Sinuosity of Ganges River

Meandering	SI > 1.5

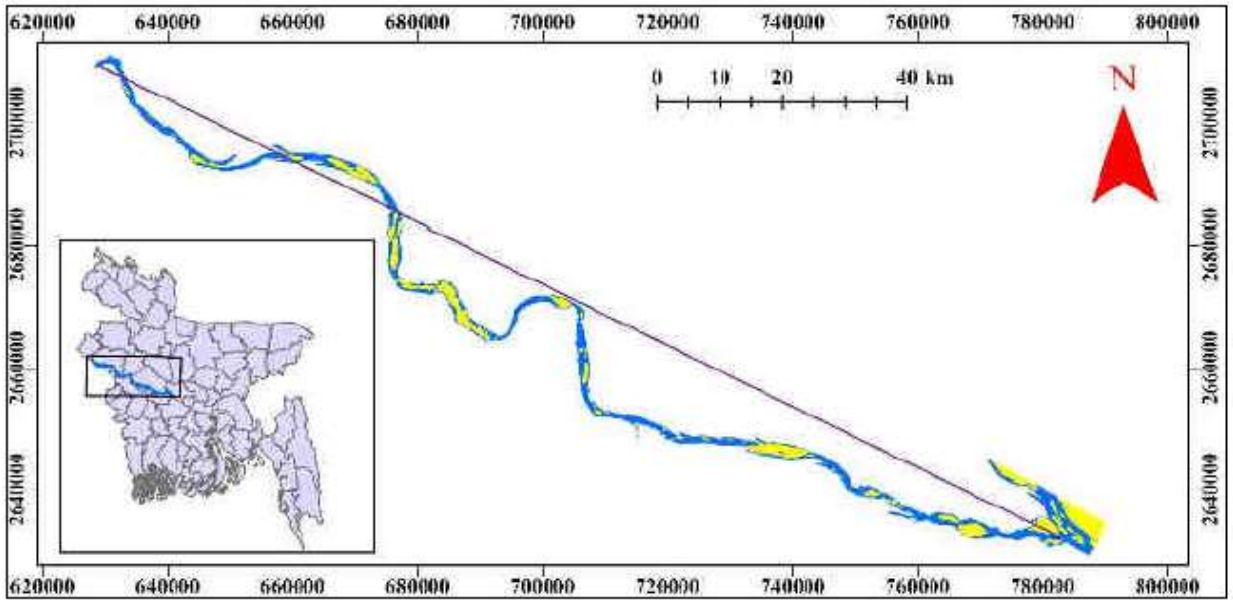


Fig. 6. Whole reach of Ganges River

Table 4. Sinuosity Index of Ganges River

Reach	No. of Bends	Meander Angle (deg)	Sinuosity according to $K = \frac{4.84}{4.84-\phi_\delta^2}$	Valley Length (km)	Meander Length (km)	Sinuosity according to $K = \frac{M}{L}$
1	1	42.31	1.127	4.15	5.33	1.28
2	2	34.20 56.57	1.079 1.252	52.43	61.34	1.17
3	2	44.90 54.00	1.145 1.225	15.77	18.94	1.20
4	2	36.72 78.23	1.093 1.626	19.93	31.39	1.58
5	1	42.12	1.126	19.25	22.44	1.17
6	3	20.30 24.96 45.00	1.027 1.041 1.146	64.63	67.08	1.04
Whole Reach	11			176.16	206.52	1.17

Sinuosity of the Ganges river from 1998 to 2025

Sinuosity of Ganges River

Meandering	SI > 1.5

Year	Mid-line distance (km)	Straight line distance	Sinuosity Index	Remarks
1998	269.31	201.86	1.33	Sinuous, but not meandering
2000	280	202.89	1.38	Sinuous, but not meandering
2005	263.82	203.36	1.30	Sinuous, but not meandering
2007	258.07	201.22	1.28	Sinuous, but not meandering
2010	259.45	202.31	1.28	Sinuous, but not meandering
2015	209.02	164.12	1.27	Sinuous, but not meandering
2018	249.48	201.83	1.24	Sinuous, but not meandering
2020	240.52	202.52	1.19	Sinuous, but not meandering
2025	253.95	201.82	1.26	Sinuous, but not meandering

Channel Patterns

River pattern means how the river looks in its plan view. River patterns provide a key to other river characteristics, both morphologic and dynamic. Low width-depth ratio (i.e. relatively narrow and deep) channels are relatively sinuous, whereas wide and shallow channels are relatively straight. Therefore, an indication of the morphology and relative stability of a river can be obtained by studying its pattern or planform.

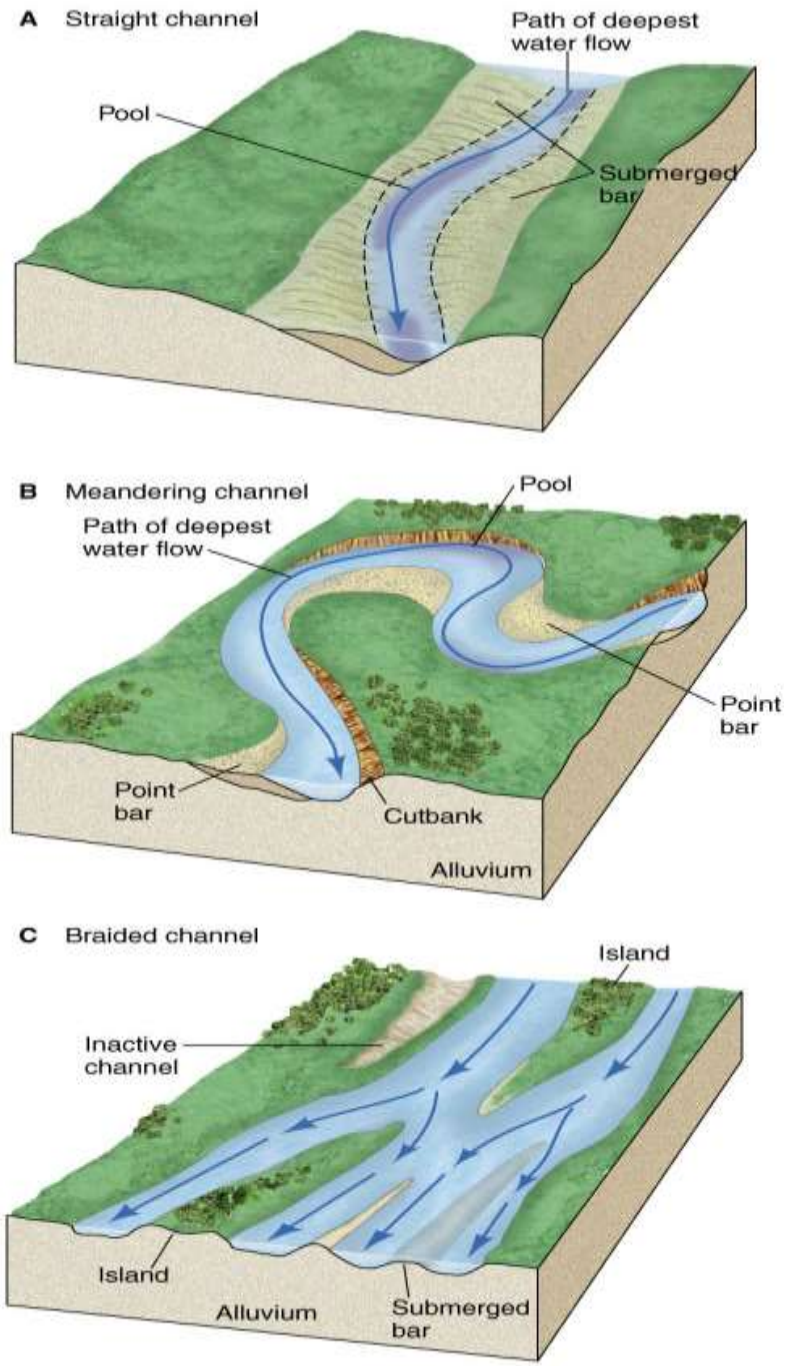
Three basic map-pattern forms of streams:

- Straight
- Meandering
- Braided

•Straight channels are rare.

•Found where streams are confined by topography or follow geologic structures (as in mountainous streams).

•The thalweg may show a meandering pattern.



