Sanitary Landfill Facts

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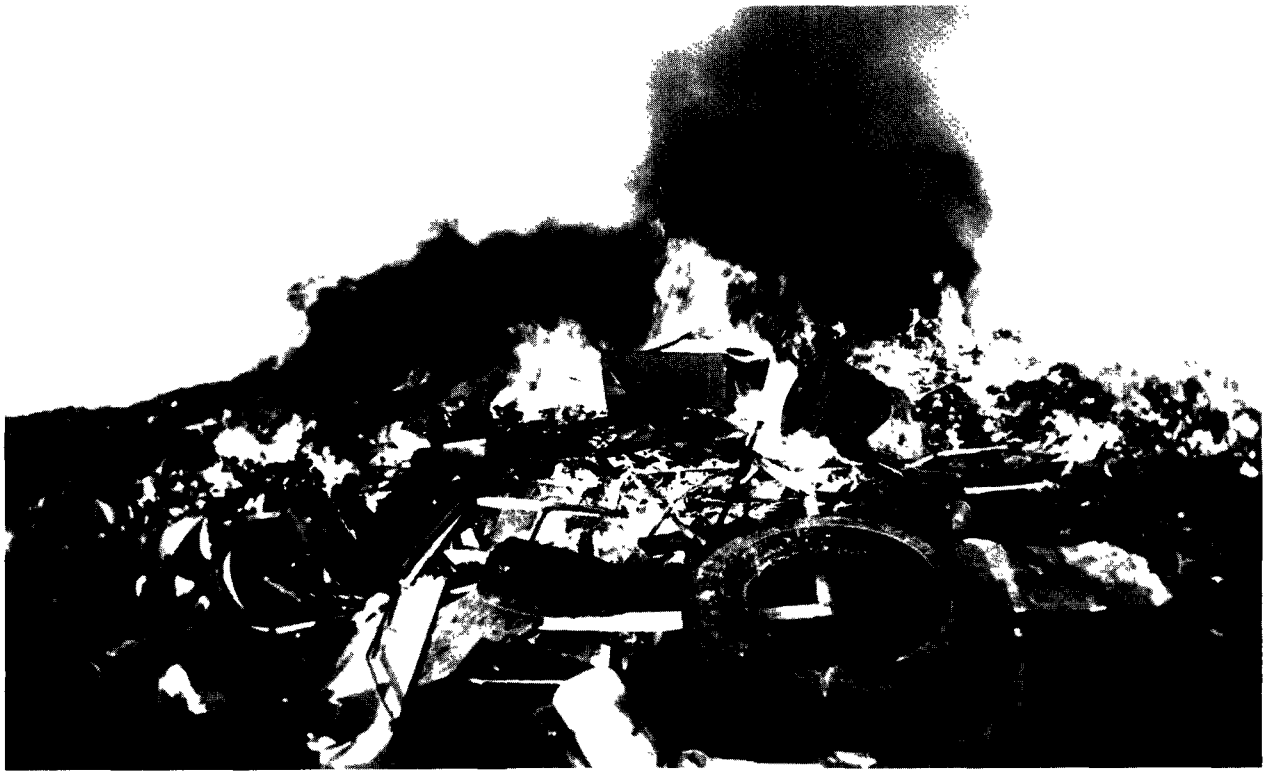

THE POLLUTED ENVIRONMENT

Our polluted environment has been the object of increasing concern. Water and air pollution have received national attention and treatment for decades, but solid waste, which has been called the third pollution, entered the national limelight only with the passage of the Solid Waste Disposal Act of 1965.

Public apathy toward the disposal of solid wastes is no longer commonplace. In many communities, the public is rejecting the traditional open burning dump. Citizens are recognizing the need for safe and sanitary management of solid wastes. Demand increases for properly engineered, effective, and economic solid waste disposal facilities.

Sanitary Landfill Facts presents general information on the state of the art of one basic, acceptable, and effective method of solid waste disposal—the sanitary landfill. This publication examines the planning, design, operation, and public health aspects of sanitary landfills. This information is offered as an aid to the growing number of people involved with planning and development of solid waste management.

—RICHARD D. VAUGHAN, *Director*
Bureau of Solid Waste Management

MISCONCEPTION

Upon hearing the term, 'sanitary landfill,' many of us immediately picture the traditional open, frequently burning, dump.
This misconception is quite natural because in many instances the term 'sanitary landfill' has been misused as the label for an open dump. The fact is, however, that a true sanitary landfill **is not an open dump.**

OPEN DUMPS ARE PARTICULARLY DANGEROUS where salvage is permitted (as in the above photograph). Open dumps contribute to air and water pollution and are sources of food for insects, rodents, birds, and other wildlife that may act as disease carriers.

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Sanitary Landfill Facts

THE SANITARY LANDFILL is defined by the American Society of Civil Engineers as: *A method of disposing of refuse on land without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation, or at such more frequent intervals as may be necessary.*[1]

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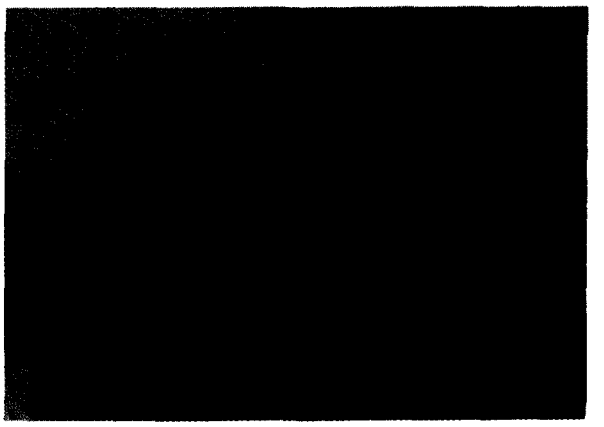
[1] See page 25 for references.

Such a landfill is a well-controlled and truly sanitary method of disposal of solid wastes upon land. It consists of four basic operations: (1) the solid wastes are deposited in a controlled manner in a prepared portion of the site; (2) the solid wastes are spread and compacted in thin layers; (3) the solid wastes are covered daily or more frequently, if necessary, with a layer of earth; (4) the cover material is compacted daily. The final result can be a golf course, tennis court, playfield, botanical garden, municipal riding ring, or whatever not-too-heavy activity the community wants.

PLANNING A SANITARY LANDFILL

A sanitary landfill is an engineering project. When sound engineering principles are applied, the result will be a successful and efficient operation. Most operational problems can be prevented in the initial development stages. This is easier and more economical than correcting the defects once the operation has begun.

The first step toward the ultimate goal of establishing a sanitary landfill operation is, of course, initial planning. Preliminary planning develops the basic groundwork for the actual engineering phases of site selection, design, and operation. Advanced planning should include consideration of: a competent designer; a public information program; a survey of solid waste practices and possible sites; methods of financing; ultimate use of the completed site; and site zoning arrangements.



The solid wastes are covered daily, or more frequently if necessary, with a layer of earth.

With perhaps a playfield in mind as the final use, the project must be guided successfully through an initial planning phase and then a well-engineered operation to reach the ultimate goal.

Competent Designer. Engineering knowledge and experience in sanitary landfill site selection, design, and operation are essential requirements of the individual or agency chosen to develop the sanitary landfill. If the planning or operating agency does not have this engineering experience and competence, every effort should be made to obtain the services of the best engineering consultant available.

Although a sanitary landfill is considered the most inexpensive of the methods of disposal, it is a mistake to assume that a successful operation requires little skill or knowledge of design and operation. The engineer or consultant is important—this is a poor place to attempt to economize. The money spent for the services of a competent designer will bring returns in a sanitary landfill operation that is successful and acceptable to the public.

Information Program. Unfortunately, many people associate impressions of open burning dumps with sanitary landfills. As a result the planning of a sanitary landfill usually meets with public opposition unless the operating agency has conducted acceptable operations elsewhere. In many communities, public acceptance of a sanitary landfill site is the most important factor in deciding whether it will exist.

Preliminary planning should include an active public information program to explain to the public what comprises a sanitary landfill operation and what benefits can be expected.

In gaining public support the designer will find it helpful to have the final use of the landfill area determined in advance. An architectural rendering or a model of the completed site as a park, playground, golf course, or other planned use, is a good public relations tool.

When opposition to the proposed sanitary landfill is exceptionally strong, the operating agency can use a temporary pilot operation to illustrate a good sanitary landfill while simultaneously soliciting newspaper and TV support and possibly even hiring professional public relations services for the program.

Operations must be exemplary in order to gain public support. The public will soon discover any discrepancies between the public information program and actual operations.

