RIVER TRANSPORTATION

Activities of Running Water:

The water that flows along the river does the following works:

a. It transports the debris
b. It erodes the river channels deeper into the bed
c. It deposits sediments at various points along the valley or delivers them to lakes or oceans

River Transportation:

River transportation is the ability of the river to carry along the particles that a stream picks up directly from its own channel or that is supplied to it by slope wash, tributaries or mass movement.

Factors affecting the transportation power of the river:

a. Size of the particles to be carried





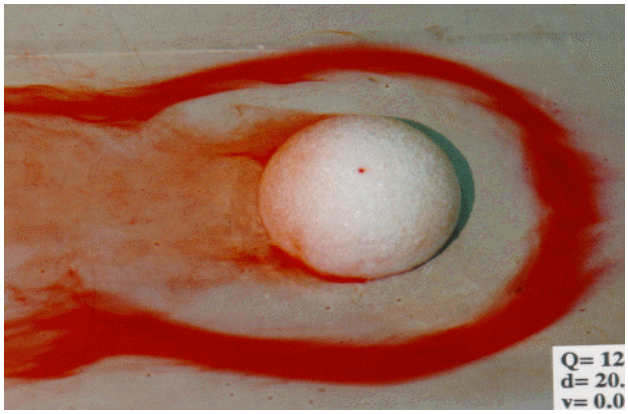
b. Volume of total load





c. Velocity of river





Some Important Definitions:

1. **Load:**

   The amount of material that a river carries at any time is called its load. Though it is a volume, it is expressed in tons.

2. **Capacity:**

   The total amount of material a river is capable of carrying under any given set conditions is called the capacity of the river.

   Capacity of a river varies approximately with the third power of the velocity if a fair proportion of all grain sizes are available ($c \infty v^3$), with a higher power if all the materials are fine grained and with a lower power if the material is coarse. The capacity is a function of discharge and velocity.

3. **Competence:**

   The maximum size of particle that a river can carry is called its competence. The competence of a river is a statement of its ability to move materials in terms of material size.

   Competence is a function of velocity only. The diameter of a particle that a river can move varies approximately with the square of the stream velocity. ($d \infty v^2$).

Classification of Load:

In rivers, load may be carried in solution up to a certain extent, or it may be carried mechanically as sediments.

a. Dissolved Load:

These are the soluble materials and are carried in solution in the form of ions. Whether a particle will go in solution depends on its chemical properties. When the sediment discharge is high, even the soluble materials may not go

in solution as the water is already saturated. Again if the particle size is too large it may not dissolve.

The amount of dissolved load depends upon: (1) Climate (heat), (2) Season (temperature) and (3) Geologic Setting (presence of sand, pebbles, etc.)

b. Suspended Load:

This is the load carried mechanically as sediment. These are the particles of solid matter that are swept along in the turbulent current of the stream and remain in suspension. The amount of this load depends upon (1) intensity of turbulence of water and (2) terminal velocity of each individual particle.

c. Bed Load:

These are solid particles, which move along the riverbed. Bed load mainly consists of gravel and sand.

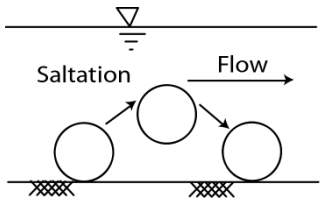
Movement of Bed Load:

Particles in the bed load move in three ways: By Saltation, by Rolling and by Sliding:

a. By Saltation:

A particle moving by saltation jumps from one point of the stream to another. First, it is picked up by a current of turbulent water and flung upwards and if it is too heavy to remain in suspension, it drops to the stream floor again at some spot downstream.



