

GUIDANCE FACT SHEET: LANDFILL DESIGN

The objective of the landfill design is to provide for safe disposal of waste while protecting the environment. Environmental receptors to be protected include soil, groundwater, surface water, and air. Landfills also are designed to maximize waste disposal quantity in the available space given site conditions/geometry and in consideration of slope stability and future potential end uses.

Landfill Configuration/Layout

The landfill configuration and layout should consider several key issues:

1. The liner system is most cost effective as height of fill increases.
2. Deeper waste placement over a smaller area reduces liquid infiltration and facilitates gas collection from vertical wells.
3. Steep side slopes can cause instability and inaccessible slopes for gas collection and cap maintenance. Instability can lead to erosion and break-out of leachate and gas. In seismic zones, side slopes need to be considerably lower than in non-seismic zones, and geotechnical evaluation (slope stability analysis) are essential to determine a safe side slope.
4. Deeper waste piles generate landfill gas (LFG) more quickly by promoting anaerobic conditions. Similarly, greater depth enhances gas collection via fewer deep wells to which a greater vacuum can be applied without air intrusion.
5. The depth to groundwater should be considered when siting a landfill. The depth to groundwater will depend on soil permeability, type of liner and leachate control systems to be constructed, and average precipitation levels. Additionally, landfills should not be located in wetlands or floodplains or near surface water bodies. The bottom liner system is usually constructed above the groundwater table.
6. Landfills must be located in areas with a suitable underlying foundation. Landfills are undesirable in areas with insufficient bearing capacity, or in karst formations.

Bottom Liner Systems

The objective of the Bottom Liner System is to protect groundwater by creating an impermeable barrier between the waste mass and underlying soils/groundwater. Liners also serve as a barrier to LFG migration, which can create an explosion or fire hazard in onsite or offsite structures.

The Bottom Liner System can be composed of one of the following:

1. Low permeability clay as either an in situ formation or via placement and compaction of clay soils with a hydraulic conductivity less than 1×10^{-7} cm/sec



2. Synthetic membrane liner systems.
3. A combination of both with the membrane placed over the top of the clay layer so that in the event of a membrane breach, leachate will encounter the clay causing it to swell and seal the liner.

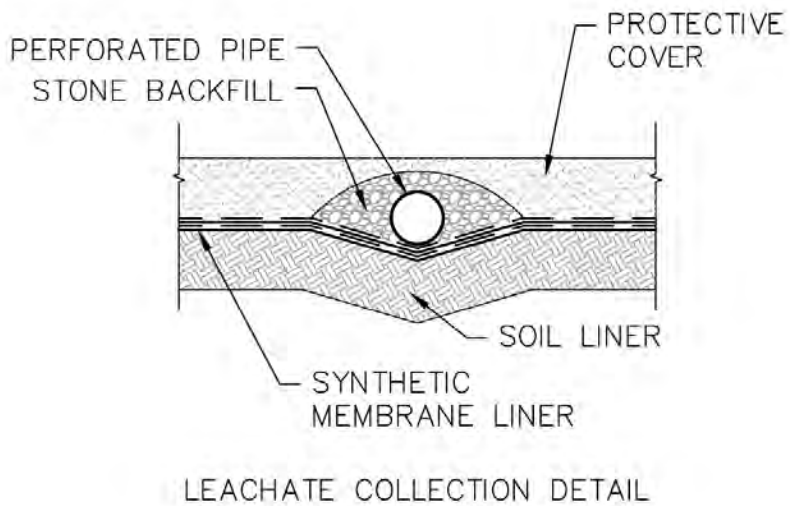
All of the above liner systems require careful construction quality control to assure that:

- Clay is compacted and placed properly to achieve permeability requirements and protected to prevent desiccation prior to waste placement.
- Membrane is joined/seamed properly to provide a complete barrier and protected against tears by equipment or waste placement activities.
- As-built survey to document liner elevations. When LFG wells are drilled in the future, it is critical to have accurate bottom liner elevations to avoid drilling through the liner system.

Leachate Collection Layer

Leachate collection is important with or without an engineered liner system. A layer of stone or sand, called a protective cover layer, is normally placed above the bottom liner system to provide a drainage medium. The protective cover layer also provides protection against anything (protruding waste or equipment) from puncturing the bottom liner system. A perforated pipe network is sometimes installed within the protective cover layer to enhance drainage of the leachate.





The bottom of the landfill needs to be gently sloped to promote leachate drainage to central locations from which it can be removed. Sites that are flat can be costly to construct, as they require creation of a slope through excavation and/or fill; and thus gently sloped sites, particularly in a valley configuration, can minimize costs. A landfill with a liner and a non-functioning leachate management system will behave like a bathtub and fill up with liquids, which is undesirable because it can lead to problems with slope stability and can inhibit operation of the LFG management system.

The typical distance between leachate pipes is 45 to 60 meters. Bottom contours are dependent on site geometry and groundwater elevations.

