

Landfill Design and Operation

Disposal sites, the final links in the waste handling chain, are usually transfer stations and sanitary landfills.

The EPA defines a landfill as an engineering method of disposing of solid waste on land. As such, landfills are required to protect the environment by spreading waste into thin layers and compacting them into the smallest practical volume. By day's end, all waste is then covered with earth. Transfer stations have their own regulations. They are required to have their floors clear of all waste by the end of the working day.

GO PUBLIC WITH PLANS. Unfortunately, much of the public still thinks a sanitary landfill and an open dump are one and the same. So if you are a public official faced with selecting a new disposal site or an expansion, you will have an education program to implement. Convincing the public that your proposed site poses no hazard or nuisance should be an important part of your planning. There are many ways to go about this, depending on your circumstances and financial resources.

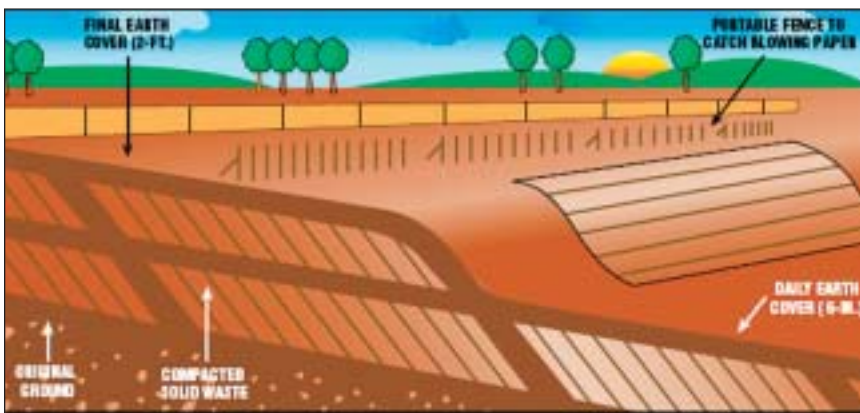
- Work closely and early with all appropriate government agencies, public officials, and regulatory personnel.

- Use a public relations firm or advertising agency to prepare credible, accurate news releases for area newspapers, and radio and TV stations.
- Agree to be interviewed by the media, but be prepared to answer questions accurately and openly.
- Take community leaders on a personal tour of a sanitary landfill and/or transfer station.
- Present your case at service clubs and community meetings with visuals that show attractively landscaped entry ways and artist renditions of ultimate land use. Anticipate questions beforehand, and be prepared with well thought-out answers.
- Count on being questioned about odors, litter, insects, vermin, noise, dust, ground and waste pollution, and hazards to children.
- Consider using billboards, radio and television promotion, perhaps even a model of a sanitary landfill and/or transfer station to display in city hall, libraries, and schools.
- Obtain professional and technical expertise in landfill and transfer station siting and waste disposal.

- Present your landfill and/or transfer station as a carefully planned and controlled project that will be an economical and publicly acceptable solution to your community's waste disposal problems.
- Show how you plan to ultimately use the site now and years after it has been closed.
- Expect and be prepared for opposition that may be lengthy and expensive.

PICK THE RIGHT SITE. A site location must be decided upon before educating the public. Several factors govern your choice of location.

- Is it the closest site available to your community?
- Is it accessible?
- Is it large enough to accommodate growth?
- Is the soil suitable for cover?
- Will the subsoil keep contaminants from escaping into the surrounding area and water supply, or will additional compaction and/or synthetic liners be required?
- Will roads around the transfer station accommodate the traffic of the collection vehicles?
- Does the transfer station location allow for maximum utilization of collection routes?
- To reduce the risk of accidents, do you have a separate dumping location available to the public?
- Is the area zoned for such use?
- Can the site be put to some beneficial use when the landfill is completed and closed?
- Will the public accept it?



Area Method of building a sanitary landfill

Operation

The cell is the basic building block of a sanitary landfill. To build a cell, waste is spread into two-ft layers or less and compacted in thin layers as tightly as practical. At the end of the day, a sufficient amount of cover earth (usually six in.) is spread over waste and compacted. Sometimes an alternative material is approved for daily cover. This may include foam, plastic, or processed landscape waste. The compacted waste and soil constitute a cell. A series of cells that adjoin each other make up a lift. One or more lifts constitute a fill.