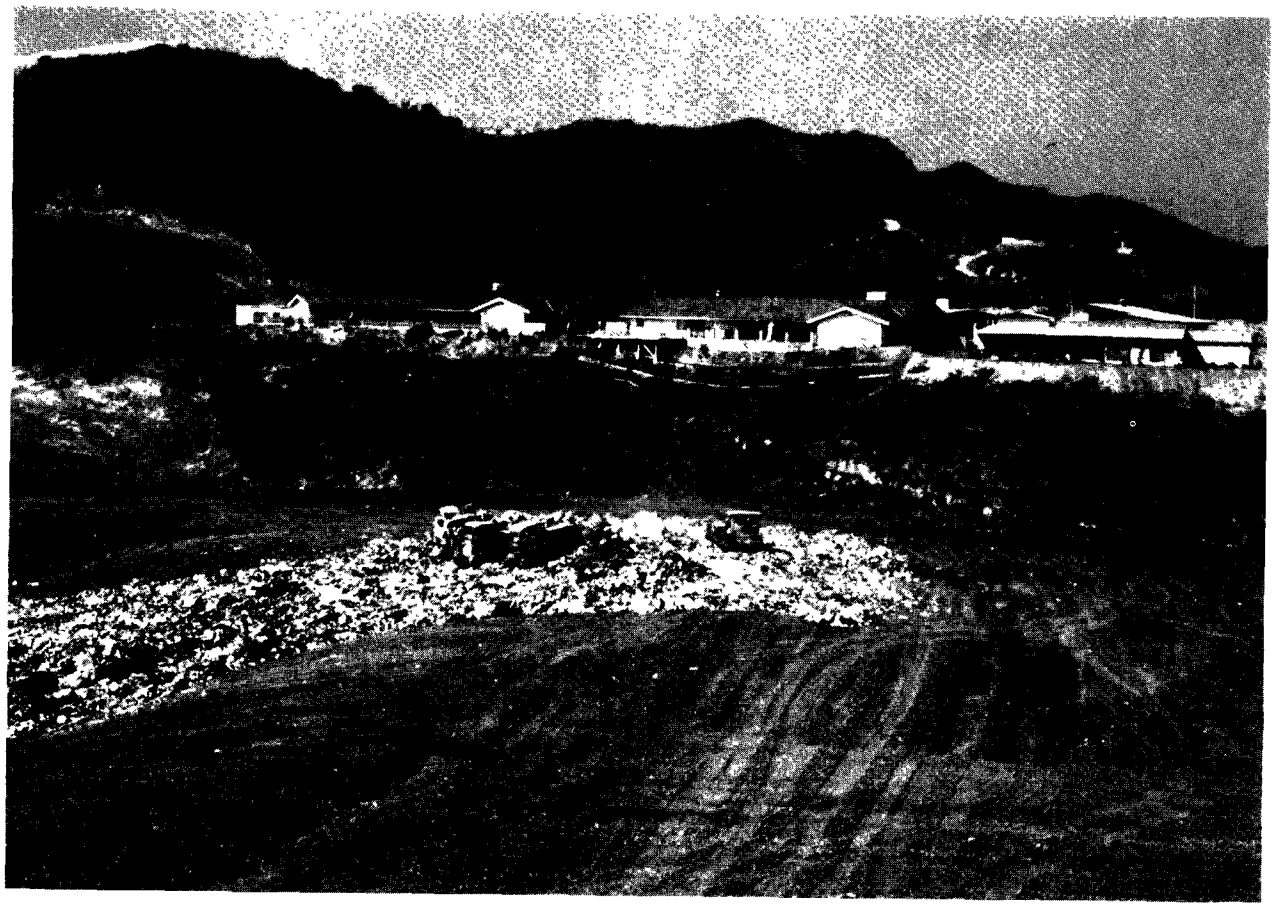
Other Considerations. The responsible officials in the preliminary planning phase must decide how the initial cost and the operating costs of the sanitary landfill will be financed.

These officials should also investigate the amount and reliability of available data concerning the quantity and characteristics of the solid wastes to be handled. If sufficient and reliable data necessary for proper site selection and design are not available, the area to be served by the sanitary landfill must be surveyed to procure the necessary information.

If at all possible, the ultimate use of the completed landfill site should be decided during the initial planning stage. Knowing the final use of the site permits the designer to plan more effectively and gains public support for the project.

Zoning restrictions have sometimes interfered with the development of an area for a sanitary landfill. Many legal problems can be avoided if preliminary planning includes arrangements for zoning potential areas for sanitary landfill operations and ultimate site use.

THIS WILL BE A GOLF COURSE.
Homes in the Mission Canyon area of Los Angeles were intentionally built overlooking a large sanitary landfill, because the owners knew that a park and golf course would be constructed on the completed fill.



SELECTING A SITE

An important engineering step toward establishing an acceptable sanitary landfill operation is site selection. As with the preliminary planning phase, proper site selection can eliminate many future operational problems. The factors to be considered when selecting a sanitary landfill site will require technical know-how and experience, and so it bears repeating that a well qualified individual or agency should be responsible for site selection.

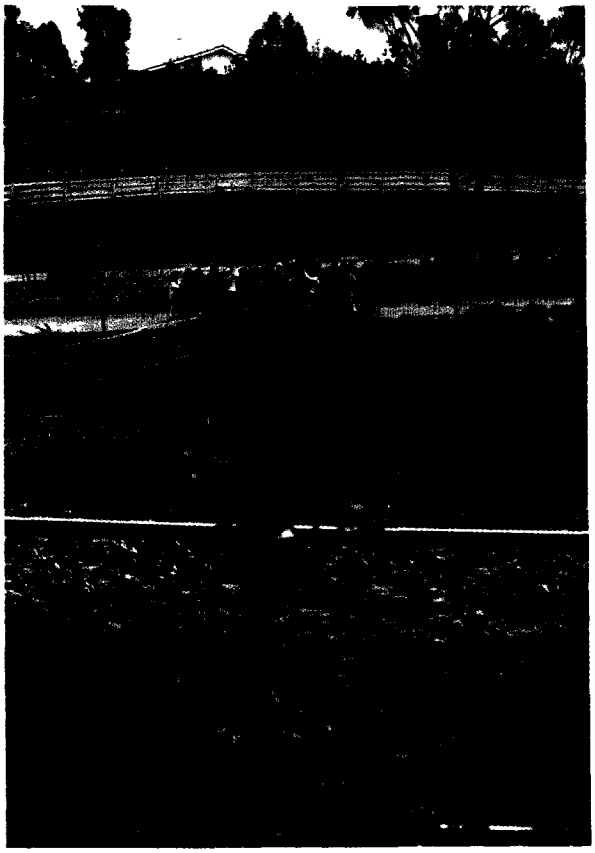
Land Requirement. The land area—or, more important, the volume of space required—is primarily dependent upon the character and quantity of the solid wastes, the efficiency of compaction of the wastes, the depth of the fill, and the desired life of the landfill. Data on the quantity and character of residential, commercial, and industrial solid wastes to be landfilled are therefore necessary for estimating the space required. In estimating volume requirements, volume reduction of the solid wastes due to compaction must be considered. The desired life of the landfill is another major factor in determining the total volume required.

The volume requirement for a sanitary landfill should be determined on the basis of the specific data and information for each individual project. As an estimate, however, using a waste generation rate of 5.3 pounds per person per day, solid waste density of 1,000 pounds per cubic yard, and one part earth cover to four parts waste, a population of 10,000 people would require 15 acre-feet of space per year.

Zoning Restrictions. A survey conducted by the American Public Works Association in 1956 indicated that a high percentage of cities are restricted by their zoning ordinances in the acquisition of disposal sites.[2] Consequently, before a full-scale investigation of a potential site is undertaken, 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. Advance planning to zone the potential landfill site areas

[2] See page 25

A botanical garden became the final layer of this completed landfill.



for sanitary landfill operation can circumvent many of these problems.

Accessibility. The site should be easily reached by trucks via highways or arterial streets. Sites requiring trucks to travel through residential areas will nomally draw many complaints. Such sites should be avoided or selected to minimize residential travel.

The roads to the site should be of width and construction adequate to handle all sizes of trucks when fully loaded, during all weather conditions. Such problems as narrow bridges, low underpasses, and steep grades on the access routes should be investigated. Since the site should be accessible at all times, it is desirable to have several access routes so that if one route is temporarily unusable the site can still be used.

Haul Distance. The haul distance is an important economic factor in selecting the sanitary landfill site. The economic distance to the site will vary from locality to locality depending upon capacity of collection vehicles, hauling time, and size and methods of the collection agency. The larger the quantity of refuse hauled per trip and the shorter the hauling time due to express roads, freeways, etc., the greater the distance the solid wastes can be hauled for the same cost.

Cover Material. The availability of cover material is another economic factor to consider, for the cost of hauling cover material to the site can be excessive. A site that has cover material close by will keep these costs at a minimum.

The field investigation of the potential site should include soil analysis to determine the suitability and the quantity of soil available for cover material. Soil with good workability and compaction characteristics is the most desirable cover material. A well graded soil has these qualities and is a good cover material.

Geology. The potential danger of ground and surface water pollution resulting from the landfill cannot be overlooked. Solid wastes ordinarily contain many contaminants and often infectious materials. Serious health hazards or nuisances can result if these pollutants are permitted to enter water supplies. Site selection should include a geological investigation of the site, possibly in conjunction with the cover material field investigation, to determine the potential of either ground or surface water pollution. The groundwater table must be located and information obtained on the historical high groundwater level and on the general movement of the groundwater.

Geological investigation should also examine the topography of the site itself and the surrounding area to determine potential flooding conditions during heavy rains and snow melts. Special attention should be given to low-lying sites that might be drainage basins for surrounding areas. Surface water drainage and flooding can quickly erode the cover material and the refuse fill.

