U.S. Department of Transportation
Federal Highway Administration

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Geohazards in Transportation
in the Appalachian Region

In the Age of Great Innovation, a Great Oversight: Water and its Control

Benjamin S. Rivers, PE
Geotechnical Engineer

Federal Highway Administration
RESOURCE CENTER

U.S. Department of Transportation
Federal Highway Administration

Nature's Grader

Water and Its Control

Water's Influence

Observations

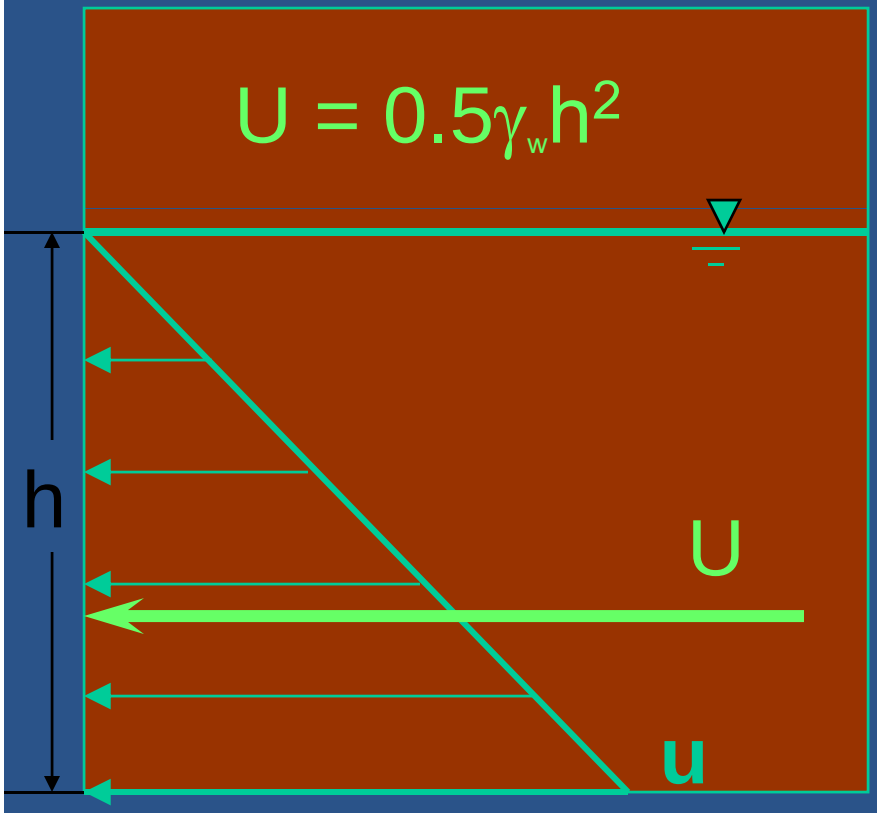
Investigations, analysis and practice

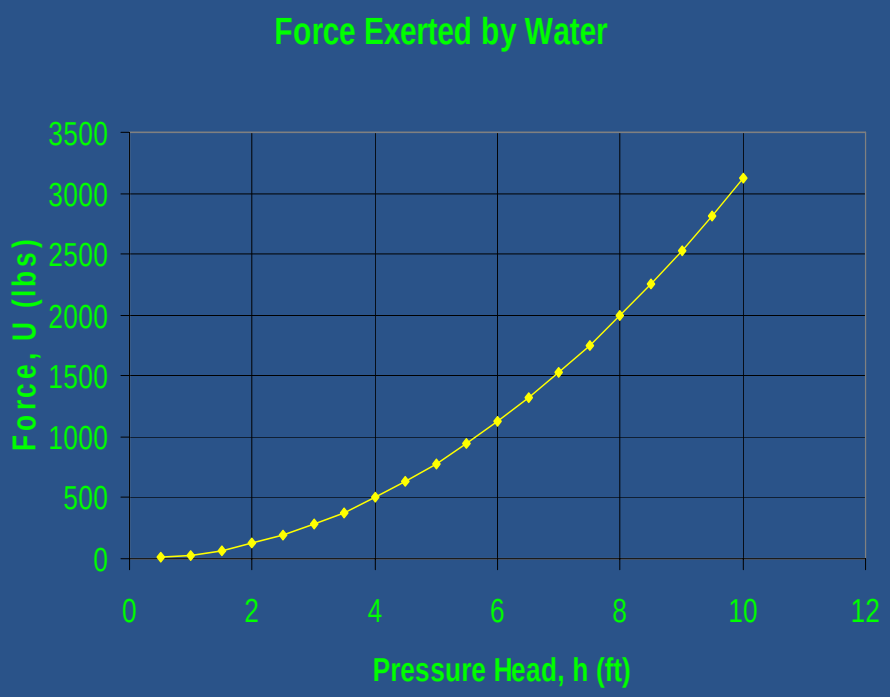
Summary

Influence of Water

- Added or Increased Water Pressure
- Decreased Effective Stress => Decreased Frictional Resistance
- For Fine-grained soils: Increased Water Content => Decreased Undrained Shear Strength
- For poorly placed fill soils: Change in water-content => Change in weight.
- Erosion (External & Internal)
- Other Affects – Degradation, dissolution, etc.

