CHAPTER 2

SUBPART B
LOCATION CRITERIA

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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 restrictions address conditions that may have adverse effects on landfill performance that could lead to releases to the environment or disruptions of natural functions (e.g., floodplain flow restrictions). Airport safety, floodplain, and wetlands criteria are intended to restrict MSWLF units in areas where sensitive natural environments and/or the public may be adversely affected.

Owners or operators must demonstrate that the location criteria have been met when Part 258 takes effect. Components of such demonstrations are identified in this section. The owner or operator of the landfill unit must also comply with all other applicable Federal and State regulations, such as State wellhead protection programs, that are not specifically identified in the Criteria. Owners or operators should note that many States are now developing Comprehensive State Ground Water Protection Programs. These programs are designed to coordinate and implement ground-water programs in the States; they may include additional requirements. Owners or operators should check with State environmental agencies concerning Comprehensive State Ground Water Protection Program requirements. Table 2-1 provides a quick reference to the location standards required by the Criteria.

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 Demonstra-tion 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

(a) Owners or operators of new MSWLF units, existing MSWLF units, and lateral expansions that are located within 10,000 feet (3,048 meters) of any airport runway end used by turbojet aircraft or within 5,000 feet (1,524 meters) of any airport runway end used by only piston-type aircraft must demonstrate that the units are designed and operated so that the MSWLF unit does not pose a bird hazard to aircraft.

(b) Owners or operators proposing to site new MSWLF units and lateral expansions within a five-mile radius of any airport runway end used by turbojet or piston-type aircraft must notify the affected airport and the Federal Aviation Administration (FAA).

(c) The owner or operator must place the demonstration in paragraph (a) in the operating record and notify the State Director that it has been placed in the operating record.

(d) For purposes of this section:

(1) <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 restricted. If the above conditions are present, the owner or operator must demonstrate that the MSWLF unit does not pose a bird hazard to aircraft and notify the State Director that the demonstration has been placed in the operating record. If the demonstration is not made, existing units must be closed in accordance with §258.16.

The regulation, based on Federal Aviation Administration (FAA) Order 5200.5A (Appendix I), prohibits the disposal of solid waste within the specified distances unless the owner or operator is able to make the required demonstration showing that the landfill is designed and operated so as not to pose bird hazards to aircraft. The regulation defines a "danger zone" within which particular care must be taken to ensure that no bird hazard arises.

Owners or operators proposing to site new units or lateral units within five miles of any airport runway end must notify both the affected airport and the FAA. This requirement is based on the FAA's position that MSWLF units located within a five mile radius of any airport runway end, and which attract or sustain hazardous bird movements across aircraft flight paths and runways, will be considered inconsistent with safe flight operations. Notification by the MSWLF owner/operator to the appropriate regional FAA office will allow FAA review of the proposal.

<u>2.2.3 Technical Considerations</u>

A demonstration that a MSWLF unit does not pose a bird hazard to aircraft within specified distances of an airport runway end should address at least three elements of the regulation:

- Is the airport facility within the regulated distance?;
- Is the runway part of a public-use airport?; and
- Does or will the existence of the landfill increase the likelihood of bird/aircraft collisions that may cause damage to the aircraft or injury to its occupants?

The first element can be addressed using existing maps showing the relationship of existing runways at the airport to the existing or proposed new unit or lateral 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 measurement, of the closest distance from the end of a runway to the nearest MSWLF unit. The measurement can be made by drawing a circle of appropriate radius (i.e., 5,000 ft., 10,000 ft, or 5 miles, depending on the airport type) from the centerline of each runway end. The measurement only should be made between the end of the runway and the nearest MSWLF unit perimeter, not between any other boundaries.

To determine whether the runway is part of a public use airport and to determine whether all applicable public airports have been identified, the MSWLF unit owner/operator should contact the airport administration or the regional FAA office. This rule does not apply to private airfields.

The MSWLF unit design features and operational practices can have a significant effect on the likelihood of increased bird/aircraft collisions. Birds may be attracted to MSWLF units to satisfy a need for water, food, nesting, or roosting. Scavenger birds such as starlings, crows, blackbirds, and gulls are most commonly associated with active landfill units. Where bird/aircraft collisions occur, these types of birds are often involved due to their flocking, feeding, roosting, and flight behaviors. Waste management techniques to reduce the supply of food to these birds include:

- Frequent covering of wastes that provide a source of food;
- Shredding, milling, or baling the waste-containing food sources; and
- Eliminating the acceptance of wastes at the landfill unit that represent a food source for birds (by alternative waste management techniques such as source separation and composting or waste minimization).

Frequent covering of wastes that represent a food source for the birds effectively reduces the availability of the food supply. Depending on site conditions such as volume and types of wastes, waste delivery schedules, and size of the working face, cover may need to be applied several times a day to keep the inactive portion of the working face small relative to the area accessible to birds. By maintaining a small working face, spreading and compaction equipment are concentrated in a small area that further disrupts scavenging by the birds.

Milling or shredding municipal solid waste breaks up food waste into smaller particle sizes and distributes the particles throughout non-food wastes, thereby diluting food wastes to a level that frequently makes the mixture no longer attractive as a food supply for birds. Similarly, baling municipal solid waste reduces the surface area of waste that may be available to scavenging birds.

The use of varying bird control techniques may prevent the birds from adjusting to a single method. Methods such as visual deterrents or sound have been used with mixed success in an attempt to discourage birds from food scavenging. Visual deterrents include realistic models (still or animated) of the bird's natural predators (e.g., humans, owls, hawks, falcons). Sounds that have had limited success as deterrents include cannons, distress calls of the scavenger birds, and sounds of its natural predators. Use of physical barriers such as fine wires strung across or near the working face have also been successfully used (see Figure 2-1). Labor intensive efforts have included falconry and firearms. Many of these methods have limited long-term effects on controlling bird populations at landfill units/facilities, as the birds adapt to the environment in which they find food.

Proper design and operation also can reduce the attraction of birds to the landfill unit through eliminating scavenger bird habitat. For example, the use of the landfill unit as a source of water can be controlled by encouraging surface drainage and by preventing the ponding of water.

Birds also may be attracted to a landfill unit as a nesting area. Use of the landfill site as a roosting or nesting area is usually limited to ground-roosting birds (e.g., gulls). Operational landfill units that do not operate continuously often provide a unique roosting habitat due to elevated ground temperatures (as a result of waste decomposition within the landfill) and freedom from disturbance. Nesting can be minimized, however, by examining the nesting patterns and requirements of undesirable birds and designing controls accordingly. For example, nesting by certain species can be controlled through the mowing and maintenance schedules at the landfill.

In addition to design features and operational procedures to control bird populations, the demonstration should address the likelihood that the MSWLF unit may increase bird/aircraft collisions. One approach to addressing this part of the airport safety criterion is to evaluate the attraction of birds to the MSWLF unit and determine whether this increased population would be expected to result in a discernible increase in bird/aircraft collisions. The evaluation of bird attraction can be based on field observations at existing facilities where similar geographic location, design features, and operational procedures are present.

All observations, measurements, data, calculations and analyses, and evaluations should be documented and included in the demonstration. The demonstration must be placed in the operating record and the State Director must be notified that it has been placed in the operating record (see Section 3.11 in Chapter 3).

If an owner or operator of an existing MSWLF unit cannot successfully demonstrate compliance with §258.10(a), then the unit must be closed in accordance with §258.60 and post-closure activities must be conducted in accordance with §258.61 (see §258.16). Closure must occur by October 9, 1996. The Director of an approved State can extend the period up to 2 years if it is demonstrated that no available alternative disposal capacity exists and the unit poses no immediate threat to human health and the environment (see Section 2.8).

In accordance with FAA guidance, if an owner or operator is proposing to locate a new unit or lateral expansion of an existing MSWLF unit within 5 miles of the end of a public-use airport runway, the affected airport and the regional FAA office must be notified to provide an opportunity to review and comment on the site. Identification of public airports in a given area can be

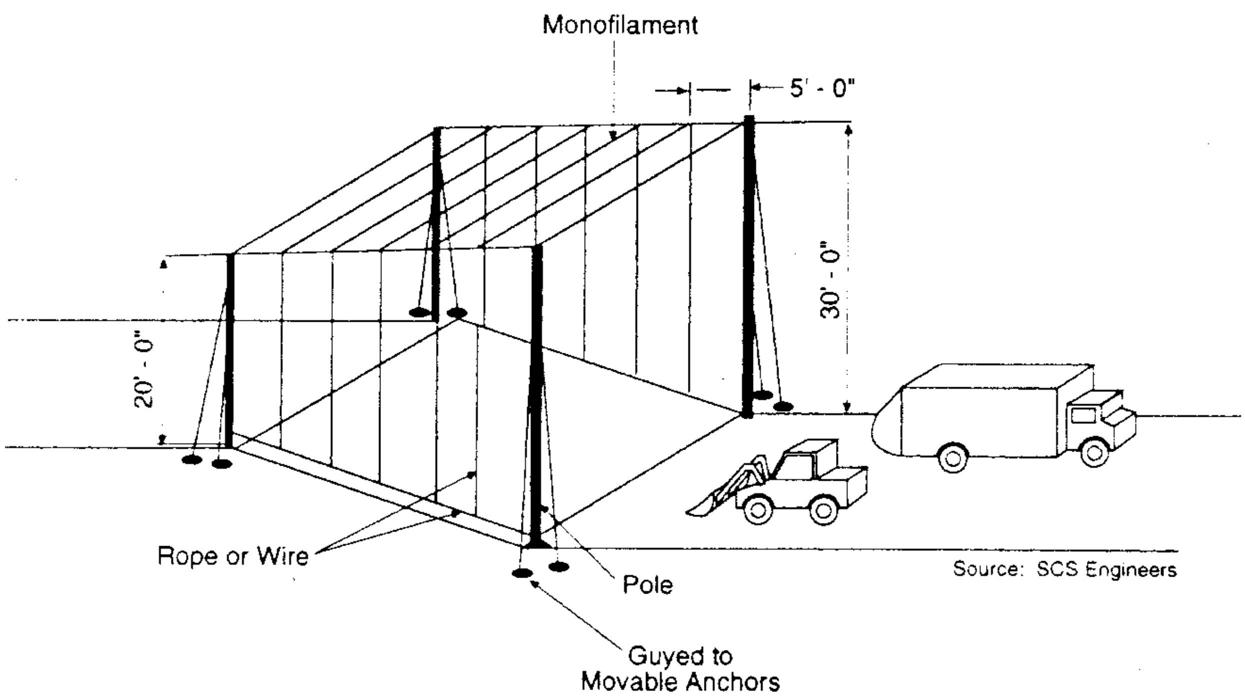


Figure 2-1.
Bird Control Device

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 lateral expansions located in 100-year floodplains must demonstrate that the unit will not restrict the flow of the 100-year flood, reduce the temporary water storage capacity of the floodplain, or result in washout of solid waste so as to pose a hazard to human health and the environment. The owner or operator must place the demonstration in the operating record and notify the State Director that it has been placed in the operating record.

