Sanitary Landfill Design and Operation

PDH Credits:

3 PDH

Course No.:

SLD101

Publication Source:

US Corp of Engineers

"Engineering and Design: Sanitary Landfills"
Pub. # EM-1110-3-177

Release Date:
April 1984

ENGINEER MANUAL

EM 1110-3-177
April 1984

ENGINEERING AND DESIGN

SANITARY LANDFILL

MOBILIZATION CONSTRUCTION

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
OFFICE OF THE CHIEF OF ENGINEERS

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DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, D.C. 20314

EM 1110-3-177

Engineer Manual
No. 1110-3-177

9 April 1984

Engineering and Design
SANITARY LANDFILL
Mobilization Construction

1. Purpose. This manual provides guidance for the construction and operation of sanitary landfills at U.S. Army mobilization facilities.

2. Applicability. This manual is applicable to all field operating activities having mobilization construction responsibilities.

3. Discussion. Criteria and standards presented herein apply to construction considered crucial to a mobilization effort. These requirements may be altered when necessary to satisfy special conditions on the basis of good engineering practice consistent with the nature of the construction. Design and construction of mobilization facilities must be completed within 180 days from the date notice to proceed is given with the projected life expectancy of five years. Hence, rapid construction of a facility should be reflected in its design. Time-consuming methods and procedures, normally preferred over quicker methods for better quality, should be de-emphasized. Lesser grade materials should be substituted for higher grade materials when the lesser grade materials would provide satisfactory service and when use of higher grade materials would extend construction time. Work items not immediately necessary for the adequate functioning of the facility should be deferred until such time as they can be completed without delaying the mobilization effort.

FOR THE COMMANDER:

PAUL F. KAVANAUGH
Colonel, Corps of Engineers
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U. S. Army Corps of Engineers
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CHAPTER 1

GENERAL

1-1. Purpose and scope. This manual prescribes methods and guidance for the construction and operation of sanitary landfills at Army mobilization facilities.

1-2. Regulatory requirements. The minimum legal requirements for all Solid Waste Disposal facilities will be in accordance with PL 94-580 and with 40 CFR 257. The criteria presented herein represent minimum design criteria which will meet the legal requirements in most cases. In instances where the local conditions or guidelines (state and local, etc.) require the use of more stringent criteria than related herein, those criteria will apply.

1-3. Health and safety objectives. Solid wastes ordinarily contain many contaminants which can produce serious health hazards or nuisances. The engineering design must result in a sanitary landfill which, when operated correctly, will preclude the following:

- Pollution of surface and ground waters.
- Air pollution by odor, dust, or smoke.
- Infestation by rats, flies, or other vermin.
- Other nuisance factors such as noise.
- Fires.
- Explosive hazard from migrating and/or collecting methane generated within the fill.

1-4. Solid waste stabilization in a sanitary landfill. The decomposition of organic material in a sanitary landfill is usually anaerobic, and the end products are primarily gases and moist humus material. Typically the gases are methane and hydrogen (both of which can be explosive), carbon dioxide, nitrogen, and hydrogen sulfide. The rate of stabilization is difficult to predict and depends on many factors including climate, moisture of the refuse, and degree of compaction.

CHAPTER 2

SITE SELECTION

2-1. General. Selection of a site is the most critical step in establishing a landfill disposal facility. For mobilization work the primary consideration is to dispose of solid waste as quickly and safely as possible. Therefore, concerns such as aesthetic, socio-economic, and ultimate use of the land factors will not be considered except where a direct effect on health-related factors will result.

2-2. Selection factors. Site selection for a sanitary landfill must be accomplished in consideration of the following:

a. Available land area. Based on the criteria presented herein, sufficient land must be available to service the 5-year design life of the mobilization facility. All zoning ordinances should be reviewed and cleared or changed to eliminate any legalities that could prevent or indefinitely hold up the use of a particular parcel of land for a sanitary landfill.

b. Haul distance. The landfill siting must be a balance between adequate distance from housing and work areas and economical haul distance. The landfill should be sited at least 750 feet from inhabited buildings and preferably so that prevailing winds are away from living areas. Adequate clearance from areas of brush and trees to prevent spread of possible fires should be provided.

c. Access to the site. Sites should be accessible to appropriate vehicles by all-weather roads leading from the public or mobilization camp road systems.

d. Vicinity of airports. Sites located in the vicinity of airports, where birds attracted to the landfill disposal facility could pose a hazard to aircraft, should be avoided.

e. Sites traversed by utilities. Sites traversed by pipes, conduits, or power lines should not be considered unless the relocation of the utility is feasible.

f. Soil and cover material. It is essential for satisfactory operation of the sanitary fill that soil conditions be suitable for preventing ground water pollution, excavating and covering the fill, and vehicle access. A soil investigation is required to determine the suitability of the area to receive the fill and the availability of cover material. Factors to consider in evaluating the soil are discussed below.

(1) Excavation. Generally cover material must be excavated, and the excavation thus formed often can be filled with solid waste.

Whether the excavation is for cover material or for a trench, it is desirable that the soil be readily excavated with the equipment available at the installation. Areas with shallow rock, hardpan, or large boulders will normally not be acceptable.

(2) Cover. Proper cover material must be available to seal the fill against infiltration and insure anaerobic conditions. An efficient seal will also control odors and prevent access to the waste by rodents and insects. Soil for cover material should not contain appreciable quantities of organic material and should be relatively free of stones larger than about 6 inches. The soil must be effectively compacted by equipment which is to be used in the operation. Soil with a relatively uniform particle size is not as readily compacted as soil containing particles with a wide range of sizes. Unless specially treated, pure sands, clays, or silts are not suitable for covering a sanitary landfill. The soil should support truck traffic throughout the year. The soil should be low in clay content for ease of changing moisture content and to avoid surface cracking. Generally a silty sand or clayey sand is preferable, but any soil which will form an effective seal is acceptable.

g. Topographic conditions. The local topography must be considered because it will affect the type of landfill operation to be used, the equipment requirements, and the extent of work necessary to make the site usable.

h. Surface-water hydrology. The existing natural drainage and runoff characteristics of the area under investigation must be considered. Therefore, the local surface water hydrology of the area becomes important. Other conditions of flooding must also be identified. Landfill disposal facilities should be located where the potential for surface drainage onto the landfill from adjacent land is minimal.

i. Geologic and hydrogeologic conditions. Geologic and hydrogeologic conditions are important parameters in establishing the environmental compatibility of the area for a landfill site. Although difficult to ascertain at times, data on these factors are necessary to assess the pollution potential of the proposed site and to establish what must be done to the site to insure that the movement of leachate or gases from the landfill will not adversely affect the quality of local ground water or contaminate other subsurface or bedrock aquifers. Highly permeable formations such as sand, gravel, porous rock, karst, and fissured bedrock are undesirable subgrades for sanitary landfills. More impermeable soils such as clay would be desirable if the material has not nor will not experience drying and cracking. For the preliminary assessment of sites, United States Geological Survey maps and state or local geologic data may provide useful information. Logs of nearby wells should also be reviewed.

j. Environmentally sensitive areas. Environmentally sensitive areas, including wetlands, 100-year floodplains, permafrost areas, critical habitats of endangered species, fault zones, and recharge zones of sole source aquifers should be avoided or receive lowest priority as potential locations for landfill disposal facilities.

