EPA

TABLE OF CONTENTS

APPENDICES

Example of Technical and Performance Standards in 40 CFR Part 258: Liners

Technical standard:
MSWLFs must be built with a composite liner consisting of a 30 mil flexible membrane liner over 2 feet compacted soil with a hydraulic conductivity of no more than 1×10^{-7} cm/sec.

Performance standard:
MSWLFs must be built in accordance with a design approved by the Director of an approved State or as specified in 40 CFR § 258.40(e) for unapproved States. The design must ensure that the concentration values listed in Table 1 of 40 CFR § 258.40 will not be exceeded in the uppermost aquifer at the relevant point of compliance, as specified by the Director of an approved

[1] The Agency originally intended to extend to Indian Tribes the same opportunity to apply for permit program approval as is available to States, but a court decision blocked this approach. See the **Tribal Process** section below for complete details.

[2] EPA finalized several revisions to 40 CFR Part 258 on October 1, 1993 (58 *FR* 51536) and issued a correction notice on October 14, 1993 (58 *FR* 53136). Questions regarding the final rule and requests for copies of the *Federal Register* notices should be made to the RCRA/Superfund Hotline at 800 424-9346.

MSWLF permitting programs under the procedures set out in 40 CFR Part 239, "Requirements for State Permit Program Determination of Adequacy," proposed on January 26, 1996 (61 *FR* 2584), to determine whether programs are adequate to ensure that MSWLF owners/operators comply with the federal standards. As of early 1998, 40 States and Territories had received full approval an

[3] *Backcountry Against Dumps v. EPA*, 100 F.3d 147 (D.C. Cir. 1996).

[4] This manual uses the term "Indian Country" as defined in 40 CFR § 258.2.

New Flexibility for Small Landfills (40 CFR §§ 258.21, 258.23, 258.60)

In addition to reestablishing the ground-water exemption for small, dry, and remote MSWLFs, the LDPFA provided additional flexibility to approved states for any small landfill that recei questions regarding these requirements may be addressed to EPA's RCRA/Superfund Hotline at 800 424-9346.

Within each chapter, the Criteria have been subdivided into smaller segments. The *Statement of Regulation* section provides a verbatim recital of the regulatory language. The second section, entitled *Applicability*, provides a general explanation of the regulations and who must comply with them. Finally, for each segment of the regulation, a *Technical Considerations* section identifies key technical issues that may need to be addressed to ensure compliance with a particular requirement. Each chapter ends with a section entitled *Further Information*, which provides references, addresses, organizations, and other information that may be of use to the reader.

Limitations of This Manual

The ability of this document to provide current guidance is limited by the technical literature that was available at the time of preparation. Technology and product development are advancing rapidly, especially in the areas of geosynthetic materials and design concepts. As experience with new waste management techniques expands in the engineering and science community, an increase in published literature, research, and technical information will follow. The owners and operators of MSWLFs are encouraged to keep abreast of innovation through technical journals, professional organizations, and technical information developed by EPA. Many of the Criteria contained in Part 258 are performance-based. Future innovative technology may provide additional means for owners/operators to meet performance standards that previously could not be met by a particular facility due to site-specific conditions.

Deadlines and Effective Dates

The original effective date for the Criteria, October 9, 1993, was revised for several categories of landfills, in response to concerns that a variety of circumstances was hampering some communities' abilities to comply by that date. Therefore, the Agency provided additional time for certain landfills to come into compliance, especially small units and those that accepted waste from the 1993 Midwest floods. As the accompanying table indicates, the extended general effective dates for all MSWLF categories have passed, and all units should now be in compliance.

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.[1,2,3] This is the effective date for location, operation, design, and closure/post-closure.	October 9, 1993	April 9, 1994	October 9, 1997; exempt from the design requirements	Up to October 9, 1994 as determined by State
Date by which to install final cover if cease receipt of waste by the general effective date.[2,3]	October 9, 1994	October 9, 1994	October 9, 1998	Within one year of date determined by State; no later than October 9, 1995
Effective date of ground-water monitoring and corrective action.[2,3]	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	Exempt from the ground-water monitoring requirements.[5]	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.[3,4]	April 9, 1997	April 9, 1997	October 9, 1997	April 9, 1997

[1] If a MSWLF unit receives waste after this date, the unit must comply with all of Part 258.
[2] See the final rule and preamble published on October 1, 1993 (58 FR 51536) for a full discussion of all changes and related conditions.
[3] See the final rule and preamble published on October 6, 1995 (60 FR 52337) for a full discussion of all changes and related conditions.
[4] See the final rule and preamble published on April 7, 1995 (60 FR 17649) for a discussion of this delay.
[5] See the final rule and preamble published on September 25, 1990 (61 FR 50409) for a discussion of the ground-water monitoring exemption.

CHAPTER 1

SUBPART A
GENERAL

CHAPTER 1
SUBPART A

TABLE OF CONTENTS

CHAPTER 1
SUBPART A
GENERAL

1.1 INTRODUCTION

Under the authority of both the Resource Conservation and Recovery Act (RCRA), as amended by the Hazardous and Solid Waste Amendments (HSWA) of 1984, and Section 405 of the Clean Water Act, the EPA issued "Solid Waste Disposal Facility Criteria" (40 CFR Part 258) on October 9, 1991. These regulations revise the "Criteria for Classification of Solid Waste Disposal Facilities and Practices," found in 40 CFR Part 257. Part 258 was established to provide minimum national criteria for all solid waste landfills that are not regulated under Subtitle C of RCRA, and that:

- Receive municipal solid waste; or
- Co-dispose sewage sludge with municipal solid waste; or
- Accept nonhazardous municipal waste combustion ash.

Part 257 remains in effect for all other non-hazardous solid waste facilities and practices.

Subpart A of the regulations

MSWLF units are not intended, nor allowed, to receive regulated quantities of hazardous wastes. Should a MSWLF owner/operator discover that a shipment contains regulated quantities of hazardous waste while still in the possession of the transporter, the owner/operator should refuse to accept the waste from the transporter. If regulated quantities of hazardous wastes are discovered after accepting the waste from the transporter, the owner/operator must return the shipment or manage the wastes in accordance with RCRA Subtitle C requirements.

Subtitle C of RCRA establishes procedures for making a hazardous waste determination. These procedures are summarized in Chapter 3 and Appendix B of this document.

1.3 PURPOSE, SCOPE, AND APPLICABILITY (cont.) 40 CFR §258.1 (c)-(e)

1.3.1 Statement of Regulation*

***[NOTE: EPA finalized several revisions to 40 CFR Part 258 on October 1, 1993 (58 FR 51536) and issued a correction notice on October 14, 1993 (58 FR 53136). These revisions delay the effective date for some categories of landfills. More detail on the content of the revisions is included in the introduction.]**

(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 Part 258, except the final cover requirement specified in Section 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 Part 258, unless otherwise specified.

(e) All MSWLF units that receive waste on or after October 9, 1993 must comply with all requirements of Part 258 unless otherwise specified.

1.3.2 Applicability

The applicability of Part 258, in its entirety or with exemptions to specific requirements, is based upon the operational status of the MSWLF unit relative to the date of publication, October 9, 1991, or the effective date of the rule, October 9, 1993 (see Figure 1-1). Three possible operational scenarios exist:

(1) The MSWLF unit received its last load of waste prior to October 9, 1991. These facilities are exempt from all requirements of the Criteria.

(2) The last load of waste was received after October 9, 1991, but before October 9, 1993. The owners and operators must comply only with the final cover requirements of §258.60(a). If the final cover is not installed within six (6) months of the last receipt of wastes, the owners and operators will be required to comply with all requirements of Part 258.

Figure 1-1
Applicability Flow Chart

(3) The MSWLF unit continues to receive waste after October 9, 1993. The owners or operators must comply with all requirements of Part 258, except where specified otherwise.

1.3.3 Technical Considerations

MSWLF units that receive the last load of waste between October 9, 1991 and October 9, 1993, must complete closure within six months of the last receipt of waste. Closure requirements are specified in Subpart F; however, these MSWLF units will be subject only to the closure requirements of §258.60(a) unless they fail to complete closure within the six-month period. The alternative cover design is not an option for MSWLF units in unapproved States.

The final cover system must be designed to minimize infiltration and erosion. The final cover must have a permeability that is less than or equal to the permeability of the bottom liner system or the natural subsoils present, or a permeability no greater than 1 x 10^{-5} cm/sec, whichever is less. The system must be composed of an erosion layer that consists of at least six inches of an earthen material capable of sustaining native plant growth and an infiltration layer that is composed of at least 18 inches of an earthen material. However, if a MSWLF unit is constructed with a synthetic membrane in the liner system, it is anticipated that the final cover also will require a synthetic liner.

1.4 SMALL LANDFILL

Director of such contamination and, thereafter, comply with Subparts D [~~and E~~]* of this Part.

* [Note: On May 7, 1993 the U.S. Court of Appeals for the District of Columbia Circuit issued an opinion that EPA did not have the authority to exempt these small landfills from the ground-water monitoring requirements (Subpart E), therefore, these small landfills can not be exempted from Subpart E. EPA is delaying the date of compliance for these units until October 9, 1995 (58 FR 51536; October 1, 1993).]

1.4.2 Applicability

The exemption from Subpart D (Design) is applicable only to owners or operators of landfill units that receive, on an annual average, less than 20 tons of solid waste per day. The exemption is allowed so long as there is no evidence of existing ground-water contamination from the MSWLF unit. In addition, the MSWLF unit must serve a community that meets one of the following two conditions:

- For at least three consecutive months of the year, the community's municipal solid waste cannot be transported by rail, truck, or ship to a regional waste management facility; or

- There is no practicable alternative for managing wastes, and the landfill unit is located in an area that receives less than 25 inches of annual precipitation.

If either of the above two conditions is met, and there is no evidence of existing ground-water contamination, the landfill unit owner or operator is eligible for the exemption from the design, ground-water monitoring, and corrective action requirements. The owner or operator must place information documenting eligibility for the exemption in the facility's operating record. Once an owner or operator can no longer demonstrate compliance with any of the conditions of the exemption, the MSWLF facility must be in compliance with Subpart D.

1.4.3 Technical Considerations

The weight criterion of 20 tons does not have to be based on actual weight measurements but may be based on weight or volume estimates. If the daily waste receipt records, which include load weights, are not available for the facility, waste volumes can be estimated by using conversion factors of 1 ton = two to three cubic yards per ton depending on the type of compaction used at the MSWLF unit. Waste weights may be determined by counting the number of trucks and estimating an average weight for each.

To determine the daily waste received, an average may be used. If the facility is not open on a daily basis, the average number should reflect that fact. For example, if a facility is open four days per week (208 days/year) and accepts 25 tons each day, then the average daily amount of waste received can be calculated as follows:

Average Daily Waste Calculation

4 days/week x 52 weeks/year = 208 days/year; and

25 tons/day x 208 days/year = 5200 tons/year; then

5200 tons/year ÷ 365 days/year = 14.25 tons/day.

The facility would meet the criteria for receiving less than 20 tons per day.

Compliance with the 20 tons per day criterion should be based on all waste received, including household waste and agricultural or industrial wastes. As defined in the regulations, household waste includes 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,

in(,) Tn17.9962885 0 TD 0.2396h received,re0 -27 T42 regulat12stations, 32ew quarT TDexemp-13. .6

consideration of technical, economic, and

Director of an approved State 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 that is deemed to be adequate by EPA under regulations published pursuant to section 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. 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 iscla

1.6.2

land surface would be covered by waste after October 9, 1993. Expansions to the existing unit have to be consistent with past operating procedures or operating practices to ensure good management.

Spreading

1.7 CONSIDERATION OF OTHER FEDERAL LAWS 40 CFR §258.3

1.7.1 Statement of Regulation

CHAPTER 2

SUBPART B
LOCATION CRITERIA

CHAPTER 2
SUBPART B

TABLE OF CONTENTS

CHAPTER 2
SUBPART B
LOCATION RESTRICTIONS

2.1 INTRODUCTION

Part 258 includes location restrictions to address both the potential effects that a municipal solid waste landfill (MSWLF) unit may have on the surrounding environment, and the effects that natural and human-made conditions may have on the performance of the landfill unit. These criteria pertain to new and existing MSWLF units and lateral expansions of existing MSWLF units. The location criteria of Subpart B cover the following:

- Airport safety;
- Floodplains;
- Wetlands;
- Fault areas;
- Seismic impact zones; and
- Unstable areas.

Floodplain, fault area, seismic impact zone, and unstable area

Table 2-1
Location Criteria Standards

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

2.2 AIRPORT SAFETY
40 CFR §258.10

2.2.1 Statement of Regulation

(b) Owners or operators proposing to site new MSWLF units and lateral

Zones4 -6.718(M0.0087 Tc7(Yes) Tj 7922f) Tj -7.0183 -

(1) <u>Airport</u> means public-use airport open to the public without prior permission and without restrictions within the physical capacities of available facilities.

(2) <u>Bird hazard</u> means an increase in the likelihood of bird/aircraft collisions that may cause damage to the aircraft or injury to its occupants.

<u>2.2.2 Applicability</u>

Owners and operators of new MSWLF units, existing MSWLF units, and lateral expansions of existing units that are located near an airport, who cannot demonstrate that the MSWLF unit does not pose a bird hazard, must close their units.

This requirement applies to owners and operators of MSWLF units located within 10,000 feet of any airport runway end used by turbojet aircraft or within 5,000 feet of any airport runway end used only by piston-type aircraft. This applies to airports open to the public without prior permission for use, and where use of available facilities is not
d

pose bird hazards to aircraft. The regulation expansion. Topographic maps (USGS 15-minute series) or State, regional, or local government agency maps providing similar or better accuracy would allow direct scaling, or

- Shredding, milling, or baling the waste-containing food sources; and
-

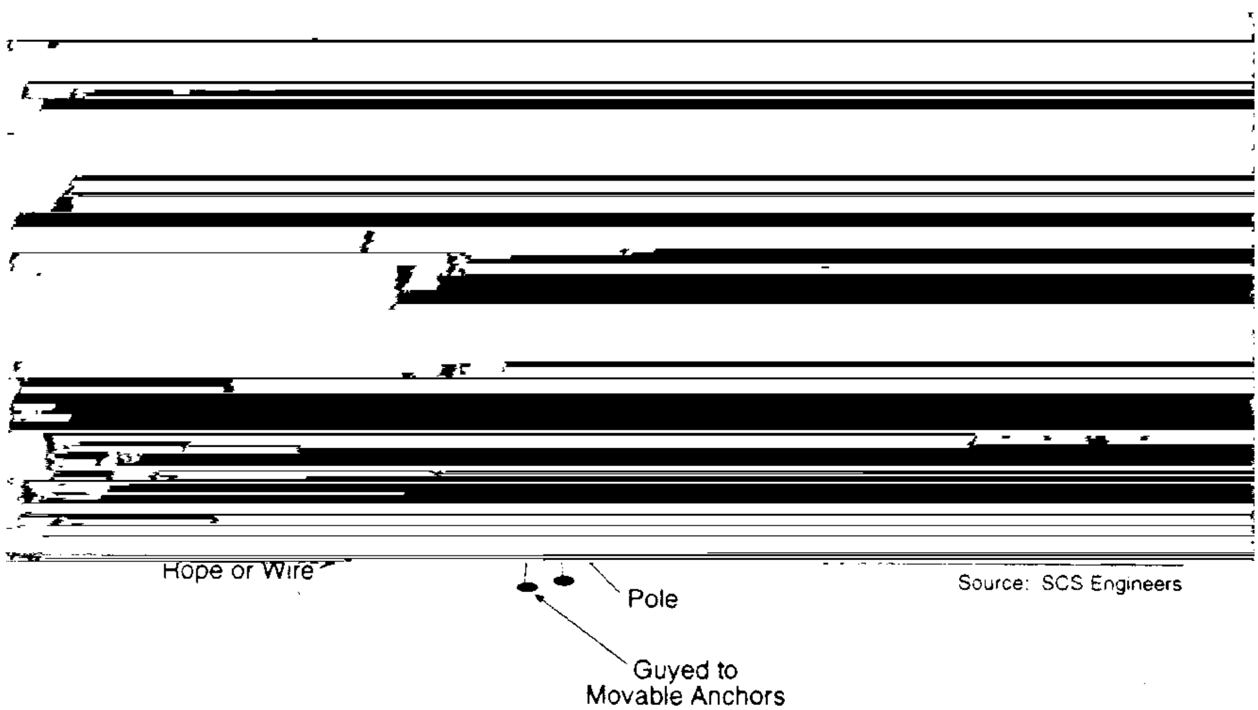


Figure 2-1.
Bird Control Device

requested from the FAA. Topographic maps (e.g., USGS 15-minute series) or other similarly accurate maps showing the relationship of the airport runway and the MSWLF unit should provide a suitable basis for determining whether the FAA should be notified.

2.3 FLOODPLAINS
40 CFR §258.11

2.3.1 Statement of Regulation

(a) Owners or operators of new MSWLF units, existing MSWLF units, and

(3) Washout means the carrying away of solid waste by waters of the base flood.

2.3.2 Applicability

Owners/operators of new MSWLF units, existing MSWLF units, and lateral

demonstrate that the units will not restrict the flow of a 100-year flood nor reduce the

in a wash-out of solid waste, must close the

and temporary storage capacity of a

is no immediate threat to human health and the environment (see Section 2.8).

2.3.3 Technical Considerations

Compliance with the floodplain criterion begins with a determination of whether the MSWLF unit is located in the 100-year floodplain. If the MSWLF unit is located i

Guidance on using FIRMs is provided in "How to Read a Flood Insurance Rate Map"

"The National Flood Insurance Program

communities that may not be involved in the National Flood Insurance Program but which have FIRMs or Floodway maps published.

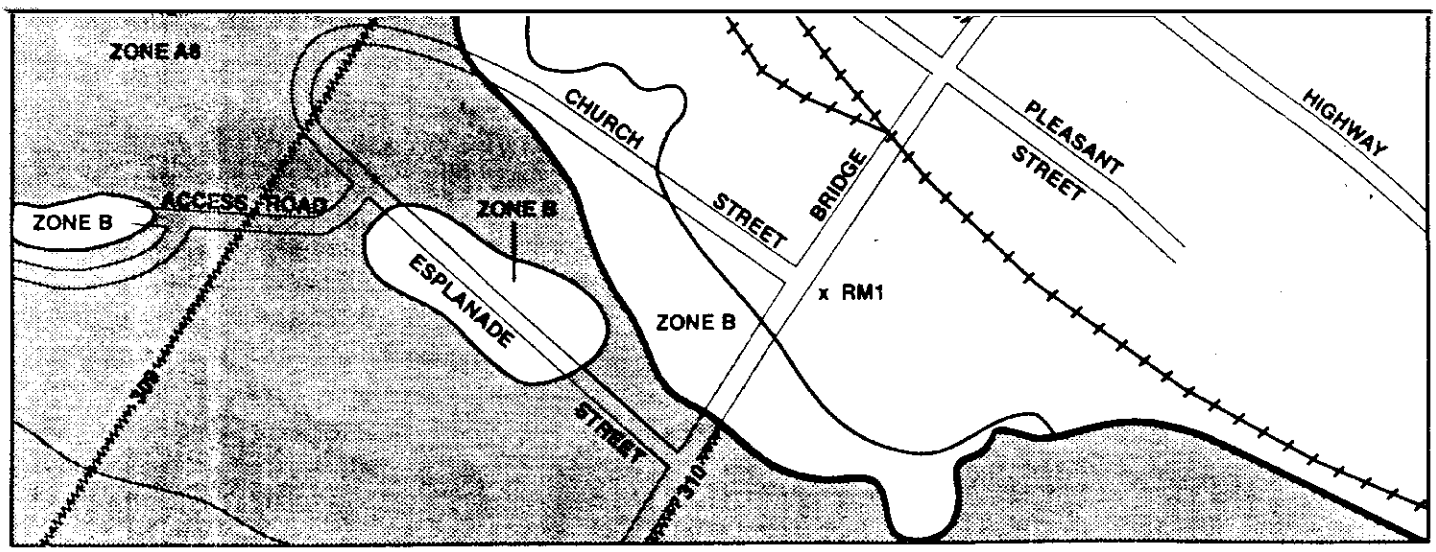


Figure 2-2
Example Section of Flood Plain Map

routing that will minimize downstream flooding); and

HEC-6 Scour and Deposition in Rivers and Reservoirs (calculates water surface and sediment bed surface profiles).

The HEC-2 model is not appropriate for simulation of sediment-laden braided stream systems or other intermittent/dry stream systems that are subject to flash flood events. Standard run-off and peak flood hydrograph methods would be more appropriate for such conditions to predict the effects of severe flooding.

There are many possible cost-effective methods to protect the MSWLF unit from flood damage including embankment designs with rip-rap, geotextiles, or other materials. Guidelines for designing with these materials may be found in Maynard (1978) and SCS (1983). Embankment design will require an estimate of river flow velocities, flow profiles (depth), and wave activity. Figure 2-3 provides a design example for dike construction and protection of the landfill surface from flood water. It addresses height requirements to control the effects of wave activity. The use of alternate erosion control methods such as gabions (cubic-shaped wire structures filled with stone), paving bricks, and mats may be considered. It should be noted, however, that the dike design in Figure 2-3 may further decrease the water storage and flow capacities.

2.4 WETLANDS
40 CFR §258.12

2.4.1 Statement of Regulation

(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 a 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;

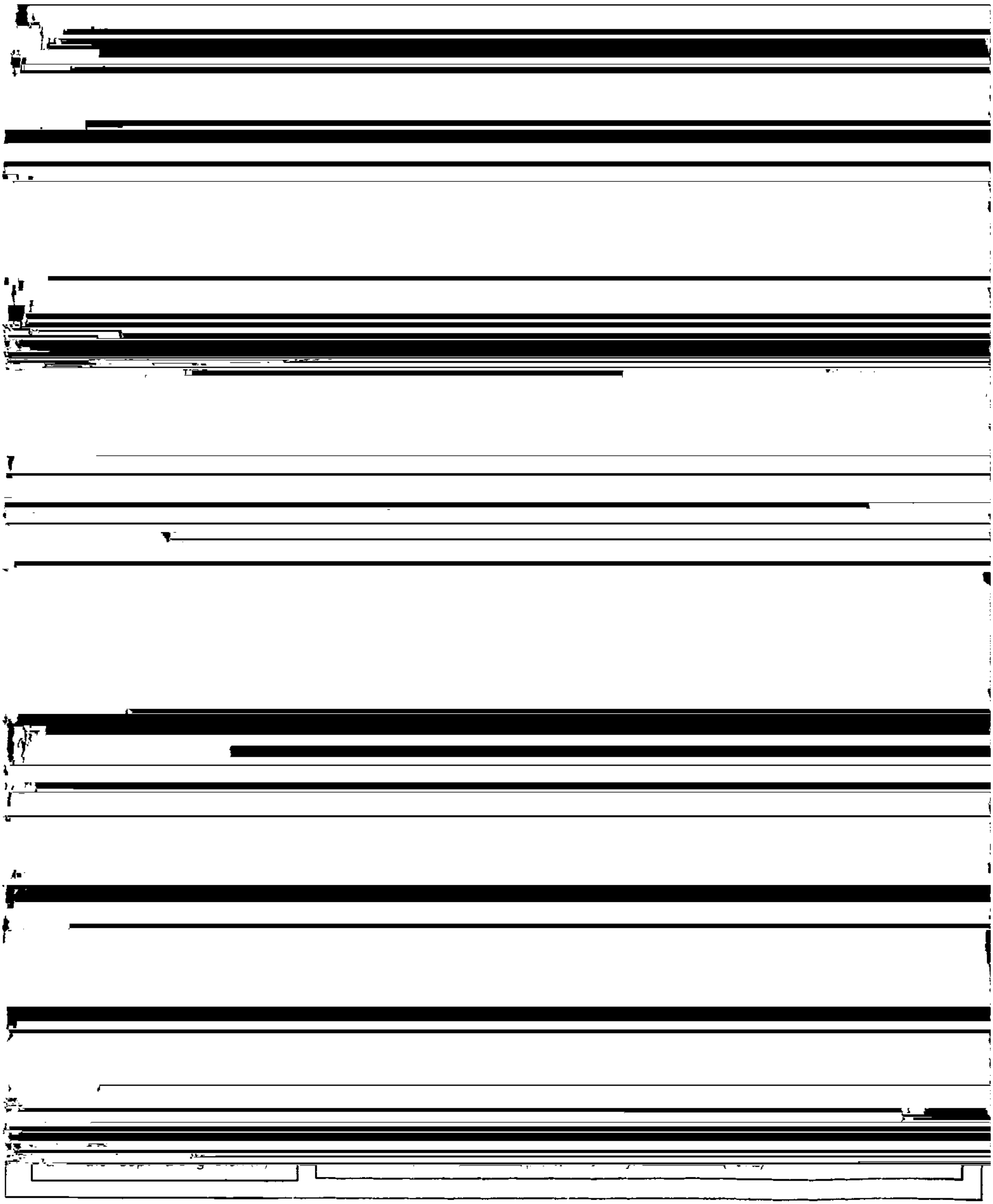


Figure 2-3. Example Floodplain Protection Dike Design

(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 wetland 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).

2.4.2 Applicability

New MSWLF units and lateral expansions in wetlands are prohibited, except in approved States. The wetland restrictions allow existing MSWLF units located in wetlands to continue operations as long as compliance with the other requirements of Part 258 can be maintained.

In addition to the regulations listed in 40 CFR §258.12(a)(2), other Federal requirements may be applicable in siting a MSWLF unit in a wetland. These include:

- Sections 401, 402, and 404 of the CWA;
- Rivers and Harbors Act of 1989;
- National Environmental Policy Act;
- Migratory Bird Conservation Act;
- Fish and Wildlife Coordination Act;
- Coastal Zone Management Act;
- Wild and Scenic Rivers Act; and the
- National Historic Preservation Act.

As authorized by the EPA, the use of wetlands for location of a MSWLF facility may require a permit from the U.S. Army

Corps of Engineers (COE). The types of wetlands present (e.g., headwater, isolated, or adjacent), the extent of the wetland impact, and the type of impact proposed will determine the applicable category of COE permit (individual or general) and the permit application procedures. The COE District Engineer should be contacted prior to permit application to determine the available categories of permits for a particular site. Wetland permitting or permit review and comment can include additional agencies at the federal, state, regional, and local level. The requirements for wetland permits should be reviewed by the owner/operator to ensure compliance with all applicable regulations.

When proposing to locate a new facility or lateral expansion in a wetland, owners or operators must be able to demonstrate that alternative sites are not available and that the impact to wetlands is unavoidable.

If it is demonstrated that impacts to the wetland are unavoidable, then all practicable efforts must be made to minimize and, when necessary, compensate for the impacts. The impacts must be compensated for by restoring degraded wetlands, enhancing or preserving existing wetlands, or creating new wetlands. It is an EPA objective that mitigation activities result in the achievement of no net loss of wetlands.

2.4.3 Technical Considerations

The term wetlands, referenced in §258.12(b), is defined in §232.2(r). The EPA currently is studying the issues involved in defining and delineating wetlands. Proposed changes to the "Federal Manual for Identifying and Delineating .

proposed in the Federal Register on August acreage and a suitable type of upland may not be present to allow construction of a new MSWLF unit or lateral expansion without wetland impacts. Wetlands evaluations may become an integral part of the siting, design, permitting, and environmental monitoring aspects of a landfill unit/facility (see Figure 2-4).

Practicable Alternatives

EPA believes that locating new MSWLF units or lateral expansions in wetlands should be done only where there are no less damaging alternatives available. Due to the extent of wetlands that may be present in certain regions, the banning of new MSWLF units or lateral expansions in wetlands could cause serious capacity problems. The flexibility of the rule allows owners or operators to demonstrate that there are no practicable alternatives to locating or laterally expanding MSWLF units in wetlands.

As part of the evaluation of practicable alternatives, the owner/operator should consider the compliance of the location with other regulations and the potential impacts of the MSWLF unit on wetlands and related resources. Locating or laterally expanding MSWLF units in wetlands requires compliance with other environmental regulations. The owner or operator must show that the operation or construction of the landfill unit will not:

- Violate any applicable State water quality standards;
- Cause or contribute to the violation of any applicable toxic effluent standard or prohibition;
- Cause or contribute to violation of any requirement for the protection of a marine sanctuary; and
- Jeopardize the continued existence of endangered or threatened species or critical habitats.

The MSWLF unit cannot cause or contribute to significant degradation of wetlands. Therefore, the owner/operator must:

- Ensure the integrity of the MSWLF unit, including consideration of the erosion, stability, and migration of native wetland soils and dredged/fill materials;
- Minimize impacts on fish, wildlife, and other aquatic resources and their habitat from the release of solid waste;
- Evaluate the effects of catastrophic release of wastes on the wetlands; and
- Assure that ecological resources in the wetlands are sufficiently protected, including consideration of the volume and chemical nature of waste managed in the MSWLF unit.

These factors were partially derived from Section 404(b)(1) of the Clean Water Act. These guidelines address the protection of the ecological resources of the wetland.

After consideration of these factors, if no practicable alternative to locating the landfill in wetlands is available, compensatory steps must be taken to achieve no net loss of wetlands as defined by acreage and

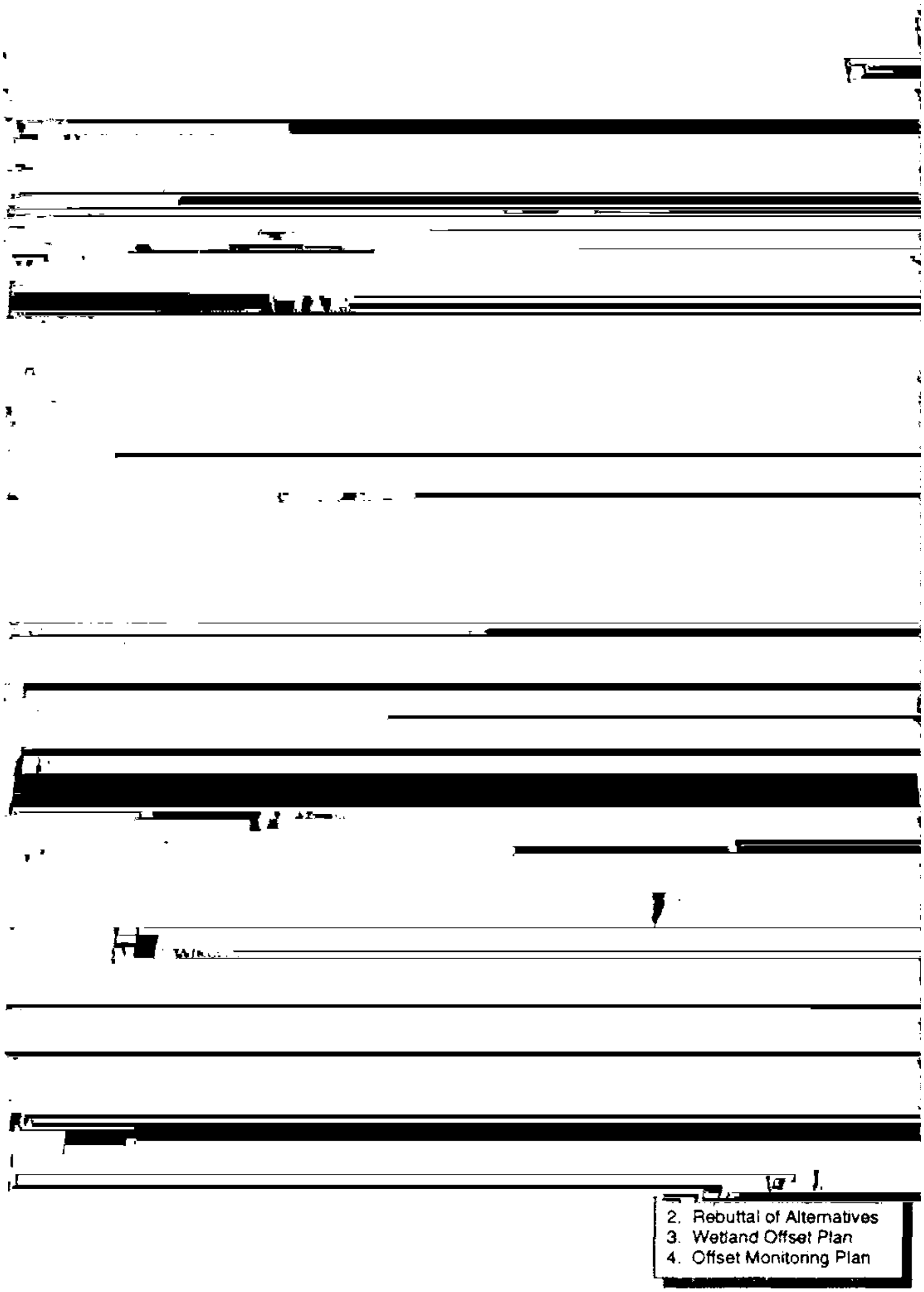


Figure 2-4
Wetlands Decision Tree for Owners/Operators in Approved States

function. The owner/operator must try to avoid and/or minimize impacts to the wetlands to the greatest extent possible. Where avoidance and minimization still result in wetland impacts, mitigation to offset impacts is required. Mitigation plans must be approved by the appropriate regulatory agencies and must achieve an agreed-upon measure of success. Examples of mitigation include restoration of degraded wetlands or creation of wetland acreage from existing uplands.

Part 258 presumes that practicable alternatives are available to locating landfill units in wetlands because landfilling is not a water-dependent activity. In an approved State, the owner or operator can rebut the presumption that a practicable alternative to the proposed landfill unit or lateral expansion is available. The term "practicable" pertains to the economic and social feasibility of alternatives (e.g., collection of waste at transfer stations and trucking to an existing landfill facility or other possible landfill sites). The feasibility evaluation may entail financial, economic, administrative, and public acceptability analyses as well as engineering considerations. Furthermore, the evaluations generally will require generation and assessment of land use, geologic, hydrologic, geographic, demographic, zoning, traffic maps, and other related information.

To rebut the presumption that an alternative practicable site exists generally will require that a site search for an alternative location be conducted. There are no standard methods for conducting site searches due to the variability of the number and hierarchy of screening criteria that may be applied in a specific case. Typical criteria may include:

- Distance from waste generation sources;
- Minimum landfill facility size requirements;
- Soil conditions;
- Proximity to ground-water users;
- Proximity of significant aquifers;
- Exclusions from protected natural areas;
- Degree of difficulty to remediate features; and
- Setbacks from roadways and residences.

Wetland Evaluations

The term "wetlands" includes swamps, marshes, bogs, and any areas that are inundated or saturated by ground water or surface water at a frequency and duration to support, and that under normal circumstances do support, a prevalence of vegetation adapted for life in saturated soil conditions. As defined under current guidelines, wetlands are identified based on the presence of hydric soils, hydrophytic vegetation, and the wetland hydrology. These characteristics also affect the functional value of a wetland in terms of its role in: supporting fish and wildlife habitats; providing aesthetic, scenic, and recreational value; accommodating flood storage; sustaining aquatic diversity; and its relationships to surrounding natural areas through nutrient retention and productivity exportation (e.g., releasing nutrients to downstream areas, providing transportable food sources).

Often, a wetland assessment will need to be conducted by a qualified and experienced multi-disciplinary team. The assessment should identify: (1) the limits of the wetland boundary based of wetland that triggers State agency

appropriate vegetation and importing low-permeability soil materials that would be conducive to forming saturated soil conditions. Excavation to form open water bodies or gradual restoration of salt water marshes by culvert expansions to promote sea water influx are other examples of compensatory mitigation.

Individual States may have offset ratios to determine how much acreage of a given functional value is required to replace the wetlands that were lost or impacted. Preservation of lands, such as through perpetual conservation easements, may be considered as a viable offset option. State offset ratios may require that for wetlands of an equivalent functional value, a larger acreage be created than was displaced.

Due to the experimental nature of creating or enhancing wetlands, a monitoring program to evaluate the progress of the effort should be considered and may be required as a wetland permit condition. The purpose of the monitoring program is to verify that the

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:

fractures in any material along which strata on one side have been displaced with respect to that on the other side.

(2) <u>Displacement</u> means the relative movement of any two sides of a fault measured in any direction.

(3) <u>Holocene</u> means the most recent epoch of the Quaternary period, extending

the present.

2.5.2 Applicability

Except in approved States, the regulation bans all new MSWLF units or lateral expansions of

considered aTw (Tj 22012 -462.8611 -0 Tc 3.2 Tw (value is requ.yd.) Tj 25otb ETh of thD 0.3056 Tc (ans the

approval by the Director of an approved State. If the demonstration is approved, it must be placed in the facility's operating record. The option to have a setback of less than 200 feet from a Holocene fault is not available in unapproved States.

2.5.3 Technical Considerations

Locating a landfill in the vicinity of an area that has experienced faulting in recent time has inherent dangers. Faulting occurs in areas where the geologic stresses exceed a geologic material's ability to withstand those stresses. Such areas also tend to be subject to earthquakes and ground failures (e.g., landslides, soil liquefaction) associated with

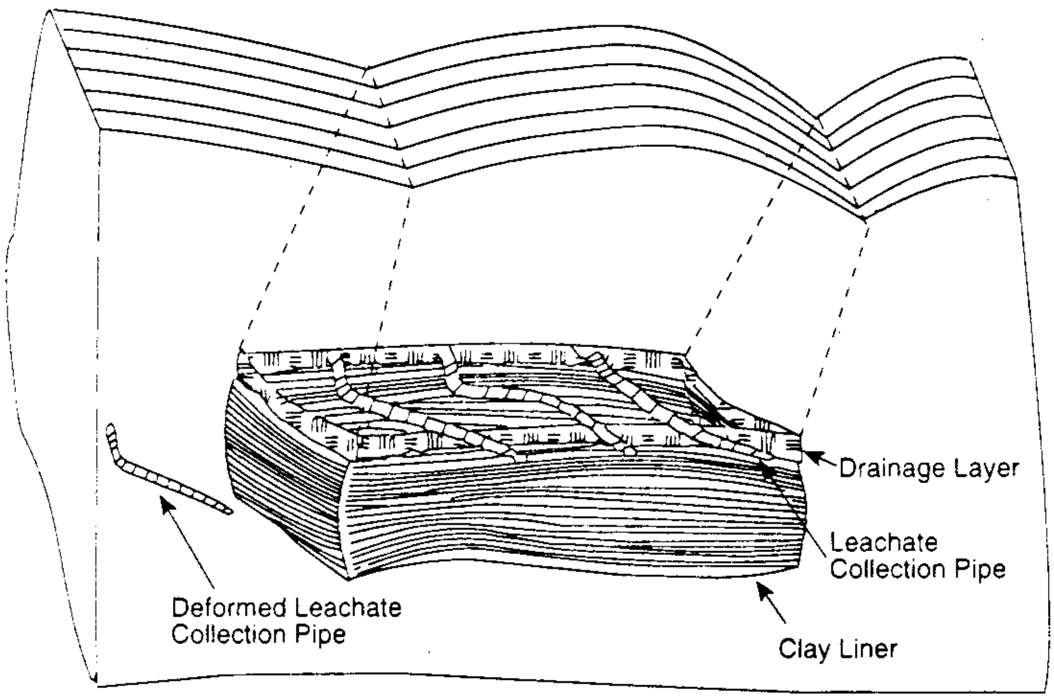
used. A series of maps known as the "Preliminary Young Fault Maps, Miscellaneous Field Investigation (MF) 916" was published by the USGS in 1978. Information about these maps can be obtained from the USGS by calling 1-800-USA-

Center in Reston, Virginia, or by calling 303-

Sales Center in Denver, Colorado.