(b) For purposes of this section:

(1) Floodplain means the lowland and relatively flat areas adjoining inland and coastal waters, including flood-prone areas of offshore islands, that are inundated by the 100-year flood.

(2) 100-year flood means a flood that has a 1-percent or greater chance of recurring in any given year or a flood of a magnitude equaled or exceeded once in 100 years on the average over a significantly long period.

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

2.3.2 Applicability

Owners/operators of new MSWLF units, existing MSWLF units, and lateral expansions of existing units located in a 100-year river floodplain who cannot demonstrate that the units will not restrict the flow of a 100-year flood nor reduce the water storage capacity, and will not result in a wash-out of solid waste, must close the unit(s). A MSWLF unit can affect the flow and temporary storage capacity of a floodplain. Higher flood levels and greater flood damage both upstream and downstream can be created and could cause a potential hazard to human health and safety. The rule does not prohibit locating a MSWLF unit in a 100-year floodplain; for example, the owner or operator is allowed to demonstrate that the unit will comply with the flow restriction, temporary storage, and washout provisions of the regulation. If a demonstration can be made that the landfill unit will not pose threats, the demonstration must be placed in the operating record, and the State Director must be notified that the demonstration was made and placed in the record. If the demonstration cannot be made for an existing MSWLF unit, then the MSWLF unit must be closed in 5 years in accordance with §258.60, and the owner or operator must conduct post-closure activities in accordance with §258.61 (see §258.16). The closure deadline may be extended for up to two years by the Director of an approved State if the owner or operator can demonstrate that no available alternative disposal capacity exists and there 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 in the 100-year floodplain, then the owner or operator must demonstrate that the unit will not pose a hazard to human health and the environment due to:

- Restricting the base flood flow;
- Reducing the temporary water storage; and
- Resulting in the washout of solid waste.

Guidance for identifying floodplains and demonstrating facility compliance is provided below.

Floodplain Identification

River floodplains are readily identifiable as the flat areas adjacent to the river's normal channel. One hundred-year floodplains represent the sedimentary deposits formed by floods that have a one percent chance of occurrence in any given year and that are identified in the flood insurance rate maps (FIRMs) and flood boundary and floodway maps published by the Federal Emergency Management Agency (FEMA) (see Figure 2-2). Areas classified as "A" zones are subject to the floodplain location restriction. Areas classified as "B" or "C" zones are not subject to the restriction, although care should be taken to design facilities capable of withstanding some potential flooding.

Guidance on using FIRMs is provided in "How to Read a Flood Insurance Rate Map" published by FEMA. FEMA also publishes "The National Flood Insurance Program Community Status Book" that lists communities that may not be involved in the National Flood Insurance Program but which have FIRMs or Floodway maps published. Maps and other FEMA publications may be obtained from the FEMA Distribution Center (see Section 2.9.2 for the address). Areas not covered by the FIRMs or Floodway maps may be included in floodplain maps available through the U.S. Army Corps of Engineers, the U.S. Geological Survey, the U.S. Soil Conservation Service, the Bureau of Land Management, the Tennessee Valley Authority, and State, Tribal, and local agencies.

Many of the river channels covered by these maps may have undergone modification for hydropower or flood control projects and, therefore, the floodplain boundaries represented may not be accurate or representative. It may be necessary to compare the floodplain map series to recent air photographs to identify current river channel modifications and land use watersheds that could affect floodplain designations. If floodplain maps are not available, and the facility is located within a floodplain, then a field study to delineate the 100-year floodplain may be required. A floodplain delineation program can be based primarily on meteorological records and physiographic information such as existing and planned watershed land use, topography, soils and geologic mapping, and air photo interpretation of geomorphologic (land form) features. The United States Water Resource Council (1977) provides information for determining

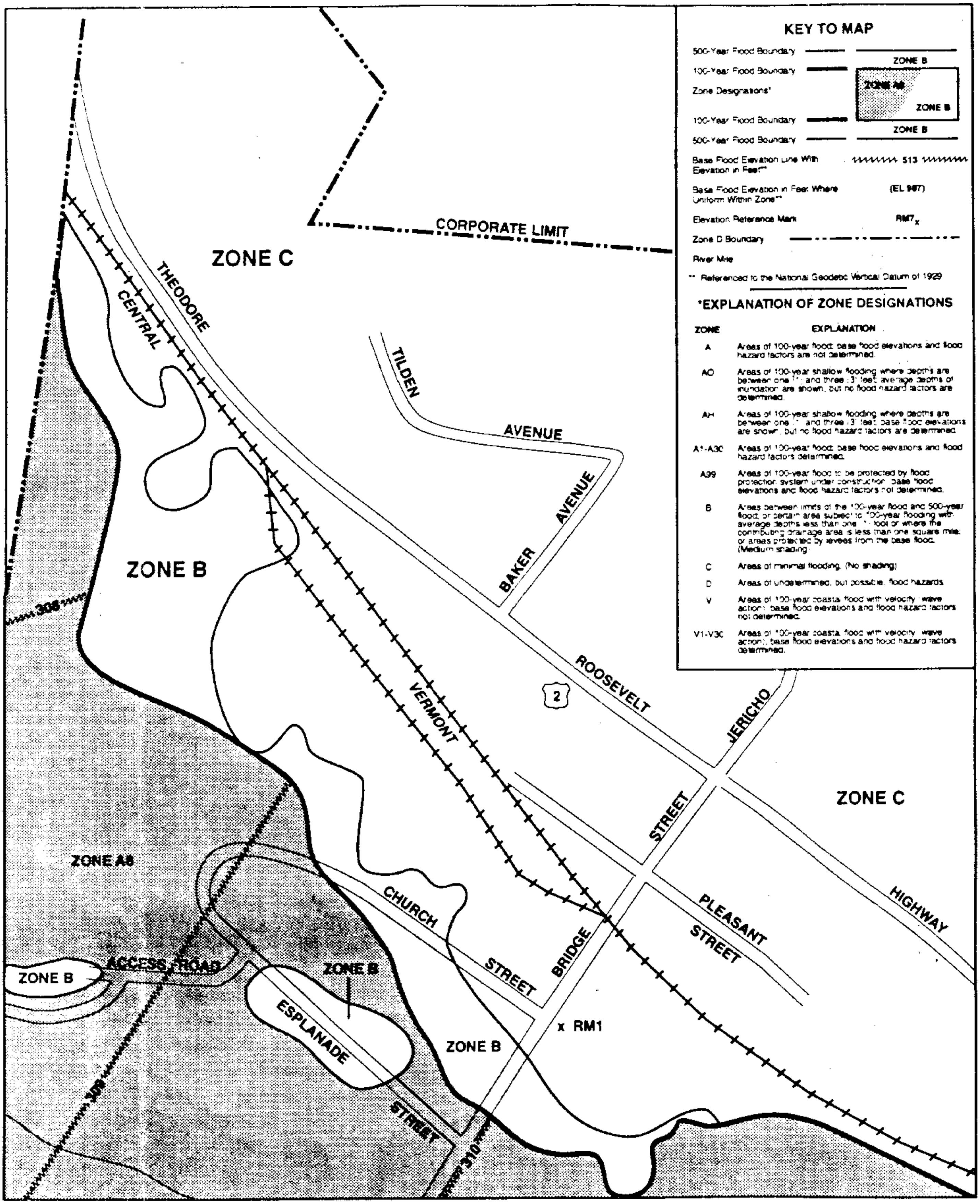


Figure 2-2
Example Section of Flood Plain Map

the potential for floods in a given location by stream gauge records. Estimation of the peak discharge also allows an estimation of the probability of exceeding the 100-year flood.

Engineering Considerations

If the MSWLF unit is within the 100-year floodplain, it must be located so that the MSWLF unit does not significantly restrict the base flood flow or significantly reduce temporary storage capacity of the floodplain. The MSWLF unit must be designed to prevent the washout of solid waste during the expected flood event. The rule requires that floodplain storage capacity, and flow restrictions that occur as the result of the MSWLF unit, do not pose a hazard to human health and the environment.

The demonstration that these considerations are met relies on estimates of the flow velocity and volume of floodplain storage in the vicinity of the MSWLF unit during the base flood. The assessment should consider the floodplain storage capacity and floodwater velocities that would likely exist in absence of the MSWLF unit. The volume occupied by a MSWLF unit in a floodplain may theoretically alter (reduce) the storage capacity and restrict flow. Raising the base flood level by more than one foot can be an indication that the MSWLF unit may reduce and restrict storage capacity flow.

The location of the MSWLF unit relative to the velocity distribution of floodwaters will greatly influence the susceptibility to washout. This type of assessment will require a conservative estimate of the shear stress on the landfill components caused by the depth, velocity, and duration of impinging river waters. Depending on the amount of inundation, the landfill unit may act as a channel side slope or bank or it may be isolated as an island within the overbank river channel. In both cases an estimate of the river velocity would be part of a proper assessment.

The assessment of flood water velocity requires that the channel cross section be known above, at, and below the landfill unit. Friction factors on the overbank are determined from the surface conditions and vegetation present. River hydrologic models may be used to simulate flow levels and estimate velocities through these river cross sections.