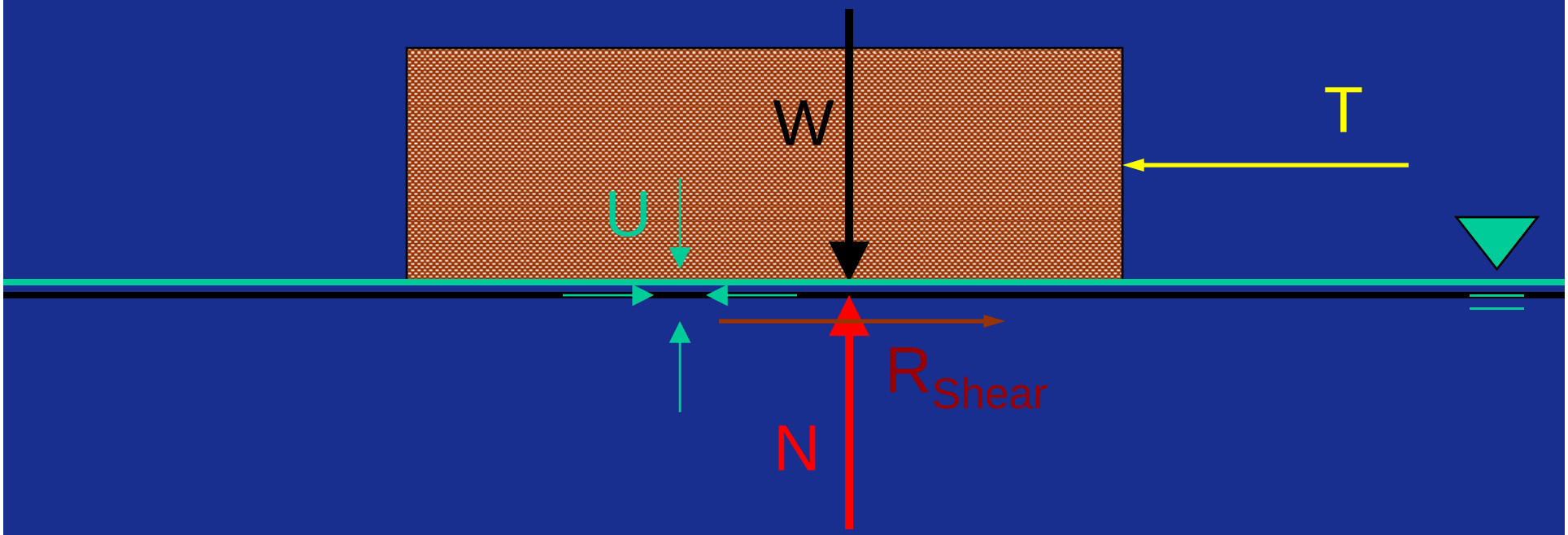
Water Pressure and Resultant Force





Effective Stress and Frictional Resistance

$$R_{Shear} = N * Tan(\phi)$$

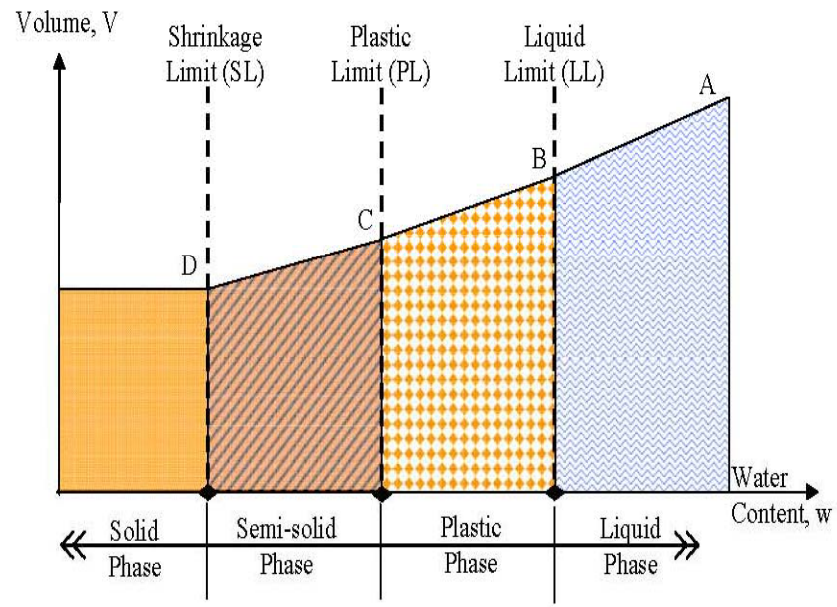


Atterberg Limits

↑ Water Content

⇊

↓ Undrained Shear Strength



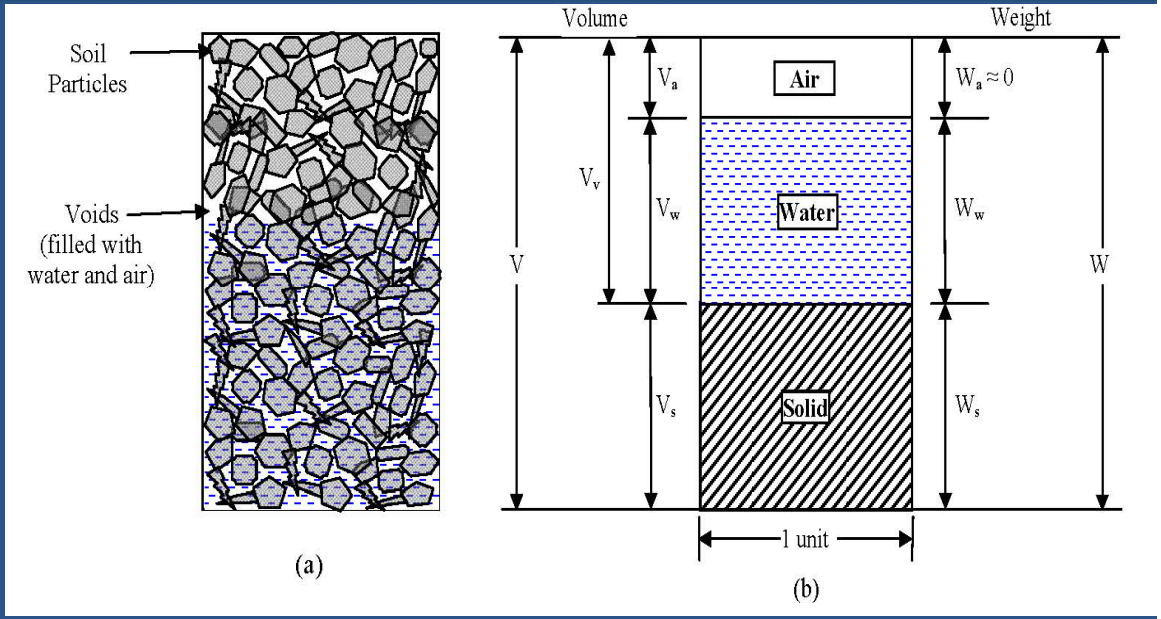
Conceptual Changes in Soil Phases as a Function of Water Content

Weight-Volume

△ Water Content

⇊

△ Total Weight



Example:

Void Ratio = 0.85

Range of Water contents: From 15% to 30%

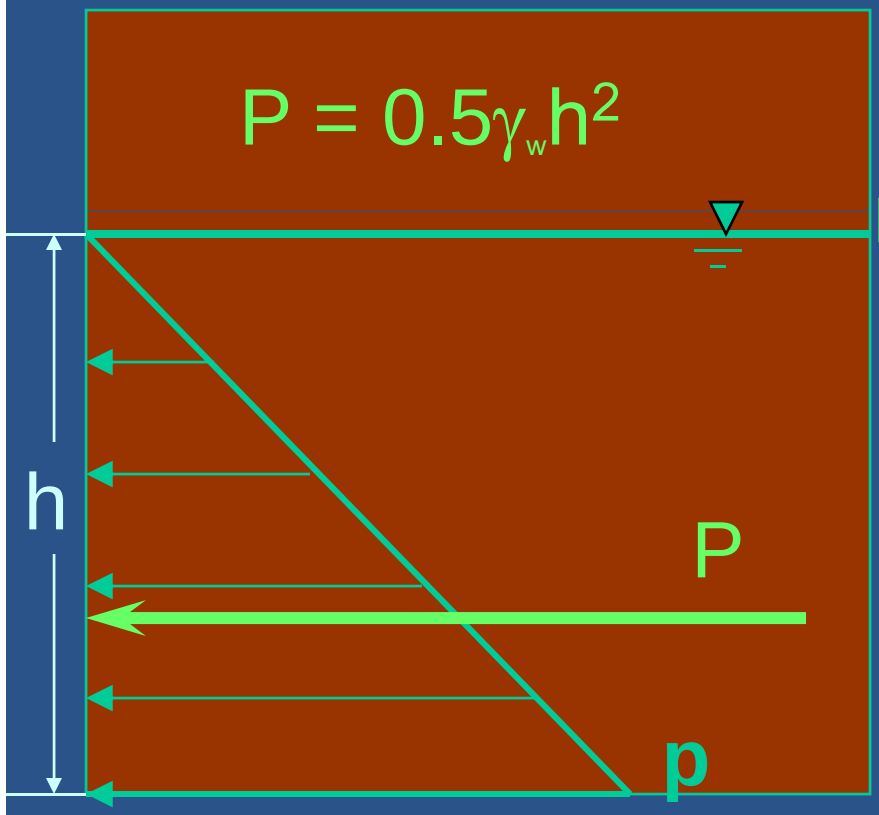
Change in Total Unit-Weight: 105pcf to 120pcf

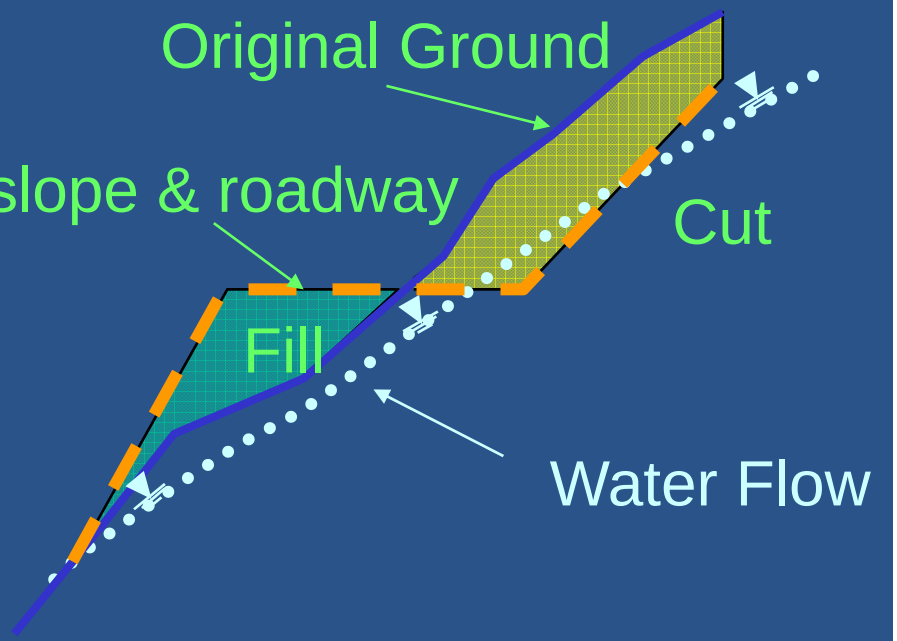
Change in weight over 30'X30' area (1' deep) = 13500lbs = 6.8 tons

So what are we missing?

