SUBTITLE D
TECHNICAL
TRAINING MANUAL

UNITED STATES
E.P.A.
REGION IV
RCRA
ENVIRONMENTAL PROTECTION AGENCY

U.S. Environmental Protection Agency
Region IV
Atlanta, Georgia

1994

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RCRA SUBTITLE D TECHNICAL TRAINING COURSE
FOR STATES IN REGION IV

AGENDA

TIME: 8:00 a.m. - 4:30 p.m.

DAY 1

Manual Section Reference		
	REGISTRATION	8:00 a.m. - 9:00 a.m.
	Session 1	9:00 a.m. - 11:45 a.m.
1.	General Overview - Robert Krasko, P.G.	
2.	Design Criteria - J.P. Giroud, PhD.	
	Soil Liners	
	LUNCH	11:45 a.m. - 12:45 p.m.
	Session 2	12:45 p.m - 4:30 p.m.
	Design Criteria (Continued) - Dr. Giroud	
	Soil Liners	
	Flexible Membrane Liners	

DAY 2

	Session 1	8:30 a.m. - 12:15 p.m.
2.	Design Criteria (Continued) - Mr. Krasko	
	Leachate Collection Systems	
3.	Construction Quality Assurance - Robert R. Turton, P.E.	
	LUNCH	12:15 p.m. - 1:15 p.m.
	Session 2	1:15 p.m. - 4:30 p.m.
4.	Gas Management Systems - Mr. Krasko	
5.	Final Cover Systems - Mr. Krasko	

DAY 3

	Session 1	8:30 a.m. - 12:15 p.m.
6.	Groundwater Monitoring - Mr. Krasko	
	LUNCH	12:15 p.m. - 1:15 p.m.
	Session 2	1:15 p.m. - 4:30 p.m.
	Groundwater Monitoring (Continued) - Mr. Krasko	
	Conclusion	

Each session will include breaks.

SCHEDULE OF RCRA SUBTITLE D TRAINING COURSES

May 24-26, 1994 - Raleigh, North Carolina

May 31-June 2, 1994 - Jackson, Mississippi

June 7-9, 1994 - Frankfort, Kentucky

June 21-23, 1994 - Orlando, Florida

SPEAKERS FOR THE EPA REGION IV
RCRA SUBTITLE D TECHNICAL TRAINING COURSE

Jean-Pierre Giroud, Ph.D

Dr. Giroud is Senior Principal, Technical Director and Chairman of the Board of Geosyntec Consultants in Boca Raton, Florida. He holds an undergraduate engineering degree from the Ecole Centrale Des Arts et Manufactures de Paris in Paris, France and advanced degrees from the University of Grenoble in France. He has been engage in the practice of geotechnical engineering since 1963, and has done concentrated research on geotextiles, geomembrances and other geosynthetics since 1969. He has been involved in installing and researching liner systems for numerous dams and waste landfills and field testing of geosynthetic landfill caps. He is the author of five books and 200 technical papers.

Robert Krasko, P.G.

Mr. Krasko is President of Groundwater and Environmental Management Services, Inc., in Lawrenceville, Georgia. He holds undergraduate degrees in biology and geology from Florida Atlantic University and has engaged in graduate studies in hydrology at Arizona State University. He is registered as a professional geologist in six states and has more than 10 years of hydrogeological experience. He has directed numerous projects connected with the study of groundwater, has experience with the study and remediation of hazardous waste landfills and has performed regulatory compliance services at multiple solid waste landfills.

Robert R. Turton, P.E.

Mr. Turton is a Principal with Golder Construction Services, Inc., where he is responsible for numerous quality assurance/quality control projects. He holds Bachelor's and Master's degrees in civil engineering from Queen's University in Kingston, Ontario, Canada. He has more than 25 years experience with large construction projects and has been Project Manager for municipal solid waste landfill design projects in Louisiana, North Carolina and Tennessee. He is registered as a professional engineer in three states.

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ATTACHMENTS:

SUBTITLE D TECHNICAL TRAINING MANUAL

Introduction

The purpose of this manual is to assist regulatory personnel in understanding the technical aspects of planning and implementing regulatory programs for municipal solid waste landfill management which are equivalent to or exceed the Federal requirements. The manual addresses the following provisions of the RCRA Subtitle D regulations:

- Design (Liner and Leachate Collection and Recovery System)
- Landfill Gas Monitoring and Management
- Final Cover
- Groundwater Monitoring

This manual is intended to convey a working knowledge of the topics covered. More in-depth training may be necessary for developing expertise in any one of the areas covered.

SUBTITLE B TECHNICAL TRAINING MANUAL

SECTION 1.0

General Overview of Municipal Solid Waste Landfill Criteria

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1.1 INTRODUCTION

Subtitle D of the Resource Conservation and Recovery Act (RCRA) directed the Environmental Protection Agency (EPA) to develop a regulatory program governing the disposal of solid waste. In response, EPA issued regulations for Municipal Solid Waste Landfills (MSWLFs), found in Title 40, Code of Federal Regulations (CFR) Part 258. This section reviews the major provisions of those regulations, referred to as the Subtitle D Regulations.

40 CFR Part 258

- Subpart A - General Requirements
- Subpart B - Location Restrictions
- Subpart C - Operating Criteria
- Subpart D - Design Criteria
- Subpart E - Groundwater Monitoring and Corrective Action
- Subpart F - Closure and Post-Closure Care
- Subpart G - Financial Assurance Criteria
- Appendix I - Constituents for Detection Monitoring
- Appendix II - List of Hazardous and Organic Constituents (for Assessment Monitoring)

This section also provides general discussions of the flexibility available to EPA- approved state programs.

1.2 MAJOR PROVISIONS OF 40 CFR PART 258

The Subtitle D regulations for MSWLFs establish minimum Federal standards that specifically address the following:

- Purpose, scope and applicability of the regulations (Subpart A),
- Definitions (Subpart A);
- Consideration of other laws (Subpart A);
- Location restrictions for facility siting and/or continued operation (Subpart B);
- Operating requirements (Subpart C);
- Liner and leachate collection system design (Subpart D);
- Groundwater monitoring (Subpart E);
- Groundwater corrective action (Subpart E);
- Closure and post-closure care (Subpart F); and
- Financial assurance (Subpart G).

The following paragraphs briefly discuss topics covered by the Subtitle D regulations. States must adopt and implement MSWLF regulatory (permit) programs with standards at least as stringent as EPA's; otherwise, the Federal regulations establish the minimum standards for MSWLFs.

1.2.1 General (Subpart A)

Subpart A describes the purpose, scope and applicability of the Subtitle D regulations, provides definitions of terms used throughout the regulations and addresses facility responsibility for compliance with other applicable rules, laws, regulations or other requirements.

1.2.1.1 *Purpose, Scope and Applicability*

The purpose of these regulations is to provide for protection of human health and the environment by establishing minimum national solid waste disposal criteria for:

- MSWLF units used to dispose of municipal solid waste under RCRA
- MSWLF units used to dispose of sewage sludge under the Clean Water Act (CWA)

The Subtitle D regulations apply to new and existing MSWLF units as well as lateral expansions of existing MSWLFs. New MSWLF units are those that did not receive waste prior to October 9, 1993. Existing MSWLF units, on the other hand, are those that were receiving solid waste as of October 9, 1993 (Figure 1-1).

MSWLF units that did not receive waste after October 9, 1991, are exempt from the EPA Subtitle D regulations, while MSWLF units that received waste after October 9, 1991, but stopped receiving waste before October 9, 1993, are exempt from all of the EPA Subtitle D regulations except for those pertaining to installation of final cover. Those MSWLF units that fail to complete cover installation within the prescribed period (see Section 1.3 -

Decision Tree for the Applicability of 40 CFR Part 258

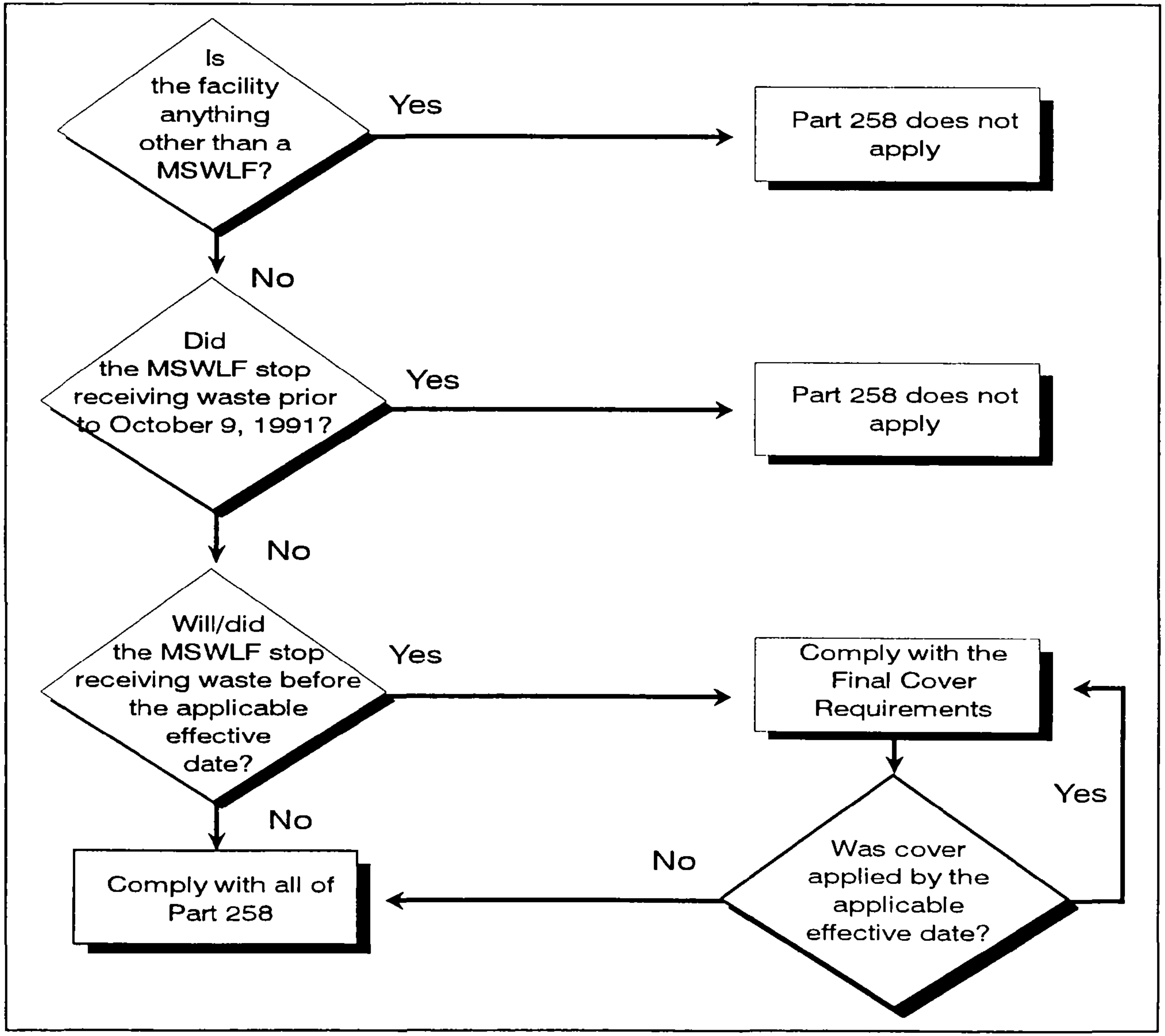


Figure 1-1
1-2

"Changes in Effective Dates") are subject to all of the Subtitle D requirements.

All other solid waste disposal facilities and practices that are not regulated under RCRA Subtitle D or Subtitle C (Hazardous Waste Regulations) are subject to the standards contained in 40 CFR Part 257, Criteria for Classification of Solid Waste Disposal Facilities and Practices.

1.2.1.2 *Definitions*

General definitions used throughout the regulations are included in Section 258.2 of the regulations while other sections contain subject-specific definitions.

1.2.1.3 *Consideration of Other Laws*

The EPA Subtitle D regulations specifically provide that all MSWLF units must comply not only with these criteria but with any other applicable Federal rules, laws, regulations or other requirements as well. This general statement covers all other Federal programs which are not specifically referenced in 40 CFR Part 258. Compliance with state and local requirements are not specifically addressed under the Federal criteria and therefore remain under the appropriate jurisdictions. However, the Federal criteria do not imply that MSWLFs are exempt from such state and local requirements.

1.2.2 Location Restrictions

Because of potential impacts from MSWLFs, the EPA regulations contain location restriction criteria for the following six areas of concern (Figure 1-2):

- Airport safety
- Floodplains
- Wetlands

Location Restrictions (Subpart B)

Restricted Location	Applies to Existing Units	Applies to New Units and Lateral Expansions	Make Demonstration to Director of an Approved State/Tribe and Retain Demonstration in Operating Record	Existing Units Must Close if Demonstration Cannot be Made
Airport	Yes	Yes	Yes	Yes
Floodplains	Yes	Yes	Yes	Yes
Wetlands	No	Yes	Yes	N/A
Fault Areas	No	Yes	Yes	N/A
Seismic Impact Zones	No	Yes	Yes	N/A
Unstable Areas	Yes	Yes	Yes	Yes

Figure 1-2
1-3

- Fault Areas
- Seismic impact zones
- Unstable areas

Owners and operators of new and lateral expansions of existing MSWLFs must demonstrate compliance with all six location restriction criteria before construction and operation can begin.

Owners and operators of existing facilities must demonstrate compliance with only three of the criteria: airport safety, floodplains and unstable areas. Existing facilities that cannot demonstrate compliance with these three criteria must close by October 9, 1996, unless an extension is provided by the Director of an EPA-approved State.

Demonstrations of compliance must be included in the Operating Record and reported to EPA or the Director of an approved State.

1.2.2.1
Airport Safety

The airport safety demonstration must show that the MSWLF is designed and operated so as not to pose a bird hazard to aircraft, if the facility is:

- Located within 10,000 feet of an airport runway used by turbojet aircraft, or
- Located within 5,000 feet of an airport runway used only by piston-type aircraft.
- The Federal Aviation Administration must also be notified if the MSWLF is located within 5 miles of an airport.

1.2.2.2
Floodplains

If the MSWLF is located in a 100-year floodplain, the floodplain demonstration must show that the facility will not:

- Restrict the flow of the 100-year flood
- Reduce the temporary water storage capacity of the floodplain
- Result in washout of solid waste so as to pose a hazard to human health and the environment

1.2.2.3
Wetlands

New MSWLF units and lateral expansions of existing units may not be located in wetlands without an appropriate demonstration by the facility owner or operator to the Director of an approved State. Such a demonstration must show that:

- No practical alternative to a wetland is available;
- No violation of State water quality standards or CWA toxic effluent standards, jeopardy for threatened or endangered species or critical habitat under the Endangered Species Act or violation of Marine Sanctuaries Act requirements will occur;
- There will be no degradation of the wetland and its ecological resources; and
- Steps have been taken to achieve no net loss of wetlands.

1.2.2.4
Fault Areas

The fault area demonstration must show that the MSWLF is not located within 200 feet of a fault that has had displacement in Holocene time, or, if allowed in EPA-approved state programs, that the facility is designed in a manner such that an alternative setback distance of less than 200 feet will prevent damage to the structural integrity of the MSWLF unit and will be protective of human health and the environment.

1.2.2.5
Seismic Impact Zones

The seismic impact zone demonstration must show that the MSWLF is not located in a seismic impact zone or, if allowed in EPA-approved state programs, demonstrate that all containment structures, including liners, leachate collection systems and surface water control systems are designed to resist the maximum horizontal acceleration in lithified earth material for the site.

1.2.2.6
Unstable Areas

If the MSWLF is located in an unstable area, the unstable area demonstration must show that engineering measures have been incorporated into the design to ensure that the integrity of the structural components will not be disrupted.

1.2.3
Operating Criteria (Subpart C)

Owners and operators of all new, existing and lateral expansions of MSWLFs must implement operating procedures to address the following criteria:

- Exclusion of hazardous waste and polychlorinated biphenyls (PCBs)
- Daily cover requirements
- Disease vector control
- Explosive gas control
- Air emissions control
- Access and illegal dumping restrictions
- Stormwater run-on/runoff control

- Surface water protection
- Liquid disposal restrictions
- Recordkeeping requirements

1.2.3.1
Exclusion of Hazardous Waste and PCBs

A program must be implemented to detect and prevent disposal of regulated hazardous waste as defined in 40 CFR Part 261 and PCBs as defined in 40 CFR Part 761.

The hazardous waste exclusion program must include the following:

- Random inspections of incoming loads or other steps to prevent acceptance of regulated hazardous wastes or PCB wastes.
- Records of inspections.
- Training of facility personnel to recognize regulated hazardous waste and PCB wastes.
- Procedures for notifying the appropriate authority (EPA or a Subtitle C authorized State) if a restricted waste (regulated hazardous waste or PCB waste) is discovered.

1.2.3.2
Daily Cover Requirements

Daily cover must be applied to the exposed waste at the end of each operating day, or more frequently if necessary, to prevent or control on-site populations of disease vectors, fires, odors, blowing litter and scavenging. The minimum daily cover requirement is 6 inches of earthen material. However, the use of alternative cover materials may be allowed by Directors of EPA-approved state programs.

1.2.3.3
Disease Vector Control

Appropriate means must be used to prevent or control onsite populations of disease vectors.

1.2.3.4
Explosive Gas Control

A program must be implemented for routinely monitoring (not less frequently than quarterly) and controlling methane gas accumulation and migration so that the methane concentrations:

- Do not exceed 25 percent of the Lower Explosive Limit (LEL) in onsite structures (1.25 percent in air); and
- Do not exceed the LEL at the site boundary (5 percent in air).

If methane gas levels exceed these limits, the following actions must be undertaken:

- Immediately - Take all necessary steps to ensure protection of human health.
- Notify the appropriate regulatory authority (EPA and/or approved state agency.)
- Within 7 days - Place the methane gas levels detected and a description of the steps taken to protect human health in the operating record.
- Within 60 days - Implement a remediation plan for the methane gas releases, place a copy of the plan in the operating record and notify EPA and/or the State Director that the remediation plan has been implemented.

1.2.3.5
Air Emissions Control

Open burning is prohibited, except for the infrequent burning of agricultural wastes, land-clearing debris, diseased trees or debris from emergency cleanup operations.

The MSWLF must also comply with the State Implementation Plan developed under the Clean Air Act.

1.2.3.6
Access and Illegal Dumping Restrictions

Access to the MSWLF must be controlled to prevent unauthorized traffic and prevent illegal dumping. Access may be controlled by artificial barriers, natural barriers or both, as appropriate.

1.2.3.7
Stormwater Run-on/Runoff Control

The MSWLF must have a plan to design, construct and maintain a run-on/runoff control system to:

- Prevent run-on to the active area from the peak discharge of a 25-year storm, and

- Collect and control runoff from the active area resulting from a 24-hour, 25-year storm.

1.2.3.8
Surface Water Protection

Discharges of pollutants and nonpoint sources of pollution that enter waters of the United States (including wetlands) that violate any requirement of the Clean Water Act and any areawide or statewide water quality management plans must be prevented.

1.2.3.9
Liquid Restrictions

No bulk or noncontainerized liquid waste may be placed in MSWLFs. Normal household liquid wastes and liquid wastes in small containers (similar in size to that normally found in household waste and designed for holding liquids for use and not storage) may be placed in MSWLFs.

Leachate or gas condensate may be placed in the MSWLF unit, but only if the facility is constructed with a composite liner and leachate collection system and the leachate or condensate was derived from the MSWLF.

1.2.3.10
Recordkeeping

The following records, at a minimum, must be retained in an operating record which must be located at or near the facility:

- Location restriction demonstrations;
- Waste exclusion program inspection records, training and notification procedures;
- Gas monitoring results and any required remediation plans;
- Design documentation for placement of leachate or gas condensate in the landfill,
- Groundwater demonstrations, certifications, findings and any monitoring, testing or analytical data;
- Closure and post-closure care plans and any required monitoring, testing or analytical data (including groundwater, landfill gas and testing or analytical data required for post closure care); and
- Financial assurance cost estimates and documentation.

Notification of placement of these documents in the operating record must be provided to the appropriate state regulatory authority. Copies of all information contained in the operating record must be furnished to the state regulatory authority (as requested) or be made available for inspection by state agency representatives at all reasonable times.

1.2.4 Design Criteria (Subpart D)

New MSWLF units and lateral expansions must be designed with a two-component composite liner that consists of the following:

- Lower component - A minimum of 2 feet of soil material compacted to a hydraulic conductivity of no more than 1×10^{-7} centimeters/second (cm/sec).

- Upper component - A minimum 30-mil flexible membrane liner (FML) installed in direct and uniform contact with the lower component. If high-density polyethylene (HDPE) is used, a minimum thickness of 60 mils is required.

- A leachate collection system which is designed and constructed to maintain less than a 30-cm (approximately 1-foot) depth of leachate over the liner.

Alternative engineering designs may be allowed by Directors of approved States provided the designs prevent release of Table 1 constituents at concentrations exceeding the Maximum Contaminant Levels (MCLs) in the uppermost aquifer at the point of compliance. The point of compliance is the waste management unit boundary or as close as site features allow. Alternative point of compliance distances, up to 150 meters from the waste management unit boundary and on land owned by the owner of the MSWLF unit, may be allowed in EPA-approved state programs.

1.2.5 Groundwater Monitoring and Corrective Action (Subpart E)

The EPA Subtitle D regulations include an extensive set of groundwater monitoring and corrective action requirements which apply to new, existing and lateral expansions of existing MSWLF units. The three principal components of the groundwater requirements are:

- **Detection Monitoring Program** - Background concentrations of specific constituents (listed in Part 258, Appendix I) must be established and used to evaluate groundwater monitoring data, which is collected semiannually to determine if a statistically significant increase (SSI) has occurred from the MSWLF. Detection monitoring must be performed throughout the active life, closure and post-closure care periods of the MSWLF.

- **Assessment Monitoring Programs** - Additional evaluations of impacts to groundwater quality must be performed for the hazardous constituents listed in Part 258, Appendix II whenever a SSI over background is detected for one or more of the detection monitoring constituents.

- **Corrective Action Assessments and Implementation** - Potential remedies must be evaluated and implemented if any Part 258, Appendix II constituents are detected above groundwater protection standards. Groundwater protection standards must be established for any Appendix II constituents detected in groundwater.

The regulations also discuss the minimum criteria for:

- Groundwater monitoring systems
- Groundwater sampling and analysis (plans and procedures)
- Statistical procedures
- Groundwater protection standards

1.2.5.1
Groundwater Detection Monitoring Programs

A detection monitoring program must be established that includes semiannual monitoring for the Appendix I constituents at background and point of compliance locations. EPA approved state programs may contain provisions for the following:

- Suspending groundwater monitoring where it can be demonstrated that there is no potential for migration of hazardous constituents from the MSWLF unit to the uppermost aquifer.
- Identifying an alternative (shorter) list of detection monitoring parameters if it can be shown that any deleted constituents are not expected to be contained in or derived from the waste.
- Designating an alternative frequency for detection monitoring. The alternative monitoring frequency must be no less than annual.
- Designating an alternative distance for locating point of compliance monitoring wells. The alternative point of compliance distance must be no greater than 150 meters from the waste management

unit boundary and on land owned by the owner of the MSWLF unit.

Once established, the groundwater detection monitoring program, including all system components (i.e., wells, piezometers or other measurement, sampling and analytical devices) must be conducted, operated and maintained in accordance with the design specifications throughout the MSWLF's active life and post-closure care period.

Within a reasonable period of time after completing each sampling and analysis, the groundwater monitoring data must be evaluated to determine whether or not there is a SSI over background values for each of the detection monitoring constituents.

In order to perform the statistical evaluations, background groundwater quality must be established for each of the monitoring constituents. Background groundwater quality data may be derived from locations that are either hydraulically upgradient from the MSWLF unit or at other locations that provide more representative background data.

Groundwater data collected from the point of compliance (detection monitoring wells) must be compared against the background data to determine if there is a SSI at any of the compliance monitoring wells. Within 14 days of determining that a SSI of one or more detection monitoring constituents has occurred, the State regulatory authority must be notified that the results have been placed in the operating record. An assessment monitoring program must be implemented within 90 days, unless it can be demonstrated that another source caused the contamination or that the SSI resulted from errors in sampling, analysis, statistical evaluation or natural variation in groundwater quality.

1.2.5.2 *Assessment Monitoring Programs*

Assessment monitoring is required whenever a SSI over background has been detected for one or more of the detection monitoring constituents. The assessment monitoring program requires that:

- Within 90 days of triggering the assessment monitoring program, and annually thereafter, groundwater must be analyzed for all of the Appendix II constituents. For any constituent detected in the downgradient wells as the result of the complete Appendix II analysis, a sufficient number of independent samples must be collected and analyzed for each well (background and downgradient) to establish background and provide for statistical evaluation of the new constituents. Within 14 days after obtaining the analytical results, the state regulatory authority must be notified that information on the Appendix II constituents that have been detected has been placed in the operating record.

- Within 90 days, and at least semiannually thereafter, groundwater must be resampled for the detection monitoring parameters (Appendix I or alternative list) and for detected Appendix II constituents.

- Groundwater protection standards must also be established for all detected Appendix II constituents.

Statistical evaluations must be conducted to determine if the detected constituents are above background and above or below the groundwater protection standards. If the concentrations of Appendix II constituents are:

- At or below background values for two consecutive sampling events, then the owner or operator of the MSWLF must notify the State Director and may return to detection monitoring.

- Above background values but below the groundwater protection standard, then the MSWLF owner or operator must continue assessment monitoring.

- Above the groundwater protection standard, then the MSWLF owner or operator must, within 14 days, notify the state regulatory agency and all appropriate local government officials that the information about Appendix II constituents which have exceeded the groundwater protection standard has been placed in the operating record.

Discovery of Appendix II constituents at concentrations above groundwater protection standards triggers additional requirements for the owner or operator, who must in addition to the steps described above:

- Characterize the nature and extent of the release by installing and sampling other additional monitoring wells as necessary.

- Install and sample at least one additional monitoring well located at the facility boundary in the direction of contaminant migration.

- Notify all persons who own or reside on land that directly overlies any part of a groundwater contamination plume that has migrated offsite.

- Initiate an assessment of corrective measures within 90 days or demonstrate that another source caused the contamination, or that the SSI resulted from error in sampling, analysis, statistical evaluation or natural variation in groundwater quality.

1.2.5.3 *Corrective Action Assessments and Implementation*

The corrective action assessment and implementation program requires evaluation of potential remedial alternatives and selection of an appropriate and acceptable remedy. This program requires in-depth evaluation of site conditions, contaminant releases and remedial technologies. Public participation in the selection process is also required. The details of this program are complex and can best be compared to similar programs under CERCLA (Remedial Investigation and Feasibility Study Program) and RCRA (RCRA Facility Investigation Program.)

1.2.5.4 *Groundwater Monitoring Systems*

The groundwater detection monitoring system must consists of a sufficient number of wells, installed at appropriate locations and depths to yield groundwater samples from the uppermost aquifer that:

- Represent the quality of background groundwater that has not been affected by leakage from a waste management unit; and

- Represent the quality of groundwater passing the relevant point of compliance or at the waste management unit boundary.

Multiunit groundwater monitoring systems instead of separate groundwater monitoring systems for each MSWLF unit may be allowed in EPA approved state programs.

1.2.5.5
Sampling and Analysis (Plans and Procedures)

The groundwater monitoring program must include detailed procedures and techniques for:

- Sample collection
- Sample preservation and shipment
- Analytical procedures
- Chain of custody control
- Quality assurance and quality control

The groundwater monitoring plans and procedures must:

- Provide for measurement of groundwater elevations immediately prior to purging (for determining purge volumes).
- Provide for measurement of water levels in all wells within a period of time short enough to avoid temporal variations (which could preclude accurate determination of groundwater flow rate and direction).

- Provide for determination of the rate and direction of groundwater flow each time groundwater is sampled
- Include procedures that are appropriate for analysis of groundwater quality.
- Include procedures that ensure results that accurately represent groundwater quality (i.e., hazardous constituent concentrations and other monitoring parameters).
- Disallow field filtering of samples prior to laboratory analysis.
- Identify the statistical method(s) that will be used in evaluating groundwater monitoring data for each constituent in each well.
- Provide for collection of a sufficient number of samples to establish groundwater quality data and accurately perform the statistical procedure(s).

1.2.5.6
Statistical Procedures

EPA has identified the following statistical methods that are applicable to evaluation of groundwater data collected at RCRA facilities:

- Parametric ANOVA
- ANOVA
- Tolerance or Prediction Intervals
- Control Chart
- Other Statistical Methods

The statistical method must, if necessary, include procedures to control or correct for seasonal and spatial variability as well as temporal correlation in the data.

The statistical method must be appropriate for the distribution of chemical parameters or hazardous constituents. If the distribution of the chemical parameters or hazardous constituents is inappropriate for a normal theory test, the data should be transformed or a distribution-free theory test should be used. If the distributions for the constituents differ, more than one statistical method may be needed.

The statistical method used must account for data below the limit of detection with one or more statistical procedures.

1.2.5.7
Groundwater Protection Standards

Groundwater protection standards must be established for each Appendix II constituent detected in the groundwater. The groundwater protection standard must be:

- The MCL, if one has been established under the Safe Drinking Water Act.
- The background concentration for the constituent if no MCL exists.
- The background concentration if it is higher than the MCL or health-based levels.
- State-established alternative groundwater protection standard for constituents with no established MCLs.

1.2.5.8
Appendix I

Appendix I of Part 258 identifies the 15 inorganic and 47 organic constituents that must be included in the groundwater detection monitoring program. However, an alternative list of constituents may be allowed in EPA-approved state programs.

1.2.5.9 *Appendix II*

Appendix II of Part 258 lists the hazardous inorganic and organic constituents which must be included in groundwater assessment monitoring programs.

1.2.6 Closure and Post-Closure Care (Subpart F)

When an MSWLF unit ceases accepting wastes and is to be closed, the Subtitle D regulations prescribe detailed procedures the unit owner must follow to accomplish closure.

1.2.6.1 *Final Cover*

A final cover system must be installed that is designed to minimize infiltration and erosion. The final cover system must consist of an erosion layer and an infiltration layer designed according to the standards described below.

- The erosion layer must consist of a minimum of 6 inches of earthen materials capable of sustaining native plant growth.
- The infiltration layer must consist of a minimum of 18 inches of earthen material that has a permeability of less than, or equal to, the permeability of any bottom liner system or natural subsoils present, or a permeability no greater than $1'10^{-5}$ cm/sec, whichever is less.
- Facilities with synthetic liner components must have a synthetic component incorporated into the final cover design.
- The erosion layer and infiltration layer must be installed in direct contact with each other.

The use of alternative final cover designs may be allowed in EPA-approved state programs.

1.2.6.2
Closure Plan

A written closure plan must be prepared that describes the steps necessary to close all MSWLF units at any point during the active life of the facility. Closure must be performed in accordance with the cover design requirements. The closure plan must include:

- A description of the final cover and the methods and procedures used to install the cover.
- An estimate of the largest area of the MSWLF unit ever requiring a cover at any time during the facility's active life.
- An estimate of the maximum inventory of wastes ever onsite over the active life of the landfill facility.
- A schedule for completing all activities necessary to satisfy the closure criteria.

Closure activities for each MSWLF unit must:

- Begin within 30 days after the date on which the final load of waste is received.
- Be completed in accordance with the facility closure plan.
- Be completed within 180 days after the closure activities began.

However, if the MSWLF unit has remaining capacity and there is a reasonable likelihood that additional wastes will be received, closure activities must begin no later than 1 year after the most recent receipt of wastes, unless an additional extension is provided for in EPA-approved state programs.

1.2.6.3 *Post-Closure Care Requirements*

Post-closure care must be conducted for 30 years, unless it is increased or decreased by the Director of an approved State. Post-closure care consists, at a minimum, of the following:

- Maintaining the integrity and effectiveness of any final cover, including making repairs to the cover as necessary to correct the effects of settlement, subsidence, erosion or other events and preventing run-on and runoff from eroding or otherwise damaging the final cover.
- Maintaining and operating the leachate collection system.
- Monitoring the groundwater and maintaining the groundwater monitoring system.
- Monitoring gas generation and maintaining any gas management systems.

A written post-closure plan must be prepared that includes:

- The description and frequency of monitoring and maintenance activities.
- The name, address, and telephone number of the person to contact concerning the facility during the post-closure period.
- A description of the planned uses of the property during the post-closure period.

1.2.7 Financial Assurance Criteria (Subpart G)

Financial assurance must be established to cover the cost of closure and post-closure care of the MSWLF unit. The amount of the financial assurance instrument must be based upon a detailed written cost estimate, in current dollars.

The cost estimate must account for hiring a third party to close the largest area of all MSWLF units ever requiring a final cover at any time during the active life of the facility when the extent and manner of its operation would make closure the most expensive.

The closure cost must be adjusted annually for inflation during the active life of the MSWLF unit and the financial assurance instrument must be adjusted, as necessary.

1.3 CHANGES IN APPLICABILITY AND EFFECTIVE DATES

The Subtitle D regulations, as revised, apply to all new and existing MSWLFs and lateral expansions of MSWLFs. The small landfill exemption provision included in the October 9, 1991, regulations is no longer applicable. These facilities must also comply with the regulations, although on a modified schedule.

The regulations also apply to facilities that closed before October 9, 1993, but do not complete closure activities by October 9, 1994.

EPA extended some of the effective dates for compliance with the Subtitle D regulations. The schedule revisions (Figure 1-3):

- Extend the effective date of the Subtitle D regulations for 6 months for certain small landfills accepting 100 tons per day or less of solid waste.

Summary of Changes to the Effective Dates of the MSWLF Criteria

	MSWLF Units Accepting Greater than 100 TPD	MSWLF Units Accepting 100 TPD or Less; Are Not on the NPL; and Are Located in a State that has Submitted an Application for Approval by 10/9/93, or on Indian Lands or Indian Country	MSWLF Units that Meet the Small Landfill Exemption in 40 CFR 258.1(f)	MSWLF Units Receiving Flood Related Waste
General Effective Date. [1] This is the effective date for location, operation, design, and closure/post-closure.	October 9, 1993	April 9, 1994	October 9, 1995	Up to October 9, 1994 as determined by State
Date by which to install final cover if receipt of waste ceased by the general effective date.	October 9, 1994	October 9, 1994	October 9, 1996	Within one year of date determined by State; no later than October 9, 1995
Effective date of groundwater monitoring and corrective action.	Prior to receipt of waste for new units; October 9, 1994 through October 9, 1996 for existing units and lateral expansions	Prior to receipt of waste for new units; October 9, 1993 for new units; October 9, 1994 through October 9, 1996 for existing units and lateral expansions	Prior to receipt of waste for new units; October 9, 1995 for new units; October 9, 1995 through October 9, 1996 for existing units and lateral expansions	October 9, 1993 for new units; October 9, 1994 through October 9, 1996 for existing units and lateral expansions
Effective date of financial assurance requirements.	April 9, 1995	April 9, 1995	October 9, 1995	April 9, 1995

[1] If a MSWLF unit receives waste after this date, the unit must comply with all of Part 258.

Figure 1-3

- Extend the effective date of the financial assurance requirements for all landfills for 1 year.

- Provide an alternative schedule for small landfills which were exempt under the October 9, 1991, regulations (prior to revision). Small landfills which were subject to the small landfill exemption must now begin to comply by October 9, 1995. This extension provides these facilities with the same 2 years between the promulgation and effective dates to prepare for compliance that was provided for all other facilities.

These extensions were intended to provide:

- Additional time for local governments and small landfills to develop the ability and resources to comply.

- Additional time for EPA to approve state programs, thereby providing opportunities for use of the flexibility provisions.

- Additional time for assessing and planning for new waste management facilities and alternatives.

- Provide equivalent planning time for small landfills which were previously exempt.

The full text of the extension provisions are included in attachments E and F, reprinted from the Federal Register announcements of October 1 and October 14, 1993.

1.4 FLEXIBILITY IN APPROVED STATES

The Subtitle D regulations establish minimum criteria for self compliance by MSWLFs. The regulations also contain numerous provisions which enable state programs that have received EPA approval to utilize site-specific information to adapt some of the requirements for practical implementation. The EPA regulations include specific conditions that the states must address in using this flexibility. EPA-approved state programs may allow for the following, which also include the corresponding section numbers.

- Location of new or lateral expansions of MSWLFs in wetlands [258.12(a)].

- Location of new or lateral expansions of MSWLFs less than 200 feet from a Holocene age fault [258.13(a)].

- Location of new or lateral expansions of MSWLFs in seismic impact zones [258.14(a)].

- Delayed closure for existing MSWLFs that cannot make the location restriction demonstrations [258.16(b)].

- Alternative daily cover [258.21(b)].

- Alternative schedules for methane gas release reporting and implementation of remedial action plans [258.23(c)(4)].

- Alternative recordkeeping locations [258.29(a)].

- Alternative recordkeeping and notification schedules (except for airport safety and notifying landowners of Appendix II releases) [258.29(c)].

- Alternative designs [258.40(a)(1)].
- Alternative location of point of compliance boundaries up to 150 meters from the waste management unit boundary [258.40(d)].
- Suspension of groundwater monitoring if no potential for groundwater impact exists [258.50(b)].
- Alternative schedules for existing MSWLFs and lateral expansions to comply with the groundwater monitoring criteria [258.50(d)].
- Deletion of Appendix I parameters for detection monitoring [258.54(a)(1)].
- Alternative schedules for Appendix I detection monitoring [258.54(b)]
- Alternative schedules for placing notification of statistical increases of Appendix I constituents over background in the operating record [258.50(g) and 258.54(c)1)].
- Multiunit groundwater monitoring systems [258.51(b)]
- Alternative schedules for placing qualified professional certifications relating to monitoring systems in the operating record [258.51(d)(2)].

- Alternative schedules for establishing assessment monitoring or demonstrating other sources or data errors [258.50(g), 258.54(c)(2) and 258.54(c)(3)].

- Alternative schedules for conducting Appendix II sampling after initiating assessment monitoring [258.50(g) and 258.55(b)].

- Alternative subset of wells for conducting Appendix II sampling for assessment monitoring [258.55(b)].

- Deletion of Appendix II parameters for assessment monitoring [258.55(b)].

- Alternative schedules for placing notification of detected Appendix II constituents in the operating record [258.50(g) and 258.55(d)(1)].

- Alternative schedules for resampling Appendix I and Appendix II constituents [258.55(c) and 258.55(d)(2)].

- Alternative schedules for placing notification of SSIs of Appendix II constituents over groundwater protection standards in the operating record [258.50(g) and 258.55(g)].

- Alternative schedules for initiating assessment of corrective measures or demonstrating other sources or data errors [258.50(g), 258.55(g)(1)(iv) and 258.56(a)].

- Alternative schedules for placing notification of remedy selection in the operating record [258.50(g) and 258.57(a)].
- No cleanup action for particular constituents if determined unnecessary [258.57(e)].
- Alternative schedules for placing notification of inability to implement a selected remedy and selection of an alternative remedy in the operating record [258.50(g) and 258.58(c)(4)].
- Alternative schedules for placing notification of remedy completion in the operating record [258.50(g) and 258.58(f)].
- Alternative schedules for beginning closure [258.60(f) and 258.60(g)].
- Discontinuation of leachate management [258.61(a)(2)].
- Decreases or increases in the post-closure care period [258.61(b)(1) and 258.61(b)(2)].
- Disturbance of the final cover [258.61(c)(3)].

References

1 U.S. Environmental Protection Agency, Design, Operation, and Closure of Municipal Solid Waste Landfills., EPA/600/K-92/002 (Washington, DC: GPO, 1993).

2. Environmental Reporter, August 13, 1993.

3. Landfill Control Technologies, Technical Tips (1993).

4. National Archives and Records Administration, Federal Register, Vol. 56 (Washington, D.C.: GPO, October 9, 1991) p. 50978.

5. National Archives and Records Administration, Federal Register, Vol. 57 (Washington, D.C: GPO, June 26, 1992) p. 28626.

6. National Archives and Records Administration, Federal Register, Vol. 58 (Washington, D.C.: GPO, October 1, 1993) p. 51536.

7. National Archives and Records Administration, Federal Register, Vol. 58 (Washington, D.C.: GPO, October 14, 1993) p. 53136.

2

SECTION 2.0

Design Criteria

Page No.

List of Figures Page No.

2.1 INTRODUCTION

The design of the MSWLF is critical to ensure that the wastes are secured in a stable environment that is protective of human health and the natural environment. This section highlights the design criteria of the Subtitle D regulations and discusses the components of an effective landfill design.

2.2 DESIGN CRITERIA

2.2.1 Design in Unapproved States

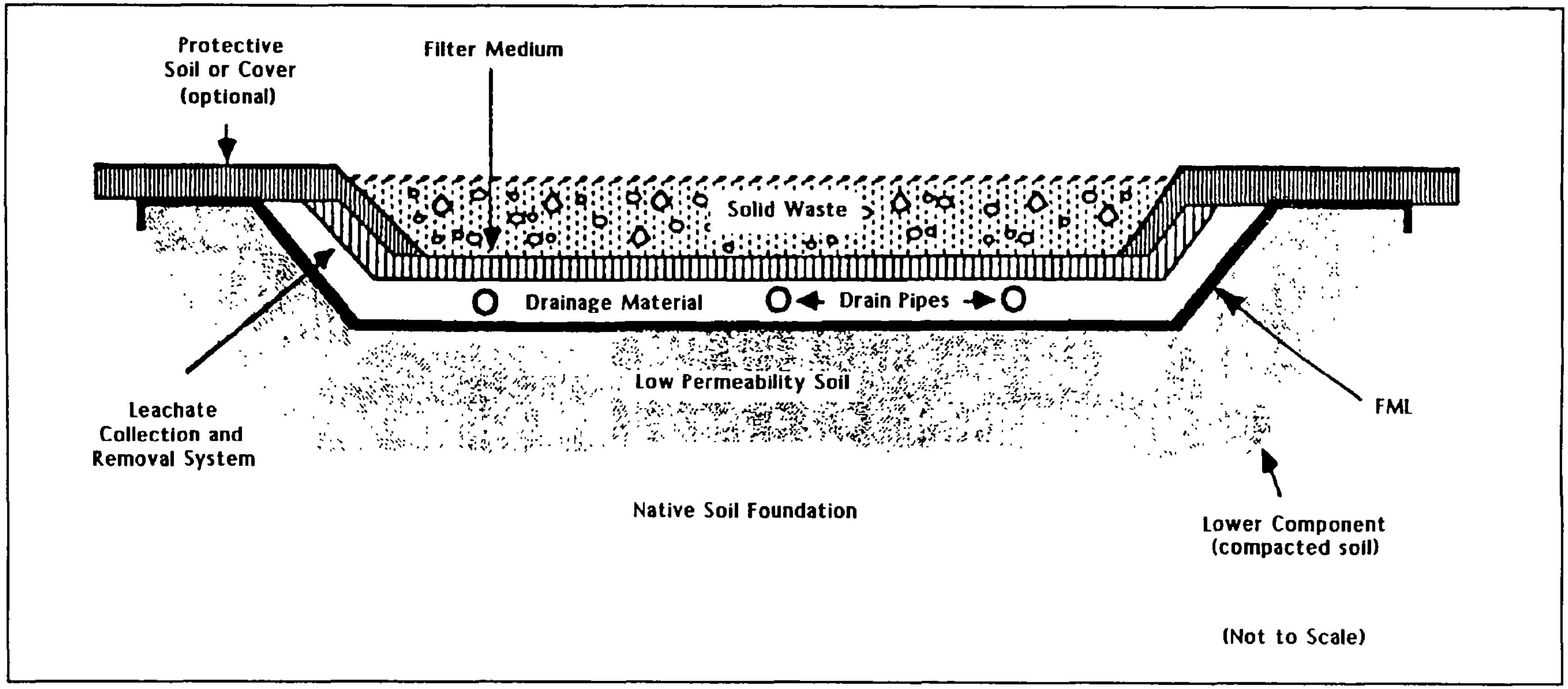
In states whose RCRA Subtitle D programs have not been approved by the EPA, MSWLFs must be designed with a (Figure 2-1):

- Composite liner consisting of an upper FML (minimum 30-mil) and a lower compacted soil layer at least 2 feet thick with a hydraulic conductivity of no more than 1×10^{-7} cm/sec;
- Leachate collection system; and
- Point of Compliance (POC) at the unit boundary.

A proposed design which differs from the Federal composite design described above may be approved if it can be demonstrated that the design protects the uppermost aquifer and the following conditions are met:

- The state determines that the design meets the Federal performance standards;
- The state petitions EPA to review its determination; and

Composite Liner and Leachate Collection System Design



(Source: EPA, 1988)

Figure 2-1
2-6A

- EPA approves the state determination or does not disapprove it in 30 days.

2.2.2 Design in Approved States

In States whose RCRA Subtitle D programs have been approved by the EPA, MSWLFs must be designed to meet the following criteria:

- Design approved by director of the approved state must ensure that the MCLs of chemicals listed in Figure 2-2 will not be exceeded in the uppermost aquifer at the POC; and

- The POC must not be more than 150 meters from unit boundary and must be on property of owner/operator.

When approving a design, the state will consider the following factors:

- Hydrogeologic characteristics of the facility and surrounding land;

- Climatic factors of the area; and

- Volume and physical and chemical characteristics of the leachate.

2.3 COMPOSITE LINER DESIGN

Composite liners are specifically described in Part 258.40.

2.3.1 Components of a Composite Liner

A composite liner consists of the following two components:

- Compacted soil layer at least 2 feet thick with a maximum hydraulic conductivity (permeability) of 1×10^{-7} cm/sec; and

Maximum Groundwater Concentrations at POC

Chemical	MCL (mg/l)
Arsenic	0.05
Barium	1
Benzene	0.005
Cadmium	0.01
Carbon tetrachloride	0.005
Chromium (hexavalent)	0.05
2,4-Dichlorophenoxy acetic acid	0.1
1,4-Dichlorobenzene	0.075
1,2-Dichloroethane	0.005
1,1-Dichloroethylene	0.007
Endrin	0.0002
Fluoride	4
Lindane	0.004
Lead	0.05
Mercury	0.002
Methoxyclor	0.1
Nitrate	10
Selenium	0.01
Silver	0.05
Toxaphene	0.005
1,1,1-Trichloromethane	0.2
Trichloroethylene	0.005
2,4,5-Trichlorophenoxy acetic acid	0.01
Vinyl chloride	0.002

Figure 2-2
2-4

- FML with minimum 30-mil thickness, or 60-mil thickness if composed of High Density Polyethylene (HDPE).

2.3.2 Advantages of a Composite Liner

A composite liner system should outperform either FMLs or clay liners alone. With a clay liner, the rate at which leachate will percolate through the liner is dependent upon:

- Hydraulic conductivity of the liner
- Head of the leachate on top of the liner
- Total area of the liner

With the addition of a FML in direct contact with the upper surface of the clay, leakage through the composite liner system is limited by

- Number of breaks or openings in the FML
- Sizes of breaks or openings in the FML

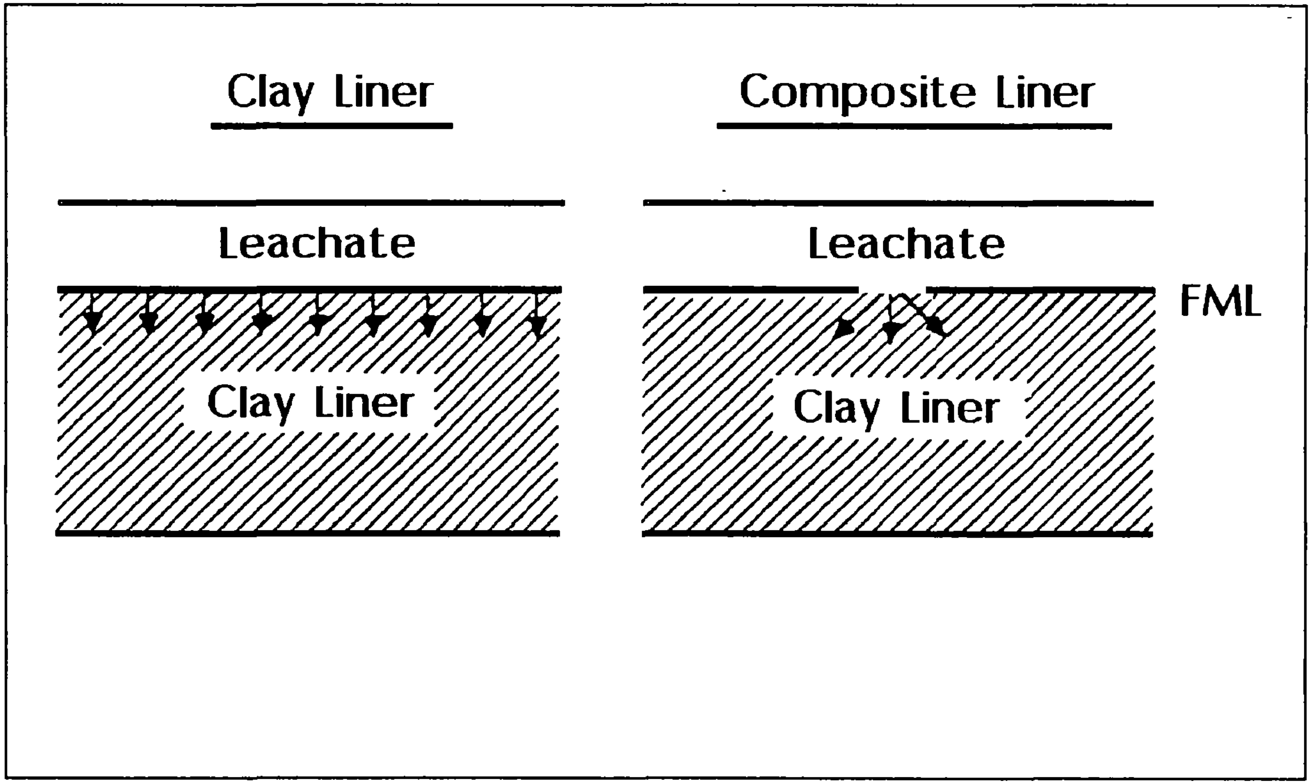
In addition, any leachate moving down through a hole or defect in the FML does not spread out between the FML and the clay liner (Figure 2-3).

2.4 COMPACTED SOIL LINER

2.4.1 Construction Material

Clay is the most important component of soil liners because the clay fraction of the soil ensures low hydraulic conductivity. EPA requires that soil liners be built so that the hydraulic conductivity is no greater than 1 x 10^{-7} cm/sec. To meet this requirement, the following characteristics of soil materials should be met:

Leachate Infiltration
Clay vs. Composite Liner



(Source: EPA, 1989)

Figure 2-3

- The soil should comprise at least 20 percent fines (fine silt- and clay-size particles which will pass through a No. 200 sieve).

- Plasticity index (PI) should be greater than 10 percent. Soils with a high PI of 30 to 40 percent are sticky and difficult to work in the field.

- Coarse fragments should be screened to no more than about 10 percent gravel-size particles. Soils with a greater percentage of coarse fragments can contain zones of gravel that have high hydraulic conductivities. Gravel is material retained on the No. 4 sieve.

- The soil should contain no soil particles or chunks of rock larger than 1 to 2 inches in diameter. If a rock diameter becomes a significant percentage of the thickness of a layer of soil, rocks may form a permeable "window" through a layer.

2.4.2 Construction Objectives

Although there are numerous factors that can contribute to soil liner failure, there are a few critical factors involved in the design and construction of a soil liner that have an effect on the liner performance. The most important variables in the construction of soil liners are the following compaction variables:

- Soil water content

- Type of compaction

- Compactive energy

- Size of soil clods
- Bonding between lifts

Of these variables, soil water content is the most critical parameter.

2.4.2.1
Soil Water Content

Figure 2-4 shows the influence of molding water content on hydraulic conductivity of the soil. Molding water content is defined as the moisture content of the soil at the time of molding or compaction.

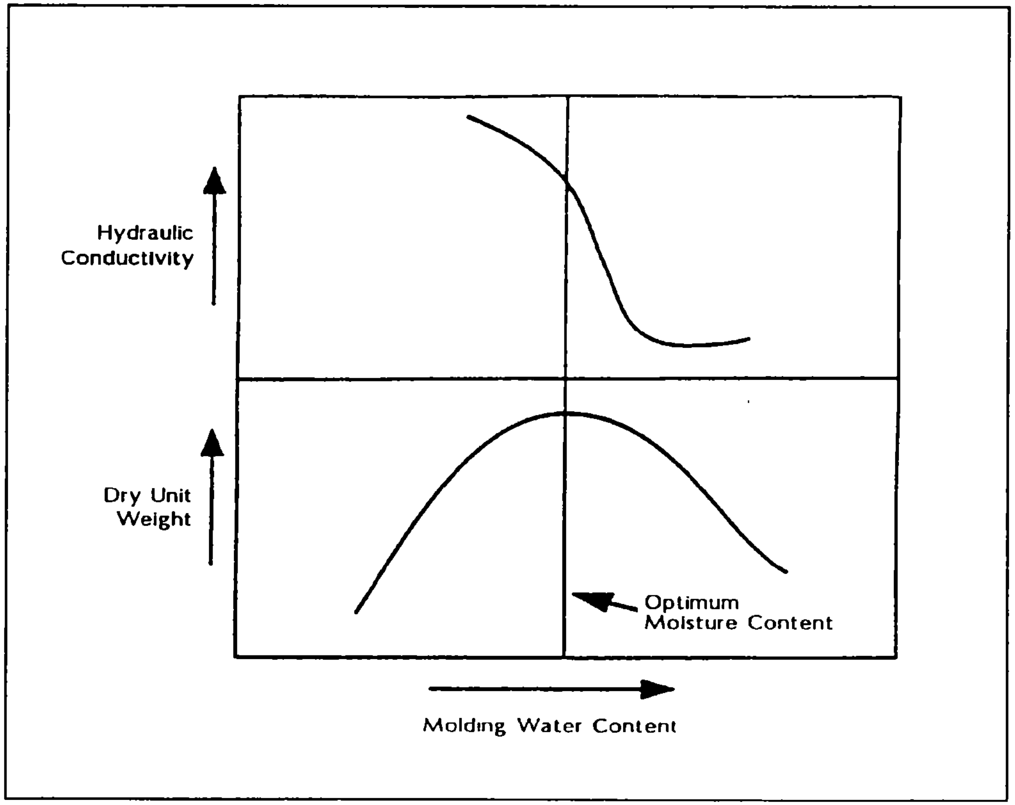
The lower half of Figure 2-4 is a compaction curve which shows the relationship between dry unit weight, or dry density of the soil, and water content of the soil. The optimum water content is the molding water content at which the maximum dry unit weight is achieved. It is preferable to compact the soil at a water content greater than optimum to achieve minimal hydraulic conductivity.

2.4.2.2
Type of Compaction

The method used in compacting the soil is an important factor in achieving low hydraulic conductivity. Static compaction is a method by which soil packed in a mold is squeezed with a piston to compress the soil. In kneading compaction, a probe or pie-shaped metal piece is pushed repeatedly into the soil. The kneading action remolds the soil and is generally more successful in breaking down clods than is the static compacting method.

The best type of field compaction equipment is a sheepsfoot roller, with rods or feet protruding from the drum and penetrating the soil, remolding it and destroying the clods. Figure 2-5A & B

Hydraulic Conductivity and Dry Unit Weight as a Function of Molding Water Content



(Source: EPA, 1989)

Figure 2-4

Compaction Equipment Guidance

<table>
<tr><th rowspan="2">Equipment type</th><th rowspan="2">Applicability</th><th rowspan="2">Compacted lift thickness, in. (cm)</th><th rowspan="2">Passes or coverages</th><th colspan="3">Dimensions and weight of equipment</th></tr>
<tr><th>Soil type</th><th>Foot contact area, in. (cm^2)</th><th>Foot contact pressures, psi (MPa)</th></tr>
<tr><td rowspan="4">Sheepsfoot rollers</td><td rowspan="4">For fine-grained soils or dirty coarse-grained soils with more than 20% passing No. 200 mesh; not suitable for clean coarse-grained soils; particularly appropriate for compaction of linings where bonding of lifts is important.</td><td rowspan="4">6
(15)</td><td rowspan="4">4-6 passes for fine-grained soil; 6-8 passes for coarse-grained soil</td><td>Fine-grained soil > PI 30</td><td>5-12
(32-77)</td><td>250-500
(17-34)</td></tr>
<tr><td>Fine-grained soil PI < 30</td><td>7-14
(45-90)</td><td>200-400
(1.4-2.8)</td></tr>
<tr><td>Coarse-grained soil</td><td>10-14
(64-90)</td><td>150-250
(1.0-1.7)</td></tr>
<tr><td colspan="3">Efficient compaction of wet soils requires less contact pressures than the same soils at lower moisture contents.</td></tr>
<tr><td rowspan="2">Rubber tire rollers</td><td>For clean, coarse-grained soils with 4-8% passing No. 200 mesh.</td><td>10
(25)</td><td>3-5</td><td rowspan="2" colspan="3">Tire inflation pressures of 60 to 80 psi (0.41-0.55 MPa) for clean granular material or base course and subgrade compaction; wheel load 18,000-25,000 lb (80-110 kN); tire inflation pressure in excess of 65 psi (0.45 MPa) for fine-grained soils of high plasticity; for uniform clean sands or silty fine sands, use large size tires with pressure of 40 to 50 psi (0.28-0.34) MPa.</td></tr>
<tr><td>For fine-grained soils or well graded, dirty coarse-grained soils with more than 8% passing No. 200 mesh.</td><td>6-8
(15-20)</td><td>4-6</td></tr>
</table>

Figure 2-5a
2-13a

Compaction Equipment Guidance (cont'd)

Equipment type	Applicability	Compacted lift thickness, in. (cm)	Passes or coverages	Dimensions and weight of equipment
Smooth wheel rollers	Appropriate for subgrade or base course compaction of well-graded sand-gravel mixture.	8-12 (20-30)	4	Tandem type rollers for base course or subgrade compaction, 10-15 ton weight (89-133 kN), 300-500 lb per lineal in. (3.4-5.6 kN lineal cm) of width of real roller.
	May be used for fine-grained soils other than in earth dams; not suitable for clean well-graded sands or silty uniform sands.	6-8 (15-20)	6	3-wheel roller for compaction of fine-grained soil; weights from 5-6 tons (40-53 kN) for materials of low plasticity to 10 tons (89 kN) for materials with high plasticity.
Vibrating baseplate compactors	For coarse-grained soils with less than about 12% passing No. 200 mesh; best suited for materials with 4-8% passing No. 200 mesh, placed thoroughly wet.	8-10 (20-25)	3	Single pads or plates should weigh no less than 20 lb (0.89 kN); may be used in tandem where working space is available; for clean coarse-grained soil, vibration frequency should be no less than 1,600 cycles per minute.

Figure 2-5b
2-13b

lists different types of compaction equipment and their uses.

2.4.2.3
Compactive Energy

Increasing the compactive energy results in

- Increase in maximum density of the soil
- Decrease in the optimum moisture content
- Lower hydraulic conductivity

The lower half of Figure 2-6 shows that with an increase in compactive energy, the maximum density of the soil increases, while the optimum moisture content decreases. The top half of Figure 2-15 shows that an increase in compactive energy also results in a lower hydraulic conductivity.

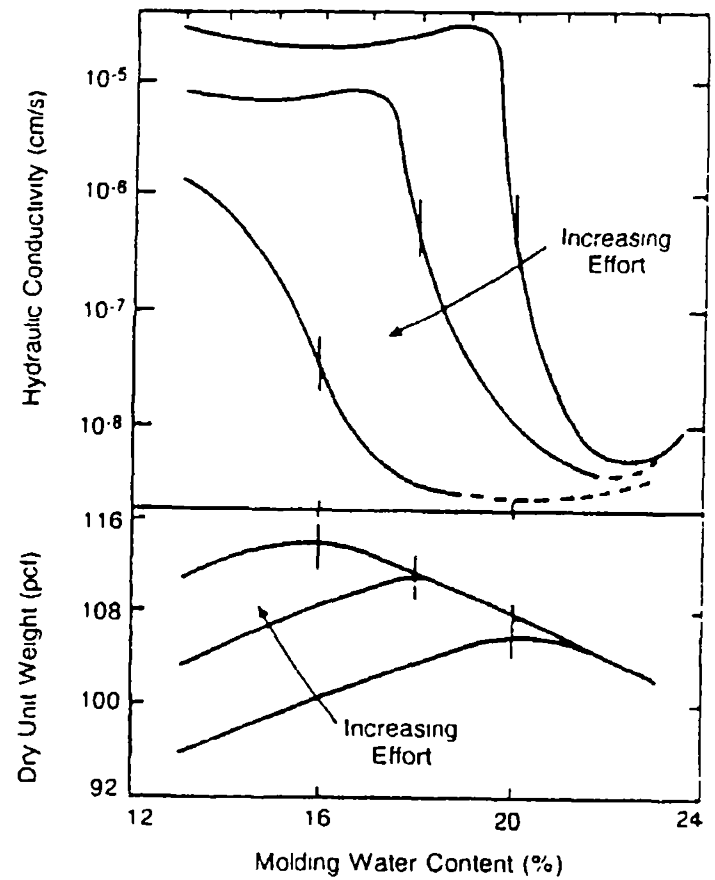
Typically, the design will specify the following compaction criteria for the clay liner:

- Dry unit weight to be 95 percent of the maximum dry unit weight
- Acceptable range of water content to be 0 percent to 4 percent wet of optimum moisture content

The compactive energy delivered to soil depends on:

- Weight of the roller
- Number of passes of the roller over a given area
- Lift thickness

Effects of Compactive Effort on Maximum Density and Hydraulic Conductivity



(Source: EPA, 1989)

Figure 2-6

2.4.2.3.1
Weight of the Roller

The heaviest rollers weigh between 50,000 and 70,000 pounds. Rollers that weigh up to 70,000 pounds may be desirable for compacting bottom liners of landfills. However, heavy rollers cannot be used if the soil is very wet or if the foundation is wet and compressible. Rollers with static weights ranging between 30,000 and 40,000 pounds are recommended for compacting low-hydraulic conductivity layers in cover systems.

2.4.2.3.2
Number of Passes

The compaction equipment must pass over the soil liner a sufficient number of times to maximize the compaction. Typically, 5 to 20 passes are required over a given lift of soil to ensure adequate compaction.

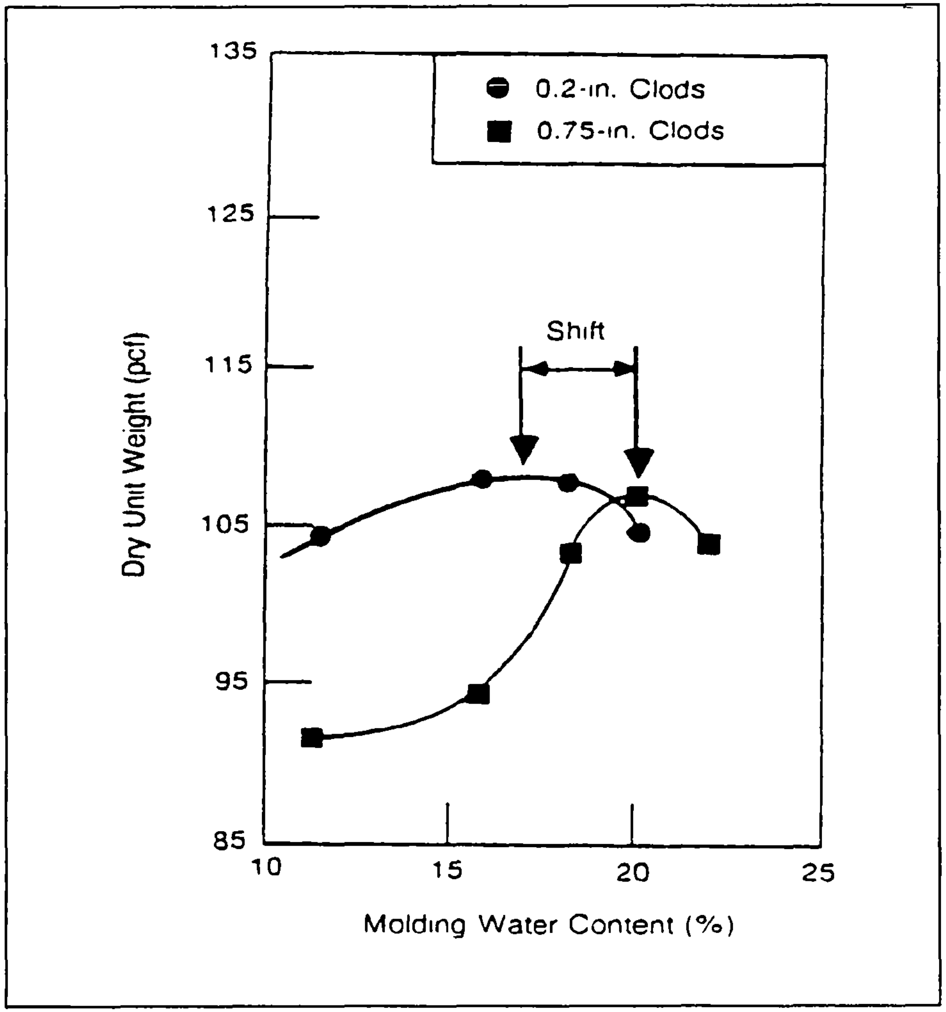
2.4.2.3.3
Lift thickness

Soil liners should be constructed in a series of compacted lifts. Determination of appropriate lift thickness is dependent on the soil characteristics, compaction equipment, firmness of the foundation materials and the anticipated compactive effort needed to achieve the required soil hydraulic conductivity. Soil liner lifts should be thin enough to allow adequate compactive effort to reach the lower portions of the lift. Thinner lifts also provide greater assurance that sufficient compaction can be achieved to provide good, homogeneous bonding between subsequent lifts. Adequate compaction of lift thickness between 5 and 10 inches is possible if appropriate equipment is used. The lift thickness of a clay liner is typically 9 inches before compaction and 6 inches after compaction.

2.4.2.4
Size of Soil Clods

The term "clod" refers to chunks of cohesive soil. For soils compacted at water content less than optimum, the soil with smaller clods has a hydraulic conductivity much lower than soil with larger clods (Figure 2-7). For soils compacted at water content higher than optimum, the size of

Effects of Soil Clod Size on Hydraulic Conductivity



(Source: EPA, 1989)

Figure 2-7
2-18

clods has a negligible effect. However, to reduce the size of clods in dry materials, a road reclaimer should be used. This device pulverizes materials with teeth that rotate on a drum at a high speed. The maximum size of clods may be specified in the construction specifications.

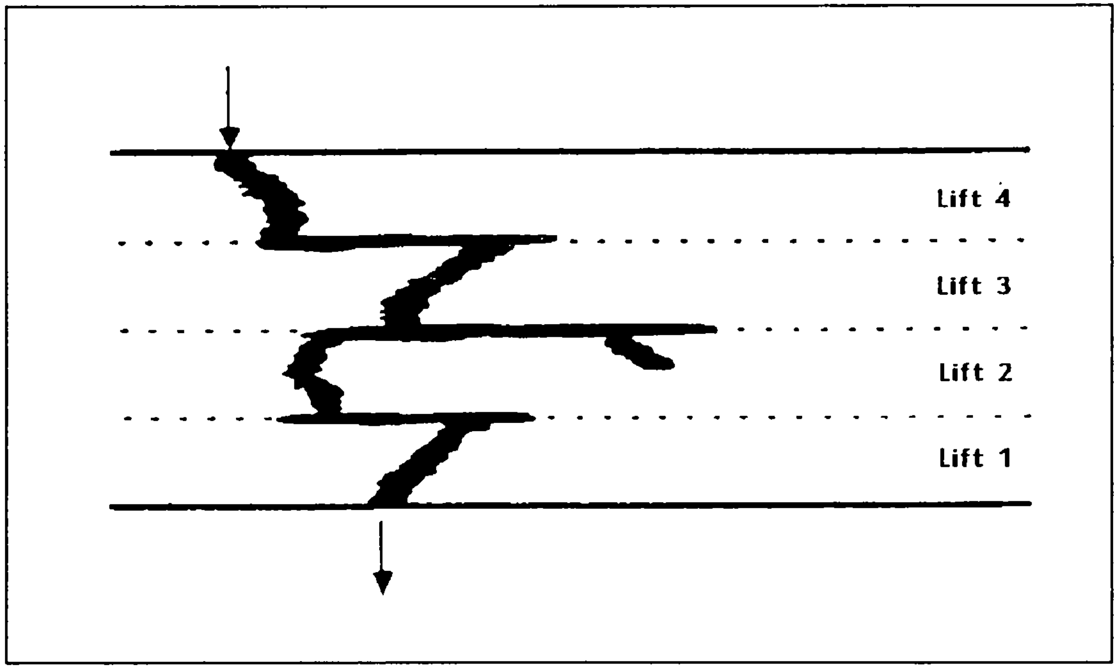
2.4.2.5
Bonding Between Lifts

The bonding between lifts is very important to the integrity of the clay liner. If the lifts are not properly bonded, hydraulic pathways can develop (Figure 2-8). Since clay normally will develop small vertical cracks, the lifts must be bonded so that the cracks in each lift will not be connected. The following guidelines will help promote good lift bonding:

- The lift height should not be greater than the length of the sheepsfoot on the compactor (Figure 2-9);
- The compactor should have a minimum weight of 40,000 pounds and a minimum sheepsfoot length of 8 inches;
- The recommended minimum number of passes the compactor should make is five; and
- The previous lift should be scarified prior to placing the next lift to provide bonding.

The most difficult area to achieve uniform compaction is on side slopes, especially at the interface between the side slope and the flat area. Clay can be placed either parallel or horizontally on the side slope (Figure 2-10). For steep slopes (2.5V:1H), the horizontal method should be used. This is done by starting at the toe of the slope and working up the slope.

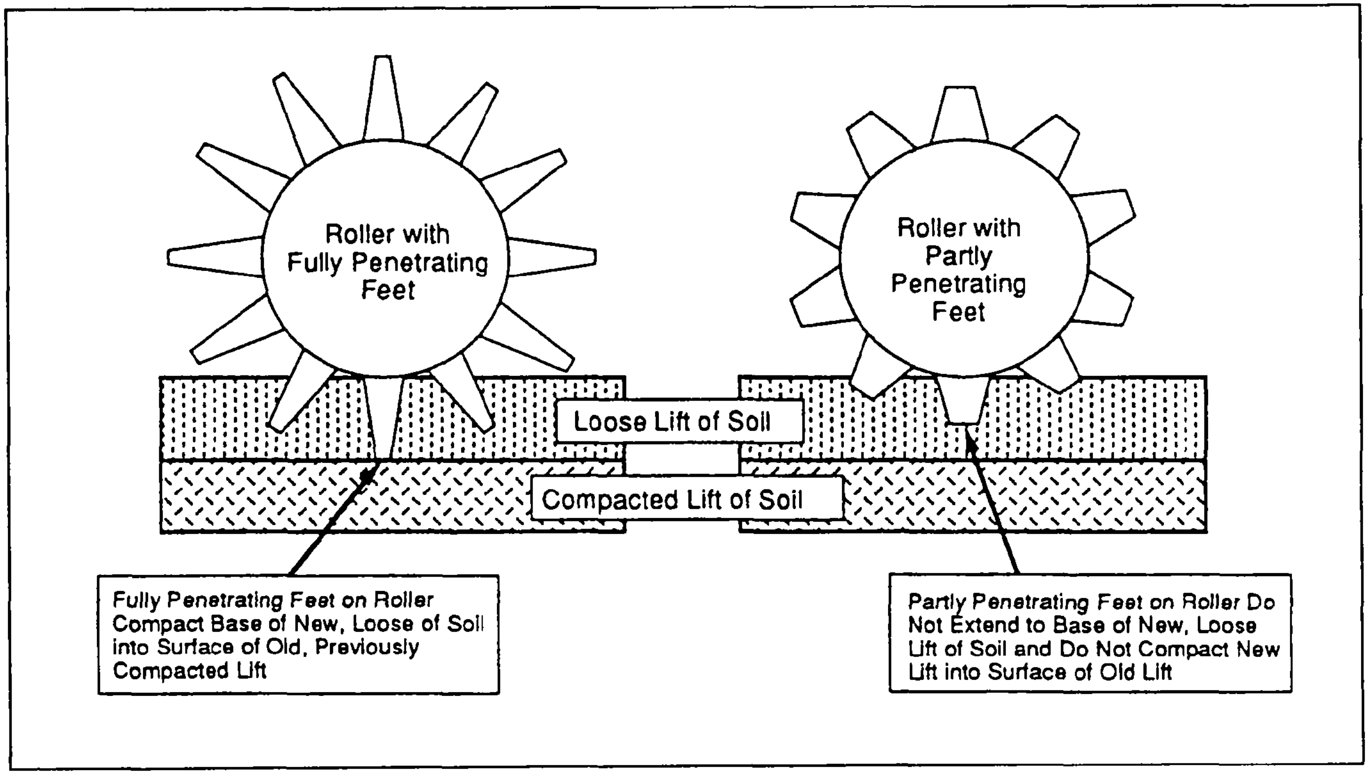
Conductivity Between Lifts



(Source: EPA, 1989)

Figure 2-8

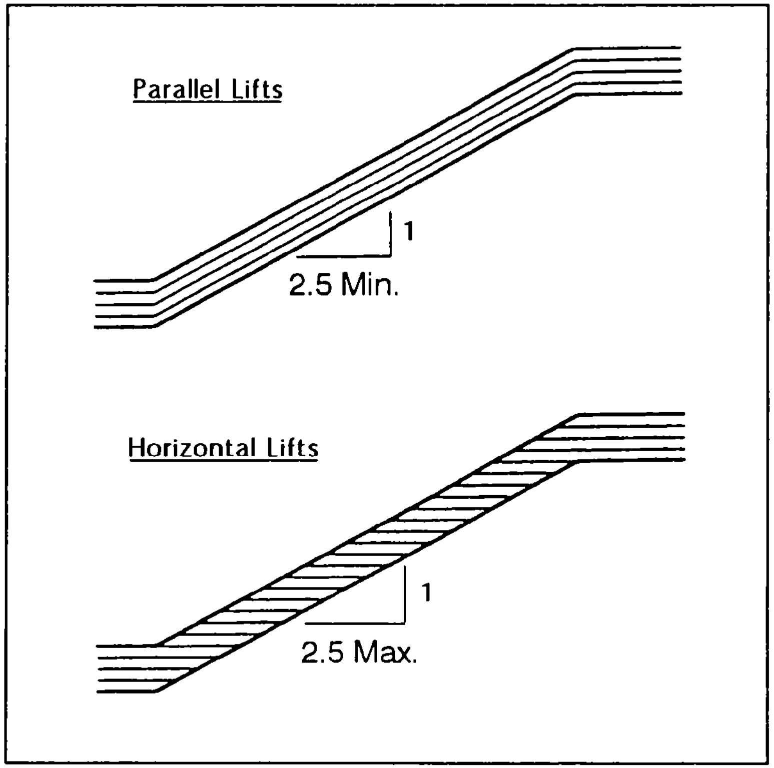
Footed Rollers with Partly and Fully Penetrating Feet



(Source: EPA, 1993)

Figure 2-9

Liner Construction on Side Slopes with Horizontal and Parallel Lifts



(Source: EPA, 1989)

Figure 2-10
2-22

2.5 FLEXIBLE MEMBRANE LINERS

2.5.1 Types and Thicknesses

FMLs are made of one or more polymers along with a variety of other ingredients such as carbon black, pigments, fillers, plasticizers, processing aids, crosslinking chemicals, anti-degradants and biocides. The polymeric materials most often used as FMLs are:

- High-density polyethylene
- Polyvinyl chloride (PVC)
- Chlorosulfonated polyethylene (CSPE)

FMLs are manufactured in thicknesses ranging from 20 to 120 mil. The minimum thickness required by the Subtitle D Regulations for FMLs is 30 mil, with the exception of HDPE, which must be at least 60 mil to allow for proper seam welding. Some advantages and disadvantages of the basic polymeric FMLs are listed in Figure 2-11 A-D.

2.5.2 Performance Criteria

There are four performance issues which determine the effectiveness of the FML. Those are

- Permeability
- Chemical Compatibility
- Mechanical Compatibility
- Durability

Some Advantages and Disadvantages of the Basic Polymers of Geomembranes

ADVANTAGES	DISADVANTAGES
Polyvinyl Chloride (PVC) Thermoplastic	
Low cost	Plasticized for flexibility
Tough without reinforcement	Poor weathering, backfill required
Lightweight as single ply	Plasticizer leaches over time
Good seams -- dielectric, solvent and heat	Poor cold crack
Large variation	Poor high -- temperature performance
	Blocking possible
Chlorinated Polyethylene (CPE) Thermoplastic	
Good weathering	Moderate cost
Easy seams -- dielectric and solvent	Plasticized with PVC
Cold crack resistance is good	Seam reliability
Chemical resistance is good	Delamination is possible
Elasticized Polyolefin (3110), Thermoplastic EPDM -- Cured Rubbers	
Good weathering	Unsupported
Lightweight as single ply	Poor high temperature performance
Cold crack resistance is good	Special seaming equipment required
Chemical resistance is good	Field repairs are difficult

Figure 2-11 a
2-25 a

Some Advantages and Disadvantages of the Basic Polymers of Geomembranes (cont'd)

ADVANTAGES	DISADVANTAGES
EPDM (4060) Thermoplastic Rubber	
Good weathering	Moderate cost
Cold crack resistance below 60 °F	Fair in high temperatures
Good seams -- heat-bonded	Blocking possible
No adhesives required	Fair chemical resistance
Butyl, Butyl/DPDM, EPDM -- Cured Rubbers	
Fair to good weathering	Moderate to high cost
Low permeability to gases	Poor field seams
High temperature resistance is good	Small panels
Nonblocking	Fair chemical resistance
Chloroprene (Neoprene) Cured Rubber	
Good weathering	High cost
Good high temperature	Fair field seams -- solvent and tape
Good chemical resistance	Fair seams to foreign surfaces

Figure 2-11 b
2-25 b

Some Advantages and Disadvantages of the Basic Polymers of Geomembranes (cont'd)

ADVANTAGES	DISADVANTAGES
High-Density Polyethylene (HDPE) Semicrystalline Thermoplastic	
Chemical resistance is good	Low-friction surfaces
Good seams -- thermal and extrusion	Stress crack sensitive
Large variations in thickness	Seam workmanship critical
Low cost	High thermal expansion/contraction
Medium-, Low-, Very-Low-Density Polyethylene (MPDE, LDPE, VLDPE) Semicrystalline Thermoplastic	
Chemical resistance is good	Moderate thermal expansion/contraction
Good seams -- thermal and extrusion	LDPE and VLDPE rarely used
Large variation in thickness	MDPE often mistaken for HDPE
Low cost	
No stress crack	

Figure 2-11 c
2-25 c

Some Advantages and Disadvantages of the Basic Polymers of Geomembranes (cont'd)

ADVANTAGES	DISADVANTAGES
Linear-Low-Density Polyethylene (LLDPE) Semicrystalline Thermoplastic	
Chemical resistance is very good	Moderate cost
Good seams -- thermal and extrusion	LLDPE newly introduced
Large variation in thickness	
High-friction surface	
No stress crack	

Figure 2-11 d
2-25 d

2.5.2.1
Permeability

The primary function of a liner system in a waste management unit is to minimize and control the flow of waste from the unit to the environment, particularly to groundwater. A properly designed FML has a low permeability to the waste contained within the liner, allowing it to perform its primary function. However, the permeability of an FML made of a particular polymer may change upon exposure to waste or leachate, depending on the composition of the waste contained by the FML. This property is the chemical resistance, or compatibility, of a particular polymer to specific chemicals.

Since plastics and rubbers exhibit various degrees of compatibility with different chemicals, a number of materials are used to manufacture FML sheeting. The material is selected based on exposure during its intended use. An FML that is compatible with a specific waste displays a low permeability toward that waste and will minimize its flow through the FML to the environment. Additional factors affecting the rate of transmission through the FML are thickness of the FML sheeting and concentration of the chemical species.

2.5.2.2
Chemical Compatibility

Chemical compatibility of FMLs and waste liquids or leachates is a critical factor in the service life of liner systems. Chemical compatibility requires that the mechanical properties of the FML remain essentially unchanged after the FML is exposed to the waste. If the seams between the sheets are made with materials other than the sheet parent products, they also must be compatible with the waste. Chemical incompatibility is due primarily to:

- Absorption of waste constituents by the FML;

- Extraction of components of the FML compound by wastes or leachates; or

- Reactions between FML constituents and wastes or leachates.

Incompatibility may result in a failure of the FML material or of the liner seams and consequent leakage of waste or leachate to the groundwater. Due to the serious consequences resulting from incompatibility, an evaluation is required prior to permitting to determine the effects that waste will have on the FML proposed for installation at a facility.

Evaluation of data obtained from compatibility testing is best performed by specialists knowledgeable in the following:

- FMLs

- FML Testing

- EPA Method 9090

EPA Method 9090 is used to assess the compatibility of a candidate FML with the specific waste liquid or leachate to be contained. Test procedure includes:

- Selection of representative samples of the waste liquid or leachate and the FML

- Preparation of the exposure cells for operation during the 120-day exposure period

- Exposure of the FML samples to the waste liquid or leachate in the simulated service environment

- Analysis of test data for trends during the 120-day exposure period

EPA has developed a computer advisory system, the Flexible Liner Evaluation Expert (FLEX), that serves as a tool to assist in interpretation of data from Method 9090 tests (Figure 2-12). This model, however, is not a substitute for review of Method 9090 test results by a trained professional.

2.5.2.3 *Mechanical Compatibility*

An FML must be mechanically compatible with the designed use of the lined facility in order to maintain its integrity during and after exposure to short- and long-term mechanical stresses. Short-term mechanical stresses can be caused by:

- Equipment traffic during liner system installation:
- Placement of materials on top of liner
- Thermal expansion and shrinkage of the FML during operation of the unit

Long-term mechanical stresses can be caused by:

- Placement of waste on top of the liner system
- Waste settlement
- Differential settlement of the subgrade

Mechanical compatibility requires adequate friction between the components of a liner system, particularly the soil subgrade and the FML, to ensure that slippage or sloughing does not occur on the slopes

Flexible Liner Evaluation Expert (FLEX)

- Computer program designed to assist reviewer in analyzing EPA Method 9090 data

- Not a substitute for review of Method 9090 test results by a trained professional

Figure 2-12

of the unit. Specifically, the foundation slopes and the subgrade materials must be considered in design equations in order to evaluate:

- The ability of an FML to support its own weight on the side slopes
- The ability of the liner system to withstand downdragging during and after filling
- The best anchorage configuration for the the liner system
- The stability of a soil cover on top of an FML

Mechanical compatibility requirements may affect the choice of FML material, including:

- Polymer type
- Fabric reinforcement
- Thickness

2.5.2.4
Durability

An FML must exhibit durability; that is, it must be able to maintain its integrity and performance characteristics over the operational life and the post-closure care period of the unit. The service life of an FML is dependent on the intrinsic durability of the FML material and on the conditions to which it is exposed. Exposure conditions can vary greatly within a given facility and an FML must resist the combined effects of several stresses, including:

- Chemical stresses
- Physical stresses
- Biological stresses

2.5.3 Engineering Properties

Numerous engineering properties must be considered when selecting an FML, including

- Interface frictional properties
- Allowable tensile strength and strain
- Puncture resistance

2.5.3.1 *Interface Frictional Properties*

Since FML surfaces are smooth and relatively slippery, the short- and long-term stability of the materials placed above and below the liners, and the entire liner system, has to be addressed. The key design parameter is the interface friction angle between the FML and the materials placed above and below the liner. During the final design stage of landfill projects, it is recommended that an interface friction test (American Society for Testing and Materials [ASTM] D-5321) be performed to determine the actual interface friction angle between the proposed FML and the soil materials in contact with the liner. Typical interface friction angles between various FMLs and soils are presented in Figure 2-13.

2.5.3.2 *Allowable Tensile Strength and Strain*

If the FML will be subjected to stretching or tensile stress, the designer has to determine the allowable strength and strain for the liners so that the FML will not elongate, causing permanent damage to the liner system. Allowable tensile strengths will depend on the type of materials used in the liner. Typical mechanical properties are listed in Figure 2-14.

Typical Range of Interface Friction Angles*

INTERFACES	FRICTION ANGLE
Geosynthetic/Soil	
Stiff Geogrid/Sand	20° to 34°
HDPE FML (smooth)/Sand	18° to 26°
PVC FML/Sand	20° to 28°
Nonwoven Fabric/Clay	21° to 29°
HDPE FML (smooth)/Clay	12° to 19°
PVC FML/Clay	13° to 20°
Nonwoven Fabric/Clay	14° to 22°
Geosynthetic/Geosynthetic	
Nonwoven Fabric/HDPE FML (smooth)	9° to 16°
Nonwoven Fabric/PVC FML	12° to 18°
Nonwoven Fabric/Drainage Net	10° to 16°
HDPE FML (smooth)/Drainage Net	8° to 15°

*NOTE: The value of interface friction angles are product-dependent. Testing is recommended based on product specifics and final intended use of the various geosynthetic products.

Figure 2-13
2-39

Typical Mechanical Properties

	HDPE	CPE	PVC
Density, gm/cm^3	> .935	1.3 - 1.37	1.24 - 1.3
Thermal coefficient of expansion	12.5×10^{-5}	4×10^{-5}	3×10^{-5}
Tensile strength, psi	4800	1800	2200
Puncture, lb/mil	2.8	1.2	2.2

Figure 2-14
2-40

2.5.3.3
Puncture Resistance

Puncture resistance is especially important during liner installation since construction equipment spreads soil materials above the FML. The following recommendations can help prevent puncturing the FML:

- Use low ground-pressure, track-type equipment in the placement of materials immediately above the liner;
- Limit maximum particle size in contact with the liner surface to three-eighths of an inch; and:
- Place minimum of 2 to 3 feet of soils on top of the liner before any equipment is operated above the liner.

2.5.4
Structural Details

Several avenues exist for potential structural failure of FMLs, including:

- Anchor trenches
- Access ramps
- Collection standpipes

2.5.4.1
Anchor Trenches

An anchor trench along the perimeter of the landfill generally is used to secure the FML during construction (to prevent sloughing or slipping down the interior side slopes). However, if anchor trenches are not properly designed, they can cause FMLs to fail in one of two ways: by ripping out or by pulling out.

Run-out calculations are available to determine the depth of burial at a trench necessary to hold a specified length of FML, or combination of FML and geofabric or geotextile (Section 2.6.2.4).

Various anchorage configurations are shown in Figure 2-15. In the "V" anchor configuration, resistance can be increased by increasing the "V" angle, however this design uses more space than other configurations. The concrete trench is not presently used.

2.5.4.2
Access Ramps

Most facilities have access ramps (illustrated in Figure 2-16) which are used by trucks during construction and by trucks bringing waste into the facility. The integrity of the FML must be maintained over the entire surface of the ramp. Ramps can fail due to traffic-induced sliding, roadway considerations and drainage; therefore, these three factors must be considered during the design and construction of access ramps.

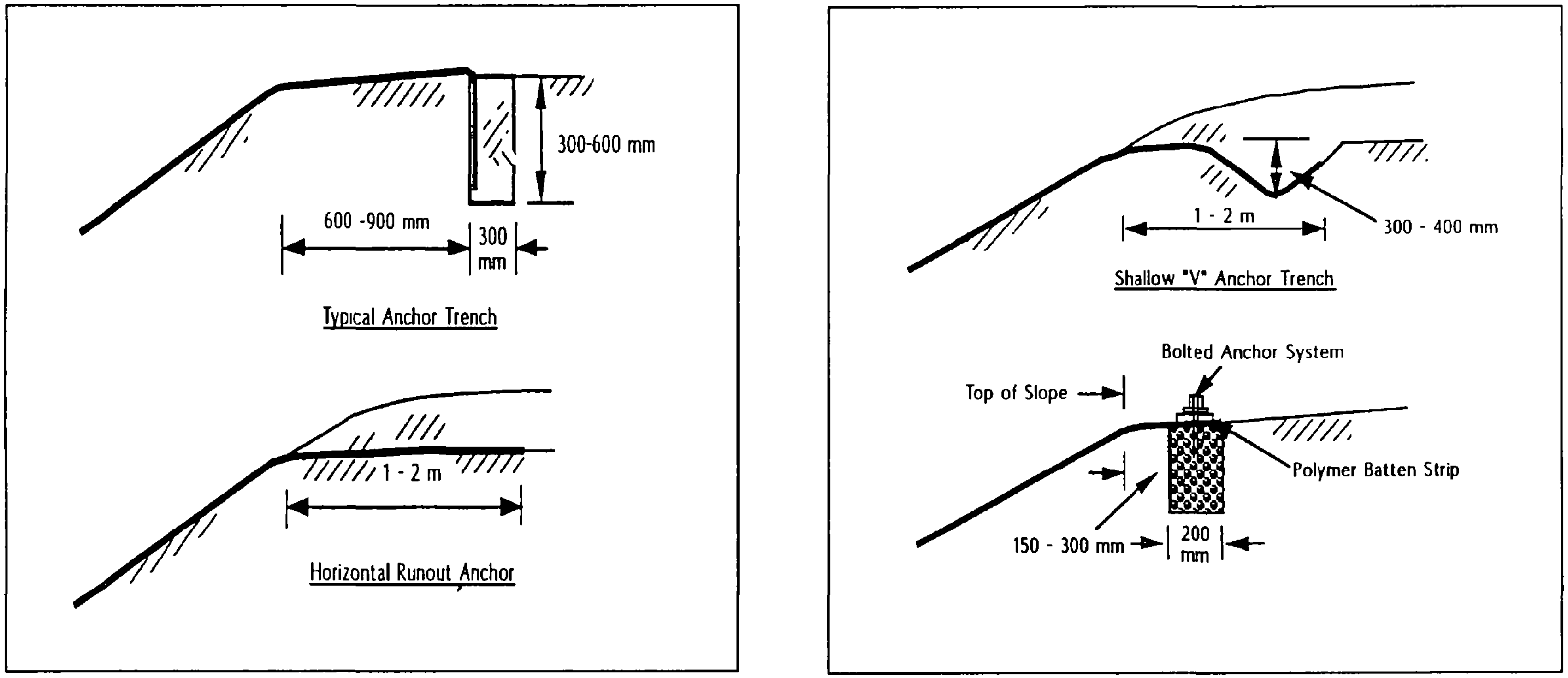
The weight of the roadway, the weight of a vehicle on the roadway and the vehicle braking force all must be considered when evaluating the potential for slippage due to traffic. The vehicle braking force should be much greater than the dead weight of the vehicles that will use it. Wheelloads also have an impact on the liner system and leachate collection system below the roadway. Trucks with maximum axle loads of 90 pounds per square inch (psi) should be allowed to use the ramps.

2.5.4.3
Collection Standpipes

Collection standpipes are used to access the leachate collection sumps (Figure 2-17). As waste settles over time, downdrag forces can have an impact on standpipes, including puncture of the FML beneath the standpipe. To reduce the amount of downdrag force from the waste, standpipes can be coated with viscous or low-friction coating, or encapsulated with multiple layers of HDPE.

Various Types of Geomembrane Anchors Trenches

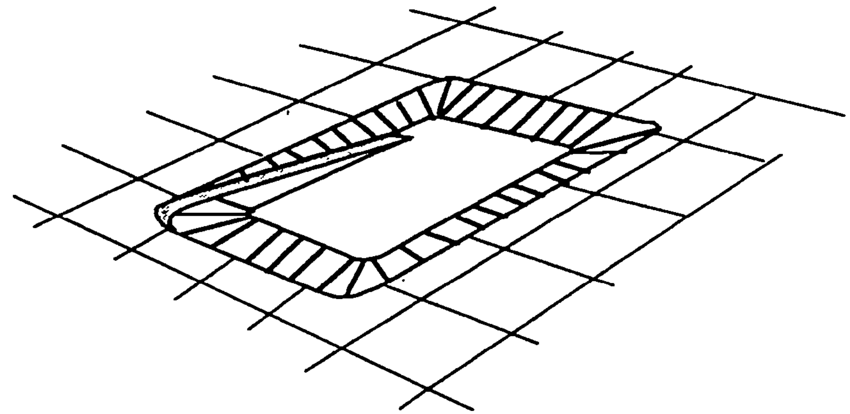
(Dimensions are Typical and for Example Only)



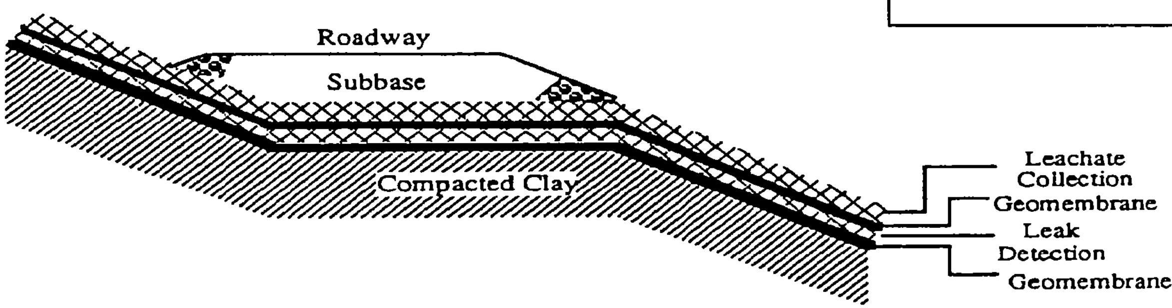
(Source: EPA, 1993)

Figure 2-15

Typical Access Ramp Geometry and Cross Section



(a) Geometry of a Typical Ramp

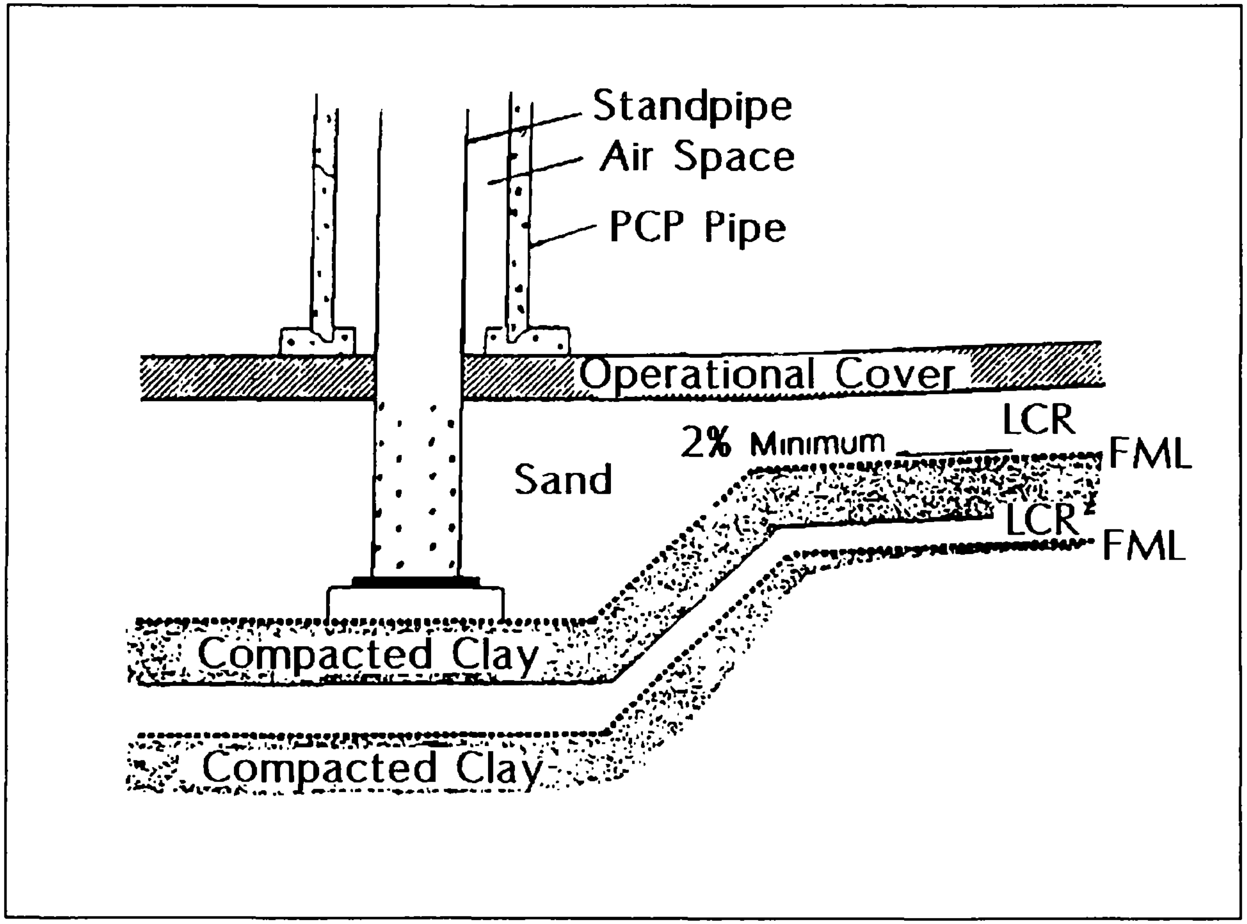


(b) Cross Section of Ramp Roadway

(Source: EPA, 1993)

Figure 2-17

Leachate Removal System with a High-Volume Sump



(Source: EPA, 1989)

Figure 2-18

2.5.5
Mechanisms of Degradation

Several mechanisms exist which can contribute to the degradation of FMLs, including:

- Ultraviolet degradation
- Chemical degradation
- Extraction degradation
- Oxidation degradation
- Biological degradation

2.5.5.1
Ultraviolet Degradation

By virtue of its short wavelength components, sunlight can enter into a polymer system and cause chain scission and bond breaking. Two approaches are taken to minimize the effects of ultraviolet degradation:

- Adding carbon black to the formulation
- Adding chemical stabilizers as scavenging agents

2.5.5.2
Chemical Degradation

Various chemicals can be aggressive to certain types of FMLs. For this reason, EPA has developed EPA Method 9090 for testing and assessing chemical resistance.

2.5.5.3
Extraction Degradation

If one or more of the components of an FML formulation are extracted, the remaining material may be compromised. The extraction of FML components occurs when plasticizers leach out of the FML, leaving a tacky substance on the surface of the material. This phenomenon may decrease the elongation capability of the FML with respect to tension, tear, and puncture modes of failure. The tests available to estimate extraction are the:

- ASTM D3083 for water extraction
- ASTM D1203 for volatile loss

2.5.5.4
Oxidation Degradation

Oxidation of polymers caused by the gases or liquids interfacing with the FML is unavoidable. Oxygen, over time, will enter into the polymer structure and can react with various components in the particular formulation.

To minimize the oxidation reaction, the polymeric formulation contains various antioxidants which neutralize free radicals. The amount of oxidation that can be neutralized, however, is limited, and once this capacity is reached, the oxidation process will proceed depending on site-specific and FML-specific conditions.

2.5.5.5
Biological Degradation

Microorganisms may interact with the plasticizers and/or fillers used in certain FMLs. Two ASTM tests have been developed to detect this type of degradation:

- G21 deals with resistance of plastics to fungi; and:
- G22 is the complementary test for bacterial resistance.

Because animals could easily burrow through an FML, its ability to withstand such forces must be a factor in landfill design and material selection.

2.5.6
Stress-Induced Mechanisms

Several stress mechanisms which can affect polymers include:

- Creep
- Stress cracking
- Freeze-thaw
- Abrasion

2.5.6.1
Creep

Creep refers to the deformation of the FML over a prolonged period of time under constant stress. It can occur at:

- side slopes
- anchor trenches
- sumps
- protrusions
- settlement locations
- folds and creases

If a liner is allowed to creep indefinitely, the FML and the materials placed above it will be damaged. According to the results of research on creep, a minimum safety factor of 3 should be maintained (i.e., ultimate breaking strength should be at least 3 times the allowable tensile strength).

2.5.6.2
Environmental Stress Cracking

Environmental stress cracking refers to the cracks developed on polyethylene (PE) liners (including HDPE) when they are subjected to both chemical (leachate) attacks and tensile stress. Environmental stress cracking can be tested for by submerging a strip of the PE liner in a representative leachate solution at 122 ^{0}F and applying a tensile load to the strip sample. Crack development is observed and documented. Most commercially available PE liners have performed well in the test; however, field observations indicate that exposed PE liners have a higher possibility of developing environmental stress cracks.

2.5.6.3
Freeze-Thaw Cycle

Freeze-thaw cycling, or the process by which a material undergoes alternating rapid extremes of temperature, has proven to have an insignificant effect on polymer strength or FML seam strength. Polymeric materials experience some stress due to warming, thereby slightly decreasing their strength; however, within the range of 0^0 to 160 ^{0}F, there is no loss of integrity. In addition, freeze-thaw is not likely to be a problem if the material is buried sufficiently deep.

2.5.6.4
Abrasion

Abrasion could potentially induce stress to the FML. However, as with freeze-thaw, abrasion should not be a problem provided that the FML is buried under enough soil.

2.6
LEACHATE COLLECTION AND REMOVAL SYSTEM (LCRS)

2.6.1
Definition and Purpose of Lcrs

Leachate refers to liquid that has passed through or emerged from solid waste and contains dissolved, suspended or immiscible materials removed from the solid waste. At MSWLF units, leachate is typically aqueous with limited, if any, immiscible fluids or dissolved solvents.

The liquids that percolate through a waste come from three sources (Figure 2-18):

Sources of Leachate Generated by a Solid Waste

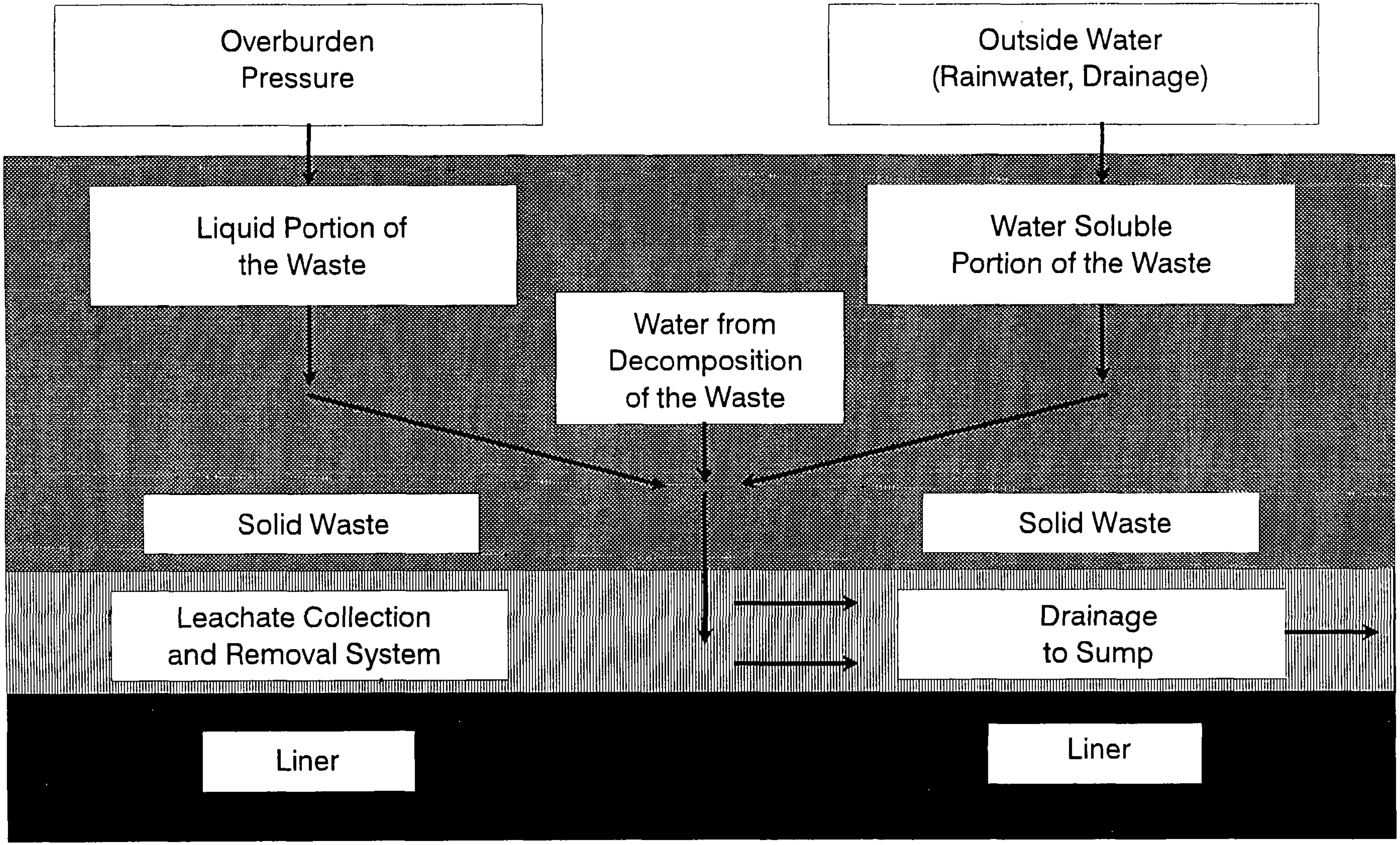


Figure 2-19
2-55

- Water from outside the containment unit (e.g. rainwater and surface drainage);
- Liquids originally in the waste; and
- Liquids generated by the decomposition of waste.

The primary function of the LCRS is to collect and convey leachate out of the landfill unit and to control the depth of the leachate above the liner. The LCRS should be designed to meet the regulatory performance standard of maintaining less than 30 cm (12 inches) depth of leachate, or "head," above the liner.

2.6.2 Typical LCRS Components

Leachate is generally collected from the landfill through sand drainage layers, synthetic drainage nets or granular drainage layers with perforated plastic collection pipes and is then removed through sumps or gravity drain carrier pipes. A typical LCRS should include the following components:

- Low-permeability base (composite liner)
- High-permeability drainage layer
- Leachate collection pipes
- Protective filter layer
- Leachate collection sumps

2.6.2.1 *Low-Permeability Base*

The typical bottom liner slope:

- Is a minimum of 2 percent after allowances for settlement at all points in each system;

- Is necessary for effective gravity drainage through the entire operating and post-closure period.

2.6.2.2
High-Permeability Drainage Layer

The high-permeability drainage layer is place directly over the liner or its protective bedding layer at a slope of at least 2 percent (the same slope necessary for the composite liner). Often the selection of a drainage material is based on the onsite availability of natural granular materials. An alternative to using natural granular materials is to use a synthetic drainage material such as a geosynthetic drainage net (geonet).

Geonets are frequently substituted for granular materials on steep sidewalls because maintaining sand on the slope during construction and operation of the landfill unit is more difficult.

2.6.2.2.1
Soil drainage layers

If the drainage layer of the LCRS is constructed of granular materials (e.g., sand or gravel), then the layer should:

- Be a minimum of 30 cm (12 inches) thick; and :

- Typically have a hydraulic conductivity of no less than 1×10^{-2} cm/sec.

In addition, it should be demonstrated that this granular drainage layer has sufficient bearing strength to support expected loads. If the landfill unit is designed on moderate-to-steep (15 percent) grades, the landfill design should include calculations demonstrating that the selected granular drainage materials will be stable on the most critical slopes (i.e., usually the steepest slope) in the design. The calculations and assumptions should be shown, especially the friction angle between the geomembrane and soil, and if possible, supported by laboratory and/or field testing.

Coarse granular materials, unlike low-permeability soils, can be placed dry and do not need to be heavily compacted. Compacting granular soils tends to grind the soil particles together, which increases the fine material and reduces hydraulic conductivity. To minimize settlement following material placement, the granular material may be compacted with a vibratory roller.

2.6.2.2.2
Geosynthetic drainage nets

Geosynthetic drainage nets (geonets) may be substituted for the granular layers of the LCRS on the bottom and sidewalls of the landfill cells. Among their advantages, geonets require less space than perforated pipe or gravel, promote rapid transmission of liquids, are lightweight and easy to install and do not require seaming. They do, however, require geotextile filters above them and can experience problems with creep and intrusion. Long-term operating and performance experience of geonets is limited because the material and its application are relatively new. Other disadvantages include limited hydraulic capacity and less protection of liner.

If a geonet is used in place of a granular drainage layer, it must meet the same performance standard (maintaining less than 30 cm of leachate above the liner). The transmissivity of a geonet can be reduced significantly by intrusion of the soil or a geotextile. A protective geotextile between the soil and geonet will help alleviate this concern.

Geonets are often used on the sidewalls of landfills because of their ease of installation. When installing a geonet on a side slope, the following is recommended:

- Secure in anchor trench.
- Strongest longitudinal length to extend down the slope.
- Tied at edges, butted or overlapped (not seamed).
- Placed loosely, not in tension.

2.6.2.3
Leachate Collection Pipes

Perforated leachate collection pipes are placed within the high-permeability drainage layer to collect leachate and carry it rapidly to a sump or collection header pipe. Perforated drainage pipes can provide good long-term performance, having been shown to transmit fluids rapidly and to maintain good service lives. The depth of the drainage layer around the pipe should be deeper than the diameter of the pipe. The pipes can be placed in trenches to provide the extra depth. In addition, the trench serves as a sump (low point) for leachate collection. Pipes can be susceptible to particulate and biological clogging similar to the drainage layer material. Furthermore, all components of the LCRS, including the collection pipes, must have sufficient strength to support the weight of:

- overlying waste;
- cover system;
- post-closure loadings; and
- stresses from operating equipment.

The component that is most vulnerable to compressive strength failure is the drainage layer piping. LCRS piping can fail by excessive deflection, which may lead to buckling or collapse. Pipe strength calculations should include resistance to wall crushing, pipe deflection and critical buckling pressure. Design equations and information for most pipe types can be obtained from the major pipe manufacturers.

The design of perforated collection pipes should consider the following factors:

- Required flow using known percolation impingement rates and pipe spacing;
- Pipe size using required flow and maximum slope; and:
- Structural strength of the pipe.

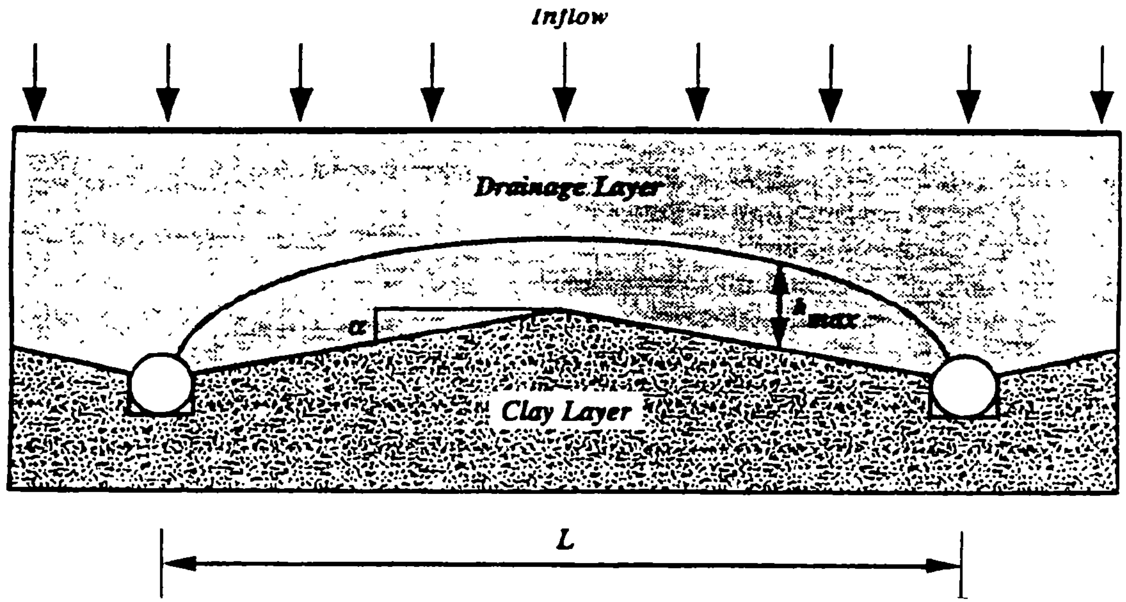
The pipe spacing may be determined by the Mound Model (Figure 2-19). Using a maximum allowable head, h_{max}, of 30 cm (12 inches), the equation is usually solved for the pipe spacing, "L".

The amount of leachate can be calculated in a variety of ways, including

- Water Balance Method
- Hydrologic Evaluation of Landfill Performance (HELP) Model

The HELP model is a computer-based mathematical water-budget model that performs daily sequential analyses to generate daily, monthly and annual estimates of runoff, evapotranspiration, lateral drainage, leakage through covers,

Definition of Terms for Mound Model Flow-Rate Calculations



$$h_{max} = \frac{L\sqrt{c}}{2}\left[\frac{\tan^2\alpha}{c} + 1 - \frac{\tan\alpha}{c}\sqrt{\tan^2\alpha + c}\right]$$

where

c = q/k
k = permeability
q = inflow rate

(Source: EPA, 1989)

Figure 2-18

leachate collection, leakage detection and leakage through clay liners and FMLs.

Clogging of the pipes and drainage layers of the LCRS can occur through several mechanisms, including

- Physical (sedimentation)
- Chemical
- Biological

Physical clogging can be minimized by proper sizing of the pipe perforations. The Army Corps of Engineers has established design criteria using graded filters to prevent physical clogging of leachate drainage layers and piping by soil sediment deposits.

Chemical clogging can occur when dissolved species in the leachate precipitate in the piping. Clogging can be minimized by periodically flushing pipes or by providing a sufficiently steep slope in the system to allow for high flow velocities for self-cleansing. These velocities are dependent on the diameter of the precipitate particles and on their specific gravity.

Biological clogging due to algae and bacterial growth can be a serious problem in MSWLFs for which there is no universally effective method of prevention. Since organic materials will be present in the landfill unit, there will be a potential for biological clogging. The system design should include features that allow for pipe system cleanings. The components of the cleaning system should include:

- A minimum of 6-inch diameter pipes to facilitate cleaning;

- Access located at major pipe intersections or bends to allow for inspections and cleaning; and:

- Valves, ports or other appurtenances to introduce biocides and/or cleaning solutions.

2.6.2.4
Protective Filter Layer

The openings in drainage materials, whether holes in pipes, voids in gravel or apertures in geonets, must be protected against clogging by accumulation of fine (silt-sized) materials. An intermediate material that has smaller openings than those of the drainage material can be used as a filter between the waste and drainage layer. Two materials used for the filter layer include

- Sand or granular soil

- Geotextiles

Sand may be used as filter material, but has the disadvantage of taking up vertical space. A granular filter layer is generally placed using the same earth-moving equipment as the granular drainage layer.

Geotextiles are often used as a filter layer. They save vertical space, are easy to install and have the added advantage of remaining stationary under load. However, because geotextiles are susceptible to biological clogging, their use in areas inundated by leachate (e.g., sumps, around leachate collection pipes and trenches) should be avoided. Another advantage of geotextiles is their light weight and ease of placement. The geotextiles are brought to the site, unrolled and held down with sandbags until they are covered with a protective layer. They are usually overlapped, not seamed. However, on slopes or in other configurations, they may be sewn.

2.6.2.5
Leachate Collection Sumps

Sumps, located in recesses at the low points within the leachate collection drainage layer, provide one method for leachate removal from the MSWLF unit. In the past, low-volume sumps have been constructed successfully from reinforced concrete pipe on a concrete footing and supported above the geomembrane on a steel plate to protect the geomembrane from puncture. Recently, however, prefabricated polyethylene structures have become available. These structures may be suitable for replacing the concrete components of the sump and have the advantage of being lighter in weight.

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3

SECTION 3.0

Construction Quality Assurance

Page No.

List of Figures Page No.

3.1 INTRODUCTION

Construction quality assurance (CQA) consists of a planned series of observations and tests to ensure that the final product meets project specifications. CQA plans, specifications, observations and tests are used to provide quantitative criteria with which to accept the final product. In order to ensure that a landfill is constructed in accordance with the required design criteria, a systematic quality assurance program is required to ensure that the proper materials, equipment and procedures are utilized during the planning and construction of the landfill and its components. This section presents the elements of a CQA plan and some of the CQA techniques utilized to inspect the components of a MSWLF.

3.2 ELEMENTS OF A CQA PLAN

Several elements included in a CQA plan are:

- Responsibility and authority
- CQA personnel requirements
- Design specifications
- Inspection activities
- Sampling requirements
- Acceptance/rejection criteria and corrective measures
- Documentation

3.2.1 Responsibility and Authority

The permitting, designing, and construction of a disposal facility involve a large number of organizations. Those organizations involved directly in CQA include the following:

- The permitting agency,
- The facility owner/operator,
- The design engineer,
- The CQA personnel,
- The construction and installation contractor(s), and
- The FML manufacturer (possibly).

These organizations are not necessarily mutually exclusive. For example, the facility owner/operator may also be the construction contractor. The CQA personnel may be employees of the facility owner/operator, of the design engineer or of an independent firm. The installer could also be the FML manufacturer or fabricator. Regardless of the relationships among the organizations, the areas of responsibility and the lines of authority for each organization must be clearly delineated in a CQA plan.

Periodic meetings and visits are necessary to ensure effective communication between all parties. Project meetings will benefit all those involved with the facility by ensuring familiarity with:

- Facility design
- Construction procedures
- Requirements of the CQA plan
- Any design changes

Examples of the types of meetings that may be held include the following:

- A preconstruction CQA meeting to resolve any uncertainties about the design or the CQA plan. This meeting should be held following the completion of the facility design and site-specific CQA plan and the award of the construction contract and should be attended by the facility owner/operator, design engineer, CQA personnel, construction contractor and the installer, if one has been selected.

- Daily meetings to review progress.

- Problem or work deficiency meetings to be held as the need arises.

All CQA meetings should be documented.

3.2.2 CQA Personnel Requirements

A CQA plan should identify the qualifications of the CQA officer and the CQA inspection personnel in terms of the training and experience necessary to fulfill their assigned responsibilities.

3.2.3 Design Specifications

Design specifications are a necessary part of the CQA plan insofar as the purpose of a CQA plan is to verify whether or not the various components of the facility and the completed facility itself meet the design specifications.

3.2.4 Inspection Activities

The inspection activities to be performed during the implementation of a CQA plan include observations and tests that ensure that the materials of construction, the construction itself and the installation of the various components of the MSWLF meet or exceed all design criteria, plans and specifications. The wide range of materials and the number of activities involved in construction of a disposal facility is reflected in the number of different inspection activities that are involved in implementing a CQA plan. The areas for CQA inspection include

- The earthworks (including the foundation, the embankments and a low-permeability soil liner in composite double-liner systems);
- The FML (from inspection of the raw materials up through inspection of the installed liner); and
- The components of the leachate collection system.

It is important to select appropriate tests for inspecting the quality of the construction materials and the work and that the procedures proposed to test the materials are well defined. For example, some ASTM standards, such as ASTM D638 which describes methods for testing the tensile properties of plastics, include a range of alternative testing procedures. Citation of the number of a standard in a CQA plan may not be enough to define the exact testing procedure to be followed.

Ideally, CQA inspections and tests should meet the following criteria:

- A CQA inspection test should be a good indicator of design quality.
- A CQA inspection test or observation should be accurate and precise. The test results or observations should be docu-

mentable (i.e., the results or observations should be numbers or well-defined terms or phrases).

- The results of a CQA inspection should be available within a short period of time so that acceptance decisions can be made without causing interference with contractor performance.

- CQA inspection tests should be easy to run using simple, rugged equipment.

- Preferably, CQA inspection tests should be nondestructive (i.e., should not damage the integrity of any component of the installed lining system).

The data generated during CQA inspection testing are typically one of two types: attribute-type data or measurement-type data. The type of data that will be reported will depend on the test method and the design specifications and on how the acceptance/rejection criteria are stated. Attribute-type data can be based on dichotomous classifications (e.g., pass/fail, acceptable/defective) or, in the case of FML destructive seam testing, classifying the results as a film-tearing bond break or a nonfilm-tearing bond break. The criteria distinguishing classifications should be clearly stated. In the case of FML seam testing, a schematic of the different ways in which tested specimens can break could be included as part of the design specifications or the CQA plan. Measurement-type data are test values which can be used to compute summary statistics such as means, variances and ranges. In cases in which there are alternative means of calculating test values, the precise method for calculating should be stated.

3.2.5 Sampling Requirements

For all types of QA testing, the sampling requirements need to be stated, including the method for determining what constitutes a representative sample.

Inspection and sampling requirements should include:

- Statements of the sampling strategy
- Size or definition of the unit to be sampled
- Size of the sample itself
- Sampling procedure
- Number of specimens to be tested per sample.

Figure 3-1 presents the recommended testing frequencies of three components of a clay-lined landfill.

There are three basic types of sampling strategies:

- 100-percent inspection
- Judgmental sampling
- Statistical sampling

3.2.5.1 *100-Percent Inspection*

One hundred percent means that inspection is made continuously on every unit of a product being manufactured or fabricated. Since performing

Recommendations For Construction of Clay-Lined Landfills

Item	Testing	Frequency
1. Clay borrow source testing	Grain size	1,000 yd^3
	Moisture content	1,000 yd^3
	Atterberg limits (liquid limit and plasticity index)	5,000 yd^3
	Moisture-density curve	5,000 yd^3 and all changes in material
	Lab permeability (remolded samples)	10,000 yd^3
2. Clay liner testing during construction	Density (nuclear or sand cone)	5 tests/acre/lift (250 yd^3)
	Moisture content	1 test/acre/lift (1,500 yd^3)
	Undisturbed permeability	1 test/acre/lift (1,500 yd^3)
	Dry density (undisturbed sample)	1 test/acre/lift (1,500 yd^3)
	Moisture content (undisturbed sample)	1 test/acre/lift (1,500 yd^3)
	Atterberg limits (liquid limit and plasticity index)	1 test/acre/lift (1,500 yd^3)
	Grain size (to the 2-micron particle size)	1 test/acre/lift (1,500 yd^3)
	Moisture - density curve (as per clay borrow requirements)	5,000 yd^3 and all changes in material
3. Granular drainage blanket testing	Grain size (to the No. 200 sieve)	1,500 yd^3
	Permeability	3,000 yd^3

Source: Wisconsin Department of Natural Resources

Figure 3-1

a 100-percent inspection of many materials and construction processes is not practical, the quality of the material or process should be estimated from testing a portion of the total materials or constructed facility. Examples of this situation include estimations of the integrity of FML seams by destructive testing and assessments of the characteristics of the soil liner in an FML/composite double liner.

3.2.5.2 *Judgmental Sampling*

Judgmental sampling refers to sampling procedures in which decisions concerning sample size, selection scheme and locations are based on considerations not derived from probability theory. The objective of such sampling may be to test typical samples that represent the whole, to test zones of suspect quality, or a combination of the two. Thus, in sampling FML seams, samples could be taken at a minimum frequency per unit of seam length from locations assigned by the CQA inspector before seaming is started and also from locations that are of suspect quality.

The success of a judgmental sampling plan is dependent on the knowledge, capability and experience of the design engineer, the CQA inspection personnel, the CQA officer and the project manager. Organizations that construct large numbers of similar projects, such as the U.S. Army Corps of Engineers or the U.S. Bureau of Reclamation, often employ judgmental sampling plans using sampling frequencies based on years of construction experience. For example, more intensive sampling may be required in areas where design specifications are more difficult to meet (e.g., field-seaming operations on the slopes of a unit). The weakness of judgmental sampling is that such methods are subject to biases and sampling errors.

3.2.5.3
Statistical Sampling

Statistical sampling methods are based on principles of probability theory and are used to estimate selected characteristics (e.g., mean, variance and percent defective) of the overall materials or construction process. These methods are more rational, calculable and documentable than judgmental methods and are recommended whenever feasible and applicable. An important element of all statistical methods is knowledge of the inherent variability of the specified characteristic to be measured. This variability can be a function of material quality, construction operations, measurement techniques and instrumentation and the skill of the CQA personnel. The weakness of specific statistical sampling methods depends on the applicability of the theoretical assumptions to the population to be sampled; for example, whether the probability distribution of sample test measurements is normal.

Knowledge about the applicability of statistical sampling methods for the CQA of constructing a waste containment unit is not well developed. In practice, a balanced CQA program uses both judgmental and statistical approaches to take advantage of the lack of bias in statistical sampling methods and the experience and judgment of qualified CQA personnel.

3.2.6
Acceptance/Rejection Criteria and Corrective Measures

The acceptance or rejection criteria for the inspection activities must be stated. The type of criteria will depend on the type of data resulting from the inspection testing. If the data being collected are attribute-type data (e.g., film-tearing bond break/nonfilm-tearing bond break for reporting the results of destructive testing of FML seams), the maximum percentage of specimens that are unacceptable per tested sample or the maximum percentage of unacceptable samples per sample block should be stated. If the data being collected are measurement-type data, acceptance/rejection criteria are based on whether a nominal level (e.g., mean median or variance) meets the design specification value(s) for a specific measurement (e.g., FML seam strength). The nature of the nominal level (i.e., whether it is a median or a mean) should be stated in the specifications.

The criteria for accepting or rejecting measurements that appear to be atypical or in error must be stated. These atypical or errant measurements, called outliers, may be an extreme manifestation of the random variability inherent in data resulting from testing a specific material or process or they may be a result of a gross deviation in the test procedure or an error in calculating or recording the numerical value.

When material or work is rejected because the CQA inspection activities indicate that it does not meet the design specifications, corrective measures must be implemented. The types of corrective measures that should be taken and the requirements for inspecting these measures should be stated.

3.2.7 Documentation

Thorough documentation is an important part of the implementation and success of a CQA plan, and documentation requirements for all CQA activities should be described in detail in the plan. These requirements should include items such as

- Daily summary reports;
- Inspection data sheets;

- Problem identification and corrective measure reports;
- Block evaluation reports;
- Acceptance reports; and
- The final documentation, which is submitted to the permitting agency.

Provisions for final storage of the CQA records should also be included in the CQA plan.

3.3 CQA FOR SOILS

Sampling and testing of the soil liner during all phases of construction is necessary to ensure quality control. Testing provides verification of visual inspections. Field density and water content are two critical parameters which must be tested frequently during construction activities. Field and laboratory determinations should be made for these parameters and for hydraulic conductivity. Specific tests and methods are listed in Figure 3-2.

A CQA plan must address the soils involved in landfill construction and should address items such as

- Site preparation
- Subgrade inspection for bottom liner
- Soil layer materials
- Placement
- Compaction

These items can serve as a CQA checklist for monitoring soil construction quality.

Methods for Testing Low-Permeability Soil Liners

Parameter to be Analyzed	Methods	Test Methods Reference
Soil type	Visual-manual procedure	ASTM D2488
	Particle size analysis	ASTM D422
	Atterberg limits	ASTM D4318
	Soil classification	ASTM D2487
Moisture content	Oven-dry method	ASTM D2216
	Nuclear method	ASTM D3017
	Calcium carbide(speedy)	AASHTO T217
In-place density	Nuclear methods	ASTM D2922
	Sand cone	ASTM D1556
	Rubber balloon	ASTM D2167
	Drive cylinder	ASTM D2937
Moisture-density relations	Standard effort	ASTM D698
	Modified effort	ASTM D1557
Strength	Unconfined compressive strength	ASTM D2166
	Triaxial compression	ASTM D2850
Cohesive soil consistency (field)	Penetration tests	ASTM D3441
	Field vane shear test	ASTM D2573
	Hand penetrometer	Horslev, 1943
Hydraulic conductivity (laboratory)	Fixed-wall double ring permeameter	EPA, 1983 SW-870
	Flexible wall permeameter	Daniel et al , 1985 SW-846 Method 9100 (EPA, 1984)
Hydraulic conductivity (field)	Sealed double-ring infiltrometer	Day and Daniel, 1985
	Sai-Anderson-Gill double-ring infiltrometer	Anderson et al , 1984

(Source: EPA, 1991)

Figure 3-2

3.3.1 Site Preparation

The following items should be checked for when observing the site preparation activities:

- Is there any evidence of landsliding? Look for large cracks in the ground or other evidence of instability.

- Are there proper controls on ground elevations? Ask how elevations were determined and where the benchmark(s) is/are located.

- Have all grasses and tree roots been excavated in areas to receive engineered barriers? Visually inspect.

3.3.2 Subgrade Inspection for Bottom Liner

The following items should be checked when inspecting the subgrade for the bottom liner:

- Is the subgrade free of organic matter? Visually inspect.

- Is the subgrade properly sloped as shown on plans? Ask for details and be sure that elevations are documented and confirmed by survey.

- Is the subgrade sufficiently strong to support equipment? Check by walking over the area; feet should not sink into soil more than 1 inch. Bounce up and down on wet soil; ground should not visually deform or quake.

- Has the subgrade been tested for density and moisture at the required frequency? Ask if tests were performed, if tests are required.

- Is the subgrade reasonably smooth? Should be able to place a long stick or rod onto surface at all locations and not see separation large enough to accommodate a fist. If surface is uneven, it should be "proof-rolled," (e.g., with smooth steel-drum roller).

3.3.3 Soil Liner Materials Inspection

The following items should be checked when inspecting the soil layer materials:

- Material should be cohesive. Check by rolling material into thread 1/8 inch in diameter; if soil crumbles and cannot be rolled into a thread, it may not have enough fines; ask for quantitative assessment.

- Have Atterberg limits been measured? Ask for this information and compare the results with the minimum required values for Liquid Limit and Plasticity Index. Ask how the samples were selected and ensure (1) random sampling supplemented by additional tests on suspect material, (2) at least one sample taken per day of operations and (3) sampling any time there is an obvious change in material or borrow source.

- For soil/bentonite liners, has sufficient bentonite been added, and has the blending been thorough? Ask how weights are controlled and how bentonite is blended.

- Check for frequency and size of gravel-size particles (greater than 4.76 millimeters or three-sixteenth inch) in diameter. Do this visually. There is usually no problem if the gravel-size particles comprise less than 10 percent of the material and the largest particles are no larger than about 2 inches. If larger particles are present, they should be removed. If more than 10 percent of the material is gravel, ask for test data that demonstrates that the gravel does not raise the permeability above the maximum allowable value

- Have grain-size analyses been performed? Ask for this information and compare the results with the minimum required value for percentage fines and the maximum allowable value for percentage of gravel. Ask how the samples were selected and ensure (1) random sampling supplemented by additional tests on suspect material, (2) at least one sample taken per day of operations and (3) sampling any time there is an obvious change in material or borrow source.

- Is there evidence of deleterious material? Look for roots, sticks, vegetation and debris such as bricks.

- Visually check water content; the material should be placed in its final location at a water content close to (within 2 to 3 percent of) the desired value. Small adjustments in water content can be made just prior to compaction, but large adjustments should be made in a separate conditioning area. One learns mainly from experience what is a satisfactory water content by using the stabilization procedures for determining plasticity index on soil.

- Check results of water content tests. Determine whether the water content of the material in the borrow pit is close to (within 2 to 3 percent of) to the acceptable range of water content. If the water content is not close, the material should be taken to a separate moisture adjustment area where the soil is slowly wetted or dried, while being repeatedly mixed, over a period of at least 48 hours to allow time for water to be evenly distributed in the soil.

- Check to make sure that the soil is wetted or dried evenly. If the soil is dried, it should be spread in a layer no thicker than about 12 inches and mixed with tilling equipment. If the soil is wetted, water should be evenly distributed over a layer and the soil mixed with tilling equipment. If the water content is changed by more than 2 to 3 percent, the moisture adjustment should be made in a separate conditioning area.

3.3.4 Placement of Soil Liner

The following items should be checked when observing the placement of the soil liner:

- Check subgrade for roughness. Except for the first lift, a new lift should never be placed on a smooth surface. Visually observe the surface to receive the new lift to be sure it has been roughened either by rolling with an extended foot roller or by using scarification equipment. Scarification, if performed, should be to a depth of approximately 1 inch.

- Check subgrade for desiccation damage. Visually inspect subgrade; look for evidence that surface has dried out. If previously compacted lift has desiccation cracks wider than one-eighth inch or is suspected of having desiccated (e.g., because of change in color), require additional water content tests. Compare water contents with values measured immediately after compaction. If necessary, excavate damaged lift(s) and rebuild.

- Check loose lift thickness. Loose lifts are normally less than 9 inches thick. Inspect visually from the edge of a lift or from grade stakes, or dig down through a loose lift and measure its thickness.

- Check for repair of any grade stake holes and be sure that grade stakes are recovered and not buried in the liner. Ask how the grade stake holes are repaired and request a demonstration. Ask what methods are used (e.g., inventory procedures) to ensure that all grade stakes are recovered.

3.3.5 Compaction of Soil Liner

The following items should be checked when observing the compaction of the soil liner:

- Check that the compactor meets requirements. Check weight, type of drum (footed or smooth), length of feet on drum and type of energy (static or vibratory).

- Check that the number of passes over an area is adequate. Ask if there is a minimum, and if so, what procedures are followed to spot check for compliance. Count the passes over a given area to confirm for at least one location.

- For liners on slopes, check to be sure compactor is not shearing the liner. On sloping landfill covers compacted with heavy equipment, the compactor tends to slip down the slope and may shear the low-permeability soil layer if the slope is too steep and/or the compactor too heavy. Look for scarps or shear surfaces.

- Check the water content and dry density of the compacted soil. Ask for test results and determine (1) whether sampling was random, with additional tests as required in suspect areas, or to be certain that at least one test was performed each day that soil was compacted; (2) how the tests were performed; (3) whether the water content tests are periodically checked with overnight oven drying, and if so, how the test results compare; (4) whether nuclear density test results (if this type of test is used) are periodically checked with the sand cone; (5) how holes made for the water content and density tests are repaired (ask for a demonstration); and (6) how the water content and density results compare with the specifications.

- Determine the protocol to be followed if a water content or dry density test fails. Ask for an explanation. Determine if a mechanism exists to overrule an erroneous water content or density test. Look for at least three passing tests required to overrule a failing test that requires repair.

3.4 CQA FOR FLEXIBLE MEMBRANE LINERS

The following issues should be considered when conducting CQA on FMLs:

- Storage at the site
- Deployment of the FML
- Field seaming and seam testing of FMLs

3.4.1 Storage At Site

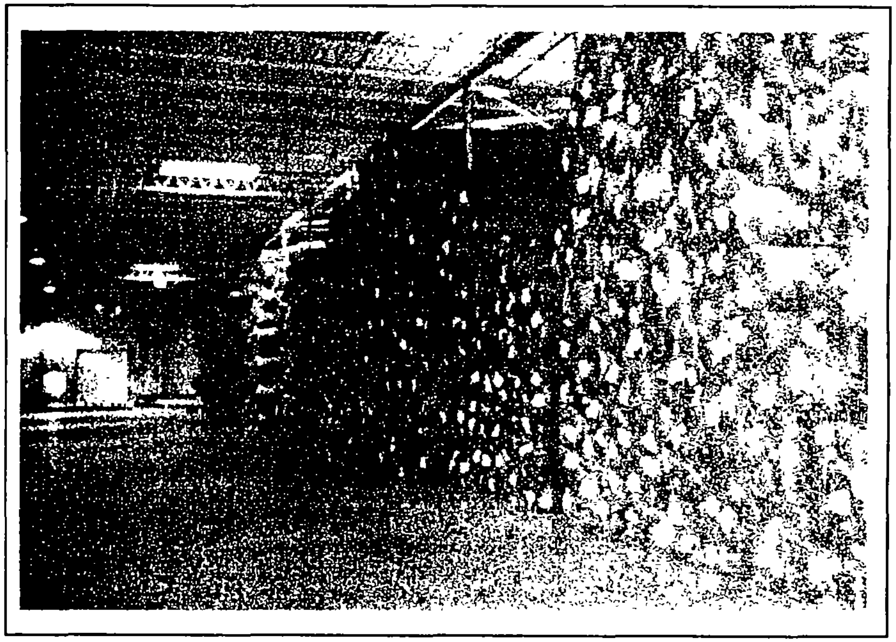
Unless the FML is used directly as it comes off the shipping trailer, a safe storage area should be provided (Figure 3-3). The rolls of FML should be elevated off the ground or at least placed on a dry soil area that does not contain vegetation, stumps or other sharp objects. Covering is usually not necessary providing the FMLs are installed within a short period of time. Palletized FMLs should also be stored onsite on dry, level ground with similar considerations. When the FMLs are to be stored on the site for months or longer, they should be covered and/or have an enclosure around them for protection.

3.4.2 Placement of the FML

Placement of the FML panels or rolls should be described in the FML layout plan (Figure 3-4). Rolls of sheeting, such as HDPE, can generally be deployed by placing a shaft through the core of the roll, which is supported and deployed using a front-end loader or a winch. Panels composed of extremely flexible liner material, such as PVC, are usually folded on pallets, requiring workers to manually unfold and place the FML (Figure 3-5).

Usually the rolls or panels are ordered in a particular direction. After a roll, or panel, is initially positioned or "spotted," it usually must be shifted slightly for exact positioning. By lifting the liner

Photographs of Temporary Storage of Geotextiles

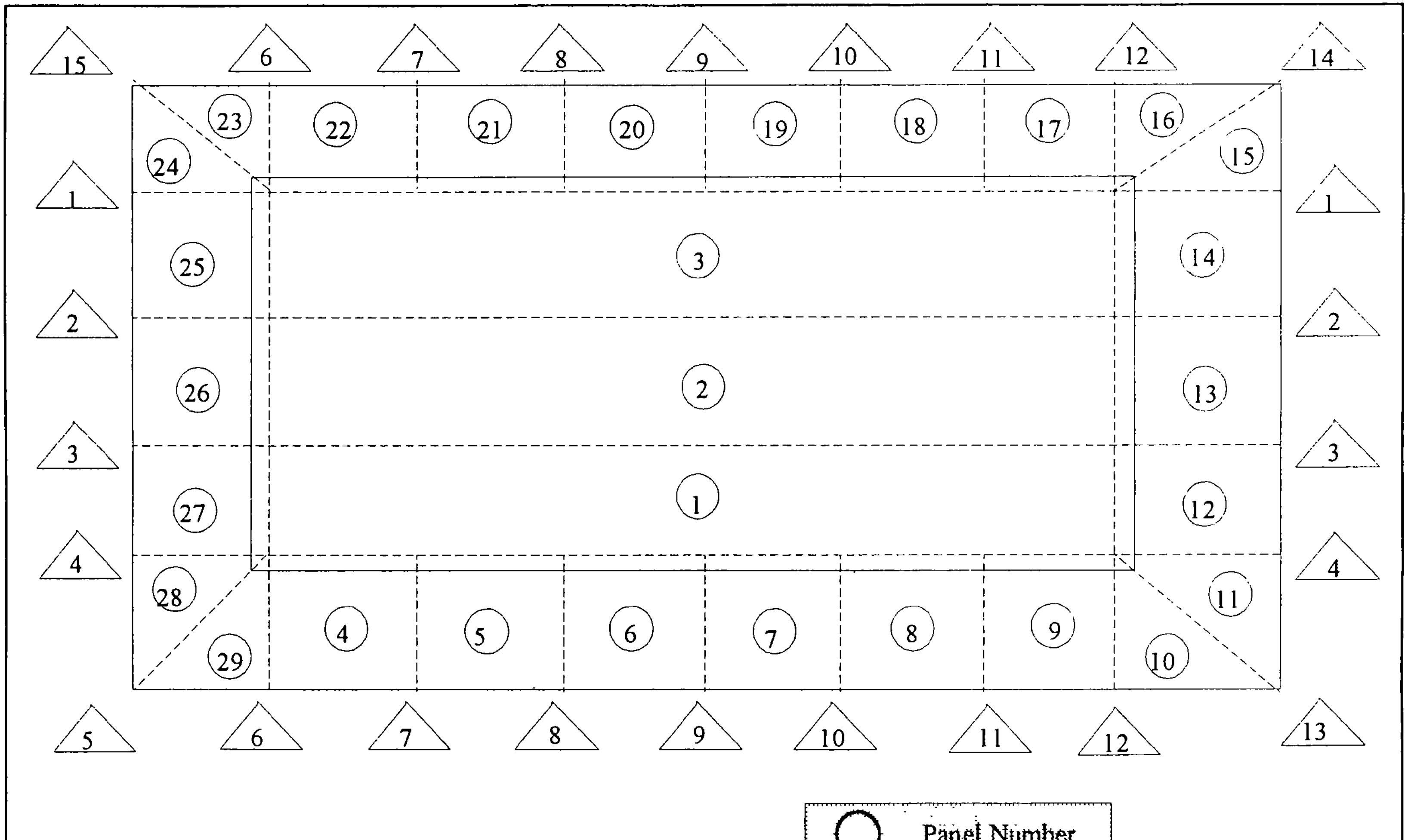


Storage at Manufacturing Facility

Storage at Field Site

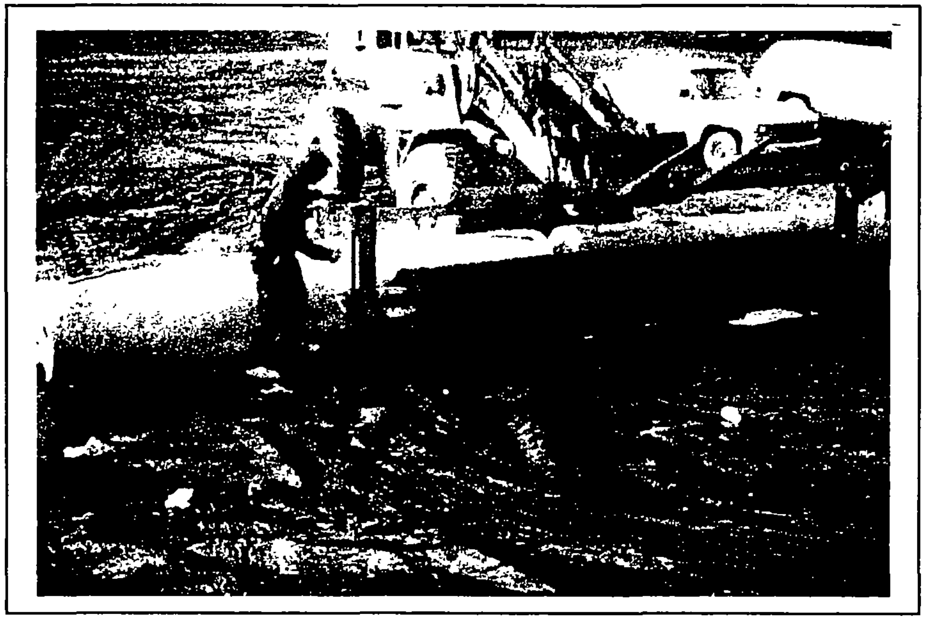
Figure 3-3

Deployment of the Geomembrane

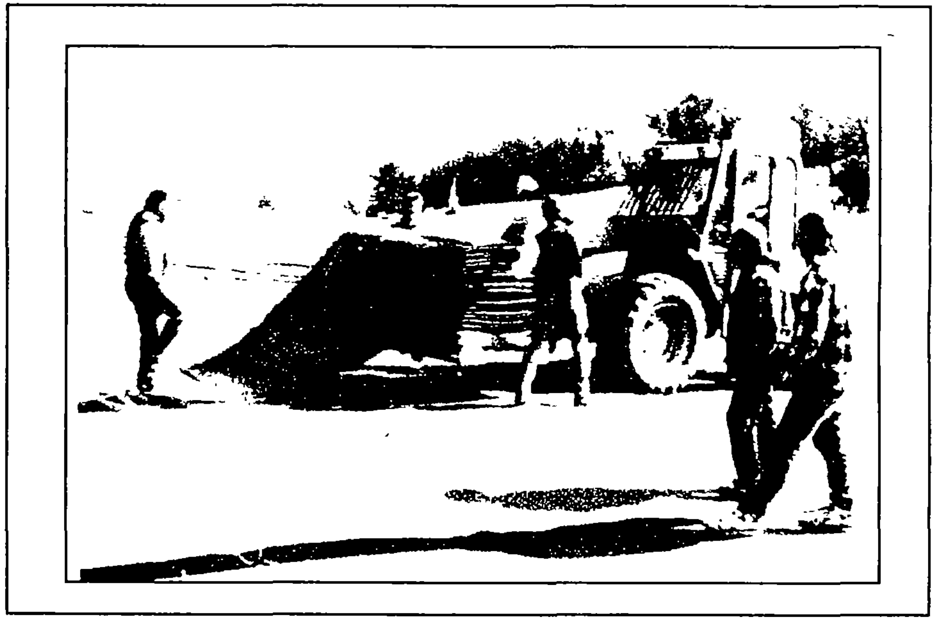


Panel-seam identification scheme

Photographs Showing the Unrolling and Unfolding of Geomembranes



Unrolling Geomembranes



Unfolding Geomembranes

(Source: EPA , 1993)

Figure 3-5

up and allowing air to get beneath some of it, the liner can sometimes be "floated" into position If this is not possible (e.g., with thick FML sheets), the liner has to be shifted by dragging it along the subgrade (or on the geosynthetic material beneath it).

The entire roll or panel must then be inspected for blemishes, scratches and imperfections. Finally, the roll or panel is weighted down with sandbags to prevent movement by wind or any other disturbance (Figure 3-6). Proper stormwater control measurements should be employed during construction to prevent erosion of the soil liner underneath the FML and the washing away of the FML.

Placement of the FML goes hand-in-hand with the seaming process; no more than the amount of sheeting that can be seamed during a shift of work day should be deployed at any one time.

3.4.3 FML Field Seams

The construction of a continuous watertight FML is critical to the containment of municipal waste and is heavily dependent on the construction of the seams bonding the sheeting together. The seams are the most likely source of failure in an FML. The quality of seams made in the field is difficult to maintain since the installer must deal with a variety of conditions, including:

- Changing weather conditions (temperature, wind and precipitation)
- Unclean site conditions
- Working on slopes

Wind Damage to Deployed Geomembrane

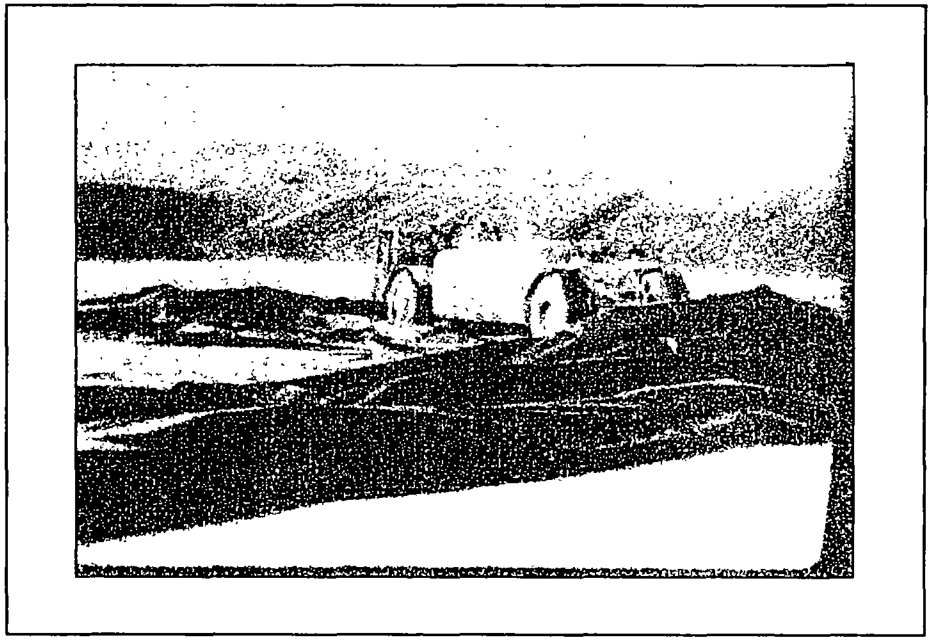


Figure 3-6
3-21

In general, for a seaming system to be acceptable, the bonding:

- Between the sheets of FMLs must be continuous for the length of the seam;
- Between the sheets must approximate the strength of the sheeting and must maintain its strength throughout the service life of the sheeting; and
- Must be capable of being formed in the field.

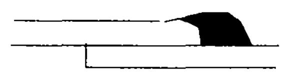
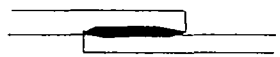
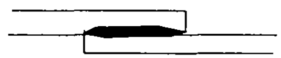
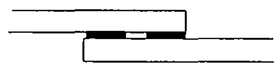
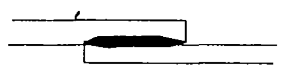
Different types of FMLs require different types of field seams and seaming methods (Figure 3-7). Field seaming methods of the most popular FMLs such as HDPE, PVC and CSPE include:

- Solvent seams
- Thermal seams

3.4.3.1
Solvent Seams

Both PVC and CSPE use solvent seams as the bonding medium between sheets. A liquid solvent is placed (using a squeeze bottle) between the two FML sheets to be joined, followed by pressure to make complete contact (Figure 3-8). In the seaming process, a portion of the two adjacent geomembranes is actually dissolved. Therefore, an excessive amount of solvent will weaken the adjoining FMLs, and too little solvent will result in a weak seam. As a result, care must be taken in the amount of solvent applied, the amount of elapsed time and time of contact and the amount of pressure applied.

