Part 3

SHALLOW SEEPAGE IN THE WEATHERED BEDROCK CREEP ZONE

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- Shallow **subsurface seepage** tends to percolate most easily through the weathered rock horizon, shown here as the reddish colored layer above the parent greenstone bedrock lying beneath.

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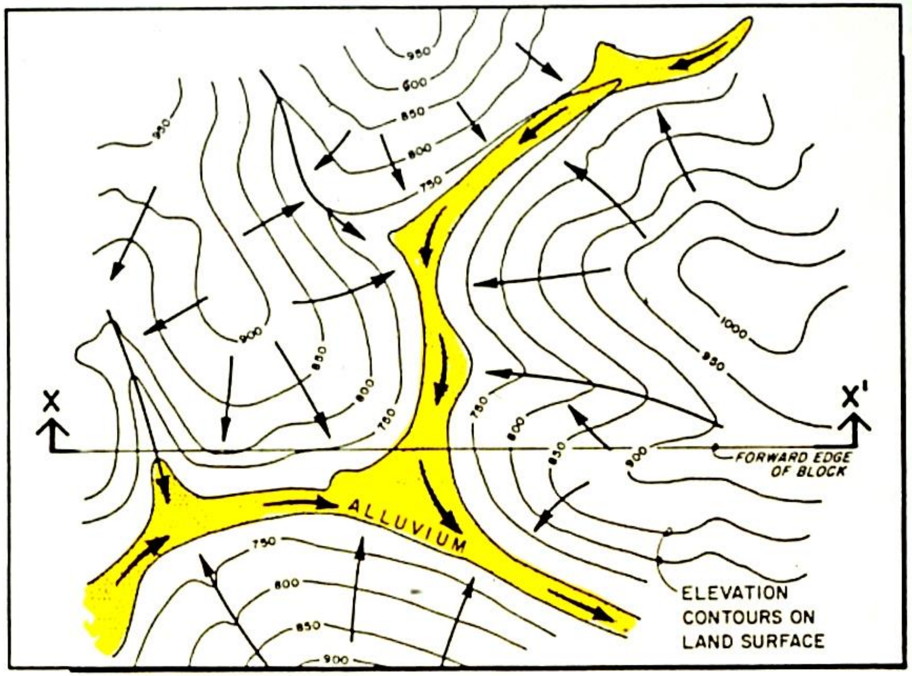
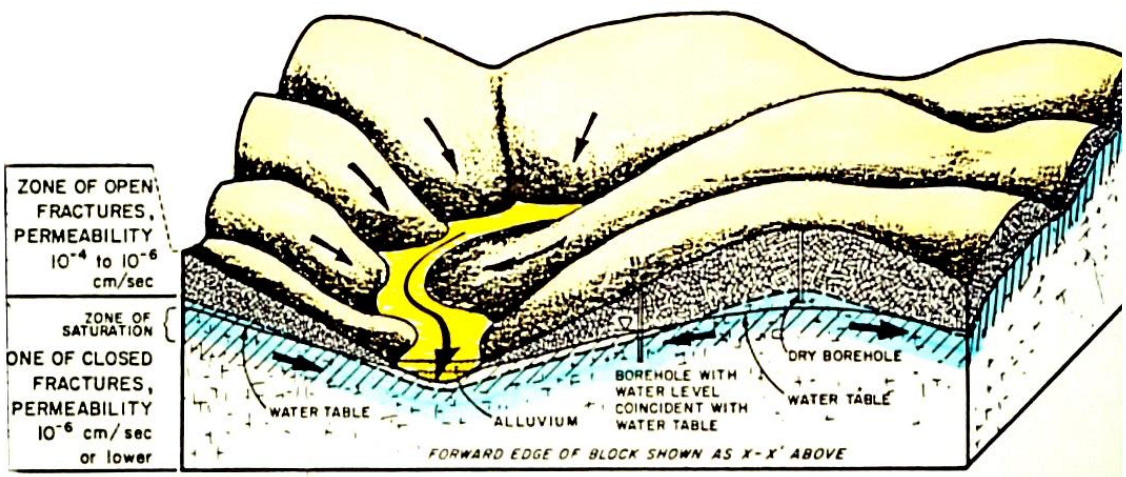
- The bedrock creep zone lying beneath slopes is usually dilated and pervious, allowing ephemeral seepage to percolate through it.