There are no hard and fast rules for cell height. While four to eight ft is common, landfills handling 250 tons a day or less may have cells less than half this height. Make the width (working face) in front of the cell as narrow as possible to concentrate compaction efforts and reduce cover material requirements. It must be wide enough to prevent congestion of trucks waiting to unload. A typical face ranges from 100 to 250 ft wide.

ESTIMATE COVER. Although landfill size and type vary, a rule of thumb for estimating the amount of cover material needed is one bank cu yd of cover material for every eight cu yd of in-place compacted waste. Historically, about 20 to 25 percent of a sanitary landfill's volume consists of soil used for cover (including daily and final covering). On smaller landfills, soil could be as high as 50 percent to meet reasonable cover requirements. Currently, well-run landfills have reduced soil cover to levels less than 20 percent of the landfill volume.

Cover material also figures in the landfill space requirement. For example, an area providing 2,000,000 cu yd of landfill space provides only 1,750,000 cu yd of refuse when the 8:1 ratio of refuse to cover is achieved. Necessary cover material will require 250,000 cu yd of available space. The type of cover material is important. If the soil is sandy or highly abrasive, a rubber-tired wheel loader or scraper might be used rather than a track-type machine. In a few instances, when satisfactory soil is unavailable or cost-prohibitive, foam is used as daily cover (if permissible).



Trench Method of building a sanitary landfill

However, soil is normally still required for intermediate and final cover.

Determine the Design

Designs may vary, but there are three basic methods of building a sanitary landfill: area method, trench method, and ramp method.

AREA METHOD. The area method is best-suited for sites where no natural slopes exist. This method can be adapted, however, to ravines, valleys, quarries, or old surface mines. Disposing of waste in a ravine site requires construction of diversion ditches for runoff water before any waste is received. Here is how the area method works: Waste is pushed into layers, compacted, and adequately covered. During succeeding days, the incoming waste is dumped at the toe of the preceding day's waste and pushed up the face, compacted, and covered at the end of each working day. A machine, such as a track-type tractor or landfill compactor, spreads and compacts the material. Soil for daily cover must be hauled in from borrow sites using a wheel tractor-scraper or articulated truck.

TRENCH METHOD. The trench method is best-suited for flat or gently sloping land where the groundwater table is deep below the surface. The chosen site should have soil that is easy to excavate and suitable for cover. Immediate availability of cover without the need of expensive specialized equipment to haul it long distances can be a major advantage of the trench method. If the landfill is to be brought above

ground level, nearby cover material can also be an advantage.

The trench does, however, have some disadvantages. If more cover material is excavated than can be used immediately, it will have to be stockpiled and moved again at an additional expense. Drainage, too, can be a problem, but it can be solved by "day lighting" one end of the trench and sloping the trench floor toward that end. Provisions must also be made to allow surface water to run off at the end of the trench.

Small trenches usually measure eight to 10 ft deep and are two to three times as wide as the machine excavating them. Larger ones may be 30 to 40 ft deep, 60 to 80 ft wide, and 200 to 300 ft long. These are suitable for sites receiving 300 to 500 tpd. Note that 500 tons is usually the limit to avoid truck traffic congestion.

There are three ways to trench:

- Excavate the entire trench, and windrow the cover material along the sides until it is needed.
- Excavate only far enough to provide a single day's working space and dirt cover. This is called the progressive trench method, and it may require handling the cover material only once.
- Excavate a second trench in segments parallel to the first one, and use the excavated material as cover for the first trench. Take care to leave at least two ft between the two trenches. This method may allow for handling the cover material only once.

RAMP METHOD. The ramp method is a variation of the area and trenching techniques. Waste is spread and compacted on an existing slope. Cover material is excavated directly in front of the waste. It is then spread over the waste and compacted. The excavated area becomes a part of the cell to be worked the following day. Similar to the progressive trench method, the ramp method is considered ideal by some operators because they do not have to haul in cover material (with its extra cost of expensive handling equipment). Because they may handle the cover only once and do not have to prepare the land in advance, they consider this an excellent way to start a landfill with a minimum of equipment. If more than one lift is required, cover will have to be hauled to the working face at an additional expense. Depth of the water table is another factor, but it is not as critical as with the trench method, which normally requires deeper excavation.

