Solid Waste Engineering

PE Review Session
Principles and Practice of Engineering:
Part B Civil Engineering

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Civil Engineering (Breadth)

ENVIRONMENTAL 20%

A. Wastewater Treatment – wastewater flow rates, unit processes.

B. Biology – toxicity, algae, stream degradation, temperature, disinfection, water taste & odor, BOD.

C. Solid/Hazardous Waste – collection, storage/transfer, treatment, disposal, quantity estimates, site & haul economics.

D. Ground Water and Well Fields – groundwater flow, aquifers (e.g., characterization).

Civil Engineering (Depth)

ENVIRONMENTAL(65%)

A. Wastewater Treatment

B. Biology (including micro & aquatic)

C. Solid/Hazardous Waste

Collection, storage/transfer, treatment, disposal, quantity estimates, site & haul economics, energy recovery, hazardous waste systems , applicable standards.

D. Ground Water and Well Fields

Dewatering, well analysis, water quality analysis, subdrain systems, groundwater flow, groundwater contamination, recharge, aquifers (e.g., characterization).

Environmental Engineering Exam Contents

A. Municipal Solid Waste (MSW), Commercial, and Industrial Wastes 10%

1. Definition and characterization of different types of solid waste
2. Sampling and measurement methods
3. Storage, collection, and transportation systems
4. Minimization, reduction, and recycling
5. Risk assessment
6. Fate and transport
7. Treatment and disposal technologies
8. Chemistry
9. Codes, standards, regulations, and guidelines
10. Engineering economics

Exam Contents (continued)

B. Hazardous Waste, Special, and Radioactive Waste 10%

1. Definition and characterization of different types of waste
2. Sampling and measurement methods
3. Storage, collection, and transportation systems
4. Minimization, reduction, and recycling
5. Risk assessment
6. Fate and transport
7. Treatment and disposal technologies
8. Chemistry
9. Health physics
10. Codes, standards, regulations, and guidelines
11. Mathematics and statistics
12. Engineering economics

