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OVERVIEW

The publication consists of two guidance documents designed to be used in tandem: The RCRA Ground-Water Monitoring Compliance Order Guidance and the Draft RCRA Ground-Water Monitoring Technical Enforcement Guidance Document. Together these two documents provide comprehensive guidance on how to identify and rectify ground-water monitoring violations at RCRA hazardous waste facilities. Both documents should be read by all individuals involved in addressing RCRA ground-water monitoring problems including regional and state enforcement officials, permit writers, field inspectors, and attorneys.

The Draft RCRA Ground-Water Monitoring Technical Enforcement Guidance Document (TEGD), provides draft guidance on how to evaluate the technical adequacy of a facility's interim status monitoring system. The document discusses each of the elements that is important to the overall adequacy of an owner/operator's monitoring system and, where possible, makes specific judgements on what activities and methodologies are appropriate to meet the terms of the regulations. Specifically, the TEGD provides guidance on how to evaluate:

- the owner/operator's hydrogeologic characterization of the facility;
- the adequacy of the number and location of ground-water monitoring wells;
- the design and construction of the monitoring wells;
- the sampling and analysis plan;
- the statistical analysis of the monitoring data; and
- the owner/operator's assessment plan.

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Enforcement officials should consider the guidance in the TEGD to help determine whether an existing monitoring system is in compliance with the regulations. In addition, enforcement officials should consider the recommendations contained in the TEGD when directing respondents to undertake ground-water activities pursuant to an enforcement order.

The RCRA Ground-Water Monitoring Compliance Order Guidance, (COG) presents the Agency's strategy for correction of ground-water problems at interim status land disposal facilities. The cornerstone of this strategy is the issuance of orders that correct existing interim status ground-water violations in a manner consistent with the needs of the RCRA permitting program. The guidance encourages the development of technical ground-water remedies that integrate the facility's interim status monitoring obligations (Part 265) with the requirements mandated by the permit application regulations (Part 270). By integrating the two sets of regulations, the Agency hopes to speed the issuance of operating and post-closure permits, thereby bringing the regulated community under the stricter requirements of Part 264 as quickly as possible.

HOW TO USE THIS MANUAL

The Compliance Order Guidance and the Draft Technical Enforcement Guidance Document have been bound together in order to emphasize that the documents should be used jointly. The COG should be read first because this document introduces the Agency's approach to ground-water compliance and provides important background information on the interrelationship of the Part 265, Part 270, and Part 264 ground-water regulations. Even individuals more interested in the technical aspects of a facility's ground-water monitoring program will benefit from the regulatory background and policy context provided by this document. Next, regional and state personnel should read the TEGD. The TEGD provides draft technical information to evaluate existing systems and develop the type of highly specific orders encouraged by the COG. As with the COG, even those

individuals not directly involved in the technical aspects of ground-water monitoring will benefit from familiarity with the criteria and information that technical staff use to design and evaluate ground-water programs.

COORDINATION IN THE ENFORCEMENT PROCESS

The implementation of this guidance will require the coordinated effort of many actors with different technical, policy, and legal expertise. Technical enforcement staff (e.g., hydrogeologists, statisticians), permit writers, field inspectors, and enforcement attorneys will all have to work together to achieve the comprehensive remedies and detailed orders envisioned by the COG. The TEGD and the COG were designed to facilitate and inform this group effort.

The coordination between actors begins before the field inspector conducts the site visit. Prior to the site visit, the technical enforcement staff member should gather and review all information available about the facility including, among other documents, the facility's Part A and Part B permit applications, previous inspection reports, and existing facility records. Next, the enforcement staff person and the field inspector should meet to develop a plan of action for the inspection. Having performed an initial evaluation of the facility, the technical staff person should be able to provide guidance to the field inspector on what further information to collect and what potential problems should be investigated during the site visit. (Further guidance on how to prepare and conduct field inspections is forthcoming in the Agency's upcoming Field Inspection Guide to be issued in draft in September). Pre-inspection planning and analysis should culminate in a written inspection plan developed jointly by the technical staff and the field inspector.

After the site inspection, coordination continues when the inspector and the technical staff meet to discuss the findings of the field

inspection. The outcome of this meeting should be a decision as to whether compliance problems may exist and what additional information, if any, is necessary to confirm the nature and extent of any potential violations. Often at this point, a follow-up inspection is appropriate to verify whether or not compliance problems exist at the facility and to gather any additional information necessary to support an enforcement action. Generally this more in-depth inspection will be performed by a technical person, most likely an engineer or hydrogeologist, who has the expertise to independently evaluate elements of the facility's ground-water monitoring program. Once back in the office, this person will be able to consider guidance in the draft TEGD and his/her own professional judgment to decide whether the owner/operator's monitoring program is technically adequate.

If the review indicates that the facility's monitoring program is not in compliance with Part 265, the technical enforcement staff and the permit writer should meet to conceptualize a technical remedy for incorporation in an order. Coordination between enforcement and permitting is essential at this point to ensure that any enforcement action taken is consistent with the long term monitoring obligations of the facility. As the COG points out, most facilities will have ground-water obligations imposed by Part 270 and Part 264 over and above those required by Part 265. A technical remedy designed to address Part 265 violations should anticipate and be consistent with the facility's future monitoring obligations pursuant to Part 264. Likewise, if the facility's operating or post-closure permit is due, the remedy in the order should require the respondent to generate any ground-water data, information, or plans required to meet the facility's permit application responsibilities pursuant to Part 270.

Once the permit writer and enforcement official decide what activities should be compelled, the enforcement staff and regional counsel must

develop an enforcement strategy to secure the desired remedy. Central to the strategy is the selection of which order authority and (where appropriate) what regulatory citations should be used to compel the required activities. The COG provides useful background information on the various order authorities and compares them with respect to the conditions for order issuance, the types of actions they may compel, and applicable appeal procedures, if any. In addition, the COG provides guidance on how to select among order authorities and how to relate specific technical inadequacies back to the regulatory language.

As a final step in the enforcement process, enforcement officials and regional counsel must develop an order to compel the desired activities. Here both documents will come into play. Enforcement officials can consider technical information provided in the draft TEGD to decide which methodologies, design configurations, and construction materials should be mandated by the order. Then enforcement staff and counsel can use the COG for suggestions on how to write ground-water orders that are easily enforced and effective at achieving the desired remedy. Together the TEGD and COG will help reduce the opportunity for wasted effort, misunderstanding, and delay by ensuring that future ground-water orders are explicit about which techniques and approaches will be considered appropriate or adequate.

Figure One illustrates the various steps in the enforcement process and highlights the level of coordination necessary to fully implement the guidance presented in this manual. While the actors and steps needed to remedy any particular ground-water problem will vary, the flow chart illustrates the highly complex task of bringing a RCRA facility back into compliance with the ground-water regulations. The Agency hopes that this manual will facilitate this task.

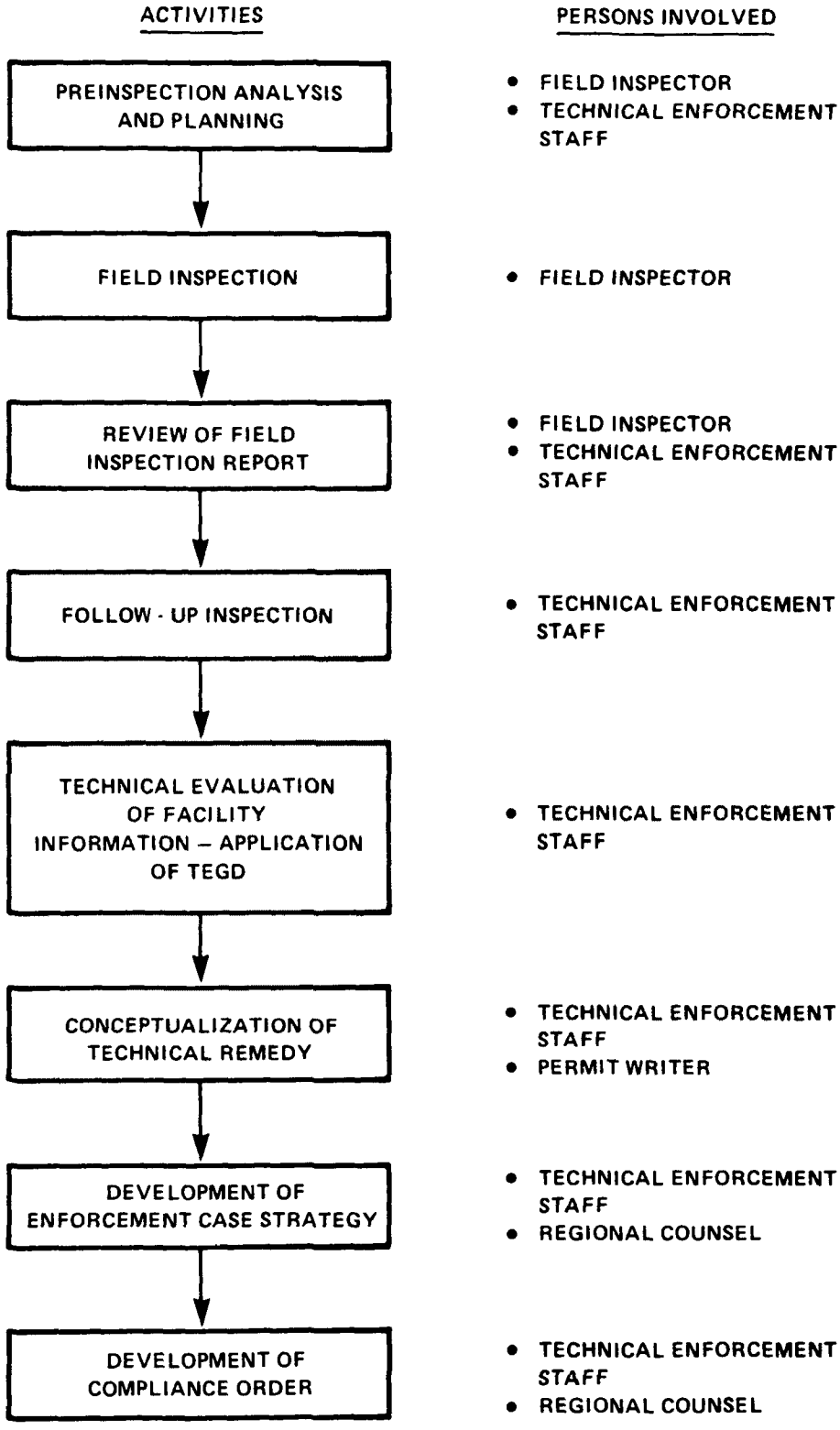

FIGURE 1. OVERVIEW OF THE ENFORCEMENT PROCESS

RCRA Ground-Water Monitoring Compliance Order Guidance

Final

August, 1985

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CHAPTER 1

INTRODUCTION

1.1 Purpose and Objectives

The purpose of this document is to guide enforcement officials in developing administrative orders to address RCRA ground-water monitoring violations at interim status land disposal facilities.[1] The document's primary objective is to promote the development of orders that correct interim status violations in a manner that is consistent with the needs of the RCRA permitting process. Enforcement personnel are encouraged to involve permit writers in the formulation of technical remedies to ensure that enforcement remedies are consistent with the long-term monitoring responsibilities of the facility.

The guidance is intended to apply to the RCRA-authorized States as well as to EPA regional offices. While State and Federal enforcement authorities may differ (e.g., states may have different order authorities or different maximum penalties), the States and EPA are enforcing essentially the same set of regulations. Therefore, remedies designed by State enforcement officials should be similar to those outlined in this document.

The document will not be concerned with policy matters such as how to decide which cases to pursue or how to decide between administrative and

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[1] This document covers only the requirements for ground-water monitoring that apply to hazardous waste management units that were in existence on November 19, 1980. It does not address monitoring requirements that may be imposed on solid waste management units as a result of the "continuing releases" provision, §3004(u) of RCRA, as amended by the Solid and Hazardous Waste Act Amendments of 1984.

judicial response. Instead, the document focuses on the formulation of technical remedies and on the appropriate technical content of orders. Specifically, it concentrates on how to fashion ground-water remedies for facilities operating during the transition period between interim status and permitting.

1.2 Significance of the Interim Status to Permitting Transition Period

The Agency and the regulated community are now entering a period unique in the life of the RCRA program -- the period after which all Part B permit applications are due, but before all facilities have been permitted. EPA and the States have already received many Part B applications. By November 8, 1985 the Part B permit applications of all the nation's land disposal facilities will be due.[2] It is likely, however, that it may take several years for EPA to process and finalize permits for all these facilities. As a result, many facilities will face a fairly long period of time between the due date of their application and the issuance or denial of a permit.

The existence of this transition period is significant because it is the only time in the life of the RCRA program that land disposal facilities will be bound by the interim status ground-water regulations (Part 265) and the permit application regulations (Part 270). It is the first time, therefore,

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[2] The Solid and Hazardous Waste Act Amendments of 1984 require all land disposal facilities to submit a Part B permit application within twelve months after the enactment of the Amendments or lose interim status. See §3005(e) of the Resource Conservation and Recovery Act (RCRA).

that enforcement officials can draw upon the authorities of both Part 265 and 270 when fashioning technical remedies at interim status facilities.

As described in Chapter 3, the Part 270 regulations impose additional monitoring and information generating requirements on the owner/operators of interim status facilities. The Agency designed the interim status (Part 265), permit application (Part 270), and permitting regulations (Part 264) to be followed in sequence. A facility moves from one phase of monitoring to the next (and from interim to permitted status) by building upon the information generated during the previous stage. The monitoring and cleanup obligations of an owner/operator also expand as the facility approaches permitting and/or the evidence of ground-water contamination increases.

Unfortunately, certain facilities have not adequately implemented even the first phase of the monitoring sequence, the installation of a competent detection monitoring network. Consequently, these owner/operators cannot provide the sampling data or plume characterization required for a Part B permit application.

Enforcement officials can help solve this problem by crafting technical remedies that integrate the requirements of Parts 265 and 270. Facilities that have failed to progress through the monitoring sequence as planned, should be required to condense the sequence so as to prepare the facility for permitting as rapidly as possible. Much of this document concentrates on exploring how enforcement officials can use the requirements of Parts

265 and 270, and other available authorities to design remedies that will ease the transition between interim and permitted status.

1.2.1 Plume Characterization Under §270.14(c)(4)

In terms of ground-water monitoring, the most significant requirement of the Part 270 regulations is the provision outlined in §270.14(c)(4). This provision requires applicants to describe any plume of contamination that has entered ground water and define its extent, and provides EPA with the authority to compel sampling for the broad list of constituents listed in Appendix VIII of Part 261 (hereafter referred to as "Appendix VIII").

This provision applies to all facilities that have detected plumes under interim status monitoring and to facilities that have not detected plumes if the facility's interim status system is not capable of detecting a plume should it occur.[3] Facilities with inadequate 265 monitoring systems should not be allowed to avoid Appendix VIII sampling and assessment activities simply because they have avoided compliance with RCRA ground-water monitoring requirements in the past. Moreover, such facilities should not be allowed to delay undertaking the more comprehensive assessment and sampling activities mandated by §270.14(c)(4), by first going back and

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[3] This interpretation has been consistently advanced in all previous guidance documents that address this issue. (See: the RCRA Permit Writer's Guidance Manual For Ground-water Protection, October 1983, p. 204; and the November 29, 1984 policy memorandum from Lee Thomas and Courtney Price, entitled, "Part B Applications with Incomplete Ground-water Monitoring Data.") Moreover, this expectation has been made known to facility owners through the Permit Applicant's Guidance Manual, May 1984 (See pps. 9-42 and 9-43).

implementing the less demanding monitoring protocol established in Part 265. Requiring these facilities to sample for Appendix VIII constituents is consistent with the language of §270.14(c)(4) and the general purposes of the Part 265 requirements.

One of the purposes of the Part 265 regulations was to prepare facilities for permitting. EPA assumed that data from detection and assessment monitoring under Part 265 would identify facilities that had contaminated ground water. These data would serve as the foundation for developing the ground-water information required to be submitted in Part B of the permit application [§270.14(c)]. Where an owner/operator has not complied with Part 265 monitoring requirements, however, EPA cannot determine whether the facility has contaminated ground water and hence cannot easily determine which ground-water monitoring program should be written into the facility's permit.

At this point in the program, allowing an applicant to comply with the literal requirements of Part 265, however, would cause unacceptable delays. An applicant that needed to "start-over" by installing or relocating monitoring wells could require as much as two and one-half years to complete the entire Part 265/Part 270 monitoring sequence (see timeline in Figure 5.2). Consequently, where EPA finds that an applicant has not instituted an adequate monitoring program under Part 265, the Agency will require owner/operators to condense the Part 265/Part 270 monitoring sequence in order to generate the ground-water data necessary for permitting (closure or post-closure) as quickly as possible. This condensed monitoring program is described in more detail in Chapter 5.

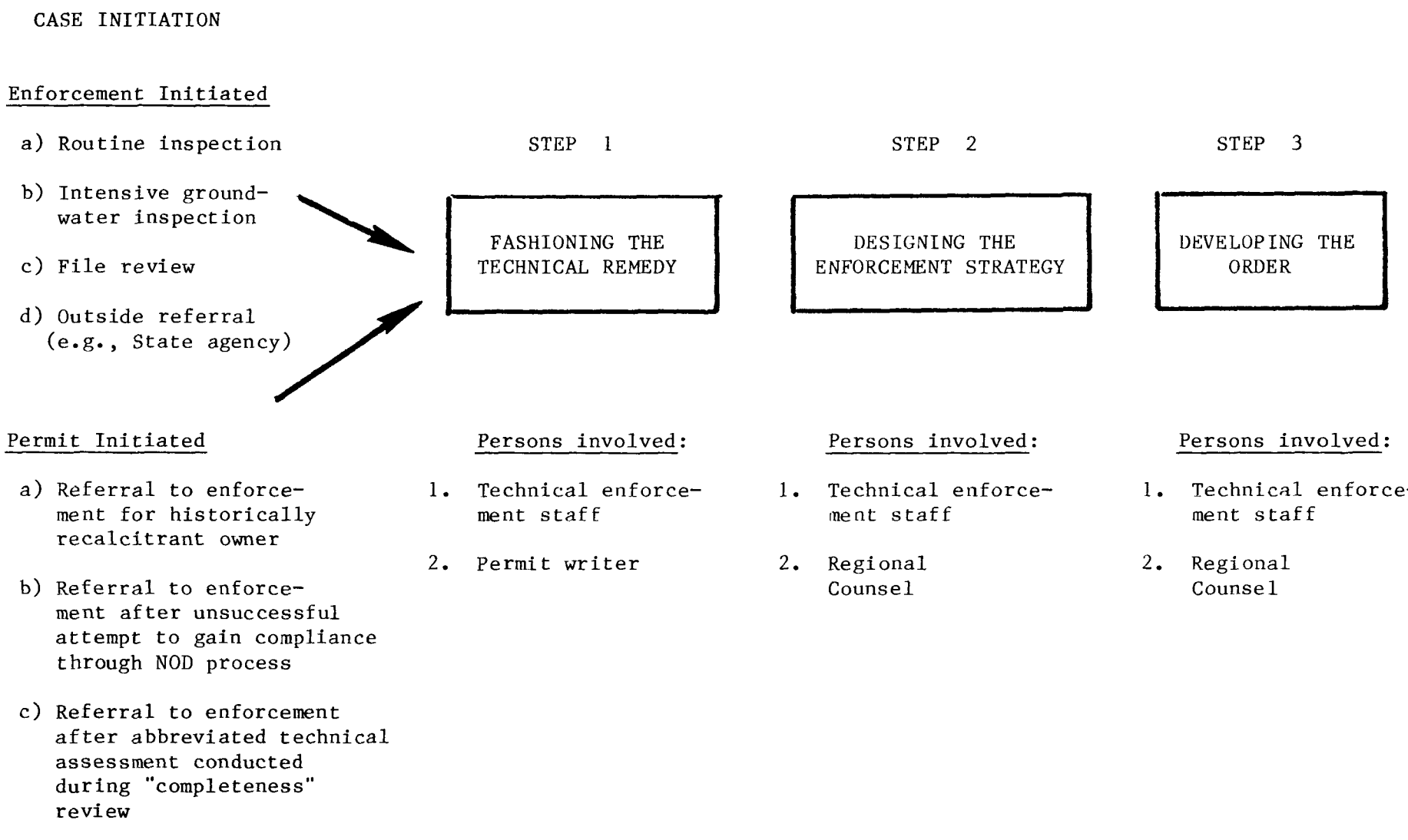
1.3 Overview of the Administrative Enforcement Process

The unique character of the transition period from interim status to permitting demands both increased coordination between permit writers and enforcement staff and a new conceptual approach to the enforcement process. The cornerstone of this new approach is the fashioning of technical groundwater remedies that satisfy the Agency's long term regulatory objectives.

To implement this approach, the Agency recommends a three-step enforcement process (see Figure 1.1). STEP 1 is to outline the technical remedy sought. In most cases, this step will require considerable planning and close coordination between the enforcement staff and the permitting staff. Enforcement officials and permit writers must work together to construct remedies that generate the information necessary for permitting while correcting deficiencies in the facility's interim status monitoring system.

STEP 2 is to develop an enforcement strategy to secure the desired remedy. Central to this effort is the selection of the order authority best suited to compel the remedy. If regulatory provisions have been violated, the enforcement staff should determine whether the desired remedy can be secured through a §3008(a) order citing these violations. (See Chapter 4 for a description of the order authorities and a discussion of their use.) If there is a question whether the entire remedy can be compelled using a §3008(a) order, enforcement staff should consider using a different enforcement authority (e.g., §3008(h), §3013, §7003 or CERCLA §106 orders), or a combination of authorities if necessary.

Figure 1.1 MODEL OF THE ENFORCEMENT PROCESS



STEP 3 of the administrative enforcement process is the development of the order. The order is the mechanism by which the Agency ensures that the desired remedy is actually executed by the facility. The goal of this step is to formalize exactly what actions the respondent must take in order to come into compliance. The more explicitly the Agency can express its expectations, the less opportunity there is for misunderstanding, wasted effort, and delay. As Chapter 6 explains, it is important to develop this specificity as early in the enforcement process as possible, although unless default is expected, it may not be necessary to express it in the compliance order accompanying the complaint. Chapter 6 provides guidance on how to write orders that are easily enforced and effective at achieving the remedy developed in STEP 1.

1.3.1 Case Initiation

Targeting cases for this enforcement process is the responsibility of both the enforcement staff and the permits staff.

In the enforcement program, cases generally evolve from the discovery of an inadequate interim status monitoring program. Inadequate systems may be identified as a result of routine facility inspections, more detailed ground-water inspections, or enforcement file reviews. Once a problem-facility is identified, enforcement staff should immediately contact the permits staff to determine the facility's status *vis a vis* the permitting program.

Early coordination with the permits staff is important for two reasons. First, the permits staff may have information on the site that could aid

in the development of an enforcement action against the facility. Where complete, for example, a Part B application can provide valuable information regarding a facility's wastes, the hydrogeology of a site, etc. Even where deficient, a Part B application can prove useful to enforcement officials by highlighting gaps in the facility owner's understanding of his/her site.

Second, coordination is necessary to avoid duplication of effort and to ensure that actions taken by the enforcement division are "consistent with" and "supportive of" the permitting process. Consistency is important so that the Agency presents a unified front to the facility. For example, before issuing a complaint the enforcement staff should know whether there is an outstanding Notice of Deficiency (NOD) compelling the same activities. "Supportive of permitting" implies consideration of the permit writer's informational needs when designing remedies. The permit writer must become involved in the enforcement process early on so that (s)he can ensure that his/her own permit-writing needs and the facility's future Part 264 monitoring needs are accurately represented and accounted for during the development of the remedy.

Cases may also enter the enforcement process via the permits staff. In fact, permit writers (by virtue of their Part B reviews) are often in the best position to identify problem cases. Permit writers are encouraged to refer cases to enforcement and use enforcement staff to facilitate the permit process.

Enforcement involvement may be appropriate, for example, when a facility has submitted a highly deficient Part B and past dealings with the company have

demonstrated that the owner/operator is unlikely to correct deficiencies in a prompt and forthright manner. In such cases, the permit writer should consider referring the case to enforcement immediately after issuing a general NOD that requires the submittal of the missing information within a very short period of time. Historically recalcitrant applicants should not be given long periods of time under the informal NOD process to generate data/information that they should have developed by the due date of their permit; rather they should be compelled to develop this information on an enforceable compliance schedule pursuant to an order. Likewise, if a permit writer has failed to make progress using the NOD mechanism, (s)he should work with the enforcement division to use formal mechanisms to compel compliance rather than continue to issue NODs.

Permit writers should also expand their initial "completeness" review of incoming Part Bs to include an abbreviated technical assessment of the ground-water monitoring portion of the application. While the permitting staff clearly does not have the resources to consider all Part B applications in full as they arrive, there are benefits in focusing briefly on the parts of each application that are particularly troublesome for the regulated community, are environmentally sensitive, or will require a long time for the facility to revise if the application is inadequate. Some aspects of an application are so central to the adequacy of the permit in general that it may be wise to perform an abbreviated assessment up front, rather than wait until the entire permit can be reviewed to discover and correct major deficiencies (e.g., the facility must install an entirely new well system before it can generate the data necessary for permitting).

The consequences of not identifying such deficiencies up front could be significant delays in the permitting process or a weakening of future enforcement cases because so much time has elapsed between the submittal of the application and the issuance of a complaint. If permit writers did conduct abbreviated reviews on the ground-water portion of incoming applications, they could refer cases with major deficiencies to the enforcement staff. Enforcement officials could then use the combined authorities of Parts 265 and 270 (or other authorities as necessary) to advance the facility to the point where the ground-water monitoring portion of the permit could be easily written when the facility's full application comes up for review.

1.3.2 Facility Management Planning

The enforcement process as described above demands a high level of coordination between the enforcement and permitting staffs. For any particular facility, the Agency and States must decide whether ground-water problems should be addressed through enforcement or through the permitting process. Facility Management Planning (FMP) is the mechanism that Regions and States should use to orchestrate this division of labor.

As described in the Revised FY85 and FY86 RCRA Implementation Plans (RIP), the draft National Permit Strategy (April 8, 1985), and the draft FMP guidance (July 12, 1985), Facility Management Planning is an Agency tool for coordinating effort and resources between the Regions/States and enforcement/permitting. Regions must develop a Facility Management Plan for all "environmentally significant" facilities according to a schedule laid out in the RIP. Each plan must identify: 1) what action(s) should

be taken at (or by) a facility; 2) what tool (e.g., order, NOD, post-closure permit) should be used to compel the action; and 3) who (State or Region, enforcement or permitting) has lead responsibility for ensuring that the action is completed.

Decisions regarding the above points evolve from a "facility analysis" conducted by representatives from Regional and State permitting and enforcement offices. During the facility analysis, the various representatives review the information available on a facility (e.g., Part B, inspection reports, etc.) and begin formulating a strategy for handling that facility in the short and long term. All strategies devised for individual facilities must be in accord with the RIP and other Agency policies.

Where actual or potential ground-water contamination exists, the strategy will generally include data or information gathering to support the long-term goal of either issuing the facility an operating permit or closing the facility and implementing corrective action for releases into ground water.

It is during the facility management planning process that enforcement officials and permit writers can initiate the type of coordination necessary to implement a range of options including this guidance. The review group, for example, may decide that eventually a facility should be issued a permit, but in the interim the Agency should use an order to compel the facility to investigate possible ground-water contamination and develop the appropriate permit application data and plans. At this point, the lead enforcement official should solicit the assistance of the permit

writer in formulating the technical remedy necessary to advance the facility toward permitting.

1.4 Relationship to "Late and Incomplete Part B Policy"

On September 9, 1983, Lee Thomas and Courtney Price issued a memorandum entitled, "Guidance on Developing Compliance Orders Under Section 3008 of the Resource Conservation and Recovery Act; Failure to Submit and Submittal of Incomplete Part B Permit Applications." This memo, commonly referred to as the "Late and Incomplete Part B Policy," affirmed the Agency's authority to take enforcement action for late and incomplete permit applications. It set out the procedures for addressing Part B violators and established a flat penalty amount that should be assessed in each case.

The Late and Incomplete Part B policy has been largely superseded by more recent policies and is further modified by this document. First, the "Enforcement Response Policy" (December 21, 1984) established that submittal of a late, incomplete or inadequate Part B is a Class I violation (see page 18). In addressing Class I violations the Enforcement Response Policy states that EPA and the States may issue warning letters prior to §3008(a) complaints if they wish but are not required to do so. Therefore, the directive in the Late and Incomplete Part B Policy that warning letters should always precede §3008(a) complaints is superseded.

Second, the Late and Incomplete Part B Policy established a flat penalty amount of $5,000.00. That requirement has since been superseded by the "RCRA Civil Penalty Policy" (May 8, 1984), which establishes a matrix that should be used to determine administrative penalty amounts. The matrix

is based on two factors, the degree of a handler's deviation from regulatory requirements and the potential for harm presented by the violation. Thus, penalty amounts should be determined individually for each Part B violator; the flat $5000.00 amount should not be applied automatically.

Finally, the Late and Incomplete Part B Policy envisioned issuing complaints that require, simply, the submittal of missing information. The Agency has since realized, however, that incomplete Part B's seldom represent mere oversights on the part of the applicant. More often, Part B's are incomplete or inadequate because the applicant failed to generate the required information and/or failed to comply with interim status requirements.

When issuing a complaint against a Part B violater, the Region or State should not merely require the respondent to "submit the information required in Section 'XYZ' of the regulations." Rather enforcement officials should determine the underlying reasons for the poor Part B and detail in the proposed order what needs to be done to ensure a proper submittal. Often the reasons behind an inadequate Part B are extremely complex, especially when the deficiencies involve ground-water monitoring. Enforcement officials can help ensure the adequacy of the next submittal by outlining in the order the nature and scope of the work to be performed. Further, Regions and States should generally assess penalties for all Part 270 violations and any contributing Part 265 violations.

1.5 Structure of this Document

This document is divided into six chapters. Chapter 2 presents an in depth discussion of the Part 265 and Part 264 ground-water monitoring regula-

tions. Chapter 3 builds upon this framework and explores the interrelationship between the two sets of regulations. These two chapters are designed to give enforcement officials the regulatory perspective they will need to design ground-water remedies that are consistent with and supportive of the permitting process.

Chapter 4 provides an overview of the enforcement tools available to secure desired remedies. It compares and contrasts the various order authorities and discusses some of the factors enforcement officials should consider when designing enforcement strategies.

Chapter 5 discusses how to fashion a technical remedy. The chapter uses a case-study approach to illustrate how enforcement officials can construct remedies that correct present violations while advancing a facility toward permitting. The chapter develops a model remedy for a typical "transition-period" facility and then describes how to use the combined authorities of Parts 265 and 270 to secure that remedy.

Finally, Chapter 6 discusses how to write an order to secure the desired remedy. The chapter emphasizes the importance of specificity in order writing and explores various strategies that may be followed in developing and issuing administrative orders. Appendix A includes a model order that illustrate some of the principles developed in this chapter.

The Agency has also prepared a draft document entitled, RCRA Ground-Water Monitoring Technical Enforcement Guidance (TEGD). This document addresses specific technical elements of ground-water monitoring system design. For example, it discusses the types of well construction methods

that the Agency considers acceptable for yielding representative water samples. The draft final version of the TEGD is dated August, 1985 and is available from the Office of Waste Programs Enforcement (OWPE).

CHAPTER 2

REGULATORY OVERVIEW

This chapter provides an overview of the Part 265 and Part 264 ground-water monitoring regulations. It attempts to abstract from the regulatory language and describe how the programs were intended to function in the real world. Enforcement and permitting officials are strongly encouraged to read this chapter even if they are familiar with the regulations.

The chapter discusses only the requirements that apply to hazardous waste management units. In accordance with the Solid and Hazardous Waste Amendments of 1984, permitted facilities may soon be required to monitor solid waste management units as well as hazardous waste management units. However, the specific requirements applicable to these units have not yet been established and will not necessarily be identical to the current Subpart F program detailed below.

2.1 Interim Status Ground-Water Monitoring - Part 265, Subpart F

The goal of the Part 265 regulations is to ensure that owners and operators of interim status landfills, land treatment facilities, and surface impoundments evaluate the impact of their facility on the uppermost aquifer underlying their site. To achieve this goal, the regulations establish a two-stage ground-water program designed to detect and characterize the migration of any wastes that escape from a facility.

The focus of both stages of the program is on evaluating the nature and extent of leakage, not on the removal or treatment of contamination should it

be detected. Removal and treatment of contamination deemed unacceptable must be dealt with through the exercise of the Agency's enforcement authorities under §3008(h) or §7003 of RCRA, §106 of CERCLA, or through the RCRA permitting process (See Chapter 4 on Order Authorities and Section 2.2.3 of this chapter).

2.1.1 Detection Monitoring

Detection monitoring, the first stage of interim status monitoring, is required at interim status land disposal facilities unless the owner/operator can demonstrate that there is a low potential for migration of hazardous waste from his/her facility to water supply wells or to surface water. The objective of detection monitoring is to determine whether a land disposal facility has leaked hazardous waste into an underlying aquifer in quantities sufficient to cause a significant change in ground-water quality.

To accomplish this objective, the regulations direct the owner/operator to install a monitoring network which includes wells located downgradient from the facility at the limit of the waste management area and wells located upgradient that are capable of providing samples representative of ground water unaffected by the facility. Although the regulations recognize that for a small site with the simplest hydrogeologic subsurface three downgradient wells and one upgradient well might suffice, the number, depth, and location of wells must ultimately be selected so that the network meets the regulatory performance standard of immediately detecting any

migration of statistically significant amounts of hazardous waste or hazardous waste constituents into the uppermost aquifer [§265.91(a)].

To determine whether leakage has occurred, the owner/operator must compare monitoring data collected downgradient from his/her facility to background water quality data established over an initial period of one year. The comparison is based on three sets of parameters designed to characterize water unaffected by the facility and to predict possible leakage of hazardous waste.

The first set of twenty parameters, listed in Part 265 Appendix III, defines the general suitability of the aquifer as a drinking water supply. These parameters were selected because they are recognized by the Safe Drinking Water Act as important to overall drinking water suitability.

The second set of parameters (chloride, iron, manganese, phenols, sodium, and sulfate) establish general ground-water quality and can be used to characterize the suitability of ground water for a variety of non-drinking uses. Information on these parameters is largely collected in anticipation of future confirmation of leakage. Should detailed assessment of ground water prove necessary, historical data on these major ion groups will help owner/operators predict the mobility of hazardous waste under actual site conditions.

The final set of parameters includes four measures selected as gross indicators of whether contamination of ground water has occurred. These four indicators - pH, specific conductance, total organic carbon (TOC), and

total organic halogen (TOX) - were chosen because of their widespread use, their well-established test procedures, and their general ability to reflect changes in the organic and inorganic composition of ground water. Faced with designing a monitoring program that would be responsive to a large undefined set of chemical compounds at unspecified concentrations, the Agency chose to rely on broad, surrogate measures that could predict whether significant contamination had occurred.

The regulations require the owner/operator to sample and analyze for all three sets of parameters quarterly for one year. Quarterly sampling is required so that seasonal effects will be incorporated into the characterization of background water quality. At the end of the first year, the owner/operator must establish background for each contamination indicator by averaging the quarterly measurements obtained for that parameter from the upgradient wells. These upgradient mean values are important because they establish the initial background concentrations to which all subsequent upgradient and downgradient concentrations will be compared.

After initial background is established, the owner/operator continues sampling on a less frequent schedule. The ground-water quality parameters (chloride, phenol, etc.) must be analyzed at least annually and the contamination indicators (TOX, pH, etc.), at least semi-annually.

At this point, however, detection monitoring begins to focus more specifically on the four contamination indicators. Each time a facility samples for a contamination indicator, the owner/operator must compare the values obtained from his/her upgradient and downgradient wells with the

mean values obtained for that parameter during the first year of background sampling. (Note that both upgradient data and downgradient data are compared to first year mean data derived from upgradient wells). The regulations specify that the facility owner should use a Student's t-test to the .01 level of significance when making comparisons [265.93(b)].

If a Student's t-test for an upgradient well shows a significant increase in the concentration or value of an indicator parameter (or any change in pH), it may mean that sources other than the facility are affecting ground water. Alternately, a change in upgradient water quality could be due to mounding of contaminated ground water beneath the facility or a change in hydraulic gradient such that originally upgradient wells are now downgradient relative to the facility. (This condition would be reflected in changes in ground-water elevation measurements over time.) Whatever the cause, a significant change in upgradient water quality should be investigated and noted in the company's annual report to the Agency [§265.94(a)(2)(ii)].

A Student's t-test for a downgradient well that shows an increase in an indicator parameter (or any change in pH), signals potential ground-water contamination and is the first indication that a facility may be leaking. If a statistically significant change is detected, the facility moves into the second phase of interim status monitoring, ground-water assessment.

2.1.2 Assessment Monitoring

Once a significant change in water quality triggers a facility into assessment, the owner/operator must notify the Agency and submit a proposed

program for determining whether hazardous wastes or their constituents have entered ground water and if so, their concentration, rate, and extent of migration [§265.93(d)(2)]. Because detection monitoring parameters are non-specific, a statistically significant change in one parameter may not necessarily represent migration of hazardous waste constituents into ground water. For example, pH could change independent of contamination if recharge patterns at the site shifted such that ground water infiltrated through formations with significant buffering capacity. The first step in assessment monitoring, therefore, is to determine whether hazardous waste constituents have indeed migrated into ground water.

In many cases, the detection monitoring network already installed at the site can be used for this purpose. Of course, use of the existing system assumes that the network is capable of detecting low part per billion levels of hazardous waste constituents (listed Appendix VII of Part 261 and in §§261.24 and 261.33) in the uppermost aquifer. If sampling reveals no contamination, the owner/operator may return to his original detection protocol or enter into a consent agreement with EPA to follow a revised protocol designed to avoid future false triggers. If, on the other hand, contamination is confirmed, the owner/operator must begin characterizing the rate and extent of migration.

Normally, assessment monitoring will require installation of additional well clusters located to define the vertical and horizontal extent of the plume. Unlike detection monitoring where wells would be placed more or less evenly along the downgradient border of the waste management

area, wells in assessment monitoring could be concentrated in one area of the site so as to track the migration of a localized discharge. In addition to direct sampling for hazardous waste constituents, the owner/operator may rely on indirect techniques, such as electrical resistivity or ground-penetrating radar, to help define the boundaries of a plume.

Based on these techniques, the owner/operator must submit to EPA (as soon as technically feasible), a written report assessing the quality of ground water at the facility (§265.93(d)(5)). After this initial assessment of ground-water contamination, the facility must continue assessment monitoring at least quarterly until the facility closes or is permitted. Additionally, the owner/operator must continue detection monitoring in any wells unaffected by the initial leak (i.e., wells away from the edge of the plume where no hazardous waste constituents have been detected or wells around other non-leaking units).

It is important to note that no direct regulatory consequences flow from a finding of contamination in assessment monitoring. The purpose of assessment monitoring is strictly to acquire information to support future decisions regarding the need for corrective action. The purpose does not include determinations of whether or not such facilities are environmentally acceptable. Strategies for cleaning up unacceptable contamination must be developed through the permitting process or through enforcement action under §3008(h), §7003, or under CERCLA §106.

2.2 Permit Regulations for Ground-water Monitoring - Part 264, Subpart F

The primary goal of Part 264 ground-water monitoring is to ensure that owners and operators of facilities handling hazardous waste detect any release of contamination into ground water and take corrective action when such contamination threatens human health or the environment. To achieve this goal, the regulations establish a three-stage program designed to detect, evaluate, and correct ground-water contamination arising from leaks or discharges from hazardous waste management facilities. The program is graduated so that the monitoring and clean-up responsibilities of the owner/operator expand as the impact of the facility on ground water becomes better understood.

2.2.1 Detection Monitoring

The first stage of the program, detection monitoring, is implemented at facilities where no hazardous constituents are known to have migrated from the facility to ground water. Applicants who are seeking permits for new facilities or for interim status facilities that have not triggered into assessment, would generally qualify for Part 264 detection monitoring (the latter assumes, of course, that the interim status monitoring network is adequate to detect contamination).

The actual monitoring requirements of Part 264 detection are similar to those already imposed under the interim status regulations. In the preamble to the regulations EPA expressed the expectation that properly designed interim status networks would be sufficient for most permit detection

systems. In Part 264 detection monitoring, however, the permittee routinely monitors for a select set of indicator parameters specified in the permit rather than for the four indicator parameters specified in the Part 265 regulations. Should the arrival of leachate from the facility be indicated by an increase (or pH decrease) of any of the parameters relative to background, the permittee must immediately sample for all constituents listed in Appendix VIII in order to determine the chemical composition of the leachate.[4] In addition, the owner/operator must submit, within 180 days, an engineering feasibility plan that outlines an approach for cleaning up ground water should clean up prove necessary [§264.98(h)(5)]. The facility in turn is obliged to move into the next phase of the Part 264 ground-water program - compliance monitoring.

2.2.2 Compliance Monitoring

The goal of compliance monitoring is to ensure that leakage of hazardous constituents (Part 261 Appendix VIII constituents) into ground water does not exceed acceptable levels. Through the permit, therefore, the Agency and the facility must specify what level of each constituent will be considered environmentally acceptable and then establish a program of routine monitoring to ensure that acceptable levels are not exceeded. If concentration limits

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[4] The Agency may use enforcement discretion so as not to require sampling for those substances that are unstable in ground water or for which there exists no EPA-approved test method. For a list of these substances see the August 16, 1984 memo from Courtney Price and Lee Thomas entitled, "Enforcing Ground-Water Monitoring Requirements in RCRA Part B Permit Applications." The Agency has also proposed to waive monitoring requirements for such substances (See 49 FR 38786, October 1, 1984).

are exceeded, the permittee must institute a corrective action program designed to bring the concentration levels back within acceptable limits.

The permit writer establishes the framework for a compliance monitoring program by incorporating a ground-water protection standard into the permit. The standard consists of four elements, each of which must be specified in the permit.

The first element of the standard is a listing of all Appendix VIII hazardous constituents present in ground water that could reasonably have been derived from the facility. The burden of demonstrating that a particular Appendix VIII constituent could not reasonably be derived from a facility, lies with the owner/operator. Claims of exclusion must be based on a detailed chemical analysis of the facility's waste and must consider possible chemical reactions that could occur in the facility or during the migration of leachate into ground water. An exclusion is also available for an individual constituent if the owner/operator can demonstrate that it is incapable of posing a substantial present or potential hazard to human health or the environment. Given this standard of proof, however, exclusions will be granted rarely; the ground-water protection standard of most facilities, therefore, will include all Appendix VIII constituents detected in ground water.

The basis for identifying the Appendix VIII constituents present in ground water will vary depending on the status of the facility at the time of establishing the protection standard. Facilities that are operating under detection monitoring permits will have identified the Appendix VIII consti-

tuents present in ground water as part of their detection monitoring responsibilities [see §264.98(h)(2)]. Facilities that have not yet received permits and are operating under Part 265 assessment monitoring, however, may have to perform additional sampling because assessment monitoring requires the determination of Appendix VII substances rather than the full complement of constituents listed in Appendix VIII. (Appendix VII is but a subset of Appendix VIII - see section 3.3 for further explanation of this point). Consequently, the facility owner in Part 265 assessment monitoring will have to undertake additional sampling and analysis before the facility can be permitted. [Note: the permit application regulations (Part 270) require facilities to characterize plumes with respect to Appendix VIII constituents (see §270.14(c)(4))].

The second element of the ground-water protection standard is the specification of a concentration limit for each hazardous constituent listed in the facility permit. Where possible, concentration limits must be based on well established numerical concentration limits for specific constituents. Where established standards are not available, the permit writer must set concentration limits so as to prevent degradation of water quality unless the owner/operator can demonstrate that a higher limit will not adversely affect public health or the environment. Following this approach, concentration limits must be set at either:

1) the maximum concentration limit for drinking water established by the National Interim Primary Drinking Water Regulations (where applicable);

2) the background level of the constituent in ground water; or

3) an alternate concentration limit (ACL) if the owner/operator can demonstrate that a higher concentration will not pose a substantial present or potential hazard to human health or the environment (§264.94).

The third and fourth elements of the ground-water protection standard are the point of compliance and the compliance period. The compliance point is the location at which the ground-water protection standard applies and hence is the point where monitoring must occur. The regulations specify that the point of compliance is the vertical surface located at the downgradient limit of the waste management area (§264.95). The compliance period is the period during which the ground-water protection standard applies. This period is equal to the active life of the facility plus the closure period [§264.96].

After the ground-water protection standard is established, the permittee must monitor ground water to ensure that the facility continues to comply with its protection standard. If properly designed and constructed, the monitoring network established for detection monitoring should be adequate for this purpose. In addition, the permittee must sample annually for Appendix VIII constituents to detect any additional substances that may have entered ground water. Should sampling reveal a new constituent, the permit writer must amend the protection standard to include a concentration limit for the new constituent.

2.2.3 Corrective Action

If compliance monitoring reveals that a facility is exceeding its ground-water protection standard (i.e., the concentration of a hazardous

constituent in ground water exceeds the maximum limit established in the permit), the facility must institute a corrective action program. The goal of corrective action is to bring the facility back into compliance with its protection standard. To achieve this goal, the facility must develop a plan for removing the hazardous constituents or for treating the constituents in place [§264.99(i)(2)]. If approved by the Agency, the permit writer will incorporate this plan into the facility permit.

The permit writer must also include in the permit a program of ground-water monitoring adequate to demonstrate the effectiveness of the corrective action measures [§264.100(d)]. At the limit of the waste management area, this program will be essentially the same as the compliance monitoring program although permit writers may want to increase the number of wells and the frequency of monitoring at or near the compliance point where the plume appears to be concentrated. Also, owner/operators will be required to install additional monitoring wells near the downgradient edge of the plume so that the Agency can monitor the effectiveness of the corrective action program.

The permittee must implement corrective action measures until compliance with the ground-water protection standard is achieved. Once contamination has been reduced below the concentration limit set in the permit, the facility may discontinue corrective action measures and corrective action monitoring, and return to the monitoring schedule established for compliance monitoring. If compliance is not achieved before the end of the compliance period

specified in the permit, the permittee must continue corrective action until monitoring shows that the ground-water protection standard has not been exceeded for three years [§264.100(f)].

2.3 Permit Application Regulations - Part 270

Part 270 of the regulations specifies the information an applicant must submit to the Agency when applying for a permit. The information requirements related to ground-water monitoring can be organized into two basic groups. The first group, outlined in §270.14(c), establishes the nature of the facility's impact on ground water, as well as the hydrogeologic characteristics of the site's subsurface and the extent of the waste management area. The second group includes the information necessary to establish one of the three Part 264 ground-water monitoring and response programs (detection monitoring, compliance monitoring, and/or corrective action).

2.3.1 Information Requirements of §270.14(c)

Section 270.14(c) includes four basic information requirements. First, applicants must present the data collected during interim status monitoring (where applicable). If the facility has implemented a satisfactory monitoring system under interim status, these data should provide information useful for determining whether hazardous constituents have entered ground water. The Permit Applicant's Guidance Manual for Hazardous Waste Land Treatment, Storage, and Disposal Facilities (May, 1984) states that this provision requires submittal of background information to support

these data as well as the data themselves. For example, the Applicant's manual instructs owner/operators to submit:

- a map showing the location of upgradient and downgradient wells;
- a copy of the facility's sample and analysis plan;
- a description of the statistical procedure used in processing the data submitted;
- copies of water analysis results; and
- a description of the design and construction of each well.

Second, the applicant must identify the uppermost aquifer and hydraulically interconnected aquifers beneath the facility property. The application must indicate ground-water flow directions and provide the basis for the aquifer identification (i.e., a report written by a qualified hydrogeologist on the hydrogeologic characteristics of the facility property supported by at least the well drilling logs and available professional literature). This information is needed to evaluate the adequacy of the ground-water monitoring system that the applicant proposes to operate after the permit is issued. (Readers are referred to the Permit Applicant's Manual for a discussion of what constitutes an adequate hydrogeologic investigation; additional guidance will be provided by the final TEGD).

Third, §270.14(c)(3) requires the applicant to delineate the waste management area, the property boundary, and the proposed point of compliance. This information should be transposed onto a topographic map along with, to the extent possible, the designation of the uppermost and any interrelated aquifers.

Finally, §270.14(c)(4) requires applicants to describe any plume of contamination that has entered ground water by:

- o delineating the extent of the plume; and
- o identifying the concentration of each Appendix VIII constituent throughout the plume or identifying the maximum concentrations of each Appendix VIII constituent in the plume.

This requirement applies to the following three categories of facilities:

1. Facilities where no interim status monitoring data are available (e.g., waste piles, facilities that wrongly claimed a waiver from interim status ground-water monitoring requirements);
2. Facilities whose interim status data indicate contamination; and
3. Facilities whose Part 265 detection monitoring system is inadequate to determine whether or not a plume of contamination exists.

As the Permit Applicant's Guide indicates (page 9-42), the permit writer will evaluate the ability of the facility's well network and sample and analysis plan to determine the presence of a plume. If EPA determines that the interim status monitoring program was inadequate to detect contamination, the applicant will be instructed to provide the information required by §270.14(c)(4).

2.3.2 Information Requirements for Appropriate Part 264 Ground-water System

Part 270 also requires permit applicants to submit information sufficient to establish the appropriate ground-water monitoring program under Part 264. The information requirements relevant to any particular facility depend on the

status of that facility at the time of permitting. If monitoring conducted pursuant to Part 265 and Section 270.14(c)(4) has not revealed contamination, the applicant must submit the information, data, and analysis necessary to implement a detection monitoring program. If monitoring has revealed the presence of hazardous constituents in ground water at the point of compliance, the applicant must outline a program of compliance monitoring and submit a study that estimates the engineering feasibility of various forms of corrective action [§270.14(c)(7)]. Where the concentration of a hazardous constituent exceeds background or an alternate concentration level proposed by the applicant, (s)he must instead submit a detailed plan for corrective action and a description of the monitoring program intended to demonstrate the adequacy of the corrective measures [§270.14(c)(8)]. Detail concerning the specific information required to support each type of monitoring program is provided in the regulations and expanded upon in the Permit Applicant's Guidance Manual §§ 9.6 - 9.8.

CHAPTER 3

REGULATORY COMPARISONS

In order to devise enforcement strategies that are consistent with and supportive of the permitting process, it is important to have an understanding of how the Parts 265 and 264 ground-water monitoring regulations interrelate. As mentioned previously, the Agency envisioned the interim status period as a time in which to develop, among other things, the information necessary to support permitting. Indeed, one of the overall goals of interim status monitoring was to generate the data necessary to decide whether the facility permit should include a detection monitoring program, a compliance monitoring program, or a program for corrective action.

In short, the Agency envisioned a smooth transition from interim status detection monitoring, through assessment, to final permitting. A facility would proceed from one phase of monitoring to the next by building upon the monitoring system implemented during the previous stage. While interim status monitoring focused on a smaller number of constituents in order to limit the routine monitoring obligations of the owner/operator, the Agency never considered the physical well networks of the Part 265 and Part 264 programs fundamentally different. Sampling protocols and schedules would change to be consistent with the new objectives of each monitoring phase, but the physical well network (if properly designed) could serve throughout the life of a facility. A Part 265 detection system, for example, may need to be expanded to meet the needs of compliance monitoring, but with proper foresight, the existing wells need not be replaced.

Unfortunately, certain interim status monitoring systems are insufficient in quality and breadth to meet the Part 265 standards. Of those that meet the minimum standards, few have been designed in expectation of the facility's future monitoring obligations. As a result, facilities that should be close to meeting their Part 264 ground-water obligations, are in fact not prepared for the permitting process.

If enforcement officials are going to help bridge this gap, they must have a thorough understanding of exactly how the Part 265 and Part 264 regulations interrelate. To aid officials in this effort, this chapter will outline the major similarities and differences between the requirements of three ground-water monitoring programs: Part 265 detection vs. Part 264 detection; Parts 264/265 detection vs. compliance monitoring; and Part 265 assessment monitoring vs. plume characterization activities conducted pursuant to §270.14(c)(4).

3.1 Part 265 vs. Part 264 Detection Monitoring

3.1.1 Well Placement

For all practical purposes, the requirements governing well placement are the same for both Part 265 and Part 264 detection monitoring. Whereas the regulatory language differs slightly, a network designed to meet the Part 265 standard should be substantially the same (in terms of well locations and depths) as one designed to meet the Part 264 standard.

Both programs include a performance standard for background well placement that requires a sufficient number of wells, installed at appropriate

locations and depths, to yield ground-water samples that are: 1) representative of the background water quality in the uppermost aquifer; and 2) unaffected by leakage from the facility [Compare §265.91(a)(1) with §264.97(a)(1) and §264.97(a)(2)].

Both programs also include similar language regarding the placement of downgradient wells, although the Part 265 regulations require placement at the "limit of the waste management area," whereas the Part 264 regulations require placement at the "point of compliance" [cf., 265.91(a)(2) and 264.97(a)(2)]. While worded differently, the physical well location dictated by both programs is, by definition, essentially the same. The regulations define the "waste management area" as "the limit projected in the horizontal plane of the area on which waste will be placed during the active life of a regulated unit" [§264.95(b)].[5] Where there is more than one unit at a facility, the waste management area is described by an imaginary line circumscribing the various units. Hence, wells in Part 265 detection monitoring must be placed at the edge of the waste management area.

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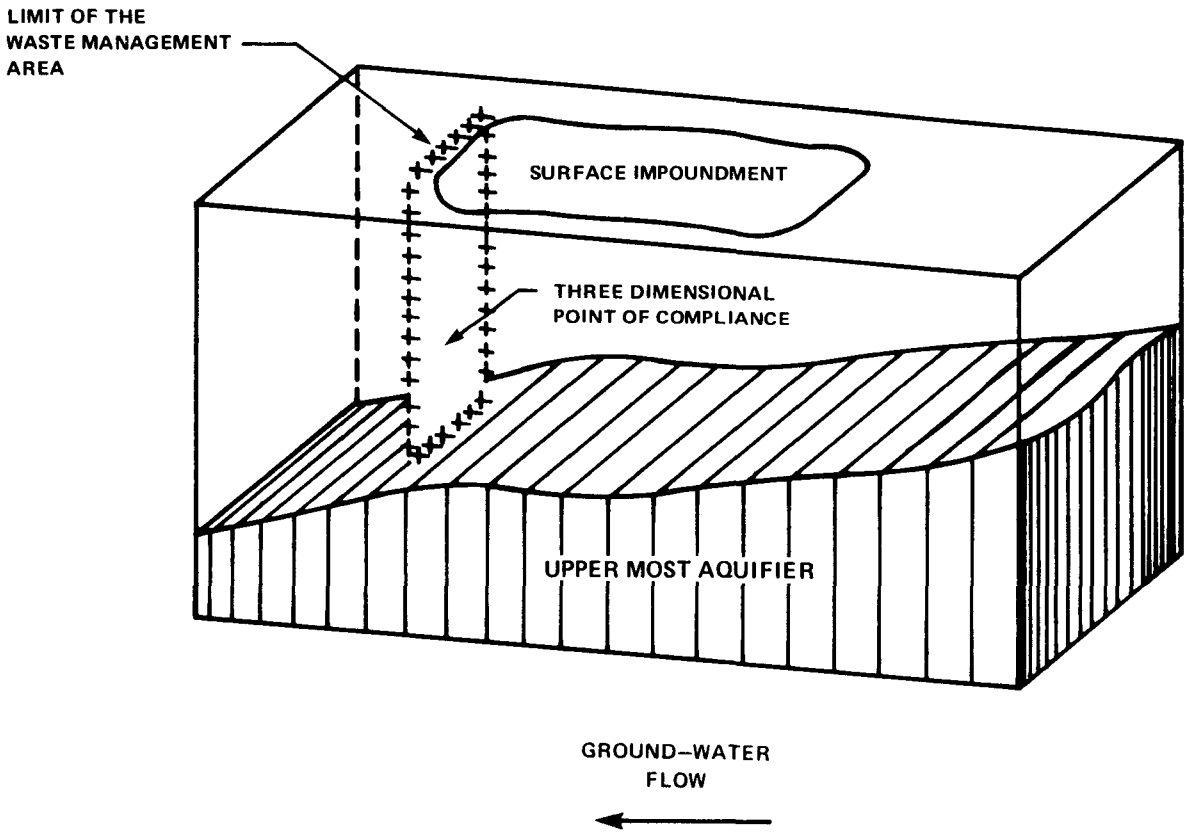
[5] The Permit Applicant's Manual further qualifies this definition by noting that for Part 265 systems, EPA will evaluate the areal extent of the waste management area at an expanding facility against the regulatory mandate to choose well locations so as "to immediately detect" the migration of hazardous waste into the uppermost aquifer. For permit applications, EPA will evaluate the proposed waste management area against the policy of designing monitoring programs so as to give an early warning of the release of contaminants. In either case, EPA does not recommend that facility owners propose a waste management area whose limit is geographically remote from the active waste handling zone. Rather, monitoring wells should be closely associated with the active zone even if this means redefining the waste management area as a facility expands.

Wells in Part 264 detection must also be placed at the edge of the waste management area because the point of compliance is, by definition, the edge of the waste management area projected downward into the uppermost aquifer [see §264.95(a)]. The point of compliance is, therefore, the limit of the waste management area described in three dimensional space (See Figure 3.1). Both regulations mandate, consequently, that wells are located along the same thin land surface. Parts 265 and 264 similarly require well spacings and depths capable of detecting statistically significant contamination in the uppermost aquifer.

Figure 3.1 RELATIONSHIP OF THE WASTE MANAGEMENT AREA TO THE POINT OF COMPLIANCE



3.1.2 Indicator Parameters

The concept of sampling for parameters designed "to indicate contamination" is the same for both Parts 265 and 264 detection monitoring. The Part 265 regulations mandate the use of four specific indicators for all facilities, whereas the Part 264 regulations require the permit writer to specify a set of site-specific indicator parameters in each facility permit. The greater latitude and scope afforded by the Part 264 regulations allows the permit writer to design the detection program around the particulars of a specific facility. Rather than rely on broad, generic measures such as TOC, the permit writer can compel sampling for specific constituents known to be in the facility's waste. As a result, a Part 264 detection system can be designed to be more sensitive than the Part 265 system specified in the interim status regulations.

3.1.3 Sampling Frequency

Both the Part 265 and Part 264 regulations require quarterly sampling for one year to establish background, and at least semi-annual sampling thereafter.

3.1.4 Appropriate Sampling Techniques

The choice of the sampling device and the appropriateness of the materials used in the device are dictated by the needs of the most sensitive constituent of interest. In general, the most sensitive constituents will be volatile

organics because as a class, volatile organics are highly susceptible to degassing and chemical interference with sampling-device materials (e.g., silicon tubing). For most monitoring applications, therefore, the sampling device will be chosen to meet the needs of volatile organics.

Given that the Part 265 detection program necessarily includes a volatile organic parameter, TOX, that can be measured reliably at the 5 ppb level (see Method 9020 in "Test Methods for Evaluating Solid Waste, SW-846), sample device selection for interim status monitoring will always be dictated by the needs of volatile organics. Therefore, if a Part 264 detection program includes sampling for any volatile organic, then the sampling devices and materials appropriate for each program would be the same. Considering that 264 detection systems almost always contain at least one volatile organic indicator, the sampling requirements of both 265 and 264 detection monitoring will be essentially equivalent in most cases.

It is conceivable, however, that a sampling device appropriate for Part 264 sampling would NOT be appropriate for Part 265 detection if the permit writer did not require sampling for any volatile organics (e.g., if the facility were a monofill of hexavalent chromium and the permit writer elected chromium as the only Part 264 detection parameter). Such a facility could use a sampling device normally inappropriate for measuring volatile organics. If, however, a chromium waste facility ever detected contamination, the regulations require the owner/operator to sample immediately for the contituents listed in Appendix VIII (including many volatile organics). The

facility owner, therefore, would have to change sampling devices to ensure that he acquired representative samples.

Recognizing this fact, it may be in the best interest of the owner/operator to consider his/her long-term monitoring needs when purchasing sampling equipment. To the extent that facility owners purchase and use equipment for detection monitoring that will still be suitable should leakage occur, the sampling mechanisms appropriate for 265 and 264 detection monitoring once again converge.

3.1.5 Statistical Comparisons

Both the Parts 265 and 264 detection monitoring regulations require the owner/operator to determine whether there has been a statistically significant increase over background for any indicator parameter specified in the program (or decrease for pH).

The statistics used to make this determination, however, vary between the programs in two important ways. First, the Part 264 detection program requires the owner/operator to use a specific Student's t-test when defining significance (the Cochran's Approximation to the Behrens Fisher Students t-test), unless he can defend another statistical technique as substantially equivalent. The Part 265 program, on the other hand, makes no allowance for an alternate statistical technique, but the regulations do not specify a particular variant of the Student's t-test; any Student's t-test is acceptable.

Second, the Part 264 detection regulations require the test to be applied to the .05 level of significance, while the 265 regulations specify a signifi-

cance level of .01. The level of significance sets the balance between the chances of the test falsely detecting contamination ("false positive") and the test failing to identify contamination that has occurred.[6] By raising the level of significance for the Part 264 standards, the Agency achieved greater assurance that the test would not fail to detect actual contamination. During the interim status period, the Agency was willing to reduce the chances of "false positives" by accepting a slightly higher probability of failing to detect leakage. This balance was acceptable for interim status because the Agency knew it would have another opportunity to investigate possible leakage during the permit application process. For the permit regulations, however, the Agency decided that a lower level of significance would unduly compromise the ability of the test to detect contamination.

3.2 Part 264 Detection Monitoring vs. Part 264 Compliance Monitoring

3.2.1 Well Placement and Network Design

Well placements for compliance monitoring more closely resemble detection monitoring networks than they do assessment networks. One should not assume that network configurations for compliance monitoring will resemble configurations suitable for Part 265 assessment monitoring simply because both programs represent a second phase of monitoring after detection monitoring. In fact, in some cases the network installed for detection monitoring will

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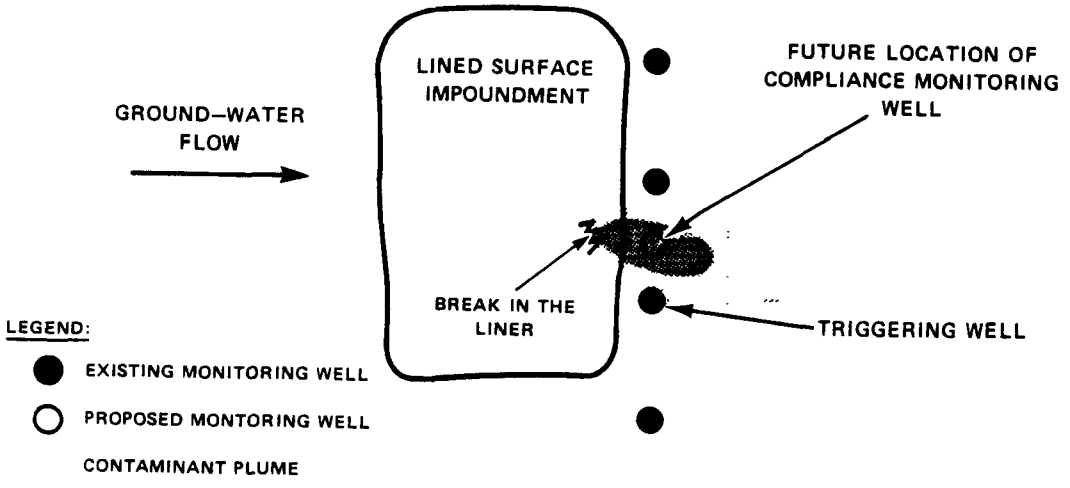
[6] Readers should note that this discussion pertains to the false positive rate caused by the statistical test alone. Many other factors, such as insufficient number of background wells, can cause a facility to trigger under detection monitoring when contamination has not actually occurred. In fact, many "false positives" are not a function of statistics, but are a function of such things as well location, sampling, and chemical analysis.

become the compliance monitoring network; all that will change is the sampling protocol and the objective of the monitoring program.

Given that compliance monitoring is meant to evaluate contamination rather than just detect it, there is a strong possibility that existing detection networks may have to be expanded to meet the broader objectives of compliance monitoring. The more complicated statistical techniques used to evaluate monitoring data during compliance monitoring, for example, may require a greater number of background wells than the statistical approach used during detection monitoring. Likewise, the permit writer may want to require additional downgradient wells in the immediate vicinity of those wells where contamination has been detected.

Additional wells are generally most appropriate when contamination has been detected in only one or two monitoring wells, indicating a localized leak. With localized leaks, only a limited amount of dispersion can occur before the plume passes the point of compliance (see Figure 3.2). As a result, more wells may be necessary to ensure that measurements of contami-

Figure 3.2



nation represent the high concentrations characteristic of the plume's center, rather than the lower concentrations normally found in the plume's periphery.

In short, in some circumstances an existing detection system may have to be expanded under compliance monitoring, but the general well configurations for detection monitoring and compliance monitoring are the same.

3.2.2 Establishing Background Concentrations

The regulations specify that background concentrations for Part 265 and Part 264 detection indicator parameters must be based on quarterly samples for one year. Under compliance monitoring, however, the regulations grant the permit writer leeway on how to establish background. (Recall that background values are very important in compliance monitoring because in many instances, these background values will be incorporated into the ground-water protection standard as "concentration limits.")

The permit writer has two options for establishing background values for compliance monitoring constituents. The permit writer may establish concentration limits based on the mean of pooled background data available at the time of permitting. To ensure that sufficient data are available for this purpose, the permit writer may require the applicant to undertake an accelerated program of background sampling prior to permitting.

Alternately, if there is a high temporal correlation between up- and downgradient concentrations, the permit writer may specify that background values be established by sampling upgradient wells each time ground water is sampled at the point of compliance. With this approach, background concentra-

tions are not established by averaging values obtained over time; rather, background values are established anew after each sampling event.

3.2.3 Sampling Frequency

Since hazardous constituents are already present in ground water when compliance monitoring begins, the regulations require a more aggressive sampling schedule for compliance monitoring than for detection monitoring. Under detection monitoring, the regulations state that sampling for indicator parameters should occur at least twice a year (once background is established) [§265.92(d)(2)]. By contrast, the compliance monitoring regulations require routine sampling of the hazardous constituents listed in the facility's protection standard at least quarterly.

3.2.4 Statistical Comparisons

Whereas the regulations specify the use of a specific t-test protocol when evaluating monitoring data obtained during detection monitoring, they do not detail specific procedures for use during compliance monitoring. The compliance monitoring regulations require that the statistical procedures used be appropriate for the distribution of data encountered and provide a reasonable balance between the probability of falsely identifying and failing to identify violations of the ground-water protection standard.

Moreover, unlike detection monitoring, the compliance monitoring regulations do not establish a particular level of significance for use when making comparisons. The high number of comparisons likely in most compliance monitoring programs will increase the probability of false

positives; therefore, permit writers are granted the latitude to choose a level of significance that will strike an appropriate balance between the probability of false positives and false negatives.

3.3 Part 265 Assessment Monitoring vs. §270.14(c)(4) Plume Characterization

Both Part 265 assessment monitoring and §270.14(c)(4) require facility owners to assess any plume of contamination that has entered ground water. The programs differ, however, in two important ways.

First, the Part 265 assessment program applies only to facilities that have detected the existence of a plume through Part 265 ground-water monitoring. The §270.14(c)(4) requirements, on the other hand, apply to any facility that has not demonstrated the absence of contamination through proper Part 265 monitoring.

Second, Part 265 assessment requires monitoring for hazardous wastes or "hazardous waste constituents" [see §265.93(d)(4)], whereas §270.14(c)(4) requires sampling for "hazardous constituents." "Hazardous constituents" are those substances listed in Appendix VIII of Part 261. "Hazardous waste constituents," as defined in §260.10, are the constituents that provided the basis for listing each of the hazardous wastes identified in Part 261 Subpart D, or a constituent listed in Table 1 of §261.24 (constituents with National Interim Drinking Water Standards under the Safe Drinking Water Act).

Appendix VII identifies the specific constituent(s) responsible for the listing of wastes from the non-specific sources in §261.31 as well as

from the specific sources contained in §261.32. In the case of any of the discarded commercial chemical products, off-specification products, and spill residues listed in §261.33, the chemical product itself is considered the constituent responsible for the listing of the substance in Part 261.

Interim status assessment monitoring, therefore, requires the owner/operator to sample for any Appendix VII constituent, any substance listed in §261.33, or any substance listed in §261.24 that is in the facility's waste. Section 270.14(c)(4), on the other hand, requires sampling for the full complement of Appendix VIII constituents.

This difference between the two programs is significant. Part 265's reliance on "hazardous waste constituents" rather than on Appendix VIII constituents could mean that certain constituents in a facility's waste would not be included in a Part 265 assessment monitoring program.

A number of factors may be responsible for the exclusion of certain constituents. First, the constituents identified in Appendix VII as the basis for listing individual wastes in Part 261, are not necessarily a complete list of all hazardous constituents contained in each waste. In developing Appendix VII, EPA did not attempt to conduct an exhaustive analysis of all constituents in the waste that could have provided a basis for the listing (§261.11 provides the criteria the Administrator must use when listing a waste). Rather, the Agency identified a few of the more commonly known constituents in each waste that could pose a substantial present or potential hazard to human health or the environment.

Second, Appendix VII only applies to listed wastes; it does not address hazardous constituents that may be present in wastes deemed hazardous because they exhibit one of the characteristics in Part 261. Table 1 of §261.24 addresses wastes exhibiting the characteristic of E.P. toxicity, but "hazardous waste constituents" do not include non-listed wastes deemed hazardous because of corrosivity, reactivity, or ignitability. Moreover, Appendix VII and Table 1 of §261.24 were not developed to address the constituents that may be formed when various wastes are mixed in a regulated unit, or when wastes react with constituents in the soil. As a result, a Part 265 assessment program could conceivably fail to include a consitituent of concern at a particular facility. It must be recalled, however, that the interim status regulations were designed to be self-implementing, not exhaustive. [7]

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[7] Chapter 4 explores the various enforcement authorities available to compel sampling for Appendix VIII constituents at interim status land disposal facilities if such sampling appears necessary. Depending on the circumstances, a §3008(a) order enforcing §270.14 (c)(4), a §3013 order or a §3008(h) may be used (See section 4.1.1 for further explanation).

CHAPTER 4

OVERVIEW OF ORDER AUTHORITIES

There are a variety of order authorities available to correct ground-water problems at RCRA hazardous waste facilities. Section 3008(a) of RCRA provides for the issuance of orders and for the commencement of civil suits when any requirement of Subtitle C is violated. RCRA also establishes enforcement authorities under Sections 3004(v), 3008(h), 3013, and 7003. Any of these authorities may be used, in certain circumstances, to address ground-water problems. In addition, the enforcement authority in §106 of CERCLA may be available in many cases.[8]

While there will undoubtedly be instances where it is most appropriate to file a civil suit under §3008(a), §3008(h), or §7003, or to initiate criminal proceedings under §§3008(d) and (e), there are three order authorities that should prove most useful in addressing inadequate ground-water monitoring programs:

- §3008(a) orders seeking penalties and/or injunctive relief for violations of Part 265 Subpart F and Part 270;
- §3008(h) orders seeking the investigation and implementation of corrective action for releases of hazardous waste or hazardous constituents; and
- §3013 orders seeking monitoring, investigations, analyses, and reporting by facilities that the Administrator has determined may present a substantial hazard to human health or the environment.

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[8] For further information on the applicability and scope of CERCLA 106 orders, see the September 8, 1984 memo on the "Use and Issuance of Administrative Orders under §106(a) of CERCLA" from Lee Thomas and Courtney Price.

This chapter will compare these three order authorities and will describe some of the factors that enforcement officials should consider when selecting which authority(ies) to use to compel a specific remedy.

4.1 Comparison of §3008(a), §3008(h), and §3013 Orders

The table on the two following pages presents a comparison of §3008(a), §3008(h), and §3013 orders with respect to the types of actions that the orders may compel, the types of situations that may trigger the issuance of an order, the burden of proof the Agency must satisfy, whether there are formal administrative proceedings that must be followed, and any special features of the authority (e.g., the ability to assess penalties). The section of the chart dealing with §3008(a) orders is divided into the following three segments:

- o §3008(a) enforcing Part 265 detection monitoring
- o §3008(a) enforcing Part 265 assessment monitoring
- o §3008(a) enforcing Part 270 requirements.

4.1.1 Actions the Orders May Require

As shown in Table 4.1, a §3008(a) order enforcing Parts 265 and 270 can be used to require the following general categories of ground-water-related activities:

- o a thorough hydrogeologic characterization of the site;
- o design and installation of a well network capable of immediately detecting contamination from the facility;
- o specification of well drilling and development methods as well as casing materials;

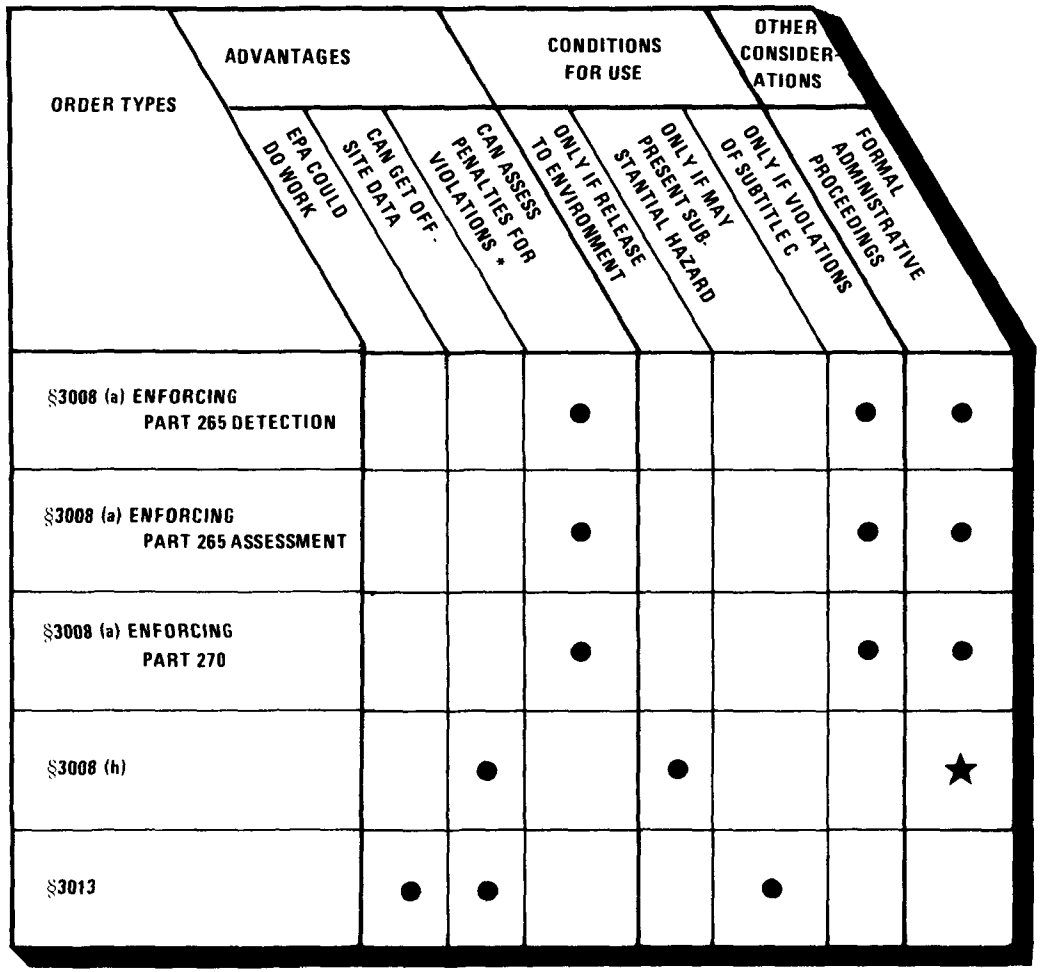
FIGURE 4.1 COMPARISON OF ORDER AUTHORITIES

ORDER TYPES	POSSIBLE TECHNICAL ELEMENTS OF ORDER																
	HYDROGEOLOGIC ASSESSMENT	WELL PLACEMENT TO DETECT PLUME	WELL PLACEMENT TO ASSESS PLUME	ABILITY TO SPECIFY CASING MATERIALS, DRILLING METHODS, ETC.	SAMPLING FOR 32 PARAMETERS*	SAMPLING FOR SUBSTANCES IN APPENDIX VII & 261.24 & .33	SAMPLING FOR SUBSTANCES IN APPENDIX VIII	SAMPLING FOR SUBSTANCES ADDITIONAL	SAMPLING FOR GROUND WATER OTHER THAN	SAMPLING IN MEDIA FOR CORRECTIVE ACTION	DESIGN OF PLAN	CLEAN UP OF GROUND WATER	CLEAN UP OF OTHER MEDIA	SAMPLING AT SOLID WASTE MGMT. UNITS	DESIGN OF PART 264 GWM PROGRAM	CLEAN UP OF GW BEYOND PROPERTY BOUNDARY	
§3008 (a) ENFORCING PART 265 DETECTION	●	●		●	●												
§3008 (a) ENFORCING PART 265 ASSESSMENT	●		●	●		●											
§3008 (a) ENFORCING PART 270	●	●	●	●	●	●	●				●					●	
§3008 (h)	●	●	●	●	●	●	●	●	●	●	●	●	●	●			●
§3013	●	●	●	●	●	●	●	●	●	●					●		

NOTES:

* PARAMETER LIST INCLUDES pH, SPECIFIC CONDUCTANCE, TOC, TOX, CHLORIDE, IRON, MANGANESE, SODIUM, PHENOLS, SULFATES, AND SUBSTANCES LISTED IN APPENDIX III OF PART 265.

FIGURE 4.1 COMPARISON OF ORDER AUTHORITIES (Continued)



* THE AGENCY HAS NOT YET ESTABLISHED THE PROCEEDINGS TO BE FOLLOWED WHEN USING §3008(h) ORDERS

NOTES:

* WHEREAS § 3008(a) IS THE ONLY AUTHORITY THAT PROVIDES FOR THE ASSESSMENT OF PENALTIES FOR REGULATORY VIOLATIONS, §3008(h) AND 3013 [AS WELL AS §3008(a)] PROVIDE FOR THE ASSESSMENT OF PENALTIES IF THE TERMS OF AN ORDER ARE VIOLATED.

- o sampling for any parameter listed in Appendix VII or VIII of Part 261 or Appendix III of Part 265, or specified in §265.92 (chloride, iron, manganese, phenols, sodium, sulphate, pH, specific conductance, total organic carbon, and total organic halogen); and

- o a design of the ground-water monitoring system that would be operated after the permit is issued.

Section 3008(h) and §3013 orders can in many cases be used to obtain the same baseline injunctive relief available under §3008(a). More significantly, orders issued under §3008(h) and §3013 may be used to address contamination of media other than ground water and releases from solid waste management units. Further, §3008(h) can be used to go beyond the investigation and monitoring stage to require actual clean up of releases into the environment.

One caution with respect to §3013 and §3008(h) orders is that they may compel only those actions that are needed to investigate or address a release of hazardous waste or hazardous constituents [§3008(h)] or a substantial hazard [§3013]. While there will be cases in which the issuance of orders under those authorities is appropriate, it may in some cases be necessary to issue a simultaneous §3008(a) order to obtain compliance with Part 265/270 requirements. Further, penalties for violations of Parts 265 and 270 may be assessed only through issuance of a §3008(a) order.

4.1.2 Conditions for Order Issuance

§3008(a) Orders

A §3008(a) order may be issued only for violation of one or more Subtitle C requirements. Therefore, when enforcement personnel and the permit writer

determine a facility's ground-water monitoring program to be technically inadequate, enforcement personnel should determine whether any of the technical inadequacies constitute violations of Part 265 Subpart F or Part 270.[9]

In some cases the regulations are specific as to what findings of fact would indicate violations. For example, if an owner/operator has installed only two downgradient wells, the facility is clearly out of compliance with §265.91(a)(2) of the regulations, the section that requires installation of at least three downgradient wells. Likewise, if a facility does not have some of the records specified in the regulations (e.g., an assessment outline), or has not performed some of the required analyses, then the owner is clearly in violation. The decision concerning the existence of a violation becomes more involved when it is based upon evaluating the adequacy of a facility's ground-water monitoring system beyond the minimum requirements.

In great part, the heightened level of analysis required to evaluate the overall adequacy of a system evolves from the regulations' reliance on broad performance standards. Given the great variability between sites in terms of wastes handled, hydrogeology, and climate, it is impossible to design a regulatory system that defines for all cases exactly what constitutes an adequate ground-water monitoring program. As a result, the Agency relies on performance standards to define "adequate."

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[9] As cited, herein, references to Part 265, Subpart F and Part 270 include requirements of authorized State programs.

The performance-oriented provisions of Subpart F set high standards for interim status ground-water monitoring systems, and enforcement personnel should not underestimate the power and applicability of this language. For example, even though the regulations establish a minimum of one background monitoring well, a single well is seldom sufficient because owner/operators must design their systems to meet the background-well performance standard listed in §265.91(a)(1). Section 265.91(a)(1) requires owner/operators to install a sufficient number of wells at appropriate locations and depths to yield samples representative of background water quality not affected by the facility. If a facility's well array does not meet this standard, the owner/operator is out of compliance with the regulations. Figure 4.2 summarizes the Part 265 and Part 270 performance standards relating to ground-water monitoring.

Figure 4.3, on pages 4-9 through 4-14, illustrates in greater detail the relationship between certain technical inadequacies of ground-water monitoring programs and the regulatory performance standards of RCRA. The left-hand side of the table lists a series of standards that must be met in order to meet the the performance standards summarized in Figure 4.2 (e.g,, background-well samples must be unaffected by the facility). The middle column includes examples of technical inadequacies that could prevent a system from meeting the left-hand standards and therefore could represent a violation of one or more of the performance standards (e.g., failure to consider flow paths of dense immiscibles when locating background wells). Finally, the right-hand column lists for each technical inadequacy the performance standard(s) that may have been violated.

FIGURE 4.2

GROUND-WATER PERFORMANCE STANDARDS
PARTS 265 and 270

CITATION	STANDARD
§265.90(a)	the owner/operator of a land disposal facility must implement a ground-water monitoring program "capable of determining the facility's impact on the quality of ground water in the uppermost aquifer underlying the facility,..." (emphasis added)
§265.91(a)	a ground-water monitoring system "must be capable of yielding ground-water samples for analysis..."
§265.91(a)(1)	the number, locations, and depths of background monitoring wells must be "sufficient to yield ground-water samples that are: (i) Representative of background ground-water quality in the uppermost aquifer near the facility; and (ii) Not affected by the facility..."
§265.91(a)(2)	the number, locations, and depths of downgradient monitoring wells must ensure that they "immediately detect any statistically significant amounts of hazardous waste or hazardous waste constituents that migrate from the waste management area to the uppermost aquifer." (emphasis added)
§265.93(d)(4)	an assessment monitoring plan must be capable of determining: "(i) Whether hazardous waste or hazardous waste constituents have entered the ground water; (ii) The rate and extent of migration of hazardous waste or hazardous waste constituents in the ground water..."
§270.14(c)(2)	the Part B applicant must submit, among other things, an "identification of the uppermost aquifer and aquifers hydraulically interconnected beneath the facility property, including ground-water flow direction and rate, and the basis for such identification (i.e., the information obtained from hydrogeologic investigations of the facility area)." (emphasis added)
§270.14(c)(4)	the Part B applicant must include in the submittal a "description of any plume of contamination that has entered the ground water from a regulated unit at the time that the application was submitted that: (i) delineates the extent of the plume..., (ii) identifies the concentration of each Appendix VIII... constituent...throughout the plume..." (emphasis added)

FIGURE 4.3

RELATIONSHIP OF TECHNICAL INADEQUACIES TO GROUND-WATER PERFORMANCE STANDARDS

Examples of Basic Elements Required by Performance Standards	Examples of Technical Inadequacies that may Constitute Violations	Regulatory Citations
1. Uppermost Aquifer must be correctly identified	• failure to consider aquifers hydraulically interconnected to the uppermost aquifer	§265.90(a) §265.91(a)(1) (a)(2) §270.14(c)(2)
	• incorrect identification of certain formations as confining layers or aquitards	§265.90(a) §265.91(a)(1) (a)(2) §270.14(c)(2)
	• failure to use test drilling and/or soil borings to characterize sub-surface hydrogeology	§265.90(a) §265.91(a)(1) (a)(2) §270.14(c)(2)
2. Ground-water flow directions and rates must be properly determined	• failure to use piezometers or wells to determine ground-water flow rates and directions (or failure to use a sufficient number of them)	§265.90(a) §265.91(a)(1) (a)(2) §270.14(c)(2)
	• failure to consider temporal variations in water levels when establishing flow directions (e.g., seasonal variations, short-term fluctuations due to pumping)	§290.90(a) §295.91(a)(1) (a)(2) §270.14(c)(2)
	• failure to assess significance of vertical gradients when evaluating flow rates and directions.	§265.90(a) §295.91(a)(1) (a)(2) §270.14(c)(2)
	• failure to use standard/consistent benchmarks when establishing water level elevations	§265.90(a) §265.91(a)(1) (a)(2) §270.14(c)(2)
	• failure of the O/O to consider the effect of local withdrawal wells on ground-water flow direction	§265.90(a) §265.91(a)(1)
	• failure of the O/O to obtain sufficient water level measurements	§265.90(a) §265.91(a)(1)

FIGURE 4.3 (continued)

Examples of Basic Elements Required by Performance Standards	Examples of Technical Inadequacies that may Constitute Violations	Regulatory Citations
3. Background wells must be located so as to yield samples that are not affected by the facility	• failure of the O/O to consider the effect of local withdrawal wells on ground-water flow direction	§265.90(a) §265.91(a)(1)
	• failure of the O/O to obtain sufficient water level measurements	§265.90(a) §265.91(a)(1)
	• failure of the O/O to consider flow path of dense immiscibles in establishing upgradient well locations	§265.90(a) §265.91(a)(1)
	• failure of the O/O to consider seasonal fluctuations in ground-water flow direction	§265.90(a) §265.91(a)(1)
	• failure to install wells hydraulically upgradient, except in cases where upgradient water quality is affected by the facility (e.g., migration of dense immiscibles in the upgradient direction, mounding of water beneath the facility)	§265.90(a) §265.91(a)(1)
	• failure of the O/O to adequately characterize subsurface hydrogeology	§265.90(a) §265.91(a)(1)
	• wells intersect only ground water that flows around facility	§265.90(a) §265.91(a)(1)
4. Background wells must be constructed so as to yield samples that are representative of in-situ ground-water quality	• wells constructed of materials that may release or sorb constituents of concern	§265.90(a) §265.91(a)
	• wells improperly sealed—contamination of sample is a concern	§265.90(a) §265.91(a) §265.91(c)
	• nested or mulitple screen wells are used and it cannot be demonstrated that there has been no movement of ground water between strata	§265.90(a) §265.91(a)(1) §265.91(a)(2)
	• improper drilling methods were used, possibly contaminating the formation	§265.90(a) §265.91(a)
	• well intake packed with materials that may contaminate sample	§265.90(a) §265.91(a) §265.91(c)

FIGURE 4.3 (continued)

Examples of Basic Elements Required by Performance Standards	Examples of Technical Inadequacies that may Constitute Violations	Regulatory Citations
Background wells must be constructed so as to yield samples that are representative of in-situ ground-water quality. (continued)	• well screens used are of an inappropriate length	§265.90(a) §265.91(a)(1) §265.91(a)(2)
	• wells developed using water other than formation water	§265.90(a) §265.91(a)
	• improper well development yielding samples with suspended sediments that may bias chemical analysis	§265.90(a) §265.91(a)
	• use of drilling muds or nonformation water during well construction that can bias results of samples collected from wells	§265.90(a) §265.91(a)
5. Downgradient monitoring wells must be located so as to ensure the immediate detection of any contamination migrating from the facility	• wells not placed immediately adjacent to waste management area	§265.90(a) §265.91(a)(2)
	• failure of O/O to consider potential pathways for dense immiscibles	§265.90(a) §265.91(a)(2)
	• inadequate vertical distribution of wells in thick or heavily stratified aquifer	§265.90(a) §265.91(a)(2)
	• inadequate horizontal distribution of wells in aquifers of varying hydraulic conductivity	§265.90(a) §265.91(a)(2)
	• likely pathways of contamination (e.g., buried stream channels, fractures, areas of high permeability) are not intersected by wells	§265.90(a) §265.91(a)(2)
	• well network covers uppermost but not interconnected aquifers	§265.90(a) §265.91(a)(2)
6. Downgradient monitoring wells must be constructed so as to yield samples that are representative of in-situ ground-water quality	See #4	

Examples of Basic Elements Required by Performance Standards	Examples of Technical Inadequacies that may Constitute Violations	Regulatory Citations
7. Samples from background and down-gradient wells must be properly collected and analyzed	• failure to evacuate stagnant water from the well before sampling	§265.90(a) §265.92(a) §265.93(d)(4) §270.14(c)(4)
	• failure to sample wells within a reasonable amount of time after well evacuation	§265.90(a) §265.92(a) §265.93(d)(4) §270.14(c)(4)
	• improper decisions regarding filtering or non-filtering of samples prior to analysis (e.g., use of filtration on samples to be analyzed for volatile organics)	§265.90(a) §265.92(a) §265.93(d)(4) §270.14(c)(4)
	• use of an inappropriate sampling device	§265.90(a) §265.92(a) §265.93(d)(4) §270.14(c)(4)
	• use of improper sample preservation techniques	§265.90(a) §265.92(a) §265.93(d)(4) §270.14(c)(4)
	• samples collected with a device that is constructed of materials that interfere with sample integrity	§265.90(a) §265.92(a) §265.93(d)(4) §270.14(c)(4)
	• samples collected with a non-dedicated sampling device that is not cleaned between sampling events	§265.90(a) §265.92(a) §265.93(d)(4) §270.14(c)(4)
	• improper use of a sampling device such that sample quality is affected (e.g., degassing of sample caused by agitation of bailer)	§265.90(a) §265.92(a) §265.93(d)(4) §270.14(c)(4)

FIGURE 4.3 (continued)

Examples of Basic Elements Required by Performance Standards	Examples of Technical Inadequacies that may Constitute Violations	Regulatory Citations
Samples from background and downgradient wells must be properly collected and analyzed (continued)	• improper handling of samples (e.g., failure to eliminate headspace from containers of samples to be analyzed for volatiles)	§265.90(a) §265.92(a) §265.93(d)(4) §270.14(c)(4)
	• failure of the sampling plan to establish procedures for sampling immiscibles (i.e., "floaters" and "sinkers")	§265.90(a) §265.92(a) §265.93(d)(4) §270.14(c)(4)
	• failure to follow appropriate QA/QC procedures	§265.90(a) §265.92(a) §265.93(d)(4) §270.14(c)(4)
	• failure to ensure sample integrity through the use of proper chain-of-custody procedures	§265.90(a) §265.92(a) §265.93(d)(4) §270.14(c)(4)
	• failure to demonstrate suitability of methods used for sample analysis (other than those specified in SW-846)	§265.90(a) §265.92(a) §265.93(d)(4) §270.14(c)(4)
	• failure to perform analysis in the field on unstable parameters or constituents (e.g., pH, Eh, specific conductance, alkalinity, dissolved oxygen)	§265.90(a) §265.92(a) §265.93(d)(4) §270.14(c)(4)
	• use of sample containers that may interfere with sample quality (e.g., synthetic containers used with volatile samples)	§265.90(a) §265.92(a) §265.93(d)(4) §270.14(c)(4)
	• failure to make proper use of sample blanks	§265.90(a) §265.92(a) §265.93(d)(4) §270.14(c)(4)

Examples of Basic Elements Required by Performance Standards	Examples of Technical Inadequacies that may Constitute Violations	Regulatory Citations
8. In Part 265 assessment monitoring the O/O must sample for the correct substances	• failure of the O/O's list of sampling parameters to include certain wastes that are listed in §261.24 or §261.33, unless adequate justification is provided	§265.93(d)(4)
	• failure of the O/O's list of sampling parameters to include Appendix VII constituents of all wastes listed under §§261.31 and 261.32, unless adequate justification is provided	§265.93(d)(4)
9. In defining the Appendix VIII makeup of a plume the O/O must sample for the correct substances	• failure of the O/O's list of sampling parameters to include all Appendix VIII constituents, unless adequate justification is provided	§270.14(c)(4)
10. In Part 265 assessment monitoring and in defining the Appendix VIII makeup of a plume the O/O must use appropriate sampling methodologies	• failure of sampling effort to identify areas outside the plume	§265.93(d)(4) §270.14(c)(4)
	• number of wells was insufficient to determine vertical and horizontal gradients in contaminant concentrations	§265.93(d)(4) §270.14(c)(4)
	• total reliance on indirect methods to characterize plume (e.g., electrical resistivity, borehole geophysics)	§265.93(d)(4) §270.14(c)(4)
11. Part B applicants who have either detected contamination or failed to implement an adequate part 265 GWM program must determine with confidence whether a plume exists and must characterize any plume	• failure of O/O to implement a monitoring program that is capable of detecting the existence of any plume that might emanate from the facility	§270.14(c)(4)
	• failure of O/O to sample both upgradient and downgradient wells for all Appendix VIII constituents	§270.14(c)(4)
	See also items #1, #2	

The technical inadequacies in Figure 4.3 are not necessarily violations in all cases. They are violations only when they result in a failure of the facility to meet one or more of the performance standards. Further, the list of technical inadequacies is not meant to be exhaustive. To a certain degree, the decision as to whether a facility's monitoring program is adequate must be made on a case-by-case basis.

§3013 Orders

Section 3013 orders may be issued to a facility only when the Administrator determines that the presence or release of hazardous waste at the facility may present a substantial hazard to human health or the environment. The facility need not be violating RCRA regulations to qualify for action under §3013.

Actual physical evidence of contamination is not necessary to support a §3013 order. In the case of a facility that has not conducted any ground-water monitoring activities, the potential for release of hazardous waste, the nature of the site's underlying hydrogeology, and the proximity of an aquifer or populated area will usually be sufficient, with expert opinion, to support a §3013 order. In some cases, the Region may wish to use §3007 authority to sample one or more wells at a facility in order to provide direct evidence of a release. Given that direct evidence is often unnecessary to establish the applicablity of §3013, the Region should probably avoid direct sampling unless it is confident that existing wells will intersect the suspected plume. Guidance issued September 26, 1984 provides further discussion of the grounds for issuance of §3013 orders. (See memo from Courtney Price and

Lee Thomas entitled, "Issuance of Administrative Orders Under Section 3013 of the Resource Conservation and Recovery Act").

§3008(h) Orders

Section 3008(h) of RCRA provides that the Administrator may issue an order or file a civil suit requiring corrective action or other appropriate response measures whenever (s)he determines that there is or has been a release of hazardous waste into the environment. Section 3008(h) actions are not limited to violations of RCRA.

As described in the September 1985 draft guidance on the scope and use of §3008(h), the Agency is interpreting the term "release" to include any spilling, leaking, pumping, pouring, emitting, erupting, discharging, injecting escaping, leaching, dumping, or disposing into the environment. To show that a release has occurred, the Administrator does not necessarily need sampling data. Such evidence as a broken dike at a surface impoundment should also support a determination that a release has occurred. In some cases, information on the contents of a land disposal unit, along with information on the site hydrogeology and the design and operating characteristics of the facility may be enough for an expert to conclude that a release has occurred.

Section 3008(h) orders (and civil suits) may be used to address releases not only to the ground water, but to other media as well. The draft §3008(h) guidance states that the authority covers releases of hazardous wastes into

surface water, air, the land surface, and the sub-surface strata. The term "hazardous waste" is not limited to those wastes listed or identified in 40 CFR Part 261. For §3008(h) purposes, the term hazardous waste also includes the hazardous constituents identified in Appendix VIII of Part 261.

4.1.3 Formal Administrative Proceedings

Orders issued and penalties assessed under §3008(a) are subject to formal administrative proceedings. Section 3008(a) proceedings are governed by 40 CFR Part 22. (See Appendix B for a diagram of the process). The Agency has not yet established the proceedings to be followed when issuing §3008(h) orders.

Part 22, which governs the issuance of §3008(a) orders, sets out a process that affords a respondent the opportunity to request a hearing on the violation, the penalty, and the remedy proposed by the Agency. Following any such hearing, the Administrative Law Judge will issue an Initial Decision that includes a proposed Final Order and may include a proposed penalty. At that point the respondent has 20 days in which to appeal the Initial Decision to the Administrator. If an appeal is not made within this time period the order becomes final and non-appealable 45 days after issuance of the Initial Decision.

Section 3013 orders are not subject to any formal administrative proceedings.

4.2 Selection Among Order Authorities

There are a number of factors that should be considered when deciding which order authority(ies) to invoke. The enforcement staff should consider first which order authorities are applicable to the actions, inactions, or conditions involved. Next, the Region should consider which of the applicable authorities provide a legal basis for requiring the remedy that the Region is seeking, including the assessment of penalties. Figure 4.1 may be consulted for a general listing of the activities that can be sought under each authority.

In most cases, there will be several options that meet the tests of applicability and coverage of the desired remedy. The enforcement options can be further narrowed by considering: 1) the strength of the evidence in support of each type of order; 2) the elements that must be established and whether they refer to regulations or must be established de novo; 3) the amount of time that is likely to pass before compliance is achieved; and 4) any complications that might arise from using certain combinations of authorities.

When estimating the amount of time that may pass before compliance with a §3008(a) order is achieved, the Regions should assess the probability of the facility appealing the order. This is particularly important where action needs to be taken quickly in order to halt or avoid a hazard or endangerment. If the facility is likely to challenge a §3008(a) order in the District Court, the Agency might elect to file a civil suit seeking preliminary injunctive relief or to issue a §3013 order (if the §3013 test could be met). Alternatively, the Agency could take action itself to

mitigate an immediate threat to public health or the environment under CERCLA §104.

When contemplating using two authorities to compel different aspects of the desired remedy, enforcement officials should keep in mind the different procedures that accompany each order. For instance, there may be cases in which a Region would consider issuing simultaneous §3008(a) and §3013 orders: a §3008(a) order to compel proper well placement and assess penalties and a §3013 order to compel sampling for constituents not listed in Parts 260-270. While simultaneous issuance of these orders is acceptable, the Region should be aware that one order is subject to administrative hearings and the other is not; therefore, appeal of the §3008(a) order may delay the full implementation of the remedy.

In general, a §3008(a) order enforcing Parts 265 and 270 and assessing penalties will be the most practical enforcement option. Such an order can be used to attain nearly any desired improvement to a ground-water monitoring program. It can also be used, as noted in Section 1.2.1, to require a facility to sample the ground water for constituents listed in Appendix VIII of Part 261.

Section 3013 and §3008(h) orders also have several common features that make them particularly attractive in certain circumstances. Both order authorities may be used to address contamination of media other than ground water. For example, either order could be used to address facilities with both ground-water and air problems. Moreover, unlike §3008(a) orders, §3008(h) and §3013 orders are not bound by the ground-water monitoring regimen specified in the regulations. Therefore, the Agency has more flexibility in

specifying monitoring parameters and sampling frequencies when issuing §3013 and §3008(h) orders.

Each order authority also has unique features that may make it particularly appropriate for certain situations. Section 3013, for example, grants the Agency the authority to perform investigatory activities and recover costs later if a respondent is incapable of or refuses to perform the necessary actions. Section 3008(h) does not provide for cost recovery, but can be used to compel facilities to go beyond the investigation stage and take corrective action if necessary. In addition, §3008(h) orders can be used to address past releases from solid waste management units and contamination extending beyond the facility boundary.

CHAPTER 5

FASHIONING A REMEDY AND DEVELOPING THE ENFORCEMENT STRATEGY

The first and perhaps most important step in developing an enforcement action for a facility with ground-water monitoring problems is fashioning an appropriate remedy. Only after outlining the desired remedy can the Region design an enforcement strategy that will best achieve the desired results.

This chapter will describe several scenarios involving problem monitoring programs and, using one common scenario as an example, will illustrate some of the principles that enforcement officials should consider when designing technical remedies. Then, using the same violator as an example, the chapter will design an enforcement strategy to compel the model remedy.

5.1 Types of Violators

Each ground-water case will, of course, have unique features. It is possible, however, to group RCRA ground-water violators into several broad categories that characterize the status of the facility at the time of enforcement review. Figure 5.1 outlines one possible scheme that divides facilities into groups based on a combined evaluation of their Part 265 system and the adequacy of their permit application. This scenario will be used later in Figure 5.3 to illustrate possible remedies and enforcement strategies for facilities with different types of ground-water violations.

The assumption in this scheme is that all the facilities listed are in violation of Part 270 because they did not generate the information necessary for permitting. In some cases, this deficiency derives from inadequate

compliance with Part 265 (facilities that have inadequate 265 detection systems, for example, will not have generated the information necessary to determine whether the facility should be permitted under detection monitoring, compliance monitoring, or corrective action). In other cases, facilities may have complied with 265, but not have completed all activities required by the permit application regulations (e.g., the facility performed some assessment activities based on Appendix VII, but did not sample for Appendix VIII as required by §270.14(c)(4)).

FIGURE 5.1

Violator Classification Scheme

Scenario	Facility Status	Possible Sources of Inadequacy
1.	No statistically significant change in Part 265 indicator parameters; Physically adequate detection network; Agency has reason to believe there is contamination.	Part 265 indicator parameters are not adequate to detect type of leachate expected from facility; site hydrogeology or facility's engineering design puts facility at high risk of leaking.
2.	No statistically significant change in Part 265 indicator parameters; Inadequate Part 265 detection system.	Well placements made based on insufficient hydrogeologic assessment; Too few wells; Inappropriate sampling device; Wells not properly developed, etc.
3.	Statistically significant change in Part 265 indicator parameters; Inadequate Part 265 detection system; Inadequate Part 265 assessment.	Owner/operator used only indirect techniques to assess plume.
4.	Statistically significant change in Part 265 indicator parameters; Adequate Part 265 assessment; Inadequate permit application.	Owner failed to identify all Appendix VIII constituents in ground water; Owner based concentration limits on insufficient background sampling; Owner failed to submit a feasibility plan for corrective action, etc.

5.2 Profile of a "Transition-Period" Violator

During the transition period between interim status and permitting, the Agency envisions encountering a considerable number of facilities of the type described in Scenario 2 (Figure 5.1). The Agency's experience to date has indicated that in certain cases, owner/operators have installed monitoring networks based on only a limited understanding of the hydrogeology underlying their site. Monitoring wells have been located based on an evaluation of local topography and, to the extent possible, evaluation of existing building foundation borings. A considerable number of owner/operators have not performed the type of detailed hydrogeologic site assessment the Agency considers essential for the design of any ground-water monitoring system. Even fewer have kept the type of well construction and design records the Agency needs to evaluate the adequacy of the physical well network already in place.

As a result, EPA expects to encounter owner/operators who consider themselves in compliance but who can not provide the background information and documentation minimally necessary to substantiate the adequacy of their Part 265 detection system. Without such information, the Agency will not be able to decide whether a facility's detection system is or is not capable of detecting contamination and hence whether the facility should be permitted under detection monitoring, compliance monitoring or corrective action. Not having detected a change in indicator parameters, however, the facility most likely will have applied for a detection monitoring permit, considering itself exempt from the assessment requirements of §270.14(c)(4).

A typical "transition" facility, therefore, could be characterized as follows:

- o the facility has failed to adequately characterize the hydrogeology underlying its site;
- o therefore, the facility's well placements are inaccurate;
- o the facility has sampled for the Part 265 indicator parameters. No statistically significant increases have been detected in existing downgradient wells;
- o the facility's Part B is due. The facility has submitted a summary of its interim status monitoring data and has proposed an expanded list of indicator parameters for Part 264 monitoring. The permit application includes procedures for establishing background values for these parameters, but does not include actual background values based on pre-permit sampling.

This chapter will use the above scenario to illustrate some of the principles enforcement officials should consider when designing remedies for facilities during the interim status to permitting transition period. The chapter uses Scenario 2 as its point of departure because a facility that has not detected contamination under interim status presents the greatest challenge to enforcement officials. Moreover, the remedies appropriate for the other scenarios presented in Figure 5.1 are but a variation of the remedy outlined in the following section for the facility described in Scenario 2.

Table 5.5 at the end of the chapter summarizes the variations on the remedy appropriate for each of the other listed scenarios.

