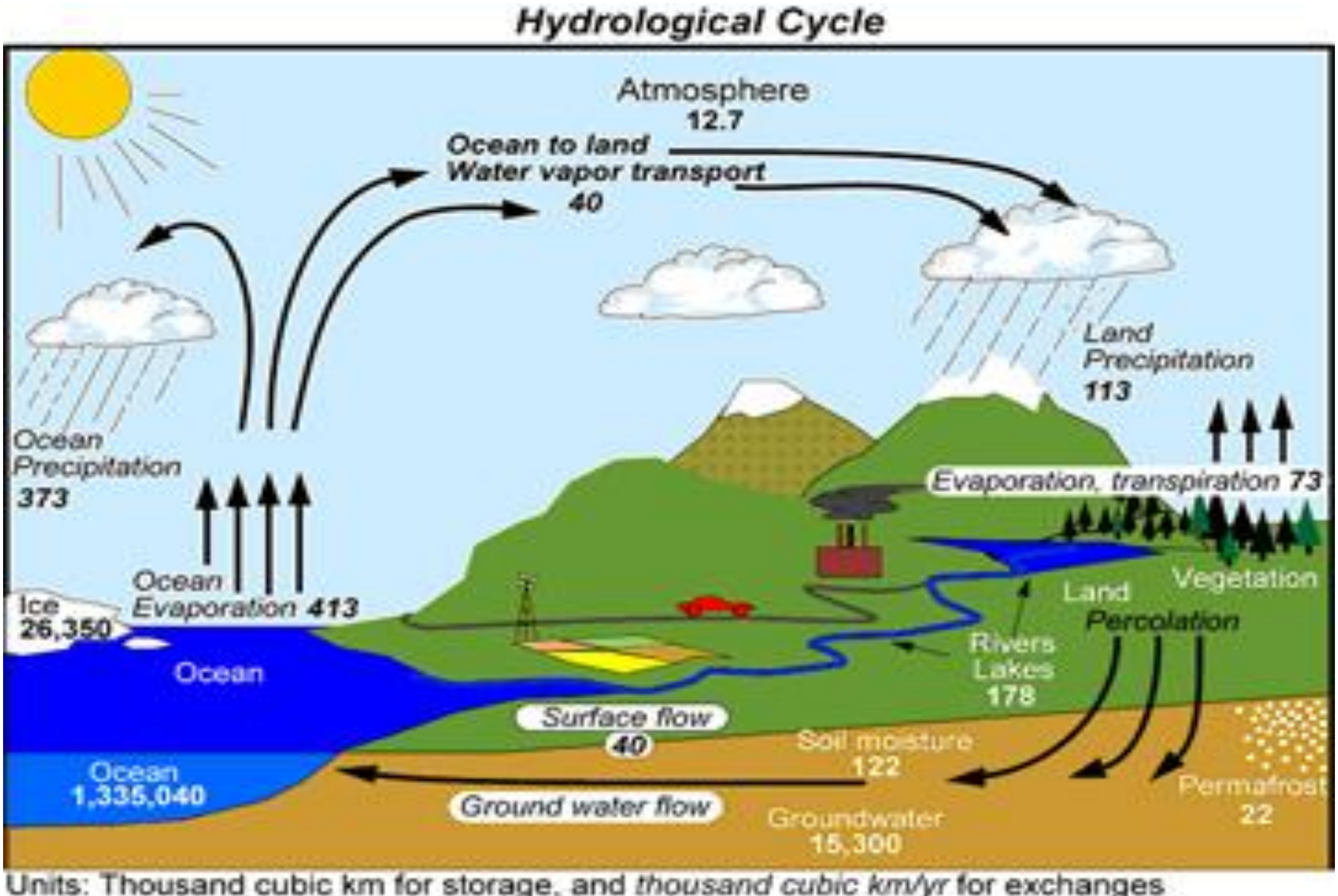
WATER RESOURCE ENGINEERING –I

UNIT-I

HYDROLOGY

Hydrology

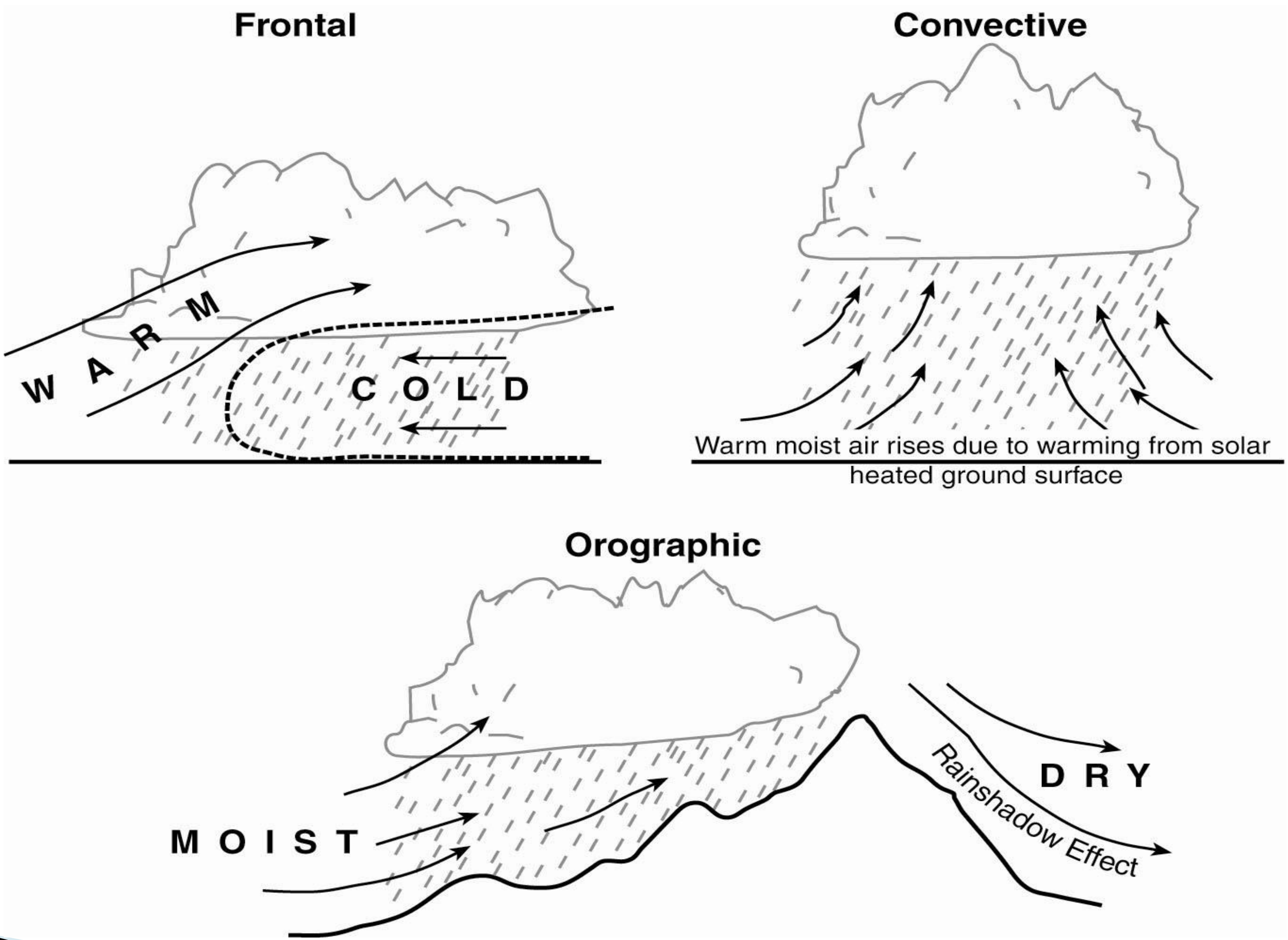
The flow of water across and through near surface environments


Hydrological Cycle
Atmosphere
12.7
Ocean to land
Water vapor transport
40
Land
Precipitation
113
Ocean
Precipitation
373
Evaporation, transpiration 73
Ocean
Evaporation 413
Ice
26,350
Land
Vegetation
Percolation
Rivers
Lakes
178
Ocean
Surface flow
40
Soil moisture
122
Ocean
1,335,040
Permafrost
22
Ground water flow
Groundwater
15,300
Units: Thousand cubic km for storage, and *thousand cubic km/yr* for exchanges

Precipitation

- Single strongest variable driving hydrologic processes
- Formed by water vapor in the atmosphere
- As air cools its ability to ‘hold’ water decreases and some turns to liquid or ice (snow)

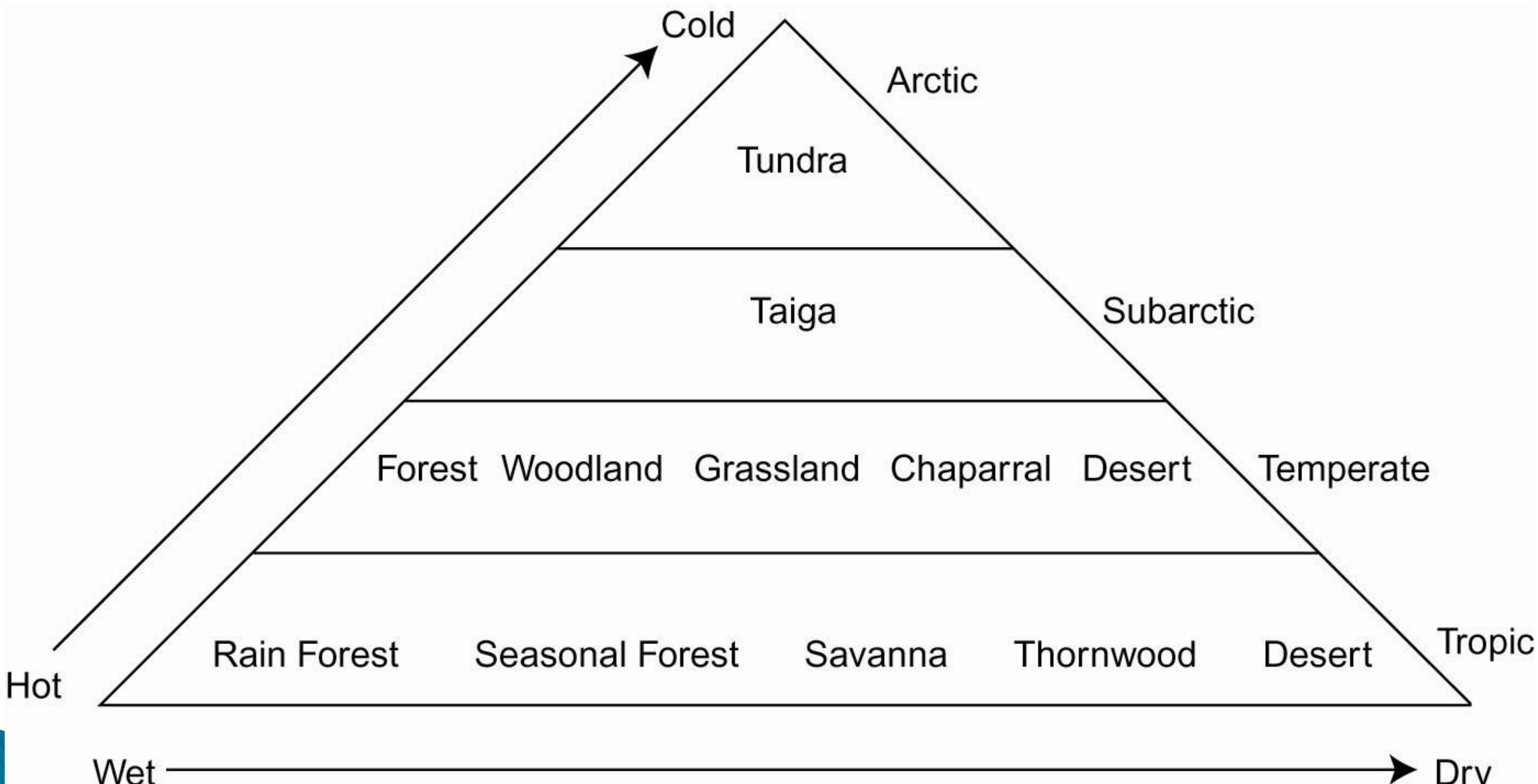
Causes of Precipitation



Weather vs. Climate Patterns

- Weather (day to day) vs. climate (years-decades and patterns)
- What are hydrologists most concerned with?
- Climate and geography result in biome classification

Biomes and Rainfall



Moisture Sources for USA

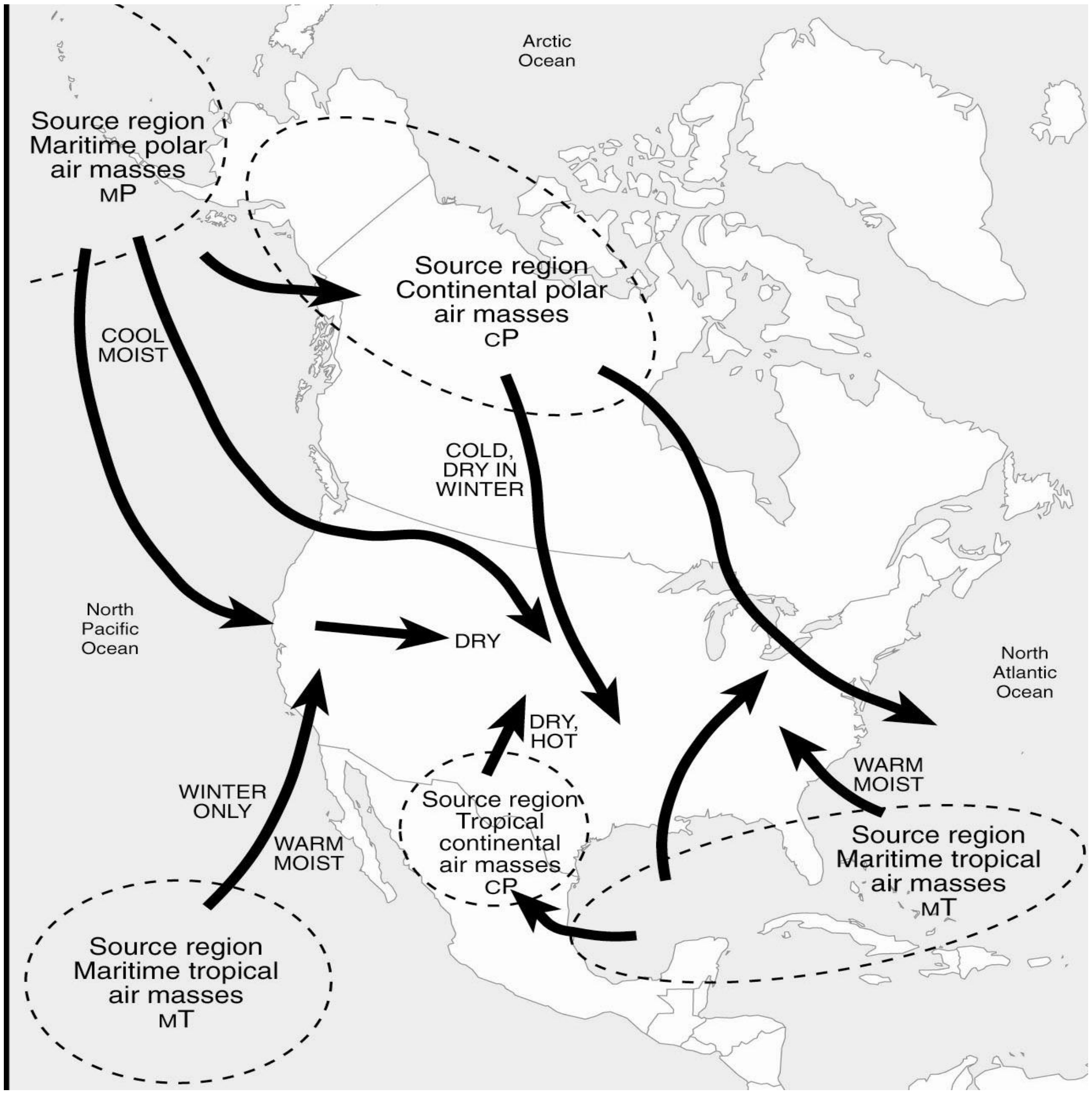
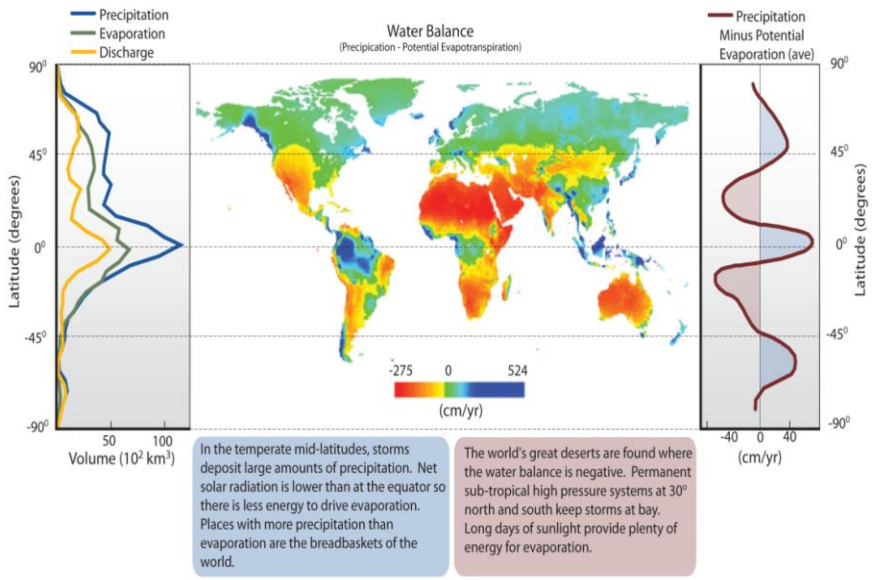


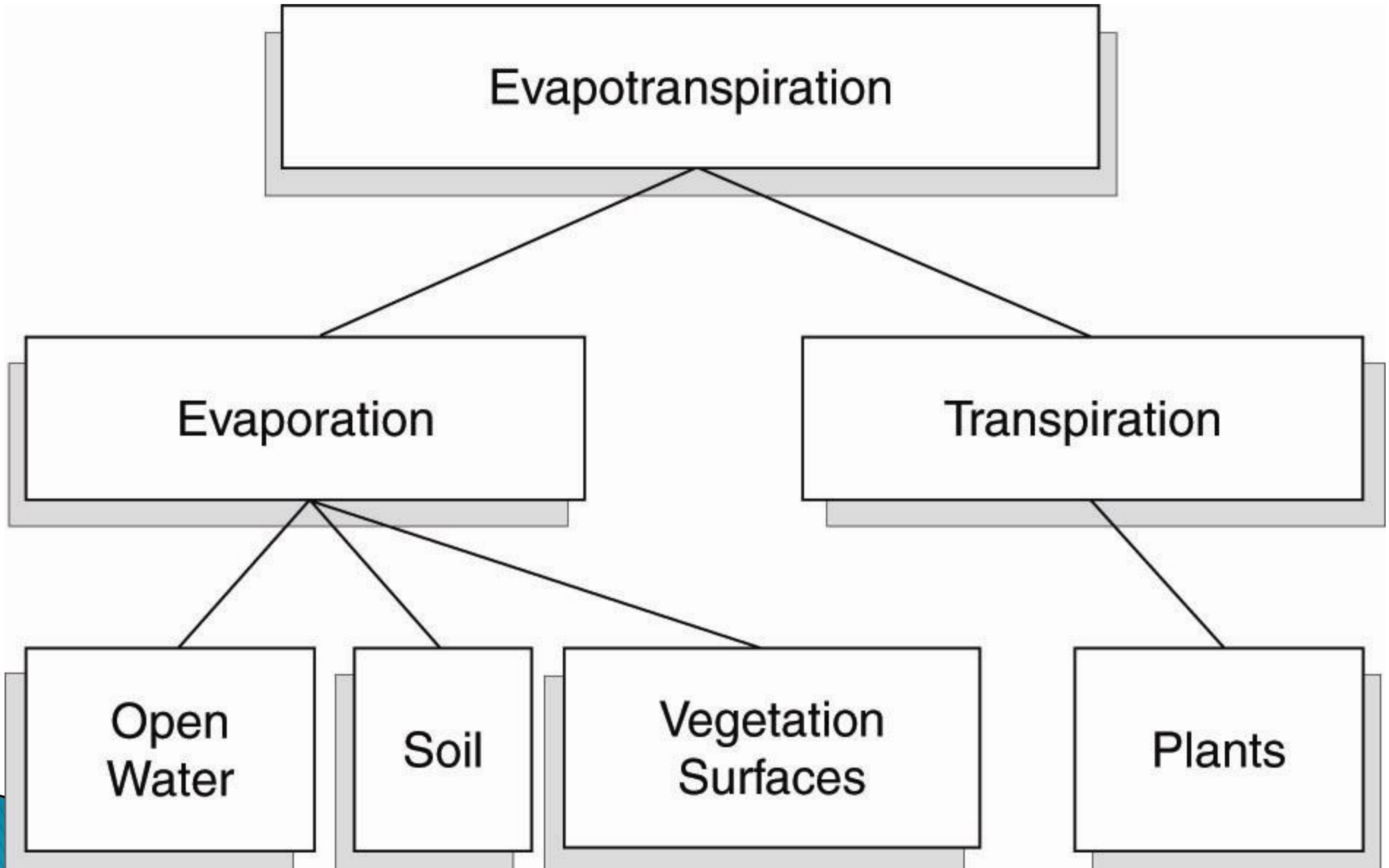
Figure 4.4 - Evapotranspiration By Latitude

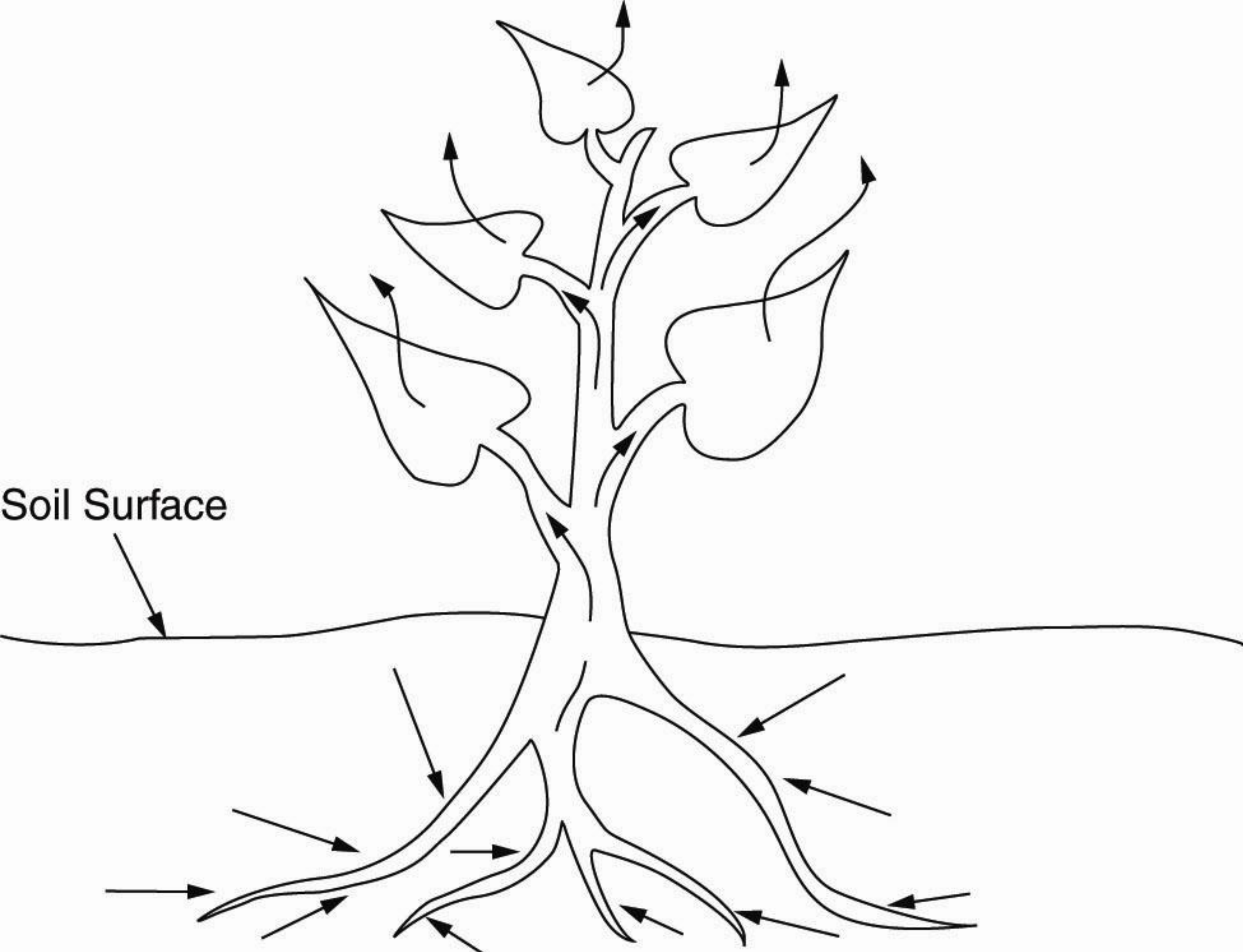
(chapter 4 - Hydrology)



Notes:
Graphic Source:
http://images.google.com/imgres?imgurl=http://gaim.unh.edu/Products/Reports/Report_6/93-97gifs/NPP/fig7b.gif&imgrefurl=http://gaim.unh.edu/Products/Reports/Report_6/NPP.html&usg=__D2ZuBiXsPdj5OGklUWy_5oZxR4o=&h=315&w=400&sz=27&hl=en&start=1&um=1&tbnid=0dtHn-onpd_YvM:&tbnh=98&tbnw=124&prev=/images%3Fq%3Dwater%2Bbalance%2Bcoefficient%26um%3D1%26hl%3Den%26sa%3DN
Evap/Discharge/precip source:
http://images.google.com/imgres?imgurl=http://www.icsu-scope.org/downloadpubs/scope13/images/fig12.2.jpg&imgrefurl=http://www.icsu-scope.org/downloadpubs/scope13/chapter12.html&usg=__nGf9b9pvFno773ZVUhKxq66GPZ0=&h=907&w=559&sz=33&hl=en&start=10&tbnid=ISKFnHFkqXJ9qM:&tbnh=147&tbnw=91&prev=/images%3Fq%3Devaporation%2Blatitude%26hl%3Den%26sa%3DG