Three Types of River Considering Planform

Straight, Braided and Meandering River



Meandering



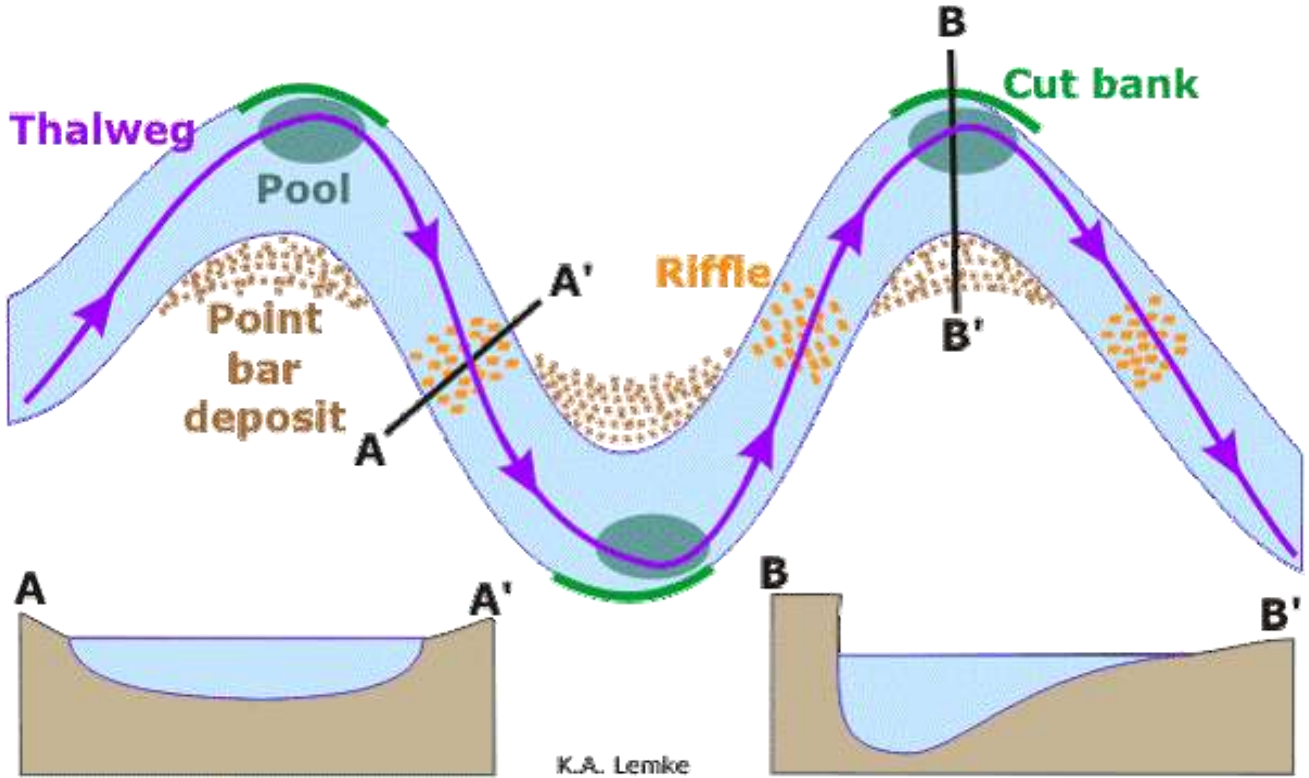
Braided



Straight

Meandering channels

Loops or meanders form as stream erodes its banks.
Erosion takes place on the outer bank and deposition takes place on the inner bank called point bar. There are alternating pools and riffles.
Meanders occur most commonly in channels that lie in fine-grained stream sediments and have gentle gradients.





Braided Streams

- If a stream is unable to move all the available load, it tends to deposit the coarsest sediment as a bar that locally divides the flow.
- Braided channels tends to form in streams having highly variable discharge, easily erodible banks, and/or a high sediment load.

- High sediment load
- Constantly changing course
- Floodplain completely occupied by channels
- Many small islands called mid-channel bars
- Usually coarse sand and gravel deposits.



Pattern Variability

Because alluvial channels are composed of sediment transported by the stream, the bed and banks are erodible; therefore, no alluvial channel is actually stable in the sense that no change occurs.

The variables affecting pattern variability are: slope, sediment load, sinuosity and width/depth ratio.

An important factor relating to pattern variability is the concept of geomorphic thresholds. Threshold velocities are required to set in motion sediment particles of a given size. With a continuous increase in velocity, threshold velocities are encountered at which movement begins; conversely, with a progressive decrease in velocity, threshold velocities are encountered at which movement ceases.

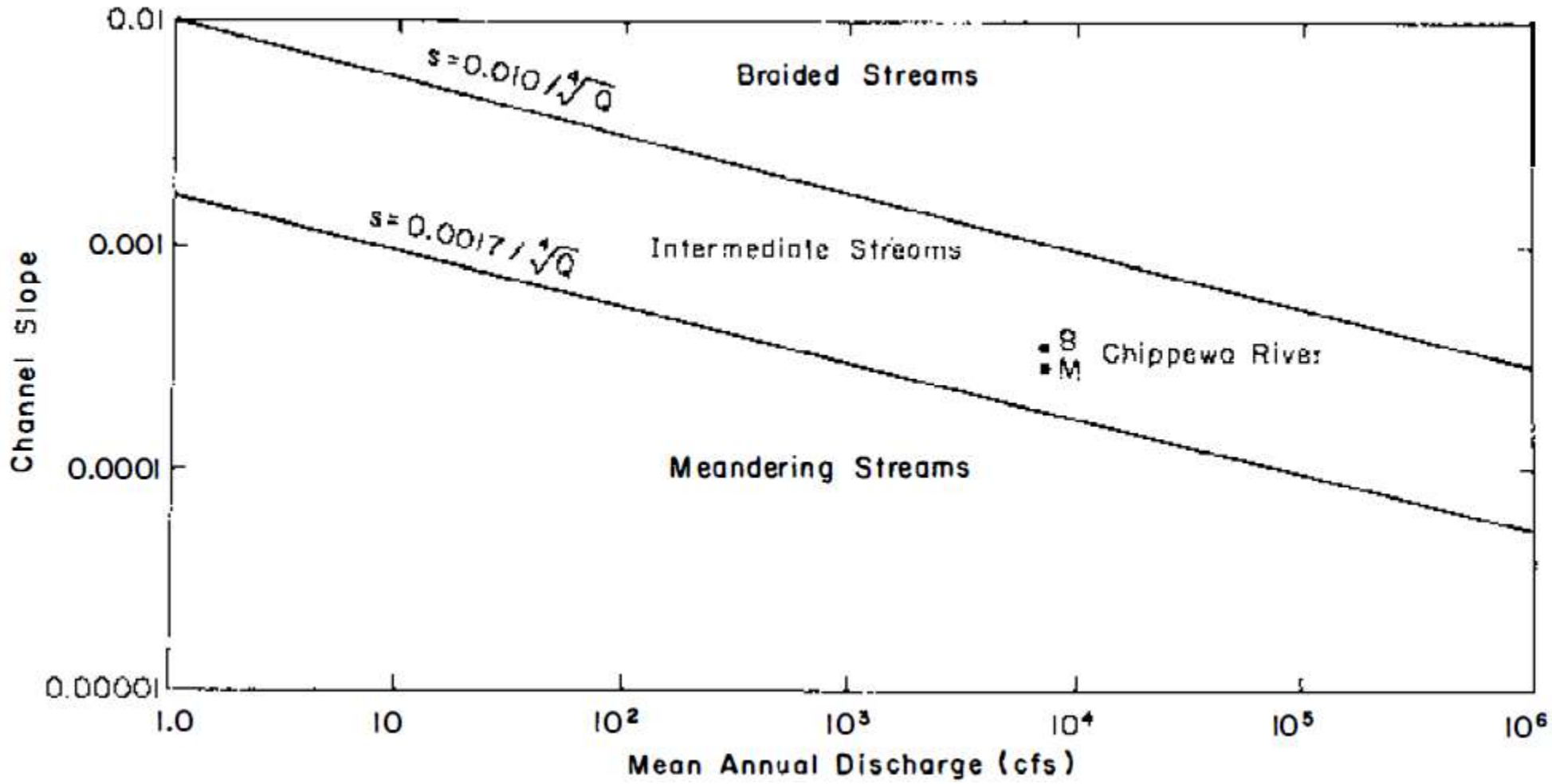
The variability of sinuosity and the range of pattern changes from meandering to braided provide excellent examples of the effects of threshold conditions. Figures indicate that there is a gradient or discharge threshold above which rivers tend to be Braided.

For a given discharge, as the valley-floor slope is progressively increased, a straight river becomes sinuous and then eventually braided at high values of stream power and sediment transport.