CHAPTER 3

SANITARY LANDFILL DESIGN

3-1. General. The designing of a sanitary landfill calls for developing a detailed description and plans that outline the steps to be taken to provide for the safe, efficient disposal of the quantities and types of solid wastes that are expected to be received. The designer outlines volume requirements, site improvements (clearing of the land, construction of roadways and buildings, fencing, utilities), and all the equipment necessary for day-to-day operations of the specific landfilling method involved. He also provides for controlling water pollution and the movement of decomposition gas.

3-2. Data for sanitary landfill planning.

a. Waste characteristics. The data on the solid waste for which disposal is required are: the types of waste, the amounts, and the variations in delivery rates. When possible, the information should be based on an analysis of solid wastes from the installation on which the project is located, or from a similar installation. For new installations, an analysis can be made based on the population to be served and other major sources of solid waste. The daily per capita quantity of solid waste for mobilization facilities will be 3 to 4 pounds of combined refuse and garbage. This rate is based on effective population which is the sum of the resident population plus one-third of the nonresident employees.

b. Operation equipment. Information on the equipment to be used, both for refuse delivery and sanitary landfill operation is required. This will include any planned changes in equipment. The capabilities of this equipment must be considered in evaluating factors such as access roads, grades, drainage, and operation in severe climates.

c. Operational methods. Methods of operating a landfill could have an effect on landfill design. Therefore, the desired method of operation should be reviewed before design commences.

3-3. Volume requirements. If the rate at which solid wastes are collected and the capacity of the proposed site are known, its useful life can be estimated.

a. Waste-to-cover ratio. The ratio of solid waste to cover material volume usually ranges between 4:1 and 3:1; it is, however, influenced by the thickness of the cover used and cell configuration. If cover material is not excavated from the fill site, this ratio may be compared with the volume of compacted soil waste and the capacity of a site determined from figure 3-1. For example, a facility having a 10,000 population and a per capita collection rate of 4 pounds per day must dispose of, in 1 year, approximately 16 acre-feet of solid waste

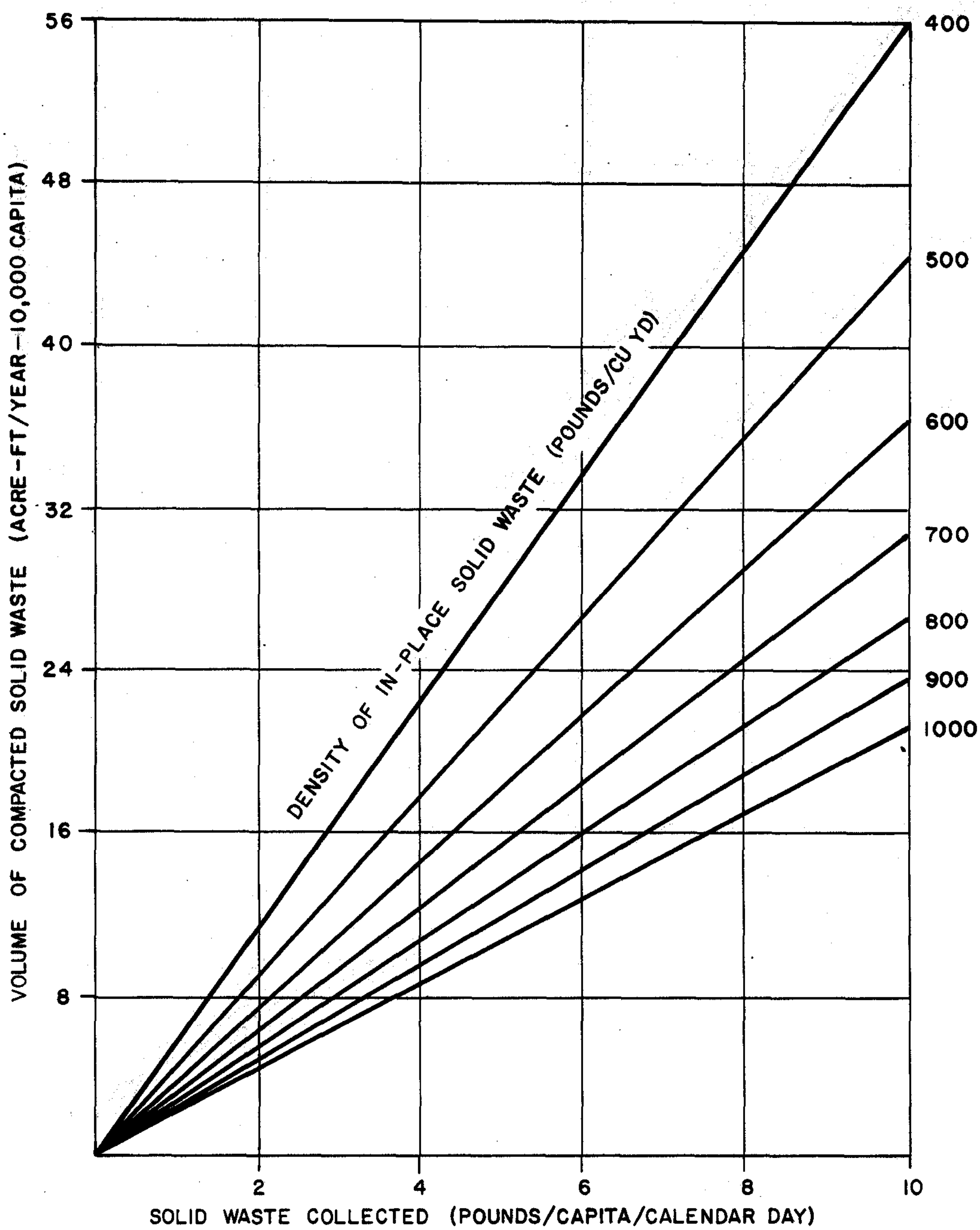

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FIGURE 3-1. YEARLY VOLUME OF COMPACTED SOLID WASTE FOR A FACILITY OF 10,000 PERSONS if it is compacted to 600 pounds per cubic yard. If it were compacted to only 400 pounds per cubic yard, the volume disposed of in 1 year would occupy nearly 24 acre-feet. The volume of soil required for the 600-pound density at a solid waste-to-cover ratio of 4:1 would be 4.0 acre-feet; the 400-pound density waste would need 6.0 acre-feet. A density of 600 pounds per cubic yard will be used for mobilization design and operation.

b. Estimate of volume. The number of tons to be disposed of at a proposed sanitary landfill can be estimated by multiplying the effective population by the daily per capita quantity, then dividing by 2,000 pounds per ton. The daily volume of compacted solid waste can then be determined by using figure 3-2. The volume of soil required to cover each day's waste is then estimated by using the appropriate solid waste-to-cover ratio.

c. Densities. Solid waste density (field density) is the weight of a unit volume of solid waste in place. Landfill density is the weight of a unit volume of in-place solid waste divided by the volume of solid waste and its cover material. Both methods of reporting density are usually expressed as pounds per cubic yard, on an in-place weight basis, including moisture, at time of the test, unless otherwise stated.