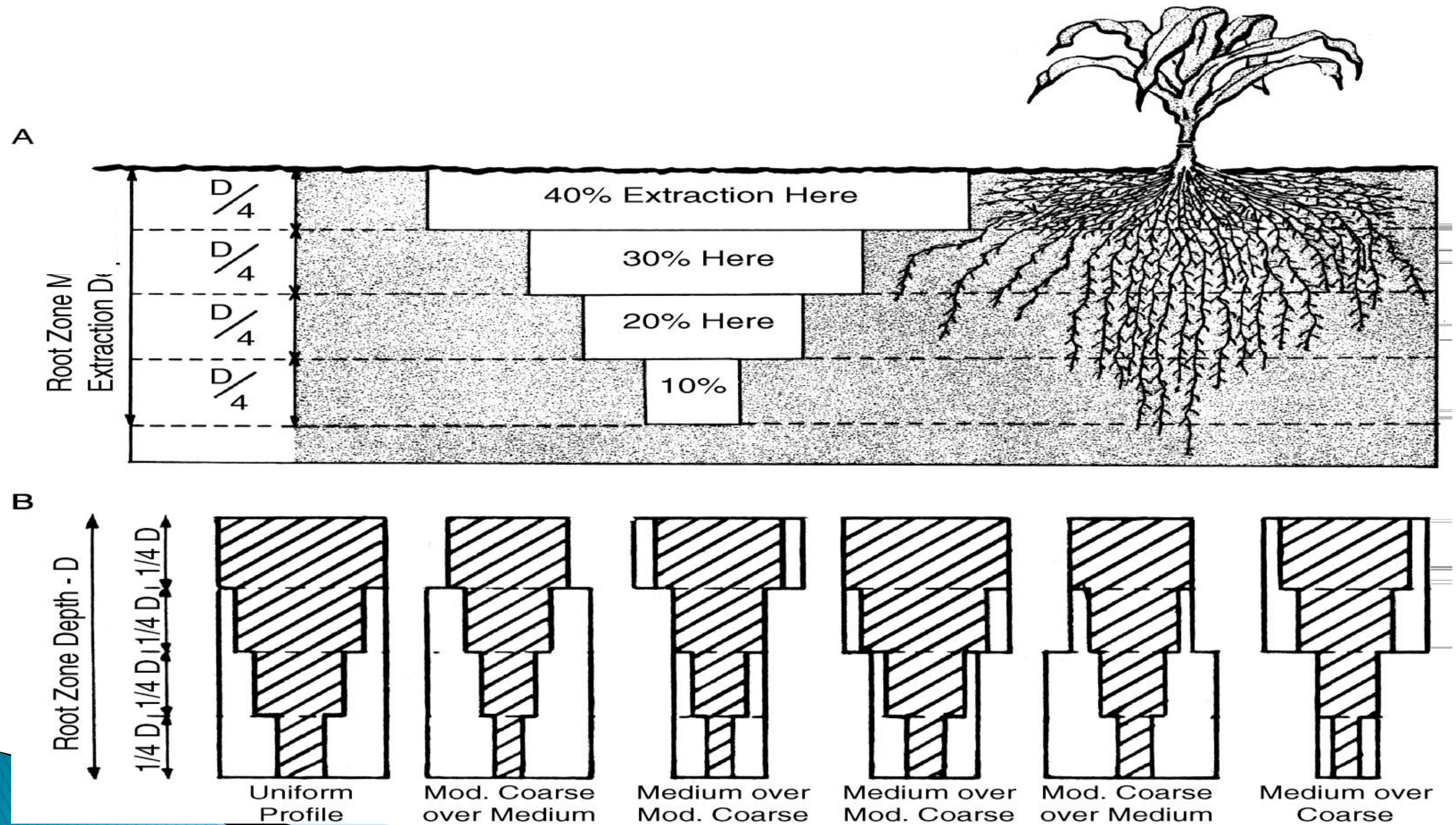
Evaporation & Transpiration



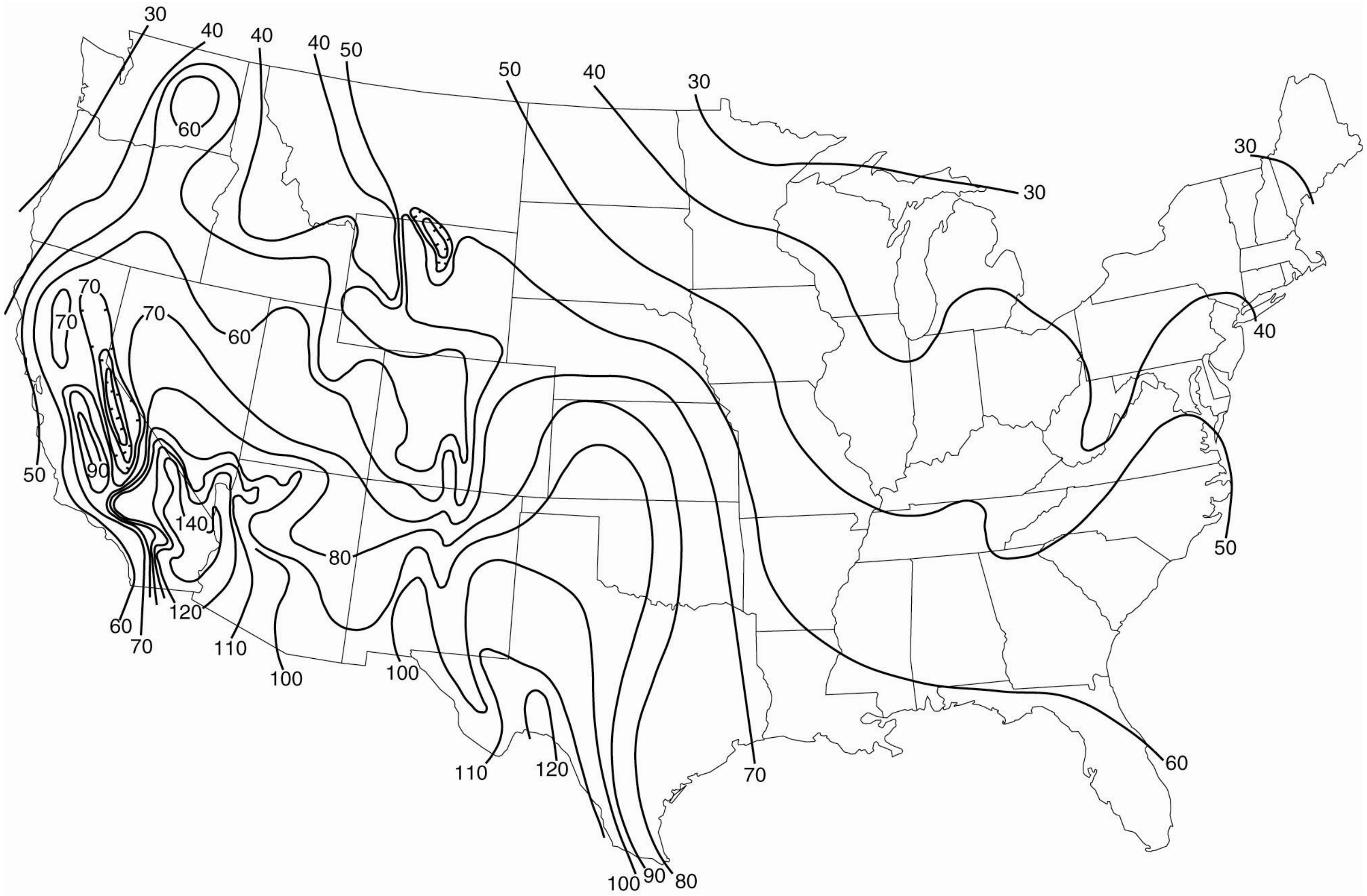

Soil Surface

Plant Transpiration

Most water absorption occurs in upper half of root zone

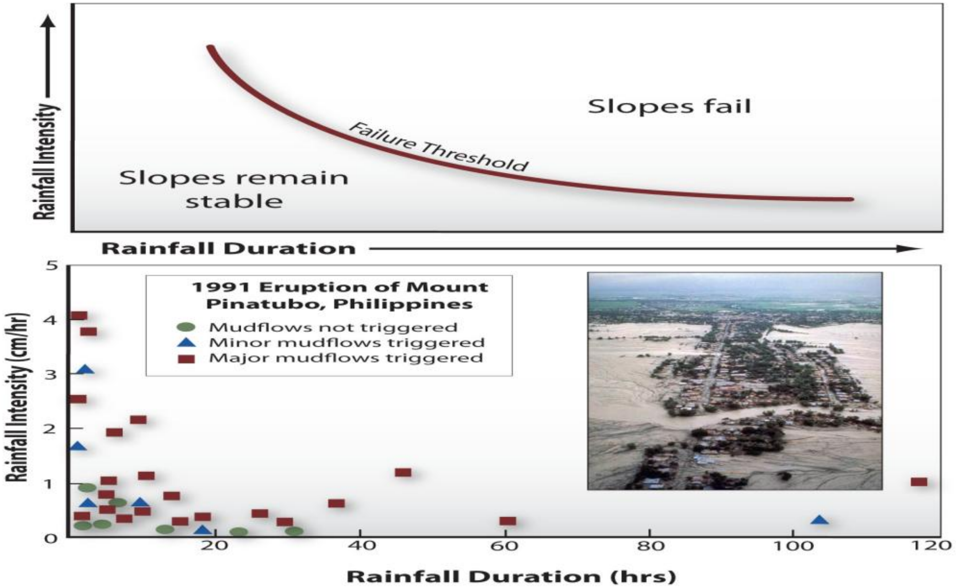


Annual Pan Evaporation in USA



Evaporating playa lake with salts around margin, eastern Washington

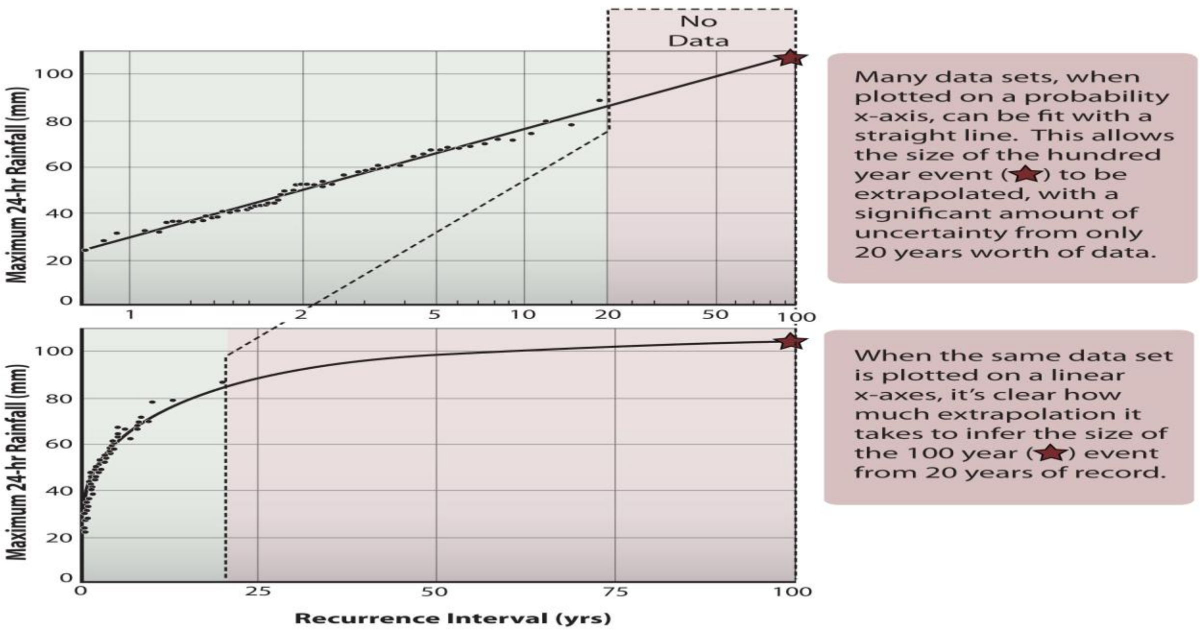
Figure 4.1 - Intensity-Duration Thresholds for Geomorphic Processes
(chapter 4 - Hydrology)



Notes:
Source upper graphic:
Pipkin, Trent, and Hazlett, Geology and the Environment. Fig 7.6, page 180
Source lower graphic:
Mt Pinotubo lahar data. Figure 10 in (http://pubs.usgs.gov/pinatubo/pierson/index.html)
Mt Pinotubo lahar picture: http://www.smate.wwu.edu/teched/geology/vo-Mt-Pinatubo.html

Landscape 7
SES.06
SES.01
SES.02
SES.12
SES.14

Figure 4.2 - Precipitation Recurrence Interval with Extrapolation
(chapter 4 - Hydrology)



Notes:
Upper panel is traced and modified
from fig 2.14 (pg 53) of Dunne and Leopold.
Data from Buffalo, NY.
Data point (3 of them) past 20 yr RI excluded

SES.14

Landscape 7

Hillslope Hydrology

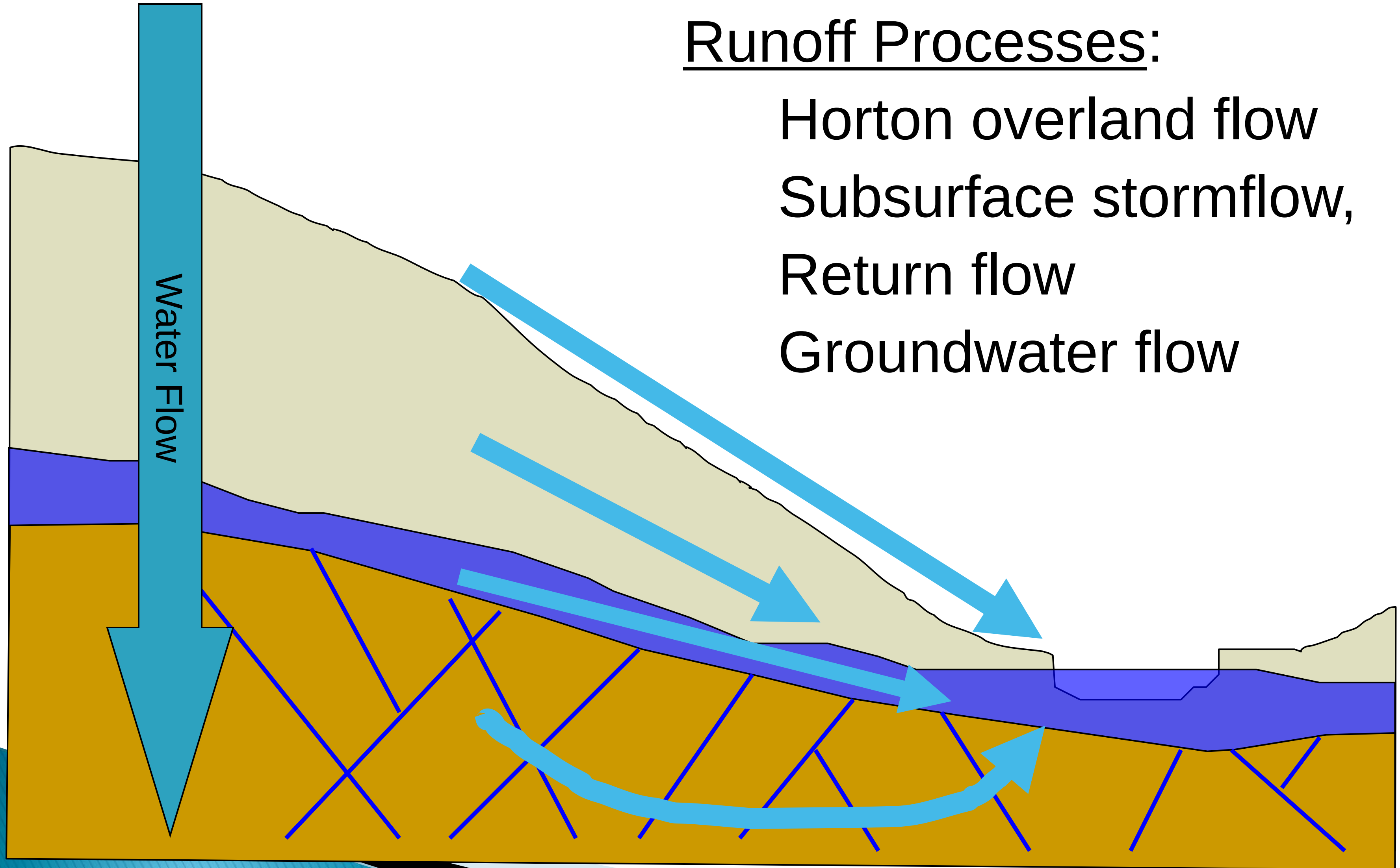
<u>Runoff Processes</u>:

Horton overland flow

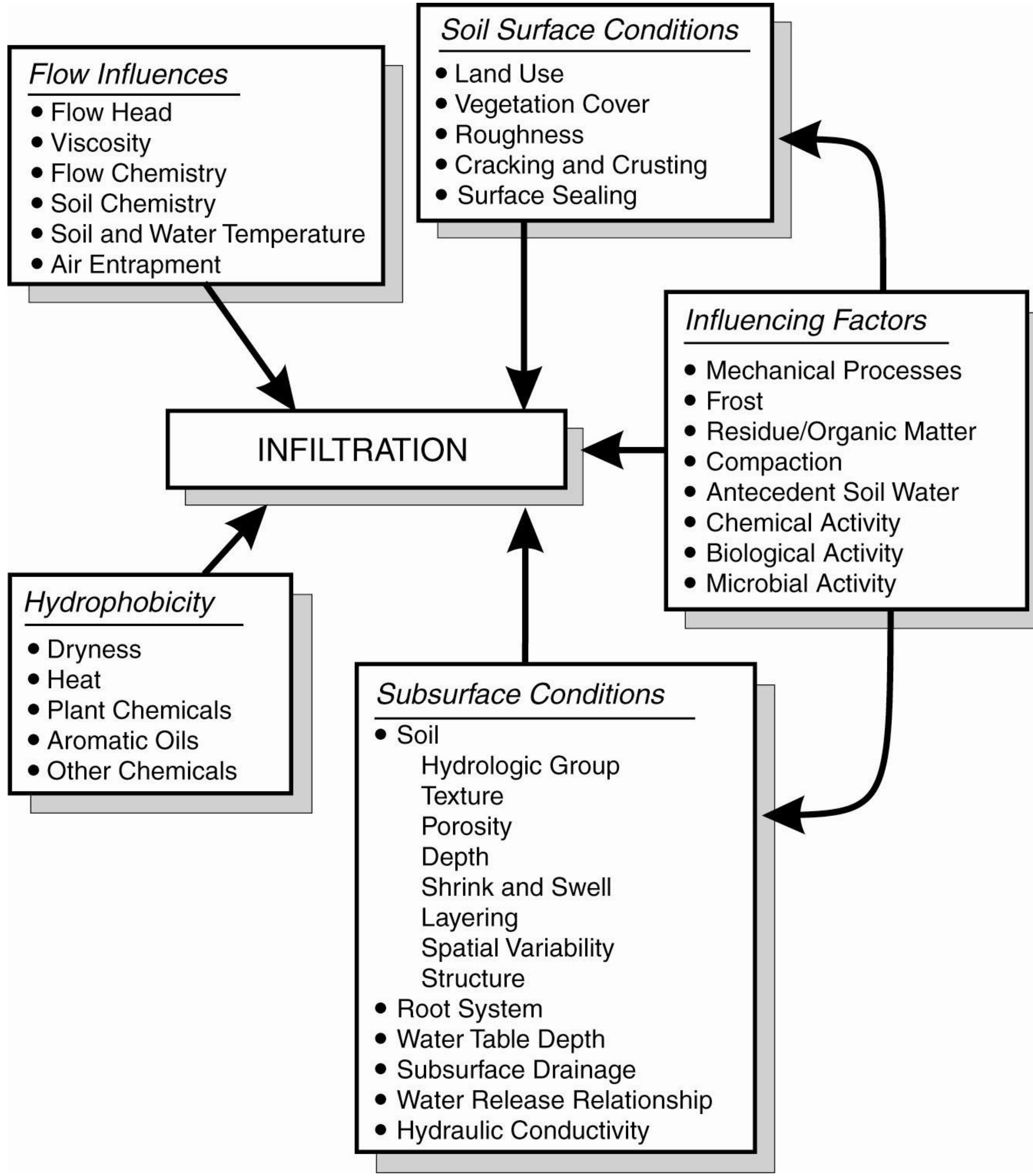
Subsurface stormflow,

Return flow

Groundwater flow



Factors Affecting Water Movement in Soils



Runoff Generation

As we discuss mechanisms, remember…

- Many processes occur simultaneously
- Shifts can occur between processes in space and time
- Antecedent wetness conditions are important
- Watershed characteristic play a central role

Horton Overland Flow

Horton overland flow occurs when the rainfall intensity exceeds the infiltration capacity

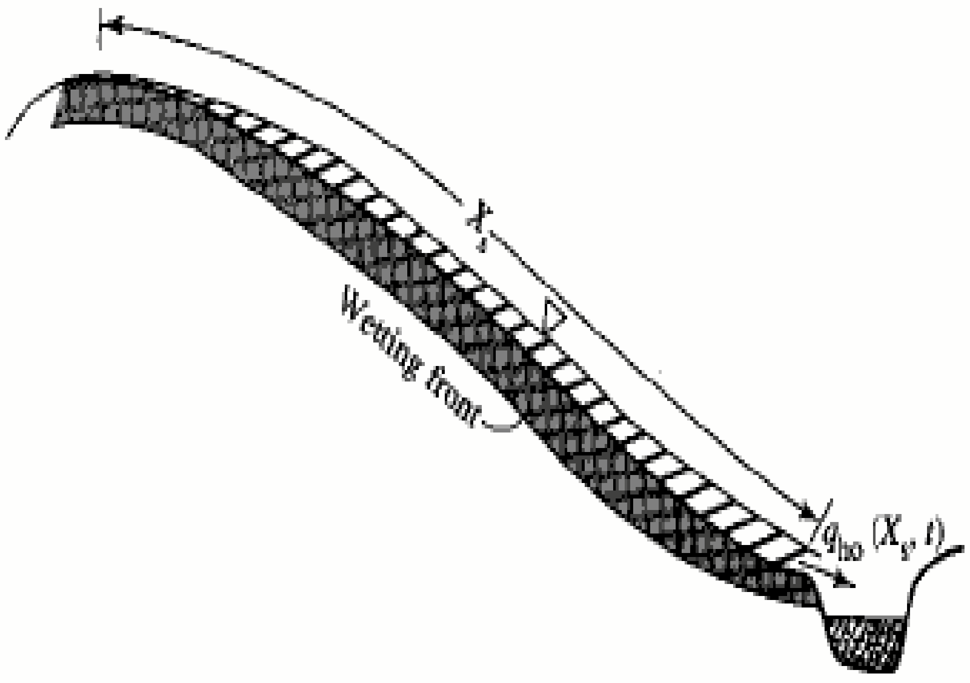
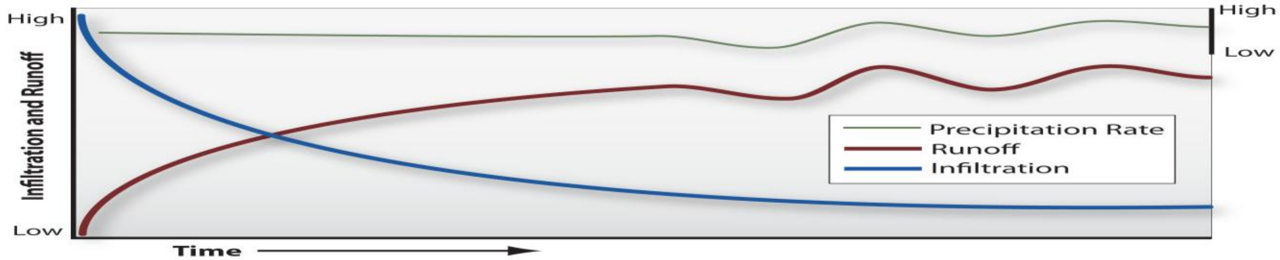


Figure 4.5 - Infiltration and Runoff over time
(chapter 4 - Hydrology)



Infiltration Trends

Infiltration rate decreases over time as dry pore spaces between soil particles fill with water. Rates of infiltration drop and become steady as the soil saturates. After saturation, the infiltration rate is a function of soil hydraulic conductivity.

Runoff Trends

Runoff increases over time because soil pores are filling with water, allowing less of the rainfall to soak into the ground. Once the soil as saturated, runoff varies with the precipitation intensity.

Landscape 7
SES.12
SES.06
SES.14

Horton Overland Flow

Once thought to be the ONLY mechanism of runoff generation

Became coded into hydrologic models still in use today

Subsequent work showed role of partial source area where Saturation overland flow is produced

Horton Overland Flow

If rainfall exceeds soil infiltration capacity:

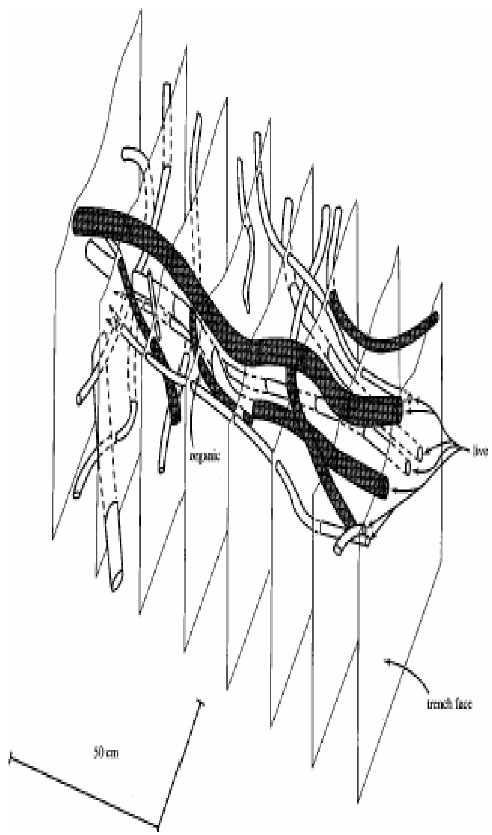
- Water fills surface depression then
- Water spills over downslope as overland flow and
- Eventually to the stream

Subsurface Stormflow

Lateral flow through soil above conductivity contrast.