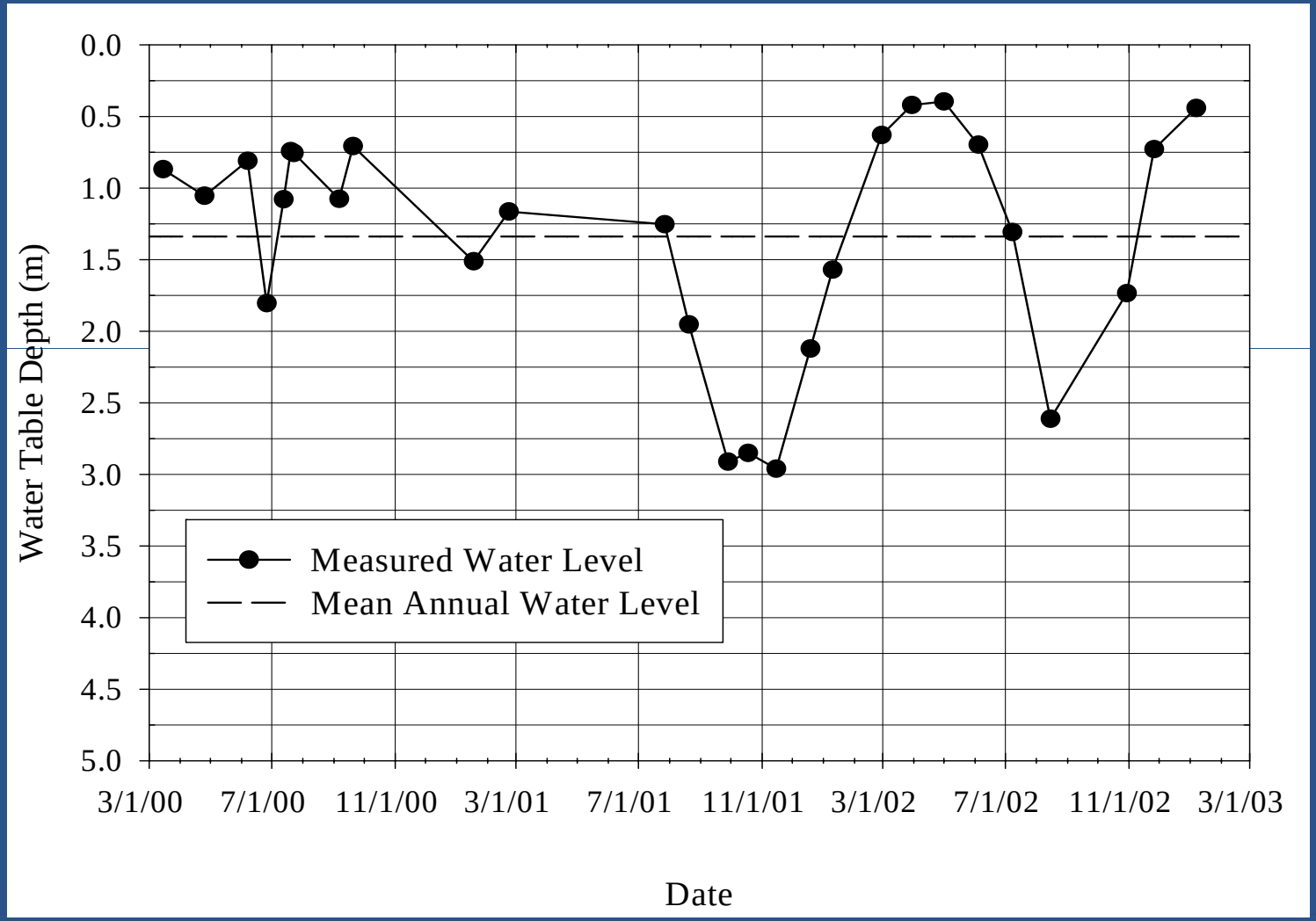
Some observations…

Dynamic World…Dynamic Conditions





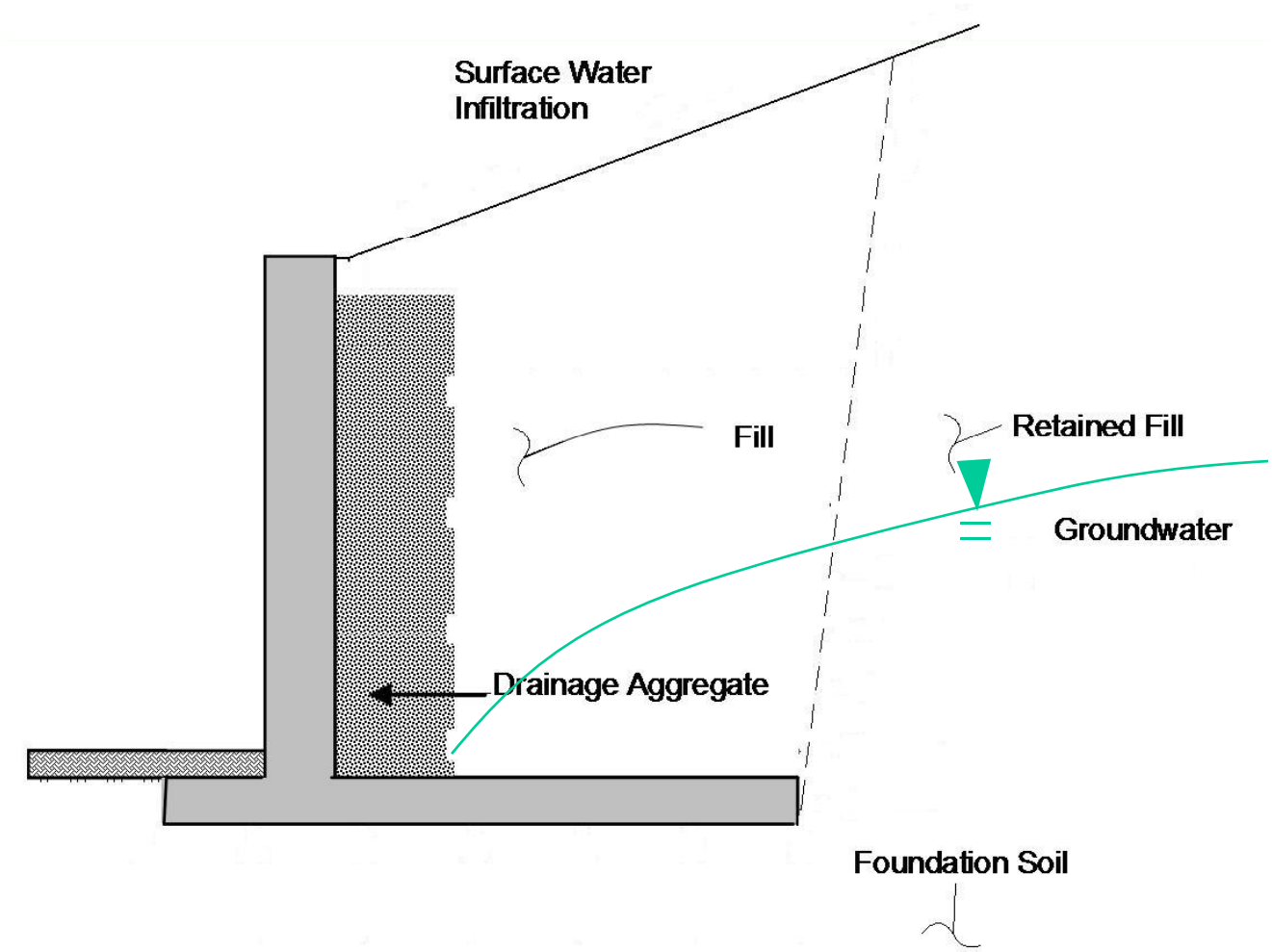
Fluctuations of Water Levels



Wall Drainage Measures

Common Assumptions…

- No build-up of water pressures
- “Free-draining” backfill
- Rankine Earthpressures



