Topic: Measurement of river discharge

DSE-4: Group B 4: HYDROLOGY AND OCEANOGRAPHY

B.A Honours in Geography: 6^{th} Semester

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Flow
Regime

Flow Generation Path

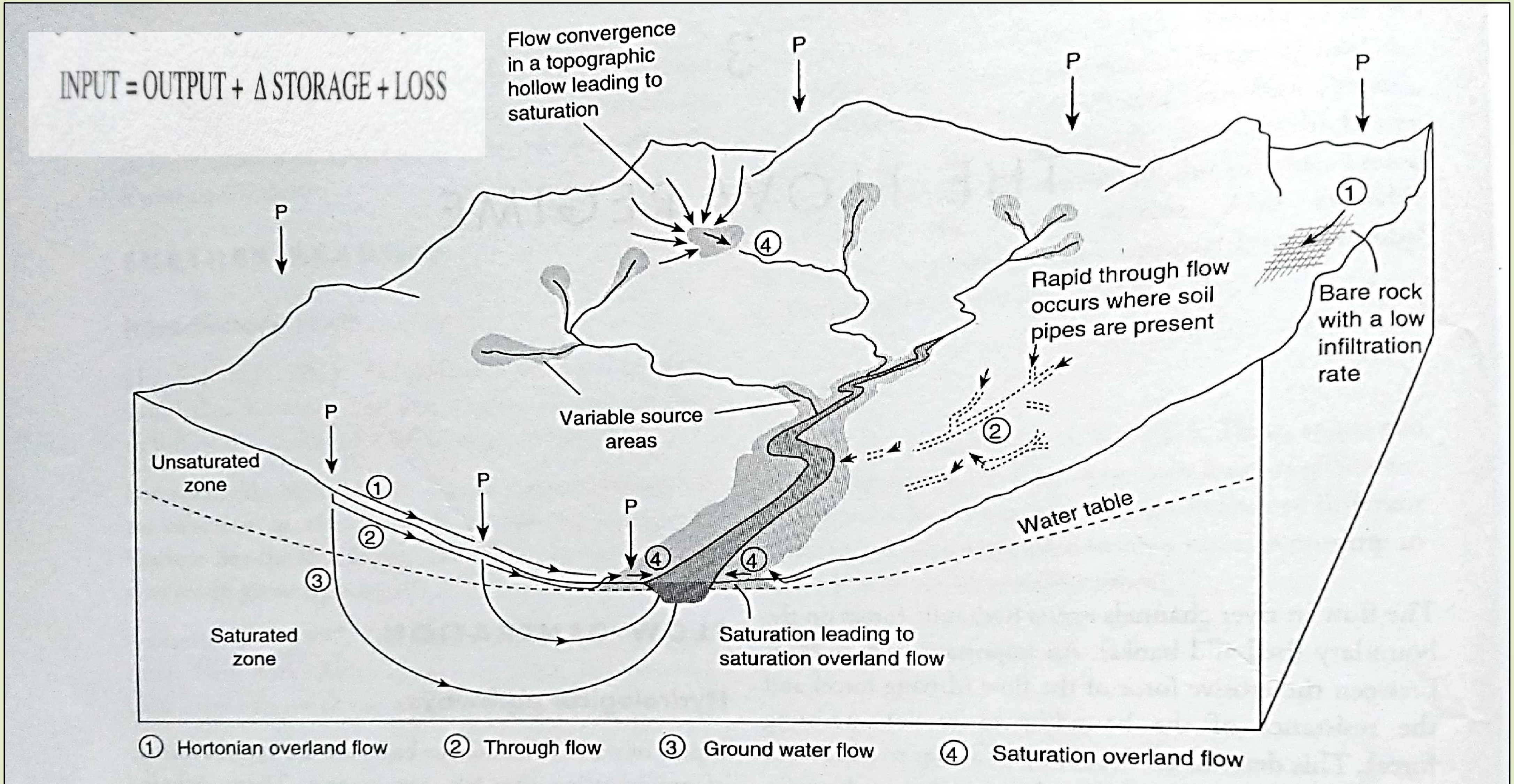
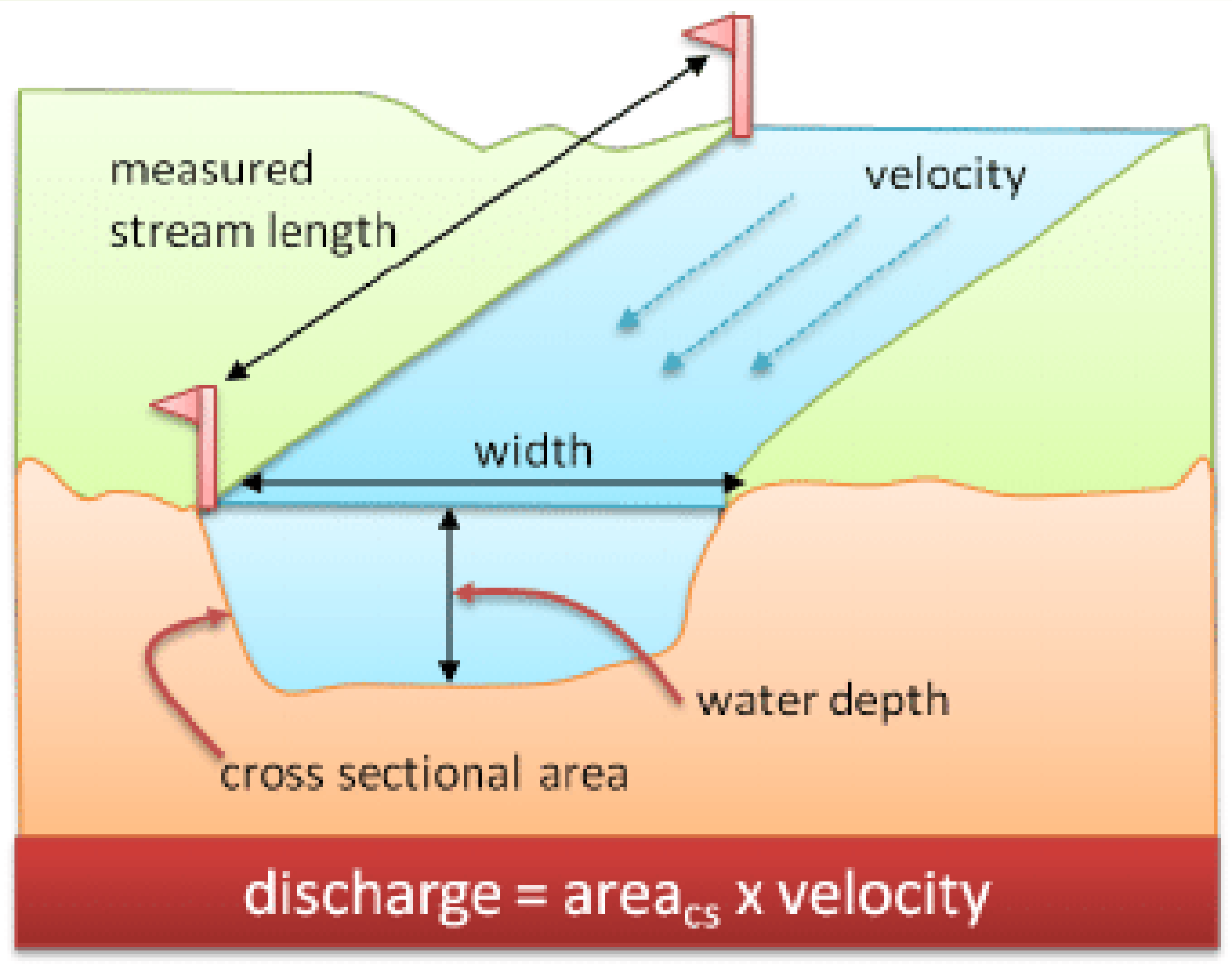


Figure 3.1 Surface and subsurface hydrological pathways.