Sites located near rivers, streams or lakes also deserve careful scrutiny. Generally, a landfill should not be located in a flood plain because of the water pollution hazard, and because

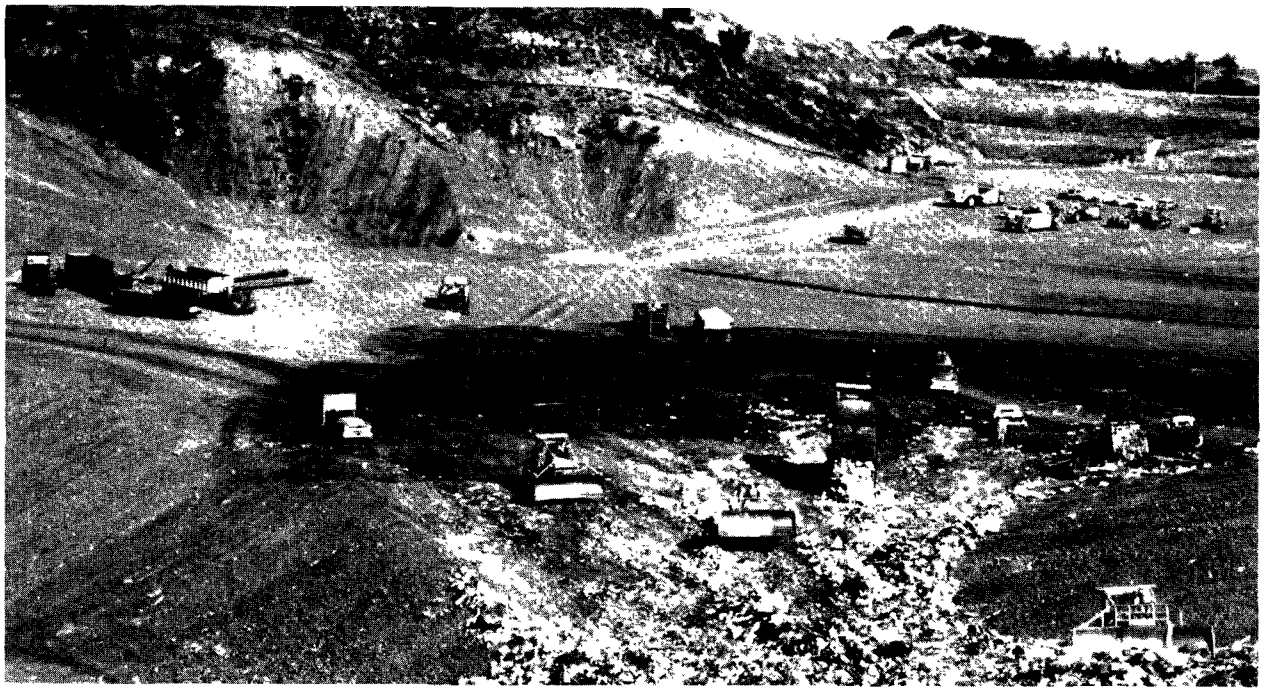
these sites can become unusable both during and after floods. Sanitary landfills that are located in such areas require special engineering design compatible with the site conditions.

Climate. In some locations, climate is important in site selection and may even dictate the method of operation. In an extremely cold locality, a site requiring excavation of trenches and cover material may become a problem because of freezing during the winter months. However, a site can be used in a wintery locale if the trenches and cover material are excavated during the summer months to carry the operation through the winter period.

In areas receiving considerable rainfall, a low-lying site may be undesirable because of flooding and muddy working conditions. In rainy areas, a desirable site would be high in relation to the surrounding area and have good drainage features.

In windy locales, a site surrounded by natural windbreaks will help to contain loose paper and minimize any dust problems.

Fire Control Facilities. Although there is little chance of fire at a sanitary landfill operated in accordance with good practices, suitable fire protection should be provided. Fires can usually be extinguished by smothering with a blanket of earth, but all sites should also have water available for fire control. Fire control facilities are especially important if residential or commercial structures are relatively close and in extremely dry areas where the fire could spread quickly and do extensive damage.



Sanitary landfill is an engineering project.
Sanitary landfills don't "just happen".

DESIGNING A SANITARY LANDFILL

The design and operational steps during development of the sanitary landfill are not distinct entities. Basic knowledge and experience in the operational aspects of a sanitary landfill are necessary for the design phase. In essence, the design phase develops the plan of operation. It consists primarily of determining the operational plan and preparing the necessary detailed plans and specifications for construction and operation. Good plans and specifications are essential for estimating costs, for obtaining bids, and for operational control and inspection.

Plans. Detailed plans should be prepared showing the existing topography and the designed contours of the completed landfill. As mentioned, it is extremely helpful when designing the final ground elevations, if the use of the completed landfill has been previously determined.

The plans should show the overall program for landfilling, the drainage features, groundwater table, location of the cover material, and the wet weather operation site. The plans should also detail all construction features such as access roads, personnel and equipment facilities, scales, fencing, signs, waterlines and other utilities.

Specifications. The plans should be complemented with a set of specifications for construction and operation. Construction specifications cover construction materials, workmanship, and equipment. Operating specifications detail the method of operation, including weighing the wastes, cross-sectioning the site at definite time intervals, thickness of cover material, depth of lifts and cells, compaction, wet weather procedures, amount, type, and size of equipment, and personnel.

OPERATING A SANITARY LANDFILL

The appearance of the sanitary landfill during operation cannot be overly stressed. The operation is the only phase of the project seen by the public. Consequently, public acceptance of the plan, design, and operation will be based solely on the operation.

A well operated sanitary landfill is the goal of the planner, the designer, and the operator. Each must have a thorough knowledge of all the factors in achieving this goal.

Supervision. A clean, orderly, and economic operation requires constant and competent supervision. It is also important to employ experienced or adequately trained personnel to operate the sanitary landfill.

~~Operating~~ Records. For continuing evaluation and future planning, detailed records should be kept of incoming material: the weights, the type, and the origin. Any deviation from the plan of operation should be recorded. Topographic surveys of the landfill should be made regularly to determine the rate of space utilization. The incoming-material data and the topographic surveys can be used to determine the amount of compaction, efficiency, land use, and operation efficiency, and to estimate the degree of decomposition and eventual settlement. Good cost-accounting records should be main-

Such a landfill entrance helps to secure public support for the project.

tained, including the initial cost of the land and equipment, and the operating cost of the labor, equipment, equipment maintenance, depreciation, etc. These data are necessary for budgetary planning, for determining the cost rates for users, and for comparison with other operations, justifying expenditures, and estimating the efficiency of operation.

Directions. Sanitary landfills, particularly those open to the public, need directional signs and markers on nearby highways to help speed traffic movement At the entrance to the site a large legible sign should be posted to inform the public of the hours of operation, cost of disposal, and rules and regulations (such as, "only covered trucks permitted"). At large sanitary landfill operations, signs should also be used on the site to direct the users to the unloading area.

On-site Roads. The on-site roads to the unloading area should be ot all-weather construction and wide enough to permit easy two-way truck travel. Road grades should be designed for the largest fully loaded trucks to travel at a reasonable rate. It is particularly important at large sites that traffic in and out of the area flow smoothly.

Methods. Sanitary landfilling consists of the basic operations of spreading, compacting, and covering. Two general methods have evolved: the area method and the trench method (Figures 1 and 2). Some schools of thought also include a third, the slope, or ramp, method. In some operations, a slope or ramp is used in combination with the area or trench methods. For this reason, the three methods will be described: area landfill, trench landfill, and the ramp, or slope, method.

In an **area sanitary landfill,** the solid wastes are placed on the land; a bulldozer or similar equipment spreads and compacts the wastes; then the wastes are covered with a layer of earth; and finally the earth cover is compacted. The area method is best suited for flat areas or gently sloping land, and is also used in quarries, ravines, valleys or where other suitable land depressions exist. Normally the earth cover material is hauled in or obtained from adjacent areas.

In a **trench sanitary landfill,** a trench is cut in the ground and the solid wastes are placed in it. The solid wastes are then spread in thin layers, compacted, and covered with earth excavated from the trench. The trench method is best suited for flat land where the water table is not near the ground surface. Normally the material excavated from the trench can be used for cover with a minimum of hauling. A disadvantage is that more than one piece of equipment may be necessary.

In the **ramp or slope method** (a variation of the area and trench landfills), the solid wastes are dumped on the side of an existing slope. After spread-

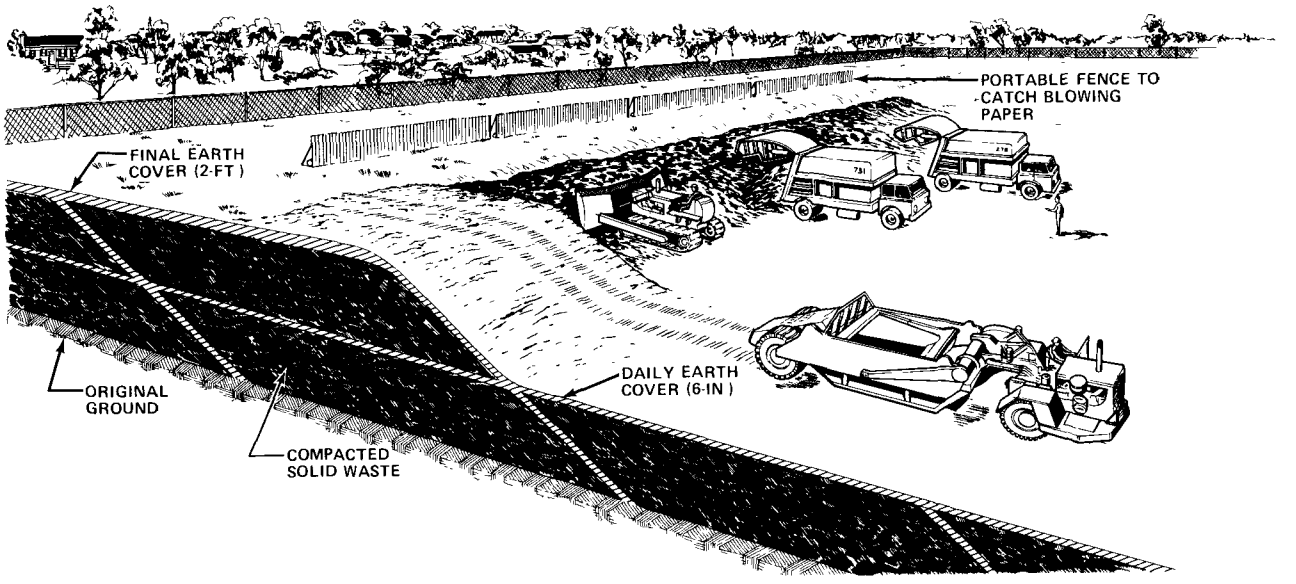


FIGURE 1. AREA METHOD. The bulldozer spreads and compacts solid wastes. The scraper (foreground) is used to haul the cover material at the end of the day's operations. Note the portable fence that catches any blowing debris. This is used with any landfill method.