SEEPAGE EFFECTS

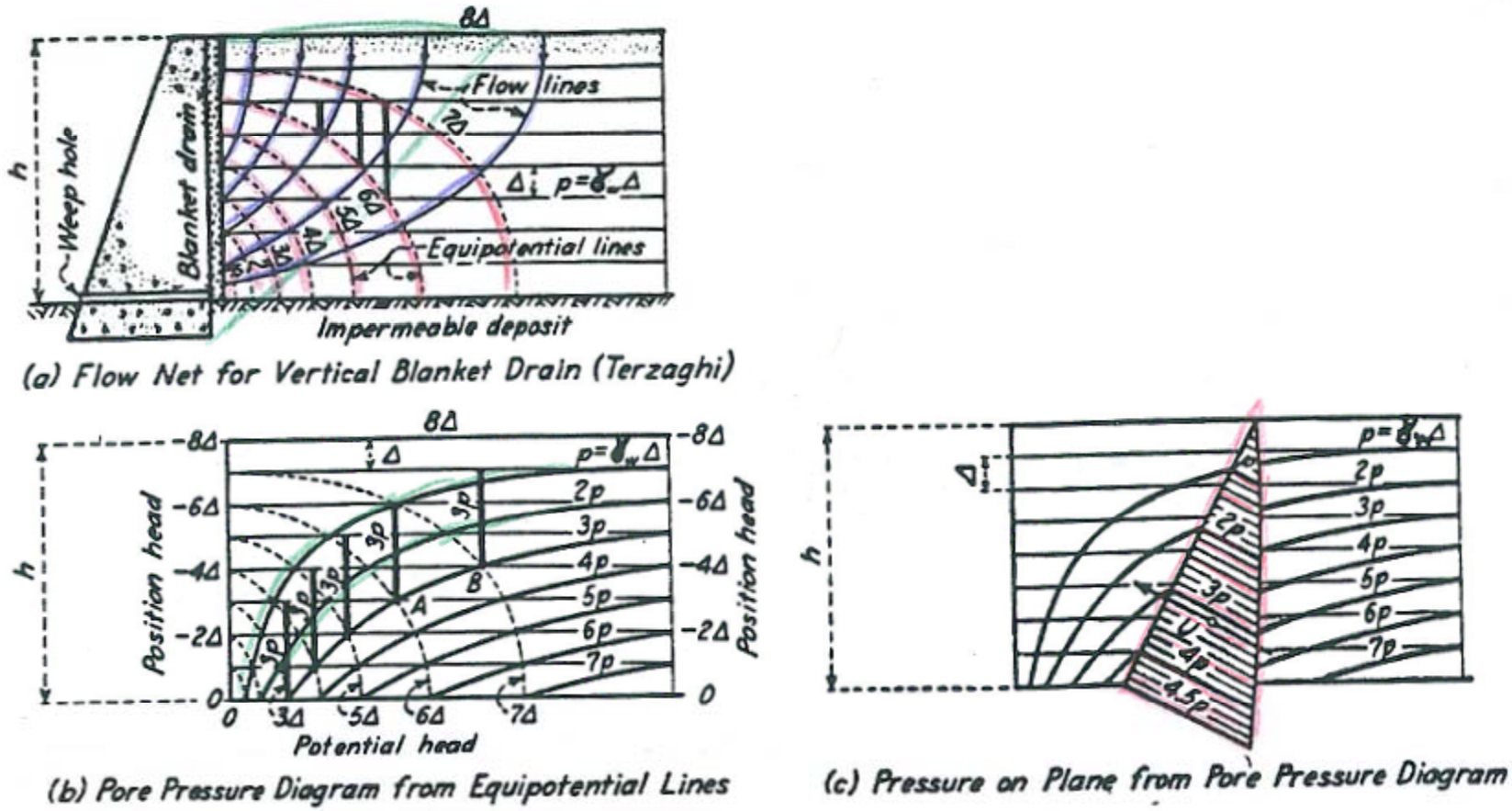
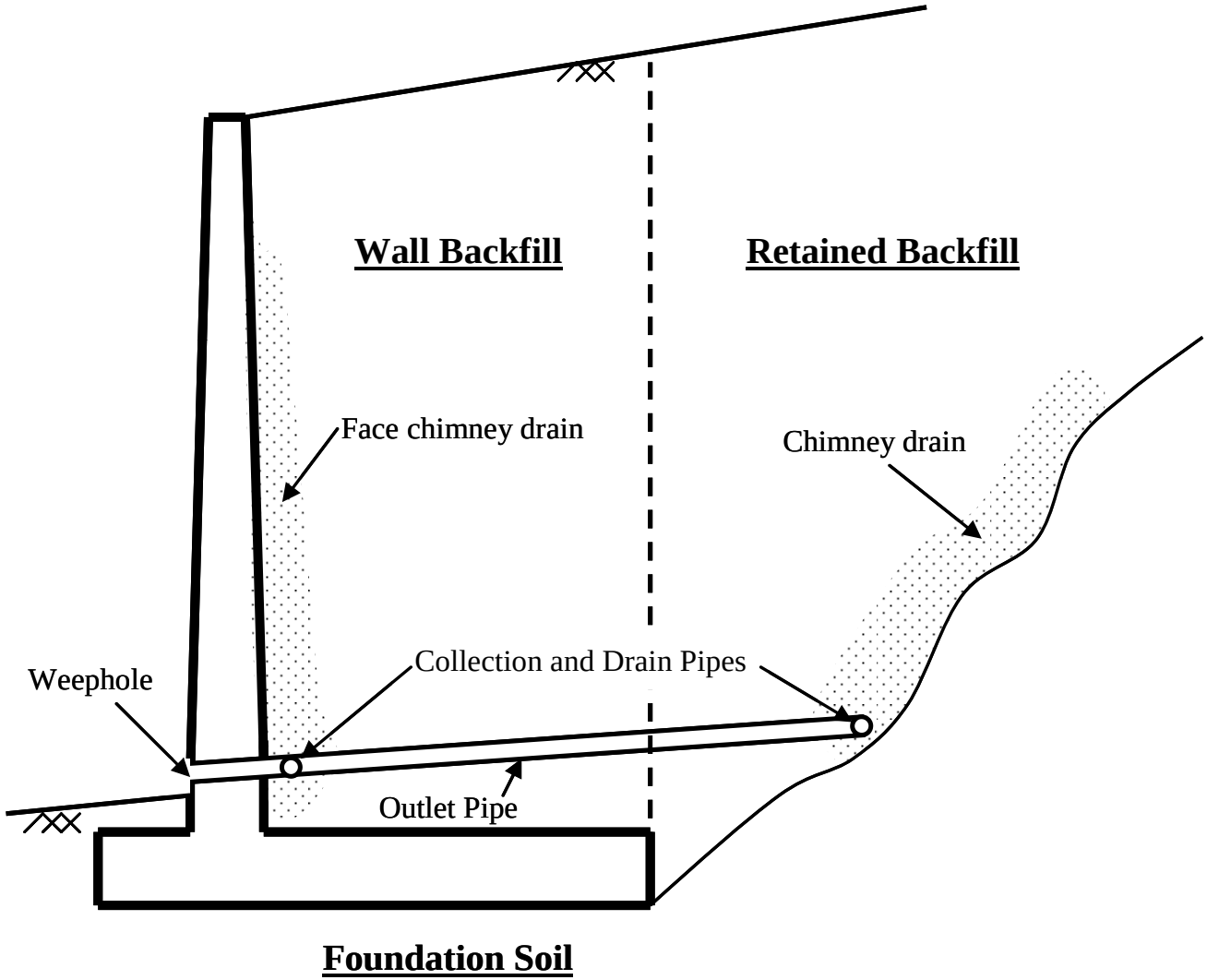
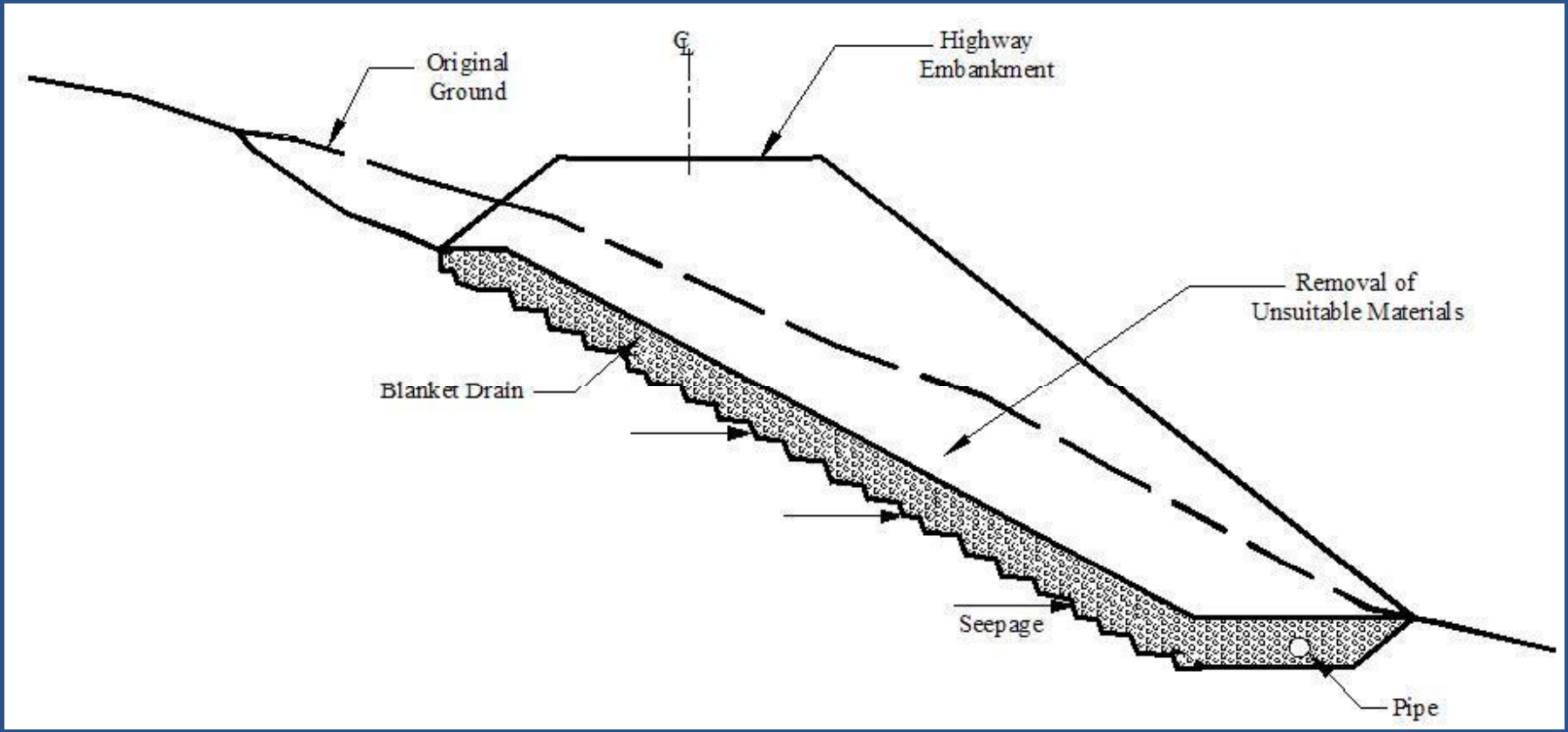