Measurement of River Discharge



Discharge = A * v

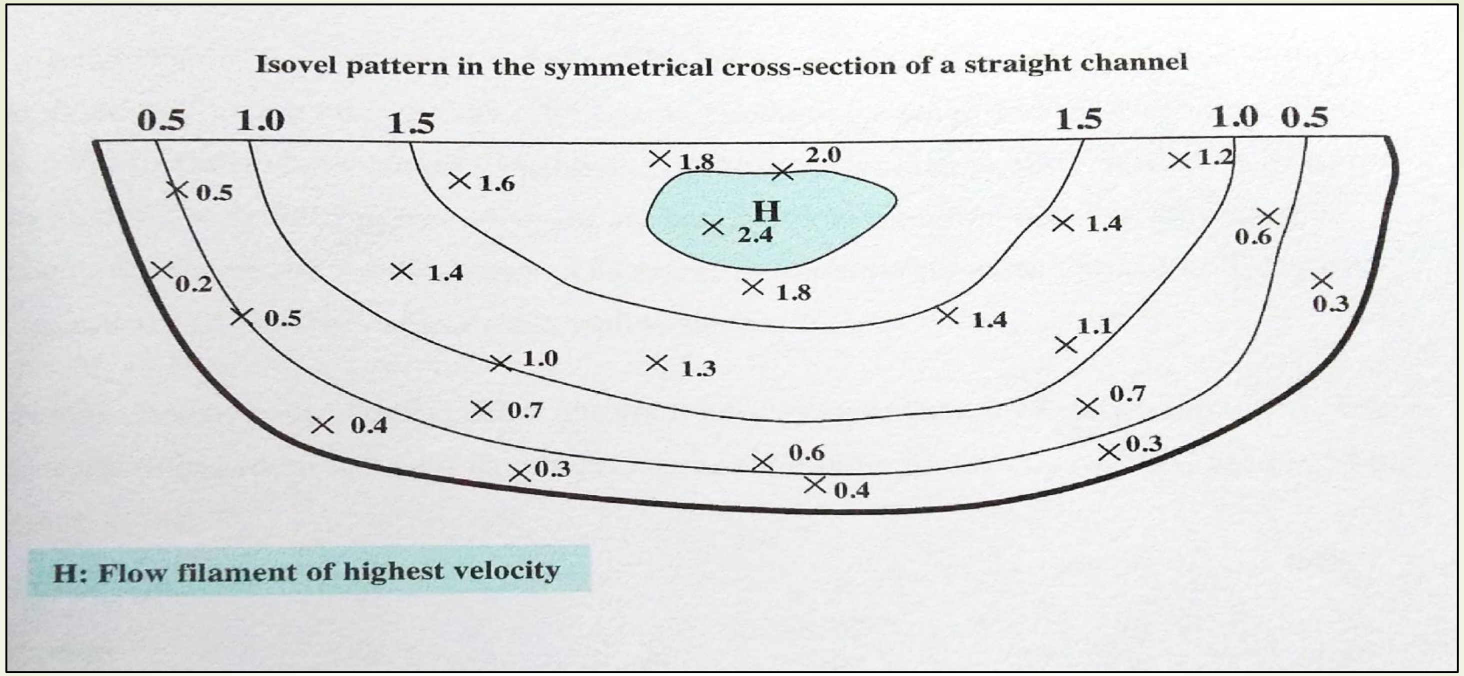
= w*d*v

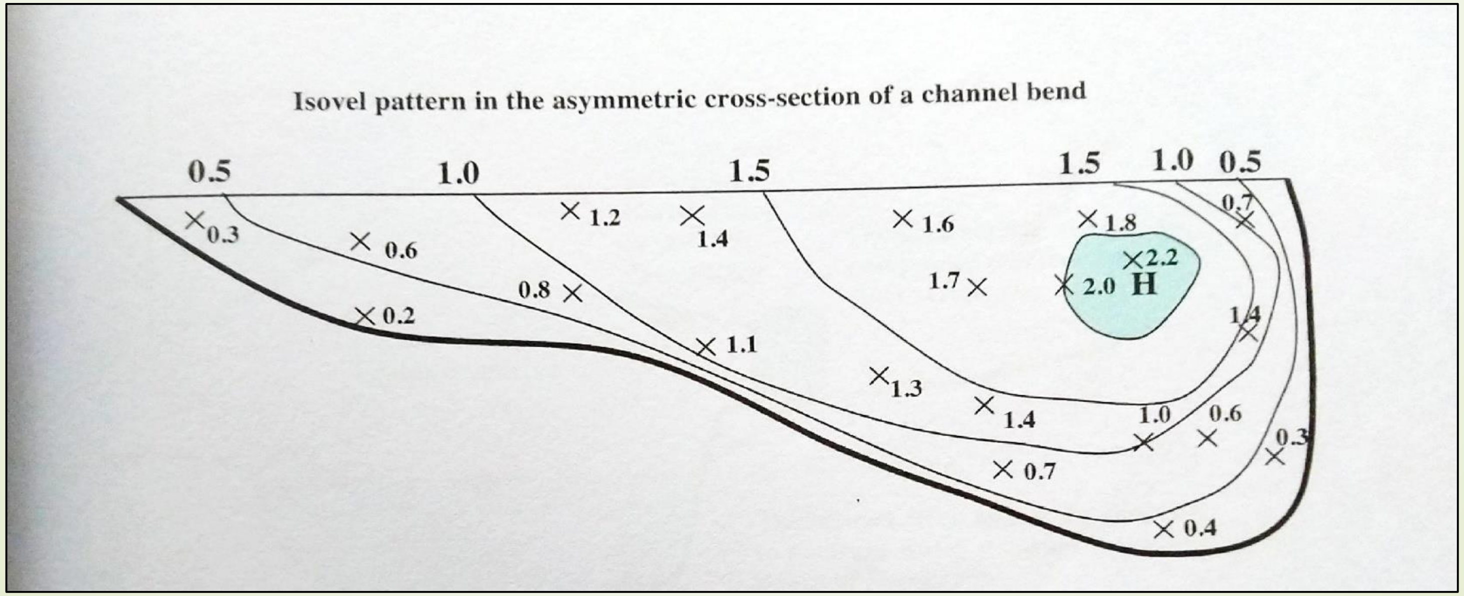
Q = Discharge

Cumec / Cusec

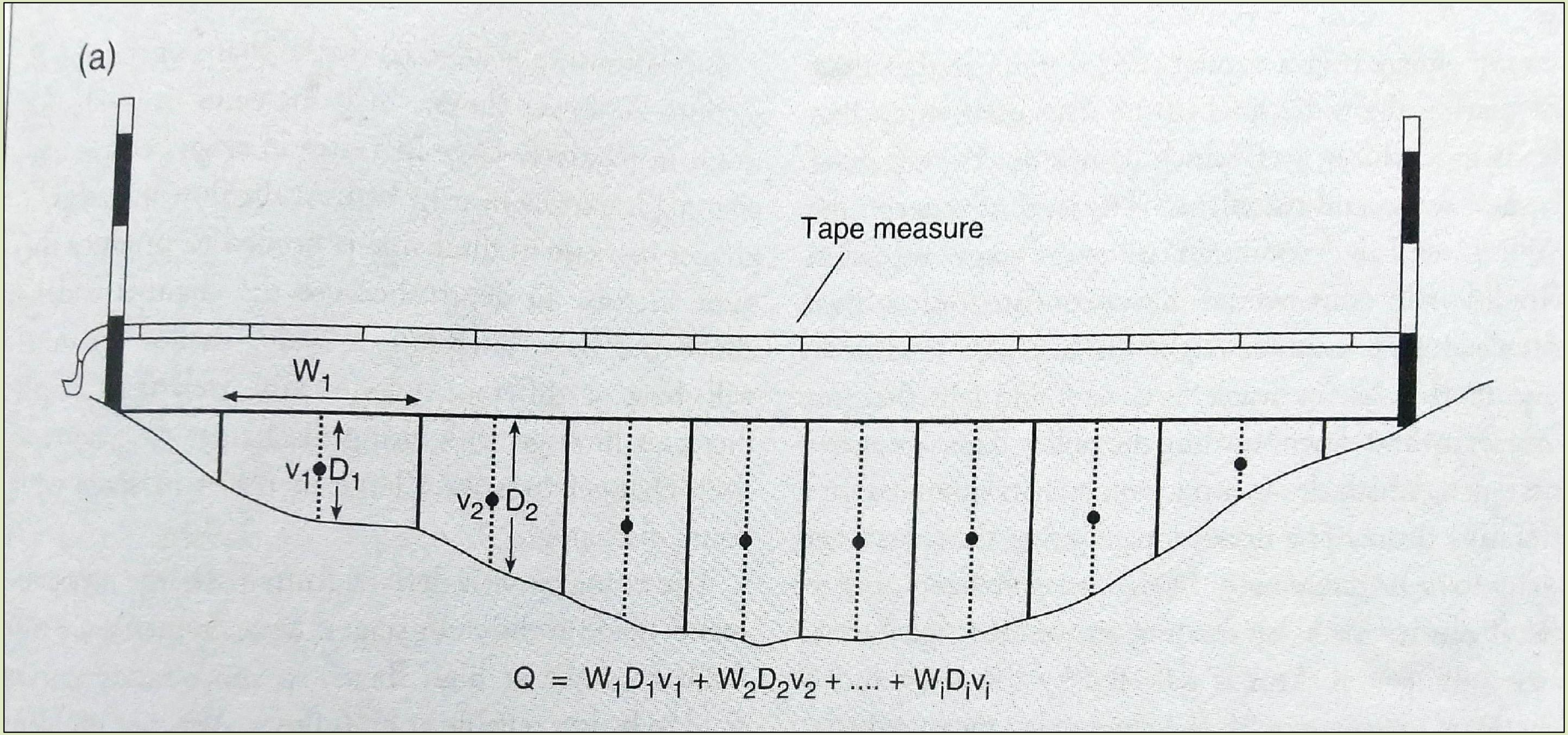
Velocity Measurement