Effect of Slope

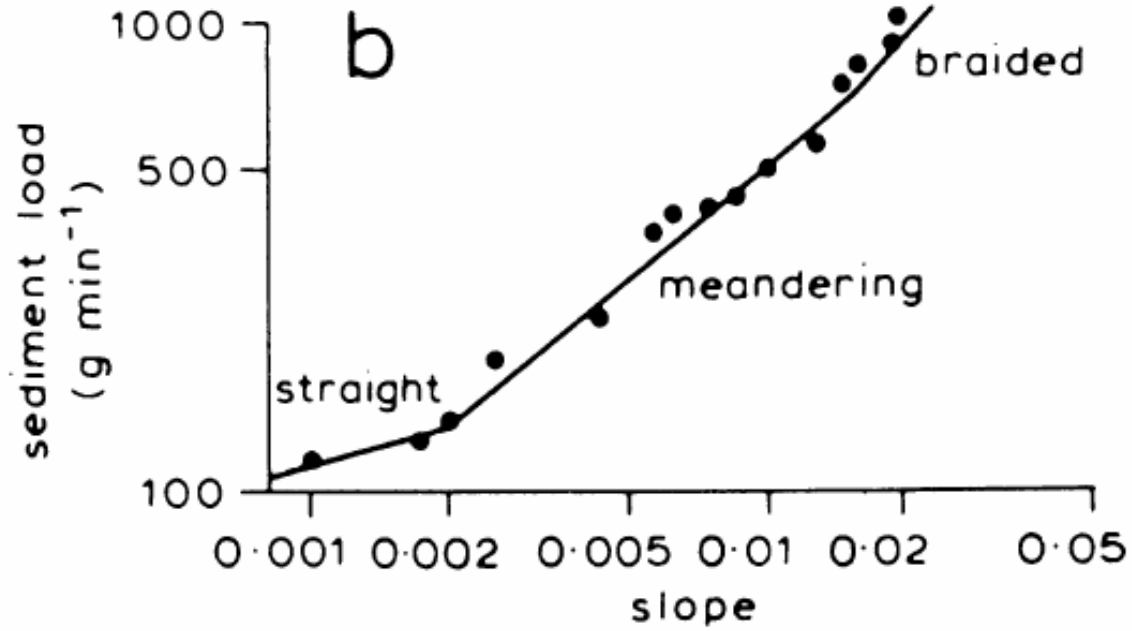
At a given discharge, meanders occur at smaller values of slope than do braids.

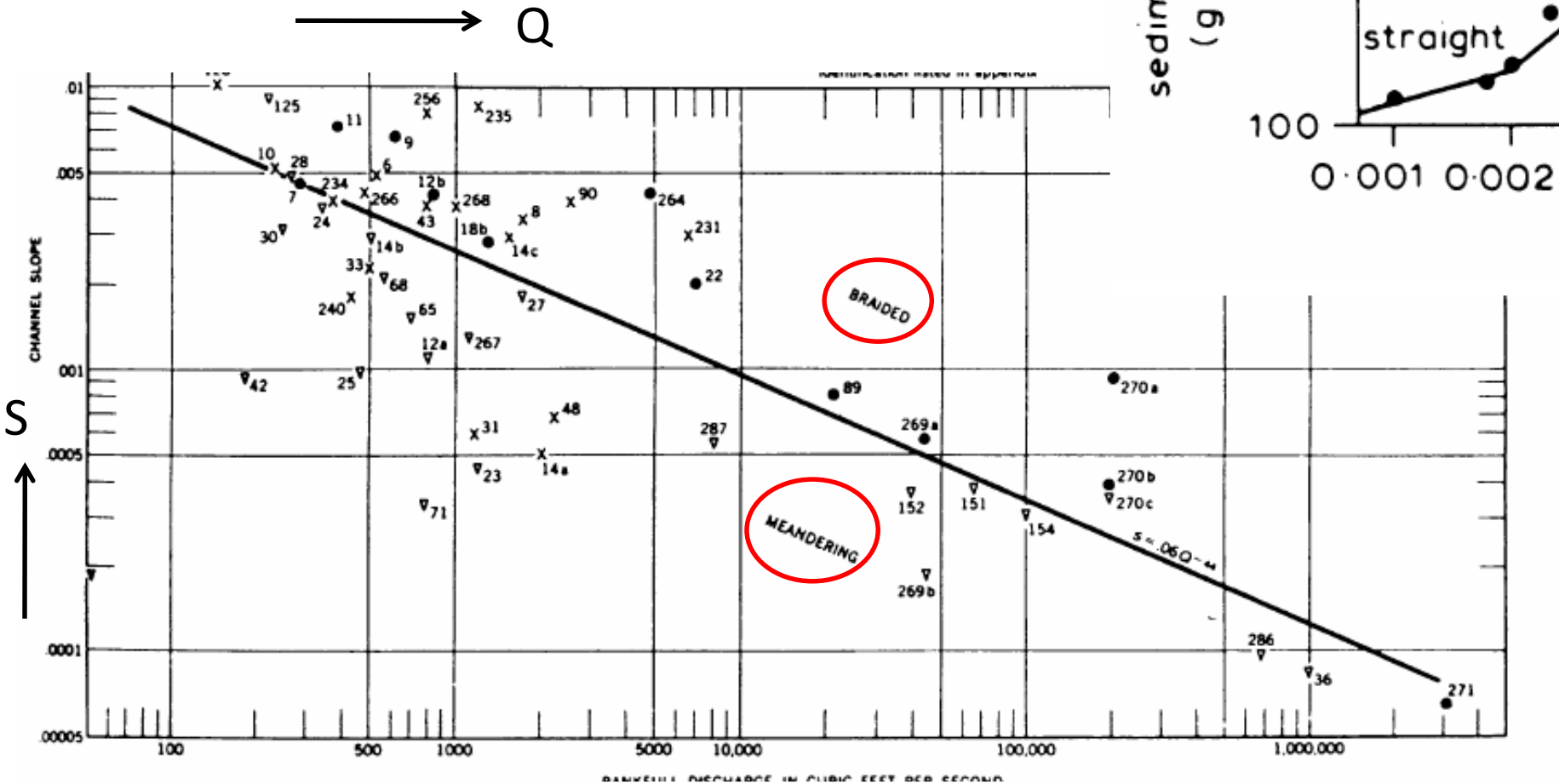
Further, at the same slope braided channels are associated with higher bankfull discharges than are meanders.



Effect of Slope and Sediment load

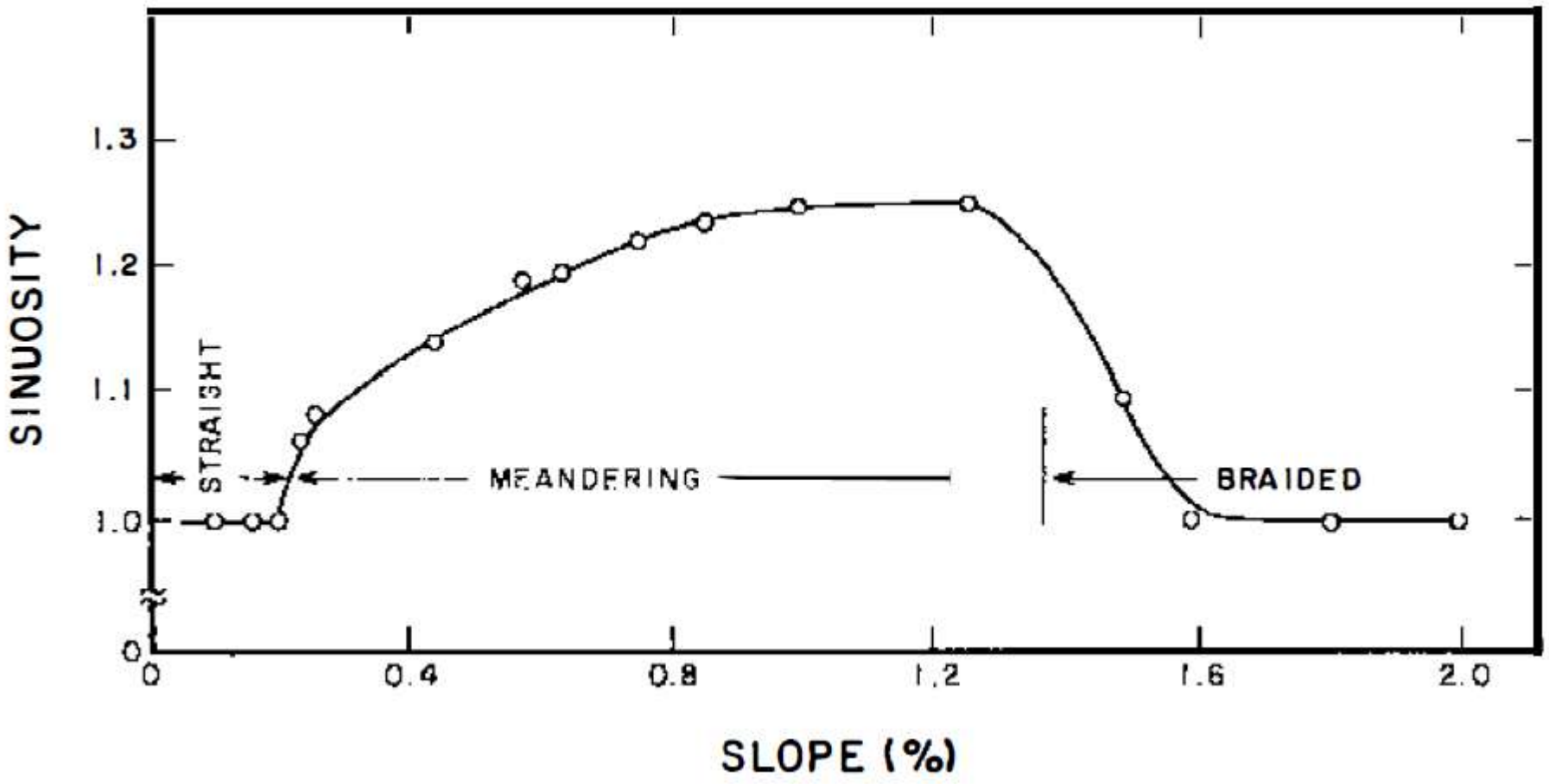
High slope is associated with sigh sediment load and braided pattern.