For locations where a fault zone has been subject to movement since the USGS maps were published in 1978, a **geologic reconnaissance** of the site and surrounding areas may be required to map fault traces and to determine the faults along which

Figure 2-5
Potential Seismic Effects



A schematic diagram of a landfill showing potential deformation of the leachate collection and removal system by seismic stresses.

Source: US EPA, 1992

- A field reconnaissance that includes walking portions of the area within 3,000 feet of the unit.

If the site fault characterization indicates that a fault or a set of faults is situated within 3,000 feet of the proposed unit, investigations should be conducted to determine the presence or absence of any faults within 200 feet of the site that have experienced movement during the Holocene period. Such investigations can include:

- Subsurface exploration, including drilling and trenching, to locate fault zones and evidence of faulting.

- Trenching perpendicular to any faults or lineaments within 200 feet of the unit.

- Determination of the age of any displacements, for example by examining displacement of surficial deposits such as glacial or older deposits (if Holocene deposits are absent).

- Examination of seismic epicenter information to look for indications of recent movement or activity along structures in a given area.

- Review of high altitude, high resolution aerial photographs with stereo-vision coverage. The photographs are produced8914 0 40689 0 TD -0 Tc 0 Tw (e) Tj 55.9243 0 TD 0 Tc 0.11

Based on this information as well as supporting maps and analyses, a qualified professional should prepare a report that

fault(s) and the associated 200-foot setback.

If requesting an alternate setback, a demonstration must be made to show that no damage to the landfill's structural integrity will result. Examples of engineering considerations and modifications that may be included in such demonstrations are as

- For zones with high probabilities of high accelerations (horizontal) within the

  designs should be developed.

  slopes should be performed to guide selection of materials and gradients for slopes.

- Where in-situ and laboratory tests

  susceptible to liquefaction, ground improvement measures like grouting, dewatering, heavy tamping, and excavation should be implemented.

- Engineering options include:

In addition, use of such measures needs to be demonstrated to be protective of human health and

acceleration will not be exceeded in 250 years, or the maximum expected horizontal

2.6.3 Technical Considerations

Background on Seismic Activity

To understand seismic activity, it is helpful to know its origin. A brief introduction to the geologic underpinnings of seismic activity is presented below.

The earth's crust is not a static system. It consists of an assemblage of earthen masses that are in slow motion. As new crust is generated from within the earth, old edges of crust collide with one another, thereby causing stress. The weaker edge is forced to move beneath the stronger edge back into the earth.

The dynamic conditions of the earth's crust can be manifested as shaking ground (seismic activity), fracturing (faulting), and volcanic eruptions. Seismic activity also can result in types of ground failure. Landslides and mass movements (e.g., slope failures) are common on slopes; soil compaction or ground subsidence tends to occur in unconsolidated valley sediments; and liquefaction of soils tends to happen in areas where sandy or silty soils that are saturated and loosely compacted become in effect, liquefied (like quicksand) due to the motion. The latter types of phenomena are addressed in Section 2.7, Unstable Areas.

Information Sources on Seismic Activity

To determine the maximum horizontal acceleration of the lithified earth material for the site (see Figure 2-6), owners or operators of MSWLF units should review the seismic 250-year interval maps in U.S. Geological Survey Miscellaneous Field Study Map MF-2120, entitled "Probabilistic Earthquake Acceleration and Velocity Maps for the United States and Puerto Rico" (Algermissen et al., 1991). To view the original of the map that is shown in Figure 2-6 (reduced in size), contact the USGS office in your area. The original map (Horizontal Acceleration - Base modified from U.S.G.S. National Atlas, 1970, Miscellaneous Field Studies, Map MF 2120) shows county lines within each State. For areas not covered by the aforementioned map, USGS State seismic maps may be used to estimate the maximum horizontal acceleration. The National Earthquake Information Center, located at the Colorado School of Mines in Golden, Colorado, can provide seismic maps of all 50 states. The Center also maintains a database of known earthquakes and fault zones.

Information on the -13.917 4.4371 h7.8799 00c 0.14eg

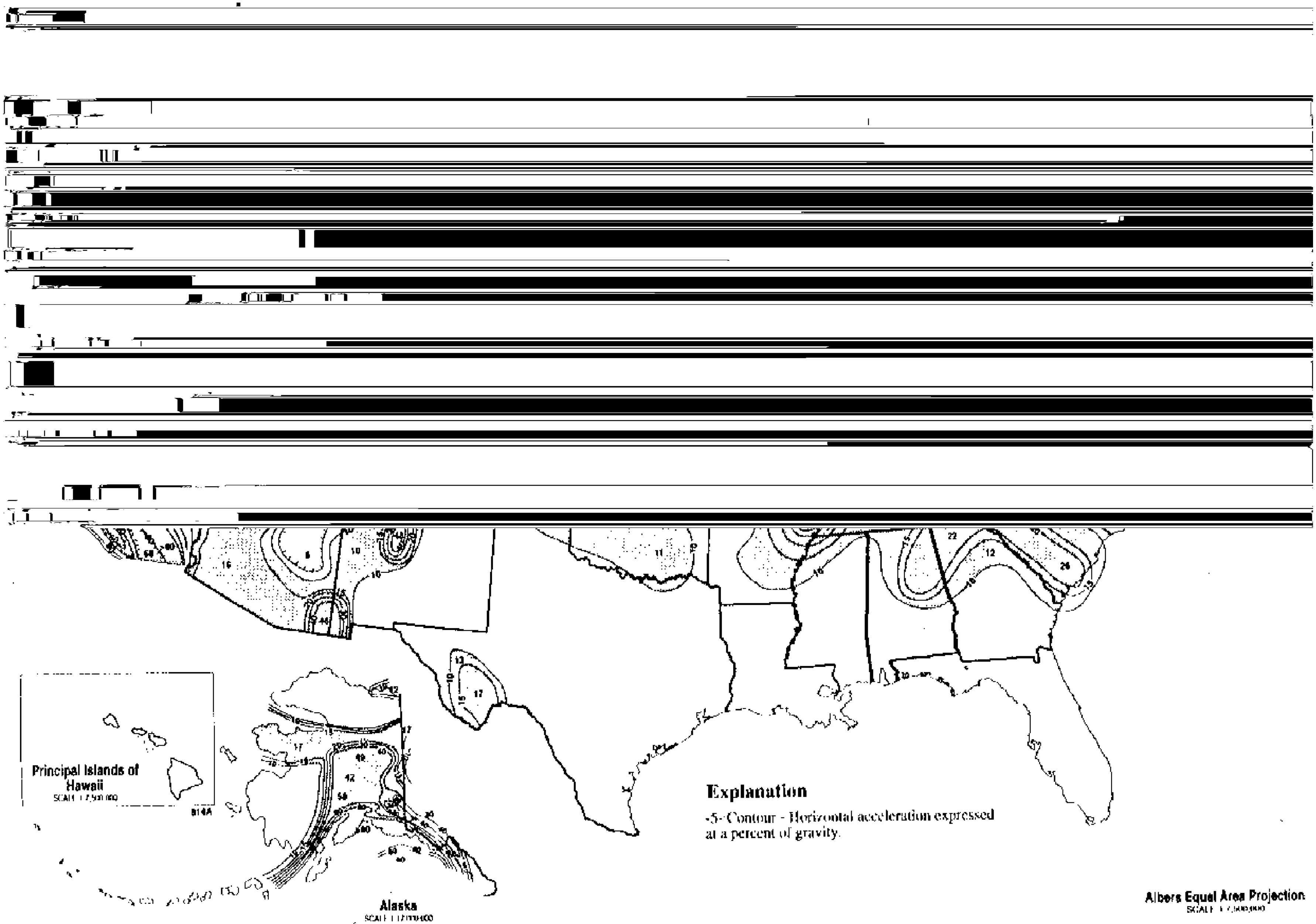


Figure 2-6. Seismic Impact Zones
(Areas with a 10% or greater probability that the maximum horizontal acceleration will exceed .10g in 250 years)

settlements of the ground surface (Winterkorn and Fang, 1975).

well-established analytical methods. Several

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) <u>Unstable area</u> 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 terrains.

(2) <u>Structural components</u> 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) <u>Poor foundation conditions</u> means those areas where features exist which indicate that a natural or man-induced event may result in inadequate foundation ructuraorttectironm.1181 085c 018.0117 Tc 0.608.6771 T1

natural

on steep or gradual slopes. They tend to have rock or soil conditions that are conducive to downslope movement of soil, rock, and/or debris (either alone or mixed with water) under the influence of gravity. Examples of mass movements include avalanches, landslides, debris slides and flows, and rock slides.

- **Karst terrains** tend to be subject to extreme incidents of differential settlement, namely complete ground collapse. Karst is a term used to describe areas that are underlain by soluble bedrock, such as limestone, where solution of the rock by water creates subterranean drainage systems that may include areas of rock collapse. These areas tend to be characterized by large subterranean and surficial voids (e.g., caverns and sinkholes) and unpredictable

ek 2168To 836-0.002 Tc 41622.38 Tw (su325 Tj588.0484 9 0.57.0037 Tc 196808 Tw41) Tj 3.3edicj 125c

assessment

- A closed landfill as the foundation for a new landfill ("piggy-backing") may be unstable unless the closed landfill has undergone complete settlement of the underlying wastes.

As part of their demonstration to site a landfill in an unstable area, owners/operators

to serve as a foundation as well as the ability of the site embankments and slopes to maintain a stable condition. Once these factors have been evaluated, a MSWLF design should be developed that will address these types of concerns and prevent possible associated damage to MSWLF structural components.

In designing a new unit or lateral expansion or re-evaluating an existing MSWLF unit, a **stability assessment** should be conducted in

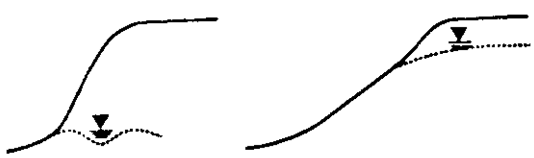
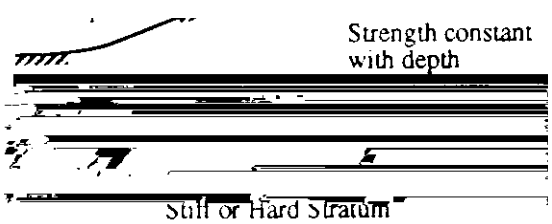
- Testing the soil properties such as water content, shear strength, plasticity, and grain size distribution.

A stability assessment should consider (USEPA, 1988):

Information on natural features can be obtained from:

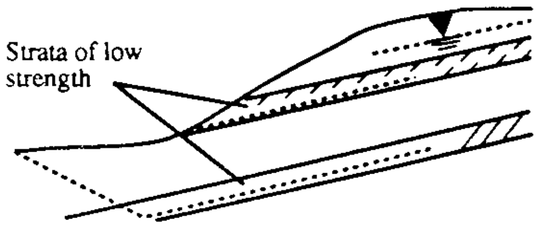
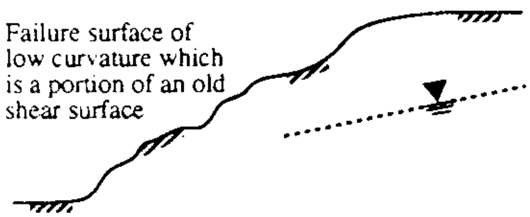
entitled "Engineering Aspects of

Principal modes of failure in soil or rock settlement,

1. Slope in Coarse-Grained Soil with Some Cohesion *Low Groundwater* Failure of thin wedge, position influenced by tension cracks *High Groundwater* Failure at relatively shallow toe circles 	• With low groundwater, failure occurs on shallow, straight, or slightly curved surface. Presence of a tension crack at the top of the slope influences failure location. With high groundwater, failure occurs on the relatively shallow toe circle whose position is determined primarily by ground elevation. • Analyze with effective stress using strengths C' and Ø' from CD tests. Pore pressure is governed by seepage condition. Internal pore pressures and external water pressures must be included.
2. Slope in Coarse-Grained, Soil Cohesion *Low Groundwater* Stable slope angle = effective friction angle *High Groundwater* Stable slope angle = ½ effective friction angle 	• Stability depends primarily on groundwater conditions. With low groundwater, failures occur as surface sloughing until slope angle flattens to friction angle. With high groundwater, stable slope is approximately 1/2 friction angle. • Analyze with effective stress using strengths C' and Ø' from CD tests. Slight cohesion appearing in test envelope is ignored. Special consideration must be given to possible flow slides in loose, saturated fine sands.
3. Slope in Normally Consolidated or Slightly Preconsolidated Clay *Location of failure depends on variation of shear strength with depth.*  	• Failure occurs on circular arcs whose position is governed by theory. Position of groundwater table does not influence stability unless its fluctuation changes strength of the clay or acts in tension cracks. • Analyze with total stresses, zoning cross section for different values of shear strengths. Determine shear strength from unconfined compression test, unconsolidated undrained triaxial test or vane shear.

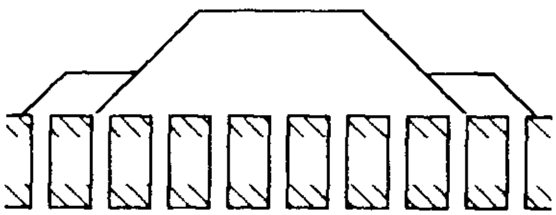
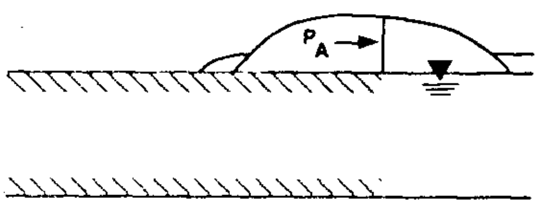
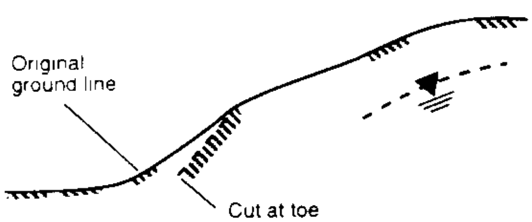
Source: Soil Mechanics, NAVFAC Design Manual 7.01

Table 2-2. Analysis of Stability of Natural Slopes

4. Slope in Stratified Soil Profile *Location of failure depends on relative strength and orientation of layers.*  	• Location of failure plane is controlled by relative strength and orientation of strata. Failure surface is combination of active and passive wedges with central sliding block chosen to conform to stratification. • Analyze with effective stress using strengths C' and Ø' for fine-grained strata and Ø' for cohesionless material.
5. Depth Creep Movements in Old Slide Mass *Bowl-shaped area of low slope (9 to 11%) bounded at top by old scarp.*  	• Strength of old slide mass decreases with magnitude of movement that has occurred previously. Most dangerous situation is in stiff, over-consolidated clay which is softened, fractured, or slickensided in the failure zone.

Source: Soil Mechanics, NAVFAC Design Manual 7.01

Table 2-2. Analysis of Stability of Natural Slopes (Continued)

1. Failure of Fill on Soft Cohesive Foundation with Sand Drains  Location of failure depends on geometry and strength of cross section.	• Usually, minimum stability occurs during placing of fill. If rate of construction is controlled, allow for gain in strength with consolidation from drainage. • Analyze with effective stress using strengths C' and Ø' from CU tests with pore pressure measurement. Apply estimated pore pressures or piezometric pressures. Analyze with total stress for rapid construction without observation of pore pressures, use shear strength from unconfined compression or unconsolidated undrained triaxial.
2. Failure of Stiff Compacted Fill on Soft Cohesive Foundation  Failure surface may be rotation on circular arc or translation with active and passive wedges.	• Usually, minimum stability obtained at end of construction. Failure may be in the form of rotation or translation, and both should be considered. • For rapid construction ignore consolidation from drainage and utilize shear strengths determined from U or UU tests or vane shear in total stress analysis. If failure strain of fill and foundation materials differ greatly, safety factor should exceed one, ignoring shear strength of fill. Analyze long-term stability using C and Ø from CU tests with effective stress analysis, applying pore pressures of
3. Failure Following Cut in Stiff Fissured Clay  Failure surface depends on pattern of fissures or depth of softening.	• Release of horizontal stresses by excavation causes expansion of clay and opening of fissures, resulting in loss of cohesive strength. • Analyze for short-term stability using C' and Ø' with total stress analysis. Analyze for long-term stability with C'_r and $Ø'_m$ based on residual strength measured in consolidated drained tests.

Source: Soil Mechanics, NAVFAC Design Manual 7.01

Table 2-3. Analysis of Stability of Cut and Fill Slopes, Conditions Varying With Time

Subsurface Exploration Programs

Foundation soil stability assessments for non-catastrophic failure require field investigations to determine soil strengths and other soil properties. *In situ* field vane shear tests commonly are conducted in addition to collection of piston samples for laboratory testing of undrained shear strengths (biaxial and triaxial). Field vanes taken at depth provide a profile of soil strength. The required field vane depth intervals vary, based on soil strength and type, and the number of

Methods of Slope Stability Analysis

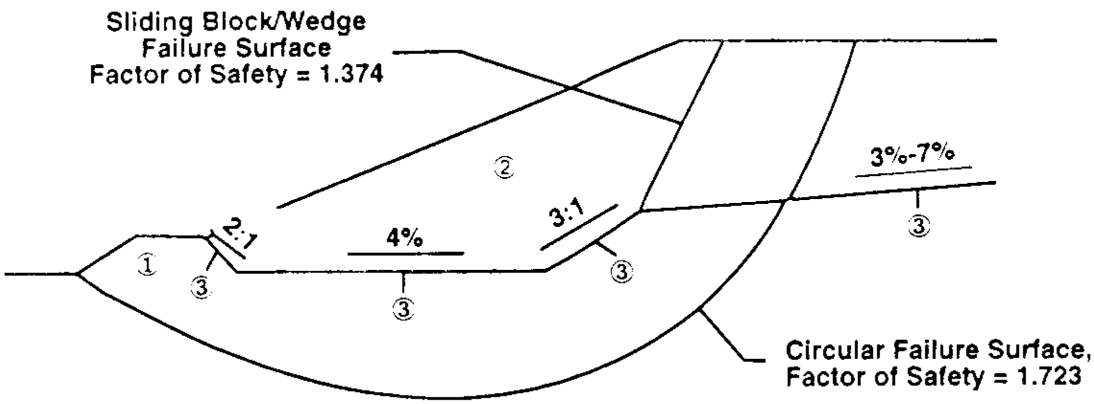
Slope stability analyses are performed for both excavated side slopes and aboveground embankments. The analyses are performed as appropriate to verify the structural integrity of a cut slope or dike. The design configuration is evaluated for its stability under all potential hydraulic and loading conditions, including conditions that may exist during construction of an expansion (e.g., excavation). Analyses typically performed are slope stability, settlement, ancom

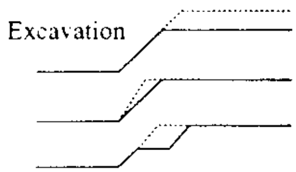
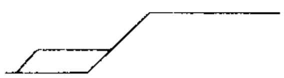
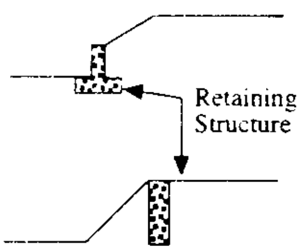
then is compared to the estimated or available shear strength of the soil to give an indication of the factor of safety (Winterkorn and Fang, 1975).

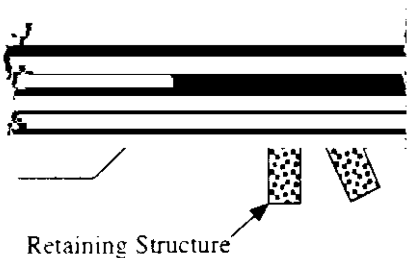
excavating a bench in the upper part of

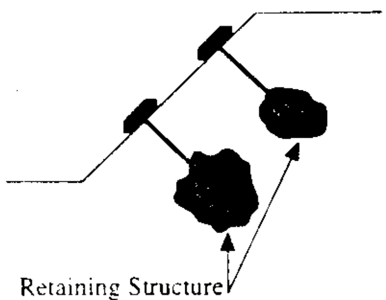
Figure 2-7
Sample Output from PC STABL Model

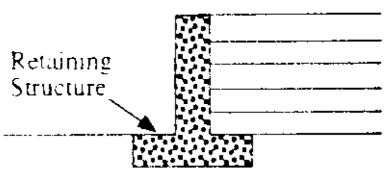
Subgrade: Internal friction angle = 32 degrees
Refuse: Internal friction angle of waste = 25 degrees
Refuse: Internal friction angle of waste = 25 degrees



Scheme	Applicable Methods	Comments
1. Changing Geometry 	1. Reduce slope height by excavation at top of slope 2.	1. Area has to be accessible to construction
		
		

<table>
<tr><th>Scheme</th><th>Applicable Methods</th><th></th></tr>
<tr><td>






</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

with steeply cut slopes where soil arching can be developed between the piles.

— The last retaining wall shown uses a cantilever setup along with soil that has been reinforced with geosynthetic material to provide a system that is highly resistant to vertical and lateral motion. This type of system is best suited for use in situations where vertically cut slopes must have lateral movement strictly controlled.

Other potential procedures for stabilizing natural and human-made slopes include the use of geotextiles and geogrids to provide additional strength, the installation of wick and toe drains to relieve excess pore pressures, grouting, and vacuum and wellpoint pumping to lower ground-water levels. In addition, surface drainage may be controlled to decrease infiltration, thereby reducing the potential for mud and debris slides in some areas. Lowering the ground-water table also may have stabilizing effects. Walls or large-diameter piling can be used to stabilize slides of relatively small dimension or to retain steep toe slopes so that failure will not extend back into a larger

Monitoring

During construction activities, it may be

because of the additional stresses placed on natural and engineered soil systems (e.g., slopes, foundations, dikes) as a result of excavation and filling activities. Post-closure slope monitoring usually is not necessary.

Important monitoring parameters may include settlement, lateral movement, and pore water pressure. Monitoring for pore water pressure is usually accomplished with

Lateral movements of structures may be detected on the surface by surveying horizontal and vertical movements. Subsurface movements may be detected by use of slope inclinometers. Settlement may be monitored by surveying ground surface elevations (on several occasions over a period of time) and comparing them with areas that are not likely to experience changes in elevations (e.g., USGS survey monuments).

Engineering Considerations for Karst Terrains

The

The first stage of demonstration is to characterize the subsurface. Subsurface drilling, sinkhole monitoring, and geophysical testing are direct means that can be used to characterize a site. Geophysical techniques

heavily compacted to achieve the needed stability. Similarly, in areas where the karst voids are relatively small and limited in extent, infilling of the void with slurry cement grout or other material may be an

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

2.8.3 Technical Considerations

The engineering considerations that should be addressed for airport safety, 100-year

are discussed in Sections 2.2, 2.3, and 2.7 of this chapter. Information and evaluations necessary for these demonstrations also are presented in these sections. If applicable demonstrations are not made by the owners or

according to the requirements of sectio

2.9 FURTHER INFORMATION

2.9.1 References

General

Linsley and Franzini, (1972). "Water Resources Engineering"; McGraw-Hill; pp. 179-184.

U.S. EPA, (1988). "Guide to Technical Resources for the Design of Land Disposal Facilities"; EPA/625/6-88/018; USEPA; Risk Reduction Engineering Laboratory and Center for Environmental Research Information; Office of Research and Development; Cincinnati, Ohio 45268.

USGS. Books and Open File Section, Branch Distribution, Box 25046, Federal Center, Denver, CO 80225.

Floodplains

COE, (1982). HEC-1, HEC-2, HEC-5, HEC-6 Computer Programs; Hydrologic Engineering Center (HEC); U.S. Army Corps of Engineers; Hydrologic Engineering Center; Davis California.

Federal Emergency Management Agency, (1980). "How to Read a Flood Insurance Rate Map"; April 1980. Available from FEMA Regional Offices.

Maynard, S.T., (1978). "Practical Riprap Design"; Hydraulics Laboratory Miscellaneous Paper H-78-7; U.S. Army Engineers Waterways Experiment Station; Vicksburg, Mississippi. SCS, (1983).

"Maryland Standards and Specifications for Soil Erosion and Sediment Control"; U.S. Soil Conservation Service; College Park, Maryland.

U.S. Water Resources Council, (1977). "Guidelines for Determining Flood Flow Frequency"; Bulletin #17A of the Hydrology Committee; revised June 1977.

Wetlands

COE, (1987). "Corps of Engineers Wetlands Delineation Manual," Technical Report (Y-87-1), Waterways Experiment Station, Jan. 1987.

COE, (1989). "Federal Manual for Identifying and Delineating Jurisdictional Wetlands," Federal Interagency Committee for Wetland Delineation; U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and U.S.D.A., Soil Conservation Service; Washington, D.C., Cooperative Technical Publication. 1989.

Fault Areas, (1992). "Aspects of Landfill Design for Stability in Seismic Zones," Hilary I. Inyang, Ph.D.

Seismic Impact Zones

Algermissen, S.T., et al., (1991). "Probabilistic Earthquake Acceleration and Velocity Maps for the United States and Puerto Rico," USGS Miscellaneous Field Study Map MF-2120.

Algermissen, S.T., et al., (1976). "Probabilistic Estimates of Maximum Acceleration and Velocity in Rock in the Contiguous United States"; Open File Report 82-1033; U.S. Geological Survey; Washington, D.C.

U.S. EPA, (1992). "Aspects of Landfill Design for Stability in Seismic Zones", Hilary I. Inyang. Ph.D.

U.S. Navy, (1983). "Design Manual-Soil Dynamics, Deep Stabilization, and Special Geotechnical Construction," NAVFAC DM-7.3; Department of the Navy; Washington, D.C.; April, 1983.

Winterkorn, H.F. and Fang, H.Y., (1975). "Foundation Engineering Handbook." Van Nostrand Reinhold. 1975.

Unstable Areas

Geoslope Programming Ltd., (1986). PC-SLOPE, Version 2.0 (May); Calgary, Alberta, Canada.

Huang, U.H., (1983). "Stability Analysis of Earth Slopes"; Van Nostrand Reinhold Co.; New York.

Koerner, R.M., (1986). "Designing with Geosynthetics"; Prentice-Hall Publishing Co.; Englewood Cliffs, New Jersey.

Lambe, W.T. and R.V. Whitman, (1969). "Soil Mechanics"; John Wiley and Sons, Inc.; New York.

Richardson, G.N. and R.M. Koerner, (1987). "Geosynthetic Design Guidance for Hazardous Waste Landfill Cells and Surface Impoundments"; Hazardous Waste Engineering Research Laboratory; USEPA, Office of Research and Development; Cincinnati, Ohio; Contract No. 68-07-3338.

Sowers, G.F., (1979). "Soil Mechanics and Foundations: Geotechnical Engineering," The MacMillan Company, New York.

Terzaghi, K. and R.B. Peck, (1967). "Soil Mechanics in Engineering Practice", 2nd Edition; John Wiley and Sons, Inc.; New York.

U.S. Navy, (1986). "Design Manual-Soil Mechanics, Foundations and Earth Structures," NAVFAC DM-7; Department of the Navy; Washington, D.C.; September 1986.

Winterhorn, H.F. and Fang, H.Y., (1975). "Foundation Engineering Handbook," Van Nostrand Reinhold, 1975.

2.9.2 Organizations

American Institute of Architects
Washington, D.C.
(202) 626-7300

Aviation Safety Institute (ASI)
Box 304
Worthington, OH 43085
(614) 885-4242

Federal Emergency Management Agency
Flood Map Distribution Center
6930 (A-F) San Thomas Road
Baltimore, Maryland 21227-6227
1-800-358-9616

Federal Emergency Management Agency
(800) 638-6620 Continental U.S. only, except Maryland
(800) 492-6605 Maryland only
(800) 638-6831 Continental U.S., Hawaii, Alaska, Puerto Rico, Guam, and the Virgin Islands

Note: The toll free numbers may be used to obtain any of the numerous FEMA publications such as "The National Flood Insurance Program Community Status Book," which is published bimonthly.

To obtain Flood Insurance Rate Maps and other flood maps, the FEMA Flood Map Distribution Center should be contacted at 1-800-358-9616.

Federal Highway Administration
400 7th St. S.W.
Washington, D.C. 20590
(202) 366-4000 (Locator)
(202) 366-0660 (Information)

Tennessee Valley Authority
412 First Street Southeast, 3rd Floor
Washington, DC 20444
(202) 479-4412

U.S. Department of Agriculture
Soil Conservation Service
P.O. Box 2890
Washington, DC 20013-2890
(Physical Location: 14th and Independence Ave. N.W.)
(202) 447-5157

U.S. Department of the Army
U.S. Army Corps of Engineers
Washington, DC 20314-1000
(202) 272-0660

U.S. Department of the Interior
Fish and Wildlife Service
1849 C Street Northwest
Washington, DC 20240
(202) 208-5634

U.S. Department of Transportation
Federal Aviation Administration
800 Independence Ave., S.W.
Washington, D.C. 20591
(202) 267-3085

U.S. Geological Survey
12201 Sunrise Valley Drive
Reston, Virginia 22092
(800) USA-MDdW2rtment of Transportation

U.S. Geological Survey
National Earthquake Information Center
Stop 967 Box 25046
Denver Federal Center
Denver, Colorado 80225
(303) 236-1500

2.9.3 Models

Adamus, P.R., et al., (1987). "Wetland Evaluation Technique (WET); Volume II: Methodology"; Operational Draft Technical Report Y-87; U.S. Army Engineer Waterways Experiment Station; Vicksburg, MS.

COE, (1982). HEC-1, HEC-2, HEC-5, HEC-6 Computer Programs; Hydrologic Engineering Center (HEC); U.S. Army Corps of Engineers; Hydrologic Engineering Center; Davis California.

Geoslope Programming Ltd., (1986). PC-SLOPE, Version 2.0 (May); Calgary, Alberta, Canada.

Lysemer, John, et al., (1979). "FLUSH: A Computer Program for Approximate 3-D Analysis"; University of California at Berkeley; March 1979. (May be obtained through the National Information Service for Earthquake Engineering at the address provided in subsection 2.9.2 of this document.)

Purdue University, Civil Engineering Dept., (1988). PC STABL, West Lafayette, IN 47907.

United States Fish and Wildlife Service, (1980). "Habitat Evaluation Procedures". ESM 102; U.S. Fish and Wildlife Service; Division of Ecological Services; Washington, D.C.

APPENDIX I

FAA Order 5200.5A

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

5200.5A

l/31/90

SUBJ: WASTE DISPOSAL SITES ON OR NEAR AIRPORTS

1

(1) Additionally, any operator proposing a new or expanded waste disposal site within 5 miles of a runway end should notify the airport and the appropriate FM Airports office so as to provide an opportunity to review and comment on the site in accordance with the guidance contained in this order. FM field offices may wish to contact the appropriate State director of the United States Department of Agriculture to assist in this review. Also, any Air Traffic control tower manager or Flight Standards District Office manager and their staffs that become aware of a proposal to develop or expand a disposal site should notify the appropriate FM Airports office.

b. The operation of a disposal site located beyond the areas described in paragraph 7 must be properly supervised to ensure compatibility with the airport.

c. If at any time the disposal site, by virtue of its location or operation, presents a potential hazard to aircraft operations the owner should take action to correct the situation or terminate operation of the facility. If the owner of the airport also owns or controls the disposal facility and is subject to Federal obligations to protect compatibility of land uses around the airport, failure to take corrective action could place the airport owner in noncompliance with its commitments to the Federal government. The appropriate FM office should immediately evaluate the situation to determine compliance with federal agreements and take such action as may be warranted under the guidelines as prescribed in Order 5190.6, Airports Compliance Requirements, current edition.

(1) Airport owners should be encouraged to make periodic inspections of current operations of existing disposal sites near a federally obligated airport where potential bird hazard problems have been reported.

d. This order is not intended to resolve all related problems but is specifically directed toward eliminating waste disposal sites, landfills and similarly titled facilities in the proximity of airports, thus providing a safer environment for aircraft operations.

e. At airports certified under Federal Aviation Regulations, part 139, the airport certification manual/specifications should require disposal site inspections at appropriate intervals for those operations meeting the criteria of paragraph 7 that cannot be closed. These inspections are necessary to assure that bird populations are not increasing and that appropriate control procedures are being established and followed. The appropriate FAA airport offices should develop working relationships with state aviation agencies and state agencies that have authority over waste disposal and landfills to stay abreast of proposed developments and expansions and apprise them of the hazards to aviation that these present.

f. When proposing a disposal site, operators should make their plans available to the appropriate state regulatory agencies. Many states have criteria concerning siting requirements specific to their jurisdictions.

g. Additional information on waste disposal, bird hazard and related problems may be obtained from the following agencies:

U.S. Department of Interior Fish and Wildlife Service
18th and C Streets, NW
Washington, DC 20240

U.S. Department of Agriculture
Animal Plant Health Inspection Service
P.O. Box 96464
Animal Damage Control Program
Room 1624 South Agriculture Building
Washington, DC 20090-6464

U.S. Environmental Protection Agency
401 M Street, SW
Washington, DC 20460

U.S. Department of Health and Human Services

c. Any waste disposal site located within a 5-mile radius of a runway end that attracts or sustains hazardous bird movements from feeding, water or roosting areas into, or across the runway and/or approach and departure patterns of aircraft.

Leonard E. Mudd
Director, Office of Airport Safety and Standards

CHAPTER 3

SUBPART C
OPERATING CRITERIA

3.2 PROCEDURES FOR EXCLUDING THE RECEIPT OF HAZARDOUS WASTE 40 CFR §258.20

3.2.1 Statement of Regulation

(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 title and polychlorinated biphenyls (PCB) wastes as defined in Part 761 of this title. This program must include, at a minimum:

(1) Random inspections of incoming loads unless the owner or operator takes other steps to ensure that incoming 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

3.2.2 Applicability

This regulation applies to all MSWLF units

1993.

The owner or operator must develop a program to detect and prevent disposal of regulated hazardous wastes or PCB wastes at the MSWLF facility. Hazardous wastes may be gases, liquids, solids, or sludges that are listed or exhibit the characteristics described in 40 CFR Part 261. Household hazardous wastes are excluded from Subtitle C

conditionally exempt small quantity generators (CESQGs) are not considered regulated hazardous wastes for purposes of complying with §258.20; therefore, these wastes may be accepted for disposal at a

program should be capable of detecting and preventing disposal of PCB wastes. PCB wastes may be liquids or non-liquids (sludges

761.60. PCB wastes do not include small(

Part 261 (termed a "listed" waste); (2) exhibits a characteristic of a hazardous waste as defined in Subpart C of 40 CFR Part 261; or (3) is a mixture of a listed hazardous waste and a non-hazardous solid waste. Characteristics of hazardous wastes as defined in Subpart C of 40 CFR Part 261 include ignitability, corrosivity, reactivity, and toxicity. The toxicity characteristic leaching procedure (TCLP) is the test method used to determine the mobility of organic and inorganic compounds present in liquid, solid, and multiphase wastes. The TCLP is presented in Appendix II of Part 261.

The MSWLF Criteria exclude CESQG waste (as defined in 40 CFR §261.5) from the definition of "regulated hazardous wastes." CESQG waste includes listed hazardous wastes or wastes that exhibit a characteristic of a hazardous waste that are generated in

These sources are not regulated under 40 CFR Part 761 and, therefore, are not part of the detection program required by §258.20. Commercial or industrial sources of PCB wastes that should be addressed by the program include:

- Mineral oil and dielectric fluids containing PCBs;
- Contaminated soil, dredged material, sewage sludge, rags, and other debris from a release of PCBs;

equipment containing dielectric fluids; and

- Hydraulic machines.

The owner or operator 23romded, rt

an individual who is trained to identify regulated hazardous or PCB wastes that would not be acceptable for disposal at the MSWLF unit. An inspection is considered satisfactory if

Inspection priority also can be given to haulers with unknown service areas, to loads brought to the facility in vehicles not typically used for disposal of municipal solid waste,

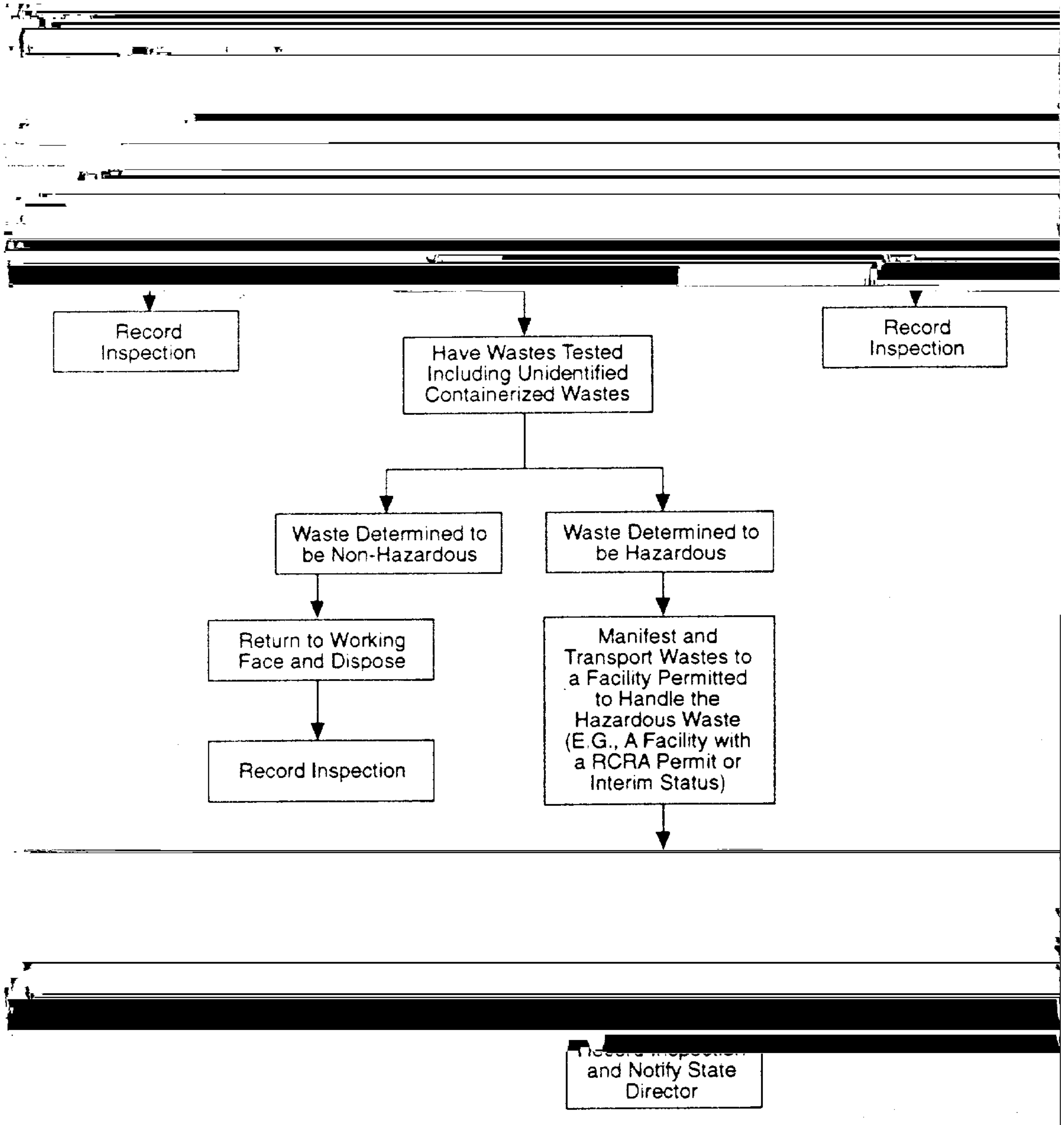


Figure 3-1
Hazardous Waste Inspection Decision Tree
Inspection Prior to Working Face

keep any such agreements concerning these alternatives in the operating record.