The Army Corps of Engineers (COE, 1982) has developed several numerical models to aid in the prediction of flood hydrographs, flow parameters, the effect of obstructions on flow levels, the simulation of flood control structures, and sediment transport. These methods may or may not be appropriate for a site; however, the following models provide well-tested analytical approaches:

HEC-1 Flood Hydrograph Package (watershed model that simulates the surface run-off response of a river basin to precipitation);

HEC-2 Water Surface Profiles (computes water surface profiles due to obstructions; evaluates floodway encroachment potential);

HEC-5 Simulation of Flood Control and Conservation Systems (simulates the sequential operation of a reservoir channel system with a branched network configuration; used to design 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

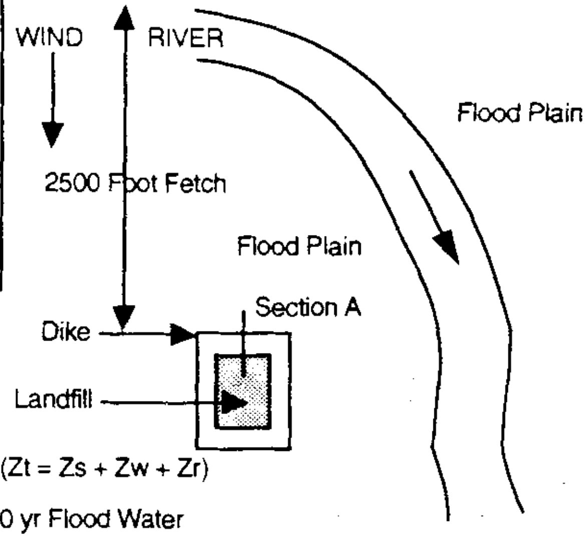
(iv) Violate any requirement under the Marine Protection, Research, and Sanctuaries Act of 1972 for the protection of a marine sanctuary;

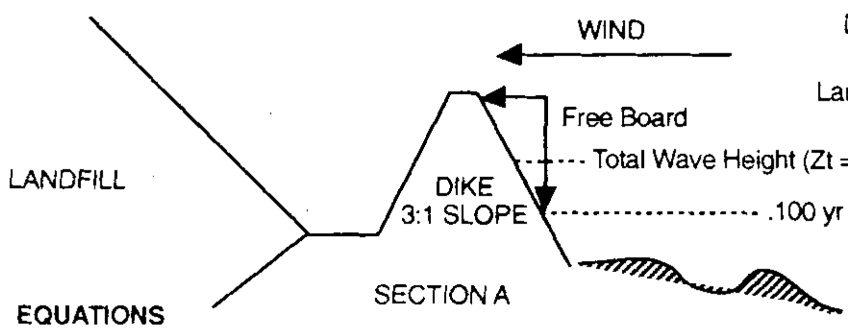
ASSUMPTIONS:

* FETCH = 2500 FT
* WIND SPEED = 50 MPH
* AVE. WATER DEPTH ALONG FETCH = 5 FT
* OVERBANK WATER VELOCITY = 0.25 FT/S

DEFINITIONS

Zs = Wave Setup (tilting of water surface upward at downwind end)
Zw = Capillary Waves Height (developed by wind over water surface)
Zr = Wave Run-up (water run-up along dike from wave impact)





EQUATIONS

$$Zr = Zw(Zr/Zw)$$

$$\lambda = 5.12 tw^2$$

$$tw = 0.46 Vw^{0.44} F^{0.28}$$

where:
Zr = Wave run-up along dike
Zr/Zw = Relative run-up ratio from chart below
λ = Wavelength
tw = Wave period
Vw = wind speed (mph)
F = fetch (miles)

$$Zw = 0.034 Vw^{1.06} F^{0.47}$$

where:
Zw = ave. height of heighest 1/3rd of waves (ft)
F = fetch (miles)

$$Zs = \frac{Vw^2 F}{1400 d}$$

where:
Zs = rise above still water level (ft)
Vw = wind speed (mph)
F = fetch (miles)
d = water depth along fetch (ft)

$$W = \frac{K\gamma H^3}{1000(0.016\gamma - 1)^3(\cos\alpha - \sin\alpha)^3}$$

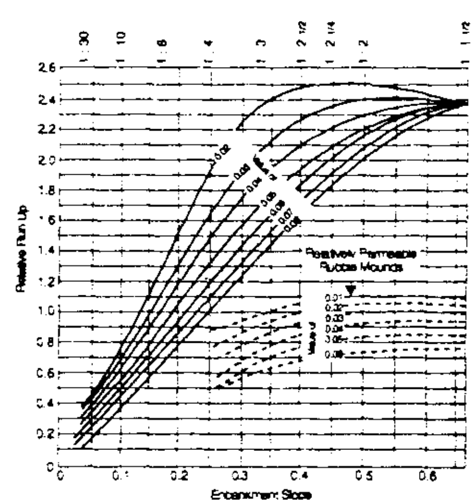
$$d = \left(\frac{6W}{\pi\gamma}\right)^{1/2}$$

where:
W = Rip - Rap stone weight (lbs)
d = Rip - Rap stone diameter
K = Coefficient (30)
γ = Stone Density (lb/cf)
H = height of design wave (ft)
α = bank slope (degrees)

SOLUTIONS

From the data provided in the assumptions at the beginning of the example:
Zs = 0.18 ft., Zw = 1.55 ft., Zr = 2.40 ft
Zt Design Height = 4.13 ft
Base 100 yr flood level = 5 ft
for Factor of Safety of 1.5
Dike Height = (1.5) (4.13 + 5) = 13.7 ft

For the Rip - Rap design given:
K = 30, γ = 120, H = 1.55 ft., a = 18°
For the protective stone on Dike
d = 0.5 ft., W = 12 lbs./stone



Wave run-up ratios vs. wave steepness and embankment slopes

Reference for Equations: U.S. Department of Interior, Bureau of Land Reclamation (1974)
Reference for Wave Run-up Chart: Linsley and Franzini (1972)

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 Jurisdictional Wetlands," 1989, are still being reviewed. [These changes were proposed in the Federal Register on August 14, 1991 (56 FR 40446) and on December 19, 1991 (56 FR 65964).] Therefore, as of January 1993, the method used for delineating a wetland is based on a previously existing document, "Army Corps of Engineers Wetlands Delineation Manual," 1987. A Memorandum of Understanding between EPA and the Department of the Army, Corps of Engineers, was amended on January 4, 1993, to state that both agencies would now use the COE 1987 manual as guidance for delineating wetlands. The methodology applied by an owner/operator to define and delineate wetlands should be in keeping with the federal guidance in place at the time of the delineation.

Because of the unique nature of wetlands, the owner/operator is required to demonstrate that the landfill unit will not cause or contribute to significant degradation of wetlands. The demonstration must be reviewed and approved by the Director of an approved State and placed in the facility operating record. This provision effectively bans the siting of new MSWLF units or lateral expansions in wetlands in unapproved States.

There are several key issues that need to be addressed if an owner or operator proposes to locate a lateral expansion or a new MSWLF unit in a wetland. These issues include: (1) review of practicable alternatives, (2) evaluation of wetland acreage and function, (3) evaluation of impacts of MSWLF units on wetlands, and (4) offsetting impacts. Although EPA has an objective of no net loss of wetlands in terms of acreage and function, it recognizes that regions of the country exist where proportionally large areas are dominated by wetlands. In these regions, sufficient 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

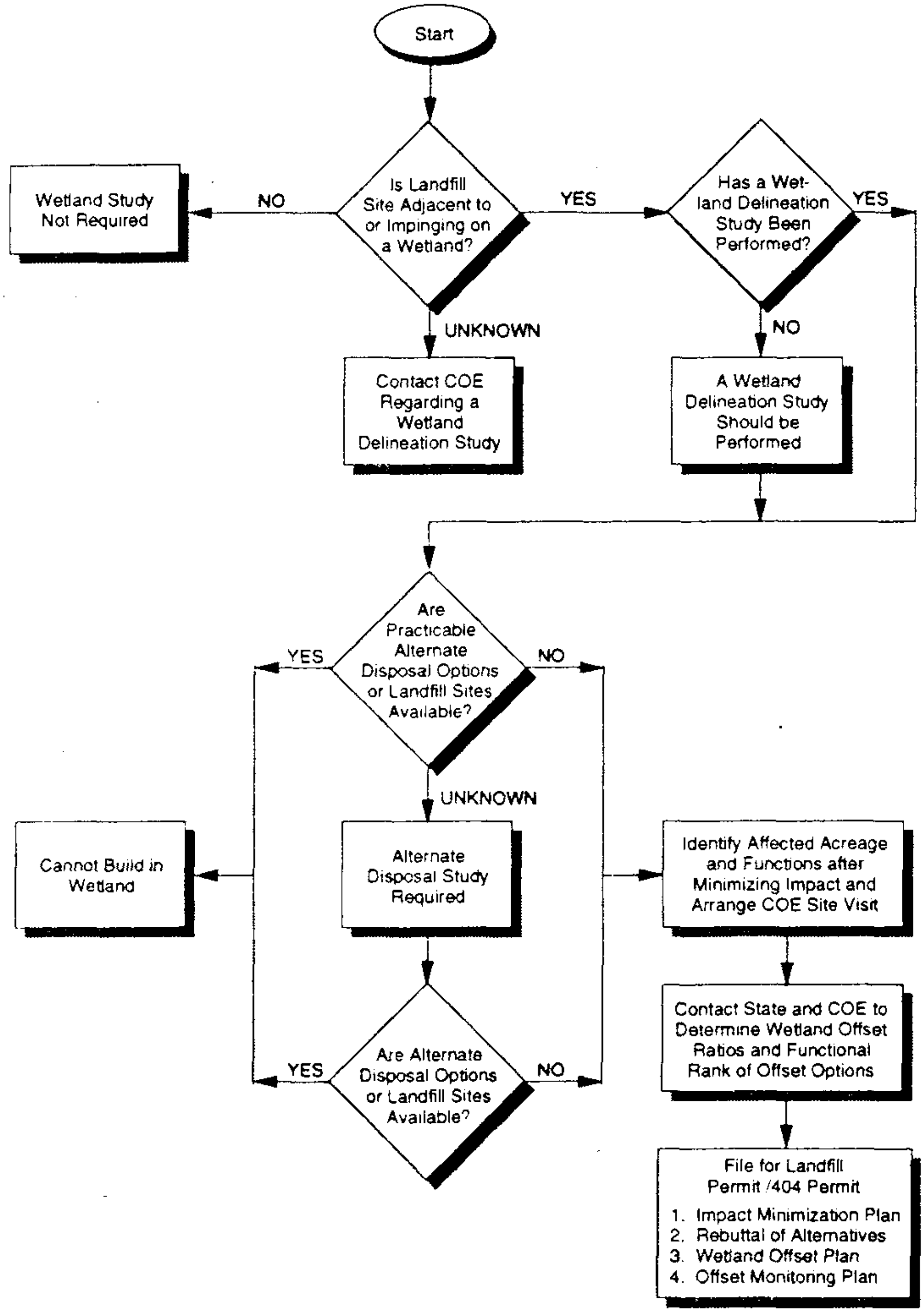


Figure 2-4
Wetlands Decision Tree for Owners/Operators in Approved States

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 on hydrology, soil types and plant types; (2) the type and relative abundance of vegetation, including trees; and (3) rare, endangered, or otherwise protected species and their habitats (if any).

The current methods used to delineate wetlands are presented in "COE Wetlands Delineation Manual," 1987. In January 1993, EPA and COE agreed to use the 1987 Manual for purposes of delineation. The Federal Manual for Identifying and Delineating Jurisdictional Wetlands (COE, 1989) contains an extensive reference list of available wetland literature. For example, lists of references for the identification of plant species characteristic of wetlands throughout the United States, hydric soils classifications, and related wetland topics are presented. USGS topographic maps, National Wetland Inventory (NWI) maps, Soil Conservation Service (SCS) soil maps, wetland inventory maps, and aerial photographs prepared locally also may provide useful information.