FIG. 16-6. Flow net and pore pressure diagram for retaining wall with vertical back drain rain water seeping into horizontal ground surface. (Huntington)

Wall Drainage Measures



Blanket Drain



Observations - Summary

- Forgetting the limitations of our assumptions
- General lack of understanding with groundwater flow and control
- Design considerations and details sometimes afterthoughts

Groundwater Investigations

- Groundwater Impacts…
- Design
  - Strength/Stability
  - Long-term Performance
- Foundation Construction
- Earthwork Construction
- Possible regulatory issues

Purpose Groundwater Investigations

Determine groundwater piezometric heads (water pressure)

Determine long term changes

Obtain groundwater samples

Piezometers/Observation Wells

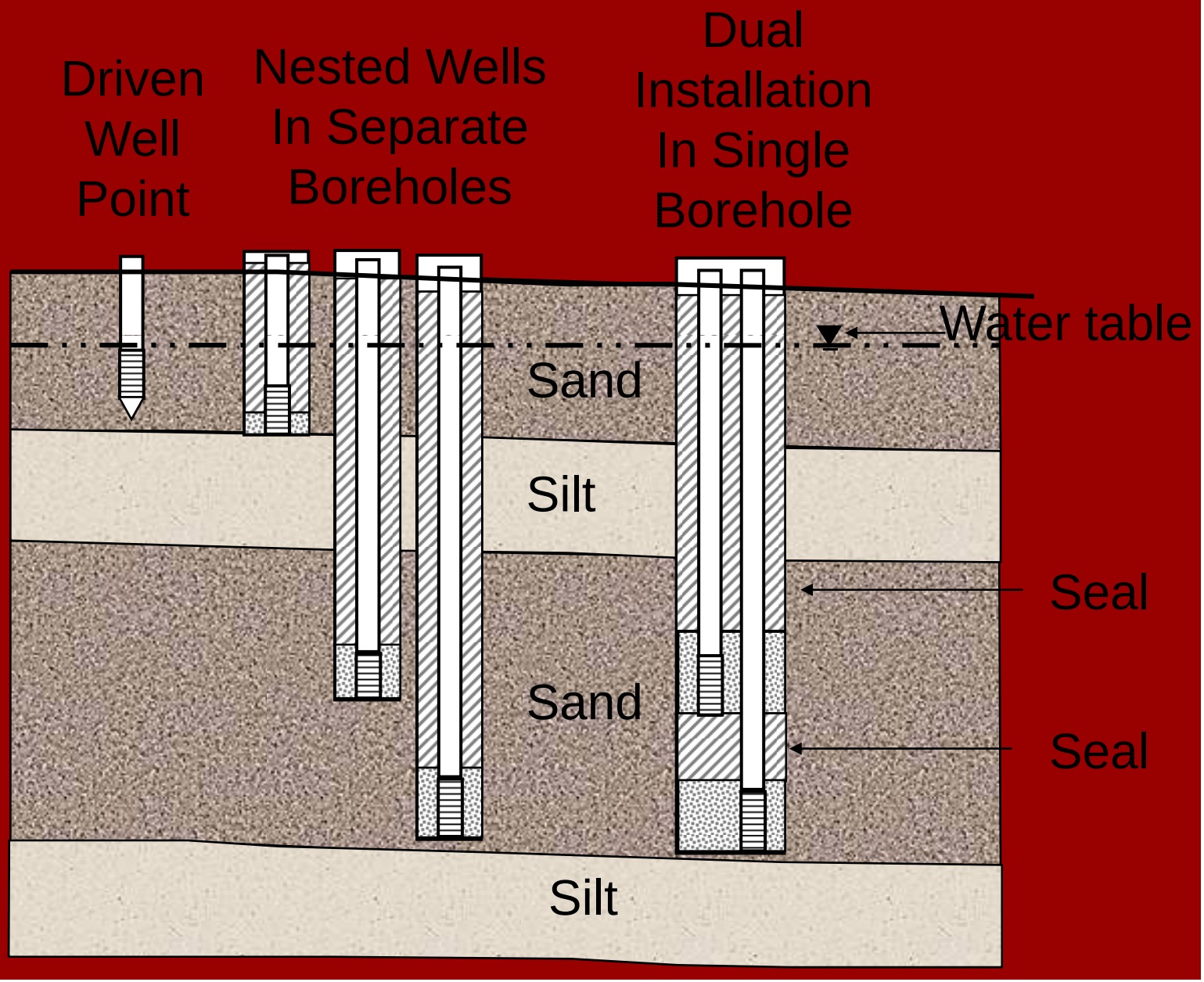
Observation/Monitoring Well:

Measures the water level or water table or an aquifer (intersects the water table)

Piezometer:

Measures the pressure in an aquifer or at a special horizon of the geological profile at a specific point

Single and Nested Piezometers



Field Permeability Tests

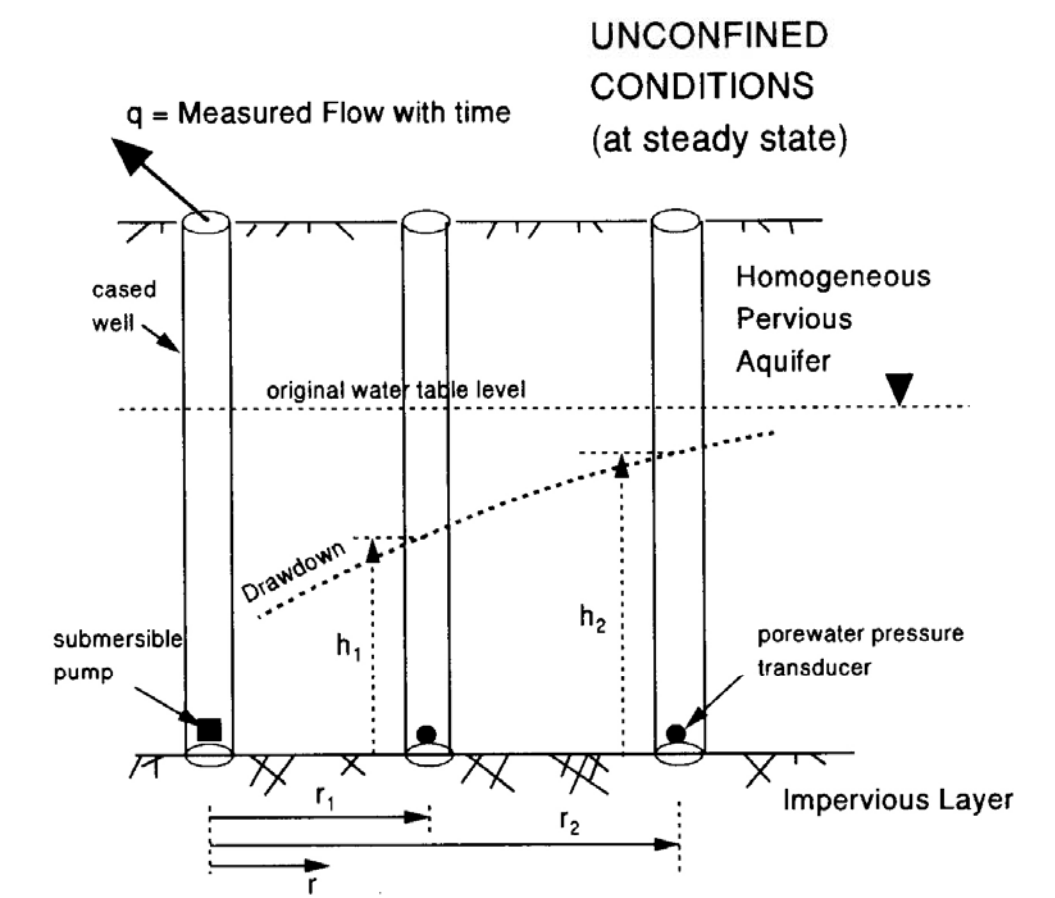
Borehole Seepage tests:

- Falling water level method
- Rising water level method
- Constant water level method

Slug tests

Well Pumping tests

Pressure Packer tests



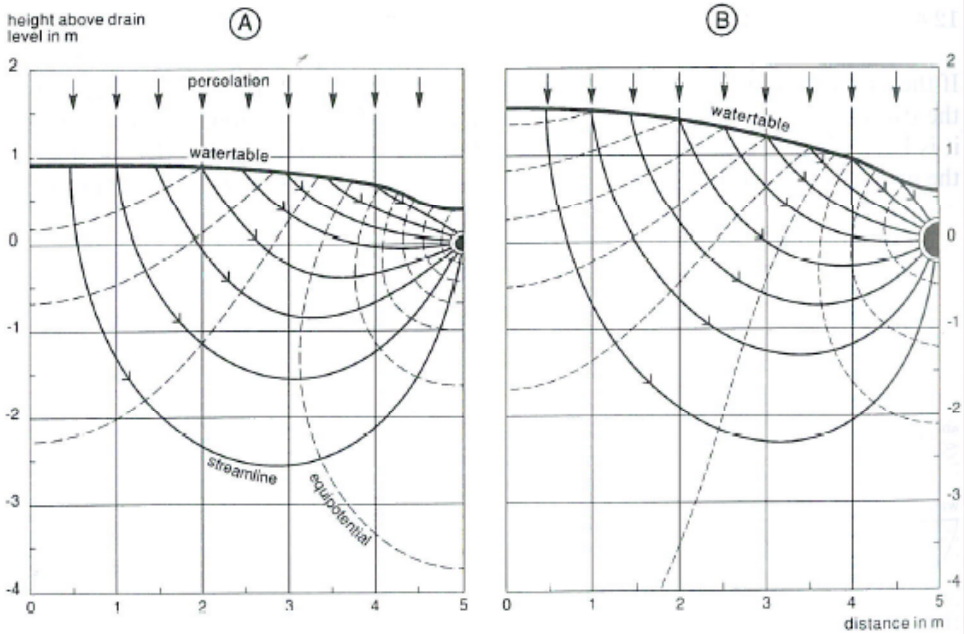


Figure 12.10 Equipotentials and streamlines of groundwater flow to drains in deep homogeneous soils A: small diameter drain, large K; B: large diameter drain, small K (Childs 1943)

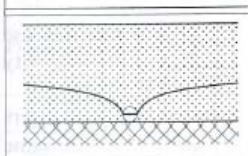
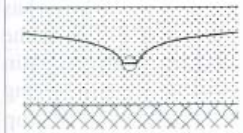
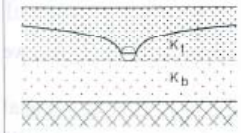
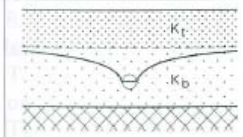
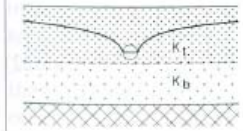
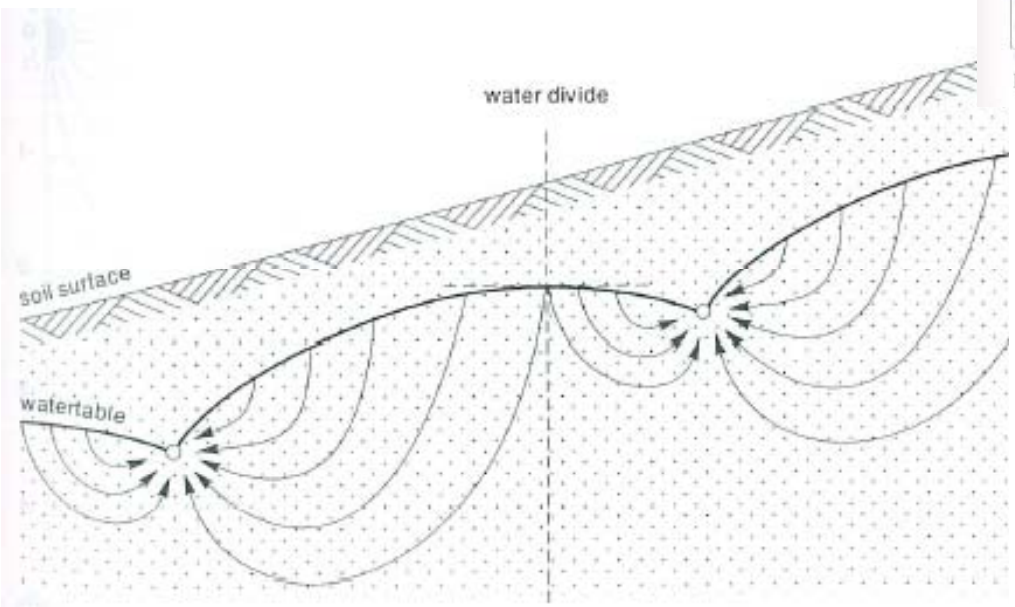
SCHEMATIZATION	SOIL PROFILE	POSITION OF DRAIN	THEORY	EQUATION
	homogeneous	on top of impervious layer	Hooghoudt/ Donnan	$q = \frac{4K(H^2 - D^2)}{L^2}$
	homogeneous	above impervious layer	Hooghoudt with equivalent depth	$q = \frac{8Kdh + 4Kh^2}{L^2}$
	two layers	at interface of the two soil layers	Hooghoudt	$q = \frac{8K_b dh + 4K_t h^2}{L^2}$
	two layers ($K_t < K_b$)	in bottom layer	Ernst	$h = q\left(\frac{D_v}{K_t} + \frac{L^2}{8K_bD_b} + \frac{L}{\pi K_b} \ln \frac{D_r}{u}\right)$
	two layers ($K_t < K_b$)	in top layer	Ernst	$h = q\left(\frac{D_v}{K_t} + \frac{L^2}{8(K_bD_b + K_tD_t)} + \frac{L}{\pi K_t} \ln \frac{\pi D_r}{u}\right)$