Recordkeeping

A record should be kept of each inspection that is performed. These records should be included and maintained in the facility operating record. Larger facilities that take large amounts of industrial and commercial wastes may use more detailed procedures than smaller facilities that accept household wastes. Inspection records may include the following information:

- The date and time wastes were received for inspection;
- Source of the wastes;
- Vehicle and driver identification; and
- All observations made by the inspector.

The Director of an approved State may establish alternative recordkeeping locations and requirements.

Training

Owners or operators must ensure that

Training also should address hazardous waste handling procedures, safety precautions, and

information is provided in training courses

Safety and Health Act (OSHA) under 29 CFR §1910.120. Information covered in these courses includes regulatory requirements under 40 CFR Parts 260 through 270, 29 CFR Part 1910, and related guidance documents that discuss such topics as: general hazardous waste management; identification of hazardous wastes; transportation of hazardous wastes; standards for hazardous waste

hazardous waste worker health and safety training and monitoring requirements.

Notification to Authorities and Proper

with all applicable Federal and State regulations.

Operators of MSWLF facilities should be prepared to handle hazardous wastes that are inadvertently received at the MSWLF facility. This may include having containers such as 55-gallon drums available on-site and retaining a list of names and telephone numbers of the nearest haulers licensed to transport hazardous waste.

Hazardous waste may be stored at the MSWLF facility for 90 days, provided that the following procedures required by 40 CFR §262.34, or applicable State requirements, are followed:

- The waste is placed in tanks or containers;
- The date of receipt of the waste is clearly marked and visible on each container;
- The container or tank is marked clearly with the words "Hazardous Waste";
- An employee is designated as the emergency coordinator who is responsible

analogous State/Tribal requirements. The owner or operator is required to:

- Obtain an EPA identification number (EPA form 8700-12 may be used to apply for an EPA identification number; State or Regional personnel may be able to provide a provisional identification number over the telephone);
- Package the waste in accordance with

  regulations under 49 CFR Parts 173, 178, and 179 (The container must be labeled, marked, and display a placard in accordance with DOT regulations on hazardous wastes under 49 CFR Part

material requirement is not related to the final cover required under §258.60.

The placement of six inches of cover controls disease vectors (birds, insects, or rodents that represent the principal transmission pathway of a human disease) by preventing egress from the waste and by preventing access to breeding environments or food sources. Covering also reduces exposure of combustible materials to ignition sources and may reduce the spread of fire if the disposed

1) Side by side (six inches of earthen materials and alternative cover) test pads;

2) Full-scale demonstration; and

3) Short-term full-scale tests.

Alternative daily cover materials may include indigenous materials or commercially-available materials. Indigenous materials are those materials that would be disposed as waste;c

Commercially developed alternatives have been on the market since the mid-1980s. Some of the commercial alternative materials require specially designed application equipment, while others use equipment generally available at most landfills. Some of the types of commercially available daily cover materials include (USEPA, 1992):

- Spreading and compacting the soil to achieve the required functions.

Extremely cold conditions may prevent the efficient excavation of soil from a borrow pit or the spreading and compaction of the soil on the waste. Extremely wet conditions (e.g., prolonged protection of human health and the environment.

3.4.3 Technical Considerations

Disease vectors such as rodents, birds, flies, and mosquitoes typically are attracted by putrescent waste and standing water, which act as a food source and breeding ground. Putrescent waste is solid waste that contains organic matter (such as food waste) capable of being decomposed by micro-organisms. A MSWLF facility typically accepts putrescent wastes.

Application of cover at the end of each operating day generally is sufficient to control disease vectors; however, other vector control alternatives may be required. These alternatives could include: reducing the size

Vectors may reach the landfill facility not only from areas adjacent to the landfill, but

and breeding of disease vectors. Such modes

collection vehicles and transfer stations. These transport modes and areas also should be included in the disease vector control program if disease vectors at the landfill facility become a problem. Keeping the collection vehicles and transfer stations covered; emptying and cleaning the collection vehicles and transfer stations; using repellents, insecticides, or rodenticides; and reproductive

disease vectors in these areas.

3.5 EXPLOSIVE GASES CONTROL

(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;

(4) The Director of an approved State may establish alternative schedules for demonstrating compliance with paragraphs

<u>explosive limit</u> (LEL) means the lowest p

- Within 7 days of detection, place in the operating record documentation that methane gas concentrations exceeded the criteria, along with a description of immediate actions taken to protect human health; and

- Within 60 days of detection, implement a remediation plan for the methane gas releases, notify the State Director, and place a copy of the remediation plan in the operating record.

Th

readily identified by its "rotten egg" smell at shallow portions of the landfill unit, which may alter microbial activity, particularly methane production and gas composition.

Migration of landfill gas is caused by concentration gradients, pressure gradients, and density gradients. The direction in which

Stressed vegetation may indicate gas migration. Landfill gas present in the soil atmosphere tends to make the soil anaerobic

asphyxiating the roots of plants. Generally, the higher the concentration of combustible gas and/or carbon dioxide and the lower th

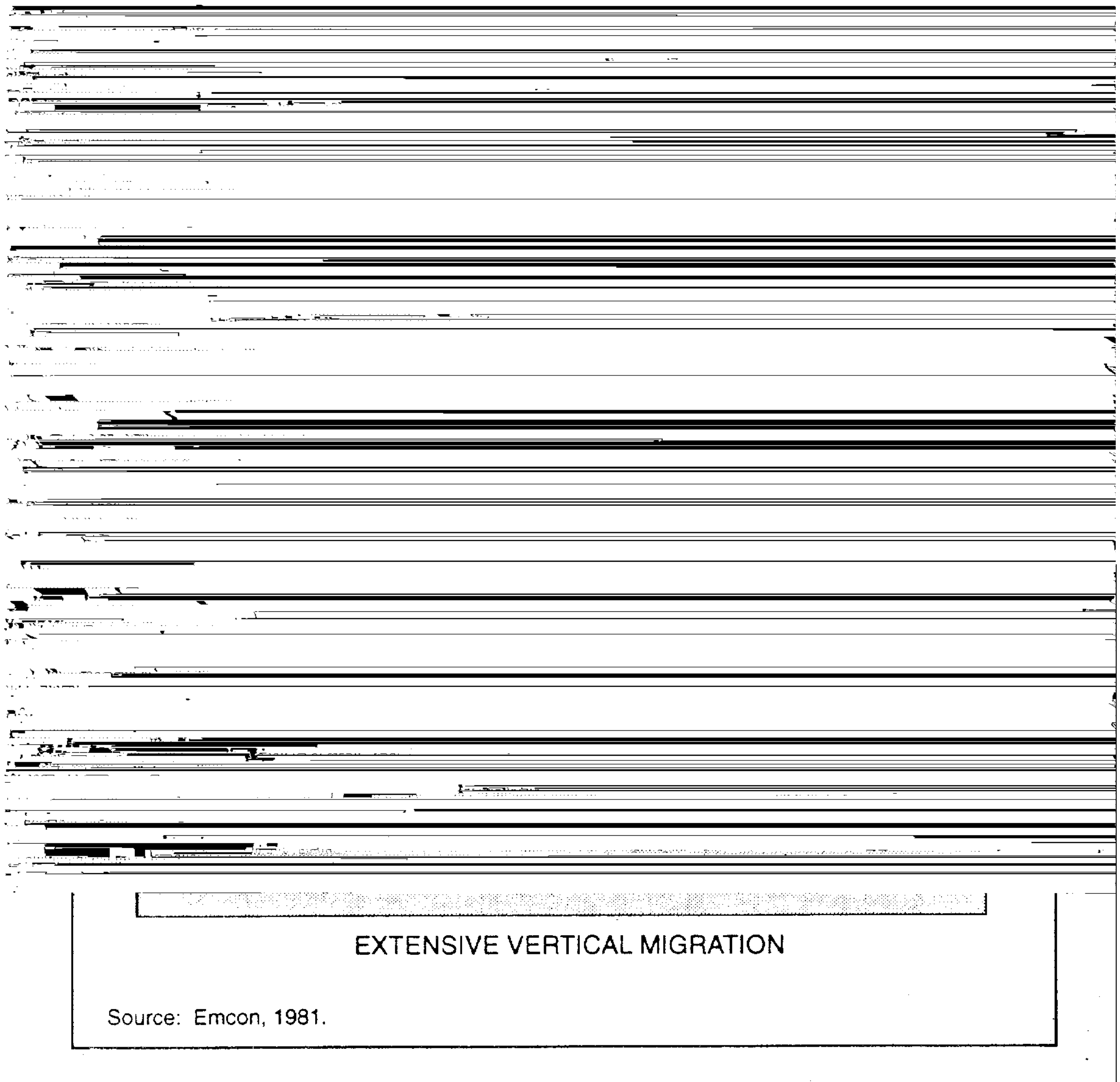


Figure 3-2
Potential Effects of
Surrounding Geology on Gas Migration

from monitoring probes installed in soil between the landfill unit and either the property boundary or structures where gas migration may pose a danger. A typical gas monitoring probe installation is depicted in Figure 3-3.

structures, and changes in landscaping or land use practices. The rate of landfill gas migration as a result of these anticipated changes and the site-specific conditions provides the basis for establishing monitoring frequency. Monitoring is to371l62 Tc7ud i

Source: Warzyn Inc.

Figure 3-3
Typical Gas Monitoring Probe

Laboratory measurements with organic vapor analyzers or gas chromatographs may be used to confirm the identity and concentrations of gas.

In addition to measuring gas composition, other indications of gas migration may be observed. These include odor (generally described as either a "sweet" or a rotten egg

soil within the area of concern. The investigation should consider possible causes of the increase in gas concentrations such as landfill operational procedures, gas control

closure activity. Based on the extent and nature of the excessive methane migration, a remedial action should be described, if the exceedance is persistent, that can be may be the use of a low-permeability passive system for the closed portion of a landfill unit (for remedial purposes) and the installation of an active system in the active portion of the landfill unit (for future use).

Selection of construction materials for either tn

150 megagrams per year (167 tons per year) or greater. Allowable control systems include open and enclosed flares, and on-site or off-site facilities that process the gas for subsequent sale or use. EPA believes that,

systems may be more cost-effective than

Passive Systems

Passive gas control systems rely on natural

Some problems have been associated with

m

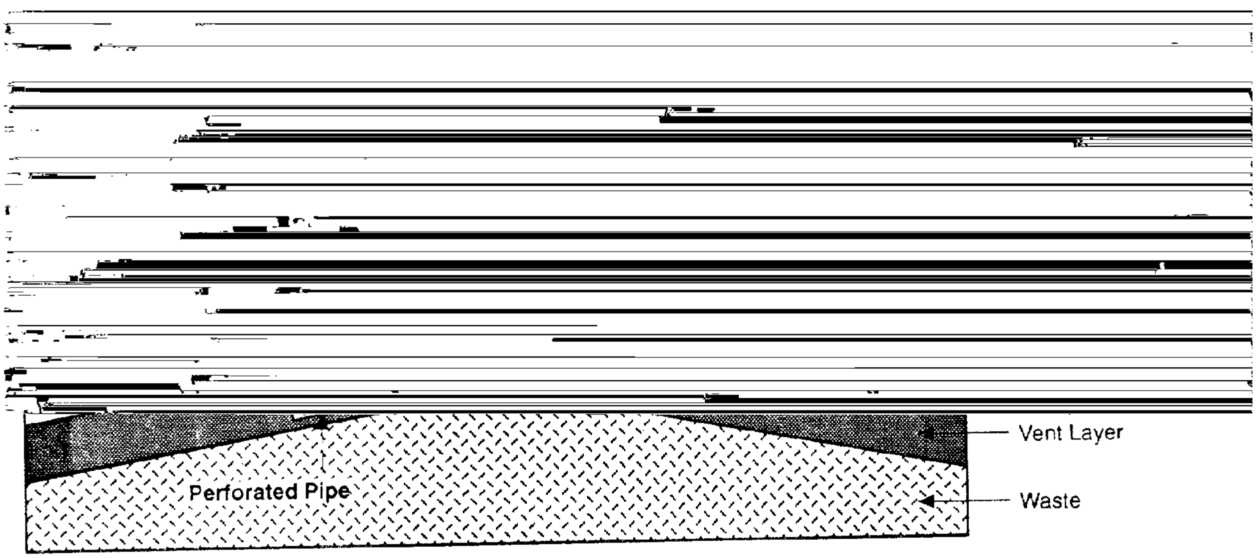


Figure 3-4
Passive Gas Control System
(Venting to Atmosphere)

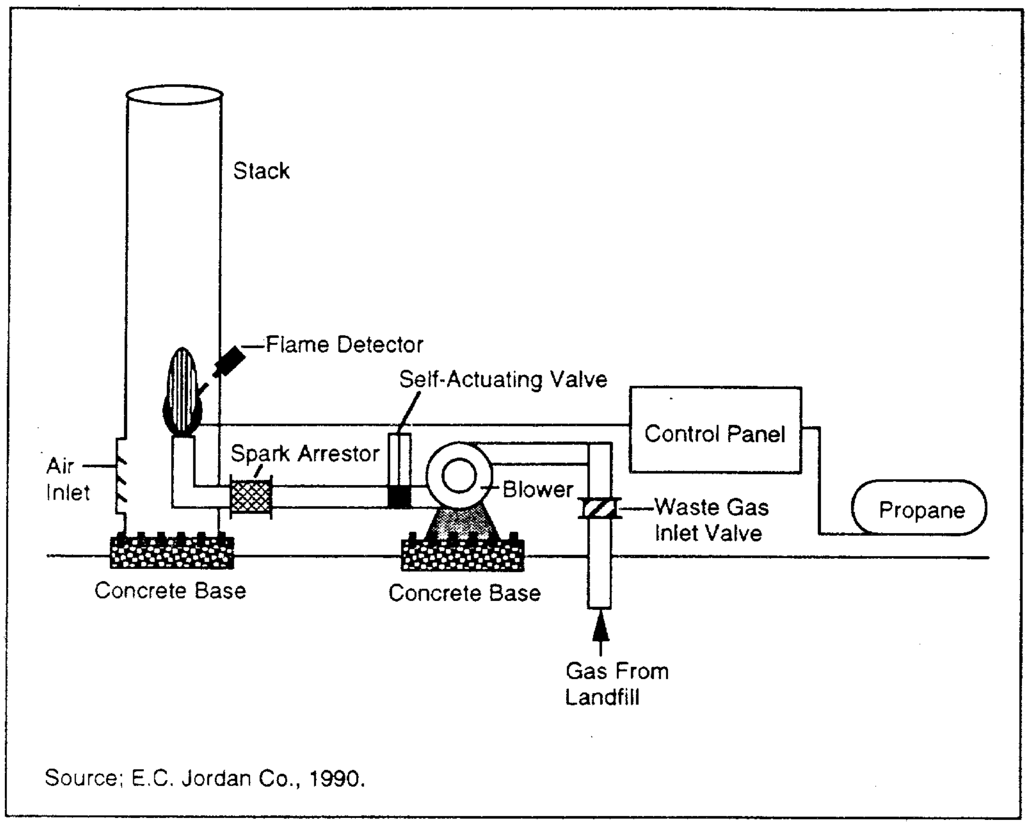


Figure 3-5. Example Schematic Diagram of a Ground-based Landfill Gas Flare

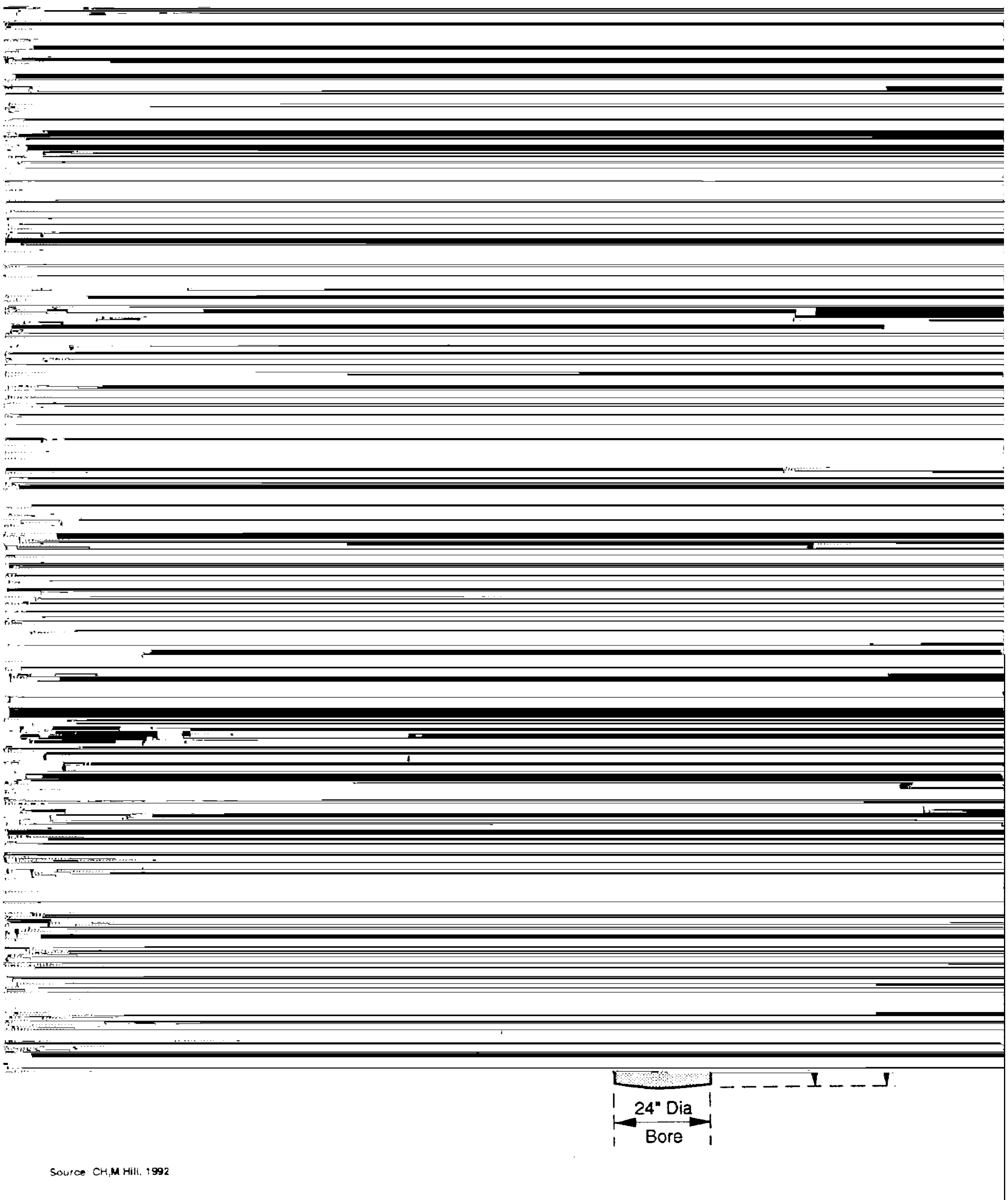


Figure 3-6 Example of a Gas Extraction Well

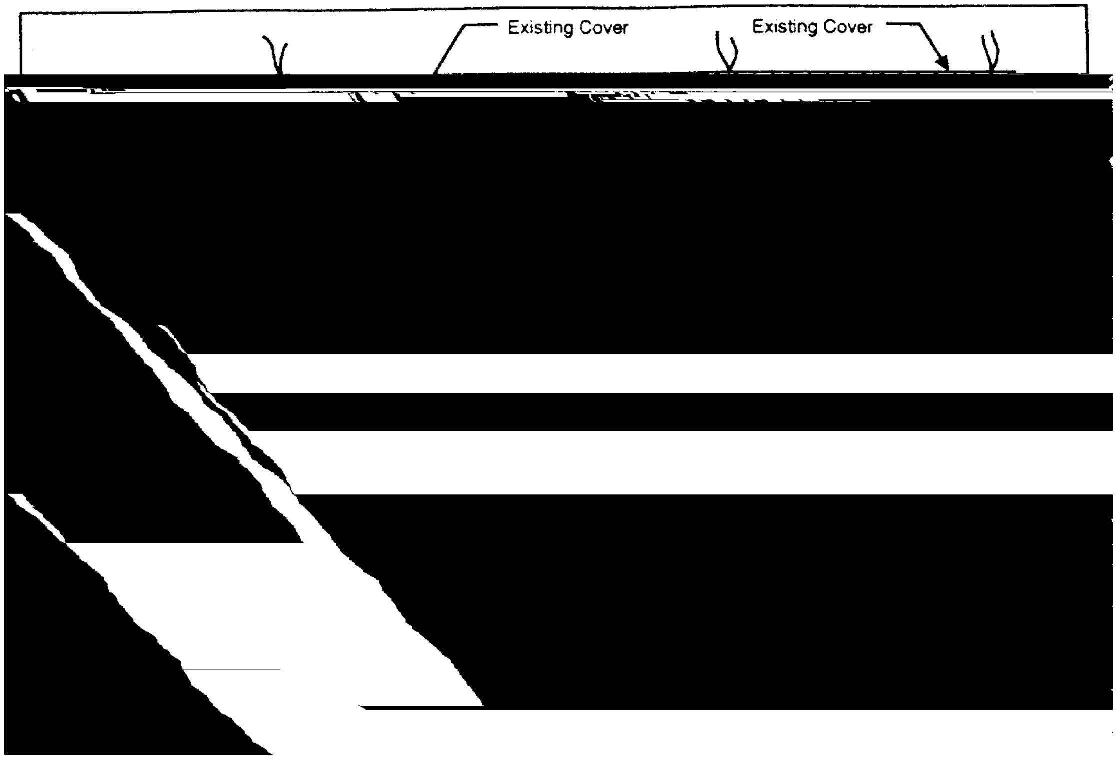


Figure 3-7A. Perimeter Extraction Trench System

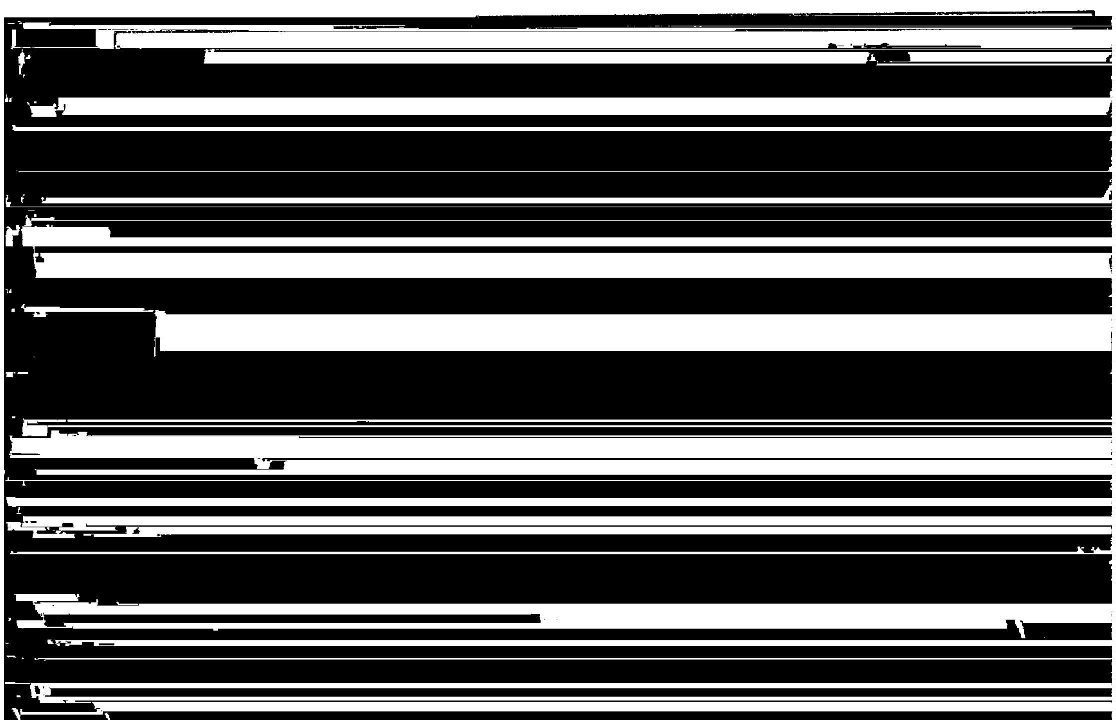


Figure 3-7B. Perimeter Extraction Trench System

Figure 3-8. The performance of active **3.6**

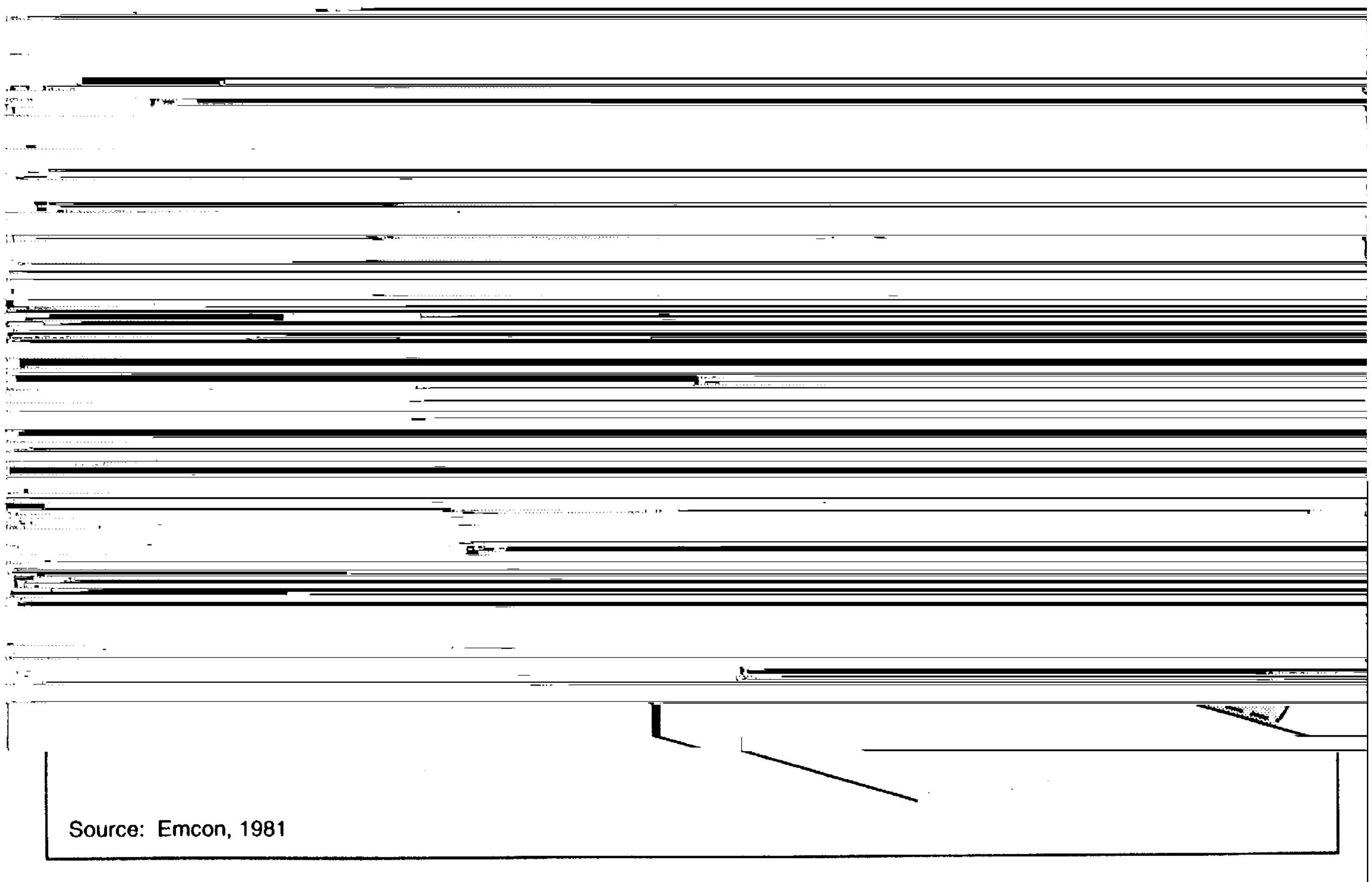


Figure 3-8
Example of an Interior Gas Collection/Recovery System

inadvertent or deliberate fires; and earth-moving activities.

Acceptable measures used to limit access of unauthorized persons to the disposal facility include gates and fences, trees, hedges, berms, ditches, and embankments. Chain link, barbed wire added to chain link, and open farm-type fencing are examples of fencing that may be used. Access to facilities should be controlled through ga

3.8.2 Applicability

wetlands, that violates any requirements of the

A MSWLF unit(s) that has a point source

MSWLF Criteria, Section 258.25. "Controlled sanitary landfills" are those that do meet the run-on and run-off requirements. The NPDES regulations specify that **uncontrolled** sanitary landfills owned or operated by municipalities of less than

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

Figure 3-9. Paint Filter Test Apparatus

have been a source of odor. In addition, a discharge point may not allow for dissipation of the leachate. (For additional information regarding the effectiveness of using leachate recirculation to enhance the rate of organic degradation, see (Reinhart and Carson, 1993).)

3.11

(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

procedures, notices, cost estimates, and financial assurance documentation.

3.11.3 Technical Considerations

The operating record should be maintained in a single location. The location may be at the facility, at corporate headquarters, or at city hall, but should be near the facility. Records should be maintained throughout the life of the facility, including the post-closure care period. Upon placement of each required document in the operating record, the State Director should be notified. The Director of an approved State may establish alternative requirements for recordkeeping, including using the State permit file for recordkeeping.

Recordkeeping at the landfill facility should include the following:

(a) Location restriction demonstrations: Demonstrations are required for any location restrictions under Subpart B. The location restrictions apply to:

- Airports;
- Floodplains;
- Wetla
- Fault areas;
- Seismic impact zones; and
- Unstable areas.

(b) Inspection records, training procedures, and notification procedures: Inspection records should include:

- Date and time wastes were received during the inspection;
- Names of the transporter and the driver;
- Source of the wastes;
- Vehicle identification numbers; and
- All observations made by the inspector.

Training records should include procedures used to train personnel on hazardous waste and on PCB waste recognition. Notification to EPA, State, and local agencies should be documented.

(c) Gas monitoring results and any remediation plans: If gas levels exceed 25 percent of the LEL for methane in any facility structures or exceed the LEL for methane at the facility boundary, the owner or operator must place in the operating record, within seven days, the methane gas levels detected, and a description of the steps taken to protect human health. Within 60 days of detection, the owner or operator must place a copy of the remediation plan used for gas releases in the operating record.

(d) MSWLF unit design documentation for placement of leachate or gas condensate in a MSWLF unit: If leachate and/or gas condensate are recirculated into the MSWLF unit, documentation of a composite liner and a leachate collection system capable of maintaining a maximum of 30 cm of leachate head in the MSWLF unit must be placed in the operating record.

(e) Demonstration, certification, monitoring, testing, or analytical finding required by the ground-water criteria: Documents to be placed in the operating

- A notice identifying the Part 258 Appendix II constituents that have exceeded the ground-water protection standard;

- An estimate of the cost of hiring a third party to close the largest area of all MSWLF units that will require final cover;

- Justification for the reduction of the closure cost estimate and the amount of

APPENDIX I

Special Waste Acceptance Agreement

[redacted]

Title ____________________ | 4. Regional Engineer ____________________ Date ________

Date ____________________ | Recertification Frequency: BI Annual ❑ Annual ❑ Semi Annual ❑

First Page to Owner/Operator; Second Page to Customer; Third Page to Laboratory

CHAPTER 4

SUBPART D
DESIGN CRITERIA

CHAPTER 4
SUBPART D

TABLE OF CONTENTS

High-Pe090eTc416.ection Systems

- Leachate removal systems (pumps, sumps, and standpipes); and
- Inspections (field observations and field and laboratory testing).

Designs based on the performance standard are described in Section 4.2. Requirements for composite liners are discussed in Section 4.3. These sections address the minimum regulatory requirements that should be considered during the design, construction, and operation of MSWLF units to ensure that they perform in a manner protective of human health and the environment. Additional features or procedures may be used to demonstrate conformance with the regulations or to control leachate release and subsequent effects. For example, during construction of a new MSWLF unit, or a lateral expansion of an existing MSWLF unit, quality control and quality assurance procedures and documentation may be used to ensure that material properties and construction methods meet the design specifications that are intended to achieve the expected level of performance. Section 4.4 presents methods to assess ground-water quality at the relevant point of compliance for performance-based designs. Section 4.5 describes the applicability of the petition process for States wishing to petition to use the performance standard.

4.2 PERFORMANCE-BASED DESIGN 40 CFR §258.40(a)(1)

4.2.1 Statement of Regulation

(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 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) *(See Statement of Regulation in Section 4.3.1 of this guidance document for the regulatory language for composite liner requirements).*

(b) *(See Statement of Regulation in Section 4.3.1 of this guidance document for the regulatory language for requirements pertaining to composite liner and leachate collection systems).*

(c) When approving a design that complies with paragraph (a)(1) of this d0.0717 Tc ((b)) T sesecy (cm) Tj 6la1Tc (pli455 0 ee6la3007li7e Tc ((b)) Tj

TABLE 1
(40 CFR 258.40; 56 FR 51022; October 9, 1991)

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	4.0
Lindane	0.004
Lead	0.05
Mercury	0.002
Methoxychlor	0.1
Nitrate	10.0
Selenium	0.01
Silver	0.05
Toxaphene	0.005
1,1,1-Trichloroethane	0.2
Trichloroethylene	0.005

water quality and the existing ground-water flow regime (e.g., flow direction, horizontal and vertical gradients, hydraulic conductivity, stratigraphy, and aquifer thickness).

An assessment should be made of the effect MSWLF facility construction will have on site hydrogeology. The assessment should focus on the reduced infiltration over the landfill area and altered surface water run-off patterns. Reduction of ground-water recharge and changes in surface water patterns resulting from landfill construction may affect ground-water gradients in some cases and may result in changes in lateral flow directions. One example of a hypothetical performance-based demonstration follows.

It is possible that a MSWLF unit located in an arid climatic zone would not produce leachate from sources of water (e.g., precipitation) other than that existing within the waste at the time of disposal. In such an environment, an owner or operator may demonstrate that significant quantities of leachate would not be produced. The demonstration should be supported by evaluating historic precipitation and evaporation data and the likelihood that the unit could be flooded as the result of

Assuming leachate is produced, the demonstration should evaluate whether constituents listed in Table 1 can be expected to be present at concentrations greater than the

must address the hydrogeologic characteristics of the facility and the surrounding land to comply with §258.40(d). The following sections describe the various parts of a demonstration in greater detail.

Leachate Characterization

Leachate characterization should include an assessment and demonstration of the quantity and composition of leachate anticipated at the proposed facility. Discussion of this

Estimates of volumetric production rates of leachate are important in evaluating the fate and transport of the constituents listed in Table 1. Leachate production rates depend on rainfall, run-on, run-off, evapotranspiration, water table elevation relative to the bottom of the landfill unit, in-place moisture content of waste, and the prevention of liquid disposal at the site. Run-on, run-off, and water table factors can

(1) The annual infiltration of precipitation and rate of leaching;

(2) The type and relative amounts of materials in the waste stream; and

(3) The age and the biological maturity of the landfill unit, which may affect the types of organic and inorganic acids generated, oxidation/reduction potential (Eh), and pH conditions.

An existing landfill unit in the same region, with similar waste stream characteristics, may provide information that will allow the owner or operator to anticipate leachate composition of the proposed landfill unit. A review of existing literature also may be required to assess anticipated leachate composition if actual data are unavailable (see U.S. EPA, 1987b). A wide range of leachate concentrations are reported in the literature with higher concentrations of specific constituents typically reported for the initial

In lieu of the existence or availability of such information, conservative analytical

anticipated leakage rates.

through geomembranes differs in principle from transport through soil liner materials. The dominant mode of leachate transport through liner components is flow through holes and penetrations of the geomembrane,

Transport through geomembranes where tears, punctures, imperfections, or seam failures are not involved is dominated by molecular diffusion. Diffusion occurs in response to a concentration gradient and is governed by Fick's first law. Diffusion rates through geomembranes are very low in comparison to hydraulic flow rates in soil liners, including compacted clays. For synthetic liners, the most significant factor influencing liner performance is penetration of the liner, including imperfect seams or pinh 8.y Tc (wit) 5 initia geomembrane and composite liner systems. Further discussion of liner leakage rates can be found in Section 4.3.3 below. For empirical data and analytical methods the reader is referred to Jayawickrama et al. (1988), Kastman (1984), Haxo (1983), Haxo et al. (1984), Radian (1987), Giroud and Bonaparte (1989, Parts I and II), and Giroud et al. (1989). Leakage assessments also may be conducted with the use of the HELP model (U.S. EPA, 1988). Version 3.0 of the model is under revision and will include an updated method to assess leakage that is based on recent research and data compiled by Giroud and Bonaparte.

Leachate Migration in the Subsurface

Leachate that escapes from a landfill unit may migrate through the unsaturated zone and eventually reach the uppermost aquifer. In some instances, however, the water table may be located above the base of the landfill unit, so that only saturated flow and transport from the landfill unit need to be considered. Once leachate reaches the water table, contaminants may be transported through the saturated zone to a point of discharge (i.e., a pumping well, a stream, a lake, etc.).