After completion of a wetland study, the impact of the MSWLF unit on wetlands and its relationship to adjacent wetlands can be assessed more effectively. During the permitting process, local, State, and federal agencies with jurisdiction over wetlands will need to be contacted to schedule a site visit. It is usually advantageous to encourage this collaboration as early as possible in the site evaluation process, especially if the State program office that is responsible for wetland protection is different from the solid waste management office. Regulations will vary significantly from State to State with regard to the size and type of wetland that triggers State agency involvement. In general, the COE will require notification and/or consultation on any proposed impact on any wetland regardless of the actual degree of the impact. Other agencies such as the Fish and Wildlife Service and the SCS may need to be contacted in some States.

Evaluation of ecological resource protection may include assessment of the value of the affected wetland. Various techniques are available for this type of evaluation, and the most appropriate technique for a specific site should be selected in conjunction with applicable regulatory agencies. Available methods include analysis of functional value, the Wetland Evaluation Technique (WET), and the Habitat Evaluation Procedure (HEP).

The 1987 Manual does not address functional value in the detail provided by the 1989 manual. The methodology for conducting a functional value assessment should be reviewed by the applicable regulatory agencies. It is important to note that functional value criteria may become a standard part of wetland delineation following revision of the federal guidance manual(s). The owner or operator should remain current with the accepted practices at the time of the delineation/assessment.

The functional value of a given wetland is dependent on its soil, plant, and hydrologic characteristics, particularly the diversity, prevalence, and extent of wetland plant species. The relationship between the wetland and surrounding areas (nutrient sinks and sources) and the ability of the wetland to support animal habitats, or rare or endangered species, contributes to the evaluation of functional value.

Other wetland and related assessment methodologies include WET and HEP. WET allows comparison of the values and functions of wetlands before and after construction of a facility, thereby projecting the impact a facility may have on a wetland. WET was developed by the Federal Highway Administration and revised by the COE (Adamus *et al*., 1987). HEP was developed by the Fish and Wildlife Service to determine the quality and quantity of available habitat for selected species. HEP and WET may be used in conjunction with each other to provide an integrated assessment.

Impact Evaluation

If the new unit or lateral expansion is to be located in a wetland, the owner or operator must demonstrate that the unit will not cause or contribute to significant degradation of the wetland. Erosion potential and stability of wetland soils and any dredged or fill material used to support the MSWLF unit should be identified as part of the wetlands evaluation. Any adverse stability or erosion problems that could affect the MSWLF or contaminant effects that could be caused by the MSWLF unit should be resolved.

All practicable steps are to be taken to minimize potential impacts of the MSWLF unit to wetlands. A number of measures that can aid in minimization of impacts are available. Appropriate measures are site-specific and should be incorporated into the design and operation of the MSWLF unit. For example, placement of ground water barriers may be required if soil and shallow ground-water conditions would cause dewatering of the wetland due to the existence of underdrain pipe systems at the facility. In many instances, however, wetlands are formed in response to perched water tables over geologic material of low hydraulic conductivity and, therefore, significant drawdown impacts may not occur.

It is possible that the landfill unit/facility will not directly displace wetlands, but that adverse effects may be caused by leachate or run-off. Engineered containment systems for both leachate and run-off should mitigate the potential for discharge to wetlands.

Additional actions and considerations relevant to mitigating impacts of fill material in wetlands that may be appropriate for MSWLF facilities are provided in Subpart H (Actions to Minimize Adverse Effects) of 40 CFR §230 (Guidelines for Specification of Disposal Sites for Dredged or Fill Materials).

Wetland Offset

All unavoidable impacts must be "offset" or compensated for to ensure that the facility has not caused, to the extent practicable, any net loss of wetland acreage. This compensatory mitigation may take the form of upgrading existing marginal or lower-quality wetlands or creating new wetlands. Wetland offset studies require review and development on a site-specific basis.

To identify potential sites that may be proposed for upgrade of existing wetlands or creation of new wetlands, a cursory assessment of surrounding wetlands and uplands should be conducted. The assessment may include a study to define the functional characteristics and inter-relationships of these potential wetland mitigation areas. An upgrade of an existing wetland may consist of transplanting 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 created/upgraded wetland is successfully established and that the intended function of the wetland becomes self-sustaining over time.

2.5 FAULT AREAS
40 CFR §258.13

2.5.1 Statement of Regulation

(a) New MSWLF units and lateral expansions shall not be located within 200 feet (60 meters) of a fault that has had displacement in Holocene time unless the owner or operator demonstrates to the Director of an approved State that an alternative setback distance of less than 200 feet (60 meters) will prevent damage to the structural integrity of the MSWLF unit and will be protective of human health and the environment.

(b) For the purposes of this section:

(1) Fault means a fracture or a zone of fractures in any material along which strata on one side have been displaced with respect to that on the other side.

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

(3) Holocene means the most recent epoch of the Quaternary period, extending from the end of the Pleistocene Epoch to the present.

2.5.2 Applicability

Except in approved States, the regulation bans all new MSWLF units or lateral expansions of existing units within 200 feet (60 meters) of the outermost boundary of a fault that has experienced displacement during the Holocene Epoch (within the last 10,000 to 12,000 years). Existing MSWLF units are neither required to close nor to retrofit if they are located in fault areas.

A variance to the 200-foot setback is provided if the owner or operator can demonstrate to the Director of an approved State that a shorter distance will prevent damage to the structural integrity of the MSWLF unit and will be protective of human health and the environment. The demonstration for a new MSWLF unit or lateral expansion requires review and 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 seismic activity. A more detailed discussion of seismic activity is presented in Section 2.6.

Proximity to a fault can cause damage through:

- Movement along the fault which can cause displacement of facility structures,
- Seismic activity associated with faulting which can cause damage to facility structures through vibratory action (see Figure 2-5), and
- Earth shaking which can cause ground failures such as slope failures.

Consequently, appropriate setbacks from fault areas are required to minimize the potential for damage.

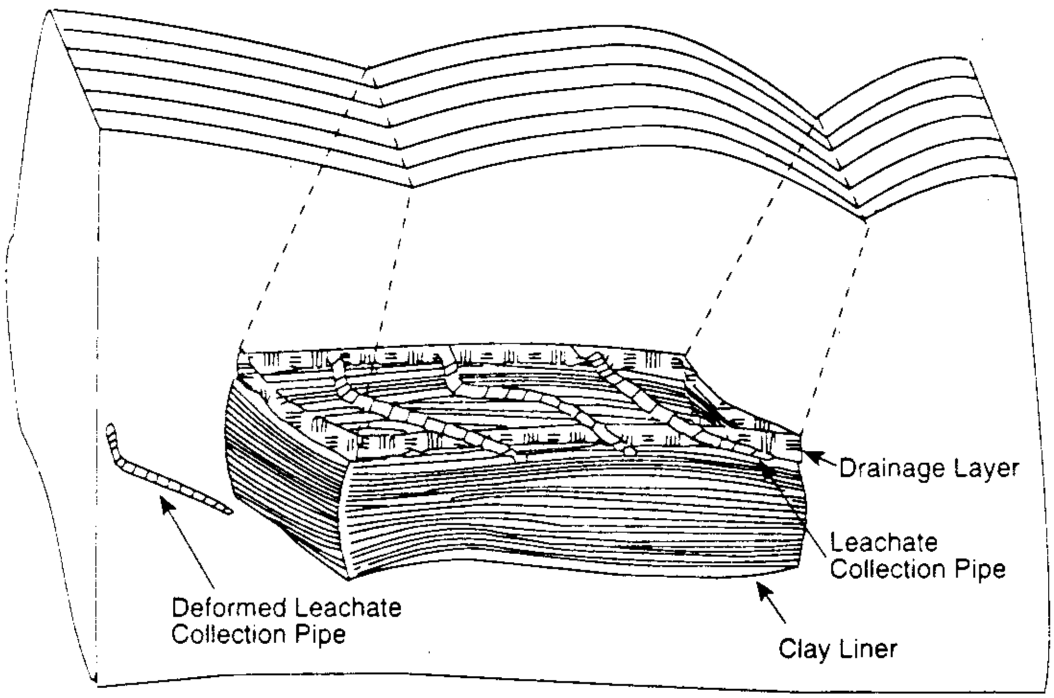
To determine if a proposed landfill unit is located in a Holocene fault area, U.S. Geological Survey (USGS) mapping can be used. A series of maps known as the "Preliminary Young Fault Maps, Miscellaneous Field Investigation (MF) 916" was published by the USGS in 1978. Information about these maps can be obtained from the USGS by calling 1-800-USA-MAPS, which reaches the USGS National Center in Reston, Virginia, or by calling 303-236-7477, which reaches the USGS Map 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 movement has occurred in Holocene time. This reconnaissance also may be necessary to support a demonstration for a setback of less than 200 feet. Additional requirements may need to be met before a new unit or lateral expansion may be approved.

A **site fault characterization** is necessary to determine whether a site is within 200 feet of a fault that has had movement during the Holocene epoch. An investigation would include obtaining information on any lineaments (linear features) that suggest the presence of faults within a 3,000-foot radius of the site. The information could be based on:

- A review of available maps, logs, reports, scientific literature, or insurance claim reports;
- An aerial reconnaissance of the area within a five-mile radius of the site, including aerial photo analysis; or

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 produced by the National Aerial Photographic Program (NAPP) and the National High Altitude Program (NHAP). Information on these photos can be obtained from the USGS EROS Data Center in Sioux Falls, South Dakota at (605) 594-615

Based on this information as well as supporting maps and analyses, a qualified professional should prepare a report that delineates the location of the Holocene 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 follows:

- For zones with high probabilities of high accelerations (horizontal) within the moderate range of 0.1g to 0.75g, seismic designs should be developed.

- Seismic stability analysis of landfill slopes should be performed to guide selection of materials and gradients for slopes.

- Where in-situ and laboratory tests indicate that a potential landfill site is susceptible to liquefaction, ground improvement measures like grouting, dewatering, heavy tamping, and excavation should be implemented.

- Engineering options include:

  — Flexible pipes,

  — Ground improvement measures (grouting, dewatering, heavy tamping, and excavation), and/or

  — Redundant precautionary measures (secondary containment system).

In addition, use of such measures needs to be demonstrated to be protective of human health and the environment. The types of engineering controls described above are similar to those that would be employed in areas that are likely to experience earthquakes.