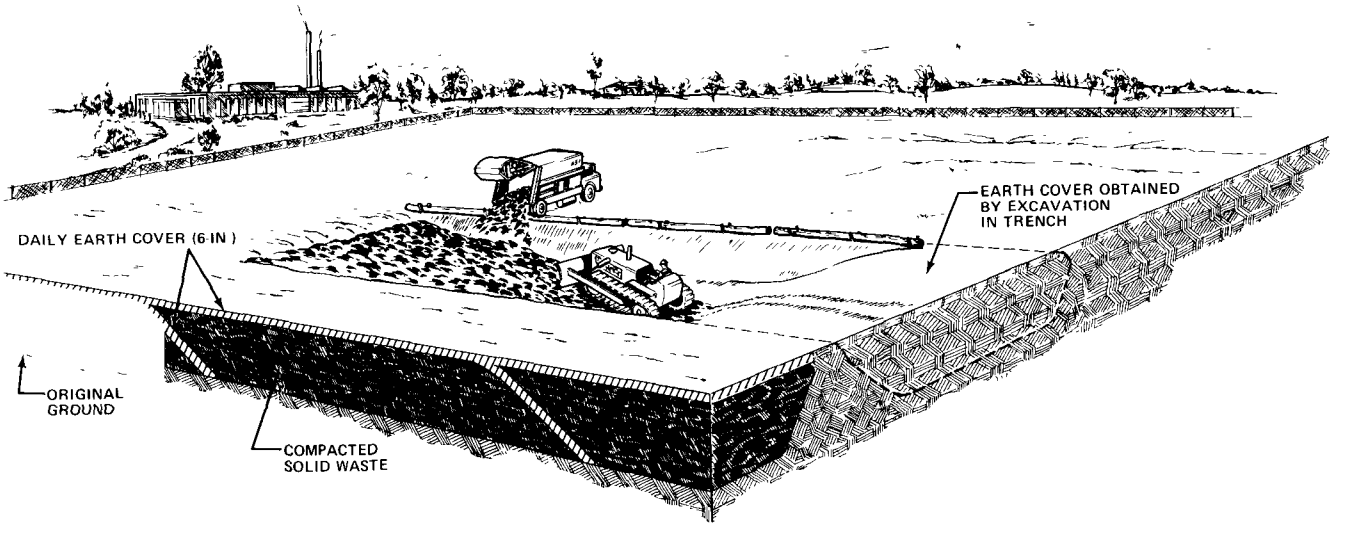


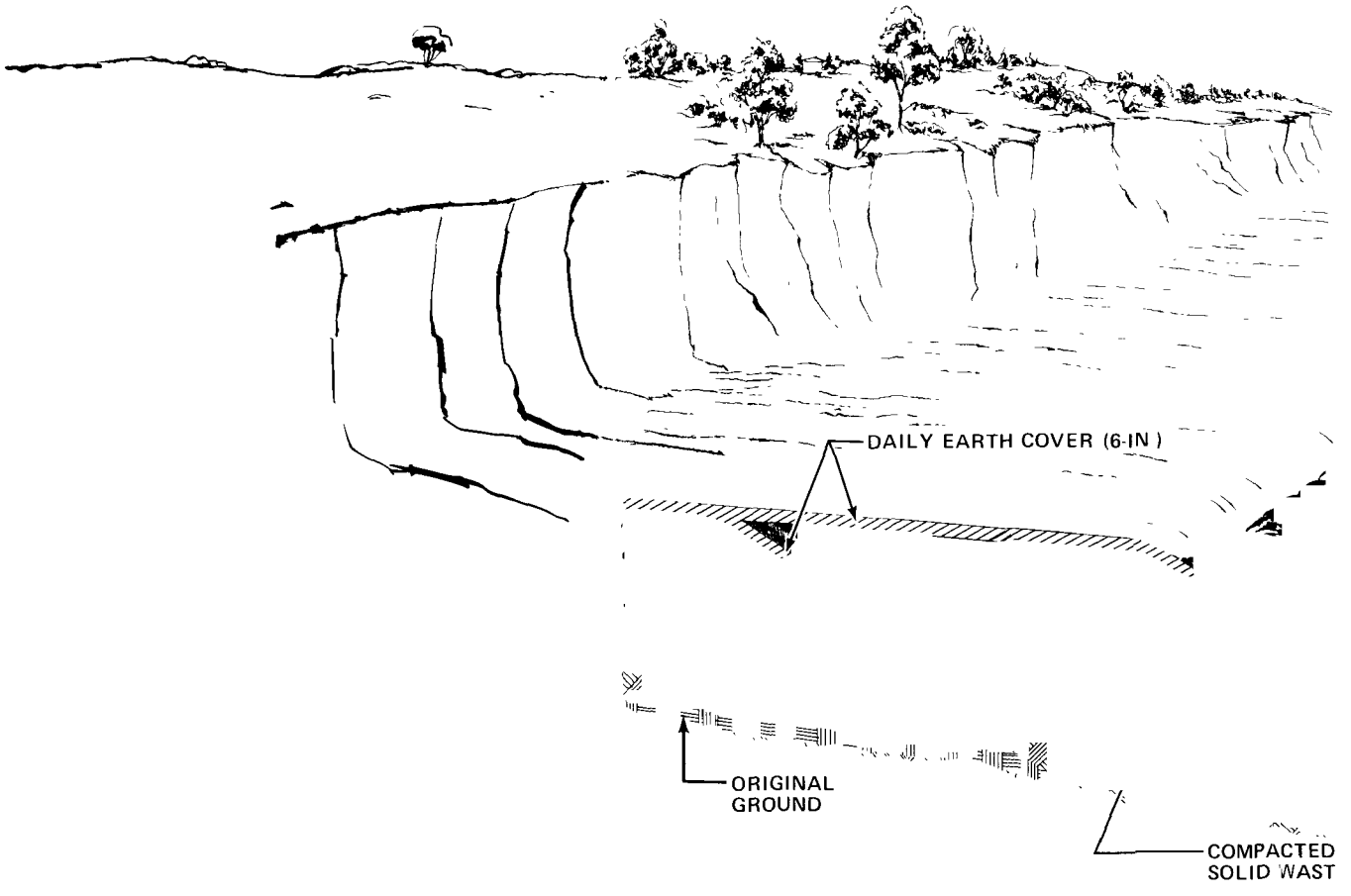
FIGURE 2. TRENCH METHOD. The waste collection truck deposits its load into the trench where the bulldozer spreads and compacts it. At the end of the day the dragline excavates soil from the future trench; this soil is used as the daily cover material. Trenches can also be excavated with a front-end loader, bulldozer, or scraper.

ing the material in thin layers on the slope, the bulldozing equipment compacts it. The cover material, usually obtained just ahead of the working face, is spread on the ramp and compacted. As a method of landfilling, this variation is generally suited to all areas. The advantage of utilizing only one piece of equipment to perform all operations makes the ramp or slope method particularly applicable to smaller operations. The slope or ramp is commonly used with either area or trench sanitary landfill (Figure 3).

Compaction. Solid wastes should be placed at the top or base of the working face, spread in layers about 2 feet thick, and compacted. If a slope or ramp is used, better compaction will normally result if the wastes are spread and compacted from the base upwards.

The degree of compaction is dependent on the character of the solid wastes, the weight and type of compacting equipment, and the number of passes the equipment makes over the material. The actual density of the landfill can

FIGURE 3. RAMP VARIATION. 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.

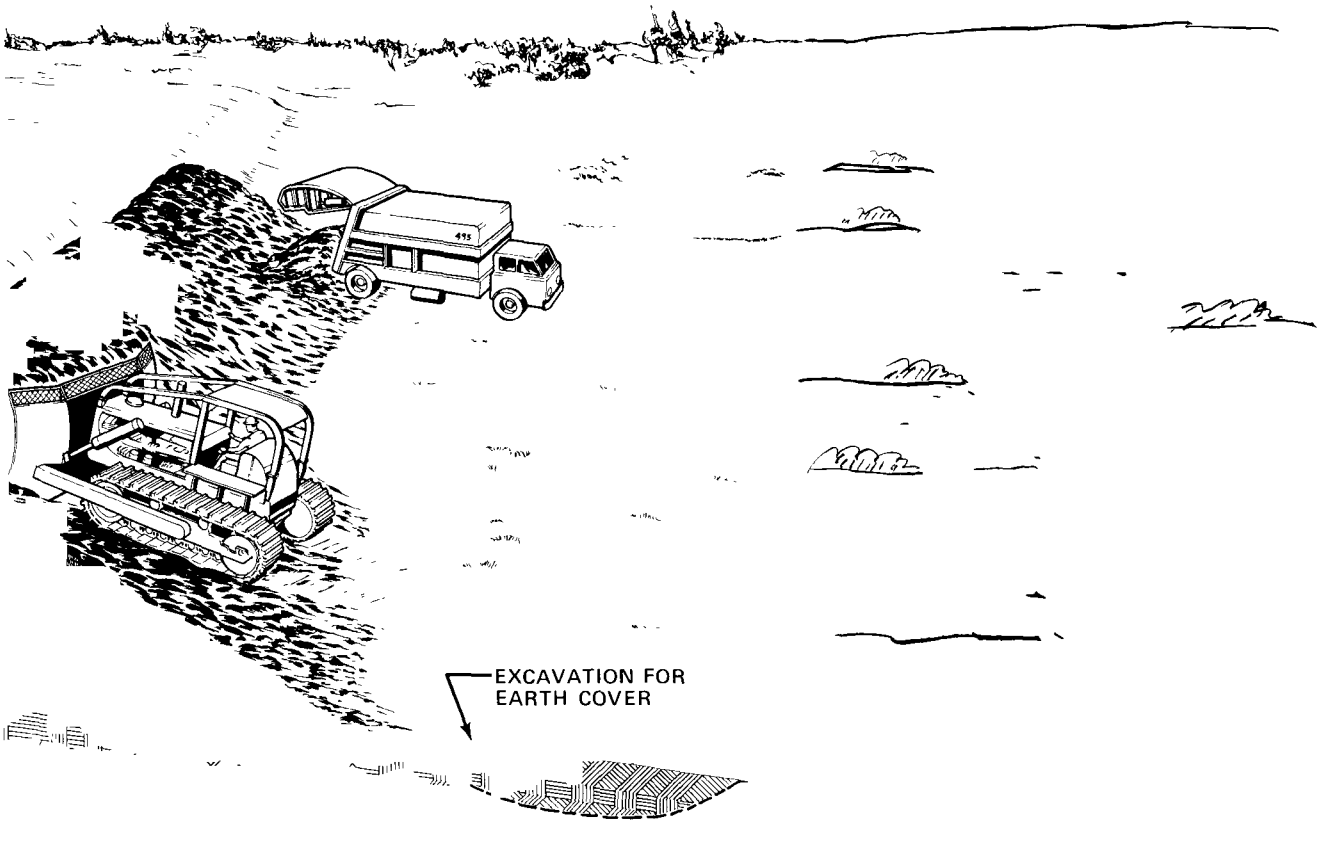


be determined from operating records and data. The degree of compaction is a useful tool to determine the rate of space usage, expected life of the landfill, and the overall efficiency of the operation.