3-4. Site improvements. The plan for a sanitary landfill should prescribe how the site will be improved to provide an orderly and sanitary operation. This may simply involve the clearing of shrubs, trees, and other obstacles that could hinder vehicle travel and landfilling operations or it could involve the construction of buildings, roads, and utilities.

a. Clearing and grubbing. Trees and brush that hinder landfill equipment or collection vehicles must be removed. Trees that cannot be pushed over should be cut as close as possible to the ground so that the stumps do not hinder compaction or obstruct vehicles. Brush and tall grass in working areas can be rolled over or grubbed. A large site should be cleared in increments to avoid erosion and scarring of the land.

b. Roads. Roads should be provided from the public road system to the site. A large site may have to have all-weather roads that lead from its entrance to the vicinity of the working area. They should be designed to support the anticipated volume of truck traffic. In general, the roadway should consist of two lanes (total minimum width, 24 feet), for two-way traffic. Grades should not exceed equipment limitations. For loaded vehicles, most uphill grades should be less than 7 percent and downhill grades less than 10. Temporary roads are normally used to deliver wastes to the working face from the permanent road system because the location of the working face is constantly changing. Temporary roads may be constructed by compacting the natural

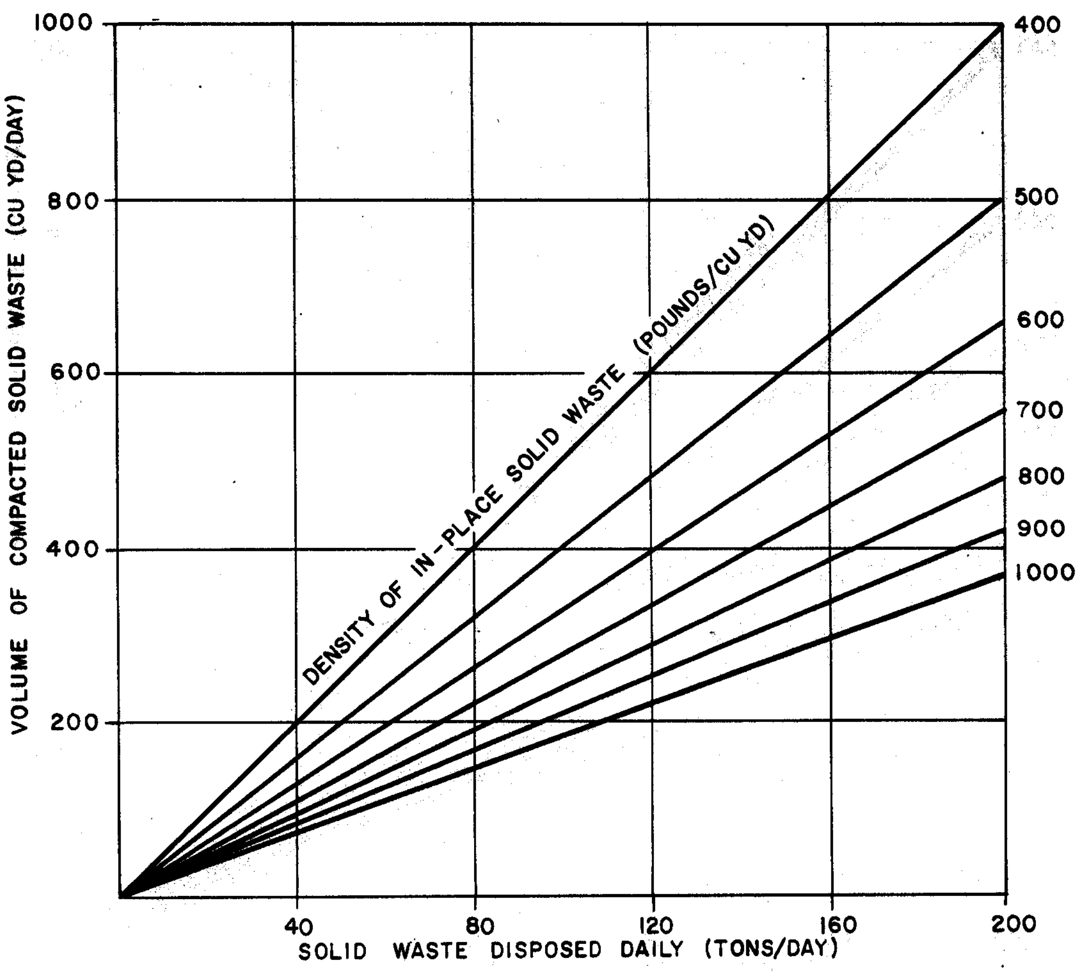

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FIGURE 3-2. DAILY VOLUME OF COMPACTED SOLID WASTE soil present and by controlling drainage or by topping them with a layer of a tractive material, such as gravel, crushed stone, cinders, broken concrete, mortar, or bricks. Lime, cement, or asphalt binders may make such roads more serviceable. If fewer than 25 round trips per day to the landfill are expected, a graded and compacted soil will usually suffice. More than 50 round trips per day generally justifies the use of calcium chloride as a dust inhibitor or such binder materials as soil cement or asphalt. A base course plus a binder is desirable if more than 100 to 150 round trips per day are anticipated.

c. Buildings. A building or construction-type field trailer should be provided for office space and employee facilities. Since a landfill operates in wet and cold weather, some protection from the elements should be provided. Operational records may also be kept at the site. Sanitary facilities should be provided for both landfill and collection personnel. Buildings should be temporary types and, preferably, be movable. The design and location of all structures should consider gas movement and differential settlement caused by the decomposing solid waste.

d. Utilities. All sanitary landfill sites should have electrical, water, and sanitary services. Remote sites may have to extend existing services or use acceptable substitutes. Portable chemical toilets can be used to avoid the high cost of extending sewer lines; potable water may be trucked in, and an electric generator may be used instead of having power lines run into the site. Water should be available for drinking, fire fighting, dust control, and employee sanitation. A sewer line may be called for, especially at large sites and those where leachate is collected and treated with domestic wastewater. Telephone or radio communications are also desirable.

e. Fencing. Peripheral and litter fences are commonly needed at sanitary landfills. The first type is used to control or limit access, keep out children and animals, screen the landfill, and delineate the property line. If vandalism and trespassing are to be discouraged, a 6-foot high fence topped with three strands of barbed wire projecting at a 45 degree angle is desirable. A wooden fence or a hedge may be used to screen the operation from view. Litter fences are used to control blowing paper in the immediate vicinity of the working face. As a general rule, trench operations require less litter fencing because the solid waste tends to be confined within the walls of the trench. At a very windy trench site, a 4-foot snow fence will usually suffice. Blowing paper is more of a problem in an area operation; 6-to 10-foot litter fences are often needed. Since the location of the working face shifts frequently, litter fences should be movable.