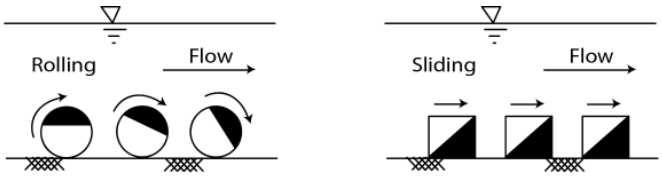


b. By Rolling and Sliding:

Some particles are too large and heavy to be picked up by the water current. But they may be pushed along the streambed and depending on their shape, they move forward either by rolling or by sliding.







Channel Changes in Flood:

We think the flood as the change in the height of water surface and subsequent inundation but apart from that, change occurs in the stream bed which we can not see because of the turbidity of water flowing through the stream.

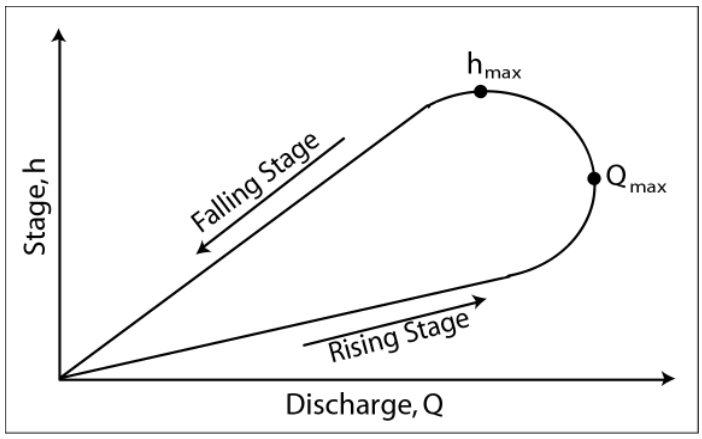


Figure: Stage-Discharge behavior in unsteady flow condition

The figure above represents the unsteady behavior of stage-discharge relationship at a location of the stream. The maximum stage and the maximum discharge occur

at different times. The changes of the channel bed form that take place during the flood need clear understanding of this unsteady behavioral pattern.

River channel changes in configuration with this rising and falling stage.

- At first the bed may be built up by large amounts of bed load supplied in the stream during the first phase of heavy runoff. [Observe the elevated bed level as a result of it]. This stage disappears soon.
- The bed is actively deepened by scour as the stream stage rises. This is quite interesting to mark the lowest elevation of the bed at the highest stage.
- In the next stage which can be identified by the falling stage of the stage-discharge curve, the stage starts to fall and the bed is built back up by the deposition of the bed load.

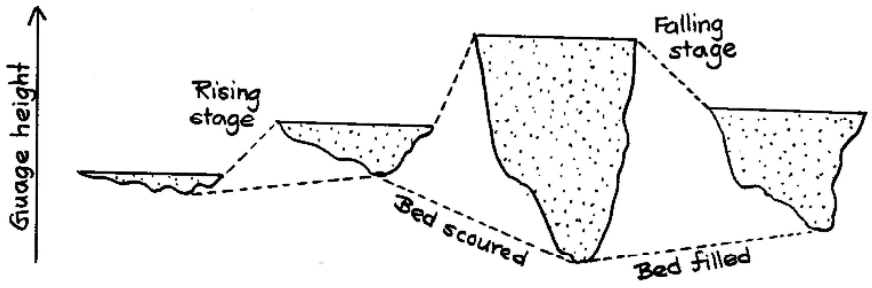


Figure: Changes in channel during the progress of a flood.

When the flood crest has passed after the decrease in the discharge, the capacity of the stream transport load also declines. Some of the particles, that are in motion, come to rest on the bed in the form of sand and gravel bars. First the largest boulders and cobblestones will cease (stop) rolling, then the pebbles and gravels and then the sand. When restored to low stage, the water may become quite clear with only a few grains of sand rolling along the bed where the current is still fast enough.

Concept of Equilibrium and Graded Stream:

As an idealized concept, an 'Equilibrium Condition' means the supply of load to a stream from its drainage basin is such that it exactly matches the capacity of stream to transport. In this type of stream, the hydraulic factors are changing continuously to bring about a state of equilibrium. This sort of stream is called a 'Graded Stream'.

