWCL), three of which are:

1. "To study and investigate all problems concerned with the quality of state waters..." [Section 62.1-44.15(2)];

2. "To establish such standards of quality and policies for any state waters....and to take all appropriate steps to prevent quality alteration contrary to the public interest or to standards or policies thus established..." [Section 62.1-44.15(3a)]; and,

3. "To issue certificates for the discharge of sewage, industrial wastes and other wastes into or adjacent to or the alteration otherwise of the physical, chemical or biological properties of state waters under prescribed conditions..." [Section 62.1-44.15(5)].

With reference to number two above, the State Water Control Board approved the adoption of ground water standards and criteria for inclusion into the Water Quality Standards (9 VAC 25-260-5 et seq.) in order to protect the quality of ground water in the Commonwealth of Virginia. Many numerical standards were adopted including, in part, ones for insecticides, herbicides, radionuclides, pH, nitrogen and total metals. These amendments became effective in 1977.

It is also important to point out two definitions contained in the SWCL in order to tie this together.

1. State waters means "all water, on the surface and under the ground, wholly or partially within or bordering the Commonwealth or within its jurisdiction." [Section 62.1-44.3]

2. Pollution refers to the "alteration of the physical, chemical or biological properties of any state waters" [See Section 62.1-44.3 for full definition.]

Based on the above citations and Section II entitled "Authority", we have the authority and need to consider the protection of ground water with each permit action.

Currently within DEQ, the Resource Conservation and Recovery Act (RCRA) Subtitle C (Hazardous Waste), RCRA Subtitle D (Solid Waste) and RCRA Subtitle I (Underground Storage Tanks) programs require ground water monitoring. The VPA and Aboveground Storage Tank (AST) ground water programs are not federally mandated but protection of ground water for these programs is required by the SWCL (as discussed above for VPA; Section 62.1-44.34:15 for AST). It is also important to note that the water quality standards for ground water are not federally mandated nor does the U. S. Environmental Protection Agency (EPA) review and approve/disapprove them.

The RCRA programs and AST program within DEQ follow the same general requirements for ground water monitoring. Therefore, in an effort to provide consistency within DEQ for ground water monitoring, this guidance will attempt to adopt, wherever appropriate, the RCRA format for monitoring requirements within the VPDES and VPA Ground Water Monitoring Plans (GWMPs). Also, there may be times when a facility already has ground water monitoring being conducted based on the requirements of another program (eg. a bulk oil storage terminal as required under the AST program). In these cases, an effort should be made, whenever possible, to use those wells to satisfy any requirements which might be placed on them by either a VPDES or VPA permit.

As can be seen on Attachments I-1 and 2, there can be a number of sources of ground water contamination. There can be overall site activities (eg. wood preservers and spray irrigation sites) which can impact ground water even without inground units. This guidance will place specific emphasis on inground wastewater treatment works units such as industrial, animal and domestic waste lagoons, pits and basins. It is recommended that any new inground treatment unit being designed to hold a wastewater which can have a potentially adverse impact on ground water quality be lined. For those which are lined, a determination can be made on the need for a GWMP to ensure continued liner integrity. In making this determination, it should be remembered that liners typically have a finite life expectancy. In that regard, the requirement for a GWMP for both new and existing facilities would be of great value. All existing facilities, either lined or unlined, will need to be evaluated based upon various information. This guidance is intended to provide the basis for that evaluation and the subsequent determination as to whether remedial action is required.

The determination as to whether a new or existing lined unit gets a GWMP may depend, in part (aside from site characteristics), on the type liner used and the waste being held. Answers to the following questions may aid in making the final decision:

1. What are the pollutants of concern in the wastewater?

2. Is it a synthetic liner, how thick is it, what protection is afforded the liner (prevent puncture)? Do they have any leak detection system installed?
3. Is it a compacted clay liner, how thick is it, was it compacted in more than one lift, were compaction tests run for permeability confirmation, is it subject to dry periods? [The permittee can have permeability tests conducted on an existing clay liner.]
4. Is the liner a compacted soil-cement or clay-cement admixture, is it concrete or asphaltic, how thick is it?
5. Is the liner compatible with the type waste?
6. Is the liner susceptible to damage based on facility operations?

NOTE: Newly installed synthetic liners must be a minimum of 20 mils thick with a written certification of liner integrity provided by the installer.

Soils used as liners shall be capable of achieving a maximum coefficient of permeability of 1×10^{-6} cm/sec or less throughout the impoundment sides and bottom. Soils should be compacted within 4 percent of the optimum moisture content to achieve a density of at least 95 percent Standard Proctor Density. Total soil liner thickness shall be a minimum of one foot after compaction of at least two separate lifts of equal thickness. The final permeability rate shall be verified, in writing, by a Professional Engineer or soils laboratory.

Each site needs to be evaluated in order to make the determinations of 1) "Do I need to require the permittee to submit a GWMP?" (Could there be or is there a problem?) or 2) "Do I need to require unit lining and/or remediation?" (How severe is the problem and how much worse can it get?).

This guidance is intended to provide the answers to the above questions and, at the same time, give some measure of regional consistency in those answers. It is intended to assist the regional permit writers in determining when to require GWMPs in both VPDES and VPA permits, based on the units either being proposed or existing and the specific site characteristics, and provide some minimum requirements for those monitoring programs. It should also assist the permit writer in reviewing the GWMPs once they are submitted by permittees or their consultants. It is intended to aid permit writers in determining when to require unit liners and/or some measure of site remediation, based on a review of the ground water monitoring data submitted by the permittee. Finally, and perhaps most important, it should help in making consistent decisions between regional offices, given similar site situations (no two sites are ever the same).

Obviously, when making such determinations, it would certainly be beneficial to have a good understanding of the hydrologic cycle (see Attachments I-3, 4 and 5) and, more importantly, hydrogeology. Davis & DeWiest, in their book entitled Hydrogeology, define it as "the study of ground water with particular emphasis given to its chemistry, mode of migration, and relation to the geologic environment." As can be seen, the definition includes the basic information necessary to make appropriate decisions, whether it be for requiring ground water monitoring, unit lining and/or remediation. Whereas this document is not a short course in hydrogeology, it is intended to provide some basic information on the subject which may aid in making sound decisions.

Typically, the first type of GWMP would be a fairly simple one which uses a minimum number of wells to determine the integrity of the unit and/or if contamination is occurring at a site. The second type plan, which would be more extensive, would be one which uses wells to delineate the contaminant plume (size, characteristics, etc.), its movement and if it has reached a particular location (eg. property line, receptor, etc.). Some of the wells could even be used for contaminant withdrawal (remediation).

In the development of GWMPs, it is important for permittees or their consultants to identify the pollutants of concern and their different reactions with the ground water. Some pollutants mix well with the ground water whereas others can be non-aqueous phase liquids (NAPLs) which are either less dense than water and float on top of the water table (LNAPLs) or more dense and sink through the aquifer to a confining formation (DNAPLs). Additionally, some pollutants are quite mobile in the ground water (depending on their chemical characteristics and the hydraulic gradient) while others are not. It is also important to know that the water table, which is the boundary between the saturated and unsaturated zones, typically conforms fairly well to the surface topography. Some exceptions to this could be where there are extensive areas of either impermeable surface cover or highly permeable areas, perhaps created by backfill (utility lines).

The U.S. Environmental Protection Agency (EPA), in both their Ground Water Handbook and Ground Water Volume II: Methodology notes that ground water monitoring is used to provide representative data/information on the existing ground water quality, determine if contamination is resulting or has resulted, and determine the spatial area of the contamination. In making these determinations, the number of monitoring wells, their placement, construction (including casing size, materials used, screen length and depth), development and security along with the sample collection, including parameters to be analyzed, preservation and analytical methods, can all be very important in the assemblage of accurate data for analysis.

Whether it is a new or existing unit which is required to have a GWMP, there is no distinction made in how the units are handled. This guidance sets forth the same requirements for both of them, be it data review criteria, or the requirement for risk analysis and/or remediation.

The sections to follow provide a more detailed discussion on monitoring wells, parameters for monitoring, frequency of monitoring, the review of submitted data, risk assessment and remedial measures. Once again, it is important to remember that it is the responsibility of permittees or their consultants to prepare well thought out GWMPs. However, the permit writer needs to be aware of this document's information in order to make better decisions on the need for a GWMP and to assist in the proper review of a submitted plan.

II. AUTHORITY

Over the years, the State Water Control Board and now DEQ have required ground water monitoring in a variety of VPDES and VPA permits based primarily on the professional judgement of the staff. Our authority for this requirement is clear under the VPA regulations. However, we recognize that, as of the time of this document's preparation, there are a number of legal challenges concerning ground water monitoring in National Pollutant Discharge Elimination System permits.

DEQ's authority to request ground water monitoring and remedial activities exists under the following statutory and regulatory provisions noted below.

Section 62.1-44.5 of the SWCL states, in part,

> "Except in compliance with a certificate issued by the Board, it shall be unlawful for any person to (i) discharge into state waters sewage, industrial wastes, other wastes, or any noxious or deleterious substances, or (ii) otherwise alter the physical, chemical or biological properties of such state waters and make them detrimental to the public health, or to animal or aquatic life, or to the uses of such waters for domestic or industrial consumption, or for recreation, or for other uses."

The same prohibition is repeated in the VPA Permit Regulation under 9 VAC 25-32-30. Whereas the VPA Regulation does not define "state waters", section 62.1-44.3 of the SWCL does (refer to definition in Section I above) and it includes ground water. Therefore, any discharge to ground water or alteration of ground water quality is prohibited except "in compliance with a certificate issued by the Board".

As noted in Section I, Section 62.1-44.15 of the SWCL sets forth powers and duties of the State Water Control Board, one of which is the issuance of certificates.

> "(5) To issue certificates for the discharge of sewage, industrial wastes and other wastes into or adjacent to or the alteration otherwise of the physical, chemical or biological properties of state waters under prescribed conditions..."

This provision of the law allows the Board to establish reasonable conditions for the protection of both surface and ground waters.

Section 62.1-44.21 of the SWCL also states, in part,

> "The Board may require every owner to furnish when requested such plans, specifications, and other pertinent information as may be necessary to determine the effect of the wastes from his discharge on the quality of state waters, or such other information as may be necessary to accomplish the purposes of this chapter."

A similar requirement for furnishing information is also found in the VPA Permit Regulation, section 9 VAC 25-32-80 G.

As one final point, the federal regulations [40 CFR 122.41(e)], the VPDES Permit Regulation (9 VAC 25-31-190 E.) and the VPA Permit Regulation (9 VAC 25-32-80 D.) require the proper operation and maintenance of the various components within the treatment works. One primary way to ensure the continued integrity of inground units and/or liners (ie. as designed) is the requirement of ground water monitoring.

In summary, the authority exists for items such as ground water monitoring, facility upgrades (in response to ground water contamination) and ground water remediation to be required. The VPDES Permit Regulation contains similar citations as the VPA Permit Regulation. However, as noted above, this is still a controversial issue for VPDES permitting and currently subject to a number of lawsuits. In that regard, if any permittee objects to either ground water monitoring or remedial activities requirements being placed within their VPDES permit, there is a recommended alternative. That is to require the permittee to complete and submit, with a permit processing fee, a separate VPA permit application. The contents of that permit would require the submittal of the GWMP, any remediation requirements and/or any additional requirements deemed necessary to address the ground water concerns.

III. CONSIDERATIONS FOR REQUIRING A GROUND WATER MONITORING PLAN

As stated in Section I, it is recommended that all new units be lined, unless the permittee can satisfactorily demonstrate that there will be no threat to ground water (eg. perhaps through the installation of a leak detection system). The permit writer's decision of when to require a GWMP for new or existing units should be based on the three items noted below.

1. Type of Waste
   a. Is the facility municipal (sanitary) or industrial?
   b. If industrial, what is the nature of the wastewater treated (type of pollutants)?

2. Type of Containment
   a. Of what materials are the units constructed (eg. concrete, steel, earthen, etc.)? [The integrity of all types of units needs to be considered.]
   b. If earthen, are they lined or unlined? [Obviously, if unlined, there is a much greater potential for ground water contamination to occur.]
   c. If lined, (i) what type of lining exists, (ii) if a soil liner, does it meet the permeability requirement of $1x10^{-6}$ cm/sec, (iii) is the lining compatible with the wastewater being treated, (iv) were proper construction/placement procedures employed, and (v) was a leak detection system installed? [The tighter the compaction, the less the permeability. EPA uses $1x10^{-7}$ cm/sec as meeting no discharge; DEQ will accept $1x10^{-6}$ cm/sec. If there is any question regarding the compatibility of the wastewater with the liner, the permittees or their consultant should supply any documenting information needed.]
3. Hydrogeologic Information
   a. type and depth of each soil [Soil characteristics play an important role in pollutant migration; clayey soils are much less transmissive than soils which are more sandy. In addition, soils which are high in clay or organic content are more adsorptive for various pollutants (eg. metals)]
   b. type of and depth to bedrock
   c. depth to seasonal water table (Is there more than two feet between water table and unit bottom?) [If the bottom of the unit is located within the seasonal water table, a GWMP should be required. In addition, if within the water table, the upward hydraulic pressure can affect the liner.]
   d. anticipated direction of ground water movement (is it towards receptors and what are they?) [If the movement is towards receptors, the need to require ground water monitoring should be weighed heavily.]
   e. proximity to surface water, springs, public water supply intakes, public and private drinking water wells, livestock or lawn watering wells, buried utility lines and other ground water receptors
   f. any existing ground water information, including any existing onsite contamination and the potential for offsite contamination

As noted earlier, it is important to keep in mind that most liners have some associated life expectancy which makes the requirement for a GWMP much more important. Unless there is good reason, it is recommended that new and existing units be required to submit a GWMP. The intent of the initial monitoring is for screening to detect potential unit leakage or ground water impacts. Should the permit writer determine that a GWMP is necessary, the program should be appropriate and reasonable, with a minimum of one upgradient and two downgradient wells. Only the necessary parameters at appropriate frequencies are required; however, the parameter selection should be broad enough to address differing pollutants based on their varying characteristics and potential for

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movement to and within the ground water. [Well installation and parameter selection are discussed in Section IV.] The second phase of a monitoring program, which may require additional wells to monitor contaminant levels and movement, may restrict the parameter selection to several specific parameters. The purpose of the second phase would be to further define the contaminant plume and/or monitor the success of any corrective actions taken.

IV. MINIMUM REQUIREMENTS FOR A GROUND WATER MONITORING PLAN

The purpose of the GWMP is to ensure that an effective strategy is developed and properly implemented to determine if contaminants from the unit (ie. treatment or storage) have entered the ground water. The GWMP is also a helpful tool to assess the concentration and migration of each contaminant once it enters the ground water. These purposes hold true for both the VPDES and VPA programs. Therefore, this guidance provides a suggested format for a GWMP and includes what is felt to be the minimum amount of information that will allow an effective and complete assessment of existing ground water quality and, if necessary, provide a good basis to continue analysis with risk assessment and remediation.

The following list represents suggested sections which should be included and addressed in full by permittees or their consultants within GWMPs and the appropriate order:

A. Introduction
B. Hydrogeologic Information
C. Monitoring Well Design and Installation
D. Parameter Selection and Sampling Frequency
E Sampling Protocol

This format is flexible and not all components of each topic will apply to each facility. Following is a brief discussion of each of the above noted sections, including items which should be considered for inclusion into each.

A. Introduction

The GWMP should identify general facility information including, but not limited to, the following:

1. The scope and objective(s) of the GWMP (ie. to monitor specific unit(s) to determine if contaminants are entering the ground water).
2. General information about the facility, including the owner, operator, location, description of facility operations (if applicable); general description of onsite wastewater treatment provisions including age, construction, operation, and historical performance; characterization of the wastewater, etc.

/d

3. The identity of the unit(s) to be included and specific background information for each unit [eg. function of the unit(s) as part of wastewater treatment process, description of unit(s), when unit(s) initially began operation, etc.].

B. Hydrogeologic Information

As can be seen on Attachment IV-1, geologists divide Virginia into five physiographic provinces. This attachment provides some basic geological information. Attachment IV-2 provides additional information on the different rock formations which lie in each physiographic province. More detailed information regarding the five provinces in Virginia may be found in the book Roadside Geology of Virginia. The recently published "Geologic Map of Virginia" available from the Virginia Division of Mineral Resources and Geology and Virginia are also good references.

Regional and site-specific geologic information is the basis on which an effective GWMP is established. In addition, this information is instrumental in later phases of ground water monitoring if contamination is detected. For example, if the monitoring wells indicate that ground water contamination has occurred, site specific geologic information will help define the contaminant plume and aid in delineating its migration (direction and rate of flow). In addition, local and regional geologic information will provide vital information for development of an accurate and representative risk assessment study.

The GWMP should identify regional and local land use, topography, geology, hydrogeologic conditions, and ground water uses for the aquifer(s) of concern. In addition, site specific geologic information is necessary to detect and define the contaminant plume(s). Information such as site geology, ground water occurrence, hydrogeology, ground water flow, and ground water quality is necessary to properly characterize the site. Ground water gradient information (ground water elevation, flow direction, gradient) should be presented on a potentiometric surface map, which is a contour map of ground water flow overlain on a surface topography map. If this information is not obtained prior to development of the GWMP then the plan should include the methodologies that will be used to obtain the data.

C. Monitoring Well Design and Installation

1. Well Number and Location

For the VPDES and VPA programs, monitoring wells are installed at a facility to determine the effect a particular unit(s) has had or may have on nearby ground water quality. Monitoring wells are normally located upgradient of the unit to determine background (upgradient) concentrations and downgradient of the unit to detect contamination from the wastes. A minimum of one upgradient and two downgradient monitoring wells are required to adequately monitor ground water; however, consideration must be given to each specific site/unit to assess the need for additional wells. To ensure proper well location, the determination of horizontal flow direction should be made prior to the installation of permanent monitoring wells. In the event this is not done, the GWMP should include contingencies to relocate or install additional wells based on the determination of ground water hydraulics and direction of flow. Site geology, site hydrology, contaminant characteristics, and the size of the area under investigation all help determine where and how many wells should be constructed. The more complicated the geology and hydrogeology, the greater the number of monitoring wells that will be required.

Upon reaching the first saturated zone, contaminants generally move horizontally in the direction of ground water flow. For this reason, monitoring wells should be located in the uppermost aquifer. If the uppermost aquifer is hydraulically connected to one or more aquifers, then all aquifers must be monitored. A perched water table should also be monitored. A perched water table is basically a temporary or transient layer of infiltrating rainwater whose downward seepage is blocked by a low permeability layer, such as clay, causing the water to temporarily "pond" on the barrier at an elevation above the "normal" water table (see Attachments I-4, IV-3 and VII-4). When monitoring of multiple aquifers is necessary, the wells should be installed with the appropriate protective casing for protection against cross-contamination between aquifers.

The onsite hydrogeologic study is an important phase of any GWMP. This information is useful in determining placement of wells and defining the onsite flow regime. During this phase, it is important to identify all potential receptors, especially buried influent/effluent lines or utilities as contaminated ground water intersecting these areas of unconsolidated fill will tend to follow them, perhaps off the site (can divert contamination away from a monitoring well if it is placed on the downgradient side). In addition, areas of fractured rocks or solution-channeled carbonate rocks (karst) create additional problems with regard to monitoring well location. The initial investigation may consist of researching existing reports, maps, or research papers to gather information, in a broad sense, on the hydrogeological regime within the site.

Boreholes and piezometers may also be drilled to obtain the onsite geologic and hydrogeologic information and to determine the flow regime. A borehole is a hole drilled or bored into the earth, usually for exploratory purposes, that may be converted into a monitoring well. A piezometer is generally a small diameter, non-pumping well used to measure the elevation of the water table or potentiometric surface. Boreholes in which permanent wells are not constructed, as well as piezometers, should be sealed with material at least an order of magnitude less permeable than the surrounding soil/sediment/rock.

As noted above, areas of fractured rocks or solution-channeled carbonate rocks present additional concerns. Monitoring well placement is difficult due to the highly directional ground water movement (fracture/solution channel patterns can be unpredictable; difficult to predict ground water flow). In these circumstances, monitoring well screening depths may be based on the fractures/ solution channels rather than only ground water levels. In this environment, the monitoring system is more effective if the wells are screened in the highly permeable downgradient fractures. Also, as this terrain can be unpredictable with regard to fracture/ solution channel patterns and ground water flow, consideration should also be given to the monitoring of any nearby springs.

The GWMP should require initial documentation research as well as actual data from onsite boreholes and piezometers prior to well installation to define onsite ground water flow. If a permittee chooses to limit the hydrogeologic investigation to the review of existing documents, the GWMP must include a contingency for well relocation based on review of hydrogeologic information gathered during subsequent monitoring well construction and monitoring.

The upgradient well should be located at a point out of the zone of influence of the monitored activity so it is not influenced by onsite activity. The initial downgradient wells should be located within 20 feet of the perimeter of the unit. For lagoons, this would mean within 20 feet of the toe of the berm. If onsite operations or hydrogeologic conditions dictate that the wells be located farther than 20 feet from the unit, they should be kept as close as practically possible to that distance and between the unit and any downgradient receptors (eg. buried utilities). Justification should be provided for the chosen location.

2. Well Diameter

Attachment IV-4 provides a typical cross-section of a monitoring well. Normally, wells less than four inches in diameter are much less expensive than larger diameter wells in terms of both cost of materials and cost of drilling. With the development of technology and the advent of a variety of commercially available small-diameter pumps (less than two inches outside diameter), two-inch inside diameter wells have become the standard in monitoring well technology.

3. Monitoring Well Drilling Methods

Among the criteria used to select an appropriate drilling method are the following factors, listed in order of importance:

a. Hydrologic information
   (1) Type of formation(s)
   (2) Depth of drilling
   (3) Depth of desired screen setting below the top of the zone of saturation
b. Type of casing (dictated in part by the types of pollutants)
c. Location of facility (eg. accessibility)
d. Design of monitoring well
e. Availability of drilling equipment

Attachment IV-5 summarizes several drilling methods, their advantages and disadvantages when used for monitoring well construction.

4. Casing and Screen

The type of material used for a monitoring well can have a distinct effect on the quality of water samples. The materials of choice should retain their structural integrity for the duration of the monitoring program under actual subsurface conditions. They should not adsorb, absorb, or leach chemical constituents that would bias representative samples. The following is a preliminary ranking of commonly used materials that are listed in order of best to worst in terms of chemical resistance:

Teflon®
Stainless Steel 316
Stainless Steel 304
Polyvinyl chloride (PVC) Type 1
Lo-Carbon Steel
Galvanized Steel
Carbon Steel

PVC is the most common casing material used in monitoring wells. However, it should be noted that when using PVC and other similar materials, such as acrylonitrile-butadiene-styrene (ABS), polypropylene, or polyethylene, for well construction, threaded joints are recommended for connecting sections together. PVC primers and adhesives contain significant levels of organic compounds that can mask the presence of other similar volatile compounds.

A well slot diameter of 0.01 inch (#10 slot screen) is recommended for the well screen (well intake). This size is sufficient to allow ground water flow into the casing in a controlled manner so as to minimize cascading down the inside of the well casing. This well slot diameter size also aids in preventing the fines in the filter pack and aquifer from entering the ground water within the casing. Commercially manufactured well screens should be the only type of well screens allowed because stricter quality assurance/quality control (QA/QC) measures are followed by these manufacturers. In addition, commercially produced well screens arrive onsite wrapped in protective covering, ready for installation.

The length of the screen depends largely on the site specific geology. A typical screen length of 10 feet is recommended and screen placement must be the same in each well to allow for valid data comparison. However, this may vary depending upon hydrogeologic conditions such as thickness of the uppermost aquifer and the pollutants involved. When determining well screen depth, consideration should also be given to the specific gravity of the contaminant and any seasonal fluctuation in the water table. In essence, monitoring wells must be constructed such that the screen is located at an optimal elevation to capture potentially contaminated groundwater. For example, for LNAPLs, unless there are unusually significant vertical ground water flow gradients, just the top portion of the aquifer needs to be screened. In general, the well screen needs to be placed such that it intersects the water table at all times during seasonal fluctuations. For

DNAPLs, just the bottom portion of the aquifer needs to be screened [screen must be on the bottom of the aquifer (or at the top of the underlying confining layer)]. This will allow for detection of the most concentrated portion of either the LNAPLs or DNAPLs, respectively. It also prevents dilution of the sample with a lot of cleaner water from either the lower or upper part of the aquifer, respectively, if longer screen lengths are used. Finally, as noted above, the upgradient and downgradient wells must be screened in the same manner to allow for valid data comparison.

5. Filter Pack/Sealing Materials

Once the casing with screened interval is installed, an "annulus" is created. By definition, the annulus is the space between borehole wall and the casing. The annulus may be seen in Attachment IV-4. Typically, the annulus is backfilled beginning at the bottom of the borehole and progressing to the ground surface.

The area surrounding the screen should be backfilled with a "filter pack". A filter pack consists of material that is chemically inert, well rounded, dimensionally stable, and of proper size in relation to the natural aquifer material and the screen slot size (ie. clean quartz, silica, or glass beads). Typically, the average filter pack grain size associated with a 0.01 inch diameter well screen is in the range of coarse sand to fine gravel. The material is placed in the annulus to prevent formation material from entering through the well screen and to stabilize the adjacent formation. The filter pack should extend from the bottom of the well screen to a minimum of two feet above the top of the well screen. Placing the filter pack above the screen allows for settlement of the filter pack material and allows a sufficient buffer between the screen and the annular seal above.

Any annular space that remains above the filter pack provides a channel for vertical movement of water and/or contaminants unless the space is sealed. The seal serves several purposes: 1) to provide protection against infiltration of surface water and potential contaminants from the ground surface down the casing/borehole annulus, 2) to seal off discrete sampling zones, and 3) to prohibit vertical migration of water.