5.3 Outline of the Remedy

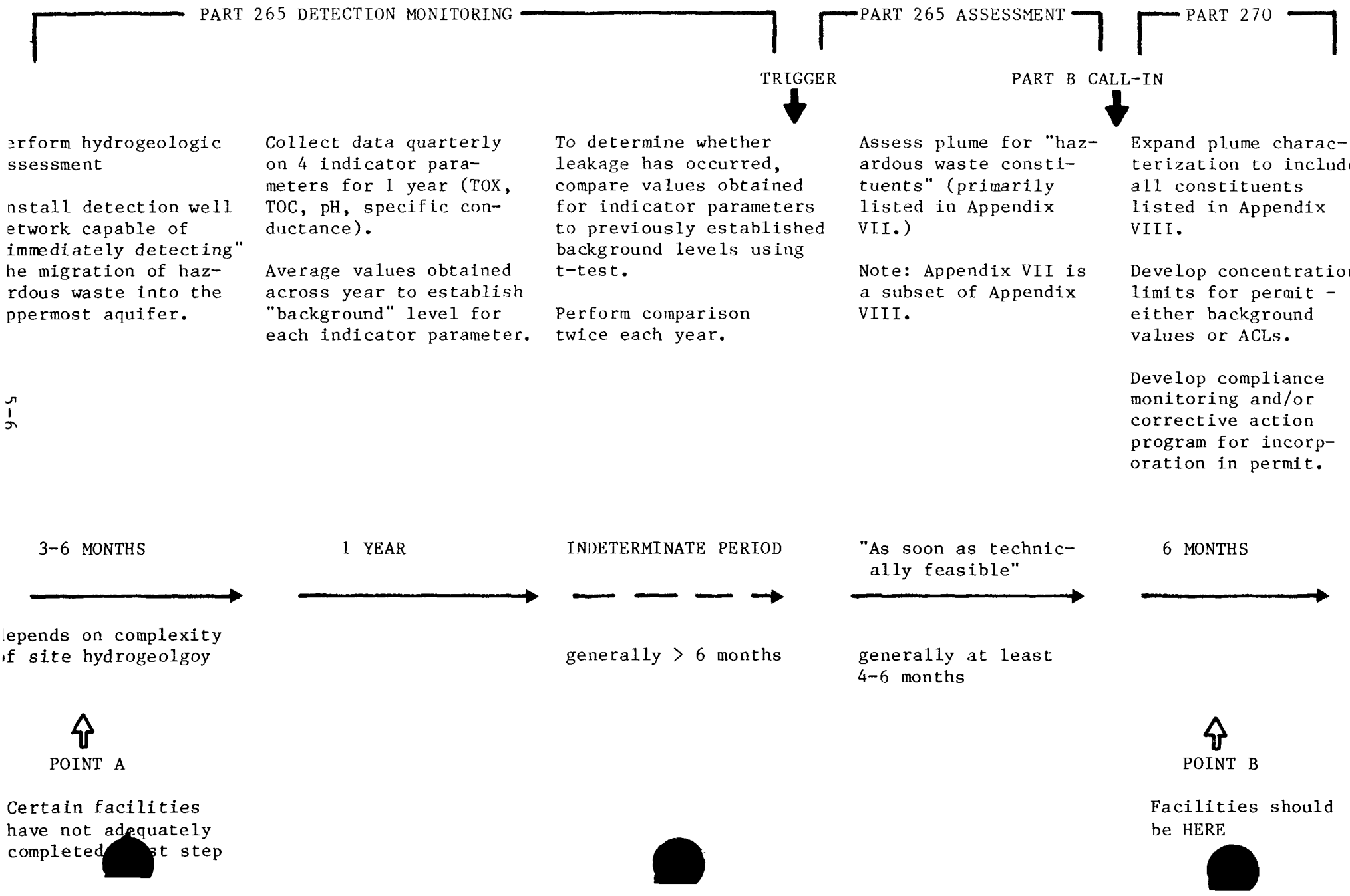
When faced with a facility that has a technically inadequate detection monitoring system, enforcement and permitting officials must consider first

what makes sense for a facility to do in light of the facility's past and future monitoring obligations. By this point in the program, an interim status facility should have installed a fully competent detection monitoring system, determined with confidence whether there was a statistically significant indication of ground-water contamination, and fully characterized any plume for both Appendix VII and VIII constituents (if contamination were detected). If a facility has not successfully completed even the first step - the installation of a competent detection system - it cannot be allowed to begin the entire sequence anew. Proceeding from the beginning would mean upgrading the detection system and sampling for one year to establish background before even the first determination of contamination is made.

As the time line in Figure 5.2 points out, proceeding through this entire sequence could take up to two and one-half years. This approach would lead to unacceptable delays in the permitting process and would penalize those facilities who had complied with the program all along. In effect, "starting over" would merely allow facilities that had avoided the costs of complying in the past, to delay the costs of full compliance for an additional period of time.

Instead, such facilities should be required to make an accelerated determination of whether or not contamination has occurred. This determination can then be used to decide what additional actions, if any, the applicant must perform to meet his/her permit application requirements.

Figure 5.2 GROUND-WATER MONITORING SEQUENCE AS ORIGINALLY ENVISIONED



Before a determination of leakage can be made, the facility must install a monitoring network capable of detecting contamination. In general, this will require such facilities to perform additional site characterization and then, based on the results, expand or replace their existing monitoring network. Once a competent detection network is in place, the facility is in a position to determine whether or not contamination has occurred.

The Agency suggests that the determination of whether contamination has occurred be made based on a comparison of upgradient and downgradient values obtained for an expanded list of indicator parameters. The indicator parameters should be selected based on the specifics of the site and should include constituents that would be expected to be at the leading edge of any plume of contamination (see Section 5.4.2). The comparison should be based on the mean of pooled data obtained through accelerated sampling over a short period of time. The plan for this determination should be designed to conclusively confirm or refute contamination in the shortest period of time possible.

If contamination <u>has</u> occurred, the facility owner must proceed to characterize the plume and, based on the results, apply for either an operating or post-closure permit that includes compliance monitoring and/or corrective action. If contamination has <u>not</u> occurred (i.e. the results of interim status monitoring were correct even though the detection system was not fully competent), then the facilty would apply for a permit as a detection monitoring facility.

Thus the preferred technical response for a facility that has not triggered under detection monitoring but has an inadequate Part 265 detection system is as follows:

1) Conduct a detailed assessment of the site's hydrogeology (fill in gaps in the facility's current understanding of the site's subsurface).

2) Install a monitoring network (or modify/expand an existing system) to meet the objectives of Parts 265/264 detection monitoring.

3) Sample for an expanded list of indicator parameters.

4) Determine whether contamination has occurred based on a comparison of upgradient and downgradient well samples obtained over a short period of time (accelerated sampling).

5) If contamination is confirmed, begin characterizing the plume based on monitoring of Appendix VIII constituents.

6) Sample to establish background for all Appendix VIII constituents detected in ground water.

7) If downgradient Appendix VIII values are significantly greater than background values, have facility develop corrective action plan and apply for corrective action permit.[10]

   If downgradient Appendix VIII values are lower than background, have facility submit a corrective action feasibility study[11] and apply for a compliance monitoring permit.

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[10] Note that if the permit is not likely to be issued quickly, the Agency may wish to initiate corrective action while the facility is still in interim status. Several authorities are available to compel such corrective action, including §3008(h), §7003 and Section 106 of CERCLA. Further, in some instances, the Agency may choose to conduct a response action under the authority of CERCLA §104.

[11] Section 270.14(c)(7) requires applicants to submit a corrective action feasibility study when applying for a compliance monitoring permit. The study must include sufficient information to predict what type of corrective action (e.g., trench recovery, pumping and treatment) would be appropriate if remedial work proved necessary at that site. It is not meant to be a fully developed plan for corrective action; such a plan must be developed pursuant to §264.99(i)(2) if the facility ever exceeds its ground-water protection standard.

The schedule of achieving the above remedy will of course depend on the particulars of the site involved, especially the complexity of the site's hydrogeology. While it is impossible to predict how long it will take (or should take) to accomplish each step, the sequence of monitoring events in this remedy should be significantly shorter than the sequence laid out in the regulations.

As illustrated in Figure 5.3, the remedy recommended in this document in effect eliminates the collection of a year's worth of background data and condenses the monitoring required by Part 265 assessment [primarily Appendix VII] and §270.14(c)(4) [Appendix VIII] into one plume characterization phase. Now confirmation (or denial) of leakage can be accomplished through accelerated sampling over a period of weeks or months rather than taking over a year.

5.4 Discussion of the Remedy

The basic elements of the remedy are the design and installation of a competent detection monitoring well network; determination of whether or not leakage has occurred based on sampling for an expanded list of parameters; and the fulfillment of all applicable Part 270 informational requirements. The following section will describe briefly certain factors enforcement officials should keep in mind when developing each aspect of the remedy. Later sections will explore the order and regulatory authorities available to compel each of the outlined activities.

5.4.1 Design and Installation of a Competent Monitoring Network

The facility owner should be required to upgrade his/her existing network to meet the detection standards of Part 265. The reader should note that if

Figure 5.3 NEW GROUND-WATER COMPLIANCE STRATEGY BASED ON CONDENSED MONITORING SEQUENCE

FACILITIES THAT HAVE NOT FORMALLY TRIGGERED	Fill in gaps in hydrogeologic assessment Upgrade existing well network to meet Part 265 standards Develop list of expanded indicator parameters that includes constituents expected to be derived from waste found at the facility	Determine whether contamination has occurred based on a comparison of data from up- and downgradient wells collected on an accelerated schedule over a short period of time. NOTE: Determination is no longer based on comparison of current values to "background" values established over 1 year.	If contamination is confirmed, begin assessing plume based on monitoring of Appendix VIII constituents Sample to establish background for all Appendix VIII constituents detected in ground water for possible inclusion in ground-water protection standard. Develop compliance monitoring and/or corrective action program for incorporation in permit
	2 to 4 MONTHS* →	2 MONTHS →	4 to 6 MONTHS →
FACILITIES THAT HAVE MANAGED TO TRIGGER DESPITE INADEQUATE DETECTION SYSTEM	→		<u>IMMEDIATELY</u> begin installation of assessment wells downgradient from "hot" well(s). <u>SIMULTANEOUSLY</u> fill in gaps in hydrogeologic assessment and upgrade detection network Proceed as above

* Time frames will vary depending on site-specific factors

an owner/operator's hydrogeologic data submitted pursuant to §270.14(c)(2) is inadequate, it is likely that the facility's detection monitoring well network is inadequate as well. The reader should also note that since the the design and construction standards for a Part 265 system are essentially the same as those required by Part 264 (see Chapter 3), the network installed for the determination of leakage proposed in the model remedy should serve equally well as the facility's Part 264 detection monitoring system if no plume is found.

5.4.2 Confirmation of Leakage Based on Expanded Sampling

Central to the determination of leakage proposed in the model remedy is the development of a list of meaningful indicator parameters. When selecting parameters, enforcement officials should not limit themselves to the four indicators listed in §265.90.[12] These parameters were selected as the best indicators available to detect a broad spectrum of possible leachates. Because the interim status regulations were meant to be self-implementing, Part 265 detection monitoring could not rely on waste-specific indicators selected for each facility. As a result these parameters are limited in their ability to indicate contamination soon after leakage.

The Part 265 indicator parameters are limited in three ways. First, the Part 265 indicator parameters are subject to sources of natural variation that can mask the presence of low levels of contamination. There are many natural sources of variation in pH, for example, that could obscure changes

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[12] See Section 5.5.2 for an explanation of the authorities available to compel sampling for a broader list of parameters.

in this parameter caused by leachate. Changes in levels of a specific parameter such as benzene, however, are not generally subject to such background "noise." Second, with the exception of TOX (which can be detected at below 20 ppb), the lower detection limit of the other parameters is not sufficiently sensitive to register some changes in water chemistry that may represent leakage. Finally, because the Part 265 indicator parameters are surrogate measures, increases in a particular chemical constituent do not necessarily cause an equivalent change in an indicator parameter. A 5 mg/l change in lead, for example, would only initiate a very small change in specific conductance (if any). The same increase in concentration would initiate a significant change, however, if the facility were sampling for lead itself.

Therefore, enforcement officials should select indicator parameters that are based on the chemical composition of the facility's waste. The enforcement official should have the facility identify both the hazardous and non-hazardous constituents of the facility's waste, including any constituents likely to form as a result of chemical reactions occurring in the facility or in the leachate as it migrates through the subsurface. Then the owner/operator should identify those constituents that can be considered the most mobile and persistent in the unsaturated and saturated zones beneath the facility. The enforcement official should then select those parameters that individually or as a group (e.g. TOX) can provide the most reliable indication of leakage. Special attention should be given to whether the parameter is easily detected in water and to the variability of the parameter in background water. If background concentrations of a potential indicator parameter are sufficiently high or exhibit a high degree of variability, the arrival of low or moderate concentrations of leachate may be masked.

The list of parameters finally selected should be representative of constituents at least as mobile as the most mobile hazardous constituent reasonably expected to be derived from the facility's waste. Concentrating on the most mobile constituents will ensure that the arrival of leachate is detected at the earliest possible time.

In addition to indicator parameters, enforcement officials should consider having the facility sample for additional parameters that characterize the general quality of water at the site (e.g., Cl^-, Fe, Mn, Na^+, SO_4, Ca^+, Mg^+, K^+, NO^{-3}, $PO_4^=$, silicate, ammonium, alkalinity or acidity). Baseline data on the inorganic chemical composition of ground water can provide an important basis for comparison and planning should the program enter the assessment phase. Information on the major anions and cations that make up the bulk of dissolved solids in water, for example, can be used to determine reactivity and solubility of hazardous constituents and therefore predict their mobility under actual site conditions.

5.4.3 Fulfillment of Applicable Part 270 Requirements

When designing the remedy, enforcement officials should include elements that address the facility's information obligations pursuant to Part 270. If contamination is confirmed, the facility must generate the remainder of the information required by §270.14(c)(4), namely the extent of migration of any plume and the concentration of all Part 261 Appendix VIII constituents present in the plume.

Enforcement officials should also ensure that the remedy includes the collection of background data on all Appendix VIII constituents detected in

ground water. For many constituents, these data will be necessary to establish concentration limits for incorporation into the facilty's ground-water protection standard. As described in section 3.2.1, the permit writer will have to set concentration limits based on the mean of pooled data available at the time of permitting (unless there is a high temporal correlation between contaminant concentrations in upgradient and downgradient wells in which case concentration limits may be established through sampling at the compliance point). Therefore, it is in the best interests of both the facility and the Agency to have sufficient data available at the time of permitting to accurately characterize the quality of the background water at the site.

To guarantee sufficient data, enforcement officials should consider incorporating in the facility's prescribed remedy an accelerated program of background sampling for Appendix VIII constituents. The frequency of sampling should be dictated by the needs of the statistical test proposed by the facility for use in compliance monitoring. The sampling schedule should also consider the need for establishing seasonal and spatial variation in contaminant levels if such variation is expected at the site. Sections 6.3 and 7.3.2 of the Permit Writer's Guidance Manual provide further guidance on these points.

In addition, the order should require the submittal of the various plans and feasibilty studies necessary to establish a compliance monitoring program or a program for corrective action pursuant to §§270.14(c)(7) or (8) (see Section 2.3.2). By placing these permit application requirements on an enforceable compliance schedule, enforcement officials can help ensure that the requirements will be fulfilled in a timely manner.

5.5 Application of Enforcement Authorities to the Remedy

Once the enforcement staff and permit writer devise an appropriate remedy, the enforcement staff must determine the order and regulatory authorities best suited to compel the desired actions. As Section 4.2 on selecting order authorities points out, there are a variety of factors enforcement officials must consider when developing an enforcement strategy.

When deciding between order authorities, officials must first establish the applicability of the order to the situation at hand (i.e., does the situation meet the conditions necessary for the issuance of a particular order). Next, the official must consider whether the order can compel all aspects of the desired remedy. Where possible, it is advantageous to secure the entire remedy through a single authority in order to save resources and avoid the possibility of different appeal procedures. Finally, enforcement officials must factor in other relevant concerns such as the facility's compliance history and whether or not it is important in the instant case to assess a penalty. In certain circumstances, features such as the ability to assess a penalty may become the deciding factor when choosing between order authorities.

This section will apply the above principles to the model remedy developed in this chapter. It will outline a preferred enforcement strategy for the model remedy and will note where changes in the remedy could suggest needed changes in the proposed strategy. Table 5.5 at the end of the chapter, summarizes various enforcement strategies for facilities with different ground-water violations and different technical remedies.

5.5.1 Selection of the Order Authority

Assume that the only information known about the Scenario 2 facility is that presented in Figure 5.1; namely, the facility is in violation of the Part 265 ground-water regulations for the following reasons:

1. the facility located its wells based on a poor understanding of the site's hydrogeology;
2. there are too few wells installed; and
3. the owner cannot demonstrate that existing wells were properly constructed.

In addition, the facility is in violation of §270.14(c)(4) because the owner made no attempt to look for and assess any plume beneath the facility before the facility's Part B due date passed.

Based on the above information alone, the most appropriate order authority for compelling the model remedy of this chapter would be a §3008(a) order enforcing Parts 265 and 270. A §3008(a) order is the authority of choice for three reasons. First, the condition for issuing a §3008(a) order has already been met - the facility is clearly in violation of the regulations. To use either of the other authorities, the Agency may have to expend additional resources to collect evidence that there may be a substantial hazard to public health or the environment [§3013] or a release of hazardous waste or constituents into the environment [§3008(h)].

Second, as the following section will explain, the entire remedy can be compelled using a §3008(a) order citing relevant sections of Parts 265 and 270. The remedy as presently conceived focuses exclusively on evaluating

the impact of the facility on ground water; hence, an order that can address other media, such as a 3013 or 3008(h) order, is not needed. Further, in this particular case, there is no reason to suspect that the threat posed by potential ground-water contamination is so compelling as to require corrective action prior to permitting. Therefore, it is not essential to use an order that can accommodate clean up of ground water during interim status. Of course, if additional evidence collected during plume characterization indicated that clean up should be pursued immediately, a §3008(h) order could be issued subsequent to the initial §3008(a) action.

Finally, a §3008(a) order has the added advantage that it can be used to assess penalties. Given that the facility has been out of compliance for the entire history of the program, the Agency should exercise its authority to assess penalties for past and continuing violations including the recovery of the facility's economic benefit of non-compliance.

Of course, if the starting scenario were different, the considerations guiding the selection of an order authority could change significantly. For example, if there were evidence of off-site contamination (e.g., a fish kill in a nearby stream) and the facility were known to delay resolution of proceedings by exercising every opportunity for appeal, enforcement officials may decide to postpone the assessment of penalties and immediately issue an order under §3013, §7003 or CERCLA §106 to avoid the time delay afforded by the administrative process. In another case, if a facility were out of compliance with the ground-water regulations and had significant soil contamination, the Region could use a §3008(h) order to achieve both compliance with

the regulations and clean-up of contaminated soil. The proper way to balance the advantages and disadvantages of each order authority can only be determined in the context of a particular situation.

5.5.2 Securing the Model Remedy Through a §3008(a) Order

As outlined in Figure 5.4, the model remedy derives directly from the regulations. Sections from Part 265 and 270 may be cited to compel additional hydrogeologic investigation and the installation of an adequate well network. Section 270.14(c)(4) may be cited to force sampling for an expanded list of parameters and to justify the comparison of upgradient and downgradient wells based on accelerated sampling. Finally, relevant sections of the Part 270 regulations may be cited to require the collection of background data on Appendix VIII constituents and the submission of other plans and data necessary for permitting.

Figure 5.4

MODEL REMEDY	REGULATORY CITES
1. Fill in gaps in the current understanding of the site's hydrogeology	§265.90(a) §265.91 §270.14(c)(2)
2. Install a monitoring network (or expand an existing system) to meet the objectives of a Part 265/264 detection system	§265.91
3. Sample for an expanded list of indicator parameters:	
Part 265 indicator parameters (TOX, TOC, pH, specific conductance)	§265.92(b)(3)

Figure 5.4 (continued)

Part 265 water quality parameters (Cl, Fe, Mn, Na, Phenols, Sulfate)	§265.92(b)(2)
Substances with National Interim Drinking Water Standards (Appendix III, Part 265)	§265.92(b)(1)
Appendix VIII of Part 261	§270.14(c)(4)
4. Determine whether contamination has occurred based on a comparison of data collected from up- and downgradient wells over a short period of time.	§270.14(c)(4)
5. If contamination is confirmed, begin assessing the plume based on monitoring of Appendix VIII constituents	§270.14(c)(4)
6. Sample to establish background for all Appendix VIII constituents detected in ground water	§270.14(c)(7)(iv)
7. Submit data and plans required for either compliance monitoring or corrective action	§270.14(c)(7) or (8)

The regulatory cites in this strategy are relatively straight forward; however, the role of §270.14(c)(4) deserves attention. As section 2.3.1 explains, the Agency may require a facility to look for and assess a plume at any facility where the owner/operator's program of interim status monitoring has detected a plume or has failed to establish definitively whether or not a plume exists.

Under §270.14(c)(4), the facility is obligated to assess the extent of any plume and sample for the full complement of Appendix VIII constituents.

Therefore, it is within the Agency's authority to require the facility to begin assessment and full Appendix VIII sampling immediately. The model technical remedy, however, limits the scope of sampling to a more manageable list of indicator parameters until the presence of a plume is confirmed or refuted. In effect, the model technical remedy refrains from immediately exercising the full power of §270.14(c)(4) in order to avoid wasted effort if indeed the facility has not leaked.

5.6 Variations on the Model Scenario

This chapter has used the facility described in scenario 2 to illustrate some of the principles enforcement officials should consider when designing technical remedies and developing enforcement strategies. As the scenario changes, the remedy appropriate for the situation and the enforcement tools available to secure that remedy change as well. Figure 5.5 (at the end of the chapter) illustrates how the technical remedy and enforcement response vary based on the status of the facility at the time of enforcement review.

It is important to note that all proposed remedies include correcting any deficiencies in the existing detection network even if the facility has already detected contamination and begun to characterize the plume. As described in the Chapter 2, a sound well network at the limit of the waste management area is critical to every phase of ground-water monitoring, from interim status monitoring to compliance and/or corrective action monitoring. Therefore, it makes sense to correct any deficiencies in the interim status detection system, because these wells will be used throughout the life of the facility. Moreover, a system may have detected a plume in one area and still be incapable

of detecting a plume at some other point. In such cases, the system should be upgraded so that it will be capable of detecting future plumes of contamination.

It is further important to note that where a facility has managed to detect a statistically significant change in indicator parameters even though its detection system is inadequate (see Scenario 2 in Figure 5.5), enforcement officials should require the facility to begin characterizing the plume downgradient from the triggering well and at the same time perform additional hydrogeologic evaluation and upgrade the detection network.

Finally, the technical remedies outlined in this chapter are appropriate not only for operating units but also for most units that are closed or are planning to close. Section 270.1(c) states that units closing after January 26, 1983 must have permits during the post-closure period.[13] For units that accepted hazardous waste after July 26, 1982, the post-closure permit would include the ground-water monitoring program set out in Part 264 and the permit application would include the ground-water monitoring data required under §270.14(c). Thus, once a closing unit's Part B application is due, enforcement officials can rely on the same range of enforcement options that are available to address operating units.

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[13] In order to implement §3005(i) of the Solid Waste Disposal Act, as amended, the Agency intends to propose amending §270.1(c) to make all units closing after July 26, 1982 subject to post-closure permits. Section 3005(i) of the revised Act makes all units receiving wastes after 7/26/82 subject to Part 264 ground-water monitoring and corrective action requirements. Since a permit is the means by which the Agency implements the Part 264 standards, the Agency considers it necessary to revise §270.1(c) in order to make all units subject to Part 264 ground-water monitoring and corrective action also subject to post closure permitting.

There are three categories of units that would not currently be subject to the Part 265/270 program outlined in this chapter. First, units that closed before January 26, 1983 are not required to obtain permits and thus are not subject to Part 270 requirements [codification rule may roll this date back to July 26, 1982]. Second, units that ceased receiving hazardous waste by July 26, 1982 are not subject to the Part 264 ground-water monitoring provisions and therefore, in applying for the permit, would not need to include the ground-water data required under §270.14(c)(4). Third, no post-closure requirements apply, and thus no permit or permit application is currently required for a surface impoundment or waste pile that closes by removing all hazardous waste and waste residues from the unit, the underlying and surrounding soil, and the ground water. The Agency is presently evaluating whether §3005(i) may require the Agency to make units that clean closed under Part 265 but received waste after 7/26/82 subject to post-closure permitting in order to implement Part 264 ground-water monitoring and corrective action.

In all of the above cases, however, the Part 265 ground-water monitoring requirements do apply and should be enforced.[14] In the case of a surface impoundment closing through removal, the Agency/State should ensure that the

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[14] The successful execution of closure responsibilities (e.g., installation of a cap, run-off and run-on control) does not absolve a facility from its Part 265 ground-water monitoring responsibilities. Section 265.117 of the regulations states that closed facilities must comply with the ground-water monitoring and reporting requirements of Subpart F for 30 years after the date of closure. Therefore to meet its post-closure care requirements, a closed or closing facility with an inadequate Part 265 monitoring network would have to upgrade its system and assess any plume of contamination detected during the post-closure care period.

closure plan provides for monitoring that is adequate to demonstrate the absence of hazardous waste in the ground water. Surface impoundments generally cannot qualify for closure by removal if any hazardous waste is present in the ground water; such impoundments must instead close as land disposal facilities.

FIGURE 5.5 VARIATIONS ON MODEL REMEDY AND ENFORCEMENT RESPONSE

FACILITY STATUS	EXAMPLE SCENARIOS	PROPOSED REMEDY	ADMINISTRATIVE ENFORCEMENT OPTIONS
1. *No* statistically significant increase in indicator parameters under Part 265 detection. Adequate hydrogeologic assessment and construction of wells. Site conditions or additional evidence suggest that leakage may have occurred.	a) Unlined lagoon contains a large volume of lead-containing wastes. High variability in background measure of specific conductance may have masked escape of lead into ground water. Subsurface is naturally acidic. Shallowness of water table and lack of liner suggest high probability of leakage.	1. Develop list of meaningful indicator parameters. 2. Sample upgradient and downgradient wells for indicators. 3. If there is a statistically significant difference between up- and downgradient wells, assess plume to determine extent of migration and concentration of all Appendix VIII constituents (new wells may be required). 4. Establish background values for all Appendix VIII constituents found in plume. 5. Develop compliance monitoring or corrective action program as appropriate	1. §3013 if substantial present or potential threat to public health or environment exists; or 2. §3008(h) if there is evidence of release of hazardous waste or constituents into the environment.
	b) Surface impoundment with synthetic liner. Wells placed at 80 ft. centers. Uniform glacial till with permeability of 10^{-5}. Nearby pond downgradient from facility is contaminated with TCE. Waste in surface impoundment is known to contain TCE. Agency suspects that there is ribbon plume escaping from leak in liner.	1. Install additional wells in area(s) of highest probability of leakage taking into account hydrogeology of site and facility design (e.g., near liner seams). Note: computer modeling may help estimate source of plume. 2. Proceed as in 1(a) above.	1. §3013 if substantial present or potential threat to public health or environment exists; or 2. §3008(h) if there is evidence of release of hazardous waste or constituents into the environment.

FIGURE 5.5 (continued)

FACILITY STATUS	EXAMPLE SCENARIOS	PROPOSED REMEDY	ADMINISTRATIVE ENFORCEMENT OPTIONS
2. Statistically significant increase in Part 265 indicator parameters. Inadequate Part 265 detection system. Inadequate Part 265 assessment.	a) Facility located wells based on regional hydrogeologic information only. Facility has only five wells in place, one considered upgradient and four considered downgradient spaced at 400 ft. centers. Facility has no drilling logs or construction specs on wells. Despite inadequacy of system, statistically significant increase in TOC detected.	1. Fill in gaps in hydrogeological assessment. 2. Based on results, install new (or expand and improve) existing detection network. 3. *Concurrently* with above, have facility submit plume characterization plan to determine extent of plume & concentration of Appendix VIII constituents present. 4. Assess plume and establish background values for all Appendix VIII constituents detected; 5. Develop compliance monitoring and/or corrective action program as appropriate.	1. §3008(a) enforcing Parts 265 and 270; 2. §3013 if substantial present or potential threat to public health or environment exists; or 3. §3008(h) if there is evidence of a release of hazardous waste or constituents into the environment.
3. Adequate detection monitoring system in place. Statistically significant increase in Part 265 indicator parameters. Inadequate Part 265 assessment monitoring program; therefore inadequate permit application.	a) Owner/operator performed adequate hydrogeologic assessment and provided drilling logs and well design specs to substantiate the adequacy of his detection network. However, the owner/operator used only ground-penetrating radar to define boundaries of plume and established rates of migration using unrealistic assumptions.	1. Have facility submit assessment plan to determine extent of plume and concentration of all Appendix VIII constituents. 2. Assess plume and establish background values for Appendix VIII constituents detected. 3. Develop compliance monitoring and/or corrective action program as appropriate.	1. §3008(a) enforcing Part 270. 2. §3013 if substantial present or potential threat to public health or environment exists; or 3. §3008(h) if there is evidence of a release of hazardous waste or constituents into the environment.

FIGURE 5.5 (continued)

FACILITY STATUS	EXAMPLE SCENARIOS	PROPOSED REMEDY	ADMINISTRATIVE ENFORCEMENT OPTIONS
4. Same as in #3, but Part 265 assessment program properly carried out. Inadequate permit application.	a) Large amounts of K006 waste disposed at site. Sampling for relevant Appendix VII constituent, hexavalent chromium, did not confirm contamination. Owner/operator applied for detection monitoring permit claiming false trigger. Facility did not sample for other organic constituents known to be in K006 waste and listed in Appendix VIII as required by §270.14(c)(4).*	1. Assess plume for all Appendix VIII constituents (can probably use same wells used for Part 265 assessment). 2. Establish background values for all Appendix VIII constituents found in plume. 3. Have owner/operator apply for compliance monitoring and/or corrective action permit as appropriate.	1. §3008(a) enforcing Part 270; 2. §3013 if substantial present or potential threat to public health or environment exists; or 3. §3008(h) if there is evidence of hazardous waste or constituents into the environment.

*K006 waste (wastewater treatment sludge from the production of chrome oxide green pigments-anhydrous and hydrated) was listed because it contains hexavalent chromium i.e., the only Appendix VII constituent related to K006 is Cr^{+6}. K006 waste, however, contains a host of organic solvents. Therefore, the owner/operator could have fulfilled his Part 265 assessment monitoring obligations by monitoring for Cr^{+6}. To fulfil his obligations under §270.14(c)(4), however, the owner/operator would have to expand his sampling and analysis program to include the organics on Appendix VIII.

FIGURE 5.5 (continued)

FACILITY STATUS	EXAMPLE SCENARIOS	PROPOSED REMEDY	ADMINISTRATIVE ENFORCEMENT OPTIONS
5. Inadequate Part 265 detection system. No statistically significant increase in parameters. Owner/operator notifies Agency that (s)he intends to close. Closure plan does not address potential ground-water problems.	a) Land disposal facility announces intent to close after submitting a highly inadequate Part B application and receiving NOD that details work to be done before application can be considered complete.	1. Have facility pursue model remedy that is outlined in Chapter 5. Closing land disposal facility has same Part 270 and Part 264 ground-water monitoring obligations (pursuant to post-closure permit) as facility applying for operating permit. 2. Pursue corrective action if warranted.	1. §3008(a) enforcing Parts 265 and 270. 2. §3008(h) if there is evidence of a release of hazardous waste or constituents into the environment.
	b) Facility submits closure plan in lieu of Part B operating or post-closure permit.	1. Call in facility's post-closure permit if not already due. 2. Where possible, enter into consent agreement that outlines steps owner/operator must take to generate adequate post-closure permit application. 3. Where agreement is not possible, issue order enforcing Part 265 that compels hydrogeologic investigation and well installation. 4. Once application due date has passed, amend complaint and have o/o proceed with aspects of model remedy that rely on authority of Part 270.	1. §3008(a) enforcing Parts 265 and 270. 2. §3008(h) if there is evidence of a release of hazardous waste or constituents into the environment.

CHAPTER 6

DEVELOPING ORDERS

The purpose of this chapter is to help enforcement officials ensure that the ground-water remedy sought by the Agency is in fact executed by the respondent. The chapter will discuss the importance of specificity in detailing the desired remedy and various strategies that may be followed in developing and issuing orders. The chapter will concentrate exclusively on how to develop the technical content of compliance orders; it will not address legal issues related to writing orders or issuing complaints. Guidance on such issues is already available in the Compliance/Enforcement Guidance Manual dated September, 1984 (See especially Chapter 7, "Administrative Actions: Civil").

6.1 Importance of Specificity

The Agency's experience to date suggests that certain members of the regulated community have failed to implement a ground-water system capable of meeting the requirements of Parts 265 and 270. This is particularly true with respect to Part 265's broad performance standards and may increase with respect to Part 270 as Part B applications are filed. As Section 4.1.2 points out, even though the regulations do not specify in detail how a system should be designed and operated, the performance language demands a rigorous program of hydrogeologic investigation, network design, well construction, and sampling and analysis.

Despite the high standards set by the regulations, certain owner/operators have ignored this performance language and have installed only four wells (three downgradient and one upgradient), in settings whose complex hydrogeology require a substantially greater number of wells.

In light of the failure of certain facilities to achieve the high standards set by the regulations, it is essential that the Agency introduce specificity into the administrative enforcement process. In the course of each administrative proceeding there must develop between the Agency and the respondent an express understanding as to what activities will constitute compliance with the regulations. Administative orders that are explicit regarding the Agency's expectations can help ensure that the actions taken by the owner/operator will be sufficient to bring the facility into compliance. Specificity regarding what will be considered appropriate or adequate, can help avoid the wasted time and effort that results when a respondent performs actions later deemed inadequate. It is clearly in the best interest of both parties to ensure that the facility's first effort to come into compliance meets the Agency's requirements.

The Agency can secure this assurance either by reviewing the owner/operator's plans for coming into compliance before the work is actually performed or by specifying up front exactly what actions are required of the respondent. An order, therefore, can be structured in one of two ways. If issued prospectively, an order may be structured around the submittal, and subsequent Agency review, of individual plans outlining the respondent's proposed actions for implementing each phase (hereafter referred to as a

"phased order"). Alternately, the Agency can issue highly explicit orders that define technically what the owner/operator must do to come into compliance.

The next two sections of this document explain the above two types of order in greater detail. Both orders place the burden of system design on the respondent, yet provide the Agency with an opportunity to veto any design before the system is actually implemented. When issuing either type of order, enforcement officials must make clear that notwithstanding compliance with the order, the respondent remains responsible for compliance and abatement of any ground-water contamination. A specific provision should be included in all orders noting that the respondent may be required to take further actions as necessary to comply with RCRA or other applicable laws.

6.2 Phased Orders for Ground-Water Monitoring Violations

The concept of phased orders is relatively new to the RCRA program. As its name implies, a phased order lays out a series of actions the respondent must take over time in order to come into compliance. Each action or phase is linked to an enforceable compliance schedule and generally includes some mandatory interaction between the respondent and the Agency. Most commonly, each phase will include the development of a plan by the respondent to accomplish a specified goal; the submittal of the plan to the Agency for review, modification, or approval; and the eventual execution of the plan by the facility owner.

A phased order format is especially well suited for addressing ground-water monitoring violations at hazardous waste facilities. In many ground-

water cases, the nature of the violation is such that neither the facility nor the Agency knows at the outset exactly what actions will be necessary and sufficient to bring a facility into compliance. Many ground-water violations, for example, derive directly from a facility's lack of understanding of the hydrogeology beneath their site. As more information is collected and interpreted, the steps appropriate for a respondent to take may change. Developing a technical remedy under such circumstances is, of necessity, a dynamic process.

A phased order, however, can accomodate these changes. By proceeding in stages, a phased order allows the Agency to structure and guide a facility's actions without locking the facility or the Agency into a specific remedy that may prove inadequate. Moreover, the order provides a mechanism for the Agency to communicate more specifically EPA's expectations regarding various aspects of the owner/operator's response. For example, the Agency can set out in the order the information a hydrogeologic assessment must yield in order to provide the level of detailed understanding the Agency considers necessary for the installation of an adequate ground-water monitoring system. Where the Agency has specific preferences on how certain types of information should be obtained (e.g., a preference for specific tests or procedures), enforcement officials can specify the use of the test in the order. Alternately, an order may list objectives or considerations that an owner/operator must incorporate into his/her decision-making. The order might specify, for example, that the owner/operator must demonstrate in the plan that a proposed sampling device: 1) minimizes the potential for degassing; and 2) minimizes the potential for adsorption and desorption of constituents.

Appendix A includes a sample order that illustrates some of the above options. This order is structured around the needs of the "transition facility" described in Chapter 5; recall that this facility has an inadequate detection monitoring system and has not detected a significant change in the Part 265 indicator parameters. The preferred technical and enforcement response for such a facility is summarized below.

Action on the Part of Facility Owner	Enforcement Authority
1) Conduct detailed assessment of site's hydrogeology (fill in gaps in current understanding of site's subsurface).	1. §265.91(a) §270.14(c)(2)
2) Install a monitoring network (modify/expand an existing system) to meet the objectives of 265/264 detection.	2. §265.91
3) Sample for an expanded list of indicator parameters.	3. §270.14(c)(4)
4) Determine whether contamination has occurred by comparing upgradient and downgradient well samples collected on an accelerated schedule.	. . . . .
5) If contamination is confirmed, begin characterizing the plume based on monitoring of Appendix VIII constituents.	. .

To implement this remedy, the sample order in Appendix A mandates the execution of six tasks:

1) Submittal of a plan to conduct a hydrogeologic assessment of the site;

2) Submittal of a list of constituents or parameters to be monitored for (Note: sampling protocol and well construction materials will be dictated by chosen indicator parameters);

3) Submittal of proposed monitoring network, including well locations, screening depths, construction methods, and design specifications (e.g., filter pack material, slot size, well diameter);

4) Submittal of a sampling and analysis plan;

5) Execution of the plans developed in steps 1, 3, and 4 (following Agency approval);

6) If contamination is confirmed, submittal of a plan outlining proposed assessment activities.

The order combines these tasks into three phases and establishes compliance deadlines for each phase. For example, the order requires the owner/operator to develop and submit the hydrogeologic assessment plan and the list of parameters by the same date (phase 1). Next, the order instructs the respondent to complete the assessment and submit the results of the investigation along with a monitoring network plan and a sampling and analysis plan by the next compliance date (phase 2). After EPA approves or modifies these plans, the order requires the respondent to make the first determination of contamination and submit the results and an assessment plan (if contamination is confirmed) by the final date (phase 3).

The sample order combines the required tasks in the above manner for the purpose of illustration only. In every case, the logical sequence of events will be dictated by the particulars of the site. Enforcement officials must use professional judgement when deciding which tasks are appropriate, how they should be combined, and what level of Agency/facility interaction the order should mandate.

6.3 Technically Specific Orders

Rather than structure the development of the technical remedy through the order itself, enforcement officials may prefer to oversee the collection of background data and the development of a proposed remedy through informal interaction and negotiations with the facility. This approach is acceptable

as long as the work done in preparation of the remedy (e.g., hydrogeologic assessment activities), and the final terms of the remedy itself (e.g., well locations, sampling schedules), are set out in a technically-specific order (usually on consent). The order may be issued before the wells are installed and the sampling conducted, or it may be issued afterwards. If negotiations become protracted and work is not proceeding expeditiously, however, the Region should issue the order and place the facility on an enforceable compliance schedule.

Whether the work is conducted before the order is issued or after, detail in the order regarding completed and proposed work will help avoid future questions of compliance with the order. The greater the specificity in the order, the easier it will be for the Agency or a court to determine whether the terms of the agreement have been met.

Enforcement officials should not underestimate the level of detail that can be incorporated into orders. Well design specifications, decontamination procedures, and sampling frequencies are all suitable for specification. In addition, enforcement officials should consider specifying certain behaviors or actions on the part of the respondent. For example, officials may wish to require that a qualified geologist be present to take field notes (e.g. drilling logs and boring logs) during all well installations and soil boring programs.

No requirement is inappropriate if it is directly related to the ability of the owner/operator to meet his regulatory obligations. Table 6.1 summarizes some of the items enforcement officials may wish to consider when developing orders.

Table 6.1 Possible Elements of a Technically-Specific Order

HYDROGEOLOGIC ASSESSMENT

Boring Program

- o Spacing of boreholes
- o Depth and location of boreholes
- o Vertical spacing of samples within each borehole
- o Sampling equipment to be used for boring program
- o Information to be logged for each borehole
- o Requirement that hydrogeologist or geotechnical engineer be present to log boreholes
- o Method for stabilizing selected boreholes until wells are installed
- o Method of data presentation
- o Requirement to use Unified Soil Classification System (USCS), Atterberg limits

Water Level Monitoring Program

- o Spacing/number of piezometers or wells
- o Method for water level measurements
- o Required precision of measurement (to the nearest 0.1 foot or to the nearest centimeter)
- o Requirement that measuring points be surveyed from established benchmarks
- o Number of hydrogeologic cross sections and appropriate scale
- o Water level contour maps
- o Identification of local sources of ground-water withdrawal and recharge and approximate schedule of use

Hydraulic Conductivities

- o Method of determining hydraulic conductivities, porosity

Additional Information Requirements

- o Description of regional geologic and hydrogeologic characteristics
- o Analysis of geomorphic or topographic features that might influence ground-water flow system
- o Zones of higher or lower permeability that might direct or restrict flow of contaminents
- o Zones of significant fracturing or channeling in consolidated deposits
- o Sand or gravel deposits in unconsolidated deposits
- o Description of manmade hydraulic structures (pipelines, french drains, ditches, etc.)
- o Soil properties including cation exchange capacity, organic content temperature profile, grain size distribution

Additional Information (continued)

- o Identification of zones of recharge and discharge
- o Interpretation of hydraulic interconnections between saturated zones

NETWORK DESIGN

Placement of Wells

- o Maximum horizontal spacings
- o Requirement for well clusters
- o Depth requirements (most in surficial aquifer, one or more in deeper aquifer
- o Exact well locations
- o Minimum number of background wells

Well Design and Construction

- o Casing material and diameter; prohibition against joining section with glues or sealants
- o Screen slot size and maximum length
- o Drilling techniques; prohibition on use of drilling muds
- o Drill decontamination procedures
- o Well development techniques; prohibition on use of water other than formation water or "certified" pure water
- o Filter pack material and method of filter-pack emplacement
- o Method and material for sealing annular space
- o Requirement for locked well caps
- o Requirement that wells be designed to last at least 30 years
- o Requirement that wells yielding turbid samples be redeveloped or replaced
- o Information to be documented during construction of each well

SAMPLING AND ANALYSIS

Analytes of Interest

- o List of parameters to be monitored for
- o Requirement to collect data on major ions and anions, e.g., Cl^-, Fe, Mn, Na^+, Ca^+, Mg^+, NO_3^-, $PO_4^=$, silicate, ammonium, alkalinity, acidity.
- o Requirement for field monitoring of pH, conductivity, and temperature for each sample

Sample Collection

- o Evacuation procedures; handling procedures for evacuation water
- o Method for sampling "floaters" and "sinkers"

Sample Collection (continued)

- o Acceptable materials for inclusion in sampling devices and/or specific device to be used
- o Performance standard for sample collection - "sampling device and methodology must be selected to yield representative samples in light of the parameters that are being monitored"
- o Requirement that sampling devices be dedicated to each well or procedures for decontaminating equipment between wells
- o Precautions on use of specific sampling devices (e.g., bladder pumps must be operated in a continuous manner so that they do not produce pulsating samples that are aerated in the return tube upon discharge; check valves must be designed and inspected to ensure that fouling problems do not reduce delivery capabilities or result in aeration of sample, etc.)
- o Specification of acceptable cords/cables to be used to lower bailers; prohibitions on use of braided cables, polyethylene or nylon cords
- o Maximum sampling rates, generally not to exceed 100 milliliters/minute

SAMPLING PRESERVATION AND HANDLING

- o Designation of appropriate sample containers - polyethylene containers with polypropylene caps when metals are analytes of interest; glass containers when organics are analytes of interest
- o Requirement to use preservation methods designated in SW-846
- o Preferred handling procedures e.g., volatile organics: no filtering or headspace in containers allowed; metals: two aliquots from each sample - one filtered and analyzed for dissolved metals, and one not-filtered and analyzed for total recoverable metals

ANALYSIS

- o Requirement for use of field blanks, standards, and spiked samples for QA/QC
- o Requirement to use analytical methods described in SW-846
- o Requirement to perform field analysis of pH, conductivity, and temperature

CHAIN OF CUSTODY

- o Minimum requirements for chain-of-custody program (e.g., sample labels, seals field log book, chain of custody record, sample analysis request sheet, laboratory log book)

DATA REVIEW AND PRESENTATION

- o Standard protocol for reporting of less than detection limit concentrations
- o Requirement that data values for each pollutant be reported using the same number of significant digits, in general at least three

DATA REVIEW AND PRESENTATION (continued)

- Requirement that units of measure for a given chemical parameter be consistent throughout report and accompany each chemical named
- Requirement that raw data be submitted in a table that lists for each concentration value: the pollutant, the well code, and the unit of measure
- Requirement that owner/operator compile the following ten statistics for each of four summary tables organized by pollutant; by pollutant-well; by pollutant-date; and by pollutant-well-date:
    - Number of lower than detection limit values
    - Total number of values
    - Mean
    - Median
    - Variance
    - Standard Variation
    - Coefficient of variation
    - Range
    - Minimum value
    - Maximum value

ADDITIONAL PLUME CHARACTERIZATION ACTIVITIES

- Requirement to use certain remote sensing (e.g., aerial photography) and geophysical techniques (e.g., electrical resistivity, ground-penetrating radar, borehole geophysics)
- Requirement to determine the physical and chemical characteristics of the facility's leachate including density, solubility, vapor pressure, viscosity, and octanol-water partition coefficient

PERMIT APPLICATION REQUIREMENTS

- Requirement to collect background data on all Appendix VIII constituents detected in ground water
- Requirement to submit applicable data, studies, and plans detailed in §270.14(c)(1) - (8)

OTHER PROVISIONS

- Schedule for implementation including stipulated penalties for missed milestones
- Penalties for past and present violations
- Procedures for plan submittal, modification, and/or approval
- Provision that incorporates all plans, reports, and schedules required by the ORDER into the ORDER itself such that any non-compliance with a plan, report or schedule consitutes non-compliance with the order

OTHER PROVISIONS (continued)

- o Clause that reserves government's right to take further action as necessary, including additional ground-water monitoring and/or cleanup, to bring respondent into compliance with RCRA other applicable State or Federal law
- o Requirement to develop and implement a community relations plan
- o Requirement to develop and implement a health and safety plan for workers involved with monitoring or corrective action
- o Requirement to designate corporate contact person, supply corporate organizational charts, and provide background information and qualifications of any contractors used to meet the terms of the ORDER
- o Clause guaranteeing site access for employees, agents or contractors of complainant to inspect and evaluate compliance with ORDER pursuant to authority in §3007 of RCRA 42 USC §6927
- o Requirement to develop Quality Assurance Project Plan in accordance with EPA guidance document QAMS - 005/80.
- o EPA idemnification clause
- o Clause guaranteeing EPA's right to take or split samples
- o Clause establishing EPA's ability to halt work if necessary
- o Effective date
- o Signature

6.4 §3008(a) Orders

The §3008(a) process can accomodate the issuance of either phased or technically-specific orders. In fact, a single order may incorporate both approaches.

The process of issuing a §3008(a) order is diagrammed in Appendix B. Briefly, the process involves the issuance of a complaint and compliance order followed by negotiations (if desired by both parties), a hearing (if requested by the respondent) and the issuance of a consent order or a final unilateral order. If a respondent does not answer the complaint, (s)he become subject to a default order. Generally, a respondent answers the complaint, requests a hearing, and then either enters into a consent agreement with the Agency or proceeds through the hearing and becomes subject to a final order issued unilaterally.

If the Agency feels confident that a particular respondent will not default, the compliance order issued with the complaint may include a broadly-stated remedy such as "compliance with Part 265 Subpart F and Part 270." Since the respondent is required to undertake remedial activities and/or pay any assessed penalty only after the consent order or final order is issued, it is only in the consent or final order that specificity becomes critical. Some Regions seem to prefer compliance orders with broadly-stated remedies, although developing a phased compliance order, which would require the respondent to develop detailed plans, should prove to be fairly simple in most cases.

The Regions should try to avoid the situation where a broadly-stated compliance order is issued with the complaint, the respondent fails to answer, and a default order is issued. In this case the terms of the compliance order may become the terms of the default order. Although respondents do not usually fail to answer complaints, especially when sizeable penalties are involved, the Region should consider the possibility of a respondent failing to answer, before deciding on a format for the compliance order.

The following describes in more detail the options available under §3008(a):

OPTION (1): The Region may issue a complaint with a phased compliance order, enter negotiations with the respondent and then follow one of several courses of action, depending on whether a settlement is reached with the respondent. If both parties are willing to settle and can reach agreement on the remedy, a consent order may be negotiated in either a phased or a technically-specific format, depending on how detailed the discussions have been in negotiating sessions. If in the course of negotiations the facility has filled in any gaps in the hydrogeologic study and the Region and respondent have agreed on such details as the list of indicator parameters and the location of wells, a consent order could be negotiated that specifies the location of wells, construction specifications, etc. The order might also specify sampling and analytical procedures and schedules, or it might require the respondent to develop and submit a plan for sampling and analysis. As noted in section 5.2, the Region might choose to enter into a consent agreement only after completion of the remedial activities by the respondent. In such

cases, the consent order should document, in detail, the work that has been completed by the respondent.

If the parties are unable to reach settlement and a hearing takes place, the Region will have the opportunity to submit a proposed final order to the Presiding Officer. The proposed final order may be phased or may be technically specific, depending on the amount of information available to the Region. In any case, the proposed order should not simply include a broad mandate, like "the owner/operator must come into compliance with Part 265 Subpart F and Part 270." It should either specify a detailed remedy itself or should require the owner/operator to develop a plan that specifies details. Unless it is clear to both parties what the order requires, it will be difficult to determine whether the facility in fact achieves compliance. If there is room for dispute as to what the order requires, it may be difficult for the Agency to enforce the terms of the order, should that later become necessary.

OPTION (2): The Region may issue a complaint with a proposed compliance order that simply requires "compliance with Part 265 Subpart F and Part 270" rather than a phased compliance order. The steps following complaint issuance would be the same as those described in Option 1. Although it is acceptable to put a broad remedy in the initial compliance order, the consent order or proposed final order must contain specificity (or require the respondent to propose the specifics). When the order goes into effect it must express what "compliance" entails. As described earlier, the Region should not use a vaguely-worded compliance order if there is a chance that the respondent will not answer the complaint.

6.5 §3013 Orders

Section 3013 orders can be issued in either a one- or two-step process. Both processes are adaptable to the issuance of either phased or specific orders. The one-step process involves one of the following:

- o issuance of a phased order requiring the sequential development, submittal, and execution of plans; or
- o issuance of a technically-specific order, after the details are worked out in negotiations with the respondent.

The two-step process involves the issuance of a preliminary order requiring the development and submittal of plans for approval, followed by the issuance of an order requiring the execution of the plans as modified by the Agency. The second order could be phased or specific, depending on the amount of information available. For example, if the remedy sought by the Agency included a significant amount of hydrogeologic investigation as well as construction and sampling of wells, the preliminary order might require the development of a plan for the hydrogeologic study and a schedule for the development and implementation of plans for later stages of the remedy. The second order would then require the owner/operator to conduct the hydrogeologic work and then sequentially develop, submit, and carry out plans for well construction and sampling.

Alternatively, the preliminary order could require the development of well construction and sampling plans, which would entail conducting a hydrogeologic investigation. The second order then would be able to specify detail as to the locations and specifications of the wells and plans for sampling and analysis.

6.6 §3008(h) Orders

Section 3008(h) orders can accomodate both phased and specific orders in a manner similar to that described in section 6.4 for §3008(a) orders.

APPENDIX A:

MODEL PHASED ORDER FOR GROUND-WATER MONITORING

EXAMPLE PHASED ORDER

Pursuant to Section(s) _____ of the Resource Conservation and Recovery Act (RCRA), 42 U.S.C. 69__ it is ordered that _____ shall comply with the following requirements:

1. Within __ calendar days of the effective date of this ORDER, respondent shall develop and submit for EPA approval a plan for conducting a hydrogeologic investigation of the site. The plan should be designed to provide the following information:

   a. A description of the regional geologic and hydrogeologic characteristics in the vicinity, including:

      1) regional stratigraphy: description of strata including strike and dip, identification of stratigraphic contacts, petrographic analysis

      2) structural geology: description of local and regional structural features (e.g., folding, faulting, tilting, jointing, etc)

      3) depositional history

      4) regional ground-water flow patterns

      5) identification and characterization of areas of recharge and discharge

   b. An analysis of any topographic features that might influence the ground-water flow system (Note that stereoscopic analysis of aerial photographs should aid in this analysis).

   c. A classification and description of the hydrogeologic properties of all the hydrogeologic units found at the site (i.e., the aquifers and any intervening saturated and unsaturated units), including:

      1) hydraulic conductivity, effective porosity

      2) lithology, grain size, sorting, degree of cementation

      3) an interpretation of hydraulic interconnections between saturated zones

d. Using a topographic map or aerial photograph as a base, submit maps of structural geology and at least four hydrogeologic cross sections showing the extent (depth, thickness, lateral extent) of all hydrogeologic units within the facility property, identifying:

   1) sand and gravel deposits in unconsolidated deposits

   2) zones of fracturing or channeling in consolidated deposits

   3) zones of higher permeability or lower permeability that might direct or restrict the flow of contaminants

   4) perched aquifers

   5) the uppermost aquifer (includes all water-bearing zones above the first confining layer that may serve as a pathway for contaminant migration including perched zones of saturation)

e. A description of water level or fluid pressure monitoring including:

   1) water-level contour and/or potentiometric maps

   2) hydrologic cross sections showing vertical gradients

   3) an interpretation of the flow system, including the vertical and horizontal components of flow

   4) an interpretation of any change in hydraulic gradients due, for instance, to tidal or seasonal influences

f. A desciption of manmade influences that may affect the hydrogeology of the site, identifying:

   1) local water-supply and production wells with an approximate schedule of pumping

   2) manmade hydraulic structures (pipelines, french drains, ditches)

The plan should include a description of the field methods and other information sources proposed for the study and a summary of which data will be collected by each method. The proposed methods should include, but are not limited to:

a. A program of soil borings, as required to adequately describe the subsurface geology of the site. The program should provide for the presence of a qualified geologist or geotechnical

engineer to log and describe the materials encountered during the boring. The program should also describe the methods proposed to stabilize selected holes until monitoring wells are installed.

b. A sufficient number of piezometers to characterize ground-water depth and gradient (both horizontal and vertical) over the entire area of the site.

c. The use of slug and/or pump tests as appropriate to determine hydraulic conductivities

NOTE: Geophysical techniques, both borehole and surficial, are effective supplementary investigative techniques that should be considered

The plan shall contain a schedule for conducting the proposed hydrogeologic assessment and shall be submitted to:

Deputy Director, Air and Waste Management Division
Environmental Protection Agency
444 RCRA Way
Anytown, USA 00001

2. Within ___ calendar days of the effective date of this ORDER, respondent shall develop and submit to EPA a list of proposed indicator parameters capable of detecting leakage of hazardous waste or hazardous constituents into ground water. The parameters should be representative of constituents at least as mobile as the most mobile constituents that could reasonably be derived from the facility's waste, and should be chosen after considering:

a. the types, quantities, and concentrations of constituents in wastes managed at the facility;

b. the mobility, stability, and persistence of waste constituents or their reaction products in the unsaturated zone beneath the waste management area;

c. the detectability of the indicator parameters, waste constituents or reaction products in ground water;

d. the concentration or value and the natural variation (known or suspected) of the proposed monitoring parameter in background ground water.

The list should include the basis for selecting each proposed indicator parameter, including any analyses or calculations performed. The basis for selection must include chemical analysis of the facility's waste and/or leachate as appropriate.

The list should also include parameters to characterize the site-specific chemistry of ground water at the site, including but not limited to the major anions and cations that make up the bulk of dissolved solids in water (i.e., Cl^-, Fe, Mn, Na^+, SO_4, Ca^+, Mg^+, K^+ NO^{-3}, $PO_4^=$, silicate, ammonium).

3. Within __ calendar days of written approval by EPA, the respondent shall promptly implement the hydrogeologic investigation plan according to the terms and schedules contained therein.

4. Within __ calendar days after completion of the hydrogeologic investigation, the respondent will submit to EPA a full report that provides the information described in paragraph 1.

5. Also within __ days after the completion of the hydrogeologic investigation, the respondent will submit to EPA a plan for the design and installation of a monitoring well network that will meet the following requirements:

   a. The upgradient wells must be capable of yielding samples that are representative of background water quality in the uppermost aquifer and are not affected by the facility. The number and location of the wells must be sufficient to: 1) characterize the spatial variability of background water; and 2) meet the needs of the statistical test proposed pursuant to paragraph __.

   b. The downgradient wells must be capable of immediately detecting any statistically significant amounts of hazardous waste or hazardous constituents that migrate from the facilty into the uppermost aquifer.

   c. The monitoring system should be designed to operate for a period of no less than thirty years.

   The plan should include the following elements:

   a. A description and map of proposed well locations, including a survey of each well's surface reference point and the elevation of its top of casing.

   b. Size and depth of wells;

   c. Desciption of well-intake design, including screen slot size and length; filter pack materials and method of filter-pack emplacement.

   d. Type of proposed well casing and screen materials. The choice of well materials should be made in light of the parameters to be monitored for and the nature of the leachate that could potentially migrate from the facility. The well materials should: 1) minimize the potential of adsorption and desorption of constituents from the samples; and 2) maintain their integrity for the expected life of the system (at least thirty years).

e. Methods used to seal the well from the surface and prevent downward migration of contaminants through the well annulus.

f. Description of the methods or procedures used to develop the wells.

6. Also within ___ days after the completion of the hydrogeologic assessment, the Respondent shall sumbit a sampling and analysis plan capable of yielding representative samples for a comparison of up- and downgradient wells. The plan should include the following elements:

a. Well evacuation procedures including volume to be evacuated prior to sampling and handling procedures for purged well water

b. Sample withdrawal techniques. Sampling equipment and materials (tubing, rope, pumps, etc.) shall be selected to yield representative samples in light of parameters to be monitored for. The sampling protocol will include field measurement of pH, conductivity, and temperature for each sample.

c. Sample handling and preservation techniques including provision for field-filtration of samples as appropriate.

d. Procedures for decontaminating sampling equipment between sampling events.

e. Procedures for measuring ground-water elevations at each sampling event

f. Chain of custody procedures to be used for all phases of sample management.

g. Laboratory analytical techniques, including EPA-approved analytical methods and quality assurance, detection levels, quality control procedures.

h. Procedures for performing a comparison of upgradient and downgradient ground water to determine whether contamination has occurred. The procedures should include:

1) A proposed method (statistical or otherwise) to compare upgradient and downdradient well water that provides a reasonable balance between the probability of falsely identifying and failing to identify contamination.

2) An accelerated sampling schedule to establish data for the comparison. In no instance shall sampling exceed __ months.

3) A proposed method for data organization and presentation.

7. By no later than __ days after EPA approval of the monitoring well network plan, Respondent shall complete the installation of the monitoring well network.

8. By no later than __ days after the installation of the monitoring well network, Respondent shall implement the sample and analysis plan, perform the comparison and submit the results to EPA for review.

9. If there is a statistically significant difference between upgradient and downgradient well water, the Respondent will develop a ground-water assessment plan capable of determining the following:

   a. The extent of migration of hazardous constituents into ground water.

   b. The concentration of each Appendix VIII constituent throughout the plume or the maximum concentration of each Appendix VIII in the plume.

   c. Background concentrations for all Appendix VIII constituents detected in ground water.

   d. Waste/leachate characteristics including specific gravity, viscosity, solubility in water, and octanol-water partition coefficient.

   e. Soil properties including cation exchange capacity, organic content, and temperature.

   The plan should describe the methods proposed to accomplish the above objectives including indirect and direct techniques. The sampling and analysis plan developed pursuant to paragraph 6 should be revised to meet the new objectives of this monitoring phase. The plan should include an expeditious schedule for the implementation of the above assessment, and should be submitted to EPA no later than 15 days after the confirmation of leakage.

10. Within __ calendar days of EPA approval of the assessment plan, the Respondent will begin to execute the plan according to the terms and schedules contained therein. Within __ days of the completion of the assessment, the Respondent will submit the results to the Agency, including all raw data collected, all calculations performed, and an interpretation of the findings.

11. Based on the results of the ground-water assessment, the Respondent will fulfill his/her obligations pursuant to §270.14(c)(7) or (8) by developing a compliance monitoring and/or corrective action program as appropriate. Respondent will submit whatever plans and engineering studies are necessary to describe the proposed program to EPA no later than ___ months after the completion of the ground-water assessment described in paragraph nine.

12. All plans, reports, and schedules required by the terms of this ORDER are, upon approval by EPA, incorporated into this ORDER. Any noncompliance with such approved studies, reports, or schedules shall be termed noncompliance with this ORDER.

13. In the event of Agency disapproval (in whole or in part) of any plan required by this ORDER, EPA shall specify any deficiencies in writing. The Respondent shall modify the plan to correct the deficiencies within ___ days from receipt of disapproval by EPA. The modified plan shall be submitted to EPA in writing for review.

    Should the Respondent take exception to all or part of EPA's disapproval, the Respondent shall submit to EPA a written statement of the grounds for the exception. Representatives of EPA and the Respondent may confer in person or by telephone in an attempt to resolve any disagreement. If agreement is reached, the resolution shall be written and signed by representatives of each party. In the event that resolution is not reached within 15 days, the Respondent shall modify the plan as required by EPA.

14. In the event that the respondent fails to:

    a. Comply with the milestones contained in paragraphs 3, 7, 8, or 10;

    b. Provide the plans and information described in paragraphs 1, 2, 4, 5, 6, 8, 9, 10, or 11;

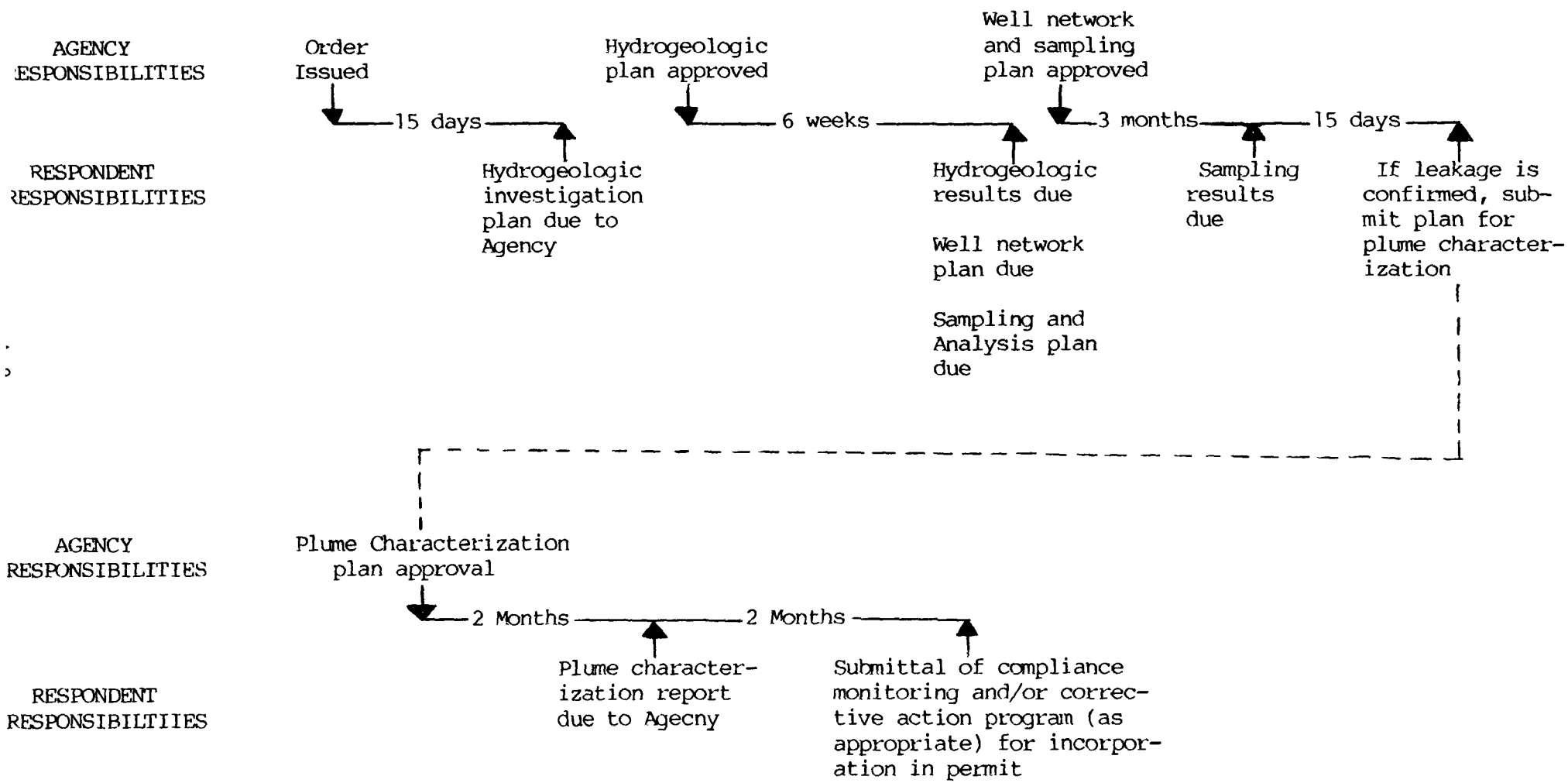
    (s)he shall pay stipulated penalties from the date of the violation as follows:

    a. $5000.00 per day for failure to comply with a milestone listed above;

    b. $1000.00 per day for failure to provide a plan or information listed above.

15. Notwithstanding compliance with the terms of this ORDER, Respondent may be required to take further actions as necessary, including additional ground-water monitoring, assessment, and/or corrective action, to come into compliance with RCRA, or other applicable state or Federal laws.

ENFORCEABLE COMPLIANCE SCHEDULE FOR MODEL ORDER

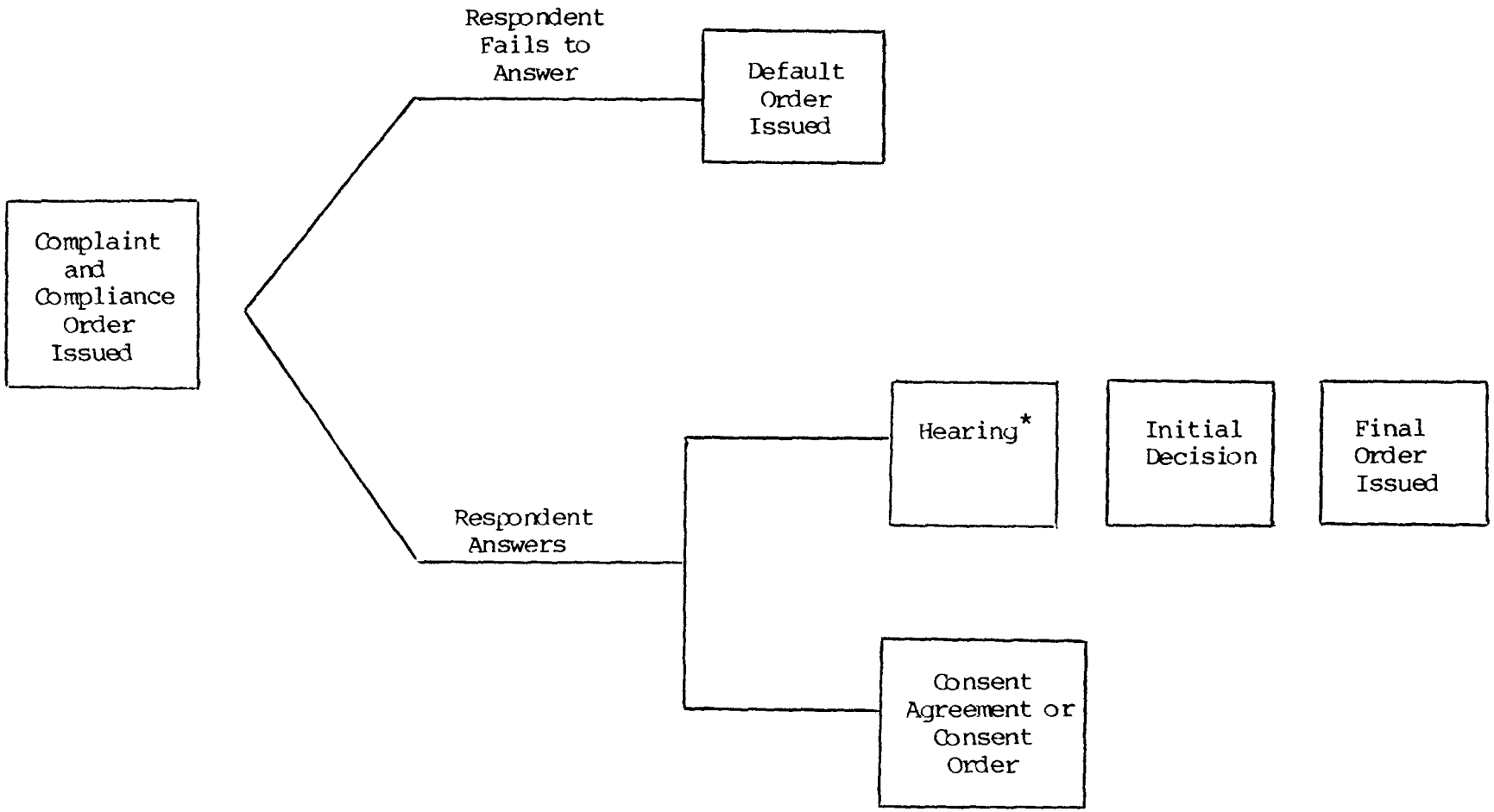


NOTE: Timeframes must be adjusted to accomodate site-specific factors

APPENDIX B:

DIAGRAM OF PART 22 ADMINISTRATIVE PROCEEDINGS

PART 22 - FORMAL ADMINISTRATIVE PROCEEDINGS



*Within 20 days after the parties are notified of the availability of the hearing transcript, any party may submit for consideration, proposed findings of fact, conclusions of law, and a proposed order, togeter with supporting briefs.

RCRA Ground-Water Monitoring Technical Enforcement Guidance Document

Draft

August, 1985

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CHAPTER ONE

CHARACTERIZATION OF SITE HYDROGEOLOGY

The adequacy of an owner/operator's ground-water monitoring program hinges, in large part, on the quality and quantity of the hydrogeologic data the owner/operator used in designing the program. Enforcement officials, therefore, should evaluate the adequacy of an owner/operator's hydrogeologic assessment as a first step towards ascertaining the overall adequacy of the detection and/or assessment monitoring network. Clearly, if the design of the well system is based upon poor data, the system cannot fulfill its intended purpose.

In performing this evaluation, enforcement officials should ask themselves two questions.

- Has the owner/operator collected enough information to: (1) have an understanding sufficient to identify potential contaminant pathways and (2) support the placement of wells capable of determining the facility's impact on the uppermost aquifer?

- Did the owner/operator use appropriate techniques to collect and interpret the information used to support well placements?

The answer to each question will, of course, depend on site specific factors. For example, sites with more heterogenous subsurfaces will require more hydrogeologic information to provide a reasonable assurance that well placements will intercept contaminant migration. Likewise, investigatory techniques that may be appropriate in one setting (given certain waste characteristics and geologic features), may be inappropriate in another.

This chapter is designed to help enforcement officials answer the above questions. It identifies various investigatory techniques that are necessary for an owner/operator to adequately characterize a site and explores the factors that enforcement officials should consider when

evaluating whether the particular investigatory program an owner/operator used was appropriate in a given case. Enforcement officials should also find this chapter useful when constructing compliance orders that include hydrogeologic investigations.

1.1 Investigatory Tasks for Hydrogeologic Assessments

In carrying out a hydrogeologic investigatory program, owner/operators should accomplish two tasks:

1. define the subsurface geology/materials; and
2. identify ground-water flow paths and rates.

A variety of investigatory techniques are available to achieve these goals and enforcement officials must evaluate whether the combination of techniques used by the owner/operator was adequate given the site specific factors at his/her facility.

There are certain investigatory techniques that all owner/operators, at a minimum, should have used to characterize their sites. Table 1-1 illustrates the universe of techniques that an owner/operator may use to perform hydrogeologic investigations. Those techniques that the owner/operator, at a minimum, should have used to define the subsurface geology or identify ground-water flow paths are identified with astericks.

Table 1-1 also presents preferred methods for presentation of the data generated from a hydrogeologic assessment. An owner/operator who has performed the level of site characterization that is necessary to design adequate ground-water monitoring programs will be able to supply any of the outputs (cross sections, maps, etc.) listed in the last column of Table 1-1 at an appropriate level of specificity.

The owner/operator's investigatory program should have included direct (e.g., borings, piezometer wells, geochemical analysis of soil samples) methods of determining the site hydrogeology. Indirect methods (e.g., aerial photography, ground penetrating radar, resistivity),

TABLE 1-1

HYDROGEOLOGIC INVESTIGATORY TECHNIQUES

INVESTIGATORY TASKS	INVESTIGATORY TECHNIQUES	DATA PRESENTATION FORMATS/ ASSESSMENT OUTPUTS
Definition of Subsurface Materials [geology]	✓ Soil borings and rock corings	✓ Narrative description of geology
	✓ Survey of existing geologic information	✓ Geologic cross sections
	✓ Material tests (grain size analyses, standard penetration tests, etc.)	✓ Geologic or soil map (1" = 200')
	• Geophysical well logs (resistivity and/or electromagnetic conductance, gamma ray, gamma density)	✓ Boring logs or coring logs
	• Surface geophysical surveys (D.C. resistivity, E.M., seismic)	• Structure contour maps of aquifer and aquitards (plan view)
	• Hydraulic conductivity measurements of cores (unsaturated zone)	• Raw data and interpretive analysis of geophysical studies
	• Aerial photography (fracture trace analysis)	✓ Raw data and interpretive analysis of material tests

(Continued)

TABLE 1-1 (Continued)

HYDROGEOLOGIC INVESTIGATORY TECHNIQUES

INVESTIGATORY TASKS	INVESTIGATORY TECHNIQUES	DATA PRESENTATION FORMATS/ ASSESSMENT OUTPUTS
Identification of Ground-Water Flowpaths [hydrology]	✓ Installation of piezometers; water level measurements at different depths	✓ Narrative description of ground-water with flow patterns
	✓ Slug tests and/or pump tests	✓ Water table or potentiometric maps (plan view) with flow lines (1" = 200')
Ground water flow directions (including vertical and horizontal components of flow)	• Tracer studies	✓ Hydrologic cross sections
Hydraulic conductivities		• Raw data and interpretive analysis of slug tests, pump tests and tracer studies

✓ Minimum techniques and corresponding outputs that should be used to define site hydrogeological conditions.

especially geophysical studies, may provide valuable sources of information that can be used to extrapolate geologic data between points where measurements with direct methods were made. However, pre-existing information or indirect methods will not alone have provided the detailed information necessary. The owner/operator's investigatory program will likely have combined the use of direct and indirect techniques and should have resulted in the complete characterization of the facility, including an identification of:

- the subsurface geology below the owner/operator's hazardous waste facility;
- the vertical and horizontal components of flow in the uppermost saturated zone below the owner/operator's site;
- the hydraulic conductivity of the uppermost saturated zone; and
- the vertical extent of the uppermost saturated unit down to the first confining layer.

The following sections outline the basic steps an owner/operator should have followed to implement an adequate site hydrogeologic study, and detail the methods that the owner/operator should have used to collect and present site hydrogeologic data.

1.2 Characterization of Subsurface Geology

In order to adequately detail the subsurface geology of the site, the owner/operator should have collected direct information identifying the lithology and structural characteristics of the subsurface. Indirect methods of geologic investigation such as geophysical studies, may be used to verify the evidence gathered by direct field methods but should not be used as a substitute for them. Geophysical studies such as seismic reflection, seismic refraction, geophysical well logging, and resistivity measurements may yield valuable information on the depth to bedrock, the types of unconsolidated material present in the subsurface soil and above bedrock, the presence of fracture zones or structural

discontinuity, and the depth to the water table. Additionally, geophysical methods may have their greatest utility in correlating the continuity of subsurface materials between boreholes. However, geophysical methods should have been used primarily to substantiate information obtained from direct sources, and in order to adequately characterize the lithology and geologic characteristics of the subsurface, the owner/operator should have used direct means of gathering hard data concerning the subsurface geologic constituents at the site. Specifically, all owner/operators should have implemented a site characterization boring program sufficient to characterize the subsurface geology below the the site.

1.2.1 Site Characterization Boring Program

The enforcement officer should determine whether an owner/operator's boring program was adequate to gather the information necessary to characterize the subsurface geology. Such a program should have entailed the installation of borings:

- at a preferred spacing of 300 feet. (Boring spacing may vary from this horizontal distance based on criteria described in Table 1-2.)
- that have been drilled to the depth of the first confining unit below the uppermost zone of saturation.
- that have continuous sample corings that have been logged in the field by a qualified geologist.
- that have had sufficient laboratory analysis to provide information as to the petrographic variation, mineralogic variation, sorting (for sedimentary units), moisture content and intrinsic permeability of each geologic unit or soil zone.

The final spacing between boreholes in an owner/operator's characterization program will ultimately, of course, depend upon site specific conditions. Usually, the boring program will be a progressive investigation where results from initial phases of study will guide subsequent decisions. For example, spacings between borings in the early phase of

TABLE 1-2

FACTORS INFLUENCING BORING WELL SPACING

FACTORS THAT MAY SUBSTANTIATE WIDER BORING SPACING:

- Simple geology (i.e., horizontal, thick, homogeneous geologic strata that are continuous across site that are unfractured and are substantiated by regional geologic information).
- Use of geophysical data to correlate well log data. Preferred methods: DC resistivity, seismic reflection or seismic refraction, geophysical well logging.
- Relatively constant hydraulic conductivity values between wells and no indication of proximal off-site influences on ground water (tidal effects, industrial, agricultural, domestic ground-water use, etc.)

FACTORS THAT MAY SUBSTANTIATE CLOSER SPACING:

- Fracture zones encountered during drilling.
- Suspected pinchout zones (i.e., discontinuous units across the site).
- Geologic formations that are tilted or folded.
- High zones of permeability that have not been defined by drilling at 300-foot intervals.
- Laterally transitional geologic units with irregular permeability (e.g., sedimentary facies changes).
- Ground-water features that are unexplained by 300-foot spacing (e.g., irregular or non-linear flow).
- Indication of proximal off-site influences on ground water.
- Non-uniform hydraulic conductivity values exist below the site.

the program may start at 300 feet. The information subsequently generated could dictate closer borings over part of the site and wider spacings between borings on other parts of the site.

The owner/operator should characterize site geology to the depth of the first confining layer below the uppermost saturated zone or ten feet into bedrock. This requires borings to be drilled to this depth. The owner/operator should drill enough borings to this depth to establish that the confining layer extends laterally across the entire site, is of sufficient thickness, and is sufficiently impermeable to impede the migration of contaminants to any stratigraphically lower, water-bearing units. (Refer to the glossary for the definition of confining layer.) It should be noted by the enforcement official that chemical bridging and transfer across, or chemical reaction with confining layer material, can occur. Therefore, the owner/operator should have addressed this problem by considering chemical compatibility of site-specific waste types and the geologic materials of the confining layer.

All coring samples should have been logged in the field by a qualified geologist (see glossary). These sample corings should have been collected with a shelby tube or split spoon sampler and represent a continuous coring of the subsurface. Drilling logs should have been prepared which detail the following information:

- gross petrography (e.g., rock type) of each geologic unit;
- gross mineralogy of each geologic unit;
- gross structural interpretation of each geologic unit and structural features crossing geologic stratum bioturbation (e.g., fractures, gouge material, solution channels, buried streams or valleys, etc.) including, when applicable, identification of depositional material;
- development of soil zones and vertical extent and description of soil type;
- depth of water bearing unit(s) and vertical extent of each;

- depth and reason for termination of borehole; and

- depth and location of any contaminant encountered in borehole. (Samples should have been collected and analyzed for Appendix VIII constituents in accordance with requirements of SW-846.)

Figure 1-1 identifies the minimum required information that should have been included in a drilling log. These items are marked with astericks.

In addition to field descriptions as described above, the owner/operator should have provided laboratory analysis of each geologic unit and soil zone. These analyses should contain the following information:

- mineralogy and mineralogic variation of each geologic unit (e.g., microscopic analysis and other methods such as X-ray diffraction as necessary);

- petrology and petrologic variation of each unit (e.g. petrographic analysis, other laboratory methods for unconsolidated materials) to determine:

  - degree of crystallinity and cementation of matrix
  - degree of sorting, size fraction, textural variation
  - rock type(s)
  - soil type
  - approximate bulk geochemistry
  - existence of microstructures that may effect or indicate fluid flow

- moisture content and moisture variation of each soil zone and geologic unit; and

- intrinsic permeability and variation of each soil zone and type and geologic unit in the unsaturated zone (indirect methods are not appropriate to determine hydraulic conductivity in the saturated zone, Section 1.3.2).

A table which describes the laboratory analysis methods necessary to provide adequate information to detail these laboratory parameters is shown in Table 1-3.

From a procedural standpoint, an owner/operator may opt to develop a scheme for selecting borehole locations in a step-wise or progressive

FIGURE 1-1

FIELD BORING LOG INFORMATION

General

- ● Project name
- *● Hole name/number
- *● Date started and finished
- *● Geologist's name
- *● Driller's name
- ● Sheet number
- *● Hole location; map and elevation
- *● Rig type
  bit size/auger size

Information Columns

- *● Depth
- *● Sample location/number
- ● Blow counts and advance rate
- *● Percent sample recovery
- *● Narrative description

Narrative Description

- ● Geologic observations:
  - *- rock type
  - *- color
  - *- gross mineralogy
  - *- gross petrography
  - - friability
  - *- moisture content
  - *- crystalinity
  - *- presence of carbonate (HCL)
  - *- fractures
  - *- solution cavities
  - *- bedding
  - *- depositional structures
  - *- organic content
  - *- odor
  - *- suspected contaminant
- ● Drilling Observations:
  - - loss of circulation
  - *- advance rates
  - - rig chatter
  - *- water levels
  - - amount of air used
  - *- drilling difficulties
  - *- changes in drilling method or equipment
  - *- ammounts and type of any liquids used
  - *- running sands
  - *- caving/hole stability
- ● Other Remarks:
  - - equipment failures
  - *- possible sources of contamination
  - *- deviations from drilling plan
  - *- weather

*Indicates items that the owner/operator should record, at a minimum.

TABLE 1-3

SUGGESTED LABORATORY METHODS FOR CORE SAMPLES

Sample Origin	Parameter	Laboratory Method	Used to Determine
Unsaturated zone	Intrinsic permeability	Falling head, static head test	Hydraulic conductivity
	Size fraction	Sieving Settling measurements	Hydraulic conductivity
	Sorting	Petrographic analysis	Hydraulic conductivity
	Specific yield	Column drawings	Porosity
	Specific retention	Centrifuge tests	Porosity
Geologic formation, unconsolidated sediments, consolidated sediments, solum	Mineralogy	Petrographic analysis	Soil type, rock type, geochemistry, potential flow paths
	Bulk geochemistry	X-ray diffraction	
	Crystallinity	Petrographic analysis	
	Roundness of grains	Petrographic analysis	
	Bedding	Petrographic analysis	
	Lamination	Petrographic analysis	
	Jointing	Petrographic analysis	
	Fracturing	Petrographic analysis	
	Sorting	Petrographic analysis	
	Solution features	Petrographic analysis	
Contaminated sample corings (e.g., soils producing higher than background organic vapor readings)	Appendix VIII (§261) Parameters	SW-846	

approach. A feature of this technique is that data and observations derived from previous boreholes are used to establish the location for the next boring. In this way, the general 300-foot borehole spacing guideline may be varied depending on the conditions encountered and logged in the previous boreholes. Such a progressive boring program is described below.

First, the owner/operator should project a grid pattern with a 300-foot interval across the site. Second, the owner/operator should initiate the boring and site characterization program, at one of the grid intersection points near the waste management area. After the completion of the first few borings, the owner/operator should check drill logs for:

- correlation of geologic profiles between soil borings;
- identification of zones of high potential hydraulic conductivity;
- indication of unusual or unpredicted geologic features such as fault zones, fracture traces, facies changes, dissolution features, buried channels, cross cutting structures, pinch out zones, etc.; and
- continuity of petrographic features such as sorting, grain size distribution, cementation, etc.

If the owner/operator is unable to adequately define such structural anomalies, zones of potential high conductivity, or to correlate petrographic features and/or geologic profiles between any two adjacent boreholes then additional intermediate boreholes should be drilled. The suggested method would be to drill intermediate boreholes, at a spacing of 150 feet and at successively shorter spacing intervals until the criteria outlined in the above bulleted items was adequately addressed.

On the other hand, if the bulleted parameters are achieved at the 300-foot spacing, it would be appropriate to switch to a wider spacing of 600 feet between adjacent boreholes. If at the 600-foot interval the criteria are again met, it would again be acceptable to switch to a wider grid spacing.

Figure 1-2 illustrates a site where an owner/operator initiated a progressive boring program. The first four borings were drilled in an area adjacent to the site that the owner/operator considered to be downgradient and thus critical to his characterization program. Drilling indicated thick massive marine sediments below a thin poorly developed soil zone. Geologic units were highly correlated and indicated little or no lateral variation in petrographic or structural components. A bedrock basement was identified in all borings and structural components of the basement/sediment interface were well defined. At this point the owner/operator switched to a wider spacing of 600 feet between boreholes. Additional borings indicated very little lateral variation and the owner/operator was justified in terminating borings at a 1200-foot interval.

At a second site, (see Figure 1-3) the owner/operator initiated his soil boring in a similar manner to that described in the first example. However, the geologic environment was more complex in nature, such as that of a fluvio-glacial depositional environment. Initial borings indicated that the subsurface was highly variable. Attempted correlation of buried structural features of high permeability and potential confining layers were inconsistent between boreholes. The owner/operator in this case switched to a shorter boring spacing of 150 linear feet. At this interval, the owner/operator was able to define some continuity between boreholes and structural features. These were still erratic but correlation between boreholes indicated that zones of high permeability and low permeability had been defined. Also at this point, the owner/operator was able to roughly determine the general ground-water directional flow and decided to concentrate further studies at the downgradient side of the waste management area. The owner/operator, at this point, initiated a geophysical surface resistivity study at the downgradient side of the waste management area and was able to support existing boring data with structural geophysical interpretation.

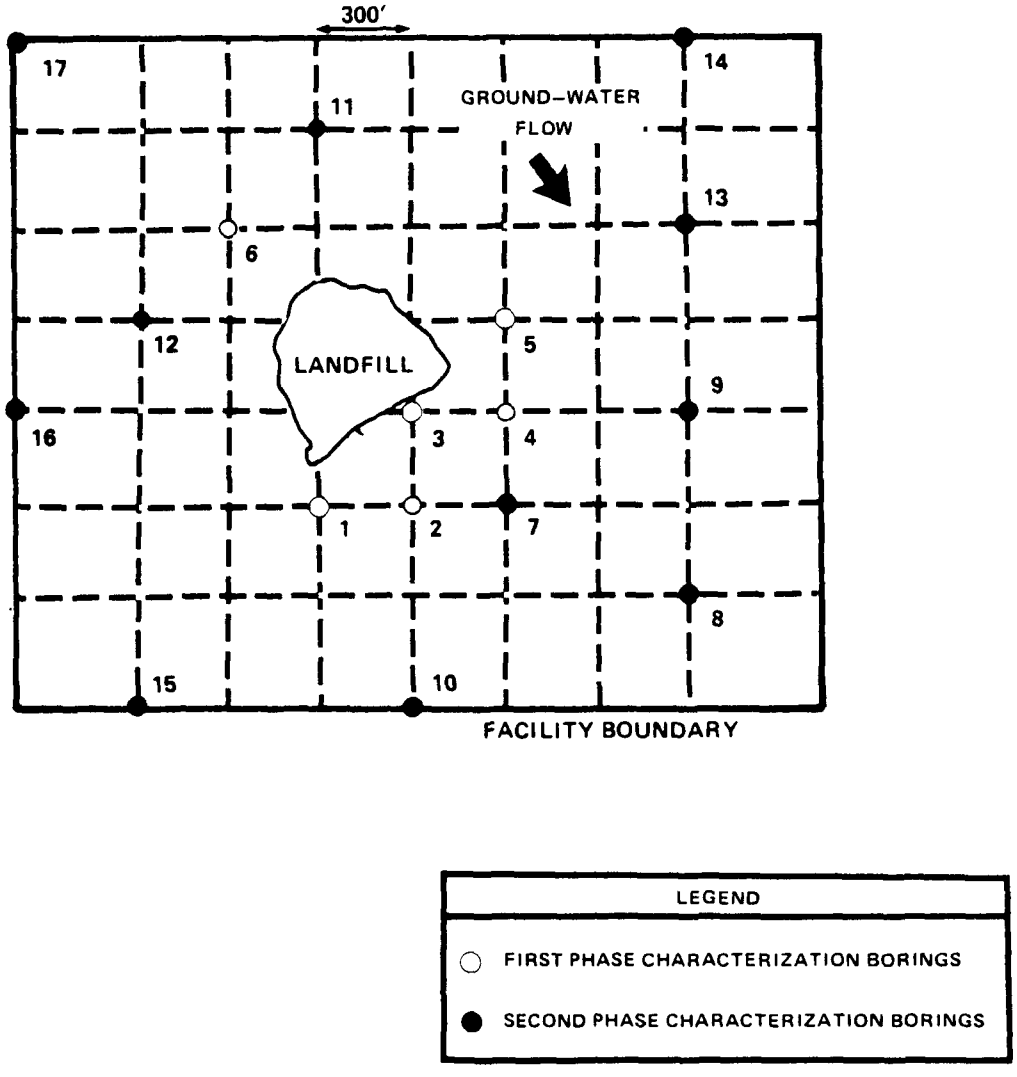

FIGURE 1-2 PROGRESSIVE BORING APPROACH : SCENARIO 1

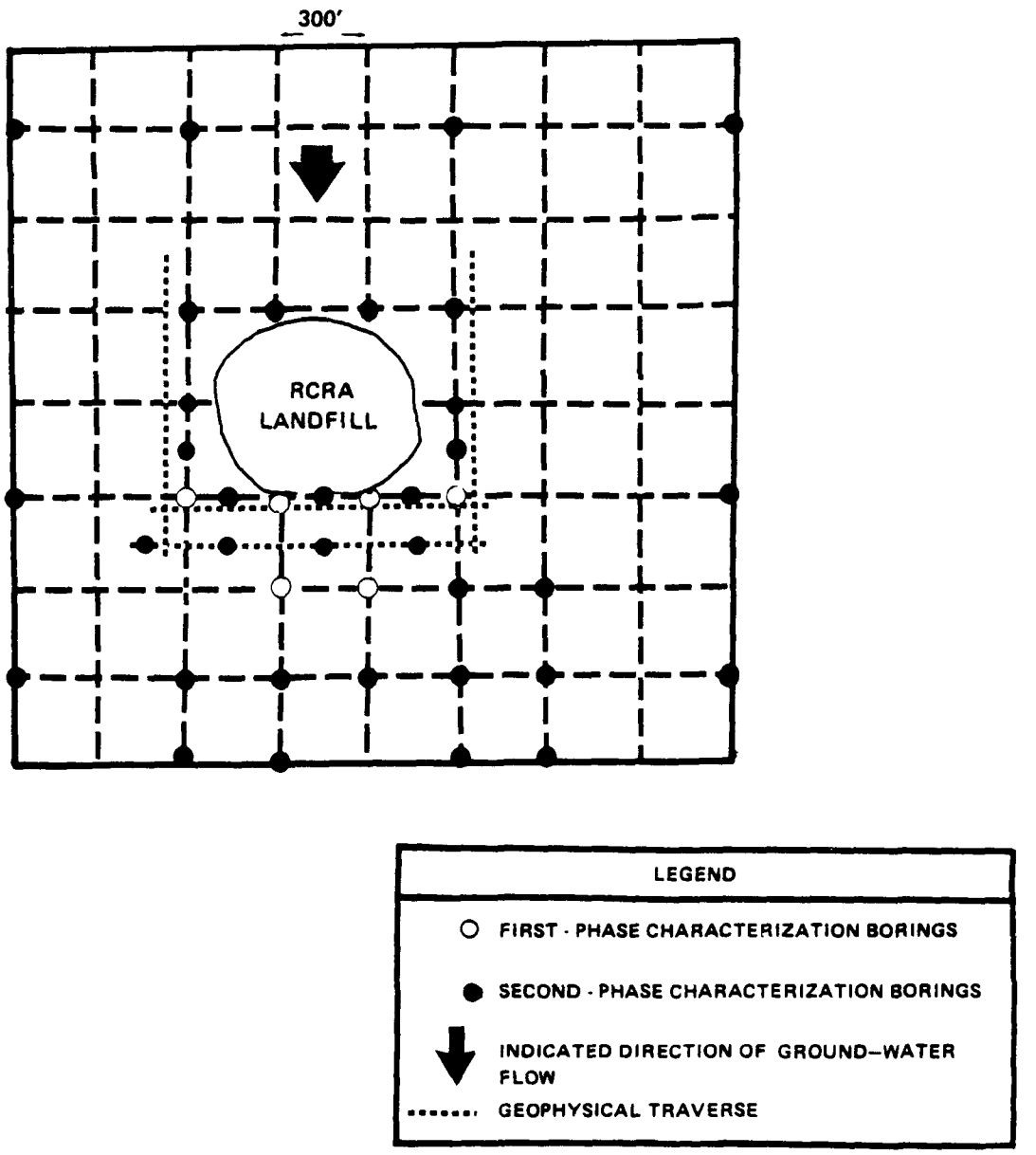

FIGURE 1-3 PROGRESSIVE BORING APPROACH: SCENARIO 2

1.2.2 Interpretation of Subsurface Geology

The enforcement official should review the owner/operator's geologic characterization and verify:

- completeness of the narrative and the accuracy of the owner/operator's interpretation, and
- that the geologic assessment addresses or provides means to resolve any information gaps that may be suggested by the geologic data.

In order to assess the completeness and accuracy of the owner/operator's narrative, the enforcement geologist should:

- examine and evaluate the raw data;
- compare his own interpretation based on the raw data alone,with that of the owner/operator; and
- identify information gaps that relate to incomplete data and/or to narrative presentation.

The enforcement officer should independently conduct the following tasks to support and develop his interpretation of the site geology:

- review drilling logs and identify major rock or soil types and establish their horizontal and vertical variability;
- construct representative cross sections from well log data;
- identify zones of suspected high permeability, or structures likely to influence contaminant migration through the unsaturated and saturated zones;
- review laboratory data and determine whether laboratory data adequately corroborates field data and that both are sufficient to define petrography and petrographic variation; and
- review mineralogic data and the owner/operator's assessment of general subsurface geochemistry and determine corroboration between analytic and field data.

After the enforcement official has interpreted the geologic data, the results should be compared to the results developed by the owner/operator. The enforcement official should:

- identify information gaps between narrative and data. Determine whether resolution requires collection of additional data or re-assessment of existing data; and

- identify any information gaps that will effect the owner/operator's ability to have adequately located his/her monitoring well system.

1.2.3 Presentation of Geologic Data

In addition to the generation and interpretation of site specific geologic data, the enforcement officer should review the owner/operator's presentation of data in geologic cross sections, topographic maps and aerial photographs. In part this requires that the enforcement officer to review the data and determine qualitatively whether information is accurate.

A minimum of four geologic cross sections should be presented by an owner/operator. These cross sections should adequately depict major geologic or structural trends and reflect geologic/structural features in relation to ground-water flow. As such, geologic cross sections should delineate such features in an orthogonal boxwork (see Figure 1-4) but nonlinear structural features or complex ground-water patterns may necessitate additional cross sections and/or nonorthogonal cross section presentation.

On each cross section, the owner/operator should have identified: the types and characteristics of the geologic materials present, the contact zones between different geologic materials, zones of high permeability or fracture, the location of each borehole, depth of termination, the screen location, and depth to the zone of saturation. If the owner/operator is unable to supply such details, the subsurface study may be inadequate. Figure 1-5 illustrates a typical, geologic cross section.

Additionally, surficial features may affect the subsurface hydrogeology. An owner/operator should have provided a surface topographic

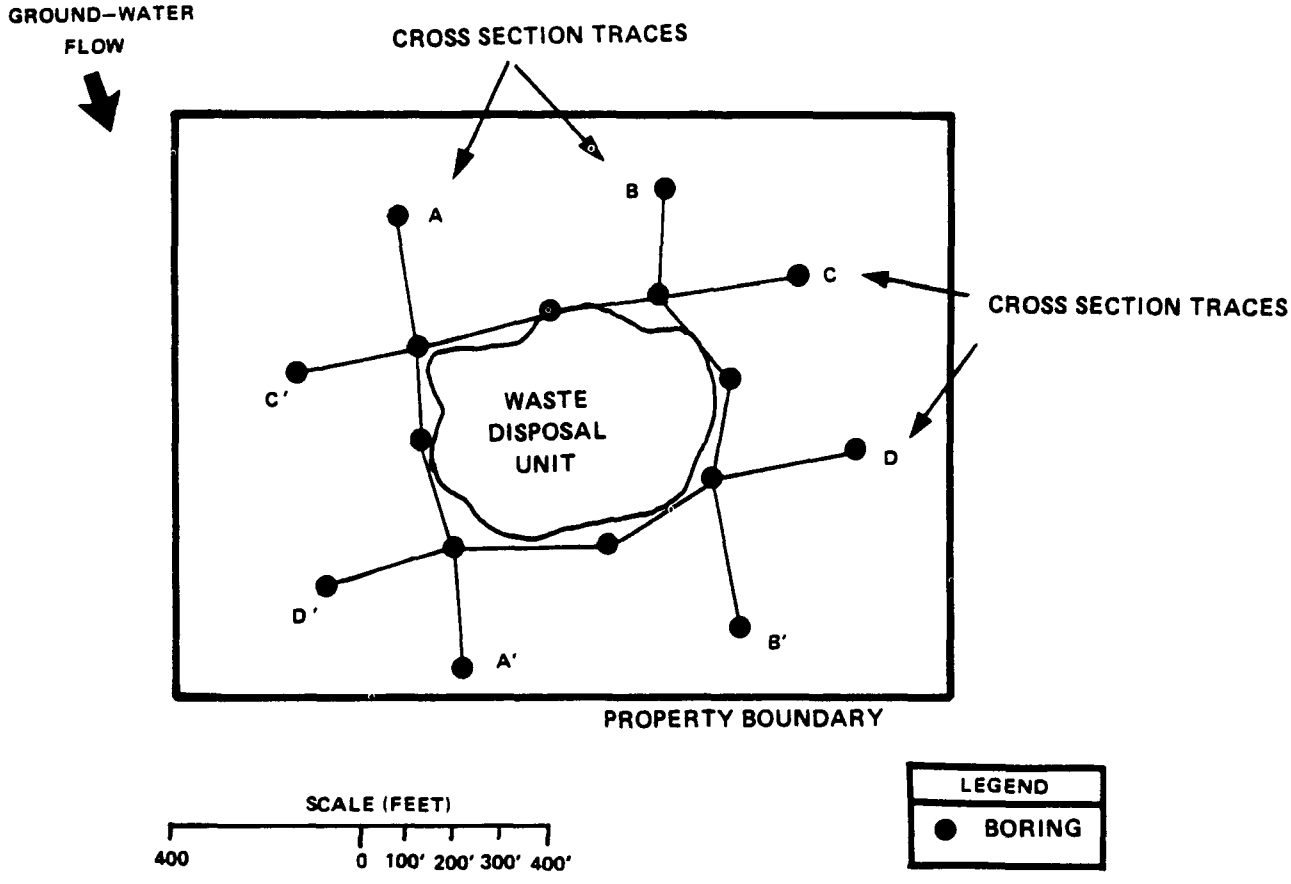

FIGURE 1-4 GEOLOGIC CROSS SECTION SURVEY PLAN

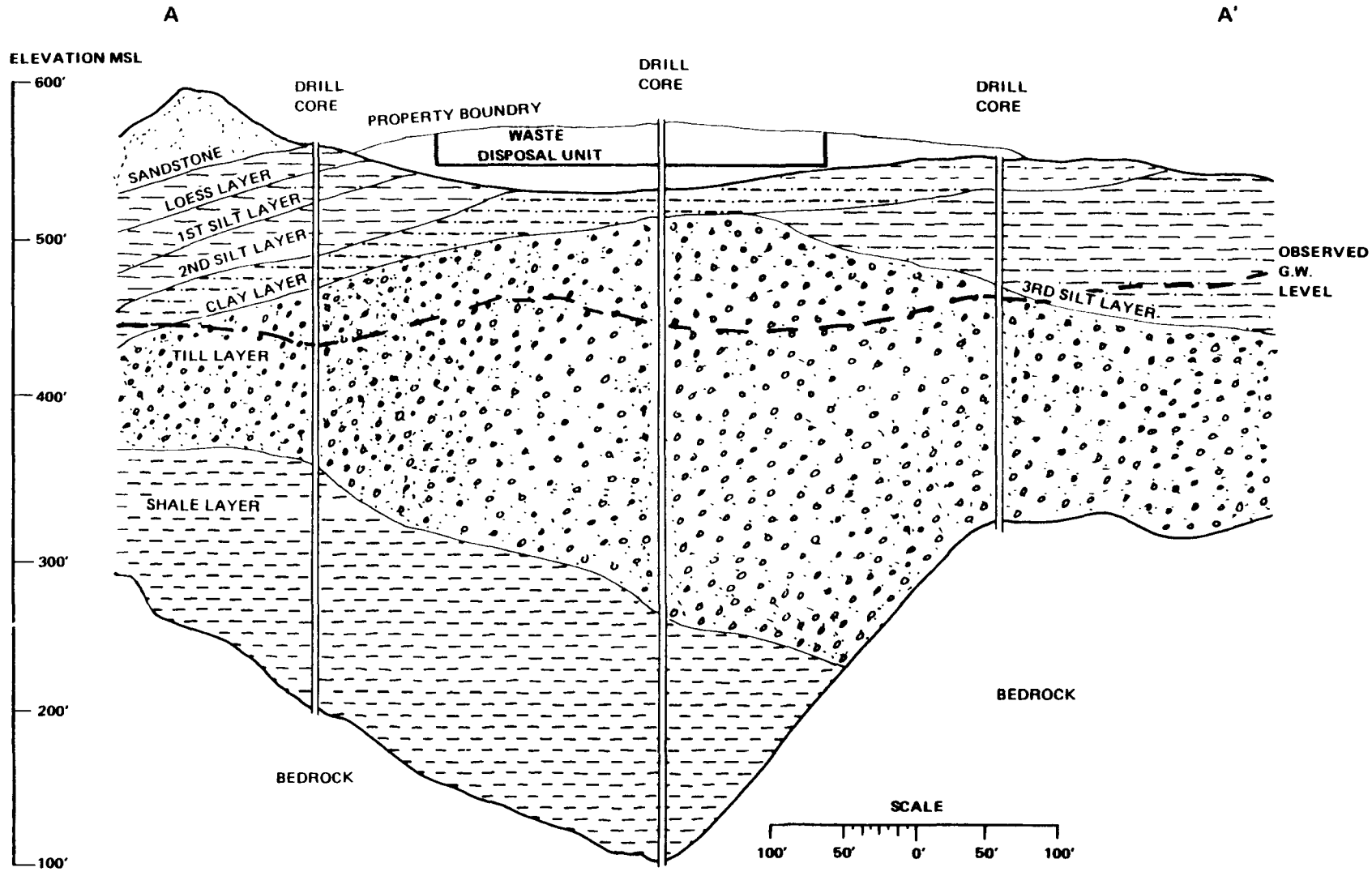

FIGURE 1-5 EXAMPLE OF AN ACCEPTABLE GEOLOGIC CROSS SECTION

map and aerial photograph of the site. The topographic map should have been constructed by a licensed surveyor and should provide contours at a maximum two-foot contour interval, locations and illustrations of man-made features (e.g., parking lots, factory buildings, drainage ditches, storm drains, pipelines, etc.), descriptions of nearby water bodies and/or off site wells, site boundaries, individual RCRA units, delineation of the waste management areas, and well and boring locations. An example of a site map is depicted in Figure 1-6. An aerial photograph of the site should depict the site and adjacent off-site features. This photograph should have the site clearly labeled. In addition, surface water bodies and adjacent municipalities or residences should be labeled.

1.3 Identification of Ground-Water Flowpaths

In addition to evaluating the owner/operator's characterization of subsurface geology, enforcement officials must decide whether owner/operators have adequately identified ground-water flowpaths. To have adequately identified flowpaths, owner/operators must have:

- established the direction of ground-water flow (including both horizontal and vertical components of flow);
- established the seasonal, temporal, and artificially induced (i.e., off-site production well pumping, agricultural use) variations in ground-water flow; and
- determined the hydraulic conductivities of the hydrogeologic units underlying their site.

In addition, enforcement officials must ensure that owner/operators used appropriate methods for obtaining the above information.

1.3.1 Determining Ground-Water Flow Directions

To locate wells so as to provide upgradient and downgradient well samples, owner/operators should have a thorough understanding of how ground water flows beneath their facility. Of particular importance is the direction of ground-water flow and the impact that external factors

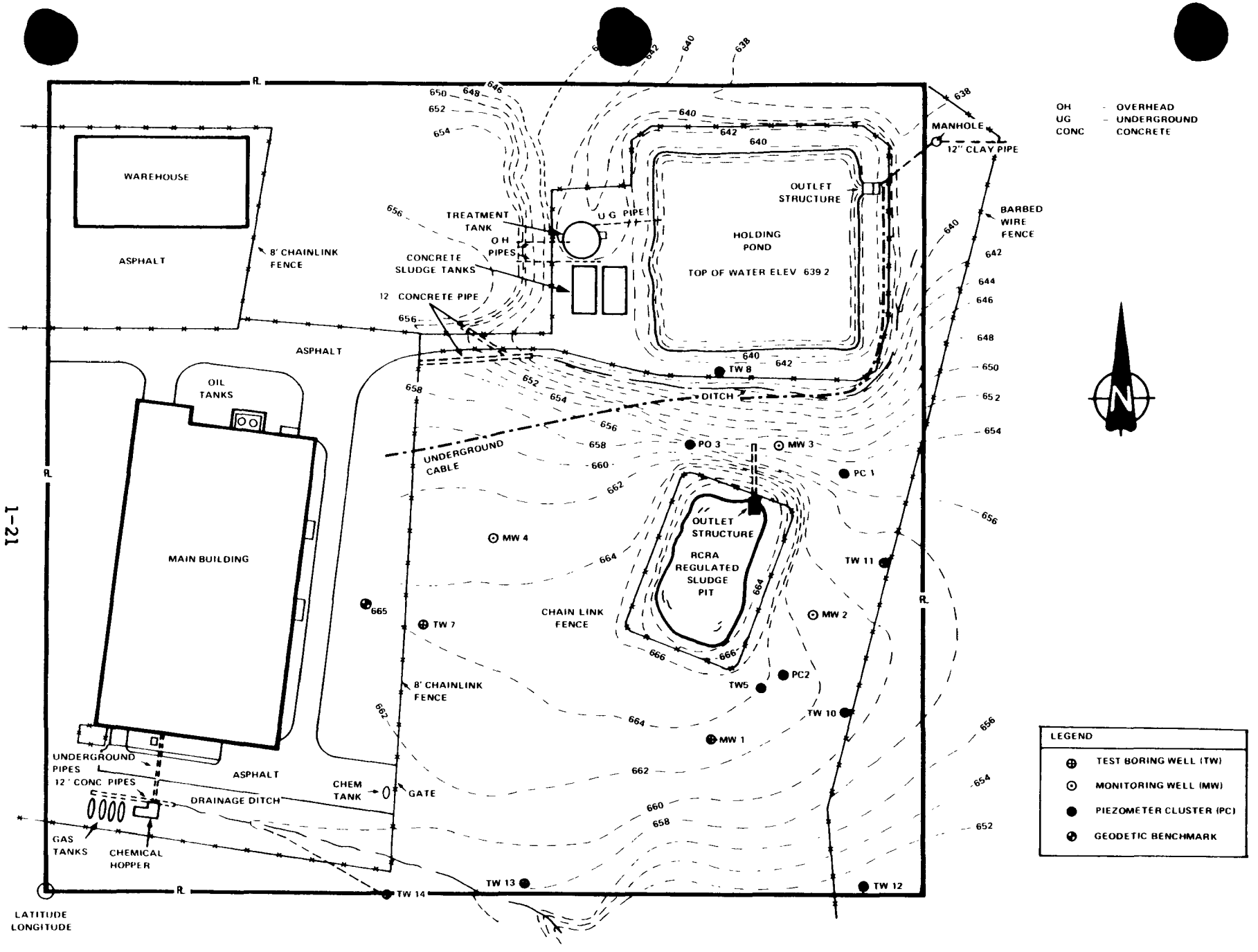

FIGURE 1-6 EXAMPLE OF A SITE MAP

(intermittent well pumping, temporal variations in recharge patterns, etc.) may have on ground-water patterns. In order for an owner/operator to have assessed these factors, a program should have been developed and implemented for precise well water level monitoring. This program should have been structured such that it provides precise well water level measurements in a sufficient number of wells and at a sufficient frequency to adequately gauge both seasonal average flow directions and to account for seasonal or temporal fluctuation of flow directions.