The migration of leachate in the subsurface depends on factors such as the volume of the degradation of contaminants. The degree of components operating at the microscopic level: mechanical dispersion and molecular diffusion. Mechanical dispersion results from variations in pore velocities within the soil or aquifer and may be more significant than molecular diffusion in environments where the flow rates are moderate to high. Molecular diffusion occurs as a result of contaminant concentration gradients; chemicals move from high concentrations to low concentrations. At very slow ground-water velocities, as occur in clays and silts, diffusion can be an important transport mechanism.

Mechanical filtration removes from ground water contaminants that are larger than the pore spaces of the soil. Thus, the effects of m

and alter its flow direction to conform to the used to describe porous flow (Darcy's Law) do not apply.

Chemical Processes Controlling Contaminant Transport in the Subsurface

Chemical processes that are important in controlling subsurface transport include precipitation/dissolution, chemical sorption, redox reactions, hydrolysis, ion exchange, and complexation. In general, these processes, except for hydrolysis, are reversible. The reversible processes tend to retard transport, but do not permanently remove a contaminant from the system. Sorption and precipitation are generally the dominant mechanisms retarding contaminant transport in the saturated zone.

Precipitation/dissolution reactions can control contaminant concentration levels. The solubility of a solid controls the equilibrium state of a chemical. When the soluble concentration of a contaminant in leachate is higher than that of the equilibrium state, precipitation occurs. When the soluble concentration is lower than the equilibrium value, the contaminant exists in solution. The precipitation of a dissolved substance may be initiated by changes in pressure, temperature, pH, concentration, or redm

generally occurs at a relatively rapid rate compared to precipitation reactions.

The dominant mechanism of organic sorption is the hydrophobic attraction between a

in some aquifers. The organic carbon content of the porous medium, and the solubility of the contaminant, are important factors for this type of sorption.

There is a direct relationship between the quantity of a substance sorbed on a particle surface and the quantity of the substance suspended in solution. Predictions about the sorption of contaminants often make use of sorption isotherms, which relate the amount of contaminant in solution to the amount

contaminants, these isotherms are usually assumed to be linear and the reaction is assumed to be instantaneous and reversible. The linear equilibrium approach to sorption may not be adequate for all situations.

Oxidation and reduction (redox) reactions involve the transfer of electrons and occur when the redox potential in leachate is different from that of the soil or aquifer environment. Redox reactions are important

e

Hydrolysis is the chemical breakdown of carbon bonds in organic substances by water and its ionic species H^+ and OH^-. Hydrolysis is dependent on pH and Eh and is most significant at high temperatures, low pH, and low redox potential. For many biodegradable contaminants, hydrolysis is slow compared to biodegradation.

Ion exchange originates primarily from exchange sites on layered silicate clays and organic matter that have a permanent negative charge. Cation exchange balances negative charges in order to maintain neutrality. The capacity of soils to exchange cations is called the cation exchange capacity (CEC). CEC is affected by the type and quantity of clay mineral present, the amount of organic matter present, and the pH of the soil. Major cations in leachate (Ca, Mg, K, Na) usually dominate the CEC sites, resulting in little attenuation in soils of trace metals in the leachate.

A smaller ion exchange effect for anions is associated with hydrous oxides. Soils typically have more negatively charged clay particles than positively charged hydrous

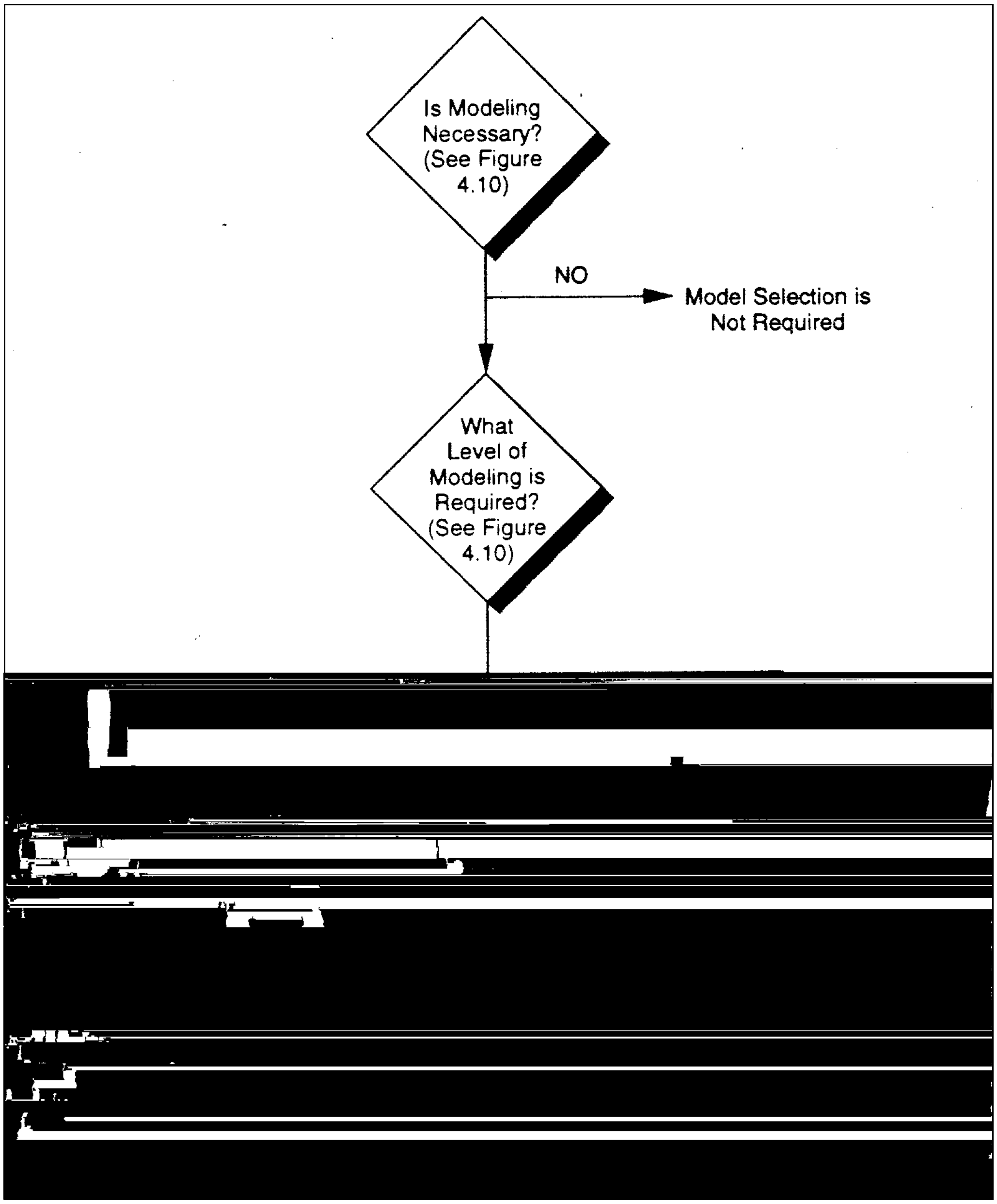
Therefore, these processes are usually grouped together as one mechanism.

Biological Processes Controlling Contaminant Transport in the Subsurface

Biodegradation of contaminants may result from the enzyme-catalyzed transformation of

Contaminants can be degraded to harmless byproducts or to more mobile and/or toxic products through one or more of several biological processes. Biodegradation of a compound depends on environmental factors such as redox potential, dissolved oxygen concentration, pH, temperature, presence of other compounds and nutrients, salinity, depth below land surface, competition among different types of organisms, and concentrations of compounds and organisms. The transformations that occur in a subsurface system are difficult to predict because of the

reactions that may occur. Quantitative predictions of the fate of biologically reactive substances are subject to a high degree of uncertainty, in part, because little i04n 2.5291 Tw (are subj simulate


Is Modeling Necessary? (See Figure 4.10)
NO
Model Selection is Not Required
What Level of Modeling is Required? (See Figure 4.10)

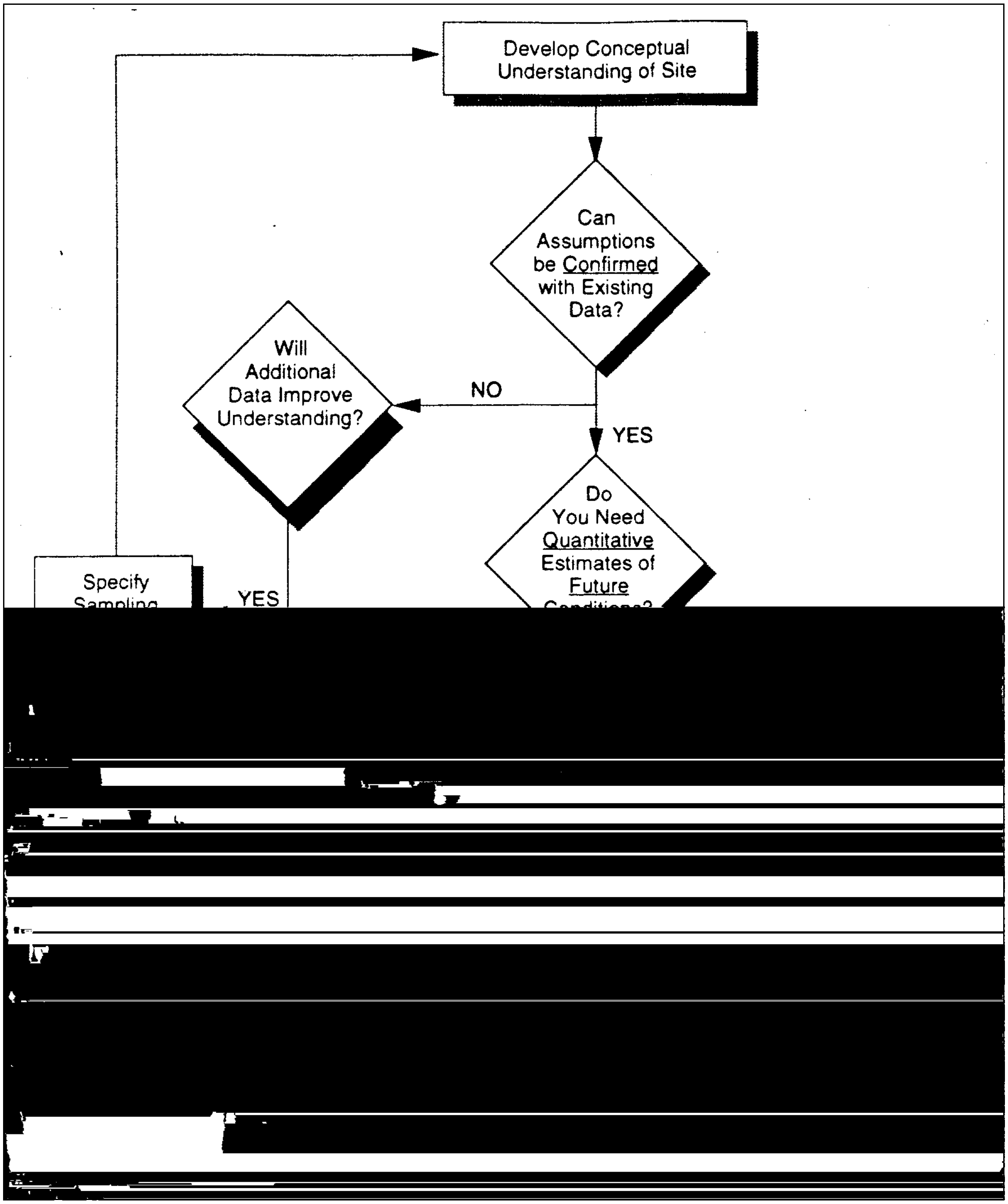


Figure 4-2
Flow Chart to Determine if Modeling is Required
(Boutwell et. al., 1986)

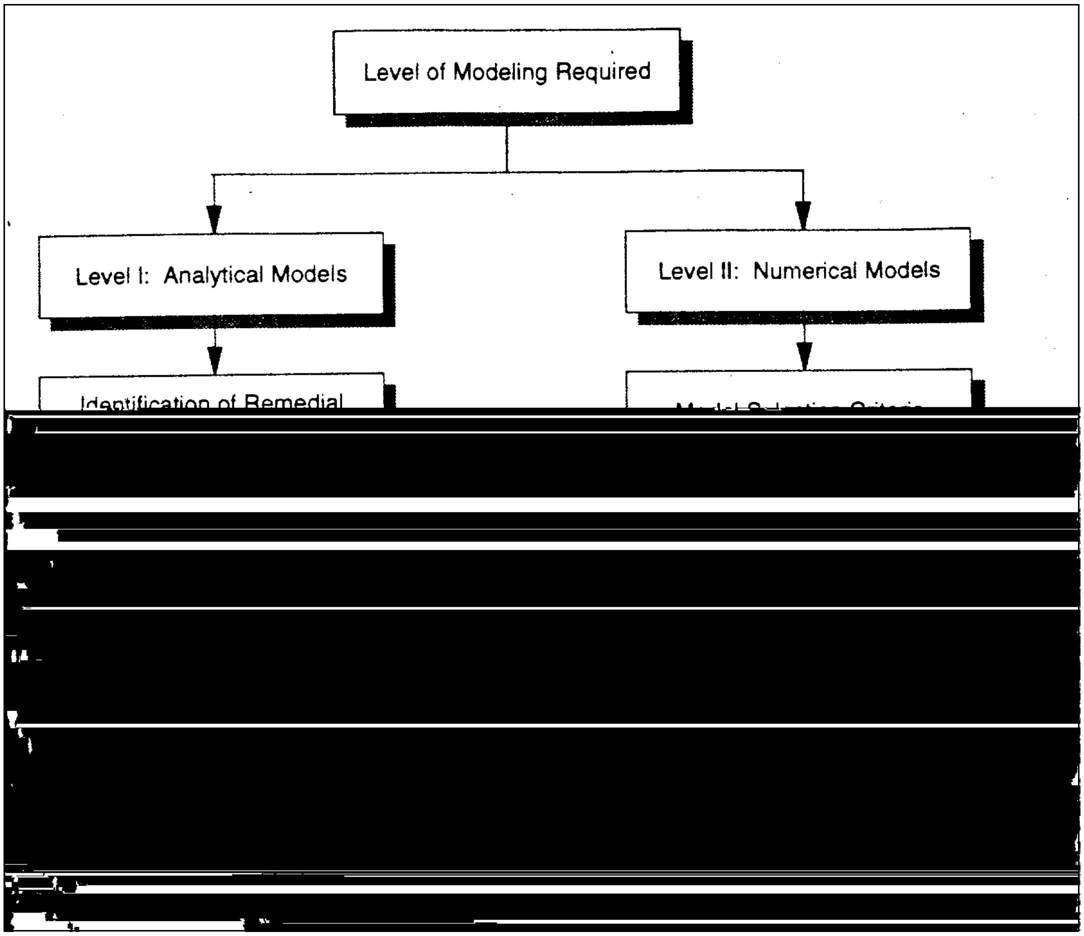


Figure 4-3
Flow Chart to Determine the Level of Modeling Required for Soil and Groundwater Systems
(Boutwell et. al., 1986)

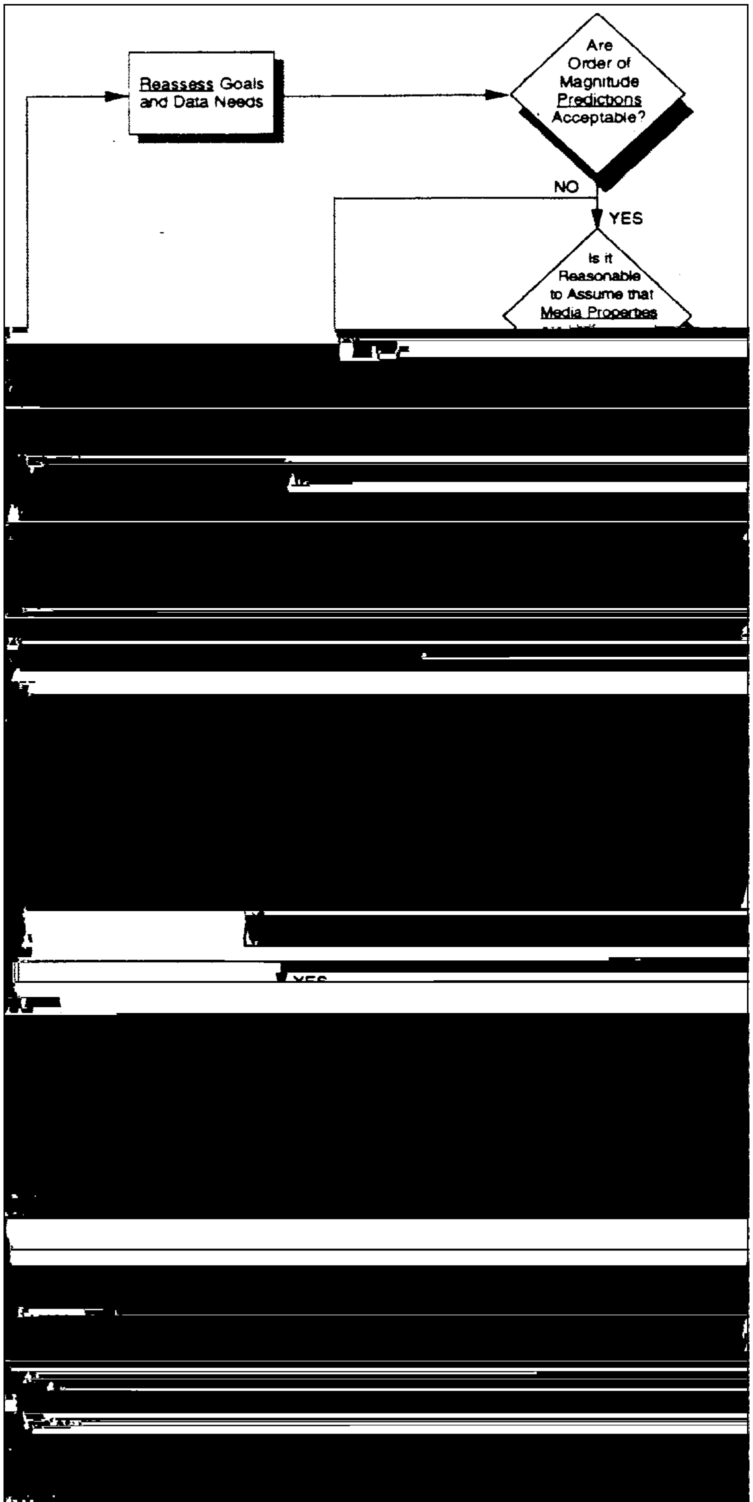


Figure 4-4
Flow Chart for Required Model Capabilities for Soil and Groundwater Systems
(Boutwell et. al., 1986)

5) limitations of the model itself. Therefore,

appropriate to assume that some ground-water flow systems have reached approximate "steady-state" conditions, which implies that the system has reached equilibrium and no significant changes are occurring over time. The assumption of steady-state conditions generally simplifies the mathematical equations used to describe flow processes, and reduces the amount of input data required.

However, assuming steady-state conditions in a system that exhibits transient behavior may produce inaccurate results. For example, climatic variables, such as precipitation, vary over time and may have strong seasonal components. In such settings, the assumption of constant recharge of the ground-water system would be incorrect. Steady-state models also may not be appropriate for evaluating the transport of chemicals which sorb or transform significantly (Mulkey et al., 1989). The choice of simulating steady-state or transient conditions should be based on the degree of temporal variability in the system.

Boundary and Initial Conditions

The solution of differential equations describing flow and transport processes requires that initial and boundary conditions be specified. The initial s e the c e beginning of the simulation. In many ground-water flow and transport models, these conditions are related to the initial hydraulic conditions in the aquifer and the initial concentration of contaminants. Boundary co Tj 34.0389fine the c sent on the borders of the system, which may be steady-state or temporally variable. The initial and boundary conditions chosen to represent a site can significantly affect the results of the simulation.

One of the most significant boundary conditions in solute transport models is the introduction

Table 4-1. Models for Application to Leachate Generation Problems (adapted from Travers and Sharp-Hansen, 1991)

Model Reference	Model Dimensions	Flow Conditions	Aquifer Conditions	Model Processes	Chemical Species	Additional Information
Bonazountas	1D/FD	Ss,Unsat	L,Hom,Iso	Ppt,Inf,	single	Seasonal Soil Compartment Model. Simulates transport of
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 4-1a. Analytical and Semi-Analytical Models for Application to Leachate Migration Problems (adapted from Travers and Sharp-Hansen, 1991)

Model	Model	Flow	Aquifer	Model	Chemical
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 4-1a. Analytical and Semi-Analytical Models for Application to Leachate Migration Problems (adapted from Travers and Sharp-Hansen, 1991) (continued)

Model Reference	Model Dimensions	Flow Conditions	Aquifer Conditions	Model Processes	Chemical Species	Additional Information
Salhotre et al. (1990)	1D(vadose zone), 3D	Ss, Sat, Usat	Uc, Hom, Iso, I. (Usat)	Adv, Dis, Ads, Dec, Vol	single	Model simulates movement of contaminants in saturated and unsaturated groundwater zones. In [redacted]

[redacted]

Table 4-1b. Finite-Difference Models for Application to Leachate Migration Problems (adapted from Travers and Sharp-Hansen, 1991) (continued)

Model Reference	Model Dimensions	Flow Conditions	Aquifer Conditions	Model Processes	Chemical Species	Additional Information
Harasimhan et al. (1986) DYNAMIX	3D	Ss, Tr, Sat	C, Uc, Hom, Het, Iso, An	Adv, Dis, Dif, Dec	multiple	Model couples a chemical specification model PHREEQE (Parkhurst et al, 1980) with a modified form of the transport code TRUMP (Edwards, 1969, 1972). Considers equilibrium reactions (see geochemical codes).
[redacted]						

Table 4-1c. Finite-Element Models for Application to Leachate Migration Problems (adapted from Travers and Sharp-Hansen, 1991)

Model	Model	Flow	Aquifer	Model	Chemical	
Cederberg et	1 D, radial	Ss, Sat	C, Uc, Hom	Adv, Dis, Dif,	multiple	Multicomponent transport model which links chemical

Table 4-1c. Finite-Element Models for Application to Leachate Migration Problems (adapted from Travers and Sharp-Hansen, 1991) (continued)

- Collect site-specific hydrogeologic data, including amount of leachate generated (see Section 4.3.3);

- Identify the contaminant(s) to be simulated and the point of compliance;

- Propose a landfill design and determine the corresponding infiltration rate; then

- Run MULTIMED and calculate the dilution attenuation factor (DAF) (i.e., the factor by which the concentration is expected to decrease between the landfill unit and the point of compliance); and

- Multiply the initial contaminant concentration by the DAF and compare the resulting concentration to the MCLs to determine if the design will meet the standard.

At this time, only contaminant transport in the unsaturated and/or saturated zones can be modeled, because the other options (i.e., surface water, air) have not yet been thoroughly tested. In addition, only steady-state transport simulations are allowed. No decay of the contaminant source term is permitted; the concentration of contaminants entering the aquifer system is assumed to be constant over time. The receptor (e.g., a drinking water well) is located directly downgradient of the facility and intercepts the contaminant plume; also, the contaminant concentration is calculated at the top of the aquifer.

The user should bear in mind that MULTIMED may not be an appropriate model for some sites. Some of the issues that should be considered before modeling efforts proceed are summarized in Table 4-2. A "no" answer to any of the questions in Table 4-2 may indicate that MULTIMED is not the most appropriate model to use. As stated above, MULTIMED utilizes analytical and semi-analytical solution techniques to solve the mathematical equations describing flow and transport. As a result, the representation of a system simulated by the model is simple, and little or no spatial or temporal variability is allowed for the parameters in the system. Thus, a highly complex hydrogeologic system cannot be accurately represented with MULTIMED.

The spatial characteristics assumed in MULTIMED should be considered when applying MULTIMED to a site. The assumption of vertical, one-dimensional unsaturated flow may be valid for facilities that receive uniform areal recharge. However, this assumption may not be valid for facilities where surface soils (covers or daily backfill) or surface slopes result in an increase of run-off in certain areas of the facility, and ponding of precipitation in others. In addition, the simulation of one-dimensional, horizontal flow in the saturated zone requires several simplifying assumptions. The saturated zone is treated as a single, horizontal aquifer with uniform properties (e.g., hydraulic conductivity). The effects of pumping or discharging wells on the ground-water flow system cannot be addressed with the MULTIMED model.

The MULTIMED model assumes steady-state flow in all applications. Some ground-water flow systems are in an approximate "steady-state," in which the amount of water entering the flow system equals the amount of water leaving the system. However, assuming steady-state conditions in a system that exhibits transient behavior may produce inaccurate results.

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 x 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.

4.3.2 Applicability

New MSWLF units and expansions of existing MSWLF units in States without appr

Standard Composite Liner Systems

difficult. The factor that most strongly influences geomembrane performance is the presence of imperfections such as improperly bonded seams, punctures and pinholes. A detailed discussion of leakage through geomembranes and composite liners can be found in Giroud and Bonaparte (1989 (Part I and Part II)). A geomembrane installed with excellent control over defects may yield the equivalent of a one-centimeter-diameter hole per acre of liner installed (Giroud and Bonaparte, 1989 (Part I and Part II)). If the geomembrane were to be placed over sand, this size imperfection under one foot of constant hydraulic head could be expected to account for as much as 3,300 gal/acre/day (31,000 liters/hectare/ day) of leakage. Based upon measurements of actual leakage through liners at facilities that have been built under rigorous control, Bonaparte and Gross (1990) have estimated an actual leakage rate, under one foot of constant head, of 200 liters/hectare/day or about 21 gallons/acre/day for landfill units.

The uniformity of the contact between the geomembrane and the soil liner is extremely important in controlling the effective flow area of leachate through the soil liner. Porous material, such as drainage sand, filter fabric,

Soil Liner

The following subsections discuss soil liner construction practices including thickness requirements, lift placement, bonding of lifts, test methods, prerequisite soil properties, quality control, and quality assurance activities.

Thickness

Two feet of soil is generally considered the minimum thickness needed to obtain adequate compaction to meet the hydraulic conductivity requirement. This thickness is considered necessary to minimize the number of cracks or imperfections through the entire liner thickness that could allow leachate migration. Both lateral and vertical imperfections may exist in a compacted soil. The two-foot minimum thickness is believed to be sufficient to inhibit hydraulic short-circuiting of the entire layer.

Soil liners should be constructed in a series of compacted lifts. Determination of appropriate lift thickness is dependent on the soil characteristics, [illegible] inch soil layer also have been recommended prior to compaction (USEPA, 1990a).

Soil liners usually are designed to be of uniform thickness with smooth slopes over the entire facility. Thicker areas may be considered wherever recessed areas for leachate collection pipes or collection sumps are located. Extra thickness and compactive efforts near edges of the side slopes may enhance bonding between the side slopes and the bottom liner. In smaller facilities, a soil liner may be designed for installation over the entire area, but in larger or multi-cell facilities, liners may be designed in segments.0.8396 5uit
22vEow (wer.) TTc 554773 0 TD 0 Tc 1.8396 Tw ( ) Tj 4.0791 0 TD -080067 Tc8484.3

includes scarifying (roughening), and possibly wetting, the top inch or so of the last lift

equipment before placing the next lift.

Placement of Soil Liners on Slopes

The method used to place the soil liner on side slopes depends on the angle and length of the slope. Gradual inclines from the toe of the slope enable continuous placement of the lifts up the slopes and provide better continuity between the bottom and sidewalls of the soil liner. When steep slopes are encountered, density40.1090 TD5Tc (h) 0.1075 Tc 0 T007letrolnships u940 T Tc 0 Tw (wate) Tj72.5231 0 TD 0.

conductivity is the key design parameter when evaluating the acceptability of the constructed soil liner. The hydraulic conductivity of a soil depends, in part, on the viscosity and density of the fluid flowing through it. While water and leachate can cause different test results, water is an acceptable fluid for testing the compacted soil liner and source materials. The effective porosity of the soil is a function of size, shape, and area of the conduits through which the liquid flows. The hydraulic conductivity of a partially saturated soil is less than the hydraulic conductivity of the 17 rof the 7 wate standard o

characterize proposed liner soils should include grain size distribution (ASTM D-422), Atterberg limits (ASTM D-4318), and compaction curves depicting moisture and density relationships using the standard or modified Proctor (ASTM D-698 or ASTM D-1557), whichever is appropriate for the compaction equipment used and the degree of firmness of the foundation materials.

Liner soils usually have at least 30 percent fines (fine silt- and clay-sized particles). Some soils with less than 30 percent fines conductivity is achieved. Wet soils, however, have low shear strengt

is difficult and may lead to inconsistent results and hydraulic conductivity for a particular soil should be established in the laboratory. Figure 4-5 shows the influence of molding water content (moisture content of the soil at the time of compaction) on hydraulic conductivity of the soil. The lower half of the diagram is a compaction curve and shows the relationship between dry unit weight, or dry density of the soil, and water content of the soil. The optimum moisture content of the soil is related to a peak value of dry density known as maximum dry density. Maximum dry density is achieved at the optimum moisture content.

The lowest hydraulic conductivity of compacted clay soil is achieved when the soil is compacted at a moisture content slightly higher than the optimum moisture content, generally in the range of 1 to 7 percent (U.S. EPA, 1989). When compacting clay, water content and compactive effort are the two factors that should be controlled to meet the maximum hydraulic conductivity criterion.

It is impractical to specify and construct a clay liner to a specific moisture content and a specific compaction (e.g., 5 percent wet of optimum and 95 percent modified Proctor density). Moisture content can be difficult to control in the field during construction; therefore, it may be more appropriate to specify a range of moisture contents and corresponding soil densities (percent compaction) that are considered appropriate to achieve the required hydraulic conductivity. Benson and Daniel (U.S. EPA, 1990) propose water content and density criteria for the construction of clay liners in which the moisture-density criteria ranges are established based on hydraulic conductivity test results. This type of approach is recommended because of the flexibility and guidance it provides to the construction contractor during soil placement. Figure 4-6 presents compaction data as a function of dry unit weight and molding water content for the construction of clay liners. The amount of soil testing required to determine these construction parameters is dependent on the degree of natural variability of the source material.

Quality assurance and quality control of soil liner materials involve both laboratory and field testing. Quality control tests are performed to ascertain compaction requirements and the moisture content of material delivered to the site. Field tests for quality assurance provide an opportunity to check representative areas of the liner for conformance to compaction specifications, including density and moisture content. Quality assurance laboratory testing is usually conducted on field samples for determination of hydraulic conductivity of the in-place liner. Laboratory testing allows full saturation of the soil samples and simulates the effects of large overburden stress on the soil, which cannot be done conveniently in the field (U.S. EPA, 1989).

Differences between laboratory and field conditions (e.g., uniformity of material, control of water content, compactive effort, compaction equipment) may make it unlikely that minimum hydraulic conductivity values measured in the laboratory on remolded, pre-construction borrow source samples are the same as the values achieved during actual liner construction. Laboratory testing on remolded soil specimens does not account for operational problems that may result in desiccation, cracking, poor bonding of lifts, and inconsistent degree of compaction on sidewalls (U.S. EPA, 1988b). The relationship between field and laboratory hydraulic conductivity testing has been

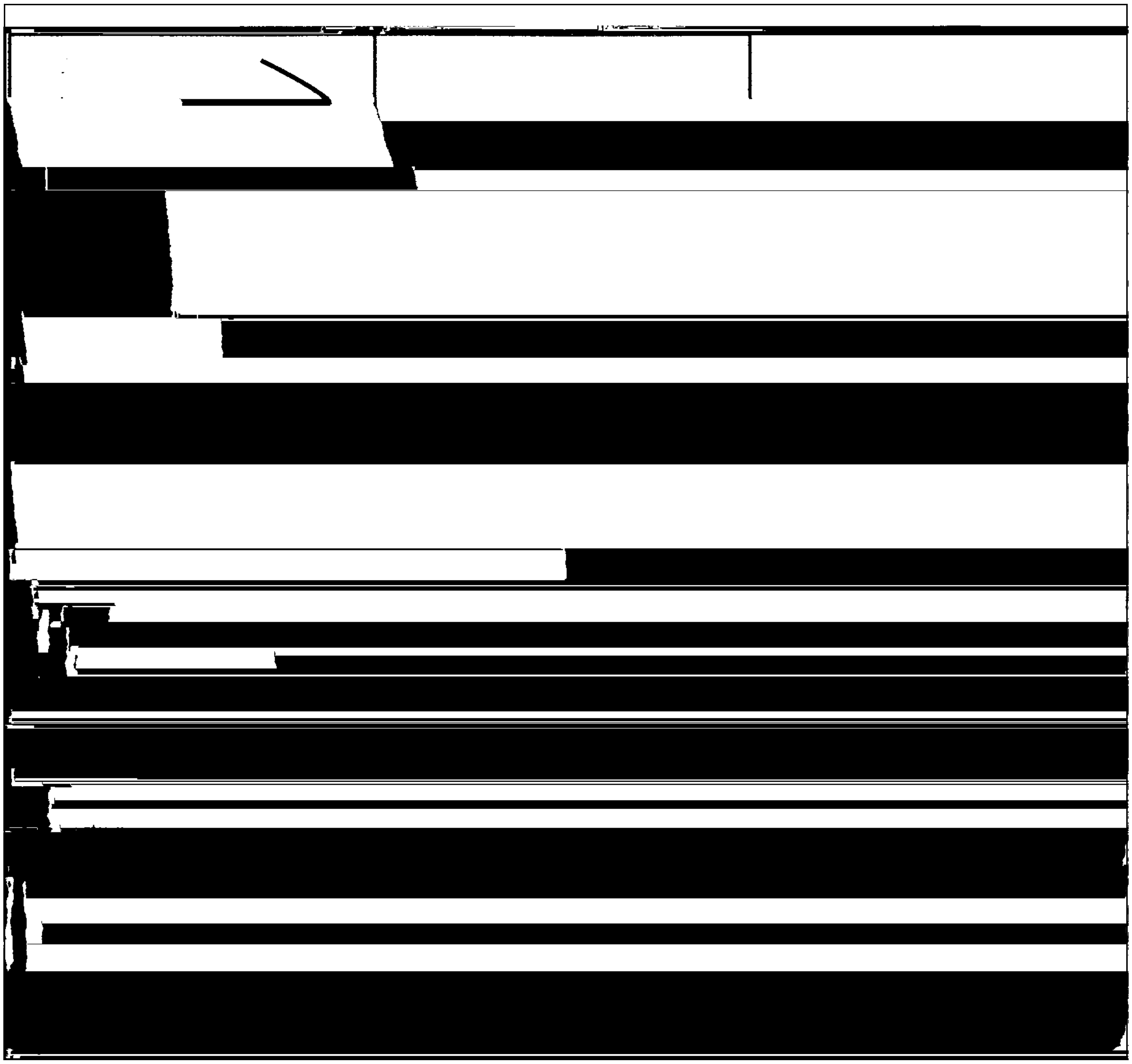


Figure 4-5
Hydraulic Conductivity and Dry Unit Weight as a Function of Molding Water Content

Figure 4-6. Compaction Data for Silty Clay

materials and construction procedures will meet performance objectives. If a test pad is constructed, if tests verify that performance objectives have been met, and if the actual soil liner is constructed to standards that equal or exceed those used in building the test pad (as verified through quality assurance), then the actual soil liner should meet or exceed performance objectives.

Other than the four types of field hydraulic conductivity tests described earlier, ASTM D 2937 "Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method" may be used to obtain in-place hydraulic conductivity of the soil liner. This test method uses a U.S. Army Corps of Engineers surface soil sampler to drive a thin-walled cylinder (typically 3-inch by 3-inch) into a completed lift of the soil liner to obtain relatively undisturbed samples for laboratory density and hydraulic conductivity testings. This test can provide useful correlation to other field and quality assurance testing results (e.g, Atterberg limits, gradation, in-place moisture and density of the soil liner) to evaluate the in-place hydraulic conductivity of the soil liner.

Soil Liner Construction

Standard p

- Soil water content; and

the

- Differential settlement in foundation soils;
- Strain requirements at the anchor trench; and
- Strain requirements over long, steep side

of the original material every thirty days. A software system entitled Flexible Liner

in the hazardous waste permitting process, may aid in interpreting EPA Method 9090 test

of both Method 9090 and FLEX is available

- The stability of a soil cover on top of a geomembrane; and

- The stability of other geosynthetic components such as geotextile or geonet on top of a geomembrane.

These requirements may affect the choice of geomembrane material, including polymer type, fabric reinforcement, thickness, and texture (e.g., smooth or textured for HDPE) (U.S. EPA, 1988). PVC also can be obtained in a roughened or file finish to increase the friction angle.

Design specifications should indicate the type of raw polymer and manufactured sheet to be used as well as the requirements for the delivery, storage, installation, and sampling of the geomembrane. Material properties can be obtained from the manufacturer-supplied average physical property values, which are published in the Geotechnical Fabrics Report's Specifier's Guide and updated annually. The minimum tensile properties of the geomembrane must be sufficient to satisfy the stresses anticipated during the service life of the geomembrane. Specific raw polymer and manufactured sheet specifications and test procedures include (U.S. EPA, 1988e, and Koerner, 1990):

Raw Polymer Specifications

- Density (ASTM D-1505);

- Melt index (ASTM D-1238);

- Carbon black (ASTM D-1603); and

- Thermogravimetric analysis (TGA) or differential scanning calorimetry (DSC).

Manufactured Sheet Specifications

- Thickness (ASTM D-1593);

- Tensile properties (ASTM D-638);

- Tear resistance (ASTM D-1004);

- Carbon black content (ASTM D-1603);

- Carbon black dispersion (ASTM D-3015);

- Dimensional stability (ASTM D-1204); and

- Stress crack resistance (ASTM D-1693).

Geomembranes may have different physical
cterresics, Tc 524 3.52c88Tj Tj -212D -0.021050115 Twd

(USEPA, 1992). In addition, scheduling soil liner construction slightly ahead of the geomembrane and drainage layer placement can reduce the exposure of the soil liner to the elements.

e io3 Tw (geomembrane.) Tj 0 -27.1142 179.6 Tf 0.076moni T(m8ntrol me52864ure;) Ti -278.7e829 Tw (Tw

Deployment, or placement, of the geomembrane panels or rolls should be described in the geomembrane layout plan. Rolls of sheeting, such as HDPE, generally can 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 geomembrane. Placement of the geomembrane goes hand-in-hand with the seaming process; no more than the amount of sheeting that can be seamed during a shift or work day should be deployed at any one time (USEPA, 1988). Panels should be weighted with sand bags if wind uplift of the membrane or excessive movement from thermal expansion is a potential problem. Proper stormwater control measurements should be employed during construction to prevent erosion of the soil liner underneath the geomembrane and the washing away of the geomembrane.

Once deployment of a section of the geomembrane is complete and each section has been visually inspected for imperfections and tested to ensure that it is the specified the geomembrane

the membrane; TbTj 56.6279 0 TD -0.0lly 1.94r6gin.upportin476inspected for51ven

tested non-destructively (U.S. EPA, 1988). Destructive testing should be done at regular intervals along the seam (see page 4-66).