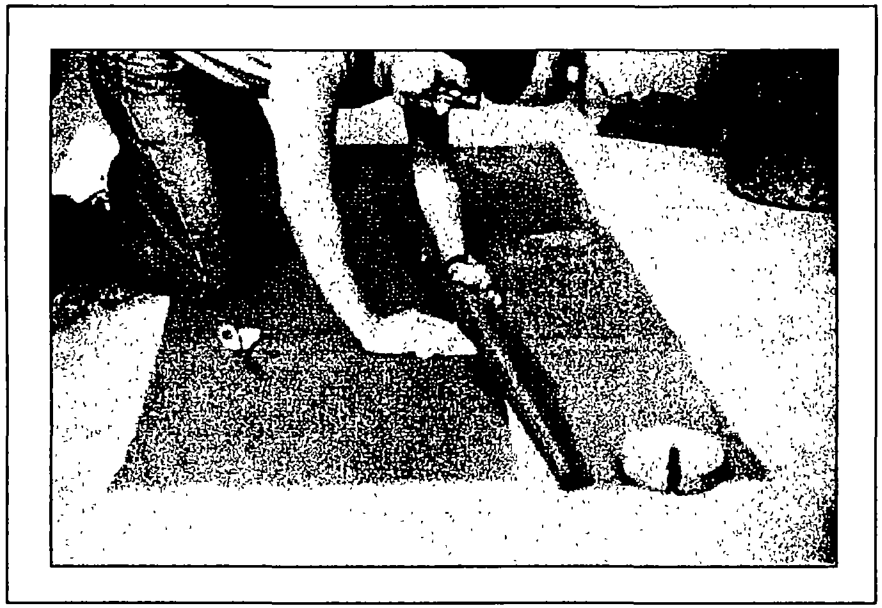
Field Seaming Techniques for Geomembranes

Method	Seam configuration	Typical rate	Comments
Fillet extrusion		100 ft./hr.	Upper and lower sheets must be ground. Upper sheet must be beveled . Height and location are hand-controlled. Can be rod- or pellet-fed. Extrudate must use same polymer compound, air heater can preheat sheet. Routinely used for difficult details.
Flat extrusion		50 ft./hr.	Good on long, flat surfaces. Highly automated machine. Difficult for side slopes Cannot be used for close details. Extrudate must use same polymer compound; air heater can preheat sheet
Hot air		50 ft./hr.	Good to tack sheets together. Hand held and automated devices. Air temperature fluctuates greatly. No extrudate added.
Hot wedge	 	300 ft./hr.	Single and double tracks available. Double track patented; built in nondestructive test. Cannot be used for close details . Highly automated machine. No extrudate added. Controlled pressure for squeeze-out.
Ultrasonic		300 ft./hr.	New technique for geomembranes. Sparse experience in the field. Capable of full automation
Electric Welding		Unknown	New technique for geomembranes. Still in development stage. Extrudate must use same polymer compound Wires provide possibility of doing spark test.

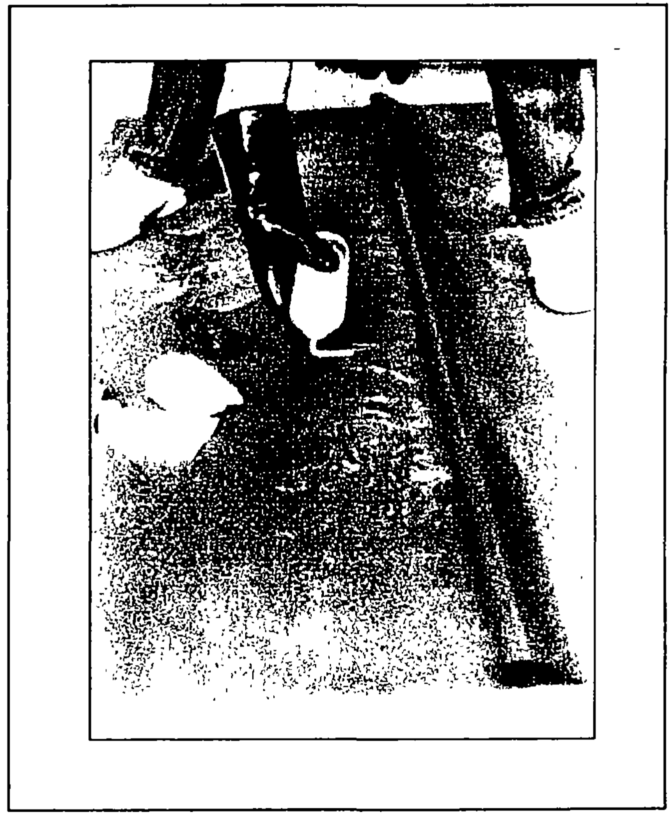
(Source: EPA 1989)

Figure 3-7
3-23

Photographs of Geomembrane Being Bonded



Alignment of test strip and cleaning of area to be bonded



Applying fusion chemical to area of lower geomembrane to be bonded

(Source: EPA, 1991)

Figure 3-8
3-25

3.4.3.2
Thermal Seams

There are a number of thermal methods that can be used on thermoplastic FML materials. In all methods, the opposing FML surfaces are truly melted into a liquid state. Temperature, time and pressure all play important roles; too much melting weakens the FML, and too little melting results in a weak seam. The types of thermal seams are:

- Hot air seaming
- Hot wedge seaming
- Extrusion welding

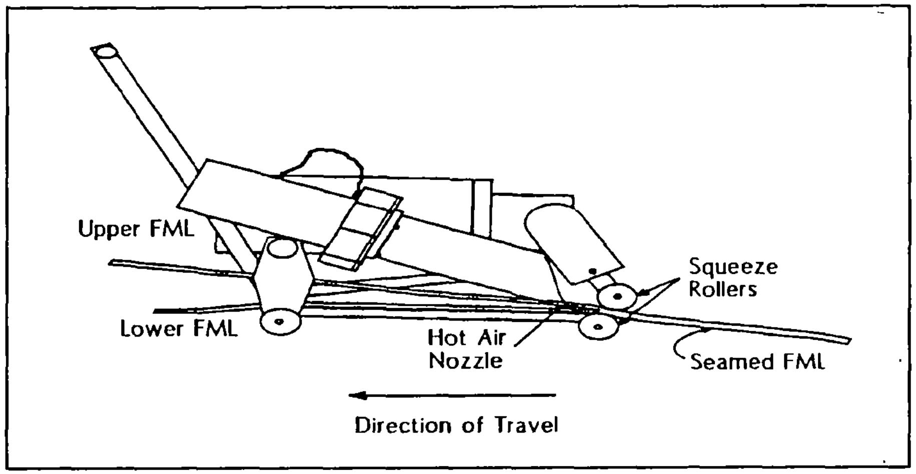
3.4.3.2.1
Hot Air Seaming

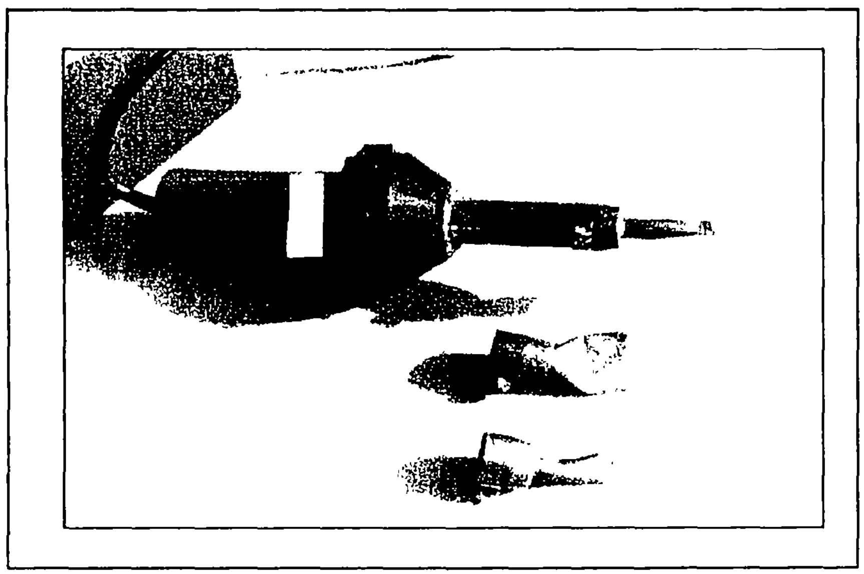
Hot air seaming uses a machine consisting of a resistance heater, a blower and temperature controls to blow air between two sheets to actually melt the opposing surfaces (Figure 3-9). Usually, temperatures greater than 260°C (500°F) are required. Immediately following the melting of the surfaces, pressure is applied by rollers. For some devices, pressure application is automated by counter-rotating knurled rollers.

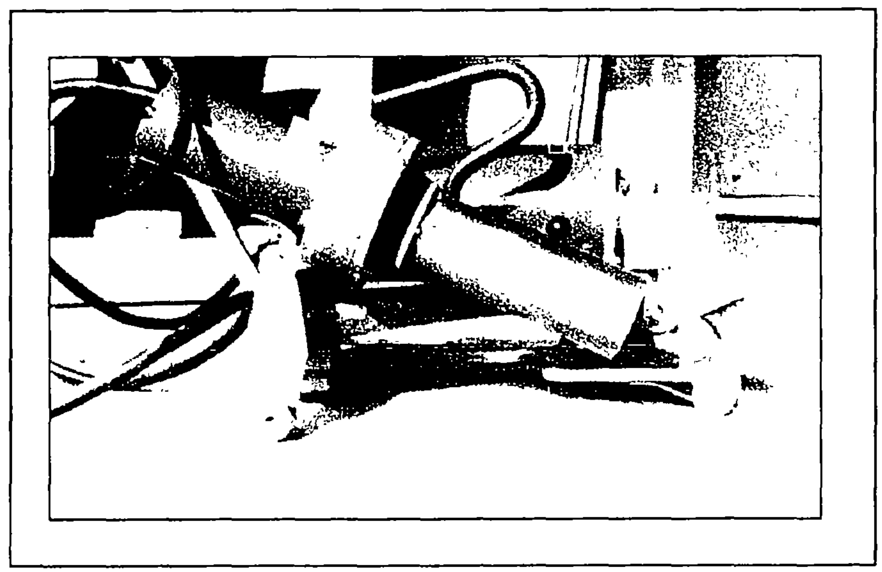
3.4.3.2.2
Hot wedge seaming

In the hot wedge or hot knife method (Figure 3-10), an electrically heated resistance element in the shape of a wedge is passed between the two sheets to be sealed. As it melts the opposing surfaces, roller pressure is applied. Most of these seaming units are automated in terms of temperature, speed of travel and amount of pressure applied. An interesting variation of the technique is the dual-hot-wedge method, which forms two parallel seams with an unbonded space between them. This space is subsequently pressurized with air and any lowering of pressure signifies a leak in the seam. Lengths of hundreds of feet can be field-tested in this one step. The hot

Cross Section of Automated Machine-Driven Hot-Air Seaming Device for Geomembranes



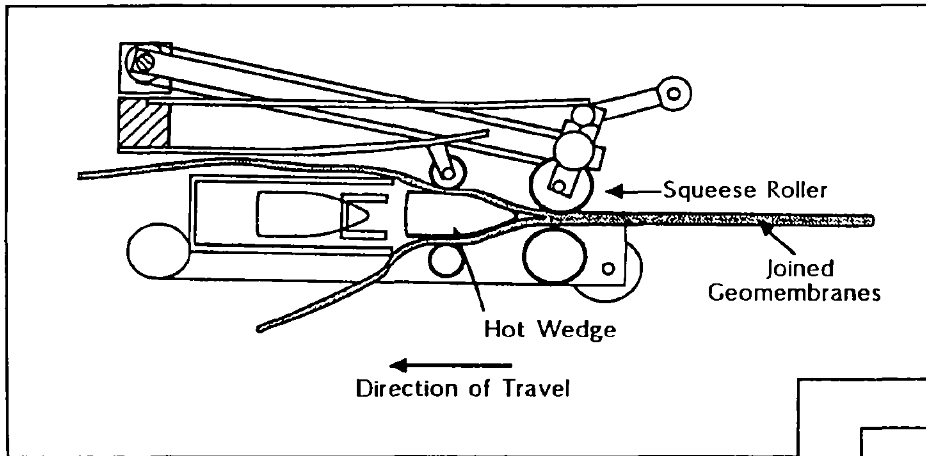


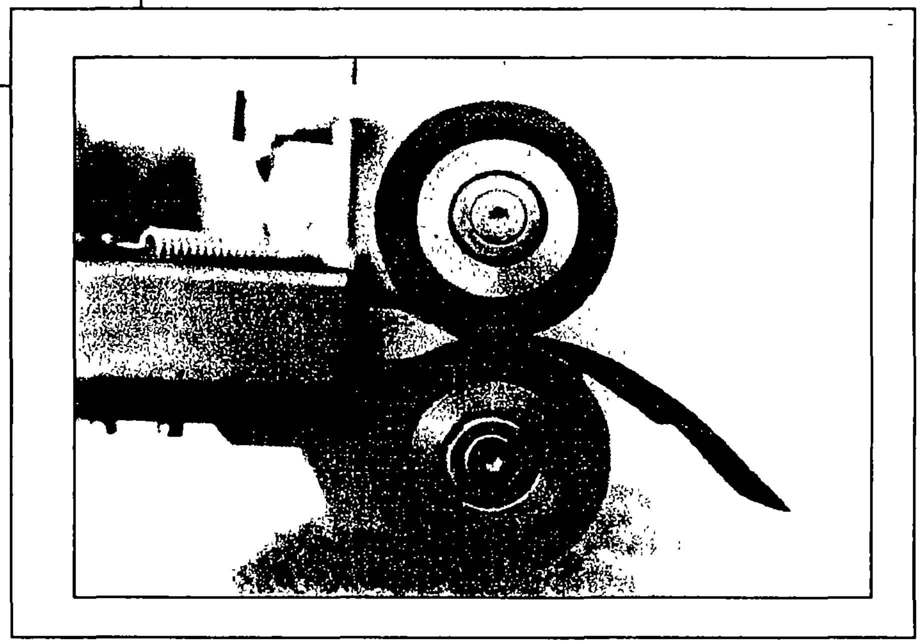


(Source: EPA, 1991)

Figure 3-9
3-27

The Hot Wedge System





(Source: EPA, 1991)

Figure 3-10

wedge or hot knife method will be described further in the section on nondestructive seam testing.

3.4.3.2.3
Extrusion welding

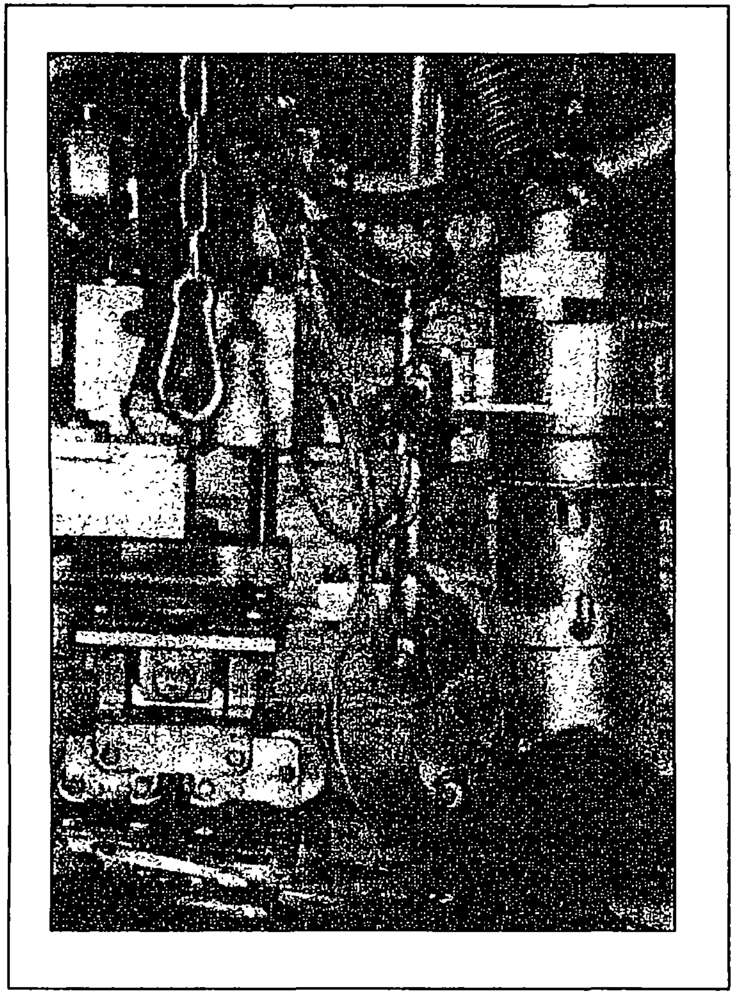
Extrusion (or fusion) welding (Figure 3-11) is used exclusively on polyethylene FMLs. It is directly parallel to metallurgical welding in that a ribbon of molten polymer is extruded between or against the two lightly buffed surfaces to be joined. The extruded ribbon causes some of the sheet material to be liquified and the entire mass then fuses together. One patented system has a mixer in the molten zone that aids in homogenizing the extruded and the molten surfaces. The technique is called flat welding when the extruded ribbon is placed between the two sheets to be joined and fillet welding when the extruded ribbon is placed over the leading edge of the seam to be bonded.

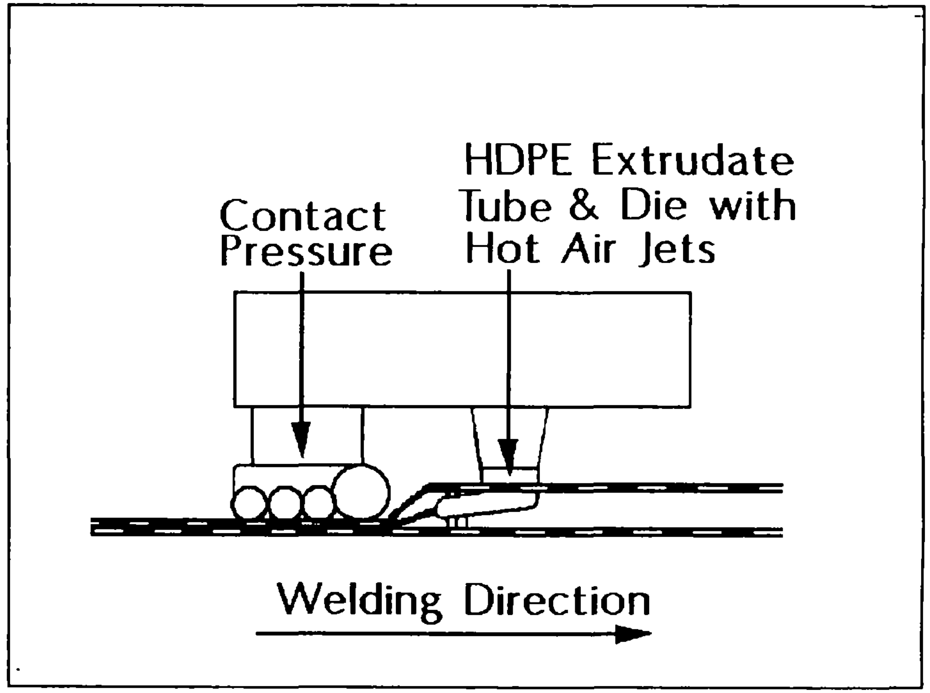
3.4.4 Seam Test

3.4.4.1
Destructive Seam Tests

After a field-seaming crew has seamed a given amount of material, it is important to evaluate performance of the seams. This may be done by cutting out a sample for laboratory testing or testing the seams directly at the field site. Given the size of FML sheet layout, selection of the number and locations of the seam test sites is an important consideration. Because each seam sample becomes a hole that must be appropriately patched and then retested, the number of field-seam samples is commonly kept to a minimum. Such sampling will reveal the soundness of the method of seaming, but not whether all of the seams are sound. Samples will ordinarily be taken at the start of the seaming operations in the morning and after the midday break. Thereafter, sampling can be done on a random or a periodic basis. One manufacturer recommends a frequency of six samples per km (6/3,300

The Extrusion Welding System





Photograph and schematic diagram of extrusion flat seaming of geomembrane sheets.

(Source: EPA, 1991)

Figure 3-11

feet) of seam on a random basis, or one sample per 150 m (1/500 feet) of seam on a uniform basis.

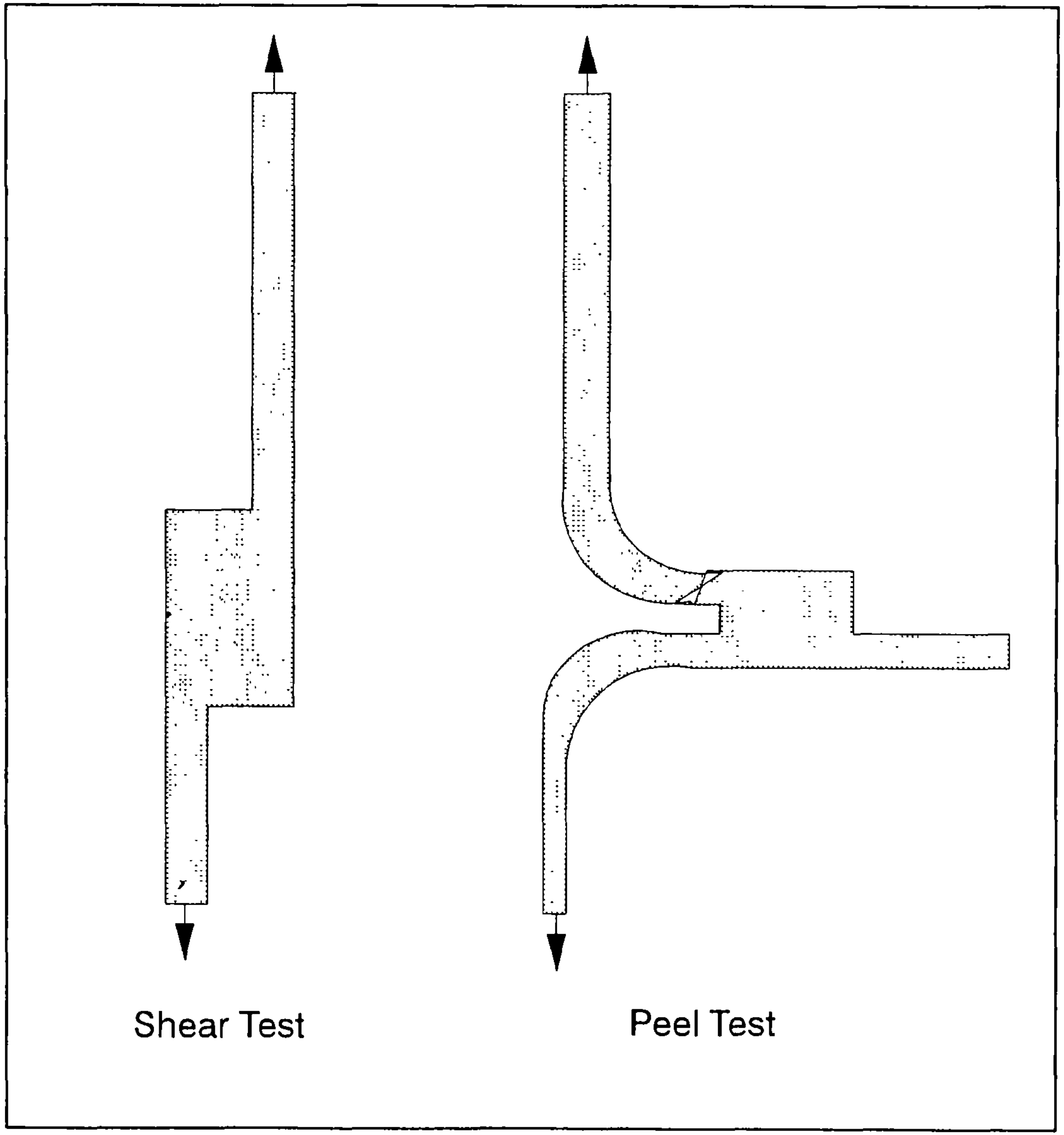
There is considerable discussion on what constitutes an acceptable seam. There is nearly universal agreement that the seam test specimen must not fail within the seamed region itself; that is, a failure must be a sheet failure on either side of the seamed region. This is called a "film-tear bond" failure. Engineers are not in agreement, however, as to the magnitude of the force required for failure. For seams tested in a shear mode, failure forces of 80 to 100 percent of the unseamed sheet strength are usually specified. For seams tested in a peel mode, failure forces of 50 to 80 percent of the unseamed sheet strength are often specified. These percentages underscore the severity of peel tests as compared to shear tests. For assessing seam quality, the peel test is preferable (Figure 3-12).

3.4.4.2 *Nondestructive Seam Tests*

A number of nondestructive seam tests exist, including (Figure 3-13a, b)

- Air lance method
- Mechanical point stress or "pick" test
- Electric sparking
- Pressurized dual seam method
- Vacuum chambers
- Ultrasonic methods

Destructive Seam Tests



(Source: EPA, 1989)

Figure 3-12

Overview of Nondestructive Seam Tests

	Primary Users		
Nondestructive Test Method	**Contractor**	**Design Engineer Inspector**	**Third-Party Inspector**
Air Lance	Yes	-	-
Pick Test	Yes	-	-
Electric Wire	Yes	Yes	-
Dual Seam (positive pressure)	Yes	Yes	-
Vacuum Chamber (negative pressure)	Yes	Yes	-
Ultrasonic Pulse Echo	-	Yes	Yes
Ultrasonic Impedance	-	Yes	Yes
Ultrasonic Shadow	-	Yes	Yes
Electric Field	Yes	Yes	Yes
Acoustic Sensing	Yes	Yes	Yes

(Source: EPA, 1989)

Figure 3-13 a

Overview of Nondestructive Seam Tests

(cont'd)

General Comments						
Non-Destructive Test Method	**Cost of Equipment**	**Speed of Tests**	**Cost of Tests**	**Type of Result**	**Recording Method**	**Operator Dependency**
Air Lance	$200	Fast	Nil	Yes-No	Manual	Very High
Pick Test	Nil	Fast	Nil	Yes-No	Manual	Very High
Electric Wire	$500	Fast	Nil	Yes-No	Manual	High
Dual Seam (positive pressure)	$200	Fast	Mod.	Yes-No	Manual	Low
Vacuum Chamber (negative pressure)	$1,000	Slow	Very High	Yes-No	Manual	High
Ultrasonic Pulse Echo	$5,000	Moderate	High	Yes-No	Automatic	Moderate
Ultrasonic Impedance	$7,000	Moderate	High	Qualitative	Automatic	Unknown
Ultrasonic Shadow	$5,000	Moderate	High	Qualitative	Automatic	Moderate
Electric Field	$20,000	Slow	High	Yes-No	Manual and Automatic	Low
Acoustic Sensing	$1,000	Fast	Nil	Yes-No	Manual	Moderate

(Source: EPA, 1989)

Figure 3-13 b

3-33 b

3.4.4.2.1
Air lance method

The air lance method projects a jet of air at approximately 350 kPa (50 lb/in^2.) pressure through an orifice of 50-mm (3/16-in.) diameter. The jet is directed beneath the upper edge of the overlapped seam to detect unbonded areas. When such an area is located, the air passes through, causing an inflation and fluttering in the localized area. This method only works on relatively thin (less than 45 mils [1.1 mm]) FMLs and only if the defect is open at the front edge of the seam, where the air jet is directed. It is strictly a contractor/installer's tool to be used in a construction quality control manner.

3.4.4.2.2
Mechanical point stress or "pick" test

In the mechanical point stress or "pick" test, the tester places a dull tool (such as a blunt screwdriver) under the top edge of a seam. With care, an individual can detect an unbonded area, since an unbonded area is easier to lift than a properly bonded area. This rapid test depends completely on the care and sensitivity of the person performing it. Only relatively thick, stiff FMLs are checked by this method. Detectability is similar to that using the air lance, but both methods are operator dependent. This test should be performed only by the installation contractor and/or FML manufacturer.

3.4.4.2.3
Electric sparking

Electric sparking is an old technique used to detect pinholes in thermoplastic liners. In this method, a high-voltage (15 to 30kV) current detects leakage to ground (through an unbonded area) by producing sparking. The method is not very sensitive to overlapped seams of the type generally used in FMLs and is used only rarely for this purpose. Today, the technique has been revived in a somewhat varied form. In the electric wire method, a copper or stainless steel wire is placed between the overlapped FML region and is actually embedded into the completed seam. After seaming, a charged probe of about 20,000 volts is connected to one end of the wire and slowly moved over the length of the seam. A seam defect between the probe and the embedded wire produces an audible alarm from the unit.

3.4.4.2.4
Pressurized dual seam

The pressurized dual seam method was mentioned earlier in connection with the dual-hot-wedge thermal seaming method. The air channel that results between the double seam is inflated using a hypodermic needle and pressurized to 200 kPa (30 lb/in^2). If no drop in pressure for a given gauged length occurs, the seam is acceptable; if a drop in pressure occurs, a number of actions can be taken:

- The distance can be systemically halved until the leak is located;
- The section can be tested by some other leak detection method; or
- A cap strip can be seamed over the entire edge.

3.4.4.2.5
Vacuum chambers

Vacuum chambers (boxes) are the most common form of nondestructive test currently used by design engineers and CQA inspectors. In the vacuum chamber method, a 1-meter (3-foot)-long box with a transparent top is placed over the seam, which has been covered with a soapy solution, and a vacuum of approximately 17 kPa (2.5 lb/in^2) is applied. If there is a leak in the seam, the vacuum is reduced due to air entering the box from beneath the liner through the leak and the soapy solution will bubble, showing the location of the leak. The test is slow to perform, and it is often difficult to achieve a vacuum-tight joint at the bottom of the box where the box passes over the seam edges. Due to the upward de-formations of the liner into the vacuum box, only FMLs with a thickness greater than 30 mils (0.75 mm) should be tested in this manner. It would be difficult to test 100 percent of the field seams by this method because of the large number of field seams and the amount of time required. This test method cannot inspect around sumps, anchor trenches or patches with any degree of assurance. The method is also essentially impossible to use on side slopes, since the downward pressure required to make a good seal cannot be obtained as it is usually done by standing on top of the box.

3.4.4.2.6
Ultrasonic methods

Ultrasonic methods may be used in a variety of seam tests. The ultrasonic equipment measures the energy transfer across a seam using two rollers: one that transmits a high frequency signal, and one that receives it. An anomaly in the signal, which is shown on an oscilloscope, indicates some change in properties, typically a void (caused by the presence of water). Ultrasonic equipment, however, will not detect a tacked, low-strength seam or dirt contamination, and the tests are highly operator-dependent. Some ultrasonic methods include:

- Ultrasonic pulse
- Ultrasonic impedance
- Ultrasonic shadow

3.5 CQA FOR LEACHATE COLLECTION AND RECOVERY SYSTEM

The purpose of leachate collection system CQA is to document that the system construction is in accordance with the design specifications. Prior to construction, all materials should be inspected to confirm that they meet the construction plans and specifications. These include:

- Geonets;
- Geotextiles;
- Pipe size, materials, and perforations;
- Granular material gradation and prefabricated structures (sumps, manholes, etc.);
- Mechanical, electrical and monitoring equipment; and
- Concrete forms and reinforcement.

The construction of the LCRS foundation (geomembrane or low-permeability soil liner) is critical. The foundation should be inspected and surveyed upon its completion to ensure that it has proper grading and is free of debris and liquids.

During construction, the following activities, as appropriate, should be observed and documented:

- Pipe bedding placement, including quality, thickness and area coverage;
- Granular filter layer placement, including material quality and thickness;
- Pipe installation, including location, configuration, grades, joints, filter layer placement and final flushing;
- Granular drainage layer placement, including protection of underlying liners, thickness, overlap with filter fabrics and geonets;

- Geonet placement, including layout, overlap and protection from clogging by granular material carried by wind or runoff during construction;

- Geotextile/geofabric placement, including coverage and overlap;

- Sumps and structure installation; and

- Mechanical and electrical equipment installation, including testing.

In addition to field observations, actual field and laboratory testing may be performed to document that the materials meet the design specifications. These activities should be documented and should include the following:

- Geonet and geotextile sampling and testing;

- Granular drainage and filter layer sampling and testing for grain size distribution; and

- Testing of pipes for leaks, obstructions, and alignments.

Upon completion of construction, each component should be inspected to identify any damage that may have occurred during its installation, or during construction of another component (e.g., pipe crushing during placement of granular drainage layer). Any damage that does occur should be repaired, and these corrective measures should be documented in the CQA records.

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4

SECTION 4.0

Landfill Gas Monitoring and Management

Page No.

List of Figures

4.1 INTRODUCTION

Unmanaged landfill gas can not only be a hazard to human health and the environment but can also cause structural problems to the landfill design components. Landfill gas, if allowed to accumulate, can result in fire, explosion and breathing conditions which are Immediately Dangerous to Life and Health (IDLH). Landfill gas can also cause odor problems and have detrimental effects on vegetation.

EPA's Subtitle D regulations require routine monitoring for methane gas accumulation and migration. The regulations also require that methane concentrations be maintained below certain levels with respect to the LEL. If regulatory action levels are exceeded, specific actions must be taken including the following: implementing immediate steps to protect human health, recording the concentrations and other pertinent information (i.e., field observations, pertinent facility design information and actions taken) in the official operating record of the landfill, implementing a remediation plan and notifying the appropriate regulatory authority (EPA or the state agencies where EPA has approved the state program) of the event within a specified time frame.

This section discusses the origin and components of the engineering systems utilized to monitor and manage landfill gas.

4.2 LANDFILL GAS GENERATION

Landfill gas generation is primarily a result of biological decomposition of the organic components of the waste. Municipal solid waste is estimated to be approximately 50 percent organic material (i.e., paper, food and agricultural/yard wastes).

4.2.1 Gas Composition

The two principal components of landfill gas are carbon dioxide (CO_2) and methane (CH_4). Minor amounts of hydrogen sulfide (H_2S), hydrogen (H_2), mercaptans and volatile organic compounds may also begenerated or released from the wastes.

The composition of gas generated in a landfill varies according to whether generation occurs in aerobic (oxygen-rich) or anaerobic (oxygen-poor) conditions. Composition also varies over time until long term, steady-state conditions are established.

- Under aerobic conditions, organic substances and oxygen are metabolized to yield carbon dioxide, water and heat, as shown in the following equation:

  Organic substances [$C_6H_{12}O_6$] + O_2
  CO_2 + H_2O + heat

- Under anaerobic conditions, organic substances are first metabolized to organic acids and then methane and carbon dioxide, as shown in the following equation:

  Organic substances [$C_6H_{12}O_6$] Organic
  Acids [COOH] CH_4 + CO_2

Methane, which is the principal component of natural gas (95 to 99 percent), is of primary concern with respect to landfill gas generation because it is combustible and flammable. Hydrogen, which is also combustible, is present at much lower concentrations because it readily reacts to form methane and hydrogen sulfide.

4.2.2
Gas Characteristics

The properties of methane, carbon dioxide and hydrogen sulfide, the most common landfill gases, may be summarized as follows:

4.2.2.1
Methane

In addition to the characteristics described, methane:

- Is colorless
- Is odorless or may have a weak odor of marsh gas
- Is tasteless
- Is a simple asphyxiant (excludes O_2)
- Reacts violently with powerful oxidizers
- Is lighter than air (molecular weight 16.05)
- Is soluble in water
- Has a LEL 5 percent by volume in air
- Has an Upper Explosive Limit (UEL) 15 percent by volume in air

4.2.2.2
Carbon Dioxide

Commonly produced in landfills, carbon dioxide:

- Is noncombustible and nonflammable
- Is colorless
- Is odorless
- Is an asphyxiant (excludes O_2)

- Is heavier than air (molecular weight 44.01)

4.2.2.3
Hydrogen Sulfide

A third gas found in landfills, hydrogen sulfide

- Is flammable
- Is colorless
- Has an offensive odor of rotten eggs [threshold detection concentration 5 parts per billion (ppb)]
- Is an olfactory desensitizer and rapidly diminishes ability to smell
- Is a very poisonous gas [IDLH 300 parts per million (ppm)]
- Is an irritant to eyes and mucous membranes
- Is an asphyxiant
- Is slightly heavier than air (molecular weight 34.08)
- Has a LEL 4 percent by volume in air
- Has an UEL 46 percent by volume in air

4.2.3
Gas Generation Phases

Landfill gas generation occurs in the following four phases, with methane being generated in the last two:

- Phase I - Aerobic Decomposition
- Phase II - Anaerobic Non-Methanogenic Decomposition

- Phase III - Anaerobic Methanogenic Decomposition
- Phase IV - Anaerobic (Steady-State) Methanogenesis

Each of these phases is described in the sections that follow. A graph showing the evolution of typical landfill gas composition is presented in Figure 4-1.

4.2.3.1
Aerobic Decomposition(Phase I)

Aerobic decomposition begins prior to placing wastes in the landfill and continues until the oxygen which is entrapped in the voids during placement and compaction is expended. This process can take several weeks or longer depending upon oxygen replenishment and/or displacement. Decreasing oxygen concentrations reduce both the biological activity and numbers of aerobic microorganisms.

4.2.3.2
Anaerobic Non-Methanogenic Decomposition (Phase II)

As oxygen becomes depleted, aerobic microorganisms are replaced by anaerobes (anaerobic microorganisms). This phase, which can last for several weeks, is characterized by increasing carbon dioxide concentrations (which may approach 65 percent), hydrogen generation and decreasing nitrogen concentrations and heat.

4.2.3.3
Anaerobic Methanogenic Decomposition (Phase III)

The anaerobic methanogenic phase begins with the production of methane. This phase, which may last for weeks or months, is characterized by a rapid rise in methane concentrations to replace carbon dioxide as the primary gas component, a continuing decline in the nitrogen concentration and depletion of hydrogen.

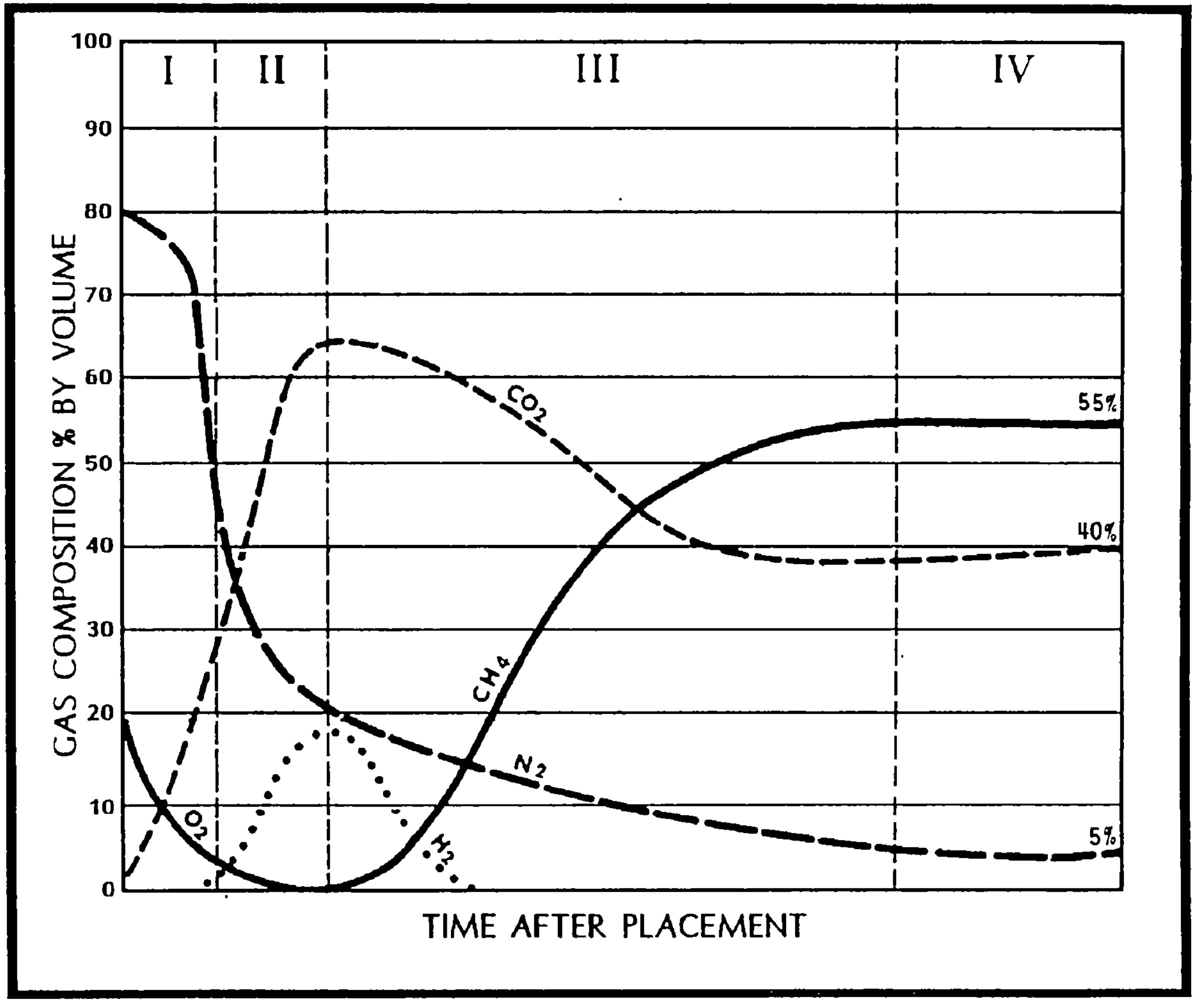
Evolution of Typical Landfill Gas Composition

I. Aerobic

II. Anaerobic, Non-Methanogenic

III. Anaerobic, Methanogenic, Unsteady

IV. Anaerobic, Methanogenic, Steady



(Modified from Farquhar and Rovers, 1973)

Figure 4-1

4.2.3.4
Anaerobic (Steady-State) Methanogenesis (Phase IV)

The methanogenesis (methane-generating) phase, which typically begins within the first 2 years after waste placement, results in decades-long steady-state methane generation with concentrations ranging between 45 to 65 percent. The other primary gas components of this phase are carbon dioxide (35 to 50 percent) and small percentages of nitrogen.

4.2.4
Factors Controlling Gas Generation

The rate and composition of landfill gas generated is dependent upon several factors:

- Moisture content
- Organic content
- Temperature and pH
- Time since waste placement
- Aerobic versus anaerobic conditions

4.2.4.1
Moisture Content

The highest methane gas generation rates occur at moisture contents ranging from 60 to 80 percent of saturation and under anaerobic conditions. Modern landfill design requirements (synthetic caps) minimize infiltration of water while creating anaerobic environments. Optimum moisture content may never be achieved or maintained in these facilities, resulting in reduced methane production rates over time. This can be beneficial in controlling gas production.

Decreased methane production may, however, affect the viability of gas (energy) recovery systems installed at the landfill. Gas production can be increased through strategies such as leachate recirculation which distributes bacteria, nutrients and moisture more uniformly within the waste.

4.2.4.2
Organic Content

Organic content of the waste is another important factor in gas generation. Methane gas generation is generally higher in municipal solid waste landfills than in construction/demolition landfills and inert industrial landfills (i.e., mining waste, fly ash and inorganic waste landfills).

4.2.4.3
Temperature and pH

Landfill temperature and pH are other factors which can affect gas generation. Methane gas generation is optimal at temperatures of 90 to 110^{o} F and within a pH range from 6.5 to 8.0. Methanogenic microorganism activity can be significantly reduced at lower temperatures and/or lower pH.

4.2.4.4
Time Since Waste Placement and Aerobic Versus Anaerobic Conditions

The impacts of time and aerobic versus anaerobic conditions on gas generation were discussed in Section 4.2.3, Gas Generation.

4.3
GAS MIGRATION

4.3.1
Gas Migration Mechanisms

Gases are transported by convection and diffusion. Convection is a migration mechanism induced by pressure gradients. Gases move from areas of high pressure to those of low pressure following the "path of least resistance." Convection resulting from buoyancy forces (methane is lighter than carbon dioxide and air) is not as significant a factor because methane and carbon dioxide are formed as a gas mixture with a density roughly equal to air. This gas mixture does not readily separate and allow methane to migrate independent of the carbon dioxide.

Diffusion is the migration of gases in response to concentration gradients. Gases will seek a uniform concentration distribution throughout the voids, moving from areas of higher concentration to those of lower concentration. Anaerobic decomposition produces a gas mixture with concentrations of methane and carbon dioxide that are much higher than those found in the surrounding air which can result in diffusion of gases through permeable (soil) landfill covers. However, uniform gas distribution is hindered by physical resistance to migration (low permeability or saturated layers). Variable rates of gas generation throughout the landfill also result in nonuniform gas distribution. Generally, diffusion plays a much smaller role in gas migration than convection.

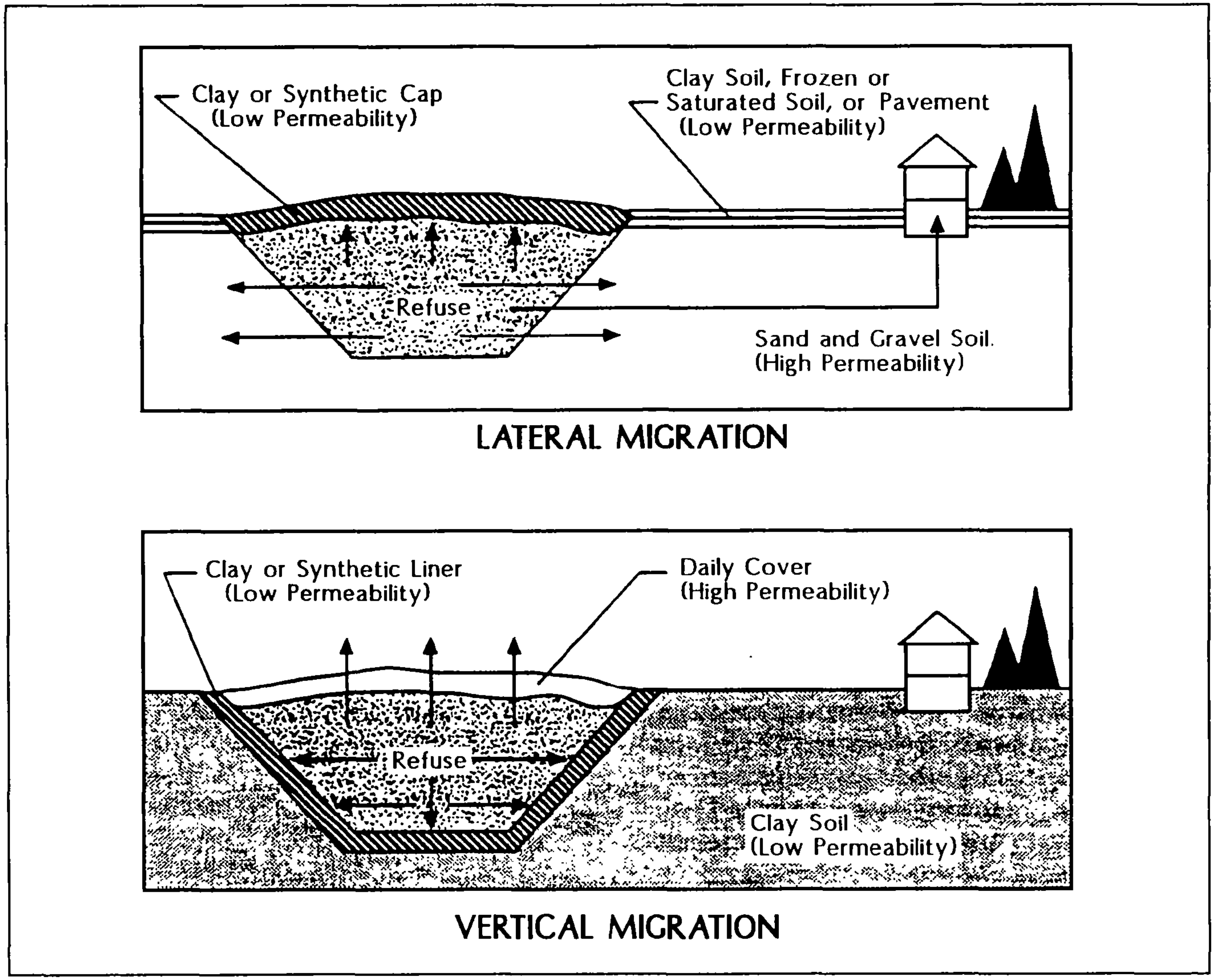
Landfill gases will migrate by convection and/or diffusion, vertically if there are no horizontal barriers, or horizontally along more permeable layers within the landfill. Permeable waste layers surrounded by low permeability or saturated layers create preferential horizontal pathways for gas migration.

4.3.2 Factors Affecting Gas Migration

Gas migration, the movement of gas within and out of a landfill, is affected by the rate of gas production and physical conditions inside and around the landfill. Low hydraulic conductivity soil layers and landfill liners are effective barriers to gas migration, while sand and gravel layers and void spaces provide effective corridors for channeling gas migration (Figure 4-2). Other channels for migration are cracks and fissures between and in lifts of waste due to differential settlement and subsidence.

Corridors at or adjacent to the landfill such as sand and gravel lenses, water conduits, drain culverts and buried utility lines can promote uncontrolled

Vertical and Lateral Migration



(Modified EMCO, 1981)

Figure 4-2
4-10

gas migration. Barriers which can impede gas migration include clay deposits, high or perched water tables, roads and compacted, low permeability soils. Figure 4-3 presents a three-dimensional view of a landfill and features affecting potential migration pathways.

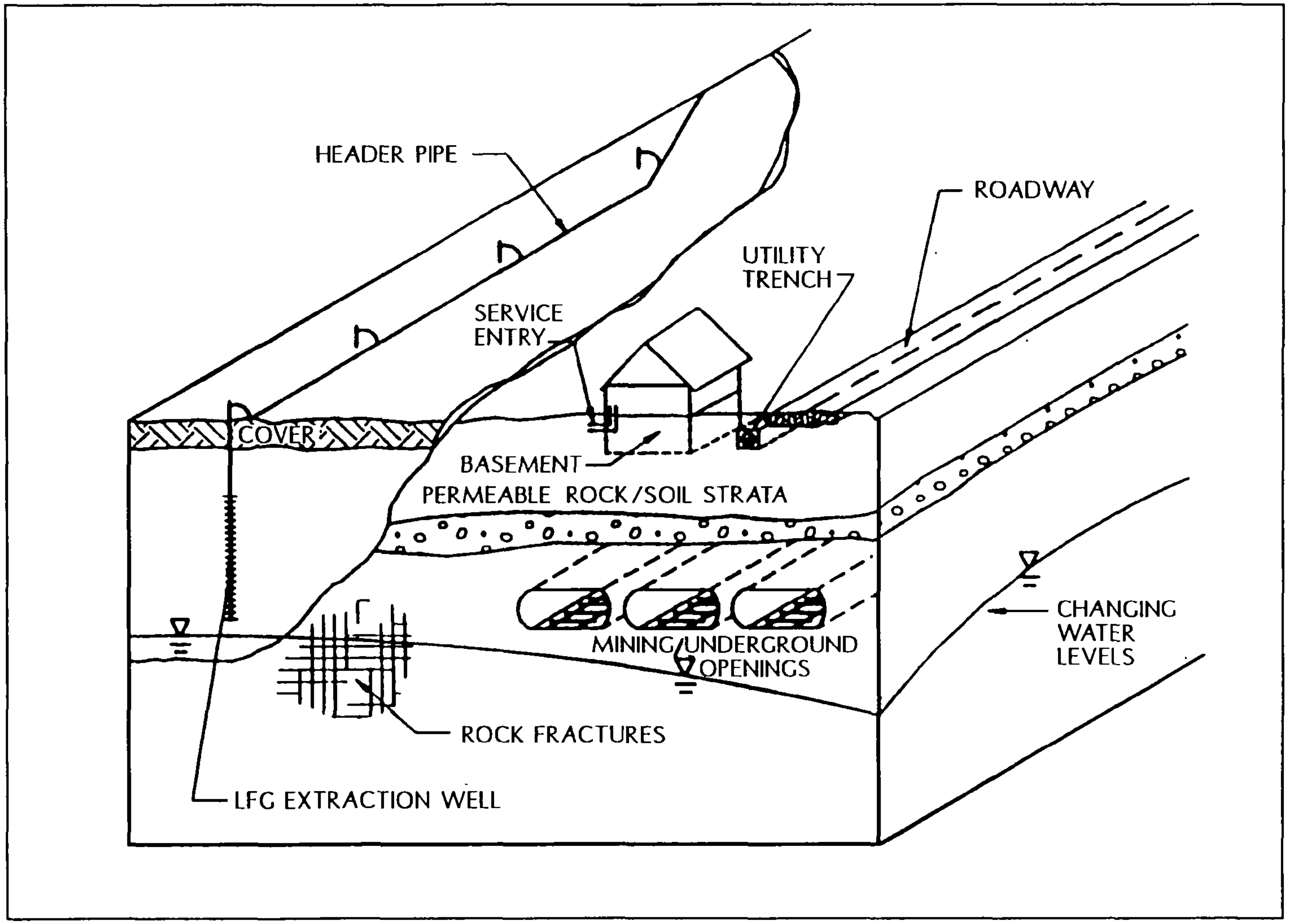
Some landfill design and operation factors which affect gas migration are:

- Landfill liner design
- Staging of cell construction
- Operation of leachate collection systems
- Incorporation of gas migration control measures
- Final cover design

Other climatic and seasonal factors which may cause variations in gas migration include the following:

- Intermittent occurrence of saturated or frozen surface soils which seals the surface and promotes lateral migration
- Barometric pressure changes which affect the rate of gas release to the surface and can induce preferential migration along different pathways
- Seasonal changes in moisture content which can change gas production rates and therefore the extent and quantity of migration

Landfill Migration Pathways



(Source: EPA, 1993)

Figure 4-3

- Infiltrating water which can displace gases in the voids and change preferential migration pathways

- Changes in soil temperature which affect the pressure gradient

4.4 GAS DETECTION MONITORING

4.4.1 Gas Detection Monitoring Program

A methane gas detection monitoring program must be implemented at all regulated MSWLFs (new, existing and lateral expansions). The routine monitoring program must ensure that methane concentrations

- Do not exceed 25 percent of the LEL (25% of 5% = 1.25% by volume in air) in facility structures excluding gas management system components, and :

- Do not exceed the LEL (5 percent by volume in air) at the facility property boundary.

At a minimum, quarterly methane gas monitoring is required for detection purposes. More frequent monitoring may be required based upon site conditions, such as:

- Increasing methane concentrations at detection monitoring locations

- Operational changes for methane gas control systems

- Operational changes for leachate collection and recirculation systems

- Landfill design changes (i.e., capping, closure or expansion)

Hourly or continuous methane detection monitoring may be necessary if the methane concentrations exceed the limits listed above. Under these conditions, the regulations also require that the following specific actions be taken within the time frames stated:

- Immediately - All necessary steps to ensure protection of human health. At a minimum, these include evacuation of personnel from the facility and notification of appropriate authorities responsible for dealing with explosive emergencies. Notify the State Director.

- Within 7 Days - Place the methane gas-level data and description of steps taken to protect human health in the operating record.

- Within 60 Days - Prepare and implement a remediation plan that describes the nature and extent of the problem and the proposed remedy. Place the remediation plan in the operating record and notify the EPA or the State Director that the plan has been implemented.

4.4.2 Monitoring SystemDesign Factors

The spacing and number of monitoring system sampling locations is unspecified in the regulations; however, they must be sufficient to provide for detection of gas migration and be protective of human health and the environment. The frequency of monitoring and the number of locations is a site-specific consideration which should be based upon

- Soil conditions (i.e., porosity, permeability and moisture content);
- Hydrogeologic conditions (i.e, thickness of unsaturated zone, continuity of permeable units and presence of impermeable barriers);
- Hydraulic conditions (i.e., depth to groundwater, infiltration potential and groundwater discharge and recharge zones);
- Facility design and changes (i.e., phasing of construction, installation of a cap, whether facility is lateral or vertical expansion);
- Location of facility structures;
- Location of property boundaries;
- Location of adjacent property structures; and
- Adjacent land uses.

4.4.3 Detection Monitoring Locations

4.4.3.1 *Ambient Conditions*

Ambient conditions should be monitored both as a safety precaution and to detect other sources of methane gas release. Ambient readings for methane and oxygen should be monitored before opening or entering any enclosed structures (wells and/or buildings). Monitoring should also be conducted while opening and prior to entering confined spaces at landfills (i.e., leachate and gas collection system entryways).

Ambient readings may indicate methane accumulation or releases from other facilities or nearby features, such as:

- Marshes, swamps and wetlands;
- Natural gas pipelines;
- Sewer lines; and
- Methane generating geologic formations.

4.4.3.2
Structures

Facility structures where gas may accumulate must be included in the monitoring program. EPA's definition of the term "structure" is broad and includes

- Pump houses
- Storage sheds
- Basements and crawl spaces
- Culverts and drains
- Any other buildings or structures where vertically or horizontally migrating gases can become trapped

4.4.3.3.
Subsurface Sampling

Two types of subsurface gas monitoring installations are commonly used: methane gas wells and gas probes. Figure 4-4 shows comparative features of gas wells and gas probes. Methane gas monitoring wells and/or probes are used to monitor gas migration between the landfill and the property boundary. Gas monitoring wells are similar in construction to groundwater monitoring wells, with granular permeable material adjacent to the screened interval and an annular seal to

Typical Landfill Gas Monitoring Well/Probe

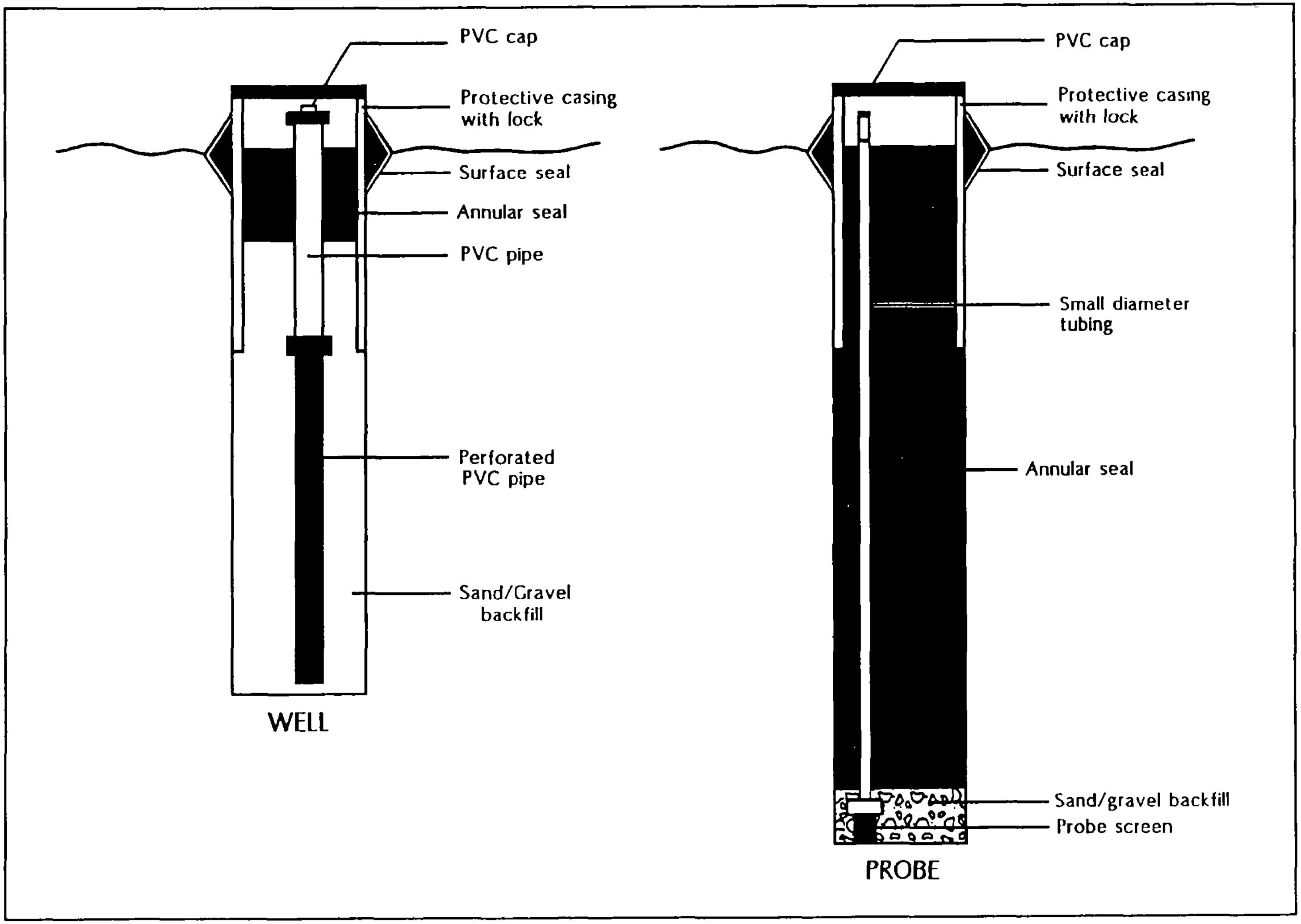


Figure 4-4

the surface. However, gas wells do not penetrate the water table; the screened interval is located within the unsaturated zone.

Gas probes are also installed in boreholes, although they are constructed with a probe tip or short interval of screen which is connected to the surface by a small-diameter tube. The monitoring interval of the gas probe is generally smaller than that of gas wells.

4.4.3.4.
Subsurface Gas Monitoring

Proper sampling techniques are essential to a gas monitoring program. Since gas monitoring wells are installed with relatively large-diameter casings (i.e., 2-inch pipe), gas concentrations within the well casing riser may not be representative of gas concentrations in the unsaturated media, necessitating evacuation of gases from the well prior to sampling. Such evacuation will help assure that gas readings are representative of gas concentrations migrating through the subsurface. When evacuating wells with a vacuum pump, the surface annulus around the evacuation line must be sealed. Otherwise, the induced vacuum will pull air in from the atmosphere (following the path of least resistance) and not from the unsaturated zone.

Evacuation may not be necessary for gas probes because of the small diameter of the tubing and the surface seal. The monitoring instrument pump can evacuate these small gas volumes and collect representative samples.

Other considerations which must be addressed in the subsurface gas monitoring program are instrumentation and oxygen and water vapor concentrations. The gas mixture in the subsurface media may be oxygen-deficient, particularly if water vapor concentrations are high as commonly occurs after rainfall events. Under such oxygen deficient conditions, instruments which measure methane by combustion (i.e., flame ionization detectors) may not provide accurate results if oxygen concentrations are below the range which will support combustion (19.5 to 25 percent). The measurement of oxygen content is essential to proper selection and operation of monitoring instruments.

4.5 PASSIVE AND ACTIVE GAS MANAGEMENT SYSTEMS

A variety of technologies are available for controlling landfill gas accumulation and migration. Landfill gas management systems are designed for two purposes: extracting gas from the landfill and controlling gas migration. Two types of systems, passive and active, are used depending upon the gas management purpose and rate of gas accumulation and migration.

The type of gas management system required is dependent upon the gas management objectives (gas removal or migration control) and a number of site factors including:

- Landfill size and age;
- Facility design (lined, capped or covered);
- Type of waste (organic content of waste);
- Waste volume and thickness; and
- Local conditions (geology, site features, adjacent land use and demographics).

Care must be taken in designing gas control systems, especially passive systems, to prevent them from providing a pathway for unwanted infiltration of surface water. Improper design could allow the vent to intercept surface runoff and pipe additional infiltration into the landfill and leachate collection system.

4.5.1 Passive Gas Management Systems

Passive gas management systems rely upon the natural forces of convection and diffusion to control landfill gas migration. Passive systems are designed to create preferential pathways for gas migration, collection and venting at controlled discharge points. Examples of passive gas management systems include the following:

- Open ditches
- Vent trenches
- Impermeable barriers
- Vent layers and vertical vents (wells)
- Substructure vents

4.5.1.1 *Open Ditches*

Open ditches can be used to provide for venting of laterally migrating gases at the perimeter of the landfill or between the landfill and the property boundary. The use of open ditches within the landfill disposal area is difficult considering the new requirements for daily cover and leachate management. The use of open ditches outside the disposal area may still be practical for controlling lateral gas migration. The effectiveness of these simple installations is also dependent upon the depth of the landfill, depth of the ditch and depth, thickness and permeability of the migration pathway.

4.5.1.2 *Vent Trenches*

Passive vent trenches are designed and constructed either to prevent lateral migration of landfill gas or to collect the gas from within the landfill.

Gravel-filled vent trenches are better than open ditches at passively venting laterally migrating landfill gas. Open vent trenches used for lateral migration control are often constructed with impenetrable barriers on the outer side of the trench, away from the methane source, to prevent migration of the landfill gas to the surrounding area.

Like open ditches, vent trenches present problems when installed within the landfill. Vent layers (discussed below) are preferable because they are designed with impenetrable barriers above the permeable layer to prevent infiltration.

Vent trenches installed outside the landfill waste disposal area often extend from the surface down to a low hydraulic conductivity soil layer or other barrier such as the water table or a Flexible Membrane Liner. These systems may be installed as deep as the bottom of the landfill if outside the waste disposal area. Cost, related to depth of installation, becomes a limiting factor in the effective application of this passive system.

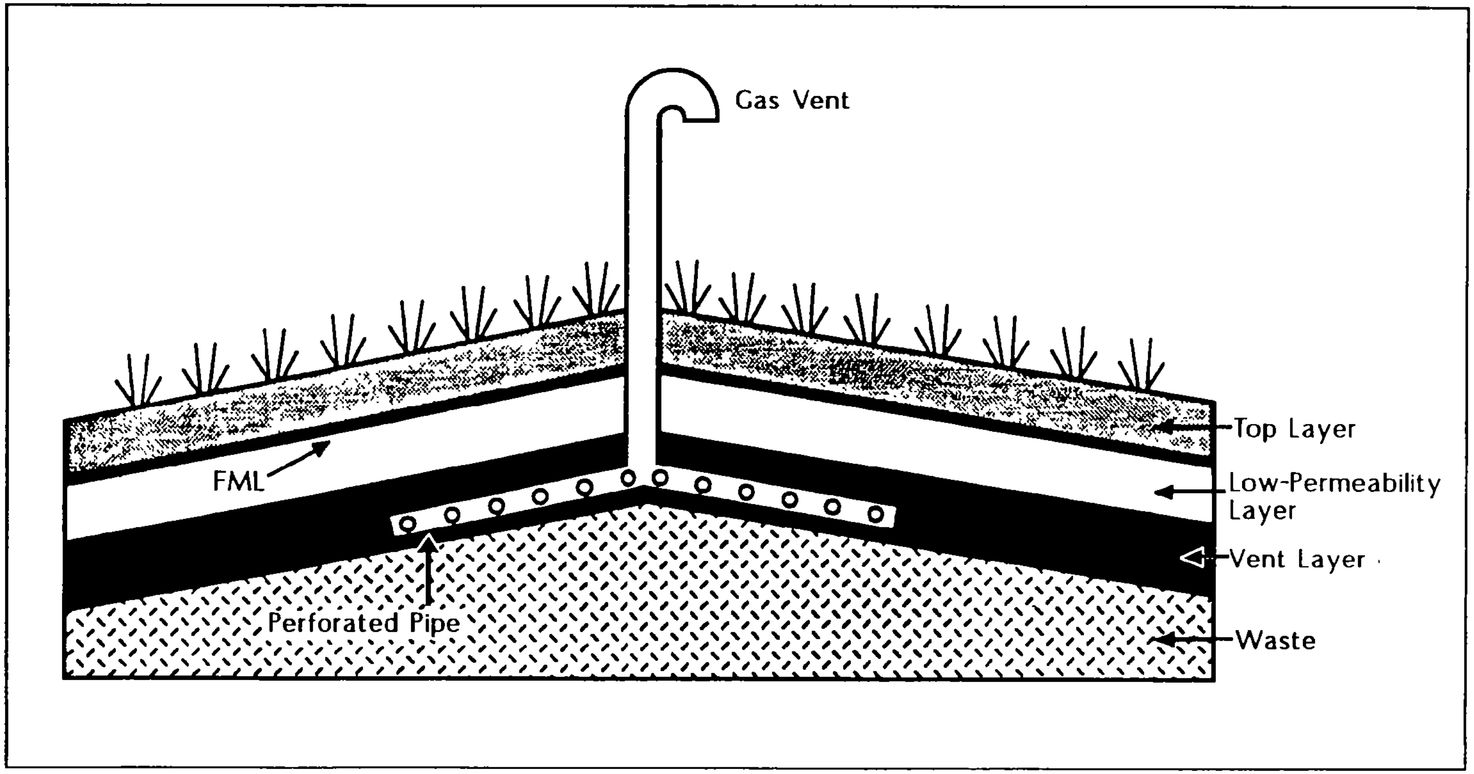
4.5.1.3 *Impermeable Barriers*

Impermeable barriers such as slurry walls can be used to create a barrier to gas migration. Other materials which also create impermeable barriers and could be used to prevent lateral gas migration are Flexible Membrane Liners or water infiltration barriers (i.e., constructed wetlands or stormwater retention/infiltration ponds).

4.5.1.4 *Vent Layers and Vertical Vents (Wells)*

Vent layers and vertical vents are gas management system components which are commonly installed within the landfill for either passive or active gas removal purposes (figures 4-5 and 4-6). Passive gas management systems may incorporate vent layers constructed of highly permeable material (i.e., gravel), composite covers and verti-

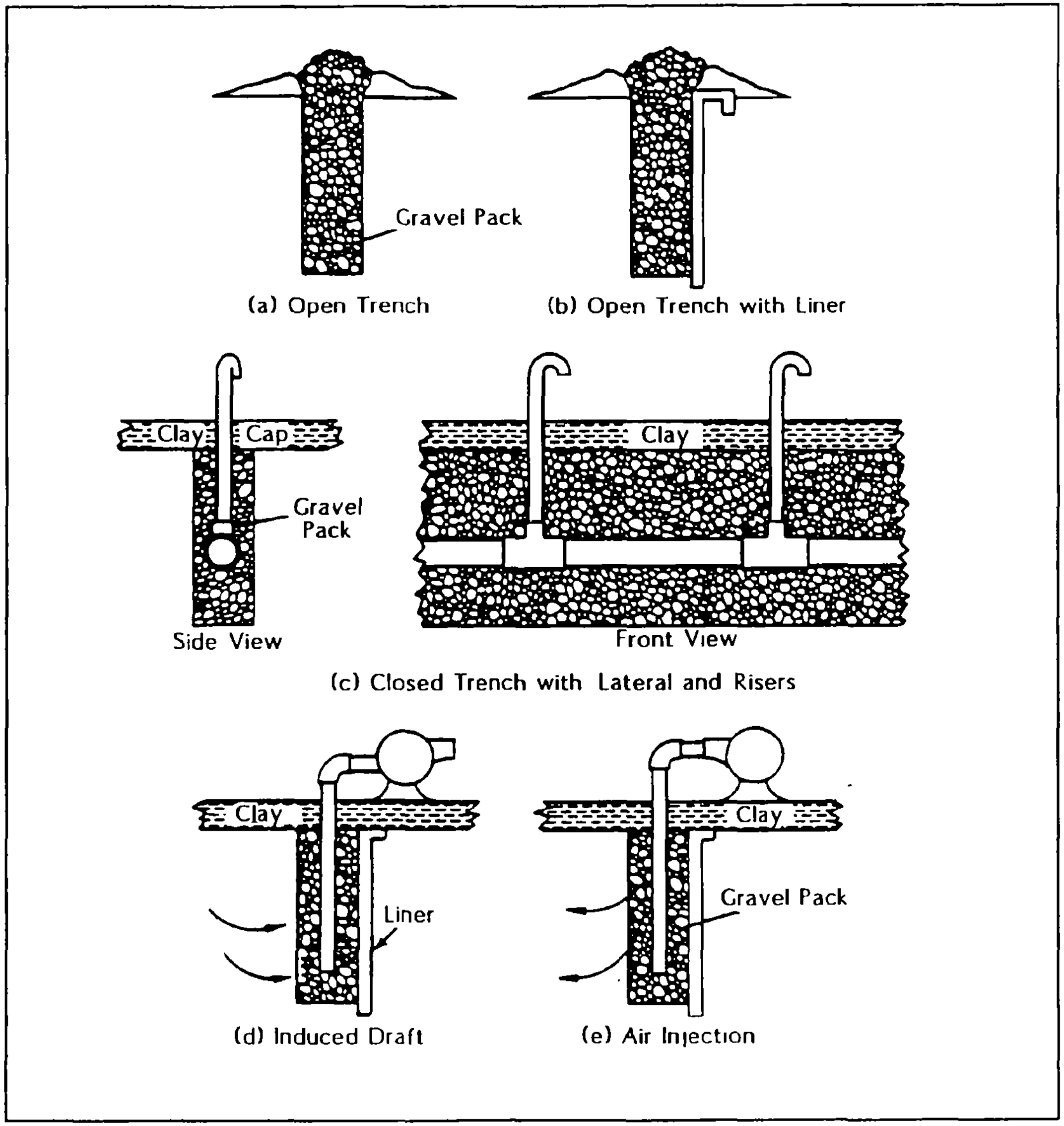
Typical Passive Vent Layer Gas Management System



(Source: EPA, 1993)

Figure 4-5
4-20

Vent Layers and Vertical Vents (Wells)



(Source: EPA, 1982)

Figure 4-6

cal vents to release gas from the landfill. The composite cover prevents uncontrolled vertical migration, while the vent layer intercepts vertically migrating gas and directs it to the surface via vent pipe(s) that are installed along the high point of the waste cell. The vertical vents (wells) may extend deeper into the landfill to provide a vertical migration pathway for gas to enter the vent layer from deeper layers within the landfill. These systems induce landfill gas to migrate vertically rather than laterally.

4.5.1.5
Substructure Vents

Substructure vent systems can be installed to prevent gases from accumulating beneath structures. Passive substructure vent systems require placement of a permeable system (piping and gravel layer) beneath the foundation slab of the structure to provide a preferential pathway for gas venting, thereby preventing migration of landfill gas into the structure. The gas must be vented away from the structure to prevent accumulation in other traps (i.e., overhangs, utility closets or the structure itself).

4.5.1.6
Active Gas Management Systems

Active gas management (extraction) systems use mechanical components to control and collect landfill gas. Active systems create positive or negative pressure gradients to drive the landfill gas to the point of extraction. Examples of active gas management systems include the following:

- Extraction systems (trenches and/or wells)
- Injection barriers
- Substructure extraction

In order to be effective, active gas extraction systems must be designed to draw gas from throughout the landfill and not preferentially from air infiltration conduits. Factors which must be considered in designing active gas extraction systems include the following:

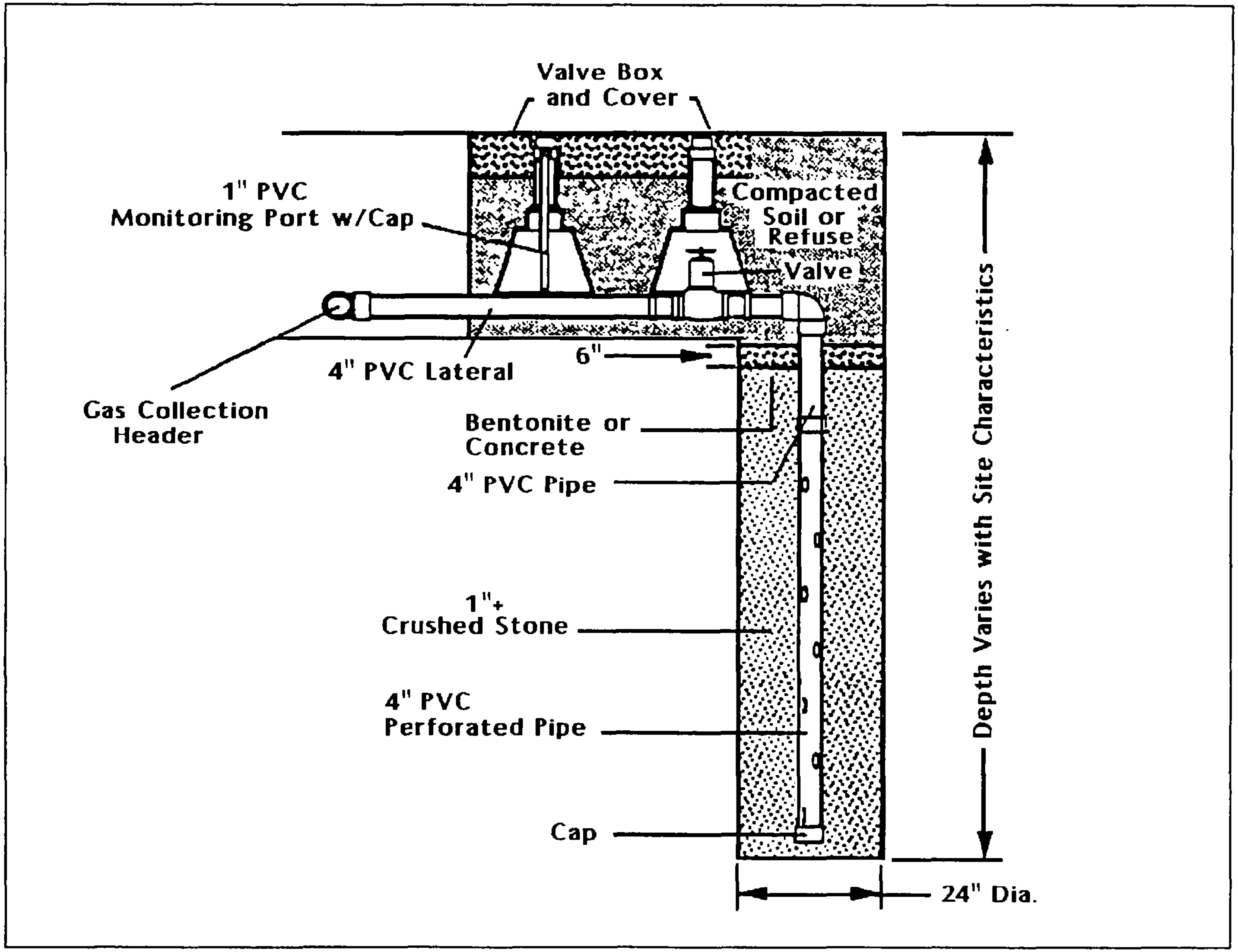
- Facility design (lined and unlined cells);
- Disposal practices (waste disposal in discrete cells); and:
- Thickness of the landfill (highest methane generation potential is in the center of the landfill where waste placement is thicker).

4.5.1.7
Extraction Systems (Trenches and/or Wells)

Active gas extraction systems may include a series of trenches and/or wells with collection headers for extracting gases from deeper layers within the landfill. Trenches are generally employed as perimeter gas extraction systems or at shallow depths within the landfill while wells are more practical as primary extraction systems in the thickest portions of the landfill. The well casings and/or piping installed within the trenches are connected to extraction blowers or pumps. Typical active gas extraction wells and trenches are shown in figures 4-7 and 4-8. Gas extraction wells do not have to extend to the bottom of the landfill since suction applied to the system is able to draw gas from a sizeable area beyond the gravel pack which surrounds the well screen.

Impermeable barriers in the cover and landfill perimeter walls increase the efficiency of active gas extraction systems since they restrict inflow of air that would dissipate the suction. These barriers also reduce the number of wells and/or trenches

Typical Gas Extraction Well

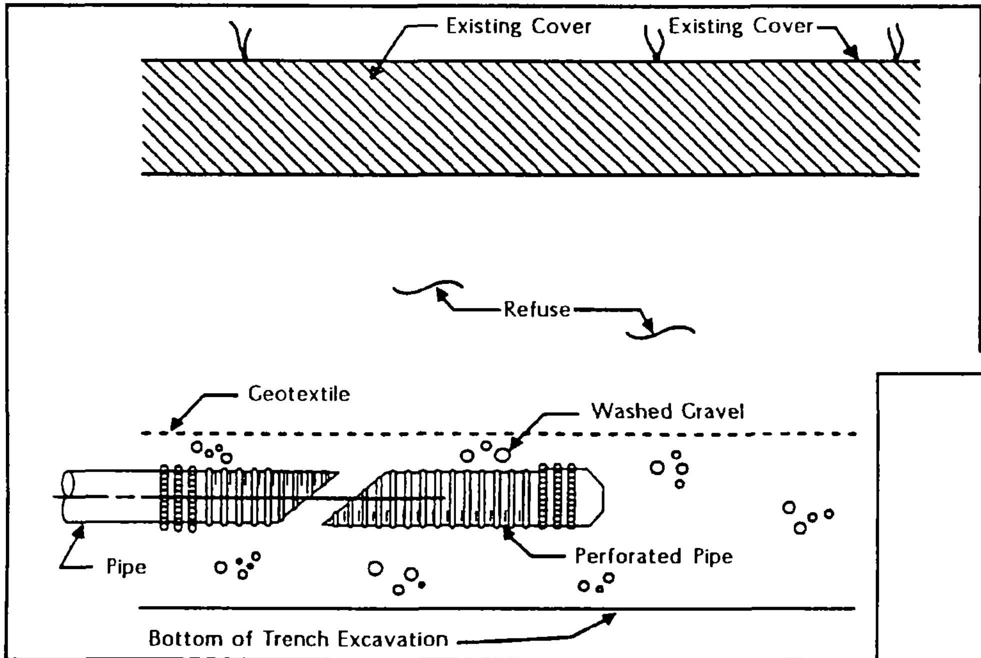


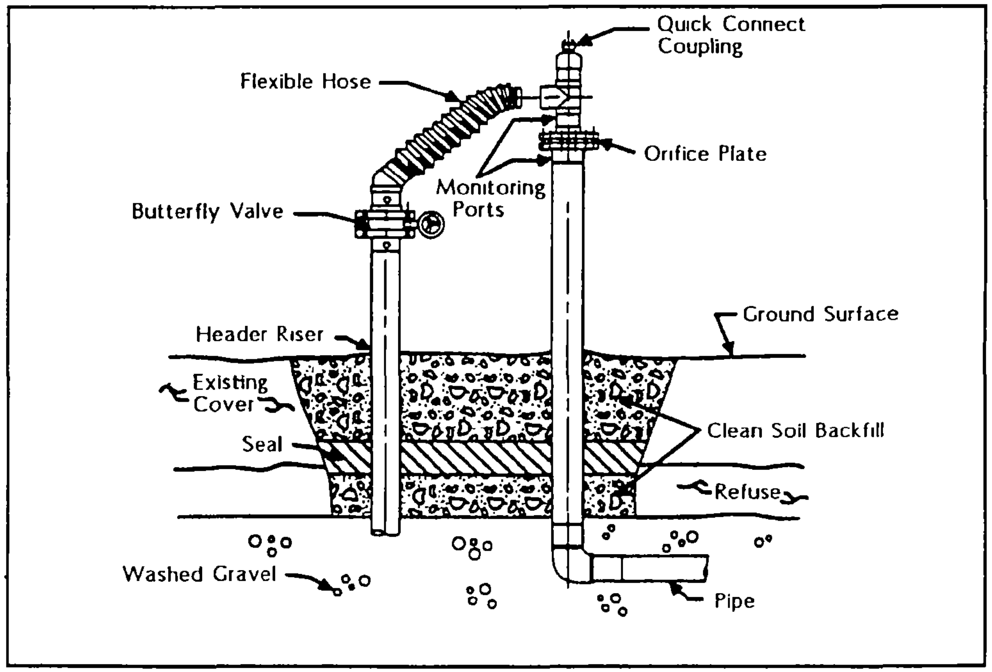
(Source: SCS, 1980)

Figure 4-7
4-23

Typical Gas Extraction

Trench and Header





(Source: SWANA, 1991)

Figure 4-8
4-24

needed and increase the heating value of the gas collected.

Gas extraction systems should be designed so that portions of the system can be disconnected or shut off as necessary to adjust for increased infiltration of surface air due to active disposal or insufficient or permeable cover. If properly designed and operated, methane gas extraction systems can be used for energy production or as the primary fuel for a flare.

4.5.1.8
Injection Barriers

Injection of air or water can be used as an active mechanism to restrict lateral migration of landfill gases. Air injection systems are installed in a perpendicular direction to the gas migration pathway. Air is injected through a header system to create a subsurface pressure gradient which restricts or reverses the direction of gas migration. Water injection barriers are not commonly used for gas migration control; however, infiltration galleries can be used to impede gas migration at shallow depths.

4.5.1.9
Substructure Extraction

Active substructure extraction systems are similar to passive substructure venting systems, but are more effective in providing for controlled removal of gases. Active substructure extraction systems can also be designed for short-term remediation purposes where the system is installed above the slab (in basements or crawl spaces).

4.6 GAS MANAGEMENT SYSTEM OPERATION AND MONITORING

Gas management systems are constructed and operated both within the landfill (primary wellfields) and at the perimeter of the landfill (either inside or outside of the landfill waste disposal area). Both types of systems must be monitored for optimal performance.

4.6.1 Primary Gas Extraction Wellfields

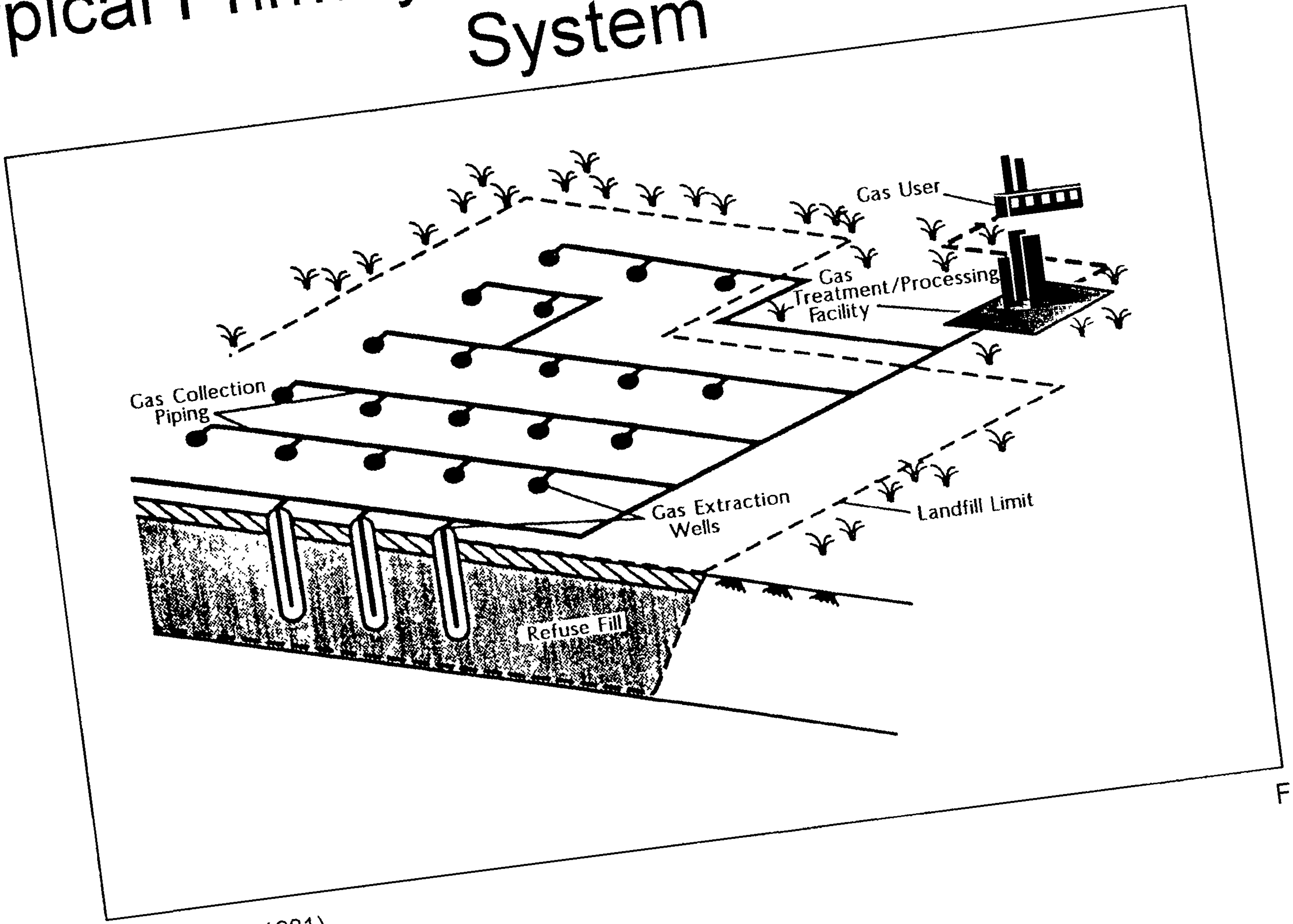
Primary (interior) gas extraction wellfields are the most efficient and often the largest component of a comprehensive gas extraction system. Their function is to collect most of the landfill gas at the point of generation (within the landfill.) Extraction wellfield systems normally include a number of wells spaced evenly over the entire landfill (Figure 4-9). Spacing and design of the extraction well field is dependent upon landfill design (lined or unlined), waste voids and layering and landfill cell configuration. Separate extraction well systems may be necessary to segregate gas extraction from high and low methane generation areas.

Improper operation of gas extraction well systems can result in excess emissions of landfill gas to the atmosphere, gas migration and overpulling of the wellfield which can disrupt anaerobic decomposition or cause subsurface fires.

The frequency of gas extraction wellfield monitoring will vary depending upon field requirements and conditions. Normal monitoring frequency for a complete field monitoring program will vary from once a week to once a month. Wellfield monitoring should not normally be extended beyond once a month, especially on active landfills. Too many things can happen which can result in inefficient or detrimental operation of the gas extraction system.

The importance of regular, timely and thorough monitoring cannot be overemphasized. Improper operation of the primary gas extraction wellfield system puts additional requirements on perimeter gas migration control systems.

Typical Primary Gas Extraction Wellfield System



(Source: EMCON, 1981)

Figure 4-9
4-25

4.6.2 Perimeter Gas Migration Control Systems

Perimeter gas migration control systems extract poor quality landfill gas that is often high in oxygen due to air intrusion at the interface of the landfill and the native soil. Operating objectives for the perimeter system are different than for the primary gas extraction wellfield system. The perimeter system provides a final opportunity to capture gas before it escapes from the landfill and migrates to adjacent properties or structures.

Perimeter gas migration control systems may be installed within the landfill near the perimeter or in native soil adjoining the landfill depending upon the design objectives for controlling gas migration. Gas migration pathways can change drastically at the perimeter, making gas quality and control difficult. For this reason, perimeter gas wells or trenches are often tied into a separate extraction system.

Perimeter gas management systems generally require more frequent monitoring on a weekly or even daily basis depending upon the methane concentration of the migrating gas. The danger of subsurface fires, caused by air intrusion, is more significant where perimeter gas management systems are operated at high extraction rates.

Landfill gas migration is usually decreased if the primary gas management system pulls gas toward the center of the landfill instead of allowing the landfill gas to be pulled toward the perimeter system. The perimeter migration system, then, only has to extract locally generated gas rather than gas already migrating towards the perimeter of the landfill.

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5

SECTION 5.0

Final Cover System

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List of Figures

5.1 INTRODUCTION

The MSWLF's final cover is subject to stresses from both the natural elements and the landfill itself. A poorly designed cover system can result in the exposure of wastes and uncontrolled releases of gas and leachate. Section 5 discusses the final cover requirements of 40 CFR 258 and the methods available to the engineer to ensure that a well-designed and maintained final cover is in place.

5.2 REGULATORY REQUIREMENTS

The Subtitle D Regulations pertaining to final cover prescribe minimum design requirements, provide for alternative designs and require preparation of a closure plan.

5.2.1 Minimum Design Requirements

The final cover system comprises an erosion layer underlain by an infiltration layer as follows:

- Erosion layer to be a minimum of 6 inches of earthen material that is capable of sustaining native plant growth; and

- Infiltration layer to be a minimum of 18 inches of earthen material that has a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present, or a permeability no greater than 1 x 10^{-5} cm/sec, whichever is less.

The final cover must have a hydraulic conductivity less than or equal to any bottom liner system or natural subsoils present in order to prevent a "bathtub" effect. This effect occurs when the cover is more permeable than the bottom liner, allowing more water to enter the landfill than can be released, causing the landfill to fill with water like a "bathtub." In no case can the final cover have a hydraulic conductivity greater than 1×10^{-5} cm/sec regardless of the permeability of the underlying liners or natural soils. If an FML is in the bottom liner, there must be an FML in the final cover to achieve a permeability that is less than or equal to that of the bottom liner (see 57 Federal Register 28626, June 26, 1992, Figure 5-1).

5.2.2 Alternate Cover Design

An alternate final cover design may be approved by the director of an approved state providing that it includes the following:

- An infiltration layer that achieves a reduction in infiltration equivalent to the minimum design requirements; and:
- An erosion layer that provides protection from wind and water erosion equivalent to the minimum design requirements.

5.2.3 Closure Plan

A written closure plan must be prepared that describes the steps necessary to close all MSWLF units at any point during the active life of the MSWLF. The closure plan must, at a minimum, include the following information:

- A description of the final cover and the methods and procedures to be used to install the cover;
- An estimate of the largest area of the MSWLF unit ever requiring a final cover at any time during the active life;
- An estimate of the maximum inventory of wastes onsite at any given time over the active life of the landfill facility; and

Minimum Final Cover Design

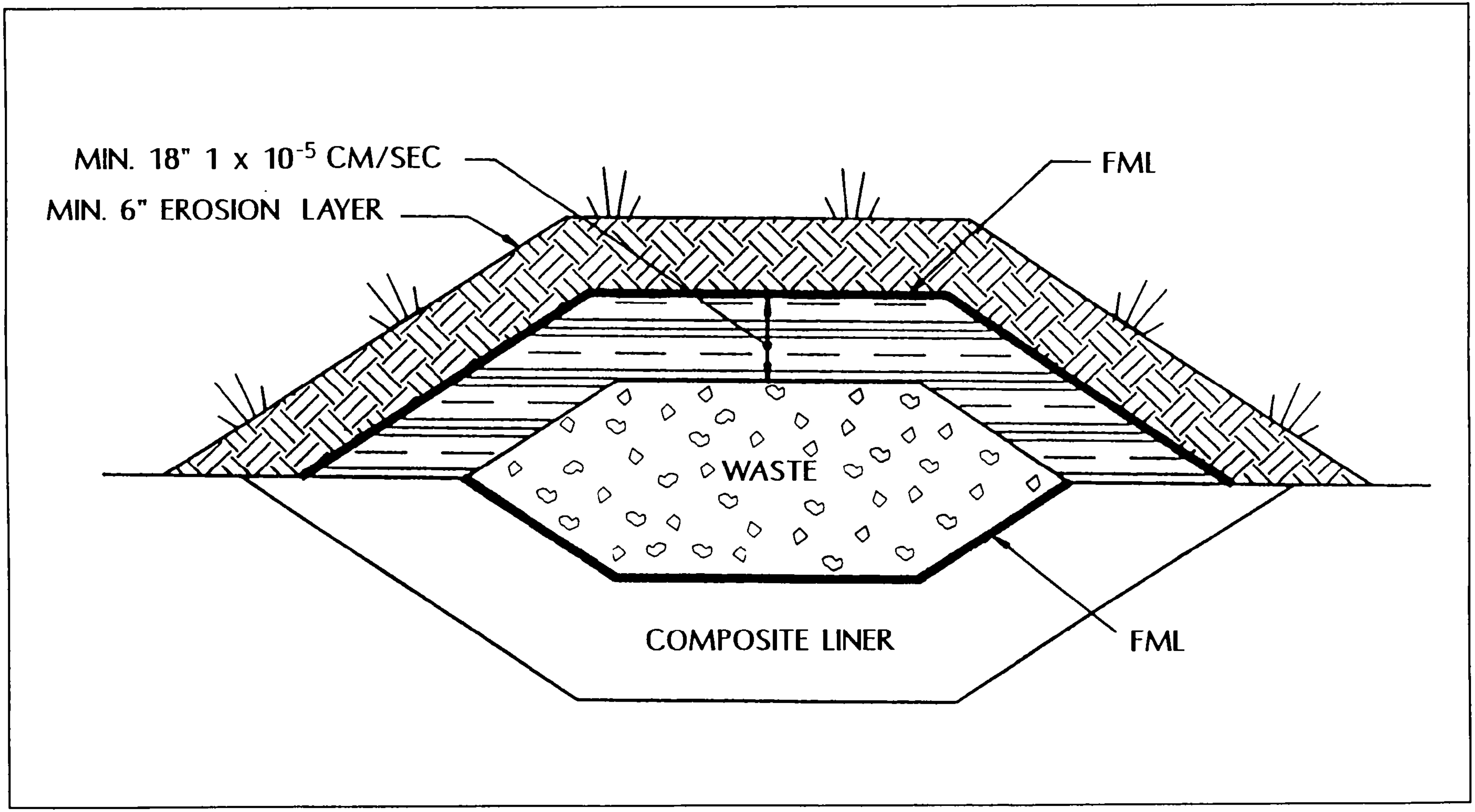


Figure 5-1

- A schedule for completing all activities necessary to satisfy the closure criteria.

5.3 TECHNICAL CONSIDERATIONS

Design criteria for a final cover system should be selected to

- Minimize infiltration of precipitation into the waste
- Promote good surface drainage
- Resist erosion
- Control landfill gas migration and/or enhance recovery
- Separate waste from vectors (e.g., animals and insects)
- Improve aesthetics
- Minimize long-term maintenance
- Protect human health and the environment
- Consider final use

The first three points listed above are directly related to the regulatory requirements. The other points are typically considered when designing cover systems for landfills.

Reduction of infiltration in a well-designed final cover system is achieved through

- Good surface drainage and runoff with minimal erosion

- Transpiration of water by plants in the vegetative cover and root zone

- Restriction of percolation through earthen material

The cover system should be designed to provide the desired level of long-term performance with minimal maintenance. Surface water runoff should be properly controlled to prevent excessive erosion and soil loss. A key to protecting the cover from erosion is the establishment of a healthy vegetative layer; however, consideration must also be given to selecting plant species that are not deeply rooted because they could damage the underlying infiltration layer. In addition, the cover system should be geotechnically stable to prevent failure, such as sliding, that may occur between the erosion and infiltration layers, within these layers or within the waste.

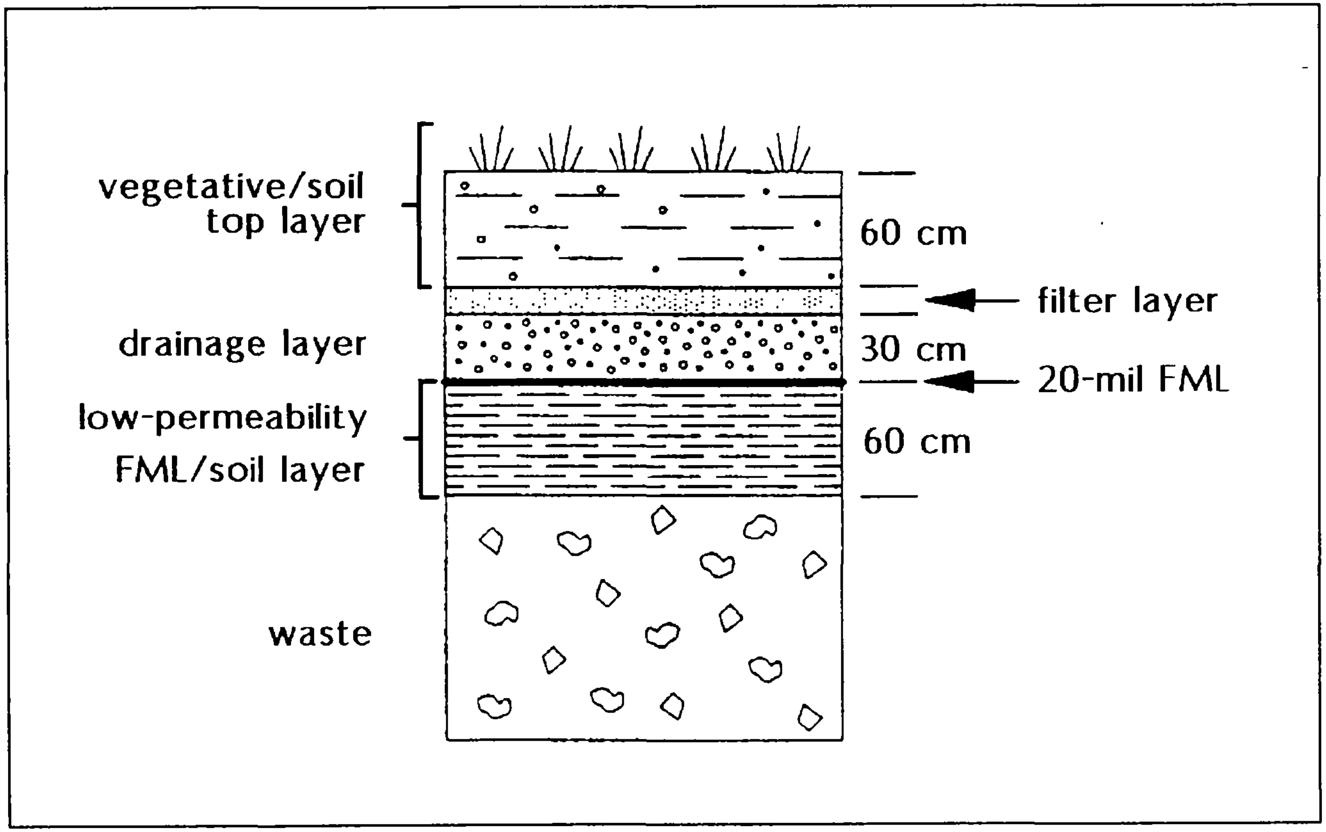
5.4 TYPICAL COMPONENTS OF A FINAL COVER SYSTEM

Although the regulations require that a final cover comprise an erosion layer and an infiltration layer, a final cover system, as shown in Figure 5-2, typically consists of the following four components:

- A compacted low-permeability soil layer (infiltration layer) placed over the waste. This soil layer is typically 60 cm (24 inches) thick and is required to have a permeability less than or equal to the bottom liner system;

- An FML with a minimum thickness of 20 mils, with bedding material above and below the FML;

Typical Final Cover Design



(Source: EPA, 1990)

Figure 5-2

- A drainage layer with a minimum hydraulic conductivity of 1×10^{-2} cm/sec and a final bottom slope of 2 percent; and

- A vegetative layer or soil cover (erosion layer) with a minimum thickness of 60 cm (24 inches) to promote growth and minimize erosion.

5.4.1 Infiltration Layer

The infiltration layer must be at least 18 inches thick, but is typically 24 inches thick. It must also consist of earthen material that has a hydraulic conductivity less than or equal to the hydraulic conductivity of any bottom liner system or natural subsoils. MSWLF units with poor or nonexistent bottom liners possessing hydraulic conductivities greater than 1×10^{-5} cm/sec must have an infiltration layer that meets the 1×10^{-5} cm/sec minimum requirement.

For units that have a composite liner with an FML, or naturally occurring soils with very low permeability (e.g., 1×10^{-8} cm/sec), the infiltration layer in the final cover will include a synthetic membrane as part of the final cover.

The earthen material used for the infiltration layer should be free of rocks, clods, debris, cobbles, rubbish and roots that may increase the hydraulic conductivity by promoting preferential flow paths. To facilitate runoff while minimizing erosion, the surface of the compacted soil should have a minimum slope of 3 percent and a maximum slope of 5 percent after allowance for settlement. It is critical that side slopes, which are frequently greater than 5 percent, be evaluated for erosion potential.

The infiltration layer is designed and constructed in a manner similar to that used for soil liners, with the following differences:

- Because the cover is generally not subject to large overburden loads, the issue of compressive stresses is less critical unless post-closure land use will entail construction of objects that exert large amounts of stress.

- The soil cover is subject to loadings from settlement of underlying materials. The extent of settlement anticipated should be evaluated and a closure and post-closure maintenance plan should be designed to compensate for the effects of settlement.

- Direct shear tests performed on construction materials should be conducted at lower shear stresses than those used for liner system designs.

The design of a final cover is site-specific and the relative performance of cover design options may be compared and evaluated by the HELP model (see section 5.7).

5.4.2 FML Layer

The minimum thickness of the FML should be no less than 20 mils (0.5 mm). This is generally believed to be the minimum acceptable thickness to meet cover objectives and still be sufficiently rugged to withstand expected stresses during construction and operation. In many cases, if not most, the thickness should be greater. If HDPE is used, the recommended minimum thickness is 60 mils due to difficulties in making consistent field seams in thinner material. The adequacy of the selected thickness should be demonstrated by an evaluation considering the type, strength and durability of the proposed FML material, its seamability and site-specific factors such as

- Types of under- and overlying layers
- Stresses of settlement
- Expected overburden
- Climatic conditions
- Subsidence

One of the causes of FML failure in landfill lining systems is chemical incompatibility, as discussed in Section 2.0. However, the FML in a final cover should not come in direct contact with any wastes, and chemical incompatibility should not be of concern. This makes it possible to accept a wider range of FML materials in cover systems.

The FML component must have the following characteristics:

- The thickness of the FML should be at least 20 mils or 60 mils if HDPE.
- The surface of the FML should have a minimum 3-percent slope after allowance for settlement.
- There should be no surface unevenness, local depressions or small mounding that create depressions capable of containing or otherwise impeding the rapid flow and drainage of infiltrating water.

- The FML should be protected by an overlying drainage layer of at least 30 cm (12 inches) of soil material (see Section 5 4 3).

- The FML should be in direct contact with the underlying compacted soil component and should be installed on a smoothed soil surface.

- The number of penetrations of the FML by designed structures (e.g., gas vents) should be minimized. Where penetrations are necessary, the FML should be sealed securely around the structure.

5.4.3 Drainage Layer

The drainage layer should be designed to minimize the amount and residence time of water coming into contact with the low-permeability layer (infiltration layer), thereby decreasing the potential for leachate generation. The drainage layer construction materials and configuration should facilitate the rapid and efficient removal of water to an exit drain.

The drainage layer should be designed, constructed and operated to function without clogging. Physical clogging may be prevented by incorporating a filter layer of soil or geosynthetic material between the top layer and the drainage layer. The prevention of biological clogging may range from limiting vegetation to shallow-rooted species to the installation of a biotic barrier.

In arid locations, the need for a drainage layer should be based on consideration of precipitation event frequency and intensity and sorptive capacity of other soil layers in the cover system. It may be possible to construct a top layer that will absorb most, if not all, of the precipitation that infiltrates into that layer, eliminating the need for a drainage layer.

If composed of granular material, such as sand, the recommended design for a drainage layer is as follows:

- Minimum thickness of 30 cm (12 inches) and minimum slope of 3 percent at the bottom of the layer, greater thickness and/or slope if necessary to provide sufficient drainage flow as determined by site-specific hydrologic modeling (e.g., HELP model, Section 5.7).

- Hydraulic conductivity of drainage material no less than 1 x 10^{-2} cm/sec at the time of installation.

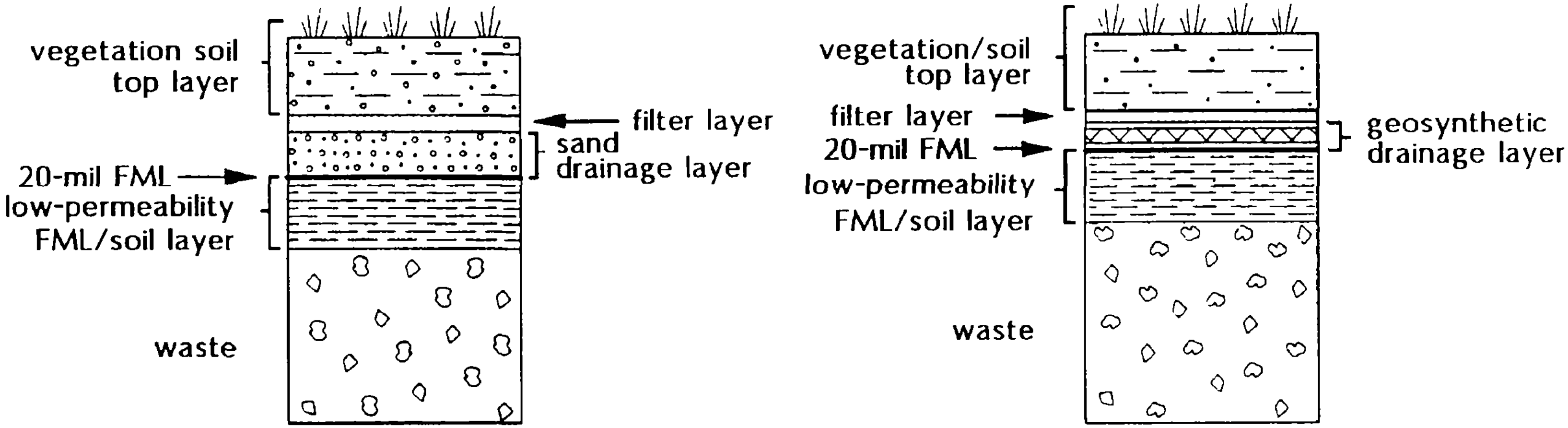
Granular material no coarser than 3/8 inch (0.95 cm), and classified as SP; should be smooth and rounded and should contain no debris that could damage the underlying FML,. nor fines that might lessen permeability.

- A filter layer (granular or synthetic) included between the drainage layer and top layer, if necessary, to prevent clogging of the drainage layer by fine particles.

If composed of geosynthetic materials, the recommended design for a drainage layer is as follows (Figure 5-3):

- Same minimum flow capability as a granular drainage layer in the same situation; hydraulic conductivity no less than 1 x 10^{-2} cm/sec under anticipated overburden for the design life.

Drainage Layer Options



Coverage with sand drainage layer.

Cover with geosynthetic drain layer.

(Source: EPA, 1989)

Figure 5-3
5-14

- Inclusion of a geosynthetic filter layer above the drainage material to prevent intrusion and clogging by the overlying top layer soil material.

- Inclusion of geosynthetic bedding beneath the drainage layer, if necessary, to increase friction and minimize slippage between the drainage layer and the underlying FML.

5.4.4 Erosion Layer

The erosion layer typically consists of two components: an upper vegetation component underlain by a soil component, usually topsoil.

The vegetation component of the erosion layer should have the following characteristics:

- Locally adapted perennial plants;

- Resistance to drought and temperature extremes;

- Roots that will not disrupt the low-permeability infiltration layer;

- Capability of thriving in low-nutrient soil with minimum nutrient addition;

- Sufficient plant density to minimize cover soil erosion to no more than 2 tons/acre/year, calculated using the USDA Universal Soil Loss Equation; and

- Capability of surviving and functioning with little or no maintenance.

The lower soil component of the erosion layer should have the following characteristics:

- A minimum thickness of 60 cm (24 inches), including at least 15 cm (6 inches) of topsoil for vegetation support; greater total thickness where required (e.g., where maximum frost penetration exceeds this depth, or where greater plant-available water storage is necessary or desirable);

- Medium texture to facilitate seed germination and plant root development;

- Final top slope, after allowance for settling and subsidence, of at least 3 percent, but no greater than 5 percent, to facilitate runoff while minimizing erosion; and

- Minimum compaction to facilitate root development and sufficient infiltration to maintain growth through drier periods.

The thickness of the erosion layer is influenced by depth of frost penetration and erosion potential. Erosion can adversely affect the performance of the final cover of a MSWLF unit by causing rills that require maintenance and repair. As previously mentioned, a healthy vegetative layer can protect the cover from erosion. Conversely, severe erosion can affect the vegetative growth.

Extreme erosion may lead to the exposure of the infiltration layer, initiate or contribute to sliding failures or expose the waste. Anticipated erosion due to surface water runoff for given design criteria may be approximated using the U.S. Department of Agriculture Universal Soil Loss Equation. By evaluating erosion loss, the design may be optimized to reduce maintenance through selection of the best available soil materials or by initially adding excess soil to increase the time required before maintenance is needed.

Parameters in the equation include the following:

X = RKLSCP
where:
X = Soil loss (tons/acre/year)
R = Rainfall erosion index
K = Soil erodibility index
L = Slope length factor
S = Slope gradient factor
C = Crop management factor
P = Erosion control practice

Values for the Universal Soil Loss Equation parameters may be obtained from the U.S. Soil Conservation Service (SCS) technical guidance document entitled "Predicting Rainfall Erosion Losses, Guidebook 537" (1978), available at local SCS offices located throughout the United States.

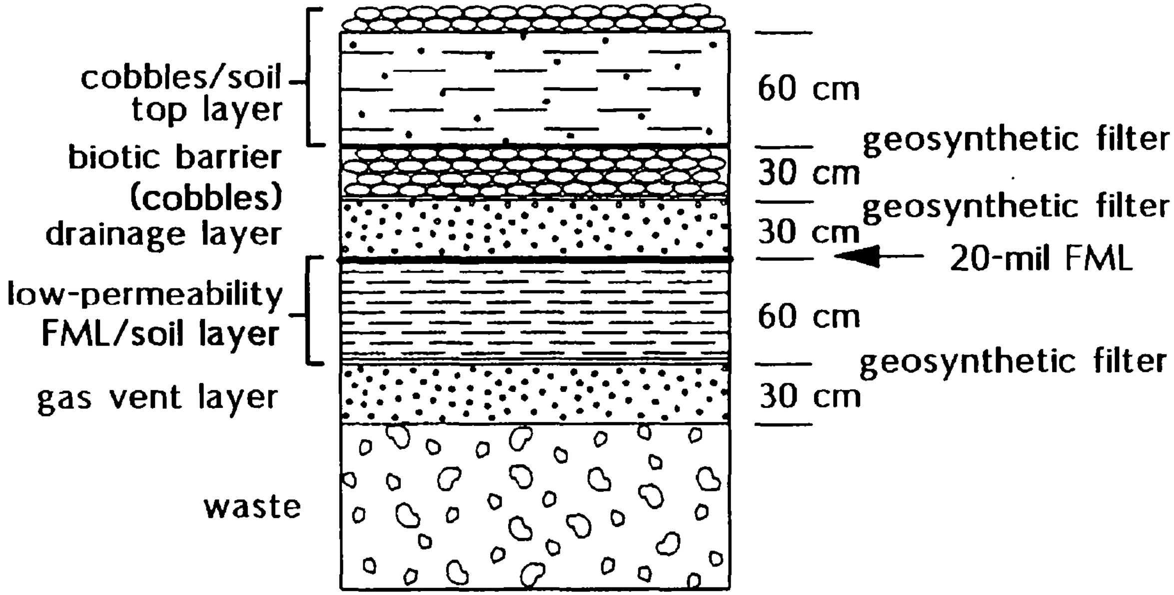
5.4.5 Optional Layers

Other components that may be used in the final cover system include a gas vent layer and a biotic layer (figures 5-4 and 5-5). These components are discussed in the following two sections.

5.4.5.1 Gas Vent Layer

If an FML is used as part of the final cover system, it will prevent the infiltration of moisture to the waste below and may contribute to the collection of waste decomposition gases, therefore necessitating a gas vent layer. The gas vent layer should be at least 30 cm (12 inches) thick and be above the waste and below the infiltration layer. Coarse-grained porous material, similar to that used in the drainage layer or equivalent-performing synthetic material, can be used.

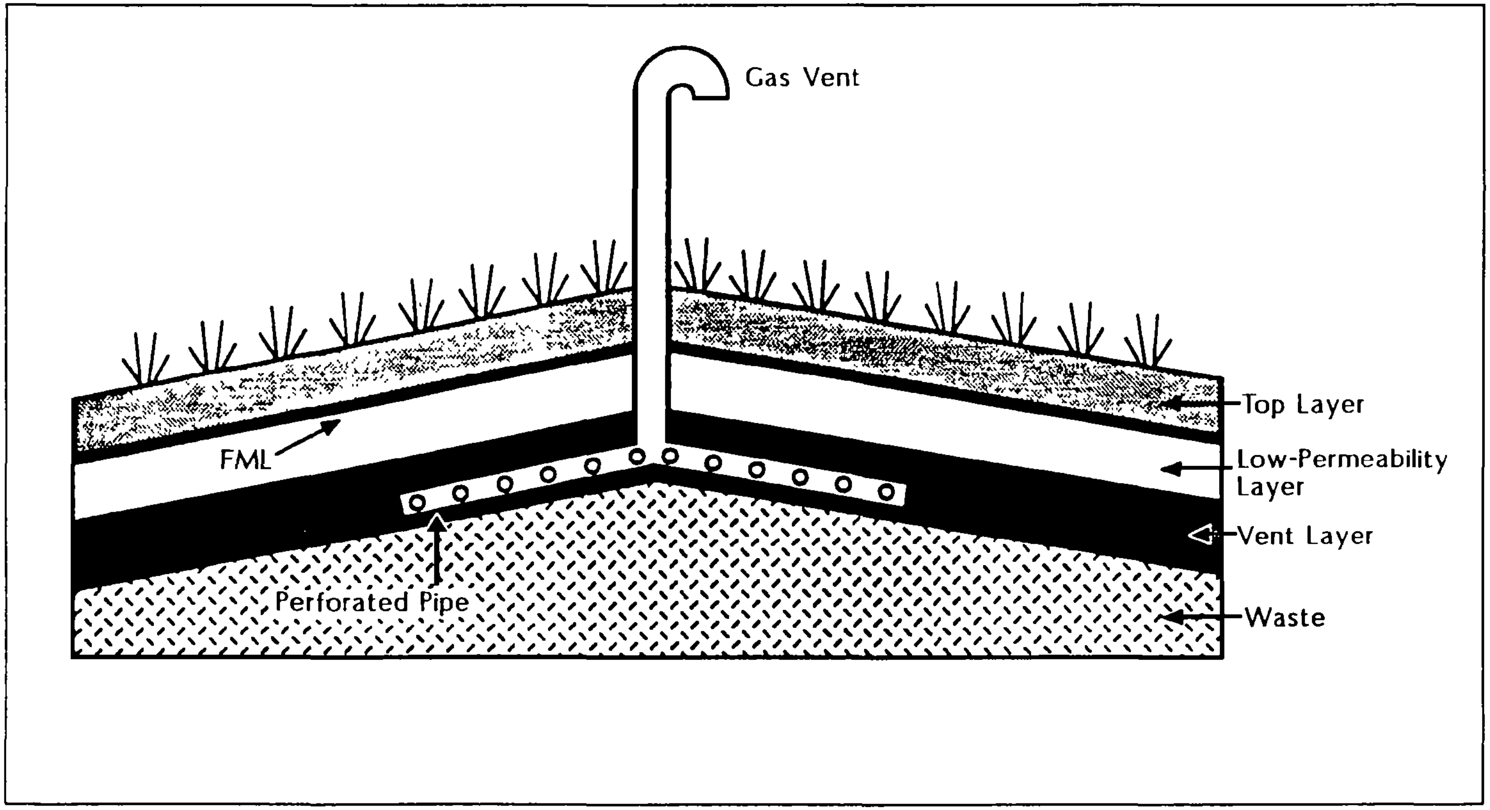
Final Cover Design with Optional Layers



(Source: EPA, 1989)

Figure 5-4

Gas Vent Layer



(Source: EPA, 1992)

Figure 5-5
5-20

Perforated, horizontal venting pipes should channel gases to a minimum number of vertical riser pipes located at a high point (in the cross section) to promote gas ventilation. To prevent clogging, a granular or geotextile filter may be needed between the venting and the low hydraulic conductivity soil or geomembrane layers.

5.4.5.2 *Biotic Layer*

Plant roots or burrowing animals (collectively called biointruders) may disrupt the drainage and the low hydraulic conductivity layers to interfere with the drainage capability of the layers. A 30 cm (12 inches) biotic barrier of cobbles directly beneath the erosion layer may stop the penetration of some deep-rooted plants and the invasion of burrowing animals. Most research on biotic barriers has been done in, and is applicable to, arid areas. Geosynthetic products that incorporate a time-released herbicide into the matrix or on the surface of the polymer may also be used to retard plant roots. The longevity of these products requires evaluation if the cover system is to serve for longer than 30 to 50 years (Figures 5-6).

5.5 NATURAL FACTORS AFFECTING FINAL COVER

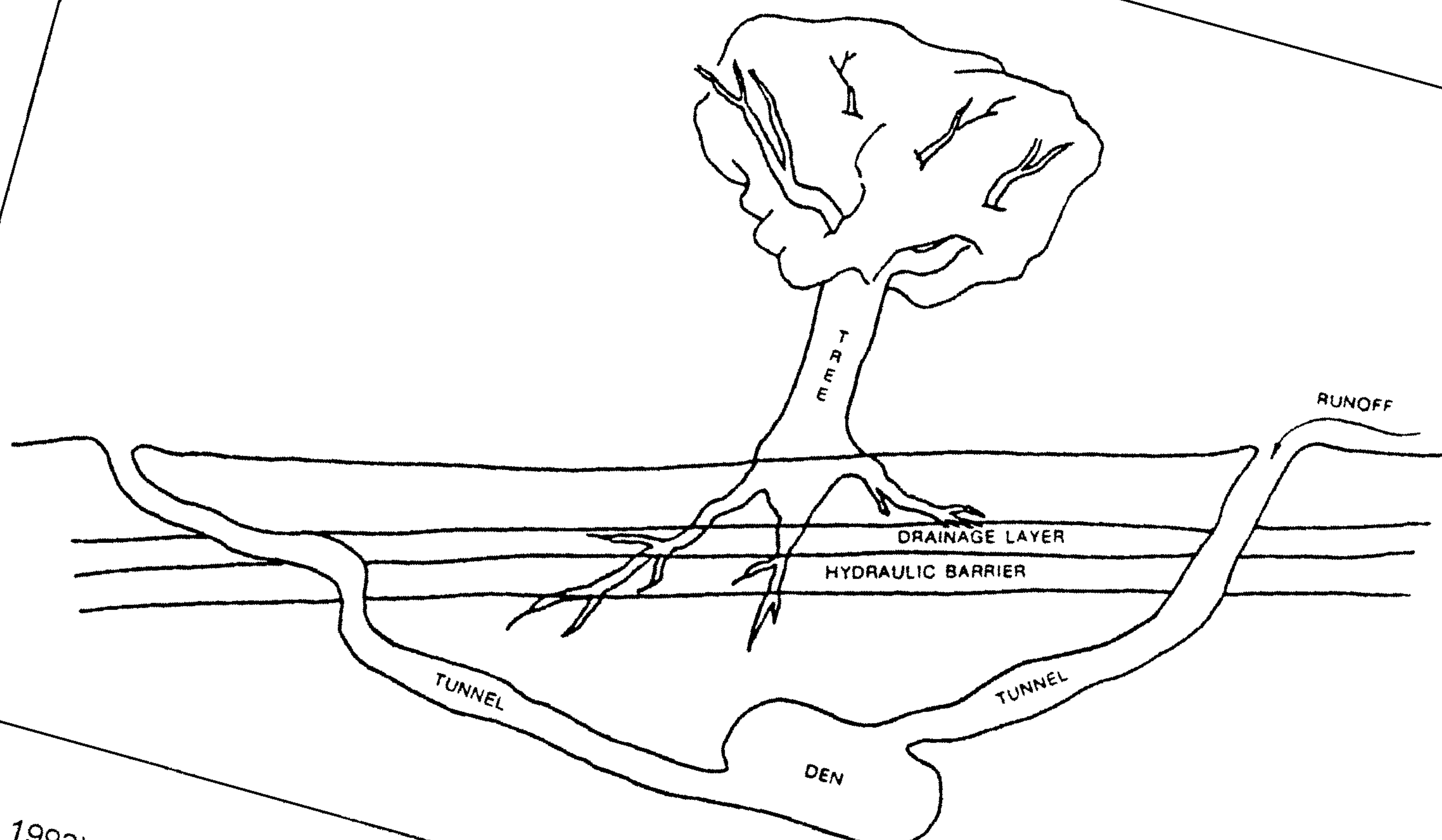
A variety of natural factors can affect the integrity of the final cover. Among those factors are:

- Settlement
- Freeze-thaw effects; and
- Desiccation

5.5.1 Settlement

Total settlement is the total downward movement of a fixed point on the surface of the cover. Differential settlement is the difference between the total settlements at two points of the cover. Excessive differential settlement of underlying

Biotic Intrusion



(Source: EPA, 1993)

Figure 5-6

waste can damage a cover system. If differential settlement occurs, tensile strains develop in the cover materials. The larger the strain, (i.e., the stretching of the material) the greater the possibility that the soil will crack and that an FML will rupture. The solution may be in waste stabilization (e.g., deep dynamic compaction or soil preloading). These technologies, however, are still emerging.

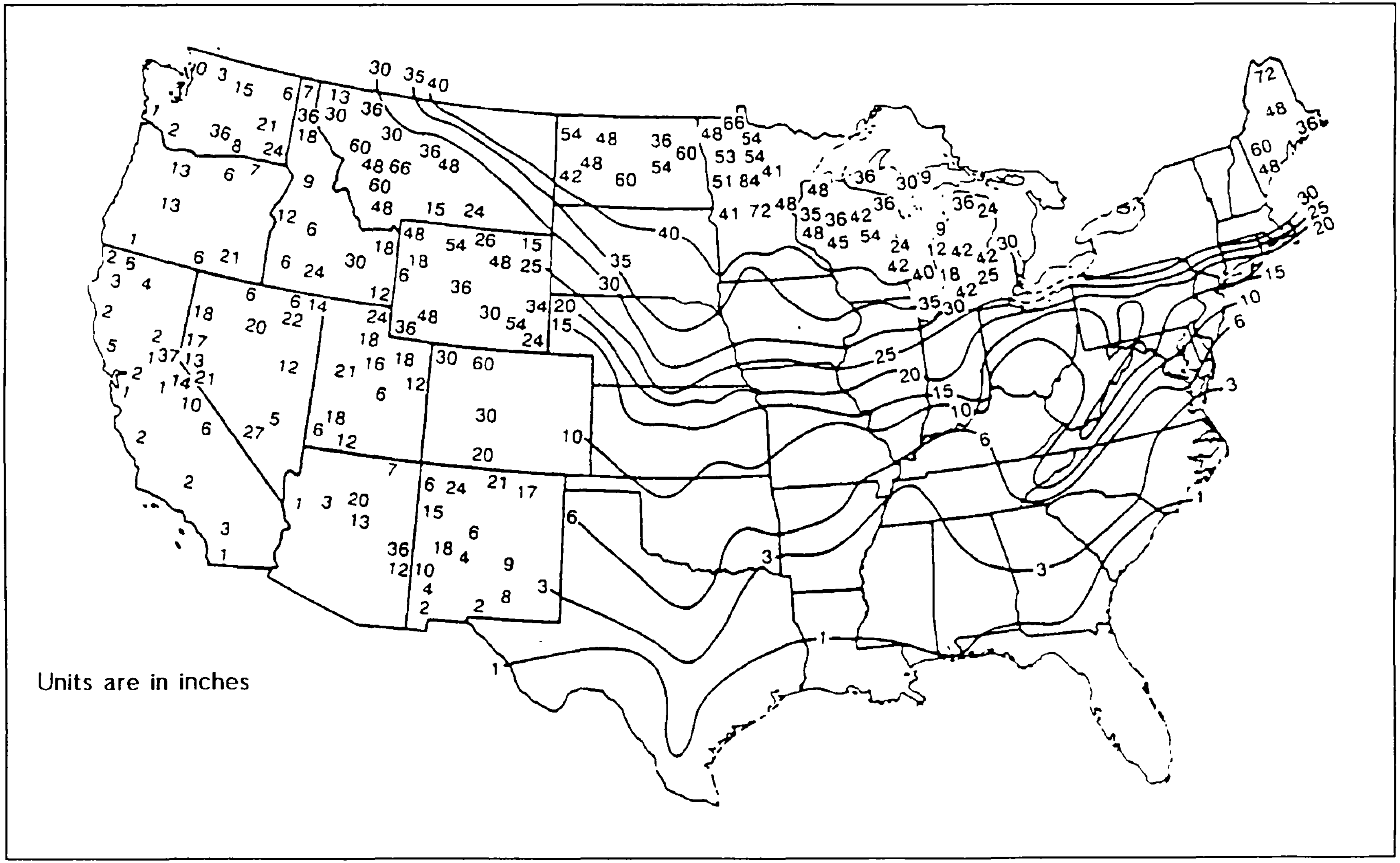
5.5.2 Freeze-Thaw Effects

Membrane and clay layers should be placed below the maximum depth of frost penetration to avoid freeze-thaw effects. Freeze-thaw effects may include development of microfractures or realignment of interstitial fines, which may increase the hydraulic conductivity of clays by more than an order of magnitude. Figure 5-7 shows the regional average depth of frost penetration. However, these values should not be used to find the maximum depth of frost penetration for a particular site. Information regarding the maximum depth of frost penetration for a particular area can be obtained from the SCS, local utilities, construction companies and local universities (Figure 5-7).

5.5.3 Desiccation

Desiccation of soil liners occurs whenever the soil liner dries, causing liner materials to crack. If desiccation occurs in a cover system, wetting of the soil may partly heal the desiccation cracks. To minimize desiccation damage, the soil layers should be kept wet during construction. A synthetic/soil composite liner system withstands desiccation damage to a greater degree than a soil liner. Tests have shown that increasing the thickness of the top layer does not prevent desiccation damage.

Regional Depth of Frost Penetration



(Source: EPA, 1989)

Figure 5-7

5.6 FINAL COVER MONITORING

Monitoring and maintaining the integrity of a final cover system as part of post-closure care is critical to ensure that the wastes are well contained and are not releasing leachate or gases to the environment. Periodic repairs and maintenance may be necessary to keep the cover in good working order. Three occurrences which should be monitored to ensure that the final cover system is functioning properly include:

- Settlement/Subsidence
- Surface Erosion
- Air emissions

5.6.1 Settlement/Subsidence

Excessive settlement and subsidence, caused by decomposition and consolidation of the wastes, can impair the integrity of the final cover system. Evidence of settlement and subsidence can commonly be found by walking the cover after a rain storm and looking for major puddles or ponding. Subsidence depressions can also be found through an annual survey of the cover using either conventional or aerial survey methods.

Subsidence depressions must be remediated below the level of the barrier system to avoid potential long-term acceleration of the subsidence. Remediation requires removing the cover system in the region of subsidence and backfilling the depression with lightweight fills. This fill may be either more waste or commercial lightweight aggregates. The full cover profile must then be rebuilt over the new fill.

5.6.2 Surface Erosion Monitoring or Maintenance

All cover systems will erode and require long-term maintenance. Cover systems with moderate slopes and an agricultural cover will typically require annual maintenance of 0.5 percent of their surface area; this percentage increases with slope. Thus, all covers that use agricultural materials require an annual inspection and repair program. Such repair may include cleaning out surface water swales, replacing cover soil and reestablishing vegetation. Areas of the cover requiring repeated repair may benefit from the use of geosynthetic erosion control blankets, or materials such as broken rock or cobbles in lieu of vegetation.'

The annual inspection should verify that the agricultural cover is being mowed at least annually to prevent the growth of deep-rooted volunteer vegetation. In arid regions of the country or during droughts, landfill covers may not be able to maintain vegetation unless the plants are very drought-resistant. This loss of vegetation is due to moisture loss in the root zone of the cover soil, resulting from characteristics of the underlying drainage system.

5.6.3 Air Emissions

Air emissions from waste storage facilities will come under increasing scrutiny in the next decade. Monitoring techniques will be similar to those used at industrial facilities and include passive sample vessels, and active pump and filter samples. The most common air contaminants coming from the waste disposal cell obviously are waste-dependent; for MSWLF wastes, these contaminants of concern are methane, vinyl chloride and benzene. Figure 5-8 presents typical allowable limits of selected air contaminants. Such limits are currently undergoing extensive review; significantly lower allowable levels are anticipated for future operations.

Threshold Limit Values of Selected Air Contaminants[a]

CONTAMINANT	TLV
Dust	1 mg/m^3
Carbon monoxide	50 ppm
Asbestos	0.2 to 2 fibers/cm (depending on asbestos type)
Benzene	10 ppm
Coal dust	2 mg/m^3
Cotton dust	0.2 mg/m^3
Grain dust	4 mg/m^3
Hydrogen sulfide	10 ppm
Nuisance particulates	10 mg/m^3
Phenol	5 ppm
Vinyl chloride	5 ppm
Wood Dust	
Hard wood	1 mg/m^3
Soft wood	5 mg/m^3

[a] Values of TLV obtained from the American Conference of Governmental Industrial Hygienists (1987)

Figure 5-8

5.7 HELP MODEL

HELP is a computer-based mathematical water-budget model that performs daily sequential analyses to generate daily, monthly and annual estimates of runoff, evapotranspiration, lateral drainage, leakage through covers, leachate collection, leachate detection and leakage through clay liners and FMLs. The HELP model was developed at the U.S. Army Corps of Engineers (USACE) Waterways Experiment Station for the EPA Office of Solid Waste to provide technical support for the RCRA and Superfund programs. It provides permit evaluators and landfill designers with a tool to rapidly evaluate and compare the performance of alternate landfill designs by simulating various hydrologic processes within the landfill environment and evaluating the integrity and performance of the unit.

The model is available to operators and regulators free of charge from the USACE Waterways Experiment Station in Vicksburg, Mississippi.

The input parameters of the model vary with the process being modeled (see Figure 5-9). Typical input parameters include

- Rainfall and Climatological Data
- Soil Type and Properties
- Cover Vegetation Type
- Landfill Design Features

Typical Output Data

- Daily Values (Optional)
- Monthly Totals and Other Values (Optional)
- Annual Totals and Other Values
- Averages and Standard Deviations of Monthly and Annual Totals
- Peak Daily Values for Simulation Period
- End-of-Simulation Water Storage Values

Figure 5-9
5-29

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6

SECTION 6.0

Groundwater Monitoring

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6.1 INTRODUCTION

The Subtitle D regulations require implementation of a routine groundwater monitoring program to assess the effectiveness of the MSWLF's containment of wastes. Waste constituents can be released to groundwater if not adequately contained by the landfill design components.

This section summarizes the groundwater monitoring requirements as defined in Subpart E of the Subtitle D regulations and discusses the components of an effective groundwater monitoring program.

6.2 APPLICABILITY

Subpart E of the Subtitle D regulations require that groundwater monitoring be performed at

- All new MSWLFs which began receiving waste after the effective date.
- Existing MSWLFs which received waste prior to the effective date and continued to receive waste after the effective date.
- Lateral expansions of existing MSWLFs.

Once established at a MSWLF, groundwater monitoring must continue throughout the facility's active life and post-closure care period.

A MSWLF may be granted an exemption from the groundwater monitoring requirements in EPA-approved state programs if it can be demonstrated that there is no potential for hazardous constituents to migrate from the MSWLF to the uppermost aquifer.

6.3 MSWLF GROUNDWATER MONITORING PROGRAMS

Two types of monitoring programs have been established to assess groundwater quality at MSWLFs:

- Detection Monitoring Program
- Assessment Monitoring Program

6.3.1 Detection Monitoring Program

Groundwater detection monitoring is required at all MSWLFs subject to the Subtitle D regulations and must be performed at all monitoring wells (Figure 6-1).

A detection monitoring program must be established that includes semiannual monitoring for the Appendix I constituents at background and point of compliance locations. EPA-approved state programs may contain provisions for:

- Suspending groundwater monitoring where it can be demonstrated that there is no potential for migration of hazardous constituents from the MSWLF unit to the uppermost aquifer.
- Identifying an alternative (shorter) list of detection monitoring parameters if it can be shown that any deleted constituents are not expected to be contained in or derived from the waste.
- Designating an alternative frequency for detection monitoring. The alternative monitoring frequency must be no less than annual.

Flow Chart of Detection Monitoring Program

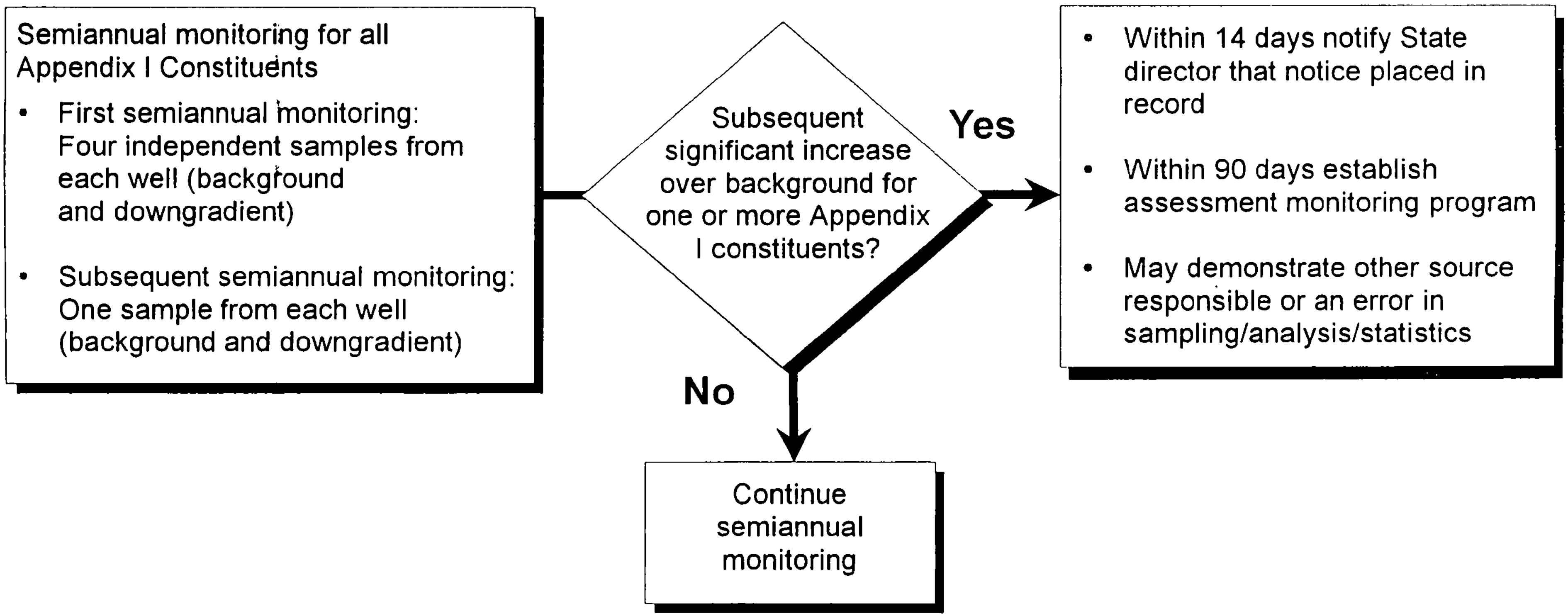


Figure 6-1
6-6

- Designating an alternative distance for locating point of compliance monitoring wells. The alternative point of compliance distance must be no greater than 150 meters from the waste management unit boundary.

Within a reasonable period of time after completing each sampling and analysis, the groundwater monitoring data must be evaluated to determine whether there is a statistically significant increase over background values for any of the detection monitoring constituents.

In order to perform the statistical evaluations, background groundwater quality must be established for each of the monitoring constituents. Background groundwater quality data may be derived from locations that are either hydraulically upgradient from the MSWLF unit or at other locations that provide more representative background data.

Groundwater data collected from the point of compliance (detection monitoring wells) must be compared against the background data to determine if there is an SSI at any of the compliance monitoring wells. Within 14 days of determining that an SSI of one or more detection monitoring constituents has occurred, the state regulatory authority must be notified that the results have been placed in the operating record. An assessment monitoring program must be implemented within 90 days, unless it can be demonstrated that another source caused the contamination or that the SSI resulted from errors in sampling, analysis, statistical evaluation or natural variation in groundwater quality.

A flow chart of the detection monitoring program is presented in Figure 6-1.

6.3.2 Assessment Monitoring Program

Assessment monitoring is required whenever a SSI over background has been detected for one or more of the detection monitoring constituents (Figure 6-2). The assessment monitoring program requires that:

- Within 90 days of triggering the assessment monitoring program, and annually thereafter, groundwater must be analyzed for all of the Appendix II constituents. For any constituent detected in the downgradient wells as the result of the complete Appendix II analysis, a sufficient number of independent samples must be collected and analyzed for each well (background and downgradient) to establish background and provide for statistical evaluation of the detected constituents. Within 14 days after obtaining the analytical results the state regulatory authority must be notified that information on the Appendix II constituents that have been detected has been placed in the operating record.

- Within 90 days, and at least semiannually thereafter, groundwater must be resampled for the detection monitoring parameters (Appendix I or alternative list) and for detected Appendix II constituents.

- Groundwater protection standards must also be established for all detected Appendix II constituents.

Flow Chart of Assessment Monitoring Program

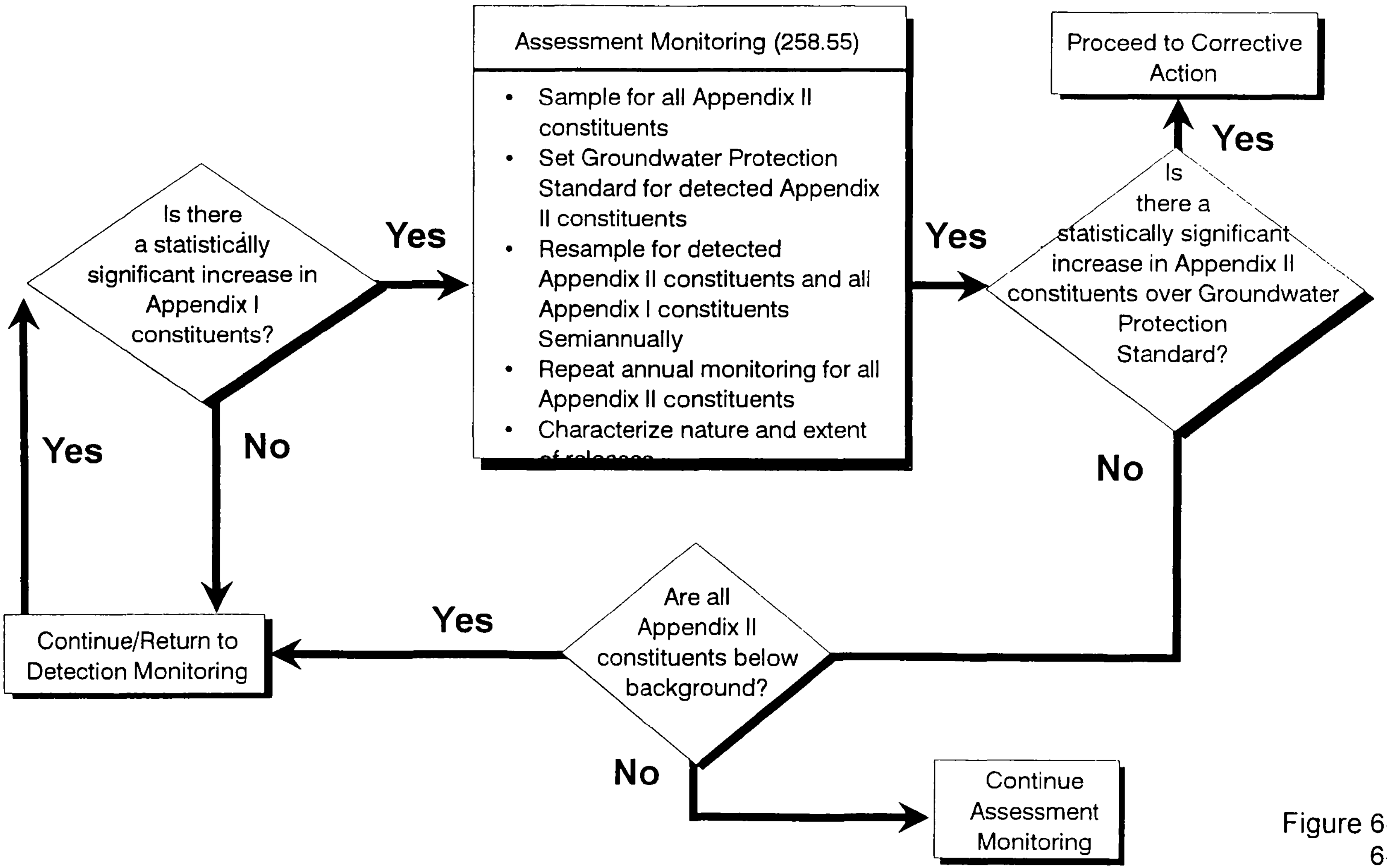


Figure 6-2
6-8

Statistical evaluations must be conducted to determine if the detected constituents are above background and above or below the groundwater protection standards. If the concentrations of Appendix II constituents are at or below background values for two consecutive sampling events, the state program may allow the MSWLF to return to detection monitoring; if above background values, but below the groundwater protection standard, then the MSWLF must continue assessment monitoring; if above the groundwater protection standard, the MSWLF must notify the State regulatory agency and all appropriate local government officials within 14 days that the information about Appendix II constituents which have exceeded the groundwater protection standard has been placed in the operating record. Additional assessment monitoring program activities must also be undertaken which include the following:

- Characterizing the nature and extent of the release.

- Installing and sampling at least one additional monitoring well located at the facility boundary in the direction of contaminant migration.

- Installing and sampling other monitoring wells as necessary.

- Notifying all persons who own or reside on land that directly overlies any part of a groundwater contamination plume that has migrated offsite.

- Initiating an assessment of corrective measures within 90 days or demonstrating that another source caused the contamination or that the SSI resulted from error in sampling, analysis, statistical evaluation or natural variation in groundwater quality.

The MSWLF is required to continue assessment monitoring through the duration of the corrective action period or until otherwise directed by the appropriate regulatory authority.

A flow chart of the assessment monitoring program is presented in Figure 6-2.

6.4 GROUNDWATER MONITORING SYSTEMS

Groundwater monitoring system must be installed at each MSWLF unit that is subject to the Subtitle D regulations.

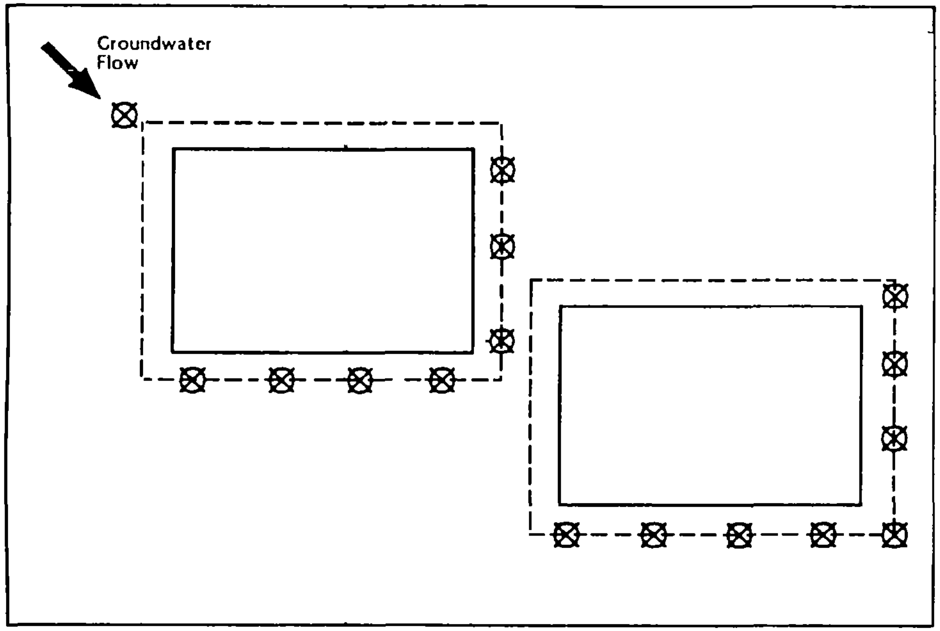
EPA-approved state programs may allow for installation of a multiunit groundwater monitoring system if the MSWLF consists of more than one MSWLF unit . Multiunit groundwater monitoring systems must meet the same objectives and requirements as individual monitoring systems and be at least as protective to human health and the environment as individual systems. A schematic comparison of single unit and multiunit monitoring systems is presented in Figure 6-3.

6.4.1 Requirements for Groundwater Monitoring Systems

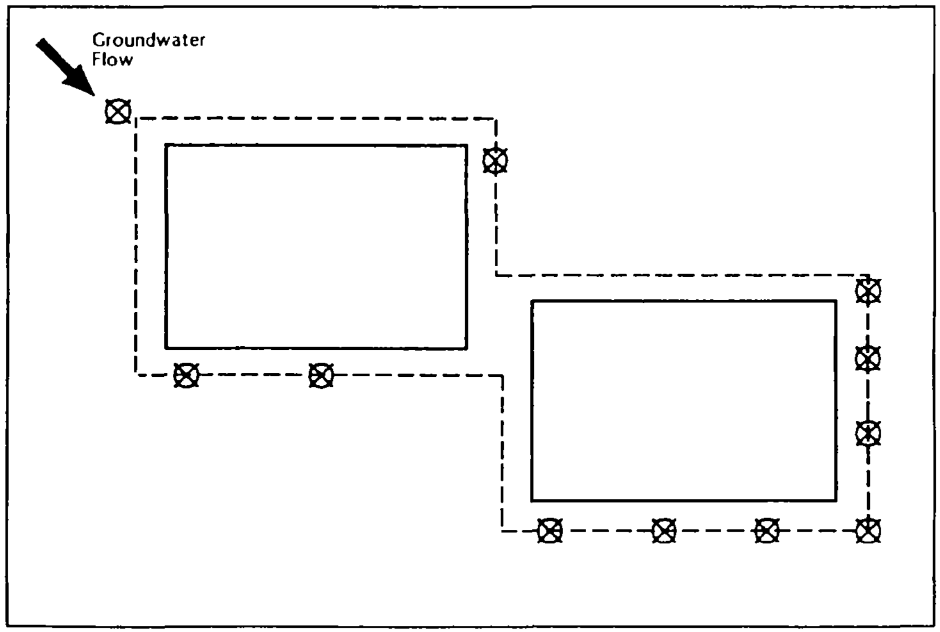
The groundwater monitoring system must yield from the uppermost aquifer samples that

- Represent background groundwater quality that has not been affected by leakage from the MSWLF unit.

Comparison of Single Unit and Multiunit Monitoring



Single Unit



Multiunit

Figure 6-3

6-10

- Represent the quality of groundwater passing the relevant point of compliance (the waste management unit boundary or an alternative distance up to 150 meters, if allowed in EPA-approved state programs).

In order to meet the above-mentioned objectives, the groundwater monitoring system must include a sufficient number of wells which have been:

- Installed at appropriate locations

- Installed to monitor appropriate depth intervals

6.4.2 Monitoring Well Performance Standards

The monitoring wells must be constructed in a manner that achieves the following minimum performance standards.

- Cased to maintain the structural integrity of the well and borehole;

- Screened and packed with an appropriate filter material (e.g., sand or gravel) to facilitate the collection of representative groundwater samples; and:

- Sealed to prevent surface water infiltration and contamination of samples and groundwater.

Additional monitoring well construction requirements include:

- Notification of the state regulatory authority that monitoring well design and installation details have been included in the MSWLF operating record.