3-5. Control of surface water. Control of surface water runoff at a landfill disposal facility is necessary in order to minimize the potential for environmental damage to ground and surface waters by direct and indirect effects. Direct surface water contamination can result from solid waste and other dissolved or suspended contaminants carried by surface runoff. Uncontrolled surface runoff can also contribute to leachate and gas generation, thereby increasing the potential for both surface and ground water contamination. Surface water courses should be diverted from the sanitary landfill and there should be no uncontrolled hydraulic connection between the landfill and standing or flowing surface water.

a. Seasonal variations. Quality, quantity, source, and seasonal variations of surface waters in the vicinity of the landfill disposal facility should be established to serve as a basis for design of any necessary surface water protection systems. Counseling and guidance in planning water management measures are available through local soil conservation districts upon request.

b. Piping and channels. Pipes may be used in gullies, ravines, and canyons that are being filled to transmit upland drainage through the site and open channels employed to divert runoff from surrounding areas (fig 3-3). Portable or permanent drainage channels may be constructed to intercept and remove runoff water. Low-cost, portable drainage channels can be made by bolting together half-sections of corrugated steel pipes. Surface water that runs off stockpiled cover material may contain suspended solids and should not be allowed to enter watercourses unless it has been ponded to remove settleable solids.

c. Sump pumps. Sump pumps may also be used. Because of operating and maintenance requirements, the use of mechanical equipment for water control is, however, strongly discouraged unless the control is needed only temporarily. If trenches or depressions are being filled, collection sumps and pumps may be used to keep them from flooding.

d. Flood plains. A dike with sufficient structural integrity should be constructed around any landfill disposal facility located within the 100-year floodplain of sufficient height to prevent inundation. Subsurface controls may also be necessary to prevent intrusion of water resulting from the temporary elevated ground water table during flooding. The top of the dike should be wide enough for maintenance work to be carried out and may be designed for use by collection and landfill vehicles.

e. Incident precipitation. Similar to surface runoff from surrounding areas, incident precipitation falling onto a landfill can result in two effects, namely, increased leachate generation and erosion of cover soil and solid waste. Techniques to carry incident precipitation from the landfill without causing erosion should be applied as follows:

(1) The final cover of the landfill should be graded such that water does not pool over the landfill. In order to minimize soil erosion, the final grade should not exceed 30 percent. Slopes longer

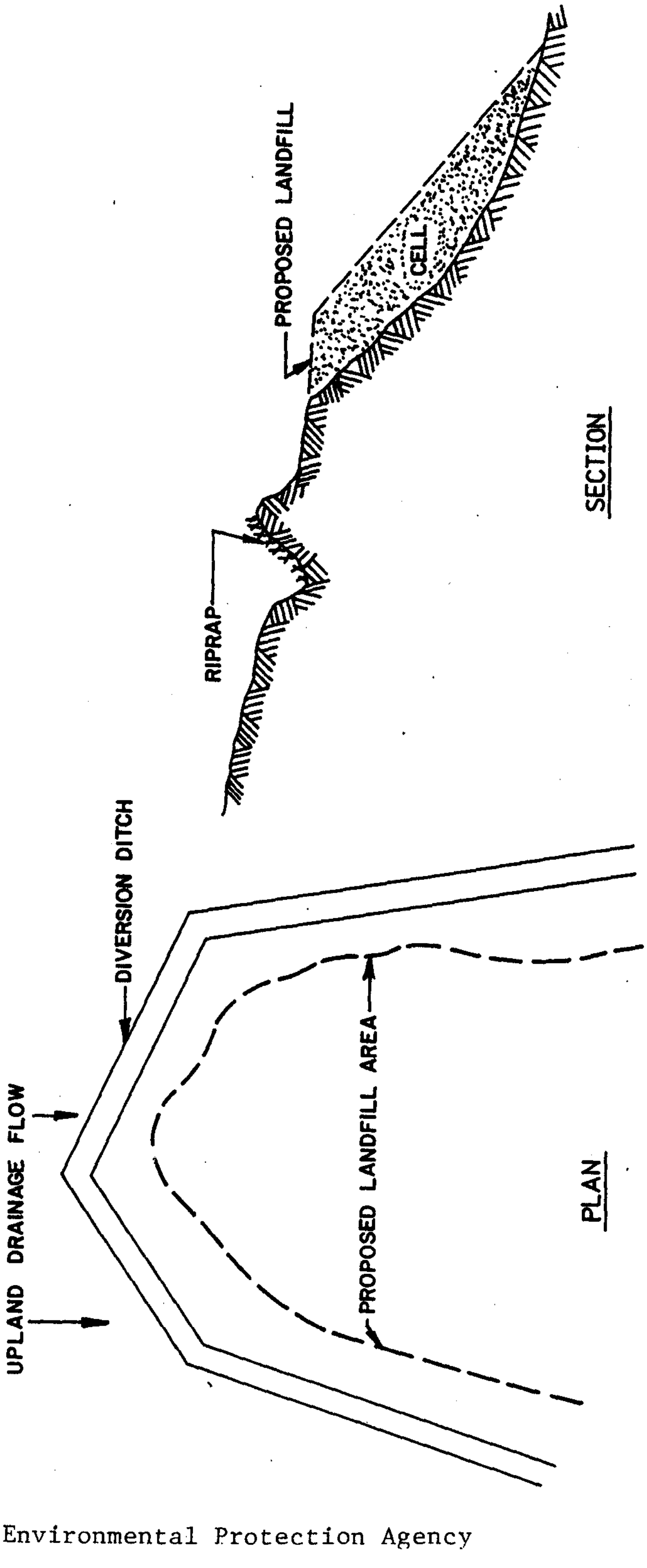

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FIGURE 3-3. PLAN AND SECTION VIEWS OF SURFACE WATER CONTROL than 25 feet may require additional erosion control measures, such as construction of horizontal terraces, of sufficient width for equipment operation, for every 20 feet rise in elevation. Minimum slope, including terraces, should be 2 percent.

(2) The final soil cover on a completed landfill disposal facility should be seeded or otherwise vegetated to minimize erosion and maximize evapotranspiration.

(3) If landfill site design incorporates minimization of leachate generation, a low permeability cover soil with a low swell and shrink tendency upon wetting and drying should be utilized to avoid cracking.

3-6. Ground water protection.

a. Ground water uses. Current and projected use of ground water resources in the vicinity of the landfill disposal facility should be determined as a basis for design of any necessary ground water protection system as follows:

(1) Establish initial (background) quality of water resources in the potential zone of influence. If ground water analyses determine that the total dissolved solids (TDS) content of the water is greater than 10,000 mg/l, then it shall be termed unusable and no protection of the ground water will be required.

(2) Establish the depth to the water table and the direction and rate of ground water flow with consideration of withdrawal rates by ground water users.

(3) Establish potential interactions of the landfill disposal facility, its hydrogeology, and the real ground and surface waters, based upon historical records and other sources of information.

b. Leachate control measures. Landfill leachate generation cannot be avoided except in some arid climates; therefore, leachate control measures for water quality protection should be incorporated in the site design when the ground water has been determined to be usable. Leachate control, when necessary with site design, should be accomplished through application of one or more of the following practices:

(1) Unless underlying ground water is determined to be unusable as a drinking water or other supply source and therefore not in need of protection, the bottom of a landfill disposal facility should be substantially (5 feet or more) above the seasonal high ground water table, to prevent direct contact of disposed solid waste and the ground water.

(2) A liner may be employed to control the movement of fluids, and many types of material can function successfully in this capacity. The rate of passage of leachate through liner materials is a function of the measured permeability of the material and the depth (or head) of leachate on the liner. In general, the rate of flow increases with depth of leachate.

(a) The variety of liner materials available include naturally occurring materials such as clays, amended natural materials such as soil cements, and artificial materials such as asphaltic materials and polymeric membranes.

(b) Liner materials which are to significantly restrict the flow of leachate from the bottom of the landfill should have the following properties.

- Permeability of 1 X 10^{-7} cm/second (about 0.1 foot/year) or less.

- Ability to resist physical and chemical attack by leachate.

- Capability of maintaining integrity for the design life.

- The practical minimum thickness for natural soil liners is 12 inches.

- The practical minimum thickness for synthetic membrane liners is 20 mils.