In addition to considering the components of flow in the horizontal direction, a methodology or program should have been undertaken by the owner/operator that accurately and directly assessed the vertical components of ground-water flow. Ground-water flow information should not be based on indirect data alone. Enforcement officials should review independently an owner/operator's methodology for obtaining information on ground-water flow and account for factors that may impact or complicate ground-water flow at the facility. The following sections detail the methods by which an owner/operator should have assessed the vertical and horizontal components of flow at the site.

1.3.1.1 Ground water level measurements

In order for the owner/operator to have initially determined the elevation of the water table in any boring well, several criteria should have been considered by the owner/operator.

- The well casing height should have been measured by a licensed surveyor to an accuracy of 0.1 feet. This may have required the placement of a geologic benchmark on the facility property.

- All well water level measurements from boring or piezometer wells used to construct a single potentiometric surface should have been collected within a twenty-four hour period.

- The method used to measure well water levels should have been adequate to attain an accuracy of 0.1 feet.

- Well water levels should have been allowed to stabilize for a minimum of twenty-four hours after well construction and development, prior to measurement. In low yield situations, recovery may take longer.

If an owner/operator cannot produce accurate documentation or provide assurance that these criteria were met during the collection of well water level measurements, this may indicate that the generated information may be of questionable validity.

1.3.1.2 Interpretation of ground-water level measurements

After the enforcement official has assured that the well water level data is valid, he should proceed to independently interpret the information. The enforcement official should:

- use the owner/operator's raw data to construct a potentiometric surface map (see Figure 1-7). The data used to develop the potentiometric map should be data from wells screened at equivalent stratigraphic horizons in the saturated zone;

- compare this data with that of the owner/operator's and determine whether the owner/operator has accurately presented the information and determine if the information is sufficient to describe ground-water flow trends; and

- identify any information gaps.

In reviewing this information, the enforcement officer should now have an approximate idea of the general flow direction; however, in order to have properly located monitoring wells, the owner/operator should have established flow directions in both the horizontal and vertical directions.

1.3.1.3 Establishing vertical components of ground-water flow

In order for the owner/operator to have determined the direction of flow, vertical components of flow must have been directly determined. To illustrate the importance of vertical flow in determining overall ground-water flow, an example is illustrated in Figure 1-8. In this situation, the owner/operator has constructed a downgradient monitoring well in what

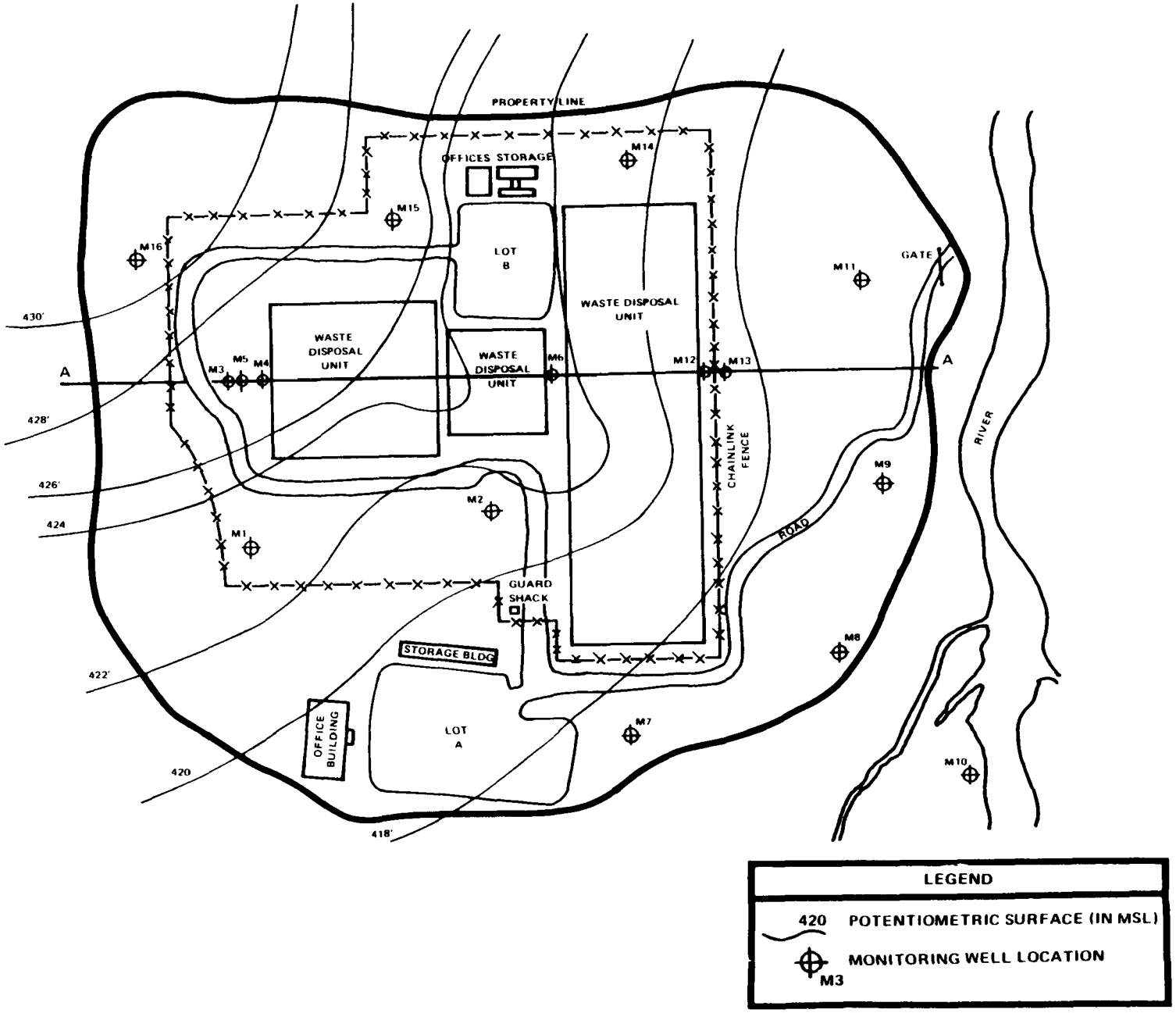

FIGURE 1-7 POTENTIOMETRIC SURFACE MAP

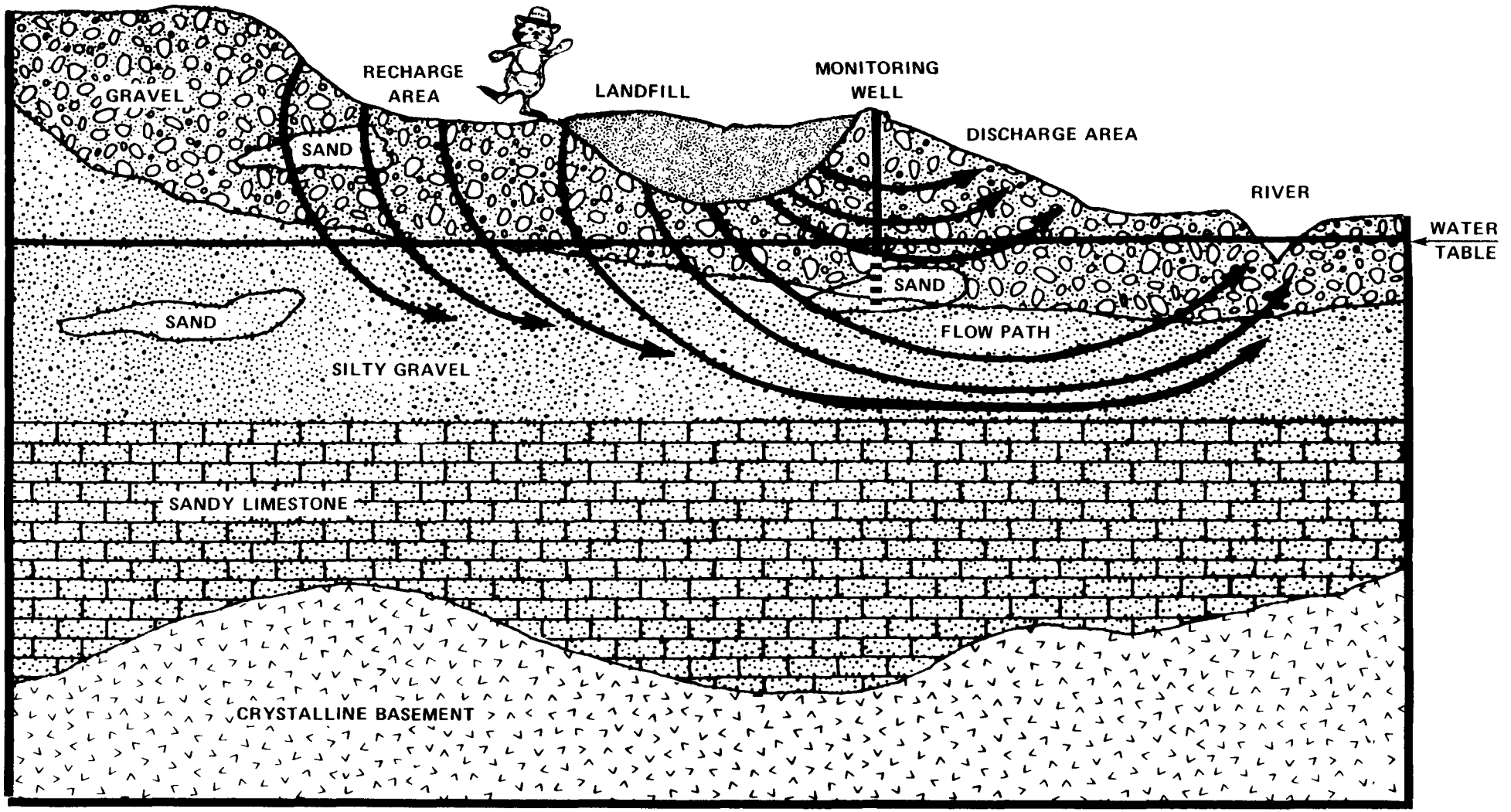

FIGURE 1-8 EXAMPLE OF IMPROPER WELL PLACEMENT BASED UPON FLOW COMPONENTS

would first appear to an appropriate location. The well site selection was based on a potentiometric surface developed from a data base of well measurements. The owner/operator determined the general direction of flow utilizing this information. Although this well placement may have at first appeared to be appropriate, the flowpaths below the hazardous waste unit are almost vertical and the well as depicted here would not intercept a contaminant flowpath from the contaminant source. Thus, it is necessary that the owner/operator assess the vertical components of flow at the regulated site as well as horizontal components.

In order to collect this information the owner/operator should have utilized direct means to determine vertical flow components. This will have required the installation of piezometers in well clusters. In order to have obtained reliable measurements the following criteria should be considered in the placement of piezometer clusters.

- Information obtained from multiple piezometer placement in single boreholes may generate erroneous data. Placement of vertically nested piezometers in closely spaced separate boreholes is the preferred method.

- Piezometer measurements should have been collected within a twenty-four hour period if measurements are to be used in any correlative presentation of data.

- Piezometer measurements should have been determined along a minimum of two vertical profiles across the site. These profiles should be cross sections roughly parallel to the direction of ground-water flow indicated by the potentiometric surface.

When reviewing piezometer information obtained from multiple placement of piezometers in single boreholes, the enforcement official should closely scrutinize the construction details for the well. It is extremely difficult to adequately seal several piezometers at discrete depths within a single borehole and special design considerations should have been considered by the owner/operator. If information is not available that details design features, it may indicate that adequate

construction considerations have not been used. Placement of piezometers in closely spaced well clusters, where piezometers have been screened at different, discrete depth intervals is more likely to produce accurate information. Additionally, multiple well clusters sample a greater proportion of the aquifer and thus may provide a greater degree of accuracy for considerations of vertical potentiometric head in the aquifer as a whole.

The information obtained from the piezometer readings should have been used by the owner/operator to construct flow nets (see Figure 1-9). These flow nets should include information as to piezometer location and depth and width of screening. The flow net in Figure 1-9 was constructed from information obtained from piezometer clusters screened at different, discrete intervals. The construction of contours is straightforward and the enforcement official should be able to verify the accuracy of the owner/operator's presentation. The enforcement official should either construct a flow net independently from the owner/operator's data or spot-check the owner/operator's presentation. It is also important to verify that the screened interval is accurately portrayed and to determine whether the piezometer is actually monitoring the water table elevation caused by the hydrostatic pressure of the desired water bearing unit.

If there is reasonable concurrence between the information presented by the owner/operator and the enforcement officer's interpretation, the enforcement officer should next interpret the flow directions from the waste management area.

1.3.1.4 Interpretation of flow direction

In considering flow directions established by the owner/operator, the enforcement official should have first:

- established that the potentiometric surface measurements are valid; and
- established that the vertical components of flow have been accurately depicted and are based on valid data.

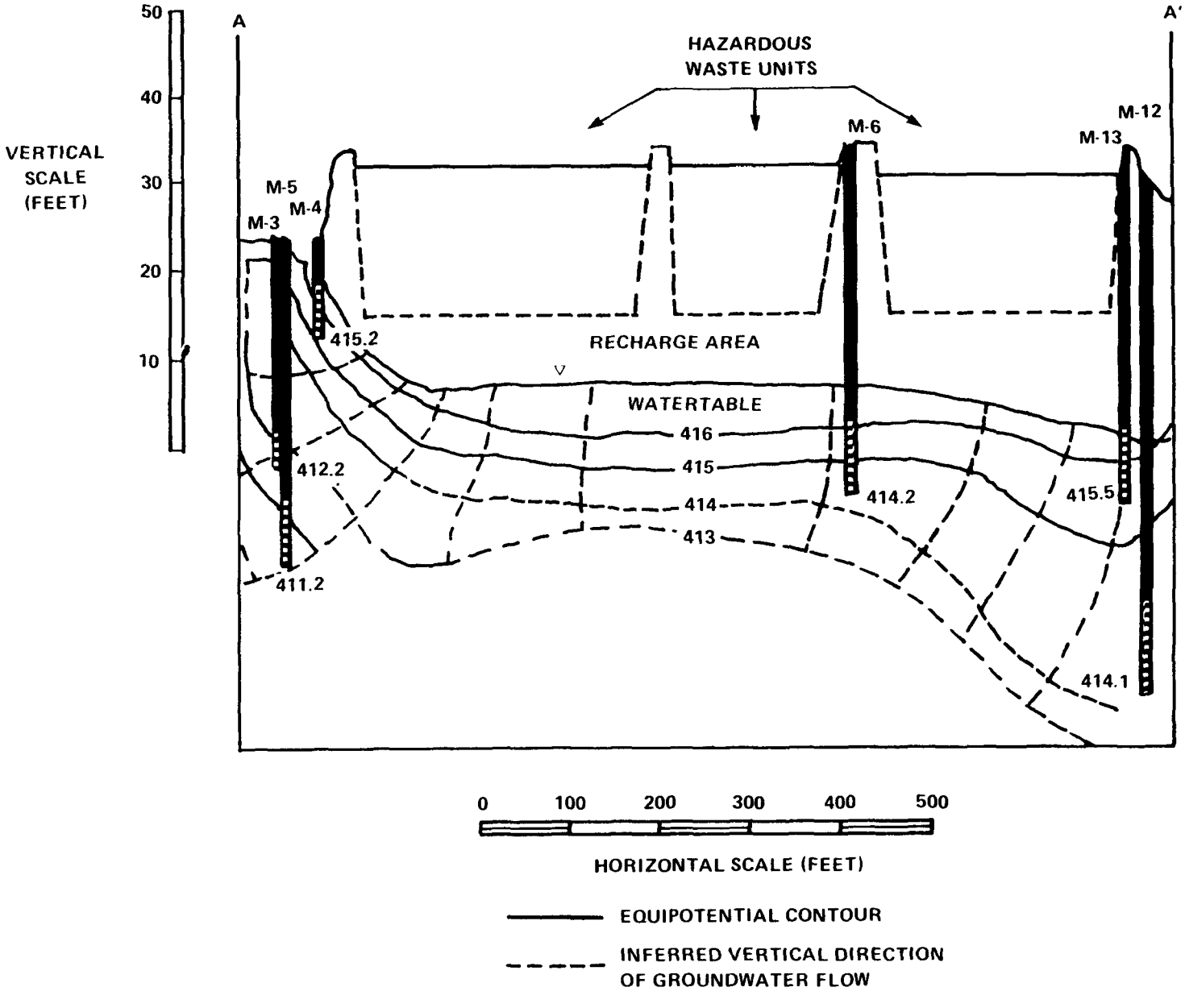

FIGURE 1-9. CROSS-SECTIONAL VIEW ILLUSTRATING FLOW NETS

At this point general considerations of ground-water flow may be estimated. The enforcement officer should construct vertical intercepts with the potentiometric contours for both the potentiometric surface map and from flow nets. Once the vertical and horizontal directions of flow are established (from points of higher head to lower head), it is possible to estimate where monitoring wells will most likely intercept contaminant flow in the vertical plane. To consider the placement that will most effectively intercept contaminant flow, a consideration of hydraulic conductivity is required.

1.3.2 Seasonal and Temporal Factors: Ground-Water Flow

It is important to note if the owner/operator has identified and assessed factors that may result in short-term or long-term variations in ground-water level and flow patterns. Such factors that may impact ground-water conditions include:

- off-site well pumping;
- tidal processes or other intermittent natural variations (e.g., river stage, etc.);
- on-site well pumping;
- off-site, on-site construction or changing land use patterns;
- deep well injection; and
- seasonal variations.

Off-site or on-site well pumping may affect both the rate and direction of ground-water flow. Municipal, industrial or agricultural ground-water use may significantly alter or change ground-water flow patterns and levels over short or long periods of time. Pumpage may be seasonal or dependent upon other complex water use patterns. The effects of pumpage thus may reflect time-continuous or discontinuous patterns. Well water level measurements must have been frequent enough to detect such water use patterns.

Natural processes such as riverine, estuarine, or marine tidal movement may result in variations of well water levels and/or ground-water quality. An owner/operator should have documented the effects of such

patterns. Seasonal patterns have a significant affect on water table levels and ground-water flow. Short term recharge patterns may affect ground-water flow patterns that are markedly different from ground-water flow patterns that are determined by seasonal averages. An owner/operator should have gauged such transitional patterns.

Additionally, an owner/operator should have implemented means for gauging long term effects on water movement that may result from on-site or off-site construction or changes in land-use patterns. Development may effect ground-water flow by altering recharge or discharge patterns. Examples of such changes might include the paving of recharge areas or damming of waterways.

In reviewing the owner/operator's assessment of ground-water flow patterns, the enforcement officer should consider whether the owner/ operator's program was sensitive to such seasonal or temporal variations. An owner/operator should have, in effect, determined not only the location of water resources but the sources and source patterns that contribute to or effect ground-water patterns below the regulated site.

1.3.3 Determining Hydraulic Conductivities

In addition to defining the direction of ground-water flow in the vertical and horizontal direction, the owner/operator must identify areas of high and low hydraulic conductivity (K) within each formation. Variations in the hydraulic conductivity of subsurface materials can create irregularities in ground-water flow paths. Areas of high hydraulic conductivity represent areas of greater ground-water flow and, if contaminants are present, zones of potential migration. Therefore, information on hydraulic conductivities is required before owner/ operators can make reasoned decisions regarding well placements.

Enforcement officials should review the owner/operator's hydrogeologic assessment report to ensure that it contains data on the hydraulic conductivities of the various geologic materials underlying the site.

In addition, enforcement officials should review the method the owner/operator used to derive the conductivity values. It may be beneficial to use analogy or laboratory methods to corroborate results of field tests; however, only field methods provide direct information that is adequate to define the hydraulic conductivity.

Hydraulic conductivity can be determined in the field using either single or multiple well tests. Single well tests, more commonly referred to as slug tests, are performed by suddenly adding or removing a slug (known volume) of water from a well or piezometer and observing the recovery of the water surface to its original level. Similar results can be achieved by pressurizing the well casing, depressing the water level, and suddenly releasing the pressure to simulate removal of water from the well.

When reviewing information obtained from slug tests, the enforcement official should consider several criteria. First, slug tests are run on one well and, as such, the information obtained from single well tests is limited in scope to the geologic area directly adjacent to the well. Second, the vertical extent of screening will control the part of the geologic formation that is being tested during the slug test. That part of the column above or below the screened interval that has not been tested during the slug test will not have been adequately tested for hydraulic conductivity. Third, the methods that the owner/operator used to collect the information obtained from slug tests should be adequate to measure accurately parameters such as changing static water (prior to initiation, during, and following completion of slug test), the amount of water added to, or removed from, the well, and the elapsed time of recovery. This is especially important in highly permeable formations where pressure transducers and high speed recording equipment should be used. Lastly, the owner/operator's interpretation of the slug test data should be consistent with the existing geologic information (boring log

data). It is, therefore, important that officials examine the owner/operator's program of slug testing to ensure that enough tests were run to provide representative measures of hydraulic conductivity and to document lateral and vertical variation of hydraulic conductivity in the hydrogeologic subsurface below the site.

Multiple well tests, more commonly referred to as pump tests, are performed by pumping water from one well and observing the resulting drawdown in nearby wells. Multiple well tests for hydraulic conductivity are advantageous because they characterize a greater proportion of the geologic subsurface and thus provide a greater amount of detail. Multiple well tests are subject to similar constraints to those listed above for single well tests. Some additional problems that should have been considered by the owner/operator conducting a multiple well test include: (1) storage of potentially contaminated water pumped from the well system and (2) potential effects of ground-water pumping on existing waste plumes. The enforcement official should closely consider the geologic constraints that the owner/operator has used to interpret the pump-test results. Incorrect assumptions regarding geology may translate into incorrect estimations of hydraulic conductivity.

In reviewing the owner/operator's hydraulic conductivity measurements, the enforcement officer should use the following criteria to determine the accuracy or completeness of information.

- Values of hydraulic conductivity between wells should not exceed one order of magnitude difference. If values exceed this difference the owner/operator may have not provided enough information to sufficiently define a potential flowpath.

- Hydraulic conductivity for multiple well tests should be considered the preferred method. They provide more complete information because they characterize a greater portion of the subsurface.

- Use of single well tests will require that more individual tests at different locations to sufficiently define hydraulic conductivity variation across the site.

- Hydraulic conductivity information generally provides average values for the entire area across a well screen. For more depth discrete information, well screens will have to be shorter. If the average hydraulic conductivity for a formation is required, entire formations may have to be screened.

It is important that hydraulic conductivity measurements define hydraulic conductivity both in a vertical and horizontal manner across an owner/operator's regulated site. In assessing the completeness of an owner/operator's hydraulic conductivity measurements, the enforcement official should also consider results from the boring program used to characterize the site geology. Zones of high permeability or fractures identified from drilling logs should have been considered in the determination of hydraulic conductivity. Additionally, information from coring logs can be used to refine the data generated by slug or pump tests.

1.4 Identification of the Uppermost Aquifer

The owner/operator is required to monitor the uppermost aquifer beneath the facility. Enforcement officials, therefore, should ensure that the owner/operator has correctly identified the uppermost aquifer. Proper identification of the uppermost aquifer is critical to ensure that monitoring wells are installed in the appropriate stratigraphic horizon(s).

The uppermost aquifer extends from the water table to the first confining layer (or ten feet into bedrock) and includes any overlying perched zones of saturation. The identification of the confining layer is an essential facet of the definition of uppermost aquifer. There should be no interconnection, based upon pumping tests, between the uppermost aquifer and lower aquifers. Consequently, the uppermost aquifer includes all interconnected water-bearing zones overlying the confining layer.

When reviewing an owner/operator's hydrologic data and the decisions the owner/operator has made regarding the identification of the

uppermost aquifer, the enforcement official should keep two important points in mind. First, the owner/operator should consider the definition of uppermost aquifer to encompass all water-bearing zones that serve as pathways for contamination migration including perched zones of saturation. Saturated formations, even those consisting of relatively impermeable materials, should be considered as part of the uppermost aquifer.* Second, the owner/operator should not consider the quality or use of ground water as a factor in the identification of the geometric dimensions of the uppermost aquifer. Even though a saturated formation may not be presently in use or may contain water not suitable for human consumption, it may act as a pathway for contaminant migration and thus is subject to monitoring.

In all cases, the obligation to assess any hydraulic interconnections and the proper definition of the uppermost aquifer rests with the owner/operator. The owner/operator should be able to prove that confining unit is of sufficient impermeability to prevent the passage of contaminants to saturated, stratigraphically lower units.

The following examples illustrate geologic settings wherein hydraulic interconnection must be demonstrated before proper identification of the uppermost aquifer may be made. The examples are not intended to be exhaustive in the situations they portray rather they are meant to provide a sample of geologic settings that result in hydraulic interconnection.

Figure 1-10 illustrates a site that preliminary drill logs indicated was underlain by a confining layer of unfractured, continuous clay. (Note: the actual geologic conditions are pictured for purposes of clarity in the figure.) In order to confirm whether the clay layer was

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*Chapter Two describes criteria useful in identifying which portions of the uppermost aquifer that should be screened. It may not be desirable for the owner/operator to screen wells in saturated, low permeability formations even though, technically, these formations are part of the uppermost aquifer. Other formations may offer a higher probability of contaminant movement and thus should be selected for monitoring.

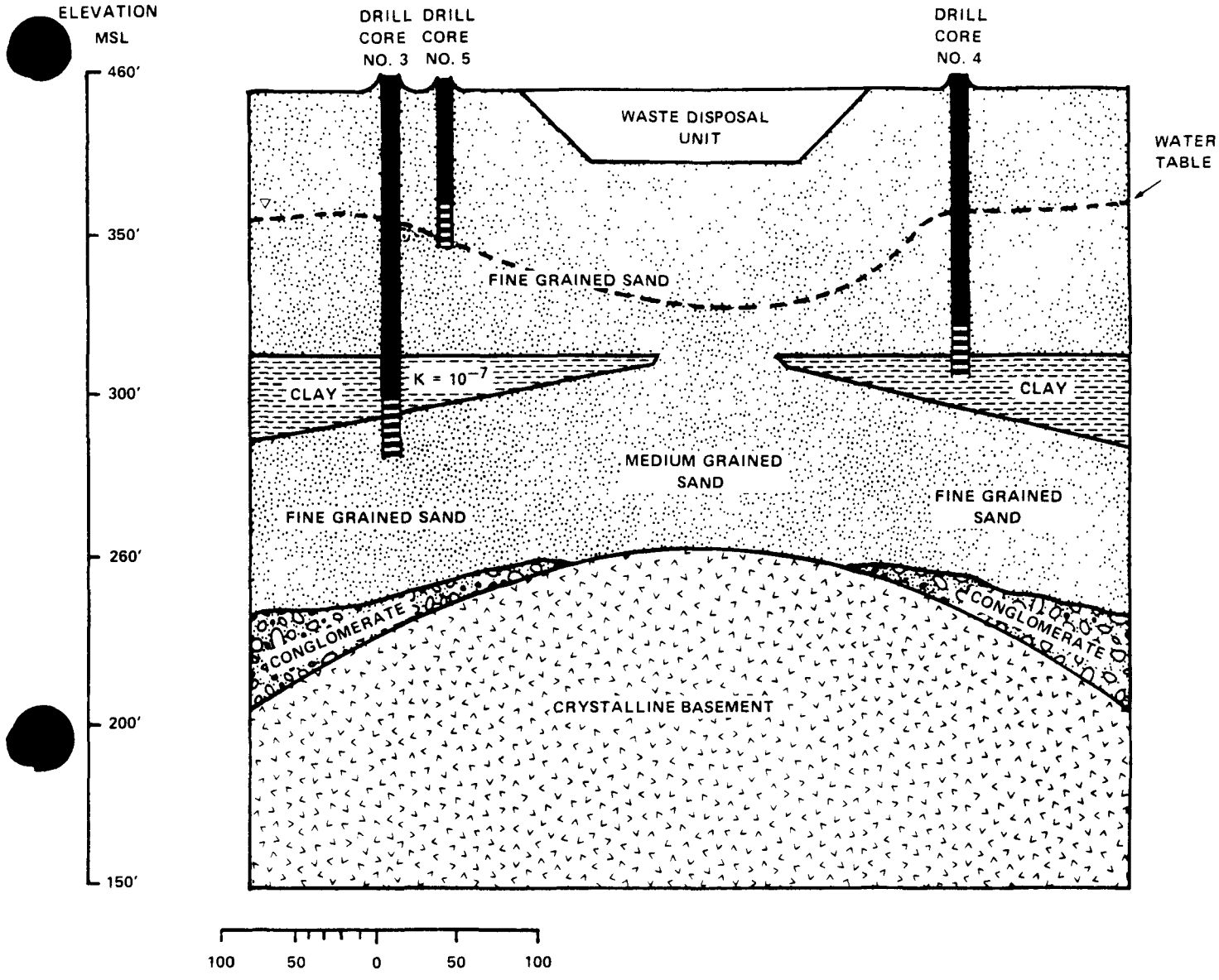

FIGURE 1-10 EXAMPLE OF HYDRAULIC INTERCONNECTION BETWEEN WATER - BEARING UNITS

continuous or discontinuous, the owner/operator conducted a pump test. A well at drill point No. 5 was screened at the uppermost part of the water table. Another well at drill point No. 3 was located closeby and screened below the clay layer. Measurable drawdown was observed in the upper well when the well below the confining was pumped. This indicated that the confining unit was not of sufficient impermeability to serve as a significant boundary to contaminant flow. In this case, the water bearing unit below the clay layer as well as the formation above the clay layer are both part of the uppermost aquifer.

In Figure 1-11, the owner/operator drilled test borings through silt and limestone formations into a sandstone unit. In the initial corings, no indication of fracturing of the limestone unit was observed. The owner/operator initially assumed that the limestone unit was dipping at a moderate slope due to differing levels of contact. However, as illustrated by the figure, actual conditions involve fracturing of the limestone formation (additional corings and geophysical studies detected fracture zones). These fractures represent hydraulic interconnection between the upper gravelly silt layer and the sandstone formation below the limestone unit. The uppermost aquifer, therefore, includes the gravelly silt formation, the limestone formation, and the sandstone formation.

Figure 1-12 illustrates a situation where perched water zones lie above the ground-water table. The uppermost aquifer includes the perched water zones and that part of the sand formation from the top of the water table to the top of the bedrock.

In Figure 1-13, initial test borings indicated that horizontal sandy units were underlain by a consolidated well-cemented, impermeable, sandstone unit. Initial borings did not indicate the presence of the buried structural anticline. The owner/operator incorrectly assumed that the sandstone unit was a confining layer that extended across the subsurface

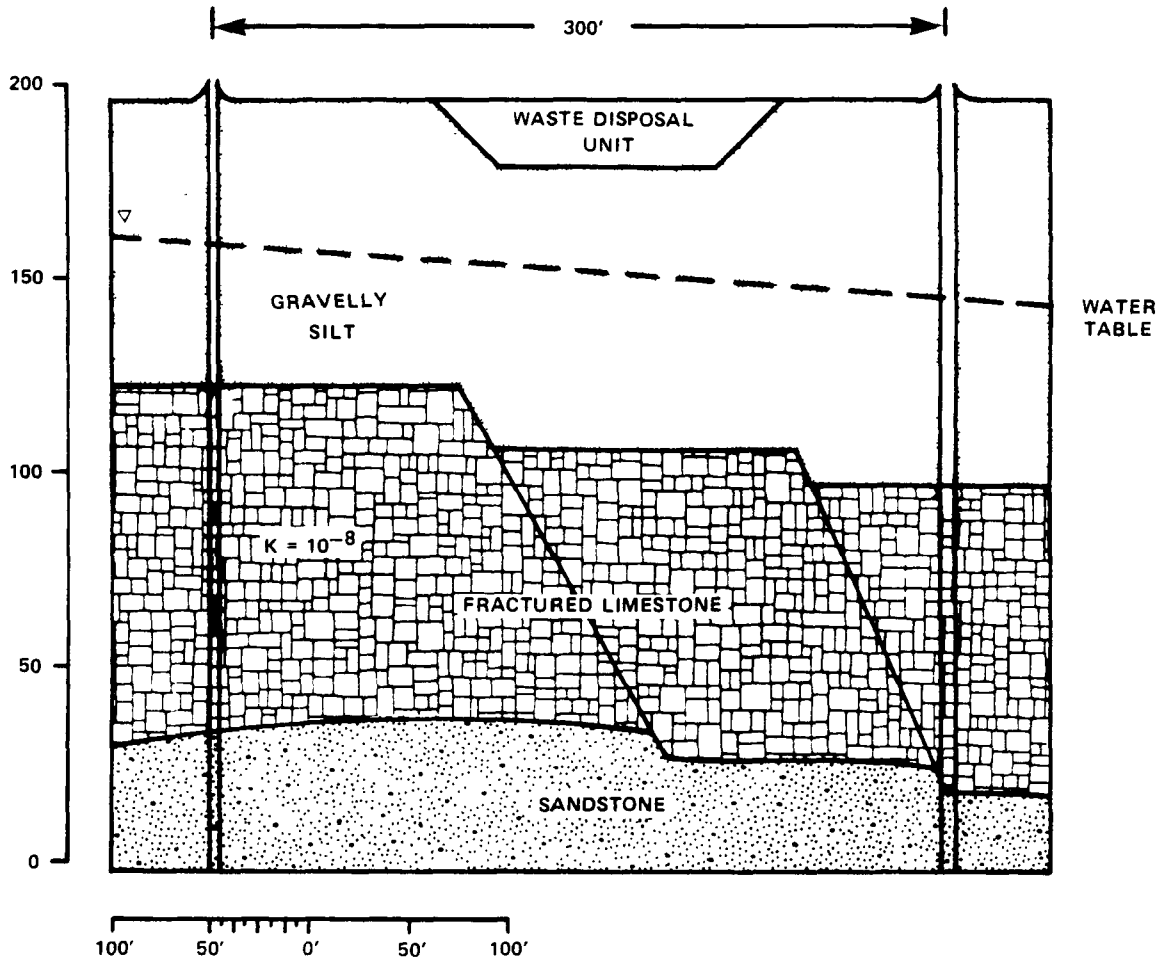

FIGURE 1-11. AN EXAMPLE OF HYDRAULIC INTERCONNECTION CAUSED BY FRACTURING

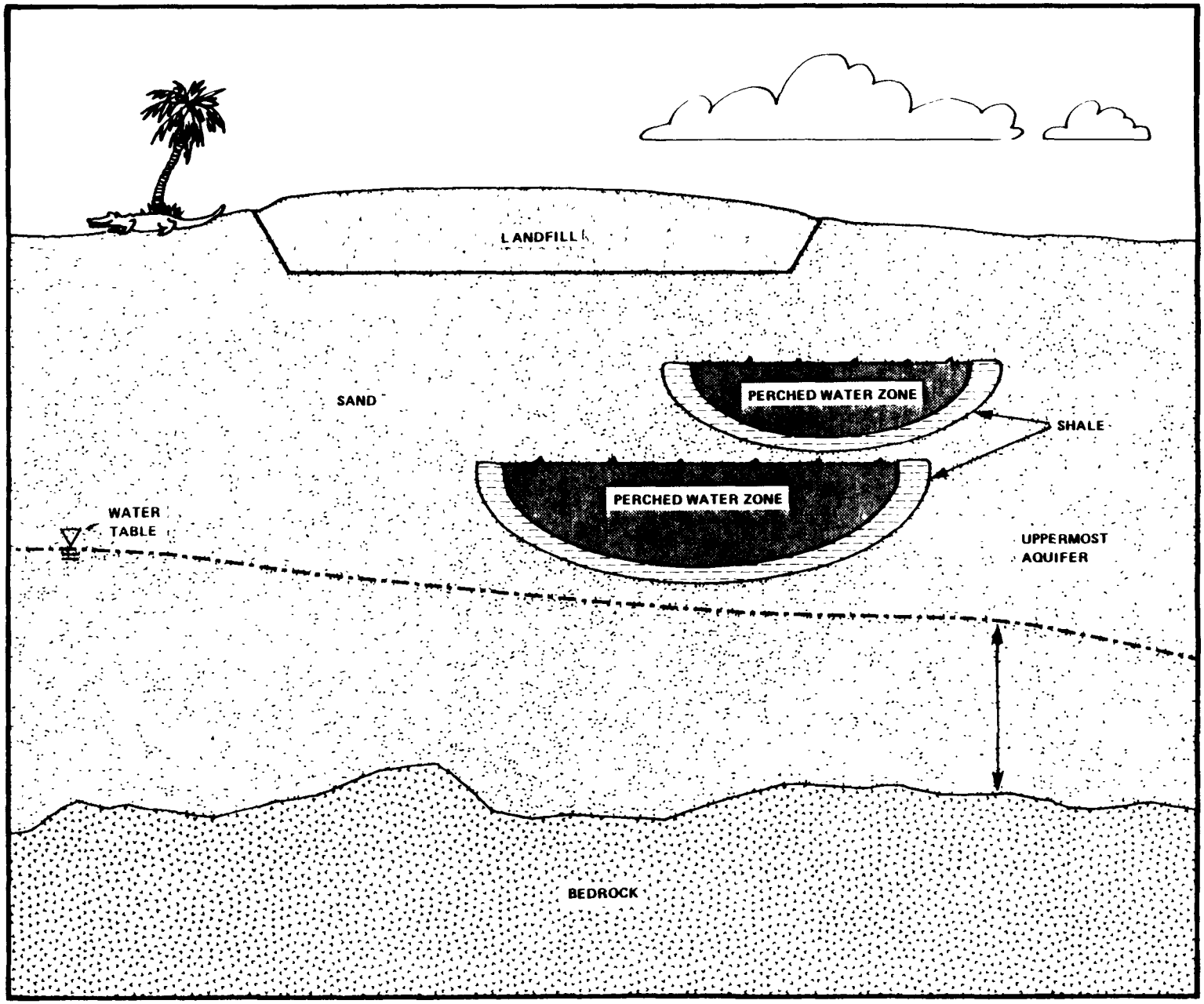

FIGURE 1-12. PERCHED WATER ZONES AS PART OF THE UPPERMOST AQUIFER

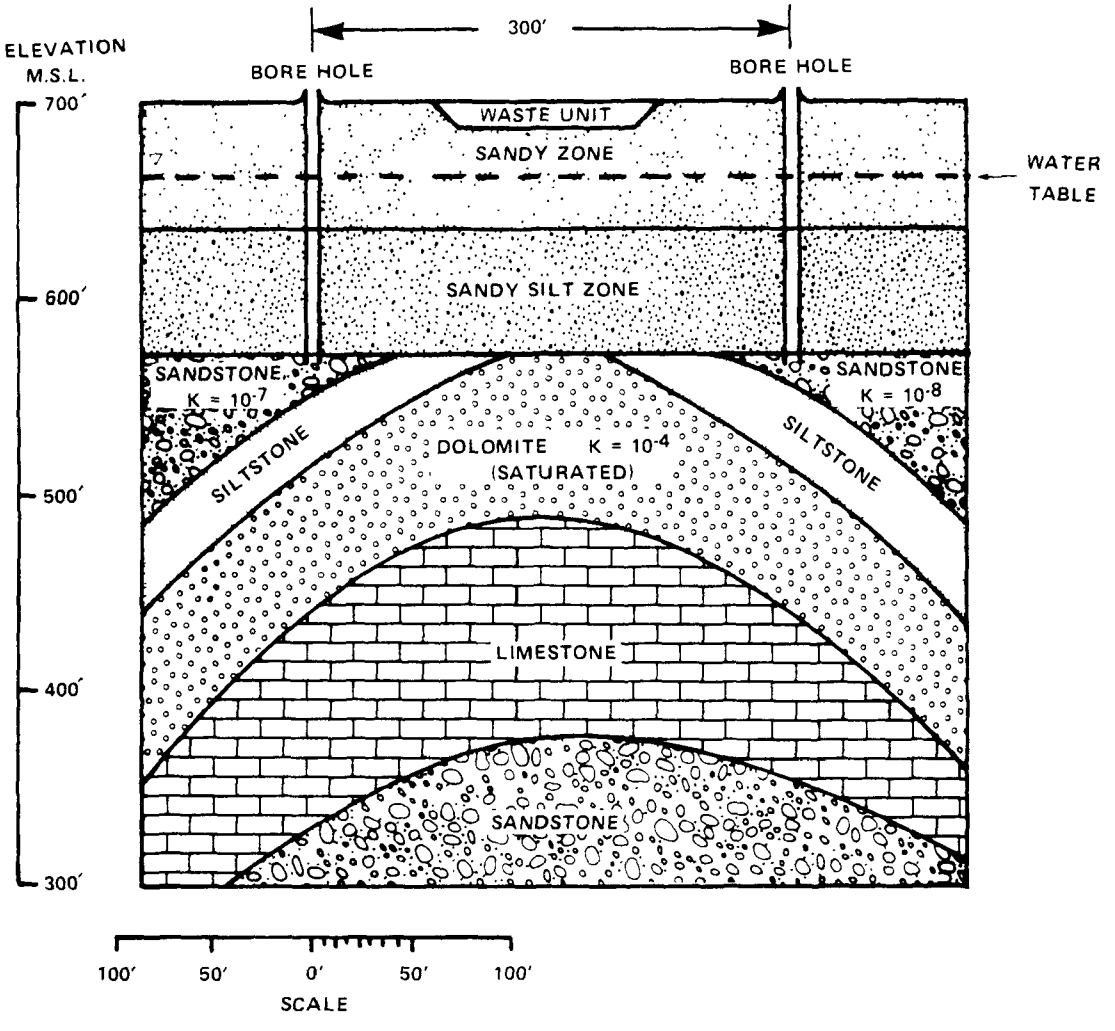

FIGURE 1-13. AN EXAMPLE OF AN UNDETECTED, STRUCTURALLY COMPLEX UPPERMOST AQUIFER

below the site. A dolomite unit, in contact with the unconsolidated sandy silts, and directly below the waste unit, is saturated and highly permeable. Additional investigation including pump tests, borings, and/or geophysical analysis better defined the subsurface. The uppermost aquifer, in this case, includes the anticlinal formations.

In Figure 1-14, unconsolidated units are underlain by a consolidated series of variable, near-shore, shallow marine sediments. The owner/operator has installed two borings near the waste management unit to identify the uppermost aquifer. Interpretation of these borings indicate that the unconsolidated units are underlain by a well cemented limestone of very low permeability. However, an undetected sandstone unit, that is laterally continuous with the limestone unit, is highly permeable and saturated and represents an undetected portion of the uppermost aquifer. Interpretation of the depositional environment of the limestone unit, coupled with a knowledge of the local or regional geology should have been used in addition to other investigatory techniques to establish the presence of the transitional lateral structural feature and thus properly define the uppermost aquifer.

A special case, and one that should receive considerable consideration by the enforcement officer, is the situation in which two saturated units are separated by a confining unit that may be chemically reactive with the leachate from a regulated unit. Such a situation is illustrated in Figure 1-15. Two considerations may apply to such a problem:

- Is the subsurface above the confining layer potentially reactive with the leachate such that it will significantly alter the leachate characteristics prior to contact with the confining unit?
- Is the reaction with the confining layer going to significantly affect the hydraulic conductivity of the water-bearing unit?

Another special case that should be considered by the enforcement official is the possibility that existing wells may provide avenues for

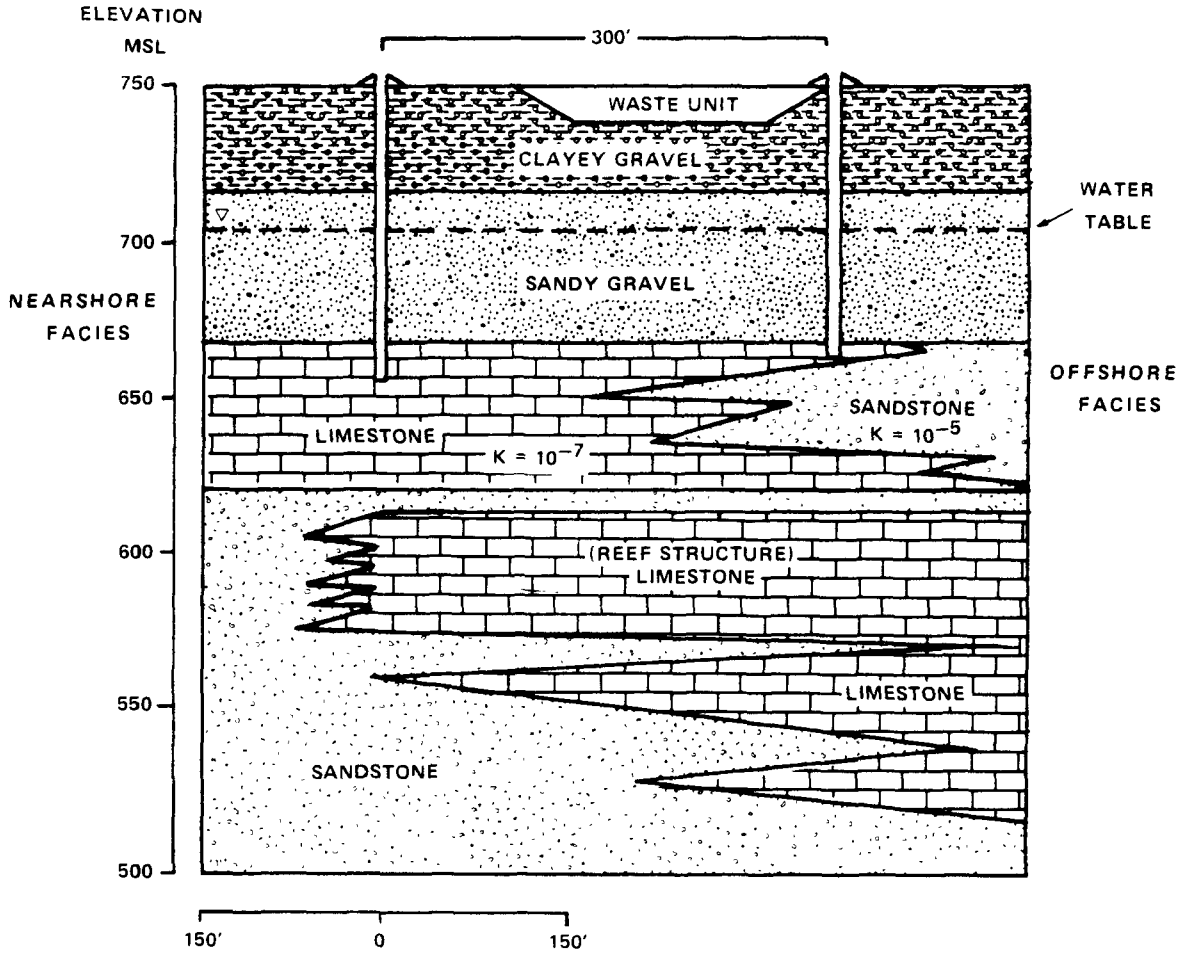

FIGURE 1-14. AN EXAMPLE OF AN UNDETECTED PORTION OF THE UPPERMOST AQUIFER (PERMEABLE SANDSTONE UNIT NEAR A COASTAL AREA)

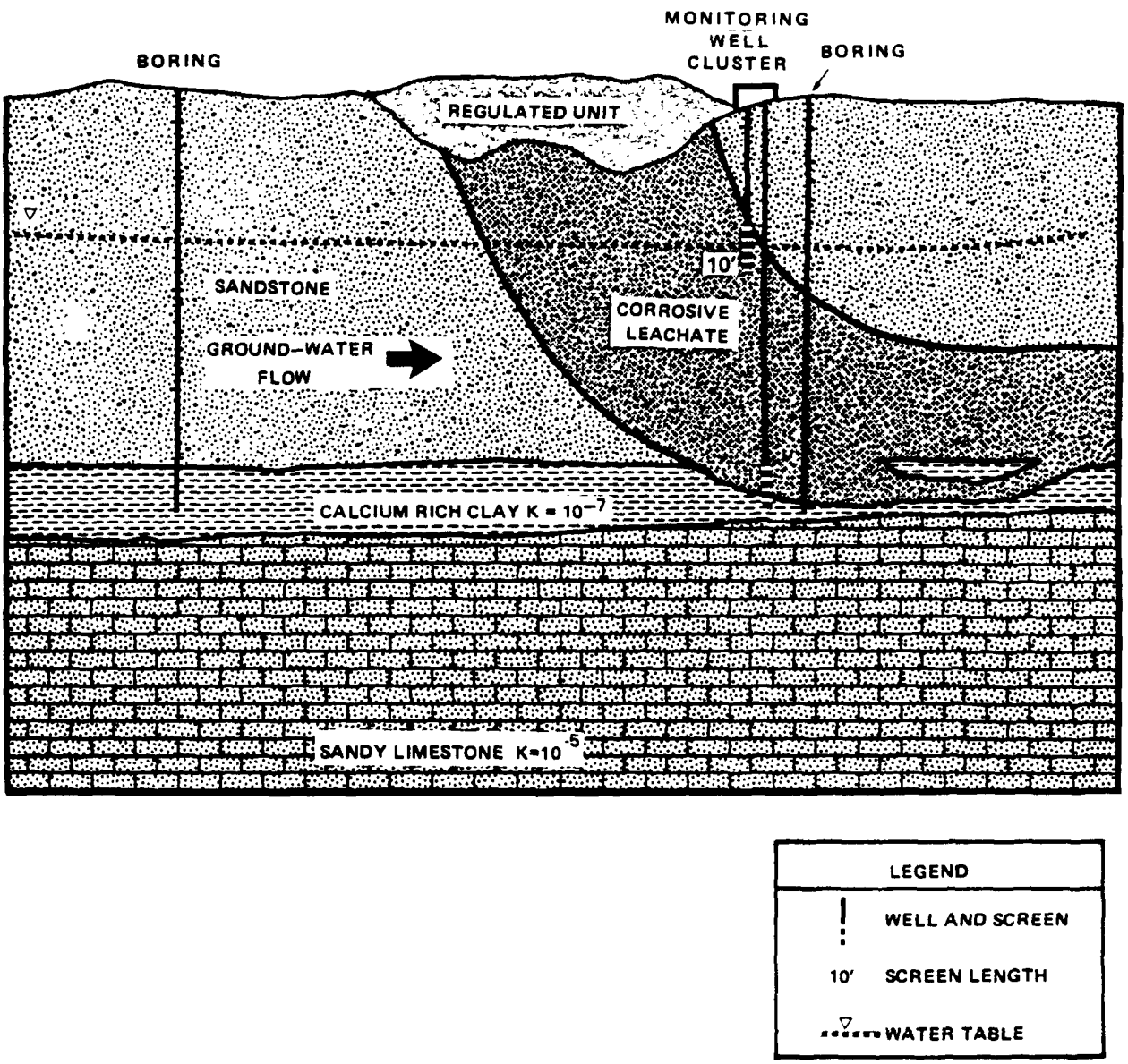

FIGURE 1-15 EXAMPLE OF A CONTAMINANT THAT MAY AFFECT THE QUALITY OF A CONFINING LAYER

hydraulic communication between hydrogeologic units. This is of special importance when considering a site where a contaminant plume may have migrated downgradient such that the plume approaches off-site wells. Such wells may not have been constructed in a manner sensitive to problems of cross-contamination between aquifers (see Chapter Four). In such an instance, the off-site wells may have to be plugged and replaced with appropriately designed wells.

CHAPTER TWO

PLACEMENT OF DETECTION MONITORING WELLS

The purpose of this chapter is to examine criteria the enforcement official should use in deciding if the owner/operator has made proper decisions regarding number and location of detection monitoring wells. In evaluating the design of an owner/operator's detection monitoring system, the enforcement official must examine the placement of upgradient and downgradient monitoring wells relative to hazardous waste management units, the spacing between wells, and the depths at which wells are screened. The minimum number of monitoring wells an owner/operator may install in a detection monitoring system is four--one upgradient well and three downgradient wells. Typically, site hydrogeology is too complex for the minimum number of wells to prove adequate in achieving the performance objectives of a detection monitoring system.

Chapter One described the level of hydrogeologic characterization that owner/operators should conduct at their sites. Collection and analysis of this data is crucial to making proper decisions regarding the placement of wells and well clusters and the selection of screened intervals for individual wells. It is likely that the enforcement official may confront situations where the owner/operator has collected little or no site hydrogeologic information or has relied exclusively on regional data to design a monitoring system. In this situation, the enforcement official should question the decisions the owner/operator has made regarding well placement and screen depths and should require the owner/operator to collect additional site information.

Upgradient monitoring wells provide background ground-water quality data in the uppermost aquifer. Upgradient wells should be (1) located beyond the upgradient extent of contamination from the hazardous waste management unit so that they reflect background water quality,

(2) screened at the same stratigraphic horizon(s) as the downgradient wells to ensure comparability of data, and (3) of sufficient number to account for heterogeneity in background ground-water quality.

Downgradient wells must be located, screened, and sufficiently numerous to provide a high level of certainty that releases of hazardous waste or hazardous waste constituents from the hazardous waste management unit(s) to the uppermost aquifer will be immediately detected. Determination of the appropriate number of wells to be included in a detection monitoring system hinges on the horizontal spacing between well locations and the vertical sampling interval of individual wells. Downgradient monitoring wells must be located at the edge of the hazardous waste management units. Distance between wells is chiefly a function of spatial heterogeneity of a site. The consideration of site specific conditions to evaluate well spacing is described in Section 2.1. The depth interval(s) over which downgradient monitoring wells should be screened is a function of (1) geologic factors influencing the potential contaminant pathways of migration to the uppermost aquifer, (2) chemical characteristics of the hazardous waste controlling its likely movement and distribution in the aquifer, and (3) hydrologic factors likely to have an impact on contaminant movement. The consideration of these factors in evaluating the design of detection monitoring systems is described in Section 2.2.

It is important to keep in mind that a properly designed detection monitoring system will provide a high level of assurance that contaminant leaks will be immediately detected. RCRA does not, however, require complete certainty that all leaks be immediately detected. A sufficient number of detection monitoring wells screened at the proper depths must be installed by the owner/operator to ensure that his ground-water monitoring system guarantees an acceptably high level of certainty that contaminant leakage will be immediately detected. Although every

detection monitoring system must ultimately be judged against site specific conditions, there are a number of criteria that enforcement officials can apply to ensure that detection monitoring systems satisfy the RCRA regulatory requirements. This chapter examines those criteria and provides examples on how enforcement officials can apply criteria in various hydrologic situations.

2.1 Placement of Downgradient Detection Monitoring Wells

This section describes criteria the enforcement official may use to evaluate decisions the owner/operator has made regarding placement of downgradient wells. Specifically, Section 2.1.1 describes criteria for evaluating the location of downgradient wells relative to waste management areas. Section 2.1.2 describes criteria for evaluating horizontal spacing between downgradient detection monitoring wells. Section 2.1.3 describes criteria for evaluating the depth of wells and vertical sampling intervals.

2.1.1 Location of Wells Relative to Waste Management Areas

In order to be able to immediately detect leaks should they occur, the owner/operator should install downgradient detection monitoring wells immediately adjacent to hazardous waste management units. In a practical sense, this means the owner/operator should install detection monitoring wells as close as physically possible to the edge of hazardous waste management unit(s). The two drawings in Figure 2-1 (A and B) illustrate the concept of the placement of wells immediately adjacent to hazardous waste management unit(s). Note how the placement of wells relative to the units shifts as a function of the direction of ground-water flow.

In geological settings exhibiting interbedded unconsolidated sands, silts, and clays (e.g., alluvial facies) where the water table is deep-seated, the lateral component of contaminant migration may carry it beyond the ground-water monitoring system before contaminants reach

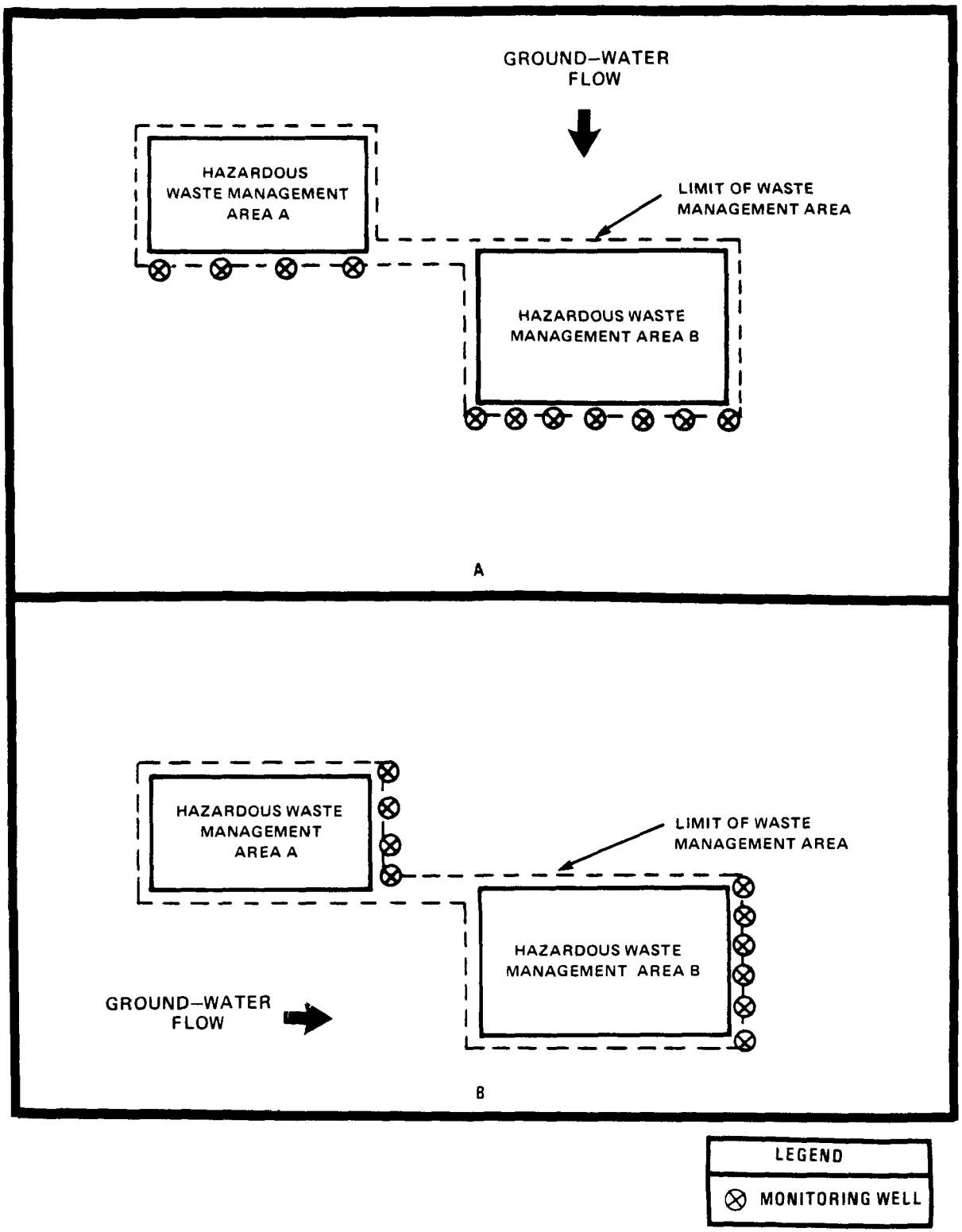

FIGURE 2-1. DOWNGRADIENT WELLS IMMEDIATELY ADJACENT TO HAZARDOUS WASTE MANAGEMENT LIMITS

ground water, and therefore beyond detection. The owner/operators could institute a program of vadose zone monitoring as a supplement to the ground-water monitoring program in such cases to provide immediate detection of any release(s) from the hazardous waste management area. Volatile organics which escape to the vadose zone, for instance, may be detected and characterized through soil gas analysis.

2.1.2 Horizontal Spacing Between Downgradient Monitoring Wells

An owner/operator's downgradient detection monitoring wells must be spaced closely enough together to assure that the ground-water monitoring system guarantees an acceptably high level of certainty that contaminant leakage will be immediately detected. The judgment as to whether the owner/operator has spaced detection monitoring wells close enough together does, of course, require analysis of site-specific conditions. Table 2-1 illustrates factors the enforcement official may use to decide if the owner/operator has made proper spacing decisions. These factors cover a variety of physical and operational aspects relating to the facility including hydrogeologic setting, facility design, waste characteristics and climate. The enforcement official should consider all factors described in Table 2-1 when evaluating well spacing.

The Agency has selected 150 feet as the point of departure from which well spacing may be compressed or expanded. By using the 150-foot spacing number as a point of departure and evaluating site specific factors, the enforcement official should be able to judge the ability of the owner/operator's monitoring system to immediately detect contaminant leakage. It should be noted that the 150-foot number is not one that enforcement officials should dogmatically apply. Site specific conditions should always drive decisions. In some cases, closer spacing is needed over all or over part of the site. In others, a wider spacing is adequate. In any event, the enforcement official is ultimately responsible for ensuring that well spacings are adequate given site

TABLE 2-1

FACTORS USED TO ADJUST HORIZONTAL SPACING OF MONITORING WELLS

WELLS MAY BE LESS THAN 150 FEET APART IF THE SITE:		WELLS MAY BE SPACED MORE THAN 150 FEET APART IF THE SITE:
• Manages or has managed liquid waste		• Has never managed liquid waste
• Is very small (i.e., the downgradient perimeter of the site is less than 150 feet)		
• Has a double liner (and may leak over a relatively small area)		
• Has waste incompatible with liner materials		
• Is an old facility, with less certainty on design features and past waste disposal practices		• Is new, with more certainty on facility design features and planned/current waste disposal practices
• Has fill material near the waste management units (where preferential flow might occur)	LESS THAN ← 150 FEET → GREATER THAN	• Uses appropriate and proven geophysical techniques to supplement monitoring wells in the detection monitoring program
• Has buried pipes, utility trenches, etc., where a point-source leak might occur		
• Has complicated geology - closely spaced fractures - faults - tight folds - solution channels - discontinuous structures		• Has simple geology - no fractures - no faults - no folds - no solution channels - continuous structures
• Has heterogenous conditions - variable hydraulic conductivity - variable lithology		• Has homogeneous conditions - uniform hydraulic conductivity - uniform lithology
• Is located in or near a recharge zone		
• Has a high (steep) or variable hydraulic gradient		• Has a low (flat) and constant hydraulic gradient

conditions. Final determination of adequate spacing will often come after comprehensive technical negotiations with the owner/operator in which each factor relating to spacing is evaluated and applied to spacing decisions. The enforcement official should, in these cases, remember that the 150-foot number is a starting point for negotiation and that the enforcement official is well within his authority to insist on closer spacing or to allow wider spacing. The following examples illustrate how site-specific factors as described in Table 2-1 may affect well spacing.

Figure 2-2 illustrates a facility which contains both a landfill and a surface impoundment. In this example, site geology is simple and homogeneous. The landfill has received very little liquid waste and its design is well documented. The surface impoundment contains a large volume of liquid waste. Monitoring wells around the landfill are spaced 225 feet apart because of simple and homogeneous site geology. Monitoring wells around the surface impoundment are spaced 75 feet apart since there exists a greater potential for the generation of narrow contaminant plumes through holes in the liner propelled by the intrinsic head of the liquid waste in the impoundment.

The two drawings in Figure 2-3 illustrate well placement based upon surficial stratigraphic complexity. In drawing A, the landfill is completely situated on homogenous geology allowing the average well spacing to prevail. Drawing B shows a facility that is situated over heterogenous geology where well spacings need to be altered to account for changes in lithology. Monitoring well spacing in the sand and gravel formation should be closer than that in the clay-silt formation. The potential for the escape from detection of more rapidly migrating narrow plumes, especially through gravel seams, is higher in sand and gravel formations than in clay-silt formations which are characterized by lower hydraulic conductivities and higher diffusivities. Figure 2-3 illustrates how well spacing should change to reflect the different lithologic units. The monitoring wells in the clay and silt are spaced at 175 feet apart.

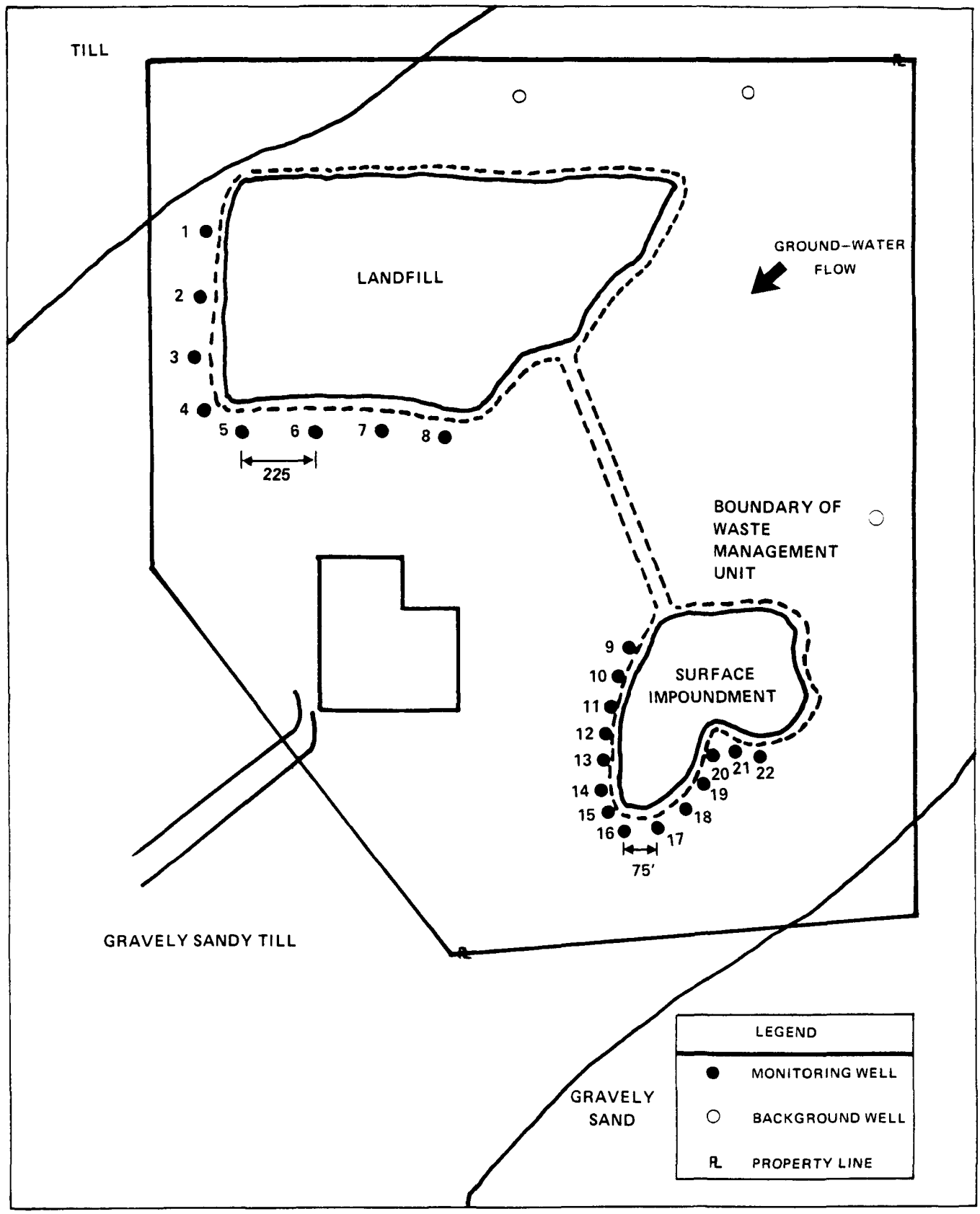

FIGURE 2-2. WELL SPACING BASED UPON WASTE CHARACTER

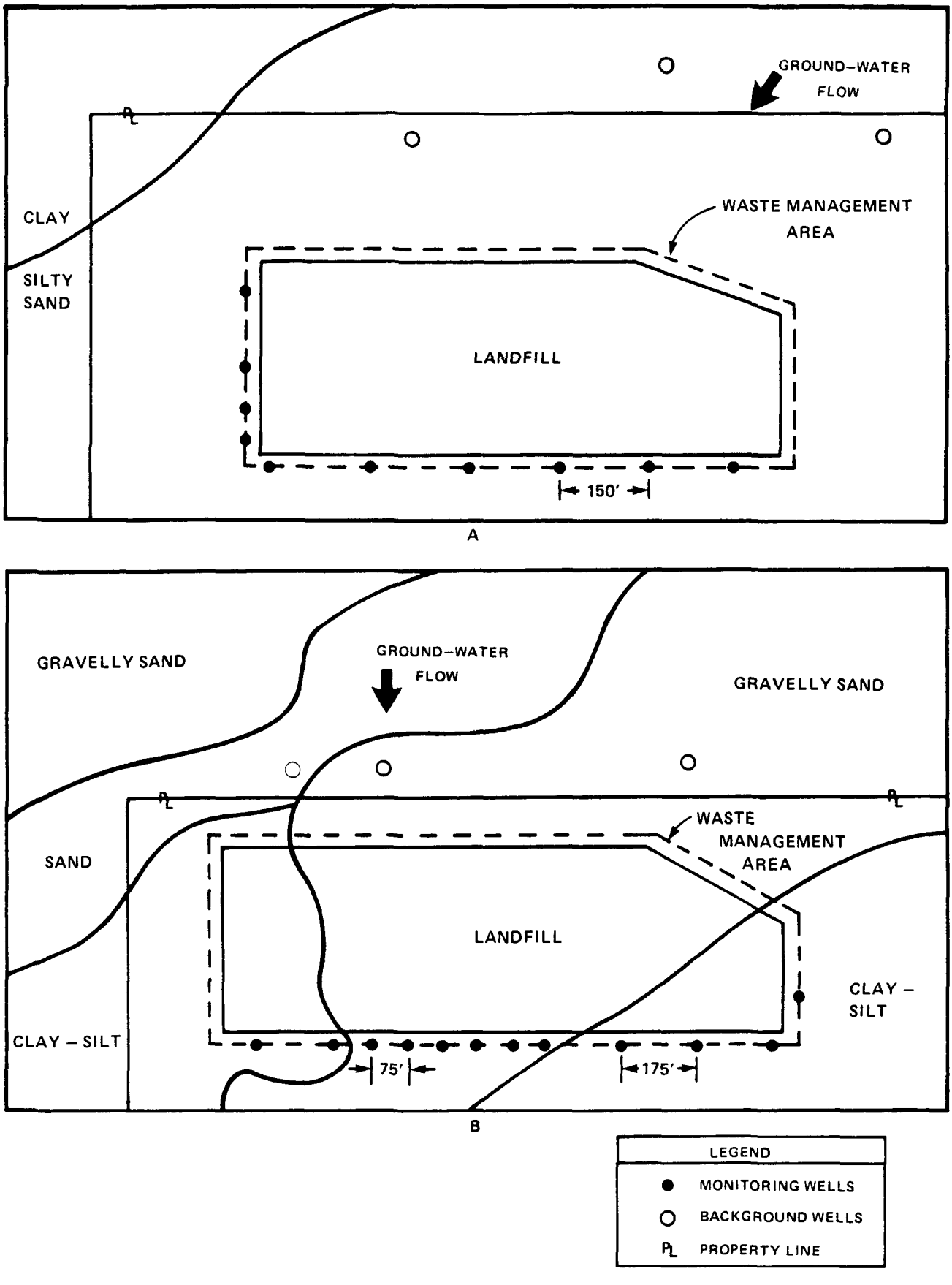

FIGURE 2-3. WELL SPACING BASED UPON SITE GEOLOGY

Figure 2-4 illustrates a facility where a landfill is situated on a small hilltop in sandy-silt overlying glacial till. The ground-water movement at the landfill is radial in all directions due to the induced hydraulic gradients caused by the mound. The site characterization data indicates more permeable fill on the edge of the facility. The swamp to the southeast is recharged from the landfill area. Since the discharge of the local ground water is into the swamp, closer well spacing is necessary to monitor potential discharge in that area. Note that since contaminants may move from this site in any radial direction that detection monitoring wells should ring the unit.

Figure 2-5 illustrates a situation where permeabilities are low (10^{-4} cm/sec) except in one area of the site which has higher permeability (10^{-2} cm/sec) which may be indicative of a preferential flow pathway. Closer well spacing is required in the area of preferential flow.

Figure 2-6 illustrates an unlined surface impoundment located on regularly-spaced nearly vertical fractures in consolidated siltstone. The wells should be located to intercept major fractures. To ensure that all levels are monitored, additional wells are located downgradient in the low permeable rock matrix. The wells (Nos. 1 through 6) appearing to be upgradient of the facility are actually downgradient due to the orientation of the fractures.

Figure 2-7 illustrates two waste disposal units on the same facility. Waste Unit A is an impoundment that is 15 years old, waste Unit B is a 5-year old landfill. The site is located on simple homogenous geology with a moderate permeability of 10^{-3} to 10^{-4} cm/sec. Because of the age of Unit A and the presence of surface liquids, there exists a greater probability of a contaminant release; therefore wells need to be much closer together than the newer Waste Unit B.

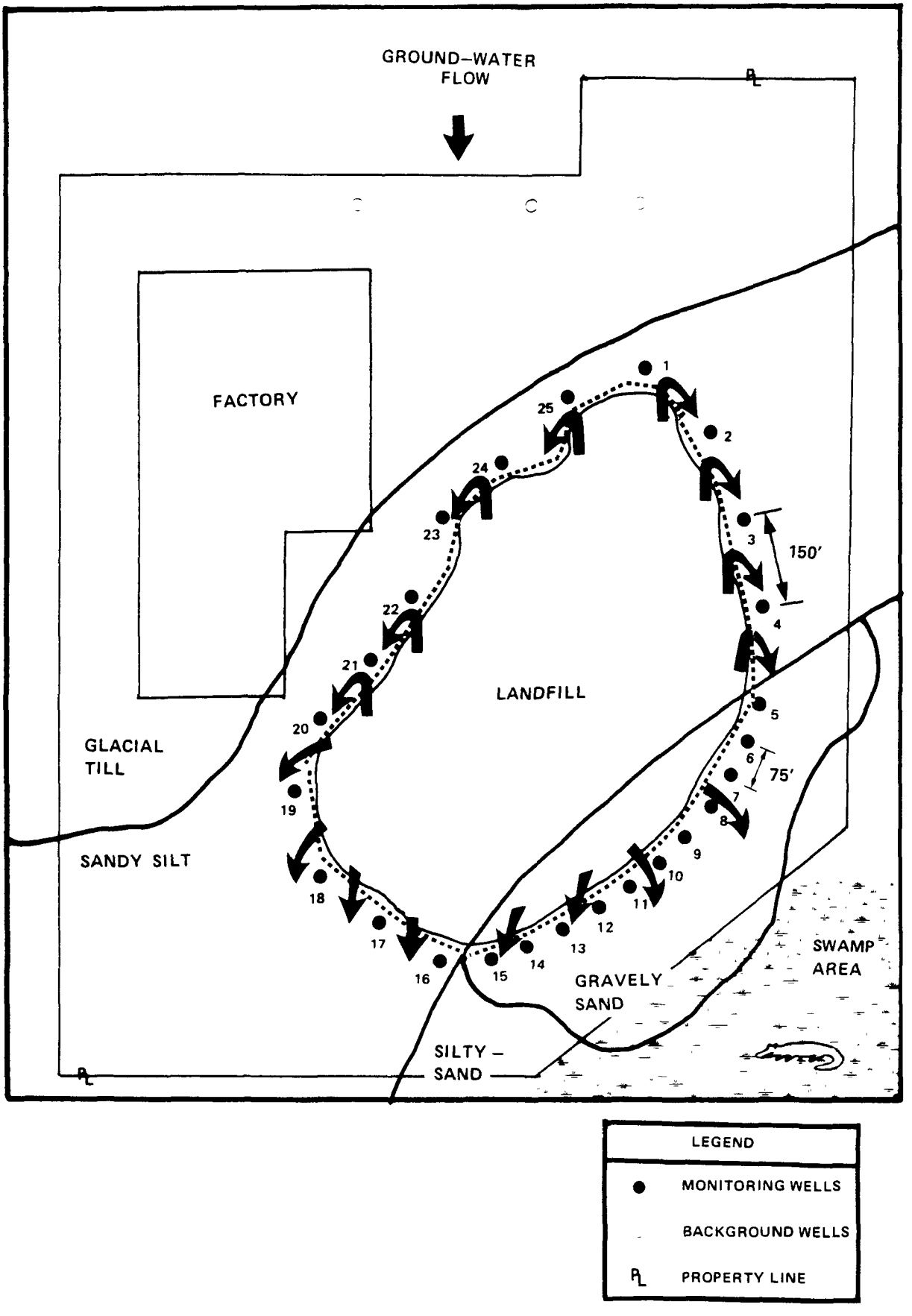

FIGURE 2-4. WELL PLACEMENT BASED UPON LOCALLY INUNDATED AREAS

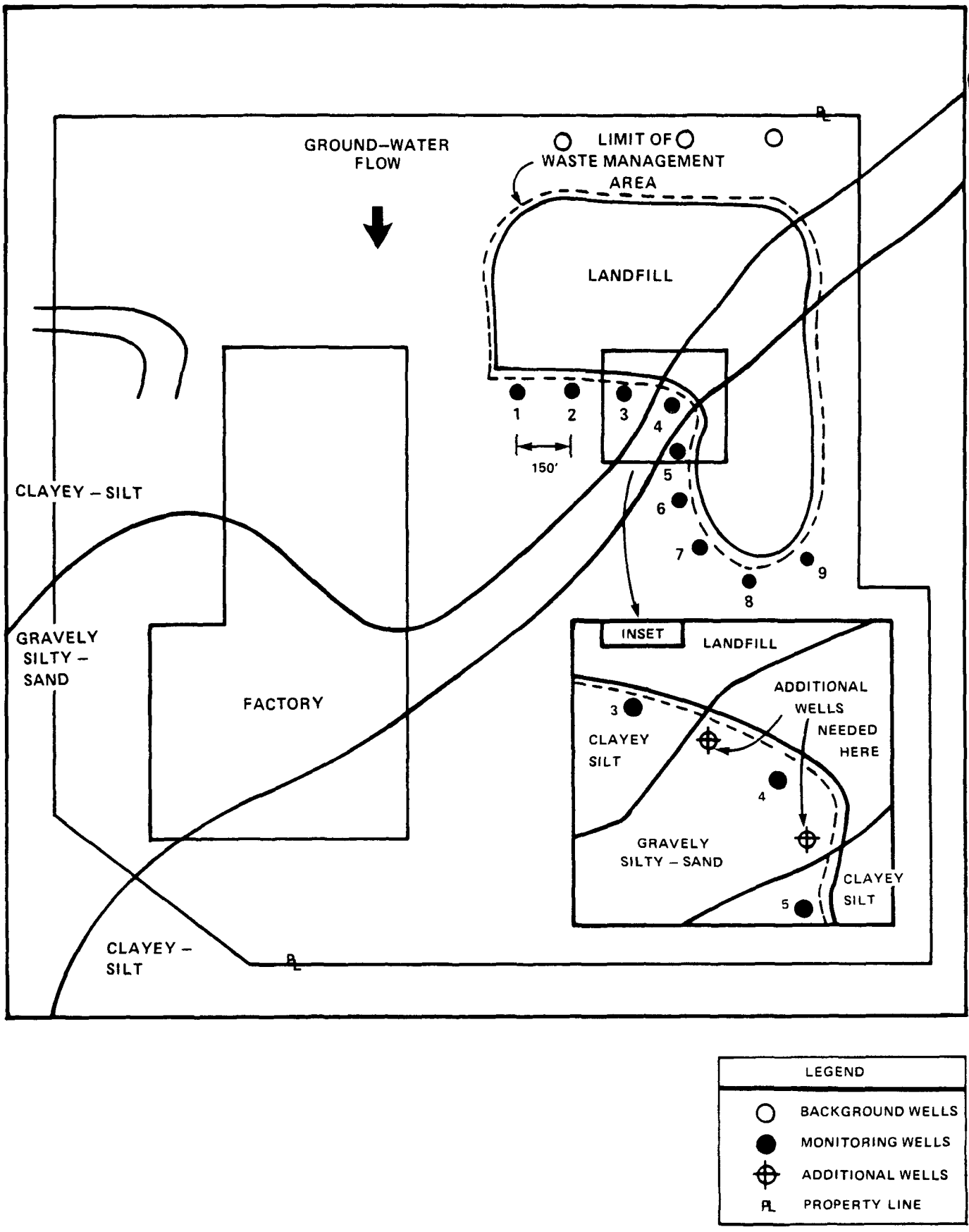

FIGURE 2-5. WELL PLACEMENT BASED UPON A CHANGE OF PREFERENTIAL ROUTES OF MIGRATION

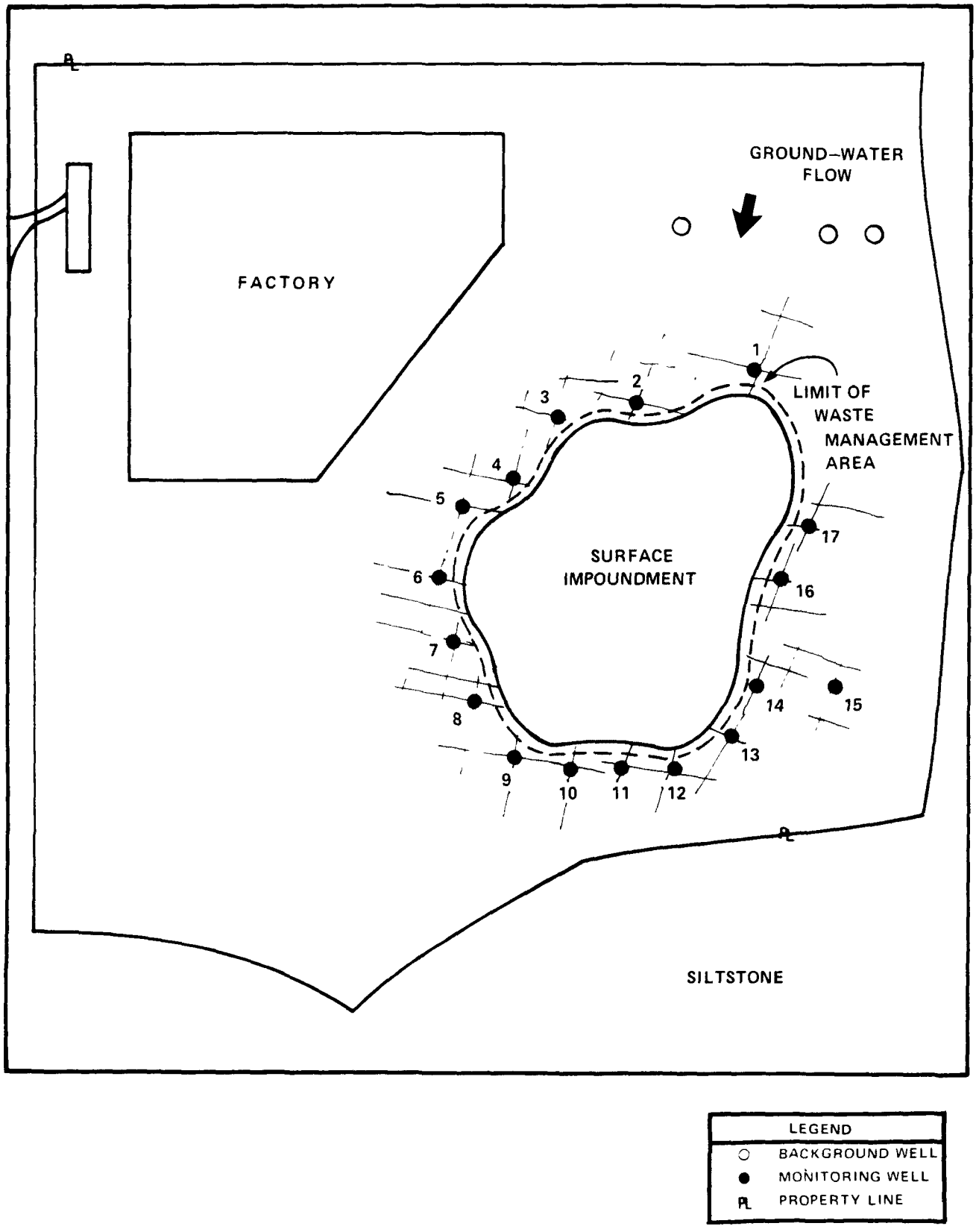

FIGURE 2-6. WELL PLACEMENT BASED UPON STRUCTURAL FRACTURING

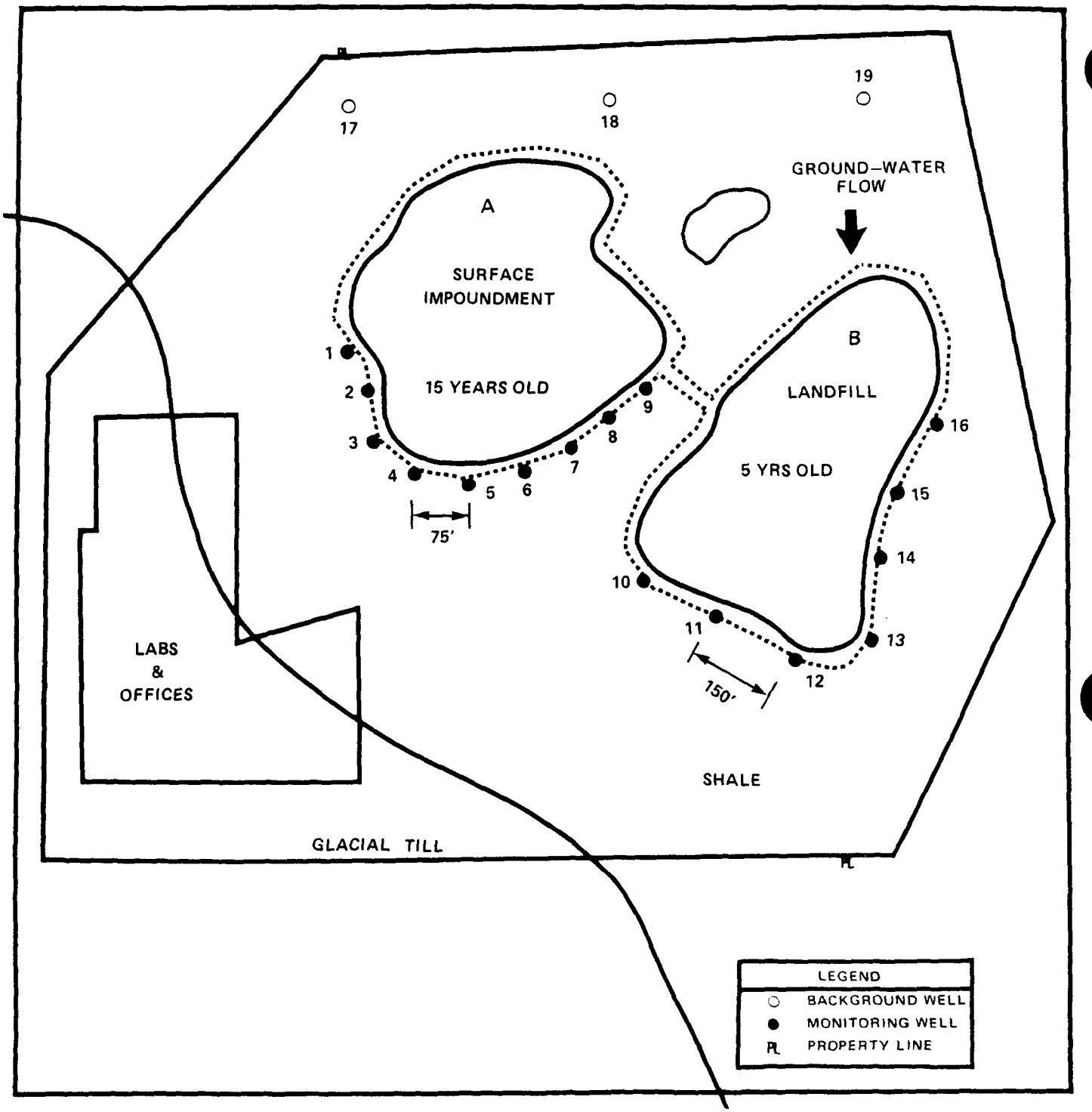

FIGURE 2-7. WELL PLACEMENT BASED UPON AGE AND WASTE CHARACTER

2.2 Depth of Wells/Vertical Sampling Interval(s)

Site-specific hydrogeological data generated by the owner/operator during the site characterization is indispensable not only to the determination of horizontal well spacing, but to the identification of the vertical sampling interval(s) as well. Proper selection of the vertical sampling interval provides the third dimension to the detection monitoring of potential contaminant pathways to the uppermost aquifer. Proper selection of the vertical sampling interval enables the owner/operator to design a detection monitoring system capable of immediately detecting a release from the hazardous waste management area with a high level of certainty. It is essential, therefore, that the owner/operator's decisions regarding vertical sampling intervals are based upon site characterization data which identify both the depth and thickness of the stratigraphic horizon(s) most likely to serve as contaminant pathways. There are several guidelines or criteria that the enforcement official should follow in evaluating owner/operator decisions. A discussion of these guidelines follows.

2.2.1 Depth of Wells

The owner/operator should know from the site characterization which stratigraphic horizons represent potential contaminant migration pathways and should screen monitoring wells at the appropriate horizon(s) to ensure immediate detection of a release. It is extremely important to screen upgradient and downgradient wells at the same stratigraphic horizon(s) to obtain comparable ground-water quality data. The determination of the depth to a potential contaminant migration pathway may be made from soil/rock cores, supplemented by geophysical and available regional hydrogeological data.

2.2.2 Thickness of the Vertical Sampling Interval(s)

Determination of the appropriate thickness of the vertical sampling interval(s) is a natural extension of the depth selection. The owner/operator should make the decision on the basis of site characterization

data. Sources could include isopach maps of highly permeable strata, and stereographs of local geologic structures generated with soil/rock cores, geophysical and regional geological data.

In most cases, screen lengths should be no longer than ten feet. Shorter screens promote better resolution of contaminant concentrations than longer ones, which is a principal goal of detection monitoring. At sites where the vertical sampling interval is greater than ten feet, the owner/operator should install a well cluster at each sampling location. A well cluster is a number of wells grouped closely together often screened at different stratigraphic horizons. The greater the extent of the vertical sampling interval, the more wells the owner/operator should place in a cluster.

It is important to remember that the vertical sampling interval is not necessarily synonymous with aquifer thickness. In other words, the owner/operator may select a vertical sampling interval which represents a fraction of the thickness of the uppermost aquifer. The selection should be made on the basis of site characterization data. A sufficiently detailed site characterization may therefore reduce the need for the owner/operator to install more speculative wells by identifying, with a reasonable degree of certainty, the preferential flow paths from the hazardous waste management area to the uppermost aquifer. The owner/operator thus tailors the selection of the vertical sampling interval to site-specific conditions.

There are situations where the owner/operator should have multiple wells at a sampling location and others where typically one well is sufficient. They are summarized in Table 2-2. Generally, the presence of immiscibles in a thick, complex saturated zone of the uppermost aquifer should prompt the owner/operator to use well clusters. Conversely, single phase contaminated ground water and a thin saturated zone within the uppermost aquifer, or isotropic hydrologic properties reduce the need for multiple wells at each sampling location. Where seasonal

TABLE 2-2

FACTORS AFFECTING NUMER OF WELLS PER LOCATION (CLUSTERS)

One Well per Sampling Location	More Than One Well Per Sampling
• No "sinkers" or "floaters" (immiscible liquid phases;) see glossary for more detail)	• Presence of sinkers or floaters
• Thin flow zone (relates to 10-foot screen exception)	• Hetergeneous uppermost aquifer; complicated geology - multiple, interconnected aquifers - variable lithology - perched water table - discontinuous structures
• Homogenous uppermost aquifer; simple geology	• Discrete fracture zones

fluctuation of the water table occurs and the owner/operator intends to sample for light phase immiscibles floating on it, the owner/operator should use screens long enough to always intercept the water table and floaters instead of installing multiple wells.

When the site characterization data indicate the presence of different but hydraulically interconnected strata, some of the wells should be screened with the bottom of the screens placed at the interface between the strata. Also, the owner/operator should have delineated through site characterization (e.g., flow net analysis) those flow zones in the aquifer(s) in which there is higher potential for contaminant movement. The owner/operator should install enough wells to ensure continuous screening in these zones. As above, these screens should not be longer than ten feet in flow zones in which a higher potential for contaminant movement exists.

The number of wells screened at different depths that an owner/operator should install at each sampling location increases with site complexity. Site factors which affect the number of wells that should be installed at each location are described in Table 2-2. The following examples illustrate how enforcement officials can use the factors discussed above to make decisions on the vertical spacing (depth) of wells and well screens.

Figure 2-8 illustrates a site where the owner/operator has adopted the use of geophysical techniques and soil gas analysis in a program of detection monitoring. The owner/operator's landfill is situated in unconsolidated silty sand and primarily contains organic wastes. The detection monitoring system in place at this facility provides for an integrated program of direct monitoring (e.g., wells), surface electromagnetic conductivity, surface resistivity, and organic vapor/soil gas analysis. (Appendix C provides information on geophysical techniques and soil/gas analysis.) Wells are located at 300-foot intervals. Geophysical

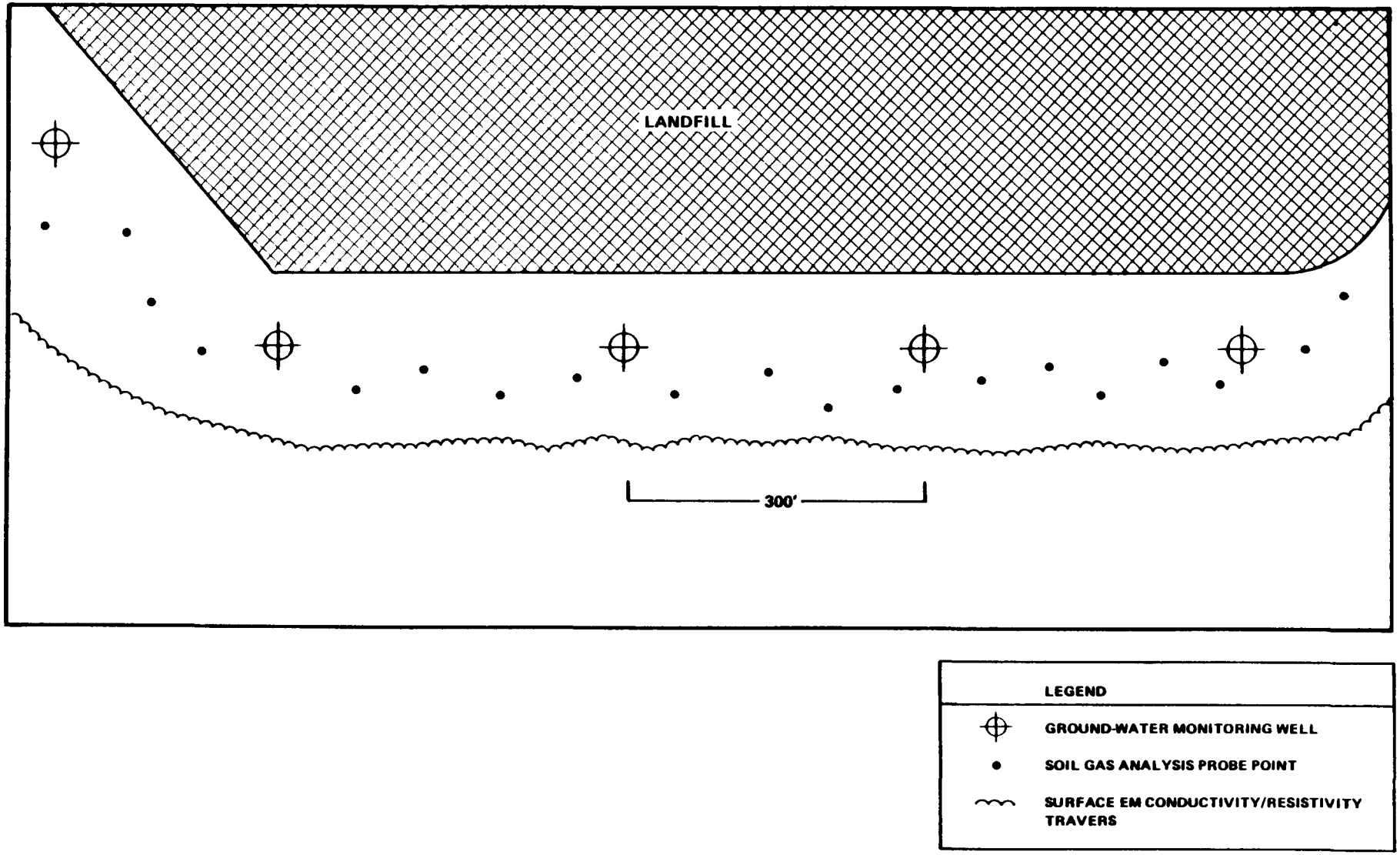

FIGURE 2-8. EXAMPLE OF WIDER MONITORING WELL SPACING DUE TO THE USE OF SUPPLEMENTARY INVESTIGATIVE TECHNIQUES

measurements and soil gas analysis supplement the collection of monitoring well data. Although the spacing between the wells has been expanded, the collection of additional data through various complementary techniques allows for adequate detection of leakage at this particular site. It should be noted, however, that the use of geophysical techniques and soil gas analysis is not a substitute for the installation of monitoring wells. There are, in fact, many situations where these methods cannot be used. In any event, the applications of these methods should not result in a drastic expansion of well spacing in a detection monitoring system.

Figure 2-9 is a cross section of a landfill site situated on a thin silty sand unit having a lower boundary of thick impermeable clay. Since the silty sand layer is the major matrix affecting ground-water flow, a double-well cluster is necessary to ensure the unit is screened at the water table and interface of the lowest confining unit. The screen at the water table must be situated and of the proper length to account for seasonal fluctuations in the water table.

Figure 2-10 shows the potential relationship between a landfill, its hydrology, and well depth. The facility is located on a thick uniform aquifer near its discharge point. Hydrological studies indicate an upward flow component between the landfill and the aquifer discharge area. Heavy and light immiscibles are expected from the facility. From this scenario, leachate is expected to move downward thereby establishing the need for only double-well clusters to detect for light and heavy phase materials. (Note: This diagram shows only one well cluster.) The shallow well should be screened at the water table to detect the presence of light phase immiscibles. The lower well should be screened where the heavier phase materials would be expected.

Figure 2-11 illustrates a landfill situated on silt underlain by discretely fractured, hydraulically connected rock. A three-well cluster is needed to adequately monitor ground-water conditions. The first well

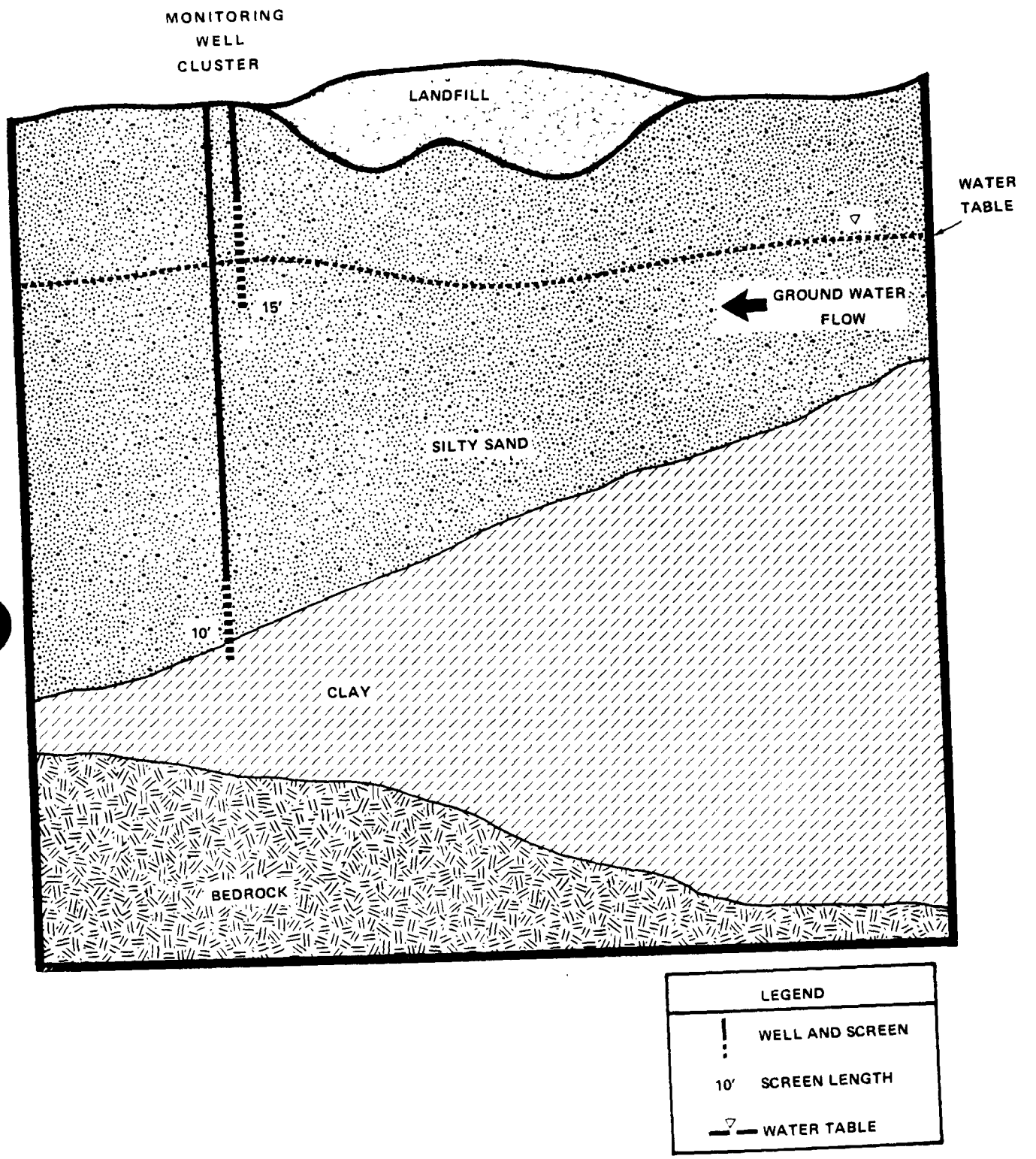

FIGURE 2-9. WELL DEPTH DETERMINATION BASED UPON FLOW–NET ANALYSIS

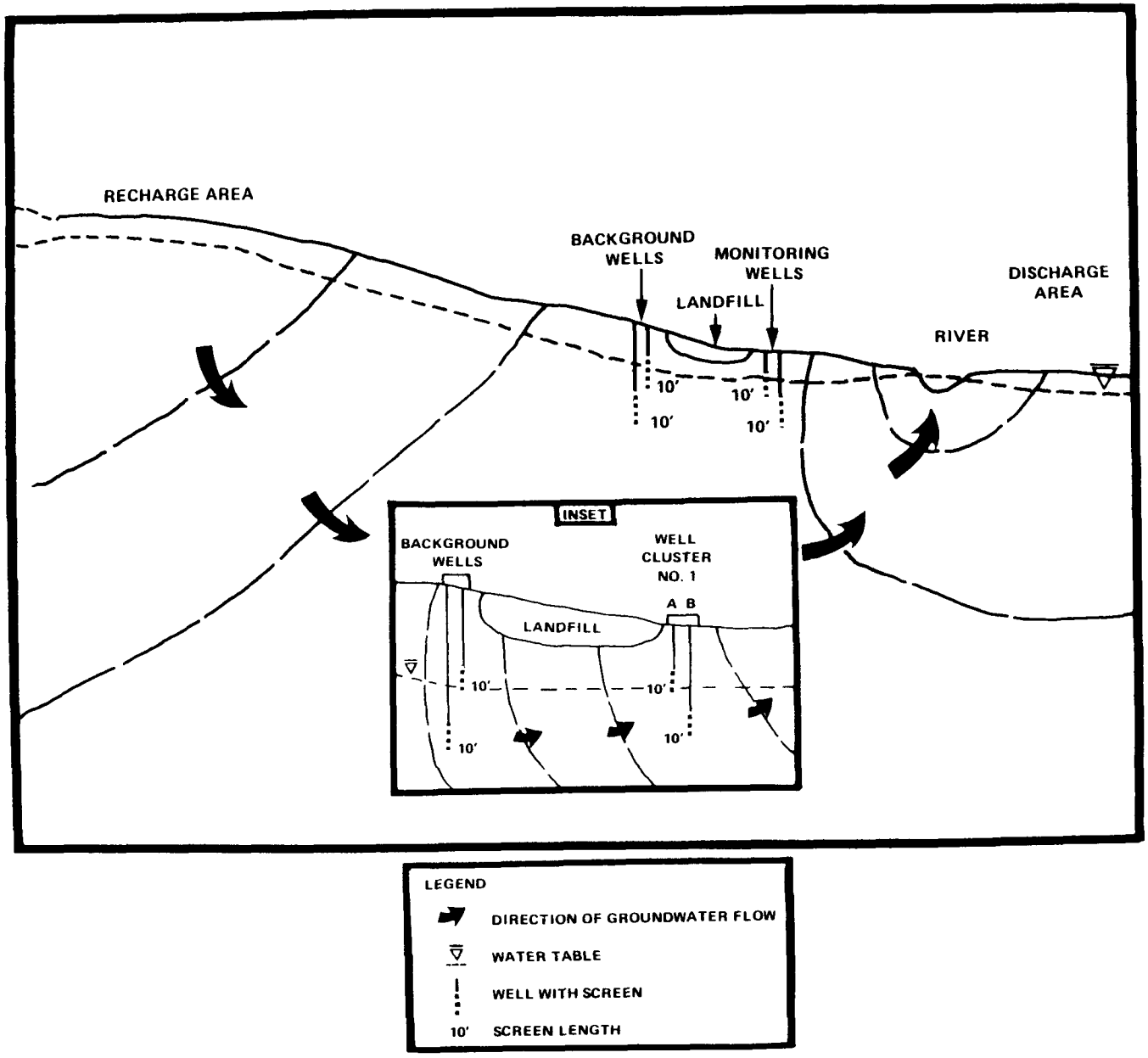

FIGURE 2-10. WELL PLACEMENT BASED UPON FLOW–NET ANALYSIS

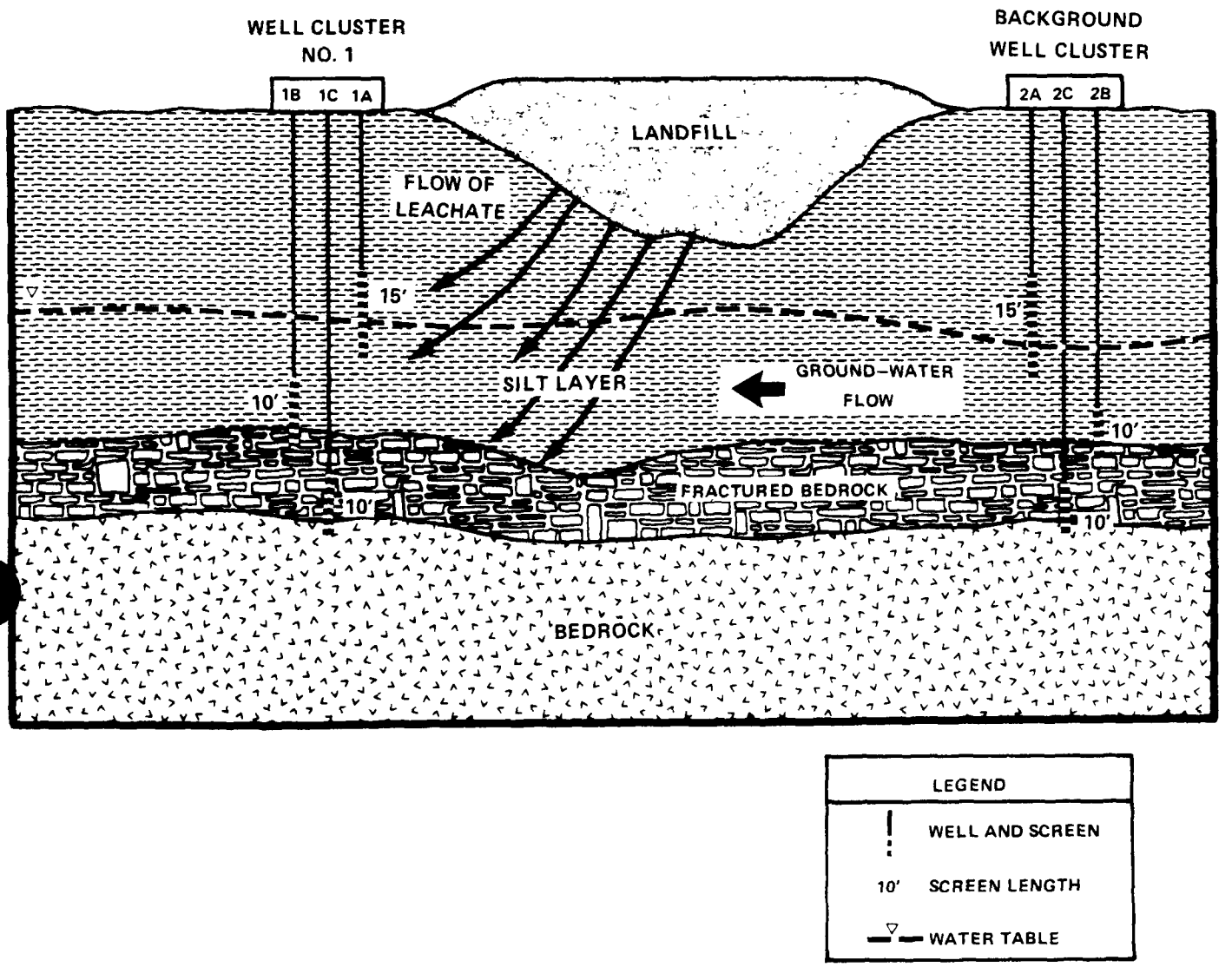

FIGURE 2-11. WELL PLACEMENT BASED UPON CHANGES IN GEOLOGY

(1A) is screened at the water table to detect light phase immiscibles. The 15-foot screen accounts for a five foot variation in the water table. The second well (1B) is screened for ten feet at the fractured rock interface to monitor ground-water movement in the fractures. The third well (1C) is screened at the interface of the fractured bedrock layer to allow for detection of contaminant movement to the first confining unit.