Effect of Sinuosity

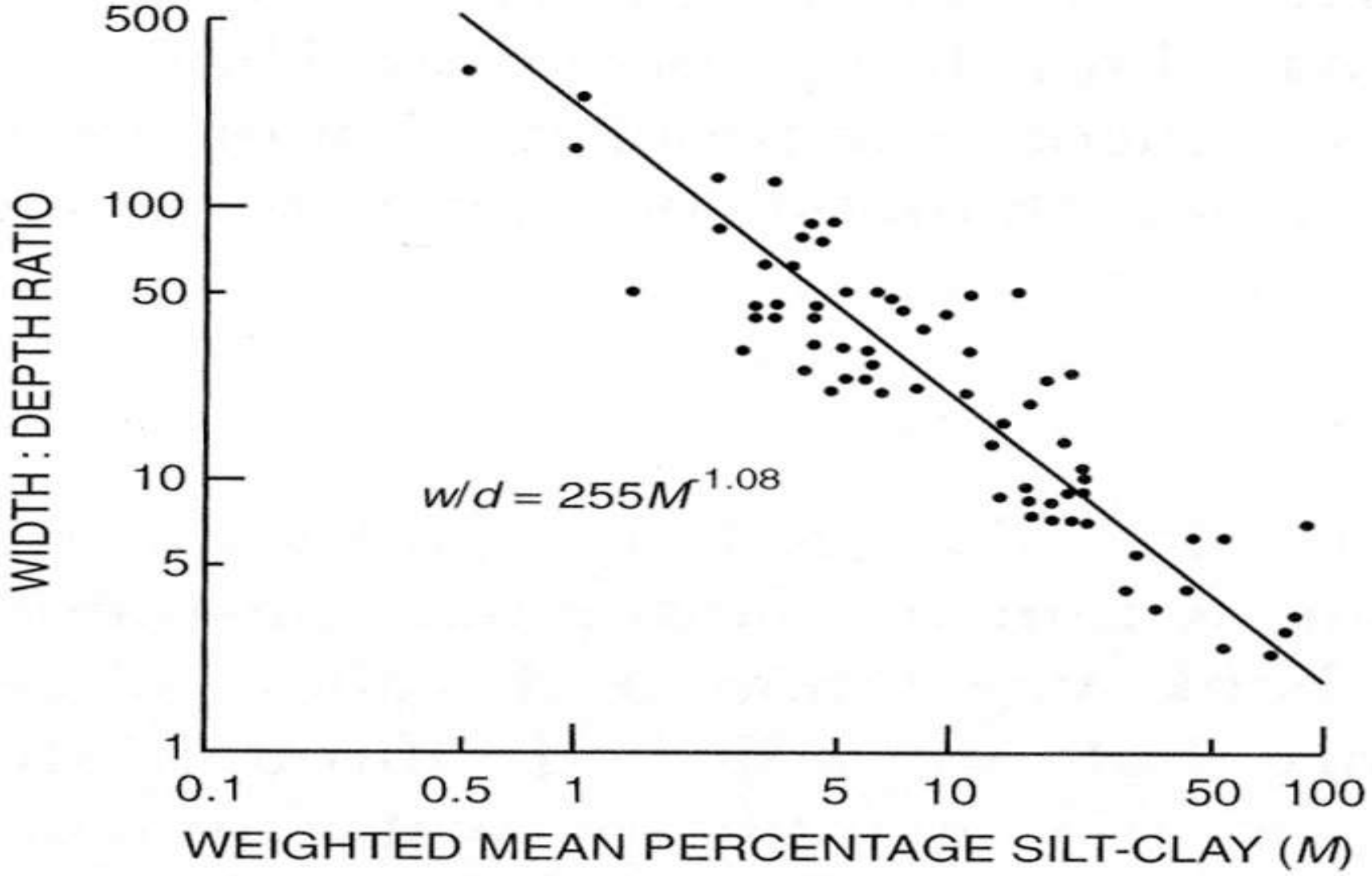
With increase in slope, sinuosity increases and straight river becomes meandering.
With further increase in slope, the sinuosity decreases and the river becomes braided.



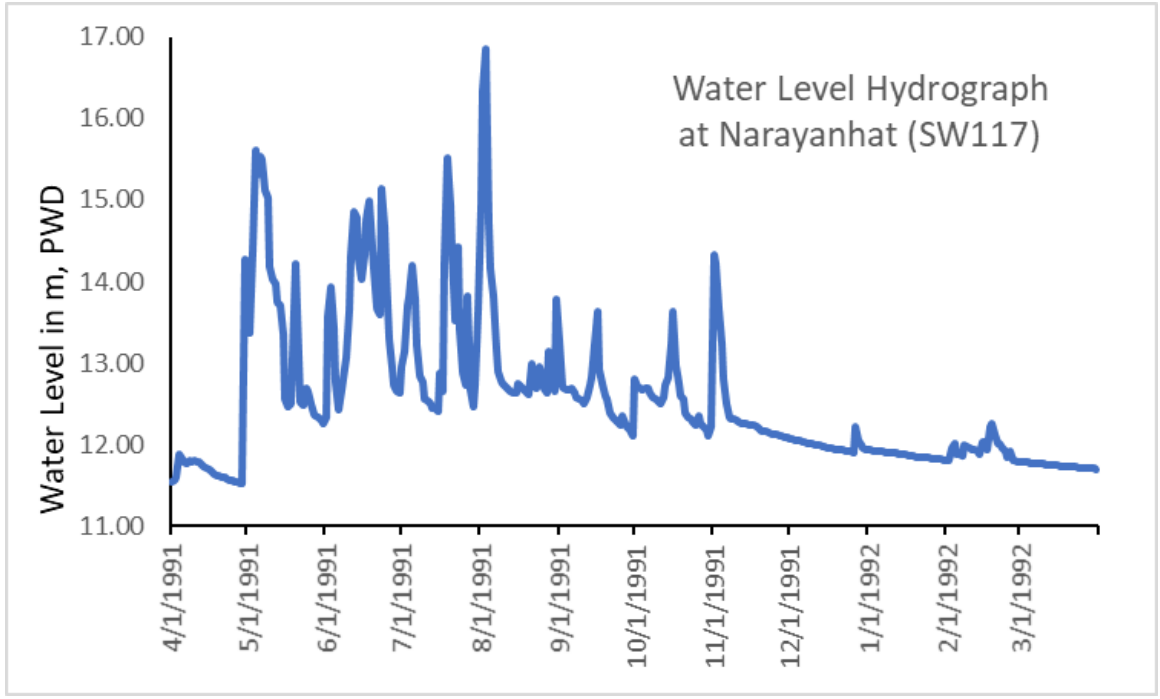
Width/Depth Ratio

Meandering channels would be more in cohesive soil with high contents of silt-clay and hence would have a low width/depth ratio (< 10).