1. Collection

2. Storage and Transfer

3. Treatment

4. Disposal

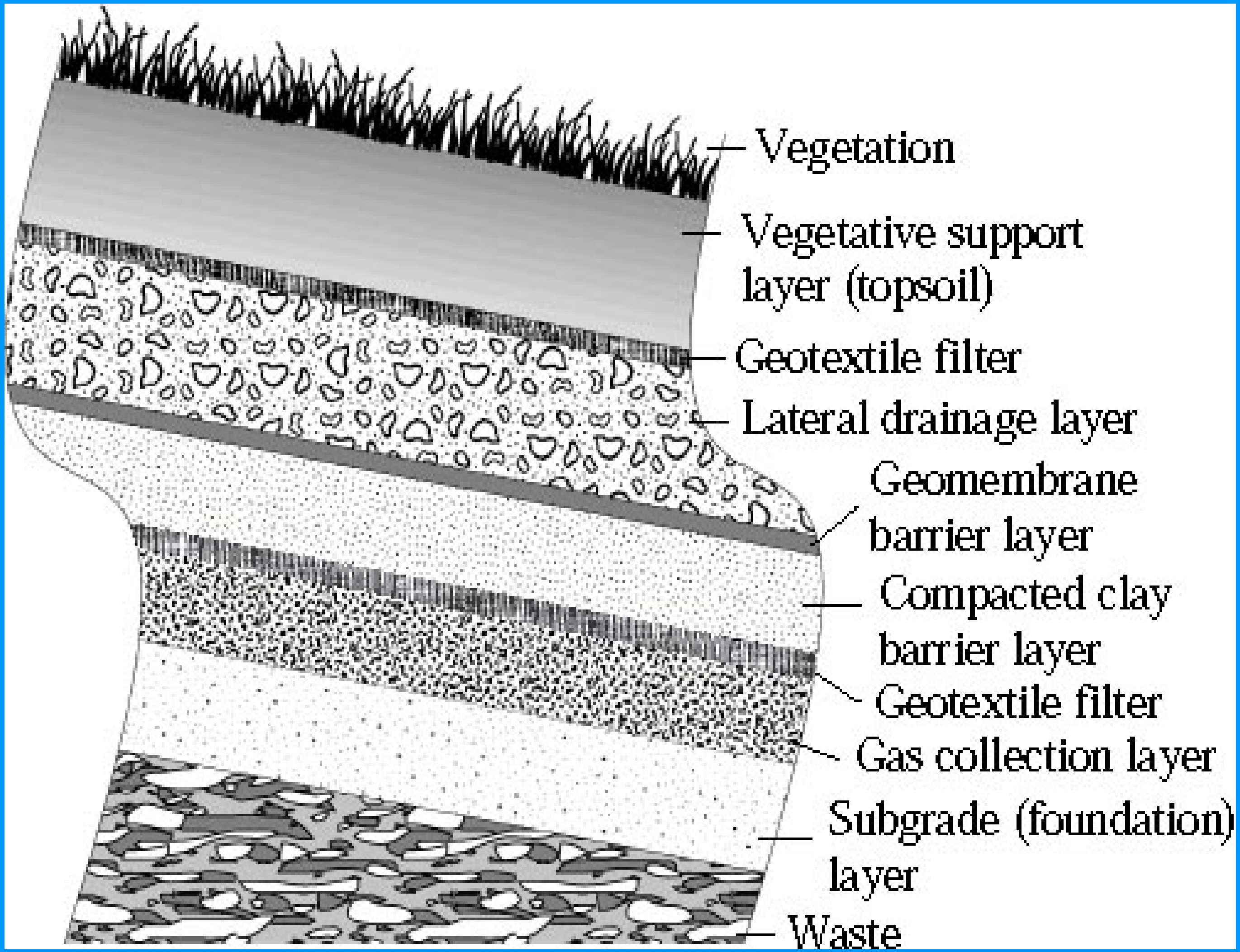
Principal Components of Landfill

- Cover System
- Leachate Collection System
- Liner System
- Stormwater Management
- Gas Management
- Environmental Monitoring