A graded stream is one in which, the slope is delicately adjusted over a period of years to provide, along with the available discharge and prevailing channel

characteristics, just the velocity required for the transportation of the load supplied to it by the drainage basin.

Based on the concept of Mackin, a geomorphologist, a **graded stream** is one which the slope is delicately adjusted over a period of years to provide, along with the availability discharge and prevailing channel characteristics, just the velocity required for the transportation of the load supplied to it by the drainage basin.

Factors Controlling Equilibrium of a Stream:

a. **Stream Discharge, Q:**

   It is usually measured in ft^3/sec or m^3/sec. It is dependent mainly on climate. The relationship $Q = A*V_m$ is important. Where, A = area of the section perpendicular to the direction of flow, and V_m = mean velocity of the section.

b. **Sediment Discharge and Size of Sediment:**

   Climate, weathering and all processes delivering sediment to the stream determine the quantity of sediment discharge (tons/day) and the size of sediment. The size of grains and the structure of the original rock material are also important criterion.

c. **Slope:**

   The slope adjusts automatically to provide the velocity necessary for transporting the amount and size of the material being delivered to the stream. If the slope is too low for transporting the sediment load, deposition occurs until the slope is sufficient for transporting. If the slope is so steep that it provides a velocity greater than that necessary to transport the load, erosion reduces the slope. This new slope will provide the velocity needed to transport the sediment load.

   Channel slope is important in determining stream velocity and so sediment transport. Generally, as the channel becomes narrower, sediment transport becomes more efficient, when narrowing of a channel occurs because of deposition on the bank, erosion of bed is likely to result. Again, when the deposition of the channel bed occurs, the erosive forces on the bank increase resulting widening of the stream.

d. Channel Shape:

The ratio of width to depth is used to describe the channel shape. The interaction of discharge, amount of sediment, slope and local factors such as bank erodability and channel alignment determine channel shape.

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Longitudinal Profile of a Stream:

The longitudinal profile of a stream is a graphic outline of the stream's gradient along its course. It provides information of the elevation of the streambed at any location, the elevation being measured with respect to some fixed datum (e.g. Mean Sea Level).

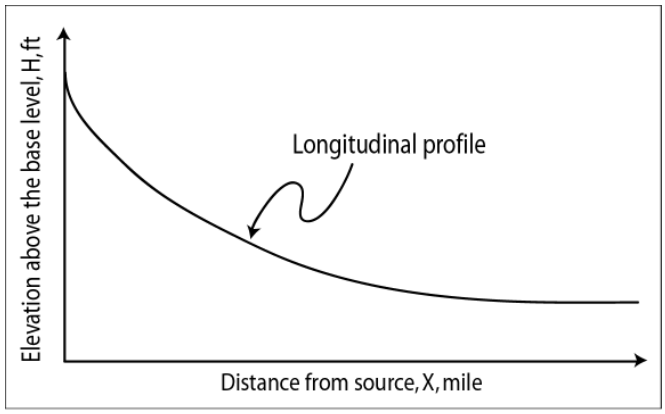
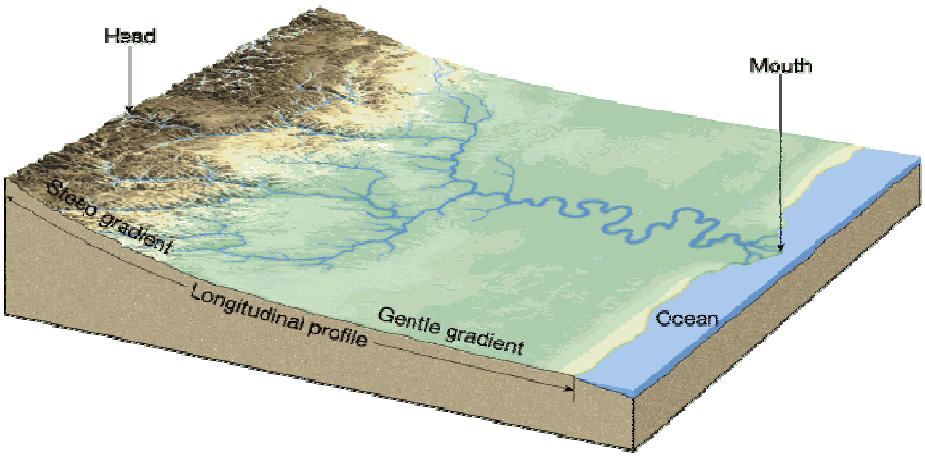