Consists of both slower matrix flow and faster macropore flow

Macropore flow, Tennessee Valley, California

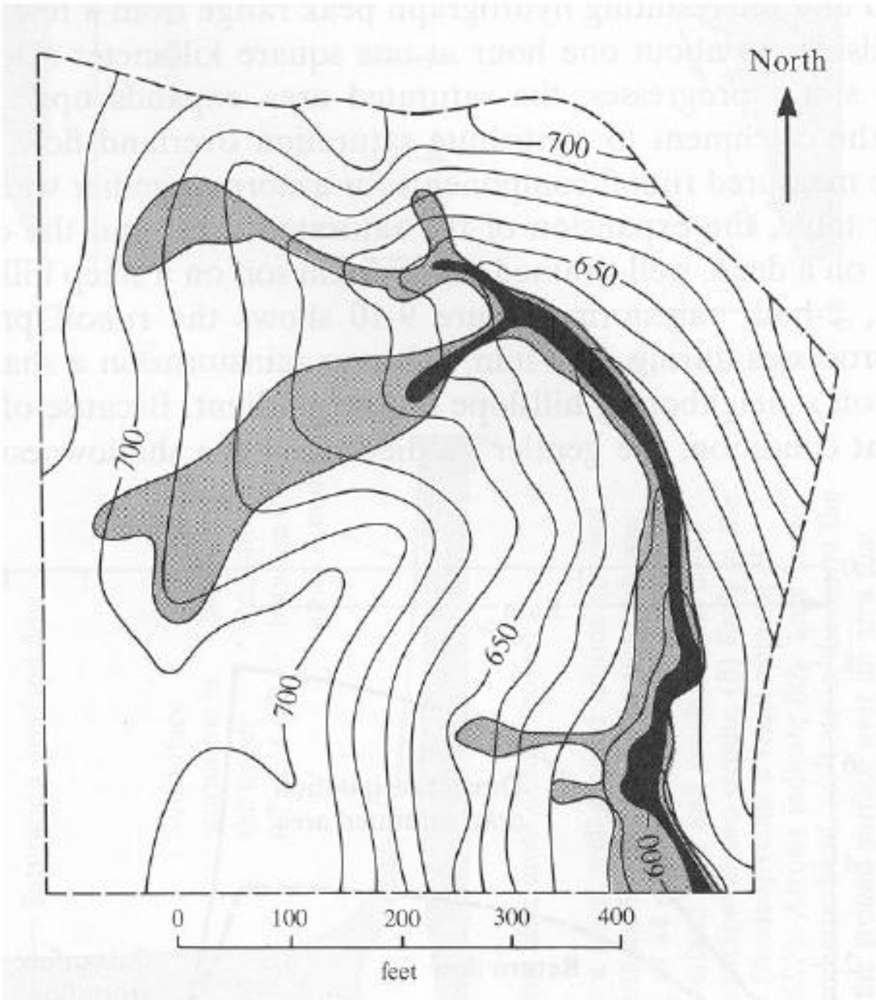


Complex Macropore Network within a Soil Matrix

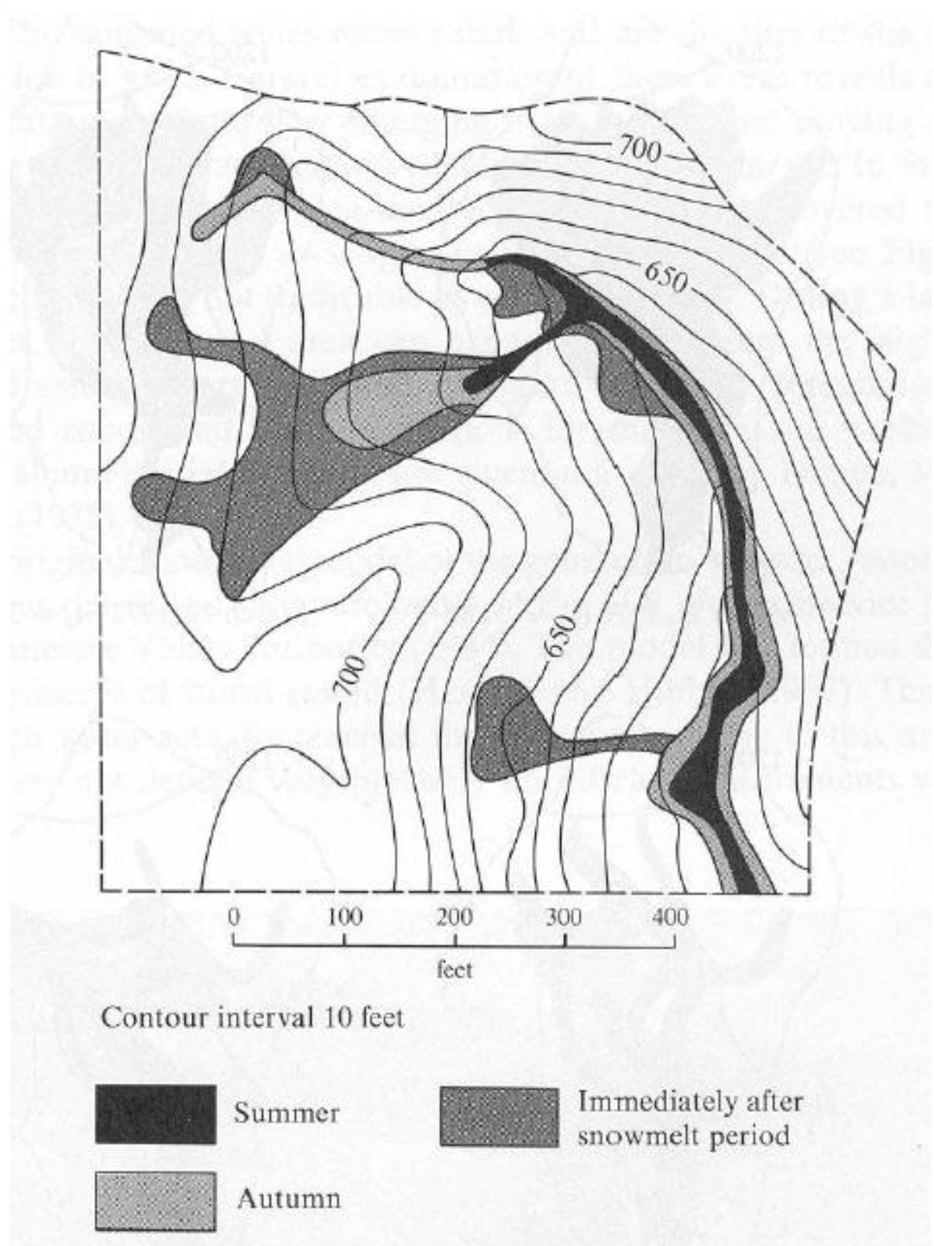
Saturation Overland Flow

Direct rainfall onto saturated areas.

Return flow from saturated soils in topographic lows and along valley bottoms where water table rises to intersect the surface.



Map of saturated areas showing expansion during a single rainstorm of 46 mm. The solid black shows the saturated area at the beginning of rain; the shaded area is saturated by the end of the storm (D&L, Fig. 9-11).



Seasonal variation of pre-storm saturated area in a catchment in Vermont (D&L, Fig. 9-12).

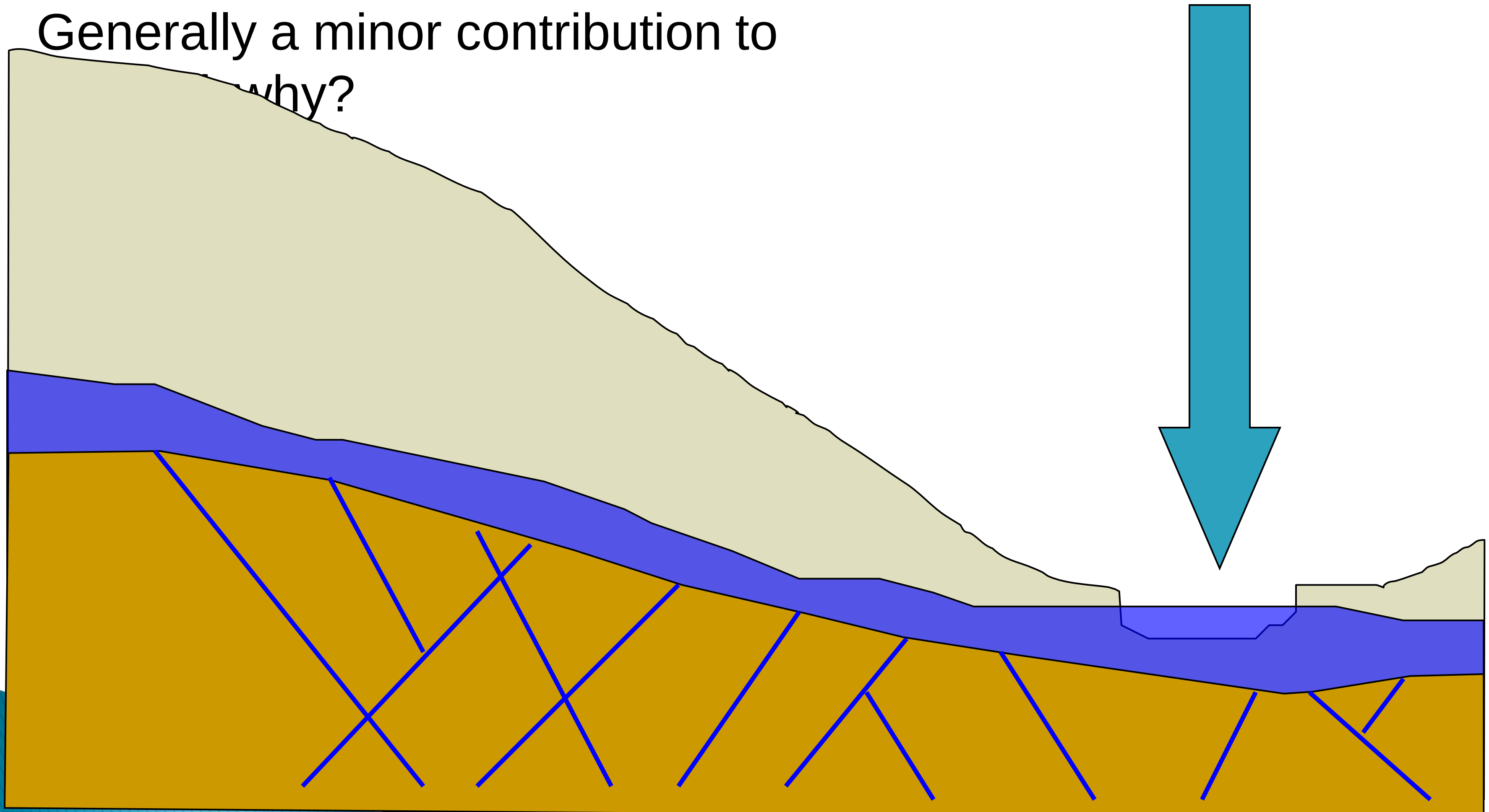
Overland flow, Tennessee Valley, California

Overland flow, Tennessee Valley, California

Direct Precipitation on Channels

Generally a minor contribution to

why?



Groundwater Flow

Driven by hydraulic gradients

$$Q = K\ I\ A$$

K is hydraulic conductivity
A is cross sectional area
I is hydraulic gradient

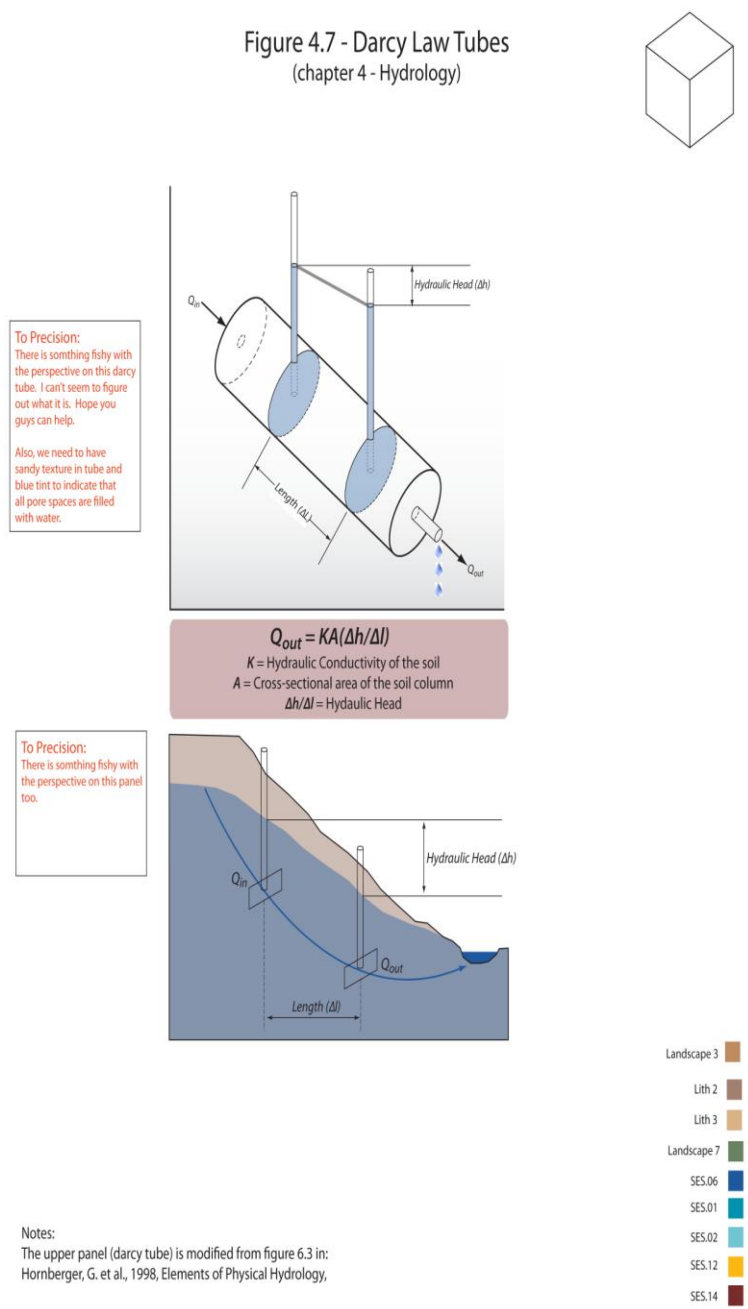
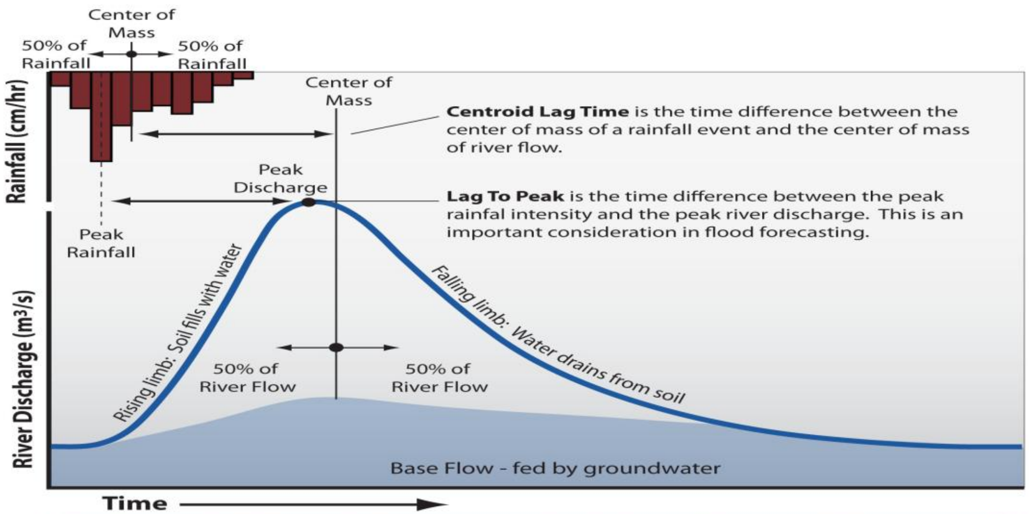


Figure 4.9 - Hydrograph Definitions
(chapter 4 - Hydrology)



Rainfall

During a **rainfall event**, the intensity at which precipitation falls on a landscape is often variable. The **peak rainfall**, a measure of the greatest intensity of rainfall, does not necessarily occur in the middle of a rainfall event. Therefore, the peak and the **center of mass** of rainfall (the point at which half of the total rainfall has fallen) often do not correspond.

Discharge

As precipitation falls across a landscape, some **infiltrates** the soil and some **runs off** and enters river channels causing discharge and river stage to rise. As the soil fills with water, more precipitation enters river channels as runoff, groundwater flow and subsurface stormflow. Stage rises until reaching the **peak**, or maximum discharge resulting from a rainfall event. As water drains from soils and from the landscape, the river stage begins to fall, eventually returning to **base flow**, which reflects normal groundwater discharge to rivers in humid regions.

Notes:
centroid lag (lc)…center of mass to center of mass.
Dunne and Leopold, p. 326
lag to peak, Dunne and Leopold, pg. 258

SES.06

SES.14

Hydrographs by Runoff Mechanism

Lag to peak
Throughflow
SOF
HOF

Peak Runoff
HOF
SOF
Throughflow

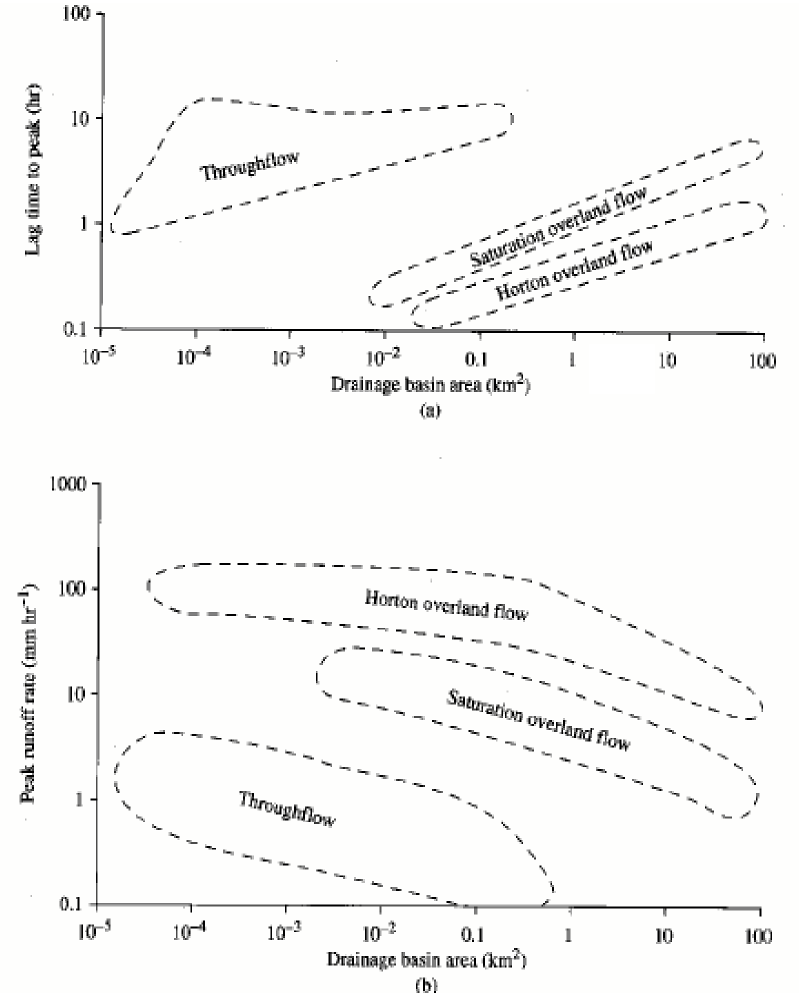


Figure 4.8- Variable Source Areas
(chapter 4 - Hydrology)

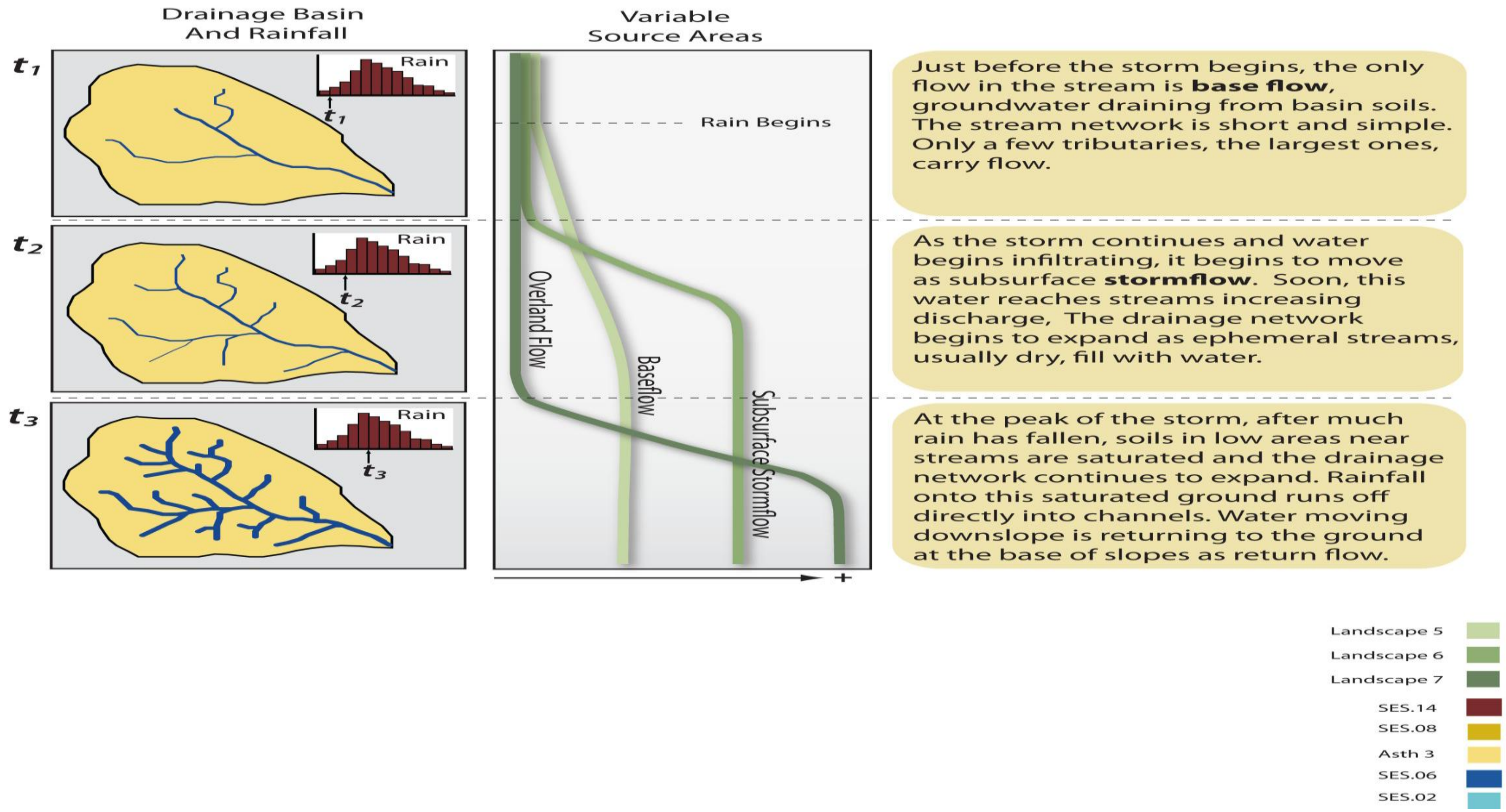


Figure 4.10 - Hydrograph: Basin Scale and Shape
(chapter 4 - Hydrology)

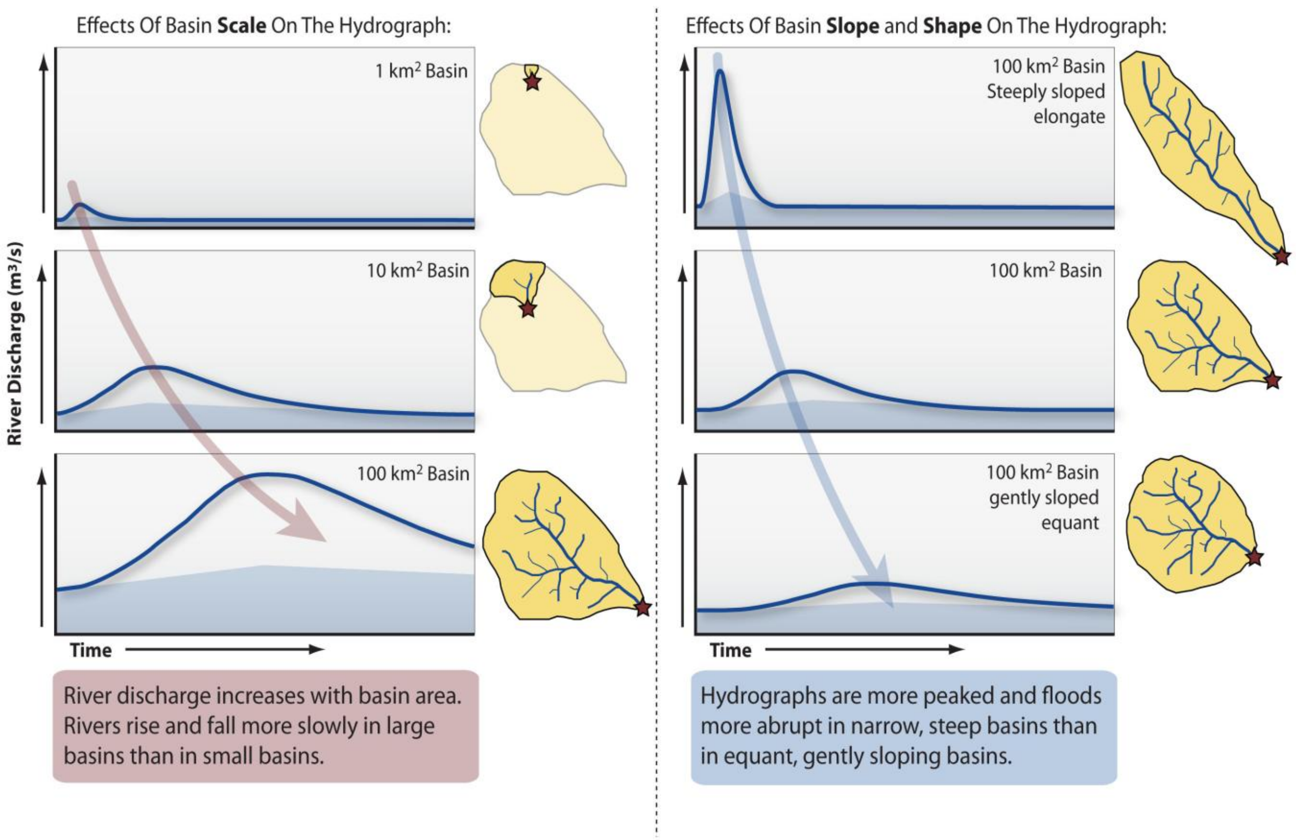
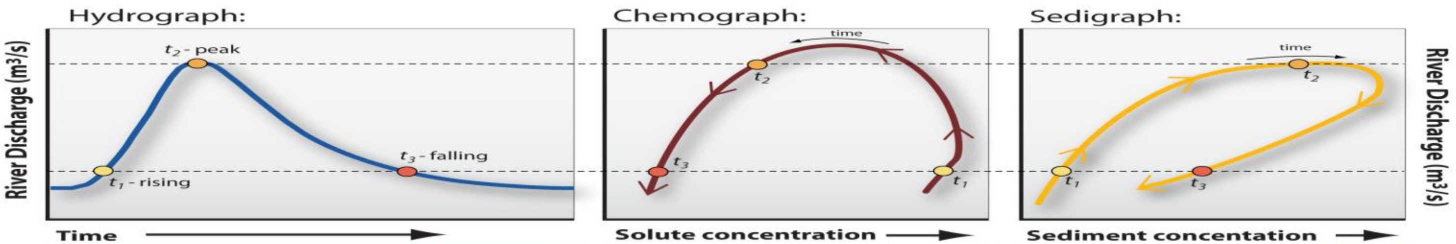


Figure 4.11 - Hydrograph, Sedigraph, Chemograph
(chapter 4 - Hydrology)



Soon after the storm begins, discharge increases above baseflow at t_1 and rises to a peak at t_2. As the storm subsides, flow diminishes until discharge returns to baseflow (t_3).

Much of the water delivered to the channel at the beginning of the storm (t_1) is old water that's been stored in pore spaces and is enriched in dissolved ions. After the storm is over (t_3), newer, more dilute water that has spent less time in the shallow subsurface enters the channel. This pattern of dissimilar ion concentration at similar discharge levels is referred to as a **Hysteresis Loop**.

As flow begins to increase, sediment doesn't begin to move until a critical shear stress is exerted on the bed. Once the bed begins to move and the armor layer becomes mobile, large amounts of fine material are released into the flow. As the storm ends, and the flow decreases, sediment continues to move through the system.

Asth 1
Asth 2
Asth 3
Lith 1
SES.12
SES.06
SES.14

Notes:
Example source material
Lawler, 2006.