Figure 2-12 illustrates a landfill situated on silt underlain by sand and gravel, weathered shale and solid bedrock. The first 50 feet of the shale is weathered. A cluster of four wells is necessary to monitor the ground water under this facility. The first well (1A) monitors the water table. The next two wells monitor the silt (1B) sand and gravel (1C) layers which are the major water bearing units. The fourth well monitors the last ten feet of the shale layer. These last two wells are primarily for the detection of heavy phase immiscibles.

Figure 2-13 illustrates a landfill situated on porous sandstone underlain by a 100-foot thick claystone unit, a coal aquifer and bedrock. The sandstone is not hydraulically connected to the confined coal aquifer. The double-well cluster (1A and 1B) should include well screens in the sandstone and in the top of the claystone. Since the claystone has low permeability, it is not necessary to monitor the coal-claystone interface. The separate confined coal aquifer does not require monitoring since slug test data from Well 2 establishes that it is not hydraulically connected to the upper layers.

2.3 Placement of Upgradient (Background) Monitoring Wells

Since the downgradient wells must be properly situated to detect contaminant discharges into the uppermost aquifer, the upgradient wells should be located and constructed to provide representative samples of ground water in the same aquifer with which the downgradient samples can be compared.

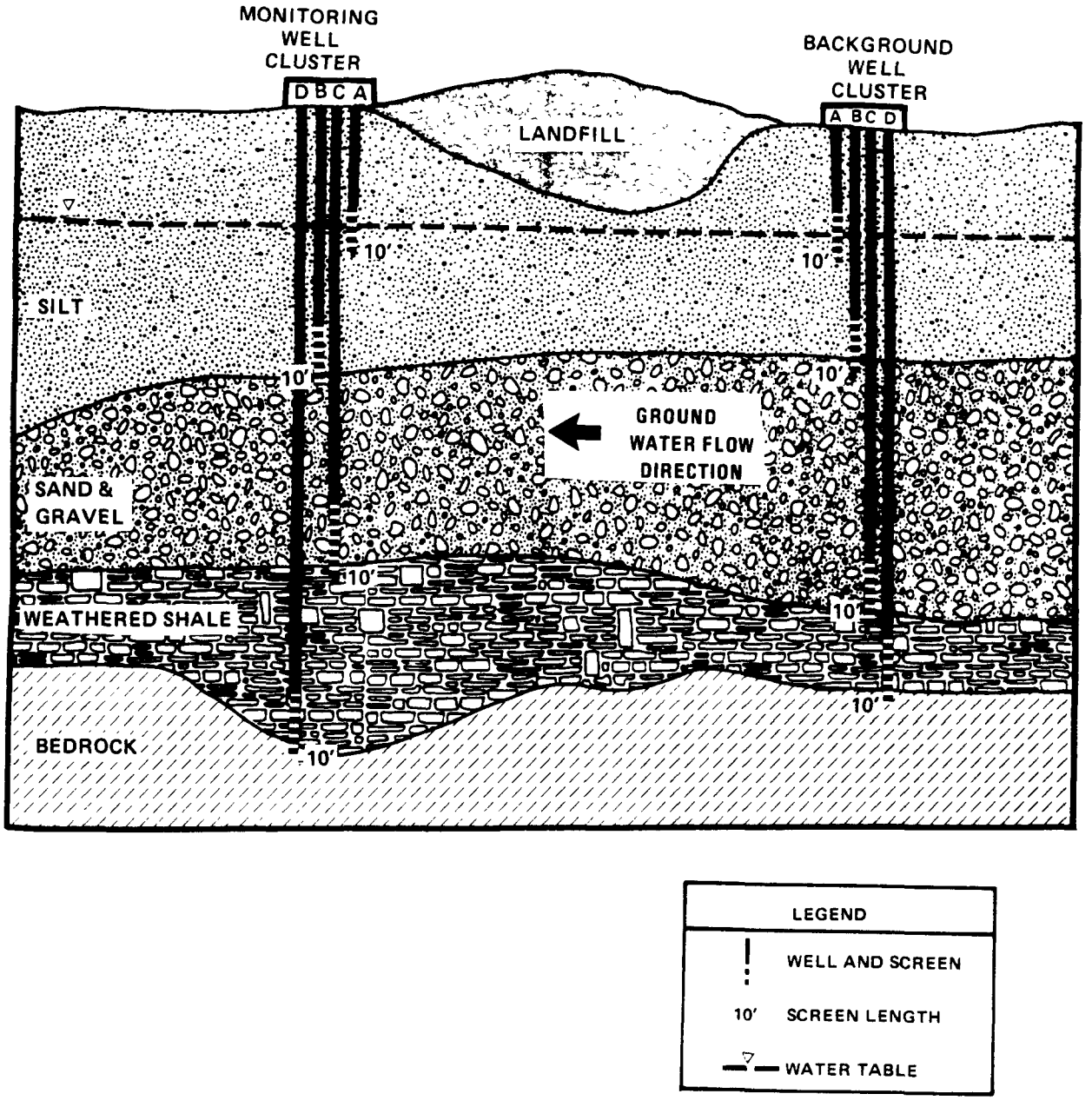

FIGURE 2-12. WELL PLACEMENT BASED UPON COMPLEX GEOLOGY

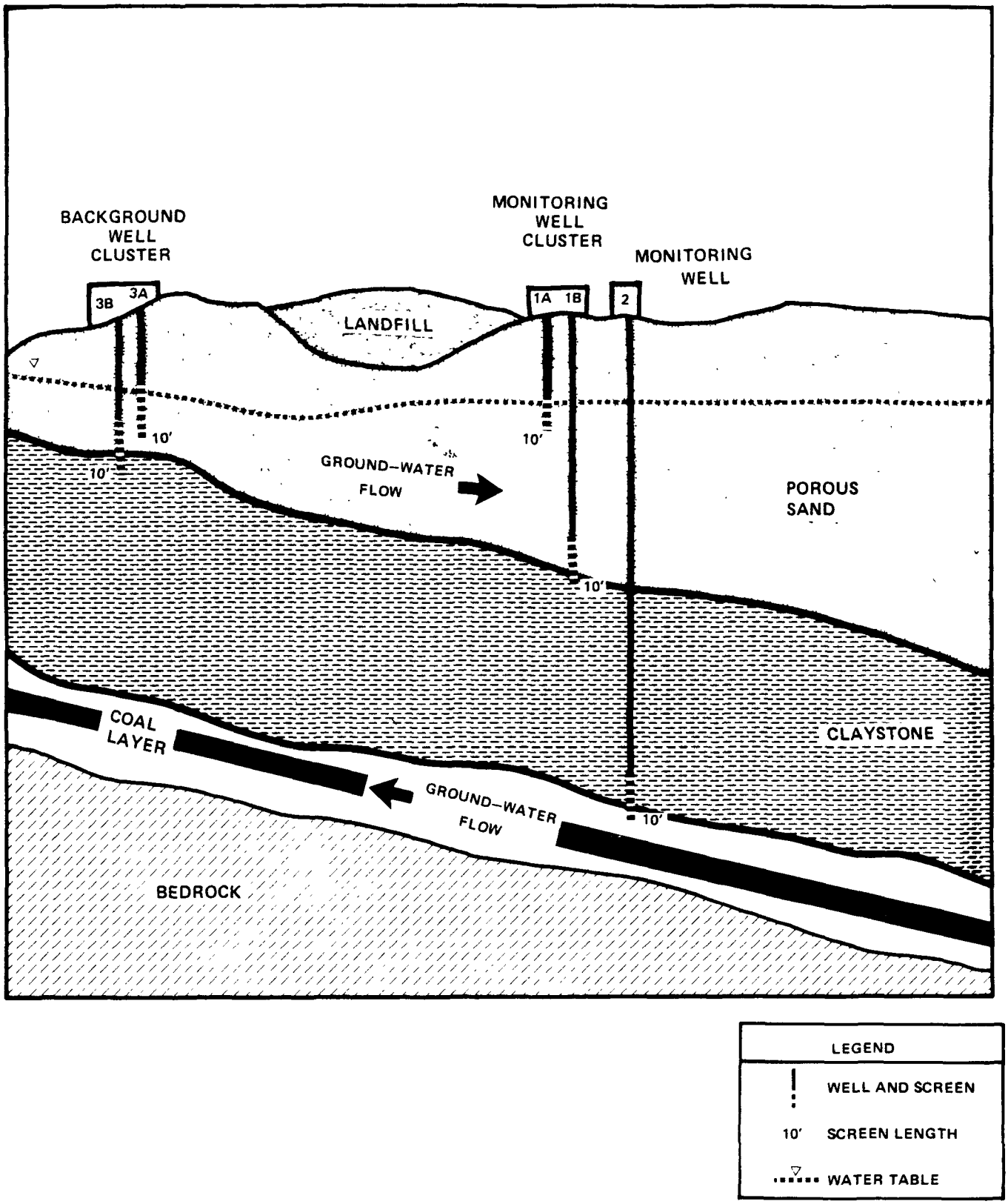

FIGURE 2-13. WELL DEPTH BASED UPON POSSIBLE HYDRAULIC CONNECTION

There are three questions the enforcement official should ask as he reviews the decisions the owner/operator has made regarding the placement of his background monitoring wells:

- Has the owner/operator located background wells far enough away from waste management areas to prevent contamination from the facility?
- Has the owner/operator installed enough wells, screened at appropriate depths, to adequately account for spatial variability in background water quality?
- Has the owner/operator used well clusters at sampling locations so that comparisons of background data with downgradient data are made within the same hydrologic unit?

The owner/operator must install background wells so that the groundwater samples taken from these wells cannot be affected by contaminant discharge from the facility. Usually, this is accomplished by locating the background wells far enough upgradient from waste management units to avoid contamination by the facility. For most sites, upgradient areas which are not likely to be affected by the facility can be readily identified from examination of water level data. However, in some special cases, locating the upgradient wells to avoid contamination is complicated.

The minimum number of wells the owner/operator may install is one. However, a facility that uses only one well for background sampling may not be able to account for spatial variability in water quality. It is, in fact, a very unusual circumstance in which only one background well is adequate such as a facility in a completely homogeneous uppermost aquifer. The owner/operator who makes comparisons of background and downgradient monitoring well results with data from only one background well increases the risk of false indication of contamination. In most cases, the owner/operator should install at least four background monitoring wells in the uppermost aquifer to account for spatial variability in background water quality data.

The owner/operator should also install enough background monitoring wells to allow for depth-discrete comparisons of water quality. This means simply that for downgradient wells completed in a particular geologic formation and at a particular depth, the owner/operator should install corresponding wells at the upgradient sampling locations so that the data can be compared on a depth-discrete basis. Figure 2-14 illustrates this concept.

It is not usually acceptable for an owner/operator to install background monitoring wells that are screened over the entire thickness of the uppermost aquifer. Screening the entire thickness of the uppermost aquifer will not allow the owner/operator to obtain depth-discrete water quality data. Instead, what the owner/operator will obtain is average water quality data for the entire thickness of the uppermost aquifer. In order to obtain depth-discrete water quality data, the owner/operator should use well screens no longer than ten feet.

In order to establish background ground-water quality, it is necessary to properly identify ground-water flow direction and place wells upgradient to the waste management area. There are several geological and hydrological situations for which determination of the upgradient location is often difficult; further site-specific examination is necessary to properly locate background wells:

1. Waste management areas above water table mounds.

2. Waste management areas located above aquifers in which ground-water flow directions change seasonally.

3. Waste management areas located close to a property boundary that is in the upgradient direction.

4. Waste facilities containing significant amounts of immiscible contaminants with densities greater than or less than water.

5. Waste management facilities located in areas where nearby surface water can influence ground-water levels (e.g., river floodplains).

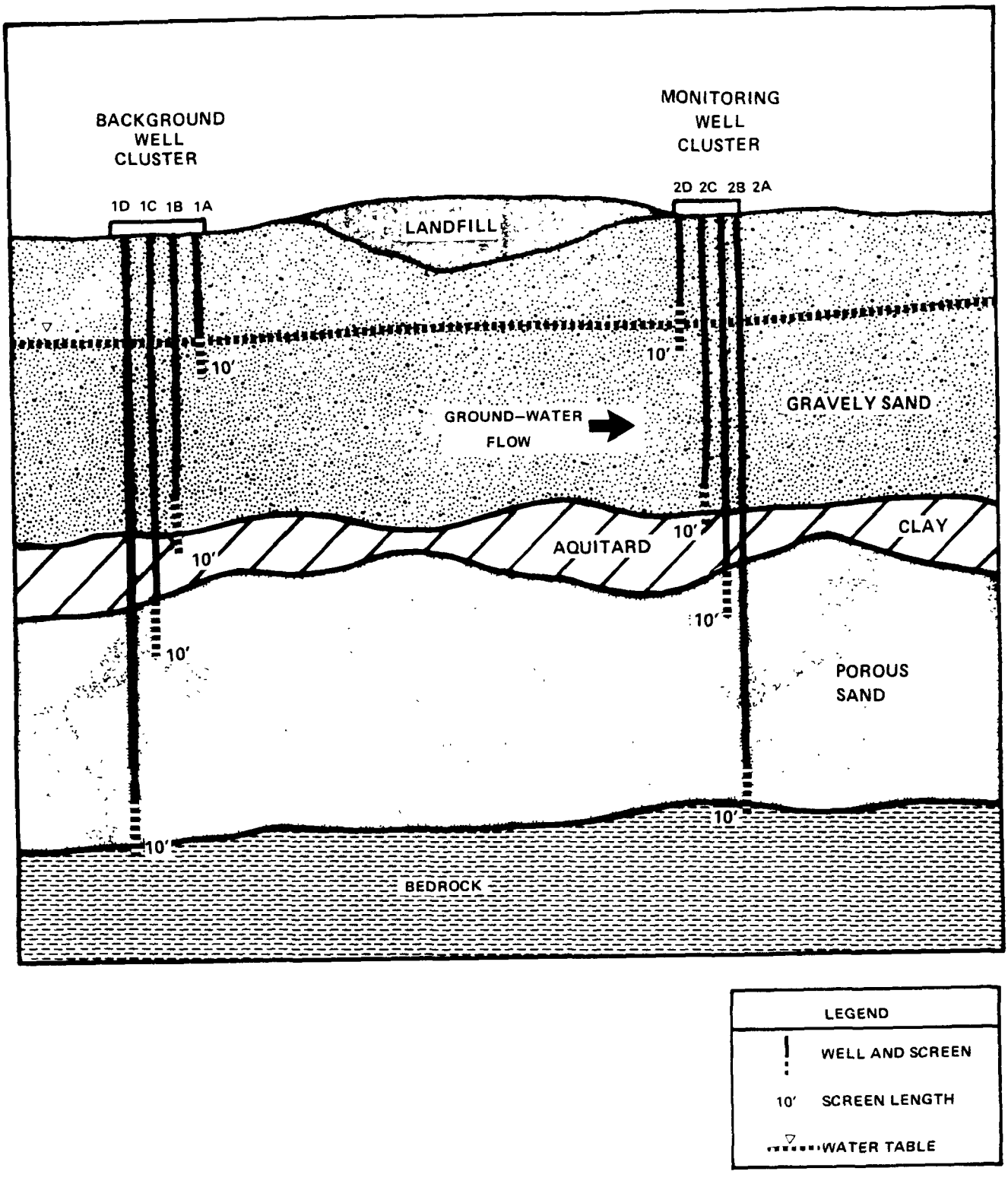

FIGURE 2-14. PLACEMENT OF BACKGROUND WELLS

6. Waste management facilities located near production for intermittently-used wells.

7. Waste management facilities located in Karst areas or faulted areas where fault zones may modify flow.

CHAPTER THREE

MONITORING WELL DESIGN AND CONSTRUCTION

The purpose of this chapter is to examine important aspects of RCRA monitoring well design and construction. Included in this chapter are discussions on the following topics:

- drilling methods for installing wells (Section 3.1);
- monitoring well construction materials (Section 3.2);
- design of well intakes (Section 3.3);
- development of wells (Section 3.4);
- documentation of well construction activity (Section 3.5);
- specialized well design (Section 3.6); and
- replacement of existing wells (Section 3.7).

3.1 Drilling Methods

A variety of well drilling methods are available for the purpose of installing ground-water monitoring wells. Of utmost importance is that the drilling method the owner/operator uses will minimize the disturbance of subsurface materials and will not cause contamination of the subsurface and ground-water. Table 3-1 illustrates the drilling methods the owner/operator should use in installing wells. The selection of the actual drilling method that an owner/operator should use at a particular site is, of course, a function of site-specific geologic conditions. Table 3-1 illustrates how geologic conditions will influence the choice of drilling method the owner/operator shoud use. The following sections discuss each drilling method and its applicability to the installation of RCRA monitoring wells. It is important to note that regardless of the drilling method the owner/operator selects, the owner/operator should steam-clean drilling equipment before use and between borehole locations to prevent cross contamination of wells.

TABLE 3-1

DRILLING METHODS FOR
VARIOUS TYPES OF GEOLOGIC SETTINGS

Geologic Environment	Drilling Methods				
	Air Rotary	Water Rotary	Cable Tool	Hollow-Stem Continuous Auger	Solid-Stem Continuous Auger*
Glaciated or unconsolidated materials less than 150 feet deep				1	2
Glaciated or unconsolidated materials greater than 150 feet deep	1	2	3		
Consolidated rock formations less than 500 feet deep (minimal or no fractured formations)	1	2	3		
Consolidated rock formations less than 500 feet deep (highly fractured formations)	1	2	3		
Consolidated rock formations more than 500 feet deep (minimal formations)	1	2	3		
Consolidated rock formations more than 500 feet deep (highly fractured formations)	1	2	3		

*Above water table.

NOTES:

1 = First choice
2 = Second choice
3 = Third choice

3.1.1 Hollow-Stem Continuous-Flight Auger

The hollow-stem continuous-flight auger rig is among the most frequently employed drill rigs for the construction of monitoring wells in unconsolidated materials. The rigs are generally mobile, fast, and inexpensive to operate. No drilling fluids are used and disturbance to the geologic materials penetrated is minimal. However, augers can only be used in unconsolidated rock and most rigs are limited to drilling to approximately 150 feet. In formations where the borehole will not stand open, the well is constructed inside the hollow-stem augers prior to their removal from the ground. Six-inch inside diameter hollow-stem augers are available for this purpose. The diameter of the well that can be constructed with this type of drill rig is limited to four inches or less. The use of hollow-stem auger drilling in heaving sand environments also presents some difficulties for the drilling crew. However, with care and the use of proper drilling procedures, this difficulty can be overcome.

3.1.2 Solid-Stem Continuous-Flight Auger

The use of solid-stem continuous-flight auger drilling techniques for monitoring well construction is limited to fine-grained unconsolidated materials that will maintain an open borehole or in consolidated sediments. The method is similar to the hollow-stem continuous augers except that the augers must be removed from the ground to allow insertion of the well casing and screen. This method is also limited to a depth of up to 150 feet. In profiles consisting of less competent materials, solid-stem auger drilling can be utilized to limited depths; however, caving of the borehole does present a problem making installation of the casing difficult to impossible. Another restriction of the solid-stem auger is the use below the water table. Again, maintaining the integrity of the borehole in the saturated zone is sometimes difficult, especially in environments of poorly consolidated sediments. Solid-stem auger drilling does not lend itself to in-place well construction as with the

hollow-stem auger. Collection of soil or formation samples is impractical, and therefore, accurately portraying the subsurface profile at the site is difficult. Solid stem augers thus cannot be used in the boring program for site characterization.

3.1.3 Cable Tool

The cable tool type of rig is relatively slow but offers many advantages that make it the useful for monitoring well construction in relatively shallow consolidated formations and unconsolidated formations. The method allows for the collection of excellent formation samples and detection of even relatively fine grained permeable zones. The installation of a steel casing as drilling progresses also provides an excellent temporary host for the construction of a monitoring well once the desired depth is reached.

Small amounts of water must be added to the hole as drilling progresses until the water table is encountered. The owner/operator should only use water that cannot itself contaminate formation water. A minimum six-inch diameter drive pipe should be used to facilitate the placement of the well casing, screen, and gravel pack, and a minimum five foot long seal prior to beginning the removal of the drive pipe. The placement of the seal in the drive pipe prior to pulling will assist in holding the gravel pack, casing, and screen in place. The drive pipe should be pulled while the sealant is still fluid and capable of flowing outward to fill the annular space vacated by the drive pipe. The drive pipe also should be pulled in sections and additional sealant added to ensure that a satisfactory seal is obtained. For the most part, cable tool rigs have been replaced by rotary rigs in most of the United States. Therefore, cable tool rigs may not be readily available in many regions.

3.1.4 Air Rotary

Rotary drilling methods operate on the principle of circulating either a fluid or air to remove the drill cuttings and maintain an open

hole as drilling progresses. The different types of rotary drilling are named according to the type of fluid and the direction of fluid flow. Air rotary drilling forces air down the drill pipe and back up the bore hole to remove the drill cuttings. The use of air rotary drilling techniques is best suited for use in hard rock formations. In soft unconsolidated formations casing is driven to keep the formations from caving.

Air rotary drilling can be used for constructing monitoring wells without affecting the quality of water from monitoring wells in hard rock formations with minimum unconsolidated overburden. The successful construction of monitoring wells using this drilling technique is dependent on the ability of the bore hole to stand open after the air circulation ceases. The air from the compressor on the rig should be filtered to ensure that oil from the compressor is not introduced into the geologic system to be monitored. Foam or joint compounds for the drill rods should not be used with air rotary drilling because of the potential for introduction of contaminants into the hydrogeologic system. The use of air rotary drilling techniques should not be used in highly polluted or hazardous environments. Contaminated solids and water that are blown out of the hole are difficult to contain and may adversely affect the drill crew and observers. Conversely, air rotary drilling techniques have actually improved safety conditions where contamination is due to volatile constituents in some instances.

3.1.5 Water Rotary

Water rotary drilling introduces water into the borehole by way of the drill pipe, circulates water back up the hole and removes drill cuttings. Great care must be taken to ensure that water used in the drilling process does not contain contaminants. If the owner/operator uses water rotary drilling to install wells, the owner/operator should analyze drilling water to ensure it is contaminant free.

There are problems associated with the use of water rotary drilling. The recognition of water-bearing zones is hampered by the addition of water into the system. Also, in poorly consolidated sediments, the drillers may have a problem with caving of the borehole prior to installation of the screen and casing. In highly fractured terrains, it may also be hard to maintain water circulation.

3.1.6 Mud Rotary

Mud rotary drilling techniques use various types of muds as the medium which is introduced into the borehole. The mud circulates back up the hole during drilling, carrying away drill cuttings much as air and water rotary methods. Muds provide the additional benefit of stabilizing the hole, especially in deep-seated highly saline formations.

There are several types of muds available at present primarily bentonite, barium, sulfate, and organic polymer types. While there are hydrogeologic conditions under which mud rotary drilling is the best option (i.e., deep-seated highly saline formations), the enforcement official should make certain that the mud(s) utilized affect neither the chemistry of ground-water samples nor the operation of the well and hence the assessment of aquifer characteristics. For example:

- Bentonite muds tighten the formation around the well thereby compromising estimates of well recovery. Bentonite may also affect local ground-water pH.
- Barium sulfate muds introduce barium to the ground water. Barium is a RCRA extraction procedure toxicity parameter and Clean Water Act priority pollutant.
- Organic polymers and compounds provide an environment for bacterial growth which, in turn, reduces the reliability of sampling results.

3.2 Monitoring Well Construction Materials

The enforcement official must ensure that the owner/operator uses well construction materials that are durable enough to resist chemical

and physical degradation and do not interfere with the quality of ground-water samples. Specific well components that are of concern include well casings, well screens, filter packs, and annular seals. Figure 3-1 is a diagram of a general cross section of a ground-water monitoring well. The following sections describe various materials the owner/operator should use in constructing the well as illustrated in Figure 3-1.

3.2.1 Well Casings and Well Screen

A variety of construction materials have been used for the casings and well screens of including, teflon*, steel (stainless, black, galvanized), PVC, polyethylene, epoxy biphenol, and polypropylene. Many of these materials, however, may affect the quality of ground-water samples and may not have the long-term structural characteristics required for RCRA monitoring wells. For examples, steel casing deteriorates in corrosive environments; PVC deteriorates when in contact with ketones, esters, and aromatic hydrocarbons; polyethylene deteriorates in contact with aromatic and halogenated hydrocarbons; and polypropylene deteriorates in contact with oxidizing acids, aliphatic hydrocarbons, and aromatic hydrocarbons. In addition, steel, PVC, polyethylene, and polypropylene may adsorb and leach constituents which may affect the quality of ground-water samples.

In constructing wells, the owner/operator should use teflon, stainless steel 316, or other proven chemically and physically stable materials for well screens and for those portions of the well casing in the saturated zone. Other noninert materials such as steel, PVC, polyethylene and polypropylene may be used as well casing above the saturated

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*The use of the term "teflon" in this report by U.S. EPA is purely as a generic expression for polytetrafluoroethylene (PTFE) materials and in no way is meant to serve as an endorsement of PTFE products under the U.S. Trademark name of E.I. DuPont DeNemours and Company.

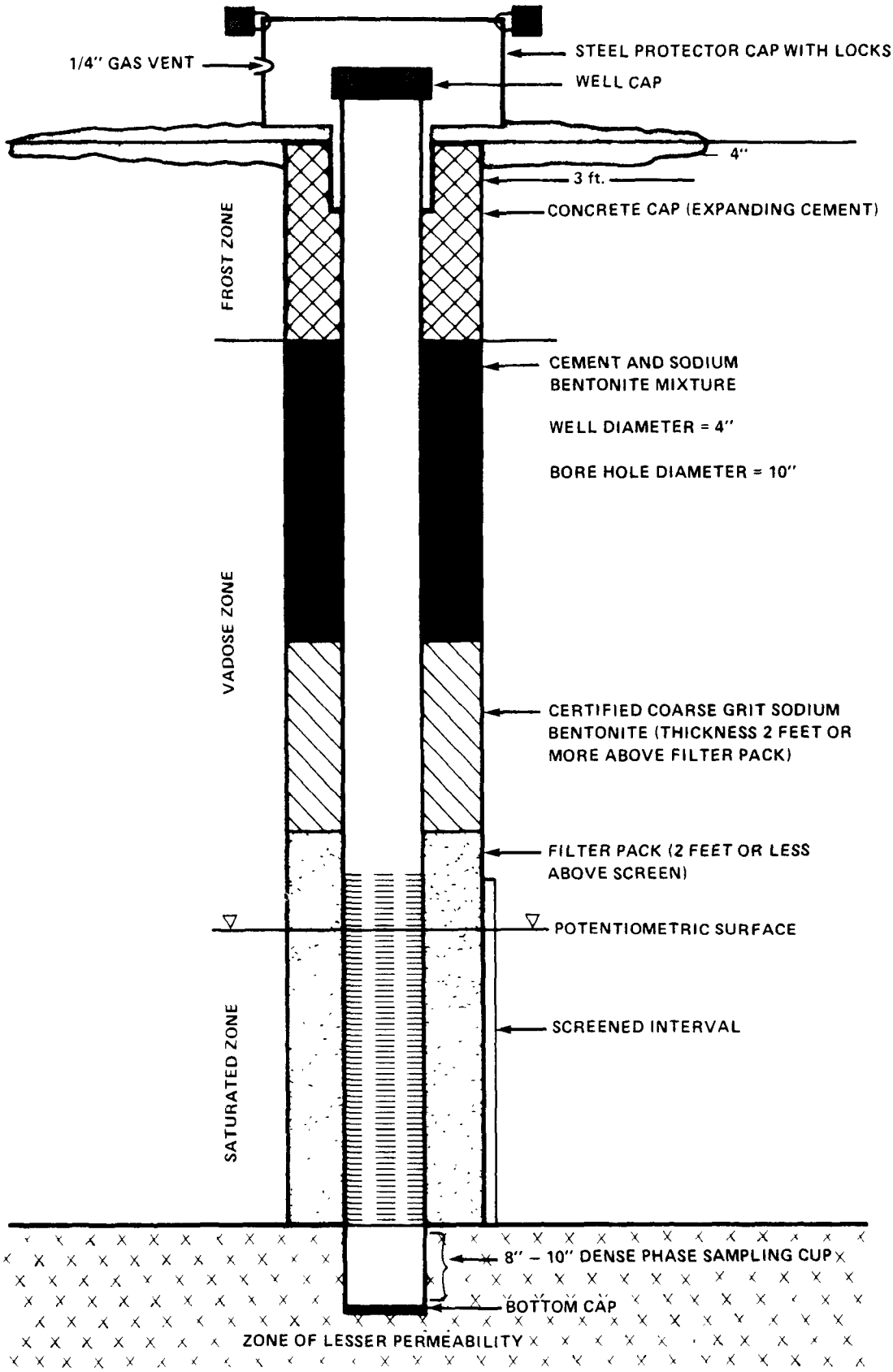

FIGURE 3-1. GENERAL MONITORING WELL – CROSS SECTION

zone. Figure 3-2 illustrates the concept of such a composite well. There are two reasons why owner/operators should use teflon or stainless steel 316 as screens and as well casing materials.

- Teflon and stainless steel 316 are more highly resistant to corrosion from a wide variety of chemical species likely to be encountered in the field than other well casing materials currently in use, e.g., polyvinyl chloride, stainless steel 304. This trait is important because it indicates that wells constructed of teflon or stainless steel 316 casings will retain their structural integrity over the long term better than those constructed of other materials. Long term structural integrity, i.e., 30 or more years, is essential to the collection of unbiased ground-water samples over the active life of the facility.

- Owner/operators of facilities whose Part B or post-closure permit application has been called are required under 270.14(c)(4) to analyze any plume(s) for Appendix VIII constituents. The remainder of facilities must monitor for Appendix VII constituents. Both appendices include organic constituents. Well construction materials should not bias the collection and analysis of low concentrations of these organic constituents by reacting with the ground-water samples. Current research suggests that teflon and stainless steel 316 do not sorb or leach trace organics constituents to the degree that other materials do, e.g., organic polymers, galvanized steel.

Plastic pipe sections must be flush threaded or have the ability to be connected by another mechanical method which will not introduce contaminants such as glue or solvents into the well. All well casings and screens should be steam cleaned prior to emplacement to ensure that all oils, greases, and waxes have been removed.

The owner/operator should normally use well casing with either a two-inch or four-inch interior diameter. Larger casing diameters, however, may be necessary where dedicated purging or sampling equipment is used or where the well is finished in a deep formation. In addition, for those wells screened at an interface between relatively tight and porous formations and where the accumulation or bottom flow of dense

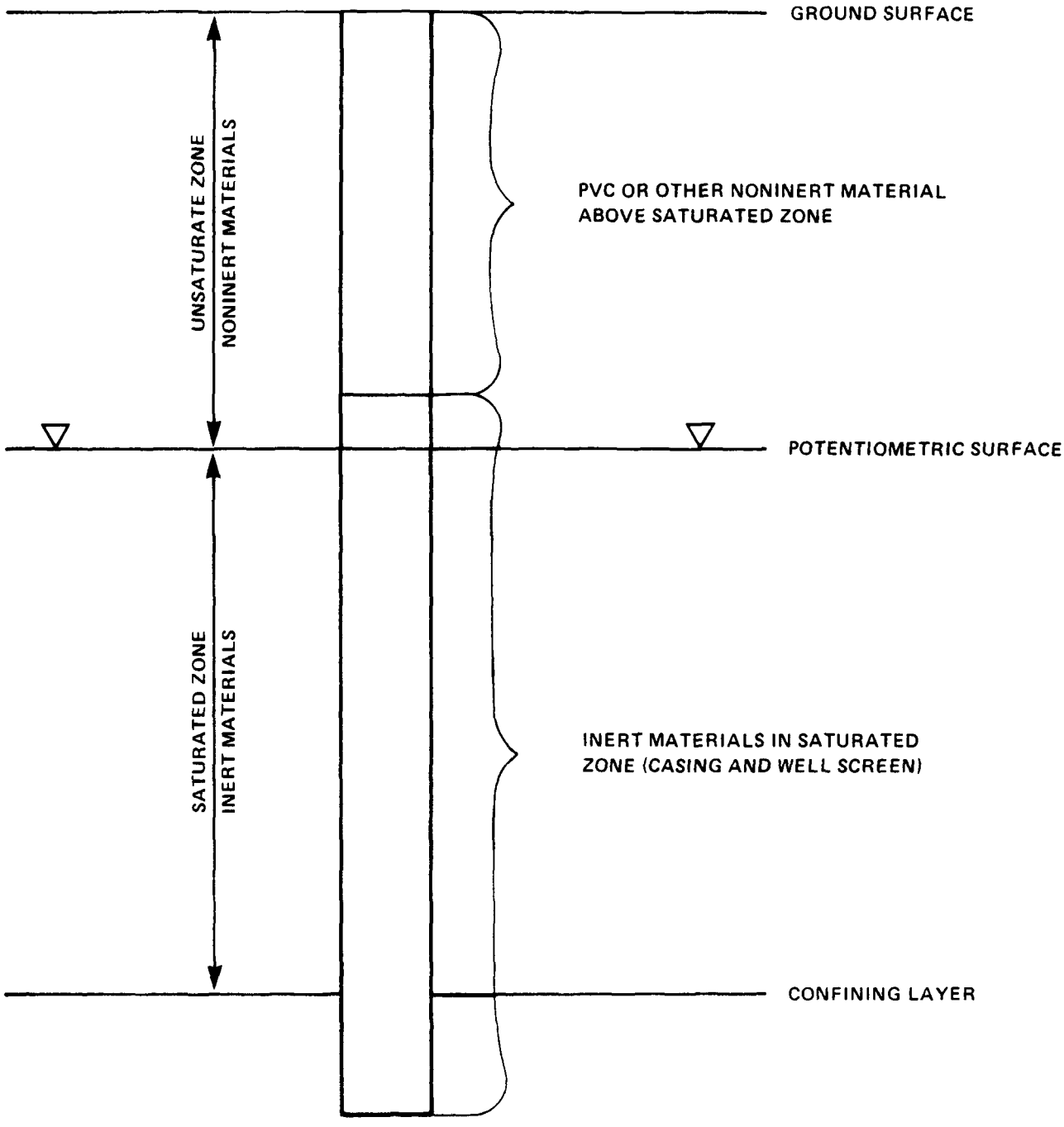

FIGURE 3-2. COMPOSITE WELL CONSTRUCTION
(INERT CONSTRUCTION MATERIALS IN SATURATED ZONE)

phase immiscibles is possible, an eight to ten-inch enclosed extension of the casing should be used to capture a sample. The top of this sampling cup should lie at the formation interface, and a dedicated bailer used to draw samples.

3.2.2 Monitoring Well Filter Pack and Annular Sealant

The materials used to construct the filter pack should be chemically inert (e.g., clean quartz sand, silica, or glass beads), well rounded, and dimensionally stable (see Section 3.3 for more detail on well intake design). Fabric filters should not be used as filter pack materials. Natural gravel packs are acceptable provided that the owner/operator conducts a sieve analysis so that the filter pack is appropriate given well screen slot size.

The materials used to seal the annular space must prevent the migration of contaminants to the sampling zone from the surface or intermediate zones and prevent cross contamination between strata. The materials should be chemically resistant to ensure seal integrity during the life of the monitoring well and chemically inert so they do not affect the quality of the ground-water samples. Figure 3-1 illustrates an appropriate distribution of annular sealants. A minimum of two feet of certified coarse grit sodium bentonite should immediately overlie the filter pack. Where the saturated zone extends above the well screen, certified coarse grit sodium bentonite only should be used. A cement and bentonite mixture, bentonite chips/pellets, or antishrink cement mixtures should be used as the annular sealant in the unsaturated zone above the certified coarse grit sodium bentonite seal and below the frost line. Above the frost line the cap should be composed of concrete blending into a cement apron extending three feet from the outer edge of the borehole.

The untreated sodium bentonite seal should be placed around the casing either by dropping it directly down the borehole or, if a hollow-stem auger is used, putting the bentonite between the casing and the inside of the auger stem. Both of these methods present a potential

for bridging. In shallow monitoring wells, a tamping device should be used to reduce this potential. In deeper wells, it may be necessary to pour a small amount of formation water down the casing to wash the bentonite down the hole.

The cement-bentonite mixture should be prepared using formation water and placed in the borehole using a tremie pipe. The tremie method ensures good sealing of the borehole from the bottom.

The remaining annular space should be sealed with expanding cement to provide for security and an adequate surface seals. Locating the interface between the cement and bentonite-cement mixture just below the frost line serves to protect the well from damage due to frost heaving. The cement should be placed in the borehole using the tremie method.

Figure 3-1 illustrates an appropriate protective steel cap around the well casing. A one-quarter inch vent hole provides an avenue for the escape of gas. The protective cap guards the casing from damage and the locking cap serves as a security device to prevent well tampering.

3.3 Well Intake Design

The owner/operator must design and construct the intake of the monitoring wells so as to: (1) allow sufficient ground-water flow to the well for sampling; (2) minimize the passage of formation materials (turbidity) into the well; and (3) ensure sufficient structural integrity to prevent the collapse of the intake structure.

For wells completed in unconsolidated materials, the intake of a monitoring well should consist of a screen or slotted casing with openings sized to ensure that formational material is prohibited from passing through the well during development. Extraneous fine-grained material (clays and silts) that have been dislodged during drilling may be left on the screen and the water in the well. These fines should be removed from the screen and surrounding area during development. The owner/operator should use commercially manufactured screens or slotted casings. Field slotting of screens should not be allowed.

The annular space between the face of the formation and the screen or slotted casing should be filled to minimize passage of formation materials into the well. The owner/operator should therefore install a filter pack in each monitoring well that is constructed on site. Further, in order to ensure discrete sample horizons, the filter pack should extent no more than two feet above the well screen as illustrated in Figure 3-1.

3.4 Well Development

After the owner/operator has completed constructing monitoring wells, natural hydraulic conductivity of the formation should be restored and all foreign sediment removed to ensure turbid-free ground-water samples.

A variety of techniques are available for developing a well. To be effective, they require reversals or surges in flow to avoid bridging by particles, which is common when flow is continuous in one direction. These reversals or surges can be created by using surge blocks, bailers, or pumps. Formation water should be used for surging the well. In low yielding water-bearing formations, an outside source of water may sometimes be introduced into the well to facilitate development. In these cases, this water should be chemically analyzed to ensure that it cannot contaminate the aquifer. The owner/operator should not use air in the development of wells. The owner/operator should steam clean all equipment used to develop a well prior to its introduction into the well.

The owner/operator must develop wells so that they are clay and silt-free. If, after development of the well is complete, it continues to yield turbid ground-water samples, the owner/operator should follow the procedure described in Figure 3-3. The acceptance/rejection value of five nephelometric turbidity units (N.T.U.) is based on the need to minimize biochemical activity and possible interference with ground-water sample quality.

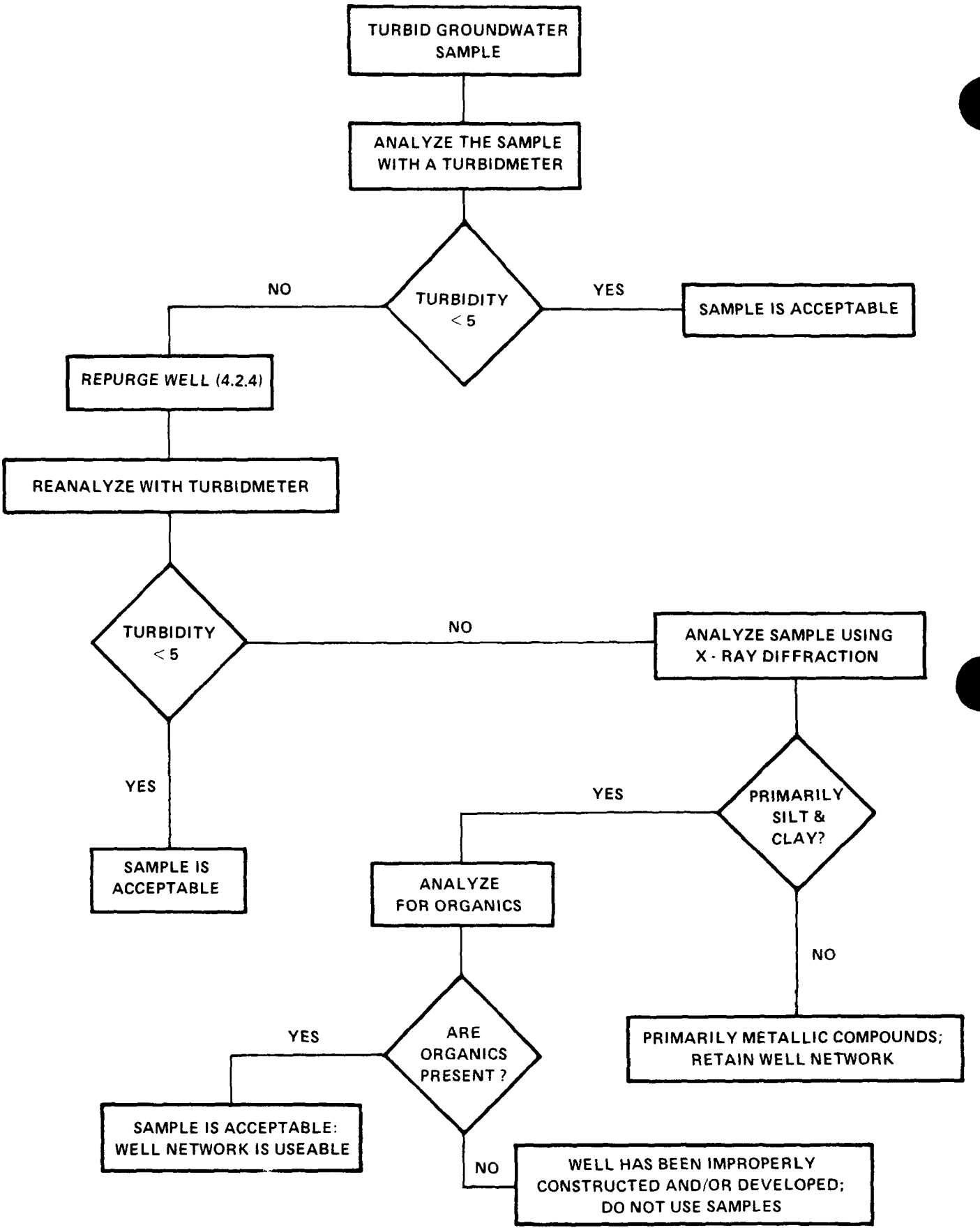

FIGURE 3-3. DECISION CHART FOR TURBID GROUND - WATER SAMPLES

3.5 Documentation of Well Design and Construction

In the context of a compliance order, the enforcement official should require the owner/operator to compile information on the design and construction of wells. Such information may include:

- date/time of construction;
- drilling method and drilling fluid used;
- well location (± 0.5 ft.);
- bore hole diameter and well casing diameter;
- well depth (± 0.1 ft.)
- drilling and lithologic logs
- casing materials;
- screen materials and design;
- casing and screen joint type;
- screen slot size/length;
- filter pack material/size;
- filter pack volume;
- filter pack placement method;
- sealant materials;
- sealant volume;
- sealant placement method;
- surface seal design/construction;
- well development procedure;
- type of protective well cap;
- ground surface elevation (± 0.01 ft.);
- well cap elevation (± 0.01 ft.).
- top of casing elevation (± 0.01 ft.); and
- detailed drawing of well (include dimensions).

3.6 Specialized Well Designs

There are two cases where owner/operators should use special monitoring well designs:

- where the owner/operator has chosen to use dedicated pumps to draw ground-water samples; and
- where light and/or dense phase immiscibles may be present.

If the owner/operator elects to use a dedicated system, it should either be a teflon or stainless steel 316 bailer, or a dedicated positive gas displacement bladder pump composed of the same two materials. The introduction of this pump, however, necessitates certain changes in the well cross section depicted in Figure 3-1. Figure 3-4 represents an appropriate cross section of a well which utilizes a dedicated positive gas displacement bladder pump as the sampling device/well evacuation device. The principal change is the addition of a two-inch diameter pump with a Teflon outlet tubing to the well. A four-inch interior diameter outer well casing should easily accommodate this additional equipment. However, should a larger pump (e.g., three inches in diameter) be required because of greater well depth or yield, a larger outer casing may prove necessary (six-inch interior diameter). The pump should be positioned midway along the screened interval, and the top of its sub-casing should extend into the well cap as depicted in Figure 3-4. The subcasing may have to be braced within the outer casing to reduce potential deformation.

If light and dense phase immiscible layers are present, the owner/operator must obtain discrete samples of them. Figures 3-5 and 3-6 illustrate well cross sections which should be used for the purpose of sampling the light phase and dense phase immiscible layers, respectively, where the owner/operator has chosen to use a dedicated positive gas displacement bladder pump. A subcasing is added to the Figure 3-1 cross section which is sampled using a bottom filling bailer. To capture a sample of light phase immiscible layers, both the outer casing and subcasing should be screened at horizons where floaters are expected. Further, the subcasing should extend to within a couple of inches of the bottom of the dense phase sampling cup to permit bailer sampling of the

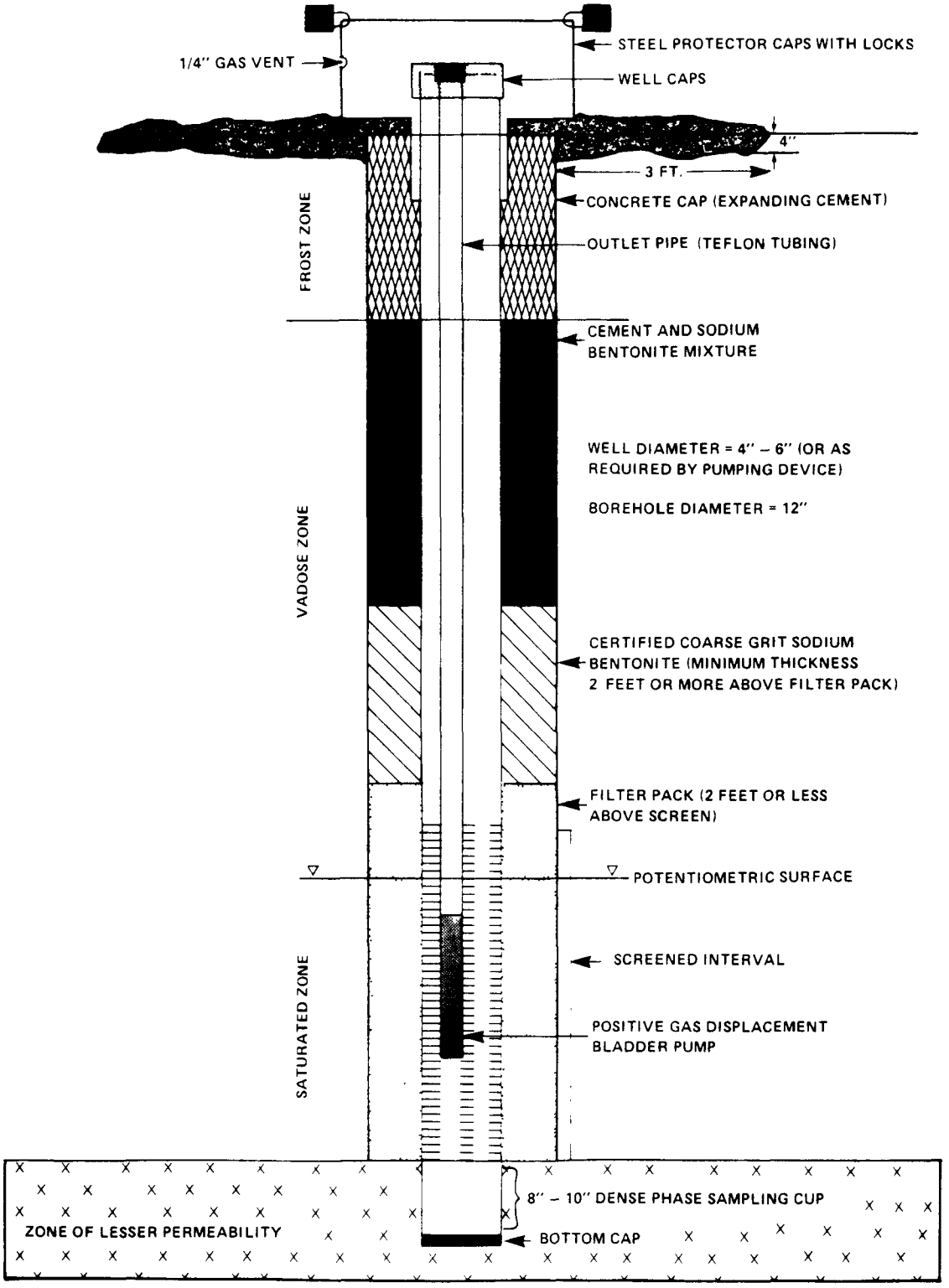

FIGURE 3-4. MONITORING WELL CROSS-SECTION – DEDICATED POSITIVE GAS PLACEMENT BLADDER PUMP

dense phase immiscible layer(s). Where well clusters are employed, one well in the cluster may be screened at horizons where floaters are expected (e.g., water table, Figure 3-5), another at horizons where dense phases are expected (e.g., aquifer/aquiclude interface, Figure 3-6), and others within other portions of the uppermost aquifer. Only those wells in the cluster intended to sample for the light phase should have a subcasing and outer casing screened to capture it, and only those wells intended to produce samples of dense phase immiscible layers should employ a subcasing extending into a dense phase sampling cup. Wells in the cluster which are not intended to generate discrete immiscible samples do not need the subcasing.

3.7 Evaluation of Existing Wells

The enforcement official must decide if wells--as designed and constructed--allow for the collection of representative ground-water samples. There are two situations the enforcement official may encounter: (1) where existing wells produce consistently turbid samples, i.e., greater than 5 N.T.U.; (2) where the owner/operator can produce little or no documentation on how the wells were designed and installed.

Turbid wells or lack of information on well design and construction may prompt the enforcement official to order the owner/operator to replace monitoring wells. In other, less obvious cases, the enforcement official must use best judgment in deciding when to order an owner/operator to replace wells. It is likely that many owner/operators have not designed or installed wells strictly in accordance with the guidance in this chapter The enforcement official must decide if the owner/operator's wells- as built--allow the owner/ operator to collect representative ground-water samples. This may not be an easy judgment to make. In cases where it is not clear if the owner/ operator's wells can produce representative ground-water samples, the enforcement official may consider requiring the owner/operator to conduct a field demonstration.

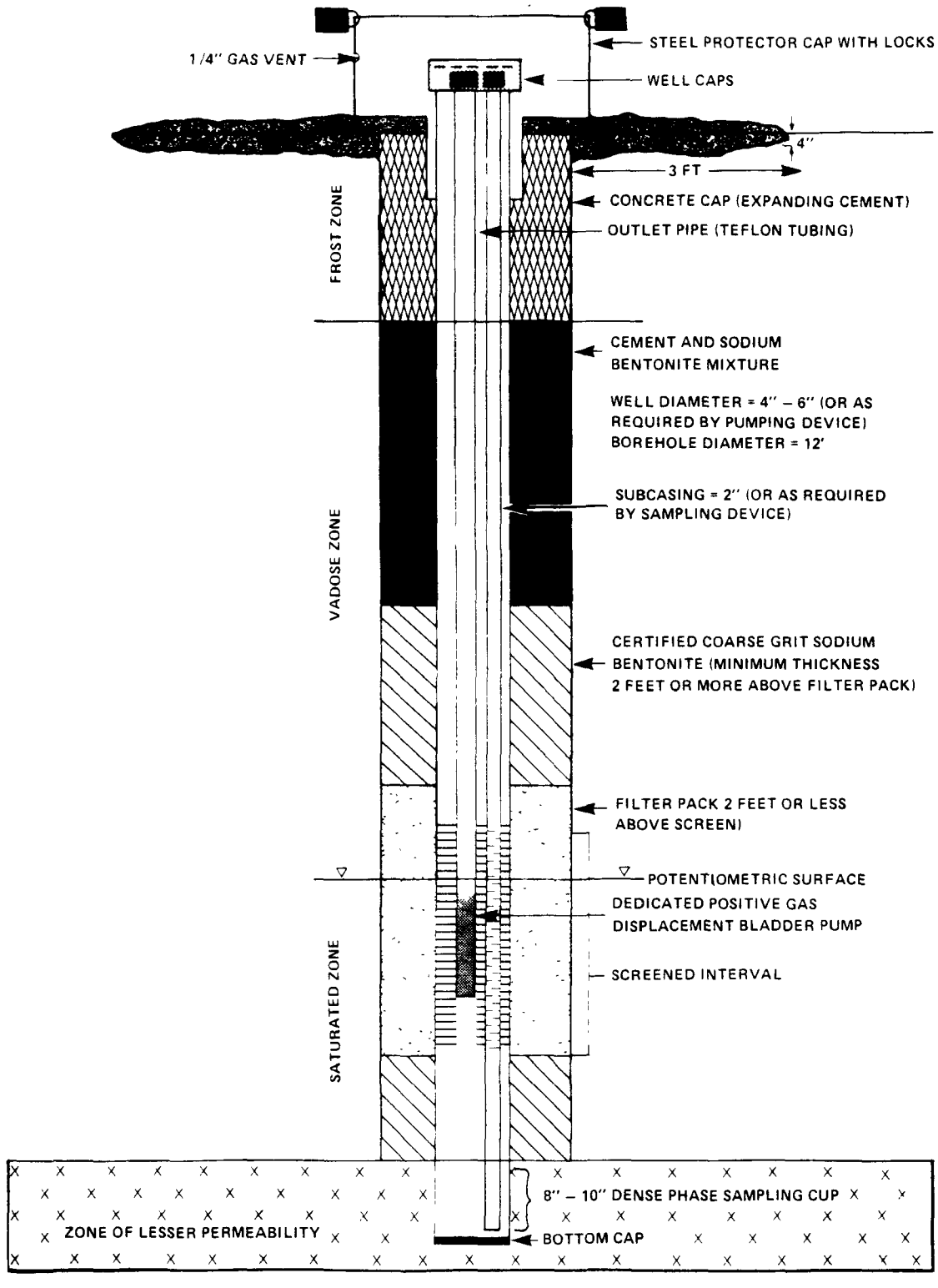

FIGURE 3-5. MONITORING WELL CROSS-SECTION – DEDICATED POSITIVE GAS DISPLACEMENT BLADDER PUMP AND SUBCASING FOR DISCRETE SAMPLING OF LIGHT PHASE IMMISCIBLE LAYERS

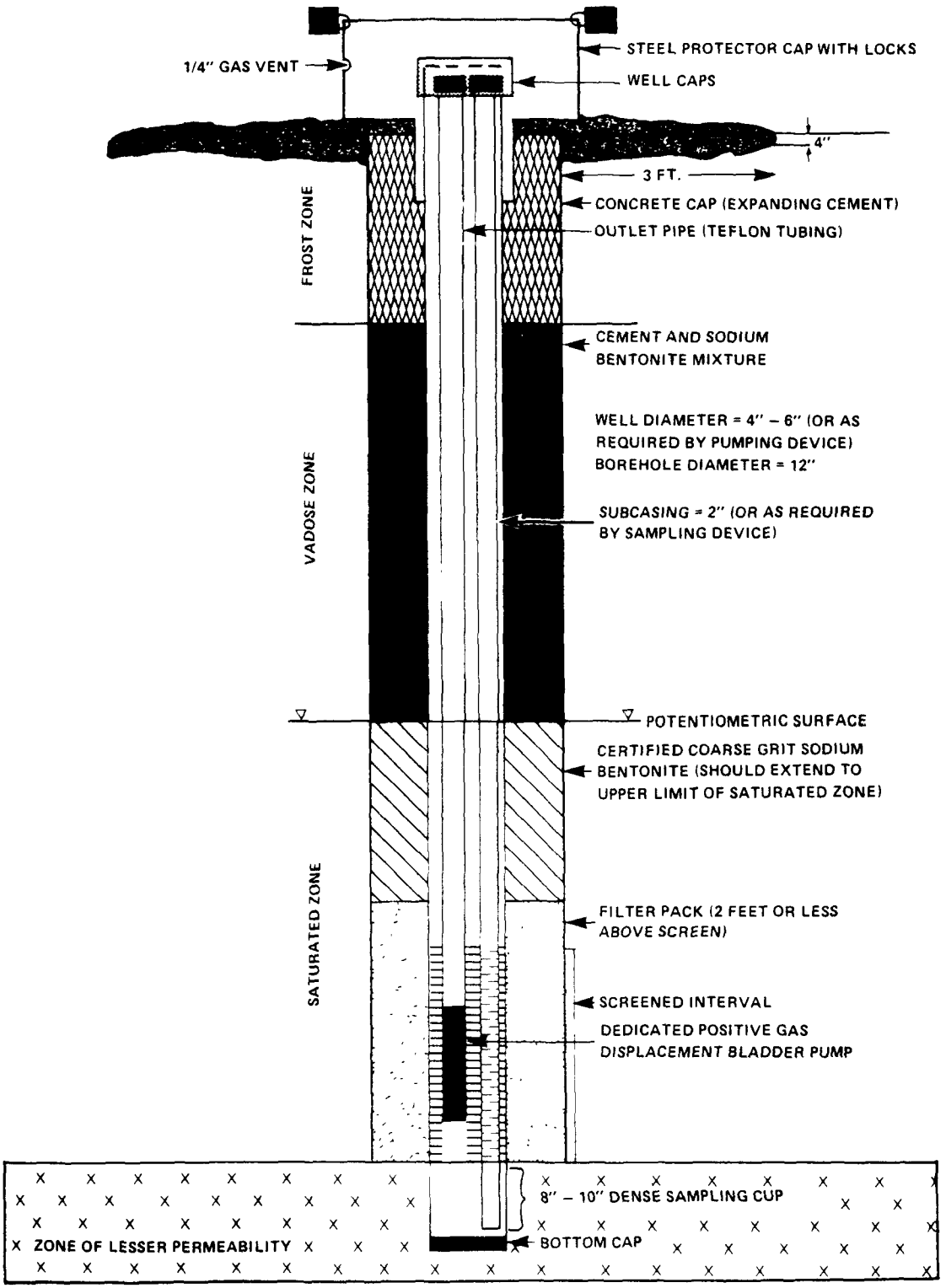

FIGURE 3-6. MONITORING WELL CROSS-SECTION – DEDICATED POSITIVE GAS DISPLACEMENT BLADDER PUMP AND SUBCASING FOR DISCRETE SAMPLING OF DENSE PHASE IMMISCIBLE LAYERS

This demonstration would involve the installation of new well(s) near existing wells. The owner/operator would sample for and analyze the same set of parameters in both wells. If parameter values are equivalent, the enforcement official should assume the owner/operator's existing wells are producing representative samples.

CHAPTER FOUR

SAMPLING AND ANALYSIS

Section 265.92 requires the owner/operator to prepare and implement a written ground-water sampling and analysis (S&A) plan. This plan must include procedures and techniques for sample collection, sample preservation and shipment, analytical procedures and chain of custody control. The owner/operator's S&A plan is an important document. It allows the enforcement official to thoroughly review how the owner/operator has structured the S&A program. Also, comparison of the written plan to field activities will allow the enforcement official to ensure the owner/operator is, in fact, properly collecting and analyzing ground-water samples. The purpose of this chapter is to describe important elements of written S&A plans and to discuss the level of detail that owner/operators should include in their plans.

EPA has observed a number of problems in the way in which owner/operators prepare their S&A plans or implement their S&A programs. Some of the more common problems are listed below.

- Owner/operators have not prepared S&A plans or do not keep plans on site.
- Plans contain very little information or do not adequately describe the S&A program the owner/operator is employing at his facility.
- Field sampling personnel are not following the written plan or are not even aware that it exists.
- Improper evacuation techniques are used particularly in regards to the identification and collection of immiscible contaminants.
- Sampling equipment is used that may alter chemical constituents in ground water.
- Sampling techniques are used that may alter chemical composition of samples particularly in regard to stripping of volatile organic compounds in samples.

- Facility personnel are not using blanks, standards, and spiked samples to correct analytical results for changes in sample quality after collection.

- Field personnel do not properly clean nondedicated sampling equipment after use.

- Field personnel are placing sampling equipment (rope, bailer, tubing) on the ground where it can become contaminated prior to use.

- Field personnel do not document their field activities adequately (e.g., keep sampling logs).

- Field personnel are not following proper chain-of-custody procedures.

- Little attention is paid to data reporting errors or anamolies.

- Facility personnel have not reviewed the QA/QC procedures being used by the laboratory that is analyzing their ground-water samples.

This chapter describes important elements in S&A plans (Section 4.1), and then discusses the level of detail the owner/operator should include in his plan in regard to each S&A element (Sections 4.2 through 4.6). Furthermore, this chapter describes important aspects of evaluating the field implementation of S&A plans (Sections 4.2 through 4.6). Section 4.7 describes how enforcement officials may examine ground-water data to identify evidence of problems in the way owner/operators acquire, process, and evaluate data.

4.1 Elements of Sampling and Analysis Plans

The owner/operator's S&A plan should, at minimum, address a number of elements. Specifically, the S&A plan should include information on:

- Sample collection (Section 4.2);
- Sample preservation and handling (Section 4.3);
- Chain of custody control (Section 4.4);
- Analytical procedures (Section 4.5); and
- Field and laboratory quality assurance/quality control (Section 4.6).

4.2 Sample Collection

4.2.1 Measurement of Static Water Level Elevation

The owner/operator's sampling and analysis plan should include provisions for measurement of static water level elevations in each well. Collection of water level elevation on a continuing basis is important to determine if horizontal and vertical flow gradients have changed since initial site characterization. A change in hydrologic conditions may necessitate modification to the design of the owner/operator's ground-water monitoring system. The S&A plan should specify the device to be used for water level measurements as well as the procedure for measuring water levels.

The owner/operator's field measurements should include depth to standing water and total depth of the well to the bottom of the intake screen structure. The measurements should be taken to 0.1 foot. Each well should have a reference point from which its water level measurement is taken. The reference point should be established by a licensed surveyor and is typically located at the top of the well casing with locking cap off. The reference point should be established in relation to mean sea level and the survey should also note the well location coordinates. The device which is used to detect the water level surface must be sufficiently sensitive so that a measurement to $\pm$0.1 foot can be obtained reliably. A steel tape will usually suffice, however, it is recommended that an electronic device (e.g., M-Scope or sounder) be used to measure depth to the surface of the ground water or light phase immiscibles.

4.2.2 Detection of Immiscible Layers

The owner/operator's S&A plan should include provisions for detecting immiscible contaminants, i.e., "floaters" and "sinkers" if the owner/operator manages wastes of this type at his facility. "Floaters" are those relatively insoluble organic liquids which are less dense than

water that spread across the water table surface. "Sinkers" are those relatively insoluble organic liquids which are more dense than water and tend to migrate vertically through the sand and gravel aquifers to the underlying aquitard. The detection of these immiscible layers requires specialized equipment which must be used before the well is evacuated for conventional sampling. The S&A plan should specify the device to be used to detect "floaters" and "sinkers" as well as the procedures to be used for detecting and sampling these contaminants.

Owner/operators should follow the procedures below for detecting the presence of light and/or dense phase immiscible organic layers should be undertaken before the well is evacuated for conventional sampling:

1. Remove the locking and protective caps.

2. Sample the air in the well head for organic vapors using either an HNU or OVA, and record measurements.

3. Determine the static liquid level using a manometer or acoustical sounder, and record the depth.

4. Lower an interface probe into the well to determine the exitence of any immiscible layer(s), light and/or dense.

The air above the well head should be sampled in order to determine the potential for fire, explosion, and/or toxic effects on workers. This test also serves as a first indication of the presence of immiscible organics. A manometer or acoustical sounder may provide an accurate reading of the depth to the surface of the liquid in the well, but neither are capable of differentiating between the water table and the surface of a floater. Nonetheless, it is very useful to determine that depth first to guide the lowering of the interface probe. The interface probe serves two related purposes. First, as it is lowered into the well, the probe registers when it is exposed to an organic liquid and thus identifies the presence of immiscible layers. Careful recording of the depths of the air/floater and floater/water interfaces establishes a measurement of the thickness of the light phase immiscible layer.

Secondly, as the probe is lowered through the light phase immiscible layer, it indicates the depth to the static water level. The presence of floaters precludes the exclusive use of sounders to make a determination of static water level. Dense phase immiscibles layers are detected by lowering the device to the bottom of the well where again the interface probe registers the presence of organic liquids.

Sampling of immiscible fractions should precede well evacuation procedures. A bottom filling bailer should be lowered to the levels at which the light and dense phase immiscibles are found and a sample taken. Care should be taken to gently lower the bailer to avoid, as much as possible, disturbing the interface between the organic liquid and water.

4.2.3 Well Evacuation

The water standing in a well prior to sampling may not be representative of in-situ ground-water quality. Therefore, the owner/operator should remove the standing water in the well so that water which is representative of the formation can replace the standing water. The owner/operator's S&A plan should include detailed, step-by-step procedures for evacuating wells. The equipment the owner/operator plans to use to evacuate wells should also be described.

The owner/operator's evacuation procedure should ensure that all stagnant water is replaced by fresh formation water upon completion of the process. The owner/operator should draw the water down from above the screen in the uppermost part of the water column to ensure fresh water from the screen will move upward.

The procedure the owner/operator should use for well evacuation depends on the yield of the well. When evacuating low yield wells, the owner/operator should evacuate wells to dryness once. As soon as the well recovers, the first samples the owner/operator should remove are the ones to be tested for volatilization sensitive parameters (e.g., total

organic halogens) and/or pH, oxidation reduction. Whenever full recovery exceeds three hours, the owner/operator should extract the remaining samples in order of their volatility as soon as sufficient volume is available for a sample for each parameter. Parameters that are not pH sensitive or subject to loss through volatilization, (such as nonvolatile or nonreactive organics) should be drawn last. At no time should an owner/operator pump a well to dryness if the recharge rate causes the formation water to vigorously cascade down the intake screen and accelerate the loss of volatiles. If this is anticipated to be a problem, the owner/operator should purge three casing volumes from the well at a rate which does not cause to recharge water to be excessively agitated. For higher yielding wells, the owner/operator should evacuate three casing volumes prior to sampling.

In order to minimize the introduction of contamination into the well positive gas displacement teflon bladder pumps are recommended for purging wells. Teflon or stainless steel bailers are also recommended purging equipment. Where these devices cannot be used, peristalitic pumps, gas-lift pumps, centrifugal pumps, and venturi pumps may be used. Some of these pumps produce volatilization and high pressure differentials, causing variability in the analysis of pH, specific conductance, metals, and volatile organic samples. They are, however, acceptable for purging the wells if sufficient time is allowed to let the water stabilize prior to sampling.

When purging equipment must be reused, it should be decontaminated with a water wash and a deionized distilled water rinse. Purging equipment which becomes heavily contaminated should be cleaned with a nonphosphate detergent wash followed by rinsing with hexane and deionized distilled water. Clean gloves should be worn by the sampling personnel. A clean plastic sheet should be placed adjacent to or around the well in order to prevent surface soils from coming in contact with the purging equipment and lines, which in turn could introduce contaminants to the well.

4.2.4 Sample Withdrawal

The technique used to withdraw a ground-water sample from a well should be selected based on a consideration of the parameters which will be analyzed in the sample. To ensure the ground-water sample is representative of the formation, it is important to avoid physically altering or chemically contaminating the sample during the withdrawal process. In order to minimize the possibility of sample contamination, the owner/operator should:

1. Use only Teflon* or stainless steel (316) sampling devices, and

2. Use dedicated samplers for each well. (If a dedicated sampler is not available for each well, the owner/operator should thoroughly clean the sampler between sampling events and the owner/operator should take blanks and analyze them to ensure cross-contamination has not occurred.)

The owner/operator's S&A plan should specify in detail the devices the owner/operator will use for sample withdrawal. The plan should state that devices are either dedicated to a specific well or are capable of being fully disassembled and cleaned between sampling events. Procedures for cleaning the sampling equipment should be included in the plan. Any special sampling procedures that the owner/operator must use to obtain samples for a particular constituent (e.g., TOX or TOC) should also be described in the plan.

When used properly, the following are acceptable sampling devices for all parameters:

- Bottom valve bailers (Teflon or stainless steel 316); and
- Positive gas displacement bladder pump

Sampling equipment should be constructed of inert material. Equipment with neoprene fittings, PVC bailers, tygon tubing, silicon rubber bladders, neoprene impellers, polyethylene, and vitron are not acceptable.

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*Tradename for polyperfluoroethylene

If the owner/operator is using bailers, "Teflon"-coated wire, single strand stainless steel wire, or monofilament should be used to raise and lower the bailer. Braided cables, polyethylene or nylon cords should not be used because it may not be possible to thoroughly decontaminate these materials prior to sampling.

The owner/operator may use Teflon or stainless steel 316 bailers for any depth well. A single positive gas displacement bladder pump or several pumps connected in series may be used for wells 150 to 400 feet deep. For wells greater than 400 feet deep, the owner/operator should use bailers with a manual or powered winch to raise and lower the device in the well.

While in the field, the enforcement official should observe the owner/operator's sampling technique to ensure that the owner/operator satisfies the following:

- Positive gas displacement bladder pumps should be operated in a continuous manner so that they do not produce pulsating samples that are aerated in the return tube or upon discharge;
- Check valves should be designed and inspected to assure that fouling problems do not reduce delivery capabilities or result in aeration of the sample;
- Sampling equipment (e.g., especially bailers) should never be dropped into the well because this will cause degassing of the water upon impact;
- The bailer's contents should be transferred to a sample container in a way that will minimize agitation and aeration; and
- Clean sampling equipment should not be placed directly on the ground or other contaminated surfaces prior to insertion into the well.

When dedicated equipment is not used for sampling (or well evacuation), the owner/operator's sampling plan should include procedures for disassembly and cleaning of equipment before each use. If the constituents of interest are inorganic, the first rinse should be a

dilute (0.1 N) hydrochloric acid or nitric acid and the second rinse should be distilled water or deionized water. Dilute hydrochloric acid is generally preferred to nitric acid when cleaning stainless steel because nitric acid may oxidize stainless steel. When organics are the constituents of concern, the owner/operator should wash equipment with a nonphosphate detergent and rinse with tap water, distilled water, acetone, and finally pesticide-quality hexane, in that order. The sampling equipment should be thoroughly dried before use to ensure that the residual cleaning agents (e.g., acetone, HCl) are not carried over to the sample.

When collecting samples using a positive gas displacement bladder pump for volatile analysis, pumping rates should not exceed 100 milliliters/minute. Higher rates can increase the loss of volatile constituents and can cause fluctuation in pH and pH sensitive analytes. Once the portions of the sample reserved for the analysis of volatile components has been collected, the owner/operator may use higher pumping rates particularly if a large sample volume must be collected.

4.2.5 In-Situ or Field Analyses

Several parameters are physically or chemically unstable and must be tested either in the borehole using a probe (in-situ) or immediately after collection using a field test kit. Examples of several unstable parameters include pH, redox potential, chlorine, dissolved oxygen, and temperature. Although specific conductivity (analogous to electrical resistance) is relatively stable, it is recommended that this characteristic be determined in the field. Most conductivity instruments require temperature compensation, therefore temperatures of the sample should be measured at the time conductivity is determined. If the owner/operator uses probes (pH electrode, specific ion electrode, thermistor) to measure any of the above parameters, it is important that this is done after well evacuation and after any samples for chemical

analysis have been collected so that the probe(s) do not contaminate the sample designated for laboratory analysis. Similarly, if the unstable parameters are to be determined in a sample withdrawn from a well, the owner/operator should split the sample into at least two separate portions, one for field testing and the other for laboratory analysis. Monitoring probes should not be placed in containers containing ground-water for laboratory analysis.

The owner/operator should complete the calibration of any in-situ monitoring equipment or field test probes and kits before each use according to the manufacturers specifications and consistent with SW-846.

4.3 Sample Preservation and Handling

Many of the constituents and parameters that are included in ground-water monitoring programs are not stable, and therefore, sample preservation is required. Test Methods for Evaluating Solid Waste - Physical Chemical Methods (SW-846, Section 1.4.6.2.3) has a discussion for each analytical technique on the choice sample preservation procedures. In addition, SW-846 (Section 1.2.2) specifies the sample containers that the owner/operator should use for each constituent or common set of parameters. The owner/operator should identify in the S&A plan which preservation methods and sample containers will be employed. Each sampling and analysis plan should also detail all procedures and techniques for transferring the samples to either a field or off-site laboratory.

Improper sample handling may lead to loss of contaminant constituents in the sample. Samples should be transferred in the field from the sampling equipment directly into to the container that has been specifically prepared for that given parameter or set of compatible parameters. It is not an acceptable practice for samples to be composited in a common container in the field and then split in the laboratory, nor poured first into a wide mouth container then transferred

into smaller jars. In regard to volatile organics, the S&A plan should specify how the samples will be transferred from the sample collection device to the sample container to reduce loss through volatilization. When using a bailer to collect samples for the analysis of volatiles, the sample may be transferred to a beaker which will facilitate the filling of a volatile organics analysis (VOA) vial. The water should be poured from the beaker to the VOA vial so that the vial overflows and no bubbles or headspace is left in the vial.

4.3.1 Sample Containers

The owner/operator's S&A plan should identify the type of sample containers to be used to collect samples as well as procedures the owner/operator will use to ensure that sample containers are free of contaminants prior to use.

When metals are the analytes of interest, polyethylene containers with polypropylene caps should be used. When organics are the analytes of interest, glass bottles with Teflon-lined caps should be used. Glass bottles may be used to store samples for metals analysis providing the caps are Teflon-lined and the appropriate preservative has been used. The plan should refer to the specific analytical method (in SW-846, Section 1.2.2) which designates an acceptable container.

Containers should be cleaned to suit the type of analysis the sample will be subjected to. When samples are to be analyzed for metals (SW-846, Method 6010), the sample containers as well as the laboratory glassware should be thoroughly washed with nonphosphate detergent and tap water, and rinsed with (1:1) nitric acid, tap water, (1:1) hydrochloric acid, tap water, and finally Type II water, in that order. Chromic acid may be useful to remove organic deposits from glassware; however, the analyst should be cautioned that the glassware must be thoroughly rinsed with water to remove the last traces of chromium. The use of chromic acid can cause a contamination problem for the determination of chromium

if the glassware is not rinsed properly. If it can be documented through an active analytical quality control program using spiked samples and reagent blanks that certain steps in the cleaning procedure are not required for routine samples, those steps may be eliminated from the procedure.

Similarly, an EPA-approved procedure (SW-846, Method 8080) is available for cleaning containers used to store samples for organics analysis. The sampling container should be emptied of any residual materials followed by washing with a nonphosphate detergent in hot water. Rinse with tap water, distilled water, acetone, and finally pesticide-quality hexane. Heavily contaminated glassware may require treatment in a muffle furnace at 400°C for 15 to 30 minutes. Glassware should be sealed/stored in a clean environment immediately after drying or cooling to prevent any accumulation of dust or other contaminants. Store inverted or capped with aluminum foil.

The cleanliness of a batch of precleaned bottles should be verified by the use of a trip blank. Each time a group of bottles is prepared for use in the field, one bottle of each type (e.g., glass, Teflon, polyethylene) should be selected from the batch and filled with deionized water. The bottles filled with the blank should be transported to the sampling location and returned to the laboratory in a manner identical to the handling procedure used for the samples. Trip blanks should be subjected to the same analysis as the ground water. Any contaminants found in the trip blanks could be attributed to (1) interaction between the sample and the container, (2) contaminated deionized water, or (3) a handling procedure which alters the sample. The concentration levels of any contaminants found in the trip blank should not be used to correct the ground-water data. The contaminant levels should be noted and if the levels are significant compared to the field sample results, the owner/operator should resample the ground water.

4.3.2 Sample Preservation

The owner/operator's S&A plan should identify sample preservation methods that the owner/operator plans to use. Methods of sample preservation are relatively limited and are generally intended to (1) retard biological action, (2) retard hydrolysis, and (3) reduce absorption effects. Preservation methods are generally limited to pH, control, chemical addition, refrigeration, and freezing. The owner/operator should refer to the specific preservation method in SW-846, Section 1.4.6.2.3 that will be used for the constituent in the sample. A summary of adequate sample containers and sample preservation measures is presented in Table 4-1.

4.3.3 Special Handling Considerations

Organics

Samples requiring analysis for organics should not be filtered. Samples should not be transferred from one container to another because losses of organic material onto the walls of the container may occur. Total organic halogens (TOX) and total organic carbon (TOC) samples should be handled and analyzed as materials containing volatile organics. No headspace should exist in the sample containers to minimize the possibility of volatilization of organics. Field logs and laboratory analysis reports should note the headspace in the sample container(s) at the time of receipt by the laboratory as well as at the time the sample was first transferred to the sample container at the wellhead.

Metals

Metals which migrate through the unsaturated (vadose) and saturated zones and arrive at a ground-water monitoring well are typically in a dissolved state. Particles (e.g., silt, clay) which may be present in the well even after well evacuation procedures may absorb or adsorb various metals species to effectively lower the dissolved metal content

TABLE 4-1

SAMPLING AND PRESERVATION PROCEDURES FOR DETECTION MONITORING[a]

Parameter	Recommended Container[b]	Preservative	Maximum Holding Time	Minimum Volume Required for Analysis
		Indicators of Ground-Water Contamination[c]		
pH	T, P, G	Field determined	2 hours	25 ml
Specific conductance	T, P, G	Field determined	None	100 ml
TOC	G, Teflon-lined cap	Cool 4°C, HCl to pH <2	28 days	4 x 15 ml
TOX	G, amber, Teflon-lined cap	Cool 4°C, add 1 ml of 1.1M sodium sulfite	7 days	4 x 15 ml
		Ground-Water Quality Characteristics		
Chloride	T, P, G	4°C	28 days	50 ml
Iron Manganese Sodium	T, P	Field Acidified[d] to pH <2 with HNO_3	6 months	200 ml
Phenols	G	4°C/H_2SO_4 to pH <2	28 days	500 ml
Sulfate	T, P, G	Cool, 4°C	28 days	50 ml
		EPA Interim Drinking Water Characteristics		
Arsenic Barium Cadmium Chromium Lead Mercury Selenium Silver	T, P	Total Metals Field acidified to pH <2 with HNO_3 Dissolved Metals 1. Field filtration (0.45 micron) 2. Acidify to pH <2 with HNO_3	6 months 6 months	1,000 ml 1,000 ml
Fluoride	T, P	Field acidified to pH <2 with HNO_3	28 days	300 ml
Nitrate	T, P, G	4°C[e]	48 hours	1,000 ml

(Continued)

TABLE 4-1 (Continued)

SAMPLING AND PRESERVATION PROCEDURES FOR DETECTION MONITORING

Parameter	Recommended Container[b]	Preservative	Maximum Holding Time	Minimum Volume Required for Analysis
Endrin Lindane Methoxychlor Toxaphene 2,4 D 2,4,5 TP Silvex	T, G	Field acidified to pH <2 with HNO_3	24 hours	1,000 ml
Radium Gross Alpha Gross Beta	P, G	Field acidified to pH <2 with HNO_3	6 months	1 gallon
Coliform bacteria	PP, G (sterilized)	Cool, 4°C	6 hours	200 ml
	Other Ground-Water Characteristics of Interest			
Cyanide	P, G	Cool, 4°C, NaOH to pH >12	14 days	500 ml
Oil and Grease	G only	Cool, 4°C H_2SO_4 to pH <2	28 days	100 ml
Hazardous constituents (§261, Appendix VIII)	G only	Cool, °4C	7 days	1 gallon[f]

[a]References: Test Methods for Evaluating Solid Waste - Physical/Chemical Methods, SW-846 (2nd edition, 1982).
Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020.
Standard Methods for the Examination of Water and Wastewater, 16th edition (1985).

[b]Container Types:
P = Plastic (polyethylene)
G = Glass
T = Teflon
PP = Polypropylene

[c]Based on the requirements for detection monitoring (§265.93), the owner/operator must collect a sufficient volume of ground water to allow for the analysis of four separate replicates.

(Continued)

TABLE 4-1 (Continued)

SAMPLING AND PRESERVATION PROCEDURES FOR DETECTION MONITORING

[d]In the event that HNO_3 cannot be used because of shipping restrictions, the sample should be refrigerated to 4°C, shipped immediately, and acidified on receipt at the laboratory.

[e]For samples from nonchlorinated drinking water supplies concentrated H_2SO_4 should be added to lower sample pH to less than 2. The sample should be analyzed before 14 days.

[f]Or as required by the procedures (SW-846) for the specific hazardous constituents being assessed.

in the well water. Ground-water samples on which metals analysis will be conducted should be split into two portions. One portion should be filtered through a 0.45 micron filter (glass fiber or membrane), transferred to a bottle, preserved with nitric acid to a pH less than 2 (Table 4-1) and analyzed for dissolved metals. The remaining portion should be transferred to a bottle, preserved with nitric acid and analyzed for total metals. Any difference in concentration between the total and dissolved fractions may be attributed to the original metal content of the particles and any migration of dissolved metals to the particles.

Blanks

Various types of blanks should be used to verify that the sample collection and handling process has not affected the quality of the field samples (see Section 4.6 for more information on field and laboratory QA/QC programs). The owner/operator should prepare each of the following field blanks and analyze them for all of the required monitoring parameters:

Trip Blank - Fill one of each type of sample bottles with deionized water, transport to the site, handle like a sample, and return to the laboratory for analysis. One trip blank per sampling event is recommended.

Equipment Blank - To ensure the sampling device has been effectively cleaned (in the laboratory or field), fill the device with deionized water or pump deionized water through the device, transfer to sample bottle(s) and return to the laboratory for analysis. One equipment blank each day ground-water monitoring wells are sampled is recommended.

The results of the analysis of the blanks should not be used to correct the ground-water data. If contaminants are found in the blanks, the source of the contamination should be identified and corrective action, including resampling, should be initiated. Other quality control samples (e.g., standards, spikes, performance evaluation samples) should be prepared and analyzed as part of the laboratory operation (see

Section 4.6.1). The owner/operator's S&A plan should include provisions for the use of trip blanks and equipment blanks as well as other QA/QC activities.

4.4 Chain of Custody

The owner/operator must describe a chain-of-custody program in the S&A plan. An adequate chain-of-custody program will allow for the tracing of possession and handling of individual samples from the time of field collection through laboratory analysis. An owner/operator's chain-of-custody program should include:

- Sample labels which prevent misidentification of samples;
- Sample seals to preserve the integrity of the sample from the time it is collected until it is opened in the laboratory;
- Field logbook to record information about each sample collection during the ground-water monitoring program;
- Chain-of-custody record to establish the documentation necessary to trace sample possession from the time of collection to analysis;
- Sample analysis request sheets which serve as official communication to the laboratory of the particular analysis(es) required for each sample and provide further evidence that the chain of custody is complete; and
- Laboratory logbook which is maintained at the laboratory and records all pertinent information about the sample.

4.4.1 Sample Labels

To prevent misidentification of samples, the owner/operator should affix legible labels to each sample container. The labels should be sufficiently durable to remain legible even when wet and should contain the following type of information:

- Sample identification number
- Name of collector
- Date and time of collection
- Place of collection
- Parameter(s) requested (if space permits)

4.4.2 Sample Seal

In cases where samples may leave the owner/operator's immediate control, such as shipment to a laboratory by a common carrier (e.g., air freight), a seal should be provided on the shipping container or individual sample bottles to ensure the samples have not been disturbed during transportation.

4.4.3 Field Logbook

An owner/operator or the individual designated to perform ground-water monitoring operation should keep an up-to-date field logbook which documents the following:

- Identification of well
- Well depth
- Static water level depth and measurement technique
- Presence of immiscible layers and detection method
- Well yield - high or low
- Collection method for immiscible layers and sample identification numbers
- Well evacuation procedure/equipment
- Sample withdrawal procedure/equipment
- Date and time of collection
- Well sampling sequence
- Types of sample containers used and sample identification numbers
- Preservative(s) used
- Parameters requested for analysis
- Field analysis data and method(s)
- Sample distribution and transporter
- Field observations on sampling event
- Name of collector

4.4.4 Chain-of-Custody Record

To establish the documentation necessary to trace sample possession from time of collection, a chain-of-custody record should be filled out and accompany every sample. The record should contain the following type of information:

- Sample number
- Signature of collector
- Date and time of collection
- Sample type (e.g., ground water, immiscible layer)

- Identification of well
- Number of containers
- Parameters requested for analysis
- Signature of person(s) involved in the chain of possession
- Inclusive dates of possession

4.4.5 Sample Analysis Request Sheet

This document should accompany the sample(s) on delivery to the laboratory and clearly identify which sample containers have been designated (e.g., use of preservatives) for each requested parameter. The record should include the following type of information:

- Name of person receiving the sample
- Laboratory sample number (if different than field number)
- Date of sample receipt
- Analyses to be performed

4.4.6 Laboratory Logbook

Once the sample has been received in the laboratory, the sample custodian and/or laboratory personnel should clearly document the processing steps which are applied to the sample. All sample preparation techniques (e.g., extraction) and instrumental methods must be identified in the logbook. Experimental conditions such as the use of specific reagents (e.g., solvents, acids), temperatures, reaction times and instrument settings should be noted. The results of the analysis of all quality control samples should be identified specific to each batch of ground-water samples analyzed. The laboratory logbook should include the time, date, and name of the person who performed each processing step.

4.5 Analytical Procedures

The owner/operator's S&A plan should describe in detail the analytical procedures that will be used to determine the concentrations of constituents or parameters of interest. These procedures should include suitable analytical methods as well as proper quality assurance and quality control protocols. The required precision, accuracy,

detection limits and percent recovery (if applicable) specifications should be clearly identified in the plan.

The S&A plan should identify one method that will be used for each specific parameter or constituent. Generally, the plan should specify a method in SW-846 or an EPA-approved method and clearly indicate if there are going to be any deviations from the stated method.

Records of ground-water analyses should include the methods used, extraction date and date of actual analysis. Data from samples which are not analyzed within recommended holding times should be considered invalid. Any deviation from an EPA-approved method (SW-846) should be adequately tested to ensure that the quality of the results meets the performance specifications (e.g., detection limit, sensitivity, precision, accuracy) of the reference method.

4.6 Field and Laboratory Quality Assurance/Quality Control

One of the fundamental responsibilities of the owner/operator is the establishment of continuing programs to ensure the reliability and validity of field and analytical laboratory data gathered as part of the overall ground-water monitoring program.

The owner/operator's S&A plan must explicitly describe the QA/QC program that will be used in the field and laboratory. Many owner/operators use commercial laboratories to conduct analyses of ground-water samples. In these cases, it is the owner/operator's responsibility to ensure that his laboratory of choice is exercising a proper QA/QC program. The QA/QC program described in the owner/operator's S&A plan must be used by the laboratory analyzing samples for the owner/operator.

4.6.1 Field QA/QC Program

The owner/operator's S&A plan should provide for the routine collection and analysis of two types of QC blanks: trip blanks and

equipment blanks. Trip blanks are used to determine if contamination is introduced from the sample containers (see Section 4.3.3). Equipment blanks are used to determine if contamination is introduced by the sample collection equipment (see Section 4.3.3).

All field equipment the owner/operator will use should be calibrated prior to field use and recalibrated periodically. The owner/operator's S&A plan should describe a program for ensuring proper calibration of field equipment. Other QA/QC practices such as sampling equipment decontamination procedures and chain of custody procedures should also be described in the owner/operator's S&A plan.

4.6.2 Laboratory QA/QC Program

The owner/operator's S&A plan should provide for the use of standards, laboratory blanks, duplicates, and spiked samples for calibration and identification of potential matrix interferences. The owner/operator should use adequate statistical procedures (e.g., QC charts) to monitor and document performance and implement an effective program to resolve testing problems (e.g., instrument maintenance, operator training). Data from QC samples (e.g., blanks, spiked samples) should be used as a measure of performance or as an indicator of potential sources of cross-contamination but should not be used to alter or correct analytical data. These data should be submitted to the Agency with the ground-water monitoring sample results.

4.7 Evaluation of the Quality of Ground-Water Data

A ground-water sampling and analysis program produces a variety of geohydrological, geophysical, and ground-water chemical constituent (GWCC) data. This section pertains primarily to the evaluation of GWCC data because these data are specifically required by the regulations, are evaluated in the statistical tests, provide the fundamental evidence used to determine whether the facility is contaminating the ground water, and

are used to determine the extent of plume migration during assessment monitoring. Also, details regarding how to obtain and identify quality geohydrological and geophysical data have been discussed in Chapters One through Three. The GWCC data may be initially presented by the laboratory on reporting sheets; these data then must be compiled and then analyzed by the owner/operator prior to submission to the state or EPA in order to evaluate the degree of ground-water contamination.

It is essential for owner/operator to make sure that during chemical analysis, compilation, laboratory reporting, computer automation, and report preparation that data are generated and processed to avoid mistakes and that data are complete and fully documented. Data must be accurately reported to have accurate analyses and valid results. If data errors do occur, statistical analyses cannot discover, correct, or ameliorate the errors.

The following discussion considers aspects of data quality that may indicate to the enforcement officer that the data acquisition, processing, and evaluation were executed poorly or incorrectly.

The specific areas that are addressed include:

- Reporting of low and zero concentration values;
- Number of significant digits;
- Missing data values;
- Outliers; and
- Units of measure.

4.7.1 Reporting of Low and Zero Concentration Values

A critical concern is the interpretation, reporting, and analysis of GWCCs that are measured at less than (LT) a detection limit of an analytical procedure. These values, which are referred to as LT detection limit values, result for a variety of reasons, and enforcement officers, during the review of data submissions, may confront a variety of codes which indicate that GWCC concentrations are below a value which can be measured with certainty.

Values that are LT a limit of detection can result when:

- GWCCs are present at extremely low concentrations;
- An insensitive analytical technique has been used; and
- The chemical matrix of the ground water interferes with the analytical technique.

Low GWCC concentrations may be reported using various conventions depending on the chemical constituent that was measured, the machine and method used, the chemical analyst, or the data base/computer manager that was responsible for automating the data in preparation for analysis and reporting. Enforcement officers may confront owner/operator data submissions where the convention was to report a code for LT a limit of detection with no accompanying number. Alternately, the owner/operator may submit data where the LT designation accompanies a number that is consistent throughout the data for that analyte. In other instances, data submissions include LT designations which accompany numbers that vary among samples. Furthermore, some analytical results may differentiate between GWCCs present but at concentrations that are LT a limit of detection and GWCCs that are not present in the sample at all. It is also possible that the enforcement officer will review data submissions where the values that accompany a LT designation are quantification limits rather than LT detection limit values. Quantification limits are generally some multiple larger (5 or 10 times) than the smallest concentration that can be measured. It is clear that the codes used to designate low GWCC concentrations may assume many forms and may indicate different results; Table 4-2 provides a listing of some low concentration codes that the enforcement officer is likely to encounter in data submissions. The purpose of Table 4-2 is not to endorse particular reporting formats, but to prepare enforcement officers for a variety of data submissions where low concentrations of GWCC are reported with different codes that may have different meanings.

TABLE 4-2
A LISTING AND DESCRIPTION OF CODES USED TO INDICATE THAT POLLUTANT CONCENTRATIONS WERE BELOW A CONCENTRATION WHICH CAN BE MEASURED ACCURATELY OR THAT THE POLLUTANTS WERE NOT PRESENT

Codes	Definition of the Acronyms	Examples of Use	Used to Indicate That the Pollutant Was Less Than a Limit of Detection	Used to Indicate That the Pollutant Was Not Present
LOD+	Limit of detection	LOD 0.421	Yes	No
LOQ+	Limit of quantification	LOQ 2.234	Yes	No
MDL++	Method detection limit	MDL 0.631	Yes	No
LT	Less than	LT, LT 0.01 LT 0.148	Yes	No
BDL	Below detection limit	BDL, BDL 0.01, BDL 0.148	Yes	No
<		<0.01, <0.148	Yes	No
Negative signs		-0.01, -0.148	Yes	No
Trace*		Trace, T	Yes	No
K		K0.01, K0.148	Yes	No
ND*	Not detected	ND	Yes	Yes
Dashes*		--	Yes	Yes
Large numbers*		999999	Yes	Yes
Zeros*		0	Yes	Yes
Blanks*			Yes	Yes

NOTES:

1. The codes, marked with a +, are the codes used when the American Chemical Society methodology is applied.
2. The code, marked with a ++, is the code that is used when the 40 CFR 136 methodology is applied.
3. The Codes column lists examples of low concentration designations that may be included in data submissions.
4. Several codes, marked with a *, have potential for being ambiguous. Their meaning depends on laboratory reporting protocols and could either indicate that the value was LT a limit of detection or not present.

The following guidelines should help the enforcement officer identify problems associated with the reporting of LT detection limit values and prescribe remedies for future owner/operator submissions:

- GWCC should be given close attention if the LT detection limit values appear to increase over time. Increasing detection limits may be used to conceal an increasing concentration trend. Table 4-3 illustrates how changing detection limits make data interpretation difficult.

- Similarly, if background data are reported without a LT designation at low concentrations and comparison downgradient data are presented at higher concentrations with a LT designation, then it is possible that LT detection limit values are being used to conceal larger downgradient concentrations.

- It is unacceptable to report only qualitative information such as LT for values that were measured below a limit of detection. The enforcement officer must ensure that numerical values accompany the LT designation so that data are available for analysis.

- LT detection limit values that are high or that vary should be reduced in future work by laboratory procedures that remove interfering constituents.

- The owner/operator must explain and follow the protocol for determining and reporting low concentration values. Enforcement officers should not allow the use of highly variable reporting formats. Instead, the protocol used for determining and reporting GWCC data at low concentrations should conform with the technique described in Appendix B of 40 CFR §136 titled "Definition and Procedure for the Determination of the Method Detection Limit-Revision 1.11." This method is similar to the methods proposed by the American Chemical Society.

- LT values should not be deleted from the analysis. Instead, LT values may be analyzed at half their reported value. This technique is simple to use and has been presented for use in the following references:

  Gilbert, R.O. and Kinnison, R.R. 1981. Statistical Methods for Estimating the Mean and Variance from Radionuclide Data Sets Containing Negative, Unreported, or Less than Values. Health Physics 40:377-390.

  Nehls, G.J. and Akland G.G. 1973. Procedures for Handling Aerometric Data. Journal of the Air Pollution Control Association 23:180-184.

TABLE 4-3

AN EXAMPLE OF A DATA SUBMISSION WHICH MAY BE CONCEALING AN INCREASING CONCENTRATION TREND AND/OR WHERE THE UNITS OF MEASURE WERE REPORTED INCORRECTLY

GROUND-WATER ARSENIC CONCENTRATIONS IN PARTS PER BILLION

- August, 1982 — 1.54
- August, 1983 — <6
- November, 1983 — <11,000*

*Reported as 11 ppm.

4.7.2 Significant Digits

All digits in a reported result that have been measured, except for the last right-hand digit (which may have been estimated visually), are said to contain only significant digits. Table 4-4 lists examples of data values with their associated number of significant digits and identifies instances in which the number of significant digits is ambiguous.

Data values for each GWCC must be reported with consistent numbers of significant digits. Using the same number of significant digits suggests that the constituents were measured with equal precision, subject to the same round-off rules, and were generated and analyzed with care and attention to detail. Several extra digits should be carried through any statistical computations that are performed.

Three ways that the number of significant digits can decrease is:

- With an order of magnitude decrease in the concentration of a chemical species;
- Reduced precision of the analytical methodology; and
- Rounding of the values.

It is acceptable for the number of significant digits to decrease if there has been an order of magnitude decrease in concentration, but it is not acceptable to have a decrease in the number of significant digits because a new analytical method with less precision has been adopted or because significant digits have been rounded off. Sometimes it is possible to determine that data have been rounded off by comparing data from one sampling episode with data from another sampling episode. Rounding should not be allowed because the number of significant digits that are reported is related to the precision of the measurement. Rounding techniques should not be used to alter the apparent precision of a measurement. Similarly, if the laboratory, chemist, data base manager, method, or units of measure change, then the number of significant digits

TABLE 4-4
EXAMPLES OF DATA VALUES AND THEIR ASSOCIATED NUMBER OF SIGNIFICANT DIGITS

Data Value	Number of Significant Digits
23,000*	2
3,437	4
567.31	5
25.01	4
1.67	3
0.30*	2
0.001**	1
0.128	3
0.120*	3

*The number of significant digits in the values with right-hand zeros is ambiguous and without the other values in the data set it is not possible to determine whether the right-hand zeros were measured. In these examples the 23,000 value is assumed to be reported to the nearest 1000, the 0.30 is measured to the nearest 100th, and 0.120 to the nearest 1000th.

**Left hand spacing zeros in values less than one are normally not considered as significant digits.

may decrease. Again, a decease in precision is unacceptable and should be corrected. Correction and verification of this problem requires that the owner/operator trace data to their earliest form which should be the original laboratory records and laboratory technician who performed the measurements. If rounding occurred during data processing, the data can be corrected. However, if the chemical analysis method changed and caused a reduction in precision, the owner/operator should be advised to resume use of the prior methodology.

The absolute number of significant digits should be sufficient to provide reasonable accuracy. A general rule to follow is that all of the indicator parameters should be reported with at least three significant digits. The importance of measuring and retaining as many significant digits as possible is illustrated in the following example. For example, if methylene chloride values are measured in µg/ℓ with two significant digits and range from 65 to 73 then an error of plus or minus 1 µg/ℓ, which is an error of one in the last significant digit, is an 11 percent error. In contrast, if the values were measured to the tenths of a µg/ℓ, that is with three significant digits, and the values ranged from 65.1 µg/ℓ to 73.1 µg/ℓ, then an error of 0.1 in the last significant digit of 65.1 would be only about a 1 percent error. If it is difficult operationally to measure a GWCC concentration with three significant digits then, using the evaluation methodology described above in the example, no more than a 10 percent error should be allowed with a one unit change in the last significant digit of a data value.

4.7.3 Missing Data Values

Owner/operators incur a substantial risk of missing an extreme environmental event and measurement of particularly large or small values if they fail to collect all of the data required for a monitoring program. This may result in an incomplete measure of environmental variability and an increased likelihood of falsely detecting contamination. Also, if assessment monitoring data are missing there is a danger that the full

extent of contamination may not be characterized. Owner/operators must take extreme care to ensure that concentration measurements result from all samples that are taken. Nevertheless, the enforcement officer is likely to confront situations where complete detection or assessment monitoring data have not been collected. The enforcement officer should have the owner/operator perform the t-test despite incomplete data collection, provided that the following criteria have been met:

- If there are data from one upgradient well and one downgradient well, statistical comparisons should still be made. If data exists for three quarters at a well, statistical comparisons should be made after applying the rule described in the next bullet.

- If only one quarter of data is missing, values should be assigned for the four missing replicates. These values should be obtained by averaging the values obtained during the other three quarters.

- If there are missing replicate measurements from a sampling event, then assign values obtained by averaging the replicate(s) which are available for that sampling event.

These guidelines have been described previously in the November 1983 EPA memorandum on statistical analyses of indicator parameter data. The intent of this methodology is to force use of the t-test, despite prior noncompliance with the data collection requirements in the regulations, so that a determination can be made as to whether assessment monitoring should begin. Regardless of whether there are sufficient data for performing the t-test, the enforcement officer should consider taking enforcement action to compel additional sampling on an accelerated schedule (see Chapter Five of the RCRA Ground-Water Monitoring Compliance Order Guidance). The enforcement officer must minimize delays in the evaluation of a facility's ground water because of prior incomplete data collection.

4.7.4 Outliers

A GWCC value that is much different than most other values in the data for the same GWCC maybe referred to as an "outlier." The reasons for outliers can be due to:

- A catastrophic unnatural occurrence such as a spill;
- Inconsistent sampling or analytical chemistry methodology;
- Errors in the transcription of data values of decimal points; and
- True but extreme GWCC concentration measurements.

The enforcement officer should attempt to have owner/operators correct outlying values if the cause of the problem can be documented and corrected by the owner/operator without delay. The data should be corrected if outliers are caused by incorrect transcription and the correct values can be obtained and documented from valid owner/operator records. Also, if an unnatural catastrophic event or methodological problem occurred, which can be documented, then data values should be from calculations with clear reference to this deletion at all relevant stages. Documentation and validation of the cause of outliers must accompany any attempt to correct or delete data values, because true but extreme values must not be altered. The enforcement officer should not accept the mere presence of an extreme value in data or the effect of an extreme value on the statistical analysis as a valid reason for the continuation of detection monitoring.

4.7.5 Units of Measure

Associated with each GWCC value is a unit of measure which must be reported accurately. Mistakes in the reporting of the units of measure can result in gross errors in the apparent concentrations of GWCCs. For example, a lead value of 30.2 might have a unit of measure of parts per billion (ppb). Alternately, the same lead value of 30.2 might have been incorrectly reported with a unit of measure in parts per million (ppm). The reported value would transform to a concentration with the units of measure in ppb as 30,200 ppb of lead or three orders of magnitude larger than it was measured. Table 4-3 presents an example of a data submission which included a value that was probably reported with incorrect units of measure.