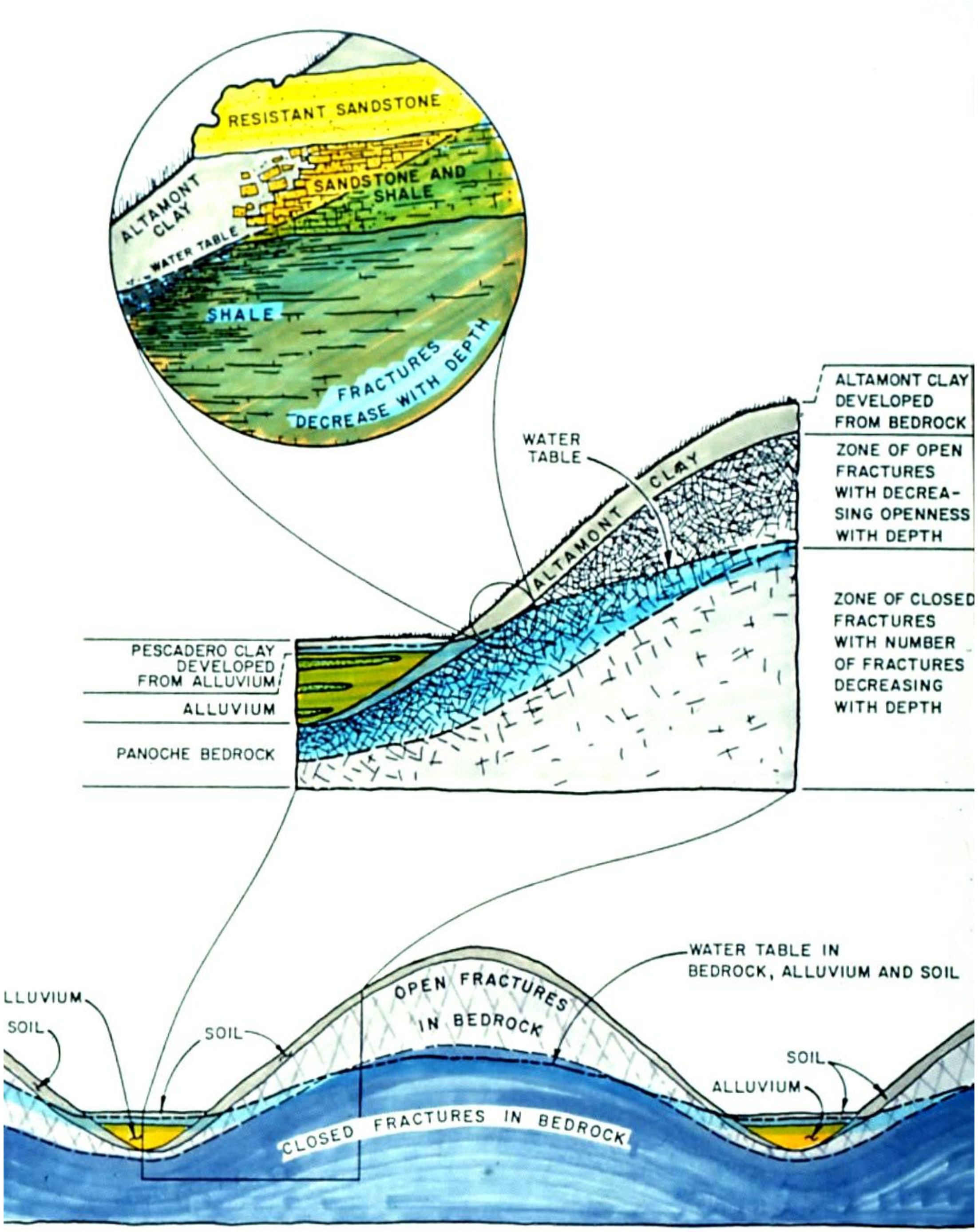


PLAN VIEW

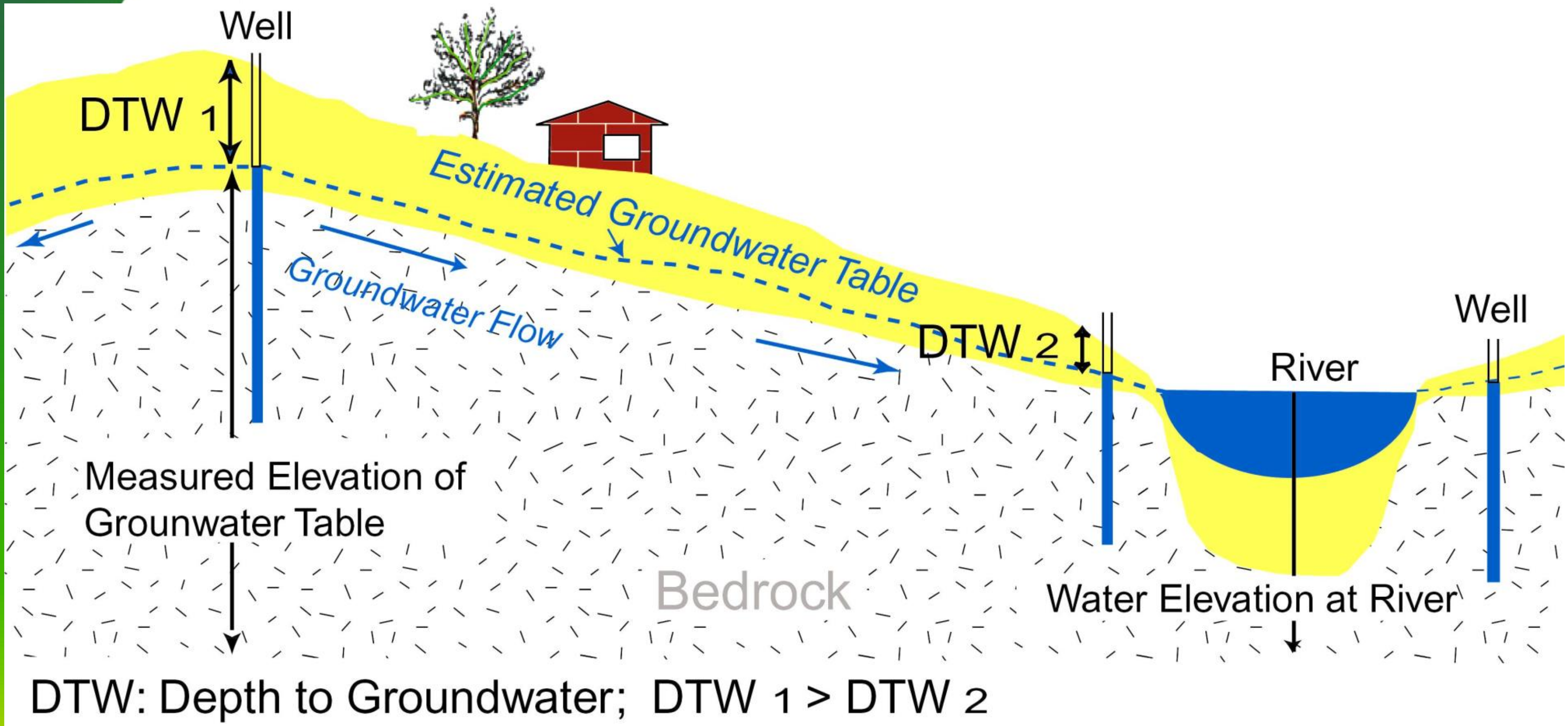


OBLIQUE VIEW

- **Seepage tends to flow downslope, mimicking the surface topography**
- **The groundwater table usually lies within or close to the weatherized/ oxidized zone, with flow towards the valley bottom, as shown here**



- The bedrock creep zone is normally coincident with the partially saturated zone lying above the permanent groundwater table
- Seasonal fluctuations in groundwater levels and flowage usually occur within this zone, shown by the light blue areas above the dark blue at lower left



- **The groundwater table tends to mimic the overlying topography (except in karst terrain), and is subject to seasonal and decadal variations, depending on precipitation and withdrawal**

