<u>Goals of Module</u>: To provide an overview of landfill leachate from its inception to ultimate disposal for the entry level professional with a focus of awareness over practical skill and understanding.

Leachate

Environmental Research and Education Foundation
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Outline

I. Definitions and Descriptions
II. Leachate Sources and Generation
III. Regulatory Requirements and Design
IV. Leachate Treatment and Disposal
V. Short and Long Term Care of Landfills

I. Definitions and Descriptions

A. Regulatory Definition
B. General Description
C. Variations Over Time
D. Chemical Composition

Regulatory Definition

EPA United States Environmental Protection Agency

- Resource Conservation and Recovery Act (RCRA)
  - Public Law 94-580 - Enacted October 21, 1976
  - *"Disposal on land has gone largely uncontrolled, resulting in numerous instances of serious effects on human health and environmental quality. The contamination of groundwaters by substances leaching from disposal sites is a primary concern."*
  - *"Leachate means a liquid that has passed through or emerged from solid waste and contains soluble, suspended, or miscible materials removed from such waste."*

Regulatory History

- <1960 No collection
- 1970's Attenuation
- 1980's Collect and Treat
- 1990's Bioreactor and Recirculation
- 2000's Re-use and Re-utilize

General Description

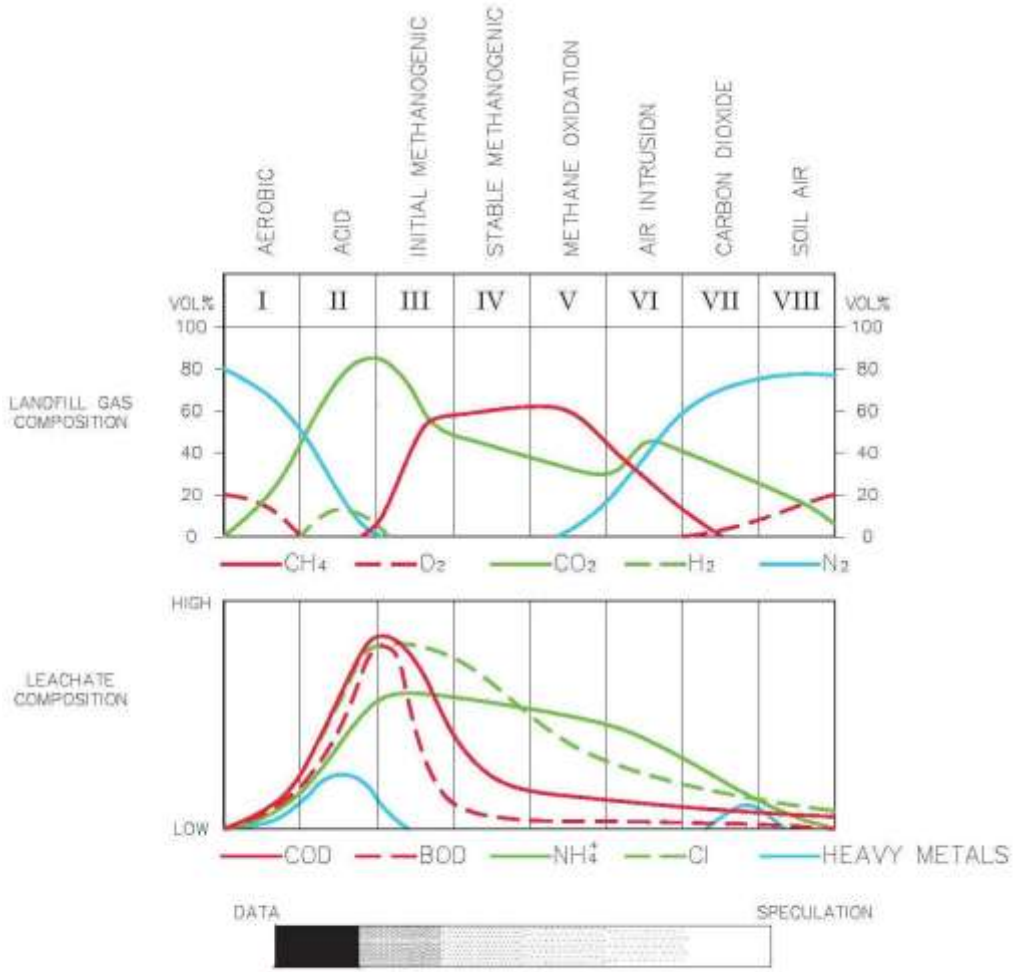
Characteristics

- *Physical state – liquid*
- *Color – clear* ⟶ *sediment laden*
- *Viscosity – non-viscous*
- *Odors – no odor* ⟶ *organic, pungent*
- *f(waste type, dilution)*

General Description

- Composition (4 major categories)
  - Dissolved Organic Matter
    - COD, TOC, BOD
  - Inorganic Macrocomponents
    - Ca, Mg, Na, K, NH4, Fe, Mn
  - Heavy Metals
    - Cd, Cr, Cu, Pb, Ni, Zn
  - Xenobiotic Organic Compounds
    - Household/industrial chemicals

Variations Over Time



(Source: Fig. 1 of Kjeldsen, et al., 2003)

Chemical Composition

Parameter	Range
pH	4.5-9
Spec. Cond. (µS cm^{-1})	2500-35000
Total Solids	2000-60000
Organic Matter	
Total Organic Carbon (TOC)	30-29000
Biological Oxygen Demand (BOD_5)	20-57000
Chemical Oxygen Demand (COD)	140-152000
BOD_5/COD (ratio)	0.02-0.80
Organic nitrogen	14-2500
Inorganic macrocomponents	
Total phophorous	0.1-23
Chloride	150-4500
Sulphate	8.0-7750
Hydrogenbicarbonate	610-7320
Sodium	70-7700
Potassium	50-3700
Ammonium-N	50-2200
Calcium	1936061.00
Magnesium	30-15000
Iron	3.0-5500
Manganese	0.03-1400
Silica	4-70[a]
Heavy Metals	
Arsenic	0.01-1
Cadmium	0.0001-0.4
Chromium	0.02-1.5
Cobolt	0.005-1.5
Copper	0.005-10
Lead	0.001-5
Mercury	0.00005-0.16
Nickel	0.015-13
Zinc	0.03-3000

[*]The ranges are based on Andreottola and Cannas (1992), Chu et al. (1994), Robinson (1995), Ehrig (1980), Ehrig (1983), Ehrig (1988), Garland and Mosher (1975), Johansen and Carlson (1976), Karstensen (1989), Krug and Ham (1997), Lu et al. (1985), Naturvardsverket (1989), Owen and Manning (1997), and Robinson and Maris (1979). [a] Values based on Owen and Manning (1997).