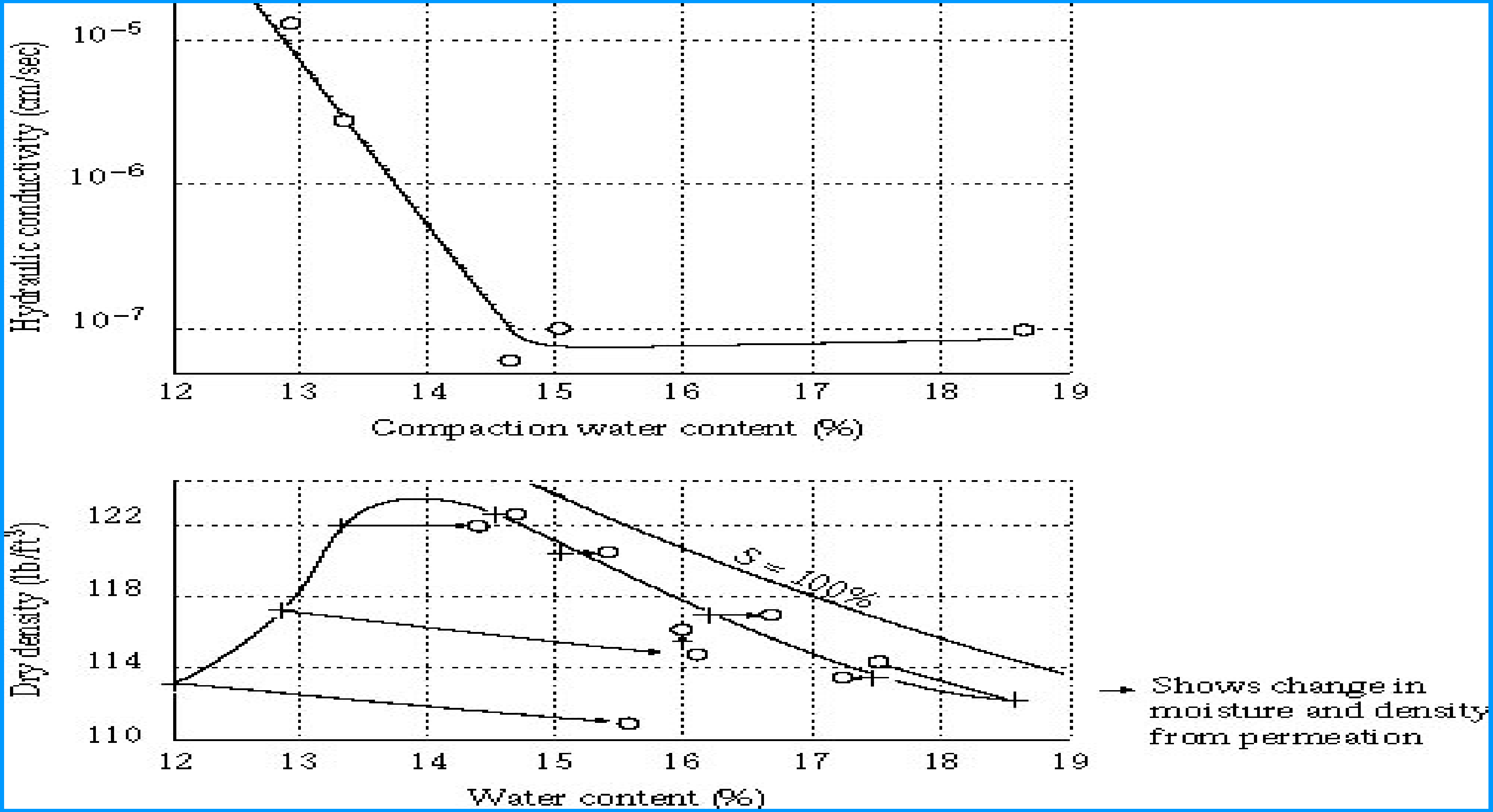
Objectives for 2 Principal Subsystems

- Cover System
  - prevent infiltration
  - minimize gas migration
  - provide surface water control
  - support vegetation
  - control vectors
- Liner System
  - prevent migration of liquid and gas
  - collect leachate
- Low permeability
- Low diffusion
- High retardation
- High strength