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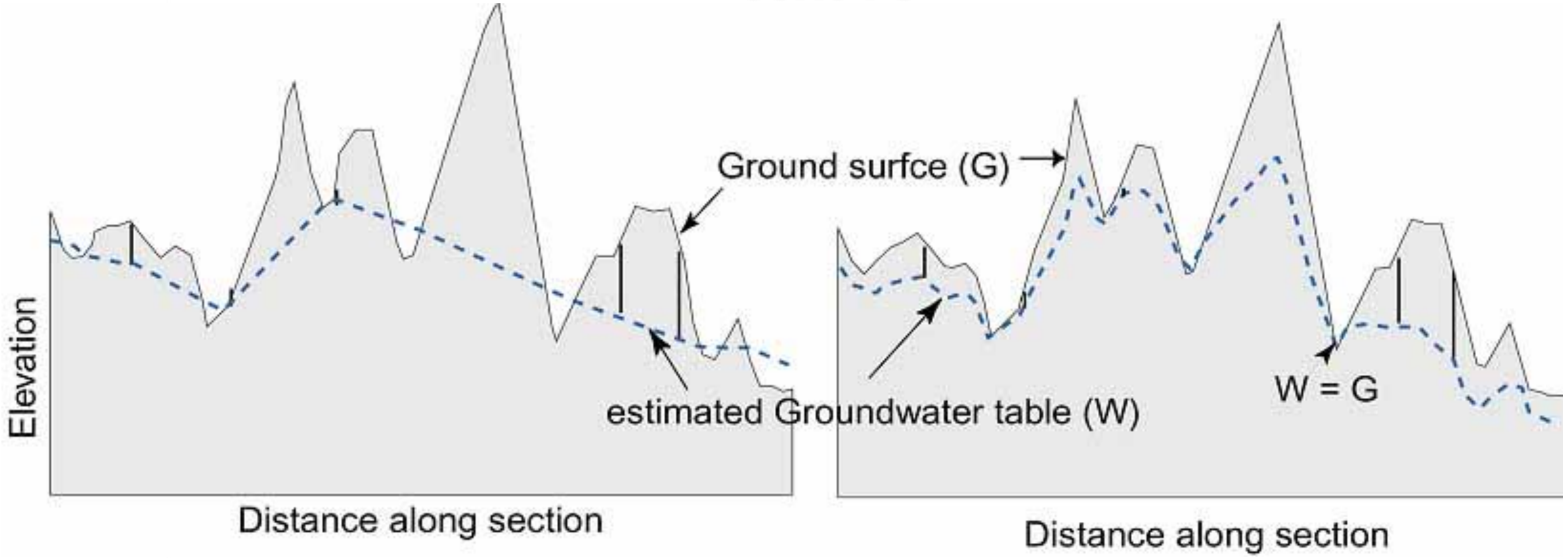
GIS software tends to oversimplify natural undulations of the ground water table



- **Predicted ground water table (gwt) using kriging in ArcGIS**
- **Very unrealistic**

- **Predicted gwt using cokriging with digital elevation model**
- **Much more realistic**

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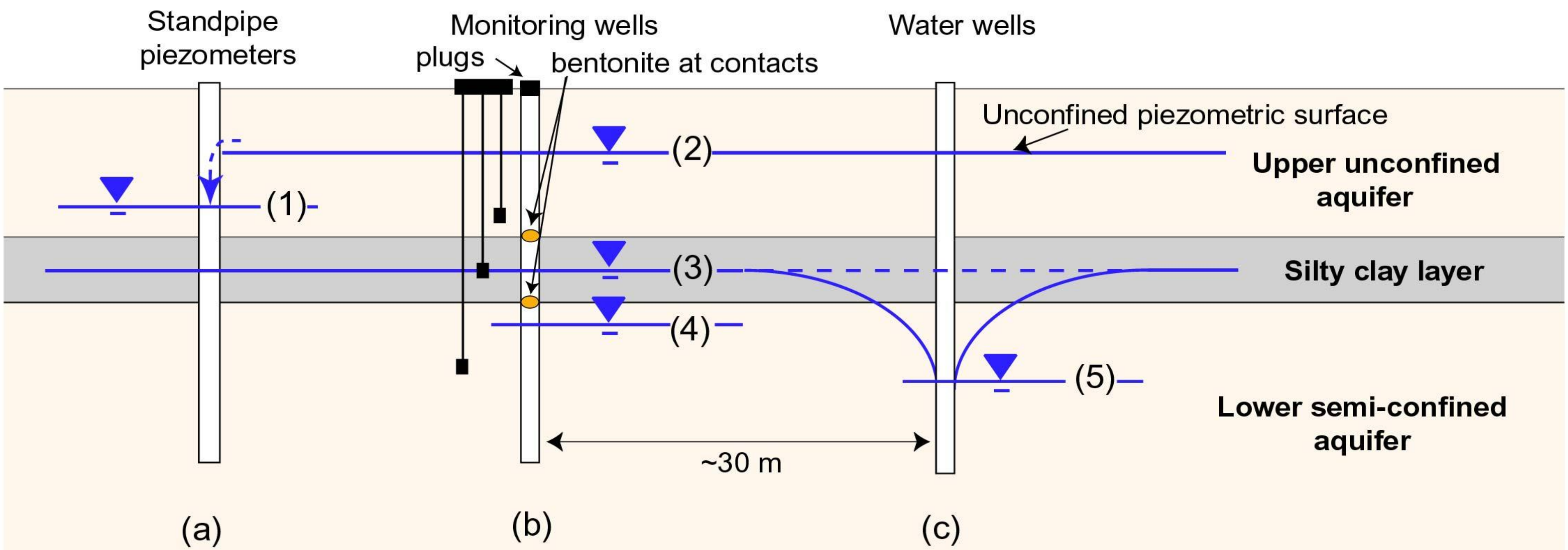
Uncertainty of Reported Groundwater Levels

Measurement errors very common



(1) - the observed level in a simple standpipe records to combined inflow from the upper unconfined layer and the lower semi-confined layer.