Attachment IV-4 shows how a typical monitoring well may be sealed. The annular sealant should consist of a minimum of two feet of bentonite pellets immediately over the filter pack when in a saturated zone. The pellets are most appropriate in a saturated zone because they will penetrate the column of water to create an effective seal. A material known as "neat cement" (a mixture of cement and water which may also contain sand, bentonite or hydrated lime) should be used as the annular sealant in the unsaturated zone above the bentonite pellet seal and below the frost line. The addition of bentonite to the cement admixture should generally be in the amount of 2 to 5 percent by weight of cement content. This will aid in reducing shrinkage and control time of setting. Locating the interface between the cement and bentonite-cement mixture below the frost line serves to protect the well from damage due to frost heaving. The remaining annular space should be sealed with expanding cement to provide for security and an adequate surface seal. The preferred method of emplacement of the bentonite-cement grout and the expanding cement is by injection with a tremie pipe from bottom to top.

6. Well Development

Development is a step of monitoring well installation that is often overlooked. During the drilling process, fine-grained materials smear the sides of the borehole, forming a mud cake that reduces the hydraulic conductivity of the materials opposite the screened part of the well. Development of the well removes mud cakes and any fluids, mainly water, which are introduced to the aquifer during the drilling process. Development also helps ensure that turbidity in the samples will be minimal. Successful well development methods include bailing, surging, and flushing with air or water. They require reversals or surges in flow to avoid bridging by particles.

7. Documentation of Monitoring Well Construction

Once the monitoring well has been installed, a borehole log and a monitoring well construction log should be submitted to DEQ for review. The following information should be included:

Borehole Log:

- Date and time of drilling
- Drilling method and drilling fluid used
- Well location (noted on a site specific well location map)
- Borehole diameter
- Well depth
- Drilling and lithologic logs
- Hydraulic conductivity of screened formations (may be determined by aquifer grain size compared to text book values, slug tests, lab permeability tests)

Monitoring Well Construction Log:

- Well casing diameter
- Casing materials
- Casing and screen joint type
- Screen size/length
- Filter pack material, size, and grain analysis
- Sealant materials (percent bentonite) and method of placement
- Surface seal design and construction
- Well development procedure
- Type of protective well cap
- Detailed drawing of well (include all dimensions)

8. Well Security

For most monitoring well installations, some precautions must be exercised to protect the surface portions of the well from damage by vehicles, lawn mowers, vandalism, etc. The top of the well should extend far enough above ground to be visible above grass, weeds, or small shrubs. The well casing should also be painted a bright color (eg. orange or yellow) and clearly numbered. The use of well protectors with a lockable cap should be required. It involves the use of a larger diameter steel casing placed around the monitoring well at the ground surface and extending several feet below the frost line.

9. Well Abandonment

The GWMP should include a description of the method for abandoning a ground water monitoring well. If future operations at a facility expand such that a monitoring well needs to be removed, it must be abandoned in a proper, safe manner. Typically, the ground surface seal, the protective pipe (if installed) and all or part of the casing material is removed. If the casing is not fully removed, it must be cut to a depth below the frost line and removed. If the well casing is removed, the well should be sealed as the casing is removed. The well should be backfilled with grout from the bottom up, using a tremie pipe, until grout flow is at the surface.

D. Parameter Selection and Sampling Frequency

1. Parameter Selection

Unless there is very good justification to the contrary, all GWMPs (municipal, industrial and animal waste) must include, as a minimum, monitoring for pH, total dissolved solids, conductivity, total organic carbon (TOC) and static water level (as related to mean sea level or some other established benchmark). The TOC is an important parameter from the standpoint of insuring that well integrity is being maintained. Other parameters would be added based on the type facility being monitored.

Animal waste and municipal facilities should also include at a minimum chlorides, fecal coliform, nitrate and ammonia. Other parameters which may be present in significant concentrations in the wastewater could also be included. It should be noted that nitrate, ammonia and chlorides are very mobile within the ground water and are, therefore, good indicator parameters to use for monitoring unit integrity. Indicator parameters are typically mobile parameters which travel the farthest the quickest and would be picked up first in a monitoring program.

For other industrial facilities, the parameter selection will be related to those specific wastewaters generated at the facility which are handled in such a way as to potentially impact ground water. Attachment IV-6 provides a listing of specific industrial categories and some of their associated pollutants and a listing of priority pollutants and some industries from which they may be expected [from the 1989 VPDES Technical Manual (rev. 1990)]. Whereas those parameters may be related to the manufacturing operation, they may or may not be specifically related to the wastewater stream of concern (eg. all or a portion of the process wastewater may go to sanitary sewerage facilities). The industrial classification codes (NAIC, SIC) can provide some information on the types of products which may be manufactured at the operation which, in turn, could give some insight on parameters to monitor. However, the permit application is probably the best place to initially look for potential parameters to monitor as the wastewater characteristics are to be provided (or estimated for proposed facilities). If the facility is regulated by the federal effluent guidelines (40 CFR 400-471), that could be another source for parameters.

As noted in Attachment IV-6, pollutants associated with industrial operations can vary widely depending on the industrial process (eg. metals, pesticides, PCBs, base neutral and acid extractables, volatiles, nutrients, etc.). Rather that requiring monitoring for a number of specific parameters listed for a given industry, the use of indicator pollutants is recommended. Attention should be given to those that are mobile within the ground water [some examples include chlorides, sulfates, ammonia, nitrates, benzene, naphthalene, trichloroethylene (TCE), perchloroethylene (PCE) and methyl-*tert*-butyl ether (MTBE)].

Finally, the Office of Water Permit Programs (OWPP) has provided guidance on ground water monitoring for several specific categories such as food processing, wood preserving, water treatment plant operations and municipal biosolids. These older guidance documents can also provide a basis for minimum parameter selection, but should be used to augment this guidance with regard to GWMPs.

The primary goal is for permittees or their consultants to develop a GWMP that is specific to the facility in question. In addition, the GWMP should not cause unnecessary monitoring and must result in the development of data that will be useful in determining the integrity of the treatment works and assuring the protection of the ground water and any receptors.

2. Sampling Frequency

The parameters selected for required monitoring (as discussed in Section IV.D.1.) should be monitored on a quarterly basis for a minimum period of two years. This is to account for variables as natural fluctuations both in water level and constituents, ground water movement rates and pollutant mobility. Ground water monitoring parameters and frequency for all facilities will be addressed and reported as part of the GWMP. This reporting format replaces prior formats required by previous guidance memoranda (eg. wood preservers), which also provided an effluent limitations page format.

Reduced monitoring frequency may be assessed on a case-by-case basis and only after the initial two years of monitoring data have been reviewed; however, in no case should it be reduced to less than once per year. Factors such as, but not limited to, ground water flow rate, rainfall amounts, as well as data assessment will be considered for reduced monitoring frequency. It should be pointed out that a reduction in monitoring frequency cannot be done automatically; the permittee must request it and provide the basis for the request. In addition, unless the plan clearly defines under what circumstances the monitoring can be reduced, the permit would need to be modified to reduce the frequency. Also, if the GWMP notes that a reduction will be made, it must be clear that it will be made only after DEQ approves the reduction. Finally, the GWMP should have provisions for increasing the monitoring back to quarterly should contamination be detected in any downgradient well.

E. Sampling Protocol

The sampling protocol is basically a step-by-step written description of the procedures used for well purging, delivering samples to the surface, handling samples in the field, and transporting samples to the laboratory. A generalized ground water sampling protocol normally includes the following steps:

1. Hydrologic Measurements
2. Well Purging and Sample Collection
3. Filtration/Preservation
4. Field Determinations
5. Field Blanks/Standards
6. Sample Storage/Transportation

Following is a brief discussion of each protocol step, including items which should be considered for inclusion into each.

1. Hydrologic Measurements

The sampling protocol should include provisions for measurement of static water elevations in each well immediately prior to purging and sampling. The accuracy of this measurement should be no less than 0.01 foot. Collection of water elevations on a continuing basis is important to determine if horizontal and vertical flow gradients have changed since initial site characterization. The sampling protocol should specify the device to be used for water level measurements, as well as the procedure for measuring water levels. Equipment should be constructed of inert materials and decontaminated prior to use at another well. It is recommended that upgradient wells be sampled prior to downgradient wells to reduce the possibility of cross-contamination.

2. Well Purging and Sample Collection

The water standing in a well prior to sampling may not be representative of *in situ* ground water quality. The standing water in the well and filter pack should be removed so that formation water can replace the stagnant water. Removal of the stagnant water is known as purging and is usually performed by pumping or bailing.

In order to minimize the introduction of contamination into the wells during purging, dedicated purging equipment is recommended for each well. Where this cannot be accomplished (must be reused from well to well), it should be thoroughly rinsed with Type II reagent grade water. To also prevent contaminant introduction, positive-gas-displacement, fluorocarbon resin bladder pumps are recommended. Fluorocarbon resin or stainless steel bailers are also recommended purging equipment. Where these devices cannot be used, peristaltic pumps, gas-lift pumps, centrifugal pumps, and venturi pumps may be used.

For the purging process, the water should be pumped until three well volumes are removed (allowing the well to recharge between each well volume removed) or until well purging parameters (ie. pH, temperature, and specific conductance) stabilize to ±10%; at that point, sample collection can be initiated. As a reference, Attachment IV-7 provides the amount of water in storage per foot of casing within the water table for different well casing diameters as well as the formula for making this calculation. As part of the GWMP, the permittee should indicate how purged well water will be disposed. It should not be discharged into ditches or storm drains.

During the sample collection process, the possibility of physically or chemically contaminating the sample during the withdrawal process must be minimized. This can be accomplished by using only fluorocarbon resin or stainless steel sampling devices, which should be dedicated for each well. If a dedicated sampler is not used, the sampler should be thoroughly rinsed with Type II reagent grade water. In addition, in some instances, field blanks should be taken to ensure cross contamination has not occurred.

The sampling protocol should specify the order in which samples are to be collected and containerized, which is dictated by the volatilization sensitivity of the parameters. A preferred collection order for some common ground water parameters is listed below.

a. Volatile organics (VOA)
b. Purgeable organic carbon (POC)
c. Purgeable organic halogens (POX)
d. Total organic halogens (TOX)
e. Total organic carbon (TOC)
f. Extractable organics
g. Total metals
h. Phenols
i. Cyanide
j. Sulfate and chloride
k. Turbidity
l. Nitrate and ammonia
m. Radionuclides

The protocol should identify the type of sample containers and the preservation techniques that will be used to collect samples. EPA approved methods listed in 40 CFR 136 (specifically 40 CFR Part 136.3, Table II "Required Containers, Preservation Techniques, and Holding Times") and/or SW-846 are recommended as standard procedures. It should be assured that the analyses which are done are at quantification limits (QLs) which are low enough to determine if there is a problem (at or below upgradient levels and below the ground water standards/criteria).

3. Filtration/Preservation

Certain parameters should be filtered (typically through a 0.45 micron filter) in the field and this should be initiated as soon as possible after collection. Filtration allows the determination of soluble constituents and is a form of preservation. Inorganic anions/cations and alkalinity are examples of constituents which should be filtered. Total metals, TOC, TOX, and other organic compounds should not be filtered because the increased handling may result in the loss of chemical constituents of interest.

4. Field Determinations

Constituents which are chemically or physically unstable must be tested either in the borehole or immediately after collection. Examples of unstable parameters include pH, temperature, specific conductance, dissolved oxygen (DO), redox potential and chlorine.

5. Field Blanks/Standards

The sampling protocol should ensure the reliability and validity of field data collected as part of the GWMP. This can be accomplished by providing for the collection and analysis of two types of QC blanks: trip blanks and equipment blanks. The equipment blanks should be taken if the purging and/or sampling equipment is not dedicated. As a minimum, trip blanks should be collected and analyzed for volatile organics.

For a trip blank, one of each type of sample bottle is filled with Type II reagent grade water and transported to the site. It is handled like a sample and returned to the laboratory for analysis of volatile organics. One trip blank per sampling event is recommended.

An equipment blank is prepared to ensure that the nondedicated purging and/or sampling device has been effectively cleaned (in the laboratory or field). The purging or sampling device is either filled with Type II reagent grade water or the Type II reagent grade water is pumped through it. The water is transferred from the device to sample bottles and returned to the laboratory for analysis. A minimum of one equipment blank for each day that the ground water monitoring wells are sampled is recommended.

6. Sample Storage/Transportation

Transportation of collected samples should be planned so as not to exceed the sample holding time before laboratory analysis. Again, the sampling protocol should comply with the sample holding times listed 40 CFR 136 (specifically 40 CFR Part 136.3, Table II "Required Containers, Preservation Techniques, and Holding Times") and/or SW-846. To ensure that the sample is not held beyond the recommended holding time and establish the documentation necessary to trace sample possession from time of collection, an adequate chain of custody record should be included in the protocol and submitted for each sampling event. The chain of custody record should contain the following information:

a. Sample number
b. Signature of collector
c. Date and time of collection
d. Sample type
e. Identification of well
f. Number of containers
g. Parameters requested for analysis
h. Signature of person involved in the chain of possession
i. Inclusive dates of possession
j. Internal temperature of shipping container when samples were placed in it
k. Internal temperature of shipping container upon opening in the laboratory

V. SCHEDULE OF COMPLIANCE FOR GWMP SUBMITTAL

Within the GWMP, the permittee needs to specify the schedule to be used both for well installation and the initiation of monitoring. Attachment V-1 is an example permit special condition for use in requesting the submittal of a GWMP. As can be noted, it does specify an outside date of 180 days after plan approval to have the wells installed and monitoring initiated. Unless there are very unusual circumstances, it is recommended that this schedule be adhered to within all VPDES and VPA permits. Any additional schedules needed for the submittal of borehole logs and monitoring well construction logs, as well as potentiometric surface maps can also be included in the condition. In addition, the permit writer may add certain minimum requirements specified within the guidance (eg. minimum number of wells, parameters to be monitored, monitoring frequency, etc.). Once the plan is submitted, it can be reviewed against the recommendations within this guidance memorandum. Attachment V-2 is an example permit special condition for use when there is already an approved GWMP and monitoring is to continue in accordance with that plan.

The example special condition in Attachments V-1 and 2 also addresses risk assessment and remediation, if it becomes necessary. Whereas 60 days has been suggested for submittal of a corrective action plan, this time allowance may be modified when dealing with unusual circumstances.

VI. RECEIPT AND REVIEW OF GROUND WATER DATA

Receipt of ground water monitoring data should be tracked like any other required permit submission. A check of the data should be made to ensure that the correct parameters are being monitored and that any necessary QLs are being met. The data should be tabulated so that periodic data reviews may be performed. At a minimum, the data should be reviewed and any adjustments to the monitoring program should be made when the permit is open for reissuance or modification.

The scattered nature of ground water monitoring data can make it very difficult to review and draw technically valid conclusions. Ground water monitoring in VPDES and VPA permits is generally required at a maximum of once per quarter and, unlike in the solid waste program, replicate samples are usually not required. Therefore, the total number of samples available for review may or may not be adequate for statistical review/analysis. The guidance outlined below is therefore considered appropriate for rough screening purposes only. Should permittees object to the statistical validity of conclusions reached as a result of this guidance, then they may always submit additional sampling and analyses to support their position. The water permit writers should feel free to request the assistance of remediation staff (or any other knowledgeable staff) in the Agency if they believe that the scope of the ground water data review, risk assessment, modeling, etc. is outside their area of expertise.

The State Water Quality Standards include an antidegradation policy for ground water which allows no degradation of quality without a socioeconomic variance. At the same time, the water quality standards indicate that ground water mixing zones may be approved on a case-by-case basis. The first cut at reviewing ground water data should determine whether there is a statistically significant difference between (1) ground water quality in the upgradient well versus each individual downgradient well (interwell) and (2) current ground water quality and the ground water quality prior to the facility/unit(s) being constructed (intrawell). Obviously, a comparison with ground water quality prior to construction of the original units cannot be performed for many older units as preconstruction data may not be available.

Solid waste permits issued by DEQ require very comprehensive ground water monitoring programs including an extensive list of parameters, large numbers of wells, replicate samples and regular statistical evaluations of the data by the permittee or their consultant. For VPDES and VPA facilities which, in the opinion of the permit writer, represent a significant threat to ground water, a more extensive monitoring program with regular data reviews provided by the permittee may be appropriate. However, such a program is not typically required of smaller inground units.

As a first cut in reviewing tabulated ground water monitoring results, the permit writer may want to review the data, comparing all downgradient results for a particular parameter and well to the upgradient results for the same parameter. If the downgradient results appear, on average, to be equal to or less than the upgradient results, then no further review may be required for that parameter at that well. If, however, there appears to be some increase in pollutants in the downgradient well, then some statistical evaluation should be performed.

The solid waste regulations (appendices 5.2 and 5.4; see Attachment VI-1) accept a number of statistical test methods for evaluating ground water data. These methods include:

1. Cochran's Approximation to the Behrens-Fisher (CABF) Student's t-Test
2. A parametric analysis of variance (ANOVA)
3. An analysis of variance (ANOVA) based on ranks
4. A tolerance or prediction interval procedure
5. A control chart approach
6. Another statistical test method that meets specified performance standards.

Of these methods, the CABF Student's t-Test and the prediction interval procedure are recommended for determining if there is a difference between upgradient and downgradient data distributions.

Both the Student's t-Test and the prediction interval procedure may be run using EPA's Ground Water Information Tracking System with Statistical Analysis Capability (GRITS/STAT) program (diskettes and user's manual for this program have been provided with this document). This software is capable of compiling ground water data as well as statistically manipulating and presenting the data in a number of formats. The Student's t-Test can also be run using a Lotus spreadsheet (diskette for this program has also been provided with this document). [NOTE: Either software package provided with this guidance may be used to evaluate ground water data. You will find that the GRITS/STAT program is somewhat cumbersome and the Lotus spreadsheet is limited to the Student's t-Test only. At some point in the future, Central Office may either develop or recommend another software package for Agency use.]

It is recommended that at least four quarterly samples be taken prior to running either statistical test. The Student's t-Test compares the means of two data sets to determine if there is a statistically significant difference between the two and it is typically used when there is a limited amount of data. The prediction interval procedure compares each downgradient data point with the predicted upper limit for the upgradient data distribution. If one or more downgradient samples lie above the upgradient's upper predicted limit, then contamination is assumed to have occurred. The upgradient upper limit is typically determined using a one-sided prediction interval with a confidence coefficient of 95%. In the event there is more than one upgradient well, then all upgradient well data should be pooled. The permit writer should look for trends in ground water contaminant data rather than relying on one datum which may indicate contamination.

Both procedures assume that the distribution of each of the two data sets being compared is normal. The assumption of normal data distributions may be checked by a number of methods. The EPA recommends using probability plots, the skewness coefficient test (for rough screening purposes), the Shapiro-Wilkes test ($n <$ or $=$ 50) and the Shapiro-Francia test ($n > 50$). The first three of these tests can be performed using the GRITS/STAT program. If the ground water monitoring data distribution is non-normal, then the permit writer should check to determine if a log-normal distribution is appropriate. If so, then the Student's t-Test or prediction interval test should be run on the log values. If the data distribution is neither normal nor log-normal, then one of the nonparametric methods should be used. The nonparametric prediction interval method is as simple as determining if the maximum downgradient value exceeds the maximum upgradient value. See Attachment VI-2 for an example ground water data review including a GRITS/STAT evaluation for normality, a GRITS/STAT Student's t-Test evaluation and the Lotus spreadsheet printout (t-test.wk1).

When results of the Student's t-Test, prediction interval procedure or any of the other tests identified above, indicate that there is a statistically significant difference between upgradient and downgradient (or preconstruction and current) data, then the facility is assumed to have violated the antidegradation policy for ground water and additional work will be required of the permittee or their consultant. This work may include additional sampling, additional wells to further define the area of contamination, fate and transport modeling, a risk assessment, and/or remediation.

VII. RISK ASSESSMENT

Where ground water data show a statistically significant increase in a pollutant from the upgradient well to the downgradient well (potential antidegradation violation), further action will be necessary. [At this point, permittees could request that they be considered under DEQ's voluntary remediation program (VRP). Part 30 of the VRP regulations (9 VAC 20-160-10 et seq.) defines which kinds of sites are potentially eligible for the VRP. In essence, only those sites where remediation is not already required by existing state and/or federal law are eligible. For the most part, units covered by VPDES and VPA permits would not qualify. However, in the event they meet the requirements and are accepted, all the risk assessment and remediation requirements of that program need to be fulfilled. Also, it is handled by the voluntary remediation staff and not by the permit writer.] For any pollutant which already exceeds the ground water standard in the upgradient well (eg. nitrates in agricultural areas), no additional increase will be allowed. When ground water monitoring data indicate that site contamination has taken place, a decision must next be made as to whether a risk assessment is required. For DEQ purposes, the first step will be for the permittee to determine if there are any onsite receptors of concern or if the ground water contamination has moved (or has a high potential to move) beyond the property boundary. If there are no onsite receptors of concern or ground water quality problems (or potential problems) at the permittee's property line (based on data and/or fate and transport information), there is no need at that time to consider requiring a risk assessment. However, if the contaminant plume has a high potential to migrate beyond the property boundary, a risk assessment should be strongly encouraged [more effective and less costly to define and remediate (if necessary) a smaller contaminant plume rather than waiting for it to increase in size with further migration]. If the pollutants have a high potential to reach an onsite receptor of concern or have migrated beyond the property line, a risk assessment will be required. The primary purpose of the risk assessment is to determine if the pollutants in the ground water will adversely affect the environment or public health.

As stated in the beginning of this document, both new and existing units are treated the same. However, they are initially discussed separately to account for the potential for different action routes (based on knowledge of when contamination may have started).

New Facilities/Inground Units

As noted in the introduction of this guidance, it is recommended that new inground treatment works designed to hold a wastewater which can have a potentially adverse impact on ground water quality be lined. If the decision was made to require the installation of ground water monitoring wells for these units and the data start showing increased levels over upgradient values, additional measures need to be taken.

Taking a proactive approach, the permittee may decide upfront to have the unit(s) relined (in all likelihood, the most cost effective approach). The permittee may elect at this point to perform a fate and transport analysis (rough estimates on the time of travel and the potential for offsite contamination can be made based on knowledge of time of unit installation, time of increased contamination and ground water flow rates). Also, assuming there is adequate distance to the property boundary, another set of downgradient wells can be installed to hopefully confirm the results of that analysis. Without the fate and transport analysis, the permittee would, as a minimum, install another set of downgradient wells, again assuming there is an adequate distance to the property boundary. If after a period of time, they too start showing increased levels over upgradient values, that would also provide some rough information to the permittee on the fate and transport of the pollutants. If ground water modeling calculations submitted show that the pollutants would be reduced to background levels at the property line, perhaps nothing needs to be done with the possible exception of placing additional wells near the property line to confirm that estimation. In any event, if contamination shows up in property boundary wells, the permittee will be required, as a minimum, to (1) reline or close out the unit and (2) conduct a risk assessment. The one possible exception to the requirement of relining or closing out the unit would be if the unit was discharging via the ground water to a surface water (receptor) either on the property or abutting the property line and instream monitoring indicated no adverse impact to the surface water.

Existing Facilities/Inground Units

Upon approval of the ground water monitoring plan, monitoring wells shall be established and ground water monitoring initiated. If the results of the data show that the downgradient wells are contaminated, another set of downgradient wells can be established, assuming there is adequate distance to the property boundary. If any well(s) located near property boundaries start to show contamination, it will be required, as a minimum, that the permittee (1) reline or close out the unit and (2) conduct a risk assessment. The exception noted above (under new facilities/inground units) for the requirement of relining or closing out the unit would apply here also.

There may be some situations where the permittee has a very large piece of property and the inground units are placed in such a manner that there are thousands of feet to his property line (based on ground water flow direction). In those instances, a smaller distance could be considered for maximum extent of contamination after which the permittee should be required to (1) reline or close out the unit and (2) conduct a risk assessment.

Ground water investigations (to include risk assessments and remedial measures) can be very costly. Site characteristics must be considered and costs could include items such as soil borings, well installations, monitoring and potential corrective measures. From that standpoint, the permittee should be encouraged to design and build a quality system in an effort to hopefully avoid these costs. However, if a ground water investigation becomes necessary, the permittee should put good upfront efforts into the development of the risk assessment with specific emphasis on the goals, any time constraints and funding. In addition, existing and future ground water uses should be considered. This should help ensure that all appropriate issues are addressed.

The purpose of the remainder of this section is to provide some definitions along with considerations to be made in the conduct of a risk assessment and to assist the staff in the review of a risk assessment, not how to conduct them. Each site is different and those site characteristics influence the conduct of each risk assessment. It is the responsibility of the permittees or their consultants to provide the risk assessment to the staff for review. The conduct and review of these documents are very important as the risk assessment ultimately determines whether some measure of remediation needs to be completed. A determination of the risk is typically made by assessing the existing zone of contamination, any potential receptors in the path of contamination and the fate and transport of the pollutants.

The zone of contamination (see Attachments VII-1 and 2) can be thought of as the spatial volume (surficial area and depth) of the pollutants in the ground water. Some pollutants of concern may have traveled in the ground water greater distances than others due to either their greater mobility with the given hydraulic gradient or various factors influencing their fate (see Attachment VII-2). It may be that the contamination is still within the confines of the permittee's property or has traveled well beyond.

In dealing with ground water, the term receptor means any place where the contaminated ground water can show up. Ground water follows the hydraulic gradient which can transport pollutants to receptors as wells (drinking water or otherwise), various surface waters (springs, streams, ponds, lakes), buried utility lines (unconsolidated fill) or other areas which have been cut into the water table. [If ground water intercepts unconsolidated fill which is not identified, it can divert contamination in an unexpected direction through this less resistant material.] In addition, separate aquifers can become contaminated due to interruptions in the confining layers (either natural or man-made). When contamination has occurred, these receptors need to be considered very carefully. Any onsite receptors become the primary focus for risk assessment with the property line and offsite receptors following in that order.

The fate and transport of pollutants is of critical importance in dealing with ground water contamination and the need for taking remedial measures. Transport refers to the movement of pollutants in the ground water (time of travel) whereas fate refers to how the pollutants may be impacted during their movement (eg. reduction via dispersion, breakdown, etc.). Understanding the processes that affect fate and transport of pollutants allows one to predict the approximate time of arrival and concentration of any given pollutant at a given receptor. It also helps in making good decisions for the installation of effective monitoring systems and proper strategies for remediation of contaminated aquifers. As an example, if an inground unit is discharging into a surface water via the ground water, stream monitoring may be required as part of the risk assessment to ensure that the surface water is not being adversely impacted. If there is no impact, no remedial measures may be necessary.