Leachate Sources and Generation

A. Waste Composition and Decomposition
B. Leachate Generation
C. Impacts of Climate on Leachate
D. Generation Analysis

Waste Composition and Decomposition

- Waste Type
  - Land Clearing and Inert Debris
  - Construction and Demolition Debris
  - Municipal Solid Waste
  - Industrial and Process Landfills
- Moisture Content
  - Food Waste ~70%
  - Wood ~20%
  - Plastic ~2%
- Paint Filter Test
  - Method 9095 (EPA SW-846)
- Anaerobic vs. Aerobic Process
  - Bioreactor (>40% moisture)
  - Wet Landfill Technology (leachate recirculation)
  - “Dry Tomb”

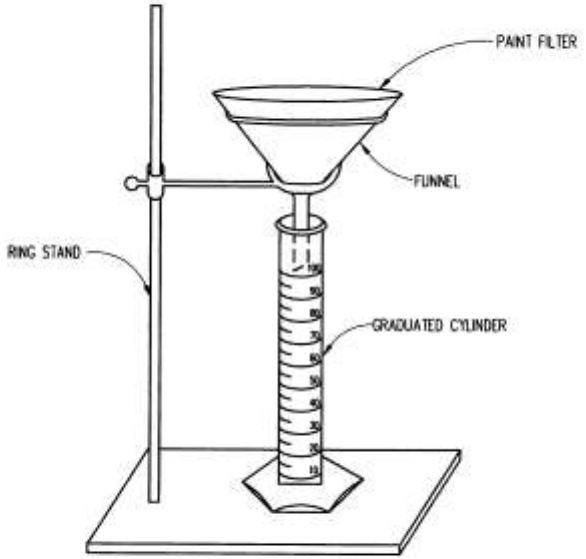
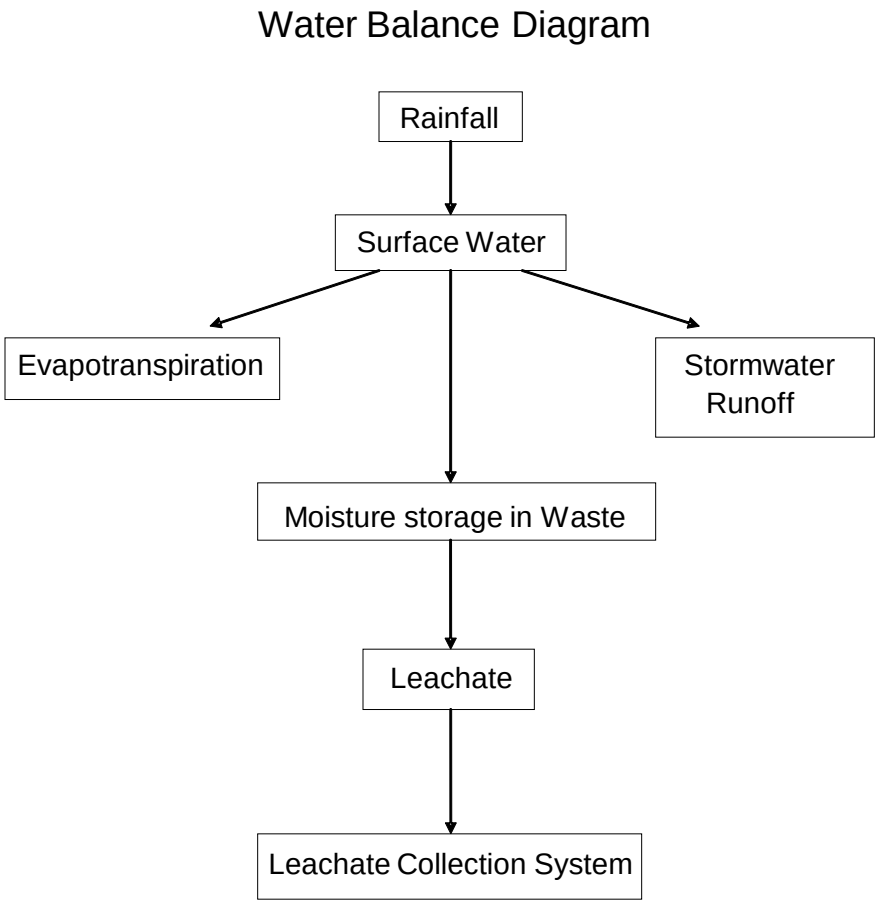


FIGURE 1. PAINT FILTER TEST APPARATUS.