Working Face. The size of the working face of the sanitary landfill operation is determined by the rate of unloading of incoming vehicles. The working face should be as narrow as possible to minimize the exposed area, but not so small as to interfere with the unloading operations and the movement of landfill equipment.

A minimum width of the working face should be approximately twice the width of the tractor to allow the tractor to move from side to side thus compacting the entire exposed surface.

Depth of Cells. Cell depth is the thickness of the solid wastes layer measured perpendicular to the working slope where the equipment travels. The depth of cells is determined largely by the size of the operation, the elevation desired of the completed fill, the depth of the trench or depression to be filled, and in some cases, the amount of cover material available. Eight feet is generally recommended as a maximum single cell depth because deeper cells usually result in fills that have excessive settlement and surface cracking. However, the cell depth of presently operated sanitary landfills varies from 2 feet to 15 feet or more.



Cover. The compacted solid wastes must be covered at the conclusion of each day, or more frequently if necessary, with a minimum of 6 inches of compacted earth. A well-graded soil having good workability and compaction characteristics is a most desirable cover material. If a well-graded soil is not available on the site, it will be necessary to adjust the covering procedures to the type of cover material available or to haul in a suitable cover material. The cover is necessary to prevent insect and rodent infestation, blowing paper, fires, the attraction of wildlife, and the release of gas and odors.

For daily cover a minimum of 6 inches of compacted soil is recommended. For intermediate cover on lifts which will not have additional lifts placed on them within a year, a minimum of 12 inches of compacted soil is recommended. A minimum of 2 feet of compacted soil is recommended for the final cover. The final cover should be placed over the fill as soon as possible to help assure that wind and water erosion does not expose the wastes. Where trees will be planted on the completed fill, a depth of 3 or more feet of compacted earth has been found necessary.

Large Items. Large bulky items such as car bodies, refrigerators, water heaters, and tree stumps, can be handled routinely with other solid wastes at large sanitary landfills that use heavy equipment. At small sanitary landfills where light equipment is normally used, special provisions may be necessary to handle bulky items.

A separate unloading area or an alternate site operated in a sanitary manner should be utilized for the disposal of bulky items that cannot be handled routinely with other solid wastes.

Blowing Paper. In a 1959 survey of sanitary landfill operations by the American Society of Civil Engineers, the operating problem most frequently reported was blowing paper.[3] The common method of controlling blowing paper is with a combination of permanent and portable fences. It is important, therefore, that the designer consider the prevailing wind direction when designing the operation. Unfortunately, under certain wind conditions paper may blow up and over the fences, so that fences do not provide complete control. Prompt compaction and covering and daily pick up of loose paper should be practiced to control windblown paper.

Maintenance. Routine maintenance will be required to maintain a clean, orderly and acceptable operation and site. It is important, particularly at public sanitary landfills, to cut grass and weeds, pick up scattered paper, maintain good access roads, control dust, and maintain immaculate employee and public facilities.

Drainage. Ponding on the landfill surface will result in excessive seepage into the landfill and must be prevented. Precautions must be taken to prevent runoff water from eroding the cover material and exposing the wastes. Adequate drainage therefore is essential both during the filling operation and for the completed landfill. Good drainage will usually require periodic regrading of the site, and the use of culverts or grassed waterways. It is recommended that the slope of the surface of the completed fill should be a minimum of 1 percent. Since the landfill will undergo uneven settlement, it may be necessary to design the original slope for more than 1 percent to maintain a 1 percent slope after settlement. To prevent erosion, however, steep slopes should be avoided.

Winter Operations. Experience has shown that with good planning and proper operating techniques, a sanitary landfill can be operated even in the severe winters of the northern states.[4] If the trench method is used, the trenches should be excavated before the cold weather. It may be necessary to stockpile cover material and cover it with straw, leaves, or other material to prevent freezing. The material should be piled loosely with minimum compaction. All snow and ice should be removed from the trenches before

[3] See page 25

[4] See page 25

use; snow fences can protect the access roads. A well-constructed, heated tractor cab enables the operator to work efficiently during the cold weather.

Wet Weather Operation. Wet weather can seriously hamper the operations of a sanitary landfill by making the soil too soft, mucky, or slippery for equipment operation. Wet weather can also seriously interfere with trenching, covering, and general traffic flow to and from the working face. For these reasons, all-weather access roads and adequate drainage should be provided.

In many cases it is advantageous to stockpile materials such as concrete rubble, broken asphalt pavement, or stone for use on the site roads during wet weather. This will minimize the cost of constructing and maintaining hard-surface roads to the unloading area. It is also desirable to provide a temporary wet weather landfill area adjacent to the all-weather road. Such sites are used only during the wet weather periods when the normal working area is not accessible.

Storm drains and debris settling basins are required to prevent storm water erosion and release of debris-laden water to off-site drainage works.

Particular attention must be given to landfills when the trench method is being used. If pumping or good drainage is not provided, the trenches will fill with water, resulting in possible ground or surface water pollution and complete shut-down of the operation.

Salvage Operation. To ensure clean and orderly sites and to prevent landfills from looking like open dumps, salvage operations should be prohibited at all sanitary landfill sites. The American Society of Civil Engineers has stated that the most objectionable disposal sites from the standpoint of appearance are generally those where the salvage activity is the greatest.[1]

[1] See page 25

PUBLIC HEALTH ASPECTS

Vector Control. In a properly operated and maintained sanitary landfill, insects and rodents are not a problem. Well-compacted wastes and cover material are the most important factors in achieving vector control. Six inches of compacted earth cover is recommended for preventing the emergence of houseflies from the fill. Good compaction of the cover material also discourages rodents from burrowing through the cover material. Good housekeeping and daily covering of the solid wastes are musts for vector control.

Water Pollution. Under certain geological conditions, the burial of solid wastes is a real potential for chemical and bacteriological pollution of ground and surface waters. Several investigations of the pollution of groundwater from landfills have indicated that if a landfill is intermittently or continuously in contact with groundwater, it can become grossly polluted and unfit for domestic or irrigational use.

Proper planning and site selection, combined with good engineering design and operation of the sanitary landfill, can normally eliminate the possibility of either surface or groundwater pollution. Some common preventive measures are: (1) locating the site at a safe distance from streams, lakes, wells, and other water sources; (2) avoiding site location above the kind of subsurface stratification that will lead the leachate from the landfill to water sources, i.e., fractured limestone; (3) using an earth cover that is nearly impervious; (4) providing suitable drainage trenches to carry the surface water away from the site.

Air Pollution. Air pollution caused by smoke should not occur. Burning is not permitted at a properly operated sanitary landfill. If an accidental fire does occur, it should be extinguished immediately.

Dust. In dry weather, dust may constitute a nuisance at a sanitary landfill operation. Dust at the unloading area can be controlled by sprinkling the unloading area and the deposited refuse with water. Other dust control measures are the planting of grass or other vegetation on the finished fill and the application of water, road oil, or calcium chloride to the access roads.

Odors. Odors are usually the result of gases from anaerobic digestion of putrescible material. They are generally considered a nuisance but can be a public health hazard.

The best control for odors is rapid and continuous coverage of solid wastes during the day and sealing surface cracks of the completed area of the landfill to prevent emissions of large concentrations of odorous gases.

Wildlife. Birds, particularly gulls, and other wildlife are common at open and burning dumps, but there is little exposed food to attract wildlife at sanitary landfills. Most good sanitary landfill operations are free from these nuisances; however, there is no guarantee that all sanitary landfills will be completely free of wildlife.

If the site is kept clean, and the solid wastes covered promptly with earth, gulls and other wildlife will be at a minimum.

Gas Production. Gases produced within a sanitary landfill consist chiefly of methane, nitrogen, carbon dioxide, hydrogen, and hydrogen sulfide. Methane gas is explosive and can be a hazard if accumulated in enclosed spaces. At landfills where methane and other gases are generated, the gases should be dissipated into the atmosphere and prevented from concentrating in sewers or other structures located on or near the site.

Hazardous Materials. Although it is not common or recommended practice, hazardous materials such as sewage solids, radioactive wastes, pathologic wastes, explosive materials, and chemicals can be disposed of at sanitary landfill sites under special conditions. The special provisions for handling and disposing of these materials will depend on local conditions. Individual handling and disposal may be necessary using a special area separate from the main operation.

The particular requirements should be considered during the design phase so that they may be included in the operational specifications.

YOU CAN FIND ALL SORTS OF USES FOR FINISHED LANDFILLS. In the Chicago area, a ski slope with toboggan run is being built from solid wastes. At Virginia Beach, boys will have a coasting ramp.

EQUIPMENT

A wide variety of equipment is on the market today from which to select the proper type and size needed for an efficient operation. 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.

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.