Figure 8.7 Summary of the steady-state equations



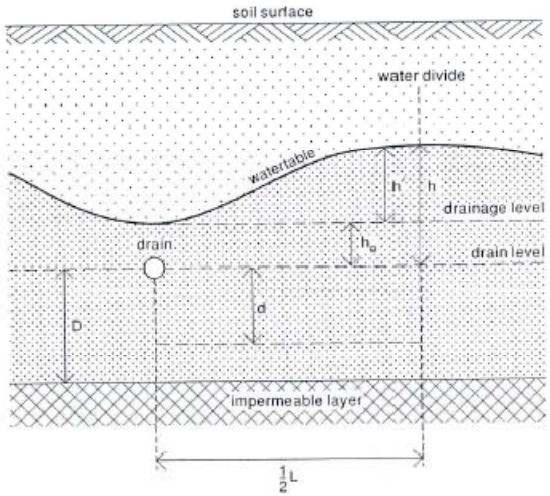
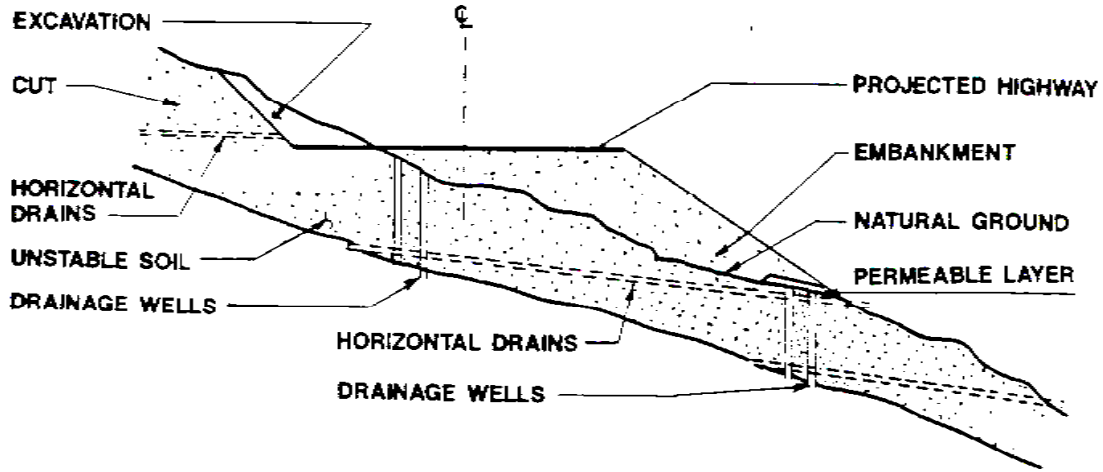
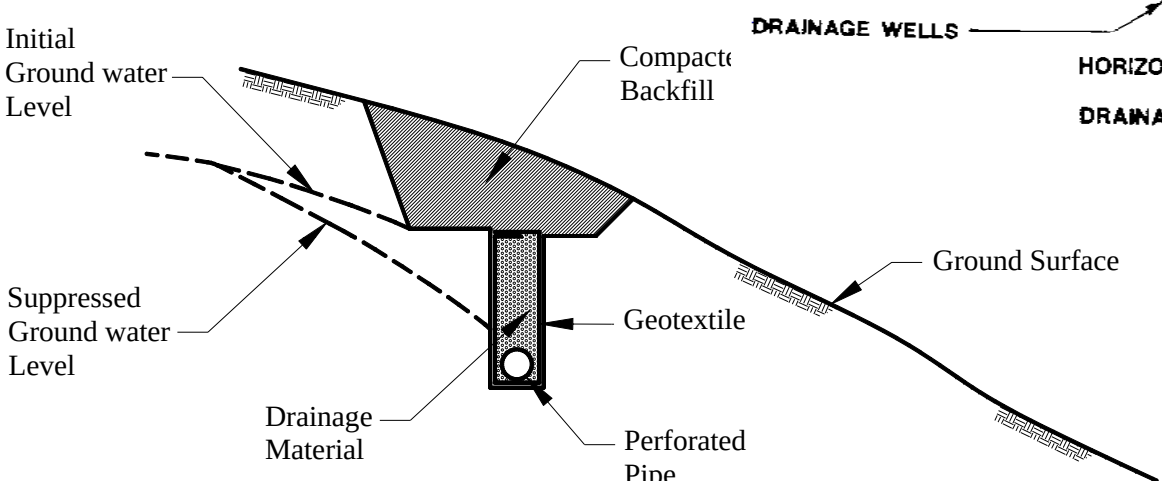
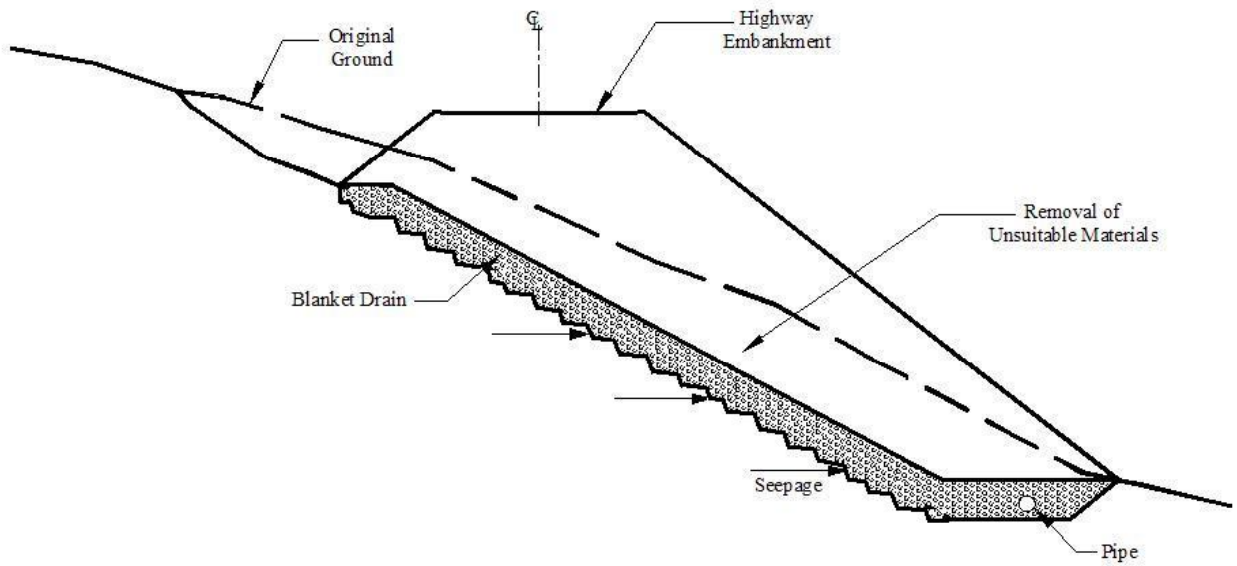