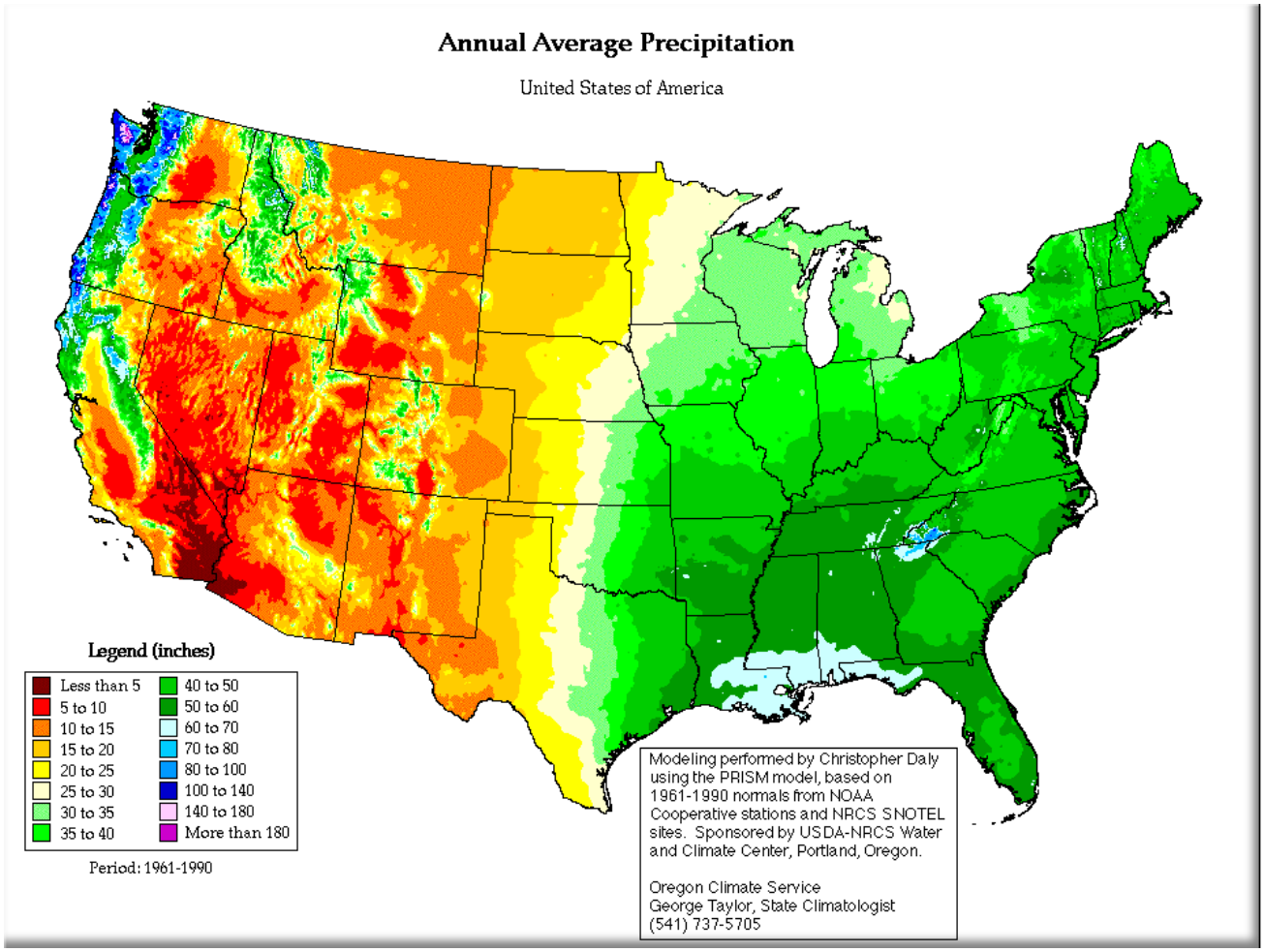
9095-3

Leachate Generation

- Rainfall (Climate)
- Infiltration (Cover)
- Moisture Content (Waste)
- Additional Liquids (Recirculation)

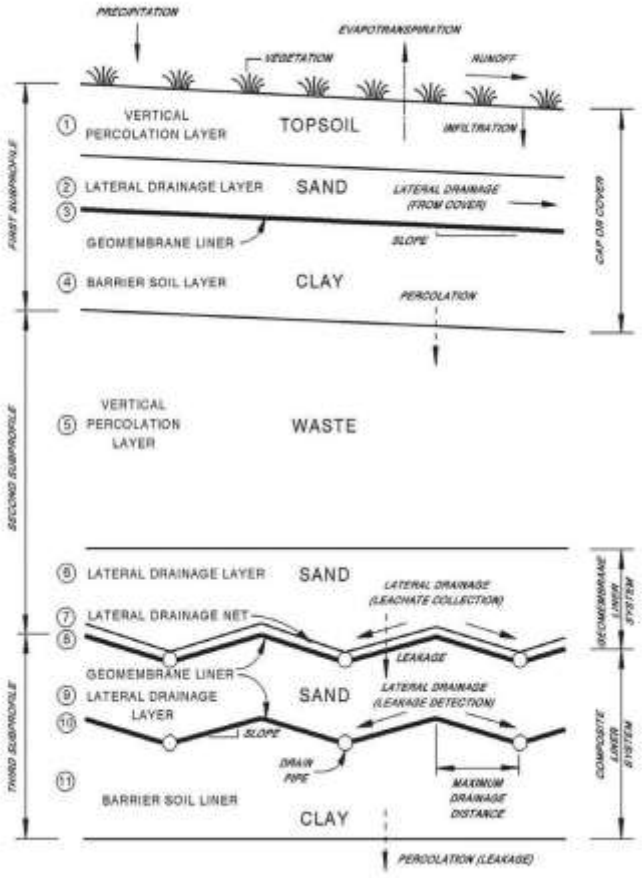


Impacts of Climate on Leachate



Generation Analysis

- HELP Model (Schroeder, 1994)
  - First developed in mid-1980's
  - "a quasi-two-dimensional hydrologic model for conducting water balance analyses of landfills, cover systems, and other solid waste containment facilities"



Regulatory Requirements

A. Landfill Design Requirements
B. Leachate Minimization and Management
C. Leachate Storage Systems

Design Requirements

Resource Conservation and Recovery Act (RCRA)

Subtitle D – Solid Waste

258.28 Liquids Restriction

“Bulk or non-containerized liquid waste may not be placed in MSWLF”

258.40 Design Criteria

1) Protective of Groundwater (Study, Design, and Monitoring)

2) Composite Liner

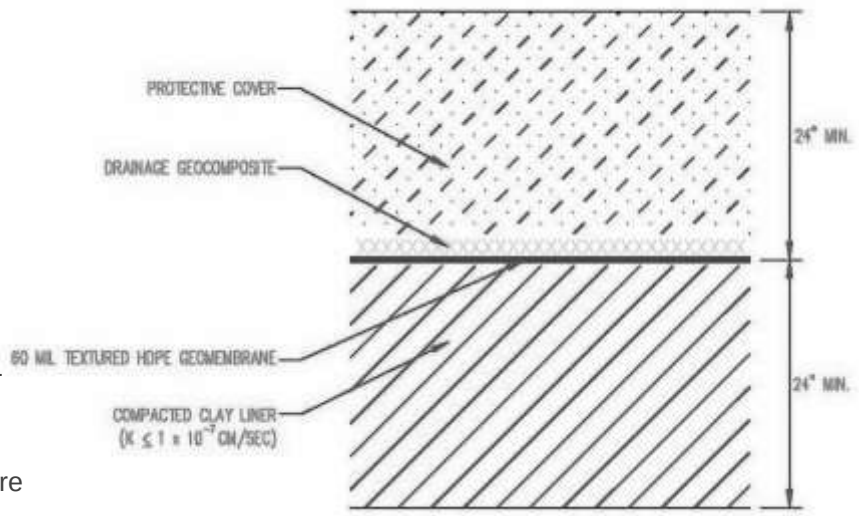
   a) Flexible membrane liner at least 30 mil thickness. FML components consisting of high density polyethylene (HDPE) shall be at least 60-mil thick.

   b) Compacted clay with a hydraulic conductivity of no more than $1x10^{-7}$ cm/sec;

   c) Alternative demonstrations

3) Leachate Collection System

   a) Collection system capable of maintaining less than 30 cm (~12”) depth of leachate over the liner



Design Requirements

Resource Conservation and Recovery Act (RCRA)

Subtitle D – Solid Waste

258.60 Closure Criteria

1) Infiltration layer with a minimum thickness of 18 inches of earthen materials that have a permeability less than or equal to the bottom liner system, natural soils present, or a permeability not greater than $1x10^{-5}$ cm/s, whichever is less.