Landfill Cover



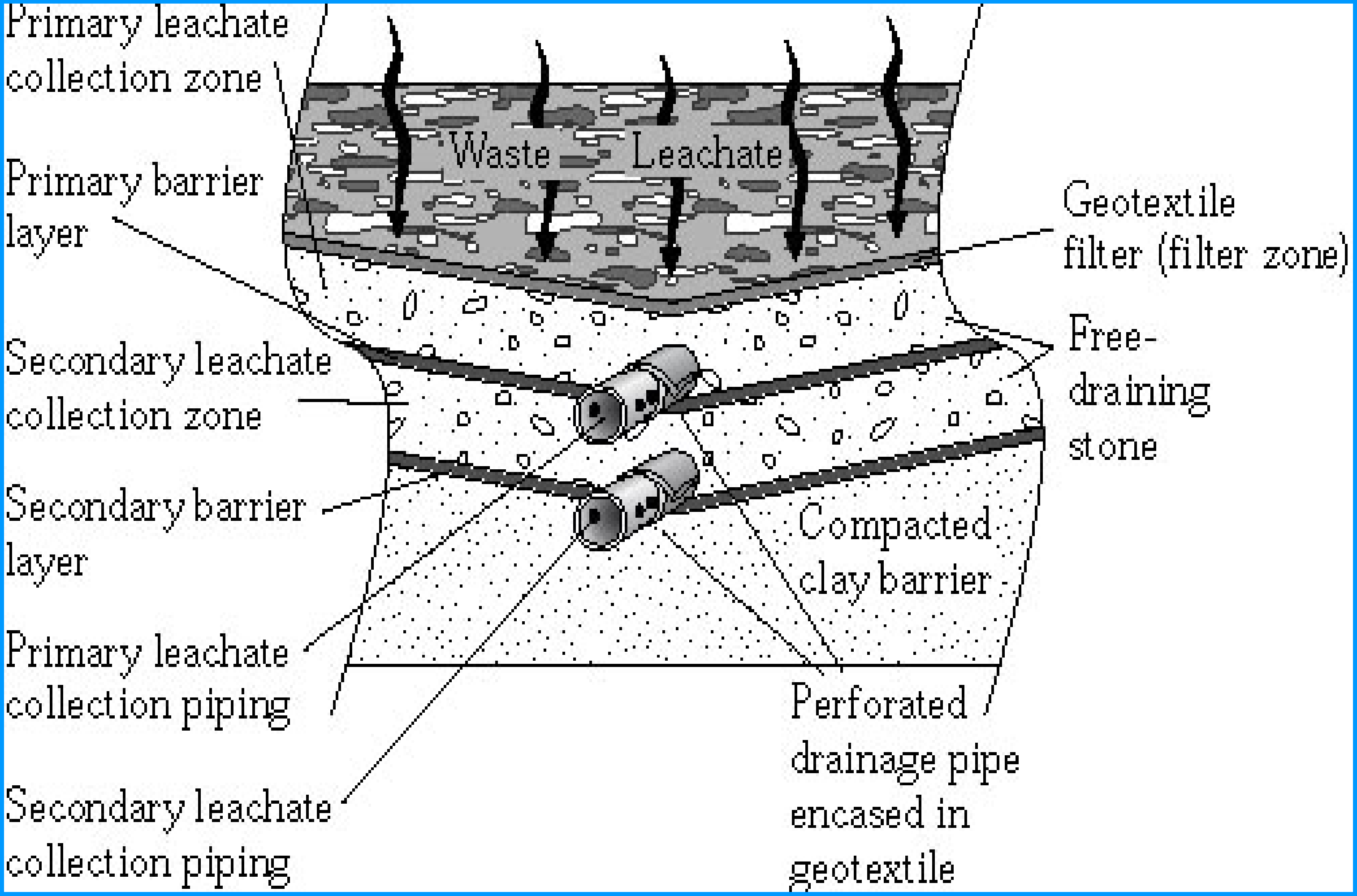
Compaction and Moisture Content



Liner and Leachate Collection

- Performance objectives:
  - function without clogging
    - minimum slope of 2%
    - granular medium, 12” thick $k > 10^{-2}$ cm/sec
    - chemically resistant materials: soil, liner, geotextile
  - minimize head < 1’
    - Darcy’s Law $Q = kiA$
    - Leachate generation rate
    - PERC = PRECIP - R/O -STORAGE -ET
  - structural stability
    - sliding, settling

Liner and Leachate Collection System



Design Factors for Soil Cover and Liner Systems

- Hydraulic Conductivity: $K<1 \times 10^{-7}$ cm/sec
  - Soil should be at least 20% fines
  - Plasticity Index > 10%, but less than 30 - 40% (too sticky)
- Coarse materials (gravel) < 10%
- No rocks >1 or 2” or organic material

Physics of Groundwater Flow

Total energy of flow of an incompressible fluid: Bernoulli's equation

$$H = total\ energy = potential\ energy + kinetic\ energy + elevation$$

$$H = \frac{P}{\gamma} + \frac{V^2}{2g} + z$$

Darcy's Law (1856)

$$Q = KA \frac{\Delta H}{\Delta L}$$

Q = flow rate (volume/time)
A = total area through which flow occurs
K = property of aquifer and water (hydraulic conductivity)
H = Head (pressure and elevation)
L = length of flow path between two points
Change in head/change in length is also called the "hydraulic gradient" or i