MODIFIED METHODS. Several modifications of basic landfill techniques are being used to extend site life, decrease the need for cover material, and save costs.

The high-rise method involves stacking and compacting layers of waste on the ground surface, then covering each layer. Layers are placed on top of the other like a pyramid. However, as the layers move upward, the slopes reduce the size of the top area. Stacking the layers above ground minimizes subsurface pollution and makes maximum use of limited land area. This method is popular in coastal areas or where the water table is high. You may need to haul cover material from other locations.

The no-cover method involves spreading and compacting waste without covering it at the end of the day. This method, however, requires certain standards regarding insect control, rats, odors, and other nuisances. Although it can extend the life of a landfill ten to 20 percent and cut operating and equipment costs, the no-cover technique has not been accepted in most locations.

SPECIAL USE AREAS. The design of a landfill should also include provisions for special circumstances. For instance:

- An area near the landfill entrance

where collection trucks can deposit their loads when wet weather prevents them from reaching the working face.

- An area for demolition debris that normally does not have to be covered every day the way routine wastes do.
- Special area or areas where toxic waste cleared for landfill disposal can be deposited.
- Areas for disposal of bulky wastes such as tree stumps.
- Storage area for appliances and junk cars, if they are received in sufficient quantity to make this provision economical and are permitted for storage.
- Areas for yard waste, including grass clippings, brush, mulch, and small branches when site is permitted for this material.
- Citizen bin for safety of small private vehicles.
- An area for a tub grinder to process landscape and wood waste.

Better Compaction = Longer Landfill Life

Selecting a new disposal site and getting approval can be challenging. Governmental officials lend a willing ear to any practical proposals that will help them extend the life of their present sites. Compaction is the best answer. Better compaction means packing more waste into less space. Here are several benefits:

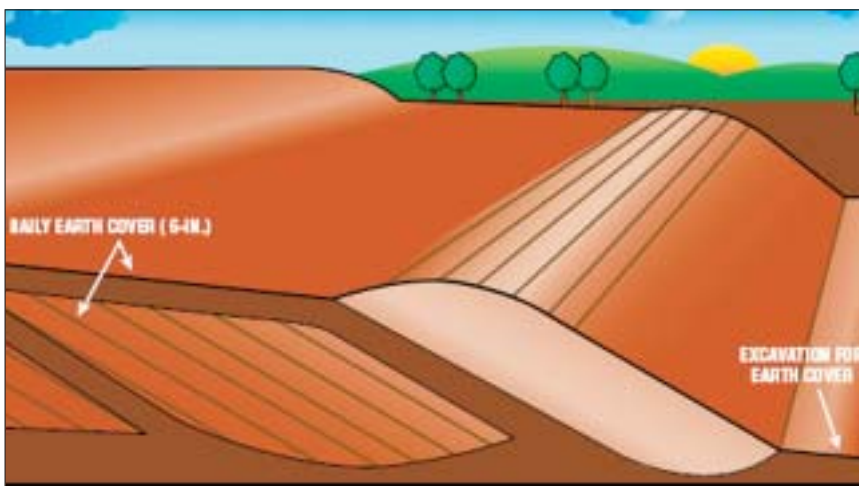
- Extends the life of the site
- Decreases settlement

- Reduces voids
- Reduces wind-blown litter
- Discourages insects and rodents
- Reduces possibility of waste washing away or being exposed during a rain
- Reduces amount of daily cover needed, thereby reducing machine excavation work
- Reduces leachate and methane migration
- Provides a more solid travel surface for refuse trucks, reducing maintenance and repairs

In the example shown in Table 1, each 200-lb increase in density (20 percent) results in an additional 1.9 years of landfill life. One method to determine the value of increased compaction is to multiply increased landfill tonnage (or yards) by the per-ton (or per-yard) tipping fee.

Using the above example, a 200 lb/yd or 20 percent increase in density results in 1.9 years of longer landfill life. At the same yearly volume, this means an additional 197,600 tons of refuse ($1.9 \times 104,000 = 197,600$). Should the per-ton tipping fee be \$30, the additional revenue at this landfill would be more than \$5.9 million ($197,600 \times \$30.00 = \$5,928,000$).