- Well installation and decommissioning in compliance with additional state regulations regarding construction, registrations and abandonment.

6.4.3 Groundwater Monitoring System Design Considerations

The essential considerations for designing groundwater monitoring systems are:

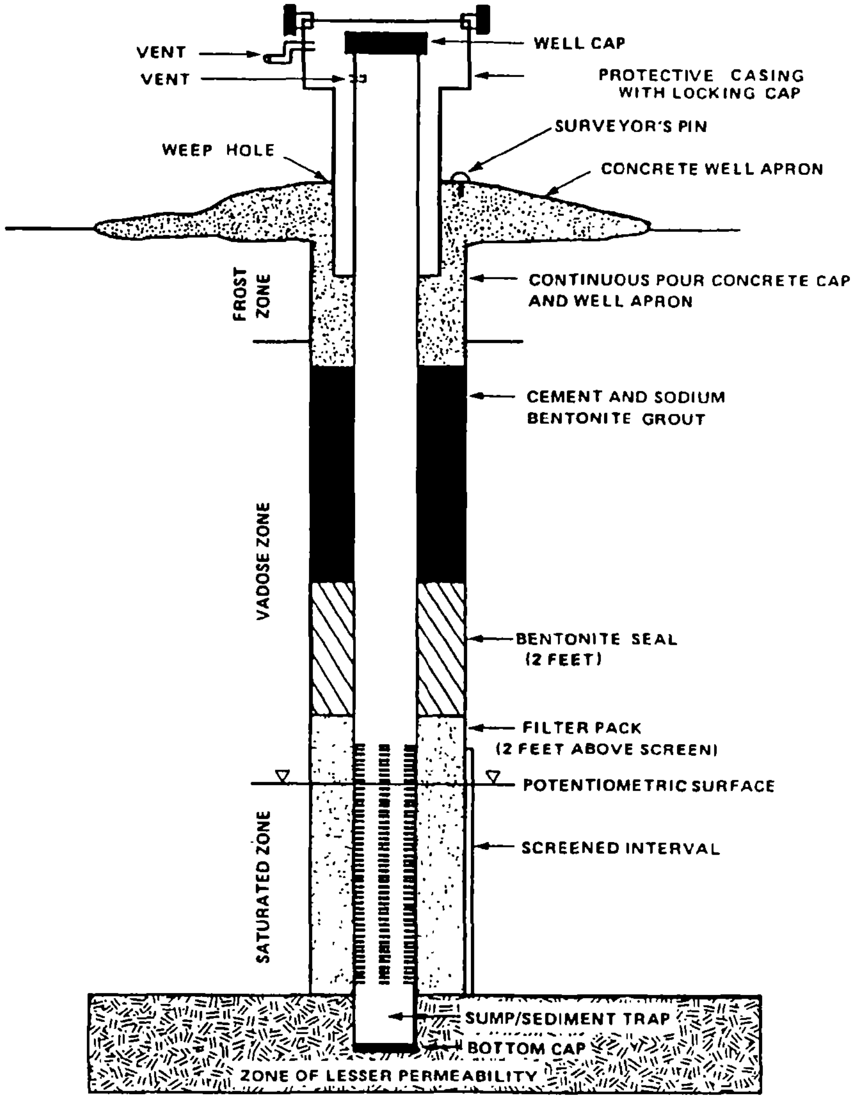
- Monitoring well design
- Construction methods
- Monitoring well placement

6.4.4 Monitoring Well Design

When properly designed and installed, the components of a monitoring well allow for the collection of an adequate volume of water from the desired water-bearing formation. A diagram of a typical monitoring well is presented in Figure 6-4. The monitoring well components include the following:

- Borehole
- Well casing
- Sump or sediment trap
- Well intake (screen)
- Filter pack
- Annular seals
- Surface seal and completion

Diagram of a Typical Monitoring Well



(Source: EPA, 1989)

Figure 6-4
6-14

A primary concern when selecting well construction materials is the use of materials that will not compromise the integrity of the well and any future analytical data. Another concern is to select materials that will be rugged enough to endure the entire monitoring period. Site conditions will generally dictate the type of materials that can be used.

6.4.4.1 *Borehole*

The borehole is the open hole in the formation that is constructed during the drilling process. Borehole diameter is dependent upon the diameter of the monitoring well materials and the drilling technique employed. The borehole should be of sufficient diameter so that well construction and placement of the filter pack and annular seal materials can proceed without major difficulties. A minimum 2-inch annular space, between the casing and the borehole wall, is necessary to ensure placement of acceptable thicknesses of filter pack, bentonite pellet seal and the annular grout seal.

For example, if the inside diameter (ID) of the casing is 4 inches, and the wall thickness is approximately a quarter inch, then the borehole will have to be 8.5 inches to provide a 2-inch annular space between the outside diameter (OD) of the casing (4-inch ID plus twice the casing wall thickness) and the borehole wall.

The 2-inch annular space will also provide room for the use of tremie pipes at a diameter up to 1.5 inches for placing the filter pack, bentonite pellet seal and annular grout seal. Larger annular spaces may be necessary depending upon drilling method, formation materials and depth of materials placement. Sometimes it is necessary to overdrill the borehole so that any soils that have not been removed, or may collapse into the borehole during auger or drill stem retrieval, will fall to the bottom of the borehole below the depth where the well intake (screen and filter pack) will be placed. The borehole can also be overdrilled to allow for placement of a sump or sediment trap in the well below the well screen.

If the borehole is overdrilled too much, it can be backfilled to the designed depth with bentonite pellets or, in some instances, the filter sand that is to be used for the filter pack.

6.4.4.2
Well Casing

The well casing is the rigid tubular material placed into the borehole to provide access from the surface of the ground to the well intake and to maintain the borehole's integrity. Casing diameter depends upon the purpose of the well and is selected to accommodate the down hole equipment (i.e., pumps, logging tools, samplers) that will be employed.

Casing diameter selection criteria include the following:

- Drilling or well installation method
- Depth of well installation
- Hydraulic characteristics of monitored zone
- Ease and extent of well development
- Required purge volume prior to sampling
- Well recovery rates after development and/or purging
- Aquifer testing requirements

- Cost

Most monitoring wells are constructed with 2- or 4-inch ID casings. The casing material must be rugged to withstand long-term monitoring activities and should be selected after consideration of the following site-specific factors:

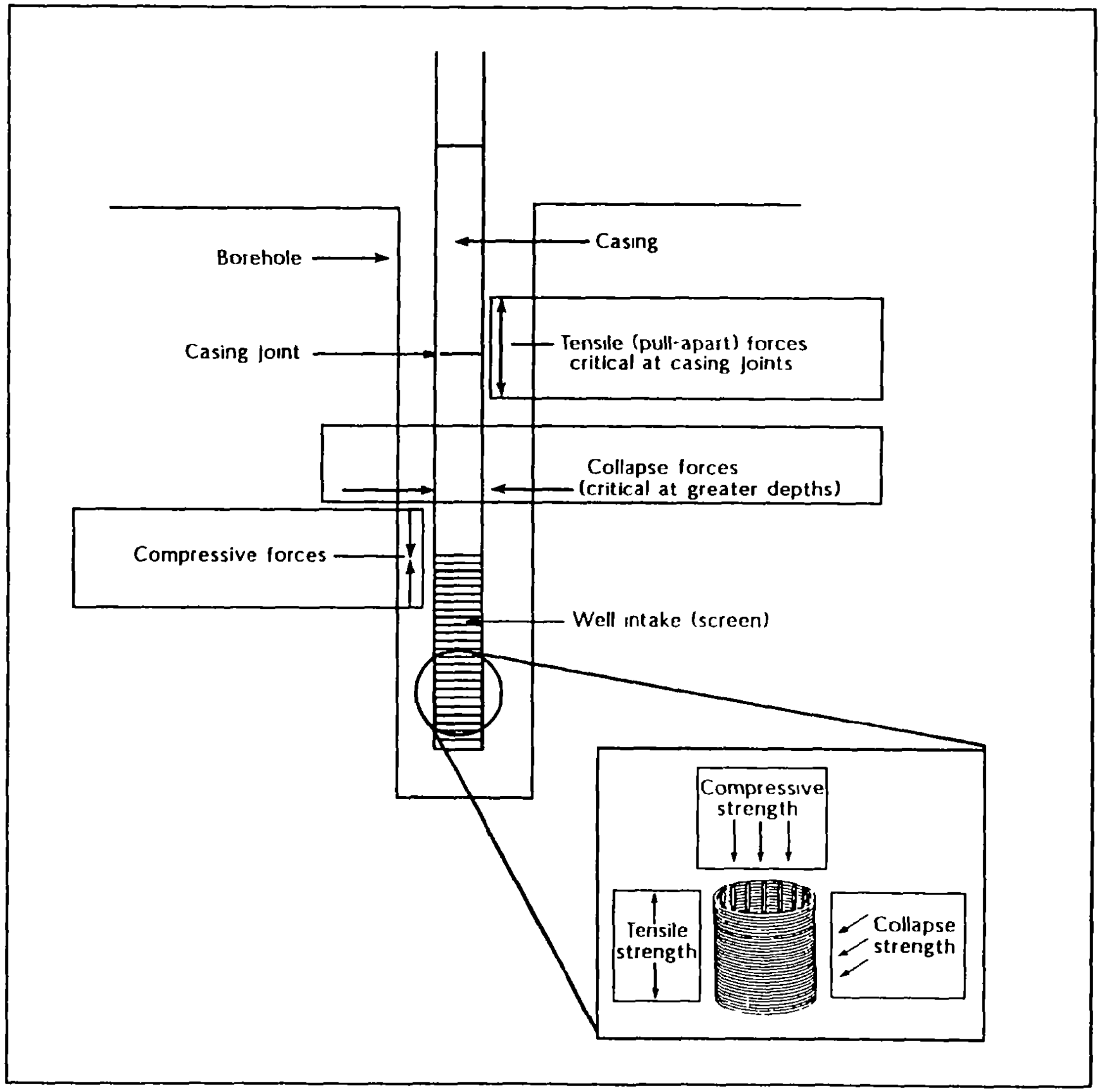
- Geological environment
- Geochemical environment (natural and contaminants)
- Design life of monitoring well
- Ease in handling
- Anticipated well depth

Forces exerted on monitoring well components which must be considered when selecting materials are presented in Figure 6-5.

Well casing and screens are available in a variety of materials including:

- Thermoplastic materials
  - Polyvinyl chloride (PVC) (not recommended in the presence of some or ganic compounds due to sorption and leaching properties)
  - Acrylonitrile butadiene styrene (ABS)
- Metallic materials
  - Carbon steel

Forces Exerted on Monitoring Well Materials



(Source: EPA, 1989)

Figure 6-5

- Stainless steel (304 and 316)

- Fluoropolymer materials

  - Polytetrafluoroethylene (PTFE)
  - Tetrafluoroethylene (TFE)
  - Fluorinated ethylene propylene (FEP)
  - Perfluoralkoxy (PFA)
  - Polyvinylidene fluoride (PVDF).

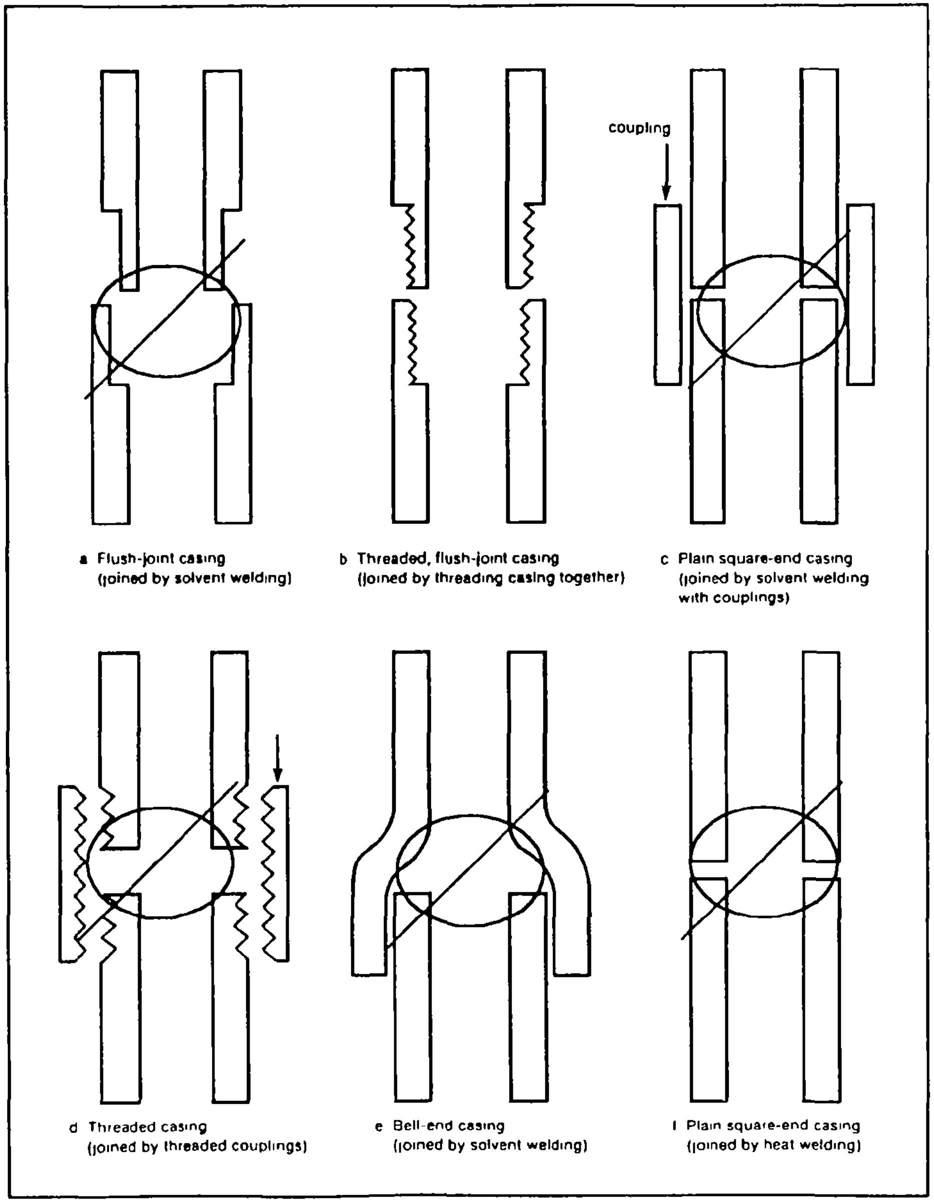
- Fiberglass

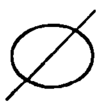
PVC and stainless steel are the two most commonly used construction materials for monitoring wells. Other materials used for construction of wells for purposes other than monitoring may not be appropriate for use in long-term monitoring programs because of their low resistance to chemical attack and potential impacts on groundwater samples.

Well materials come in sections which must be joined during construction (Figure 6-6.) The preferred joining method for monitoring wells is with flush-threaded connections. Flush-threaded materials are completed with male and female threaded ends which when screwed together form a joint which is uniform on both the inner and outer sides. Welded or solvent-glued joints can impact groundwater quality and should not be used for monitoring wells.

A plug or cap, constructed of the same material as the casing, is placed at the bottom of the well string (casing and screen) to prevent the filter

Types of Well Casing Joints





Note: Not used for monitoring wells.

(Source: EPA, 1989)

Figure 6-6

pack and unconsolidated materials at the bottom of the borehole from creeping up into the well.

6.4.4.3
Sump or Sediment Trap

Sumps or sediment traps serve as catch basins or storage areas for sediments that flow into the well and drop out of suspension. A sump usually consists of a 2- to 10-foot section of well casing located below the well screen. Sumps are added to the well screens when the wells are screened in aquifers that are naturally turbid and will not yield clear formation water (free of visible sediment) even after extensive development. The sediment can then be periodically pumped out of the sump, preventing the well screen from becoming "silted up."

6.4.4.4
Well Intake (Screen)

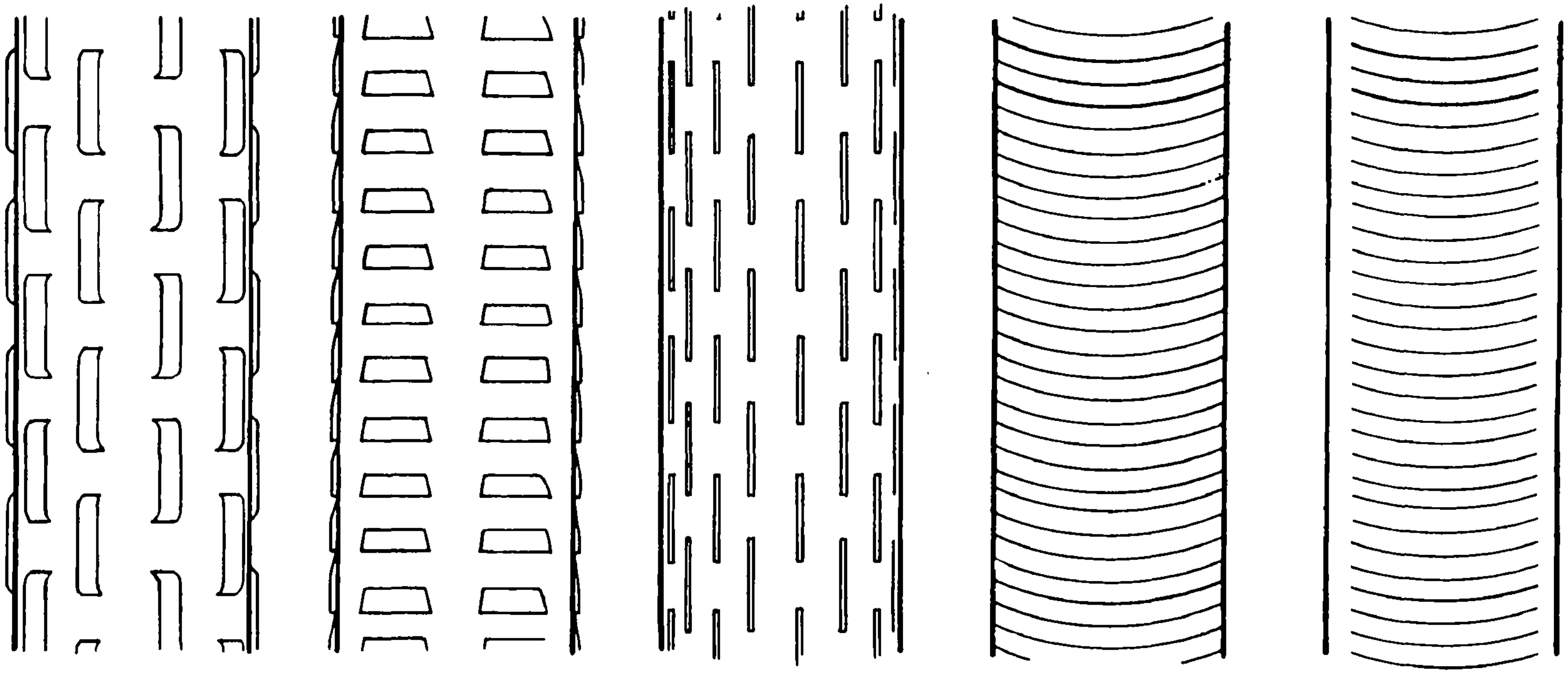
The well intake is a slotted or perforated section of the casing that permits groundwater to flow into the well (Figure 6-7). The well intake is designed in conjunction with the filter pack to maximize groundwater inflow and minimize the inflow of suspended solids from the formation.

Continuous wire wrap or machine-slotted well intakes (screens) are typically used for monitoring wells. (Perforated well intakes are more common in water supply applications.) Monitoring well intake design factors include

- Corrosion and chemical resistance
- Screen length
- Screen type
- Screen opening size (slot size)

Screen slot size selection is dependent upon

Types of Well Intakes (Screens)



(Source: EPA, 1989)

Figure 6-7
6-20

- The grain size of the formation materials in wells constructed with natural (formation) filter packs; or:

- The grain size selected for the artificial filter pack.

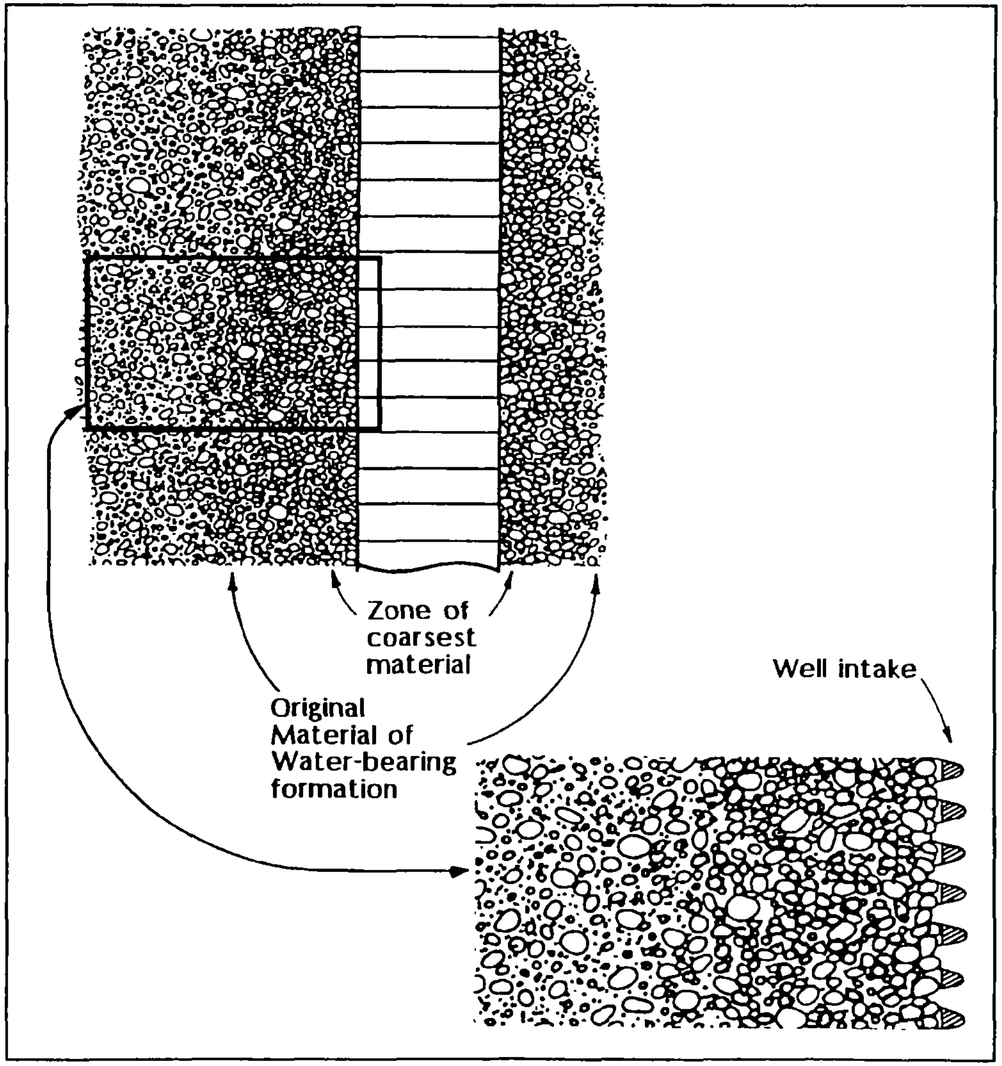
Typical screen slot widths used for monitoring wells range in size from 0.006 inch to 0.030 inch. The most common slot width for PVC materials used in formations with an abundance of fines is 0.010 inch.

Well screen length depends upon the thickness of the monitoring interval. Shorter screen intervals provide information concerning a specific section of the formation, whereas larger screen intervals are best used to monitor the presence of gross contamination in the aquifer. The length of well screens in permanent monitoring wells should be great enough to effectively monitor the interval, or zone of interest, during water level fluctuations. Well screens designed for long-term monitoring purposes are normally not less than 5 feet in length and rarely exceed 20 feet. The most commonly used screen length is 10 feet.

6.4.4.5 Filter Packs

Filter packs (Figure 6-8) are composed of granular materials placed around the well intake (screen). They restrict the movement of formation-fine materials (silt and clay particles) into the well while permitting groundwater to enter the well. The filter pack material should consist of clean, well-rounded to rounded particles of siliceous composition. The grain-size distribution, or particle sizes, of the filter pack materials should be selected to retain 90 percent of the formation materials. Two types of filter packs are

Envelope of Coarse-Grained Material Around Well Screen (Filter Pack)



(Source: EPA, 1989)

Figure 6-8
6-22

typically utilized in unconsolidated, or poorly-consolidated materials: natural and artificial.

6.4.4.5.1
Natural filter packs

Natural filter packs are constructed by allowing the surrounding formation to collapse around the well intake. The well is then developed (pumped) in a manner that creates an envelope of coarser-grained materials around the intake. In wells with natural filter packs, the diameter of the well casing and well intake is selected to closely approximate the diameter of the borehole, and the well intake is designed in association with the grain size of the formation. Natural filter pack wells are most commonly installed in permeable, coarse-grained formations.

6.4.4.5.2
Artificial filter packs

Artificial filter packs are constructed by placing coarser, permeable materials (typically sand) in the annular space between the well intake and the natural formation.

Artificial filter packs serve several purposes:

- Filter fine-grained materials
- Stabilize the borehole
- Minimize settlement of materials above the well intake
- Increase the effective diameter of the well
- Increase the amount of water flowing into the well

Artificial filter packs generally allow the slot size to be considerably larger than if screened in the natural formation. Design factors for an artificial filter pack include

- Grain size distribution of formation
- Filter pack grain size
- Intake opening (slot size)
- Intake length
- Filter pack length
- Filter pack thickness
- Filter pack material

An artificial filter pack should extend from the bottom of the well intake to approximately 2 to 5 feet above the top of the well intake. The thickness of the filter pack should be at least 2 to 4 inches.

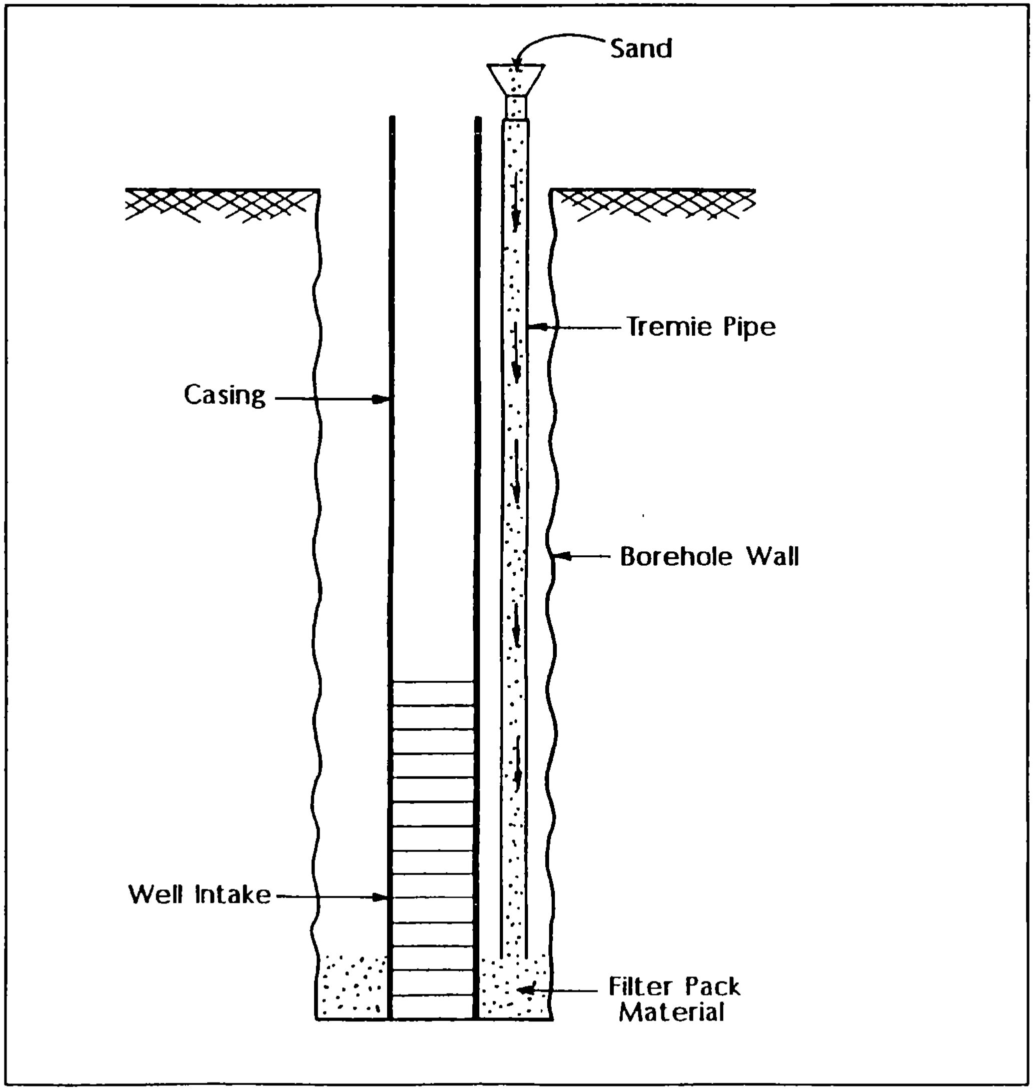
Filter pack materials must be chemically inert to preserve the natural chemistry of the groundwater. The material should be well-rounded to enhance permeability and should contain less than 5 percent nonsiliceous material. The most commonly used filter pack material is clean quartz sand.

6.4.4.5.3
Filter Pack Placement

Filter pack material should be placed into the borehole under the bottom of the well screen to provide a firm footing and to filter flow beneath the screened interval. The filter pack should also extend a minimum of 2 feet above the top of the well screen. Filter pack should be placed by the tremie or positive displacement method (Figure 6-9) in deep wells and when using rotary wash drilling methods.

Placing the filter pack by "pouring" (Figure 6-10) may be acceptable in certain situations (i.e., at

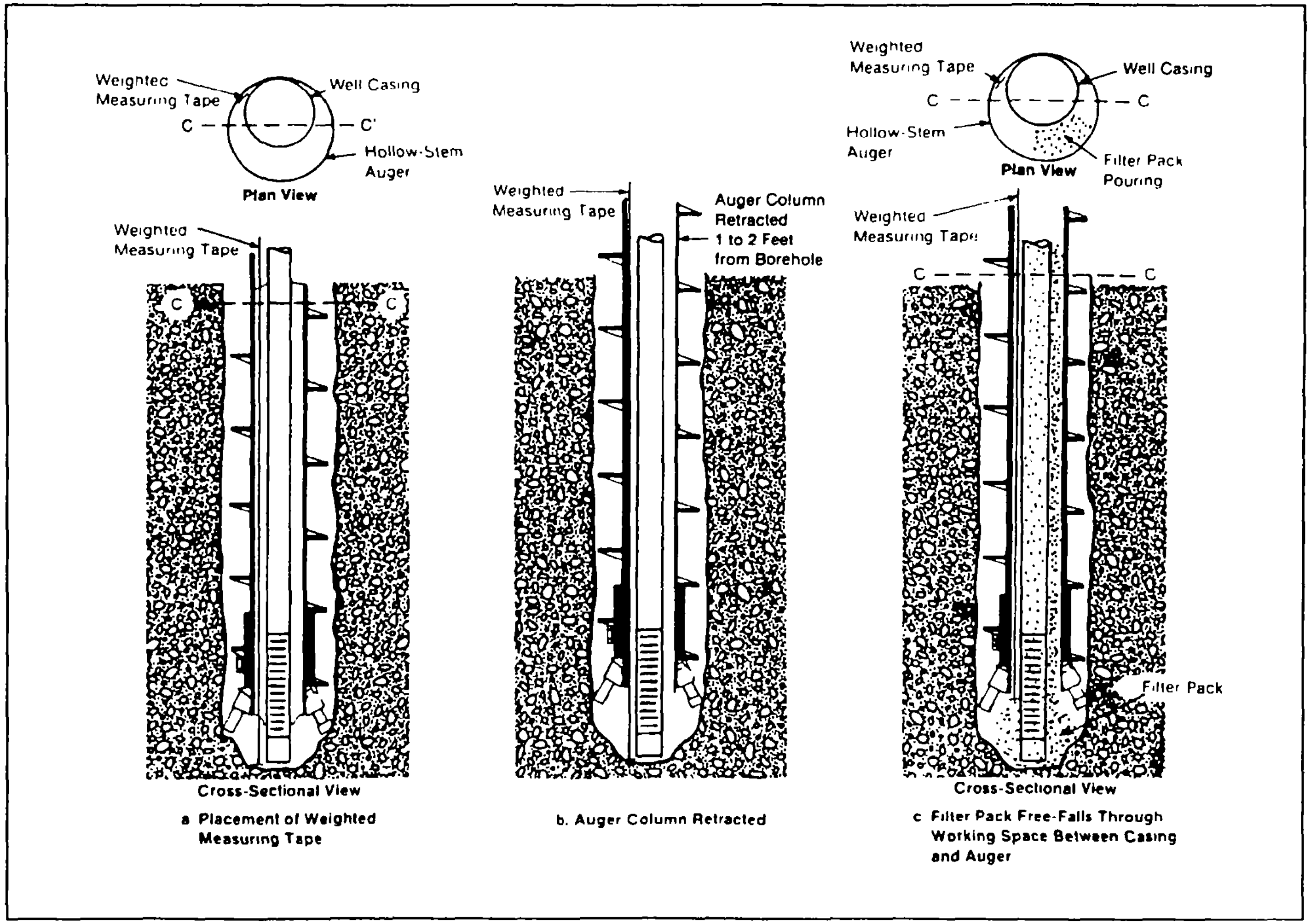
Tremie Pipe Emplacement of Artificial Filter Pack Materials



(Source: EPA, 1989)

Figure 6-9
6-26

Free-Fall Method of Filter Pack Emplacement with a Hollow-Stem Auger



(Source: EPA, 1989)

Figure 6-10

shallow depths and when accomplishing installation through hollow-stem augers).

6.4.4.6
Filter Pack And Well Screen Design

The majority of monitoring wells are installed in shallow water-bearing units that consist of silts, clays and sands in various combinations. These shallow water-bearing units are not generally characteristic of sand aquifers used for drinking water. The relatively high silt and clay content often make it difficult to design wells that yield low turbidity water. Selection of well screen slot size and filter pack grain size is often controlled by manufacturing capabilities and not technical design factors. In these instances the filter pack material is selected based upon the smallest screen slot width available (i.e., 0.010 machine-slotted PVC) and the best available appropriately graded silica sand.

Ideally, the filter pack and well screen design should be based on the results of a sieve analysis conducted on soil samples collected from the aquifer or the formation(s) that will be monitored. The data from the sieve analysis are plotted on a grain-size distribution graph, and a grain-size distribution curve is generated. The uniformity coefficient (Cu) of the aquifer material is determined from the grain-size distribution curve. The Cu is the ratio of the 60 percent finer material (D60) to the 10 percent finer material (D10)

$$Cu = \frac{D60}{D10}$$

The Cu ratio is a way of grading or rating the uniformity of grain size. For example, a Cu of unity means that the individual grain sizes of the material are nearly all the same, while a Cu with a large number means a large range of sizes. As a general rule, a Cu of 2.5 or less should be used in designing the filter pack and well screen.

6.4.4.7
Annular Seals

There are two types of seals installed in the annular space above the filter pack: filter pack seal (bentonite pellet seal or plug) and annular grout seal.

The purpose of the annular seals are to:

- Protect the chemical integrity of the filter pack
- Eliminate infiltration of surface water
- Prohibit vertical migration of groundwater between water-bearing zones
- Seal discrete sampling zones

Annular seal materials must comply with the following design requirements:

- Allow for installation from ground surface.
- Hydrate or set within a reasonable period of time.
- Provide a positive seal between the casing and formation.
- Be chemically inert.
- Be resistant to physical or chemical deterioration.
- Be impermeable to fluids.

The annular seal materials most commonly used for monitoring well construction are bentonite and cement.

6.4.4.7.1
Filter pack seal (bentonite pellet seal or plug)

A seal consisting of a high solids, pure bentonite material or other inert materials must be placed on top of the filter pack to prevent infiltration of the cement grout into the screened well interval. The bentonite seal should be a minimum of 2 feet in thickness.

Bentonite pellets or bentonite slurries are commonly used to form the filter pack seal depending upon the depth of placement, method of placement and thickness of seal required. The preferred method of placing bentonite slurries and/or pellets is by the tremie method (or through the hollow-stem augers for pellets.) Placement by these methods minimizes the risk of bridging in the borehole and ensures placement of the bentonite seal at the proper interval.

Pouring the bentonite pellets directly into the borehole can be performed in shallow boreholes (generally less than 50 feet) where the annular space is large enough to prevent bridging. The bentonite pellet seals should be measured with a tape to ensure placement at the proper intervals. The bentonite pellets must be hydrated either by placement in the formation water or by adding potable water, if placed above the water table.

6.4.4.7.2
Annular grout seal

The annular space between the casing and the borehole wall must be sealed above the bentonite filter pack seal to within approximately 2 feet of the ground surface (or below the frost line, whichever is deeper). Annular grout seals may consist of: high solids, pure bentonite grout, a neat cement grout or a cement/bentonite grout.

6.4.4.7.3
Bentonite

Bentonite is a hydrous aluminum silicate clay that, when mixed with water, typically expands 10 to 15 times its dry volume. Bentonite quickly forms an extremely dense, low-permeability clay mass that provides a tight seal between the casing and the adjacent formation.

Potential problems with bentonite include

- Relatively high pH of 8.5 to 10.5
- High cation exchange capacity

These characteristics may impact the ambient water chemistry; therefore, it is important to ensure that the seal is at least 2 to 3 feet above the top of the well intakes.

6.4.4.7.4
Cement

Cement is a calcium carbonate mixture that when hydrated forms a hard, impermeable seal in the annulus. Cement grouts are generally mixed using 6.5 to 7 gallons of water per 94-pound bag of Type I portland cement. Bentonite may be added (5 to 10 percent) to the cement grout to increase the elasticity of the grout.

Potential problems with utilizing cement as an annular seal include:

- Highly alkaline pH of 10 to 12
- Relatively long set time
- Shrinkage during setting
- Aboveground mixing

6.4.4.8
Surface Seal and Completion

Surface seals are required to prevent surface runoff from entering the borehole annulus and to protect the well from damage. Surface seals are constructed of cement and extend from the ground surface to below the frost line. Two types of surface completion structures are typically utilized for monitoring wells:

- Above-grade completion
- Flush completion

6.4.4.8.1
Above-Grade Completion

Above-grade-completed wells typically involve the placement of an outer protective casing around the actual well casing. The protective casing is usually steel or aluminum and is anchored into the cement surface seal (pad) prior to setting. The finished pad is sloped so that drainage will flow away from the protective casing and off of the pad.

The protective casing should be equipped with a cover that can be locked to prevent unauthorized access. The dimensions of the protective casing should be sufficient to provide clearance around the inner well casing, i.e., should not contact the inner well casing.

A vent hole should be drilled or cut into the top of the well casing cap and in the outer protective cover to permit pressure equalization. The protective casing should also have a weep hole installed just above the interface with the concrete pad to prevent water from standing inside of ~~the protective casing~~.

If above-grade-completed monitoring wells are located in high traffic areas, additional protection may be required (i.e., steel pipes, rails and/or other steel structures). Steel barrier pipes, 3 to 4 inches in diameter, are generally installed to a minimum depth of 2 feet below the ground surface and set in a concrete footing. The barriers should extend a minimum of 3 feet above ground surface or higher, if necessary, to provide good visibility. Concrete can also be placed into the steel pipe to provide additional strength.

6.4.4.8.2
Flush Completion

Flush-completed wells are completed below the ground surface. They are commonly utilized in high traffic areas where above-grade completions would disrupt surface activities or be subject to damage (i.e., parking lots or roadways.) These wells involve the utilization of a subsurface vault or well box that is installed around the well casing. To protect from heaving, the vault must be anchored below the frost line. The well vault is sealed with a locking flush-mount lid that prevents surface water infiltration. These wells should also be completed with a water-tight well cap.

The well is accessed for sampling and/or measurement from within the well vault. The water- and air-tight nature of these seals affects water levels in these wells. Upon opening the wells, the water levels must be allowed to equilibrate prior to measuring groundwater elevations.

6.4.5
Construction Methods

Construction methods for monitoring wells include:

- Drilling techniques
- Monitoring well development
- Well construction documentation
- Well abandonment

6.4.5.1
Drilling Techniques

Several drilling methods (Figure 6-11) are commonly used for installing groundwater monitoring wells, including the following:

- Auger drilling methods
- Rotary drilling methods
- Other drilling methods

Drilling method selection should be based upon the following objectives:

- Preserve the natural properties of the subsurface formation materials.
- Avoid contamination and/or cross-contamination of aquifers.
- Allow for collection of representative samples of formation materials.
- Provide for proper placement of well construction materials including filter pack and annular sealants.
- Allow for elimination or removal of drilling-induced impacts (i.e., fluids) and collection of representative groundwater samples.

It is preferable, when possible, to select a drilling method that allows for installation of the well materials (casing and screen), filter pack and annular seals prior to removal of the drilling tools (augers) or fluids (water). This is commonly done when using hollow-stem augers to advance the borehole. Construction of the well through the

Drilling Methods for Various Types of Geologic Settings

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

* Above potentiometric surface.

Note: Although several methods are suggested as appropriate for similar conditions, one method may be more suitable than the others.

Figure 6-11

augers helps to minimize construction problems associated with borehole collapse.

Rotary wash drilling methods develop a drilling mud (water and formation clays) which helps to stabilize the borehole during well construction. However, installation of the well materials must be preceded by thinning or replacement of the thick drilling mud with water; otherwise the mud will become entrapped within the filter pack. Inadequate removal of drilling mud prior to well construction may make it impossible to adequately develop the well after completion.

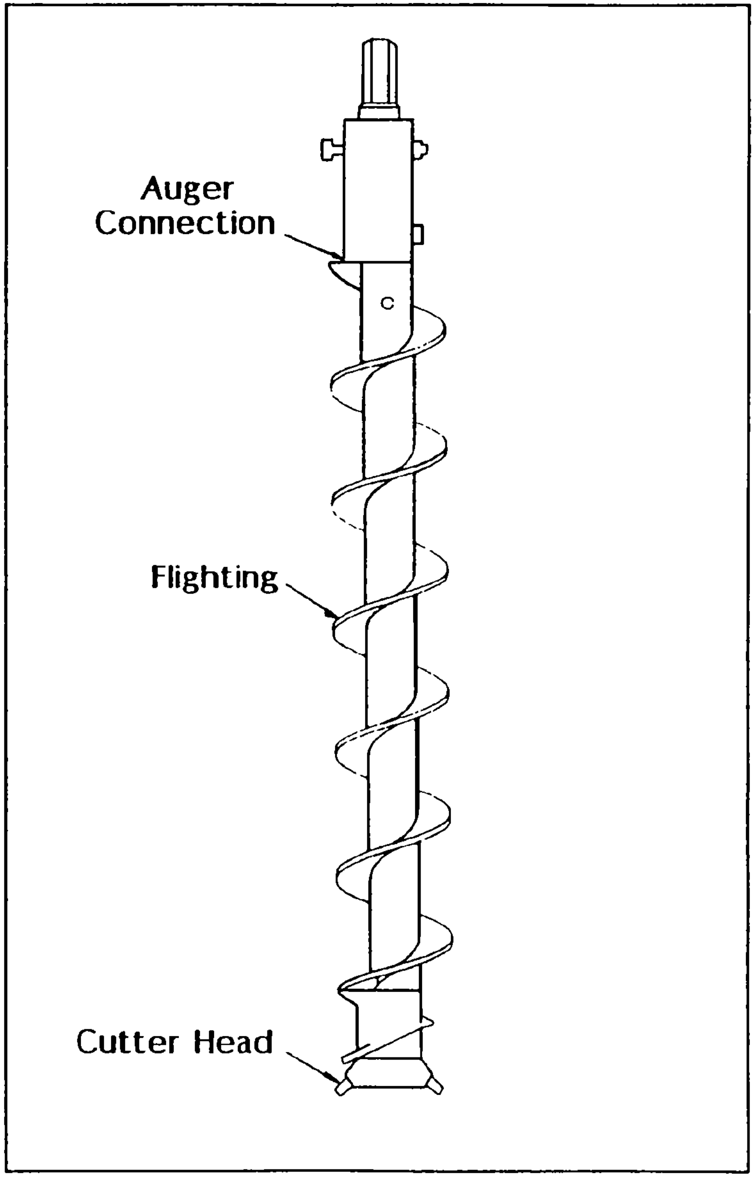
6.4.5.1.1
Auger Drilling Methods

Two types of augers are commonly used for drilling wells: solid-stem augers and hollow-stem augers. Both types can be used in unconsolidated soils and semi-consolidated (weathered rock) materials, but not in competent rock. An advantage of auger drilling methods is that they can be employed without introducing foreign materials into the borehole (i.e., drilling fluids), thus minimizing the potential for cross-contamination.

6.4.5.1.1.1
Solid-stem auger

Solid-stem augers consist of a solid stem or shaft with a continuous, spiralled steel flight welded to the stem (Figure 6-12). Auger sections (flights) are connected to the auger bit. When rotated, cuttings are transported to the surface. This auger method can be used in cohesive and semicohesive soils that do not have a tendency to collapse when disturbed. Boreholes can be augered to depths of 200 feet or more (depending on the auger size), but generally boreholes are augered to depths less than 150 feet. Applications and limitations of solid-stem auger drilling are presented in Figure 6-13.

Diagram of a Solid-Stem Auger



(Source: EPA, 1989)

Figure 6-12

Applications and Limitations of Solid-Stem Augers

Applications	Limitations
Shallow soils investigations	Unacceptable soil samples unless split-spoon or thin-wall samples are taken
Soil samples	Soil sample data limited to areas and depths where stable soils are predominant
Vadose zone monitoring wells	Unable to install monitoring wells in most unconsolidated aquifers because of borehole caving upon auger removal
Monitoring wells in saturated, stable soils	Depth capability decreases as diameter of auger increases
Identification of depth to bedrock	Monitoring well diameter limited by auger diameter

Figure 6-13

6-36

Soil sample collection is difficult with solid-stem augering because the soils are mixed by the continuous flighting of the cuttings. Monitoring well installation may also be difficult because the augers must be removed prior to placement of the well materials, allowing for borehole collapse.

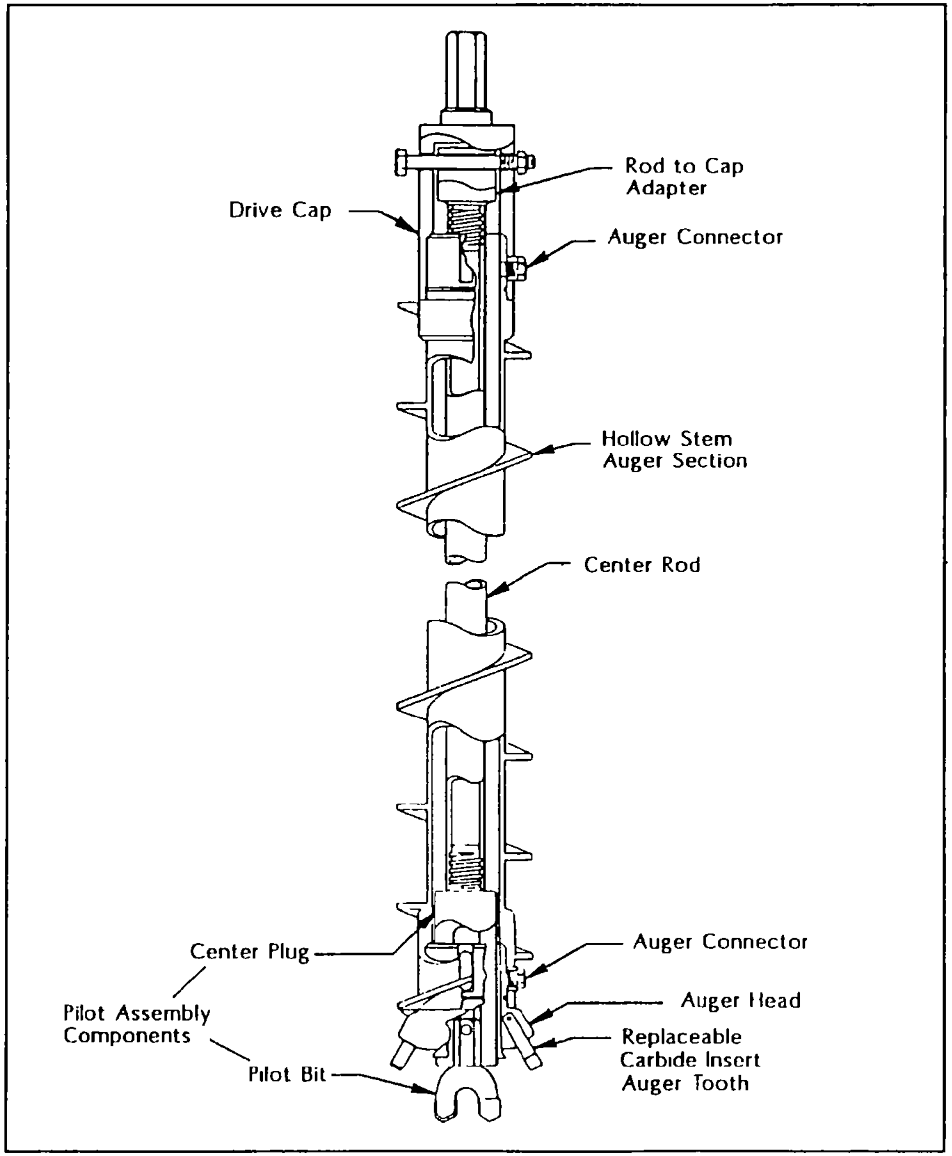
6.4.5.1.1.2
Hollow-Stem Auger

Hollow-stem augers consist of a hollow, steel stem or shaft with a continuous, spiralled steel flight welded onto the exterior of the stem (Figure 6-14). As with solid-stem augers, the cuttings are removed from the borehole by continuous flighting. Hollow-stem augers are utilized in all unconsolidated formations. Boreholes can be augered to depths of 150 feet or more (depending on the auger size), but generally boreholes are augered to depths less than 100 feet. Applications and limitations of hollow-stem auger drilling are presented in Figure 6-15.

Unlike the solid-stem augers, the open-center core allows the hollow-stem augers to act as a temporary casing for soil sample collection and well installation. Soil samples are commonly collected with split-spoon or thin-walled (shelby tube) samplers for characterization of site geology (figures 6-16 and 6-17).

Monitoring wells can be installed inside hollow-stem augers to reduce the potential for caving of formation materials during placement of the well materials. However, retracting the augers while installing monitoring wells in caving formation conditions can be difficult. A pilot-bit assembly or bottom plug can be fastened to the bottom of the augers to keep soils and/or water from clogging the bottom of the augers during drilling (figures 6-18 and 6-19). Sometimes potable water is poured into the augers to equalize pressure and

Diagram of a Hollow-Stem Auger



(Source: EPA, 1989)

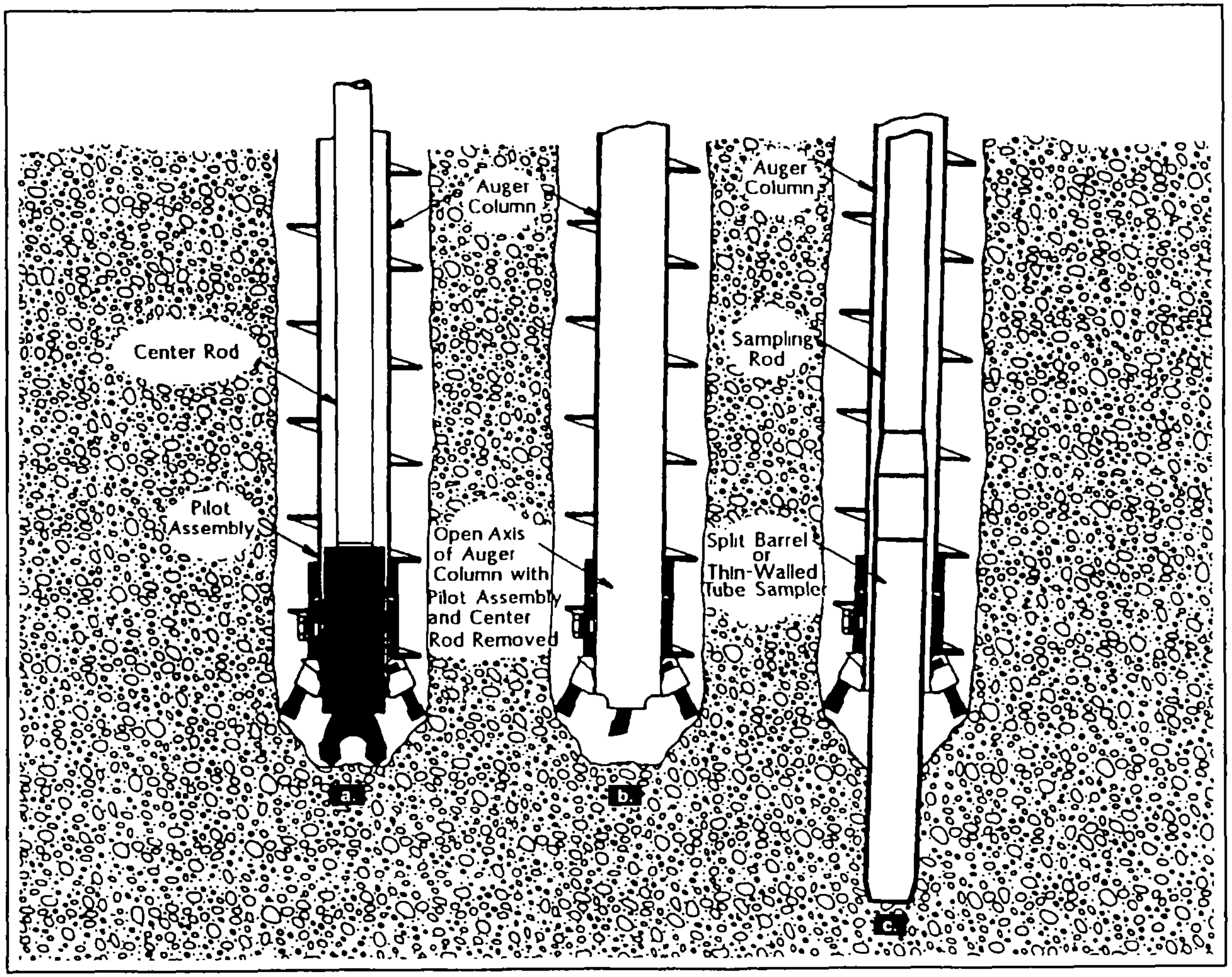
Figure 6-14

Applications and Limitations of Hollow-Stem Augers

Applications	Limitations
All types of soil investigations	Difficulty in preserving sample integrity in heaving formations
Permits good soil sampling with split-spoon or thin-wall samplers	Formation invasion by water or drilling mud if used to control heaving
Water quality sampling	Possible cross contamination of aquifers where annular space not positively controlled by water or drilling mud or surface casing
Monitoring well installation in all unconsolidated formations	Limited diameter of augers limits casing size
Can serve as temporary casing for coring rock	Smearing of clays may seal off aquifer to be monitored
	Can be used in stable formations to set surface casing

Figure 6-15

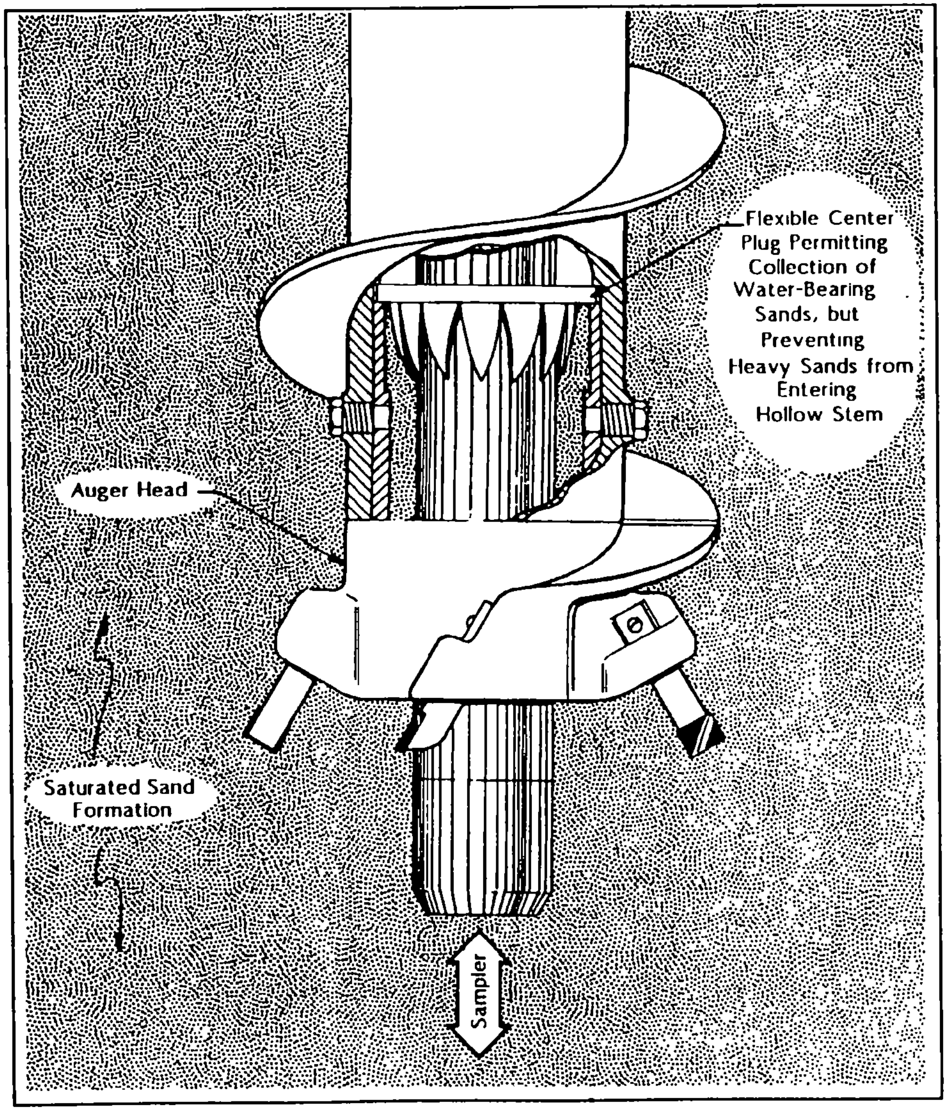
Sequential Steps in Hollow-Stem Drilling and Sampling



(Source: EPA, 1989)

Figure 6-16

Flexible Center Plug in Hollow-Stem Auger Bit



(Source: EPA, 1989)

Figure 6-17
6-40

Hollow-Stem Auger with Pilot-Bit Assembly

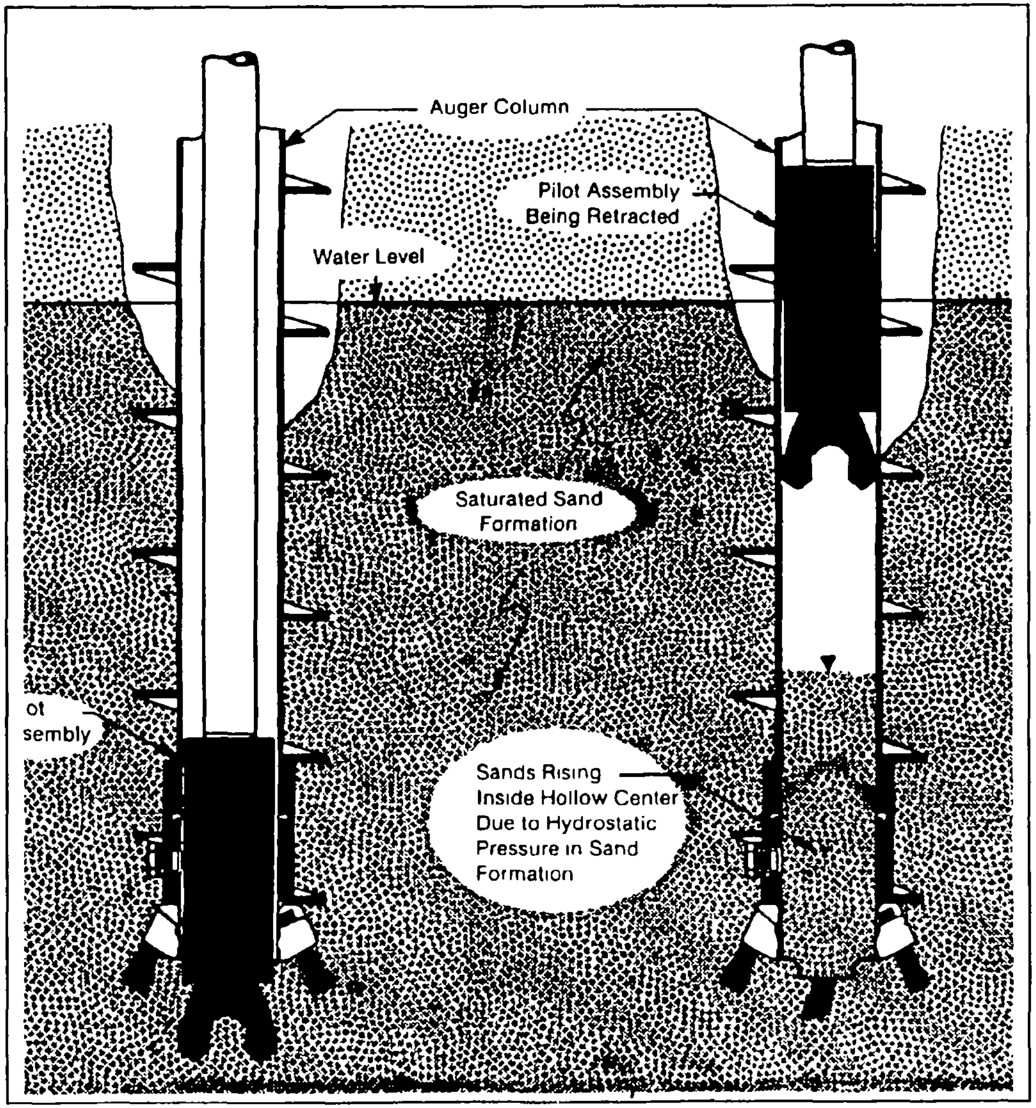


Figure 6-18

Hollow-Stem Auger with Knock-Out Bottom Plug

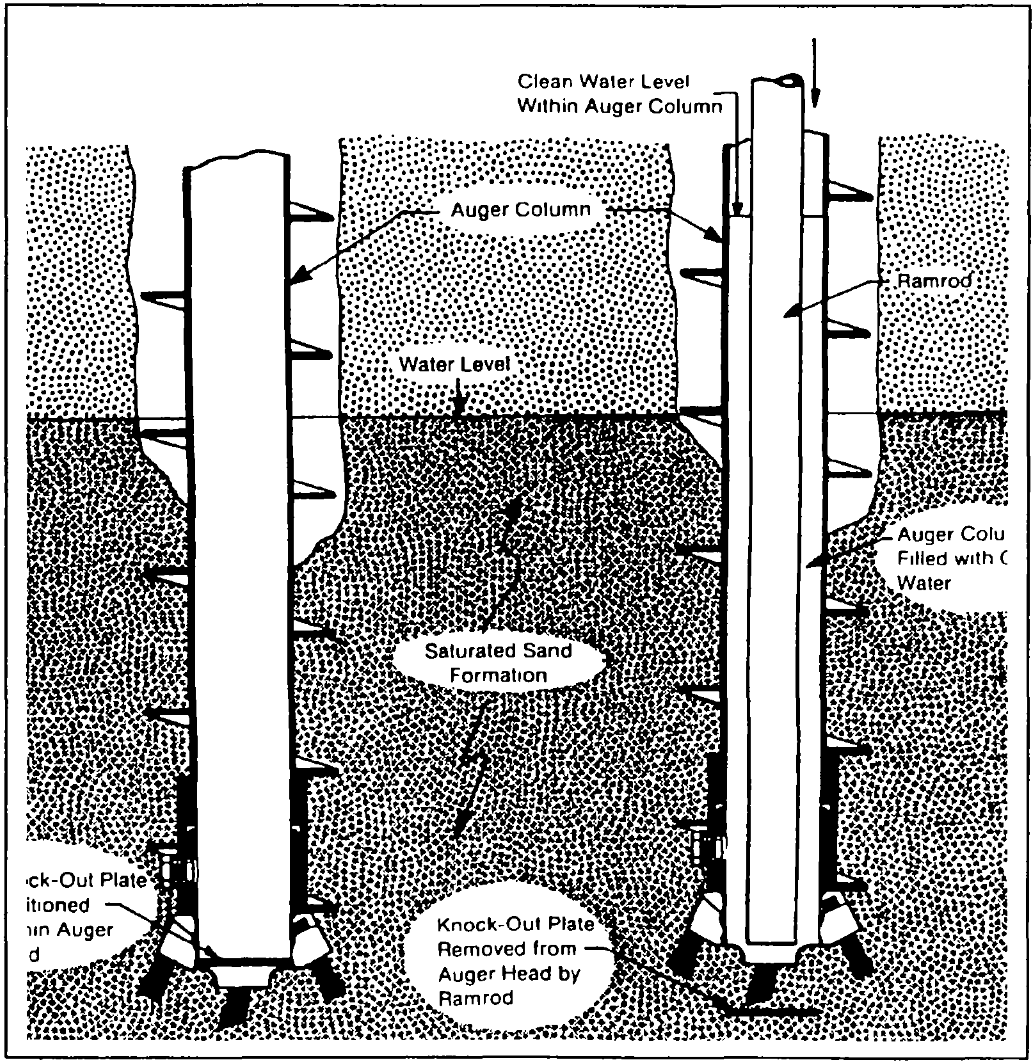


Figure 6-19
6-42

prevent the inflow of formation materials into the augers when the bottom plug is removed.

6.4.5.1.2
Rotary drilling methods

Rotary drilling methods use a hollow drill pipe (drill stem) coupled to a drilling bit that rotates and cuts through the soils (Figure 6-20). The cuttings produced from the rotation of the drilling bit are transported to the surface by drilling fluids which generally consist of water, drilling mud or air. The drilling fluid is pumped down through the drill pipe and out through the bottom of the drilling bit (or the reverse - down the annular space and up the drill pipe in reverse rotary drilling.) The drilling fluids not only carry the cuttings to the surface but also keep the drilling bit cool, stabilize the borehole and prevent the inflow of formation materials and fluids.

Rotary drilling provides for rapid borehole advancement in both consolidated and unconsolidated formations and is not subject to depth limitations. Applications and limitations of direct mud rotary and air rotary drilling are presented in figures 6-21 and 6-22.

When considering rotary drilling methods, it is important to evaluate the potential for contamination from the fluids introduced into the borehole. Rotary drilling with water as the drilling fluid is preferred, followed by air and, lastly, by mud. The two rotary drilling methods most commonly utilized to construct monitoring well boreholes are water rotary (rotary wash) and air rotary drilling.

6.4.5.1.2.1
Rotary wash drilling

Rotary wash drilling (with water) is preferred for environmental drilling because potable water is the only fluid introduced into the borehole during drilling. The drilling water does not clog the for-

Diagram of a Direct Rotary Drilling System

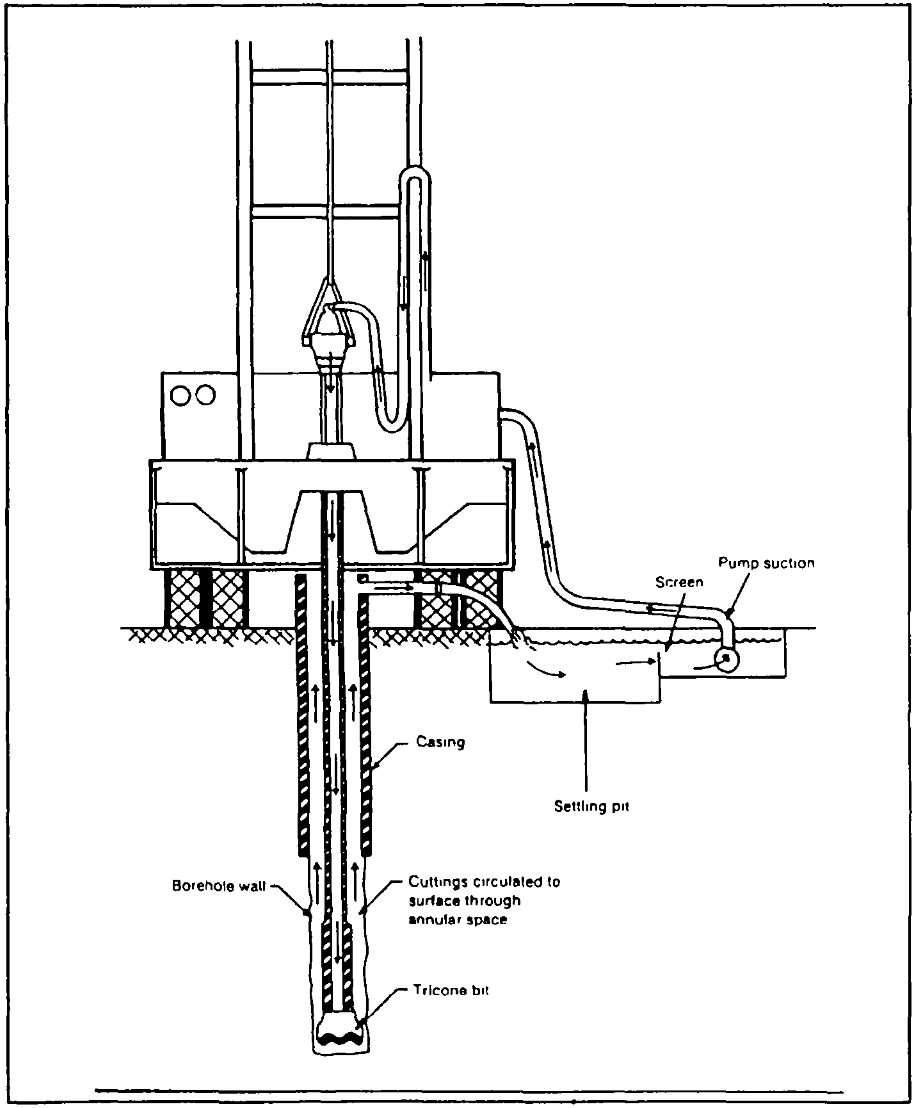


Figure 6-20
6-43

Applications and Limitations of Direct Mud Rotary Drilling

Applications	Limitations
Rapid drilling of clay, silt and reasonably compacted sand and gravel	Difficult to remove drilling mud and wall cake from outer perimeter of filter pack during development
Allows split-spoon or thin-wall sampling in unconsolidated materials	Bentonite or other drilling fluid additives may influence quality of groundwater samples
Allows core sampling in consolidated rock	Circulated (ditch) samples poor for monitoring well screen selection
Drilling rigs widely available	Split-spoon and thin-wall samplers are expensive and of questionable cost effectiveness at depths greater than 150 feet
Abundant and flexible range of tool sizes and depth capabilities	Wireline coring techniques for sampling both unconsolidated and consolidated formations often not available locally
Very sophisticated drilling and mud programs available	Difficult to identify aquifers
Development of geophysical borehole logs	Drilling fluid invasion of permeable zones may compromise validity of subsequent monitoring well samples

Figure 6-21

Applications and Limitations of Air Rotary Drilling

Applications	Limitations
Rapid drilling of semiconsolidated and consolidated rock	Surface casing frequently required to protect top of hole
Good quality/reliable formation samples (particularly if small quantities of water and surfactant are used)	Drilling restricted to semiconsolidated and consolidated formations
Equipment generally available	Samples reliable but occur as small particles that are difficult to interpret
Allows easy and quick identification of lithologic changes	Drying effect of air may mask lower yield water-producing zones
Allows identification of most water-bearing zones	Air stream requires contaminant filtration
Allows estimation of yields in strong water-producing zones with short "down time"	Air may modify chemical or biological conditions. Recovery time is uncertain.

Figure 6-22
6-45

mation materials, thus reducing well development time. The drilling water will, however, flow out into the surrounding formation materials (if permeable) and mix with the natural formation water Generally, most of the drilling water will be recovered during well development.

Lithologic sample collection is good via split-spoon and thin-walled samplers; however, drilling fluid circulation must be stopped while the drill string is removed and then replaced to collect the samples.

6.4.5.1.2.2
Air rotary drilling

Air rotary drilling utilizes air instead of water (or mud) as the circulation medium. Compressed air is forced through the drill rods to cool the bit and force the cuttings up the annular space. This method provides good lithologic samples and allows good estimation of most water-bearing zones.

Air rotary drilling is difficult in unconsolidated formations due to borehole collapse. The problem can be alleviated with the utilization of a casing driver that advances an outer casing along with the rotary bit. Down-hole hammer bits are often utilized in hard, consolidated formations to achieve better penetration.

When using air rotary, an in-line organic filter system must be installed on the air compressor to filter the air coming from the compressor. Air compressors that do not have in-line organic filter systems may introduce contaminants into the borehole and formation. A cyclone velocity dissipator or similar containment system should also be used to funnel the cuttings to one location instead of letting the cuttings blow uncontrolled out of the borehole.

6.4.5.1.2.3
Mud rotary drilling

Mud rotary is the least preferred rotary method Drilling with mud (bentonite or other additives mixed with water to create a thicker drilling fluid) has the tendency to clog the water-bearing formation and may influence the chemistry of the groundwater. The drilling fluids lost to the formation will have to be removed during development before the well can be sampled. Only potable water and pure (no additives) bentonite drilling muds should be used for environmental drilling.

6.4.5.1.3
Other Drilling Methods

Other types of drilling procedures are also available such as cable-tool (figures 6-23 and 6-24), jetting and bucket-auger boring methods. These methods are used in the installation of water and irrigation wells, but are not commonly used for monitoring well installation.

6.4.5.1.4
Cleaning and decontamination

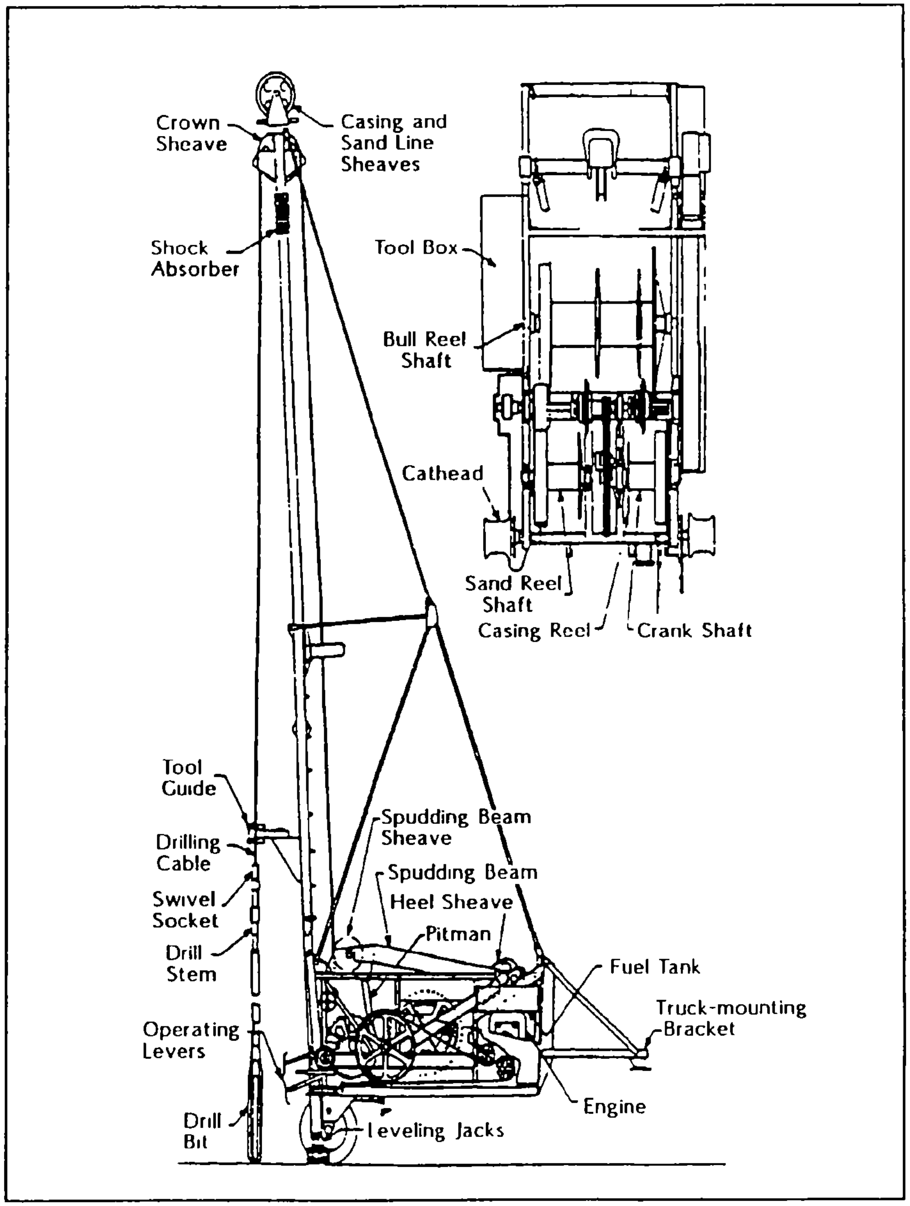
Drilling rigs, drilling and sampling equipment and all other associated equipment involved in the drilling, sampling and well construction activities must be cleaned and decontaminated prior to drilling each borehole. Oil or grease should not be used to lubricate drill stem threads or any other drilling equipment that might come in contact with the borehole.

The well casing and screen materials must be cleaned prior to installation, to remove any manufacturing residues, labeling or other materials which they may have contacted.

6.4.5.2
Monitoring Well Development

A monitoring well must be developed before a sample that is considered representative of groundwater can be collected. The primary objective of monitoring well development is to restore the formation adjacent to the well to its original (predrilling) condition by correcting the damage inflicted on the formation during drilling and construction of the

Diagram of a Cable Tool Drilling System



(Source: Buckeye Drill Company/Bucyrus-Erie Company, 1982)

Figure 6-23
6-46

Applications and Limitations of Cable Tool Drilling

Applications	Limitations
Drilling of all types of geologic formations	Drilling relatively slow
Almost any depth and diameter range	Heaving of unconsolidated materials must be controlled
Ease of monitoring well installation	Equipment available more commonly in central, north central and northeast sections of the United States
Ease and practicality of well development	
Excellent samples of coarse-grained materials	

Figure 6-24
6-47

well. All forms of well development require the removal of water from the well.

Three factors influence the development of a monitoring well:

- Type of geologic material
- Design and completion of the well
- Type of drilling technology employed

The following procedures are generally used to develop monitoring wells:

- Bailing
- Surging
- Pumping/Overpumping/Backwashing
- Air lift

These methods can be used either individually or in combination to achieve the most effective well development. Other development methods used in water supply well applications are not recommended because of their potential impacts on the aquifer formation and groundwater chemistry.

Monitoring wells should be developed until the water is free of visible sediment and the pH, temperature and specific conductivity have stabilized. In most cases, the above requirements can be satisfied; however, in some cases, the pH, temperature and specific conductivity stabilize, but the water remains turbid. When groundwater remains turbid, the well may still contain well construction materials (such as drilling mud in the form of a mud cake) and/or formation soils that have not been washed out of the borehole.

Excessive or thick drilling muds cannot be flushed out of a borehole with one or two well volumes of purge water. Continuous flushing for several days may be necessary to complete the well development. Likewise, wells screened in silty and clayey formations may require more extensive development to reduce turbidity.

In instances where the groundwater is contaminated or is suspected to be contaminated, the well development procedures must address health and safety precautions and proper storage and disposal of the development water.

6.4.5.2.1
Bailing

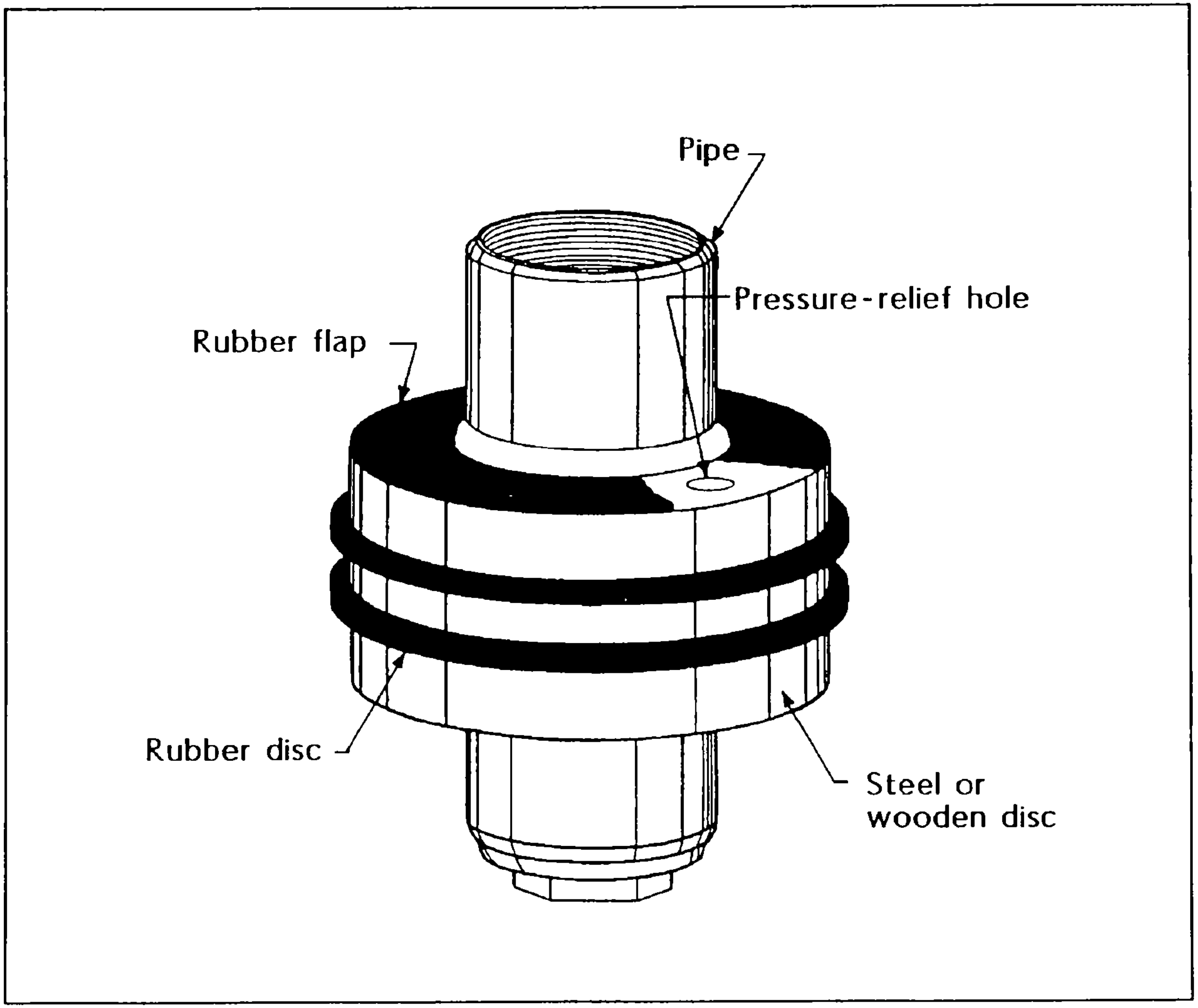
Bailing is effective for developing shallow monitoring wells in relatively clean, permeable formations. The alternative dropping and retrieval of the bailer agitates the formation sufficiently to remove the fine material from around the filter pack. Bailing may be performed by hand or with a drill rig setup.

6.4.5.2.2
Surging

Surging is performed by raising and dropping the surging apparatus (i.e., surge block, pump, bailer, etc.) to drive water into and out of the filter pack. This in and out flow agitates the filter pack causing proper seating of the filter pack materials by disrupting bridging and helps to remove fine particles trapped within the filter pack.

Surge blocks (Figure 6-25) are devices designed for this purpose which can be raised and dropped with a drill rig or in smaller and shallower settings by hand. Surging can also be used effectively in conjunction with bailing or

Diagram of a Typical Surge Block



(Source: Driscoll, 1986)

Figure 6-25

pumping. The bailer or pump can be raised and lowered causing the surging action between evacuation episodes.

6.4.5.2.3
Pumping/ overpumping/backwashing

Pumping is a common method utilized to develop monitoring wells. A pump is placed in the well to remove water and to loosen particulate matter. With overpumping, the pump rate is set at a level that exceeds the formation's ability to produce water, thereby flushing out the filter pack more effectively. In both methods, the pump must be periodically stopped and started to allow water to recharge the well. Backwashing ("rawhiding") or allowing water to flow from the pump and piping back into the well can impact water quality in the well. A similar surging effect can be produced by using the pump like a surge block (raising and lowering) to loosen fine particles and eliminate bridging of the filter pack materials.

The well is usually considered adequately developed when the turbidity, pH, temperature and specific conductivity of the groundwater reach a stabilized point. Stabilization is achieved after three consistent, consecutive readings are logged during the development.

6.4.5.2.4
Air Lift

Air lifting, using the eductor method (which does not expose the formation to the air or compressed gas (nitrogen)), can be used to develop monitoring wells. The air line is fed into the well through an eductor pipe. The discharge point of the air line is located within the eductor pipe allowing the air to rise to the surface within the eductor pipe, drawing formation water up with it. Direct air lifting (without an eductor system) allows air to directly contact the well materials and potentially impact water quality. Direct air lifting is not recommended for development of monitoring wells.

6.4.5.3
Well Construction Documentation

All pertinent data collected during well construction (drilling and development) operations should be recorded in a field logbook. Each borehole location should be recorded and referenced to the site map and/or site datum (benchmark) so that each location can be permanently established. It is important that drilling logs be concise, complete and presented in a manner that is easily understood. Drilling and development information that should be recorded as part of the logging data includes the following:

- Borehole number and location
- Method of drilling
- Type of drilling equipment, driller and drilling company
- Type of well (permanent or temporary)
- Drilling and sampling dates and times
- Depth of sampling and description
- Type and size of casing
- Type and size of well screen
- Depth to well screen
- Type of pump and pumping rate
- Depth to water table and date and time measured
- Development method
- Volume of water purged for development

The well coordinates and elevations must be surveyed and recorded as part of the construction details. Elevations for the protective casing, top of well casing (at a specified point or notch) and grade should be surveyed by a licensed surveyor to the nearest 0.01 foot.

6.4.5.4
Well Abandonment

When a decision is made to abandon a boring or monitoring well, the borehole must be sealed in such a manner that it cannot act as a conduit for migration of contaminants either from the ground surface to the water table or between aquifers. The preferred method of abandonment is to completely remove any well casing and screen from the borehole prior to backfilling with an appropriate grout material (cement or bentonite grout, neat cement or concrete.) The backfill material should be placed into the borehole from the bottom to the top by pressure-grouting using the positive displacement method (tremie method).

Wells that cannot be removed may have to be grouted with the casing left in the borehole. In this case, the tremie pipe should be placed near the bottom of the well to allow the grout to fill the well from the bottom to the top.

6.4.6
Placement of Monitoring Wells

Placement of monitoring wells (i.e., number, spacing and depths) to meet the groundwater monitoring program objectives at MSWLFs requires an understanding of the site hydrogeology. Hydrogeologic factors which must be considered when designing groundwater monitoring systems include

- Type of stratigraphy
- Types of soils and/or rock

- Depth to bedrock
- Saturated and unsaturated materials overlying the uppermost aquifer
- Materials comprising the uppermost aquifer
- Materials comprising the lower boundary of the uppermost aquifer
- Depth to groundwater
- Aquifer thickness
- Groundwater flow direction and rate
- Seasonal and temporal groundwater fluctuations
- Presence of perched water tables
- Topography
- Surface drainage patterns and features

Other factors which may affect groundwater monitoring system design are:

- Location of the landfill
- Location of private and public water supply wells
- Location of surface water intakes
- Municipal water service areas
- Location of watersheds and recharge areas

- Location of 100-year floodplains

6.4.6.1
Hydrogeologic Characterization

Visual inspection of the area may be sufficient to evaluate and determine the surface conditions and their general relationship to the subsurface conditions. However, in most cases, surface and subsurface conditions cannot be adequately correlated by site inspections alone. Generally, more detailed studies involving test drilling must be conducted to adequately characterize the site hydrogeology. Hydrogeologic characterization of the site must be performed by qualified individuals.

Characterization of the local hydrogeologic setting involves both review of available information and site-specific hydrogeologic investigations.

6.4.6.1.1
Existing information

A review of existing information on local and regional geology and hydrogeology is the first step in any hydrogeologic characterization study. The site should be located on a U.S. Geological Survey (USGS) 7.5-minute topographic quadrangle map, U.S. Department of Agriculture (USDA) soil map, aerial photograph and any other appropriate maps that show topography and general relationships between surface features. This will help to identify sources of available information that will need to be reviewed.

Various local and regional sources of information are available to obtain information on the site hydrogeologic setting. These sources include:

- State Geological Surveys
- State Department of Agriculture
- USDA Soil Conservation Service (SCS) Office

- U.S. Environmental Protection Agency
- State Departments of Natural Resources and Environmental Protection

State geological surveys and the USGS have various types of water-related papers and reports on all phases of groundwater studies in each state. Other Federal agencies with water programs which may provide information are:

- Army Corps of Engineers
- Bureau of Reclamation
- Forest Service
- Science and Education Administration
- Public Health Service
- Bureau of Mines

City and county governments also have departments that deal with water-related projects and which may be able to provide data for the local area. A review of wells installed in the area of interest may provide background information on subsurface conditions. Other sources include colleges, universities and professional/technical associations such as the following: American Association of Petroleum Geologists, American Institute of Mining and Metallurgical Engineers, American Water Well Association, National Ground Water Association, Association of Engineering Geologists and Geological Society of America.

Some states require well drillers to be licensed and/or submit state-prescribed forms for reporting work performed on wells; these forms are available to the public.

6.4.6.1.2
Site-specific hydrogeologic investigation

Site-specific hydrogeologic investigations must be designed to adequately interpret the site geology and hydrology; therefore, the scope of the investigation is directly related to the complexity of the underlying geology.

The hydrogeological investigation should include the installation of boreholes, piezometers and monitoring wells, as necessary, to evaluate the properties of the materials comprising the underlying geologic units. These properties include:

- Lithology
- Thickness
- Stratigraphy
- Hydraulic conductivity
- Porosity
- Effective porosity
- Depth to bedrock

Other geologic and hydrologic features which, if present, must be characterized in the site-specific investigation include:

- Slopes
- Streams
- Springs

- Gullies
- Trenches
- Solution features
- Karst terrain
- Sinkholes
- Dikes
- Sills
- Faults
- Mines
- Groundwater discharge features
- Groundwater recharge/discharge areas

The site hydrogeologic characterization must also consider natural and man-made conditions that have the potential for causing water level fluctuations, such as:

- Tidal variations
- River stage changes
- Flood pool changes of reservoirs
- High volume production wells
- Injection wells

Site-specific hydrogeologic characterization studies should include the following components:

- Field observations
- Drilling and materials testing programs
- Other characterization techniques
- Data presentation, interpretation and evaluation

6.4.6.2
Field Observations

Field observations of the site should, at a minimum, include information on

- Topographic setting
- Springs, streams and other drainage features
- Existing or abandoned wells
- Groundwater recharge and discharge features
- Rock outcrops (including trends in strike and dip) and other features that may affect site suitability or the ability to effectively monitor the site

6.4.6.3
Drilling and Materials Testing Programs

The drilling and materials testing program of a hydrogeologic characterization study should provide for a sufficient number of boreholes, piezometers and wells to use in developing an adequate understanding of the subsurface conditions and groundwater flow regime of the uppermost aquifer at the site. The number and depths of boreholes, piezometers and wells, as described below, should be determined based upon the homogeneity of the geologic and hydrogeologic characteristics of the subsurface media.

6.4.6.3.1
Boreholes

Exploratory boreholes should be installed to the bottom of the uppermost aquifer to determine the aquifer thickness and composition of the lower confining material. Continuous cores, while more expensive than interval sampling (sampling on 5-foot intervals), provide a better understanding of lithology and site stratigraphy. Boreholes should be installed systematically throughout the site until an adequate quantity of data has been collected to define subsurface conditions. Factors which influence the density of boreholes are presented in Figure 6-26.

6.4.6.3.2
Piezometers

Piezometers are simplified or temporary well installations designed to provide hydraulic head (groundwater level) data at discrete intervals. Piezometers are used to determine groundwater levels and flow directions at the site. Piezometers are cost-effective tools that aid in designing monitoring systems with optimal well placement. They can also be used to supplement collection of water-level data from monitoring wells.

6.4.6.3.3
Monitoring wells

Initial monitoring wells should be installed at the site to measure the hydraulic conductivity of the various geologic materials. Hydraulic conductivity is generally measured by utilizing slug tests or pumping tests, which are also effective techniques to provide information on hydraulic interconnection between the formations.

6.4.6.3.4
Materials testing

Samples of geologic materials collected from the boreholes should be tested to determine the properties of the materials which, at a minimum, should include:

- Formation descriptions

Factors Influencing the Density of Boreholes

Factors That May Substantiate Reduced Density of Boreholes	Factors That May Substantiate Increased Density of Boreholes
Simple geology (e.g., horizontal, thick, homogeneous geologic strata that are continuous across site and are unfractured) substantiated by site-specific geologic information.	Fracture zones, conduits in karst terrains. Tilted or folded geologic formations.
Use of electric cone penetrometer surveys with additional tools (i.e., d.c. resistivity, sampling).	Suspected pinchout zones (i.e., discontinuous strata across the site).
Use of surface geophysical methods to correlate hydrogeologic data between boreholes.	Laterally transitional geologic units with irregular hydraulic conductivity (e.g., sedimentary facies changes).

Figure 6-26
6-62

- Soil classification (based upon the Unified Soil Classification System)
- Standard penetration-resistance
- Soil moisture content
- Grain size distribution
- Soil particle specific gravity
- Porosity and effective porosity
- Hydraulic conductivity

6.4.6.4
Other Characterization Techniques

Subsurface hydrogeologic conditions may be investigated using a variety of other geologic, hydrologic, geophysical, geotechnical and engineering techniques. Techniques that may be used for hydrogeologic characterization studies are summarized in Figure 6-27.

6.4.6.4.1
Data presentation, interpretation and evaluation

Geologic and hydrogeologic information must be interpreted and evaluated before the interrelationships between the individual pieces of data can be understood. A variety of techniques are used for presenting hydrogeologic information, including:

- Site location maps
- Stratigraphic cross sections and fence diagrams
- Data tables and graphs
- Potentiometric maps and flow nets
- Narrative description

Summary of Hydrogeologic Investigation Techniques

- Review of existing geologic information
- Geophysical techniques (surface and borehole)
- Mapping - topography, geology, soil
- Cone penetrometer surveys
- Aerial photography
- Groundwater modeling
- Review of available hydrologic information
- Water levels measured in piezometers and wells
- Aquifer tests (slug tests, pump tests, packer tests)
- Vadose zone monitoring
- Tracer studies
- Groundwater quality analyses
- Meteorological and climatological data gathering
- Surface water chemistry and flow data

Figure 6-27
6-64

- Other information

These techniques are described below in more detail. A detailed summary of other data presentation and interpretation techniques is presented in Figure 6-28a and Figure 6-28b.

6.4.6.4.2
Site location maps

A site map locating all soil boreholes, piezometers, monitoring wells and other relevant site features is essential for proper interpretation of geologic and hydrogeologic data. The site map should be developed with accurate horizontal and vertical control and, at a minimum, be tied to a permanent onsite bench mark.

6.4.6.4.3
Stratigraphic cross-sections and fence diagrams

Cross sections and fence diagrams are graphic techniques for presenting and interpreting lithologic and hydrogeologic data (figures 6-29 and 6-30.) These techniques are used to present data from the individual boring logs and to extrapolate between the boreholes to develop a two- or three-dimensional understanding of subsurface geology and hydrology. Stratigraphic and hydrogeologic (aquifers) units can be depicted as well as potentiometric data.

6.4.6.4.4
Data tables and graphs

Summarization of hydrogeologic data in tables and graphs is essential to understanding the data relationships. Data tables and graphs should be used to prepare and support the interpretations presented in the narrative discussion of site hydrogeology. Examples of tabular and graphic data presentations include:

- Tables of groundwater and surface water elevation data
- Hydrographs of water elevation data for individual wells

Summary of Other Data Presentation and Interpretation Techniques

- Narrative summary of site geology and hydrology
- Narrative summary of site geochemistry stratigraphic column
- Geologic cross sections and fence diagrams
- Topographic maps
- Geologic maps
- Soil maps
- Boring and/or coring logs
- Structure contour maps
- Isopach maps
- Raw data and interpretive analysis of surface and borehole geophysical studies
- Raw data and interpretive analysis of materials tests

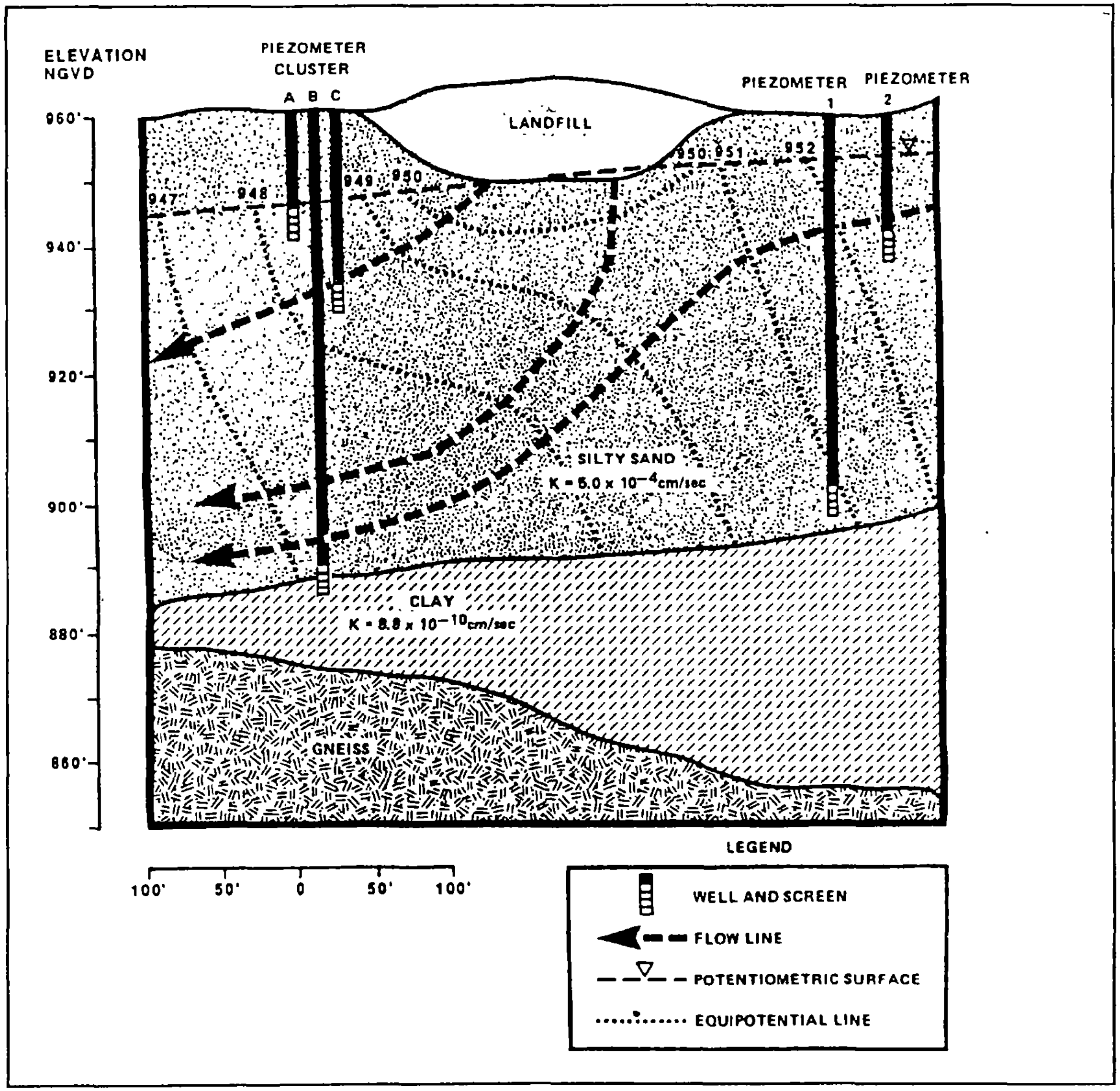
Figure 6-28 a
6-66 a

Summary of Other Data Presentation and Interpretation Techniques (cont'd)

- Aerial photographs
- Results of modelling efforts
- Piper, stiff and other geochemical diagrams
- Hydrogeochemical maps
- Water-table and potentiometric surface maps
- Maps of recharge and discharge areas
- Horizontal and vertical flow nets
- Fracture trace maps
- Maps of flow routes in karst terrains
- Hydrographs
- Estimates of hydraulic conductivity, hydraulic gradient, rate of groundwater flow
- Raw data and interpretive analysis of aquifer tests

Figure 6-28 b
6-66 b

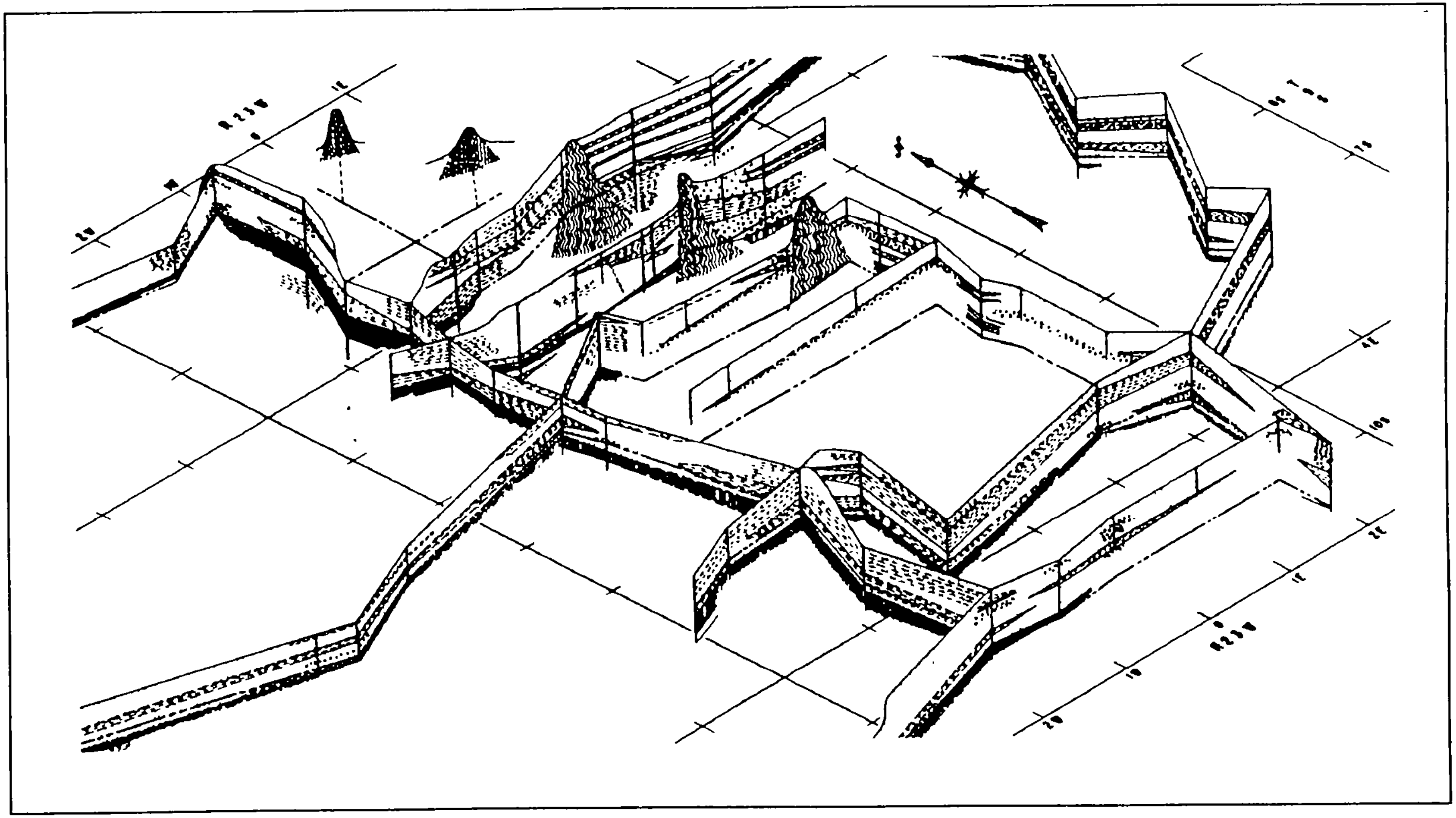
Simple Geologic Cross Section



(Source: EPA, 1989)

Figure 6-29

Typical Fence Diagram



(Source: USDI, 1981)

Figure 6-30
Figure 6-68

- Other information

Tabular and graphic presentations can be used to:

- Develop an understanding of seasonal water table fluctuations
- Estimate the long-term seasonal high water table
- Evaluate climatological impacts on groundwater

6.4.6.4.5
Potentiometric maps and flow nets

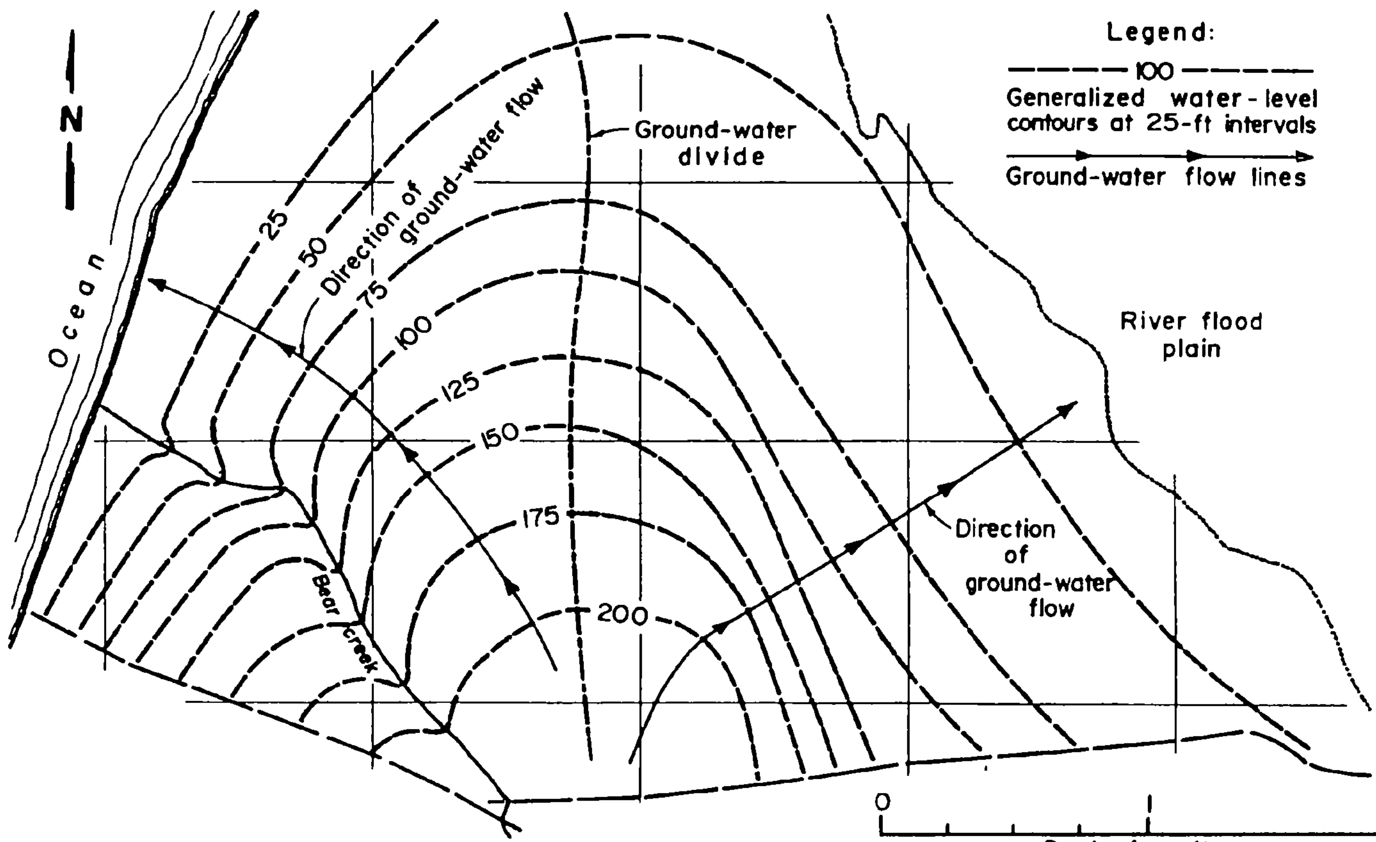
Potentiometric maps and flow nets (figures 6-31 through 6-33) are techniques for evaluating the horizontal and vertical aspects of groundwater flow including

- Flow directions
- Flow rates
- Hydraulic gradients

Potentiometric maps of water table and groundwater potentiometric surfaces (confined aquifers) should be developed for each set of water-level data. Each set of data provides additional information on the long-term consistency and/or variability of groundwater flow directions and rates.

Separate potentiometric maps must be developed for each aquifer or water-bearing zone that is encountered at the site. The maps should include the location of all monitoring points (boreholes, piezometers and monitoring wells) and the groundwater elevation data at each location used to generate the potentiometric

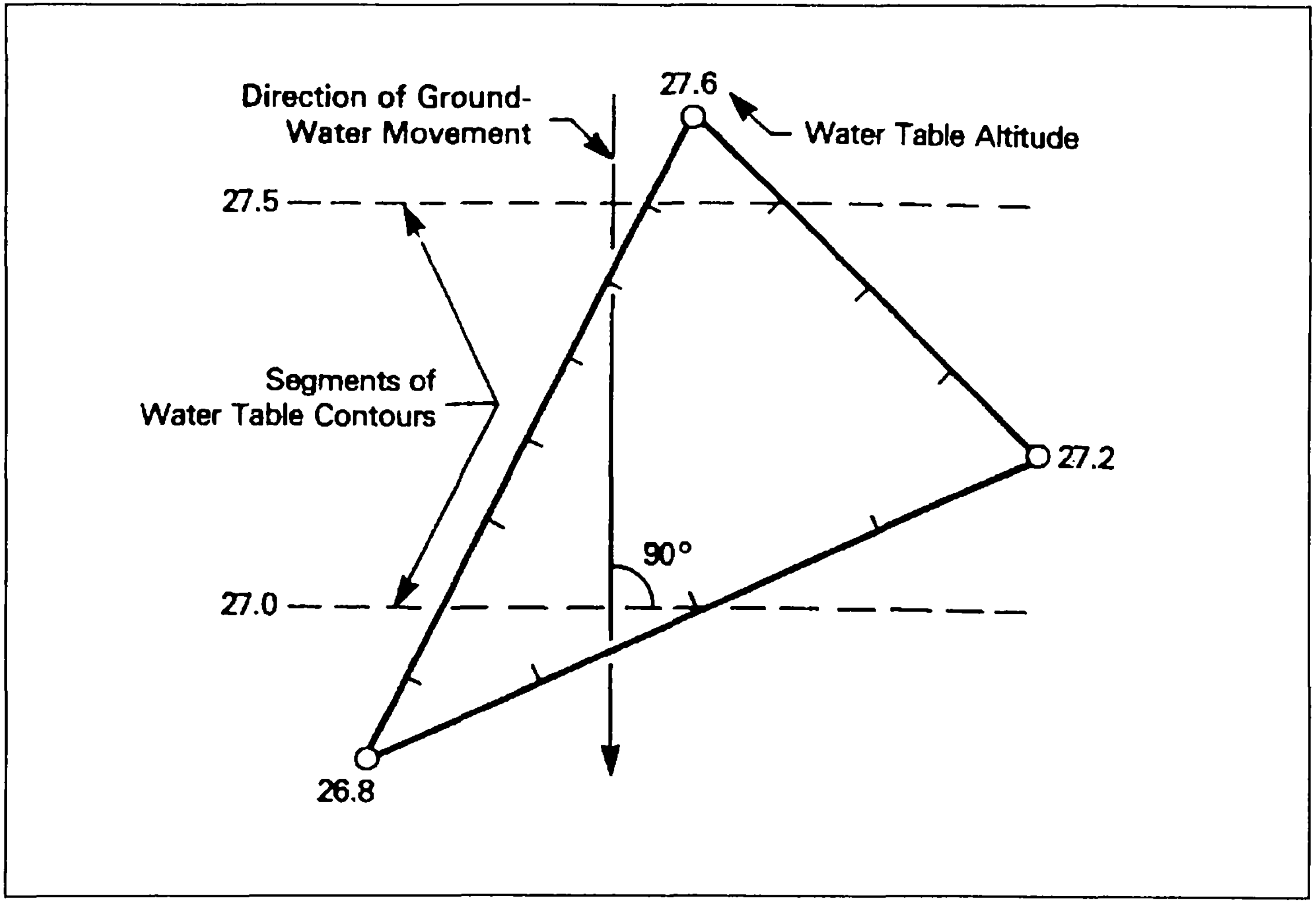
Typical Potentiometric Map



(Source: Johnson, 1975)

Figure 6-31

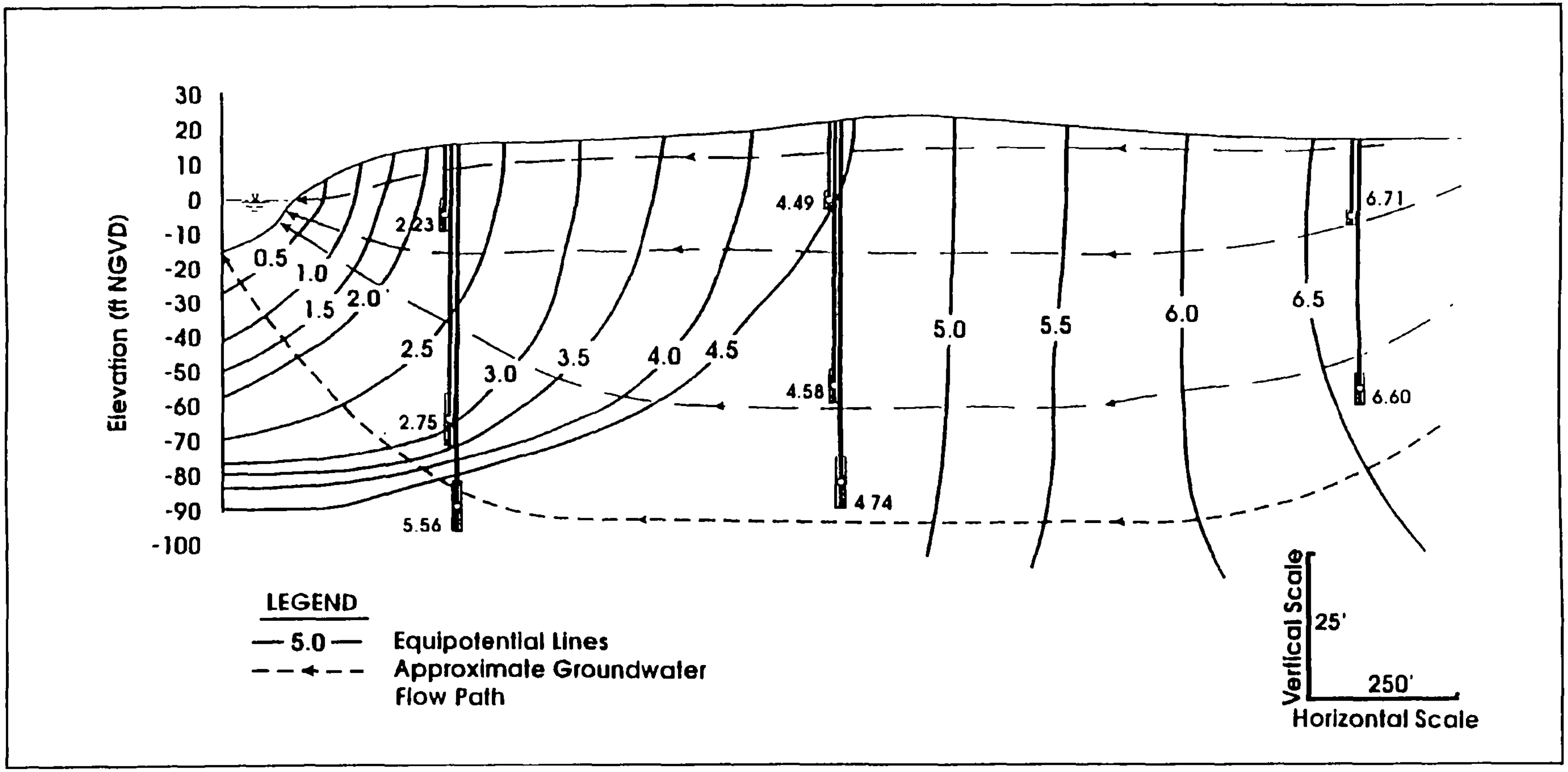
Interpolating Potentiometric Data



(Source: EPA, 1987)

Figure 6-32

Typical Flow Net



contours. The direction of groundwater flow should also be identified on the map.

Flow nets are similar to potentiometric maps in their presentation of data, but their value is generally less understood. Flow nets enable presentation of the vertical component of groundwater flow, which is essential to proper placement of monitoring well screens to intercept potential contaminant migration pathways.

6.4.6.4.6
Narrative Description of Hydrogeology

Hydrogeologic characterizations should include a detailed narrative description of the geologic and hydrogeologic evaluations for the following two very important reasons:

- Many readers, with all levels of hydrogeologic expertise, may be required to review and/or use hydrogeologic characterization information. Inadequate explanation and/or clarification of interpretations and conclusions may lead to misunderstanding and/or misuse of the information.

- The procedures and methods used to interpret and evaluate the hydrogeologic data must be reproducible by other qualified professionals at future dates when additional information becomes available. Inadequate documentation of hydrogeologic characterizations often diminishes the quality and usefulness of the data.

6.4.6.4.7
Other information

Other information including boring logs, field logs and notes, piezometer and well construction records and field observations provide valuable information for characterizing site hydrogeology.

6.4.6.5
Well Location Selection

Once the hydrogeologic characterization of the site has been completed, the groundwater monitoring system can be designed and installed. The number and location of the monitoring wells must be selected to monitor the pathways of contaminant migration and the background groundwater quality.

Background wells should be placed upgradient of the MSWLF or at other locations that provide data that is representative of background groundwater quality. Background wells must be properly positioned to ensure that the groundwater collected from the well has not been impacted by the MSWLF and that variabilities in the background groundwater quality are assessed. Multiple background wells may be necessary to provide a better characterization of groundwater quality variability and provide more representative background data for statistical analysis.

Downgradient wells must ensure adequate characterization of groundwater passing through the point of compliance (in approved states) or at the MSWLF boundary (in unapproved states). The wells must ensure the detection of contamination in the uppermost aquifer. Typically, a series of wells are installed along the downgradient boundary of the MSWLF. The number and spacing of the wells must be selected based on the site-specific hydrogeologic characterization. Generally, the more complex the geologic settings, the greater the number of monitoring wells that will be required.

Numerous factors influence the spacing and number of wells required to adequately monitor contaminant releases. These factors include the following:

- Type of wastes proposed for or disposed at the MSWLF
- Hydraulic gradients
- Complexity of geology
- Existence of preferential flow patterns
- Groundwater velocity and transverse dispersivity

Detailed summaries of factors influencing well spacing and number of wells per location are presented in figures 6-34 and 6-35.

6.4.6.6
Groundwater Velocity and Dispersivity

Groundwater velocity and dispersivity are two key factors in selecting well spacings. These factors control the rate of longitudinal and lateral (transverse) dispersion of contaminants in the groundwater. Figure 6-36 shows examples of contaminant migration in high- and low-velocity groundwater settings. Contaminants will migrate farther in the longitudinal direction in high velocity settings, developing elongate plumes which can pass between widely spaced monitoring wells.

The shape of a contaminant plume is also controlled by the transverse dispersivity. Figure 6-37 presents a cross-sectional view of low- and high-transverse dispersivity contaminant plumes. High transverse dispersivities will result in greater lateral spreading of contaminants in a shorter distance. Sites with high groundwater velocities and low transverse dispersivity will require the closest well spacings.

Factors Influencing Well Spacing

Wells Intervals May Be Closer If The Site:	Well Intervals May Be Wider If The Site:
Manages or has managed liquid waste	
Is very small	
Has fill material near the waste management units (where preferential flow might occur)	
Has buried pipes, utility trenches, etc., where a point-source leak might occur	
Has complicated geology	Has simple geology
- closely spaced fractures	- no fractures
- faults	- no faults
- tight folds	- no folds
- solution channels	- no solution channels
- discontinuous structures	- continuous structures
Has heterogeneous conditions	Has homogeneous conditions
- variable hydraulic conductivity	- uniform hydraulic conductivity
- variable lithology	- uniform lithology
Is located in or near a recharge zone	Has a low (flat) and constant hydraulic gradient
Has a steep or variable hydraulic gradient	Is characterized by high dispersivity potential
Is characterized by low dispersivity potential	Has a low seepage velocity
Has a high seepage velocity	

(Source: EPA, 1989)

Figure 6-34
6-73

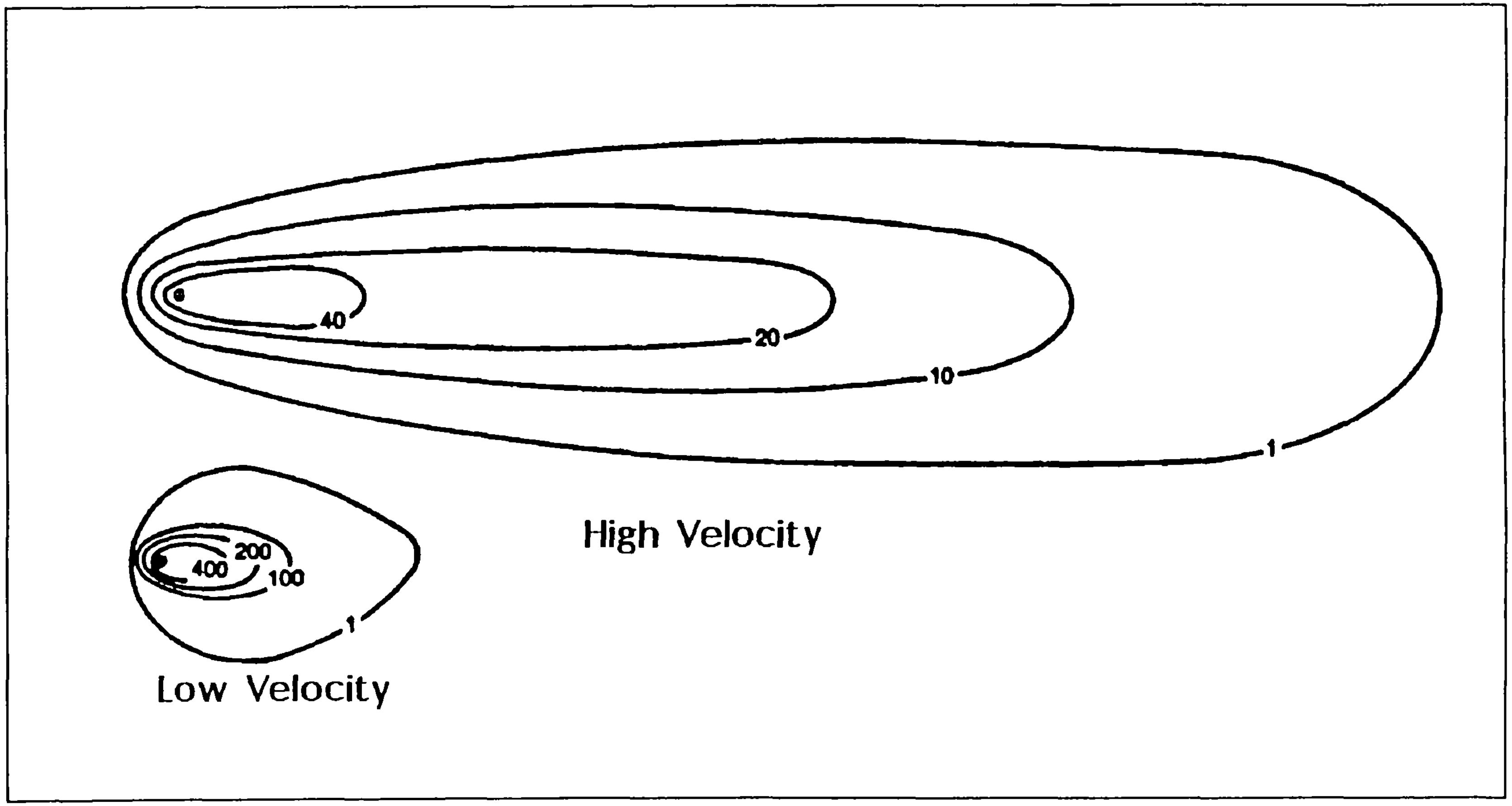
Factors Influencing Number of Wells Per Location

One Well Per Sampling Location	More Than One Well Per Sampling
No "sinkers" or "floaters"	Presence of sinkers or floaters
Thin flow zone (relative to screen length)	Heterogeneous uppermost aquifer; complicated geology
Homogeneous uppermost aquifer; simple geology	- multiple, interconnected aquifers - variable lithology - perched water zone - discontinuous structures
	Discrete fracture zones

(Source: EPA, 1989)

Figure 6-35
6-74

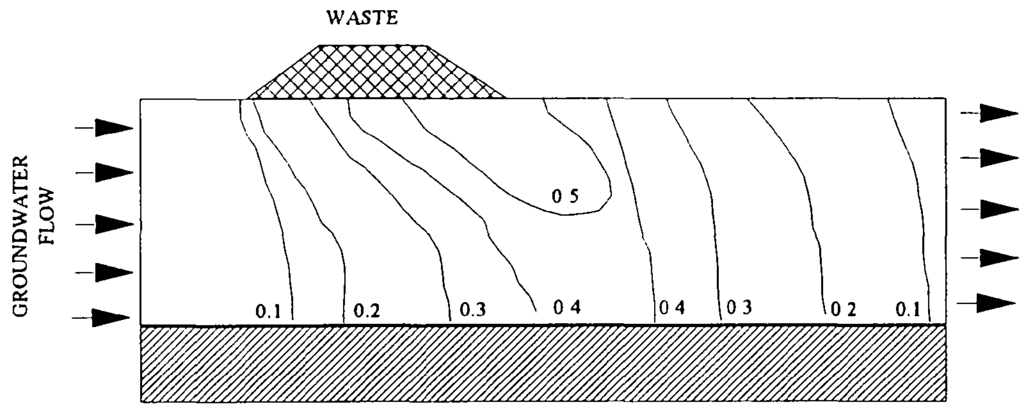
Contaminant Migration in High- and Low-Velocity Groundwater Settings



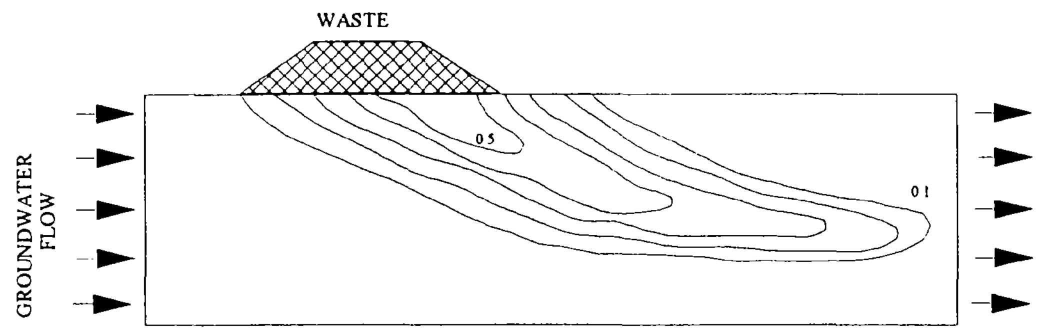
(Source: EPA, 1990)

Figure 6-36
6-75

Contaminant Migration in High- and Low-Transverse Dispersity Settings



High Transverse Dispersivity



Low Transverse Dispersivity

Figure 6-37
6-76

6.4.6.7
Mounding Effects and Groundwater Reversals

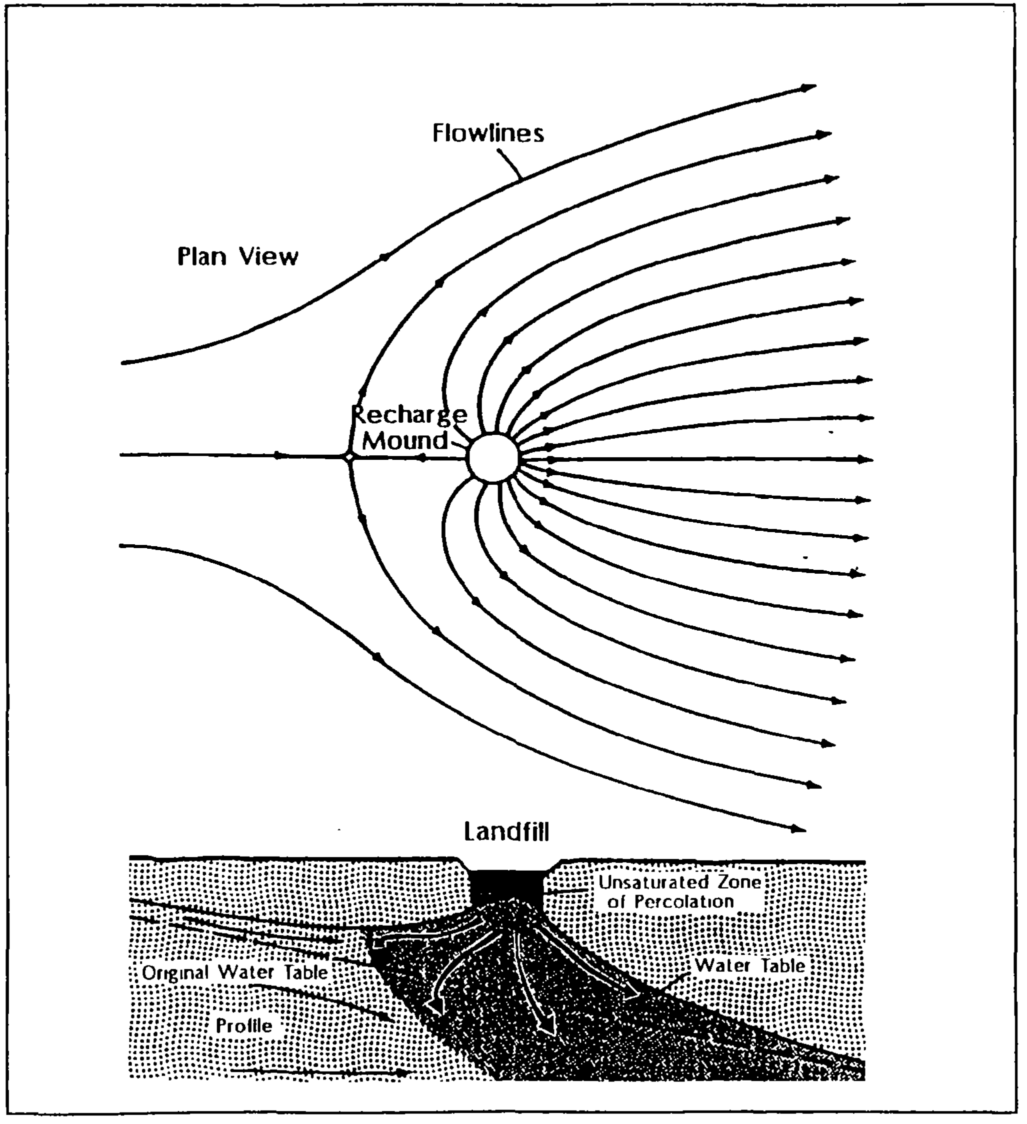
Infiltration of leachate through the landfill liner may result in the mounding of the water table beneath the unit (Figure 6-38.) This mounding effect can influence the direction of groundwater flow in the immediate vicinity of the MSWLF. During operation of the groundwater monitoring system, downgradient wells will have been used to monitor for contaminant releases, and background wells will have been placed in upgradient locations not normally subject to influence from the landfill. When significant mounding occurs, the area immediately surrounding the landfill, in all directions, may be downgradient. This can result in contaminant migration to the upgradient or background locations. When groundwater monitoring data indicates significant mounding, point of compliance groundwater monitoring wells may be required around the entire MSWLF unit.

Mounding or other changes in site hydrology may result in seasonal or permanent reversals of groundwater flow direction. Groundwater flow reversals occur when water levels at the downgradient monitoring locations rise and become equal to or greater than the water level at the upgradient edge of the unit. Mounding and/or reversals in groundwater flow may require redesign of the groundwater monitoring system.

6.4.6.8
Examples of Monitoring Well Siting Scenarios

Several examples of monitoring well siting scenarios are presented in figures 6-39 through 6-51.