The following guidelines should help the enforcement officer ensure that data values are reported consistently and unambiguously:

- The units of measure should accompany each chemical parameter name. Laboratory data sheets that include a statement "values are reported in ppm unless otherwise noted" should generally be discouraged but at least reviewed in detail by the enforcement officer. It is common to find errors in reporting the units of measure on this type of data reporting sheet.

- The units of measure for a given chemical parameter must be consistent throughout the report.

- Finally, reporting forms for detection monitoring, as specified in the EPA November 1983 memorandum, and the data presentation methods described in Chapter Five should help to reduce problems associated with the reporting of units of measure.

CHAPTER FIVE

STATISTICAL ANALYSIS OF DETECTION MONITORING DATA

Owner/operators of hazardous waste facilities must implement a ground-water monitoring program capable of determining if a facility has had a significant effect on the quality of the ground water. This determination is based on the results of a statistical test. This chapter discusses the data that should be collected to perform the statistical test, and what actions should be taken based on the results of the statistical test. A general description of statistical techniques is described below. A more specific description, which includes the computational details and an example, appears in Appendix B.

5.1 Methods for Presenting Detection Monitoring Data

Data reporting sheets such as those presented in the November 30, 1983, EPA memorandum titled "Guidance on Implementation of Subpart F Requirements for Statistically Significant Increases in Indicator Parameter Values" should be used when owner/operators present data as required by §265.94(a). The enforcement official should make sure that owner/operators are aware of and use standardized data reporting sheets.

The enforcement official should have in the file all of the ground-water data that have been collected to date from the facility. An explicit presentation of the statistical test methodology should also be in the file for the facility.

5.2 Introductory Topics: Available t-Tests, Definition of Terms, and Components of Variability

Several introductory topics are discussed in this section which pertain to the statistical analysis of detection monitoring data. First, the statistical tests that the owner/operator can use to analyze detection monitoring data are discussed. Then definitions of the terms background,

upgradient, and downgradient are presented. Finally, the measurement of environmental variability and its relationship to the number of upgradient wells, analytical replicates, and the statistical test that should be used is reviewed.

The interim status regulations specify that a students t-test be used to determine whether there has been a significant increase in any ground-water contamination indicator parameter (IP) in any well. The §265 regulations do not, however, require a specific students t-test. The owner/operator has the latitude within the regulations to choose a t-test which will accommodate the data that have been collected. One reason that interim status facilities frequently adopt the Cochran's Approximation to the Behrens-Fisher (CABF) t-test is that the §264 permit regulations require the use of the CABF t-test, unless an equivalent statistical test is accepted by the Regional Administrator. Other t-tests are available for the owner/operators to use in th analysis of their interim status detection monitoring data. One alternative t-test, which has been recommended for use in public comment and in the November 1983 memorandum on interim status statistical analyses, is referred to as the averaged replicate (AR) t-test. The AR t-test is a reasonable test for owner/operators to apply to their interim status detection monitoring data because it removes the excessive weight that the analytical or split sample replicates have on the background variability and may help reduce statistically caused false positives. The owner/operator may perform the t-test of choice, but the results must be presented and action taken based on the results of only one type of t-test.

It should be noted that although owner/operators have latitude with respect to the statistical test that is used, there is much less choice with regard to the data collection requirements. Also, despite which t-test is used the comparisons which are required to be made must not change. A general example of the last two points is that, regardless of

the t-test the owner/operator has decided to use, a background data set should be collected and compared to the data from each well individually each time they are sampled.

Three terms which are used frequently in discussions regarding the interim status detection monitoring statistical analysis are: background, upgradient, and downgradient. The terms upgradient and downgradient describe well locations (e.g., with respect to the groundwater hydraulics) and performance (e.g., downgradient wells must be able to immediately detect contamination). The terms upgradient and downgradient also describe the data collected from those wells. The term background refers to a special set of upgradient data that should have been collected beginning in November 1981 and ending in November 1982 from all the wells upgradient and unaffected by the facility. In addition, unlike references to upgradient or downgradient data which are well specific, references to background data concern all data collected from all upgradient wells during the period when background levels are being established. It may also be necessary, during the administration of enforcement cases when background data have not been collected properly, to require accelerated data collection and have background data collected concomitantly with the data collected from the downgradient wells.

The issue of the components of variability in background groundwater data have been of concern to enforcement officials. The concern has been that some owner/operators historically have had a tendency to install the minimum of one upgradient well. The result is a background data set which includes no component of spatial variability because only one upgradient well has been sampled. Also, the background data are influenced heavily by analytical variability because of the requirement to obtain four measurements per sample. The split sample replicates are valuable for ensuring that owner/operator laboratories are operating with

a degree of quality control. However, the background data set should also include a component of spatial variability and not be influenced heavily by the typically small component of analytical variability. Many owner/operators have installed a minimum, but not necessarily acceptable, number of upgradient wells (e.g., one upgradient well). Two recommendations are provided to help with this problem. First, the owner/operator should install additional upgradient wells to ensure measurement of spatial variation in the ground waters in the upgradient area. Second, the AR t-test can be used by owner/operators to essentially remove the excessive influence that the analytical replicate variability has on the CABF t-test.

5.3 Statistical Analysis of the First Year's Data

As described above, owner/operators should have measured the background concentrations of ground-water parameters within one year of the effective date of the interim status Subpart F regulations. The initial background concentrations of the Appendix III parameters in §265.92(b)(1), the ground-water quality parameters in §265.92(b)(2), and the ground-water contamination (or indicator) parameters in §265.92(b)(3) should have been established by monitoring upgradient wells quarterly for a year. Four replicate measurements should have been obtained from each well during each sampling episode for the indicator parameters.

The background mean and variance should have been determined using all of the data obtained for the §265.92(b)(3) parameters during the first year of sampling from the wells that were upgradient of the facility. It should be noted that one primary difference between the CABF t-test and the AR t-test is the method used to determine the background mean and variance. These summary statistics, which describe the background concentrations, form the basis against which all subsequent upgradient and downgradient concentration measurements will be compared. The methods used to estimate the background mean ($\bar{X}_b$) and variance (s_b^2) for the CABF and AR t-tests are described in Appendix B.

5.4 Statistical Analysis of Detection Monitoring Data After the First Year

Detection monitoring data collected after the first year should be used to compare with the background data to determine if there is a suggestion that contamination may have occurred. A t-test is used to make this determination. A significant increase in the mean concentration of any IP in any downgradient well, that is statistically larger than the background concentration, suggests that contamination may have occurred. (NOTE: In the case of pH, the t-test is conducted such that an increase or decrease is detected. All future references to significant statistical increases imply in the case of pH that a significant statistical change is being evaluated.)

All of the upgradient and downgradient wells must be sampled after the first year. The ground-water quality parameters in §265.92(b)(2) must be measured at least annually but are not analyzed statistically. The IPs in §265.92(b)(3) must be measured in at least four replicate measurements from each sample from each well in the detection monitoring network at least semi-annually.

The data collected must be used to calculate an arithmetic mean and variance at least semi-annually for each IP from each well. The methodology for computing the mean and variance from data collected after the first year is the same methodology used to compute the background mean and variance.

5.4.1 Comparison of Background Data Collected the First Year With Upgradient Data Collected in Subsequent Years

When the t-test for an upgradient well as required by §265.93(c)(1) shows a significant increase in the concentration of an IP, there is a suggestion that IP concentrations in the upgradient ground water may be increasing. There are several reasons why the statistical test may indicate that the upgradient concentrations have increased. These include:

- Ground-water flow direction was determined incorrectly and hazardous waste constituents have migrated into the upgradient wells.

- Ground-water flow direction was determined correctly, but hazardous waste constituents are moving in a direction that is opposite of the ground-water flow.

- Upgradient wells were located in a mound caused by the facility.

- A source of contamination unrelated to the facility was detected.

- An inconsistent methodology (e.g., well construction materials, sampling and analysis techniques) has been used which resulted in concentration differences that are unrelated to any change in the concentration of IPs in the ground water.

- The t-test falsely indicated a difference between the background data and upgradient data when actually there was no difference.

The cause of the increase in upgradient concentrations will be important to the enforcement official if the owner/operator establishes successfully during the first determination under assessment that no contaminants have entered the ground water. Prior to reinstating the detection monitoring program the owner/operator may request that, because of the increase in background concentrations identified with the background versus upgradient comparisons, the historical data are unrepresentative of background conditions and should be modified.

Several recommendations are presented which will help the enforcement officer decide whether and how the background data set can be corrected:

- The enforcement officer should require that the owner/operator perform the following prior to modification of the background data. First, it must be explained exactly why the background data set should be modified. These demonstrations must be based upon data and considerations which are documented thoroughly. The owner/operator must also indicate specifically how the background data set will be modified. Finally, it must be shown that changes in the background data will not delay the ground-water sampling and anlaysis program.

- Before any modifications are made to the data the enforcement official should make sure that it is not possible to conduct the statistical comparisons using existing data. Although some data sets have a sparse amount of data, it may be possible to use the recommendations in the section on missing data to impute the values that were not collected and still make a statistical comparison of background versus downgradient data. It may also be possible to use data that were collected from upgradient wells after the first year.

- Many data sets will be unusable because of unacceptable analytical chemistry, hydrogeological considerations, or the physical construct of the well system, for example, when wells have been located in an area affected by the facility. Modification of the background data set may require installation and sampling of a new well system. In this case, it may be necessary to require that background data from upgradient wells be collected on an accelerated schedule concomitantly with downgradient data.

5.4.2 Comparison of Background Data Collected During the First Year With Downgradient Data Collected in Subsequent Years

When the t-test for a downgradient well shows a significant increase this suggests that the facility may be affecting the ground water. The owner/operator must immediately resample and collect multiple ground-water samples from those downgradient wells where a significant increase in concentration was detected as required by §265.93(c)(2). The additional ground-water samples are to be split in two and analyzed to determine by reapplying the t-test using the resampling data whether the significant increase was a result of laboratory error or the result of ground-water contamination. If the initial results are due to laboratory error and no significant increase has occurred, the detection program may continue.

If the additional analyses performed under §265.93(c)(2) confirm the significant increase, the owner/operator's facility is in interim status assessment monitoring and must, without exception, begin immediately the requirements of assessment monitoring. Ground-water contamination cannot be evaluated satisfactorily with a continuation of detection monitoring.

It is essential that the enforcement official determine that all data collected from the site hydrogeologic characterization is adequate to define the vertical and horizontal extent of the saturated zone of potential contamination. The reliability of all phases of the site ground-water monitoring program and the efficacy of any subsequent corrective action efforts hinge upon the quality of the owner/operator's site hydrogeologic characterization.

CHAPTER SIX

ASSESSMENT MONITORING

Once the owner/operator has detected contaminant leakage via his detection monitoring efforts, the owner/operator must undertake a more aggressive ground-water program called assessment monitoring. Specifically, the owner/operator must determine the vertical and horizontal concentration profiles of all the hazardous waste constituents in the plume(s) escaping from waste management areas. In addition, the owner/operator must establish the rate and extent of contaminant migration. The blueprint for an assessment monitoring program is the owner/operator's written assessment monitoring plan. This is an extremely important document, serving several purposes:

1. It presents a detailed procedure for determining the rate of migration, extent, and hazardous waste constituent composition of the release.

2. It provides a mechanism for obtaining data necessary to the permit application process, principally the §270.14(c) information requirement.

3. It provides a mechanism for obtaining data necessary for subsequent corrective actions at facilities.

The Agency has observed a number of problems in the way owner/operators prepare and/or implement their assessment monitoring plans.

- Many owner/operators lack satisfactory knowledge of site hydrogeologic conditions. As a result these owner/operators cannot make informed decisions on how to carry out their assessment programs. The owner/operator should have collected abundant site hydrogeologic information prior to the installation of the detection monitoring system in the site characterization phase.

- Many owner/operators fail to provide enough information in their assessment plans to allow the Agency to scrutinize their decision-making or to evaluate their assumptions.

- Some owner/operators fail to implement their assessment programs quickly enough or they implement programs that will take too long to provide information on plume extent and migration.

- Some owner/operators do not support geophysical investigation with a sufficient monitoring well network. Geophysical methods are valuable in confirmation of conclusions through sampling and as in interpolative tool between wells, but they are insufficient at present by themselves.

- Many owner/operators greatly underestimate the level of effort the Agency expects of them in characterizing plume migration. In most cases, assessment monitoring is an intensive effort that will require the owner/operator to install numerous monitoring wells. The owner/operator must track and characterize both the horizontal and vertical components of the plume (i.e., a three dimensional characterization).

- Many owner/operators do not follow their written plans or fail to update their plan on the basis of information gained through assessment programs.

For facilities in assessment monitoring the enforcement official's main emphasis should be on (1) scrutinizing the adequacy of the owner/operator's written assessment monitoring plan; and (2) reviewing the owner/operator's implementation of the plan in the field.

There are a number of elements that the owner/operator should include in the assessment monitoring plan.

- narrative discussion of the hydrogeologic conditions at the owner/operator's site; identification of potential contaminant pathways (Section 6.1);

- description of the owner/operator's detection monitoring system (Section 6.2);

- description of the approach the owner/operator will use to make the first determination (false positives rationale) (Section 6.3);

- description of the investigatory approach the owner/operator will use to fully characterize rate and extent of contaminant migration; identification and discussion of investigatory phases (Section 6.4);

- discussion of number, location and depth of wells the owner/operator will initially install as well as strategy for installing more wells in subsequent investigatory phases (Section 6.5);

- information on well design and construction (Section 6.6);

- a description of the sampling and analytical program the owner/operator will use to obtain and analyze ground-water monitoring data (Section 6.7);

- description of data collection and analysis procedures the owner/operator plans to employ (Section 6.8); and

- a schedule for the implementation of each phase of the assessment program (Section 6.9);

6.1 Description of Hydrogeologic Conditions

An owner/operator cannot conduct an adequate assessment monitoring program without a thorough understanding of site hydrogeologic conditions. A thorough understanding of hydrogeologic conditions, garnered through site characterization activities (refer to Chapter One), allows the owner/operator to identify likely contaminant pathways. Identification of these pathways allows the owner/operator to focus efforts on tracking and characterizing plume movement. It is important to note that the initial site characterization carried out by the owner/operator should provide enough hydrogeologic information to allow the owner/operator to not only design a detection monitoring system but also plan and carry out an assessment monitoring program. Except for cases where some additional site information is needed (see §6.5.1), the owner/operator should not, as part of the assessment monitoring program, conduct hydrogeologic site characterization. This characterization should have been completed prior to the design of detection monitoring systems.

The owner/operator's assessment plan should describe in detailed narrative form what hydrogeologic conditions exist at the owner/operator's

site. The plan should describe the potential pathways of constituent migration at the site including depth to water in aquifer, aquifer connections to surface water and/or deeper aquifers, flow rate and direction, and any structions such as fractures and faults which could affect migration. The owner/operator's plan should also describe how hydrogeologic conditions have influenced the type of assessment effort that will be used to characterize plume migration. This portion of the owner/operator's assessment plan should recapitulate the hydrogeologic investigatory program the owner/operator undertook prior to installing a detection monitoring system (see Chapter One). It should describe the investigatory approach the owner/operator used to characterize subsurface geology and hydrology, the nature and extent of field investigatory activities, the results of the investigation, and explicit discussion as to how those results have guided decisions the owner/operator has made in regards to the planning and implementation of his assessment monitoring program. As part of the plan, the owner/operator should append various supporting documentation such as those described in Table 1-1.

6.2 Description of Detection Monitoring System

The owner/operator's assessment plan should describe the detection monitoring system in place at the owner/operator's facility. Of key concern is that the existing well system is capable of detecting all contaminant leakage that may be escaping from the facility. If the owner/operator's detection monitoring system is deficient either in design or operation, plumes may escape the notice of the owner/operator. This portion of the owner/operator's assessment plan should describe the physical layout of the owner/operator's detection monitoring well system (e.g., horizontal and vertical orientation of individual wells) and identify assumptions the owner/operator used in designing the detection monitoring system (particularly how hydrogeologic condition affected decision making).

6.3 Description of Approach for Making First Determination - False Positives

Chapter Five described requirements that owner/operators must meet in terms of statistical analysis of detection monitoring data. Once an owner/operator has verified a statistically significant increase in contaminant concentration in a well(s), the owner/operator must shift from detection to assessment monitoring. Figure 6-1 illustrates the sequence of events that occur once an owner/operator shifts to assessment monitoring. Of particular interest are those situations where the owner/operator feels that contamination may have been falsely indicated and describes in his assessment plan a short term program to substantiate or disprove the false positive claim (i.e., false positive investigation is focus of first determination - §265.93(d)(5)).

Assessment plans focusing on substantiating a false positive claim should only be entertained when an owner/operator's detection monitoring system is properly designed. If an owner/operator's detection monitoring system is inadequate, it is difficult to evaluate whether leakage has occurred by sampling for specific constituents in the existing monitoring network. Substantiation of a false positive claim would be a lengthy process potentially involving hydrogeologic work, the installation of a new detection well network and additional sampling. In those cases, officials should reject a false positive analysis as the focus of the first determination when the existing system is inadequate and instead require the owner/operator to (1) correct deficiencies in the detection monitoring system; and (2) concurrently initiate a comprehensive assessment program downgradient from the triggering well(s).

If, however, an owner/operator's detection monitoring system is adequately designed, the owner/operator may propose as his first determination a short-term sampling program--generally no longer than 30 days- that will investigate whether the statistical change noted in Part 265 indicator parameters truly represents migration of leachate into

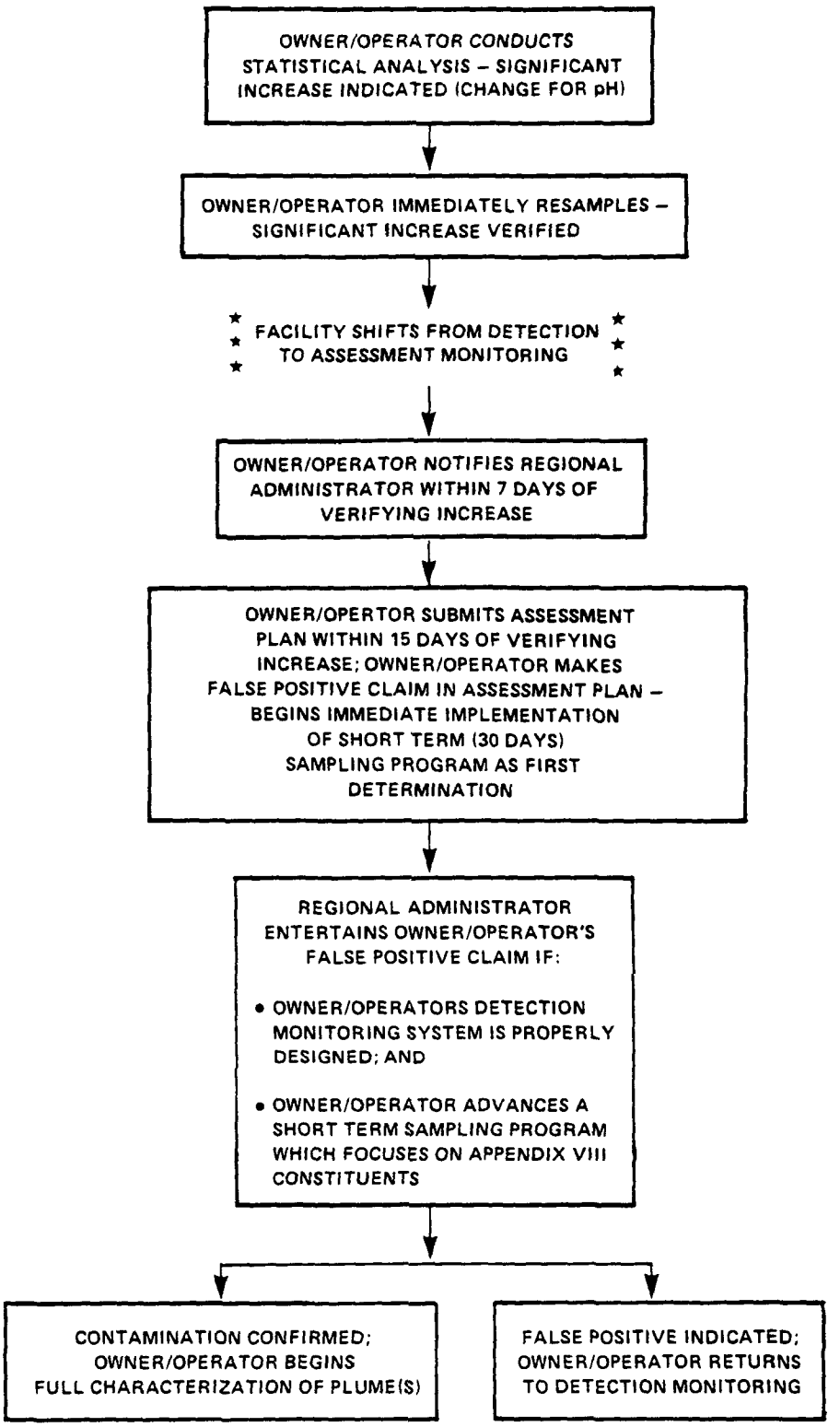


FIGURE 6-1. PROCEDURE FOR EVALUATING FALSE POSITIVE CLAIMS BY OWNER/OPERATORS

the uppermost aquifer. For units subject only to the Part 265 standards, the short-term sampling program must, at a minimum, confirm that no hazardous waste constituents (Appendix VII) have migrated into the uppermost aquifer. For units subject to the Part 270 requirements (because they are seeking an operating permit or the Agency has called in their post-closure permit), the owner/operator should include constituents selected from Appendix VIII in the sampling program.

After conducting the short-term sampling program (constituting the first determination), the owner/operator must submit to the Regional Administrator a written report describing the ground-water quality. If the sampling program confirms that leakage has not occurred, the owner/operator may reinstate the detection monitoring program or enter into a consent agreement with the Agency to follow a revised detection protocol designed to avoid future false triggers. If, however, the short-term sampling confirms that leakage has in fact occurred, the owner/operator must immediately begin implementation of assessment activities to characterize rate and extent of contaminant migration.

6.4 Description of Approach for Conducting Assessment

A variety of investigatory techniques are available for use during a ground-water quality assessment. They can be broadly categorized as either direct or indirect methods of investigation.

All assessment programs should be designed around the direct method of actual collection of a sample with subsequent chemical analysis to determine actual water quality (i.e., installation of monitoring wells). Other methods of investigation may be used when appropriate to choose the locations for well construction. For certain aspects of an assessment, such as defining plume location, the use of both direct and indirect methods may be the most efficient approach.

The methods planned for use in an assessment should be clearly specified and evaluated to ensure that the performance standard

established for assessments can be met. Evaluating the use of direct and indirect methods are discussed separately below.

6.4.1 Use of Direct Methods

Ground-water monitoring wells, either existing or newly installed, are necessary to provide sampling data to establish the concentration of hazardous constituents released from the hazardous waste management, and the rate and extent of their migration. The owner/operator should construct assessment monitoring wells and conduct sampling and analysis in a manner that provides reliable data. Chapters Three and Four, respectively, present guidance in these areas.

At facilities where it is known or suspected that volatile organics have been released to the uppermost aquifer, organic vapor analysis of soil gas from shallow holes may provide an initial indication of the areal extent of the plume. To this end, the owner/operator may use an organic vapor analyzer (OVA) to measure the volatile organic constituents in shallow hand-augered holes. Alternatively, the owner/operator may extract a sample of soil gas from a shallow hole and have it analyzed in the field using a portable gas chromatograph. These techniques are limited to situations where volatile organics are present. Further, the presence of intervening, saturated, low permeability sediments strongly interferes with the ability to extract a gas sample. Although it is not necessarily a limitation, optimal gas chromatography results are obtained when the analyte is matched with the highest resolution technique, e.g., electron capture/halogenated species.

Descriptions of the direct methods that will be employed during assessment monitoring should be included in the assessment plan. These descriptions should be sufficiently detailed to allow the method to be evaluated and to ensure that the method will be properly executed.

6.4.2 Use of Indirect Methods

A variety of methods are currently available for identifying and, to a limited extent, characterizing contamination in the uppermost aquifer.

There are several geophysical techniques of potential use to an owner/operator including electrical resistivity, electromagnetic conductivity, ground penetrating radar, and borehole geophysics. Remote sensing and aerial photography are additional indirect methods an owner/operator may find useful. These techniques, with the exception of aerial photographic methods, operate by measuring selected physical parameters in the subsurface such as electrical conductivity, resistivity, and temperature.

The value of indirect methods is not the provision of detailed, constituent-specific data for which they presently are clearly limited, but rather for demarcating the general areal extent of the plume. This is extremely important to the owner/operator for two reasons:

1. Knowing the outline of the plume before additional wells are constructed reduces the need for speculative wells. The assessment monitoring program therefore becomes more efficient since well placement is guided by analytical data.

2. As the plume migrates and its margins change, the owner/operator may track its motion and see where new wells may be needed.

There are drawbacks to the exclusive use of geophysical techniques in assessment monitoring relating to the high level of detail necessary to characterize the chemical composition of a ground-water plume. For these methods to be successful in this way the contaminant(s) of interest must induce a change in the subsurface parameter measured. This change, in turn, must be distinguishable from ambient conditions. For example, the electrical properties of organic hazardous constituents are generally attenuated or masked by subsurface material properties. Unless these constituents are present in a thick, immiscible layer, they generally will not register during resistivity or conductivity surveys. Moreover, nonuniform subsurface conditions may obscure low levels of certain contaminants in ground water. Another drawback to the exclusive use of geophysical methods at present is their inability to measure specific concentrations of individual constituents or provide good vertical resolution of constituent concentration. In addition, man-made structures such as powerline towers, buried pipelines, roads, and parking lots

may interfere with the performance and reliability of may geophysical methods. The owner/operator should therefore only use indirect methods to guide the installation of an assessment monitoring system and to provide an ongoing check of the extent of contaminant migration.

6.4.3 Mathematical Modeling of Contaminant Movement

Mathematical and/or computer modeling may provide information useful to the owner/operator during assessment monitoring. The owner/operator should not, however, depend solely on mathematical models to guide the placement of assessment monitoring wells. The high spatial and temporal variability of conditions encountered in the field do not lend themselves to the simplification and assumptions necessary to model something as highly site-specific as an assessment of the extent and rate of migration of a contaminant plume. Furthermore, such extensive initial data is often required as to render unclear what benefit is derived from modeling as opposed to using direct or indirect methods.

Where a model is to be used, the owner/operator should make site-specific measurements to verify the parameters to be used in the model. The hydrologic parameters required to describe saturated flow include: hydraulic conductivity (vertical and horizontal); hydraulic gradient; specific yield (unconfined aquifer) or specific storage (confined aquifer). The parameters required to describe contaminant flow include the apparent velocity of the pollutant, dispersion and diffusion coefficients of the pollutants in the medium, the adsorbtion of pollutants in the medium (retardation), and factors necessary to describe degradation of pollutants. The dispersion coefficient is a function of the apparent velocity and dispersivity, and cannot be directly measured unless an extensive test with tracers is performed. Retardation calculations are based on soil bulk density, effective porosity and cation exchange capacity. Retardation can also be determined from the octanol-water partition coefficient and fractional portion of organic matter in

representative volumes of soil. Degradation of pollutants depend upon the type of constituents and the probability for chemical and biological decay.

Background ground-water quality (e.g., indicator parameters plus Cl^-, Fe, Mn, Na^+, SO_4, Ca^+, Mg^+, NO_3^-, $PO_4^=$, silicate, ammonium, alkalinity or acidity) is important to determine the reactivity and solubility of hazardous constituents in ground water and therefore is useful in predicting their mobility under actual site conditions. The physical and chemical characteristics of the site-specific wastes (e.g., density, solubility, vapor pressure, viscosity, and octanol-water partition coefficient) and hazardous waste constituents should also be known to reliably model constituent movement.

Mathematical models can be analytical equations by which the hydraulic head or concentration of a contaminant at any location are calculated. The phrase "mathematical models" is more often used to refer to algorithms that represent the governing equations of water flow and mass transport that can only be solved with computers. The use of computer models enables an analysis of complex conditions that better describe the actual environment. Any model requires the recognition of inherent assumptions, the application of appropriate boundary conditions, and the selection of a coherent set of input parameters.

Required parameters that can be measured directly should be determined with consideration of selecting representative samples and with an understanding of how input of a parameter will influence the output (e.g., affect of assuming homogeneous conditions in a heterogeneous environment). All parameters measured or assumed and adjusted during model calibration should be reasonable and varied within reasonable ranges. Modeling is not only useful in guiding direct measurements, but can also be useful in predicting future events. When applying all models, emphasis should be placed on the usefulness of the model to the

specific problem at the site, calibration and verification with past and present data, and careful application in the predictive mode.

A partial list of computer models that could be employed at a site include: Modular 3-Dimensional Finite Difference Groundwater Flow Model (USGS), to evaluate complex hydrologic conditions; Computer Model of Two-Dimensional Solute Transport and Dispersion in Ground Water (USGS) or the Illinois State Water Survey Random Walk Solute Transport Model, to predict contaminant transport; the AT123D model to calculate concentrations isopleths for transient contaminant flow in one, two, or three dimensions under hydraulic flow conditions; and the FEMWASTE model, developed by Oakridge National Laboratory, which can predict contaminant migration in both the saturated and unsaturated zones.

If an owner/operator plans to use a model to guide an assessment monitoring program, the owner/operator must be able and willing to describe how the model works as well as explain all assumptions used in applying the model to the site in question.

6.5 Description of Sampling Number, Location, and Depth

The regulations require that the assessment plan specify the number, location and depth of wells that will be installed as part of the assessment. As the discussion on assessment methodology provided in Section 6.4 has indicated, the owner/operator may use other sampling techniques (e.g., indirect methods and coring) in addition to the installation of permanent monitoring wells to augment the data generated by wells during assessment. The owner/operator's assessment plans should, however, specify the number, location, and depth of wells that will be installed to characterize rate and extent of migration, and constituent concentrations, and present explanations for the decisions.

It may not always be possible for the owner/operator to identify at the outset of an assessment the exact number, location, and depth of all sampling that will be required to meet the goals of an assessment. In

many cases the investigations undertaken to characterize contamination during an assessment will proceed in phases in which data gained in one round of sampling will guide the next round of sampling. For example, surface geophysical techniques can be effectively used in tandem with the installation of monitoring wells as a first phase in the assessment program to obtain a rough outline of the contaminant plume. Based on these findings, a sampling program may subsequently be undertaken to more clearly define the three-dimensional limits of the contaminant plume. In the third phase, a sampling program to determine the concentrations of hazardous waste constituents in the interior of the plume may be undertaken. In this case, a detailed description of the approach that will be used to investigate the site should be included in the assessment plan. This description should clearly identify the number, location, and depth of any sampling planned for the initial phase of the investigation. In addition, the outline should clearly identify what basis will be used to select subsequent sampling locations, including the geologic strata that are likely to be sampled and the anticipated density of sampling. In general, a minimum of seven well clusters should be installed to define the extent of contamination and concentration of contaminants in the horizontal plane (see Section 6.5.2). Each well cluster should consist of a minimum of five wells at varing depths to profile the vertical extent of migration (see Section 6.5.3).

6.5.1 Collection of Additional Site Information

The hydrogeologic site characterization requirements for the detection monitoring program include:

- The subsurface geology below the owner/operator's hazardous waste facility.
- The vertical and horizontal components of flow in the uppermost saturated zone below the owner/operator's site.
- The hydraulic conductivity of the uppermost aquifer.
- The vertical extent of the uppermost aquifer down to the first confining layer.

If this characterization does not include all the hydrogeologic information necessary to characterize the rate of contaminant movement, the owner/operator should obtain this additional information for the assessment phase. Examples of the additional information that may be needed to determine the rate of contaminant movement include: mineralogy of the materials in the migration pathway; ion exchange capacity of the material; organic carbon content of the materials; background water quality of the pathway (e.g., major cations and anions); the temperature of ground water in the migration pathway; and the effective porosity of the material in the pathway. This information will help define the transport mechanisms which are most important at the site. All information collected during the investigation of the plume (i.e., boring logs, core analysis, etc.) should be recorded and the hydrogeologic descriptions of the site updated when appropriate.

Prior to assessment well placement, a good estimation of plume geometry can be determined from a review of current and past site characterizations. For example, piezometer readings surrounding the contaminated detection well can be taken to determine the current hydraulic gradient. When these values are compared to the potentiometric surface map developed during the site investigation, the general direction of plume migration can be approximated. Any seasonal or regional fluctuations should be considered during this comparison. A review of the facility's subsurface geology may also identify preferential pathways of contaminant migration.

To limit drilling speculative wells, geophysical and modeling methods can also be employed to yield a rough outline of the plume. This expedites the assessment monitoring program. Monitoring wells can then be strategically placed to precisely define the plume geometry.

6.5.2 Sampling Density

The program of sampling undertaken during the assessment should clearly identify the full extent of hazardous waste constituent migration

and establish the concentration of individual constituents throughout the plume. In the initial phase of the assessment program the owner/operator's well installation/sampling should concentrate on bounding those areas that have been contaminated by the facility. A minimum of seven well clusters should be installed to define the extent of contamination and concentration of contaminants in the horizontal plane as illustrated in Figure 6-2. Three well clusters should be installed in a line downgradient from the triggering well cluster. Two of these clusters should be installed in the plume; one cluster should be installed beyond the plume. Four well clusters should be installed in a line that is perpendicular to the direction of contaminant flow. Two of these clusters should be installed in the plume, and two of these clusters should be installed beyond the plume. This network of monitoring wells, with a minimum of seven wells, will thoroughly define the horizontal boundaries of the plume, and will identify and quantitate contaminants.

The well density or amount of sampling undertaken to completely identify the furthest extent of migration should be determined by the variability in subsurface geology present at the site. Formations such as unconsolidated deposits with numerous interbedded lenses of varying permeability or consolidated rock with numerous fracture traces will require a greater amount of sampling to ensure that all contamination is detected.

Sampling is also required to characterize the interior of any plume detected at the site. This is important because the migration of many constituents will be retarded by natural attenuative processes. Sampling at the periphery of the plume may not identify all the constituents from the facility that are reaching ground water and the concentration of waste constituents detected at the periphery of the plume may be significantly less than in the interior of the plume. Patterns of concentration of individual constituents can be established throughout

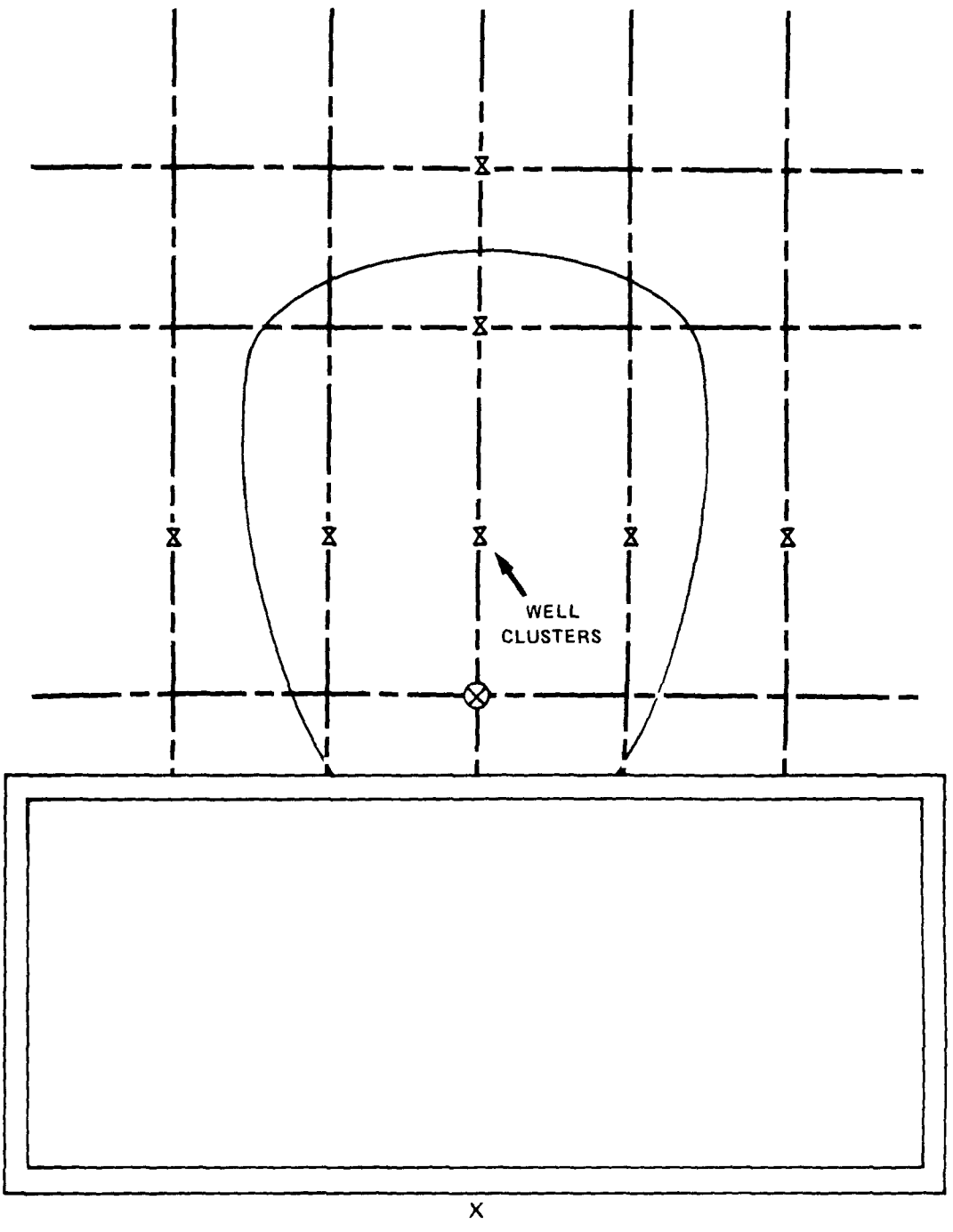


FIGURE 6-2. INITIAL PLACEMENT OF WELL CLUSTERS TO DEFINE THE EXTENT OF CONTAMINATION IN THE HORIZONTAL PLANE

the plume by sampling along several lines that perpendicularly transect the plume. The number of transects and spacing between sampling points should be based on the size of the plume and variability in geology observed at the site. Sampling locations should also be selected so as to identify those areas of maximum contamination within the plume. In addition to the expected contaminants, the plume may contain constituent degradation products as well as reaction products.

6.5.3 Sampling Depths

The owner/operator should specify in the assessment plan the depth at which samples will be taken at each of the planned sampling locations. These sampling depths should be sufficient to profile the vertical distribution of hazardous waste constituents at the site. Vertical sampling should identify the full extent of vertical constituent migration. Vertical concentration gradients including maximum concentration of each hazardous waste constituent in the subsurface should similarly be identified. The amount of vertical sampling required at a specific site will depend on the thickness of the plume and the vertical variability observed in the geology of the site. All potential migration pathways should be sampled. The sampling program should clearly bound the vertical extent of migration by identifying those areas on the periphery of the plume that have not been contaminated.

In order to establish vertical concentration gradients of hazardous waste constituents in the plume, the owner/operator must obtain a continuous sample of the plume, which means well clusters should be employed. The owner/operator, however, cannot know the vertical extent of the plume; therefore, the first well in the cluster should be screened at the horizon contamination was discovered, bearing in mind the 10-foot screen length guidance. Additional wells in the cluster should be screened, where appropriate, above and below the initial well's sampling interval until the margins of the plume are established. In general, five wells per cluster are suggested, three within the plume and one each

above and below its vertical margins. Care must be taken in placing contiguously screened wells close together since one's drawdown may influence the next and thus change the horizon from which its samples are drawn. Alternation of lower and higher screens should reduce this effect (see Figure 6-3).

The specifications of sampling depths included in assessment plans should clearly identify the interval over which each sample will be taken. It is important that these sampling intervals be sufficiently discrete to permit vertical profiling of constituent concentrations in ground water at each sampling location. Sampling will only provide measurements of the average contaminant concentration over the interval from which that sample is taken. Samples taken from wells screened over a large interval will be subject to dilution effects from uncontaminated ground water lying outside the plume limits. Except for certain conditions described in Chapter Two, the screened interval should be kept at a maximum of ten feet, and in cases in which small vertical concentration gradients are expected, smaller sampling intervals are appropriate.

A series of five wells per cluster is suggested to completely profile the vertical boundaries of the plume. This will also enable the identification of vertical concentration gradients and maximum concentrations of contaminants.

As part of the progressive assessment monitoring program, the owner/operator can use geophysical techniques to help verify the adequacy of the placement of his assessment monitoring network. Adjustments to the assessment monitoring program may be needed to reflect plume migration and changes in direction.

6.6 Description of Monitoring Well Design And Construction

The monitoring well design and construction requirements for assessment monitoring well networks are equivalent to the detection requirements presented in Chapter Three.

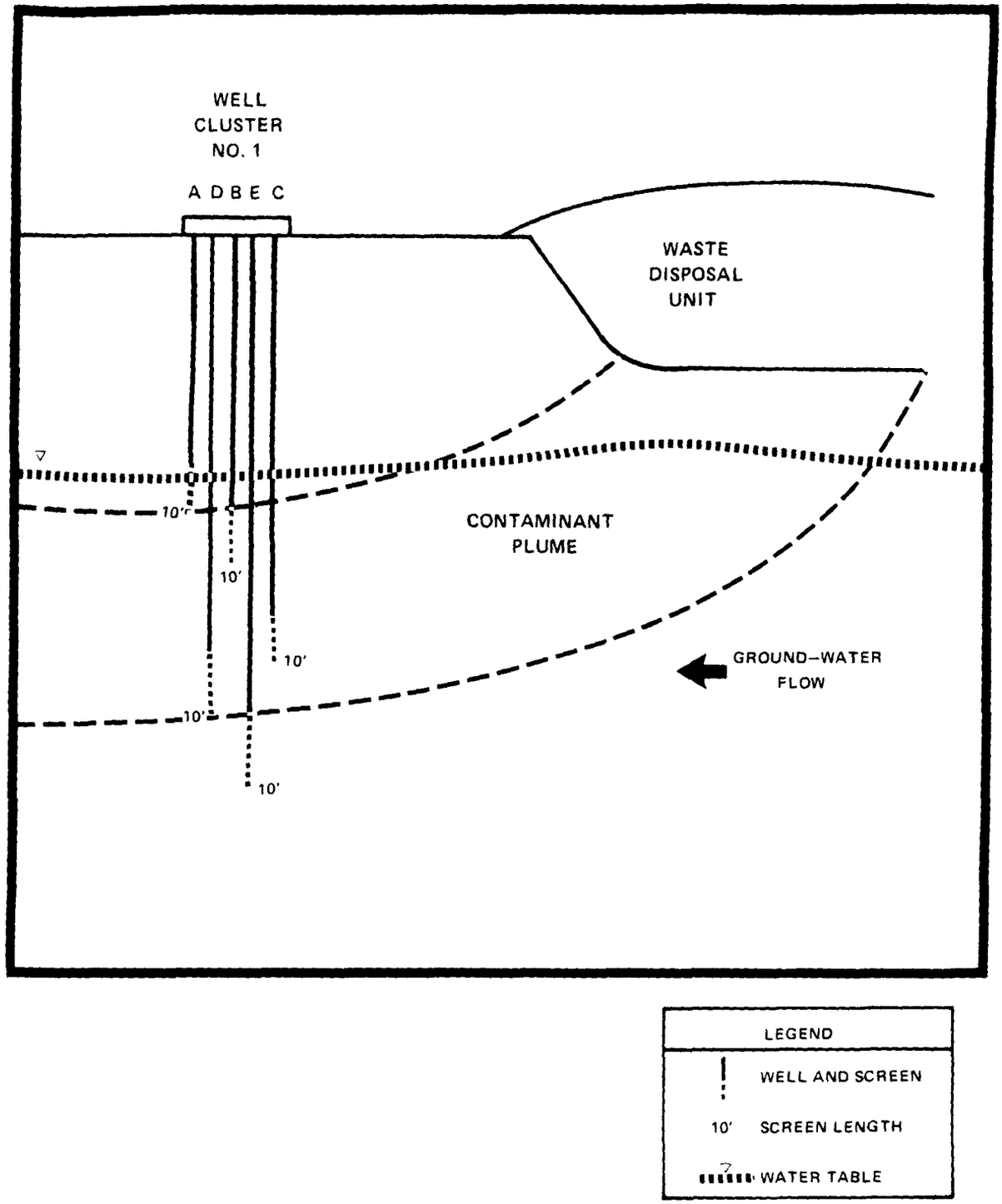


FIGURE 6-3. VERTICAL WELL CLUSTER PLACEMENT

6.7 Description of Sampling and Analysis Procedures

The owner/operator's sampling and analysis plan should be updated to reflect the different analytical requirements of assessment monitoring. Otherwise, the sampling and analysis plan used by the owner/operator in his detection monitoring program (see Chapter Four) should suffice for assessment monitoring.

The assessment plan should identify the parameters the owner/operator will monitor for and should describe why these parameters are suitable for determining the presence and concentration of hazardous waste or hazardous waste constituents migrating from the facility in the ground water. At a minimum, the owner/operator's assessment plan should include monitoring for all hazardous waste constituents that are in the facility's waste. Hazardous waste constituents, as defined in §260.10, include all constituents listed in Appendix VII of Part 261, all constituents included in Table 1 of §261.24, and any constituent listed in Section 261.33.

Facilities that are seeking an operating permit, also have additional plume characterization responsibilities pursuant to Part 270. Section 270.14(c)(4) requires permit applicants to expand their monitoring from hazardus waste constituents (primarily Appendix VII) to the full complement of Appendix VIII constituents (Note: Appendix VII is a subset of Appendix VIII). Therefore, when a unit is subject to the Part 270 requirements (either because they are seeking an operating permit or because the Agency has called in their post-closure permit), the Agency recommends that an owner/operator's assessment plan includes parameters that will satisfy the requirements of both Part 265 and Part 270.

Figure 6-4 illustrates in greater detail the sampling protocol that the Agency recommends for units that are subject to both Part 265 and Part 270. First, the owner/operator should perform an Appendix VIII scan

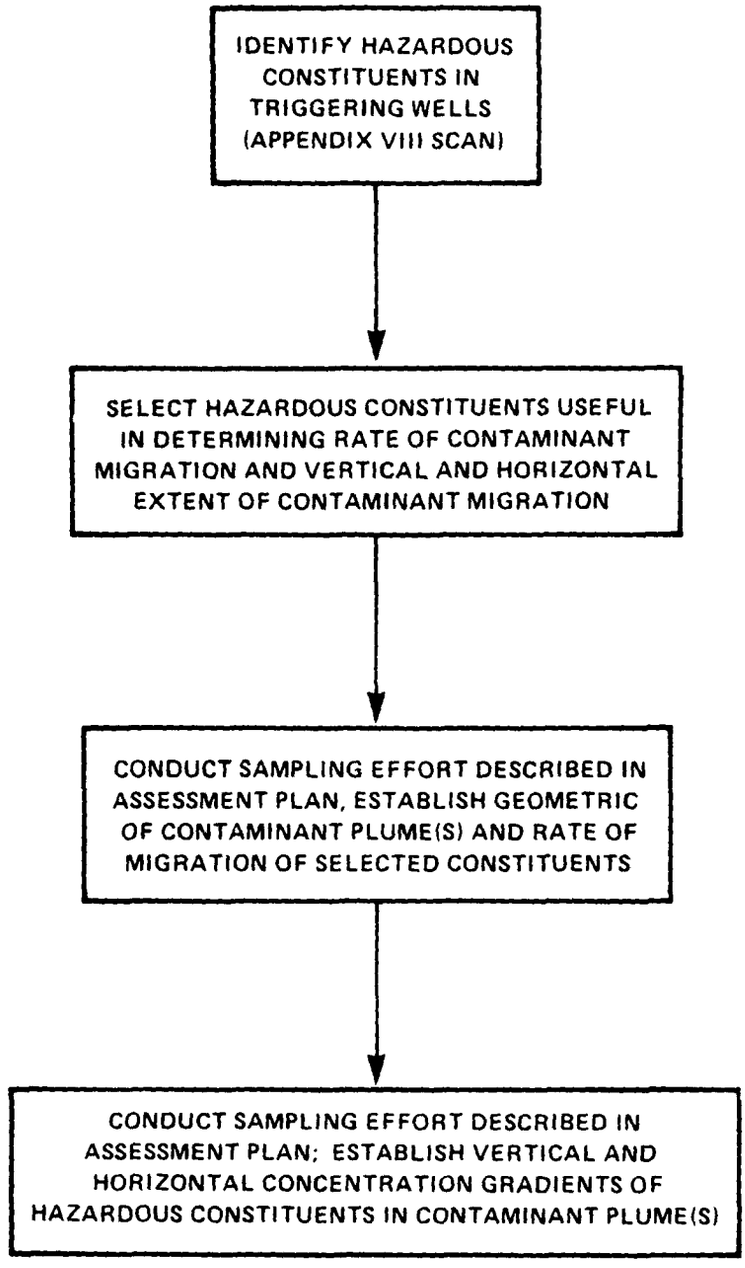


FIGURE 6-4. SELECTION OF PLUME CHARACTERIZATION PARAMETERS FOR UNITS SUBJECT TO PART 265 AND PART 270

of samples from triggering detection monitoring wells. This scan will provide the owner/operator with a list of hazardous constituents in the wells which may be migrating into the uppermost aquifer. The owner/operator should select constituents for inclusion in a sampling program to establish geometric dimensions of the contaminant plume(s) and the rate of migration of the plume(s). Once the owner/operator has established the geometric dimensions of the contaminant plume(s), he should sample for additional Appendix VIII constituents to establish vertical and horizontal concentration gradients in the plume(s).

6.8 Procedures for Evaluating Assessment Monitoring Data

The assessment plan must stipulate and document procedures for the evaluation of assessment monitoring data. These procedures vary in a site-specific manner but must all result in determinations of the rate of migration, extent, and hazardous constituent composition of the contaminant plume. In some cases, where the release is obvious and/or chemically simple, it may be possible to characterize it readily from a descriptive presentation of concentrations found in monitoring wells and geophysical characterization. In other cases, where contamination is less obvious or the release is chemically complex, the owner/operator should employ a statistical inference approach. Owner/operators should plan initially to take a descriptive approach to data analysis in order to broadly delineate the extent of contamination. Statistical comparisons of assessment monitoring data between wells and/or over time may subsequently be necessary should the descriptive approach provide no clear resolution of the rate of migration, extent, and hazardous constituent composition of the release.

The objective of assessment monitoring is to estimate the rate and extent of migration and the concentration of constituents in the plume. Data are therefore collected from a set of assessment monitoring wells that will allow characterization of the dimensions and concentrations of

ground-water constituents (GWCCs) in the plume. In addition, compared to detection monitoring, the number of chemical species that are analyzed in assessment increases. Because the amount of data collected in assessment is more voluminous than detection monitoring, the methods used to analyze assessment monitoring data emphasize organization, data reduction, simplification, and summary.

Assessment monitoring will include the measurement of many more GWCC in a more extensive well network than detection monitoring. These requirements necessitate the collection of large amounts of data during the assessment monitoring program. Consequently, it is extremely important for the enforcement officer to make sure that the owner/ operators specify in their assessment plans the data evaluation procedures required by 265.93(d)(3)(iii).

Specific evaluation and reporting procedures are presented below which the owner/operator should follow when recording and evaluating assessment monitoring data. These procedures are used to structure, analyze, simplify and present the ground-water monitoring data to help the enforcement officer evaluate the extent and concentration of ground-water contaminants. There are four evaluations or reporting procedures that should be described in the assessment plan and that should be used to record data in the on-site archives required by 265.94(b):

- Listing of Data
- Summary Statistics Tables
- Data Simplification
- Plotting of Data

6.8.1 Listing of the Data

A list of all the detection monitoring data and the assessment monitoring data that have been collected should be available to

enforcement officers when they review on-site records. First, data as originally reported and verified by the analytical laboratory for those measures requiring laboratory evaluation or as recorded in the field for those measures collected at the time of sampling should be available to the enforcement officer. These reporting forms should include information which indicates that quality control samples (e.g., field and filter blanks) were obtained in the field. Also the laboratory reporting should indicate that both the field quality control samples were analyzed and that the laboratory has performed and reported standard quality control procedures performed in the laboratory (e.g., recovery analyses, analytical replicates etc.).

The listing of GWCC concentration data should follow a format similar to Table 6-1. The variables which should be included in the listing are codes that identify the GWCC, well, date, unit of measure, whether the value was LT a limit of detection and the concentration of the GWCC. Also the listing should include the results of and codes identifying the quality control analyses that were performed. GWCC concentrations measured as LT a limit of detection should be indicated and if possible the GWCC concentration that was measured should be reported with the LT designation. Otherwise, the value that accompanies the LT designation should be the accepted detection limit for the method that was used. Documentation that describes the meaning of the codes used in the listing is required to eliminate ambiguity (e.g. Pb=lead, ppm=parts per million). The listing of GWCC data must include all measurements from all wells since the facility began sampling, including samples obtained during detection monitoring.

The listing should be organized to allow quick reference to specific data values. One categorization would be to first group by GWCC, then well code, and finally the date, as shown in Table 6-1. For example, all lead measurements should be together, followed by all chromium measurements, etc. The values for each GWCC from one well should be grouped and

TABLE 6-1
AN EXAMPLE OF HOW ASSESSMENT MONITORING DATA SHOULD BE LISTED

GWCC	WELL	REPLICATE	ALIQUOT	DATE	LT DETECTION	CONCENTRATION	UNITS
LEAD (UG/L)	7A	1	A	12JAN85		29.82	PPB
LEAD (UG/L)	7A	1	A	17FEB85		28.43	PPB
LEAD (UG/L)	7A	1	B	17FEB85		28.29	PPB
LEAD (UG/L)	7A	2	A	17FEB85		28.17	PPB
LEAD (UG/L)	7A	2	B	17FEB85		28.30	PPB
LEAD (UG/L)	9A	1	A	26APR84	<	10.00	PPB
LEAD (UG/L)	9A	1	B	26APR84	<	10.00	PPB
LEAD (UG/L)	9A	2	A	26APR84		20.60	PPB
LEAD (UG/L)	9A	1	A	05MAY84		21.20	PPB
LEAD (UG/L)	9A	2	A	05MAY84		21.80	PPB
LEAD (UG/L)	9B	1	A	26APR84		67.20	PPB
LEAD (UG/L)	9B	1	B	26APR84		67.80	PPB
LEAD (UG/L)	9B	2	A	26APR84		64.10	PPB
LEAD (UG/L)	9B	1	A	05MAY84		38.90	PPB
LEAD (UG/L)	9B	2	A	05MAY84		39.60	PPB
LEAD (UG/L)	9B	1	A	15JUN84		57.22	PPB
LEAD (UG/L)	9B	1	A	15JUL84		20.12	PPB
TRICHLOROETHYLENE (UG/L)	1A	1	A	26APR84	<	10.00	PPB
TRICHLOROETHYLENE (UG/L)	1A	1	A	05MAY84	<	10.00	PPB
TRICHLOROETHYLENE (UG/L)	1A	1	A	15JUN84	<	10.00	PPB
TRICHLOROETHYLENE (UG/L)	1A	1	A	15JUL84		11.10	PPB
TRICHLOROETHYLENE (UG/L)	1A	1	A	15AUG84	<	10.00	PPB
TRICHLOROETHYLENE (UG/L)	1A	1	A	15SEP84		10.10	PPB
TRICHLOROETHYLENE (UG/L)	1A	1	A	16OCT84		10.70	PPB
TRICHLOROETHYLENE (UG/L)	1A	1	A	18NOV84		10.00	PPB
TRICHLOROETHYLENE (UG/L)	1A	1	A	20DEC84	<	10.00	PPB
TRICHLOROETHYLENE (UG/L)	1A	1	A	12JAN85	<	10.00	PPB
TRICHLOROETHYLENE (UG/L)	1A	1	A	17FEB85	<	10.00	PPB
TRICHLOROETHYLENE (UG/L)	10A	1	A	26APR84		17.00	PPB
TRICHLOROETHYLENE (UG/L)	10A	1	B	26APR84		17.30	PPB
TRICHLOROETHYLENE (UG/L)	10A	2	A	26APR84		17.60	PPB
TRICHLOROETHYLENE (UG/L)	10A	1	A	05MAY84		21.00	PPB
TRICHLOROETHYLENE (UG/L)	10A	2	A	05MAY84		21.40	PPB
TRICHLOROETHYLENE (UG/L)	10A	1	A	15JUN84		21.20	PPB
TRICHLOROETHYLENE (UG/L)	10A	1	A	15AUG84		22.90	PPB
TRICHLOROETHYLENE (UG/L)	10A	1	A	15SEP84		19.40	PPB
TRICHLOROETHYLENE (UG/L)	10A	1	A	16OCT84		19.60	PPB
TRICHLOROETHYLENE (UG/L)	10A	1	A	18NOV84		30.10	PPB
TRICHLOROETHYLENE (UG/L)	10A	1	A	20DEC84		31.60	PPB
TRICHLOROETHYLENE (UG/L)	10A	1	A	12JAN85		33.60	PPB
TRICHLOROETHYLENE (UG/L)	10A	1	A	17FEB85		27.80	PPB
TRICHLOROETHYLENE (UG/L)	10A	1	B	17FEB85		27.80	PPB
TRICHLOROETHYLENE (UG/L)	10A	2	A	17FEB85		26.40	PPB
TRICHLOROETHYLENE (UG/L)	10A	2	B	17FEB85		26.50	PPB
TRICHLOROETHYLENE (UG/L)	10B	1	A	26APR84		65.10	PPB
TRICHLOROETHYLENE (UG/L)	10B	1	B	26APR84		65.80	PPB
TRICHLOROETHYLENE (UG/L)	10B	2	A	26APR84		65.40	PPB
TRICHLOROETHYLENE (UG/L)	10B	1	A	05MAY84		84.00	PPB
TRICHLOROETHYLENE (UG/L)	10B	2	A	05MAY84		83.70	PPB
TRICHLORDETHYLENE (UG/L)	10B	1	A	15JUN84		69.00	PPB
TRICHLOROETHYLENE (UG/L)	10B	1	A	15JUL84		68.40	PPB
TRICHLOROETHYLENE (UG/L)	10B	1	A	15AUG84		93.40	PPB
TRICHLOROETHYLENE (UG/L)	10B	1	A	15SEP84		98.90	PPB
TRICHLOROETHYLENE (UG/L)	10B	1	A	16OCT84		88.50	PPB

ordered by date followed by the data from the next well and so on for all wells in the ground-water monitoring system. Alternate sortings of the data listing may also be useful to the enforcement officer.

The data listing is not intended to function alone as an analytic tool but the enforcement officer can use the data listing to assist in the review of the GWCC data. First, the ordered list of data will allow the enforcement officer quick reference to every GWCC concentration measurement if, for example, a spurious result was found in a supporting data analysis or report. Also, the enforcement officer can, by requiring a consistent and orderly data listing, encourage the owner/operator to correct many of the data quality problems, which occur frequently on "raw" laboratory reporting sheets. Finally, data can be placed more easily onto a State or regional computer if the data are organized and reported consistently in a listing rather than on laboratory reporting sheets which may have only the sample number identification rather than well codes, dates of sampling, etc.

6.8.2 Summary Statistics Tables

The ground-water monitoring data should be summarized and presented in tabular formats. Eight summary statistics should be calculated and used in each of four summary tables. The eight summary statistics are:

- Number of LT detection limit values
- Total number of values
- Mean
- Median
- Standard deviation
- Coefficient of variation
- Minimum value
- Maximum value

The methodology used to estimate these summary statistics can be found in many statistical textbooks.

The four tables of summary statistics should include summaries by:

- GWCC summary (e.g., Table 6-2)
- GWCC summary by well (e.g., Table 6-3)
- GWCC summary by well and date (e.g., Table 6-4)
- quality control data

The tables should be formatted so that there are from one to three columns on the left side of each table which provide data identifying, where applicable, the GWCC, well, and date. Eight columns, one for each summary statistic, should be to the right of the identifying columns. There will be one row for each category that is being summarized. A summary statistics table by GWCC, for example, will have a number of rows equal to the number of GWCC that have been sampled. The GWCC-well table will have a number of rows which equals the number of GWCCs measured times the number of wells in the monitoring system (provided that each GWCC was measured at least once in each well). The GWCC-well-date table will be the largest table and each row should be prefixed with a GWCC, well, and date code. The statistics in the GWCC-well-date table should summarize all replicate sampling that was performed for each GWCC, from each well, during each sampling.

The sample sizes, ranges, minimum, and maximum values will provide a rapid means for checking whether errors appear in the data. It will also facilitate rapid evaluation of GWCC concentrations over the entire ground-water monitoring system. In addition, the summary statistics will allow evaluation of spatial change in GWCC concentrations which include identifying the rate and extent of migration of the GWCC plume.

The quality control data should be provided whenever assessment monitoring data are submitted by an owner/operator. The quality control data can be submitted in the format they are received from the laboratory provided that all data are clearly documented. The quality control samples taken in the field (e.g., field and sampling equipment blanks)

TABLE 6-2

AN EXAMPLE OF HOW DATA SHOULD BE SUMMARIZED BY GWCC

GWCC	SAMPLE SIZE	NUMBER OF LT DETECTION LIMIT VALUES	MEAN	MEDIAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	MINIMUM	MAXIMUM
CHROMIUM (UG/L)	129	14	50.83	32.10	59.43	117	5.00	345.21
METHYLENE CHLORIDE (UG/L)	137	37	21.45	14.30	23.17	108	5.00	112.70
LEAD (UG/L)	129	15	50.31	20.43	168.22	334	1.00	1879.23
TRICHLOROETHYLENE (UG/L)	139	32	31.21	20.40	27.68	88.7	5.00	98.90

TABLE 6-3
AN EXAMPLE OF HOW DATA SHOULD BE SUMMARIZED BY GWCC/WELL COMBINATION

GWCC	WELL	SAMPLE SIZE	NUMBER OF LT DETECTION LIMIT VALUES	MEAN	MEDIAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	MINIMUM	MAXIMUM
CHROMIUM (UG/L)	1A	9	3	8.74	10.20	2.83	32.3	5.00	11.24
CHROMIUM (UG/L)	10A	16	0	63.57	49.00	38.99	61.3	30.90	140.00
CHROMIUM (UG/L)	10B	17	0	89.15	48.92	93.16	105	10.10	324.00
CHROMIUM (UG/L)	11A	2	0	13.51	13.51	1.70	12.6	12.31	14.72
CHROMIUM (UG/L)	12A	11	0	135.74	109.32	100.49	74.0	16.23	345.21
CHROMIUM (UG/L)	13A	11	0	27.36	28.09	3.83	14.0	20.86	32.53
CHROMIUM (UG/L)	14A	10	0	45.22	48.06	7.08	15.7	32.63	57.03
CHROMIUM (UG/L)	15A	9	0	27.76	29.69	5.13	18.5	18.62	32.01
CHROMIUM (UG/L)	16A	9	0	54.82	79.47	36.21	66.1	11.89	87.31
CHROMIUM (UG/L)	17A	3	1	10.51	12.31	4.87	46.3	5.00	14.23
CHROMIUM (UG/L)	3A	9	7	6.29	5.00	2.58	41.1	5.00	11.51
CHROMIUM (UG/L)	7A	11	0	59.64	58.71	12.48	20.9	46.91	85.01
CHROMIUM (UG/L)	9A	5	0	21.12	15.00	9.41	44.5	13.80	32.10
CHROMIUM (UG/L)	9B	7	3	11.40	11.10	7.05	61.9	5.00	21.60
METHYLENE CHLORIDE (UG/L)	1A	11	7	7.40	5.00	3.76	50.9	5.00	16.40
METHYLENE CHLORIDE (UG/L)	10A	16	0	13.66	12.95	2.26	16.6	11.00	16.90
METHYLENE CHLORIDE (UG/L)	10B	17	0	22.91	21.50	4.20	18.3	19.70	34.20
METHYLENE CHLORIDE (UG/L)	11A	2	2	5.00	5.00	0.00	0.0	5.00	5.00
METHYLENE CHLORIDE (UG/L)	12A	11	0	39.28	23.60	30.97	78.8	14.30	98.40
METHYLENE CHLORIDE (UG/L)	13A	11	0	20.73	18.90	7.36	35.5	11.00	28.60
METHYLENE CHLORIDE (UG/L)	14A	10	0	86.21	76.95	18.25	21.2	70.10	112.70
METHYLENE CHLORIDE (UG/L)	15A	9	1	11.27	11.90	2.44	21.7	5.00	12.90
METHYLENE CHLORIDE (UG/L)	16A	9	0	30.40	28.70	7.75	25.5	16.70	40.10
METHYLENE CHLORIDE (UG/L)	17A	3	3	5.00	5.00	0.00	0.0	5.00	5.00
METHYLENE CHLORIDE (UG/L)	2A	2	2	5.00	5.00	0.00	0.0	5.00	5.00
METHYLENE CHLORIDE (UG/L)	3A	11	10	5.60	5.00	1.99	35.5	5.00	11.60

TABLE 6-4

AN EXAMPLE OF HOW DATA SHOULD BE SUMMARIZED BY GWCC/WELL/DATE COMBINATION

GWCC	WELL	DATE	TOTAL NUMBER OF VALUES	NUMBER OF LT DETECTION LIMIT VALUES	MEAN	MEDIAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	MINIMUM	MAXIMUM
CHROMIUM (UG/L)	3A	17FEB85	1	1	5.00	5.00	.	.	5.00	5.00
CHROMIUM (UG/L)	7A	15JUL84	1	0	85.01	85.01	.	.	85.01	85.01
CHROMIUM (UG/L)	7A	15AUG84	1	0	73.52	73.52	.	.	73.52	73.52
CHROMIUM (UG/L)	7A	15SEP84	1	0	67.50	67.50	.	.	67.50	67.50
CHROMIUM (UG/L)	7A	16OCT84	1	0	64.38	64.38	.	.	64.38	64.38
CHROMIUM (UG/L)	7A	16NOV84	1	0	60.01	60.01	.	.	60.01	60.01
CHROMIUM (UG/L)	7A	20DEC84	1	0	58.71	58.71	.	.	58.71	58.71
CHROMIUM (UG/L)	7A	12JAN85	1	0	58.70	58.70	.	.	58.70	58.70
CHROMIUM (UG/L)	7A	17FEB85	4	0	47.05	46.95	0.22	0.5	46.91	47.38
CHROMIUM (UG/L)	9A	26APR84	3	0	14.27	14.00	0.64	4.5	13.80	15.00
CHROMIUM (UG/L)	9A	05MAY84	2	0	31.40	31.40	0.99	3.2	30.70	32.10
CHROMIUM (UG/L)	9B	26APR84	3	1	9.47	11.10	3.91	41.4	5.00	12.30
CHROMIUM (UG/L)	9B	05MAY84	2	0	20.70	20.70	1.27	6.1	19.80	21.60
CHROMIUM (UG/L)	9B	15JUN84	1	1	5.00	5.00	.	.	5.00	5.00
CHROMIUM (UG/L)	9B	15JUL84	1	1	5.00	5.00	.	.	5.00	5.00
METHYLENE CHLORIDE (UG/L)	1A	26APR84	1	1	5.00	5.00	.	.	5.00	5.00
METHYLENE CHLORIDE (UG/L)	1A	05MAY84	1	1	5.00	5.00	.	.	5.00	5.00
METHYLENE CHLORIDE (UG/L)	1A	15JUN84	1	0	10.00	10.00	.	.	10.00	10.00
METHYLENE CHLORIDE (UG/L)	1A	15JUL84	1	0	10.00	10.00	.	.	10.00	10.00
METHYLENE CHLORIDE (UG/L)	1A	15AUG84	1	1	5.00	5.00	.	.	5.00	5.00
METHYLENE CHLORIDE (UG/L)	1A	15SEP84	1	1	5.00	5.00	.	.	5.00	5.00
METHYLENE CHLORIDE (UG/L)	1A	16OCT84	1	0	16.40	16.40	.	.	16.40	16.40
METHYLENE CHLORIDE (UG/L)	1A	18NOV84	1	1	5.00	5.00	.	.	5.00	5.00
METHYLENE CHLORIDE (UG/L)	1A	20DEC84	1	0	10.00	10.00	.	.	10.00	10.00
METHYLENE CHLORIDE (UG/L)	1A	12JAN85	1	1	5.00	5.00	.	.	5.00	5.00
METHYLENE CHLORIDE (UG/L)	1A	17FEB85	1	1	5.00	5.00	.	.	5.00	5.00

may not be identified when the samples are supplied to the laboratory, but should be identified in assessment monitoring data submissions. Owner/operators should ensure that the laboratories provide the quality control data that accompanies the data resulting from the analysis of field samples.

6.8.3 Data Simplification

Ranking procedures which are described in this section are useful for simplifying and interpreting spatial trends in GWCC concentrations by allowing rapid determination of which wells have the overall highest and lowest GWCC concentration. Table 6-5 presents an example of a data set analyzed by a ranking procedure.

The ranking can be performed using the mean, median, maximum, or minimum concentration values in the summary statistics table which describes the values from each GWCC-well combination. For example, the mean concentration from each well is ranked from lowest to highest for each GWCC. The well with the lowest mean concentration of a GWCC will receive a value of 1; the well with the next highest concentration of the same GWCC will receive a value of 2, and so on. If two or more wells have the identical mean concentration then the ranks for these wells will be averaged and applied to all wells with the same mean concentration. This procedure should be repeated for each GWCC which was detected at least once at every well in the monitoring system. The pH values may be ranked from highest to lowest rather than from lowest to highest depending on whether the ground-water contamination is likely to result in an increase or decrease in pH. It is also useful to calculate an overall average rank for each well by averaging the ranks for each GWCC associated with the well. These ranks should be presented in a table using GWCCs as column headings and well codes as row headings. It is advisable to group GWCCs with similar chemistry (e.g., volatile organics, metals, salts, etc.) and order the rows based on the wells with spacial

TABLE 6-5

AN EXAMPLE OF HOW RANKS OF THE MEAN CONCENTRATIONS FOR EACH GWCC/WELL COMBINATION CAN BE USED TO SIMPLIFY AND PRESENT CONCENTRATION DATA COLLECTED FOR A VARIETY OF GWCCs IN A NUMBER OF MONITORING WELLS

WELL	RANK OF MEAN CHROMIUM CONCENTRATION	RANK OF MEAN LEAD CONCENTRATION	RANK OF MEAN TCE CONCENTRATION	RANK OF MEAN MC CONCENTRATION	AVERAGE WELL RANK ACROSS GWCC
17A	3	3	1	3	2.50
2A	3	3	.	.	3.00
4A	3	3	.	.	3.00
11A	5	3	4	3	3.75
3A	1	6	2	6	3.75
9A	6	3	5	3	4.25
1A	2	8	3	7	5.00
9B	4	7	12	8	7.75
15A	8	9	6	11	8.50
13A	7	12	10	9	9.50
10A	12	10	11	10	10.75
14A	9	16	7	12	11.00
7A	11	11	9	15	11.50
12A	14	15	8	14	12.75
16A	10	14	14	13	12.75
10B	13	13	13	16	13.75

proximity (e.g., upgradient, downgradient in plume, downgradient out of plume, shallow screen depth). This will facilitate identification of specific groups of wells where high concentrations of GWCC were detected.

6.8.4 Graphic Displays of Data

6.8.4.1 Plotting Data Over Time

Ground-water data should be plotted to allow evaluation of temporal changes in GWCC concentrations over time. Each plot should consist of a X or horizontal axis which represents time with year and month identified at intervals. The Y or vertical axis should represent the concentrations of GWCCs. The plots may be constructed using the mean values from the GWCC-well-date summary statistics table and one plot could be presented for each GWCC/well combination as in Figure 6-5. Alternately, it may be more insightful to plot the data from several wells or GWCCs on one graph provided the lines do not overlap excessively as in Figure 6-6.

Data plotting will allow the enforcement officer to evaluate changes in GWCC concentration over time that might be due to surface hydrological events, hydrogeology, or facility releases. In addition, insights regarding geochemical interactions may also be revealed by examining whether changes in some GWCCs result in expected changes in other GWCCs.

6.8.4.2 Plotting Data on Maps

It may also be useful to plot data on facility maps so that trends in GWCCs both vertically and horizontally can be evaluated. The summary statistics from the GWCC-well table can be used to provide data for plotting. A map of the facility, which identifies well locations, should be used to depict horizontal trends in concentrations. Geological cross sections and/or facility map may be usefulfor plotting vertical trends in GWCC concentrations. The mean concentrations can be placed near each well location similar to the construction of potentiometric maps described in earlier chapters. It may also be useful to plot isopleth contours of concentration on the maps.

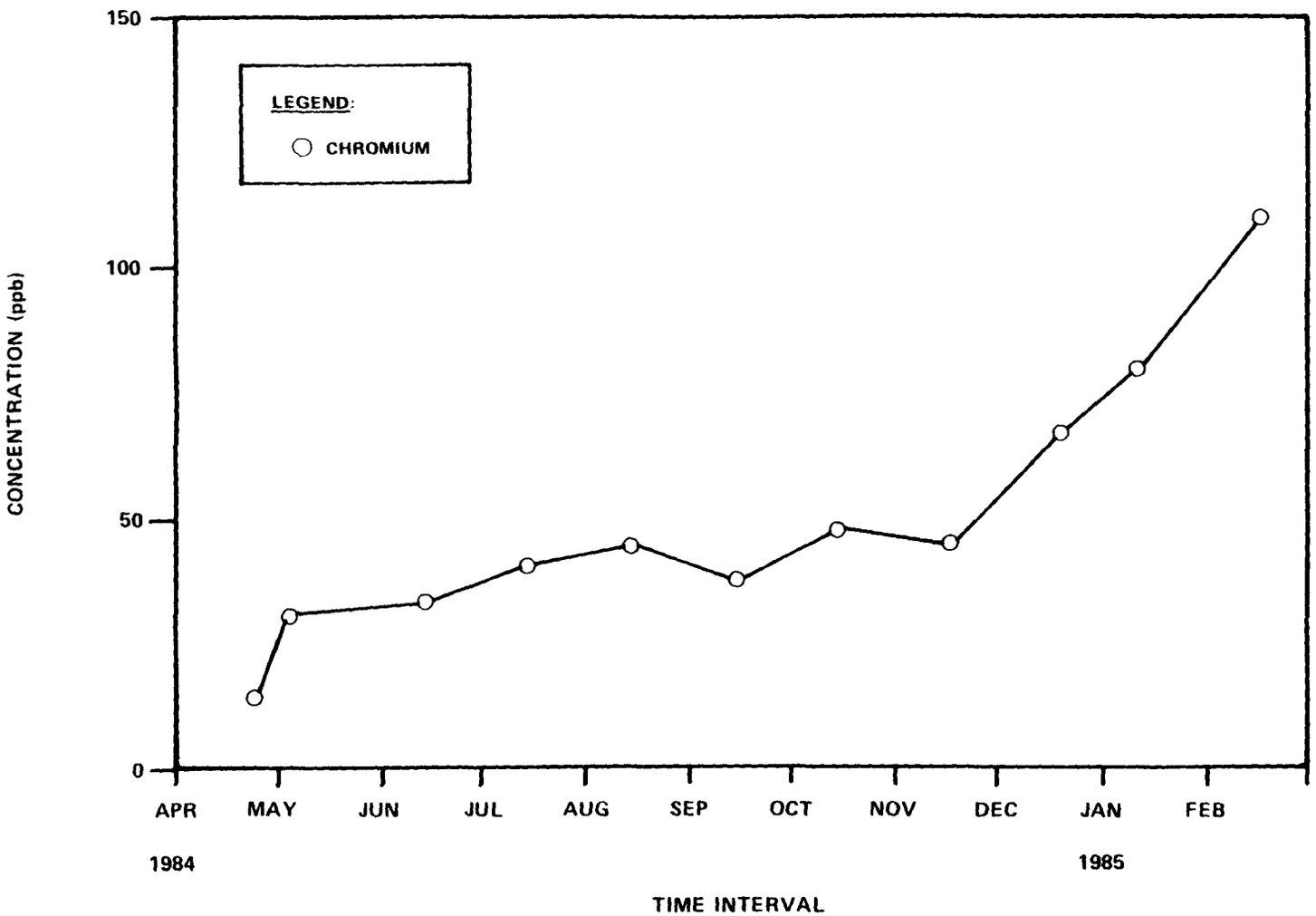


FIGURE 6-5. PLOT OF CHROMIUM CONCENTRATIONS OVER TIME (WELL 9A)

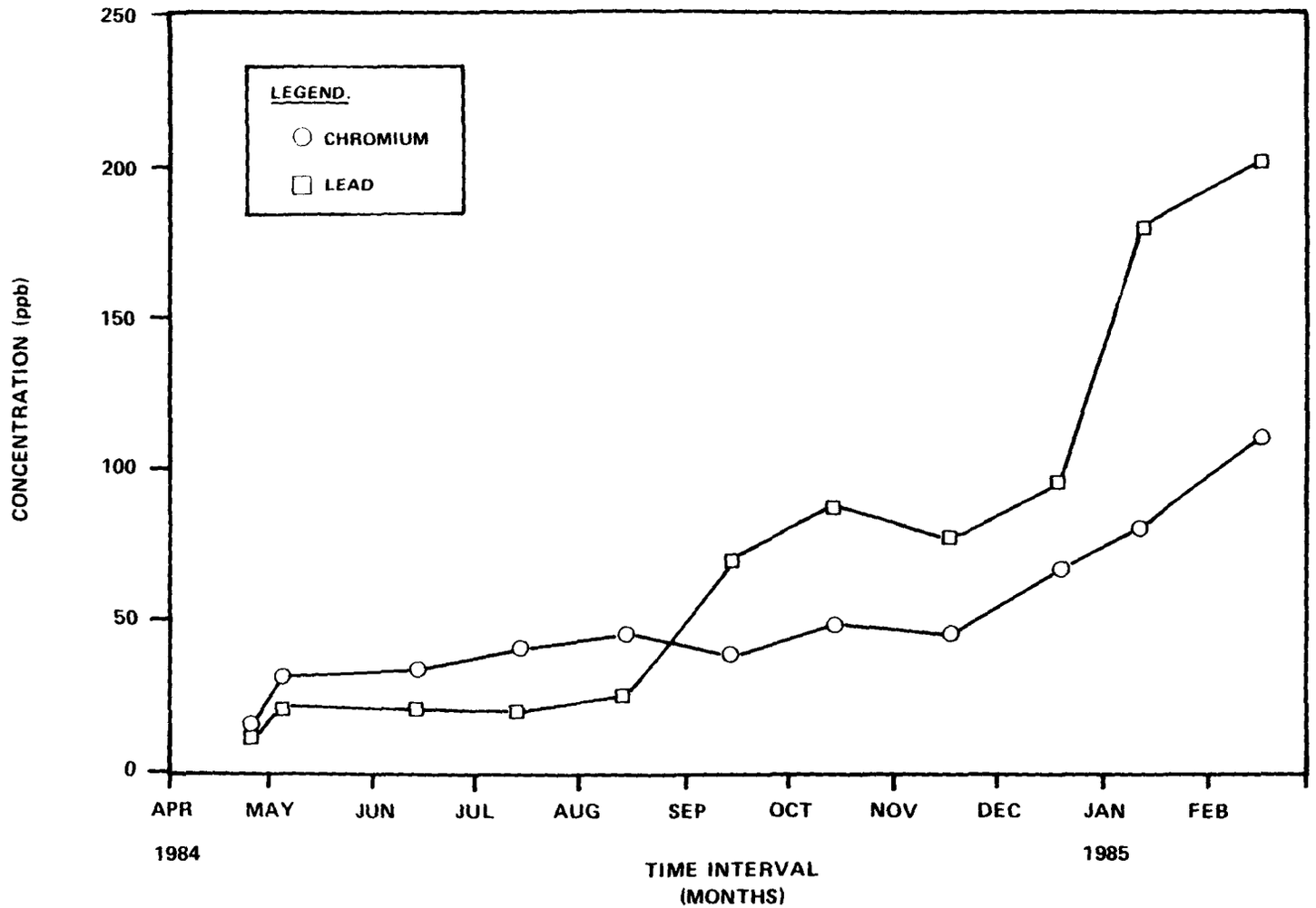


FIGURE 6-6. CHROMIUM AND LEAD CONCENTRATIONS OVER TIME (WELL 9A)

6.9 Rate of Migration

An assessment plan should specify the procedures the owner/operator will use to determine the rate of constituent migration in ground water. A rapid approach will generally be required for determining the rate of migration during interim status assessments. Migration rates can be determined by monitoring the concentration of GWCCs over a period of time in monitoring wells aligned in the direction of flow. If these wells are located both at the edge of the plume and in the interior of the plume, subsequent analysis of the monitoring data can then provide an accurate determination of the rate of migration both of the contaminant front as a whole and of individual constituents within the plume. This approach does not necessarily provide a reliable determination of the migration rates that will occur as the contaminant plume continues to move away from the facility in light of potential changes in geohydrologic conditions. More importantly, this approach requires the collection of a time series of data of sufficient duration and frequency to gauge the movement of contaminants. Such a delay is normally inappropriate during initial assessment of ground-water contamination since a relatively quick determination or at least an estimate of migration rates is required to deduce the impact of ground-water contamination and to formulate an appropriate reaction. Estimates of migration rates can be obtained from aquifer properties obtained during the site investigation, and knowledge of the physico-chemical properties of contaminants known to be present. By recognizing the various factors which can effect transport processes of the GWCCs, the owner/operator can obtain approximate potential migration rates during an initial assessment phase. Continued monitoring of the plume to verify rates of migration during assessment monitoring established at a facility should serve as a basis for identifying additional monitoring well locations.

Initial approximations of contaminant migration rates based on ground-water flow rates are not reliable without verification because of

potential differential transport rates among various classes of chemical constituents. Differential transport rates are caused by several factors including:

- Dispersion due to diffusion and mechanical mixing
- Retardation due to adsorption and electrostatic interactions
- Transformation due to physical, chemical, and/or biological processes

Dispersion results in the overall dilution of the contaminant; however, chromatographic separation of the contaminant constituents and differential dispersal effects can result in a contaminant arriving at a particular location before the arrival time computed solely on average ground-water flow rates. Alternately, retardation processes can delay the arrival of contaminants beyond that calculated by the average ground-water flow rates. Local geology will also affect constituent migration rates. Relating constituent migration rates to ground-water flow rates is appropriate for a quick approximation during the initial assessment phase, but this should be followed by a more comprehensive study of migration rates.

Simple slug tests are not the preferred method for determining the rate of contaminant migration. The slug test is limited to the immediate vicinity where it is performed and its results often cannot be projected across an entire site.

At those facilities where sufficient immiscible contaminants have leaked to form and migrate as a separate immiscible phase (see Figure 6-7), additional analysis will be necessary to evaluate the migration of these contaminants away from the facility. Chapter Five contains a discussion of the ground-water monitoring techniques that can be used to sample multi-phased contamination. The formation of separate phases of immiscible contaminants in the subsurface is largely controlled

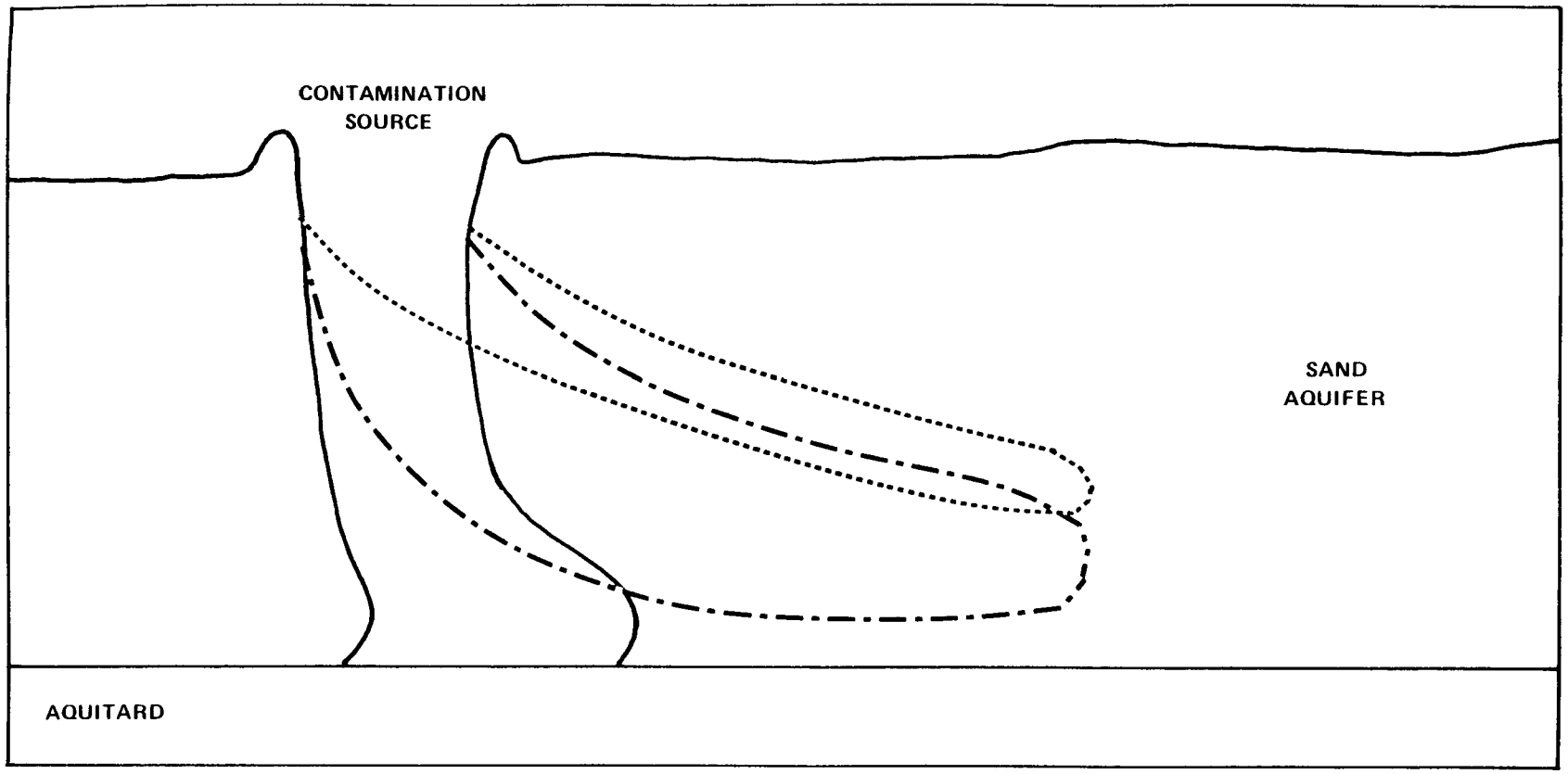


FIGURE 6-7. GENERAL SCHEMATIC OF MULTIPHASE CONTAMINATION IN A SAND AQUIFER

by the rate of infiltration of the immiscible contaminant and the solubility of that contaminant in ground water. Immiscible contaminants generally have some limited solubility in water. Thus, some amount of immiscible contaminant leaking from the facility will enter into solution in groundwater and migrate away from the facility as dissolved constituents. However, if the amount of immiscible reaching ground water exceeds the ability of ground water to dissolve it, the ground water in the upper portion of the water-table aquifer will become saturated and the contaminant will form a separate immiscible phase.

At this point the behavior and migration of the contaminants present in the immiscible phase will be strongly influenced by its density relative to ground water. If the immiscibles are less dense than ground water, the immiscibles will tend to coalesce on the surface of the water table and form and migrate as a separate immiscible layer floating on ground water. If the density of the immiscible contaminants is similar to that of ground water, the immiscible will tend to mix and flow as a separate phase with the ground water, creating a condition of multiphase flow.

If the density of the immiscibles is greater than ground water, the immiscibles will tend to sink in the aquifer (see Figure 6-7). As the immiscibles sink and reach unaffected ground water in a deeper portion of the aquifer, more of the immiscible contaminant will tend to enter into solution in ground water and begin to migrate as dissolved constituents. However, if enough of the dense immiscible contaminants are present, some portion of these contaminants will continue to sink as a separate immiscible phase until a formation of reduced permeability is reached. At this point, these contaminants will tend to coalesce and migrate as a layer of dense immiscibles resting on the geologic barrier.

In each of these cases, the contaminants present in the separate immiscible phase may migrate away from the facility at rates different

than that of ground water. In many cases, they will migrate at rates slower than or equivalent to ground water, but in some cases migration rates can be greater. In addition, migration of the immiscibles may not be in the direction of ground-water flow. However, it is important to reemphasize that some amount of these contaminants will invariably dissolve in ground water and migrate away from the facility as dissolved constituents.

Light immiscible contaminants will migrate downgradient to form a floating layer above the saturated zone (see Figure 6-7). The slope of the water table and the direction of ground-water flow will dictate the movement of this light immiscible layer. Important factors involved in its migration rate include the intrinsic permeability of the medium and the density and viscosity of the contaminants. With time, an ellipsoidal plume develops overlying the saturated zone as depicted in Figure 6-7. While it is possible to analyze the behavior of the light immiscible layer using analytical or numerical models, the most practical approach for determining the rate and direction of migration of such a light immiscible layer during an assessment may be to observe its behavior over time with appropriately located monitoring wells.

The migration of a layer of dense immiscibles resting on a confining layer may be strongly influenced by gravity. Depending on the slope of the confining layer, the immiscible layer may move with or against the flow of ground water. Consequently, the evaluation of the rate and direction of migration of a dense immiscible layer is best determined by clearly identifying the configuration of the barrier on which the layer is migrating. The direction of migration and estimates of migration rates can then be obtained by including the gravitational forces induced by the slope of the confining layer in the gradients used to calculate flow rates. A program of continued monitoring of the dense immiscible layer should always be included in the assessment plan to verify direction and rate of flow.

6.10 Reviewing Schedule Of Implementation

The assessment plan should specify a schedule of implementation. When reviewing schedules the particulars of each assessment program will have to be considered, including the amount of work involved in the assessment and other local factors such as weather and availability of equipment and personnel. The schedule should include a sufficient number of milestones so that the Agency can judge whether sufficient progress is being made toward the completion of the assessment during its implementation. Any continued monitoring undertaken during the maintenance phase of assessment should be scheduled at least on a quarterly basis.

Activities planned to initially determine if contamination has actually occurred should not unnecessarily delay the implementation of a comprehensive assessment. When an extensive program to collect additional data to remedy inadequacies in currently available data is to be undertaken these activities should require only a short period for completion. Additional analysis of water quality data should require no more than fifteen days to thirty days. Sampling to determine actual concentrations of HWC's should require only time enough for sample collection and analysis followed by a brief period for subsequent analysis of the data.

A thorough discussion of monitoring well placement, and monitoring well design and construction can be found in Chapters Two and Three, respectively. A discussion of the ground-water monitoring techniques necessary to effectively characterize a multi-phase containment migration is also given in Chapter Four of this document.

GLOSSARY

GLOSSARY

Annular Space - The open space formed between the borehole and the well casing.

Anticline - A fold, usually from 100 meters to 300 kilometers in width, that is convex upward with the oldest strata at the center.

Appendix VIII Constituents - A list of 297 toxic constituents (§Part 261) which if present in a waste may make the waste hazardous if the waste poses a substantial hazard to human health or the environment when improperly treated, stored, transported or disposed.

Aquiclude - A geologic formation which may contain ground water but is incapable of transmitting significant quantitites under normal hydraulic gradients.

Aquitard - A geologic formation of low permeability which can store or transmit ground water in significant quantities but typically at a very slow rate.

Assessment Monitoring - A program of monitoring under interim status after a release to ground water has been determined wherein the rate of migration extent and hazardous constituent concentration gradients of the contamination must be identified.

Assessment Plan - The written detailed plan drawn up by an owner/operator which describes and explains the procedures the owner/operator intends to take to perform assessment monitoring.

Background Concentrations - A schedule of sampling and analysis that is completed during the first year of monitoring. All wells in the monitoring system must be sampled on a quarterly basis for the drinking water suitability, ground-water quality, and contamination indicator parameters. For each upgradient well, at least four replicate measurements must be made for the contamination indicator parameters. These replicate measurements must be posted and the initial background arithmetric mean and variance calculated.

Basement - The oldest rocks recognized in a given area, a complex of metamorphic and igneous rocks that underlies all the sedimentary formations.

Bentonite - A sedimentary rock largely comprised of clay minerals that have a great ability to absorb water and swell in volume.

Borehole Geophysics (Geophysical Borehole Logging) - A general term that encompasses all techniques in which a sensing device is lowered into a borehole for the purpose of characterizing the associated geologic formations and their fluids. The results can be interpreted to determine lithology, geometry resistivity, bulk density, porosity, permeability, and moisture content and to define the source, movement, and physical/ chemical characteristics of ground water.

Coefficient of Variation - The standard deviation divided by the mean of a set of data. (Note: the coefficient of variation can be expressed as a percentage by multiplying the number obtained by 100).

Confined Aquifer - An aquifer under greater than atmospheric pressure bounded above and below by impermeable layer or layers of distinctly lower permeability (aquitard) than the aquifer itself.

Confining Layer - A geologic stratum formation exhibiting low permeability having little or no intrinsic permeability.

Core - A continuous columnar sample of the lithologic units extracted from a borehole. Such a sample preserves stratigraphic contacts and structural features.

Direct Methods for Hydrogeological Investigations - Methods (e.g, boreholes and monitoring wells) which entail the excavation or drilling, collection, observation, and analysis of geologic materials and water samples.

Dispersivity - Ability of a contaminant to disperse within the ground water due to molecular diffusion and mechanical mixing.

Disposal Facility - A facility or part of a facility complex at which hazardous waste is intentionally placed into or on any land or water, and at which waste will remain after closure of the facility.

Downgradient - Direction of decreasing hydrostatic pressure.

Downgradient Well - A well which has been installed hydraulically downgradient of the site, and is capable of detecting the migration of contaminants from a regulated facility. Regulations require the installation of three or more downgradient wells depending upon the site-specific hydrogeological conditions and potential zones of contaminant migration.

Drilling Mud - Fluids which are used during the drilling of a borehole or well to wash soil uttings away from the drill bit and adjust the specific gravity of the liquid in the borehole so that the sides of the hole do not cave in prior to installation of a casing.

Electrical Resistivity (ER) - A surficial geophysical method whereby known current is applied to spaced electrodes in the ground and the resulting electrical resistance used to detect changes in earth materials between and below the electrodes. ER is particularly useful for facilities receiving electrically conductive wastes (e.g., inorganic) at sites characterized by settings having minimal quantities of high resistance materials.

Electromagnetic Conductivity (EM) - A surficial geophysical method whereby induced currents are produced and measured in conductive formations from electromagnetic waves generated at the surface. EM is used to define shallow ground water zones characterized by high dissolved solids content.

Floaters - Light phase organic liquids in ground water capable of forming an immiscible layer which can float on the water table.

Flow Net - A set of intersecting equipotential lines and flow lines representing a two-dimensional steady flow through porous media.

Fluvio-Glacial Depositional Environment - A complex melange of glacially borne and riverine sediments deposited at the head of a melting glacier. The sediments range in grain size from clays to boulders, and in places are typically unsorted.

Geophysical Borehole Logging - See Borehole Geophysics.

Ground Penetrating Radar (GPR) - A geophysical method used to identify surface formations which will reflect electromagnetic radiation. GPR is useful for defining the boundaries of buried trenches and other subsurface installations on the basis of time-domain reflectrometry.

Ground-Water Detection Monitoring Program - A monitoring well system capable of yielding groundwater samples for analysis. Upgradient wells must be installed to obtain representative background ground-water quality in the uppermost aquifer and be unaffected by the facility. Downgradient wells must be placed immediately adjacent to the hazardous waste management area(s) to detect hazardous waste or hazardous waste constituents migrating from the facility.

Hazardous Waste Constituent - A constituent listed as hazardous by EPA based upon the criteria cited in Part 261, Subpart D, or a constituent listed in Table 1 of §261.24.

Hazardous Waste Management - The systematic control of the collection, source separation, storage, transportation, processing, treatment, recovery, and disposal of hazardous waste.

Hazardous Waste Management Area - The area within a facility's property boundary which encompasses one or more hazardous waste management units or cells. Detection monitoring wells should be placed on the immediate perimeter of this area and spaced based upon the site-specific hydrogeological characteristics.

Hydraulic Conductivity - A coefficient of proportionality which describes the rate at which a fluid can move through a permeable medium. It is a function of the media and of the fluid flowing through it.

Indicator Parameters - pH, specific conductance, total organic carbon (TOC), total organic halogens (TOX).

Indirect Methods for Hydrogeological Investigations - Methods which include the measurement or remote sensing of various physical and/or chemical properties of the earth (e.g., electromagnetic conductivity, electrical resistivity, specific conductance, geophysical logging, aerial photography).

Intrinsic Permeability - Relates to the relative ease of a porous medium to transmit liquid under a hydraulic gradient, and is independent of the liquid itself.

Ion Exchange Capacity - Measured ability of a formation to adsorb charged atoms or molecules.

Karst Topography - A topographic area which has been created by the dissolution of a carbonate rock terrain. This type of topography is characterized by sinkholes, caverns, and lack of surface streams.

Landfill - A disposal facility or part of a facility where hazardous waste is placed in or on the land and which is not a land treatment facility, a surface impoundment, or an injection well. A landfill should not be used to store materials containing free liquids.

Leachate - A liquid including any suspended components in the liquid that has percolated through or drained from hazardous waste.

Less Than Detection Limits - A phrase meaning that a chemical constituent was either not identified or not quantified at the lowest level of sensitivity of the analytical method being employed by the laboratory. Therefore, the chemical constituent either is not present in the sample, or is present but in such a small concentration it could not be measured by the analytical procedure.

Liner - A continuous layer of natural or man-made materials beneath or on the sides of a surface impoundment, landfill, or landfill cell, which restricts the downward or lateral escape of hazardous waste, hazardous waste constituents, or leachate.

Lithology - The systematic description of rocks, in terms of mineral composition and texture.

Maximum Value - In a set of data, the measurement having the highest numerical value.

Mean - The sum of all measurements collected over a statistically significant period of time (e.g., one year) divided by the number of measurements.

Median - The middle point in a set of measurements ranked by numerical value. If there are an even number of measurements, the medium is the mean of the two central measurements.

Minimum Value - In a set of data, the measurement having the lowest numerical value.

Mounding - A phenomenon usually created by the recharge of ground water from a manmade structure into a permeable geologic material. Associated ground-water flow will be away from the manmade structure in all directions.

Number of LT Dtection Limit Values - The number of times a chemical parameter was not detected by a given analytical procedure over a statistically significant period of time (e.g., one year).

Octanol-Water Partition Coefficient - A coefficient representing the ratio of solubility of a compound in octanol to its solubility in water. As the octanol-water partition coefficient increases, water solubility decreases.

PVC - Polyvinyl chloride.

Petrographic Analysis - Systematic description and classification of rocks.

Phreatic Zone - See Saturated Zone.

Piezometers - Generally a small diameter, non-pumping well used to measure the elevation of the water table or potentiometric surface.

Potentiometric Surface (Piezometric Surface) - The surface that represents the level to which water from a given aquifer will rise by hydrostatic pressure. When the water-bearing zone is the uppermost unconfined aquifer, the potentionmetric surface is identical to the water table.

Pump Test - A test made by pumping a well for a period of time and observing the change in hydraulic head in adjacent wells. A pump test may be used to determine degree of hydraulic interconnection between different water-bearing units as well as the recharge rate of a well.

Qualified Geologist - A professional (e.g., degree, experience, or certified) specializing in the study of the earth material science.

Regional Administrator - The Regional Administrator of the appropriate Regional Office of the Environmental Protection Agency, or the authorized representative.

Regulated Unit - Hazardous waste management unit. The number of regulated units will define the extent of the hazardous waste management area.

Sampling and Analysis Plan - A detailed document describing the procedures which will be used to collect, handle, and analyze groundwater samples for detection or assessment monitoring parameters. The plan should detail all quality control measures which will be implemented to ensure sample collection, analysis, and data presentation activities meet the prescribed requirements.

Saturated Zone (Phreatic Zone) - A subsurface zone below in which the interstitial space of a porous medium is completely filled with water.

Seismic Prospecting - Any of the various geophysical methods for characterizing subsurface properties based on the analysis of elastic waves artificially generated at the surface (e.g., seismic reflection, seismic refraction).

Shelby Tube or Split Spoon Sampler - Devices used in conjunction with a drilling rig to obtain an undisturbed core sample of the strata.

Significant Digits - The number of digits reported in the result of a calculation or measurement (exclusive of following zeroes).

Sinkers - Dense phase organic liquids which coalesce in an immersible layer at the bottom of the saturated zone.

Slug Test - An aquifer test made by either pouring a small charge of water into a well or by withdrawing a slug of water from the well and monitoring the length of time the well requires to return to static water level conditions. This test is often employed to determine hydraulic conductivity.

Standard Deviation - The positive square root of the variance. (The variance is the average of the squares of the differences between the actual measurements and the mean.)

Surface Impoundment - A facility or part of a facility which is a natural topographic depression, man-made excavation, or diked area formed primarily of earthen materials (although it may be lined with man-made materials), which is designed to hold an accumulation of liquid wastes or wastes containing free liquids, and which is not an injection well. Examples of surface impoundments are holding, storage, settling, and aeration pits, ponds, and lagoons.

T-Test - The t-test is a statistical method used to determine the significance of difference or change between sets of initial background and subsequent parameter values.

TOC - Total organic carbon (SW-46, Method 9060).

TOX - Total organic halogens (SW-846, Method 9020).

Teflon - Tradename for polyperfluorethylene.

Total Number of Values - The number of measurements (including less than detection values) made for a chemical parameter over a statistically significant period of time (e.g., one year).

Tremie Method - Method whereby bentonite/cement slurries are pumped uniformly within the annular space of a well.

Unsaturated Zone - A subsurface zone above the water table in which the interstices of a porous medium are only partially filled with water. Also referred to as Vadose Zone.

Upgradient - Direction of increasing hydrostatic pressure.

Upgradient Well - One or more wells which are placed hydraulically upgradient of the site and are capable of yielding ground-water samples that are representative of regional conditions and are not affected by the regulated facility.

Uppermost Aquifer - The geological formation nearest the natural ground surface that is an aquifer, as well as all lower water-bearing units that are hydraulically interconnected with it, and overlying or perched water-bearing zones.

Vadose Zone - See Unsaturated Zone.

Volatile Constituents - Solid or liquid compounds which are relatively unstable at standard temperature and pressure and undergo spontaneous phase change to a gaseous state.

Water Table - The water level surface below the ground at which the vadose zone ends and the phreatic zone begins. It is the level to which a well screened in the unconfined aquifer would fill with water.

Well - A shaft or pit dug or bored into the earth, generally of a cylindrical form, and often walled with tubing or pipe to prevent the earth from caving in.

Well Cluster - A well cluster consists of two or more wells completed (screened) to different depths in a single borehole or a series of boreholes in close proximity to each other. From these wells, water samples that are representative of the different horizons within one or more aquifers can be collected.

Well Evacuation - Process of removing stagnant water from a well prior to sampling.

X-Ray Diffraction - An analytical technique used to determine the inorganic constituent content in solid materials. The sample is exposed to x-ray radiation and the x-rays are refracted in patterns which are characteristic of the individual inorganic constituents (e.g., NaCl).

Zone of Potential Contaminant Migration - Any subsurface formation or layer which is permeable and would preferentially channel the flow of contaminants away from a regulated facility.

APPENDIX A

EVALUATION WORKSHEETS

APPENDIX A.1

CHARACTERIZATION OF SITE HYDROGEOLOGY WORKSHEET

The following worksheets have been designed to assist the enforcement official in evaluating the program the owner/operator used in characterizing hydrogeologic conditions at his site. This series of worksheets has been compiled to parallel the information presented in Chapter 1 of the TEGD.