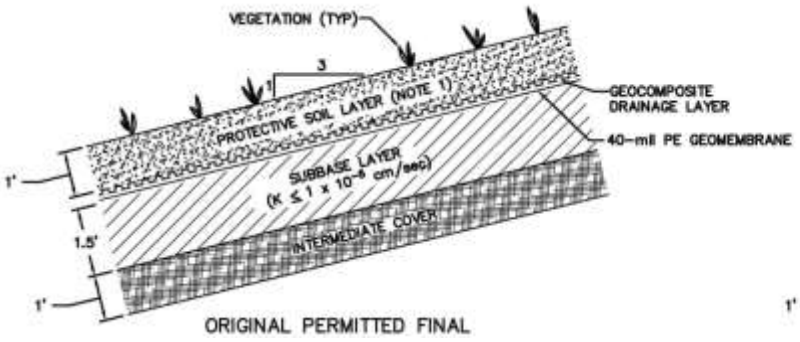
2) An erosion layer with a minimum thickness of six inches of earthen materials with capabilities of sustaining native plant growth.

3) Alternative demonstrations.

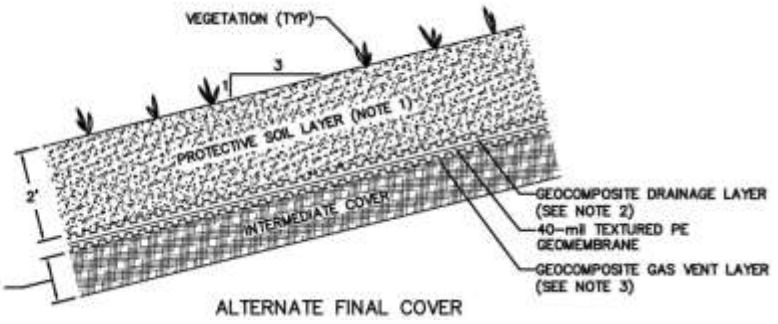
258.61 Post-closure Care Requirements

1) Cover must remain in place for a minimum of 30 years. *Authorized state directors may increase of shorted these periods.*

2) Maintain the integrity and effectiveness of the final cover.



ORIGINAL PERMITTED FINAL



ALTERNATE FINAL COVER

Design Requirements

Resource Conservation and Recovery Act (RCRA)

Subtitle D – Solid Waste

258.21 Cover Material Requirements

1) Cover disposed solid waste with six inches of earthen material at the end of each operating day, or at more frequent intervals if necessary.

2) Alternative Demonstrations

258.26 Run-on/run-off Control Systems

1) Design, construct, and maintain a run-on control system to prevent flow onto the active portion of the landfill during the peak discharge from a 24-hour, 25-year storm.

Leachate Minimization and Management

- Stages of development
  - Open
  - Active
  - Inactive (Interim)
  - Closed (Final)

Generation Analysis

LEACHATE GENERATION RATES:

1-Year, 24-Hour Design Storm Depth = 3.00 inches **(US Weather Bureau TP-40)**

Open: 81,457 gallons/acre/day

Active: 1,200 gallons/acre/day

Interim: 500 gallons/acre/day

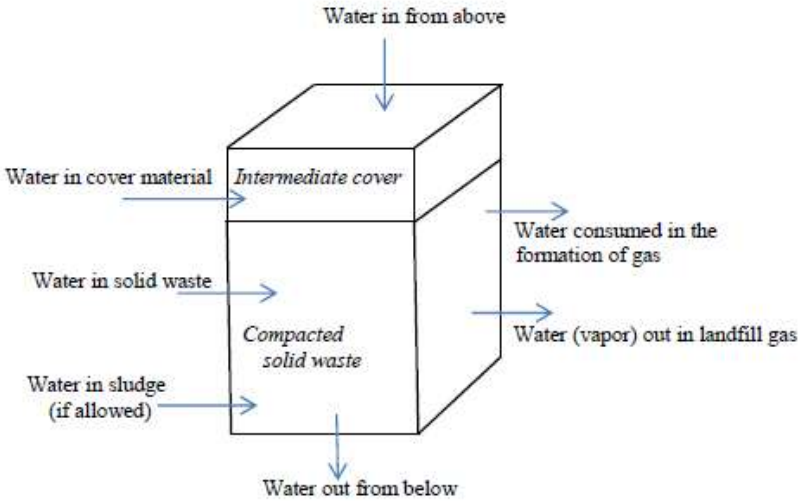
Final: 100 gallons/acre/day

OPEN		ACTIVE		INTERIM		FINAL		TOTAL
Acres	GPD	Acres	GPD	Acres	GPD	Acres	GPD	GPD
A. Completion of Phase 1 Operations								
0.0	0	0.0	0	47.0	23,500	0.0	0	23,500
B. Filling of Phase 2A								
2.0	162,914	10.0	12,000	63.1	31,550	0.0	0	206,464
C. Filling of Phase 2B								
2.0	162,914	6.0	7,200	84.9	42,450	0.0	0	212,564
D. Completion of Initial Filling of Phases 1 & 2 (Value is "Typical" Leachate Generation Rate)								
0.0	0	0.0	0	92.9	46,450	0.0	0	46,450
E. Closure of Phases 1 & 2 (Value is "Typical" for Post-Closure Conditions)								
0.0	0	0.0	0	0.0	0	92.9	9,290	9,290

