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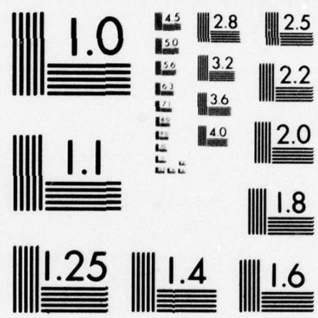

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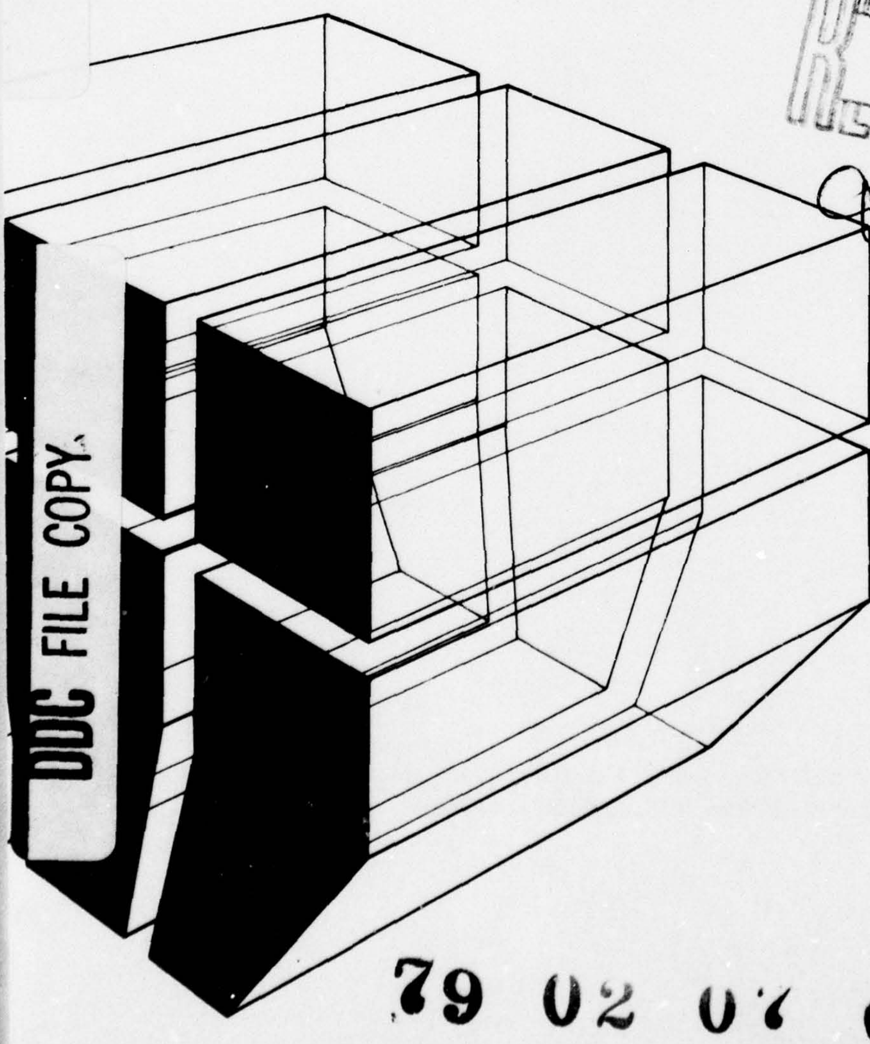
TECHNICAL REPORT N-57
December 1978

SIMPLIFIED SANITARY LANDFILL DESIGN AND OPERATION ANALYSIS

by
G. L. Gerdes
B. A. Donahue



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This report surveys and summarizes state-of-the-art practices in the design and operation of sanitary landfills. It was written at the request of the Office of the Chief of Engineers to be used as guidance for the Facility Engineers at Army military installations. All aspects of sanitary landfills are covered, including site selection, design,

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pollution control, operation, and final closure. Special attention is given to the U.S. Environmental Protection Agency's "Guidelines for the Land Disposal of Solid Waste," which are mandatory for Federal agencies.

FOREWORD

The U.S. Army Construction Engineering Research Laboratory conducted this study for the Directorate of Military Construction, Office of the Chief of Engineers, under QCR item 1.030106 (4) Solid Waste Management (CONUS and TO), Project 4A762720A896, "Environmental Quality for Construction and Operation of Military Facilities"; Task T2, "Pollution Abatement System"; Work Unit 007, "Solid Waste Management, Recycle, Resource Recovery for Military Facilities." A. P. Norwood was the OCE Technical Monitor. B. A. Donahue of the CERL Environmental Division (EN) was Principal Investigator, and G. L. Gerdes was the Associate Investigator. Dr. R. K. Jain is Chief of EN.

COL J. E. Hays is the Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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SIMPLIFIED SANITARY LANDFILL DESIGN AND
OPERATION ANALYSIS

1 INTRODUCTION

Background

Solid wastes must be disposed of properly to minimize adverse effects on the natural environment. Sanitary landfills provide the least expensive and most often used method of disposing of such wastes. The basic process involved is to spread and compact the waste to the smallest practical volume and then to cover it with soil using accepted operating methods in a manner which will protect the environment. It is imperative that sanitary landfills be constructed and operated according to a well-thought-out plan. The major goal in designing such a landfill is to choose a site and an operating plan that are not only the least costly but that are also aesthetically acceptable and environmentally sound.

Purpose

The purpose of this report is to provide design and operational guidance to engineering personnel responsible for the design and operation of sanitary landfills at military facilities. This report is intended to help the Facility Engineer comply with state and Federal environmental regulations.

Approach

In preparing this guidance, current technical data on the design and operation of sanitary landfills were analyzed. Military and U.S. Environmental Protection Agency (USEPA) regulations[1,2] for Federal facilities were also analyzed to determine their bearing on sanitary landfill operation requirements for the Army. This information was then arranged into a logical sequence and condensed to eliminate nonessential details.

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1 "Guidelines for Land Disposal of Solid Wastes," Federal Regulations Part 241, *Environmental Reporter* (28 February 1977), pp 101:1104-101:1109.

2 *Refuse Collection and Disposal*, TM 5-634 (Department of the Army, 1958), pp 22-23.

Scope

Because sanitary landfill design is site-specific, this report deals mostly with the general aspects of design. It discusses the items that must be included in the design plan at a landfill and indicates topics on which the engineer should seek more detailed guidance from other sources. Figure 1 is a flow sheet of the major elements and subelements of the design process which are included in this report.

Mode of Technology Transfer

The results of this study will be used as primary reference information in updating TM 5-634, *Refuse Collection and Disposal Repairs and Utilities*, July 1958, and TM 5-814-5, *Sanitary Landfill*, October 1973.

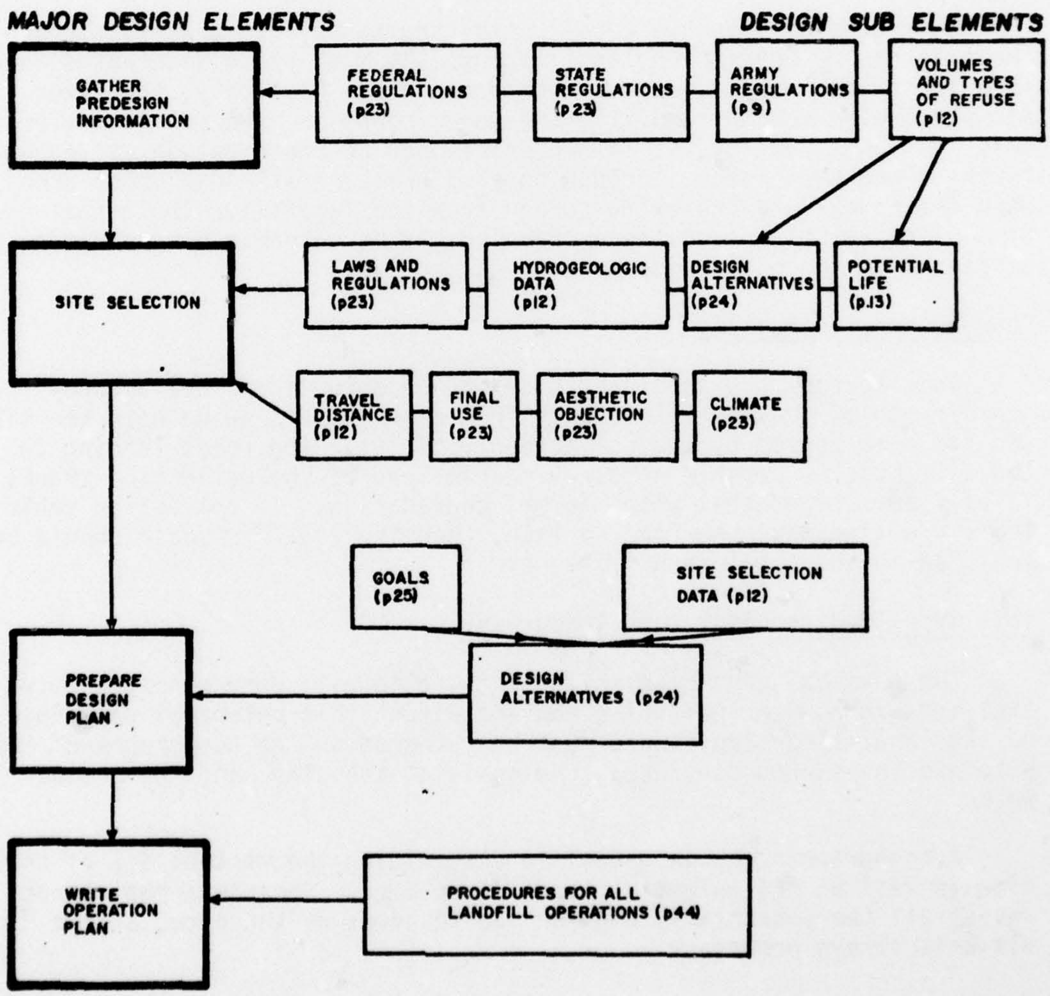

Figure 1. Flow sheet for sanitary landfill design.