(c) Artificial liner material, if selected, should be placed upon a carefully prepared base of selected material which will prevent liner puncture while providing uniform support and should be covered with suitable material that will further protect the liner from damage and provide a drainage blanket for the leachate collection system. Approximately 2 feet of material is effective in protecting a liner from mechanical damage (puncture). The lowest 6 inches of material should be highly permeable to allow the leachate collection system to function properly.

(d) Removal of leachate collected on a liner should be incorporated into the design of a lined landfill to avoid surface seepage and relieve hydraulic pressure on the liner. To facilitate leachate removal, liner materials should be sloped to one or more points and covered with a layer of highly permeable material such as pea gravel. A grade of 1 percent or more should be utilized.

(e) Once collected, landfill leachate should be disposed to the land or surface water in an environmentally sound manner to protect surface and ground water quality. (Public Law 92-500 requires a permit for the discharge of collected leachate to surface water.)

- Leachate treatment and disposal should consist, as a minimum, of a lined waste stabilization pond with controlled discharge.

- Raw or treated landfill leachate should be discharged into a municipal or industrial wastewater treatment system only if this discharge will not impede the operation of the wastewater treatment system. Limited experience has shown that when raw municipal solid waste leachate volume exceeds about 5 percent of the total wastewater treatment plant flow, interruption of biological treatment processes may occur.

- Raw or treated leachate can be disposed by controlled application onto the surface of the land provided sufficient acreage is available and hydrology, soil type, vegetation, topography, and climate for leachate disposal have been considered, and surface or ground water contamination will not occur.

- Recirculation of collected landfill leachate onto active or completed sections of the landfill can reduce leachate constituent concentrations by chemical and biological processes and may be effective in reducing leachate volume. This technique can result in, at least, partial stabilization of young (0 to 5 years) landfill leachates which are relatively concentrated in comparison with rather old stabilized landfill leachates.

3-7. Gas control. Control of gases from a landfill disposal facility may be accomplished by techniques which: minimize the production of decomposition gases or occurrence of other harmful gases, control the escape of gases into the atmosphere, and minimize the migration of gases into soils surrounding the site. Gas control should be accomplished in accordance with the following:

a. Minimize infiltration. Leachate and runoff control measures which are intended to minimize the infiltration of water into a solid waste landfill may also reduce gas generation, primarily CH_4 and CO_2 resulting from decomposition of disposed organic solid waste.

b. Prohibit volatile substances. Volatile solid waste materials or wastes with a known high potential for release of harmful gases as a result of chemical reaction should not be accepted for disposal at a landfill disposal facility where such gases are normally required to be minimized or avoided.

c. Encapsulate the solid waste. Encapsulation of solid waste in a landfill (e.g., low permeability liner and final cover) to prevent or minimize infiltrating water should be coupled with an effective ventilation system to remove decomposition gas from the landfill, as necessary.

d. Allow vertical migration of gases. If a relatively porous material is used for cover at a landfill, which does not impede infiltrating water, gases should migrate vertically out of the landfill surface, except when frozen or saturated, for dissipation into the atmosphere. However, deep landfills may experience gas pressure buildup, regardless of cover used.

e. Review surrounding land area. Since horizontal migration of gases from landfills (due to both diffusion and pressure gradients) through surrounding soils is common, a review of the land area surrounding the landfill proper should be performed. For shallow landfills, a "rule of thumb" for estimating potential gas migration is a distance equal to 10 times the maximum depth of the landfill below original grade. If nearby underground utilities exist, additional reviews along the utility corridor should be performed.

f. Passive barriers. Passive barriers which may be considered for the prevention of horizontal migration of gases include:

(1) Cutoff walls constructed of naturally occurring materials, such as compacted moist clays, or artificial materials, such as asphaltic or polymeric materials.

(a) To assure effectiveness, the cutoff wall should extend from the ground surface down to a gas impervious layer (e.g., bedrock or ground water) below the bottom of the landfill.

(b) Even though polymeric materials may be virtually impermeable to water, they should be evaluated for permeability to gases.

(c) Even when compacted, clays and other soils are impermeable to gases only when water saturated.

(2) Venting systems, installed either on or off the landfill proper, consist of either gravel-filled trenches, perforated pipes, or both.

(a) Perforated pipes have been shown to be of limited effectiveness except in the immediate vicinity of the pipe and are therefore not recommended for reduction of pressure in a landfill, when used alone.

(b) Gravel-filled trenches, while generally more effective than perforated pipes, still permit some migration of gases across the trench, especially when covered by snow or ice.

(c) Gravel-filled trenches equipped with vertical perforated pipes have been shown to reduce the effect of temporary covers such as ice or snow but remain of limited effectiveness in landfill gas migration control.

(d) Gravel-filled trenches must usually be equipped for removal of water or leachate from the trench bottom and are susceptible to plugging by biomass buildup.

(3) Combination passive barriers installed off the landfill, which consist of gravel-filled trenches in combination with an impermeable barrier installed on the side of the trench opposite the landfill, provide good protection against horizontal gas migration when keyed to a gas impermeable strata below the landfill.

3-8. Plans for design, construction, operations, and maintenance of sites. Plans for design, construction, operations, and maintenance of sites should include:

a. Evidence. Evidence of compliance with applicable state and Federal regulations.

b. Detailing. Careful detailing of all design and operational considerations necessary to bring site conditions to an acceptable level.

c. Presentation and discussion. A clear presentation and discussion of any separate areas which have been incorporated into the landfill design for disposal of specific wastes requiring special or separate handling.

d. Other. Other pertinent information, such as:

(1) Initial and final topographies at contour intervals of 5 feet or less as specified by the state and local regulatory authorities.

(2) Land use and zoning within, at least, one-quarter mile of the site showing the location of all private wells, water courses, rock outcroppings, roads, and buildings.

(3) Location of all airports within 2 miles of the site.

(4) Location of all utilities within, at least, 500 feet of the site.

(5) Temporary and permanent all-weather access roads.

(6) Screening and other nuisance control measures.

(7) Narrative descriptions, with associated technical drawings, indicating site development and operation procedures.

(8) Contingency plans.

3-9. Cover material. The cover material selected should provide for a balance among the major functions of:

- Vehicle traffic.
- Water infiltration control.
- Gas migration control.
- Fire resistance.
- Erosion control.
- Vector control.
- Support of vegetation.

CHAPTER 4

SANITARY LANDFILL OPERATIONS

4-1. General. Proper site selection and design alone are insufficient to result in a landfill which provides for the protection of public health and the environment. To achieve such protection, operation of a landfill should be based upon these guidelines or other equivalent practices.

4-2. Criteria. A facility for the landfill disposal of solid waste should be operated in accordance with the following:

a. Acceptable wastes. In general, only wastes for which the facility has been specifically designed should be accepted for disposal; however, other wastes may be accepted if it has been demonstrated to the responsible agency that they can be satisfactorily disposed within the design capability or after appropriate facility modifications.

(1) Specific wastes, whose chemical, biological or physical characteristics are not compatible with disposal site design, location, or operation and which could pose an unacceptable environmental or health effect or pose a threat to the safety of personnel or users of the facility, should be prohibited from acceptance for disposal.