Leachate Minimization and Management

- Open
  - Leachate Management System
    - Drainage Layers
      - Gravel
      - Sand
      - Drainage Net
    - Collection Piping
  - Stormwater Separation
    - Geosynthetic Rain Cover
    - Separation Berms
    - Pipe Connections

Leachate Minimization and Management



"Field Capacity"

$$\Delta S_{SW} = W_{SW} + W_{TS} + W_{CM} + W_{A(R)} - W_{LG} - W_{WV} - W_E + W_{B(L)}$$

Where

ΔS_{SW} = change in the amount of water stored in the solid waste in the landfill, lb/yd^3

W_{SW} = water (moisture) in incoming solid waste, lb/yd^3

W_{TS} = water (moisture) in incoming treatment plant sludge, lb/yd^3

W_{CM} = water (moisture) in cover material, lb/yd^3

$W_{A(R)}$ = water from above (for upper landfill layer water from above corresponds to rainfall or water from snowfall), lb/yd^2

W_{LG} = water lost in the formation of landfill gas, lb/yd^3

W_{WV} = water lost as saturated water vapor with landfill gas, lb/yd^3

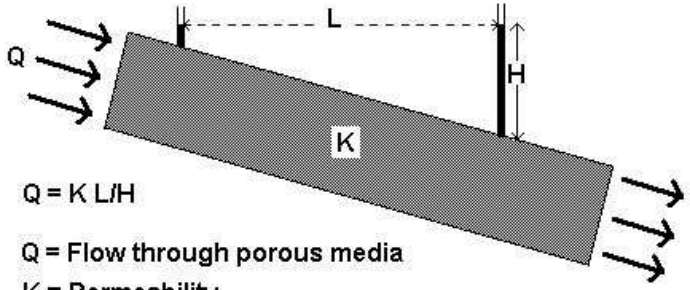
W_E = water lost due to surface evaporation, lb/yd^2

$W_{B(L)}$ = water leaving from the bottom of element (for the cell placed directly above a leachate collection system, water from the bottom corresponds to leachate), lb/yd^2

Ref. Tchobanoglous, G.H. Theisen, and S.A. Virgil, *Integrated Solid Waste Management Engineering Principles and Management Issues,* McGraw-Hill, New York, 1993.

Leachate Collection System

Filtration vs. Flow



Q = K L/H

Q = Flow through porous media

K = Permeability

L/H = Hydraulic gradient

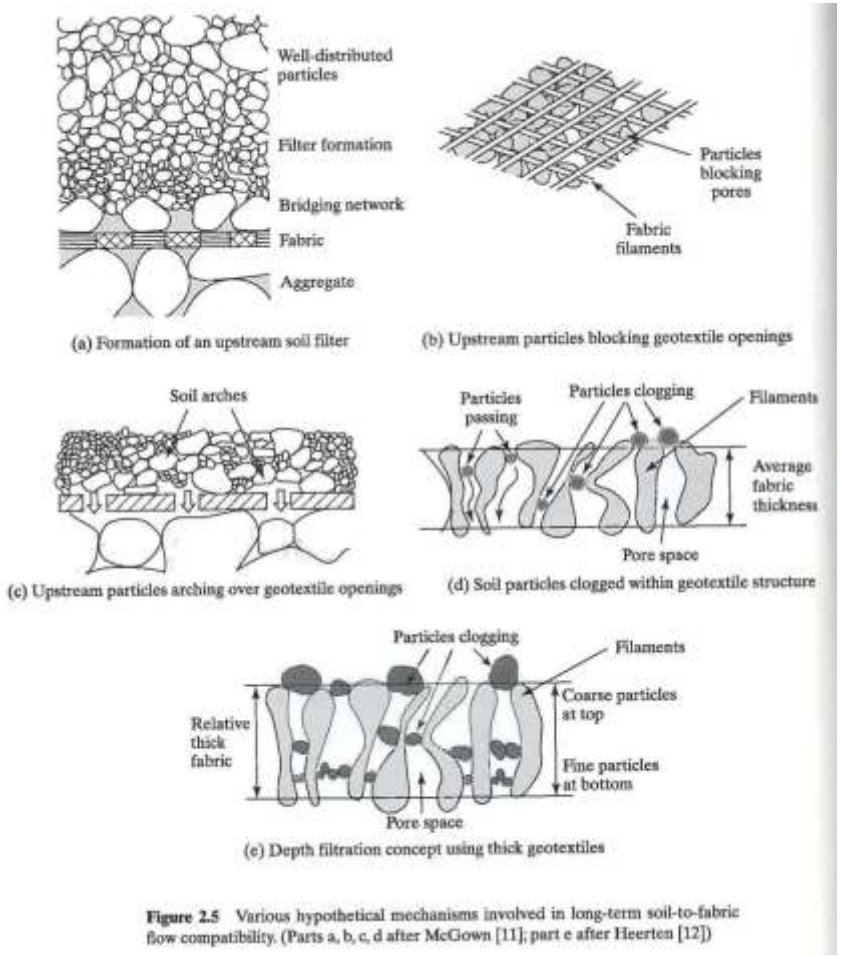
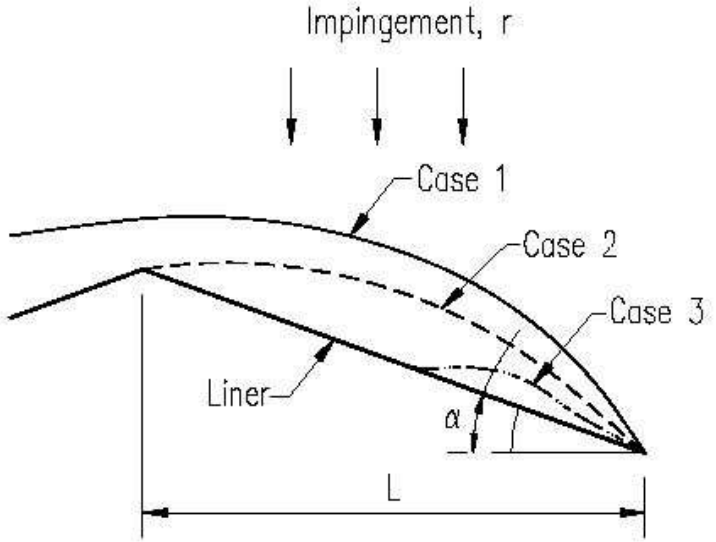