Water balance of drainage basins

Net difference between precipitation and evaporation yields streamflow or groundwater

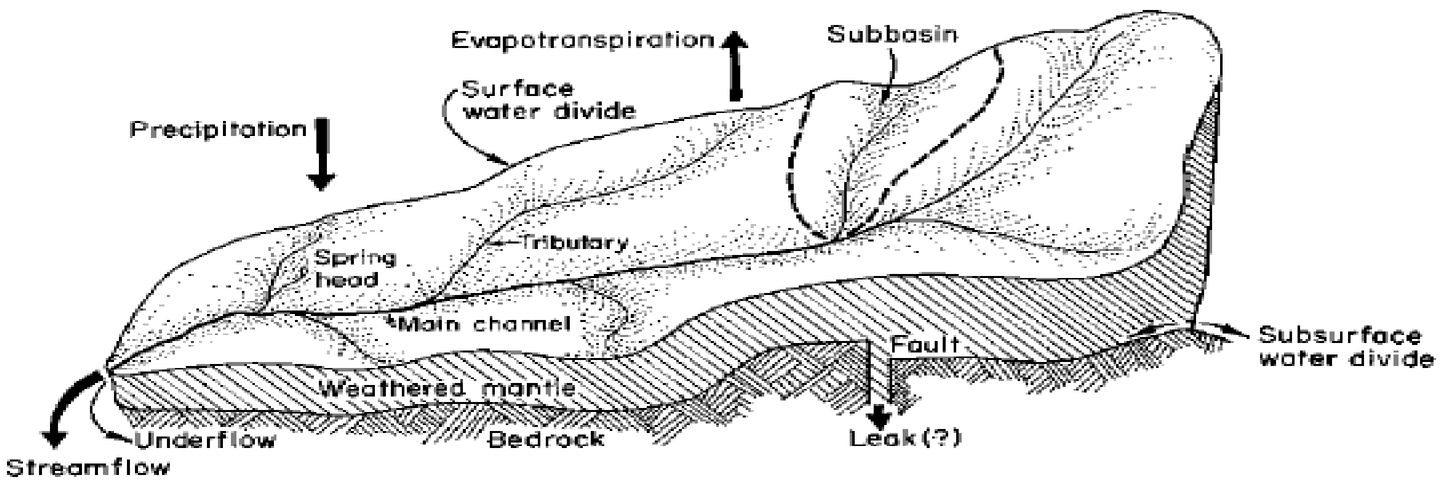


Fig 2-3. Diagram showing terms essential to describe the drainage basin and its water balance. Underflow is unmeasured streamflow in sands, gravels and rocks beneath the channel bed.

Watershed Urbanization

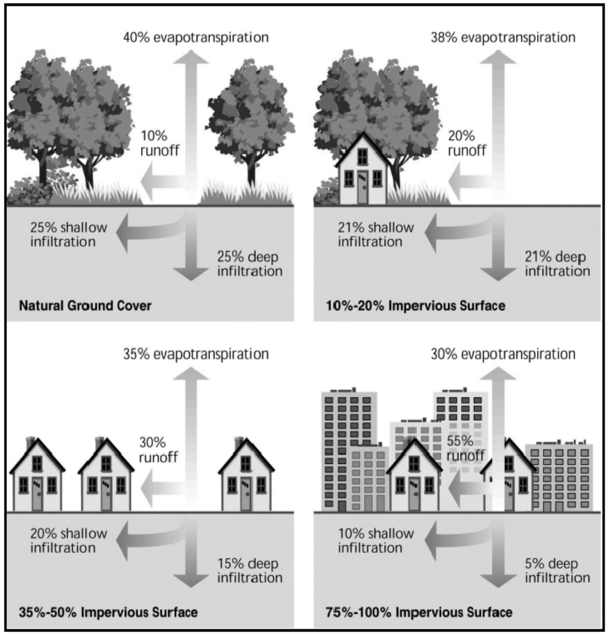
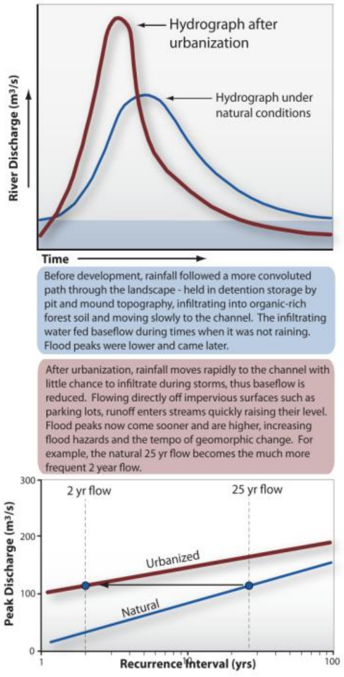


Figure 1.2: Relationship Between Impervious Cover and Surface Runoff

Source: Federal Interagency SRWG, 2000

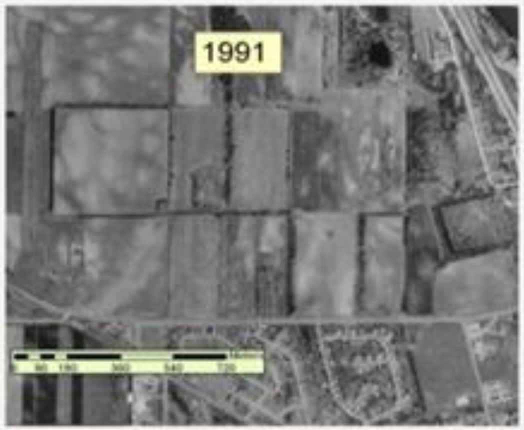
Figure 4.13 - Pre- and Post-Development Hydrographs
(chapter 4 - Hydrology)



Notes:
Source for data in lower panel (traced from plot):
http://images.google.com/imgres?imgurl=http://www.trincoll.edu/~jgourley/GEOS%2520112%2520Stream%2520Discharge_files/h_flood_recurrence.jpg&imgrefurl=http://www.trincoll.edu/~jgourley/GEOS%2520112%2520Stream%2520Discharge.htm&usg=__HbkmlI4au70H9u6k6KH_xhzrtuA=&h=622&w=1000&sz=77&hl=en&start=5&um=1&tbnid=ZtcFydiORiv8uM:&tbnh=93&tbnw=149&prev=/images%3Fq%3Dflood%2Brecurrence%2Binterval%26um%3D1%26hl%3Den%26sa%3DN

SES.14
SES.06

Urbanization



Northern Saint Peter, MN, in 1991. Most of the land was used for agriculture.

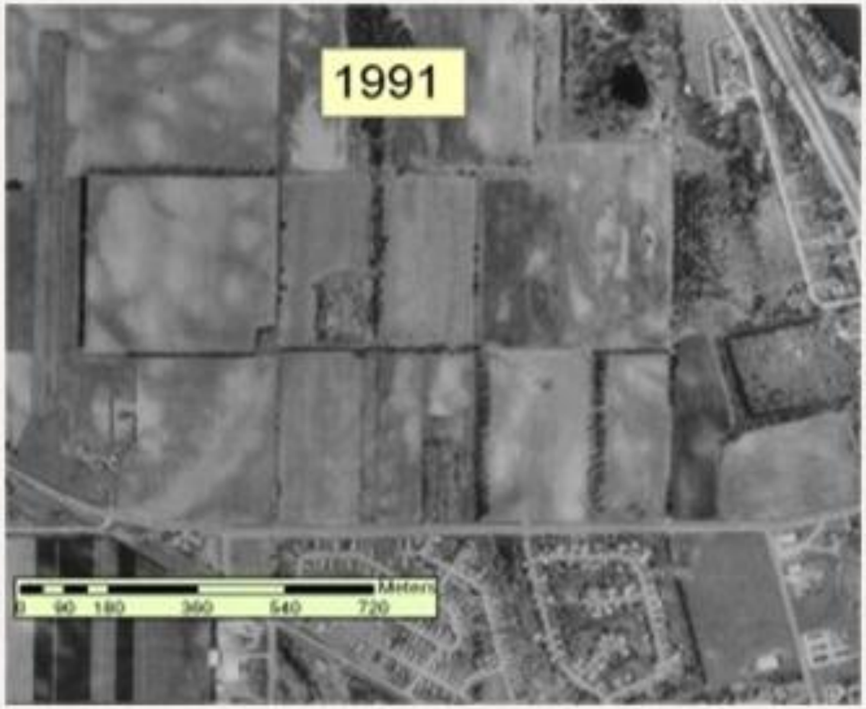
By 2008, urban growth had increased the impermeable surfaces in this part of Saint Peter by 30 percent.

- Minnesota, New Jersey and most other states are facing population and development increases. Flood water is increasingly difficult to handle: little infiltration occurs, floodwaters arrive sooner and are deeper.
- Natural and agricultural lowlands are being developed: detention basins are being lost. Surface flow is much faster than groundwater.

UNIT-II

HYDROGRAPH ANALYSIS

Urbanization



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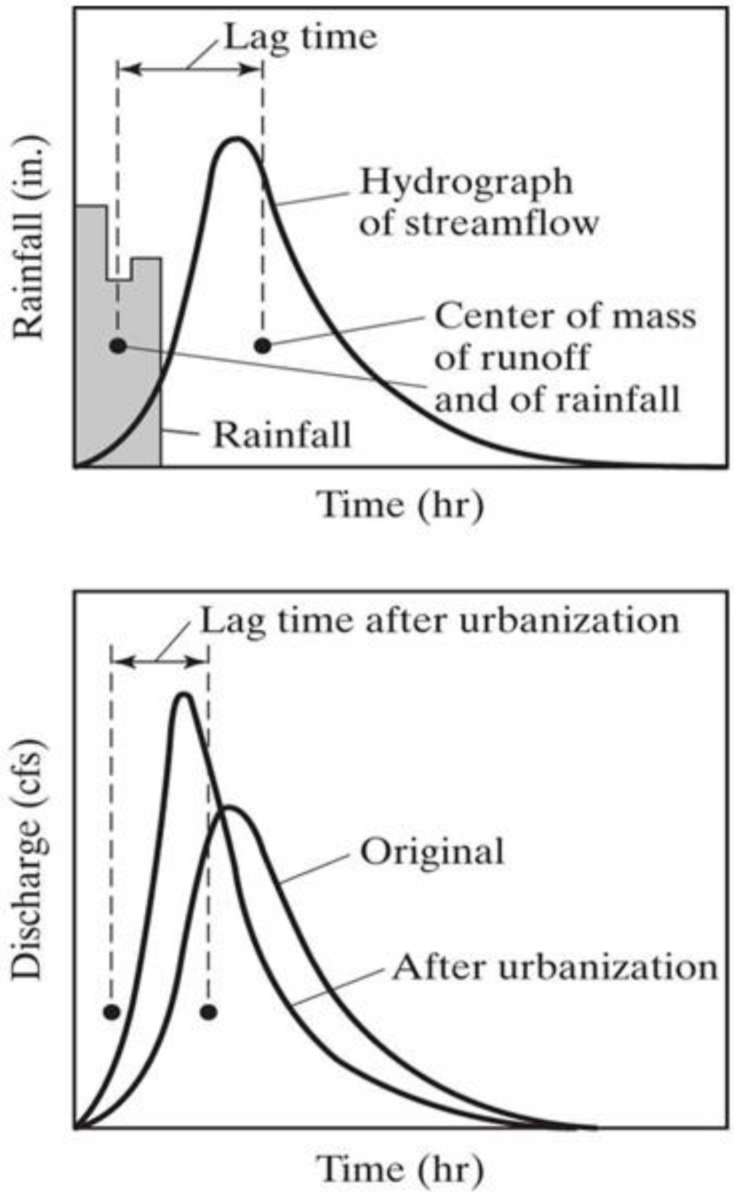
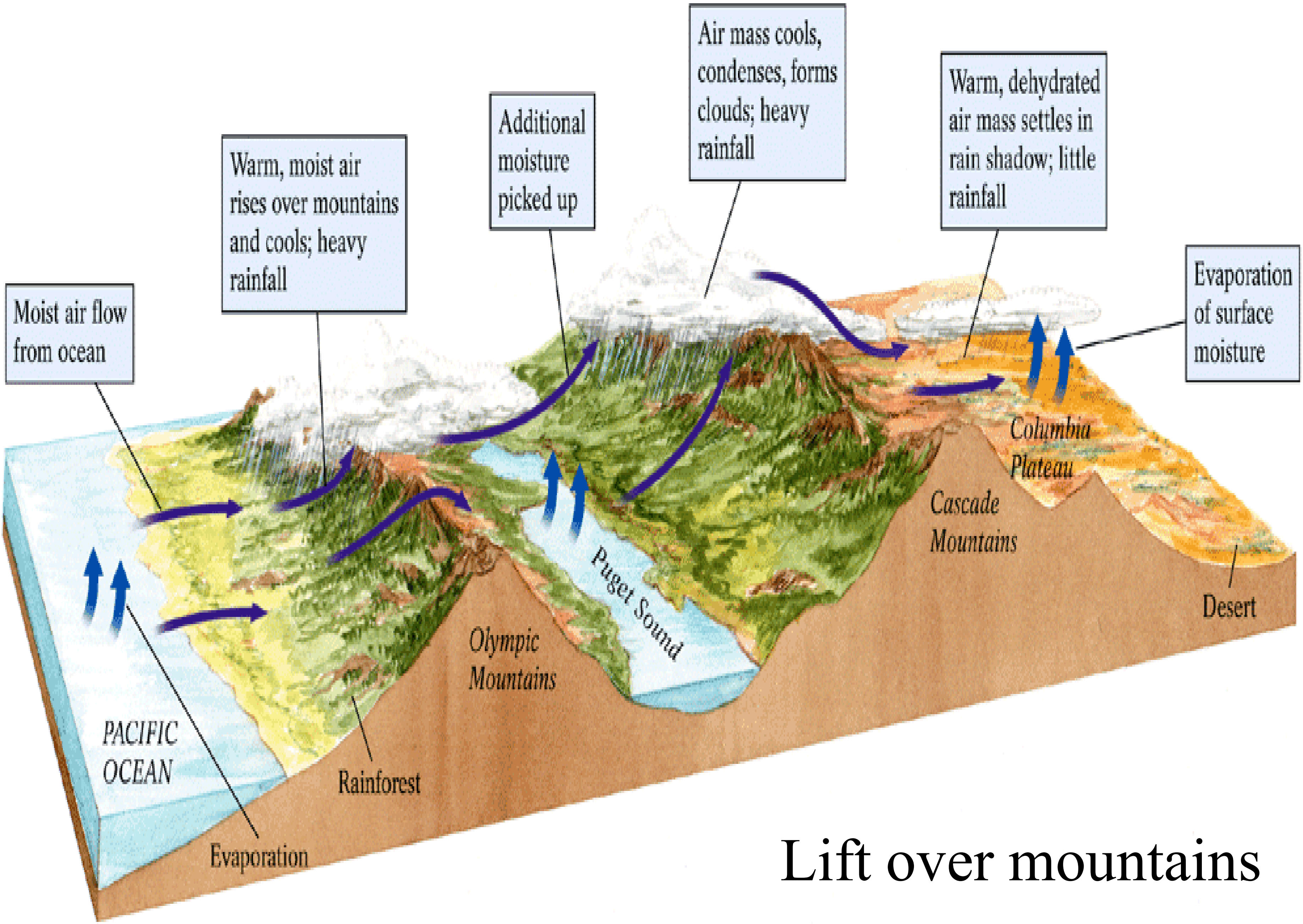


(a)

Without permeable floodplains, infiltration does not occur and floods are much more frequent. Peak flow is higher and arrives much sooner than in wild or rural areas.



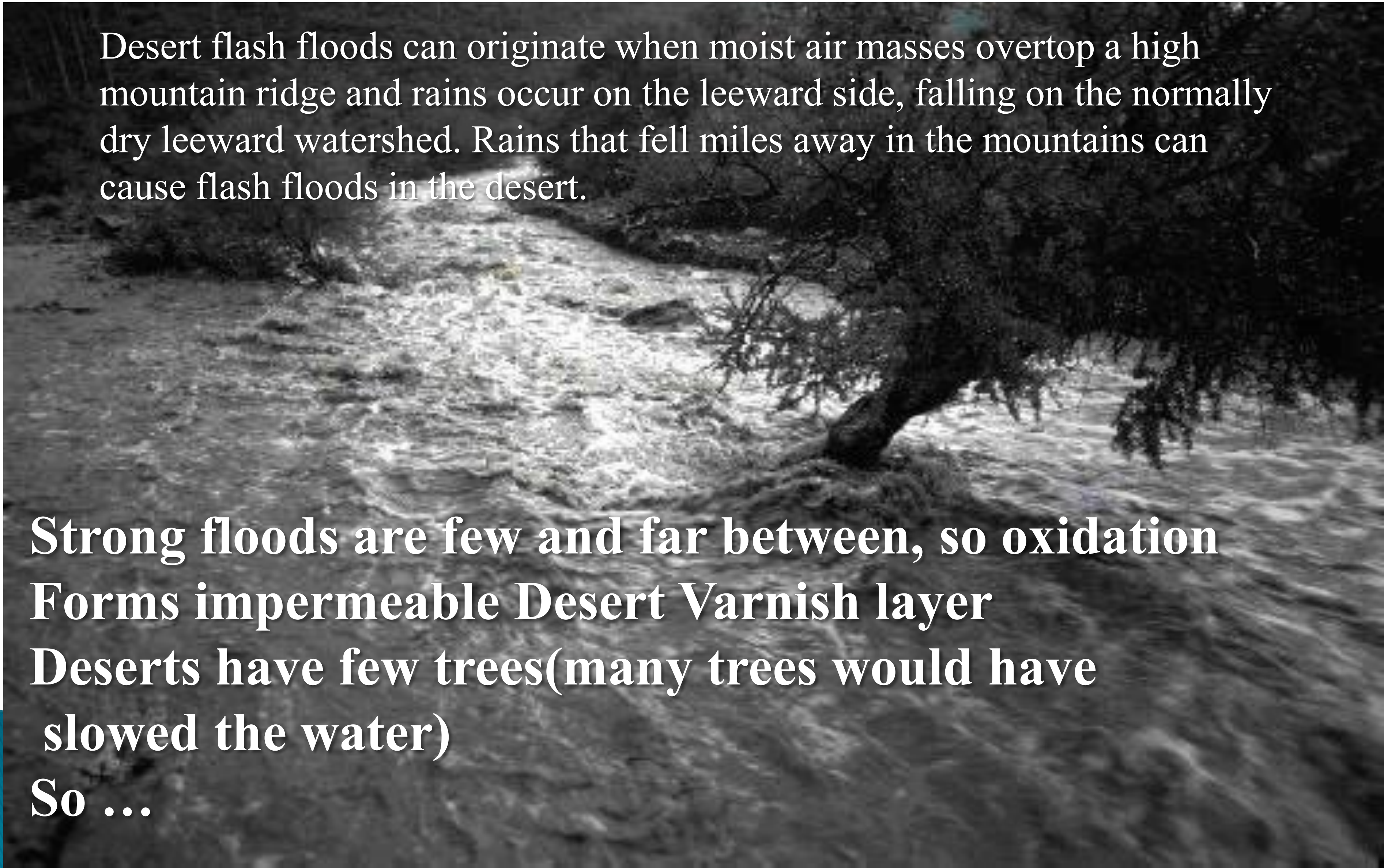
Lift over mountains

Flash Floods in Rain-Shadow Deserts

Normally, windward side gets rain, leeward side gets a desert.

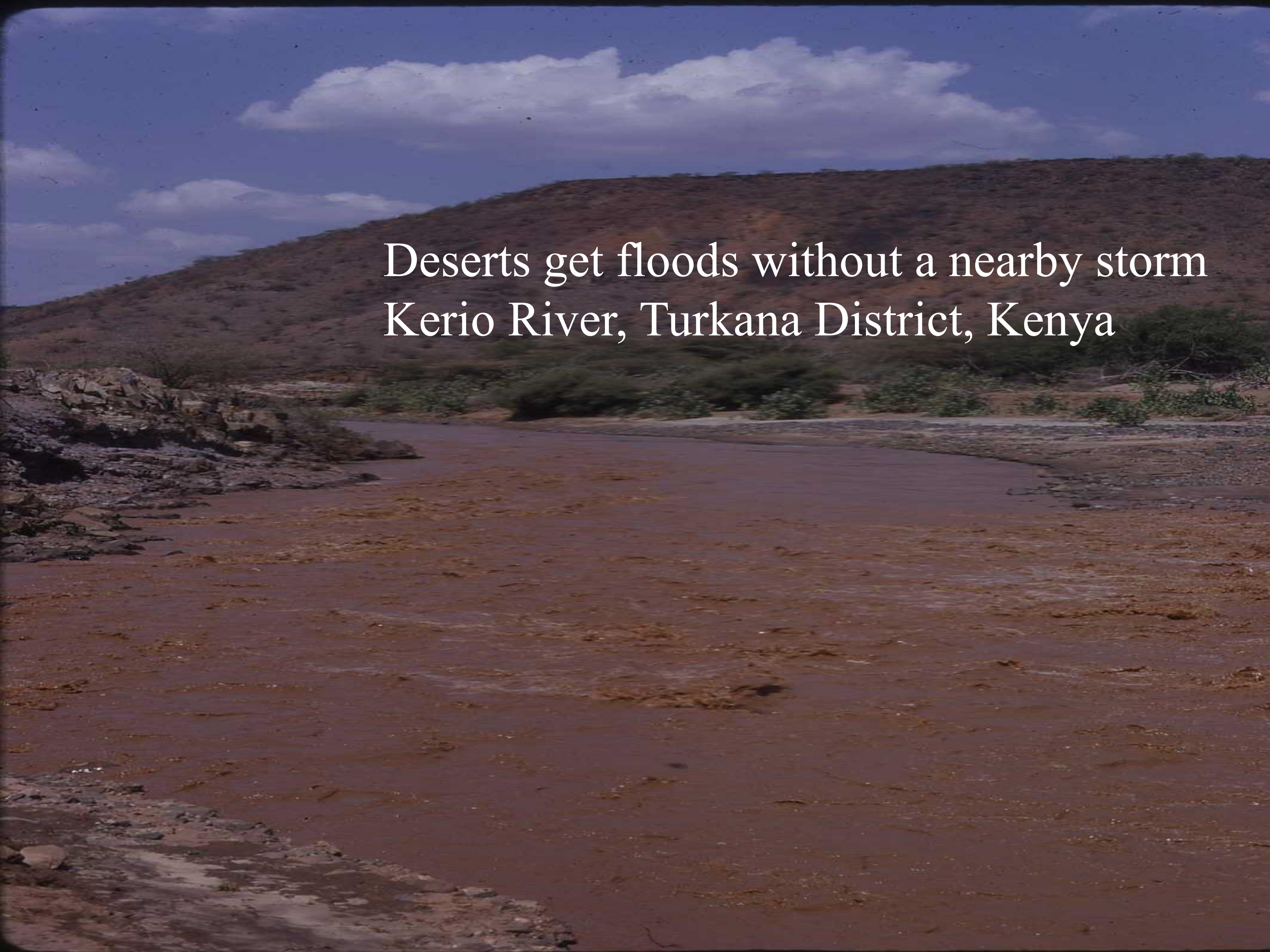
- Air is forced to rise over a mountain range
- Air cools with increasing altitude on the windward flank
- Condensation and precipitation occur at high elevations.
- As the air descends the lee side, it warms up
and can absorb moisture creating a **rain shadow**
- Precipitation in the lee is relatively rare.

Flash Floods

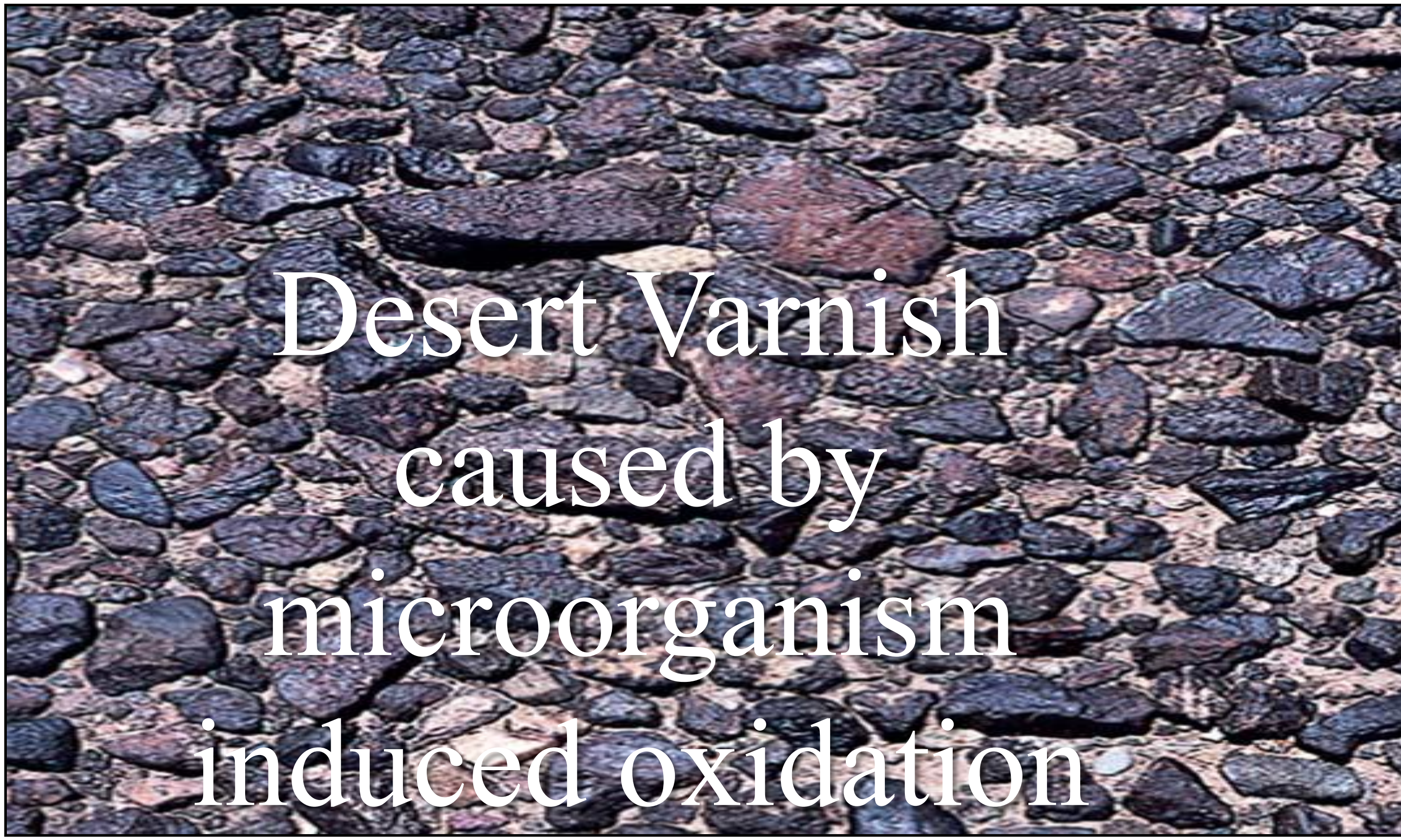


Desert flash floods can originate when moist air masses overtop a high mountain ridge and rains occur on the leeward side, falling on the normally dry leeward watershed. Rains that fell miles away in the mountains can cause flash floods in the desert.