The transport (rate of pollutant movement) depends upon the hydraulic conductivity/transmissivity of subsurface soils/geologic formations and the hydraulic gradient, both in direction of ground water flow and the pollutant chemical characteristics. In a very basic sense, conductivity/transmissivity refers to the ease with which the ground water flows through the subsurface and porosity refers to the spaces between the individual particles making up the subsurface (it defines the amount of water which can be held within a given subsurface area). The hydraulic gradient is basically the slope of the water table in the direction of maximum head decrease. It can be mapped similarly to surface topography on a topographic map and typically does follow the contour of the land (see Attachments VII-3 and 4).

The fate (pollutant concentration with movement) can be due to a variety of processes, some of the more important ones being dispersion, filtration, sorption, time rate release of contaminates, and distance of travel. As pollutants migrate further from their source, they typically decrease in concentration via the above processes. Dispersion is both the horizontal and vertical mixing of the pollutants with the ground water (via diffusion or hydrodynamic processes) and is directly related to the ground water velocity. Filtration is the removal of particulates which is directly related to the porosity or the size of the spaces between particles. Sorption is an ionic bonding of pollutants to the subsurface surfaces. It is important to note that most subsurfaces are negatively charged so there is basically no retardation in the movement of negatively charged ions (eg. chloride, sulfate and nitrate). However, metallic ions which are positively charged can become bonded. It is also important to note that the exchange capacity of clayey and organic soils is much higher than sandy soils and that the pH of the ground water is very influential in this process. Finally, the rate and concentration at which the pollutants are being released from the source influences how quickly they will decrease with distance via the above processes.

In summary, when conducting the risk assessment, the first item which needs to be completed is to identify all the potential receptors (including onsite) within a given distance of the pollutant source. Next, the existing zone of contamination must be defined to ensure that potential receptors have not already been impacted. [As previously noted, contaminated ground water which intersects areas of unconsolidated fill (eg. buried influent/ effluent lines or utilities) will tend to follow them off the site.] Then, pollutant concentrations at receptors need to be predicted based on ground water flow rates and pollutant dispersion characteristics. A variety of fate and transport models ranging from simple analytical "desk-top" calculations to complex three-dimensional numerical computer models are available for this purpose. The complexity of the model method selected depends upon the complexity of the site conditions and the consequences of errors. Finally, based on all the above information regarding fate and transport, a decision needs to be made as to whether any corrective actions are necessary in order to protect the potential receptors (assuming they have not already been impacted).

The Risk Exposure and Analysis Modeling System (REAMS) is a widely accepted modeling tool, contains several different modules and is valuable in assessing various risks. As an example, there are modules which can address items as 1) the downward movement of the contaminants through the unsaturated zone, 2) the fate and transport of contaminants through the ground water system, and 3) the fate of contaminants when the ground water enters a receiving stream. REAMS can also address acceptable risk levels to human health which are typical of what EPA uses. The bottom line is that some measure of remediation is required if contamination to a receptor is either likely or has occurred and the contamination poses either an environmental or public health threat.

VIII. GROUND WATER REMEDIATION

In instances where ground water data show contamination from new and existing units, relining the unit or closing it out will eliminate the source of contamination. This is the initial step towards correcting the problem (note the exception under new and existing facilities/inground units) and, in reality, the first decision made in the remediation process. It could prove to be an interim measure or a final one. Depending on the pollutants and receptors, leaving the ground water alone at that point may be all that is necessary (decompose naturally). However, that decision would also depend on the existing and future uses of the impacted ground water, the potential receptors in the path of the contaminant plume and the fate and transport of the pollutants, as discussed under the risk assessment section.

If, based on the risk assessment, some remedial measures need to be taken in addition to relining or closing out the lagoon, that information should also be included in the recommendations by the permittee along with the measures to be taken. Again, remedial measures are site specific and need to be assessed on the bases of time constraint and cost/benefit ratio. Time constraints come into play based on how quickly some measure(s) may need to be accomplished in order to protect receptors (ie. rate of ground water flow impacts this factor). In addition, the cost/benefit ratio should assume that the default future use of the ground water is a source of drinking water. Typically, the most critical instance for additional remedial measures would be if a drinking water well has or is likely to be impacted (public health concern). In this case, it may be more reasonable to mitigate by providing a new and/or deeper well into a different aquifer (assuming the deeper aquifers are not also impacted by the pollutants and are suitable for a drinking water source). The remedial measure may also be to provide an alternate public/private water supply. If that is not practical, other remedial measures are available for use.

Again, because remedial measures are site-specific, this section is not intended to provide instruction on how to complete remediation, but to discuss various means by which it can be accomplished. The remedial method chosen can dictate what further items need to be completed and for what length of time (eg. operational monitoring, pumping, ground water treatment, associated operations and maintenance, post-operational monitoring and site closure).

There are various measures of ground water remediation. Some can be surface water controls which minimize infiltration of precipitation. Some can be barriers to ground water flow; they restrict or redirect ground water flow. There are hydrodynamic controls which involve either actively or passively removing ground water and others involving injection of clean or treated water. Finally, there are methods for in-situ treatment of pollutants. These methods can be used either separately or in combination.

A contaminated site can be controlled to some degree by installing surface water controls. Changing the surface contour can diminish infiltration; there may now be different areas for runon and runoff. Vegetating the site can also aid in minimizing infiltration as evapotranspiration increases. Finally, using a site cap (eg. clay or asphalt) can prevent localized infiltration of precipitation.

Ground water barriers are no more than mechanically installed low permeability layers. They can be installed upgradient of the pollutant source to keep the ground water from flowing through it by redirecting the ground water around it. They can also be used downgradient to prevent further migration of the pollutants and to contain ground water for pumping. There are a number of materials and types of barriers which can be installed, three of which will be described below. Slurry walls are installed by digging a trench to a given depth and keeping it filled with a clay-water mixture (5-7% bentonite). The clay in the mixture plugs the soil spaces forming a low-permeability layer. The trench is then backfilled with a soil-bentonite or cement-bentonite mixture or concrete. Grouting involves filling voids and cracks in the soil and rocks by injecting portland cement or sodium silicate through tubes into the ground and withdrawing them during injecting. Again, this creates a physical barrier. Finally, sheet piling can be driven to also form a physical barrier. See Attachment VIII-1 for some illustrations of ground water barrier use.

Hydrodynamic controls can also be installed either upgradient or downgradient of the pollutant source and can be used to remove ground water, assist in flushing a zone of contamination and change the direction of ground water flow. One of these controls is the installation of recovery wells to actively pump the ground water for treatment (see Attachment VIII-2). In these cases, the zone of contamination can be controlled to prevent further migration as the hydraulic gradient is changed; ground water is pulled towards the cone of depression established by the pumping. [See Attachments VIII-3, 4 and 5 for illustrations showing a cone of depression.] In addition, subsurface drainage can be used either upgradient of the pollutant source to reduce ground water flow through it or downgradient to prevent further migration of pollutants. They are mechanically installed areas of high permeability (eg. can use gravel and perforated piping). They too can be used to create a change in the hydraulic gradient, either removing the upgradient ground water or pulling the downgradient ground water into the drainage system for removal and treatment (see Attachment VIII-6). Finally, injection wells can also be installed for pumping clean water or treated ground water back into the aquifer. These wells can be used to divert ground water flow by artificially changing the hydraulic gradient (see Attachment VIII-7). They are more commonly installed upgradient of the pollutant source for reinjection of treated ground water which helps to purge the zone of contamination and form a "closed loop" system of contaminated ground water containment and cleanup (see Attachment VIII-8).

There are many instances where both ground water barriers and hydrodynamic controls can be utilized together. Attachment VIII-1 also shows some examples of combined usage.

In cases where the risk assessment recommends remediation via the use of wells or drainage systems to withdraw, treat and discharge or reinject the treated water, some recommendations of proposed endpoints for the remedial activity and post-operational monitoring should also be included. This will provide a point at which the ground water pumping system could be shut down or the drainage system could be plugged. At that time, post-operational monitoring of the wells would be conducted for a period of time (eg. one year) to ensure that the ground water remains "clean".

Finally, there are methods of *in situ* treatment of ground water, depending on the pollutants. In some instances, natural biodegradation can reduce pollutants (eg. organics). This would show up as part of the fate and transport determinations. In addition, the natural processes can be enhanced by the addition of nutrients and/or oxygen via injection wells.

The permit writer needs to remember that if the remediation measures include the discharge of contaminated ground water, either treated or untreated, to surface waters, a VPDES permit will need to be in place to address discharge monitoring and/or limitations. In those instances, a special condition could also be included in the permit which would require compliance with the approved risk assessment (any needed changes to the approved risk assessment would not necessitate a permit modification). If the receptor happens to be a surface water, consideration should be given to requiring a permit condition for monitoring upstream and downstream of the impact area. This will ensure that either the ground water discharge to the surface water is having, and continues to have, no adverse impact on water quality or the corrective measures have eliminated the pollutant impact, especially when no remedial measures other than lining are involved. Also, if any injection wells are proposed, they are subject to the Underground Injection Control (UIC) program which is currently administered by the EPA.

IX. SUMMARY

As previously noted, this guidance is intended for the following:

1. To address the need for the lining of various types of new in-ground treatment units (eg. lagoons, pits, basins);

2. To assist the regional permit writers in determining when to require ground water monitoring programs in permits;

3. To provide some minimum requirements for ground water monitoring programs;

4. To provide standard guidance in the review of submitted ground water data in order to determine if a leaking unit, either new or existing, needs to be lined/relined/closed out and a risk assessment completed;

5. To assist the regional offices in making consistent decisions with regard to requiring liners, monitoring plans and risk analyses, given similar site situations; and,

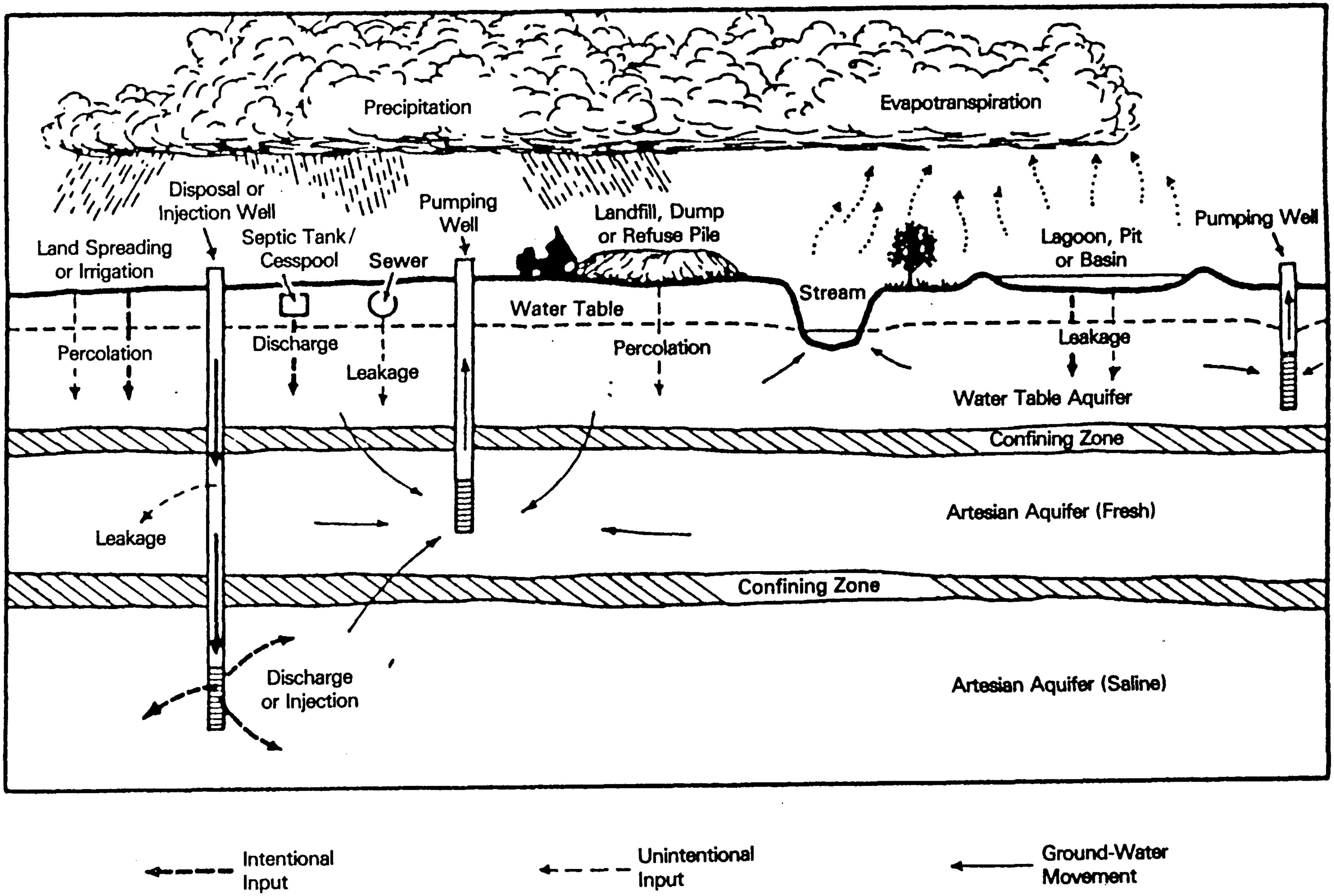
6. To discuss what considerations are made in performing a risk assessment and provide some of the primary types of site remediation measures in order to give the permit writer a better technical basis for reviewing them.

DISCLAIMER

This document provides technical and procedural guidance to the permit staff on ground water issues relative to both VPDES and VPA permits. This document is guidance only. It does not establish or affect legal rights or obligations. It does not establish a binding norm and is not finally determinative of the issues addressed. Agency decisions in any particular case will be made applying the State Water Control Law, the Federal Clean Water Act and the implementation regulations on the basis of the site-specific facts when permits are issued.

ATTACHMENTS I-1 TO I-5

Figure 1-5 Sources of ground-water contamination (from Geraghty and Miller, 1985).



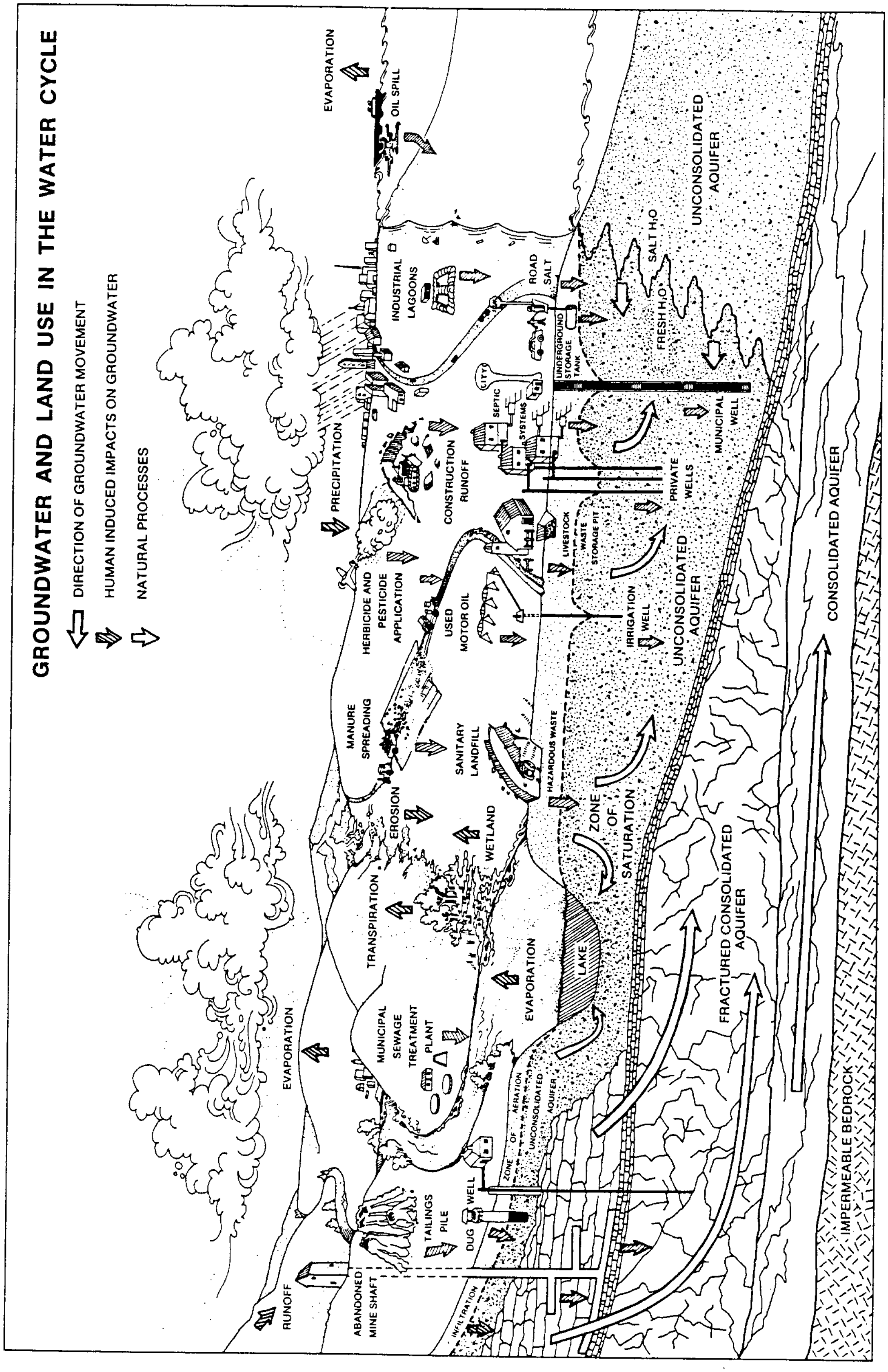

GROUNDWATER AND LAND USE IN THE WATER CYCLE
DIRECTION OF GROUNDWATER MOVEMENT
HUMAN INDUCED IMPACTS ON GROUNDWATER
NATURAL PROCESSES
RUNOFF
ABANDONED MINE SHAFT
TAILINGS PILE
DUG WELL
WELL
INFILTRATION
ZONE OF AERATION
UNCONSOLIDATED AQUIFER
EVAPORATION
MUNICIPAL SEWAGE TREATMENT PLANT
EVAPORATION
LAKE
TRANSPIRATION
WETLAND
EROSION
ZONE OF SATURATION
FRACTURED CONSOLIDATED AQUIFER
MANURE SPREADING
SANITARY LANDFILL
HAZARDOUS WASTE
HERBICIDE AND PESTICIDE APPLICATION
USED MOTOR OIL
IRRIGATION WELL
UNCONSOLIDATED AQUIFER
PRECIPITATION
CONSTRUCTION RUNOFF
LIVESTOCK WASTE STORAGE PIT
UNCONSOLIDATED AQUIFER
SEPTIC SYSTEMS
PRIVATE WELLS
CITY
MUNICIPAL WELL
UNDERGROUND STORAGE TANK
INDUSTRIAL LAGOONS
ROAD SALT
FRESH H_2O
SALT H_2O
UNCONSOLIDATED AQUIFER
EVAPORATION
OIL SPILL
CONSOLIDATED AQUIFER
IMPERMEABLE BEDROCK

Figure 3

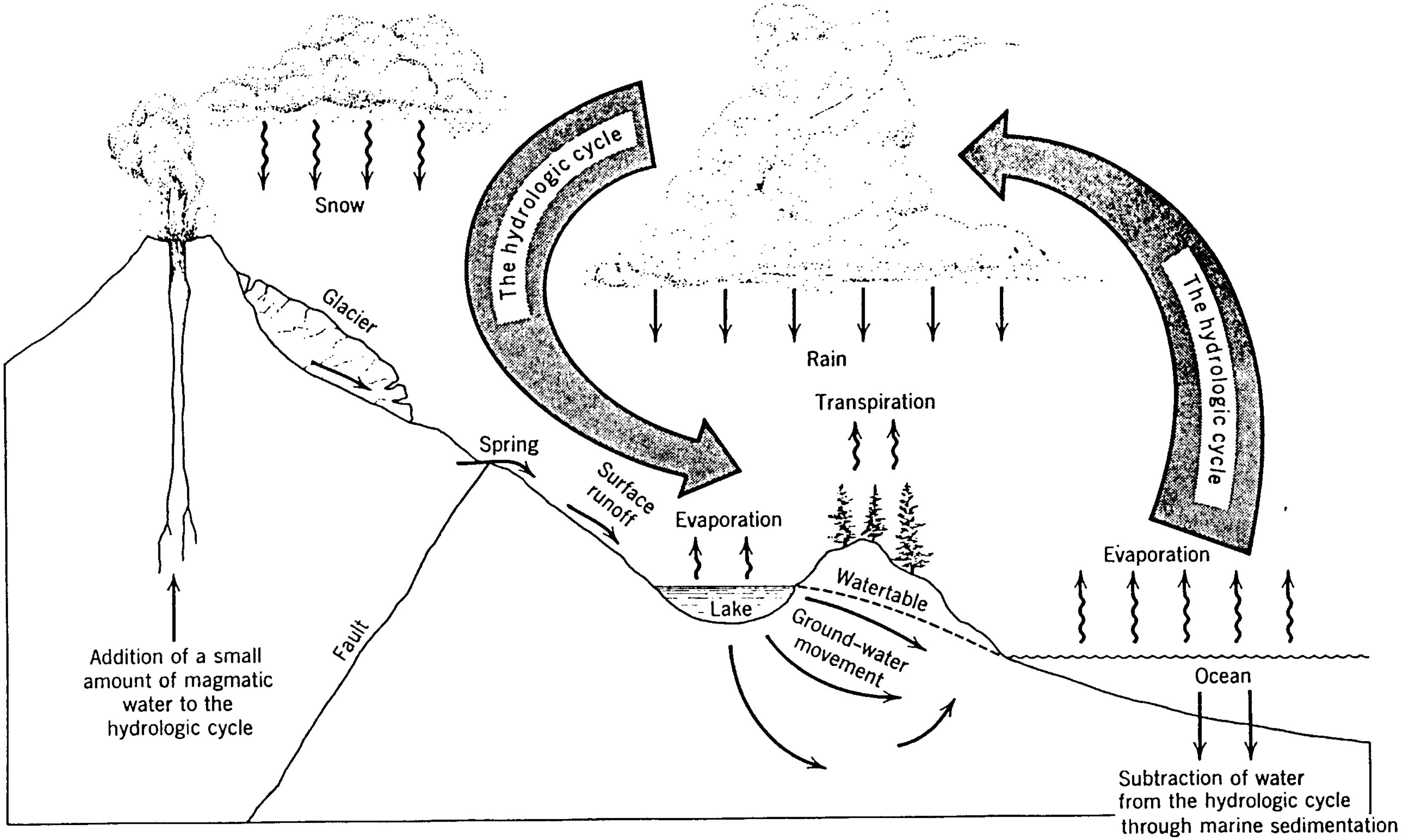


Figure 2.1 The hydrologic cycle.