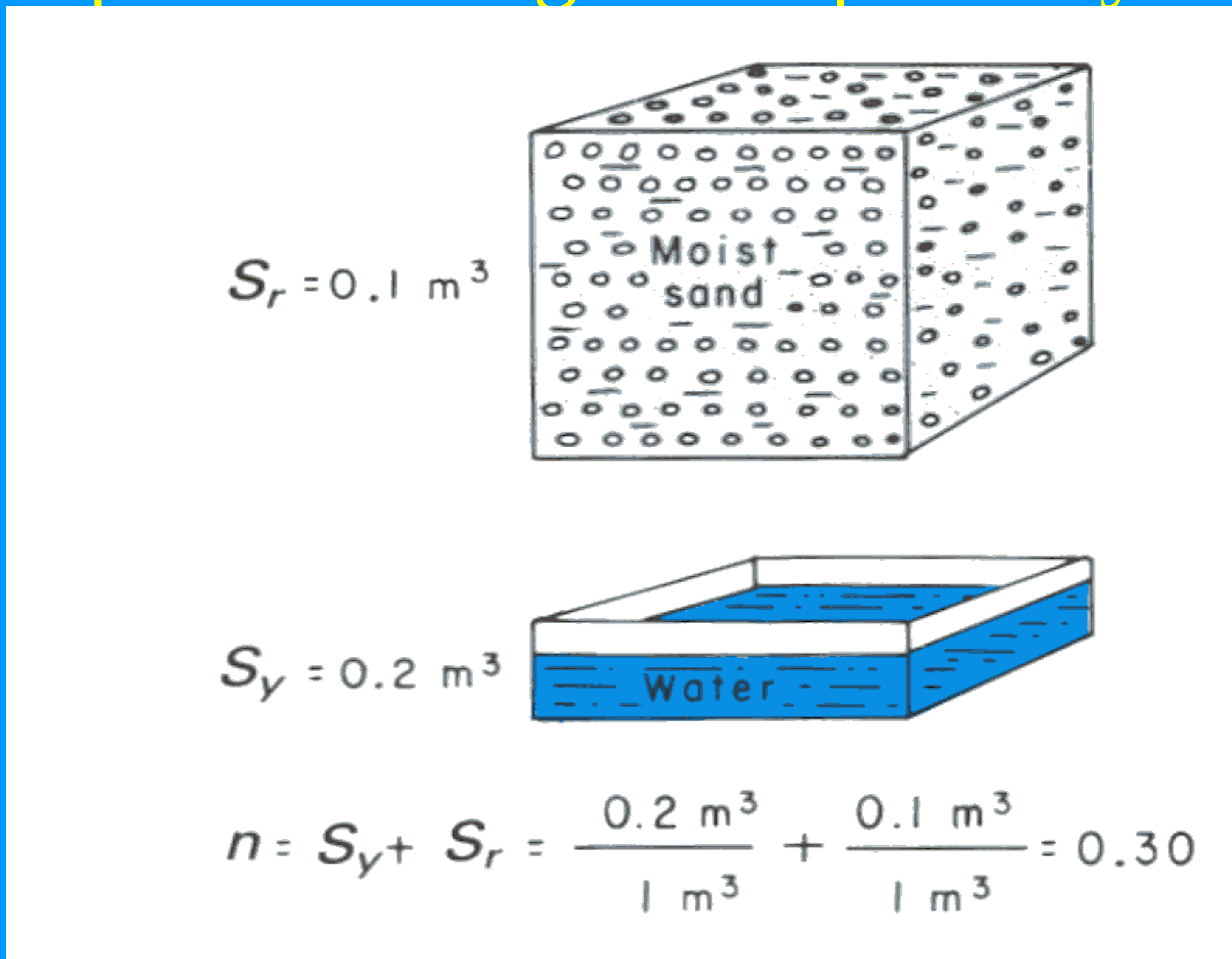
Darcy Velocity and Seepage Velocity

$$v = ki$$

$$v_s = \frac{v}{n} = \frac{ki}{n}$$

$$n = \frac{V_v}{V_t}$$

Specific storage and specific yield



Specific yield (continued)

- Water that drains by gravity
- Volume of water drained per volume of aquifer material
- Dimensionless
- porosity = specific yield + specific storage