Velocity Profile: Isovel Pattern

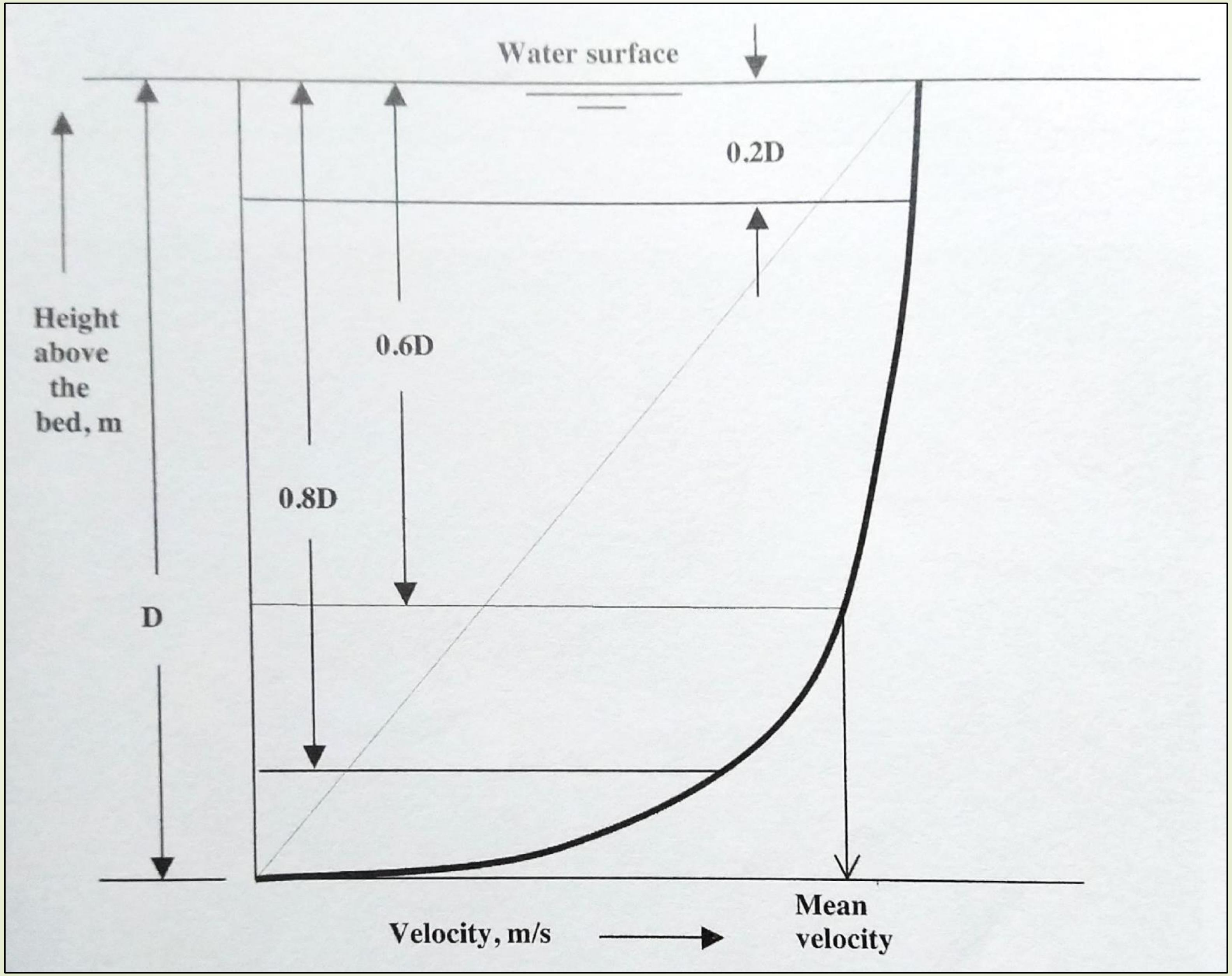




Discharge Measurement: Velocity-Area Method (Instantaneous



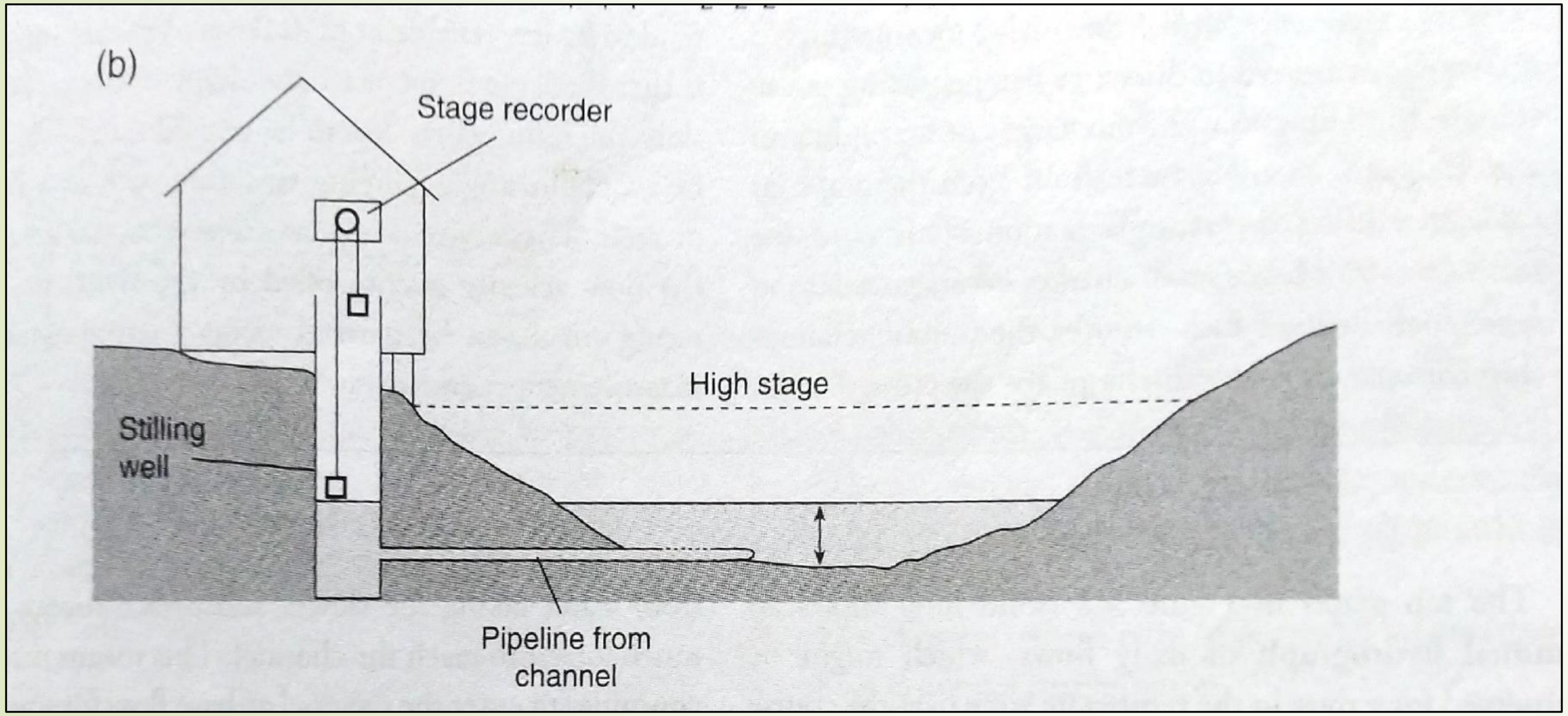
Recommended depth for velocity measurement