Figure 2.5 Various hypothetical mechanisms involved in long-term soil-to-fabric flow compatibility. (Parts a, b, c, d after McGown [11]; part e after Heerten [12])

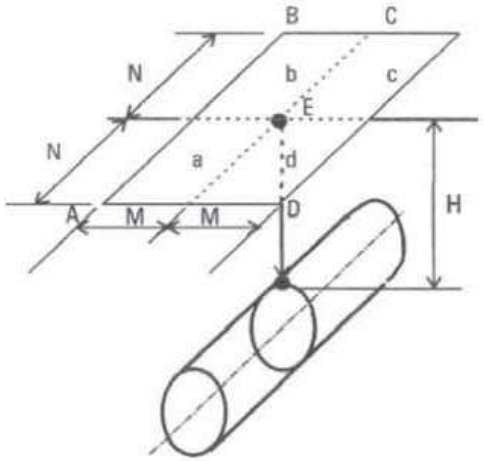
Leachate System Design

- Lateral Drainage Systems
  - McEnroe Equation
    - Case 1 – has a saw-tooth bottom, with the liquid mound overtopping the peak.
    - Case 2 - has the liquid mound starting at the peak of the saw-tooth.
    - Case 3 - has the mound starting below the peak of the tooth.
    - Cases 2 &3 - appropriate for modeling a liner on an infinite slope with collector pipes uniformly spaced down the slope.

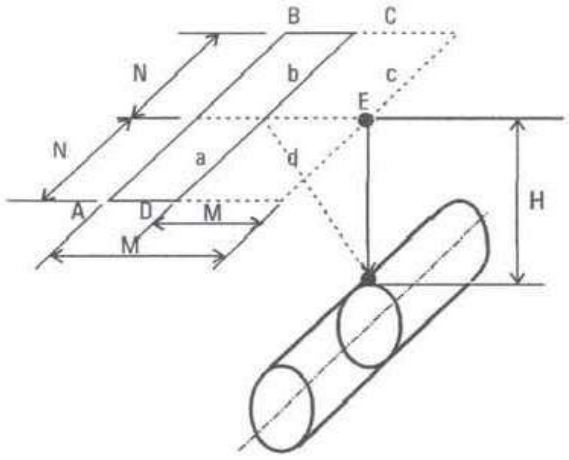


Leachate Collection Piping

- Design Considerations
  - Flow capacity
  - Perforations
  - Loading
    - Deflection
    - Bending
  - Cleaning
  - Inspection/Access
  - Gas Collection



A. Distributed Load Over Pipe



B. Distributed Load Not Over Pipe

Leachate Management Conditions

- Active
  - Daily Cover
  - Alternative Daily Cover
    - Rain Cover (Tarps)
    - Spray-On Covers
  - Slope
  - Run-On Controls

Leachate Management Conditions

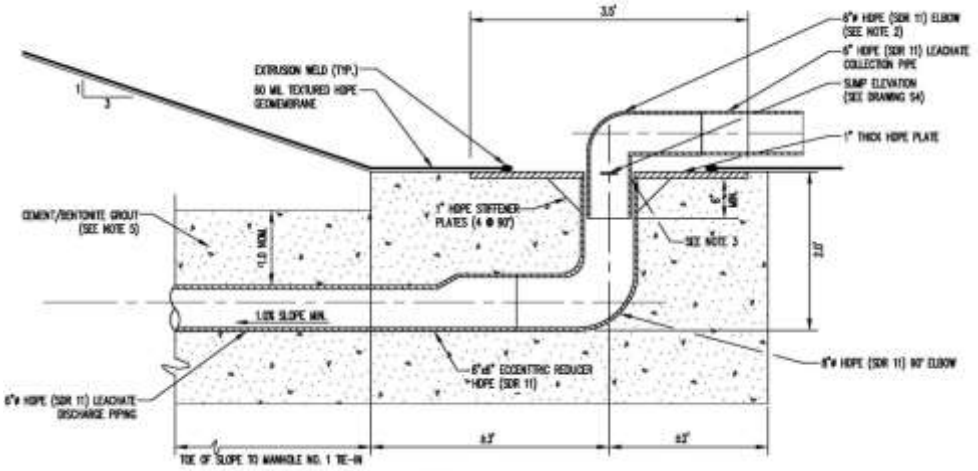
- Inactive
  - Soil Cover
  - Rain Cover
  - Slope
  - Management

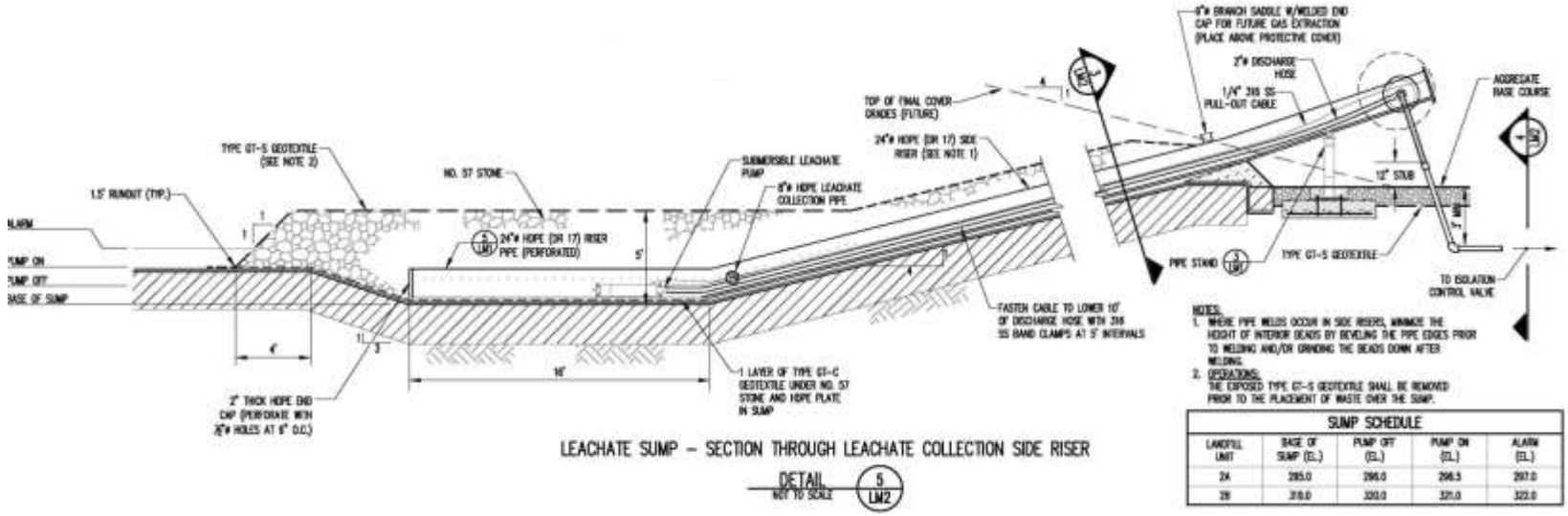
Leachate Management Conditions

- Final Cover
  - Soil
  - Low Permeability
  - Geosynthetic
  - Phyto
  - Exposed