2 SITE SELECTION

Site selection is the most important step in landfill development. The physical characteristics of the site almost totally govern the design of the fill. The following sections discuss several factors the designer should take into account when choosing a site: travel distance and proximity to built-up area; road access and quality; soil type, hydrogeology, and topography; landfill life; climate; final land use; aesthetic considerations; and laws and regulations.

Travel Distance

While the distance that collection trucks have to travel to reach the site has no bearing on landfill cost, it must be considered because it affects total solid waste management costs. Obviously, the fewer miles traveled to the landfill, the more economical the collection process will be. However, it is preferable not to route refuse collection trucks along main roads, through housing areas, or through troop areas when the trucks are traveling to and from the landfill. The actual cost of hauling versus the distance traveled may be determined by consulting personnel in the buildings and grounds section.

Road Access and Quality

Road access to a candidate site can be determined from a topographic map of the installation or from other maps showing both the site and the area served by the collection vehicles. The roads leading to the site must be capable of carrying the load of the collection trucks in all types of weather with minimal degradation. If collection vehicle traffic will damage the road surface, then the cost of repair should be included in the total landfill cost.

Soil Type, Hydrogeology, and Topography

The physical characteristics of the site will determine the potential for groundwater pollution and the effect this potential will have on the landfill design. Data must be gathered on the topography of the site and the surrounding area, the soils at the site, and the groundwater.

A topographic map is useful in determining the workability of the site as well as the potential landfill volumes. Because a map cannot reveal all the potentially good or bad features of the site, a site visit is always necessary.

The soil at the site should be analyzed to determine its suitability as a cover material and to determine the effect that the subsoil will have on controlling groundwater pollution. Table 1 may be helpful in determining the soil's suitability.

Groundwater quality and flow data are also needed to determine the potential for pollution from a landfill. Soil permeability, flow velocity, groundwater table depth, variations in the water table level, and the location of bedrock and other impermeable layers should be known. Tables 2, 3, and 4 and Figures 2 and 3 give additional information about soil classifications and their water flow characteristics.

Soil and hydrogeology data are somewhat expensive to gather. To save on design costs, this information should be obtained only for a site which will be considered for final selection. The control of pollution from sanitary landfills will be discussed later in this report.

Landfill Life

To determine when to start the process of locating another landfill site, it is essential to know how long the site being considered can be used. Its lifetime is determined by the volume of available space that can be filled with compacted refuse and the rate at which the refuse is deposited.

The amount of space available at the site depends on the topography of the site and the method used to make the fill. Information on landfilling methods is given in Chapters 3 and 6.

Data on the amount of refuse that will be deposited should be available from the records of previous disposal sites, provided that the number of persons at the installation has not changed significantly. These data are available from the previous year's "Facilities Engineering Technical Data Sheets," DA Form 2788, Part IV, Activity Code M2200. If previous disposal records are thought to be inaccurate or are not available, then a haulage survey can be done to determine the amount of refuse being collected. Guidance for conducting such a survey can be found in *Installation Solid Waste Survey Guidelines.*[3]

Now the volume of landfilled waste can be estimated. Figures 4 through 7 give information that may be useful in determining the volume of the compacted refuse. To use the graphs, the designer must determine specific per capita rate of waste generation from the information shown

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[3] G. W. Schanche, L. A. Greep, and B. A. Donahue, *Installation Solid Waste Survey Guidelines*, Technical Report E-75/ADA018879 (U.S. Army Construction Engineering Research Laboratory [CERL], 1975

Table 1

Suitability of General Soil Types as Cover Materials
(From D. R. Brunner and D. J. Keller, *Sanitary Landfill Design and Operations*, Publication No. SW-65ts [U.S. Environmental Protection Agency, 1972], p 14.)

Function	Clean gravel	Clayey-silty gravel	Clean sand	Clayey-silty sand	Silt	Clay
Prevent rodents from burrowing or tunneling	G	F-G	G	P	P	P
Keep flies from emerging	P	F	P	G	G	E+
Minimize moisture entering fill	P	F-G	P	G-E	G-E	E+
Minimize landfill gas venting through cover	P	F-G	P	G-E	G-E	E+
Provide pleasing appearance and control blowing paper	E	E	E	E	E	E
Grow vegetation	P	G	P-F	E	G-E	F-G
Be permeable for venting decomposition gas++	E	P	G	P	P	P

E, excellent; G, good; F, fair; P, poor.
+Except when cracks extend through the entire cover.
++Only if well drained.

Table 2

Unified Soil Classification System and Characteristics Pertinent to Sanitary Landfills

(From D. R. Brunner and D. J. Keller, *Sanitary Landfill Design and Operations*, Publication No. SW-65ts [U.S. Environmental Protection Agency, 1972], p 17.)

Major Divisions		SYMBOL			NAME	Potential Frost Action	Drainage Characteristics*	Value for Embankments	Permeability cm per sec	Compaction Ch
		Letter	Hatching	Color						
COARSE-GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW		RED	Well-graded gravels or gravel-sand mixtures, little or no fines	None to very slight	Excellent	Very stable, pervious shells of dikes and dams	$k > 10^{-2}$	Good, tractor, r steel-wheeled ro
		GP			Poorly graded gravels or gravel-sand mixtures, little or no fines	None to very slight	Excellent	Reasonably stable, pervious shells of dikes and dams	$k > 10^{-2}$	Good, tractor, r steel-wheeled ro
		GM		YELLOW	Silty gravels, gravel-sand-silt mixtures	Slight to medium	Fair to poor Poor to practically impervious	Reasonably stable, not particularly suited to shells, but may be used for impervious cores or blankets	$k = 10^{-3}$ to 10^{-6}	Good, with close rubber-tired, sh roller
		GC			Clayey gravels, gravel-sand-clay mixtures	Slight to medium	Poor to practically impervious	Fairly stable, may be used for impervious core	$k = 10^{-6}$ to $.10^{-8}$	Fair, rubber-tir roller
	SAND AND SANDY SOILS	SW		RED	Well-graded sands or gravelly sands little or no fines	None to very slight	Excellent	Very stable, pervious sections slope protection required	$k > 10^{-3}$	Good, tractor
		SP			Poorly graded sands or gravelly sands, little or no fines	None to very slight	Excellent	Reasonably stable, may be used in dike section with flat slopes	$k > 10^{-3}$	Good, tractor
		SM		YELLOW	Silty sands, sand-silt mixtures	Slight to high	Fair to poor Poor to practically impervious	Fairly stable, not particularly suited to shells, but may be used for impervious cores or dikes	$k = 10^{-3}$ to 10^{-6}	Good, with close rubber-tired, sh roller
		SC			Clayey sands, sand-clay mixtures	Slight to high	Poor to practically impervious	Fairly stable, use for impervious core for flood control structures	$k = 10^{-6}$ to 10^{-8}	Fair, sheepsfoot rubber-tired
FINE-GRAINED SOILS	SILTS AND CLAYS LL IS LESS THAN 50	ML		GREEN	Inorganic silts and very fine sands rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Medium to very high	Fair to poor	Poor stability, may be used for embankments with proper control	$k = 10^{-3}$ to 10^{-6}	Good to poor, cl essential, rubbe roller, sheepsfo
		CL			Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Medium to high	Practically impervious	Stable, impervious cores and blankets	$k = 10^{-6}$ to 10^{-8}	Fair to good, she roller, rubber-ti
		OL			Organic silts and organic silt-clays of low plasticity	Medium to high	Poor	Not suitable for embankments	$k = 10^{-4}$ to 10^{-6}	Fair to poor, she roller
	SILTS AND CLAYS LL IS GREATER THAN 50	MH		BLUE	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Medium to very high	Fair to poor	Poor stability, core of hydraulic dam, not desirable in rolled fill construction	$k = 10^{-4}$ to 10^{-6}	Poor to very poor roller
		CH			Inorganic clays of high plasticity, fat clays	Medium	Practically impervious	Fair stability with flat slopes, thin cores, blankets and dike sections	$k = 10^{-6}$ to 10^{-8}	Fair to poor, she roller
		OH			Organic clays of medium to high plasticity, organic silts	Medium	Practically impervious	Not suitable for embankments	$k = 10^{-6}$ to 10^{-8}	Poor to very poor roller
HIGHLY ORGANIC SOILS		Pt		Orange	Peat and other highly organic soils			NOT RECOMMENDED FOR SANITARY LANDFILL CONSTRUCTION		

*Values are for guidance only; design should be based on test results.

†The equipment listed will usually produce the desired densities after a reasonable number of passes when moisture conditions and thickness of lift are properly controlled.

†Compacted soil at optimum moisture content for Standard AASHO (Standard Proctor) compactive effort.