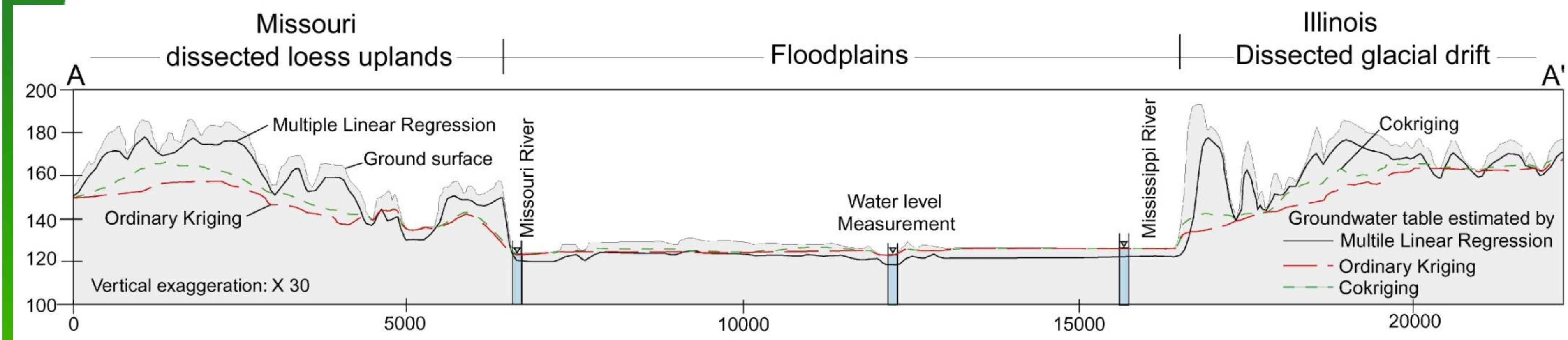
(2) - the true groundwater level in the upper unconfined aquifer.

(3) - the true groundwater level of the lower semi-confined aquifer, within the silty clay aquiclude.

(4) - where groundwater level would typically be recorded, at the time of drilling (atod).

(5) - the reported groundwater level in an active water well, subject to conical drawdown.

Beware of GIS-driven predictions of groundwater levels



- **Most geoenvironmental and geohydrology studies presently employ the geostatistical method of kriging to estimate groundwater levels, using available well records.**
- **Cokriging that includes dissected ground surface as a covariable usually provides a more realistic prediction.**
- **Note that multiple regression overestimates in the uplands and underestimates the true values beneath the flood plains.**

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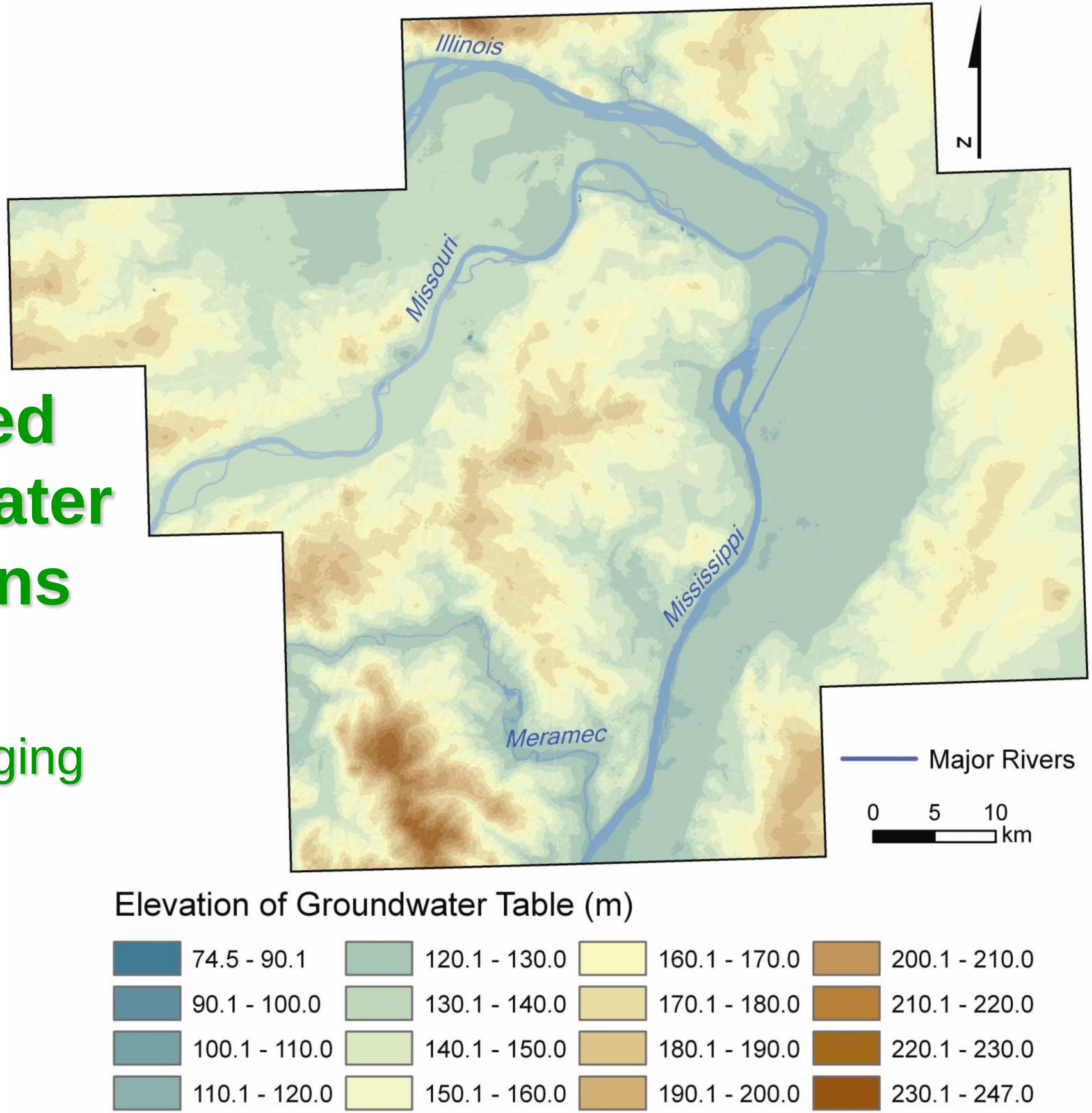
Predicted Groundwater Elevations