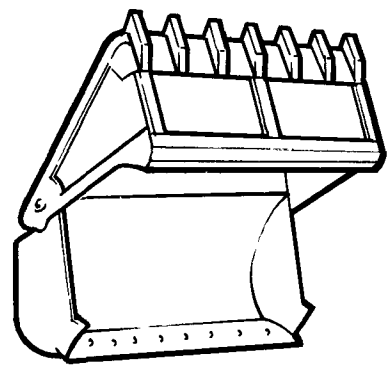
Other equipment used at sanitary landfills are scrapers, compactors, draglines, and graders. This type of equipment is normally found only at large sanitary landfills where specialized equipment increases the overall efficiency.

Size. The size of the equipment is dependent primarily on the size of the operation. Small sanitary landfills for communities 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.

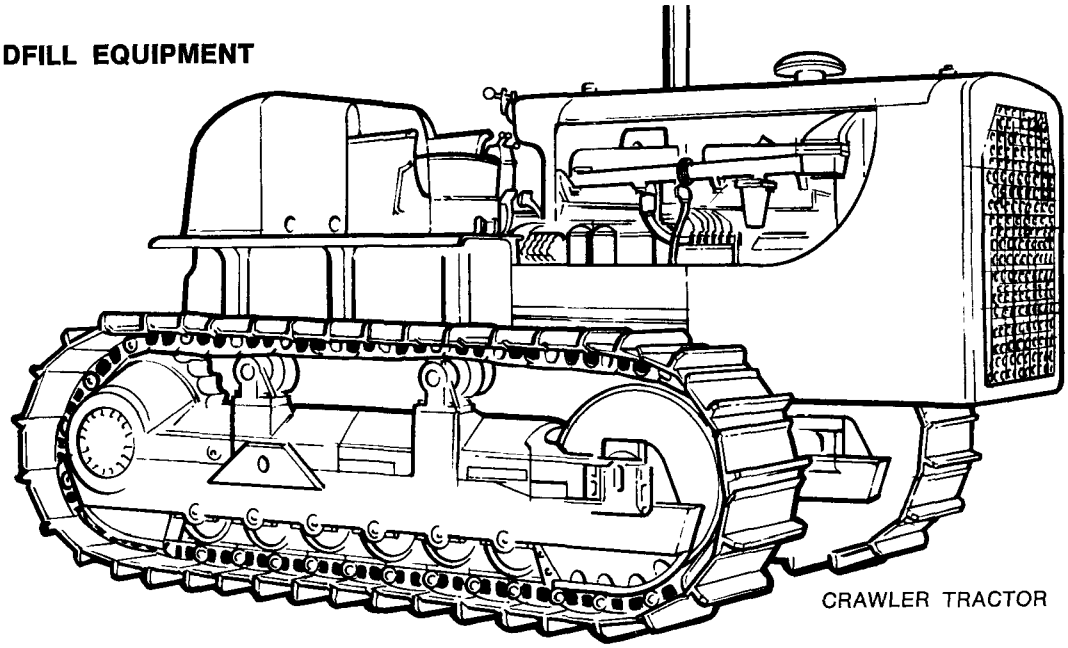
Amount. Sanitary landfills servicing 50,000 people or fewer, or handling about 155 tons of solid wastes per day or less, normally can manage well with one piece of equipment, but provisions must be made for standby equipment. It is preferable that a second piece of equipment be purchased and used for replacement during breakdown and routine maintenance periods of the regular equipment Arrangements can normally be made, however, with another public agency or private concern for the use or rental of replacement equipment on short notice in case of a breakdown of the regular equipment.

At large sanitary landfills serving more than 100,000 people, 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 1 a general guide is given for the selection of the type, size, and amount of equipment for various sizes of sanitary landfills.