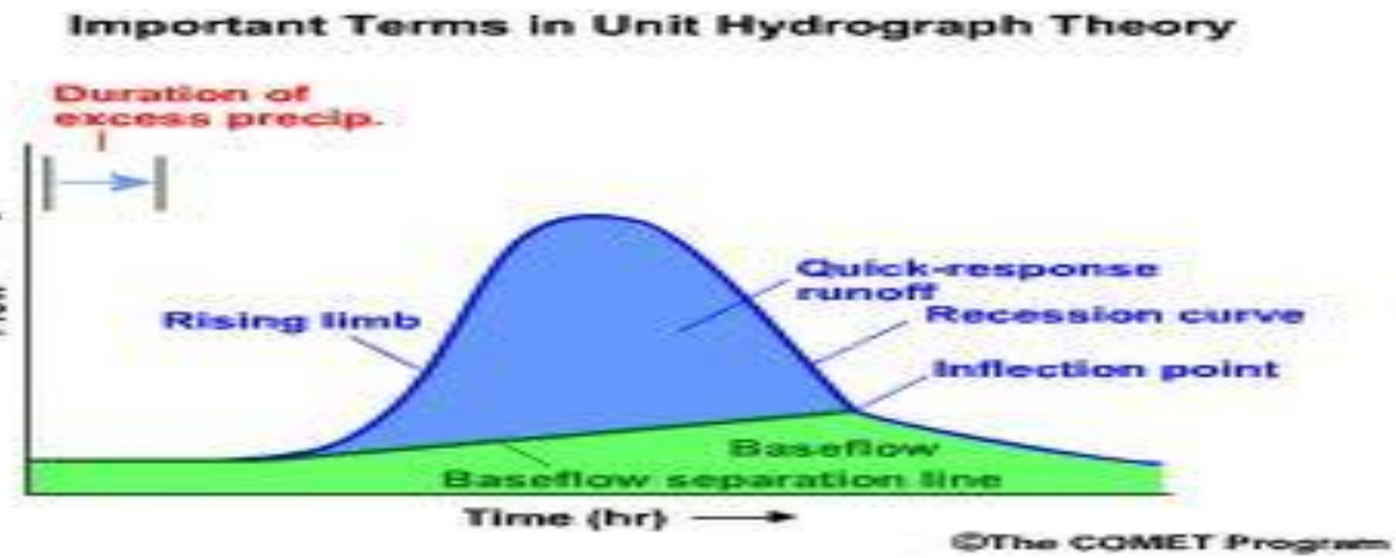
Strong floods are few and far between, so oxidation
Forms impermeable Desert Varnish layer
Deserts have few trees(many trees would have slowed the water)
So …


Deserts get floods without a nearby storm
Kerio River, Turkana District, Kenya

Impermeable surfaces slow infiltration
Cause Flash Floods

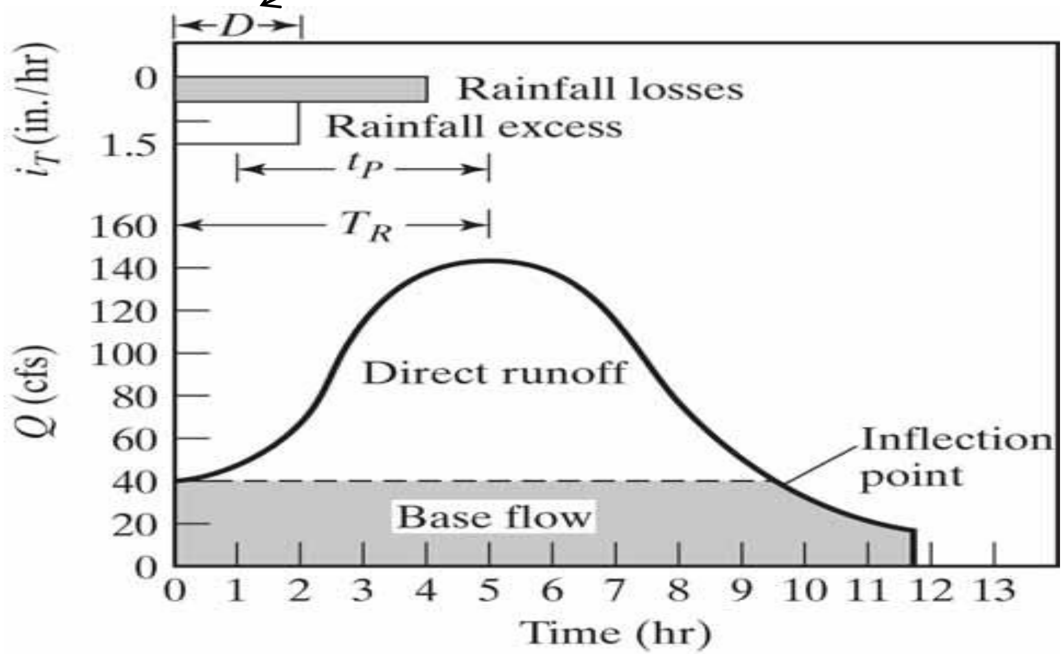


Chapter Two (continued)
Unit Hydrograph Method



Here net rain is 1 in/hr x 2 hrs = 2 inches over 2 hr storm

We want 1 inch over 2 hr storm for 2 hour UH



(a)

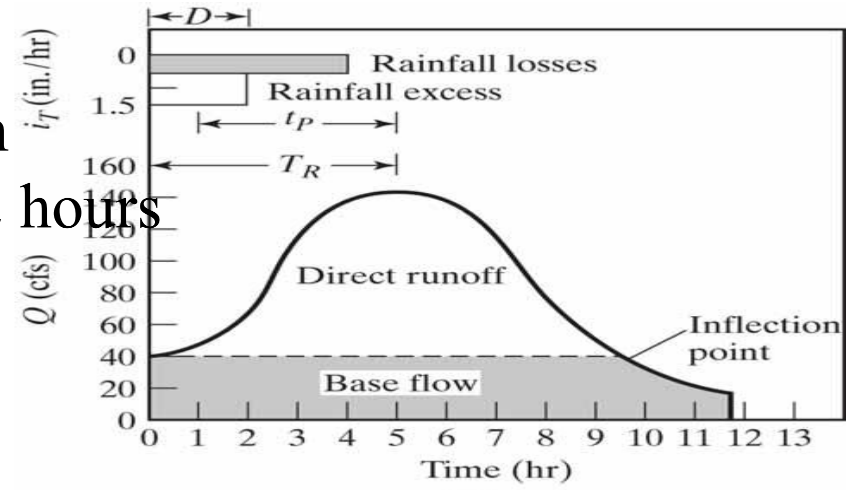
t_p = Lag time or time to peak

T_R = time of rise

A typical Storm gross hyetograph and gross hydrograph. The gross hydrograph can be converted to a unit hydrograph (1 inch over 1 hour, .5 inches over 2 hours, .33333 inches over 3 hours, etc.) by subtracting the base flow (gives a net hydrograph), calculating the total Direct Runoff flow from the net hyetograph , then scaling the hydrograph ordinates by the same multiplier to give the total flow of 1 inch over the storm duration.

D = duration of excess rain

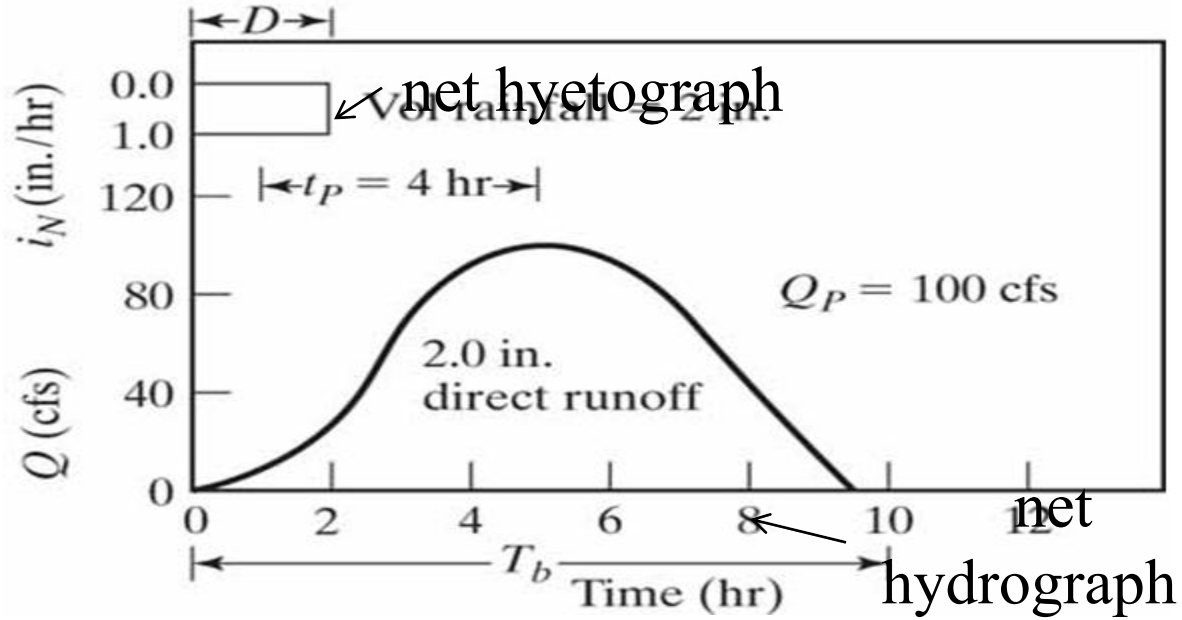
Look at hyetograph, here 2 hours



(a)

- **Unit Hydrograph**
  Hydrograph usually consists of a fairly regular lower portion that changes slowly throughout the year and a rapidly fluctuating component that represents the immediate response to rainfall.
  The lower, slowly changing portion is termed base flow. The rapidly fluctuating component is called direct runoff. This distinction is made because the **unit hydrograph** is essentially a tool for determining the direct runoff response to rainfall.

A Unit Hydrograph has 1.0 inches of Direct Runoff for the storm duration.



To get a unit hydrograph, UH, first we remove the base flow amount from the hydrograph, as shown, and calculate the net rainfall by removing the infiltration and retention storage from the hyetograph. Then scale the new hydrograph units to yield a unit hydrograph for, say<u>, 1 inch for one hour, or 1/2 in/hr for 2 hours, or 1/3 in/hr for 3 hr, etc.</u>

Here we start with 2 inches for 2 hours [redacted] hour for 2 hours. To get a 2-hour UH, we want 1/2 inches/hour for two hours. So we have to divide the hydrograph ordinates by 2.

Example 2-3: Convert the direct runoff hydrograph below to a 2-HR UH.
In the hyetograph $\Phi = 0.5$ in/hr
In the hydrograph, base flow = 100 cfs

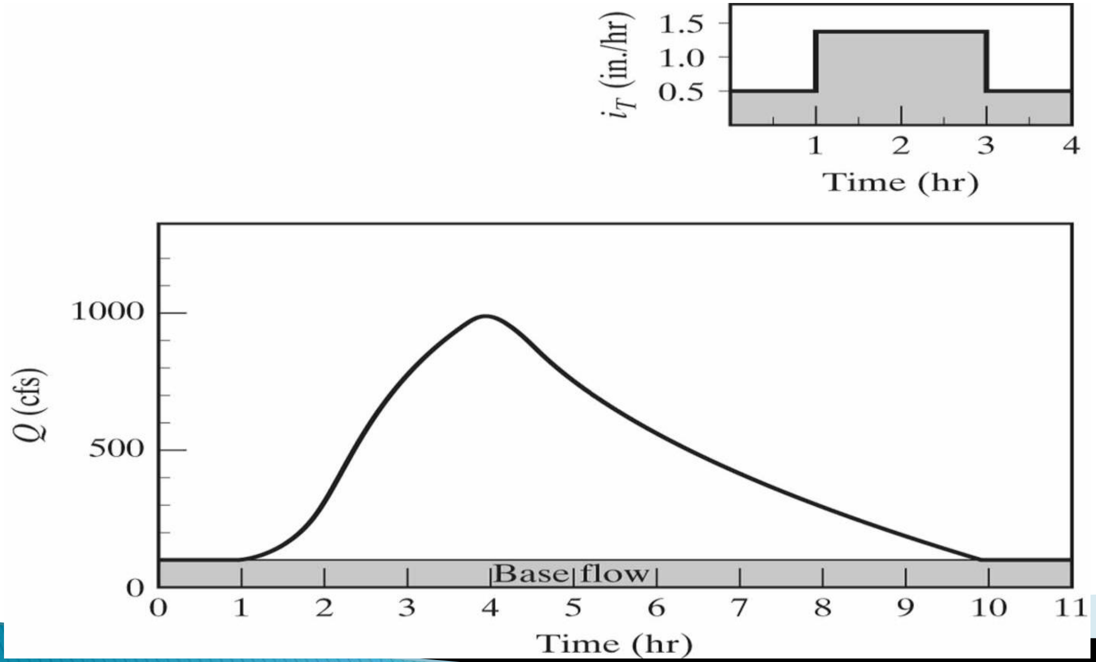
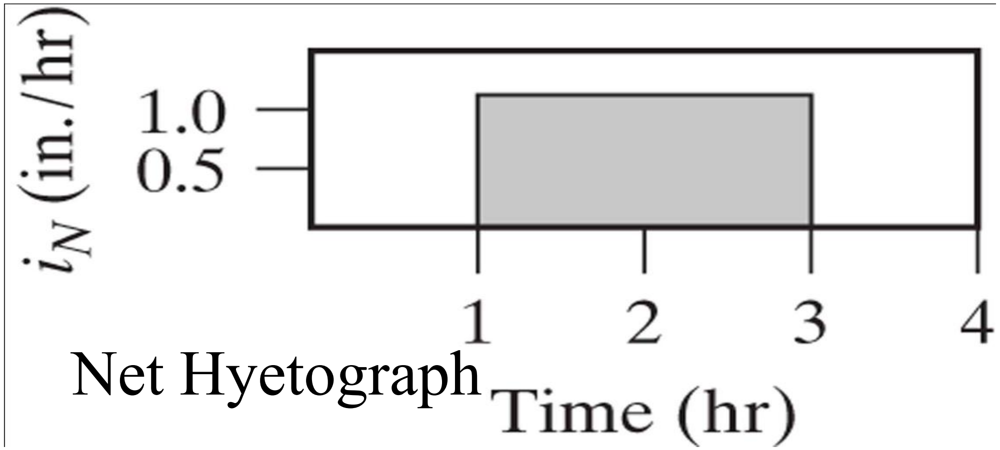
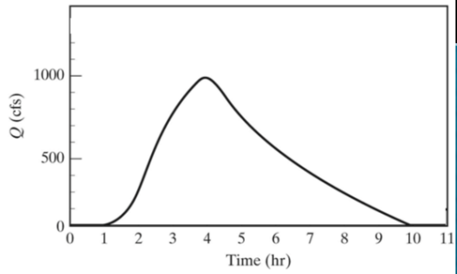


Figure E2-3a

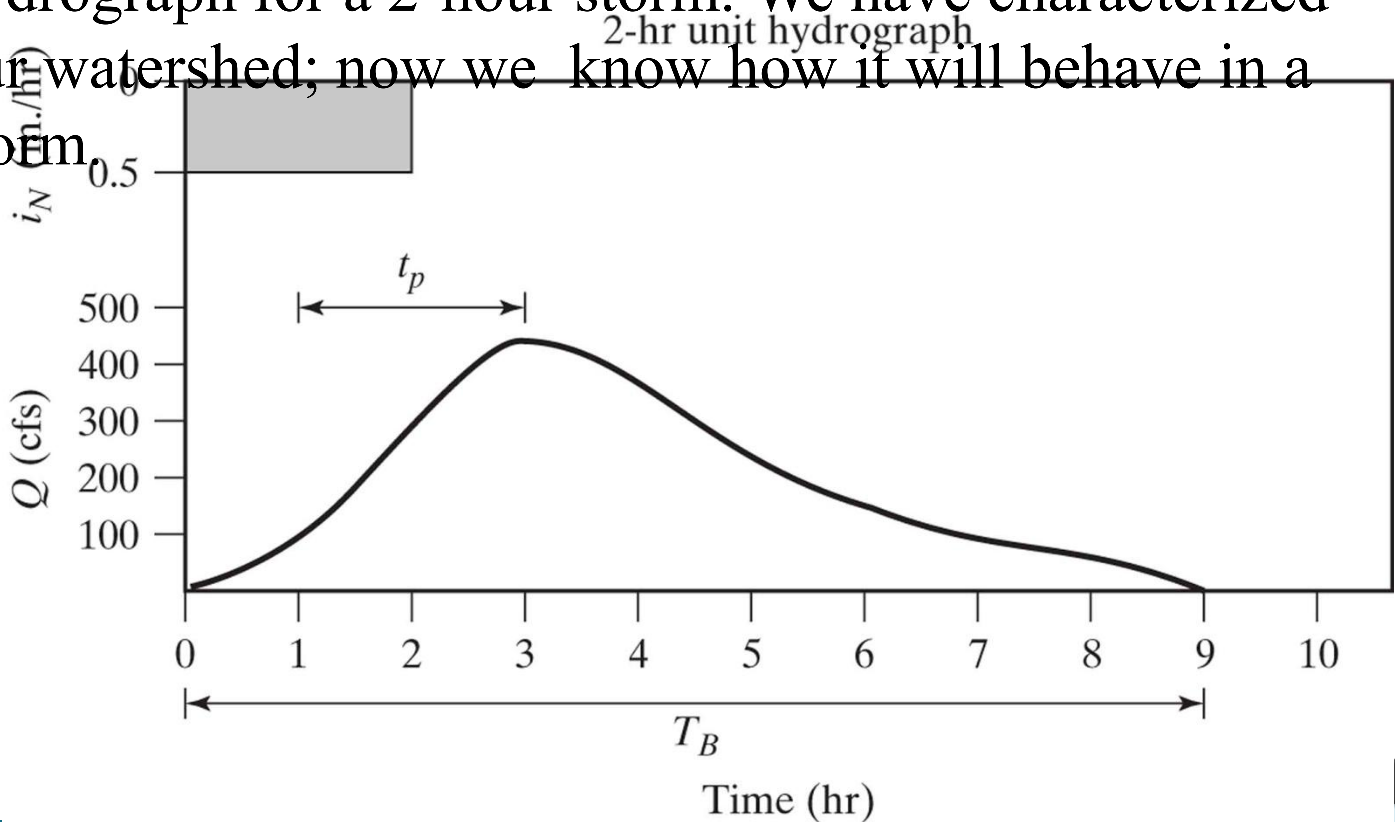
Draw the Net Hyetograph, and calculate the total direct runoff, in inches, over the watershed.



1 in/hr x 2 hours = 2 inches, so 2 inches for a 2 hour storm. This is twice too big. We want 1 inch total for the storm, so we must divide each NET hydrograph ordinate by 2



We removed the base flow from the gross hydrograph, then divided each ordinate by two, to get a unit hydrograph for a 2-hour storm. We have characterized our watershed; now we know how it will behave in a storm.



his

example, then you will do a similar homework.

UNIT-III

Ground Water

Ground Water

- ground water: the water that lies beneath the ground surface, filling the pore space between grains in bodies of sediment and clastic sedimentary rock, and filling cracks and crevices in all types of rock
- ground water is a major economic resource, particularly in the dry western areas of the US and Canada
- source of ground water is rain and snow that falls to the ground a portion of which percolates down into the ground to become ground water

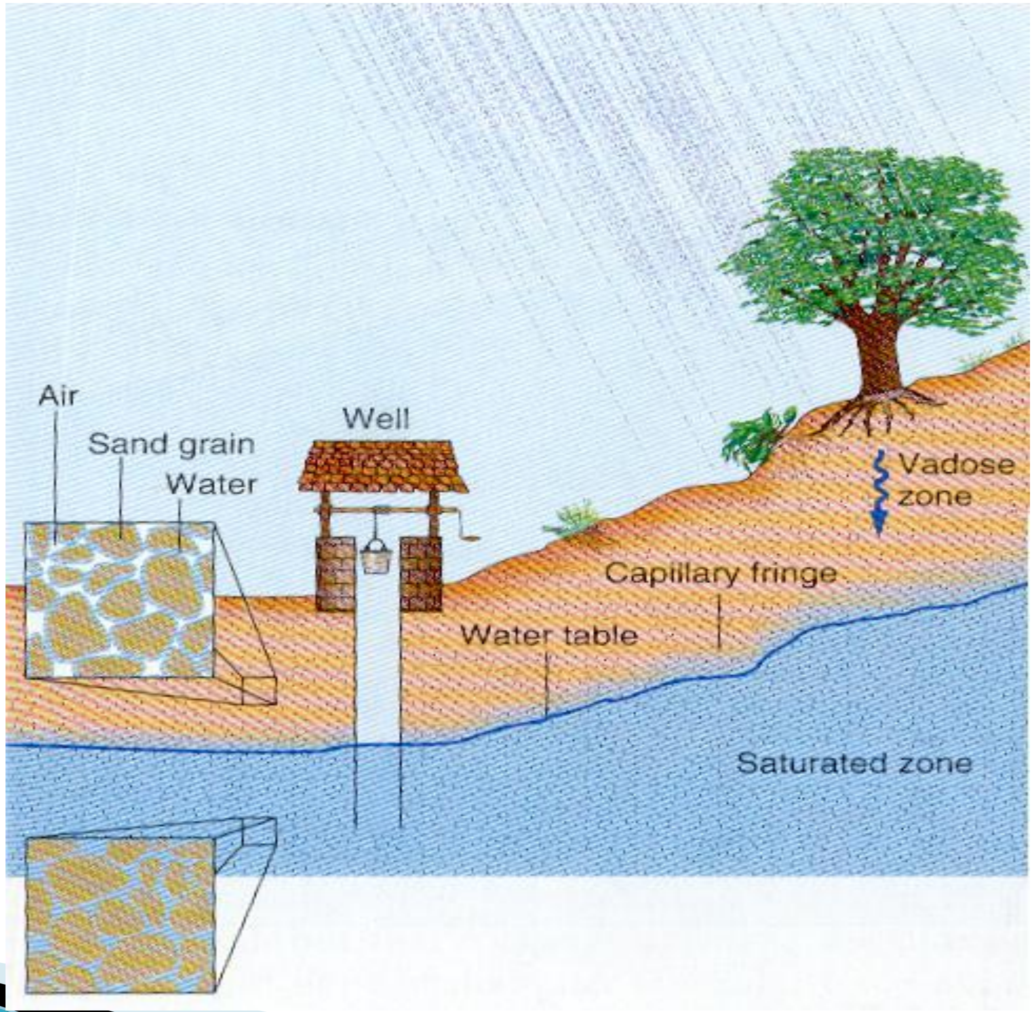
Porosity and Permeability

- porosity: the percentage of rock or sediment that consists of voids or openings
- permeability: the capacity of a rock to transmit a fluid such as water or petroleum through pores and fractures
- porous: a rock that holds much water
- permeable: a rock that allows water to flow easily through it
- impermeable: a rock that does not allow water to flow through it easily

The Water Table

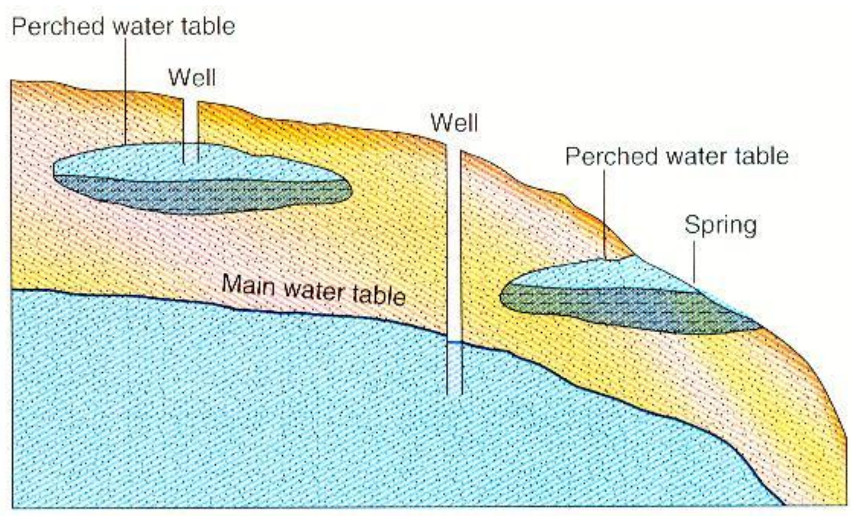
- saturated zone: the subsurface zone in which all rock openings are filled with water
- water table: the upper surface of the zone of saturation
- vadose zone: a subsurface zone in which rock openings are generally unsaturated and filled partly with air and partly with water; above the saturated zone
- capillary fringe: a transition zone with higher moisture content at the base of the vadose zone just above the water table

The Water Table (cont.)



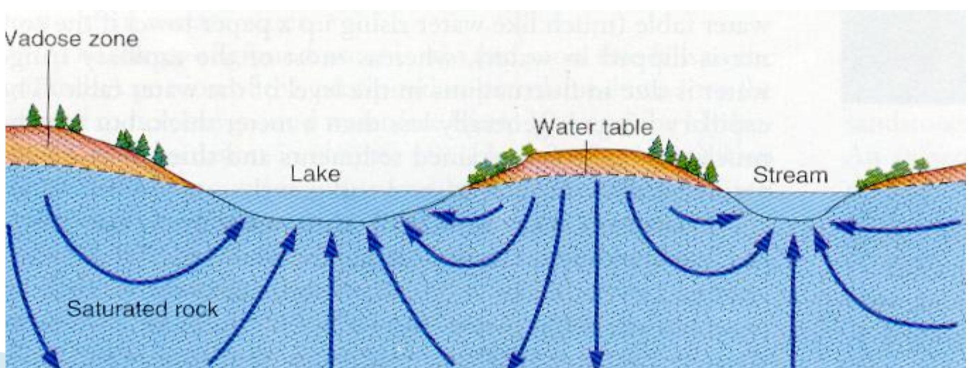
The Water Table (cont.)

- perched water table: the top of a body of ground water separated from the main water table beneath it by a zone that is not saturated



The Movement of Ground Water

- most ground water moves relatively slowly through rock underground
- because it moves in response to differences in water pressure and elevation, water within the upper part of the saturated zone tends to move downward following the slope of the water table



Move[illegible]f ground water beneath a sloping water table in uniformly permeable rock. Near the su[illegible]e ground water tends to flow parallel to the sloping water table

Movement of Ground Water (cont.)

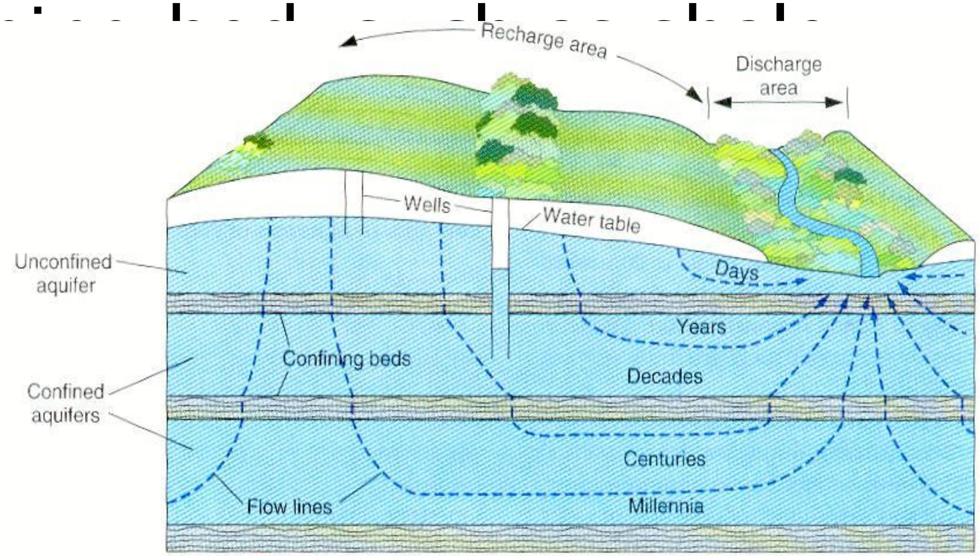
- factors affecting the flow of ground water:
  - the slope of the water table – the steeper the water table, the faster ground water moves
  - permeability – if rock pores are small and poorly connected, water moves slowly; when openings are large and well connected, the flow of water is more rapid

Aquifers

- aquifer: a body of saturated rock or sediment through which water can move easily
- good aquifers include sandstone, conglomerate, well-joined limestone, bodies of sand and gravel, and some fragmental or fractured volcanic rocks such as columnar basalt
- aquitards: when the porosity of a rock is 1% or less and therefore retards the flow of ground water

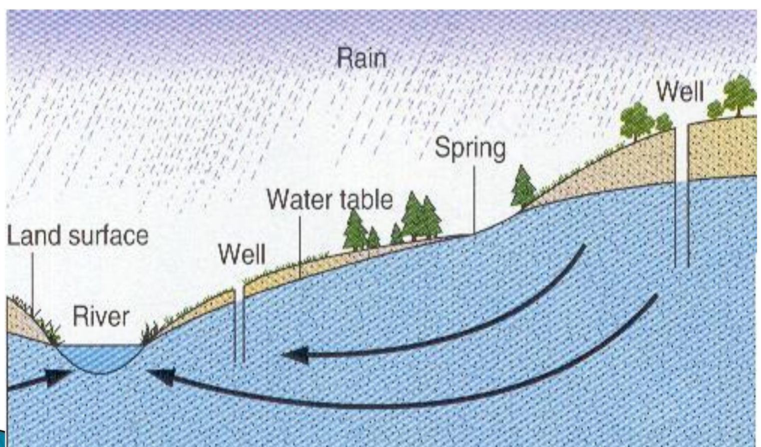
Aquifers (cont.)