Loose residential and commercial wastes weigh about 400 to 500 lb/cu yd. A refuse collection truck will increase that density to 800 to 1,000 lb/cu yd. At the landfill, in-place refuse density can vary from 600 to 1,500 lb. Moderate compaction should provide densities of 800 to 1,000 lb. But by dumping and



Ramp Method of building a sanitary landfill

Table I. Example of Increased Compaction on Potential Landfill Life*

Compaction	Landfill Life	Gain
1,000 lb/cu yd	9.6 years	0.0 years
1,200 lb/cu yd	11.5 years	1.9 years
1,400 lb/cu yd	13.4 years	3.8 years
1,600 lb/cu yd	15.3 years	5.7 years
1,800 lb/cu yd	17.2 years	7.6 years

*Landfill Refuse Capacity: 2,000,000 cu yd

Yearly Volume: 104,000 tons

pushing the waste into the fill, densities are considerably less...as low as 600 lb/cu yd.

Greatest compaction is achieved in landfills that accept a high proportion of demolition debris such as brick, stone, and concrete. Densities of as much as 2,500 lb/cu yd can be achieved. It is common for construction and demolition materials to have specific landfills.

Cover material will add another 100 to 200 lb/cu yd to landfill compaction density.

COMPACTION FACTORS. Several factors affect compaction.

- Refuse layer thickness is the most important factor. To obtain the greatest density, waste should be spread in layers not more than two ft deep and compacted. The thicker the layer, the less densely a machine can compact it.
- The number of passes a compaction machine makes over the refuse is another factor that affects density. A pass is defined as a machine traveling over refuse one time in one direction. Whatever the machine, it should make three to four machine passes to achieve best results. More than four passes does not achieve enough additional density to make them economical.
- Slopes should be kept to a minimum of 4:1 or less. A level surface allows the best compaction.

However, working refuse up a slope does have advantages:

- The working slope covers less area than a flat working face, reducing lit-

ter problems and the amount of cover material needed.

- When a machine works uphill, rather than downhill, it is easier to achieve a more uniform lift thickness over the entire area since refuse material will not roll ahead of the blade and pile up at the toe on the slope.

Having noted these situations, it must be emphasized that in almost all cases, flatter is better for maximum compaction.

MOISTURE CONTENT. Compaction density is considerably affected by moisture content. Water softens and acts as a lubricant for material such as paper and cardboard, and permits tighter consolidation. Field tests show that moisture content varies from 10 to 80 percent, depending on whether the season is wet or dry. The optimum moisture content for maximum compaction is about 50 percent. A minimum amount of moisture can increase refuse compaction density by ten percent. While higher moisture content can provide higher in-place densities, it also increases the amount of leachate formation.

Other Factors

Several factors affect the operation of a landfill. As a result, they must be carefully considered in planning an efficient disposal system.

WET WEATHER. This is a major factor to consider. Although main access roads may be all-weather construction, you should prevent roads leading to the working face or the cover borrow site

from becoming quagmires. This can be accomplished by spreading gravel, cinders, crushed rock, or small-size demolition rubble on the haul roads. In wet weather, it is wise to restrict landfill equipment from operating on the roads.

TIRES. Disposing of tires can be a headache. In fact, most landfill sites are prohibited from accepting them. Tires are resilient and almost impossible to compact. As a result, they literally push themselves up through the waste cell. To help eliminate such a problem:

- Consider alternative tire disposal methods, such as shredding and recycling.
- Spread tires out in single layers at the toe or bottom of the fill. If they come into the fill at the end of the day, store them until the next day.
- Spread incoming brush over the tires. It acts as a woven mat to keep them flat. If brush is not available, cover tires with construction or demolition waste such as boards, plywood, or sheet rock.

WIRE. Wire is another difficult material to handle. Wire from bed springs, fences, and cable can wrap around the wheel axles and undercarriages of landfill machines and cause damage. Such material should be pushed to the toe of the fill, taking care that it does not roll or slide under the dozer blade. Then brush or demolition debris should be placed over it to keep it from working up and entangling itself in machines.

SETTLING. The rate and extent of settlement will depend on the type of waste, depth of the fill, how fast the

waste decomposes, compaction density, and the ratio of cover material to waste. Most settling occurs during the first three to five years after the refuse has been buried. Even after a landfill is closed out, cracks and depressions should be filled and drainage problems corrected until the land has completely stabilized.