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Drainage acteristics*	Value for Embankments	Permeability cm per sec	Compaction Characteristics†	Std AASHO Max Unit Dry Weight lb per cu ft†	Requirements for Seepage Control
Excellent	Very stable, pervious shells of dikes and dams	$k > 10^{-2}$	Good, tractor, rubber-tired steel-wheeled roller	125-135	Positive cutoff
Excellent	Reasonably stable, pervious shells of dikes and dams	$k > 10^{-2}$	Good, tractor, rubber-tired steel-wheeled roller	115-125	Positive cutoff
Fair to poor Poor to ractically mpervious	Reasonably stable, not particularly suited to shells, but may be used for impervious cores or blankets	$k = 10^{-3}$ to 10^{-6}	Good, with close control, rubber-tired, sheepsfoot roller	120-135	Toe trench to none
Poor to ractically mpervious	Fairly stable, may be used for impervious core	$k = 10^{-6}$ to 10^{-8}	Fair, rubber-tired, sheepsfoot roller	115-130	None
xcellent	Very stable, pervious sections slope protection required	$k > 10^{-3}$	Good, tractor	110-130	Upstream blanket and toe drainage or wells
xcellent	Reasonably stable, may be used in dike section with flat slopes	$k > 10^{-3}$	Good, tractor	100-120	Upstream blanket and toe drainage or wells
Fair to poor Poor to ractically mpervious	Fairly stable, not particularly suited to shells, but may be used for impervious cores or dikes	$k = 10^{-3}$ to 10^{-6}	Good, with close control, rubber-tired, sheepsfoot roller	110-125	Upstream blanket and toe drainage or wells
Poor to ractically mpervious	Fairly stable, use for impervious core for flood control structures	$k = 10^{-6}$ to 10^{-8}	Fair, sheepsfoot roller, rubber-tired	105-125	None
Fair to poor	Poor stability, may be used for embankments with proper control	$k = 10^{-3}$ to 10^{-6}	Good to poor, close control essential, rubber-tired roller, sheepsfoot roller	95-120	Toe trench to none
ractically mpervious	Stable, impervious cores and blankets	$k = 10^{-6}$ to 10^{-8}	Fair to good, sheepsfoot roller, rubber-tired	95-120	None
Poor	Not suitable for embankments	$k = 10^{-4}$ to 10^{-6}	Fair to poor, sheepsfoot roller	80-100	None
air to poor	Poor stability, core of hydraulic dam, not desirable in rolled fill construction	$k = 10^{-4}$ to 10^{-6}	Poor to very poor, sheepsfoot roller	70-95	None
ractically mpervious	Fair stability with flat slopes, thin cores, blankets and dike sections	$k = 10^{-6}$ to 10^{-8}	Fair to poor, sheepsfoot roller	75-105	None
actically pervious	Not suitable for embankments	$k = 10^{-6}$ to 10^{-8}	Poor to very poor, sheepsfoot roller	65-100	None
	NOT RECOMMENDED FOR SANITARY LANDFILL CONSTRUCTION				

ce the desired passes when ft are properly

†Compacted soil at optimum moisture content for Standard AASHO (Standard Proctor) compactive effort.

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Table 3

Ability of Soil to Transmit Water
(From J. Reindl, "Landfill Course," *Solid Waste Management*, Vol 20, No. 7 [1977], p 31.)

Permeability, cm/sec

10^2 10 1	10^{-1} 10^{-2} 10^{-3}	10^{-4} 10^{-5} 10^{-6}	10^{-7} 10^{-8} 10^{-9}
Clean gravel	Clean sands; mixtures of clean sands and gravels	Very fine sands, silts; mixtures of sand, silt, and clay; glacial fill; stratified clays; etc.	Unweathered clays
10^6 10^5	10^4 10^3 10^2 10	1 10^{-1} 10^{-2}	10^{-3} 10^{-4}

Permeability, gal/day/ft^2

Table 4

Soil Limitation Ratings for Trench-Type Sanitary Landfills (From J. Reindl, "Landfill Course," *Solid Waste Management*, Vol 20, No. 8 [1977], p 56.)

Item affecting use		Degree of soil limitation Slight[2]	Moderate[2]	Severe
Depth to seasonal high water table		Not class determining if more than 72 in.		Less than 72 in.
Soil drainage class		Excessively drained, somewhat excessively drained, well drained, and some[3] moderately well drained	Somewhat poorly drained and some[3] moderately well drained	Poorly drained and very poorly drained
Flooding		None	Rare	Occasional or frequent
Permeability[4]		Less than 2.0 in./hr	Less than 2.0 in./hr	More than 2.0 in./hr
Slope		0-15 pct	15-25 pct	More than 25 pct
Soil texture[5] (dominant to a depth of 60 in.)		Sandy loam, loam, silt loam, sandy clay loam	Silty clay loam[6] clay loam. sandy clay, loamy sand	Silty clay, clay, muck, peat, gravel, sand
Depth to bedrock	Hard	More than 72 in.	More than 72 in.	Less than 72 in.
	Rippable	More than 60 in.	Less than 60 in.	Less than 60 in.
Stoniness class[7]		0 and 1	2	3, 4, and 5
Rockiness class[7]		0	0	1, 2, 3, 4, and 5

Chart is based on soil depth (5-6 feet) commonly investigated in making soil surveys. [2]If probability is high that the soil material to a depth of 10-15 feet will not alter a rating of *slight* or *moderate* indicate this by an appropriate footnote, such as "Probably *slight* to a depth of 12 feet," or "Probably *moderate* to a depth of 12 feet." [3]Soil drainage classes do not correlate exactly with depth to seasonal water table; the overlap of moderately well drained soils into two limitation classes allows some of the wetter moderately well drained soils (mostly in the Northeast) to be given a limitation rating of *moderate*. [4]Reflects ability of soil to retard movement of leachate from the landfills; may not reflect a limitation in arid and semiarid areas. [5]Reflects ease of digging and moving (workability) and trafficability in the immediate area of the trench where there may not be surfaced roads. [6]Soils high in expansive clays may need to be given a limitation rating of severe. [7]For class definitions, see the Soil Conservation Service *Soil Survey Manual*.

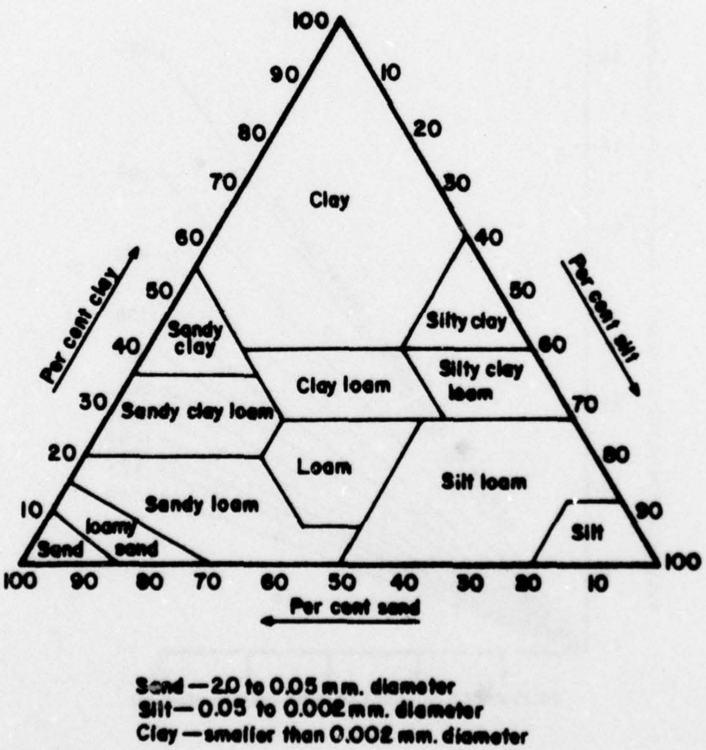

Figure 2. U.S. Department of Agriculture textural classification chart. (From D.R. Brunner and D.J. Keller, *Sanitary Landfill Design and Operation*, Publication No. SW-65ts [U.S. Environmental Protection Agency, 1972], p 16).

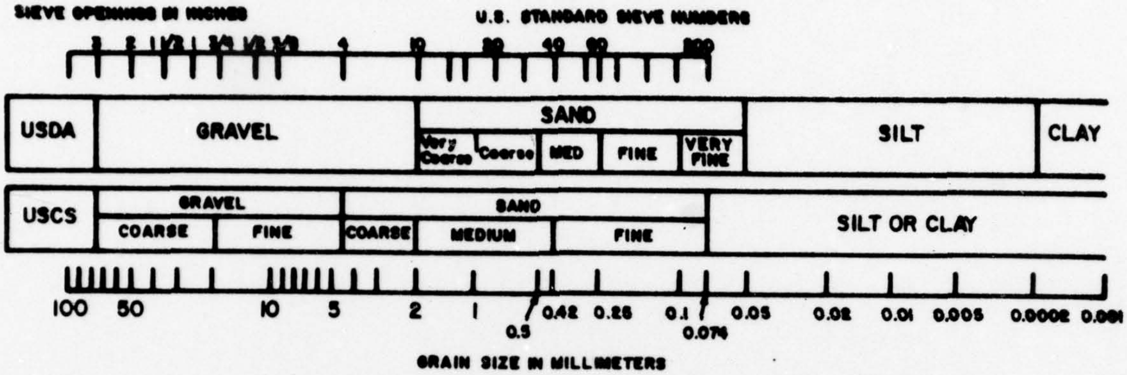

Figure 3. Comparison of particle-size scales. (From D.R. Brunner and D.J. Keller, *Sanitary Landfill Design and Operation,* Publication No. SW-65ts [U.S. Environmental Protection Agency, 1972], p 16.)