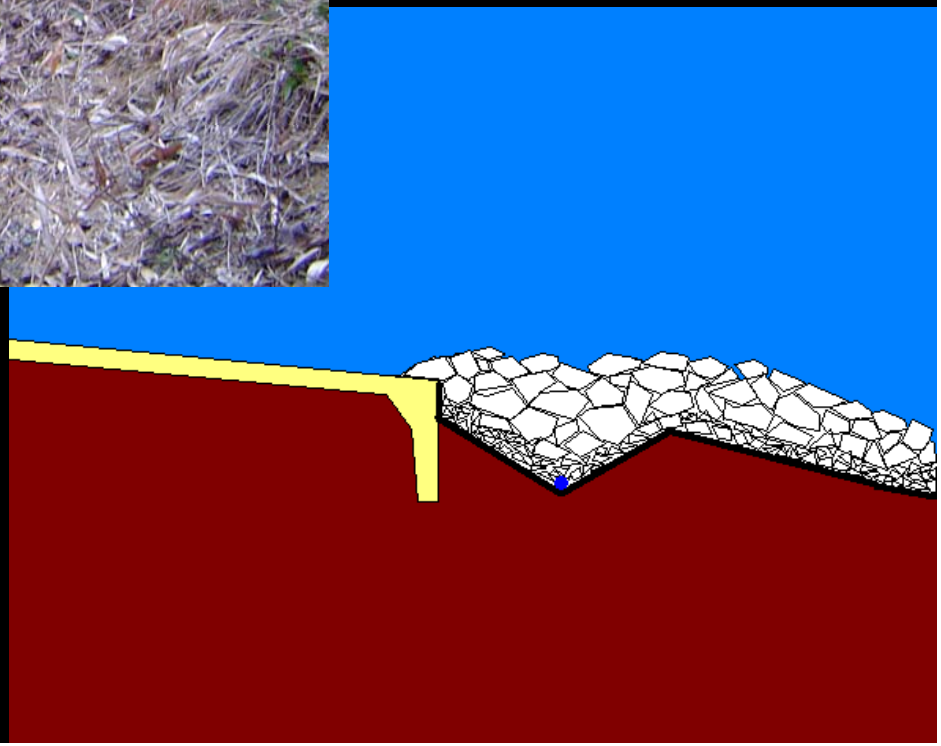
Figure 12.19 Drains with entrance resistance (symbols as defined for Equations 12.17 – 12.19)

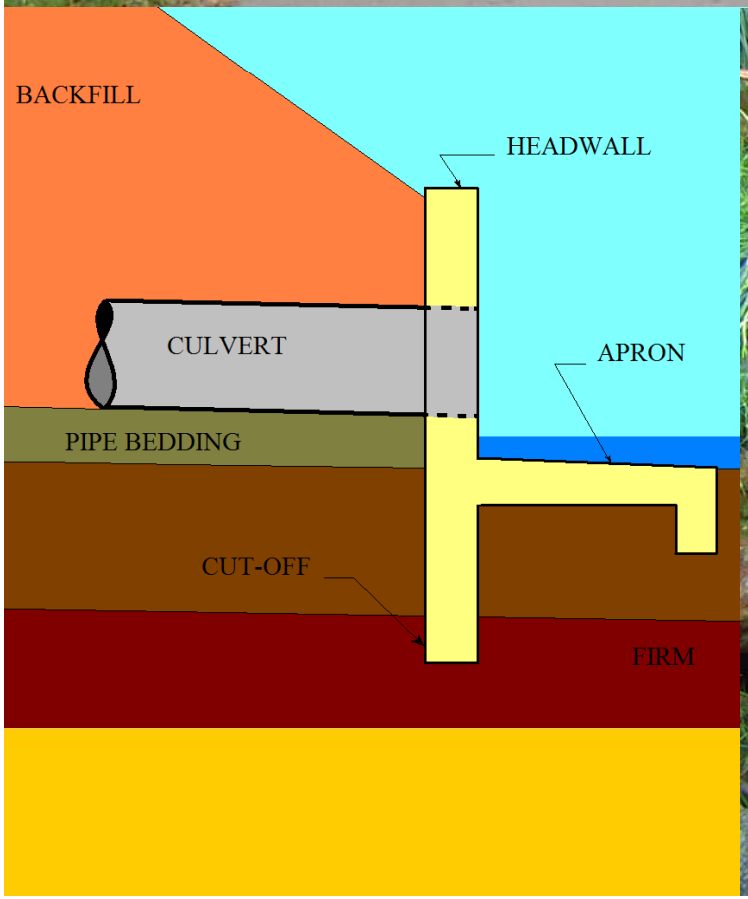
Drainage Control Systems - Examples










BACKFILL
HEADWALL
CULVERT
APRON
PIPE BEDDING
CUT-OFF
FIRM

Summary

- Simplicity – Control Water
- Details are very affordable
- Drainage systems typically provide great benefit at very little expense
- Renewed emphasis and understanding is needed

Pool Fund Study – Subsurface Drainage for Landslide and Slope Stabilization - WADOT (Lead State)

Objectives:

- Provide best practices and guidance for subsurface drainage applications for slope stabilization, including subsurface investigation and testing, groundwater-flow characterization, analysis, drain configurations and design, installation methods, monitoring, and maintenance.

- Evaluate new applications of existing and innovative materials and technologies for stabilizing slopes using subsurface drainage.

NHI 132081: Slope Maintenance & Slide Restoration Course

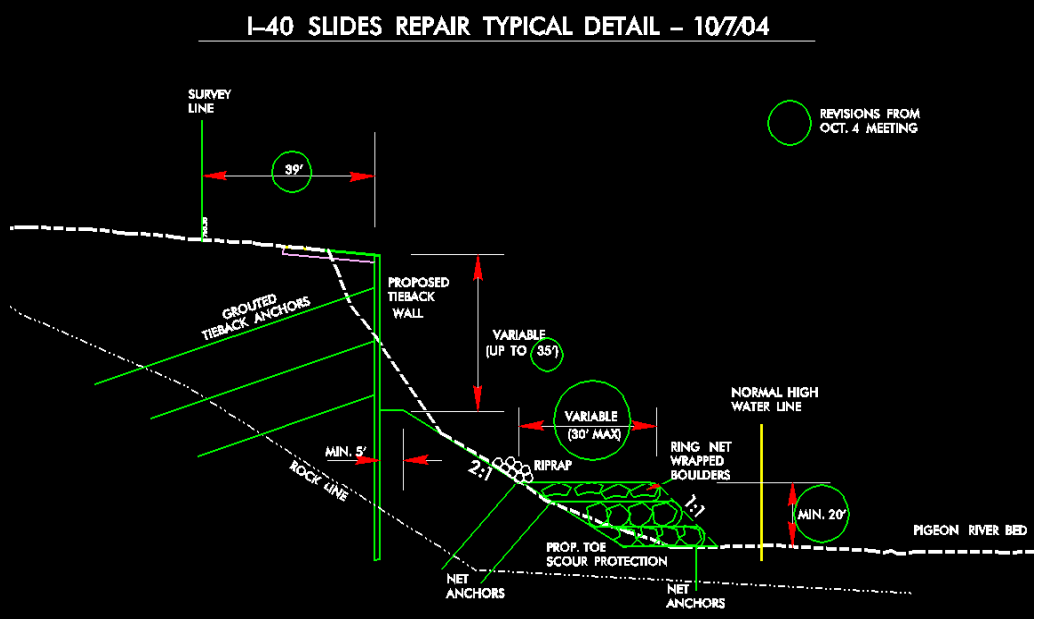
For: Federal, State and local maintenance, geotechnical and operations engineers, geologists, asset management specialists, and maintenance managers and supervisors involved in assessing, maintaining, managing and repairing cut-slopes, fill-slopes and associated features.

Course Goals:

- Conditions and mechanisms that effect deterioration and stability of slopes
- Roles and responsibilities of maintaining, managing, and repairing highway slopes
- Communication and coordination between the various responsible parties and disciplines.

Coarse Goals (continued):

- Costs associated with preventative slope maintenance measures and repair costs after failure
- Fundamental elements, benefits and limitations of Slope and Rock Fall Hazard Management Systems
- Methods used to prevent and repair slope distress and failures



Questions?