(2) PL 94-580 restricts the acceptance of any hazardous waste to landfills which were not specifically designed for that waste. Designer should note which of these wastes may be handled at each facility, and operating personnel should be made aware of any restrictions.

b. Cover material. Cover material should be applied, as necessary, to minimize fire hazards, odors, blowing litter, vector food and harborage; control gas venting and infiltration of precipitation; discourage scavenging; and provide an aesthetic appearance.

(1) A minimum of 6 inches of soil cover material should be applied daily.

(2) Cells which will not have additional wastes placed on them for 3 months or more should be covered with 12 inches of cover material.

(3) Most soil materials can satisfy the purpose of cover soil. However, if minimization of infiltration is necessary, relatively low permeability cover material should be utilized and placed at the steepest allowable grade in order to encourage runoff. Low permeability soils will remain effective only if the soil has a low

shrink-swell potential or if the soil moisture can be maintained to prevent cracks from shrinkage and swelling.

(4) The completed landfill should be covered with 6 inches of clay or other suitable material with permeability equal to or less than 1 X 10^{-7} cm/second or equivalent, followed by a minimum cover of 18 inches of additional soil to complete the final cover and support vegetation. Deeply rooted vegetation may require an even greater depth of suitable soil.

c. Compaction. In order to conserve landfill disposal site capacity and preserve land resources, solid wastes should be incorporated into the landfill in the smallest practicable volume.

(1) For most solid waste materials, landfill compaction equipment is necessary for volume reduction.

(2) Compaction or other volume reduction may take place at or before delivery to the landfill, by utilizing balers, shredders, or stationary compactors.

(3) Compaction of solid waste and cover soil reduces the attraction of rodents and vectors and the potential for fires.

(4) Open burning of solid waste for volume reduction should not be practiced at landfill disposal facilities.

4-3. Landfilling methods. The designer of a sanitary landfill should prescribe the method of construction and the procedures to be followed in the disposing of the solid waste, because there is no "best method" for all sites. The method selected depends on the physical conditions involved and the amount and types of solid waste to be handled. The two basic landfilling methods are trench and area; other approaches are only modifications. In general, the trench method is used when the ground water is low and the soil is more than 6 feet deep. It is best employed on flat or gently rolling land. The area method can be followed on most topographies and is often used if large quantities of solid waste must be disposed of. At many sites, a combination of the two methods is used.

a. Cell construction. The building block common to both methods is the cell. All the solid waste received is spread and compacted in layers within a confined area. At the end of each working day, or more frequently, it is covered completely with a thin, continuous layer of soil, which is then also compacted. The compacted waste and soil cover constitute a cell. A series of adjoining cells all of the same height makes up a lift (fig 4-1). The completed fill consists of one or more lifts.

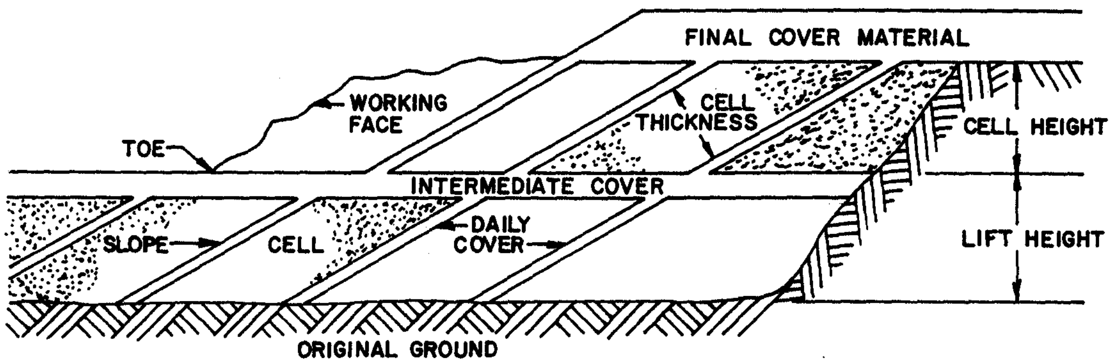

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FIGURE 4-1. SANITARY LANDFILL CONSTRUCTION

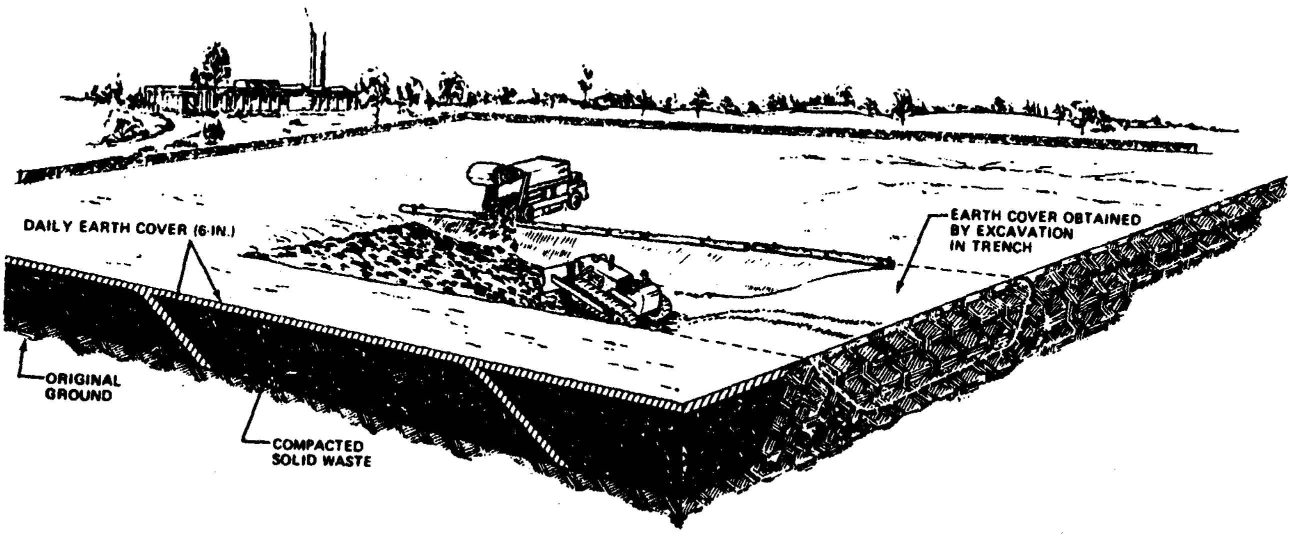
(1) The dimensions of the cell are determined by the volume of the compacted waste, and this, in turn, depends on the density of the in-place solid waste. The field density of most compacted solid waste within the cell for mobilization work should be at least 600 pounds per cubic yard. Higher figures may be difficult to achieve if trimmings from bushes and trees, plastic turnings, or synthetic fibers predominate. Because these materials normally tend to rebound when the compacting load is released, they should be spread in layers up to 2 feet thick, then covered with 6 inches of soil. Over this, mixed solid waste should be spread and compacted. The overlying weight keeps the fluffy or elastic materials reasonably compressed.

(2) An orderly operation should be achieved by maintaining a narrow working face (that portion of the uncompleted cell on which additional waste is spread and compacted). It should be wide enough to prevent a backlog of trucks waiting to dump, but not be so wide that it becomes impractical to manage properly--never over 150 feet.