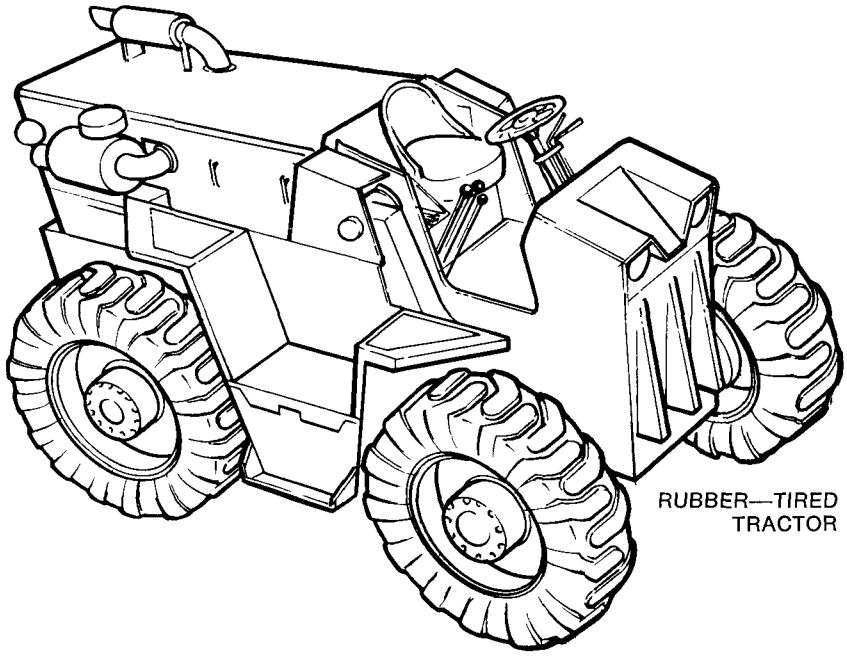


MULTIPURPOSE BUCKET

STANDARD LANDFILL EQUIPMENT

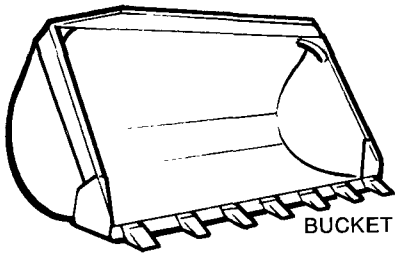


CRAWLER TRACTOR

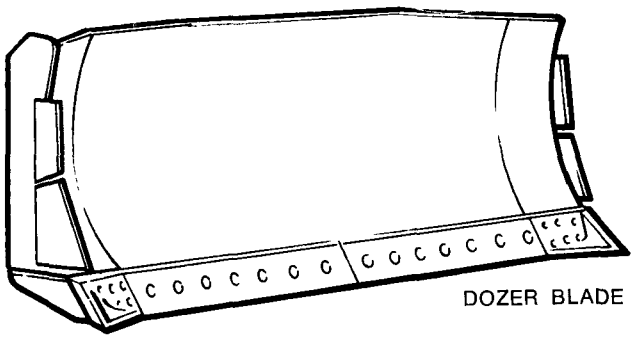


RUBBER—TIRED TRACTOR

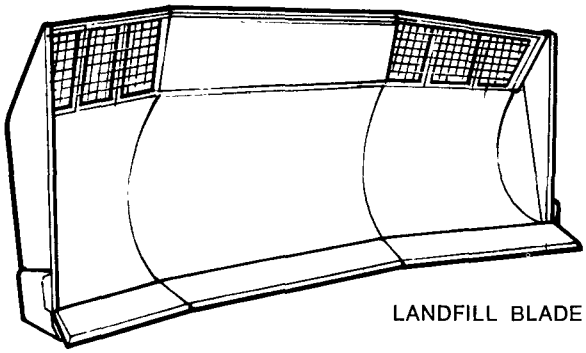
FRONT-END ACCESSORIES



BUCKET

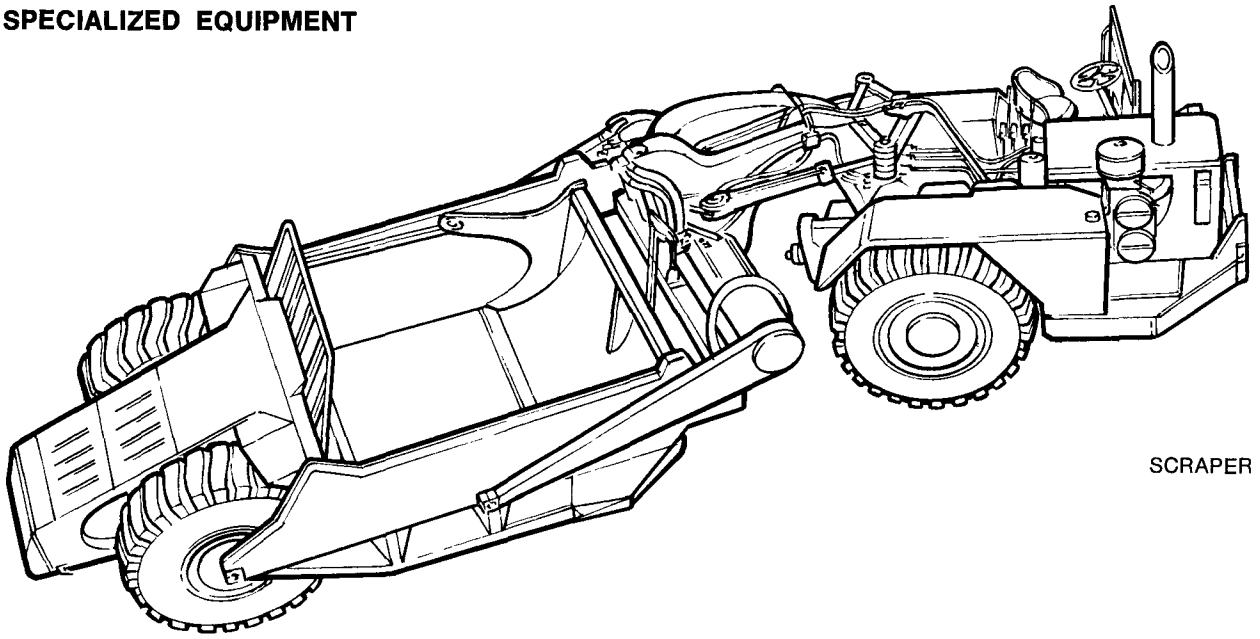


DOZER BLADE

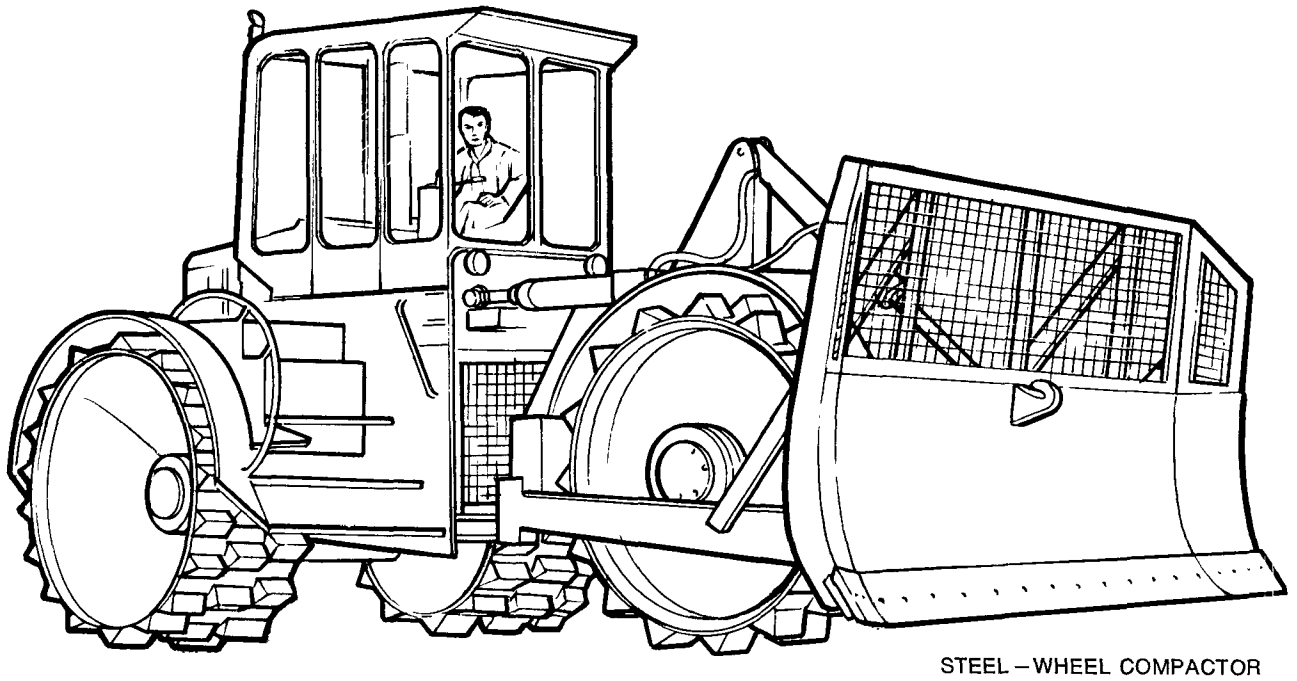


LANDFILL BLADE

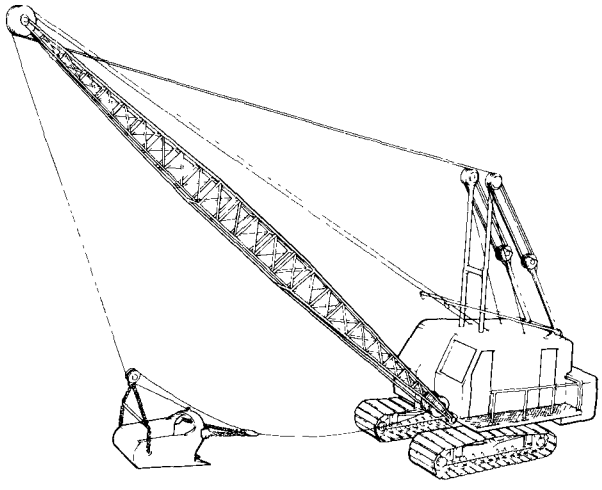
SPECIALIZED EQUIPMENT



SCRAPER



STEEL – WHEEL COMPACTOR



DRAGLINE

FACILITIES

A small sanitary landfill operation will usually require only a small building for storing hand tools, equipment parts, etc., and a shelter with sanitary facilities for the employees. A single building may serve both purposes.

A large sanitary landfill operation should have a maintenance and storage garage for equipment and an administration building. If the scales are not adjacent to the administration building, a scale house may also be needed. Sanitary facilities should be available for both employees and the public. In addition, it is recommended that locker rooms and showers be provided for the employees.

Table 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

COSTS

The cost of a sanitary landfill consists of the initial investment for land, equipment, and construction features, and the operating costs.

Initial Investment. The magnitude of the initial investment depends on the size and sophistication of the landfill. A typical breakdown of the major items that normally constitute the initial investment is as follows:

1. Land
2. Planning and designing
   a. Consultant
   b. Solid wastes survey
   c. Site investigation
   d. Design, plans, specifications
3. Site development
   a. Land development— clearing, landscaping, drainage features, etc.
   b. Access roads
   c. Utilities— water, electricity, telephone
   d. Fencing, signs
4. Facilities
   a. Administration
   b. Equipment maintenance
   c. Sanitation
   d. Weight scales
5. Equipment— tractor, scraper, etc.

Generally, the major portion of the initial investment is for the purchase of the land and equipment. Often a sizable part of the initial investment for land and equipment can be recovered through the development or use of the land and the salvage value of the equipment.

If funds are not available for the proposed investment, consideration should be given to leasing land or equipment, or both, to spread the cost over the life of operation.

Operating Cost. The operating cost of a sanitary landfill depends on the cost of labor and equipment, the method of operation, and the efficiency of the operation. The principal items in operating cost are:

1. Personnel
2. Equipment
   a. Operating expenses— gas, oil, etc.
   b. Maintenance and repair
   c. Rental, depreciation, or amortization
3. Cover material— material and haul costs
4. Administration and overhead
5. Miscellaneous tools, utilities, insurance, maintenance to roads, fences, facilities, drainage features, etc

Wages ordinarily make up about 40 to 50 percent of the total operating cost. Equipment equals 30 to 40 percent; cover material, administration, overhead, and miscellaneous amount to about 20 percent.

The operating costs per ton versus the amount of solid wastes handled in tons and the population equivalent may be charted (Figure 4).

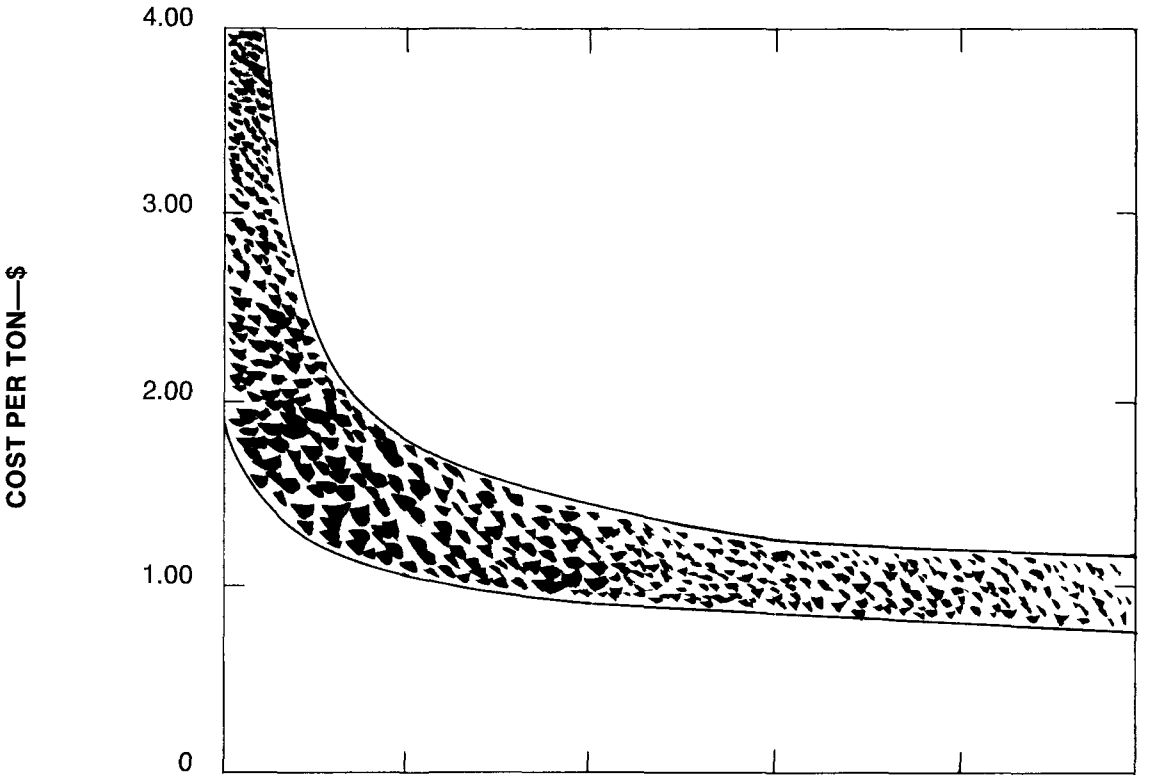
The operating cost of a small operation handling less than 50,000 tons per year varies from $1.25 to approximately $5.00 per ton. This wide range is primarily due to the low efficiency of the smaller operations which are usually operated on a part-time basis.

Full-time personnel, full-time use of equipment, specialized equipment,

better management, and other factors that lead to high efficiency are possible at large sanitary landfill operations. The increased efficiency results in lower unit cost of disposal. The unit cost of a large landfill handling more than 50,000 tons per year will generally fall between $0.75 to $2.00 per ton.