2.6 SEISMIC IMPACT ZONES
40 CFR §258.14

2.6.1 Statement of Regulation

(a) New MSWLF units and lateral expansions shall not be located in seismic impact zones, unless the owner or operator demonstrates to the Director of an approved State that all containment structures, including liners, leachate collection systems, and surface water control systems, are designed to resist the maximum horizontal acceleration in lithified earth material for the site. The owner or operator must place the demonstration in the operating record and notify the State Director that it has been placed in the operating record.

(b) For the purposes of this section:

(1) Seismic impact zone means an area with a ten percent or greater probability that the maximum horizontal acceleration in lithified earth material, expressed as a percentage of the earth's gravitational pull (g), will exceed 0.10g in 250 years.

(2) Maximum horizontal acceleration in lithified earth material means the maximum expected horizontal acceleration depicted on a seismic hazard map, with a 90 percent or greater probability that the acceleration will not be exceeded in 250 years, or the maximum expected horizontal acceleration based on a site-specific seismic risk assessment.

(3) Lithified earth material means all rock, including all naturally occurring and naturally formed aggregates or masses of minerals or small particles of older rock that formed by crystallization of magma or by induration of loose sediments. This term does not include man-made materials, such as fill, concrete, and asphalt, or unconsolidated earth materials, soil, or regolith lying at or near the earth surface.

2.6.2 Applicability

New MSWLF units and lateral expansions in seismic impact zones are prohibited, except in approved States. A seismic impact zone is an area that has a ten percent or greater probability that the maximum expected horizontal acceleration in lithified earth material, expressed as a percentage of the earth's gravitational pull (g), will exceed 0.10g in 250 years.

The regulation prohibits locating new units or lateral expansions in a seismic impact zone unless the owner or operator can demonstrate that the structural components of the unit (e.g., liners, leachate collection systems, final cover, and surface water control systems) are designed to resist the maximum horizontal acceleration in lithified earth material at the site. Existing units are not required to be retrofitted. Owners or operators of new units or lateral expansions must notify the Director of an approved State and place the demonstration of compliance with the conditions of the restriction in the operating record.

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 location of earthquake epicenters and intensities may be available through State Geologic Surveys or the Earthquake Information Center. For information concerning potential earthquakes in specific areas, the Geologic Risk Assessment Branch of USGS may be of assistance. Other organizations that study the effects of earthquakes on engineered structures include the National Information Service for Earthquake Engineering, the Building Seismic Safety Council, the National Institute of Science and Technology, and the American Institute of Architects.

Landfill Planning and Engineering in Areas of Seismic Activity

Studies indicate that during earthquakes, superficial (shallow) slides and differential displacement tend to be produced, rather than massive slope failures (U.S. Navy 1983). Stresses created by superficial failures can affect the liner and final cover

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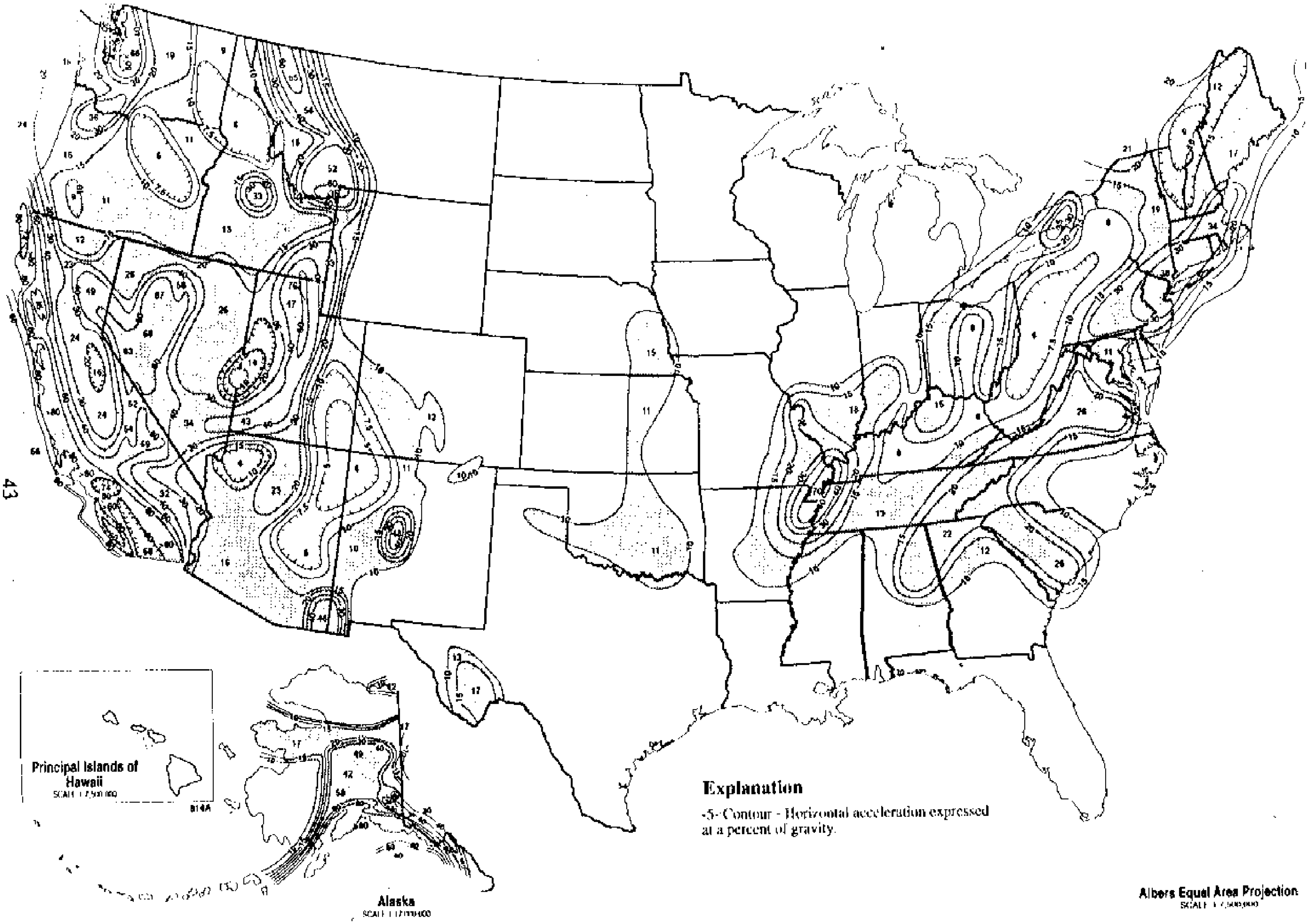


Figure 2-6. Seismic Impact Zones
(Areas with a 10% or greater probability that the maximum horizontal acceleration will exceed .10g in 250 years)

systems as well as the leachate and gas collection and removal systems. Tensional stresses within the liner system can result in fracturing of the soil liner and/or tearing of the flexible membrane liner. Thus, when selecting suitable sites from many potential sites during the siting process, the owner/operator should try to avoid a site with:

- Holocene fault zones,
- Sites with potential ground motion, and
- Sites with liquefaction potential.

If one of the above types of sites is selected, the owner/operator must consider the costs associated with the development of the site.

If, due to a lack of suitable alternatives, a site is chosen that is located in a seismic impact zone, a demonstration must be made to the Director of an approved State that the design of the unit's structural components (e.g., liners, leachate collection, final covers, run-on and run-off systems) will resist the maximum horizontal acceleration in lithified materials at the site. As part of the demonstration, owner/operators must:

- Determine the expected peak ground acceleration from a maximum strength earthquake that could occur in the area,

- Determine the site-specific seismic hazards such as soil settlement, and

- Design the facility to withstand the expected peak ground acceleration.

The design of the slopes, leachate collection system, and other structural components should have built-in conservative design factors. Additionally, redundant precautionary measures should be designed and built into the various landfill systems.

For those units located in an area with an estimated maximum horizontal acceleration greater than 0.1g, an evaluation of seismic effects should consider both foundation soil stability and waste stability under seismic loading. Conditions that may be considered for the evaluation include the construction phase (maximum open excavation depth of new cell adjacent to an existing unit), closure activities (prior to final consolidation of both waste and subsoil), and post-closure care (after final consolidation of both waste and foundation soil). If the maximum horizontal acceleration is less than or equal to 0.1g, then the design of the unit will not have to incorporate an evaluation of seismic effects unless the facility will be situated in an area with low strength foundation soils or soils with potential for liquefaction. The facility should be assessed for the effects of seismic activity even if the horizontal acceleration is expected to be less than 0.1g.

In determining the potential effects of seismic activity on a structure, an engineering evaluation should examine soil behavior with respect to earthquake intensity. When evaluating soil characteristics, it is necessary to know the soil strength as well as the magnitude or intensity of the earthquake in terms of peak acceleration. Other soil characteristics, including degree of compaction, sorting (organization of the soil particles), and degree of saturation, may need to be considered because of their potential influence on site conditions. For example, deposits of loose granular soils may be compacted by the ground vibrations induced by an earthquake. Such volume reductions could result in large uniform or differential settlements of the ground surface (Winterkorn and Fang, 1975).

Well-compacted cohesionless embankments or reasonably flat slopes in insensitive clay are less likely to fail under moderate seismic shocks (up to 0.15g and 0.20g acceleration). Embankments made of insensitive cohesive soils founded on cohesive soils or rock may withstand even greater seismic shocks. For earthen embankments in seismic regions, designs with internal drainage and core material most resistant to fracturing should be considered. Slope materials vulnerable to earthquake shocks are described below (U.S. Navy, 1983):

- Very steep slopes of weak, fractured and brittle rocks or unsaturated loess are vulnerable to transient shocks caused by tensional faulting;
- Loess and saturated sand may be liquefied by seismic shocks causing the sudden collapse of structures and flow slides;
- Similar effects are possible in sensitive cohesive soils when natural moisture exceeds the soil's liquid limit; and
- Dry cohesionless material on a slope at an angle of repose will respond to seismic shock by shallow sloughing and slight flattening of the slope.

In general, loess, deltaic soils, floodplain soils, and loose fills are highly susceptible to liquefaction under saturated conditions (USEPA, 1992).

Geotechnical stability investigations frequently incorporate the use of computer models to reduce the computational time of well-established analytical methods. Several computer software packages are available that approximate the anticipated dynamic forces of the design earthquake by resolving the forces into a static analysis of loading on design cross sections. A conservative approach would incorporate both vertical and horizontal forces caused by bedrock acceleration if it can be shown that the types of material of interest are susceptible to the vertical force component. Typically, the horizontal force caused by bedrock acceleration is the major force to be considered in the seismic stability analysis. Examples of computer models include PC-Slope by Geoslope Programming (1986), and FLUSH by the University of California.

Design modifications to accommodate an earthquake may include shallower waste sideslopes, more conservative design of dikes and run-off controls, and additional contingencies for leachate collection should primary systems be disrupted. Strengths of the landfill components should be able to withstand these additional forces with an acceptable factor of safety. The use of professionals experienced in seismic analysis is strongly recommended for design of facilities located in areas of high seismic risk.