I. Review of Site Hydrogeologic Investigatory Techniques

A. Was the site investigation and/or data collection performed by a qualified geologist? (Y/N)____

B. Did the owner/operator survey the following existing regional data:

1. U.S.G.S. Maps? (Y/N)____
2. Water supply well logs? (Y/N)____
3. Other (specify) _____
_____

C. Did the owner/operator use the following direct techniques in the hydrogeologic assessment:

1. Soil borings/rock corings? (Y/N)____
2. Materials tests (e.g., grain size analyses, standard penetration tests, etc.)? (Y/N)____
3. Piezometer installation for water level measurements at different depths? (Y/N)____
4. Slug tests? (Y/N)____
5. Pump tests? (Y/N)____
6. Geochemical analyses of soil samples? (Y/N)____
7. Other (specify) _____
_____

D. Did the owner/operator use the following indirect techniques to supplement direct techniques data:

1. Geophysical well logs? (Y/N)____
2. Tracer studies? (Y/N)____
3. Resistivity and/or electromagnetic conductance? (Y/N)____
4. Seismic Survey? (Y/N)____
5. Hydraulic conductivity measurements of cores? (Y/N)____

6. Aerial photography? (Y/N)____
7. Ground penetrating radar? (Y/N)____
8. Other (specify) _____
_____

E. Did the owner/operator document and present the raw data from the site hydrogeologic assessment? (Y/N)____

F. Did the owner/operator document methods (criteria) used to correlate and analyze the information? (Y/N)____

G. Did the owner/operator prepare the following:

1. Narrative description of geology? (Y/N)____
2. Geologic cross sections? (Y/N)____
3. Geologic and soil maps? (Y/N)____
4. Boring/coring logs? (Y/N)____
5. Structure contour maps of aquifer and aquitard? (Y/N)____
6. Narrative description of ground-water flows? (Y/N)____
7. Water table/potentiometric map? (Y/N)____
8. Hydrologic cross sections? (Y/N)____

H. Did the owner/operator obtain a regional map of the area and delineate the facility? (Y/N)____

I. If yes, does this map illustrate:

1. Surficial geology features? (Y/N)____
2. Streams, rivers, lakes, or wetlands near the facility? (Y/N)____
3. Discharging or recharging wells near the facility? (Y/N)____

J. Did the owner/operator obtain a regional hydrogeologic map? (Y/N)____

K. If yes, does this hydrogeologic map indicate:

1. Major areas of recharge/discharge? (Y/N)____
2. Regional ground-water flow direction? (Y/N)____
3. Potentiometric contours which are consistent with observed water level elevations? (Y/N)____

L. Did the owner/operator prepare a facility site map? (Y/N)____

M. If yes, does the site map show:

1. Regulated units of the facility (e.g., landfill areas, impoundments)? (Y/N)____
2. Any seeps, springs, streams, ponds, or wetlands? (Y/N)____

3. Location of monitoring wells, soil borings, or test pits? (Y/N)____
4. How many regulated units does the facility have? _____
   If more than one regulated unit then,
   - Does the waste management area encompass all regulated units? (Y/N)____
     Or
   - Is a waste management area delineated for each regulated unit? (Y/N)____

II. Characterization of Subsurface Geology of Site

A. Soil boring/test pit program:

1. Were the soil borings/test pits performed under the supervision of a qualified professional? (Y/N)____
2. Were the borings placed 300 feet apart? (Y/N)____
3. If not, did the owner/operator provide documentation for selecting the spacing for borings? (Y/N)____
4. Were the borings drilled to the depth of the first confining unit below the uppermost zone of saturation or ten feet into bedrock? (Y/N)____
5. Indicate the method(s) of drilling:
   - Auger (hollow or solid stem) _____
   - Mud rotary _____
   - Air rotary _____
   - Reverse rotary _____
   - Cable tool _____
   - Jetting _____
   - Other (specify) _____
6. Were continuous sample corings taken? (Y/N)____
7. How were the samples obtained (check method[s])
   - Split spoon _____
   - Shelby tube, or similar _____
   - Rock coring _____
   - Ditch sampling _____
   - Other (explain) _____

   _____

   _____
8. Were the continuous sample corings logged by a qualified geologist? (Y/N)____
9. Does the field boring log include the following information:
   - Hole name/number? (Y/N)____
   - Date stared and finished? (Y/N)____
   - Geologist's name? (Y/N)____

- Driller's name? (Y/N)____
- Hole location (i.e., map and elevation)? (Y/N)____
- Drill rig type and bit/auger size? (Y/N)____
- Gross petrography (e.g., rock type) of each geologic unit? (Y/N)____
- Gross mineralogy of each geologic unit? (Y/N)____
- Gross structural interpretation of each geologic unit and structural features (e.g., fractures, gouge material, solution channels, buried streams or valleys, identification of depositional material)? (Y/N)____
- Development of soil zones and vertical extent and description of soil type? (Y/N)____
- Depth of water bearing unit(s) and vertical extent of each? (Y/N)____
- Depth and reason for termination of borehole? (Y/N)____
- Depth and location of any contaminant encountered in borehole? (Y/N)____
- Sample location/number? (Y/N)____
- Percent sample recovery? (Y/N)____
- Narrative descriptions of:
  -- Geologic observations? (Y/N)____
  -- Drilling observations? (Y/N)____

10. Were the following analytical tests performed on the core samples:
    - Mineralogy (e.g., microscopic tests and x-ray diffraction)? (Y/N)____
    - Petrographic analysis:
      - degree of crystallinity and cementation of matrix? (Y/N)____
      - degree of sorting, size fraction (i.e, sieving), textural variations? (Y/N)____
      - rock type(s)? (Y/N)____
      - soil type? (Y/N)____
      - approximate bulk geochemistry? (Y/N)____
      - existence of microstructures that may effect or indicate fluid flow? (Y/N)____

    - Falling head tests? (Y/N)____
    - Static head tests? (Y/N)____
    - Settling measurements? (Y/N)____
    - Centrifuge tests? (Y/N)____
    - Column drawings? (Y/N)____

B. Verification of subsurface geological data

1. Has the owner/operator used indirect geophysical methods to supplement geological conditions between borehole locations? (Y/N)____

2. Does the number of borings and analytical data indicate that the confining layer displays a low enough permeability to impede the migration of contaminants to any stratigraphically lower water-bearing units? (Y/N)____
3. Is the confining layer laterally continuous across the entire site? (Y/N)____
4. Did the owner/operator consider the chemical compatibility of the site-specific waste types and the geologic materials of the confining layer? (Y/N)____
5. Did the geologic assessment address or provide means for resolution of any information gaps of geologic data? (Y/N)____
6. Does the laboratory data corroborate the field data for petrography? (Y/N)____
7. Does the laboratory data corroborate the field data for mineralogy and subsurface geochemistry? (Y/N)____

C. Presentation of geologic data

1. Did the owner/operator present at least four geologic cross sections of the site? (Y/N)____
2. Do each of these cross sections:
   - identify the types and characteristics of the geologic materials present? (Y/N)____
   - define the contact zones between different geologic materials? (Y/N)____
   - note the zones of high permeability or fracture? (Y/N)____
   - give detailed borehole information including:
     -- location of borehole? (Y/N)____
     -- depth of termination? (Y/N)____
     -- location of screen (if applicable)? (Y/N)____
     -- depth of zone of saturation? (Y/N)____
3. Did the owner/operator provide a topographic map which was constructed by a licensed surveyor? (Y/N)____
4. Does the topographic map provide:
   - contours at a maximum interval of two-feet? (Y/N)____
   - locations and illustrations of man-made features (e.g., parking lots, factory buildings, drainage ditches, storm drains, pipelines, etc.)? (Y/N)____
   - descriptions of nearby water bodies? (Y/N)____
   - descriptions of off-site wells? (Y/N)____
   - site boundaries? (Y/N)____
   - individual RCRA units? (Y/N)____
   - delineation of the waste management area(s)? (Y/N)____
   - well and boring locations? (Y/N)____

5. Did the owner/operator provide an aerial photograph depicting the site and adjacent off-site features? (Y/N)____
6. Does the photograph clearly show surface water bodies, adjacent municipalities, and residences and are these clearly labelled? (Y/N)____

III. Identification of Ground-Water Flowpaths

A. Ground-water flow direction

1. Was the well casing height measured by a licensed surveyor to the nearest 0.1 feet? (Y/N)____
2. Were the well water level measurements taken within a 24 hour period? (Y/N)____
3. Were the well water level measurements taken to the nearest 0.1 feet? (Y/N)____
4. Were the well water levels allowed to stabilize after construction and development for a minimum of 24 hours prior to measurements? (Y/N)____
5. Was the water level information obtained from (check appropriate one):
   - multiple piezometers placement in single boreholes? _____
   - vertically nested piezometers in closely spaced separate boreholes? _____
6. Did the owner/operator provide construction details for the piezometers? (Y/N)____
7. How were the static water levels measured (check method(s).
   - Electric water sounder _____
   - Wetted tape _____
   - Air line _____
   - Other (explain) _____

   _____
8. Was the well water level measured in wells drilled to an equivalent depth below the saturated zone, or screened at an equivalent depth below the saturated zone? (Y/N)____
9. Has the owner/operator provided a site water table (potentiometric) contour map? If yes, (Y/N)____
   - Do the potentiometric contours appear logical based on topography and presented data? (Consult water level data) (Y/N)____
   - Are ground-water flowlines indicated? (Y/N)____
   - Are static water levels shown? (Y/N)____
   - Can hydraulic gradients be estimated? (Y/N)____

10. Did the owner/operator develop two, or more, hydrologic cross sections of the vertical flow component across the site? (Y/N)____

11. Do the owner/operator's flow nets include:
    - piezometer locations? (Y/N)____
    - depth of screening? (Y/N)____
    - width of screening? (Y/N)____

B. Seasonal and temporal fluctuations in ground-water level

1. Do fluctuations in static water levels occur? (Y/N)____
    - If yes, are the fluctuations caused by any of the following:
        -- Off-site well pumping (Y/N)____
        -- Tidal processes or other intermittent natural variations (e.g., river stage, etc.) (Y/N)____
        -- On-site well pumping (Y/N)____
        -- Off-site, on-site construction or changing land use patterns (Y/N)____
        -- Deep well injection (Y/N)____
        -- Seasonal variations (Y/N)____
        -- Other (specify) _____
2. Has the owner/operator documented the source and patterns that contribute to or affect the ground-water patterns below the waste management (Y/N)____
3. Do the water level fluctuations alter the general ground-water gradients and flow directions? (Y/N)____
4. Based on water level data, do any head differentials occur that may indicate a vertical flow component in the saturated zone? (Y/N)____
5. Did the owner/operator implement means for gauging long term effects on water movement that may result from on-site or off-site construction or changes in land-use patterns? (Y/N)____

C. Hydraulic conductivity

1. How were hydraulic conductivities of the subsurface materials determined?
    - Single-well tests (slug tests)? (Y/N)____
    - Multiple-well tests (pump tests)? (Y/N)____
2. If single-well tests were conducted, was it done by:
    - Adding or removing a known volume of water, Or (Y/N)____
    - Pressurizing well casing (Y/N)____

3. If single well tests were conducted in a highly permeable formation, were pressure transducers and high-speed recording equipment used to record the rapidly changing water levels? (Y/N)____
4. Since single well tests only measure hydraulic conductivity in a limited area, were enough tests run to ensure a representative measure of conductivity in each hydrogeologic unit? (Y/N)____
5. Is the owner/operator's slug test data (if applicable) consistent with existing geologic information (e.g., boring logs)? (Y/N)____
6. Were other hydraulic conductivity properties determined? (Y/N)____
7. If yes, provide any of the following data, if available:
   - Transmissivity _____
   - Storage coefficient _____
   - Leakage _____
   - Permeability _____
   - Porosity _____
   - Specific capacity _____
   - Other (specify) _____

D. Identification of the uppermost aquifer

1. Has the extent of the uppermost saturated zone (aquifer) in the facility area been defined? If yes, (Y/N)____
   - Are soil boring/test pit logs included? (Y/N)____
   - Are geologic cross-sections included? (Y/N)____
2. Is there evidence of confining (competent, unfractured, continuous, and low permeability) layers beneath the site? (Y/N)____
   - If yes, was continuity demonstrated through the evidence of lack of drawdown in the upper well when separate, closely-spaced wells (one screened at the uppermost part of the water table, and the other screened on the lower side of the confining layer) are pumped simultaneously? (Y/N)____
3. Was hydraulic conductivity of the confining unit determined to be less than 10^{-7} cm/sec through direct field measurements? (Y/N)____
4. Does potential for other hydraulic interconnection exist (e.g., lateral incontinuity between geologic units, facies changes, fracture zones, cross cutting structures, or chemical corrosion/alteration of geologic units by leachate)? (Y/N)____

IV. Conclusions

A. Subsurface geology

1. Has sufficient data been collected to adequately define petrography and petrographic variation? (Y/N)____
2. Has the subsurface geochemistry been adequately defined? (Y/N)____
3. Was the boring/coring program adequate to define subsurface geologic variation? (Y/N)____
4. Was the owner/operator's narrative description complete and accurate in its interpretation of the data? (Y/N)____
5. Does the geologic assessment address or provide means to resolve any information gaps? (Y/N)____

B. Ground-water flowpaths

1. Did the owner/operator adequately establish the horizontal and vertical components of ground-water flow? (Y/N)____
2. Were appropriate methods used to establish ground-water flowpaths? (Y/N)____
3. Did the owner/operator provide accurate documentation? (Y/N)____
4. Are the potentiometric surface measurements valid? (Y/N)____
5. Did the owner/operator adequately consider the seasonal and temporal effects on the ground-water? (Y/N)____
6. Were sufficient hydraulic conductivity tests performed to document lateral and vertical variation in hydraulic conductivity in the entire hydrogeologic subsurface below the site? (Y/N)____

C. Uppermost aquifer

1. Did the owner/operator adequately define the uppermost aquifer? (Y/N)____

APPENDIX A.2

PLACEMENT OF DETECTION MONITORING WELLS WORKSHEET

The following worksheets are designed to assist the enforcement officer's evaluation of an owner/operator's approach for selecting the number, location, and depth of all detection phase monitoring wells. This series of worksheets has been compiled to closely track the information presented in Chapter 2 of the TEGD. The guide for the evaluation of an owner/operator's placement of monitoring wells is highly dependent upon a thorough characterization of the site hydrogeology as described in Chapter 1 of the TEGD and Appendix A.1 worksheets.

I. Placement of Downgradient Detection Monitoring Wells

A. Are the ground-water monitoring wells or clusters located immediately adjacent to the waste management area? (Y/N)____

B. How far apart (i.e., what is the spacing?) between detection monitoring well locations?

_____

_____

_____

_____

C. Does the owner/operator provide a rationale for the location of each monitoring well or cluster? (Y/N)____

D. Does the owner/operator provide an explanation for the spacing of the ground-water monitoring wells? (Y/N)____

E. Has the owner/operator identified the vertical sampling interval(s) of each monitoring well or cluster, i.e., depth and thickness? (Y/N)____

F. Does the owner/operator provide an explanation for the depth and thickness of the vertical sampling interval(s) for each monitoring well or cluster? (Y/N)____

G. What length screens has the owner/operator employed in the ground-water monitoring wells on site?

_____

_____

_____

_____

H. Does the owner/operator provide an explanation for the screen length(s) chosen? (Y/N)____

I. Do the actual locations of monitoring wells or clusters correspond to those identified by teh owner/operator? (Y/N)____

II. Placement of Upgradient Monitoring Wells

A. Has the owner/operator documented the location of each upgradient monitoring well or cluster? (Y/N)____

B. Does the owner/operator provide an explanation for the location(s) of the upgradient monitoring wells? (Y/N)____

C. Has the owner/operator provided a rationale for the depth and thickness of the vertical sampling interval for each background monitoring well or cluster? (Y/N)____

D. What length screens has the owner/operator employed in the background monitoring well(s)?

_____

_____

_____

_____

E. Does the owner/operator provide an explanation for the screen length(s) chosen? (Y/N)____

F. Does the actual location of each background monitoring well or cluster correspond to that identified by the owner/operator? (Y/N)____

III. Conclusions

A. Downgradient Wells

Do the location, spacing, and vertical sampling interval(s) of the ground-water monitoring wells or clusters in the detection monitoring system allow the immediate detection of a release of hazardous waste or constituents from the hazardous waste management area to the uppermost aquifer? (Y/N)____

B. Upgradient Wells

Do the location and vertical sampling interval(s) of the upgradient (background) ground-water monitoring wells ensure the capability of collecting ground-water samples representatiave of upgradient (background) ground-water quality including any ambient heterogeneous chemical characteristics? (Y/N)____

APPENDIX A.3

MONITORING WELL DESIGN AND CONSTRUCTION WORKSHEET

The following worksheets have been designed to assist the enforcement officer in evaluating the techniques used by an owner/operator for designing and constructing monitoring wells. This series of worksheets has been compiled to parallel the information presented in Chapter 3 of the TEGD.

I. Monitoring Well Design

A. Complete the attached well construction summary sheet for the monitoring well unless similar documentation is already available from the owner/operator. Include the locations where the well intercepts changes in geological formation.

II. Drilling Methods

A. What drilling method was used for the well?

- Hollow-stem auger _____
- Solid-stem auger _____
- Mud rotary _____
- Air rotary _____
- Reverse rotary _____
- Cable tool _____
- Jetting _____
- Air drill with casing hammer _____
- Other (specify) _____

B. Were any cutting fluids (including water) or additives used during drilling? (Y/N)____

If yes, specify

Type of drilling fluid _____

Source of water used _____

Foam _____

Polymers _____

Other _____

C. Was the cutting fluid, or additive, analyzed? (Y/N)____

D. Was the drilling equipment steam-cleaned prior to drilling the well? (Y/N)____

E. Was compressed air used during drilling? (Y/N)____

1. If yes, was the air treated to remove oil (e.g., filtered)? (Y/N)____

PROJECT _____

SITE _____

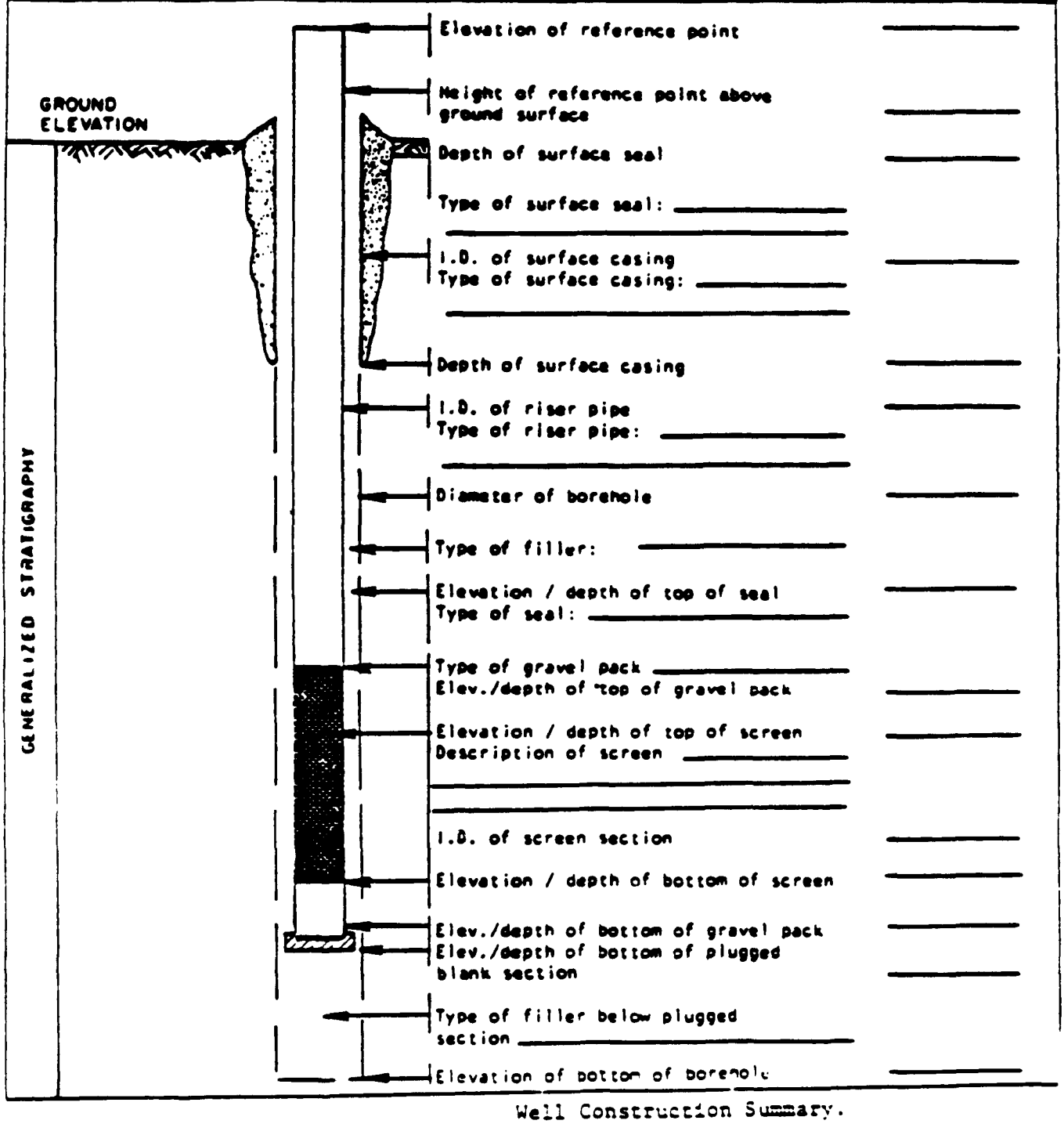
COORDINATES _____

DATE COMPLETED _____

SUPERVISED BY _____

WELL NO. _____

AQUIFER _____



Well Construction Summary.

F. Did the owner/operator document procedure for establishing the water table? (Y/N)____

1. If yes, how was the location established?

_____
_____
_____
_____
_____

G. Formation samples

1. Were continuous formation sample cores collected during drilling? (Y/N)____
2. How were the samples obtained?
   - Split spoon _____
   - Shelby tube _____
   - Core drill _____
   - Other (specify) _____
3. Indicate the frequency at which formation samples were collected _____
   _____
4. Identify if any physical and/or chemical tests were performed on the formation samples (specify) _____
   _____
   _____ ___

III. Monitoring Well Construction Materials

List of Potential Construction Materials for the Saturated Zone

1. Stainless steel (316)
2. Teflon

A. Identify construction materials (by number) and diameters (ID/OD)

	Material	Diameter (ID/OD)
1. Primary Casing	_____	_____
2. Secondary or outside casing (double construction)	_____	_____
3. Screen	_____	_____

B. How are the sections of casing and screen connected?
   - Pipe sections threaded _____
   - Couplings (friction) with adhesive or solvent _____
   - Couplings (friction) with retainer screws _____
   - Other (specify) _____ _____

C. Were the materials steam-cleaned prior to installation? (Y/N)____

IV. Well Intake Design and Well Development

A. Was a well intake screen installed? (Y/N)____
   1. What is the length of the screen for the well?
      _____
   2. Is the screen manufactured? (Y/N)____

B. Was a filter pack installed? (Y/N)____
   1. Has a turbidity measurement of the well water ever been made? (Y/N)____

C. Well development
   1. What technique was used for well development?
      - Surge block _____
      - Bailer _____
      - Air surging _____
      - Water pumping _____
      - Other (specify) _____

V. Annular Space Seals

A. Is the annular space in the saturated zone directly above the filter pack filled with?
   - Sodium bentonite (specify type and grit)
     _____
   - Cement (specify neat or concrete) _____
   - Other (specify) _____

   1. Was the seal installed by?
      - Dropping material down the hole and tamping _____
      - Dropping material down the inside of hollow-stem auger _____
      - Tremie pipe method _____
      - Other (specify) _____

B. Was a different seal used in the unsaturated zone? (Y/N)____
   If yes,
   1. Was this seal made with?
      - Sodium bentonite (specify type and grit) _____
        _____
      - Cement (specify neat or concrete) _____
      - Other (specify) _____
   2. Was this seal installed by?
      - Dropping material down the hole and tamping _____
      - Dropping material down the inside of hollow-stem auger _____
      - Tremie pipe method _____
      - Other (specify) _____

C. Is the upper portion of the borehole sealed with a concrete cap to prevent infiltration from the surface? (Y/N)____

D. Is the well fitted with an above-ground protective device? (Y/N)____

E. Has the protective cover been installed with locks to prevent tampering? (Y/N)____

VI. Field Tests/Field Demonstration

A. Do field measurements of the following agree with reported data:
   1. Casing diameter? (Y/N)____
   2. Well depth? (Y/N)____
   3. Water level elevation? (Y/N)____

B. If the existing well is being field demonstrated, complete Questions 1 through 7.
   1. Is the location of the demonstration well hydraulically equivalent to the existing well? (Y/N)____
   2. Was the demonstration well installed using EPA-approved methods and materials? (Y/N)____
   3. How were the wells evacuated (e.g., bailer or bladder pump)?
      existing well: _____
      demonstration well: _____
   4. Were the wells sampled concurrently? (Y/N)____
   5. Were the wells each sampled using the appropriate EPA methodology? (Y/N)____
   6. What parameters were the ground water samples analyzed for?
      _____
      _____
      _____
      _____
      _____
   7. Are the values for these parameters equivalent for each well (i.e., within the acceptable standard deviations)? (Y/N)____

VII. Conclusions

A. Do the design and construction of the owner/operator's ground-water monitoring wells permit depth discrete ground-water samples to be taken? (Y/N)____

B. Are the samples representative of ground-water quality? (Y/N)____

C. Are the ground-water monitoring wells structurally stable? (Y/N)____

D. Does the ground-water monitoring well's design and construction permit an accurate assessment of aquifer characteristics? (Y/N)____

APPENDIX A.4

SAMPLING AND ANALYSIS WORKSHEET

The following worksheets have been designed to assist the enforcement officer in evaluating the techniques an owner/operator uses to collect and analyze ground-water samples. This series of worksheets have been compiled based on the information provided in Chapter 4 of the TEGD.

I. Review of Sample Collection Procedures

A. Measurement of well depths elevation:

1. Are measurements of both depth to standing water and depth to the bottom of the well made? (Y/N)____
2. Are measurements taken to the nearest centimeter or 0.1 feet? (Y/N)____
3. What device is used?

_____

4. Is there a reference point established by a licensed surveyor? (Y/N)____

B. Detection of immiscible layers:

1. Are procedures used which will detect light phase immiscible layers? (Y/N)____
2. Are procedures used which will detect heavy phase immiscible layers? (Y/N)____

C. Sampling of immiscible layers:

1. Are the immiscible layers sampled separately prior to well evacuation? (Y/N)____
2. Do the procedures used minimize mixing with water soluble phases? (Y/N)____

D. Well evacuation:

1. Are low yielding wells evacuated to dryness? (Y/N)____
2. Are high yielding wells evacuated so that at least three casing volumes are removed? (Y/N)____
3. What device is used to evacuate the wells?

_____

4. If any problems are encountered (e.g., equipment malfunction) are they noted in a field logbook? (Y/N)____

E. Sample withdrawal:

1. For low yielding wells, are samples for volatiles, pH, and oxidation/reduction potential drawn first after the well recovers? (Y/N)____

2. Are samples withdrawn with either Teflon or stainless steel (316) sampling devices? (Y/N)____
3. Are sampling devices either bottom valve bailers or positive gas displacement bladder pumps? (Y/N)____
4. If bailers are used, is "Teflon"-coated wire, single strand stainless steel wire, or monofilament used to raise and lower the bailer? (Y/N)____
5. If bladder pumps are used, are they operated in a continuous manner to prevent aeration of the sample? (Y/N)____
6. If bailers are used, are they lowered slowly to prevent degassing of the water? (Y/N)____
7. If bailers are used, are the contents transferred to the sample container in a way that will minimize agitation and aeration? (Y/N)____
8. Is care taken to avoid placing clean sampling equipment on the ground or other contaminated surfaces prior to insertion into the well? (Y/N)____
9. If dedicated sampling equipment is not used, is equipment disassembled and thoroughly cleaned between samples? (Y/N)____
10. If samples are for inorganic analysis, does the cleaning procedure include the following sequential steps:
    a. Dilute acid rinse (HNO_3 or HCl)? (Y/N)____
    b. Distilled/deionized water rinse? (Y/N)____
11. If samples are for organic analysis, does the cleaning procedure include the following sequential steps:
    a. Nonphosphate detergent wash? (Y/N)____
    b. Tap water rinse? (Y/N)____
    c. Distilled/deionized water rinse? (Y/N)____
    d. Acetone rinse? (Y/N)____
    e. Pesticide-grade hexane rinse? (Y/N)____
12. Is sampling equipment thoroughly dry before use? (Y/N)____
13. Are equipment blanks taken to ensure that sample cross-contamination has not occurred? (Y/N)____
14. If volatile samples are taken with a positive gas displacement bladder pump, are pumping rates below 100 ml/min? (Y/N)____

F. In-situ or field analyses:
1. Are the following labile (chemically unstable) parameters determined in the field:
    a. pH? (Y/N)____
    b. Temperature? (Y/N)____
    c. Specific conductivity? (Y/N)____
    d. Redox potential? (Y/N)____
    e. Chlorine? (Y/N)____
    f. Dissolved oxygen? (Y/N)____
    g. Turbidity? (Y/N)____
    h. Other (specify) _____

2. For in-situ determinations, are they made after well evacuation and sample removal? (Y/N)____
3. If sample is withdrawn from the well, is parameter measured from a split portion? (Y/N)____
4. Is monitoring equipment calibrated according to manufacturers' specifications and consistent with SW-846? (Y/N)____
5. Is the date, procedure, and maintenance for equipment calibration documented in the field logbook? (Y/N)____

II. Review of Sample Preservation and Handling Procedures

A. Sample containers:
1. Are samples transferred from the sampling device directly to their compatible containers? (Y/N)____
2. Are sample containers for metals (inorganics) analyses polyethylene with polypropylene caps? (Y/N)____
3. Are sample containers for organics analysis glass bottles with Teflon-lined caps? (Y/N)____
4. If glass bottles are used for metals samples are the caps Teflon-lined? (Y/N)____
5. Are the sample containers for metal analyses cleaned using these sequential steps?
   a. Nonphosphate detergent wash? (Y/N)____
   b. 1:1 nitric acid rinse? (Y/N)____
   c. Tap water rinse? (Y/N)____
   d. 1:1 hydrochloric acid rinse? (Y/N)____
   e. Tap water rinse? (Y/N)____
   f. Distilled/deionized water rinse? (Y/N)____
6. Are the sample containers for organic analyses cleaned using these sequential steps?
   a. Nonphosphate detergent/hot water wash? (Y/N)____
   b. Tap water rinse? (Y/N)____
   c. Distilled/deionized water rinse? (Y/N)____
   d. Acetone rinse? (Y/N)____
   e. Pesticide-grade hexane rinse? (Y/N)____
7. Are trip blanks used for each sample container type to verify cleanliness? (Y/N)____

B. Sample preservation procedures:
1. Are samples for the following analyses cooled to 4°C:
   a. TOC? (Y/N)____
   b. TOX? (Y/N)____
   c. Chloride? (Y/N)____
   d. Phenols? (Y/N)____
   e. Sulfate? (Y/N)____
   f. Nitrate? (Y/N)____

g. Coliform bacteria? (Y/N)____
h. Cyanide? (Y/N)____
i. Oil and grease? (Y/N)____
j. Hazardous constituents (§261, Appendix VIII)? (Y/N)____

2. Are samples for the following analyses field acidified to pH <2 with HNO_3:
   a. Iron? (Y/N)____
   b. Manganese? (Y/N)____
   c. Sodium? (Y/N)____
   d. Total metals? (Y/N)____
   e. Dissolved metals? (Y/N)____
   f. Fluoride? (Y/N)____
   g. Endrin? (Y/N)____
   h. Lindane? (Y/N)____
   i. Methoxychlor? (Y/N)____
   j. Toxaphene? (Y/N)____
   k. 2,4 D? (Y/N)____
   l. 2,4,5, TP Silvex? (Y/N)____
   m. Radium? (Y/N)____
   n. Gross alpha? (Y/N)____
   o. Gross beta? (Y/N)____
3. Are samples for the following analyses field acidified to pH <2 with H_2SO_4:
   a. Phenols? (Y/N)____
   b. Oil and grease? (Y/N)____
4. Is the sample for TOC analyses field acidified to pH <2 with HCl? (Y/N)____
5. Is the sample for TOX analysis preserved with 1 ml of 1.1 M sodium sulfite? (Y/N)____
6. Is the sample for cyanide analysis preserved with NaOH to pH >12? (Y/N)____

C. Special handling considerations:
1. Are organic samples handled without filtering? (Y/N)____
2. Are samples for volatile organics transferred to the appropriate vials to eliminate headspace over the sample? (Y/N)____
3. Are samples for metal analysis split into two portions? (Y/N)____
4. Is the sample for dissolved metals filtered through a 0.45 micron filter? (Y/N)____
5. Is the second portion not filtered and analyzed for total metals? (Y/N)____
6. Is one equipment blank prepared each day of ground-water sampling? (Y/N)____

III. Review of Analytical Procedures

A. Laboratory analysis procedures:
   1. Are all samples analyzed using an EPA-approved method (SW-846)? (Y/N)____
   2. Are appropriate QA/QC measures used in laboratory analysis (e.g., blanks, spikes, standards)? (Y/N)____
   3. Are detection limits and percent recovery (if applicable) provided for each parameter? (Y/N)____
   4. If a new analytical method or laboratory is used, are split samples run for comparison purposes? (Y/N)____
   5. Are samples analyzed within specified holding times? (Y/N)____

B. Laboratory logbook:
   1. Is a laboratory logbook maintained? (Y/N)____
   2. Are experimental conditions (e.g., temperature, humidity, etc.) noted? (Y/N)____
   3. If a sample for volatile analysis is received with headspace, is this noted? (Y/N)____
   4. Are the results for all QC samples identified? (Y/N)____
   5. Is the time, date, and name of person noted for each processing step? (Y/N)____

IV. Review of Chain-of-Custody Procedures

A. Sample labels:
   1. Are sample labels used? (Y/N)____
   2. Do they provide the following information:
      a. Sample identification number? (Y/N)____
      b. Name of collector? (Y/N)____
      c. Date and time of collection? (Y/N)____
      d. Place of collection? (Y/N)____
      e. Parameter(s) requested and preservatives used: (Y/N)____
   3. Do they remain legible even if wet? (Y/N)____

B. Sample seals:
   1. Are sample seals placed on those containers to ensure the samples are not altered? (Y/N)____

C. Field logbook:
   1. Is a field logbook maintained? (Y/N)____
   2. Does it document the following:
      a. Purpose of sampling (e.g., detection or assessment)? (Y/N)____
      b. Location of well(s)? (Y/N)____
      c. Total depth of each well? (Y/N)____
      d. Static water level depth and measurement technique? (Y/N)____

e. Presence of immiscible layers and detection method? (Y/N)____
f. Collection method for immiscible layers and sample identification numbers? (Y/N)____
g. Well evacuation procedures? (Y/N)____
h. Sample withdrawal procedure? (Y/N)____
i. Date and time of collection? (Y/N)____
j. Well sampling sequence? (Y/N)____
k. Types of sample containers and sample identification numbers? (Y/N)____
l. Preservative(s) used? (Y/N)____
m. Parameters requested? (Y/N)____
n. Field analysis data and method(s)? (Y/N)____
o. Sample distribution and transporter? (Y/N)____
p. Field observations? (Y/N)____
- Unusual well recharge rates? (Y/N)____
- Equipment malfunction(s)? (Y/N)____
- Possible sample contamination? (Y/N)____
- Sampling rate? (Y/N)____

q. Field team members? (Y/N)____

D. Chain-of-custody record:
1. Is a chain-of-custody record included with each sample? (Y/N)____
2. Does it document the following:
a. Sample number? (Y/N)____
b. Signature of collector? (Y/N)____
c. Date and time of collection? (Y/N)____
d. Sample type? (Y/N)____
e. Station location? (Y/N)____
f. Number of containers? (Y/N)____
g. Parameters requested? (Y/N)____
h. Signatures of persons involved in the chain-of-possession? (Y/N)____
i. Inclusive dates of possession? (Y/N)____

E. Sample analysis request sheet:
1. Does a sample analysis request sheet accompany each sample? (Y/N)____
2. Does the request sheet document the following:
a. Name of person receiving the sample? (Y/N)____
b. Date of sample receipt? (Y/N)____
c. Laboratory sample number (if different than field number)? (Y/N)____
d. Analyses to be performed? (Y/N)____

F. Laboratory logbook:
1. Is a laboratory logbook maintained? (Y/N)____
2. If so, does it document the following:
a. Sample preparation techniques (e.g., extraction)? (Y/N)____
b. Instrumental methods? (Y/N)____
c. Experimental conditions? (Y/N)____

V. Review of Quality Assurance/Quality Control

A. Is the validity and reliability of the laboratory and field generated data ensured by a QA/QC program? (Y/N)____

B. Does the QA/QC program include:
   1. Documentation of any deviations from approved procedures? (Y/N)____
   2. Documentation of analytical results for:
      a. Blanks? (Y/N)____
      b. Standards? (Y/N)____
      c. Duplicates? (Y/N)____
      d. Spiked samples? (Y/N)____

C. Are approved statistical methods used? (Y/N)____

D. Are QC samples used to correct data? (Y/N)____

E. Are all data critically examined to ensure it has been properly calculated and reported? (Y/N)____

VI. Review of Indicators of Data Quality

A. Reporting of low and zero concentration values:
   1. Do specific concentration values accompanying measurements reported as less than a limit of detection? (Y/N)____
   2. Is the magnitude of detection limits consistent throughout the data set for each parameter? (Y/N)____
   3. Have techniques described in Appendix B of 40 CFR §136 been used to determine the detection limits? (Y/N)____
   4. Has the method for using less than detection limit data in presentations and statistical analysis been documented? (Y/N)____

B. Significant digits:
   1. Are constituent concentrations reported with a consistent number of significant digits? (Y/N)____
   2. Are all indicator parameters reported with at least three significant digits? (Y/N)____

C. Missing data values:
   1. Is the monitoring data set complete? (Y/N)____
   2. Are t-test comparisons between upgradient and downgradient wells attempted despite missing data provided that:
      a. At least one upgradient and one downgradient well were sampled? (Y/N)____

b. In the case of a missing quarterly sampling set, values are assigned by averaging corresponding values for the other three quarters? (Y/N)____

c. In the case of missing replicate values from a sampling event, values are assigned by averaging the replicate(s) which are available for that sampling event? (Y/N)____

D. Outliers:

1. Have extreme values (outliers) of constituent concentrations deleted or otherwise modified because of:
   a. Incorrect transcription? (Y/N)____
   b. Methodological problems or an unnatural catastrophic event? (Y/N)____
   c. Are these above occurrences fully documented? (Y/N)____
2. Are true but extreme values unaltered and incorporated in the analysis? (Y/N)____

E. Units of measure:

1. Are all units of measure reported accurately? (Y/N)____
2. Are the units of measure for a given chemical parameter used consistently throughout the report? (Y/N)____
3. Do the reporting formats clearly indicate consistent units of measure throughout so that no ambiguity exists (i.e., do the units accompany each parameter instead of a statement, "all values are ppm unless otherwise stated")? (Y/N)____

VII. Conclusions

A. Does the sampling and analysis plan permit the owner/operator to detect and, where applicable, assess the nature and extent of a release of hazardous constituents to ground water from the monitored hazardous waste management facility? (Y/N)____

APPENDIX A.5

PRESENTING DETECTION MONITORING DATA WORKSHEET

The following worksheets have been designed to assist the enforcement official in evaluating the method an owner/operator uses in presenting and statistically analyzing detection monitoring data. This series of worksheets has been compiled to parallel the information provided in Chapter 5 of the TEGD.

I. Presenting Detection Monitoring Data

A. Is the owner/operator using the reporting sheets as described in the TEGD (Chapter 5)? (Y/N)____

B. Have all the detection monitoring data collected by the facility been obtained and reviewed? (Y/N)____

II. T-test and Number of Wells

A. Which t-test is in use:
   1. Cochran's approximation to the Behrens-Fisher (CABF t-test)? _____
   2. Averaged replicate t-test (AR t-test)? _____
   3. Other, describe: _____
      _____

B. Does the facility have more than one upgradient monitoring well? (Y/N)____

III. First Year's Data

A. Have upgradient wells been monitored to establish background concentrations of the following data on a quarterly basis for one year:
   1. Appendix III parameters (§265.92(b)(1))? (Y/N)____
   2. Ground-water quality parameters (§265.92(b)(2))? (Y/N)____
   3. Ground-water contamination indicator parameters (§265.92(b)(3))? (Y/N)____

B. Were four replicate measurements obtained from each upgradient well during the first year of quarterly detection monitoring for indicator parameters [§265.92(b)(3)]? (Y/N)____

C. Have the background mean and variance been determined for the §265.92(b)(3) parameters using all the data obtained from the upgradient wells during the first year of sampling? (Y/N)____

IV. Subsequent Year's Data

A. Is monitoring data collected after the first year being compared with background data to determine possible groundwater contamination? (Y/N)____

B. Is the identified approved t-test being used properly to determine possible ground-water contamination? (Y/N)____

C. Are the ground-water quality parameters in §265.92(b)(2) being measured at least annually? (Y/N)____

D. Are the indicator parameters in §265.92(b)(3) being measured in at least four replicate samples from each well in the detection monitoring network at least semi-annually? (Y/N)____

E. Are the indicator parameters collected on a semi-annual basis being used to estimate the mean and variance? (Y/N)____

F. Is the elevation of the water table at each monitoring well determined each time a sample is collected? (Y/N)____

V. Conclusions

A. Is the owner/operator adequately reporting and statistically analyzing the facility's monitoring well data? (Y/N)____

B. If the t-test indicated a significant incease in IP's for downgradient wells, were they resampled and reanalyzed? (Y/N)____

C. If the resampling still indicated a significant increase, was assessment monitoring begun? (Y/N)____

APPENDIX A.6

ASSESSMENT MONITORING

The following worksheets have been designed to assist the enforcement officer in evaluating an owner/operator's assessment phase ground-water monitoring program. This series of worksheets has been compiled to parallel the information presented in Chapter 6 of the TEGD.

I. Review of Hydrogeologic Descriptions

A. Has the site's hydrogeologic setting been well characterized (refer to Appendix A.1 of TEGD)? (Y/N)____
   1. Has the regional and local hydrogeologic setting been thoroughly described? (Y/N)____
   2. Is there sufficient direct field information? (Y/N)____
   3. Is the information accurate and reliable? (Y/N)____
   4. Was the evaluation performed by a hydrogeologist? (Y/N)____
   5. Did indirect investigatory methods correlate with direct methods? (Y/N)____
   6. Have all possible migration pathways been identified? (Y/N)____
   7. Will the description of the hydrogeologic setting aid in characterizing the rate and extent of the plume migration? (Y/N)____

II. Review of Detection Monitoring System Description

A. Is the detection monitoring system capable of detecting all contaminant leakage that may be escaping from the facility (refer to Appendix A.2 of TEGD)? (Y/N)____
   1. Are the well designs and construction parameters fully documented? (Y/N)____
   2. Have the downgradient wells been strategically located so as to intercept migrating contaminants? (Y/N)____
   3. Are upgradient wells positioned so that they are not effected by the facility? (Y/N)____
   4. Are the screened intervals 10 feet or less? (Y/N)____
   5. Are the well construction materials (e.g., casing, screen, seals, packing) comprised of material that will not affect the ground-water quality? (Y/N)____

III. Review of Description of Approach for Making First Determination

A. Did the detection monitoring system consistently yield statistically equivalent concentrations for all indicator parameters? (Y/N)____

B. If no:

1. Were the results based on the Student's t-test at the 0.01 level of significance? (Single-tailed t-test for testing significant increases and two-tailed t-test for testing significant differences in pH values.) (Y/N)____
2. Were the calculations performed correctly? (Y/N)____
3. If the results are deemed as a false positive, did the owner/operator fully document the reasoning? (Y/N)____
4. Is there any reasonable cause to believe that faulty data are responsible for the false positive claim? (Y/N)____
5. Can or will deficiencies in well design, sample collection, sample preservation, or analysis be corrected? (Y/N)____
6. If the owner/operator intends to collect additional data to remedy any inadequacies, will this collection result in an acceptable delay in assessing the extent of contamination at the site? (Y/N)____
7. Will positive results of these determinations initiate a drilling program for assessment monitoring? (Y/N)____

IV. Review of Approach for Conducting Assessment

A. Have the assessment monitoring objectives been clearly defined in the assessment plan? (Y/N)____

1. Does the plan include analysis and/or re-evaluation to determine if significant contamination has occurred in any of the detection monitoring wells? (Y/N)____
2. Does the plan provide for a comprehensive program of investigation to fully characterize the rate and extent of contaminant migration from the facility? (Y/N)____
3. Does the plan call for determining the concentrations of hazardous wastes and hazardous waste constituents in the ground water? (Y/N)____
4. Does the plan employ a quarterly monitoring program? (Y/N)____

B. Does the assessment plan identify the investigatory methods that will be used in the assessment phase? (Y/N)____

1. Is the role of each method in the evaluation fully described? (Y/N)____
2. Does the plan provide sufficient descriptions of the direct methods to be used? (Y/N)____
3. Does the plan provide sufficient descriptions of the indirect methods to be used? (Y/N)____
4. Will the method contribute to the further characterization of the contaminant movement? (Y/N)____

C. Are the investigatory techniques utilized in the assessment program based on direct methods? (Y/N)____
   1. Does the assessment approach incorporate indirect methods to further support direct methods? (Y/N)____
   2. Will the planned methods called for in the assessment approach ultimately meet performance standards for assessment monitoring? (Y/N)____
   3. Are the procedures well defined? (Y/N)____
   4. Does the approach provide for monitoring wells similar in design and construction as the detection monitoring wells? (Y/N)____
   5. Does the approach employ taking samples during drilling or collecting core samples for further analysis? (Y/N)____

D. Are the indirect methods to be used based on reliable and accepted geophysical techniques? (Y/N)____
   1. Are they capable of detecting subsurface changes resulting from contaminant migration at the site? (Y/N)____
   2. Is the measurement at an appropriate level of sensitivity to detect ground-water quality changes at the site? (Y/N)____
   3. Is the method appropriate considering the nature of the subsurface materials? (Y/N)____
   4. Does the approach consider the limitations of these methods? (Y/N)____
   5. Will the extent of contamination and constituent concentration be based on direct methods and sound engineering judgment? (Using indirect methods to further substantiate the findings) (Y/N)____

E. Does the assessment approach incorporate any mathematical modeling to predict contaminant movement? (Y/N)____
   1. Will site specific measurements be utilized to accurately portray the subsurface? (Y/N)____
   2. Will the derived data be reliable? (Y/N)____
   3. Have the assumptions been identified? (Y/N)____
   4. Have the physical and chemical properties of the site-specific wastes and hazardous waste constituents been identified? (Y/N)____

V. Review of Assessment Monitoring Wells

A. Does the assessment plan specify:
   1. The number, location, and depth of wells? (Y/N)____
   2. The rationale for their placement and identify the basis that will be used to select subsequent sampling locations and depths in later assessment phases? (Y/N)____

B. Does the assessment period consist of a phased investigation so that data gained in initial rounds may help guide subsequent rounds? (Y/N)____

1. Do initial rounds incorporate geophysical techniques to approximate the limits of the contaminant plume? (Y/N)____
2. Has information from the triggering well (well showing elevated contaminant concentrations) been incorporated in the initial design and specifications? (Y/N)____
3. Is the sampling program designed adequately to portray a three dimensional plume configuration? (Y/N)____
4. Are evaluation procedures in place that will provide further guidance for subsequent monitoring? (Y/N)____

C. Does sufficient hydrogeologic data exist in the direction of the contaminant plume? (Y/N)____

1. Does the subsurface setting provide any information on possible transport mechanisms and attenuation processes? (Y/N)____
2. Are provisions made to secure additional data as needed? (Y/N)____
3. Are hydrogeologic descriptions updated as additional data become available? (Y/N)____

D. Sampling density:

1. Are a minimum of seven well clusters installed? (Y/N)____
2. Are the well clusters placed both perpendicular and parallel to plume migration from the triggering well? (Y/N)____
3. Are the well clusters placed both inside and outside the contaminant plume to identify its horizontal boundaries? (Y/N)____
4. Are sampling locations situated so as to identify areas of maximum contaminant concentration within the plume? (Y/N)____
5. Does the sampling density correlate with the size of the plume and the geologic variability? (Y/N)____

E. Sampling depths:

1. Are the intervals over which the samples are collected clearly identified? (Y/N)____
2. Are the well screens within each cluster positioned to sample the full extent of the predicted vertical distribution of hazardous waste constituents? (Y/N)____
3. Are the well screens depth discrete to the extent possible to minimize dilution effects? (Y/N)____
4. Are there a minimum of five wells per cluster? (Y/N)____
   - Are at least three wells screened within the plume? (Y/N)____
   - Are at least two wells screened above and below the plume, respectively? (Y/N)____

5. Are the wells placed alternating lower and higher screened wells to reduce the effect of drawdown on the sampling horizons? (Y/N)____
6. Are there high fluctuations in ground-water levels, or is the subsurface characterized by fractured consolidated formations that may otherwise require screen lengths greater than 10 feet? (Y/N)____
7. Are the wells screened to identify vertical concentration gradients and maximum concentrations of the contaminants? (Y/N)____

VI. Review of Monitoring Well Design and Construction

A. Are the well design and construction specification requirements equivalent to the detection requirements detailed in Chapter 3? (Y/N)____

B. Are well design and construction details provided for:
1. Drilling methods? (Y/N)____
2. Well construction materials? (Y/N)____
3. Well diameter? (Y/N)____
4. Well intake structures and procedures for well development? (Y/N)____
5. Placement of annular seals? (Y/N)____

C. Are all these details approved and recommended considering the characteristics of the site? (Y/N)____

VII. Review of Sampling and Analysis Procedures

A. Does the list of monitoring parameters include all hazardous waste constituents from the facility? (Y/N)____
1. Does the water quality parameter list include other important indicators not classified as hazardous waste constituents? (Y/N)____
2. Does the owner/operator provide documentation for the listed wastes which are not included? (Y/N)____

B. Have the procedures been detailed for sample collection? (Y/N)____
1. Do the procedures include evacuation of the borehole prior to sample collection? (Y/N)____
2. Are special procedures delineated for collection of separate phase immiscible contaminants? (Y/N)____
3. Has the equipment been identified? (Y/N)____
4. Do the procedures include decontamination of equipment? (Y/N)____
5. Have pumping rates, duration, and position in the well from which water will be evacuated been specified? (Y/N)____

C. Do the procedures include provisions for sample preservation and shipment? (Y/N)____

D. Do the procedures specify:
   1. Type of sample containers? (Y/N)___
   2. Filtering procedures? (Y/N)____
   3. Preservation techniques? (Y/N)____
   4. Storage and time elements involved? (Y/N)____
   5. Proper documentation? (Y/N)____

E. Do these procedures correspond to recommended procedures (SW-846 or EPA-approved procedures) for sampling and preservation? (Y/N)____

F. Do the sampling and analysis procedures identify analytical procedures for each of the identified monitoring parameters? (Y/N)____

G. Do the analytical procedures include:
   1. Detailed description and reference of approved analytical methods? (Y/N)____
   2. QA/QC procedures? (Y/N)____
   3. Location of laboratory performing analysis? (Y/N)____
   4. Proper documentation? (Y/N)____

H. Does the sampling and analysis plan establish procedures for chain of custody control? (Y/N)____

I. Do these procedures include:
   1. Sample labels? (Y/N)____
   2. Sample seals? (Y/N)____
   3. Field logbook? (Y/N)____
   4. Chain of custody record? (Y/N)____
   5. Sample analysis request sheet? (Y/N)____
   6. Laboratory logbook? (Y/N)____

J. Do the procedures specify how assessment monitoring data will be evaluated to determine if contamination has actually occurred? (Y/N)____
   1. Will the evaluation delineate the full extent of contaminant migration? (Y/N)____
   2. Will significant changes in containment concentration or movement be identified? (Y/N)____
   3. Are the evaluation procedures suitable and objective? (Y/N)____

K. Does the assessment plan clearly describe the procedures that will be used for evaluating monitoring data during the assessment? (Y/N)____

L. Does the plan provide for evaluation of its methodologies to ensure each method is properly executed during the assessment period? (Y/N)____

M. Is a list of all detection monitoring and assessment monitoring (if applicable) data available from the owner/operator? (Y/N)____
   1. Do these lists include:
      - Field quality control samples (e.g., sample container and equipment blanks)? (Y/N)____
      - Laboratory quality control samples (e.g., replicates, spiked samples, etc.)? (Y/N)____
   2. Are the lists prepared using a format which presents:
      - Codes that identify GWCCs? (Y/N)____
      - Well number? (Y/N)____
      - Date? (Y/N)____
      - Units of measure? (Y/N)____
      - Less than (LT) detection limit values? (Y/N)____
      - Concentrations of GWCCs? (Y/N)____

N. Has the owner/operator prepared summary statistics tables of the GWCC data? (Y/N)____
   1. Do the summary statistics tables include:
      - Number of LT detection limit values? (Y/N)____
      - Total number of values? (Y/N)____
      - Mean? (Y/N)____
      - Median? (Y/N)____
      - Standard deviation? (Y/N)____
      - Coefficient of variation? (Y/N)____
      - Minimum value? (Y/N)____
      - Maximum value? (Y/N)____
   2. Are there summary statistics tables that present:
      - GWCC? (Y/N)____
      - GWCC by well number? (Y/N)____
      - GWCC by well number and date? (Y/N)____
      - Quality control data? (Y/N)____

O. Has the owner/operator simplified the statistical data? (Y/N)____
   1. Was the data simplified using a ranking procedure for each GWCC-well combination? (Y/N)____
   2. Has the ranking procedure been applied to each GWCC which was detected at least once at every well in the monitoring system? (Y/N)____

P. Did the owner/operator display the data graphically? (Y/N)____
   1. Were the data plotted graphically to evaluate temporal changes? (Y/N)____
   2. Were the data plotted on facility maps to evaluate spacial trends? (Y/N)____

VIII. Review of Migration Rates

A. Did the owner/operator's assessment plan specify the procedures to be used to determine the rate of constituent migration in the ground-water? (Y/N)____

B. Do the procedures incorporate a periodic re-evaluation of sampling data to continually monitor the rate and extent of contaminant migration? (Y/N)____
   1. Do the procedures clearly establish ground-water flow rates and direction downgradient from the detection wells? (Y/N)____
   2. Are the methods employed suitable for these determinations? (Y/N)____
   3. Are the limitations of these methods known and documented? (Y/N)____
   4. Do the evaluations incorporate chemical and physical characteristics of the contaminants and the media? (Y/N)____
   5. Are adsorptive and degradative processes considered in determining any retardation of contaminant movement? (Y/N)____
   6. Have the assumptions been identified and documented? (Y/N)____

C. Does the assessment plan evaluate the presence of immiscible phase layers? (Y/N)____
   1. Do the procedures specify detection and collection of light and dense phase immiscibles prior to well evacuation? (Y/N)____
   2. Has the owner/operator used the slope of the water table and the velocity of ground-water flow to estimate light phase immiscible migration? (Y/N)____
   3. Has the owner/operator defined the configuration of the confining layer to predict dense phase immiscible migration? (Y/N)____

IX. Reviewing Schedule of Implementation

A. Has the owner/operator specified a schedule of implementation in the assessment plan? (Y/N)____

B. Does the schedule for implementing assessment monitoring data include a timetable for a comprehensive site evaluation for contamination? (Y/N)____

C. Does the timetable include:
   1. A number of milestones used to judge if sufficient progress is being made toward the completion of the assessment during implementation? (Y/N)____
   2. The determination if contamination has occurred? (Y/N)____
   3. Completing an initial comprehensive assessment of contamination at the site? (Y/N)____
   4. Implementing a program for continued monitoring after fully characterizing contamination at the site? (Y/N)____

D. Does this represent an acceptable time frame? (Y/N)____

X. Conclusions

A. Has the owner/operator adequately characterized site hydrogeology to determine contaminant migration? (Y/N)____

B. Is the detection monitoring system adequately designed and constructed to immediately detect any contaminant release? (Y/N)____

C. Are the procedures used to make a first determination of contamination adequate? (Y/N)____

D. Is the assessment plan adequate to detect, characterize, and track contaminant migration? (Y/N)____

E. Will the assessment monitoring wells, given site hydrogeologic conditions, define the extent and concentration of contamination in the horizontal and vertical planes? (Y/N)____

F. Are the assessment monitoring wells adequately designed and constructed? (Y/N)____

G. Are the sampling and analysis procedures adequate to provide true measures of contamination? (Y/N)____

H. Do the procedures used for evaluation of assessment monitoring data result in determinations of the rate of migration, extent of migration, and hazardous constituent composition of the contaminant plume? (Y/N)____

I. Are the data collected at sufficient duration and frequency to adequately determine the rate of migration? (Y/N)____

J. Is the schedule of implementation adequate? (Y/N)____

K. Is the owner/operator's assessment monitoring plan adequate? (Y/N)____

1. If the owner/operator had to implement his assessment monitoring plan, was it implemented satisfactorily? (Y/N)____

APPENDIX B

METHODOLOGY AND EXAMPLE APPLICATIONS THAT DESCRIBE THE USE OF COCHRAN'S APPROXIMATION TO THE BEHRENS-FISHER AND THE AVERAGED REPLICATE T-TESTS

BACKGROUND

This appendix presents t-test methodologies that may be used by owner/operators to analyze interim status detection monitoring groundwater data. The 40 CFR §265 Subpart F regulations require that owner/operators use a students t-test to determine whether individual wells in the monitoring network contain any indicator parameter concentrations which are statistically greater than background concentrations measured during the first year of sampling. Several different t-tests can be constructed to analyze interim status detection monitoring data and during interim status, an owner/operator may choose a t-test which is found to be most applicable to the data being analyzed. However, owner/operators must understand that for interim status facilities enforcement officers will only accept one t-test methodology, which must be documented with explicit examples and technical references.

Two suggested t-test methodologies are presented in this appendix. Cochran's Approximation to the Behrens-Fisher (CABF) t-test and a t-test termed the Averaged Replicate (AR) t-test. These tests are described with the following organization: an introduction, methodology used to analyze the first year's data, and methodology used to analyze data collected after the first year. After presentation of the methods an example is analyzed using the CABF and AR methods.

COCHRAN'S APPROXIMATION TO THE BEHRENS-FISHER T-TEST

Introduction

The methodology for the CABF is presented for several reasons. First, the CABF test is referenced explicitly in the 40 CFR §264 permit regulations. Prior guidance has directed use of the CABF t-test. The CABF t-test is also widely documented and presented in many statistical textbooks as a t-test for use when two groups of unpaired data with different variances are under comparison. Although the CABF t-test has been criticized widely because it may not match well with the groundwater data collected by interim status facilities, it will be described because it is presently being used by interim status facilities.

Methodology Used to Analyze the First Year's Data

Data collected during the first year from the upgradient wells are used to estimate the background mean and variance. All of the data collected from the upgradient wells must be used. If sampling were more frequent than quarterly or if multiple upgradient wells yielded data then all of these data should be included in the background mean and variance.

The background mean ($\bar{X}_b$) for the CABF t-test is:

$$\bar{X}_b = \sum_{i=1}^{n_b} \sum_{j=1}^{o_b} \sum_{k=1}^{p_b} X_{ijk}/N_b$$

X_{ijk} = Background concentration measurement from the ith well, the jth sampling period, and the kth replicate measurement. Where i=1 to n_b, j=1 to o_b, and k=1 to p_b.

N_b = Number of background measurements.

The background variance (s_b^2) for the CABF t-test is:

$$s_b^2 = \sum_{i=1}^{n_b} \sum_{j=1}^{o_b} \sum_{k=1}^{p_b} (X_{ijk} - \bar{X}_b)^2/N_b-1$$

Methodology Used to Analyze Data Collected After the First Year

The data for each parameter from each monitoring well, from each sampling event (upgradient and downgradient wells) after the first year must be compared individually with the background data collected during the first year. Four replicate measurements should be taken from each well for each indicator parameter (IP) during every semi-annual sampling event. These monitoring data are used to calculate a mean and variance for every IP at every monitoring well each time the well system is sampled.

The mean ($\bar{X}_m$) for monitoring well m for the CABF test is:

$$\bar{X}_m = \sum_{k=1}^{p_m} X_{km}/N_m$$

where: X_{km} = the kth replicate measurement from the mth monitoring well. Where k=1 to p_m.

N_m = number of replicate measurements from monitoring well m.

The variance (s_m^2) for monitoring well m for the CABF test is:

$$s_m^2 = \sum_{k=1}^{p_m} (X_{km} - \bar{X}_m)^2/N_m-1$$

The mean and variance of the background data from each sampling event in each monitoring well are used to estimate a Behrens-Fisher test t-statistic (t*).

The Behrens-Fisher t-statistic (t*) is calculated as follows:

$$t^* = \frac{\bar{X}_m - \bar{X}_b}{\sqrt{\frac{s_m^2}{N_m} + \frac{s_b^2}{N_b}}}$$

Cochran's approximation of the critical t-statistic (t_c) at the 0.01 level of significance is used as the basis of comparison with t*.

The critical t-statistic (t_c) is calculated as follows:

$$t_c = \frac{W_b\, t_b + W_m\, t_m}{W_b + W_m}$$

where: $W_b = s_b^2/N_b$

$W_m = s_m^2/N_m$

t_b = The critical value from Table B-1 with (N_b-1) degrees of freedom.

t_m = The critical value from Table B-1 with (N_m-1) degrees of freedom.

(NOTE: If pH is being tested use the two-tailed critical values, otherwise use the one-tailed critical values).

The t* is then compared with t_c using the following decision rules:

- If specific conductivity, TOC, and TOX are being evaluated and if t* is less than t_c then there is no statistical indication that the IP concentrations are larger in the well under comparison than in the background data. If t* is larger than t_c then there is a statistical indication that IP concentrations are larger in the well under comparison.
- If pH is being evaluated and if |t*| (which is the absolute value of t* or t* without a + or - sign) is less than t_c then there is no statistical indication that pH has changed. If |t*| is larger than t_c then there is an indication that pH has changed statistically. If t* is negative then pH increased if t* is positive pH decreased.

TABLE B-1

ONE AND TWO TAILED CRITICAL t VALUES AT THE .01 LEVEL OF SIGNIFICANCE

Degrees of Freedom	One Tailed	Two Tailed
1	31.821	62.657
2	6.965	9.925
3	4.541	5.841
4	3.747	4.604
5	3.365	4.032
6	3.143	3.707
7	2.998	3.499
8	2.896	3.355
9	2.821	3.250
10	2.764	3.169
11	2.718	3.106
12	2.618	3.055
13	2.650	3.012
14	2.642	2.977
15	2.602	2.947
16	2.583	2.921
17	2.567	2.898
18	2.552	2.878
19	2.539	2.861
20	2.528	2.845
21	2.518	2.831
22	2.508	2.819
23	2.500	2.807
24	2.492	2.797
25	2.485	2.787
26	2.479	2.779
27	2.473	2.771
28	2.467	2.763
29	2.462	2.756
30	2.457	2.750
40	2.423	2.704
60	2.390	2.660
120	2.358	2.617
∞	2.326	2.576

Adapted from Table III, Statistical Tables for Biological, Agricultural, and Medical Research, Fisher and Yates, 1949.

AVERAGED REPLICATE T-TEST

Introduction

The averaged replicate (AR) t-test methodology is presented for several reasons. First, the AR t-test has been suggested for use in public comment and was recommended subsequently for use in a memorandum from Skinner in November, 1983. Also, the AR t-test removes the heavy influence that split sample or replicate variability exerts on the overall estimate of variability in the background data. It has been suggested that the AR t-test may help alleviate statistical contributions to the problem of incorrect indication of contamination.

Methodology Used to Analyze the First Year's Data

Similar to the CABF t-test the background mean and variance must be calculated. This is done by first averaging the replicate measurements and then using these replicate averages to calculate the background mean and variance as described below.

Background Mean:

$$\bar{x}_{ij} = \sum_{k=1}^{p_b} (x_{ijk}/p_b)$$

$$\bar{x}_b = \sum_{i=1}^{n_b} \sum_{j=1}^{o_b} (\bar{x}_{ij}/M_b)$$

where: M_b = The number of samples taken during the collection of background data. M_b does not include the replicate measurements. In a complete data set M_b is equal to n_b times o_b.

Background Variance:

$$s_b^2 = \sum_{i=1}^{n_b} \sum_{j=1}^{o_b} (\bar{x}_{ij} - \bar{x}_b)/M_b - 1$$

Methodology Used to Analyze Data Collected After the First Year

The requirements and objectives of sampling after the first year are the same regardless of the test being applied. For the AR t-test only the average concentration for each well ($\bar{x}_m$) is used in the calculation of the t-test. A description of the sampling requirements and method for calculating $\bar{x}_m$ are described in the prior section for the CABF test. No variance is computed for the monitoring data collected after the first year when using the AR test.

The AR t-statistic is calculated as follows:

$$t^* = \frac{\bar{x}_m - \bar{x}_b}{s_b^2 \sqrt{1 - 1/M_b}}$$

Instead of calculating the critical t-statistic as described for the CABF t-test, the critical t-statistic (t_c) is obtained directly from Table B-1. The t_c is the value from Table B-1 which corresponds to $M_b - 1$ degrees of freedom. The t* and t_c values are compared using the same decision rules that are described above for the CABF t-test.

AN EXAMPLE OF APPLYING THE CABF AND AR T-TESTS TO A SET OF DETECTION MONITORING DATA COLLECTED FROM AN INTERIM STATUS FACILITY

This section presents statistical analyses of data collected from a properly designed and sampled interim status detection monitoring system. Table B-2 presents an example of total organic halide (TOX) values measured in parts per billion (ppb) collected from upgradient wells during the first year of detection monitoring. This detection monitoring system consists of four upgradient wells that were sampled bimonthly. Four replicate samples were taken from each upgradient well at each sampling. The array of wells, sampled bimonthly, allows spatial and temporal evaluation of the upgradient ground-water quality. The statistics describing the first years background data are presented in Table B-3 and were computed using the CABF and AR methodology described above.

TABLE B-2

AN EXAMPLE OF TOX DATA COLLECTED DURING THE FIRST YEAR FROM AN UPGRADIENT WELL SYSTEM. THE OVERALL MEAN IS 65.2 ppb. THE VALUE IN PARENTHESIS WAS MISSING AND WAS ESTIMATED USING THE METHOD DESCRIBED FOR MISSING VALUES.

Month	Well Code	Replicate	TOX Value (ppb)	Difference Between the Overall Mean and the Value	Squared Difference
1	1	A	67.4	- 2.2	4.84
		B	67.2	- 2.0	4.00
		C	68.0	- 2.8	7.84
		D	67.1	- 1.9	3.61
	REPLICATE MEAN =		67.43	- 2.23	4.97
	2	A	66.6	- 1.40	1.96
		B	67.1	- 1.90	3.61
		C	65.9	- 0.70	0.49
		D	66.3	- 0.10	1.21
	REPLICATE MEAN =		66.48	- 1.28	1.64
	3	A	68.0	- 2.80	7.84
		B	67.5	- 2.30	5.29
		C	67.6	- 2.40	5.76
		D	67.6	- 2.40	5.76
	REPLICATE MEAN =		67.68	- 2.48	6.15
	4	A	60.1	5.10	26.01
		B	59.1	6.10	37.21
		C	58.7	6.50	42.25
		D	62.1	3.10	9.61
	REPLICATE MEAN =		60.0	5.20	27.04
3	1	A	65.2	0.0	0.0
		B	63.0	2.20	4.84
		C	62.7	2.50	6.25
		D	64.0	1.20	1.44
	REPLICATE MEAN =		63.73	1.47	2.16
	2	A	60.9	4.30	18.49
		B	61.7	3.50	12.25
		C	62.8	2.40	5.76
		D	62.2	3.00	9.00
	REPLICATE MEAN =		61.9	3.30	10.89

TABLE B-2 (Continued)

Month	Well Code	Replicate	TOX Value (ppb)	Difference Between the Overall Mean and the Value	Squared Difference
	3	A	63.2	2.00	4.00
		B	63.0	2.20	4.84
		C	62.7	2.50	6.25
		D	62.9	2.30	5.29
	REPLICATE MEAN =		62.95	2.25	5.06
	4	A	57.8	7.40	54.76
		B	58.2	7.00	49.00
		C	58.0	7.20	51.84
		D	58.7	6.50	42.25
	REPLICATE MEAN =		58.18	7.02	49.28
5	1	A	65.0	0.20	0.04
		B	65.2	0.0	0.0
		C	66.8	- 1.60	1.56
		D	66.3	- 1.10	1.21
	REPLICATE MEAN =		65.83	- 0.63	0.40
	2	A	60.9	4.30	18.49
		B	61.3	3.90	15.21
		C	62.0	3.20	10.24
		D	61.7	3.50	12.54
	REPLICATE MEAN =		61.48	3.72	13.84
	3	A	63.0	2.20	4.84
		B	63.2	2.00	4.00
		C	62.7	2.50	6.25
		D	61.9	3.50	10.89
	REPLICATE MEAN =		62.7	2.50	6.25
	4	A	56.3	8.90	79.21
		B	57.8	7.40	54.76
		C	57.9	7.30	53.29
		D	58.1	7.10	50.41
	REPLICATE MEAN =		57.53	7.67	58.83

(Continued)

TABLE B-2 (Continued)

Month	Well Code	Replicate	TOX Value (ppb)	Difference Between the Overall Mean and the Value	Squared Difference
7	1	A	63.2	2.00	4.00
		B	63.2	2.00	4.00
		C	63.8	1.40	1.96
		D	63.8	1.40	1.96
	REPLICATE MEAN =		63.5	1.70	2.89
	2	A	64.0	1.20	1.44
		B	63.6	1.60	2.56
		C	63.8	1.40	1.96
		D	64.0	1.20	1.44
	REPLICATE MEAN =		63.85	1.35	1.82
	3	A	65.6	- 0.40	0.16
		B	67.9	- 2.70	7.29
		C	70.2	- 5.00	25.00
		D	68.1	- 2.90	8.41
	REPLICATE MEAN =		67.95	- 2.75	7.56
	4	A	64.8	0.40	0.16
		B	64.0	1.20	1.44
		C	65.2	0.0	0.0
		D	(64.7)	0.5	0.25
	REPLICATE MEAN =		64.68	1.52	0.27
9	1	A	65.7	- 0.50	0.25
		B	65.9	- 0.70	0.49
		C	64.2	1.00	0.64
		D	66.0	0.80	0.64
	REPLICATE MEAN =		65.45	- 0.25	0.06
	2	A	63.8	1.40	1.96
		B	64.2	1.00	1.00
		C	64.7	0.50	0.25
		D	64.0	1.20	1.44
	REPLICATE MEAN =		64.18	1.20	1.04

(Continued)

TABLE B-2 (Continued)

Month	Well Code	Replicate	TOX Value (ppb)	Difference Between the Overall Mean and the Value	Squared Difference
	3	A	65.0	0.20	0.04
		B	65.1	0.10	0.01
		C	65.9	- 0.70	0.49
		D	66.3	- 1.10	1.21
	REPLICATE MEAN =		65.58	- 0.38	0.14
	4	A	61.8	3.40	11.56
		B	61.4	3.80	14.44
		C	61.3	3.90	15.81
		D	51.1	4.10	16.81
	REPLICATE MEAN =		61.4	3.80	14.44
11	1	A	69.7	- 4.50	20.25
		B	72.0	- 6.80	46.24
		C	71.5	- 6.30	39.69
		D	70.6	- 5.40	29.16
	REPLICATE MEAN =		70.95	- 5.75	33.06
	2	A	73.4	- 8.20	67.24
		B	75.2	-10.00	100.00
		C	76.0	-10.80	116.64
		D	75.4	-10.20	104.04
	REPLICATE MEAN =		75.0	- 9.80	96.04
	3	A	71.1	- 5.90	34.81
		B	74.0	- 8.80	77.44
		C	72.3	- 7.10	50.41
		D	73.7	- 8.50	72.25
	REPLICATE MEAN =		72.78	- 7.58	57.46
	4	A	72.7	- 7.50	56.25
		B	74.9	- 9.70	94.09
		C	73.0	- 7.80	60.84
		D	73.6	- 8.40	70.56
	REPLICATE MEAN =		73.55	- 8.35	69.72

TABLE B-3

SUMMARY STATISTICS DESCRIBING THE FIRST YEAR'S BACKGROUND TOX DATA PRESENTED IN TABLE B-2 USING THE COCHRAN'S APPROXIMATION TO THE BEHRENS-FISHER AND THE AVERAGED REPLICATE t-TESTS

Cochran's Approximation of the Behrens-Fisher t-Test	Average Replicate t-Test
Total number of replicate measurements:	Total number of replicate averages:
$N_b = 96$	$M_b = 24$
Degrees of freedom:	Degrees of freedom:
$N_b - 1 = 95$	$M_b - 1 = 23$
Background Mean:	Background Mean:
$\bar{X}_b = \sum_{i=1}^{n_b} \sum_{j=1}^{o_b} \sum_{k=1}^{p_b} X_{ijk}/N_b$	$\bar{X}_b = \sum_{i=1}^{n_b} \sum_{j=1}^{o_b} \bar{X}_{ij}/M_b$
$= (67.4 + 67.2 + 68.0 + 67.1 + 66.6 + \ldots + 73.6)/96$	$= (67.43 + 66.48 + 67.68 + \ldots. + 73.55)/24$
Background Variance:	Background Variance:
$s_b^2 = [(67.4 - 65.2)^2 + (68.0 - 65.2)^2 + \ldots + (73.6 - 65.2)^2]/95$	$s_b^2 = [(67.43 - 65.2)^2 + (66.48 - 65.2)^2 + \ldots. + (73.55 - 65.2)^2]/23$
$= 20.38$	$= 20.48$

After the first year four replicate measurements are collected from each upgradient and downgradient well. The measurements from each well are evaluated individually by the t-test. In this example the TOX data from a single semiannual sampling event are presented in Table B-4. Data from the four background wells (1-4) which were sampled during the first year and from the six downgradient wells (5-10) are compared using the CABF and AR methods.

Table B-5 presents the statistics used in conducting the CABF t-test and Table B-6 presents the statistics used in conducting the AR t-test. It is apparent from the comparison of these tables that there is less computational effort required to conduct the AR t-test. Also, notice in Table B-5 that the CABF test indicated that well 5 had significantly larger concentrations than the background data (because $t^* > t_c$), but that the results of the AR test presented in Table B-6 indicated no significant difference. The reason that the CABF test indicated a significant difference is because the variance among the replicate samples in well 5 as shown in Table B-4 was larger than any other well.

Table B-7 describes specifically, using data from well 6, how to perform the calculations for the CABF and AR t-tests for data that are collected after the first year.

TABLE B-4

AN EXAMPLE OF TOX DATA, TAKEN DURING A SEMI-ANNUAL SAMPLING EVENT, THAT WILL BE USED TO COMPARE WITH THE BACKGROUND TOX DATA MEASURED DURING THE FIRST YEAR.

Location of the Well	Well Code	Replicate	TOX Value (ppb)	Difference Between the Overall Mean and the Value	Squared Difference
Upgradient	1	A	64.8	- 0.12	0.0625
		B	64.2	0.48	0.1225
		C	65.0	- 0.32	0.2025
		D	64.7	- 0.02	0.0225
	REPLICATE MEAN =		64.68		s_1^2 = 0.3476
	2	A	65.7	- 0.27	0.0729
		B	65.3	0.13	0.0169
		C	65.6	0.17	0.0289
		D	65.1	0.33	0.1089
	REPLICATE MEAN =		65.43		s_2^2 = 0.2276
	3	A	64.8	0.18	0.0324
		B	65.2	0.22	0.0484
		C	64.9	0.08	0.0064
		D	65.0	0.02	0.0004
	REPLICATE MEAN =		65.43		s_3^2 = 0.0876
	4	A	65.3	- 0.02	0.0004
		B	65.3	- 0.02	0.0004
		C	65.3	- 0.02	0.0004
		D	65.2	0.08	0.0064
	REPLICATE MEAN =		65.28		s_4^2 = 0.0076
Downgradient	5	A	68.4	0.20	0.0400
		B	69.7	- 1.10	1.2100
		C	68.6	0.0	0.0
		D	67.7	0.90	0.8100
	REPLICATE MEAN =		68.6		s_5^2 = 2.0600

(Continued)

TABLE B-4 (Continued)

Location of the Well	Well Code	Replicate	TOX Value (ppb)	Difference Between the Overall Mean and the Value	Squared Difference
Downgradient	6	A	66.3	- 0.05	0.0025
		B	66.2	0.05	0.0025
		C	65.7	0.55	0.3025
		D	66.8	- 0.55	0.3025
	REPLICATE MEAN =		66.25		s_6^2 = 0.6100
	7	A	64.7	0.33	0.1089
		B	65.3	0.27	0.0729
		C	65.0	0.03	0.0009
		D	65.1	0.07	0.0049
	REPLICATE MEAN =		65.03		s_7^2 = 0.1876
	8	A	64.2	0.13	0.0169
		B	64.5	- 0.17	0.0289
		C	64.3	0.03	0.0009
		D	64.3	0.03	0.0009
	REPLICATE MEAN =		64.33		s_8^2 = 0.0476
	9	A	66.7	1.45	2.1025
		B	63.4	1.85	3.4225
		C	65.2	0.05	0.0025
		D	65.7	- 0.45	0.2025
	REPLICATE MEAN =		65.25		s_9^2 = 0.1876
	10	A	62.8	0.38	0.1444
		B	63.4	- 0.22	0.0484
		C	63.3	- 0.12	0.0144
		D	63.2	- 0.02	0.0004
	REPLICATE MEAN =		63.18		s_{10}^2 = 0.2076

TABLE B-5

A SUMMARY OF THE COCHRAN's APPROXIMATION TO THE BEHRENS-FISHER t-TEST
APPLIED TO THE TOX DATA PRESENTED IN TABLES B-2 AND B-4

Location of the Well	Well Code	$\bar{X}_m - \bar{X}_b$	$W_m = s^2/N_m$	$W_m + W_b$	$\sqrt{W_m + W_b}$	$W_m t_m + W_b t_b$	t*	t_c
Upgradient	1	-0.52	0.0869	0.2992	0.5470	0.8980	-0.951	3.001
	2	0.23	0.0659	0.2692	0.5189	0.2584	0.443	2.829
	3	-0.22	0.0219	0.2341	0.4839	0.6028	-0.455	2.574
	4	0.08	0.0019	0.2142	0.4628	0.5120	0.173	2.390
Downgradient	5	3.40	0.5150	0.7273	0.8528	2.8420	3.987	3.908
	6	1.05	0.1525	0.3648	0.6040	1.1959	1.738	3.782
	7	-0.17	0.0469	0.2592	0.5091	0.7164	-0.334	1.764
	8	-0.87	0.0119	0.2242	0.4735	0.5574	-1.837	2.486
	9	0.05	1.4325	1.6448	1.2825	7.0083	0.039	4.261
	10	-2.02	0.0519	0.2642	0.5140	0.7390	-3.930	2.797

$W_b = s_b^2/N_b = 0.2123$, $t_b(\alpha = .01, 95) = 2.371$, $t_m(\alpha = .01, 3) = 4.541$

TABLE B-6

A SUMMARY OF THE AVERAGED REPLICATE t-TEST APPLIED TO THE TOX DATA PRESENTED IN TABLES B-2 AND B-4

Location of the Well	Well Code	$\bar{X}_m - \bar{X}_b$	t*
Upgradient	1	- 0.65	- 0.117
	2	0.23	0.052
	3	- 0.22	-0.050
	4	0.08	0.018
Downgradient	5	3.40	0.767
	6	1.05	0.237
	7	- 0.17	- 0.038
	8	- 0.87	- 0.196
	9	0.05	0.011
	10	- 2.02	0.456

t_c (α = .01,23) = 2.500

$s_b\sqrt{1 - 1/M_b} = 4.526\sqrt{1-1/24} = 4.431$

TABLE B-7

A COMPARISON OF THE COCHRAN'S APPROXIMATION OF THE BEHRENS-FISHER AND THE AVERAGED REPLICATE t-TEST METHODS APPLIED TO DATA COLLECTED AFTER THE FIRST YEAR OF MONITORING FROM DOWNGRADIENT MONITORING WELL 6

Cochran's Approximation of the Behrens-Fisher t-Test	Average Replicate t-Test
The mean ($\bar{X}_m$) is:	The mean ($\bar{X}_m$) is:
$\bar{X}_m = \sum_{k=1}^{p_m} X_{km}/N_m$	$\bar{X}_m = \sum_{k=1}^{p_m} X_{km}/N_m$
$= 66.3 + 66.2 + 65.7 + 66.8/4$	$= 66.3 + 66.2 + 65.7 + 66.8/4$
$= 66.25$	$= 66.25$
The variance (s_m^2) is:	No variance is computed for the monitoring data collected after the first year when using the AR t-test
$s_m^2 = \sum_{k=1}^{p_m} (X_{km} - \bar{X}_m)^2/N_m - 1$	
$= (66.3 - 66.25)^2 + (66.2 - 66.25)^2 +$ $(65.7 - 66.25)^2 + (66.8 - 66.25)^2/4-1$	
$= 0.6100$	
The test statistic (t*) is:	The test statistic (t*) is:
$t^* = \frac{\bar{X}_m - \bar{X}_b}{\sqrt{\frac{s_m^2}{N_m} + \frac{s_b^2}{N_b}}}$	$t^* = \frac{\bar{X}_m - \bar{X}_b}{s_b\sqrt{1 - 1/M_b}}$
$= \frac{1.05}{0.6040} = 1.738$	$= \frac{1.05}{4.526\sqrt{1 - 1/24}} = 0.237$

(Continued)

TABLE B-7 (Continued)

Cochran's Approximation of the Behrens-Fisher t-Test	Average Replicate t-Test
The critical t value (t_c) is: $t_c = \frac{W_m t_m + W_b t_b}{W_m + W_b}$ $= \frac{(.15525)(4.541) + (2.123)(2.371)}{.1525 + .2123}$ $= \frac{1.1959}{0.3648} = 3.278$	The critical t value (t_c) is obtained from the one-tailed t-table (Table B-1) with M_b-1 degrees of freedom. $t_c = 2.500$
Decision of whether significantly larger concentrations have been measured in the monitoring well under evaluation.	Decision of whether significantly larger concentrations have been measured in the monitoring well under evaluation.
One-tailed: • If $t^* > t_c$ then significantly larger concentrations are indicated. • $t^* = 1.738 < t_c = 3.278$ therefore no significant differences were indicated.	One-tailed: • If $t^* > t_c$ then significantly larger concentrations are indicated. • $t^* = 0.237 < t_c = 2.500$ therefore no significant differences were indicated.

APPENDIX C

DESCRIPTION OF SELECTED GEOPHYSICAL METHODS AND ORGANIC VAPOR ANALYSIS

APPENDIX C

SELECTED GEOPHYSICAL METHODS AND ORGANIC VAPOR ANALYSIS

This Appendix is a presentation of several investigative techniques capable of augmenting data gathered from boreholes and ground-water monitoring wells. The five methods are:

1. Ground Penetrating Radar (GPR)
2. Electromagnetic Conductivity (EM)
3. Resistivity
4. Seismic Refraction/Reflection
5. Organic Vapor/Soil Gas Analysis

The summaries of EM and resistivity focus on surficial and not borehole methods. Although surficial and borehole techniques operate under the same physical principles, the reader should be aware that surficial and borehole techniques have different characteristics. Surficial methods can be undertaken without regard to the number of location or boreholes therefore providing a great deal of flexibility to the investigation without disturbing the subsurface. Borehole EM and resistivity, however, offer a much higher degree of resolution at depth in the vicinity of a single borehole or between two or more.

The effectiveness of geophysical methods and organic vapor/soil gas analysis increases if several techniques are used conjunctively. For instance, EM, resistivity and organic vapor analysis are highly correlative in the field where organic contamination exists.

GROUND PENETRATING RADAR (GPR)*

Ground penetrating radar (GPR) uses high frequency radio waves to acquire subsurface information. From a small antenna which is moved slowly scross the surface of the ground, energy is radiated downward into the subsurface, then reflected back to the receiving antenna, where variations in the return signal are continuously recorded; this produces a continuous cross-sectional "picture" or profile of shallow subsurface conditions. These responses are caused by radar wave reflections from interfaces of materials having different electrical properties. Such reflections are often associated with natural geohydrologic conditions such as bedding, cementation, moisture and clay content, voids, fractures, and intrusions, as well as man-made objects. The radar method has been used at numerous HWS to evaluate natural soil and rock conditions, as well as to detect buried wastes.

Radar responds to changes in soil and rock conditions. An interface between two soil or rock layers having sufficiently different electrical properties will show up in the radar profile. Buried pipes and other discrete objects will also be detected.

Depth of penetration is highly site-specific, being dependent upon the properties of the site's soil and rock. The method is limited in depth by attenuation, primarily due to the higher electrical conductivity of subsurface materials. Generally, better overall penetration is achieved in dry, sandy or rocky areas; poorer results are obtained in moist, clayey or conductive soils. However, many times data can be obtained from a considerable depth in saturated materials, if the specific conductance of the pore fluid is sufficiently low. Radar penetration from one to ten meters is common.

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*GPR has been called by various names: ground piercing radar, ground probing radar and subsurface impulse radar. It is also known as an electromagnetic method (which in fact it is); however, since there are many other methods which are also electromagnetic, the term GPR has come into common use today, and will be used herein.

The continuous nature of the radar method offers a number of advantages over some of the other geophysical methods. The continuous vertical profile produced by radar permits much more data to be gathered along a traverse, thereby providing a substantial increase in detail. The high speed of data acquisition permits many lines to be run across a site, and in some cases, total site coverage is economically feasible. Reconnaissance work or coverage of large areas can be accomplished using a vehicle to tow the radar antenna at speeds up to 8 KPH. Very high resolution work or work in areas where vehicles cannot travel can be accomplished by towing the antenna by hand at much slower speeds. Resolution ranges from centimeters to several meters depending upon the antenna (frequency) used.

Initial in-field analysis of the data is permitted by the picture-like quality of the radar results. Despite its simple graphic format, there are many pitfalls in the use of radar, and experienced personnel are required for its operation and for the interpretation of radar data.

Radar has effectively mapped soil layers, depth of bedrock, buried stream channels, rock fractures, and cavities in natural settings.

Radar applications to HWS assessments include:

- Evaluation of the natural soil and geologic conditions.
- Location and delineation of buried waste materials, including both bulk and drummed wastes.
- Location and delineation of contaminant plume areas.
- Location and mapping of buried utilities (both metallic and non-metallic).

The radar system discussed in this document is a readily available impulse radar system. Continuous wave (CW) or other impulse systems exist, but they are generally one of a kind, being experimental instruments, and are not discussed here.

Figure C-1 shows a simplified block diagram of a radar system. The system consists of a control unit, antenna, graphic recorder, and an optional magnetic tape recorder. In operation, the electronics are typically mounted in a vehicle. The antenna is connected by a cable by hand. System power is usually supplied by a small gasoline generator. Various antennas may be used with the system to optimize the survey results for individual site conditions and specific requirements.

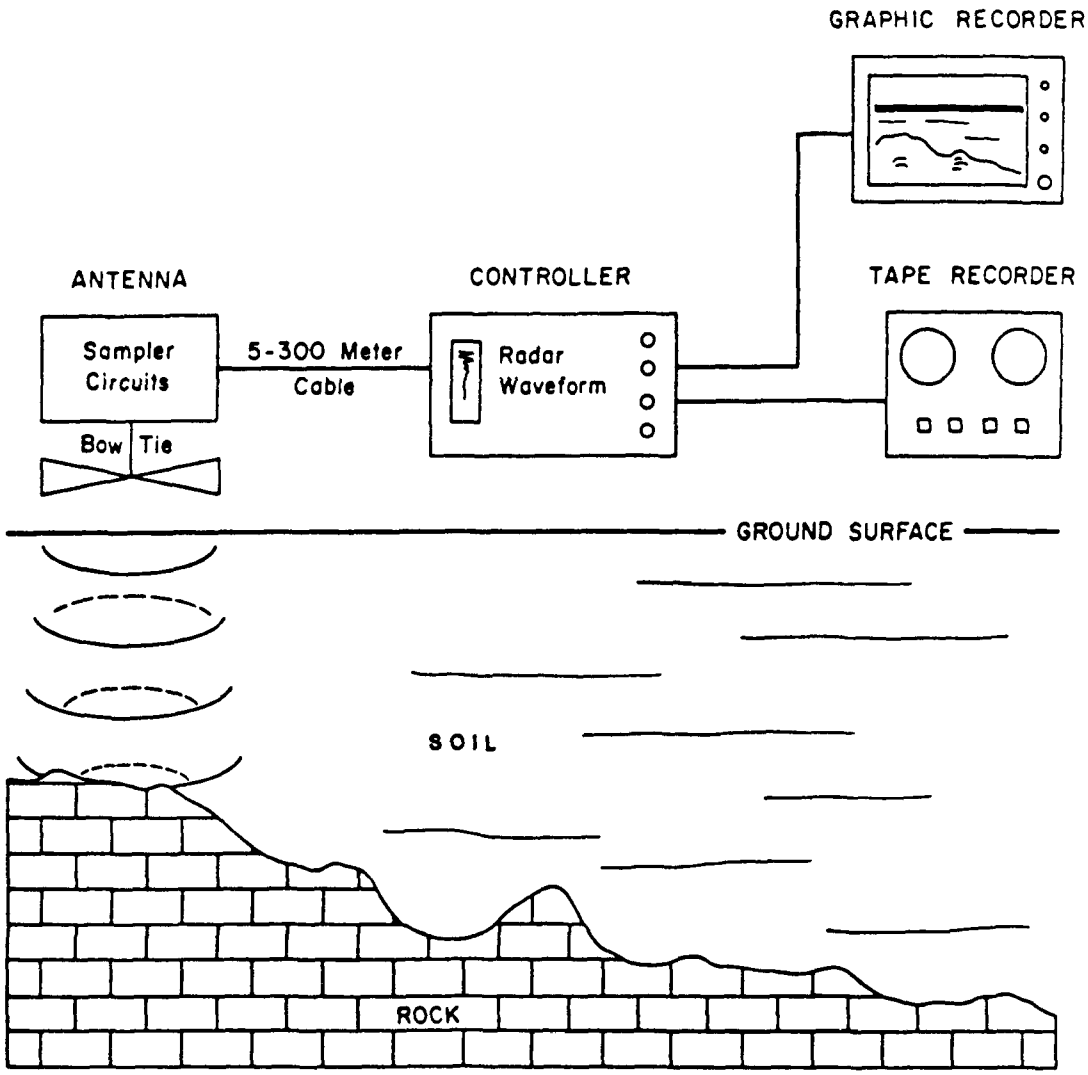

FIGURE C-1

BLOCK DIAGRAM OF GROUND PENETRATING RADAR SYSTEM.
RADAR WAVES ARE REFLECTED FROM SOIL/ROCK INTERFACE.

ELECTROMAGNETICS (EM)*

The electromagnetic (EM) method provides a means of measuring the electrical conductivity of subsurface soil, rock and ground water. Electrical conductivity is a function of the type of soil and rock, its porosity, its permeability, and the fluids which fill the pore space. In most cases, the conductivity (specific conductance) of the pore fluids will dominate the measurement. Accordingly, the EM method is applicable both to assessment of natural geohydrologic conditions and to mapping of many types of contaminant plumes. Additionally, trench boundaries, buried wastes and drums, as well as metallic utility lines can be located with EM techniques.

Natural variations in subsurface conductivity may be caused by changes in soil moisture content, ground water specific conductance, depth of soil cover over rock, and thickness of soil and rock layers. Changes in basic soil or rock types, and structural features such as fractures or voids may also produce changes in conductivity. Localized deposits of natural organics, clay, sand, gravel, or salt rich zones will also affect subsurface conductivity.

Many contaminants will produce an increase in free ion concentration when introduced into the soil or ground water systems. This increase over background conductivity enables detection and mapping of contaminaed soil and ground water at HWS, landfills, and impoundments. Large amounts

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*The term electromagnetic has been used in contemporary literature as a descriptive term for other geophysical methods, including GPR and metal detectors which are based on electromagnetic principles. However, this document will use electromagnetic (EM) to specifically imply the measurement of subsurface conductivites by low-frequency electromagnetic induction. This is in keeping with the traditional use of the term in the geophysical industry from which the EM methods originated. While the authors recognize that there are many electromagnetic systems and manufacturers, the discussion in this section is based solely on instruments which are calibrated to read in electrical conductivity units and which have been effectively and extensively used at hazardous waste sites.

of organic fluids such as diesel fuel can displace the normal soil moisture, causing a decrease in conductivity which may also be mapped, although this is not commonly done. The mapping of a plume will usually define the local flow direction of contaminants. Contaminant migration rates can be established by comparing measurements taken at different times.

The absolute values of conductivity for geologic materials (and contaminants) are not necessarily diagnostic in themselves, but the variations in conductivity, laterally and with depth, are significant. It is this variation which enables the investigator to rapidly find anomalous conditions.

Since the EM method does not require ground contact, measurements may be made quite rapidly. Lateral variations in conductivity can be detected and mapped by a field technique called profiling. Profiling measurements may be made to depths ranging from 0.75 to 60 meters. Instrumentation and field procedures have been developed recently which make it possible to obtain continuous EM profiling data to a depth of 15 meters. The data is recorded using strip chart and magnetic tape recorders. This continuous measurement allows increased rates of data acquisition and improved resolution for mapping small geohydrologic features. Further, recorded data enhanced by computer processing has proved invaluable in the evaluation of complex hazardous waste sites. The excellent lateral resolution obtained from EM profiling data has been used to advantage in efforts to outline closely-spaced burial pits, to reveal the migration of contaminants into the surrounding soil, or to delineate fracture patterns.

Vertical variations in conductivity can also be detected by the EM method. A station measurement technique called sounding is employed for this purpose. Data can be acquired from depths ranging from 0.75 to 60 meters. This range of depth is achieved by combining results from

a variety of EM instruments, each requiring different field application techniques. Other EM systems are capable of sounding to depths of 1,000 feet or more, but have not yet been used at HWS and are not adaptable to continuous measurements.

Profiling is the most effective use of the EM method. Continuous profiling can be used in many applications to increase resolution, data density, and permit total site coverage at critical sites.

At HWS applications of EM can provide:

- Assessment of natural geohydrologic conditions;
- Locating and mapping of burial trenches and pits containing drums and/or bulk wastes;
- Locating and mapping of plume boundaries;
- Determination of flow direction in both unsaturated and saturated zones;
- Rate of plume movement by comparing measurements taken at different times; and
- Locating and mapping of utility pipes and cables which may affect other geophysical measurements, or whose trench may provide a permeable pathway for contaminant flow.

This document discusses only those instruments which are designed and calibrated to read directly in units of conductivity.

The basic principle of operation of the electromagnetic method is shown in Figure C-2. The transmitter coil radiates an electromagnetic field which induces eddy currents in the earth below the instrument. Each of these eddy current loops, in turn, generates a secondary electromagnetic field which is proportional to the magnitude of the current flowing within that loop. A part of the secondary magnetic field from each loop is intercepted by the receiver coil and produces an output voltage which (within limits) is linearly related to subsurface

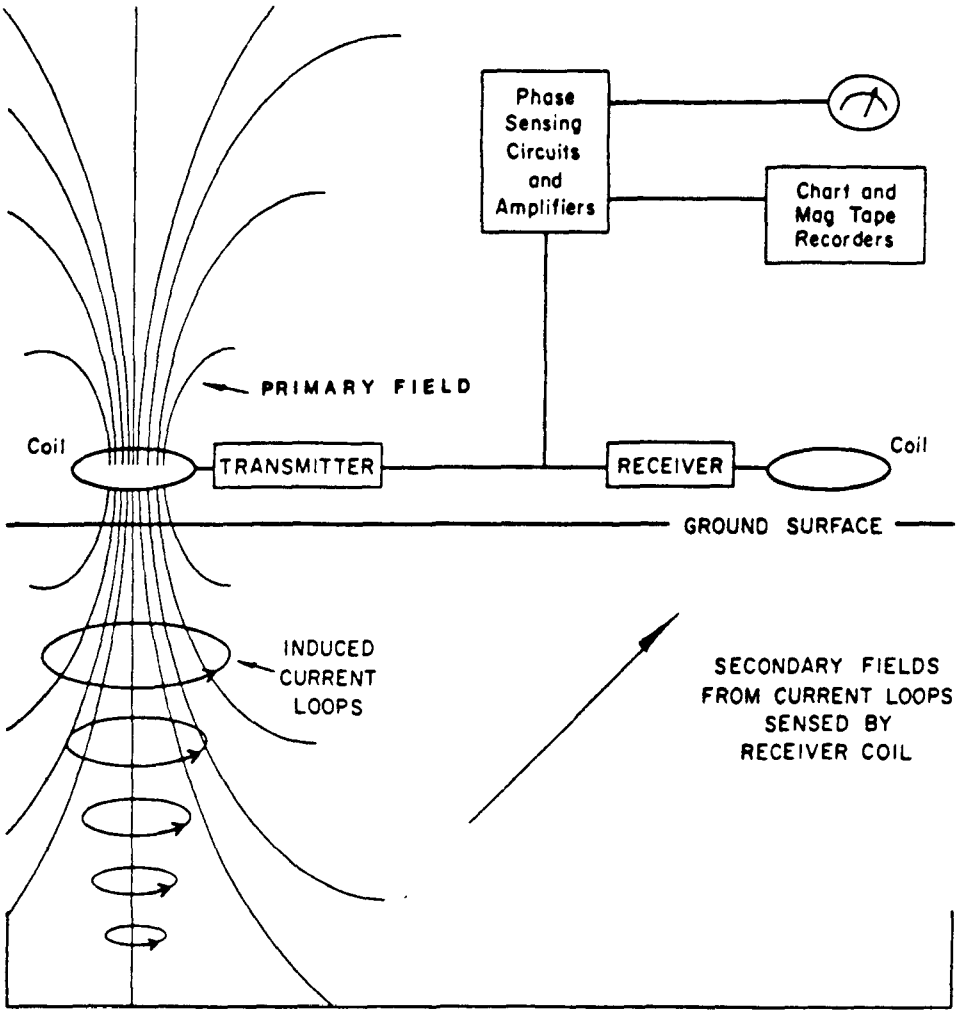


FIGURE C-2

BLOCK DIAGRAM SHOWING EM PRINCIPLE OF OPERATIONS

conductivity. This reading is a bulk measurement of conductivity; the cumulative response to subsurface conditions ranging all the way from the surface to the effective depth of the instrument.

The sampling depth of EM equipment is related to the instrument's coil spacing. Instruments with coil spacings of 1, 4, 10, 20, and 40 meters are commercially available. The nominal sampling depth of an EM system is taken to be approximately 1.5 times the coil spacing. Accordingly, the nominal depth of response for the coil spacings given above is 1.5, 6, 15, 30, and 60 meters.

The conductivity value resulting from an EM insrument is a composite, and represents the combined effects of the thickness of soil or rock layers, their depths, and the specific conductivities of the materials. The instrument reading represents the combination of these effects, extending from the surface to the arbitrary depth range of the instrument. The resulting values are influenced more strongly by shallow materials than by deeper layers, and this must be taken into consideration when interpreting the data. Conductivity conditions from the surface to the instrument's nominal depth range contribute about 75 percent of the instrument's response. However, contributions from highly conductive materials lying at greater depths may have a significant effect on the reading.

EM instruments are calibrated to read subsurface conductivity in millimhos per meter (mm/m). These units are related to resistivity units in the following manner:

1000/(millimhos/meter) = 1 ohm-meter
1000/(millimhos/meter) = 3.28 ohm-feet
1 millimho/meter = 1 siemen

The advantage of using millimhos/meter is that the common range of resistivities from 1 to 1000 ohm-meters is covered by the range of conductivities from 1000 to 1 millimhos/meter. This makes conversion of units relatively easy.

Most soil and rock minerals, when dry, have very low conductivities (Figure C-3). On rare occasions, conductive minerals like magnetite, graphite and pyrite occur in sufficient concentrations to greatly increase natural subsurface conductivity. Most often, conductivity is overwhelmingly influenced by water content and the following soil/rock parameters:

- The porosity and permeability of the material;
- the extent to which the pore space is saturated;
- the concentration of dissolved electrolytes and colloids in the pore fluids; and
- the temperature and phase state (i.e., liquid or ice) of the pore water.

A unique conductivity value cannot be assigned to a particular material, because the interrelationships of soil composition, structure and pore fluids are highly variable in nature.

In areas surrounding HWS, contaminants may escape into the soil and the ground-water system. In many cases, these fluids contribute large amouns of electrolytes and colloids to both the unsaturated and saturated zones. In either case, the ground conductivity may be greatly affected, sometimes increasing by one to three orders of magnitude above background values. However, if the natural variations in subsurface conductivity are very low, contaminant plumes of only 10 to 20 percent above background may be mapped.

In the case of spills involving heavy nonpolar, organic fluids such as diesel oil, the normal soil moisture may be displaced, or a sizeable pool of oil may develop at the water table. In these cases, subsurface conductivites may decrease causing a negative EM anomaly. (A negative anomaly will occur only if substantial quantities of nonconductive contaminants are present.)

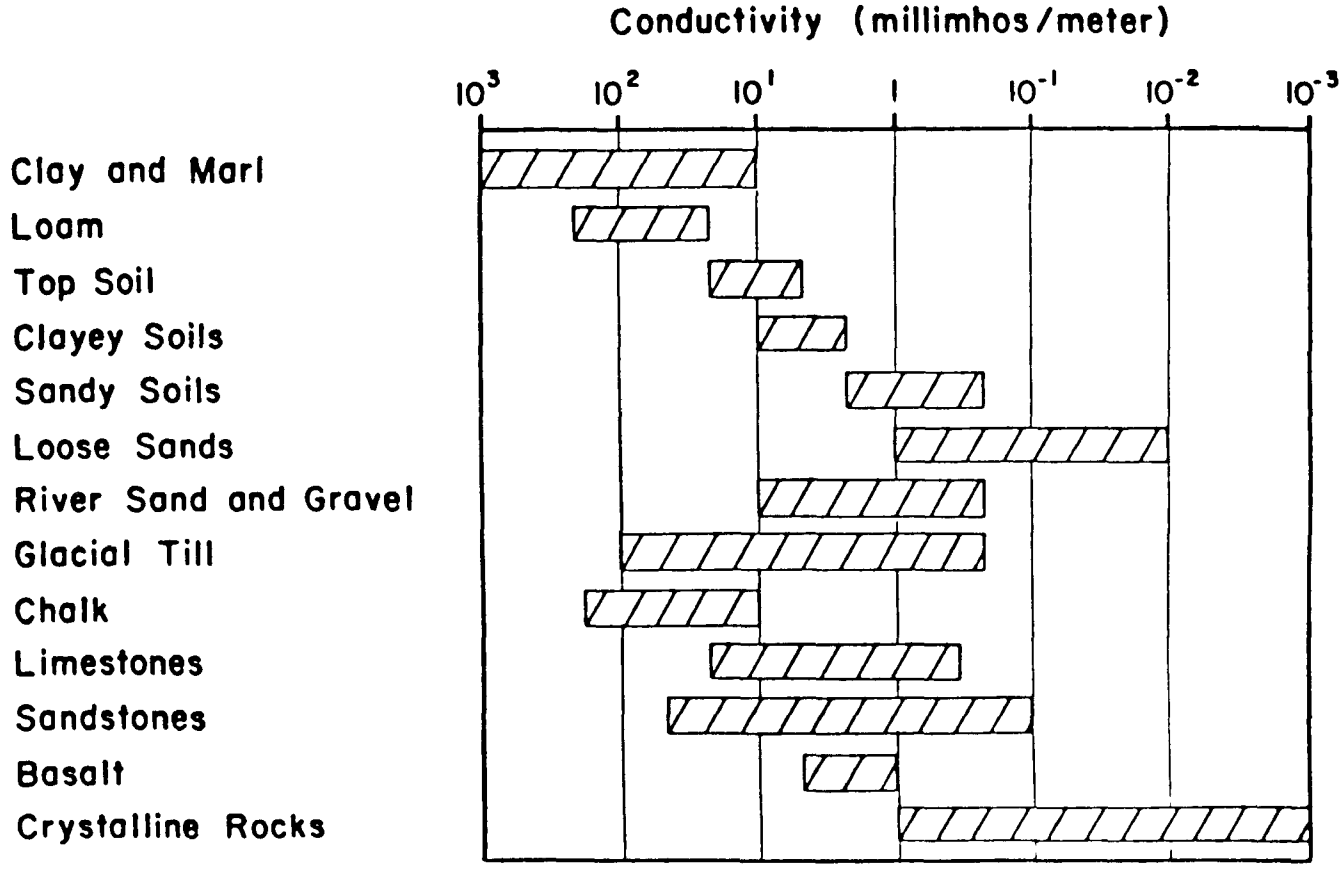


FIGURE C-3

RANGE OF ELECTRICAL CONDUCTIVTIES IN NATURAL SOIL AND ROCK.
(Modified After Culley et al.)

RESISTIVITY

The resistivity method is used to measure the electrical resistivity of the geohydrologic section which includes the soil, rock, and ground water. Accordingly, the method may be used to assess lateral changes and vertical cross sections of the natural geohydrologic settings. In addition, it can be used to evaluate contaminant plumes and locate buried wastes at hazardous waste sites.

Application of the method requires that an electrical current be injected into the ground by a pair of surface electrodes. The resulting potential field (voltage) is measured at the surface between a second pair of electrodes. The subsurface resistivity can be calculated by knowing the electrode separation and geometry of the electrode positions, applied current, and measured voltage. (Resistivity is the reciprocal of conductivity, the parameter directly measured by the EM technique.)

In general, most soil and rock minerals are electrical insulators (highly resistive); hence the flow of current is conducted primarily through the moisture-filled pore spaces within the soil and rock. Therefore, the resistivity of soils and rocks is predominantly controlled by the porosity and permeability of the system, the amount of pore water, and the concentration of dissolved solids in the pore water.

The resistivity technique may be used for "profiling" or "sounding." Profiling provides a means of mapping lateral changes in subsurface electrical properties. This field technique is well suited to the delineation of contaminant plumes and the detection and location of changes in natural geohydrologic conditions. Sounding provides a means of determining the vertical changes in subsurface electrical properties. Interpretation of sounding data provides the depth and thickness of subsurface layers having different resistivities. Commonly up to four layers may be resolved with this technique.

Applications of the resistivity method at hazardous waste sites include:

- Locating and mapping contaminant plumes;
- Establishing direction and rate of flow of contaminant plumes;
- Defining burial sites by
  - locating trenches,
  - defining trench boundaries,
  - determining the depths of trenches; and
- Defining natural geohydrologic conditions such as
  - depth to water table or to water-bearing horizons,
  - depth to bedrock, thickness of soil, etc.

Most dry mineral components of soil and rock are highly resistive except for a few metallic ore minerals. Under most circumstances, the amount of soil/rock moisture dominates the mesurement greatly reducing the resistivity value. Current flow is essentially electrolytic, being conducted by water contained within pores and cracks. A few minerals like clays actually contribute to conduction. In general, soils and rocks become less resistive as:

- Moisture or water content increases;
- Porosity and permeability of the formation increases;
- Dissolved solid and colloid (electrolyte) content increases; and
- Temperature increases (a minor factor, except in areas of permafrost).