Figure: Schematic diagram of longitudinal profile of a stream



The longitudinal profile of is a function of the following variables:

- Discharge
- Load delivered to the channel
- Size of debris,
- Velocity of flow
- Flow resistance
- Depth of flow
- Width of the channel
- Slope of the channel

Note: The base level of a river or stream is the lowest point to which it can flow

Equation of Longitudinal Profile:

Assumption:

The tendency of a stream to erode at any particular point along its profile is directly proportional to the height of the stream above the base level.

If, H = Elevation above base level or MSL in ft

X = Distance downstream from source in mile

Then based on the assumption,

$$\frac{dH}{dX} \propto -H$$

$$or, \frac{dH}{dX} = -bH$$

$$or, \frac{dH}{H} = -bdX$$

$$or, \int \frac{dH}{H} = \int -bdX$$

$$or, \ln H = -bX + \ln C$$

$$or, \ln H - \ln C = -bX$$

$$or, \ln\left(\frac{H}{C}\right) = -bX$$

$$or, \frac{H}{C} = e^{-bX}$$

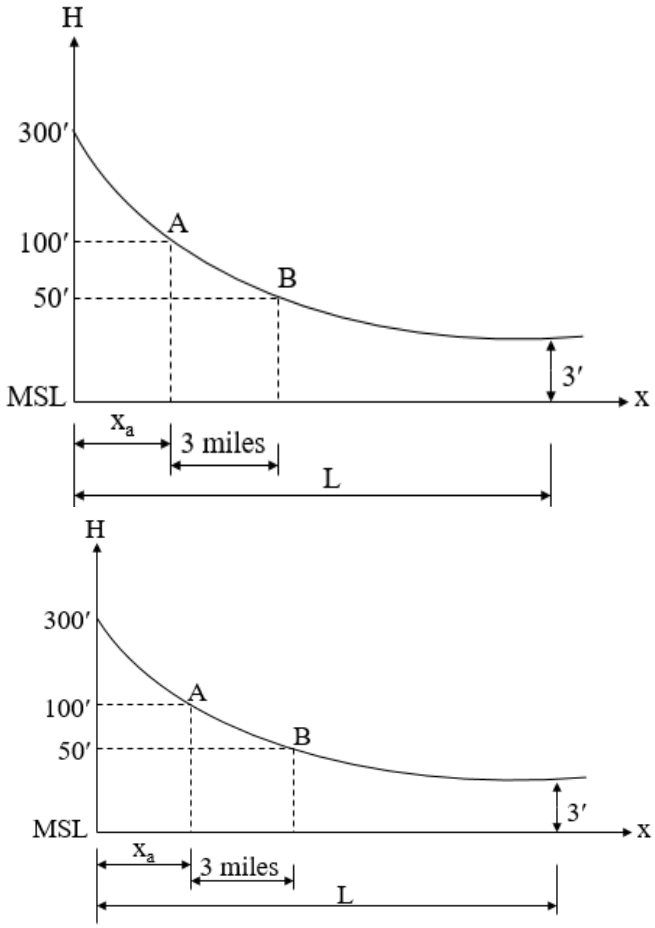
This is the equation of the longitudinal bed profile.

Here, $\frac{dH}{dX}$ is slope. At upstream, elevation is higher and hence slope is greater, so erodability is high. Here flash flood occurs as the water goes down very quickly. On the other hand, at downstream, slope is less, erodability is less but long time stagnation of water takes place while flood.