Consistent quality in fabricating field seams is

that may affect seaming should be monitored and controlled during installation. An inspection should be conducted in accordance with a construction quality assurance plan to document the integrity of field seams. Factors affecting the seaming process include (U.S. EPA, 1988):

- Ambient temperature at which the seams are made;
- Relative humidity;
- Control of panel lift-up by wind;
- The effect of clouds on the geomembrane temperature;
- Water content of the subsurface beneath the geomembrane;
- The supporting surface on which the seaming is bonded;
- Quality and consistency of the chemical or welding material;

materials removed from the solid waste. At MSWLF units, leachate is typically aqueous with limited, if any, immiscible fluids or dissolved solvents. The primary function of the leachate collection system is to collect and convey leachate out of the landfill unit and to control the depth of the leachate above the liner. The leachate collection system (LCS) 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. The 30-cm head allowance is a design standard and the Agency recognizes that this design standard may be exceeded for relatively short periods of time during the active life of the unit. Flow of leachate through imperfections in the liner system increases with an increase in leachate head above the liner. Maintaining a low leachate level above the liner helps to improve the performance of the composite liner.

Leachate is generally collected from the [illegible]

layer to collect leachate and carry it rapidly to a sump or collection header pipe;

- A protective filter layer over the high permeability drainage material, if necessary, to prevent physical clogging of the material by fine-grained material; and

- Leachate collection sumps or header pipe system where leachate can be removed.

The design, construction, and operation of the percent grade as a post-settlement design objective (U.S. EPA, 1991b).

High-Permeability Drainage Layer

The high-permeability drainage layer is placed directly over the liner or its protective bedding layer at a slope of at least two percent (the same slope necessary for the composite liner). Often the selection of a drainage material is based on the on-site availability of natural granular materials. In some regions of the country, hauling costs may be very high for sand and gravel, or appropriate materials

friction angle between the geomembrane and soil, and if possible, supported by laboratory

designation of GW or GP on the Unified Soils Classification Chart can be expected to have a hydraulic conductivity of greater than 0.01 cm/sec, while sands identified as SW or SP can be expected to have a coefficient of permeability greater than 0.001 cm/sec. The sand or gravel drains leachate that enters the drainage layer to prevent 30 cm (12 in) or moreflayer to Tcact7a43 0 T usually at least an order of magnitude greater than the impingement rate after final closure. The critical design condition for meeting the 30 cm (12 in) criterion can therefore be expected during the operating life. The designer may evaluate the sensitivity of a design to meet the 30 cm (12 in) criterion as a result of changes in impingement rates

Granular materials are generally placed using 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. If laboratory transmissivity tests are performed, they should be done under conditions, loads, and configurations that closely replicate the actual field conditions. It is important that the transmissivity value used in the leachate collection system design critical specification is the ability to transmit fluids under load. The specifications also should include a minimum transmissivity under expected landfill operating (dynamic) or completion (static) loads. The specifications for thickness and types of material should be identified on the drawings or in the materials section of the specifications, and should be consistent with the design calculations (U.S. EPA, 1988).

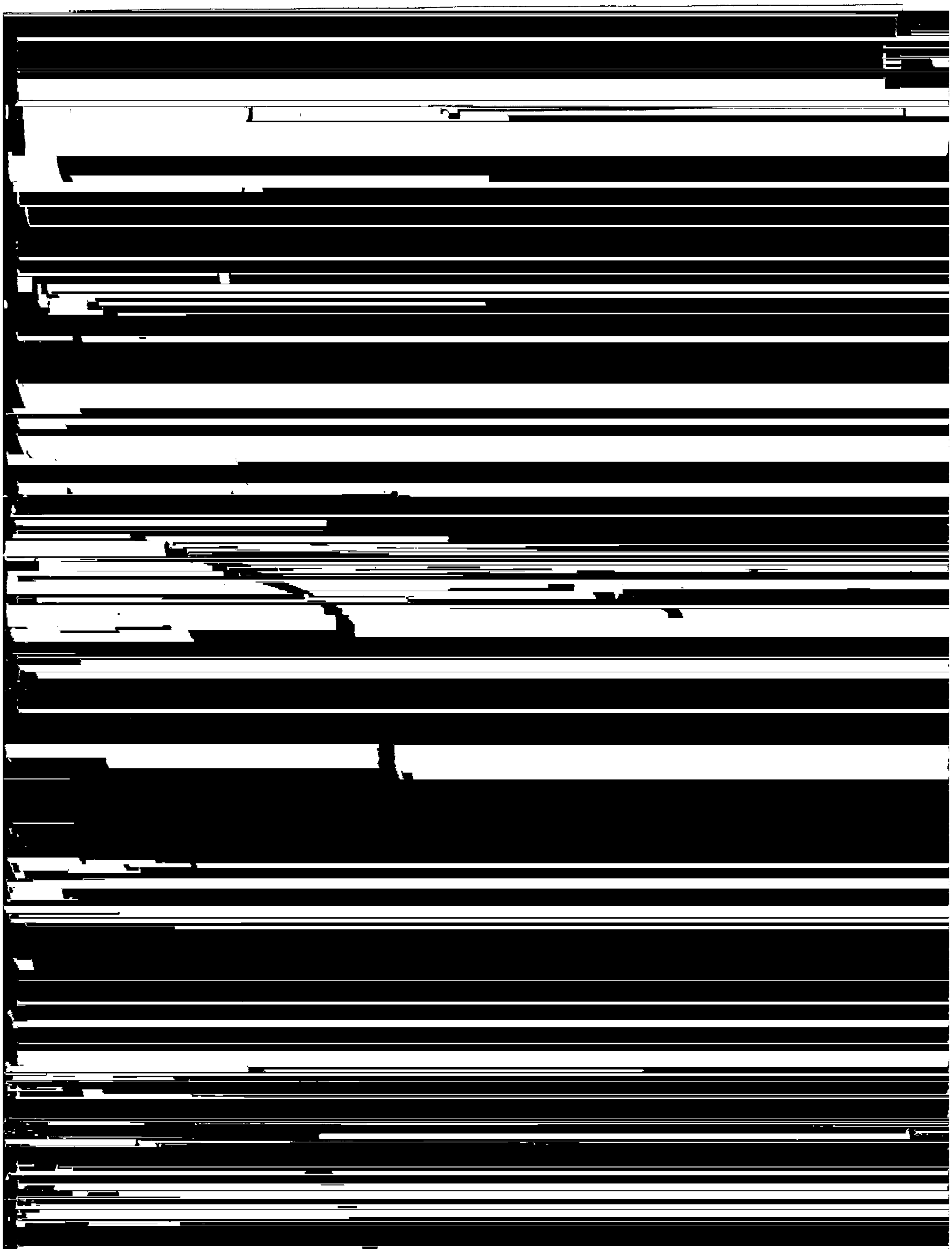


Figure 4-7. Flow Rate Curves for Geonets in Two Composite Liner Configurations

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

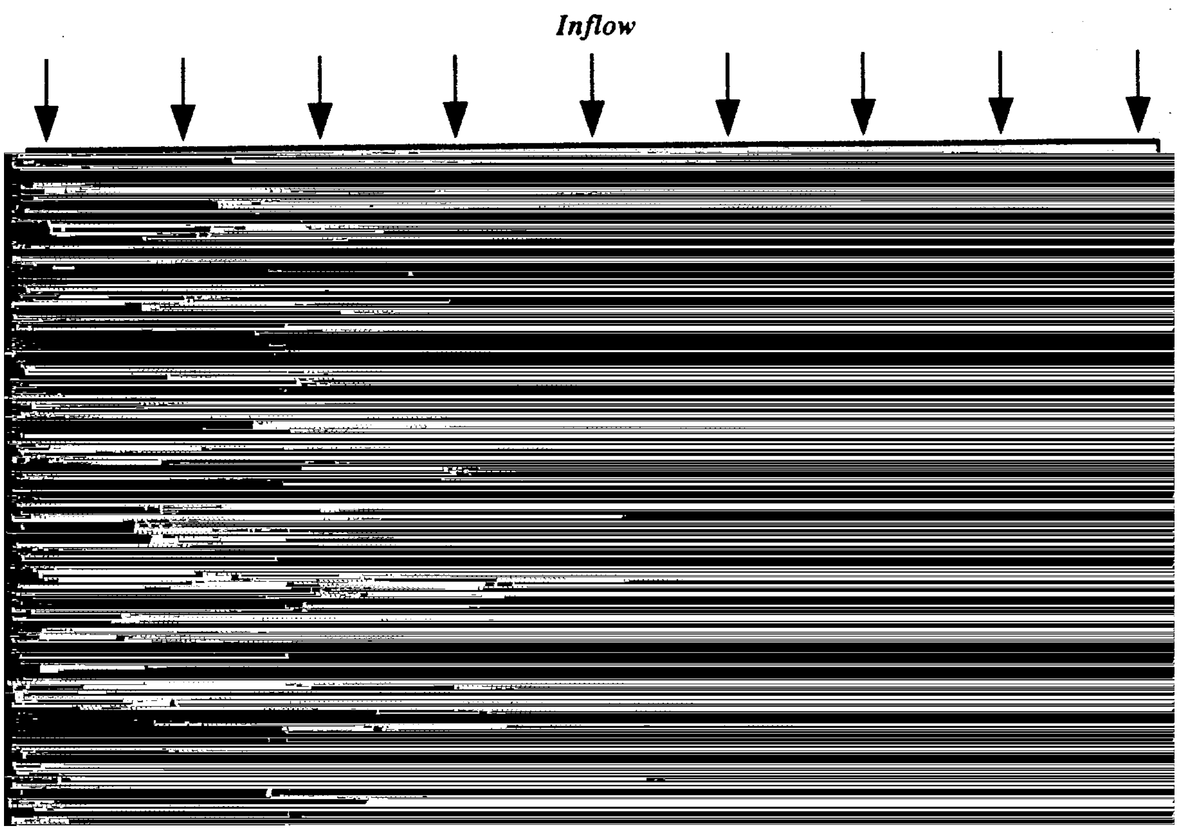


Figure 4-8. Definition of Terms for Mound Model Flow Rate Calculations

storage, evapotranspiration, and lateral drainage. The program estimates run-off drainage and leachate that are expected to result from a wide variety of landfill conditions, including open, partially open, and closed landfill cells. The model also may be used to estimate the depth of leachate above the bottom liner of the landfill unit. The results may be used to compare designs or to aid in the design of leachate collection systems (U.S. EPA, 1988).

Once the percolation and pipe spacing are known, the design flow rate can be obtained using the curve in Figure 4-9. The amount of

- Diameter and wall thickness;
- Size and distribution of slots and perforations;
- Type of coatings (if any) used in the pipe manufacturing; and
- Type of pipe bedding material and required compaction used to support the pipes.

The construction drawings and specifications should clearly indicate the type of bedding to be used under the pipes a

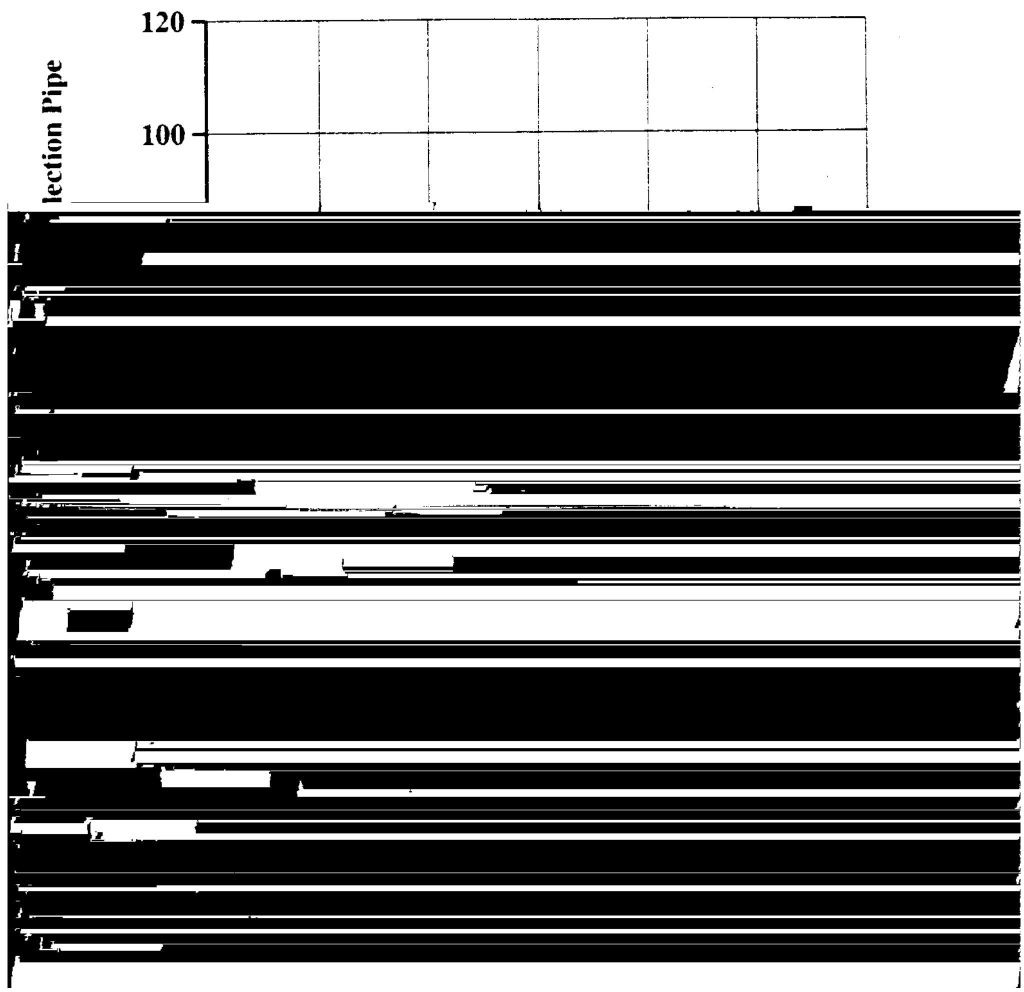


Figure 4-9. Required Capacity of Leachate Collection Pipe

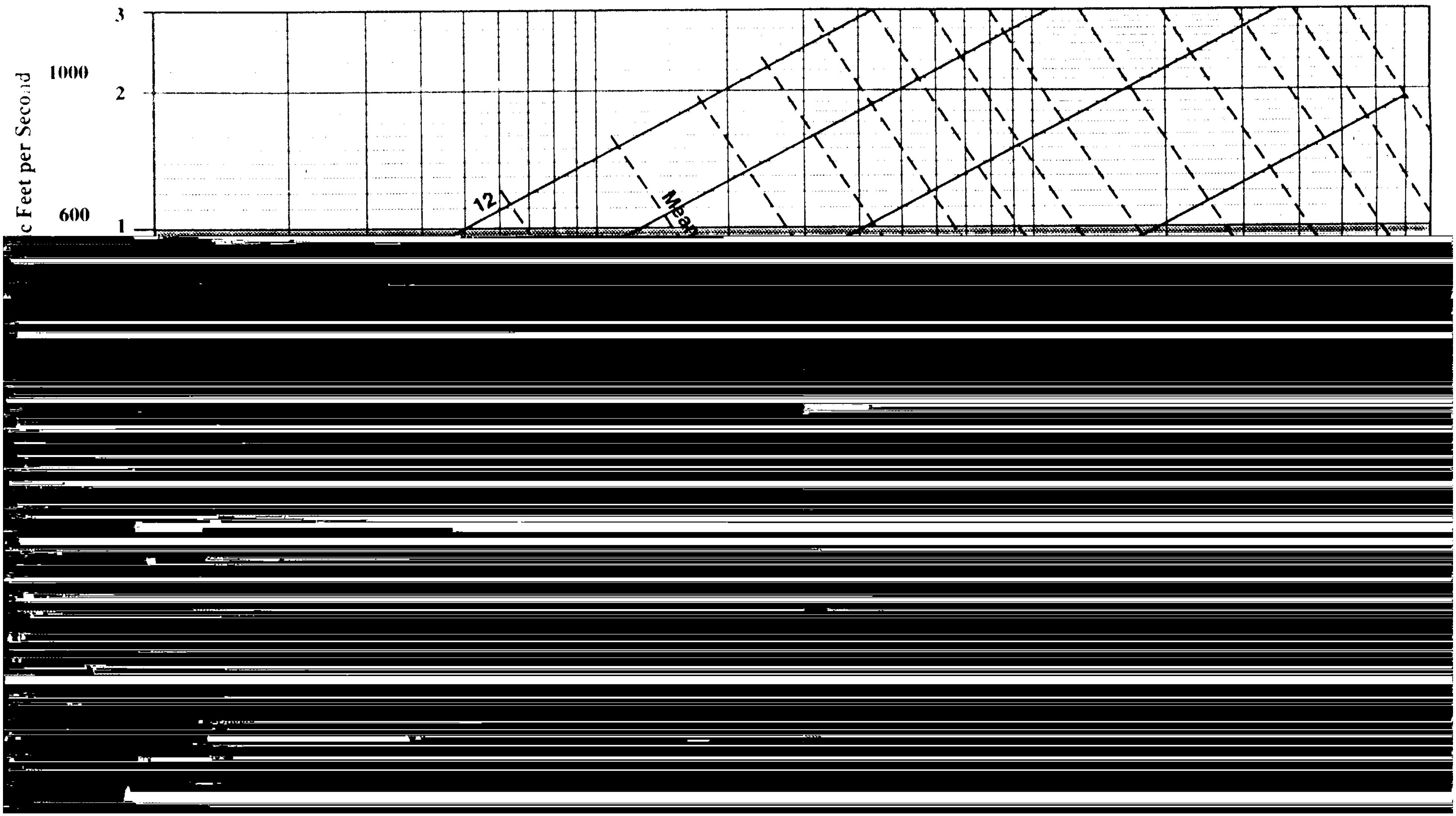


Figure 4-10. Leachate Collection Pipe Sizing Chart

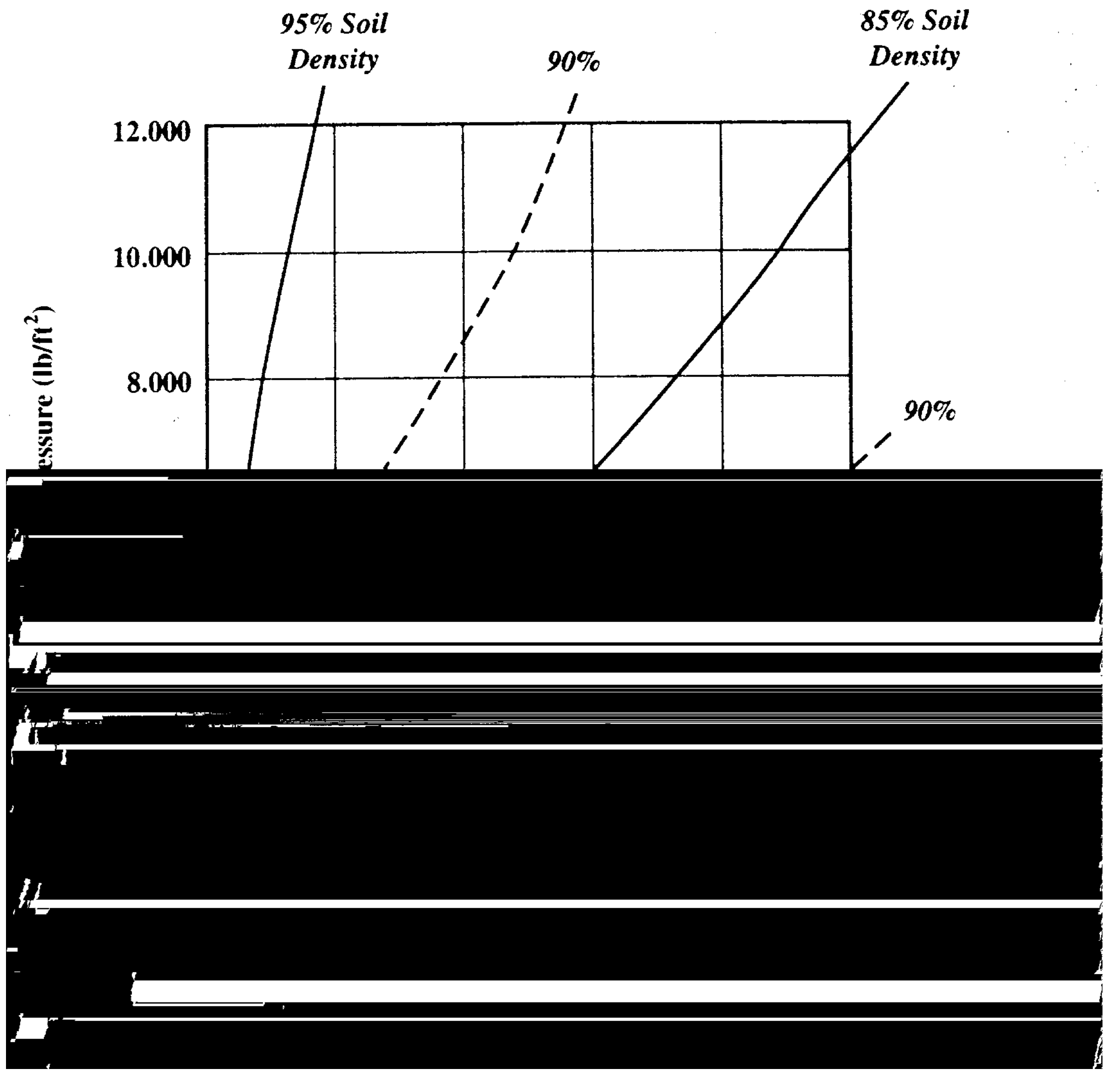


Figure 4-11. Vertical Ring Deflection Versus Vertical Soil Pressure for 18-inch Corrugated Polyethylene in High Pressure Soil Cell

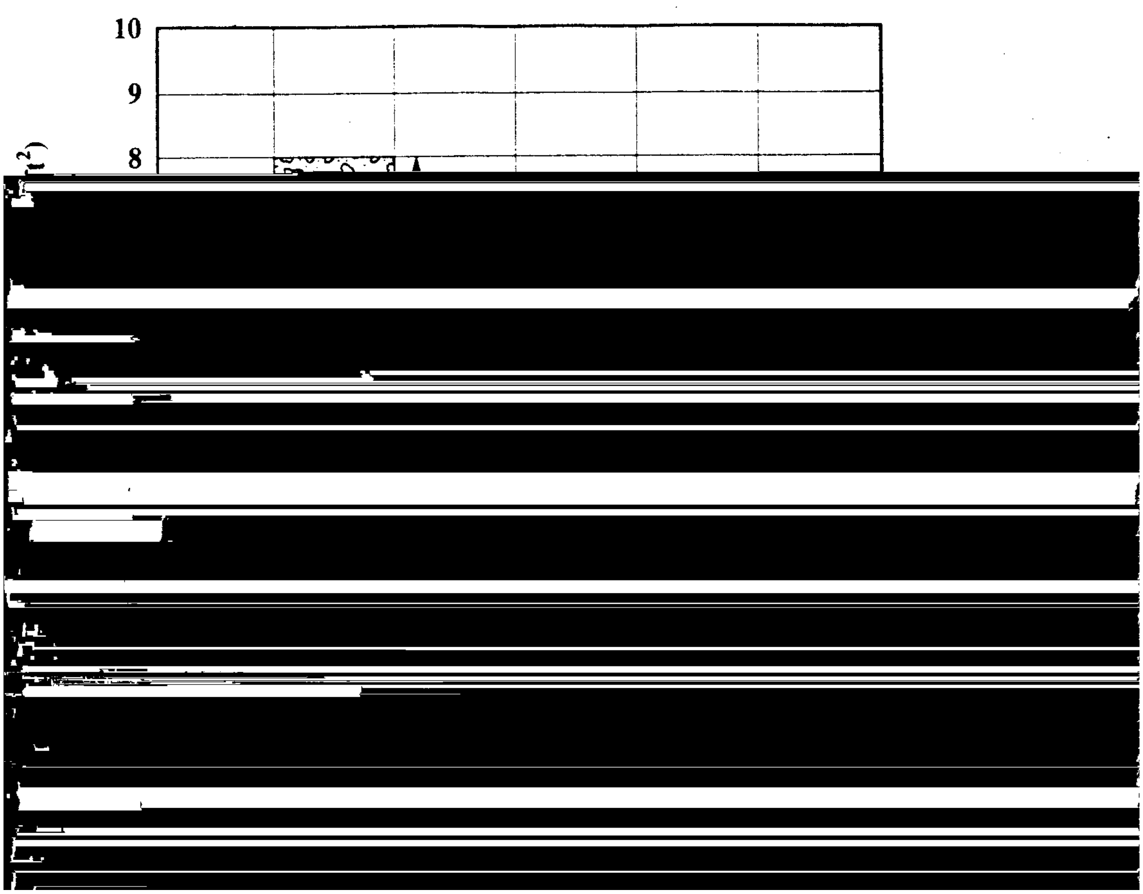


Figure 4-12. Example of the Effect of Trench Geometry and Pipe Sizing on Ring Deflection

Engineers (GCA Corporation, 1983) has established design criteria using graded filters to prevent physical clogging of leachate drainage layers and piping by soil sediment deposits. When installing graded filters, caution should be taken to prevent segregation of the material (USEPA, 1991a).

Clogging of the pipes and drainage layers of the leachate collection system can occur through several other mechanisms, including chemical and biological fouling (USEPA, 1988). The LCS should be designed with a cleanout access capable of reaching all parts of the collection system with standard pipe cleaning equipment.

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. ASCE (1969) discusses these relationships. Generally, flow velocities should be in the range of one or two feet per second to allow for self-cleansing of the piping (U.S. EPA, 1988).

h shoul60 Layer

Biological clogging due to algae and bacterial growth can be a serious problem in MSWLF units. There are no universally effective methods of preventing such biological growth. 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 (U.S. EPA, 1991b):

- A minimum of six-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.

In its discussion of drainage layer protection, the following section includes further information concerning protection of pipes using filter layers.

Protection of the High-Permeability Drainage Layer

The openings in drainage materials, whether
hble6si0.083terscussion 137.490 TD26.0533 Tc 004127 Tw (

There are three parts to an analysis of a sand filter that is placed above drainage material. The first determines whether or not the filter allows adequate flow of liquids. The second evaluates whether the void spaces are small enough to prevent solids from being lost from the upstream materials. The third estimates the long-term clogging behavior of the filter (U.S. EPA, 1989).

h the r

in the design of granular soil (sand filter) materials. The filter material should have its specifications should indicate the extent of the envelope.a

these AOS values should match those used in the design calculations (U.S. EPA, 1988).

One of the advantages 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 (U.S. EPA, 1988).

As with granular filter layers, it is important that the design drawings be clear in their designation of geotext

operational problems. Because they may run cover and then through the cover itself. If a gravity drainage pipe that requires geomembrane penetration is used, a high degree of care should be exercised in both the design and construction of the penetration. The penetration should be designed and constructed in a manner that allows nondestructive quality control testing of 100 percent of the seal between the pipe and the geomembrane. If not properly constructed and fabricated, geomembrane penetrations can become a source of leakage through the geomembrane.

Other Design Considerations

The stability of the individual leachate collection system components placed on geomembrane-covered slopes should be considered. A method for calculating the factor of safety (FS) against sliding for soils placed on a sloped geomembrane surface is provided in Koerner (1990). This method considersp4. TD -o87.60483 Tc 155w1g3306 Tw 4371 TD -0.0203 4 0 TDs198 Tc 0 crTh on8092D 0.0072

sliding material to tear the geomembrane officer's objectivity. Regulatory

construction has been performed in accordance with the plans and technical specifications. Construction testing generally includes tests of soil moisture content, density, lift thickness, and hydraulic conductivity.

The method of determining compliance with the maximum hydraulic conductivity criterion should be specified in the QA/QC plan. Some methods have included the use of the criterion as a maximum value that never should be exceeded, while other methods have used statistical techniques to estimate the true mean. The sample collection program should be designed to work with the method of compliance determination. Selection of sample collection points should be made on a random basis.

Thin wall sampling tubes generally are used to collect compacted clay samples for laboratory hydraulic conductivity testing. It is important to minimize disturbance of the sample being collected. Tubes pushed into the soil by a backho434.ds11.0379 Tj 9.519.3444 Tw (acce8.9) Tj 4 Tc 0 Tw (o) Tj ET BT d 0 TD 08

Quality assurance testing for soil liners includes the same testing requirements as specified above for control testing. Generally, the tests are performed less frequently and are performed by an individual or an entity independent of the

quality assurance (CQA) officer are essential to document quality of construction. The CQA officer's responsibilities and those of the CQA officer's staff members may include:

- Communicating with the contractor;
- Interpreting and clarifying project drawings and specifications with the designer, owner, and contractor;
- Recommending acceptance or

  work completed by the construction contractor;
- Submitting blind samples (e.g., duplicates and blanks) for analysis by

- Reporting to the owner/operator on monitoring results.

Soil Liner Pilot Construction (Test Fill)

A pilot construction or test fill is a small-scale test pad that can be used to verify that the soil, equipment, and construction procedures can produce a liner that performs according to the construction drawings and specifications. An owner or operator may want to consider the option of constructing a test fill prior to the construction of the liner. A test pad is useful not only in teaching people how to build a soil liner, it also can function as a construction quality assurance tool. If the variables used to build a test pad that achieves a $1x10^{-7}$ cm/sec hydraulic conductivity are followed exactly, then the completed full-size liner should meet the regulatory requirements (U.S. EPA, 1989). A test fill may be a cost-effective method for the contractor to evaluate the construction methods and borrow source. Specific factors that can be examined/tested during construction of a test fill include (U.S. EPA, 1988b):

- Preparation and compaction of foundation material to the required bearing strength;

- Methods of controlling uniformity of the soil material;

- Compactive effort (e.g., type of equipment, number of passes) to achieve required soil density and hydraulic conductivity;

- Lift thickness and placement procedures to achieve uniformity of density throughout a lift and the absence of apparent boundary effects between lifts or between placements in the same lift;

- Procedures for protecting against desiccation cracking or other site- and season-specific failure mechanisms for the finished liner or intermediate lifts;

- Measuring the hydraulic conductivity on the test fill in the field and collecting samples of field-compacted soil for laboratory testing;

- Test procedures for controlling the quality of construction;

- Ability of different types of soil to meet hydraulic conductivity requirements in the field; and

- Skill and competence of the construction team, including equipment operators and quality control specialists.

Geomembrane Quality Assurance/ Quality Control Testing

As with the construction of soil liners, installation of geomembrane liners should be in conformance with a quality assurance/quality control plan. Tests performed to evaluate the integrity of geomembrane seams are generally considered to be either "destructive" or "non-destructive."

Destructive Testing

tests are performed on samples from the installed seams.

Quality assurance testing generally requires that an independent laboratory perform peel and shear tests of samples from installed seams. The samples may be collected randomly or in areas of suspect quality. HDPE seams are generally tested at intervals equivalent to one sample per every 300 to 400 feet of installed seam for extrusion welds, and every 500 feet for fusion-welded seams. Extrusion seams on HDPE require grinding prior to welding, which can greatly diminish parent material strengths if excessive grinding occurs. Detailed discussion of polyethylene welding protocol can be found in U.S. EPA (1991a). For dual hot wedge seams in HDPE, both the inner and outer seam may be subjected to destructive shear tests at the independent laboratory. Destructive samples of installed seam welds are generally cut into several pieces and distributed to:

- The installer to perform construction quality control field testing;
- The owner/operator to retain and appropriately catalog or archive; and
- An independent laboratory for peel and shear testing.

If the test results for a seam sample do not pass the acceptance/rejection criteria, then samples are cut from the same field seam on both sides of the rejected sample location. Samples!

uTj 68.1758 BT 1 0 0 1 83 TD 0.5638Tc 0 Tw (rtaken TD 0.156ve BT 1 0 0 4787 TD

seam or reseaming the affected area (U.S. EPA, 1988). In situations where the seams

may have to be retrained.

Non-Destructive Testing

Non-destructive test methods are conducted in the field on an in-place geomembrane. These test methods determine the integrity of the geomembrane field seams. Non-destructive test methods include the probe test, air lance, vacuum box, ultrasonic methods (pulse echo, shadow and impedance plane), electrical spark test, pressurized dual seam, electrical resistivity, and hydrostatic tests. Detailed discussion of these test methods may be found in U.S. EPA (1991a). Seam sections that fail appropriate, non-destructive tests must be carefully delineated, patched or reseamed, and retested. Large patches or reseamed areas should be subjected to destructive test procedures for quality assurance purposes.

the degree to which non-destructive and destructive test methods will be used in

.32a Tc 52 1.74338 Tw (insta336 0 TDerform co636 8ee) Tj 170.3793.6386 0 1916 Tcl

- Observation of seam overlap, seam preparation prior to seaming, and material underlying the liner;
- Observation of destructive testing conducted on scrap test welds prior to seaming;
- Observation of destructive seam sampling, submission of the samples to an independent testing laboratory, and review of results for conformance to specifications;
- Observation of all seams and panels for defects due to manufacturing and/or handling and placement;
- Observation of all pipe penetration boots and welds in the liner;

they meet the construction plans and specifications. These include (U.S. EPA, 1988):

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

The

fabrics and geonets if applicable, and weather conditions;

- Geonet placement including layout, overlap, and protection from clogging

4.4 RELEVANT POINT OF COMPLIANCE

(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 w

direction, and the volume of ground-water flow. Background ground-water quality data should be used to establish baseline concentrations of the monitoring constituents. This information will be required as input to determine if contaminants from the landfill unit have been released and have migrated to the relevant point of compliance.

Ground-Water Receptors

The goal of establishing the relevant point of compliance is to ensure early detection of contamination of the uppermost aquifer. The distance to the relevant point of compliance should allow sufficient time for corrective measures to be implemented prior to the migration of contaminants to private or public water supply wells.

Existing users of ground water immediately downgradient from the facility should be identified on a map. Users located at a downgradient point where contaminants

unit, should be determined prior to establishing the relevant point of compliance (see Section 5.6.3). The performance standard for landfill design requires that landfill units be designed so that the concentrations listed in Table 1 are not exceeded at a relevant point of compliance. Issues for approved States to consider are whether the ground water is

be used as a drinking water source when

the ground water is not currently or reasonably expected to be used for drinking water, the State may allow the relevant point of compliance to be set near the 150-meter limit.

Public Health, Welfare, Safety

potential overall effect on public health, welfare, and safety of the proposed relevant point of compliance. Issues that should be e

Practicable Capability of the Owner or Operator

If the relevant point of compliance is placed farther from the waste management unit boundary, the volume of water requiring treatment, should the ground water become contaminated, will increase. One or more of the following conditions could affect the owner's or operator's practicable capability (technical **e**

4.5 PETITION PROCESS 40 CFR §258.40(e)

4.5.1 Statement of Regulation

(a) - (d) *(See Statement of Regulation in Sections 4.2.1, 4.3.1, and 4.4.1 of this guidance document for regulatory language.)*

Owners or operators of MSWLF units should contact the municipal solid waste regulatory department in their State to determine if their State has been approved by the U.S. EPA.

4.6 FURTHER INFORMATION

4.6.1 REFERENCES

(Specific to Performance-Based Design Assessment and Solute Transport Modeling)

Abriola, L.M., and G.F. Pinder, (1985a). A Multiphase Approach to the Modeling of Porous Media Contamination by Organic Compounds 1. Equation Development. Water Resources Research 21(1):11-18.

Abriola, L.M., and G.F. Pinder, (1985b). A Multiphase Approach to the Modeling of Porous Media Contamination by Organic Compounds 2. Numerical Simulation. Water Resources Research 21(1):19-26.

Aller, L., T. Bennett, J.H. Lehr, R.J. Petty, and G. Hackett, (1987). DRASTIC: A Standardized System for Evaluation Ground Water Pollution Potential Using Hydrogeologic Settings. EPA-600/2-87-035, Kerr Environmental Research Lab, U.S. Environmental Protection Agency, Ada, Oklahoma. 455 pp.

Auerbach, S.I., C. Andrews, D. Eyman, D.D. Huff, P.A. Palmer, and W.R. Uhte, (1984). Report of the Panel on Land Disposal. In: Disposal of Industrial and Domestic Wastes: Land and Sea Alternatives. National Research Council. National Academy Press. Washington, DC. pp. 73-100.

Beljin, M.S., (1985). A Program Package of Analytical Models for Solute Transport in Groundwater "SOLUTE". BAS15, International Groundwater Modeling Center, Holcomb Research Institute, Butler University, Indianapolis, Indiana. 163 pp.

Bond, F., and S. Hwang, (1988). Selection Criteria for Mathematical Models Used in Exposure Assessments: Groundwater Models. EPA/600/8-88/075, U.S. Environmental Protection Agency, Washington, DC.

Boutwell, S.H., S.M. Brown, B.R. Roberts, and D.F. Atwood, (1986). Modeling Remedial Actions at Uncontrolled Hazardous Waste Sites. EPA/540/2-85/001, U.S. Environmental Protection Agency, Athens, Georgia.

Cederberg, G.A., R.L. Street, and J.O. Leckie, (1985). A Groundwater Mass Transport and Equilibrium Chemistry Model for Multicomponent Systems. Water Resources Research, 21(8):1095-1104.

Dean, J.D., P.S. Huyakorn, A.S. Donigian, Jr., K.S. Voos, R.W. Schanz, Y.J.Meeks, and R.F. Carsel, (1989). Risk of Unsaturated/Saturated Transport and Transformation of Chemical Concentrations (RUSTIC). EPA/600/3-89/048a, U.S. EPA, Athens, Georgia.

Gureghian, A.

Prickett, T.A., T.G. Naymik, and C.G. Lonnquist, (1981). A Random-Walk Solute Transport Model for Selected Groundwater Quality Evaluations. Bulletin 65, Illinois State Water

Travis, B., (1984). TRACR3D: A Model of Flow and Transport in Porous/Fractured Media. LA-9667-MS. Los Alamos National Laboratory, Los Alamos, New Mexico.

Unge, M.J., K.V. Summers, and S.A. Gherini, (1986). MYGRT: An IBM Personal Computer Code for Simulation Solute Migration in Groundwater, User's Manual. EA-4545-CCM. Electric Power Research Institute, Palo Alto, California.

U.S. EPA, (1988). Superfund Exposure Assessment Manual. EPA/540/1-88/001, Washington, DC. NTIS No. PB89-135859. 157 pp.