- Produced using cokriging



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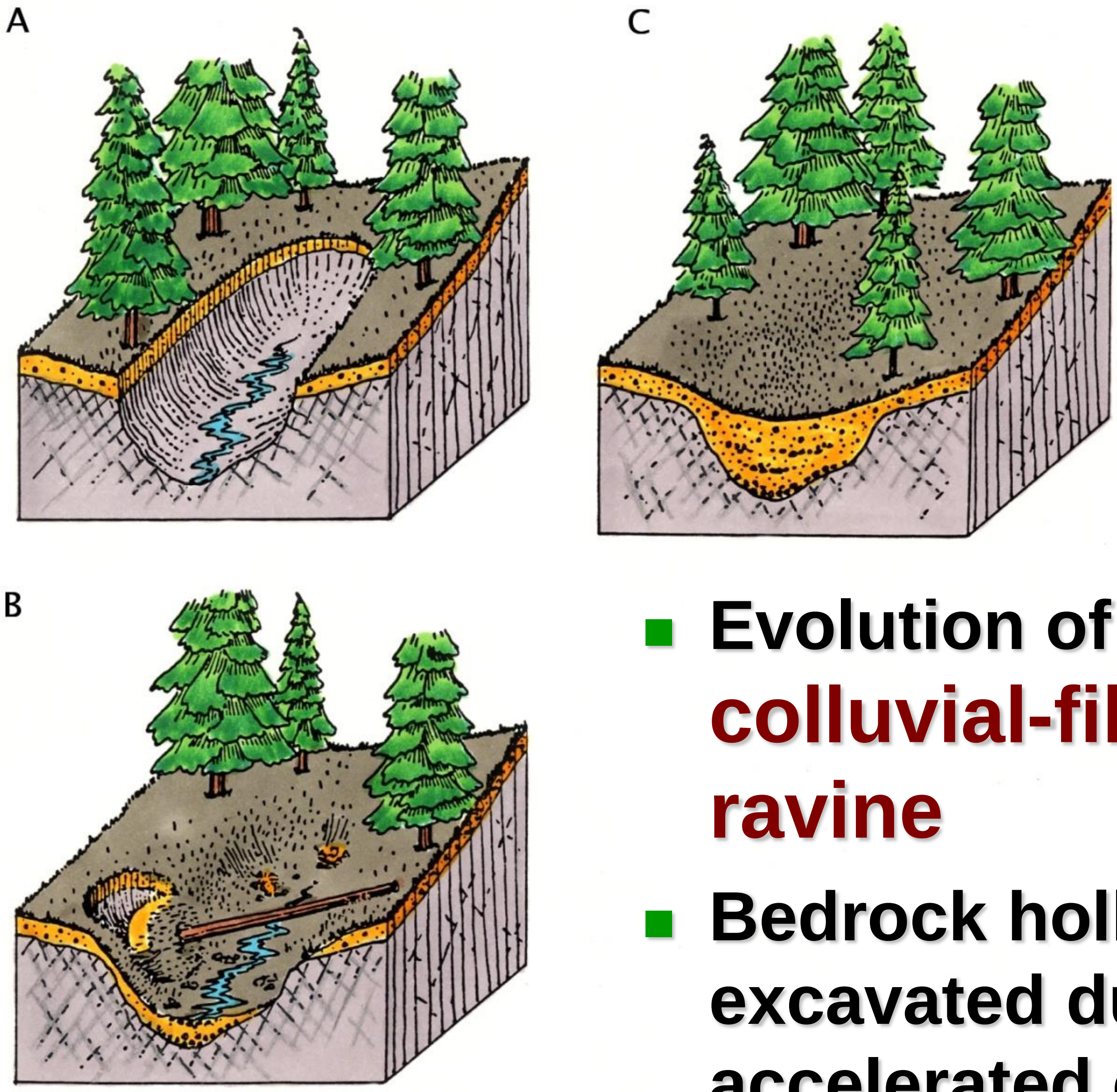

The most common geomorphic feature in America

- Evolution of a typical **colluvial-filled bedrock ravine**
- Bedrock hollows are excavated during periods of accelerated erosion, then slowly infill during periods of aggradation

- **Colluvial filled bedrock ravines are the most common landform in the world. Shallow groundwater tends to be concentrated towards the mouths of these zero-order basins**