2.7 UNSTABLE AREAS
40 CFR §258.15

2.7.1 Statement of Regulation

(a) Owners or operators of new MSWLF units, existing MSWLF units, and lateral expansions located in an unstable area must demonstrate that engineering measures have been incorporated into the MSWLF unit's

design to ensure that the integrity of the structural components of the MSWLF unit will not be disrupted. The owner or operator must place the demonstration in the operating record and notify the State Director that it has been placed in the operating record. The owner or operator must consider the following factors, at a minimum, when determining whether an area is unstable:

(1) On-site or local soil conditions that may result in significant differential settling;

(2) On-site or local geologic or geomorphologic features; and

(3) On-site or local human-made features or events (both surface and subsurface).

(b) For purposes of this section:

(1) Unstable area means a location that is susceptible to natural or human-induced events or forces capable of impairing the integrity of some or all of the landfill structural components responsible for preventing releases from a landfill. Unstable areas can include poor foundation conditions, areas susceptible to mass movements, and Karst terrains.

(2) Structural components means liners, leachate collection systems, final covers, run-on/run-off systems, and any other component used in the construction and operation of the MSWLF that is necessary for protection of human health and the environment.

(3) Poor foundation conditions means those areas where features exist which indicate that a natural or man-induced event may result in inadequate foundation support for the structural components of a MSWLF unit.

(4) Areas susceptible to mass movement means those areas of influence (i.e., areas characterized as having an active or substantial possibility of mass movement) where the movement of earth material at, beneath, or adjacent to the MSWLF unit, because of natural or man-induced events, results in the downslope transport of soil and rock material by means of gravitational influence. Areas of mass movement include, but are not limited to, landslides, avalanches, debris slides and flows, solifluction, block sliding, and rock fall.

(5) Karst terrains means areas where karst topography, with its characteristic surface and subterranean features, is developed as the result of dissolution of limestone, dolomite, or other soluble rock. Characteristic physiographic features present in karst terrains include, but are not limited to, sinkholes, sinking streams, caves, large springs, and blind valleys.

2.7.2 Applicability

Owners/operators of new MSWLF units, existing MSWLF units, and lateral expansions of units that are located in unstable areas must demonstrate the structural integrity of the unit. Existing units for which a successful demonstration cannot be made must be closed. The regulation applies to new units, existing units, and lateral expansions that are located on sites classified as unstable areas. Unstable areas are areas susceptible to natural or human-induced events or forces that are capable of impairing or destroying the integrity of some or all of the structural components. Structural components consist of liners, leachate collection systems, final cover systems, run-on and run-off control systems, and any other component necessary for protection of human health and the environment.

MSWLF units can be located in unstable areas, but the owner or operator must demonstrate that the structural integrity of the MSWLF unit will not be disrupted. The demonstration must show that engineering measures have been incorporated into the design of the unit to ensure the integrity of the structural components. Existing MSWLF units that do not meet the demonstration must be closed within 5 years in accordance with §258.60, and owners and operators must undertake post-closure activities in accordance with §258.61. The Director of an approved State can grant a 2-year extension to the closure requirement under two conditions: (1) no disposal alternative is available, and (2) no immediate threat is posed to human health and the environment.

2.7.3 Technical Considerations

Again, for the purposes of this discussion, natural unstable areas include those areas that have poor soils for foundations, are susceptible to mass movement, or have karst features.

- **Areas with soils that make poor foundations** have soils that are expansive or settle suddenly. Such areas may lose their ability to support a foundation when subjected to natural (e.g., heavy rain) or man-made events (e.g., explosions).

  — Expansive soils usually are clay-rich soils that, because of their molecular structure, tend to swell and shrink by taking up and releasing water and thus are sensitive to a variable hydrologic regime. Such soils include: smectite (montmorillonite group) and vermiculite clays; bentonite is a smectite-rich clay. In addition, soils rich in "white alkali" (sodium sulfate), anhydrite (calcium sulfate), or pyrite (iron sulfide) also may exhibit swelling as water content increases. Such soils tend to be found in the arid western states.

  — Soils that are subject to rapid settlement (subsidence) include loess, unconsolidated clays, and wetland soils. Loess, which is found in the central states, is a wind-deposited silt that is moisture-deficient and tends to compact upon wetting. Unconsolidated clays, which can be found in the southwestern states, can undergo considerable compaction when fluids such as water or oil are removed. Similarly, wetland soils, which by their nature are water-bearing, also tend to be subject to subsidence when water is withdrawn.

- Another type of unstable area is an **area that is subject to mass movement**. Such areas can be situated 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 surface and ground-water flow (e.g., sinking streams and large springs). Other rocks such as dolomite or gypsum also may be subject to solution effects.

Examples of human-induced unstable areas are described below:

- The presence of cut and/or fill slopes during construction of the MSWLF unit may cause slippage of existing soil or rock.

- Excessive drawdown of ground water increases the effective overburden on the foundation soils underneath the MSWLF unit, which may cause excessive settlement or bearing capacity failure on the foundation soils.

- 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 must assess the ability of the soils and/or rock 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 order to avoid or prevent a destabilizing event from impairing the structural integrity of the landfill component systems. A stability assessment involves essentially three components: an evaluation of subsurface conditions, an analysis of slope stability, and an examination of related design needs. An evaluation of subsurface conditions requires:

- Assessing the stability of foundation soils, adjacent embankments, and slopes;

- Investigating the geotechnical and geological characteristics of the site to establish soil strengths and other engineering properties by performing standard penetration tests, field vane shear tests, and laboratory tests; and

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

A stability assessment should consider (USEPA, 1988):

- The adequacy of the subsurface exploration program;
- The liquefaction potential of the embankment, slopes, and foundation soils;
- The expected behavior of the embankment, slopes, and foundation soils when they are subjected to seismic activity;
- The potential for seepage-induced failure; and
- The potential for differential settlement.

In addition, a qualified professional must assess, at a minimum, natural conditions (e.g., soil, geology, geomorphology) as well as human-made features or events (both subsurface and surface) that could cause differential settlement of ground. Natural conditions can be highly unpredictable and destructive, especially if amplified by human-induced changes to the environment. Specific examples of natural or human-induced phenomena include: debris flows resulting from heavy rainfall in a small watershed; the rapid formation of a sinkhole as a result of excessive local or regional ground water withdrawal in a limestone region; earth displacement by faulting activity; and rockfalls along a cliff face caused by vibrations resulting from the detonation of explosives or sonic booms.

Information on natural features can be obtained from:

- The USGS National Atlas map entitled "Engineering Aspects of Karst," published in 1984;
- Regional or local soil maps;
- Aerial photographs (especially in karst areas); and
- Site-specific investigations.

To examine an area for possible sources of human-induced ground instability, the site and surrounding area should be examined for activities related to extensive withdrawal of oil, gas, or water from subsurface units as well as construction or other operations that may result in ground motion (e.g., blasting).

Types of Failures

Failures occur when the driving forces imposed on the soils or engineered structures exceed the resisting forces of the material. The ratio of the resisting force to the driving force is considered the factor of safety (FS). At an FS value less than 1.0, failure will occur by definition. There is a high probability that, due to natural variability and the degree of accuracy in measurements, interpreted soil conditions will not be precisely representative of the actual soil conditions. Therefore, failure may not occur exactly at the calculated value, so factors of safety greater than 1.0 are required for the design. For plastic soils such as clay, movement or deformation (creep) may occur at a higher factor of safety prior to catastrophic failure.

Principal modes of failure in soil or rock include:

- Rotation (change of orientation) of an earthen mass on a curved slip surface approximated by a circular arc;
- Translation (change of position) of an earthen mass on a planar surface whose length is large compared to depth below ground;
- Displacement of a wedge-shaped mass along one or more planes of weakness;
- Earth and mud flows in loose clayey and silty soils; and
- Debris flows in coarse-grained soils.

For the purposes of this discussion, three types of failures can occur at a landfill unit: settlement, loss of bearing strength, and sinkhole collapse.

- If not properly engineered, a landfill in an unstable area may undergo extreme **settlement**, which can result in structural failure. Differential settlement is a particular mode of failure that generally occurs beneath a landfill in response to consolidation and dewatering of the foundation soils during and following waste loading.

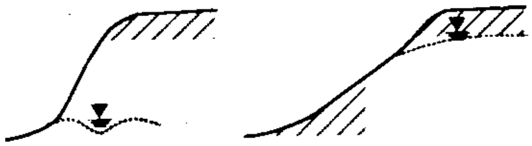
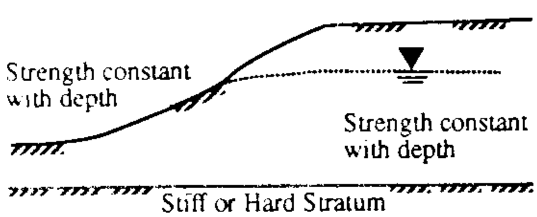
  Settlement beneath a landfill unit, both total and differential, should be assessed and compared to the elongation strength and flexure properties of the liner and leachate collection pipe system. Even small amounts of settlement can seriously damage leachate collection piping and sumps. The analysis will provide an estimate of maximum settlement, which can be used to aid in estimating differential settlement.

  Allowable settlement is typically expressed as a function of total settlement because differential settlement is more difficult to predict. However, differential settlement is a more serious threat to the integrity of the structure than total settlement. Differential settlement also is discussed in Section 6.3 of Chapter 6.

- **Loss of bearing strength** is a failure mode that tends to occur in areas that have soils that tend to expand, rapidly settle, or liquefy, thereby causing failure or reducing performance of overlying MSWLF components. Another example of loss of bearing strength involves failures that have occurred at operating sites where excavations for landfill expansions adjacent to the filled areas reduced the mass of the soil at the toe of the slope, thereby reducing the overall strength (resisting force) of the foundation soil.

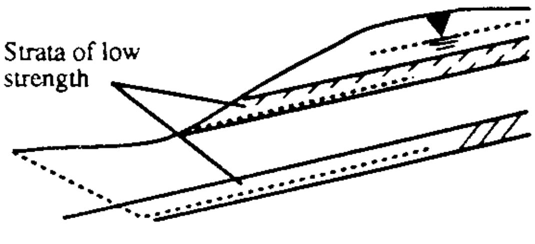
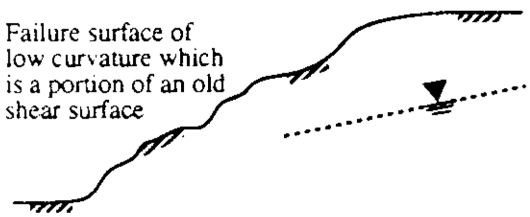
- **Catastrophic collapse in the form of sinkholes** is a type of failure that occurs in karst regions. As water, especially acidic water, percolates through limestone (calcium carbonate), the soluble carbonate material dissolves, forming cavities and caverns. Land overlying caverns can collapse suddenly, resulting in sinkhole features that can be 100 feet or more in depth and 300 feet or more in width.