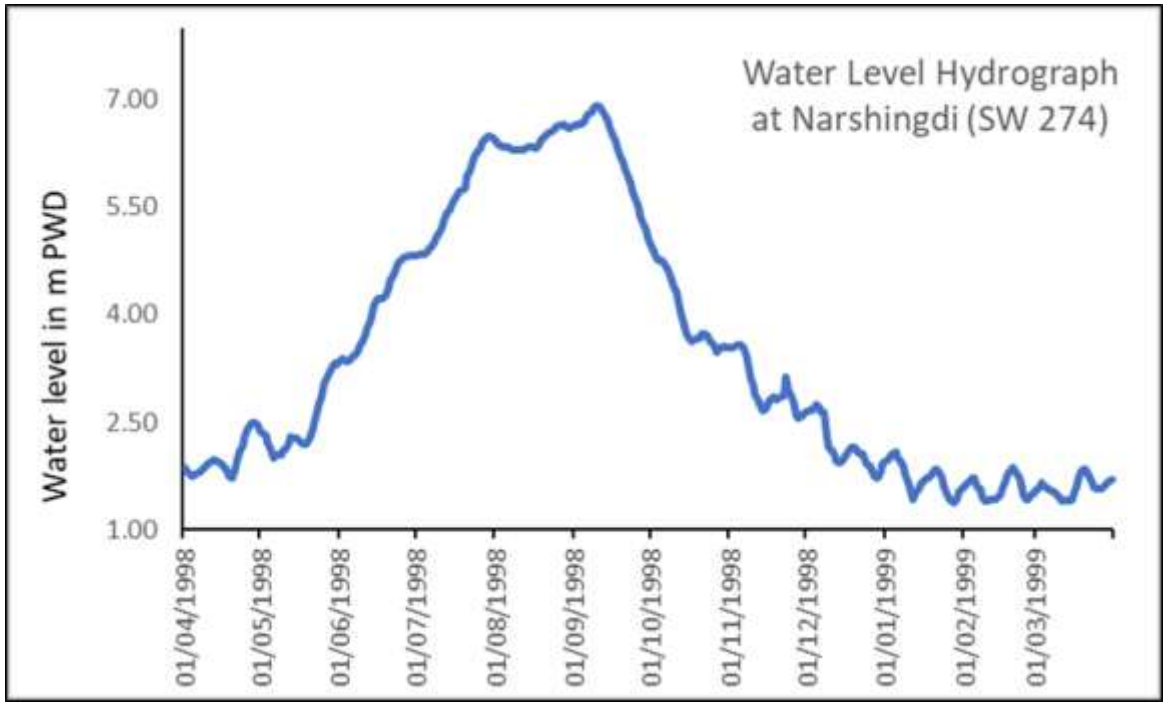
High width/depth ratio is associated with bed load (low % silt-clay) and braided channel.



Classification based on flooding: Normal and Flashy River



Water level hydrograph of Halda River at Narayanhat station (SW 117) for the hydrological year 1991-1992



Water level hydrograph of Meghna River at Narshingdi station (SW 274) for the hydrological year 1998-1999

In Bangladesh, some of the rivers in the NE and SE regions are classified as flashy rivers. These rivers in the hills/hill slopes respond quickly to rainfall (short duration high floods) during the pre-monsoon season and cause widespread damage during the Boro season (Boro rice in the Haor areas of Sylhet).

Effect of Discharge

All types of channels are formed at similar average discharges in the field and in the laboratory by changes of valley slope and sediment supply.

The bankfull, average, or mean-annual discharge (Q) determine to a large extent channel dimensions such as width, depth, meander amplitude, and meander wavelength, but the quantity of water moving through a channel (Q) does not generally affect the basic pattern.

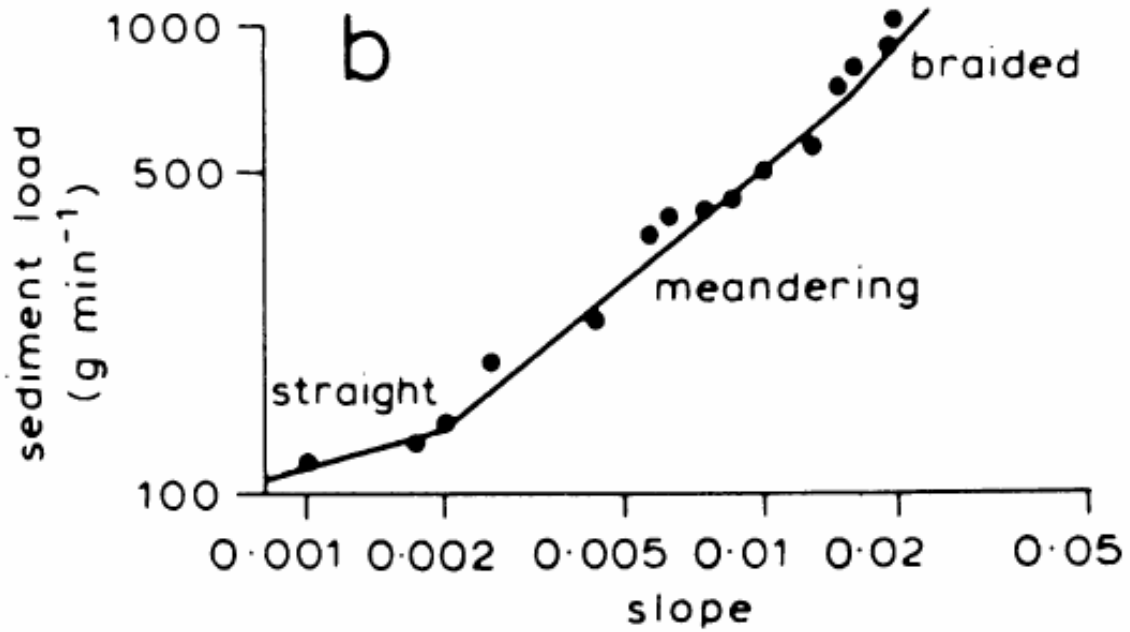
The type of sediment load transported by the river also plays a role in pattern. Channels that transport relatively low sand-and-gravel (bed load) loads are more likely to be sinuous, and they are not braided.

At low slopes and with low sediment loads (i.e. low velocity and low stream power), the experimental channels remained straight. As the slope of the surface on which the experimental channel flowed was increased, velocity, stream power, and sediment transport all increased.

Bank erosion became important, and a sinuous pattern with alternate bars developed. At the highest slopes, with high energy and high sediment load, the channel became braided.