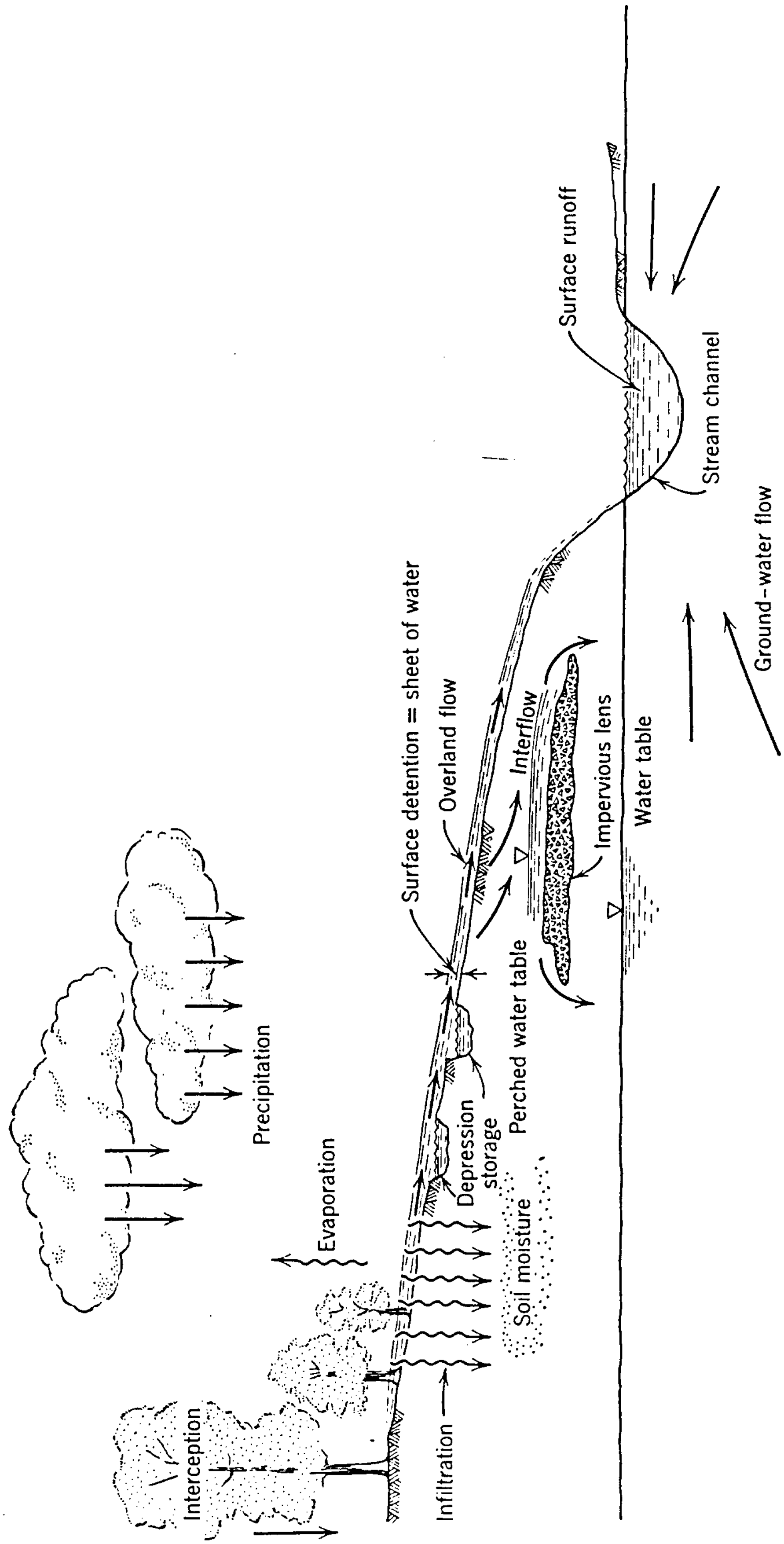
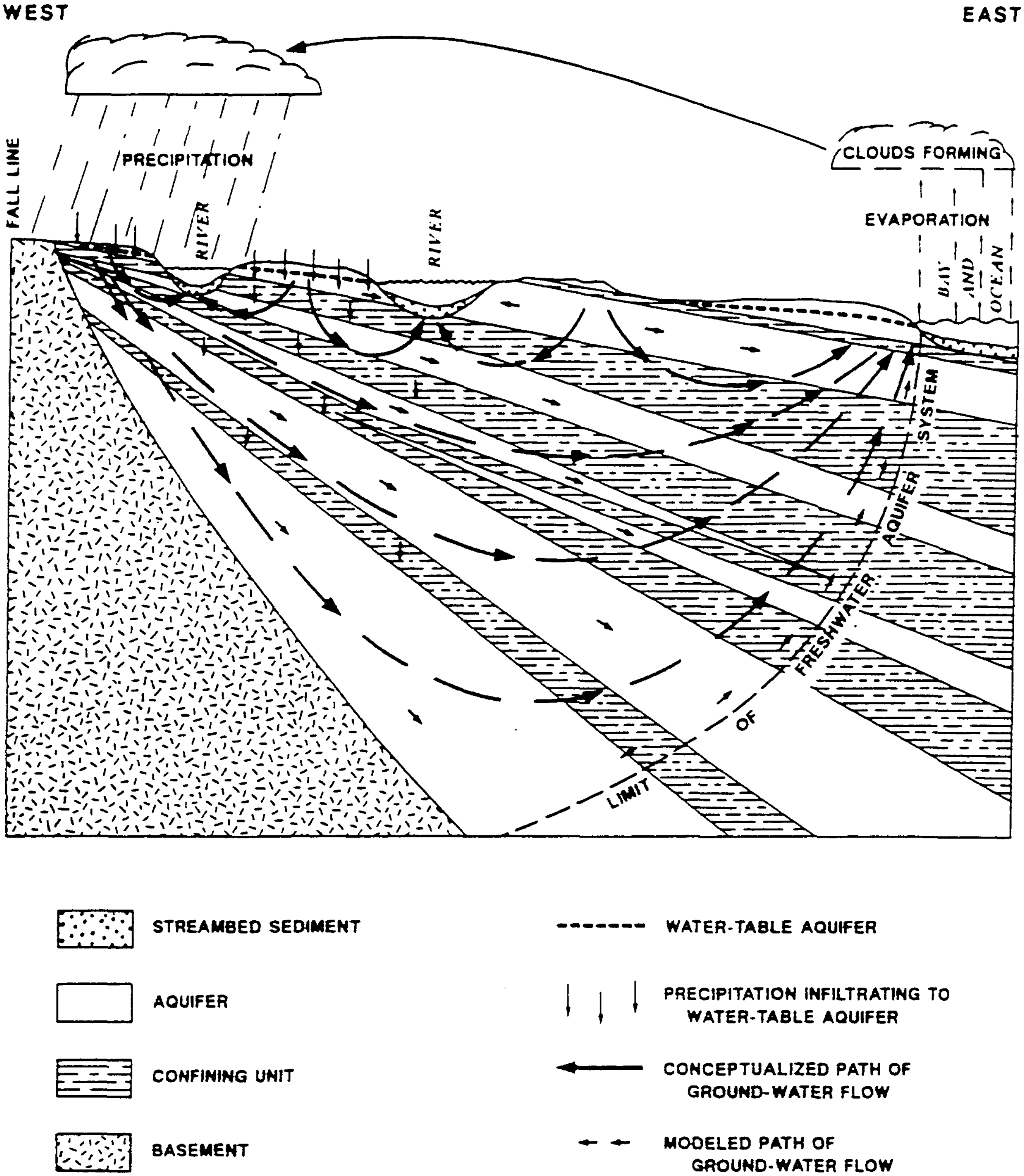


Figure 2.3 Simple picture of a runoff cycle.



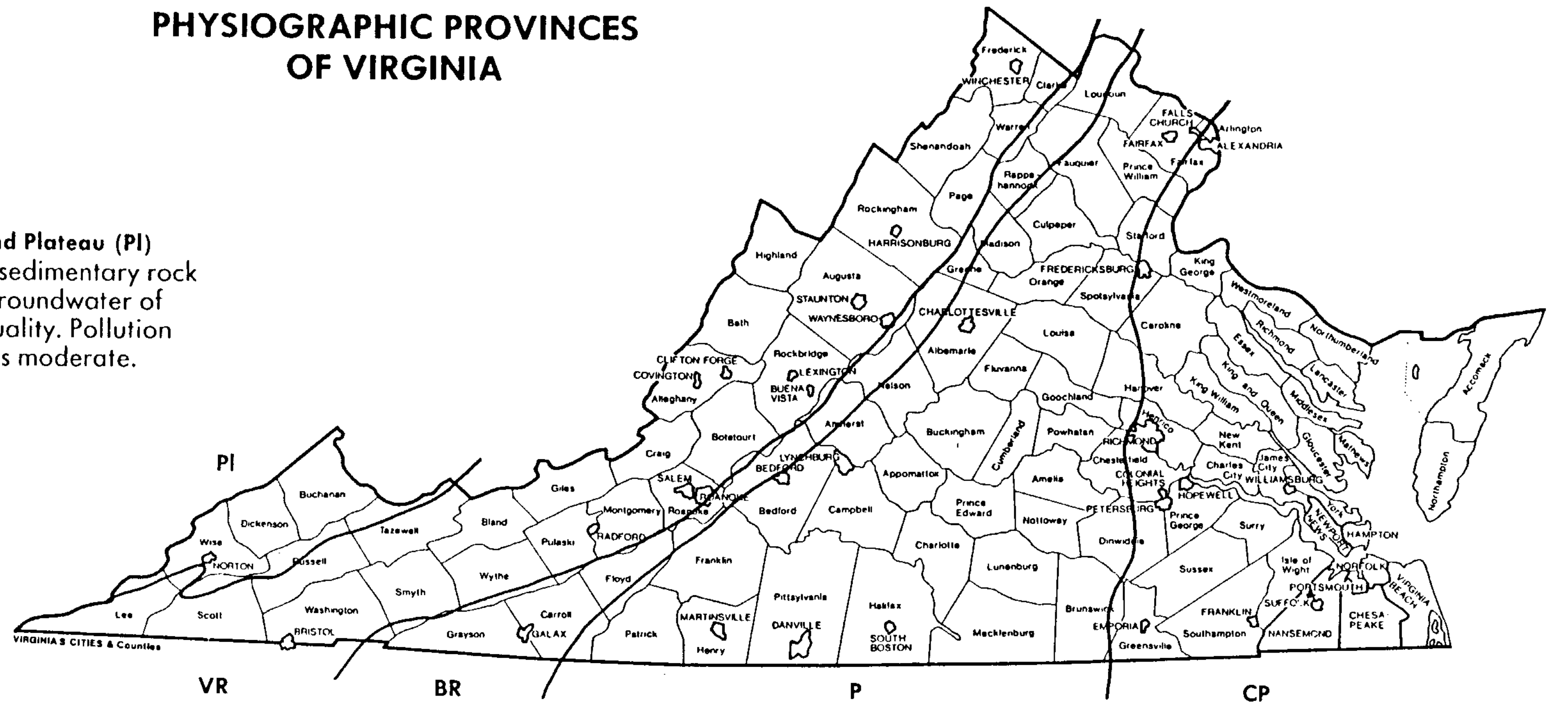
Generalized hydrologic cycle for the Coastal Plain Physiographic Province

Adopted from, "Ground-Water Resources of the York-James Peninsula of Virginia" U.S. Geological Survey Water Resources Investigations Report 88-4059

ATTACHMENTS IV-1 TO IV-7

Figure 1

PHYSIOGRAPHIC PROVINCES OF VIRGINIA



Cumberland Plateau (PI)
Geology: sedimentary rock yielding groundwater of varying quality. Pollution potential is moderate.

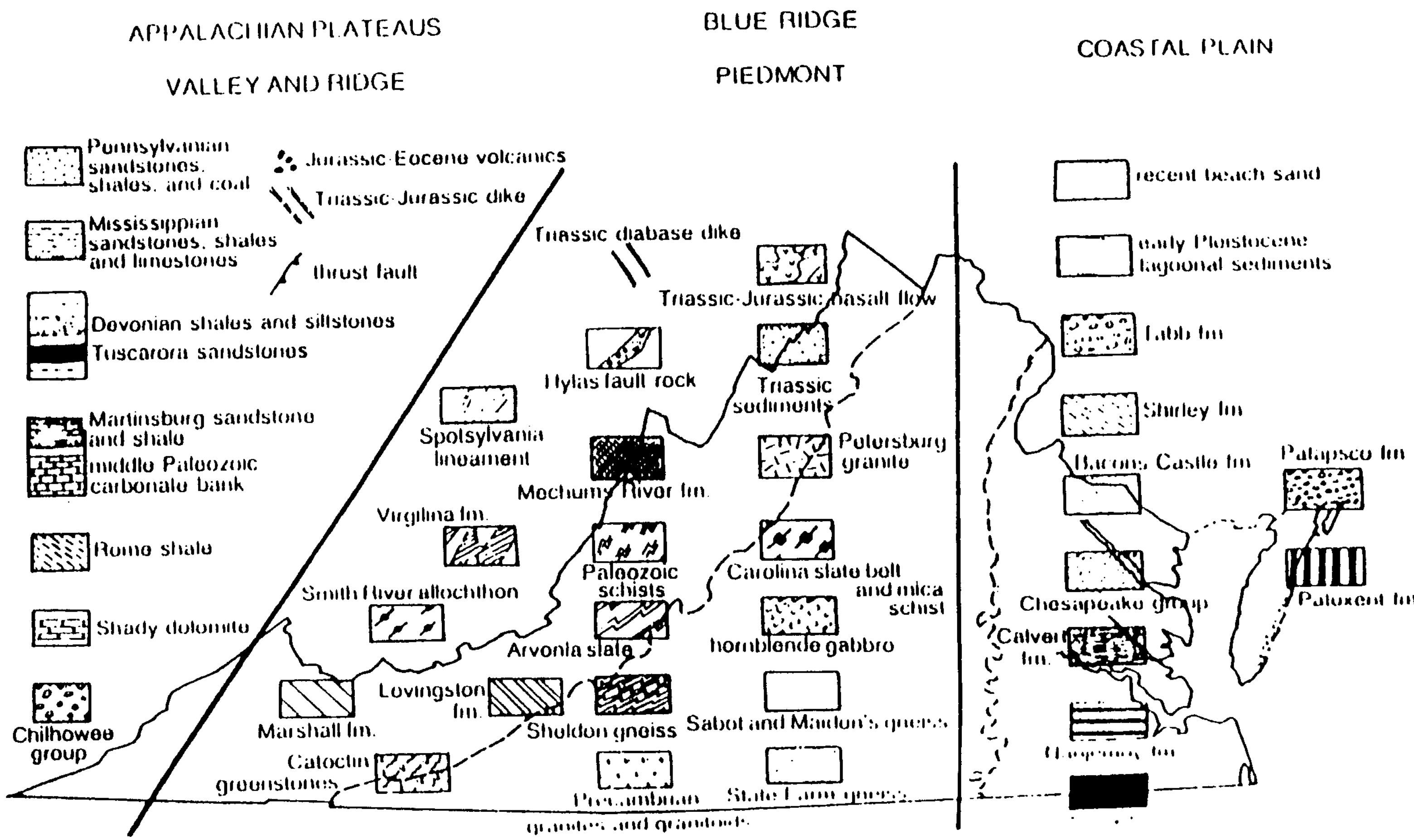
Valley and Ridge (VR)
Geology: sedimentary rocks including limestone, dolomite, and shale. In limestone areas, rapid movement of groundwater makes pollution potential high.

Blue Ridge (BR)
Geology: impervious rock. Well yields are low. Water found in cracks or fissures may move rapidly leading to high pollution potential

Piedmont (P)
Geology: diverse leading to wide range of water quality and availability. Pollution potential is low to moderate.

Coastal Plain (CP)
Geology: unconsolidated sand, clay, marl and shell strata. Groundwater is abundant and use is high. Geology and population density make pollution potential high.

Map symbols used for rock types.



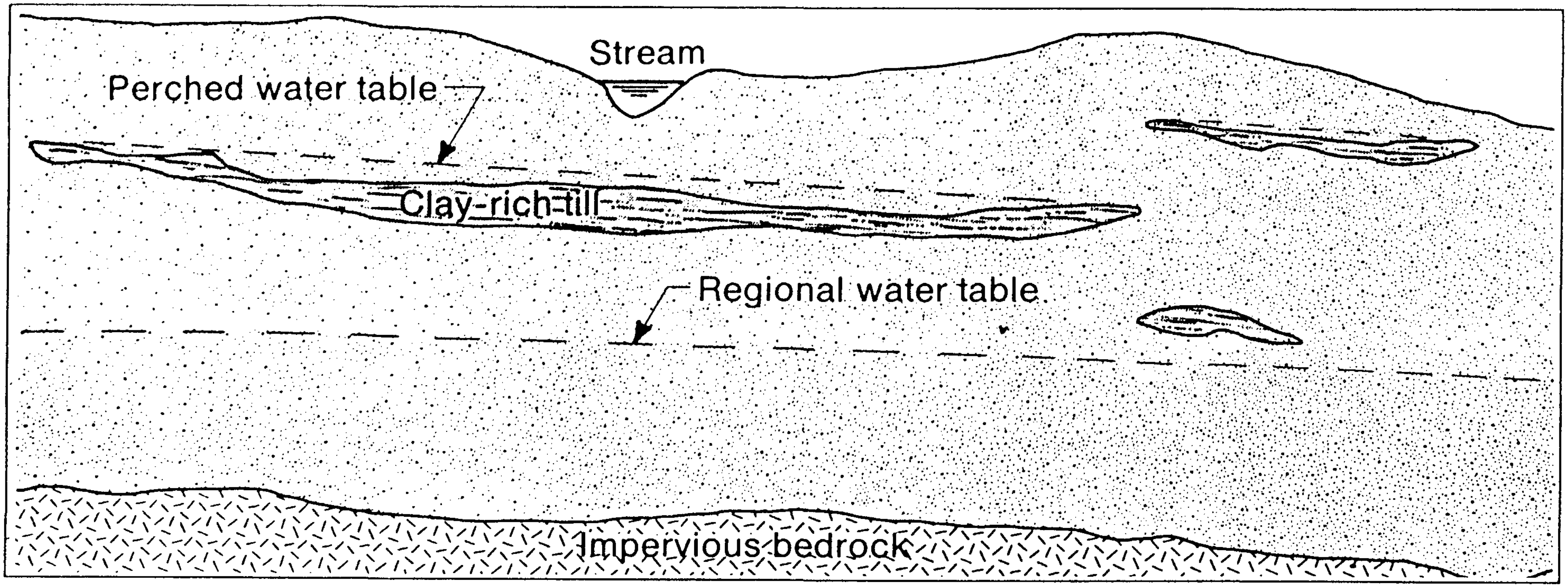


Figure 5.3. Perched water table supported by stringers of clay-rich till.

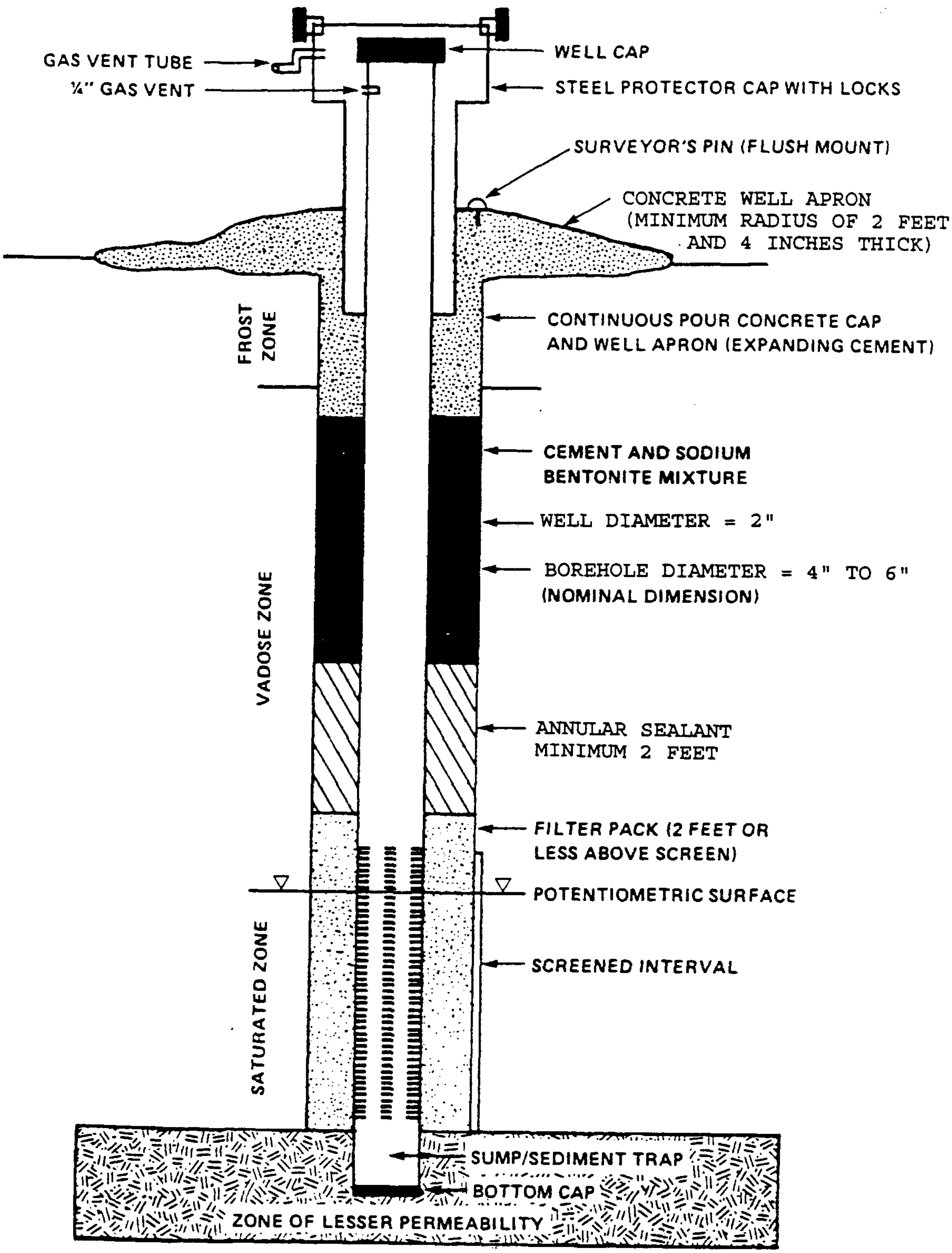


FIGURE 3-1. GENERAL MONITORING WELL – CROSS SECTION

Table 5-1 Advantages and Disadvantages of Selected Drilling Methods for Monitoring Well Construction.

Method	Drilling Principle	Advantages	Disadvantages
Drive Point	1.25 to 2 inch ID casing with pointed screen mechanically depth.	Inexpensive. Easy to install, by hand if necessary. Water samples can be collected as driving proceeds. Depending on overburden, a good seal between casing and formation can be achieved.	Difficult to sample from smaller diameter drive points if water level is below suction lift. Bailing possible. No formation samples can be collected. Limited to fairly soft materials. Hard to penetrate compact, gravelly materials. Hard to develop. Screen may become clogged if thick clays are penetrated. PVC and Teflon® casing and screen are not strong enough to be driven. Must use metal construction materials which may influence some water quality determinations.
Auger, Hollow- and Solid-stem	Successive 5-foot flights of spiral-shaped drill stem are rotated into the ground to create a hole. Cuttings are brought to the surface by the turning action of the auger.	Inexpensive. Fairly simple operation. Small rigs can get to difficult-to-reach areas. Quick set-up time. Can quickly construct shallow wells in firm, noncavey materials. No drilling fluid required. Use of hollow-stem augers greatly facilitates collection of split-spoon samples. Small-diameter wells can be built inside hollow-stem flights when geologic materials are cavey.	Depth of penetration limited, especially in cavey materials. Maximum depths 150 feet. Cannot be used in rock or well-cemented formations. Difficult to drill in cobbles/boulders. Log of well is difficult to interpret without collection of split spoons due to the lag time for cuttings to reach ground surface. Vertical leakage of water through borehole during drilling is likely to occur. Solid-stem limited to fine grained, unconsolidated materials that will not collapse when unsupported. With hollow-stem flights, heaving materials can present a problem. May need to add water down auger to control heaving or wash materials from auger before completing well.
Jetting	Washing action of water forced out of the bottom of the drill rod clears hole to allow penetration. Cuttings brought to surface by water flowing up the outside of the drill rod.	Inexpensive. Driller often not needed for shallow holes. In firm, noncavey deposits where hole will stand open, well construction fairly simple.	Somewhat slow, especially with increasing depth. Extremely difficult to use in very coarse materials, i.e., cobbles/boulders. A water supply is needed that is under enough pressure to penetrate the geologic materials present. Difficult to interpret sequence of geologic materials from cuttings. Maximum depth 150 feet, depending on geology and water pressure capabilities.
Cable-tool (Percussion)	Hole created by dropping a heavy "string" of drill tools into well bore, crusing materials at bottom. Cuttings are removed occasionally by bailer. Generally, casing is driven just ahead of the bottom of the hole; a hole greater than 6 inches in diameter is usually made.	Can be used in rock formations as well as unconsolidated formations. Fairly accurate logs can be prepared from cuttings if collected often enough. Driving a casing ahead of hole minimizes cross-contamination by vertical leakage of formation waters. Core samples can be obtained easily.	Requires an experienced driller. Heavy steel drive pipe used to keep hole open and drilling "tools" can limit accessibility. Cannot run some geophysical logs due to presence of drive pipe. Relatively slow drilling method.

Table 5-1 (continued)

Method	Drilling Principle	Advantages	Disadvantages
Hydraulic Rotary	Rotating bit breaks formation; cuttings are brought to the surface by a circulating fluid (mud). Mud is forced down the interior of the drill stem, out the bit, and up the annulus between the drill stem and hole wall. Cuttings are removed by settling in a "mud pit" at the ground surface and the mud is circulated back down the drill stem.	Drilling is fairly quick in all types of geologic materials. Borehole will stay open from formation of a mud wall on sides of borehole by the circulating drilling mud. Eases geophysical logging and well construction. Geologic cores can be collected. Virtually unlimited depths possible.	Expensive, requires experienced driller and fair amount of peripheral equipment. Completed well may be difficult to develop, especially small-diameter wells, because of mud wall on borehole. Geologic logging by visual inspection of cuttings is fair due to presence of drilling mud. Thin beds of sand, gravel, or clay may be missed. Presence of drilling mud can contaminate water samples, especially the organic, biodegradable muds. Circulation of drilling fluid through a contaminated zone can create a hazard at the ground surface with the mud pit and cross-contaminate clean zones during circulation.
Reverse Rotary	Similar to Hydraulic Rotary method except the drilling fluid is circulated down the borehole outside the drill stem and is pumped up the inside, just the reverse of the normal rotary method. Water is used as the drilling fluid, rather than a mud, and the hole is kept open by the hydrostatic pressure of the water standing in the borehole.	Creates a very "clean" hole, not dirtied with drilling mud. Can be used in all geologic formations. Very deep penetrations possible. Split-spoon sampling possible.	A large water supply is needed to maintain hydrostatic pressure in deep holes and when highly conductive formations are encountered. Expensive—experienced driller and much peripheral equipment required. Hole diameters are usually large, commonly 18 inches or greater. Cross-contamination from circulating water likely. Geologic samples brough to surface are generally poor, circulating water will "wash" finer materials from sample.
Air Rotary	Very similar to Hydraulic Rotary, the main difference being that air is used as the primary drilling fluid as opposed to mud or water.	Can be used in all geologic formations; most successful in highly fractured environments. Useful at any depth. Fairly quick. Drilling mud or water not required.	Relatively expensive. Cross-contamination from vertical communication possible. Air will be mixed with water in the hole and that which is blown from the hole, potentially creating unwanted reactions with contaminants; may affect "representative" samples. Cuttings and water blown from the hole can pose a hazard to crew and surrounding environment if toxic compounds encountered. Organic foam additives to aid cuttings removal may contaminate samples.
Air-Percussion Rotary or Downhole-Hammer	Air Rotary with a reciprocating hammer connected to the bit to fracture rock.	Very fast penetrations. Useful in all geologic formations. Only small amounts of water needed for dust and bit temperature control. Cross-contamination potential can be reduced by driving casing.	Relatively expensive. As with most hydraulic rotary methods, the rig is fairly heavy, limiting accessibility. Vertical mixing of water and air creates cross-contamination potential. Hazard posed to surface environment if toxic compounds encountered. Organic foam additives for cuttings removal may contaminate samples.