- unconfined aquifer: a partially filed aquifer exposed to the land surface and marked by a rising and falling water table
- confined aquifer (artesian aquifer): an aquifer completely filled with pressurized water and separated from the land surface by a relatively impermeable confi

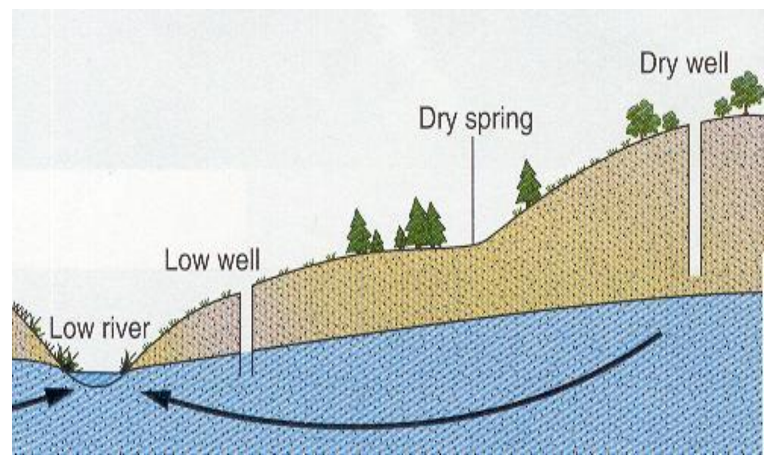


Wells

- well: a deep hole, generally cylindrical, that is dug of drilled into the ground to penetrate an aquifer within the saturated zone
- recharge: the addition of new water to the saturated zone
- the water table in an unconfined aquifer rises in wet seasons and falls in dry seasons as water drains out of the saturated zone into rivers



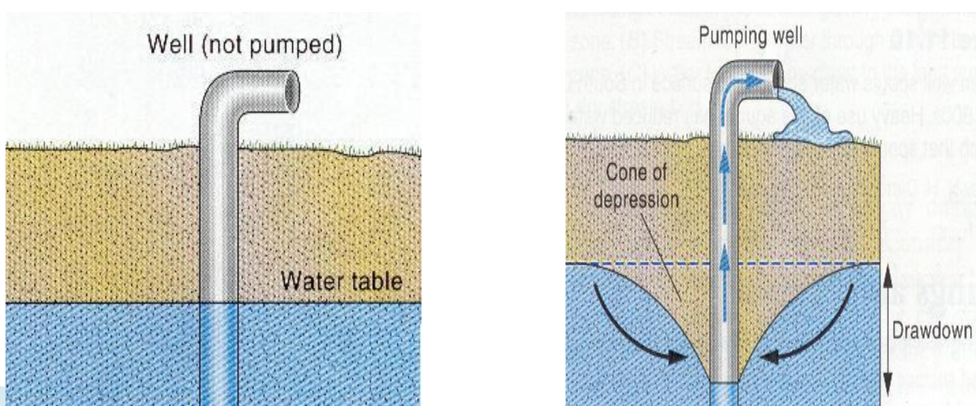
Wet season: water table and rivers are high; springs and wells flow readily



Dry season: water table and rivers are low; some springs and wells dry up

Wells (cont.)

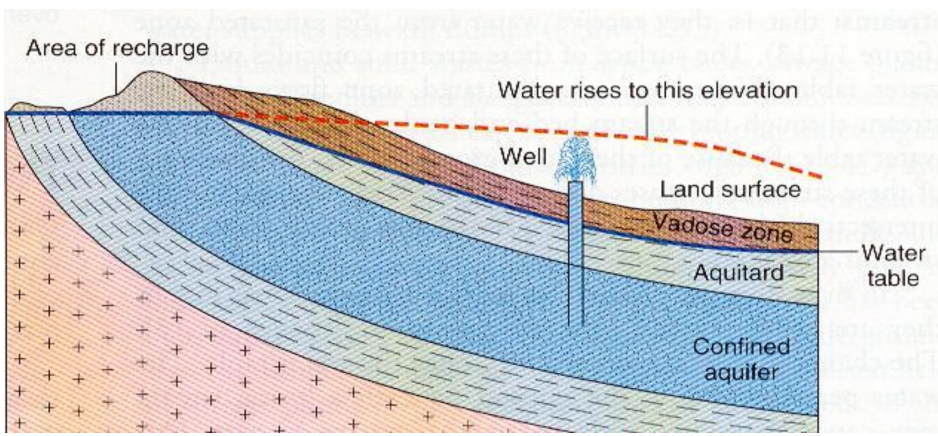
- cone of depression: a depression of the water table formed around a well when water is pumped out; it is shaped like an inverted cone
- drawdown: the lowering of the water table near a pumped well

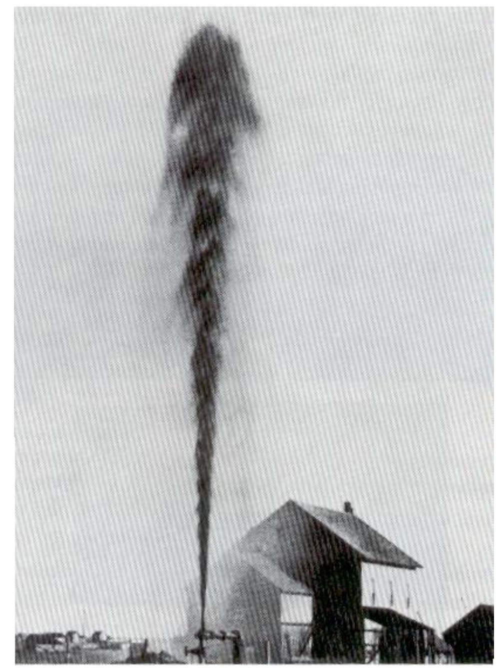


mping well lowers the water table into a cone of depression

Wells (cont.)

- artesian well: a well in which water rises above the aquifer

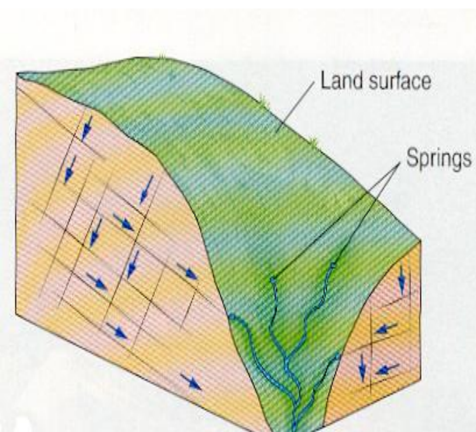




Artesian well spouts water above land surface in South Dakota, early 1900s. Heave use of this aquifer has reduced water pressure so much that spouts do not occur today

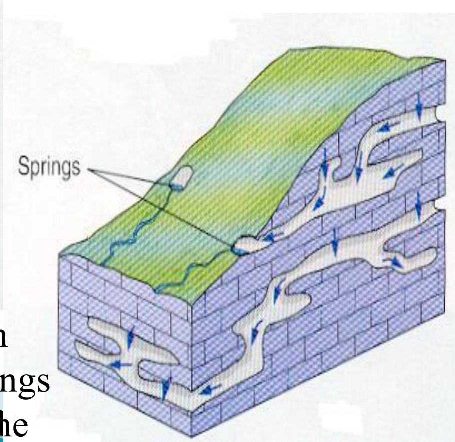
Springs and Streams

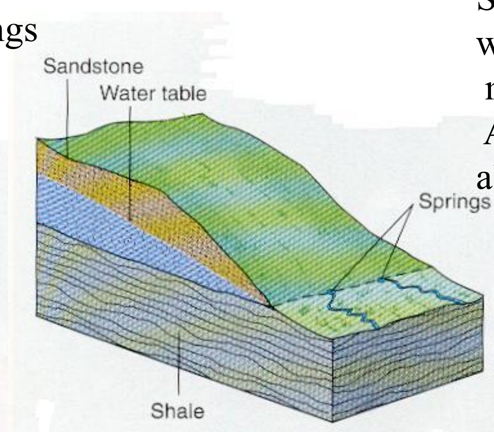
- spring: a place where water flows naturally from rock onto the land surface
- some springs discharge where the water table intersects the land surface, but they also occur where water flows out from caverns or along fractures, faults, or rock contacts that come to the surface



Water moves along fractures in crystalline rock and forms springs where the fractures intersect the land surface

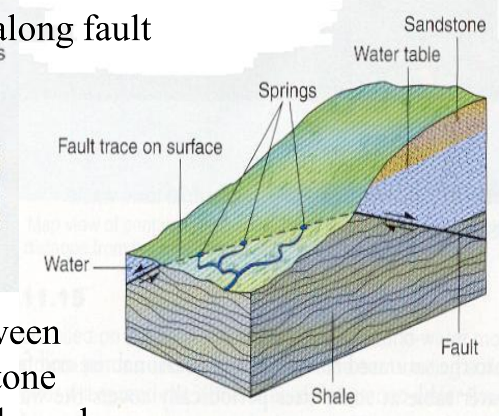
Water enters caves along joints in limestone and exits as springs at the mouths of caves





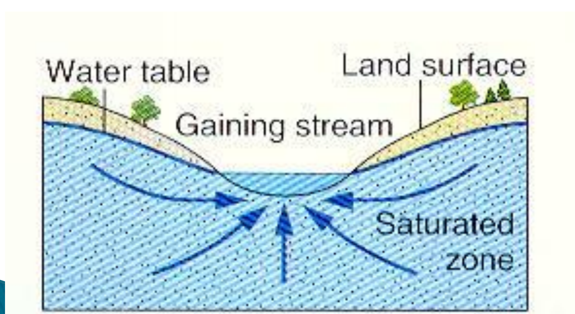
Springs form at the contact between a permeable rock such as sandstone and an underlying less permeable rock such as shale

Springs can form along faults when permeable rock has been moved against less permeable roc
Arrows show relative motion along fault

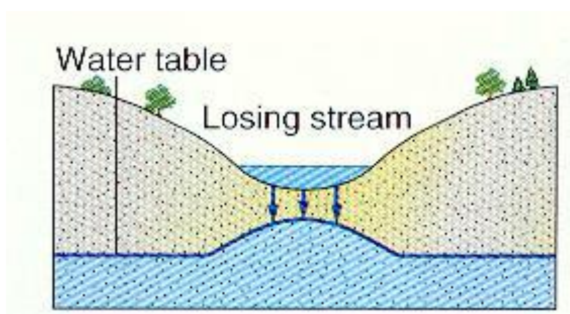


Springs and Streams (cont.)

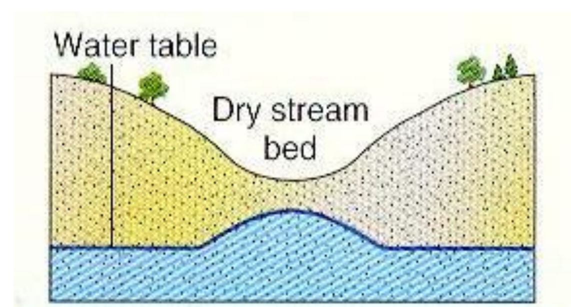
- gaining stream: a stream that receives water from the zone of saturation
- losing stream: a stream that looses water to the zone of saturation



Stream gaining water from saturated zone



Stream losing water through stream bed to saturated zone



Water table can be close to the land surface beneath a dry stream bed

Pollution of Ground Water

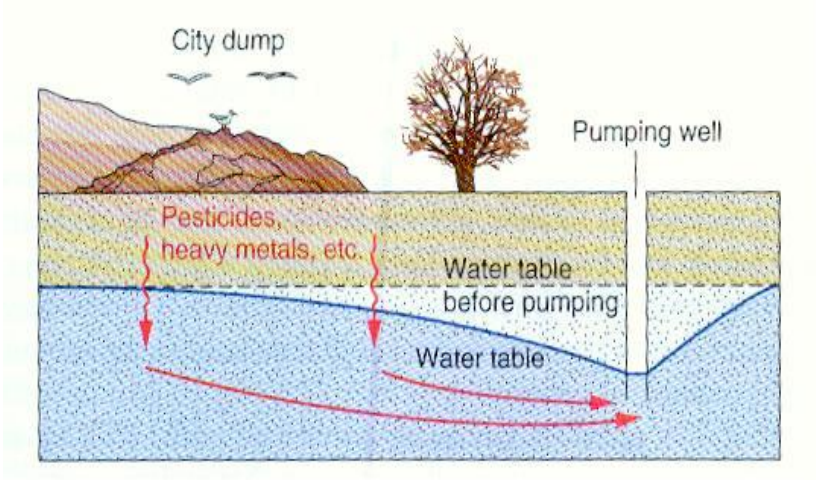
- pesticides, herbicides, fertilizers: chemicals that are applied to agricultural crops that can find their way into ground water when rain or irrigation water leaches the poisons downward into the soil
- rain can also leach pollutants from city dumps into ground-water supplies
- Heavy metals such as mercury, lead, chromium, copper, and cadmium, together with household chemicals and poisons, can all be concentrated in ground-water supplies beneath dumps

Pollution of Ground Water (cont.)

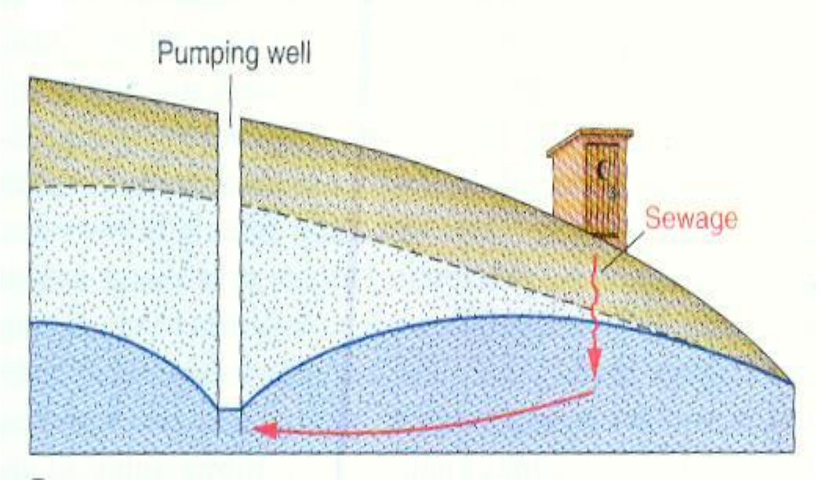
- liquid and solid wastes from septic tanks, sewage plants, and animal feedlots and slaughterhouses may contain bacteria, viruses, and parasites that can contaminate ground water
- acid mine drainage from coal and metal mines can contaminate both surface and ground water
- radioactive waste can cause the pollution of ground water due to the shallow burial of low-level solid and liquid radioactive wastes from the nuclear power industry

Pollution of Ground Water (cont.)

- pumping wells can cause or aggravate ground-water pollution



Water table steepens near a dump, increasing the velocity of ground-water flow and drawing pollutants into a well



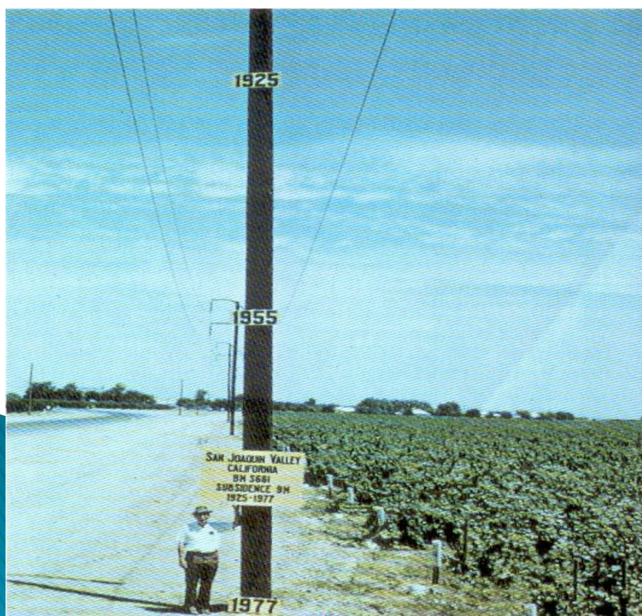
Water-table slope is reversed by pumping, changing direction of the ground-water flow, and polluting the well

Balancing Withdrawal and Recharge

- a local supply of groundwater will last indefinitely if it is withdrawn for use at a rate equal to or less than the rate of recharge to the aquifer
- if ground water is withdrawn faster than it is being recharged, however, the supply is being reduced and will one day be gone

Balancing Withdrawal and Recharge

- heavy use of ground water can result in:
    - a regional water table dropping
    - deepening of a well which means more electricity is needed to pump the water to the surface
    - the ground surface settling because the water no longer supports the rock and sediment



Subsidence of the land surface caused by the extraction of ground
water, near Mendota, San Joaquin Valley, CA. Signs on the
pole indicate the positions of the land surface in 1925, 1955, and
1977. The land sank 30 feet in 52 years.

Balancing Withdrawal and Recharge (cont.)

- to avoid the problems of falling water tables, subsidence, and compaction, many towns use artificial recharge to increase recharge; natural floodwaters or treated industrial or domestic wastewaters are stored in infiltration ponds in the surface to increase the rate of water percolation into the ground

Effects of Ground-Water Action

- caves (or caverns): naturally formed underground chamber
- most caves develop when slightly acidic ground water dissolves limestone along joints and bedding planes, opening up cavern systems as calcite is carried away in solution
- most caves probably are formed by ground water circulating below the water table

$$H_2O + CO_2 + CaCO_3 \Leftrightarrow Ca^{++} + 2HCO_3^-$$

water	carbon dioxide	calcite in limestone	calcium ion	bicarbonate ion

$\rightarrow$

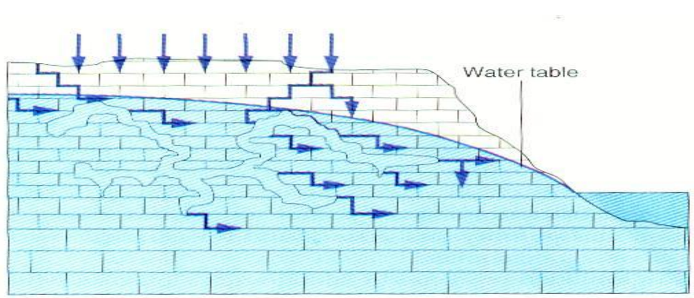
development of caves (solution)

$\leftarrow$

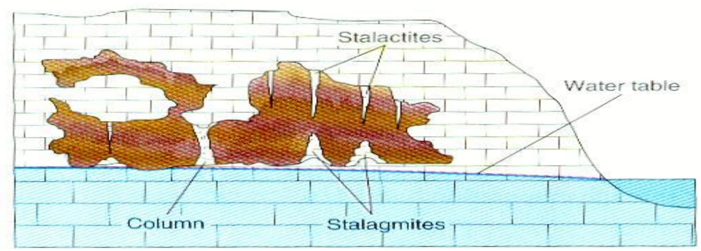
development of flowstone and dripstone (precipitation)

Effects of Ground-Water Action (cont.)

- stalactites: icicle-like pendants of dripstone hanging from cave ceilings, generally slender and are commonly aligned along cracks in the ceiling, which act as conduits for ground water
- stalagmites: cone-shaped masses of drip-stone formed on cave floors, generally directly bel



Water moves along fractures and bedding planes in limestone, dissolving the limestone to form caves below the water table



Falling water table allows cave system, now greatly enlarged, to fill with air. Calcite precipitation forms stalactites, stalagmites, and columns above the water table

Effects of Ground-Water Action (cont.)

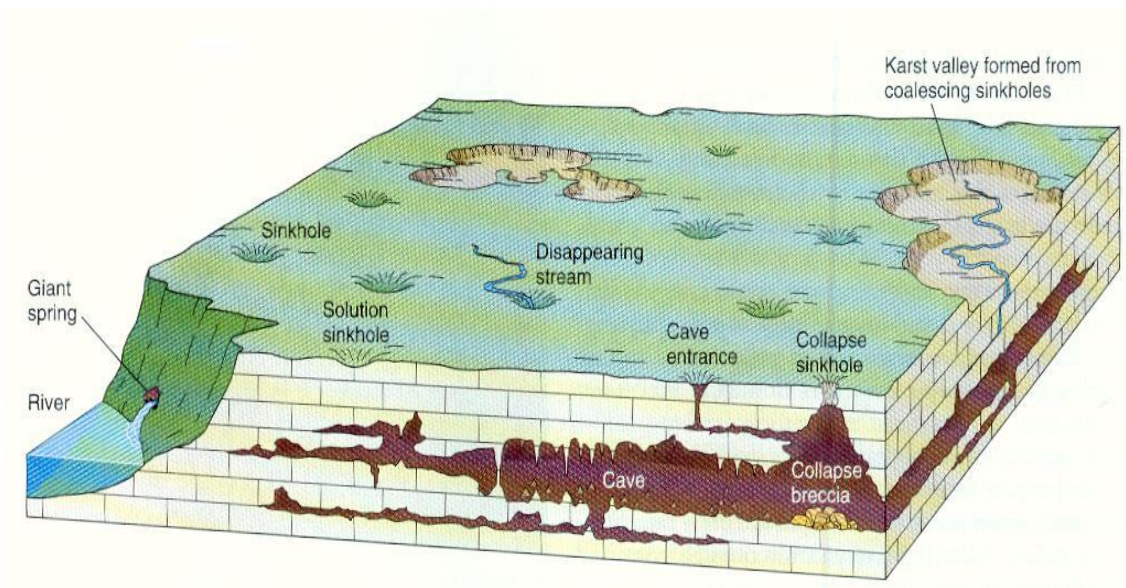
- sinkholes: closed depressions found on land surfaces underlain by limestone; they form either by the collapse of a cave roof or by solution as descending water enlarges a crack in limestone

A collapse sinkhole that formed suddenly in Winter Park, Florida, in 1981

Trees grow in a sinkhole formed in limestone near Mammoth Cave, Kentucky

Effects of Ground-Water Action (cont.)

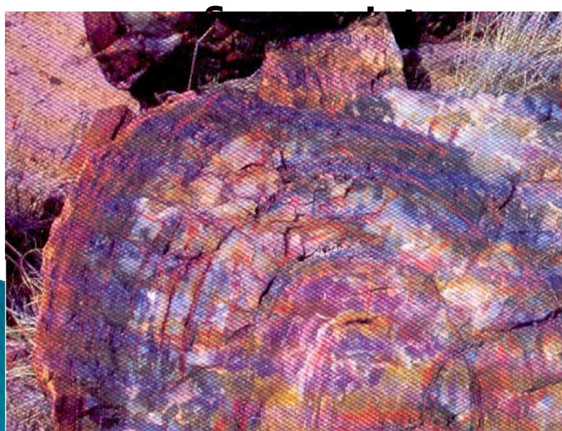
- karst topography: an area with many sinkholes and with cave systems beneath the land surface



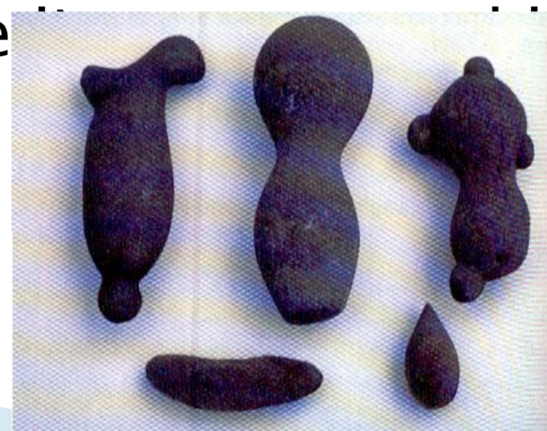
Karst topography is marked by underground caves and numerous surface sinkholes. A major river may cross the region, but small surface streams generally disappear down sinkholes

Effects of Ground-Water Action (cont.)