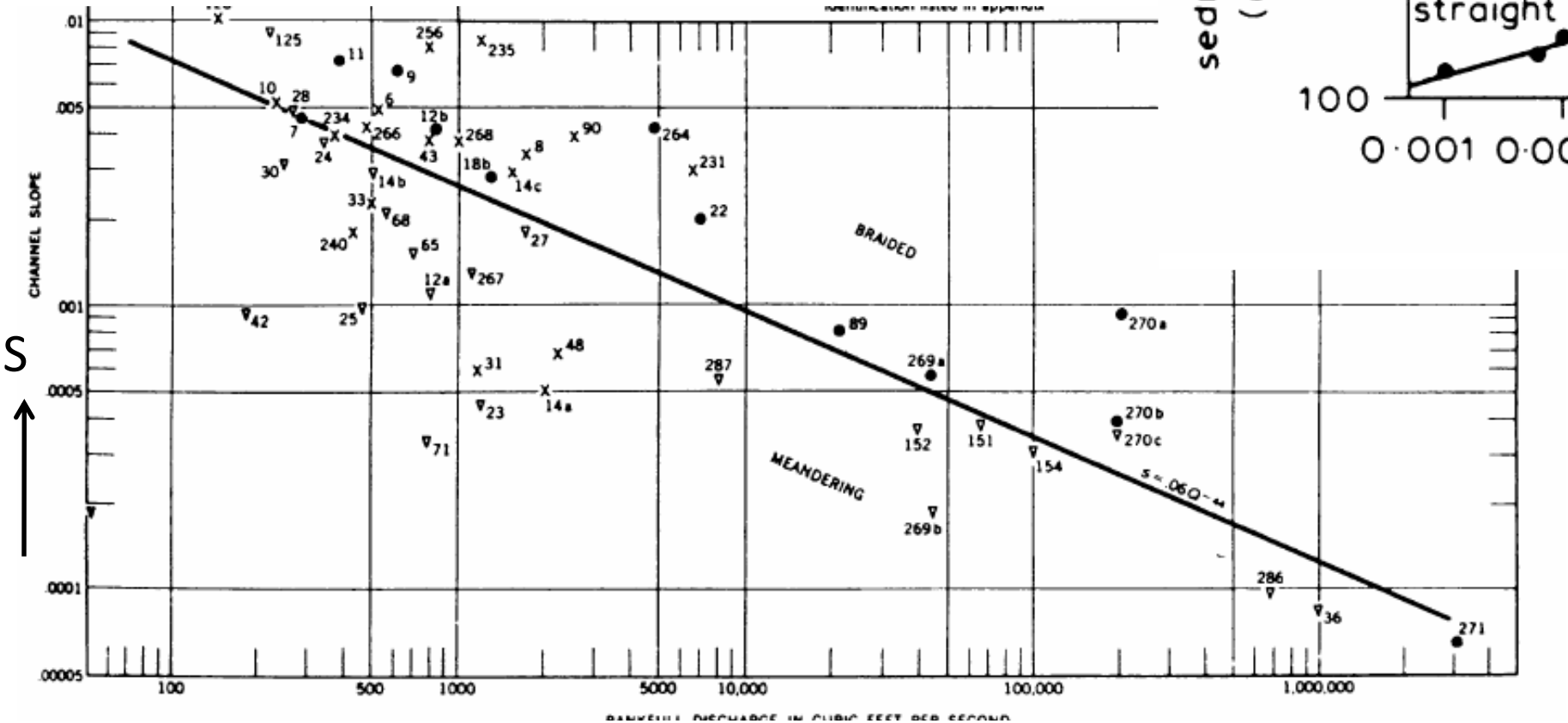
Effect of Slope and Sediment load

High slope is associated with sigh sediment load and braided pattern.



Q →

S ↑



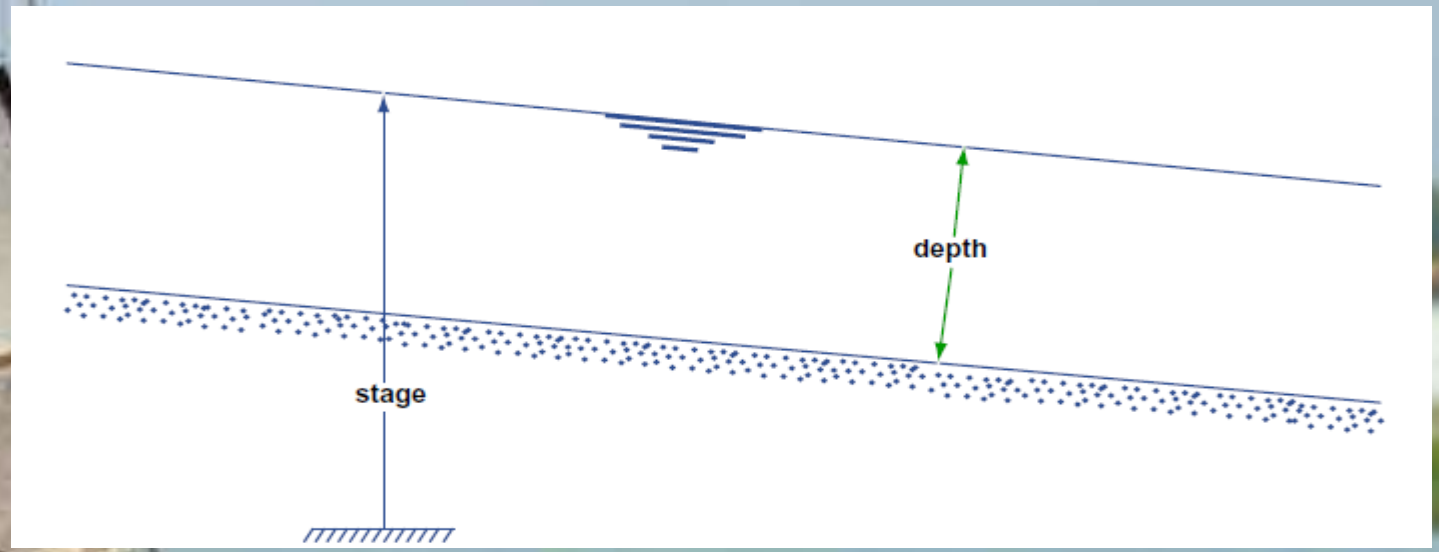
A classification of alluvial channels should be based not only on channel pattern (planform) but also on the variables that influence channel morphology.

This is particularly true if the classification is to provide information on channel stability.

Numerous empirical relations demonstrate that alluvial channel dimensions (width and depth) are largely due to water discharge, whereas channel shape and pattern (planform) are related to the slope and type and amount of sediment load moved through the channel.

Hydraulic Geometry of Rivers

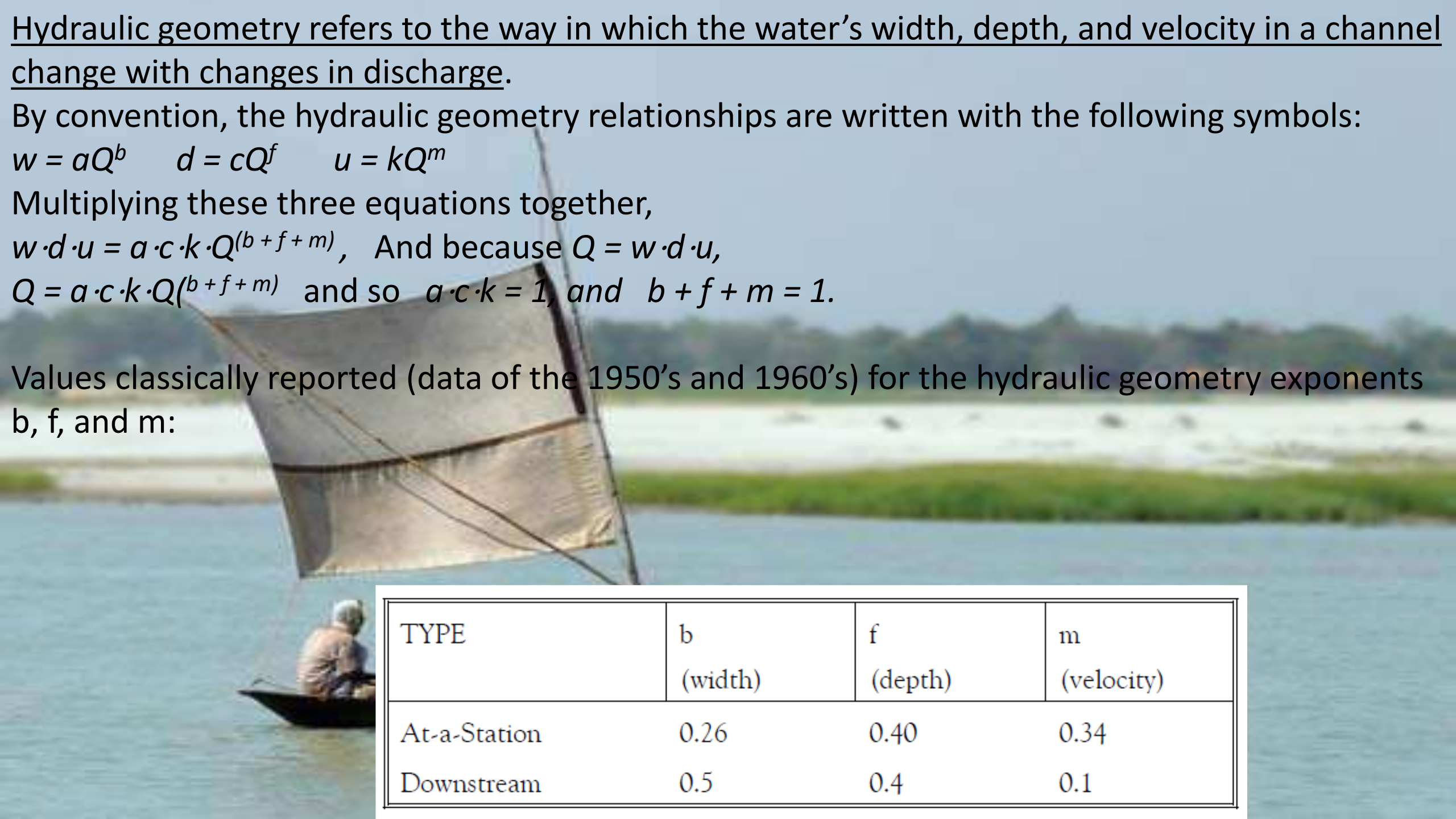
Two parameters of a river that are monitored to characterize a river are: stage and discharge.
Stage (h) – refers to the height of the water surface with respect to a datum (usually mean sea level). Stage is related to the depth but the two are not the same.