U.S. EPA, (1993). Compilation of Ground-Water Models; PB93-209401; U.S. EPA; Office of Solid Waste; Washington, D.C.

van der Heijde, P.K., Y. Bachmat, J. Bredehoeft, B. Andrews, D. Holtz, and S. Sebastian, (1985). Groundwater Management: The Use of Numerical Models. American Geophysical Union, Washington, D.C.

van der Heijde, P.K., and M.S. Beljin, (1988a). Model Assessment for Delineating Wellhead Protection Areas. EPA-440/6-88-002, U.S. EPA, Washington, DC.

van der Heijde, P.K., El-Kadi, A.I., and S.A. Williams, (1988b). Groundwater Modeling: An Overview and Status Report. EPA/600/2-89/028, U.S. EPA, Ada, Oklahoma.

van Genuchten, M.T., (1978). Simulation Models and Their Application to Landfill Disposal Siting; A Review of Current Technology. In Land Disposal of Hazardous Wastes. EPA-660/9-78-016, U.S. EPA, Cincinnati, Ohio.

van Genuchten, M.T., and W.J. Alves, (1982). Analytical Solutions of the One-Dimensional Convective-Dispersive Solute Transport Equation. USDA, Technique Bulletin No. 1661. U.S. Department of Agriculture, Washington, DC.

Versar, Inc., (1987). Current and Suggested Practices in the Validation of Exposure Assessment Models, Draft Report. Prepared for U.S. EPA Office of Health and Environmental Assessment, Exposure Assessment Group, Washington, DC. EPA Contract No. 69-02-4254, Work Assignment No. 55.

Voss, C.I., (1984). SUTRA: A Finite Element Simulation Model for Saturated-Unsaturated Fluid

Weaver, J., C.G. Enfield, S. Yates, D. Kreamer, and D. White, (1989). Predicting Subsurface Contaminant Transport and Transformation: Considerations for Model Selection and Field

FHWA, (1985). "FHWA Geotextile Engineering Manual." Contract No.l DTF H61-83-C-00150.

FHWA, (1990). "Geotextile Design & Construction Guidelines. Contract No. FHWA DTFH61-86-C-00102.

GCA Corporation, (1983). "Draft Permit Writers' Guidance Manual for Hazardous Waste Treatment, Storage, and Disposal Facility"; 1983.

8 a o 6 o

Kastman, Kenneth A., (1984). "Hazardous Waste Landfill Geomembrane: Design, Installation and

U.S. EPA, (1988d). "Multimedia Exposure Assessment Model for Evaluating the Land Disposal of Hazardous Wastes, Volume I."; Woodward-Clyde Consultants, Oakland, CA 94607-4014 for U.S. EPA; Environmental Research Laboratory; Office of Research and Development; Athens, Georgia 30613.

U.S. EPA, (1988e). "Lining of Waste Containment and Other Impoundment Facilities"; EPA/600/2-88/052; U.S. EPA; Risk Reduction Engineering Laboratories; Cincinnati, Ohio 45268. NTIS PB-89-129670.

U.S. EPA, (1989). "Seminar Publication - Requirements for Hazardous Waste Landfill Design, Construction and Closure"; EPA/625/4-89/022; U.S. EPA; Center for Environmental Research Information; Office of Research and Development; Cincinnati, Ohio 45268.

U.S. EPA, (1990a). "Seminars - Design and Construction of RCRA/CERCLA Final Covers", CERI 90-50; U.S. EPA; Office of Research and Development; Washington, DC 20460.

U.S. EPA, (1990b). "Draft - LDCRS Flow Data from Operating Units - Technical Support for Proposed Liner/Leak Detection System Rule"; Geoservices, Inc. Consulting Engineers; Norcross, Georgia 30093.

U.S. EPA, (1990c). "Relationship of Laboratory- and Field-Determined Hydraulic Conductivity in Compacted Clay Layer"; EPA/600/2-90/025; U.S. EPA; Risk Reduction Engineering Laboratory; Cincinnati, Ohio 45268. NTIS PB-90-257775.

U.S. EPA, (1991a). "Technical Guidance Document: Inspection Techniques for the Fabrication of Geomembrane Field Seams"; EPA 530/SW-91/051, May 1991, Cincinnati, Ohio.

U.S. EPA, (1991b). "Landfill Leachate Clogging of Geotextiles (and Soil) Filters"; EPA/600/2-91/025, August 1991; Risk Reduction Engineering Laboratory; Cincinnati, Ohio, 45268. NTIS PB-91-213660.

U.S. EPA, (1992). "Technical Guidance Document: Construction Quality Management for Remedial Action and Remedial Design Waste Containment Systems"; EPA/540/R-92/073, October 1992; Risk Reduction Engineering Laboratory, Cincinnati, Ohio 45268 and Technology Innovation Office, Washington, D.C. 20460.

4.6.3 Models

List of Contacts for Obtaining Leachate Generation and Leachate Migration Models

Center for Exposure Assessment Modeling (CEAM), U.S. EPA, Office of Research and Development, Environmental Research Laboratory, Athens, Georgia 30605-2720, Model Distribution Coordinator (706) 546-3549, Electronic Bulletin Board System (706) 546-3402: MULTIMED, PRZM, FEMWATER/FEMWASTE, LEWASTE/3DLEWASTE

Electric Power Research Institute, Palo Alto, California, (214) 655-8883: MYGRT, FASTCHEM

Geo-Trans Inc., 46050 Manekin Plaza, Suite 100, Sterling, VA 20166, (703) 444-7000: SWANFLOW, SWIFT, SWIFT II, SWIFT III, SWIFT/386.

Geraghty & Miller, Inc., Modeling Group, 10700 Parkridge Boulevard, Suite 600 Reston, VA 22091: MODFLOW[386], MODPATH[386], MOC[386], SUTRA[386], Quickflow,

International Groundwater Modeling Center, Colorado School of Mines, Golden, Colorado (303) 273-3103: SOLUTE, Walton35, SEFTRAN, TRAFRAP,

National Technical Information Services (NTIS), 5285 Port Royal Road, Springfield, VA 22161, (703) 487-4650: HELP

Dr. Zubair Saleem, U.S. EPA, 401 M Street SW, Washington, DC, 20460, (202) 260-4767: EPACML, VHS

Scientific Software Group, P.O. Box 23041, Washington, DC 20026-3041 (703) 620-9214: HST3D, MODFLOW, MOC, SUTRA, AQUA, SWIMEV.

CHAPTER 5

SUBPART E
GROUND-WATER MONITORING AND CORRECTIVE ACTION

CHAPTER 5
SUBPART E

TABLE OF CONTENTS

5.5.3 Technical Considerations 5.5.2 Applicability

CHAPTER 5
SUBPART E
GROUND-WATER MONITORING
AND CORRECTIVE ACTION

5.1 INTRODUCTION

The Criteria establish ground-water monitoring and corrective action requirements for all existing and new MSWLF units and lateral expansions of existing units except where the Director of an approved State suspends the requirements because there is no potential for migration of leachate constituents from the unit to the uppermost aquifer. The Criteria include requirements for the location, design, and installation of ground-water monitoring systems and set standards for ground-water sampling and analysis. They also provide specific statistical methods and decision criteria for identifying a significant change in ground-water quality. If a significant change in ground-water quality occurs, the Criteria require an assessment of the nature and extent of contamination followed by an evaluation and implementation of remedial measures.

Portions of this chapter are based on a draft technical document developed for EPA's hazardous waste program. This document, "RCRA Ground-Water Monitoring: Draft Technical Guidance" (EPA/530-R-93-001), is undergoing internal review, and may change. EPA chose to incorporate the information from the draft document into this chapter because the draft contained the most recent information available.

5.2 APPLICABILITY
40 CFR §258.50 (a) & (b)

5.2.1 Statement of Regulation

active life of the unit and the post-closure care period. This demonstration must be

scientist and approved by the Director oU4 0 TD 0.008

5.2.2 Applicability

The ground-water monitoring requirements apply to all existing MSWLF units, lateral expansions of existing units, and new MSWLF units that receive waste after October 9, 1993. The requirements for ground-water monitoring may be suspended if the Director of an approved State finds that no potential exists for migration of hazardous constituents from the MSWLF unit to the uppermost aquifer during the active life of the unit, including closure or post-closure care periods.

The "no potential for migration" demonstration must be based upon site-specific information relevant to the fate and transport of any hazardous constituents that may be expected to be released from the unit. The predictions of fate and transport must identify the maximum anticipated concentrations of constituents migrating to the uppermost aquifer so that a protective assessment of the potential effects to human health and the environment can be made. A successful demonstration could exempt the MSWLF unit from requirements of §§258.51 through 258.55, which include installation of ground-water monitoring systems, and sampling and analysis for both detection and assessment monitoring constituents. *Preparing No-Migration Demonstrations for Municipal Solid Waste Disposal Facilities-Screening Tool* is a guidance document describing a process owners/ operators can use to prepare a no-migration demonstration (NMD) requesting suspension of the ground-water monitoring requirements.

5.2.3 Technical Considerations

All MSWLF units that receive waste after the effective date of Part 258 must comply with the ground-water monitoring requirements. The Director of an approved State may exempt an owner/operator from the ground-water monitoring requirements at §258.51 through §258.55 if the owner or operator demonstrates that there is no potential for hazardous constituent migration to the uppermost aquifer throughout the operating, closure, and post-closure care periods of the unit. Owners and operators of MSWLFs not located in approved States will not be eligible for this waiver and will be required to comply with all ground-water monitoring requirements. The "no-migration" demonstration must be certified by a qualified ground-water scientist and approved by the Director of an approved State. It must be based on site-specific field measurements and sampling and analyses to determine the physical, chemical, and biological processes affecting the fate and transport of hazardous constituents. The demonstration must be supported by site-specific data and predictions of the maximum contaminant migration. Site-specific information must include, at a minimum, the information necessary to evaluate or interpret the effects of the following properties or processes on contaminant fate and transport:

grocientist 0.5577 ef25450 TD 0 Tc 3.719 62 Tj 158.36 0

- Climatic Conditions, including annual precipitation, leachate generation estimates, and effects on leachate quality;

- Leachate Characteristics, including transport processes n ncludinla d

Mo

transport should be biased toward over-estimating transport and the anticipated concentrations. Assumptions and site specific data that are used in the fate and

5.3 COMPLIANCE SCHEDULE 40 CFR § 258.50 (c)

5.3.1 Statement of Regulation*

***[NOTE: EPA finalized several revisions to 40 CFR Part 258 on October 1, 1993 (58 FR 51536), and these revisions delay the effective date for some categories of landfills. More detail on the content of the revisions is included in the introduction.]**

(c) Owners and operators of MSWLF units must comply with the ground-water

(4) New MSWLF units must be in compliance with the ground-water

§§258.51 - 258.55 before waste can be

5.3.2 Applicability

The rule establishes a self-implementing schedule for owners or operators in States with programs that are deemed inadequate or not yet approved. As indicated in the

depends on the distance of the MSWLF unit from

Table 5-1. Compliance Schedule for Existing Units and Lateral Expansions in States with Unapproved Programs

Distance From Water Supply Intake	Time to Comply From October 9, 1991
One mile or less	3 Years
More than one mile but less than two miles	4 Years
More than two miles	5 Years

should provide sufficient time for the owner or operator to conduct site investigation and characterization studies to comply with the requirements of 40 CFR §258.51 through §258.55. For those facilities closest to drinking water intakes, the period provides 2 to 3 years to assess seasonal variability in ground-water quality. A drinking water intake includes water supplied to a user from either a surface water or ground-water source.

5.4 ALTERNATIVE COMPLIANCE SCHEDULES 40 CFR 258.50 (d)(e) & (g)

5.4.1 Statement of Regulation

(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 Dirt5ved StatWLF

(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) ***(See Section 5.5 for technical guidance on qualifications of a ground-water scientist.)***

(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

5.4.2 Applicability

The Director of an approved State may establish an alternative schedule for requiring owners/operators of existing units

ground-water monitoring requirements. The alternative schedule is to ensure that at least fifty percent of all existing MSWLF

by October 9, 1994 and that all units are in compliance by October 9, 1996.

In establishing the alternative schedule, the Director of an approved State may use site-specific information to assess the relative risks posed by different waste management units and will allow priorities to be develo sampling and analysis requirements of §§258.54 and 258.55, as well as corrective action requirements of §§258.56, 258.57, and 258.58. See Table 5-2 for a summary of notification requirements for which approved States may establish alternative schedules.

5.4.3 Technical Considerations

The rule allows approved States flexibility in establishing alternate ground-water monitoring compliance schedules. In setting an alternative schedule, the State will consider potential impacts to human health and the environment. Approved States have the option to address MSWLF units that have environmental problems immediately. In establishing alternative schedules for installing ground-water monitoring systems at existing MSWLF units, the Director of an approved State may consider information including the age and design of existing facilities. Using this type of information, in conjunction with a knowledge of the wastes disposed, the Director should be able to qualitatively assess or rank facilities based on their risk to local ground-water resources.

5.5 QUALIFICATIONS 40 CFR 258.50 (f)

5.5.1 Statement of Regulation

(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

Table 5-2. Summary of Notification Requirements

Section	Description
§258.51(d)(2)	14 day notification period after well installation certification by a qualified ground-water scientist (GWS)
§258.54(c)(1)	14 day notification period after finding a statistical increase over background for detection parameter(s)
§258.55(d)(1)	14 day notification period after detection of Appendix II constituents
§258.57(a)	14 day notification period after selection of corrective measures
§258.58(c)(4)	14 day notification period prior to implementing alternative measures
§258.58(f)	14 day notification period after remedy has been completed and certified by GWS

the natural sciences or engineering and has sufficient training and experience in ground-water 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

5.5.3 Technical Considerations

A qualified ground-water scientist must certify work performed pursuant to the following provisions of the ground-water monitoring and corrective action requirements:

- No potential for migration demonstration (§258.50(b)) addressed in the order in which they appear in this guidance document.

Many State environmental regulatory agencies have ground-water scientists on staff. The owner or operator of a MSWLF unit or facility is not necessarily required to obtain certification from an independent (e.g., consulting) ground-water scientist and may, if agreed to by the Director in an approved State, obtain approval by the Director in lieu of certification by an outside individual.

5.6 GROUND-WATER MONITORING SYSTEMS 40 CFR §258.51 (a)(b)(d)

5.6.1 Statement of Regulation

(a) A ground-water monitoring system must

representative than that provided by the upgradient wells; and

(2) Represent the quality of ground water passing 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. 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

of ground-water contamination in the uppermost aquifer. When physical obstacles preclude installation of ground-

point of compliance at existing units, the

installed at the closest practicable

States that are deemed not in compliance with the regulations must have a monitoring system for each unit.

A qualified ground-water scientist must certify that the number, spacing, and depths of the monitoring wells are appropriate for the MSWLF unit. This certification must be placed in the operating records. The State Director must be notified within 14 days that the certification was placed in the operating record.

5.6.3 Technical Considerations

The objective of a ground-water monitoring system is to intercept ground water that has been contaminated by leachate from the MSWLF unit. Early contaminant detection is important to allow sufficient time for corrective measures to be developed and implemented before sensitive receptors are significantly affected. To accomplish this objective, the monitoring wells should be located to sample ground water from the uppermost aquifer at the closest practicable distance from the waste management unit boundary. An alternative distance that is protective of human health and the environment may be granted by the Director of an approved State. Since the monitoring program is intended to operate through the post-closure period, the location, design, and installation of monitoring wells should address both existing conditions and anticipated facility development, as well as expected changes in ground-water flow.

Uppermost Aquifer

Monitoring wells must be placed to provide representative ground-water samples from the uppermost aquifer. The uppermost aquifer is defined in §258.2 as "the geologic formation nearest to the natural ground surface that is an aquifer, as well as lower aquifers that are hydraulically interconnected with this aquifer within the facility property boundary." These lower aquifers may be separated physically from the uppermost aquifer by less permeable strata (having a lower hydraulic conductivity) that are often terme primarily by the mineral composition of the geologic unit comprising the aquifer. As ground water moves from one geologic unit to another, its chemical composition may change. To reduce the probability of detecting naturally occurring differences in ground-water quality between background and downgradient locations, only ground-water samples collected from the same geologic unit should be compared.

Ground-water quality in areas where the geology is complex can be difficult to characterize. As a result, the rule allows the owner or operator flexibility in determining where to locate wells that will be used to establish background water quality.

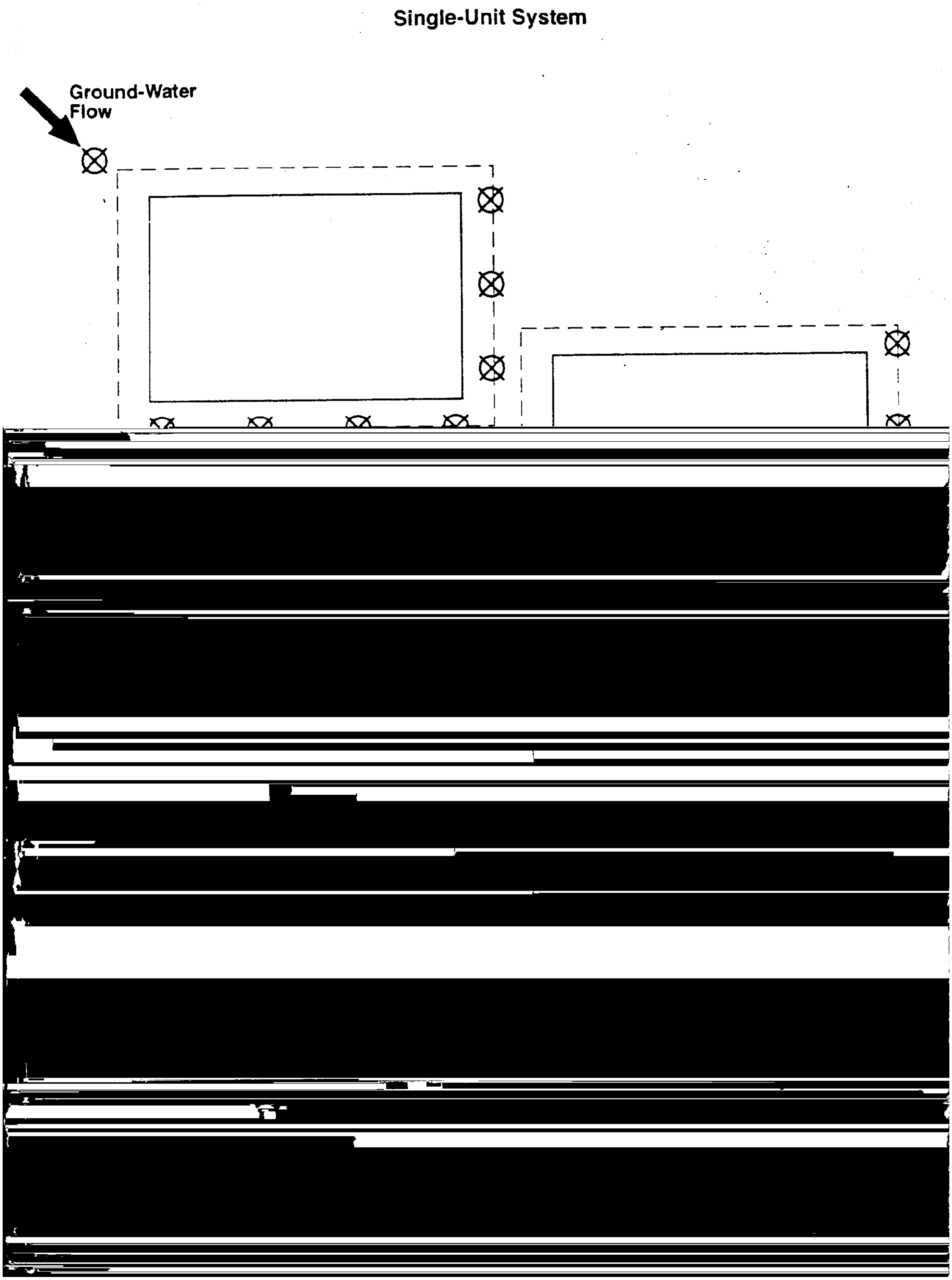
If the facility is new, ground-water samples collected from both upgradient and downgradient locations prior to waste disposal can be used to establish background water quality. The sampling should be conducted to account for both seasonal and spatial variability in ground-water quality.

Determining background ground-water quality by sampling wells that are not hydraulically upgradient may be necessary where hydrogeologic conditions do not allow the owner or operator to determine which wells are hydraulically upgradient. Additionally, background ground-water quality may be determined by sampling wells that provide ground-water samples as representative or more representative than those provided by upgradient wells. These conditions include the following:

- The facility is located near production wells that influence the direction of ground-water flow.
- Upgradient ground-water quality is affected by a source of contamination other than the MSWLF unit.
- The proposed or existing landfill overlies a ground-water divide or local
- Geologic units present at downgradient locations are absent at upgradient locations.
- Karst terrain or fault zones modify flow.
- Nearby surface water influences ground-water flow directions.
- Waste management areas are located close to a property boundary that is upgradient of the facility.

A multi-unit ground-water monitoring system does not have wells at individual MSWLF unit boundaries. Instead, an imaginary line is drawn around all of the units at the facility. (See Figure 5-1 for a comparison of single unit and multi-unit systems.) This line constitutes the relevant point of compliance. The option to establish a multi-unit monitoring system is restricted to facilities located in approved States.

Figure 5-1. Comparison of Single Unit and Multi-Unit Monitoring System



- Information on the waste management history of the site, including:
  - A chronological history of the site, including descriptions of wastes managed on-site
  - A summary of documented releases
  - Details on the structural integrity of the MSWLF unit and physical controls on waste migration
- A literature review, including:
  - Reports of research performed in the area of the site
  - Journal articles
  - Studies and reports available from local, regional, and State offices (e.g., geologic surveys, water boards, and environmental agencies)
  - Studies available from Federal offices, such as USGS or USEPA
- Information from file searches, including:
  - Reports 0.23l571a986w (t8(e from Federa5008742w (3737g..i./F0 12 1e./F 0.2319462 -13.6771 TD 0

Characterizing Site Geology

complete, the owner/operator will have information that he/she can use to develop a plan to characterize site hydrogeology

include a subsurface boring program. A boring program is necessary to define site hydrogeology and the small-scale geology

usually requires more than one iteration.

refine the conceptual model of the site derived from the preliminary investigation.

The subsurface boring program should be

- The initial number of boreholes and their spacing is based on the information obtained during the preliminary
- Additional boreholes should be installed

  about the site.

n

include electric, sonic, and nuclear logging. Surface geophysical techniques include

- Seasonal/temporal, natural, and

temporal fluctuations in ground-water flow directions. Ground-water flow direction(s) should be determined from water levels measured in wells screened in the same hydro-stratigraphic position. In heterogeneous geologic settings (i.e., settings in which the hydraulic conductivities of the subsurface materials vary with location in the subsurface), long well screens can intercept stratigraphic horizons with different (e.g., contrasting) ground-water flow directions and different heads. In this situation, the resulting water levels will not provide the depth-discrete head measurements required for accurate determination of the ground-water flow direction.

In addition to evaluating the component of ground-water flow in the horizontal direction, a program should be undertaken to assess the vertical component of ground-water flow. Vertical ground-water flow information should be based, at least in part, on field data from wells and piezometers, such as multi-level wells, piezometer clusters, or multi-level sampling devices, where appropriate. The following sections provide acceptable methods for assessing the vertical and horizontal components of flow at a site.

Ground-Water Level Measurements

the waste types managed at the facility) in the subsurface at the facility, both the depth(s) to the immiscible layer(s) and the thickness(es) of the immiscible layer(s) in the well should be recorded.

For the purpose of measuring total head, piezometers and wells should have as short a screened interval as possible. Specifically, the screens in piezometers or wells that are used to measure head should generally be less than 10 feet long. In circumstances including the following, well screens longer than 10 feet may be warranted:

- Natural water level fluctuations

- The interval monitored is slightly greater than the appropriate screen length (e.g., the interval monitored is 12 feet thick).

- The aquifer monitored is homogeneous and extremely thick (e.g., greater than 300 feet); thus, a longer screen (e.g., a 20-foot screen) represents a fairly discrete interval.

The head measured in a well with a long

different heads over the entire length of the

design of a piezometer/well nest should be considered carefully. Placement of piezometers/wells in closely spaced boreholes, where piezometers/wells have been screened at different, discrete depth intervals, is likel

Further information can be obtained from Freeze and Cherry (1979).

Determining Hydraulic Conductivity

A commonly used test for determining horizontal hydraulic conductivity with a single well is the slug test. A slug test is performed by suddenly adding, removing, or displacing a known volume of water from a well and observing the time that it takes for the water level to recover to its original level (Freeze and Cherry, 1979). Similar results can be achieved by pressurizing the well casing, depressing the water level, and suddenly releasing the pressure to simulate the removal of water from the well. In most cases, EPA recommends that water not be introduced into wells during aquifer tests to avoid altering ground-water chemistry. Single-well tests are limited in scope to the area directly adjacent to the well screen. The vertical extent of the well screen generally defines the part of the geologic formation that is being tested.

A modified version of the slug test, known as the multilevel slug test, is capable of providing depth-discrete measurements of hydraulic conductivity. The drawback of the multilevel slug test is that the test relies on the ability of the investigator to isolate a portion of the aquifer using a packer. Ne

to provide hydraulic conductivity data for that zone. Multiple-well tests for hydraulic conductivity characterize a greater proportion of the subsurface than single-well tests and, thus, provide average values of hydraulic conductivity. Multiple-well tests require measurement of parameters similar to those required for single-well tests (e.g., time, drawdown). When using aquifer test data to determine aquifer parameters, it is important that the solution assumptions can be applied to site conditions. Aquifer test solutions are available for a wide variety of hydrogeologic settings, but are often applied incorrectly by inexperienced persons. Incorrect assumptions regarding hydrogeology (e.g., aquifer boundaries, aquifer lithology, and aquifer thickness) may translate into incorrect estimations of

water scientist with experience in designing and interpreting aquifer tests should be consulted to ensure that aquifer test solution methods fit the hydrogeologic setting. Kruseman and deRidder (1989) provide a comprehensive discussion of aquifer tests.

Certain aquifer tests are inappropriate for use in karst terrains characterized by a well-developed conduit flow system, and they also may be inappropriate in fractured bedrock. When a well located in a karst conduit or a large fracture is pumped, the water level in the conduit is lowered. This lowering produces a drawdown that is not radial (as in a granular aquifer) but is instead a trough-like depression parallel to the pumped conduit or fracture. Radial flow equations do not apply to drawdown data collected during such a pump test. This means that a conventional semi-log plot of drawdown versus time is inappropriate for the purpose of determining the aquifer's transmissivity and storativity. Aquifer tests in karst aquifers can be useful, but valid determinations of hydraulic conductivity, storativity, and transmissivity may be impossible. However, an aquifer test can provide information on the presence of conduits, on storage characteristics, and on the percentage of Darcian flow. McGlew and Thomas (1984) provide a more detailed discussion of the appropriate use of aquifer tests in fractured bedrock and on the suitable interpretation of test data. Dye tracing also is used to determine the rate and direction of ground-water flow in karst settings (Section 5.2.4).

Several additional factors should be considered when planning an aquifer test:

- Owners and operators should provide for the proper storage and disposal of potentially contaminated ground water pumped from the well system.

- Owners and operators should consider the potential effects of pumping on existing plumes of contaminated ground water.

- In designing aquifer tests and interpreting aquifer test data, owners/operators should account and correct for seasonal, temporal, and anthropogenic effects on the potentiometric surface or water table. This is usually done by installing piezometers outside the influence of the stressed aquifer. These piezometers should be continuously monitored during the aquifer test.

- Owners and operators should be aware that, in a very high hydraulic conductivity aquifer, the screen size and/or filter pack used in the test well can affect an aquifer test. If a very small screen size is used, and the pack is improperly graded, the test may reflect the characteristics of the filter pack, rather than the aquifer.

- EPA recommends the use of a step-drawdown test to provide a basis for selecting discharge rates prior to conducting a full-scale pumping test. This will ensure that the pumping rate chosen for the subsequent pumping test(s) can be sustained without exceeding the available drawdown of the pumped wells. In addition, this test will produce a measurable drawdown in the observation wells.

Certain flowmeters recently have been recognized for their ability to provide accurate and vertically discrete measurements of hydraulic conductivity. One of these, the impeller flowmeter, is available commercially. More sensitive types of flowmeters (i.e., the heat-pulse flowmeter and electromagnetic flowmeter) should be available in the near future. Use of the impeller flowmeter requires running a caliper log to measure the uniformity of the diameter of the well screen. The well is then pumped with a small pump operated at a constant flow rate. The flowmeter is lowered into the well, and the discharge rate is measured every few feet by raising the flowmeter in the well. Hydraulic conductivity values can be calculated from the recorded data using the Cooper-Jacob (1946) formula for horizontal flow to a well. Use of the impeller flowmeter is limited at sites where the presence of low permeability materials does not allow pumping of the wells at rates sufficient to operate the flowmeter. The application of flowmeters in the measure of hydraulic conductivity is described by Molz et al. (1990) and Molz et al. (1989).

hydraulic properties of the tested material). Special attention should be given to the selection of the appropriate test method and test conditions and to quality control of laboratory results. McWhorter and Sunada (1977), Freeze and Cherry (1979), and Sevee (1991) discuss determining hydraulic conductivity in the laboratory. Laboratory tests may provide the best estimates of hydraulic conductivity for materials in the unsaturated zone, but they are likely to be less accurate than field methods for materials in the saturated zone (Cantor et al., 1987).

Determining Ground-Water Flow Rate

Tl894 0 Td (d1Tj 0.0196 Tc (Tl894 0 Td v9911 Tw pl

o

determining flow rates in heterogeneous and/or anisotropic systems and should be consulted prior to calculating flow rates.

Interpreting and Presenting Data

The following sections offer guidance on interpreting and presenting hydrogeologic data collected during the site characterization process. Graphical representations of data, such as cross sections and maps, are typically extremely helpful both when evaluating data and when presenting data to interested individuals.

Interpreting Hydrogeologic Data

Once the site characterization data have

preliminary investigation to verify the collected information.

field data corroborate and are

porosity, hydraulic conductivity, lateral and vertical stratigraphic relationships, and ground-water flow directions and rates.

After the hydrogeologic data are interpreted, the findings should be reviewed to:

additional data or reassessm 0.8m 0.2248 4. T

- The ground-water flow rate should be based on accurate measurements o

Geologic and soil maps should be based on

A potentiometric surface map or water table map should be prepared for each water-bearing zone that comprises the uppermost aquifer. Potentiometric surface and water table maps should show both the direction and rate of ground-water flow and the locations of all piezometers and wells on which they are based. The water level measurements for all piezometers and wells on which the potentiometric surface map or water table map is based should be shown on the potentiometric surface or water table map. If seasonal or temporal variations in ground-water flow occur at the site, a sufficient number of potentiometric surface or wa

a conceptual model. This model is the integrated picture of the hydrogeologic system and the waste management setting. The final conceptual model must be a site-specific description of the unsaturated zone, the uppermost aquifer, and its confining units. The model should contain all of the information necessary to design a ground-water monitoring system.

Monitoring Well Placement

This section separately addresses the lateral placement and the vertical sampling intervals of point of compliance wells.

Point of compliance monitoring wells should be placed laterally along the downgradient edge of the MSWLF unit to intercept potential pathways for contaminant migration. The local ground-water flow direction and gradient are the major factors in determining the lateral

In some settings, the ground-water flow direction may reverse seasonally (depending on precipitation), change as a result of tidal influences or river and lake stage fluctuations, or change temporally as a result of well-pumping or changing land use patt determining the lateral placement of monitoring wells.

Vertical Placement and Screen Lengths

Proper selection of the vertical sampling interval is necessary to ensure that the monitoring system is capable of detecting a release from the MSWLF unit. The vertical position and lengths of well intakes are functions of (1) hydro-geologic factors that determine the distribution of, and fluid/vapor phase transport within, potential pathways of contaminant migration to and within the uppermost aquifer, and (2) the chemical and physical characteristics of

the boring program, and from samples collected while drilling the monitoring well.

geophysical data, available regional/local

provide the vertical distribution of hydraulic conductivity. The vertical sampling interval is not necessarily synonymous with aquifer thickness. Monitoring wells are often screened at intervals that represent a portion of the thickness of the aquifer. When monitoring an unconfined aquifer, the well screen typically should be positioned so that a portion of the well screen is in the saturated zone and a portion of the well screen is in the unsaturated zone (i.e., the

of contafactorw (orol is iakes ar4 Tj 8 3.3593 0 T0 0.2516 TTc 4.9208 phase Tw TwTc (in8.Tj 9.8379 0

Figure 5-2
Upgradient and Downgradient
Designations for Idealized MSWLF

contaminants may occur as light non aqueous phase liquids (LNAPLs), which are lighter than water, and DNAPLs, which are denser than water. LNAPLs migrate in the capillary zone just above the water table. Wells installed to monitor LNAPLs should be screened at the water table/capillary zone interface, and the screened interval should intercept the water table at its minimum and maximum elevation. LNAPLs may become trapped in residual form in the vadose zone

- "Down-the-dip" of lower hydraulic conductivity units that act as confining layers, both upgradient and downgradient of the waste management area.

wand d.0539 Tc (illi htnTw.2396e Tc j 4Tw (d

Because of the nature of DNAPL migration (i.e., along structural, rather than hydraulic, gradients), wells installed to monitor DNAPLs may need to be installed both upgradient and downgradient of the wast

! 0 TET BT TD 0 1 96.9. ioj 5e wam /F0 12omef 10 Tw (d)(I62 0 019 TD 0.32j 10052 wasti 10149191 0 .1Tc uct11wl depr

5.7 GROUND-WATER MONITORING WELL DESIGN AND CONSTRUCTION 40 CFR §258.51 (c)

5.7.1 Statement of Regulation

(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.

§258.52 [Reserved].

5.7.2 Applicability

The requirements for monitoring well design, installation, and maintenance are applicable to all wells installed at existing units, lateral expansions of units, and new MSWLF units. The design, installation, and decommissioning of any monitoring well must be documented in the operating record of the facility and certified by a qualified ground-water scientist. Documentation is required for wells, piezometers, sampling devices, and water level measurement instruments used in the monitoring program.

The monitoring wells must be cased to protect the integrity of the borehole. The design and construction of the well directly affects the quality and representativeness of the samples collected. The well casing must have a screened or perforated interval to allow the entrance of water into the well casing. The annular space between the well screen and the formation wall must be packed with material to inhibit the migration of formation material into the well. The well screen must have openings sized according to the packing material used. The annular space above the filter pack must be sealed to provide a discrete sampling interval.

All monitoring wells, piezometers, and sampling and analytical devices must be maintained in a manner that ensures their continued performance according to design specifications over the life of the monitoring program.

5.7.3 Technical Considerations

The design, installation, and maintenance of monitoring wells will affect the consistency and accuracy of samples collected. The design must be based on site-specific information. The formation material (lithology and grain size distribution) will determine the selection of proper packing and sealant materials, and the stratigraphy will determine the screen length for the interval to be monitored. Installation practices should be specified and overseen to ensure that the monitoring well is installed as designed and will perform as intended. This section will discuss the factors that must be considered when designing monitoring wells. Each well must be tailored to suit the hydrogeological setting, the contaminants to be monitored, and other site-specific factors. Figure 5-3 depicts the components of a typical monitoring well installation.

The following sections provide a brief overview of monitoring well design and construction. More comprehensive discussions are provided in USEPA (1989f) and USEPA (1992a).

Selection of Drilling Method

The method chosen for drilling a monitoring well depends largely on the following factors (USEPA, 1989f):

- Versatility of the drilling method
- Relative drilling cost
- Sample reliability (ground-water, soil, unconsolidated material, or rock samples)
- Availability of drilling equipment
- Accessibility of the drilling site
- Relative time required for well installation and development
- Ability of the drilling technology to preserve natural conditions
- Ability to install a well of desired diameter and depth
- Relative ease of well completion and development, including the ability to install the well in the given hydrogeologic setting.

In addition to these factors, USEPA (1989f) includes matrices to assist in selecting an appropriate drilling method. These matrices list the most commonly used drilling techniques for monitoring well installation, taking into consideration hydrogeologic settings and the objectives of the monitoring program.

The following basic performance objectives should guide the selection of drilling procedures for installing monitoring wells:

- Drilling should be performed in a manner that preserves the natural properties of the subsurface materials.
- Contamination and/or cross-contamination of ground water and aquifer materials during drilling should

  the collection of representative samples of rock, unconsolidated materials, and soil.
- The drilling method should allow the

  appropriate location for the screened

- The drilling method should allow for

  annular sealants. The borehole should be at least 4 inches larger in diameter

  casing and screen to allow adequate

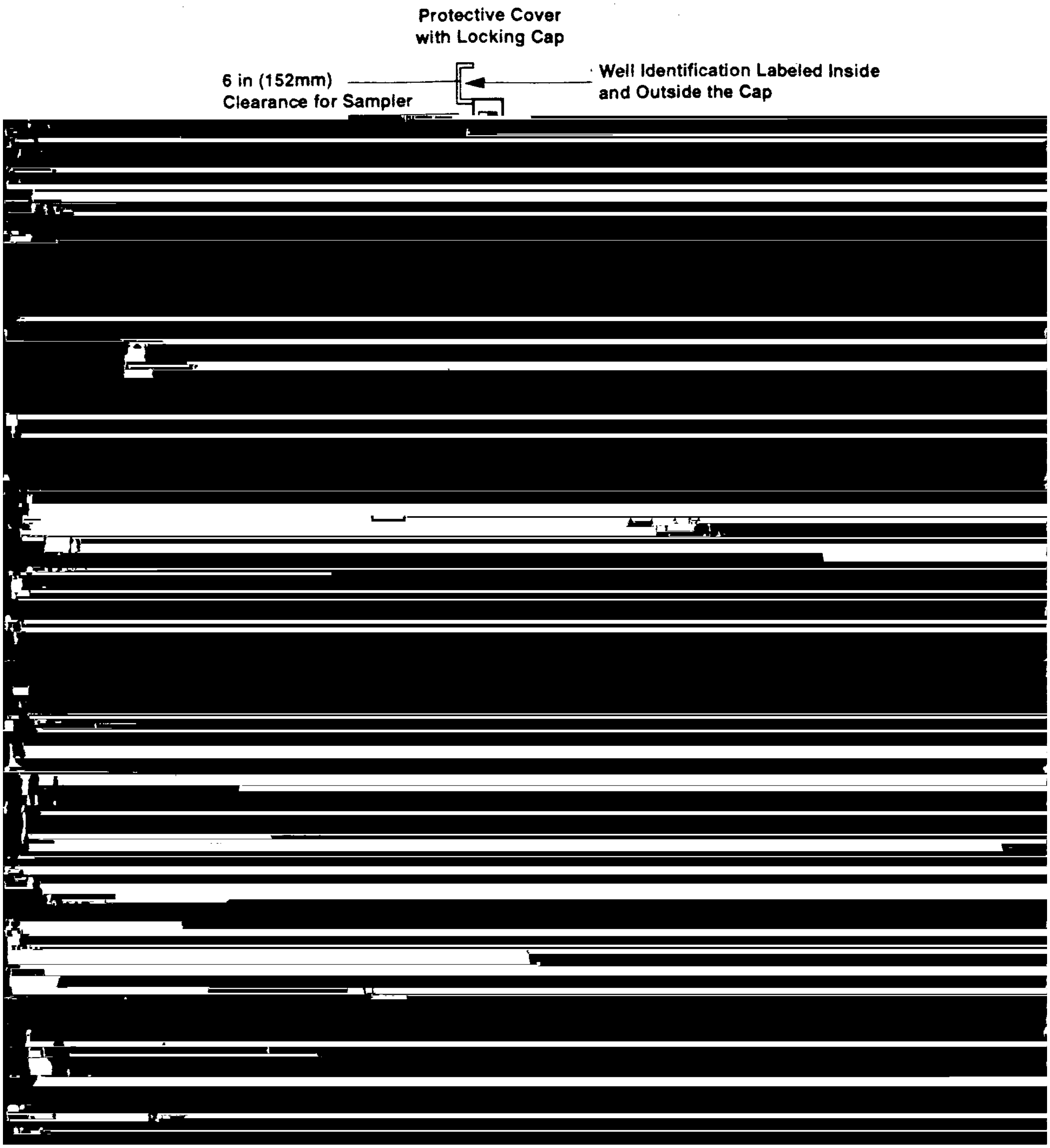


Figure 5.3. Example of a Monitoring Well Design-Single Cased Well

space for placement of the filter pack and annular sealants.