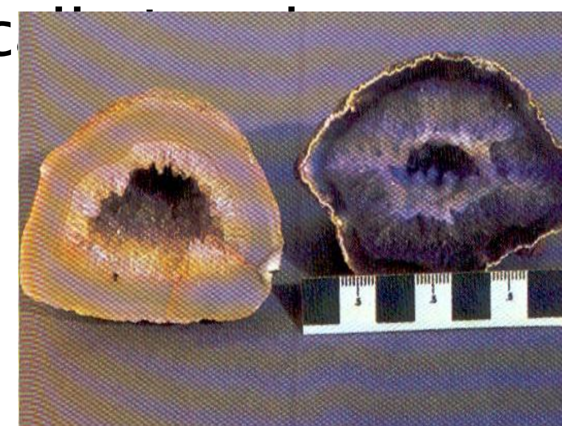
- petrified wood: develops when porous buried wood is either filled in or replaced by inorganic silica carried in by ground water
- concentration: a hard, round mass that develops when a considerable amount of cementing material precipitates locally in a rock, often around an organic nucleus
- geodes: partly hollow, globe-shaped bodies



Petrified log



tions that have weathered out of shale



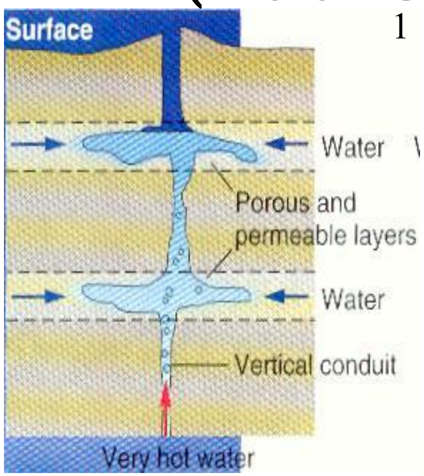
Geodes

Hot Water Underground

- hot springs: springs in which the water is warmer than human body temperature
- water can gain heat in two ways while underground:
  - ground water may circulate near a magma chamber or a body of cooling igneous rock
  - ground water may circulate unusually deep in the earth

Hot Water Underground

- geyser: a type of hot spring that periodically erupts hot water and stream; the water is generally near boiling (100°C)



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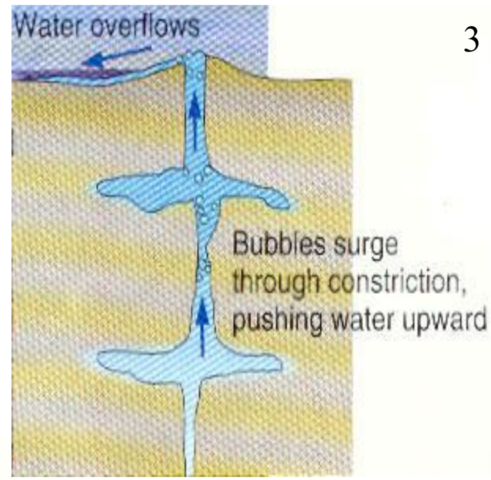

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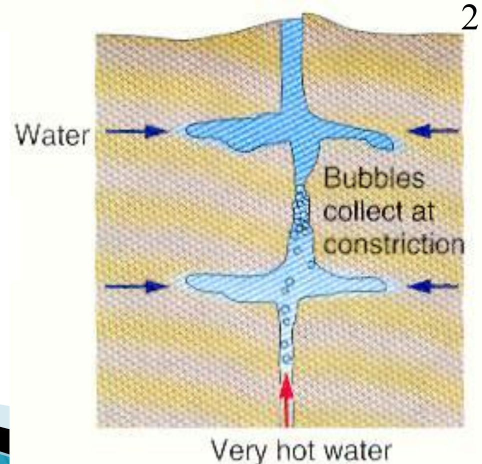

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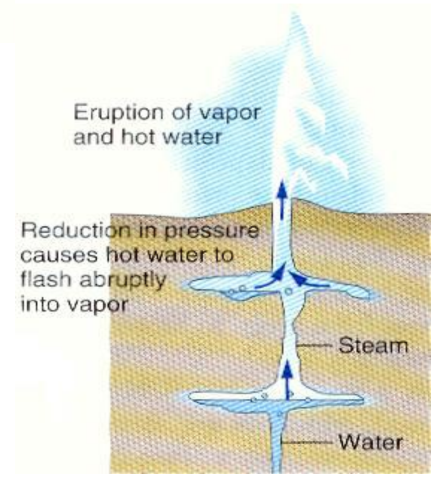


4

Geothermal Energy

- Electricity can be generated by harnessing naturally occurring stream and hot water in areas that are exceptionally hot underground (geothermal areas);
- nonelectric uses of geothermal energy include space heating, as well as paper manufacturing, ore processing, and food preparation

Ground Water

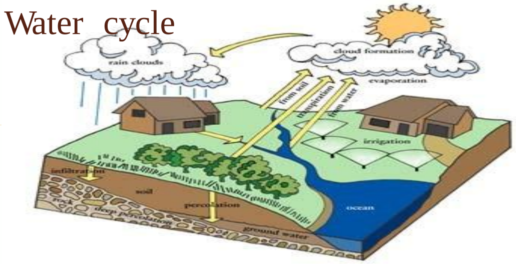
UNIT–IV

SOIL WATER–PLANT RELATIONSHIP

Soil, Plant & Water Relationships

Dr. Ron Sheffield
LSU Ag Center, Biological & Agricultural Engineering rsheffield@agcenter.lsu.edu

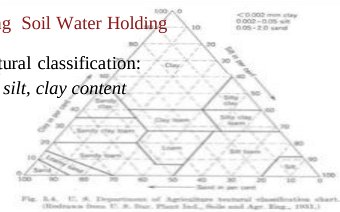
Water cycle



Soil, Plant & Water Relationships

Understanding Soil Water Holding Capacity

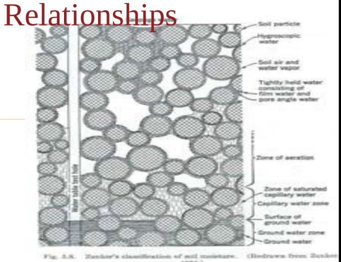
- Soil textural classification:
  - *Sand, silt, clay content*



Soil, Plant & Water Relationships

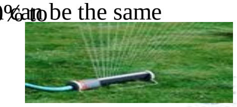
Understanding Soil Water Holding Capacity

- Soil textural classification:
  - Sand, silt, clay content
  - Voids (air spaces) in the soil
  - How water is held in the soil



Porosity

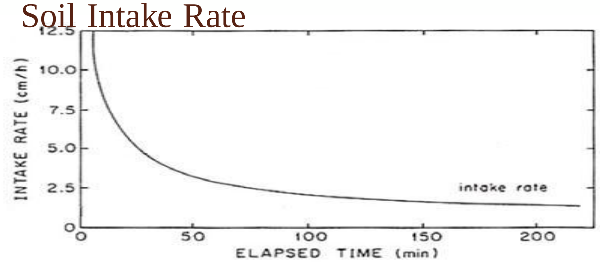
- Porosity is a measure of how much pore space exists in the soil
- Volume of pores/volume of the soil x 100
- Porosity is given as % and may be 30% to 40% in soil and higher in artificial media
  - Porosity of a clay and a silt loam can be the same



Permeability

- How fast can water move into/through the soil (inches/hour)?
- Higher in dry soil/lower in wet soil
- Higher in soils with larger pore spaces (sands, loams, amended soils, potting mix)
- Lower in soils with smaller pore spaces (silts, clays, compacted soil or soil layer)

Soil Intake Rate



Permeability

- Saturated permeability for clay soils may be <0.06”/hour
- Saturated permeability for silt loam soils may be 0.2”/hour
  - Permeability generally declines with compaction, rainfall, irrigation, increased moisture content, decreased organic matter or amendments, and increased density

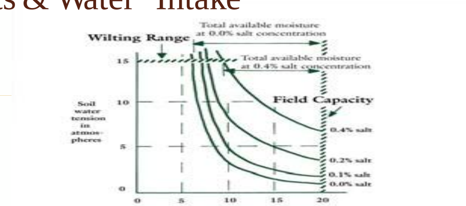
Compaction

- Compaction reduces porosity, infiltration, and water holding capacity
- Compaction can be increased by traffic, tillage, impact (mechanical or hydraulic), and chemical changes (sodium, calcium)

Salts

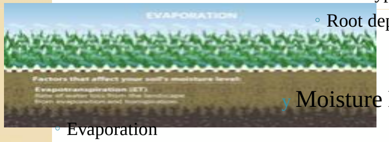
- Due to the dissolved ions in salty water it takes more pressure for water taken up into plants
- As salt concentrations increase it reduces the availability of water to plants

Salts & Water Intake



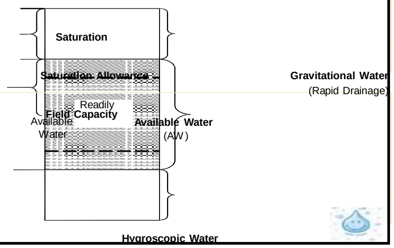
Soil is a Reservoir

- Capacity
  - Soil type
  - Root depth

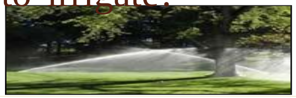


- Moisture Level
  - Evaporation
  - Rain
  - Irrigation

The Soil Reservoir



Why do we want to irrigate?



To replace rain water that has evaporated.

Evapotranspiration (ET)

- Evaporation of water from the soil or plants surfaces and transpired from leaves.
- It is typically measured in inches
- Weather conditions affect ET:
  - Solar radiation
  - Temperature
  - Wind
  - Humidity

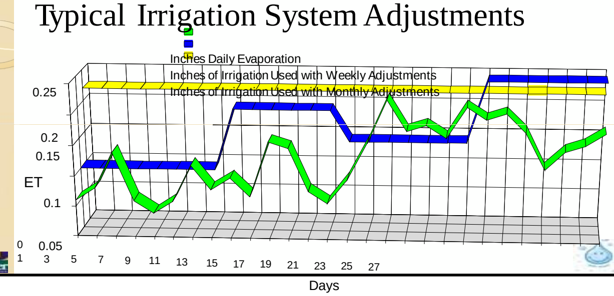
Effective Rain Fall

- Measurement of rain is as important as the measurement of ET
- Rainfall that runs off is NOT effective rain
  - Soil percolation rate and slope limit effective rain.
- Rainfall replenishes soil moisture
- Rain that soaks below the roots is NOT effective rain
  - A soil moisture balance calculation determines when the root zone is saturated.

Irrigation Requirement

- ET – Effective Rain = Irrigation Requirement
- The Irrigation Requirement is met when sprinklers run long enough to return the soil moisture level back to desired levels – no more / no less.

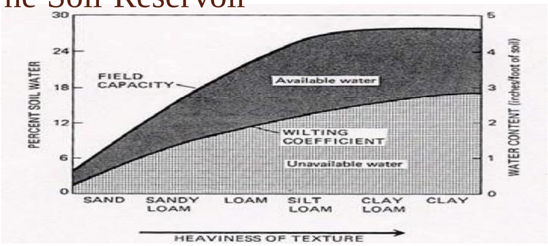
Typical Irrigation System Adjustments



Benefits of ET-Based Water Management

- Efficient Water Use
  - Save Money
  - Preserve Natural Resources
- Healthy Landscapes
  - Watered when needed
  - Watered right

The Soil Reservoir



ORGANIC MATTER &

Soil, Plant & Water Relationships

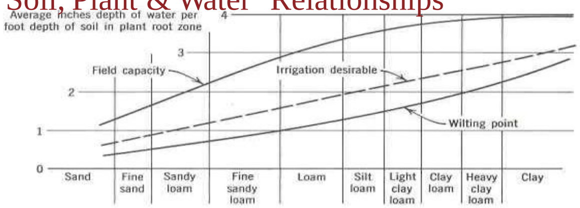


Fig. 5.12. Simplified comparison of the water-holding characteristics of different textured soils. (Courtesy U. S. Department of Agriculture, 1955.)

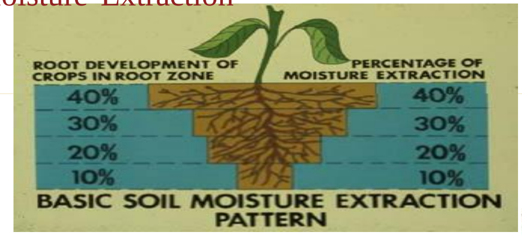
Soil, Plant & Water Relationships

Table 3.1. Range in available water-holding capacity of soils of different texture

Soil texture	Water-holding capacity: Range mm/m	Water-holding capacity: Average mm/m
1. Very coarse texture—very coarse sands	33 to 62	42
2. Coarse texture—course sands, fine sands, and loamy sands	62 to 104	83
3. Moderately coarse texture—sandy loams	104 to 145	125
4. Medium texture—very fine sandy loams, loams, and silt loams	125 to 192	167
5. Moderately fine texture—clay loams, silty clay loams, and sandy clay loams	145 to 208	183
6. Fine texture—sandy clays, silty clays, and clays	133 to 208	192
7. Peats and mucks	167 to 250	208

NOTE: 1 mm/m = 0.012 in./ft.

Moisture Extraction

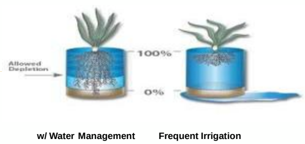


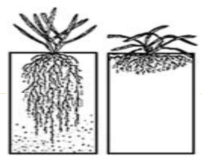
Soil, Plant & Water Relationships

Where do plants get their water?

- Soil root zone = available water
  - 1.5 inches of water can be held in the soil (per foot of soil) ~ 0.75 in. of that is *available*
- Typical sandy soils:
  - Typical root zone: 1 to 1.5 ft.

Water Management





w/ Water Management Frequent Irrigation

Soil, Plant & Water Relationships

Concept:

- MAD – Management-allowed deficit/depletion
  Percentage of available water within the soil that you will allow to be removed before you irrigate
- MAD %
  - 25-40, Shallow-rooted, high value fruit and vegetable crops
  - 40-50, Orchards, vineyards, berries, ornamentals, and medium rooted row crops
  - 50, mature trees, forage crops, grain crops, and deep-rooted row crops

Soil, Plant & Water Relationships

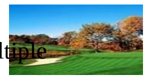
How much do you apply during an irrigation?:

$$d_x = (MAD/100) * W_a * Z$$

d_x = maximum net depth of water to be applied per irrigation (mm/inches)
MAD = management-allowed depletion (%)
W_a = available water-holding capacity of the soil (mm/m or in./ft)
Z = effective root depth, (m or ft)

Slope effects

- Sloping terrain will increase the chance of runoff water infiltration
  - The greater the slope, greater will the problems will be
  - Consider splitting irrigation in multiple cycles



Soil, Plant & Water Relationships

UNIT –V
IRRIGATION AND CANAL DESIGN

DEFINITION

- **An artificial channel filled with water and designed for navigation, or for irrigating land,etc.**

- **An artificial watercourse or extensively modified natural channel used for inland water transport and/or the control and diversion of water for drainage or irrigation**

A canal boat traverses the longest and highest aqueduct in the UK.

TYPES OF CANAL

(BASED ON USE)

. *There are two types of canal:*

- ❖**Aqueducts**: **water supply canals that are used for the conveyance and delivery of potable water for human consumption, municipal uses, and agriculture irrigation.**

- ❖**Waterways**: **navigable transportation canals used for carrying ships and boats shipping goods and conveying people.**

TYPES OF CANAL

(BASED ON DISCHARGE)

- MAIN CANAL
- BRANCH CANAL
- MAJOR DISTRIBUTARY
- MINOR DISTRIBUTARY
- WATER COURSE OR FIELD CHANNEL

MAIN CANAL

- **Main Canal takes off directly from the upstream side of weir head works or dam.**

- **Usually no direct cultivation is proposed**

The Danube-Black Sea Canal in Romania

The Alter Strom, in the sea resort of Germany

BRANCH CANAL

- ❖ **All offtakes from main canal with head discharge of 14-15 cumecs and above are termed as branch canals.**

- ❖ **Acts as feeder channel for major distributaries**

A BRANCH CANAL IN MADRAS

MAJOR DISTRIBUTARY

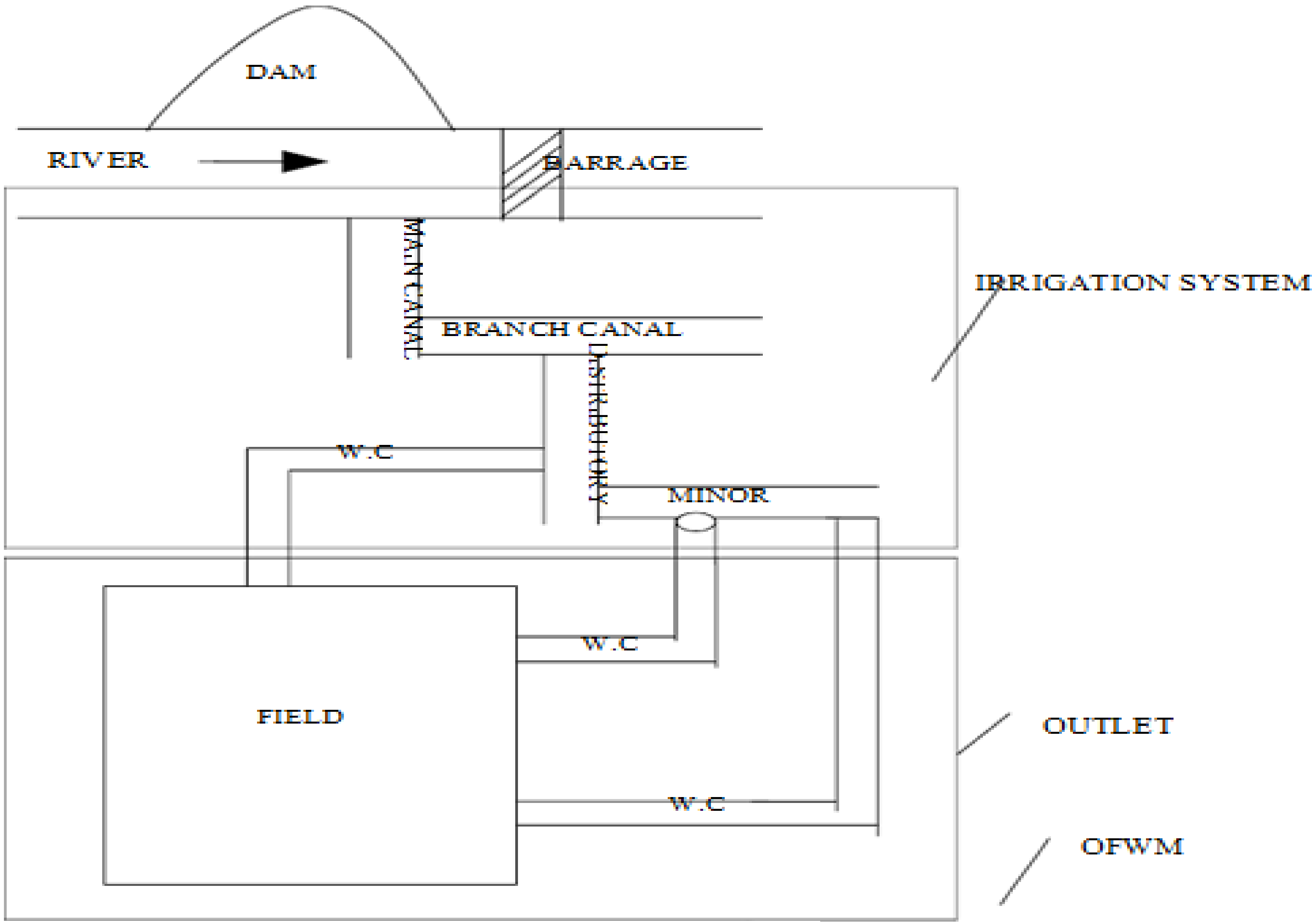
- All offtakes from main canal or branch canal with head discharge from 0.028 to 15 cumecs are termed as major distributarie

MINOR DISTRIBUTARY

- All offtakes taking off from a major distributary carrying discharge less than 0.25 cumec are termed as minor distributaries

WATER COURSE

- Small channels which carry water from the outlets of a major or minor distributary or a branch canal to the fields to be irrigated.



OFWM – ON FARM WATER MANAGEMENT

W.C – WATER COURSE

TYPES OF CANAL

(Based on Lining being Provided or not)

1. **Unlined canals**

2. **Lined canals**

UNLINED CANAL

- **An unlined canal is the one which has its bed and banks made up of natural soil through which it is constructed and not provided with a lining of impervious material**

Disadvantages of unlined canals

- **Water velocities higher than 0.7 m/s are not tolerable because of erosion. The low operating velocities require large cross-sectional areas**
- **High seepage and conveyance water losses result in waterlogging of adjacent land.**
- **Danger of canal bank breakage caused by overtopping, erosion and animal burrowing.**
- **Profuse growth of aquatic weeds retards the flow and causes heavy maintenance cost.**

ILL-EFFECTS OF WATER LOGGING

1. Water seeping from canals down to the soil below may, at times, raise the ground water very close to the ground level.

2. This may result in blocking all the voids in the soil and obstructing the plant roots to breathe.

3. Normal cultivation operations, such as tilling, ploughing, etc. cannot be easily carried out in wet soils.

Seepage and conveyance water losses

Canal side breakage due to animal burrowing

Profuse weed growth, and too closely sited settlements

All these reasons lead to adoption of lining of canals, though the cost may be prohibitive. Hence, before suggesting a possible lining for a canal, it is necessary to evaluate the cost vis-à-vis the savings due to reduction in water loss through seepage.

LINED CANAL

- **A lined canal is provided with a lining of impervious material on its bed and banks to prevent the seepage of water**

Types of canal lining

1. Concrete lining

2.Shotcrete lining

3.Brick or burnt clay tile lining

4. Boulder Lining

A PICTURE OF A LINED CANAL

Irrigation canal layout

- ❖As far as possible, curves should be avoided in the alignment of canals
- ❖The curves lead to disturbance of flow and a tendency to silt on the inner bend and scour the toe of the outer (concave) bend.
- ❖If curves have to be provided; they should be as gentle as possible.
- ❖The permissible minimum radius of curvature for a channel curve is shorter for lined canals than unlined ones
- ❖The alignment should be such that the cutting and filling of earth or rock should be balanced, as far as possible.

Type of canal	Capacity of canal (m^3/s)	Minimum radius (m)
Unlined canals	80 and above	1500
	30 to 80	1000
	15 to 30	600
	3 to 15	300
	0.3 to 3	150
	Less than 3	90
Lined canals	280 and above	900
	200 to 280	750
	140 to 200	600
	70 to 140	450
	40 to 70	300
	10 to 40	200
	3 to 10	150
	0.3 to 3	100
	Less than 0.3	50

Drainage of land for Canal Irrigation

- ❖A proper design of canal irrigation system should also consist provision of a suitable drainage system for removal of excess water.

- ❖The drainage system help to drain out storm water as well, and thus to prevent its percolation and to ensure easy disposal.

TYPES OF DRAINAGE SYSTEM

- **Surface Drainage**

  - ✓ **These constitute open ditches, field drains, proper land grading and related structures.**
  - ✓ **Land grading, or properly sloping the land towards the field drains, is an important method for effecting surface drainage.**

TYPES OF DRAINAGE SYSTEM

❖ Sub-Surface Drainage

✓ These are installed to lower the water table
✓ Consists of underground pipes which collect water and remove it through a network of such pipes.

Impact of Irrigation

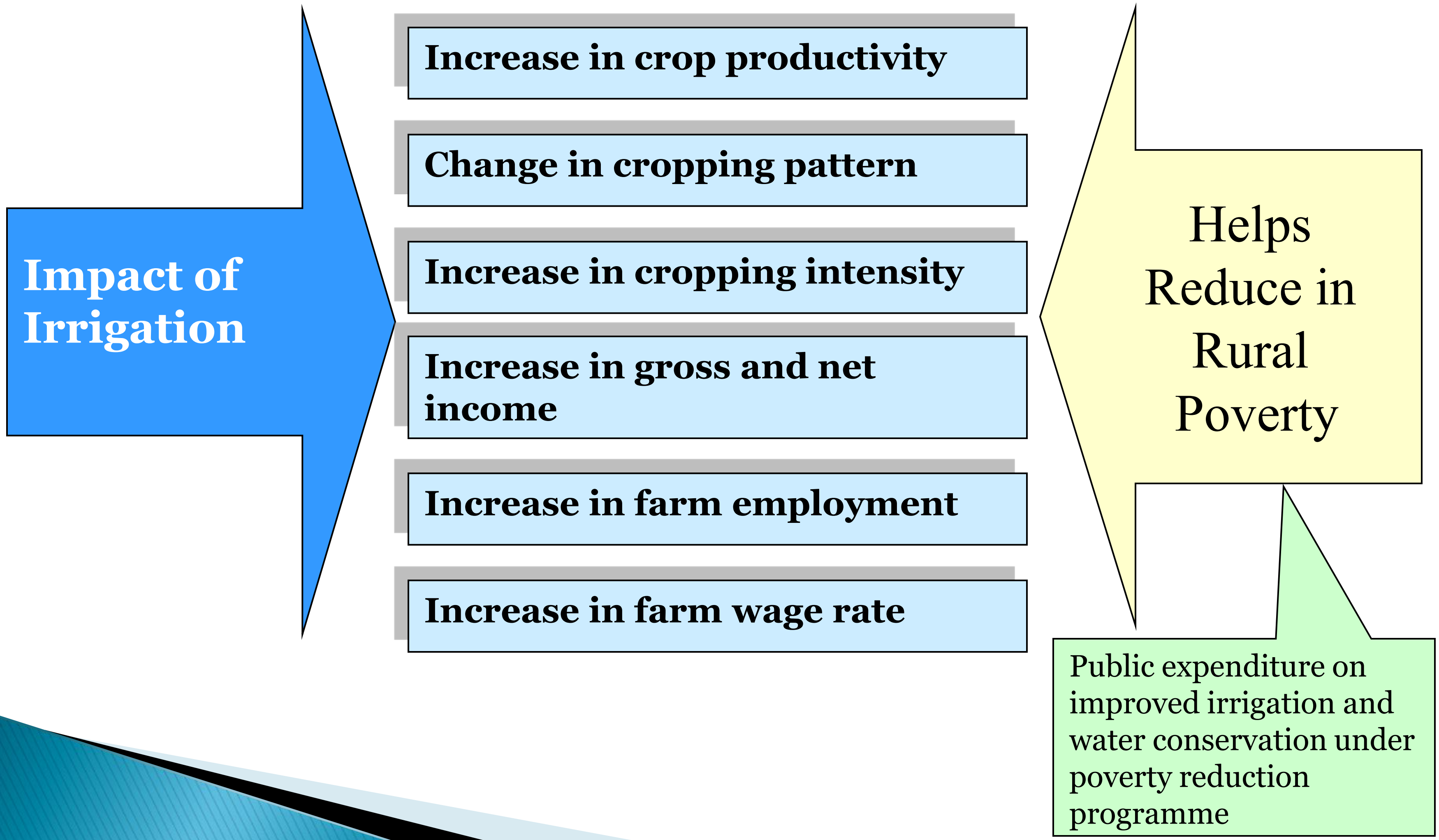


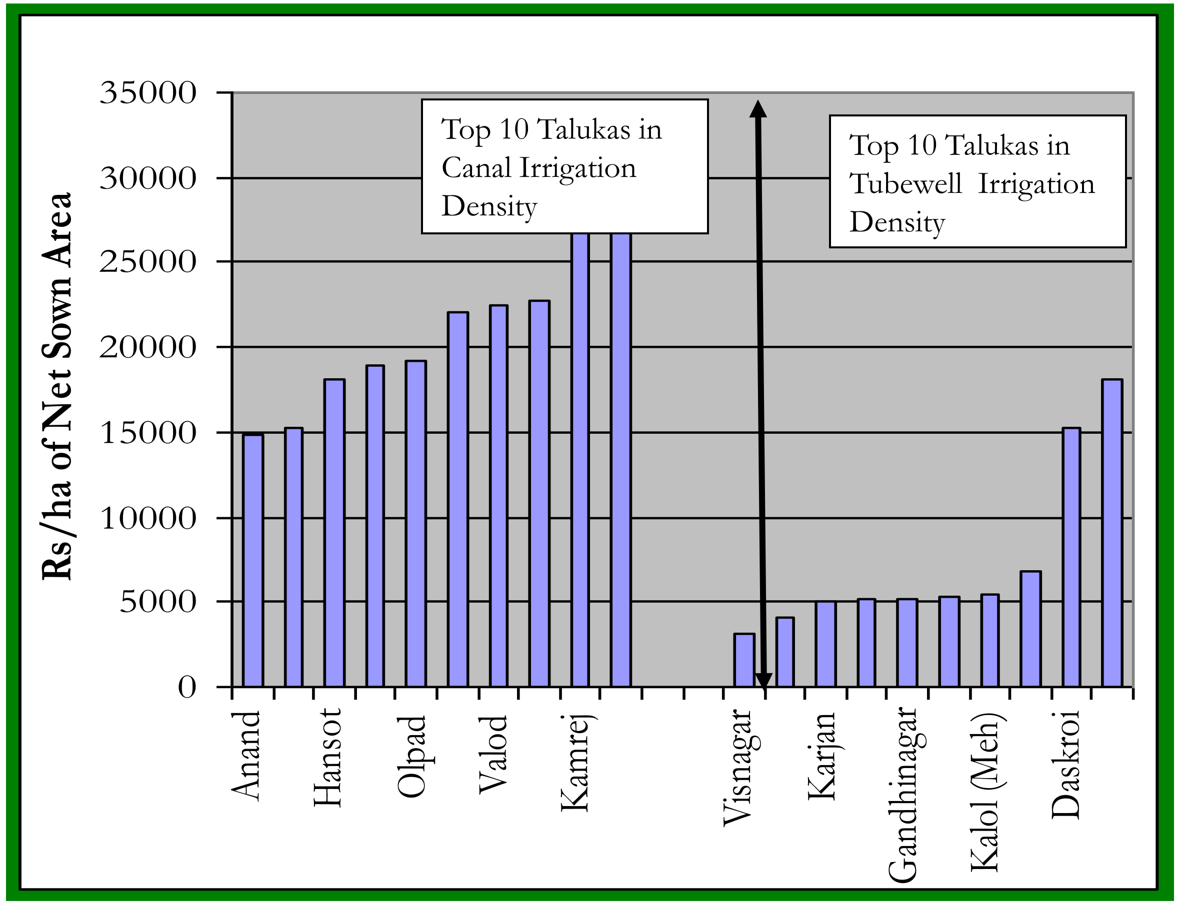
Table 8: average production cost for different crops

Items	Alfalfa	Okra	Tomato	Cucumber	Eggplant
	Cost US$/ha	Cost US$/ha	Cost US$/ha	Cost US$/ha	Cost US$/ha
Tillage	39	39	39	39	39
Seeds	173	13	13	13	13
Fertilizers	24	48	48	48	48
Fuel	450	397	397	397	397
Labour	96	49	49	49	49
Lubricant & oil	20	20	20	20	20
Spare parts	20	20	20	20	20
Transportation, tax...etc	00	400	400	400	400
Total production cost	822	986	986	986	986
Total income	2,851	1,551	2,400	1,200	1,330
Profit	2,029	565	1,414	214	344