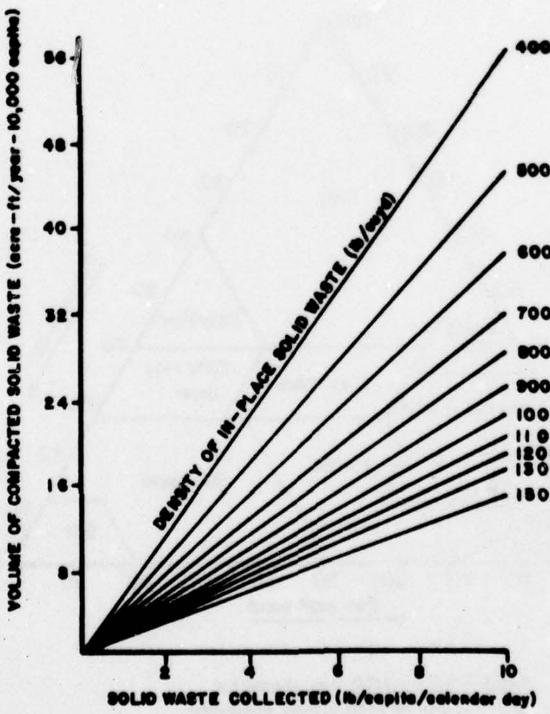

Figure 4. Determining the yearly volume of compacted solid waste generated by a community of 10,000 people. (From D.R. Brunner and D.J. Keller, *Sanitary Landfill Design and Operation,* Publication No. SW-65ts [U.S. Environmental Protection Agency, 1972], p 20.

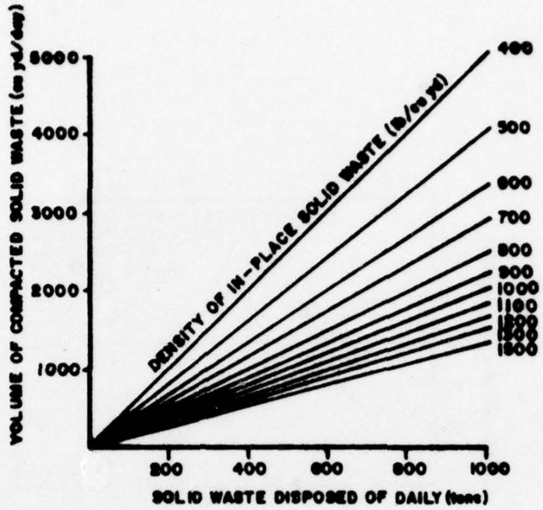

Figure 5. Determining the daily volume of compacted solid waste generated by large communitites. (From D.R. Brunner and D.J. Keller, *Sanitary Landfill Design and Operation,* Publication No. SW-65ts [U.S. Environmental Protection Agency, 1972], p 20.

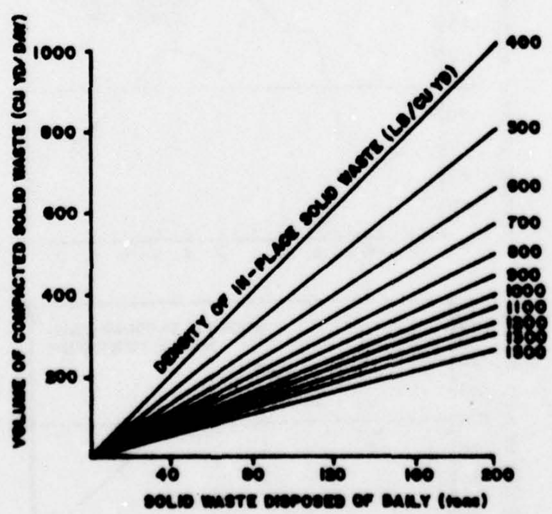

Figure 6. Determining the daily volume of compacted solid waste generated by small communities. (From D.R. Brunner and D.J. Keller, *Sanitary Landfill Design and Operation*, Publication No. SW-65ts [U.S. Environmental Protection Agency, 1972], p 21.

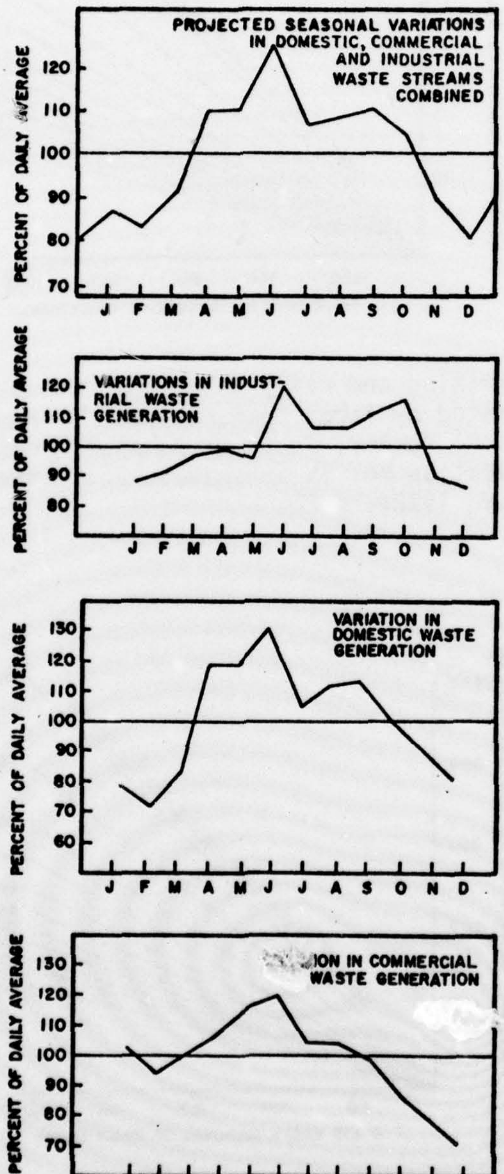

Figure 7. Seasonal variations in solid waste generation. (From J. Reindl, "Landfill Course, "*Solid Waste Management,* Vol 20, No. 4 [1977]), p 55.

on the "Facilities Engineering Technical Data Sheets" or haulage survey data. The designer next assumes an in-place density; 750 to 1000 lb/cu yd (445 to 593 kg/m^3) is considered to be a typical density range.

Cover material must be accounted for in determining the landfill life. Such material will usually make up 20 to 25 percent of the total landfill volume.

Climate

Because the landfill must be operated whenever refuse can be collected, the site chosen should be one at which adverse weather will have a minimal effect on the operation. The effects of heavy rains and snow should be considered, as well as the possibility of a litter problem caused by high winds.

Final Use

Having a final use in mind for a proposed site may make it easier to obtain approval for use of the site. In the private sector most completed landfill sites are used as recreation areas, such as ball fields or ski hills, or for agriculture. Additional uses that may be considered are a parade ground, a training area, or a horseback-riding ground. It is not recommended that the completed site be used for a golf course, because the frequent watering may cause a pollution problem; uses involving vehicles are not recommended, because they will disturb the final cover. It is generally recommended that structures not be placed over a landfill because it makes a poor foundation; in addition, the methane gas produced in the landfill would be both an explosion hazard and a health hazard.

Aesthetic Objections

Sanitary landfills still suffer from the stigma of being considered "dumps." The thought of having a landfill next door is not appealing to most people, no matter how sanitary it is. Objections to a proposed site may arise from facilities or housing areas nearby. To allow time to deal with objections or to select a new site if the one originally chosen is not approved by state authorities or higher headquarters, the site selection process should begin as early as possible.

Laws and Regulations

During the site selection and design processes, the designer should maintain close contact with USEPA and state regulatory officials. It should be ascertained that the site chosen meets Federal and state requirements before site development is begun. Occasionally, laws not directly associated with solid waste disposal may affect site selection.

For example, a Federal Aviation Administration regulation prohibits the construction of a landfill within 10,000 ft (3048 m) of a commercial airfield runway, even though a properly designed and operated sanitary landfill will not attract flocks of birds as open dumps have in the past.

Design Alternatives

The design of a landfill site is a somewhat subjective process, with each designer seeing different possibilities for an area. It is therefore useful to have many people suggest alternative layouts for the potential sites. Then, considering all of the alternatives for all of the sites, a selection can be made.

3 DESIGN

Design Steps

The landfill design process consists of five steps.

The first is to set goals. First priority must be given to meeting current pollution control laws and regulations. Other goals include allowing for the capability to dispose of all the types of waste that may be expected at the site; allowing for a specific final use of the land; and accommodating any other requirements placed on the landfill by the facility. Usually the best design would be the one which is most economical. However, there may be goals with higher priority than immediate cost. For example, additional pollution control measures may be added to the design because of an expected new regulation. The priority of the various goals and objectives should be used to guide selection of the optimum design for the landfill.

The second step in the design process is to obtain data. The necessary data are normally collected during the site selection process.

The third step is to identify design alternatives. As mentioned before, it is helpful to have several people of different backgrounds submit ideas for the site layout and development. Landfill operators, landscapers, other design engineers, and equipment operators are a few types of people who may be consulted.

Evaluating the design alternatives and selecting the optimum plan is the fourth step. It calls for a thorough engineering analysis of all workable and reasonable plans.

The last step is to prepare the final design, which should include all information gathered about the site, the economic evaluation of the final design, an operation plan, an evaluation of the environmental effects, and the projected land use after closing.

Site Layout

As shown in Figure 8, the landfill site is divided into four areas:

1. The perimeter, an outside border of trees or fence around the site which is used to break the wind, to catch blowing litter, to maintain security, and to prevent unauthorized use of the landfill.