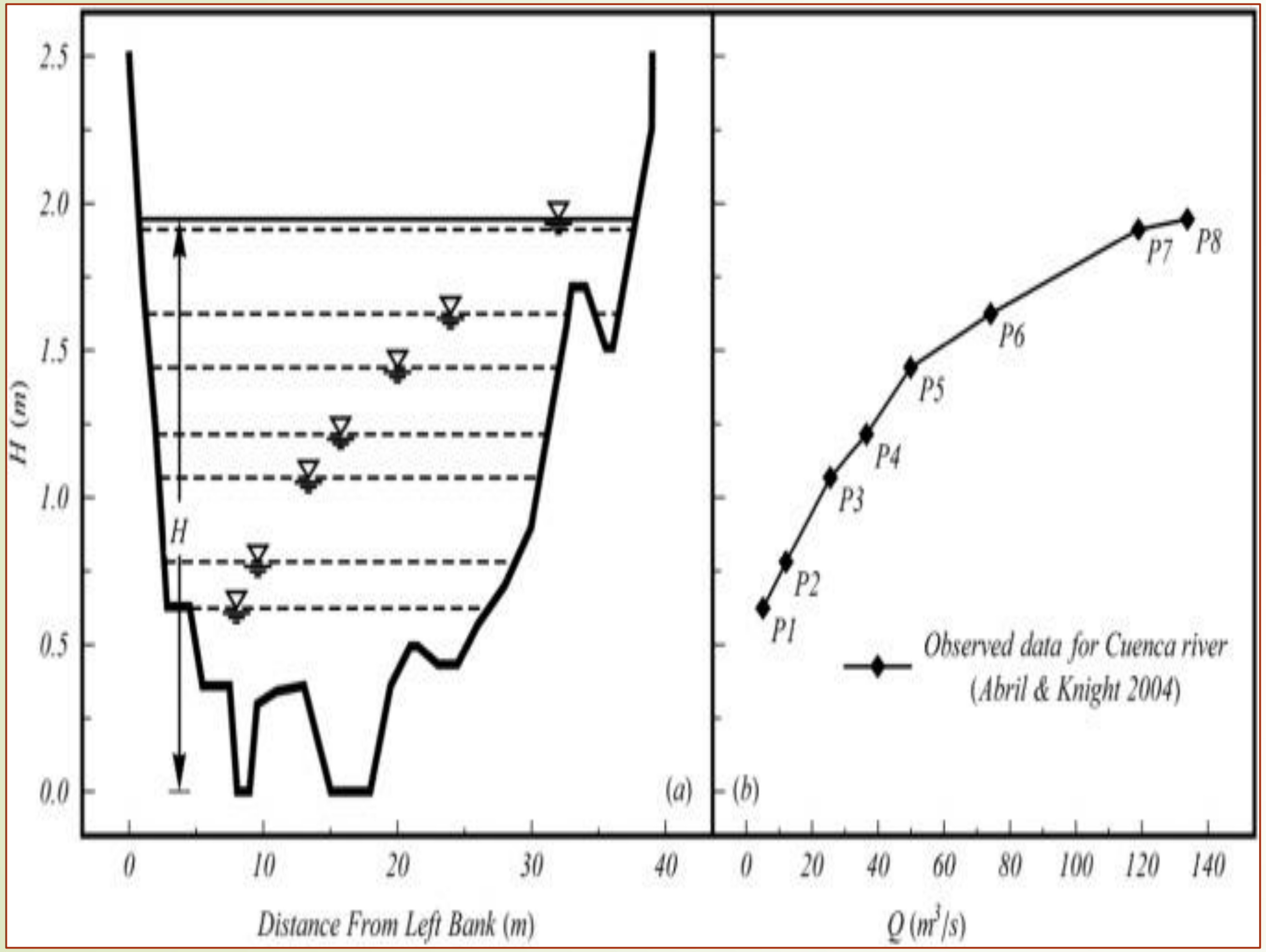
Discharge Measurement: Stage-discharge Method (Continuous

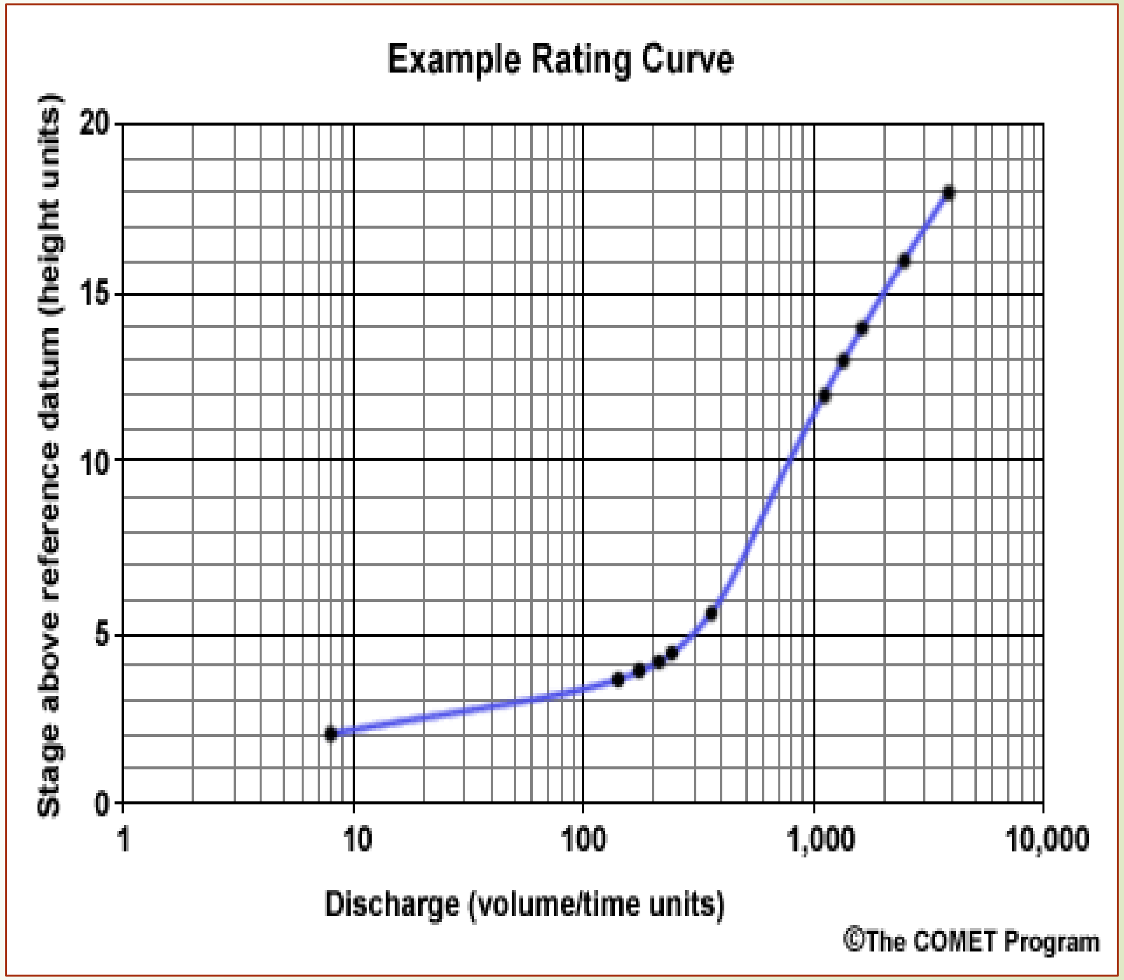
- Stage indicate Gauge height or the height of surface level of river water

- Representative discharge measurement



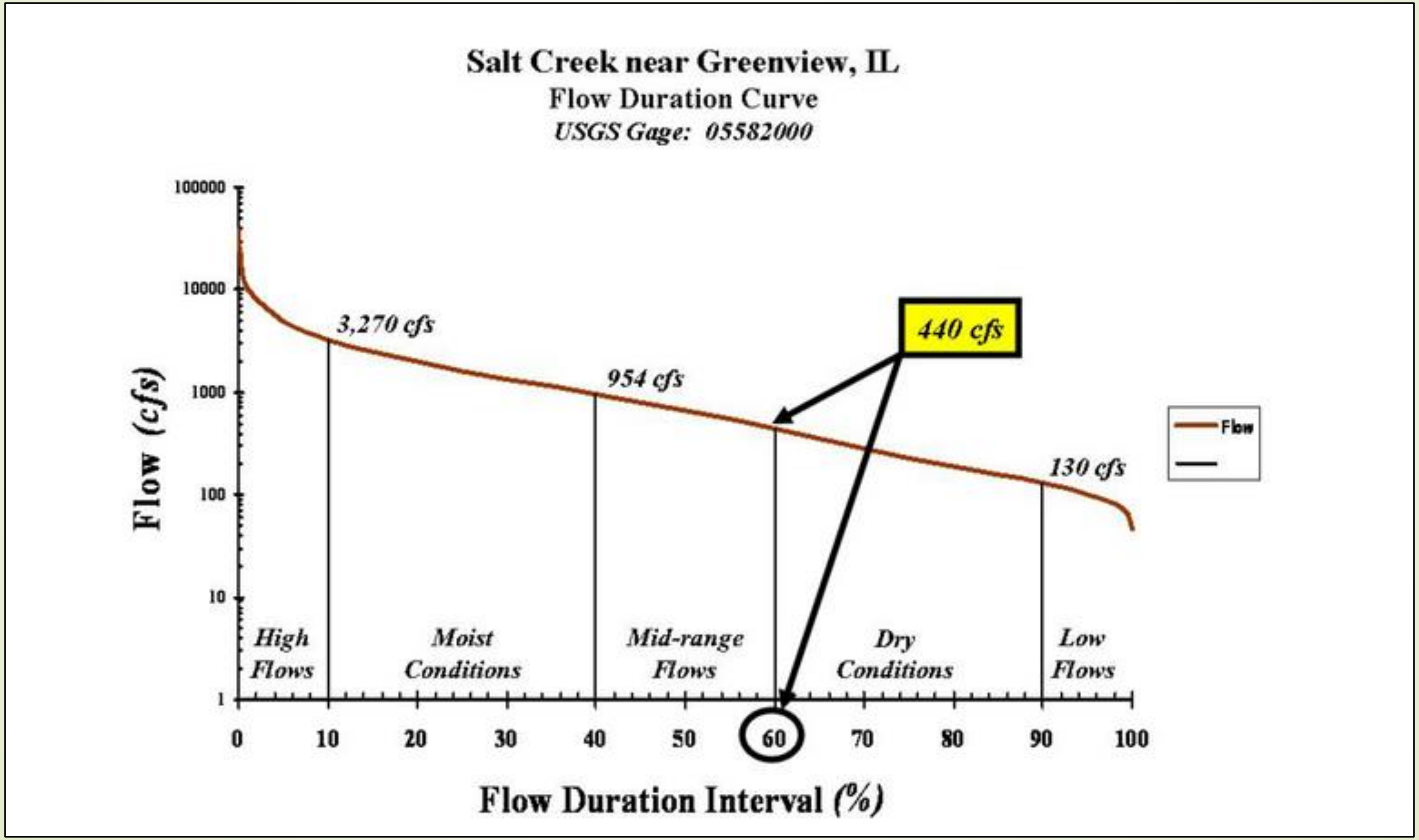
Rating Curve (Stage-discharge relationship / Gauge-discharge r