(3) The height of a cell is not restricted. However, operations must be such that the required cover material is placed and compacted on a daily basis.

b. Cover material. Cover material volume requirements are dependent on the surface area of waste to be covered and the thickness of soil needed to perform particular functions. Cell configuration can greatly affect the volume of cover material needed. The surface area to be covered should therefore be kept minimal. In general, the cell should be about square, and its sides should be sloped as steeply as practical operation will permit. Side slopes of 20 to 30 degrees will not only keep the surface area, and hence the cover material volume, at a minimum but will also aid in shredding and obtaining good compaction of solid waste, particularly if it is spread in layers not greater than 2 feet thick and worked from the bottom of the slope to the top.

c. Trench method. Waste is spread and compacted in an excavated trench. Cover material, which is taken from the spoil of the excavation, is spread and compacted over the waste to form the basic cell structure (fig 4-2). In this method, cover material is readily available as a result of the excavation. Spoil material not needed for daily cover may be stockpiled and later used as a cover for an area fill operation designed for the top of the completed trench fill operation. Cohesive soils, such as glacial till or clayey silt, are desirable for use in a trench operation because the walls between the trenches can be thin and nearly vertical. The trenches can, therefore, be spaced very closely. Weather and the length of time the trench is to remain open also affect soil stability and must, therefore, be considered when the slope of the trench walls is being designed. If the trenches are alined perpendicularly to the prevailing wind, this can greatly reduce the amount of blowing litter. The trench can be as deep as soil and ground water conditions safely allow, and it should be



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THE WASTE COLLECTION TRUCK DEPOSITS ITS LOAD INTO THE TRENCH WHERE THE BULLDOZER SPREADS AND COMPACTS IT. AT THE END OF THE DAY SOIL IS EXCAVATED FROM THE FUTURE TRENCH AND USED AS THE DAILY COVER MATERIAL.

FIGURE 4-2. TRENCH METHOD

at least twice as wide as any compacting equipment that will work in it. The equipment at the site may excavate the trench continuously at a rate geared to landfilling requirements. At small sites, excavation may be done on a contract basis.

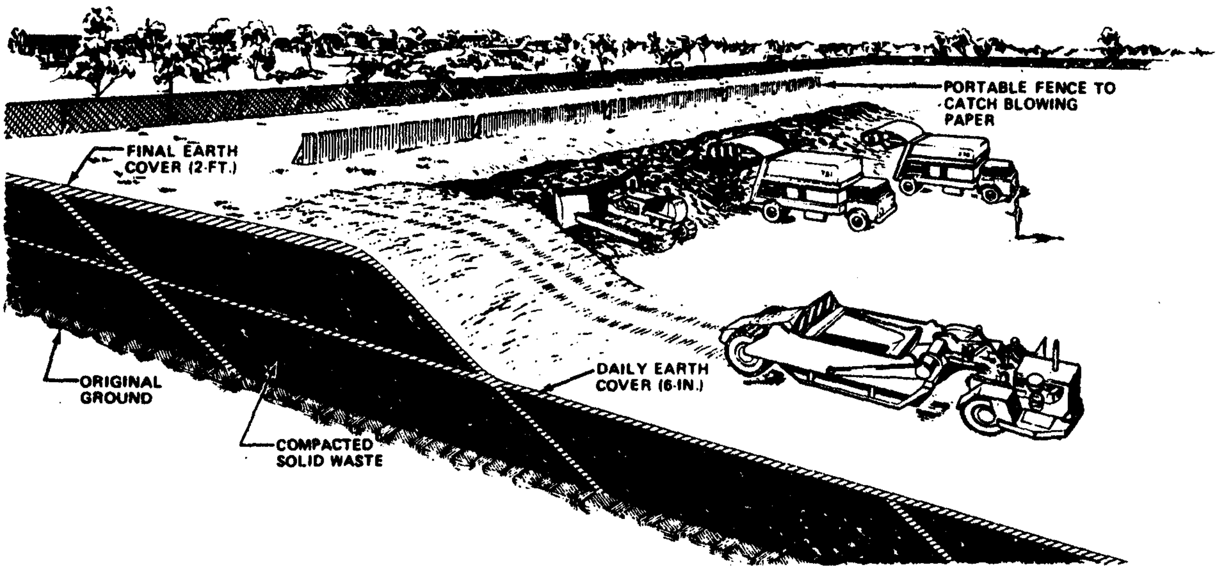
d. Area method. In this method, the waste is spread and compacted on the natural surface of the ground, and cover material is spread and compacted over it (fig 4-3). The area method is used on flat or gently sloping land and also in quarries, strip mines, ravines, valleys, or other land depressions.

e. Combination methods. A sanitary landfill does not need to be operated by using only the area or trench method. Combinations of the two are possible, and flexibility is, therefore, one of sanitary landfilling's greatest assets. The methods used can be varied according to the constraints of a particular site.

(1) One common variation is the progressive slope or ramp method, in which the solid waste is spread and compacted on a slope. Cover material is obtained directly in front of the working face and compacted on the waste (fig 4-4). In this way, a small excavation is made for a portion of the next day's waste. This technique allows for more efficient use of the disposal site when a single lift is constructed than the area method does, because cover does not have to be imported, and a portion of the waste is deposited below the original surface.

(2) Both methods might have to be used at the same site if an extremely large amount of solid waste must be disposed of. For example, at a site with a thick soil zone over much of it but with only a shallow soil over the remainder, the designer would use the trench method in the thick soil zone and use the extra spoil material obtained to carry out the area method over the rest of the site. When a site has been developed by either method, additional lifts can be constructed using the area method by having cover material hauled in. The final surface of the completed landfill should be so designed that ponding of precipitation does not occur. Settlement must, therefore, be considered. Grading of the final surface should induce drainage but not be so extreme that the cover material is eroded. Side slopes of the completed surface should be 3 to 1 or flatter to minimize maintenance.

4-4. Equipment. The size, the type, and the amount of equipment required at a sanitary landfill depend on the size and method of operation and to some degree on the experience and preference of the designer and equipment operators.