Leachate Management

- Removal
  - Sumps
    - Gravity
    - Mechanical





SUMP SCHEDULE

LANDFILL UNIT	BASE OF SUMP (EL.)	PUMP OFF (EL.)	PUMP ON (EL.)	ALARM (EL.)
2A	285.0	296.0	296.5	297.0
2B	318.0	320.0	321.0	322.0

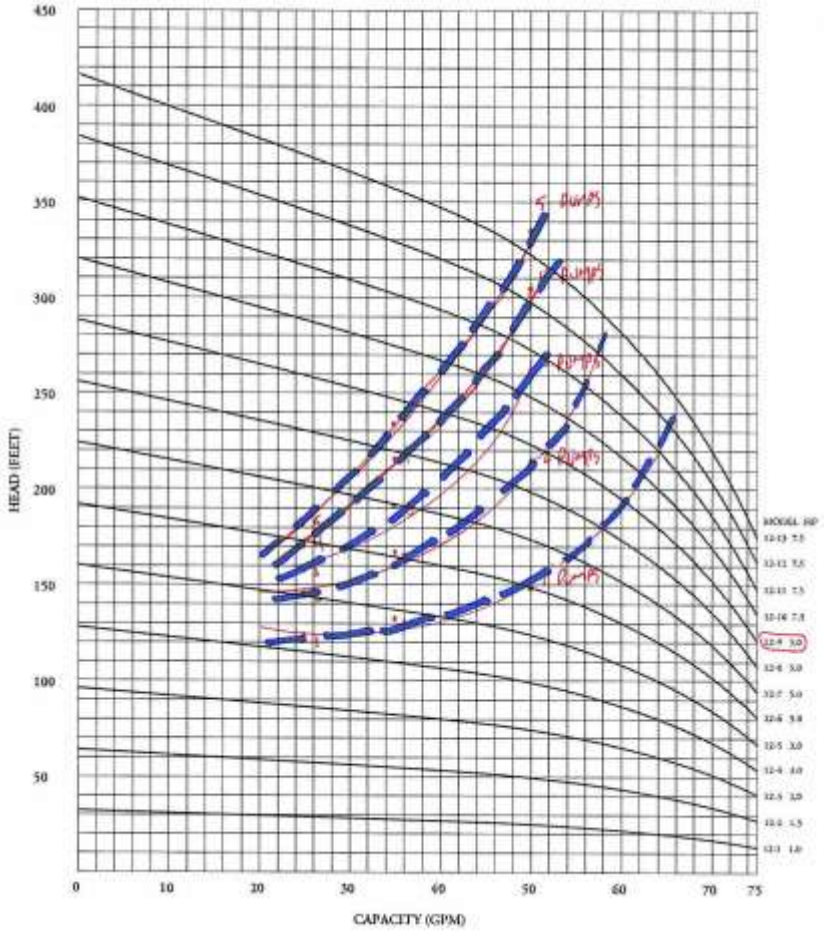
Pumping Systems

Sized according to balance energy by the Bernoulli equation.

The equation has been modified as follows:

$TDH = H_e + H_f + H_m$

Where: TDH = Total Dynamic Head, feet
H_e = Elevation Head, feet
H_f = Friction Head, feet
H_m = Minor Losses, feet



Leachate Storage Systems

- Above Ground Storage
  - Steel Tanks
    - Bolted
    - Welded
    - Glass Lined
    - Stainless
    - Expoxy Coated
    - Lined
  - Plastic
    - Tanks
    - Impoundments
- Storage Lagoons and Ponds
  - Geosynthetic
  - Concrete

Secondary Containment

- Protects for spills and ruptures
- Typically designed for 110% tank capacity
- Procedural management of stormwater release
- Documentation

Treatment and Disposal

- On-Site Re-Use and Management
- Direct Discharge
- Land Application
- Treatment

On-Site Re-Use and Management

- Leachate Recirculation
  - Lateral Drainage System Competence
  - Enhancement vs. Saturation
  - Gas Generation
- Re-Use in Spray-On ADC's

On-Site Re-Use and Management

- Evaporation
  - Gas
    - Landfill Gas
    - Propane
    - Natural Gas
  - Residual Sludge
    - Concentrated