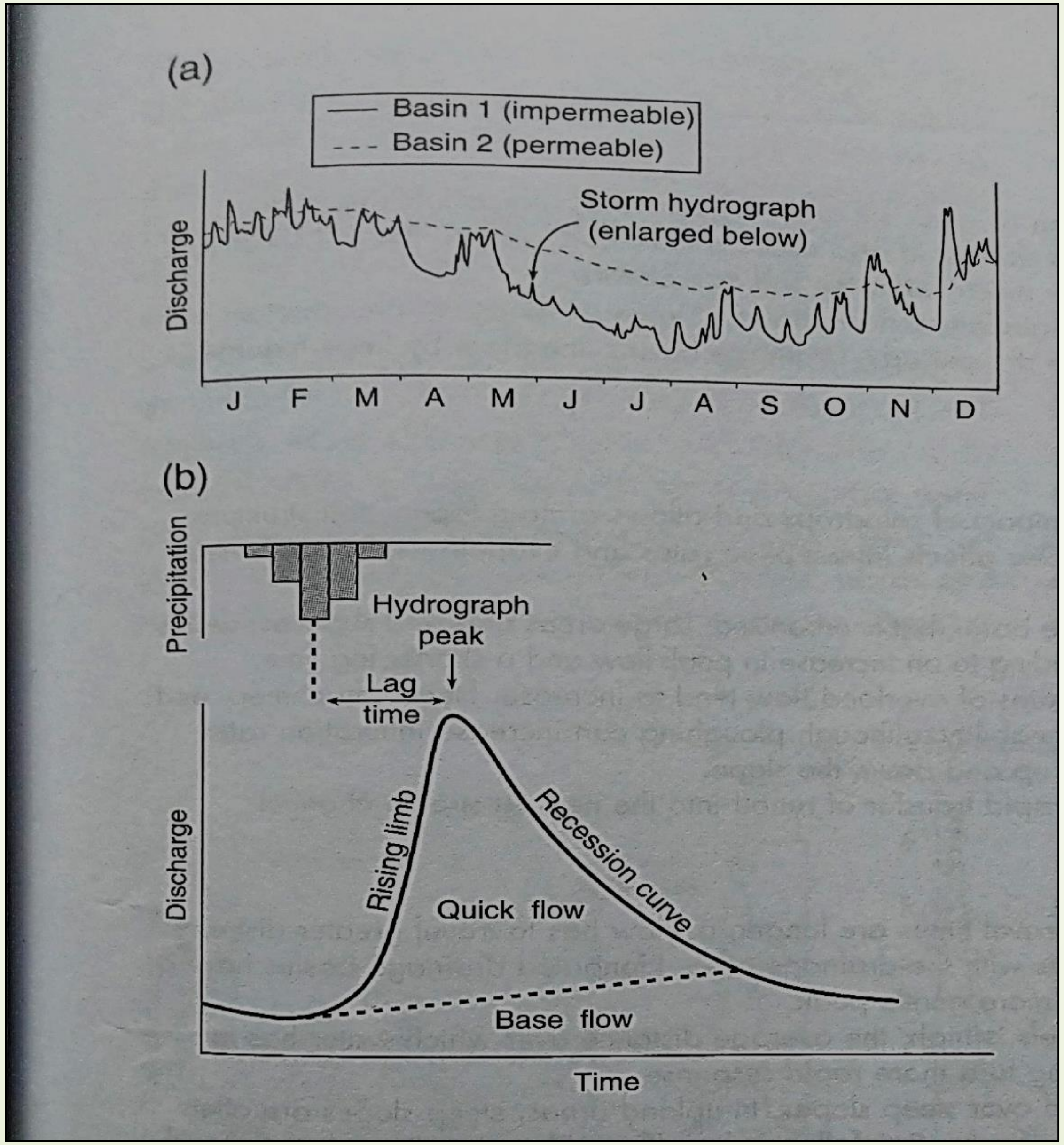


Flow Duration Curve

❖ **Percentage time a given discharge is equaled or exceeded**



Storm Hydrograph and Lag time



Controller of Flow regime/Discharge/Velocity

- **Soils and Geology**

  (1) Soil type and thickness (2) Permeability

- **Vegetation and Land use**

  (1) Vegetation type and density (2) Urban area (3) Grazing and cultivation

- **Physiographic Characteristics**

  (1) Drainage basin size and shape (2) Drainage density (3) topography

- **Channel Characteristics**

  (1) Channel and flood plain resistance (2) Flood plain storage (3) evaporation loss

- **Meteorological Factors**

  (1) Previous condition (2) Rainfall intensity (3) Rainfall Duration

Velocity Calculation by Manning's equation

Manning's Equation

$$V = \frac{1.49 * R^{2/3} s^{1/2}}{n}$$

V	= Avg. velocity (length/time, usually ft/s)
s	= Water surface slope (unitless)
R	= Hydraulic radius (length, usually ft)
n	= Roughness coefficient
1.49	= English units conversion factor, set to 1.0 for metric

- A conversion factor of 1.49 is applied when using English units. For metric units, the conversion is 1.0.

Discharge Calculation by Manning’s equation

Deriving Discharge Using Manning's Equation

$$V = \frac{1.49 * R^{2/3} s^{1/2}}{n}$$

$$Q = V * A$$

$$Q = \frac{1.49 * R^{2/3} s^{1/2}}{n} * A$$

Q = Discharge (vol/time, usually cfs)

A = Channel cross-sectional area (usually ft^2)

❑ What is Manning Equation???

- Robert Manning (1816-1897) born in France and was an accountant before becoming a self-taught engineer.
- He developed this equation as part of his work as chief engineer for the Irish Office of Public Works and published the results in 1891 at the age of 75.

*** Relationship between the depth, velocity, and the discharge within a channel.

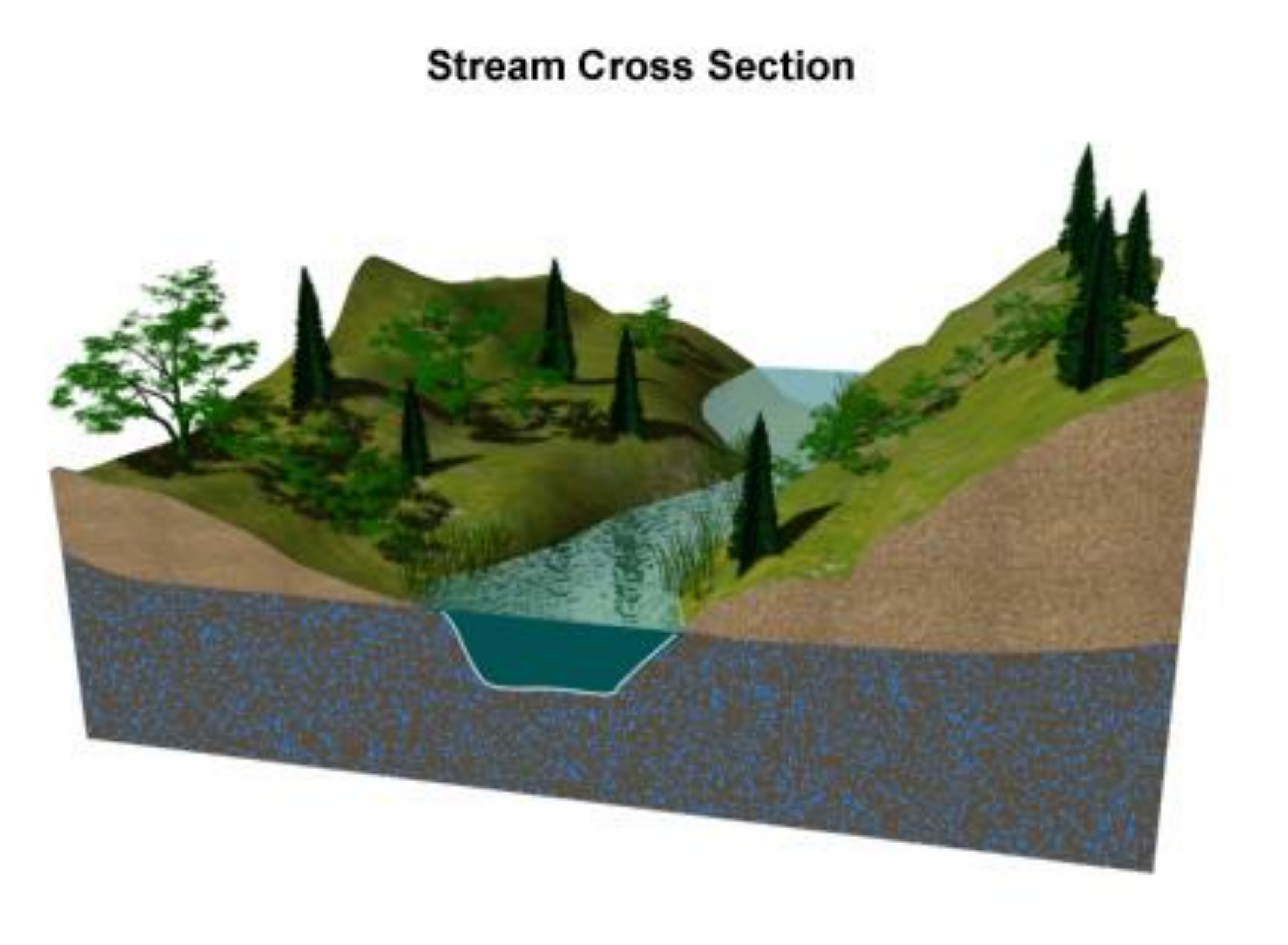
❑ What is Manning Equation???