Leachate drains to a sump where a submersible pump extracts it. Gravity systems may be feasible under certain conditions such as: canyon fills, side slope landfills, above grade mounds with no excavation.

Collected leachate can be managed by:

- evaporation from ponds.
- pre-treated and discharged to sewer.
- treated and discharged to waterway.
- re-circulated.
- direct discharge or hauling to waste water treatment plant.
- destruction in LFG-fueled leachate evaporations

Leachate Recirculation creates a Bioreactor and should only be considered at well managed stable landfills due to slope stability concerns. Some of the benefits of leachate recirculation include:

- increases LFG generation rate significantly.
- can improve density, thereby providing additional waste disposal capacity.
- provides a method to manage leachate.

Leachate can be recirculated through surface (for example, spray irrigation or tanker truck application), or subsurface methods (for example, vertical injection wells or horizontal trenches). Normally, it is not as effective to inject liquids into vertical LFG extraction wells.

Whatever treatment system is used, the pipes, tanks, pumps and all other equipment must be designed to handle the volume of flow expected, so that leachate is not released to the environment.

Final Cover Systems

The final slopes of the landfill are typically graded to 3 horizontal to 1 vertical or flatter. Benches are included every 4 to 10 meters of vertical height for slope stability and stormwater management. A final cover system is constructed over the final slopes of the waste mass.

The final cover system can be composed of natural clay soils, a combination soil/synthetic membrane liner system, or soil cover only with vegetation.



A synthetic membrane provides the most effective barrier to moisture infiltration and also can enhance LFG collection by inhibiting air intrusion and improving the quality (high methane, low oxygen concentrations) of the collected LFG. Conversely, lack of moisture in the waste mass can inhibit LFG generation as methane producing microbes need moisture to thrive. Selection of an appropriate cap material should consider available materials and associated costs, landfill moisture conditions, climate, leachate management costs, and gas

collection objectives.

Construction quality control is also required for the final cover system. A soil layer is placed over the final cover system for vegetative growth. Normally grasses or vegetation with a shallow root system is planted in the vegetative soil layer.

Stormwater Management

Stormwater Management includes run-on and run-off controls, and often involves perimeter drainage around the landfilling and leachate treatment areas. Run-on controls prevent surface water from coming into contact with the waste mass. This will reduce leachate production and leachate generation since any stormwater that comes in contact with waste is considered leachate.

Properly designed run-off controls allow stormwater to run-off from the landfill surface while minimizing erosion. Run-off controls include diversion ditches, silt fence, downdrains, and stormwater management ponds.

Stormwater management controls must be designed based on the amount of rainfall received at the landfill. Typically, a 25-year, 24-hour storm event is used to design stormwater management features. The filling sequence of the landfill must be considered when designing stormwater management controls.

Construction Costs

The cost to construct a bottom liner system with a leachate protection layer costs approximately in the low hundreds of thousands of dollars (U.S.) per acre. Costs can be mitigated for a soil liner if appropriate soil materials are readily available. If a membrane liner is required and must be imported, the cost to construct a bottom liner system can increase significantly. The cost to construct a cap system with associated stormwater management features costs roughly a half to a third the cost of a bottom liner system.



Landfill Gas Management

As waste decomposes, it produces landfill gas which must be collected and managed. Landfill gas management options are described in a separate fact sheet. The landfill gas management system should be designed and taken into consideration during design of the final cover and stormwater management systems.

Other Design Factors

1. Scales improve billing and provide good record of waste history. Allows for planning, observing trends, and predicting needs for operation and LF expansion, LFG recovery. Computerized weights can be received at the municipality in real-time with automatically analyzed regular reports generated for purposes of performance monitoring of vehicles as well as landfill operations.
2. The use of fencing and other security measures provides protection against theft and vandalism, prevents trespassers from being injured, and keeps wildlife and domestic animals from consuming contaminated waste materials.
3. Buffer areas can be designed into the landfill perimeter to minimize disturbances (for example, odors and noise) to neighbors, to create a zone for bioaerosols and particulates to be contained and gaseous emissions to be dissipated, for visual aesthetics that promote public acceptance, and as carbon sequestration zones for emission offset.

4. Groundwater and gas monitoring networks should be installed to ensure that leachate is not impacting groundwater and that explosive gases are not migrating from the property. Methane monitors should be installed within on-site buildings to ensure that LFG is not accumulating within the building.
5. A citizen's waste drop-off and recycling area that is separate from the working face provides for safe operation of the landfill since citizens will not be unloading their vehicles near heavy equipment.
6. Surrounding infrastructure should be considered when new landfills are sited. Infrastructure considerations include the road network leading to the landfill, available electricity, water supply, wastewater treatment and sewer options, and communication systems. A possible alternative to on-site leachate treatment is transport of leachate in tankerized vehicles for off-site treatment at a public wastewater facility.

Sources of Additional Information

- The World Bank. www.worldbank.org/solidwaste