SECTION VI-D

SIGNIFICANT EFFLUENT DISCHARGES OF CONVENTIONAL AND *NONCONVENTIONAL* POLLUTANTS BY INDUSTRIAL SOURCE

Industry	Significant Pollutant Discharges
Dairy	BOD, TSS, TDS, COD, pH, color, phosphorous
Grain Mills	BOD, TSS, TDS, COD, pH
Canned and Preserved Fruits and Vegetables	BOD
Canned and Preserved Seafood	BOD, TSS, COD, oil and grease
Sugar	BOD, TSS, TDS, COD, pH
Textiles	BOD, TSS, TDS, COD, pH, color, oil and grease, chromium
Cement	TSS, TDS, pH
Feedlots	BOD, TSS, TDS, COD, ammonia
Metal Finishing and Electroplating	TSS, pH, cyanide, phosphorous, fluoride, chrome, copper, lead, zinc, cadmium, iron, nickel
Organic Chemicals Manufacturing	TSS, TDS, COD, oil and grease, ammonia, phenol
Inorganic Chemicals	TSS, TDS, COD, pH, chrome, mercury
Plastics and Synthetics	BOD, TSS, TDS, COD, pH, oil and grease, ammonia, fluoride, chrome, phenol
Soap and Detergents	BOD, TSS, TDS, COD, pH, oil and grease
Fertilizer	TSS, pH, phosphorous, ammonia, fluoride
Petroleum	BOD, oil and grease, ammonia, chrome, zinc, sulfide, phenol
Iron and Steel	BOD, cyanide, oil and grease, phosphorous, ammonia, lead, zinc, sulfide, manganese
Nonferrous Metals	TSS, TDS, pH, oil and grease, fluoride, copper, lead, zinc, cadmium, arsenic, selenium
Phosphates	TSS, TDS, pH, phosphorous, fluoride, zinc, iron, arsenic
Steam Electric Power	TSS, pH, oil and grease, phosphorous, chrome, copper, zinc, phenol
Ferroalloys	TSS, pH, cyanide, ammonia, chrome, iron, manganese, phenol
Leather Tanning and Finishing	BOD, TSS, COD, pH, oil and grease, chrome, sulfide
Glass	BOD, TSS, TDS, COD, pH, color, oil and grease, phosphorous, phenol

SECTION VI-D

Asbestos	BOD, TDS, COD, pH
Rubber	BOD, TSS, TDS, COD, oil and grease, lead, zinc
Timber	BOD, TSS, COD, pH, color, oil and grease, phenol
Pulp and Paper	BOD, TSS, pH, color
Meat	BOD, TDS, COD, color, oil and grease
Paint and Ink	BOD, TSS, TDS, COD, pH, color, oil and grease, chrome, copper, lead, zinc, cadmium, iron, mercury
Auto and Other Laundries	BOD, TSS, COD, pH, oil and grease, chrome, copper, lead, zinc, cadmium, iron, nickel
Water Supply	TSS, TDS, COD, color, fluoride
Steam Supply	TSS, pH, oil and grease, phosphorous, chrome, copper, zinc, iron, phenol
Miscellaneous Foods and Beverages	BOD, TSS, COD, pH, oil and grease
Miscellaneous Chemicals	BOD, TSS, TDS, COD, pH, cyanide, oil and grease, chrome, zinc, iron, nitrate nitrogen, phenol, boron

SIGNIFICANT EFFLUENT DISCHARGES OF SOME PRIORITY POLLUTANTS BY INDUSTRIAL SOURCE

INDUSTRY	SIGNIFICANT POLLUTANT DISCHARGES
Soaps and Detergents:	thallium, zinc, chromium, copper, lead
Adhesives and Sealants:	no significant presence of priority pollutants in effluent.
Leather:	2,4,6-trichlorophenol, chloroform, 1,2-dichlorobenzene 1,4-dichlorobenzene, ethyl benzene, methylene chloride, napthalene, zinc, pentachloraphenol, phenol, bis (2-ethylhexyl) phthalate, tetrachloroethylene, toluene, chromium, copper, cyanide, lead, nickel
Textiles:	benzene, 1,2,4-trichlorobenzene, 1,1,1-trichloroethane, chloroform, 1,2-dichlorobenzene, ethylbenzene, methylene chloride, napthalene, thallium, zinc, pentachlorophenol, phenol, bis (2-ethylhexyl) phthalate, di-n-butylphthalate, diethyl phthalate, tetrachloroethylene, toluene, trichloroethylene, antimony, arsenic, beryllium, cadmium, chromium, copper, cyanide, lead, mercury, nickel, selenium, silver
Gum & Wood:	benzene, methylene chloride, zinc, toluene, arsenic, cadmium, *chromium*, copper, lead, nickel, silver
Pulp & Paper:	2,4,6-trichlorophenol, chloroform, methylene chloride, zinc, phenol, dioxin, bis (2-ethylhexyl) phthalate, di-n-butyl phthalate, antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver
Timber:	acenaphthene, benzene, chloroform, ethylbenzene, fluoranthene, methylene chloride, napthalene, thallium, zinc, pentachlorophenol, phenol, 1,2-benzanthracene, benzo (a) pyrene, 3,4-benzofluoranthene, 11,12-benzofluoranthene, chrysene, acenaphthylene, anthracene, fluorene, phenanthrene, indeno (1,2,3-cd) pyrene, pyrene, toluene, antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver

Printing and Publishing:	benzene, 1,1,1-trichloroethane, chloroform, 1,1-dichloroethylene, ethylbenzene, methylene chloride, dichlorobromomethane, chlorodibromomethane, napthalene, zinc, phenol, bis (2-ethylhexyl) phthalate, butyl benzyl phthalate, di-n-butyl phthalate, toluene, trichloroethylene, antimony, arsenic, cadmium, chromium, copper, cyanide, lead, mercury, nickel, silver
Paint & Ink:	benzene, 1,1,1-trichloroethane, chloroform, ethylbenzene, methylene chloride, napthalene, zinc, phenol, bis (2-ethylhexyl) phthalate, di-n-butyl phthalate, tetrachloroethylene, toluene, trichloroethylene, arsenic, beryllium, cadmium, chromium, copper, cyanide, lead, mercury, nickel
Pesticides:	benzene, carbon tetrachloride, 1,2-dichloroethane, 1,1,1-trichloroethane, chloroform, ethylbenzene, methylene chloride, zinc, phenol, bis (2-ethylhexyl) phthalate, toluene, trichloroethylene, chromium, copper, lead, nickel
Pharmaceuticals:	benzene, carbon tetrachloride, 1,2-dichloroethane, 1,1,1-trichloroethane, chloroform, 1,1-dichloroethylene, ethylbenzene, methylene chloride, trichlorofluoromethane, zinc, phenol, bis (2-ethylhexyl) phthalate, toluene, chromium, copper, cyanide, nickel
Organics & Plastics:	acenaphthene, acrylonitrile, benzene, carbon tetrachloride, chlorobenzene, 1,2-dichloroethane, 1,1,1-trichloroethane, 1,1-dichloroethane, 1,1,2-trichloroethane, 1,1,2,2-tetrachloroethane, bis (2-chloroethyl) ether, 2-chloroethyl vinyl ether (mixed), 2,4,6-trichlorophenol, chloroform, 2-chlorophenol, 1,2-dichlorobenzene,

Organic & Plastics Cont:	1,3-dichlorobenzene, 1,4-dichlorobenzene, 1,1-dichloroethylene, 1,2-trans-dichloroethylene, 2,4-dichlorophenol, 1,2-dichloropropane, 1,3-dichloropropene, 2,4-dimethylphenol, 1,4-dinitrotoluene, 2,6-dinitrotoluene, 1,2-diphenylhydrazine, ethylbenzene, fluoranthene, bis (2-chloroisopropyl) ether, methylene chloride, bromoform, dichlorobromomethane, trichloro-fluoromethane, chlorodibromomethane, isophorone, napthalene, nitrobenzene, thallium, zinc, 2-nitrophenol, 4-nitrophenol, 2,4-dinitrophenol N-nitrosodiphenylamine, pentachlorophenol, phenol, bis (2-ethylhexyl) phthalate, butyl benzyl phthalate, di-n-butyl phthalate, di-n-octyl phthalate, diethyl phthalate, dimethyl phthalate, 1,2-benzanthracene, chrysene, acenaphthylene, anthracene, fluorene, phenanthrene, pyrene, tetrachloroethylene, toluene, trichloroethylene, lindane, PCB-1242, PCB-1254, PCB-1221, PCB-1232, PCB-1248, PCB-1260, PCB-1016, antimony, arsenic, beryllium, cadmium, chromium, copper, cyanide, lead, mercury, nickel, selenium, silver
Rubber:	chloroform, ethylbenzene, methylene chloride, zinc, phenol, bis (2-ethylhexyl) phthalate, toluene, chromium, copper, nickel
Coal Mining:	acrylonitrile, benzene, benzidine, 1,1,1-trichloroethane, 1,1,2,2-tetrachloroethane, chloroform, 1,2-trans-dichloroethylene, methylene chloride, napthalene, zinc, bis (2-ethylhexyl) phthalate, di-n-octyl phthalate, anthracene, phenanthrene, toluene, arsenic, chromium, copper, lead, nickel, selenium

Ore Mining:	zinc, bis (2 ethylhexyl) phthalate, di-n-butyl phthalate, diethyl phthalate, antimony, arsenic, beryllium, cadmium, chromium, copper, cyanide, lead, mercury, nickel, selenium, silver
Paving & Roofing:	no significant presence of priority pollutants in effluent
Steam & Electric:	benzene, 1,1,1-trichloroethane, chloroform, 1,1-dichloroethylene, ethylbenzene, methylene chloride, zinc, phenol, bis (2-ethylhexyl) phthalate, di-n-butyl phthalate, di-n-octyl phthalate, toluene, beryllium, cadmium, chromium, copper, lead, nickel
Petroleum Refining:	benzene, 1,1,2,2-tetrachloroethane, chloroform, 1,2-trans-dichloroethylene, 2,4-dimethylphenol, ethylbenzene, methylene chloride, napthalene, zinc, phenol, bis (2-ethylhexyl) phthalate, chrysene, anthracene, fluorene, phenanthrene, pyrene, toluene, trichloroethylene, chromium, copper, cyanide, lead, nickel
Iron & Steel:	benzene, 2,4,6-trichlorophenol, parachlorometa cresol, chloroform, 1,2-trans-dichloroethylene, 2,4-dimethylphenol, ethylbenzene, fluoranthene, methylene chloride, napthalene, zinc, 2,4-dinitrophenol, 4,6-dinitro-o-cresol, pentachlorophenol, phenol, bis (2-ethylhexyl) phthalate, butyl benzyl phthalate, di-n-butyl phthalate, di-n-octyl phthalate, diethyl phthalate, dimethyl phthalate, 1,2-benzathracene, benzo (a) pyrene, 3,4-benzofluoranthene, 11,12-benzofluoranthene, chrysene, acenaphthylene, anthracene, fluorene, phenanthrene, pyrene, toluene, antimony, arsenic

Foundries:	2,4,6-trichlorophenol, chloroform, 2,4-dichlorophenol, 2,4-dimethylphenol, fluoranthene, zinc, pentachlorophenol, phenol, bis (2-ethylhexyl) phthalate, butyl benzyl phthalate, di-n-butyl phthalate, diethyl phthalate, dimethyl phthalate, acenaphthylene, anthracene, phenanthrene, pyrene, antimony, arsenic, cadmium, chromium, copper, cyanide, lead, mercury, nickel, selenium, silver
Electroplating:	silver, zinc, chromium, copper, lead, nickel
Nonferrous metals:	benzene, 1,2-dichloroethane, 1,1,2,2-tetrachloroethane, chloroform, 1,1-dichloroethylene, methylene chloride, zinc, bis (2-ethylhexyl) phthalate, di-n-butyl phthalate, diethyl phthalate, tetrachloroethylene, toluene, trichloroethylene, antimony, arsenic, beryllium, cadmium, chromium, copper, cyanide, lead, mercury, nickel, selenium
Batteries:	metals data is not complete
Coil Coating:	zinc, chromium, copper, lead
Photographic:	methylene chloride, di-n-butyl phthalate, metals data is not complete
Inorganic Chemicals:	benzene, chloroform, methylene chloride, thallium, zinc, phenol, bis (2-ethylhexyl) phthalate, di-n-butyl phthalate, toluene, arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver
Electrical:	chloroform, methylene chloride
Auto & Other Laundries:	chloroform, methylene chloride, napthalene, zinc, bis (2-ethylhexyl) phthalate, butyl benzyl phthalate, tetrachloroethylene, antimony, arsenic, cadmium, chromium, copper, lead
Phosphates:	chloroform, trichloroethylene, metals data not complete
Plastics Processing:	metals data not complete

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Explosives:	DNT
Porcelain/Enameling:	zinc, chromium, lead, nickel
Landfill:	leachate may be a significant source of priority pollutants in effluent
Mechanical Products:	1,1,1-trichloroethane, 1,1-dichloroethane, chloroform, 1,1-dichloroethylene, 1,2-trans-dichloroethylene, methylene chloride, napthalene, phenol, bis (2-ethylhexyl) phthalate, tetrachloroethylene, toluene, trichloroethylene

Source: Subcommittee Hearings 96th Congress - see Bibliography

EPA PRIORITY POLLUTANTS BY MAJOR USERS AND POINT SOURCES

EPA PRIORITY POLLUTANTS	MAJOR USERS AND POINT SOURCES
Acenaphthene 01	ACE occurs in coal and petroleum products. It is used in dye mfg, plastics mfg, insecticide and fungicide mfg. (see PAH)
Acrolein 02	Acrolein is used in plasticizers, polyurethane intermediates, copolymers, textiles, photography, paper mfg, and coatings for aluminum and steel panels. All agricultural uses have been discontinued. Acrolein is toxic to mammals.
Acrylonitrile 03	AN is used in the manufacture of copolymers for the production of acrylic and modacrylic fibers. Other major uses are in the production of a wide variety of plastic products and food packaging.
Benzene 04	Benzene is produced in coal processing and coal coking operations. It is also used as an intermediate for synthesis in the chemical and pharmaceutical industries, in the mfr. of styrene, *cyclohexane*, detergents, pesticides, as a thinner for lacquer, as a degreasing and cleaning agent, as a solvent in the rubber industry and in preparation and use of inks in the graphic arts industries.
Benzidine 05	The Azo compounds of benzidine are important as dyes for industrial use.
Carbon Tetrachloride 06	CT is a common industrial and chemical solvent.
Chlorobenzene 07	CB is used for the synthesis of ortho and para nitrochlorobenzenes, as a solvent, in phenol manufacturing and in DDT manufacturing.
1,2,4-Trichlorobenzene 08	1,2,4-TCB is used as a dye carrier, herbicide intermediate, heat transfer medium, dielectric fluid in transformers, degreaser, lubricant and as a potential insecticide against termites.

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Hexachlorobenzene 09	HCB was used in dye manufacturing, as an intermediate in organic synthesis, porosity controller in the manufacturing of electrodes, wood preservative and as an additive in pyrotechnic compositions for the military.
1,2-Dichloroethane 10 1,1,1-Trichloroethane 11 Hexachloroethane 12 1,1-Dichloroethane 13 1,1,2-Trichloroethane 14 1,1,2,2-Tetrachloraethane 15 Chloroethane 16	CEs are produced in large quantities and used for production of tetraethyl lead and vinyl chloride. They are widely used as solvents, degreasing agents, fumigants, and cutting fluids. Some are used in mfg of plastics, textiles and in the synthesis of other chemicals. All are toxic to some degree; toxicity and bioconcentrating potential increases with the degree of chlorination.
Bis (2-Chloroethyl) Ether 18 2-Chloroethylvinyl Ether 19 Bis (2-Chloroisopropyl) Ether 42 Bis (2-Chloroethoxy) Methane 43	These solvents are used for polymerization reactions, pesticide manufacture, industrial organic synthesis, textile treatment, mfg of glycol products and mfg of rubber. Several members of this class of compounds are listed as human carcinogens.
2-Chloronaphthalene 20:	Theoretically, 76 individual isomers of napthalene are possible and may exist. The commercial products are usually mixtures with various degrees of chlorination, and are presently manufactured and marketed in the US under the tradename, Holowaxes R. Significant environmental exposure may result when these compounds are used as oil additives, in the electroplating industry, and in the fabric dyeing industry. Chlorinated naphthalenes, like PCBs, exhibit a high degree of chemical and thermal stability. Several members of this group of compounds are toxic to fish and mammals.

2,4,6-Trichlorophenol 2,4,6-TCP 21
2-Chlorophenol 2-CP 24
2,4-Dichlorophenol 2,4-DCP 31
Pentachlorophenol PCP 64
2,3,7,8-Tetrachlorodibenzo-p-Dioxin TCDD 129

Chlorinated Phenols are used as intermediates in the synthesis of dyes, pigments, phenolic resins, pesticides, and herbicides. Certain CPs are also used directly as flea repellants, fungicides, wood preservatives mold inhibitors, antiseptics, disinfectants, and antigumming agents for gasoline.

2,4,6-TCP is used as a germicide, bactericide, glue and wood preservative, mildewicide.

2-CP is used as an intermediate in the mfr. of fungicides, slimicides, bactericides, antiseptics, disinfectants and wood preservatives.

2,4-DCP is used as a mothproofing compound, antiseptic, miticide and to produce the herbicide 2,4-D.

PCP is used as a herbicide, wood preservative, insecticide and molluscicide.

TCDD is considered the most toxic of all the dioxins. See the entry for 129.

CPs may be produced inadvertently by chlorination reactions which take place during the disinfection of wastewater effluents containing phenols. Chlorophenols and certain chlorocresols have been shown to be toxic to aquatic life, mammals, and man.

Chloroform 23

Chloroform is used mainly as a chemical solvent and as an intermediate in the production of refrigerants, plastics, and pharmaceuticals. It is a mammalian carcinogen.

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1,2-Dichlorobenzene 1,2-DCB 25 1,3-Dichlorobenzene 1,3-DCB 26 1,4-Dichlorobenzene 1,4-DCB 27 3,3-Dichlorobenzidene 3,3-DCB 28	The major uses of 1,2-DCB are as a process solvent in the mfr. of toluene diisocyanate and as an intermediate in the synthesis of dyestuffs, herbicides, and degreasers. 1,3-DCB - no information found. 1,4-DCB is primarily used as an air deodorant and as an insecticide. 3,3-DCB is used in the production of dyes and pigments and as a curing agent for polyurethanes. It has been shown to be a carcinogen in non-human mammals, and is a suspected human carcinogen.
1,1-Dichloroethylene 1,1-DEC 29	1,1-DCE is the most important of the 3 isomers in the DCE group. It is used as a chemical intermediate in the synthesis of methyl chloroform and in the production of polyvinylidene chloride copolymers (PVDCs). The impermeability of PVDCs make them useful primarily as barrier coatings in the packaging industry. Polymers with high vinylidene chloride (1,1-DCE) content such as <u>Saran</u> are widely used in the food packaging industry. 1,1-DCE polymers have also been used in the mfr. of non-flammable synthetic fiber, interior coatings for ship tanks, railroad cars, fuel storage tanks, and for coating of steel pipes and structures. It is toxic to fish and is a suspected human carcinogen.
1,2-Trans-Dichloroethylene trans-1,2-DCE 30	Trans-1,2-DCE is used as an industrial solvent for organic materials, dye extractions, perfumes, lacquers, thermoplastics, and organic synthesis. It is moderately toxic. It is flammable and a dangerous fire hazard.

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1,2-Dichloropropane 32	DCP is an oil and fat solvent used in dry cleaning and degreasing processes. It is flammable and toxic.
1,2-Dichloropropylene 33	no information found
2,4-Dimethylphenol 34	2,4-DMP is a naturally occurring compound from the cresol fraction of petroleum or coal tars. It's used commercially as an important chemical feedstock for the mfr. of phenolic antioxidants. disinfectants, solvents, pharmaceuticals, insecticides, fungicides, plasticizers, rubber chemicals, wetting agents, dyestuffs, and is an additive or constituent of lubricants, gasolines, and cresylic acid. It is toxic to aquatic organisms and mammals.
2,4-Dinitrotoluene 2,4-DNT 35 2,6-Dinitrotoluene 2,6-DNT 36	DNT is an ingredient of explosives for commercial and military use because of its waterproofing action and explosive potential. It's also used as a chemical stabilizer in the mfg of smokeless powder, and as a raw material for dyestuffs. Both are suspected human carcinogens.
1,2-Diphenylhydrazine 37	DPH is used in the synthesis of phenyl butazone and as the starting material in the mfr. of benzidine, an intermediate in the production of dyes. It is toxic to fish and is a possible human carcinogen.
Ethylbenzene 38	EB is used in the plastic and rubber industries as an initial substrate reactant in the production of styrene. Significant quantities are used in the paint industry, as diluents in agricultural sprays for insecticides, and in gasoline blends.

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Fluoranthene 39	F is a polynuclear aromatic hydrocarbon (PAH) produced by the combustion of organic raw materials such as coal and petroleum. There is no commercial use for fluoranthene. It is toxic to aquatic organisms.
4-Chlorophenyl Phenyl Ether 40 4-Bromophenyl Phenyl Ether 41	No information available, other than these may be carcinogens.
Methylene Chloride dichloromethane	MC is a common industrial solvent found in insecticides, metal cleaners, paints, varnish removers, aerosol sprays and plastics processing.
Methyl Chloride chloromethane 45	Methyl Chloride is used as a refrigerant, methylating agent, dewaxing agent, and catalytic solvent in synthetic rubber production and in mfr. of herbicides and plastics.
Methyl Bromide bromomethane	MB is used as a fumigant, fire extinguisher, refrigerant, and insecticide.
Bromoform tribromomethane 47	TBM is used in pharmaceutical mfr., as an ingredient in fire resistant chemicals and as a solvent for waxes, grease and oil.
Dichlorobromomethane 48	DCB is used as a reagent in research, and has no commercial use.
Chlorodibromomethane 51	CDB is used in organic chemicals synthesis and research.
Trichlorofluoromethane Freon 11[R] Dichlorodifluoromethane Freon 12[R] Halon [R] Freon	Freon compounds (containing fluorine) have a high degree of chemical stability, relatively low toxicity, and they are nonflammable. Applications range from use as propellants to refrigerants and solvents. There is potential for ozone depletion by these halogenated substances as they generate chlorine atoms in the ozone-rich region of the stratosphere.

Hexachlorobutadiene 52	HCBD is used as a solvent for many organic substances; it's used by producers to recover chlorine, as an intermediate in the mfr. of rubber compounds, lubricants, and as a fluid for gyroscopes. Environmental contamination results primarily during disposal of wastes containing HCBD from chlorinated hydrocarbon industries. It is a suspected human carcinogen because of animal toxicity.
Hexachlorocyclopentadiene 53	Hex has current major uses in the manufacture of flame retardant compounds used in plastics, foams and other polymers. Hex was the key intermediate in the mfr. of the organochlorine pesticides whose usage is now banned or restricted: chlordane, aldrin, dieldrin, heptachlor, isodrin, endrin, mirex, and kepone. Hex enters the environment primarily through discharges and emissions from pesticide production facilities. Hex is toxic to fish and mammals.
Isophorone 54	Isophorone is an excellent solvent for many oils, fats, gums, and natural and synthetic resins. It is also used as a solvent for cellulose derivatives, lacquers, and pesticide formulations. It's a chemical intermediate and is utilized in plant growth retardants. *Isophorone* is especially toxic to saltwater invertebrate species. It is also toxic to mammals.
Naphthalene 55	Nap is the single most abundant ingredient in coal tar. This compound is used as an intermediate in the production of dye compounds and the formulation of solvents, lubricants, and motor fuels. It is no longer used as a moth repellant, insecticide, vermicide, and intestinal antiseptic. Nap will bioconcentrate and is very toxic to aquatic organisms.

Nitrobenzene 56	The principal use of NB is for reaction to aniline, which is widely used as an ingredient for dyes, rubber, and *medicines*. It's also used in metal polishes, shoe black, perfume, and as a combustible propellant. NB is highly toxic to mammals and humans.
2-Nitrophenol 57 4-Nitrophenol 58	The nitrophenol isomers are used primarily as intermediates for the production of dyes, pigments, pharmaceuticals, rubber chemicals, lumber preservatives, photographic chemicals and pesticidal and fungicidal agents. As a result, the major source for environmental release of nitrophenols is likely to be from production plants and chemical firms where the compounds are used as intermediates.
2,4-Dinitrophenol 59	Of the 6 isomeric forms of dinitrophenol, 2,4-dinitrophenol is most important. It is used primarily as a chemical intermediate for the production of sulfur dyes, azo dyes, photochemicals, pest control agents, wood preservatives and explosives.
4,6-Dinitro-o-Cresol 60	Of the 6 isomeric forms, the only one important is 4,6-dinitro-o-cresol. DNOC is used primarily as a blossom thinning agent on fruit trees and as a fungicide, miticide, and insecticide on fruit trees during the dormant season.
N-Nitrosodimethyamine 61 N-Nitrosodiphenylamine 62 N-Nitrosodi-n-Propylamine 63	N-nitrosodiphenylamine is used as a vulcanizing retarder in rubber processing and in the mfr. of pesticides. Other N-nitroso compounds are produced primarily as research chemicals and not for commercial purposes. The N-nitrosamines comprise some of the most potent carcinogenic and toxic compounds known.
Pentachlorophenol 64	(see the other chlorinated phenols)

Phenol 65	Phenol is a large volume industrial chemical produced almost entirely as an intermediate for the preparation of other chemicals, including synthetic polymers and plastics intermediates. Although phenol is less toxic than the chlorinated phenols, it's hazard to aquatic and terrestrial life has been demonstrated.
Bis (2-Ethylhexyl) Phthalate 66 Butyl Benzyl Phthalate 67 Di-n-Butyl Phthalate 68 Di-n-Octyl Phthalate 69 Diethyl Phthalate 70 Dimethyl Phthalate 71	The Phthalate Esters represent a large family of chemicals widely used as plasticizers, primarily in the production of polyvinyl chloride (PVC) resins. The isomers have important commercial applications as starting materials for plastics and textiles, and in materials for the construction, automotive, household products, clothing, cosmetics, toys, packaging and medical products industries. These compounds are released to water during production and waste disposal of the plastic products. PEs will bioconcentrate in aquatic organisms.
Polynuclear Aromatic Hydrocarbons PAH	PAHs are formed as a result of incomplete combustion of organic compounds with insufficient oxygen. Generally, the less efficient the combustion process, the higher the PAH *emissions*. Major PAH sources are heat and power generation, including *emissions* from coal, oil, wood-burning stoves and furnaces, refuse burning, and industrial activities involving coke ovens and coal refuse piles. The PAH class of compounds contains numerous potent carcinogens.
Acenaphthene 01	ACE is used in the mfr. of dyestuffs, plastics, insecticides and fungicides.
Acenaphthylene 77	ACN is used as an intermediate in the mfr. of dyestuffs, plastics, insecticides and fungicides.
Anthracene 78	An important raw material for mfr. of dyestuffs, synthetic fibers, plastics and monocrystals. Anthracene is also very toxic to fish.