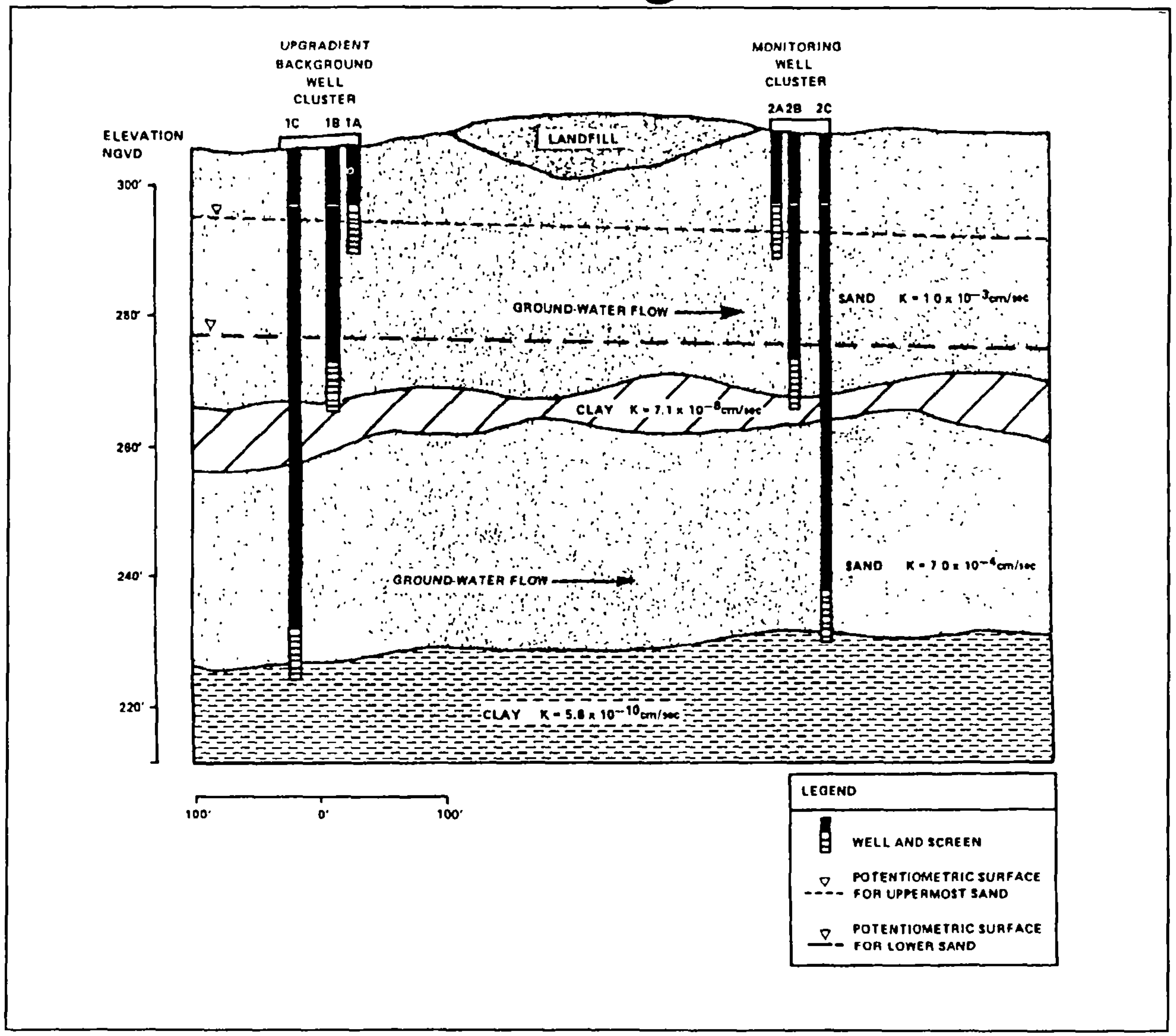
Mounding Effects on Contaminant Migration



(Source: EPA, 1990)

Figure 6-38
6-77

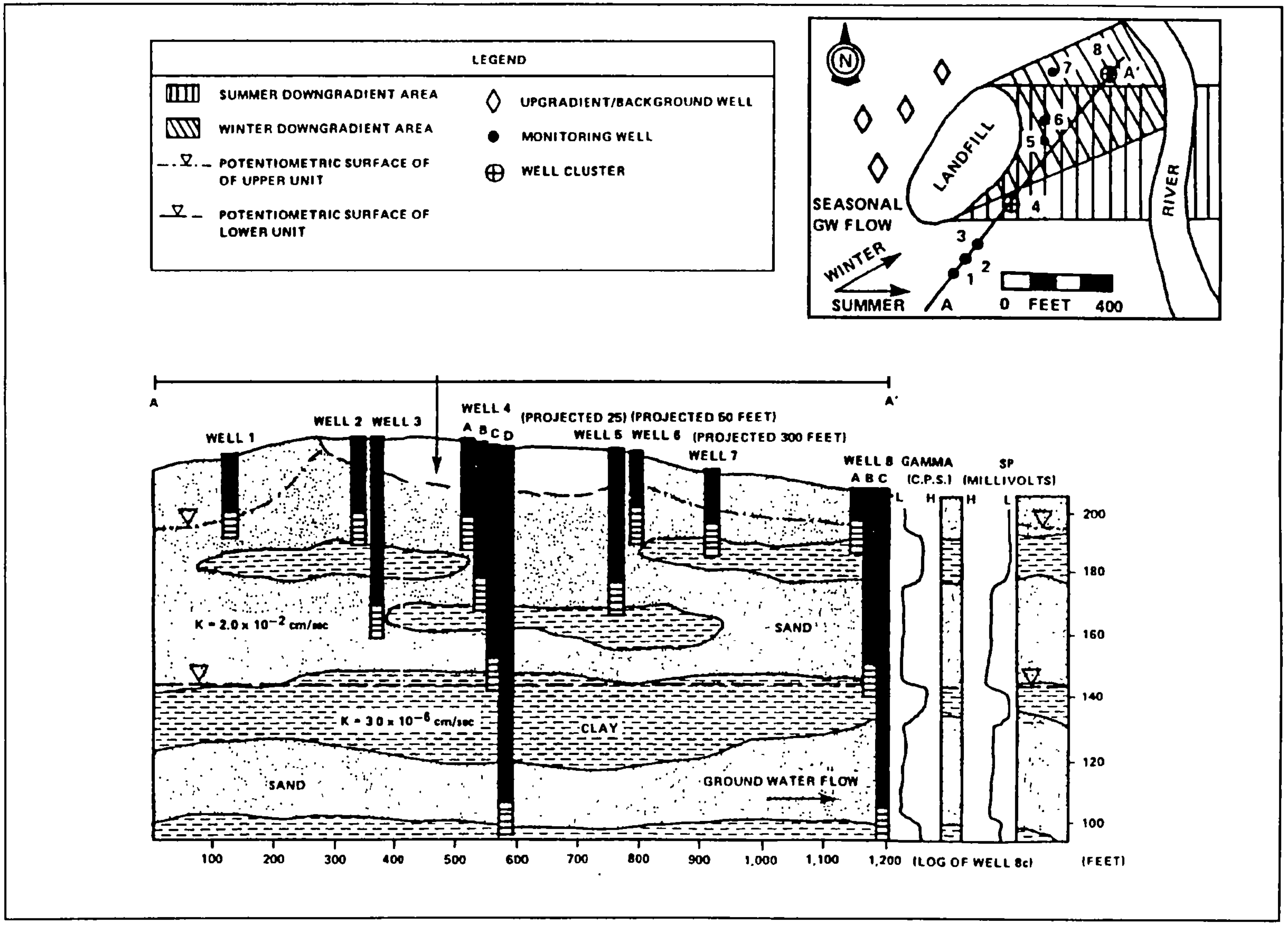
Monitoring System for Simple Geologic Setting



(Source EPA, 1989)

Figure 6-39
6-78

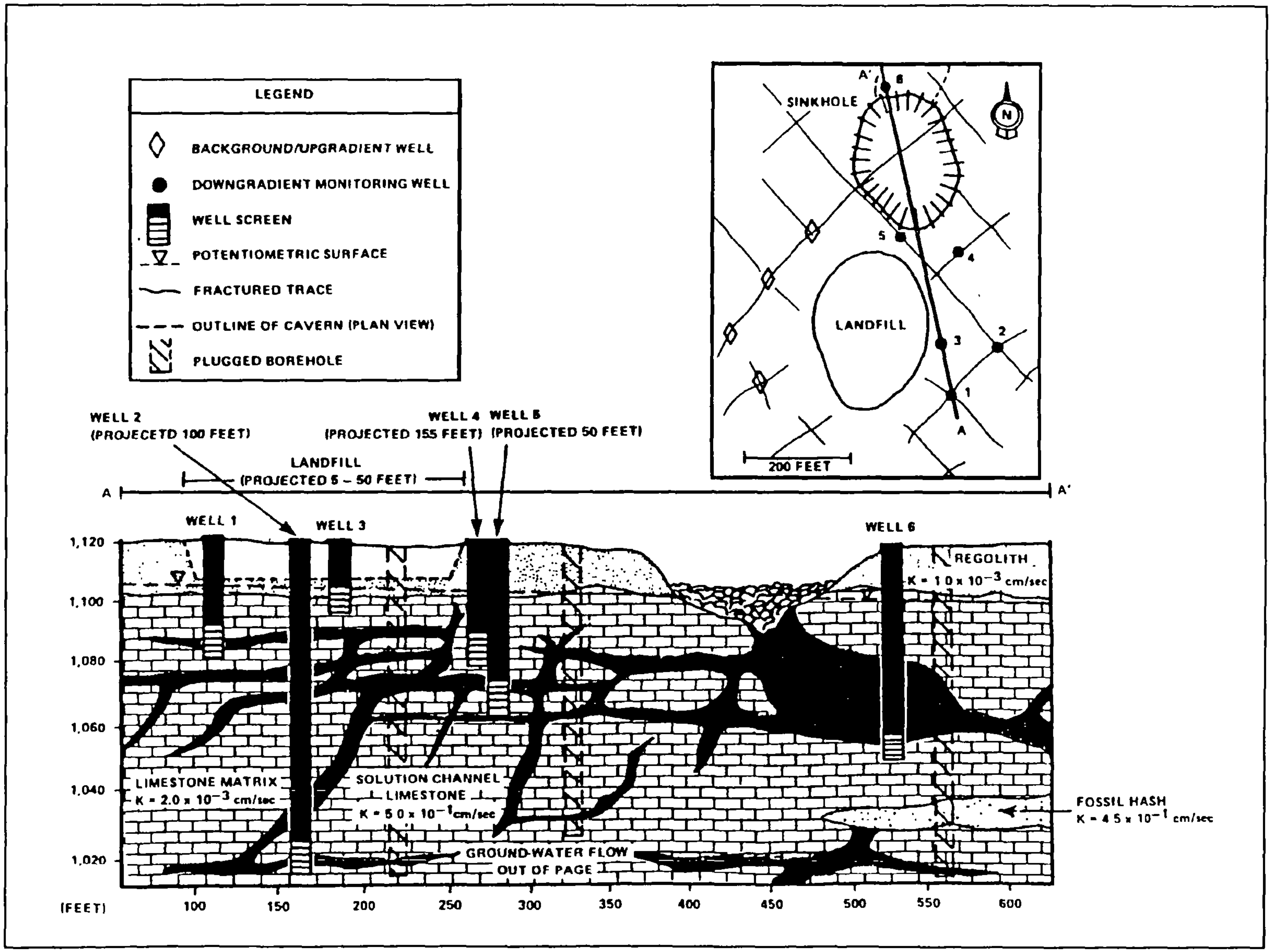
Monitoring System for Complex Geologic Setting



(Source: EPA, 1989)

Figure 6-40

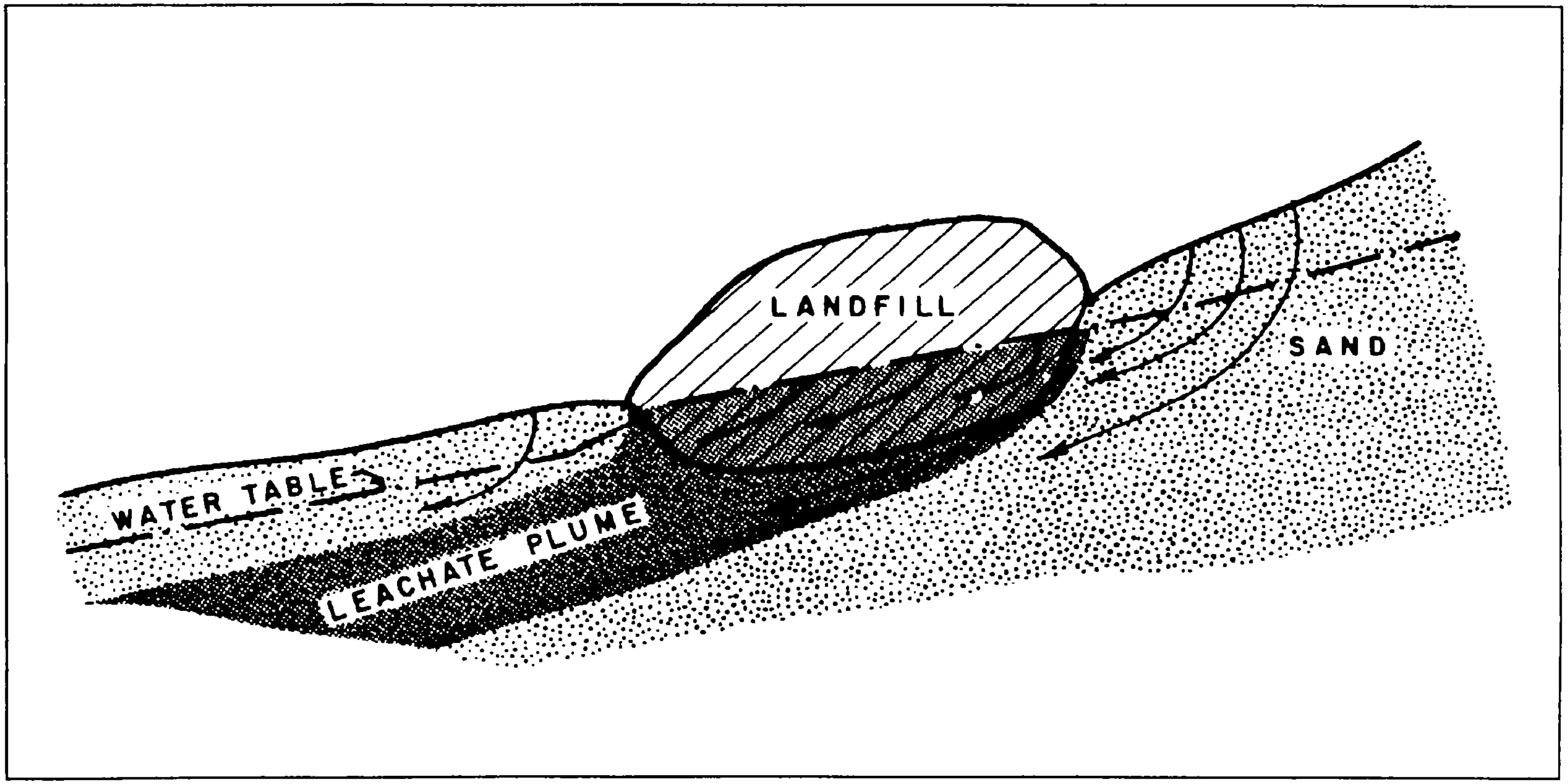
Monitoring System for Karst Geology



(Source: EPA, 1989)

Figure 6-41

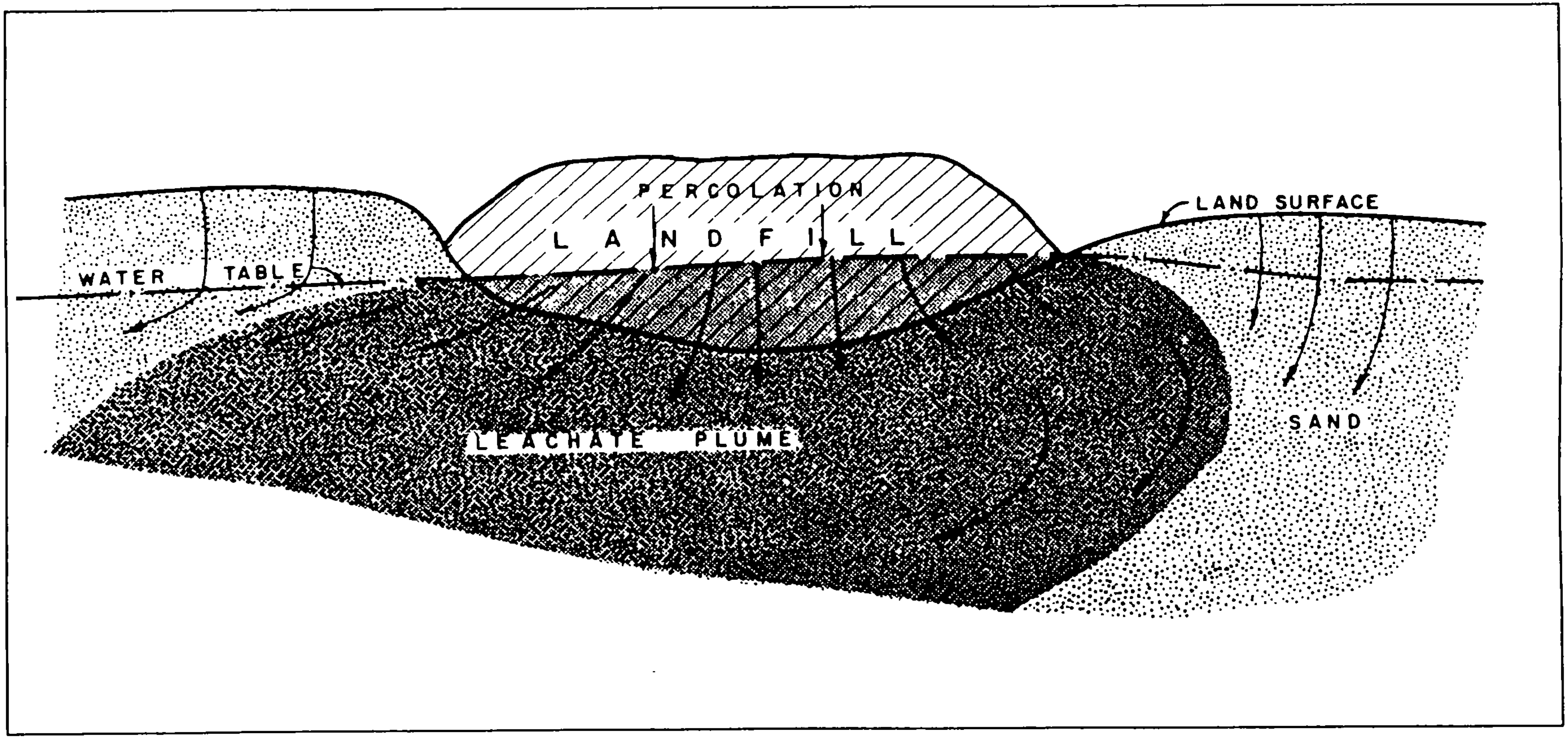
Contaminant Migration - Scenario 1



(Source: EPA, 1977)

Figure 6-42

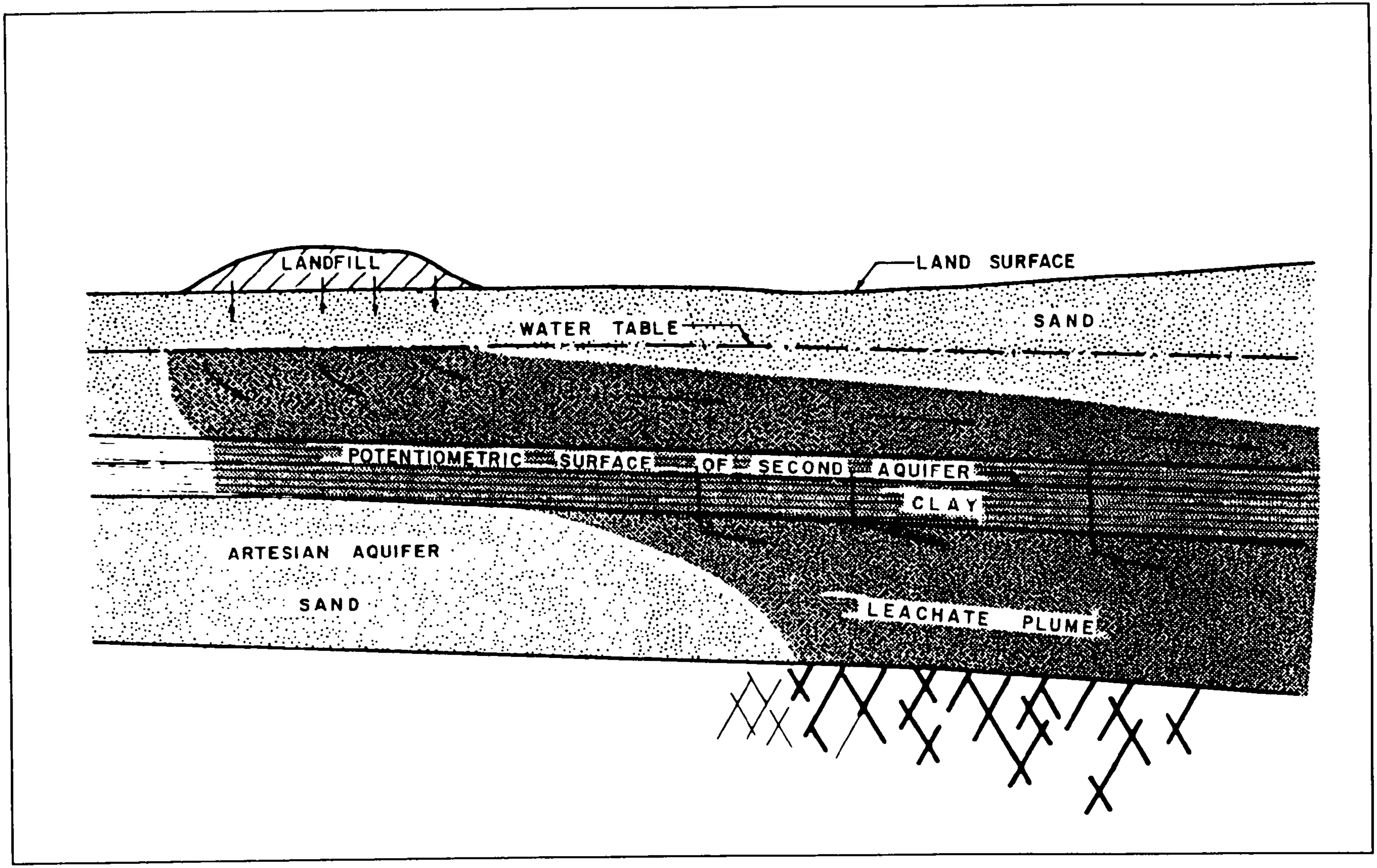
Contaminant Migration - Scenario 2



(Source: EPA, 1977)

Figure 6-43
6-82

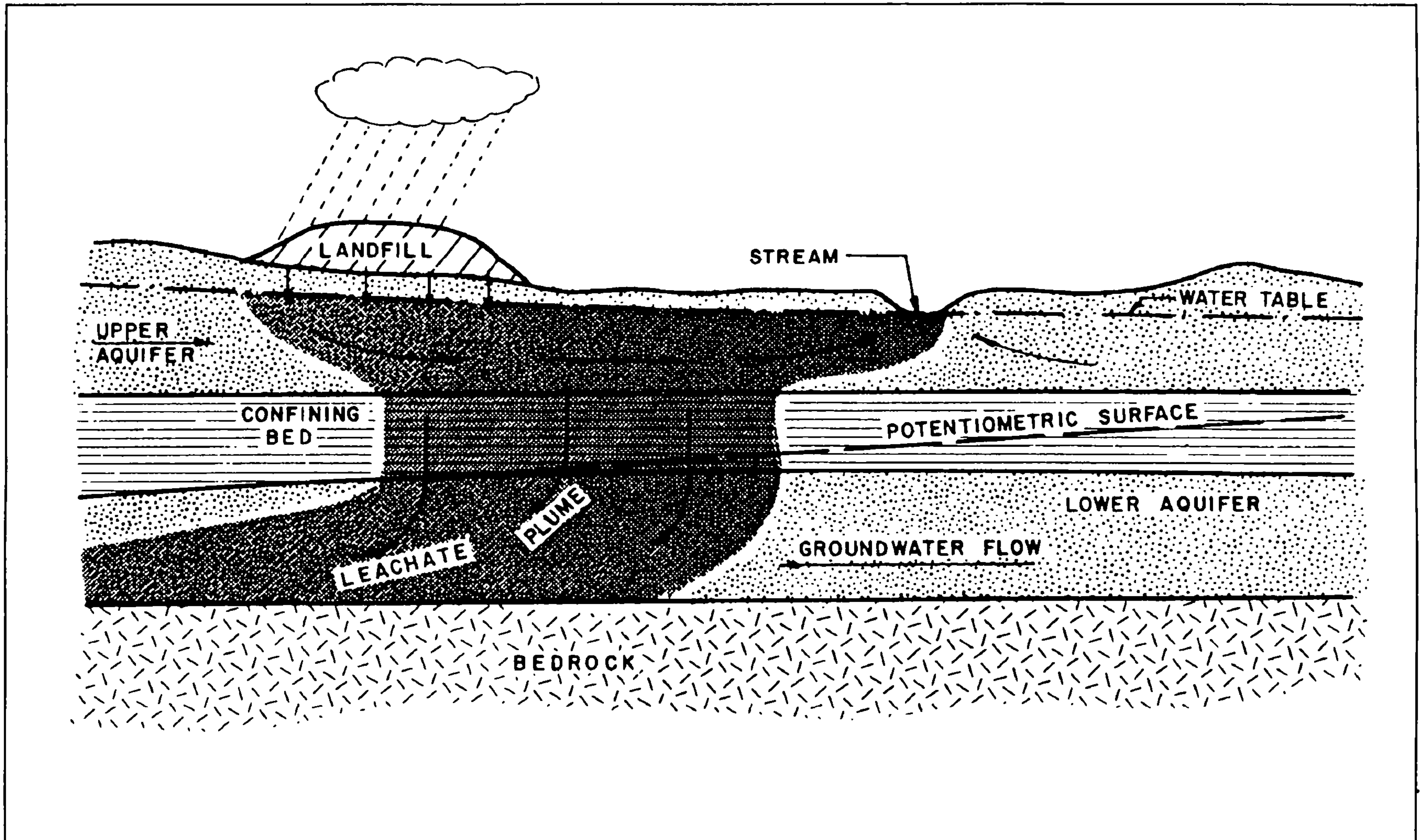
Contaminant Migration - Scenario 3



(Source: EPA, 1977)

Figure 6-44

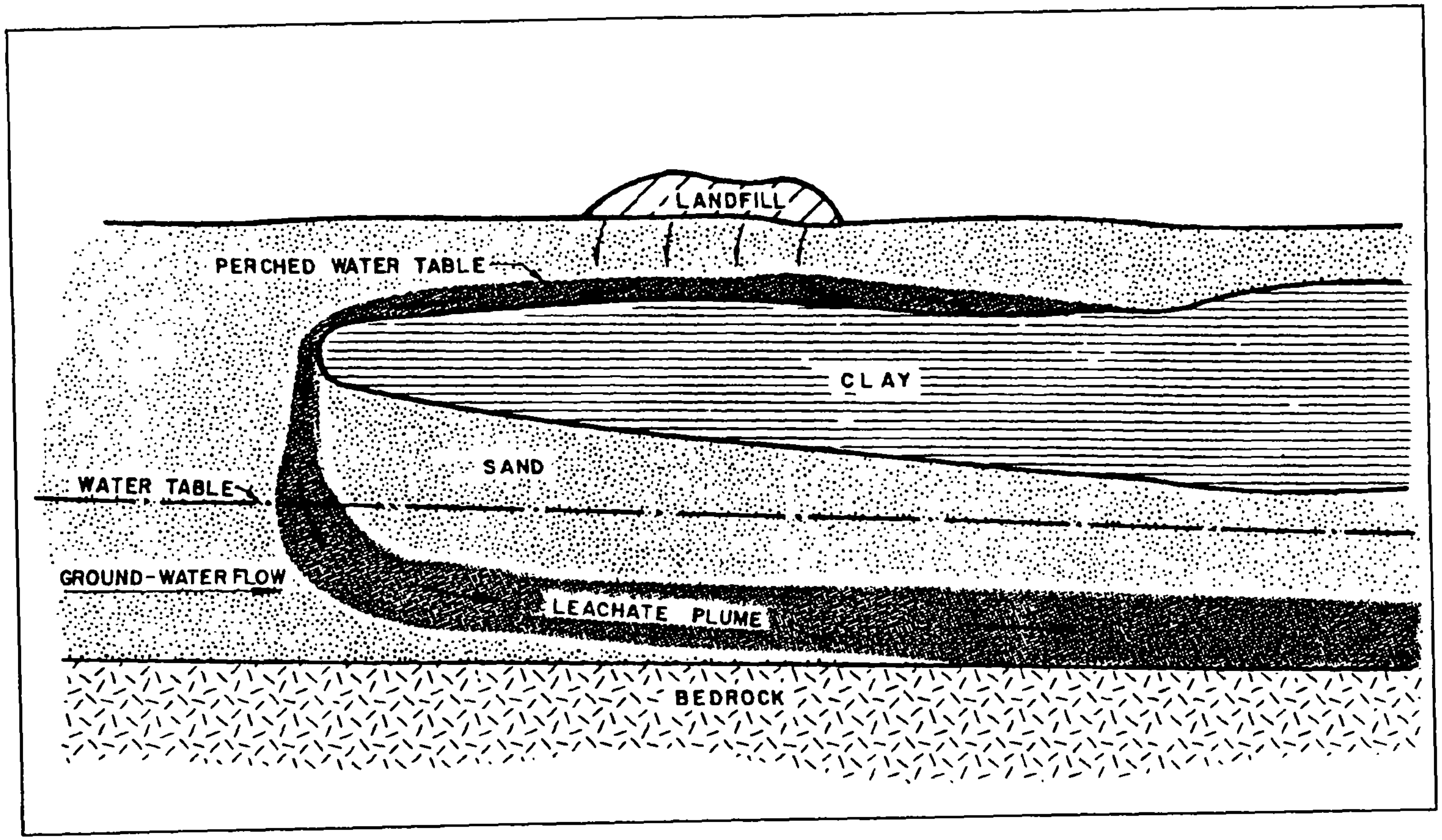
Contaminant Migration - Scenario 4



(Source: EPA, 1977)

Figure 6-45

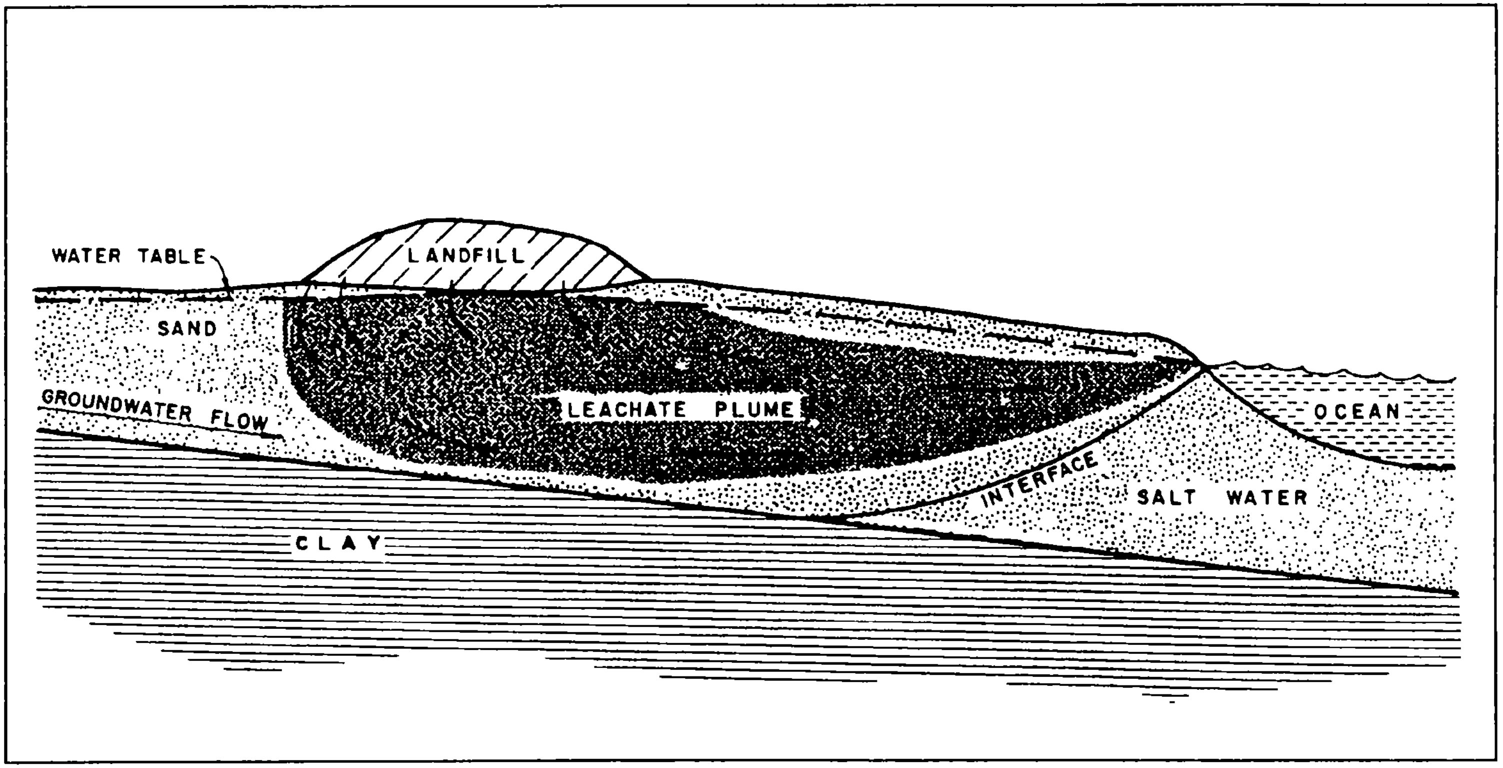
Contaminant Migration - Scenario 5



(Source: EPA, 1977)

Figure 6-46
6-85

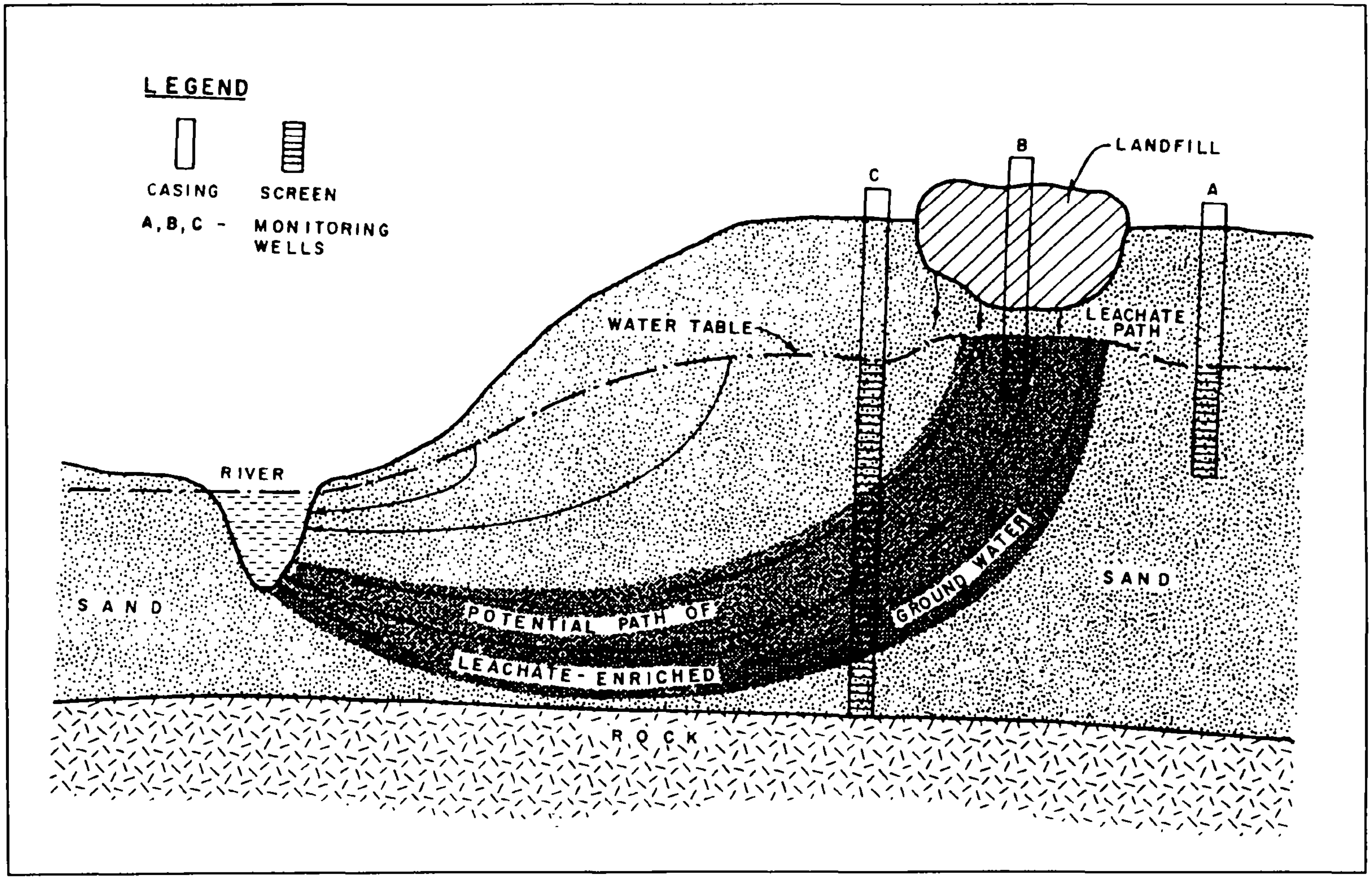
Contaminant Migration - Scenario 6



(Source: EPA, 1977)

Figure 6-47
6-86

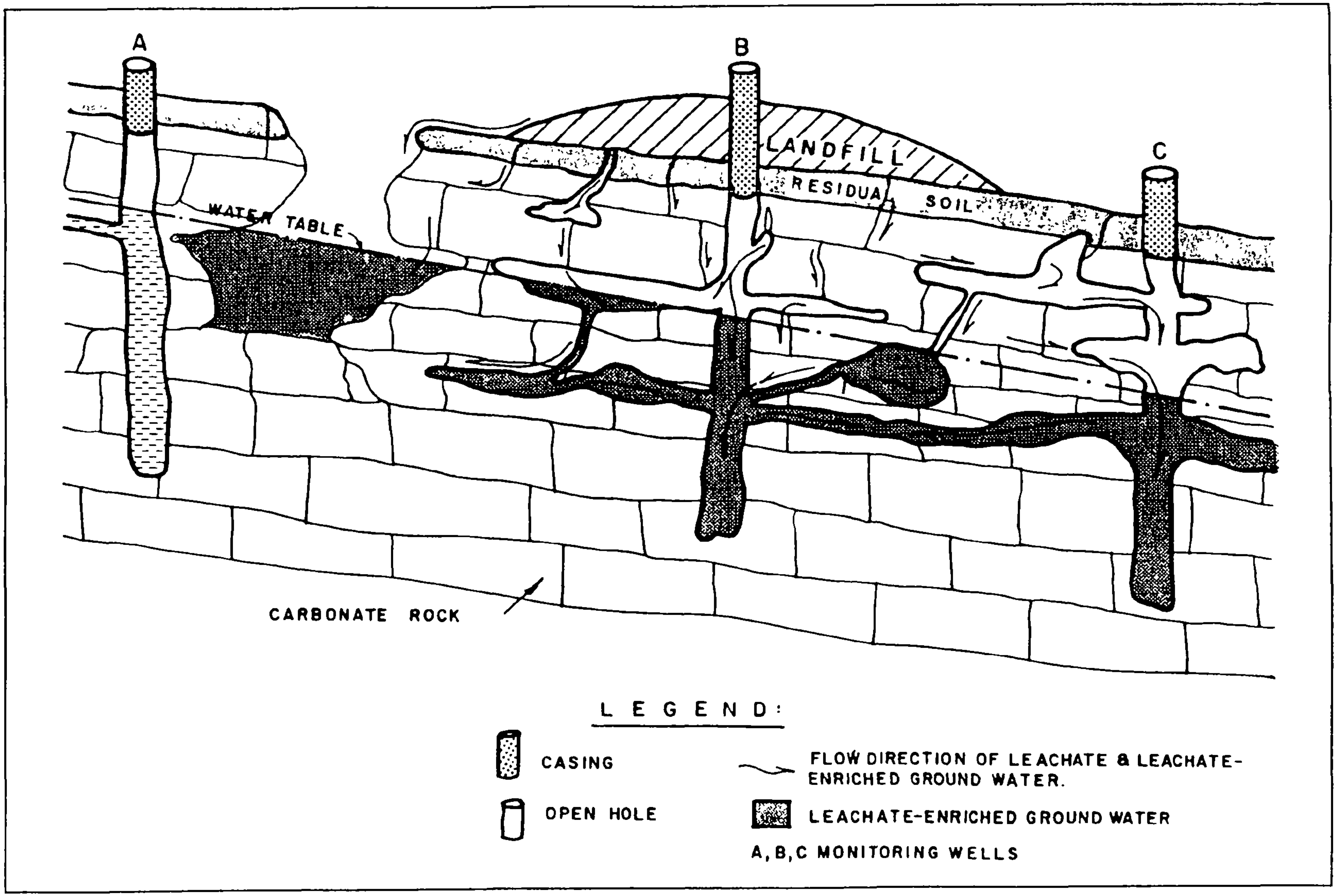
Contaminant Migration - Scenario 7



(Source: EPA, 1977)

Figure 6-48

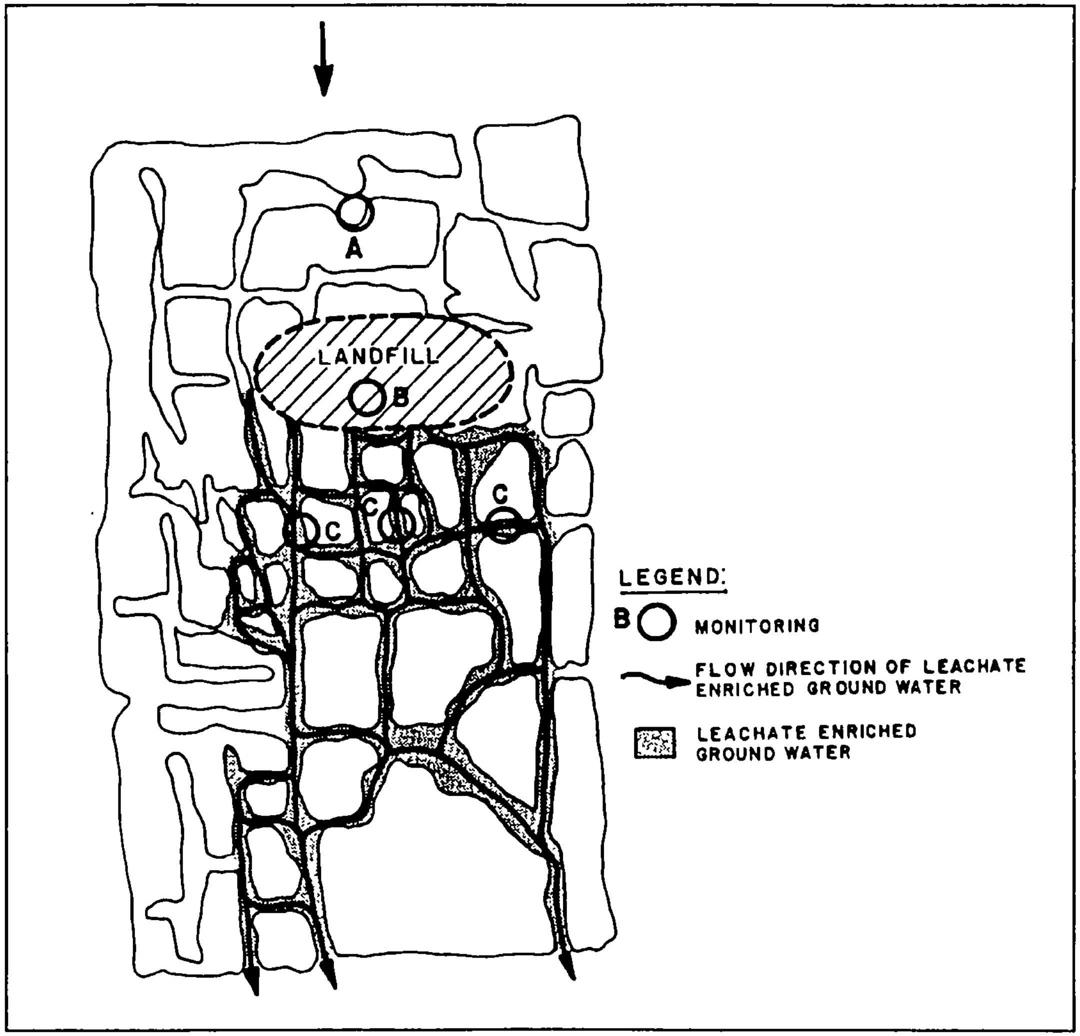
Contaminant Migration - Scenario 8



(Source: EPA, 1977)

Figure 6-49
6-88

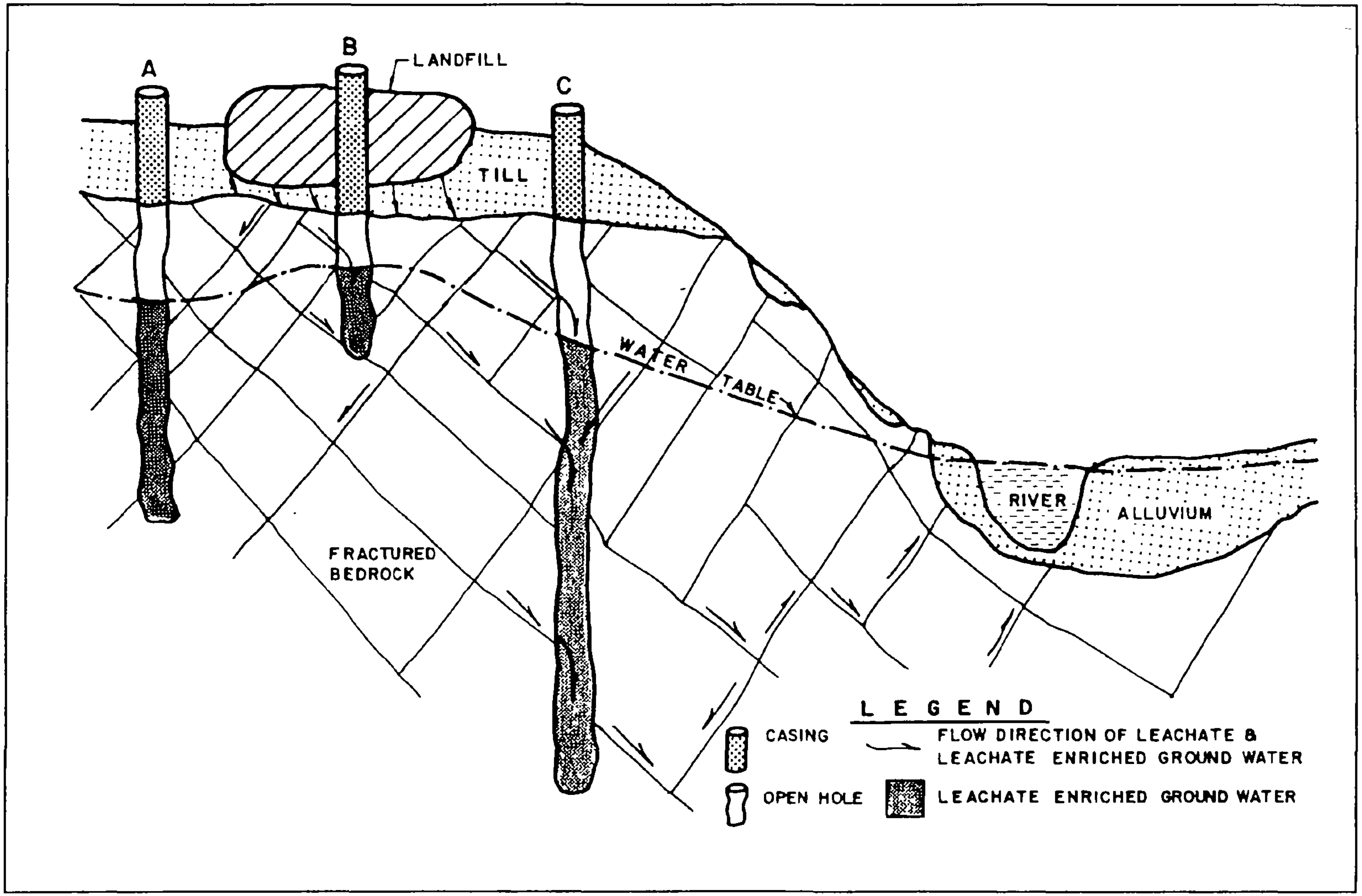
Contaminant Migration - Scenario 8 (Surface View)



(Source: EPA, 1977)

Figure 6-50

Contaminant Migration - Scenario 9



(Source: EPA, 1977)

Figure 6-51
6-90

6.5 GROUNDWATER SAMPLING AND ANALYTICAL REQUIREMENTS

A groundwater monitoring program which includes a sampling and analysis program and provisions for evaluating groundwater data must be implemented at all regulated MSWLFs. The sampling and analysis program must provide for consistent procedures to ensure an accurate representation of groundwater quality in background and downgradient wells.

The sampling and analysis program must include procedures for the following.

- Sample collection
- Sample preservation and shipment
- Analytical procedures
- Chain-of-custody control
- Quality assurance and quality control
- Statistical evaluation
- Establishment of groundwater protection standards

The monitoring program must also provide for evaluation of groundwater analytical data using appropriate statistical methods and evaluation of groundwater flow direction and rate for each sampling event.

6.5.1 Sample Collection

Typically, groundwater samples are collected as grab samples: individual samples which are collected from a single location at a specific time or period of time generally not exceeding 15 minutes. Samples may be collected with bailers, pumps, suction devices or other techniques provided the sampling apparatus

- Minimizes operator error
- Can be decontaminated
- Minimizes disturbance of the physical and chemical nature of the groundwater
- Allows for adequate flow control

Background samples should be collected before downgradient samples to minimize the potential for contamination of the background wells. Additionally, all down-hole sampling equipment must be thoroughly decontaminated to prevent cross-contamination and the introduction of chemicals or materials that may impact the groundwater chemistry.

Only sampling of monitoring wells is addressed in the MSWLF regulations. However, groundwater monitoring may also be performed at other types of wells (private and/or public water supply and/or irrigation wells), groundwater discharges (i.e., seeps and springs) or surface waters that receive groundwater discharges.

Prior to sampling, the wells must be purged to ensure that the groundwater samples collected are representative of the formation. Well purging and sample collection procedures must be documented in the field logbook. Each sample should be assigned a unique number to eliminate potential interpretation errors. Sample volume and holding times are dictated by the analytical method selected. A generalized flow diagram of groundwater sampling steps is presented in Figure 6-52.

Generalized Flow Diagram of Groundwater Sampling Steps

STEPS	PROCEDURES
Well Inspection	Hydrologic Measurements
	↓
Well Purging	Removal or Isolation of Stagnant Water
	↓
Sample Collection, Field Determinations	Determination of Well-Purging Parameters
	↓
	Volatile Organic Substances
	↓
	Large Volume Samples for Organic Compound Determinations
Preservation Field Blanks Standards	↓
Storage Transport	Trace Metal Samples and Assorted Inorganic Species

(Source: EPA, 1987)

Figure 6-52
6-93

6.5.1.1
Groundwater Level Measurement

Groundwater monitoring programs must include procedures for determining the water level at each of the groundwater monitoring wells and/or sampling stations. The measurement of groundwater levels in monitoring wells (and other wells, piezometers and surface water stations) is generally conducted in conjunction with sampling.

Groundwater levels are measured for two purposes:

- Development of potentiometric maps and determination of groundwater flow directions and rates.

- Determination of the presampling purge volumes for each well.

Groundwater levels measured for development of potentiometric maps must be collected in the shortest possible time period to avoid temporal variations in groundwater elevation data which could preclude accurate determination of groundwater flow directions and rates.

The water level and total well depth must also be measured prior to purging to determine the height of water in the well and the required purge volume. The height of the column of water in the well is the difference between the total depth of the well and the depth to water (both measured from the reference point on the top of the well casing.) The height of the column of water can then be used to calculate the volume of water in the well. The volume of water in the well can be determined by the following formula:

$$V = 0.041\ d^2h$$

Where

V = volume of water in gallons

d = inside diameter of well in inches

h = depth of water in feet

A quick reference nomograph or table may be used, if preferred.

Total well depth can be determined by lowering a weighted tape or electric water level indicator to the bottom of the well. Because of frictional and buoyancy effects, it may be difficult to determine when the tape end is touching the bottom of the well. Care must be taken to ensure accurate measurements. Total well depth measurements should be recorded to the nearest 0.1 foot.

A variety of mechanical and/or electrical water level indicator methods are used for measuring groundwater levels, including:

- Electric Water Level Indicator
- Acoustic Water Level Indicator
- Popper or Bell Sounder
- Weighted Tape
- Chalked Tape
- Other Methods

These methods are described in more detail below:

6.5.1.1.1
Electric Water Level Indicator

This instrument consists of a spool of dual conductor wire, a probe attached to the end, and an indicator (meter, light and/or buzzer.) A typical electric water level indicator is shown in Figure 6-53. When the probe comes in contact with the water the circuit is closed and the indicator registers the contact. The depth to water is read from markings on the wire. Measurements can be recorded to the nearest 0.01 foot. This is the most commonly used method for measuring groundwater levels.

6.5.1.1.2
Acoustic water level indicator

Acoustic water level indicators which determine water levels based on the measured return of an emitted acoustical impulse are also available. These instruments must be evaluated to ensure that accurate measurements can be recorded to the nearest 0.01 foot.

6.5.1.1.3
Popper or bell sounder

A bell- or cup-shaped weight that is hollow on the bottom is attached to a measuring tape and lowered into the well. A "popping" sound is made when the weight strikes the surface of the water. Measurements can only be accurately recorded to the nearest 0.1 foot; therefore, this method is not acceptable for measurements at MSWLFs.

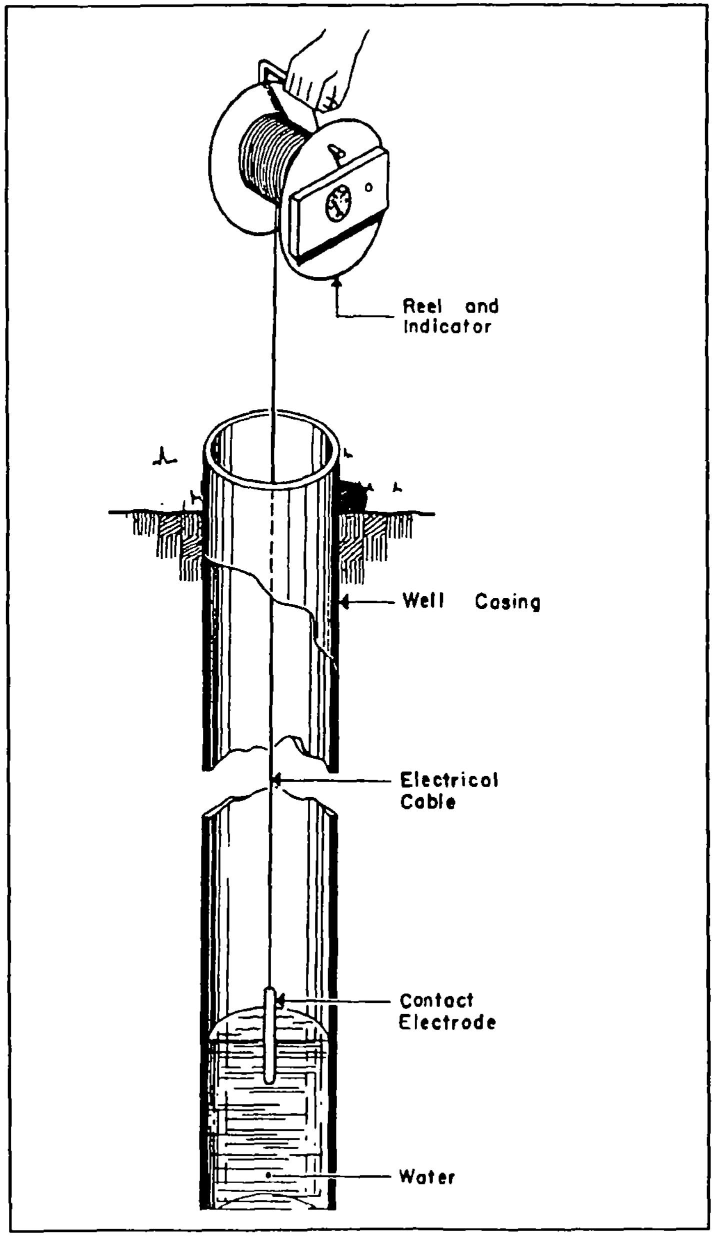
6.5.1.1.4
Weighted tape

This method is similar to the "bell sounder" method, except that any suitable weight, not necessarily one designed to create an audible pop, can be used to suspend the tape. Measurements can only be accurately recorded to the nearest 0.1 foot; therefore, this method is not acceptable for measurements at MSWLFs.

6.5.1.1.5
Chalked tape

Chalk rubbed on a weighted tape will discolor or be removed when in contact with water. Distance to the water surface can be obtained by subtracting the wet chalked length from the total measured length. The tape must be withdrawn

Typical Electric Water Level Indicator



(Source: Johnson, 1975)

Figure 6-53
6-96

from the well quickly because water will rise up the chalk due to capillary action. Measurements can be recorded to the nearest 0.01 foot; however, this method is not recommended if samples are to be collected for analyses of organic or inorganic contaminants.

6.5.1.1.6
Other methods

There are other types of water level indicators and recorders available, such as float recorders, air line pressure methods and pressure transducer recording methods. These methods are primarily used for closed systems or permanent monitoring wells. Accuracies for these methods vary and should be evaluated before selection. Any method not capable of providing measurements to within 0.01 foot is not acceptable for measurements at MSWLFs.

6.5.1.2
Purging

Monitoring wells must be purged before collecting groundwater samples. The purging objective is to clear the well of stagnant water which is not representative of aquifer conditions. Depending upon well construction (diameter and depth), a variety of purging methods may be used. Regardless of which method is used, the objective is to remove nonrepresentative water.

Generally wells are purged of three to five times the volume of water standing in the well or until the values for groundwater indicator parameters (pH, specific conductivity and temperature) stabilize. Groundwater turbidity may also be a factor used to determine when adequate purging has occured.

Normally, a combination of methods is employed (i.e., pH, specific conductivity and temperature are measured at intervals during the purging of three to five volumes of water). Additional purging may be required if the indicator parameters have not stabilized or if the sample turbidity has not been reduced to a level that will not impact analytical results. Purging should continue until the objective of providing representative samples is achieved.

If a well is purged dry, this generally constitutes an adequate purge and the well can be sampled following recovery. However, purging should not be conducted with the intention of purging the well dry If a well is purged dry as a result of excessively rapid evacuation, water that has been trapped in the filter pack may inappropriately comprise the sample. In addition, as water reenters the well, it may cascade down the well screen, resulting in stripping of volatile contaminants.

Well purging can be accomplished by using dedicated pumps installed in the wells or, when dedicated pumps are not available, by using either peristaltic, turbine, bladder, centrifugal or other appropriate pumps, depending on the well depth. Purging with pumps should be performed from the top of the standing water column and not deep into the column. This is done so that water will be pulled from the formation into the screened area of the well and up through the casing to the point of removal, thereby removing the entire static volume of water. If a purging pump is placed deep into the water column, the water above the pump may not be removed and the subsequent samples collected may not be representative of the groundwater.

Disposable, cleaned reusable or dedicated bailers are commonly used to purge and sample shallow monitoring wells. Purging with bailing requires special precautions to prevent volatilization of organic constituents and/or stirring up of sediments in the well. Bailers must be lowered into and removed from the water column gently to avoid creating turbulence.

6.5.1.3
Sampling Equipment Decontamination

All nondedicated or nondisposable purging and sampling equipment (i.e., pumps or reusable bailers) must be decontaminated before placement into each monitoring well. Disposable equipment (i.e., ropes, hoses, etc.) must be replaced with new materials before purging and sampling each well. Careful consideration must be given to using nondedicated equipment where wells are excessively contaminated with oily compounds because it may be difficult to adequately decontaminate the equipment. Dedicated or disposable sampling equipment should be used in highly contaminated groundwater settings if possible.

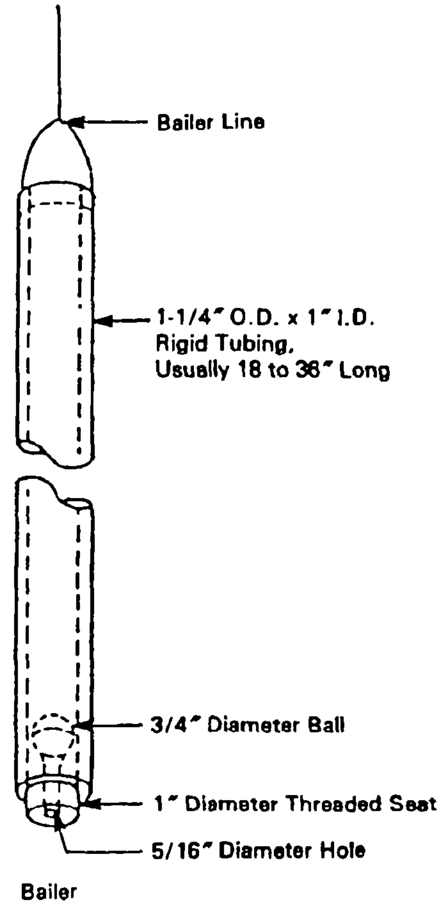
6.5.1.4
Sampling Procedures

Samples should be collected following purging in wells that are not purged to dryness. Wells that are purged dry can be sampled only after adequate recovery of groundwater for sample collection.

Groundwater samples are generally collected with bailers and/or certain types of pumps (i.e., bladder pumps) or using the vacuum bottle method (figures 6-54 through 6-56). Pumps used for collecting groundwater samples must not adversely impact the sample chemistry. Adverse impacts can result from

- Cavitation and/or excessive turbulence
- Leaching of constituents from pump/plumbing components
- Direct contact of air or other fluids with the sample

Typical Sampling Bailer

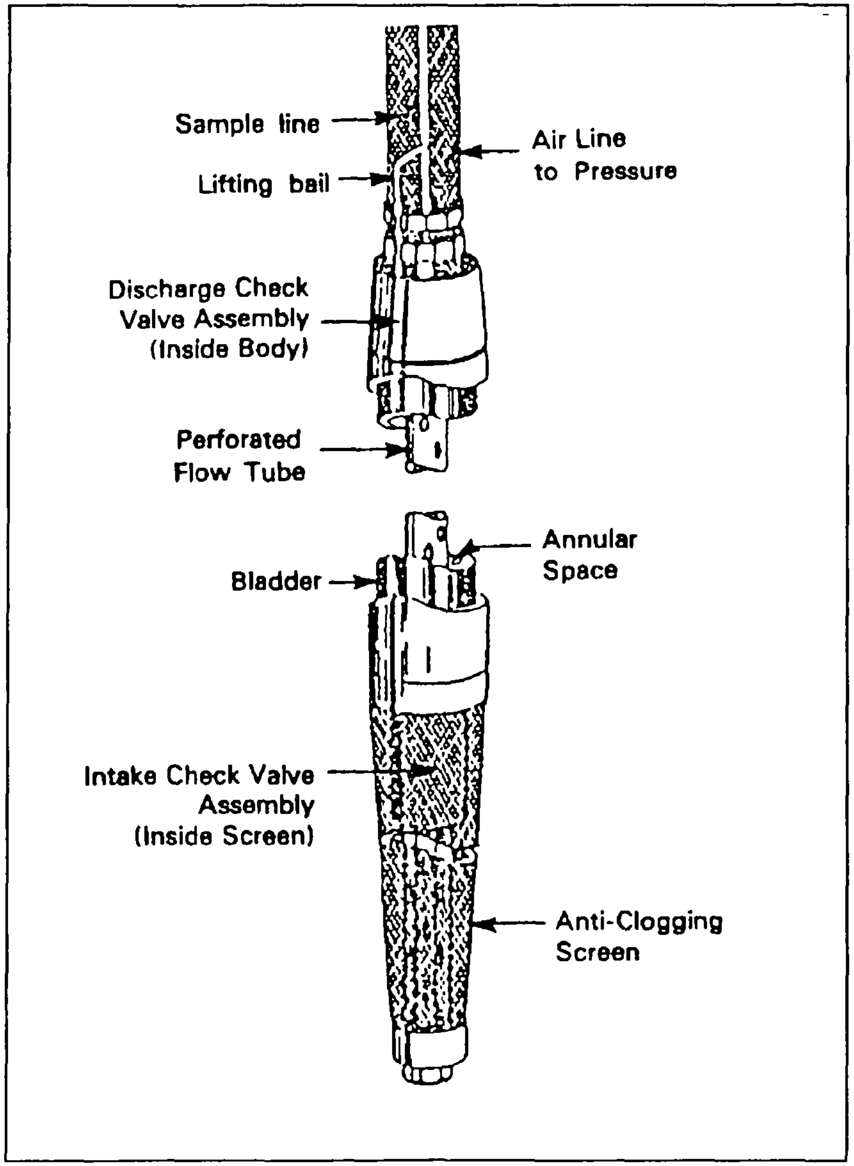


Notes:
1. Sampler length can be increased for special applications
2. Fabrication materials can be selected to meet analysis requirements and in situ chemical environment
3. Tubing sizes can be modified for special applications

(Source: EPA, 1987)

Figure 6-54

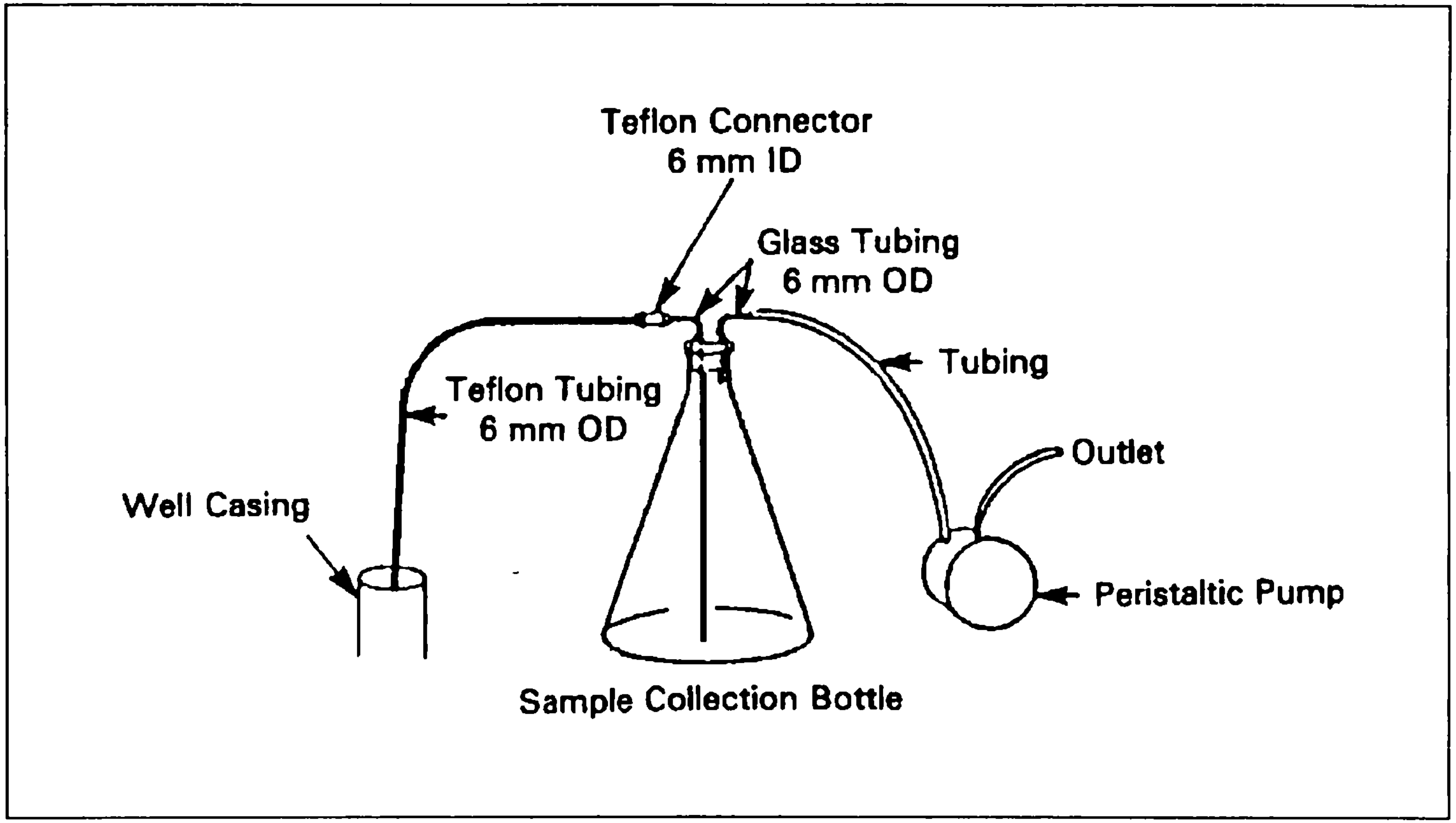
Typical Bladder Pump



(Source: EPA, 1987)

Figure 6-55
6-99

Typical Vacuum Bottle Sample Collection Method



(Source: EPA, 1987)

Figure 6-56
6-100

6.5.1.5
Filtering

Filtering of groundwater samples collected for monitoring at MSWLFs is not currently allowed. However, it is generally understood that sample turbidity may be a factor contributing to total concentrations of some inorganic (metal) constituents and that proper monitoring well installation, development and well purging techniques may not resolve turbidity problems.

Inorganic constituents (metals) associated with suspended (particulate) matter in turbid samples may adversely impact analytical results. When problems with sample turbidity cannot be resolved through additional well development or special purging and sampling precautions, it may be practical to collect both filtered and nonfiltered samples. Both sets of data may enable quantification of dissolved and suspended fractions of inorganic constituents and help in determining if releases have occurred or if metals concentrations are related to soil chemistry.

6.5.2
Sample Preservation and Shipment

Once collected, the samples must be preserved to ensure that the integrity of the samples is maintained during shipment to the laboratory. Preservation techniques are defined by the analytical methodology and include

- pH control
- Addition of chemicals
- Temperature control

The samples must be packaged for shipment to the laboratory in a manner that minimizes sample disturbance or potential for breakage.

6.5.3 Chain-of-Custody

Chain-of-custody procedures are required to ensure that the integrity of the samples can be verified. These procedures include the labeling, sealing and documentation of the samples. The chain-of-custody tracks the handling of the samples from collection to analysis.

A sample or other physical evidence is in custody if it is:

- In the sampler's actual possession;
- In the sampler's view, after being in his/her physical possession;
- Secured to prevent tampering after being in the sampler's physical possession; and
- Placed in a designated secure area.

Sample custody must be documented on a Chain-of-Custody Record which contains spaces for the following information:

- Project number;
- Project or facility name;
- Sampler's and/or sampling team leader's signature;
- Sampling location numbers, date and time of sample collection;
- Total number of sample containers for each sample;
- Total number of individual containers for each type of analysis; and

- The samplers' and transferees' signatures for each transfer of sample custody.

6.5.4 Analytical Procedures

The selected analytical methodologies must be sufficient to provide an accurate representation of the groundwater quality. Rather than specifying which analytical methods must be used, the Subtitle D regulations require that the monitoring program be protective of human health and the environment. The regulations also require that the statistical method selected to evaluate the groundwater data use the lowest practical quantitation limit (pql) that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions. Therefore, the analytical methods selected must take into consideration the appropriate groundwater protection standards and provide for the lowest practical quantitation limits.

6.5.5 Quality Assurance/ Quality Control

Quality Assurance/Quality Control (QA/QC) programs provide controls to ensure that field and analytical activities are performed in a consistent and well-documented manner. The QA/QC procedures also ensure that the samples are collected and evaluated accurately for site-related contamination. QA/QC programs may require collection and analysis of additional samples for quality control purposes. The most commonly collected quality control samples are the following:

- Split sample -- A sample which has been portioned into two or more containers from a single sample container or sample mixing container.

- Duplicate sample -- Two or more samples collected simultaneously into separate containers from the same source under identical conditions.

- Trip blank -- Trip blanks are prepared prior to the sampling event in the actual sample container and are kept with the investigative samples throughout the sampling event. They are then packaged for shipment with the other samples and sent for analysis. At no time after their preparation are the sample containers to be opened before they reach the laboratory. Volatile organic trip blanks are used to determine if samples were contaminated during storage and transportation to the laboratory.

- Equipment blank -- Equipment blanks are defined as samples which are obtained by running organic-free water over/through sample collection equipment after it has been cleaned. These samples are used to determine if cleaning procedures were adequate.

- Field blank Organic-free water is taken to the field in sealed containers and poured into the appropriate sample containers. This is done to determine if any contaminants present in the area may have an effect on the sample integrity. Field blanks should be collected in dusty environments and/or from areas where volatile organic contamination is present in the atmosphere and originating from a source other than the source being sampled.

The QA/QC program should also include procedures for field decontamination of reusable equipment (if dedicated and/or disposable equipment is not used) to eliminate the potential cross-contamination of samples.

Sampling information should be recorded in bound field logbooks. Preferably, a logbook should be dedicated to an individual facility. All entries should be dated and include the time of entry. Furthermore, each page should be dated and signed. A diagonal line should be drawn (and initialed) at the end of any entries to void any blank space.

All aspects of sample collection and handling, as well as visual observations, should be documented in the field logbooks. All sample collection equipment (where appropriate), field analytical equipment and equipment utilized to make physical measurements should be identified in the field logbooks. All calculations, results and calibration data for field sampling, field analytical and field physical measurement equipment should also be recorded in the field logbooks.

All entries in field logbooks should be dated, legible and contain accurate documentation of project activities.

6.5.6 Statistical Evaluations

The Subtitle D regulations identify the following statistical methods for evaluating groundwater data to determine if statistically significant increases of chemical constituents have occurred:

- Parametric Analysis of Variance (ANOVA)

- ANOVA based on ranks
- Tolerance or prediction intervals
- Control chart
- Other statistical methods

The regulations identify specific performance criteria for selecting an appropriate statistical method. The statistical method must

- Be appropriate for the distribution of data for the chemical parameters or hazardous constituents being evaluated. Most statistical methods assume a normal bell curve distribution. If the distribution of the data is not normal, then the data must be transformed or a distribution-free theory test must be used. More than one statistical method may be needed if the distributions for the constituents differ.
- Account for data below the limit of detection with one or more statistical procedures.
- Include procedures to control or correct for seasonal and spatial variability as well as temporal correlation in the data, if necessary.
- Use analytical data that has been derived using the lowest pqls that can be reliably achieved.

The following Type I error performance standards apply to individual and multiple-comparison procedures (but not tolerance intervals, prediction intervals or control charts):

- Individual well comparison procedures used to compare data for individual compliance wells with background concentrations (or groundwater protection standards) must be performed at a Type I error level no less than 0.01 (i.e., 99 percent of the time a true statement about the data will be accepted as true).

- For multiple-comparison procedures, the Type I experiment error rate must be no less than 0.05 (95 percent of the time a true statement will be found to be true).

6.5.6.1
Parametric ANOVA

Parametric ANOVA methods must include estimation and testing of the contrasts between the mean value for each point of compliance well and the background mean value. These comparisons must be performed for each constituent included in the monitoring program, as necessary.

6.5.6.2
ANOVA Based on Ranks

ANOVA based on ranks method must include estimation and testing of the contrasts between the median value for each compliance well constituent and the background median levels for that constituent.

6.5.6.3
Tolerance or Prediction Intervals

Tolerance or prediction interval procedures provide for the establishment of an acceptable range of values for each constituent. The acceptable range of values (values that could be observed without there being a release) is derived from the distribution of constituent concentrations in the background data. The level of each constituent in each compliance well is then compared to the upper limit (upper and lower limits for pH) of the tolerance or prediction interval to determine if a statistically significant increase has occured.

6.5.6.4
Control Chart

A control chart approach gives control limits for each constituent that when exceeded in a compliance well indicates that a statistically significant increase has occurred.

6.5.6.5
Other Statistical Methods

Other statistical test method(s) may be used provided they meet performance standards identified above.

6.5.7
Groundwater Protection Standards

Groundwater protection standards must be established for each Appendix II constituent detected in the groundwater. The groundwater protection standard must be

- The MCL, if one has been established under the Safe Drinking Water Act;
- The background concentration for the constituent if no MCL exists;
- The background concentration, if it is higher than the MCL or health-based levels; or
- State-established alternative groundwater protection standards for constituents with no established MCLs.

6.6
CONTAMINANT FATE AND TRANSPORT PROCESSES

The basic understanding of the fate and transport of contaminants in the subsurface can be used to design cost-effective groundwater monitoring systems, safer waste disposal facilities and subsequent corrective actions, if necessary. The physical and chemical characteristics of the contaminants and the hydrogeologic settings of the subsurface control the movement of contaminants in the porous media. The concepts of fate and transport can be used to predict the time of arrival and concentration of contaminants at a designated receptor point (such as monitoring wells, surface water bodies and water supply wells.) The contaminants may exist in groundwater either in aqueous form or nonaqueous form.

The three fundamental processes through which a contaminant is transported and transformed in the subsurface include physical, chemical and biological processes (Figure 6-57).

6.6.1 Physical Processes

The four physical processes affecting contaminant fate and transport are

- Advection
- Dispersion
- Diffusion
- Retardation

6.6.1.1 *Advection*

Advection is the most important contaminant transport process. Contaminants are advectively transported as a component of groundwater in direct relation to groundwater flow. This process is nonreactive and is controlled by the hydraulic conductivity of the subsurface media and the hydraulic gradient. Advective transport is rate- and direction-dependent.

6.6.1.2 *Dispersion*

Dispersion is the mixing of fluids due to the heterogeneity of the media permeability (Figure 6-58). Typically, the dispersion mechanism reduces the contaminant concentrations in the

Aqueous Phase Contaminant Fate and Transport Process

- Physical Processes
- Chemical Processes
- Biological Processes

Figure 6-57
6-109

Dispersion in a Porous Media

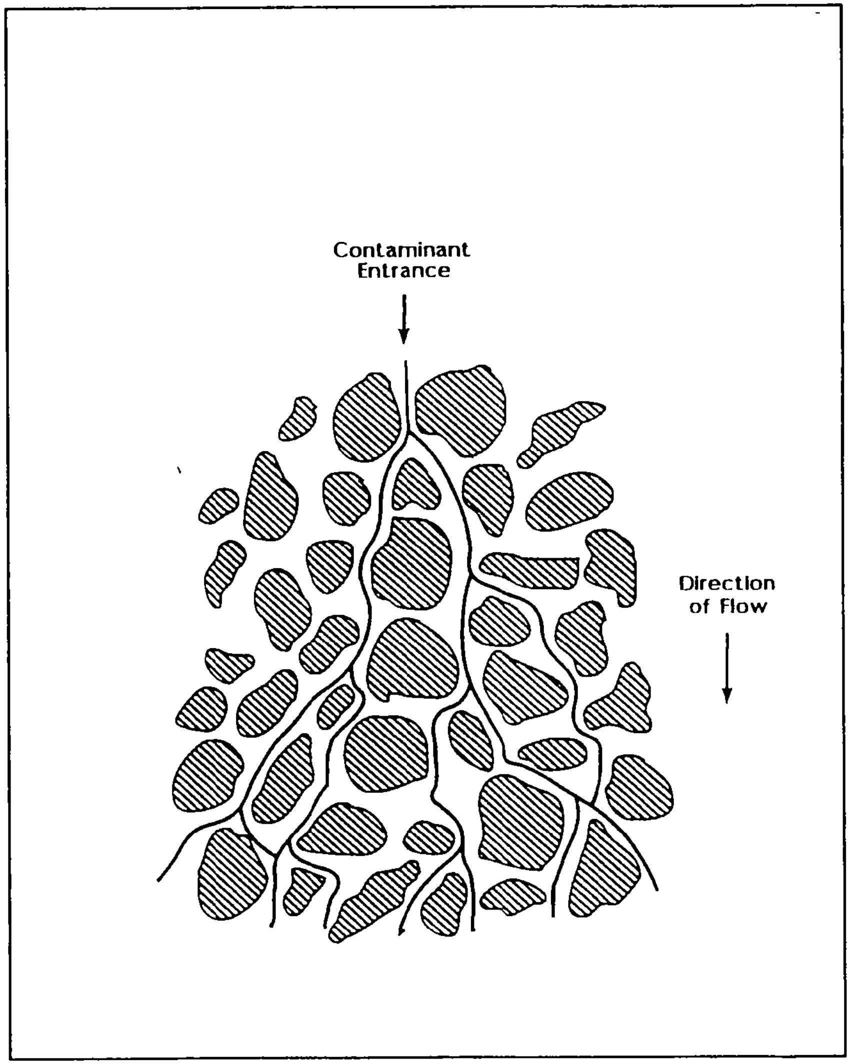


Figure 6-58

plume by spreading to a greater extent both in longitudinal and transverse directions. The longitudinal dispersion is typically greater than transverse dispersion by an order of magnitude resulting in long and thin plumes. If transverse dispersion is greater than longitudinal, the contaminant plume will spread over the entire thickness of the aquifer.

6.6.1.3
Diffusion

Diffusion refers to the spreading of a contaminant in response to concentration gradients. Typically, in a homogenous porous media with high permeability, the effect of diffusion processes are considered insignificant in comparison to advection and dispersion. However, in low-permeability formations, such as clay liners, diffusion is a dominant transport process. The transport of inorganic ions through clay liners is predominantly through diffusion.

6.6.1.4
Retardation

Retardation slows down the movement of contaminants in the porous media. Retardation is dependent on chemical reactions such as sorption/desorption and the partitioning of contaminants into the soil organic matter. The retardation factor, in its simplest form, can be defined as the ratio of velocity of the groundwater to the velocity of the contaminant in the porous media.

6.6.2
Chemical Processes

The seven chemical processes affecting contaminant fate and transport are:

- Sorption
- Dissolution/precipitation
- Acid-base reactions

- Complexation
- Hydrolysis/substitution
- Redox reactions
- Radioactive decay

6.6.2.1
Sorption

Sorption is the most important chemical process controlling the rate of movement of contaminants. This process leads to the partitioning of the contaminant between the groundwater and the media. The organic content of the media and contaminant solubility are key factors in sorption. Sorption is typically represented as the partitioning coefficient (K_p) which is the ratio of contaminant concentration in the soil fraction to the contaminant concentration in the groundwater.

6.6.2.2
Dissolution/Precipitation

Dissolution and precipitation are chemical processes that either add contaminants to or remove contaminants from the groundwater. Dissolution of minerals in the media determines the natural composition of groundwater. Precipitation is the opposite of dissolution and involves the removal of contaminants out of the aqueous solution. These reactions are important attenuation mechanisms that control the concentration of contaminants in the groundwater.

6.6.2.3
Acid-Base Reactions

Acid-base reactions affect the pH of the groundwater which in turn affect the rate of contaminant solubility and transport.

6.6.2.4
Complexation

In a complexation reaction, a metal ion reacts with an anion (ligand). The metal and the ligand bind together to form a new, more soluble species, thereby increasing the contaminant mobility. Complexation also decreases the amount of "free" ions in solution which can adsorb onto the media. Organic ligands generally form stronger complexes. The common organic ligands are amines, pyridines, phenols and naturally occurring humic materials. Inorganic ligands found in the subsurface include hydroxide, chloride, ammonia, cyanide and polyphosphates.

6.6.2.5
Hydrolysis/Substitution

Hydrolysis is the direct reaction of dissolved compounds with water while substitution is the reaction with a component ion of water. Hydrolysis and substitution are important processes in abiotic (nonbilogical) chemical degradation. Hydrolysis and substitution reactions often result in organic compounds which are more soluble and biodegradable.

6.6.2.6
Redox Reactions

The number of electrons associated with an element dictates its oxidation state. Elements can exist in several oxidation states. Redox (reduction-oxidation) reactions involve a change in the oxidation state of elements (i.e., the transfer of electrons.) Redox reactions affect contaminant transport by influencing other chemical processes (i.e., solubility, adsorption, etc.) For example: hexavalent chromium (Cr^{-6}) is a toxic, mobile anion whereas trivalent chromium (Cr^{-3}) is inert, relatively insoluble and strongly adsorbs to surfaces. Redox reactions can result in the creation of constituents which are more or less harmful and/or mobile.

6.6.2.7
Radioactive Decay

Radioactive decay is an irreversible decline in the activity of a radionuclide through a nuclear reaction.

6.6.3
Biological Processes

Biological processes result in degradation and transformation of organic compounds and incorporation of inorganic ions in complex organic compounds. The rates of biological processes are controlled by the presence of microorganisms and redox conditions. Biodegradation is commonly used as a remediation process resulting in the reduction of contaminant concentrations in the aquifer.

6.6.4 Nonaqueous-Phase Liquids

Liquids that do not rapidly dissolve in water and can exist as a separate fluid are known as Nonaqueous-Phase Liquids (NAPLs) (Figure 6-59). NAPLs are subdivided into two classes: those that are lighter than water, Light NAPLs (LNAPLs), and those with a density greater than water, Dense NAPLs (DNAPLs).

NAPLs persist in the subsurface environment for long periods of time and have the ability to contaminate large volumes of groundwater. Greater understanding of the transport and dissolution of NAPLs is necessary to implement cost-effective monitoring and corrective actions.

6.6.4.1 *Light Nonaqueous-Phase Liquids*

LNAPLs enter the unsaturated zone and flow through the central portion of the unsaturated zone. If the amount of LNAPL released is small, the product will flow until residual saturation is reached. Infiltrating water dissolves certain components within the LNAPLs (e.g., benzene and toluene) and carries them into the groundwater. The dissolved constituent then forms a plume of contaminants in the groundwater (Figure 6-60).

If a large volume of LNAPL is released, the product flows through the unsaturated pore space to the top of the saturated zone. As the head created by the infiltrating product increases, the water table is depressed and the product begins to collect in the depressions. If the source of the

Non Aqueous-Phase Liquids

- LNAPLs

  - Lighter than water
  - Floats on water table
  - Hydrocarbon fuels such as:
    gasoline, fuel oil, heating oil and kerosene

- DNAPLs

  - Denser than water
  - Chlorinated hydrocarbons such as:
    TCE; PCE; 1,1,1-TCA and PCBs

Figure 6-59
6-113

Movement of LNAPLs into the Subsurface

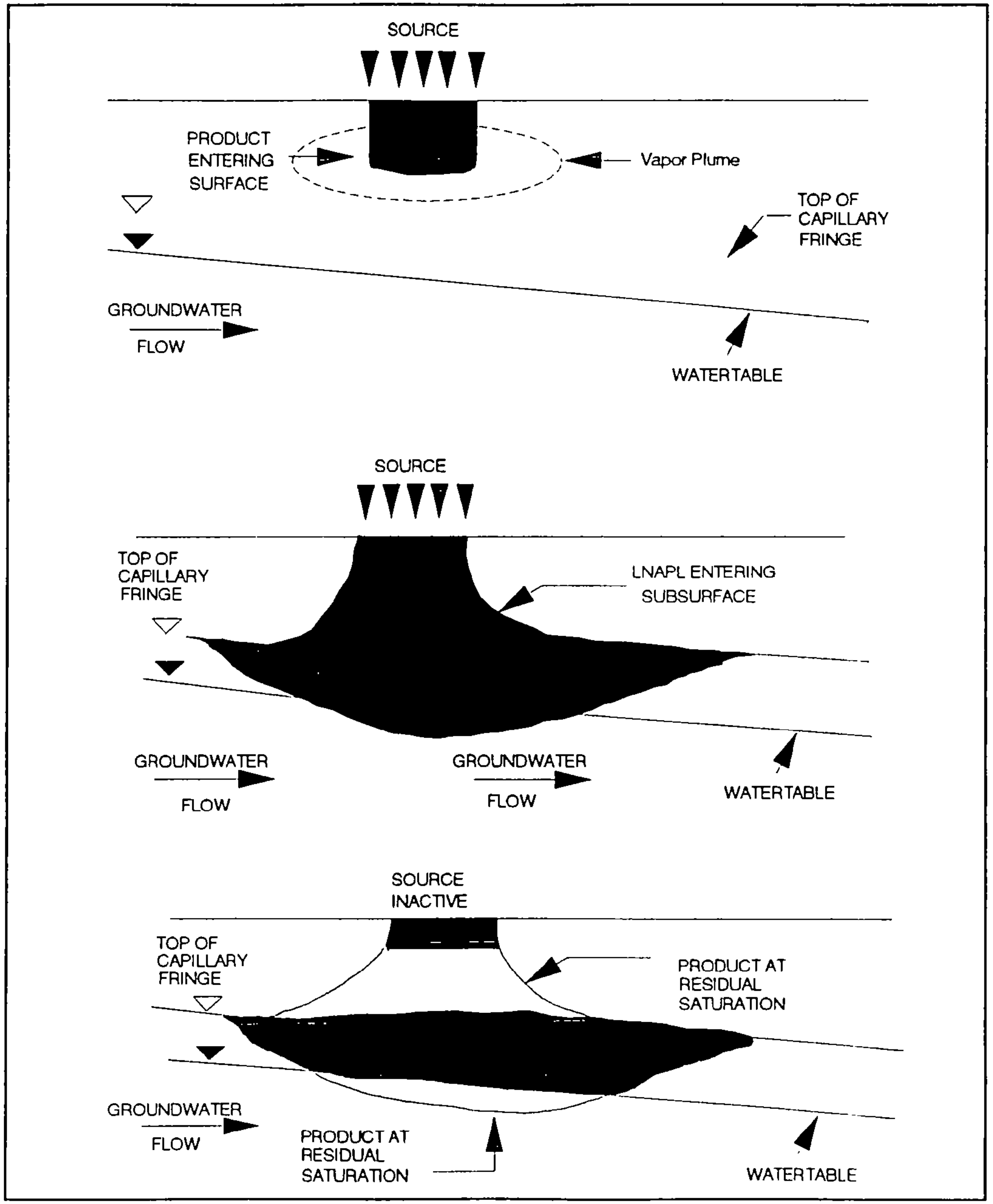


Figure 6-60
6-114

LNAPL is then removed, the LNAPL within the vadose zone continues to flow under the influence of gravity until reaching residual saturation. The LNAPL continues to collect on top of the water table and spread laterally.

Seasonal water table variations result in the spreading of contaminants (LNAPLs) over a greater thickness of the aquifer.

6.6.4.2
Dense Nonaqueous-Phase Liquids

DNAPLs can have great mobility in the subsurface as a result of their relatively low solubility, high density and low viscosity. DNAPLs do not readily mix with water and, therefore, remain as a separate phase. The high density of these liquids provides a driving force that can carry the product deep into the aquifer. The combination of high density and low viscosity is particularly important with regard to the transport of DNAPLs in the subsurface.

DNAPLs flow through the unsaturated zone, toward the water table, under the influence of gravity (Figure 6-61) . If the amount of DNAPLs released is small, the material will be retained in the unsaturated zone. Infiltrating water will dissolve the residual DNAPL constituents and transport them to the water table creating a separate dissolved phased chemical contaminant plume.

If a greater amounts of DNAPLs are release, the DNAPLs flow until reaching the saturated zone. Once there, the DNAPLs begin to penetrate the aquifer. However, to do this the DNAPLs must displace the water by overcoming the capillary forces between the water and the aquifer medium. The critical height of DNAPLs required to overcome the capillary forces varies for different contaminants. After penetrating the aquifer, the

Movement of DNAPLs into the Subsurface

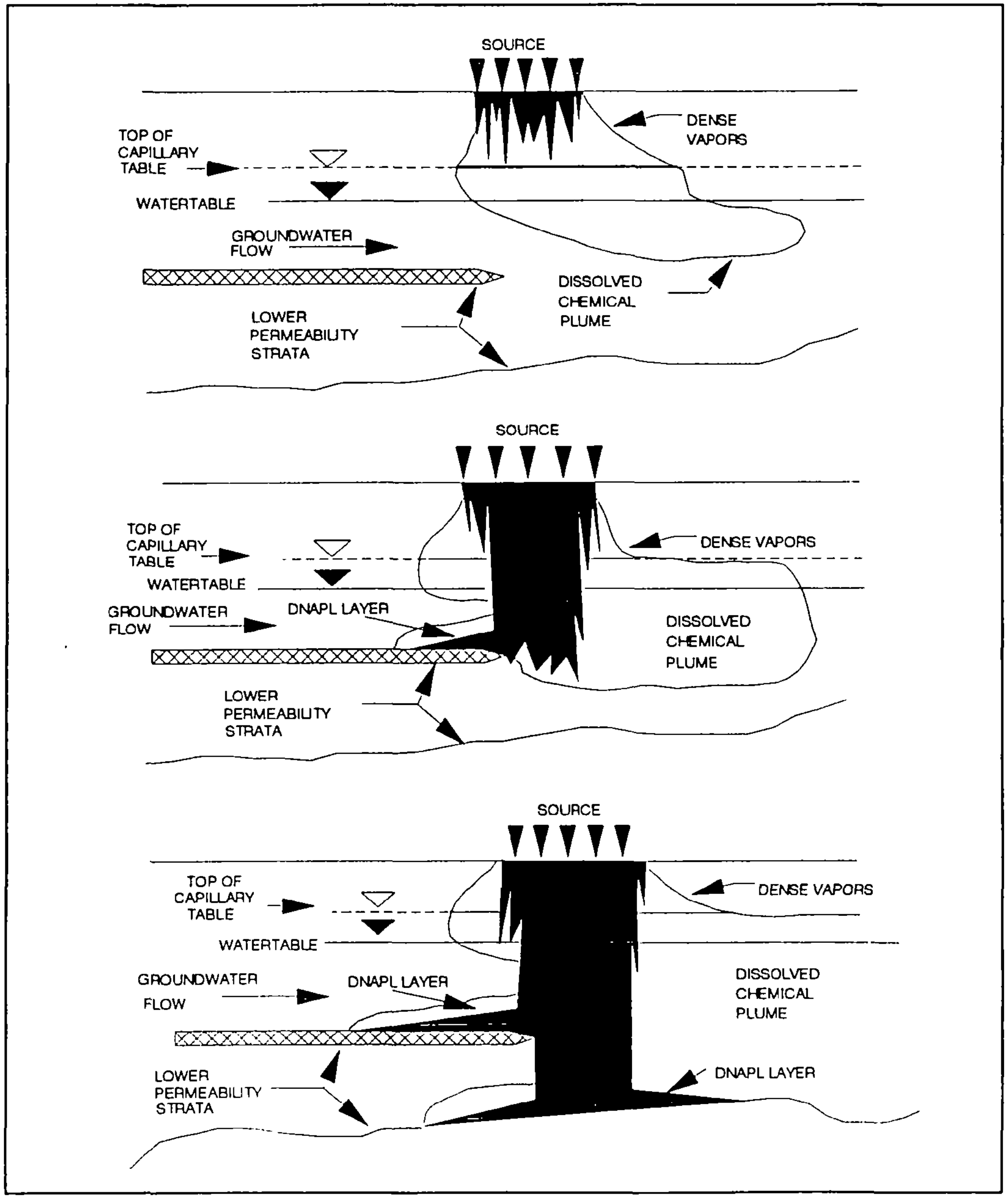


Figure 6-61
6-115

DNAPLs continue through the saturated zone until only a residual amount of the material is retained in the unsaturated zone. The DNAPLs are then dissolved by the passing groundwater resulting in a plume of contaminated water.

6.6.5 Delineation of Extent of Contamination/Additional Monitoring

Determining both the horizontal and vertical extent of a contaminant plume is a complex problem. In addition to sampling through groundwater monitoring wells, certain geophysical testing can also be used. For example, if leachate has high levels of total dissolved solids, electrical resistivity surveys can be used to delineate the plume. The location of additional monitoring wells should be based on groundwater flow direction, site hydrogeologic settings and the nature of the contaminants.

The placement of wells screened at varying depths throughout the saturated zone of the uppermost aquifer provides monitoring for constituents that may exhibit preferential flow patterns within the aquifer. Leachates that have properties different from those of water may flow through the soil/groundwater matrix at directions and rates different from those of water, creating flow patterns influenced by density variations. Installation of well clusters may be required in thick formations to avoid dilution of contaminants as discussed in the section on groundwater monitoring systems.

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7

SECTION 7.0

Corrective Action

7.1 CORRECTIVE ACTION AS END RESULT

The Subtitle D regulations include requirements for corrective actions to address contaminant releases to groundwater. Although corrective action is beyond the scope of this course, the following brief discussion is included.

MSWLFs are required to implement a Corrective Action Program if a statistically significant increase above the groundwater protection standard has occurred for any of the Appendix II constituents. The Corrective Action Program must include:

- Characterization of the nature and extent of the release
- Assessment of corrective measures
- Remedy selection and implementation

Characterization of the nature and extent of any release is required as a component of the assessment monitoring program which precedes assessment of corrective measures. However, additional characterization may be necessary to facilitate adequate assessment of corrective measures.

Assessment of corrective measures must be initiated within 90 days after determination that a statistically significant increase of Appendix II constituents has occurred. The assessment must evaluate the effectiveness of potential corrective measures to meet the regulatory requirements and objectives for remedial actions. Each applicable corrective measure must be assessed to determine the following:

- Performance
- Reliability
- Ease of implementation
- Potential impacts (safety, cross media and exposure)
- Time required to begin and complete the remedy
- Costs of implementation
- Institutional requirements (i.e., state or local permits or other environmental or public health requirements)

The assessment of corrective measures must be completed within a reasonable period of time. Upon completion, the results of the assessment must be discussed in a public meeting prior to formal selection of the remedy.

The corrective remedy selected must meet the following standards:

- Be protective of human health and the environment
- Attain the groundwater protection standard
- Control the source(s) so as to reduce or eliminate further releases

A number of factors must be considered in selecting corrective remedies:

- Long- and short-term effectiveness and protection
- Long-term reliability
- Short-term risks during implementation
- Potential reduction of existing risks and residual risks
- Effectiveness in controlling further releases
- Type and degree of long-term management required
- Time required to achieve full protection
- Potential for exposure to remaining wastes
- Potential need for replacement of the remedy components
- Degree of difficulty associated with implementation
- Availability of equipment and specialists
- Availability, capacity and location of treatment, storage and disposal services
- Need to coordinate and obtain approvals and permits
- Degree to which community concerns are addressed

- Technical and economic capability of the responsible parties

The corrective remedy must include the following components:

- Interim measures (as necessary) to ensure the protection of human health and the environment
- Schedule for implementation and completion
- Establishment of a corrective action groundwater monitoring program

The corrective remedy must included a schedule for initiating and completing remedial activities within a reasonable period of time. The following factors should be considered in developing the schedule:

- Extent and nature of contamination
- Practical capabilities of the remedy to achieve the remedial objectives
- Availability of treatment or disposal capacity for wastes generated
- Desirability of utilizing future technologies which may offer significant advantages over available technologies
- Potential risks from exposure to contamination prior to completion
- Resource value of the aquifer
- Practicable capability of the responsible party

Corrective action remedies are considered complete when the following requirements are met:

- The groundwater protection standards have not been exceeded (using the statistical procedures) for a period of three consecutive years

- All actions required to complete the remedy have been satisfied

A

ATTACHMENT A

"Flexible Membrane Liners," by Gregory N. Richardson

FLEXIBLE MEMBRANE LINERS

Gregory N. Richardson

1. INTRODUCTION

This session discusses material and design considerations for flexible membrane liners (FMLs) within solid waste facilities constructed to satisfy 6NYCRR Part 360. It highlights some of the problems encountered in applying the 1-dimensional regulatory liner profile to actual 3-dimensional landfill "bathtub" systems. Under Part 360, the minimum acceptable liner profiles for municipal solid waste landfills are as follows (360-2.13):

- Primary Leachate Collector (24-inch @ 10^{-3} cm/sec)
- Primary Composite Liner (18-inch *(see note) + FML)
- Secondary Leachate Collector (12-inch @ 10^{-2} cm/sec)
- Secondary Composite Liner (24-inch @ 10^{-7} cm/sec + FML)

The soil component of the primary composite liner is required to achieve less than $1x10^{-7}$ cm/sec permeability only in the upper 6-inches. To minimize potential compaction induce damage to the secondary composite liner, the lower 12-inches of the soil component in the primary composite must only achieve $1x10^{-5}$ cm/sec. permeability. For slopes greater than 25%, the primary liner consists of only an FML and a geonet can be used to construct the secondary leachate collection system. These concessions are made due to slope stability considerations as discussed later in this session.

COMPOSITE LINERS: CLAY VERSUS FML

The reliance within Part 360 on composite liners composed of a synthetic FML overlying a lower permeability soil is an extension of EPA's minimum technology guidance for hazardous waste containment systems. The advantages of a composite liner have been clearly established and will be discussed herein.

Understanding the basic hydraulic mechanisms for synthetic liners and clay liners is very important in appreciating the advantages of a composite liner. Clay liners are controlled by Darcy's law (Q = kiA). In clay liners, the factors that most influence liner performance are **hydraulic head and soil permeability**. Clay liners have a higher hydraulic conductivity and thickness than do synthetic liners. Additionally, leachate leaking through a clay liner will

* upper 6 inches @ 10^{-7} cm/sec, lower 12 inches @ 10^{-5} cm/sec

undergo chemical reactions that reduce the concentration of contaminants in the leachate.

Leakage through a synthetic liner is controlled by Fick's first law, which applies to the process of liquid diffusion through the liner membrane. The diffusion process is similar to flow governed by Darcy's law except it is driven by concentration gradients and not by hydraulic head. Diffusion rates in membranes are very low in comparison to hydraulic flow rates even in clays. In synthetic liners, therefore, the factor that most influences liner performance is **penetrations.** Synthetic liners may have imperfect seams or pinholes, which can greatly increase the amount of leachate that leaks out of the landfill.

EPA's rationale for favoring a composite liner system is based both on increasing the efficiency of the liquid collection systems and to reduce the potential for leakage out of the liner system. A laboratory evaluation of the reduced leakage rates afforded by composite liners was funded by EPA in the late 80's. Table 1 is extracted from this study and clearly shows that a composite liner will reduce leakage orders of magnitude when compared to an FML resting on a drainage media. The key requirement in this improved performance from composite liner is that both components of the liner must be in intimate contact. Thus the introduction of a geotextile beneath the FML will destroy the composite action of the two components and result in a significant increase in leakage. Accordingly, the use of a geotextile beneath an FML to increase the puncture resistance of the FML is dangerous.

3. MATERIAL CONSIDERATIONS

Synthetics are made up of polymers-natural or synthetic compounds of high molecular weight. Under Part 360, the only restrictions on the selection of a polymer are 1) the FML must have a minimum thickness of 60 mils,2) the FML must have a permeability less than $1x10^{-12}$ cm/sec, and 3). The FML must not chemically react with the anticipated leachate. Different polymeric materials may be used in the construction of FMLs:

- Thermoplastics-polyvinyl chloride (PVC)
- Crystalline thermoplastics-high density polyethylene (HDPE), linear low density polyethylene (LLDPE)
- Thermoplastic elastomers-chlorinated polyethylene (CPE), chlorylsulfonated polyethylene (CSPE)
- Elastomers-neoprene, ethylene propylene diene monomer (EPDM)

Typical compositions of polymeric geomembranes are depicted in Table 2. As the table shows, the membranes contain various admixtures such as oils and fillers that are added to aid manufacturing of the FML but may affect future performance. In addition, many polymer FMLs will cure once installed, and the strength and elongation characteristics of certain FMLs will change with time. It is important therefore to select polymers for FML construction with care. Chemical compatibility, manufacturing considerations, stress-strain characteristics, survivability, and permeability are some of the key issues that must be considered.

3.1 *CHEMICAL COMPATIBILITY*

The chemical compatibility of a FML with waste leachate is an important material consideration. Chemical compatibility and EPA Method 9090 tests must be performed on the synthetics that will be used to construct FMLs. (EPA Method 9090 tests are discussed in more detail in Session Five.) Unfortunately, there usually is a lag period between the time these tests are performed and the actual construction of a facility. It is very rare that at the time of the 9090 test, enough material is purchased to construct the liner. This means that the material used for testing is not typically from the same production lot as the synthetics installed in the field.

The molecular structure of different polymers can be analyzed through differential scanning calorimeter or thermogravimetric testing. This testing or "fingerprinting" can ensure that the same material used for the 9090 test was used in the field. Figure 1 was provided by a HDPE manufacturer, and the fingerprints depicted are all from high density polyethylenes. Chemical compatibility of extrusion welding rods with polyethylene sheets is also a concern.

3.2 *MANUFACTURING CONSIDERATIONS*

FML sheets are produced in various ways:

- Extrusion-HDPE
- Calendaring-PVC
- Spraying-Urethane

In general, manufacturers are producing high quality geomembrane sheets. However, the compatibility of extrusion welding rods and high density polyethylene sheets can be a problem. Some manufacturing processes can cause high density polyethylene to crease. When this material creases, stress fractures will result. If the material is taken into the field to be placed, abrasion damage will occur on the creases. Manufacturers have been working to resolve this problem and, for the most par, sheets of acceptable quality are not being produced.

STRESS-STRAIN CHARACTERISTICS

Table 3 depicts typical mechanical properties of HDPE, CPE, and PVC. Tensile strength is a fundamental design consideration. Figure 2 shows the uniaxial stress-strain performance of HDPE, CPE, and PVC. As 600, 800, 1,100, and 1,300 percent strain is developed, the samples fail. When biaxial tension is applied to HDPE, the material fails at strains less than 20 percent. In fact, HDPE can fail at strains much less than other flexible membranes when subjected to biaxial tensions common in the field.

Another stress-strain consideration is that high density polyethylene, a material used frequently at hazardous waste facilities, has a high degree of thermal coefficient of expansion - three to four times that of other flexible membranes. This means that during the course of a day (particularly in the summer), 100-degrees Fahrenheit (°F) variations in the temperature of the sheeting are routinely measured. A 600-foot long panel, for example, may grow 6 feet during a day.

3.3 *SURVIVABILITY*

Various test may be used to determine the survivability of unexposed polymeric geomembranes (Table 4). Puncture tests frequently are used to estimate the survivability of FMLs in the field. During a puncture test, a 5/16 steel rod with rounded edges is pushed down through the membrane. A very flexible membrane that has a high strain capacity under biaxial tension may allow that rod to penetrate almost to the bottom of the chamber rupture. Such a membrane has a very low penetration force but a very high penetration elongation, and may have great survivability in the field. High density polyethylenes will give a very high penetration force, but have very high brittle failure. Thus, puncture data may not properly predict field survivability.

3.4 *PERMEABILITY*

Permeability of a FML is evaluated using the Water Vapor Transmission test (ASTM E96). A sample of the membrane is placed on top of a small aluminum cup containing a small amount of water. The cup is then placed in a controlled humidity and temperature chamber. The humidity in the chamber is typically 20 percent relative humidity, while the humidity in the cup is 100 percent. Thus, a concentration gradient is set up across the membrane. Moisture diffuses through the membrane and with the liquid level in the cup is reduced. The rate at which moisture is moving through the membrane is measured. From that rate, the permeability of the membrane is calculated with the simple diffusion equation (Fick's first law). It is important to remember than even if a liner is installed correctly with no holes, penetrations, punctures, or defects, liquid will still diffuse through the membrane.

A final comment must be made regarding the Part 360 requirement for 10^{-12} cm/sec permeability in the FML. Table 5 lists WVT data for Typical FML's. The water vapor permeance is defined as the WVT divided by the pressure difference across the FML. Permeability is then defined as the product of the permeance and thickness of the FML. Table 5 lists equivalent permeabilities for common FML's. If the FML must have less than $1x10^{-12}$ cm/sec permeability, then a polyethylene liner will be required.

TABLE 5 FML PERMEABILITY
(Data from Haxo, 1989)

Polymer	Thickness Mils	WVT(1) $gm^{-2}\ d^{-1}$	Permeability(2) cm/sec
CPE	30	.32	$2x10^{-12}$
	38	.55	$4x10^{-12}$
CSPE	30	.60	$4x10^{-12}$
	38	.41	$3x10^{-12}$
EPDM	38	.25	$1.6x10^{-12}$
LDPE	30	.05	$3.2x10^{-13}$
HDPE	30	.0177	$1x10^{-13}$
	100	.006	$1x3x10^{-11}$
PVC	20	3.0	$1x3x10^{-11}$
	30	1.8	$1x3x10^{-11}$

(1) $1gm^{-2}\ d^{-1}$ = 1.07 gallon/acre/day

(2) 1 metric perm mil = $2.167x10^{-12}$ cm/sec

4. DESIGN ELEMENTS

A number of design elements must be considered in the construction of flexible membrane liners: (1) 6NYCRR Part 360 guidance, (2) stress considerations, (3) structural details, and (4) panel fabrication.

4.1 *6NYCRR PART 360 GUIDANCE*

Part 360 establishes minimum values for the components within the landfill liner. For the FML component, these minimum values are:

- 60 mil minimum thickness, and
- Permeability less than $1x10^{-12}$ cm/sec.

Thus the basic design will begin with these values

4.2 *STRESS*

Stress considerations must be considered for side slopes and the bottom of a landfill. For side slopes, self-weight (the weight of the membrane itself) and waste settlement must be considered; for the bottom of the facility, localized settlement and normal compression must be considered.

The primary FML must be able to support its own weight on the side slopes. In order to calculate self-weight, the FML specific gravity, friction angle, FML thickness, and FML yield stress must be known (Figure 3).

Waste settlement is another consideration. As waste settles in the landfill, a downward force will act on the primary FML. A low friction component between the FML and underlying material, putting tension on the primary FML. A 12-inch direct shear test is used to measure the friction angle between the FML and underlying material.

An example of the effects of waste settlement can be illustrated by a recent incident at a hazardous waste landfill facility in California. At this facility, waste settlement led to sliding of the waste, causing the standpipes (used to monitor secondary leachate collection sumps) to move 60 to 90 feet downslope in 1 day. Because there was a very low coefficient of friction between the primary liner and the geonet, the waste (which was deposited in a canyon) slid down the canyon. There was also a failure zone between the secondary liner and the clay. A two-dimensional slope stability analysis at the site indicated a factor of safety greater than one. A three-dimensional slope stability analysis of the canyon landfill indicated a factor of safety greater than one. A three-dimensional slope stability anaylsis, however, showed the safety factor had dropped below one. Three-dimensional slope stability analyses should therefore be considered with canyon and trench landfills.

Since more trenches are being used in double FML landfills, the impact of waste settlement along such trenches should be considered. Figure 4 is a simple evaluation of the impact of waste settlement along trenches on the FML. Settlements along trenches will cause strain in the membrane, even if the trench is a very minor ditch. Recalling that when biaxial tension is applied to high density polyethylene, the material fails at a 16 to 17 percent strain, it is possible that the membrane will fail at a moderate settlement ratio.

Another consideration is the normal load placed on the membranes as waste is piled higher. Many of the new materials on the market, particularly some of the linear low density polyethylene (LLDPE) liners, will take a tremendous amount of normal load without failure. The high density polyethylenes, on the other hand, have a tendency to high brittle failure.

4.3 *STRUCTURAL DETAILS*

Double liner systems are more prone to defects in the structural details (anchorage, access ramps, collection standpipes, and penetrations) than single liner systems.

4.3.1 Anchorage

Anchor trenches can cause FMLs to fail in one of two way: by ripping or by pulling out. The pullout mode is easier to correct. it is possible to calculate pullout capacity for FMLs placed in various anchorage configurations (Figure 5). In the "V" anchor configuration, resistance can be increased by increasing the "V" angle. A drawback to using the "V" design is that it uses more space. The concrete trench is rarely used. Typical calculations for these anchorage configurations are given in Figure 6.

No rigorous solution exists for a common soil backfilled anchorage trench. In general a trench 12-inches wide by 12 to 18-inches deep will be sufficient to develop the full tensile capacity of the FML. Trenches larger than this will only lead to a tearing failure in the membrane.

4.3.2 Ramps

Most facilities have access ramps (Figure 7), which are used by trucks during construction and by trucks bringing waste into the facility. Figure 8 depicts a cross section of a typical access ramp. The double FML integrity must be maintained over the entire surface of the ramp. Because ramps can fail due to traffic-induced sliding, roadway considerations, and drainage, these three factors must be considered during the design and construction of access ramps.

The weight of the roadway, the weight of a vehicle on the roadway, and the vehicle braking force all must be considered when evaluating the potential for slippage due to traffic (Figure 9). The vehicle braking force should be much larger than the dead weight of the vehicles that will use it. Wheelloads also have an impact on the double FML system and the two leachate collection systems below the roadway. Trucks with maximum axle loads (some much higher than the legal highway loads) and 90 psi tires should be able to use the ramps. Figure 10 illustrates how to verify that wheel contact loading will not damage the FML. Swells or small drains may be constructed along the inboard side of a roadway to ensure that the ramp will adequately drain water from the roadway. Figure 11 illustrates how to verify that a ramp will drain water adequately. The liner system, which must be protected from tires, should be armored in the area of the drainage swells. A sand subgrade contained by a geotextile beneath the roadway can prevent local sloughing and local slope failures along the side of the roadway where the drains are located. The sand subgrade tied together with geotextile layers forms, basically, long sandbags stacked on top of one another.

4.3.3 Vertical Standpipes

Landfills have two leachate collection and removal systems (LCRSs): a primary LCRS and a secondary LCRS. any leachate that penetrates the primary system and enters the secondary system must be removed. Vertical standpipes are used to access the primary leachate collection sumps. As waste settles over time, downdrag forces can have an impact on standpipes. Those downdrag forces can lead to puncture of the primary FML beneath the standpipe.

To reduce the amount of downdrag force on the waste pile, standpipes can be coated with viscous or low friction coating. Standpipes can be encapsulated with coefficient of friction that helps reduce the amount of downdrge force on the waste piles. Figure 12 illustrates how to evaluate the potential downdrag forces acting on standpipes and how to compare coatings for reducing these forces.

Downdrag forces also affect the foundation or subgrade beneath the standpipe. If the foundation is rigid, poured concrete, there is a potential for significant strain gradients. A flexible foundation will provide a more gradual transition and spread the distribution of contact pressures over a larger portion of the FML than will a rigid foundation. To soften rigid foundations, encapsulated steel plates may be installed beneath the foundation as shown in Figure 13.

4.3.4 Standpipe Penetrations

The secondary leachate collection system may be accessed by either a sidewall standpipe that penetrates the primary liner above the waste mass, or by a sump gravity drain pipe that lies below the landfill containment system (Figure 14). Both standpipes have key operational weaknesses. The sidewall standpipe must be accessible at the surface so that a pump can be lowered to the sump. Because there is a possibility that the sump pipe could be struck at the surface, it should not be attached in any manner to either liners. The gravity drain line lies beyond the secondary liner so that failure of this line would result in release of leachate to the environment. For this reason, a double-wall pipe is recommended between the sump and the catchbasin.

4.3.5 Wind Damage

During the installation of FMLs, care must be taken to avoid damage from wind. Figure 15 shows maximum wind speeds in the United States. Designers should determine if wind will affect an installation and, if so, how many sandbags will be needed to anchor the FML panels as they are being placed in the field. Figure 16 shows how to calculate the required sandbag spacing for FML panels during placements. Wind-uplift pressure must be known to make this calculation. Using the data in Table 5, the uplift pressures acting on the membranes may be calculated. Note that 6NYCRR Part 6 does not allow FML placement in winds exceeding 20 mph.

4.4 *PANEL FABRICATION*

The final design aspect to consider is the FML panel layout of the facility. Three factors should be considered when designing a FML panel layout: (1) seams should run up and down on the slope, not horizontally; (2) the field seam length should be minimized whenever possible; and (3) when possible, there should be no penetration of a FML below the top of the waste.

6NYCRR Part 360 specifically requires that field seams should be oriented parallel to the line of the maximum slope, that the number of field seams should be minimized in corners and irregularly-shaped locations, and that no horizontal seams should be less than 5-feet from the toe of the slope toward the inside of the cell.

Panels must be properly identified to know where they fit in the facility. Figure 17 depicts the panel-seam identification scheme used for this purpose. This numbering scheme also assures a high quality installation, since seam numbers are used to inventory all samples cut from the FML panel during installation. The samples cut from the panels are tested to ensure the installation is of high quality. Quality assurance and the panel-seam identification scheme are discussed in more detail in Session VI.

REFERENCES

Brown, K. W. et al, Qualification of Leak Rates Through Holes in Landfill Liners, EPA Grant Nol. CR810940, EPA Office of Research and Development, 1987.

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Knipschield, F.W. 1985. Material, Selection, and Dimensioning of Geomembranes for Groundwater Protection, **Waste and Refuse**. Schmidt Publisher, Vol. 22.

Richardson, G.N. and R. M. Koerner, 1988, Geosynthetic Design Guidance for Hazardous Waste Landfill Cells and Surface Impoundments, EPA/600/52-87/097.

TABLE 1 CALCULATED FLOW RATES (M^3 YR^{-1}) FOR A RANGE OF HOLE SIZES IN FLEXIBLE MEMBRANE LINERS OVER SOILS OF DIFFERENT CONDUCTIVITIES. THE VALUES ARE GIVEN FOR THREE HEADS

K_{sat} (cm/s)	Hole diameter (cm) 0.08	0.16	0.64	1.27
		H = 0.3 M		
3.40×10^{-4}	19.30	31.50	43.20	50.60
3.40×10^{-5}	4.30	4.88	6.28	7.30
3.40×10^{-6}	0.54	0.60	0.77	0.89
3.40×10^{-7}	0.066	0.072	0.095	0.107
		H = 1.0 M		
1.30×10^{-1}		126.10	2,286.00	6,748.00
3.40×10^{-4}	42.30	87.80	128.00	147.00
3.40×10^{-5}	12.80	14.80	18.70	21.40
3.40×10^{-6}	1.66	1.83	2.29	2.61
3.40×10^{-7}	0.20	0.22	0.28	0.32
		H = 10.0 M		
3.40×10^{-4}	167.0	438.0	1,030.00	1,170.00
3.40×10^{-5}	84.6	123.1	153.50	171.30
3.40×10^{-6}	14.3	15.6	18.80	21.00
3.40×10^{-7}	1.8	1.9	2.30	2.60

Table 2 Basic Composition of Polymeric Geomembrane

Component	Composition of Compound Type (parts by weight) Crosslinked	Thermoplastic	Semicrystalline
Polymer or alloy	100	100	100
Oil or plasticizer	5-40	5-55	0-10
Fillers:	5-40	5-40	2-5
Carbon Black	5-40	5-40	--
Inorganics			
Antidegradants	1-2	1-2	1
Crosslinking system:			
Inorganic system	5-9	--	--
Sulfur system	5-9	--	--

Source: Haxo, H. E. 1986. Quality Assurance of Geomembranes Used as Linings for Hazardous Waste Containment. In: Geotextiles and Geomembranes, Vol. 3, No. 4. London, England.

Table 3 Typical Mechanical Properties

	HDPE	CPE	PVC
Density, gm/cm^3	> .935	1.3 - 1.37	1.24 - 1.3
Thermal coefficient of expansion	12.5×10^{-5}	4×10^{-5}	3×10^{-5}
Tensile strength, psi	4800	1800	2200
Puncture, lb/mil	2.8	1.2	2.2

Table 4 Test Methods for Unexposed Polymeric Geomembranes

Property	Membrane Liner Without Fabric Reinforcement: Thermoplastic	Crosslinked	Semicrystalline	Fabric Reinforced
Analytical Properties				
Volatiles	MTM-1[a]	MTM-1[a]	MTM-1[a]	MTM-1[a] (on selvage and reinforced sheeting)
Extractables	MTM-2[a]	MTM-2[a]	MTM-2[a]	MTM-2[a] (on selvage and reinforced sheeting)
Ash	ASTM D297, Section 34	ASTM D297, Section 34	ASTM D297, Section 34	ASTM D297, Section 34 (on selvage)
Specific gravity	ASTM D792, Method A	ASTM D297, Section 15	ASTM D792, Method A	ASTM D792, Method A (on selvage)
Thermal analysis:				
Differential scanning calorimetry (DSC)	NA	NA	Yes	NA
Thermogravimetry (TGA)	Yes	Yes	Yes	Yes
Physical Properties				
Thickness - total	ASTM D638	ASTM D412	ASTM D638	ASTM D751, Section 6
Coating over fabric	NA	NA	NA	Optical method
Tensile properties	ASTM D882, ASTM D638	ASTM D412	ASTM D638 (modified)	ASTM D751, Method A and B (ASTM D638 on selvage)
Tear resistance	ASTM D1004 (modified)	ASTM D624	ASTM D1004 Die C	ASTM D751, Tongue method (modified)
Modulus of elasticity	NA	NA	ASTM D882, Method A	NA
Hardness	ASTM D2240 Duro A or D	ASTM D2240 Duro A or D	ASTM D2240 Duro A or D	ASTM D2240 Duro A or D (selvage only)
Puncture resistance	FTMS 101B, Method 2065	FTMS 101B, Method 2065	FTMS 101B, Method 2065	FTMS 101B, Methods 2031 and 2065
Hydrostatic resistance	NA	NA	ASTM D751, Method A	ASTM D751, Method A
Seam strength:				
In shear	ASTM D882, Method A (modified)	ASTM D882, Method A (modified)	ASTM D882, Method A (modified)	ASTM D751, Method A (modified)
In peel	ASTM D413, Mach Method Type 1 (modified)	ASTM D413, Mach Method Type 1 (modified)	ASTM D413, Mach Method Type 1 (modified)	ASTM D413, Mach Method Type 1 (modified)
Ply adhesion	NA	NA	NA	ASTM D413, Mach Method Type 1 ASTM D751, Sections 39-42
Environmental and Aging Effects				
Ozone cracking	ASTM D1149	ASTM D1149	NA	ASTM D1149
Environmental stress cracking	NA	NA	ASTM D1693	NA
Low temperature testing	ASTM D1790	ASTM D746	ASTM D1790 ASTM D746	ASTM D2136
Tensile properties at elevated temperature	ASTM D638 (modified)	ASTM D412 (modified)	ASTM D638 (modified)	ASTM D751 Method B (modified)
Dimensional stability	ASTM D1204	ASTM D1204	ASTM D1204	ASTM D1204

Table 3 Wind-Uplift Forces, PSF (Factory Mutual System)

Height Above Ground (ft)	Wind Isotach, mph										
	City, Suburban Areas, Towns, and Wooded Areas					Flat, Open Country, or Open Coastal Belt > 1500 ft from Coast					
	70	80	90	100	110	70	80	90	100	110	120
0-15	10[a]	11	14	17	20	14	18	23	29	35	14
30	10	13	17	21	25	16	21	27	33	40	48
50	12	15	19	24	29	18	24	30	37	44	35
75	14	18	22	27	33	20	26	33	40	49	85

[a]Uplift pressures in PSF

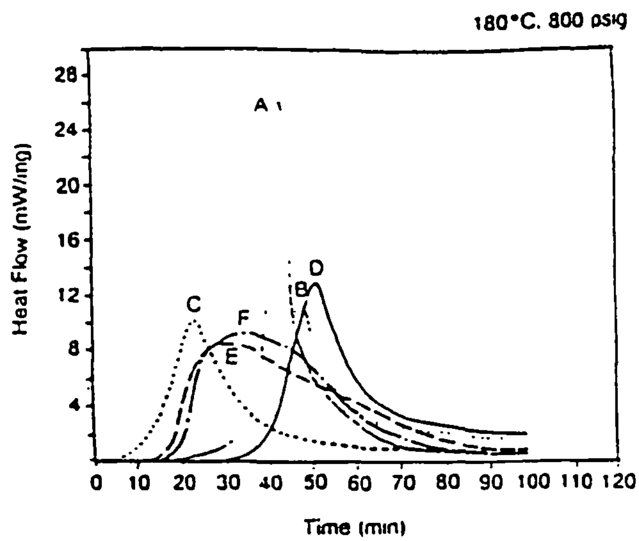


Figure 1 Comparison of "fingerprints" of exothermic peak shapes.

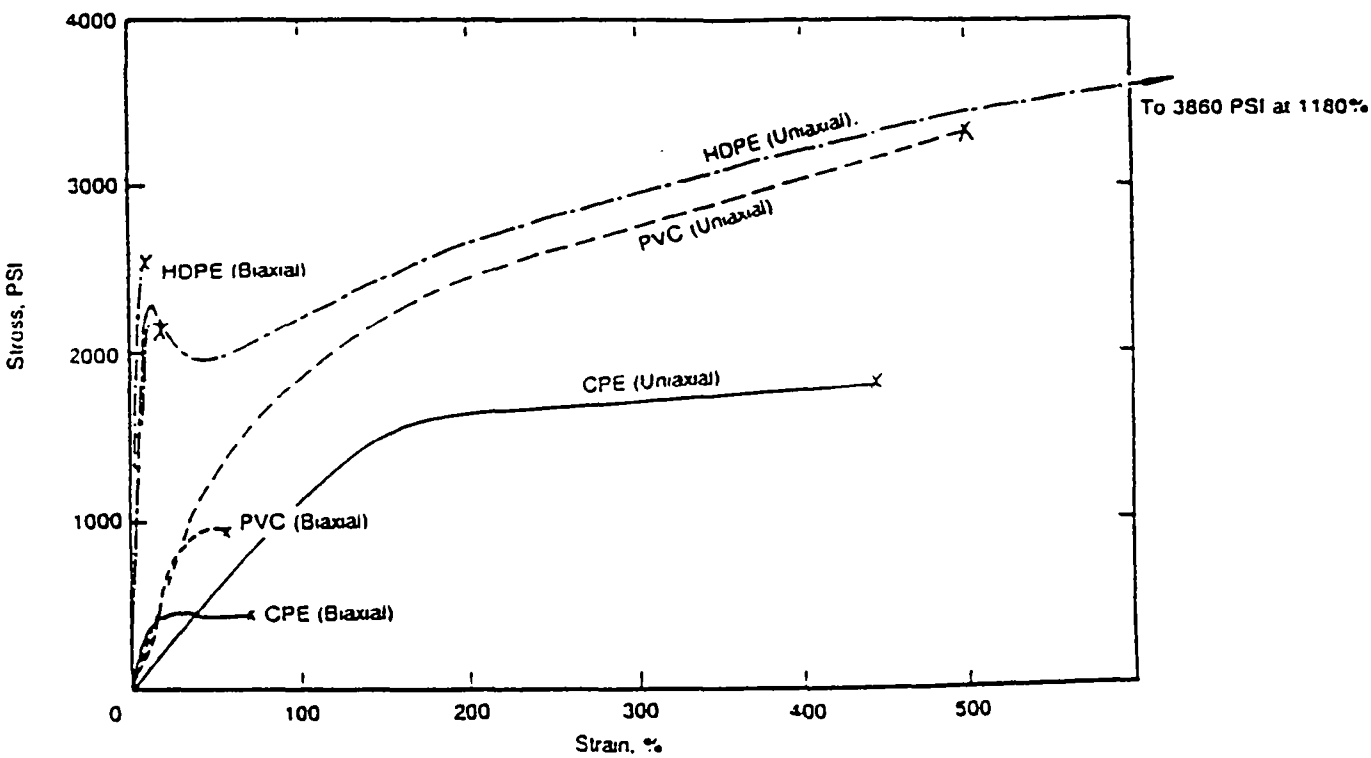


Figure 2 FML stress-strain performance (uniaxial—Koerner, Richardson; biaxial—Steffen).

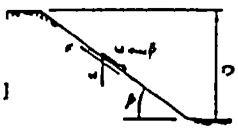
Cell Component: FLEXIBLE MEMBRANE LINER

Consideration: TENSILE STRESS - LINER WEIGHT; EVALUATE ABILITY OF FML TO SUPPORT ITS OWN WEIGHT ON THE SIDE SLOPES.

Required Material Properties	Range	Test	Standard
FML SPECIFIC GRAVITY, G	0.92 to 1.4		
FRICTION ANGLE · FML-TO-LCR, δ_L	10° to 45°	DIRECT SHEAR	PROPOSED ASTM
FML THICKNESS, t	30 to 120 mil		
FML YIELD STRESS, σ_Y	1000 to 6000 (psi)	TENSILE	ASTM D638

Analysis Procedure:

(1) CALCULATE FML TENSILE FORCE, T



$T = W \sin\beta - F \quad (\geq 0)$

WHERE W = LINER WEIGHT

$= [G \gamma_w t][1.0/\sin\beta]$

$F = W \cos\beta \tan \delta_L$

(2) CALCULATE FML TENSILE STRESS, σ

$\sigma = T/A$ WHERE AREA = 1' × t

(3) OBTAIN LABORATORY FML YIELD STRESS, σ_Y

(4) CALCULATE DESIGN RATIO

$DR = \sigma_Y / \sigma$

Design Ratio:
$DR_{min} = 10$ ON YIELD

References:

Example:

GIVEN:
- 60 mil HDPE
- FML SPECIFIC GRAVITY, G = 0.941
- FRICTION ANGLE FML-TO-LCR, $\delta_L = 20°$
- D = 120 ft
- $\beta = 30°$

(1) CALCULATE FML TENSILE FORCE, T

$W = [0.941 \times 62.4 \times \frac{.060}{12}] \times [1 \times 120/\sin 30°]$
$= 70.5$ lb/ft

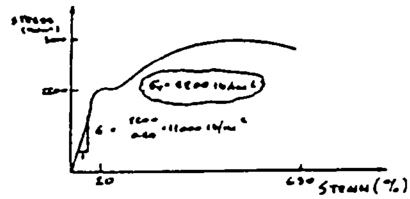
$F = 70.5 \cos 30° \tan 20°$
$= 22.2$ lb/ft

$T = 70.5 \sin 30° - 22.2$
$= \underline{13.0 \text{ lb/ft}}$

(2) CALCULATE FML TENSILE STRESS, σ

$\sigma = 13.0/(1 \times \frac{.060}{12}) = 2600$ lb/ft²
$= \underline{18.0}$ lb/in²

(3) OBTAIN LABORATORY FML YIELD STRESS



(4) CALCULATE DESIGN RATIO

$DR = 2200/18 = \underline{122}$ $\underline{OK}$

Example No. 5.14

FIGURE 3

Cell Component: FLEXIBLE MEMBRANE LINER

Consideration: LOCALIZED SUBSIDENCE: EVALUATE STRAINS INDUCED IN FML BY LOCALIZED SUBSIDENCE.

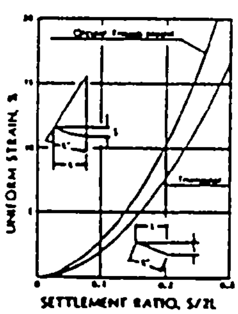
Required Material Properties	Range	Test	Standard
· TENSILE STRENGTH OF FML		WIDE-WIDTH	ASTM-D
· THICKNESS OF FML			ASTM
· SOIL-FML FRICTION ANGLE		DIRECT SHEAR	ASTM (TENTATIVE)

Analysis Procedure:

(1) ESTIMATE SUBSIDENCE GEOMETRY
- WIDTH OF SUBSIDENCE, L = WIDTH OF UNDERLYING EXCAVATION + 45° EXTENSIONS THROUGH SUPPORT LAYER
- DEPTH OF SUBSIDENCE, S (MAXIMUM) = 20% DEPTH OF EXCAVATION

(2) OBTAIN UNIFORM STRAIN FROM FIGURE 3.4

· SETTLEMENT RATIO = $\frac{\text{DEPTH}}{\text{WIDTH}} = \frac{S}{L}$
→ ϵ



(3) CALCULATE ADDITIONAL DEFORMABLE LENGTH

$X = \frac{f_c d}{2 \lambda f_1}$

f_c = ALLOWABLE STRESS FOR FML
d = THICKNESS OF FML
λ = NORMAL STRESS
f_1 = FRICTION COEFFICIENT

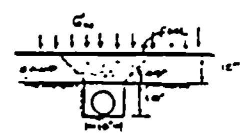
(4) REVISE STRAIN

$\epsilon' = [\epsilon \times L]/(L + 2X/12]$

Design Ratio:
NOT APPLICABLE

References:
KNIPSCHIELD (1985)

Example:



GIVEN:
- 60 mil HDPE
- TENSILE STRENGTH = 1500 psi
- SOIL-FML FRICTION = 10°
- σ_N = 6 ksf

(1) ESTIMATE SUBSIDENCE GEOMETRY

· WIDTH = 18" + 2×12" = 42"
· DEPTH = .2 × 18" = 3.6" } SETTLEMENT RATIO = .086

(2) OBTAIN UNIFORM STRAIN, FIG. 3.4

SETTLEMENT RATIO = 0.086 → ϵ = 20%

(3) CALCULATE ADDITIONAL DEFORMABLE LENGTH

$X = \frac{1500 \times .060}{2 \times [\frac{6000}{144}] \times .176}$ $\tan 10° = .176$

= 5.9 in

(4) REVISE STRAIN

$\epsilon' = \frac{.02 \times 42"}{42" + 5.9}$ = .0189 = $\underline{\underline{1.89\%}}$ STRAIN

STRAIN AT YIELD = $\underline{20\%}$ ∴ $\underline{OK}$

(ϵ_{ult} = 600%)

Example No. 3.16

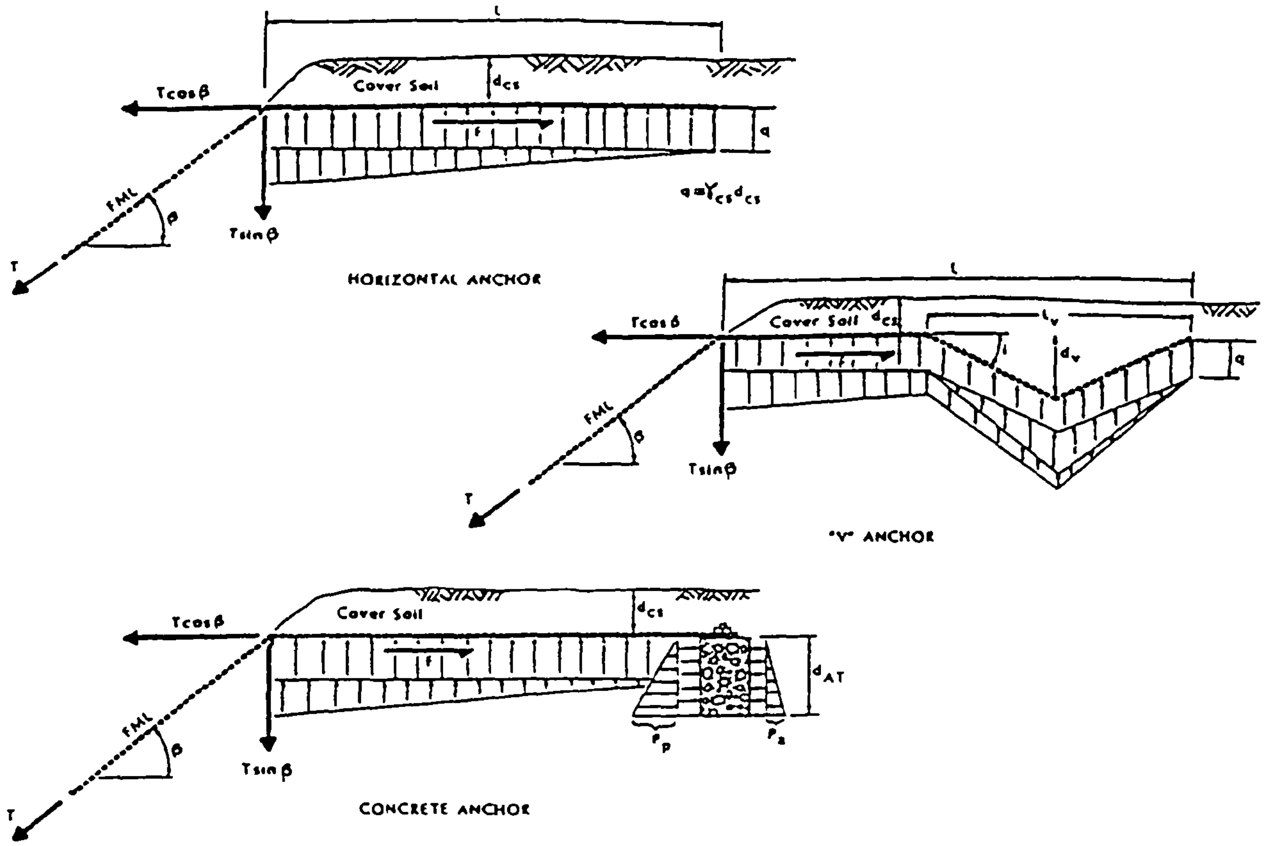


Figure 5 Forces and variables—anchor analysis.

Cell Component: FLEXIBLE MEMBRANE LINING

Consideration: FML ANCHORAGE - CALCULATE ANCHOR CAPACITY FOR FML PLACED IN VARIOUS ANCHORAGE CONFIGURATIONS.

Required Material Properties	Range	Test	Standard
• Soil/FML Friction Angle	12–20°	Direct Shear	ASTM Proposed
• Soil Friction Angle	25–38°	Triaxial	ASTM Proposed

Analysis Procedure:

(1) DEFINE ANCHOR VARIABLES

- GEOMETRY
  - SLOPE ANGLE β
  - EMBEDMENT LENGTH, L
  - SOIL COVER, d_{cs}
  - ANCHOR DEPTH, d_{AT}
- MATERIAL
  - SOIL FRICTION ANGLE, ϕ
  - SOIL/FML FRICTION ANGLE, δ
  - SOIL UNIT WEIGHT, γ_{cs}

(2) SOLVE FOR ANCHOR CAPACITY

HORIZONTAL ANCHOR

$$T = \frac{qL\tan\delta}{(DR)\cos\beta - \sin\beta\tan\delta}$$

"V" ANCHOR

$$T = \frac{\tan\delta\left[q\left(L_{cs} + \frac{L_v}{\cos i}\right) + \frac{d_v L_v \gamma_{cs}}{\cos i}\right]}{(DR)\cos\beta - \sin\beta\tan\delta}$$

CONCRETE ANCHOR

$$T = \frac{qL\tan\delta + (K_p - K_a)\left[\frac{1}{2}\gamma_{cs} d_{AT}^2 + q\,d_{AT}\right]}{(DR)\cos\beta - \sin\beta\tan\delta}$$

ANCHOR TRENCH

$$T = \frac{qL\tan\delta + (K' + K_a)\tan\delta\left[\frac{1}{2}\gamma_{cs} d_{AT}^2 + q\,d_{AT}\right]}{(DR)\cos\beta - \sin\beta\tan\delta}$$

$K' = K_p$ or K_o

REF FIGURES 3.9 & 3.10

Design Ratio: NOT APPLICABLE

References:

Example:

GIVEN: GEOMETRY
- $\beta = 18.4°$ (3:1 SLOPE)
- L = 6 FT
- d_{cs} = 2 FT
- DR = 1.5 MINIMUM

SOIL
- $\phi = 35°$
- $\delta = 13°$
- γ_{cs} = 120 PCF

(1) DEFINE VARIABLES

$q = \gamma_{cs} d_{cs} = 120 \times 2 = 240$ PSF

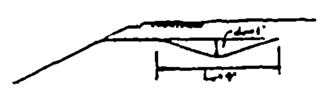
(2) SOLVE FOR ANCHOR CAPACITY

- HORIZONTAL (NO ANCHOR)

$T = \frac{240 \times 6 \text{ FT} \tan 13°}{1.5\cos 18.4° - \sin 18.4° \tan 13°} = \underline{248 \text{ lb/ft}}$

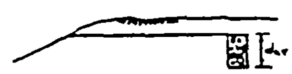
- "V" TRENCH
  - L_v = 4'
  - d_v = 1'

  } i = 26.5°



T = [illegible] / 1.339 = 313 lb/ft

- CONCRETE ANCHOR
  - d_{AT} = 2'-0"
  - $\phi = 35° \Rightarrow K_a = .27$, $K_p = 3.7$



T = [illegible] / 1.339 = $\underline{1990}$ lb/ft

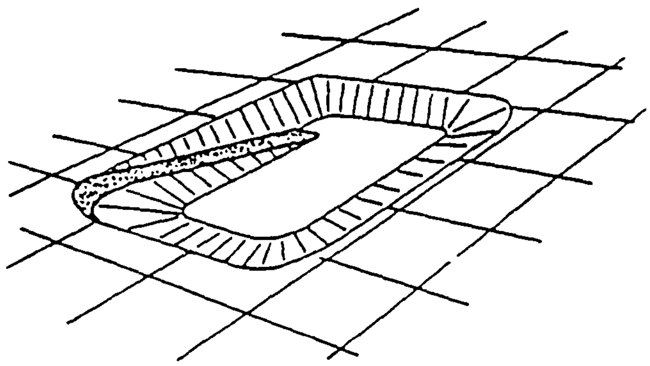
- ANCHOR TRENCH
  - d_{AT} = 2'-0"
  - $\phi = 35° \Rightarrow K_o = .426$

$[T]_{KP}$ = [illegible] / 1.339 = 135 / 599 lb/ft

$[T]_{K_o}$ = [illegible] / 1.339 = 334 lb/ft

Example No. 3.17

FIGURE 6



igure 7 Geometry of typical ramp.

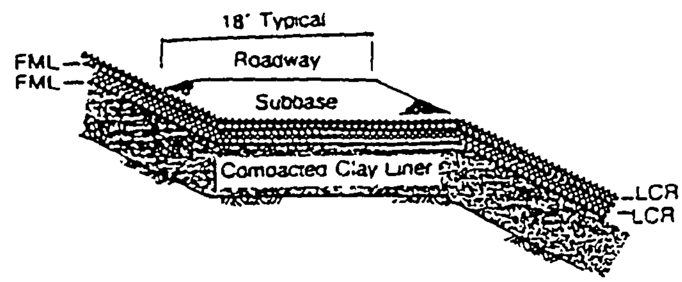


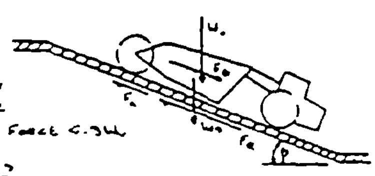
Figure 8 Cross section of typical access ramp.

Cell Component: Ramp

Consideration: Sliding: verify that ramp sub-base is stable under load

Required Material Properties	Range	Test	Standard
Soil - LCR friction angle, δ_{sl} Soil - FML friction angle, δ_{sf} LCR - FML friction angle, δ_{lf}	20 - 35° 14 - 22° 10 - 18°	Direct Shear	ASTM

Analysis Procedure:



(1) Define Driving Forces

W_r = weight of roadway

W_v = weight of vehicle

F_B = vehicle braking force $\approx .3 W_v$

(2) Define Resisting Forces

F_R = Frictional force @ base of roadway

$= (W_r + W_v) \times \cos\beta \times \tan\delta_{min}$

where δ_{min} is the minimum friction interface angle

F_A = Adhesion Force

$= WL \times C_{min}$ W = ramp width L = ramp length

where C_{min} is the minimum interface adhesion

(3) Define Design Ratio, DR

$$DR = \frac{\text{Resisting Forces}}{\text{Driving Forces}}$$

$$DR = \frac{F_R + F_A}{(W_r + W_v)\sin\beta + F_B}$$

Design Ratio:

DR_{min} = 3.0 with static loads

2.0 with dynamic loads

References:

Example:

Given:

- Equipment = 55 ton Pan
- Friction/Adhesion:

	δ	c
Soil - LCR	31°	200 psf
Soil - FML	18°	50 psf
FML - LCR	12°	0

- Ramp Geometry:

Width = 18' Length = 150' Thickness = 24" β = 8°

- Ramp Subbase:

γ = 130 pcf ϕ = 36° c = 0

(1) Define Driving Forces

W_r = Weight of Roadway = 150 × 18 × 2 × 130 = 702 kip

W_v = Vehicle Weight = 55 ton = 110 kip

F_B = Braking Force = .3 × 110 = 33 kip

(2) Define Resisting Forces

δ_{min} = 12° C_{min} = 0 → F_A = 0

F_R = (702 + 110) × cos 8° × tan 12°

= 170.9 kips

(3) Define Design Ratios, DR

$$DR_{static} = \frac{170.9}{(702+110)\sin 8°} = \frac{170.9}{113} = 1.51 \text{ NG}$$

$$DR_{dynamic} = \frac{170.9}{113 + 33} = \frac{170.9}{146} = 1.17 \text{ NG}$$

Recommend placing drain layer of sand between LCR and FML to increase friction angle δ_{min}

Example No. 4.1

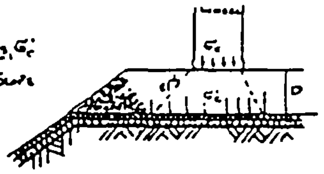
Figure 9 Calculation of ramp stability.

Cell Component: Ramp

Consideration: Wheel Loading – verify that wheel loading will not damage FML.

Required Material Properties	Range	Test	Standard
FML Compressive Strength σ		Compression	
Roadway Subbase Friction Angle ϕ	25 – 40°	Triaxial	ASTM Proposed
[illegible]			

Analysis Procedure:



(1) Define Field Contact Stress, σ_c'

Assuming 2:1 Distribution Slope

$$\sigma_c' = \sigma_c \left[\frac{R^2}{(R+D)^2}\right]$$

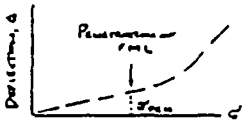
where D = Roadway thickness.

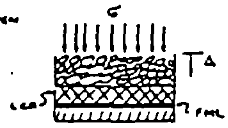
R = effective radius of tire contact $= [P/\pi \sigma_c]^{1/2}$

P = axle load

σ_c = tire contact pressure

(2) Measure FML Compressive Strength, σ_{pen}





(3) Define Design Ratio DR

$$DR = \frac{\text{Comp Strength}}{\text{Contact Stress}} = \frac{\sigma_{pen}}{\sigma_c'}$$

Design Ratio:

DR_{min} 3.0 @ 10% Penetration

References:

Bomes (19??)

Example:

Given:

- Wheel Loading
  - 55 Ton axle w/ 4 wheels → 27.5 kip Wheel Load
  - Ground Contact Pressure = 55 psi
- Roadway
  - Thickness, D = 2'-0"

(1) Define Field Contact Stress, σ_c

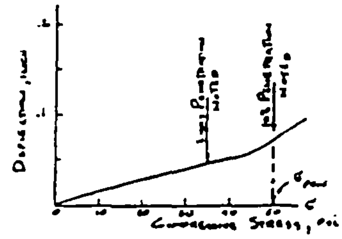
R = effective radius $= [27500/\pi \cdot 55]^{1/2} = 12.6$ in

D = thickness = 2' = 24"

$$\sigma_c' = 55 \cdot \left[\frac{12.6^2}{(12.6+24)^2}\right]$$

$\sigma_c' = 6.5$ psi

(2) Measure FML Compressive Strength, σ_{pen}



$\sigma_{pen}' = 50$ psi

(3) Define Design Ratio, DR

$$DR = \frac{\sigma_{pen}}{\sigma_c'} = \frac{50}{6.5} = \underline{7.7}$$

Example No. 4.3

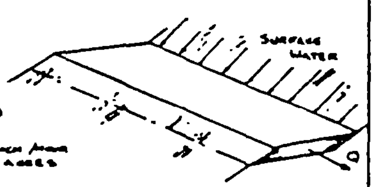
FIGURE 10

Cell Component: Ramp

Consideration: Drainage: verify that ramp will adequately drain surface water from roadway.

Required Material Properties	Range	Test	Standard
· In-plane flow of LCR, θ	10^{-4} cm²/sec	Transmissivity	ASTM D4716
· Permeability, K, of subbase	10^{-2}–10^{-4} cm/sec	Permeability	ASTM D2434
[illegible]			

Analysis Procedure:



(1) Estimate Flow Rate, Q

$Q = C I A_w$ (ft³/sec)

where C = 1.0

I = rainfall, inch/hour

A_w = watershed, acres

(2) Estimate Flow Capacity of LCR + Roadway Q_{act}

$Q_{act} = Q_{road} + Q_{lcr}$

where $Q_{road} = K i A$ — A = area, i = gradient = tangent of slope

$Q_{lcr} = \theta i W$ — W = width of LCR

(3) Calculate Design Ratio, DR

$$DR = \frac{\text{Flow Capacity}}{\text{Flow Rate}} = \frac{Q_{act}}{Q}$$

Design Ratio:

$DR_{min} > 1.5$

References:

Example:

Given:

- Ramp Parameters: Width = 18' Thickness = 2'-0"
  - $K = 1 \times 10^{-4}$ cm/sec = 3.3×10^{-6} ft/sec
  - Slope, $\beta = 8° \to i = \tan 8° = 0.14$
- Surface Water: A_w = watershed = .4 acres
  - I = rainfall = 3 in/hour
- Primary LCR: $\theta = 5 \times 10^{-5}$ m²/sec = 32.3×10^{-5} ft²/sec

(1) Estimate Flow Rate, Q

$Q = C I A_w$

$= 1 \times 3 \times .4 = \underline{1.2}$ ft³/sec

(2) Estimate Flow Capacity of LCR + Roadway

$Q_{lcr} = \theta i W$

$= 32.3 \times 10^{-5} \times 0.14 \times 18$

$= 8.14 \times 10^{-4}$ ft³/sec

$Q_{road} = K i A$

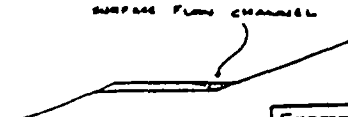
$= 3.3 \times 10^{-6} \times 0.14 \times 18 \times 2$

$= 1.66 \times 10^{-5}$ ft³/sec

(3) Calculate Design Ratio, DR

$$DR = \frac{Q_{lcr} + Q_{road}}{Q} = \frac{1.66 \times 10^{-5} + 8.14 \times 10^{-4}}{1.2} = 2 \times 10^{-3} \quad \text{NG}$$

Recommend: Flow capacity within roadway is insufficient, therefore provide surface flow channel



Example No. 4.2

FIGURE 11

Cell Component: Standpipe

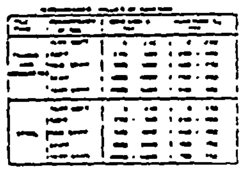
Consideration: Down-Drag: Evaluate potential down-drag forces acting on standpipe and consider coatings for reduction of these forces

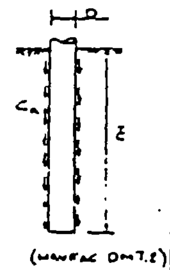
Required Material Properties	Range	Test	Standard
Cohesion of Clay Fill		Triaxial	ASTM [illegible]

Analysis Procedure:

(1) Standpipe Downdrag without Coating

$$Q_{drag} = C_A \pi D z$$





Obtain C_a from above data

(2) Standpipe Downdrag with Bitumen Coating

Assuming Reduction Factor = 6

$$\bar{Q}_{drag} = Q_{drag}/6$$

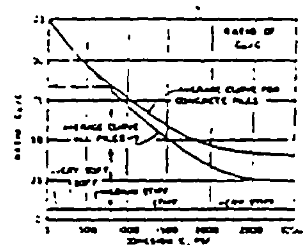
Design Ratio:
Not Applicable

References:
Vesic (1977)
Navfac DM 7.2 (1982)

Example:
Given:
- Standpipe (RCP)
  - Diameter, D = 48"
  - Depth, Z = 55'
- Clay Backfill
  - Cohesion = 800 psf (medium stiff)

(1) Standpipe Downdrag without Coating

Ratio $C_a/C = 0.85$
$\Rightarrow C_A = .85 \times 800 = 680$ psf



$Q_{drag} = 680 \times \pi \times 4 \times 65$
$= 555000$ lb
$= 555$ kips

(2) Standpipe Downdrag with Coating

$\bar{Q}_{drag} = 555/6$
$= 92.5$ kips

Example No. 4.4

Figure. 12 Evaluation of potential downdrag forces on standpipes with and without coating.

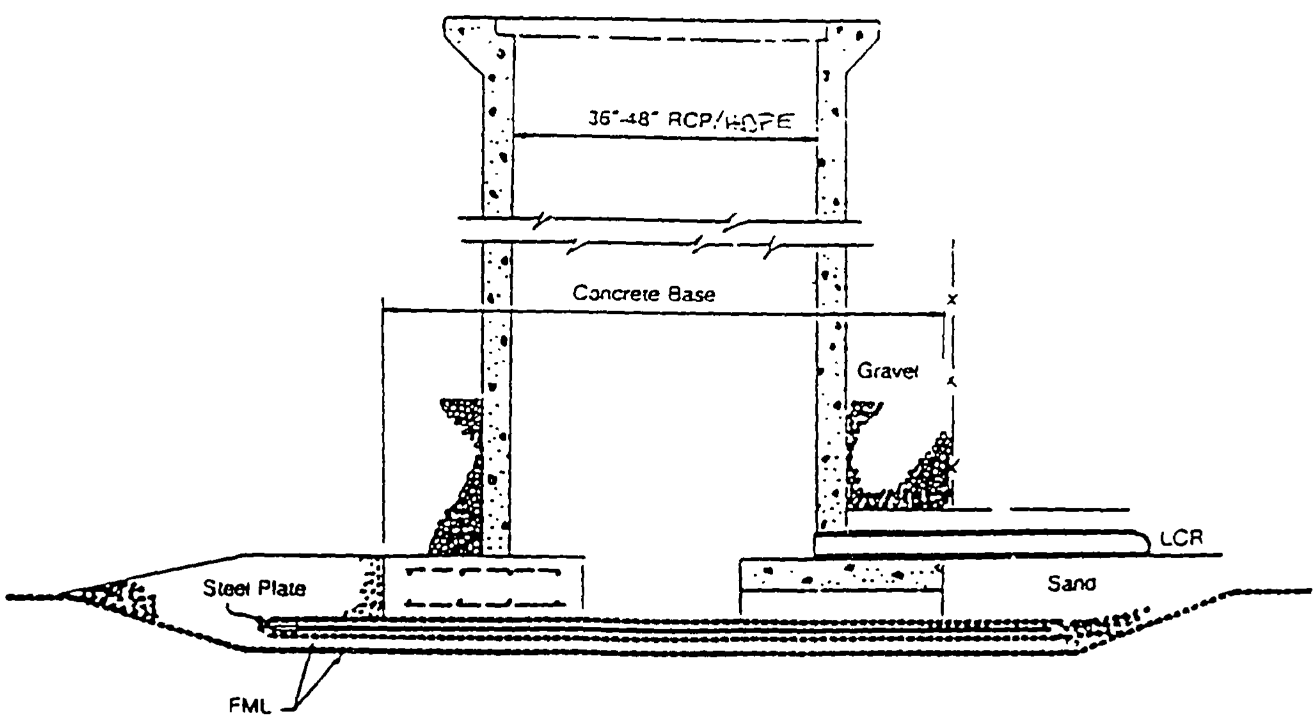
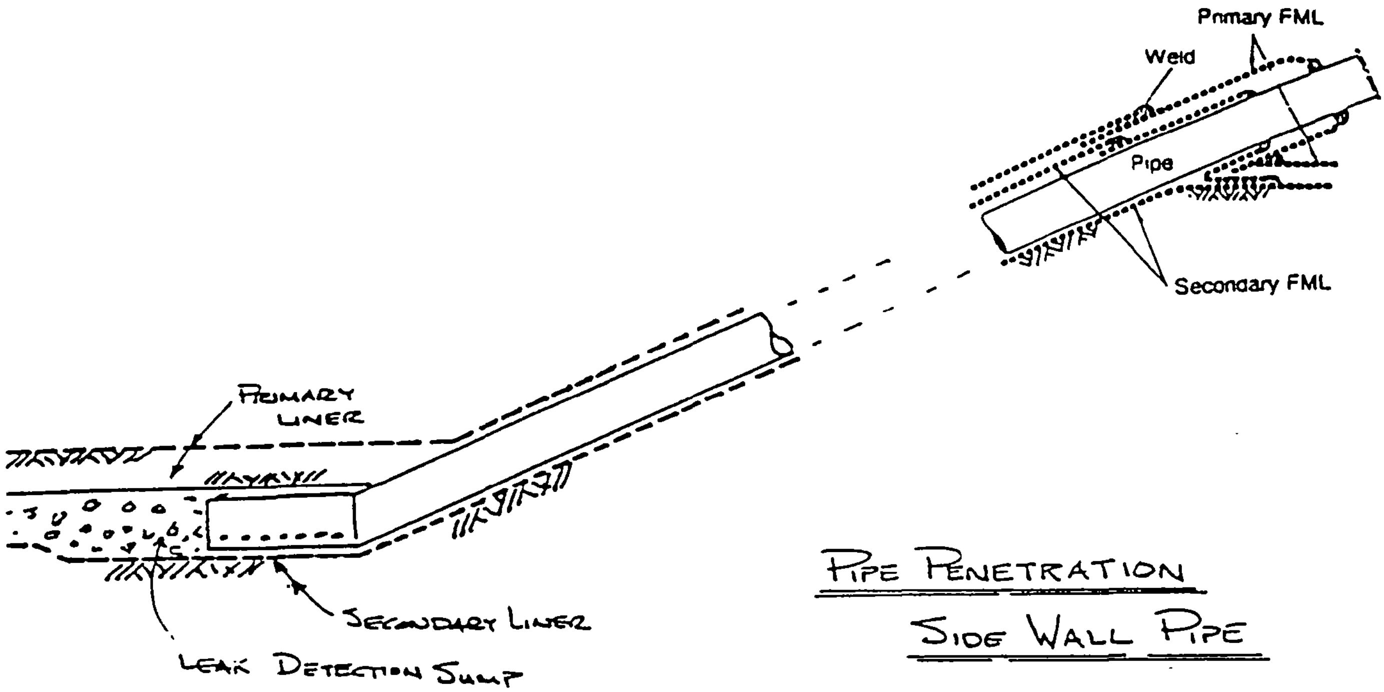
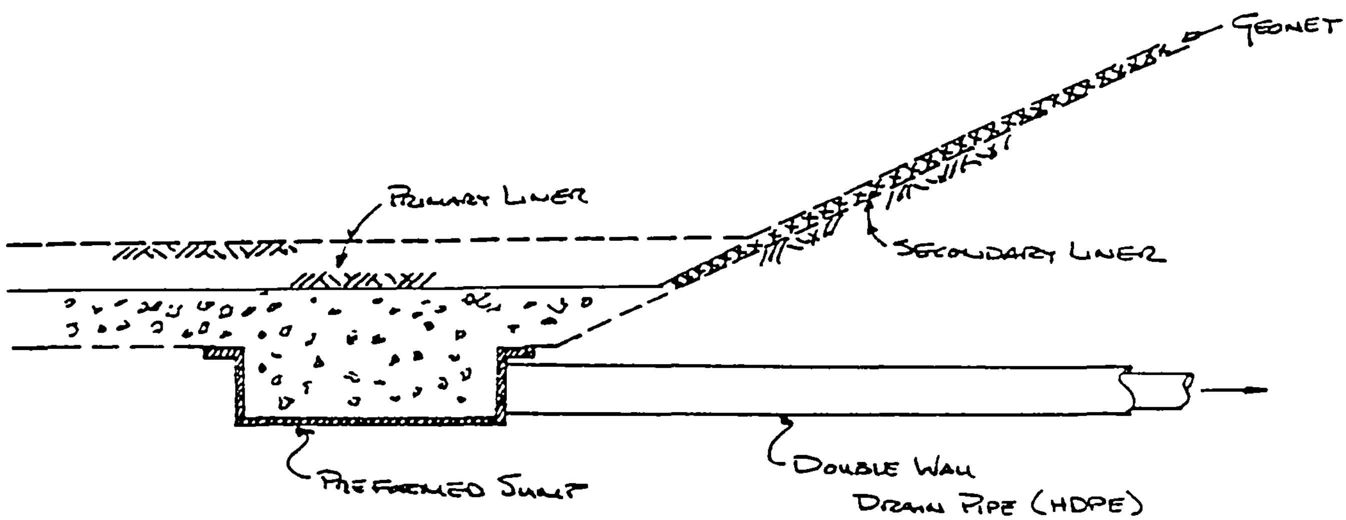


Figure 13 Details of standpipe/drain.



PIPE PENETRATION
SIDE WALL PIPE



PIPE PENETRATION
SUMP GRAVITY DRAIN

FIGURE 14 PIPE PENETRATIONS

Cell Component: Flexible Membrane

Consideration: Wind Lift: Calculate the required sandbag spacing for FML/FMC panels during placement

Required Material Properties	Range	Test	Standard
Flexible Membrane · Unit weight	3-20 oz/sy	Density	ASTM D792

Analysis Procedure:

(1) Determine Design Maximum Wind Speed, V_{wind}

· Use site specific data or reference Fig 6.2

(2) Determine Wind-uplift Pressure, P_{wind}

· Reference Table 6.2 w/ $V_{wind} \rightarrow P_{wind}$

Note: Perform linear interpolation for depth coeff

(3) Calculate Sand Bag Spacing

· W_s = weight of sandbag

· Tributary area = P_{wind}/W_s = TA

(4) Calculate Design Ratio

DR = TA/[actual field tributary area]

Design Ratio:

DR_{min} = 1.1 (Short-Term Only)

References:

Factory Mutual System

Example:

Given:

· Philadelphia PA

· Annual Extreme Wind Speed (Fig 6.2)

V_{wind} = 80 mph

· Wind = 100 yr Extreme, Open Country

· FML Depth = -20 → +20 ft

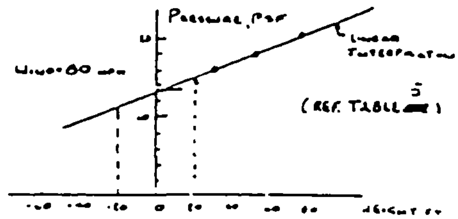
· Sandbag = 80 lb @ 1 per 10 sq. ft

· Height to FM = -20 ft, 0 ft, +20 ft

(1) Determine Design Maximum Wind Speed, V_{wind}

V_{wind} = 80 mph (Ref Fig 6.2)

(2) Determine Wind Uplift Pressure, P_{wind}



Depth -20 ft = 11 psf

0 ft = 14 psf

20 ft = 15 psf

(3) Calculate Sand Bag Spacing

-20 ft = 80 lb / 11 psf = 7.3 sq. ft

0 ft = 80 lb / 14 psf = 5.7 sq ft

+20 ft = 80 lb / 15 psf = 5.3 sq ft

(4) Calculate Design Ratios

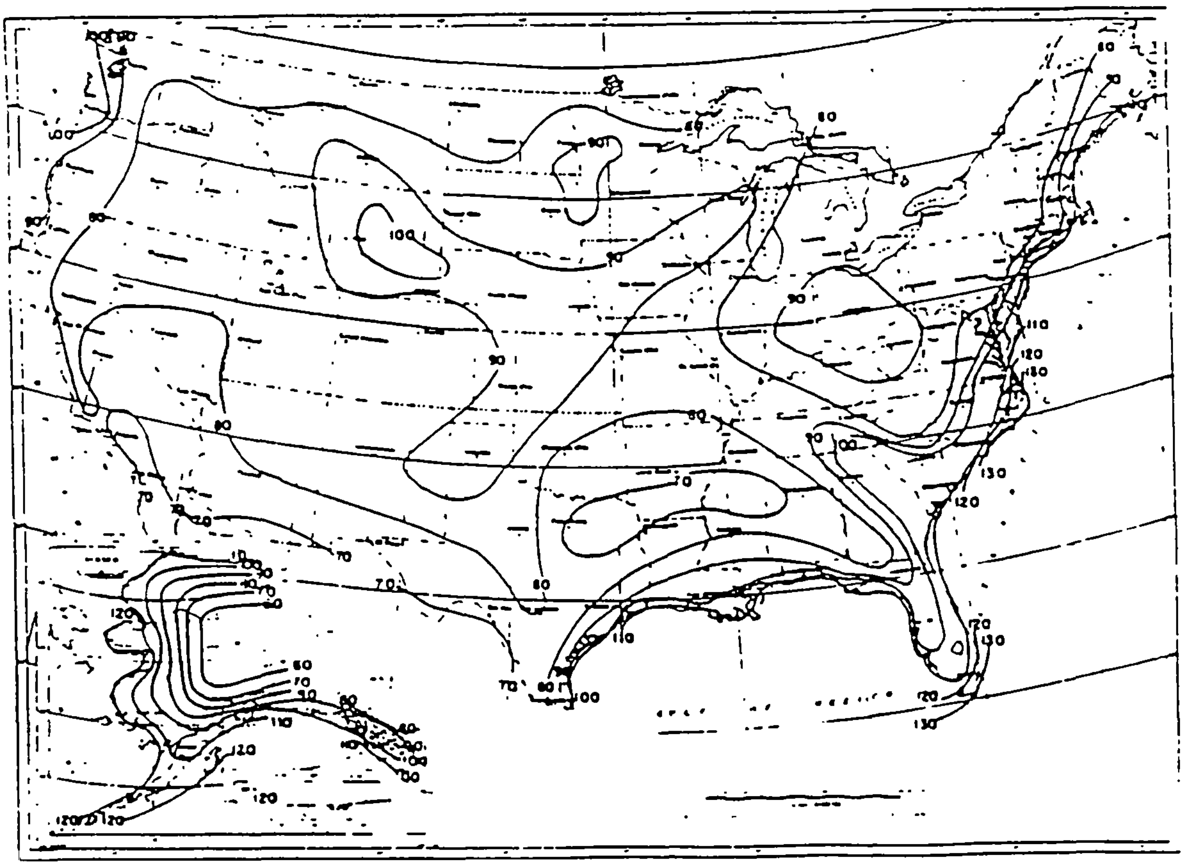
-20 ft = 7.3/10.0 = 0.73 NG

0 ft = 5.7/10.0 = 0.57 NG

+20 ft = 5.3/10.0 = 0.53 NG

Example No. 6.1

Figure 15 Calculation of required sandbag spacing for FML/FMC panels.