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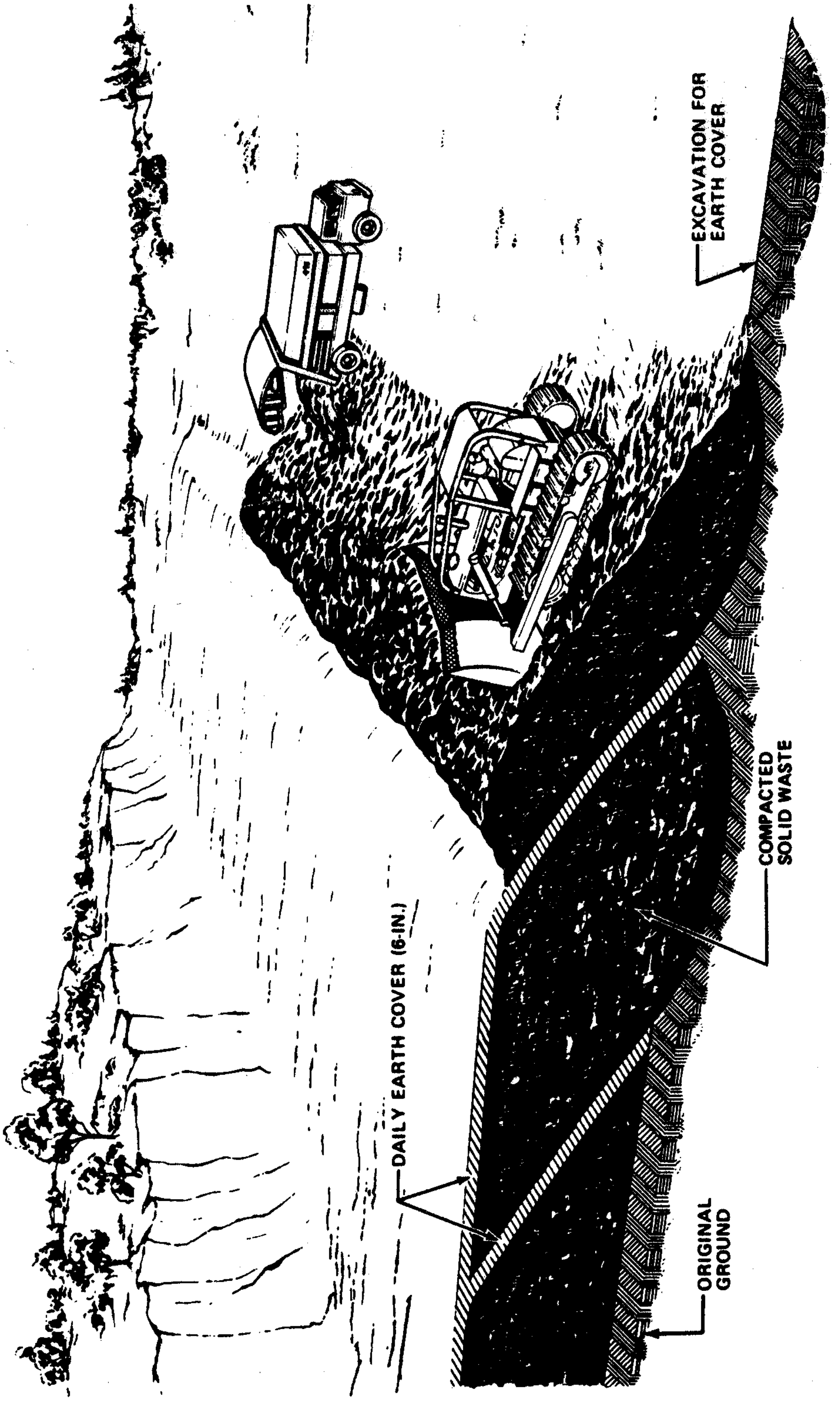
THE BULLDOZER SPREADS AND COMPACTS SOLID WASTES. THE SCRAPER (FOREGROUND) IS USED TO HAUL THE COVER MATERIAL AT THE END OF THE DAY'S OPERATIONS. NOTE THE PORTABLE FENCE THAT CATCHES ANY BLOWING DEBRIS. THIS IS USED WITH ANY LANDFILL METHOD.

FIGURE 4-3. AREA METHOD



SOLID WASTES ARE SPREAD AND COMPACTED ON A SLOPE. THE DAILY CELL MAY BE COVERED WITH EARTH SCRAPED FROM THE BASE OF THE RAMP. THIS VARIATION IS USED WITH EITHER THE AREA OR TRENCH METHOD.

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FIGURE 4-4. PROGRESSIVE SLOPE METHOD

a. Types. The most common equipment used on sanitary landfills is the crawler or rubber-tired tractor. The tractor can be used with a dozer blade, trash blade, or a front-end loader. A tractor is versatile and can normally perform all the operations: spreading, compacting, covering, trenching, and even hauling the cover material. The decision on whether to select a rubber-tired or a crawler-type tractor and a dozer blade, trash blade, or front-end loader must be based on the conditions at each individual site and the equipment's availability. Other equipment used at sanitary landfills are scrapers, compactors, draglines, and graders. This type of equipment is normally found only at large sanitary landfills where specialized equipment increases the overall efficiency.

b. Size. The size of the equipment is dependent primarily on the size of the operation. Small sanitary landfills for camps of 15,000 or fewer, or sanitary landfills handling 46 tons of solid wastes per day or less, can operate successfully with one tractor of the 5- to 15-ton range. Heavier equipment in the 15- to 30-ton range or larger can handle more waste and achieve better compaction. Heavy equipment is recommended for sanitary landfill sites serving more than 15,000 people or handling more than 46 tons per day.

c. Amount. Sanitary landfills servicing 50,000 people or fewer, or handling about 155 tons of solid wastes per day or less, normally can manage well with one piece of equipment, but provisions must be made for standby equipment. It is preferable that a second piece of equipment be used for replacement during breakdown and routine maintenance periods of the regular equipment. At large sanitary landfills serving more than 100,000 persons, or handling more than 310 tons of solid wastes per day, more than one piece of equipment will be required. At these sites, specialized equipment can be utilized to increase efficiency and minimize costs. In table 4-1, a general guide is given for the selection of the type, size, and amount of equipment for various sizes of sanitary landfills.

4-5. Effect of climate on sanitary landfill. Adverse climate can severely limit the capability of the sanitary landfill, but this can be partially overcome by preplanning and operational techniques.

a. Cold weather. Extremely cold weather can greatly reduce the biological activity in a sanitary landfill. In some regions where winter temperatures are less than minus 30 degrees F., only minimal waste stabilization occurs. A serious problem in cold regions is frozen soil. This can be overcome to some extent by excavating for the fill during the summer season and stockpiling cover material.

b. Wet weather. The major problem in wet weather is maintaining maneuverability of the refuse delivery vehicles and equipment. This can be provided in the design by selecting a site that is well drained

Table 4-1. Average Equipment Requirements

Population	Daily tonnage	No.	Equipment Type	Size in lbs	Accessory*
0 to 15,000	0 to 46	1	Tractor crawler or rubber-tired	10,000 to 30,000	Dozer blade Landfill blade Front-end loader (1- to 2-yd)
15,000 to 50,000	46 to 155	1	Tractor crawler or rubber-tired	30,000 to 60,000	Dozer blade Landfill blade Front-end loader (2- to 4-yd) Multipurpose bucket
		*	Scraper Dragline Water truck		
50,000 to 100,000	155 to 310	1 to 2	Tractor crawler or rubber-tired	30,000 or more	Dozer blade Landfill blade Front-end loader (2- to 5-yd) Multipurpose bucket
		*	Scraper Dragline Water truck		
100,000 or more	310 or more	2 or more	Tractor crawler or rubber-tired	45,000 or more	Dozer blade Landfill blade Front-end loader Multipurpose bucket
		*	Scraper Dragline Steel-wheel compactor Road grader Water truck		

* Optional. Dependent on individual need.

U.S. Department of Health, Education, and Welfare and with soil that has adequate trafficability when wet. Operational practices can also reduce the effect of this problem. Surface drainage can usually be diverted from open excavations by careful grading.

c. Dry weather. Dry weather problems in a sanitary landfill are mainly operational such as blowing dust or paper. A certain amount of moisture is needed for the biological activity in the refuse; however, it is unusual to have to add water for this purpose. Control of blowing refuse can be accomplished by prompt covering and by the use of portable fences downwind of the open face of the fill.

APPENDIX A

REFERENCES

Government Publications.

Environmental Protection Agency (EPA).
401 M Street S.W., Washington, D. C. 20460

PL 92-500	Federal Water Pollution Control Act Amendments of 1972.
PL 94-580	The Resource Conservation and Recovery Act of 1976 (RCRA).
40 CFR 257	Criteria for Classification of Solid Waste Disposal Facilities and Practices.
SW-65ts	Sanitary Landfill Design and Operation, 1971