- There are several empirical methods used to examine the relationship between the depth, velocity, and the discharge within a channel.

- The most commonly used method is Manning's equation.

- The method is best suited for uniform, steady-state open channel flow.

- Manning's equation examines the relationship between the depth, slope, hydraulic radius, and channel roughness to the velocity and discharge within a channel.



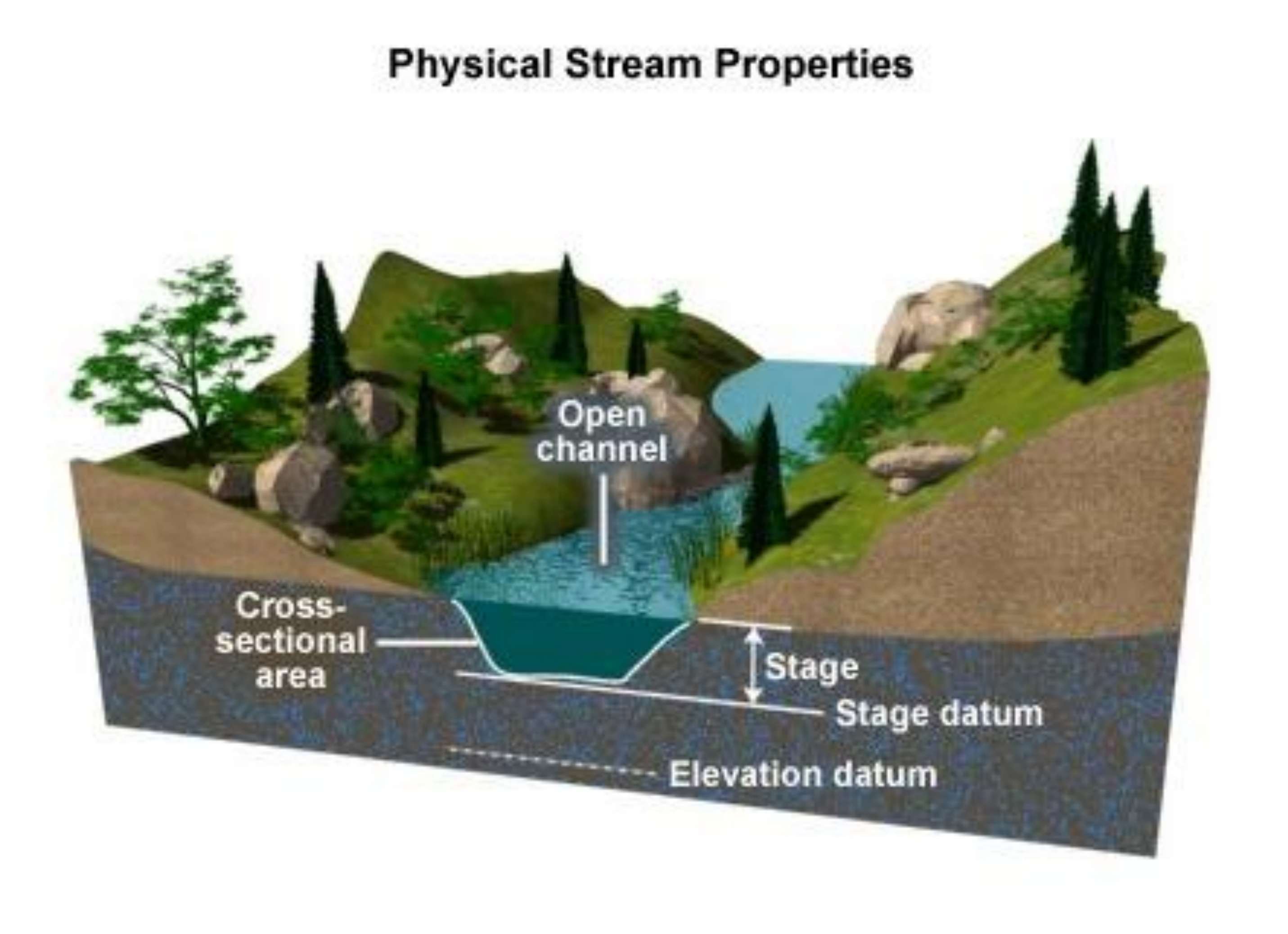
CHANNEL AND STREAMFLOW PROPERTIES

The term **open channel** refers to a natural stream channel or drainage channel where flow is open to the atmosphere and moves by gravity, as opposed to flow under pressure.

The **cross-sectional area** is the area of flowing water as measured from bank to bank.

An **elevation datum** is the vertical height-reference, based on mean sea level. The elevation allows slope between gauging stations to be determined by providing an objective fixed reference. Note that this reference may lie below the elevation of the streambed.

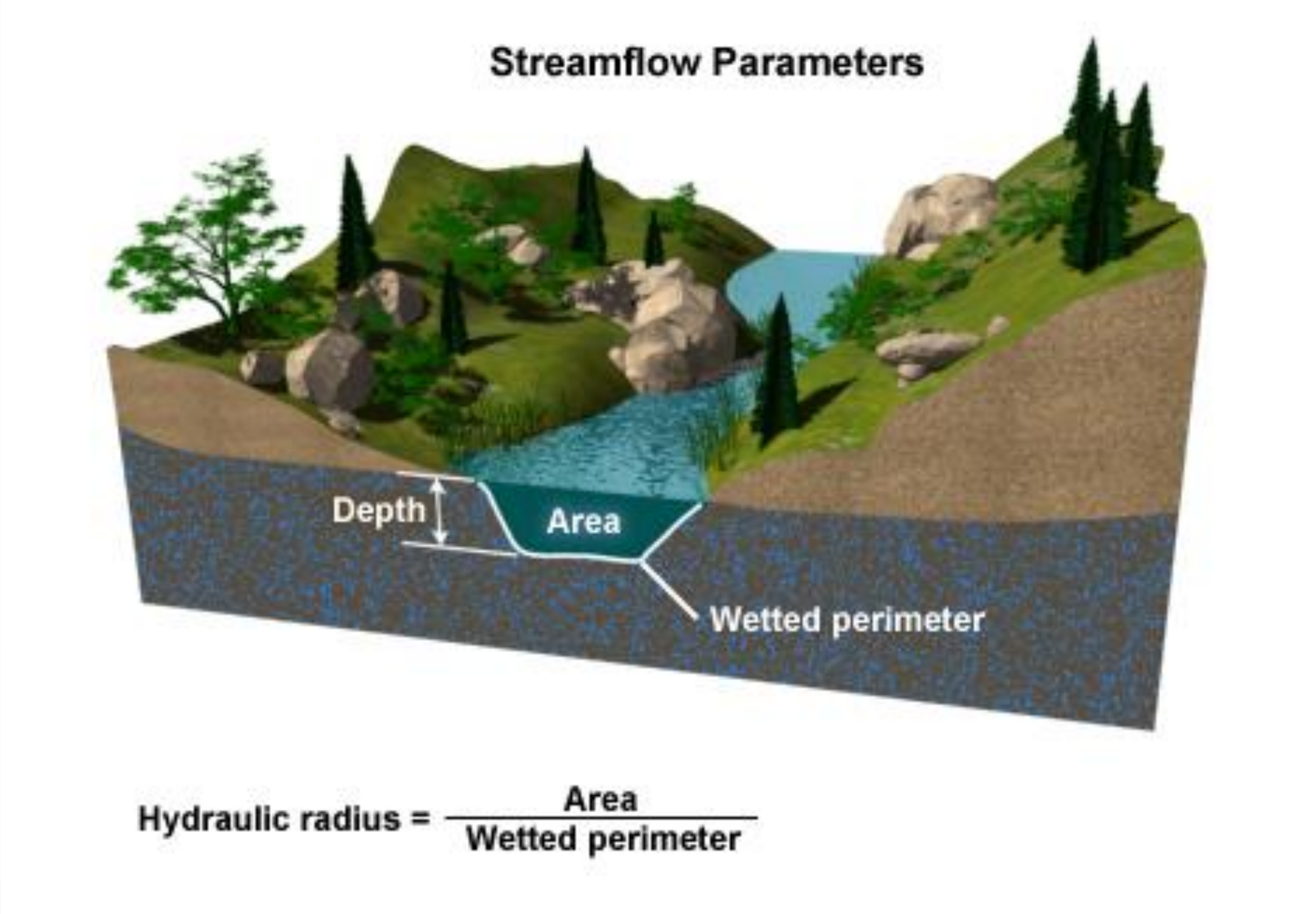
The **stage datum** is the elevation of the established low water level. It is unique to each gauging site and is used to determine stage.