Discharge (Q) - of a river is the volume rate of flow past a given cross section, measured in cubic meters per second, m^3/sec(cumecs).

$Q = VA = wdU$

Where Q is discharge past a cross section of area A (width w x depth d) of mean velocity U of that cross section.



Hydraulic geometry refers to the way in which the water's width, depth, and velocity in a channel change with changes in discharge.

By convention, the hydraulic geometry relationships are written with the following symbols:

$w = aQ^b$ $d = cQ^f$ $u = kQ^m$

Multiplying these three equations together,

$w \cdot d \cdot u = a \cdot c \cdot k \cdot Q^{(b+f+m)}$, And because $Q = w \cdot d \cdot u$,

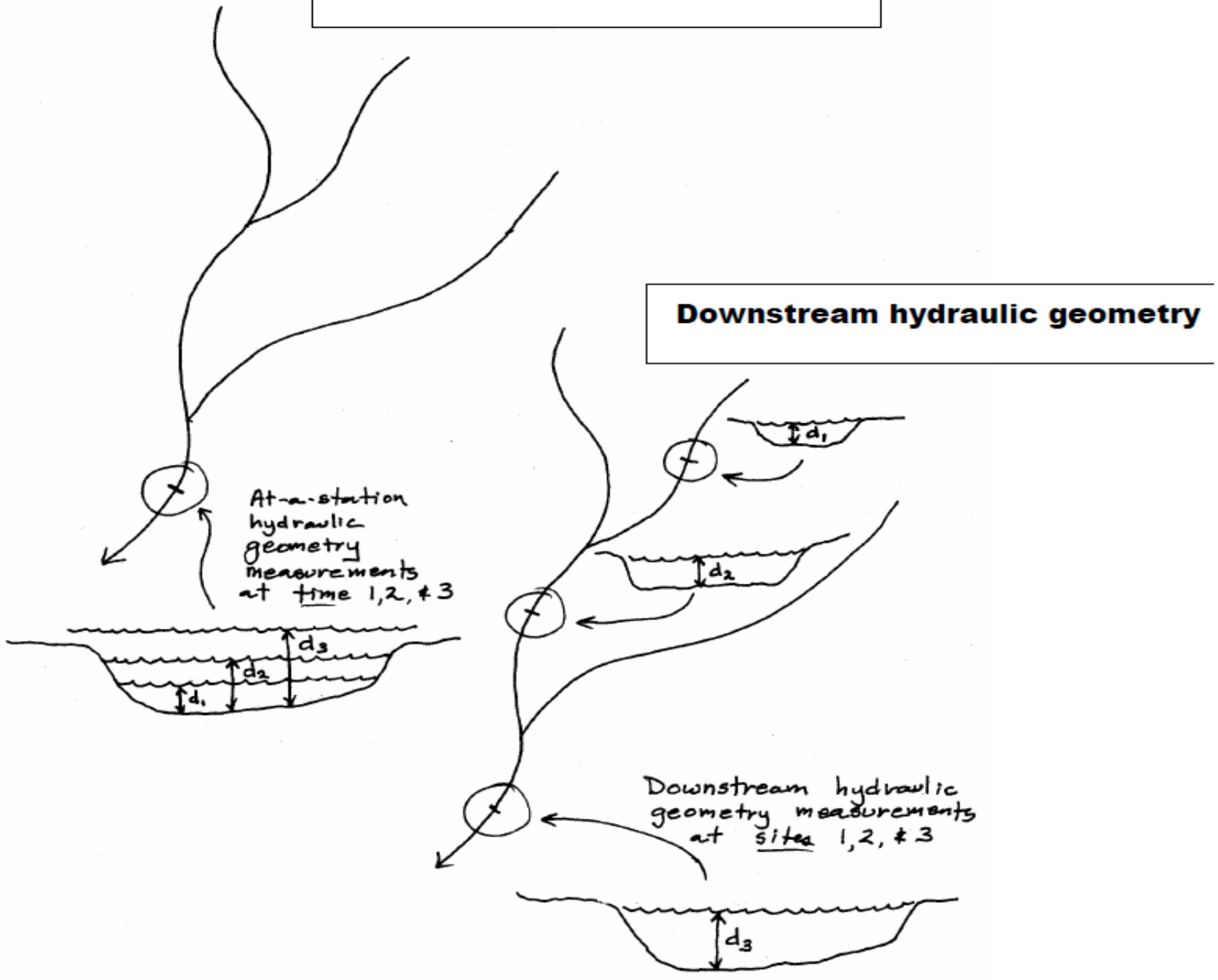
$Q = a \cdot c \cdot k \cdot Q^{(b+f+m)}$ and so $a \cdot c \cdot k = 1$, and $b + f + m = 1$.

Values classically reported (data of the 1950's and 1960's) for the hydraulic geometry exponents b, f, and m:

TYPE	b (width)	f (depth)	m (velocity)
At-a-Station	0.26	0.40	0.34
Downstream	0.5	0.4	0.1