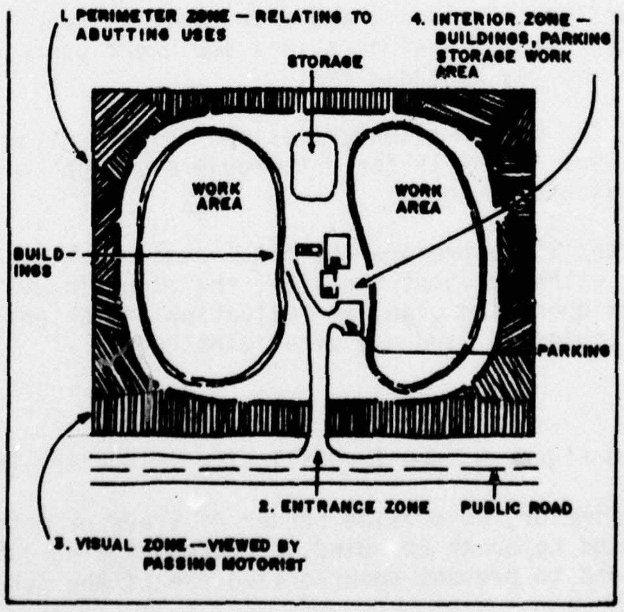

Figure 8. Four zones of sanitary landfill. (From J. Reindl, "Landfill Course," *Solid Waste Management*, Vol 20, No. 10 [1977], p 46.)

2. The entrance, which should be put in a place of easy and safe access for collection vehicles, and away from hills, railroads, and busy intersections.

3. The visual zone, that area which can be seen from outside; while it is not an integral part of the landfill design in some situations it may be important for it to give a positive impression of the operation.

4. The interior area, where the actual landfilling operations take place. Most of this report will deal only with the operations in the interior zone.

Before the layout of the interior zone can be drawn, a landfilling method must be chosen. The three basic methods of burying the refuse are: area, ramp, and trench. All three methods involve shaping 1 day's refuse into a cell by spreading and compacting it in layers. The cell should be 8 to 10 ft (2.4 to 3.0 m) deep, and as wide and long as the designer determines is necessary for the most efficient burial.

The difference among the three methods is in the way the site is excavated. The area method, illustrated in Figure 9, requires the least excavation because the refuse is merely placed on a flat surface and covered with soil. The cover material can be hauled to the site, or it can be obtained by excavating the surface of the site. The ramp or progressive slope method, shown in Figure 10, entails gouging out the cover material for a cell from the ground immediately in front of the working face of the cell. This technique makes a pit in which to place the next day's refuse. The trench method is shown in Figure 11. A trench, up to 20 ft (6.1 m) deep and usually about 20 ft (6.1 m) wide is excavated to a length that will hold at least 2 weeks' refuse. The soil taken from the trench is used as cover material for the same trench or for another trench in the process of being filled.

Site data will determine which method should be used for the landfill operation. In flat areas with low groundwater levels, the trench method is best. It is good in areas where little additional cover material is available. The area or ramp methods are more suitable where the groundwater table is closer to the surface, where there is available cover material, or where there are natural depressions in the land.

Once the method for landfilling has been selected, the layout can be determined. The location of the cells, the sequence in which they will be filled, and the final landscape of the fill can be designed. Provisions for temporary access roads and drainage must also be made in the sequencing.

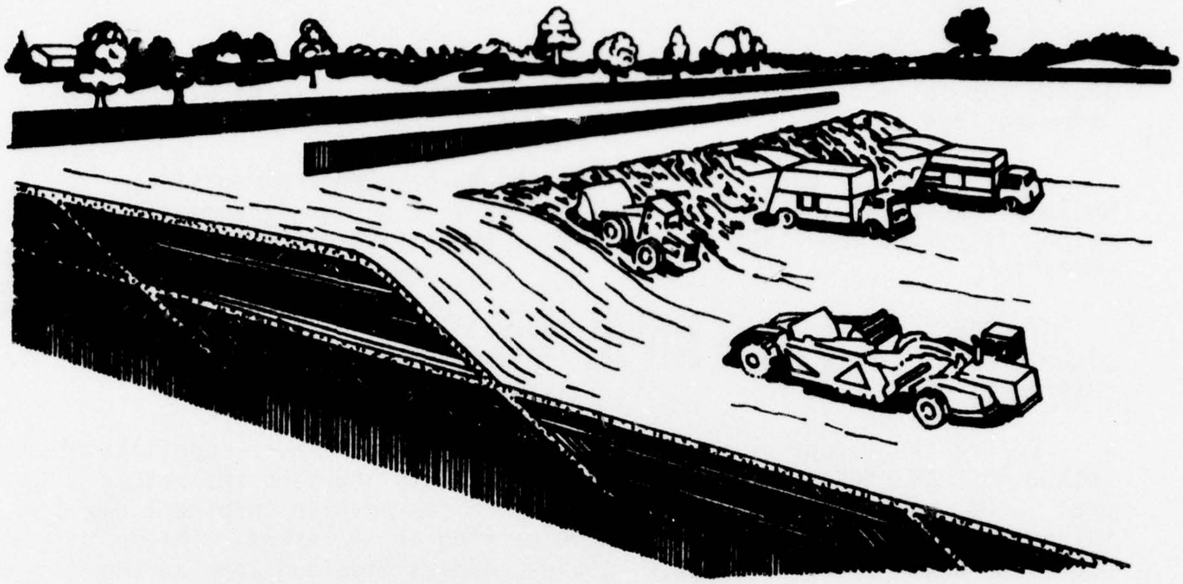

Figure 9. Area method of burying waste. (From D.R. Brunner and D.J. Keller, *Sanitary Landfill Design and Operation*, Publication No. SW 65-ts [U.S. Environmental Protection Agency, 1972], p 28.)

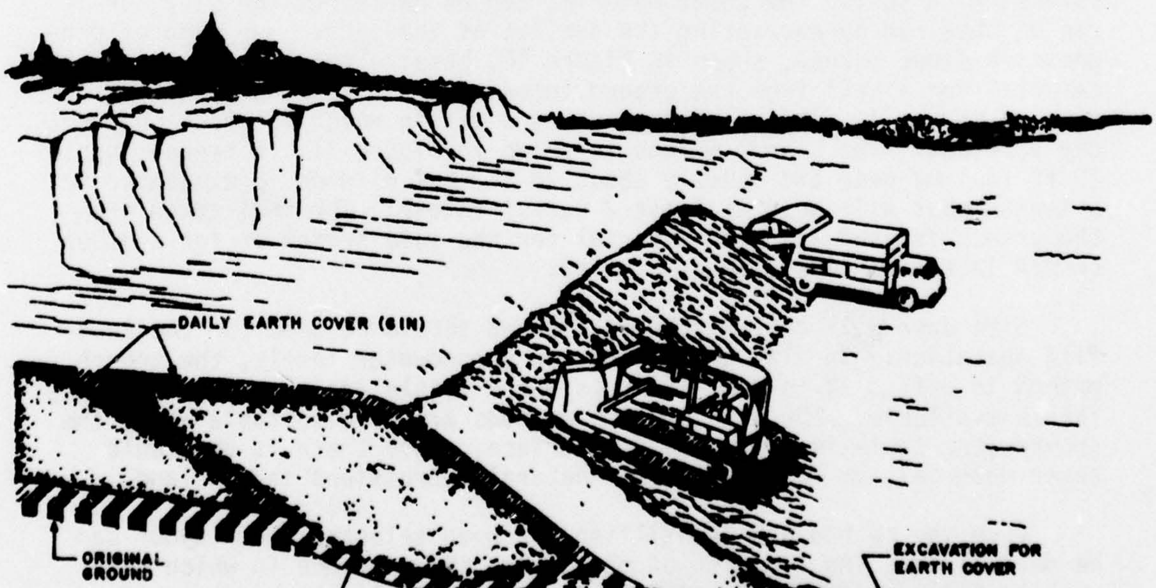

Figure 10. Ramp method of burying waste. (From D.R. Brunner and D.J. Keller, *Sanitary Landfill Design and Operations*, Publication No. SW-65ts [U.S. Environmental Protection Agency, 1972], p 29.)

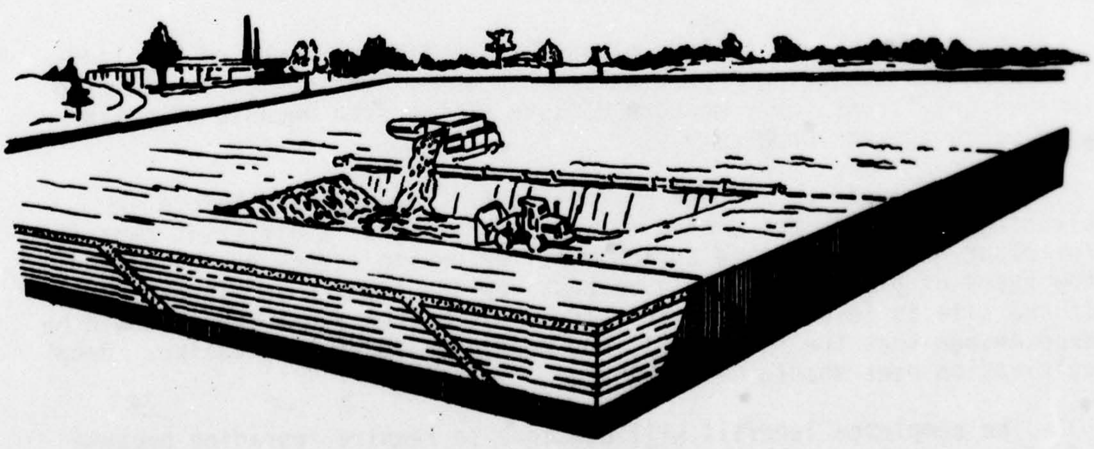

Figure 11. Trench method of burying waste. (From D.R. Brunner and D.J. Keller, *Sanitary Landfill Design and Operations*, Publication No. SW-65ts [U.S. Environmental Protection Agency, 1972], p 29.)