Tables 2-2 and 2-3 provide examples of analytical considerations for mode of failure assessments in both natural and human-made slopes.

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.

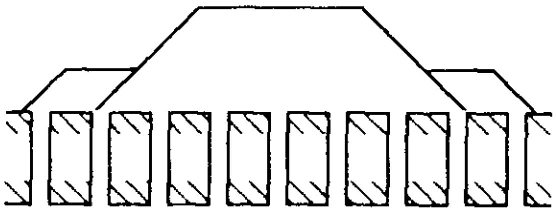
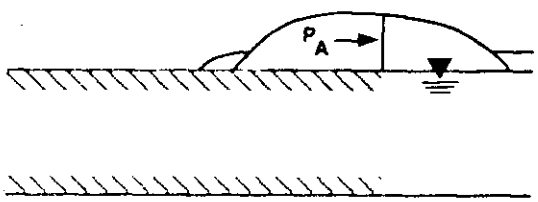
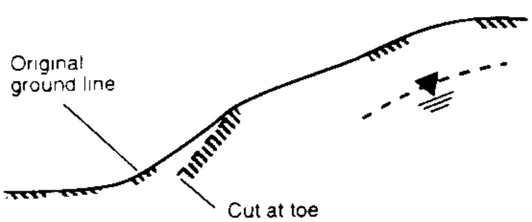
Source: Soil Mechanics, NAVFAC Design Manual 7.01

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 borings required depends on the variability of the soils, the site size, and landfill unit dimensions. Borings and field vane testing should consider the anticipated design to identify segments of the facility where critical cross sections are likely to occur. Critical sections are where factors of safety are anticipated to be lowest.

Other tests that are conducted to characterize a soil include determination of water content, Atterberg limits, grain size distribution, consolidation, effective porosity, and saturated hydraulic conductivity. The site hydrogeologic conditions should be assessed to determine if soils are saturated or unsaturated.

Catastrophic failures, such as sinkhole collapse in karst terrains or fault displacement during an earthquake, are more difficult to predict. Subsurface karst structures may have surface topographic expressions such as circular depressions over subsiding solution caverns. Subsurface borings or geophysical techniques may provide reliable means of identifying the occurrence, depth, and size of solution cavities that have the potential for catastrophic collapse.

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, and liquefaction. Factor of safety rationale and selection for different conditions are described by Huang (1983) and Terzaghi and Peck (1967). Table 2-4 lists recommended minimum factor of safety values for slopes. Many States may provide their own minimum factor of safety requirements.

There are numerous methods currently available for performing slope stability analyses. Method selection should be based on the soil properties and the anticipated mode of failure. Rationale for selecting a specific method should be provided.

The majority of these methods may be categorized as "limit equilibrium" methods in which driving and resisting forces are determined and compared. The basic assumption of the limit equilibrium approach is that the failure criterion is satisfied along an assumed failure surface. This surface may be a straight line, circular arc, logarithmic spiral, or other irregular plane. A free body diagram of the driving forces acting on the slope is constructed using assumed or known values of the forces. Next, the soil's shear resistance as it pertains to establishing equilibrium is calculated. This calculated shear resistance

Table 2-4

Recommended Minimum Values of Factor of Safety for Slope Stability Analyses

	Uncertainty of Strength Measurements	
Consequences of Slope Failure	Small[1]	Large[2]
No imminent danger to human life or major environmental impact if slope fails	1.25 (1.2)*	1.5 (1.3)
Imminent danger to human life or major environmental impact if slope fails	1.5 (1.3)	2.0 or greater (1.7 or greater)

[1] The uncertainty of the strength measurements is smallest when the soil conditions are uniform and high quality strength test data provide a consistent, complete, and logical picture of the strength characteristics.

[2] The uncertainty of the strength measurements is greatest when the soil conditions are complex and when available strength data do not provide a consistent, complete, and logical picture of the strength characteristics.

* Numbers without parentheses apply for static conditions and those within parentheses apply to seismic conditions.

Source: EPA Guide to Technical Resources for the Design of Land Disposal Facilities.

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).

Methods that consider only the whole free body as a single unit include the Culmann method and the friction circle method. Another approach is to divide the free body into vertical slices and to consider the equilibrium of each slice. Several versions of the slice method are available; the best known are the Swedish Circle method and the Bishop method. Discussions of these and other methods may be found in Winterkorn and Fang (1975), Lambe and Whitman (1969), and U.S. Navy (1986).

A computer program that is widely used for slope stability analysis is PC STABL, a two-dimensional model that computes the minimum critical factors of safety between layer interfaces. This model uses the method of vertical slices to analyze the slope and calculate the factor of safety. PC STABL can account for heterogeneous soil systems, anisotropic soil strength properties, excess pore water pressure due to shear, static ground water and surface water, pseudostatic earthquake loading, surcharge boundary loading, and tieback loading. The program is written in FORTRAN IV and can be run on a PC. Figure 2-7 presents a typical output from the model.

Design for Slope Stabilization

Methods for slope stabilization are presented in Table 2-5 and are summarized below.

- The first illustration shows that stability can be increased by changing the slope geometry through reduction of the slope height, flattening the slope angle, or excavating a bench in the upper part of the slope.

- The second illustration shows how compacted earth or rock fill can be placed in the form of a berm at and beyond the slope's toe to buttress the slope. To prevent the development of undesirable water pressure behind the berm, a drainage system may be placed behind the berm at the base of the slope.

- The third illustration presents several types of retaining structures. These structures generally involve drilling and/or excavation followed by constructing cast-in-place concrete piles and/or slabs.

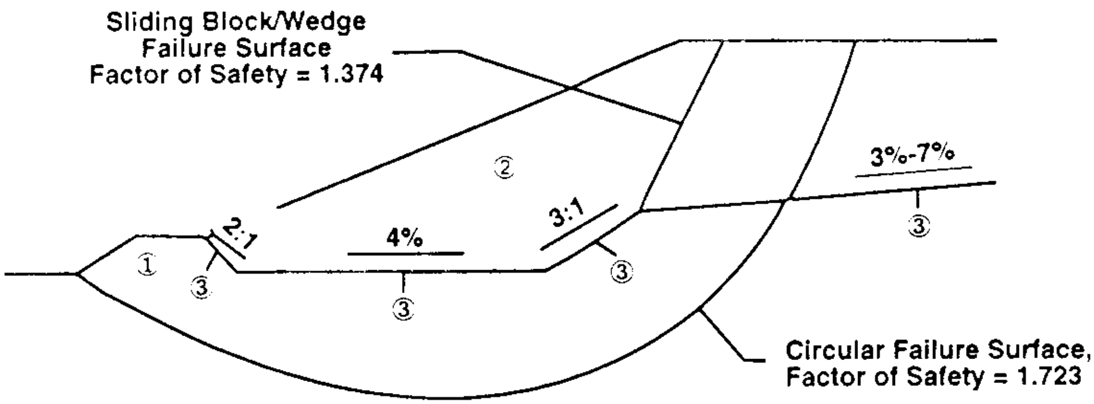
    — The T-shaped cantilever wall design enables some of the retained soil to contribute to the stability of the structure and is advisable for use on slopes that have vertical cuts.

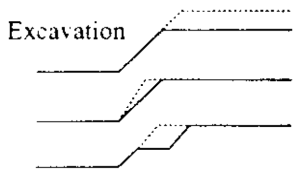
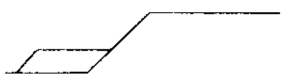
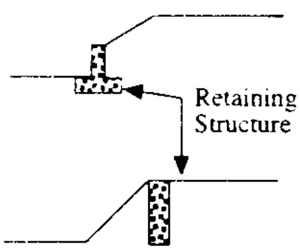
    — Closely-spaced vertical piles placed along the top of the slope area provide reinforcement against slope failure through a soil arching effect that is created between the piles. This type of retaining system is advisable for use on steeply cut slopes.

    — Vertical piles also may be designed with a tie back component at an angle to the vertical to develop a high resistance to lateral forces. This type of wall is recommended for use in areas

Figure 2-7
Sample Output from PC STABL Model

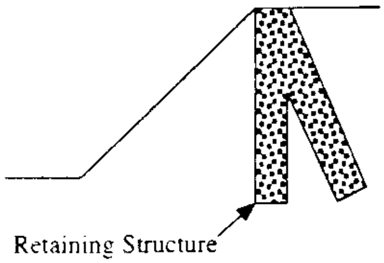
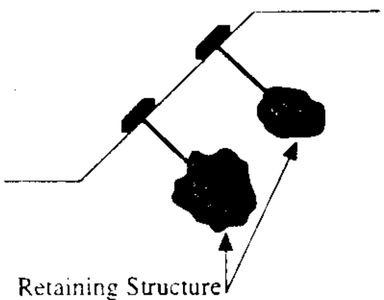
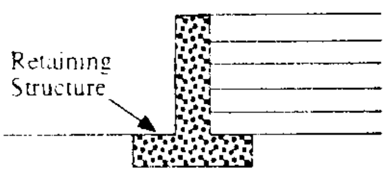
① Subgrade: Internal friction angle = 32 degrees
② Refuse: Internal friction angle of waste = 25 degrees
③ Refuse: Internal friction angle of waste = 25 degrees



Scheme	Applicable Methods	Comments
1. Changing Geometry  	1. Reduce slope height by excavation at top of slope 2. Flatten the slope angle. 3. Excavate a bench in upper part of slope.	1. Area has to be accessible to construction equipment. Disposal site needed for excavated soil. Drainage sometimes incorporated in this method.
2. Earth Berm Fill 	1. Compacted earth or rock berm placed at end beyond the toe. Drainage may be provided behind the berm.	1. Sufficient width and thickness of berm required so failure will not occur below or through the berm.
3. Retaining Structures  	1. Retaining wall: crib or cantilever type. 2. Drilled, cast-in-place vertical piles and/or slabs founded well below bottom slide plane. Generally 18 to 36 inches in diameter and 4- to 8-foot spacing. Larger diameter piles at closer spacing may be required in some cases with mitigate failures of cuts in highly fissured clays.	1. Usually expensive. Cantilever walls might have to be tied back. 2. Spacing should be such that soil can arch between piles. Grade beam can be used to tie piles together. Very large diameter (6 feet±) piles have been used for deep slide.