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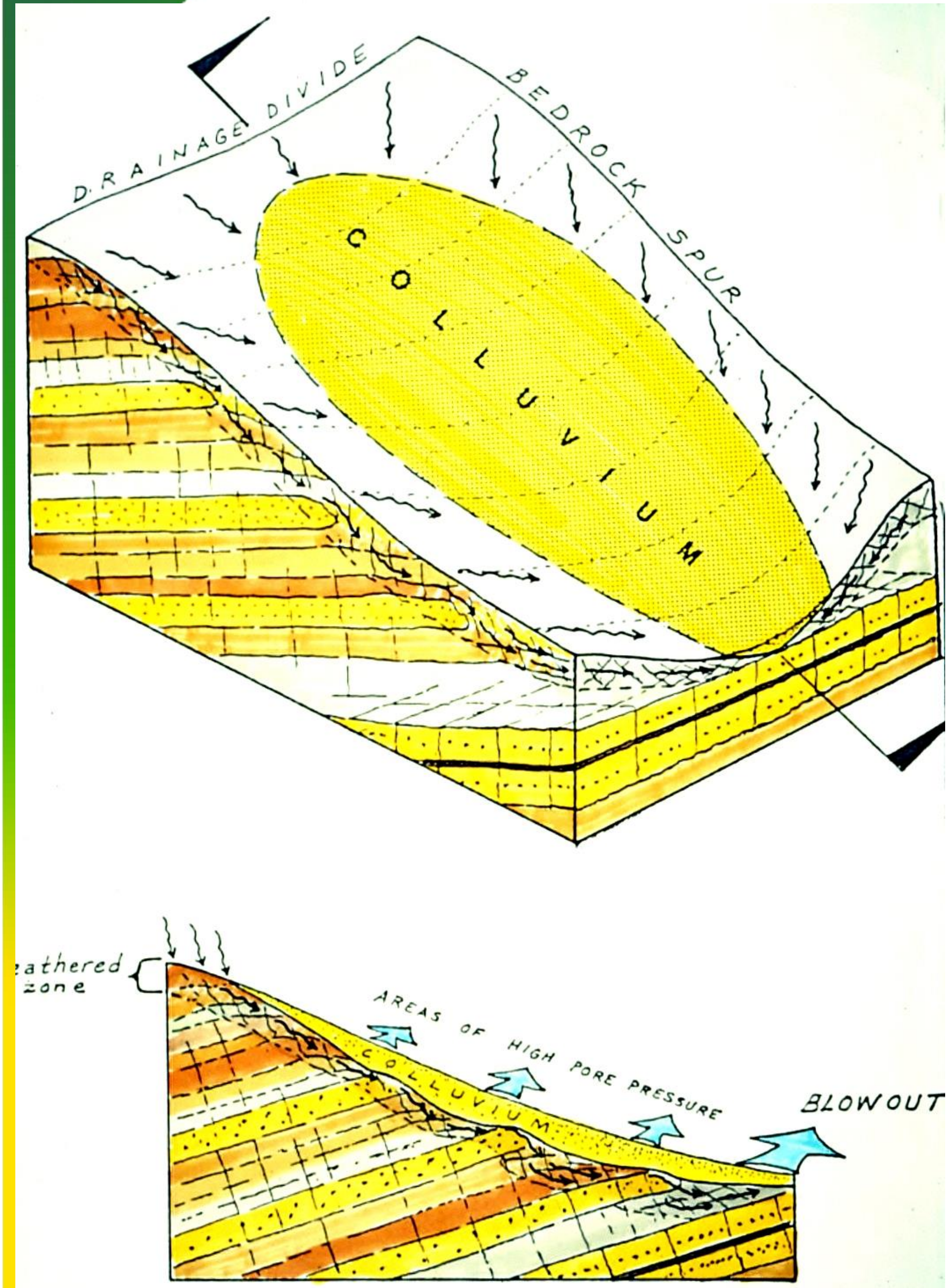
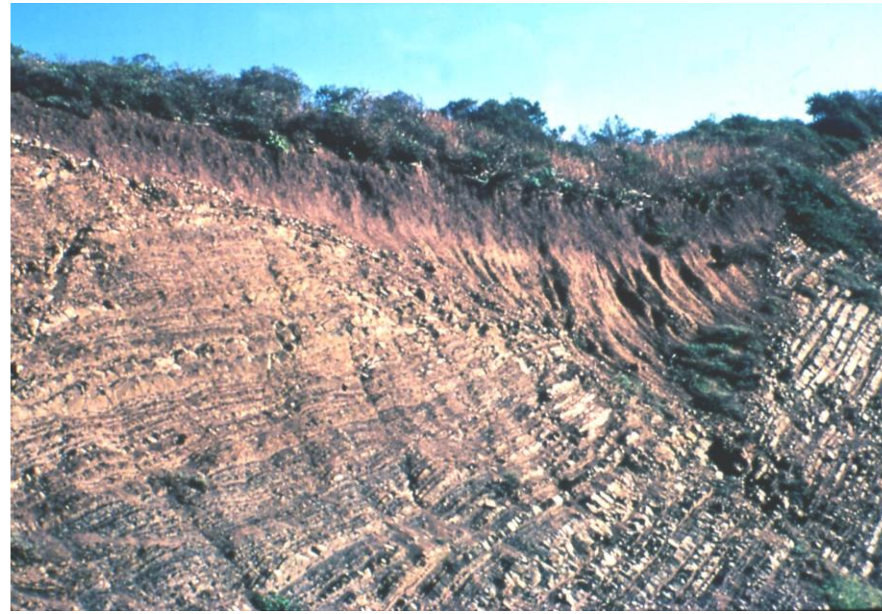
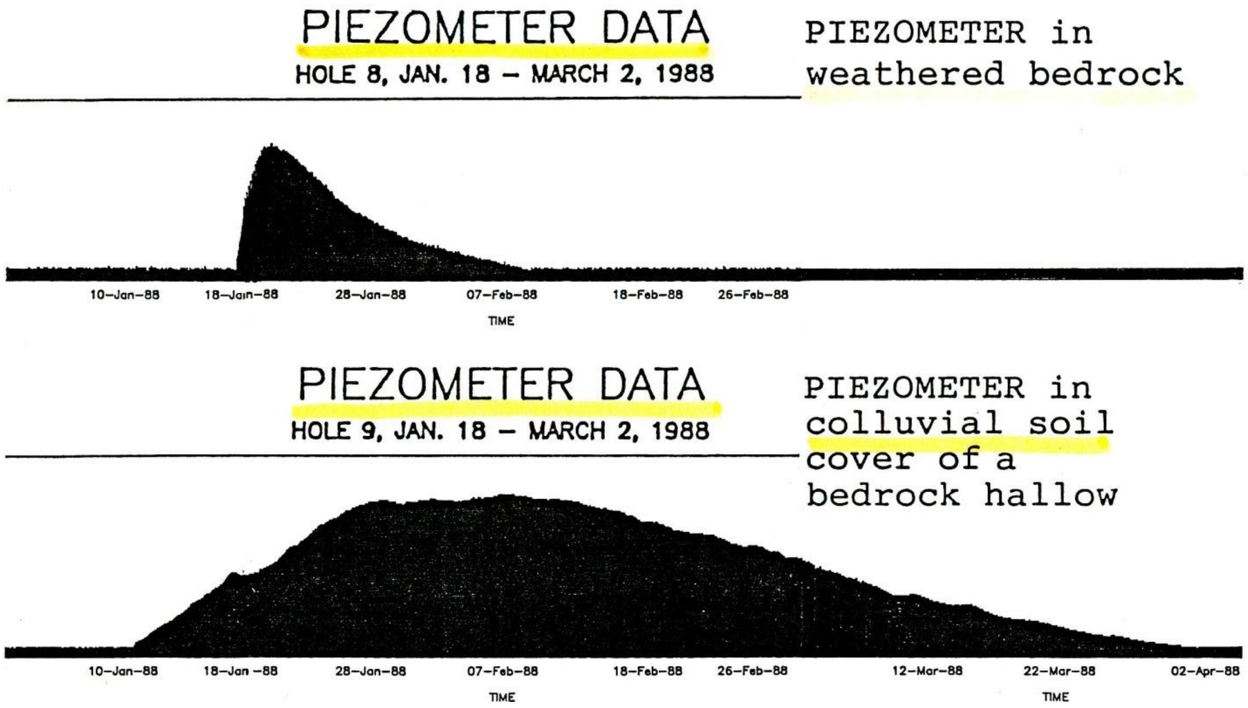