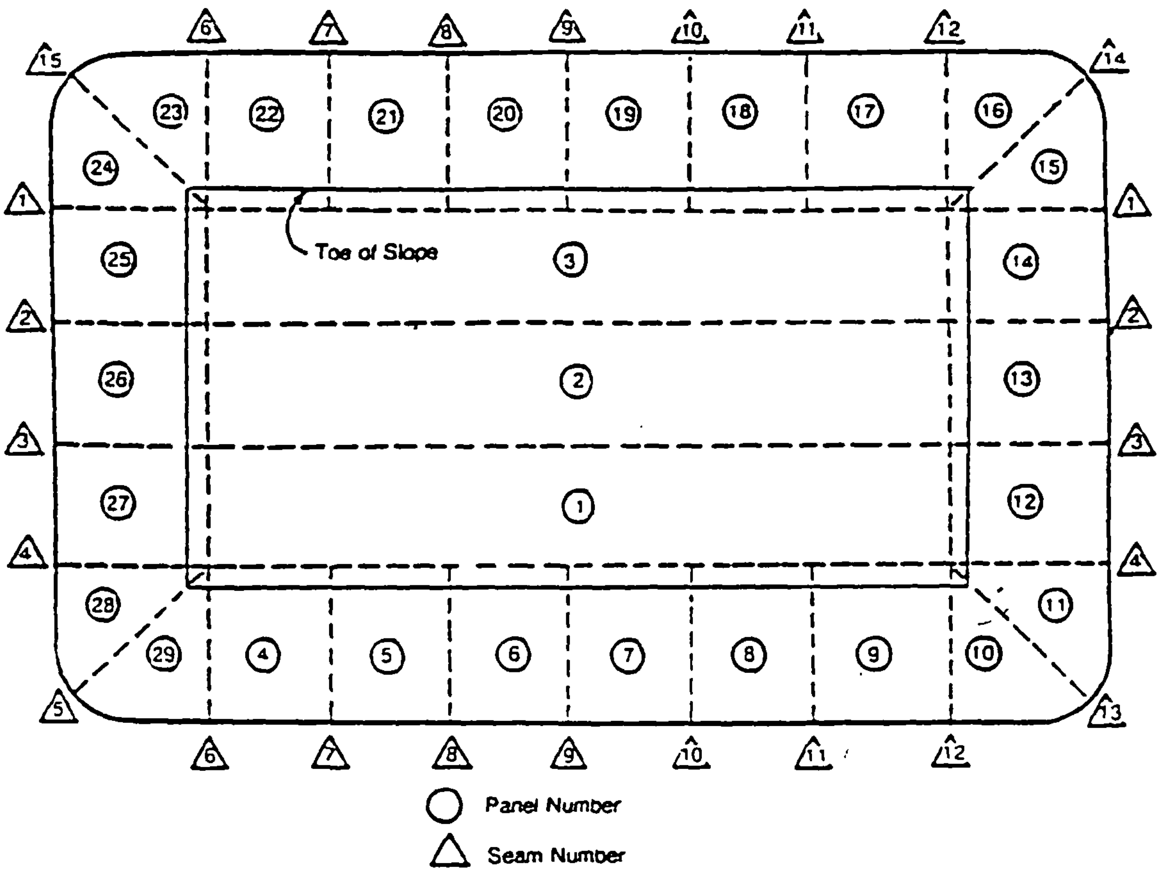


Figure 17 Panel-seam identificarton scheme.

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B

ATTACHMENT B

Method 9090, Compatibility Test for Wastes and Membrane Liners

METHOD 9090

COMPATIBILITY TEST FOR WASTES AND MEMBRANE LINERS

1.0 SCOPE AND APPLICATION

1.1 Method 9090 is intended for use in determining the effects of chemicals in a surface impoundment, waste pile, or landfill on the physical properties of flexible membrane liner (FML) materials intended to contain them. Data from these tests will assist in deciding whether a given liner material is acceptable for the intended application.

2.0 SUMMARY OF METHOD

2.1 In order to estimate waste/liner compatibility, the liner material is immersed in the chemical environment for minimum periods of 120 days at room temperature (23 $\pm$ 2°C) and at 50 $\pm$ 2°C. In cases where the FML will be used in a chemical environment at elevated temperatures, the immersion testing shall be run at the elevated temperatures if they are expected to be higher than 50°C. Whenever possible, the use of longer exposure times is recommended. Comparison of measurements of the membrane's physical properties, taken periodically before and after contact with the waste fluid, is used to estimate the compatibility of the liner with the waste over time.

3.0 INTERFERENCES (Not Applicable)

4.0 APPARATUS AND MATERIALS

NOTE: In general, the following definitions will be used in this method:

1. Sample -- a representative piece of the liner material proposed for use that is of sufficient size to allow for the removal of all necessary specimens.
2. Specimen -- a piece of material, cut from a sample, appropriately shaped and prepared so that it is ready to use for a test.

4.1 Exposure tank: Of a size sufficient to contain the samples, with provisions for supporting the samples so that they do not touch the bottom or sides of the tank or each other, and for stirring the liquid in the tank. The tank should be compatible with the waste fluid and impermeable to any of the constituents they are intended to contain. The tank shall be equipped with a means for maintaining the solution at room temperature (23 $\pm$ 2° C) and 50 $\pm$ 2°C and for preventing evaporation of the solution (e.g., use a cover equipped with a reflux condenser, or seal the tank with a Teflon gasket and use an airtight cover). Both sides of the liner material shall be exposed to the chemical environment. The pressure inside the tank must be the same as that outside the tank. If the liner has a side that (1) is not exposed to the waste in actual use and (2) is not designed to withstand exposure to the chemical environment, then such a liner may be treated with only the barrier surface exposed.

4.2 Stress-strain machine suitable for measuring elongation, tensile strength, tear resistance, puncture resistance, modulus of elasticity, and ply adhesion.

4.3 Jig for testing puncture resistance for use with FTMS 101C, Method 2065.

4.4 Liner sample labels and holders made of materials known to be resistant to the specific wastes.

4.5 Oven at 105 ± 2°C.

4.6 Dial micrometer.

4.7 Analytical balance.

4.8 Apparatus for determining extractable content of liner materials.

NOTE: A minimum quantity of representative waste fluid necessary to conduct this test has not been specified in this method because the amount will vary depending upon the waste compostion and the type of liner material. For example, certain organic waste constituents, if present in the representative waste fluid, can be absorbed by the liner material, thereby changing the concentration of the chemicals in the waste. This change in waste composition may require the waste fluid to be replaced at least monthly in order to maintain representative conditions in the waste fluid. The amount of waste fluid necessary to maintain representative waste conditions will depend on factors such as the volume of constituents absorbed by the specific liner material and the concentration of the chemical constituents in the waste.

5.0 REAGENTS (Not Applicable)

6.0 SAMPLE COLLECTION, PRESERVATION, AND HANDLING

6.1 For information on what constitutes a representative sample of the waste fluid, refer to the following guidance document:

Permit Applicants' Guidance Manual for Hazardous Waste Land Treatment, Storage, and Disposal Facilities; Final Draft; Chap. 5, pp. 15-17; Chap. 6, pp. 18-21; and Chap. 8, pp. 13-16, May 1984.

7.0 PROCEDURE

7.1 Obtain a representative sample of the waste fluid. If a waste sample is received in more than one container, blend thoroughly. Note any signs of stratification. If stratification exists, liner samples must be placed in each of the phases. In cases where the waste fluid is expected to stratify and the phases cannot be separated, the number of immersed samples per exposure period can be increased (e.g., if the waste fluid has two phases, then 2 samples per exposure period are needed) so that test samples exposed at each level of the waste can be tested. If the waste to be contained in the land disposal unit is in solid form, generate a synthetic leachate (See Step 7.9.1).

7.2 Perform the following tests on <u>unexposed</u> samples of the polymeric membrane liner material at 23 ± 2°C and 50 ± 2°C (see Steps 7.9.2 and 7.9.3 below for additional tests suggested for specific circumstances). Tests for tear resistance and tensile properties are to be performed according to the protocols referenced in Table 1. See Figure 1 for cutting patterns for nonreinforced liners, Figure 2 for cutting patterns for reinforced liners, and Figure 3 for cutting patterns for semicrystalline liners. (Table 2, at the end of this method, gives characteristics of various polymeric liner materials.)

1. Tear resistance, machine and transverse directions, three specimens each direction for nonreinforced liner materials only. See Table 1 for appropriate test method, the recommended test speed, and the values to be reported.

2. Puncture resistance, two specimens, FTMS 101C, Method 2065. See Figure 1, 2, or 3, as applicable, for sample cutting patterns.

3. Tensile properties, machine and transverse directions, three tensile specimens in each direction. See Table 1 for appropriate test method, the recommended test speed, and the values to be reported. See Figure 4 for tensile dumbbell cutting pattern dimensions for nonreinforced liner samples.

4. Hardness, three specimens, Duro A (Duro D if Duro A reading is greater than 80), ASTM D2240. The hardness specimen thickness for Duro A is 1/4 in., and for Duro D it is 1/8 in. The specimen dimensions are 1 in. by 1 in.

5. Elongation at break. This test is to be performed only on membrane materials that do not have a fabric or other nonelastomeric support as part of the liner.

6. Modulus of elasticity, machine and transverse directions, two specimens each direction for semicrystalline liner materials only, ASTM D882 modified Method A (see Table 1).

7. Volatiles content, SW 870, Appendix III-D.

8. Extractables content, SW 870, Appendix III-E.

TABLE 1. PHYSICAL TESTING OF EXPOSED MEMBRANES IN LINER-WASTE LIQUID COMPATIBILITY TEST

Type of compound and construction	Crosslinked or vulcanized	Thermoplastic	Semi-crystalline	Fabric-reinforced[a]
Tensile properties				
Method	ASTM D412	ASTM D638	ASTM D638	ASTM D751, Mtd B
Type of specimen	Dumbbell[b]	Dumbbell[b]	Dumbbell[b]	1-in. wide strip and 2- in. jaw separation
Number of specimens	3 in each direction	3 in each direction	3 in each direction	3 in each direction
Speed of test	20 ipm	20 ipm	2 ipm	12 ipm
Values to be reported	Tensile strength, psi Elongation at break, % Tensile set after break, % Stress at 100 and 200% elongation, psi	Tensile strength, psi Elongation at break, % Tensile set after break, % Stress at 100 and 200% elongation, psi	Tensile stress at yield, psi Elongation at yield, % Tensile strength at break, psi Elongation at break, % Tensile set after break, % Stress at 100 and 200% elongation, psi	Tensile at fabric break, ppi Elongation at fabric break, % Tensile at ultimate break, ppi Elongation at ultimate break, % Tensile set after break, % Stress at 100 and 200% elongation, ppi
Modulus of elasticity				
Method	c	c	ASTM D882, Mtd A	c
Type of specimen	...	...	Strip: 0.5-in. wide and 6-in. long at a 2-in. jaw separation	...
Number of specimens	...	...	2 in each direction	...
Speed of test	...	...	0.2 ipm	
Values reported	...	...	Greatest slope of initial stress-strain curve, psi	...
Tear resistance				
Method	ASTM D624	ASTM D1004	ASTM D1004	d
Type of specimen	Die C	e	e	...
Number of specimens	3 in each direction	3 in each direction	2 in each direction	...
Speed of test	20 ipm	20 ipm	2 ipm	...
Values reported	Stress, ppi	Stress, ppi	Maximum stress, ppi	...
Puncture resistance				
Method	FTMS 101C, Method 2065	FTMS 101C, Method 2065	FTMS 101C, Method 2065	FTMS 101C, Method 2065
Type of specimen	2-in. square	2-in. square	2-in. square	2-in. square
Number of specimens	2	2	2	2
Speed of test	20 ipm	20 ipm	20 ipm	20 ipm
Values reported	Gage, mil Stress, lb Elongation, in.	Gage, mil Stress, lb Elongation, in.	Gage, mil Stress, lb Elongation, in.	Gage, mil Stress, lb Elongation, in.

[a]Can be thermoplastic, crosslinked or vulcanized membrane.
[b]See Figure 3.
[c]Not performed on this material.
[d]No tear resistance test is recommended for fabric-reinforced sheetings in the immersion study.
[e]Same as ASTM D624, Die C.

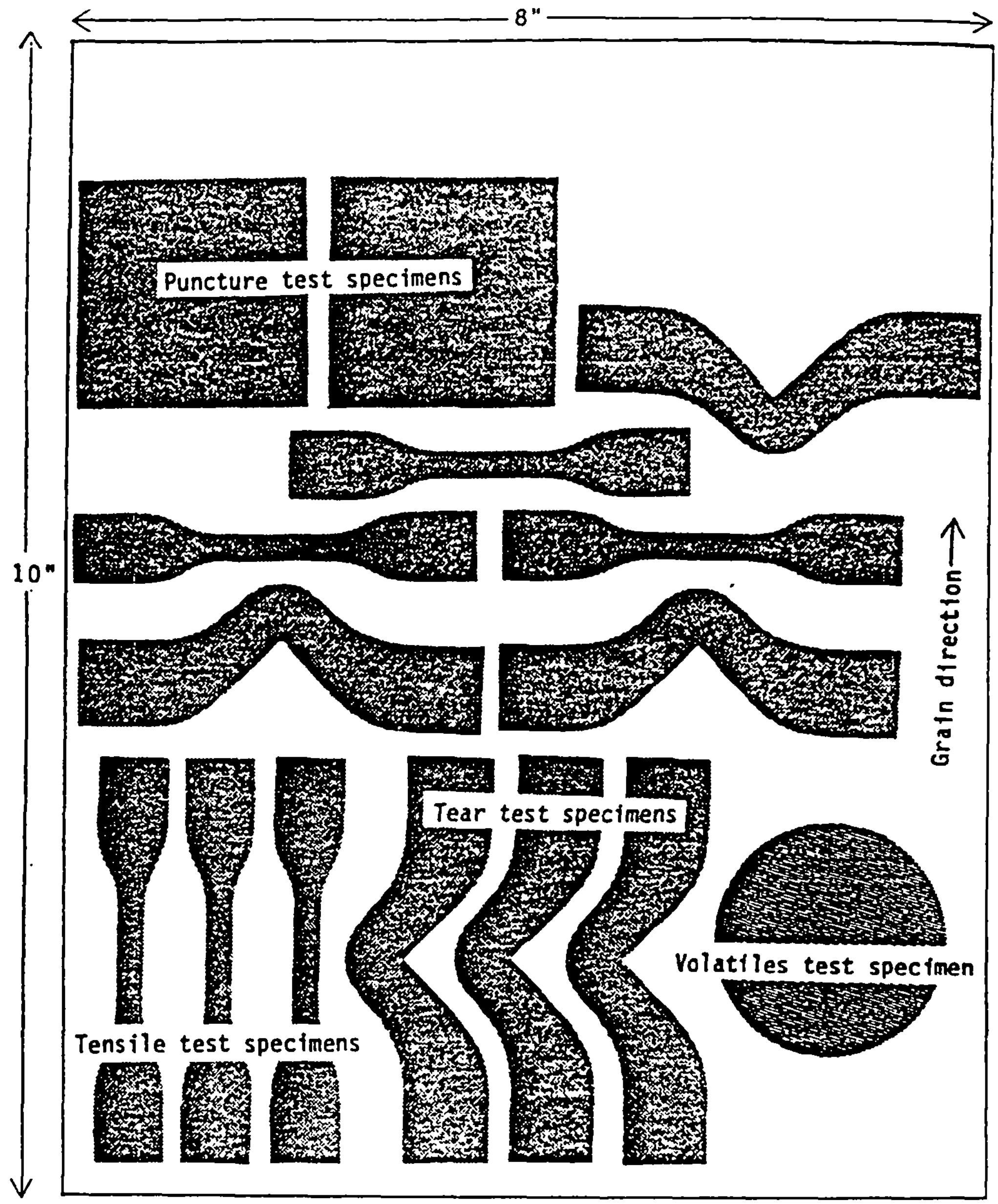


Figure 1. Suggested pattern for cutting test specimens from nonreinforced crosslinked or thermoplastic immersed liner samples.

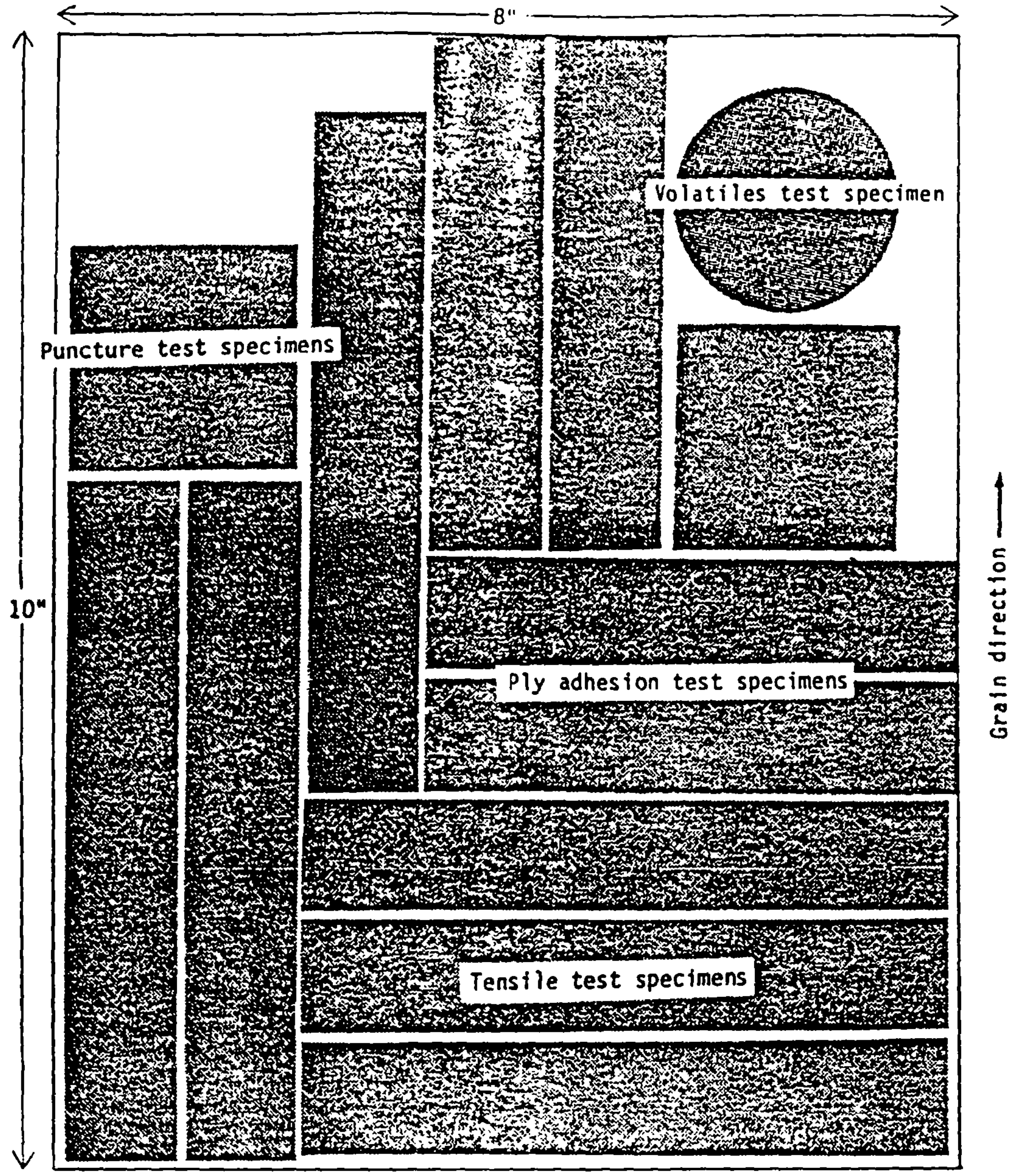


Figure 2. Suggested pattern for cutting test specimens from fabric reinforced immersed liner samples. Note: To avoid edge effects, cut specimens 1/8 - 1/4 inch in from edge of immersed sample.

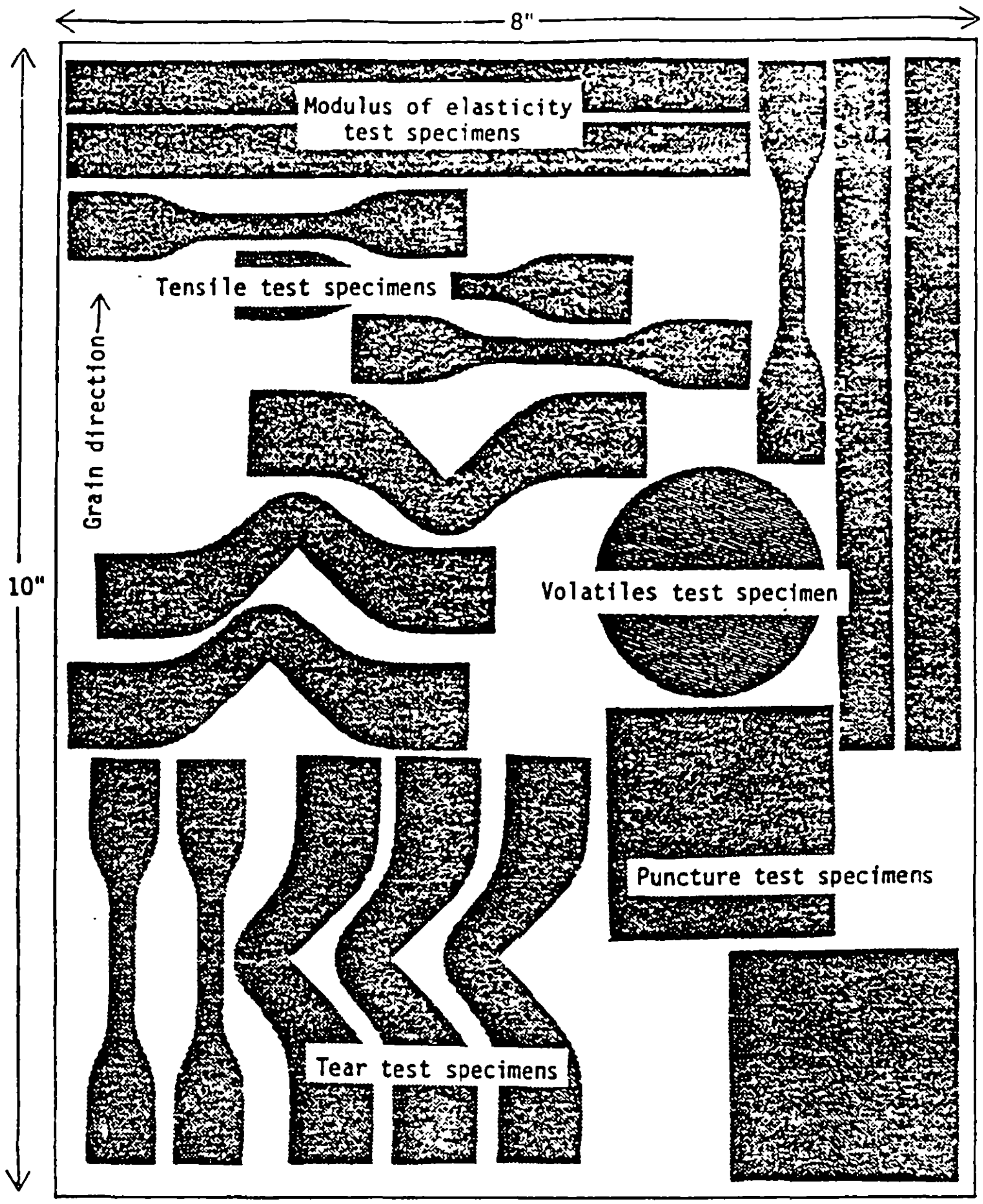
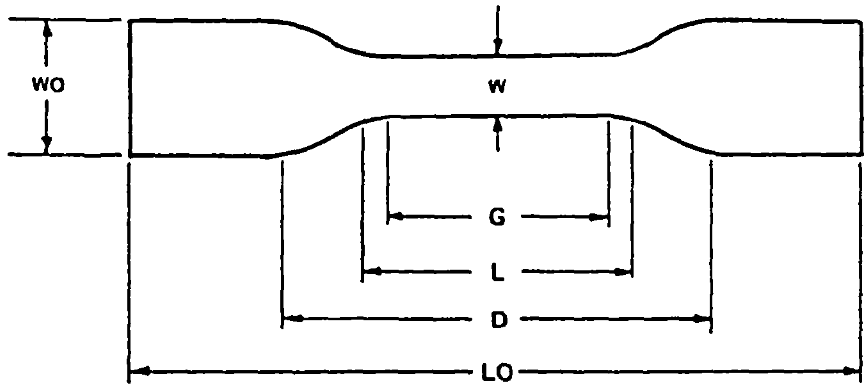


Figure 3. Suggested pattern for cutting test specimens from semicrystalline immersed liner samples. Note: To avoid edge effects, cut specimens 1/8 - 1/4 inch in from edge of immersed sample.



W	- Width of narrow section	0.25 inches
L	- Length of narrow section	1.25 inches
WO	- Width overall	0.625 inches
LO	- Length overall	3.50 inches
G	- Gage length	1.00 inches
D	- Distance between grips	2.00 inches

Figure 4. Die for tensile dumbbell (nonreinforced liners) having the following dimensions.

9. Specific gravity, three specimens, ASTM D792 Method A.

10. Ply adhesion, machine and transverse directions, two specimens each direction for fabric reinforced liner materials only, ASTM D413 Machine Method, Type A -- 180 degree peel.

11. Hydrostatic resistance test, ASTM D751 Method A, Procedure 1.

7.3 For each test condition, cut five pieces of the lining material of a size to fit the sample holder, or at least 8 in. by 10 in. The fifth sample is an extra sample. Inspect all samples for flaws and discard unsatisfactory ones. Liner materials with fabric reinforcement require close inspection to ensure that threads of the samples are evenly spaced and straight at 90°. Samples containing a fiber scrim support may be flood-coated along the exposed edges with a solution recommended by the liner manufacturer, or another procedure should be used to prevent the scrim from being directly exposed. The flood-coating solution will typically contain 5-15% solids dissolved in a solvent. The solids content can be the liner formula or the base polymer.

Measure the following:

1. Gauge thickness, in. -- average of the four corners.

2. Mass, lb. -- to one-hundredth of a lb.

3. Length, in. -- average of the lengths of the two sides plus the length measured through the liner center.

4. Width, in. -- average of the widths of the two ends plus the width measured through the liner center.

NOTE: Do not cut these liner samples into the test specimen shapes shown in Figure 1, 2, or 3 at this time. Test specimens will be cut as specified in 7.7, <u>after</u> exposure to the waste fluid.

7.4 Label the liner samples (e.g., notch or use metal staples to identify the sample) and hang in the waste fluid by a wire hanger or a weight. Different liner materials should be immersed in separate tanks to avoid exchange of plasticizers and soluble constituents when plasticized membranes are being tested. Expose the liner samples to the stirred waste fluid held at room temperature and at 50 ± 2°C.

7.5 At the end of 30, 60, 90, and 120 days of exposure, remove one liner sample from each test condition to determine the membrane's physical properties (see Steps 7.6 and 7.7). Allow the liner sample to cool in the waste fluid until the waste fluid has a stable room temperature. Wipe off as much waste as possible and rinse briefly with water. Place wet sample in a labeled polyethylene bag or aluminum foil to prevent the sample from drying out. The liner sample should be tested as soon as possible after removal from the waste fluid at room temperature, but in no case later than 24 hr after removal.

7.6 To test the immersed sample, wipe off any remaining waste and rinse with deionized water. Blot sample dry and measure the following as in Step 7.3:

1. Gauge thickness, in.

2. Mass, lb.

3. Length, in.

4. Width, in.

7.7 Perform the following tests on the exposed samples (see Steps 7.9.2 and 7.9.3 below for additional tests suggested for specific circumstances). Tests for tear resistance and tensile properties are to be performed according to the protocols referenced in Table 1. Die-cut test specimens following suggested cutting patterns. See Figure 1 for cutting patterns for nonreinforced liners, Figure 2 for cutting patterns for reinforced liners, and Figure 3 for semicrystalline liners.

1. Tear resistance, machine and transverse directions, three specimens each direction for materials without fabric reinforcement. See Table 1 for appropriate test method, the recommended test specimen and speed of test, and the values to be reported.

2. Puncture resistance, two specimens, FTMS 101C, Method 2065. See Figure 1, 2, or 3, as applicable, for sample cutting patterns.

3. Tensile properties, machine and transverse directions, three specimens each direction. See Table 1 for appropriate test method, the recommended test specimen and speed of test, and the values to be reported. See Figure 4 for tensile dumbbell cutting pattern dimensions for nonreinforced liner samples.

4. Hardness, three specimens, Duro A (Duro D if Duro A reading is greater than 80), ASTM 2240. The hardness specimen thickness for Duro A is 1/4 in., and for Duro D is 1/8 in. The specimen dimensions are 1 in. by 1 in.

5. Elongation at break. This test is to be performed only on membrane materials that do not have a fabric or other nonelastomeric support as part of the liner.

6. Modulus of elasticity, machine and transverse directions, two specimens each direction for semicrystalline liner materials only, ASTM D882 modified Method A (see Table 1).

7. Volatiles content, SW 870, Appendix III-D.

8. Extractables content, SW 870, Appendix III-E.

9. Ply adhesion, machine and transverse directions, two specimens each direction for fabric reinforced liner materials only, ASTM D413 Machine Method, Type A -- 180 degree peel.

10. Hydrostatic resistance test, ASTM D751 Method A, Procedure 1.

7.8 Results and reporting:

7.8.1 Plot the curve for each property over the time period 0 to 120 days and display the spread in data points.

7.8.2 Report all raw, tabulated, and plotted data. Recommended methods for collecting and presenting information are described in the documents listed under Step 6.1 and in related agency guidance manuals.

7.8.3 Summarize the raw test results as follows:

1. Percent change in thickness.

2. Percent change in mass.

3. Percent change in area (provide length and width dimensions).

4. Percent retention of physical properties.

5. Change, in points, of hardness reading.

6. The modulus of elasticity calculated in pounds-force per square inch.

7. Percent volatiles of unexposed and exposed liner material.

8. Percent extractables of unexposed and exposed liner material.

9. The adhesion value, determined in accordance with ASTM D413, Section 12.2.

10. The pressure and time elapsed at the first appearance of water through the flexible membrane liner for the hydrostatic resistance test.

7.9 The following additional procedures are suggested in specific situations:

7.9.1 For the generation of a synthetic leachate, the Agency suggests the use of the Toxicity Characteristic Leaching Procedure (TCLP) that was proposed in the Federal Register on June 13, 1986, Vol. 51, No. 114, p. 21685.

7.9.2 For semicrystalline membrane liners, the Agency suggests the determination of the potential for environmental stress cracking. The test that can be used to make this determination is either ASTM D1693 or the National Bureau of Standards Constant Tensile Load. The evaluation of the results should be provided by an expert in this field.

7.9.3 For field seams, the Agency suggests the determination of seam strength in shear and peel modes. To determine seam strength in peel mode, the test ASTM D413 can be used. To determine seam strength in shear mode for nonreinforced FMLs, the test ASTM D3083 can be used, and for reinforced FMLs, the test ASTM D751, Grab Method, can be used at a speed of 12 in. per min. The evaluation of the results should be provided by an expert in this field.

8.0 QUALITY CONTROL

8.1 Determine the mechanical properties of identical nonimmersed and immersed liner samples in accordance with the standard methods for the specific physical property test. Conduct mechanical property tests on nonimmersed and immersed liner samples prepared from the same sample or lot of material in the same manner and run under identical conditions. Test liner samples immediately after they are removed from the room temperature test solution.

9.0 METHOD PERFORMANCE

9.1 No data provided.

10.0 REFERENCES

10.1 None required.

TABLE 2. POLYMERS USED IN FLEXIBLE MEMBRANE LINERS

Thermoplastic Materials (TP)

CPE (Chlorinated polyethylene)[a]

A family of polymers produced by a chemical reaction of chlorine on polyethylene. The resulting thermoplastic elastomers contain 25 to 45% chlorine by weight and 0 to 25% crystallinity.

CSPE (Chlorosulfonated polyethylene)[a]

A family of polymers that are produced by the reaction of polyethylene with chlorine and sulfur dioxide, usually containing 25 to 43% chlorine and 1.0 to 1.4% sulfur. Chlorosulfonated polyethylene is also known as hypalon.

EIA (Ethylene interpolymer alloy)[a]

A blend of EVA and polyvinyl chloride resulting in a thermoplastic elastomer.

PVC (Polyvinyl chloride)[a]

A synthetic thermoplastic polymer made by polymerizing vinyl chloride monomer or vinyl chloride/vinyl acetate monomers. Normally rigid and containing 50% of plasticizers.

PVC-CPE (Polyvinyl chloride - chlorinated polyethylene alloy)[a]

A blend of polyvinyl chloride and chlorinated polyethylene.

TN-PVC (Thermoplastic nitrile-polyvinyl choloride)[a]

An alloy of thermoplastic unvulcanized nitrile rubber and polyvinyl chloride.

Vulcanized Materials (XL)

Butyl rubber[a]

A synthetic rubber based on isobutylene and a small amount of isoprene to provide sites for vulcanization.

---

[a]Also supplied reinforced with fabric.

TABLE 2. (Continued)

EPDM (Ethylene propylene diene monomer)[a,b]

A synthetic elastomer based on ethylene, propylene, and a small amount of nonconjugated diene to provide sites for vulcanization.

CM (Cross-linked chlorinated polyethylene)

No definition available by EPA.

CO, ECO (Epichlorohydrin polymers)[a]

Synthetic rubber, including two epichlorohydrin-based elastomers that are saturated, high-molecular-weight aliphatic polyethers with chloromethyl side chains. The two types include homopolymer (CO) and a copolymer of epichlorohydrin and ethylene oxide (ECO).

CR (Polychloroprene)[a]

Generic name for a synthetic rubber based primarily on chlorobutadiene. Polychloroprene is also known as neoprene.

Semicrystalline Materials (CX)

HDPE - (High-density polyethylene)

A polymer prepared by the low-pressure polymerization of ethylene as the principal monomer.

HDPE - A (High-density polyethylene/rubber alloy)

A blend of high-density polyethylene and rubber.

LLDPE (Liner low-density polyethylene)

A low-density polyethylene produced by the copolymerization of ethylene with various alpha olefins in the presence of suitable catalysts.

PEL (Polyester elastomer)

A segmented thermoplastic copolyester elastomer containing recurring long-chain ester units derived from dicarboxylic acids and long-chain glycols and short-chain ester units derived from dicarboxylic acids and low-molecular-weight diols.

---

[a]Also supplied reinforced with fabric.
[b]Also supplied as a thermoplastic.

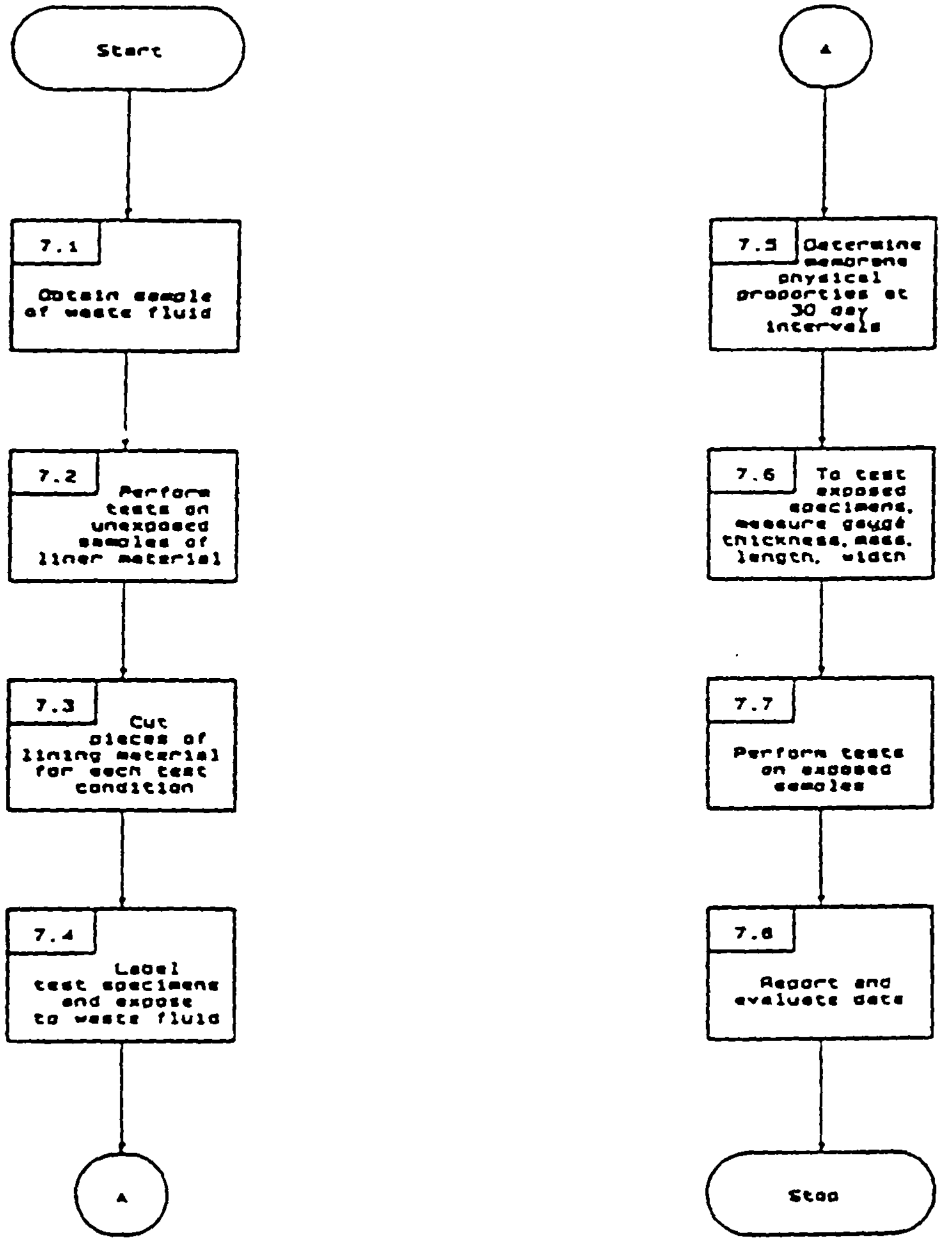
TABLE 2. (Continued)

PE-EP-A (Polyethylene ethylene/propylene alloy)

A blend of polyethylene and ethylene and propylene polymer resulting in a thermoplastic elastomer.

T-EPDM (Thermoplastic EPDM)

An ethylene-propylene diene monomer blend resulting in a thermoplastic elastomer.


Start
7.1
Obtain sample of waste fluid
7.2
Perform tests on unexposed samples of liner material
7.3
Cut pieces of lining material for each test condition
7.4
Label test specimens and expose to waste fluid
A
A
7.5
Determine membrane physical properties at 30 day intervals
7.6
To test exposed specimens, measure gauge thickness, mass, length, width
7.7
Perform tests on exposed samples
7.8
Report and evaluate data
Stop

C

ATTACHMENT C

Observations and Tests for the Construction Quality Assurance and Quality Control of Hazardous Waste Disposal Facilities

OBSERVATIONS AND TESTS FOR THE CONSTRUCTION QUALITY ASSURANCE AND QUALITY CONTROL OF HAZARDOUS WASTE DISPOSAL FACILITIES

This appendix lists observations that should be made and tests that should be performed for the construction quality assurance of the following components of hazardous waste disposal facilities:

- Foundations.

- Embankments.

- Low-permeability soil liner.

- Leachate collection system.

Methods for testing FMLs are presented and discussed in Chapter 4. This appendix is based on Appendix A of the EPA Technical Guidance Document, "Construction Quality Assurance for Hazardous Waste Land Disposal Facilities" (Northeim and Truesdale, 1986). Table M-1 lists the observations and tests by component.

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C143-78. "Test Method for Slump of Portland Cement Concrete," Section 04.02.

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C231-82. "Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method," Section 04.02.

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D1556-82. "Test Method for Density of Soil in Place by the Sand-Cone Method," Section 04.08.

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D2166-85. "Test Method for Unconfined Compressive Strength of Cohesive Soil," Section 04.08.

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TABLE M-1. OBSERVATIONS AND TESTS FOR THE CONSTRUCTION QUALITY ASSURANCE AND QUALITY CONTROL OF HAZARDOUS WASTE DISPOSAL FACILITIES

Facility component	Factors to be inspected	Inspection methods	Test method reference
Foundation	Removal of unsuitable materials	Observation	NA
	Proof rolling of subgrade	Observation	NA
	Filling of fissures or voids	Observation	NA
	Compaction of soil backfill	(See low-permeability soil liner component)	...
	Surface finishing/compaction	Observation	NA
	Sterilization	Supplier's certification and observation	NA
	Slope	Surveying	NA
	Depth of excavation	Surveying	NA
	Seepage	Observation	NA
	Soil type (index properties)	Visual-manual procedure	ASTM D2488
		Particle-size analysis	ASTM D422
		Atterberg limits	ASTM D4318
		Soil classification	ASTM D2487
	Cohesive soil consistency (field)	Penetration tests	ASTM D3441
		Field vane shear test	ASTM D2573
		Hand penetrometer	Horslev, 1943
		Handheld torvane	Lanz, 1968
		Field expedient unconfined compression	TM 5-530 (U.S. of Army, 1971)

continued . . .

TABLE M-1 (CONTINUED)

Facility component	Factors to be inspected	Inspection methods	Test method reference
	Strength (laboratory)	Unconfined compressive strength	ASTM D2166
		Triaxial compression	ASTM D2850
Embankments	Dike slopes	Surveying	NA
	Dike dimensions	Surveying; observations	NA
	Compacted soil	(See foundation component)	...
	Drainage system	(See leachate collection system component)	...
	Erosion control measures	(See cover system component)	...
Low-permeability soil liner	Coverage	Observation	NA
	Thickness	Surveying; measurement	NA
	Clod size	Observation	NA
	Tying together of lifts	Observation	NA
	Slope	Surveying	...
	Installation of protective cover	Observation	NA
	Soil type (index properties)	Visual-manual procedure Particle-size analysis Atterberg limits Soil classification	ASTM D2488 ASTM D422 ASTM D4318 ASTM D2487

continued . . .

TABLE M-1 (CONTINUED)

Facility component	Factors to be inspected	Inspection methods	Test method reference
	Moisture content	Oven-dry method	ASTM D2166
		Nuclear method	ASTM D3017
		Calcium carbide (speedy)	AASHTO T217
		Frying pan (alcohol or gas burner)	Spigolon & Kelley, 1984
	In-place density	Nuclear methods	ASTM D2922
		Sand cone	ASTM D1556
		Rubber balloon	ASTM D2167
		Drive cylinder	ASTM D2937
	Moisture-density relations	Standard proctor	ASTM D698
		Modified proctor	ASTM D1557
	Strength (laboratory)	Unconfined compressive strength	ASTM D2166
		Triaxial compression	ASTM D2850
		Unconfined compressive strength for soil cement	ASTM D1633
	Cohesive soil consistency (field)	Penetration tests	ASTM D3441
		Field vane shear test	ASTM D2573
		Hand penetrometer	Horslev, 1943
		Handheld torvane	Lanz, 1968
		Field expedient unconfined compression	TM 5-530 (U.S. Dept. of Army, 1971)
	Permeability (laboratory)	Flexible wall	Daniel et al, 1984 Daniel et al, 1985 SW-846, Method 9100 (EPA, 1986)

Continued . . .

TABLE M-1 (CONTINUED)

Facility component	Factors to be inspected	Inspection methods	Test method reference
	Permeability (field)	Large diameter single-ring infiltrometer	Day and Daniel, 1985
		Sai-Anderson infiltrometer	Anderson et al, 1984
	Susceptibility to frost damage	Susceptibility classification	Chamberlin, 1981
		Soil-cement freeze-thaw test	ASTM D560
	Volume change	Consolidometer (undisturbed or remolded sample)	Holtz, 1965
		Soil-cement wet-dry test	ASTM D559
		Soil-cement freeze-thaw test	ASTM D560
Leachate collection system:			
- Granular drainage and filter layers	Thickness	Surveying; measurement	NA
	Coverage	Observation	NA
	Soil type	Visual-manual procedure	ASTM D2488
		Particle-size analysis	ASTM D422
		Soil classification	ASTM D2487
	Density	Nuclear methods	ASTM D2922
		Sand cone	ASTM D1556
		Rubber balloon	ASTM D2167
	Permeability (laboratory)	Constant head	ASTM D2434

continued . . .

TABLE M-1 (CONTINUED)

Facility component	Factors to be inspected	Inspection methods	Test method reference
- Synthetic drainage and filter layers	Material type	Manufacturer's certification	NA
	Handling and storage	Observation	NA
	Coverage	Observation	NA
	Overlap	Observation	NA
	Temporary anchoring	Observation	NA
	Folds and wrinkles	Observation	NA
	Geotextile properties	Tensile strength	Horz, 1984
		Puncture or burst resistance	Horz, 1984
		Tear resistance	Horz, 1984
		Flexibility	Horz, 1984
		Outdoor weatherability	Horz, 1984
		Short-term chemical resistance	Horz, 1984
		Fabric permeability	Horz, 1984
		Percent open area	Horz, 1984
- Pipes	Material type	Manufacturer's certification	NA
	Handling and storage	Observation	NA

continued . . .

TABLE M-1 (CONTINUED)

Facility component	Factors to be inspected	Inspection methods	Test method reference
	Location	Surveying	NA
	Layout	Surveying	NA
	Orientation of perforations	Observation	NA
Cast-in-place concrete structures	Sampling	Sampling fresh concrete	ASTM C172
	Consistency	Slump of portland cement	ASTM C143
	Compressive strength	Making, curing, and testing concrete specimens	ASTM C31
	Air content	Pressure method	ASTM C231
	Unit weight, yield, and air content	Gravimetric method	ASTM C138
	Form work inspection	Observation	NA
Electrical and mechanical equipment	Equipment type	Manufacturer's certification	NA
	Material type	Manufacturer's certification	NA
	Operation	As per manufacturer's instructions	NA
	Electrical connections	As per manufacturer's instructions	NA
	Insulation	As per manufacturer's instructions	NA
	Grounding	As per manufacturer's instructions	NA

Source: Northeim and Truesdale, 1986, pp 83-88.

D

ATTACHMENT D

Solid Waste Disposal Facility Criteria Final Rule

These amendments correct all of the deficiencies identified in the Nashville/Davidson County portion of the Tennessee SIP except the recordkeeping requirements. This remaining deficiency will be acted upon in a separate notice. Therefore, the requirements of section 182(a)(2)(A) for Reasonably Available Control Technology have been met for the Nashville/Davidson County portion of the Tennessee SIP.

Final Action

This action is being taken without prior proposal because the changes are noncontroversial and EPA anticipates no significant comments on them. The public should be advised that this action will be effective August 25, 1992. However, if notice is received within 30 days that someone wishes to submit adverse or critical comments, this action will be withdrawn and two subsequent notices will be published before the effective date. One notice will withdraw the final action and another will begin a new rulemaking by announcing a proposal of the action and establishing a comment period.

Under section 307(b)(1) of the Act, petitions for judicial review of this action must be filed in the United States Court of Appeals for the appropriate circuit by August 25, 1992. Filing a petition for reconsideration by the Administrator of this final rule does not affect the finality of this rule for the purposes of judicial review nor does it extend the time within which a petition for judicial review may be filed, and shall not postpone the effectiveness of such rule of action. This action may not be challenged later in proceedings to enforce its requirements [See 307(b)(2)].

This action has been classified as a Table 2 action by the Regional Administrator under the procedures published in the **Federal Register** on January 19, 1989 (54 FR 2214–2225). On January 6, 1989, the Office of Management and Budget waived Table 2 and 3 SIP revisions (54 FR 2222) from the requirements of section 3 of Executive Order 12291 for two years. EPA has submitted a request for a permanent waiver for Table 2 and Table 3 SIP revisions. OMB has agreed to continue the temporary waiver until such time as it rules on EPA's request.

Nothing in this action shall be construed as permitting or allowing or establishing a precedent for any future request for a revision to any State Implementation Plan. Each request for revision to the State Implementation Plan shall be considered separately in light of specific technical, economic and environmental factors and in relation to relevant statutory and regulatory requirements.

List of Subjects in 40 CFR Part 52

Air pollution control, Hydrocarbons, Incorporation by reference, Intergovernmental relations, Ozone, Reporting and recordkeeping requirements.

Dated: May 21, 1992.

Patrick M. Tobin,

Acting Regional Administrator.

Part 52 of chapter I, title 40, Code of Federal Regulations, is amended as follows:

PART 52—[AMENDED]

1. The authority citation for part 52 continues to read as follows:

Authority: 42 U.S.C. 7401–7671q.

Subpart RR—Tennessee

2. Section 52.2220 is amended by adding paragraph (c)(105) to read as follows:

§ 52.2220 Identification of plan.

* * * * *

(c) * * *

(105) Amendments to the Nashville/Davidson County portion of Tennessee's SIP, Regulation No. 7—Regulation for Control of Volatile Organic Compounds submitted on July 3, 1991, October 4, 1991, and January 2, 1992.

(i) *Incorporation by reference.*

(A) Regulation No. 7—Regulation for the Control of Volatile Organic Compounds, effective December 10, 1991.

(ii) *Other material.*

(A) Letter of July 3, 1991, from the Metropolitan Health Department for Nashville/Davidson County.

(B) Letter of October 4, 1991, from the Metropolitan Health Department for Nashville/Davidson County.

(C) Letter of January 2, 1991, from the Metropolitan Health Department for Nashville/Davidson County.

3. Section 52.2225 is amended by revising paragraphs (a) introductory text and (a)(1) to read as follows:

§ 52.2225 VOC rule deficiency correction.

(a) Revisions to the sections 7–3, 7–13, and 7–24 of the Tennessee regulations are approved. These amendments are in response to the Clean Air Act section 182(a)(2)(A) requirement to submit RACT rules correcting deficiencies in the existing SIP in accordance with EPA's pre-amendment guidance. These deficiencies were first noted in a letter from Greer Tidwell, the EPA Region IV Administrator, to Governor McWherter on May 26, 1988, and clarified in a letter dated June 10, 1988, from Winston Smith, EPA Region IV Air Division Director, to Paul Bontrager, Director of the Air Pollution Control Division of the Metropolitan Health Department for Nashville/Davidson County, and were further identified in EPA guidance including the Blue Book and the proposed Post-87 policy. The following deficiency in the Tennessee Regulations, however, has not been corrected.

(1) Section 7–25, "Recordkeeping and Reporting Requirements" Nashville/Davidson County committed in a letter dated May 7, 1991, to include a separate provision that requires records to be maintained for at least two years. This additional provision, which is scheduled for a July 15, 1992, public hearing, will be submitted to EPA shortly after that date and will be acted upon separately.

* * * * *

[FR Doc. 92–14685 Filed 6–25–92; 8:45 am]

BILLING CODE 6560–50–M

[EPA/OSW–FR–92–4146–6]

40 CFR Parts 257 and 258

Solid Waste Disposal Facility Criteria

AGENCY: Environmental Protection Agency (EPA)

ACTION: Final rule; corrections.

SUMMARY: EPA is correcting errors in the preamble and rule language for the Solid Waste Disposal Facility Criteria for municipal solid waste landfills that appeared in the **Federal Register** on October 9, 1991 (56 FR 50978). This correction notice will resolve the minor misunderstandings that the regulated community has called to the Agency's attention. The Agency also is clarifying its interpretation of the final cover requirements for the Criteria.

FOR FURTHER INFORMATION CONTACT: Mr. Paul Cassidy at (202) 260–4662 or Mr. Allen Geswein at (202) 260–4687.

SUPPLEMENTARY INFORMATION: On October 9, 1991, EPA promulgated a rule under Subtitle D of the Resource Conservation and Recovery Act and section 405 of the Clean Water Act pertaining to the disposal of solid waste and sewage sludge in municipal solid waste landfills (MSWLFs) (56 FR 50978 (October 9, 1991)). The preamble and rule language contained minor editorial and typographical errors that EPA is correcting in this notice. The Agency also is clarifying its interpretation of that part of the MSWLF rule concerning the design of a final cover under § 258.60(a)).

The MSWLF rule requires that owners/operators "must install a final cover system that is designed to minimize infiltration and erosion" (40 CFR 258.60(a). As specified in the rule, the final cover system must be comprised of an infiltration layer that is "a minimum of 18 inches of earthen material that has a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present, or a permeability no greater than 1 x 10^{-5} cm/sec, whichever is less" and an erosion layer that must consist of a "minimum of 6 inches of earthen material that is capable of sustaining native plant growth" (40 CFR 258.60 (a)(1) and (2)).

EPA established the requirement for a final cover infiltration layer, which includes a permeability standard, to prevent the "bathtub effect" from occurring. The "bathtub effect" occurs when a landfill fills up with liquids because the infiltration layer of the final cover is more permeable than the bottom liner system or natural subsoils present. Such an effect greatly increases the potential for the formation and migration of leachate (56 FR 50978, 51095 (October 9, 1991)).

Some members of the public have questioned the applicability of the permeability standard contained in § 258.6(a)(1) to a MSWLF that has a synthetic membrane on the bottom of the landfill. They have interpreted § 258.60(a)(1) to suggest that only 18 inches of earthen material is required as an infiltration layer even when the landfill has a synthetic membrane on the bottom.

Such an interpretation of the permeability standard contained in § 258.60(a)(1) is incorrect. EPA intended, and has always interpreted, the language in this section to be a performance standard that requires the permeability of the final cover be less than or equal to that of the bottom liner system or natural subsoils present, whichever is less. To achieve this, it requires as a minimum the use of 18 inches of earthen material. While this standard does not explicitly require the use of a synthetic membrane in the final cover, the Agency anticipates that if a MSWLF has a synthetic membrane in the bottom of the unit, then the infiltration layer in the final cover will, in all likelihood given today's technologies, include a synthetic membrane as part of the final cover. This is so because it generally is not currently possible to have an earthen material infiltration layer as part of the final cover that has a permeability of less than or equal to the permeability of a synthetic membrane. The Agency established this requirement because if a MSWLF were constructed with a bottom synthetic membrane, but covered only with 18 inches of earthen material as the infiltration layer, the bathtub effect would likely occur, and the Agency's overriding reason for establishing the permeability standard in § 258.60(a)(1) would be negated.

If a synthetic membrane needs to be included in the final cover, the Agency recommends that a minimum thickness of 20 mils be used. (In the case of high density polyethylene (HDPE), a minimum 60 mils is necessary to ensure proper seaming of the synthetic membrane.) The synthetic portion of the final cover does not have to be the same type or thickness as the membrane used in the bottom of the facility since the performance standard is concerned with the permeability standard.

This interpretation is not new. It is clear from reviewing the Regulatory Impact Analysis (RIA) and the preamble to the final rule (see 56 FR 50987) that the Agency had always interpreted this rule language to mean if there was a synthetic membrane in the bottom of a MSWLF, a synthetic membrane would, given today's technologies, be necessary as part of the final cover. The Agency has recently issued an Environmental Fact Sheet (EPA/530-SW-91-084, March 1992) that further highlights this interpretation.

The following are illustrations of the correct interpretation of this rule language. These illustrations present typical designs of MSWLFs and the corresponding correct final cover as required under § 258.60(a).

MSWLF design	Minimum final cover
No liner (in-situ soils)	Minimum infiltration layer of 18-inches of 1 × 10^{-5} cm/sec earthen material overlain by a minimum 6-inch erosion layer
Recompacted 1 × 10^{-5} cm/sec. soil liner.	Minimum infiltration layer of 18-inches of 1 × 10^{-5} cm/sec earthen material overlain by a minimum 6-inch erosion layer
Composite liner (60 mil synthetic over 3 foot recompacted 1 × 10^{-7} soil liner)	Minimum infiltration layer of 18-inches of 1 × 10^{-5} cm/sec earthen material overlain by a synthetic liner (Agency recommends minimum 20 mils, if HDPE 60 mils) overlain by minimum 6-inch erosion layer

To correct any misunderstanding regarding the permeability standard of the final cover design, the Agency is today revising the language of § 258.60(a) to provide further clarification. This revision is intended to eliminate any confusion regarding the correct interpretation of this rule language. This clarifying language does not remove any of the flexibility in § 258.60(b) regarding alternative final cover designs approved by the Director of a State/Tribal program that has been deemed adequate by EPA.

The other technical corrections being made today involve editorial changes, typographical changes, and minor corrections to dates, and are necessary to make the Code of Federal Regulations accurate.

Dated. June 15, 1992.

Don R. Clay,

Assistant Administrator.

The following corrections are made in FRL-4011-9, the Solid Waste Disposal Facility Criteria; final rule published in the **Federal Register** on October 9, 1991 (56 FR 50978):

1. On page 51001—Figure 1, third rectangle in the right side of the flow chart, change "You must comply only with the final cover requirements of § 258.60(a)(2)" to read "You must comply only with the final cover requirements of § 258.60(a)".

2. On page 51010—Figure 5, second decision diamond on the left side of the flow chart, change "Are All Appendix II Constituents Below Background" to read "Are All Appendix II Constituents At Or Below Background".

3. On page 51012, third column, last paragraph, fourth sentence, change "Figure 1 indicates, for example, that if your MSWLF will not receive waste after the effective date, only the final cover requirements of § 258.60(a)(2) will apply" to read "Figure 1 indicates, for example, that if your MSWLF will not receive waste after the effective date, only the final cover requirements of § 258.60(a) will apply".

4. On page 51018, first column, line 10 of the definition of "Municipal solid waste landfill unit," revise "solid waste, nonhazardous sludge, small" to read "solid waste, nonhazardous sludge, conditionally exempt small".

PART 258—[AMENDED]

§ 258.14 [Amended]

5. On page 51019, second column, lines 6 and 7 of § 258.14(b)(1), revise the phrase "paragraph (g) of this section" to read "(g)".

§ 258.25 [Amended]

6. On page 51021, first column, revise the title "§ 258.25 Run-on/run-off control systems" to read "§ 258.26 Run-on/run-off control systems".

§ 258.50 [Amended]

7. On page 51022, second column, § 258.50 Applicability, last line of paragraph (c)(1), revise "by October 9, 1996;" to read "by October 9, 1994;".

§ 258.60 [Amended]

8. On page 51028, second column, § 258.60 Closure criteria paragraph (a) is revised to read as follows:

(a) Owners or operators of all MSWLF units must install a final cover system that is designed to minimize infiltration and erosion. The final cover system must be designed and constructed to:

(1) Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present, or a permeability no greater than 1×10^{-5} cm/sec, whichever is less, and

(2) Minimize infiltration through the closed MSWLF by the use of an infiltration layer that contains a minimum 18-inches of earthen material, and

(3) Minimize erosion of the final cover by the use of an erosion layer that contains a minimum 6-inches of earthen material that is capable of sustaining native plant growth.

9. On page 51028, third column, line 15, paragraph (b)(1) revise "in paragraph (a)(1) of this section, and" to read "paragraphs (a)(1) and (a)(2) of this section, and".

10. On page 51028, third column, § 258.60 Closure criteria, paragraph (b)(2) revise "specified in paragraph (a)(2) of this section." to read "specified in paragraph (a)(3) of this section."

11. On page 51028, third column, § 258.60 Closure criteria, paragraph (c), revise "all MSWLF units at any point during its active life" to read "all MSWLF units at any point during their active life".

§ 258.61 [Amended]

12. On page 51029, second column, § 258.61 Post-closure care requirements, paragraph (a)(2), revise "§ 258.40. The Director of an approved" to read "§ 258.40, if applicable. The Director of an approved".

13. On page 51029, second and third columns, § 258.61 Post closure care requirements, paragraph (d), revise "October 9, 1991," to read "October 9, 1993,".

§ 258.71 [Amended]

14. On page 51029, third column, § 258.71 Financial assurance for closure, lines 4 and 5 of paragraph (a), revise "the largest area of all MSWLF unit ever" to read "the largest area of all MSWLF units ever".

[FR Doc. 92–15137 Filed 6–25–92; 8:45 am]

BILLING CODE 6560-50-M

40 CFR Part 268

[FRL-4148-6]

Hazardous Waste Management System: Land Disposal Restrictions

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice to approve storage of lead-bearing hazardous materials case-by-case capacity variance.

SUMMARY: In the final rule establishing land disposal restrictions for Third Third hazardous wastes (55 FR 22520), EPA granted a two-year national capacity variance to allow the continued storage of lead-bearing hazardous materials in waste piles (considered a form of land disposal) prior to smelting. The variance has now expired and these untreated wastes became prohibited from land disposal on May 8, 1992. At the time it granted the national capacity variance, the Agency indicated its intent to address the concerns raised by the secondary lead smelting industry to allow the continued storage of these materials in piles prior to lead recovery. While the Agency has published a proposal that would address this problem, the Agency has not yet finalized such a rule. The Agency believes that the continued storage of these lead-bearing hazardous materials in piles at smelting facilities prior to recovery is preferable to any alternative management available and consistent with the Agency's goal of waste minimization. Although the Agency is developing a solution that would allow the continued management of these wastes prior to lead recovery, until final standards are issued, it would be infeasible as a practical matter for regulated parties to design and construct the capacity to store the materials properly. This practical infeasibility results in an industry-wide, short term unavailability of non-land based storage capacity preceding treatment.

Therefore, EPA is taking regulatory action to approve an extension of the LDR effective date applicable to owners and operators of secondary lead smelters who are engaged in the reclamation of lead-bearing hazardous materials. This extension applies only to lead-bearing hazardous wastes placed in a staging area immediately prior to being introduced into a lead smelter. EPA believes that this extension to the LDR effective date is appropriate and consistent with the Agency's overall objective of encouraging recycling. No further applications will be required at this time from persons granted the extension of this action. However, EPA is requiring such persons to maintain certain recordkeeping, and to meet certain other requirements to qualify for the extension.

EFFECTIVE DATE: This notice becomes effective on June 5, 1992.

ADDRESSES: The official record for this notice is identified as Docket Number F-92-CD2P-FFFFF, and is located in the EPA RCRA Docket, room 2427, U.S. Environmental Protection Agency, 401 M Street SW., Washington, DC 20460. The docket is open from 9 a.m. to 4 p.m., Monday through Friday, except on Federal holidays. The public must make an appointment to review docket materials by calling (202) 260–9327. The public may copy a maximum of 100 pages from any regulatory document at no cost. Additional copies cost $0.20 per page.

FOR FURTHER INFORMATION CONTACT: For general information contact the RCRA Hotline at (800) 424–9346 toll-free or (703) 920–9810 locally. For information on specific aspects of this notice, contact Nick Vizzone, Office of Solid Waste, Capacity Programs Branch (OS–321W), U.S. Environmental Protection Agency, 401 M Street SW., Washington, DC 20460, (703) 308–8477

SUPPLEMENTARY INFORMATION:

Outline

I. Background

A. History

In 1984, Congress enacted the Hazardous and Solid Waste Amendments (HSWA), which amended the Resource Conservation and Recovery Act (RCRA). Among other things, HSWA required EPA to develop regulations that would impose, on a phased schedule, restrictions on the land disposal of hazardous wastes. In particular, sections 3004 (d) through (g) prohibit the land disposal of certain hazardous wastes by specified dates in order to protect human health and the environment. In addition, section 3004(m) requires EPA to set "levels or methods of treatment, if any, which substantially diminish the toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents from the waste so that short-term and long-term threats to

E

ATTACHMENT E

Solid Waste Disposal Facility Criteria;
Delay of Compliance and Effective Dates

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 258

[FRL-4782-4/EPA530-Z-93-012]

Solid Waste Disposal Facility Criteria; Delay of Compliance and Effective Dates

AGENCY: Environmental Protection Agency (EPA).

ACTION: Final rule.

SUMMARY: On October 9, 1991, EPA promulgated revised Federal criteria for Municipal Solid Waste Landfills (MSWLFs) under subtitle D of the Resource Conservation and Recovery Act (RCRA). Today's final rule amends these criteria by delaying the general date for compliance with the criteria until April 9, 1994 for certain small landfills and by delaying the effective date of subpart G, Financial Assurance, until April 9, 1995 for all MSWLFs. In addition, the MSWLF criteria are amended by removing the exemption from the ground-water monitoring requirements and delaying the date for compliance with all requirements of the MSWLF criteria for two years for owners and operators of MSWLF units in arid and remote areas that meet the qualifications of the small landfill exemption in the MSWLF criteria. Additionally, the date of final cover installation is extended for owners/operators of MSWLFs units that cease receipt of waste by their compliance date. Finally, the compliance date is delayed for certain MSWLFs in the mid-west receiving flood-related waste from a federally designated disaster area. Because states/Tribes may have earlier effective dates or other requirements in their own state/Tribal regulations, owners and operators of MSWLFs are encouraged to consult with their state/Tribe.

EFFECTIVE DATES: The amendments in this final rule are effective October 9, 1993, except for the amendments to §§ 258.70 and 258.74 in subpart G which are effective April 9, 1995.

The effective date of subpart G of part 258 (§§ 258.70 through 258.74) which was added at 56 FR 51016 is delayed from April 9, 1994 until April 9, 1995. See "II. Background, A. Effective Dates" under SUPPLEMENTARY INFORMATION for further information about this effective date.

ADDRESSES: The public record for this rulemaking (docket Number F-93-XMLP-FFFFF) is located at the RCRA Docket Information Center, (OS-305), U.S. Environmental Protection Agency Headquarters, 401 M Street SW., Washington, DC 20460. The public docket is located at EPA Headquarters and is available for viewing from 9 a.m to 4 p.m., Monday through Friday, excluding Federal holidays. Appointments may be made by calling (202) 260-9327. Copies cost $0.15/page Charges under $25.00 are waived.

FOR FURTHER INFORMATION CONTACT: For general information, contact the RCRA/Superfund Hotline, Office of Solid Waste, U.S. Environmental Protection Agency, 401 M Street SW., Washington, DC 20460, (800) 424-9346, TDD (800) 553-7672 (hearing impaired); in the Washington, DC metropolitan area the number is (703) 920-9810, TDD (703) 486-3323.

For more detailed information on specific aspects of this final rule, contact David Hockey or Allen Geswein, Office of Solid Waste (OS-301), U.S. Environmental Protection Agency, 401 M Street SW., Washington, DC 20460, (202) 260-1099.

SUPPLEMENTARY INFORMATION:

Preamble Outline

I. Authority

EPA is promulgating these regulations under the authority of sections 2002 and 4010(c) of the Resource Conservation and Recovery Act of 1976, as amended. RCRA section 2002 provides the EPA Administrator with the authority to promulgate regulations as are necessary to carry out her functions under the Act. 42 U.S.C. 6912. Under section 4010(c) of RCRA, the EPA Administrator is required to promulgate revised criteria for facilities that may receive household hazardous waste (HHW) or small quantity generator (SQG) waste. The criteria shall be those necessary to protect human health and the environment. At the same time, in promulgating these revised criteria, the Administrator may take into account the practicable capabilities of facilities that may receive HHW or SQG waste. 42 U.S.C. 6949a(c). EPA has interpreted "practicable capability" to include both the costs which facilities will incur in complying with the revised criteria and the technical capability of facilities that must comply with the regulations. 56 FR 50978, 50983-84 (October 9, 1991); 53 FR 33314, 3325 (August 30, 1988). EPA has taken practicable capability of MSWLF owners and operators into account in modifying the effective date of the revised criteria as set forth in this Federal Register notice.

II. Background

A Clarification of Effective Dates

By delaying the compliance dates of the MSWLF criteria in a number of ways, this rule relieves restrictions that part 258 would have imposed on those facilities that would have otherwise had to have complied with the criteria by the effective dates set forth in the rule published on October 9, 1991. 56 FR 50978. Because this rule relieves, rather than imposes, regulatory burdens, delaying the effective date of today's rule is not necessary in order to allow time for the regulatory community to comply. In addition, EPA believes that it has good cause to make today's rule effective in less than 30 days. If the rule's effective date were delayed until 30 days after today's publication, all owners and operators of MSWLFs that fall within the ambit of this rule would have to meet the deadline already established in part 258, which had a general effective date of October 9, 1993. 40 CFR 258.1 (e) and (j). Such a result would negate the entire effect of this rule, which is to provide some regulatory relief for certain owners/operators of MSWLFs that are finding it extremely difficult for a variety of reasons (including floods in the

Midwest) to comply with the original effective dates in part 258. Thus, the Agency believes that it has the authority to make today's rule effective in less than 30 days in accordance with section 553 of the Administrative Procedures Act, 5 U.S.C. 553(d) (1) and (3).

B. Overview of the Subtitle D Effective Dates as Promulgated on October 9, 1991

On October 9, 1991, EPA promulgated a rule under subtitle D of the Resource Conservation and Recovery Act and section 405 of the Clean Water Act pertaining to the disposal of solid waste and sewage sludge in MSWLFs (56 FR 50978 (October 9, 1991)). The regulations and effective dates of the criteria were originally promulgated as follows. The criteria applied to owners and operators of all MSWLF units that receive waste on or after October 9, 1993. Landfill owners and operators that stopped accepting waste before October 9, 1991 were not required to comply with the regulations. Those landfill owners and operators that stop accepting waste between October 9, 1991 and October 9, 1993 were exempt from all of the regulatory requirements except for the final cover (found in 40 CFR 258.60(a)), which had to be applied within six months of last receipt of waste. Owners and operators that continued to receive waste beyond the October 9, 1993 effective date were required to comply with the remainder of the landfill regulations (including location restrictions, operation, design, ground-water monitoring and corrective action, closure and post-closure, and financial assurance). Additionally, the regulations provided for a phase-in of two of the more costly requirements: the financial assurance requirements (effective April 9, 1994) and ground-water monitoring and corrective action requirements (effective October 9, 1994 through October 9, 1996). Finally, the regulations allowed for an exemption from the design, ground-water monitoring and corrective action provisions for very small arid and remote landfills that met the criteria of 258.1(f).

C. Implementation of the MSWLF Criteria

Section 4005(c)(1)(B) of RCRA, as amended, requires states to develop and implement permit programs or other systems of prior approval and conditions to ensure that the MSWLFs are complying with the MSWLF criteria. (The Agency intends to extend to Indian Tribes the same opportunity to apply for permit program approval as is available to states. Providing Tribes with the opportunity to apply for approval to adopt and implement MSWLF permit programs, while not a statutory requirement in RCRA section 4005(c)(1)(B), is consistent with EPA's Indian Policy. The Agency plans to propose the concept of Tribal permit program approval when a tentative notice of permit program adequacy is published for the first Indian Tribe seeking program approval.) EPA's implementation role is largely to review and determine whether these state/Tribal permit programs are adequate. EPA believes that for permit programs to be considered adequate, a state/Tribe must have the capability of issuing permits or some other form of prior approval for all MSWLFs in the state/Tribe, and must establish requirements adequate to ensure that owners and operators will comply with the federal landfill criteria. A state/Tribe also must be able to ensure compliance through monitoring and enforcement actions and must provide for public participation in their permitting and enforcement actions.

EPA-approved state/Tribal permit programs have the opportunity to exercise more flexibility and discretion in implementing the criteria according to local conditions and needs. Owners and operators of MSWLF units located within the jurisdiction of a state/Tribe with an approved program may benefit from this potential flexibility, which extends to many parts of the MSWLF regulations. For example, owners and operators of MSWLF units in unapproved states/Tribes must design their new units and lateral expansions of existing units with a composite liner in compliance with 40 CFR 258.40(b), whereas approved states/Tribes may allow an owner/operator to use an alternative design based on the performance standard described in 40 CFR 258.40(a). Because of the flexibility provided to an approved state permit program, and because state permit program approval is mandated by section 4005(c)(1)(B) of RCRA, EPA fully expects that most states will apply for and receive full approval of their MSWLF permit programs, thereby maintaining the lead role in implementing and enforcing the MSWLF Criteria promulgated under 40 CFR part 258

States are currently in various stages of the program approval process. Some states have received full program approval, while several states have received "partial" program approval, whereby only some portions of the state permit program have been approved while the remainder of the program is awaiting approval pending completion of statutory and/or regulatory changes by the state. In situations where a state permit program is not approved, or where portions of a program are not approved (in the case of a partial approval), the MSWLF criteria (or unapproved portions of criteria) are implemented by the owner and operator, with no Federal permitting program or interaction. In such situations, where the MSWLF criteria are "self-implementing", each owner/operator must document compliance and maintain this documentation in the operating record.

D. Summary of Proposed Rule

When the municipal solid waste landfill criteria were developed, EPA included a number of features that serve to facilitate owners' and operators' ability to come into compliance by the promulgated effective dates. These features include phased-in effective dates, certain exemptions for very small arid and remote landfills, and numerous opportunities for flexibility in states/Tribes with EPA-approved permit programs. Despite these features, the Agency received a significant number of requests to extend the effective date of the MSWLF criteria. These requests came primarily from local governments that own/operate smaller landfills who related their problems with meeting the effective date, including: (1) inability to comply with unfunded federal requirements; (2) lack of flexibility in unapproved states; and (3) delays in gaining access to new waste management facilities. Therefore, on July 28, 1993, the Agency proposed to amend the municipal solid waste landfill criteria (58 FR 40568) to extend the effective date of the Criteria. The proposal was not intended to change the environmentally protective features of the MSWLF criteria, but would provide certain owners and operators with additional time to come into compliance with the MSWLF criteria requirements.

The July 28th notice proposed to amend the criteria in four areas. First, the Agency proposed to delay the effective date of the criteria until April 9, 1994 for certain small landfills that: dispose of 100 tons of waste per day or less; are located in a state that has submitted an application for permit program approval by October 9, 1993 or are located on Indian Lands; and are not currently on the National Priorities List. Second, EPA proposed to delay the effective date of Subpart G, Financial Assurance, until April 9, 1995 for all MSWLFs. Third, in response to a U.S. Court of Appeals decision, *Sierra Club v. United States Environmental Protection Agency*, 992 F.2d 337 (D.C.

Cir. 1993), the Agency proposed to remove the exemption from the ground-water monitoring requirements in 40 CFR 258.50–258.55, for owners and operators of MSWLF units in arid and remote areas that meet the qualifications of the small landfill exemption outlined in 40 CFR 258.1(f). Additionally, EPA proposed to extend the effective date for all requirements of the MSWLF criteria for a period of two years, until October 9, 1995, for all MSWLF units in arid and remote areas that qualify for the small landfill exemption under 258.1(f). Lastly, the Agency proposed to amend the final cover requirements by requiring owners/operators of MSWLF units that cease receipt of waste by their effective date to complete final cover installation by October 9, 1994 except for very small MSWLFs. Very small MSWLFs in arid and remote areas that qualify for the small landfill exemption (under 258.1(f)) and cease receipt of waste before their effective date of October 9, 1995 must complete final cover installation by October 9, 1996.

III. Response to Comments and Analysis of Issues

The 30-day comment period for the July 28th proposed rule ended on August 27, 1993. The Agency received over 300 comments on the proposal. This section summarizes and addresses the major comments as they relate to the four major amendments in the July 28, 1993 proposal. The Agency received a number of comments on the MSWLF criteria not directly related to the issue of delaying the effective date. The discussion that follows is limited to the major issues relevant to the July 28th proposal. A discussion of the remaining comments can be found in a background document available in the RCRA Docket Information Center.

A. Delaying the General Effective Date

In the July 28th proposal, EPA requested comment on a proposed six-month delay of the effective date (to April 9, 1994) for MSWLFs accepting 100 TPD or less of any combination of household, commercial, or industrial solid waste on an average annual basis that are located in either a state that has submitted an application for permit program approval by October 9, 1993 or on Indian lands and are not on the Superfund National Priorities List (NPL). The majority of commentors were generally in favor of the proposed delay. The major comments submitted on this portion of the proposal are summarized below.

1. A Six-Month Time Frame

The proposed rule provided for a one-time, six-month delay of the general effective date. Some commentors questioned the appropriateness of the Agency's choice of a six-month delay of the effective date. Proposals from commentors ranged from total opposition to any delay to enthusiastic support for a longer delay by as much as two years. Commentors who supported the extension cited many reasons, including the following: (1) inability to comply with unfunded federal requirements; (2) lack of flexibility in unapproved states; and (3) delays in gaining access to a new waste management facility. As for those who supported a longer delay by as much as two years, these commentors believed that six months was too short based on their specific situation. As stated in the proposal, the Agency chose a six-month delay to accommodate the parties most in need—owners and operators, such as small communities (including local governments that own/operate MSWLFs)—who have made good faith efforts to seek alternative disposal facilities and need some limited additional time to complete those efforts. 58 FR 40570–71. While six months may not be enough time for all owners and operators to complete all necessary actions, EPA does not want to further delay the implementation of the criteria promulgated almost two years ago. This additional time is not designed to solve the problems facing communities that recently started the siting process or who are many months or years away from operating a new facility. Lengthy delays could increase the potential for environmental problems (e.g., failure to close substandard landfills) and would penalize those who took the necessary steps to comply with the October 9, 1993 effective date. Therefore, the Agency did not find these arguments to delay the effective date beyond six months to be persuasive.

Other commentors suggested that EPA should delay the general effective date for more than six months to allow EPA more time to approve additional state permit programs. EPA has determined that, on the average, review and approval of a typical state permit program application can be completed within approximately six months. Based on current information from states, EPA believes that all or almost all states will submit an application for approval by October 9, 1993. This six-month extension will ensure in most cases that the federal criteria would not become effective before the state permit program was approved, thus allowing many owners and operators to avoid the situation of gearing up to meet federal standards and then, a few months later, changing to meet newly approved state standards. In addition, this additional time will allow a vast majority of MSWLF owners and operators to take advantage of the flexibility and the potential cost savings available when states are approved.

2. 100 Tons Per Day or Less Size Limitation

The proposed rule limited the six-month extension to smaller landfills that accept 100 tons per day or less of any combination of household, commercial, or industrial solid waste The Agency received a number of comments on this restriction. Some commentors suggested an increased tonnage limit (up to 750 TPD), while others questioned the need to limit the extension based on the amount of waste accepted by the landfill and felt that the extension should be available to owners and operators regardless of the amount of waste accepted per day (i.e., a blanket extension). As stated in the proposal, the Agency believes that the 100 TPD or less cut-off is representative of the majority of smaller community landfills that have had the most difficulty coming into full compliance by the October 9, 1993 deadline, because financial conditions, legal challenges, and geography have created significant obstacles to compliance, often despite good-faith efforts to comply. For example, many of the smaller landfills intend to close, and their users will instead send their waste to a regional waste management facility where they can take advantage of economies of scale. The process of regionalization, including closure of their existing MSWLF and construction of a new transfer station, has taken more time than many small communities had originally anticipated. Additionally, the Agency is concerned that increasing the tonnage or allowing a "blanket" or unlimited extension, as suggested by some commentors, would not fulfill EPA's goal of granting relief to only those most in need—primarily small communities. By setting the limit at 100 TPD, the Agency targets relief to the greatest extent possible while ensuring that most waste, as of October 9, 1993, will be disposed in accordance with the requirements of 40 CFR part 258. As discussed in the proposal, setting the limit at 100 tons per day would provide potential relief to approximately 75 percent of the MSWLFs in the country which manage only about 15 percent of the total national waste stream

One commentor argued that the Agency should have adhered to its own definition, in the October 9, 1991 rule, of a small landfill used for the small landfill exemption found at 258.1(f) (i.e., 20 tons per day). In developing the proposed size limitation, EPA found that landfills accepting no more than 100 tons per day of solid waste tend to be those experiencing the most severe budget and technical problems. The Agency did not set the waste acceptance limit for this extension at 20 tons per day, because the scope of the problem appeared to extend to somewhat larger landfills, primarily those serving communities with a population up to a range of 45,000 to 57,000 (i.e., landfills accepting approximately 100 tons per day). Additionally, a portion of the landfills accepting 20 TPD or less will qualify for the two year delay of all of the MSWLF criteria (see subsection D; Very Small Arid and Remote MSWLF Extension), if they meet the criteria of the small landfill exemption in 258.1(f). Therefore, the Agency is retaining the 100 TPD limit in the final rule. As in the proposal, it is important to note that the effective date for MSWLF units accepting greater than 100 TPD will continue to be October 9, 1993.

In the proposed rule, the Agency solicited comments on whether two calculations were necessary to determine whether an MSWLF unit qualified and continued to be eligible for the extension. First, to qualify for the extension, the MSWLF unit would have had to dispose of 100 tons per day or less of solid waste between October 9, 1991 and October 9, 1992. Second, the owner/operator of the MSWLF unit would not be allowed to dispose of more than an average of 100 TPD of solid waste each month between October 9, 1993 and April 9, 1994. The "historical" (e.g., October 9, 1991 through October 9, 1992) time frame was suggested mainly to assure that larger landfills would not alter the amount of waste they are presently accepting in order to take advantage of today's six-month extension, while the monthly average calculation was intended to ensure that the "small" landfills would remain so during the extension period. As discussed in this preamble, today's extension is intended for smaller landfills already in existence.

A few commentors generally supported the need for an historical time frame calculation to determine that the MSWLF qualifying for the extension was indeed a small landfill. However, numerous commentors, including many small landfill owners and operators, cited many reasons why they believed the proposed method of determining the historical time frame (i.e., based on the average collected during the year October 9, 1991 through October 9, 1992) was unnecessarily restrictive. For example, commentors felt the historical time frame did not consider that unusual circumstances (e.g., sudden additional incoming waste due to closure of a neighboring landfill during the target year) may have increased the quantity of waste to a landfill during the target period. Commentors also were concerned that a great deal of time and resources could be spent in determining whether or not a landfill, with no scales or past records, qualified for the extension. Commentors noted that recordkeeping at small landfills, usually staffed part-time, may be non-existent for the historical time period, may not be organized in a way that identifies the daily tonnage, nor allows such a time period to be readily identified. These commentors felt that such resources and time would be better spent upgrading the landfill or finding waste management alternatives. One commentor argued that their landfill did not begin receiving waste until after the historical time period and therefore has no records.

The Agency recognizes that some of these situations could prevent some otherwise deserving landfills from qualifying for the six-month extension. Today's rule is intended to grant needed relief to certain MSWLF owners and operators in a manner that does not disqualify truly deserving facilities and does not increase owner/operator record-keeping burden in order to qualify for the extension. In an effort to balance the need to limit the extension to only small landfills, while at the same time limiting the burden on those who qualify, today's final rule provides that the extension is for units that "disposed of 100 tons per day or less of solid waste during a representative period prior to October 9, 1993." The historical measurement of waste receipt should be based on the average acceptance of waste over a representative period prior to October 9, 1993, as determined by the owner/operator. In determining the historical measurement of waste, the Agency recommends that owners and operators determine the average receipt of waste during the period of October 9, 1991 through October 9, 1992. This period of time should provide the most current representative "snapshot" of waste receipt at a MSWLF unit. Waste receipt at MSWLF units after October 1992 may not be as representative due to changes in practices (either downsizing or upgrading) as a result of the impending October 9, 1993 effective date. However, in the instance that the owner/operator does not have records for this period, or believes that this period is not representative of their past receipt of waste, then the owner/operator may choose an alternative period (e.g., the most recent twelve consecutive month period not impacted by extraneous circumstances). The historical calculation method adopted for today's extension is implicitly the same as the historical measurement method MSWLF owners and operators use in determining if their MSWLF will meet the small landfill exemption (less than 20 TPD) of 258.1(f). Owners and operators therefore will have the flexibility to base their historical determination of average waste receipt on their available records while considering special circumstances.

It is the responsibility of the owner/operator to document an historical acceptance of waste of 100 TPD or less. The Agency will not require owners and operators to maintain records on the amount of waste the facility accepts, but if the owner/operator believes that the facility may be close to the 100 TPD limit, then it may be in the owner/operators' best interest to develop and maintain some indication on the amount of waste accepted given the possibility of citizen suits being filed under section 7002 of RCRA.

Commentors supported the proposed monthly calculation during the extension period to continue to qualify for the extension. Therefore, MSWLFs will continue to be required to accept 100 TPD or less based on a monthly average during the time period of October 9, 1993 until April 9, 1994 to qualify for an extension.

Finally, the proposed rule requested comment on methods of calculating the tons per day accepted by facilities. EPA suggested two methods: (1) divide the total annual amount of waste received by 365 days or (2) conduct a one-time measurement of a day's typical full trash-hauling vehicles, then estimate the weight from volume of trash-hauling vehicles by using a conversion factor (e.g., one ton equal to three cubic yards of waste) or using sales/acceptance receipts from trash haulers. Commentors generally agreed that both of these methods to calculate the acceptance of waste would suffice for the majority of their situations. Several commentors suggested the use of a conversion factor of one ton equal to five cubic yards of noncompacted waste. Rather than set strict calculation methods, the Agency believes that the approach should remain flexible whereby the owner/

operator use reasonable and defensible assumptions in calculating their tonnage.

3. Lateral Expansions

The proposed rule limited the extension to existing units and to lateral expansions of existing units to accommodate trench and area fills. A few commentors were concerned that landfills qualifying for the extension would laterally expand over a larger area than actually needed, thus greatly increasing the size of their existing unit by the new April 9, 1994 effective date. The commentors proposed that EPA limit the capacity of MSWLF unit lateral expansions to not exceed six-months of capacity for the entire MSWLF unit. The Agency feels that this type of limitation would create an unnecessary complication for owners and operators in implementation of this extension and that this issue already is addressed in the current definition of an existing unit. The definition of "existing MSWLF unit" in § 258.2, defines such a unit as one that is receiving solid waste as of the effective date of the landfill criteria with the caveat that waste placement in the unit be consistent with past operating practices or modified practices to ensure good management. The Agency has interpreted this to mean that an existing unit is defined by the areal extent of waste (sometimes referred to as the waste "footprint") placed as of the effective date of the criteria and that the spreading of waste over a large area to avoid the liner requirements is not acceptable (see 56 FR 51041, October 9, 1991).

A commentor suggested that EPA should only have granted an exemption to landfills that were undertaking vertical expansions, and not extend the exemption to lateral expansions. As noted earlier, the major difficulties in meeting the criteria deadline appear to fall mainly on smaller community landfills and the extension therefore is largely directed at such landfills. Many of these smaller landfills use trench and area fill practices. For example, in a trench fill operation, a small trench is excavated, filled, and covered in a relatively short period of time. As the old trench is filled, it is extended to accommodate additional waste. This extension is by definition a lateral expansion. Limiting the extension to vertical expansions would therefore disrupt these customary practices and limit the extension to considerably fewer landfills than EPA intended. Therefore, today's final rule continues to allow existing units and lateral expansions of existing units to receive the six-month extension.

4. State Submittal of a Permit Program Application

The proposed rule limited the six-month extension only to owners and operators of MSWLFs in states that have submitted an application for permit program approval by October 9, 1993 or are located on Indian Lands. Some commentors questioned the need for the state to have submitted an application in order for the owner/operator to qualify for the extension. The Agency continues to work toward its goal of approving all states and Tribes (to the extent they apply). Approval of State/Tribal permit programs is a high priority and the Agency does not want the extension to detract from this goal. EPA believes that the linkage of the extension to submission of an application will serve as impetus for states to submit their applications by October 9, 1993 and for advancing the Agency's goal of approving all states by April 9, 1994. In fact, the Agency now believes that every state except Iowa will submit an application by October 9, 1993.

In the proposed rule, the Agency indicated that when it published the final rule, it would include a list of states who have submitted an application by the date on which the final rule was signed. 58 FR 40572. Because most states have now submitted an application, for purposes of simplicity, the following is a list of those states who have not submitted an application as of the date of signature: Alaska, American Samoa, Arizona, Guam, Hawaii, Iowa, Maine, New Jersey, Northern Marianas, Ohio, Puerto Rico, Rhode Island, and the Virgin Islands. Because most of these states are expected to apply between the date of signature and October 9, 1993, owners and operators of MSWLF units located in these states are encouraged to contact their state to find out whether the State has submitted an application by October 9, 1993.

Due to the time and resources required to deal with the effects of the Great Flood of 1993, the state of Iowa has indicated that it will not be able to apply for approval of its permit program by October 9, 1993, although the state had originally planned to do so. In an effort not to penalize those small landfills in need of relief located in the state of Iowa, the final rule does not include the requirement that Iowa submit a permit program application by October 9, 1993 for owners and operators in that state to take advantage of the six-month delay. Owners and operators in Iowa, however, will be required to meet all other requirements to qualify for the six-month extension in today's final rule.

In the proposal, the Agency provided that owners and operators of MSWLFs located on Indian lands would be eligible for the six month extension even if the Tribe had not submitted an application for permit program approval by October 9, 1993. As discussed in the proposal, RCRA does not require Indian Tribes to develop a permit program for MSWLFs. Because many of the landfills on Indian lands could qualify for today's six-month extension by virtue of the fact that they accept less than 100 TPD and are not on the National Priorities List, the Agency proposed to allow MSWLF units on Indian lands to take advantage of the six-month extension, even if the Indian Tribe has not submitted an application for permit program approval by October 9, 1993. Commentors agreed with this provision as long as all other requirements for the extension are fulfilled. Therefore, today's final rule allows owners/operators located on Indian Lands to be granted the six-month extension as long as all of the other requirements of this rule are met.

No comments were received that suggested changes to the proposed definitions of "Indian land or Indian country" and "Indian Tribe or Tribe." Therefore, these definitions are retained in today's final rule. While the definition of Tribes in today's final rule does not explicitly include Alaska Native Villages, EPA believes that, to the extent these entities exercise substantial governmental duties and powers, they would be eligible to apply for permit program approval. For purposes of today's rule, as with Indian lands in other States, EPA is allowing landfills on Native Village Lands to be eligible for the six-month extension whether or not the Village has submitted an application for permit program approval.

Some commentors suggested that EPA delegate to states who have submitted a permit program application by October 9, 1993 more flexibility in implementation of the delay. Commentors suggested, for example, that such states should have the flexibility to: Determine the need for a delay on a site-by-site basis, to grant longer than a six-month extension, or to waive the 100 TPD limit. As discussed throughout this preamble, the Agency set the length of the extension and size criteria so as to target limited relief for those MSWLF units in greatest need—small landfills. Therefore, in order to maintain this focus, the Agency will continue to require that these criteria be used as the minimum national criteria.

However, other commentors were concerned that a delay of the criteria would undermine states' efforts in implementing the MSWLF criteria (e.g., oppose state's existing closure schedules for substandard landfills). As stated in the proposal, a state/Tribe, regardless of its permit program approval status, may impose more stringent effective dates and/or more stringent criteria for qualifying for an extension (e.g., maintain current closure schedules) if they so choose. Therefore, the extension should not have the negative effect predicted by these commentors.

5. National Priorities List

The proposed rule did not extend the six-month extension to MSWLFs currently on the Superfund National Priorities List as published in appendix B to 40 CFR part 300. Commentors agreed with this exclusion; therefore, the final rule retains this provision. Some commentors suggested that the extension be further restricted by disallowing any MSWLF that is on a state Superfund list or in violation of another state environmental regulation. As discussed in the previous section, states may always be more stringent (e.g., prevent MSWLFs on their state Superfund lists from gaining an extension) in their approach to the extension.

6. Other Limitations Suggested by Commentors

A few commentors requested that EPA limit the extension to prohibit MSWLFs that qualify from accepting non-hazardous industrial waste. Under the criteria as promulgated on October 9, 1991, MSWLFs may accept non-hazardous industrial waste to be co-disposed with household waste. The Agency did not limit today's extension in the manner suggested for the following reasons: (1) The prohibition of non-hazardous industrial waste would be difficult to implement and enforce; (2) this waste stream typically represents a small fraction of the entire waste sent to a MSWLF; (3) for some generators, the local MSWLF represents the only economical method of disposal of their non-hazardous industrial waste; and (4) this is a one-time extension for a short period of time (i.e., six months). Therefore, the final rule will allow MSWLFs qualifying for the extension to accept non-hazardous industrial waste for co-disposal with household waste.

Finally, some commentors suggested that in order to qualify for the extension, the MSWLF must be in compliance with all of the location restrictions of subpart B of the criteria by the effective date. EPA did not limit the extension based on a facility meeting the location restrictions because many of the restrictions (e.g., wetlands, fault areas, seismic zones) do not apply to existing units, the major target of the extension. In addition, under the criteria as promulgated, existing units that cannot meet the requirements for airports, floodplains, or unstable areas already have until October 9, 1996 to close (unchanged by today's rule). Limiting the extension for these facilities would not have much of an effect. Therefore, today's final rule does not place location restrictions on MSWLFs eligible for the extension.

B. Delaying the Financial Assurance Effective Date

The proposed rule provided for a one-year extension of the financial assurance requirements (from April 9, 1994 to April 9, 1995) for all MSWLFs, regardless of size. The majority of commentors supported the need to extend the financial assurance requirements. Commentors noted that the one-year delay provides time for the owners and operators to budget and to acquire the appropriate financial assurance mechanism for their MSWLFs. The Agency, in setting the original April 9, 1994 effective date for the financial assurance requirements, believed that this date would allow adequate time to promulgate a financial test for local governments and another test for corporations (see 56 FR 50978). However, the Agency currently estimates that neither financial test will be promulgated within the time frame anticipated. The Agency believes that local governments should have these financial tests available to them before the financial responsibility provisions become effective. The delay of one year provided in this rule should enable EPA to finish promulgation of these tests and should ensure that owners and operators will have the opportunity to evaluate their needs based on these financial tests. As a result, many local governments will be able to realize a significant decrease in the cost of compliance with the financial responsibility requirements, while assuring that the costs associated with closure, post-closure, and known corrective action at the MSWLFs will be met.

A few commentors suggested that EPA extend the effective date of the financial assurance requirements beyond the proposed one-year delay. The Agency anticipates that the one year extension will be sufficient time to complete the proposal and promulgation of the financial tests. EPA also believes that one year should provide adequate notice to affected parties so they may determine whether they satisfy the applicable financial test criteria for all of the obligations associated with their facilities or whether they need to obtain an alternate instrument for some or all of their obligations. The Agency notes that approved states/Tribes have the flexibility to develop alternative financial mechanisms that meet the criteria specified in § 258.74(l) for use by their owners and operators. This may include development of a state financial test. Therefore, today's final rule retains the one year extension for financial assurance.

C. Very Small Arid and Remote MSWLF Extension

1. Commentor-Suggested Limitations to Qualify for the Two-Year Extension

The October 9, 1991 Final Rule for the MSWLF Criteria included an exemption for owners and operators of certain small MSWLF units from the design (subpart D) and ground-water monitoring and corrective action (subpart E) requirements of the Criteria. See 40 CFR 258.1(f). To qualify for the exemption, the small landfill had to accept less than 20 tons per day, on an average annual basis, exhibit no evidence of ground-water contamination, and serve either:

(i) A community that experiences an annual interruption of at least three consecutive months of surface transportation that prevents access to a regional waste management facility, or

(ii) A community that has no practicable waste management alternative and the landfill unit is located in an area that annually receives less than or equal to 25 inches of precipitation.

In adopting this limited exemption, the Agency maintained that it had complied with the statutory standard to protect human health and the environment, taking into account the practicable capabilities of small landfill owners and operators. See discussion in 56 FR 50991.

In January 1992, the Sierra Club and the Natural Resources Defense Council (NRDC) filed a petition with the U.S. Court of Appeals, District of Columbia Circuit, for review of the subtitle D criteria. The Sierra Club and NRDC suit alleged, among other things, that EPA acted illegally when it exempted these small landfills from the ground-water monitoring requirements. On May 7, 1993, the United States Court of Appeals for the District of Columbia Circuit issued an opinion pertaining to the Sierra Club and NRDC challenge to the small landfill exemption. *Sierra Club* v. *United States Environmental Protection Agency,* 992 F.2d 337 (DC Cir. 1993).

The Court held that under section 4010(c), the only factor EPA could consider in determining whether facilities must monitor their ground water was whether such monitoring was "necessary to detect contamination," not whether such monitoring is "practicable." The Court noted that while EPA could consider the practicable capabilities of facilities in determining the extent or kind of ground-water monitoring that a landfill owner/operator must conduct, EPA could not justify the complete exemption from ground-water monitoring requirements. Thus, the Court vacated the small landfill exemption as it pertains to ground-water monitoring, directing the Agency to "* * * revise its rule to require ground-water monitoring at all landfills." (The Court decision did not affect the small landfill exemption as it pertains to the design requirements.)

Therefore, today's final rule, as required by the Court, modifies the small landfill exemption whereby, owners and operators of MSWLF units that meet the qualifications outlined in § 258.1(f) are no longer exempt from ground-water monitoring requirements in 40 CFR 258.50–258.55.

The proposed rule, while removing the exemption from ground-water monitoring for these very small landfills, provided a two-year extension of the effective date for those landfills in order for them to rethink and act on their waste management options in light of the Court ruling. Some commentors proposed limiting the two-year extension to only the ground-water monitoring requirements of part 258. The Agency believes that many of those facilities that qualified for the small landfill exemption made a decision to remain open based on the costs of operation without ground-water monitoring. These landfills acted in good faith, and should therefore be allowed to reconsider their overall decision now that the costs have fundamentally changed. These facilities should be given a similar amount of time that other facilities have had to make such decisions. (All MSWLFs were originally given two years notice following promulgation of the criteria during which time they could decide whether to remain in operation when the criteria take effect.) Therefore, the final rule provides for an extension for all of the MSWLF criteria requirements, for a period of two years, for all MSWLF units that qualify for the small landfill exemption (§ 258.1(f)). (It is important to note that this extension is independent of, and not in addition to, the six-month extension for MSWLF units accepting less than 100 TPD.)

2. Alternatives for Ground-Water Monitoring

The U.S. Court of Appeals, in its decision, did not preclude the possibility that the Agency could establish separate ground-water monitoring standards for the small dry/remote landfills that take such factors as size, location, and climate into account. Therefore, in the proposal, EPA requested comments on alternative ground-water monitoring requirements for these facilities.

While the Agency received a number of comments supporting alternative ground-water monitoring requirements for these very small landfills, several commentors requested additional time to provide suggested alternatives. Therefore, the Agency will continue to maintain an open dialogue with all interested parties to discuss whether alternative ground-water monitoring requirements should be established and will continue to accept information on alternatives. Information and suggestions on alternative ground-water monitoring requirements can be sent to "Alternative Ground-Water Monitoring", Office of Solid Waste (OS–301), U.S. Environmental Protection Agency Headquarters, 401 M Street, SW., Washington, DC 20460.

Commentors also suggested that the Agency set an effective date for the ground-water monitoring requirements for these very small landfills two years after the promulgation of regulations regarding alternative ground-water monitoring for these facilities. The point of today's action is to respond to the Court's mandate. At this time, the Agency is still investigating this issue and cannot be certain that practicable alternatives for detecting ground-water contamination will exist for MSWLF units that would qualify for the exemption under § 258.1(f). Therefore, today's final rule does not tie the effective date of ground-water monitoring for landfills that qualify for the small/arid and remote exemption to promulgation of alternative ground-water monitoring requirements.

D. Modification of Closure Provisions for Owners/Operators Ceasing Receipt of Waste by Their Respective Effective Date

The proposed rule modified the closure requirements for MSWLFs ceasing receipt of waste before the effective date by requiring these owners and operators to complete cover installation by October 9, 1994 rather than six months after last receipt of waste. Commentors agreed with the assessment of the problems associated with completion of closure activities within six months of last receipt of waste. Some commentors restated their view that the requirement to finish closure during the late fall/winter months of October through March would be most difficult and subject their facilities to delays, if not rendering it impossible to complete within the six month time frame.

A few commentors suggested that the Agency extend the completion date for closure activities beyond the proposed October 9, 1994 to accommodate their specific situation. EPA believes that the October 9, 1994 deadline provides sufficient time for owners and operators of closing landfills to complete cover installation. This would mean that owners/operators that are subject to the October 9, 1993 effective date would have at least one year to install a cover, while owners and operators of landfills subject to the April 9, 1994 effective date would have at least six months to install a cover. Both time frames should provide at least six months of moderate weather during which to plan and install a landfill cover.

Therefore, the final rule retains the requirement that owners and operators ceasing receipt of waste before their effective date (either October 9, 1993 or April 9, 1994) complete cover installation by October 9, 1994. Owners/operators of very small landfills that qualify for the extension in 258.1(f) who cease receipt of waste prior to the new effective date of October 9, 1995 must complete cover installation by October 9, 1996. As in the October 9, 1991 final rule, owners and operators failing to install a cover by these new dates will subject the MSWLF unit to all of the requirements of part 258.

E. MSWLFs Receiving Flood Debris

A tremendous volume of debris from the Great Flood of 1993 in the Midwest is expected to strain the capacity of certain MSWLFs in that region as well as interfere with their efforts to comply with the criteria. On July 28, 1993, EPA asked for comments in the proposal on how to accommodate landfills that will be affected by this flood-related debris, given the original October 9, 1993 effective date for the MSWLF criteria and the extensions proposed at that time. The comments received generally acknowledge the need to provide some relief to such landfills. While some commentors requested a special two-year or open-ended extension, others indicated that six months would generally suffice, based on past experience in dealing with floods and on existing landfill capacity. Several commentors requested that states be delegated the authority to grant targeted relief to MSWLFs within their state that were in need.

After reviewing and considering comments, the Agency developed a regulatory scenario that meets the Agency's dual goals of granting relief to those MSWLF units affected by the flood of '93 while maintaining simplicity for the purpose of implementation. The final rule contains a two-stage approach for extending the effective date for such landfills, which is independent of the extensions discussed earlier in this preamble (e.g., for MSWLFs receiving less than 100 TPD).

First, existing MSWLF units and lateral expansions of existing MSWLF units may continue to receive waste up to April 9, 1994, without being subject to part 258 (except the final cover requirement), if the state determines that they are needed to receive flood-related waste from a Federally-designated disaster area resulting from the Great Flood of 1993. This provision responds to EPA's belief that in most cases, six months will be adequate to handle flood-related waste especially for historically smaller landfills that ordinarily would have qualified for the six-month extension for landfills receiving less than 100 TPD, but now exceed the tonnage limit due to acceptance of flood debris. As with today's six-month extension for MSWLF units accepting 100 TPD or less, the extension for MSWLF units accepting flood-related waste is limited only to existing units and lateral expansions of existing units; it is not intended for new units.

Second, existing MSWLF units and lateral expansions of existing MSWLF units that have received a six (6) month extension, may continue to receive waste without being subject to part 258 (except the final cover requirements), for an additional period of time up to six (6) months beyond April 9, 1994, if the state determines that the MSWLF unit is needed to receive flood-related waste from a Federally-designated disaster area resulting from the Great Flood of 1993. This second provision will allow those states that believe that their owners and operators may need to operate for an additional period of time after April 9, 1994, to continue to operate up to another six months without being subject to part 258, only on an as-needed basis determined by the state. EPA encourages states to limit the use of this additional six month extension only to situations where local hardships will occur if the site is not available for continued flood cleanup activities. EPA does not intend this flood-related extension to delay compliance any longer than is necessary to meet clean-up needs, especially for larger facilities that are not subject to the general six-month extension discussed earlier. In no case, however, may a state extend the effective date for these landfills beyond October 9, 1994.

Owners and operators of MSWLF units who receive an extension to receive flood waste and cease receipt of waste at the end of that extension, must complete cover installation within one year of the date on which the extension ended, but in no case shall the cover installation extend beyond October 9, 1995. Owners and operators of MSWLF units that continue to accept waste after their extension expires must comply with all of the part 258 requirements, including: (1) The ground-water monitoring requirements in accordance with the schedule in 258.50(c) or in accordance with an approved state/tribe schedule and (2) the financial assurance requirements by April 9, 1995.

F. Other Issues Pertaining to the July 28, 1993 Proposal

1. Sewage Sludge Disposal

Commentors agreed that EPA should not grant removal credits authority to a POTW unless the POTW sends its sewage sludge to a MSWLF unit that complies with the full panoply of the part 258 rule requirements. Hence, EPA will not grant removal credits authority to POTWs if they send their sludge to landfills using one of today's extensions (e.g., small landfills that choose to take advantage of the six-month extension, or very small landfills that qualify for the two-year extension), since such landfills will not be in full compliance with part 258.

2. Effects of the Extension on Source Reduction and Recycling

One commentor felt that an extension to the MSWLF criteria effective date would undercut recycling and source reduction due to continuation of "cheap" landfill tipping fees. EPA promotes an integrated waste management approach favoring source reduction and recycling as the preferred options. EPA does not believe that this rule will create significant negative effects on the Agency's goal of increasing cost-effective source reduction and recycling. This is a limited extension, in most cases lasting only for a six month time frame and as discussed earlier, affecting only 15 percent of all waste. In addition, many states have already closed or are in the process of closing their inadequate landfills that would fail to meet the MSWLF criteria requirements. The overall effect of the criteria continues to be supportive of both safer disposal and more incentives for alternatives to disposal.

IV. Summary of This Rule

Table I provides a summary of the changes to the effective dates of the MSWLF criteria as outlined in today's final rule.

TABLE I.—SUMMARY OF CHANGES TO THE EFFECTIVE DATES OF THE MSWLF CRITERIA

	MSWLF units accepting greater than 100 TPD	MSWLF units accepting less than 100 TPD; are not on the NPL; and are located in a state that has submitted an application for approval by 10/9/93	MSWLF units that meet the small landfill exemption in 40 CFR § 258.1(f)	MSWLF units receiving flood-related waste
General effective date[1]	October 9, 1993	April 9, 1994	October 9, 1995	Up to October 9, 1994 as determined by State in six month intervals.

TABLE 1.—SUMMARY OF CHANGES TO THE EFFECTIVE DATES OF THE MSWLF CRITERIA—Continued

	MSWLF units accepting greater than 100 TPD	MSWLF units accepting less than 100 TPD; are not on the NPL; and are located in a state that has submitted an application for approval by 10/9/93	MSWLF units that meet the small landfill exemption in 40 CFR § 258.1(f)	MSWLF units receiving flood-related waste
This is the effective date for location, operation, design, and closure/post-closure.				
Date by which to close if cease receipt of waste by the general effective date.	October 9, 1994	October 9, 1994	October 9, 1996	Within one year of date determined by State; no later than October 9, 1995.
Effective date of groundwater monitoring and corrective action.	Prior to receipt of waste for new units; October 9, 1994 through October 9, 1996 for existing units and lateral expansions.	October 9, 1994 for new units; October 9, 1994 through October 9, 1996 for existing and lateral expansions.	October 9, 1995 for new units; October 9, 1996 for existing and lateral expansions.	October 9, 1994 for new units; October 9, 1994 through October 9, 1996 for existing and lateral expansions.
Effective date of financial assurance requirements.	April 9, 1995	April 9, 1995	October 9, 1995	April 9, 1995.

[1] If a MSWLF receives waste after this date the unit must comply with all of Part 258.

V. Economic and Regulatory Impacts

A. Regulatory Impact Analysis

Under Executive Order 12291, EPA must determine whether a new regulation is a "major" rule and prepare a Regulatory Impact Analysis (RIA) in connection with a major rule. A "major" rule is defined as one that is likely to result in: (1) an annual effect on the economy of $100 million or more; (2) a major increase in costs or prices for consumers, individual industries, Federal, state/Tribal, and local government agencies or geographic regions; or (3) significant adverse effects on competition, employment, investment, productivity, innovation or on the ability of U.S.-based enterprises to compete with foreign-based enterprises in domestic or export markets.

The amendments to the regulations outlined in this rule will, except for the provision requiring dry/remote very small landfills to perform ground-water monitoring, have the effect of reducing requirements imposed by the 40 CFR Part 258 criteria. While the Agency estimates that increased costs to households for the ground-water monitoring requirements added as a result of the Court's decision may be significant for some of the very smallest communities, the Agency does not believe that this is a major rule for the purposes of determining whether to conduct an RIA. Moreover, under today's final rule, owners and operators of MSWLF units that meet the small landfill exemption of § 258.1 (f) are provided regulatory relief by a delayed effective date.

EPA has updated and revised the cost estimates reported in the preamble for the proposal for today's rule. A detailed explanation of unit costs and methodology can be found in a technical memorandum to the docket.

In estimating the national annualized costs attributable to the removal of the ground-water monitoring exemption for dry/small landfills, the Agency defined small landfills as those accepting less than 20 tons per day (TPD), and dry landfills as those located in areas receiving less than 25 inches of precipitation per year. (The Agency does not have complete data on the number of very small landfills that qualify for the exemption because they are remote; that is, because they experience three consecutive months with no surface transportation. However, the Agency believes that most of these landfills are captured in the assumptions used to develop the estimated number of small arid landfills.) EPA assumed a universe of 750 dry/small landfills will be operating in 1995 (approximately 517 1 TPD landfills and 232 10 TPD landfills). This estimate is derived from the municipal landfill survey of 1986, and is based upon the closure dates reported by landfills at that time. EPA assumes landfills which reported closure dates prior to 1995 will have closed and those communities have turned to larger landfills which would not be affected by today's rule. For landfills which reported closure dates after 1995, EPA estimated ground-water monitoring costs.

EPA developed national costs estimates using most of the assumptions used in the Regulatory Impact Analysis (RIA) developed for the revised Criteria. For the purposes of this analysis, EPA assumed that landfills would monitor ground water during the operating life and for a thirty year post-closure care period (the post-closure care period requirement may vary in an approved state). EPA estimated costs for two representative sizes under 20 TPD: A 10 TPD landfill and a 1 TPD landfill. The Agency assumed that for a 10 TPD landfill, five well clusters, with three wells each would be used. For a one TPD landfill, EPA assumed three well clusters with three wells each would be used. EPA used average unit capital costs for ground-water monitoring, assuming a well depth of 140 feet. The Agency recognizes that these average costs may underestimate costs to some individual landfills which, due to remoteness or site-specific characteristics (e.g., high depth to ground water), may have higher well construction costs than estimated. For example, the depth to ground water in some dry areas can be several hundred feet. Digging the wells deeper will likely result in additional costs of approximately $35 to $50 for each additional foot. This means that the difference in cost of a well cluster extending to 140 feet versus a well cluster extending to 300 feet would be approximately 25% more for the well construction costs, which would increase the initial hydrogeologic study and construction costs incurred in one year by approximately 8 percent for a 1 TPD landfill and 11 percent for a 10 TPD landfill. Additional well depths would likewise continue to increase costs. One commentor from Nevada indicated that the depth to ground water can be over 1,000 feet. Clearly the costs of digging a well in this situation will be higher than estimated here.

Additionally, the costs of well construction in remote areas could be higher if an expense to transport equipment to the site is incurred. This may be a significant cost to communities which are very remote and have limited access.

EPA assumed it will cost less to comply with the ground-water monitoring requirements in today's rule for landfills located in states already requiring ground-water monitoring (39 states required ground-water monitoring in 1991).

EPA assumed that landfills with short remaining lives would distribute the costs of the ground-water monitoring over the life of the new replacement landfill.[1] This is a reasonable assumption for municipalities which control tipping fees for residents and have the ability to spread the costs of ground-water monitoring over a longer time period. It will not always be possible for private landfill owners to annualized these costs over post-closure years.

EPA estimates that the national annualized costs of requiring ground-water monitoring for all dry/small landfills is approximately $13 million per year (in 1992 dollars). This estimate represents potential costs resulting from the court decision to require ground-water monitoring for all dry/small landfills. EPA expects, however, that some dry/small landfills would have joined a regionalized waste management system prior to the implementation date, and thus will not incur these ground-water monitoring costs.

Costs to individual landfills will vary greatly. Landfills located in states which already require ground-water monitoring may not experience any additional costs. Landfills located in states with no ground-water requirements may incur the full cost of ground-water monitoring.

Size will affect landfill cost. EPA estimates that the annualized cost (for thirty years) for ground-water monitoring at a 10 TPD landfill, with a ten year operating life, would be approximately $32,000 or $32 per household per year. The annualized cost for ground-water monitoring at a 1 TPD landfill, with a ten year operating life, would be approximately $22,000 or $222 per household per year. Clearly, costs to the very small landfills (e.g., 1 TPD) may be high per household.

The Agency does not believe a significant number of MSWLFs will experience corrective action costs due to the Court's decision for several reasons. First, it is unlikely that continued operation of these small landfills will result in ground-water contamination that requires corrective action. Because these landfills generally are located in dry areas receiving less than 25 inches of precipitation per year, very little leachate will be available for release to the ground water. Additionally, many of these dry/small landfills are situated above aquifers that typically are located several hundred feet below the ground surface, thereby creating a significant natural barrier to threat of contamination. Second, even if these landfill owners and operators detected contamination that would trigger corrective action, the MSWLF criteria currently allow the Director of a state with an EPA-approved permit program to waive corrective action under the circumstances outlined in 40 CFR 258.57(e). Third, of the small landfills that would have qualified for the small landfill exemption, it is difficult to estimate the number of these landfills that will continue to operate now that they are required to perform ground-water monitoring. Many will choose to close because of these new requirements.

Thus, given these factors, it is difficult to estimate the national cost impact of corrective action on these small landfills. The Agency believes that few would contaminate ground water and be required to perform these clean-up activities. However, if a landfill did trigger corrective action in a state that required clean-up, the Agency estimates that the average total annualized cost (over 20 years) of corrective action for that landfill would range from approximately $160,000 to $350,000 per year. These costs assume pump and treat clean-up technology and a 40-year post-closure care period.

Again, most of the cost assumptions in this estimate are based on unit cost assumptions from the Regulatory Impact Analysis for the Revised Subtitle D Criteria found in docket number F-91-CMLF-FFFFF.

The Agency believes that the final rule does not meet the definition of a major regulation. Thus, the Agency is not conducting a Regulatory Impact Analysis at this time. Today's final rule has been submitted to the Office of Management and Budget (OMB) for review as required by Executive Order 12291.

B. Regulatory Flexibility Act

The Regulatory Flexibility Act (5 U.S.C. 601 et seq.) requires an agency to prepare, and make available for public comment, a regulatory flexibility analysis that describes the impact of a proposed or final rule on small entities (i.e., small businesses, small organizations, and small governmental jurisdictions). No regulatory flexibility analysis is required if the head of an agency certifies the rule will not have significant economic impact on a substantial number of small entities.

The estimates of potential total annualized costs for specific landfills are discussed above in Section V-A. However, not all landfills will experience these costs. Many landfills are located in states that already require ground-water monitoring and/or corrective action and thus there would be little incremental cost to these landfills due to the court decision. In addition, EPA believes there will be a reduction in small landfills over time as these landfills close and communities regionalize.

The amendments to 40 CFR part 258, except for the provision requiring dry/remote small landfills accepting less than 20 TPD to perform ground-water monitoring, have the general effect of reducing the requirements of the part 258 criteria, thereby imposing no additional economic impact to small entities.

The provision requiring dry/remote landfills accepting less than 20 TPD to perform ground-water monitoring could have a significant economic impact on some of these small entities. Agency data indicate that economic impact will vary with size, with larger landfills experiencing a relatively moderate cost increase per household when compared to smaller landfills where economies of scale are not available. Agency data indicate that the average annualized costs of ground-water monitoring for a MSWLF unit accepting approximately 10 TPD operating for 10 years would cost about $30 per household when annualized over 30 years ($65 per household when annualized over only the 10 year operating life). For landfills accepting less than one TPD (the Agency estimates that over one-half of all MSWLF units that qualify for the

[1] For example, a landfill which is expected to close in five years would distribute the costs across the five years plus the twenty years a new replacement landfill would operate. This ability to average costs of existing landfills and new replacement landfills was assumed in the RIA. Because the cost analysis in the RIA indicates that, except in the most remote or unaccessible areas, costs per ton for using a larger regional landfill is less expensive than for small landfills, EPA assumed communities would use regional waste facilities upon closure of small landfills. Since requirements for large landfills are not being affected by today's very small landfill ground-water monitoring requirements, no costs of the replacement landfill are included in cost estimates presented today.

exemption are in this size category), the average annualized cost would be about $220 per household when annualized over 30 years ($450 per household if annualized over only the 10 year operating life).

The Agency believes that estimated costs of $220 per household for the very smallest communities are significant. In the RIA for the revised criteria, the Agency used a threshold of $100 per household to identify moderate impacts. For the RIA, the Agency also looked at a second threshold; the Agency considered incremental costs that were greater than one percent of median household income as being "significant." 1990 Census data indicates that median household income across the United States is $30,000. However, EPA recognizes that several communities have median household incomes below the national median. 1989 Census data indicate that 13.1 percent of all persons live below poverty level. Poverty level for a three person household is defined as $9,900 income per year. In communities where household incomes are below the national median, a $100 or higher cost per household could be close to one percent of household income and thus have a significant impact. Again, cost figures presented here are rough estimates using national unit costs; labor and equipment costs will vary per site and may be more expensive in rural, remote areas of the country. Also, the Agency assumed a specific ground-water monitoring system of 3 or 5 wells clusters depending on the size of the landfill. To the extent that landfills use different systems, costs will vary.

The Agency does not have a precise count of small landfills that will be affected by this rule. According to the 1986 landfill survey, many of the small landfills had plans to close by 1995. Others have closed as communities participate in regionalized waste management. Therefore, while EPA estimates, according to information from the 1986 survey, that there may be approximately 750 landfills that could be affected by today's rule, it is unclear how many actually are in this universe today.

While the Agency believes that the costs described above may have substantial impacts on some of the very smallest communities, the court decision leaves the Agency no choice but to promulgate these changes to ground-water monitoring requirements for dry/small landfills. However, as mentioned earlier, the Agency continues to solicit information on alternative ground-water monitoring procedures that could accommodate the practicable capability of small landfills through consideration of size, location, and climate, while ensuring that the program is adequate to detect contamination. It is the Agency's goal to identify alternative monitoring methods that would reduce the cost impacts described above.

C. Paperwork Reduction Act

The Agency has determined that there are no new reporting, notification, or recordkeeping provisions associated with today's final rule.

List of Subjects in 40 CFR Part 258

Corrective action, Ground-water monitoring, Household hazardous waste, Liner requirements, Liquids in landfills, State/Tribal permit program approval and adequacy, Security measures, Small quantity generators, Waste disposal, Water pollution control.

Dated: September 27, 1993.

Carol M. Browner,

Administrator.

For reasons set out in the preamble, title 40, chapter I, of the Code of Federal Regulations is amended as follows:

PART 258—CRITERIA FOR MUNICIPAL SOLID WASTE LANDFILLS

1. The authority citation for part 258 is revised to read as follows:

Authority: 42 U.S.C. 6907(a)(3), 6912(a), 6944(a) and 6949(c); 33 U.S.C. 1345 (d) and (e).

2. Section 258.1 is amended by revising paragraphs (d), (e), (f)(1) introductory text, (f)(3), and (j) to read as follows:

§ 258.1 Purpose, scope, and applicability.

* * * * *

(d)(1) MSWLF units that meet the conditions of 258.1(e)(2) and receive waste after October 9, 1991 but stop receiving waste before April 9, 1994, are exempt from all the requirements of this part 258, except the final cover requirement specified in § 258.60(a). The final cover must be installed by October 9, 1994. Owners or operators of MSWLF units described in this paragraph that fail to complete cover installation by October 9, 1994 will be subject to all the requirements of this part 258, unless otherwise specified.

(2) MSWLF units that meet the conditions of § 258.1(e)(3) and receive waste after October 9, 1991 but stop receiving waste before the date designated by the state pursuant to 258.1(e)(3), are exempt from all the requirements of this part 258, except the final cover requirement specified in § 258.60(a). The final cover must be installed within one year after the date designated by the state pursuant to 258.1(e)(3). Owners or operators of MSWLF units described in this paragraph that fail to complete cover installation within one year after the date designated by the state pursuant to 258.1(e)(3) will be subject to all the requirements of this part 258, unless otherwise specified.

(3) MSWLF units that meet the conditions of 258.1(f)(1) and receive waste after October 9, 1991 but stop receiving waste before October 9, 1995, are exempt from all the requirements of this part 258, except the final cover requirement specified in 258.60(a). The final cover must be installed by October 9, 1996. Owners or operators of MSWLF units described in this paragraph that fail to complete cover installation by October 9, 1996 will be subject to all the requirements of this part 258, unless otherwise specified.

(4) MSWLF units that do not meet the conditions of 258.1 (e)(2), (e)(3), or (f) and receive waste after October 9, 1991 but stop receiving waste before October 9, 1993, are exempt from all the requirements this part 258, except the final cover requirement specified in 258.60(a). The final cover must be installed by October 9, 1994. Owners or operators of MSWLF units described in this paragraph that fail to complete cover installation by October 9, 1994 will be subject to all the requirements of this part 258, unless otherwise specified.

(e)(1) The compliance date for all requirements of this part 258, unless otherwise specified, is October 9, 1993 for all MSWLF units that receive waste on or after October 9, 1993, except those units that qualify for an extension under (e)(2), (3), or (4) of this section.

(2) The compliance date for all requirements of this part 258, unless otherwise specified, is April 9, 1994 for an existing MSWLF unit or a lateral expansion of an existing MSWLF unit that meets the following conditions:

(i) The MSWLF unit disposed of 100 tons per day or less of solid waste during a representative period prior to October 9, 1993;

(ii) The unit does not dispose of more than an average of 100 TPD of solid waste each month between October 9, 1993 and April 9, 1994;

(iii) The MSWLF unit is located in a state that has submitted an application for permit program approval to EPA by October 9, 1993, is located in the state of Iowa, or is located on Indian Lands or Indian Country; and

(iv) The MSWLF unit is not on the National Priorities List (NPL) as found in Appendix B to 40 CFR part 300.

(3) The compliance date for all requirements of this part 258, unless otherwise specified, for an existing MSWLF unit or lateral expansion of an existing MSWLF unit receiving flood-related waste from federally-designated areas within the major disasters declared for the states of Iowa, Illinois, Minnesota, Wisconsin, Missouri, Nebraska, Kansas, North Dakota, and South Dakota by the President during the summer of 1993 pursuant to 42 U.S.C. 5121 *et seq.*, shall be designated by the state in which the MSWLF unit is located in accordance with the following:

(i) The MSWLF unit may continue to accept waste up to April 9, 1994 without being subject to part 258, if the state in which the MSWLF unit is located determines that the MSWLF unit is needed to receive flood-related waste from a federally-designated disaster area as specified in (e)(3) of this section.

(ii) The MSWLF unit that receives an extension under paragraph (e)(3)(i) of this section may continue to accept waste up to an additional six months beyond April 9, 1994 without being subject to part 258, if the state in which the MSWLF unit is located determines that the MSWLF unit is needed to receive flood-related waste from a federally-designated disaster area specified in (e)(3) of this section.

(iii) In no case shall a MSWLF unit receiving an extension under paragraph (e)(3) (i) or (ii) of this section accept waste beyond October 9, 1994 without being subject to part 258.

(4) The compliance date for all requirements of this part 258, unless otherwise specified, is October 9, 1995 for a MSWLF unit that meets the conditions for the exemption in paragraph (f)(1) of this section.

(f)(1) Owners or operators of new MSWLF units, existing MSWLF units, and lateral expansions that dispose of less than twenty (20) tons of municipal solid waste daily, based on an annual average, are exempt from subpart D of this part, so long as there is no evidence of ground-water contamination from the MSWLF unit, and the MSWLF unit serves:

* * * * *

(3) If the owner or operator of a new MSWLF unit, existing MSWLF unit, or lateral expansion has knowledge of ground-water contamination resulting from the unit that has asserted the exemption in paragraph (f)(1)(i) or (f)(1)(ii) of this section, the owner or operator must notify the state Director of such contamination and, thereafter, comply with subpart D of this part.

* * * * *

(j) Subpart G of this part is effective April 9, 1995, except for MSWLF units meeting the requirements of paragraph (f)(1) of this section, in which case the effective date of subpart G is October 9, 1995.

* * * * *

3. Section 258.2 is amended by revising the definitions of "Existing MSWLF unit" and "New MSWLF unit" and by adding definitions for "Indian lands" and "Indian tribe" to read as follows:

258.2 Definitions.

* * * * *

Existing MSWLF unit means any municipal solid waste landfill unit that is receiving solid waste as of the appropriate dates specified in § 258.1(e). Waste placement in existing units must be consistent with past operating practices or modified practices to ensure good management.

* * * * *

Indian lands or *Indian country* means:

(1) All land within the limits of any Indian reservation under the jurisdiction of the United States Government, notwithstanding the issuance of any patent, and including rights-of-way running throughout the reservation;

(2) All dependent Indian communities within the borders of the United States whether within the original or subsequently acquired territory thereof, and whether within or without the limits of the State; and

(3) All Indian allotments, the Indian titles to which have not been extinguished, including rights of way running through the same.

Indian Tribe or *Tribe* means any Indian tribe, band, nation, or community recognized by the Secretary of the Interior and exercising substantial governmental duties and powers on Indian lands.

* * * * *

New MSWLF unit means any municipal solid waste landfill unit that has not received waste prior to October 9, 1993, or prior to October 9, 1995 if the MSWLF unit meets the conditions of § 258.1(f)(1).

* * * * *

4. Section 258.50 is amended by revising paragraph (c) introductory text, by redesignating paragraphs (e), (f) and (g) as paragraphs (f), (g), and (h); and by adding paragraph (e) to read as follows.

258.50 Applicability.

* * * * *

(c) Owners and operators of MSWLF units, except those meeting the conditions of 258.1(f), must comply with the ground-water monitoring requirements of this part according to the following schedule unless an alternative schedule is specified under paragraph (d) of this section:

* * * * *

(e) Owners and operators of all MSWLF units that meet the conditions of 258.1(f)(1) must comply with the ground-water monitoring requirements of this part according to the following schedule:

(1) All MSWLF units less than two miles from a drinking water intake (surface or subsurface) must be in compliance with the ground-water monitoring requirements specified in 258.51 through 258.55 by October 9, 1995;

(2) All MSWLF units greater than two miles from a drinking water intake (surface or subsurface) must be in compliance with the ground-water monitoring requirements specified in 258.51 through 258.55 by October 9, 1996.

* * * * *

5. Section 258.70 is amended by revising paragraph (b) to read as follows

§ 258.70 Applicability and effective date.

* * * * *

(b) The requirements of this section are effective April 9, 1995 except for MSWLF units meeting the conditions of 258.1(f)(1), in which case the effective date is October 9, 1995.

6. Section 258.74 is amended by revising paragraph (a)(5) to read as follows:

§ 258.74 Allowable mechanisms.

* * * * *

(a) * * *

(5) The initial payment into the trust fund must be made before the initial receipt of waste or before the effective date the requirements of this section (April 9, 1995, or October 9, 1995 for MSWLF units meeting the conditions of 258.1(f)(1)), whichever is later, in the case of closure and post-closure care, or no later than 120 days after the corrective action remedy has been selected in accordance with the requirements of 258.58.

* * * * *

7. Section 258.74 is amended by revising the third sentence of paragraph (b)(1); by revising the second sentence of paragraph (c)(1); and by revising the second sentence of paragraph (d)(1) to read as follows:

§ 258.74 Allowable mechanisms.

* * * * *

(b) * * *

(1) * * * The bond must be effective before the initial receipt of waste or before the effective date of the requirements of this section (April 9, 1995, or October 9, 1995 for MSWLF units meeting the conditions of 258.1(f)(1)), whichever is later, in the case of closure and post-closure care, or no later than 120 days after the corrective action remedy has been selected in accordance with the requirements of § 258.58.

* * * * *

(c) * * *

(1) * * * The letter of credit must be effective before the initial receipt of waste or before the effective date of the requirements of this section (April 9, 1995, or October 9, 1995 for MSWLF units meeting the conditions of 258.1(f)(1)), whichever is later, in the case of closure and post-closure care, or no later than 120 days after the corrective action remedy has been selected in accordance with the requirements of § 258.58.

* * * * *

(d) * * *

(1) * * * The insurance must be effective before the initial receipt of waste or before the effective date of the requirements of this section (April 9, 1995, or October 9, 1995 for MSWLF units meeting the conditions of 258.1(f)(1)), whichever is later, in the case of closure and post-closure care, or no later than 120 days after the corrective action remedy has been selected in accordance with the requirements of § 258.58.

* * * * *

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dealers, or traders) that provides a reasonable basis to determine fair market value by disseminating either recent price quotations (including rates, yields, or other pricing information) of one or more identified brokers, dealers, or traders or actual prices (including rates, yields, or other pricing information) of recent transactions. An interdealer market does not include a directory or listing of brokers, dealers, or traders for specific contracts (such as yellow sheets) that provides neither price quotations nor actual prices of recent transactions.

(ii) *Debt market.* A debt market exists with respect to a debt instrument if price quotations for the instrument are readily available from brokers, dealers, or traders. A debt market does not exist with respect to a debt instrument if—

(A) No other outstanding debt instrument of the issuer (or of any person who guarantees the debt instrument) is traded on an established financial market described in paragraph (b)(1)(i), (ii), (iii), (iv), (v), or (vi) of this section (other traded debt);

(B) The original stated principal amount of the issue that includes the debt instrument does not exceed $25 million;

(C) The conditions and covenants relating to the issuer's performance with respect to the debt instrument are materially less restrictive than the conditions and covenants included in all of the issuer's other traded debt (e.g., the debt instrument is subject to an economically significant subordination provision whereas the issuer's other traded debt is senior); or

(D) The maturity date of the debt instrument is more than 3 years after the latest maturity date of the issuer's other traded debt.

(c) *Notional principal contracts.* For purposes of section 1092(d)—

(1) A notional principal contract (as defined in § 1.446–3(c)(1)) constitutes personal property of a type that is actively traded if contracts based on the same or substantially similar specified indices are purchased, sold, or entered into on an established financial market within the meaning of paragraph (b) of this section; and

(2) The rights and obligations of a party to a notional principal contract are rights and obligations with respect to personal property and constitute an interest in personal property.

(d) *Effective dates.* Paragraph (b)(1)(vii) of this section applies to positions entered into on or after October 14, 1993. Paragraph (c) of this section applies to positions entered into on or after July 8, 1991.

Approved: October 4, 1993

Margaret Milner Richardson,

Commissioner of Internal Revenue.

Leslie Samuels,

Assistant Secretary of the Treasury.

[FR Doc. 93–25192 Filed 10–8–93; 1:26 pm]

BILLING CODE 4830-01-U

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 258

[FRL–4788–5]

Solid Waste Disposal Facility Criteria; Delay of the Effective Date

AGENCY: Environmental Protection Agency (EPA).

ACTION: Final rule; corrections.

SUMMARY: EPA is making technical corrections to the Table "Summary of Changes to the Effective Dates of the MSWLF Criteria" which was included in the preamble to the final rule "Solid Waste Disposal Facility Criteria; Delay of the Effective Date" that appeared in the Federal Register on October 1, 1993 (58 FR 51536). This correction notice will amend errors that appear in the portion of the table related to "Effective date of ground-water monitoring and corrective action."

EFFECTIVE DATE: October 14, 1993.

FOR FURTHER INFORMATION CONTACT: Mr. David Hockey (202) 260–7596.

SUPPLEMENTARY INFORMATION: On October 1, 1993, EPA promulgated a final rule under Subtitle D of the Resource Conservation and Recovery Act and section 405 of the Clean Water Act delaying the effective date of the Municipal Solid Waste Landfill Criteria (58 FR 51536). The preamble to the rule included a table on pages 51543 and 51544 that summarized the effective dates of the final rule. That rule contained minor editorial errors that EPA is correcting in this action. The corrections are for the table "Summary of Changes to the Effective Dates of the MSWLF Criteria" for the row titled "Effective date of ground-water monitoring and corrective action." For the category of MSWLF units accepting 100 TPD or less; are not on the NPL; and are located in a state that has submitted an application for approval by 10/9/93: the effective date for new units should read October 9, 1993 and not October 9, 1994. For the category of MSWLF units that meet the small landfill exemption in 40 CFR 258.1(f): the effective date for existing units and lateral expansions should read October 9, 1995 through October 9, 1996 and not October 9, 1996 only. For the category of MSWLF units receiving flood-related waste: the effective date for new units should read October 9, 1993 and not October 9, 1994.

Correction of Publication

Accordingly, the final rule is corrected by revising the table on pages 51543 and 51544 to read as follows:

SUMMARY OF CHANGES TO THE EFFECTIVE DATES OF THE MSWLF CRITERIA[1]

	MSWLF units accepting greater than 100 TPD	MSWLF units accepting 100 TPD or less; are not on the NPL; and are located in a state that has submitted an application for approval by 10/9/93	MSWLF units that meet the small landfill exemption in 40 CFR § 258.1(f)	MSWLF units receiving flood-related waste
General effective date[2]	October 9, 1993	April 9, 1994	October 9, 1995	Up to October 9, 1994 as determined by State.
This is the effective date for location, operation, design, and closure/post-closure.				
Date by which to install final cover if cease receipt of waste by the general effective date.	October 9, 1994	October 9, 1994	October 9, 1996	Within one year of date determined by State; no later than October 9, 1995.

SUMMARY OF CHANGES TO THE EFFECTIVE DATES OF THE MSWLF CRITERIA[1]—Continued

	MSWLF units accepting greater than 100 TPD	MSWLF units accepting 100 TPD or less; are not on the NPL; and are located in a state that has submitted an application for approval by 10/9/93	MSWLF units that meet the small landfill exemption in 40 CFR § 258.1(f)	MSWLF units receiving flood-related waste
Effective date of ground-water monitoring and corrective action.	Prior to receipt of waste for new units; October 9, 1994 through October 9, 1996 for existing units and lateral expansions.	October 9, 1993 for new units; October 9, 1994 through October 9, 1996 for existing units and lateral expansions.	October 9, 1995 for new units; October 9, 1995 through October 9, 1996 for existing units and lateral expansions.	October 9, 1993 for new units; October 9, 1994 through October 9, 1996 for existing units and lateral expansions.
Effective date of financial assurance requirements.	April 9, 1995	April 9, 1995	October 9, 1995	April 9, 1995.

[1] This Table provides a summary of the major changes to the effective dates. See the final rule and preamble published on October 1, 1993 (58 *FR* 51536) for a full discussion of all changes and related conditions. All other versions of this table, including the version in the October 1, 1993 Federal Register (58 FR 51536) on pages 51543 and 51544, are obsolete.

[2] If a MSWLF unit receives waste after this date, the unit must comply with all of Part 258.

Authority

EPA is promulgating these regulations under the authority of sections 2002 and 4010(c) of the Resource Conservation and Recovery Act of 1976, as amended, 42 USC 6912.

Dated: October 5, 1993.

Walter W. Kovalick, Jr.,

Acting Assistant Administrator, Office of Solid Waste and Emergency Response.

[FR Doc. 93–25100 Filed 10–13–93; 8:45 am]

BILLING CODE 6560–50–P

GENERAL SERVICES ADMINISTRATION

41 CFR Part 302–6

[FTR Amendment 31]

RIN 3090–AE92

Federal Travel Regulation; Increase in Maximum Reimbursement Limitations for Real Estate Sale and Purchase Expenses

AGENCY: Federal Supply Service, GSA.

ACTION: Final rule.

SUMMARY: This final rule amends the Federal Travel Regulation (FTR) to increase the maximum dollar limitations on reimbursement for allowable real estate sale and purchase expenses incident to a change of official station. Section 5724a(a)(4)(B) of title 5, United States Code requires that the dollar limitations be updated effective October 1 of each year based on the percent change, if any, in the Consumer Price Index for All Urban Consumers, United States City Average, Housing Component, for December of the preceding year over December of the second preceding year. This final rule will have a favorable impact on Federal employees authorized to relocate in the interest of the Government since it increases relocation allowance maximums.

EFFECTIVE DATE: This final rule is effective October 1, 1993, and applies to employees whose effective date of transfer is on or after October 1, 1993. For purposes of this regulation, the effective date of transfer is the date on which the employee reports for duty at the new official station.

FOR FURTHER INFORMATION CONTACT: Jane E. Groat, Transportation Management Division (FBX), Washington, DC 20406, telephone 703–305–5745.

SUPPLEMENTARY INFORMATION: This final rule makes the annual adjustment to the maximum reimbursement limitations for the sale and purchase of an employee's residence when the employee transfers in the interest of the Government. The total amount of expenses that may be reimbursed in connection with the sale of a residence shall not exceed 10 percent of the actual sale price or $21,340, whichever is the lesser amount. The total amount of expenses that may be reimbursed in connection with the purchase of a residence shall not exceed 5 percent of the purchase price or $10,669, whichever is the lesser amount.

The General Services Administration (GSA) has determined that this rule is not a major rule for the purposes of Executive Order 12291 of February 17, 1981, because it is not likely to result in an annual effect on the economy of $100 million or more; a major increase in costs to consumers or others; or significant adverse effects. GSA has based all administrative decisions underlying this rule on adequate information concerning the need for, and consequences of, this rule; has determined that the potential benefits to society from this rule outweigh the potential costs and has maximized the net benefits; and has chosen the alternative approach involving the least net cost to society.

List of Subjects in 41 CFR Part 302–6

Government employees, Relocation allowances and entitlements, Transfers

For the reasons set out in the preamble, 41 CFR part 302–6 is amended as follows:

PART 302–6—ALLOWANCE FOR EXPENSES INCURRED IN CONNECTION WITH RESIDENCE TRANSACTIONS

1. The authority citation for part 302–6 continues to read as follows:

Authority: 5 U.S.C. 5721–5734; 20 U.S.C. 905(a); E.O. 11609, 36 FR 13747, 3 CFR, 1971–1975 Comp., p. 586.

302–6.2 [Amended]

2. Section 302–6.2 is amended by removing the amount "$20,799" in paragraph (g)(1), and adding in its place the amount "$21,340"; and by removing the amount "$10,399" in paragraph (g)(2) and adding in its place the amount "$10,669".

Dated: September 8, 1993.

Roger W. Johnson,

Administrator of General Services.

[FR Doc. 93–25183 Filed 10–13–93; 8:45 am]

BILLING CODE 6820–24–F

F

ATTACHMENT F

Solid Waste Disposal Criteria Delay of the Effective Date

dealers, or traders) that provides a reasonable basis to determine fair market value by disseminating either recent price quotations (including rates, yields, or other pricing information) of one or more identified brokers, dealers, or traders or actual prices (including rates, yields, or other pricing information) of recent transactions. An interdealer market does not include a directory or listing of brokers, dealers, or traders for specific contracts (such as yellow sheets) that provides neither price quotations nor actual prices of recent transactions.

(ii) *Debt market.* A debt market exists with respect to a debt instrument if price quotations for the instrument are readily available from brokers, dealers, or traders. A debt market does not exist with respect to a debt instrument if—

(A) No other outstanding debt instrument of the issuer (or of any person who guarantees the debt instrument) is traded on an established financial market described in paragraph (b)(1)(i), (ii), (iii), (iv), (v), or (vi) of this section (other traded debt);

(B) The original stated principal amount of the issue that includes the debt instrument does not exceed $25 million;

(C) The conditions and covenants relating to the issuer's performance with respect to the debt instrument are materially less restrictive than the conditions and covenants included in all of the issuer's other traded debt (e.g., the debt instrument is subject to an economically significant subordination provision whereas the issuer's other traded debt is senior); or

(D) The maturity date of the debt instrument is more than 3 years after the latest maturity date of the issuer's other traded debt.

(c) *Notional principal contracts.* For purposes of section 1092(d)—

(1) A notional principal contract (as defined in § 1.446-3(c)(1)) constitutes personal property of a type that is actively traded if contracts based on the same or substantially similar specified indices are purchased, sold, or entered into on an established financial market within the meaning of paragraph (b) of this section; and

(2) The rights and obligations of a party to a notional principal contract are rights and obligations with respect to personal property and constitute an interest in personal property.

(d) *Effective dates.* Paragraph (b)(1)(vii) of this section applies to positions entered into on or after October 14, 1993. Paragraph (c) of this section applies to positions entered into on or after July 8, 1991.

Approved: October 4, 1993

Margaret Milner Richardson,

Commissioner of Internal Revenue.

Leslie Samuels,

Assistant Secretary of the Treasury.

[FR Doc. 93-25192 Filed 10-8-93; 1:26 pm]

BILLING CODE 4830-01-U

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 258

[FRL-4788-5]

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ACTION: Final rule; corrections.

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SUMMARY OF CHANGES TO THE EFFECTIVE DATES OF THE MSWLF CRITERIA [1]—Continued

	MSWLF units accepting greater than 100 TPD	MSWLF units accepting 100 TPD or less; are not on the NPL; and are located in a state that has submitted an application for approval by 10/9/93	MSWLF units that meet the small landfill exemption in 40 CFR §258.1(f)	MSWLF units receiving flood-related waste
Effective date of ground-water monitoring and corrective action.	Prior to receipt of waste for new units; October 9, 1994 through October 9, 1996 for existing units and lateral expansions.	October 9, 1993 for new units; October 9, 1994 through October 9, 1996 for existing units and lateral expansions.	October 9, 1995 for new units; October 9, 1995 through October 9, 1996 for existing units and lateral expansions.	October 9, 1993 for new units; October 9, 1994 through October 9, 1996 for existing units and lateral expansions.
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[2] If a MSWLF unit receives waste after this date, the unit must comply with all of Part 258.

Authority

EPA is promulgating these regulations under the authority of sections 2002 and 4010(c) of the Resource Conservation and Recovery Act of 1976, as amended. 42 USC 6912.

Dated: October 5, 1993.

Walter W. Kovalick, Jr.,

Acting Assistant Administrator, Office of Solid Waste and Emergency Response.

[FR Doc. 93–25100 Filed 10–13–93; 8:45 am]

BILLING CODE 6560-50-P

GENERAL SERVICES ADMINISTRATION

41 CFR Part 302–6

[FTR Amendment 31]

RIN 3090–AE92

Federal Travel Regulation; Increase in Maximum Reimbursement Limitations for Real Estate Sale and Purchase Expenses

AGENCY: Federal Supply Service, GSA.

ACTION: Final rule.

SUMMARY: This final rule amends the Federal Travel Regulation (FTR) to increase the maximum dollar limitations on reimbursement for allowable real estate sale and purchase expenses incident to a change of official station. Section 5724a(a)(4)(B) of title 5, United States Code requires that the dollar limitations be updated effective October 1 of each year based on the percent change, if any, in the Consumer Price Index for All Urban Consumers, United States City Average, Housing Component, for December of the preceding year over December of the second preceding year. This final rule will have a favorable impact on Federal employees authorized to relocate in the interest of the Government since it increases relocation allowance maximums.

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FOR FURTHER INFORMATION CONTACT: Jane E. Groat, Transportation Management Division (FBX), Washington, DC 20406, telephone 703–305–5745.

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The General Services Administration (GSA) has determined that this rule is not a major rule for the purposes of Executive Order 12291 of February 17, 1981, because it is not likely to result in an annual effect on the economy of $100 million or more; a major increase in costs to consumers or others; or significant adverse effects. GSA has based all administrative decisions underlying this rule on adequate information concerning the need for, and consequences of, this rule; has determined that the potential benefits to society from this rule outweigh the potential costs and has maximized the net benefits; and has chosen the alternative approach involving the least net cost to society.

List of Subjects in 41 CFR Part 302–6

Government employees, Relocation allowances and entitlements, Transfers.

For the reasons set out in the preamble, 41 CFR part 302–6 is amended as follows:

PART 302–6—ALLOWANCE FOR EXPENSES INCURRED IN CONNECTION WITH RESIDENCE TRANSACTIONS

1. The authority citation for part 302–6 continues to read as follows:

Authority: 5 U.S.C. 5721–5734; 20 U.S.C. 905(a); E.O. 11609, 36 FR 13747, 3 CFR, 1971–1975 Comp., p. 586.

302–6.2 [Amended]

2. Section 302–6.2 is amended by removing the amount "$20,799" in paragraph (g)(1), and adding in its place the amount "$21,340"; and by removing the amount "$10,399" in paragraph (g)(2) and adding in its place the amount "$10,669".

Dated: September 8, 1993.

Roger W. Johnson,

Administrator of General Services.

[FR Doc. 93–25183 Filed 10–13–93; 8:45 am]

BILLING CODE 6820–24–F

G

ATTACHMENT G

40 CFR 257; 40 CFR 258

agency determines there is sufficient interest.

(c) The State shall comply with the requirements of Office of Management and Budget Circular No. A-95.

(d) Copies of the final work program shall be placed in the State information depositories maintained under § 256.60(a)(2).

§ 256.62 Requirements for public participation in State regulatory development.

(a) The State shall conduct public hearings (and public meetings where the State determines there is sufficient interest) on State legislation and regulations, in accord with the State administrative procedures act, to solicit reactions and recommendations. Following the public hearings, a responsiveness summary shall be prepared and made available to the public in accord with 40 CFR 25.8.

(b) In advance of the hearings and meetings required by paragraph (a) of this section, the State shall prepare a fact sheet on proposed regulations or legislation, mail the fact sheet to agencies, organizations and individuals on the list maintained under § 256.60(a)(1) and place the fact sheet in the State information depositories maintained under § 256.60(a)(2).

§ 256.63 Requirements for public participation in the permitting of facilities.

(a) Before approving a permit application (or renewal of a permit) for a resource recovery or solid waste disposal facility the State shall hold a public hearing to solicit public reaction and recommendations on the proposed permit application if the State determines there is a significant degree of public interest in the proposed permit.

(b) This hearing shall be held in accord with 40 CFR 25.5.

§ 256.64 Requirements for public participation in the open dump inventory.

(a) The State shall provide an opportunity for public participation prior to submission of any classification of a facility as an open dump to the Federal Government. The State shall accomplish this by providing notice as specified in § 256.64(b) or by using other State administrative procedures which provide equivalent public participation.

(b) The State may satisfy the requirement of § 256.64(a) by providing written notice of the availability of the results of its classifications to all parties on the list required under § 256.60(a)(1) at least 30 days before initial submission of these classifications to the Federal Government. For those parties on the list required under § 256.60(a)(1) who are owners or operators of facilities classified as open dumps, such notice shall indicate that the facility has been so classified.

[46 FR 47052, Sept. 23, 1981]

§ 256.65 Recommendations for public participation.

(a) State and substate planning agencies should establish an advisory group, or utilize an existing group, to provide recommendations on major policy and program decisions. The advisory group's membership should reflect a balanced viewpoint in accord with 40 CFR 25.7(c).

(b) State and substate planning agencies should develop public education programs designed to encourage informed public participation in the development and implementation of solid waste management plans.

[44 FR 45079, July 31, 1979. Redesignated and amended at 46 FR 47052, Sept. 23, 1981]

PART 257—CRITERIA FOR CLASSIFICATION OF SOLID WASTE DISPOSAL FACILITIES AND PRACTICES

Sec.

Open dump means a facility for the disposal of solid waste which does not comply with this part.

Practice means the act of disposal of solid waste.

Sanitary landfill means a facility for the disposal of solid waste which complies with this part.

Sludge means any solid, semisolid, or liquid waste generated from a municipal, commercial, or industrial wastewater treatment plant, water supply treatment plant, or air pollution control facility or any other such waste having similar characteristics and effect.

Solid waste means any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities, but does not include solid or dissolved materials in domestic sewage, or solid or dissolved material in irrigation return flows or industrial discharges which are point sources subject to permits under section 402 of the Federal Water Pollution Control Act, as amended (86 Stat. 880), or source, special nuclear, or byproduct material as defined by the Atomic Energy Act of 1954, as amended (68 Stat. 923).

State means any of the several States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, Guam, American Samoa, and the Commonwealth of the Northern Mariana Islands.

[44 FR 53460, Sept. 13, 1979; 44 FR 58910, Oct. 12, 1979; 56 FR 51016, Oct. 9, 1991]

EFFECTIVE DATE NOTE: At 56 FR 51016, Oct. 9, 1991, § 257.2 revised the definition for "facility", and added definitions for "land application unit," "landfill," "municipal solid waste landfill unit," "surface impoundment," and "waste pile", effective October 9, 1993. For the convenience of the user, the revised and added text is set forth below:

§ 257.2 Definitions.

* * * * *

Facility means all contiguous land and structures, other appurtenances, and improvements on the land used for the disposal of solid waste.

* * * * *

Land application unit means an area where wastes are applied onto or incorporated into the soil surface (excluding manure spreading operations) for agricultural purposes or for treatment and disposal.

Landfill means an area of land or an excavation in which wastes are placed for permanent disposal, and that is not a land application unit, surface impoundment, injection well, or waste pile.

* * * * *

Municipal solid waste landfill (MSWLF) unit means a discrete area of land or an excavation that receives household waste, and that is not a land application unit, surface impoundment, injection well, or waste pile, as those terms are defined in this section. A MSWLF unit also may receive other types of RCRA Subtitle D wastes, such as commercial solid waste, nonhazardous sludge, and industrial solid waste. Such a landfill may be publicly or privately owned. An MSWLF unit may be a new MSWLF unit, an existing MSWLF unit or a lateral expansion.

* * * * *

Surface impoundment or *impoundment* means a facility or part of a facility that is a natural topographic depression, human-made excavation, or diked area formed primarily of earthern materials (although it may be lined with human-made materials), that is designed to hold an accumulation of liquid wastes or wastes containing free liquids and that is not an injection well. Examples of surface impoundments are holding storage, settling, and aeration pits, ponds, and lagoons.

Waste pile or *pile* means any noncontainerized accumulation of solid, nonflowing waste that is used for treatment or storage.

§ 257.3 Criteria for classification of solid waste disposal facilities and practices.

Solid waste disposal facilities or practices which violate any of the following criteria pose a reasonable probability of adverse effects on health or the environment:

§ 257.3-1 Floodplains.

(a) Facilities or practices in floodplains shall not restrict the flow of the base flood, reduce the temporary water storage capacity of the floodplain, or result in washout of solid waste, so as to pose a hazard to human life, wildlife, or land or water resources.

(b) As used in this section:

(1) *Based flood* means a flood that has a 1 percent or greater chance of recurring in any year or a flood of a magnitude equalled or exceeded once in 100 years on the average over a significantly long period.

(2) *Floodplain* means the lowland and relatively flat areas adjoining inland and coastal waters, including flood-prone areas of offshore islands, which are inundated by the base flood.

(3) *Washout* means the carrying away of solid waste by waters of the base flood.

[44 FR 53460, Sept. 13, 1979; 44 FR 54708, Sept. 21, 1979]

§ 257.3-2 Endangered species.

(a) Facilities or practices shall not cause or contribute to the taking of any endangered or threatened species of plants, fish, or wildlife.

(b) The facility or practice shall not result in the destruction or adverse modification of the critical habitat of endangered or threatened species as identified in 50 CFR Part 17.