Figure C-4 illustrates the range of resistivity found in commonly-occurring soils and rocks. Very dry sand, gravel, or rock as encountered in arid or semi-arid areas will have very high resistivity. As the empty pore spaces fill with water, resistivity will drop. Conversely, the resistivity of earth materials which occur below the water table but lack pore space (such as massive granite and limestone) will be relatively high and will be primarily controlled by current conduction along cracks

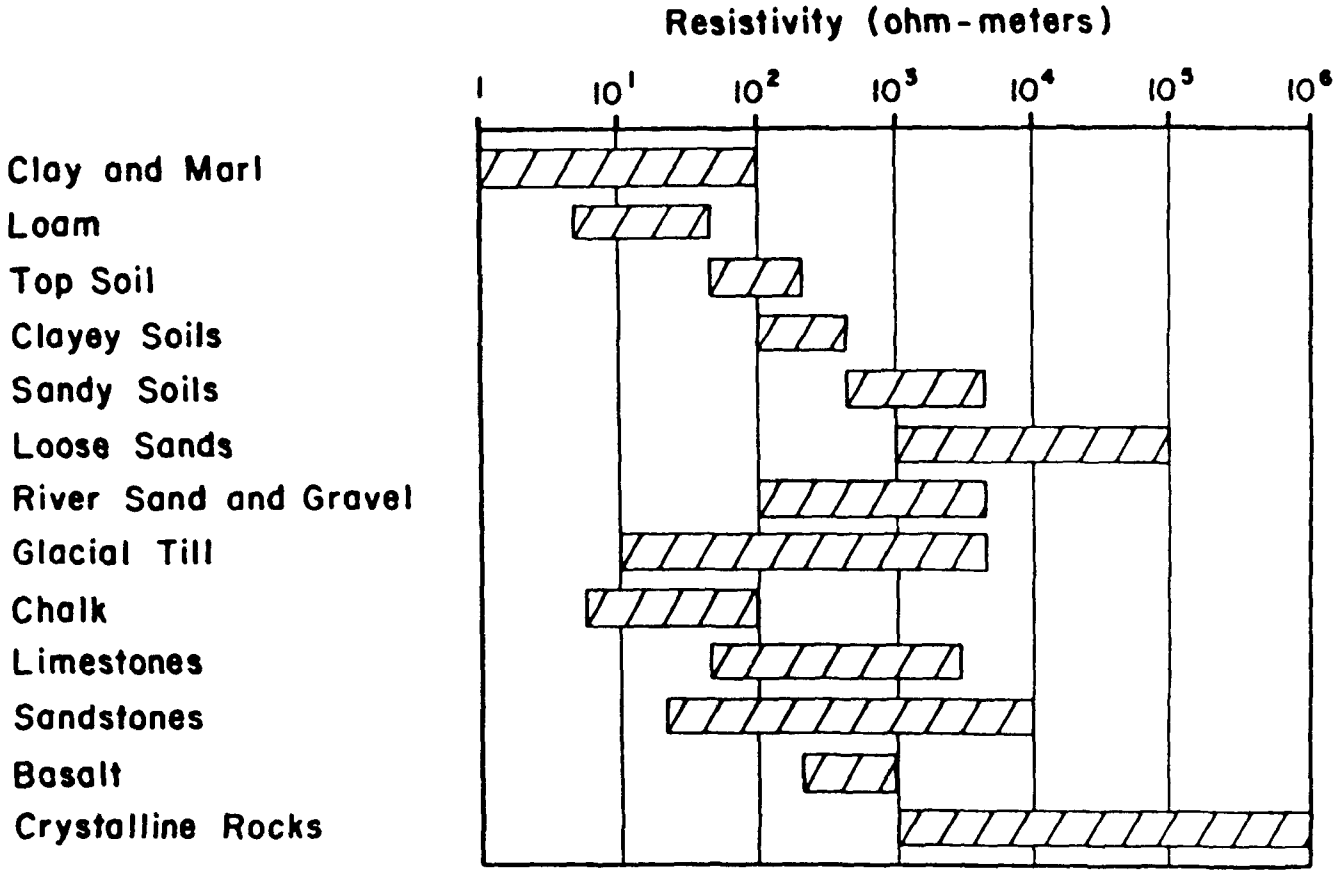


FIGURE C-4

RANGE OF RESISTIVITIES IN COMMONLY-OCCURRING SOILS AND ROCKS
(Modified after Culley et al.)

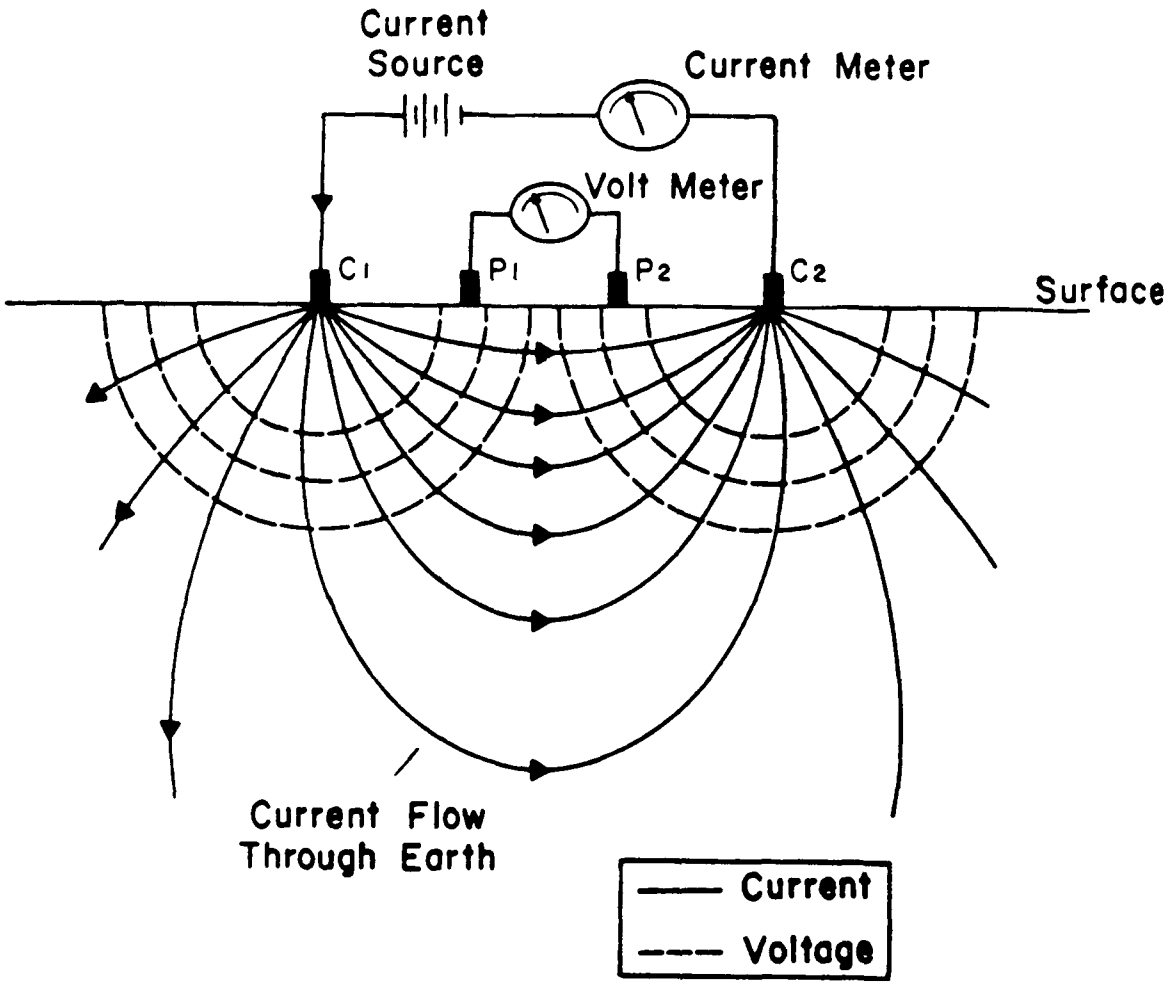
and fissures in the formation. Clayey soils and shale layers generally have low resistivity values, due to their inherent moisture and clay mineral content. In all cases, an increase in the electrolyte, total dissolved solids (TDS) or specific conductance of the system will cause a marked increase in current conduction and a corresponding drop in resistivity. This fact makes resistivity an excellent technique for the detection and mapping of conductive contaminant plumes.

It is important to note that no geologic unit or plume has a unique or characteristic resistivity value. Its measured resistivity is dependent on the natural soil and rock present, the relative amount of moisture, and its specific conductance. However, the natural resistivity value of a particular formation or unit may remain within a small range for a given area.

Figure C-5 is a schematic diagram showing the basic principles of operation. The resistivity method is inherently limited to station measurements, since electrodes must be in physical and electrical contact with the ground. This requirement makes the resistivity method slower than a noncontract method such as EM.

Many different types of electrode spacing arrays may be used to make resistivity measurements; the more commonly used include Wenner, Schlumberger, and dipole-dipole. Due to its simple electrical geometry, the Wenner array will be used as an example in the remainder of this section; however, its use is not necessarily recommended for all site conditions. The choice of array will depend upon project objectives and site conditions and should be made by an experienced geophysicist.

Using the Wenner array, potential electrodes are centered on a line between the current electrodes; and equal spacing between electrodes is maintained. These "A" spacings used during HWS evaluation commonly range from 0.3 meter to more than 100 meters. The depth of measurement is related to the "A" spacing and may vary depending upon the geohydrology.



Apparent resistivity values using the Wenner array are calculated from the measured voltage and current and the spacing between electrodes as shown in the following equation:

$$a = 2\ A\ V/I$$

where a = apparent resistivity (ohm-meters or ohm-feet)
A = "A" spacing (meters or feet)
V = potential (volts)
I = current (ampers)

FIGURE C-5

DIAGRAM SHOWING BASIC CONCEPT OF RESISTIVITY MEASUREMENT

Current is injected into the ground by the two outer electrtodes which are connected by cables to a DC or low-frequency AC current source. (If true DC is used, special nonpolarizing electrodes must be used.) The distribution of current within the earth is influenced by the relative resistivity of subsurface features. For example, homogenous subsurface conditions will have the uniform current flow distribution and will yield a resistivity value characteristic of the sampled section. On the other hand, current distribution may be pulled downward by a low-resistivity (lower than that of the surface layer, due to the influence of the lower resistivity material at depth.

The current flow within the subsurface produces an electric field with lines of equal potential, perpendicular to the lines of current (Figure C-5). The potential field is measured by a voltmeter at the two inner electrodes.

SEISMIC REFRACTION

Seismic refraction techniques are used to determine the thickness and depth of geologic layers and the travel time or velocity of seismic waves within the layers. Seismic refraction methods are often used to map depths to specific horizons such as bedrock, clay layers, and water table. In addition to mapping natural features, other secondary applications of the seismic method include the location and definition of burial pits and trenches at HWS.

Seismic waves transmitted into the subsurface travel at different velocites in various types of soil and rock and are refracted (or bent) at the interfaces between layers. This refraction affects their path of travel. An array of geophones on the surface measures the travel time of the seismic waves from the source to the geophones at a number of spacings. The time required for the wave to complete this path is measured, permitting a determination to be made of the number of layers, the thicknesses of the layers and their depths, as well as the seismic velocity of each layer. The wave velocity in each layer is directly related to its material properties such as density and hardness.

A seismic source, geophones, and a seismograph are required to make the measurments. The seismic source may be a simple sledge hammer with which to strike the ground. Explosives and any other seismic sources may be utilized for deeper or special applications. Geophones implanted in the surface of the ground translate the received vibrations of seismic energy into an electrical signal. This signal is displayed on the seismograph, permitting measurement of the arrival time of the seismic wave. Since the seismic method measures small ground vibrations, it is inherently susceptible to vibration noise from a variety of natural and cultural sources.

At HWS, seismic refraction can be used to define natural geohydrologic conditions, including thickness and depth of soil and rock layers,

their composition and physical properties, and depth to bedrock or water table. It can also be used for the detection and location of anomalous features, such as pits and trenches, and for evaluation of the depth of burial sites or landfills. (In contrast to seismic refraction, the reflection technique, which is common in petroleum exploration, has not been applied to HWS. This is primarily because the method cannot be effectively utilized at depths of less than 20 meters.)

Although a number of elastic waves are inherently associated with the method, conventional seismic refraction methods that have been employed at HWS are concerned only with the compressional wave (primary or P-wave). The compressional wave is also the first to arrive which makes its identification relatively easy.

These waves move through subsurface layers. The density of a layer and its elastic properties determine the speed or velocity at which the seismic wave will travel through the layer. The porosity, mineral composition, and water content of the layer affect both its density and elasticity. Table C-1 lists a range of compressional wave velocities in common geologic materials. It can be seen from these tables that the seismic velocities for different types of soil and rock overlap, so knowing the velocities of these layers alone does not permit a unique determination of their composition. However, if this knowledge is combined with geologic information, it can be used intelligently to identify geologic strata.

In general, velocity values are greater for:

- dense rocks than light rocks.
- older rocks than younger rocks.
- igneous rocks than sedimentary rocks.
- solid rocks than rocks with cracks or fractures.

TABLE C-1

RANGE OF VELOCITIES FOR COMPRESSIONAL WAVES IN SOIL AND ROCK
(After Jakosky, 1950)

Material	Velocity (Meters/sec)
Weathered surface material	305 - 610
Gravel or dry sand	465 - 915
Sand (wet)	610 - 1,830
Sandstone	1,830 - 3,970
Shale	2,750 - 4,270
Chalk	1,830 - 3,970
Limestone	2,140 - 6,100
Salt	4,270 - 5,190
Granite	4,380 - 5,800
Metamorphic rocks	3,050 - 7,020

- unweathered rocks than weathered rocks.
- consolidated sediments than unconsolidated sediments.
- water-saturated unconsolidated sediments than dry unconsolidated sediments.
- wet soils than dry soils.

Figure C-6 shows a schematic view of a 12-channel seismic system in use and the compessional waves traveling through a two-layered system of soil over bedrock. A seismic source produces seismic waves which travel in all directions into the ground. The seismic refraction method, however, is concerned only with the waves shown in Figure C-6. One of these waves, the direct wave, travels parallel to the surface of the ground. A seismic sensor (geophone) detects the direct wave as it moves along the surface layer. The time of travel along this path is related to the distance between the sensor and the source and the material composi.., the layer.

If a denser layer with a higher velocity, such as bedrock, exists below the surface soils, some of the seismic waves will be bent or refracted as they enter the bedrock. This phenomenon is similar to the refraction of light rays when light passes from air into water and is described by Snell's law. One of these refracted waves, crossing the interface at a critical angle, will move parallel to the top of the bedrock at the higher velocity of the bedrock. The seismic wave travelling along this interface will continually release energy back into the upper layer by refraction. These waves may then be detected in the surface at various distances from the source (Figure C-6).

Beyond a certain distance (called the critical distance), the refracted wave will arrive at a geophone before the direct wave. This happens even though the refraction path is longer, because a sufficient portion of the wave's path occurs in the higher velocity bedrock.

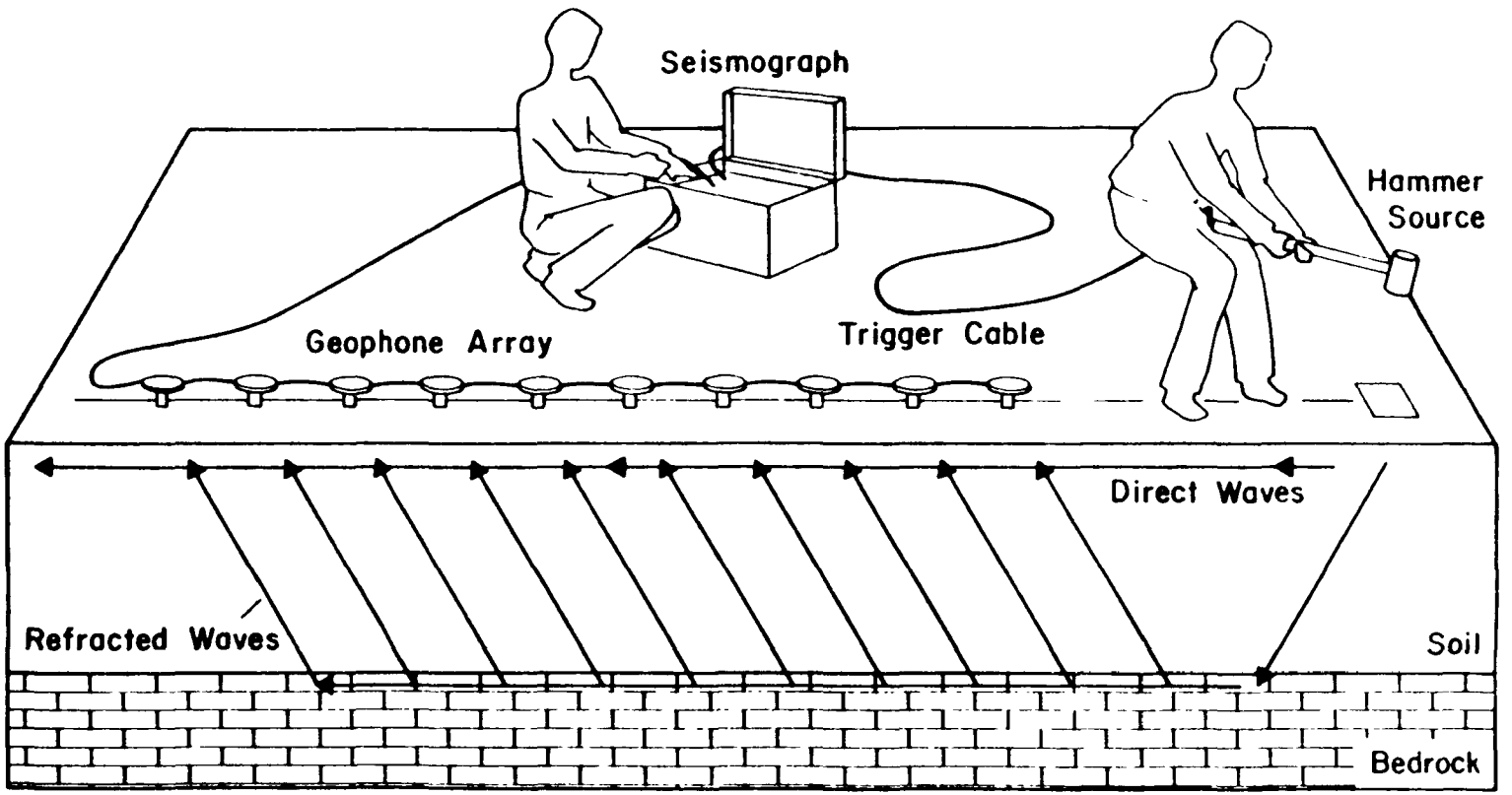


FIGURE C-6

FIELD LAYOUT OF A 12-CHANNEL SEISMOGRAPH SHOWING THE PATH
OF DIRECT AND REFRACTED SEISMIC WAVES IN A TWO-LAYER SOIL/ROCK SYSTEM

Measurement of these first arrival times and their distances from the source permits calculation of layer velocities, thicknesses and bedrock depth. Application of the seismic method is generally limited to resolving three to four layers.

The preceding concepts are based upon the fundamental assumptions that:

1. Seismic velocities of geologic layers must increase with depth. This requirement is generally met at most sites.

2. Layers must be of sufficient thickness to permit detection.

3. Sesimic velocities of layers must be sufficiently different to permit resolution of individual layers.

There is no way to establish from the seismic data alone whether a hidden layer (due to 1 and 2 above) is present; therefore, correlation to a boring log or geologic knowledge of the site must be used to provide a cross check. If such data is not available, the interpreter must take this into consideration in evaluating the data.

Variations in the thickness of the shallow soil zone, inhomogeneities within a layer, or irregularities between layers will often produce geologic scatter or anomalies in the data. This data scatter is useful information, revealing some of the natural variability of the site. For example, a zone containing a number of large boulders in a glacial till deposit will yield inconsistent arrival times, due to variable seismic velocities between the boulders and the clay matrix. An extremely irregular bedrock surface as is often encountered in karst limestone terrain, likewise, will produce scatter in the seismic data.

The seismic refraction technique uses the equipment shown in Figure C-6. The seismic source is often a simple ten-pound sledge hammer or drop weight which strikes the ground, generating a seismic impulse. Explosives and a variety of other excitation sources are also used for the greater energy levels rquired for information at deeper layers.

Seismic waves are detected by geophones implanted in the surface of the ground at various distances from the source. The geophone converts the seismic wave's mechanical vibration into an electrical signal in a manner similar to that of a microphone. This signal is carried by cable to the seismograph.

The seismograph is an instrument which electronically amplifies and then displays the received seismic signal from the geophone. The display may be a cathode ray tube, a single-channel strip chart, or a thermal printer, commonly used on multi-channel systems. The identification and measurement of the arrival time of the first wave from the seismic source is obtained from this presentation. The time is measured in milliseconds, with zero time or start of trace intitiated by the source, which provides a trigger signal to the seismograph.

Travel time is plotted against source-to-geophone distance producing a time/distance (T/D) plot.

- The number of line segments indicates the number of layers.
- The slope of each line segment is inversely proportional to the seismic velocity in the corresponding layer.
- Break points in the plot (critical distance, X) are used with the velocities to calculate layer depth.

The seismic line must be centered over the required information area and overall line length must be three to five times the maximum depth of interest. Resolution is determined by the geophone spacing. Spacings of 3 to 15 meters are commonly used; however, closer spacings may be necessary for very high resolution of shallow geologic sections.

ORGANIC VAPOR/SOIL GAS ANALYSIS

Organic contaminant vapors present in the vadose zone may be assessed using a variety of techniques. One method is the use of organic vapor detectors such as OVAs, explosimeters and Draeger tubes to detect volatile organics. Two major strategies may be adopted, jointly or separately, depending on whether wells are in place at the time of investigation:

1. Monitoring the well head space.

2. Monitoring the vadose zone directly by lowering a probe into shallow, hand-augurred holes.

Gaseous sample constituents can be identified in detail using a portable gas chromatograph. An alternative methodology is an analysis of soil gas. Under this methodology, a ten-liter sample of soil gas is drawn through a probe which is mechanically driven into the ground to a depth of about ten feet. Two cubic centimeters of gas are injected into a portable gas chromatograph to ascertain its organic constituents. It is useful to know what class of organics is present in order to choose the gas chromatography method which provides the highest resolution, i.e., photoionization/aromatics, electron-capture/halogenated hydrocarbons. The 2 cc sample is injected by syringe to the gas chromatograph through a dewatering napthalon tubing. This method is limited in two major ways:

1. Coarse, pebbly/cobbly strata prevent penetration of the probe, in which case holes may be hand-augured.

2. The presence of shallow, saturated zones, especially low permeability formations severely restricts the development of a gas envelope and thus limits the applicability of the method. Soil gas analysis is a vadose zone monitoring technique and cannot be used effectively where the water table or saturation is shallow.

Organic vapor/soil gas analysis is most effective when used in conjunction with other investigative methods. Although it provides an

analysis of the volatile organics and thus provides a preliminary characterization of the subsurface contamination, it is limited to a fraction of the total hazardous constituents and needs augmentation.

CHAPTER 3

DRAFT

GROUND WATER

I. INTRODUCTION

The essential objective of the PA/SI in relation to ground water is to determine for each solid waste management unit at the RCRA facility whether or not the unit has released or is likely to have released hazardous wastes or constitutents to the uppermost aquifer. For units which have identified releases, or for which there is a substantial likelihood of a release, further investigations will be required of the owner/operator to actually determine the extent of a release(s) and/or to characterize the release and begin the development of a program of corrective measures.

The determination as to the need for further ground water investigations at a unit must be made on a case-by-case basis, considering the various relevant factors which are unique to each unit. For some units the potential for ground water contamination will not be difficult to assess, and the determination of need for further investigations will be relatively straightforward. For other units, however, the potential for contamination will be less than obvious, and the determination will necessarily be based on judgement of the individuals conducting and reviewing the results of the PA/SI, combined in some cases with actual sampling and analysis.

In making determinations from the PA/SI as to the need for additional ground water investigations, it must be recognized that comprehensive ground water investigations will typically require a considerable investment of time and resources for both the owner/operator in conducting the actual investigations, and for the reviewing agency in reviewing technical plans, hydrogeologic data and analytical results. This economic and resource concern must be balanced against the essential mandate of protecting human health and the environment; i.e., the need to identify ground water contamination and begin the process of cleaning up that contamination.

It is therefore the dual function of the PA/SI to conservatively identify situations which merit additonal ground water investigations, and at the same time to avoid requiring unnecessary investigations.

II. UNITS OF CONCERN

Each solid waste managment unit at the facility should be evaluated for its potential to be causing or to have caused ground water contamination. The exception to this is for "regulated units"; i.e., landfills, surface impoundments, waste piles and land treatment units which received wastes after July 26, 1983. Releases to ground water from regulated units must be addressed in permits according to the requirements of Subpart F of Part 264 (or cor-

responding State regulations), rather than through the §3004(u) authority. Thus, investigation of ground water contamination from regulated units will not be part of the PA/SI.

III. EXISTING GROUND WATER MONITORING SYSTEMS

An assessment should be made in the preliminary assessment and the site investigation of any existing ground water monitoring systems at the facility which may be capable of detecting releases from solid waste management units (swmus) at the facility. Some swmus may have a monitoring system installed specifically for the unit. In other cases a monitoring system placed at a regulated unit(s) or other units may also be capable of monitoring the swmu. An example of this might be a closed landfill cell surrounded by several active cells.

If it is determined from the preliminary assessment that an existing system is installed at a swmu, that system should be carefully examined for its technical adequacy [i.e., to what extent does it meet the general performance standard in §264.97(a)]. Information required to assess the adequacy of an existing monitoring would include: detailed information on geology and hydrogeology at the unit, waste characteristics, background and downgradient water quality data, boring logs, well design information, and sampling and analytical procedures.

In evaluating whether a monitoring system which was installed at another unit(s) (such as a regulated unit) may be capable of also detecting releases from a swmu, particular attention must be paid to such features as proximity of the swmu to the regulated unit, the direction of ground water flow, well locations in relation to the swmu, and whether or not the appropriate constituents are being monitored for the wastes in the swmu. Figure 3-1 provides a graphic illustration of three different situations in which existing monitoring systems at regulated units may or may not also adequately monitor a swmu.

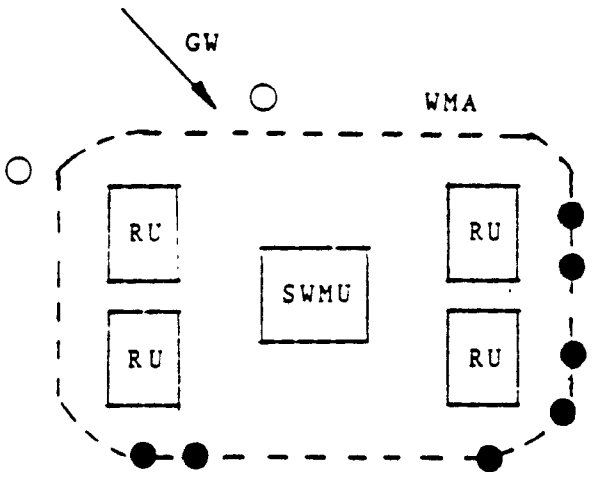
If an existing ground water monitoring system and program of sampling and analysis is determined to be adequate to detect releases to ground water from the solid waste management unit, and recent analytical data (e.g., within the past three months) indicate that there have been no releases, no further investigations should be required of the owner/operator. If the existing system is not adequate, and the investigator determines that there is a likelihood of ground water releases from the unit (see below), the owner/operator should be required to conduct additional investigations as necessary, and install additional monitoring wells and/or analyze for more or different constituents, as part of the remedial investigation phase. Phase II of the technical guidance will address design of appropriate monitoring systems and analytical programs for solid waste management units.

There may be situations where existing monitoring systems are adequate to detect contamination from the unit and no contamination

FIGURE 3-1

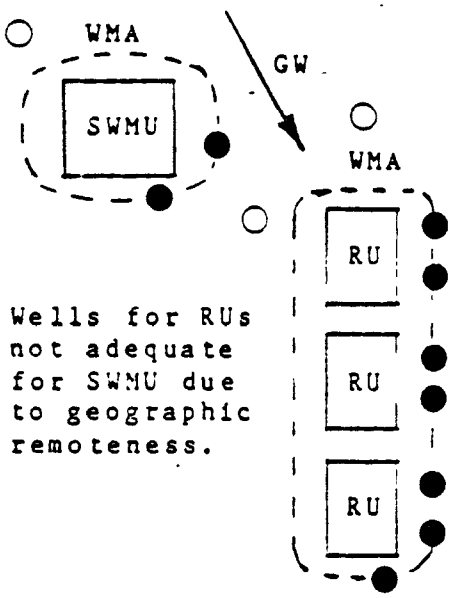
MONITORING WELL LOCATION

Case One



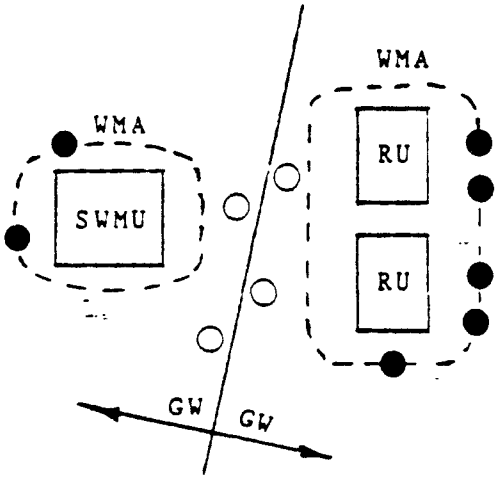
No new wells may be needed for SWMU if all units are closely spaced.

Case Two



Wells for RUs not adequate for SWMU due to geographic remoteness.

Case Three



New wells needed for SWMU due to presence of a ground-wter divide.

Key

SWMU = solid waste management unit
RU = regulated unit
WMA = waste management area
○ = background monitoring well
● = downgradient monitoring well
GW = ground-water flow direction

Note: Drawings not to scale.

has yet been evidenced, but based on the type of unit, its design, the wastes managed or other factors, there is a likelihood of a ground water release in the future. In such situations, the owner/operator should be required (as a permit condition, if the facility is permitted) to maintain the system and carry out an appropriate sampling/analysis program.

IV. UNIT ASSESSMENT FOR GROUND WATER

Each swmu at the facility which is not adequately monitored by an existing ground water monitoring system, and which contains or has contained wastes capable of releasing hazardous constituents to ground water, must be assessed to determine the likelihood of ground water releases, and thus the need for further ground water investigations. This unit assessment will be based on the information gathered in the preliminary assessment, inspection of the unit during the site inspection, and other information generated as necessary. The unit assessment should be made based on the following:

- o An understanding of the overall potential of the unit to cause ground water releases;
- o An understanding of the primary mechanisms by which releases may occur from the unit;
- o An assessment of unit-specific factors which, singly or in combination, indicate the relative likelihood of ground water releases from the unit; and
- o Exposure potential.

A discussion of each of these elements of the unit assessment follows.

V. POTENTIAL FOR AND MECHANISMS OF GROUND WATER RELEASES

The general potential for ground water contamination from a swmu is, to a great extent, dependent upon the nature and function of the unit. This is reflected in RCRA hazardous waste regulations. For example, ground water monitoring is not a requirement for container storage units, while with few exceptions monitoring is required for landfills. It is thus necessary, in making an assessment of the likelihood of ground water releases from a unit, to first consider the relative potential of the unit to release. Table 3-1 presents a generalized ranking, in rough descending order, of the different types of swmus and their overall potential for causing ground water contamination, and a listing of the most common mechanisms by which ground water releases can occur from each unit type. Section VIII of this chapter also provides for each type of unit examples of units which would and which would not merit further ground water investigations.

TABLE 3-1. UNIT POTENTIAL FOR GROUND WATER RELEASES AND MECHANISMS OF RELEASE

Unit Type	Release Mechanism
Class IV Injection Well	o Wastes are injected directly into the subsurface o Escape of wastes from well casing o Spillage or other releases from waste handling operations at the well head
Surface Impoundment	o Migration of wastes/constituents through liners (if present) and soils o Damage to liners o Overflow events and other spillage outside the impoundment o Seepage through dikes to surface and/or subsurface
Landfill	o Migration of leachate through liners (if present) and soils o Precipitation runoff to surrounding surface and subsurface o Spills and other releases outside the containment area from loading/unloading operations
Land Treatment Unit	o Migration of constituents through the unsaturated zone o Precipitation runoff to surrounding surface and subsurface
Class I Injection Well	o Migration of wastes from the injection zone through confining geologic strata to upper aquifers o Escape of wastes from well casings o Spillage or other releases from waste handling operations at the well head
Underground Tank	o Tank shell failure o Leaks from piping and ancillary equipment o Spillage from coupling/uncoupling operations o Overflow
Waste Pile	o Leachate migration through liner (if present) and soils o Precipitation runoff to surface/subsurface
In-ground Tanks	o Overflow o Tank wall failure o Leaks from ancillary equipment o Spillage from coupling/uncoupling operations

Container Storage Unit	o Spills from containers/container failure and subsequent migration through liners (if any) and soils o Precipitation runoff from storage areas
Above Ground Tank	o Overflow o Shell failure o Leaks from ancillary equipment o Coupling/uncoupling operations
Incinerator	o Spillage or other releases fro waste handling/ preparation activities o Spills due to mechanical failure

It should be understood that Table 3-1 is intended only to provide a very theoretical sense of the relative potential of units to cause ground water releases. Unit-specific factors (as described below) must be evaluated in determining whether further ground water investigations are needed for a particular unit.

VI. EVALUATION OF UNIT-SPECIFIC FACTORS

The following unit-specific factors should be evaluated in assessing a swmu for ground water releases:

A. Unit design
B. Site geology/hydrogeology
C. Waste characteristics
D. Operational history
E. Physical integrity of the unit
F. Evidence of contamination

In making a unit assessment attention should be paid to how two or more of the above factors may combine to suggest whether or not releases are have occurred. For example, examination of an above ground tank may reveal evidence of soil contamination ("F" above) adjacent to the unit. However, the operational history of the unit ("D") reveals that the tank has been in operation for only six months, the tank is in good condition ("E"), and records indicate that the contamination occurred as a single, relatively small overflow event. In addition, the waste ("C") is known to be relatively non-mobile, and clay soils underlie the facility, with an uppermost aquifer that is quite deep ("B"). In this situation, the likelihood of a release to ground water is very remote, and further investigations would not be indicated.

The factors listed above are discussed in more detail, as follows:

A. Unit Design. Focus of evaluation:

- o Does the unit have engineered features designed to prevent releases to ground water?
- o Are such features adequate?
- o Capacity and dimensions

Examples of design features of concern for specific types of units are given in Section VIII of this chapter.

B. Site Geology/Hydrogeology. Focus of evaluation:

- o What is the potential for releases of any wastes or constituents from the unit to contaminate ground water, based on soil characteristics, geologic formations, climate, aquifer location, subsurface drainage patterns, seasonal variations and other factors?

This evaluation should rely on standard geologic and hydrogeologic principles, using whatever information is available on the subsurface characteristics of the site. If information on subsurface characteristics indicates that the potential for contamination of ground water is very low (e.g., facility overlying thick formation of low permeability clay, in an arid area with a very deep aquifer), further ground water investigations would be needed only for units for which other factors indicate a very high potential for causing contamination (e.g., a Class IV injection well). Likewise, if ground water is particularly vulnerable (e.g., facility overlies sandy soils and a shallow aquifer in a high recharge area), a correspondingly low threshold would be applied in determining the need for additonal ground water investigations.

Where very little is known of a facility's subsurface characteristics, other unit-specific factors will need to be weighed more heavily in making the ground water assessment. In many cases, evaluation of unit design and waste characteristics alone may be sufficient to determine that ground water investigations are necessary, even though very little may be known about subsurface characteristics. An example of this could be a large, unlined surface impoundment.

C. Waste Characteristics. Focus of evaluation:

- o What is the potential for wastes managed in the unit to migrate to the uppermost aquifer, based on their concentration, physical/chemical properties, and behavior in water and soils?

There is considerable variation in the relative likelihood of different hazardous constituents to actually migrate from a given unit through the unsaturated zone and into and through ground water. Many of the constituents in Appendix VIII are essentially insoluble in water (at neutral pH) and/or bind tightly to soil particles, reducing the likelihood of contamination of ground water. The investigator should consider the potential mobility of the waste(s) in a unit, in combination with other unit-specific factors.

The relative mobility of waste constituents can be expressed by the sorption equilibrium constant (K_d). The K_d value for a given constituent is an estimate of its tendency to sorb to soil particles or organic matter. Appendix 3-1 provides a listing of the sorption equilibrium constant for specific constituents, as measured by the octanol/water partition coefficient (K_{ow}) method. Note that not all Appendix VIII constituents are represented on the Table; the Agency is presently conducting further studies to develop K_{ow} values for the remaining constituents.

It should be understood that there are several limitations on the use of this measure of mobility. Firstly, the actual value for a given constituent is variable according to actual site soil characteristics and other factors. Secondly, the presence of other wastes may substantially alter the behavior of a given constituent;

where a number of wastes are present in a unit (e.g., in a commercial landfill), the values given in Appendix 3-1 will have little application.

D. Operational History of the Unit. Focus of evaluation:

- o To what extent, and how, does the operational history of the unit indicate that a release to ground water from the unit may have occurred?

Operational factors which may influence the likelihood of ground water releases may include:

--Service life of the unit. Units which have been managing wastes for long periods of time will usually have a greater likelihood of releases than units which have been operating for short periods of time. For example, an underground tank which has been in service for six months will have a much smaller likelihood of leakage due to corrosion than will a twenty-year old underground tank.

--Operational status. In some cases, the operational status of a storage unit (e.g., closed, inactive, decomissioned) may have an effect on the relative likelihood of a ground water release.

--Operating procedures. Proper maintenance, regular inspections, and procedures for ensuring waste compatibility with the unit may provide indication that a unit is unlikely to have released (this is particularly true for storage units such as tanks and container storage areas). Evidence of good operational practices may be available from owner/operator records, and/or visual observation or historical inspection reports. Conversely, poor operating practices (e.g., underground tanks which are never leak tested or inspected internally, storage of open containers of wastes) may indicate relatively greater potential for ground water releases.

E. Physical Condition of Unit. Focus of evaluation:

- o Does the physical condition of the unit indicate a likelihood of releases that may contaminate ground water?

Examples of how physical condition of certain types of units may indicate potential for releases are given in Section VIII of this chapter.

F. Evidence of Release. Focus of evaluation:

- o Is there evidence, either visual or from existing sampling data of soils and/or ground water, which indicates that a release to ground water has or is likely to have occurred?

- o Is additional sampling data necessary to determine the

need for further ground water investigations at the unit? If so, how should such sampling/analysis be conducted?

In some cases, visual examination of a unit or the area surrounding the unit may reveal substantial soil contamination (e.g., discolored soil, lack of or distressed vegetation), as an indication of possible contamination. An organic sheen on nearby surface water may similarly provide indication of contamination.

At some facilities, ground water sampling data from existing monitoring wells at the facility, or from wells or springs near the facility may be available and may indicate the presence of hazardous constituents which could have migrated from a unit(s) at the facility. Such data may not be conclusive evidence of a release from any unit, due to the variabilities inherent in ground water flow, background ground water quality, errors or deficiencies in sampling and analysis, and other factors. However, if existing ground water data does exist from nearby wells or springs, and suggests contamination, even though wells may not have been placed for the purpose of monitoring the unit(s) and relatively little may be known of subsurface characteristics, such data should be considered a very strong indication of the need for further, more intensive ground water investigations for the facility.

If, from an evaluation of all of the above factors--unit design, site geology/hydrogeology, waste characteristics, operational history, physical condition, and existing evidence of contamination--it is not possible to make a reasonably assured determination as to whether a ground water release from the unit has or is likely to have occurred, the investigation should consider whether additional sampling and analysis of soils and/or ground water should be done to enable the determination to be made. The following are examples of situations where additional sampling might be indicated:

- Evaluation of unit-specific factors indicates that a release has probably not occurred, but there is need for an extra measure of certainty before a determination can be made that no ground water investigations are necessary.
- The evaluation indicates a likelihood of releases to ground water from the unit, but more definitive evidence is necessary to establish the need for extensive remedial investigations (or immediate corrective measures).

An illustration of a situation in which sampling would be called for is as follows: An outdoor, unsurfaced area at a facility was used as a container storage area for a number of years, but has not been used since 1980. The facility is located in an area with sandy soils. Inspection of the area reveals vegetation growing on the area, with no visible signs of contamination. However, a review of the operating history of the facility indicates that the volume of wastes stored in this location was very large, and a number of enforcement actions for serious interim status violations have been initiated against the facility, and State inspection records from the late 1970's indicate generally poor housekeeping

practices. Because of these uncertainties, soil sampling of the area would be recommended.

In some cases, sampling and analysis of soils may yield sufficient evidence to enable the investigator to determine the likelihood of a release to ground water. In other situations, sampling of ground water from existing nearby wells or springs would be advisable if there is reason to believe that constituents from the unit could migrate to such wells or springs.

For any sampling of soils or ground water conducted as part of the site investigation, the constituents to be analyzed should be those which would be expected to migrate from the unit, based on what is known of the wastes managed in the unit. When little is known of the wastes managed in the unit, the investigator will have to exercise judgement as to the appropriate parameters and constituents to be analyzed.

Appendix 3-2 provides three different lists which may be used in determining which parameters and constituents should be analyzed for in ground water. Each of the lists has been developed using data from monitoring data at CERCLA sites, and as such reflects the experience of the Agency as to the types of compounds which are most typically found in contaminated ground water at various types of sites. List A in Appendix 3-2 is a list of basic parameters which may be useful in providing a general indication of the existence of contamination. The list is analogous to, but an expansion of, the four basic monitoring parameters required under interim status. List B provides three more specific listings of constituents which have typically been detected at specific industries-metal finishing, iron and steel manufacturing, and pesticides manufacturing. These industry-specific lists may be used in combination with List A if the facility is engaged in one of these three industries. Additional lists for specific industries are being developed. List C is a more complete listing of the most commonly detected constituents from CERCLA sites. This list may be used, if necessary, as a supplement to List A, in situations where little is known of the wastes in the unit, and the facility is not engaged in any of the three industries listed above.

Actual installation of new ground water monitoring wells as necessary will typically take place during trhe remedial investigation phase, and will not normally be done as part of the site investigation. The determination as to the need for additional ground water investigations at a unit should be able to be made without having to install new wells. However, installation of new monitoring wells and ground water sampling and analysis is not precluded as a part of a site investigation. An example of a situation in which installation of new wells might be done is as follows:

- o Evaluation of unit-specific factors reveals that a release has probably not occurred, but an extra degree of certainty is desirable, due to the presence of down gradient drinking water wells (see Section VII on exposure potential); and

- o A sufficient amount of information is available on site hydrogeology to enable reasonably well designed and located wells to be installed without substantial preliminary subsurface investigations; and

- o The wells can be installed, sampled and analyses obtained within a relatively short period of time.

VII. EXPOSURE POTENTIAL

The potential for exposure of human populations to hazardous constituents in ground water which may be occurring or could potentially occur from releases to ground water from the facility should be considered by the investigator in making determinations of the need for further ground water investigations. If the potential for exposure to ground water contamination from a facility is high, a greater degree of certainty will be necessary in making determinations that further investigations are not needed at the facility. Likewise, if potential for exposure is low, fewer or less extensive investigations may be required of the owner/operator. To illustrate, information available to the investigator may reveal that drinking water wells are located within a relatively short distance from the facility (e.g., 1/4 mile), and that these wells are located down gradient from the facility and ground water flow is relatively rapid. In this situation, the potential for exposure to the drinking water well users is relatively high, and a substantial degree of certainty would therefore be needed in determining that ground water releases are unlikely at the facility. Thus, for an underground tank at the facility which stores highly mobile and toxic wastes but which would otherwise be judged unlikely to be causing contamination (based on design, age, etc.), it may be prudent to require in the remedial investigation phase installation of some type of monitoring system for the tank. Conversely, there may be some situations in which the potential for human exposure to ground water contamination from a unit would be extremely low, and would thus suggest that ground water investigations for a unit might be unnecessary.

VIII. ILLUSTRATIONS

As a means of illustrating and summarizing the foregoing discussion, Table 3-2 is intended to provide specific examples of the kinds of units which would and which would not merit remedial ground water investigations, based on the general potential for contamination, unit specific factors, and exposure potential. This table is not intended to be a complete listing of the types of units and situations which are expected to be encountered at RCRA-regulated facilities. It is rather meant to give a sense of the types of unit scenarios in which remedial investigations generally would and would not be needed.

TABLE 3-2. UNIT ILLUSTRATIONS

Unit Type	Further Investigation Needed	Further Investigation Not Needed
Class IV Injection Wells	o All Class IV wells	o None
Surface Impoundments	o Unlined, active impoundments o Impoundments which closed with wastes in-place o Inactive or active clay-lined impoundments which held wastes for more than a very short period of time (e.g., >1 month) o Small, synthetic lined impoundments with evidence or records of liner deterioration and/or rupture o Unlined impoundments which closed by removal of wastes, but at which no ground water monitoring system, or an inadequate system, is installed	o Units which closed by removal of wastes ("clean closed") in accordance with §265.228(b) or §264.228(a)(1) (see footnote #1) o Small, clay or synthetic lined impoundments which held relatively non-mobile wastes (e.g., certain fly ashes) for a short period of time o Impoundments which were synthetically or concrete lined, whose liners have been removed, and where adequate soil sampling and physical evidence conclusively demonstrates that no leakage occurred from the unit
Landfills	o Closed/inactive commercial landfill units o Landfill units containing substantial quantities of municipal-type solid waste o Unlined monofills of wastes with relatively non-mobile constituents, in areas with high water tables o Closed, clay-lined landfill units containing relatively mobile and/or toxic containerized or non-containerized wastes o Areas of facilities with heavily contaminated soils resulting from routine, systematic and deliberate placement of wastes on the soil (e.g., wood preservative "kick-back" areas	o Small rubbish dumps o Monofills of wastes having very low potential for migration of constituents to ground water (e.g., insoluble metal salts, certain fly ashes), and which have been adequately capped or covered by structures, in locations where the uppermost aquifer would never come in direct contact with the wastes o Small units containing wastes with relatively non-mobile constituents in arid areas with deep aquifers, which are constructed with well-designed liners and leachate collection systems and/or which are situated over relatively impermeable natural geologic formations (e.g., clay deposits)

Treatment Units	o Active or inactive land treatment units in non-arid areas on which substantial amounts of wastes have been placed	o Units on which wastes were placed only once, in very small amounts, in an area with a deep water table o A very small (e.g., 0.1 hectare) experimental land treatment plot which was operated for a limited period of time, in an area with a deep water table, where results of soil testing indicate complete biological degradation
Class I Injection Wells	o See footnote #2	o See footnote #2
Underground Tanks	o Old steel tanks (e.g., >10 years old) installed without external or internal coatings or cathodic protection, which have not recently been leak-tested or had an internal inspection by a qualified inspector o Steel tanks which have been in frequent or constant contact with ground water for a relatively long period of time o Steel or fiberglass tanks for which recent internal inspection and/or leak test indicates lack of tank integrity o Relatively new, well designed tank (e.g., cathodically protected) storing highly corrosive and/or highly mobile or toxic wastes, in an area with high water table and nearby downgradient drinking water wells	o Relatively new, well designed tank (e.g., external and internal epoxy coating and cathodic protection) storing non-corrosive and/or relatively non-mobile wastes/constituents, not likely to come in direct contact with ground water o Tank with full secondary containment (e.g., vaulted tank with leak detection system) o Tank with recent internal inspection and/or "state of the art" leak test which indicates that the tank is sound o Relatively new (e.g., <10 years) metal tank storing compatible wastes (e.g., solvents) in an arid area with clay soils
Waste Piles	o Outdoor pile containing relatively mobile wastes, not situated on a liner or base, in area with porous soils and/or shallow aquifer o Large outdoor pile containing wastes with particularly toxic constituents, with physical evidence of substantial migration of wastes outside the containment structure, in area with nearby downgradient drinking water wells	o Indoor pile with no free liquids o Covered outdoor pile situated on impermeable (e.g., well engineered synthetic or concrete) base with adequate containment system for run-on and run-off o Outdoor pile containing relatively non-mobile wastes (e.g., certain fly ashes) situated on clay soils in area of deep water table

In-ground Tanks	o Relatively old concrete tank containing large volumes of wastes, with visible and substantial deterioration of exposed walls, or for which recent internal inspection indicates serious cracking of walls or other signs of serious deterioration of concrete o Large concrete tank with no protective internal coating or liner, holding highly toxic and/or mobile wastes in area of high water table and downgradient drinking water wells o Tank with visible evidence of extensive soil contamination from apparent (or recorded) overflow events or other operational or structural failures, in area with porous soils	o Relatively small tank with adequate liner/coating, with record of frequent inspections and maintenance schedule o Relatively new, lined/coated tank in good condition, with no evidence of releases
Container Storage Units	o Containers stored outdoors on bare soil, with visible signs of substantial soil contamination, in area of porous soils and/or shallow aquifer o Outdoor area on which very large volumes of waste containers have been stored for relatively long periods of time (e.g., >10 years) with improper storage practices (e.g., open containers) and/or inadequate containment structures, with downgradient drinking water wells and/or highly toxic/mobile wastes	o Indoor container area with adequate containment structure o Outdoor storage area with adequate containment system, with no visible evidence of contamination o Relatively small outdoor area where waste containers were placed for only a short period of time, with no evidence of serious contamination
Above Ground Tanks	o Large, outdoor metal tanks situated on soil surface with visible structural deterioration, holding highly mobile and/or toxic wastes, in area with shallow aquifer and downgradient drinking water wells o Old, outdoor tank with visible evidence of massive soil contamination due to apparent (or recorded) overflow events, in area of porous soils	o Small, indoor tanks with secondary containment o Outdoor tanks elevated above soil surface, with secondary containment structures o Outdoor tank in good condition situated on concrete pad, with no visible or recorded evidence of substantial release

	o Large tank situated on soil surface, for which recent internal inspection indicates severe corrosion on bottom, in area of vulnerable hydrogeology	
Incinerators	o Outdoor incinerator with visible evidence of surrounding massive soil contamination resulting from apparent system/ operation malfunction	o Indoor incinerator with no apparent evidence of significant releases to outside environment

Footnotes:

1/ For such units, monitoring data should be carefully examined for evidence of ground water contamination; this is of particular concern for units which stored only characteristic waste.

2/ Class I wells inject hazardous wastes beneath the lowermost formation containing an underground source of drinking water (USDW) within one quarter mile of the well bore. The Agency realizes that there are concerns associated with installing monitoring wells (often deep into the earth's crust) to detemine whether Class I injections are adversely affecting USDWs, including the uppermost aquifer. Such concerns include: the length of time (e.g., hundreds or thousands of years) it may take to detect a release from the injection zone to the monitoring wells; and the risks associated with installing deep monitoring wells which could later serve as conduits for the rise of injected waste into useable aquifers. Therefore, the Agency has provided discretionary authority to the State underground injection control (UIC) Director to require monitoring wells only when he beieves them to be necessary. In such cases the Director will prescribe the number and location of monitoring wells and the parameters to be analyzed.

The Agency is gathering additional information on the fate of Class I injections. For example, an evaluation will be made to develop procedures that can be used to identify when Class I injections have migrated beyond their permitted injection zones. Until such procedures can be developed, the Agency will continue to limit the circumstances under which monitoring wells will be required.

APPENDIX 3-1. SORPTION EQUILIBRIUM CONSTANT AS EXPRESSED BY WATER-OCTANOL PARTITION COEFFICIENT (K_{OW})*

CHEM ABST SYS #	NAME OF WASTE MATERIAL	LOG_K_OW
75-15-0	CARBON DISULFIDE	
108-90-7	CHLOROBENZENE	2.87
1319-77-3	CRESOLS	2.15
95-50-1	1,2-DICHLOROBENZENE	3.58
75-09-2	METHYLENE CHLORIDE	1.26
75-69-4	TRICHLOROMONOFLUOROMETHANE	2.52
6-83-1	ISOBUTYL ALCOHOL	0.74
78-93-3	METHYL ETHYL KETONE	0.30
98-95-3	NITROBENZENE	1.90
110-86-1	PYRIDINE	0.68
-4	TETRACHLOROETHYLENE	3.03
56-23-5	CARBON TETRACHLORIDE	2.96
58-90-2	2,3,4,6-TETRACHLOROPHENOL	4.00
108-88-3	TOLUENE	2.52
71-55-6	METHYLCHLOROFORM	2.50
79-01-6	TRICHLOROETHYLENE	2.29
95-95-4	2,4,5-TRICHLOROPHENOL	3.86
88-06-2	2,4,6-TRICHLOROPHENOL	3.58
87-86-5	PENTACHLOROPHENOL	5.06
	1,2,2-TRICHLORO-1,2,2-TRIFLUOROETHANE	3.10
	ETHYLBENZENE	3.36
20859-73-8	ALUMINUM PHOSPHIDE	
7778-39-4	ARSENIC ACID	

CHEM ABST SYS #	NAME OF WASTE MATERIAL	LOG_K_OW
1327-53-3	ARSENIC(V)OXIDE	
1303-28-2	ARSENIC(III)OXIDE	
542-62-1	BARIUM CYANIDE	
598-31-2	BROMOACETONE	
592-01-8	CALCIUM CYANIDE	
107-20-0	CHLOROACETALDEHYDE	0.40
544-92-3	COPPER CYANIDES	
57-12-5	SOLUBLE CYANIDE SALTS N.O.S.	
460-19-5	CYANOGEN	
506-77-4	CHLORINE CYANIDE	
696-28-6	DICHLOROPHENYLARSINE	
692-42-2	DIETHYLARSINE	
7782-41-4	FLUORINE	
74-90-8	HYDROGEN CYANIDE	
557-19-7	NICKEL CYANIDE	
10102-43-9	NITRIC OXIDE	
10102-44-0	NITROGEN DIOXIDE	
10544-72-6	NITROGEN DIOXIDE	
75-44-5	PHOSGENE	
7803-51-2	PHOSPHINE	
151-50-8	POTASSIUM CYANIDE	
506-61-6	POTASSIUM SILVER CYANIDE	
506-64-9	SILVER CYANIDE	

* Note: Low value indicates greater mobility; high value indicates lesser mobility

Expressed in log values

CHEM ABST SYS #	NAME OF WASTE MATERIAL	LOG_K_OW
143-33-9	SODIUM CYANIDE	
57-24-9	STRYCHNINE AND SALTS	-0.05
557-21-1	ZINC CYANIDE	
75-36-5	ACETYL CHLORIDE	0.89
79-10-7	ACRYLIC ACID	0.18
98-09-9	BENZENESULFONYL CHLORIDE	1.93
353-50-4	CARBONYL FLUORIDE	
3165-93-3	4-CHLORO-O-TOLUIDINE, HYDROCHLORIDE	
64-18-6	FORMIC ACID	
7664-39-3	HYDROFLUORIC ACID	
-06-4	HYDROGEN SULFIDE	
75-60-5	CACODYLIC ACID	
79-22-1	METHYL CHLOROCARBONATE	
1338-23-4	METHYL ETHYL KETONE PEROXIDE	
108-95-2	PHENOL	1.49
7783-00-8	SELENIOUS ACID	
636-21-5	O-TOLUIDINE HYDROCHLORIDE	
506-68-3	CYANOGEN BROMIDE	
7440-38-2	ARSENIC	
81-81-2	WARFARIN	2.05
309-00-2	ALDRIN	
107-18-6	ALLYL ALCOHOL	-0.22
7440-41-7	BERYLLIUM DUST	

CHEM ABST SYS #	NAME OF WASTE MATERIAL	LOG_K_OW
542-88-1	BIS-(CHLOROMETHYL)ETHER	1.06
357-57-3	BRUCINE	0.10
88-85-7	DINOSEB	4.07
60-57-1	DIELDRIN	
298-04-4	DISULFOTON	
311-45-5	DIETHYL-P-NITROPHENYL PHOSPHATE	
51-28-5	2,4-DINITROPHENOL	1.92
115-29-7	ENDOSULFAN	
62-74-8	FLUOROACETIC.ACID,SODIUM.SALT	
60-34-4	METHYL HYDRAZINE	-0.71
75-86-5	2-METHYLLACTONITRILE	-0.51
116-06-3	ALDICARB	1.31
298-00-0	METHYL PARATHION	
55-63-0	NITROGLYCERINE	0.34
62-75-9	N-NITROSODIMETHYLAMINE	
4549-40-0	N-NITROSOMETHYLVINYLAMINE	
20816-12-0	OSMIUM TETROXIDE	
56-38-2	PARATHION	
62-38-4	PHENYL MERCURIC ACETATE	
52-85-7	FAMPHUR	1.95
107-19-7	PROPARGYL ALCOHOL	-1.09
26628-22-8	SODIUM AZIDE	
78-00-2	TETRAETHYL LEAD	

CHEM ABST SYS #	NAME OF WASTE MATERIAL	LOG_K_OW
7446-18-6	THALLIUM(I)SULFATE	
1314-62-1	VANADIUM PENTOXIDE	
1314-84-7	ZINC PHOSPHIDE	
79-06-1	ACRYLAMIDE	0.88
107-13-1	ACRYLONITRILE	0.07
50-07-7	MITOMYCIN C	-2.42
62-53-3	ANILINE	0.93
225-51-4	BENZ(C)ACRIDINE	
56-55-3	BENZ(A)ANTHRACENE	
50-32-8	BENZO(A)PYRENE	6.16
74-83-9	METHYL BROMIDE	1.09
[redacted]	1-BUTANOL	0.87
106-89-8	1-CHLORO-2,3-EPOXYPROPANE	-0.18
107-30-2	CHLOROMETHYL METHYL ETHER	0.45
218-01-9	CHRYSENE	5.75
123-73-9	CROTONALDEHYDE	1.42
50-29-3	DDT	6.95
53-70-3	DIBENZO(A,H)ANTHRACENE	6.88
189-55-9	1,2,7,8DIBENZOPYRENE	
96-12-8	1,2-DIBROMO-3-CHLOROPROPANE	2.15
106-93-4	ETHYLENE DIBROMIDE	1.68
764-41-0	1,4-DICHLORO-2-BUTENE	1.73
1615-80-1	N,N'-DIETHYLHYDRAZINE	

CHEM ABST SYS #	NAME OF WASTE MATERIAL	LOG_K_OW
56-53-1	DIETHYLSTILBESTROL	5.04
77-78-1	DIMETHYL SULFATE	0.06
123-91-1	1,4-DIOXANE	-0.08
75-21-8	ETHYLENE OXIDE	-0.77
110-00-9	FURAN	1.36
302-01-2	HYDRAZINE	
193-39-5	INDENO(1,2,3-CD)PYRENE	6.62
7439-97-6	MERCURY	
67-56-1	METHANOL	-0.75
91-80-5	METHAPYRILENE	
56-49-5	3-METHYLCHOLANTHRENE	6.95
101-14-4	4,4-METHYLENE-BIS-(2-CHLOROANILINE)	3.96
79-46-9	2-NITROPROPANE	0.59
684-93-5	N-NITROSO-N-METHYLUREA	[illegible]
930-55-2	N-NITROSOPYRROLIDINE	[illegible]
82-68-8	PENTACHLORONITROBENZENE	4.89
23950-58-5	PRONAMIDE	
50-55-5	RESERPINE	4.81
62-56-6	THIOUREA	-1.22
66-75-1	URACIL MUSTARD	
51-79-6	ETHYL CARBAMATE	-0.15
13981-37-8	NICKEL	
616-23-9	2,3-DICHLOROPROPANOL AND DICHLOROPROPANOLS	0.30

CHEM ABST SYS #	NAME OF WASTE MATERIAL	LOG_K_OW
96-18-4	1,2,3-TRICHLOROPROPANE	1.85
7440-36-0	ANTIMONY	
208-96-8	ACENAPHTHYLENE	3.80
205-99-2	BENZO(B)FLUORANTHENE	
12002-48-1	TRICHLOROBENZENE	
122-39-4	DIPHENYLAMINE	3.65
108-45-2	M-PHENYLENEDIAMINE	-0.30
118-96-7	TNT	2.40
591-08-2	ACETAMIDE, N-(AMINOTHIOXOMETHYL)-	-0.87
107-02-8	ACROLEIN	0.88
[illegible]-96-4	5-(AMINOMETHYL)-3-ISOXAZOLOL	-0.20
504-24-5	4-AMINOPYRIDINE	-0.36
108-98-5	THIOPHENOL	2.55
5344-82-1	1-(3-CHLOROPHENYL)THIOUREA	1.78
542-76-7	PROPANENITRILE, 3-CHLORO-	0.22
297-97-2	O,O-DIETHYL O-PYRAZINYL PHOSPHOROTHIOATE	1.16
55-91-4	DIISOPROPYL FLUOROPHOSPHATE	1.08
60-51-5	DIMETHOATE	-1.00
541-53-7	2,4-DITHIOBIURET	-0.85
151-56-4	AZIRIDINE	-1.10
640-19-7	ACETAMIDE, 2-FLUORO-	-1.12
76-44-8	HEPTACHLOR	
465-73-6	ISODRIN	4.77

CHEM ABST SYS #	NAME OF WASTE MATERIAL	LOG_K_OW
757-58-4	HEXAETHYL-TETRA-PHOSPHATE	
16752-77-5	METHOMYL	
75-55-8	2-METHYLAZIRIDINE	-0.57
86-88-4	ALPHA-NAPHTHYLTHIOUREA	1.95
152-16-9	OCTAMETHYLPYROPHOSPHORAMIDE	6.28
298-02-2	PHORATE	
1314-96-1	STRONTIUM SULFIDE	
107-49-3	TETRAETHYLPYROPHOSPHATE	
509-14-8	TETRANITROMETHANE	0.79
1314-32-5	THALLIC OXIDE	
12039-52-0	THALLIUM(I)SELENITE	
8001-35-2	TOXAPHENE	
67-64-1	ACETONE	-0.24
75-05-8	ACETONITRILE	-0.33
53-96-3	2-ACETYLAMINOFLUORENE	
61-82-5	AMITROLE	
492-80-8	AURAMINE	2.92
115-02-6	AZASERINE	
71-43-2	BENZENE	2.13
92-87-5	BENZIDINE	1.48
98-07-7	BENZOTRICHLORIDE	4.14
111-44-4	DICHLOROETHYL ETHER	1.14
494-03-1	CHLORNAPHAZINE	

CHEM ABST SYS #	NAME OF WASTE MATERIAL	LOG_K_OW
117-81-7	BIS(2-ETHYLHEXYL)PHTHALATE	*6.00
13765-19-0	CALCIUM CHROMATE	
305-03-3	CHLORAMBUCIL	
57-74-9	CHLORDANE, TECHNICAL	
75-01-4	VINYL CHLORIDE	1.38
67-66-3	CHLOROFORM	1.96
91-58-7	BETA-CHLORNAPHTHALENE	4.05
108-94-1	CYCLOHEXANONE	0.86
50-18-0	CYCLOPHOSPHAMIDE	
20830-81-3	DAUNOMYCIN	
[illegible]-54-8	DDD	
2303-16-4	DIALLATE	
91-94-1	3,3'-DICHLOROBENZIDINE	3.54
107-06-2	ETHANE, 1,2-DICHLORO-	1.48
75-35-4	1,1-DICHLOROETHYLENE	2.13
78-87-5	1,2-DICHLOROPROPANE	1.94
124-40-3	DIMETHYLAMINE	
60-11-7	DIMETHYLAMINOAZOBENZENE	-3.94
57-97-6	7,12-DIMETHYLBENZ(A)ANTHRACENE	7.02
119-93-7	3,3'-DIMETHYLBENZIDINE	2.80
79-44-7	DIMETHYLCARBAMOYL CHLORIDE	1.66
57-14-7	1,1-DIMETHYLHYDRAZINE	-1.47
540-73-8	1,2-DIMETHYLHYDRAZINE	

CHEM ABST SYS #	NAME OF WASTE MATERIAL	LOG_K_OW
105-67-9	2,4-DIMETHYLPHENOL	2.81
121-14-2	2,4-DINITROTOLUENE	2.30
606-20-2	2,6-DINITROTOLUENE	2.30
117-84-0	DI-N-OCTYL PHTHALATE	*6.00
122-66-7	1,2-DIPHENYLHYDRAZINE	3.00
142-84-7	DIPROPYLAMINE	1.67
621-64-7	DI-N-PROPYLNITROSAMINE	1.42
111-54-6	ETHYLENE-BIS-(DITHIOCARBAMIC ACID)	
96-45-7	ETHYLENE THIOUREA	0.31
62-50-0	ETHYL METHANESULFONATE	0.09
50-00-0	FORMALDEHYDE	
118-74-1	HEXACHLOROBENZENE	5.43
87-68-3	HEXACHLOROBUTADIENE	4.24
58-89-9	LINDANE	3.43
67-72-1	HEXACHLOROETHANE	4.22
74-88-4	METHYL IODIDE	1.48
143-50-0	KEPONE	
303-34-4	LASIOCARPINE	
301-04-2	LEAD ACETATE	
1335-32-6	LEAD SUBACETATE	
109-77-3	MALONONITRILE	-1.19
148-82-3	MELPHALAN	
108-10-1	METHYL ISOBUTYL KETONE	1.25

CHEM ABST #	NAME OF WASTE MATERIAL	LOG_K_OW
80-62-6	METHYL METHACRYLATE	1.10
70-25-7	N-METHYL-N-NITRO-N-NITROSOGUANIDINE	
56-04-2	METHYLTHIOURACIL	1.43
91-20-3	NAPHTHALENE	3.34
91-59-8	2-NAPHTHYLAMINE	2.11
100-02-7	P-NITROPHENOL	1.87
924-16-3	N-NITROSO-DI-N-BUTYLAMINE	2.50
1116-54-7	N-NITROSO-DI-ETHANOLAMINE	-1.54
55-18-5	N-NITROSO-DI-ETHYLAMINE	0.34
759-73-9	N-NITROSO-N-ETHYLUREA	0.33
615-53-2	N-NITROSO-N-METHYLURETHANE	2.20
[illegible]55-4	N-NITROSOPIPERIDINE	0.36
1314-80-3	PHOSPHOROUS SULFIDE	
1120-71-4	1,3-PROPANE SULTONE	-0.47
94-59-7	SAFROLE	2.36
7488-56-4	SELENIUM DISULFIDE	
18883-66-4	STREPTOZOCIN	
630-20-6	1,1,1,2-TETRACHLOROETHANE	2.81
79-34-5	1,1,2,2-TETRACHLOROETHANE	2.42
109-99-9	TETRAHYDROFURAN	0.37
563-68-8	THALLIUM(I)ACETATE	
6533-73-9	THALLIUM (I) CARBONATE	
7791-12-0	THALLIUM (I) CHLORIDE	

CHEM ABST SYS #	NAME OF WASTE MATERIAL	LOG_K_[illegible]
10102-45-1	THALLIUM (I) NITRATE	
62-55-5	THIOACETAMIDE	-0.34
95-80-7	TOLUENEDIAMINE	0.36
584-84-9	TOLUENE DIISOCYANATE	2.36
79-00-5	1,1,2-TRICHLOROETHANE	1.91
93-76-5	2,4,5-T	3.45
93-72-1	SILVEX	3.46
126-72-7	TRIS (2,3-DIBROMOPROPYL) PHOSPHATE	3.20
1330-20-7	XYLENE	
137-26-8	THIRAM	3.20
99-65-0	M-DINITROBENZENE	1.64
	PHOSPHORODITHIOIC ACID,O,O,S-TRIETHYL ESTER	
	PHOSPHOROTHIOIC ACID, O,O,O-TRIETHYL ESTER	
107-05-1	3-CHLOROPROPENE	[illegible]
126-99-8	2-CHLORO 1,3-BUTADIENE	[illegible]
131-74-8	AMMONIUM PICRATE	
106-47-8	P-CHLOROANILIE	1.94
100-44-7	BENZYL CHLORIDE	2.30
131-89-5	4,6DI-NITRO-O-CYCLOHEXYLPHENOL	
51-43-4	EPINEPHRINE	-0.71
39196-18-4	THIOFANOX	1.83
122-09-8	ALPHA,ALPHA-DIMETHYLPHENETHYLAMINE	2.20
534-52-1	4,6-DINITRO-O-CRESOL AND SALTS	2.58

CHEM ABST SYS #	NAME OF WASTE MATERIAL	LOG_K_OW
72-20-8	ENDRIN	
624-83-9	METHYL ISOCYANATE	0.99
628-86-4	MERCURY FULMINATE	
13463-39-3	NICKEL CARBONYL	
54-11-5	NICOTINE AND SALTS	1.13
100-01-6	P-NITROANILINE	1.32
145-73-3	ENDOTHALL	
103-85-5	N-PHENYLTHIOUREA	0.77
107-12-0	PROPANENITRILE	0.16
630-10-4	SELENOUREA	
3689-24-5	TETRAETHYLDITHIOPYROPHOSPHATE	
-19-6	THIOSEMICARBAZIDE	
594-42-3	TRICHLOROMETHANETHIOL	1.81
7803-55-6	AMMONIUM VANADATE	
75-07-0	ACETALDEHYDE	-0.21
98-86-2	ACETOPHENONE	1.61
98-87-3	BENZAL CHLORIDE	3.24
111-91-1	BIS(2-CHLOROETHOXY)METHANE	0.80
108-60-1	BIS(2-CHLOROISOPROPYL) ETHER	1.68
101-55-3	1-BROMO-4-PHENOXY BENZENE	5.27
75-87-6	CHLORAL	1.66
510-15-6	ETHYL-4,4'-DICHLOROBENZILATE	4.41
59-50-7	4-CHLORO-M-CRESOL	3.16

CHEM ABST SYS #	NAME OF WASTE MATERIAL	LOG_K_OW
110-75-8	2-CHLOROETHYL VINYL ETHER	2.25
74-87-3	METHYL CHLORIDE	0.95
95-57-8	O-CHLOROPHENOL	2.22
92-82-8	CUMENE	3.77
110-82-7	CYCLOHEXANE	3.42
74-95-3	METHANE, DIBROMO	1.54
84-74-2	DIBUTYL PHTHALATE	4.80
541-73-1	1,3-DICHLOROBENZENE	3.58
106-46-7	1,4-DICHLOROBENZENE	3.53
75-71-8	DICHLORODIFLUOROMETHANE	2.08
75-34-3	ETHANE, 1,1-DICHLORO-	1.80
156-60-5	1,2-DICHLOROETHYLENE	1.53
120-83-2	2,4-DICHLOROPHENOL	3.06
87-65-0	2,6-DICHLOROPHENOL	2.8
542-75-6	1,3-DICHLOROPROPENE	1.83
1464-53-5	2,2'-BIOXIRANE	-1.35
3288-58-2	O,O-DIETHYL-S-METHYL-DITHIOPHOSPHATE	
84-66-2	DIETHYL PHTHALATE	2.54
94-58-6	DIHYDROSAFROLE	2.91
119-90-4	3,3'-DIMETHOXYBENZIDINE	1.73
80-15-9	ALPHA,ALPHA-DIMETHYLBENZHYDROPEROXIDE	2.20
131-11-3	DIMETHYL PHTHALATE	1.56
141-78-6	ETHYL ACETATE	0.71

CHEM ABST SYS #	NAME OF WASTE MATERIAL	LOG_K_OW
140-88-5	ETHYL ACRYLATE	1.32
60-29-7	ETHYL ETHER	0.92
97-63-2	ETHYLMETHACRYLATE	1.64
206-44-0	FLUORANTHENE	4.98
98-01-1	FURFURAL	1.00
765-34-4	GLYCIDYLALDEHYDE	
77-47-4	HEXACHLOROCYCLOPENTADIENE	4.27
70-30-4	HEXACHLOROPHENE	>6.00
9004-66-4	IRON DEXTRAN	
120-58-1	ISOSAFROLE	2.45
[illegible]-27-7	LEAD PHOSPHATE	
108-31-6	MALEIC ANHYDRIDE	0.14
123-33-1	MALEIC HYDRAZIDE	
126-98-7	METHACRYLONITRILE	0.39
74-93-1	METHANETHIOL	0.60
130-15-4	1,4-NAPHTHAQUINONE	1.12
134-32-7	1-NAPHTHYLAMINE	2.11
99-55-8	5-NITRO-O-TOLUIDINE	1.98
123-63-7	PARALDEHYDE	1.06
608-93-5	PENTACHLOROBENZENE	5.71
76-01-7	PENTACHLOROETHANE	3.32
504-60-9	1,3-PENTADIENE	2.48
62-44-2	PHENACETIN	1.84

CHEM ABST SYS #	NAME OF WASTE MATERIAL	LOG_K_OW
85-44-9	PHTHALIC ANHYDRIDE	1.32
109-06-8	2-PICOLINE	1.34
107-10-8	1-PROPANAMINE	0.43
106-51-4	P-BENZOQUINONE	-0.61
108-46-3	RESORCINAL	0.82
81-07-2	SACCHARIN AND SALTS	
95-94-3	1,2,4,5-TETRACHLOROBENZENE	5.00
75-25-2	BROMOFORM	2.38
99-35-4	SYM-TRINITROBENZENE	1.38
72-57-1	TRYPAN BLUE	
94-75-7	2,4-D, SALTS AND ESTERS	2.70
1888-71-7	HEXACHLOROPROPENE	4.14
72-43-5	METHOXYCHLOR	
7440-43-9	CADMIUM	
1333-82-0	CHROMIUM VI	
7439-92-1	LEAD	
	FERRIC FERROCYANIDE	

APPENDIX 3-2

LISTS OF GROUND-WATER MONITORING PARAMETERS

LISTS A, B, C

LIST A

Parameter	Chemical Abstract System Number
sodium	7440-23-5
calcium	7400-70-2
magnesium	7439-95-4
sulfate	
chloride	
pH	
total organic carbon	
total organic halogen	
total phenols	
1,1,1-trichloroethene	71-55-6
lead	7439-97-6
cadmium	7440-43-9

LIST B1

INDUSTRY SPECIFIC PARAMETERS
METALFINISHING

Parameter	Chemical Abstract System Number
chromium	7440-47-3
copper	7550-50-8
cyanide	57-12-5
iron	7439-89-6
zinc	7440-66-6
trichloroethene	79-01-6
tetrachloroethylene	127-18-4
vinyl chloride	75-01-4
phenanthrene	85-01-8
nickel	

LIST B3

PESTICIDES

Parameter	Chemical Abstract System Number
arsenic	7440-38-2
cyanide	57-12-5
copper	7550-50-8
benzene	71-43-2
carbon tetrachloride	56-23-5
chlordane	57-74-9
chlorobenzene	67-66-3
chloroform	108-90-7
1,4-dichlorobenzene	106-46-7
2,4-dichlorophenol	120-83-2
heptachlor	76-44-8
hexachlorocyclopentadiene	77-47-4
methyl chloride	74-87-3
methylene chloride	75-09-2
4-nitrophenol	100-02-7
phenol	108-95-2
tetrachloroethylene	127-18-4
toluene	108-88-3
Manufactured pesticides*	

*Any specific pesticides, residues, off-specification products, or other similiar items known to have been disposed of at the site, or, in the case of a dedicated facility, known to have been manufactured at the site.

LIST B2

IRON AND STEEL

Parameter	Chemical Abstract System Number
arsenic	7440-38-2
chromium	7440-47-3
cyanide	57-12-5
tin	7440-31-5
zinc	7440-66-6
benzene	71-43-2
benzo(a)pyrene	50-32-8
tetrachloroethylene	127-18-4

LIST C

Parameter	Chemical Abstract System Number
bis(2-ethylhexyl)phthalate	117-81-7
PCB-1016	12674-11-2
PCB-1221	11104-28-2
PCB-1232	11141-16-5
PCB-1248	12672-29-6
PCB-1254	11097-69-1
PCB-1260	11096-82-5
PCB-1242	53469-21-9
arsenic	7440-38-2
benzene	71-43-2
chlorobenzene	108-90-7
ethyl benzene	100-41-4
toluene	108-88-3
chromium	7440-47-3
copper	7550-50-8
cyanide	57-12-5
tetrachloroethylene	127-18-4
vinyl chloride	75-01-4
trichoroethylene	79-01-6
iron	7439-89-6
manganese	7439-96-5
naphthalene	91-20-3
nickel	7440-02-0
phenanthrene	85-01-8
phenol	108-95-2
zinc	7440-6-6

SECTION ONE

PLANNING AND CONDUCTING THE SITE INVESTIGATION

I. INTRODUCTION

The site investigation (SI) is the second phase in evaluating SWMU's for releases to the environment. The SI builds upon the data collected during the preliminary assessment (PA) and in general involves collecting new information through visual observation. Where appropriate, the SI can also involve sample collection and analysis.

The purpose of an SI is to: (1) identify units/facilities that pose no problem, (2) prioritize facilities for further investigation, and (3) identify the scope of subsequent remedial investigations or immediate corrective action. This will be accomplished by evaluating the potential for exposure to humans and the environment via surface water, ground water, air, soil, and subsurface gas.

As a rule, the SI takes considerably more time than the PA to complete. Unlike the PA which involves mostly desk work, the SI involves both desk and field work.

The scope of the SI involves collecting additional data through a comprehensive visual survey and, at some facilities, sample collection.

This chapter of the Corrective Action Guidance will address the overall process involved in conducting a SI--beginning with supplementary background data collection through writing a final SI report. Each section of this Chapter will discuss the various steps involved in performing an SI. These steps are identified in Figure 1. The evaluation stage will not be discussed in this chapter. It is the subject of the succeeding chapters.

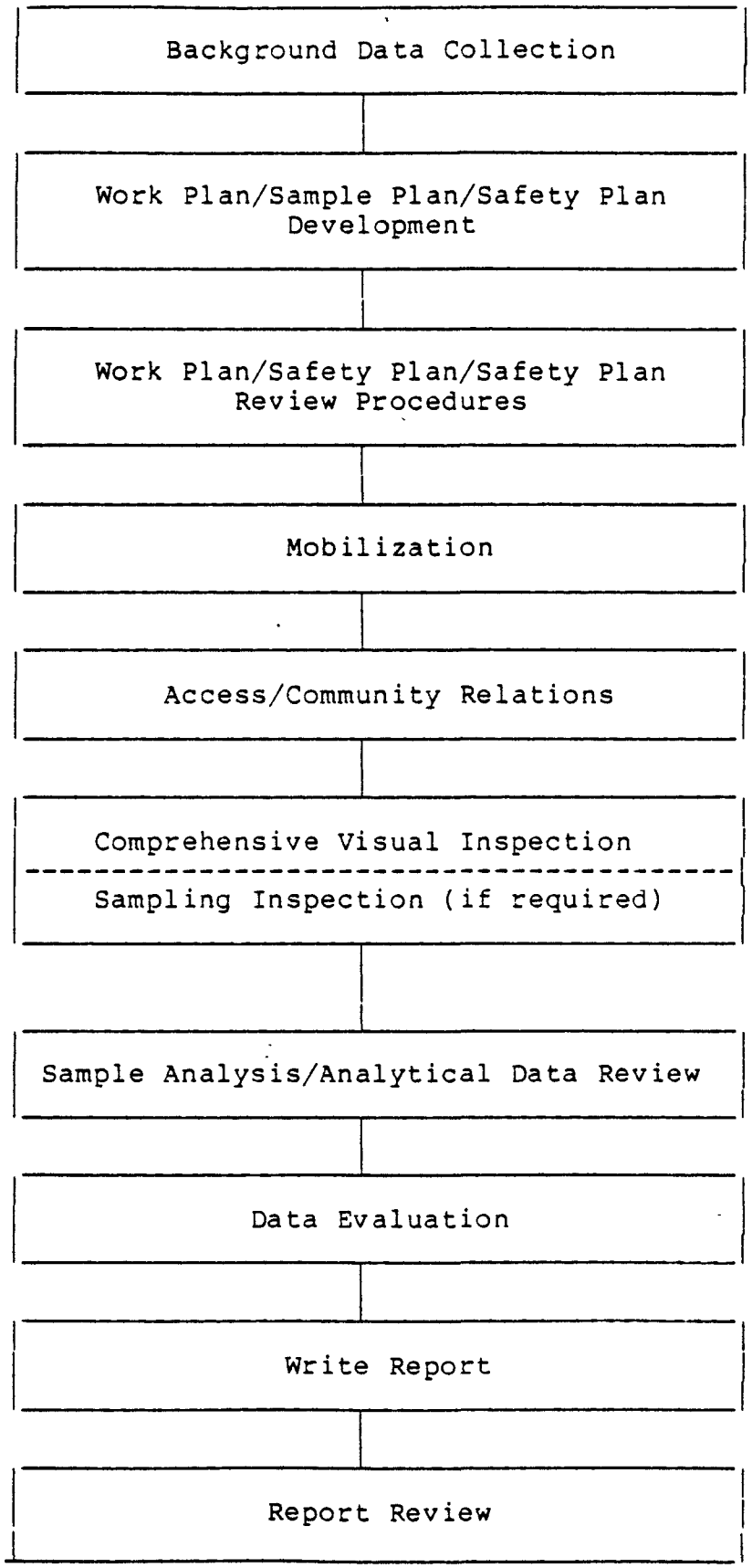
II. BACKGROUND DATA COLLECTION

The purpose of this step in the site investigation process is to gather the data necessary to prepare a work plan, safety plan and sampling plan (if required) for the facility and possibly collect site data not developed during the PA. Most of the time, if the PA was performed properly, it should not be necessary to collect additional site data. However, if there are significant gaps between the time the PA is completed and the SI begins then it may be necessary to update PA information. In another instance, the background data simply may be lacking in some relevant data that should have been collected during the PA. If additional site specific data must be collected, this should not take a lot of time, on the average.

The more thoroughly this stage of SI is done the more focused the field activities will be and the less field time and resources it should take. If key data is missing in the four categories identified in the guidance on preliminary assessments <u>especially</u> (1) waste charcterization (2) designated operational characteristics, and (3) migration pathways characterization, the reviewer should determine if all possible sources of the information have

FIGURE 1

STEP-BY-STEP BREAKDOWN OF A SITE INSPECTION



been considered. These pieces of information are perhaps the most important data needed to conduct an effective and efficient site inspection. Information on the nature of waste disposed in each unit is essential to determine if it is even necessary to pursue evaluating a unit or facility. If there are no wastes of concern, then it is not necessary to proceed further. Waste data will guide the inspector in what to look for if sampling is performed. The design and operational data and physical geography/geology of the site is essential to identifying whether there is a possibility for a release from a unit, how quickly materials will release and, if so, where to look for the release.

This information is invaluable in focusing SI field efforts, especially sampling if it is necessary. For example, certain types of compounds tend to preferentially migrate via surface water sediments or ground water; i.e., heavy metals and higher molecular weight organics. Where this occurs, it would be unfruitful to look for releases of such constituents in the aqueous phase of surface water. Other materials tend to bind extremely well to certain soil types and are essentially contained in the site. Others do not bind well in certain soils or photo-degrade. These materials are not likely to be observed away from the surface.

At this stage, if gaps in data remain or the data collected is not sufficiently detailed to be of use, then the owner/operator should be directed to provide this information. For example, USGS maps may not be sufficiently detailed to understand where contaminants may migrate, or information previously submitted by the owner/operator may be too general. The inspector should

develop a list of data gaps and request, by letter, the owner/operator to submit the information. The letter should be as specific as possible, identifying the type of information requested, the source (or possible sources) of the information, and the due date for the response.

After all sources have been exhausted, it is possible that gaps in data may persist especially data on old abandoned SWMUs that have changed ownership a number of times. Where these data are absent or inadequate then the SI field work will tend to be larger and broader in scope, generally involve more sampling, and require the more comprehensive full priority pollutant analyses. Data gaps may also lead the inspector to decide that all further investigations should be conducted by the owner/operator as part of an RI--the purpose of which is to obtain the data to decide if a release of concern is likely.

After all available information describing facility-specific units, features, and waste types is collected, the reviewer will need to consider technical/non-site specific data that will detail the chemical, physical properties of waste and the physical environment. This information is necessary to determine:

(1) what the characteristics of the waste type indicate about the route via which the waste will preferentially migrate (i.e. via air, surface water, soils, ground water, subsurface gas or some combination of these)

(2) what the characteristics of the surrounding environment --soils, geology, hydrogeology, weather, indicate about the rate of contaminant migration (i.e. will soil typee, geology, hydrogeology, or weather contain, slow, or facilitate the migration of contaminants),

There are two prime sources of information describing waste and physical environment characteristics--reference materials and periodicals. At the end of this chapter are some useful reference materials.

Appendix A is a list of the more volatile and hazardous constituent associated with certain industry's wastes. This will assist the reviewer in identifying which volatiles to look for with the portable field instruments (Hnu, OVA, detector tubes) and what gases to use in calibrating the instruments.

Appendix B, List B is a list of ground water monitoring parameters for a handful of industry types. This list will identify the contaminant characteristics of certain industries which one is likely to detect and, therefore, analyze for in ground water.

Appendix C is a list of commonly identified pollutants and where one might expect to find the contaminants if they have been released into the surface water route.

Also attached as Appendix D is a list of other standard reference manuals too large to be included in this guidance that are also useful in characterizing the waste and physical environment and a cryptic identification of the type of information the reference material provides.

Appendix C is not attached.

Most of this information will be used in the development of the sampling and safety plans as well as data interpretation. For the sample plan development, the reference material will aid in locating optimum sampling locations and determining which constituents to analyze for. For the safety plan development, the reference material coupled with prior experience with the facility, will aid in identifying the type of protective clothing needed and the appropriate respiratory protection.

III. PREPARATION OF WORK PLANS, SAFETY PLANS, AND SAMPLING PLANS

After all the necessary data has been collected, work plans and safety plans must be prepared. If sampling is required, a sampling plan must be developed. The plans document the procedures to be used, the resources needed and the rationale for the activities to be undertaken. These documents insure that all the necessary planning, preparation and review has been done before field work begins. They provide a basis for later interpreting the results of the site inspection and documentation of the procedures and technical approach used in the event of future enforcement action.

A. Work Plan

The work plan is the umbrella plan that pulls all three plans together. The work plan provides for the efficient scheduling of resources such as manpower, equipment and laboratory services. The work plan should include the following:

- Introduction. This section should briefly describe (a few paragraphs) the facility and the objectives of the SI--i.e. conduct visual inspection, collect samples, etc. This section is for the benifit of the person reviewing the plan and to document the rationale in the event of future enforcement action.

- Investigation procedures. This includes identifying the specific standard operating procedures (SOPs) and field quality control (QC) procedures to be used. Appendix D contains an example check-off list of SOPs and QA procedures to be used in during the field work. Use of a check-off list prevents weighting down the work plan with reams of boilerplate SOPs. If the owner/operator is collecting the samples, a copy of the SOPs and QA procedures should be provided.

- Personnel requirements. This identifies all persons needed to conduct the field activities including support personnel and their specific responsibilities.

- Equipment requirement. All safety and sampling equipment and supplies should be identified plus any other support or non-standard equipment and supplies. Attached in Appendix E is an example equipment list.

- Contractual services. Any contractual services needed to accomplish the field work.

- Waste disposal procedures. All waste generated as part of the site investigation activities, such as disposable suits, gloves, sampling materials, must be disposed of in an appropriate manner in accordance with RCRA regulations. (In most cases it should be possible to get the owner/ operator to agree to dispose of the waste material at his facility.)

- Special training requirements. If any new equipment or procedures are to be use then mini training should be arranged.

Special consideration must be given to aspects of the work which may vary greatly from site to site. Each one of the following areas can greatly affect the time, expense, manpower and equipment needed for the project.

- hazards - What physical or chemical hazards may be encountered? Are there open manholes, deep embankments, low power lines, methane gas vapors, deteriorating surface features, poison ivy, snakes? Is the facility especially large?

- o facility location - How far is the facility from the home office? Will samples need to be shipped by overnight courrier to the laboratory? How far away is the nearest overnight shipping office? How accessible is the facility, especially inactive areas?

- o timing - Can the facility be visually inspected or will snow obscure facility features? Will the surface waters or ground be frozen such as to limit sampling? Will work performed in the winter be limited by short daylight hours? Will work performed in the summer wear out field personnel quickly? How will the season of the year affect water levels? Will leachate springs be visible during the dry season?

B. Sample Plan

Not all sites will be sampled during the SI state therefore in some situations in will not be necessary to prepare a sampling plan. If sampling is required, the following is a discussion of the plan's contents.

1. Contents of Sample Plan

It will always be the responsibility of EPA to prepare the sampling plan and the investigation procedures portion of the workplan, regardless of whether EPA or the owner/operator actually performs the sample collection. This will minimize or eliminate the risk of bias that could be introduced by the owner/operator during the sample collection and analyses.

The sample plan is encorporated into the work plan and identifies the sampling locations, rationale and logistics. The following outlines the contents of a sampling plan with a brief discussion of each component.

o Field operation.

The sampling plan should discuss the sequence for conducting the field activities. The specific functions of each individual should be identified in the work plan. For example, specific individuals need to be identified to take samples, maintain the field log book, monitor the site with instruments, collect samples.

o Sampling locations/rationale.

As precisely as possible, the location of each sample should be identified. A site map should be prepared to guide the inspectors to the appropriate location. Each sample type should be identified--soil, sediments, surface water, VOA, air, ground water and whether the sample is collected for metal, organics, BOD analysis, etc. The volume of sample to be collected and the number of samples collected should be identified. A justification for the selection of each sampling location should be provided.

o Analytical requirements.

The sampling plan should discuss the specific parameters for which each sample is to be analyzed.

o Sample Handling.

The preservation techniques and material for each sample should be identified. If sample filtering is needed, that should

be identified in this section including an explanation of its use. The containers used for each sample collection episode should be described including the tools, supplies, and equipment needed to collect the samples. Any procedure not covered by SOP's or different from the SOP's should be delineated here.

o Quality Assurance Samples.

The number and type of quality assurance samples should be identified in the plan--specifically the number of blanks, duplicates, or spikes. The "rules of thumb" for QA samples are discussed later in this section.

o Sample Decontamination.

The reageants and any special procedures associated with sample bottle decontamination should be identified in the sampling plan.

o Sampling reports/documentation.

The sampling plan should describe all sampling forms that should be filled out including chain-of-custody forms, sample receipt forms, sample traffic reports, sample tags. If any split samples are to be collected then instructions as to who should receive the splits should be identified here.

2. Quality Assurance/Quality Control Program for Sampling

All samples should be collected in accordance with the appropriate quality assurance (QA) and quality control (QC). QA is the total program for assuring the reliability of monitoring and measurement data. SOP's are the cornerstone to a QA program. SOP's are the exact, detailed procedures for performing a specific

task such as purging a shallow well, collecting a surface water sample, etc. The SOP's insure that the methods, techniques, and procedures for collecting technical data are correct and reproducable. SOP's are developed by persons with considerable experience in the particular activity and represent the best way to collect the sample for a specific situation. They also insure that a person collecting the same type of sample somewhere else or later on is performing it in the same way. This becomes particularly important in interpreting the results of the sample collection and in the defense of data in court later.

The field sampling activities should be supported by preparing and submitting several sets of quality control samples. These include blanks, spikes, duplicates, and splits.

o Blanks

There are two kinds of blanks of concern for this type of work: trip blanks and field blanks. Trip blanks are used to determine if inadvertent contamination is introduced from the sample containers or from an activity other than sample collection such as sample shipment, storage. Blanks are prepared by the sampler using distilled deionized water of known high purity. These bottles are then sent with the othe sample bottles to the field but are not opened. One set of trip blanks for each analytical parameter group (e.g., organics, metals, volatiles) should be prepared and submitted for each day of sampling at a particular site.

Field blanks are used to determine if contamination is introduced by the sample collection activities or sampling

environment. They are prepared by bringing a quantity of distilled deionized water to the field and "preparing" a sample by pouring the water into the bottles. They can also be prepared by pouring the sample through sample collection devices such as bailers. A field blank should be generated for each day of sampling at a particular site.

Blanks should be submitted in the same manner as the other field samples, with no distinguishing labeling or markings.

o Spikes

Spikes are samples to which a known amount of a compound has been added and are used to determine if contamination or error is introduced into samples as a result of laboratory procedures. One spiked sample is recommended for every ten field samples. Spiked samples are prepared by the laboratory performing the analyses after the samples are received at the laboratory. Although spikes are generally not handled by field personnel, they are part of the QA process and should be specified in the sampling plan.

o Duplicates

Duplicate samples are another method of checking on the precision of a laboratory's analytical methods. One duplicate sample should be taken for every ten samples collected at a facility. Duplicates are prepared by collecting one portion of sample, homogenizing it and dividing the sample into equal portions.

o Splits

Splits are identical portions of samples split between EPA and the ownr/operator. Splits are required only if the owner/operator is responsible for collecting and analyzing the samples. Split samples are used to evaluate the accuracy of analyses performed by a laboratory. Splits are prepared in the field exactly like a duplicate, but unlike duplicates, splits are always analyzed by different laboratories. The owner/operator should be instructed to prepare a split of all samples. The EPA inspector will then select two samples for EPA to analyze from among all the samples.

C. Safety Plan

A safety plan should be prepared for each field visits. All safety plans should be prepared in accordance with appropriate EPA guidance. (See EPA's Standard Operating Guides (SOSG's) for specific guidance on selecting the appropriate level of protection and how to prepare a safety plan.) The safety plan is usually prepared last and is tailored to the SI activities. For some SIs, the safety plan will be very simple and require few protective measures. Other, more problemsome sites, may require use of higher levels of protection. For example, if the SI involves sampling lagoons then the safety requirements will probably be more involved than an SI that involves simple visual reconnaissance.

Attached at the end of this section Appendix F is Chapter 9 from EPA's SOSG's. The SOSG's were prepared in accordance with EPA and other Federal health and safety guideline, regulations and orders. This attachment discusses the steps involved in developing a safety plan and elaborates on the contents of each section of

the plan. Provided below is a brief outline of the contents of the plan. Refer to the Exhibit at the end of this section for more detail.

- o Describe Known Hazards and Risks
- o List Key Personnel and Alternates
- o Identify Levels of Protection to be Worn
- o Identify Work Areas
- o Identify Access Control Procedures
- o Describe Decontamination Procedures
- o Describe Site Monitoring Program
- o Identify Special Training Required
- o Describe Weather-Related Precautions

IV. WORK PLAN/SAMPLING PLAN/SAFETY PLAN REVIEW PROCEDURES

Once the work plan, sampling plan and safety plans have been prepared, the plans should be reviewed by

- o other members of the team,
- o designated specialists/informal peer review, and
- o appropriate decision officials.

The purpose of this internal review is to ensure that the plans are complete, that the plans meet the goals of the site inspection and that all the appropriate quality assurance requirements for the field work are met. Most importantly, the internal review will assist in eliminating any unnecessary sampling and ensuring the proper focus for the SI.

The other members of the team review the plans to first understand their roles in the field activities and second to make

sure all the appropriate safety and field equipment they will need to perform their activity is accounted for.

The plans should also be circulated to individuals within the office with specialties in the various disciplines associated with the field work--geologists, geohydrologist, chemists, botanists, engineers, occupational health specialist (safety officer). These individuals will provide insights into areas with which the person preparing the plan may not be well aquainted. They would comment on the technical approach described in the plans to insure that sound technical judgment is applied and double check for any possible inadvertent mistakes or omissions.

Lastly, the plans should be reviewed and approved (signed) by an appropriate decision official--at least a first line supervisor. This person would be responsible for insuring that the plan meets all Agency and internal requirements as well as meets the goals of the investigation.

V. MOBILIZATION

In this stage of the SI all the necessary equipment and supplies are collected, all the equipment checked to insure they are functioning properly, all the appropriate pieces available, and any arrangements for sample analysis are made. If any additional supplies need to be procured they should be done at this stage. Also, if any unique contractual or equipment rental is required this should be done in this stage.

Equipment check-out and callibration is a very important task in this stage. Out in the field is not the time to discover that the battery is dead, the OVA carrier gas is empty, or the Hnu lamp is broken. Each instrument should be checked following the SOP for that particular instrument. The day of or before the instrument is to be used, the instrument should be callibrated. At the completion of the checkout and callibration (1) the date of callibration, (2) person checking out or callibrating the instrument, (3) the callibration standards used, and (4) a notation of deviation from SOP check out or callibration procedures should all be noted in the field or instrument checkout logbook.

If the work plan specifies sampling, then it is necessary at this stage to confirm the availablity of analytical space in the laboratory, especially if samples will be analyzed by the EPA Contract Lab Program (CLP).

VI. ACCESS/COMMUNITY RELATIONS

A. Owner/Operator Access

Prior to conducting the field work, the inspector must contact the owner/operator to schedule a time for the SI team to enter the site and perform the necessary field activities. Although it is possible that there has been considerable contact with the owner/operator about impending field work, the appropriate regional person should contact the owner/operator to verify dates and the nature of the field activities--sample collection, picture taking, facility inspection, instrument monitoring.

If the owner/operator is responsible for collecting and analyzing the samples, then the EPA official should contact the owner/operator to schedule a date to oversee the field activities. The sampling plan and procedures for performing the sample collection should be sent to the owner/operator sufficiently ahead of time for him to obtain the appropriate support. If EPA is collecting and analyzing the samples, EPA must offer the owner/operator a split of all samples collected. If the owner/operator wishes to have splits, he should be instructed to provide analytical sample bottles for the splits.

All arrangements should be followed with a letter confirming the dates and field activities. If access is denied, specific guidance on what to do is provided at the end of this section in Appendix G.

In some cases it may be necessary to access adjacent or nearby properties in order to conduct a visual inspection or collect samples. This may include industries and residents. They too should receive verbal as well as written notification of the dates and nature of the work.

Although the RCRA inspector is authorized to inspect a facility and collect samples and photographs, the owner/operator can require that the inspection and sample collection activities be conducted to protect his or her rights. The admissibility of data in court, should the owner/operator file suit against EPA, may later be challenged if the data was collected in violation of the owner/operator rights. For this reason, the inspector should not appear or act in a coersive or threating manner. The owner/operator is free to observe inspection activities, unless

the owner/operator is interfering with the safe or technically sound conduct of the site inspection.

The owner/operator has the right to request confidential treatment of certain data. The inspector should avoid agreeing to this to the greatest extent possible since it poses a problem with later using the information in public proceedings under RCRA or even under CERCLA. It also poses a sizable burder on EPA to control the data. If data deemed confidential by the owner/operator is needed to properly evaluate the facility then a precise description of the confidential data should be identified in the field log book. The inspector should instruct the owner/operator to follow up with a letter identifying the confidential data and and explaning the reason why the data is business confidential. EPA regulations governing treatment and handling of confidential data are delineated in 40 CFR Part 2, Subpart B, Sections 2.201-2.309.

B. Community Relations

If it will be necessary to conduct any field activities in or near residential or non-industrial business areas, then appropriate local officials should be contacted ahead of time. It is difficult to remain unobtrusive while conducting site inspections particularly if field workers are wearing protective clothing. Moreover, the presence of "official" people collecting samples can cause undue alarm. In some cases, it will be difficult to prevent this but prior, well handled community contact can minimize the alarm. Each of the regions has a community relation

staff to deal with the public for hazardous waste site investigations. These individuals can assist in identifying appropriate local community contact for a particular area.

The Office of Solid Waste is preparing guidance on community relations that will be available later this year. This document will provide specific guidance on when and how to implement a community relations program at RCRA facilities.

VII. COMPREHENSIVE VISUAL INSPECTION

The scope of the field work can vary depending upon whether sample collection will be needed. The field inspection may involve at a minimum conducting a thorough visual inspection at the facility to confirm information previously collected and to gather more information about a facility where data is lacking. If sample collection will be required, the SI will often be broken into two stages--the first stage wil be to conduct a comprehensive visual inspection to gather data about units and releases and to identify prime sampling locations. The second stage will involve collecting samples. If the owner/operator is collecting samples, an EPA person should be present to observe the activities to ensure conformance to the work plan, record field activities in the log book, resolve any field related problems that develop, and ensure proper field quality control. In some cases, it may be possible to eliminate EPA oversight in this phase of the SI if EPA personnel are confident of the integrity of the owner/operator and quality of his work.

There are a host of different aspects associated with conducting a field inspection. This section will discuss the key aspects of a site inspection that involves both a visual inspection plus sample collection, the sequence of field activities, photography, logbook maintenance, and chain-of-custody.

A. Sequence of Field Activities

Almost all site investigations will follow the same sequence of events. Frequently, the only element that varies is the time required to perform the event. The following is a list of tasks in sequential order.

(1) Site Arrival

During this step, the team arrives at the site, notifies the owner/operator of arrival and sets up the command post and decontamination line/access control points.

(2) Observation/Field Activity

During this stage of the field work the inspectors are:

- o making visual observations,
- o maintaining a field logbook of observations,
- o taking photographs, and
- o monitoring for vapor emissions.

(3) Decontamination/Demobilization

At this stage all persons and equipment exiting the site are decontaminated. This occurs not only at the completion of all field work but each time persons exit the site, including rest breaks.

In many cases, decontamination may be very simple--simply removing disposable coverals and washing field boots. In other cases, expecially if sampling is performed, then a more involved decontamination will be needed. For example, it will probably require decontaminating field persons, sample bottles, and sampling and field equipment.

All clothing and support materials that will not be reused must be containerized either for transport and eventual disposal or to leave on the site.

(4) Site Exit

At this stage the team leader should check out with the owner/operator. If requested, the team leader should provide the owner/operator with a receipt describing the photographs taken.

B. Photography

Photographs collected during the SI should be taken with regular 35mm cameras. Use of unusual filters should be avoided as they tend to discolor the picture and may unfairly bias the result by making leachate seeps or lagoon look worse than real life. The exact type of camera (including i.d. number), film (i.e., Fuji, asa 200), and any unusual lenses used must be identified in the field logbook.

If during the performance of the site inspection, the owner/operator withdraws his consent for EPA to be on his facility then any data collected up to that point is admissible data. The

inspectors may chose after leaving the site to collect visual information from outsite facility property. If this occurs, then the data collected must be in plain view from the facility boundary. Special lenses such as telephoto lens, and binoculars are not acceptable to use from off-site; regular 35mm cameras are acceptable.

Photographs should be taken to document the conditions of the facility and procedures used in inspection activities. Two sets of photographs should be taken in the event one camera does not function or film processing is poor.

The following identifies the type of pictures that should be taken:

- o representative overall picture(s) of facility,
- o posted signs identifying ownership of facility,
- o evidence of releases--leachate seeps, pools, discolored water, or strained soils,
- o individual units--lagoons, drums, landfill, etc.,
- o visual evidence of poor facility maintenance.
- o adjacent land use, and
- o area of easy access by unauthorized persons.

C. Logbook Maintenance

The logbook is perhaps the most important document generated during the site inpection. It will serve as the basis for pre-

paring the final SI report, interpreting data, describing the site, and most importantly, defending the work done and results obtained in any future legal proceedings under RCRA or CERCLA.

A unique logbook should be assigned for each site and each visit to the site. Logbook should be bound and each page sequentially number. Entries into the logbook should be chronological --a time notation should introduce each entry. Mistakes in the logbook should be lined out and initialed. The logbooks should be maintained with indelible ink.

The following is a list of the types of entries that should be made in the logbook:

- All personnel on site during each phase of the on site work;
- All instruments used during the field work with unique identification numbers;
- Description of film used;
- Description of the weather and changes in the weather;
- Result of field measurements--distances, instrument readings, well measurements;
- Factual description of structures and features--wells and well construction, units, containment structures, buildings, roads, topographic and geomorphic features;

- Signs of contamination--oily discharges, discolored surfaces, dead or stressed vegetation;
- Sketches of facility layout, structured features and points of contamination;
- Map of facility showing point and direction of photographs; and
- Any other relevant items.

For photographic documentation, the following information should be noted in the logbook.

- The sequence of picture number
- If more than one camera is used, identification of camera (print or slide)
- person taking picture
- description of picture

Each page of the logbook should be signed by the person keeping the logbook and counter-signed by a person accompanying the logbook keeper.

VIII. SAMPLING INSPECTION

If sample collection is required, it is sometimes possible to combine the sampling effort with the comprehensive visual inspection. This would most likely occur where the inspector(s) has recently visited the site, is thoroughly acquainted with the facility and is able to identify in advance where samples are to be taken. If it is not possible to combine the comprehensive visual inspection with sample collection, the visual inspection should be geared towards gathering data to develop the sampling plan.

The following is a discussion of activities associated with a field visit to collect samples.

A. Sequence of Field Activities

In most instances, the sequence of field activities is the same regardless of whether the purpose is to collect samples or conduct comprehensive visual observations.

(1) Site Arrival

This step is the same as previously discussed except that the inspector should hold a briefing with the EPA field team or owner/operator team to review the days events and ensure that each team member understands their responsibilities.

(2) Preliminary Site Entry

The preliminary site entry is the first step of the field activity. The purpose of the initial site entry is to screen the facility for situations posing a threat to health, and to support logistical needs of the site investigations. Preliminary site entry

will ensure that there have been no changes on site since the last visit. When a formal site entry is necessary, at least two team members should walk through the areas of the facility where work is anticipated with portable instruments to determine if there are any vapor releases or radiation emissions, if there is adequate oxygen, or if there are any explosive atmospheres. the site since the last visit. Depending upon the climate from one day to the next, the concentration of volatiles, explosive gases and oxygen can change. Secondly, it is extremely difficult for field personnel to screen the site while collecting samples, taking pictures, and maintaining a field log book.

At the end of this step the team leader should evaluate whether any information collected during the initial site entry changes any of the plans. For example, it may be possible to downgrade the level of protection.

In some cases, it may not be necessary to conduct an initial site entry if the inspector has had recent contact with the facility and is confident that the site conditions have not changed. The site inspector may have adequate, first-hand information on the facility to insure that the facility poses no threat to the health of the inspector. Where the inspector has little data on the facility, or is unsure of the reliability or completeness of existing data, then an initial site entry to screen the site is appropriate.

This step becomes especially important for sampling inspections. It is extremely difficult to monitor a site with portable instruments while collecting samples, taking pictures and maintaining a field log book. If a quick screen is performed

prior to sampling, then the logistics of field work will be simplified.

(3) Sample Activity

During this stage of the field work, the following tasks are occurring:

- o collecting samples,
- o photographing sample collection,
- o maintaining the logbook, and
- o monitoring for vapor emissions.

Regardless of who is performing the sample collection, continuous monitoring for vapor emissions is needed to detect air releases from sampling activities. If the owner/operator is collecting the samples, the EPA field team's prime responsibility is to document precisely the sequence of sampling activities, the procedures and instruments used, and a description of the samples (including location, depth, appearance, etc.).

The EPA Regional offices have developed SOP's for most SI sampling tasks under the CERCLA program. For the most part these SOP's are applicable to RCRA field activities. If the SOP's are not applicable or appropriate for the particular field activity then a new SOP should be developed. In some cases, only minor modifications are necessary. Were modification to existing SOP's are made, then the exact modifications must be noted in the field logbook.

(4) Decontamination/Demobilization

This stage is the same for a comprehensive visual SI. In addition to personnel and equipment decontamination, all samples must be decontaminated. All sample identification forms, sample shipping forms, chain-of-custody forms, sample receipts, and sample traffic forms are completed. Some of the information on these forms can be filled in prior to the sampling and is in fact recommended due to the number of forms and time required to complete these. Examples of each of these forms are contained in Appendix H All samples are packaged for safe transport. If samples are to be shipped by express carriers, then the samples are packaged in accordance with DOT specifications for shipping of hazardous materials.