- **Most colluvial filled ravines tend to be spoon shaped, as shown here**
- **Hydraulic uplift promoted by seepage in the weathered bedrock tends to concentrate at bedrock "highs", as shown at lower left**



- **Water levels recorded by piezometers placed on the bedrock rib adjacent to a colluvial filled ravine (upper diagram), and another in the axis of the colluvial deposit (lower diagram). Note how quickly the water enters the weathered rock and how slowly it drains from the colluvium**

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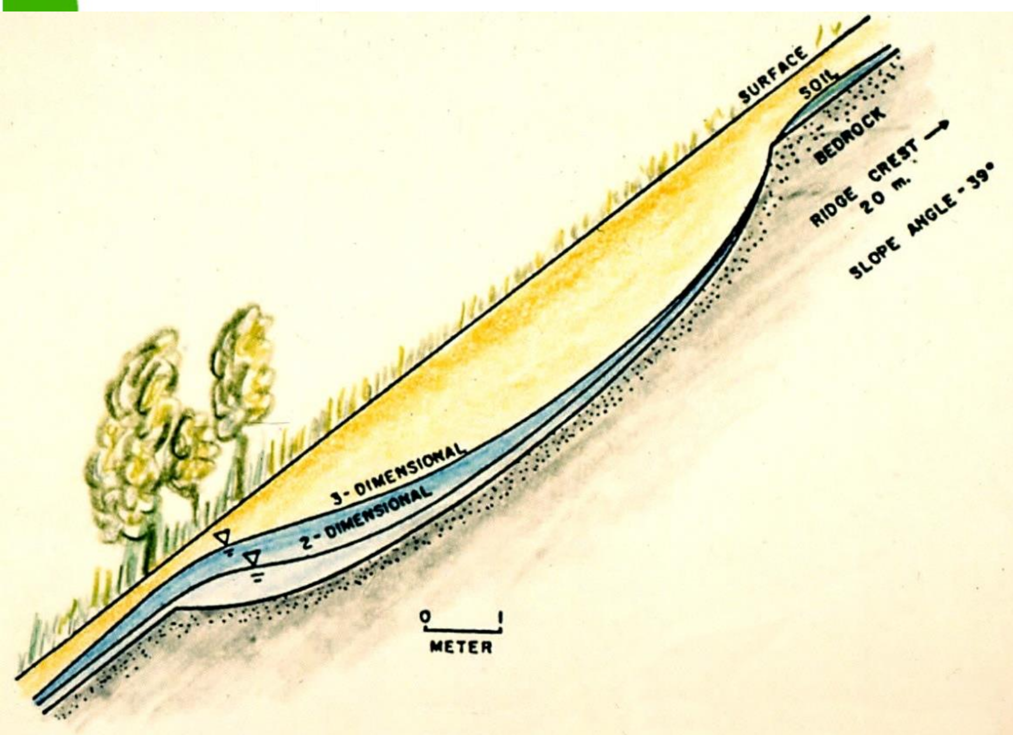
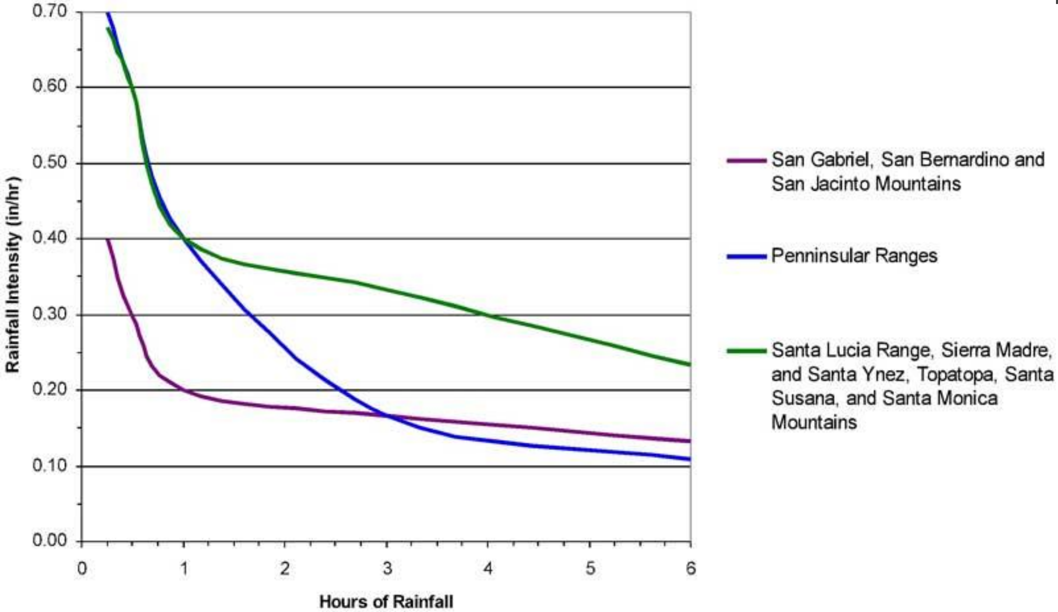