Benzo (a) anthracene 72	Known animal carcinogen.
Benzo (b) fluoroanthene 75	
3,4-Benzofluoroanthene 74	Not commercially produced in USA, this compound is a known animal carcinogen.
Benzo (ghi) perylene 79	This is a significant mutagen with no known commercial use.
Benzo (a) pyrene 73	This is one of the most commonly found PAHs and one of the most hazardous.
Chrysene 76	Not commercially produced in USA, this is a possible human carcinogen.
Dibenzo (a,h) Anthracene 82	This is one of the more potent carcinogens in the PAH class.
Fluoranthene 39	Not commercially used in USA, fluoranthene is toxic to aquatic organisms.
Fluorene 80	Intermediate in mfr. dye stuffs, polyradicals for resins. Not produced commercially in USA. Toxic to fish. Human carcinogen. Found in creosote plant groundwater and in wood preservative sludges.
Indeno (1,2,3-cd) pyrene 83	Persistent in environment, it is also a known animal carcinogen.
Naphthalene 55	NAP is used as an intermediate in the mfr. of dyestuffs, plastics and pesticides.
Phenanthrene 81	
Pyrene 84	Not commercially produced in USA
Tetrachloroethylene 85	Tet-CE is used in commercial dry cleaning and metal degreasing industries. Although it is released in to water by production plants, consumer industries, and household sewage, levels are low due to its high volatility. It is toxic to aquatic organisms and humans.

Trichloroethylene 87	As a degreasing solvent in metal industries, TCE has also been used as a household and industrial drycleaning solvent, an extractive solvent in foods, and was an inhalation *anesthetic* during certain short-term surgical procedures. Some industries that use TCE are cleaners, pharmaceuticals, drycleaners, electronic equipment, fat processors, mechanics, metal cleaners, printers, resin compounders and varnishes and paints. TCE is toxic to fish and is a potential human carcinogen.
Toluene 86	70% of the toluene produced is converted to benzene and the remainder is used to produce chemicals: solvents for paints and gasoline additives. The discharge of toluene to the environment is estimated 99.3% atmospheric emissions and 0.7% wastewaters. Toluene is toxic to fish.
Vinyl Chloride 88	Vinyl chloride and polyvinylchloride are used in the mfr. of numerous PVC products in building and construction, by the automotive industry for electrical wire insulation and cables, piping, industrial and household equipment, packaging for food products, medical supplies, and is depended upon heavily by the rubber, paper and glass industries. Vinyl chloride is toxic and carcinogenic to humans.
Aldrin 89 Dieldrin 90	Aldrin and Dieldrin belong to the group of organochlorine insecticides which include DDT, BHC etc. Except for termite control, use of aldrin has been cancelled in USA. Both chemicals were used for control of corn pests and citrus pests. These two compounds are very toxic to most forms of life, including mammals. Dieldrin is very persistent in the environment, and it bioconcentrates in the food chain. All uses of dieldrin have been cancelled in the USA.

Chlordane 91	Another organochlorine pesticide, chlordane was used extensively for termite control in the USA until cancellation. Chlordane is highly toxic to aquatic organisms and mammals. It will bioconcentrate in many aquatic species, and is very persistent in the environment.
4,4-DDT 92 4,4-DDE 93 4,4-DDD 94	These are members of the class of organochlorine based, broad spectrum insecticides heavily used in agricultural areas where large amounts of residues may still be present. DDT and its metabolites are very toxic, persistent in the environment, and bioconcentrate in wildlife and humans.
Alpha-*Endosulfan* 95 Beta-Endosulfan 96 Endosulfan Sulfate 97	Another organochlorine based, broad spectrum insecticide, endosulfan use is currently restricted by EPA, but significant commercial use for insect control on vegetables, fruits and tobacco continues. It is very toxic to fish and bioconcentrates in aquatic species. It is also very toxic to cattle and humans.
Endrin 98 Endrin Aldehyde 99	Endrin is chlorinated hydrocarbon insecticide, and enters the environment primarily as a result of direct applications to soil and crops. Waste material discharge from endrin mfr. and formulating plants and disposal of empty containers also contribute to residue levels. Endrin was used to control many pests such as termites, army worms, grasshoppers and cotton bollworm. Endrin has high toxicity to mammals and fish.
Heptachlor 100 Heptachlor Epoxide 101	Heptachlor is another chlorinated hydrocarbon based, broad spectrum insecticide. All uses other than for termite control are suspended by EPA. It bioconcentrates in the food chain, is highly toxic to aquatic organisms, is persistent and a possible carcinogen.

Hexachlorocyclohexane Alpha-BHC 102 Beta-BHC 103 Gamma-BHC 104 Delta-BHC 105	This is another of the organochlorine based, broad spectrum insecticides. Lindane, the gamma BHC, is the only one still being used (under restricted use by EPA) for seed treatment and on fruit and nut trees and vegetables. The isomers have different mammalian toxicities. All gamma HCH is imported, so there is no exposure during mfr. in this country. All 4 isomers listed are suspected human carcinogens.
Polychlorinated Biphenyls PCB - 1242 106 PCB - 1254 107 PCB - 1221 108 PCB - 1232 109 PCB - 1248 110 PCB - 1260 111 PCB - 1016 112	PCB products were marketed for closed electrical systems such as transformers and capacitors prior to 1971. They were used in plasticizers, heat transfer fluids, hydraulic and vacuum pump fluids, compressors, and lubricants. The PCB group is very toxic to man and animals, is very persistent and bioconcentrates in the aquatic environment.
Toxaphene 113	Tox was the most heavily used insecticide in the USA before 1980; this broad spectrum chlorinated hydrocarbon pesticide replaced many of the agricultural applications of DDT. It was primarily used in agricultural crop applications, mainly cotton. EPA cancelled registration 1982 except for a few minor uses.
Antimony 114	Antimony increases hardness and lowers the melting point of alloys with lead, bismuth, tin, copper, nickel, iron and cobalt and has large uses in bearings, ammunition and antimonial lead. Antimony trioxide is commercially important as a flame retarding agent. Antimony trisulfide is also flame retardant and is used in mfr. of fireworks and matches. Common in effluents from mining and mfr. operations.

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Arsenic 115	Arsenic is used in the mfr. of glass, cloth, electrical semiconductors, fungicides, wood preservatives, and as growth stimulants for plants and animals. The principal emission source for arsenic in the US is coal-fueled power plants.
Asbestos 116	This fibrous, easily woven calcium - magnesium silicate is used in heat resistant insulators, cement products, floor tile, paper products, paint and caulking, furnace and hot pipe coverings, fireproof gloves, clothing and brake linings. Asbestos is a known human carcinogen.
Beryllium 117	Beryllium is used in metal alloys, nuclear weapons and test reactors, in aircraft brakes, as a heat shielding material in space craft, and as a component of solid rocket fuel. The most significant source of environmental pollution is from the burning of fossil fuels.
Cadmium 118	Cadmium is found in zinc and lead ores and in sludge from zinc sulfate purification. It's used in soft solder and solder for aluminum, electroplating, process engraving, cadmium vapor lamps, storage batteries, and the mfr. of paint and pigments.
Chromium 119	Chromium is used widely in the electroplating, metal finishing, textile, leather tanning, paints, pigments, and wood preservatives industries.
Copper 120	Sources of copper include corrosion of brass and copper pipe by acidic waters, industrial effluents and fallout, sewage treatment plant effluents, and the use of copper compounds as aquatic algicides. Major industrial sources include smelting and refining industries, copper wire mills, coal burning industries, and iron and steel producing industries.

Copper (cont.)	Precipitation of atmospheric fallout may be a significant source of copper to the aquatic environment in industrial and mining areas.
Cyanide 121	Compounds containing the cyanide group are used and easily found in many industrial process effluents, such as those from the steel, petroleum, plastics, synthetic fibers, metal plating, mining and chemical industries.
Lead 122	Lead is used in electroplating, refining, metallurgy, construction materials, radiation protective devices, plastics, pigments for paint, ammunition and electronic equipment.
Mercury 123	Mercury is used as a cathode in the electrolytic preparation of chlorine and caustic soda. Other uses are in electrical apparatus (lamps, arc rectifiers, and mercury battery cells), industrial and control instruments (switches, thermometers, barometers) and for general laboratory purposes. Mercury has also been used in antifouling and mildew proofing paints and in formulations used to control fungal diseases of seeds, bulbs, plants and vegetables. Minor uses include dental amalgams, catalysts, pulp and paper manufacture, pharmaceuticals, metallurgy and mining.
Nickel 124	Significant environmental sources of nickel result from the burning of coal and other fossil fuels and discharges from electroplating and smelting industries.
Selenium 125	Selenium is used in photocopying, and in the mfr. of glass, electronic devices, pigments, dyes and insecticides. It is also used in veterinary medicines and dandruff shampoos.

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Silver 126

Principal industrial uses of silver are in photographic materials, electroplating, as a conductor, in dental alloys, solder and brazing alloys, paints, jewelry, silverware, coinage, and mirror production.

Thallium 127

Industrial uses of thallium include the mfr. of alloys, electronic devices and special glass.

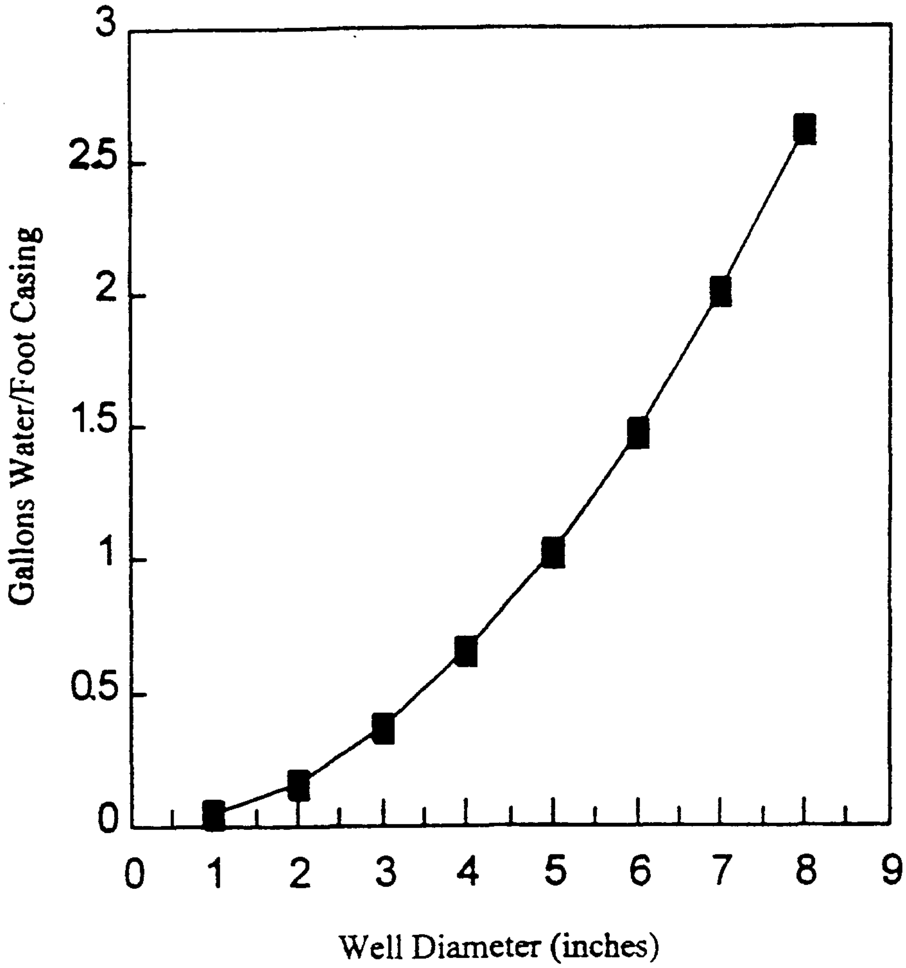
Zinc 128

Zinc is used in galvanizing steel, for producing alloys and as an ingredient in rubber and paints.

2,3,7,8-Tetrachlorodibenzo-p- Dioxin
TCDD 129

TCDD is a contaminant of herbicides, 2,4,5-T, 2,4-D or combinations of the two. TCDD is one of the most toxic substances known. Aquatic environmental exposure may be a result of runoff from soils treated with TCDD - containing herbicides. Another source of TCDD is created when bleaching shredded wood pulp during the manufacture of kraft fiber for paper products.

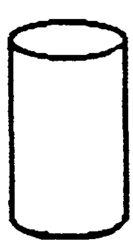
Volume of Water Stored Per Foot of Well Casing



Data

1" = 0.041 gal/ft.
2" = 0.163 gal/ft.
3" = 0.367 gal/ft.
4" = 0.653 gal/ft.
5" = 1.02 gal/ft.
6" = 1.469 gal/ft.
7" = 1.999 gal/ft.
8" = 2.611 gal/ft.

Volume of a cylinder



$V = \Pi r^2 d$
<u>where</u>:
V = volume
Π = 3.14
r = radius
d = depth

Example: 5 in. diameter well with 11 ft. of water

Note: 5 in. = 0.417 ft, r = 0.209 ft.
1 cu.ft. = 7.481 gal

$V = 3.14(0.209)^2(11)$
= 1.509 cu.ft.
(1.509 cu.ft.)(7.481gal/cu.ft.) = 11.29 gal

ATTACHMENTS V-1 TO V-2

16

USE THIS CONDITION WHEN REQUESTING A NEW GROUND WATER MONITORING PLAN

Ground Water Monitoring Plan

Within 90 days of the effective date of this permit, the permittee shall submit to the Board's Regional Office an approvable ground water monitoring plan. The purpose of this plan will be to determine if the system integrity is being maintained and to indicate if activities at the site are resulting in violations of the Board's Ground Water Standards. This plan must be approved by the ____________ Regional Office. As a minimum, the plan should contain the following sections:

A. Introduction
B. Geologic Information
C. Monitoring Well Design and Installation (Borehole and monitoring well records shall be submitted after well installation)
D. Parameters To Be Monitored and Sampling Frequency (As a minimum, all parameters will be monitored quarterly for a period of two years)
E. Sampling Protocol

All monitoring wells shall be installed and monitoring initiated within 180 days of plan approval. Once approved, the plan shall be incorporated into the permit by reference with the next modification or reissuance and become an enforceable part of this permit.

If monitoring results indicate that any unit has contaminated the ground water, the permittee shall submit a corrective action plan within 60 days of being notified by the regional office. The plan shall set forth the steps to be taken by the permittee to ensure that the contamination source is eliminated or that the contaminant plume is contained on the permittee's property. In addition, based on the extent of contamination, a risk analysis may be required. Once approved, this plan and/or analysis shall become an enforceable part of this permit.

NOTE TO PERMIT WRITER: Any additional schedules needed for the submittal of borehole logs and monitoring well construction logs, as well as potentiometric surface maps can also be included in the condition. In addition, the permit writer may add certain minimum requirements specified within the guidance (eg. minimum number of wells, parameters to be monitored, monitoring frequency, etc.). Finally, for large facilities, the condition could require the permittee to perform the statistics on the ground water data (at a 5% level of significance).

USE THIS CONDITION WHEN A MONITORING PLAN HAS BEEN APPROVED AND MONITORING IS TO CONTINUE UNDER THAT APPROVED PLAN (INSERT APPROVAL DATE)

Ground Water Monitoring Plan

The permittee shall continue sampling and reporting in accordance with the ground water monitoring plan approved on (DATE). The purpose of this plan is to determine if the system integrity is being maintained and to indicate if activities at the site are resulting in violations of the Board's Ground Water Standards. The approved plan is an enforceable part of the permit. Any changes to the plan must be submitted for approval to the ___________ Regional Office.

If monitoring results indicate that any unit has contaminated the ground water, the permittee shall submit a corrective action plan within 60 days of being notified by the regional office. The plan shall set forth the steps to be taken by the permittee to ensure that the contamination source is eliminated or that the contaminant plume is contained on the permittee's property. In addition, based on the extent of contamination, a risk analysis may be required. Once approved, this plan and/or analysis shall be incorporated into the permit by reference and become an enforceable part of this permit.

ATTACHMENTS VI-1 TO VI-2

APPENDIX 5.2
COCHRAN'S APPROXIMATION TO THE BEHRENS-FISHER
STUDENT'S t-TEST

Using all the available background data (n_b readings), calculate the background mean (X_b) and background variance (s_b2). For the single monitoring well under investigation (n_m readings), calculate the monitoring mean ($_m$) and monitoring variance (s_m2).

For any set of data ($X_{1,2}...X_n$) the mean is calculated by:

$$\bar{x} = \frac{X_1 + X_2 + \dots X_n}{n}$$

and the variance is calculated by:

$$s^2 = \frac{(X_1 - \bar{X})^2 + (X_2 - \bar{X})^2 + \dots + (X_n - \bar{X})^2}{n - 1}$$

where "n" denotes the number of observations in the set of data.

The t-test uses these data summary measures to calculate a t-statistic (t^*) and a comparison t-statistic (t_c). The t^* value is compared to the t_c value and a conclusion reached as to whether there has been a statistically significant change in any indicator parameter.

The t-statistic for all parameters except pH and similar monitoring parameters is:

$$t^* = \frac{\bar{x}_m - \bar{x}_n}{\left[\frac{s_m^2}{n_m} + \frac{s_n^2}{n_n}\right]^{\frac{1}{2}}}$$

If the value of this t-statistic is negative then there is no significant difference between the monitoring data and background data. It should be noted that significantly small negative values may be indicative of a failure of the assumption made for test validity or errors have been made in collecting the background data.

The t-statistic (t_c), against which t^* will be compared, necessitates finding t_b and t_m from standard (one-tailed) tables where:

> t_b = t-tables with (n_b-1) degrees of freedom, at the 0.05 level of significance.
>
> t_m = t-tables with (n_m-1) degrees of freedom, at the 0.05 level of significance.

Finally, the special weightings W_b and W_m are defined as:

$$W_B = \frac{s_B^2}{n_B} \text{ and } W_m = \frac{s_m^2}{n_m}$$

and so the comparison t-statistic is:

$$t_c = \frac{W_B \cdot t_B + W_m \cdot t_m}{W_B + W_m}$$

The t-statistic (t^*) is now compared with the comparison t-statistic (t_c) using the following decision-rule:

> If t^* is equal to or larger than t_c, then conclude that there most likely has been a significant increase in this specific parameter.
>
> If t^* is less than t_c, then conclude that most likely there has not been a change in this specific parameter.

Standard t-Tables

0.05 Level of Significance

Degrees of Freedom	t Values	
	One Tail	Two Tail
1	6.314	12.706
2	2.920	4.303
3	2.353	3.182
4	2.132	2.776
5	2.015	2.571
6	1.943	2.447
7	1.895	2.365
8	1.860	2.306
9	1.833	2.262
10	1.812	2.228
11	1.796	2.201
12	1.782	2.179
13	1.771	2.160
14	1.761	2.145
15	1.753	2.131
16	1.746	2.120
17	1.740	2.110
18	1.734	2.101
19	1.729	2.093
20	1.725	2.086
21	1.721	2.080
22	1.717	2.074
23	1.714	2.069
24	1.711	2.064
25	1.708	2.060
30	1.697	2.042
40	1.684	2.021

The t-statistic for testing pH and similar monitoring parameters is constructed in the same manner as previously described except the negative sign (if any) is discarded and the caveat concerning the negative value is ignored. The standard (two-tailed) tables are used in the construction t_c for pH and similar monitoring parameters.

APPENDIX 5.4
STATISTICAL TESTS METHODS

A. Acceptable Test Methods. The following statistical test methods may be used to evaluate groundwater monitoring data:

1. A *parametric analysis of variance* (ANOVA) followed by multiple comparisons procedures to identify statistically significant evidence of contamination. The method must include estimation and testing of the contrasts between each compliance well's mean and the background mean levels for each constituent.

2. An *analysis of variance* (ANOVA) *based on ranks* followed by multiple comparisons procedures to identify statistically significant evidence of contamination. The method must include estimation and testing of the contrasts between each compliance well's median and the background median levels for each constituent.

3. A *tolerance or prediction interval procedure* in which an interval for each constituent is established from the distribution of the background data, and the level of each constituent in each compliance well is compared to the upper tolerance or prediction limit.

4. A *control chart approach* that gives control limits for each constituent.

5. Another statistical test method that meets the performance standards specified below. Based on the justification submitted to the Department, the Director may approve the use of an alternative test. The justification must demonstrate that the alternative method meets the performance standards shown below.

B. Performance Standards. Any statistical method chosen by the owner or operator shall comply with the following performance standards, as appropriate:

1. The statistical method used to evaluate groundwater monitoring data shall be appropriate for the distribution of monitoring parameters or constituents. If the distribution is shown by the owner or operator to be inappropriate for a normal theory test, then the data should be transformed or a distribution-free theory test should be used. If the distributions for the constituents differ, more than one statistical method may be needed.

2. If an individual well comparison procedure is used to compare an individual compliance well constituent concentration with background constituent concentrations or a groundwater protection standard, the test shall be done at a Type I error level no less than 0.01 for each testing period. If a multiple comparisons procedure is used, the Type I experiment-wise error rate for each testing period shall be no less than 0,05; however, the Type I error of no less than 0.01 for individual well comparisons must be maintained. This performance standard does not apply to tolerance intervals, prediction intervals, or control charts.

3. If a control chart approach is used to evaluate groundwater monitoring data, the specific type of control chart and its associated parameter values shall be protective of human health and the environment. The parameters shall be determined after considering the number of samples in the background data base, the data distribution, and the range of the concentration values for each constituent of concern.

4. If a tolerance interval or a predictional interval is used to evaluate groundwater monitoring data, the levels of confidence and, for tolerance intervals, the percentage of the population that the interval must contain, shall be protective of human health and the environment. These parameters shall be determined after considering the number of samples in the background data base, the data distribution, and the range of the concentration values for each constituent of concern.

5. The statistical method shall account for data below the limit of detection with one or more statistical procedures that are protective of human health and the environment. Any practical quantitation limit (PQL) that is used in the statistical method shall be the lowest concentration level that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions that are available to the facility.

6. If necessary, the statistical method shall include procedures to control or correct for seasonal and spatial variability as well as temporal correlation in the data.

EXAMPLE GROUND WATER DATA REVIEW PROBLEM:

Given the following ground water monitoring data for one upgradient (MW1) and one downgradient (MW2) well, determine if the facility causes a significant increase in the level of nitrates in the ground water.

Sampling Date	Nitrates (NO_3)	
	MW1	MW2
1/1/98	1.0	1.4
1/15/98	1.0	1.5
2/1/98	1.5	2.1
2/15/98	2.25	2.75
3/1/98	3.5	4.2
3/15/98	4.0	4.4
4/1/98	3.5	4.1
4/15/98	2.3	2.8
5/1/98	1.5	2.04
5/15/98	1.0	1.4
6/1/98	1.0	1.5

Solution:

The first step is to check the data to determine whether the assumption of a normal distribution is valid. The data are entered into GRITS (see GRITS data printout) and evaluated for normality (see GRITS normality printouts) using the Shapiro-Wilkes Test. In this example, the program indicates that the data from neither well are normally distributed. The log-transferred data, however, do pass the screening and may be evaluated using the Student's t-Test. The GRITS Student's t-Test printout indicates that the difference between the two data sets is not statistically significant (at a 5% level of significance).

A printout from the Lotus Student's t-Test (T-TEST.WK1) is also included. The data in "T-TEST.WK1" were converted to natural log (ln) values prior to entry. You will note that GRITS and "T-TEST.WK1" produce the same value for t-statistic but that the comparison values are not the same. This is because although the GRITS printout indicates that the CABF Student t-Test was used, the program actually uses the more commonly used Welch's Student's t-Test. The Welch's Student's t-Test calculates the degrees of freedom in a different manner and will give a slightly different comparison value. The comparison values generally differ by a small percentage and both Student's t-Test methods are considered to be statistically valid and suitable for evaluation of normally distributed ground water data.