$$S_y = \frac{1}{A}\frac{dV}{dh}$$

$$A = \text{aquifer area}$$

$$V = \text{volume of water} (\pm)$$

$$h = \text{water table elevation}$$

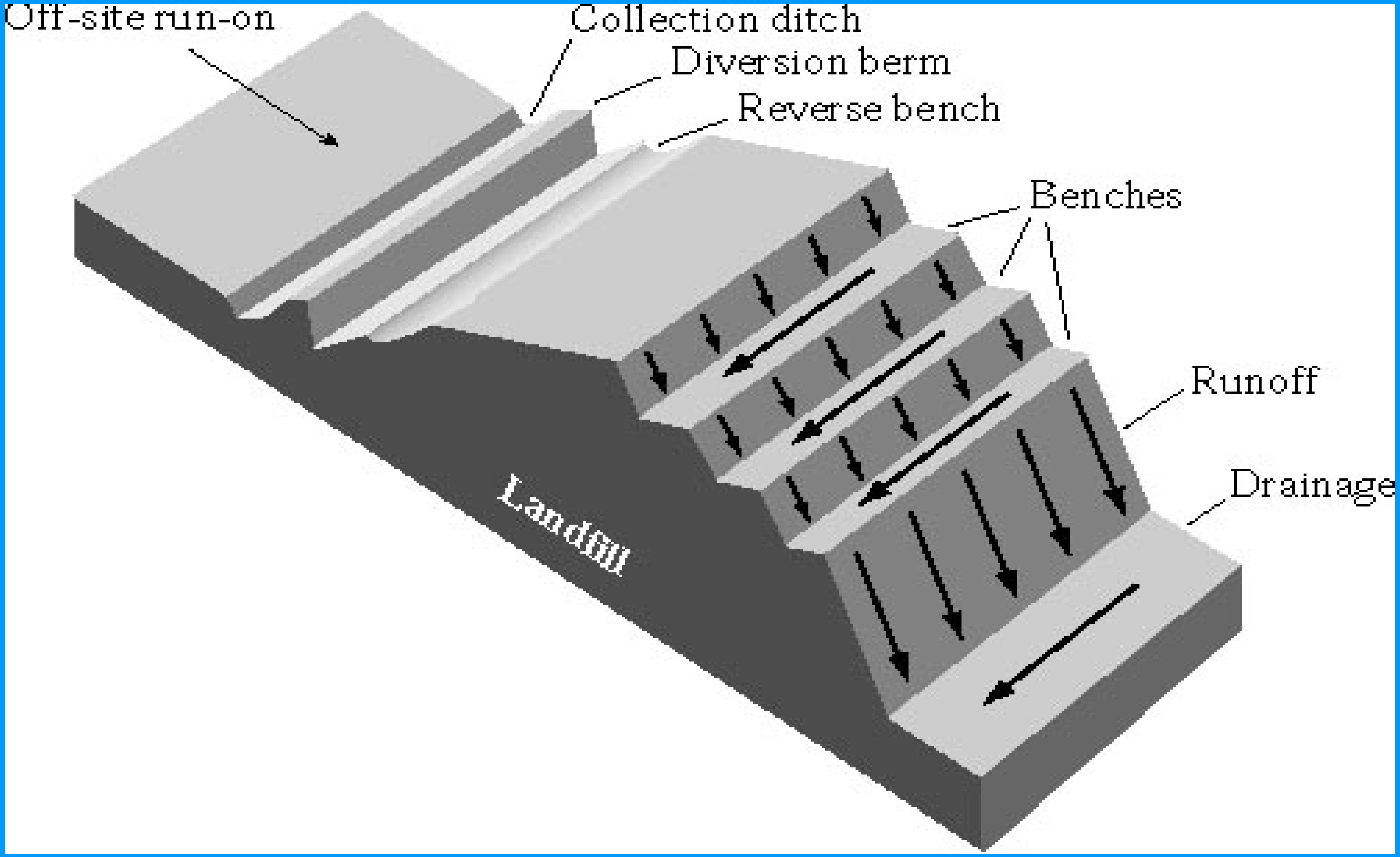
Example problem

Water table drops 5 ft from an aquifer with an areal extent of 3.5 acres. If $S_y = 0.04$, find volume of water released.

Problem

- Determine maximum flow rate (cf/day) from a leachate collection system for a landfill with the following characteristics:
  - rectangular 1200’ x 600’, with six 200’ wide collection zones along long side
  - bottom slope 0.02 ft/ft.
  - maximum head - 0.8 ft
  - sand drainage layer $k=10^{-2}$ cm/sec (28.35 ft/day)

Surface Water Control



Hydraulic Analysis – Open Channel

- Manning Equation

$$V = \frac{k}{n} R^{2/3} S^{1/2} \qquad R = \frac{A}{WP}$$

- Continuity Equation

$$V = \frac{Q}{A}$$

V= velocity (ft/s or m/s)

K= 1 (SI) or 1.486 (english)

R= hydraulic radius (ft or m)

S= friction slope

n= Manning's roughness coefficient

Q= discharge (cfs or m^3/sec)