LITTER. Windblown litter is a persistent operating nuisance, and controlling it should be a major concern. There are several ways to handle the problem:

- Keep the size of the working face as small as possible.
- Cover cell portions as they are constructed.
- Install litter fences near unloading and spreading area. Pick up litter frequently. Letting it accumulate along fences renders them ineffective.
- Post and enforce regulations to restrict hauling uncovered loads into the landfill.
- Unload wastes at the bottom of a sloped work face. Wind cannot pick them up as readily there.
- When building a trench-type disposal site, build trenches at right angles to prevailing winds.

GAS AND LEACHATE. The greatest threats may be the unseen ones: gas and leachate. Gas is generated by waste decomposition. Leachate forms as surface or groundwater seeps through wastes, picking up chemicals and biological contaminants. Landfill gas such as methane can seep into nearby buildings and cause fires and asphyxiation. Leachate can find its way into walls, streams, and lakes, poisoning drinking water and killing fish. Both gas and leachate can be controlled with proper landfill engineering and operating techniques. Gas generation can also be a plus because it can be sold for additional revenue. Several types of passive and active gas-venting systems can be installed at a landfill. Their objective is to keep possibly dangerous levels of methane from diffusing underground. Passive systems let the gas vent itself out of the landfill and active systems pump the gas out. Passive systems need little attention. Active systems require periodic maintenance. Sinking monitoring wells to

check gas generation helps determine the system's effectiveness.

Liquid that intrudes into the landfill to create leachate comes from four sources: groundwater, liquids placed in the landfill, rain or snow falling in the fill, and surface runoff flowing in. The site operator can limit leachate with proper design and operation. The generation of leachate can be reduced by compacting waste properly, spreading and compacting cover to the right depth, and building and maintaining proper surface drains around the site. Leachate can be controlled by placing liners at the landfill base and installing systems to collect the contaminant before it seeps out of the landfill. The liners' purpose is twofold, as they also keep groundwater from entering the site. Some sites depend on natural dissipation to control the movement of leachate.

Installing control devices will be an ongoing process during the site's operation. Careful installation and proper maintenance are essential. Install leachate controls as new areas open, or as old areas are finished. Monitor wells frequently to determine whether unacceptable leachate amounts are escaping from the landfill. Consult government regulations to make certain your program is in compliance.


COVER. The right cover material and proper handling techniques help control nuisances as well as health and environmental problems. Cover material:

- Must be compacted to provide a tight seal.
 - Must be free of organic material and large objects.
 - Must not crack excessively when dry.
- Cover material is valuable and provides the following benefits:
- Helps seal in odors and prevents water from entering compacted waste.
 - Prevents the breeding of insects and eliminates a source of food and shelter for rodents and birds.
 - Prevents fires and controls litter.
 - Provides a dense, stable fill that can serve as a good road base.

A few landfills have been allowed to permit limited rain water entry to facilitate waste decomposition.

WEIGHING. Keeping accurate statistics on incoming waste amounts is the only way to get reliable information to determine current and future landfill needs. Weighing the waste as it comes into the landfill is the best way to gather this data. Such weighing provides the most equitable basis for establishing tipping fees. It also provides the necessary input for cost analysis of the operation. Weighing also gives the operator a way to check the volume of waste cells and the amount of cover that is used. Scale facilities are an important part of the landfill facilities. However, because a scale facility for a small landfill is sometimes hard to justify, finding another method for gathering information about the amount of incoming waste is essential. A periodic vehicle count is one way a landfill can collect this data. Relating this to tonnage or cubic yard capacity of each truck gives a reasonable estimate of the tonnage (yardage) coming in each day. Remember that such a count should be made on representative days of the week and carried on throughout the year to figure in seasonal variations.

FIRES. Because most landfill fires start from outside sources rather than spontaneous combustion, an operational fire-fighting plan is necessary. Here are some suggestions:

- Prohibit smoking on or near the working face. Post signs and enforce the rule.
- Supply all landfill equipment with extinguishers sufficient enough to put out small fires.
- Use the water wagon's high pressure stream to put out fires.
- Put down bigger fires by spreading them out with a dozer, for example, and covering them with dirt.
- Divert drivers bringing in smoking or burning loads to a safe area away from the working face.
- Remember that daily earth cover can keep fire within a cell, preventing it from spreading throughout the landfill. 

The preceding is based on information supplied by Caterpillar, Inc. (www.cat.com).