GRITS DATA PRINTOUT

Page 1 08/13/98

GROUND WATER DATA BASE PRINTOUT

FACILITY: any old lagoon,any city,VA WELL: mw1
FCID: VA1 NUMBER OF SAMPLE DATES: 11
PARAMETER: Nitrate

DATE	RESULT	UNITS	DATA QUAL	METHOD
01/01/98	1.000	mg/l		
01/15/98	1.000	mg/l		
02/01/98	1.500	mg/l		
02/15/98	2.250	mg/l		
03/01/98	3.500	mg/l		
03/15/98	4.000	mg/l		
04/01/98	3.500	mg/l		
04/15/98	2.300	mg/l		
05/01/98	1.500	mg/l		
05/15/98	1.000	mg/l		
06/01/98	1.000	mg/l		

Page 1 08/13/98

GROUND WATER DATA BASE PRINTOUT

FACILITY: any old lagoon,any city,VA WELL: mw2
FCID: VA1 NUMBER OF SAMPLE DATES: 11
PARAMETER: Nitrate

DATE	RESULT	UNITS	DATA QUAL	METHOD
01/01/98	1.400	mg/l		
01/15/98	1.500	mg/l		
02/01/98	2.100	mg/l		
02/15/98	2.750	mg/l		
03/01/98	4.200	mg/l		
03/15/98	4.400	mg/l		
04/01/98	4.100	mg/l		
04/15/98	2.800	mg/l		
05/01/98	2.040	mg/l		
05/15/98	1.400	mg/l		
06/01/98	1.500	mg/l		

GRITS NORMALITY TEST - MW1

Normality Tests

Report Printed: 08-13-1998 09:48

Facility:VA1 any old lagoon

Address:any street

City:any city ST:VA Zip:
County:ACCOMACK

Contact:
Phone:( ) -

Permit Type:Background

Constituent:NO3 Nitrate

CAS Number:14797-55-8
MCL: 0.000 mg/l
ACL: 0.000 mg/l
Detect Limit: 0.000 mg/l

Start Date:Jan 01 1998
End Date:Jun 01 1998

Normality Test on Observations for wells listed below:

Well:mwl Position:Upgradient Observations:11

Scale	Minimum	Maximum	Mean	Std Dev
Original:	1.000	4.000	2.050	1.146
Log:	0.000	1.386	0.577	0.555

Pooled Statistics
Observations: 11

Statistic	Original Scale	Log Scale
Mean:	2.050	0.577
Std Dev:	1.146	0.555
Skewness:	0.598	0.245
Kurtosis:	-1.190	-1.493
Minimum:	1.000	0.000
Maximum:	4.000	1.386
CV:	0.559	0.962

Shapiro-Wilk Statistics

Scale	Test Statistic	5% Critical Value	1% Critical Value
Original:	0.8357*	0.8500	0.7920
Log:	0.8545	0.8500	0.7920

* Indicates statistically significant evidence of non-normality.
GRITS/STAT Version 5.0

GRITS NORMALITY TEST - MW2

Normality Tests

Report Printed: 08-13-1998 09:49

Facility:VA1 any old lagoon

Address:any street

City:any city ST:VA Zip:
County:ACCOMACK

Contact:
Phone:( ) -

Permit Type:Background

Constituent:NO3 Nitrate

CAS Number:14797-55-8
MCL: 0.000 mg/l
ACL: 0.000 mg/l
Detect Limit: 0.000 mg/l

Start Date:Jan 01 1998
End Date:Jun 01 1998

Normality Test on Observations for wells listed below:

Well:mw2 Position:Downgradient Observations:11

Scale	Minimum	Maximum	Mean	Std Dev
Original:	1.400	4.400	2.563	1.182
Log:	0.336	1.482	0.846	0.455

Pooled Statistics
Observations: 11

Statistic	Original Scale	Log Scale
Mean:	2.563	0.846
Std Dev:	1.182	0.455
Skewness:	0.538	0.237
Kurtosis:	-1.279	-1.461
Minimum:	1.400	0.336
Maximum:	4.400	1.482
CV:	0.461	0.537

Shapiro-Wilk Statistics

Scale	Test Statistic	5% Critical Value	1% Critical Value
Original:	0.8433*	0.8500	0.7920
Log:	0.8722	0.8500	0.7920

* Indicates statistically significant evidence of non-normality.
GRITS/STAT Version 5.0

Welch's
~~CABF~~ T Test

GRITS STUDENT'S t-TEST

Report Printed: 08-13-1998 10:00

Facility:VA1 any old lagoon

Address:any street

City:any city ST:VA Zip:
County:ACCOMACK

Contact:
Phone:( ) -

Permit Type:Background

Constituent:NO3 Nitrate

CAS Number:14797-55-8
MCL: 0.000 mg/l
ACL: 0.000 mg/l
Detect Limit: 0.000 mg/l

Start Date:Jan 01 1998
End Date:Jun 01 1998

Data Mode:Log Transformed

Background Wells

Well ID	N	%ND	Max Value	Min Value	Mean	Std Dev
mw1	11	0	1.39	0.00	0.58	0.55

Compliance Wells

Well ID	N	%ND	Max Value	Min Value	Mean	Std Dev
mw2	11	0	1.48	0.34	0.85	0.45

	Background/Upgradient	Compliance/DownGradient
Wells	mw1	mw2
Observations	11	11
Mean	0.5770	0.8462
Variance	0.3079	0.2067
Standard Error	0.2163	
Degrees of Freedom	19.2557	
Significance Level(α)	0.0500	

t-Statistic: 1.2445 Critical Value: 1.7280
Since the t-statistic does not exceed Critical Value, the hypothesis of equal medians is not rejected.

LOTUS SPREADSHEET STUDENT'S t-TEST PRINTOUT

Cochran's Approximation to the Behrens-Fisher Student's t-Test (at a 5% Level of Significance)
To use this spreadsheet, please fill in only the shaded boxes.

What is the number of observations in the set of background data? 11
What is the number of observations in the set of monitoring data? 11
Input your data points into the chart.

	Background	Monitored Site	[Xb-Xb(ave)]^2	[Xm-Xm(ave)]^2
1	0	0.336	0.33282409917	0.260285487603
2	0	0.405	0.33282409917	0.194641396694
3	0.405	0.742	0.02955273554	0.01085385124
4	0.811	1.012	0.05479855372	0.027495669421
5	1.253	1.435	0.45709891736	0.34670685124
6	1.386	1.482	0.65462809917	0.404264760331
7	1.253	1.412	0.45709891736	0.320150214876
8	0.833	1.03	0.06558255372	0.033789123967
9	0.405	0.713	0.02955273554	0.017737396694
10	0	0.336	0.33282409917	0.260285487603
11	0	0.405	0.33282409917	0.194641396694
12			0	0
13			0	0
14			0	0
15			0	0
16			0	0
17			0	0
18			0	0
19			0	0
20			0	0

Xb(ave)= 0.576909091 Xm(ave)= 0.8461818182

Tb= 1.812
Tm= 1.812

S2b= 0.307960891 = (Xb1-Xb(ave))^2+(Xb2-Xb(ave))^2...(Xbn-Xb(ave))^2/(Nb-1)
S2m= 0.207085164 = (Xm1-Xm(ave))^2+(Xm2-Xm(ave))^2...(Xmn-Xm(ave))^2/(Nm-1)

Tstar= 1.244416266 If Tstar is negative, there is no signigicant difference between the monitoring data and the background data.
= [Xm(ave)-Xb(ave)]/sqrt(S2m/Nm + S2b/Nb)

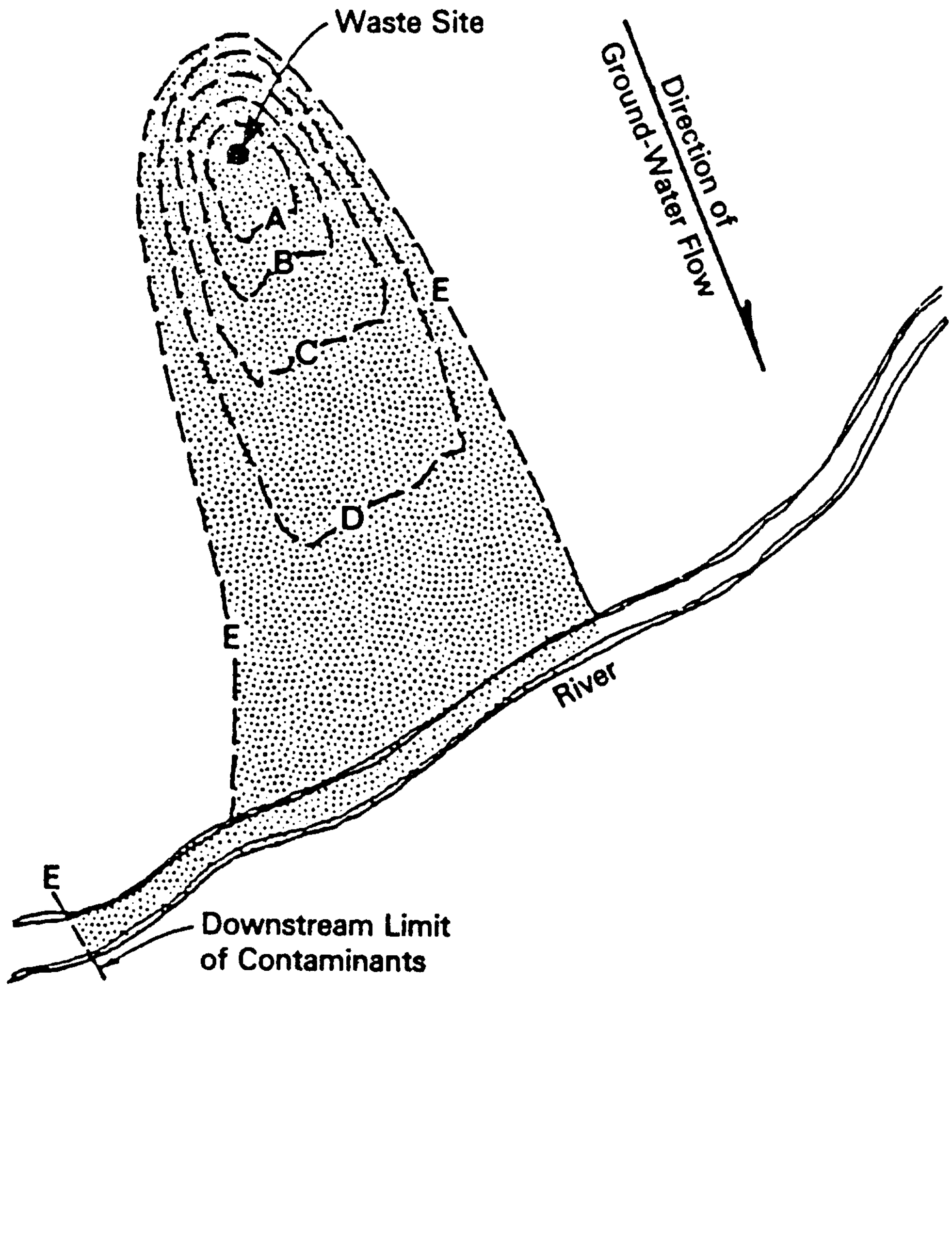
Wb= 0.027996445 = S2b/Nb
Wm= 0.018825924 = S2m/Nm

Tcomp= 1.812 If Tstar is equal to or larger than Tcomp, then there most likely is a significant increase in this parameter.
=(Wb*Tb + Wm*Tm)/(Wb + Wm)

If Tstar is less than Tcomp, then conclude that most likely there has not been a change in this specific parameter.

ATTACHMENTS VII-1 TO VII-4

Figure 1-18 Constant release but variable constituent source (from LeGreud, 1965).



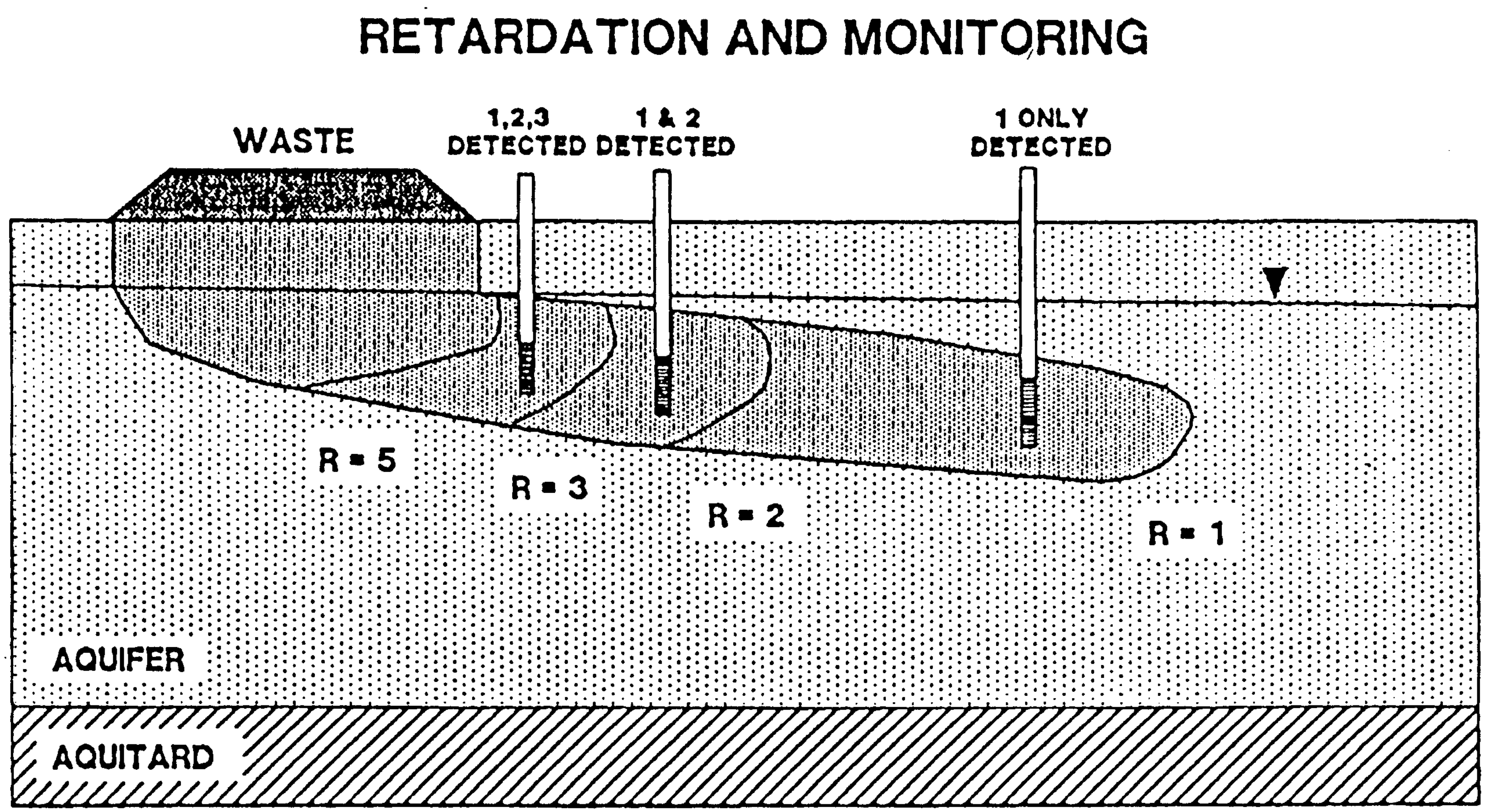
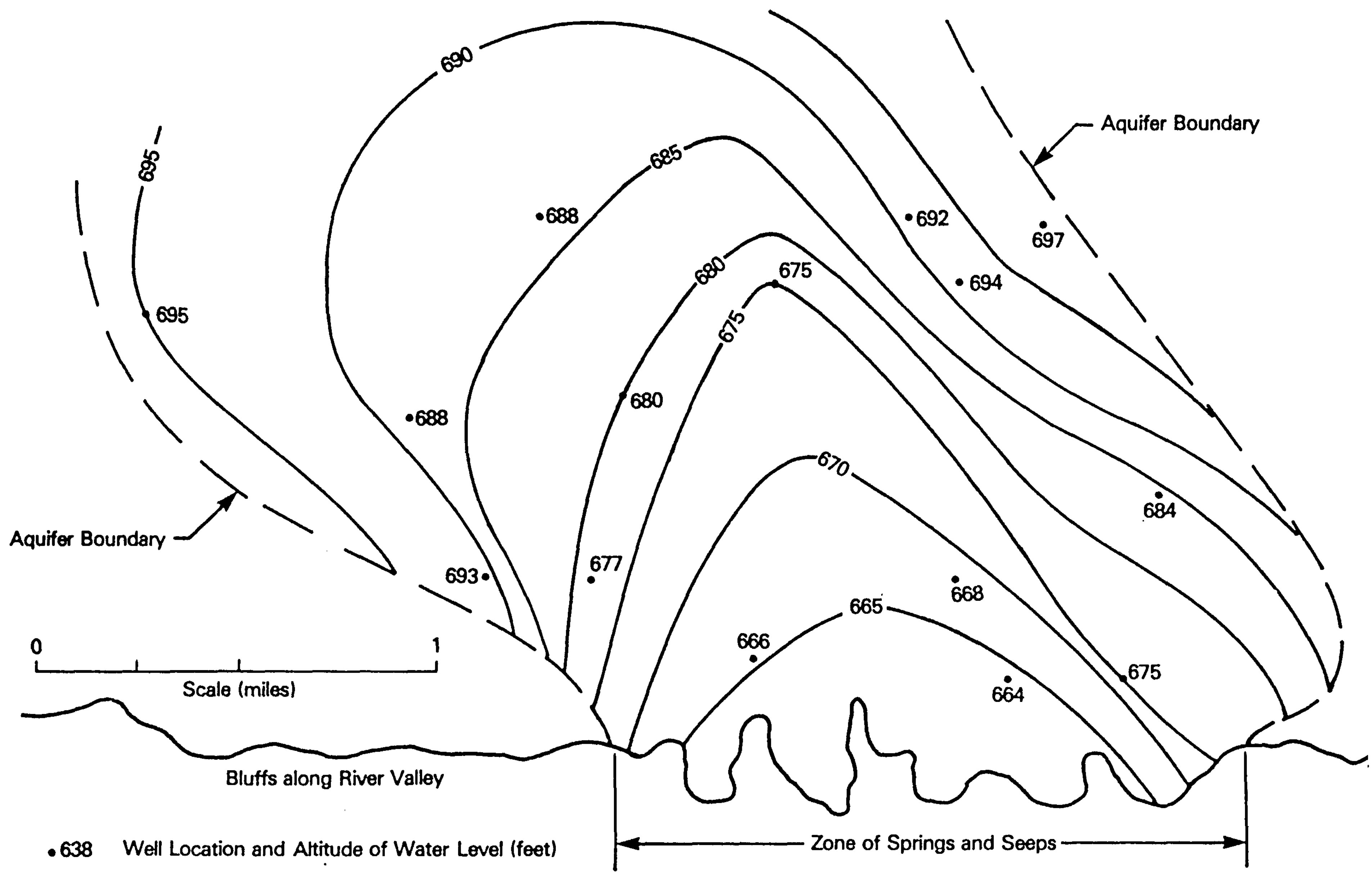


Figure 3-6. Transport of Contaminants with Varying Retardation Factors at a Waste Site (Palmer and Johnson, 1989a)

Figure 4-28 A potentiometric surface map representing the hydraulic gradient.



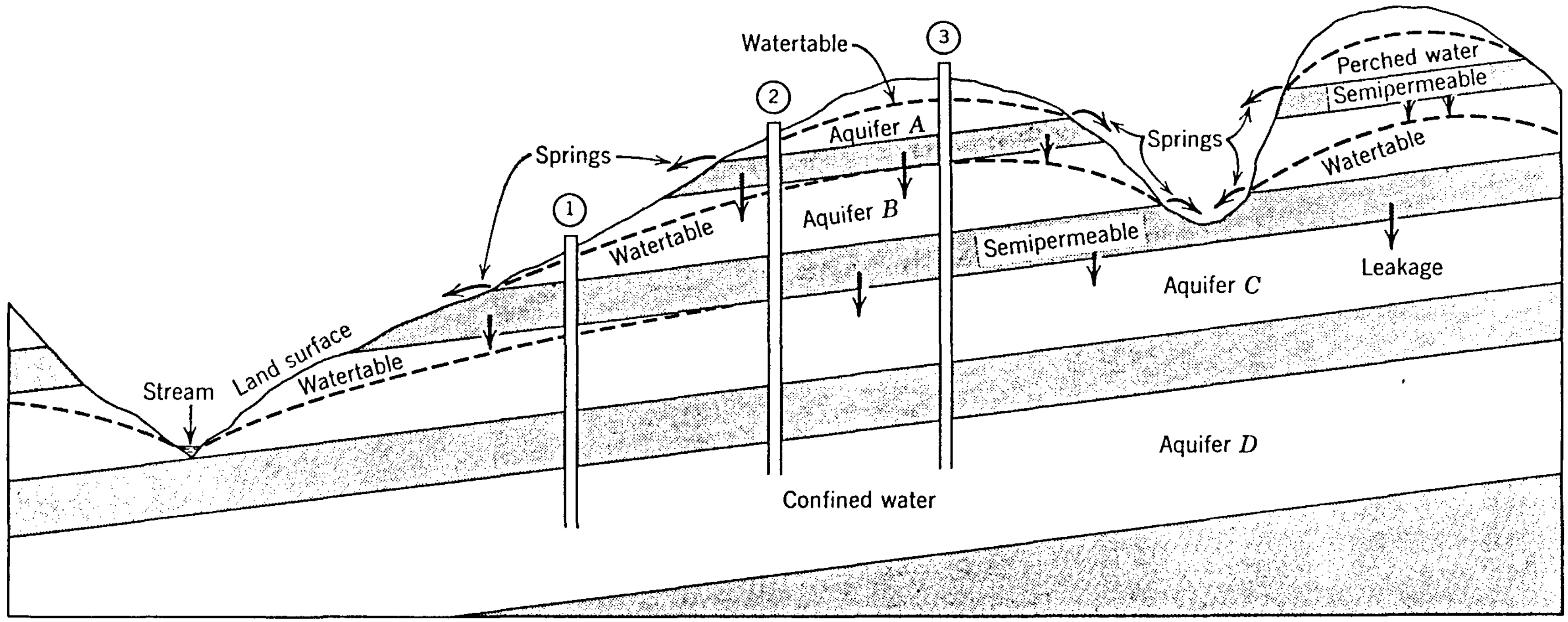


Figure 2.20 Confined, unconfined, and perched water in a simple stratigraphic sequence of sandstone and shale.

ATTACHMENTS VIII-1 TO VIII-8

Figure 9a. Plan of downgradient placement (Spooner et al., 1984).

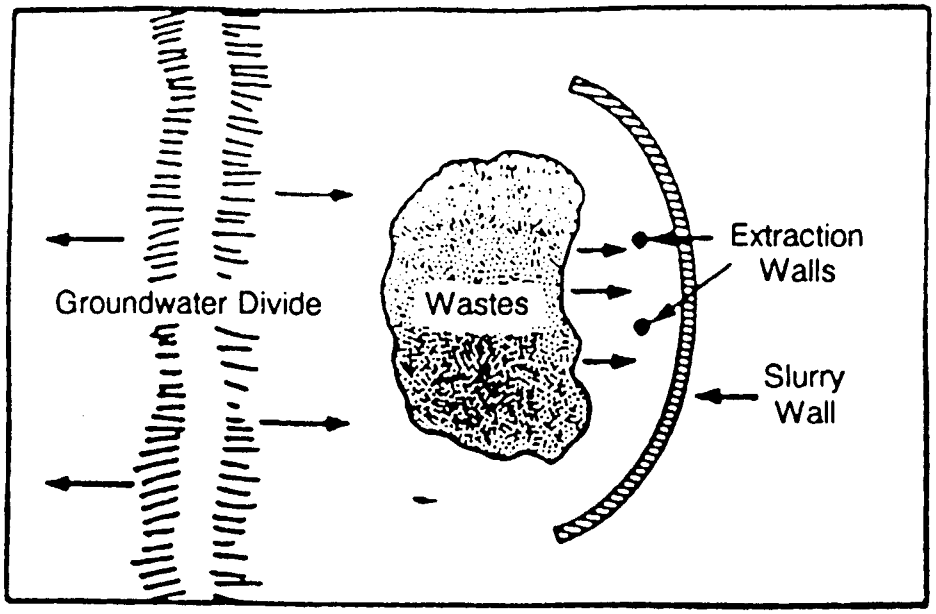


Figure 9b. Plan of upgradient placement with drain (Spooner et al., 1984).

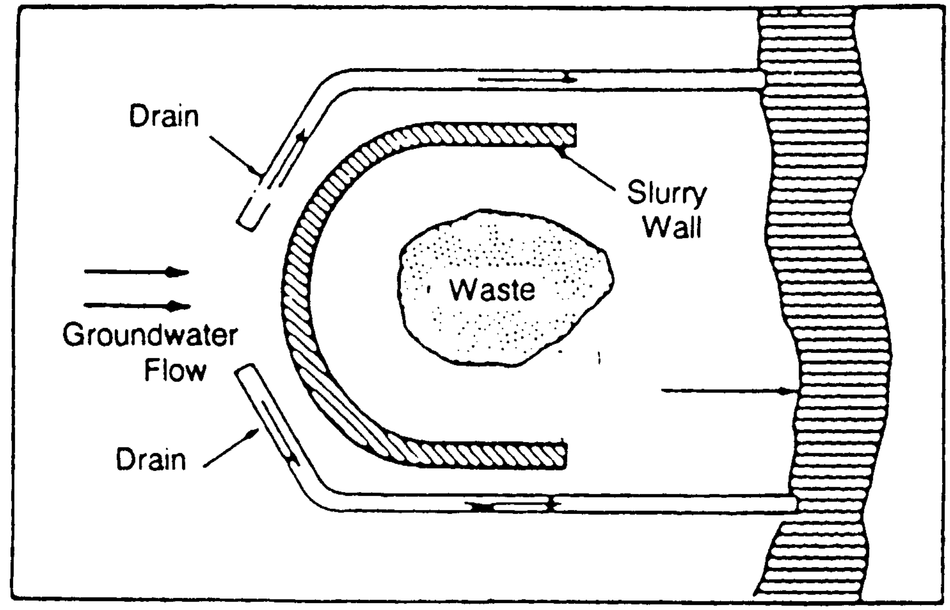


Figure 9c. Plan of circumferential wall placement (Spooner et al., 1984).