- The drilling method should allow for the collection of representative ground-water samples. Drilling fluids (including air) should be used only when minimal impact to the surrounding formation and ground water can be ensured.

The following guidelines apply to the use of

Monitoring Well Design

Well Casing and Screen Materials

A casing and well screen are installed in a ground-water monitoring well for several reasons: to provide access from the surface of the ground to some point in the

and to prevent hydraulic communicatiosu

due to suspension in the borehole, grouting, development, purging, pumping, and sampling and forces exerted on them by the surrounding geologic materials.

- Monitoring well casing and screen materials should not chemically alter ground-water samples, especially with respect to the analytes of concern, as a result of their sorbing, desorbing, or leaching analytes. For example, if chromium is an analyte of interest, the well casing or screen should not increase or decrease the amount of chromium in the ground water. Any material leaching from the casing or screen should not be an analyte of interest or interfere in the analysis of an analyte of interest.

In addition, monitoring well casing and screen materials should be relatively easy to install into the borehole during construction of the monitoring well.

The selection of the most suitable well casing and screen materials should consider site-specific factors, including:

- Depth to the water-bearing zone(s) to be monitored and the anticipated well depth

- Geologic environment

- Geochemistry of soil, unconsolidated material, and rock over the entire interval in which the well is to be cased

- Geochemistry of the ground water at the site, as determined through an initial analysis of samples from both background wells and downgradient wells and including:

  - Natural ground-water geochemistry

  - Nature of suspected or known contaminants

  - Concentration of suspected or known contaminants

- Design life of the monitoring well.

Casing materials widely available for use in ground-water monitoring wells can be divided into three categories:

1) <u>Fluoropolymer materials</u>, including polytetrafluoroethylene (PTFE), tetrafluoroethylene (TFE), fluorinated ethylene propylene (FEP), perfluoroalkoxy (PFA), and polyvinylidene fluoride (PVDF)

2) <u>Metallic materials</u>, including carbon steel, low-carbon steel, galvanized steel, and stainless steel (304 and 316)

3) <u>Thermoplastic materials</u>, including polyvinyl chloride (PVC) and acrylonitrile butadiene styrene (ABS).

In addition to these three categories of materials, fiberglass-reinforced plastic (FRP) has been used for monitoring applications. Because FRP has not yet been used in general application across the country, very little data are available on its characteristics and performance. All well construction materials possess strength-related characteristics and chemical resistance/chemical interference characteristics that influence their performance in site-specific hydrogeologic and contaminant-related monitoring situations.

The casing must be made of a material strong enough to last for the life of the well. Tensile strength is needed primarily during well installation when the casing is lowered into the hole. The joint strength will determine the maximum length of a section that can be suspended from tsc640 [illegible]

selecting monitoring well materials. Metallic casing materials are more subject

materials are more susceptible to chemical degradation. The geochemistry of the formation water influences the degree to which these processes occur. If ground-water chemistry affects the structural integrity of the casing, then the samples [illegible] components should not be used unless an elec

threaded joints should be used on

that should be used to clean casing and screen materials.

because the owner/operator will need to

of the 50 percent retained size of the formation material (USEPA, 1990).

Filter pack material should be installed in a manner that prevents bridging and particle-size segregation. Filter pack material installed below the water table should generally be tremied into the annular space. Allowing filter pack material to fall by gravity (free fall) into the annular space is only appropriate when wells are relatively shallow, when the filter pack has a uniform grain size, and when the filter pack material can be poured continuously into the well without stopping.

operators should remember that the entire length of the annular space filled with filter

monitored zone. Moreover, if the filter pack/sand extends from the screened zone into an overlying zone, a conduit for hydraulic connection is created between the two zones.

Annular Sealants

Proper sealing of the annular space between the well casing and the borehole wall is required to prevent contamination of samples and the ground water. Adequate

w1c9r At9841ba.11TD -0.0089 C70Tj -462.3812.2440arequired

A locking protective casing should be installed around the well casing to prevent damage or unauthorized entry. The protective casing should be anchored below the frost line (where applicable) into the surface seal and extend at least 18 inches above the surface of the ground. A 1/4-inch

unavoidable, such as in active roadways, a protective structure, such as a utility vault or meter box, should be installed around the well casing. In addition, measures should be taken to prevent the accumulation of surface water in the protective structure and around the well intake. These measures unless changes in ground-water flow patterns/direction, or damage caused by freeze/thaw or desiccation processes, are noted. In such cases, the Regional Administrator may require that well casings

When development is initiated, a wide range of grain sizes of the natural material is drawn into the well, and the well typically produces very turbid water. However, as development continues and the natural

incorrect determination of ground-water flow direction.

Background ground-water quality must be established at all upgradient or background wells. The background water quality may be determined from wells that are not upgradient of the MSWLF unit, provided that the wells yield representative ground-water samples.

The sampling program must be designed in consideration of the anticipated statistical

- Chain of custody control

The ground-water monitoring program must be documented in the operating record of the facility.

The objectives of the monitoring program should clearly define the quality of the data

ground-water chemistry due to the operation monitoring). (See the discussion under Section 5.10.3 on collecting independent samples to determine background.) More frequent sampling may be selected. For example, quarterly sampling may be conducted to evaluate seasonal effects on ground-water quality.

The frequency of sample collection during assessment monitoring activities will depend on site-specific hydrogeologic conditions and contaminant properties. The frequency of sampling is intended to obtain a data set that is statistically independent of the previous set. Guidance to estimate this

Measurements of the static water level and the depth to the well bottom can be made with a wetted steel tape. Electronic water level measuring devices may also be used. Accepted standard operating procedures call for the static water level to be accurately measured to within 0.01 foot (USEPA,

be made at all monitoring wells and well clusters in a time frame that avoids changes that may occur as a result of barometric pressure changes, significant infiltration events, or aquifer pumping. To prevent possible cross contamination of wells, water level measurement devices mustade atbec 9.49 Tc 98t 0

If a bailer must be used to sample the well, the well should be purged by placing the pump intake immediately below the air/water interface. This will ensure that all of the water in the casing and filter pack is purged, and it will minimize the possibility of mixing and/or sampling stagnant water when the bailer is lowered down into the well and subsequently retrieved (Keeley and Boateng, 1987). Similarly, purging should be performed at the air/water interface if sampling is not performed immediately after the well is purged without removing the pump.

decontaminated prior to use. If the purged

opportunity to exchan

STEP	PROCEDURE	ESSENTIAL ELEMENTS
Well Inspection	Hydrologic Measurements	Water Level Measurements
	↓	
Well Purging	Removal or Isolation of Stagnant Water	Representative Water Access
	↓	
	Determination of Well-Purging Parameters (pH, Eh, -π, Ω)*	Verification of Representative Water Sample Access

Sample Containers

To avoid altering sample quality, the samples should be transferred from the sampling equipment directly into a prepared container. Proper sample containers for each constituent or group of constituents are identified in SW-846 (USEPA, 1986b). Samples should never be composited in a common container in the field and then split. Sample containers should be cleaned in a manner that is appropriate for the constituents to be analyzed. Cleaning procedures are provided by USEPA (ol06ubble

maintains sample quality. Samples should

they are collected. These conditions should be maintained until the samples are received at the laboratory. Sample containers generally are packed in picnic coolers or special containers for shipment.

Polystyrene foam, vermiculite, and "bubble pack" are frequently used to pack sample containers to prevent breakage. Ice is placed in sealed plastic bags and added to the cooler. All related paperwork is sealed in a plastic bag and taped to the inside top of planning and sampling activities is

- Internal

- Internal temperature of field and shipping containers.

Sample Analysis Request Sheet

A sample analysis request sheet should accompany the sample(s) to the laboratory and clearly identify which sample containers have been designated for each requested parameter and the preservation methods used. The record should include the following types of information:

- Name of person receiving the sample
- Laboratory sample number (if different from field number)
- Date of sample receipt
- Analyses to be performed (including desired analytical method)
- Information that may be useful to the laboratory (e.g., type and quantity of preservatives added, unusual conditions).

Laboratory Records

Once the sample has been received in the laboratory, the sample custodian and/or laboratory personnel should clearly document the processing steps that are applied to the sample. All sample preparation (e.g., extraction) an
apap

ground-water samples analyzed. The

results, the owner/operator should resample the ground water. The owner/operator should prepare the QC samples as recommended in Chapter One of SW-846 and at the frequency recommended by Chapter One of SW-846 and should analyze them for all of the required monitoring parameters. Other QA/QC practices, such as sampling equipment calibration, equipment decontamination procedures, and chain-of-custody procedures, are discussed in other sections of this chapter and should be described in the owner/operator's QAPjP.

Validation

The analytical data report provided by the laboratory will present all data measured by the laboratory but will not adjust those data for field or laboratory quality control indicators. This means that just because data have been reported, they are not necessarily an accurate representation of the quality of the ground water. For example, acetone and methylene chloride are often used in laboratories as cleaning and extraction solvents and, consequently, are

Equipment rinsate samples are used to assess the efficacy of sampling equipment decontamination procedures. The data validation process uses the results from all of these QC samples to determine if the reported analytical data accurately describe the samples. All reported data must be evaluated -- a reported value of "non-detect" is a quantitative report just like a numerical value and must be validated.

The data validation process must also consider the presence and quality of other

(e.g., calibration frequency and descriptors,

criteria for data quality are described in the quality assurance project plan (QAPjP) or sampling and analysis plan (SAP). These documents may reference criteria from some other source, (e.g., the USEPA Contract Laboratory Program). The performance criteria must be correctly specified and must be used for data validation. It is a waste of time and money to evaluate data against standards other than those used to generate them.

this validation should be the classification of data as acceptable or unacceptable <u>for the purposes of the project</u>. In some cases, data may be further qualified, based either on insufficient data or marginal performance (i.e., qualitative uses only, estimated concentration, etc.).

Documentation

The ground-water monitoring program required by §258.50 through §258.55 relies on documentation to demonstrate compliance. The operating record of the MSWLF should include a complete description of the program as well as periodic implementation reports.

At a minimum, the following aspects of the ground-water monitoring program should be described or included in the operating record:

- The Sampling and Analysis plan that details sample parameters, sampling frequency, sample collection, preservation, and analytical methods to be used, shipping procedures, and chain-of-custody procedures;

- The Quality Assurance Project Plan (QAPjP) and Data Quality Objectives (DQOs);

- The locations of monitoring wells;

- The design, installation, development, and decommission of monitoring wells, piezometers, and other measurement, sampling, and analytical devices;

- Site hydrogeology;

- Statistical methods to be used to evaluate ground-water monitoring data and demonstrate compliance with the performance standard;

- Approved demonstration that monitoring requirements are suspended (if applicable);

- Boring logs;

- Piezometer and well construction logs for the ground-water monitoring system.

5.9 STATISTICAL ANALYSIS 40 CFR §258.53 (g)-(i)

<u>5.9.1 Statement of Regulation</u>

(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 eac

N The followed by multipl comparisons procedures to identif e statistically significant evidence of contamination. The method mus

estimation and testing of the contrasts (2) If

(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.

5.9.2 Applicability

The statistical analysis requirements are applicable to all existing units, new units, and lateral expansions of existing units for which ground-water monitoring is required. The use of statistical procedures to evaluate monitoring data shall be used for the duration of the monitoring program, including the post-closure care period.

The owner or operator must indicate in the operating record the statistical method that will be used in the analysis of ground-water monitoring results. The data objectives of the monitoring, in terms of the number of samples collected and the frequency of collection, must be consistent with the statistical method selected.

Several options for analysis of ground-water data are provided in the criteria. Other methods e operatingroures to e825 that are protective of human health and the environment. Generally, this is meant to include

useful for selecting other methods (Dixon shall be protective of human health and the environment

4) The level of confidence and percentage of the population contained in an interval shall be protective of human health and the environment

5) The method must account for data below the limit of detection (less than the PQL) in T5a.17)(sur4 0T610 Ttig1ap192contained01Tj9ij59 0 Tc T0.97715 mannT3s (a (whole

Multiple Well Comparisons

downgradient combined) are screened in the same stratigraphic unit, then the appropriate statistical comparison method is a multiple well comparison using the ANOVA

procedure assumes that the data from each well group come from the same type (e.g.,

Individual Well Comparisons

When only two wells (e.g., a single background and a single compliance point well) are being compared, owners or operators should not perform the parametric or

monitoring data. Such data may be adjusted

degree of change over time. Guidance for and limitations of intra-well comparison techniques are provided in USEPA (1989) and USEPA (1992b).

the heavy metals (constituents 1-15 in Appendix I), 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 background ground-water.

(b) The monitoring frequency for all constituents listed in Appendix I, or the alternative list approved in accordance with paragraph (a)(2), 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), 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), 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 or the alternative list approved in accordance with paragraph (a)(2), at any monitoring wellfac4012 0t 1ED 0.2566 Tc -0.1367rents

background

- A statistical error
- A sampling error.

The demonstration that one of these reasons is responsible for the statistically significant increase over background must be certified by a qualified ground-water scientist or approved by the Director of an approved State. If a successful demonstration is made and documented, the owner or operator may continue detection monitoring.

If a successful demonstration is not made within 90 days, the owner or operator must initiate an assessment monitoring program. A flow chart for a detection monitoring program in a State whose program has not been approved by EPA is provided in Figure 5-5.

5.10.3 Technical Considerations

If there is a statistically significant increase over background during detection monitoring for one or more constituents listed in Appendix I of Part 258 (or an alternative list of parameters in an approved State), the owner or operator is required to begin assessment monitoring. The requirement to conduct assessment monitoring will not change, even if the Director of an approved State allows the monitoring of geochemical parameters in lieu of some or all of the metals listed in Appendix I. If an owner or operator suspects that a statistically significant increase in a geochemical parameter is caused by natural variation in ground-water quality or a source other than a MSWLF unit, a demonstration to this effect must be documented in a report to avoid proceeding to assessment monitoring.

Independent Sampling for Background

The ground-water monitoring requirements specify
collected from each well to establish background during the first semiannual monitoring event. This is because almost all statistical procedures are based on the assumption that samples are independent of each other. In other words, independent samples more accurately reflect the true range of natural variability in the ground

independent samples are more accurate. Replicate samples, whether field replicates or lab splits, are not statistically independent measurements.

It may be necessary to gather the independent samples over a range of time

differences. If seasonal differences are not

positives increases (monitoring results indicate a release, when a release has not occurred). The sampling interval chosen must ensure that sampling is being done on different volumes of ground water. To determine the appropriate interval between sample collection events that will ensure independence, the owner or operator can determine the site's effective porosity, hydraulic conductivity, and hydraulic gradient and use this information to calculate ground-water velocity (USEPA, 1989). Knowing the velocity of the ground water should enable an owner/operator to establish an interval that ensures the four samples are being collected from four different volumes of water. For additional information on establishing sampling interval, see *Statistical Analysis of Groundwater Monitoring Data at RCRA*

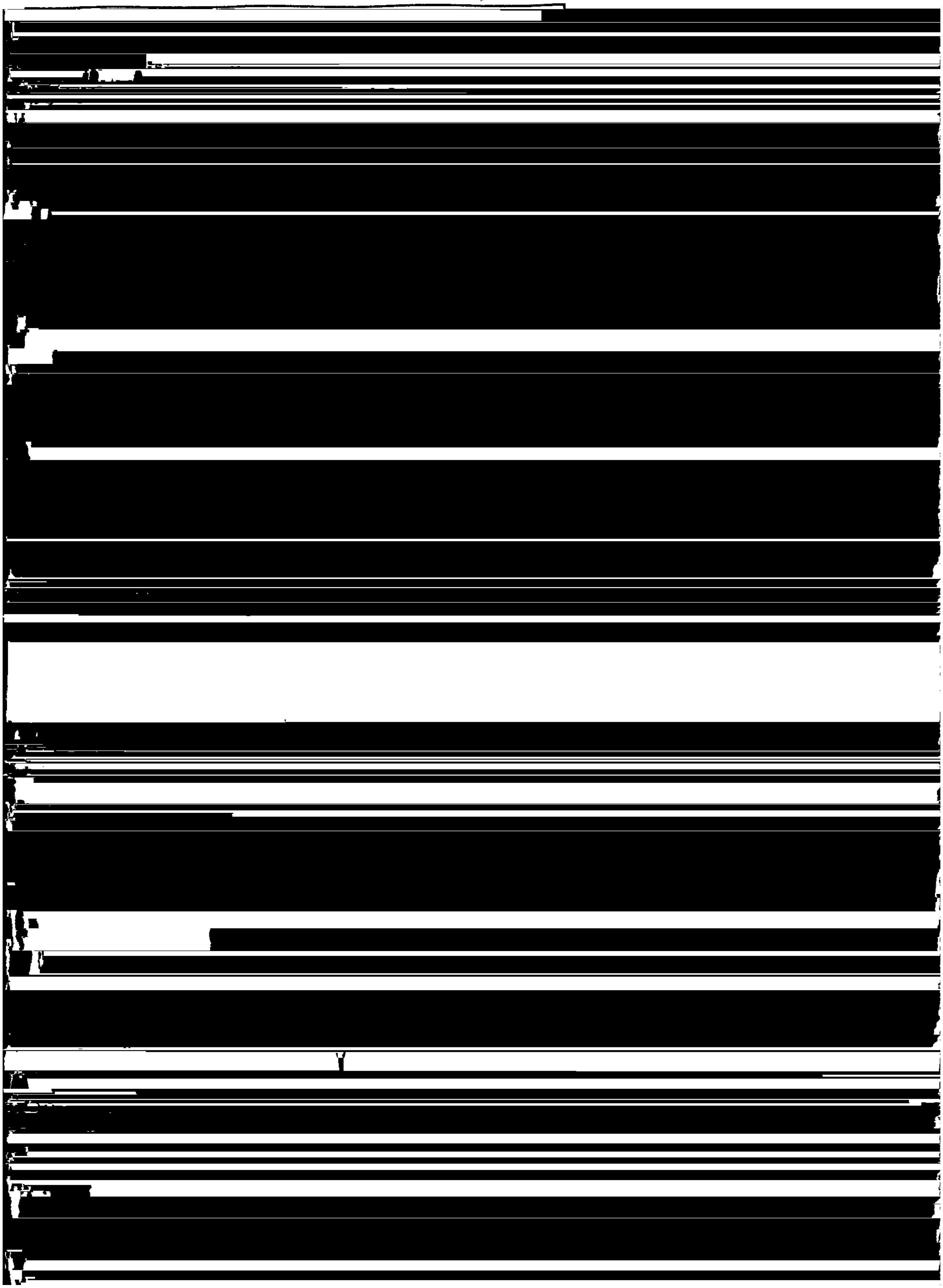


Figure 5-5. Detection Monitoring Program

Facilities - Interim Final Guidance, (USEPA, 1989).

Alternative List/Removal of Parameters

An alternative list of Appendix I

constituents from Appendix I may be acceptable. Usually, a waste would have to to

determination. The owner or operator may

presence or absence of certain constituent

2) Hydraulic conductivity of the aquifer

2) A comprehensive audit of sampling

(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

I to this Part or in the alternative list approved in accordance with §258.54(a)(2), and for those constituents in Appendix II 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

analyzed during these sampling events. The Director of an approved State may

frequency during the active life (including closure) and the post closure

this paragraph. The alternative

the alternate list approved in accordance

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.

5.11.2 Applicability

Assessment monitoring is required at all existing units, lateral expansions, and new facilities whenever any of the constituents listed in Appendix I are detected at a concentration that is a statistically significant increase over background values. Figure 5-6 presents a flow chart pertaining to applicability requirements.

Within 90 days of beginning assessment monitoring, the owner or operator must resample all downgradient wells and analyze the samples for all Appendix II constituents. If any new constituents are identified in this process, four independent samples must be collected from all upgradient and downgradient wells and analyzed for those new constituents to establish background concentrations. The complete list of Appendix II constituents must be monitored in each well annually for the duration of the assessment monitoring program. In an approved State, the Director may reduce the number of Appendix II constituents to be analyzed if it can be reasonably sh5 (ma)

may specify an appropriate subset of wells to be included in the assessment monitoring

also may specify an alternative frequency for repeated sampling and analysis of Appendix II constituents. This frequency may be decreased or increased based upon consideration of the factors in §258.55(c)(1)-(6). These options for assessment monitoring programs are available only with the approval of the Director of an approved State.

the initial sampling for Appendix II

the owner or operator must place the results in the operating record and notify the State Director that this notice has been placed in the operating record.

Within 90 days of receiving these initial results, the owner or operator must resample all wells for all Appendix I and detected

list of constituents must be sampled at least semiannually thereafter, and the list must be updated annually to include any newly detected Appendix II constituents.

Within the 90-day period, the owner or operator must establish background values and ground-water protection standards (GWPSs) for all Appendix II constituents detected. The requirements for determining GWPSs are provided in §258.55(h). If the concentrations of all Appendix II constituents are at or below the background values after two independent, consecutive sampling events, the owner or operator may return to detection monitoring after

sampling events, any detected Appendix II constituent is statistically above background but below the GWPSs, the assessment monitoring program must be continued.

5.11.3 Technical Considerations

The purpose of assessment monitoring is to evaluate the nature and extent of contamination. The assessment monitoring

the owner or operator must collect at least one sample from each downgradient well and analyze the samples for the Appendix II parameters. If a downgradient well has

constituent, four independent samples must

downgradient wells to establish background for the new constituent(s). The date, well locations, parametersTc 0 Tw dient w8. us2Is4.149314

2) Hydraulic conductivity of the aquifer and unsaturated zone;

3) Ground-water flow rates;

4) Minimum distance of travel (between the MSWLF unit edge to downgradient monitoring wells); and

5) Nature (fate and transport) of the detected constituents.

The Director of an approved State also may allow an alternate frequency, other than semiannual, for the monitoring of Appendix I and detected Appendix II constituents.

The monitoring frequency must be sufficient to allow detection of ground-water contamination. If contamination is detected early, the volume of ground water contaminated will be smaller and the required remedial response will be less burdensome. Additional information on the alternate frequency can be found in Section 5.10.3.

In an approved State, the Director may specify a subset of wells that can be monitored for Appendix II constituents to confirm a release and track the plume of contamination during assessment monitoring. The owner or operator should work closely with the State in developing a monitoring plan that targets the specific areas of concern, if possible. This may represent a substantial cost savings, especially at large facilities for which only a very small percentage of wells showed exceedances above background. The use of a subset of wells likely will be feasible only in cases where the direction and rate of flow are relatively constant.

5.12 ASSESSMENT MONITORING PROGRAM 40 CFR §258.55(g)

5.12.1 Statement of Regulation

(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);

(ii4 Tc 0.TD 0. Tj 1.otice ha

(2) May demonstrate that a sourc

Release Investigation

If the GWPS is exceeded, a series of actions must be taken. These actions are described in the next several paragraphs. The owner or operator must investigate the extent of the release by installing additional monitoring wells and obtaining additional ground-water samples. The investigation should identify plume geometry, both laterally and vertically. Prior to such field activities, records of site operation and

semiannually or at an alternative frequency

State. The initial sample must be analyzed for all Appendix II constituents.

Notification of Adjoining Residents and Property Owners

If ground-water monitoring indicates that contamination has migrated offsite, the owner or operator must notify property owners (-sdd5-Up_Line<</B 620.1828 /J 1 >>)98 0

Return to Detection Monitoring

A facility conducting assessment monitoring may return to detection monitoring if the concentrations of all Appendix II constituents are at or below backgroun

(3) For constituents for which the

identified under subparagraph (1) above or health based levels identified under §258.55(i)(1), the background

the ground water, the complexity of the site hydrogeology, and the facility's proximity to sensitive receptors. Corrective measures are generally approached from two directions: 1) identify and remediate the source of contamination and 2) identify and remediate the known contamination. Because each case will be site-specific, the owner or operator should be prepared to document that, to the best of his or her technical and financial abilities, a diligent effort has been made to complete the assessment in the shortest time practicable.

The factors listed in §258.56(c)(1) must be considered in assessing corrective measures. These general factors are discussed below in terms of source evaluation, plume delineation, ground-water assessment, and corrective measures assessment.

Source Evaluation

As part of the assessment of corrective measures, the owner or operator will need to identify the nature of the source of the release. The first step in this identification is a review of all available site information regarding facility design, wastes received, and onsite management practices. For newer facilities, this may be a relatively simple task. However, at some older facilities, detailed records of the facility's (e.g., unlined leachate storage ponds, failed cover system, leaky leachate transport pipes, past conditions of contaminated storm overflow), such information should be considered as part of the assessment of corrective measures.

Existing site geology and hydrogeology information, ground-water monitoring results, and topographic and cultural information must be documented clearly and accurately. This information may include soil boring logs, test pit and monitoring well

data, and other information collected during facility design or operation. The information should be expressed in a manner that will aid interpretation of data. Such data may include isopach maps of the thickness of the upper aquifer and important

contaminants, flow nets, cross-sections, and

interpretation that may be useful in a source evaluation is presented in *RCRA Facility Investigation Guidance: Volume I - Development of an RFI Work Plan and General Considerations for RCRA Facility Investigations*, (USEPA 1989a), *RCRA Facility Investigation Guidance: Volume IV - Case Study Examples*, (USEPA 1989d), and *Practical Guide For Assessing and Remediating, Contaminated Sites* least one additional well must be added at the property boundary in the direction of contaminant migration to allow timely notification to potentially affected parties if contamination migrates offsite.

The following circumstances may require additional monitoring wells:

- Facilities that have not determined the horizontal and vertical extent of the contaminant plume
- Locations where the subsurface is heterogeneous or where ground-water flow patterns are difficult to establish
- Mounding associated with MSWLF units.

Because the requirements for additional monitoring are site-specific, the regulation does not specifically establish cases where additional wells are necessary or establish the number of additional wells that must be installed.

During the plume delineation process, the owner or operator is not relieved from co

and effective porosity) should be developed for modeling contaminant transport if sufficient data are not available. Anisotropy and heterogeneity of the aquifer must be evaluated, as well as magnitude and

present and predicted plume configuration.

ground-water contamination at MSWLF units involve pump and treat or in-situ biological technologies (bio-remediation).

on the size of the plume, the pumping characteristics of the aquifer, and the chemical transport phenomena. Source

measures to reduce the rate of contaminant migration should be included in the costs of

water modeling of the plume may be initiated to establish the following:

- The locations and pumping rates of withdrawal and/or injection wells

concentrations at exposure points

which affect the accuracy of the model. These assumptions include boundary conditions, the degree and spatial variability of anisotropy, dispersivity, effective porosity, stratigraphy, and the algorithms used to solve contaminant transport equations. Model selection should be appropriate for the amount of data available, and the technical uncertainty of the model results must be documented by a sensitivity analysis on the input parameters. A sensitivity analysis is generally done after model calibration by varying one input parametert be do .5577 0 TD 0 Tc 11Tc 027177 0 078water arilllly done afincludicah8.0484 79 9/3och BTo Tc

- Stratigraphy and hydraulic properties of the aquifer

- Treatment concentration goals and objectives.

The owner or operator should consider whether immediate measures to limit further plume migration (e.g., containment options) or measures to minimize further introduction of contaminants to ground water are necessary.

- Bench-scale treatability studies conducted to assess potential effectiveness of options
- Selection of technology(ies) and proposal preparation for regulatory and public review and comment
- Full-scale pilot study for verification of treatability and optimization of the selected technology
- Initiation of full-scale treatment technology with adjustments, as necessary
- Continuation of remedial action until treatment goals are achieved.

Corrective Measures Assessment

To compare different treatment options, substantial amounts of technical information must be assembled and assessed. The objective of this information-gathering task is to identify the following items for each treatment technology:

- The expected performance of individual approaches
- The time frame when individual approaches can realistically be implemented
- The technical feasibility of the remediation, including new and innovative technologies, performance, reliability and ease of implementation, safety and cross media impacts
- The anticipated time frame when remediation should be complete
- The anticipated cost of the remediation, including capital expenditures, design, ongoing engineering, and monitoring of results
- Technical and financial capability of the owner or operator to successfully complete the remediation
- Disposal requirements for treatment residuals
- Other regulatory or institutional requirements, including State and local permits, prohibitions, or environmental restrictions that may affect the implementation of the proposed remedial activity.

The performance objectives of the corrective measures should be considered in terms of source reduction, cleanup goals, and cleanup time frame. Source reduction would include measures to reduce or stop further releases and may include the repair of existing facility components (liner systems, leachate storage pond liners, piping systems, cover systems), upgrading of components (liners and cover systems), or premature closure in extreme cases. The technology proposed as a cleanup measure should be the best available technology, given the practicable capability of the owner or operator.

The technologies identified should be reliable, based on their previous performance; however, new innovative technologies are not discouraged if they can be shown, with a reasonable degree of confidence, to be reliable.

Because most treatment processes, including biorestoration,te (prem) Tj 26.6343 0 r5 0iTj 24.2348 -0.

different media (e.g., air stripping of volatile compounds), the impacts of such potential releases must be evaluated. Releases to air may constitute a worker health and safety concern and must be addressed as part of the alternatives assessment process. Other cross media impacts, including transfer of contaminants from soils to ground water, surface water, or air, should be assessed and addressed in the assessment of corrective actions. Guidance for addressing air and soil transport and contamination is provided in USEPA (1989b) and USEPA (1989c).

Analyses should be conducted on treatment options to determine whether or not they are protective of human health and the environment. Environmental monitoring of exposure routes (air and water) may necessitate health monitoring for personnel involved in treatment activities if unacceptable levels$_h$ of exposure are possible.

of a qualified professional and will

- Low transmissivity and low future user demand.

Often, it may be advantageous for the owner or operator to consider implementing

- Preventing additional leachate generation that may reach a liner failure

shelter during operations or capping

(i) Magnitude of reduction of existing risks;

(ii) MagnitudeMag

(ii) The extent to which treatment technologies may be used.

5.16.3 Technical Considerations

The owner or operator must consider specific topics to satisfy the performance criteria under selection of the fina

releases of contaminants to the environment,

remedy to meet or exceed the GWPSs. The owner or operator must make a reasonable

Effectiveness of Source Reduction

Source control measures identified in previous sections should be discussed in terms of their expected effectiveness. If source control consists of the removal and re-disposal of wastes, the residual materials, such as contaminated soils above the water table, should be quantified and their potential to cause further contamination evaluated. Engineering controls intended to upgrade or repair deficient conditions in landfill component systems, including cover systems, should be quantified in terms of anticipated effectiveness according to current and future conditions. This assessment may indicate to what extent it is technically and financially practicable to make use of existing technologies. The decision against using a certain technology may be based on health considerations and the potential for unacceptable exposure(s) to both workers and the public.

Implementation of Remedial Action

The ease of implementing the proposed remedial action will affect the schedule and startup success of the remedial action. The following key factors need to be assessed:

- The availability of technical expertise

- Construction of equipment or technology

-

Technical considerations, including pH

or the ability to inject nutrients, may need to be considered, depending on the proposed treatment method. Potential impacts, such as potential cross-media contamination, need to be reviewed as part of the overall feasibility of the project.

The schedule of remedial activities should identify the start and end points of the following periods:

- Permitting phase

- Construction and startup period, during which initial implementation success will be evaluated, including time to correct any unexpected problems

- Time when full-scale treatment will be initiated and duration of treatment period

source control measures, including the

associated
with interim management and disposal of waste materials or treatment residuals.

identified early in the process and those

implementation occurs in the shortest practicable period.

p

5.17.2 Applicability a

In setting the implementation schedule, the owner or operator should assess the risk to human health and the environment within the timeframe of reaching treatment objectives. If the risk is unacceptable, considering health-based assessments of exposure paths and exposure limits, the implementation time schedule must be accelerated or the selected remedy altered to provide an acceptable risk level in a timely manner.

Establishment of the schedule also may include consideration of the resource value of the aquifer, as it pertains to current and future use, proximity to users, quality and quantity of ground water, agricultural value and uses (irrigation water source or impact on adjacent agricultural lands), and the availability of alternative supplies of water of similar quantity and quality. Based on these factors, a relative assessment of the aquifer's resource value to the local community can be established. Impacts to the resource and the degree of financial or health-related distress by users should be considered. The implementation timeframe should attempt to minimize the loss of value of the resource to users. The possibility that alternative water supplies will have to be developed as part of the remedial activities may need to be considered.

Because owners or operators may not be knowledgeable in remediation activities, reliance on the owner or operator to devise the schedule for remediation may be

5.18 SELECTION OF REMEDY 40 CFR §258.57 (e)-(f)

5.18.1 Statement of Regulation

(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 an

(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 potential source of drinking water; and

(ii) Is not hydraulically connected with waters to which the hazardous

migrate in a concentration(s) that would exceed the ground-water protection standards established under §258.55(h)
s

(f) A determination by the Director of an approved State pursuant to paragraph (e) above shall not affect the authority of

from implementing some or all of the corrective measure requirements. The owner (e.g., movement in response to ground-water pumping or release of volatile organics to the atmosphere) and that the no aa

(iii) Demonstrates compliance with ground-water protection standard pursuant to paragraph (e) of this section.

(vii) Other situations that may pose threats to human health and the environment.

<u>5.19.2 Applicability</u>

These provisions apply to facilities that are required to initiate and complete corrective actions.

The owner or operator is required to continue to implement its ground water assessment monitoring program to evaluate the effectiveness of remedial actions and to demonstrate that the remedial objectives have been attained at the completion of remedial activities.

Additionally, the owner or operator must take any interim actions to protect human health and the environment. The interim measures must serve to mitigate actual threats

ground water degradation or the spread of the contaminant plume, replacement of the system with an alternative measure may be

condition of the aquifer must be monitored

may be necessary to install additional monitoring wells to more clearly evaluate remediation progress. Also, if it becomes

achievable technically, in a realistic time-frame, the performance objectives of the corrective measure must be reviewed and amended as necessary.

Interim Measures

health and the environment exist prior to or during implementation of the corrective action, the owner or operator is required to take interim measures to protect receptors.

5.20 IMPLEMENTATION OF THE CORRECTIVE ACTION PROGRAM 40 CFR §258.58 (b)-(d)

5.20.1 Statement of Regulation

(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

equipment, units, devices, or structures that are:

(i) Technically practicable; and

(ii) Consistent with the overall

(4) Notify the State Director within 14 days that a report justifying the alternative measures prior to implementing the alternative measure [illegible] contamination and to control the sources of contamination. Prior to implementing alternative measures, the owner or operator must notify the Director of an approved State within 14 days that a report justifying the alternative measures has been placed in the operating record.

All wastes that are manage

- Inappropriately applied technology

5.21 IMPLEMENTATION OF THE CORRECTIVE ACTION PROGRAM 40 CFR §258.58 (e)-(g)

5.21.1 Statement of Regulation

(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

(iii) Accuracy of monitoring or modeling techniques, including any seasonal, meteorological, or other environmental variabilities that may

water.

(3) All actions required to complete the

(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

Appendix II constituent concentrations are below the GWPSs. Upon completion of all remedial actions, the owner or operator must certify to such, at which point the owner or operator is released from financial assurance requirements.

5.21.3 Technical Considerations

The regulatory period of compliance is 3 consecutive years at all points within the contaminant plume that lie beyond the ground-water monitoring system unless the Director of an approved State specifies an alternative length of time. Compliance is achieved when the concentrations of Appendix II constituents do not exceed the GWPSs for a predetermined length of time.

State. Upon completion of the remedial action, in accordance with §258.58(e), the owner or operator is released from the financial assurance requirements pertaining to corrective actions.

require an alternate time period (other than

determining an alternate period the Director must consider the following:

- The extent and concentration of the release(s)

- The behavior characteristics (fate and transport) of the hazardous constituents in the ground water (e.g., mobility,

5.22 FURTHER INFORMATION

5.22.1 References

Aitchison, J., and J.A.C. Brown (1969). "The Lognormal Distribution"; Cambridge University Press; Cambridge.

American Water Works Association (1984). "Abandonment of Test Holes, Partially Completed Wells and Completed Wells." Appendix I. American Water Works Association Standard for Water Wells, American Water Works Association, Denver, CO, pp 45-47.

Barari, A., and L.S. Hedges (1985). "Movement of Water in Glacial Till." Proceedings of the 17th International Congress of International Association of Hydrogeologists.

Barcelona, M.J., J.A. Helfrich and E.E. Garske, (1985). "Sampling Tube Effects on Groundwater Samples"; Analytical Chemistry 47(2): 460-464.

Barcelona, M.J., J.P. Gibb, J.A. Helfrich, and E.E. Garske, (1985b). "Practical Guide for Ground-Water Sampling," USEPA, Cooperative Agreement #CR-809966-01, EPA/600/2-85/104, 169 pp.

Barcelona, M.J., et al. 1990. Contamination of Ground Water: Prevention, Assessment, Restoration. Pollution Technology Review No. 184, Noyes Data Corporation, Park Ridge, NJ, 213 pp.

Cantor, L.W., R.C. Knox, and D.M. Fairchild (1987). Ground-Water Quality Protection. Lewis Publishers, Inc., Chelsea, MI.

Cooper, H.H., Jr., and C.E. Jacob (1946). "A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well-Field History." American Geophys. Union Trans., V. 27, No. 4.

Daniel, D.E., H.M. Liljestrand, G.P. Broderick, and J.J. Bounders, Jr. (1988). "Interaction of Earthen

Fetter, C.W., Jr. (1980). Applied Hydrogeology. Charles E. Merrill Publishing Co., Columbus, OH.

Freeze, R.A. and J.A. Cherry, (1979). Groundwater; Prentice-Hall, Inc.; Englewood Cliffs, New Jersey.

Gibbons, J.D., (1976). "Nonparametric Methods for Quantitative Analysis"; Holt, Rinehart, and Winston Publishing Co.; New York, New York.

Gilbert, R.O., (1987). Statistical Methods for Environmental Pollution Monitoring; Van Nostrand Reinhold Co.; New York, New York.

Heath, R.C. (1982). Basic Ground-Water Hydrology. U.S. Geological Survey Water Supply Paper 2220, 84 pp.