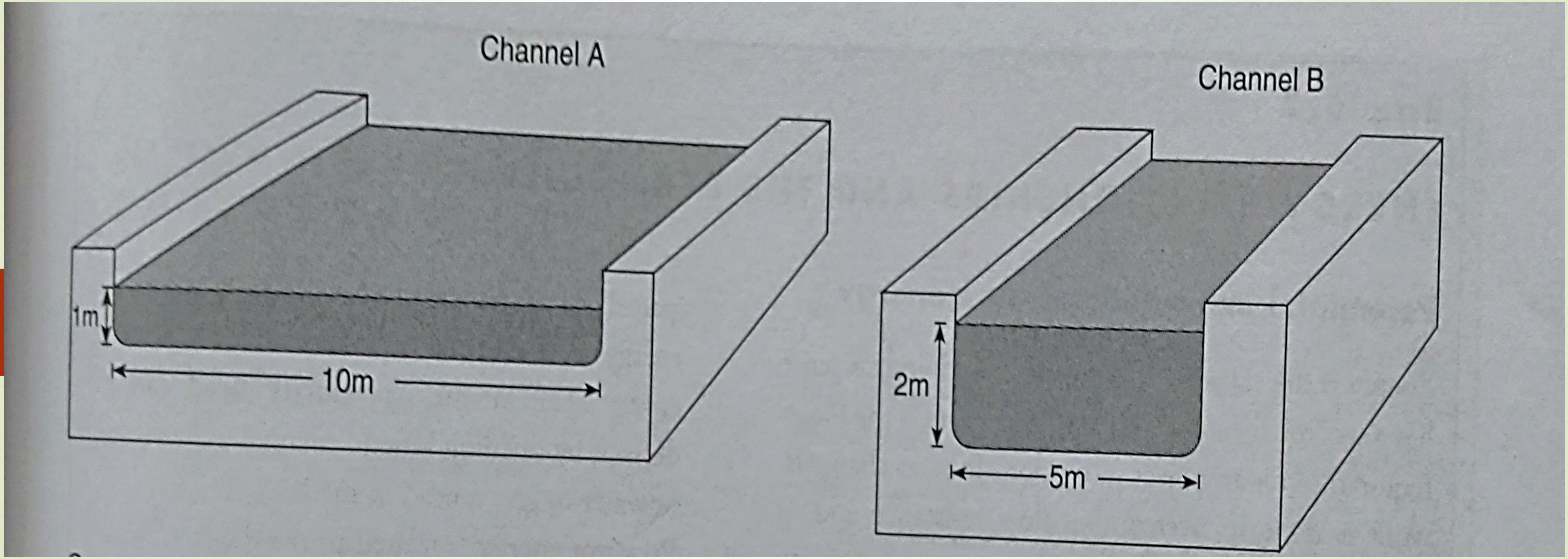
The **wetted perimeter** is the length of the wetted edge of a channel cross section containing flowing water.

The **hydraulic radius** is a physical characteristic of a streambed. It is the cross-sectional area of the channel divided by the wetted perimeter.

A **roughness coefficient** is used to describe the channel friction that acts to slow down the streamflow. Trees and boulders would have a higher coefficient than the concrete lining of an engineered drainage channel.



- Cross-section area = ? A = 10 sq m B = 10 sq m
- Wetted Perimeter = ? A = 10+1+1 m B = 5+2+2 m
- Hydraulic Radius = ? A= 10/12 = 0.83 B = 10/9 = 1.11 m

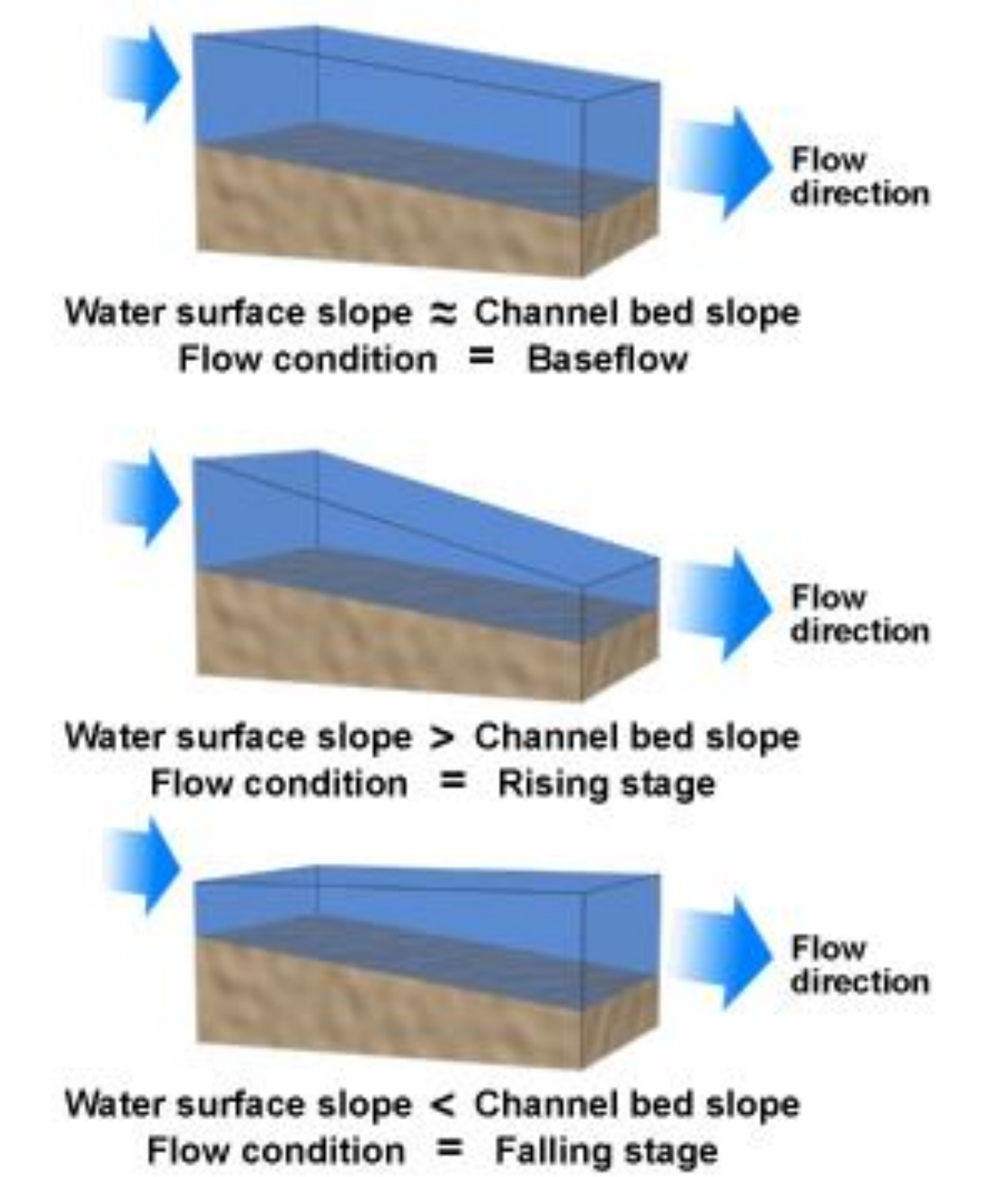


SLOPE AND STAGE RELATIONSHIP

The **water surface slope** is the angle of the water surface relative to the horizontal. It may or may not be parallel to the channel bed slope. This angle can be found by measuring the change in water surface elevation between two points along the stream.