(c) As used in this section:

(1) *Endangered or threatened species* means any species listed as such pursuant to section 4 of the Endangered Species Act.

(2) *Destruction or adverse modification* means a direct or indirect alteration of critical habitat which appreciably diminishes the likelihood of the survival and recovery of threatened or endangered species using that habitat.

(3) *Taking* means harassing, harming, pursuing, hunting, wounding, killing, trapping, capturing, or collecting or attempting to engage in such conduct.

§ 257.3-3 Surface water.

(a) For purposes of section 4004(a) of the Act, a facility shall not cause a discharge of pollutants into waters of the United States that is in violation of the requirements of the National Pollutant Discharge Elimination System (NPDES) under section 402 of the Clean Water Act, as amended.

(b) For purposes of section 4004(a) of the Act, a facility shall not cause a discharge of dredged material or fill material to waters of the United States that is in violation of the requirements under section 404 of the Clean Water Act, as amended.

(c) A facility or practice shall not cause non-point source pollution of waters of the United States that violates applicable legal requirements implementing an areawide or Statewide water quality management plan that has been approved by the Administrator under section 208 of the Clean Water Act, as amended.

(d) Definitions of the terms "Discharge of dredged material", "Point source", "Pollutant", "Waters of the United States", and "Wetlands" can be found in the Clean Water Act, as amended, 33 U.S.C. 1251 et seq., and implementing regulations, specifically 33 CFR Part 323 (42 FR 37122, July 19, 1977).

[44 FR 53460, Sept. 13, 1979, as amended at 46 FR 47052, Sept. 23, 1981]

§ 257.3-4 Ground water.

(a) A facility or practice shall not contaminate an underground drinking water source beyond the solid waste boundary or beyond an alternative boundary specified in accordance with paragraph (b) of this section.

(b)(1) For purposes of section 1008(a)(3) of the Act or section 405(d) of the CWA, a party charged with open dumping or a violation of section 405(e) may demonstrate that compliance should be determined at an alternative boundary in lieu of the solid waste boundary. The court shall establish such an alternative boundary only if it finds that such a change would not result in contamination of ground water which may be needed or used for human consumption. This finding shall be based on analysis and consideration of all of the following factors that are relevant:

(i) The hydrogeological characteristics of the facility and surrounding land, including any natural attenuation and dilution characteristics of the aquifer;

(ii) The volume and physical and chemical characteristics of the leachate;

(iii) The quantity, quality, and direction of flow of ground water underlying the facility;

(iv) The proximity and withdrawal rates of ground-water users;

(v) The availability of alternative drinking water supplies;

(vi) The existing quality of the ground water, including other sources of contamination and their cumulative impacts on the ground water;

(vii) Public health, safety, and welfare effects.

(2) For purposes of sections 4004(a) and 1008(a)(3), the State may establish an alternative boundary for a facility to be used in lieu of the solid waste boundary only if it finds that such a change would not result in the contamination of ground water which may be needed or used for human consumption. Such a finding shall be based on an analysis and consideration of all of the factors identified in paragraph (b)(1) of this section that are relevant.

(c) As used in this section:

(1) *Aquifer* means a geologic formation, group of formations, or portion of a formation capable of yielding usable quantities of ground water to wells or springs.

(2) *Contaminate* means introduce a substance that would cause:

(i) The concentration of that substance in the ground water to exceed the maximum contaminant level specified in Appendix I, or

(ii) An increase in the concentration of that substance in the ground water where the existing concentration of that substance exceeds the maximum contaminant level specified in Appendix I.

(3) *Ground water* means water below the land surface in the zone of saturation.

(4) *Underground drinking water source* means:

(i) An aquifer supplying drinking water for human consumption, or

(ii) An aquifer in which the ground water contains less than 10,000 mg/1 total dissolved solids.

(5) *Solid waste boundary* means the outermost perimeter of the solid waste (projected in the horizontal plane) as it would exist at completion of the disposal activity.

[44 FR 53460, Sept. 13, 1979, as amended at 46 FR 47052, Sept. 23, 1981]

§ 257.3-5 Application to land used for the production of food-chain crops (interim final).

(a) *Cadmium.* A facility or practice concerning application of solid waste to within one meter (three feet) of the surface of land used for the production of food-chain crops shall not exist or occur, unless in compliance with all requirements of paragraphs (a)(1) (i) through (iii) of this section or all requirements of paragraphs (a)(2) (i) through (iv) of this section.

(1)(i) The pH of the solid waste and soil mixture is 6.5 or greater at the time of each solid waste application, except for solid waste containing cadmium at concentrations of 2 mg/kg (dry weight) or less.

(ii) The annual application of cadmium from solid waste does not exceed 0.5 kilograms per hectare (kg/ha) on land used for production of tobacco, leafy vegetables or root crops grown for human consumption. For other food-chain crops, the annual cadmium application rate does not exceed:

Time period	Annual Cd application rate (kg/ha)
Present to June 30, 1984	2.0
July 1, 1984 to December 31, 1986	1 25
Beginning January 1, 1987	0.5

(iii) The cumulative application of cadmium from solid waste does not exceed the levels in either paragraph (a)(1)(iii)(A) or (B) of this section.

(A)

Soil cation exchange capacity (meq/100g)	Maximum cumulative application (kg/ha)	
	Background soil pH less than 6.5	Background soil pH more than 6 5
Less than 5	5	5
5 to 15	5	10
More than 15	5	20

(B) For soils with a background pH of less than 6.5, the cumulative cadmium application rate does not exceed the levels below: *Provided*, That the pH of the solid waste and soil mixture is adjusted to and maintained at 6.5 or greater whenever food-chain crops are grown.

Soil cation exchange capacity (meq/100g)	Maximum cumulative application (kg/ha)
Less than 5	5
5 to 15	10
More than 15	20

(2)(i) The only food-chain crop produced is animal feed.

(ii) The pH of the solid waste and soil mixture is 6.5 or greater at the time of solid waste application or at the time the crop is planted, whichever occurs later, and this pH level is maintained whenever food-chain crops are grown.

(iii) There is a facility operating plan which demonstrates how the animal feed will be distributed to preclude ingestion by humans. The facility operating plan describes the measures to be taken to safeguard against possible health hazards from cadmium entering the food chain, which may result from alternative land uses.

(iv) Future property owners are notified by a stipulation in the land record or property deed which states that the property has received solid waste at high cadmium application rates and that food-chain crops should not be grown, due to a possible health hazard.

(b) *Polychlorinated Biphenyls (PCBs)*. Solid waste containing concentrations of PCBs equal to or greater than 10 mg/kg (dry weight) is incorporated into the soil when applied to land used for producing animal feed, including pasture crops for animals raised for milk. Incorporation of the solid waste into the soil is not required if it is assured that the PCB content is less than 0.2 mg/kg (actual weight) in animal feed or less than 1.5 mg/kg (fat basis) in milk.

(c) As used in this section:

(1) *Animal feed* means any crop grown for consumption by animals, such as pasture crops, forage, and grain.

(2) *Background soil pH* means the pH of the soil prior to the addition of substances that alter the hydrogen ion concentration.

(3) *Cation exchange capacity* means the sum of exchangeable cations a soil can absorb expressed in milli-equivalents per 100 grams of soil as determined by sampling the soil to the depth of cultivation or solid waste placement, whichever is greater, and analyzing by the summation method for distinctly acid soils or the sodium acetate method for neutral, calcareous or saline soils ("Methods of Soil Analysis, Agronomy Monograph No. 9." C. A. Black, ed., American Society of Agronomy, Madison, Wisconsin. pp 891-901, 1965).

(4) *Food-chain crops* means tobacco, crops grown for human consumption, and animal feed for animals whose products are consumed by humans.

(5) *Incorporated into the soil* means the injection of solid waste beneath the surface of the soil or the mixing of solid waste with the surface soil.

(6) *Pasture crops* means crops such as legumes, grasses, grain stubble and stover which are consumed by animals while grazing.

(7) *pH* means the logarithm of the reciprocal of hydrogen ion concentration.

(8) *Root crops* means plants whose edible parts are grown below the surface of the soil.

(9) *Soil pH* is the value obtained by sampling the soil to the depth of cultivation or solid waste placement, whichever is greater, and analyzing by the electrometric method. ("Methods of Soil Analysis, Agronomy Monograph No. 9," C.A. Black, ed., American Society of Agronomy, Madison, Wisconsin, pp. 914-926, 1965.)

[44 FR 53460, Sept. 13, 1979; 44 FR 54708, Sept. 21, 1979]

§ 257.3-6 Disease.

(a) *Disease Vectors*. The facility or practice shall not exist or occur unless the on-site population of disease vectors is minimized through the periodic application of cover material or other techniques as appropriate so as to protect public health.

(b) *Sewage sludge and septic tank pumpings (Interim Final).* A facility or practice involving disposal of sewage sludge or septic tank pumpings shall not exist or occur unless in compliance with paragraphs (b) (1), (2) or (3) of this section.

(1) Sewage sludge that is applied to the land surface or is incorporated into the soil is treated by a Process to Significantly Reduce Pathogens prior to application or incorporation. Public access to the facility is controlled for at least 12 months, and grazing by animals whose products are consumed by humans is prevented for at least one month. Processes to Significantly Reduce Pathogens are listed in Appendix II, Section A. (These provisions do not apply to sewage sludge disposed of by a trenching or burial operation.)

(2) Septic tank pumpings that are applied to the land surface or incorporated into the soil are treated by a Process to Significantly Reduce Pathogens (as listed in Appendix II, Section A), prior to application or incorporation, unless public access to the facility is controlled for at least 12 months and unless grazing by animals whose products are consumed by humans is prevented for at least one month. (These provisions do not apply to septic tank pumpings disposed of by a trenching or burial operation.)

(3) Sewage sludge or septic tank pumpings that are applied to the land surface or are incorporated into the soil are treated by a Process to Further Reduce Pathogens, prior to application or incorporation, if crops for direct human consumption are grown within 18 months subsequent to application or incorporation. Such treatment is not required if there is no contact between the solid waste and the edible portion of the crop; however, in this case the solid waste is treated by a Process to Significantly Reduce Pathogens, prior to application; public access to the facility is controlled for at least 12 months; and grazing by animals whose products are consumed by humans is prevented for at least one month. If crops for direct human consumption are not grown within 18 months of application or incorporation, the requirements of paragraphs (b) (1) and (2) of this section apply. Processes to Further Reduce Pathogens are listed in Appendix II, Section B.

(c) As used in this section:

(1) *Crops for direct human consumption* means crops that are consumed by humans without processing to minimize pathogens prior to distribution to the consumer.

(2) *Disease vector* means rodents, flies, and mosquitoes capable of transmitting disease to humans.

(3) *Incorporated into the soil* means the injection of solid waste beneath the surface of the soil or the mixing of solid waste with the surface soil.

(4) *Periodic application of cover material* means the application and compaction of soil or other suitable material over disposed solid waste at the end of each operating day or at such frequencies and in such a manner as to reduce the risk of fire and to impede vectors access to the waste.

(5) *Trenching or burial operation* means the placement of sewage sludge or septic tank pumpings in a trench or other natural or man-made depression and the covering with soil or other suitable material at the end of each operating day such that the wastes do not migrate to the surface.

[44 FR 53460, Sept. 13, 1979; 44 FR 54708, Sept. 21, 1979]

§ 257.3-7 Air.

(a) The facility or practice shall not engage in open burning of residential, commercial, institutional or industrial solid waste. This requirement does not apply to infrequent burning of agricultural wastes in the field, silvicultural wastes for forest management purposes, land-clearing debris, diseased trees, debris from emergency clean-up operations, and ordnance.

(b) For purposes of section 4004(a) of the Act, the facility shall not violate applicable requirements developed under a State Implementation Plan (SIP) approved or promulgated by the Administrator pursuant to section 110 of the Clean Air Act, as amended.

(c) As used in this section "open burning" means the combustion of solid waste without (1) control of combustion air to maintain adequate temperature for efficient combustion, (2) containment of the combustion reaction in an enclosed device to provide sufficient residence time and mixing for complete combustion, and (3) control of the emission of the combustion products.

[44 FR 53460, Sept. 13, 1979; 44 FR 54708, Sept. 21, 1979, as amended at 46 FR 47052, Sept. 23, 1981]

§ 257.3-8 Safety.

(a) *Explosive gases.* The concentration of explosive gases generated by the facility or practice shall not exceed:

(1) Twenty-five percent (25%) of the lower explosive limit for the gases in facility structures (excluding gas control or recovery system components); and

(2) The lower explosive limit for the gases at the property boundary.

(b) *Fires.* A facility or practice shall not pose a hazard to the safety of persons or property from fires. This may be accomplished through compliance with § 257.3-7 and through the periodic application of cover material or other techniques as appropriate.

(c) *Bird hazards to aircraft.* A facility or practice disposing of putrescible wastes that may attract birds and which occurs within 10,000 feet (3,048 meters) of any airport runway used by turbojet aircraft or within 5,000 feet (1,524 meters) of any airport runway used by only piston-type aircraft shall not pose a bird hazard to aircraft.

(d) *Access.* A facility or practice shall not allow uncontrolled public access so as to expose the public to potential health and safety hazards at the disposal site.

(e) As used in this section:

(1) *Airport* means public-use airport open to the public without prior permission and without restrictions within the physical capacities of available facilities.

(2) *Bird hazard* means an increase in the likelihood of bird/aircraft collisions that may cause damage to the aircraft or injury to its occupants.

(3) *Explosive gas* means methane (CH_4).

(4) *Facility structures* means any buildings and sheds or utility or drainage lines on the facility.

(5) *Lower explosive limit* means the lowest percent by volume of a mixture of explosive gases which will propagate a flame in air at 25°C and atmospheric pressure.

(6) *Periodic application of cover material* means the application and compaction of soil or other suitable material over disposed solid waste at the end of each operating day or at such frequencies and in such a manner as to reduce the risk of fire and to impede disease vectors' access to the waste.

(7) *Putrescible wastes* means solid waste which contains organic matter capable of being decomposed by microorganisms and of such a character and proportion as to be capable of attracting or providing food for birds.

§ 257.4 Effective date.

These criteria become effective October 15, 1979.

Appendix I to 40 CFR Part 257—Maximum Contaminant Levels (MCLs)

The maximum contaminant levels promulgated herein are for use in determining whether solid waste disposal activities comply with the ground-water criteria (§ 257.3-4). Analytical methods for these contaminants may be found in 40 CFR Part 141 which should be consulted in its entirety.

1. *Maximum contaminant levels for inorganic chemicals.* The following are the maximum levels of inorganic chemicals other than fluoride:

Contaminant	Level (milligrams per liter)
Arsenic	0 05
Barium	1
Cadmium	0 010
Chromium	0 05
Lead	0 05
Mercury	0 002
Nitrate (as N)	10
Selenium	0 01
Silver	0 05

The maximum contaminant levels for fluoride are:

Temperature [1] degrees Fahrenheit	Degrees Celsius	Level (milligrams per liter)
53 7 and below	12 and below	2 4
53.8 to 58.3	12.1 to 14.6	2.2
58 4 to 63 8	14.7 to 17 6	2 0
63.9 to 70 6	17 7 to 21.4	1.8
70.7 to 79.2	21.5 to 26.2	1.6
79 3 to 90 5	26.3 to 32.5	1.4

[1] Annual average of the maximum daily air temperature

2. *Maximum contaminant levels for organic chemicals.* The following are the maximum contaminant levels for organic chemicals:

	Level (milligrams per liter)
(a) Chlorinated hydrocarbons:	
Endrin (1,2,3,4,10,10-Hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo, endo-5,8-dimethano naphthalene)	0.0002
Lindane (1,2,3,4,5,6-Hexachlorocyclohexane, gamma isomer	0.004
Methoxychlor (1,1,1-Trichloro-2,2-bis (p-methoxyphenyl) ethane)	0.1
Toxaphene ($C_{10}H_{10}Cl_8$-Technical chlorinated camphene, 67 to 69 percent chlorine)	0.005
(b) Chlorophenoxys:	
2,4-D (2,4-Dichlorophenoxy-acetic acid)	0.1
2,4,5-TP Silvex (2,4,5-Trichlorophen- oxy-propionic acid)	0.01

3. *Maximum microbiological contaminant levels.* The maximum contaminant level for coliform bacteria from any one well is as follows:

(a) using the membrane filter technique:

(1) Four coliform bacteria per 100 milliliters if one sample is taken, or

(2) Four coliform bacteria per 100 milliliters in more than one sample of all the samples analyzed in one month.

(b) Using the five tube most probable number procedure, (the fermentation tube method) in accordance with the analytical recommendations set forth in "Standard Methods for Examination of Water and Waste Water", American Public Health Association, 13th Ed. pp. 662-688, and using a Standard sample, each portion being one fifth of the sample:

(1) If the standard portion is 10 milliliters, coliform in any five consecutive samples from a well shall not be present in three or more of the 25 portions, or

(2) If the standard portion is 100 milliliters, coliform in any five consecutive samples from a well shall not be present in five portions in any of five samples or in more than fifteen of the 25 portions.

4. *Maximum contaminant levels for radium-226, radium-228, and gross alpha particle radioactivity.* The following are the maximum contaminant levels for radium-226, radium-228, and gross alpha particle radioactivity:

(a) Combined radium-226 and radium-228—5 pCi/l;

(b) Gross alpha particle activity (including radium-226 but excluding radon and uranium)—15 pCi/l.

EFFECTIVE DATE NOTE: At 56 FR 51016, Oct. 9, 1991, Appendix I to 40 CFR Part 257 was revised efective October 9, 1993. For the convience of the user, the revised text is set forth below:

APPENDIX I TO 40 CFR PART 257—MAXIMUM CONTAMINANT LEVELS (MCLS)

MAXIMUM CONTAMINANT LEVELS (MCLS) PROMULGATED UNDER THE SAFE DRINKING WATER ACT

Chemical	CAS No	MCL (mg/l)
Arsenic	7440-38-2	0 05
Barium	7440-39-3	1 0
Benzene	71-343-2	0 005
Cadmium	7440-43-9	0 01
Carbon tetrachloride	56-23-5	0 005
Chromium (hexavalent)	7440-47-3	0 05
2,4-Dichlorophenoxy acetic acid	94-75-7	0 1
1,4-Dichlorobenzene	106-46-7	0 075
1,2-Dichloroethane	107-06-2	0 005
1,1-Dichloroethylene	75-35-4	0.007
Endrin	75-20-8	0 0002
Fluoride	7	4 0
Lindane	58-89-9	0 004
Lead	7439-92-1	0.05
Mercury	7439-97-6	0 002
Methoxychlor	72-43-5	0 1
Nitrate		10 0
Selenium	7782-49-2	0.01
Silver	7440-22-4	0 05
Toxaphene	8001-35-2	0 005
1,1,1-Trichloroethane	71-55-6	0 2
Trichloroethylene	79-01-6	0 005
2,4,5-Trichlorophenoxy acetic acid	93-76-5	0 01
Vinyl chloride	75-01-4	0 002

APPENDIX II TO PART 257

A. Processes to Significantly Reduce Pathogens

Aerobic digestion: The process is conducted by agitating sludge with air or oxygen to maintain aerobic conditions at residence times ranging from 60 days at 15° C to 40 days at 20° C, with a volatile solids reduction of at least 38 percent.

Air Drying: Liquid sludge is allowed to drain and/or dry on under-drained sand beds, or paved or unpaved basins in which the sludge is at a depth of nine inches. A minimum of three months is needed, two months of which temperatures average on a daily basis above 0° C.

Anaerobic digestion: The process is conducted in the absence of air at residence times ranging from 60 days at 20° C to 15 days at 35° to 55° C, with a volatile solids reduction of at least 38 percent.

Composting: Using the within-vessel, static aerated pile or windrow composting methods, the solid waste is maintained at minimum operating conditions of 40° C for 5 days. For four hours during this period the temperature exceeds 55° C.

Lime Stabilization: Sufficient lime is added to produce a pH of 12 after 2 hours of contact.

Other methods: Other methods or operating conditions may be acceptable if pathogens and vector attraction of the waste (volatile solids) are reduced to an extent equivalent to the reduction achieved by any of the above methods.

B. Processes to Further Reduce Pathogens

Composting: Using the within-vessel composting method, the solid waste is maintained at operating conditions of 55° C or greater for three days. Using the static aerated pile composting method, the solid waste is maintained at operating conditions of 55° C or greater for three days. Using the windrow composting method, the solid waste attains a temperature of 55° C or greater for at least 15 days during the composting period. Also, during the high temperature period, there will be a minimum of five turnings of the windrow.

Heat drying: Dewatered sludge cake is dried by direct or indirect contact with hot gases, and moisture content is reduced to 10 percent or lower. Sludge particles reach temperatures well in excess of 80° C, or the wet bulb temperature of the gas stream in contact with the sludge at the point where it leaves the dryer is in excess of 80° C.

Heat treatment: Liquid sludge is heated to temperatures of 180° C for 30 minutes.

Thermophilic Aerobic Digestion: Liquid sludge is agitated with air or oxygen to maintain aerobic conditions at residence times of 10 days at 55-60° C, with a volatile solids reduction of at least 38 percent.

Other methods: Other methods or operating conditions may be acceptable if pathogens and vector attraction of the waste (volatile solids) are reduced to an extent equivalent to the reduction achieved by any of the above methods.

Any of the processes listed below, if added to the processes described in Section A above, further reduce pathogens. Because the processes listed below, on their own, do not reduce the attraction of disease vectors, they are only add-on in nature.

Beta ray irradiation: Sludge is irradiated with beta rays from an accelerator at dosages of at least 1.0 megarad at room temperature (ca. 20° C).

Gamma ray irradiation: Sludge is irradiated with gamma rays from certain isotopes, such as ^{60}Cobalt and ^{137}Cesium, at dosages of at least 1.0 megarad at room temperature (ca. 20° C).

Pasteurization: Sludge is maintained for at least 30 minutes at a minimum temperature of 70° C.

Other methods: Other methods or operating conditions may be acceptable if pathogens are reduced to an extent equivalent to the reduction achieved by any of the above add-on methods.

PART 258—CRITERIA FOR MUNICIPAL SOLID WASTE LANDFILLS (Eff. 10-9-93)

Subpart A—General

Subpart B—Location Restrictions

Subpart C—Operating Criteria

Subpart D—Design Criteria

Subpart E—Ground-Water Monitoring and Corrective Action

AUTHORITY: 42 U.S.C. 6907(a)(3), 6944(a) and 6949(c); 33 U.S.C. 1345 (d) and (e).

SOURCE: 56 FR 51016, Oct. 9, 1991, unless otherwise noted.

EFFECTIVE DATE NOTE: At 56 FR 51016, Oct. 9, 1991, part 258 was added, effective October 9, 1993, except subpart G, which is effective April 9, 1994.

Subpart A—General

§ 258.1 Purpose, scope, and applicability.

(a) The purpose of this part is to establish minimum national criteria under the Resource Conservation and Recovery Act (RCRA or the Act), as amended, for all municipal solid waste landfill (MSWLF) units and under the Clean Water Act, as amended, for municipal solid waste landfills that are used to dispose of sewage sludge. These minimum national criteria ensure the protection of human health and the environment.

(b) These Criteria apply to owners and operators of new MSWLF units, existing MSWLF units, and lateral expansions, except as otherwise specifically provided in this part; all other solid waste disposal facilities and practices that are not regulated under Subtitle C of RCRA are subject to the criteria contained in part 257 of this chapter.

(c) These Criteria do not apply to municipal solid waste landfill units that do not receive waste after October 9, 1991.

(d) MSWLF units that receive waste after October 9, 1991 but stop receiving waste before October 9, 1993 are exempt from all the requirements of this part 258, except the final cover requirement specified in § 258.60(a). The final cover must be installed within six months of last receipt of wastes. Owners or operators of MSWLF units described in this paragraph that fail to complete cover installation within this six month period will be subject to all the requirements of this part 258, unless otherwise specified.

(e) All MSWLF units that receive waste on or after October 9, 1993 must comply with all requirements of this part 258 unless otherwise specified.

(f)(1) Owners or operators of new MSWLF units, existing MSWLF units, and lateral expansions that dispose of less than twenty (20) tons of municipal solid waste daily, based on an annual average are exempt from subparts D and E of this part, so long as there is no evidence of existing ground-water contamination from the MSWLF unit, and the MSWLF unit serves:

(i) A community that experiences an annual interruption of at least three consecutive months of surface transportation that prevents access to a regional waste management facility, or

(ii) A community that has no practicable waste management alternative and the landfill unit is located in an area that annually receives less than or equal to 25 inches of precipitation.

(2) Owners or operators of new MSWLF units, existing MSWLF units, and lateral expansions that meet the criteria in paragraph (f)(1)(i) or (f)(1)(ii) of this section must place in the operating record information demonstrating this.

(3) If the owner or operator of a new MSWLF unit, existing MSWLF unit, or lateral expansion has knowledge of ground-water contamination resulting from the unit that has asserted the exemption in paragraph (f)(1)(i) or (f)(1)(ii) of this section, the owner or

operator must notify the State Director of such contamination and, thereafter, comply with subparts D and E of this part.

(g) Municipal solid waste landfill units failing to satisfy these criteria are considered open dumps for purposes of State solid waste management planning under RCRA.

(h) Municipal solid waste landfill units failing to satisfy these criteria constitute open dumps, which are prohibited under section 4005 of RCRA.

(i) Municipal solid waste landfill units containing sewage sludge and failing to satisfy these Criteria violate sections 309 and 405(e) of the Clean Water Act.

(j) The effective date of this part is October 9, 1993, except subpart G of this part 258 is effective April 9, 1994.

§ 258.2 Definitions.

Unless otherwise noted, all terms contained in this part are defined by their plain meaning. This section contains definitions for terms that appear throughout this part; additional definitions appear in the specific sections to which they apply.

Active life means the period of operation beginning with the initial receipt of solid waste and ending at completion of closure activities in accordance with § 258.60 of this part.

Active portion means that part of a facility or unit that has received or is receiving wastes and that has not been closed in accordance with § 258.60 of this part.

Aquifer means a geological formation, group of formations, or porton of a formation capable of yielding significant quantities of ground water to wells or springs.

Commercial solid waste means all types of solid waste generated by stores, offices, restaurants, warehouses, and other nonmanufacturing activities, excluding residential and industrial wastes.

Director of an approved State means the chief administrative officer of a State agency responsible for implementing the State municipal solid waste permit program or other system of prior approval that is deemed to be adequate by EPA under regulations published pursuant to sections 2002 and 4005 of RCRA.

Existing MSWLF unit means any municipal solid waste landfill unit that is receiving solid waste as of the effective date of this part (October 9, 1993). Waste placement in existing units must be consistent with past operating practices or modified practices to ensure good management.

Facility means all contiguous land and structures, other appurtenances, and improvements on the land used for the disposal of solid waste.

Ground water means water below the land surface in a zone of saturation.

Household waste means any solid waste (including garbage, trash, and sanitary waste in septic tanks) derived from households (including single and multiple residences, hotels and motels, bunkhouses, ranger stations, crew quarters, campgrounds, picnic grounds, and day-use recreation areas).

Industrial solid waste means solid waste generated by manufacturing or industrial processes that is not a hazardous waste regulated under subtitle C of RCRA. Such waste may include, but is not limited to, waste resulting from the following manufacturing processes: Electric power generation; fertilizer/agricultural chemicals; food and related products/by-products; inorganic chemicals; iron and steel manufacturing; leather and leather products; nonferrous metals manufacturing/foundries; organic chemicals; plastics and resins manufacturing; pulp and paper industry; rubber and miscellaneous plastic products; stone, glass, clay, and concrete products; textile manufacturing; transportation equipment; and water treatment. This term does not include mining waste or oil and gas waste.

Lateral expansion means a horizontal expansion of the waste boundaries of an existing MSWLF unit.

Leachate means a liquid that has passed through or emerged from solid waste and contains soluble, suspended, or miscible materials removed from such waste.

Municipal solid waste landfill unit means a discrete area of land or an excavation that receives household waste, and that is not a land application unit, surface impoundment, injection well, or waste pile, as those terms are defined under § 257.2. A MSWLF unit also may receive other types of RCRA subtitle D wastes, such as commercial solid waste, nonhazardous sludge, conditionally exempt small quantity generator waste and industrial solid waste. Such a landfill may be publicly or privately owned. A MSWLF unit may be a new MSWLF unit, an existing MSWLF unit or a lateral expansion.

New MSWLF unit means any municipal solid waste landfill unit that has not received waste prior to the effective date of this part (October 9, 1993).

Open burning means the combustion of solid waste without:

(1) Control of combustion air to maintain adequate temperature for efficient combustion,

(2) Containment of the combustion reaction in an enclosed device to provide sufficient residence time and mixing for complete combustion, and

(3) Control of the emission of the combustion products.

Operator means the person(s) responsible for the overall operation of a facility or part of a facility.

Owner means the person(s) who owns a facility or part of a facility.

Run-off means any rainwater, leachate, or other liquid that drains over land from any part of a facility.

Run-on means any rainwater, leachate, or other liquid that drains over land onto any part of a facility.

Saturated zone means that part of the earth's crust in which all voids are filled with water.

Sludge means any solid, semi-solid, or liquid waste generated from a municipal, commercial, or industrial wastewater treatment plant, water supply treatment plant, or air pollution control facility exclusive of the treated effluent from a wastewater treatment plant.

Solid waste means any garbage, or refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semi-solid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities, but does not include solid or dissolved materials in domestic sewage, or solid or dissolved materials in irrigation return flows or industrial discharges that are point sources subject to permit under 33 U.S.C. 1342, or source, special nuclear, or by-product material as defined by the Atomic Energy Act of 1954, as amended (68 Stat. 923).

State means any of the several States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, Guam, American Samoa, and the Commonwealth of the Northern Mariana Islands.

State Director means the chief administrative officer of the State agency responsible for implementing the State municipal solid waste permit program or other system of prior approval.

Uppermost aquifer means the geologic formation nearest the natural ground surface that is an aquifer, as well as, lower aquifers that are hydraulically interconnected with this aquifer within the facility's property boundary.

Waste management unit boundary means a vertical surface located at the hydraulically downgradient limit of the unit. This vertical surface extends down into the uppermost aquifer.

[56 FR 51016, Oct. 9, 1991; 57 FR 28627, June 26, 1992]

§ 258.3 Consideration of other Federal laws.

The owner or operator of a municipal solid waste landfill unit must comply with any other applicable Federal rules, laws, regulations, or other requirements.

§§ 258.4—258.9 [Reserved]

Subpart B—Location Restrictions

§ 258.10 Airport safety.

(a) Owners or operators of new MSWLF units, existing MSWLF units, and lateral expansions that are located within 10,000 feet (3,048 meters) of any airport runway end used by turbojet aircraft or within 5,000 feet (1,524 meters) of any airport runway end used by only piston-type aircraft must demonstrate that the units are designed and operated so that the MSWLF unit does not pose a bird hazard to aircraft.

(b) Owners or operators proposing to site new MSWLF units and lateral expansions within a five-mile radius of any airport runway end used by turbojet or piston-type aircraft must notify the affected airport and the Federal Aviation Administration (FAA).

(c) The owner or operator must place the demonstration in paragraph (a) of this section in the operating record and notify the State Director that it has been placed in the operating record.

(d) For purposes of this section:

(1) *Airport* means public-use airport open to the public without prior permission and without restrictions within the physical capacities of available facilities.

(2) *Bird hazard* means an increase in the likelihood of bird/aircraft collisions that may cause damage to the aircraft or injury to its occupants.

§ 258.11 Floodplains.

(a) Owners or operators of new MSWLF units, existing MSWLF units, and lateral expansions located in 100-year floodplains must demonstrate that the unit will not restrict the flow of the 100-year flood, reduce the temporary water storage capacity of the floodplain, or result in washout of solid waste so as to pose a hazard to human health and the environment. The owner or operator must place the demonstration in the operating record and notify the State Director that it has been placed in the operating record.

(b) For purposes of this section:

(1) *Floodplain* means the lowland and relatively flat areas adjoining inland and coastal waters, including flood-prone areas of offshore islands, that are inundated by the 100-year flood.

(2) *100-year flood* means a flood that has a 1-percent or greater chance of recurring in any given year or a flood of a magnitude equalled or exceeded once in 100 years on the average over a significantly long period.

(3) *Washout* means the carrying away of solid waste by waters of the base flood.

§ 258.12 Wetlands.

(a) New MSWLF units and lateral expansions shall not be located in wetlands, unless the owner or operator can make the following demonstrations to the Director of an approved State:

(1) Where applicable under section 404 of the Clean Water Act or applicable State wetlands laws, the presumption that practicable alternative to the proposed landfill is available which does not involve wetlands is clearly rebutted;

(2) The construction and operation of the MSWLF unit will not:

(i) Cause or contribute to violations of any applicable State water quality standard,

(ii) Violate, any applicable toxic effluent standard or prohibition under Section 307 of the Clean Water Act,

(iii) Jeopardize the continued existence of endangered or threatened species or result in the destruction or adverse modification of a critical habitat, protected under the Endangered Species Act of 1973, and

(iv) Violate any requirement under the Marine Protection, Research, and Sanctuaries Act of 1972 for the protection of a marine sanctuary;

(3) The MSWLF unit will not cause or contribute to significant degradation of wetlands. The owner or operator must demonstrate the integrity of the MSWLF unit and its ability to protect ecological resources by addressing the following factors:

(i) Erosion, stability, and migration potential of native wetland soils, muds and deposits used to support the MSWLF unit;

(ii) Erosion, stability, and migration potential of dredged and fill materials used to support the MSWLF unit;

(iii) The volume and chemical nature of the waste managed in the MSWLF unit;

(iv) Impacts on fish, wildlife, and other aquatic resources and their habitat from release of the solid waste;

(v) The potential effects of catastrophic release of waste to the wetland and the resulting impacts on the environment; and

(vi) Any additional factors, as necessary, to demonstrate that ecological resources in the wetland are sufficiently protected.

(4) To the extent required under section 404 of the Clean Water Act or applicable State wetlands laws, steps have been taken to attempt to achieve no net loss of wetlands (as defined by acreage and function) by first avoiding impacts to wetlands to the maximum extent practicable as required by paragraph (a)(1) of this section, then minimizing unavoidable impacts to the maximum extent practicable, and finally offsetting remaining unavoidable wetland impacts through all appropriate and practicable compensatory mitigation actions (e.g., restoration of existing degraded wetlands or creation of man-made wetlands); and

(5) Sufficient information is available to make a reasonable determination with respect to these demonstrations.

(b) For purposes of this section, *wetlands* means those areas that are defined in 40 CFR 232.2(r).

§ 258.13 Fault areas.

(a) New MSWLF units and lateral expansions shall not be located within 200 feet (60 meters) of a fault that has had displacement in Holocene time unless the owner or operator demonstrates to the Director of an approved State that an alternative setback distance of less than 200 feet (60 meters) will prevent damage to the structural integrity of the MSWLF unit and will be protective of human health and the environment.

(b) For the purposes of this section:

(1) *Fault* means a fracture or a zone of fractures in any material along which strata on one side have been displaced with respect to that on the other side.

(2) *Displacement* means the relative movement of any two sides of a fault measured in any direction.

(3) *Holocene* means the most recent epoch of the Quaternary period, extending from the end of the Pleistocene Epoch to the present.

§ 258.14 Seismic impact zones.

(a) New MSWLF units and lateral expansions shall not be located in seismic impact zones, unless the owner or operator demonstrates to the Director of an approved State/Tribe that all containment structures, including liners, leachate collection systems, and surface water control systems, are designed to resist the maximum horizontal acceleration in lithified earth material for the site. The owner or operator must place the demonstration in the operating record and notify the State Director that it has been placed in the operating record.

(b) For the purposes of this section:

(1) *Seismic impact zone* means an area with a ten percent or greater probability that the maximum horizontal acceleration in lithified earth material, expressed as a percentage of the earth's gravitational pull (g), will exceed 0.10g in 250 years.

(2) *Maximum horizontal acceleration in lithified earth material* means the maximum expected horizontal acceleration depicted on a seismic hazard map, with a 90 percent or greater probability that the acceleration will not be exceeded in 250 years, or the maximum expected horizontal acceleration based on a site-specific seismic risk assessment.

(3) *Lithified earth material* means all rock, including all naturally occurring and naturally formed aggregates or masses of minerals or small particles of older rock that formed by crystallization of magma or by induration of loose sediments. This term does not include man-made materials, such as fill, concrete, and asphalt, or unconsolidated earth materials, soil, or regolith lying at or near the earth surface.

[56 FR 51016, Oct. 9, 1991; 57 FR 28627, June 26, 1992]

§ 258.15 Unstable areas.

(a) Owners or operators of new MSWLF units, existing MSWLF units, and lateral expansions located in an unstable area must demonstrate that engineering measures have been incorporated into the MSWLF unit's design to ensure that the integrity of the structural components of the MSWLF unit will not be disrupted. The owner or operator must place the demonstration in the operating record and notify the State Director that it has been placed in the operating record. The owner or operator must consider the following factors, at a minimum, when determining whether an area is unstable:

(1) On-site or local soil conditions that may result in significant differential settling;

(2) On-site or local geologic or geomorphologic features; and

(3) On-site or local human-made features or events (both surface and subsurface).

(b) For purposes of this section:

(1) *Unstable area* means a location that is susceptible to natural or human-induced events or forces capable of impairing the integrity of some or all of the landfill structural components responsible for preventing releases from a landfill. Unstable areas can include poor foundation conditions, areas susceptible to mass movements, and Karst terranes.

(2) *Structural components* means liners, leachate collection systems, final covers, run-on/run-off systems, and any other component used in the construction and operation of the MSWLF that is necessary for protection of human health and the environment.

(3) *Poor foundation conditions* means those areas where features exist which indicate that a natural or man-induced event may result in inadequate foundation support for the structural components of an MSWLF unit.

(4) *Areas susceptible to mass movement* means those areas of influence (i.e., areas characterized as having an active or substantial possibility of mass movement) where the movement of earth material at, beneath, or adjacent to the MSWLF unit, because of natural or man-induced events, results in the downslope transport of soil and rock material by means of gravitational influence. Areas of mass movement include, but are not limited to, landslides, avalanches, debris slides and flows, soil fluction, block sliding, and rock fall.

(5) *Karst terranes* means areas where karst topography, with its characteristic surface and subterranean features, is developed as the result of dissolution of limestone, dolomite, or other soluble rock. Characteristic physiographic features present in karst terranes include, but are not limited to, sinkholes, sinking streams, caves, large springs, and blind valleys.

§ 258.16 Closure of existing municipal solid waste landfill units.

(a) Existing MSWLF units that cannot make the demonstration specified in § 258.10(a), pertaining to airports, § 258.11(a), pertaining to floodplains, or § 258.15(a), pertaining to unstable areas, must close by October 9, 1996, in accordance with § 258.60 of this part and conduct post-closure activities in accordance with § 258.61 of this part.

(b) The deadline for closure required by paragraph (a) of this section may be extended up to two years if the owner or operator demonstrates to the Director of an approved State that:

(1) There is no available alternative disposal capacity;

(2) There is no immediate threat to human health and the environment.

NOTE TO SUBPART B: Owners or operators of MSWLFs should be aware that a State in which their landfill is located or is to be located, may have adopted a state wellhead protection program in accordance with section 1428 of the Safe Drinking Water Act. Such state wellhead protection programs may impose additional requirements on owners or operators of MSWLFs than those set forth in this part.

§§ 258.17—258.19 [Reserved]

Subpart C—Operating Criteria

§ 258.20 Procedures for excluding the receipt of hazardous waste.

(a) Owners or operators of all MSWLF units must implement a program at the facility for detecting and preventing the disposal of regulated hazardous wastes as defined in part 261 of this chapter and polychlorinated biphenyls (PCB) wastes as defined in part 761 of this chapter. This program must include, at a minimum:

(1) Random inspections of incoming loads unless the owner or operator takes other steps to ensure that in-

coming loads do not contain regulated hazardous wastes or PCB wastes;

(2) Records of any inspections;

(3) Training of facility personnel to recognize regulated hazardous waste and PCB wastes; and

(4) Notification of State Director of authorized States under Subtitle C of RCRA or the EPA Regional Administrator if in an unauthorized State if a regulated hazardous waste or PCB waste is discovered at the facility.

(b) For purposes of this section, *regulated hazardous waste* means a solid waste that is a hazardous waste, as defined in 40 CFR 261.3, that is not excluded from regulation as a hazardous waste under 40 CFR 261.4(b) or was not generated by a conditionally exempt small quantity generator as defined in § 261.5 of this chapter.

§ 258.21 Cover material requirements.

(a) Except as provided in paragraph (b) of this section, the owners or operators of all MSWLF units must cover disposed solid waste with six inches of earthen material at the end of each operating day, or at more frequent intervals if necessary, to control disease vectors, fires, odors, blowing litter, and scavenging.

(b) Alternative materials of an alternative thickness (other than at least six inches of earthen material) may be approved by the Director of an approved State if the owner or operator demonstrates that the alternative material and thickness control disease vectors, fires, odors, blowing litter, and scavenging without presenting a threat to human health and the environment.

(c) The Director of an approved State may grant a temporary waiver from the requirement of paragraph (a) and (b) of this section if the owner or operator demonstrates that there are extreme seasonal climatic conditions that make meeting such requirements impractical.

§ 258.22 Disease vector control.

(a) Owners or operators of all MSWLF units must prevent or control on-site populations of disease vectors using techniques appropriate for the protection of human health and the environment.

(b) For purposes of this section, *disease vectors* means any rodents, flies, mosquitoes, or other animals, including insects, capable of transmitting disease to humans.

§ 258.23 Explosive gases control.

(a) Owners or operators of all MSWLF units must ensure that:

(1) The concentration of methane gas generated by the facility does not exceed 25 percent of the lower explosive limit for methane in facility structures (excluding gas control or recovery system components); and

(2) The concentration of methane gas does not exceed the lower explosive limit for methane at the facility property boundary.

(b) Owners or operators of all MSWLF units must implement a routine methane monitoring program to ensure that the standards of paragraph (a) of this section are met.

(1) The type and frequency of monitoring must be determined based on the following factors:

(i) Soil conditions;

(ii) The hydrogeologic conditions surrounding the facility;

(iii) The hydraulic conditions surrounding the facility; and

(iv) The location of facility structures and property boundaries.

(2) The minimum frequency of monitoring shall be quarterly.

(c) If methane gas levels exceeding the limits specified in paragraph (a) of this section are detected, the owner or operator must:

(1) Immediately take all necessary steps to ensure protection of human health and notify the State Director;

(2) Within seven days of detection, place in the operating record the methane gas levels detected and a description of the steps taken to protect human health; and

(3) Within 60 days of detection, implement a remediation plan for the methane gas releases, place a copy of the plan in the operating record, and notify the State Director that the plan has been implemented. The plan shall describe the nature and extent of the problem and the proposed remedy.

(4) The Director of an approved State may establish alternative sched-

ules for demonstrating compliance with paragraphs (c) (2) and (3) of this section.

(d) For purposes of this section, *lower explosive limit* means the lowest percent by volume of a mixture of explosive gases in air that will propagate a flame at 25°C and atmospheric pressure.

§ 258.24 Air criteria.

(a) Owners or operators of all MSWLFs must ensure that the units not violate any applicable requirements developed under a State Implementation Plan (SIP) approved or promulgated by the Administrator pursuant to section 110 of the Clean Air Act, as amended.

(b) Open burning of solid waste, except for the infrequent burning of agricultural wastes, silvicultural wastes, landclearing debris, diseased trees, or debris from emergency cleanup operations, is prohibited at all MSWLF units.

§ 258.25 Access requirements.

Owners or operators of all MSWLF units must control public access and prevent unauthorized vehicular traffic and illegal dumping of wastes by using artificial barriers, natural barriers, or both, as appropriate to protect human health and the environment.

§ 258.26 Run-on/run-off control systems.

(a) Owners or operators of all MSWLF units must design, construct, and maintain:

(1) A run-on control system to prevent flow onto the active portion of the landfill during the peak discharge from a 25-year storm;

(2) A run-off control system from the active portion of the landfill to collect and control at least the water volume resulting from a 24-hour, 25-year storm.

(b) Run-off from the active portion of the landfill unit must be handled in accordance with § 258.27(a) of this part.

[56 FR 51016, Oct. 9, 1991; 57 FR 28627, June 26, 1992]

§ 258.27 Surface water requirements.

MSWLF units shall not:

(a) Cause a discharge of pollutants into waters of the United States, including wetlands, that violates any requirements of the Clean Water Act, including, but not limited to, the National Pollutant Discharge Elimination System (NPDES) requirements, pursuant to section 402.

(b) Cause the discharge of a nonpoint source of pollution to waters of the United States, including wetlands, that violates any requirement of an area-wide or State-wide water quality management plan that has been approved under section 208 or 319 of the Clean Water Act, as amended.

§ 258.28 Liquids restrictions.

(a) Bulk or noncontainerized liquid waste may not be placed in MSWLF units unless:

(1) The waste is household waste other than septic waste; or

(2) The waste is leachate or gas condensate derived from the MSWLF unit and the MSWLF unit, whether it is a new or existing MSWLF, or lateral expansion, is designed with a composite liner and leachate collection system as described in § 258.40(a)(2) of this part. The owner or operator must place the demonstration in the operating record and notify the State Director that it has been placed in the operating record.

(b) Containers holding liquid waste may not be placed in a MSWLF unit unless:

(1) The container is a small container similar in size to that normally found in household waste;

(2) The container is designed to hold liquids for use other than storage; or

(3) The waste is household waste.

(c) For purposes of this section:

(1) *Liquid waste* means any waste material that is determined to contain "free liquids" as defined by Method 9095 (Paint Filter Liquids Test), as described in "Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods" (EPA Pub. No. SW-846).

(2) *Gas condensate* means the liquid generated as a result of gas recovery process(es) at the MSWLF unit.

§ 258.29 Recordkeeping requirements.

(a) The owner or operator of a MSWLF unit must record and retain near the facility in an operating record or in an alternative location approved by the Director of an approved State the following information as it becomes available:

(1) Any location restriction demonstration required under subpart B of this part;

(2) Inspection records, training procedures, and notification procedures required in § 258.20 of this part;

(3) Gas monitoring results from monitoring and any remediation plans required by § 258.23 of this part;

(4) Any MSWLF unit design documentation for placement of leachate or gas condensate in a MSWLF unit as required under § 258.28(a)(2) of this part;

(5) Any demonstration, certification, finding, monitoring, testing, or analytical data required by subpart E of this part;

(6) Closure and post-closure care plans and any monitoring, testing, or analytical data as required by §§ 258.60 and 258.61 of this part; and

(7) Any cost estimates and financial assurance documentation required by subpart G of this part.

(8) Any information demonstrating compliance with small community exemption as required by § 258.1(f)(2).

(b) The owner/operator must notify the State Director when the documents from paragraph (a) of this section have been placed or added to the operating record, and all information contained in the operating record must be furnished upon request to the State Director or be made available at all reasonable times for inspection by the State Director.

(c) The Director of an approved State can set alternative schedules for recordkeeping and notification requirements as specified in paragraphs (a) and (b) of this section, except for the notification requirements in § 258.10(b) and § 258.55(g)(1)(iii).

§§ 258.30—258.39 [Reserved]

Subpart D—Design Criteria

§ 258.40 Design criteria.

(a) New MSWLF units and lateral expansions shall be constructed:

(1) In accordance with a design approved by the Director of an approved State or as specified in § 258.40(e) for unapproved States. The design must ensure that the concentration values listed in Table 1 of this section will not be exceeded in the uppermost aquifer at the relevant point of compliance, as specified by the Director of an approved State under paragraph (d) of this section, or

(2) With a composite liner, as defined in paragraph (b) of this section and a leachate collection system that is designed and constructed to maintain less than a 30-cm depth of leachate over the liner.

(b) For purposes of this section, *composite liner* means a system consisting of two components; the upper component must consist of a minimum 30-mil flexible membrane liner (FML), and the lower component must consist of at least a two-foot layer of compacted soil with a hydraulic conductivity of no more than 1×10^{-7} cm/sec. FML components consisting of high density polyethylene (HDPE) shall be at least 60-mil thick. The FML component must be installed in direct and uniform contact with the compacted soil component.

(c) When approving a design that complies with paragraph (a)(1) of this section, the Director of an approved State shall consider at least the following factors:

(1) The hydrogeologic characteristics of the facility and surrounding land;

(2) The climatic factors of the area; and

(3) The volume and physical and chemical characteristics of the leachate.

(d) The relevant point of compliance specified by the Director of an approved State shall be no more than 150 meters from the waste management unit boundary and shall be located on land owned by the owner of the

MSWLF unit. In determining the relevant point of compliance State Director shall consider at least the following factors:

(1) The hydrogeologic characteristics of the facility and surrounding land;

(2) The volume and physical and chemical characteristics of the leachate;

(3) The quantity, quality, and direction, of flow of ground water;

(4) The proximity and withdrawal rate of the ground-water users;

(5) The availability of alternative drinking water supplies;

(6) The existing quality of the ground water, including other sources of contamination and their cumulative impacts on the ground water, and whether the ground water is currently used or reasonably expected to be used for drinking water;

(7) Public health, safety, and welfare effects; and

(8) Practicable capability of the owner or operator.

(e) If EPA does not promulgate a rule establishing the procedures and requirements for State compliance with RCRA section 4005(c)(1)(B) by October 9, 1993, owners and operators in unapproved States may utilize a design meeting the performance standard in § 258.40(a)(1) if the following conditions are met:

(1) The State determines the design meets the performance standard in § 258.40(a)(1);

(2) The State petitions EPA to review its determination; and

(3) EPA approves the State determination or does not disapprove the determination within 30 days.

NOTE TO SUBPART D: 40 CFR part 239 is reserved to establish the procedures and requirements for State compliance with RCRA section 4005(c)(1)(B).

TABLE 1

Chemical	MCL (mg/l)
Arsenic	0.05
Barium	1.0
Benzene	0.005
Cadmium	0.01
Carbon tetrachloride	0.005
Chromium (hexavalent)	0.05
2,4-Dichlorophenoxy acetic acid	0.1
1,4-Dichlorobenzene	0.075
1,2-Dichloroethane	0.005
1,1-Dichloroethylene	0.007
Endrin	0.0002
Fluoride	4
Lindane	0.004
Lead	0.05
Mercury	0.002
Methoxychlor	0.1
Nitrate	10
Selenium	0.01
Silver	0.05
Toxaphene	0.005
1,1,1-Trichloromethane	0.2
Trichloroethylene	0.005
2,4,5-Trichlorophenoxy acetic acid	0.01
Vinyl Chloride	0.002

Subpart E—Ground-Water Monitoring and Corrective Action

§ 258.50 Applicability.

(a) The requirements in this part apply to MSWLF units, except as provided in paragraph (b) of this section.

(b) Ground-water monitoring requirements under § 258.51 through § 258.55 of this part may be suspended by the Director of an approved State for a MSWLF unit if the owner or operator can demonstrate that there is no potential for migration of hazardous constituents from that MSWLF unit to the uppermost aquifer (as defined in § 258.2) during the active life of the unit and the post-closure care period. This demonstration must be certified by a qualified ground-water scientist and approved by the Director of an approved State, and must be based upon:

(1) Site-specific field collected measurements, sampling, and analysis of physical, chemical, and biological processes affecting contaminant fate and transport, and

(2) Contaminant fate and transport predictions that maximize contaminant migration and consider impacts on human health and environment.

(c) Owners and operators of MSWLF units must comply with the ground-water monitoring requirements of this part according to the following schedule unless an alternative schedule is specified under paragraph (d) of this section:

(1) Existing MSWLF units and lateral expansions less than one mile from a drinking water intake (surface or subsurface) must be in compliance with the ground-water monitoring requirements specified in §§ 258.51-258.55 by October 9, 1994;

(2) Existing MSWLF units and lateral expansions greater than one mile but less than two miles from a drinking water intake (surface or subsurface) must be in compliance with the ground-water monitoring requirements specified in §§ 258.51-258.55 by October 9, 1995;

(3) Existing MSWLF units and lateral expansions greater than two miles from a drinking water intake (surface or subsurface) must be in compliance with the ground-water monitoring requirements specified in §§ 258.51-258.55 by October 9, 1996.

(4) New MSWLF units must be in compliance with the ground-water monitoring requirements specified in §§ 258.51-258.55 before waste can be placed in the unit.

(d) The Director of an approved State may specify an alternative schedule for the owners or operators of existing MSWLF units and lateral expansions to comply with the ground-water monitoring requirements specified in §§ 258.51-258.55. This schedule must ensure that 50 percent of all existing MSWLF units are in compliance by October 9, 1994 and all existing MSWLF units are in compliance by October 9, 1996. In setting the compliance schedule, the Director of an approved State must consider potential risks posed by the unit to human health and the environment. The following factors should be considered in determining potential risk:

(1) Proximity of human and environmental receptors;

(2) Design of the MSWLF unit;

(3) Age of the MSWLF unit;

(4) The size of the MSWLF unit; and

(5) Types and quantities of wastes disposed including sewage sludge; and

(6) Resource value of the underlying aquifer, including:

(i) Current and future uses;

(ii) Proximity and withdrawal rate of users; and

(iii) Ground-water quality and quantity.

(e) Once established at a MSWLF unit, ground-water monitoring shall be conducted throughout the active life and post-closure care period of that MSWLF unit as specified in § 258.61.

(f) For the purposes of this subpart, a *qualified ground-water scientist* is a scientist or engineer who has received a baccalaureate or post-graduate degree in the natural sciences or engineering and has sufficient training and experience in groundwater hydrology and related fields as may be demonstrated by State registration, professional Certifications, or completion of accredited university programs that enable that individual to make sound professional judgements regarding ground-water monitoring, contaminant fate and transport, and corrective-action.

(g) The Director of an approved State may establish alternative schedules for demonstrating compliance with § 258.51(d)(2), pertaining to notification of placement of certification in operating record; § 258.54(c)(1), pertaining to notification that statistically significant increase (SSI) notice is in operating record; § 258.54(c) (2) and (3), pertaining to an assessment monitoring program; § 258.55(b), pertaining to sampling and analyzing Appendix II constituents; § 258.55(d)(1), pertaining to placement of notice (Appendix II constituents detected) in record and notification of notice in record; § 258.55(d)(2), pertaining to sampling for appendix I and II to this part; § 258.55(g), pertaining to notification (and placement of notice in record) of SSI above ground-water protection standard; §§ 258.55(g)(1)(iv) and 258.56(a), pertaining to assessment of corrective measures; § 258.57(a), pertaining to selection of remedy and notification of placement in record; § 258.58(c)(4), pertaining to notification of placement in record (alternative corrective action measures); and § 258.58(f), pertaining to notification of placement in record (certification of remedy completed).

[56 FR 51016, Oct. 9, 1991; 57 FR 28628, June 26, 1992]

§ 258.51 Ground-water monitoring systems.

(a) A ground-water monitoring system must be installed that consists of a sufficient number of wells, installed at appropriate locations and depths, to yield ground-water samples from the uppermost aquifer (as defined in § 258.2) that:

(1) Represent the quality of background ground water that has not been affected by leakage from a unit. A determination of background quality may include sampling of wells that are not hydraulically upgradient of the waste management area where:

(i) Hydrogeologic conditions do not allow the owner or operator to determine what wells are hydraulically upgradient; or

(ii) Sampling at other wells will provide an indication of background ground-water quality that is as representative or more representative than that provided by the upgradient wells; and

(2) Represent the quality of ground water passing the relevant point of compliance specified by Director of an approved State under § 258.40(d) or at the waste management unit boundary in unapproved States. The downgradient monitoring system must be installed at the relevant point of compliance specified by the Director of an approved State under § 258.40(d) or at the waste management unit boundary in unapproved States that ensures detection of ground-water contamination in the uppermost aquifer. When physical obstacles preclude installation of ground-water monitoring wells at the relevant point of compliance at existing units, the down-gradient monitoring system may be installed at the closest practicable distance hydraulically down-gradient from the relevant point of compliance specified by the Director of an approved State under § 258.40 that ensure detection of groundwater contamination in the uppermost aquifer.

(b) The Director of an approved State may approve a multiunit ground-water monitoring system instead of separate ground-water monitoring systems for each MSWLF unit when the facility has several units, provided the multi-unit ground-water monitoring system meets the requirement of § 258.51(a) and will be as protective of human health and the environment as individual monitoring systems for each MSWLF unit, based on the following factors:

(1) Number, spacing, and orientation of the MSWLF units;

(2) Hydrogeologic setting;

(3) Site history;

(4) Engineering design of the MSWLF units, and

(5) Type of waste accepted at the MSWLF units.

(c) Monitoring wells must be cased in a manner that maintains the integrity of the monitoring well bore hole. This casing must be screened or perforated and packed with gravel or sand, where necessary, to enable collection of ground-water samples. The annular space (i.e., the space between the bore hole and well casing) above the sampling depth must be sealed to prevent contamination of samples and the ground water.

(1) The owner or operator must notify the State Director that the design, installation, development, and decommission of any monitoring wells, piezometers and other measurement, sampling, and analytical devices documentation has been placed in the operating record; and

(2) The monitoring wells, piezometers, and other measurement, sampling, and analytical devices must be operated and maintained so that they perform to design specifications throughout the life of the monitoring program.

(d) The number, spacing, and depths of monitoring systems shall be:

(1) Determined based upon site-specific technical information that must include thorough characterization of:

(i) Aquifer thickness, ground-water flow rate, ground-water flow direction including seasonal and temporal fluctuations in ground-water flow; and

(ii) Saturated and unsaturated geologic units and fill materials overlying the uppermost aquifer, materials comprising the uppermost aquifer, and materials comprising the confining unit defining the lower boundary of the uppermost aquifer; including, but not limited to: Thicknesses, stratigraphy, lithology, hydraulic conductivities, porosities and effective porosities.

(2) Certified by a qualified ground-water scientist or approved by the Director of an approved State. Within 14 days of this certification, the owner or operator must notify the State Director that the certification has been placed in the operating record.

§ 258.52 [Reserved]

§ 258.53 **Ground-water sampling and analysis requirements.**

(a) The ground-water monitoring program must include consistent sampling and analysis procedures that are designed to ensure monitoring results that provide an accurate representation of ground-water quality at the background and downgradient wells installed in compliance with § 258.51(a) of this part. The owner or operator must notify the State Director that the sampling and analysis program documentation has been placed in the operating record and the program must include procedures and techniques for:

(1) Sample collection;

(2) Sample preservation and shipment;

(3) Analytical procedures;

(4) Chain of custody control; and

(5) Quality assurance and quality control.

(b) The ground-water monitoring program must include sampling and analytical methods that are appropriate for ground-water sampling and that accurately measure hazardous constituents and other monitoring parameters in ground-water samples. Ground-water samples shall not be field-filtered prior to laboratory analysis.

(c) The sampling procedures and frequency must be protective of human health and the environment.

(d) Ground-water elevations must be measured in each well immediately prior to purging, each time ground water is sampled. The owner or operator must determine the rate and direction of ground-water flow each time ground water is sampled. Ground-water elevations in wells which monitor the same waste management area must be measured within a period of time short enough to avoid temporal variations in ground-water flow which could preclude accurate determination of ground-water flow rate and direction.

(e) The owner or operator must establish background ground-water quality in a hydraulically upgradient or background well(s) for each of the monitoring parameters or constituents required in the particular ground-water monitoring program that applies to the MSWLF unit, as determined under § 258.54(a) or § 258.55(a) of this part. Background ground-water quality may be established at wells that are not located hydraulically upgradient from the MSWLF unit if it meets the requirements of § 258.51(a)(1).

(f) The number of samples collected to establish ground-water quality data must be consistent with the appropriate statistical procedures determined pursuant to paragraph (g) of this section. The sampling procedures shall be those specified under § 258.54(b) for detection monitoring, § 258.55 (b) and (d) for assessment monitoring, and § 258.56(b) of corrective action.

(g) The owner or operator must specify in the operating record one of the following statistical methods to be used in evaluating ground-water monitoring data for each hazardous constituent. The statistical test chosen shall be conducted separately for each hazardous constituent in each well.

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

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

(3) A tolerance or prediction interval procedure in which an interval for each constituent is established from

the distribution of the background data, and the level of each constituent in each compliance well is compared to the upper tolerance or prediction limit.

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

(5) Another statistical test method that meets the performance standards of § 258.53(h). The owner or operator must place a justification for this alternative in the operating record and notify the State Director of the use of this alternative test. The justification must demonstrate that the alternative method meets the performance standards of § 258.53(h).

(h) Any statistical method chosen under § 258.53(g) shall comply with the following performance standards, as appropriate:

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

(2) If an individual well comparison procedure is used to compare an individual compliance well constituent concentration with background constituent concentrations or a ground-water protection standard, the test shall be done at a Type I error level no less than 0.01 for each testing period. If a multiple comparisons procedure is used, the Type I experiment wise error rate for each testing period shall be no less than 0.05; however, the Type I error of no less than 0.01 for individual well comparisons must be maintained. This performance standard does not apply to tolerance intervals, prediction intervals, or control charts.

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

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

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

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

(i) The owner or operator must determine whether or not there is a statistically significant increase over background values for each parameter or constituent required in the particular ground-water monitoring program that applies to the MSWLF unit, as determined under §§ 258.54(a) or 258.55(a) of this part.

(1) In determining whether a statistically significant increase has occurred, the owner or operator must compare the ground-water quality of each parameter or constituent at each monitoring well designated pursuant to § 258.51(a)(2) to the background value of that constituent, according to the statistical procedures and performance standards specified under paragraphs (g) and (h) of this section.

(2) Within a reasonable period of time after completing sampling and analysis, the owner or operator must determine whether there has been a statistically significant increase over background at each monitoring well.

§ 258.54 **Detection monitoring program.**

(a) Detection monitoring is required at MSWLF units at all ground-water monitoring wells defined under §§ 258.51 (a)(1) and (a)(2) of this part. At a minimum, a detection monitoring program must include the monitoring for the constituents listed in appendix I to this part.

(1) The Director of an approved State may delete any of the appendix I monitoring parameters for a MSWLF unit if it can be shown that the removed constituents are not reasonably expected to be in or derived from the waste contained in the unit.

(2) The Director of an approved State may establish an alternative list of inorganic indicator parameters for a MSWLF unit, in lieu of some or all of the heavy metals (constituents 1-15 in appendix I to this part), if the alternative parameters provide a reliable indication of inorganic releases from the MSWLF unit to the ground water. In determining alternative parameters, the Director shall consider the following factors:

(i) The types, quantities, and concentrations of constituents in wastes managed at the MSWLF unit;

(ii) The mobility, stability, and persistence of waste constituents or their reaction products in the unsaturated zone beneath the MSWLF unit;

(iii) The detectability of indicator parameters, waste constituents, and reaction products in the ground water; and

(iv) The concentration or values and coefficients of variation of monitoring parameters or constituents in the groundwater background.

(b) The monitoring frequency for all constituents listed in appendix I to this part, or in the alternative list approved in accordance with paragraph (a)(2) of this section, shall be at least semiannual during the active life of the facility (including closure) and the post-closure period. A minimum of four independent samples from each well (background and downgradient) must be collected and analyzed for the appendix I constituents, or the alternative list approved in accordance with paragraph (a)(2) of this section, during the first semiannual sampling event. At least one sample from each well (background and downgradient) must be collected and analyzed during subsequent semiannual sampling events. The Director of an approved State may specify an appropriate alternative frequency for repeated sampling and analysis for appendix I constituents, or the alternative list approved in accordance with paragraph (a)(2) of this section, during the active life (including closure) and the post-closure care period. The alternative frequency during the active life (including closure) shall be no less than annual. The alternative frequency shall be based on consideration of the following factors:

(1) Lithology of the aquifer and unsaturated zone;

(2) Hydraulic conductivity of the aquifer and unsaturated zone;

(3) Ground-water flow rates;

(4) Minimum distance between upgradient edge of the MSWLF unit and downgradient monitoring well screen (minimum distance of travel); and

(5) Resource value of the aquifer.

(c) If the owner or operator determines, pursuant to § 258.53(g) of this part, that there is a statistically significant increase over background for one or more of the constituents listed in appendix I to this part or in the alternative list approved in accordance with paragraph (a)(2) of this section, at any monitoring well at the boundary specified under § 258.51(a)(2), the owner or operator:

(1) Must, within 14 days of this finding, place a notice in the operating record indicating which constituents have shown statistically significant changes from background levels, and notify the State director that this notice was placed in the operating record; and

(2) Must establish an assessment monitoring program meeting the requirements of § 258.55 of this part within 90 days except as provided for in paragraph (c)(3) of this section.

(3) The owner/operator may demonstrate that a source other than a MSWLF unit caused the contamination or that the statistically significant increase resulted from error in sampling, analysis, statistical evaluation, or natural variation in ground-water quality. A report documenting this demonstration must be certified by a qualified ground-water scientist or approved by the Director of an approved State and be placed in the operating record. If a successful demonstration is made and documented, the owner or operator may continue detection monitoring as specified in this section. If, after 90 days, a successful demonstration is not made, the owner or operator must initiate an assessment monitoring program as required in § 258.55.

§ 258.55 Assessment monitoring program.

(a) Assessment monitoring is required whenever a statistically significant increase over background has been detected for one or more of the constituents listed in the appendix I to this part or in the alternative list approved in accordance with § 258.54(a)(2).

(b) Within 90 days of triggering an assessment monitoring program, and annually thereafter, the owner or operator must sample and analyze the ground water for all constituents identified in appendix II to this part. A minimum of one sample from each downgradient well must be collected and analyzed during each sampling event. For any constituent detected in the downgradient wells as a result of the complete appendix II analysis, a minimum of four independent samples from each well (background and downgradient) must be collected and analyzed to establish background for the constituents. The Director of an approved State may specify an appropriate subset of wells to be sampled and analyzed for appendix II constituents during assessment monitoring. The Director of an approved State may delete any of the appendix II monitoring parameters for a MSWLF unit if it can be shown that the removed constituents are not reasonably expected to be in or derived from the waste contained in the unit.

(c) The Director of an approved State may specify an appropriate alternate frequency for repeated sampling and analysis for the full set of appendix II constituents required by § 258.55(b) of this part, during the active life (including closure) and post-closure care of the unit considering the following factors:

(1) Lithology of the aquifer and unsaturated zone;

(2) Hydraulic conductivity of the aquifer and unsaturated zone;

(3) Ground-water flow rates;

(4) Minimum distance between upgradient edge of the MSWLF unit and downgradient monitoring well screen (minimum distance of travel);

(5) Resource value of the aquifer; and

(6) Nature (fate and transport) of any constituents detected in response to this section.

(d) After obtaining the results from the initial or subsequent sampling events required in paragraph (b) of this section, the owner or operator must:

(1) Within 14 days, place a notice in the operating record identifying the appendix II constituents that have been detected and notify the State Director that this notice has been placed in the operating record;

(2) Within 90 days, and on at least a semiannual basis thereafter, resample all wells specified by § 258.51(a), conduct analyses for all constituents in appendix I to this part or in the alternative list approved in accordance with § 258.54(a)(2), and for those constituents in appendix II to this part that are detected in response to paragraph (b) of this section, and record their concentrations in the facility operating record. At least one sample from each well (background and downgradient) must be collected and analyzed during these sampling events. The Director of an approved State may specify an alternative monitoring frequency during the active life (including closure) and the post-closure period for the constituents referred to in this paragraph. The alternative frequency for appendix I constituents, or the alternative list approved in accordance with § 258.54(a)(2), during the active life (including closure) shall be

no less than annual. The alternative frequency shall be based on consideration of the factors specified in paragraph (c) of this section;

(3) Establish background concentrations for any constituents detected pursuant to paragraph (b) or (d)(2) of this section; and

(4) Establish ground-water protection standards for all constituents detected pursuant to paragraph (b) or (d) of this section. The ground-water protection standards shall be established in accordance with paragraphs (h) or (i) of this section.

(e) If the concentrations of all appendix II constituents are shown to be at or below background values, using the statistical procedures in § 258.53(g), for two consecutive sampling events, the owner or operator must notify the State Director of this finding and may return to detection monitoring.

(f) If the concentrations of any appendix II constituents are above background values, but all concentrations are below the ground-water protection standard established under paragraphs (h) or (i) of this section, using the statistical procedures in § 258.53(g), the owner or operator must continue assessment monitoring in accordance with this section.

(g) If one or more appendix II constituents are detected at statistically significant levels above the ground-water protection standard established under paragraphs (h) or (i) of this section in any sampling event, the owner or operator must, within 14 days of this finding, place a notice in the operating record identifying the appendix II constituents that have exceeded the ground-water protection standard and notify the State Director and all appropriate local government officials that the notice has been placed in the operating record. The owner or operator also:

(1)(i) Must characterize the nature and extent of the release by installing additional monitoring wells as necessary;

(ii) Must install at least one additional monitoring well at the facility boundary in the direction of contaminant migration and sample this well in accordance with § 258.55(d)(2);

(iii) Must notify all persons who own the land or reside on the land that directly overlies any part of the plume of contamination if contaminants have migrated off-site if indicated by sampling of wells in accordance with § 258.55 (g)(1); and

(iv) Must initiate an assessment of corrective measures as required by § 255.56 of this part within 90 days; or

(2) May demonstrate that a source other than a MSWLF unit caused the contamination, or that the SSI increase resulted from error in sampling, analysis, statistical evaluation, or natural variation in ground-water quality. A report documenting this demonstration must be certified by a qualified ground-water scientist or approved by the Director of an approved State and placed in the operating record. If a successful demonstration is made the owner or operator must continue monitoring in accordance with the assessment monitoring program pursuant to § 258.55, and may return to detection monitoring if the appendix II constituents are at or below background as specified in § 258.55(e). Until a successful demonstration is made, the owner or operator must comply with § 258.55(g) including initiating an assessment of corrective measures.

(h) The owner or operator must establish a ground-water protection standard for each appendix II constituent detected in the ground-water. The ground-water protection standard shall be:

(1) For constituents for which a maximum contaminant level (MCL) has been promulgated under section 1412 of the Safe Drinking Water Act (codified) under 40 CFR part 141, the MCL for that constituent;

(2) For constituents for which MCLs have not been promulgated, the background concentration for the constituent established from wells in accordance with § 258.51(a)(1); or

(3) For constituents for which the background level is higher than the MCL identified under paragraph (h)(1) of this section or health based levels identified under § 258.55(i)(1), the background concentration.

(i) The Director of an approved State may establish an alternative ground-water protection standard for constituents for which MCLs have not been established. These ground-water protection standards shall be appropriate health based levels that satisfy the following criteria:

(1) The level is derived in a manner consistent with Agency guidelines for assessing the health risks of environmental pollutants (51 FR 33992, 34006, 34014, 34028, Sept. 24, 1986);

(2) The level is based on scientifically valid studies conducted in accordance with the Toxic Substances Control Act Good Laboratory Practice Standards (40 CFR part 792) or equivalent;

(3) For carcinogens, the level represents a concentration associated with an excess lifetime cancer risk level (due to continuous lifetime exposure) with the 1×10^{-4} to 1×10^{-6} range; and

(4) For systemic toxicants, the level represents a concentration to which the human population (including sensitive subgroups) could be exposed to on a daily basis that is likely to be without appreciable risk of deleterious effects during a lifetime. For purposes of this subpart, systemic toxicants include toxic chemicals that cause effects other than cancer or mutation.

(j) In establishing ground-water protection standards under paragraph (i) of this section, the Director of an approved State may consider the following:

(1) Multiple contaminants in the ground water;

(2) Exposure threats to sensitive environmental receptors; and

(3) Other site-specific exposure or potential exposure to ground water.

§ 258.56 Assessment of corrective measures.

(a) Within 90 days of finding that any of the constituents listed in appendix II to this part have been detected at a statistically significant level exceeding the ground-water protection standards defined under § 258.55 (h) or (i) of this part, the owner or operator must initiate an assessment of corrective measures. Such an assessment must be completed within a reasonable period of time.

(b) The owner or operator must continue to monitor in accordance with the assessment monitoring program as specified in § 258.55.

(c) The assessment shall include an analysis of the effectiveness of potential corrective measures in meeting all of the requirements and objectives of the remedy as described under § 258.57, addressing at least the following:

(1) The performance, reliability, ease of implementation, and potential impacts of appropriate potential remedies, including safety impacts, cross-media impacts, and control of exposure to any residual contamination;

(2) The time required to begin and complete the remedy;

(3) The costs of remedy implementation; and

(4) The institutional requirements such as State or local permit requirements or other environmental or public health requirements that may substantially affect implementation of the remedy(s).

(d) The owner or operator must discuss the results of the corrective measures assessment, prior to the selection of remedy, in a public meeting with interested and affected parties.

§ 258.57 Selection of remedy.

(a) Based on the results of the corrective measures assessment conducted under § 258.56, the owner or operator must select a remedy that, at a minimum, meets the standards listed in paragraph (b) of this section. The owner or operator must notify the State Director, within 14 days of selecting a remedy, a report describing the selected remedy has been placed in the operating record and how it meets the standards in paragraph (b) of this section.

(b) Remedies must:

(1) Be protective of human health and the environment;

(2) Attain the ground-water protection standard as specified pursuant to §§ 258.55 (h) or (i);

(3) Control the source(s) of releases so as to reduce or eliminate, to the maximum extent practicable, further releases of appendix II constituents into the environment that may pose a threat to human health or the environment; and

(4) Comply with standards for management of wastes as specified in § 258.58(d).

(c) In selecting a remedy that meets the standards of § 258.57(b), the owner or operator shall consider the following evaluation factors:

(1) The long- and short-term effectiveness and protectiveness of the potential remedy(s), along with the degree of certainty that the remedy will prove successful based on consideration of the following:

(i) Magnitude of reduction of existing risks;

(ii) Magnitude of residual risks in terms of likelihood of further releases due to waste remaining following implementation of a remedy;

(iii) The type and degree of long-term management required, including monitoring, operation, and maintenance;

(iv) Short-term risks that might be posed to the community, workers, or the environment during implementation of such a remedy, including potential threats to human health and the environment associated with excavation, transportation, and redisposal of containment;

(v) Time until full protection is achieved;

(vi) Potential for exposure of humans and environmental receptors to remaining wastes, considering the potential threat to human health and the environment associated with excavation, transportation, redisposal, or containment;

(vii) Long-term reliability of the engineering and institutional controls; and

(viii) Potential need for replacement of the remedy.

(2) The effectiveness of the remedy in controlling the source to reduce further releases based on consideration of the following factors:

(i) The extent to which containment practices will reduce further releases;

(ii) The extent to which treatment technologies may be used.

(3) The ease or difficulty of implementing a potential remedy(s) based on consideration of the following types of factors:

(i) Degree of difficulty associated with constructing the technology;

(ii) Expected operational reliability of the technologies;

(iii) Need to coordinate with and obtain necessary approvals and permits from other agencies;

(iv) Availability of necessary equipment and specialists; and

(v) Available capacity and location of needed treatment, storage, and disposal services.

(4) Practicable capability of the owner or operator, including a consideration of the technical and economic capability.

(5) The degree to which community concerns are addressed by a potential remedy(s).

(d) The owner or operator shall specify as part of the selected remedy a schedule(s) for initiating and completing remedial activities. Such a schedule must require the initiation of remedial activities within a reasonable period of time taking into consideration the factors set forth in paragraphs (d) (1)-(8) of this section. The owner or operator must consider the following factors in determining the schedule of remedial activities:

(1) Extent and nature of contamination;

(2) Practical capabilities of remedial technologies in achieving compliance with ground-water protection standards established under § 258.55 (g) or (h) and other objectives of the remedy;

(3) Availability of treatment or disposal capacity for wastes managed during implementation of the remedy;

(4) Desirability of utilizing technologies that are not currently available, but which may offer significant advantages over already available technologies in terms of effectiveness, reliability, safety, or ability to achieve remedial objectives;

(5) Potential risks to human health and the environment from exposure to contamination prior to completion of the remedy;

(6) Resource value of the aquifer including:

(i) Current and future uses;

(ii) Proximity and withdrawal rate of users;

(iii) Ground-water quantity and quality;

(iv) The potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to waste constituent;

(v) The hydrogeologic characteristic of the facility and surrounding land;

(vi) Ground-water removal and treatment costs; and

(vii) The cost and availability of alternative water supplies.

(7) Practicable capability of the owner or operator.

(8) Other relevant factors.

(e) The Director of an approved State may determine that remediation of a release of an appendix II constituent from a MSWLF unit is not necessary if the owner or operator demonstrates to the satisfaction of the Director of the approved State that:

(1) The ground-water is additionally contaminated by substances that have originated from a source other than a MSWLF unit and those substances are present in concentrations such that cleanup of the release from the MSWLF unit would provide no significant reduction in risk to actual or potential receptors; or

(2) The constituent(s) is present in ground water that:

(i) Is not currently or reasonably expected to be a source of drinking water; and

(ii) Is not hydraulically connected with waters to which the hazardous constituents are migrating or are likely to migrate in a concentration(s) that would exceed the ground-water protection standards established under § 258.55 (h) or (i); or

(3) Remediation of the release(s) is technically impracticable; or

(4) Remediation results in unacceptable cross-media impacts.

(f) A determination by the Director of an approved State pursuant to paragraph (e) of this section shall not affect the authority of the State to require the owner or operator to undertake source control measures or other measures that may be necessary to eliminate or minimize further releases to the ground-water, to prevent exposure to the ground-water, or to remediate the ground-water to concentrations that are technically practicable and significantly reduce threats to

§ 258.58 Implementation of the corrective action program.

(a) Based on the schedule established under § 258.57(d) for initiation and completion of remedial activities the owner/operator must:

(1) Establish and implement a corrective action ground-water monitoring program that:

(i) At a minimum, meet the requirements of an assessment monitoring program under § 258.55;

(ii) Indicate the effectiveness of the corrective action remedy; and

(iii) Demonstrate compliance with ground-water protection standard pursuant to paragraph (e) of this section.

(2) Implement the corrective action remedy selected under § 258.57; and

(3) Take any interim measures necessary to ensure the protection of human health and the environment. Interim measures should, to the greatest extent practicable, be consistent with the objectives of and contribute to the performance of any remedy that may be required pursuant to § 258.57. The following factors must be considered by an owner or operator in determining whether interim measures are necessary:

(i) Time required to develop and implement a final remedy;

(ii) Actual or potential exposure of nearby populations or environmental receptors to hazardous constituents;

(iii) Actual or potential contamination of drinking water supplies or sensitive ecosystems;

(iv) Further degradation of the ground-water that may occur if remedial action is not initiated expeditiously;

(v) Weather conditions that may cause hazardous constituents to migrate or be released;

(vi) Risks of fire or explosion, or potential for exposure to hazardous constituents as a result of an accident or failure of a container or handling system; and

(vii) Other situations that may pose threats to human health and the environment.

(b) An owner or operator may determine, based on information developed after implementation of the remedy has begun or other information, that compliance with requirements of § 258.57(b) are not being achieved through the remedy selected. In such cases, the owner or operator must implement other methods or techniques that could practicably achieve compliance with the requirements, unless the owner or operator makes the determination under § 258.58(c).

(c) If the owner or operator determines that compliance with requirements under § 258.57(b) cannot be practically achieved with any currently available methods, the owner or operator must:

(1) Obtain certification of a qualified ground-water scientist or approval by the Director of an approved State that compliance with requirements under § 258.57(b) cannot be practically achieved with any currently available methods;

(2) Implement alternate measures to control exposure of humans or the environment to residual contamination, as necessary to protect human health and the environment; and

(3) Implement alternate measures for control of the sources of contamination, or for removal or decontamination of equipment, units, devices, or structures that are:

(i) Technically practicable; and

(ii) Consistent with the overall objective of the remedy.

(4) Notify the State Director within 14 days that a report justifying the alternative measures prior to implementing the alternative measures has been placed in the operating record.

(d) All solid wastes that are managed pursuant to a remedy required under § 258.57, or an interim measure required under § 258.58(a)(3), shall be managed in a manner:

(1) That is protective of human health and the environment; and

(2) That complies with applicable RCRA requirements.

(e) Remedies selected pursuant to § 258.57 shall be considered complete when:

(1) The owner or operator complies with the ground-water protection standards established under §§ 258.55(h) or (i) at all points within the plume of contamination that lie beyond the ground-water monitoring well system established under § 258.51(a).

(2) Compliance with the ground-water protection standards established under §§ 258.55(h) or (i) has been achieved by demonstrating that concentrations of appendix II constituents have not exceeded the ground-water protection standard(s) for a period of three consecutive years using the statistical procedures and performance standards in § 258.53(g) and (h). The Director of an approved State may specify an alternative length of time during which the owner or operator must demonstrate that concentrations of appendix II constituents have not exceeded the ground-water protection standard(s) taking into consideration:

(i) Extent and concentration of the release(s);

(ii) Behavior characteristics of the hazardous constituents in the ground-water;

(iii) Accuracy of monitoring or modeling techniques, including any seasonal, meteorological, or other environmental variabilities that may affect the accuracy; and

(iv) Characteristics of the ground-water.

(3) All actions required to complete the remedy have been satisfied.

(f) Upon completion of the remedy, the owner or operator must notify the State Director within 14 days that a certification that the remedy has been completed in compliance with the requirements of § 258.58(e) has been placed in the operating record. The certification must be signed by the owner or operator and by a qualified ground-water scientist or approved by the Director of an approved State.

(g) When, upon completion of the certification, the owner or operator determines that the corrective action remedy has been completed in accordance with the requirements under paragraph (e) of this section, the owner or operator shall be released from the requirements for financial assurance for corrective action under § 258.73.

§ 258.59 [Reserved]

Subpart F—Closure And Post-Closure Care

§ 258.60 Closure criteria.

(a) Owners or operators of all MSWLF units must install a final cover system that is designed to minimize infiltration and erosion. The final cover system must be designed and constructed to:

(1) Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present, or a permeability no greater than 1×10^{-5} cm/sec, whichever is less, and

(2) Minimize infiltration through the closed MSWLF by the use of an infiltration layer that contains a minimum 18-inches of earthen material, and

(3) Minimize erosion of the final cover by the use of an erosion layer that contains a minimum 6-inches of earthen material that is capable of sustaining native plant growth.

(b) The Director of an approved State may approve an alternative final cover design that includes:

(1) An infiltration layer that achieves an equivalent reduction in infiltration as the infiltration layer specified in paragraphs (a)(1) and (a)(2) of this section, and

(2) An erosion layer that provides equivalent protection from wind and water erosion as the erosion layer specified in paragraph (a)(3) of this section.

(c) The owner or operator must prepare a written closure plan that describes the steps necessary to close all MSWLF units at any point during their active life in accordance with the cover design requirements in § 258.60(a) or (b), as applicable. The closure plan, at a minimum, must include the following information:

(1) A description of the final cover, designed in accordance with § 258.60(a) and the methods and procedures to be used to install the cover;

(2) An estimate of the largest area of the MSWLF unit ever requiring a final cover as required under § 258.60(a) at [illegible] the active life;

(3) An estimate of the maximum inventory of wastes ever on-site over the active life of the landfill facility; and

(4) A schedule for completing all activities necessary to satisfy the closure criteria in § 258.60.

(d) The owner or operator must notify the State Director that a closure plan has been prepared and placed in the operating record no later than the effective date of this part, or by the initial receipt of waste, whichever is later.

(e) Prior to beginning closure of each MSWLF unit as specified in § 258.60(f), an owner or operator must notify the State Director that a notice of the intent to close the unit has been placed in the operating record.

(f) The owner or operator must begin closure activities of each MSWLF unit no later than 30 days after the date on which the MSWLF unit receives the known final receipt of wastes or, if the MSWLF unit has remaining capacity and there is a reasonable likelihood that the MSWLF unit will receive additional wastes, no later than one year after the most recent receipt of wastes. Extensions beyond the one-year deadline for beginning closure may be granted by the Director of an approved State if the owner or operator demonstrates that the MSWLF unit has the capacity to receive additional wastes and the owner or operator has taken and will continue to take all steps necessary to prevent threats to human health and the environmental from the unclosed MSWLF unit.

(g) The owner or operator of all MSWLF units must complete closure activities of each MSWLF unit in accordance with the closure plan within 180 days following the beginning of closure as specified in paragraph (f) of this section. Extensions of the closure period may be granted by the Director of an approved State if the owner or operator demonstrates that closure will, of necessity, take longer than 180 days and he has taken and will continue to take all steps to prevent threats to human health and the environment from the unclosed MSWLF unit.

(h) Following closure of each MSWLF unit, the owner or operator must notify the State Director that a certification, signed by an independent registered professional engineer or approved by Director of an approved State, verifying that closure has been completed in accordance with the closure plan, has been placed in the operating record.

(i) (1) Following closure of all MSWLF units, the owner or operator must record a notation on the deed to the landfill facility property, or some other instrument that is normally examined during title search, and notify the State Director that the notation has been recorded and a copy has been placed in the operating record.

(2) The notation on the deed must in perpetuity notify any potential purchaser of the property that:

(i) The land has been used as a landfill facility; and

(ii) Its use is restricted under § 258.61(c)(3).

(j) The owner or operator may request permission from the Director of an approved State to remove the notation from the deed if all wastes are removed from the facility.

[56 FR 51016, Oct. 9, 1991; 57 FR 28628, June 26, 1992]

§ 258.61 **Post-closure care requirements.**

(a) Following closure of each MSWLF unit, the owner or operator must conduct post-closure care. Post-closure care must be conducted for 30 years, except as provided under paragraph (b) of this section, and consist of at least the following:

(1) Maintaining the integrity and effectiveness of any final cover, including making repairs to the cover as necessary to correct the effects of settlement, subsidence, erosion, or other events, and preventing run-on and run-off from eroding or otherwise damaging the final cover;

(2) Maintaining and operating the leachate collection system in accordance with the requirements in § 258.40, if applicable. The Director of an approved State may allow the owner or operator to stop managing leachate if the owner or operator demonstrates that leachate no longer poses a threat to human health and the environment;

(3) Monitoring the ground water in accordance with the requirements of subpart E of this part and maintaining the ground-water monitoring system, if applicable; and

(4) Maintaining and operating the gas monitoring system in accordance with the requirements of § 258.23.

(b) The length of the post-closure care period may be:

(1) Decreased by the Director of an approved State if the owner or operator demonstrates that the reduced period is sufficient to protect human health and the environment and this demonstration is approved by the Director of an approved State; or

(2) Increased by the Director of an approved State if the Director of an approved State determines that the lengthened period is necessary to protect human health and the environment.

(c) The owner or operator of all MSWLF units must prepare a written post-closure plan that includes, at a minimum, the following information:

(1) A description of the monitoring and maintenance activities required in § 258.61(a) for each MSWLF unit, and the frequency at which these activities will be performed;

(2) Name, address, and telephone number of the person or office to contact about the facility during the post-closure period; and

(3) A description of the planned uses of the property during the post-closure period. Post-closure use of the property shall not disturb the integrity of the final cover, liner(s), or any other components of the containment system, or the function of the monitoring systems unless necessary to comply with the requirements in this Part 258. The Director of an approved State may approve any other disturbance if the owner or operator demonstrates that disturbance of the final cover, liner or other component of the containment system, including any removal of waste, will not increase the potential threat to human health or the environment.

(d) The owner or operator must notify the State Director that a post-closure plan has been prepared and placed in the operating record no later than the effective date of this part, October 9, 1993, or by the initial receipt of waste, whichever is later.

(e) Following completion of the post-closure care period for each MSWLF unit, the owner or operator must notify the State Director that a certification, signed by an independent registered professional engineer or approved by the Director of an approved State, verifying that post-closure care has been completed in accordance with the post-closure plan, has been placed in the operating record.

[56 FR 51016, Oct. 9, 1991; 57 FR 28628, June 26, 1992]

§§ 258.62—258.69 [Reserved]

Subpart G—Financial Assurance Criteria

SOURCE: 56 FR 51029, Oct. 9, 1991, unless otherwise noted.

EFFECTIVE DATE NOTE: At 56 FR 51029, Oct. 9, 1991, Subpart G of Part 258 was added, effective April 9, 1994.

§ 258.70 Applicability and effective date.

(a) The requirements of this section apply to owners and operators of all MSWLF units, except owners or operators who are State or Federal government entities whose debts and liabilities are the debts and liabilities of a State or the United States.

(b) The requirements of this section are effective April 9, 1994.

§ 258.71 Financial assurance for closure.

(a) The owner or operator must have a detailed written estimate, in current dollars, of the cost of hiring a third party to close the largest area of all MSWLF units ever requiring a final cover as required under § 258.60 at any time during the active life in accordance with the closure plan. The owner or operator must notify the State Director that the estimate has been placed in the operating record.

(1) The cost estimate must equal the cost of closing the largest area of all MSWLF unit ever requiring a final cover at any time during the active life when the extent and manner of its operation would make closure the most expensive, as indicated by its closure plan (see § 8.60(c)(2) of this part).

(2) During the active life of the [illegible] owner or operator must annually adjust the closure cost estimate for inflation.

(3) The owner or operator must increase the closure cost estimate and the amount of financial assurance provided under paragraph (b) of this section if changes to the closure plan or MSWLF unit conditions increase the maximum cost of closure at any time during the remaining active life.

(4) The owner or operator may reduce the closure cost estimate and the amount of financial assurance provided under paragraph (b) of this section if the cost estimate exceeds the maximum cost of closure at any time during the remaining life of the MSWLF unit. The owner or operator must notify the State Director that the justification for the reduction of the closure cost estimate and the amount of financial assurance has been placed in the operating record.

(b) The owner or operator of each MSWLF unit must establish financial assurance for closure of the MSWLF unit in compliance with § 258.74. The owner or operator must provide continuous coverage for closure until released from financial assurance requirements by demonstrating compliance with § 258.60(h) and (i).

[56 FR 51029, Oct. 9, 1991; 57 FR 28628, June 26, 1992]

§ 258.72 Financial assurance for post-closure care.

(a) The owner or operator must have a detailed written estimate, in current dollars, of the cost of hiring a third party to conduct post-closure care for the MSWLF unit in compliance with the post-closure plan developed under § 258.61 of this part. The post-closure cost estimate used to demonstrate financial assurance in paragraph (b) of this section must account for the total costs of conducting post-closure care, including annual and periodic costs as described in the post-closure plan over the entire post-closure care period. The owner or operator must notify the State Director that the estimate has been placed in the operating record.

(1) The cost estimate for post-closure care must be based on the most expensive costs of post-closure care during the post-closure care period.

(2) During the active life of the MSWLF unit and during the post-closure care period, the owner or operator must annually adjust the post-closure cost estimate for inflation.

(3) The owner or operator must increase the post-closure care cost estimate and the amount of financial assurance provided under paragraph (b) of this section if changes in the post-closure plan or MSWLF unit conditions increase the maximum costs of post-closure care.

(4) The owner or operator may reduce the post-closure cost estimate and the amount of financial assurance provided under paragraph (b) of this section if the cost estimate exceeds the maximum costs of post-closure care remaining over the post-closure care period. The owner or operator must notify the State Director that the justification for the reduction of the post-closure cost estimate and the amount of financial assurance has been placed in the operating record.

(b) The owner or operator of each MSWLF unit must establish, in a manner in accordance with § 258.74, financial assurance for the costs of post-closure care as required under § 258.61 of this part. The owner or operator must provide continuous coverage for post-closure care until released from financial assurance requirements for post-closure care by demonstrating compliance with § 258.61(e).

§ 258.73 Financial assurance for corrective action.

(a) An owner or operator of a MSWLF unit required to undertake a corrective action program under § 258.58 of this part must have a detailed written estimate, in current dollars, of the cost of hiring a third party to perform the corrective action in accordance with the program required under § 258.58 of this part. The corrective action cost estimate must account for the total costs of corrective action activities as described in the corrective action plan for the entire corrective action period. The owner or operator must notify the State Director that the estimate has been placed in the operating record.

(1) The owner or operator must annually adjust the estimate for inflation until the corrective action program is completed in accordance with § 258.58(f) of this part.

(2) The owner or operator must increase the corrective action cost estimate and the amount of financial assurance provided under paragraph (b) of this section if changes in the corrective action program or MSWLF unit conditions increase the maximum costs of corrective action.

(3) The owner or operator may reduce the amount of the corrective action cost estimate and the amount of financial assurance provided under paragraph (b) of this section if the cost estimate exceeds the maximum remaining costs of corrective action. The owner or operator must notify the State Director that the justification for the reduction of the corrective action cost estimate and the amount of financial assurance has been placed in the operating record.

(b) The owner or operator of each MSWLF unit required to undertake a corrective action program under § 258.58 of this part must establish, in a manner in accordance with § 258.74, financial assurance for the most recent corrective action program. The owner or operator must provide continuous coverage for corrective action until released from financial assurance requirements for corrective action by demonstrating compliance with § 258.58 (f) and (g).

§ 258.74 Allowable mechanisms.

The mechanisms used to demonstrate financial assurance under this section must ensure that the funds necessary to meet the costs of closure, post-closure care, and corrective action for known releases will be available whenever they are needed. Owners and operators must choose from the options specified in paragraphs (a) through (j) of this section.

(a) *Trust Fund.* (1) An owner or operator may satisfy the requirements of this section by establishing a trust fund which conforms to the requirements of this paragraph. The trustee must be an entity which has the authority to act as a trustee and whose trust operations are regulated and examined by a Federal or State agency.

A copy of the trust agreement must be placed in the facility's operating record.

(2) Payments into the trust fund must be made annually by the owner or operator over the term of the initial permit or over the remaining life of the MSWLF unit, whichever is shorter, in the case of a trust fund for closure or post-closure care, or over one-half of the estimated length of the corrective action program in the case of corrective action for known releases. This period is referred to as the pay-in period.

(3) For a trust fund used to demonstrate financial assurance for closure and post-closure care, the first payment into the fund must be at least equal to the current cost estimate for closure or post-closure care, except as provided in paragraph (j) of this section, divided by the number of years in the pay-in period as defined in paragraph (a)(2) of this section. The amount of subsequent payments must be determined by the following formula:

$$\text{Next Payment} = \frac{CE-CV}{Y}$$

where CE is the current cost estimate for closure or post-closure care (updated for inflation or other changes), CV is the current value of the trust fund, and Y is the number of years remaining in the pay-in period.

(4) For a trust fund used to demonstrate financial assurance for corrective action, the first payment into the trust fund must be at least equal to one-half of the current cost estimate for corrective action, except as provided in paragraph (j) of this section, divided by the number of years in the corrective action pay-in period as defined in paragraph (a)(2) of this section. The amount of subsequent payments must be determined by the following formula:

$$\text{Next Payment} = \frac{RB-CV}{Y}$$

where RB is the most recent estimate of the required trust fund balance for corrective action (i.e., the total costs that will be incurred during the second half of the corrective action period), CV is the current value of the trust fund, and Y is the number of years remaining on the pay-in period.

(5) The initial payment into the trust fund must be made before the initial receipt of waste or before the effective date of this section (April 9, 1994), whichever is later, in the case of closure and post-closure care, or no later than 120 days after the corrective action remedy has been selected in accordance with the requirements of § 258.58.

(6) If the owner or operator establishes a trust fund after having used one or more alternate mechanisms specified in this section, the initial payment into the trust fund must be at least the amount that the fund would contain if the trust fund were established initially and annual payments made according to the specifications of this paragraph and § 270.74(a) of this section, as applicable.

(7) The owner or operator, or other person authorized to conduct closure, post-closure care, or corrective action activities may request reimbursement from the trustee for these expenditures. Requests for reimbursement will be granted by the trustee only if sufficient funds are remaining in the trust fund to cover the remaining costs of closure, post-closure care, or corrective action, and if justification and documentation of the cost is placed in the operating record. The owner or operator must notify the State Director that the documentation of the justification for reimbursement has been placed in the operating record and that reimbursement has been received.

(8) The trust fund may be terminated by the owner or operator only if the owner or operator substitutes alternate financial assurance as specified in this section or if he is no longer required to demonstrate financial responsibility in accordance with the requirements of §§ 258.71(b), 258.72(b), or 258.73(b).

(b) *Surety Bond Guaranteeing Payment or Performance.* (1) An owner or operator may demonstrate financial assurance for closure or post-closure care by obtaining a payment or performance surety bond which conforms to the requirements of this paragraph. An owner or operator may demonstrate financial assurance for corrective action by obtaining a performance bond which conforms to the requirements of this paragraph. The bond must be effective before the initial receipt of waste or before the effective date of this section (April 9, 1994), whichever is later, in the case of closure and post-closure care, or no later than 120 days after the corrective action remedy has been selected in accordance with the requirements of § 258.58. The owner or operator must notify the State Director that a copy of the bond has been placed in the operating record. The surety company issuing the bond must, at a minimum, be among those listed as acceptable sureties on Federal bonds in Circular 570 of the U.S. Department of the Treasury.

(2) The penal sum of the bond must be in an amount at least equal to the current closure, post-closure care or corrective action cost estimate, whichever is applicable, except as provided in § 258.74(k).

(3) Under the terms of the bond, the surety will become liable on the bond obligation when the owner or operator fails to perform as guaranteed by the bond.

(4) The owner or operator must establish a standby trust fund. The standby trust fund must meet the requirements of § 258.74(a) except the requirements for initial payment and subsequent annual payments specified in § 258.74 (a)(2), (3), (4) and (5).

(5) Payments made under the terms of the bond will be deposited by the surety directly into the standby trust fund. Payments from the trust fund must be approved by the trustee.

(6) Under the terms of the bond, the surety may cancel the bond by sending notice of cancellation by certified mail to the owner and operator and to the State Director 120 days in advance of cancellation. If the surety cancels the bond, the owner or operator must obtain alternate financial assurance as specified in this section.

(7) The owner or operator may cancel the bond only if alternate financial assurance is substituted as specified in this section or if the owner or operator is no longer required to demonstrate financial responsibility in accordance with § 258.71(b), 258.72(b) or 258.73(b).

(c) *Letter of Credit.* (1) An owner or operator may satisfy the requirements of this section by obtaining an irrevocable standby letter of credit which conforms to the requirements of this paragraph. The letter of credit must be effective before the initial receipt of waste or before the effective date of this section (April 9, 1994), whichever is later, in the case of closure and post-closure care, or no later than 120 days after the corrective action remedy has been selected in accordance with the requirements of § 258.58. The owner or operator must notify the State Director that a copy of the letter of credit has been placed in the operating record. The issuing institution must be an entity which has the authority to issue letters of credit and whose letter-of-credit operations are regulated and examined by a Federal or State agency.

(2) A letter from the owner or operator referring to the letter of credit by number, issuing institution, and date, and providing the following information: Name, and address of the facility, and the amount of funds assured, must be included with the letter of credit in the operating record.

(3) The letter of credit must be irrevocable and issued for a period of at least one year in an amount at least equal to the current cost estimate for closure, post-closure care or corrective action, whichever is applicable, except as provided in § 258.74(a). The letter of credit must provide that the expiration date will be automatically extended for a period of at least one year unless the issuing institution has cancelled the letter of credit by sending notice of cancellation by certified mail to the owner and operator and to the State Director 120 days in advance of cancellation. If the letter of credit is cancelled by the issuing institution, the owner or operator must obtain alternate financial assurance.

(4) The owner or operator may cancel the letter of credit only if alternate financial assurance is substituted as specified in this section or if the

owner or operator is released from the requirements of this section in accordance with § 258.71(b), 258.72(b) or 258.73(b).

(d) *Insurance.* (1) An owner or operator may demonstrate financial assurance for closure and post-closure care by obtaining insurance which conforms to the requirements of this paragraph. The insurance must be effective before the initial receipt of waste or before the effective date of this section (April 9, 1994), whichever is later. At a minimum, the insurer must be licensed to transact the business of insurance, or eligible to provide insurance as an excess or surplus lines insurer, in one or more States. The owner or operator must notify the State Director that a copy of the insurance policy has been placed in the operating record.

(2) The closure or post-closure care insurance policy must guarantee that funds will be available to close the MSWLF unit whenever final closure occurs or to provide post-closure care for the MSWLF unit whenever the post-closure care period begins, whichever is applicable. The policy must also guarantee that once closure or post-closure care begins, the insurer will be responsible for the paying out of funds to the owner or operator or other person authorized to conduct closure or post-closure care, up to an amount equal to the face amount of the policy.

(3) The insurance policy must be issued for a face amount at least equal to the current cost estimate for closure or post-closure care, whichever is applicable, except as provided in § 258.74(a). The term *face amount* means the total amount the insurer is obligated to pay under the policy. Actual payments by the insurer will not change the face amount, although the insurer's future liability will be lowered by the amount of the payments.

(4) An owner or operator, or any other person authorized to conduct closure or post-closure care, may receive reimbursements for closure or post-closure expenditures, whichever is applicable. Requests for reimbursement will be granted by the insurer only if the remaining value of the policy is sufficient to cover the remaining costs of closure or post-closure care, and if justification and documentation of the cost is placed in the operating record. The owner or operator must notify the State Director that the documentation of the justification for reimbursement has been placed in the operating record and that reimbursement has been received.

(5) Each policy must contain a provision allowing assignment of the policy to a successor owner or operator. Such assignment may be conditional upon consent of the insurer, provided that such consent is not unreasonably refused.

(6) The insurance policy must provide that the insurer may not cancel, terminate or fail to renew the policy except for failure to pay the premium. The automatic renewal of the policy must, at a minimum, provide the insured with the option of renewal at the face amount of the expiring policy. If there is a failure to pay the premium, the insurer may cancel the policy by sending notice of cancellation by certified mail to the owner and operator and to the State Director 120 days in advance of cancellation. If the insurer cancels the policy, the owner or operator must obtain alternate financial assurance as specified in this section.

(7) For insurance policies providing coverage for post-closure care, commencing on the date that liability to make payments pursuant to the policy accrues, the insurer will thereafter annually increase the face amount of the policy. Such increase must be equivalent to the face amount of the policy, less any payments made, multiplied by an amount equivalent to 85 percent of the most recent investment rate or of the equivalent coupon-issue yield announced by the U.S. Treasury for 26-week Treasury securities.

(8) The owner or operator may cancel the insurance policy only if alternate financial assurance is substituted as specified in this section or if the owner or operator, is no longer required to demonstrate financial responsibility in accordance with the requirements of § 258.71(b), 258.72(b) or 258.73(b).

(e) *Corporate Financial Test.* [Reserved]

(f) *Local Government Financial Test.* [Reserved]

(g) *Corporate Guarantee.* [Reserved]

(h) *Local Government Guarantee.* [Reserved]

(i) *State-Approved Mechanism.* An owner or operator may satisfy the requirements of this section by obtaining any other mechanism that meets the criteria specified in § 258.74(1), and that is approved by the Director of an approved State.

(j) *State Assumption of Responsibility.* If the State Director either assumes legal responsibility for an owner or operator's compliance with the closure, post-closure care and/or corrective action requirements of this part, or assures that the funds will be available from State sources to cover the requirements, the owner or operator will be in compliance with the requirements of this section. Any State assumption of responsibility must meet the criteria specified in § 258.74(1).

(k) *Use of Multiple Financial Mechanisms.* An owner or operator may satisfy the requirements of this section by establishing more than one financial mechanism per facility. The mechanisms must be as specified in paragraphs (a), (b), (c), (d), (e), (f), (g), (h), (i), and (j) of this section, except that it is the combination of mechanisms, rather than the single mechanism, which must provide financial assurance for an amount at least equal to the current cost estimate for closure, post-closure care or corrective action, whichever is applicable. The financial test and a guarantee provided by a corporate parent, sibling, or grandparent may not be combined if the financial statements of the two firms are consolidated.

(l) The language of the mechanisms listed in paragraphs (a), (b), (c), (d), (e), (f), (g), (h), (i), and (j) of this section must ensure that the instruments satisfy the following criteria:

(1) The financial assurance mechanisms must ensure that the amount of funds assured is sufficient to cover the costs of closure, post-closure care, and corrective action for known releases when needed;

(2) The financial assurance mechanisms must ensure that funds will be available in a timely fashion when needed;

(3) The financial assurance mechanisms must be obtained by the owner or operator by the effective date of these requirements or prior to the initial receipt of solid waste, whichever is later, in the case of closure and post-closure care, and no later that 120 days after the corrective action remedy has been selected in accordance with the requirements of § 258.58, until the owner or operator is released from the financial assurance requirements under §§ 258.71, 258.72 and 258.73.

(4) The financial assurance mechanisms must be legally valid, binding, and enforceable under State and Federal law.

Appendix I to Part 258—Constituents for Detection Monitoring [1]

Common name [2]	CAS RN [3]
Inorganic Constituents:	
(1) Antimony	(Total)
(2) Arsenic	(Total)
(3) Barium	(Total)
(4) Beryllium	(Total)
(5) Cadmium	(Total)
(6) Chromium	(Total)
(7) Cobalt	(Total)
(8) Copper	(Total)
(9) Lead	(Total)
(10) Nickel	(Total)
(11) Selenium	(Total)
(12) Silver	(Total)
(13) Thallium	(Total)
(14) Vanadium	(Total)
(15) Zinc	(Total)
Organic Constituents:	
(16) Acetone	67-64-1
(17) Acrylonitrile	107-13-1
(18) Benzene	71-43-2
(19) Bromochloromethane	74-97-5
(20) Bromodichloromethane	75-27-4
(21) Bromoform; Tribromomethane	75-25-2
(22) Carbon disulfide	75-15-0
(23) Carbon tetrachloride	56-23-5
(24) Chlorobenzene	108-90-7
(25) Chloroethane; Ethyl chloride	75-00-3
(26) Chloroform; Trichloromethane	67-66-3
(27) Dibromochloromethane; Chlorodibromomethane	124-48-1
(28) 1,2-Dibromo-3-chloropropane; DBCP	96-12-8
(29) 1,2-Dibromoethane; Ethylene dibromide; EDB	106-93-4
(30) o-Dichlorobenzene; 1,2-Dichlorobenzene	95-50-1

—Continued

Common name [2]	CAS RN [3]
(31) p-Dichlorobenzene; 1,4-Dichlorobenzene	106–46–7
(32) trans-1,4-Dichloro-2-butene	110–57–6
(33) 1,1-Dichloroethane; Ethylidene chloride	75–34–3
(34) 1,2-Dichloroethane; Ethylene dichloride	107–06–2
(35) 1,1-Dichloroethylene; 1,1-Dichloroethene; Vinylidene chloride	75–35–4
(36) cis-1,2-Dichloroethylene; cis-1,2-Dichloroethene	156–59–2
(37) trans-1,2-Dichloroethylene; trans-1,2-Dichloroethene	156–60–5
(38) 1,2-Dichloropropane; Propylene dichloride	78–87–5
(39) cis-1,3-Dichloropropene	10061–01–5
(40) trans-1,3-Dichloropropene	10061–02–6
(41) Ethylbenzene	100–41–4
(42) 2-Hexanone; Methyl butyl ketone	591–78–6
(43) Methyl bromide; Bromomethane	74–83–9
(44) Methyl chloride; Chloromethane	74–87–3
(45) Methylene bromide; Dibromomethane	74–95–3
(46) Methylene chloride; Dichloromethane	75–09–2
(47) Methyl ethyl ketone; MEK; 2-Butanone	78–93–3
(48) Methyl iodide; Iodomethane	74–88–4
(49) 4-Methyl-2-pentanone; Methyl isobutyl ketone	108–10–1
(50) Styrene	100–42–5

—Continued

Common name [2]	CAS RN [3]
(51) 1,1,1,2-Tetrachloroethane	630–20–6
(52) 1,1,2,2-Tetrachloroethane	79–34–5
(53) Tetrachloroethylene; Tetrachloroethene; Perchloroethylene	127–18–4
(54) Toluene	108–88–3
(55) 1,1,1-Trichloroethane; Methylchloroform	71–55–6
(56) 1,1,2-Trichloroethane	79–00–5
(57) Trichloroethylene; Trichloroethene	79–01–6
(58) Trichlorofluoromethane; CFC-11	75–69–4
(59) 1,2,3-Trichloropropane	96–18–4
(60) Vinyl acetate	108–05–4
(61) Vinyl chloride	75–01–4
(62) Xylenes	1330–20–7

[1] This list contains 47 volatile organics for which possible analytical procedures provided in EPA Report SW–846 "Test Methods for Evaluating Solid Waste," third edition, November 1986, as revised December 1987, includes Method 8260; and 15 metals for which SW–846 provides either Method 6010 or a method from the 7000 series of methods.

[2] Common names are those widely used in government regulations, scientific publications, and commerce; synonyms exist for many chemicals.

[3] Chemical Abstracts Service registry number. Where "Total" is entered, all species in the ground water that contain this element are included.

APPENDIX II TO PART 258—LIST OF HAZARDOUS INORGANIC AND ORGANIC CONSTITUENTS [1]

Common Name [2]	CAS RN [3]	Chemical abstracts service index name [4]	Suggested methods [5]	PQL (µg/L) [6]
Acenaphthene	83-32-9	Acenaphthylene, 1,2-dihydro-	8100	200
			8270	10
Acenaphthylene	208-96-8	Acenaphthylene	8100	200
			8270	10
Acetone	67-64-1	2-Propanone	8260	100
Acetonitrile; Methyl cyanide	75-05-8	Acetonitrile	8015	100
Acetophenone	98-86-2	Ethanone, 1-phenyl-	8270	10
2-Acetylaminofluorene; 2-AAF	53-96-3	Acetamide, N-9H-fluoren-2-yl-	8270	20
Acrolein	107-02-8	2-Propenal	8030	5
			8260	100
Acrylonitrile	107-13-1	2-Propenenitrile	8030	5
			8260	200
Aldrin	309-00-2	1,4:5,8-Dimethanonaphthalene, 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro- (1α,4α,4aβ,5α,8α,8aβ)-	8080	0.05
			8270	10
Allyl chloride	107-05-1	1-Propene, 3-chloro-	8010	5
			8260	10
4-Aminobiphenyl	92-67-1	[1,1'-Biphenyl]-4-amine	8270	20
Anthracene	120-12-7	Anthracene	8100	200
			8270	10
Antimony	(Total)	Antimony	6010	300
			7040	2000
			7041	30
Arsenic	(Total)	Arsenic	6010	500
			7060	10
			7061	20
Barium	(Total)	Barium	6010	20
			7080	1000

—Continued

Common Name [2]	CAS RN [3]	Chemical abstracts service index name [4]	Suggested methods [5]	PQL (µg/L) [6]
Benzene	71-43-2	Benzene	8020 8021 8260	2 0.1 5
Benzo[a]anthracene; Benzanthracene	56-55-3	Benz[a]anthracene	8100 8270	200 10
Benzo[b]fluoranthene	205-99-2	Benz[e]acephenanthrylene	8100 8270	200 10
Benzo[k]fluoranthene	207-08-9	Benzo[k]fluoranthene	8100 8270	200 10
Benzo[ghi]perylene	191-24-2	Benzo[ghi]perylene	8100 8270	200 10
Benzo[a]pyrene	50-32-8	Benzo[a]pyrene	8100 8270	200 10
Benzyl alcohol	100-51-6	Benzenemethanol	8270	20
Beryllium	(Total)	Beryllium	6010 7090 7091	3 50 2
alpha-BHC	319-84-6	Cyclohexane, 1,2,3,4,5,6-hexachloro-, (1α,2α,3β,4α,5β,6β)-.	8080 8270	0.05 10
beta-BHC	319-85-7	Cyclohexane, 1,2,3,4,5,6-hexachloro-, (1α,2β,3α,4β,5α,6β)-.	8080 8270	0.05 20
delta-BHC	319-86-8	Cyclohexane, 1,2,3,4,5,6-hexachloro-, (1α,2α,3α,4β,5α,6β)-.	8080 8270	0.1 20
gamma-BHC; Lindane	58-89-9	Cyclohexane, 1,2,3,4,5,6-hexachloro-, (1α,2α,3β,4α,5α,6β)-.	8080 8270	0.05 20
Bis(2-chloroethoxy)methane	111-91-1	Ethane, 1,1'-[methylenebis(oxy)]bis[2-chloro-.	8110 8270	5 10
Bis(2-chloroethyl) ether; Dichloroethyl ether.	111-44-4	Ethane, 1,1'-oxybis[2-chloro-	8110 8270	3 10
Bis-(2-chloro-1-methylethyl) ether; 2,2'-Dichlorodiisopropyl ether; DCIP, See note 7	108-60-1	Propane, 2,2'-oxybis[1-chloro-	8110 8270	10 10
Bis(2-ethylhexyl) phthalate	117-81-7	1,2-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester.	8060	20
Bromochloromethane; Chlorobromomethane.	74-97-5	Methane, bromochloro-	8021 8260	0 5
Bromodichloromethane; Dibromochloromethane.	75-27-4	Methane, bromodichloro-	8010 8021 8260	1 0.2 5
Bromoform, Tribromomethane	75-25-2	Methane, tribromo-	8010 8021 8260	2 15 5
4-Bromophenyl phenyl ether	101-55-3	Benzene, 1-bromo-4-phenoxy-	8110 8270	25 10
Butyl benzyl phthalate; Benzyl butyl phthalate.	85-68-7	1,2-Benzenedicarboxylic acid, butyl phenylmethyl ester.	8060 8270	5 10
Cadmium	(Total)	Cadmium	6010 7130 7131	40 50 1
Carbon disulfide	75-15-0	Carbon disulfide	8260	100
Carbon tetrachloride	56-23-5	Methane, tetrachloro-	8010 8021 8260	1 0.1 10
Chlordane	See Note 8	4,7-Methano-1H-indene, 1,2,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-.	8080 8270	0.1 50
p-Chloroaniline	106-47-8	Benzenamine, 4-chloro-	8270	20
Chlorobenzene	108-90-7	Benzene, chloro-	8010 8020 8021 8260	2 2 0.1 5
Chlorobenzilate	510-15-6	Benzeneacetic acid, 4-chloro-α-(4-chlorophenyl)-α-hydroxy-, ethyl ester.	8270	10
p-Chloro-m-cresol, 4-Chloro-3-methylphenol	59-50-7	Phenol, 4-chloro-3-methyl-	8040 8270	5 20
Chloroethane; Ethyl chloride	75-00-3	Ethane, chloro-	8010 8021 8260	5 1 10

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Common Name [2]	CAS RN [3]	Chemical abstracts service index name [4]	Suggested methods [5]	PQL (µg/L) [6]
Chloroform; Trichloromethane	67-66-3	Methane, trichloro-	8010	0.5
			8021	0.2
			8260	5
2-Chloronaphthalene	91-58-7	Naphthalene, 2-chloro-	8120	10
			8270	10
2-Chlorophenol	95-57-8	Phenol, 2-chloro-	8040	5
			8270	10
4-Chlorophenyl phenyl ether	7005-72-3	Benzene, 1-chloro-4-phenoxy-	8110	40
			8270	10
Chloroprene	126-99-8	1,3-Butadiene, 2-chloro-	8010	50
			8260	20
Chromium	(Total)	Chromium	6010	70
			7190	500
			7191	10
Chrysene	218-01-9	Chrysene	8100	200
			8270	10
Cobalt	(Total)	Cobalt	6010	70
			7200	500
			7201	10
Copper	(Total)	Copper	6010	60
			7210	200
			7211	10
m-Cresol; 3-methylphenol	108-39-4	Phenol, 3-methyl-	8270	10
o-Cresol; 2-methylphenol	95-48-7	Phenol, 2-methyl-	8270	10
p-Cresol; 4-methylphenol	106-44-5	Phenol, 4-methyl-	8270	10
Cyanide	57-12-5	Cyanide	9010	200
2,4-D; 2,4-Dichlorophenoxyacetic acid	94-75-7	Acetic acid, (2,4-dichlorophenoxy)-	8150	10
4,4′-DDD	72-54-8	Benzene 1,1′-(2,2-dichloroethylidene)bis[4-chloro-.	8080	0.1
			8270	10
4,4′-DDE	72-55-9	Benzene, 1,1′-(dichloroethyenylidene)bis[4-chloro-.	8080	0.05
			8270	10
4,4′-DDT	50-29-3	Benzene, 1,1′-(2,2,2-trichloroethylidene)bis[4-chloro-.	8080	0.1
			8270	10
Diallate	2303-16-4	Carbamothioic acid, bis(1-methylethyl)-,S-(2,3-dichloro-2-propenyl) ester.	8270	10
Dibenz[a,h]anthracene	53-70-3	Dibenz[a,h]anthracene	8100	200
			8270	10
Dibenzofuran	132-64-9	Dibenzofuran	8270	10
Dibromochloromethane; Chlorodibromomethane.	124-48-1	Methane, dibromochloro-	8010	1
			8021	0.3
			8260	5
1,2-Dibromo-3-chloropropane; DBCP	96-12-8	Propane, 1,2-dibrome-3-chloro-	8011	0.1
			8021	30
			8260	25
1,2-Dibromoethane; Ethylene dribromide; EDB.	106-93-4	Ethane, 1,2-dibromo-	8011	0.1
			8021	10
			8260	5
Di-n-butyl phthalate	84-74-2	1,2-Benzenedicarboxylic acid, dibutyl ester.	8060	5
			8270	10
o-Dichlorobenzene; 1,2-Dichlorobenzene	95-50-1	Benzene, 1,2-dichloro-	8010	2
			8020	5
			8021	0.5
			8120	10
			8260	5
			8270	10
m-Dichlorobenzene; 1,3-Dichlorobenzene	541-73-1	Benzene, 1,3-Dichloro-	8010	5
			8020	5
			8021	0.2
			8120	10
			8260	5
			8270	10
p-Dichlorobenzene; 1,4-Dichlorobenzene	106-46-7	Benzene, 1,4-dichloro-	8010	2
			8020	5
			8021	0.1
			8120	15
			8260	5
			8270	10

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Common Name [2]	CAS RN [3]	Chemical abstracts service index name [4]	Suggested methods [5]	PQL (µg/L) [6]
3,3'-Dichlorobenzidine	91-94-1	[1,1'-Biphenyl]-4,4'-diamine, 3,3'-dichloro-.	8270	20
trans-1,4-Dichloro-2-butene	110-57-6	2-Butene, 1,4-dichloro-, (E)-	8260	100
Dichlorodifluoromethane; CFC 12;	75-71-8	Methane, dichlorodifluoro-	8021	0.5
			8260	5
1,1-Dichloroethane; Ethyldidene chloride	75-34-3	Ethane, 1,1-dichloro-	8010	1
			8021	0.5
			8260	5
1,2-Dichloroethane; Ethylene dichloride	107-06-2	Ethane, 1,1-dichloro-	8010	0.5
			8021	0.3
			8260	5
1,1-Dichloroethylene; 1,1-Dichloroethene; Vinylidene chloride.	75-35-4	Ethene, 1,1-dichloro-	8010	1
			8021	0.5
			8260	5
cis-1,2-Dichloroethylene; cis-1,2-Dichloroethene.	156-59-2	Ethene, 1,2-dichloro-, (Z)-	8021	0.2
			8260	5
trans-1,2-Dichloroethylene trans-1,2-Dichloroethene.	156-60-5	Ethene, 1,2-dichloro-, (E)-	8010	1
			8021	0.5
			8260	5
2,4-Dichlorophenol	120-83-2	Phenol, 2,4-dichloro-	8040	5
			8270	10
2,6-Dichlorophenol	87-65-0	Phenol, 2,6-dichloro-	8270	10
1,2-Dichloropropane; Propylene dichloride	78-87-5	Propane, 1,2-dichloro-	8010	0.5
			8021	0.05
			8260	5
1,3-Dichloropropane; Trimethylene dichloride.	142-28-9	Propane, 1,3-dichloro-	8021	0.3
			8260	5
2,2-Dichloropropane; Isopropylidene chloride.	594-20-7	Propane, 2,2-dichloro-	8021	0.5
			8260	15
1,1-Dichloropropene	563-58-6	1-Propene, 1,1-dichloro-	8021	0.2
			8260	5
cis-1,3-Dichloropropene	10061-01-5	1-Propene, 1,3-dichloro-, (Z)-	8010	20
			8260	10
trans-1,3-Dichloropropene	10061-02-6	1-Propene, 1,3-dichloro-, (E)-	8010	5
			8260	10
Dieldrin	60-57-1	2,7:3,6-Dimethanonaphth[2,3-b]oxirene, 3,4,5,6,9,9-hexa, chloro-1a,2,2a,3,6,6a,7,7a-octahydro-, (1aα,2β,2aα,3β,6β,6aα,7β,7aα)-.	8080	0.05
			8270	10
Diethyl phthalate	84-66-2	1,2-Benzenedicarboxylic acid, diethyl ester.	8060	5
			8270	10
0,0-Diethyl 0-2-pyrazinyl phosphorothioate; Thionazin.	297-97-2	Phosphorothioic acid, 0,0-diethyl 0-pyrazinyl ester.	8141	5
			8270	20
Dimethoate	60-51-5	Phosphorodithioic acid, 0,0-dimethyl S-[2-(methylamino)-2-oxoethyl] ester.	8141	3
			8270	20
p-(Dimethylamino)azobenzene	60-11-7	Benzenamine, N,N-dimethyl-4-(phenylazo)-.	8270	10
7,12-Dimethylbenz[a]anthracene	57-97-6	Benz[a]anthracene, 7,12-dimethyl-	8270	10
3,3'-Dimethylbenzidine	119-93-7	[1,1'-Biphenyl]-4,4'-diamine, 3,3'-dimethyl-.	8270	10
2,4-Dimethylphenol; m-Xylenol	105-67-9	Phenol, 2,4-dimethyl-	8040	5
			8270	10
Dimethyl phthalate	131-11-3	1,2-Benzenedicarboxylic acid, dimethyl ester.	8060	5
			8270	10
m-Dinitrobenzene	99-65-0	Benzene, 1,3-dinitro-	8270	20
4,6-Dinitro-o-cresol 4,6-Dinitro-2-methylphenol.	534-52-1	Phenol, 2-methyl-4,6-dinitro	8040	150
			8270	50
2,4-Dinitrophenol;	51-28-5	Phenol, 2,4-dinitro-	8040	150
			8270	50
2,4-Dinitrotoluene	121-14-2	Benzene, 1-methyl-2,4-dinitro-	8090	0.2
			8270	10
2,6-Dinitrotoluene	606-20-2	Benzene, 2-methyl-1,3-dinitro-	8090	0.1
			8270	10
Dinoseb, DNBP; 2-sec-Butyl-4,6-dinitrophenol.	88-85-7	Phenol, 2-(1-methylpropyl)-4,6-dinitro-	8150	1
			8270	20
Di-n-octyl phthalate	117-84-0	1,2-Benzenedicarboxylic acid, dioctyl ester.	8060	30
			8270	10
Diphenylamine	122-39-4	Benzenamine, N-phenyl-	8270	10

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Common Name [2]	CAS RN [3]	Chemical abstracts service index name [4]	Suggested methods [5]	PQL (µg/L) [6]
Disulfoton	298-04-4	Phosphorodithioic acid, 0,0-diethyl S-[2-(ethylthio)ethyl] ester.	8140 8141 8270	2 0.5 10
Endosulfan I	959-98-8	6,9-Methano-2,4,3-benzodioxathiepin, 6,7,8,9,10,10-hexa-chloro-1,5,5a,6,9,9a-hexahydro-, 3-oxide,	8080 8270	0.1 20
Endosulfan II	33213-65-9	6,9-Methano-2,4,3-benzodioxathiepin, 6,7,8,9,10,10-hexa-chloro-1,5,5a,6,9,9a-hexahydro-, 3-oxide, (3α,5aα,6β,9β,9aα)-.	8080 8270	0.05 20
Endosulfan sulfate	1031-07-8	6,9-Methano-2,4,3-benzodioxathiepin, 6,7,8,9,10,10-hexa-chloro-1,5,5a,6,9,9a-hexahydro-,3-3-dioxide.	8080 8270	0.5 10
Endrin	72-20-8	2,7:3,6-Dimethanonaphth[2,3-b]oxirene, 3,4,5,6,9,9-hexachloro-1a,2,2a,3,6,6a,7,7a-octahydro-, (1aα, 2β,2aβ,3α,6α,6aβ,7β,7aα)-.	8080 8270	0.1 20
Endrin aldehyde	7421-93-4	1,2,4-Methenocyclopenta[cd]pentalene-5-carboxaldehyde, 2,2a,3,3,4,7-hexachlorodecahydro-, (1α,2β,2aβ,4β,4aβ,5β,6aβ,6bβ,7R*)-.	8080 8270	0.2 10
Ethylbenzene	100-41-4	Benzene, ethyl-	8020 8221 8260	2 0.05 5
Ethyl methacrylate	97-63-2	2-Propenoic acid, 2-methyl-, ethyl ester	8015 8260 8270	5 10 10
Ethyl methanesulfonate	62-50-0	Methanesulfonic acid, ethyl ester	8270	20
Famphur	52-85-7	Phosphorothioic acid, 0-[4-[(dimethylamino)sulfonyl]phenyl] 0,0-dimethyl ester.	8270	20
Fluoranthene	206-44-0	Fluoranthene	8100 8270	200 10
Fluorene	86-73-7	9H-Fluorene	8100 8270	200 10
Heptachlor	76-44-8	4,7-Methano-1H-indene, 1,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-.	8080 8270	0.05 10
Heptachlor epoxide	1024-57-3	2,5-Methano-2H-indeno[1,2-b]oxirene, 2,3,4,5,6,7,7-heptachloro-1a,1b,5,5a,6,6a-hexahydro-, (1aα, 1bβ, 2α, 5α, 5aβ, 6β, 6aα).	8080 8270	1 10
Hexachlorobenzene	118-74-1	Benzene, hexachloro-	8120 8270	0 5 10
Hexachlorobutadiene	87-68-3	1,3-Butadiene, 1,1,2,3,4,4-hexachloro-	8021 8120 8260 8270	0.5 5 10 10
Hexachlorocyclopentadiene	77-47-4	1,3-Cyclopentadiene, 1,2,3,4,5,5-hexachloro-.	8120 8270	5 10
Hexachloroethane	67-72-1	Ethane, hexachloro-	8120 8260 8270	0 5 10 10
Hexachloropropene	1888-71-7	1-Propene, 1,1,2,3,3,3-hexachloro-	8270	10
2-Hexanone; Methyl butyl ketone	591-78-6	2-Hexanone	8260	50
Indeno(1,2,3-cd)pyrene	193-39-5	Indeno(1,2,3-cd)pyrene	8100 8270	200 10
Isobutyl alcohol	78-83-1	1-Propanol, 2-methyl-	8015 8240	50 100
Isodrin	465-73-6	1,4,5,8-Dimethanonaphthalene,1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a hexahydro-(1α,4α,4aβ,5β,8β,8aβ)-.	8270 8260	20 10
Isophorone	78-59-1	2-Cyclohexen-1-one, 3,5,5-trimethyl-	8090 8270	60 10
Isosafrole	120-58-1	1,3-Benzodioxole, 5-(1-propenyl)-	8270	10
Kepone	143-50-0	1,3,4-Metheno-2H-cyclobuta[cd]pentalen-2-one, 1,1a,3,3a,4,5,5,5a,5b,6-decachlorooctahydro-	8270	20

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Common Name [2]	CAS RN [3]	Chemical abstracts service index name [4]	Suggested methods [5]	PQL (μg/L) [6]
Lead	(Total)	Lead	6010	400
			7420	1000
			7421	10
Mercury	(Total)	Mercury	7470	2
Methacrylonitrile	126-98-7	2-Propenenitrile, 2-methyl-	8015	5
			8260	100
Methapyrilene	91-80-5	1,2-Ethanediamine, N,N-dimethyl-N'-2-pyridinyl-N1/2-thienylmethyl)-.	8270	100
Methoxychlor	72-43-5	Benzene,1,1'-(2,2,2,trichloroethylidene)bis[4-methoxy-	8080	2
			8270	10
Methyl bromide; Bromomethane	74-83-9	Methane, bromo-	8010	20
			8021	10
Methyl chloride; Chloromethane	74-87-3	Methane, chloro-	8010	1
			8021	0.3
3-Methylcholanthrene	56-49-5	Benz[j]aceanthrylene, 1,2-dihydro-3-methyl-.	8270	10
Methyl ethyl ketone; MEK; 2-Butanone	78-93-3	2-Butanone	8015	10
			8260	100
Methyl iodide; Iodomethane	74-88-4	Methane, iodo-	8010	40
			8260	10
Methyl methacrylate	80-62-6	2-Propenoic acid, 2-methyl-, methyl ester	8015	2
			8260	30
Methyl methanesulfonate	66-27-3	Methanesulfonic acid, methyl ester	8270	10
2-Methylnaphthalene	91-57-6	Naphthalene, 2-methyl-	8270	10
Methyl parathion; Parathion methyl	298-00-0	Phosphorothioic acid, 0,0-dimethyl	8140	0.5
			8141	1
			8270	10
4-Methyl-2-pentanone; Methyl isobutyl ketone.	108-10-1	2-Pentanone, 4-methyl-	8015	5
			8260	100
Methylene bromide; Dibromomethane	74-95-3	Methane, dibromo-	8010	15
			8021	20
			8260	10
Methylene chloride; Dichloromethane	75-09-2	Methane, dichloro-	8010	5
			8021	0.2
			8260	10
Naphthalene	91-20-3	Naphthalene	8021	0.5
			8100	200
			8260	5
			8270	10
1,4-Naphthoquinone	130-15-4	1,4-Naphthalenedione	8270	10
1-Naphthylamine	134-32-7	1-Naphthalenamine	8270	10
2-Naphthylamine	91-59-8	2-Naphthalenamine	8270	10
Nickel	(Total)	Nickel	6010	150
			7520	400
o-Nitroaniline; 2-Nitroaniline	88-74-4	Benzenamine, 2-nitro-	8270	50
m-Nitroaniline; 3-Nitroanile	99-09-2	Benzenamine, 3-nitro-	8270	50
p-Nitroaniline; 4-Nitroaniline	100-01-6	Benzenamine, 4-nitro	8270	20
Nitrobenzene	98-95-3	Benzene, nitro-	8090	40
			8270	10
o-Nitrophenol; 2-Nitrophenol	88-75-5	Phenol, 2-nitro-	8040	5
			8270	10
p-Nitrophenol; 4-Nitrophenol	100-02-7	Phenol, 4-nitro-	8040	10
			8270	50
N-Nitrosodi-n-butylamine	924-16-3	1-Butanamine, N-butyl-N-nitroso-	8270	10
N-Nitrosodiethylamine	55-18-5	Ethanamine, N-ethyl-N-nitroso-	8270	20
N-Nitrosodimethylamine	62-75-9	Methanamine, N-methyl-N-nitroso-	8070	2
N-Nitrosodiphenylamine	86-30-6	Benzenamine, N-nitroso-N-phenyl-	8070	5
N-Nitrosodipropylamine; N-Nitroso-N-dipropylamine; Di-n-propylnitrosamine.	621-64-7	1-Propanamine, N-nitroso-N-propyl-	8070	10
N-Nitrosomethylethalamine	10595-95-6	Ethanamine, N-methyl-N-nitroso-	8270	10
N-Nitrosopiperidine	100-75-4	Piperidine, 1-nitroso-	8270	20
N-Nitrosopyrrolidine	930-55-2	Pyrrolidine, 1-nitroso-	8270	40
5-Nitro-o-toluidine	99-55-8	Benzenamine, 2-methyl-5-nitro-	8270	10
Parathion	56-38-2	Phosphorothioic acid, 0,0-diethyl 0-(4-nitrophenyl) ester.	8141	0.5
			8270	10
Pentachlorobenzene	608-93-5	Benzene, pentachloro-	8270	10
Pentachloronitrobenzene	82-68-8	Benzene, pentachloronitro-	8270	20

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Common Name [2]	CAS RN [3]	Chemical abstracts service index name [4]	Suggested methods [5]	PQL (µg/L) [6]
Pentachlorophenol	87-86-5	Phenol, pentachloro-	8040	5
Phenacetin	62-44-2	Acetamide, N-(4-ethoxyphenl)	8270	50
Phenanthrene	85-01-8	Phenanthrene	8270	20
			8100	200
			8270	10
Phenol	108-95-2	Phenol	8040	1
p-Phenylenediamine	106-50-3	1,4-Benzenediamine	8270	10
Phorate	298-02-2	Phosphorodithioic acid, 0,0-diethyl S-[(ethylthio)methyl] ester.	8140	2
			8141	0.5
			8270	10
Polychlorinated biphenyls; PCBs; Aroclors	See Note 9	1,1'-Biphenyl, chloro derivatives	8080	50
			8270	200
Pronamide	23950-58-5	Benzamide, 3,5-dichloro-N-(1,1-dimethyl-2-propynyl)-.	8270	10
Propionitrile; Ethyl cyanide	107-12-0	Propanenitrile	8015	60
			8260	150
Pyrene	129-00-0	Pyrene	8100	200
			8270	10
Safrole	94-59-7	1,3-Benzodioxole, 5-(2-propenyl)-	8270	10
Selenium	(Total)	Selenium	6010	750
			7740	20
			7741	20
Silver	(Total)	Silver	6010	70
			7760	100
			7761	10
Silvex; 2,4,5-TP	93-72-1	Propanoic acid, 2-(2,4,5-trichlorophenoxy)-.	8150	2
Styrene	100-42-5	Benzene, ethenyl-	8020	1
			8021	0.1
			8260	10
Sulfide	18496-25-8	Sulfide	9030	4000
2,4,5-T; 2,4,5-Trichlorophenoxyacetic acid	93-76-5	Acetic acid, (2,4,5-trichlorophenoxy)-	8150	2
1,2,4,5-Tetrachlorobenzene	95-94-3	Benzene, 1,2,4,5-tetrachloro-	8270	10
1,1,1,2-Tetrachloroethane	630-20-6	Ethane, 1,1,1,2-tetrachloro-	8010	5
			8021	0.05
			8260	5
1,1,2,2-Tetrachloroethane	79-34-5	Ethane, 1,1,2,2-tetrachloro-	8010	0.5
			8021	0.1
			8260	5
Tetrachloroethylene; Tetrachloroethene; Perchloroethylene.	127-18-4	Ethene, tetrachloro-	8010	0.5
			8021	0.5
			8260	5
2,3,4,6-Tetrachlorophenol	58-90-2	Phenol, 2,3,4,6-tetrachloro-	8270	10
Thallium	(Total)	Thallium	6010	400
			7840	1000
			7841	10
Tin	(Total)	Tin	6010	40
Toluene	108-88-3	Benzene, methyl-	8020	2
			8021	0.1
			8260	5
o-Toluidine	95-53-4	Benzenamine, 2-methyl-	8270	10
Toxaphene	See Note 10	Toxaphene	8080	2
1,2,4-Trichlorobenzene	120-82-1	Benzene, 1,2,4-trichloro-	8021	0.3
			8120	0.5
			8260	10
			8270	10
1,1,1-Trichloroethane; Methylchloroform	71-55-6	Ethane, 1,1,1-trichloro-	8010	0.3
			8021	0.3
			8260	5
1,1,2-Trichloroethane	79-00-5	Ethane, 1,1,2-trichloro-	8010	0.2
			8260	5
Trichloroethylene; Trichloroethene	79-01-6	Ethene, trichloro-	8010	1
			8021	0.2
			8260	5
Trichlorofluoromethane, CFC-11	75-69-4	Methane, trichlorofluoro-	8010	10
			8021	0.3
			8260	5
2,4,5-Trichlorophenol	95-95-4	Phenol, 2,4,5-trichloro-	8270	10

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Common Name [2]	CAS RN [3]	Chemical abstracts service index name [4]	Suggested methods [5]	PQL (μg/L) [6]
2,4,6-Trichlorophenol	88-06-2	Phenol, 2,4,6-trichloro-	8040	5
			8270	10
1,2,3-Trichloropropane	96-18-4	Propane, 1,2,3-trichloro-	8010	10
			8021	5
			8260	15
0,0,0-Triethyl phosphorothioate	126-68-1	Phosphorothioic acid, 0,0,0-triethylester	8270	10
sym-Trinitrobenzene	99-35-4	Benzene, 1,3,5-trinitro-	8270	10
Vanadium	(Total)	Vanadium	6010	80
			7910	2000
			7911	40
Vinyl acetate	108-05-4	Acetic acid, ethenyl ester	8260	50
Vinyl chloride; Chloroethene	75-01-4	Ethene, chloro-	8010	2
			8021	0.4
			8260	10
Xylene (total)	See Note 11	Benzene, dimethyl-	8020	5
			8021	0.2
			8260	5
Zinc	(Total)	Zinc	6010	20
			7950	50
			7951	0.5

Notes

[1] The regulatory requirements pertain only to the list of substances; the right hand columns (Methods and PQL) are given for informational purposes only. See also footnotes 5 and 6.

[2] Common names are those widely used in government regulations, scientific publications, and commerce; synonyms exist for many chemicals.

[3] Chemical Abstracts Service registry number. Where "Total" is entered, all species in the ground water that contain this element are included.

[4] CAS index are those used in the 9th Collective Index.

[5] Suggested Methods refer to analytical procedure numbers used in EPA Report SW-846 "Test Methods for Evaluating Solid Waste", third edition, November 1986, as revised, December 1987. Analytical details can be found in SW-846 and in documentation on file at the agency. CAUTION: The methods listed are representative SW-846 procedures and may not always be the most suitable method(s) for monitoring an analyte under the regulations.

[6] Practical Quantitation Limits (PQLs) are the lowest concentrations of analytes in ground waters that can be reliably determined within specified limits of precision and accuracy by the indicated methods under routine laboratory operating conditions. The PQLs listed are generally stated to one significant figure. PQLs are based on 5 mL samples for volatile organics and 1 L samples for semivolatile organics. CAUTION: The PQL values in many cases are based only on a general estimate for the method and not on a determination for individual compounds; PQLs are not a part of the regulation.

[7] This substance is often called Bis(2-chloroisopropyl) ether, the name Chemical Abstracts Service applies to its noncommercial isomer, Propane, 2,2''-oxybis[2-chloro- (CAS RN 39638-32-9).

[8] Chlordane: This entry includes alpha-chlordane (CAS RN 5103-71-9), beta-chlordane (CAS RN 5103-74-2), gamma-chlordane (CAS RN 5566-34-7), and constituents of chlordane (CAS RN 57-74-9 and CAS RN 12789-03-6). PQL shown is for technical chlordane PQLs of specific isomers are about 20 μg/L by method 8270.

[9] Polychlorinated biphenyls (CAS RN 1336-36-3); this category contains congener chemicals, including constituents of Aroclor 1016 (CAS RN 12674-11-2), Aroclor 1221 (CAS RN 11104-28-2), Aroclor 1232 (CAS RN 11141-16-5), Aroclor 1242 (CAS RN 53469-21-9), Aroclor 1248 (CAS RN 12672-29-6), Aroclor 1254 (CAS RN 11097-69-1), and Aroclor 1260 (CAS RN 11096-82-5). The PQL shown is an average value for PCB congeners.

[10] Toxaphene: This entry includes congener chemicals contained in technical toxaphene (CAS RN 8001-35-2), i.e., chlorinated camphene.

[11] Xylene (total): This entry includes o-xylene (CAS RN 96-47-6), m-xylene (CAS RN 108-38-3), p-xylene (CAS RN 106-42-3), and unspecified xylenes (dimethylbenzenes) (CAS RN 1330-20-7). PQLs for method 8021 are 0.2 for o-xylene and 0.1 for m- or p-xylene. The PQL for m-xylene is 2.0 μg/L by method 8020 or 8260.

PART 259—STANDARDS FOR THE TRACKING AND MANAGEMENT OF MEDICAL WASTE

Subpart A—General

Subpart B—Definitions

Subpart C—Covered States

Subpart D—Regulated Medical Waste

Subpart E—Pre-Transport Requirements

H

ATTACHMENT H

RCRA Section 4005, 42 U.S.C. 6945

and facilities for conservation of energy or materials which contribute to the waste stream or for the recovery of energy and materials from municipal waste and make recommendations to appropriate governmental authorities for overcoming such impediments;

(C) assist municipalities within the State in developing plans, programs, and projects to conserve resources or recover energy and materials from municipal waste; and

(D) coordinate the resource conservation and recovery planning under subparagraph (C).

(2) The analysis referred to in paragraph (1)(A) shall include—

(A) the evaluation of, and establishment of priorities among, market opportunities for industrial and commercial users of all types (including public utilities and industrial parks) to utilize energy and materials recovered from municipal waste;

(B) comparisons of the relative costs of energy recovered from municipal waste in relation to the costs of energy derived from fossil fuels and other sources;

(C) studies of the transportation and storage problems and other problems associated with the development of energy and materials recovery technology, including curbside source separation;

(D) the evaluation and establishment of priorities among ways of conserving energy or materials which contribute to the waste stream;

(E) comparison of the relative total costs between conserving resources and disposing of or recovering such waste; and

(F) studies of impediments to resource conservation or recovery, including business practices, transportation requirements, or storage difficulties.

Such studies and analyses shall also include studies of other sources of solid waste from which energy and materials may be recovered or minimized.

(d) Size of waste-to-energy facilities

Notwithstanding any of the above requirements, it is the intention of this chapter and the planning process developed pursuant to this chapter that in determining the size of the waste-to-energy facility, adequate provision shall be given to the present and reasonably anticipated future needs of the recycling and resource recovery interest within the area encompassed by the planning process.

(Pub.L. 89–272, Title II, § 4003, as added Oct. 21, 1976, Pub.L. 94–580, § 2, 90 Stat. 2814, and amended Oct. 15, 1980, Pub.L. 96–463, § 5(a), (b), 94 Stat. 2056, Oct. 21, 1980, Pub.L. 96–482, §§ 18, 32(d), 94 Stat. 2345, 2353; Nov. 8, 1984, Pub.L. 98–616, Title III, § 301(b), Title V, § 502(h), 98 Stat. 3267, 3277.)

§ 6944. Criteria for sanitary landfills; sanitary landfills required for all disposal [SWDA § 4004]

(a) Criteria for sanitary landfills

Not later than one year after October 21, 1976, after consultation with the States, and after notice and public hearings, the Administrator shall promulgate regulations containing criteria for determining which facilities shall be classified as sanitary landfills and which shall be classified as open dumps within the meaning of this chapter. At a minimum, such criteria shall provide that a facility may be classified as a sanitary landfill and not an open dump only if there is no reasonable probability of adverse effects on health or the environment from disposal of solid waste at such facility. Such regulations may provide for the classification of the types of sanitary landfills.

(b) Disposal required to be in sanitary landfills, etc.

For purposes of complying with section 6943(2) of this title each State plan shall prohibit the establishment of open dumps and contain a requirement that disposal of all solid waste within the State shall be in compliance with such section 6943(2) of this title.

(c) Effective date

The prohibition contained in subsection (b) of this section shall take effect on the date six months after the date of promulgation of regulations under subsection (a) of this section.

(Pub.L. 89–272, Title II, § 4004, as added Oct. 21, 1976, Pub.L. 94–580, § 2, 90 Stat. 2815, and amended Nov. 8, 1984, Pub.L. 98–616, Title III, § 302(b), 98 Stat. 3268.)

Code of Federal Regulations

Solid waste disposal facilities and practices, criteria for classification of, see 40 CFR 257.1 et seq

§ 6945. Upgrading of open dumps [SWDA § 4005]

(a) Closing or upgrading of existing open dumps

Upon promulgation of criteria under section 6907(a)(3) of this title, any solid waste management practice or disposal of solid waste or hazardous waste which constitutes the open dumping of solid waste or hazardous waste is prohibited, except in the case of any practice or disposal of solid waste under a timetable or schedule for compliance established under this section. The prohibition contained in the preceding sentence shall be enforceable under section 6972 of this title against persons engaged in the act of open dumping. For purposes of complying with section 6943(a)(2) and 6943(a)(3) of this title, each State plan shall contain a requirement that all existing disposal facilities or sites for solid waste in such State which are open dumps listed in the inventory under subsection (b) of this section shall comply with such measures as may be promulgated by the Administrator to eliminate health hazards and minimize potential health hazards. Each such plan shall establish, for any entity which demonstrates that it has considered other public or private alternatives for solid waste management to comply with the prohibition on open dumping and is unable to utilize such alternatives to so comply, a timetable or schedule for compliance for such practice or disposal of solid waste which specifies a schedule of remedial measures, including an enforceable sequence of actions or operations, leading to compliance with the prohibition on open dumping of solid waste within a reasonable time (not to exceed 5 years from the date of publication of criteria under section 6907(a)(3) of this title).

(b) Inventory

To assist the States in complying with section 6943(a)(3) of this title, not later than one year after promulgation of regulations under section 6944 of this title, the Administrator, with the cooperation of the Bureau of the Census shall publish an inventory of all disposal facilities or sites in the United States which are open dumps within the meaning of this chapter.

(c) Control of hazardous disposal

(1)(A) Not later than 36 months after November 8, 1984, each State shall adopt and implement a permit program or other system of prior approval and conditions to assure that each solid waste management facility within such State which may receive hazardous household waste or hazardous waste due to the provision of section 6921(d) of this title for small quantity generators (otherwise not subject to the requirement for a permit under section 6925 of this title) will comply with the applicable criteria promulgated under section 6944(a) and 6907(a)(3) of this title.

(B) Not later than eighteen months after the promulgation of revised criteria under section 6944(a) of this title (as required by section 6949a(c) of this title), each State shall adopt and implement a permit program or other system or [1] prior approval and conditions, to assure that each solid waste management facility within such State which may receive hazardous household waste or hazardous waste due to the provision of section 6921(d) of this title for small quantity generators (otherwise not subject to the requirement for a permit under section 6925 of this title) will comply with the criteria revised under section 6944(a) of this title.

(C) The Administrator shall determine whether each State has developed an adequate program under this paragraph. The Administrator may make such a determination in conjunction with approval, disapproval or partial approval of a State plan under section 6947 of this title.

(2)(A) In any State that the Administrator determines has not adopted an adequate program for such facilities under paragraph (1)(B) by the date provided in such paragraph, the Administrator may use the authorities available under sections 6927 and 6928 of this title to enforce the prohibition contained in subsection (a) of this section with respect of such facilities.

(B) For purposes of this paragraph, the term "requirement of this subchapter" in section 6928 of this title shall be deemed to include criteria promulgated by the Administrator under sections 6907(a)(3) and 6944(a) of this title, and the term "hazardous wastes" in section 6927 of this title shall be deemed to include solid waste at facilities that may handle hazardous household wastes or hazardous wastes from small quantity generators.

(Pub.L. 89-272, Title II, § 4005, as added Oct. 21, 1976, Pub.L. 94-580, § 2, 90 Stat. 2815, and amended Oct. 21, 1980, Pub.L. 96-482, § 19(a), (b), 94 Stat. 2345; Nov. 8, 1984, Pub.L. 98-616, Title III, § 302(c), Title IV, § 403(c), Title V, § 502(c), 98 Stat. 3268, 3272, 3276.)

[1] So in original. Probably should be "of".

§ 6946. Procedure for development and implementation of State plan [SWDA § 4006]

(a) Identification of regions

Within one hundred and eighty days after publication of guidelines under section 6942(a) of this title (relating to identification of regions), the Governor of each State, after consultation with local elected officials, shall promulgate regulations based on such guidelines identifying the boundaries of each area within the State which, as a result of urban concentrations, geographic conditions, markets, and other factors, is appropriate for carrying out regional solid waste management. Such regulations may be modified from time to time (identifying additional or different regions) pursuant to such guidelines.

(b) Identification of State and local agencies and responsibilities

(1) Within one hundred and eighty days after the Governor promulgates regulations under subsection (a) of this section, for purposes of facilitating the development and implementation of a State plan

I

ATTACHMENT I

Clean Water Act, Section 208, 33 U.S.C. 1288

§ 1288. Areawide waste treatment management [FWPCA § 208]

(a) Identification and designation of areas having substantial water quality control problems

For the purpose of encouraging and facilitating the development and implementation of areawide waste treatment management plans—

(1) The Administrator, within ninety days after October 18, 1972, and after consultation with appropriate Federal, State, and local authorities, shall by regulation publish guidelines for the identification of those areas which, as a result of urban-industrial concentrations or other factors, have substantial water quality control problems.

(2) The Governor of each State, within sixty days after publication of the guidelines issued pursuant to paragraph (1) of this subsection, shall identify each area within the State which, as a result of urban-industrial concentrations or other factors, has substantial water quality control problems. Not later than one hundred and twenty days following such identification and after consultation with appropriate elected and other officials of local governments having jurisdiction in such areas, the Governor shall designate (A) the boundaries of each such area, and (B) a single representative organization, including elected officials from local governments or their designees, capable of developing effective areawide waste treatment management plans for such area. The Governor may in the same manner at any later time identify any additional area (or modify an existing area) for which he determines areawide waste treatment management to be appropriate, designate the boundaries of such area, and designate an organization capable of developing effective areawide waste treatment management plans for such area.

(3) With respect to any area which, pursuant to the guidelines published under paragraph (1) of this subsection, is located in two or more States, the Governors of the respective States shall consult and cooperate in carrying out the provisions of paragraph (2), with a view toward designating the boundaries of the interstate area having common water quality control problems and for which areawide waste treatment management plans would be most effective, and toward designating, within one hundred and eighty days after publication of guidelines issued pursuant to paragraph (1) of this subsection, of a single representative organization capable of developing effective areawide waste treatment management plans for such area.

(4) If a Governor does not act, either by designating or determining not to make a designation under paragraph (2) of this subsection, within the time required by such paragraph, or if, in the case of an interstate area, the Governors of the States involved do not designate a planning organization within the time required by paragraph (3) of this subsection, the chief elected officials of local governments within an area may by agreement designate (A) the boundaries for such an area, and (B) a single representative organization including elected officials from such local governments, or their designees, capable of developing an areawide waste treatment management plan for such area.

(5) Existing regional agencies may be designated under paragraphs (2), (3), and (4) of this subsection.

(6) The State shall act as a planning agency for all portions of such State which are not designated under paragraphs (2), (3), or (4) of this subsection.

(7) Designations under this subsection shall be subject to the approval of the Administrator.

(b) Planning process

(1)(A) Not later than one year after the date of designation of any organization under subsection (a) of this section such organization shall have in operation a continuing areawide waste treatment management planning process consistent with section 1281 of this title. Plans prepared in accordance with this process shall contain alternatives for waste treatment management, and be applicable to all wastes generated within the area involved. The initial plan prepared in accordance with such process shall be certified by the Governor and submitted to the Administrator not later than two years after the planning process is in operation.