Site Development Plan

The sanitary landfill design must incorporate a site development plan which has been prepared or approved by a professional engineer. The USEPA guidelines state that the following items should be included in this plan:

1. Topographic maps of initial and final contours of the site showing intervals of 5 ft (1.5 m) or less.

2. Maps and descriptions of land uses within 1/4 mile (0.4 km) of the site showing roads, buildings, wells, and any geologic features which would affect surface or groundwater flow.

3. Location of utilities within 500 ft (150 m) of the site.

4. Employee convenience and equipment maintenance facilities. These might include toilet facilities, drinking water, storage, and tools and hardware necessary for the maintenance of equipment and grounds.

Operation Plan

An operation plan or manual written for personnel working at the landfill, especially the operators, comprises a part of the design. This plan should contain information specific to the site or installation. An operation manual is required by some state regulatory agencies. Chapter 6 contains more detailed information about what should be included in this part of the design.

Final Use

The design should include plans for the final closure of the landfill and the succeeding future use of the site. The design should also include provisions for premature closure of the site because of pollution or management problems.

The soil used as a cover material should be analyzed before any planting is done on the closed fill. Each soil has a different capacity for plant growth. A state agricultural extension agency can recommend the types of plants that would be best for the final cover landscaping. If the site is to become an agricultural area, the final cover should be deep enough that the refuse will not be disturbed by cultivation. Deep cultivation uses should be prohibited.

The completed landfill will continue to require regrading because of uneven settlement of the solid waste. This grading is done chiefly to prevent ponding on the landfill cover. Landfills can settle as much as 50 percent within 5 years of closure, although they normally settle in much less than that. The load-carrying capacity of a finished landfill is estimated to be 500 to 800 lb/sq ft (2440 to 3900 kg/m^3). However, there will be inconsistencies due to factors such as gas pockets and nonhomogeneous waste. Because of settlement and continuing gas production, constructing buildings on the completed fill is not permitted without prior approval of HQDA (DAEN-MPA) Washington, DC 20314.

The USEPA recommends that a detailed description of the closed site, including a plot, should be filed with the area's land recording authority. The description should include the location of the waste, the depth of the fill and cover, and other information pertinent to the future use of the site. At most sites, it will be required to include provisions for monitoring and controlling gas and leachate production and discharge.

4 POLLUTION CONTROL

The Design Problem

A major goal of the sanitary landfill is to eliminate all harmful environmental effects and the unpleasant aesthetics of refuse disposal. The sanitary landfill can be considered a treatment plant for garbage. It is up to the designer to insure that the treatment is effective. The Water Pollution Control Act (Public Law 92-500) requires that a land disposal site be designed and operated so that there is no detrimental effect on surface and groundwater used to supply drinking water.

Leachate is water that has come in contact with landfilled refuse and has flowed out of the landfill. Refuse will absorb about 2 gal of water per cubic foot (267 ℓ/m^3). After the refuse is saturated, leachate is formed. The amount depends on the amount of water flowing through the refuse. The two main sources of the water that forms leachate are: surface water infiltration and groundwater movement.

Once leachate has moved out of the landfill, it can pollute groundwater supplies, nearby lakes, and streams. Leachate is normally acidic because of the large amount of carbon dioxide (CO_2) produced during biological degradation of the refuse. In combination with water, the CO_2 produces carbonic acid. This acid solution can dissolve salts and minerals from the refuse and soil into the leachate. Along with the organic compounds in the liquid, the leachate can have a biological oxygen demand (BOD), a chemical oxygen demand (COD), and a total solids concentration up to 100 times greater than raw sewage. Table 5 shows the range of concentrations for the pollutants frequently found in leachate.

The landfill design should show the potential for leachate formation and the measures taken to control it. Hydrogeologic data obtained from the site area should show the landfill's potential zone of influence. The design should show the current and future uses of water in this zone. Elevations of the bottom of the refuse and the highest expected level of the groundwater table should be shown, along with a groundwater quality analysis. If groundwater contamination is a possibility, sampling stations and a testing program should be included in the design of an operation plan. This leachate monitoring will be mandatory in almost all cases.

Unfortunately, the largest uncertainty in landfill design is not knowing whether the standard design procedure will effectively eliminate pollution. Normally, the pollutants in leachate are thought to be removed by soil attenuation. The soil acts as an ion-exchange and filter medium. However, because not enough is known about the mechanism of soil attenuation and because the subsoil characteristics are seldom homogeneous, it is very difficult to predict the pollution potential of a

Table 5

Leachate Composition in Parts per Million (From J. Reindl, "Landfill Course," *Solid Waste Management*, Vol 20, No. 6 (1977], p 48.)

Constituent	Concentration
Biochemical oxygen demand (5 day)	81-33,360
Hardness	0-22,800
Total Phosphorous	0-130
Ammonia Nitrogen	0-1,106
Calcium	60-7,200
Chloride	4.7-2,467
Sodium	0-7,700
Potassium	28-3,770
Sulfate	1-1,558
Manganese	0.09-125
Magnesium	17-15,600
Iron	0-2,820
Zinc	0-370
Copper	0-9.9
Lead	0.10-2.0
Cadmium	0.03-17
Alkalinity	0-20,850

landfill site. Hence it is difficult to decide whether gas and leachate collection systems should be included in the landfill design. The best recommendation that can be made in this report is that the designer follow the regulations established in the particular area and request additional guidance from state agencies and the USEPA. Seeking such guidance should be the first design step after site data have been collected and the site has been selected.

Control Methods

Gas and leachate pollution can be controlled by managing the production of these effluents, directing their movement, and treating them. Managing the production seeks to achieve one of two goals: preventing the gas and leachate from being formed, or exhausting the gas and leachate potential as quickly as possible.

A finite amount of gas and leachate can be produced by the refuse in a landfill. If these effluents can be collected over a short time, then the potential for further pollution from the landfill can be eliminated. The expense of collection systems does increase construction costs, and operating costs are temporarily increased while the gas and leachate are being collected. The leachate that is collected can be recycled through the landfill, treated on site, or drained into a sanitary sewer. However, introducing untreated leachate into a sewer system is not recommended, because it could cause problems at the sewage treatment plant, and recycling leachate back through the landfill may not be an adequate solution. The most viable method of leachate pollution control is to treat the leachate on site. This would be either a complete treatment system to meet effluent discharge standards, or a pretreatment system for discharge into a sanitary sewer. The most cost-effective method will be site-specific.

Preventing gas and leachate from forming is the control method used most often. Natural diffusion, dilution, and attenuation are depended on for treatment.

Controlling the amount of water entering the refuse has the greatest effect on gas and leachate production. The designer may reduce the amount of water entering the fill through careful selection of the landfill location, the cover material, the cover slope, the final cover vegetation, and the surface drainage. But it is nearly impossible to completely eliminate gas and leachate production.

The landfill should never be located where the refuse will be in direct contact with surface water or the groundwater table. If at all avoidable, the landfill should not be in a floodplain. If it must be constructed in a floodplain, however, the refuse should be protected from at least a 100-year flood by dykes and other suitable means. If the landfill is located in a watershed carrying a large amount of runoff, such as a ravine, then the water must be rerouted around the site, as shown in Figure 12.

The soil used as cover material should be of low permeability. Table 3 (p 17) shows the permeability of different soil types.

The cover material should be sloped so that most water will run off the surface of the fill. Drainage water outside the fill should be diverted away from the fill, and drainage water from within the fill site should be routed so that there is no standing water, while at the same time minimizing erosion. To stop infiltration, the vegetation on the final cover should be a type that requires a large amount of water. Table 6 shows the water needs of some general types of plants.

Because of site limitations, it is not always possible to prevent leachate from forming. In that case, procedures for stopping the movement of leachate must be considered. Two major methods are available. First, wells can be drilled in and around the landfill and the leachate can be pumped out. This approach can be expensive but may be discontinued after the pollutant concentration in the leachate reaches a safe level. The second method is to create an impermeable layer between the refuse and the groundwater. The layer, which is emplaced during site preparation, can be made of materials such as clay, bentonite, plastic, or asphalt. Leachate collection pipes can be installed over the liner. The cost of leachate control must be weighed against the cost of using another site where such controls would not be needed.

Gas Production and Control

Through a series of microbial degradations, the organic material in refuse is broken down into a gas consisting of about one-half CO_2 and one-half CH_4 (methane). Figure 13 illustrates the variation in methane production with time. Methane is flammable, can cause asphyxiation, and kills vegetation. It is therefore important that gas control be part of a landfill design.

Gas tends to migrate in the path of least resistance. A study of the soils and geology of the area will determine potential flow patterns. If the landfill is next to porous material, then gas control measures should be taken.