A COMPARITIVE STUDY BETWEEN CANAL IRRIGATION & GROUNDWATER IRRIGATION

Land Productivity in Canal and GW Irrigation

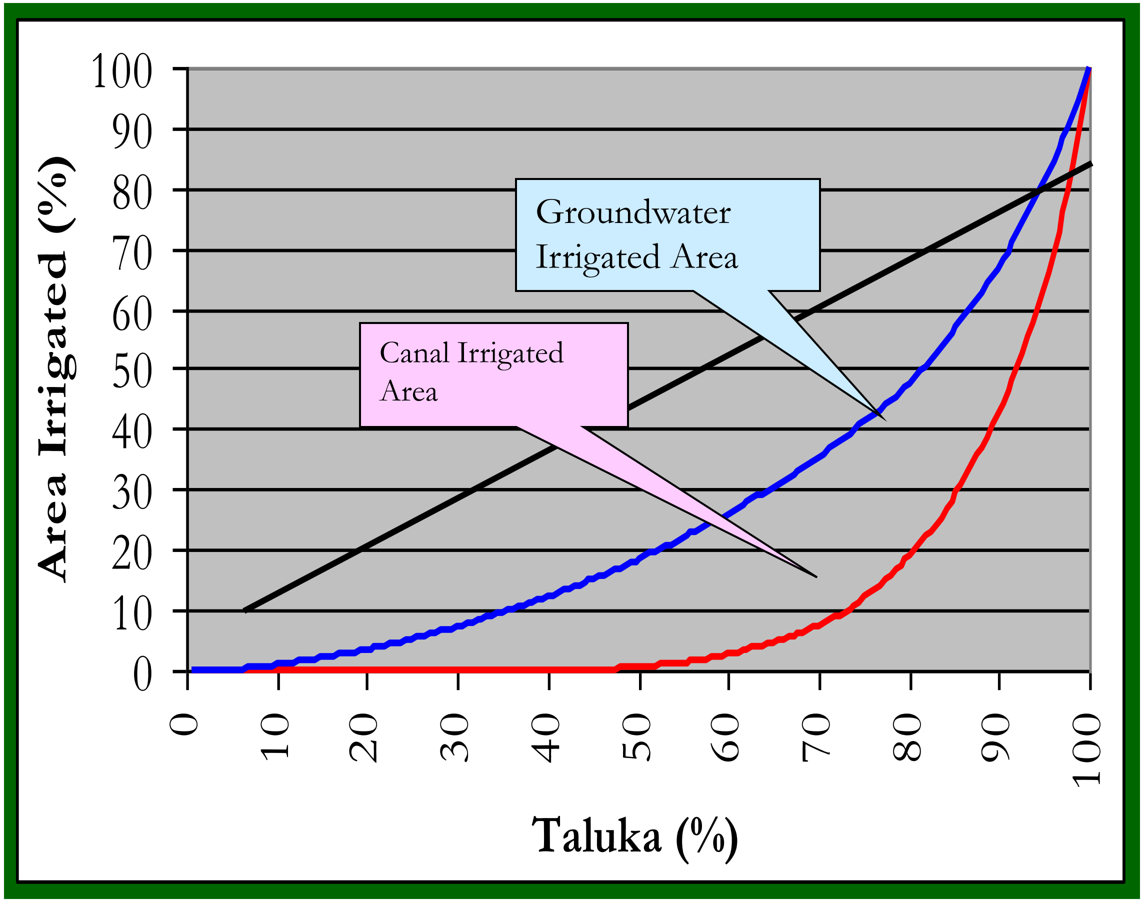
- ❖ **Higher land productivity in talukas with higher canal Irrigation density**
- ❖ **Lower land productivity in talukas with higher GW irrigation density**



DATA BASED ON TALUKAS OF GUJARAT

Distribution of GW and Canal Irrigation in Gujarat

- ❖ **95% of Gujarat's canal irrigation is concentrated in 20% talukas**
- ❖ **Canal systems imply "All for some"**
- ❖ **Groundwater irrigation imply "Some for all"**



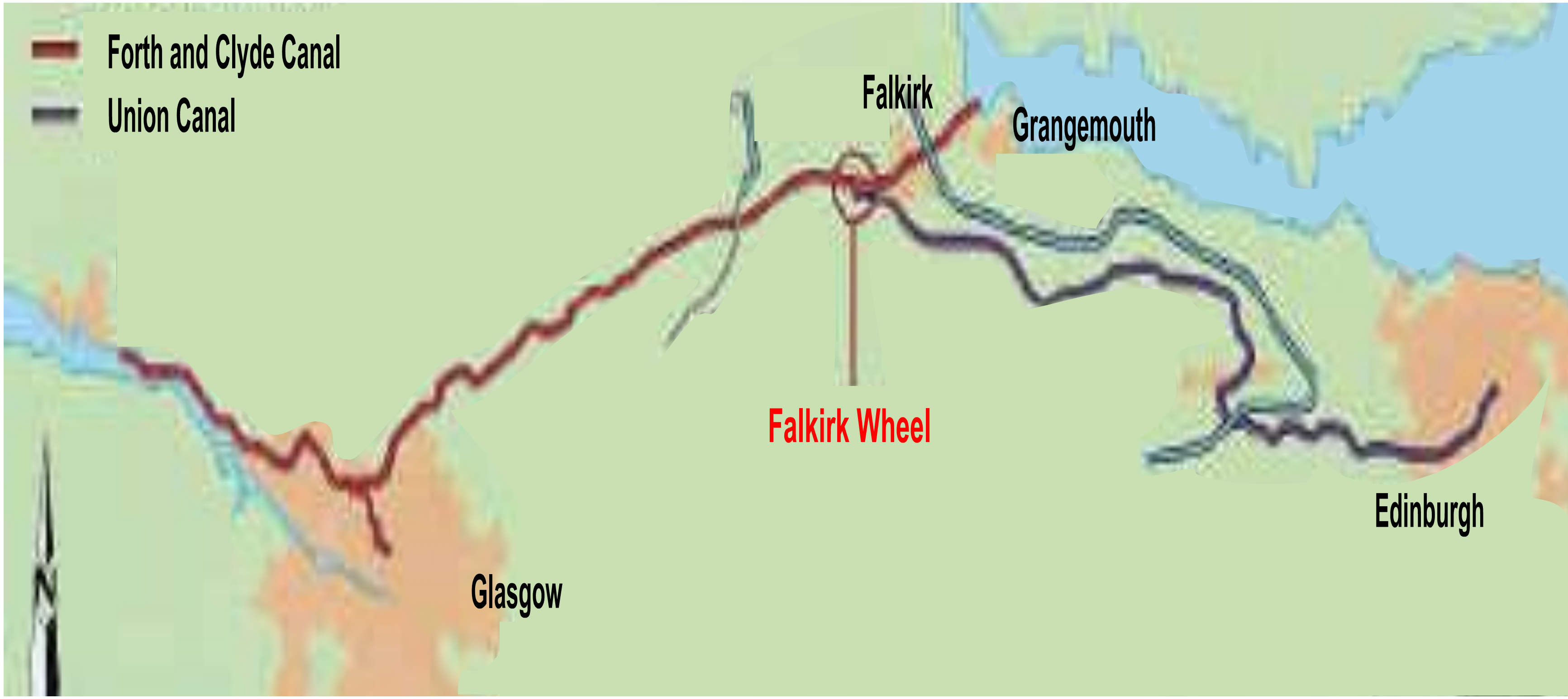
THE SCENARIO IS GRADUALLY CHANGING WITH THE COMING UP OF THE SARDAR SAROVAR(NARMADA) PROJECT

CANAL

A PROBLEM

&

ITS SOLUTION



At the beginning there were two canals:

Canal Forth and Clyde was built in 1777

Canal Union between Falkirk and Edinburgh was finished in 1822

Because of geographical difficulties,
which created a difference of 79ft.in elevation,
the two canals were connected by 11 locks.

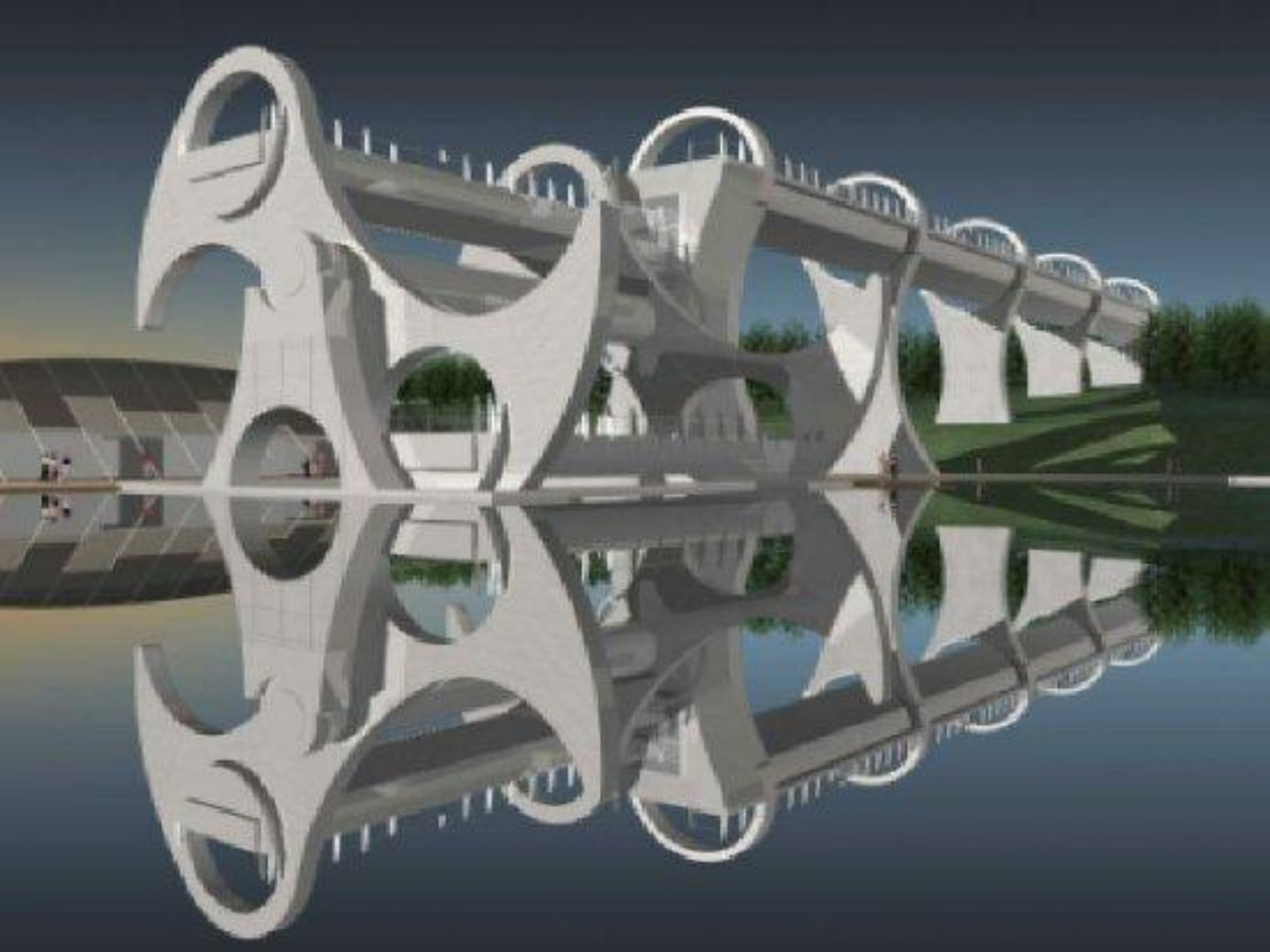
In 1963, after 150 yrs of existence of this water way with 11 locks the construction of a huge water carousel started.

This extraordinary idea was finished in 2002 and became a symbol of Scotland.

This invention saves not only time but also energy.

&

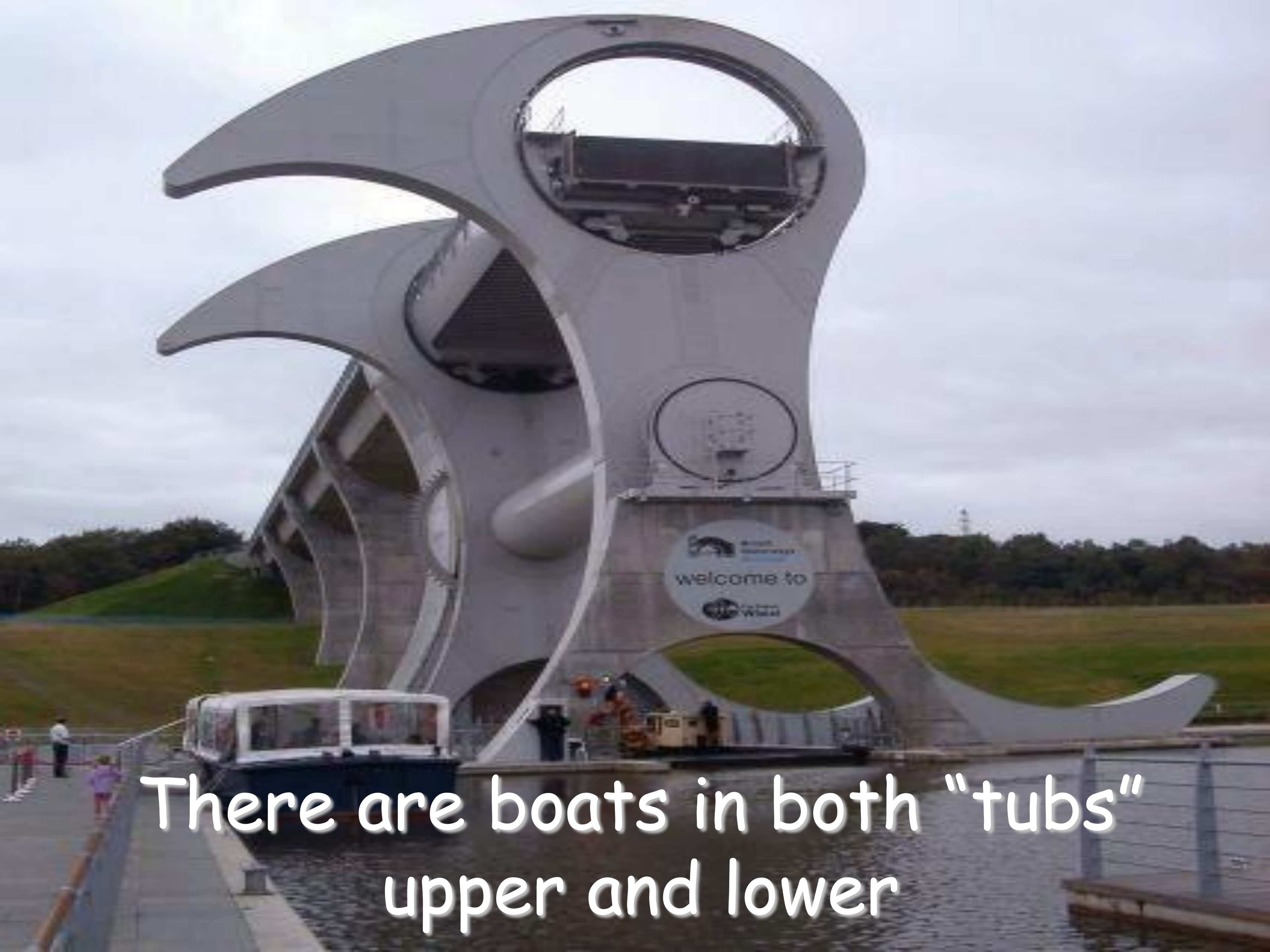
THE RESULT IS



This is the only rotational boat transporter in the world.
It has two arms and each arm forms a kind of huge tub filled with water.
Boats enter the tub, then the tub locks up and the huge arm starts rotating.

Entrance to lower canal

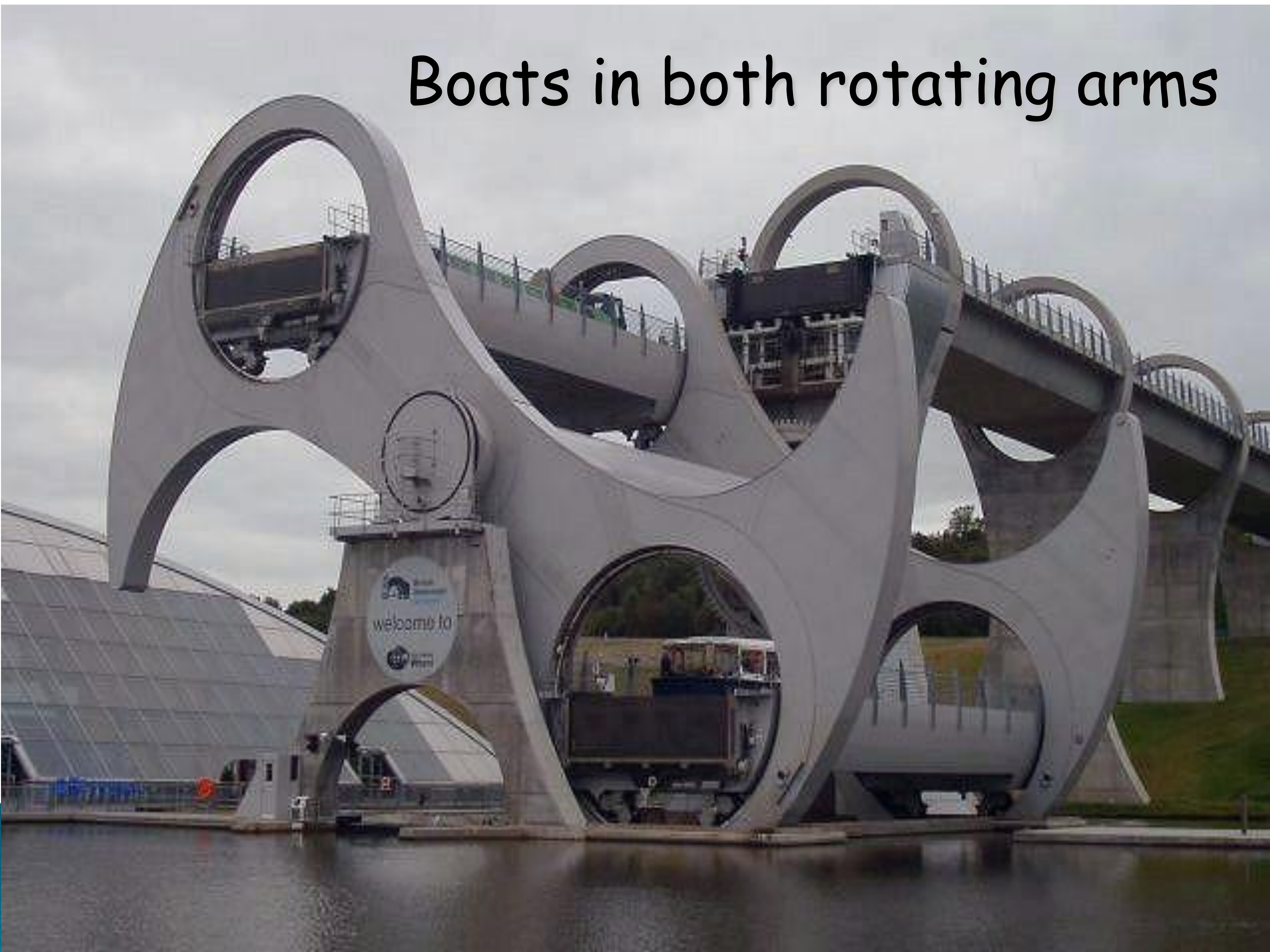
A Boat is approaching the upper“tub”



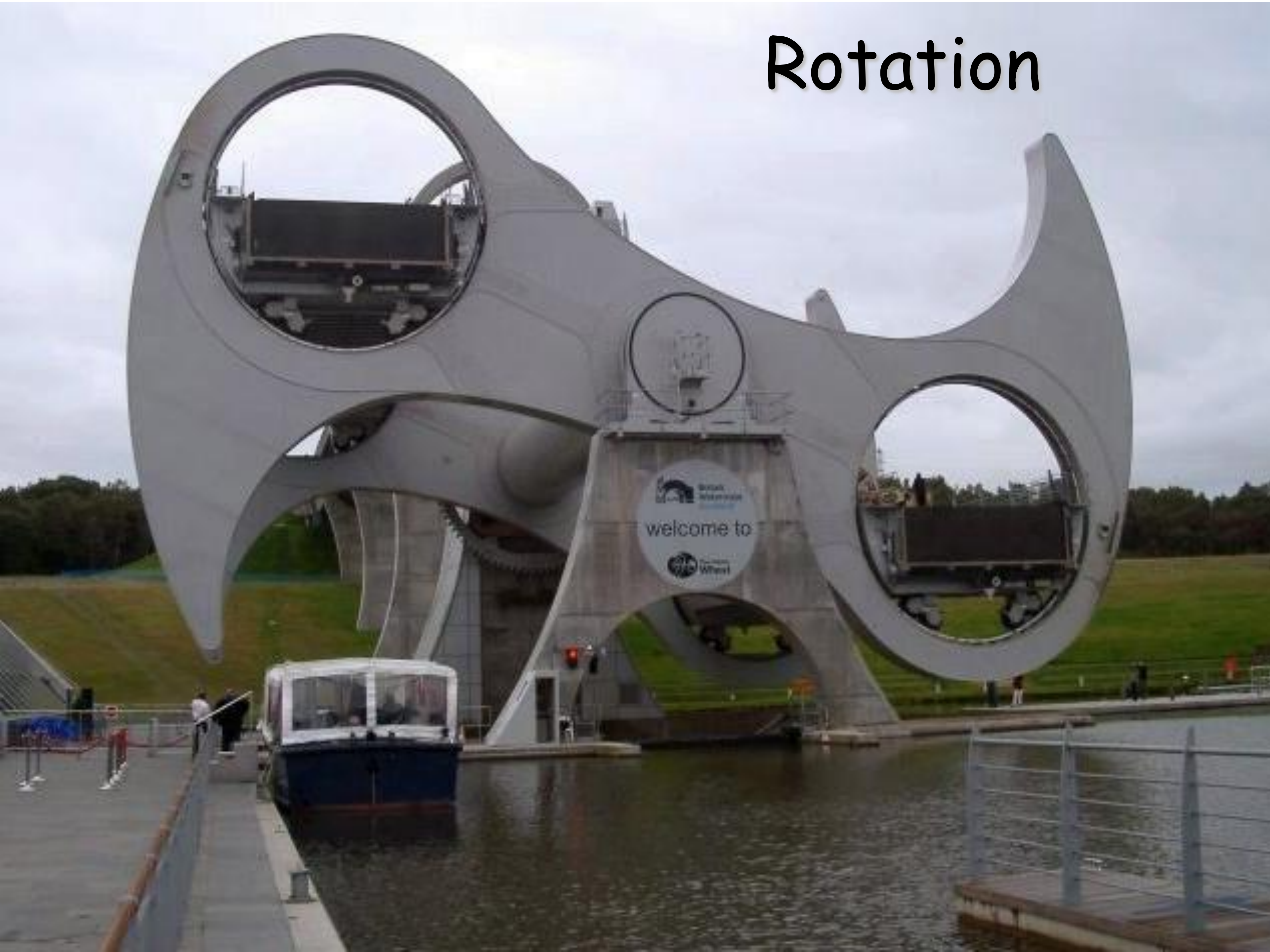
There are boats in both "tubs" upper and lower


Rotation is starting

Boats in both rotating arms



Rotation



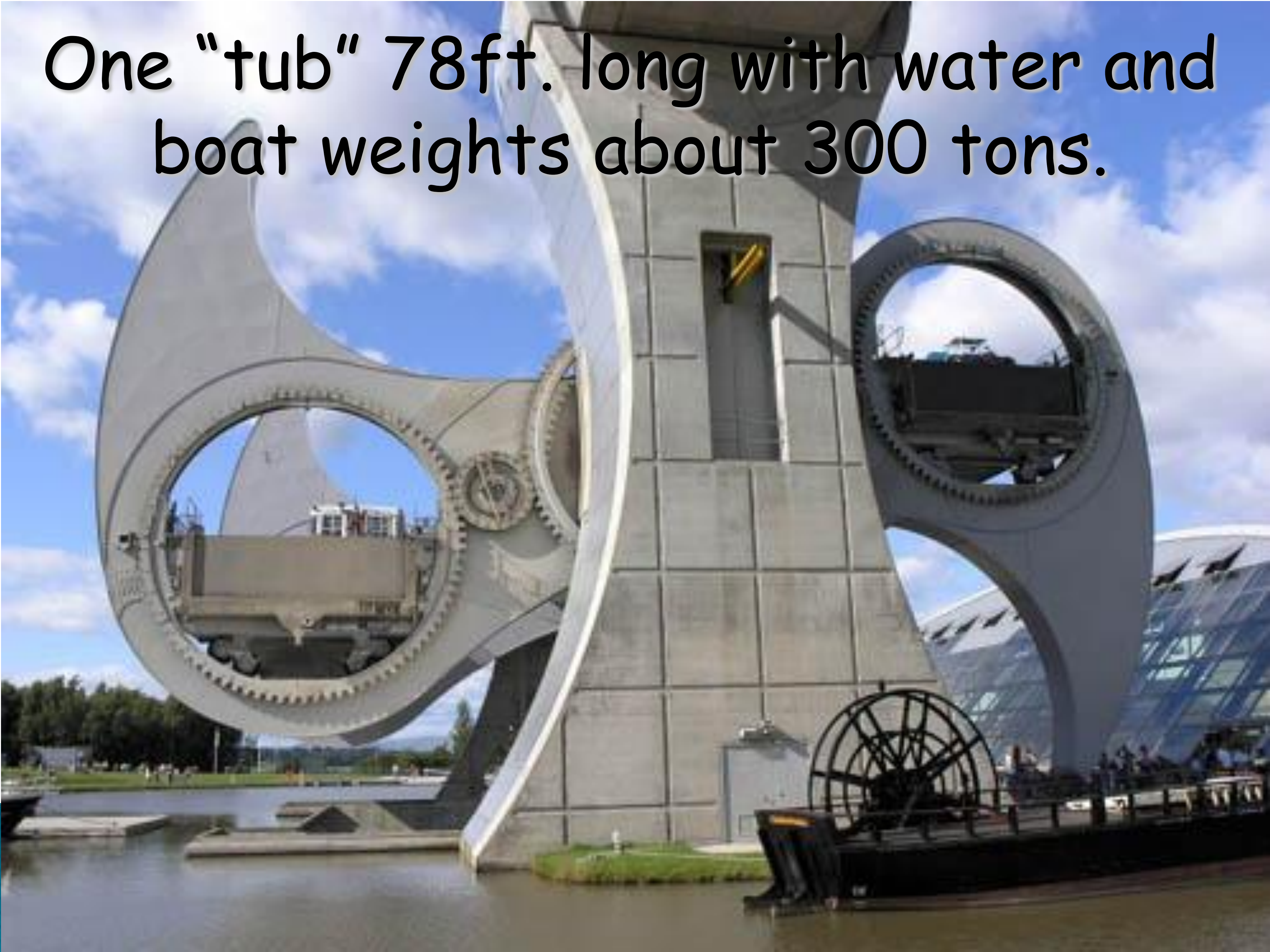
BarrettWells

Just before "landing"


welcome to
Wheel

Closing the gate , regulation of level of water and “tubs” rotation takes 15 min. only.

One “tub” 78ft. long with water and boat weights about 300 tons.



The “tubs” are filled according the Archimedes’ Law.

So the weight of “tubs” are balanced.

To open the upper and lower lock and turn the whole system by 180◦ they need an engine of 22.5 kW which only use 1.5 kWh

THANK YOU