(B) For any agency designated after 1975 under subsection (a) of this section and for all portions of a State for which the State is required to act as the planning agency in accordance with subsection (a)(6) of this section, the initial plan prepared in accordance with such process shall be certified by the Governor and submitted to the Administrator not later than three years after the receipt of the initial grant award authorized under subsection (f) of this section.

(2) Any plan prepared under such process shall include, but not be limited to—

(A) the identification of treatment works necessary to meet the anticipated municipal and industrial waste treatment needs of the area over a twenty-year period, annually updated (including an analysis of alternative waste treatment systems), including any requirements for the acquisition of land for treatment purposes; the necessary waste water collection and urban storm water runoff systems; and a program to provide the necessary financial arrangements for the development of such treatment works, and an identification of open space and recreation opportunities that can be expected to result from improved water quality, including consideration of potential use of lands associated with treatment works and increased access to water-based recreation;

(B) the establishment of construction priorities for such treatment works and time schedules for the initiation and completion of all treatment works;

(C) the establishment of a regulatory program to—

(i) implement the waste treatment management requirements of section 1281(c) of this title,

(ii) regulate the location, modification, and construction of any facilities within such area which may result in any discharge in such area, and

(iii) assure that any industrial or commercial wastes discharged into any treatment works in such area meet applicable pretreatment requirements;

(D) the identification of those agencies necessary to construct, operate, and maintain all facilities required by the plan and otherwise to carry out the plan;

(E) the identification of the measures necessary to carry out the plan (including financing), the period of time necessary to carry out the plan, the costs of carrying out the plan within such time, and the economic, social, and environmental impact of carrying out the plan within such time;

(F) a process to (i) identify, if appropriate, agriculturally and silviculturally related nonpoint sources of pollution, including return flows from irrigated agriculture, and their cumulative effects, runoff from manure disposal areas, and from land used for livestock and crop production, and (ii) set forth procedures and methods (including land use requirements) to control to the extent feasible such sources;

(G) a process to (i) identify, if appropriate, mine-related sources of pollution including new, current, and abandoned surface and underground mine runoff, and (ii) set forth procedures and methods (including land use requirements) to control to the extent feasible such sources;

(H) a process to (i) identify construction activity related sources of pollution, and (ii) set forth procedures and methods (including land use requirements) to control to the extent feasible such sources;

(I) a process to (i) identify, if appropriate, salt water intrusion into rivers, lakes, and estuaries resulting from reduction of fresh water flow from any cause, including irrigation, obstruction, ground water extraction, and diversion, and (ii) set forth procedures and methods to control such intrusion to the extent feasible where such procedures and methods are otherwise a part of the waste treatment management plan;

(J) a process to control the disposition of all residual waste generated in such area which could affect water quality; and

(K) a process to control the disposal of pollutants on land or in subsurface excavations within such area to protect ground and surface water quality.

(3) Areawide waste treatment management plans shall be certified annually by the Governor or his designee (or Governors or their designees, where more than one State is involved) as being consistent with applicable basin plans and such areawide waste treatment management plans shall be submitted to the Administrator for his approval.

(4)(A) Whenever the Governor of any State determines (and notifies the Administrator) that consistency with a statewide regulatory program under section 1313 of this title so requires, the requirements of clauses (F) through (K) of paragraph (2) of this subsection shall be developed and submitted by the Governor to the Administrator for approval for application to a class or category of activity throughout such State.

(B) Any program submitted under subparagraph (A) of this paragraph which, in whole or in part, is to control the discharge or other placement of dredged or fill material into the navigable waters shall include the following:

(i) A consultation process which includes the State agency with primary jurisdiction over fish and wildlife resources.

(ii) A process to identify and manage the discharge or other placement of dredged or fill material which adversely affects navigable waters, which shall complement and be coordinated with a State program under section 1344 of this title conducted pursuant to this chapter.

(iii) A process to assure that any activity conducted pursuant to a best management practice will comply with the guidelines established under section 1344(b)(1) of this title, and sections 1317 and 1343 of this title.

(iv) A process to assure that any activity conducted pursuant to a best management practice can be terminated or modified for cause including, but not limited to, the following:

(I) violation of any condition of the best management practice;

(II) change in any activity that requires either a temporary or permanent reduction or elimination of the discharge pursuant to the best management practice.

(v) A process to assure continued coordination with Federal and Federal-State water-related planning and reviewing processes, including the National Wetlands Inventory.

(C) If the Governor of a State obtains approval from the Administrator of a statewide regulatory program which meets the requirements of subparagraph (B) of this paragraph and if such State is administering a permit program under section 1344 of this title, no person shall be required to obtain an individual permit pursuant to such section, or to comply with a general permit issued pursuant to such section, with respect to any appropriate activity within such State for which a best management practice has been approved by the Administrator under the program approved by the Administrator pursuant to this paragraph.

(D)(i) Whenever the Administrator determines after public hearing that a State is not administering a program approved under this section in accordance with the requirements of this section, the Administrator shall so notify the State, and if appropriate corrective action is not taken within a reasonable time, not to exceed ninety days, the Administrator shall withdraw approval of such program. The Administrator shall not withdraw approval of any such program unless he shall first have notified the State, and made public, in writing, the reasons for such withdrawal.

(ii) In the case of a State with a program submitted and approved under this paragraph, the Administrator shall withdraw approval of such program under this subparagraph only for a substantial failure of the State to administer its program in accordance with the requirements of this paragraph.

(c) Regional operating agencies

(1) The Governor of each State, in consultation with the planning agency designated under subsection (a) of this section, at the time a plan is submitted to the Administrator, shall designate one or more waste treatment management agencies (which may be an existing or newly created local, regional, or State agency or political subdivision) for each area designated under subsection (a) of this section and submit such designations to the Administrator.

(2) The Administrator shall accept any such designation, unless, within 120 days of such designation, he finds that the designated management agency (or agencies) does not have adequate authority—

(A) to carry out appropriate portions of an areawide waste treatment management plan developed under subsection (b) of this section;

(B) to manage effectively waste treatment works and related facilities serving such area in conformance with any plan required by subsection (b) of this section;

(C) directly or by contract, to design and construct new works, and to operate and maintain new and existing works as required by any plan developed pursuant to subsection (b) of this section;

(D) to accept and utilize grants, or other funds from any source, for waste treatment management purposes;

(E) to raise revenues, including the assessment of waste treatment charges;

(F) to incur short- and long-term indebtedness;

(G) to assure in implementation of an areawide waste treatment management plan that each participating community pays its proportionate share of treatment costs;

(H) to refuse to receive any wastes from any municipality or subdivision thereof, which does not comply with any provisions of an approved plan under this section applicable to such area; and

(I) to accept for treatment industrial wastes.

(d) Conformity of works with area plan

After a waste treatment management agency having the authority required by subsection (c) of this section has been designated under such subsection for an area and a plan for such area has been approved under subsection (b) of this section, the Administrator shall not make any grant for construction of a publicly owned treatment works under section 1281(g)(1) of this title within such area except to such designated agency and for works in conformity with such plan.

(e) Permits not to conflict with approved plans

No permit under section 1342 of this title shall be issued for any point source which is in conflict with a plan approved pursuant to subsection (b) of this section.

(f) Grants

(1) The Administrator shall make grants to any agency designated under subsection (a) of this section for payment of the reasonable costs of developing and operating a continuing areawide waste treatment management planning process under subsection (b) of this section.

(2) For the two-year period beginning on the date the first grant is made under paragraph (1) of this subsection to an agency, if such first grant is made before October 1, 1977, the amount of each such grant to such agency shall be 100 per centum of the costs of developing and operating a continuing areawide waste treatment management planning process under subsection (b) of this section, and thereafter the amount granted to such agency shall not exceed 75 per centum of such costs in each succeeding one-year period. In the case of any other grant made to an agency under such paragraph (1) of this subsection, the amount of such grant shall not exceed 75 per centum of the costs of developing and operating a continuing areawide waste treatment management planning process in any year.

(3) Each applicant for a grant under this subsection shall submit to the Administrator for his approval each proposal for which a grant is applied for under this subsection. The Administrator shall act upon such proposal as soon as practicable after it has been submitted, and his approval of that proposal shall be deemed a contractual obligation of the United States for the payment of its contribution to such proposal, subject to such amounts as are provided in appropriation Acts. There is authorized to be appropriated to carry out this subsection not to exceed $50,000,000 for the fiscal year ending June 30, 1973, not to exceed $100,000,000 for the fiscal year ending June 30, 1974, not to exceed $150,000,000 per fiscal year for the fiscal years ending June 30, 1975, September 30, 1977, September 30, 1978, September 30, 1979, and September 30, 1980, not to exceed $100,000,000 per fiscal year for the fiscal years ending September 30, 1981, and September 30, 1982, and such sums as may be necessary for fiscal years 1983 through 1990.

(g) Technical assistance by Administrator

The Administrator is authorized, upon request of the Governor or the designated planning agency, and without reimbursement, to consult with, and provide technical assistance to, any agency designated under subsection (a) of this section in the development of areawide waste treatment management plans under subsection (b) of this section.

(h) Technical assistance by Secretary of the Army

(1) The Secretary of the Army, acting through the Chief of Engineers, in cooperation with the Administrator is authorized and directed, upon request of the Governor or the designated planning organization, to consult with, and provide technical assistance to, any agency designed[1] under subsection (a) of this section in developing and operating a continuing areawide waste treatment management planning process under subsection (b) of this section.

(2) There is authorized to be appropriated to the Secretary of the Army, to carry out this subsection, not to exceed $50,000,000 per fiscal year for the fiscal years ending June 30, 1973, and June 30, 1974.

(i) State best management practices program

(1) The Secretary of the Interior, acting through the Director of the United States Fish and Wildlife Service, shall, upon request of the Governor of a State, and without reimbursement, provide technical assistance to such State in developing a statewide program for submission to the Administrator under subsection (b)(4)(B) of this section and in implementing such program after its approval.

(2) There is authorized to be appropriated to the Secretary of the Interior $6,000,000 to complete the National Wetlands Inventory of the United States, by December 31, 1981, and to provide information from such Inventory to States as it becomes available to assist such States in the development and operation of programs under this chapter.

(j) Agricultural cost sharing

(1) The Secretary of Agriculture, with the concurrence of the Administrator, and acting through the Soil Conservation Service and such other agencies of the Department of Agriculture as the Secretary may designate, is authorized and directed to establish and administer a program to enter into contracts, subject to such amounts as are provided in advance by appropriation acts, of not less than five years nor more than ten years with owners and operators having control of rural land for the purpose of installing and maintaining measures incorporating best management practices to control nonpoint source pollution for improved water quality in those States or areas for which the Administrator has approved a plan under subsection (b) of this section where the practices to which the contracts apply are certified by the management agency designated under subsection (c)(1) of this section to be consistent with such plans and will result in improved water quality. Such contracts may be entered into during the period ending not later than September 31, 1988. Under such contracts the land owner or operator shall agree—

(i) to effectuate a plan approved by a soil conservation district, where one exists, under this section for his farm, ranch, or other land substantially in accordance with the schedule outlined therein unless any requirement thereof is waived or modified by the Secretary;

(ii) to forfeit all rights to further payments or grants under the contract and refund to the United States all payments and grants received thereunder, with interest, upon his violation of the contract at any stage during the time he has control of the land if the Secretary, after considering the recommendations of the soil conservation district, where one exists, and the Administrator, determines that such violation is of such a nature as to warrant termination of the contract, or to make refunds or accept such payment adjustments as the Secretary may deem appropriate if he determines that the violation by the owner or operator does not warrant termination of the contract;

(iii) upon transfer of his right and interest in the farm, ranch, or other land during the contract period to forfeit all rights to further payments or grants under the contract and refund to the United States all payments or grants received thereunder, with interest, unless the transferee of any such land agrees with the Secretary to assume all obligations of the contract;

(iv) not to adopt any practice specified by the Secretary on the advice of the Administrator in the contract as a practice which would tend to defeat the purposes of the contract;

(v) to such additional provisions as the Secretary determines are desirable and includes in the contract to effectuate the purposes of the program or to facilitate the practical administration of the program.

(2) In return for such agreement by the landowner or operator the Secretary shall agree to provide technical assistance and share the cost of carrying out those conservation practices and measures set forth in the contract for which he determines that cost sharing is appropriate and in the public interest and which are approved for cost sharing by the agency designated to implement the plan developed under subsection (b) of this section. The portion of such cost (including labor) to be shared shall be that part which the Secretary determines is necessary and appropriate to effectuate the installation of the water quality management practices and measures under the contract, but not to exceed 50 per centum of the total cost of the measures set forth in the contract; except the Secretary may increase the matching cost share where he determines that (1) the main benefits to be derived from the measures are related to improving offsite water quality, and (2) the matching share requirement would place a burden on the landowner which would probably prevent him from participating in the program.

(3) The Secretary may terminate any contract with a landowner or operator by mutual agreement with the owner or operator if the Secretary determines that such termination would be in the public interest, and may agree to such modification of contracts previously entered into as he may determine to be desirable to carry out the purposes of the program or facilitate the practical administration thereof or to accomplish equitable treatment with respect to other conservation, land use, or water quality programs.

(4) In providing assistance under this subsection the Secretary will give priority to those areas and sources that have the most significant effect upon water quality. Additional investigations or plans may be made, where necessary, to supplement approved water quality management plans, in order to determine priorities.

(5) The Secretary shall, where practicable, enter into agreements with soil conservation districts, State soil and water conservation agencies, or State

water quality agencies to administer all or part of the program established in this subsection under regulations developed by the Secretary. Such agreements shall provide for the submission of such reports as the Secretary deems necessary, and for payment by the United States of such portion of the costs incurred in the administration of the program as the Secretary may deem appropriate.

(6) The contracts under this subsection shall be entered into only in areas where the management agency designated under subsection (c)(1) of this section assures an adequate level of participation by owners and operators having control of rural land in such areas. Within such areas the local soil conservation district, where one exists, together with the Secretary of Agriculture, will determine the priority of assistance among individual land owners and operators to assure that the most critical water quality problems are addressed.

(7) The Secretary, in consultation with the Administrator and subject to section 1314(k) of this title, shall, not later than September 30, 1978, promulgate regulations for carrying out this subsection and for support and cooperation with other Federal and non-Federal agencies for implementation of this subsection.

(8) This program shall not be used to authorize or finance projects that would otherwise be eligible for assistance under the terms of Public Law 83-566 [16 U.S.C.A. § 1001 et seq.].

(9) There are hereby authorized to be appropriated to the Secretary of Agriculture $200,000,000 for fiscal year 1979, $400,000,000 for fiscal year 1980, $100,000,000 for fiscal year 1981, $100,000,000 for fiscal year 1982, and such sums as may be necessary for fiscal years 1983 through 1990, to carry out this subsection. The program authorized under this subsection shall be in addition to, and not in substitution of, other programs in such area authorized by this or any other public law.

(June 30, 1948, c. 758, Title II, § 208, as added Oct. 18, 1972, Pub.L. 92-500, § 2, 86 Stat. 839, and amended Dec. 27, 1977, Pub.L. 95-217, §§ 4(e), 31, 32, 33(a), 34, 35, 91 Stat. 1566, 1576-1579; Oct. 21, 1980, Pub.L. 96-483, § 1(d), (e), 94 Stat. 2360; Feb. 4, 1987, Pub.L. 100-4, Title I, § 101(d), (e), 101 Stat. 9.)

J

ATTACHMENT J

Clean Water Act, Section 319, 33 U.S.C. 1329

(b) Procedures and guidelines

The Administrator shall by regulation establish any procedures and guidelines which the Administrator deems necessary to carry out this section. Such regulations shall require the application to such discharge of each criterion, factor, procedure, and requirement applicable to a permit issued under section 1342 of this title, as the Administrator determines necessary to carry out the objective of this chapter.

(c) State administration

Each State desiring to administer its own permit program within its jurisdiction for discharge of a specific pollutant or pollutants under controlled conditions associated with an approved aquaculture project may do so if upon submission of such program the Administrator determines such program is adequate to carry out the objective of this chapter.

(June 30, 1948, c. 758, Title III, § 318, as added Oct. 18, 1972, Pub.L. 92-500, § 2, 86 Stat. 877, and amended Dec. 27, 1977, Pub.L. 95-217, § 63, 91 Stat. 1599.)

Cross References

Enforcement of provisions of this section, see section 1319 of this title.
Illegality of pollutant discharges except as in compliance with this section, see section 1311 of this title.
Permit for discharge of pollutants except as provided in this section, see section 1342 of this title.

Code of Federal Regulations

Environmental Protection Agency administered permit programs: the National Pollutant Discharge Elimination System, see 40 CFR 122.1 et seq.
State program requirements, see 40 CFR 123.1 et seq.

§ 1329. Nonpoint source management programs [FWPCA § 319]

(a) State assessment reports

(1) Contents

The Governor of each State shall, after notice and opportunity for public comment, prepare and submit to the Administrator for approval, a report which—

(A) identifies those navigable waters within the State which, without additional action to control nonpoint sources of pollution, cannot reasonably be expected to attain or maintain applicable water quality standards or the goals and requirements of this chapter;

(B) identifies those categories and subcategories of nonpoint sources or, where appropriate, particular nonpoint sources which add significant pollution to each portion of the navigable waters identified under subparagraph (A) in amounts which contribute to such portion not meeting such water quality standards or such goals and requirements;

(C) describes the process, including intergovernmental coordination and public participation, for identifying best management practices and measures to control each category and subcategory of nonpoint sources and, where appropriate, particular nonpoint sources identified under subparagraph (B) and to reduce, to the maximum extent practicable, the level of pollution resulting from such category, subcategory, or source; and

(D) identifies and describes State and local programs for controlling pollution added from nonpoint sources to, and improving the quality of, each such portion of the navigable waters, including but not limited to those programs which are receiving Federal assistance under subsections (h) and (i) of this section.

(2) Information used in preparation

In developing the report required by this section, the State (A) may rely upon information developed pursuant to sections 1288, 1313(e), 1314(f), 1315(b), and 1324 of this title, and other information as appropriate, and (B) may utilize appropriate elements of the waste treatment management plans developed pursuant to sections 1288(b) and 1313 of this title, to the extent such elements are consistent with and fulfill the requirements of this section.

(b) State management programs

(1) In general

The Governor of each State, for that State or in combination with adjacent States, shall, after notice and opportunity for public comment, prepare and submit to the Administrator for approval a management program which such State proposes to implement in the first four fiscal years beginning after the date of submission of such management program for controlling pollution added from nonpoint sources to the navigable waters within the State and improving the quality of such waters.

(2) Specific contents

Each management program proposed for implementation under this subsection shall include each of the following:

(A) An identification of the best management practices and measures which will be undertaken to reduce pollutant loadings resulting from each category, subcategory, or particular nonpoint source designated under paragraph

(1)(B), taking into account the impact of the practice on ground water quality.

(B) An identification of programs (including, as appropriate, nonregulatory or regulatory programs for enforcement, technical assistance, financial assistance, education, training, technology transfer, and demonstration projects) to achieve implementation of the best management practices by the categories, subcategories, and particular nonpoint sources designated under subparagraph (A).

(C) A schedule containing annual milestones for (i) utilization of the program implementation methods identified in subparagraph (B), and (ii) implementation of the best management practices identified in subparagraph (A) by the categories, subcategories, or particular nonpoint sources designated under paragraph (1)(B). Such schedule shall provide for utilization of the best management practices at the earliest practicable date.

(D) A certification of the attorney general of the State or States (or the chief attorney of any State water pollution control agency which has independent legal counsel) that the laws of the State or States, as the case may be, provide adequate authority to implement such management program or, if there is not such adequate authority, a list of such additional authorities as will be necessary to implement such management program. A schedule and commitment by the State or States to seek such additional authorities as expeditiously as practicable.

(E) Sources of Federal and other assistance and funding (other than assistance provided under subsections (h) and (i) of this section) which will be available in each of such fiscal years for supporting implementation of such practices and measures and the purposes for which such assistance will be used in each of such fiscal years.

(F) An identification of Federal financial assistance programs and Federal development projects for which the State will review individual assistance applications or development projects for their effect on water quality pursuant to the procedures set forth in Executive Order 12372 as in effect on September 17, 1983, to determine whether such assistance applications or development projects would be consistent with the program prepared under this subsection; for the purposes of this subparagraph, identification shall not be limited to the assistance programs or development projects subject to Executive Order 12372 but may include any programs listed in the most recent Catalog of Federal Domestic Assistance which may have an effect on the purposes and objectives of the State's nonpoint source pollution management program.

(3) Utilization of local and private experts

In developing and implementing a management program under this subsection, a State shall, to the maximum extent practicable, involve local public and private agencies and organizations which have expertise in control of nonpoint sources of pollution.

(4) Development on watershed basis

A State shall, to the maximum extent practicable, develop and implement a management program under this subsection on a watershed-by-watershed basis within such State.

(c) Administrative provisions

(1) Cooperation requirement

Any report required by subsection (a) of this section and any management program and report required by subsection (b) of this section shall be developed in cooperation with local, substate regional, and interstate entities which are actively planning for the implementation of nonpoint source pollution controls and have either been certified by the Administrator in accordance with section 1288 of this title, have worked jointly with the State on water quality management planning under section 1285(j) of this title, or have been designated by the State legislative body or Governor as water quality management planning agencies for their geographic areas.

(2) Time period for submission of reports and management programs

Each report and management program shall be submitted to the Administrator during the 18–month period beginning on February 4, 1987.

(d) Approval or disapproval of reports and management programs

(1) Deadline

Subject to paragraph (2), not later than 180 days after the date of submission to the Administrator of any report or management program under this section (other than subsections (h), (i), and (k) of this section), the Administrator shall either approve or disapprove such report or management program, as the case may be. The Administrator may approve a portion of a management program under this subsection. If the Administrator does not disapprove a report, management program, or portion of a management program in such 180-day period, such report, management program, or portion shall be deemed approved for purposes of this section.

(2) Procedure for disapproval

If, after notice and opportunity for public comment and consultation with appropriate Federal and State agencies and other interested persons, the Administrator determines that—

(A) the proposed management program or any portion thereof does not meet the requirements of subsection (b)(2) of this section or is not likely to satisfy, in whole or in part, the goals and requirements of this chapter;

(B) adequate authority does not exist, or adequate resources are not available, to implement such program or portion;

(C) the schedule for implementing such program or portion is not sufficiently expeditious; or

(D) the practices and measures proposed in such program or portion are not adequate to reduce the level of pollution in navigable waters in the State resulting from nonpoint sources and to improve the quality of navigable waters in the State;

the Administrator shall within 6 months of the receipt of the proposed program notify the State of any revisions or modifications necessary to obtain approval. The State shall thereupon have an additional 3 months to submit its revised management program and the Administrator shall approve or disapprove such revised program within three months of receipt.

(3) Failure of State to submit report

If a Governor of a State does not submit the report required by subsection (a) of this section within the period specified by subsection (c)(2) of this section, the Administrator shall, within 30 months after February 4, 1987, prepare a report for such State which makes the identifications required by paragraphs (1)(A) and (1)(B) of subsection (a) of this section. Upon completion of the requirement of the preceding sentence and after notice and opportunity for comment, the Administrator shall report to Congress on his actions pursuant to this section.

(e) Local management programs; technical assistance

If a State fails to submit a management program under subsection (b) of this section or the Administrator does not approve such a management program, a local public agency or organization which has expertise in, and authority to, control water pollution resulting from nonpoint sources in any area of such State which the Administrator determines is of sufficient geographic size may, with approval of such State, request the Administrator to provide, and the Administrator shall provide, technical assistance to such agency or organization in developing for such area a management program which is described in subsection (b) of this section and can be approved pursuant to subsection (d) of this section. After development of such management program, such agency or organization shall submit such management program to the Administrator for approval. If the Administrator approves such management program, such agency or organization shall be eligible to receive financial assistance under subsection (h) of this section for implementation of such management program as if such agency or organization were a State for which a report submitted under subsection (a) of this section and a management program submitted under subsection (b) of this section were approved under this section. Such financial assistance shall be subject to the same terms and conditions as assistance provided to a State under subsection (h) of this section.

(f) Technical assistance for States

Upon request of a State, the Administrator may provide technical assistance to such State in developing a management program approved under subsection (b) of this section for those portions of the navigable waters requested by such State.

(g) Interstate management conference

(1) Convening of conference; notification; purpose

If any portion of the navigable waters in any State which is implementing a management program approved under this section is not meeting applicable water quality standards or the goals and requirements of this chapter as a result, in whole or in part, of pollution from nonpoint sources in another State, such State may petition the Administrator to convene, and the Administrator shall convene, a management conference of all States which contribute significant pollution resulting from nonpoint sources to such portion. If, on the basis of information available, the Administrator determines that a State is not meeting applicable water quality standards or the goals and requirements of this chapter as a result, in whole or in part, of significant pollution from nonpoint sources in another State, the Administrator shall notify such States. The Administrator may convene a management conference under this paragraph not later than 180 days after giving such notification, whether or not the State which is not meeting such standards requests such conference. The purpose of such conference shall be to develop an agreement among such States to reduce the level of pollution in such portion resulting from nonpoint sources and to improve the water quality of such portion. Nothing in such agreement shall supersede or abrogate rights to quantities of water which have been established by interstate water compacts, Supreme Court decrees, or State water laws. This subsection shall not apply to any pollution which is subject to the Colorado River Basin Salinity Control Act [43 U.S.C.A. § 1571 et seq.]. The requirement that the Administrator convene a management conference shall not be subject to the provisions of section 1365 of this title.

(2) State management program requirement

To the extent that the States reach agreement through such conference, the management programs of the States which are parties to such agreements and which contribute significant pollution to the navigable waters or portions thereof not meeting applicable water quality standards or goals and requirements of this chapter will be revised to reflect such agreement. Such management programs shall be consistent with Federal and State law.

(h) Grant program

(1) Grants for implementation of management programs

Upon application of a State for which a report submitted under subsection (a) of this section and a management program submitted under subsection (b) of this section is approved under this section, the Administrator shall make grants, subject to such terms and conditions as the Administrator considers appropriate, under this subsection to such State for the purpose of assisting the State in implementing such management program. Funds reserved pursuant to section 1285(j)(5) of this title may be used to develop and implement such management program.

(2) Applications

An application for a grant under this subsection in any fiscal year shall be in such form and shall contain such other information as the Administrator may require, including an identification and description of the best management practices and measures which the State proposes to assist, encourage, or require in such year with the Federal assistance to be provided under the grant.

(3) Federal share

The Federal share of the cost of each management program implemented with Federal assistance under this subsection in any fiscal year shall not exceed 60 percent of the cost incurred by the State in implementing such management program and shall be made on condition that the non-Federal share is provided from non-Federal sources.

(4) Limitation on grant amounts

Notwithstanding any other provision of this subsection, not more than 15 percent of the amount appropriated to carry out this subsection may be used to make grants to any one State, including any grants to any local public agency or organization with authority to control pollution from nonpoint sources in any area of such State.

(5) Priority for effective mechanisms

For each fiscal year beginning after September 30, 1987, the Administrator may give priority in making grants under this subsection, and shall give consideration in determining the Federal share of any such grant, to States which have implemented or are proposing to implement management programs which will—

(A) control particularly difficult or serious nonpoint source pollution problems, including, but not limited to, problems resulting from mining activities;

(B) implement innovative methods or practices for controlling nonpoint sources of pollution, including regulatory programs where the Administrator deems appropriate;

(C) control interstate nonpoint source pollution problems; or

(D) carry out ground water quality protection activities which the Administrator determines are part of a comprehensive nonpoint source pollution control program, including research, planning, ground water assessments, demonstration programs, enforcement, technical assistance, education, and training to protect ground water quality from nonpoint sources of pollution.

(6) Availability for obligation

The funds granted to each State pursuant to this subsection in a fiscal year shall remain available for obligation by such State for the fiscal year for which appropriated. The amount of any such funds not obligated by the end of such fiscal year shall be available to the Administrator for granting to other States under this subsection in the next fiscal year.

(7) Limitation on use of funds

States may use funds from grants made pursuant to this section for financial assistance to persons only to the extent that such assistance is related to the costs of demonstration projects.

(8) Satisfactory progress

No grant may be made under this subsection in any fiscal year to a State which in the preceding fiscal year received a grant under this subsection unless the Administrator determines that such State made satisfactory progress in such preceding fiscal year in meeting the schedule specified by such State under subsection (b)(2) of this section.

(9) Maintenance of effort

No grant may be made to a State under this subsection in any fiscal year unless such State enters into such agreements with the Administrator as the Administrator may require to ensure that such State will maintain its aggregate expenditures from all other sources for programs for controlling pollution added to the navigable waters in such State from nonpoint sources and improving the quality of such waters at or above the average level of such expenditures in its two fiscal years preceding February 4, 1987.

(10) Request for information

The Administrator may request such information, data, and reports as he considers necessary to make the determination of continuing eligibility for grants under this section.

(11) Reporting and other requirements

Each State shall report to the Administrator on an annual basis concerning (A) its progress in meeting the schedule of milestones submitted pursuant to subsection (b)(2)(C) of this section, and (B) to the extent that appropriate information is available, reductions in nonpoint source pollutant loading and improvements in water quality for those navigable waters or watersheds within the State which were identified pursuant to subsection (a)(1)(A) of this section resulting from implementation of the management program.

(12) Limitation on administrative costs

For purposes of this subsection, administrative costs in the form of salaries, overhead, or indirect costs for services provided and charged against activities and programs carried out with a grant under this subsection shall not exceed in any fiscal year 10 percent of the amount of the grant in such year, except that costs of implementing enforcement and regulatory activities, education, training, technical assistance, demonstration projects, and technology transfer programs shall not be subject to this limitation.

(i) Grants for protecting groundwater quality

(1) Eligible applicants and activities

Upon application of a State for which a report submitted under subsection (a) of this section and a plan submitted under subsection (b) of this section is approved under this section, the Administrator shall make grants under this subsection to such State for the purpose of assisting such State in carrying out groundwater quality protection activities which the Administrator determines will advance the State toward implementation of a comprehensive nonpoint source pollution control program. Such activities shall include, but not be limited to, research, planning, groundwater assessments, demonstration programs, enforcement, technical assistance, education and training to protect the quality of groundwater and to prevent contamination of groundwater from nonpoint sources of pollution.

(2) Applications

An application for a grant under this subsection shall be in such form and shall contain such information as the Administrator may require.

(3) Federal share; maximum amount

The Federal share of the cost of assisting a State in carrying out groundwater protection activities in any fiscal year under this subsection shall be 50 percent of the costs incurred by the State in carrying out such activities, except that the maximum amount of Federal assistance which any State may receive under this subsection in any fiscal year shall not exceed $150,000.

(4) Report

The Administrator shall include in each report transmitted under subsection (m) of this section a report on the activities and programs implemented under this subsection during the preceding fiscal year.

(j) Authorization of appropriations

There is authorized to be appropriated to carry out subsections (h) and (i) of this section not to exceed $70,000,000 for fiscal year 1988, $100,000,000 per fiscal year for each of fiscal years 1989 and 1990, and $130,000,000 for fiscal year 1991; except that for each of such fiscal years not to exceed $7,500,000 may be made available to carry out subsection (i) of this section. Sums appropriated pursuant to this subsection shall remain available until expended.

(k) Consistency of other programs and projects with management programs

The Administrator shall transmit to the Office of Management and Budget and the appropriate Federal departments and agencies a list of those assistance programs and development projects identified by each State under subsection (b)(2)(F) of this section for which individual assistance applications and projects will be reviewed pursuant to the procedures set forth in Executive Order 12372 as in effect on September 17, 1983. Beginning not later than sixty days after receiving notification by the Administrator, each Federal department and agency shall modify existing regulations to allow States to review individual development projects and assistance applications under the identified Federal assistance programs and shall accommodate, according to the requirements and definitions of Executive Order 12372, as in effect on September 17, 1983, the concerns of the State regarding the consistency of such applications or projects with the State nonpoint source pollution management program.

(*l*) Collection of information

The Administrator shall collect and make available, through publications and other appropriate means, information pertaining to management practices and implementation methods, including, but not limited to, (1) information concerning the costs and relative efficiencies of best management practices for reducing nonpoint source pollution; and (2) available data concerning the relationship between water quality and implementation of various management practices to control nonpoint sources of pollution.

(m) Reports of Administrator

(1) Annual reports

Not later than January 1, 1988, and each January 1 thereafter, the Administrator shall transmit to the Committee on Public Works and Transportation of the House of Representatives and the Committee on Environment and Public Works of the Senate, a report for the preceding fiscal year on the activities and programs implemented under this section and the progress made in reducing pollution in the navigable waters resulting from nonpoint sources and improving the quality of such waters.

(2) Final report

Not later than January 1, 1990, the Administrator shall transmit to Congress a final report on the activities carried out under this section. Such report, at a minimum, shall—

(A) describe the management programs being implemented by the States by types and amount of affected navigable waters, categories and subcategories of nonpoint sources, and types of best management practices being implemented;

(B) describe the experiences of the States in adhering to schedules and implementing best management practices;

(C) describe the amount and purpose of grants awarded pursuant to subsections (h) and (i) of this section;

(D) identify, to the extent that information is available, the progress made in reducing pollutant loads and improving water quality in the navigable waters;

(E) indicate what further actions need to be taken to attain and maintain in those navigable waters (i) applicable water quality standards, and (ii) the goals and requirements of this chapter;

(F) include recommendations of the Administrator concerning future programs (including enforcement programs) for controlling pollution from nonpoint sources; and

(G) identify the activities and programs of departments, agencies, and instrumentalities of the United States which are inconsistent with the management programs submitted by the States and recommend modifications so that such activities and programs are consistent with and assist the States in implementation of such management programs.

(n) Set aside for administrative personnel

Not less than 5 percent of the funds appropriated pursuant to subsection (j) of this section for any fiscal year shall be available to the Administrator to maintain personnel levels at the Environmental Protection Agency at levels which are adequate to carry out this section in such year.

K

ATTACHMENT K

Clean Water Act, Section 402, 33 U.S.C. 1342

will not violate the applicable provisions of section 1311, 1312, 1313, 1316, or 1317 of this title.

(5) Any Federal license or permit with respect to which a certification has been obtained under paragraph (1) of this subsection may be suspended or revoked by the Federal agency issuing such license or permit upon the entering of a judgment under this chapter that such facility or activity has been operated in violation of the applicable provisions of section 1311, 1312, 1313, 1316, or 1317 of this title.

(6) Except with respect to a permit issued under section 1342 of this title, in any case where actual construction of a facility has been lawfully commenced prior to April 3, 1970, no certification shall be required under this subsection for a license or permit issued after April 3, 1970, to operate such facility, except that any such license or permit issued without certification shall terminate April 3, 1973, unless prior to such termination date the person having such license or permit submits to the Federal agency which issued such license or permit a certification and otherwise meets the requirements of this section.

[(7) Redesignated (6)].

(b) Compliance with other provisions of law setting applicable water quality requirements

Nothing in this section shall be construed to limit the authority of any department or agency pursuant to any other provision of law to require compliance with any applicable water quality requirements. The Administrator shall, upon the request of any Federal department or agency, or State or interstate agency, or applicant, provide, for the purpose of this section, any relevant information on applicable effluent limitations, or other limitations, standards, regulations, or requirements, or water quality criteria, and shall, when requested by any such department or agency or State or interstate agency, or applicant, comment on any methods to comply with such limitations, standards, regulations, requirements, or criteria.

(c) Authority of Secretary of the Army to permit use of spoil disposal areas by Federal licensees or permittees

In order to implement the provisions of this section, the Secretary of the Army, acting through the Chief of Engineers, is authorized, if he deems it to be in the public interest, to permit the use of spoil disposal areas under his jurisdiction by Federal licensees or permittees, and to make an appropriate charge for such use. Moneys received from such licensees or permittees shall be deposited in the Treasury as miscellaneous receipts.

(d) Limitations and monitoring requirements of certification

Any certification provided under this section shall set forth any effluent limitations and other limitations, and monitoring requirements necessary to assure that any applicant for a Federal license or permit will comply with any applicable effluent limitations and other limitations, under section 1311 or 1312 of this title, standard of performance under section 1316 of this title, or prohibition, effluent standard, or pretreatment standard under section 1317 of this title, and with any other appropriate requirement of State law set forth in such certification, and shall become a condition on any Federal license or permit subject to the provisions of this section.

(June 30, 1948, c. 758, Title IV, § 401, as added Oct. 18, 1972, Pub.L. 92-500, § 2, 86 Stat. 877, and amended Dec. 27, 1977, Pub.L. 95-217, §§ 61(b), 64, 91 Stat. 1598, 1599.)

Cross References

Citizen suits for violation of effluent standards, see section 1365 of this title.
Licensing authority of any Federal agency under environmental policy provisions, see section 1371 of this title.
Test procedures for analysis of pollutants to include factors to be provided in any certification pursuant to this section, see section 1314 of this title.

Library References

Health and Environment ⇐25.7(13).
C.J.S. Health and Environment § 107 et seq.

§ 1342. National pollutant discharge elimination system [FWPCA § 402]

(a) Permits for discharge of pollutants

(1) Except as provided in sections 1328 and 1344 of this title, the Administrator may, after opportunity for public hearing, issue a permit for the discharge of any pollutant, or combination of pollutants, notwithstanding section 1311(a) of this title, upon condition that such discharge will meet either (A) all applicable requirements under sections 1311, 1312, 1316, 1317, 1318, and 1343 of this title, or (B) prior to the taking of necessary implementing actions relating to all such requirements, such conditions as the Administrator determines are necessary to carry out the provisions of this chapter.

(2) The Administrator shall prescribe conditions for such permits to assure compliance with the requirements of paragraph (1) of this subsection, including conditions on data and information collection, reporting, and such other requirements as he deems appropriate.

(3) The permit program of the Administrator under paragraph (1) of this subsection, and permits

issued thereunder, shall be subject to the same terms, conditions, and requirements as apply to a State permit program and permits issued thereunder under subsection (b) of this section.

(4) All permits for discharges into the navigable waters issued pursuant to section 407 of this title shall be deemed to be permits issued under this subchapter, and permits issued under this subchapter shall be deemed to be permits issued under section 407 of this title, and shall continue in force and effect for their term unless revoked, modified, or suspended in accordance with the provisions of this chapter.

(5) No permit for a discharge into the navigable waters shall be issued under section 407 of this title after October 18, 1972. Each application for a permit under section 407 of this title, pending on October 18, 1972, shall be deemed to be an application for a permit under this section. The Administrator shall authorize a State, which he determines has the capability of administering a permit program which will carry out the objectives of this chapter to issue permits for discharges into the navigable waters within the jurisdiction of such State. The Administrator may exercise the authority granted him by the preceding sentence only during the period which begins on October 18, 1972, and ends either on the ninetieth day after the date of the first promulgation of guidelines required by section 1314(i)(2) of this title, or the date of approval by the Administrator of a permit program for such State under subsection (b) of this section, whichever date first occurs, and no such authorization to a State shall extend beyond the last day of such period. Each such permit shall be subject to such conditions as the Administrator determines are necessary to carry out the provisions of this chapter. No such permit shall issue if the Administrator objects to such issuance.

(b) State permit programs

At any time after the promulgation of the guidelines required by subsection (i)(2) of section 1314 of this title, the Governor of each State desiring to administer its own permit program for discharges into navigable waters within its jurisdiction may submit to the Administrator a full and complete description of the program it proposes to establish and administer under State law or under an interstate compact. In addition, such State shall submit a statement from the attorney general (or the attorney for those State water pollution control agencies which have independent legal counsel), or from the chief legal officer in the case of an interstate agency, that the laws of such State, or the interstate compact, as the case may be, provide adequate authority to carry out the described program. The Administrator shall approve each submitted program unless he determines that adequate authority does not exist:

(1) To issue permits which—

(A) apply, and insure compliance with, any applicable requirements of sections 1311, 1312, 1316, 1317, and 1343 of this title;

(B) are for fixed terms not exceeding five years; and

(C) can be terminated or modified for cause including, but not limited to, the following:

(i) violation of any condition of the permit;

(ii) obtaining a permit by misrepresentation, or failure to disclose fully all relevant facts;

(iii) change in any condition that requires either a temporary or permanent reduction or elimination of the permitted discharge;

(D) control the disposal of pollutants into wells;

(2)(A) To issue permits which apply, and insure compliance with, all applicable requirements of section 1318 of this title; or

(B) To inspect, monitor, enter, and require reports to at least the same extent as required in section 1318 of this title;

(3) To insure that the public, and any other State the waters of which may be affected, receive notice of each application for a permit and to provide an opportunity for public hearing before a ruling on each such application;

(4) To insure that the Administrator receives notice of each application (including a copy thereof) for a permit;

(5) To insure that any State (other than the permitting State), whose waters may be affected by the issuance of a permit may submit written recommendations to the permitting State (and the Administrator) with respect to any permit application and, if any part of such written recommendations are not accepted by the permitting State, that the permitting State will notify such affected State (and the Administrator) in writing of its failure to so accept such recommendations together with its reasons for so doing;

(6) To insure that no permit will be issued if, in the judgment of the Secretary of the Army acting through the Chief of Engineers, after consultation with the Secretary of the department in which the

Coast Guard is operating, anchorage and navigation of any of the navigable waters would be substantially impaired thereby;

(7) To abate violations of the permit or the permit program, including civil and criminal penalties and other ways and means of enforcement;

(8) To insure that any permit for a discharge from a publicly owned treatment works includes conditions to require the identification in terms of character and volume of pollutants of any significant source introducing pollutants subject to pretreatment standards under section 1317(b) of this title into such works and a program to assure compliance with such pretreatment standards by each such source, in addition to adequate notice to the permitting agency of (A) new introductions into such works of pollutants from any source which would be a new source as defined in section 1316 of this title if such source were discharging pollutants, (B) new introductions of pollutants into such works from a source which would be subject to section 1311 of this title if it were discharging such pollutants, or (C) a substantial change in volume or character of pollutants being introduced into such works by a source introducing pollutants into such works at the time of issuance of the permit. Such notice shall include information on the quality and quantity of effluent to be introduced into such treatment works and any anticipated impact of such change in the quantity or quality of effluent to be discharged from such publicly owned treatment works; and

(9) To insure that any industrial user of any publicly owned treatment works will comply with sections 1284(b), 1317, and 1318 of this title.

(c) Suspension of Federal program upon submission of State program; withdrawal of approval of State program; return of State program to Administrator

(1) Not later than ninety days after the date on which a State has submitted a program (or revision thereof) pursuant to subsection (b) of this section, the Administrator shall suspend the issuance of permits under subsection (a) of this section as to those discharges subject to such program unless he determines that the State permit program does not meet the requirements of subsection (b) of this section or does not conform to the guidelines issued under section 1314(i)(2) of this title. If the Administrator so determines, he shall notify the State of any revisions or modifications necessary to conform to such requirements or guidelines.

(2) Any State permit program under this section shall at all times be in accordance with this section and guidelines promulgated pursuant to section 1314(i)(2) of this title.

(3) Whenever the Administrator determines after public hearing that a State is not administering a program approved under this section in accordance with requirements of this section, he shall so notify the State and, if appropriate corrective action is not taken within a reasonable time, not to exceed ninety days, the Administrator shall withdraw approval of such program. The Administrator shall not withdraw approval of any such program unless he shall first have notified the State, and made public, in writing, the reasons for such withdrawal.

(4) Limitations on partial permit program returns and withdrawals.—

A State may return to the Administrator administration, and the Administrator may withdraw under paragraph (3) of this subsection approval, of—

(A) a State partial permit program approved under subsection (n)(3) of this section only if the entire permit program being administered by the State department or agency at the time is returned or withdrawn; and

(B) a State partial permit program approved under subsection (n)(4) of this section only if an entire phased component of the permit program being administered by the State at the time is returned or withdrawn.

(d) Notification of Administrator

(1) Each State shall transmit to the Administrator a copy of each permit application received by such State and provide notice to the Administrator of every action related to the consideration of such permit application, including each permit proposed to be issued by such State.

(2) No permit shall issue (A) if the Administrator within ninety days of the date of his notification under subsection (b)(5) of this section objects in writing to the issuance of such permit, or (B) if the Administrator within ninety days of the date of transmittal of the proposed permit by the State objects in writing to the issuance of such permit as being outside the guidelines and requirements of this chapter. Whenever the Administrator objects to the issuance of a permit under this paragraph such written objection shall contain a statement of the reasons for such objection and the effluent limitations and conditions which such permit would include if it were issued by the Administrator.

(3) The Administrator may, as to any permit application, waive paragraph (2) of this subsection.

(4) In any case where, after December 27, 1977, the Administrator, pursuant to paragraph (2) of this subsection, objects to the issuance of a permit, on request of the State, a public hearing shall be held by the Administrator on such objection. If the State does not resubmit such permit revised to meet such objection within 30 days after completion of the hearing, or, if no hearing is requested within 90 days after the date of such objection, the Administrator may issue the permit pursuant to subsection (a) of this section for such source in accordance with the guidelines and requirements of this chapter.

(e) Waiver of notification requirement

In accordance with guidelines promulgated pursuant to subsection (i)(2) of section 1314 of this title, the Administrator is authorized to waive the requirements of subsection (d) of this section at the time he approves a program pursuant to subsection (b) of this section for any category (including any class, type, or size within such category) of point sources within the State submitting such program.

(f) Point source categories

The Administrator shall promulgate regulations establishing categories of point sources which he determines shall not be subject to the requirements of subsection (d) of this section in any State with a program approved pursuant to subsection (b) of this section. The Administrator may distinguish among classes, types, and sizes within any category of point sources.

(g) Other regulations for safe transportation, handling, carriage, storage, and stowage of pollutants

Any permit issued under this section for the discharge of pollutants into the navigable waters from a vessel or other floating craft shall be subject to any applicable regulations promulgated by the Secretary of the department in which the Coast Guard is operating, establishing specifications for safe transportation, handling, carriage, storage, and stowage of pollutants.

(h) Violation of permit conditions; restriction or prohibition upon introduction of pollutant by source not previously utilizing treatment works

In the event any condition of a permit for discharges from a treatment works (as defined in section 1292 of this title) which is publicly owned is violated, a State with a program approved under subsection (b) of this section or the Administrator, where no State program is approved or where the Administrator determines pursuant to section 1319(a) of this title that a State with an approved program has not commenced appropriate enforcement action with respect to such permit, may proceed in a court of competent jurisdiction to restrict or prohibit the introduction of any pollutant into such treatment works by a source not utilizing such treatment works prior to the finding that such condition was violated.

(i) Federal enforcement not limited

Nothing in this section shall be construed to limit the authority of the Administrator to take action pursuant to section 1319 of this title.

(j) Public information

A copy of each permit application and each permit issued under this section shall be available to the public. Such permit application or permit, or portion thereof, shall further be available on request for the purpose of reproduction.

(k) Compliance with permits

Compliance with a permit issued pursuant to this section shall be deemed compliance, for purposes of sections 1319 and 1365 of this title, with sections 1311, 1312, 1316, 1317, and 1343 of this title, except any standard imposed under section 1317 of this title for a toxic pollutant injurious to human health. Until December 31, 1974, in any case where a permit for discharge has been applied for pursuant to this section, but final administrative disposition of such application has not been made, such discharge shall not be a violation of (1) section 1311, 1316, or 1342 of this title, or (2) section 407 of this title, unless the Administrator or other plaintiff proves that final administrative disposition of such application has not been made because of the failure of the applicant to furnish information reasonably required or requested in order to process the application. For the 180-day period beginning on October 18, 1972, in the case of any point source discharging any pollutant or combination of pollutants immediately prior to such date which source is not subject to section 407 of this title, the discharge by such source shall not be a violation of this chapter if such a source applies for a permit for discharge pursuant to this section within such 180-day period.

(l) Limitation on permit requirement

(1) Agricultural return flows

The Administrator shall not require a permit under this section for discharges composed entirely of return flows from irrigated agriculture, nor shall the Administrator directly or indirectly, require any State to require such a permit.

(2) Stormwater runoff from oil, gas, and mining operations

The Administrator shall not require a permit under this section, nor shall the Administrator directly or indirectly require any State to require a permit, for discharges of stormwater runoff from mining operations or oil and gas exploration, production, processing, or treatment operations or transmission facilities, composed entirely of flows which are from conveyances or systems of conveyances (including but not limited to pipes, conduits, ditches, and channels) used for collecting and conveying precipitation runoff and which are not contaminated by contact with, or do not come into contact with, any overburden, raw material, intermediate products, finished product, byproduct, or waste products located on the site of such operations.

(m) Additional pretreatment of conventional pollutants not required

To the extent a treatment works (as defined in section 1292 of this title) which is publicly owned is not meeting the requirements of a permit issued under this section for such treatment works as a result of inadequate design or operation of such treatment works, the Administrator, in issuing a permit under this section, shall not require pretreatment by a person introducing conventional pollutants identified pursuant to section 1314(a)(4) of this title into such treatment works other than pretreatment required to assure compliance with pretreatment standards under subsection (b)(8) of this section and section 1317(b)(1) of this title. Nothing in this subsection shall affect the Administrator's authority under sections 1317 and 1319 of this title, affect State and local authority under sections 1317(b)(4) and 1370 of this title, relieve such treatment works of its obligations to meet requirements established under this chapter, or otherwise preclude such works from pursuing whatever feasible options are available to meet its responsibility to comply with its permit under this section.

(n) Partial permit program

(1) State submission

The Governor of a State may submit under subsection (b) of this section a permit program for a portion of the discharges into the navigable waters in such State.

(2) Minimum coverage

A partial permit program under this subsection shall cover, at a minimum, administration of a major category of the discharges into the navigable waters of the State or a major component of the permit program required by subsection (b) of this section.

(3) Approval of major category partial permit programs

The Administrator may approve a partial permit program covering administration of a major category of discharges under this subsection if—

(A) such program represents a complete permit program and covers all of the discharges under the jurisdiction of a department or agency of the State; and

(B) the Administrator determines that the partial program represents a significant and identifiable part of the State program required by subsection (b) of this section.

(4) Approval of major component partial permit programs

The Administrator may approve under this subsection a partial and phased permit program covering administration of a major component (including discharge categories) of a State permit program required by subsection (b) of this section if—

(A) the Administrator determines that the partial program represents a significant and identifiable part of the State program required by subsection (b) of this section; and

(B) the State submits, and the Administrator approves, a plan for the State to assume administration by phases of the remainder of the State program required by subsection (b) of this section by a specified date not more than 5 years after submission of the partial program under this subsection and agrees to make all reasonable efforts to assume such administration by such date.

(*o*) Anti-backsliding

(1) General prohibition

In the case of effluent limitations established on the basis of subsection (a)(1)(B) of this section, a permit may not be renewed, reissued, or modified on the basis of effluent guidelines promulgated under section 1314(b) of this title subsequent to the original issuance of such permit, to contain effluent limitations which are less stringent than the comparable effluent limitations in the previous permit. In the case of effluent limitations established on the basis of section 1311(b)(1)(C) or section 1313(d) or (e) of this title, a permit may not be renewed, reissued, or modified to contain effluent limitations which are less stringent than the comparable effluent limitations in the previous permit except in compliance with section 1313(d)(4) of this title.

(2) Exceptions

A permit with respect to which paragraph (1) applies may be renewed, reissued, or modified to contain a less stringent effluent limitation applicable to a pollutant if—

(A) material and substantial alterations or additions to the permitted facility occurred after permit issuance which justify the application of a less stringent effluent limitation;

(B)(i) information is available which was not available at the time of permit issuance (other than revised regulations, guidance, or test methods) and which would have justified the application of a less stringent effluent limitation at the time of permit issuance; or

(ii) the Administrator determines that technical mistakes or mistaken interpretations of law were made in issuing the permit under subsection (a)(1)(B) of this section;

(C) a less stringent effluent limitation is necessary because of events over which the permittee has no control and for which there is no reasonably available remedy;

(D) the permittee has received a permit modification under section 1311(c), 1311(g), 1311(h), 1311(i), 1311(k), 1311(n), or 1326(a) of this title; or

(E) the permittee has installed the treatment facilities required to meet the effluent limitations in the previous permit and has properly operated and maintained the facilities but has nevertheless been unable to achieve the previous effluent limitations, in which case the limitations in the reviewed, reissued, or modified permit may reflect the level of pollutant control actually achieved (but shall not be less stringent than required by effluent guidelines in effect at the time of permit renewal, reissuance, or modification).

Subparagraph (B) shall not apply to any revised waste load allocations or any alternative grounds for translating water quality standards into effluent limitations, except where the cumulative effect of such revised allocations results in a decrease in the amount of pollutants discharged into the concerned waters, and such revised allocations are not the result of a discharger eliminating or substantially reducing its discharge of pollutants due to complying with the requirements of this chapter or for reasons otherwise unrelated to water quality.

(3) Limitations

In no event may a permit with respect to which paragraph (1) applies be renewed, reissued, or modified to contain an effluent limitation which is less stringent than required by effluent guidelines in effect at the time the permit is renewed, reissued, or modified. In no event may such a permit to discharge into waters be renewed, reissued, or modified to contain a less stringent effluent limitation if the implementation of such limitation would result in a violation of a water quality standard under section 1313 of this title applicable to such waters.

(p) Municipal and industrial stormwater discharges

(1) General rule

Prior to October 1, 1992, the Administrator or the State (in the case of a permit program approved under this section) shall not require a permit under this section for discharges composed entirely of stormwater.

(2) Exceptions

Paragraph (1) shall not apply with respect to the following stormwater discharges:

(A) A discharge with respect to which a permit has been issued under this section before February 4, 1987.

(B) A discharge associated with industrial activity.

(C) A discharge from a municipal separate storm sewer system serving a population of 250,000 or more.

(D) A discharge from a municipal separate storm sewer system serving a population of 100,000 or more but less than 250,000.

(E) A discharge for which the Administrator or the State, as the case may be, determines that the stormwater discharge contributes to a violation of a water quality standard or is a significant contributor of pollutants to waters of the United States.

(3) Permit requirements

(A) Industrial discharges

Permits for discharges associated with industrial activity shall meet all applicable provisions of this section and section 1311 of this title.

(B) Municipal discharge

Permits for discharges from municipal storm sewers—

(i) may be issued on a system- or jurisdiction-wide basis;

(ii) shall include a requirement to effectively prohibit non-stormwater discharges into the storm sewers; and

(iii) shall require controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and system, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants.

(4) Permit application requirements

(A) Industrial and large municipal discharges

Not later than 2 years after February 4, 1987, the Administrator shall establish regulations setting forth the permit application requirements for stormwater discharges described in paragraphs (2)(B) and (2)(C). Applications for permits for such discharges shall be filed no later than 3 years after February 4, 1987. Not later than 4 years after February 4, 1987, the Administrator or the State, as the case may be, shall issue or deny each such permit. Any such permit shall provide for compliance as expeditiously as practicable, but in no event later than 3 years after the date of issuance of such permit.

(B) Other municipal discharges

Not later than 4 years after February 4, 1987, the Administrator shall establish regulations setting forth the permit application requirements for stormwater discharges described in paragraph (2)(D). Applications for permits for such discharges shall be filed no later than 5 years after February 4, 1987. Not later than 6 years after February 4, 1987, the Administrator or the State, as the case may be, shall issue or deny each such permit. Any such permit shall provide for compliance as expeditiously as practicable, but in no event later than 3 years after the date of issuance of such permit.

(5) Studies

The Administrator, in consultation with the States, shall conduct a study for the purposes of—

(A) identifying those stormwater discharges or classes of stormwater discharges for which permits are not required pursuant to paragraphs (1) and (2) of this subsection;

(B) determining, to the maximum extent practicable, the nature and extent of pollutants in such discharges; and

(C) establishing procedures and methods to control stormwater discharges to the extent necessary to mitigate impacts on water quality.

Not later than October 1, 1988, the Administrator shall submit to Congress a report on the results of the study described in subparagraphs (A) and (B). Not later than October 1, 1989, the Administrator shall submit to Congress a report on the results of the study described in subparagraph (C).

(6) Regulations

Not later than October 1, 1992, the Administrator, in consultation with State and local officials, shall issue regulations (based on the results of the studies conducted under paragraph (5)) which designate stormwater discharges, other than those discharges described in paragraph (2), to be regulated to protect water quality and shall establish a comprehensive program to regulate such designated sources. The program shall, at a minimum, (A) establish priorities, (B) establish requirements for State stormwater management programs, and (C) establish expeditious deadlines. The program may include performance standards, guidelines, guidance, and management practices and treatment requirements, as appropriate.

L

ATTACHMENT L

Clean Water Act, Section 404, 33 U.S.C. 1344

to plankton, fish, shellfish, wildlife, shorelines, and beaches;

(B) the effect of disposal of pollutants on marine life including the transfer, concentration, and dispersal of pollutants or their byproducts through biological, physical, and chemical processes; changes in marine ecosystem diversity, productivity, and stability; and species and community population changes;

(C) the effect of disposal, of pollutants on esthetic, recreation, and economic values;

(D) the persistence and permanence of the effects of disposal of pollutants;

(E) the effect of the disposal of varying rates, of particular volumes and concentrations of pollutants;

(F) other possible locations and methods of disposal or recycling of pollutants including land-based alternatives; and

(G) the effect on alternate uses of the oceans, such as mineral exploitation and scientific study.

(2) In any event where insufficient information exists on any proposed discharge to make a reasonable judgment on any of the guidelines established pursuant to this subsection no permit shall be issued under section 1342 of this title.

(June 30, 1948, c. 758, Title IV, § 403, as added Oct. 18, 1972, Pub.L. 92-500, § 2, 86 Stat. 883.)

Cross References

Best management practices for industry, see section 1314 of this title.
Determination of State's authority to issue permits for dredged or fill material, see section 1344 of this title.
Field laboratory and research facilities, see section 1254 of this title.
Modification of effluent limitation requirements for point sources, see section 1311 of this title.
Permits for discharge of pollutants, see section 1342 of this title.
Planning process to assure compliance with this section, see section 1288 of this title

§ 1344. Permits for dredged or fill material [FWPCA § 404]

(a) Discharge into navigable waters at specified disposal sites

The Secretary may issue permits, after notice and opportunity for public hearings for the discharge of dredged or fill material into the navigable waters at specified disposal sites. Not later than the fifteenth day after the date an applicant submits all the information required to complete an application for a permit under this subsection, the Secretary shall publish the notice required by this subsection.

(b) Specification for disposal sites

Subject to subsection (c) of this section, each such disposal site shall be specified for each such permit by the Secretary (1) through the application of guidelines developed by the Administrator, in conjunction with the Secretary, which guidelines shall be based upon criteria comparable to the criteria applicable to the territorial seas, the contiguous zone, and the ocean under section 1343(c) of this title, and (2) in any case where such guidelines under clause (1) alone would prohibit the specification of a site, through the application additionally of the economic impact of the site on navigation and anchorage.

(c) Denial or restriction of use of defined areas as disposal sites

The Administrator is authorized to prohibit the specification (including the withdrawal of specification) of any defined area as a disposal site, and he is authorized to deny or restrict the use of any defined area for specification (including the withdrawal of specification) as a disposal site, whenever he determines, after notice and opportunity for public hearings, that the discharge of such materials into such area will have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas (including spawning and breeding areas), wildlife, or recreational areas. Before making such determination, the Administrator shall consult with the Secretary. The Administrator shall set forth in writing and make public his findings and his reasons for making any determination under this subsection.

(d) "Secretary" defined

The term "Secretary" as used in this section means the Secretary of the Army, acting through the Chief of Engineers.

(e) General permits on State, regional, or nationwide basis

(1) In carrying out his functions relating to the discharge of dredged or fill material under this section, the Secretary may, after notice and opportunity for public hearing, issue general permits on a State, regional, or nationwide basis for any category of activities involving discharges of dredged or fill material if the Secretary determines that the activities in such category are similar in nature, will cause only minimal adverse environmental effects when performed separately, and will have only minimal cumulative adverse effect on the environment. Any general permit issued under this subsection shall (A) be based on the guidelines described in subsection (b)(1) of this section, and (B) set forth the

requirements and standards which shall apply to any activity authorized by such general permit.

(2) No general permit issued under this subsection shall be for a period of more than five years after the date of its issuance and such general permit may be revoked or modified by the Secretary if, after opportunity for public hearing, the Secretary determines that the activities authorized by such general permit have an adverse impact on the environment or such activities are more appropriately authorized by individual permits.

(f) Non-prohibited discharge of dredged or fill material

(1) Except as provided in paragraph (2) of this subsection, the discharge of dredged or fill material—

(A) from normal farming, silviculture, and ranching activities such as plowing, seeding, cultivating, minor drainage, harvesting for the production of food, fiber, and forest products, or upland soil and water conservation practices;

(B) for the purpose of maintenance, including emergency reconstruction of recently damaged parts, of currently serviceable structures such as dikes, dams, levees, groins, riprap, breakwaters, causeways, and bridge abutments or approaches, and transportation structures;

(C) for the purpose of construction or maintenance of farm or stock ponds or irrigation ditches, or the maintenance of drainage ditches;

(D) for the purpose of construction of temporary sedimentation basins on a construction site which does not include placement of fill material into the navigable waters;

(E) for the purpose of construction or maintenance of farm roads or forest roads, or temporary roads for moving mining equipment, where such roads are constructed and maintained, in accordance with best management practices, to assure that flow and circulation patterns and chemical and biological characteristics of the navigable waters are not impaired, that the reach of the navigable waters is not reduced, and that any adverse effect on the aquatic environment will be otherwise minimized;

(F) resulting from any activity with respect to which a State has an approved program under section 1288(b)(4) of this title which meets the requirements of subparagraphs (B) and (C) of such section,

is not prohibited by or otherwise subject to regulation under this section or section 1311(a) or 1342 of this title (except for effluent standards or prohibitions under section 1317 of this title).

(2) Any discharge of dredged or fill material into the navigable waters incidental to any activity having as its purpose bringing an area of the navigable waters into a use to which it was not previously subject, where the flow or circulation of navigable waters may be impaired or the reach of such waters be reduced, shall be required to have a permit under this section.

(g) State administration

(1) The Governor of any State desiring to administer its own individual and general permit program for the discharge of dredged or fill material into the navigable waters (other than those waters which are presently used, or are susceptible to use in their natural condition or by reasonable improvement as a means to transport interstate or foreign commerce shoreward to their ordinary high water mark, including all waters which are subject to the ebb and flow of the tide shoreward to their mean high water mark, or mean higher high water mark on the west coast, including wetlands adjacent thereto) within its jurisdiction may submit to the Administrator a full and complete description of the program it proposes to establish and administer under State law or under an interstate compact. In addition, such State shall submit a statement from the attorney general (or the attorney for those State agencies which have independent legal counsel), or from the chief legal officer in the case of an interstate agency, that the laws of such State, or the interstate compact, as the case may be, provide adequate authority to carry out the described program.

(2) Not later than the tenth day after the date of the receipt of the program and statement submitted by any State under paragraph (1) of this subsection, the Administrator shall provide copies of such program and statement to the Secretary and the Secretary of the Interior, acting through the Director of the United States Fish and Wildlife Service.

(3) Not later than the ninetieth day after the date of the receipt by the Administrator of the program and statement submitted by any State, under paragraph (1) of this subsection, the Secretary and the Secretary of the Interior, acting through the Director of the United States Fish and Wildlife Service, shall submit any comments with respect to such program and statement to the Administrator in writing.

(h) Determination of State's authority to issue permits under State program; approval; notification; transfers to State program

(1) Not later than the one-hundred-twentieth day after the date of the receipt by the Administrator of a program and statement submitted by any State under paragraph (1) of this subsection, the Administrator shall determine, taking into account any comments submitted by the Secretary and the Secretary of the Interior, acting through the Director of the United States Fish and Wildlife Service, pursuant to subsection (g) of this section, whether such State has the following authority with respect to the issuance of permits pursuant to such program:

(A) To issue permits which—

(i) apply, and assure compliance with, any applicable requirements of this section, including, but not limited to, the guidelines established under subsection (b)(1) of this section, and sections 1317 and 1343 of this title;

(ii) are for fixed terms not exceeding five years; and

(iii) can be terminated or modified for cause including, but not limited to, the following:

(I) violation of any condition of the permit;

(II) obtaining a permit by misrepresentation, or failure to disclose fully all relevant facts;

(III) change in any condition that requires either a temporary or permanent reduction or elimination of the permitted discharge.

(B) To issue permits which apply, and assure compliance with, all applicable requirements of section 1318 of this title, or to inspect, monitor, enter, and require reports to at least the same extent as required in section 1318 of this title.

(C) To assure that the public, and any other State the waters of which may be affected, receive notice of each application for a permit and to provide an opportunity for public hearing before a ruling on each such application.

(D) To assure that the Administrator receives notice of each application (including a copy thereof) for a permit.

(E) To assure that any State (other than the permitting State), whose waters may be affected by the issuance of a permit may submit written recommendations to the permitting State (and the Administrator) with respect to any permit application and, if any part of such written recommendations are not accepted by the permitting State, that the permitting State will notify such affected State (and the Administrator) in writing of its failure to so accept such recommendations together with its reasons for so doing.

(F) To assure that no permit will be issued if, in the judgment of the Secretary, after consultation with the Secretary of the department in which the Coast Guard is operating, anchorage and navigation of any of the navigable waters would be substantially impaired thereby.

(G) To abate violations of the permit or the permit program, including civil and criminal penalties and other ways and means of enforcement.

(H) To assure continued coordination with Federal and Federal-State water-related planning and review processes.

(2) If, with respect to a State program submitted under subsection (g)(1) of this section, the Administrator determines that such State—

(A) has the authority set forth in paragraph (1) of this subsection, the Administrator shall approve the program and so notify (i) such State and (ii) the Secretary, who upon subsequent notification from such State that it is administering such program, shall suspend the issuance of permits under subsections (a) and (e) of this section for activities with respect to which a permit may be issued pursuant to such State program; or

(B) does not have the authority set forth in paragraph (1) of this subsection, the Administrator shall so notify such State, which notification shall also describe the revisions or modifications necessary so that such State may resubmit such program for a determination by the Administrator under this subsection.

(3) If the Administrator fails to make a determination with respect to any program submitted by a State under subsection (g)(1) of this section within one-hundred-twenty days after the date of the receipt of such program, such program shall be deemed approved pursuant to paragraph (2)(A) of this subsection and the Administrator shall so notify such State and the Secretary who, upon subsequent notifieation from such State that it is administering such program, shall suspend the issuance of permits under subsection (a) and (e) of this section for activities with respect to which a permit may be issued by such State.

(4) After the Secretary receives notification from the Administrator under paragraph (2) or (3) of this subsection that a State permit program has been approved, the Secretary shall transfer any applications for permits pending before the Secretary for activities with respect to which a permit may be

issued pursuant to such State program to such State for appropriate action.

(5) Upon notification from a State with a permit program approved under this subsection that such State intends to administer and enforce the terms and conditions of a general permit issued by the Secretary under subsection (e) of this section with respect to activities in such State to which such general permit applies, the Secretary shall suspend the administration and enforcement of such general permit with respect to such activities.

(i) Withdrawal of approval

Whenever the Administrator determines after public hearing that a State is not administering a program approved under subsection (h)(2)(A) of this section, in accordance with this section, including, but not limited to, the guidelines established under subsection (b)(1) of this section, the Administrator shall so notify the State, and, if appropriate corrective action is not taken within a reasonable time, not to exceed ninety days after the date of the receipt of such notification, the Administrator shall (1) withdraw approval of such program until the Administrator determines such corrective action has been taken, and (2) notify the Secretary that the Secretary shall resume the program for the issuance of permits under subsections (a) and (e) of this section for activities with respect to which the State was issuing permits and that such authority of the Secretary shall continue in effect until such time as the Administrator makes the determination described in clause (1) of this subsection and such State again has an approved program.

(j) Copies of applications for State permits and proposed general permits to be transmitted to Administrator

Each State which is administering a permit program pursuant to this section shall transmit to the Administrator (1) a copy of each permit application received by such State and provide notice to the Administrator of every action related to the consideration of such permit application, including each permit proposed to be issued by such State, and (2) a copy of each proposed general permit which such State intends to issue. Not later than the tenth day after the date of the receipt of such permit application or such proposed general permit, the Administrator shall provide copies of such permit application or such proposed general permit to the Secretary and the Secretary of the Interior, acting through the Director of the United States Fish and Wildlife Service. If the Administrator intends to provide written comments to such State with respect to such permit application or such proposed general permit, he shall so notify such State not later than the thirtieth day after the date of the receipt of such application or such proposed general permit and provide such written comments to such State, after consideration of any comments made in writing with respect to such application or such proposed general permit by the Secretary and the Secretary of the Interior, acting through the Director of the United States Fish and Wildlife Service, not later than the ninetieth day after the date of such receipt. If such State is so notified by the Administrator, it shall not issue the proposed permit until after the receipt of such comments from the Administrator, or after such ninetieth day, whichever first occurs. Such State shall not issue such proposed permit after such ninetieth day if it has received such written comments in which the Administrator objects (A) to the issuance of such proposed permit and such proposed permit is one that has been submitted to the Administrator pursuant to subsection (h)(1)(E) of this section, or (B) to the issuance of such proposed permit as being outside the requirements of this section, including, but not limited to, the guidelines developed under subsection (b)(1) of this section unless it modifies such proposed permit in accordance with such comments. Whenever the Administrator objects to the issuance of a permit under the preceding sentence such written objection shall contain a statement of the reasons for such objection and the conditions which such permit would include if it were issued by the Administrator. In any case where the Administrator objects to the issuance of a permit, on request of the State, a public hearing shall be held by the Administrator on such objection. If the State does not resubmit such permit revised to meet such objection within 30 days after completion of the hearing or, if no hearing is requested within 90 days after the date of such objection, the Secretary may issue the permit pursuant to subsection (a) or (e) of this section, as the case may be, for such source in accordance with the guidelines and requirements of this chapter.

(k) Waiver

In accordance with guidelines promulgated pursuant to subsection (i)(2) of section 1314 of this title, the Administrator is authorized to waive the requirements of subsection (j) of this section at the time of the approval of a program pursuant to subsection (h)(2)(A) of this section for any category (including any class, type, or size within such category) of discharge within the State submitting such program.

(*l*) Categories of discharges not subject to requirements

The Administrator shall promulgate regulations establishing categories of discharges which he determines shall not be subject to the requirements of subsection (j) of this section in any State with a program approved pursuant to subsection (h)(2)(A) of this section. The Administrator may distinguish among classes, types, and sizes within any category of discharges.

(m) Comments on permit applications or proposed general permits by Secretary of the Interior acting through Director of United States Fish and Wildlife Service

Not later than the ninetieth day after the date on which the Secretary notifies the Secretary of the Interior, acting through the Director of the United States Fish and Wildlife Service that (1) an application for a permit under subsection (a) of this section has been received by the Secretary, or (2) the Secretary proposes to issue a general permit under subsection (e) of this section, the Secretary of the Interior, acting through the Director of the United States Fish and Wildlife Service, shall submit any comments with respect to such application or such proposed general permit in writing to the Secretary.

(n) Enforcement authority not limited

Nothing in this section shall be construed to limit the authority of the Administrator to take action pursuant to section 1319 of this title.

(*o*) Public availability of permits and permit applications

A copy of each permit application and each permit issued under this section shall be available to the public. Such permit application or portion thereof, shall further be available on request for the purpose of reproduction.

(p) Compliance

Compliance with a permit issued pursuant to this section, including any activity carried out pursuant to a general permit issued under this section, shall be deemed compliance, for purposes of sections 1319 and 1365 of this title, with sections 1311, 1317, and 1343 of this title.

(q) Minimization of duplication, needless paperwork, and delays in issuance; agreements

Not later than the one-hundred-eightieth day after December 27, 1977, the Secretary shall enter into agreements with the Administrator, the Secretaries of the Departments of Agriculture, Commerce, Interior, and Transportation, and the heads of other appropriate Federal agencies to minimize, to the maximum extent practicable, duplication, needless paperwork, and delays in the issuance of permits under this section. Such agreements shall be developed to assure that, to the maximum extent practicable, a decision with respect to an application for a permit under subsection (a) of this section will be made not later than the ninetieth day after the date the notice for such application is published under subsection (a) of this section.

(r) Federal projects specifically authorized by Congress

The discharge of dredged or fill material as part of the construction of a Federal project specifically authorized by Congress, whether prior to or on or after December 27, 1977, is not prohibited by or otherwise subject to regulation under this section, or a State program approved under this section, or section 1311(a) or 1342 of this title (except for effluent standards or prohibitions under section 1317 of this title), if information on the effects of such discharge, including consideration of the guidelines developed under subsection (b)(1) of this section, is included in an environmental impact statement for such project pursuant to the National Environmental Policy Act of 1969 [42 U.S.C.A. § 4321 et seq.] and such environmental impact statement has been submitted to Congress before the actual discharge of dredged or fill material in connection with the construction of such project and prior to either authorization of such project or an appropriation of funds for such construction.

(s) Violation of permits

(1) Whenever on the basis of any information available to him the Secretary finds that any person is in violation of any condition or limitation set forth in a permit issued by the Secretary under this section, the Secretary shall issue an order requiring such person to comply with such condition or limitation, or the Secretary shall bring a civil action in accordance with paragraph (3) of this subsection.

(2) A copy of any order issued under this subsection shall be sent immediately by the Secretary to the State in which the violation occurs and other affected States. Any order issued under this subsection shall be by personal service and shall state with reasonable specificity the nature of the violation, specify a time for compliance, not to exceed thirty days, which the Secretary determines is reasonable, taking into account the seriousness of the violation and any good faith efforts to comply with applicable requirements. In any case in which an order under this subsection is issued to a corporation, a copy of such order shall be served on any appropriate corporate officers.

(3) The Secretary is authorized to commence a civil action for appropriate relief, including a permanent or temporary injunction for any violation for which he is authorized to issue a compliance order under paragraph (1) of this subsection. Any action under this paragraph may be brought in the district court of the United States for the district in which the defendant is located or resides or is doing business, and such court shall have jurisdiction to restrain such violation and to require compliance. Notice of the commencement of such acton[1] shall be given immediately to the appropriate State.

(4) Any person who violates any condition or limitation in a permit issued by the Secretary under this section, and any person who violates any order issued by the Secretary under paragraph (1) of this subsection, shall be subject to a civil penalty not to exceed $25,000 per day for each violation. In determining the amount of a civil penalty the court shall consider the seriousness of the violation or violations, the economic benefit (if any) resulting from the violation, any history of such violations, any good-faith efforts to comply with the applicable requirements, the economic impact of the penalty on the violator, and such other matters as justice may require.

(t) Navigable waters within State jurisdiction

Nothing in this section shall preclude or deny the right of any State or interstate agency to control the discharge of dredged or fill material in any portion of the navigable waters within the jurisdiction of such State, including any activity of any Federal agency, and each such agency shall comply with such State or interstate requirements both substantive and procedural to control the discharge of dredged or fill material to the same extent that any person is subject to such requirements. This section shall not be construed as affecting or impairing the authority of the Secretary to maintain navigation.

(June 30, 1948, c. 758, Title IV, § 404, as added Oct. 18, 1972, Pub.L. 92–500, § 2, 86 Stat. 884, and amended Dec. 27, 1977, Pub.L. 95–217, § 67(a), (b), 91 Stat. 1600; Feb. 4, 1987, Pub.L. 100–4, Title III, § 313(d), 101 Stat. 45.)

[1] So in original. Probably should read "action"

Cross References

Areawide waste treatment management, compliance with guidelines established under this section, see section 1288 of this title.
Definition of "federally permitted release", see section 9601 of Title 42, The Public Health and Welfare.
Enforcement of permit provisions, see section 1319 of this title
Grant to State for reasonable cost of administering an approved program under this section, see section 1285 of this title.
Illegality of pollutant discharges except as in compliance with this section, see section 1311 of this title.
Permits for discharge of pollutants, see section 1342 of this title.
Records and reports, see section 1318 of this title.
State management of permit program, see section 1254 of this title.

Code of Federal Regulations

Enforcement, supervision and inspection, see 33 CFR 326.1 et seq.
General regulatory policies, see 33 CFR 320.1 et seq.
Nationwide permits, see 33 CFR 330.1 et seq.
Permits for discharges of dredged or fill material into waters of the United States, see 33 CFR 323.1 et seq.
Procedures applicable to dredged and fill material, see 40 CFR 230.1 et seq., 231.1 et seq.
Processing of Department of the Army permits, see 33 CFR 325.1 et seq.
Public hearings, see 33 CFR 327.1 et seq.
State program transfer regulations, see 40 CFR 233.1 et seq.

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Navigating through the Wetlands Act. Marsha Wolf and Lewis Goldshore, 120 N.J.L.J. 645 (1987).

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Wetlands and agricultural: Environmental regulation and the limits of private property. Gerald Torres, 34 U.Kan.L.Rev. 539 (1986).

§ 1345. Disposal or use of sewage sludge [FWPCA § 405]

(a) Permit

Notwithstanding any other provision of this chapter or of any other law, in any case where the disposal of sewage sludge resulting from the operation of a treatment works as defined in section 1292 of this title (including the removal of in-place sewage sludge from one location and its deposit at another location) would result in any pollutant from such sewage sludge entering the navigable waters, such disposal is prohibited except in accordance with a permit issued by the Administrator under section 1342 of this title.

(b) Issuance of permit; regulations

The Administrator shall issue regulations governing the issuance of permits for the disposal of sewage sludge subject to subsection (a) of this section and section 1342 of this title. Such regulations shall require the application to such disposal of each criterion, factor, procedure, and requirement applicable to a permit issued under section 1342 of this title.

M

ATTACHMENT M

Report of Workshop on Geosynthetic Clay Liners

EPA Report No. 600/R-93/171
August, 1993

REPORT OF WORKSHOP ON GEOSYNTHETIC CLAY LINERS

by

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DISCLAIMER

The information in the document has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement number CR-815546-01-0. It has been subject to the Agency's peer and administrative review and has been approved for publication as a U.S. EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The United States Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the U.S. EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the U.S. EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

This report documents the available information concerning manufactured materials that might be utilized in liner and cover systems for landfills, impoundments, site remediation projects, and secondary containment structures. The information compiled in this report was obtained from literature, from information supplied by manufacturers, and from discussions at a 2-day workshop held on June 7 and 8, 1992 in Cincinnati. This report will be useful to scientists, engineers, and regulatory staff who are considering use of these types of materials.

E. Timothy Oppelt
Director
Risk Reduction Engineering Laboratory

ABSTRACT

A workshop was held at the Risk Reduction Engineering Laboratory in Cincinnati, Ohio, on June 9-10, 1992 to discuss geosynthetic clay liners (GCLs). The purpose of the workshop was to present and discuss the most recent information available on the use of GCLs. This information will be of use to EPA program and regional officials, state regulatory officials, permit writers, and designers of waste disposal facilities.

Information about GCLs was first presented by manufacturers. Four commercial GCL producers manufacture distinctly different products from a variety of materials. One common feature, however, of all GCLs is a thin layer of bentonite clay. Two of the four manufacturers mix an adhesive with the clay while the other two use no adhesive but instead needle punch two geotextiles together with the bentonite sandwiched between the geotextiles. The manufacturers focused their discussions on technical developments, recent research results, quality control, and comparison of GCLs to compacted clay liners (CCLs).

Testing procedures were discussed next. A variety of conformance and performance tests can be performed, but standard test methods are lacking. In addition, no consensus has been reached on the types of tests that should be required or the appropriate frequency of testing. Interpretation of test data is not always free of ambiguity due in part to a lack of standard testing methods.

The performance of geomembrane/GCL composite liners was discussed at length. The hydraulic contact between the clay and geomembrane was the focus. If a geotextile separates the clay from the geomembrane (as is the case with most GCLs), and there is a defect in the geomembrane, some lateral spreading of liquid will take place in the geotextile. Although some equations are available to estimate the effect of the geotextile, more research is needed to quantify geomembrane/GCL composite behavior more fully.

Owner/operators of waste disposal facilities described their experiences with GCLs. Experience varies widely; some companies have used GCLs extensively while others have used them rarely. Experience seems to have been good to date but concern was expressed about the need for further refinement of construction quality assurance procedures and resolution of several technical issues.

Recent research findings at the University of Texas and Drexel University's Geosynthetic Research Institute were described. The response of GCLs to differential settlement, such as would be experienced in cover systems placed over compressible waste, has been studied. Most of the GCLs tested maintained low hydraulic conductivity even when subjected to large

differential settlement. The hydration, swelling, and strength of the bentonite in GCLs varies depending upon the fluid (water or leachate) being used. The need to test with the site-specific liquid was apparent.

The issue of equivalency of a GCL to a CCL was discussed. A number of criteria might be applied, but only a few seem truly rational. Steady-state water flux and solute flux are obvious and clear criteria that should usually be part of an equivalency analysis. Other criteria can be applied but most are much less meaningful in terms of addressing regulatory compliance.

Finally, regulatory acceptance of GCLs was discussed. Although numerous site-specific approvals of GCLs have been given by regulatory agencies, no blanket approvals or disapprovals were identified. The EPA's RCRA Subtitle D regulations prescribe a geomembrane/CCL for unapproved states but in approved states allow for equivalent designs to be accepted by state regulatory agencies.

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CHAPTER 1
INTRODUCTION

On June 7-8, 1990, the United States Environmental Protection Agency (EPA) held a workshop to discuss the use of alternative barriers in the design of cover and/or liner systems. The focus of the workshop was on the potential use of geosynthetic clay liners (GCLs) as an alternative barrier. Since that introductory conference, a significant amount of information has been gathered through research and field applications. For this reason, another workshop on the use of GCLs was held on July 9-10, 1992 at the EPA's Risk Reduction Engineering Laboratory in Cincinnati, Ohio.

The purpose of the second workshop was to present and discuss the most recent research available on the use of GCLs. As the use of GCLs has expanded dramatically over the last few years, it is important that EPA program and regional officials, state regulatory officials, permit writers, and designers keep up to date on the latest information available on the use of these products.

The information discussed at the workshop held on July 9-10, 1992 was as follows:

1) Manufacturer's Information. A compilation of information available on each of the major GCL products was presented by the manufacturing sector. (Presented by representatives for Bentofix®, Bentomat®, Claymax®, and Gundseal®)

2) Testing Procedures. The use of different testing methods and procedures to determine the physical properties of GCLs was discussed. (Presented by Richard Brown, John Boschuk, and Robert Bachus)

3) Intimate Contact. The mechanisms of intimate hydraulic contact between geomembranes and GCLs were discussed. (Presented by John Bove)

4) Owner/Operator Experiences. An overview of information on the field application of GCLs was presented by owner/operators of landfills. (Presented by representatives of Waste Management of North America, Browning-Ferris Industries, Chambers Development, and Laidlaw)

5) Recent Research. The most recent research carried out by Drexel University and the University of Texas at Austin was discussed. (Presented by Robert Koerner, David Daniel, Mark LaGatta, B. Tom Boardman, and Hsin-Yu Shan)

6) Equivalency. The equivalency of a GCL to a compacted clay liner was discussed. (Presented by David Daniel)

7) Technical and Regulatory Concerns. An open discussion was held on the technical concerns of the use of GCLs. (Presented by David Daniel and Robert Landreth)

The purpose of this report is to summarize the information presented at the GCL workshop held on July 9-10, 1992. This report does not represent the full extent of the information available on geosynthetic clay liners. Readers are directed to the summary of the GCL workshop held on June 7-8, 1990 for additional information (EPA 600/2-91/002). Rather, this report augments the proceedings from the first workshop.

Information on Bentofix®, Bentomat®, Claymax®, and Gundseal® is presented in Chapter 2. Testing Procedures are discussed in Chapter 3. Intimate contact is discussed in Chapter 4. Owner/operator experiences are listed in Chapter 5. Recent university research is discussed in Chapter 6. Equivalency concerns are addressed in Chapter 7. Technical concerns are voiced in Chapter 8. A list of references and published papers and reports on GCLs is included in Chapter 9. A list of attendees is presented in the Appendix.

CHAPTER 2
MANUFACTURER'S INFORMATION

At the present time, there are four major products available on the geosynthetic clay liner (GCL) market. These four products are Bentofix®, Bentomat®, Claymax®, and Gundseal®. Each product has its own unique properties.

The manufacturer of each product was asked to speak about technical discoveries that had been made since the previous meeting. The information presented in this chapter was provided by the manufacturer's speaker.

2.1 Bentofix® (By Georg Heerten, Naue-Fasertechniik GmbH & Co.)

Bentofix®, which was developed in 1987, is produced by the German company Naue-Fasertechnik and was introduced to the North American market in 1991 through the joint venture company Albarrie Naue Ltd. establishing an additional production facility in Canada. Bentofix® is designed as a layer of loose granular or powdered bentonite held between two non-woven geotextiles by a series of thin needle punched fibers (Fig. 2.1). Needle punching keeps the bentonite in place before and after hydration, and the needle punching is said to increase the internal shear strength of the GCL.

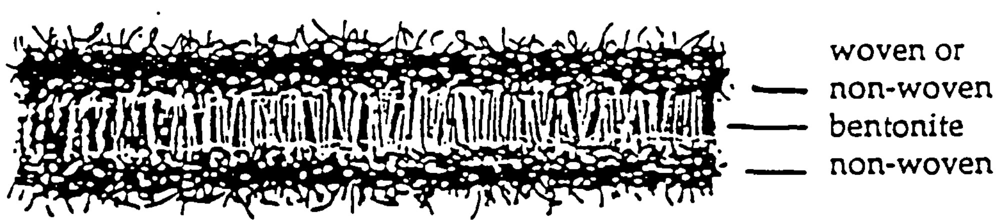


Figure 2.1 Needle Punched System of Bentofix®

2.1.1 Benefits of Needle Punching

Naue-Fasertechnik's purpose for needle punching a layer of loose bentonite between two non-woven geotextiles was to create a sturdy GCL that could withstand the rigors of installation. The needle punching helps to keep the bentonite in place even after hydration. For this reason, the manufacturer states that Bentofix® can be installed during rainy conditions or underwater.

A GCL bound by needle punched fibers is said to allow for the installation on steep slopes (up to 1.5 : 1), by preventing sliding between the components of the GCL, while also increasing the internal shear strength of the GCL as a whole.

2.1.2 Non-Woven Geotextiles

The manufacturer stresses the importance of the robustness of the geotextiles incorporated into the GCL. To allow the GCL to be needle punched together, at least one layer must be a non-woven geotextile. Both geotextile components must pass filter criteria in order to prevent the migration of bentonite out of the GCL. The upper layer non-woven geotextile must also be puncture resistant. For this reason, the top cover layer geotextile must have a minimum mass/area of .25 kg/m^2 and pass a German puncture test. However, a .12 kg/m^2 woven geotextile may also be used. The manufacturer has not had the opportunity to measure the hydraulic conductivity of a deformed section of Bentofix® after passing the puncture test. This is still being investigated.

To avoid lateral wicking in the upper non-woven geotextile, when a geomembrane is placed on the GCL to form a composite liner, the pore space of the upper geotextile is filled with powdered bentonite. The bentonite powder is said to be fixed by a patented system which fills the non-woven pores. This system is also said to improve the intimate contact between a GCL and an overlying geomembrane by reducing the amount of loose powdered bentonite dust where the two come in contact.

2.1.3 Bentonite

Bentofix® can be manufactured with powdered bentonite with 87% of the mixture having a grain size less than 0.002 mm, or as a granular bentonite in the size range of 0.5 to 4 mm. Due to its finer grain size, the powdered bentonite will hydrate much quicker than a granular bentonite. Granular bentonite used to be necessary when Bentofix® was used in conjunction with a geomembrane because the powdered bentonite would create welding difficulties for the overlying geomembrane. The manufacturer is said to have solved the problem of loose powdered bentonite influencing the welding process of geomembranes by fixing the bentonite to the geotextile, which addresses the intimate contact issue at the same time.

2.1.4 Laboratory Measurement of Hydraulic Conductivity

The manufacturer recommends that the procedures outlined in Table 2.1 be observed for the proper measurement of the hydraulic conductivity of a GCL. Differences in GCL sample preparations can lead to large variations in the measured value of hydraulic conductivity.

Table 2.1 Measurement of Hydraulic Conductivity for GCLs

Procedure	Important Steps	Possible Problems
Sampling	1) Exact Cutting (Stamping) 2) No bentonite loss on edges 3) Edge wetting	1) Flow around edge 2) Air encapsulation
Installation	1) Soaking filter plate 2) Applying flexible membrane carefully	1) Air slows down swelling 2) Loss of bentonite
Test Procedure	1) Proper saturation time (50 hours minimum) 2) Cell pressure (30 kPa minimum) 3) Hydraulic gradient	1) Inadequate water Adsorption
Calculation	1) Measurement of hydrated sample thickness	1) Incorrect calculation

2.1.5 Overlaps

In the past, the overlapping seams had to be filled with loose powdered bentonite or a hydrated bentonite paste. This will not be necessary in the future due to the upper layer non-woven geotextile being filled with bentonite powder. This system is said to provide a more intimate contact along the GCL overlap.

A prefabricated velcro system has also been designed to prevent displacement along the overlaps due to movements during or after the covering process.

2.1.6 Installation Procedures

Bentofix® will have the printing on the upper geotextile as well as an overlap mark. Naue-Fasertechnik has also developed an installation manual which is delivered to each customer in advance. According to the manufacturer a correct overlap can be achieved, and wicking in the non-woven plane can be prevented, if the installation instructions are followed correctly.

2.1.7 Case Histories

1) Geomembrane Protection. In an effort to prevent the puncture of an underlying geomembrane by the placement of a granular drainage material with large particles (16 to 32 mm), Bentofix® has also been used as a cushion layer over the geomembrane. The GCL not only protects the geomembrane, but provides an additional seal, as well.

2) Vertical Gas Barrier. In an effort to prevent the seepage of landfill gas and leachate, Bentofix® was placed in a vertical cutoff trench surrounding a landfill. Apparently the soil moisture was sufficient to hydrate the bentonite resulting in a sufficient gas barrier.

3) Sealing a Canal. In an effort to seal a canal and cofferdam, Bentofix® was successfully installed in an underwater operation. The manufacturer states that the needle punching allowed the GCL to withstand the immediate swelling and the following installation procedure all while underwater.

4) Groundwater Protection System. In an effort to catch the run off from de-icing impurities at the Munich II Airport, over 700,000 m^2 of Bentofix® was installed. The project has proved successful to date.

2.1.8 Supplemental Information

After the conference, Mr. Klaus Stief submitted additional information. Because Bentofix® was developed in Germany, the manufacturer has followed German and European regulations for landfills particularly closely. The following is a summary of Mr. Stief's perspective on European policy on landfill linings.

The Commission of the European Communities published in May 1992 a proposed set of regulations for landfills. The proposal calls for liner systems, leachate collection systems, and engineered cover systems. The lining system may consist of natural, low-permeability soil, or lacking such soil, engineered liners must be used. There are no specific requirements for engineered liners; the use of GCLs is in no way restricted.

Current German regulations are more stringent. The general liner requirement in Germany is for a single composite liner consisting of a geomembrane placed on 0.75 to 1.5 m of low-permeability compacted soil. Similar requirements exist for the cap, although the soil liner component has a smaller minimum thickness (0.5 m).

2.2 Bentomat® (By Robert Trauger, CETCO)

Bentomat® is manufactured by the Colloid Environmental Technology Company (CETCO), which is a subsidiary of the American Colloid Company. The representative from CETCO briefly discussed the results of recent laboratory testing on Bentomat®, but mainly concentrated on the highlights and advantages of the use of GCLs in the waste management industry.

2.2.1 A Brief History of Waste Management Practices

For several decades, the only practical means of waste containment was the construction of a hydraulic barrier consisting of a layer of compacted clay. Unfortunately, the possibility of complete containment to the extent that a 1977 US EPA report on landfill liners suggested a "different approach," whereby "pollution would be lessened by designing landfill liners for higher permeability and by selectively attenuating the most toxic pollutants from the leachate..."

This novel idea of emphasizing attenuation over containment was never implemented due to the emergence of geomembrane technology in the 1980's. The near zero hydraulic conductivity of geomembranes made the concept of true containment appear attainable. After a decade of technical progress, geomembranes are now accepted by most designers as a required component of landfill liners. The composite liner system, in which a geomembrane is placed over a clay layer, was another fundamental advance as designers abandoned attenuation considerations in favor of containment. Leakage rates through well constructed composite liners are far lower than through geomembranes or compacted clay liners (CCLs) alone. The only development missing in the shift to containment oriented landfills was a series of federal regulations for landfill liner design.

The US EPA has just recently released the long awaited federal rules on landfill design for municipal solid waste landfills. Unfortunately, GCLs were not well established when the rules were drafted, so there is not yet a federal policy on the role of GCLs in landfills.

2.2.2 The Potential Role of Geosynthetic Clay Liners in Landfills

Some have suggested that GCLs are not merely a convenient substitute for clay liners but instead represent the next step towards the goal of total waste containment. GCLs have an extremely low, uniform hydraulic conductivity and are not subject to the many materials and construction related problems that commonly plague CCLs. Potential landfill liner cross sections reflecting this design goal are shown in Fig. 2.2 and 2.3.

2.2.3 Future Directions for Research and Discussion

The GCL is an important innovation in lining technology, but its performance can be undermined by poor design and installation. As with any emerging technology, additional field and laboratory research is necessary to strengthen the feedback loop for better designs, installations, and products. Since the last GCL workshop held two years ago, a vast amount of useful data has been obtained for Bentomat®. Some of the data are shown in Tables 2.2 and 2.3. More work needs to be done, however, to realize the full performance capabilities of GCLs. Some of the most important remaining issues which the technical, regulatory, and manufacturing communities must address are discussed in succeeding subsections.

2.2.3.1 Intimate Contact

Concern has been expressed that the upper geotextile of a GCL could prevent intimate contact between the geomembrane and the bentonite clay and facilitate lateral movement along the interface. Overall leakage could consequently increase because liquid is distributed over a broader area. However, lateral movement may only occur at low confining stress, and the quantification of the phenomenon is incomplete. When considering this issue one must assess the theoretical advantages of geomembrane/CCL intimate contact with respect to the many performance and installation advantages of a geomembrane/GCL liner system.

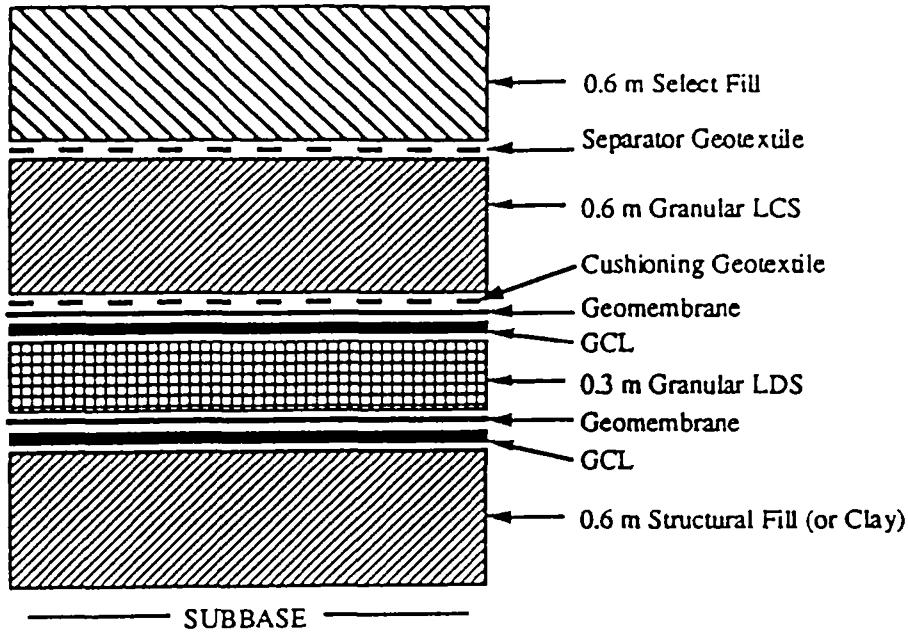


Figure 2.2 Potential Double Composite Liner System

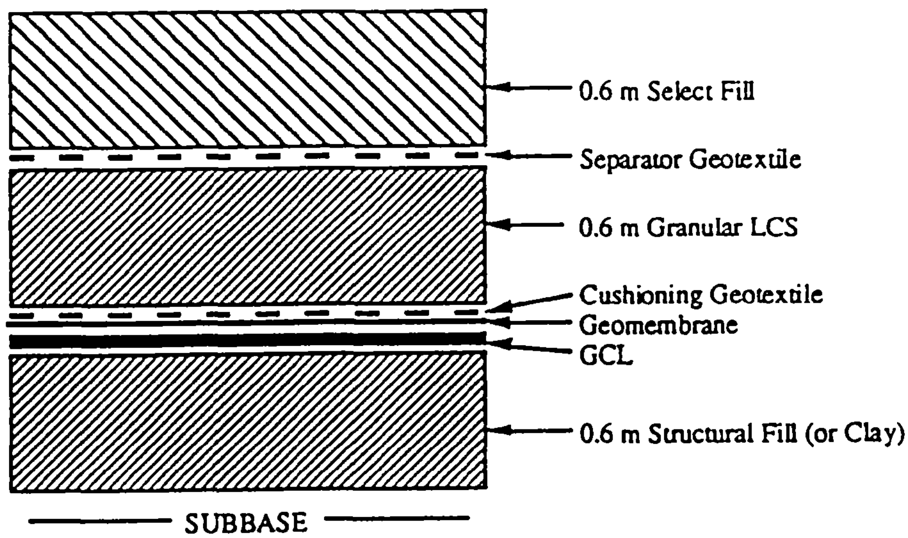


Figure 2.3 Potential Single Composite Liner System

Table 2.2 Summary of Triaxial Permeability Test Data on Bentomat®

TEST LAB*	DATE	PRODUCT	MAX. EFFECTIVE CONF STRESS(KPA)	HEAD(M)	GRADIENT	TOTAL TIME(HRS)	PERMEABILITY (CM/SEC)
J & L	07-05-90	SS	56.5	.3	30	26	2.1×10^{-9}
			73	3.7	380	6	7.5×10^{-10}
			90.9	7.3	760	13	5.8×10^{-10}
			107	11	1100	4	6.6×10^{-10}
		CS	56.5	.3	35	62	5.6×10^{-9}
			73	3.7	450	19	1.1×10^{-9}
			90.9	7.3	900	46	9.8×10^{-10}
			107	11	1315	2	2.6×10^{-9}
J & L	09-21-90	SS	56.5	.3	30	36	7.3×10^{-10}**
			73	3.7	400	28	7.3×10^{-10}
			90.9	7.3	800	7	1.4×10^{-9}
J & L	12-17-90	CS	N/A	9.1	2250	25	1.4×10^{-9}
Geosyntec	12-20-90	CS	N/A	4.6	N/A	72	2.0×10^{-9}
J & L	01-08-91	CS	129	11	1800	25	1.6×10^{-9}
ACC	05-02-91	CS	207	2.1	200	216	3.6×10^{-9}†
J & L	07-05-91	SS	255	2.7	530	4	2.1×10^{-10}
D & M	07-15-91	PL	393	16	217	190	6.8×10^{-10}††
Geosyntec	07-31-91	PL	34	2	160	720	3.0×10^{-9}**
Nelson	09-04-91	SS	34	3.7	360	1440	3.5×10^{-9}‡
ACC	06-18-91	SS	34	7.0	840	3600	3.0×10^{-9}‡

Notes:

* J & L = J & L Testing Company, Inc., Canonsburg, PA
Geosyntec = Geosyntec Consultants, Norcross, GA
D & M = Dames & Moore, Salt Lake City, UT
ACC = American Colloid Company, Arlington Heights, IL
Nelson = Robert L. Nelson & Associates, Schaumburg, IL

** Permeant was landfill leachate

† Permeant was salt water

†† Permeant was 600 ppm NaCN

‡ Permeant was liquid fertilizer

Table 2.3 Summary of Direct Shear Test Data on Bentomat®

LAB*	DATE	INTERFACE**	NORMAL STRESSES(KPA)	MOISTURE CONDITION†	SHEAR RATE	FRICTION ANGLE(DEG)
J & L	05-30-90	NW/Sand	7 / 14 / 21	Hydrated	0.5 mm/min	35
		NW/Sand	"	Dry	"	28
		NW/Clay	"	Hydrated	"	41
		NW/Clay	"	Dry	"	31
STS	09-11-90	NW/1 mm Text. HDPE	240 / 360 / 480	Dry	5 mm/min	18
		NW/2 mm Text. HDPE	"	Dry	"	37
		W/2 mm Text. HDPE	"	Dry	"	24
J & L	11-06-90	NW/Sandy Soil	14 /24 / 34	Dry	0.5 mm/min	23
GRI	04-18-91	Internal	3 / 7 / 14 / 34 / 69 / 140 / 240	Dry	0.89 mm/min	42
			0.83 / 3 / 7 / 34 /.69	Hydrated	"	37
			0.83 / 3 / 7 / 34 / 69	Hydrated††	"	39
STS	05-28-91	NW/1 mm Text. HDPE	240 / 360 / 480	Hydrated	5 mm/min	20
		W/2 mm Text. HDPE	"	Hydrated	"	19
UTA	08-12-91	Internal	41 / 62 / 96 / 130	Hydrated	0.5 mm/min	26
J & L	09-09-91	W/Soil Cover	4 / 8.6 / 13.0	Hydrated	0.89 mm/min	22.5
		W/Geonet	"	Hydrated	"	17
		NW/2B Stone	"	Hydrated	"	53
TRI	05-06-92	W/1.5 mm Text. VLDPE	14 / 55 / 96	Hydrated	1 mm/min	22
		W/1.5 mmSm. VLDPE	14 / 55 / 96	Hydrated	"	14

Notes:

* J & L = J & L Testing Company, Inc., Canonsburg, PA (used a 75 mm Wykeham Farrance direct shear device)
STS = STS Consultants Ltd., Northbrook, IL (used a custom-made 300 mm shear box)
GRI = Geosynthetic Research Institute, Drexel University, Philadelphia, PA (used a Wykeham Farrance device)
UTA = University of Texas at Austin, Civil Engineering Laboratory (used a 60 mm direct shear box)
TRI = TRI Environmental Inc., Austin, TX (used a 300 mm direct shear box)

** NW = Non-woven geotextile of Bentomat
W = Woven geotextile of Bentomat

† "Dry" = sample tested in the as-received moisture state.
"Hydrated" = sample was hydrated prior to testing, although the actual hydration methods vary.
Samples were hydrated with distilled water unless otherwise noted.

†† Hydrated in leachate.

2.2.3.2 Puncture Concerns

There has been a great deal of concern over the potential for a GCL to be more susceptible to puncture damage. This concern is often cited by regulators as reason not to allow the use of GCLs. Liner systems in today's modern landfills are more controlled than ever before and great care is usually taken to prevent the possibility of puncture from above and below the liner. With GCLs, these practices must be even more strongly emphasized, especially in the post construction stage. The construction of a sound foundation and the placement of cover material over the liner system must be rigidly controlled. If deemed necessary, additional cover layers should be placed on the liner system to further preclude the possibility of puncture. In other words, puncture prevention should be emphasized during the construction process.

2.2.3.3 Construction Quality Assurance

GCLs can be easily and rapidly installed in comparison to geomembranes and CCLs, yet a stringent construction quality assurance (CQA) plan must be implemented. The best design and the most explicit project specifications mean nothing if the installation is faulty. Comprehensive and realistic CQA programs should be developed by GCL manufacturers and engineers. These programs should detail installation criteria as well as materials conformance criteria. The certification program under development by the National Institute for Certification of Engineering Technologists (NICET) will be extremely valuable for providing trained GCL installers, but more input is needed from installers regarding methods of installation which minimize the potential for GCL damage.

2.2.3.4 Research Directives

The long term compatibility of a hydrated bentonite layer with the variety of organic and inorganic chemicals it may encounter needs to be investigated. Due to time constraints, these tests are inconvenient to run in a controlled, repeatable fashion. New test methods may need to be developed to provide meaningful data in a reasonable period of time. Results of this research, however, could lead to improvements in contaminant resistant clays.

Direct shear testing is another area requiring additional research. There is a seemingly limitless variety of soil and geosynthetic materials which may be used in conjunction with a GCL. Each interface has its own unique frictional characteristics, and the designer needs a reliable evaluation of the applicable friction angles to perform a slope stability analysis. A relatively sizable database is already available, but more information is needed.

A long term, full scale field study of GCLs would also be informative. The effects of freeze/thaw, desiccation, and settlement could all be observed on a large scale.

2.2.3.5 Test Standards

The engineering and performance characteristics of GCLs are typically evaluated using ASTM methods for soils and geosynthetics. For the geosynthetic components of GCLs, these test methods are already acceptable or only require minor modifications. Unfortunately there are no currently recognized standards for preparing GCL test samples, for determining the quality of the bentonite component, or for testing the entire product as a whole. At this time, all of the major GCL manufacturers are working with ASTM to develop the necessary standards.

2.2.4 Conclusion

The rapid increase in the use of GCLs over the past two years has made intrepid pioneers out of manufacturers, regulators, and installers. Still, a watchful eye must be maintained over the types of applications and designs in which GCLs are specified. A poorly conceived design, or a careless installation, can only serve to undermine the credibility that the industry has striven to attain. In the coming years, everyone is urged to share his information and experiences so that the state of the art can be advanced to the benefit of everyone involved with geosynthetic clay liners.

2.3 Claymax® (By Walter Grube, Jr., James Clem Corporation)

Claymax® is manufactured by the Clem Environmental Corporation, which is a branch of the James Clem Corporation. Claymax® was the first GCL product to be designed and introduced onto the market.

Claymax® produces two products. The Claymax® 200R is the original product which consists of a layer of granular sodium bentonite sandwiched between an upper primary woven geotextile and a lower secondary open weave geotextile. Other materials can be specified for the lower backing depending on site specific needs. Claymax® 200R is normally installed with the primary geotextile on top, but this may be reversed depending on site-specific requirements. Claymax® 500SP has recently been introduced as a material with high shear and tensile strength properties. The increase in strength has been achieved by stitch-bonding the primary and secondary backing materials together and by increasing the tensile strength of the backing materials themselves.

2.3.1 Benefits of Using a GCL

The manufacturer discussed four reasons to use a GCL. These reasons are discussed in more detail below.

1) Stop Seepage. In an effort to reduce seepage, a GCL can be used to fulfill the low permeability requirement and as a design alternative to a compacted clay liner. In order to attain this low permeability, the in place overlapping GCLs must have seam integrity and the ability to successfully self heal.

2) Quality Control. The high degree of quality assurance/quality control (QA/QC) in the materials and manufacture of the GCL make it an attractive alternative to compacted clay liners. The manufacturer also states that they will provide field and technical support to ensure QA/QC. Also, the GCL customer may perform independent conformance testing.

3) Standards of the Industry. Both the bentonite and geosynthetic industries have a history of reliable standards and guidelines. The GCL manufacturers are working with various standard-writing organizations in an effort to ensure a high level of QA/QC.

4) Lack of Clay Reserves. Many regions do not have significant clay reserves. As an example, the landfill cover design recommended by the US EPA, shown in Fig. 2.4, is considered. As an alternative to a compacted clay liner, the manufacturer recommends the landfill cover design shown in Fig. 2.5, which has been modified to incorporate a GCL.

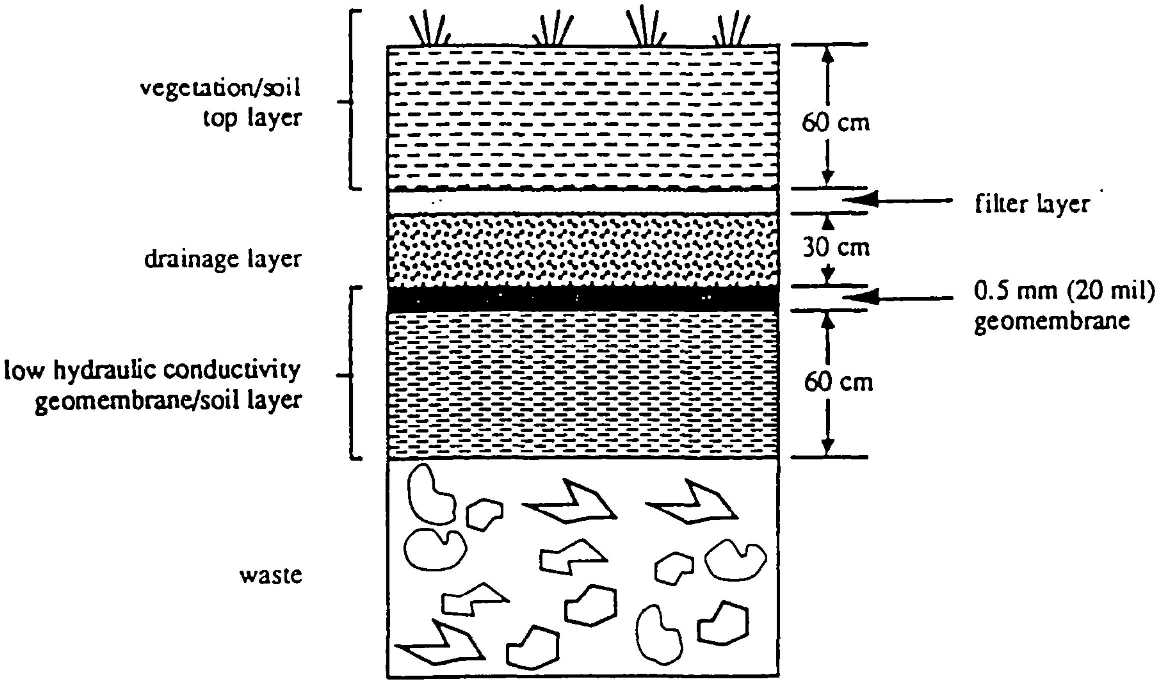


Figure 2.4 US EPA Recommended Landfill Cover Design (EPA/625/4-91/025)

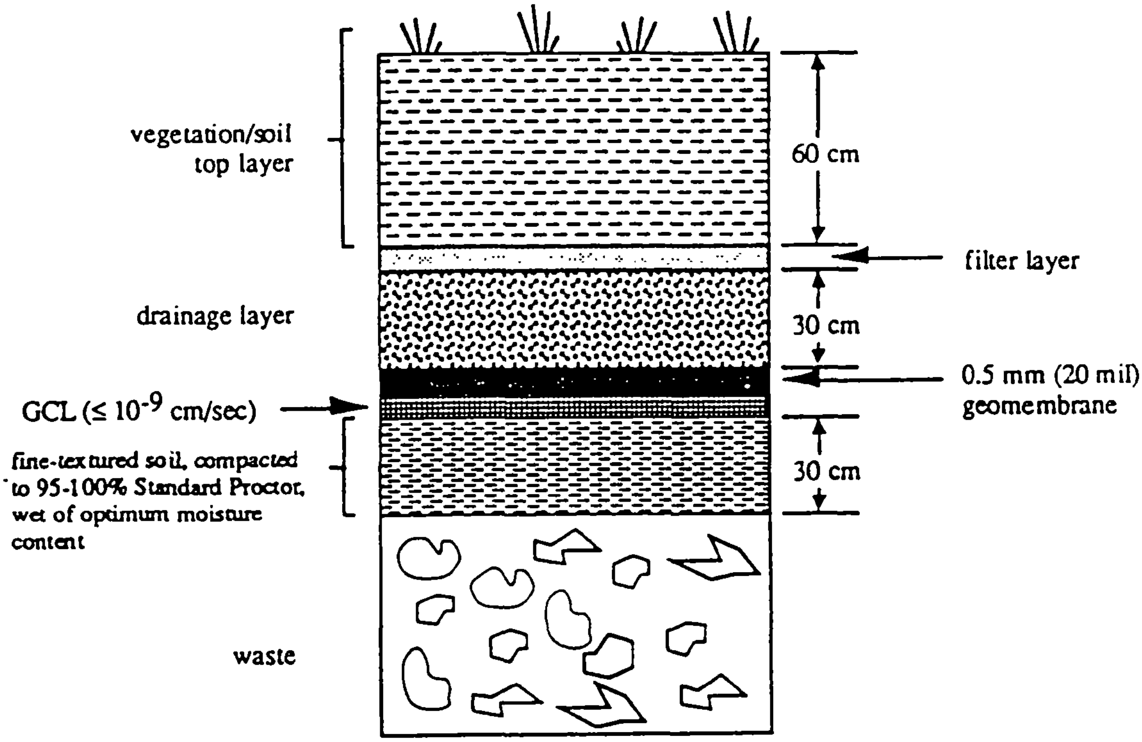


Figure 2.5 Potential Landfill Cover Design Incorporating a GCL

2.3.2 Quality Management

While data can be collected from small scale samples in the laboratory, how will the product perform as a whole in the field? This is where construction quality assurance for the GCL product becomes important.

The manufacturer states that the Clem quality management program is independent of manufacturing, and follows all applicable and relevant standard ASTM/API test methods. With each product sent to a client, a certification of compliance is included detailing the properties of that particular shipment.

A summary of the quality management program undertaken at the James Clem Corporation is shown in Fig. 2.6, and in Tables 2.4, 2.5, 2.6, and 2.7. Two partial lists of available testing data are shown in Tables 2.8 and 2.9.

2.3.3 Available Information on Claymax®

The manufacturer states that the following information is available on the Claymax® product:

1) Case histories
2) Laboratory data
    a) Compatibility studies
    b) Shear resistance
    c) Overlapped seam/damaged liner permeability tests
    d) Freeze/thaw tests
3) Customer assistance
    a) Engineers guide to GCL specifications
    b) Engineers guide to GCL CQA programs
4) Design models and comparison studies
    a) Slope stability analyses
    b) Comparative flows (clay vs. Claymax®)
    c) Composite liner system comparative flow rates
    d) Bentonite quantity calculations at seams

2.4 Gundseal® (By James Anderson, Gundle Lining Systems, Inc.)

Gundseal® is manufactured by Gundle Lining Systems, Inc. The Gundseal® GCL consists of a layer of bentonite (5 kg/m^2) adhered to a geomembrane. Depending on the types of fluids that may come in contact with

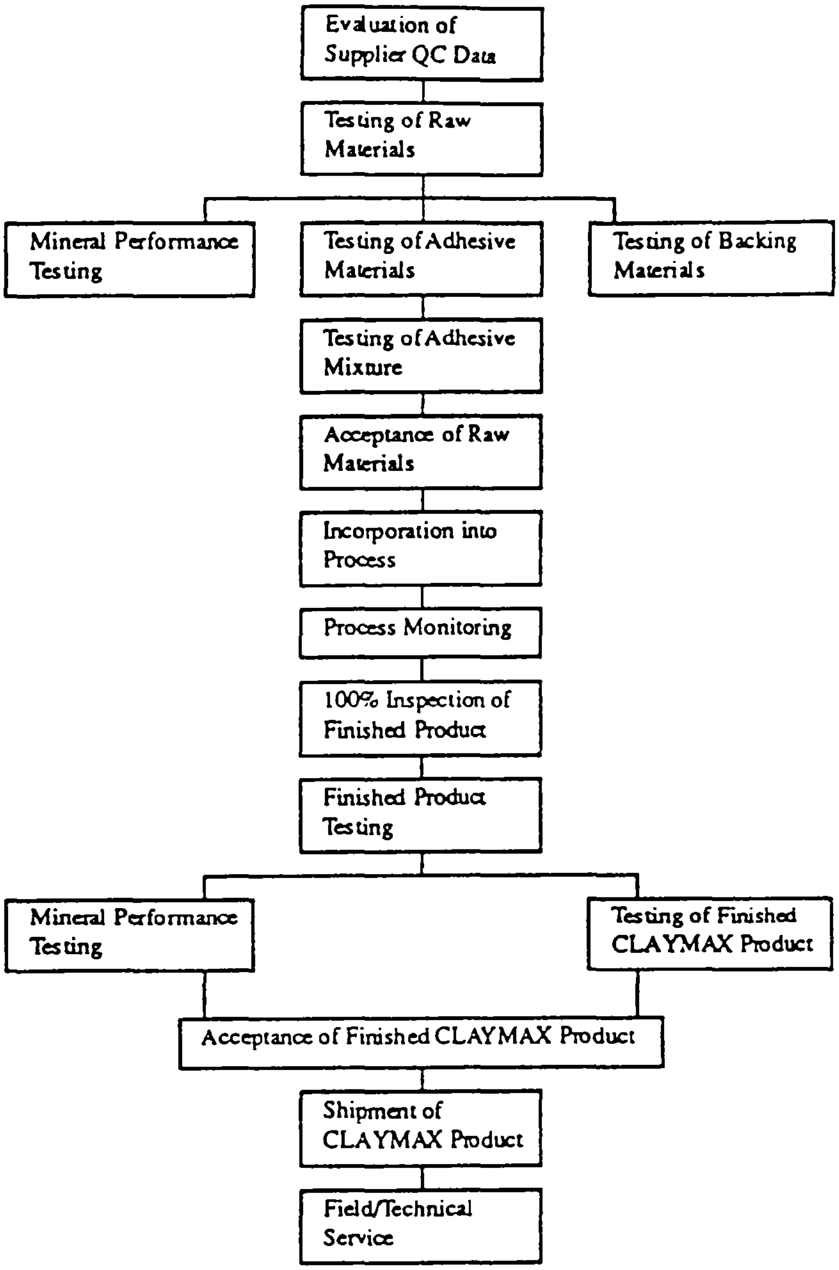


Fig. 2.6 Clem Quality Management Program Summary

Table 2.4 Claymax® Mineral Performance Testing

TEST	AS DELIVERED			AS REMOVED FROM FINISHED CLAYMAX		
	Performed?	Criteria	Frequency	Performed?	Criteria	Frequency
Gradation	X	per specs	8-10 per rail car	-	-	-
Moisture Content	X	< 10%	"	X	25% max.	2000 m² max.
pH	X	8-10.5	"	X	-	"
Plate Water Adsorption	X	860% min.	"	X	-	"
Free Swell	X	25 ml min.	"	X	27 ml min.	"
Fluid Loss	X	18 ml max.	"	X	12 ml max.	"

Table 2.5 Claymax® Backing Material Testing

TEST	SUPPLIER TESTED	CLEM TESTED	ACCEPTANCE CRITERIA (MARV)	CLEM TESTING FREQUENCY
Grab Tensile Strength	X	X	400 N	7-10 per delivered truckload
Grab Tensile Elongation	X	X	15%	"
Puncture Strength	X	X	220 N	"
Mullin Burst	X	-	1700 kPa	"
Unit Weight	X	-	0.12 kg/m²	"
Wide Width Tensile	X	-	11 N/mm	"

Table 2.6 Claymax® Inspection andTesting

TEST	MINIMUM TESTING FREQUENCY	ACCEPTANCE CRITERIA
Bentonite Content	2000 m²	4.6 kg/m² MARV
Composite Thickness	2000 m²	5.0 mm MARV
Bentonite Thickness	2000 m²	4.3 mm MARV
Permeability	70,000 m²	$< 5 \times 10^{-9}$ cm/sec @ 14 kPa
Overlapped Seam Permeability (no granular bentonite)	70,000 m²	$< 5 \times 10^{-9}$ cm/sec @ 14 kPa

Table 2.7 Claymax® GCL Material Specifications

	PROPERTY	TEST METHOD *	UNITS	CLAYMAX STYLE 200R	CLAYMAX STYLE 500SP
BENTONITE PROPERTIES **	Sodium Montmorillonite Content	X-Ray Diffraction	%	90 (typ)	90 (typ)
	Free Swell	USP-NF-XVII	ML	27 (MARV)	27 (MARV)
	Fluid Loss	API 13 B	ML	12 (Max. A.R.V.)	12 (Max. A.R.V.)
	Moisture Content †	ASTM D4643	%	20 (typ)	20 (typ)
ADHESIVE	Adhesion	Visual		Continuous Adhesion to Backing Material	Continuous Adhesion to Backing Material
PHYSICAL PROPERTIES	Thickness (excluding fabric)	ASTM D1777	MM	4.3 (MARV)	4.3 (MARV)
	Composite Thickness	ASTM D1777	MM	5 (MARV)	5 (MARV)
	Wide Width Tensile	ASTM D4595	N/MM	11 (typ) ††	18 (typ)
	Grab Tensile	ASTM D4632	N	400 (MARV) ††	400 (MARV) ††
	Bentonite Content † @ 20% moisture	Weigh 12" X Roll Width	KG/M^2	4.6 (MARV)	4.6 (MARV)
	Shear Resistance				
	Hydrated	ASTM D35.01.81.07 (draft)	DEG	>10	>40
	Dry		DEG	>35	>40
HYDRAULIC PROPERTIES	Permeability				
	A) 14 kPa Effective Stress	ASTM D5084	CM/S	5×10^{-9} (Max. A.R.V.)	5×10^{-9} (Max. A.R.V.)
	B) 200 kPa Effective Stress	ASTM D5084	CM/S	$< 5 \times 10^{-10}$ (typ)	$< 5 \times 10^{-10}$ (typ)
	Permeability (14 kPa effective stress)				
	C) 50 mm Overlapped Claymax (without the use of granular bentonite between the seams)	ASTM D5084	CM/S	$< 5 \times 10^{-9}$ (typ)	$< 5 \times 10^{-9}$ (typ)
	D) Damaged Claymax (3 each, 25 mm holes)	ASTM D5084	CM/S	$< 5 \times 10^{-9}$ (typ)	N/A ‡
	E) Claymax underneath damaged HDPE geo-membrane (25 mm hole)	ASTM D5084	CM/S	$< 5 \times 10^{-9}$ (typ)	N/A ‡
	F) after 3 Wet/Dry Cycles	ASTM D5084	CM/S	$< 5 \times 10^{-9}$ (typ)	N/A ‡
	G) after 5 Freeze/Thaw Cycles	ASTM D5084	CM/S	$< 5 \times 10^{-9}$ (typ)	N/A ‡

* Standard test methods modified where appropriate to facilitate testing a Geosynthetic Clay Liner (GCL).
** Properties of bentonite removed from finished GCL product.
† D4643 modified to included wet weight as the denominator.
†† Machine (warp) direction of primary backing.
‡ Testing in progress.

Table 2.8 Partial List of Claymax® Hydraulic Conductivity Testing Data

	RANGE OF RESULTS
Standard CLAYMAX 200R	2-4 x 10^{-9} cm//sec
CLAYMAX 500SP	2-4 x 10^{-9} cm/sec
25 mm hole prior to hydration*	3-5 x 10^{-9} cm/sec
50 mm overlapped seam*	3-5 x 10^{-9} cm/sec

* = self-healing tests on damaged liner and tests on overlapped seams were performed on both CLAYMAX 200R and CLAYMAX 500SP.

Testing Parameters (ASTM D5084)
- 100-150 mm permeameter cells
- 5 kPa during hydration
- 14 kPa effective stress during consolidation

Table 2.9 Partial List of Claymax® Frictional Resistance Data

INTERFACE	FRICTION ANGLE (°)	ADHESION (KPA)
PBM: smooth HDPE	12	1
PBM: textured HDPE	22	1.9
SBM: smooth HDPE*	11	3
SBM: textured HDPE*	24	1.4
SBM: textured VLDPE	30	2.4
PBM: sand	29	0
PBM: #57 stone	31	1.6
INTERNAL	**FRICTION ANGLE (°)**	**COHESION (KPA)**
CLAYMAX 200R	12	0.2
CLAYMAX 500SP	N/A	24

PBM = Primary Backing Material
SBM = Secondary Backing Material

* = test done on CLAYMAX 500SP

the GCL, the bentonite can either be a Wyoming sodium bentonite or a treated, contaminant-resistant bentonite. The geomembrane can be either a HDPE or VLDPE with a thickness ranging from 20 to 80 mils (0.5 to 2.0 mm). Textured geomembranes can be used, as well.

Gundseal® can be installed in two ways. The first configuration is with the geomembrane side facing downward against the subgrade, and with the bentonite side facing upward against an overlying geomembrane, forming a composite system. The second configuration is with the bentonite side facing downward against the subgrade. Certain design criteria must be applied depending on how the Gundseal® is to be installed.

2.4.1 Gundseal® Composite System

When Gundseal® is applied underneath a geomembrane with the bentonite side facing upward, a composite liner system is formed. The success of the composite system is a function of the hydraulic conductivity of the system, the effectiveness of overlapped seams, the degree of intimate contact with overlying geomembrane, the internal shear strength of the bentonite, and the interfacial friction resistance between the components of the system.

2.4.1.1 Hydraulic Conductivity

The hydraulic conductivity of an intact specimen of Gundseal® has been reported to be less than 4×10^{-12} cm/s. Researchers at the University of Texas (Daniel & Shan, 1992) and at GeoSyntec Consultants (1991) have reported that the bentonite element of Gundseal® alone has a hydraulic conductivity between 1×10^{-9} and 1×10^{-10} cm/s. Therefore, the 3 mm thick layer of bentonite, when considered by itself, is equivalent to at least 300 mm of 1×10^{-7} cm/s clay. The Gundseal® system, consisting of the geomembrane and the layer of bentonite, is equivalent to well over 900 mm of 1×10^{-7} cm/s clay.

2.4.1.2 Overlapped Seams

When Gundseal® panels are overlapped, close contact is developed between the bentonite portion of one panel and the geomembrane portion of the other. Researchers at the University of Texas (Estornell, 1991) investigated the effectiveness of this overlap by performing large scale tests on two separate overlapping specimens. One sample had an overlap of 40 mm, while the other sample had an overlap of 75 mm. Two feet of gravel and one foot of water were placed over each of the specimens. During the five-month-long test, no outflow was noted through either of the overlapping specimens. Additional testing has been performed by GeoSyntec Consultants (1991) and no flow was noted through the overlapped seams after one hundred hours.

2.4.1.3 Composite Action

The effectiveness of the overlapped seams indicates that a good composite action is formed between a geomembrane and the hydrated bentonite. Additional research at the University of Texas (Estornell, 1991) has shown that the bentonite portion of Gundseal® is able to seal off defects in an overlying geomembrane. At the University of Texas, slits and holes were cut into a geomembrane. This geomembrane was placed on top of the bentonite portion of Gundseal®, and the system was covered with gravel and water. These tests were performed for five months, during which time no flow was observed through the system. After five months, the tests were dismantled and the condition of the GCL was observed. Around the largest hole (75 mm diameter) in the geomembrane, only a 130 mm diameter area was wetted on the bentonite, thus indicating excellent intimate contact and composite action (Fig. 2.7).

The effectiveness of intimate contact between Gundseal® and an overlying geomembrane was also investigated by the engineers at GeoSyntec Consultants (1991). Their results indicated that the hydrated bentonite can effectively seal a defect in an overlying geomembrane. Water contents were taken from the bentonite portion of Gundseal® directly beneath a 1 mm diameter hole. The water content tests indicated a significant reduction in the water content of the bentonite radially away from the hole (Fig. 2.8).

2.4.1.4 Internal Shear Strength

The internal shear strength of the bentonite portion of Gundseal® has been investigated by both the Geosynthetic Research Institute (1991) and the University of Texas (Daniel and Shan, 1992). The internal friction angle for the bentonite portion of Gundseal® in an unhydrated state (water content = 17%) was found to range from 22° to 26°. The manufacturer states that due to the effectiveness of composite action with an overlying geomembrane, the bentonite portion of Gundseal® will remain basically unhydrated. Thus the internal

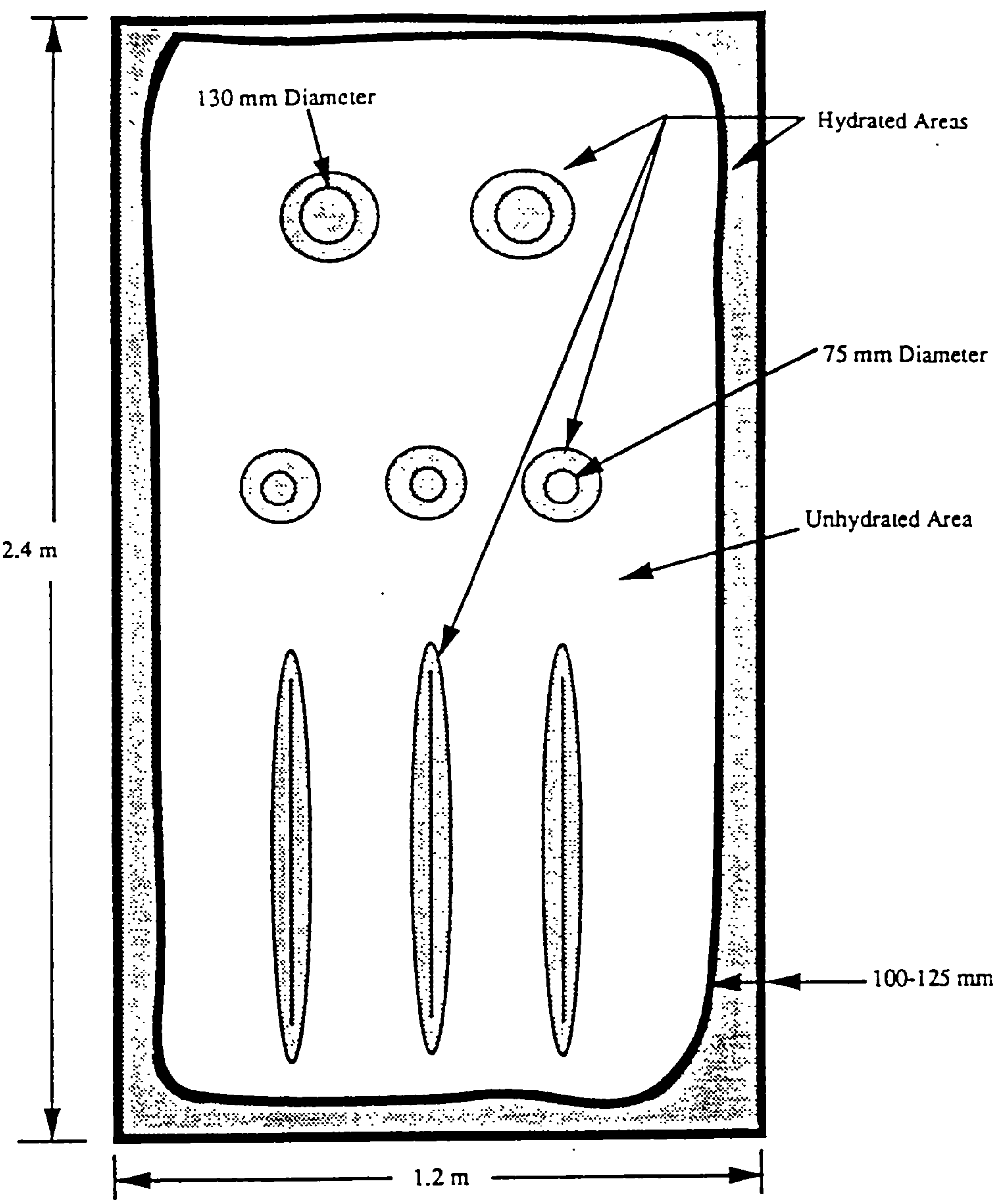
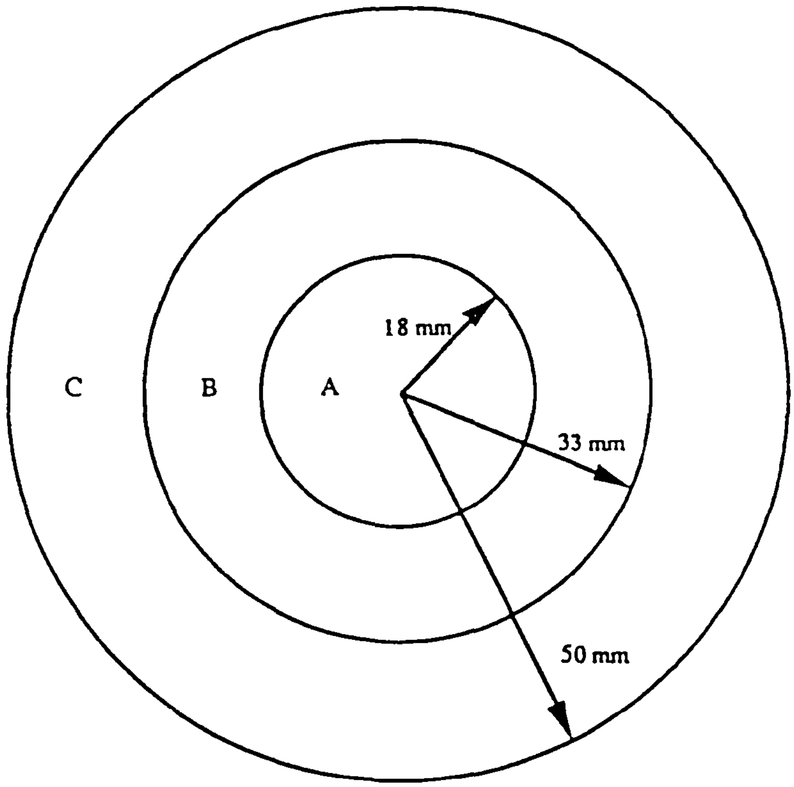


Figure 2.7 Composite Action Test with Overlying Defective Geomembrane (after Estornell, 1991)



Initial Specimen Conditions: Water Content - 7.3%

Final Specimen Conditions: Water Contents:
- Section A - 77.2%
- Section B - 30.2%
- Section C - 24.0%

Figure 2.8 Variations in Bentonite Water Content beneath a Defective Geomembrane (after Geosyntec Consultants, 1991) friction angle of 22° to 26° can be used by designers if the bentonite remains "dry."

2.4.1.5 Interfacial Friction Resistance

The interfacial friction angle between the smooth sheet geomembrane portion of Gundseal® and the subgrade soil can be assumed to be approximately 16° (Koerner, 1990). If a higher interfacial friction resistance is necessary, the interfacial friction angle between a textured geomembrane portion of Gundseal® and the subgrade soil can be assumed to range from 25° to 32° (Koerner, 1990).

The interfacial friction angle between the dry bentonite portion of Gundseal® and the overlying geomembrane can be assumed to be 16° for smooth sheet (Koerner, 1990) and 32° for a textured sheet (Westinghouse Inc., 1991).

2.4.2 Gundseal® as a Single Liner System

In some cases, engineers and designers desire to use Gundseal® as a single liner system. This can occur in liner systems for reservoirs, disposal sites, and at hydrocarbon storage tank facilities. The major factors affecting the performance of Gundseal® in these areas are soil suction, hydraulic conductivity, internal shear strength, and subgrade contamination.

2.4.2.1 Soil Suction

The University of Texas (Daniel and Shan, 1992) recently completed a study on the effect of subgrade moisture content on the bentonite portion of Gundseal® when the GCL was installed beneath a layer of medium grained sand with the bentonite side of Gundseal® in contact with the sand. It was found that the dry bentonite has a very high suction value of 7500 kPa and will draw moisture from the sand. The amount of moisture "sucked up" by the bentonite depends upon the moisture in the sand. Equilibrium can be reached between the bentonite and the sand in a period varying from 2 to 14 days (Fig. 2.9).

2.4.2.2 Hydraulic Conductivity

If the bentonite side of Gundseal® is placed in contact with the subgrade soil, the bentonite will hydrate. Depending on the initial water content on the subgrade soil, the final water content of the bentonite can range from 50% to over 145%.

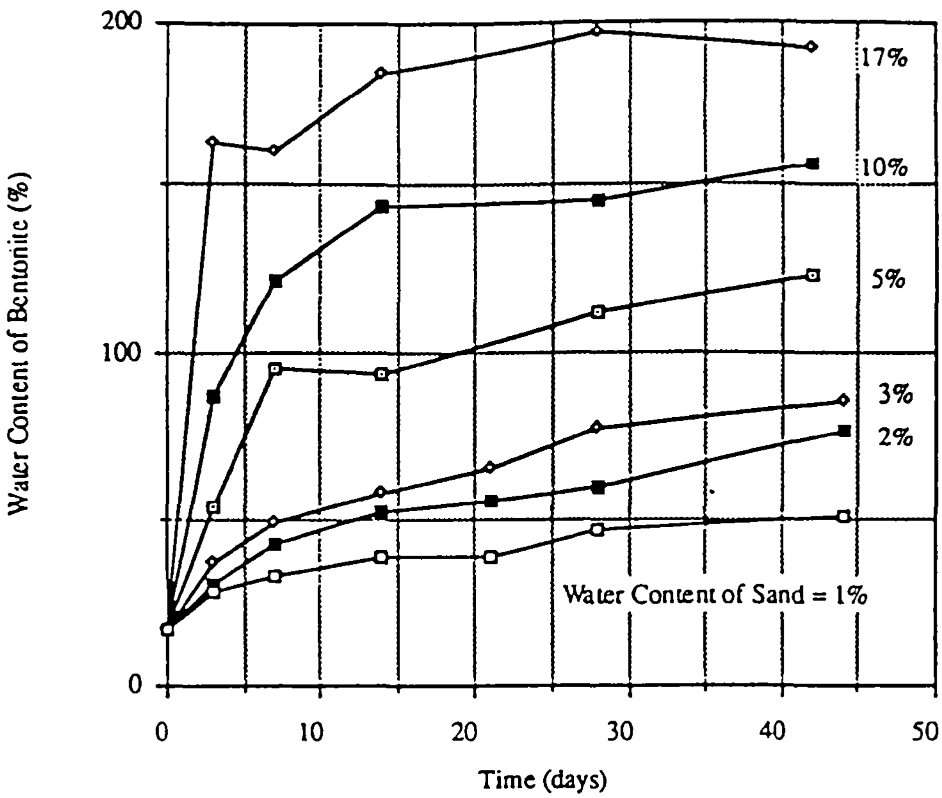


Figure 2.9 Water Content vs. Time for Samples of Gundseal® Placed Within Sands of Varying Water Content (Daniel & Shan, 1992)

The hydraulic conductivity of the bentonite portion of Gundseal® as a function of the initial water content of the bentonite was recently studied at the University of Texas (Daniel and Shan, 1992). Various hydrocarbons were used as the permeant liquid in the study. The results are shown in Table 2.10.

2.4.2.3 Internal Shear Strength

The internal shear strength of the bentonite portion of Gundseal® has been investigated by both the Geosynthetic Research Institute (1991) and the University of Texas (Daniel and Shan, 1992). The internal friction angle for the bentonite portion of Gundseal® in a hydrated (wet) state was found to 19° at a total normal stress less than 36 kPa, and 7° at higher normal stresses. Therefore, care must be taken to take into account the effect of normal stress when using a friction angle in a stability analysis.

Table 2.10 Permeability to Various Hydrocarbons as a Function of Initial Bentonite Water Content (Daniel & Shan, 1992)

PERMEANT LIQUID	PERMEABILITY (CM/S)				
	$w_0 = 17\%$	$w_0 = 50\%$	$w_0 = 100\%$	$w_0 = 125\%$	$w_0 = 145\%$
Benzene	3×10^{-5}	2×10^{-5}	5×10^{-9}	No Flow	No Flow
Gasoline	4×10^{-5}	4×10^{-5}	4×10^{-9}	No Flow	No Flow
Methanol	3×10^{-5}	3×10^{-5}	3×10^{-9}	No Flow	No Flow
MTBE	2×10^{-5}	3×10^{-6}	$<1 \times 10^{-9}$	No Flow	No Flow
TCE	4×10^{-5}	4×10^{-5}	3×10^{-8}	No Flow	No Flow
Water	2×10^{-9}	--	--	--	--

2.4.2.4 Seams

When Gundseal® is installed with the bentonite side facing down, the manufacturer recommends that tape be placed along the seam to prevent overlying cover soils from separating the seams.

Alternatively, the overlapping geomembrane of the Gundseal® can be heat seamed with fillet extrusion welding, or cap strip seams, to form a seamed membrane composite barrier.

2.4.2.5 Geotextile Separator

When placed in contact with the subsoil, the bentonite portion of Gundseal® will draw in moisture and become hydrated. While this reduces the permeability to hydrocarbons, it also reduces the internal friction angle of the bentonite. Therefore, in order to maintain the integrity of the bentonite and to prevent contamination from the lower soils, it may be necessary, in cases of nonuniform subgrades, to use a geotextile to maintain a separation between the bentonite and the lower subgrade soils.

2.4.3 Conclusion

Research has indicated that Gundseal® is an effective replacement for clay in landfill liner systems and covers. Concern has been expressed, upon occasion, by engineers, contractors, and regulators that the thin geosynthetic clay liners, such as Gundseal®, are susceptible to damage during installation. However, the installation of geosynthetic clay liners is much easier than the construction of compacted clay liners, and when the contractors utilize the same care that is needed to install a geomembrane, an effective liner or cover system is in place and protecting the environment.

CHAPTER 3
TESTING PROCEDURES

As GCLs are still relatively new to the market, the methods used to test and to interpret these tests are still in their initial stages. Each of the major GCL manufacturers is currently working to create standard methods of testing these products. Until these standards are completed, it will be up to testing companies and design engineers to decide how to set up and interpret the results of testing on GCLs. The major problem is variable results arising from different testing procedures.

Three speakers were given the opportunity to speak directly about testing procedures. The first spoke about the number of different ways one can assess the quality of the bentonite being used in the GCL product. The second spoke about the number of laboratory tests one can perform in order to determine the basic design parameters necessary to decide whether the product will perform as anticipated. The third spoke specifically about how to determine and interpret the shear strength of a GCL.

3.1 Quality Assessment for Bentonite Sealants (By Richard K. Brown, WYO-BEN, Inc.)

The use of bentonite as an environmental sealant in the development of low permeability horizontal barriers to fluid movement has become an accepted and standard practice in landfill and lagoon construction for waste containment. Despite this, and despite the fact that there are an abundance of methods available for assessing quality in bentonite, there is as yet no standard practice or accepted criteria for assessing the quality of the bentonite which is used in this capacity. This paper presents a summary of those methods which may be used for this purpose, along with a brief discussion of the suitability of each method for this task.

3.1.1 Bentonite

Any discussion of test methods used to define bentonite quality would be incomplete without a brief discussion of what bentonite is and how it works.

Bentonite is a clay composed primarily of the crystalline, hydrous alumino-silicate mineral montmorillonite. As a result, the unique physicochemical characteristics of montmorillonite define the performance capabilities of bentonite. Montmorillonite particles typically exist as minute, very broad, extremely thin, three-layered crystals which have negative electrical charges expressed on their surfaces. The presence of these charges causes inorganic cations and polar molecules, such as water, to be attracted by and absorbed to the montmorillonite crystal surfaces. There is strong evidence to indicate that water which is absorbed by montmorillonite crystals becomes bound in layers many molecules in thickness in a crystalline or quasi-crystalline arrangement similar to that found in ice. The thickness of the bound water layer is controlled by the negative electrical charge density on the montmorillonite crystal surfaces. This is modified, however, by the effect of the particular absorbed cations which are present, with sodium ions (Na^+) enhancing the effect while all other cations diminish it to varying degrees.

In dry bentonite, montmorillonite crystals tend to be arranged in a densely packed surface to surface facing structure similar to the arrangement of cards in a deck of cards. Water added to dry bentonite will be absorbed onto the crystal surfaces causing adjacent crystals to move further apart. This expansion will continue, as more water is added to the system up to the adsorption limits of the montmorillonite. This process is the cause of the swelling phenomenon observed when bentonites are wetted.

Studies have shown that the crystalline nature of the water absorbed by montmorillonite crystals appears to cause it to be immobile or to act as a highly viscous fluid, depending upon the hydraulic gradient under which it is placed. It is this resistance to flow found in the absorbed water layer on montmorillonite crystals which is the fundamental basis for the sealing capability exhibited by bentonite.

As a result, those test methods which can be used to define the water adsorption and swelling capability of bentonite should offer the best possibility of indicating sealing capability. This statement holds true only for natural, untreated bentonite or bentonite products, however. Many of the additives which are commonly used to treat bentonite sealants mask this mechanism making the definition of bentonite quality very difficult to accurately determine.

3.1.2 Primary Test Methods

The methods presented here are those which, directly or indirectly, define the sealing capability of bentonite and appear to offer the most promise, either singularly or in combination, for defining quality in bentonite sealants.

3.1.2.1. Permeameter Testing

By far the best, most accurate and most direct way of assessing the quality of a bentonite sealant would be to test its hydraulic conductivity under a standard set of test conditions. Several bentonite manufacturing companies have, in fact, established permeability performance tests specific for their own products. Unfortunately, these tests often vary in their methods and conditions making broad comparisons between products difficult. Although a standard test method now exists to facilitate this type of testing (ASTM D 5084-90) there has, to date, been no unified effort by any group to establish test conditions under which such quality testing might be accomplished. Nevertheless, standard test conditions for permeameter testing can be adopted by testing firms for project specific comparison testing in order to determine relative quality of competing bentonite sealant products.

The absence of any standardized hydraulic conductivity test data for bentonite sealant products, coupled with the high equipment cost for permeameters and slowness in obtaining test results, has led to the use of a number of other test methods which serve as indirect indicators of sealing capability.

3.1.2.2 Swell Tests

Swell tests measure the ability of a bentonite to adsorb water by measuring the increase in volume of a mass of bentonite which occurs during the adsorption process. Several methods are available which allow measurement of various aspects of the swelling characteristic.

3.1.2.2.1 Free Swell Test

This test method measures the swollen volume of a sample of powdered, dried bentonite which has been added in numerous small increments over a period of time to 100 ml of distilled water in a 100 ml graduated cylinder. Measurement of bentonite volume is made from the gradations on the cylinder.

Typically, this measurement is taken after the cylinder has set, undisturbed, for 2 to 24 hours following the final bentonite addition. In theory, this procedure gives the test bentonite the opportunity to adsorb water and swell in an uninhibited and unconfined fashion yielding a good representation of the swelling capacity of the clay. This method is easily used, requires little equipment, and typically has good reproducibility. Variations in the rate of bentonite addition, the amount of bentonite added at each addition, and the setting time allowed can all affect the result, however. Despite this, the results of this test method appear to correlate well with the results of hydraulic conductivity testing. Although no standard method currently exists for this test, one is now being developed by ASTM.

3.1.2.2.2 Modified Free Swell Index Test

This test method, developed by Sivapullaiah et al. (1987) for clays generally, measures the settled volume of clay sediment resulting from 3 additions of clay which have been mixed into a volume of water, typically 100 ml, in a graduated cylinder of suitable size, and then allowed to set, undisturbed, for 24 hours. The sediment volume is measured using the graduations on the cylinder. The resulting volume is then used to calculate the "Modified Free Swell Index" of the clay using a formula which takes into account both the weight and specific gravity of the solids used. This test is relatively simple to conduct and appears to have good reproducibility for most bentonite materials. The definition of sediment layer boundaries can be a problem when testing some high quality natural sodium bentonites as well as with some treated bentonite products, however. Reschke and Haug (1991) report that the results of this test method show good correlation with the results of hydraulic conductivity testing for compacted soil/bentonite mixtures (not pure bentonite).

3.1.2.2.3 Swelling Pressure Test

This test is included here because intuition suggests that swelling pressure should inversely correlate strongly with hydraulic conductivity. No published data have been found which establishes this correlation, however. Measurement of the pressure exerted by hydrating bentonite as it adsorbs water and swells in a confined space is typically done using consolidometers (Oscarson, et al., 1990).

As a result, this test requires both sophisticated equipment and personnel in order to properly conduct it. This may limit the wide spread use of this method.

3.1.2.3 Plate Water Absorption (PWA) Test

This test method measures the ability of a sample of powdered, dried bentonite to "absorb" water when placed on a piece of filter paper on a porous stone in a covered, water filled tray for 18 hours. The procedure for conducting this test has been standardized as ASTM E 946. When properly conducted this test is accurate to approximately $\pm$ 5%, with test values for bentonites ranging from 200 to 1100. The test is very sensitive to a number of conditions, such as variations in the thickness of the bentonite sample on the filter paper, the number of samples placed on each porous stone, the water level within the test tray, and to even minor fluctuations in temperature during the period of the test. Failure to adequately control these can result in swings in test results and very poor reproducibility. As a result experienced personnel are required for this test in order to obtain consistent results. Results from this test method appear to correlate well with the results from hydraulic conductivity testing and with the results of free swell testing. There appears to be very poor correlation between PWA test results and modified free swell test results, however.

3.1.2.4 Liquid Limit Test

This test, as standardized in ASTM D 4318, sets forth a method for determining the water content of a soil at the boundary between the soil's plastic and liquid states. This method provides us another way to measure the water adsorption capability of bentonite. Sivapullaiah et al. (1987) state that the liquid limit, when expressed on a volume basis (volume of water to volume of soil), shows a strong correlation with the modified free swell index test results. Limited data presented by Reschke and Haug (1991) suggests a strong correlation between liquid limit (as normally calculated) and both the modified free swell index and hydraulic conductivity test results for high quality sodium bentonites. These same data suggest little correlation for low quality sodium bentonites. The simplicity of this test makes it a desirable one for use in assessing sealing bentonite quality. However, additional testing is necessary to establish the relationship between liquid limit and hydraulic conductivity.

3.1.3 Secondary Test Methods

The methods described here are those which may be used in addition to the primary test methods to further assist in defining quality in bentonite sealants. These methods do not, by themselves, yield enough information to be used as independent tests. As a result these tests should never be used as the sole criterion in determining bentonite quality.

3.1.3.1 Apparent Colloid Content Test

This test method measures the fraction of a 2% water-dispersed sample of bentonite that remains in suspension after an 18 to 24 hour settling period. In theory, this test should be capable of measuring the montmorillonite content of a bentonite sample because montmorillonite crystals should all be smaller than the 0.5 micron size threshold delimiting colloidal size particles which, by definition, are small enough to stay permanently in aqueous suspension. Unfortunately, factors such as incomplete sample dispersion, flocculation due to chemical contaminants, and the effects of various additives all act to bias the test results. In effect this test is simply a larger version of the Modified Free Swell Index Test which was previously described, although different methods of analysis are used in this method. When analyzed using the criteria of the Modified Free Swell Index Test the results produced by the apparent Colloid Content Test do not duplicate the results of the other test. Further, the Apparent Colloid Content Test does not correlate strongly with the any of the primary tests, exhibiting only moderate correlation with the Free Swell Test and the PWA Test.

3.1.3.2 X-Ray Diffraction (XRD) Mineralogical Analysis

X-Ray Diffraction analysis of a bentonite sample can be used to determine its approximate mineralogical composition. However, because XRD is a semi-quantitative method absolute percent compositions are not possible. Further, while some inferences can be drawn from the results of this test as to the quality of the montmorillonite crystals in a sample it is not possible to make any accurate statements about sealing capabilities of the bentonite sample being tested based solely on XRD results. At best, this method can be expected to provide only a close approximation of the amount of montmorillonite present in a sample.