Three methods can be used to control gas migration from landfills: trenches, wells, and barriers. Wells and trenches, shown in Figures 14 and 15, are used to vent the gas to the surface, where it diffuses into the air or is collected. Recent studies have shown that wells are not always effective and that trenches are a much better method. Wells can be improved by placing pumps over them to expel the gas. The trench is

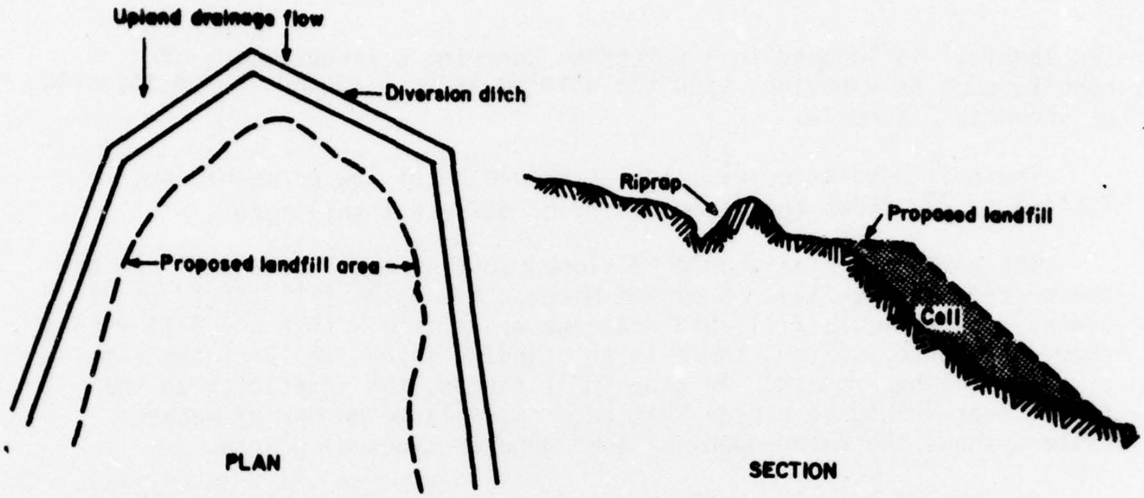

Figure 12. Transmitting upland drainage around a landfill. (From D.R. Brunner and D.J. Keller, *Sanitary Landfill Design and Operation,* Publication No. SW-65ts [U.S. Environmental Protection Agency, 1972], p 23.)

Table 6

Approximate Seasonal Consumption of Water
(From J. Reindl, "Landfill Course," *Solid Waste Management*, Vol 20, No. 6 (1977], p 31.)

Growth	Inches	Growth	Inches
Coniferous Trees	4-9	Alfalfa and Clover	2.5 up
Deciduous Trees	7-10	Oats	28-40
Rye	18 up	Meadow Grass	22-60
Wheat	20-22	Lucern Grass	26-65

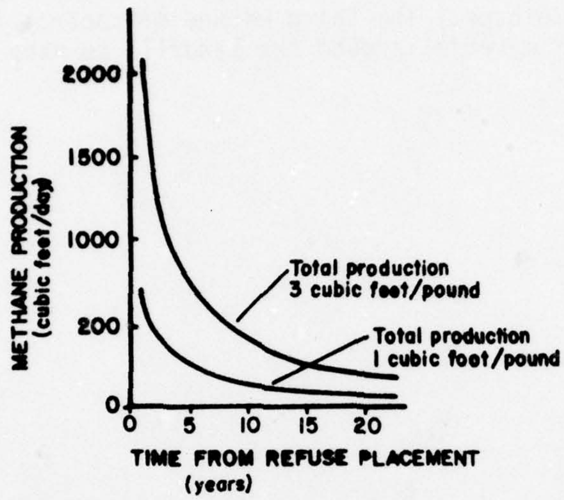

Figure 13. Estimate of methane production from a 1000-ton landfill. (From J. Reindl, "Landfill Course," *Solid Waste Management*, Vol 20, No. 6 [1977], p 23.)

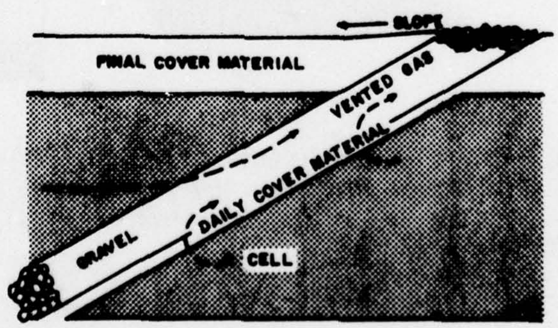

Figure 14. Gravel-filled gas-venting well. (From D.R. Brunner and D.J. Keller, *Sanitary Landfill Design and Operation*, Publication No. SW-65ts [U.S. Environmental Protection Agency, 1972], p 25.)

dug to the lowest level of the landfill, then backfilled with gravel to allow the gas to escape. The third method of control is to place an impermeable wall of material around the landfill to stop migration of gas through the soil.

Figure 15. Gravel-filled gas-venting trench. (From D.R. Brunner and D.J. Keller, *Sanitary Landfill Design and Operation*, Publication No. SW-65ts [U.S. Environmental Protection Agency, 1972], p 25.)

5 EQUIPMENT

The equipment which can be used at a landfill serves four purposes: compacting, loading, dozing, and transporting earth. Recently, specialized compacting equipment has become popular at landfills. Compactors have specially designed steel wheels with cleats that increase the compaction efficiency. Information about landfill compactor selection can be found in a forthcoming CERL Technical Report, *Sanitary Landfill Compactor Evaluation*. Loaders are used to transport the cover material or to load the material into trucks which then transport it to the working face of the fill. The loader can also be used to spread and compact the waste, especially in smaller operations where it is too expensive to have both a loader and a compactor. A dozer is used to excavate the cell area and also to spread and compact the refuse.

Loaders and dozers are available in both tracked and wheeled models. The tracked models are slower but are better suited for situations in which the compaction weight must be spread over a larger area.

The equipment used to transport cover material to the cell is largely determined by how far the material has to travel. A crawler-loader can economically transfer cover material from a distance of up to 300 ft (90 m). Rubber-tired loaders can carry the material up to 600 ft (180 m). For greater distances, dump trucks and scrapers are used.

Special earth-handling equipment may be used at a landfill. When the trench method is used, a dragline can be efficient in constructing the entire trench prior to its use. Backhoes are occasionally used but are not very efficient for landfill operations.

Tables 7 through 10 will be helpful in determining the equipment needed for the landfill. If feasible, additional equipment may be purchased or rented for replacement of equipment undergoing repair or maintenance.

Table 7

Performance Characteristics of Landfill Equipment*+
(From D. R. Brunner and D. J. Keller, *Sanitary Landfill Design and Operations*, Publication No. SW-65ts [U.S. Environmental Protection Agency, 1972], p 45.)

Equipment	Solid Waste Spreading	Solid Waste Compacting	Cover Material Excavating	Cover Material Spreading	Cover Material Compacting	Cover Material Hauling
Crawler dozer	E	G	E	E	G	NA
Crawler loader	G	G	E	G	G	NA
Rubber-tired dozer	E	G	F	G	G	NA
Rubber-tired loader	G	G	F	G	G	NA
Landfill compactor	E	E	P	G	E	NA
Scraper	NA	NA	G	E	NA	E
Dragline	NA	NA	E	F	NA	NA

*Basis of evaluation: Easily workable soil and cover material haul distance greater than 1,000 ft.
+Rating Key: E, excellent; G, good; F, fair; P, poor; NA, not applicable.

Table 8

Landfill Equipment Needs
(From D. R. Brunner and D. J. Keller, *Sanitary Landfill Design and Operations*, Publication No. SW-65ts [U.S. Environmental Protection Agency, 1972], p 45.)

Solid waste handled (tons/8hr)	Crawler loader Flywheel horsepower	Crawler loader Weight* (lb)	Crawler dozer Flywheel horsepower	Crawler dozer Weight* (lb)	Rubber-tired loader Flywheel horsepower	Rubber-tired loader Weight* (lb)
0-20	<70	<20,000	<80	<15,000	<100	<20,000
20-50	70	20,000	80	15,000	100	20,000
	to	to	to	to	to	to
	100	25,000	110	20,000	120	22,500
50-130	100	25,000	110	20,000	120	22,500
	to	to	to	to	to	to
	130	32,500	130	25,000	150	27,500
130-250	150	32,500	150	30,000	150	27,500
	to	to	to	to	to	to
	190	45,000	180	35,000	190	35,000
250-500	combination of machines		250	47,500	combination of machines	
			to	to		
			280	52,000		
500-plus	COMBINATION OF MACHINES					

Note: Compiled from assorted promotional material from equipment manufacturers and based on ability of one machine in stated class to spread, compact, and cover within 300 ft of working face.
*Basic weight without bucket, blade, or other accessories.

Table 9

Recommended and Optional Accessories for Landfill Equipment
(From D. R. Brunner and D. J. Keller, *Sanitary Landfill Design and Operations*, Publication No. SW-65ts [U.S. Environmental Protection Agency, 1972], p44.)

Accessory	Dozers (Crawler	Rubber-tired)	Loaders (Crawler	Rubber-tired)	Landfill Compactor
Dozer blade	0	0	-	-	0
U-blade	0	0	-	-	0
Landfill blade	R	R	0	0	R
Hydraulic controls	R	R	R	R	R
Rippers	0-	0	-	-	-
Engine screens	R	R	R	R	R
Radiator guards, hinged	R	R	R	R	R
Cab or helmet air conditioning	0	0	0	0	0
Ballast weights	0	0	R	R	R
Multiple-purpose bucket	-	-	R	R	-
General-purpose bucket	-	-	0	0	-
Reversible fan	R	R	R	R	R
Steel-guarded tires	-	R	-	R	-
Life arm extensions	-	-	0	0	-
Cleaner bars	-	-	-	-	R
Roll bars	R	R	R	R	R
Backing warning system	R	R	R	R	R

0 = Optional R = Recommended

Table 10

Approximate Earthmoving Capacities for Average Soils
(From J. Reindl, "Landfill Course," *Supplemental Course Information.*)

Capacity of Units, Cubic Yards	One-Way Haul Distance (ft)								
	0	100	200	300	400	500	600	800	1000
	Cubic Yards/Hour								
Tracked Loader									
1-1/4	40	30	25	20	15	15	10	10	5
1-1/2	50	35	30	25	20	15	15	15	10
2	80	60	45	40	35	30	25	20	20
Rubber-Tired Loader									
1-1/4	45	40	35	30	25	25	20	20	15
1-1/2	55	45	40	35	35	30	25	25	20
2	90	80	70	60	55	50	45	40	35
Pulled Scrapers									
14					190	170	150	125	100
12					165	145	125	100	75
7					90	80	75	60	55
Self-Propelled Scrapers									
20					400	380	340	300	
14					250	240	210	180	
11					170	160	140	120	

	Dragline Productivity Cu Yd/Hour - 90° Swing							
Bucket Size, cubic yards	3/4	1	1-1/4	1-1/2	2	2-1/2	3	4
Productivity	55	70	90	100	120	140	160	200

6 OPERATION PLAN

The operation plan is an integral part of the landfill design. It is a manual written for the use of the operator and other landfill personnel stating in plain language how the landfill is to be operated. This chapter presents information and guidelines to assist the designer in developing the plan.