(5) Site Exit

This stage is similar to the procedure discussed previously. In addition, the inspector should deliver a receipt describing the samples collected. The inspector should obtain a written acknowledgement of the receipt of sample form. If the owner/operator requested split samples, then the samples would be left with him at this time.

B. Photography

The same principles previously discussed apply to sample collection tasks. Photographs should be taken of:

- posted signs identifying ownership of facility,
- sampling locations, and

- o sampling activities.

C. Logbook Maintenance

The same principles discussed previously also apply here. The following is a list of the additional types of entries that should be made in the logbook for sampling inspections:

- o description of sample (appearance),
- o exact depth from which sample taken,
- o description of location of sample,
- o map(s) identifying site layout and sampling points
- o field calculations,
- o decontamination procedures used between collection of each sample,
- o any deviation from SOPs, and
- o any other relevant item.

E. Chain-of-Custody

All samples collected (including blanks and spikes) should be maintained under chain-of-custody. The purpose of chain-of-custody is to insure that data collected during the SI is not tampered with before it is analyzed. Chain-of-custody traces the possession of a sample from the time of collection, through all transfers of custody, to when it is received in the laboratory, where internal laboratory chain-of-custody procedures take over. For samples that are spiked in the laboratory, chain-of-custody

should be maintained from the time the sample is prepared in the laboratory to when it is received in the laboratory for analysis.

Specific chain-of-custody procedures are included in the SOP of chain-of-custody.

IX. SAMPLE SHIPMENT/ANALYSIS OF SAMPLES

At this stage of the SI, any samples that were collected by the EPA or splits of samples collected by the owner/operator, are delivered to the laboratory and the samples analyzed. If the analysis is performed by the EPA Contact Lab Program (CLP) then most samples will have to be shipped by overnight courrier. This will involve driving the samples to the closest overnight courrier office and completing the appropriate sample shipment forms. Most samples collected at hazardous waste facilities are regulated by the Dept. of Transportation requlations governing shipping of hazardous materials. SOP's covering sample shipping are available in each of the regional offices or in EPA safety training manuals. The time involved in analyzing samples can vary from 40 days to three to four months.

X. ANALYTICAL DATA REVIEW

Upon receipt of analytical results, the data must be reviewed to insure that the results are valid. This particular step can take a considerable amount of time depending upon the backlog of data packages requiring review. The EPA Regional Environmental Services Divisions (ESDs) are responsible for quality assurance review of analytical data. In some cases, some or all of the

responsibility for data review is delegated to the group responsible for collecting the samples.

Some of the data review responsibilities can be delegated to the persons collecting the samples and do not require involved training or experience to perform. Primarily these involve ensuring that all deliverables required by the CLP are included in the data package, checking that all forms are completed within the requirements of the contract, flagging missing data or incomplete forms, and reporting these to the appropriate person for follow-up. Depending upon the arrangements in the particular Region, the preliminary data review can also involve completing a checklist of questions which summarize key quality assurance items in the data package.

With the results provided by this preliminary data review, missing data will be requested and the ESD's will perform a qualitative analysis of the data. Based on the abundance of laboratory internal quality assurance data provided in the data packages the ESD determines if the data results are valid.

At the completion of the analytical data review, all the data collected to that point is evaluated to determine if a release or potential for release has occurred. The substance of the data evaluation stage is contained in the succeeding chapters.

XI. FINAL REPORT/FILES

After evaluating all the data, a brief report summarizing the results, findings, and recommendations, should be prepared. This report should not on average be more than fifteen pages long. In some cases the report may be longer for a particularly

complicated site.

The report should identify the areas or units that are releasing or suspected to be releasing and the basis for these findings. The report should also recommend, area (or units) where no further action, immediate interim corrective action, or remedial investigation is required. The basis for these recommendations should be clearly substantiated in the report. The relative priority of the facility for follow up investigation should be explained. In addition, where further action is recommended, the report should also describe the scope of further action.

The following is a recommended outline for a SI report. It may not be necessary to discuss all the items identified in the outline if the discussion is clearly irrelevant to the particular site. For example, it may not be necessary to elaborate on the geology or hydrology of an area if the only unit of concern is an inactive above ground storage facility with no problem spill, discharge or overflow problems.

- Site Background

This section should summarize, among other things, the location of the facility, the types of hazardous waste handling practices (by unit), which units are regulated, the layout of the facility (include a map), how long the facility and units have been in operation, and the site ownership. This section is not intended to repeat detailed data already provided in the Part B application or CERCLA SI report. The report should briefly summarize data found in other documets, and describe new data identified.

o Environmental Setting

This section should describe, in summary form, the media surrounding the facility--the relevant climatic, geological, hydrogeological, and topographical factors. Maps, sketches, and selected photographs would be included in this section to further describe the physical environment. Also included in this section would be a discussion of target populations and environments--including public and private water supply ground and surface water intakes, protected areas, parks, wetlands, affected irrigated crops and livestock.

o Unit/Waste Description

This section would discuss the types of units found at the facility and their tendency to cause releases into the air, ground water, surface water, soil and subsurface gas. This section would discuss the relevant design and operational features that exist or do not exist to adequately contain hazardous wastes or releases of hazardous wastes. This discussion would also include situations where it is unknown what type of design or operational features existed to control or contain hazardous waste. As part of this discussion, the types of wastes handled by each unit would be described.

o Laboratory Results

This section would discuss the results of previous and new analytical results. Much of the information in this section would be presented in tabular form and would be accompanied with maps locating sample collection points.

o Toxicological Characteristics

This section would discuss toxicological characteristics of the wastes releasing or suspected to be releasing into the environment. The report would focus only on the most toxic and persistent chemicals releasing.

o Conclusions and Recommendations

This section would present the findings and conclusions from those findings. Documented releases should be discussed in this section as well as findings that releases are soon or likely to occur. Areas where insufficient data document a release should be discussed. Units that are found not to be releasing should be identified and discussed. Recommendations for further action on units not eliminated from further consideration should be presented. Where the facility or some portion of the facility is recommended for an RI or corrective action, brief and generalized discussion of the scope of further work should be included. Recommendation for deferral of further action should also be explained in this section.

o Bibliography

This section would identify all sources of information used in the evaluation and preparation of the SI report. This portion would be essential if the facility is referred to the CERCLA program for consideration for the National Priorities List (NPL).

o Appendices

Any relevant memorandum, reports, pages from reports, maps, etc. that elaborate upon or further substantiate information in

the SI report would be attached in this section.

A copy of the final report plus all memoranda, photographs, logbooks, trip reports, workplans, sampling plans, safety plans, sample tags, chain-of-custody forms, records of communication, plus any new reports or documents uncovered in the course of conducting the SI, should be entered into the official facility file. All this information will be used as evidentiary documentation in any future court proceedings.

CHAPTER FIVE

SURFACE WATER

I. INTRODUCTION

The site investigation for surface water should determine whether solid waste management units at the facility have released and/or will continue to release hazardous wastes or hazardous constituents to surface water.[1] For units with identified releases, or for which there is a substantial likelihood of a release, the owner or operator will be required to conduct further investigations to actually determine the extent of a release(s) and/or to characterize the release and begin developing a corrective measures program.

Although EPA is primarily concerned with releases to surface water, such releases can also migrate overland and potentially expose human and environmental receptors. Releases to surface water and off-site may result from point source discharges, spills, leaks, surface run-off, or floods.

The investigator will need to make determinations regarding the need for further investigation at a unit on a case-by-case basis, considering factors that are unique to each unit. For some units, it may be relatively easy to assess the potential for surface water contamination and to determine the need to conduct further investigations. For other units, it may be more difficult to make these determinations and the investigator will need to use judgment in deciding whether further investigations are warranted.

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[1] Surface water includes any stream, river, lake, bay, wetland, estuary, and intermittent stream.

Releases that result in surface water or off-site contamination can be difficult to identify because of their intermittent nature. For example, a surface impoundment may regularly overflow and release hazardous constituents during periods of heavy rainfall. However, unless the site investigation is conducted during a heavy rainfall, the investigator will not observe the release. Therefore, he/she should evaluate each unit at the facility for its potential to cause surface water releases and examine the site for evidence that indicates such releases have occurred or occur on a regular basis. The investigator will also need to assess whether such releases threaten human health and the environment before determining that further investigations are necessary.

The comprehensive investigations called for in the second phase of the corrective action process require a considerable investment of time and resources for both the owner or operator in conducting the investigation, and for the agency in reviewing technical plans and analytical results. Therefore, the PA/SI should serve the dual function of identifying situations which merit further investigations for surface water releases, and at the same time avoiding unnecessary investigations.

This chapter describes the factors the investigator should consider in assessing specific units and the site for their potential to cause releases to surface water. It also describes the kinds of evidence the investigator should look for to identify whether or not a release has taken place and factors to consider in assessing the potential for releases to threaten human health and the environment.

II. POTENTIAL FOR SURFACE WATER RELEASES FROM THE FACILITY

Four factors are important in assessing the potential for surface water contamination from a facility. They are:

- o the proximity of the facility to surface water;
- o the potential for releases to migrate from the facility to surface water or directly to off-site receptors;
- o the design and physical condition of solid waste management units at the facility; and
- o the type of wastes contained in these units.

The importance of each of these factors is discussed below.

Proximity to Surface Water and Release Migration Potential

The potential for surface water contamination from a facility is directly related to the facility's proximity to surface water. Facilities located along rivers or other surface water bodies are more likely to have surface water releases than facilities located in arid areas, far from significant surface water bodies. As the distance to surface water increases, it becomes more likely that hazardous constituents in surface run-off will sorb to soils or move downward in the unsaturated zone and result in ground water contamination.

The potential for surface run-off from the facility to migrate overland to nearby receptors is only of concern when the facility is located adjacent to populated areas and no barrier (e.g., runoff control system) exists to prevent further overland migration.

Proximity is not the only factor that affects the potential for releases to migrate to surface water or drain off-site. The facility slope indicates the potential for run-off or spills to

migrate from the facility. For example, releases from a facility located in a depressed area are unlikely to leave the site as surface run-off. The composition of the soil and the slope and vegetation of the terrain between the facility and the nearest surface water body will also affect the migration potential of the release. For example, a facility located close to surface water may have a low potential for surface water releases if the intervening terrain is characterized by sandy soils and heavy vegetation. In this case, run-off is more likely to migrate down into the unsaturated and saturated zones rather than to migrate laterally overland to surface water. However, facilities located in areas characterized by clayey soil, and where there is less extensive vegetation between the site and nearby surface water, have a greater potential for releases to surface water.

The level of rainfall and the frequency of significant storm events also affect the potential for run-off from the facility to contaminate surface water. As mentioned earlier in this chapter, surface water releases are often intermittent and result from run-off generated during periods of heavy rainfall. A facility located in an area characterized by frequent major storm events is more likely to generate large volumes of surface run-off than a facility located in an area where major storm events are less frequent.

The assimilative capacity of the closest surface water body also affects the migration potential of releases from a facility. Large streams with high flow rates will tend to degrade or mix and dilute constituents more rapidly than smaller streams with lower flow rates.

The investigator will need to consider all of these factors -- proximity to surface water, soil composition, slope and vegetation characteristics of the facility and the intervening terrain, assimilative capacity of nearby streams, rainfall, and the frequency of major storm events -- to determine how the facility's location affects the potential for releases to surface water or the movement of surface run-off to off-site receptors.

Unit Design and Physical Condition

As with the other media, the potential for surface water contamination from a solid waste management unit is largely dependent on the nature and function of the unit. For example, open units that contain liquids (e.g., surface impoundments) have a greater potential for surface water releases than closed landfill cells that have been properly capped.

Table 5-1 ranks types of solid waste management units, in a loose descending order on the basis of their potential for having releases that cause surface water contamination or migrate off-site as surface run-off. The table is intended to provide a general sense of the relative potential for units to cause these types of releases. The investigator will also need to evaluate unit-specific factors in determining the potential for surface water releases from a particular unit.

The major unit-specific factors the investigator should evaluate include:

- o unit design. The investigator should determine whether the unit has engineered features (e.g., run-off control systems) that are designed to prevent releases to surface water. If such features are in place, the investigator should evaluate whether they are adequate (in terms of capacity, engineering, etc.) to prevent releases.

Table 5-1. UNIT POTENTIAL FOR SURFACE WATER RELEASES AND MECHANISMS OF RELEASE

Unit Type	Release Mechanism
Landfill	o Migration of run-off outside the unit's run-off collection and containment system
	o Migration of spills and other releases outside the containment area from loading and unloading operations
Surface Impoundment	o Releases from overtopping
	o Seepage through dikes to surrounding areas (i.e., soils, pavement, etc.)
Waste Pile	o Migration of run-off outside the unit's run-off collection and containment system
	o Migration of spills and other releases outside the containment area from loading and unloading operations
Container Storage Area	o Migration of run-off outside the containment area
Land Treatment Unit	o Migration of run-off outside the containment area
Above-ground Tank	o Releases from overflow
	o Leaks through tank shell
	o Spills from coupling/uncoupling operations
In-ground Tank	o Releases from overflow
	o Spills from coupling/uncoupling operations
Incinerator	o Spills or other releases from waste handling/preparation activities
	o Spills due to mechanical failure
Class I and V Injection Well	o Spills from waste handling operations at the well head

* The two remaining solid waste management units; waste transfer stations, and waste recycling operations generally have mechanisms of release similar to tanks.

making these determinations. To the extent waste information is available, the investigator may be able to take these factors into account. Each factor is discussed more fully below.

1. Mass. The mass of a contaminant relative to the volume of the receiving water body is one of the primary factors governing the environmental significance of a release. The high volumes of water present in some rivers and lakes will dilute many contaminants so that concentrations are below levels that impact human health or the environment. Volume and flow rate govern the ability of a water body to assimilate a contaminant. Larger bodies of water can assimilate higher quantities of pollutants than smaller ones, and more turbulent streams and rivers expedite the mixing and dilution process and assimilate pollutants more quickly than slow moving or stagnant bodies of water.

2. Transport Mechanisms. The transport mechanisms governing the movement of pollutants control their ultimate destination. The primary transport mechanisms are sedimentation, volatilization, and downstream transport in the water column. The strucutre and properties of each constituent will govern which mechanisms dominate their transport. While most constituents can be affected by all three transport mechanisms, it is possible in most cases to partition a constituent to one primary destination. This information can be used to predict where specific constituents will result in potential exposures. A brief description of each fate and transport mechanism follows:

- o sedimentation. Sedimentation refers to the tendency of a constituent to sorb onto suspended organic sediments carried in water bodies. Sorption can be modeled using a sorption isotherm, which predicts the relative tendency of a constituent to be partitioned to suspended particles

or to remain dissolved in the water. The sorption partition coefficient, K_{sw}, describes the tendency of a constituent to be dissolved in the water phase or to be sorbed onto a particle. Once a constituent has become sorbed to a particle in the water, it will usually join the bottom sediments of the system.

- o volatilization. Compounds exhibiting a strong tendency to volatilize from water will pose little risk to human health or the environment through surface water exposures. Many chlorinated solvents will almost completely volatilize from a moving stream within several miles. Compounds with large Henry's Law constants will have the greatest potential for volatilization. It will be accentuated in turbulent water systems such as fast moving streams, where the turbulence speeds up the transfer of contaminants from water to air.

- o downstream transport. Relatively immiscible organic compounds with densities less than water (e.g., oily wastes) will tend to float on water surfaces in slicks, where they may pose a significant threat to water fowl. Other immiscible compounds which are heavier than water will tend to sink into the sediments where they will remain largely undissolved in the water column. Dissolved constituents will be transported downstream in rivers and dispersed in lakes where they will be subject to natural fate processes.

3. Persistence. Many fate processes can combine to degrade a pollutant to a level below which there is no significant risk. Among the many fate processes are: hydrolysis, photolysis, oxidation/reduction, biotransformation, and bioaccumulation. Many references will report a value for a chemical's half-life in water based upon a combination of these processes. In this way, one can make a general assessment of a constituent's persistence in the environment. The most persistent constituents (e.g., PCBs, dioxins, etc.) will not be significantly degraded by any of the fate processes mentioned above and should generally be considered to pose a considerable risk. Bioaccumulation deserves special mention due to the unusual threat it poses to animals in the food chain. Concentrations of constituents that bioaccumulate in fish and shellfish may be higher in the fish than they were in the

original release. Pollutants that bioaccumulate should be given special consideration in water bodies used for recreational or commercial fishing.

4. Toxicity. The most pertinent factor in assessing the significance of a release of hazardous constituents to surface water will often be the intrinsic toxicity of each individual contaminant. Large releases of certain non-carcinogens may be assimilated in streams or lakes without consequence to human health or the environment. However, low concentrations of highly toxic and/or persistent constituents like dioxin, PCBs, arsenic, and cyanides may pose a significant human health risk. Unfortunately, toxicity information for many of the Appendix VIII constituents is incomplete. For this reason, it will often be advisable to consider highly persistent constituents to be of the greatest concern, because exposures can occur over a considerable length of time with unknown consequences.

While the overall fate and transport of a constituent in a surface water system will depend on the specific characteristics of the system, it is possible to generally describe the likely fate and transport for certain classes of contaminants. If the investigator knows the wastes in the unit, this information may help in determining which contaminants are of particular concern for surface water releases.

- metals (e.g., arsenic, chromium, cyanide, and mercury) usually adsorb and accumulate in sediments in rivers and lakes. The rate at which they concentrate in the sediments will depend on the organic content of the suspended solids in the system and on the concentration of clays in the water. Most metals will exhibit a tendency to bioaccumulate in both shellfish and finfish. They will therefore pose the greatest threat to human health in waters known to be used for recreational and commerical fishing.

- o chlorinated pesticides (e.g., DDT, chlordane, lindane, heptachlor, toxaphene, etc.) may be subject to several fate and transport processes simultaneously. They have been shown to volatilize, sorb onto sediments, biodegrade, and bioaccumulate. In large quantities, chlorinated pesticides mmay pose a significant risk from exposure throughout the water body.

- o halogenated aliphatic hydrocarbons (e.g., trichlorethane, tetrachlorethene, chloromethane, etc.) generally exhibit a strong tendency to volatilize from water. Large quantities of these pollutants can be stripped from fast-moving, turbulent streams, reducing their risk for water-associated exposures. Although they will not tend to be transported downstream, they generally do not degrade significantly in the environment. Many of these compounds may still pose a significant risk at low concentrations due to their toxicity.

- o polycyclic aromatic hydrocarbons (e.g., napthalene, phenanthrene, benzo(a) pyrene, etc.) will tend to adsorb to bottom sediments. These pollutants are generally susceptible to biodegration and hydrolysis in surface water systems. Because they do not tend to bioaccumulate, releases characterized by low concentrations of these pollutants are likely to be of little concern.

Summary of Factors Affecting the Potential for Release

The investigator should consider all of the factors described above to determine a unit's surface water release potential. In addition, in assessing a unit's potential for surface water releases, the investigator should consider how the various factors affect each other. For example, an aboveground tank containing relatively toxic, persistent waste and located within 1000 feet of a river may not have a secondary containment or other system in place to collect liquid waste that could leak or overflow from the tank. However, the facility's records indicate that the tank is relatively new, well designed, and well constructed, and that it is inspected regularly for evidence of leaks. In this case, there is only a low potential for a release to surface water, and no further investigation would be necessary.

Alternatively, the same situation with an older tank that shows signs of deterioration may require further investigation.

III. EVIDENCE OF SURFACE WATER RELEASES

If the investigator determines that certain units at the facility have the potential to cause releases to surface water, he/she should inspect the area around the units of concern and the area between the unit and the closest surface water body for evidence of a release. In addition, if the facility is located adjacent to surface water, the investigator should examine the surface water for evidence of releases. The investigator should look for the following types of evidence:

- unpermitted discharges to surface water that require NPDES or Section 404 permits. Hazardous waste facilities may be using certain practices that require permits under the Clean Water Act. The investigator should examine the site for the following types of discharges and determine whether these discharges are permitted:

  -- discharges from collection and holding facilities (e.g., tanks, basins, surface impoundments, etc.);
  -- discharges of contaminated ground water from a counterpumping activity;
  -- discharges from a leachate collection/treatment system;
  -- placement of dredge or fill material in the water; and
  -- units (including old fill material that is now considered hazardous waste) in surface water.

- visible evidence of uncontrolled run-off from units at the facility. If releases have occurred or are occurring at a unit there is likely to be evidence around the unit that indicates a release is taking place. Because of the intermittent nature of most surface water releases, it is particularly important to examine the site and nearby surface water for physical evidence of release. The investigator should look for:

  -- observable contaminated run-off or leachate seeps;
  -- drainage patterns that indicate possible run-off from units at the facility;
  -- evidence of wash-outs or floods, such as highly eroded soil, damaged trees, etc.;
  -- discolored soil, standing water, or dead vegetation along drainage patterns leading from the unit; and
  -- discolored surface water, sediment or dead aquatic vegetation.

Use of Sampling to Support Other Evidence Obtained

Depending on the other evidence collected, it may be desirable to sample run-off, on-site soils, standing water, surface water, and/or surface water sediments. While the Agency expects that in general, it will not be necessary to take samples during the PA/SI, there may be certain situations where sampling can confirm other evidence that a release has taken place at a unit or that there is no release from a unit. Sampling should only be conducted to verify or confirm other evidence collected.

For example, inspection of units and the facility may indicate the potential for surface water releases (e.g., tanks at the facility are older and inadequately designed; many have contained toxic wastes for more than 20 years; and the facility is located adjacent to a relatively small stream). While there is no visible evidence of leaks or fractures in the tanks, other evidence indicates that surface water releases are taking place (e.g., run-off in drainage channels leading from the units is discolored, and there is dead vegetation along the drainage channels). In this case, the investigator may want to sample run-off in the channels for indications of contamination.

In general, simple field tests or sampling may be adequate to obtain a positive confirmation of surface water or surface run-off contamination. More thorough sampling may be necessary to confirm that the contamination results from a particular unit, but this more detailed sampling may be completed as part of the next phase of the corrective action process. If the investigator determines that sampling is necessary, he/she should follow the procedures that are provided in Appendix __. Procedures for

analyzing samples for hazardous constituents described in 40 CFR Part 261, Subparts C and D, can be found in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846)."

IV. EXPOSURE POTENTIAL

If the investigator observes discharges or releases to surface water or other evidence that such releases are taking place, he/she may choose to use exposure information (to the extent it is available for the facility) to: 1) determine the need for further investigations; and/or 2) set priorities for conducting further investigations.

The following types of information are useful in evaluating the exposure potential of surface water releases:

- information on the use of the surface water body that receives the release. The investigator should determine the use of the surface water body (e.g., no use, commercial or industrial, irrigation, economically important resource (e.g., shellfish, commercial food preparation, recreation, or drinking). A release is more likely to significantly impact surface water that is used as a drinking water source than surface water in industrial areas that have a commercial or industrial use.

- information on the location of any drinking or irrigation water intakes listed in public records or otherwise known within a reasonable distance of the release.

- information on the nature and extent of the contact human and environmental receptors are likely to have with run-off from the facility.

V. SUMMARY AND EXAMPLES

This chapter has identified certain unit-specific and site-specific characteristics that should be evaluated to determine the potential for surface water releases or releases that migrate off-site in surface run-off. These characteristics include: the proximity of the facility to surface water; factors such as soil

type, slope, and vegetation of the intervening terrain that affect the migration potential of a release; the design and physical condition of solid waste management units at the facility; and the type of waste contained in the solid waste management units. The investigator should examine each of these factors and how they relate to each other in determining the potential for surface water releases from units at the facility.

Once the investigator determines that the potential for surface water releases exists at a facility, he/she should examine areas surrounding the units of concern and the site as a whole for evidence that releases have occurred or are occurring at a facility. Due to the intermittent nature of most surface water releases, it is important to look for physical evidence such as drainage patterns, dead vegetation, etc., that indicates that releases have taken place. The investigator should also consider the potential for exposure from these releases before making a determination that further investigation is necessary.

Table 5-2 provides examples of situations that are likely to require further investigation and situations that probably will not require further investigation.

Table 5-2
UNIT ILLUSTRATIONS

Unit Type	Further Investigation Needed	Further Investigation Not Needed
Landfills	Closed units, inadequate or deteriorating cover, no run-off control system; drainage patterns indicate contaminant migration (i.e., discolored soil and/or dead vegetation); near downgradient surface water/off-site receptors	Operating units with adequate run-off control systems Closed units with adequate caps or covers; no evidence of run-off from the unit
Waste Piles	Closed units, waste inadequately covered, no run-off control system; drainage patterns indicate migration of contaminants; near surface water	Operating units with run-off control systems Closed units with adequate caps or covers; no evidence of run-off from the unit
Surface Impoundments	Operating/closed units with inadequate freeboard or deteriorating dikes; located adjacent to stream that has downstream drinking water intakes Operating/closed units with deteriorating dikes; evidence of release; near surface water	Older operating/closed units with adequate freeboard and overtopping controls; limited potential for off-site exposure; more than 3 miles from nearest surface water
Container Storage Areas	Inactive units with leaking containers; visible evidence of soil contamination; no run-off control system, drainage channels indicate migration of hazardous constituents	Operating units with new, well sealed containers; or adequate run-off controls Inactive units with well sealed containers; adequate run-off controls; limited potential for off-site exposure, no nearby downgradient surface water
Land Treatment Units	Inactive/operating units with visible evidence of soil contamination; unit design allows run-off; near downgradient surface water and/or off-site receptors	Inactive/operating units with adequate run-off controls; limited potential for off-site exposure

Table 5-2 (Continued)
UNIT ILLUSTRATIONS

Unit Type	Further Investigation Needed	Further Investigation Not Needed
Tanks	Older concrete units with no secondary containment, some visible deterioration; visible evidence suggests some overland migration of hazardous constituents; near surface water	Well-designed, constructed units; inspected regularly; no evidence of leaks
	Unit with visible evidence of soil contamination from apparent (or recorded) overflow events or other operational or structural failures; unit in area with clayey soil, near surface water	Older units that shown signs of deterioration; no potential for off-site migration of constituents
Incinerators	Evidence of recurring spills that result from waste handling operations; drainage channels leading from the unit indicate contaminant migration; near surface water	Design ensures containment of spills that could occur during waste handling operations
Class I/ IV Injection Wells	Evidence of recurring spills that result from waste handling operations; drainage channels leading from the unit indicate contaminant migration; near surface water	Design ensures containment of spills that could occur during waste handling operations

CHAPTER SIX

AIR

I. INTRODUCTION

The site investigation for air should determine whether solid waste management units at the facility have released or are likely to have released hazardous wastes or constituents to the air. Owners or operators of units with identified releases or that have a substantial likelihood of a release will be required to conduct further investigations to actually determine the extent of a release(s) and/or to characterize the release and begin developing a corrective measures program.

In general, two types of air releases can occur at solid waste management units:

- o releases that are continuous in nature, and
- o releases that are intermittent or catastrophic in nature.

This guidance is primarily concerned with evaluating the likelihood and significance of continuous releases. It is assumed that all units that expose hazardous waste to the ambient atmosphere have air releases; the investigator will need to use judgment in determining whether these releases are significant enough to warrant further investigation. For some units it may be relatively easy to make these determinations; for other units, these determinations may be more difficult.

Because the comprehensive investigations called for in the second phase of the corrective action process require a considerable investment of time and resources for both the owner or operator and for the agency, the PA/SI should serve the dual role of identifying situations which merit further investigations for air

releases while at the same time avoiding unnecessary investigations.

This chapter describes the factors the investigator should consider in evaluating specific units and the facility as a whole for their potential to cause air releases. It then describes the kinds of evidence the investigator should look for to determine that a release has taken place and factors to consider in assessing the potential for releases to threaten human health and the environment.

II. POTENTIAL FOR AIR RELEASES FROM THE FACILITY

Three factors are important in assessing the potential for significant air releases from a facility. They are:

- o unit characteristics, such as size, type and use;
- o types of wastes/constituents in the unit; and
- o potential for mitigating exposure resulting from the release.

This section describes each of these factors in greater detail.

Unit Characteristics that Affect the Potential for Air Releases

When conducting the site investigation for air, Agency personnel should assess both RCRA-regulated and non-RCRA units and should focus the investigation on operating units. Operating units have the greatest potential for air releases because they actively expose wastes to the air on a continuous basis. Wastes in closed, inactive units are usually covered. There may be some exposure to the air if a cover has eroded or broken down, but air releases resulting from these situations are likely to be insignificant.

When assessing the potential for releases, the key factors to examine include:

- o unit size. The size of a unit determines the mass of potential contaminants available for release. In addition, volatilization rates are likely to be larger from open units (e.g., surface impoundments and open tanks) with large surface areas and shallow depths.

- o purpose of the unit (treatment, storage, or disposal). In general, units in which active treatment is occurring have the greatest potential for air releases. In many cases, treatment is designed to promote volatilization of constituents. In other cases, this is not the main purpose of the treatment method in use. However, the resultant mixing and movement of wastes leads to high volatilization rates.

- o design of the unit. Units in which wastes are in direct contact with the atmosphere have a higher potential for releases than closed or covered units.

- o current operational status. The nature of air releases is such that the majority of the mass available for release will be released shortly after the waste is placed in the unit. Thus, as mentioned, operating units are of greater concern than closed units. This is particularly true for unit types and wastes for which volatilization is important. Units with potential particulate releases may continue to release contaminants well after closure, especially if the unit has been poorly maintained.

- o unit specific factors. There are specific design and operational factors associated with each unit type which are useful in evaluating the possible magnitude of a potential release. These factors are summarized in Table 6-1.

In addition to considering the individual unit sizes, the investigator should be aware of the total area used for solid waste management at a facility. Although individual units may have small releases, the total release from a facility can be significant. Table 6-1 lists specific considerations for particularly important unit types.

In assessing a unit's potential for air release, the investigator should be aware of the importance of interactions between the various unit characteristics listed above and the characteristics of the wastes placed in the unit. It is important to examine how these two factors combine to result in an air release.

Table 6-1

UNIT POTENTIAL FOR AIR RELEASES
AND MECHANISMS OF RELEASE

Unit Type	Characteristics and Mechanisims of Release
Operating Surface Impoundments	o Wastes directly exposed to atmosphere promotes vapor phase emissions o Large surface areas and shallow depths promote increased volatilization o Mechanical treatment methods (such as aeration) increase volatilization
Open Roofed Tanks	o Wastes directly exposed to atmosphere (promotes vapor phase emissions) o Mechanical treatment or frequent mixing will increase volatilization
Landfills	o Volatilization of vapor phase constituents through the sub-surface and daily/permanent cover o Poor or no daily cover increases volatilization o Open trench fill operations allow direct exposure of waste to atmosphere o Volatile gases transported by convection of biogenic gases released via routine landfill venting (particularly important in sanitary/hazardous mixed fills) o Particulate releases generated by machinery during filling operations o Particulate releases due to wind erosion of cover and/or exposed wastes
Land Treatment Units	o Wastes normally in direct contact with atmosphere o Application techniques which maximize waste contact with atmosphere, such as surface spreading or spray irrigation promote increased volatilization o Particulate releases due to wind erosion
Waste Piles	o Particulate emissions from uncovered waste piles o Location of waste pile in open area with no erosion protection promotes particulate generation o Waste handling activities on and around pile increase emissions o Volatile emissions are likely to be rare, but can occur based on waste composition

Table 6-1 continued

Unit type	Characteristics and Mechanisims of Release
Drum Storage Areas	o Vaporization from drums frequently left open to atmosphere or from poorly sealed drums. o Vapor emissions from areas containing leaking drums
Covered Tanks	o Volatile releases from pressure venting, poorly sealed access ports, or improperly operated and maintained valves and seals.
Incinerators	o Stack emissions of particulates o Stack emissions of volatile constituents. High temperatures may cause volatilization of low vapor pressure organics and metals. o Volatile releases via malfunctioning valves during incinerator charging
Non-RCRA Wastewater Treatment Ponds and Tanks	o Low concentration wastes may volatilize due to large surface area and active waste treatment. Releases can be significat releases due to generally large treatment capacities
Other Design and Operating Practices	o Inadequate spill collection systems promote intermittent air releases o Lack of vapor collection systems for use during container/tank cleaning operations o Absence of dust suppression or particulate control measures

For example, a facility may have several large operating surface impoundments, suggesting a potential for large air releases. However, if the facility is a steel manufacturer treating only spent pickle liquor in these ponds, it is unlikely any air release will occur because the hazardous constituents in the waste are non-volatile, soluble metals.

The following section discusses the waste and constituent-specific factors the investigator should consider in assessing a waste's potential to release airborne constituents.

Types of Waste Contained in the Unit

Only certain hazardous constituents have a significant potential for air releases. This section identifies these constituents and the factors that affect the magnitude of their release.

Volatile constituents of concern for air releases include organic vapors and volatile metals (e.g., arsenic and mercury). Table 6-2 lists a select number of hazardous chemical compounds which EPA's Office of Air Quality Planning and Standards (OAQPS) considers to be of prime concern with respect to vapor phase air releases. The table also lists the RCRA waste codes for waste streams that contain these constituents to aid in their identification.

Table 6-3 lists hazardous constituents that are of special concern for particulate air releases. Particulate emissions from solid waste management units can contain organic material, heavy metals, or both. The heavy metals shown in Table 6-2 are predominantly associated with particulate releases, although

Table 6-2
HAZARDOUS CONSTITUENTS OF CONCERN AS VAPOR RELEASES

Hazardous Constituent	RCRA Waste Codes
Acetaldehyde	K001,U001
Acrolein	K012
Acrylonitrile	K011,K012,K013,U009
Allylchloride	F024,F025
Benzene	F024,F025,K001,K014,K019,K083,K085,K103,K105
Benzyl chloride	K015,K085,P028
Carbon Tetrachloride	F001,F024,F025,K016,K016,K020,K021,K073,U211
Chlorobenzene	F001,F002,F024,F025,K015,K016,K085,K105
Chloroform	F002,F024,F025,K009,K010,K016,K019,K020, K073,K021,K029,U044
Chloroprene	F024,F025
Cresols	F004,U052
Cumene (isopropylbenzene)	U055
1,4-dichlorobenzene	F002,F024,F025,K016,K085,K105,U072
1,2-dichloroethane	K018,K019,K020,K029,K030,K096,F024,F025,U077
Dichloromethane	F001,F002,F024,F025,K009,K010,K021,U080
Dioxin	F020,F021,F022,F023,F028
Epichlorohydrin	K017,K019,K020,U041
Ethylbenzene	F003
Ethylene oxide	U115
Formaldehyde	K009,K010,K038,K040,U122
Hexachlorobutadiene	F024,F025,K040,K016,K018,K030,U128
Hexachlorocyclopentadiene	F024,F025,K032,K033,K034,U130

Table 6-2 (Continued)
HAZARDOUS CONSTITUENTS OF CONCERN AS VAPOR RELEASES

Hazardous Constituent	RCRA Waste Codes
Hydrogen cyanide	F007,F009,F010,K013,K060
Hydrogen flouride	
Hydrogen sulfide	
Maleic anhydride	K023,K093,U147
Methyl acetate	
N-Dimethylnitrosamine	U100
Naphthalene	F024,F025,K001,K035,K060,K087,U165
Nitrobenzene	F004,K025,K083,K103,U169
Nitrosomorpholine	
Phenol	K001,K022,K087,U188
Phosgene	P095
Phthalic anhydride	K016,K023,K024,K093,K094,U190
Polychlorinated biphenyls Aroclor 1242 Aroclor 1248 Aroclor 1254 Aroclor 1260	K085
Propylene oxide	
1,1,2,2-tetrachloroethane	F024,F025,K016,K019,K020,K021,K030,K095, K096,U209
Tetrachloroethylene	F001,F002,F024,F025,K016,K018,K109,K020, K021,U210
Toluene	F005,F024,F025,K015,K036,K037,U220
1,1,1-trichloroethane	F001,F002,F024,F025,K019,K020,K023,K029, K073,K095,K096,U226
Trichloroethylene	F001,F002,F024,F025,K016,K018,K019,K020,U228
Vinylchloride	K019,K020,K023,K029,K028,F024,F025,U043
Vinylidenechloride	F003,F025,K019,K020,F024,K029,U078
Xylenes	F020,U239

Table 6-3
HAZARDOUS CONSTITUENTS OF
CONCERN AS PARTICULATE RELEASES

Hazardous Constituent	RCRA Waste Codes
Arsenic	D000,D004,K060,K021,K084,P010, P011,P012
Asbestos	U013
Beryllium	D000,D006,P015
Cadmium	D000,D006,F006,F007,F008,F009, F061,F062, F064,F065,F067,F068,F069
Chromium	D000,D007,F006,F007,F008,F009,F002, F064,F069,F086,
Lead	D000,D008,F006,F009,K003,K044,K048, K052,K061,K062,K064,K069 K086,P110
Mercury	D008,K071,K106
Nickle	F006,F007,F008,F009

both arsenic and mercury may be present as vapor phase releases due to their relatively high vapor pressures. Similarly, the organic compounds shown in Table 6-2 may also be found adsorbed or bound to soil and/or other particulate matter releases.

The investigator should examine all available information on wastes handled at the facility to determine the presence of any of the wastes or constituents referenced above.

Waste Characteristics that Affect the Magnitude of Release

The physical form of the waste contained in a solid waste management unit will determine to a great extent the potential for air releases from the unit. Wastes may be solid, dilute aqueous solutions, dilute organic solutions, or concentrated solutions. Air releases from solid wastes, such as those placed in landfills or waste piles, will be governed by different principles than govern releases from liquid wastes. Liquid wastes will exhibit potentials for air release that depend upon the strength of the solution and the type of solvent (e.g., water or organic compounds such as oil or chlorinated solvents) in the unit.

The concentration of specific constituents in each unit is another factor governing the potential magnitude of air releases. The higher the concentration of a particular constituent present in a unit, the greater is its potential for significant air release. However, the intrinsic potential for a constituent to volatilize depends on chemical and physical properties that very greatly between different constituents. Accordingly, a highly concentrated solution of one constituent may result in a lower release potential than a dilute concentration of another constituent.

As indicated earlier, the two types of emissions of greatest concern are volatiles and particulates. Each type of emission has its own set of characteristics which can help the investigator assess the potential magnitude of a release. These characteristics are discussed below and summarized in Table 6-4, which outlines the likely unit types and appropriate parameters to consider when evaluating airborne releases from different types of waste streams.

Volatile emissions. Constituent-specific physical and chemical parameters are very important indicators of the potential magnitude of a vapor-phase release. In some situations, these parameters can be used to develop constants which can provide the investigator with a useful means of quantifying relative release potential. The parameters most important when assessing the volatilization of a constituent include the following:

- o water solubility. The solubility in water indicates the maximum concentration at which a constituent can dissolve in water at a given temperature. This value can help the investigator estimate the distribution of a constituent between the dissolved aqueous phase in the unit and the undissolved solid or immiscible liquid phase. Considered in combination with the constituent's vapor pressure, it can provide a relative assessment of the potential magnitude of volatilization of a constituent from an aqueous environment (see discussion of Henry's Law constant below).

- o vapor pressure. Vapor pressure measures the pressure of vapor in equilibrium with a pure liquid. It is best used in a relative sense, constituents with high vapor pressures are more likely to have significant releases than those with low vapor pressures, depending on other factors such as relative solubility and concentrations (i.e. at high concentrations significant releases can occur even though a constituents vapor pressure is relatively low).

- o octanol/water partition coefficient. The octanol/water partition coefficient indicates the tendency of an organic constituent to sorb to organic constituents in the soil or waste matrices of a unit. Vapors with high octanol/water partition coefficients will adsorb readily to organic

Table 6-4
Parameters and Measures for Use in Evaluating
Potential Air Releases of Hazardous Waste Constituents

Emission and Waste Type	Units of Concern[1/]	Useful Parameters and Measures
A. Vapor Phase Emissions		
-- Dilute Aqueous Solution[2/]	Surface Imp., Tanks, Containers	Solubility, Vapor Pressure, Partial Pressure,[3/] Henry's Law
-- Conc. Aqueous Solution[2/]	Tanks, Containers, Surface Imp.	Solubility, Vapor Pressure, Partial Pressure, Raoults Law
-- Immiscible Liquid	Containers, Tanks	Vapor Pressure, Partial Pressure
-- Solid	Landfills, Waste Piles, Land Trt.	Vapor Pressure, Partial Pressure, Octanol/Water Partition Coeff.
B. Particulate Emissions		
-- Solid	Landfills, Waste Piles, Land Trt.	Particle Size Distribution, Site Activities, Management Methods

1/ Incinerators are not specifically listed on this table because of the unique issues concerning air emissions from these units. Incinerators can burn all the forms of waste listed in this table. the potential for release from these units is primarily a function of incinerator operating conditions and emission controls, rather than waste characteristics.

2/ Although the octanol/water partition coefficient of a constituent is usually not an important characteristic in these waste streams, there are conditions where it can be critical. Specifically, in waste containing high concentrations of organic particulates, constituents with high octanol/water partition coefficients will adsorb to the particulates. They will become part of the sludge or sediment matrix, rather than volatilizing from the unit.

3/ Applicable to mixtures of volatile components.

carbon, rather than volatilizing to the atmosphere. This is particularly important in landfills and land treatment units, where high organic carbon contents can significantly reduce the release of vapor phase constituents.

- o partial pressure. For constituents in a mixture, particularly in a solid matrix, the partial pressure of a constituent will be more significant than the pure vapor pressure. In general, the greater the partial pressure, the greater the potential significance of the release. Partial pressures will be difficult to obtain. However, when waste characterization data is available partial pressures can be calculated using methods commonly found in engineering and environmental science handbooks.

The investigator should examine each of the above parameters in combination with each other and with the specific characteristics of the unit of interest. Several measures are available to help the investigator with this assessment, provided they are applied to the appropriate waste types and units. These measures include:

- o Henry's Law constant. Henry's law constant is the ratio of the vapor pressure of a constituent and its aqueous solubility (at equilibrium). It can be used to assess the relative ease with which the compound may be removed from the aqueous phase via vaporization. It is accurate only when used concerning low concentration wastes in aqueous solution. Thus it will be most useful when the unit being assessed is a surface impoundment or tank containing dilute wastewaters. Generally, when the value of Henry's Law constant is less than 10E-7 atm-m^3 the constituent will not volatilize from water. As the value increases the potential for significant vaporization increases, and when it is greater than 10E-3 rapid volatilization will occur. Henry's Law constants for many potentially significant constituents are listed in table 6-2.

- o Raoult's Law - Raoult's Law can be used to predict releases from concentrated aqueous solutions (i.e. solutions over 10% solute). This will be most useful when the unit of concern entails container storage, tank storage, or treatment of concentrated waste streams.

For solid wastes, imiscible liquids, and wastes disposed of in landfills, land treatment, or waste piles there are no simple measures that can be used to assess the potential for volatilization

of a constituent. The investigator will need to consider the appropriate chemical, physical, and unit parameters, and then use his/her best judgment in determining the potential for release. Table 6-4 summarizes the chemical parameters the investigator should consider when assessing the different waste physical form/unit combinations.

Particulate emissions. The likelihood of particulate releases at hazardous waste management facilities is generally associated with landfills, land treatment units and/or waste piles. The severity of particulate releases is governed by different parameters than those that affect vapor-phase releases. The primary physical parameter will be the particle size distribution. Incinerators will always release some particulates in the exhaust stack, and they may cover a wide range of sizes. Information on the particle size distribution can be helpful in assessing the potential risks to humans, as the primary concern will be with the smaller, inhalable particulates.

Three mechanism are particularly important in the generation of particulate releases at hazardous waste facilities, and the investigator should examine the site for evidence that these practices are occurring. They are:

- wind erosion: In general, the unit's location will affect the potential for the wind to erode wastes in the unit. The unit's location and orientation with respect to the prevailing winds and large structures on site will determine the unit's vulnerability to wind erosion and the potential for particulate releases. Agency personnel should determine the location of SWMUs of concern with respect to prevailing winds and the use of wind screens (both natural and man-made) and daily covers to determine the unit's vulnerability to wind erosion.

- o reentrainment by moving vehicles on soil, paved, and unpaved roads: Vehicles moving on site can generate fugitive dust emissions. Factors affecting dust emissions generation include the amount of daily vehicular traffic at the site and the average size of the vehicles.

- o operational activities: These include the movement of soils or hazardous wastes by dozers, loading by front-end loaders, and other activities associated with landfilling or waste piles may cause fugitive dust emissions.

Potential for Mitigating Exposure

In assessing the potential significance of air releases from a solid waste management unit or a facility with several units, the investigator needs to consider several factors that act to reduce the concentrations of airborne contaminants. Two classes of factors are important:

- o atmospheric/geographic conditions, which are directly related to the amount of atmospheric dispersion available for contaminant dilution; and

- o contaminant specific factors, such as decay rates and particulate size.

Both of these factors can significantly reduce the concentration of released constituents, thereby reducing the importance of a release. However, under some specific conditions, the effect of these factors is limited considerably.

Atmospheric/geographic factors. Atmospheric dispersion can rapidly dilute the mass of a contaminant released from a solid waste management unit. In many cases, a contaminant's concentration decreases as the distance from the source of release increases. However, specific atmospheric conditions and geographic factors can greatly limit the amount of dispersion. When assessing air releases, the investigator needs to consider whether any of these conditions are important at the site in question.

Conditions and factors that limit dispersion include:

- o narrow valleys and urban areas containing large buildings (artificial canyons);
- o areas dominated by off-shore breezes;
- o areas with atmospheric conditions dominated by neutral air stability; and
- o areas with atmospheric conditions known to frequently result in inversions (low average wind speeds, mountain basins, etc.

All of these conditions contribute to higher than normal concentrations, thus increasing the significance of a release. The investigator may be able to obtain some of this information from local weather data bases as part of the preliminary assessment. However, collection of this information will probably require a site inspection.

Constituent-Specific Factors

Two important constituent-specific factors can also affect the airborne concentration of a released contaminant. For vapor phase contaminants, persistence is the most important factor, and for particulate contaminants, particle size is the principal concern.

The persistence of an airborne contaminant is primarily governed by a constituent's photolysis rate. Pollutants with high photolysis rates (i.e., those with an atmospheric half-life of 1 day) will degrade rapidly, resulting in a significant decrease in concentration and therefore exposure.

For particulate releases, the size distribution of the particles in the release plays an important role in both dispersion and actual exposure. Large particles will settle out of the air more rapidly than small particles, thus they will not travel as

far off-site or be diluted as much by dispersion. Very small particles (i.e., those that are less than 5 microns in diameter), are considered to be respirable and thus present a greater health hazard than larger particles. Particulate releases containing a high proportion of small particles are therefore of greatest concern. The inspector should examine the source of the particulate emissions to obtain information on particle size.

III. EVIDENCE OF AIRBORNE RELEASES

Positive identification of airborne contaminants at a site is an important part of determining whether a significant air release has occurred. However, because air releases are difficult to observe and monitor, it will generally be difficult to make a positive identification. In addition, it is doubtful that adequate monitoring data will be readily available for a specific site. The investigator will most likely have to rely on circumstantial evidence based on available data, or, in some cases, on sampling data collected during the site investigation.

Available Data Collection Methods and Sources

The most useful information for determining if a release is or has occurred is on-site monitoring data. As mentioned above, it is unlikely that this type of information will be available for most sites. Sources of this information include the owner or operator, EPA regional offices, state, county or local departments of health, or OSHA. Even if this information is available, the investigator should carefully assess its usefulness, paying particular attention to proper collection of background samples and the time and weather conditions when samples were taken.

Other useful data includes citizen complaints concerning both odor and observed particulate emissions. It is important to note however, that the absence of odor does not imply the absence of vapor releases, since many constituents have high odor thresholds. OSHA may have, in addition to air monitoring data, collected health or personal monitoring data from site workers. This information may also suggest the presence of a release.

The Role of Sampling

EPA expects that in most cases, sampling will not be necessary during the PA/SI to determine whether to conduct further investigations at the unit for air releases. However, there may be situations where the investigator may want to take samples or require the owner or operator to take samples. For example, the investigator may wish to obtain specific information on the types and concentrations of specific hazardous constituents in the unit to get a better indication of the potential magnitude of an air release. Another reason to conduct sampling would be to confirm a finding that a release or a potential air release from the unit warrants further investigation.

The permit writer may choose to use monitoring equipment, such as an organic vapor analyzer or a forced air particulate filter, around the perimeter of the unit to confirm a suspected release from a unit. However, without the proper collection of background samples as well as time series sampling, the use of such monitoring equipment during the course of a site inspection can not confirm that a release is not taking place.

The investigator can require the owner or operator to sample or monitor in certain situations. These are likely to be situa-

tions where the Agency can specify the number and location of samples, sampling or monitoring methods, and the procedures for analyzing samples.

IV. POTENTIAL FOR EXPOSURE

Exposure information, to the extent it is available for the facility, will help in assessing whether and to what extent air releases from the facility could affect human health and the environment. Again, at this stage in the corrective action process, the information and the analysis will largely be qualitative. However, this information can help in determining the need to conduct further investigations, (e.g., depending on the population density around the site); and in setting priorities for the remedial investigation stage of the process.

Population density and distance from the source are the primary factors in determining the significance of a potential exposure. Distance should be measured from the unit(s) containing the waste rather than from the facility boundary, although total facility emissions from all solid waste management units must also be kept in mind. Most importantly, the investigator should consider the density of the population residing within an approximately four-mile radius, as well as transients such as workers in factories, offices, restaurants, motels, or students. Travelers that pass through the area should not be included in any count.

The most significant exposure potential will occur in situations when there is a high population density within a 1/4 mile radius of the site. However, because concentrations can be quite high, even low density populations in such close proximity to the site are of concern. Dispersion can significantly reduce concen-

trations as distance from a site increases. Thus, the significance of high population density at larger distances from the site is reduced, particularly when the distance is four miles or more.

The investigator needs to consider the relationship between distance, concentration, and population density in evaluating the significance of an exposure potential. An additional factor to consider is the population located along the line of the most predominant wind direction at a site. Because the PA/SI is primarily concerned with continuous releases, populations located along this line downwind of the site are more likely to receive significant exposures than populations located along other vectors.

If the investigator determines that a solid waste management unit is releasing large volumes of unsaturated hydrocarbons, he/she may need to consider population density over a much larger area than a four mile radius. These constituents contribute to the formation of photochemical smog and ozone, which, in combination with other regional pollutant releases, can cause significant exposures over a wide geographic area.

V. SUMMARY

This chapter has identified a number of factors that affect a facility's potential to have significant air releases that warrant further investigation. These factors include:

- unit characteristics, such as size, type and use;
- types and characteristics of wastes placed in the unit; and
- the potential of locational factors and constituent-specific factors to mitigate the significance of the release.

The first section of this chapter described all of these factors

in some detail in order to give the investigator a better basis for determining whether a release is significant or not. While many units can be expected to have air releases, most of these releases -- either because of certain unit characteristics, concentrations of specific constituents in the waste, atmospheric dispersion characteristics, distance to receptors, etc. -- will not be significant enough to warrant further investigation. The investigator will need to consider each of the factors described in Section I of this chapter in determining the potential for significant releases from solid water management units at the facility.

The investigator should use evidence (to the extent it is available) that identifies the presence of releases and information on the potential for human exposure to assist in making these determinations.

Table 6-5 provides examples of situations that are likely to require further investigation and situations that probably will not require further investigation for air releases.

Table 6-5
Unit Illustrations

Unit Type	Further Investigation Needed	Further Investigation Not Needed
Surface Impoundments (RCRA and non-RCRA)	Surface impoundments that contain large quantities of highly volatile wastes listed in Table 6-2	Units closed by removal of wastes Units handling wastewaters containing only non-volatile metals
Open Roofed Tanks	Open tanks containing large quantities of highly volatile wastes listed in Table 6-2	Units treating or storing wastewaters containing only non-volatile metals
Landfills	Landfills with inadequate daily cover and compaction operating procedures in areas with strong prevailing winds in close proximity to populations	Monofills of wastes which contain only non-volatile metals and which use daily cover and compaction to control particulates Monofills of wastes containing only organic constituents having high octanol/water partition coefficients and which use daily cover and compaction to control particulate emissions Small landfills closed in accordance with closure provisions in §264.310 Units which have been closed for a long period of time and that are being managed using a stable cover system

Table 6-5 cont.

Unit Type	Further Investigation Needed	Further Investigation Not Needed
Land Treatment	Land treatmet units containing large quantities of highly volatile wastes described in Table 6-2 and located in areas with strong prevailing winds and nearby populations	Closed units which were used experimentally or for a single application of waste and for which wind erosion controls are being used
Waste Piles	Outdoor, uncovered waste piles receiving large quantities of wastes described in Table 6-3	Most indoor piles Outdoor piles properly covered, located in areas which minimize wind erosion, and which contain only constituents with very low vapor pressures
Drum Storage Areas	Outdoor storage areas poorly maintained with evidence of frequent open drum storage, poorly sealed drums, and/or leaking drums containing wastes described in Table 6-2.	Most indoor storage areas Well maintained outdoor storage areas in which wastes containing low vapor pressure constituents are stored
Covered Tanks	Poorly maintained units containing cracks, corrosion, or poorly sealed access ports which contain large volumes of highly volatile wastes described in Table 6-2	Most covered units
Incinerators[1/]	All unpermitted units	Well maintained and permitted incinerators with inspection records detailing proper operation

1/ By design all incinerators release gases and some particulate matter into the atmosphere. The investigator should thoroughly investigate all units for improper and hazardous releases.

APPENDIX MATERIAL

TABLE 5-1 HAZARDOUS CONSTITUENTS OF CONCERN AS POTENTIAL VAPOR RELEASES

Hazardous constituent	Formula	CAS No.	RCRA waste codes	Synonyms	Manufacturing sources	Uses and formulations
Acetaldehyde	CH_3CHO	75-07-0	U001, P001	Acetic aldehyde, aldehyde, ethanal, ethylaldehyde	Organic chemical mfg.	Organic chemical mfg, perfumes, flavors, aniline dyes, plastics, synthetic rubber mfg., silvering mirrors, hardening gelatin fibers
Acrolein	CH_2CHCHO	107-02-8	U007	Acrylaldehyde, acrylic aldehyde, ally aldehyde, propenal		
Acrylonitrile	CH_2CHCN	107-13-1	U009, U012, U151, U163	Vinyl cyanide, cyanoethylene, propene nitrile, AN		Production of acrylic and mod-acrylic fibers, manufacturing of acrylonitrile butadiene-styrene (ABS) and styrene acrylonitrile resins, fumigant
Allyl chloride	CH_2CHCH_2Cl	107-05-1	U027, P028	1-chloro-2-propene, 3-chloropropylene, chloroallylene, a-chloropropylene		
Benzene	C_6H_6	71-43-2	U019, P021, U001, U012, U019, U037, U063, U088, U105, U220	Benzol, phenyl hydride, coal naphtha, phene, benzole, cyclo-hexatriene	Petroleum refining, solvent recovery, coal tar distillation, coal processing, coal coking	Mfg. styrene, phenol, detergents, organic chemicals, plastics and resins, synthetic rubber, aviation fuel, pharmaceuticals, dyes, explosives, PCB, gasoline, tanning, flavors and perfumes, paints and coatings, nylon intermediates, food processing, photographic chemicals
Benzyl chloride	$C_6H_5CH_2Cl$	100-44-7	U015, U085, P028	a-chlorotoluene		Dyes and intermediates
Carbon tetrachloride	CCl_4	56-23-5	U211, U209, P023, U033, U036, U020, U041, U073, U211	Tetrachloromethane, perchloromethane		Fire extinguisher mfg., dry cleaning operations, mfg. of chlorofluoro- [illegible] C, solvent, veterinary medicine, metal degreasing, fumigant, chlorinating organic chemicals
Chlorobenzene	C_6H_5Cl	108-90-7	U037, U032, U026 U023, U015, U070, U083, U037	Monochlorobenzene chlorobenzol, phenyl chloride, MCB		Solvent recovery plants, intermediate in dyestuffs mfg., mfg. aniline, insecticide, phenol, chloronitrobenzene

(continued)

Appendix A

TABLE 5-1 (CONTINUED)

Hazardous Constituent	Formula	CAS No.	RCRA waste codes	Synonyms	Manufacturing sources	Uses and formulations
Chloroform	$CHCl_3$	67-66-3	U002, U024, U035, U044, U081, U150, U151, U154, U159, U161, U211	Trichloromethane	Organic chemical industry	Mfg. fluorocarbon refrigerants, propellants and plastics, mfg. anesthetics and pharmaceuticals, fumigant, solvent, sweetener, fire extinguishers mfg., electronic components mfg., analytical chemistry, insecticide
Chloroprene	$H_2C=CCl-CH=CH_2$	126-99-8	U024, U073	2-chloro-1,3-butadiene, chlorobutadiene monochloroprene		
Cresols	$CH_3C_6H_4OH$	1319-77-3 95-48-7(o-) 108-39-4(p-) 108-68-9(m-)	U052, U052	Cresylic acid, hydroxytoluene, methyl phenol, cresylene	Coal tar refining, petroleum refining, organic chemical mfg., ore processing	Disinfectant, food antioxidant, perfume mfg., dye mfg., plastics and resin mfg., herbicide mfg., tricresylphosphate mfg., ore flotation, textile
Cumene	$C_6H_5CH(CH_3)_2$	98-82-8	U055	Isopropyl benzene, 2-phenyl propane	Petroleum refining, coal tar distillation, organic chemical industry	Mfg. of acetone, alpha methyl-styrene, phenol, polymerization catalyst, di-isopropylbenzene, component motor fuel, catalyst for acrylic and polyester-type resins, solvent, asphalt and naphtha constituent
1,4-dichlorobenzene	$C_6H_4Cl_2$	106-46-7	U072, U025, U037, U038, U058, U105, U072	1,4-dichlorobenzene, DCB, 1,4-DCB, PDB, PARA	Organic chemical industry	Mfg. moth repellents, mfg. air deodorizers, mfg. dyes and intermediates, pharmaceutical mfg., soil fumigant, pesticide
1,2-dichloroethane	$C_2H_4Cl_2$	107-06-2	U077, U078, U079, U080, U082, U084, U085, U086, U087, U088, U089, U090, U091, U092, U095, U096, U097, U098, U099, U101, U102, U107, U108, U109, U110, U111, U112, U113, U114, U115, U116, U117, U118, U119, U120, U121, U122, U123, U124, U125, U126, U127, U128, U129, U130, U131, U132, U133, U134, U135, U136, U137, U138, U139, U140, U141, U142, U143, U144, U145, U146, U147, U148, U149, U150, U151, U152, U153, U154, U155, U156, U157, U158, U159, U160, U161, U162, U163, U164, U165, U166, U167, U168, U169, U170, U171, U172, U173, U174, U175, U176, U177, U178, U179, U180, U181, U182, U183, U184, U185, U186, U187, U188, U189, U190, U191, U192, U193, U194, U195, U196, U197, U198, U199, U200, U201, U202, U203, U204, U205, U206, U207, U208, U209, U210, U211, U212, U213, U214, U215, U216, U217, U218, U219, U220, U221, U222, U223, U224, U225, U226, U227, U228, U229, U230, U231, U232, U233, U234, U235, U236, U237, U238, U239, U240, U241, U242, U243, U244, U245, U246, U247, U248, U249, U250, U251, U252, U253, U254, U255, U256, U257, U258, U259, U260, U261, U262, U263, U264, U265, U266, U267, U268, U269, U270, U271, U272, U273, U274, U275, U276, U277, U278, U279, U280, U281, U282, U283, U284, U285, U286, U287, U288, U289, U290, U291, U292, U293, U294, U295, U296, U297, U298, U299, U300, U301, U302, U303, U304, U305, U306, U307, U308, U309, U310, U311, U312, U313, U314, U315, U316, U317, U318, U319, U320, U321, U322, U323, U324, U325, U326, U327, U328, U329, U330, U331, U332, U333, U334, U335, U336, U337, U338, U339, U340, U341, U342, U343, U344, U345, U346, U347, U348, U349, U350, U351, U352, U353, U354, U355, U356, U357, U358, U359, U360, U361, U362, U363, U364, U365, U366, U367, U368, U369, U370, U371, U372, U373, U374, U375, U376, U377, U378, U379, U380, U381, U382, U383, U384, U385, U386, U387, U388, U389, U390, U391, U392, U393, U394, U395, U396, U397, U398, U399, U400, U401, U402, U403, U404, U405, U406, U407, U408, U409, U410, U411, U412, U413, U414, U415, U416, U417, U418, U419, U420, U421, U422, U423, U424, U425, U426, U427, U428, U429, U430, U431, U432, U433, U434, U435, U436, U437, U438, U439, U440, U441, U442, U443, U444, U445, U446, U447, U448, U449, U450, U451, U452, U453, U454, U455, U456, U457, U458, U459, U460, U461, U462, U463, U464, U465, U466, U467, U468, U469, U470, U471, U472, U473, U474, U475, U476, U477, U478, U479, U480, U481, U482, U483, U484, U485, U486, U487, U488, U489, U490, U491, U492, U493, U494, U495, U496, U497, U498, U499, U500, U501, U502, U503, U504, U505, U506, U507, U508, U509, U510, U511, U512, U513, U514, U515, U516, U517, U518, U519, U520, U521, U522, U523, U524, U525, U526, U527, U528, U529, U530, U531, U532, U533, U534, U535, U536, U537, U538, U539, U540, U541, U542, U543, U544, U545, U546, U547, U548, U549, U550, U551, U552, U553, U554, U555, U556, U557, U558, U559, U560, U561, U562, U563, U564, U565, U566, U567, U568, U569, U570, U571, U572, U573, U574, U575, U576, U577, U578, U579, U580, U581, U582, U583, U584, U585, U586, U587, U588, U589, U590, U591, U592, U593, U594, U595, U596, U597, U598, U599, U600, U601, U602, U603, U604, U605, U606, U607, U608, U609, U610, U611, U612, U613, U614, U615, U616, U617, U618, U619, U620, U621, U622, U623, U624, U625, U626, U627, U628, U629, U630, U631, U632, U633, U634, U635, U636, U637, U638, U639, U640, U641, U642, U643, U644, U645, U646, U647, U648, U649, U650, U651, U652, U653, U654, U655, U656, U657, U658, U659, U660, U661, U662, U663, U664, U665, U666, U667, U668, U669, U670, U671, U672, U673, U674, U675, U676, U677, U678, U679, U680, U681, U682, U683, U684, U685, U686, U687, U688, U689, U690, U691, U692, U693, U694, U695, U696, U697, U698, U699, U700, U701, U702, U703, U704, U705, U706, U707, U708, U709, U710, U711, U712, U713, U714, U715, U716, U717, U718, U719, U720, U721, U722, U723, U724, U725, U726, U727, U728, U729, U730, U731, U732, U733, U734, U735, U736, U737, U738, U739, U740, U741, U742, U743, U744, U745, U746, U747, U748, U749, U750, U751, U752, U753, U754, U755, U756, U757, U758, U759, U760, U761, U762, U763, U764, U765, U766, U767, U768, U769, U770, U771, U772, U773, U774, U775, U776, U777, U778, U779, U780, U781, U782, U783, U784, U785, U786, U787, U788, U789, U790, U791, U792, U793, U794, U795, U796, U797, U798, U799, U800, U801, U802, U803, U804, U805, U806, U807, U808, U809, U810, U811, U812, U813, U814, U815, U816, U817, U818, U819, U820, U821, U822, U823, U824, U825, U826, U827, U828, U829, U830, U831, U832, U833, U834, U835, U836, U837, U838, U839, U840, U841, U842, U843, U844, U845, U846, U847, U848, U849, U850, U851, U852, U853, U854, U855, U856, U857, U858, U859, U860, U861, U862, U863, U864, U865, U866, U867, U868, U869, U870, U871, U872, U873, U874, U875, U876, U877, U878, U879, U880, U881, U882, U883, U884, U885, U886, U887, U888, U889, U890, U891, U892, U893, U894, U895, U896, U897, U898, U899, U900, U901, U902, U903, U904, U905, U906, U907, U908, U909, U910, U911, U912, U913, U914, U915, U916, U917, U918, U919, U920, U921, U922, U923, U924, U925, U926, U927, U928, U929, U930, U931, U932, U933, U934, U935, U936, U937, U938, U939, U940, U941, U942, U943, U944, U945, U946, U947, U948, U949, U950, U951, U952, U953, U954, U955, U956, U957, U958, U959, U960, U961, U962, U963, U964, U965, U966, U967, U968, U969, U970, U971, U972, U973, U974, U975, U976, U977, U978, U979, U980, U981, U982, U983, U984, U985, U986, U987, U988, U989, U990, U991, U992, U993, U994, U995, U996, U997, U998, U999, U1000	Ethylene dichloride, ethylene dichloride, ethylene chloride, glycol dichloride, sym-dichloroethane	Organic chemical industry	Mfg. of vinyl chloride, mfg. of tetraethyl lead, intermediate insecticidal fumigant, tobacco flavoring, constituent in paint, varnish and finish removals, metal degreaser, constituent in soaps and scouring compounds, wetting and penetrating agents, organic chemical synthesis and ore flotation, ingredient in cosmetics (nail lacquer)

(continued)

TABLE 5-1 (CONTINUED)

Hazardous constituent	Formula	CAS No.	RCRA waste codes	Synonyms	Manufacturing sources	Uses and formulations
Dichloromethane	CH_2Cl_2	75-09-2	F001,F002,F024, F025,U009,U080, U021,U080	Methylene chloride methylene dichloride methylene bichloride		Paint stripping and solvent degreasing, mfg. aerosols, photographic films, synthetic fibers, refrigerant, fumigant, solvent, textile and leather coatings, pharmaceutical, used in plastics processing, spotting agent, dewaxing, organic synthetics, blowing agent in foams
Dioxin	$C_{12}H_4Cl_4O_2$	1746-01-6	F020,F021,F022, F023,F028	2,3,7,8 tetra-chlorodibenzo-p-dioxin, Tetrachlorodibenzo-p-dioxine 1613, 2,3,7,8-TCDD		
Epichlorohydrin	CH_2OCHCH_2Cl	106-89-8	U041,U019,U070, P04	2, Chloropropylene oxide 1, chloro-2,3-epoxypropane, chloromethyl-oxirane, 2 epichloronydrin		Mfg. of epoxy resins, surface active agents, pharmaceuticals, insecticides, agricultural chemicals, textile chemicals, coatings, adhesives, ion exchange resins, solvents, plasticizers, glycidyl esters, ethynyl-ethylenic alcohol, and fatty acid derivatives
Ethylbenzene	$C_6H_5CH_2CH_3$	100-41-4	F003	Ethylbenzol, phenylethane, EB	Petroleum refining, organic chemical industry	Styrene mfg., acetophenone mfg., solvent, asphalt constituent, naphtha constituent
Ethylene oxide	H_2COCH_2	75-21-8	U115	1,2-Epoxyethane oxirane Dimethylene oxide Anprolene, EO Ethenoxide		
Formaldehyde	HCHO	50-00-0	U009,U010,U018, U060,U122	Oxomethane Oxymethylene Methylene oxide Formic aldehyde Methyl aldehyde Formalin Methanol		

(continued)

TABLE 5-1 (CONTINUED)

Hazardous constituent	Formula	CAS No.	RCRA waste codes	Synonyms	Manufacturing sources	Uses and formulations
Hexachloro-butadiene	C_4Cl_6	608-73-1	F024, F025, K040, K016, K018, K030, U128	HCBD, HCBU, Hexachlor	Organic chemical industry	Solvent for natural rubber, synthetic rubber and other polymers, heat transfer liquid, transformer liquid, hydraulic fluid, washing liquor for removing hydrocarbons
Hexachloro-cyclopentadiene	C_5Cl_6	77-47-4	F024, F025, K032, K033, K034, U130	C-56®, HCCPD Hex, perchloro-pentadiene		Key intermediate in the synthesis of insecticides including aldrin, dieldrin, endrin, endosulfan, heptachlor, chlordane, toxaphene, and mirex. Used to derive non-flammable resins and shock-proof plastics, acids, esters, ketones, and fluorocarbons
Hydrogen cyanide	HCN	74-90-8	F007, F009, F010, K013, K060	Hydrocyanic acid Prussic acid Formonitrile		
Hydrogen fluoride	HF	7664-39-3		Hydrofluoric acid gas, Fluorohydric acid gas, Anhydrous hydrofluoric acid gas		
Hydrogen sulfide	H_2S	7783-06-4		Sulfurated hydrogen, Hydrosulfuric acid, Stink damp		
Maleic anhydride	$C_4H_2O_3$	108-31-6	K021, K091, U147	2,5-Furandione, 2,5-Furandione, cis-Butenedioic anhydride, Toxilic anhydride		
Methyl acetate	CH_3COOCH_3	79-20-9		Acetic acid, Methyl ester, Methyl acetic ester, Methyl ethanoate		

(continued)

TABLE 5-1 (CONTINUED)

Hazardous constituent	Formula	CAS No.	RCRA waste codes	Synonyms	Manufacturing sources	Users and formulations
N-Dimethyl-nitrosamine	$(CH_3)_2NNO$	62-75-9	U100	N-nitrosodimethyl-amine, Nitrous dimethyl-amide, Dimethylnitrosamine, DMN, DMNA		
Naphthalene	$C_{10}H_8$	91-20-3	F024, F025, K001, K035, K060, K087, U165,	Tar camphor, Naphthalin, Moth flake, White tar, Moth balls	Petroleum refining, coal tar distillation	Mothball mfg., mfg. alpha and beta naphthols and pesticides, fungicides, dyes, detergents and wetting agents, phthalic anhydride, synthetic resins, celluloid, lampblack, smokeless powder, solvent, lubricants, motor fuel mfg., cutting fluid synthetic tanning, preservative, emulsion breaker, asphalt and naphtha constituent, petroleum, coal tar
Nitrobenzene	$C_6H_5NO_2$	98-95-3	F004, K025, K083, K103, U169	Nitrobenzol, Oil of mirbane, Oil of bitter almonds	Organic chemical industry	Mfg. aniline and dyestuffs, solvent recovery plants, mfg. rubber chemicals, drugs, photographic chemicals, refining lubricants oils, solvent in TNT production, solvent for cellulose ethers, cellulose acetate mfg., constituent in metal polish and shoe polish formulations
Phenol	C_6H_5OH	108-95-2	K001, K0[illegible], U18d	Carbolic acid, Phenic acid, Phenylic acid, Phenyl hydrate, Hydroxybenzene, Monohydroxybenzene		
Phosgene	$COCl_2$	75-44-4	P095	Carbonyl chloride, Carbon oxychloride, Carbonic acid dichloride, Chloroformyl chloride, Combat gas		

(continued)

TABLE 5-1 (CONTINUED)

Hazardous constituent	Formula	CAS No.	RCRA waste codes	Synonyms	Manufacturing sources	Uses and formulations
Phthalic anhydride	$C_8H_4O_3$	85-44-9	U028, U023, U024, U093, U094, U190	Phthalic acid anhydride, Benzene-o-dicarboxylic acid anhydride, Phthalandione	Plants oxidizing xylenes, naphthalene	Plasticizer mfg., specialty chemical mfg., mfg. synthetic fibers, mfg. dyes, pigments, pharmaceuticals, insecticides, chlorinated products
Polychlorinated biphenyls (42%Cl) (54% Cl)	$C_{12}H_{(10-n)}Cl_n$	1336-36-3	U085	PCBs, Chlorodiphenyls, Aroclors, Kanechlors		Used in electrical industry in capacitors and transformers. Used in formulation of lubricating and cutting oils, pesticides, adhesives, plastics, inks, paints and sealants
Propylene oxide	CH_3CHCH_2O	75-56-9		1,2-Epoxypropane, Methylethylene oxide, Methyl oxirane, Propene oxide		
1,1,2,2-tetrachloroethane	$CHCl_2CHCl_2$	79-34-5	F024, F025, U018, U019, U020, U121, U130, U095, U096, U209	Acetylene tetrachloride, Ethane tetrachloride	Organic chemical industry	Mfg. 1,1-dichloroethylene, solvent for rubber and other organic materials, insecticide mfg., bleach mfg., paint, varnish, rust remover mfg., soil fumigant, cleaning and degreasing metals, photo films, resins and waxes, extractant of oils and fats
Tetrachloroethylene	CCl_2CCl_2	127-18-4	F001, F002, F024, F025, U018, U019, U020, U210	Perchloroethylene, Ethylene tetrachloride, Carbon dichloride, Perclene, PCE, Tetrachloromethene	Organic chemical industry	Dry cleaning operations, metal degreasing, solvents for fats, greases, waxes, rubber, gums, caffeine from coffee, removal soot from industrial boilers, mfg. paint removers, printing inks, mfg. trichloroacetic acid, vermifuge, heat transfer medium, mfg. of fluorocarbons

(continued)

TABLE 5-1 (CONTINUED)

Hazardous constituent	Formula	CAS No.	RCRA waste codes	Synonyms	Manufacturing sources	Uses and formulations
Toluene	$C_6H_5CH_3$	108-88-3	F005, F024, F025, K015, K016, K037 U220	Toluol, Methyl benzene, Phenyl methane, Methyl benzol	Petroleum refining coal tar distillation	Mfg. benzene derivatives, caprolactam, saccharin, medicines, dyes, perfumes, TNT, solvent recovery plants, component gasoline, solvent for paints and coatings, gums, resins, rubber and vinyl organosols, diluent and thinner in nitrocellulose lacquers, adhesive solvent in plastic toys and model airplanes, detergent mfg., asphalt and naphtha constituent
1,1,1-Trichloroethane	CH_3CCl_3	71-55-6	F001, F002, F024, F025, K019, K020, K028, K029, K071, K095, K096, U226	Methyl chloroform		
Trichloro-ethylene	$ClCH=CCl_2$	79-01-6	F001, F002, F024, F025, K016, K018, K019, K020, U228	Ethylene trichloride, Ethinyl trichloride, Trichloroethene, TCE, TCE	Organic chemical industry	Dry cleaning operations and metal degreasing, solvents for fats, greases, waxes, solvent for cellulose esters and ethers, solvent for dyeing, refrigerant and heat exchange liquid, organic synthesis, fumigant, anesthetic
Vinyl chloride	$CH_2=CHCl$	75-01-4	F019, K020, K023, K029, K030, K043 F025, U043	Chloroethylene Chloro-ethene Monochloroethylene MVC		PVC and copolymers, adhesives for plastics
Vinylidene chloride	CH_2CCl_2	75-35-4	F003, F025, K019, K020, K024, K029, U078	1,1-Dichloroethylene, DCE, VDC, 1,1 Dichloroethene		Adhesives, component of synthetic fibers
Xylene	$C_6H_4(CH_3)_2$	1330-20-7	F020, U239	Xylol, Dimethyl benzene	Petroleum distillation, coal tar distillation, coal gas distillation, organic chemical industry	Mfg. phthalic acid and anhydride, mfg. terephthalic acid for polyester, solvent recovery plants, specialty chemical mfg., mfg. isophthalic acid, aviation gasoline, protective coatings mfg., solvent for ethyd resins, lacquers, enamels, rubber cements, dye mfg., insecticide mfg., pharmaceutical mfg., asphalt and naphtha constituent

TABLE 5-2 HAZARDOUS CONSTITUENTS OF CONCERN AS POTENTIAL PARTICULATE RELEASES

Hazardous constituent	Formula	CAS No.	RCRA waste code	Synonyms; some common compound names	Uses and formulations
Arsenic	As	7440-38-2 (7778-44-1)	D000, D004, K060, K021, K084, P010, P011, P012	Arsine (AsH_3) Arsenic trioxide (As_2O_3) Arsenic trichloride ($AsCl_3$) calcium arsenate ($Ca_3(AsO_4)_2$)	Arsenates and arsenites are used as insecticides, herbicides, larvicides, and pesticides, $AsCl_3$ in pharmaceuticals, pigments, mfg. glass, textile printing, tanning, taxidermy, and antifouling agents, control sludge formation in lubricating oils. AsH_3 may be generated in metal pickling operations, or when inorganic arsenic compounds contact sources of hydrogen
Asbestos		1332-21-4	D013		Used in construction industry. Floor tiles, asbestos cements, roofing felts and shingles, insulation materials; textiles, brake linings and clutch facings, paper, paints, plastics, roof coatings
Beryllium	Be	7440-41-7	D000, D010, P015	Beryllium chloride Beryllium fluoride Beryllium nitrate	Moderator for fusion reactions, reflector in reactor core; mfg. of ceramics and refractories, chemical reagent
Cadmium	Cd	7440-43-9	D000, D006, F006, F007, F008, F009, F061, F062, F064, F065, F067, F068, F069	Cadmium acetate Cadmium bromide Cadmium chloride	Used in electroplating; electrode of alkaline storage batteries, fungicides; insecticides, fertilizers; polymerization catalysts, pigments, paints, glass, photographic industry
Chromium	Cr	7440-47-3 (7738-94-5)	D000, D007, F006 F007, F008, F009, K002, K004-K069, K086	Chromic acid chromium trioxide chromium anhydride	Chromium trioxide is used in chrome plating, tanning, copper stripping, aluminum anodizing, as a catalyst, refractories, in organic synthesis and photography.
Lead	Pb	7439-92-1	D000, D008, F006-F009, K003, K044, K045-K052, K061, K062, K064-K069, K086	Lead arsenate ($PbHAsO_4$) Lead acetate Lead chloride Lead fluoborate Lead fluoride Lead iodide	Lead arsenates in insecticides and veterinary medicine, mfg. tetraethyl lead and organic and inorganic lead compounds, pigments for paints, enamels, and varnishes, storage batteries, flint glass; as a glaze in ceramics, litharge rubber,

(continued)

TABLE 5-2 (CONTINUED)

Hazardous constituent	Formula	CAS No.	RCRA waste code	Synonyms; some common compound names	Uses and formulations
Lead (cont.)				Lead nitrate Lead stearate Lead sulfate Lead sulfide Lead thiocyanate	plastics, electronic devices
		(78-00-2) (75-74-1)	P110	Tetraethyl lead ($Pb(C_2H_5)_4$) Tetramethyl lead ($Pb(CH_3)_4$)	
Mercury	Hg	7439-97-6	D009,K071,K106	Quick silver	Liquid cathode in production of caustic and chloride; used in electrical apparatus and control instruments
		(502-39-6)		Methyl mercury dicyandiamide ($CH_3Hg.NHC(NH)NHCN$): cyanomethyl mercury) guanidine, panogen	Used as disinfectants, fungicides for treating seeds, antiseptics, herbicides, preservatives, mildewproofing agents, germicides, bactericides
		(107-27-7)		Ethyl mercuric chloride (C_2H_5HgCl): Ceresan, ethyl mercuric phosphate, new Ceresan, Ceresan M	
		(62-38-4)		Phenyl mercuric acetate: PMA Mercuric cyanide Mercuric nitrate Mercuric sulfate Mercuric thiocyanate Mercurous nitrate	Used in gold, silver, bronze, and tin-plating; tanning and dyeing, felt-making, taxidermy, textile mfg.; photography and photoengraving, paints and pigments, pharmaceutical industry
		(7487-94-7)		Mercuric chloride	
Nickle	Ni	7440-02-0	F006,F007,F008, F009	Nickle ammonium sulfate Nickle chloride Nickle hydroxide Nickle nitrate Nickle sulfate Nickle carbonyl	Electroplating, casting operations; magnetic tapes, nickle-cadmium batteries; nickle soaps in crankcase oil, enamels, ceramics, glass, catalyst

Appendix B

LIST B1

INDUSTRY SPECIFIC PARAMETERS
METALFINISHING

Parameter	Chemical Abstract System Number
chromium	7440-47-3
copper	7550-50-8
cyanide	57-12-5
iron	7439-89-6
zinc	7440-66-6
trichloroethene	79-01-6
tetrachloroethylene	127-18-4
vinyl chloride	75-01-4
phenanthrene	85-01-8
nickel	

LIST B2

IRON AND STEEL

Parameter	Chemical Abstract System Number
arsenic	7440-38-2
chromium	7440-47-3
cyanide	57-12-5
tin	7440-31-5
zinc	7440-66-6
benzene	71-43-2
benzo(a)pyrene	50-32-8
tetrachloroethylene	127-18-4

LIST B3

PESTICIDES

Parameter	Chemical Abstract System Number
arsenic	7440-38-2
cyanide	57-12-5
copper	7550-50-8
benzene	71-43-2
carbon tetrachloride	56-23-5
chlordane	57-74-9
chlorobenzene	67-66-3
chloroform	108-90-7
1,4-dichlorobenzene	106-46-7
2,4-dichlorophenol	120-83-2
heptachlor	76-44-8
hexachlorocyclopentadiene	77-47-4
methyl chloride	74-87-3
methylene chloride	75-09-2
4-nitrophenol	100-02-7
phenol	108-95-2
tetrachloroethylene	127-18-4
toluene	108-88-3
Manufactured pesticides*	

*Any specific pesticides, residues, off-specification products, or other similiar items known to have been disposed of at the site, or, in the case of a dedicated facility, known to have been manufactured at the site.

LIST C

Parameter	Chemical Abstract System Number
bis(2-ethylhexyl)phthalate	117-81-7
PCB-1016	12674-11-2
PCB-1221	11104-28-2
PCB-1232	11141-16-5
PCB-1248	12672-29-6
PCB-1254	11097-69-1
PCB-1260	11096-82-5
PCB-1242	53469-21-9
arsenic	7440-38-2
benzene	71-43-2
chlorobenzene	108-90-7
ethyl benzene	100-41-4
toluene	108-88-3
chromium	7440-47-3
copper	7550-50-8
cyanide	57-12-5
tetrachloroethylene	127-18-4
vinyl chloride	75-01-4
trichoroethylene	79-01-6
iron	7439-89-6
manganese	7439-96-5
naphthalene	91-20-3
nickel	7440-02-0
phenanthrene	85-01-8
phenol	108-95-2
zinc	7440-6-6

LIST D

Parameter	Chemical Abstract System Number
3,3'-dichlorobenzidine	91-94-1
benzidene	92-87-5
endrin aldehyde	7421-93-4
bis(2-ethylhexyl)phthalate	117-81-7
butylbenzylphthalate	85-68-7
di-n-butylphthalate	84-74-2
di-n-octylphthalate	117-84-0
diethylphthalate	84-66-2
dimethylphthalate	131-11-3
hexachlorobutadiene	87-68-3
hexachlorocyclopentadiene	77-47-4
aldrin	309-00-2
N-nitrosodi-n-propylamine	621-64-7
heptachlor expoxide	1024-57-3
dieldrin	60-57-1
endrin	72-20-8
2-butanone	78-93-3
isophorone	78-59-1
acetone	67-64-1
acrolein	107-02-8
acrylonitrile	107-13-1
heptachlor	76-44-8
chlordane	57-74-9
alpha-endosulfan	115-29-7
beta-endosulfan	115-29-7
endosulfan sulfate	1031-07-8
fluroene	86-73-7
acenaphthalene	208-96-8
acenaphthene	83-32-9
vinyl acetate	108-05-4
aluminum	7429-90-5
anthracene	120-12-7
antimony	7440-36-0
PCB-1016	12674-11-2
PCB-1221	11104-28-2
PCB-1232	11141-16-5
PCB-1248	12672-29-6
PCB-1254	11097-69-1
PCB-1260	11096-82-5
PCB-1242	53469-21-9
arsenic	7440-38-2
barium	7440-39-3
benzo(a)anthracene	56-55-3
3,4-benzofluoranthene	205-99-2
N-nitrosodiphenylamine	86-30-6
benzene	71-43-2
4,4'-DDE	72-55-9
4,4'-DDD	72-54-8
1,2,4-trichlorobenzene	120-82-1
1,2-dichlorobenzene	95-50-1

LIST D (Continued)

Parameter	Chemical Abstract System Number
1,3-dichlorobenzene	541-73-1
1,4-dichlorobenzene	106-46-7
4,4'-DDT	50-29-3
4-bromophenylphenylether	101-55-3
4-chlorophenylphenylether	7005-72-3
2,4-dinitrotoluene	121-14-2
2,6-dinitrotoluene	606-20-2
chlorobenzene	108-90-7
ethylbenzene	100-41-4
hexachlorobenzene	118-71-1
toluene	108-88-3
nitrobenzene	98-95-3
benzo(a)pyrene	50-32-8
benzo(ghi)perylene	191-24-2
benzo(k)fluoranthene	207-08-9
beryllium	7440-41-7
cadmium	7440-43-9
calcium	7400-70-2
carbon disulfide	75-15-0
chromium	7440-47-3
chrysene	218-01-9
cobalt	7440-48-4
copper	7550-50-3
cyanide	57-12-5
alpha-BHC	319-84-6
beta-BHC	319-85-7
delta-BHC	319-86-8
gamma-BHC	58-89-9
dibenzo(a,h)anthracene	53-70-3
2,3,7,8-TCDD	1746-01-6
bis(2-chloroethoxy)methane	111-91-1
bis(2-chloroethyl)ether	111-44-4
1,1,1-trichloroethene	71-55-6
1,1,2,2-tetrachloroethylene	79-34-5
1,1,2-trichloroethene	79-00-5
1,1-dichloroethene	75-34-3
1,2-dichloroethene	107-06-2
chloroethane	75-00-3
hexachloroethene	67-72-1
2-chloroethylvinyl ether	110-75-8
1,1-dichloroethylene	75-35-4
1,2-dichloroethylene	156-60-5
vinyl chloride	75-01-4
tetrachloroethylene	127-18-4
trichloroethene	79-01-6
flouroanthene	206-44-0
1,2-diphenylhydrazine	122-66-7
indeno(1,2,3-cd)pyrene	193-39-5
iron	7439-89-6
lead	7439-97-6

LIST D (Continued)

Parameter	Chemical Abstract System Number
magnesium	7439-95-4
manganese	7439-96-5
mercury	7439-97-6
n-nitrosodimethylamine	62-75-9
methyl bromide	74-83-9
dichlorobromomethane	75-27-4
methyl chloride	74-87-3
chlorodibromomethane	124-48-1
methylene chloride	75-09-2
dichlorodifluoromethane	75-71-8
carbon tetrachloride	56-23-5
bromoform	75-25-2
chloroform	67-66-3
trichlorofluoromethane	75-69-4
naphthalene	91-20-3
2-chloronaphthalene	91-58-7
nickel	7440-02-0
phenanthrene	85-01-8
phenol	108-95-2
2,4,5-trichlorophenol	95-95-4
2,4,6-trichlorophenol	88-06-2
2,4-dichlorophenol	120-83-2
2,4-dimethylphenol	105-67-9
2,4-dinitrophenol	51-28-5
2-chlorophenol	95-57-8
4,6-dinitro-o-cresol	534-52-1
2-nitrophenol	88-75-5
p-chloro-m-cresol	59-50-7
4-methylphenol	106-44-5
4-nitrophenol	100-02-7
pentachlorophenol	87-86-5
potassium	7440-09- 7
1,2-dichloropropane	78-87-5
bis(2-chloroisopropylether)	39638-32-9
1,2-dichloropropylene	542-75-6
pyrene	129-00-0
selenium	7782-49-2
silver	7440-22-4
sodium	7440-23-5
thallium	7440-28-0
tin	7440-31-5
toxaphene	8001-35-2
vanadium	7440-62-2
zinc	7440-66-6

Appendix C

SAMPLING PRIORITIES FOR ENVIRONMENTAL POLLUTANTS

Compounds are characterized on the basis of persistence, accumulative capacity and volatility. "X" indicates the appropriate environmental compartment(s) for initial sampling.

Compound	Environmental Compartment		
	Water	Sediment	Biota
METALS AND INORGANICS			
Antimony	X		
Arsenic		X	X
Asbestos	X		
Beryllium		X	X
Cadmium		X	X
Chromium		X	X
Copper		X	X
Cyanides	X		
Lead		X	X
Mercury		X	X
Nickel		X	X
Selenium		X	X
Silver		X	X
Thallium		X	X
Zinc		X	X
PESTICIDES			
Acrolein		X	X
Aldrin	X		X
Chlordane		X	X
DDD		X	X
DDE		X	X
DDT		X	X
Dieldrin		X	X
Endosulfan and endosulfan sulfate		X	
Endrin and endrin aldehyde	X	X	X
Heptachlor		X	X
Heptachlor epoxide	X	X	X
Hexachlorocyclohexane (α,β,δ isomers)	X	X	
γ-Hexachlorocyclohexane (lindane)	X	X	
Isophorone	X		
TCDD		X	X
Toxaphene		X	X

Appendix D

REFERENCED STANDARD OPERATING GUIDELINES FOR PROJECT ACTIVITIES

Please check off the following tasks that will be performed during the course of the project. Then, at the bottom of the page and on subsequent pages, describe fully, for each task, the appropriate procedures and actions that will be taken to provide both quality assurance and quality control. If a given task has standard operating guidance (SOG) that is documented, please refer to that guidance. The primary reference would be State Agency Standard Operating Procedures. List others as appropriate.

Document/Section	Description
_____	Ambient Air Sampling (OVA, HNU, etc.)
_____	Ground-Water Sampling
_____	Surface-Water Sampling
_____	Soil/Sediment Sampling
_____	Tap Water Sampling
_____	Land Surveying
_____	Electrical Resistivity Survey
_____	Electromagnetic Survey
_____	Magnetometer Survey
_____	Metal Detection Survey
_____	Ground Penetrating Radar Survey
_____	Seismic Survey
_____	Water Level Measurements
_____	Perimeter Survey
_____	Site Inspection
_____	Soil Borings/Well Installation
_____	Bedrock Fracture Analysis
_____	Pump/Permeability Tests
_____	Preparation of Water Table Maps
_____	Preparation of Bedrock Contour Maps

APPLICABILITY

The following portions of the NUS Superfund Division Quality Assurance Manual are applicable to the performance of specific work elements defined in TDD #N/A to State. The quality assurance procedures recognized in Region II FIT follow applicable operating guidelines provided in the preeceeding section of this work plan.

( )	Number	Subject
___	QAP 2.5	Work Plans
___	QAP 3.1	Control of Remedial Design Activities
___	QAP 4.1	Field Data Collection
___	QAP 4.2	Data Reduction, Validation, and Reporting
___	QAP 5.1	Preparation of Procurement Documents
___	QAP 5.2	Subcontractor Quality Assurance Requirements
___	QAP 6.1	Preparation of Instructions and Procedures
___	QAP 7.1	Identification of Controlled Evidentiary Documents
___	QAP 7.2	Issuance and Distribution of Controlled Documents
___	QAP 7.3	Development, Documentation, Verification, and Retention of Software Programs
___	QAP 7.4	Technical Reports
___	QAP 7.5	Interim Document Review Procedure
___	QAP 8.1	Control of Procurement Activities
___	QAP 8.2	Evaluation and Selection of Subcontractors
___	QAP 9.1.F2	Chain of Custody
___	QAP 9.2.F2	Sample Control
___	QAP 10.1	Analysis Techniques
___	QAP 11.1	Offsite Reconnaissance
___	QAP 11.2	Onsite Inspections
___	QAP 12.1	Implementation of Measuring and Test Equipment Controls Materials
___	QAP 13.1	Packaging, Marking, Labeling, and Shipping of Samples from Hazardous-Waste Sites
___	QAP 14.1	Nonconformance Reporting, Evaluation, and Disposition
___	QAP 15.1	Implementation and Documentation of Corrective Actions
___	QAP 16.1	Storage and Retrieval of Quality Assurance Records
___	QAP 17.4	Preparation for Audit
___	QAP 17.6	Quality Notices

SAMPLING PRIORITIES FOR ENVIRONMENTAL POLLUTANTS
PAGE THREE

Compound	Environmental Compartment		
	Water	Sediment	Biota
ETHERS (Continued)			
Bis(2-chloroisopropyl)ether	X		
2-Chloroethyl vinyl ether	X	X	
4-Chlorophenyl phenyl ether		X	X
4-Bromophenyl phenyl ether		X	X
Bis(2-chloroethoxy) methane	X		
MONOCYCLIC AROMATICS			
Benzene		X	
Chlorobenzene		X	X
1,2-Dichlorobenzene (o-dichlorobenzene)		X	X
1,3-Dichlorobenzene (m-dichlorobenzene)		X	X
1,4-Dichlorobenzene (p-dichlorobenzene)		X	X
1,2,4-Trichlorobenzene		X	X
Hexachlorobenzene		X	X
Ethylbenzene		X	
Nitrobenzene		X	
Toluene		X	
2,4-Dinitrotoluene		X	
2,6-Dinitrotoluene		X	
PHENOLS AND CRESOLS			
Phenol	X		
2-Chlorophenol	X		
2,4-Dichlorophenol	X		
2,4,6-Trichlorophenol		X	
Pentachlorophenol		X	X
2-Nitrophenol		X	
4-Nitrophenol		X	
2,4-Dinitrophenol		X	
2,4-Dimethylphenol		X	X
p-Chloro-m-cresol		X	
4,6-Dinitro-p-cresol		X	

* These compounds have been removed from the EPA priority pollutant list.

Appendix E

EXPENDABLE EQUIPMENT

Item	Quantity Packaged	Amount Required
CHEMICALS		
Acetone	5 gal.	1
Acetone	1 gal.	
Trichloroethane	5 gal.	
Trichloroethane	1 gal.	
Methylene-chloride	5 gal.	
Methylene-chloride	1 gal.	
Hexane	1 gal.	1
Gasoline	1 gal.	1
Gasoline	5 gal.	
Nitric Acid	1 gal.	
Nitric Acid	5 ml.	2 Boxes
Sodium Hydroxide	1 liter	
Motor Oil	1 qt.	1
2-Cycle Oil	1/2 pt.	
Alconox	1 gal.	1
Baking Soda	2 lb. box	
SAMPLE CONTAINERS		
40 ml. VOA Bottles	1 each	10
½ gal. Amber Bottle	1 each	10
1 liter Amber Bottle	1 each	
8 oz. Glass Jars	1 each	
1 liter Plastic Bottles	1 each	10 5
Plastic Bags 8" x 12"	100 box	
Plastic Bags 10" x 12"	100 box	
Plastic Bags 12" x 20"	100 box	
Paint Cans w/lid & snaps	1 gal.	
Paint Cans w/lid & snaps	½ gal.	
Paint Cans w/lid & snaps	1 qt.	
Vermiculite	4 cu. ft.	
BOOTS		
Butyl Rubber Boots		2
Hip Boots Size _____		
Latex Boot Covers		5
Tyvek Boot Covers		

EXPENDABLE EQUIPMENT (Cont'd)

Item	Quantity Packaged	Amount Required
FILM		
C-135-36-100-Prints	1 roll	
C-135-36-200-Prints	1 roll	
C-135-36-400-Prints	1 roll	2
C-135-24-100-Prints	1 roll	
C-135-24-200-Prints	1 roll	
C-135-24-400-Prints	1 roll	
C-135-12-100-Prints	1 roll	
C-135-12-200-Prints	1 roll	
C-135-12-400-Prints	1 roll	
C-135-36-200-Slide	1 roll	
C-135-36-25-Slide	1 roll	2
B&W-135-20-400-Prints	1 roll	
SX-70 Polaroid	1 sgl. pack	
Kodamatic	1 sgl. pack	
STATIONERY SUPPLIES		
Graph Paper		
Manilla Tags		
Paper Towels		2 Rolls
Felt Tip Markers		4
Ball Point Pens		2
Indelible Ink Pens		2
ROPE		
Nylon 3/16"	600' roll	1 Roll
Nylon 1/4"	1000' roll	
Manila 1/4	100' roll	
Manila 1/2	50' roll	
TAPE		
Clear Plastic	1 each	2
Duct	1 roll	2
Elec. Vinyl	1 roll	
Filament	1 roll	4
Flagging	100' roll	
Masking	1 roll	1
Transparent	1 each	

NON-EXPENDABLE EQUIPMENT

Equipment	Amount Required
CAMERAS	
Cannon AE1	2
Polariod One Step	
Polaroid SX70	
Camera bag	
Binoculars	
AIR MONITORING	
HNU Photoionization Detector	1
Draeger Tubes Type HCN + H_2S	2 Boxes
Organic Vapor Analyzer	1
OVA Chart Recorder	
Explosimeter	1
Combination Explosimeter and O_2 Indicator	
Oxygen Indicator	1
Draeger Tube Hand Pump	1
H_2S Gas Indicator	1
Mercury Sniffer	
Photovac	
METERS	
Radiation Mini-Alert	1
Conductivity Meter	
pH Meter	1
Resistivity Meter (Bison)	
Resistivity Meter (Soil Test)	
Metal Detector	
SURVEYING EQUIPMENT	
Optical Rangefinder	
Level, Hand 2X	
Brunton Transit w/case	
Compass	
200' Fiberglass Measuring Tape	
300' Fiberglass Measuring Tape	1

NON-EXPENDABLE EQUIPMENT (cont'd)

Equipment	Amount Required
POWER EQUIPMENT	
Digger Mobile	
3 HP Water Pump w/gas can	
Generator w/gas can	1
Power Auger w/gas can	
Extension Cord-Heavy Duty 100"	1
Extension Cord-Light Duty 25"	
Remote Drum Opener	
PERSONAL PROTECTION	
Hard Hat	5
Safety Goggles	5
Safety Glasses	
Splash Shield	2
Full Face Respirator	
Respiratory Cartridges	
Butyl Rubber Apron	2
Encapsulated Suits	
Life Vests	
Rain Jacket	
Rain Pants	
SELF CONTAINED BREATHING APPARATUS	
401 SCBA	
Dual Purpose SCBA	5
CASCADE System	
45 cu. ft. Composite Tanks	10
Umbilical Breathing Air Lines (50' Sec)	
Umbilical Breathing Air System	
330 cu. ft. Class "D" Breathing Air Cylinder	
STANDBY SAFETY EQUIPMENT	
20# Fire Extinguishers	1
O_2 Resuscitator	1
Stretcher	1
Eye Wash	1
Trauma Kit	1

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON D C 20460

NOV 19 1984

Appendix F

OFFICE OF
SOLID WASTE AND EMERGENCY RESPONSE

MEMORANDUM

SUBJECT: Standard Operating Safety Guides, November 1984

FROM: William N. Hedeman, Jr., Director
Office of Emergency and Remedial Response

TO: Regional Office Addressees

The enclosed Standard Operating Safety Guides, November 1984 replaces the Interim Standard Operating Guides, Revised September 1982. The Guides have been updated and revised to reflect additional experience EPA personnel have gained in responding to environmental incidents involving hazardous substances.

The Standard Operating Safety Guides are in accordance and consistent with the procedures for employee health and safety contained in EPA's Occupational Health and Safety Manual, Chapter 9, Hazardous Substances Responses, (1440 TN12), May 5, 1984.

The guides are not meant to be a comprehensive safety manual for incident response. Rather, they provide information on health and safety to complement professional judgement and experience, and to supplement existing Regional office safety procedures.

If you have any questions or comments concerning the guides, please contact Mr. Stephen Lingle, Director, Hazardous Response Support Division or Mr. J. Stephen Dorrler, Chief, Environmental Response Team.

Enclosure

Addressees

Director, Ofc. of Emergence & Remedial Resp., Region II
Director, Hazardous Waste Mgmt. Div., Region III
Director, Air & Waste Management Division,
Regions IV, VI, VII. VIII
Director, Waste Mgmt. Div., Regions I & V
Director, Toxics & Waste Mgmt. Div., Region IX
Director, Air & Waste Division X

cc: Gene Lucero, OWPE
John Skinner, OSW

- Address emergency medical care for injuries and toxicological problems.

- Describe requirements for an environmental surveillance program.

- Specify any routine and special training required for responders.

- Establish procedures for protecting workers from weather-related problems.

III. SITE SAFETY PLAN SCOPE AND DETAIL

The plan's scope, detail, and length is based on:

- Information available about the incident.

- Time available to prepare a site-specific plan.

- Reason for responding.

Three general categories of response exist - emergencies, characterizations and remedial actions. Although considerations for personnel safety are generic and independent of the response category, in scope, detail, and length safety requirements and plans vary considerably. These variations are generally due to the reason for responding (or category of response) , information available, and the severity of the incident with its concomitant dangers to the responder.

A. Emergencies

1. Situation:

Emergencies generally require prompt action to prevent or reduce undesirable affects. Immediate hazards of fire, explosion, and release of toxic vapors or gases are of prime concern. Emergencies vary greatly in respect to types and quantities of material, numbers of responders, type of work required, population affected, and other factors. Emergencies last from a few hours to a few days.

- Information available: Varies from none to much. Usually information about the chemicals involved and their associated hazards is quickly obtained in transportation-related incidents, or incidents involving fixed facilities. Determining the substances involved in some incidents, such as mysterious spills, requires considerable time and effort.

- Time available: Little time, generally requires prompt action to bring the incident under control.

- Reason for response: To implement prompt and immediate

C. Remedial Actions

1. Situation:

Remedial actions are cleanups which last over a long period of time. They commence after more immediate problems at an emergency have been controlled, or they involve the mitigation of hazards and restoration of abandoned hazardous waste sites. Numerous activities are required involving many people a logistics and support base, extensive equipment, and more involved work activities. Remedial actions may require months to years to completely accomplish.

- Information available: Much known about on-site hazards.
- Time available: Ample time for work planning.
- Reason for response: Systematic and complete control, cleanup, and restoration.

2. Effects on Plan:

Since ample time is available before work commences, site safety plan tends to be comprehensive and detailed. From prior investigations much detail may be known about the materials or hazards at the site and extent of contamination.

IV. SITE SAFETY PLAN DEVELOPMENT

To develop the plan as much background information as possible should be obtained, time permitting, about the incident. This would include, but not be limited to:

- Incident location and name.
- Site description.
- Chemicals and quantities involved.
- Hazards associated with each chemical.
- Behavior and dispersion of material involved.
- Types of containers, storage, or transportation methods.
- Physical hazards.
- Prevailing weather condition and forecast.
- Surrounding populations and land use.
- Ecologically sensitive areas.

- Designate Levels of Protection to be Worn

  The Levels of Protection to be worn at locations on-site or by work functions must be designated. This includes the specific types of respirators and clothing to be worn for each level. No one shall be permitted in areas requiring personnel protective equipment unless they have been trained in its use and are wearing it.

- Delineate Work Areas

  Work areas (exclusion zone, contamination reduction zone, and support zone) need to be designated on the site map and the map posted. The size of zones, zone boundaries, and access control points into each zone must be marked and made known to all site workers.

- List Control Procedures

  Control procedures must be implemented to prevent unauthorized access. Site security procedures - fences, signs, security patrols and check-in procedures - must be established. Procedures must also be established to control authorized personnel into work zones where personnel protection is required.

- Establish Decontamination Procedures

  Decontamination procedures for personnel and equipment must be established. Arrangements must also be made for the proper disposal of contaminated material, solutions, and equipment.

- Address Requirements for an Environmental Surveillance Program

  A program to monitor site hazards must be implemented. This would include air monitoring and sampling, and other kinds of media sampling at or around the site that would indicate chemicals present, their hazards, possible migration, and associated safety requirements.

- Specify Any Routine and Special Training Required

  Personnel must be trained not only in general safety procedures and use of safety equipment, but in any specialized work they may be expected to do.

- Establish Procedures for Weather-Related Problems

  Weather conditions can affect site work. Temperature extremes, high winds, storms, etc. impact on personnel safety. Work practices must be established to protect workers from the effects of weather and shelters provided, when necessary. Temperature extremes especially heat and its effect on people wearing protective clothing, must be considered and procedures established to monitor for and minimize heat stress.

- Address emergency medical care.

  -- Determine location of nearest medical or emergency care facility. Determine their capability to handle chemical exposure cases.

  -- Arrange for treating, admitting, and transporting of injured or exposed workers.

  -- Post the medical or emergency care facilities location, travel time, directions, and telephone number.

  -- Determine local physician's office location, travel directions, availability, and post telephone number if other medical care is not available.

  -- Determine nearest ambulance service and post telephone number.

  -- List responding organization's physicians, safety officers, or toxicologists name and telephone number. Also include nearest poison control center, if applicable.

  -- Maintain accurate records on any exposure or potential exposure of site workers during an emergency (or routine operations). The minimum amount of information needed (along with any medical test results) for personnel exposure records is contained in Annex 8.

- Advise workers of their duties during an emergency. In particular, it is imperative that the site safety officers, standby rescue personnel, decontamination workers, and emergency medical technicians practice emergency procedures.

- Incorporate into the plan, procedures for the decontamination of injured workers and for their transport to medical care facilities. Contamination of transport vehicles, medical care facilities, or of medical personnel may occur and should be addressed in the plan. Whenever feasible these procedures should be discussed with appropriate medical personnel in advance of operations.

- Establish procedures in cooperation with local and state officials for evacuating residents who live near the site.

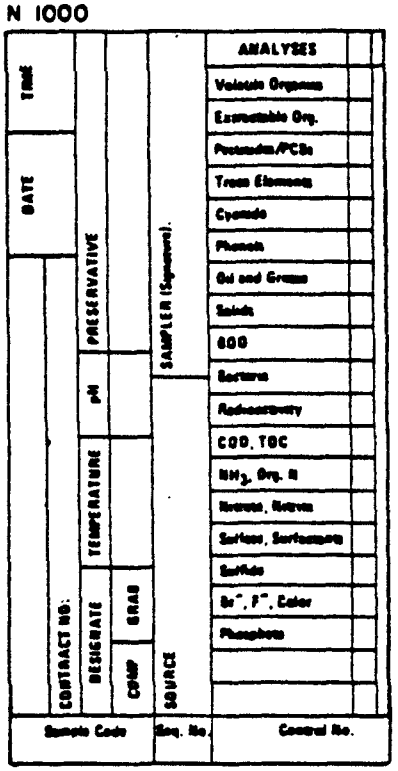
VII. IMPLEMENTATION OF THE SITE SAFETY PLAN

The site safety plan, (standard operating safety procedure or a generic safety plan for emergency response) must be written to avoid misinterpretation, ambiguity, and mistakes that verbal orders cause. The plan must be reviewed and approved by qualified personnel. Once the safety plan is implemented, its needs to be periodically examined and modified, if necessary, to reflect any changes in site work and conditions.

Appendix F

Sample Tag

N 1000



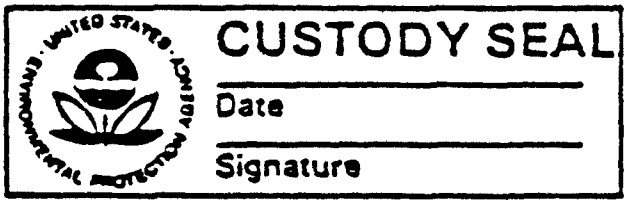


FIGURE 4: **Example of EPA Chain-of-Custody Seal**

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