A= Cross section area of flow

WP = wetted perimeter

Manning's n

RipRap: 0.04

Corrugated Metal Pipe: 0.02 - 0.03

Natural, clean, straight: 0.025 - 0.03

Weedy, winding: 0.075 - 0.15

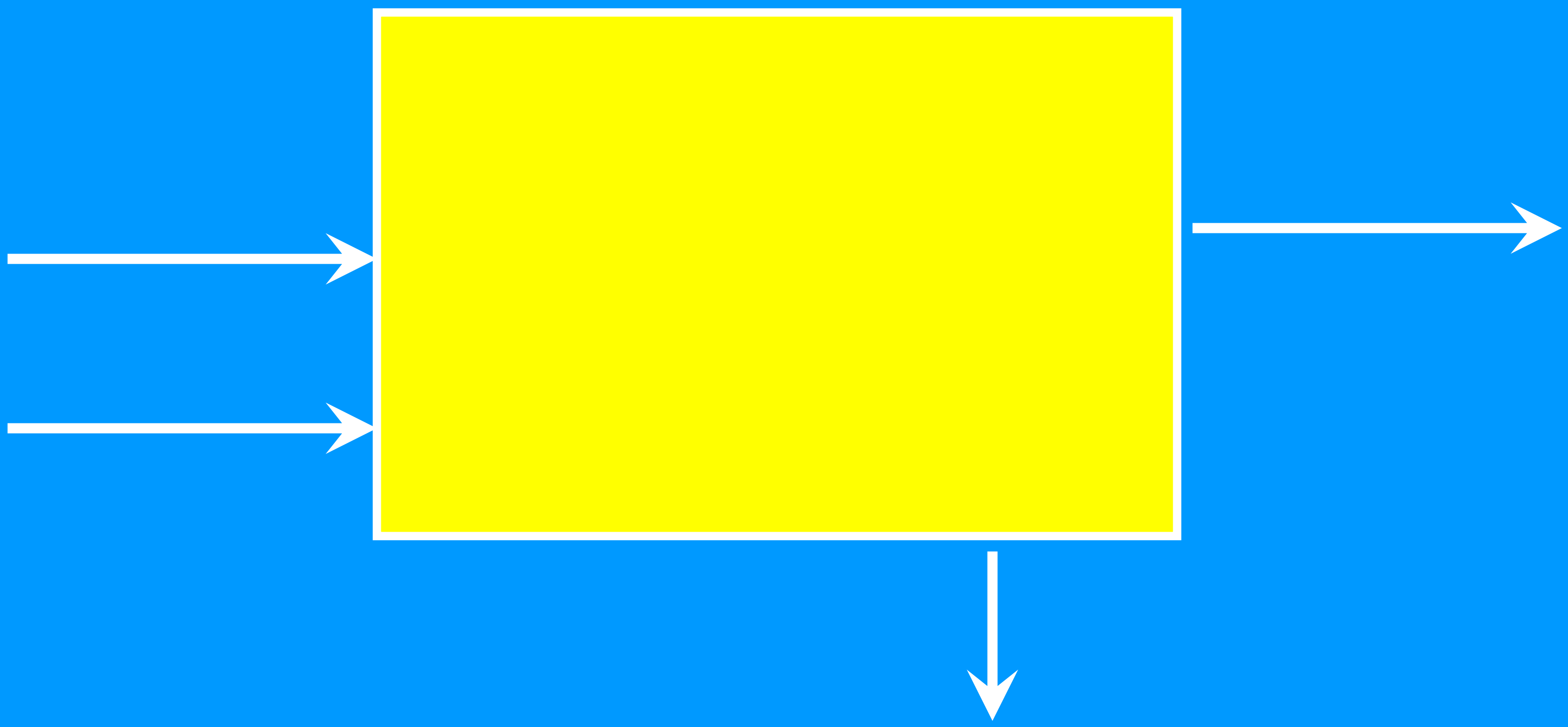
Water Balance for A Landfill Cell

- Change in storage = Sum of inputs – sum of outputs
- Inputs: moisture in incoming waste, cover materials, precipitation
- Outputs: vapor in landfill gas, microbial biomass, evaporation, leachate (percolation)

5. Quantity Estimates

Mass Balance

Accumulation = Inflow – Outflow + Generation



6. Site and Haul Economics

7. Energy Recovery

8. Hazardous Waste Systems

9. Applicable Standards

Landfill Siting Requirements

6 NYCRR Part 360 (Solid) 373 (Hazardous)

- Objectives:
  - *site characteristics should complement engineered system.*
  - *avoid environmentally sensitive areas (natural and human environment)*
  - Native soil K =10^{-5} cm/sec or less
  - Greater than 10 feet separation to aquifer or bedrock
  - Not located in recharge areas
  - Waste must be at least five feet above 100-yr flood plain
  - Place waste a minimum 50 feet from property line
  - Separation from surface waters

NYSDEC Liner System Standards (Part 373-2.14)

- Top liner
- Composite bottom liner
  - lower component 3 feet of compacted soil (k<10-7 cm/sec)
- Action Leakage Rate: 5 gal/acre/day
  - 22 gal/acre/day for BAT liner

Leachate Collection System Guidance

Loading rate (gpd/ac)	600 – 1000
Max Head (in)	9-12
Pipe Spacing (ft)	60-400
Pipe Dia (in)	6-8
Pipe material	PVC or HDPE
Pipe Slope (%)	0.5-2
Drainage slope (%)	0.2-2

Vesilind, et al p 136

References

- Vesilind et al. 2002. Solid Waste Engineering.
- Tchobanoglous et al. 1993. Integrated Solid Waste Management.
- McBean, et al. 1995. Solid Waste Landfill Engineering and Design.