To compare the true cost of sanitary landfilling with that of incineration or composting, it is essential that the costs and returns of the initial investments and the hauling costs be considered along with the total disposal costs including the disposal of incinerator residue and noncompostable materials The hauling costs of a collection system that uses the sanitary landfill disposal method may be higher than the hauling costs of a system using incineration or composting, since sanitary landfills are generally located farther from the waste-generating area than are incinerators or compost plants. A sanitary landfill, however, may increase the value of a plot of unusable land by converting the site to a playground, golf course, park. . . . , thereby obtaining a major investment cost advantage over incineration and composting.

FIGURE 4. SANITARY LANDFILL OPERATING COSTS



TONS PER YEAR	0	100,000	200,000	300,000	400,000	500,000
TONS PER DAY [1]	0	320	640	960	1280	1600
POPULATION [2]	0	122,000	244,000	366,000	488,000	610,000

[1] Based on 6-day work week.

[2] Based on national average of 4.5 lbs per person per calendar day.

COMPLETED SANITARY LANDFILL

Decomposition. Little information is available on the decomposition of buried material in a sanitary landfill. It is extremely difficult to predict the time required for complete decomposition. Many items, particularly paper, have been found unchanged in landfills that had been completed for 15 to 25 years. The rate of decomposition is primarily dependent upon the moisture content and generally takes place at a very slow rate.

Decomposition of the wastes will result in the production of gases, principally methane, carbon dioxide, nitrogen, hydrogen, and hydrogen sulfide. The rate of gas production will usually reach a peak within the first 2 years and then slowly taper off.

Methane gas causes the most concern because of its explosive character. Precautions should be taken that will prevent the gas from concentrating in sewers or other structures located on or near the landfill.

Settlement. Settlement of the landfill is dependent on the depth of the fill, composition, compaction of the material, moisture content, and other factors. Studies have indicated that approximately 90 percent of the ultimate settlement will occur in the first 5 years. The final 10 percent will occur over a much longer period. As a rough indication of the amount of settlement that might occur, several Los Angeles area sanitary landfills, 90 to 110 feet deep, have settled 2.5 to 5.5 feet in 3 years.

Underground Fires. Although underground fires rarely occur in a completed landfill, the possibility does exist. All underground fires should be dug up and extinguished. The cell construction of a sanitary landfill helps to confine and restrict the spread of the fire should one occur.

Maintenance. Completed landfills generally require maintenance because of differential settlement. Maintenance consists primarily of resloping the surface to maintain good drainage and filling in small depressions that result from uneven settlement.

Uses. Completed landfills have been used for recreational purposes—parks, playgrounds, or golf courses. Parking and storage areas or botanical gardens are other final uses. Because of settling and gas problems, construction of buildings on completed landfills generally has been avoided; in several locations, however, one-story rambling-type buildings and airport runways for light aircraft have been constructed directly on sanitary landfills. In such cases, it is important for the designer to avoid concentrated foundation loading, which can result in uneven settlement and cracking of the structure. The designer must provide the means to allow the gas to dissipate to the atmosphere and not into the structure.

Multi-story buildings can be built over completed landfills, using steel and concrete pilings, and special engineering design.

SANITARY LANDFILL PROJECTS

The Solid Waste Disposal Act of 1965 provided funds for surveys, demonstrations, studies, and investigations of new and improved technology of solid

waste disposal. Awards up to two-thirds the cost of the project are made. Information on existing projects and requirements for new ones are available from the Bureau of Solid Waste Management regional offices listed on page 30.

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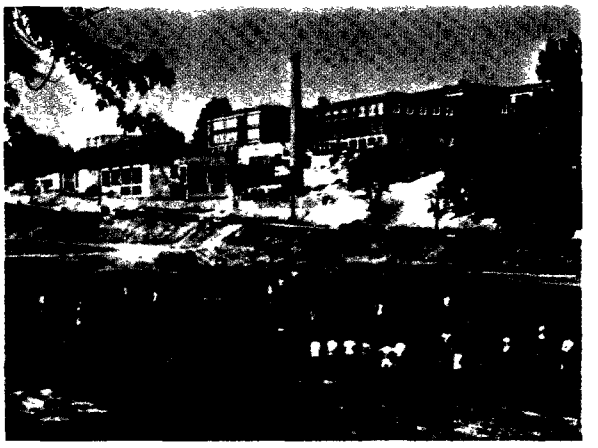

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Most of the photographs in this publication have been provided by users and long-term supporters of the sanitary landfill method. In particular, the authors wish to thank the County Sanitation Districts of Los Angeles County and the Recreation Department, City of Rockville, Maryland.

A motion picture, "Sanitary Landfill: One Part Earth to Four Parts Refuse", may be borrowed free of charge. The film covers all aspects of landfill planning and operation and is 24 minutes, sound, color, 16 mm, order number M-1740-X. Request by number from the National Medical Audiovisual Center (Annex), Station K, Atlanta, Georgia 30024.

Table 2. ADVANTAGES AND DI

ADVANTAGES

1. Where land is available, a sanitary landfill is usually the most economical method of solid waste disposal.
2. The initial investment is low compared with other disposal methods.
3. A sanitary landfill is a complete or final disposal method as compared to incineration and composting which require additional treatment or disposal operations for residue, quenching water, unusable materials, etc.
4. A sanitary landfill can be put into operation within a short period of time.
5. A sanitary landfill can receive all types of solid wastes, eliminating the necessity of separate collections.
6. A sanitary landfill is flexible; increased quantities of solid wastes can be disposed of with little additional personnel and equipment.
7. Submarginal land may be reclaimed for use as parking lots, playgrounds, golf courses, airports, etc.

Well-designed landfill sites may be planned for final use as outdoor amphitheatres.

ITAGES OF SANITARY LANDFILL

DISADVANTAGES

1. In highly populated areas, suitable land may not be available within economical hauling distance.
2. Proper sanitary landfill standards must be adhered to daily or the operation may result in an open dump.
3. Sanitary landfills located in residential areas can result in extreme public opposition.
4. A completed landfill will settle and require periodic maintenance.
5. Special design and construction must be utilized for buildings constructed on completed landfill because of the settlement factor.
6. Methane, an explosive gas, and the other gases produced from the decomposition of the wastes may become a hazard or nuisance problem and interfere with the use of the completed landfill.

WHERE FURTHER INFORMATION ON SANITARY LANDFILLS MAY BE OBTAINED

Region I—Boston

John Fitzgerald Kennedy Building
Boston, Massachusetts 02203
Phone: 617-223-6687

Region II—New York

Room 834-H Federal Office Building
26 Federal Plaza
New York, New York 10017
Phone: 212-264-2523

Region III—Charlottesville

220 7th Street, N. E.
Charlottesville, Virginia 22901
Phone: 703-296-1417

Region IV—Atlanta

Room 404, 50 Seventh St., N. E.
Atlanta, Georgia 30323
Phone: 404-526-2921

Region V—Chicago

Room 712, New Post Office Building
433 West Van Buren Street
Chicago, Illinois 60607
Phone: 312-353-6560

Region VI—Kansas City

601 East 12th Street
Kansas City, Missouri 64106
Phone: 816-374-3307

Region VII—Dallas

1114 Commerce Street
Dallas, Texas 75202
Phone: 214-749-2007 or 2008

Region VIII—Denver

9017 Federal Office Building
19th & Stout Streets
Denver, Colorado 80202
Phone: 303-297-4456

Region IX—San Francisco

Federal Office Building
50 Fulton Street
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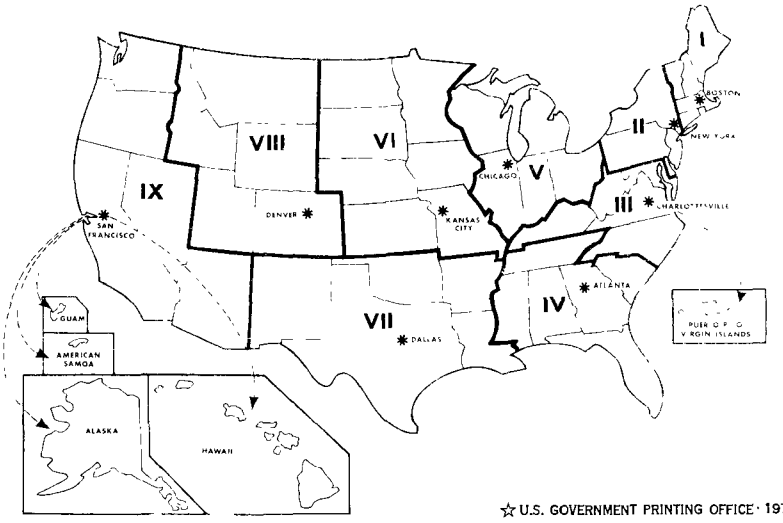

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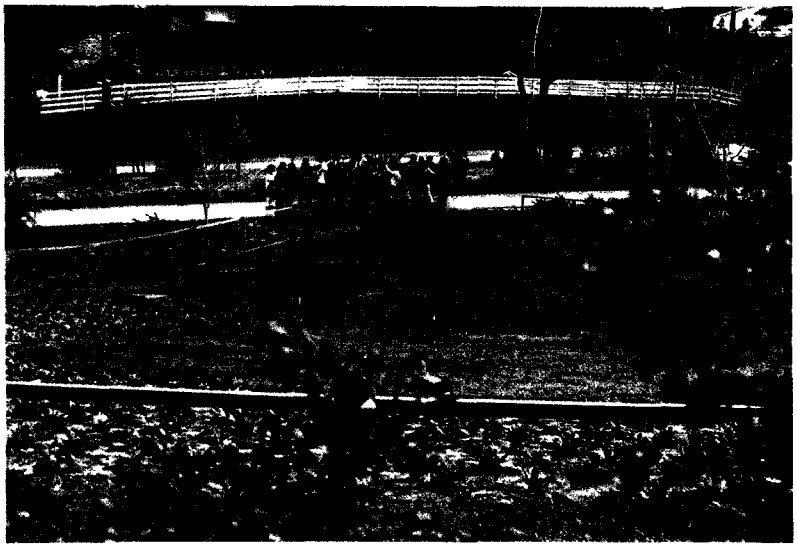

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