Worked Out Example:

Find the length of a river having the source at an elevation of 300 ft above MSL. The distance between two points A (RL – 100 ft) and B (RL – 50 ft) along the course is 3 miles. The river terminate at the sea where the stream level has an elevation of 3 ft above MSL.

Solution

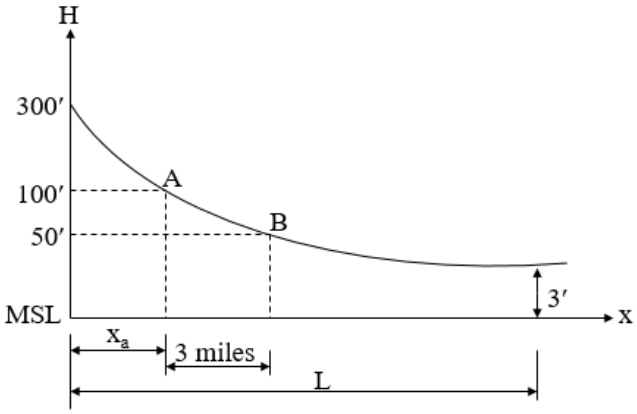


From the eqn of longitudinal profile, we know,

$H = Ce^{-bx}$

For, $H = 300'$ *and* $x = 0$, *we can write,*

$300 = Ce^{-bx0} = Ce^{0} = C$ ----------(1)

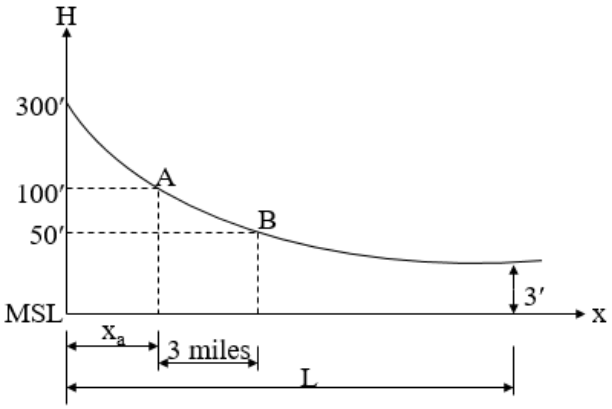


For, $H = 100'$ *and* $x = x_a$, *we can write,*

$$100 = Ce^{-bx_a} \quad \text{----------(2)}$$

For, $H = 50'$ *and* $x = (x_a + 3)$

$$50 = Ce^{-b(x_a+3)} \quad \text{----------(3)}$$



Dividing eqn (2) *by* (3), *we get,*

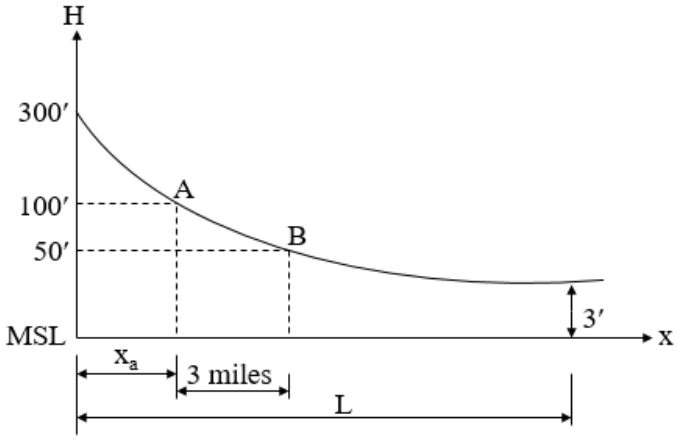
$$\frac{100}{50} = \frac{Ce^{-bx_a}}{Ce^{-b(x_a+3)}}$$