3.1.3.3 Cation Exchange Capacity (CEC)

The methods used to determine CEC measure the negative charge present on the montmorillonite crystals in a bentonite. Although other, more accurate methods are available, the CEC of bentonite is most often measured by determining the ability of a sample to adsorb the positively charged dye, methylene blue. The Methylene Blue Dye Test has been standardized by the American Petroleum Institute. The Methylene Blue Dye Test is capable of yielding consistent, reproducible results when properly performed, although these results are generally slightly lower than those produced by other CEC determination methods.

3.1.3.4 Specific Surface Area

This test provides a measure of the montmorillonite crystal surface area upon which water can potentially be adsorbed. Generally, higher surface area values should be indicative of high quality bentonites having low hydraulic conductivity. Limited data presented by Reschke and Haug (1991) show only moderate correlation between surface area and hydraulic conductivity.

3.1.3.5 Chemistry

Definition of the gross chemical composition of bentonite, using X-Ray Fluorescence or wet chemistry techniques, as well as definition of the exchangeable cations present, using both wet chemistry and flame photometry, can offer insights into bentonite quality. For example, Reschke and Haug (1991) found that a strong correlation existed in the bentonites they tested between the $SiO_2Al_2O_3$ ratio and the quality of the material, while Alther (1986) found the ratio of exchangeable sodium, calcium and magnesium had a significant effect on the rheological and contamination resistance properties of bentonite. It must be remembered, however, that the results of bentonite chemical analysis are only useful when they are evaluated in the context of the results from other testing. A wide variety of relationships between gross chemical and exchangeable cation chemistries which would yield similar quality bentonites are no doubt possible.

3.1.4 Conclusion

Quality in bentonite sealants is specifically defined by the level of impermeability or hydraulic conductivity achievable by a particular bentonite.

Permeameter testing under a set of standard test conditions, therefore, offers the most direct method of determining the quality of a bentonite sealant product. Where this cannot be done, the water adsorption and swelling capabilities of a bentonite, which are both fundamental characteristics of the sealing process, may also be tested as indirect indicators of sealing effectiveness. A variety of test methods may also be employed to define other bentonite characteristics such as mineralogical composition, specific surface area, cation exchange capacity, and others which, in combination with the results of water adsorption and/or swelling tests, can serve to give a more complete picture of the quality of bentonite sealants. However, additional test methods do not provide sufficient information about the mechanism of the sealing process to enable them to be used independently or as the principal method for determining bentonite sealant quality.

3.2 Conformance Testing of Geosynthetic Clay Liners (By John Boschuk, Jr., J & L Engineering, Inc.)

As part of important construction activities using man-made or natural materials, the engineer needs verification that specific materials for the project conform to the design requirements and will perform as anticipated. Over the past several years, a number of basic tests for each of the major geosynthetic types have evolved and are included in specifications as conformance tests. These tests are typically performed on material samples taken from the rolls as they are manufactured or from the rolls on-site before the material is deployed.

Geosynthetic clay liners are increasingly being used in many projects and may be considered relatively new to many engineers and regulators. Conformance testing for these products is not yet well defined. The purpose of this discussion is to suggest guidelines for testing methods and test frequencies necessary to verify conformance of the materials with the design engineer's requirements.

Unlike most other single-material-component geosynthetics, GCLs are a combination of two or three different elements fused together to create a single composite material. Two of the three elements consist of man-made geosynthetics and the third is a processed natural material containing additives to bond the particles, assist in fusing the material to the geosynthetic or to improve performance of the bentonite.

Considering the differences in the products, two basic choices exist for conformance tests:

1) Test the individual elements of the composite.
2) Test the composite as a single material.

The first option is generally very difficult to exercise since the components are bonded together. Separating the layers to perform tests on each material component would probably damage the components and yield misleading test results. Consequently, it is more logical to test the products as a composite. Furthermore, the designer selected the material to function as a composite and the design is based on the geosynthetic working as a composite.

3.2.1 Testing Options

As part of the research for this paper, the author queried the major users of the material to determine what conformance tests they typically perform on GCLs. Not surprising, testing has generally been limited to hydraulic conductivity of the GCL, coupled with manufacturer's certifications. Often no conformance testing is performed and verification is limited only to manufacturer's certifications.

Further research indicates that no specific conformance, or even quality control, testing of these products is typically specified other than hydraulic conductivity. Verification is usually limited to visual inspections and visual field checks to insure the material is not saturated until it is sealed and covered with a confining load.

Before suggesting test protocols, an evaluation of the engineering properties is warranted. First and foremost, the GCL products are being marketed as a low permeability barrier. Consequently, hydraulic conductivity and compatibility with the liquid to be retained should be emphasized. However, there are several other important considerations, e.g., shear strength.

3.2.1.1 Shear Strength

As part of the design, the engineer may need to evaluate shear strength of the composite and develop design properties for the material. Once production of the material commences, verification of conformance to performance characteristics would then be warranted.

3.2.1.2 Tensile Properties

For some designs the product may be subject to short term tensile stresses such as during deployment. In this case the engineer would determine what allowable tensile loads can be applied to the product without adversely affecting other properties. Once these maximum allowable stresses are determined, conformance testing would be specified to insure that the production materials meet these standards.

In other instances, a design may require the product to be subjected to unavoidable long term or residual stresses. If this is the case, long term creep strains may occur and reduce its performance characteristics. Once the engineer determines the maximum allowable sustained stress, criteria can be established for design testing to verify material capabilities. Due to the duration of creep testing, conformance testing is probably not warranted if the design carefully considers these conditions.

3.2.1.3 Puncture Resistance

These products all have some puncture resistance capability. The engineer's design testing program would evaluate how the material will perform under the design conditions. Conformance testing is most likely not warranted to verify this property. Competent field visual observations to insure that the GCL is installed properly should suffice to insure performance.

3.2.1.4 Biaxial Stresses

Under certain conditions GCLs may be subject to differential settlements such as in landfill cover systems. As part of the design, the engineer may perform tests to assess performance and to establish design parameters. These assessments may include biaxial stress tests followed by other engineering tests on the stressed material. With these properties established, conformance testing under biaxial conditions may be warranted to verify material compliance with critical design criteria.

3.2.1.5 Freeze-Thaw and Desiccation

GCLs contain bentonite which can be subjected to freeze-thaw and desiccation that may affect performance. As part of the design process, these conditions are evaluated and the design adjusted to accommodate these concerns. Although conformance testing may be warranted under certain unique conditions, bentonite supplied for these products is generally very uniform and accompanied by supplier certifications and supplier QC testing. Research to date also indicates that bentonite has unique healing properties after freeze-thaw and desiccation. Proper design to accommodate freeze-thaw and desiccation, coupled with supplier testing and certification documents, will most likely be sufficient to insure satisfactory performance.

3.2.2 Suggested List of Conformance Tests for GCLs

Considering these design and performance elements a suggested list of conformance tests is presented as a recommendation to design engineers:

3.2.2.1 Hydraulic Conductivity Testing

Two types of hydraulic conductivity tests are available: flexible-wall permeameters (ASTM D5084) and rigid-wall permeameters. A schematic of each is presented in Fig. 3.1 and 3.2. A modified large-scale rigid wall apparatus, which is large enough to test seams in these products, is shown in Fig. 3.3. When specifying these tests, it is recommended that the permeant be similar to the liquids which will be exposed to the in-place material. Hydraulic gradients and pressures should be specified by the engineer. Extreme care should be exercised to insure the material is saturated and sealed at the sample edges.

3.2.2.2 Shear Strength Testing

Direct shear tests through the plane of bentonite can be performed on either the standard 100 mm shear box or 305 mm shear box. J&L Engineering has performed comparative tests with these products using both types of apparatus and found the 100 mm shear box to be satisfactory for GCL materials. The engineer should specify normal loads, rates of strain, liquid of saturation, fixity conditions, and preferred size of sample. Figures 3.4 and 3.5 present schematics of the test configurations and fixity conditions.

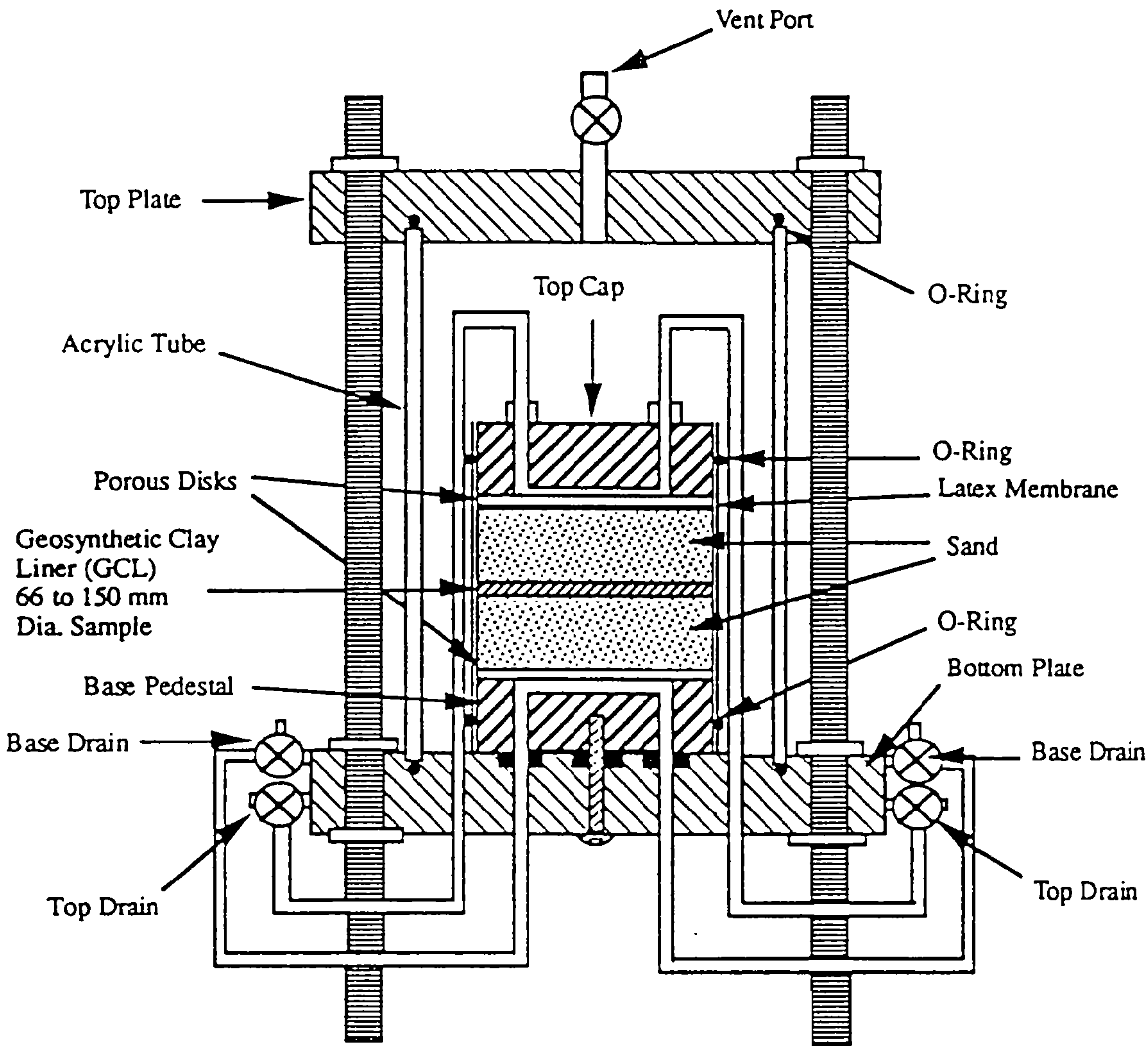


Figure 3.1 Flexible-Wall Apparatus

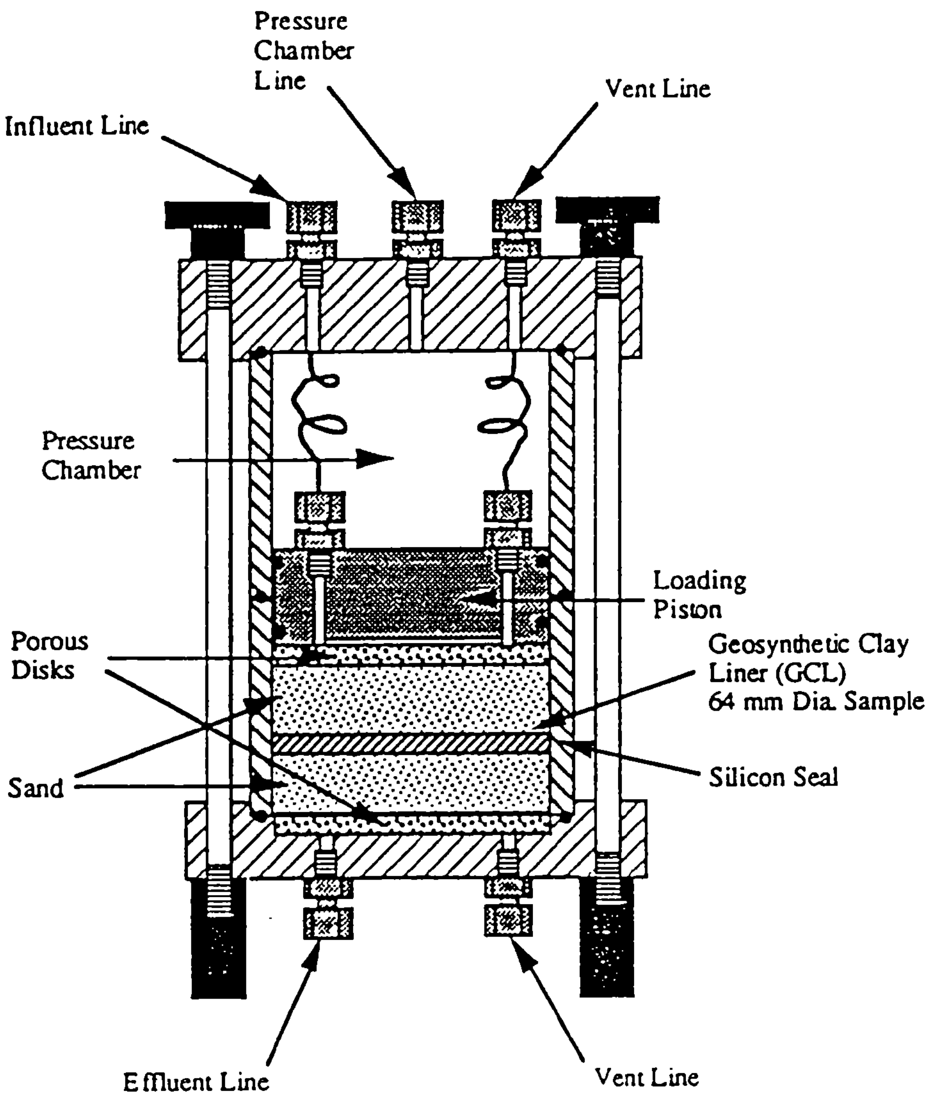


Figure 3.2 Rigid-Wall Apparatus

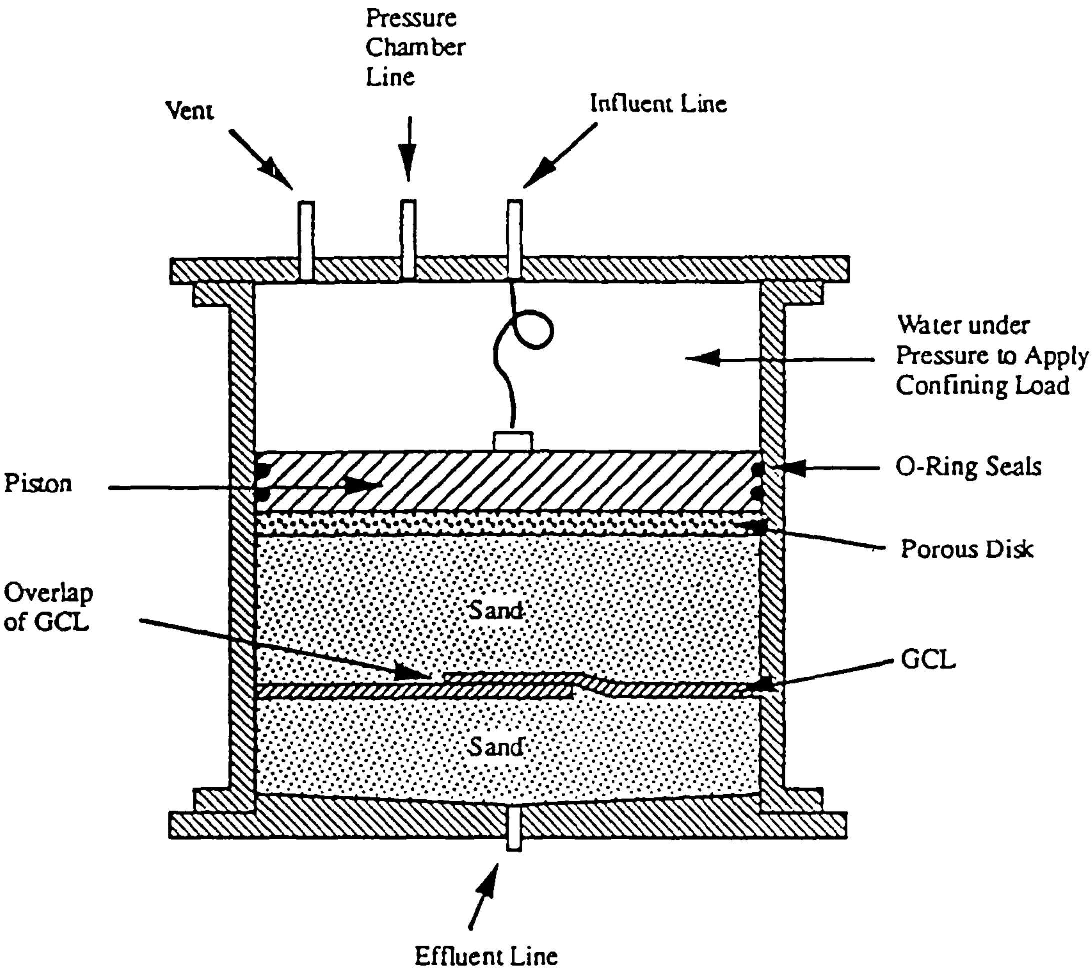


Figure 3.3 Large Diameter Rigid-Wall Apparatus

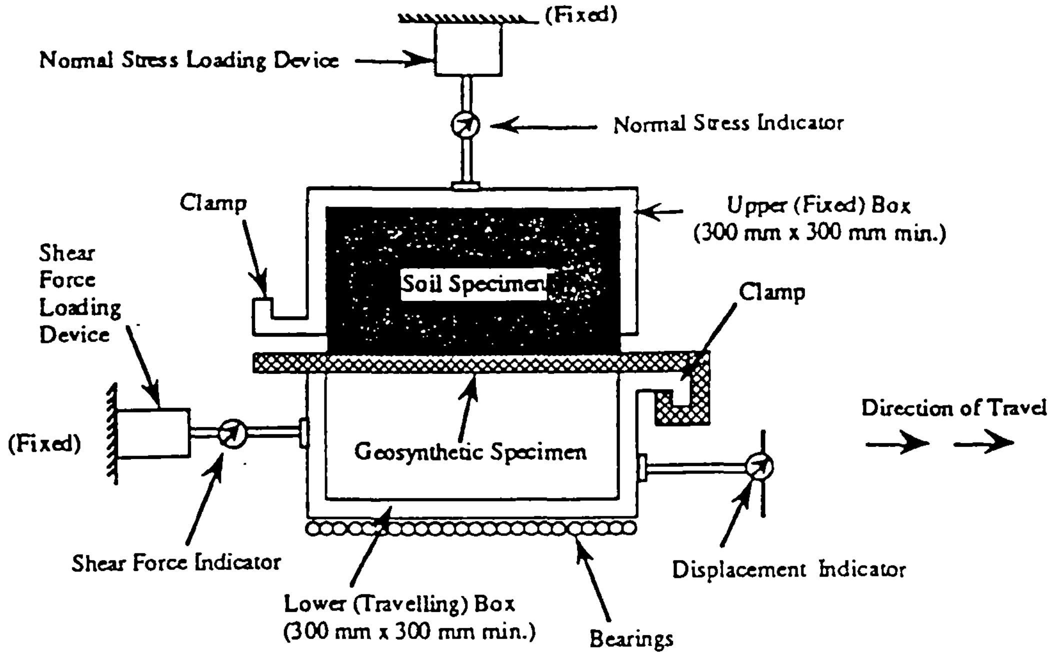


Figure 3.4 Typical Direct Shear Friction Apparatus Schematic

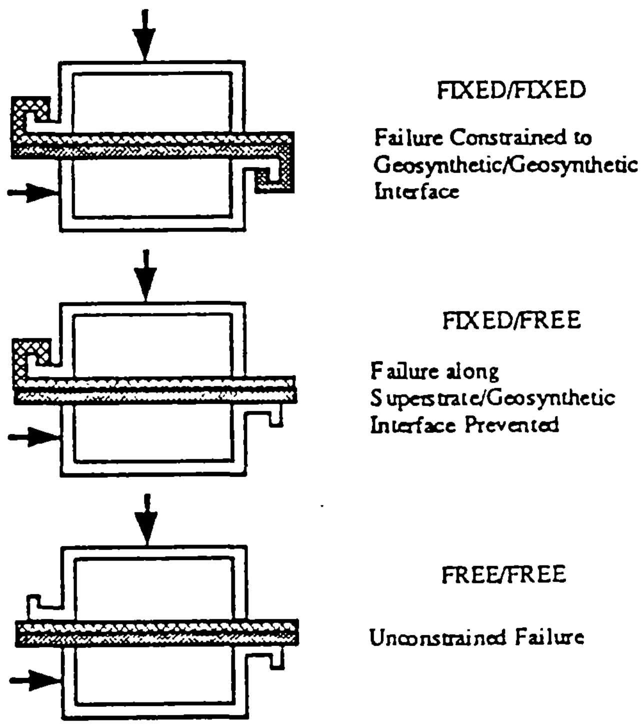


Figure 3.5 Geosynthetic/Geosynthetic Direct Shear Testing

3.2.2.3 Tensile Property Testing

For short term peak stress considerations, wide-width tensile testing per ASTM D4595 is the most appropriate nationally recognized test procedure available (Fig. 3.6). Care must be exercised to insure that the multiple composite is properly clamped. The engineer may have to specify the grip type to insure comparable results between the design and conformance tests, which may be performed by different laboratories. As previously discussed, peak stresses may develop during deployment of the GCL. Therefore, this testing would be performed on the dry products.

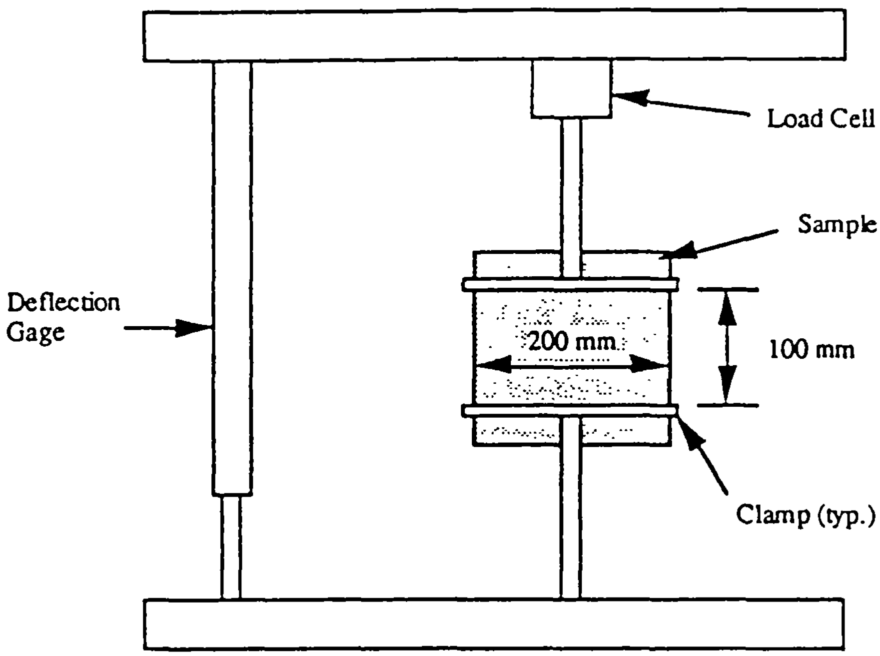


Figure 3.6 Wide Width Tensile Test Schematic (Source: John Boschuk)

Creep testing is probably not warranted in that the design addresses this issue and creep testing requires a long period of time to perform. If required to insure compliance, the material should be saturated with the same type of liquid the product will be exposed to in the field (Fig. 3.7).

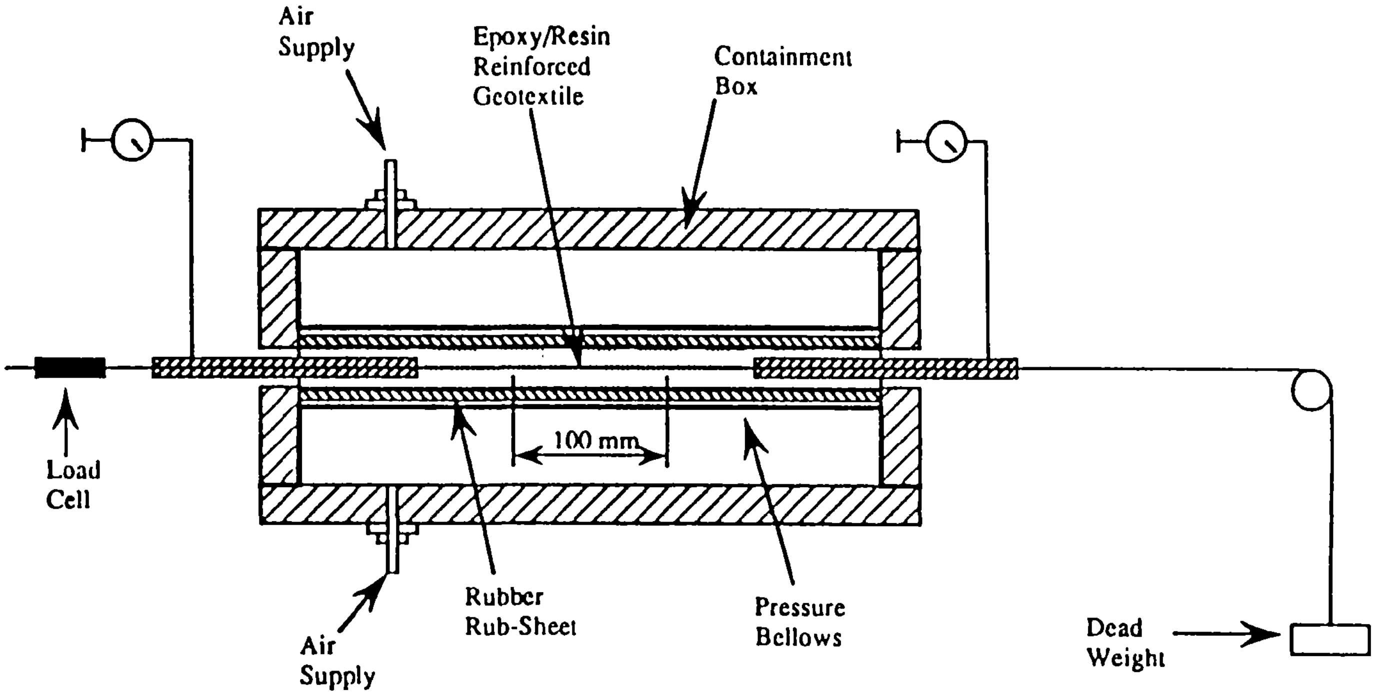


Figure 3.7 Cross Section of a Horizontal Containment Box in a Confined Creep Test Mode
(Source: John Boschuk)

3.2.2.4 Biaxial Stress Testing

Biaxial testing per GRI Test Method GM4 can be specified as a conformance test to assess material bonding performance under conditions similar to those in the field. The fluid used in the test should be similar to the fluid the material will be exposed to in the field. The engineer should specify the fluid, pressures, rate of pressure increase and allowable deflections (Fig. 3.8).

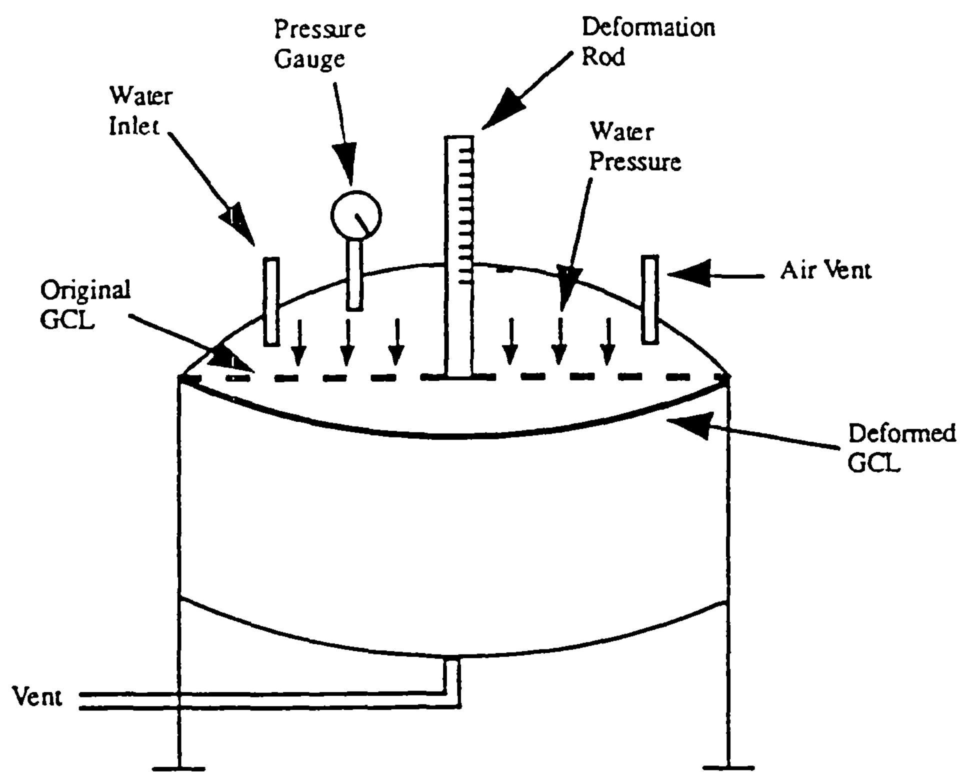


Figure 3.8 Biaxial Test Apparatus Schematic (Source: John Boschuk)

3.2.3 Testing Frequency

Typically, conformance tests are performed at a rate of one test series per 9000 m^2 of product manufactured during a single run. If products are obtained from a stockpile consisting of materials from different runs, testing frequencies should be increased to insure that all runs are adequately tested. Recently, at several projects of which Mr. Boschuk is aware, the testing frequency has been increased to one test series per 4600 m^2 of product. The engineer may have to negotiate this frequency with regulatory authorities.

3.2.4 Conclusion

GCLs are relatively new to the industry and conformance tests are still evolving. This presentation attempts to present technical considerations to establish a conformance test program for GCLs which focuses on verification of the designed performance properties of the product for its specific application. Testing frequencies have also been suggested based on the testing frequencies used for other geosynthetic materials.

It is important to note that these products are still evolving. Manufacturers may be adjusting and changing the geosynthetics used in their products, adjusting the methods of bonding the materials and even the types and distribution of the bentonite used in the products. It is important that whatever product is evaluated in the design be the same product used in the field. Specifications need to address this issue and the manufacturer should be consulted to insure the product tested in the design is the same product used during construction.

3.3 The Determination and Interpretation of Shear Strength (By Robert Bachus, GeoSyntec Consultants)

The topic of shear strength is familiar to anyone associated with geoenvironmental engineering. With the development of geosynthetic clay liners (GCLs), engineers are now faced with the task of evaluating the ability of GCLs to transmit shear at an interface, or through the liner system. The solution to this is to simulate expected field conditions in the laboratory in an attempt to model and test the expected mode of shearing failure. The problem is that the "shear strength" of the GCL is actually composed of three distinct components (internal shear strength, interfacial frictional resistance, and tensile strength). This breakdown into the different components of shear strength coupled with the fact that lab and/or field conditions greatly influence their value, makes the fundamentals of shear strength much more complex than most people realize.

3.3.1 Test Conditions

The shear strength of a GCL must be determined under conditions matching those anticipated in the field. When incorporating a friction angle into a slope stability analysis one cannot expect any degree of accuracy if that friction angle was determined under conditions varying widely from those in the field analysis. The variation in normal stresses, degree and type of fluid hydration, rate of shear, and method of failure are all important variables that a designing engineer must consider.

3.3.1.1 Normal Stress

Over a small range of normal stresses there may appear to be a linear relationship between normal stress and shear stress at failure (Mohr-Coulomb failure envelope), but if taken over a broader range of normal stresses, this relationship may not be linear. Therefore, the shear strength parameters of angle of internal friction (Φ') and cohesion (c') are not constant and depend upon the range of normal stresses over which they are determined. Unfortunately, friction angles and cohesion values are often published without any reference to the normal stress at which they were determined. One must remember that Φ' and c' are not inherent properties of a GCL, but rather a convenient way of representing the shear and normal stresses acting along a plane at the time of failure.

3.3.1.2 Hydration Conditions

In addition to the type of fluid and the length of time for hydration, the method used to hydrate the GCL can affect the measured internal shear strength. For example, prior to direct shear testing, a GCL sample can be hydrated under a normal load in or out of the shear box. Due to sample disturbance caused by unloading and reloading, the sample hydrated outside the shear box will have a different shear strength than the undisturbed sample hydrated within the shear box.

Another concept to consider is when should a hydrated GCL be considered saturated? The bentonite within a GCL is generally a non-homogeneous mixture of individual nodules. These nodules will tend to adsorb any free water. Thus, at what water content will adsorption cease, and the sample be considered saturated?

3.3.1.3 Rate of Shear

One of the testing variables most often overlooked is the rate at which the sample is sheared. The slower a hydrated sample is sheared, the more time excess pore water pressures have to dissipate. Thus the shear strength of a saturated GCL is directly related to how quickly the sample is sheared.

This is why geoenvironmental engineers specify whether the shear strength parameters Φ' and c' are for drained or undrained conditions. If a hydrated sample is loaded slowly enough that excess pore water pressures have time to dissipate, then the test is considered drained. If an engineer performs a long term slope stability analysis (i.e. drained conditions), he must test a representative sample under drained conditions as well. Due to the low hydraulic conductivity of sodium bentonite, a direct shear test cannot be carried out in a day on a GCL. Using the methods proposed by Gibson and Henkel (1954), the time to failure can be estimated for very soft clays as $t_{failure} = 50t_{50}$, where t_{50} is the time required to achieve 50% consolidation under the normal stress being used. Using a constant shear rate of 0.02 mm/hr (1.31×10^{-5} in/min), researchers at the University of Texas (Daniel & Shan, 1991) found that the peak shear stress was typically reached after 5 to 20 days of shearing for GCLs incorporating sodium bentonite. Only two samples failed in less than five days. Based on previous consolidation tests, the calculated minimum time to failure was approximately 3 days. Thus, for these tests, the rate of shearing was slow enough to ensure full dissipation of excess pore water pressure at the time of failure.

Hydrated sodium bentonite clays have also been known to be susceptible to creep. What effect does the long term sustained transmission of shear loads have on the shear strength of a hydrated GCL? This question requires further study.

3.3.1.4 Method of Failure

The type of testing equipment can predetermine the mode of failure of a GCL. A direct shear test would be used to determine the internal shear strength of a GCL, while an inclined tilt table would be used to measure interfacial friction resistance. Finding the tensile or internal shear strength of a stitch bonded or needle punched GCL can be more difficult due to localized stress concentrations caused by the stitching. Direct shear tests have been modified in order to force the failure plane through the stitch or needle punch bonding.

3.3.2 Conclusion

While a lot of time and money can be put into measuring the shear strength of GCLs, this information will not be very effective if it is not interpreted correctly. One must remember that there is a non-linear relationship between normal stress and shear stress at failure (curved failure envelope). Not only are Φ' and c' affected by normal stress, but also by the degree and fluid of hydration. The testing conditions must always be specified when determining the shear strength of a GCL. These testing conditions not only should match anticipated field conditions, but should also be listed with the final results in order that others may understand how to interpret the results.

CHAPTER 4
INTIMATE HYDRAULIC CONTACT WITH GEOMEMBRANE

4.1 Intimate Contact for GCL/Geomembrane Composite Liner Systems (By John Bove, Hazen and Sawyer, P.C.)

The concept of "intimate contact" within composite liner systems for waste disposal and storage facilities is not a new one. The intimate contact approach is intended to minimize the lateral migration of fluid that may pass through defects in the geomembrane, which is typically the upper component of the composite liner. This concept enhances the contribution of the soil liner component of the composite system in minimizing leakage through the liner and discourages the use of a geotextile directly beneath the geomembrane.

Empirical and theoretical analyses of composite liner performance persuasively highlight the advantages of intimate contact. Analyses indicate that the presence of a high transmissivity drainage medium directly below the geomembrane may increase the leakage rate through the liner by several orders of magnitude compared with a composite system with good contact between the components.

4.1.1 In-Situ Behavior of a GCL

Depending on the in situ conditions, the GCL may exhibit behavior similar to anything ranging from a thin geotextile to a compacted soil liner in good contact with the geomembrane. When considering the use of a GCL as a substitute for the compacted soil component, it is important to understand the mechanisms that may interrupt the ability to attain "intimate contact." Possible mechanisms include:

- Excessive transmissivity within the upper GCL geotextile (e. g., an excessively thick upper geotextile)
- Gaps, cracks, or breaks in GCL or at GCL panel ends
- Imperfections in overlapped GCL seams
- Localized wrinkles in GCL and/or geomembrane

- Uneven GCL subgrade surface

If a designer, owner/operator, or regulator believes that the presence of the mechanisms listed above, or any others not listed, will prevent "intimate contact," the use of GCLs in place of soil may be restricted. This provides a challenge to the producers and users of GCLs.

4.1.2 The Case For Geotextile Placement Within a Composite Liner

The use of a thin geotextile between the soil and geomembrane components of the soil liner system, while providing a drainage pathway, can only transmit a finite quantity of fluid that has passed through a geomembrane defect. This quantity is one or two orders of magnitude less than the upper bound theoretical volume predicted by research conducted by the EPA (assuming that the quantity of leachate at a given hydraulic head is always available at the defect location). For thinner geotextiles with relatively low hydraulic transmissivity, the volume of fluid that can be laterally transmitted may be smaller than the quantity of fluid potentially generated by consolidating soils or the dehydration of a GCL.

Even though a quantity of fluid can be transmitted laterally, it must still pass through the bentonite component of a GCL before it can be considered as leakage through the composite liner. For an intact GCL having a hydraulic conductivity in the range of $1x10^{-9}$ to $1x10^{-10}$ cm/s, this is a difficult task. In reality though, the flow through the system is most likely to be controlled by the apparent hydraulic conductivity and transmissivity of GCL seams and defects, rather than the upper layer geotextile alone.

In an effort to increase slope stability, a separate geotextile placed between the geomembrane and the underlying soil liner may actually allow for the dissipation of excess pore water pressures. Thus, an increase in the internal shear strength is realized at the expense of an increase in lateral flow.

4.1.3 Evaluation of Potential Leakage Rates

A significant step in understanding the future role of GCLs in composite liner systems would be to define "intimate contact" in terms that may be measured in the laboratory or the field. Clearly a composite system can allow "some" volume of lateral drainage and still function as intended. The Action Leakage Rate (ALR) quantity of 187 L/hectare/day often used for double lined systems with leak detection layers can provide some perspective on allowable leakage rates per defect.

For the evaluation of localized fluid transmission at the geomembrane/GCL interface (i.e. where "intimate contact" has not been attained), the quantity of leakage through a defect is a function of the hydraulic head, size of the defect, and the properties of the GCL. If a defect having an area of 1 cm^2 is considered with a constant head of 30 cm (1 ft), then the leakage quantity through a GCL specimen is mainly a function of the following GCL properties:

- Initial transmissivity of the upper GCL geotextile
- Rate of hydration of the bentonite
- Extrusion of bentonite into the upper GCL geotextile (i.e. long term transmissivity of the upper GCL geotextile)
- Continuity of the leakage source (i.e. steady state)
- Vertical percolation rate through the GCL (initial and long term)

If it is assumed that bentonite can intrude into the pores of the upper geotextile, the hydraulic transmissivity of that interface will decrease. While the rate of leakage may be initially high, it could decrease with time to a level that is insignificant in terms of the leakage quantities through the composite liner.

4.1.4 Ongoing Research

The issue of whether migrating bentonite can reduce the transmissivity of the upper geotextile has been evaluated in laboratory research funded by the GCL manufacturers. There has been a lot of attention paid to the initial leakage rates as opposed to the longer term rate. With relatively small scale laboratory GCL specimens (150 to 300 mm diameter), the fluid initially introduced to the GCL through the geomembrane defect often flows out of a radial flow device before the GCL can hydrate. If the test specimens were larger in diameter (600 to 1500 mm), it is conceivable that lateral flow from the edge of the specimens would not be observed even from the GCL specimens with the highest initial leakage rate. From a design standpoint, this is the critical behavior to quantify.

To begin to define the role of a GCL in an "intimate contact" composite liner, the investigation of the rates of hydration of larger GCL specimens at the geomembrane interface should be coupled with ongoing research on GCL seams and shrink/swell behavior to estimate the effective radius of saturation of a GCL. This radius will determine the area that has been essentially saturated such that vertical percolation through the bentonite component of the GCL will begin to occur. This area can be used to estimate long term leakage through the composite liner. This is the quantity that is of the greatest concern to the waste industry and will provide the information necessary to evaluate the use of GCLs. If the maximum computed leakage is acceptable, then GCLs can be considered as a replacement for portions of or all of the compacted soil component.

4.2 Questions from the Audience

Upon the conclusion of his lecture, Mr. Bove held a question/answer session where several important topics were discussed.

1) From the point of view of intimate contact, what is the difference between a compacted clay liner and a GCL?

Ans) The use of a GCL potentially introduces an interface that allows flow. The important point though, is how much flow occurs, and can we get sufficiently low flow with either the compacted clay or the GCL?

2) As the upper geotextile of a hydrated GCL is said to be "plugged up" with migrating bentonite, why is there such a concern for the transmissivity of the upper geotextile?

Ans) From a regulatory standpoint, a geotextile is a geotextile whether it is incorporated into a GCL or not. And if the placement of a geotextile beneath a geomembrane is unacceptable, then the same goes for a GCL incorporating an upper layer geotextile. One could make the geotextile thin enough that lateral flow does not become a big issue over time, or one could have the mentality that there is no geotextile that is satisfactory.

While manufacturers and testing companies may claim that once hydrated, a GCL makes good contact with an overlying geomembrane, until this is demonstrated on a full scale sample, some skepticism will remain.

3) Could a layer of condensed water between a geomembrane and a compacted clay liner be a potential pathway for lateral transmission?

Ans) Depending on the overburden stress, it would most likely provide a localized pathway as opposed to a continuous one.

4) Which provides better intimate contact, a smooth or textured geomembrane?

Ans) This is a difficult question that depends on a lot of factors. For example, if one has a very hard compacted clay liner and a textured geomembrane under low normal loading, one could easily imagine high levels of lateral flow if the geomembrane does not penetrate the liner.

5) If the concern revolves around a damaged geomembrane, why not place a thick geotextile or a GCL protection layer on top of the geomembrane in order to prevent damage as it is done in Germany?

Ans) This is a good point in that designers need to get out of the mode that a GCL will just replace the layer of compacted clay. A new design philosophy is necessary to realize the full potential use of a GCL.

4.3 Final Comments

Part of the purpose of displaying ranges of geotextile transmissivity data was to show that the amount of water that can potentially move laterally the geotextile component of a GCL is very small. Furthermore, the distance traveled by this liquid is limited by GCL hydration. Mr. Bove stated that the risk of significant leakage through a GCL in this mode is very small, especially in double composite liner systems.

The question of intimate contact between a geomembrane and a compacted clay liner was raised by several people. It was pointed out that wrinkles in the geomembrane make intimate contact with a compacted clay liner questionable.

CHAPTER 5
OWNER/OPERATOR EXPERIENCES AND CONCERNS

Representatives from four waste disposal companies were given the opportunity to voice their opinions on the use and performance of GCLs. While one company representative was very confident of the ability of GCLs to perform, the others expressed concerns over several technical issues.

5.1 Clarke Lundell, Representing Waste Management of North America, Inc.

Up to now, the use of GCLs has been limited to a backup role. Typically, GCLs are placed as a redundant seepage barrier in secondary liner systems for which only a single geomembrane liner is required. The company is reluctant to make a general statement about whether a GCL can be used alone in the primary liner when no secondary liner is present. This decision would be dependent on the geologic conditions at the site.

There needs to be more information gathered about GCLs. While it appears that the products do work, more work is needed to determine why they work.

Some of the issues that need to be investigated are:

- Intimate contact with a geomembrane
- Frictional properties
- Hydration and swelling
- Quality assurance
- Storage
- Deployment
    - –What equipment should be used?
    - –What about soft subgrade?
    - –Weather factors

5.2 Charles Rivette, Representing Browning-Ferris Industries (BFI)

While GCLs have been used within the company, there is not a general consensus on them yet. If one polled a representative from each of their 100 landfill sites, one would most likely get 100 different answers. Within their sites in the United States, the use of GCLs has mostly been limited to sumps, header pipes, and as secondary containment for leachate and fuel storage. However, in Italy, BFI has some sites in use, or permitted for later use, where a GCL is the primary seepage barrier. The most likely future use of GCLs will be in cover systems used to cap older landfills that were closed in the 1960s.

The company still has some concerns about the products. Some of these concerns are:

- Construction

  –There is still some concern about how to successfully install a GCL. An example was given describing a site in Louisiana where a GCL was installed below an HDPE geomembrane. Before installers could completely seal off the upper geomembrane, a sudden rain storm hydrated the yet unfinished liner. The effort involved in the ensuing clean up and reinstallation was enormous.
- Quality assurance/quality control (QA/QC)

  –QA/QC is not only important for construction, but for the manufacturing of the products, as well.
- Cost

  –Due to the high costs of clay in the Northeast, and along the West coast, GCLs are more likely to be used. In the South and Midwest, where suitable clay is readily available, compacted clay liners are going to continue to be used extensively.
- Interface friction

  –The use of canyons and valleys for landfill sites has become more common. Unfortunately, during interim fill conditions there exists the possibility of a massive wedge failure for bottom slopes of only 2 to 4 %. While they would like to attain a factor of safety of 2 for their designs, they often cannot even achieve a factor of 1.5 when using current interface friction values in their analysis.

  –The values of interfacial friction angles measured so far have been highly variable. They would like to see more repeatability of results.

At the present time, BFI has one site in use and at least three liners in the process of design and/or obtaining a permit where a composite HDPE/GCL system is serving as the primary liner. In each case, the design is necessary due to the lack of local clay soils at the site.

5.3 Kurt Shaner, Representing Chambers Development Company, Inc.

At the present time, Chambers operates or is in the process of permitting 20 municipal solid waste landfills. GCLs are incorporated into the liner system at 10 of these sites. Of these 10, 5 sites are in operation, 3 are permitted with construction ongoing, and 2 are in the permitting process. The most common application of the GCLs has been in the formation of primary composite liners at double lined sites.

While the company views GCLs as a positive development in the area of liner technology, is still has some concerns. Some of these concerns include:

- Quality Assurance Standards

  -Uniform procedures for the QA/QC of the manufacturing and installation of GCLs are needed.
- Shear Strength Determination

  -Repeatable results for the testing of internal and interface friction need to be determined. This testing should account for variables such as normal stress, shear rate, amount of hydration, hydration liquid, etc. Potentially, a data base could be created to correlate between each of the variable parameters and frictional resistance.
- Construction Considerations

  -Some problems with premature hydration have been encountered due to leaking trailers and precipitation events. While not a problem with the performance of the material, it does illustrate a difficulty with the installation of the product.

Perhaps the greatest benefit of the use of GCLs is the ease of their installation compared to CCLs. The installation of GCLs does not require compaction nor the control of moisture content and can be completed in cold weather. The non-applicability of these factors improves the probable quality of an installation, especially when placed to form a primary composite liner.

5.4 John Workman, Representing Laidlaw Waste Systems

Due to the abundance of clay at each of their sites, Laidlaw has never incorporated GCLs into any of their designs. For GCLs to be used at a future date, the reliability of the product will have to be well established. Some of the criteria used to ensure this reliability are discussed below:

- Efficiency
  –The efficiency of a liner system refers to its ability to shed water. Efficiency is a measure of the amount of leachate diverted to a drainage sump versus the amount that percolates through the liner.
- Damage resistance
  –There is the human element of big, bulky equipment being operated at sites. This equipment, if improperly handled, can damage a liner.
- Long term performance
  –Chemical resistance
  –Leakage potential
  –Break through potential
- Constructability
- Availability
  –The company is not opposed to the use of GCLs. It has just always had a readily available source of clay at its sites. There are some sites that do not have clay, and the use of a GCL may be warranted at these sites.

CHAPTER 6
RECENT RESEARCH

Representatives from the University of Texas and Drexel University were given the opportunity to discuss the results of the most recent research undertaken at their respective universities. Research at the University of Texas has tended to focus on large-scale hydraulic conductivity testing and on the stability of final covers. Research at Drexel University has concentrated on the hydration behavior, swelling characteristics, and internal shear strength of GCLs.

6.1 The Hydraulic Conductivity of Large Scale Intact, Overlapped, and Composite Geosynthetic Clay Liners (By David Daniel University of Texas)

The hydraulic conductivity of three 2.8 m^2 geosynthetic clay liners (GCLs) was measured. The apparatus is shown in Fig. 6.1. Tests were performed on Bentomat®, Claymax® 200R, and Gundseal. The GCLs were placed above a drainage medium and covered with 0.3 or 0.6 m of gravel. A constant hydraulic head of 0.3 or 0.6 m was established. Tests were conducted on either a single piece of material (control sample) or on two pieces of material that were overlapped 37 or 75 mm. (Gundseal) or 75 or 150 mm. (Bentomat® and Claymax® 200R). Tests showed that overlapped panels self sealed; flow rates through the overlapped GCLs were about the same as those through the control samples.

A defective high density polyethylene (HDPE) geomembrane was placed on top of samples of GCL material, covered with gravel, and then flooded with water. Effective composite behavior did not occur with those GCLs that contained a geotextile between the defective geomembrane and bentonite but did occur for the GCL in which the defective geomembrane was in direct contact with the bentonite in the GCL.

Further details on this research is provided by Estornell (1991) and Estornell and Daniel (1992).

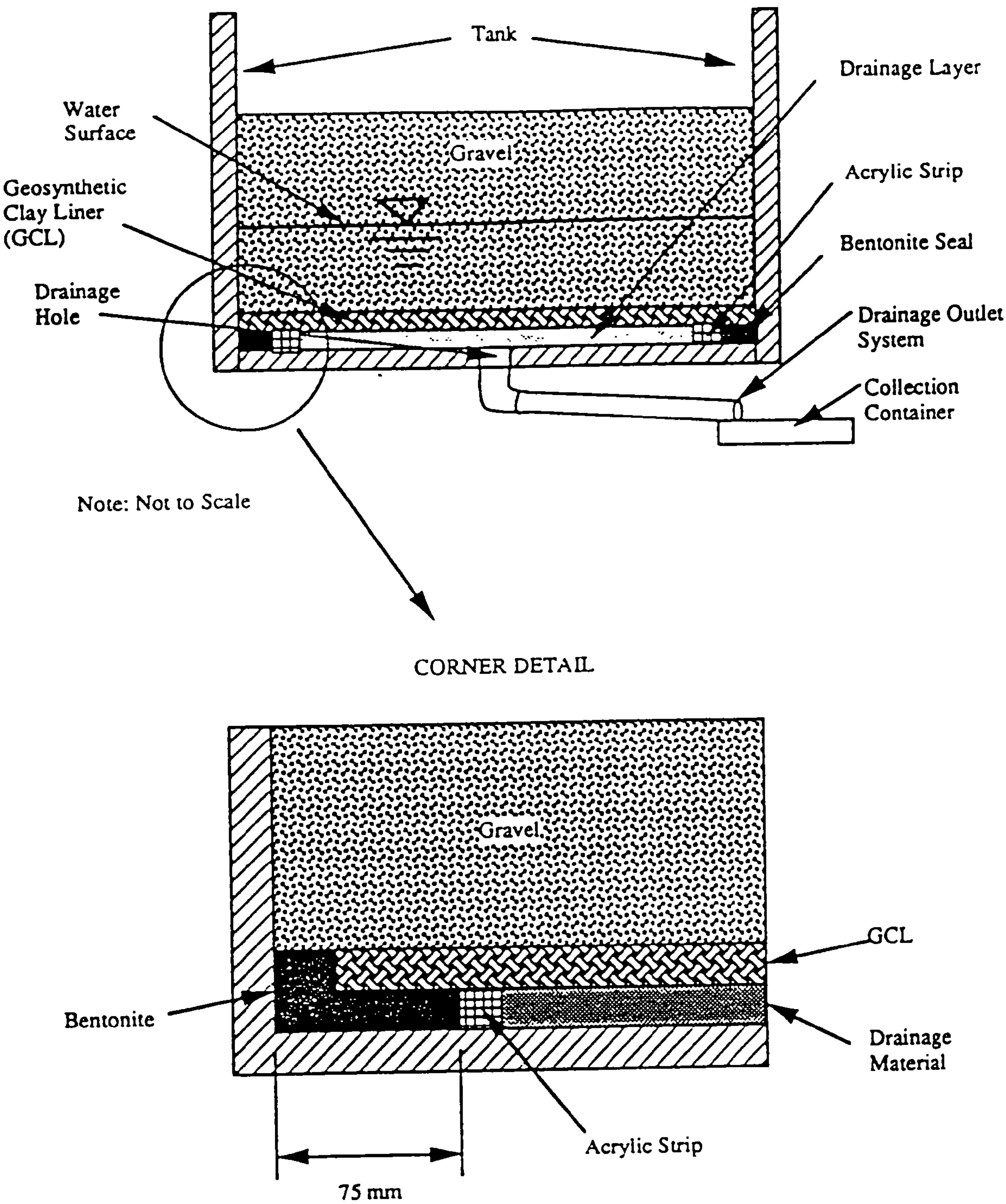


Figure 6.1 Cross Sectional View of Test Set Up

6.2 The Effect of Differential Settlement on the Hydraulic Conductivity of Geosynthetic Clay Liners (By Mark LaGatta and B. Tom Boardman, University of Texas)

One of the more likely future uses of a GCL is as a component in the final cover of a municipal solid waste landfill. Subsidence generally occurs beneath the final cover due to biochemical decay of waste, collapse of underlying materials, or consolidation of saturated waste material. Unlike a wide embankment fill, the landfill will most likely not settle as a uniform mass. There will be localized settlements randomly distributed across the cover. Unfortunately, these localized settlements tend to cause the most damage to a flexible cover due to tensile strains caused by large differential settlement.

In an attempt to determine the effects of settlement on the hydraulic conductivity of a GCL, Mr. LaGatta modified the steel tanks developed originally by Estornell. A wood frame and a large, deflatable, water-filled bladder were placed in the bottom of each tank to allow settlement to occur. By opening a valve beneath each tank, the rate and amount of settlement could be controlled after the installation of the GCL (Fig. 6.2 and 6.3).

Both intact and overlapping samples were tested. A conservative overlap of 225 mm was used. The overlapping samples were aligned with the overlap running parallel to the length of the tank and the deflatable bladder. A non symmetrical bladder was used to ensure one dimensional distortion and tensile strains.

Mr. LaGatta has studied the effects of differential settlement on a hydrated GCL. The full size GCL samples were hydrated within the tank after the GCLs had been covered with 0.6 m of gravel. The valve to the bladder was then opened, and a series of incremental settlements were induced beneath the GCL. The effect of each incremental settlement on the hydraulic conductivity of the deformed GCL was then closely monitored.

Intact and overlapping samples of Bentomat®, Claymax® 200R, and Gundseal were tested. The effective normal stress was approximately 7.6 kPa for each test. The results are shown in Fig. 6.4 through 6.11. There was no measured outflow for either the intact or overlapping samples of Gundseal at any deformation.

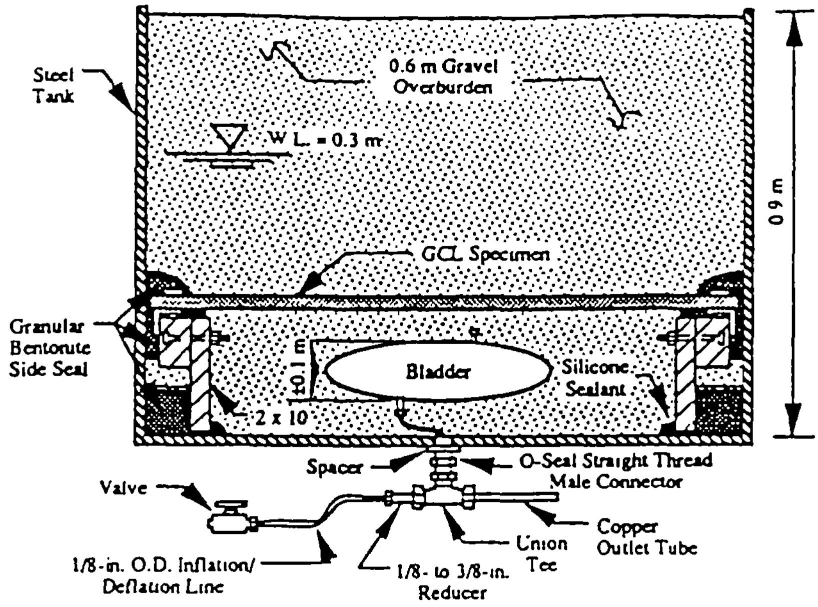


Figure 6.2 Cross Sectional View of Modified Test Set Up

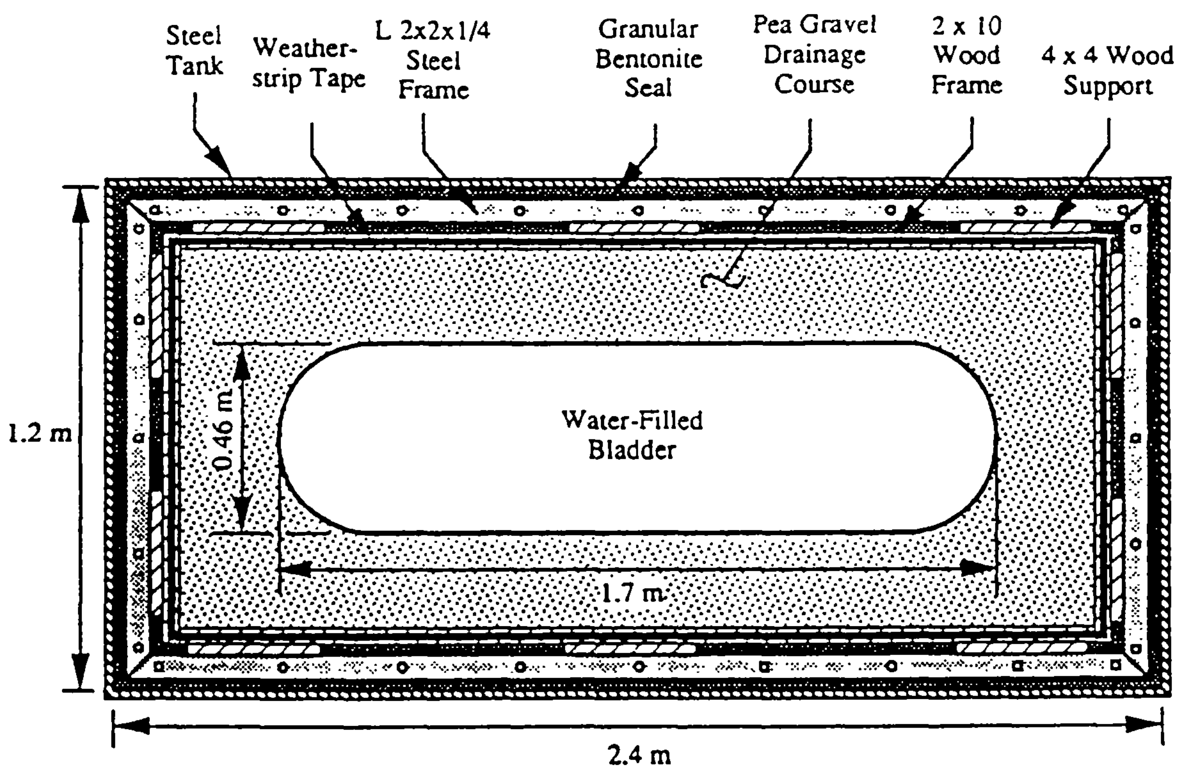


Figure 6.3 Plan View of Tank and Deflatable Bladder

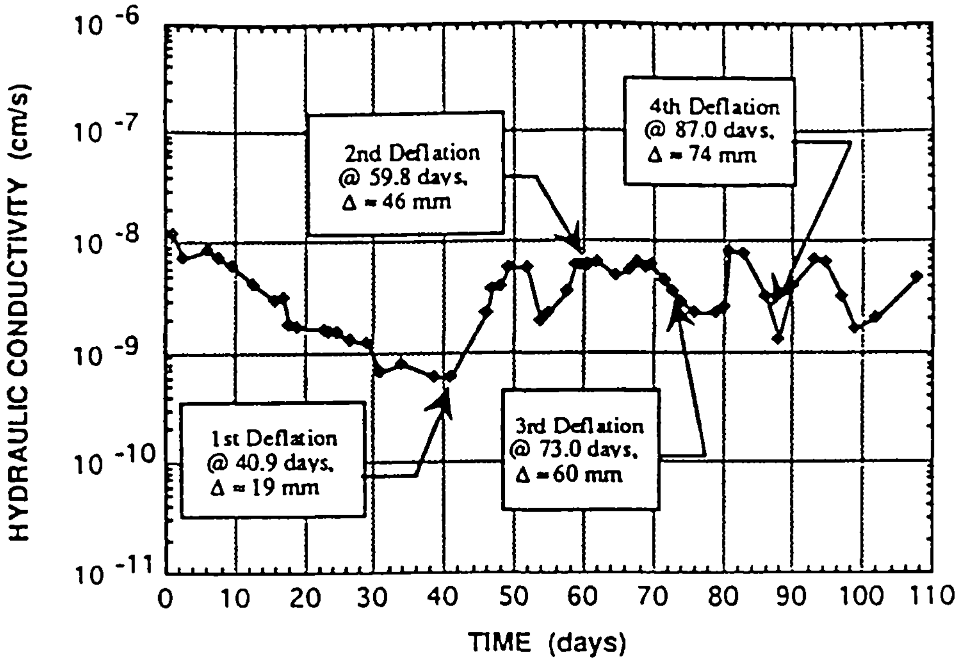


Figure 6.4 Hydraulic Conductivity vs. Time for Intact Bentomat® Sample IHS-2-D

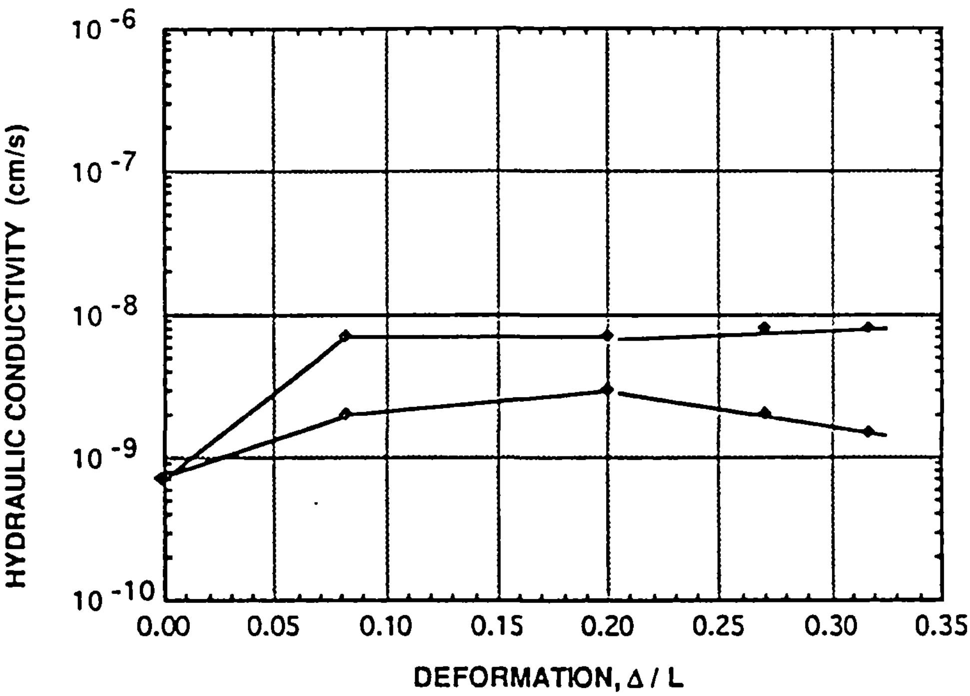


Figure 6.5 Hydraulic Conductivity vs. Deformation for Intact Bentomat® Sample IHS-2-D

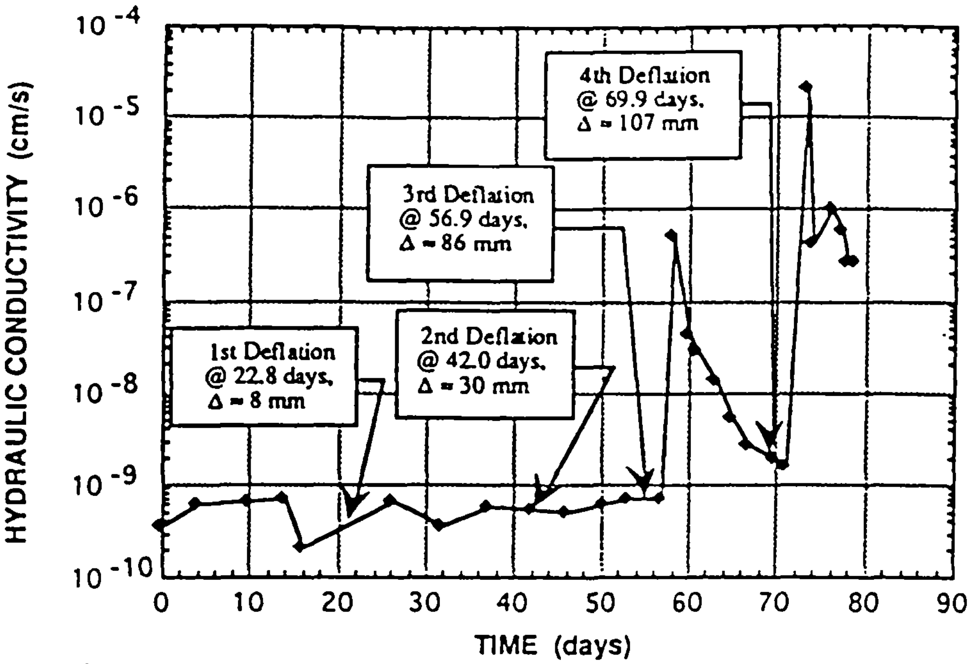


Figure 6.6 Hydraulic Conductivity vs. Time for Overlapped Bentomat® Sample OHS-2-C

Note: Loose 0.25 lb/ft bentonite placed along outer edge of overlap as opposed to centerline of overlap

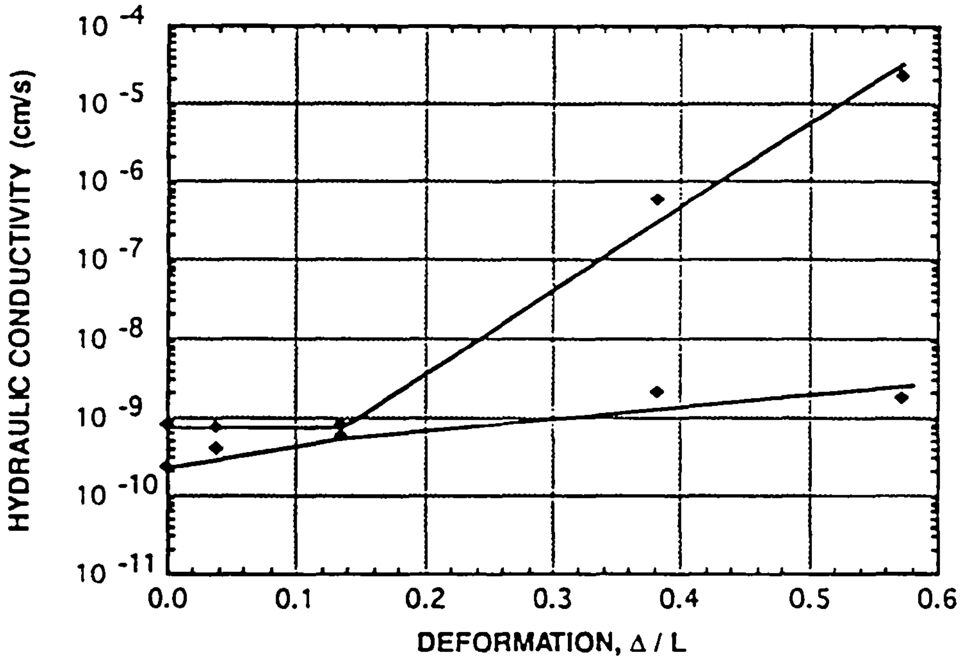


Figure 6.7 Hydraulic Conductivity vs. Deformation for Overlapped Sample OHS-2-C

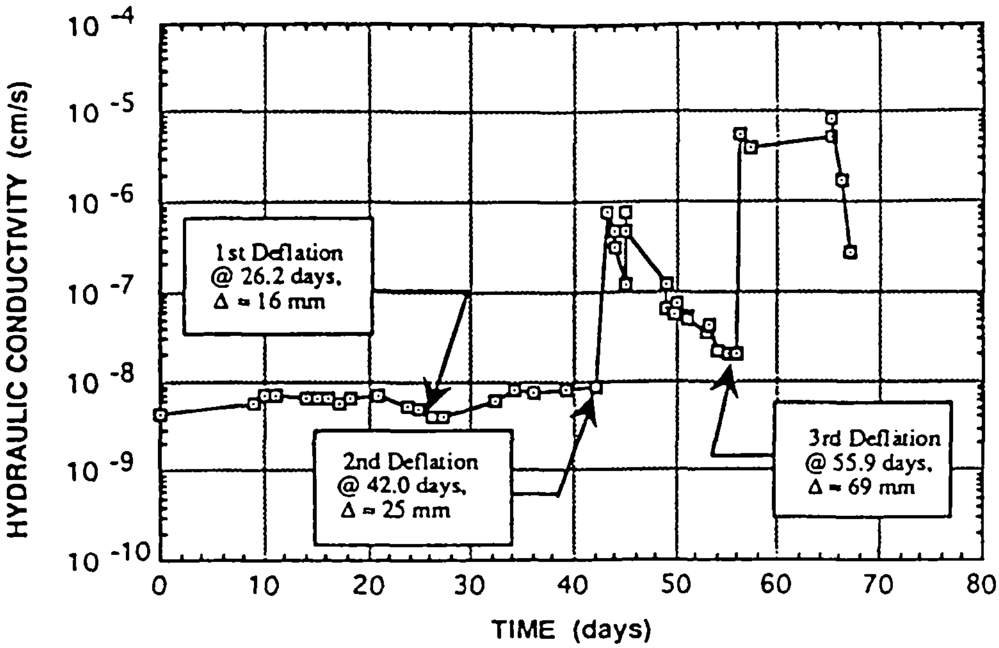


Figure 6.8 Hydraulic Conductivity vs. Time for Intact Claymax® Sample IHS-1-A

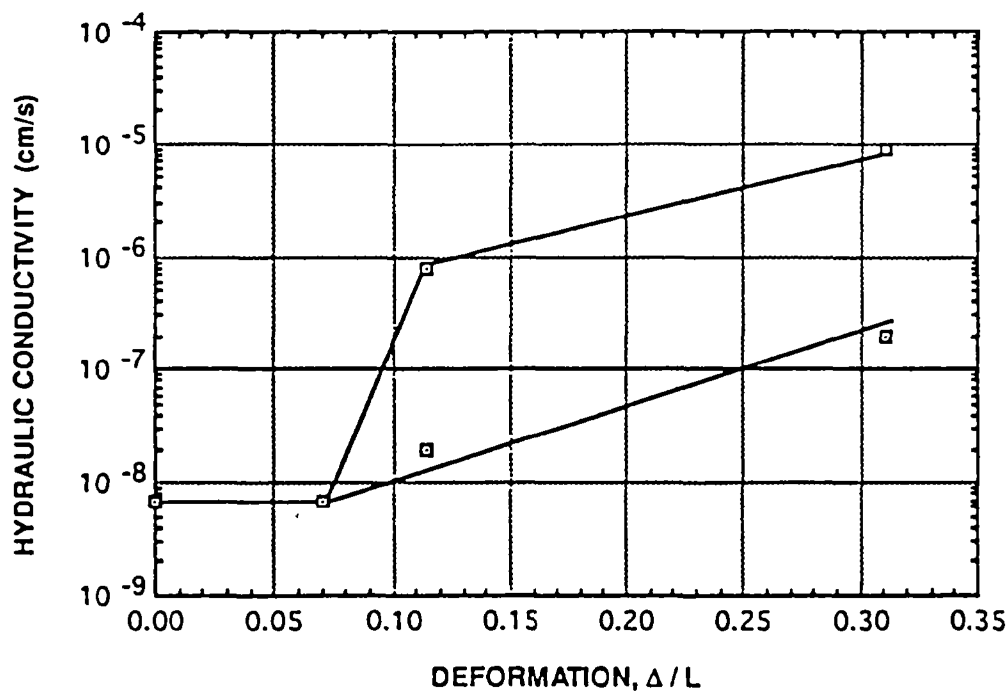


Figure 6.9 Hydraulic Conductivity vs. Deformation for Intact Claymax® Sample IHS-1-A

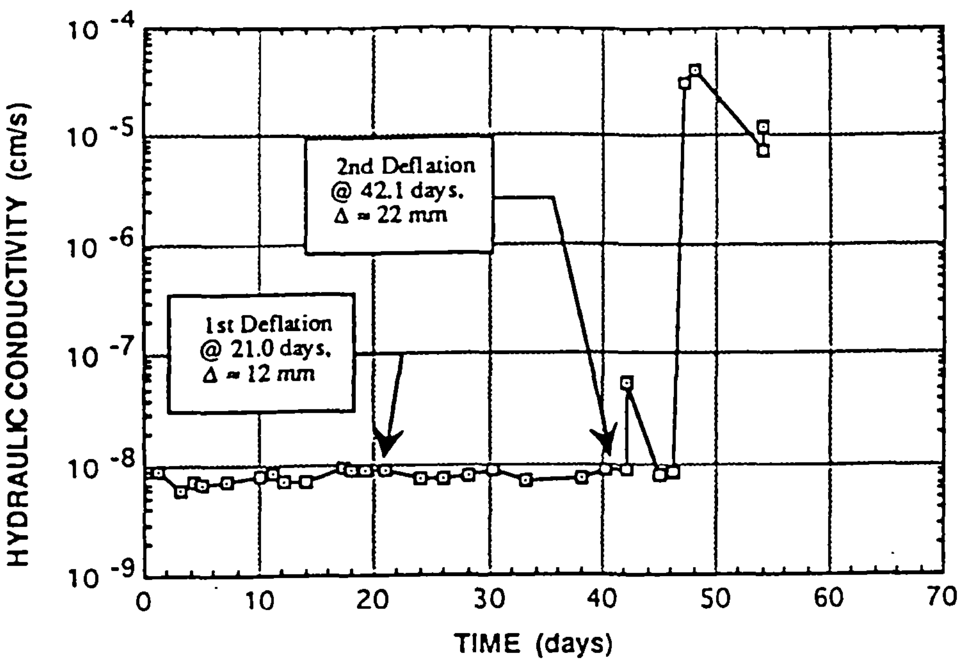


Figure 6.10 Hydraulic Conductivity vs. Time for Overlapped Claymax® Sample OHS-1-F

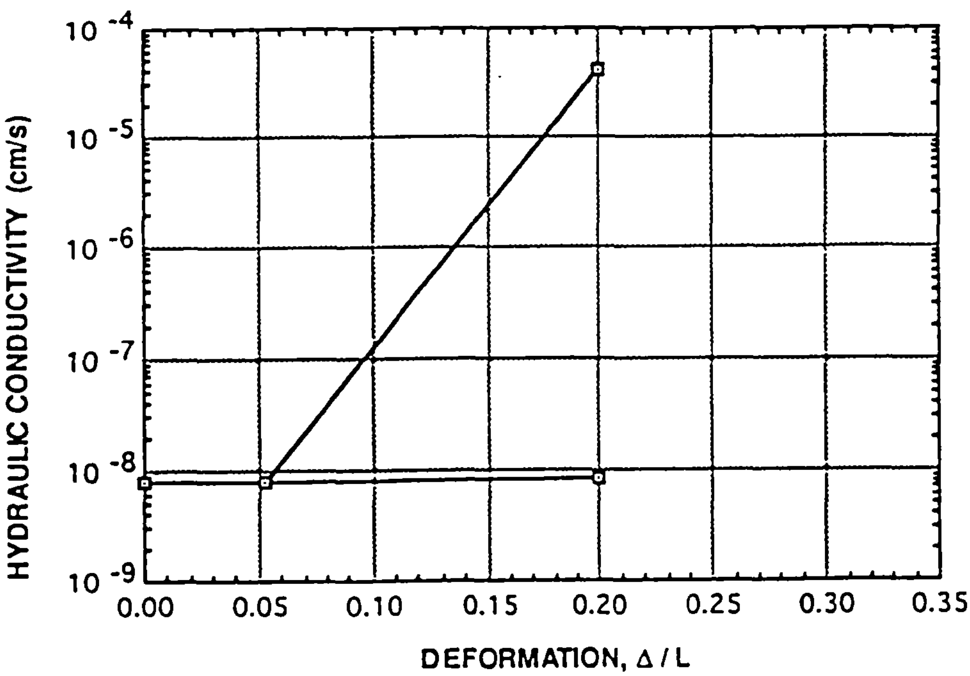


Figure 6.11 Hydraulic Conductivity vs. Deformation for Overlapped Sample OHS-1-F

Mr. Boardman is studying the effects of differential settlement on unhydrated, overlapping GCLs. After the installation of the dry GCL, a large settlement is induced beneath the sample. The deformed GCL is then slowly hydrated over a span of several days. The ability of the deformed sample to self heal at the overlap is then closely monitored. The results of two tests are shown in Fig. 6.12 and 6.13. Both intact and overlapping samples of Bentomat®, Claymax®, and Gundseal will be tested to determine the effect of the overlap. A conservative overlap of 225 mm is being used. More details may be found in LaGatta (1992).

6.3 Stability of Final Covers Placed on Slopes with Geosynthetic Clay Liners (By Hsin-Yu Shan, University of Texas)

There has been some concern about the use of GCLs in sloping final cover systems. Even with geogrid reinforcement, a GCL will lose strength and potentially deform once hydrated. This concern needs to be addressed as GCLs are expected to be more common in final cover systems.

A typical profile of a final cover incorporating a GCL is shown in Fig. 6.14. The current slope design method is the limit equilibrium method. Unfortunately, there is no way to predict the amount of deformation with this method. In an effort to predict this deformation, Mr. Shan developed a numerical model incorporating the properties of the top soil, geogrid, GCL, and cover soil. The profile of the slope used in the model is shown in Fig. 6.15.

The model has been simplified by reducing the number of possible interfacial friction values to the most critical one and by representing the tensile resistance of all of the geosynthetics by one material (a geogrid). The top soil is assumed to be 0.9 m thick and to have a unit weight of 15.7 kN/m^3. For the range of expected normal stresses, Φ' and c' are assumed to be 30° and 4.8 kPa, respectively, for the top soil. The degree of hydration of the GCL can be varied.

The numerical model was developed as a finite element program. Some results of the model are shown in Fig. 6.16 and 6.17. As expected, for a given slope, the lower the minimum interfacial friction angle, the higher the relative displacement, and the higher the tension within the geogrid.

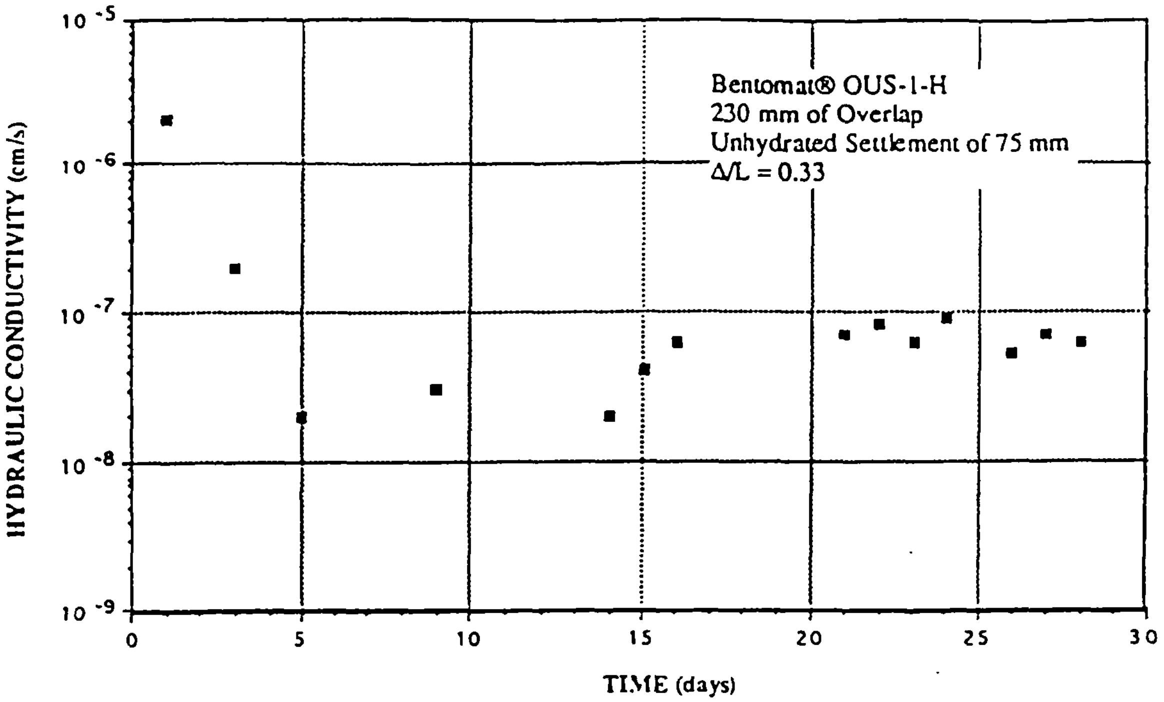


Figure 6.12 Hydraulic Conductivity of Bentomat® after a Large Settlement Prior to Hydration

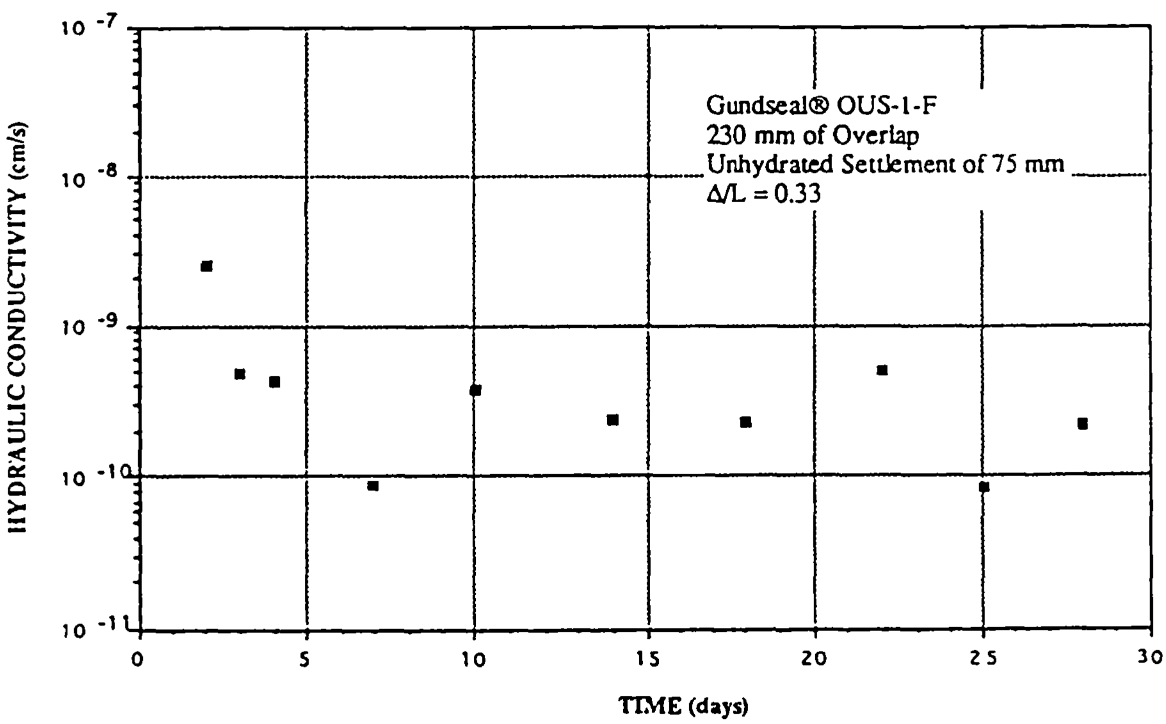


Figure 6.13 Hydraulic Conductivity of Gundseal® after a Large Settlement Prior to Hydration

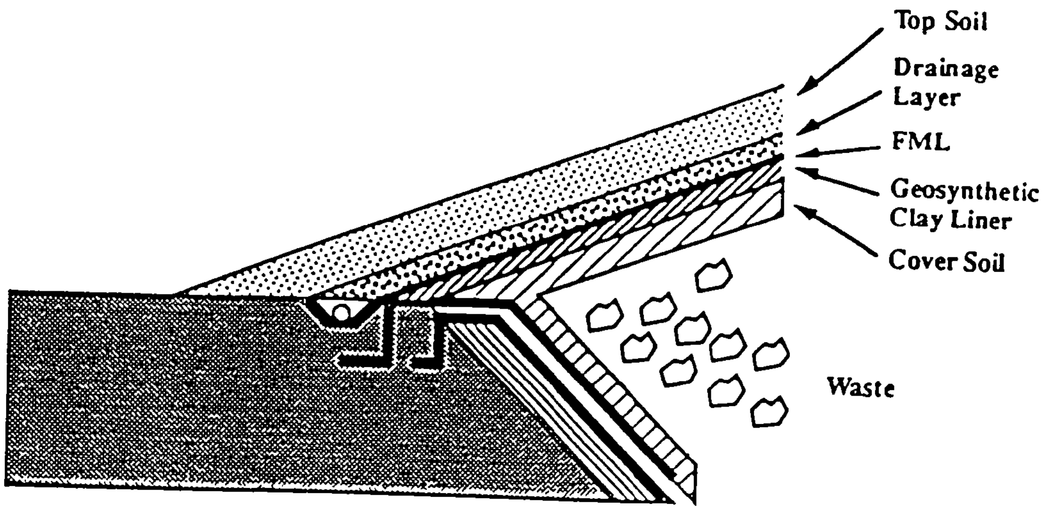


Figure 6.14 Typical Profile of Final Cover with Geosynthetic Clay Liners

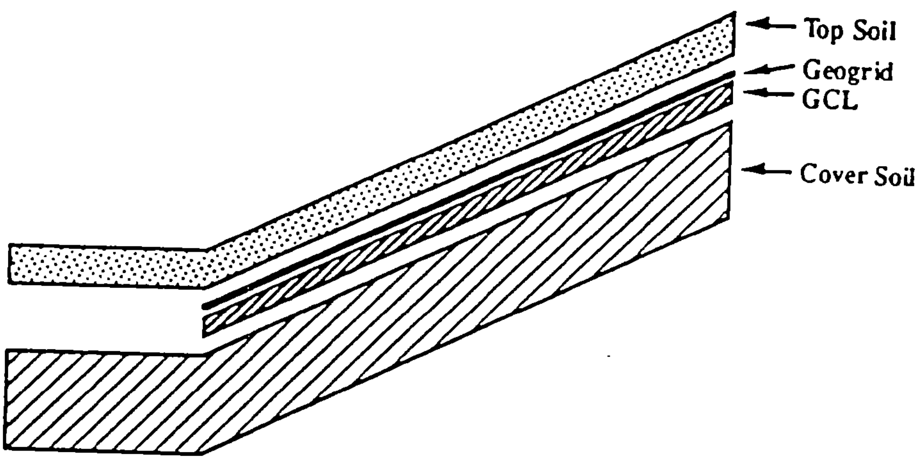


Figure 6.15 Profile of the Slope Used for Computations

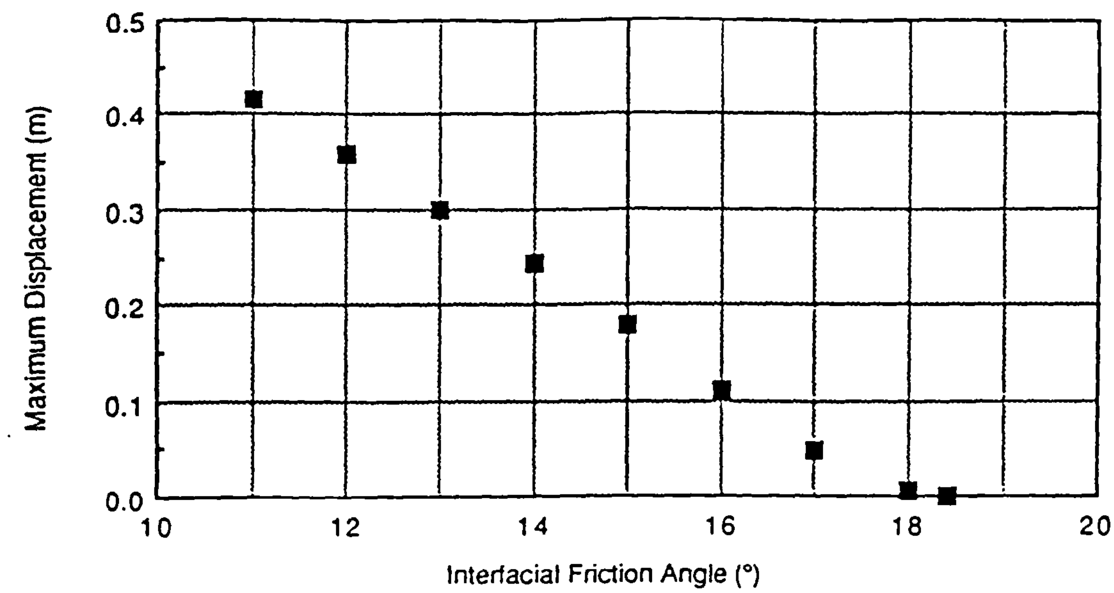


Figure 6.16 Relationship between Maximum Interfacial Displacement and Minimum Interfacial Friction Angle for a 3:1 Slope

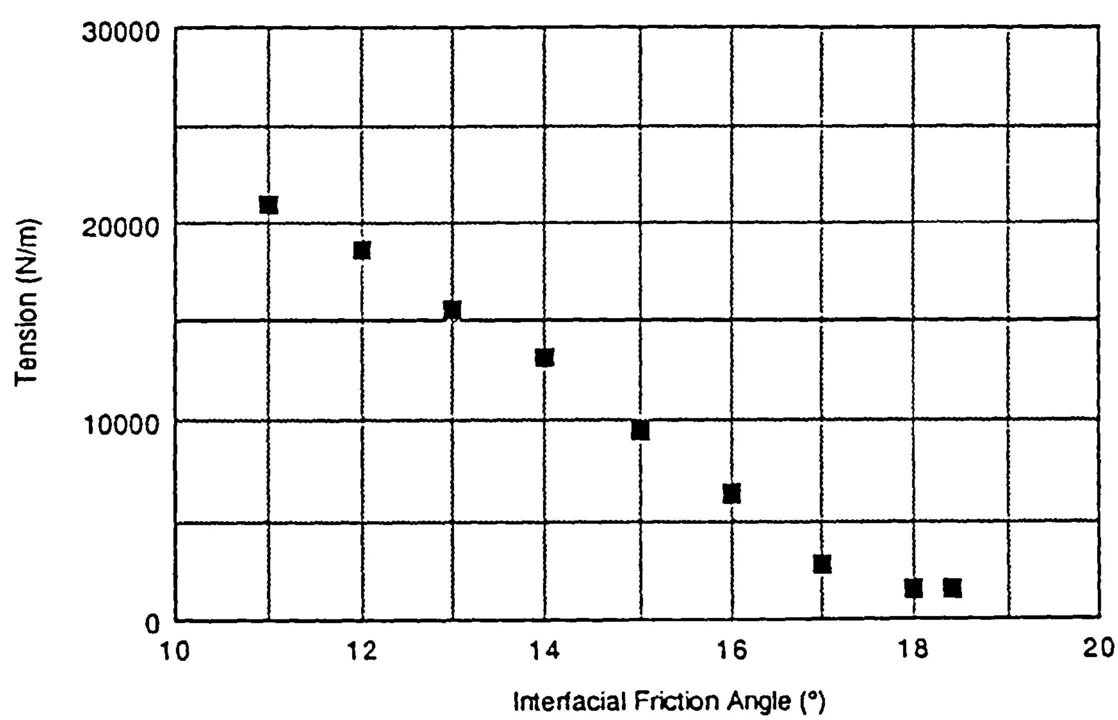


Figure 6.17 Relationship between Tension in the Geogrid and the Minimum Interfacial Friction Angle for a 3:1 Slope

While this analysis is still in its initial stages, it is hoped that by running the model over a range of conditions one can draw conclusions about:

- The probable short and long term shear strength parameters of GCLs
- The possibility of using GCLs on slopes without excessive deformation occurring
- The usefulness of design schemes to reinforce the slope

6.4 The Hydration Behavior and Mid-Plane Shear Strength of Four Geosynthetic Clay Liners (By Robert Koerner, Drexel University)

The focus of GCL research and development at Drexel University's Geosynthetic Research Institute (GRI) is on the hydration behavior of the various products and on their mid-plane shear strength. Work is ongoing with four different commercially available products: Bentofix®, Bentomat®, Claymax®, and Gundseal®. Each of these products have been evaluated in five different liquids: distilled water, tap water, mild leachate, harsh leachate, and diesel fuel.

The first series of tests focused on the hydration behavior under varying normal stresses. These hydration tests were conducted on 150 by 150 mm samples contained in steel boxes with perforated loading plates so that the hydrating liquid was available to hydrate the entire surface area of the test samples. The deformation curves shown in Fig. 6.18 display the following information:

- The products swelled from highest to lowest amounts in the following order: distilled water or tap water, mild leachate, harsh leachate, and diesel fuel
- For a given hydration liquid, Claymax® swells the most, followed by Gundseal®, Bentomat®, and Bentofix® in descending order. Clearly, the needle punching of Bentomat ® and Bentofix® restrained the swelling in these latter two products

Upon completion of the hydration tests, the samples were carefully removed from their respective test devices and trimmed to fit in a 100 by 100 mm direct shear test device. The location of the shear plane was set at the mid-plane of each of the test specimens. The test specimens were sheared at a strain rate of

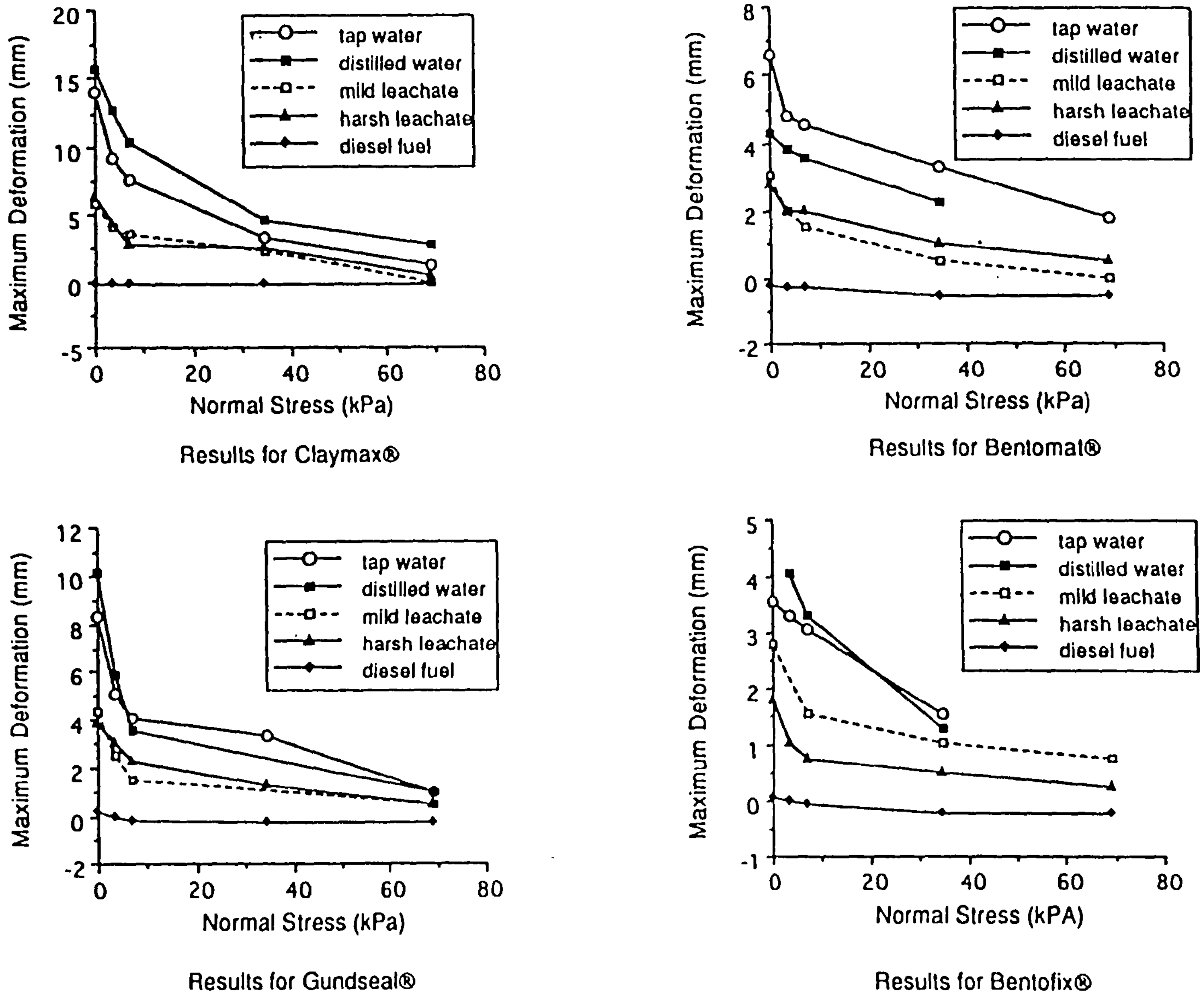


Figure 6.18 Hydration of GCLs Using Different Liquids

0.9 mm/min and were designated as "constrained-swell" tests. Direct shear tests were conducted on all samples and counterpointed against parallel sets of tests in the dry (or as received) state and also against "free-swell" tests in which the test specimens were hydrated in the same liquids but without any normal stress. The direct shear tests produced the shear strength parameters Φ and c shown in Table 6.1. The data indicate the following trends.

- The products are strongest in the dry "as-received" condition and the weakest in the free-swell condition. The constrained-swell condition is intermediate between the two extremes.
- Needle-punching significantly increases shear strength.
- The hydrating liquid can affect strength.
- Hydration with distilled water yields the lowest shear strength and can be used as a conservative liquid.
- Products with fiber reinforcement required much larger displacements than unreinforced products to reach their limiting shear stress.

Table 6.1 . Direct Shear Test Results Summary (Drexel University)

Hydrating Fluid	GCL Type	Measured Property	Dry*	Constrained Swell**	Free Swell***
Distilled Water	Claymax	Ø (degrees)	37	16	0
		C(kPa)	6.9	3	4
	Gundseal	Ø (degrees)	26	19	0
		C(kPa)	50	5	3
	Bentomat	Ø (degrees)	42	37	23
		C(kPa)	14	6	5
	Bentofix	Ø (degrees)	36	31	10
		C(kPa)	68	7	9.0
Tap Water	Claymax	Ø (degrees)	37	18	0
		C(kPa)	6.9	3	3
	Gundseal	Ø (degrees)	26	18	0
		C(kPa)	50	5	3
	Bentomat	Ø (degrees)	42	43	26
		C(kPa)	14	6	10
	Bentofix	Ø (degrees)	36	34	15
		C(kPa)	68	6.9	7
Mild Leachate	Claymax	Ø (degrees)	37	24	4
		C(kPa)	6.9	6	3
	Gundseal	Ø (degrees)	26	18	13
		C(kPa)	50	5	4
	Bentomat	Ø (degrees)	42	39	25
		C(kPa)	14	8.3	14
	Bentofix	Ø (degrees)	36	43	20
		C(kPa)	68	5	12
Harsh Leachate	Claymax	Ø (degrees)	37	19	0
		C(kPa)	6.9	6	3
	Gundseal	Ø (degrees)	26	13	0
		C(kPa)	50	7.6	3
	Bentomat	Ø (degrees)	42	45	32
		C(kPa)	14	5	12
	Bentofix	Ø (degrees)	36	39	30
		C(kPa)	68	4	8.3
Diesel Fuel	Claymax	Ø (degrees)	37	44	38
		C(kPa)	6.9	4	6
	Gundseal	Ø (degrees)	26	24	29
		C(kPa)	50	4	6
	Bentomat	Ø (degrees)	42	42	40
		C(kPa)	14	6	5
	Bentofix	Ø (degrees)	36	51	46
		C(kPa)	68	4	5

Notes:

- * Dry refers to product as-received, placed under desired normal stress, then sheared at midplane.
- ** Constrained swell refers to product hydrated under desired normal stress, i.e., constrained swell, then sheared at midplane.
- *** Free swell refers to product hydrated under zero normal stress, then placed under desired normal stress, and then sheared at midplane.

CHAPTER 7
EQUIVALENCY

7.1 Equivalency (By David Daniel, University of Texas)

7.1.1 Potential Applications

If one wants to substitute a geosynthetic clay liner (GCL) for a required compacted clay liner (CCL), one will generally have to demonstrate that the proposed GCL will provide equivalent or better performance to a CCL. Equivalency analyses may be required for:

- Final Cover Systems:
  - Single GCL Versus Single CCL Liner
  - Geomembrane/GCL Composite Liner Versus Geomembrane/CCL Composite Liner

- Single Liner Systems:
  - Single GCL Versus Single CCL Liner
  - Geomembrane/GCL Composite Liner Versus Geomembrane/CCL Composite Liner

- Double Liner Systems:
  - Geomembrane/GCL Composite Liner Versus Geomembrane/CCL Composite Liner in Primary Liner
  - Geomembrane/GCL Composite Liner Versus Geomembrane/CCL Composite Liner in Secondary Liner

The Solid Waste Disposal Facility Criteria found at 40 CFR Part 258 apply to municipal solid waste landfills and treat the area of "equivalency" differently for final covers and liners. Final cover systems are to be designed to minimize infiltration and erosion, therefore, designs other than the minimum requirements of §258.60 (a) could be approved using an "equivalency" demonstration. However, alternatives to the composite liner design in §258.40 (a) (2) are not approved based on "equivalency" demonstrations but must meet the performance standard at §258.40 (a) (1). Different standards apply to facilities that receive hazardous waste regulated under Subtitle C of RCRA and to CERCLA clean-up sites.

The designs for Subtitle C and CERCLA are evaluated based on the site-specific design. Innovative use of modern materials is encouraged, providing they meet the requirements of the law.

7.1.2 Differences Between CCLs and GCLs

Some of the differences between compacted clay liners and geosynthetic clay liners are listed in Table 7.1. Some of the potentially important (depending upon specific application) relative advantages of CCLs and GCLs may be summarized as follows:

- Advantages of compacted clay liners (CCLs):
  - The large thickness of CCLs makes them virtually puncture proof
  - The large thickness of CCLs makes them relatively insensitive to small imperfections in any one lift
  - The large thickness of CCLs gives them substantial capacity for adsorption of leachate
  - The large thickness of CCLs delays the discharge of water and solutes from the base of liners
  - There is a long history of use of CCLs
  - Intimate hydraulic contact with a geomembrane is not an issue for CCLs
  - Many regulatory agencies require CCLs; use of another type of liner may require demonstration of equivalency to a CCL.
  - A CCL is a logical choice if suitable clay is available locally
  - Testing procedures are reasonably well established for CCLs.

- Advantages of geosynthetic clay liners (GCLs):
  - Small thickness of GCLs leads to low consumption of space
  - Construction of GCLs is rapid and simple
  - Heavy equipment is not needed to install a GCL, which is beneficial if the GCL is underlain by a geosynthetic material

Table 7.1 Differences Between GCLs and CCLs

Characteristic	Geosynthetic Clay Liner	Compacted Clay Liner
Materials	Bentonite Clay, Adhesives, Geotextiles, and Geomembranes	Native Soils or Blend of Soil and Bentonite
Construction	Manufactured and Then Installed in the Field	Constructed in the Field
Thickness	Approximately 10 mm	Approximately 0.5 to 1.0 m
Hydraulic Conductivity of Clay	10^{-10} to 10^{-8} cm/s (Typical)	10^{-8} to 10^{-7} cm/s (Typical)
Speed and Ease Construction	Rapid, Simple Installation	Slow, Complicated Construction
Water Content at Time of Construction	Essentially Dry; Cannot Desiccate During Construction and Produces No Consolidation Water	Nearly Saturated; Can Desiccate and Can Produce Consolidation Water
Cost	$5 to $11 per Square Meter	Highly Variable (Estimated Range: $8 to $32 per Square Meter)
Experience Level	Limited Due to Newness	Has Been Used for Many Decades

- Some inclement weather delays (e.g., freezing temperatures) that stop construction of CCLs are not experienced with GCLs
- Because a GCL is a manufactured material, a consistent and uniform material can be produced
- Because GCLs are manufactured materials many of the specialized performance properties can be determined and need not be repeatedly re-determined
- GCLs can accommodate large differential settlement
- Quality assurance is simpler for a GCL compared to a CCL
- GCLs are more easily repaired than CCLs
- GCLs can probably better withstand freeze/thaw and wet/dry cycles than CCLs
- Unlike CCLs, GCLs are not vulnerable to desiccation damage during construction

7.1.3 Criteria for Equivalency

Three issues should be addressed when one compares a GCL to a CCL and considers the equivalency of a GCL to a CCL:

1. Hydraulic issues
2. Physical/mechanical issues
3. Construction issues

The specific issues that might have to be addressed for a specific site are listed in Table 7.2.

7.1.4 Hydraulic Issues

Hydraulic issues are the easiest to quantify. The criteria are discussed separately.

7.1.4.1 Steady Flux of Water

Flux of water is usually assessed by comparing the long-term, steady state water flux for the CCL and GCL. The flux of water (v) through an individual layer of porous material is defined from Darcy's Law as:

Table 7.2 Potential Equivalency Issues

Category	Criterion for Evaluation	Relevant for: Liners	Covers
Hydraulic Issues	Steady Flux of Water	X	X
	Steady Solute Flux	X	
	Adsorption Capacity	X	
	Breakout Time:		
	-Water	X	X
	-Solute	X	
	Production of Consolidation Water	X	X
Physical/ Mechanical Issues	Freeze-Thaw	X*	X
	Wet-Dry		X
	Total Settlement	X**	X
	Differential Settlement	X**	X
	Slope Stability	X***	X
	Erosion		X
	Bearing Capacity	X	
Construction Issues	Puncture Resistance	X	X
	Subgrade Condition	X	X
	Ease of Placement	X	X
	Speed of Construction	X	X
	Availability of Materials	X	X
	Weather Constraints	X	X
	Quality Assurance	X	X

Notes:

* Relevant only until liner is covered sufficiently to prevent freezing
** Settlement of liners usually of concern only in certain circumstances, e.g., vertical expansions
*** Stability of liner may not be relevant after filling (except canyon landfills)

$$v = k\,\frac{H+L}{L} \tag{7.1}$$

where k is the hydraulic conductivity, H is the depth of liquid ponded on the liner, and L is the thickness of the liner. The water pressure on the base of the liner is assumed to be zero in Eq. 7.1.

For a GCL, Eq. 7.1 is applicable only for flow through the bentonite component; if the GCL contains a geomembrane, water flux will be controlled by water vapor diffusion through the geomembrane component. The geomembrane component, if present, should be considered in the equivalency analysis and in computation of water flux. Also, Eq. 7.1 applies to a CCL or GCL liner alone; composite action with a geomembrane is considered later.

The flux ratio for water, F_W, is defined as:

$$F_w = \frac{v_{GCL}}{v_{CCL}} \tag{7.2}$$

or:

$$F_w = \frac{k_{GCL}\,\dfrac{H+L_{GCL}}{L_{GCL}}}{k_{CCL}\,\dfrac{H+L_{CCL}}{L_{CCL}}} \tag{7.3}$$

For example, for a GCL without a geomembrane component, if:

$k_{GCL} = 1 \times 10^{-9}$ cm/s $= 1 \times 10^{-11}$ m/s
H = 0.3 m (1 ft)
L_{GCL} = 7 mm = 0.007 m
$K_{CCL} = 1 \times 10^{-7}$ cm/s $= 1 \times 10^{-9}$ m/s
L_{CCL} = 0.9 m (3 ft)

then F_W from Eq. 7.3 equals 0.3. So long as $F_W \leq 1$, equivalency in terms of water flux is demonstrated, i.e., the rate of water flow through the GCL is less than or equal to that through the CCL. Most GCLs can be shown to be equivalent to a CCL that has a hydraulic conductivity of 1×10^{-7} cm/s in terms of steady water flux. If the GCL contains a geomembrane, the flux ratio will be even less than that computed from Eq. 7.3.

A composite liner consists of a geomembrane placed in contact with a low-permeability soil. A geomembrane/GCL composite may be considered as an alternate to a geomembrane/CCL composite. If so, flow through the composite should be analyzed. Flow through a flaw in a geomembrane in a composite liner depends on the hydraulic conductivity of the clay component, the hydraulic gradient across the clay component, the hydraulic contact between the geomembrane and the clay component, and the presence of a geomembrane within the GCL. No equations have been published for computing flow rates through a defect in a geomembrane component of a geomembrane/GCL composite liner. However, published information can be used to make comparative estimates. Equivalency evaluations would clearly be product and perhaps site specific.

7.1.4.2 Steady Solute Flux

The maximum flux is the steady-state flux. Long-term, steady solute flux, which is relevant only for liners, may be analyzed on the basis of advection alone, diffusion alone, or advection plus diffusion. As will be seen later, the assumptions necessary to analyze steady diffusion and steady advection-plus-diffusion are inconsistent with the processes themselves, and only the case of advection is relevant for steady-state conditions. Nevertheless, for completeness, the methods for analyzing steady diffusion and steady diffusion-plus-advection are presented so that these processes can be understood.

It is assumed that the concentration of a solute of concern in the leachate remains constant. The advective mass flux, $v_{m,A}$, is:

$$v_{m,A} = c_{leachate}\, k \frac{H + L}{L} \tag{7.4}$$

where $c_{leachate}$ is the concentration of the solute of interest in the leachate. The advective mass flux ratio, $F_{m,A}$ is defined as:

$$F_{m,A} = \frac{v_{m\ A(GCL)}}{v_{m\ A(CCL)}} \tag{7.5}$$

or:

$$F_{m,A} = \frac{q_{leachate}\, k_{GCL}\, \dfrac{H + L_{GCL}}{L_{GCL}}}{q_{leachate}\, k_{CCL}\, \dfrac{H + L_{CCL}}{L_{CCL}}} \tag{7.6}$$

or:

$$F_{m,A} = \frac{k_{GCL}\, \dfrac{H+L_{GCL}}{L_{GCL}}}{k_{CCL}\, \dfrac{H+L_{CCL}}{L_{CCL}}} = F_w \tag{7.7}$$

It is noted that $q_{leachate}$ cancels out of Eq. 7.6. Because $F_{m,A} = F_w$ (Eq. 7.7), if one has demonstrated equivalency of steady water flux, one has also demonstrated equivalency of steady mass flux of solute caused by advection.

Solutes in leachate can also migrate through clay liners by molecular diffusion. Steady diffusion of solutes is usually analyzed with Fick's first law, which states that:

$$v_D = D\ \theta\ \frac{\Delta c}{L} \tag{7.8}$$

where v_D is the diffusive mass flux, D is the diffusion coefficient for the solute of interest, θ is the volumetric water content, Δc is the difference in concentration of the solute between the top and bottom of the liner, and L is the thickness of the liner.

The diffusive mass flux ratio ($F_{m,D}$) is defined as

$$F_{m,D} = \frac{F_{m\,D(GCL)}}{F_{m\,D(CCL)}} \tag{7.9}$$

or:

$$F_{m,D} = \frac{D_{GCL}\, \theta_{GCL}\, \dfrac{\Delta c}{L_{GCL}}}{D_{CCL}\, \theta_{CCL}\, \dfrac{\Delta c}{L_{CCL}}} \tag{7.10}$$

or:

$$F_{m,D} = \frac{D_{GCL}}{D_{CCL}} \frac{\theta_{GCL}}{\theta_{CCL}} \frac{L_{CCL}}{L_{GCL}} \tag{7.11}$$

Limited data exist on diffusion coefficients in clay liners. Data developed for compacted kaolinite at the University of Texas indicate that $D \approx 6 \times 10^{-10}\ m^2/s$ for the non-reactive solute chlorine. For one GCL tested, the diffusion coefficient for the bentonite in the GCL was approximately $2 \times 10^{-10}\ m^2/s$. If, for example, one assumes:

$$\frac{D_{GCL}}{D_{CCL}} = \frac{2 \times 10^{-10}}{6 \times 10^{-10}} = 0.33$$

$$\frac{\theta_{GCL}}{\theta_{CCL}} = \frac{0.6}{0.4} = 1.5$$

$$\frac{L_{CCL}}{L_{GCL}} = \frac{0.9\ m}{0.007\ m} = 129$$

then one computes a diffusive mass flux ratio of:

$$F_{m,D} = (0.33)\,(1.5)\,(129) = 64$$

In this example, the GCL is not equivalent to the CCL since there would be more diffusive mass flux through the GCL than CCL. In general the calculated steady, diffusive mass flux through the bentonite within the GCL is always expected to be greater than the steady, diffusive mass flux through the CCL. However, for those GCLs that have a geomembrane component, the geomembrane, which has an extremely low diffusion coefficient for most solutes, should be considered and will tend to greatly reduce the steady, diffusive mass flux.

As mentioned earlier, the assumptions necessary for computing steady diffusive flux are inconsistent with the process itself. The problem is that a contradiction exists in the boundary conditions. Diffusion is driven by a concentration gradient, Δc. Over time, the solute of interest in the leachate will diffuse to the base of the liner, and the concentration at the base of the liner will eventually equal the concentration on top of the liner, i.e., the concentration in the leachate (which is assumed to be constant). Thus, the diffusion-driving concentration gradient becomes zero and diffusive transport ceases. The only way that steady diffusion could develop through a liner would be for fresh water to continually flush the underside of the liner to maintain a concentration gradient across the liner. For nearly all sites, the case of steady diffusion will be irrelevant and need not be considered.

It may be argued that neither advection alone nor diffusion alone is important -- solutes will migrate through soil liners by advection plus diffusion. The total mass flux due to advection plus diffusion ($v_{m,A+D}$) is generally assumed to be:

$$v_{m,A+D} = v_{m,A} + v_{m,D} \tag{7.12}$$

and the ratio of advective plus diffusive mass flux, $F_{m,A+D}$, may be defined as:

$$F_{m,A+D} = \frac{v_{m\ A+D\ (GCL)}}{v_{m\ A+D\ (CCL)}} \tag{7.13}$$

Although Eq. 7.13 can be applied, it should not be applied because the assumed conditions are physically impossible for long-term, steady conditions. If advection carries solutes downward through the liner, then at steady state the base of the liner must necessarily be saturated with leachate. If the base is saturated with leachate, then $\Delta c = 0$ and $v_{m,D} = 0$. Thus, when one analyzes long-term, steady mass flux of a solute through a GCL or CCL, only advective transport need generally be considered.

In some cases, one may wish to analyze transient conditions that lead up to steady conditions, in which case both advective and diffusive transport should be considered. If the GCL contains a geomembrane, the presence of the geomembrane should be taken into account.

7.1.4.3 Adsorption Capacity

The adsorption capacity of a clay liner may be relevant only for liners (not covers). Regulations generally have no specific adsorption requirements.

Adsorption of organics tends to be different from adsorption by inorganics. Adsorption of inorganics is controlled by cation exchange reactions and geochemical processes such as precipitation. Adsorption of organic solutes is generally assumed to be controlled by the amount of organic carbon in the soil and a partition coefficient for the solute (which is characterized by the octanol-water partition coefficient or water solubility of the organic species).

For inorganics, the maximum adsorbed mass per unit cross-sectional area of liner (C) resulting from cation exchange processes may be defined as follows:

$$C = CEC\,\rho_d\,L \tag{7.14}$$

where CEC is the cation exchange capacity (maximum mass of solute sorbed per unit mass of dry soil), ρ_d is the dry mass density of the soil, and L is the thickness of the liner. The ratio of thickness of a typical GCL to a CCL is small (on the order of 0.01). Thus, in order for a GCL to have equivalent cation adsorption capacity to a CCL, the adsorption coefficient of the GCL would have to be at least 100 times that of the CCL.

The cation exchange capacity of bentonite clay is typically on the order of 100 to 150 meq/100g. Natural soil materials used to construct CCLs have typical CECs in the range of 3 to 30 meq/100g. The ratio of cation adsorption capacities, denoted F_{CEC}, is:

$$F_{CEC} = \frac{C_{GCL}}{C_{CCL}} = \frac{CEC_{GCL}}{CEC_{CCL}}\,\frac{\rho_{d\,GCL}}{\rho_{d\,CCL}}\,\frac{L_{GCL}}{L_{CCL}} \tag{7.15}$$

For the typical range of values, F_{CEC} would be expected to be in the range of 0.03 to 0.75. It appears unlikely that equivalency can be demonstrated for cation adsorption capacity using the expressions just presented. However, it must be understood that adsorption of inorganic species is a complex process. Cation exchange is just one of several processes that can affect adsorption. Precipitation of inorganic solutes can be a far more important mechanism than cation exchange, and pH is often a dominant variable controlling precipitation processes in many geochemical environments. Thus, site-specific factors, and not just simple comparisons of CECs and relative soil masses, will often need to be considered when relative adsorption capacities are compared.

Non-polar organic solutes are sorbed by carbon present in the soil. The carbon content of bentonite in GCLs is capable of estimation, but CCLs will be highly variable in their organic carbon content. Although site-specific assessments would be required (due to variability of CCLs), equivalency of a GCL to a CCL probably cannot be demonstrated in terms of capacity to adsorb non-polar constituents in leachate to the bentonite because the mass of bentonite present in a GCL is far less than the mass of soil present in a CCL.

Adsorption is only relevant in the short term. When steady state mass transport is reached, adsorption capacity is exhausted. Equivalency in terms of adsorption, if evaluated at all, should be evaluated in terms of a specified performance period. For example, suppose the performance period being considered is 30 years. If the adsorption capacity of neither the CCL nor the GCL is exhausted after 30 years, both types of liner have "reserve" adsorption capacity and may be considered equivalent for the performance period. Alternatively, if either or both is exceeded, breakthrough of solute will occur and other issues, e.g., steady state solute flux, will require consideration.

7.1.4.4 Time to Initiate Discharge of Water from Base of Liner

GCLs are initially unsaturated with water whereas CCLs are often very close to saturation. When liquid first enters the upper surface of the liner, no liquid initially discharges from the base of the liner. The GCL might be compared to the CCL in terms of time to achieve discharge of water from the bottom of the liner. Again, for those GCLs that contain a geomembrane, the presence of the geomembrane should be taken into account.

The time to achieve discharge of water from the base is difficult to describe in general terms. For CCLs, the time depends greatly upon the hydraulic conductivity, initial water content, and tendency to swell. For GCLs, the time is usually fairly short (a few weeks), although for GCLs that contain a geomembrane, the time may be much greater. A comparison of time to initiate discharge of water from the base of the liner would have to be performed on a site specific basis.

The time to initiate discharge of water from the base of a liner is not relevant in the long term and often will not be relevant even in the short term. Most designs assume that water will be discharged from the base of a liner and do not make any assumptions about how long this process will take.

7.1.4.5 Breakthrough Time for Solute

The breakthrough time for a solute, which is not relevant for covers, is the time required for a solute to travel from the top to the bottom of a liner. However, theoretically, the time required for an infinitely small concentration of solute to breakthrough to the base of a liner is zero for a thick or thin liner. Thus, breakthrough time is not a uniquely defined parameter -- the time depends upon the concentration of interest. In this section, it is assumed that the breakthrough time for a GCL is compared to that of a CCL for the same concentration at the base of the clay liner.

Because of the thinness of GCLs, diffusion will generally cause the breakthrough time of a thin layer of bentonite to be less than for a CCL. Even for GCLs that contain a geomembrane, diffusion of organic solutes across the geomembrane tends to occur quickly, but at a very low mass flux. However, diffusion of inorganics through the geomembrane would be nil. Equivalency depends on the GCL and the chemicals of concern.

One must carefully consider whether the breakthrough time for solutes is relevant. In the long term, breakthrough time is irrelevant -- breakthrough will eventually occur in all liner systems with an outward gradient. The important long-term issue is solute flux.

Steady-state flux represents a worst-case scenario, i.e., largest mass flux. Time-dependent flux, before steady state, also may need to be considered in certain situations.

7.1.4.6 Production of Consolidation Water

When clayey soils are loaded, water tends to be slowly squeezed out of the soil via a process known as "consolidation." The production of consolidation may or may not be of any concern, depending upon site-specific conditions. Examples of potential problems associated with the production of consolidation water include reduced stability at the geomembrane/clay liner interface (the consolidation water from the clay liner tends to reduce stability through increased water pressure at the interface) and collection of liquids in a leak detection layer for double composite liners.

Compacted clay liners are nearly saturated with water at the time of construction. When CCLs are loaded, substantial quantities of water are often squeezed out of the liner. For example, if a 1-m-thick liner is saturated with water and compresses just 2 percent of its original thickness due to consolidation, the amount of water squeezed out of the liner would be approximately 200,000 liters of water per hectare (20,000 gallons per acre).

Geosynthetic clay liners are essentially dry when they are constructed and cannot produce consolidation water unless they are first soaked with water and then compressed. Normally, GCLs do not have an opportunity to become saturated before they are loaded. However, a saturated GCL will produce far less consolidation water than a saturated CCL. Thus, GCLs are superior to CCLs in terms of minimizing production of consolidation water.

7.1.5 Physical/Mechanical Issues

The physical/mechanical issues that might be considered in an equivalency analysis include freeze/thaw effects, wet/dry effects, response to total settlement, response to differential settlement, stability on slopes, and vulnerability to erosion. Some issues are relevant for liners but all are relevant for covers (Table 7.2).

7.1.5.1 Freeze/Thaw Resistance

Compacted clay liners are known to be vulnerable to large increases in hydraulic conductivity from freeze/thaw. Limited laboratory data indicate that GCLs do not undergo increases in hydraulic conductivity as a result of freeze/thaw (Shan and Daniel, 1991). In addition, for those GCLs that contain a geomembrane, the geomembrane is unaffected by freeze/thaw. Thus, from the available data, GCLs appear to be superior to CCLs in terms of freeze/thaw resistance.

7.1.5.2 Wet/Dry Effects

Wetting and drying of CCLs and GCLs can cause either type of clay liner to swell or shrink. The main concern with clay liners that are wet and then dry out, is that desiccation can lead to cracking and an increase in hydraulic conductivity.

Limited laboratory data indicate that when dry, cracked CCLs are rewetted, the clay swells and any cracks are partially closed, leading to partial recovery of the original, low hydraulic conductivity. In contrast, the available data show that the high swelling of bentonite results in full self healing and full recovery of the original, low hydraulic conductivity when dried, cracked GCLs are rewetted. In addition, for those GCLs that contain a geomembrane, the geomembrane is insensitive to wet/dry effects. Thus, GCLs appear to be more than equivalent to CCLs in terms of ability to self-heal if the material is wetted, dried, and then rewetted.

7.1.5.3 Response to Total Settlement

Total settlement refers to block-like settlement without significant bending or distortion. It is believed that GCLs and CCLs would respond similarly to total settlement.

7.1.5.4 Response to Differential Settlement

Recent research by LaGatta (1992) indicates that some GCLs maintain their low hydraulic conductivity even when subjected to large differential settlements. In all probability, GCLs are more resistant to damage from differential settlement than CCLs (LaGatta, 1992). For example, for a depression with a diameter of 1 m that subsides 0.5 m, the liner will undergo approximately 10% tensile strain. While the data discussed in LaGatta (1992) suggests that GCLs can function under such conditions, it is known that CCLs cannot and will suffer tension cracks at 1% tensile strain or less.

7.1.5.5 Stability on Slopes

The shear strength of GCLs is very sensitive to the water content and type of GCL (Shan and Daniel, 1991; and Daniel and Shan, 1992). Water-saturated GCLs that have adhesive-bonded bentonite have angles of internal friction for consolidated-drained conditions of approximately 10 degrees. Dry materials are 2 to 3 times as strong as water-saturated GCLs. Also, needle-punched and stitch-bonded GCLs tend to have high strengths. The shear strength of CCLs varies widely, depending on materials, water content, and compaction conditions.

In stability analyses, one often must consider not only internal shear failure but interfacial shear with an adjacent layer, e.g., a geomembrane. Also, shear strength may be of short-or long-term concern, or both. No general statement can be made about probable equivalency of a GCL to a CCL because the assessment depends on specific materials, the degree to which the bentonite punctured by a piece of construction equipment. Thus, GCLs will not have equivalent puncture resistance to CCLs. However, quality assurance and quality control procedures can be established and implemented to make the probability of a puncture during construction extremely low. Ultimately, site-specific conditions and quality assurance procedures will determine whether puncture is a relevant issue that deserves serious consideration.

7.1.6.2 Effect of Subgrade Condition

Compacted clay liners are constructed with heavy equipment. If the subgrade is compressible (e.g, solid waste), the GCL, which can be installed with light-weight equipment, will be easier to construct. On the other hand, stones and rocks can puncture a GCL but not a CCL; if the subgrade contains stones or rocks, the integrity of the GCL may be compromised. Thus, equivalency of a GCL to a CCL in terms of the effect of subgrade depends on the condition of the subgrade and will have to be evaluated on a site-specific basis.

7.1.6.3 Ease of Placement or Construction

A GCL will always be easier to place than a CCL, unless weather conditions are adverse (e.g., constant rain), in which case even a CCL will also be difficult to construct. In general, GCLs are equivalent to or better than CCLs in terms of ease of placement or construction.

7.1.6.4 Speed of Construction

Geosynthetic clay liners can be placed much more quickly than CCLs. Equivalency is obvious.

7.1.6.5 Availability of Materials

Suitable clays for construction of a CCL may or may not be available locally, depending on the site. Because GCLs are a manufactured material, they are readily available and can be shipped to a site quickly. The cost of shipment is not a large percentage of the total cost of a GCL. Thus, GCLs will often be superior to CCLs in terms of availability of materials.

7.1.6.6 Weather Constraints

Compacted clay liners are difficult to construct when soils are wet, heavy precipitation is occurring, the weather is extremely dry (clay desiccates), the soil is frozen, or the temperature is below freezing. Geosynthetic clay liners are difficult to construct during precipitation. Weather constraints generally favor GCLs.

Some GCLs must be covered before they get wet. If a geomembrane will be placed over the GCL, the GCL must be covered almost immediately with the geomembrane. Additional weather constraints, e.g., wind speed, may apply to the geomembrane and, indirectly, influence the GCL. The fact that many GCLs must be covered before they are hydrated is a significant weather constraint for GCLs that does not exist for CCLs. However, CCLs have weather constraints, too: CCLs must not be allowed to freeze or desiccate (GCLs cannot desiccate during construction because they are dry, and dry GCLs are unaffected by freezing temperatures).

Equivalency in terms of weather constraints must be considered on a site-specific basis, but weather constraints generally favor GCLs over CCLs.

7.1.6.7 Quality Assurance Requirements

Quality assurance (QA) requirements are less extensive for GCLs compared to CCLs, but no less critical. There is no reason to suspect that QA is more difficult for a GCL than a CCL. However, testing procedures and observational techniques are well established for CCLs but are not for GCLs. The GCL industry and the Geosynthetic Research Institute (GRI) are working hard through GRI and ASTM to established testing methods. While it would appear that GCLs and CCLs are equivalent in terms of QA requirements, more work needs to be done to establish standard test methods for GCLs.

7.1.7 Summary of Equivalency Issues

Table 7.3 summarizes the preceding discussion of equivalency. Equivalency can be demonstrated generically in many categories. However, in two categories, equivalency probably cannot be demonstrated: (1) GCLs do not have adsorption capacity equivalent to CCLs; and (2) GCLs do not have the puncture resistance of CCLs. The adsorption capacity has no relevancy to covers.

Table 7.3 Summary of Equivalency Assessment

		Equivalency of GCL to CCL		
Category	Criterion for Evaluation	Probably Equivalent	Probably Not Equivalent	Product or Site Specific
Hydraulic Issues	Steady Flux of Water			X
	Steady Solute Flux			X
	Adsorption Capacity		X	
	Breakthrough Time:			
	-Water			X
	-Solute		X	
	Consolidation Water	X		
Physical/ Mechanical Issues	Freeze-Thaw	X		
	Wet-Dry	X		
	Total Settlement	X		
	Differential Settlement	X		
	Slope Stability			X
	Erosion			X
	Bearing Capacity			X
Construction Issues	Puncture Resistance		X	
	Subgrade Condition			X
	Ease of Placement	X		
	Speed of Construction	X		
	Availability of Materials	X		
	Weather Constraints	X		
	Quality Assurance	X		

For liners, the issue of adsorption capacity may or may not be relevant, depending on project-specific details. Although thin GCLs can be punctured during construction, the problem is of more concern for liners (due to higher stresses), and careful QA may be capable of addressing this potential problem for both liners and covers.

As suggested by Table 7.3, many equivalency issues depend on the GCL product and the particular conditions unique to a given site. Equivalency will clearly have to be evaluated on a case-by-case basis.

7.2 Discussion

A brief discussion took place after the presentation. Comments were made that there is a large need to establish criteria for analysis of equivalency. The potential criteria are numerous, but many may not apply. Also, differences in liners and covers were emphasized and the special problems in analyzing geomembrane/clay liner composites were briefly discussed.

CHAPTER 8
TECHNICAL CONCERNS

Even though a wide variety of research has been performed on geosynthetic clay liners (GCLs), many people expressed concern about how GCLs will perform in the field. The research, while providing some insight into the properties of GCLs, can often be difficult to interpret and relate back to a real-life field condition. Because of this, there are still unanswered questions and concerns relating to the full-scale field behavior of GCLs. In an effort to identify and address specific concerns, an open discussion was held.

8.1 The Effect of Freezing on Saturated Sodium Bentonite

The hydraulic conductivity of one GCL incorporating sodium bentonite has been shown to be unaffected by several freeze/thaw cycles in one series of laboratory experiments (Shan and Daniel, 1991). Similar results have been obtained for other GCLs in tests performed in commercial laboratories. Thus, the limited laboratory data show no detrimental effects from freeze-thaw but there have been no full scale field tests performed to verify the results of laboratory tests.

8.2 The Flow of Bentonite out of a GCL on a Side Slope

Bentonite would most likely not flow out of a GCL on a slope because:

- If a GCL is installed with an overlying geomembrane, the chances are that the GCL will never get sufficiently hydrated to allow the clay to "flow".

- If the GCL did become hydrated, consolidation would take place due to the stress of cover soils, and the internal shear strength of the GCL would go up.

- If a needle punched or stitch bonded GCL is used it is difficult to imagine the clay moving between the confining geotextiles.

8.3 Designing for Side Slopes

Two sets of data are needed to design for side slope stability when using GCLs:

1) Shear strength test data simulating the failure mode deemed important by the designing engineer:

    - Short term direct shear tests
    - Long term creep tests

2) Wide width tensile strength data. When conducting this test, one must consider the effect of confining stress on the results. Research at Drexel University (1992) has shown that the confining stress will not influence the tensile strength of a GCL incorporating a woven slit film geotextile.

8.4 Possibility of Overlaps Pulling Apart Due to Wet/Dry Cycles

This is why GCLs should always be installed with some sort of overburden stress. Not only can the overburden soil prevent damage to the GCL, but over burden will also prevent the overlap width from changing if moist GCLs dry and shrink. The GCL products can also be modified to prevent overlap movement. Bentofix® can be made with a velcro strip along the overlap, Claymax® or Bentomat® can be sewn (by hand) along the overlap as a prayer seam with a strong monofilament thread, and the geomembrane components of Gundseal can be welded together.

8.5 Steep Slopes

The use of geogrids and high strength geotextiles should be considered, as the long term shear and tensile strength of a GCL is questionable.

8.6 Long Term Physical Stability

Which will physically last longer, a GCL or a CCL? This depends on the environment to which the liner will be exposed. While CCLs have traditionally had problems due to desiccation cracking in hot, arid climates, GCLs have shown the ability to quickly swell and self-heal even after being dried out. The mineral components of both the CCL and GCL would hypothetically last forever as clay is in the final stage of weathering. The long-term performance of the geotextiles and needle punching is questionable, though.

8.7 Long Term Shear Strength

The internal shear strength of a GCL will go down as the bentonite hydrates. How long will it take for a GCL to become hydrated? Is it reasonable to assume that the entire GCL becomes hydrated?

8.8 Biotic Instabilities

How does one prevent animals and plants from burrowing into the final cover? While a thick CCL could prevent damage, how can a thin GCL prevent damage from occurring? One could possibly place a wire screen in the upper layer, but how effective would this really be?

CHAPTER 9

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15. SUPPLEMENTARY NOTES

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16. ABSTRACT

A workshop was held in Cincinnati, Ohio, to discuss the most recent information on the use of Geosynthetic Clay Liners (GCL's). Manufacturers discussed technical developments, recent research results, quality control and compared GCL's to compacted clay liners (CCL's). There are no standard test methods and no standard method was agreed upon. A discussion of performance indicated that GCL's provided low hydraulic conductivity, but more information is needed to quantify geomembrane and GCL composite behavior, and to confirm recent research at the University of Texas and at Drexel University, which indicated that most GCL's tested maintained low hydraulic conductivity even when subjected to large differential settlement.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Lining Bentonite Clays Tensile Strength Sheer Strength	Geosynthetic Clay Liners Geotextile Geomembrane	

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
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ATTACHMENT N

Technical Tips, Bulletin #101, Landfill Fires

LANDTEC
LANDFILL CONTROL TECHNOLOGIES

TECHNICAL TIPS

Landfill Fires

There are two types of landfill fires:

☐ Above ground - surface fires usually occur on the landfill working face The fire is easily discovered and extinguished by suffocation and/or removing the source of combustion If ignored, the fire can grow large and become dangerous

☐ Underground - subsurface fires usually start out small and localized If left unattended, the fire can spread and can be extremely difficult to extinguish

Requirements for fires - All must be present to support combustion

☐ Combustible materials - especially those with a low threshold for combustion such as petroleum based products, tars and oils

☐ Elevated temperatures - high temperatures are required to initiate combustion Temperatures generated during aerobic and anaerobic decomposition within a landfill can reach as high as 160° F (70° C)

☐ Oxygen - air is essential for combustion. Control a fire's air supply and you can smother a fire

Differences between surface & subsurface fires

☐ Surface fires are extinguished by removing combustible materials, ignition sources (heat) or oxygen

☐ Subsurface fires are far harder to control. Combustible materials are not easily removed and temperatures cannot be easily changed However, if the source of oxygen is eliminated or sufficiently restricted, the fire can be smothered Typically this provides the best approach

Sources of Oxygen intrusion into the landfill

☐ *Passive Air Intrusion* sources are cracks/fissures in the cover, inadequate cover material, wind impaction on the surface, or diffusion of the atmosphere through the surface.

☐ *Active Air Intrusion - collection system design* Poorly designed gas collectors can allow air intrusion at the well-bore or into shallow collection zones Subsurface piping not designed to withstand soil loads and landfill settlement can break along collection headers or laterals near the surface prompting air intrusion

☐ *Active Air Intrusion - operation of collection system* Excessive gas extraction is called "overpull" Localized overpull caused by an improperly operated or balanced gas extraction system can cause air intrusion

Preventing Underground Fires

☐ Prevention is the best policy *Eliminate conditions which can initiate subsurface fires*

☐ Eliminate atmospheric intrusion through fissures and cracks in the cover *The solution is to repair them and maintain the cover.* Poor surface cover or no cover is not permissible.

☐ Well-bore seals must be effective to prevent intrusion Common seals are Bentonite (clay), native soil, and impermeable barriers like LANDTEC's Well-Bore Seal (WBS-100)
- Bentonite seals dry out, crack and may leak Bentonite settles at a different rate than surrounding trash and expands and contracts at a different rate than the surrounding cover
- Native soil seals are cheap and available but can be very porous and settle at different rates than the surrounding trash
- Well-bore seals such as LANDTEC's WBS-100 provide an effective seal because they extend beyond the well-bore region and are made of impermeable materials They also prevent landfill gas leakage at the well casing/landfill interface

☐ Operation of the gas collection system can be improved by utilizing proper flow control at each gas extraction wellhead to prevent overpull and air intrusion. This can minimize the potential for fires A properly designed wellhead, such as LANDTEC's Accu-Flo series, provides important data that can help a landfill technician prevent and/or detect subsurface fires before they become serious or spread LANDTEC's Accu-Flo wellhead provides the technician with the following information
- An integrated gas temperature indicator
- Built-in flow metering to determine accurate gas extraction flow rates at the wellhead
- A port for sampling gas composition, i.e methane, oxygen, carbon dioxide levels in the landfill gas
- Ports for measurement of the static and impact pressures at the wellhead

If you suspect a fire exists

☐ Check local ground temperatures If elevated, perform a soil temperature survey of the surface to determine the spatial distribution of the elevated temperatures with respect to background temperatures

☐ Inspect the surface of the landfill in the vicinity of the suspected fire for fissures, cracks, erosion, or other areas where air (oxygen) may be readily entering the landfill

☐ Monitor the gas temperature of the extraction wells in the fire area to determine if elevated gas temperatures are present

- ☐ Monitor the carbon monoxide levels in the gas extraction wells in the suspected area to determine if elevated levels of carbon monoxide are present (Carbon monoxide gas is a by-product of combustion)
- ☐ Inspect the gas wellheads internal components in the impacted area for the presence of soot and combustion odors
- ☐ Inspect the suspected area for signs of smoke or vapor (best seen in the early morning) emitting from the surface of the landfill
- ☐ Inspect the ground around the impacted area for signs of accelerated subsidence USE CAUTION – subsurface fires can undermine areas of the landfill that could result in collapse of surface areas and creates an extremely hazardous situation for personnel who could fall into an extremely hot pit Areas that are suspect should be barricaded and safety precautions taken Bulldozers and heavy equipment must be kept away from the region until it is deemed safe. REMEMBER - DO NOT WORK ALONE – USE SAFETY PRECAUTIONS AT ALL TIMES.
- ☐ Inspect the gas extraction system for signs of damage due to heat or combustion Turn off, isolate or bypass affected systems Seal damaged wells. Reduce the gas extraction rates from all operating wells in the affected area to minimize atmospheric intrusion

Is the fire shallow or deep?

- ☐ Use the data obtained from surveying the surface soil temperatures and from monitoring the gas extraction wells flow rates and gas temperatures to help determine the intensity of the fire and potential depth

Shallow fires

- ☐ Cautiously excavate the fire zone and completely remove all combustible materials Inspect the affected area to determine that temperatures within the excavation have returned to background levels Backfill the excavation with clean inert material and replace the cover material to its original integrity
- ☐ Continue to monitor soil surface temperatures to ensure that they have returned to normal background levels

Deep fires

- ☐ Use precautionary measures mentioned earlier Eliminate any and all potential sources of atmospheric intrusion
- ☐ Reduce the gas extraction rates at all wells in the vicinity of the fire
- ☐ Continue monitoring gas extraction rates and gas temperatures to determine if the fire is diminishing
- ☐ Fill-in any surface subsidence and restore landfill cover grading as required
- ☐ If the above fails, consider the following measures (given the proper authorization from regulators) Inject water into the fire zone to quench it Saturate the surface cover with water each day to maximize its seal and minimize air intrusion Other options include smothering the fire by injecting liquid nitrogen or carbon dioxide into existing or new wells placed in the zone of the fire (costly)

In Conclusion

- ☐ Never underestimate the potential danger of a landfill fire A proactive approach in preventing landfill fires is the safest and most cost-effective method
- ☐ Practice preventive measures each and every day to keep the potential for fires at a minimum
- ☐ Most importantly, maintain the landfill surface cover and operate the gas extraction system as required to prevent air intrusion into the landfill

Additional LANDTEC Information

Product and technical information is available on LANDTEC's wellheads, well-bore seals, knock-outs, pumping stations, instrumentation, condensate/leachate treatment, flares and landfill gas management software

LANDTEC also provides technical and educational literature on specific landfill subjects and issues Please call our toll free West Coast number 1-800-821-0496 (8 a m - 5 p m) for additional information or placement on our mailing list

The above suggestions and information may not apply to all situations and are offered only as general advice.

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ATTACHMENT O

Technical Tips, Bulletin #103, Health and Safety

Bulletin #103

LANDTEC

LANDFILL CONTROL TECHNOLOGIES

TECHNICAL TIPS

Health & Safety Issues

Landfill Owners/Operators Employer Responsibilities

Includes the health and safety of all on-the-job employees including short and long-term exposure to potential hazards while working at a landfill site Employers·

- ☐ Must determine which landfill jobs bring employees in contact with vapors, liquids and particulates that could cause short or long-term health problems
- ☐ Must comply with the numerous health and safety laws that apply to normal working activities, engineering, construction, excavation and drilling activities Specialized activities require separate plans, programs and training in accordance with applicable regulations

Liability

- ☐ Federal and state laws mandate requirements and place the burden of proof on the employer to demonstrate regulatory compliance.
- ☐ Safety and health issues must be adequately addressed to avoid significant potential liability problems.

Employer Must Demonstrate Adequate Compliance

- ☐ Employers must provide health and safety programs and training for potential hazards that could be encountered while working on the landfill site including
  - Exposure to dangerous gases - hydrogen sulfide, carbon monoxide, methane and others.
  - Exposure to dangerous chemicals - vinyl chloride, benzene, toluene, methylene chloride, etc.
  - Exposure to unsanitary or infectious wastes
  - Exposure to dangerous minerals and compounds - including asbestos, heavy metals, acids and caustics
  - Exposure to radioactive materials.
  - Exposure to shock-sensitive compounds that may violently react or explode
  - Exposure to a combination of working conditions that might promote heat stress, dehydration, hearing loss, or breathing difficulties

Required Health and Safety Programs

Individual state OSHA statutes typically address the following

- ☐ Accident Prevention Program (General Safety)
- ☐ Hazard Communication and "Right-To-Know" Program
- ☐ Respiratory Protection Program
- ☐ Medical Monitoring Program
- ☐ Safety Training Program including Hazardous Materials and Hazardous Waste Site Training, if applicable (29CFR1910 120)
- ☐ Personnel and Work Environment Monitoring Program
- ☐ Record Keeping & Maintenance for all of the above programs

Accident Prevention Program

- ☐ A written Accident Prevention Program is the first basic building block of an overall Health and Safety Plan
- ☐ The program should cover company policies, objectives, specific assignments of responsibility, the availability and location of resources

Hazard Communication Standards

- ☐ The Hazard Communication Program must inform and train employees how to safely use the various chemicals with which they come in contact.
- ☐ Material Safety Data Sheets (MSDS) must be maintained on-site and personnel must be trained in their understanding and use
  - Survey the site for all products, even those only used occasionally
  - Keep MSDS files updated and accessible Require that employees and subcontractors working on the site be made aware of the file according to "right-to-know" programs

Respiratory Protection Program

- ☐ A written respiratory protection program is legally required at sites where it is necessary to employ the use of respiratory protection equipment.
  - Site characterization will identify the need for protection from organic vapors, acid gases, and particulates
  - Respirators are not approved for use against vapors which have poor warning properties
- ☐ There is considerable specialized training required before respirators are used at a site
- ☐ Many activities on municipal solid waste landfills may be safely done without respirators However, there are many instances where protection will be required and qualified parties may have to provide them when drilling, excavating, trenching, working in confined spaces, or doing hot work in potentially dangerous environments

Medical Monitoring Program

- ☐ This may be required for work on hazardous waste sites depending on project-specific conditions On sites which are permitted as non-hazardous but may contain hazardous materials or emit known hazardous constituents at concentrations which may be above a specified level of concern, the need for, and extent of medical surveillance becomes a legal and business decision

- ☐ Superfund Sites require a medical monitoring program for 30 years for all involved staff

Safety Training Program

- ☐ Safety is another basic program that has several functions
  - Teaches and informs employees about basic safety concerns
  - Addresses job-specific hazards likely to be encountered
  - Fulfills certain legal notification and training requirements under state and federal laws.
  - Heightens employee awareness in general about safety.
- ☐ If work includes potential exposure to hazardous materials at hazardous waste sites, then very specialized training will be required

Personnel & Work Environment Monitoring Program

- ☐ An employer must monitor employees and/or the work environment whenever they know, or suspect, there may be a risk for employee exposure
- ☐ Threshold exposure limits must be evaluated by a thorough site characterization survey. Due consideration should be given to uncontrolled environments and changing conditions, such as during well drilling activities.
- ☐ Monitoring or sampling techniques may include equipment that provides protection or alerts those in the work environment including: methane sensors, combustible gas analyzers, hydrogen sulfide monitors, carbon monoxide detectors, oxygen analyzers, etc They may be used regularly or during certain specific activities such as drilling, trenching, excavation or other work
- ☐ Monitoring perimeter or additional sampling should be determined based on the types of hazards, risks present, and the extent of exposure for the work to be performed

Records Maintenance

- ☐ Accurate, reproducible, and verifiable records are essential for an effective overall health and safety program
- ☐ Where specific compliance cannot be easily demonstrated, various records and programs may indirectly show the intent to comply

Program Implementation

- ☐ To be effective, health and safety programs must be practical and clear Hazards, risks, and dangers must be put in proper perspective or the program can become very costly and unwieldy The burden of proof for compliance of a program is squarely on the employer
- ☐ Effective programs deal with all the issues, and balance the trade-offs that are required to deal with changing guidelines and standards
- ☐ The more industry participates in the promulgating of the standards, and develops the specialized training required, the more realistic and workable programs become
- ☐ There are real costs involved in program implementation Do not discount them
  - Specialized equipment may be required for proper monitoring
  - Site characterization and testing is expensive.
  - Special clothing, masks, ear plugs, and other gear impact O&M
  - Don't forget to include the costs necessary to monitor and upgrade programs on a regular basis
- ☐ Excessive, unrealistic or inappropriate controls can lead to safety risks and cause accidents and injuries. Good common sense and good judgement should be allowed to prevail

In Conclusion

- ☐ Employers will incur additional health and safety issues once landfill gas control begins at a landfill site Likewise, needs and responsibilities will change as the site changes from open to closed
- ☐ Besides providing new equipment and supplies, management must diligently review and enforce compliance until new habits and procedures are developed. Also, the new rules and requirements must be included in updated job descriptions
- ☐ Management must establish routine audit and monitoring programs to assure compliance.
- ☐ It is easy to become complacent. Continued training, ongoing discussion, re-evaluation, quality control auditing, and updating of programs is necessary at regular intervals

The above suggestions and information does not apply to all landfills or situations and is offered only as a generic guideline. State and federal laws and specific company policies can change at any time.

A special thanks to James H Wheeler, author of Safety and Liability in Landfill Gas Recovery and Control – Concepts, Trends and New Concerns which was presented at the 10th International Landfill Gas Symposium of the GRCDA (SWANA), February, 1987 Used with permission

Additional LANDTEC Information

Information on LANDTEC's products which are specifically designed to work together in landfill applications include landfill gas collection products, measurement & instrumentation equipment, condensate/leachate treatment systems, flares and landfill gas management software

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RCRA SUBTITLE D COURSE EVALUATION QUESTIONNAIRE

Please indicate how you feel about the following components of the course.

Please rate each presentation as follows:
1 - excellent/highly relevant
2 - very good
3 - satisfactory
4 - marginally satisfactory
5 - unsatisfactory/poor

Please explain your answers where possible.

QUESTION	1	2	3	4	5	COMMENT
1. How would you rate this course in terms of meeting your needs for Subtitle D technical training?						
2. How would you rate the following items?						
a. Selection of topics covered.						
b. Rate at which topics were covered.						
c. Educational level at which topics were covered.						
d. Detail in which topics were covered.						
e. Balance of theory with application.						
f. Use of the manual as a learning tool.						
g. Use of the manual as a future reference tool.						
h. How well the different topics/chapters blended together to support each other.						
i. Use of charts and tables in the manual.						
j. Use of visual aids as a learning tool.						
k. Ability of the course to hold your interest.						

COURSE EVALUATION QUESTIONNAIRE (Continued)

Please make whatever additional comments you think are relevant to an evaluation of this course. You may want to expand upon comments made in various portions of this questionnaire or to say something you have not had an opportunity to say.

Please specify number of years working with facilities that manage solid waste and describe your experience.