Source: Soil Mechanics, NAVFAC Design Manual 7.01

Table 2-5
Methods of Stabilizing Excavation Slopes

Scheme	Applicable Methods	Comments
	3. Drilled, cast-in-place vertical piles tied back with battered piles or a deadman. Piles founded well below slide plane. Generally, 12 to 30 inches in diameter and at least 4- to 8-foot spacing.	3. Space close enough so soil will arch between piles. Piles can be tied together with grade beam.
	4. Earth and rock anchors and rock bolts.	4. Can be used for high slopes, and in very restricted areas. Conservative design should be used, especially for permanent support. Use may be essential for slopes in rocks where joints dip toward excavation, and such joints daylight in the slope.
	5. Reinforced earth.	5. Usually expensive
4. Other methods	See TABLE 7, NAVFAC DM-7.2, Chapter 1	

Source: Soil Mechanics, NAVFAC Design Manual 7.01

Table 2-5 (continued)
Methods of Stabilizing Excavation Slopes

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 mass (U.S. Navy, 1986). For more detailed information regarding slope stabilization design, refer to Winterkorn and Fang (1975), U.S. Navy (1986), and Sowers (1979). Richardson and Koerner (1987) and Koerner (1986) provide design guidance for geosynthetics in both landfill and general applications.

Monitoring

During construction activities, it may be appropriate to monitor slope stability 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 piezometers screened in the sensitive strata. 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 principal concern with karst terrains is progressive and/or catastrophic failure of subsurface conditions due to the presence of sinkholes, solution cavities, and subterranean caverns. The unpredictable and catastrophic nature of subsidence in these areas makes them difficult to develop as landfill sites. Before situating a MSWLF in a karst region, the subject site should be characterized thoroughly.

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 include tests using electromagnetic conductivity, seismic refraction, ground-penetrating radar, gravity, and electrical resistivity. Interpretation and applicability of different geophysical techniques should be reviewed by a qualified geophysicist. Often more than one technique should be employed to confirm and correlate findings and anomalies. Subsurface drilling is recommended highly for verifying the results of geophysical investigations.

Additional information on karst conditions can come from remote sensing techniques, such as aerial photograph interpretation. Surface mapping of karst features can help to provide an understanding of structural patterns and relationships in karst terrains. An understanding of local carbonate geology and stratigraphy can aid in the interpretation of both remote sensing and geophysical techniques.

A demonstration that engineering measures have been incorporated into a unit located in a karst terrain may include both initial design and site modifications. A relatively simple engineering modification that can be used to mitigate karst terrain problems is ground-water and surface water control and conveyance. Such water control measures are used to minimize the rate of dissolution within known near-surface limestone. This means of controlling karst development may not be applicable to all karst situations. In areas where development of karst topography tends to be minor, loose soils overlying the limestone may be excavated or 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 option.

In general, due to the unpredictable and catastrophic nature of ground failure in such areas, engineering solutions that try to compensate for the weak geologic structures by constructing manmade ground supports tend to be complex and costly. For example, reinforced raft (or mat) foundations could be used to compensate for lack of ground strength in some karst areas. Raft foundations are a type of "floating foundation" that consist of a concrete footing that extends over a very large area. Such foundations are used where soils have a low bearing capacity or where soil conditions are variable and erratic; these foundations are able to reduce and distribute loads. However, it should be noted that, in some instances, raft foundations may not necessarily be able to prevent the extreme type of collapse and settlement that can occur in karst areas. In addition, the construction of raft foundations can be very costly, depending on the size of the area.

2.8 CLOSURE OF EXISTING MUNICIPAL SOLID WASTE LANDFILL UNITS 40 CFR §258.16

2.8.1 Statement of Regulation

(a) Existing MSWLF units that cannot make the demonstration specified in §§258.10(a), pertaining to airports, 258.11(a), pertaining to floodplains, and 258.15(a), pertaining to unstable areas,

must close by October 9, 1996, in accordance with §258.60 of this part and conduct post-closure activities in accordance with §258.61 of this part.

(b) The deadline for closure required by paragraph (a) of this section may be extended up to two years if the owner or operator demonstrates to the Director of an approved State that:

(1) There is no available alternative disposal capacity;

(2) There is no immediate threat to human health and the environment.

2.8.2 Applicability

These requirements are applicable to all MSWLF units that receive waste after October 9, 1993 and cannot meet the airport safety, floodplain, or unstable area requirements. The owner or operator is required to demonstrate that the facility: (1) will not pose a bird hazard to aircraft under §258.10(a); (2) is designed to prevent washout of solid waste, will not restrict floodplain storage capacity, or increase floodwater flow in a 100-year floodplain under §258.11(a); and 3) can withstand damage to landfill structural component systems (e.g., liners, leachate collection, and other engineered structures) as a result of unstable conditions under §258.15(a). If any of these demonstrations cannot be made, the landfill must close by October 9, 1996. In approved States, the closure deadline may be extended up to two additional years if it can be shown that alternative disposal capacity is not available and that the MSWLF unit does not pose an immediate threat to human health and the environment.

2.8.3 Technical Considerations

The engineering considerations that should be addressed for airport safety, 100-year floodplain encroachment, and unstable areas 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 operators, the landfill unit(s) must be closed according to the requirements of section §258.60 by October 9, 1996.

For MSWLF units located in approved States, this deadline may be extended if there is no immediate threat to human health and the environment and no waste disposal alternative is available. The demonstration of no disposal alternative should consider all waste management facilities, including landfills, municipal waste combustors, and recycling facilities. The demonstration for the two-year extension should consider the impacts on human health and the environment as they relate to airport safety, 100-year floodplains, or unstable areas.

§§258.17-258.19 [Reserved].

2.9 FURTHER INFORMATION

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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.

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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

American Society of Civil Engineers
345 East 47th St.
New York, NY 10017-2398
(212) 705-7496

Building Seismic Safety Council
201 L Street, Northwest Suite 400
Washington, D.C. 20005
(202) 289-7800

Bureau of Land Management
1849 C St. N.W.
Washington, D.C. 20240
(202) 343-7220 (Locator)
(202) 343-5717 (Information)

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)

Hydrologic Engineering Center (HEC Models)
U.S. Army Corps of Engineers
609 Second St.
Davis, CA 95616
(916) 756-1104

National Information Service for Earthquake Engineering (NISEE)
University of California, Berkeley
404A Davis Hall
Berkeley, CA 94720
(415) 642-5113
(415) 643-5246 (FAX)

National Oceanic and Atmospheric Administration
Office of Legislative Affairs
1825 Connecticut Avenue Northwest
Room 627
Washington, DC 20235
(202) 208-5717

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-MAPS

U.S. Geological Survey
Branch of Geologic Risk Assessment
Stop 966 Box 25046
Denver, Colorado 80225
(303) 236-1629

U.S. Geological Survey
EROS Data Center
Sioux Falls, South Dakota 57198
(605) 594-6151

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. PURPOSE. This order provides guidance concerning the establishment, elimination or monitoring of landfills, open dumps, waste disposal sites or similarly titled facilities on or in the vicinity of airports.

2. DISTRIBUTION. This order is distributed to the division level in the Offices of Airport Planning and Programming Airport Safety and Standards, Air Traffic Evaluations and Analysis Aviation Safety Oversight, Air Traffic Operations Service, and Flight Standards Service; to the division level in the regional Airports, Air Traffic, and Flight Standards Divisions; to the director level at the Aeronautical Center and the FAA Technical Center, and a limited distribution to all Airport District Offices, Flight Standards Field Offices, and Air Traffic Facilities.

3. CANCELLATION. Order 5200.5, FAA Guidance Concerning Sanitary Landfills On Or Near Airports, dated October 16, 1974, is canceled.

4. BACKGROUND. Landfills, garbage dumps, sewer or fish waste outfalls and other similarly licensed or titled facilities used for operations to process, bury, store or otherwise dispose of waste, trash and refuse will attract rodents and birds. Where the dump is ignited and produces smoke, an additional attractant is created. All of the above are undesirable and potential hazards to aviation since they erode the safety of the airport environment. The FM neither approves nor disapproves locations of the facilities above. Such action is the responsibility of the Environmental Protection Agency and/or the appropriate state and local agencies. The role of the FAA is to ensure that airport owners and operators meet their contractual obligations to the United States government regarding compatible land uses in the vicinity of the airport. While the chance of an unforeseeable, random bird strike in flight will always exist, it is nevertheless possible to define conditions within fairly narrow limits where the risk is increased. Those high-risk conditions exist in the approach and departure patterns and landing areas on and in the vicinity of airports. The number of bird strikes reported on aircraft is a matter of continuing concern to the FM and to airport management. Various observations support the conclusion that waste disposal sites are artificial attractants to birds. Accordingly, disposal sites located in the vicinity of an airport are potentially incompatible with safe flight operations. Those sites that are not compatible need to be eliminated. Airport owners need guidance in making those decisions and the FM must be in a position to assist. Some airports are not under the jurisdiction of the community or local governing body having control of land usage in the vicinity of the airport. In these areas, the airport owner should use its resources and exert its best efforts to close or control waste disposal operations within the general vicinity of the airport.

5. EXPLANATION OF CHANGES. The following list outlines the major changes to Order 5200.5:

a. Recent developments and new techniques of waste disposal warranted updating and clarification of what constitutes a sanitary landfill. This listing of new titles for waste disposal was outlined in paragraph 4.

b. Due to a reorganization which placed the Animal Damage Control Branch of the U.S. Department of Interior Fish and Wildlife Service under the jurisdiction of the U.S. Department of Agriculture an address addition was necessary

c. A zone of notification was added to the criteria which should provide the appropriate FM Airports office an opportunity to comment on the proposed disposal site during the selection process.

6. ACTION.

a. Waste disposal sites located or proposed to be located within the areas established for an airport by the guidelines set forth in paragraphs 7 a b, and c of this order should not be allowed to operate. If a waste disposal site is incompatible with an airport in accordance with guidelines of paragraph 7 and cannot be closed within a reasonable time, it should be operated in accordance with the criteria and instructions issued by Federal agencies such as the Environmental Protection Agency and the Department of Health and Human Services, and other such regulatory bodies that may have applicable requirements. The appropriate FM airports office should advise airport owners, operators and waste disposal proponents against locating, permitting or concurring in the location of a landfill or similar facility on or in the vicinity of airports.

(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
200 Independence Avenue, SW
Washington, DC 20201

7. CRITERIA. Disposal sites will be considered as incompatible if located within areas established for the airport through the application of the following criteria:

a. Waste disposal sites located within 10,000 feet of any runway end used or planned to be used by turbine powered aircraft

b. Waste disposal sites located within 5,000 feet of any runway end used only by piston powered aircraft.

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