$$or,\ 2 = e^{-bx_a + b(x_a+3)}$$

$$or,\ 2 = e^{3b}$$

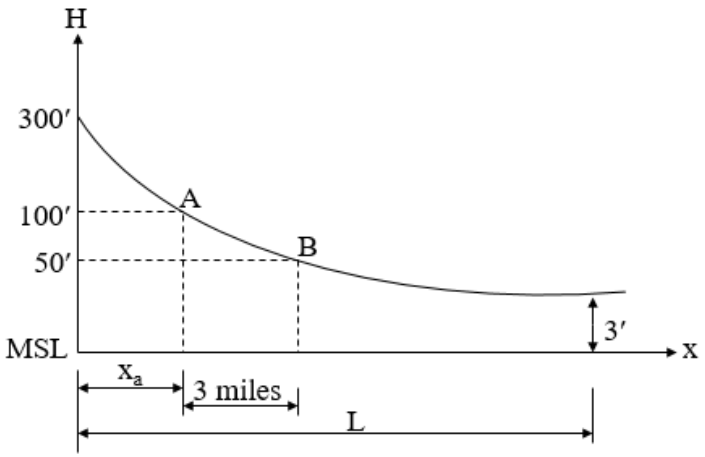
$$or,\ 3b = \log_e 2$$

$$\therefore b = 0.231$$



So, the longitudinal profile of the river can be expressed as,

$$H = 300e^{-0.231x} \quad \text{----------(4)}$$



Putting $H = 3'$ *and* $x = L$ *in eqn* (4), *we get,*

$$3 = 300e^{-0.231L}$$

$$or, -0.231L = \log_e 0.01$$

$$or, -0.231L = -4.605$$

$$\therefore L = 19.93 \text{ miles}$$

Readjustment of the Stream Grade:

A graded stream delicately adjusted to its environment of supply of water and rock waste from the upstream sources is highly sensitive to changes in those controls. Changes in climate and in land surface of the watershed bring changes in discharge and load at downstream points and these changes in turn require channel readjustment.

1. Effect of Increase in bed load:

Increase of bed load beyond stream capacity

→ Accumulation of coarse sediment on the stream bed

→ Elevation of stream bed

→ Aggradation

As consequence of aggradation:

a. In the upstream direction:

Reduction of the channel slope in the upstream direction

→ Reduction of the stream capacity in the reach

→ Accumulation of bed materials in the upstream direction

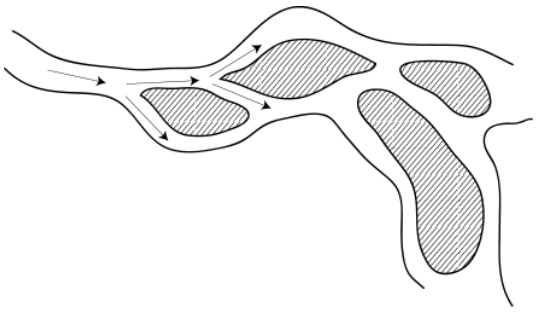
b. In the downstream direction:

Increase in the channel slope

→ Increase in velocity

→ Bed material is dragged downstream

Aggradation changes the channel cross section from a narrow and deep form to a wide and shallow one. Continuous formation of bars divides the flow into multiple directions which gives rise to 'braided channel'.



2. Effect of Decrease in bed load:

Due to the decrease of the bed load, a channel precisely graded is no longer in equilibrium. As a result:

Scouring of stream

→ Trenching into the alluvium and lowering of stream profile

→ Degradation (channel trenching)

As a result of this, the channel takes a narrower cross section and develops steep, wall-like banks of alluvium. After this channel trenching, the former floodplain is free from annual flooding and becomes a 'stream terrace'.

After degradation has taken place, the stream will normally attain a new and lower profile of equilibrium. When the new equilibrium is established the stream will usually develop meanders and will shift laterally to form a new floodplain. In many cases alternate cycles of aggradation and degradation produce a very complex series of terraces. These reflect the changing response of the stream to climatic changes.