Modeling pore pressures using finite elements

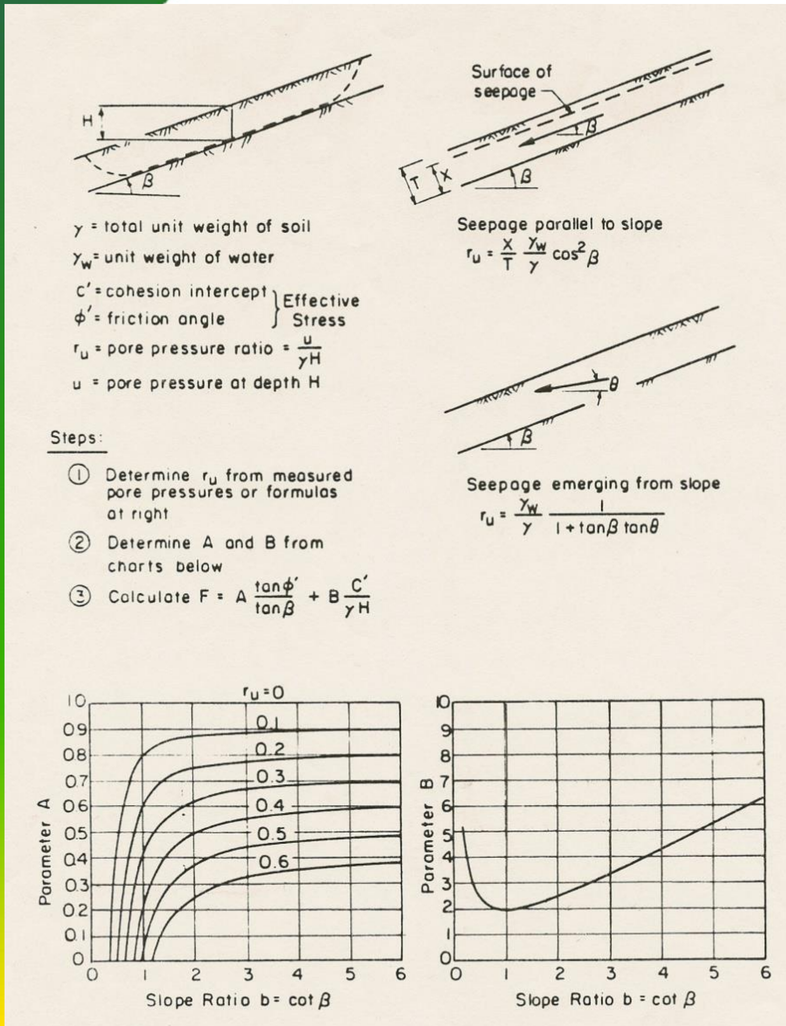
- **Seepage forces tend to concentrate towards the lower end of a spoon-shaped bedrock ravine, as shown here**
- **This diagram shows the predicted position of trapped groundwater using 2D and 3D solutions**
- **Two feet of seepage head can “lift” 4.5 feet of saturated colluvium off the slope**

Trigger thresholds for debris flows



- The USGS has empirically derived rainfall intensity vs duration trigger thresholds for many areas of the USA
- Those at lower left are for Central and Southern California Coast Ranges

Transient Pore Pressures



- An **Infinite Slope Analysis** can be performed to illustrate how a few feet of excess pore pressure can trigger such failures

- Transient pore pressures develop during periods of sustained intense precipitation, occasionally triggering explosive "**blow-out**" failures, like that shown here

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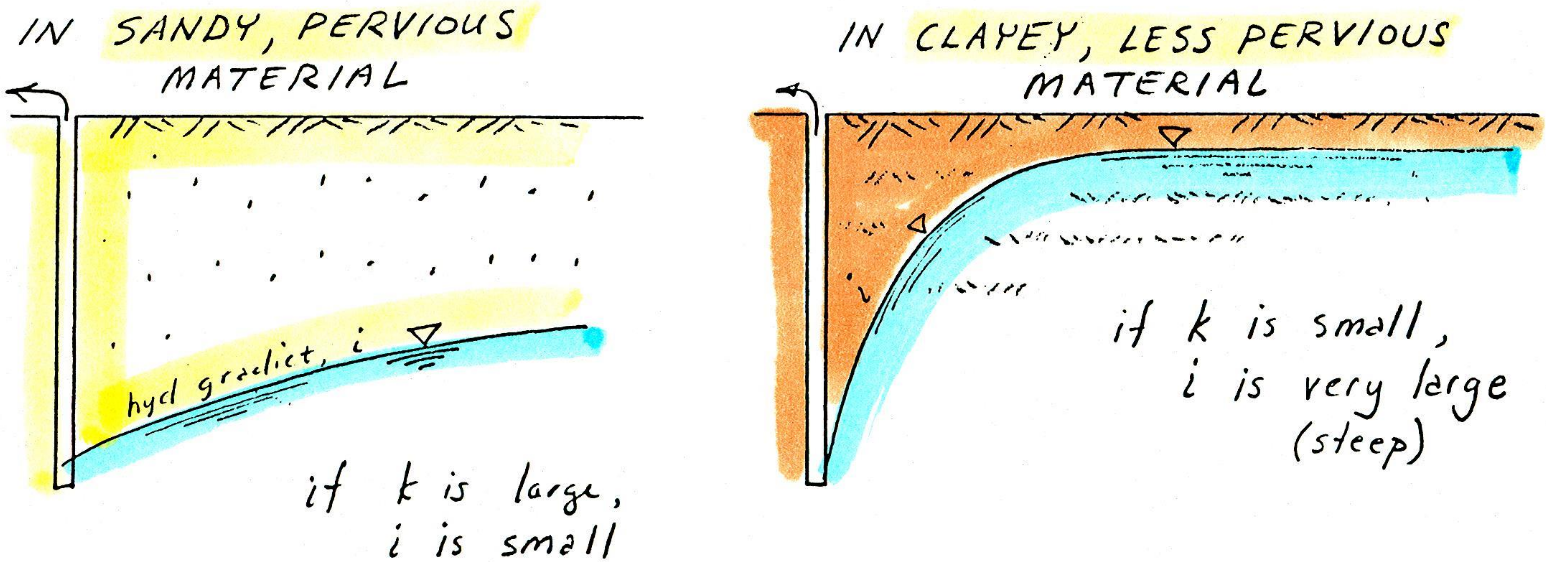
BASIC PRECEPTS OF GROUNDWATER FLOW

Darcy's Law: $Q = kiA$;

or Quantity of Flow = (permeability)(hydraulic gradient)(Cross Sectional Area of Flow)

e.g. Well drawdown



- **Permeability (k) and the hydraulic gradient (i) are more or less inversely proportional (see sketches above)**
- **Low permeability materials don't tend to transmit significant quantities of water**