Waste Characteristics

The quantity of refuse disposed of at the site will determine the expected life of the site, cover material requirements and cell size, and equipment and personnel requirements. The types of waste will determine if any special handling techniques or temporary storage facilities will be needed.

Wastes Excluded

The operators, regular users, and collection personnel should have a list of wastes to be excluded from the landfill. Such wastes are those which because of their chemical, biological, or other characteristics cannot be properly disposed of at the landfill without causing a potential hazard.

Bulky Wastes

The plan should include procedures for dealing with tires and other bulky wastes. Normally, the bulky wastes are put at the bottom of the cell so that they are buried by the incoming refuse. They may be put aside on the day they are delivered so that they may be put at the bottom of a new cell the next morning. Bulky wastes can also be crushed against solid ground before they are put into the bottom of the working face of a cell. Demolition debris should also be put into the bottom of the cell.

Tires have a tendency to float to the surface of a landfill if they are not buried deeply. In some operations the tires are even fastened to the bottom of the fill, or a special machine is used to shred them. Demolition debris may be used to anchor tires.

Sludges

Water and wastewater treatment plant sludges should be free of water and may be placed at the working face with the refuse. Incinerator and air pollution residues should be put into the working face in such a manner as not to create dust problems.

Hazardous Wastes

Recommendations and approval for the handling of special and hazardous wastes should be obtained from the state agencies regulating the disposal of these wastes. Among the wastes in this category are pesticides and pesticide containers, explosives and their containers, wet sludges, bulk liquids and semiliquids, manure, industrial wastes, and infectious hospital wastes.

Animal Carcasses

Normally, state regulations deal with the handling of dead animals. In the absence of such regulations, small animals may be placed on the working face with the rest of the refuse. Larger carcasses should be buried separately and covered in a manner to encourage runoff of precipitation.

Cell Construction

The weight of the compacting vehicle will cause a great deal of pressure at the surface of the working face, but the weight is rapidly distributed over a larger area as depth increases. Hence, the refuse should be spread in layers not more than 2 ft (0.6 m) thick before it is compacted. The compacting vehicle should drive over the refuse two to five times for best compaction. Figure 16 compares the refuse density to the cell thickness after specified numbers of passes by the compactor.

The slope of the working face of the cell has traditionally been 30 degrees. However, it has been shown that a flatter slope will provide greater compaction and reduced equipment wear. The flatter slope has the drawbacks of poorer drainage and increased cover material requirements. A 20- to 30- degree slope is recommended.

The daily cover should consist of at least 6 in. (0.15 m) of soil. This depth will stop flies and mosquitoes from breeding, discourage rodents from burrowing, and control bird problems. Intermediate cover on a refuse cell which will remain exposed for 1 week to 1 year should be at least 1 ft (0.3 m) thick. The final cover used to close the landfill should be at least 2 ft (0.6 m) or more thick, depending on the final use of the area.

Surface Water Diversion

Surface water runoff should be diverted away from the working face by trenches, tiles, or grading. Because this water is being diverted to minimize infiltration, the amount of runoff will be larger than normal and the water may contain a high concentration of soil. If there is a potential problem of stream siltation or of flooding other areas, a catch basin may be necessary to hold the runoff.

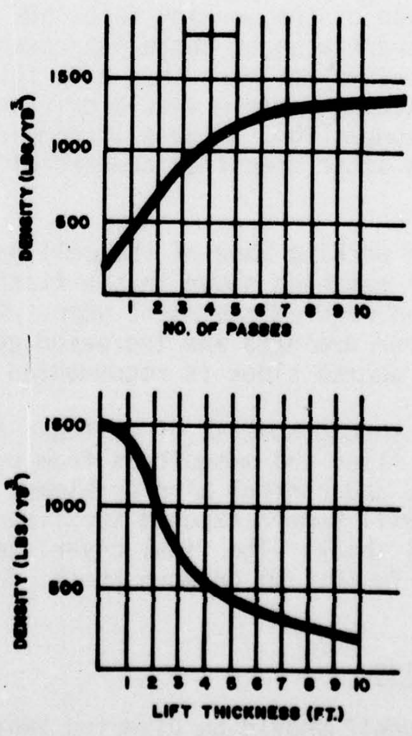

Figure 16. Density of refuse. (From J. Reindl, "Landfill Course," *Solid Waste Management*, Vol 20, No. 11 [1977], p 60.)

Cold-Weather Operations

In locations where winter temperatures are often below freezing, excavation of cover material will become difficult. In these cases, cover material should be stockpiled during summer for use in the winter. This cover material should be kept dry and not allowed to freeze.

Dust Control

While dust control will not be an everyday requirement, the operation plan should provide for times when it does become a problem. Two common methods of dust control are to use a water wagon, or calcium chloride. The water wagon is probably the best method because it is least expensive, and it can also be used for fire control. Spreading oil as a dust control measure is prohibited by AR 420-47.

Litter Control

Litter control is important because of the bad image litter gives the landfill operation. Several methods can be used:

1. Wastes should be deposited from the collection trucks at the bottom of the cell where they are less likely to be caught by the wind.

2. The landfill should be designed so that the prevailing wind will blow directly into the face of the refuse. If the trench method is used, the trench should be at a right angle to the wind.

3. Temporary and permanent fences should be used. A permanent fence around the edge of the fill site will stop litter as well as provide security. Temporary fences can be placed downwind of the working face and moved as the operation progresses. Both fences should be routinely cleared of litter.

4. Trees can be planted along the perimeter of the landfill to act as a windbreak.

Rodent Control

Rodents can be a problem before and after a landfill is completed. Normal sanitary landfill operation should keep the rodent population at a minimum. If rodents become a problem during operation of the fill, however, the final closure of the fill may force them to migrate to another part of the installation, such as nearby housing. If this possibility exists, the division handling pest control should be contacted to arrange for extermination of the rodents prior to the closure of the landfill.

Site Accessibility

It may be necessary to allow individuals to bring wastes to the landfill. The operation plan should state whether such access is allowed and, if so, under what conditions and at what times. The plan should not allow individual dumping to interfere with any of the landfill operations. The site should be accessible only when landfill personnel are on duty. For use after hours, large containers could be placed near the entrance. Scavenging (people removing items from the deposited refuse) is dangerous and should be prohibited.

Safety

The accident rate for solid waste collection and disposal is 11 times higher than the average for all industry. Before completing the operation plan, the landfill designer should work with the safety office of the installation to make sure a strong safety program is included in the plan.

The operation must adhere to the provisions of the Occupational Safety and Health Act of 1970 (Public Law 91-596) as they apply to sanitary landfill operation. A safety manual should be written and made available to all employees. Safety devices such as hard hats, safety glasses, gloves, and footwear should be provided to the employees. Equipment safety measures such as rollover protection, seat belts, reverse warning sounders, and fire extinguishers should be provided on the compaction and earthmoving equipment.

Procedures should be established to control fires occurring in the refuse being delivered, at the working face, or in the landfill equipment. Provisions should be made for easy communication between the site operator and the employees and between the landfill and other post facilities.

Equipment

Maintenance schedules are provided by the equipment manufacturers. These schedules should be included in the operation plan, as should the routine daily checks made by the equipment operator.

Special Circumstances

The operation plan should include procedures for breakdowns, shutdowns, and unexpected natural occurrences. Pieces of equipment will sometimes be unavailable because of the need for maintenance. Suitable temporary replacements should be available, possibly from another facility shop. Shutdowns may occur as a result of such events as employee strikes or regulatory actions. An alternate plan for operating the fill or for disposing of the refuse should be prepared. Provisions should also be made to minimize the effects of natural occurrences such as floods, heavy snows, earthquakes, or high winds.

Records

Records should be kept of the following items:

1. Major operational problems and complaints.

2. The environmental impact of the site and the effectiveness of gas and leachate control. These records should include the results of groundwater, gas, and leachate sampling and analysis both upstream and downstream of the site.

3. Vector control efforts.

4. Dust and litter control efforts.

5. Measurements of the amount of solid waste handled. The data should be gathered by the routine or periodic use of scales and topographic surveys of the site.

6. Descriptions and sources of materials received.

Traffic Control

Traffic control signs should be placed to maintain an orderly traffic pattern. If necessary, access to hazardous areas may be restricted. The working face area should not be blocked by unattended vehicles.

Personnel

The number of people needed at the landfill site usually depends on the number of pieces of equipment to be operated. A scale operator may be needed if there are scales on the site. Laborers will be needed to control litter and dust, to direct traffic and equipment, and to maintain landfill equipment. Larger landfills may need a foreman, and most landfills need an operator. All personnel should be trained in the efficient operation of the fill under both normal and adverse conditions.

7 CONCLUSIONS

Each Army landfill site is unique and requires a detailed engineering study prior to use. The design guidelines in this report are intended to be of general assistance to Facility Engineers in supervising preparation of the detailed engineering studies required for sanitary landfill design and operation.

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