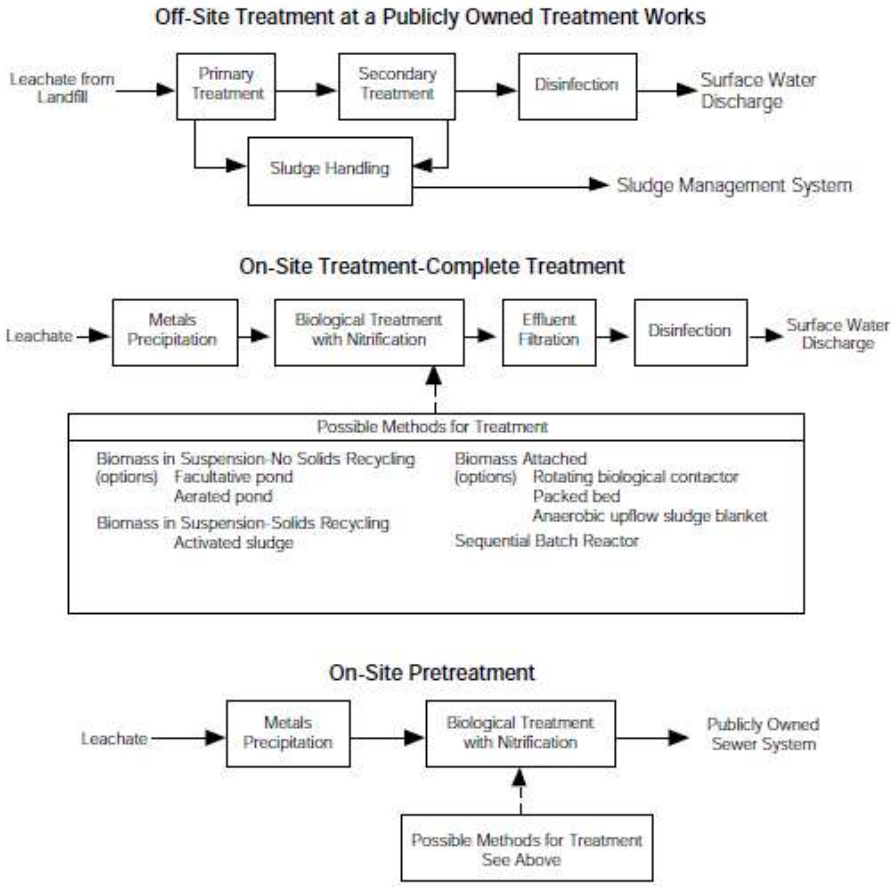
Direct Discharge

- Publicly Owned Treatment Works (POTW)
  - Discharge Permits
    - Limits (Quality and Quantity)
    - Pre-Treatment may be required
    - Large vs. Small Facilities
    - Sampling and Monitoring
    - Variations over Time
    - Pump and Haul

Land Application

- Spray Application
  - NPDES Permits
  - Agronomic Rates
  - Pre-Treatment Required
- Constructed Wetlands
  - NPDES Permits
  - Biological Uptake
  - Pre-Treatment Required
  - Final Polishing

Treatment



Source: G. Farquhar. 1994

Treatment

- Biological – Removal of Organics
  - Activated Sludge
  - Aeration Stabilization Basins
  - Anaerobic Lagoons

Treatment

- Physical/Chemical Treatment
  - Removal of Suspended Matter, Organics, Metals
  - Air Stripping-volatile organic and ammonia removal
  - Neutralization-pH control
  - Filtration-suspended matter removal
  - Evaporation-liquid removal
  - Precipitation-metal and anion removal
  - Reverse Osmosis-dilute solution of inorganics
  - Oxidation-organics removal and detoxification
  - Adsorption-organics removal

Short and Long Term Care

- Liner Integrity Protection
- Groundwater Monitoring and Corrective Action
- Leachate Releases (Seeps)

Liner Integrity

- Protecting the Liner
  - Initial waste placement must be considered when operating a lined landfill.
  - Penetrations through the liner must be corrected.

Groundwater Monitoring

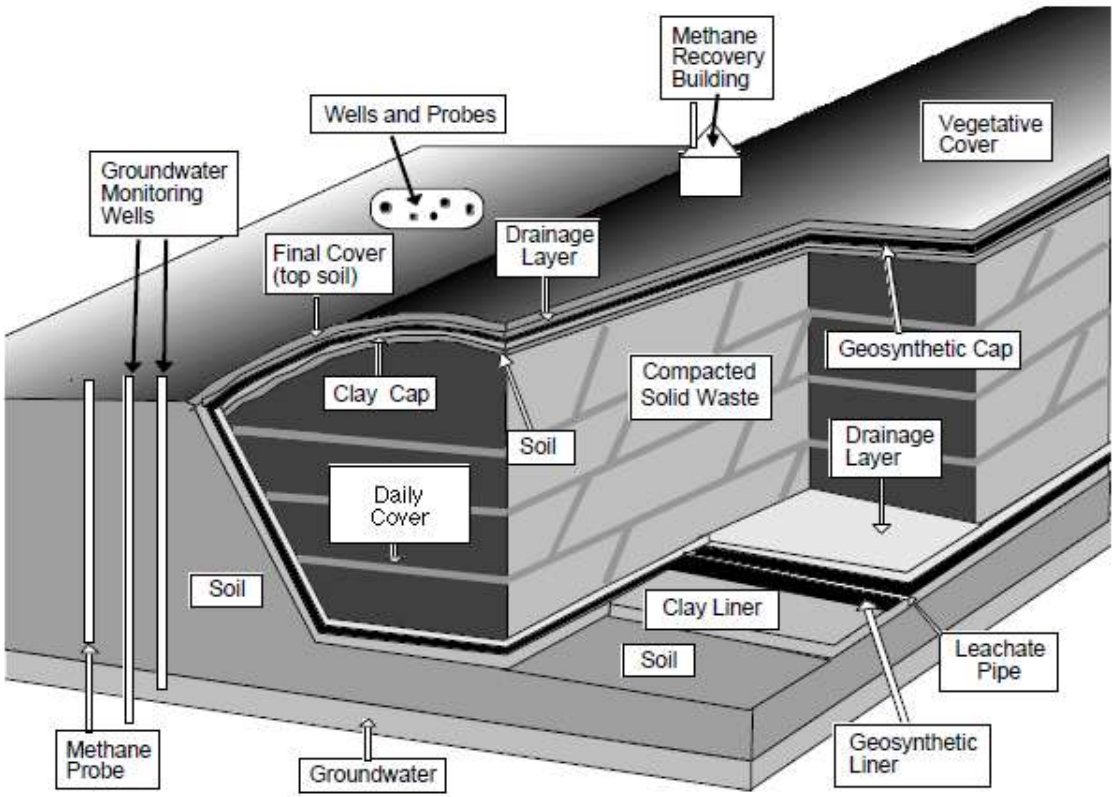
- Groundwater Monitoring and Corrective Actions
  - RCRA established requirements for a groundwater protection program consisting of four components:
  - Groundwater monitoring program.
  - Detection monitoring programs.
  - Assessment monitoring program.
  - Corrective action program.
- Groundwater Monitoring Detects Landfill Releases

Leachate Releases

- Leachate Releases (Seeps)
  - Liquids (leachate) can escape a landfill's daily, intermediate, or final cover.
  - Leachate seeps will appear as moist and discolored areas on the ground.
  - Leachate seeps can impact surface water.
  - Corrective actions must be taken to eliminate and prevent leachate seeps.

Summary

Schematic of a Typical Municipal Solid Waste Landfill



Source: P. O'Leary and P. Walsh, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* 1991-1992

- Source: US EPA Decision Makers' Guide to Solid Waste Management, Volume II, EPA530-R-95-023, August 1995, p. 9-10.

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