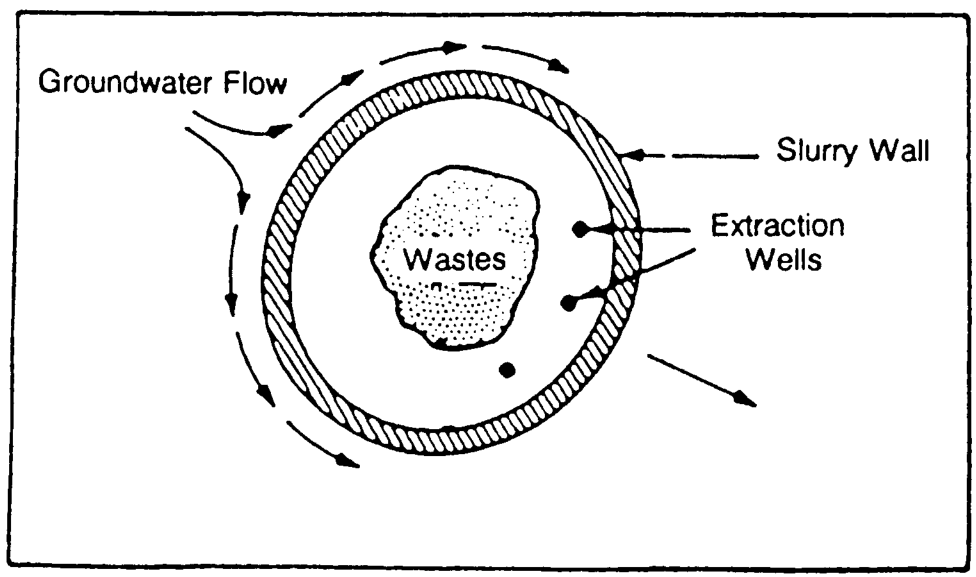
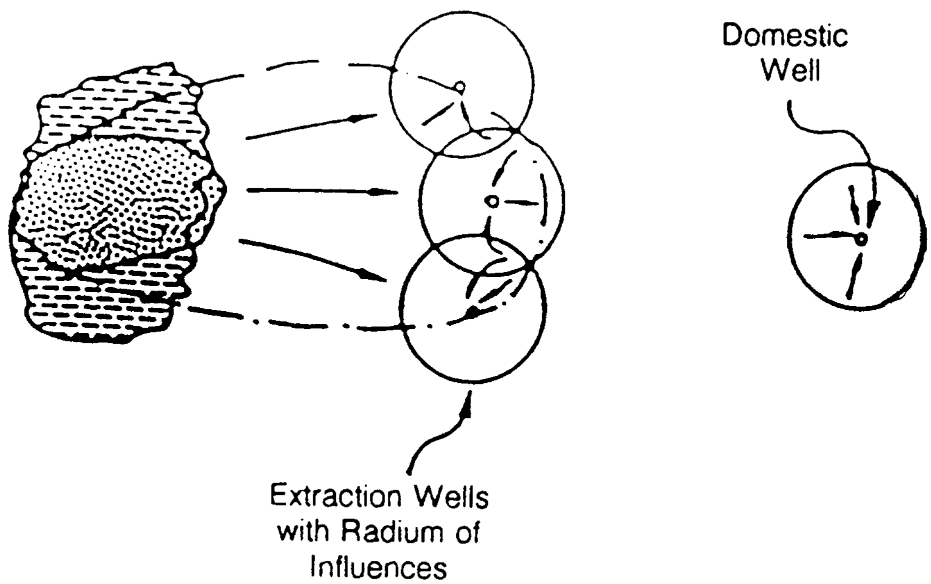


Figure 7a. **Containment using extraction wells (U.S. EPA, 1985).**



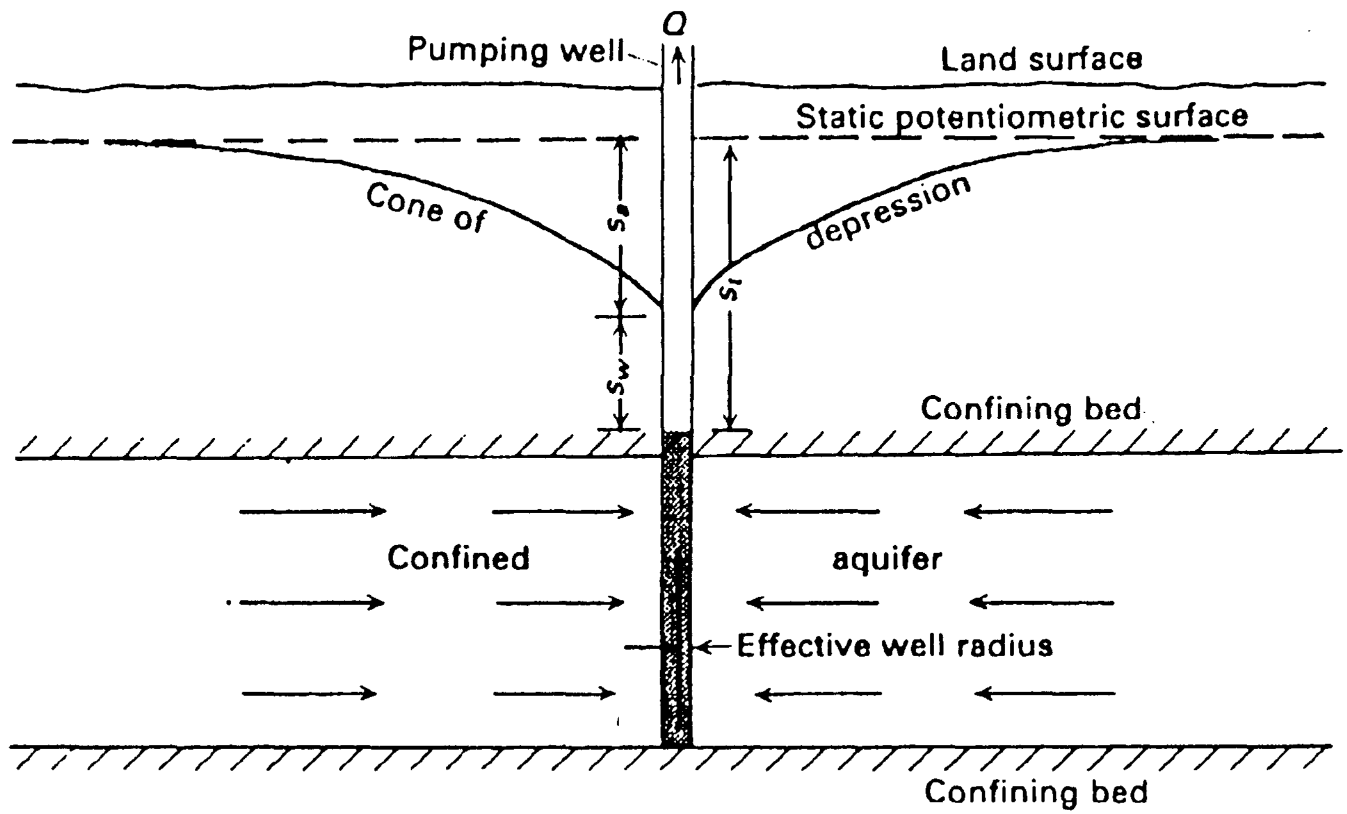


Figure 5-11. Two Components of Total Drawdown in a Pumping Well

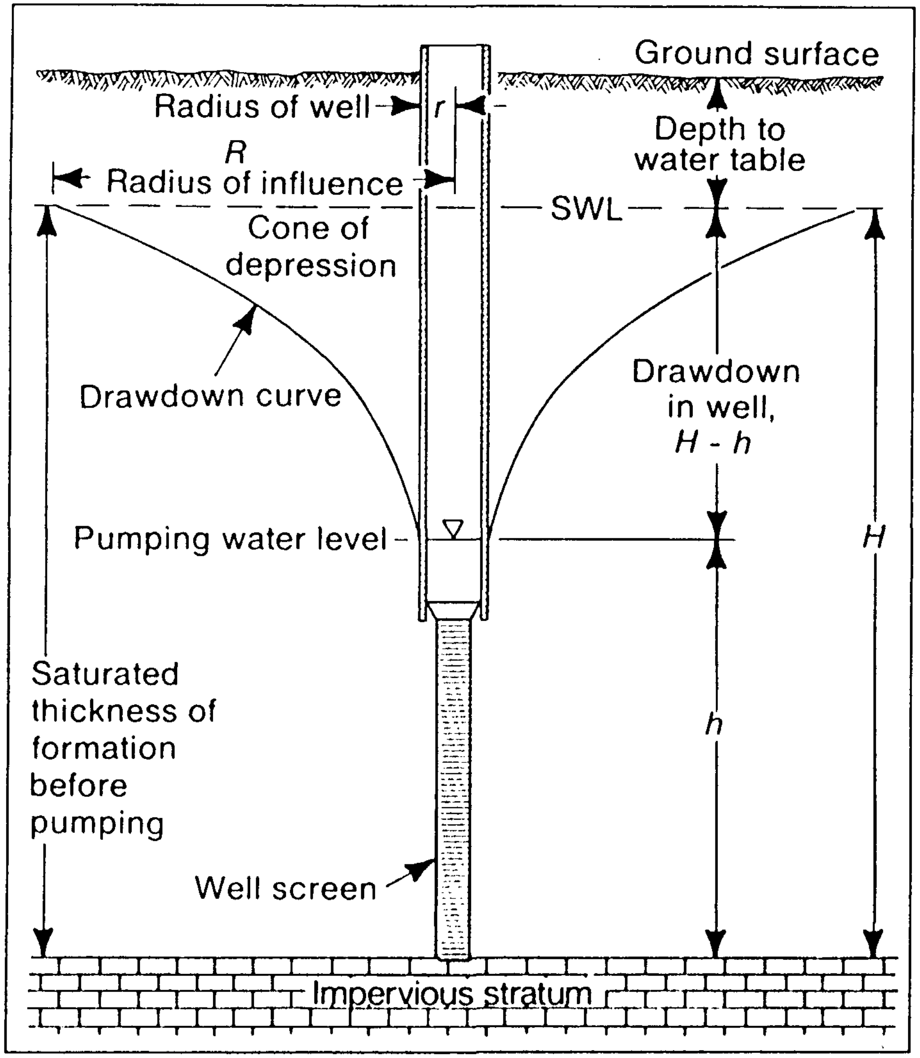


Figure 9.8. Well in an unconfined aquifer showing the meaning of the various terms used in the equilibrium equation.

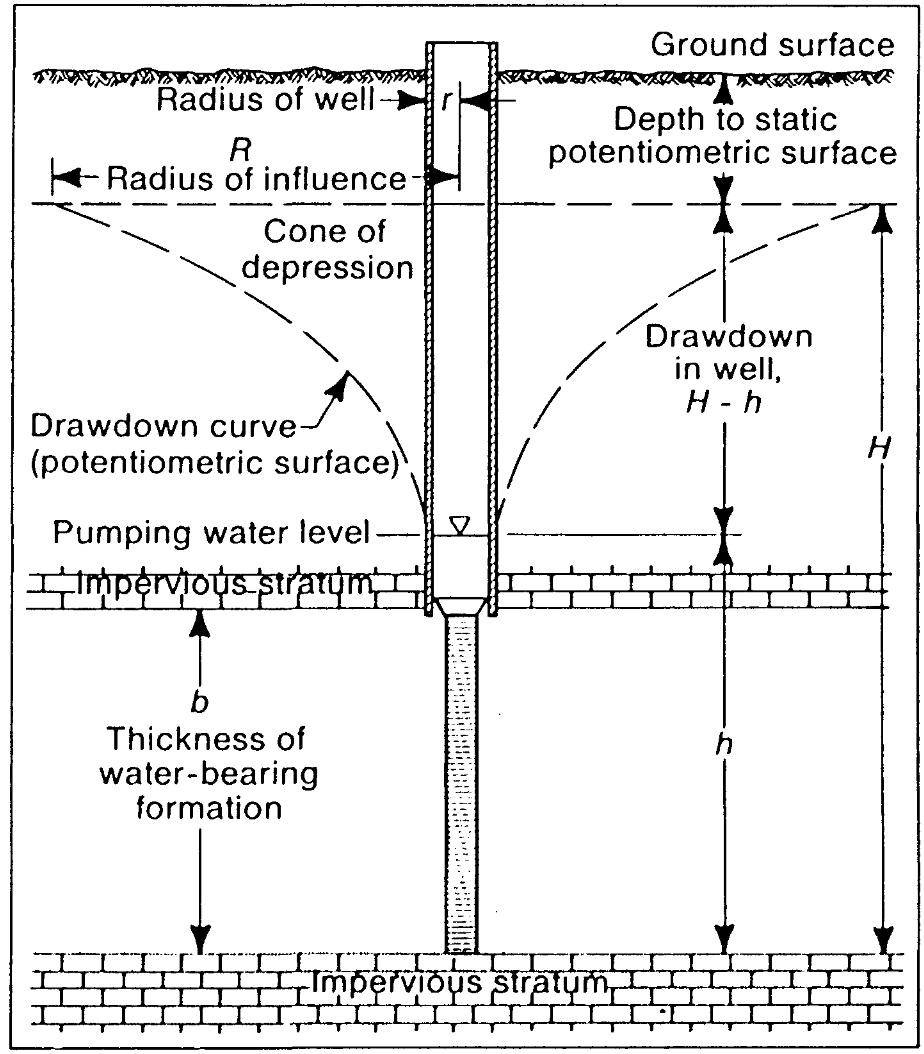


Figure 9.9. Well in a confined aquifer showing the meaning of various terms used in the equilibrium equation.

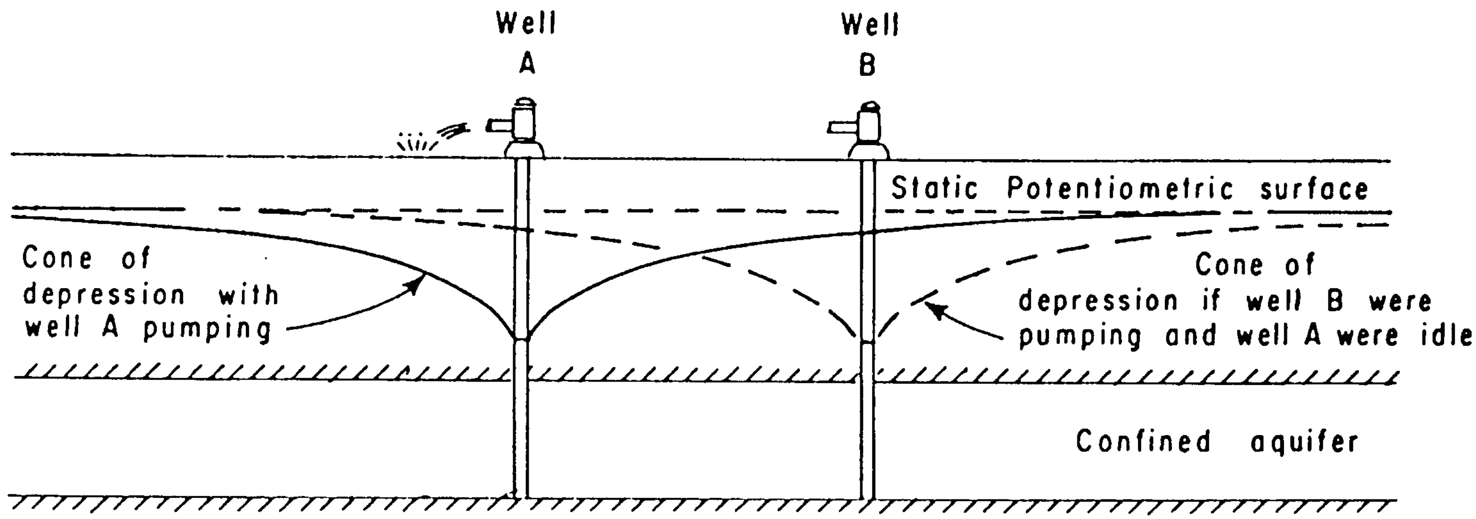


Figure 5-14. Cone of Depression When Well A or B is Pumped

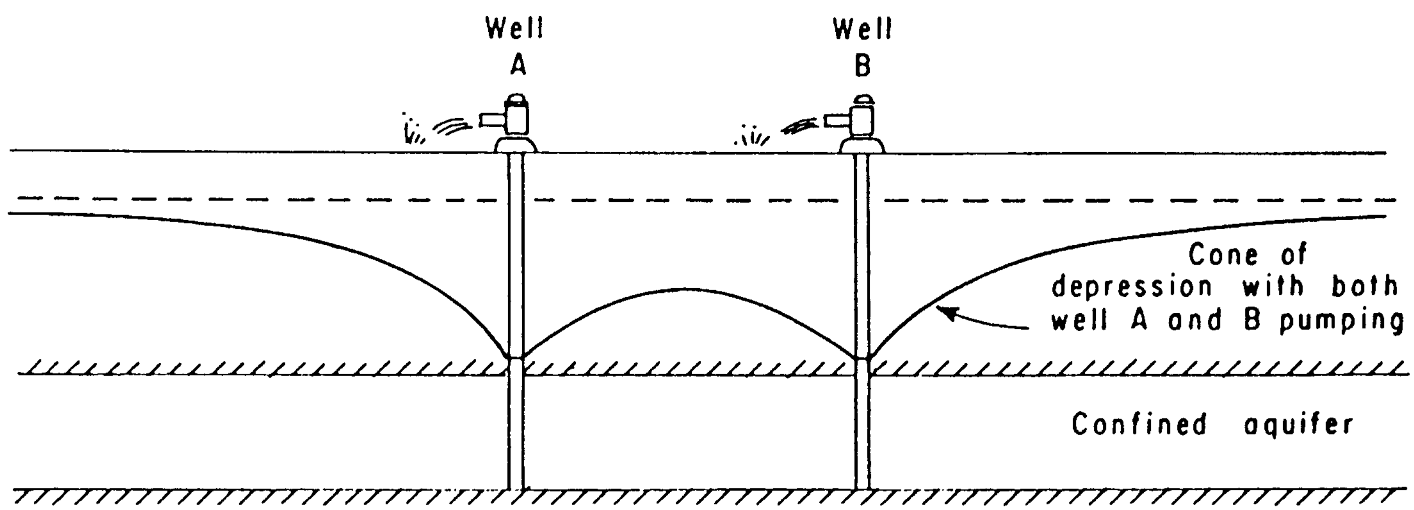


Figure 5-15. Total Drawdown Caused by Overlapping Cones of Depression

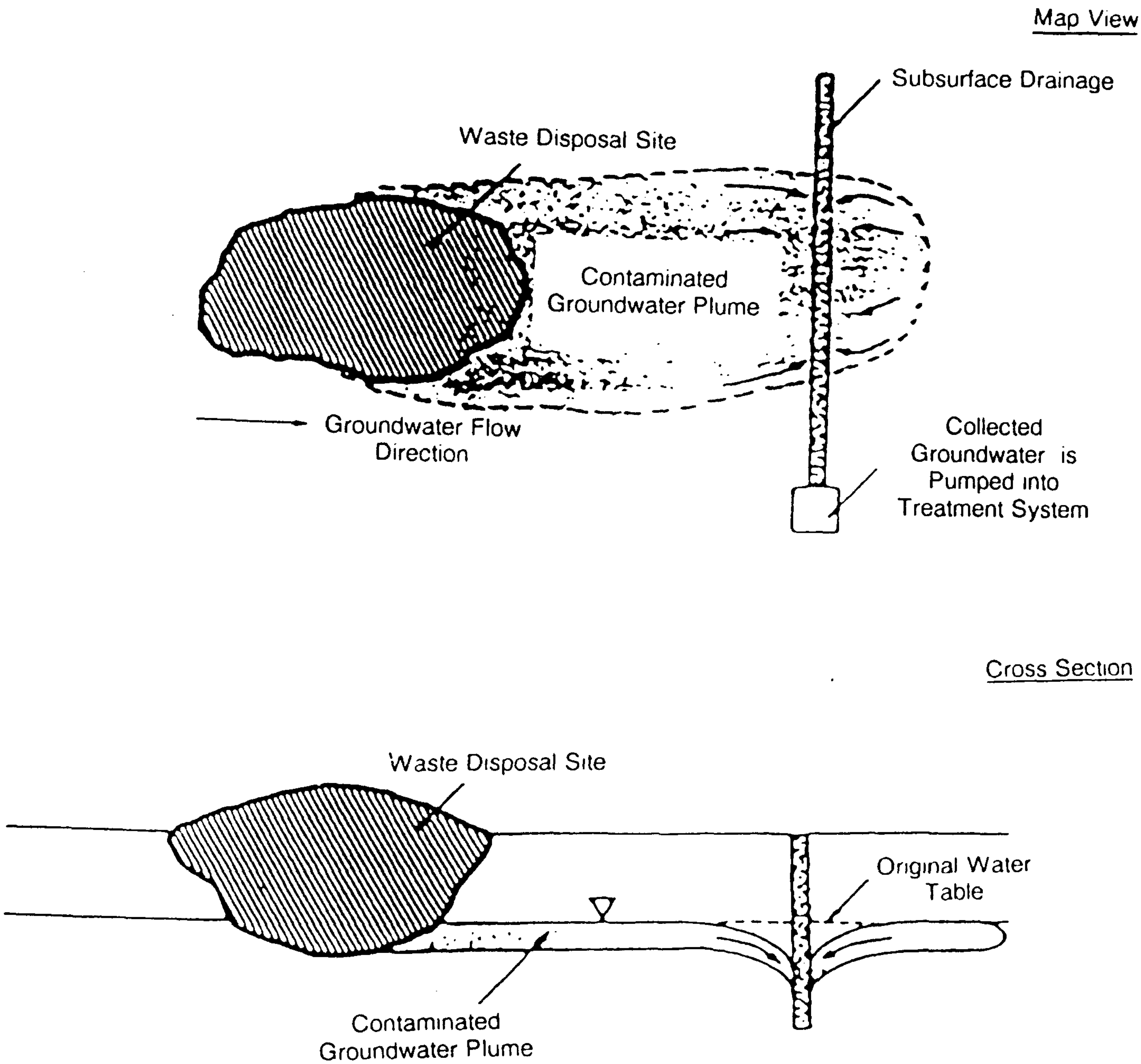
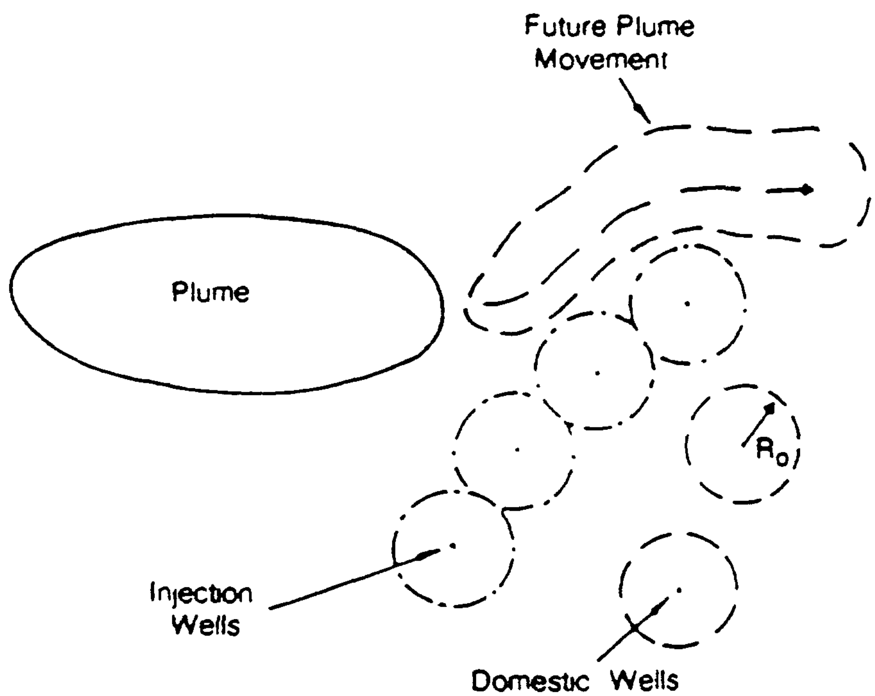


Figure 8. The use of subsurface drainage to contain a leachate plume (U.S. EPA, 1985).

Figure 7b. Plume diversion using injection wells (U.S. EPA, 1985).



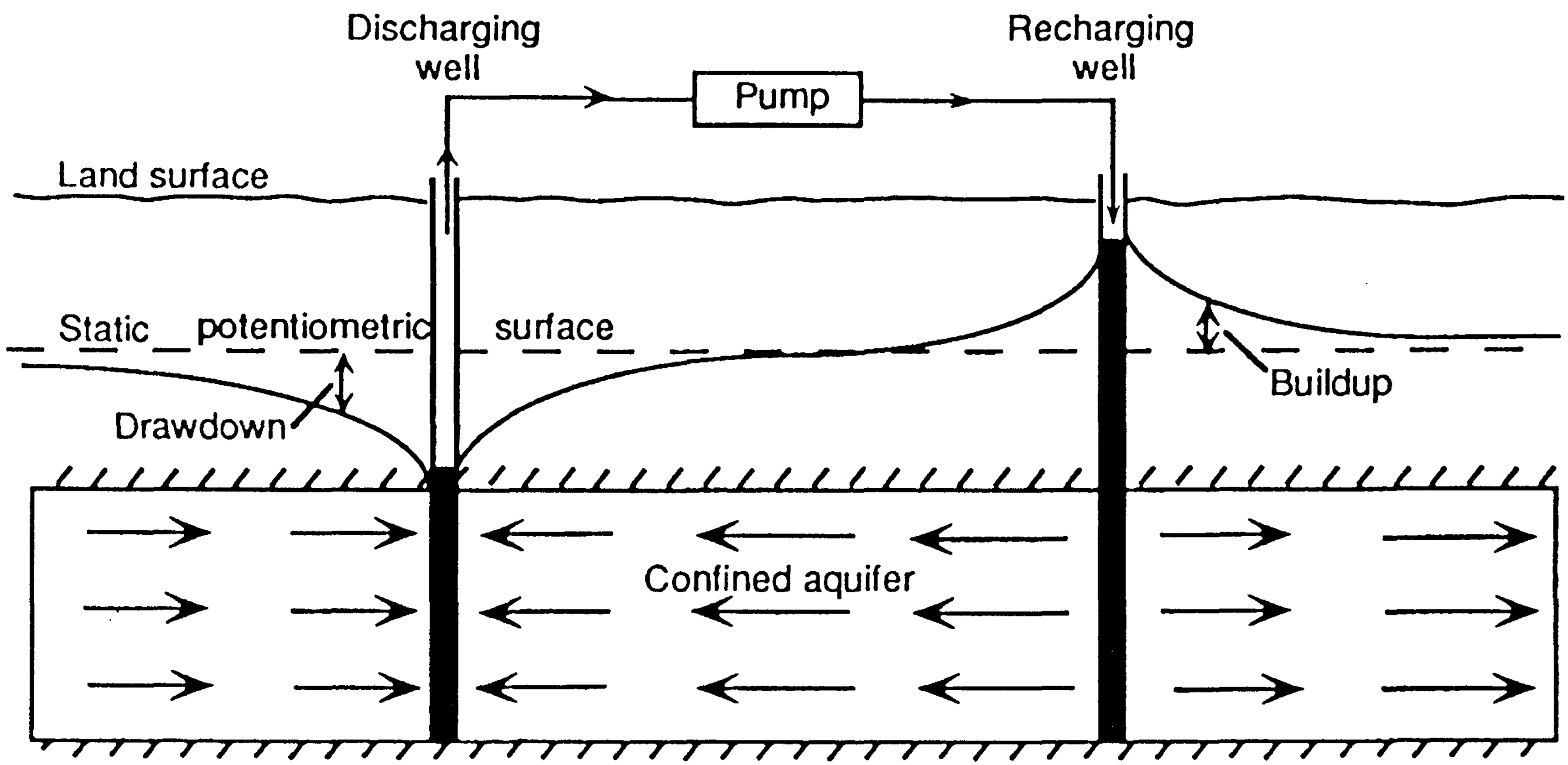


Figure 5-16. Cones of Depression and Buildup Surrounding Discharging and Recharging Wells