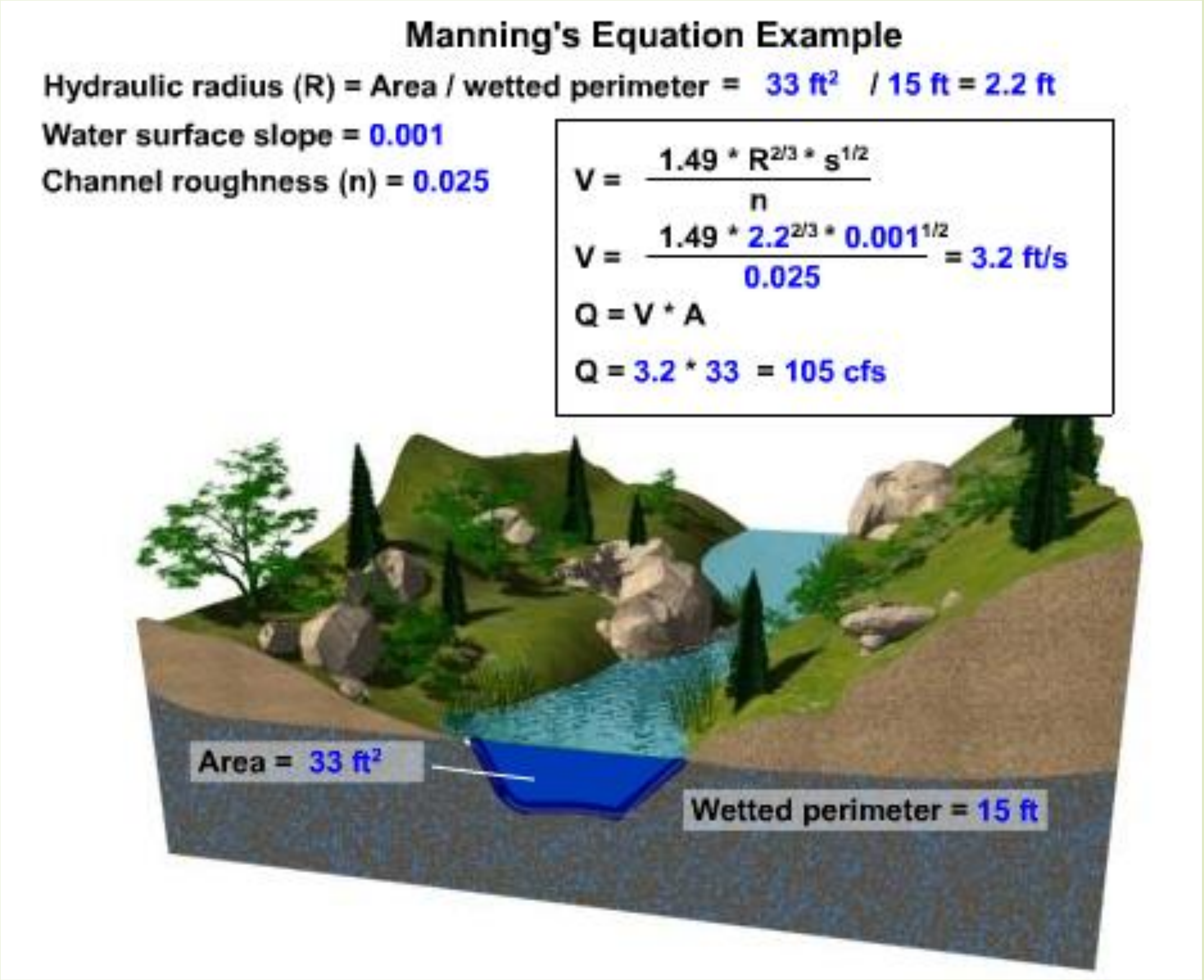
The **channel bed slope** is the angle of the channel bed surface relative to the horizontal. It may or may not be parallel to the water surface. This angle can be found by measuring the change in channel bed elevation between two points along the stream.

- Under baseflow conditions, the water surface slope is about the same as the channel bed slope. This is typical of flow conditions between runoff events.
- Under rising stage conditions, the water surface slope is greater than the channel bed slope. This occurs when a flood wave is approaching.
- When the stage is falling, the water surface slope is less than the channel bed slope. This occurs after a flood wave has passed a location.



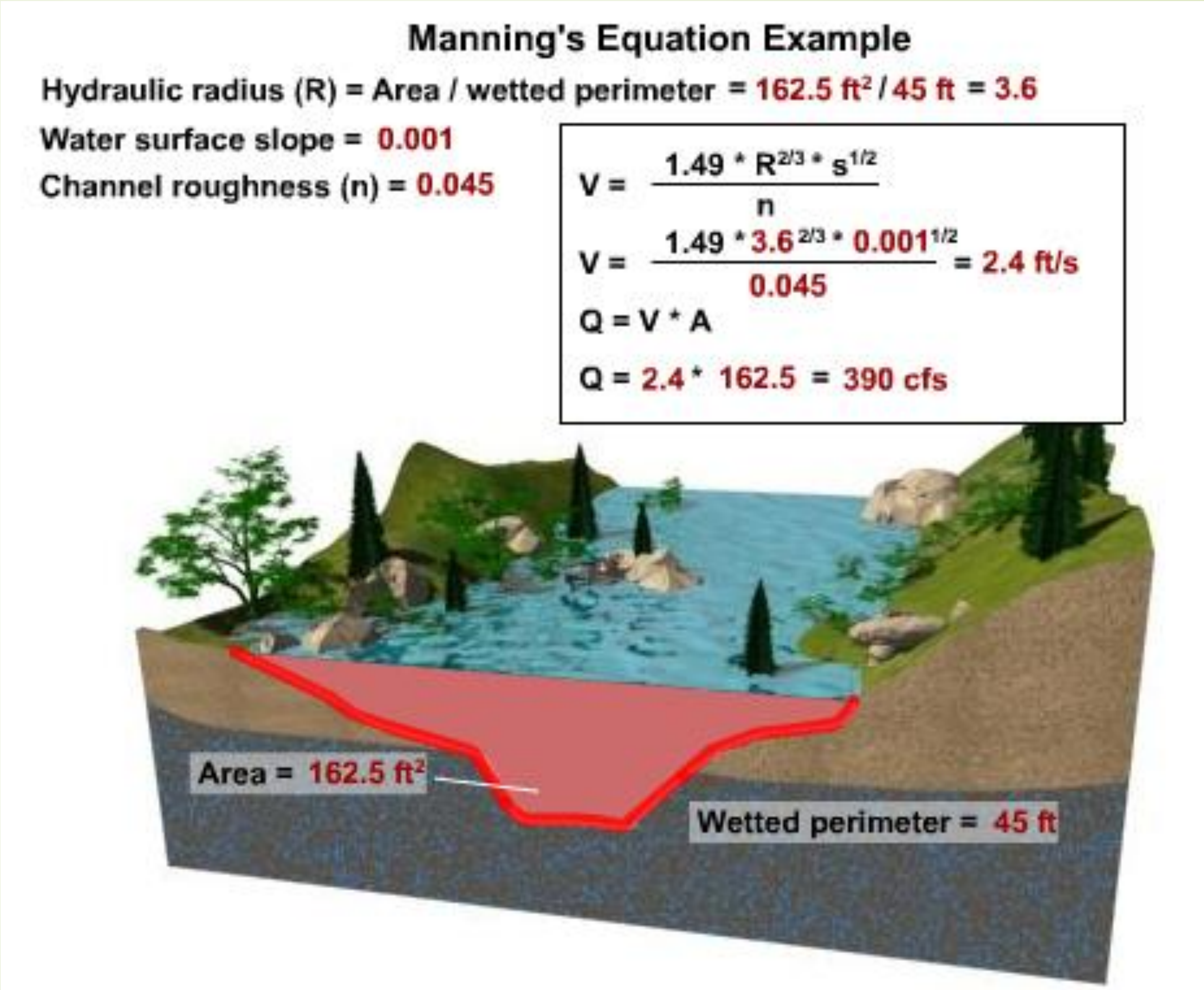
Applying Manning’s Equation:

❖ Low stage condition



Applying Manning’s Equation:

❖ **High stage condition**



Effects of Roughness and Stage on Discharge Calculation

	Low flow	Rougher High flow	Smoother High flow
Area (A) (ft^2)	33	160	160
Wetted perimeter (ft)	15	45	45
Hydraulic Radius (R) (ft)	2.2	3.6	3.6
Roughness (n)	0.025	0.045	0.025
Slope (S)	0.001	0.001	0.001
Velocity (V) (ft/s)	3.2	2.5	4.4
Discharge (Q) (ft^3/s)	105.6	400	704

- ✓ The first column shows values for a low water situation.
- ✓ As the water rises, the second column shows the changes to the wetted perimeter and cross-section area. These changes, in turn, change the hydraulic radius 'R' value.
- ✓ The discharge is higher for the raised stage though the average velocity is less than in the low water case. The discharge is about 4 times greater even though the depth of the water is only approximately doubled in this example.
- ✓ The third column shows the calculation if the roughness factor were to stay the same as in the low-flow condition. Now the discharge is about seven times as great as the low stage case.

Manning Equation Value

NATURAL STREAM			
Type of Channel and Description	**Minimum**	**Normal**	**Maximum**
1. Minor Stream (top width at flood stage < 100 ft)			
a. Stream on plain			
(1) Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
(2) Same as above, but more stones or weeds	0.030	0.035	0.040
(3) Clean, winding, some pools or shoals	0.033	0.040	0.045
(4) Same as above, but some weeds or stones	0.035	0.045	0.050
(5) Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
(6) Same as (4), but more stones	0.045	0.050	0.060
(7) Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
(8) Very weedy reaches, deep pools, or floodway with heavy stand of timber and underbrush	0.075	0.100	0.150