Hsieh, P.A., and S.P. Neuman (1985). "Field Determination of the Three - Dimensional Hydraulic Conductivity Teasor of Anisotropic Media." Water Resources Research, V. 21, No. 11.

Kearl, P.M., N.E. Korte, and T.A. Cronk. 1992. "Suggested Modifications to Ground Water Sampling Procedures Based on Observations from the Colloidal Borescope." Ground-Water Monitoring Review, Spring, pp. 155-160.

Kruseman, G.P., and N.A. de Ridder (1989). "Analysis and Evaluation of Pumping Test Data," International Institute for Land Reclamation and Improvement/ILRI, Bulletin II, 4th Edition.

Lamb, B. and T. Kinney (1989). "Decommissioning Wells - Techniques and Pitfalls." Proceedings of the Third National Outdoor Action Conference on Aquifer Restoration, Ground-Water Monitoring and Geophysical Methods, NWWA, May 22-25, 1989, pp 217-228.

McGlew, P.J. and J.E. Thomas (1984). "Determining Contaminant Migration Pathways in Fractured Bedrock." Proceedings of the Fifth National Conference on Management of Uncontrolled Hazardous Waste Sites.

McWhorter, D.B., and D.K. Sunada (1977). Ground-Water Hydrology and Hydraulics. Water Resources Publications, Fort Collins, CO.

Miller, J.C. and J.N. Miller, (1986). Statistics for Analytical Chemistry; John Wiley and Sons; New York, New York.

Molz, F.J., O. Guven and J.G. Melville (1990). "A New Approach and Methodologies for Characterizing the Hydrogeologic Properties of Aquifers." EPA Project Summary. EPA 600/52-90/002.

Molz, F.J., R.H. Norin, A.E. Hess, J.G. Melville, and O. Guven (1989) "The Impeller Meter for Measuring Aquifer Permeability Variations: Evaluation and Comparison with Other Tests." Water Resources Research, V 25, No. 7, pp 1677-1683.

Puls, R.W. and R.M. Powell. 1992. "Acquisition of Representative Ground Water Quality Samples for Metals." Ground-Water Monitoring Review, Summer, pp. 167-176.

Puls, R.W., R.M. Powell, D.A. Clark, and C.J. Paul. 1991. "Facilitated Transport of Inorganic Contaminants in Ground Water: Part II." Colloidal Transport, EPA/600/M-91/040, 12 pp.

Puls, R.W., and M.J. Barcelona. 1989a. "Filtration of Ground Water Samples for Metals Analysis." Hazardous Waste and Hazardous Materials, v. 6, No. 4.

Puls, R.W., and M.J. Barcelona. 1989b. "Ground Water Sampling for Metals Analysis." USEPA Superfund Ground Water Issue, EPA/504/4-89/001, 6 pp.

Sevee, J. (1991). "Methods and Procedures for Defining Aquifer Parameters," in D.M. Nielsen, ed., Practical Handbook of Ground-Water Monitoring. Lewis Publishers, Chelsea, MI.

USEPA (1975). Tc -6192 TjD 0.4931uwel CnstruActio (Practiesg) Tj ET1587.24 2648 2 28296 0.72 re f

U

USEPA, (1989). "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities-Interim Final Guidance"; EPA/530-SW-89-026; U.S. EP

USGS, (1989). "Chapter C2, Computer Model of Two-Dimensional Solute Transport and Dispersion in Groundwater"; L.F. Konikow and J.D. Bredehoeft; Book 7; U.S. Geological Survey; U.S. Department of Interior.

Way, S.C., and C.R. McKee (1982). "In-Situ Determination of Thre9Fee (1982).aquife r Permeabilities." Ground Water, V. 20, No. 5.

CHAPTER 6

SUBPART F
CLOSURE AND POST-CLOSURE

CHAPTER 6
SUBPART F

TABLE OF CONTENTS

(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.

6.2.2 Applicability

These final cover requirements apply to all MSWLF units required to close in accordance with Part 258, including MSWLF units that received wastes after October 9, 1991 but stopped receiving wastes prior to October 9, 1993. Units closing during this two-year period are required to install a final cover.

The final cover system required to close a MSWLF unit, whether the unit is an existing unit, a new unit, or a lateral expansion of an existing unit, must be composed of an infiltration layer that is a minimum of 18 inches thick, overlain by an erosion layer that is a minimum of 6 inches thick.

The final cover should minimize, over the long term, liquid infiltration into the waste. The final cover must have a hydraulic conductivity less than or equal to any bottom liner system or natural subsoils present to prevent a "bathtub" effect. In no case can the final cover have a hydraulic conductivity greater than 1×10^{-5} cm/sec regardless of the permeability of underlying liners or natural subsoils. If a synthetic membrane is in the bottom liner, there must be a flexible membrane liner (FML) in the final cover to achieve a permeability that is less than or equal to the permeability of the bottom liner. Currently, it is not possible to construct an earthen liner with a permeability less than or equal to a synthetic

In approved States, an alternate cover

long-term performance with minimal maintenance. Surface water run-off should be properly controlled to prevent excessive erosion and soil loss. Establishment of a healthy vegetative layer is key to protecting the cover from erosion. However, consideration also must 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. Figure 6-1 illustrates the minimum requirements for the final cover system.

Infiltration Layer

The infiltration layer must be at least 18 inches thick and consist of earthen material that has a hydraulic conductivity (coefficient of permeability) less than or equal to the hydraulic conductivity of any bottom liner system or natural subsoils. MSWLF units with poor or non-existent 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. Figure 6-2 presents an example of a final cover with a hydraulic conductivity less than or equal to the hydraulic conductivity of the bottom liner system.

For units that have a composite liner with a FML, or naturally occurring soils with very low permeability (e.g., 1 x 10

Figure 6-3a. Figure 6-3b shows a final cover system for a MSWLF unit that has both a double FML and double leachate collection system.

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 run-off 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.

Membrane and clay layers should be placed

penetration to avoid freeze-thaw effects (U.S. EPA, 1989b). Freeze-thaw effects may include development of microfractures or realignment of interstitial fines, which can increase the hydraulic conductivity of clays by more than an order of magnitude (U.S. EPA, 1990). Infiltration layers may be subject to desiccation, depending on climate and soil water retention in the erosion layer. Fracturing and volumetric shrinking of the clay due to water loss may increase the hydraulic conductivity of the infiltration layer. Figure 6-4 shows the regional average depth of frost penetration; however, these values should not be used to

for a particular area of concern at a particular site. Information regarding the

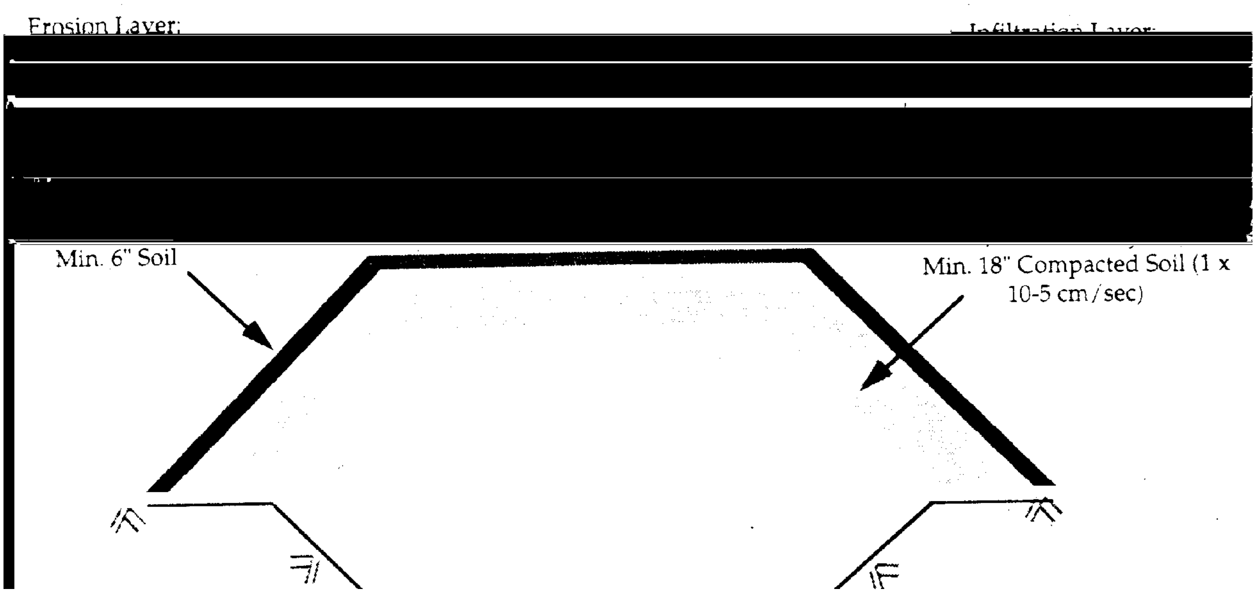


Figure 6-1
Example of Minimum Final Cover Requirements

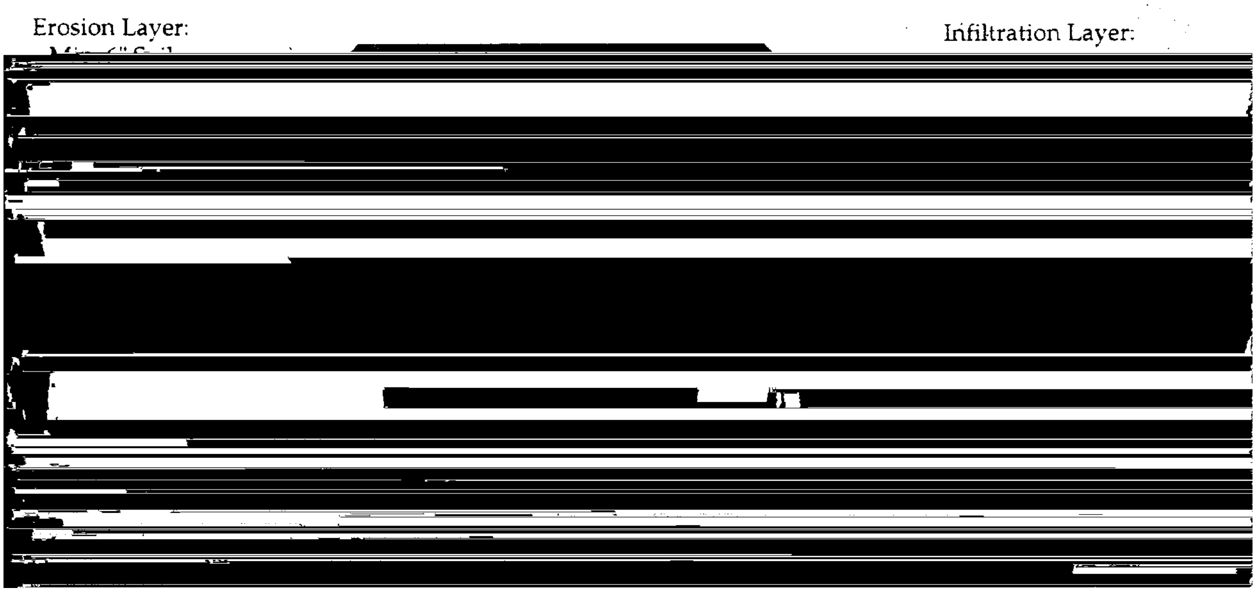


Figure 6-2
Example of Final Cover With Hydraulic Conductivity(K) ≤ K of Liner

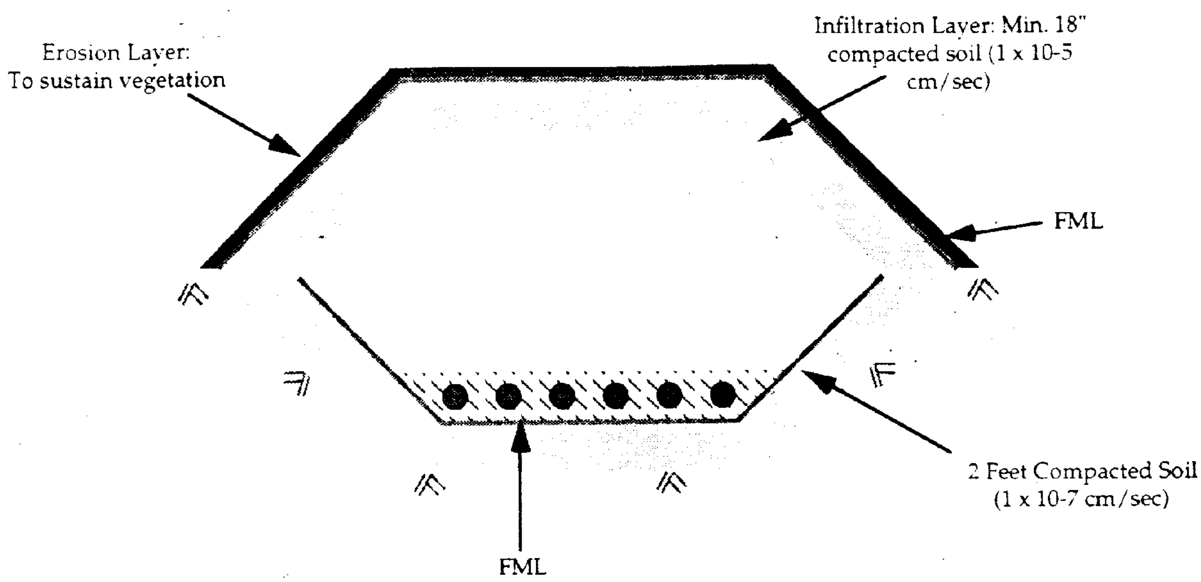


Figure 6-3a
Example of Final Cover Design for a MSWLF Unit With a FML and Leachate Collection System

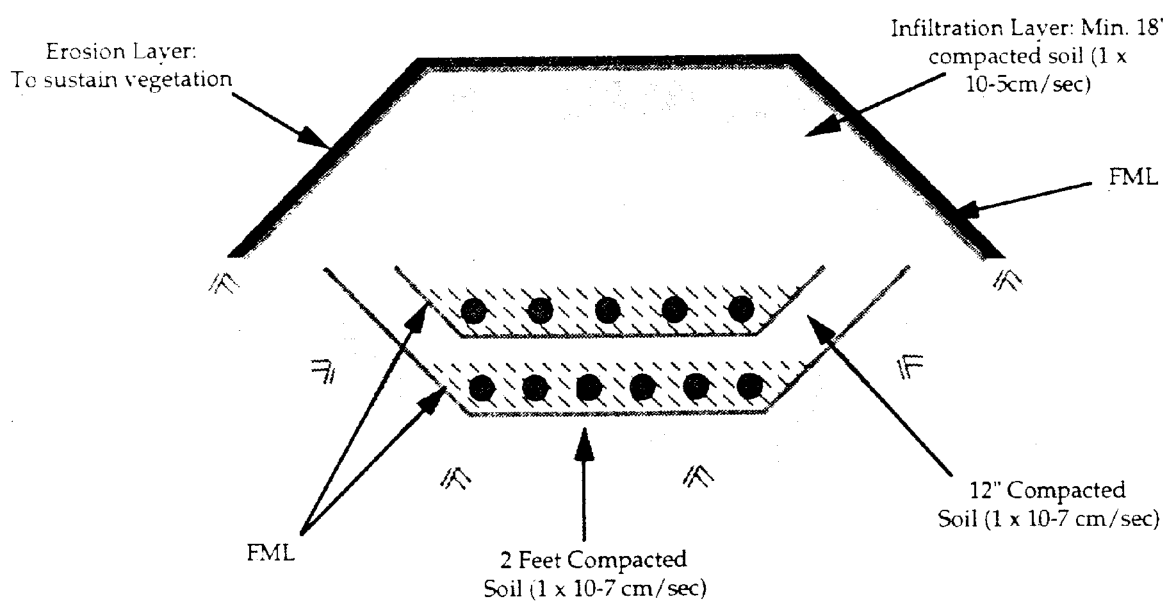


Figure 6-3b
Example of Final Cover Design for a MSWLF Unit With a Double FML and Leachate Collection System

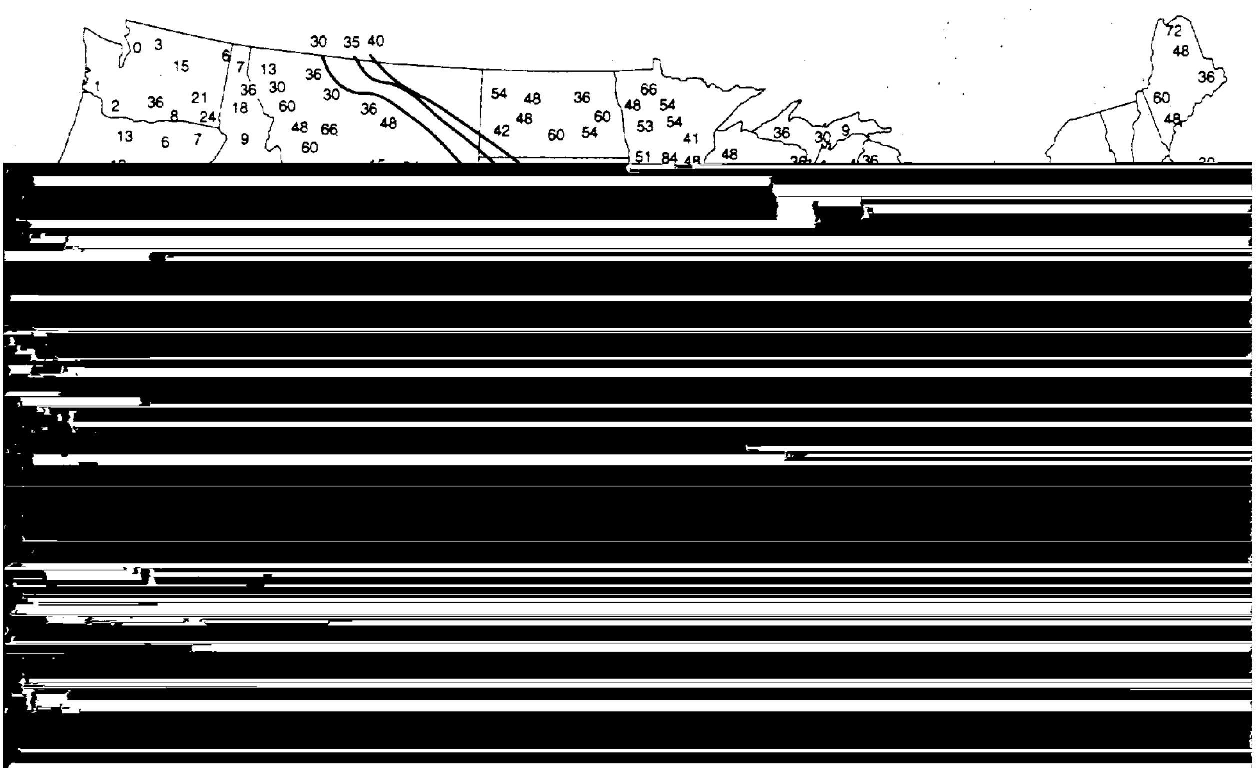


Figure 6-4
Regional Depth of Frost Penetration in Inches

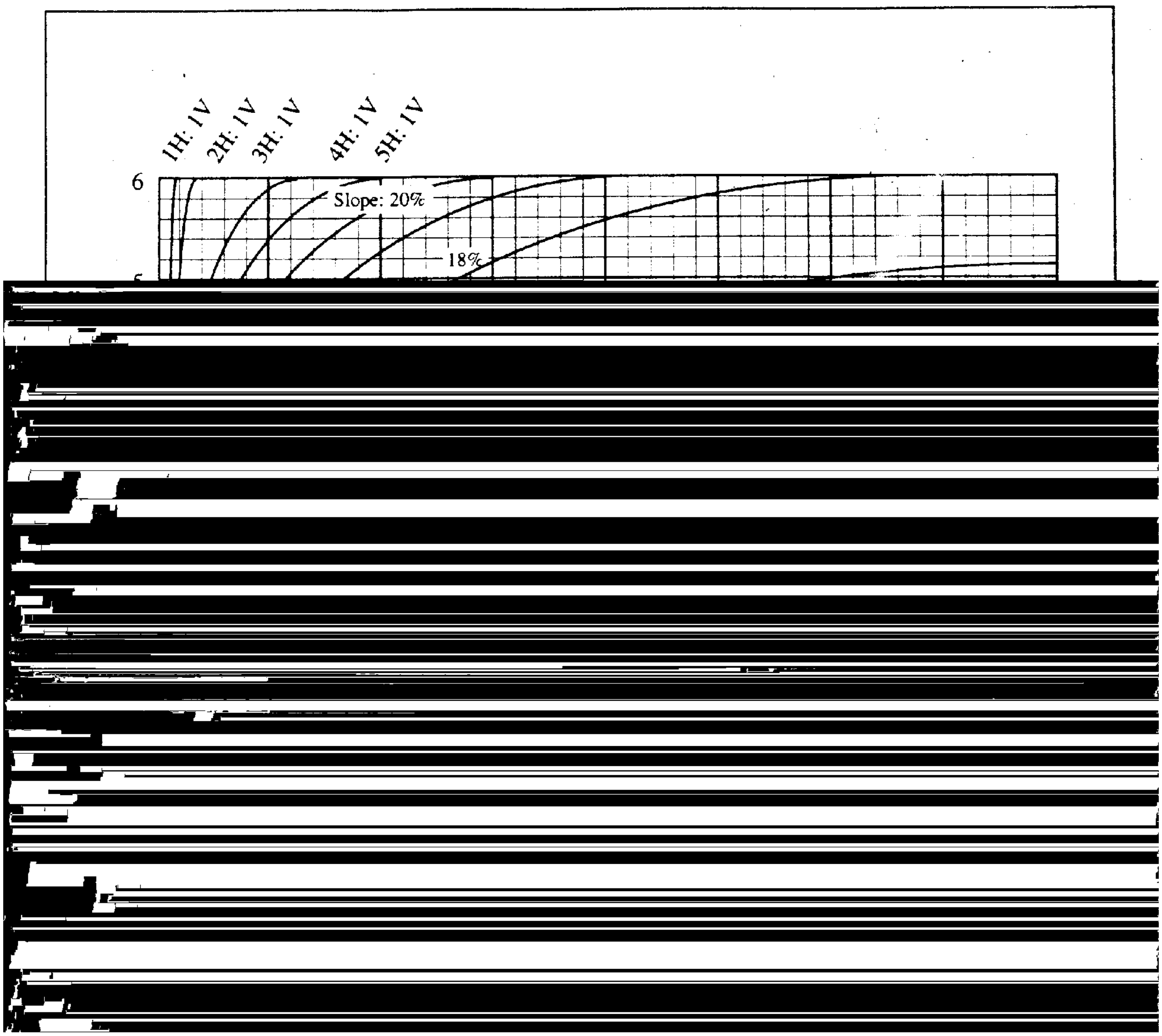


Figure 6-5
Soil Erosion Due to Slope

specifications and characteristics (U.S. EPA, 1989b):

- Locally adapted perennial plants that are resistant to drought and temperature extremes;
- Roots that will not disrupt the low-permeability layer;
- The ability to thrive in low-nutrient soil with minimum nutrient addition;
- Sufficient plant density to minimize cover soil erosion;
- The ability to survive and function with little or no maintenance (i.e., self-supportive); and
- Sufficient variety of plant species to continue to achieve these characteristics and specifications over time.

The use of deep-rooted shrubs and trees is generally inappropriate because the root systems may penetrate the infiltration layer and create preferential pathways of percolation. Plant species with fibrous or

Selection of the soil for the vegetative cover (erosion layer) should include consideration

species of the vegetation selected, mulching, and seeding time. Loamy soils with a sufficient organic content generally are

sand in loamy soils provides an environment conducive to seed germination and root

The Director of an approved State can allow

problems (e.g., the use of pavement or other material) in areas that are not capable of

6.3 ALTERNATIVE FINAL COVER

40 CFR §258.60(b)

6.3.1 Statement of Regulation

(b) The Director of an approved State may approve an alternative final cover design that includes:

(1) AnfSuff cover U.S.

{ 1 ¿ T D 0 . 1 j

the minimum design specified in The erosion layer may be made o

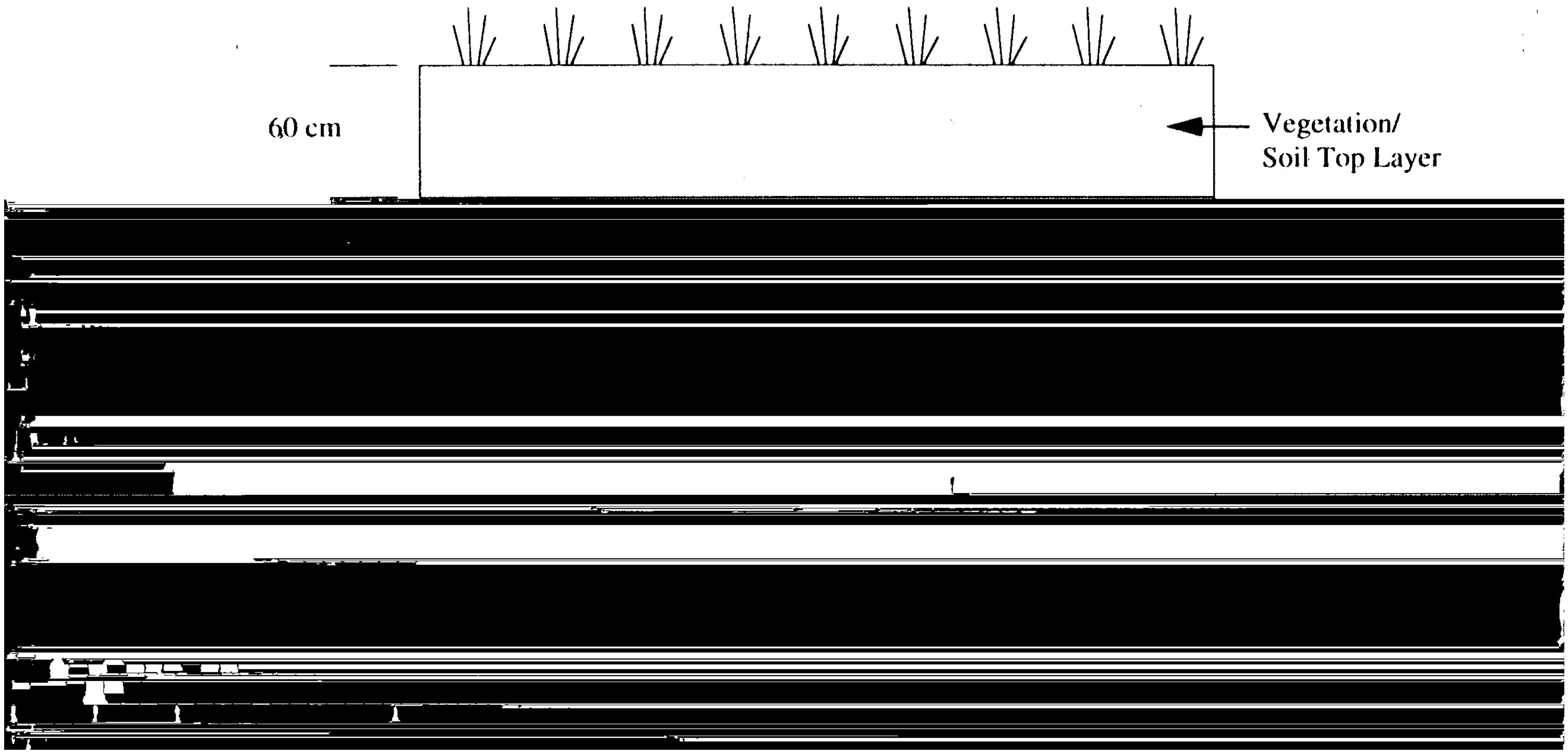


Figure 6-6
Example of an Alternative Final Cover Design

leachate generation is diminished. Caution should be taken when using a drainage layer because this layer may prematurely draw moisture from the erosion layer that is needed to sustain vegetation.

If a drainage layer is used, owners or operators should consider methods to minimize physical clogging of the drainage layer by root systems or soil particles. A filter layer, composed of either a low nutrient

evaluate the relative expected performance to an exterior collection point can be provided by means such as horizontal pipes patterned laterally throughout the gas vent layer, which channel gases to vertical risers or lateral headers. If vertical risers are used, their number should be minimized (as they are frequently vandalized) and located at high points in the cross-section (U.S. EPA, 1989b).

Biotic Layer

Deep plant roots or burrowing animals (collectively called biointruders) may disrupt the drainage and the low hydraulic conductivity layers, thereby interfering with the drainage capability of the layers. A 30-cm (12-inch) biotic barrier of cobbles may be minimized by compacting the waste during daily operation of the landfill unit or by landfilling baled waste. Organic wastes will continue to degrade and deteriorate after closure of the landfill unit.

Several models have been developed to analyze the process of differential settlement. Most models equate the layered cover to a beam or column undergoing deflection due to various loading conditions. While these models are useful to designers in understanding the qualitative relationship between the various land disposal unit characteristics and in identifying the constraining factors, accurate quantitative analytical methods have not been developed (U.S. EPA, 1988).

If the amount of total settlement can be estimated, either from an analytical approach or from empirical relationships from data collected during the operating life of the facility, the designer should attempt to estimate the potential strain imposed on the cover system components. Due to the uncertainties inherent in the settlement analysis, a biaxial strain calculation should be sufficient to estimate the stresses that may be imposed on the cover system. The amount of strain that a liner is capable of enduring may be as low as several percent; for geomembranes, it may be 5 to 12 percent (U.S. EPA, 1990). Geomembrane testing may be included as part of the design process to estimate safety factors against cover system failure.

The cover system may be designed with a greater thickness and/or slope to compensate for settlement after closure. However, even if settlement and subsidence are considered in the design of the final cover, ponding may still occur after closure and can be corrected during post-closure maintenance. The cost estimate for post-closure maintenance should include earthwork required to regrade the final cover due to total and differential settlements. Based on the estimates of total and differential settlements from the modeling methods described earlier, it may be appropriate to assume that a certain percentage of the total area needs regrading and then incorporate the costs into the overall post-closure maintenance cost estimate.

Sliding Instability

The slope angle, slope length, and overlying soil load limit the stability of component interfaceshe, (geomembrane it may be appropriate with soil 6pmod0.10slop
(ge stabi9 -6

The closure plan must describe all areas of the MSWLF unit that are subject to Part 258 regulations and that are not closed in accordance with §258.60. Portions of the landfill unit that have not received a final cover must be included in the estimate. The area to be covered at any point during the active life of the operating unit can be determined by examining design and planned operation procedures and by comparing the procedures with construction records, operation records, and field observations. Units are operated frequently in phases, with some phases conducted on top of previously deposited waste. If the owner or operator routinely closes landfill cells as they are filled, the plan should indicate the greatest number of cells open at one time.

The estimate must account for the maximum amount of waste on-site that may need to be disposed in the MSWLF unit over the life of the facility (this includes any waste on-site yet to be disposed). The maximum volume of waste ever on-site can be estimated from the maximum capacity of each unit and any operational procedures that may involve

tra8.9367 9367 867 0 Tethe plan sho.261916 Tc5Tj 12.957: 83.ethe plan 3 Tw (pr (e 8.97 9367 867 e

7/

i

- Preparing construction contract documents and securing a contractor;

i i

§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 environment 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). Extensions The owner or operator ma

notify the State Director that a certification, signed by an independent registered professional engineer or approved by Director of an approved

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

- Begin closure within 30 days of the last receipt of waste (or 1 year if there is remaining capacity and it is likely that it will be used);

- Complete closure within 180 days following the beginning of closure (in approved States, the period of time to begin or complete closure may be extended by the Director);

- Obtain a certification, by an independent registered professional engineer, that closure was completed in accordance with the closure plan;

- Place the certificate in the operating record and notify the State Director; and

- Note on a deed (or some other instrument) that the land was used as a landfill and that its use is restricted. Should all wastes be removed from the unit in an approved State, the owner or operator may request permission from the Director to remove the note on the deed.

6.5.3 Technical Considerations

Closure activities must begin within 30 days of the last receipt of waste and must be completed within 180 days. Some MSWLF units, such as those in seasonal population areas, may have remaining capacity but will not receive the next load of waste for a lengthy period of time. These MSWLF units must receive waste within one year or they must close. Extensions to both the 1-year and the 180-day requirements may be available to owners or operators of MSWLF units in approved States. An extension may be granted if the owner or operator can demonstrate that there is remaining capacity or that additional time is needed to complete closure. These typically examined during a title search, that the property was used as a MSWLF unit and that its use is restricted under 40 CFR §258.61(c)(3). Section 258.61(c)(3) states:

"... Post-closure use of the property shall not disturb the integrity of the final cover, liner(s), or any other components of the containment systems or the function of the monitoring systems unless necessary to comply with the requirements of Part 258...and... 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."

These restrictions are described further in Section 6.7 (Post-Closure Plan) of this document.

The owner or operator may request permission from the Director of an approved State to remove the notation to a deed. The request should document that all wastes have been removed from the facility. Such documentation may include photographs, ground-water and soil testing in the area

care must be conducted for 30 years, except as provided under paragraph (b) of this part, 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

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 and maintaining the ground-water monitoring system, if applicable; and

(4) Maintaining and operating

pipes, gas monitoring systems, and monitoring wells.

For larger facilities, annual aerial photography may be a useful way to document the extent of vegetative stress and settlement if either of these has been observed during routine inspections. It is important to coordinate the photography with the site "walkover" to verify interpretations made from aerial photographs. Aerial photography should not be used in place of a site walkover but in conjunction with the site walkover. An EPA document (U.S. EPA 1987) provides further information on using aerial photography for inspecting a landfill facility. (See the Reference section at the end of this chapter.)

Topographic surveys of the landfill unit(s) on vvement may be used to determine whether settlement has occurred. These should be repeated every few years until settlement behavior is established. If settlement plates are

Erosion may lead to increased infiltration of surface water into the landfill. Areas

Certain types of vegetative cover (e.g., turf-type grasses) may require mowing at least two times a year. Mowing can aid in suppression of weed and brush growth, and can increase the vigor of certain grass species. Alternatively, certain cover types (e.g., native prairie grasses) require less frequent mowing (once every three years) and may be suitable for certain climates and facilities where a low-maintenance regime is preferable. For certain cover types, fertilization schedules may be necessary to sustain desirable vegetative growth. Fertilization schedules should be based on the cover type present. Annual or biennial

grasses, while legumes and native vegetation may require little or no fertilizer once established. Insecticides may be used to eliminate insect populations that are detrimental to vegetation. Insecticides properly, the gas collection systems should be flushed and pressure-cleaned.

At some landfill facilities, leachate concentrations eventually may become low enough so as not to pose a threat to human health or the environment. In an approved State, the Director may allow an owner or operator to cease managing leachate if the owner or operator can demonstrate that the leachate no longer poses a threat to human health and the environment. The demonstration should address direct

6.7 POST-CLOSURE PLAN 40 CFR §258.61(c)-(e)

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.

6.7.2 Applicability

Owners and operators of existing units, new units, and lateral expansions of existing MSWLF units that stop receiving waste
r

- The procedure for verifying that post-closure care was provided in accordance with the plan.

In approved States only, the owner or operator may request the Director to approve a use that disturbs the final cover based on a demonstration that the use will not increase the potential threat to human health and the environment.

6.7.3 Technical Considerations

The State Director must be notified that a post-closure plan, describing the

MSWLF unit, has been placed in the

should provide a schedule for routine maintenance of the MSWLF unit systems. These systems include the final cover

6.8 FURTHER INFORMATION

6.8.1 References

Giroud, J.P., Bonaparte, R., Beech, J.F., and Gross, B.A., "Design of Soil Layer -Geosynthetic Systems Overlying Voids". Journal of Geotextiles and Geomembranes, Vol. 9, No. 1, 1990, pp. 11-50.

Richardson, G.N. and R.M. Koerner, (1987). "Geosynthetic Design Guidance for Hazardous Waste Landfill Cells and Surface Impoundments"; Hazardous Waste Engineering Research Laboratory; USEPA, Office of Research and Development; Cincinnati, Ohio; Contract No. 68-07-3338.

U.S. EPA, (1987). "Design, Construction and Maintenance of Cover Systems for Hazardous Waste: An Engineering Guidance Document"; PB87-19156; EPA/600/2-87/039; U.S. Department of Commerce, National Technical Information Service; U.S. Army Engineering Waterways Experiment Station; Vicksburg, Mississippi.

U.S. EPA, (1988). "Guide to Technical Resources for the Design of Land Disposal Facilities"; EPA/625/6-88/018; U.S. EPA; Risk Reduction Engineering Laboratory and Center for Environmental Research Information; Office of Research and Development; Cincinnati, Ohio 45268.

U.S. EPA, (1989a). "Seminar Publication - Requirements for Hazardous Waste Landfill Design, Construction and Closure"; EPA/625/4-89/022; U.S. EPA; Center for Environmental Research Information; Office of Research and Development; Cincinnati, Ohio 45268.

U.S. EPA, (1989b). "Technical Guidance Document: Final Covers on Hazardous Waste Landfills and Surface Impoundments"; EPA/530-SW-89-047; U.S. EPA; Office of Solid Waste and Emergency Response; Washington, D.C. 20460.

U.S. EPA, (1989c). "Interim Final: RCRA Facility Investigation (RFI) Guidance"; EPA 530/SW-89-031; U.S. EPA; Waste Management Division; Office of Solid Waste; U.S. Environmental Protection Agency; Volumes I-IV; May 1989.

U.S. EPA, (1989d). "Interim Final: Risk Assessment Guidance For Superfund; Human Health Evaluation Manual Part A"; OS-230; U.S. EPA; Office of Solid Waste and Emergency Response; July 1989.

U.S. EPA, (1991). "Seminar Publications - Design and Construction of RCRA/CERCLA Final Covers"; EPA/625/4-91/025; U.S. EPA, Office of Research and Development; Washington, D.C. 20460.

6.8.2 Organizations

U.S. Department of Agriculture
Soil Conservation Service (SCS)
P.O. Box 2890
Washington, D.C. 20013-2890
(Physical Location: 14th St. and Independence Ave. NW.)
(202) 447-5157

Note: This is the address of the SCS headquarters. To obtain the SCS technical guidance document concerning the Universal Soil Loss Equation (entitled "Predicting Rainfall Erosion Loss, Guidebook 537," 1978), contact SCS regional offices located throughout the United States.

6.8.3 Models

Schroeder, et al., (1988). "The Hydrologic Evaluation of Landfill Performance (HELP) Model"; U.S.EPA; U.S. Army Engineer Waterways Experiment Station; Vicksburg, MS 39181-0631; October 1988.

Schroeder, P.R., A.C. Gibson, J.M. Morgan, T.M. Walski, (1984). "The Hydrologic Evaluation of Landfill Performance (HELP) Model, Volume I - Users Guide for Version I (EPA/530-SW-84-009), and Volume II - Documentation for Version I (EPA/530-SW-84-010); U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, June 1984.

6.8.4 Databases

Integrated Risk Information System (IRIS), U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, Ohio.