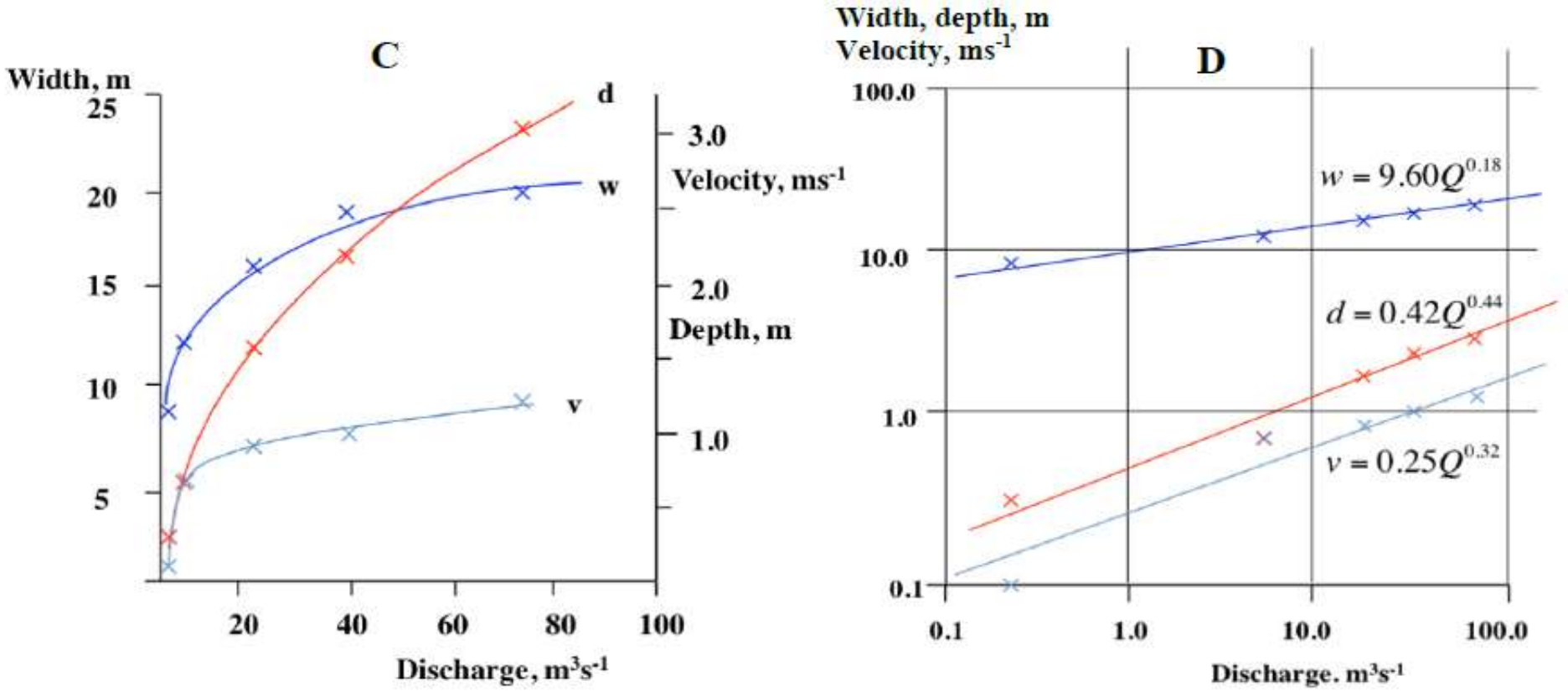
At-a-station hydraulic geometry

Downstream hydraulic geometry

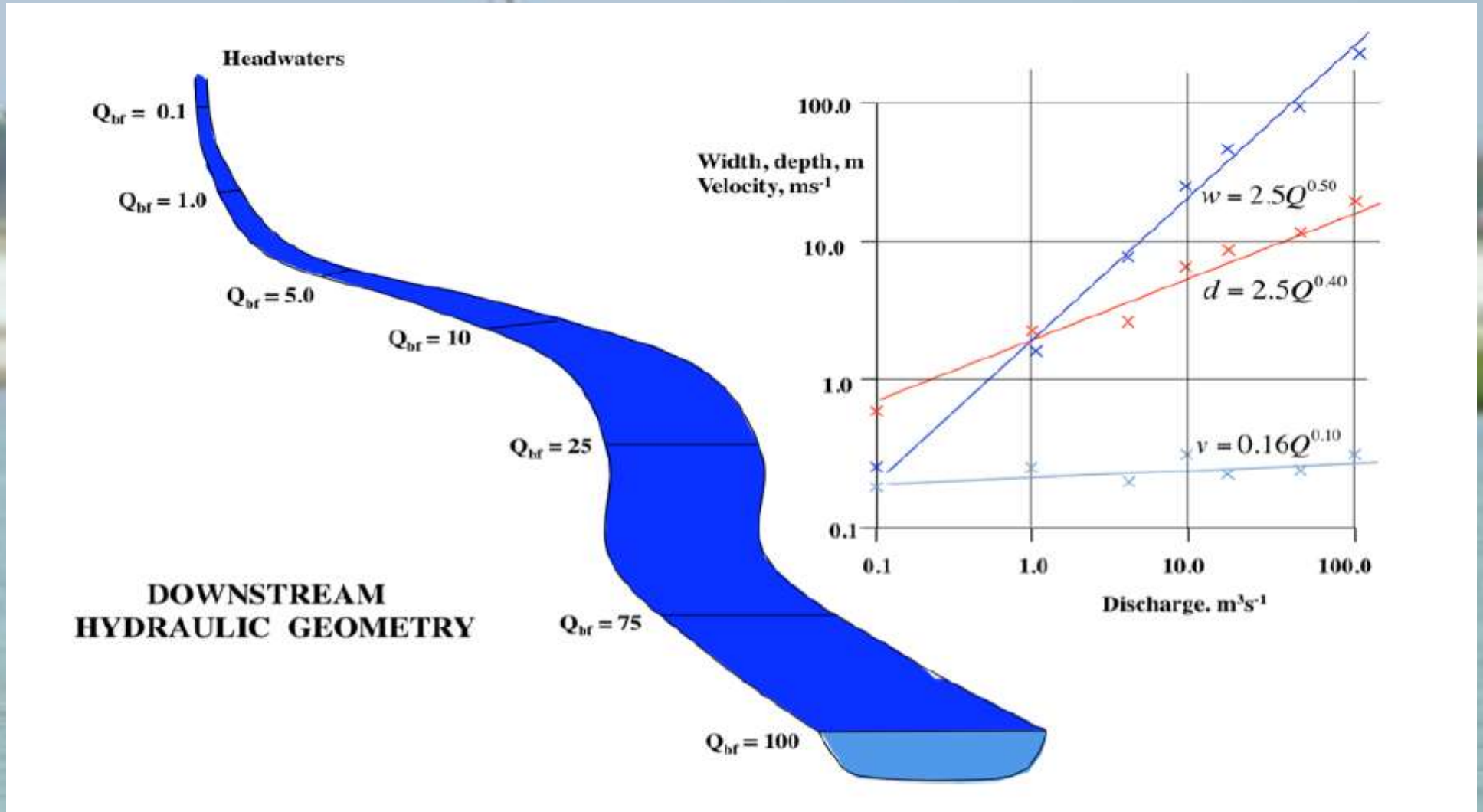


Hydraulic geometry of river channels comes in two formats: (a) at-a-station hydraulic geometry and (b) downstream hydraulic geometry.

At-a-station hydraulic geometry defines the relations among w, d, v and Q as discharge varies at one location (or station) in the channel. It describes how the channel dimensions and form change as discharge varies *over time*.



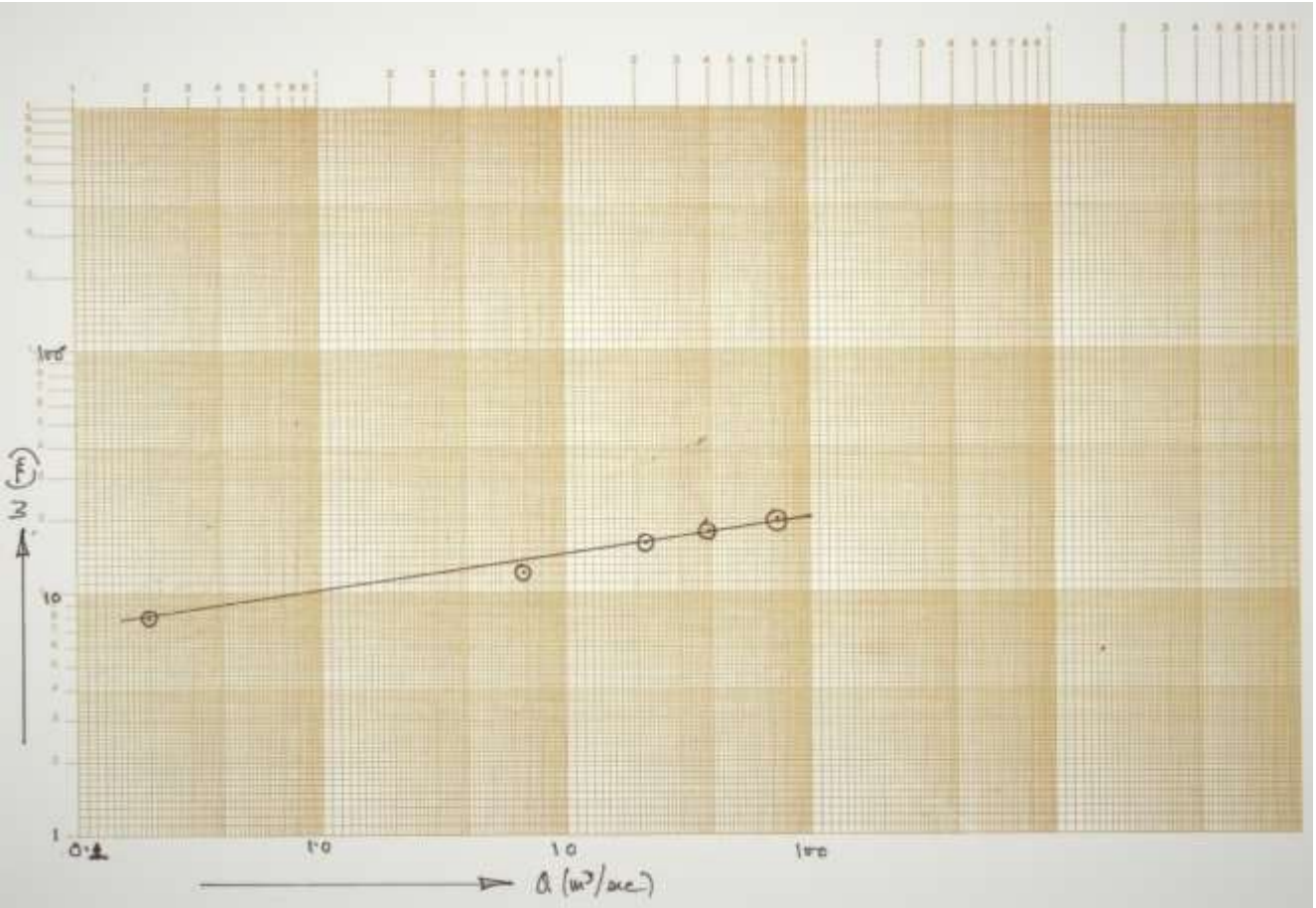
Downstream hydraulic geometry defines the channel changes that occur in response to increasing discharge along a river as tributaries add flow to the system. That is, it describes the changing spatial pattern of hydraulic geometry associated with increasing drainage area and associated discharge.



Problem: If data are given it is possible to develop the hydraulic geometry relationships. If two relationships are known, it is possible to find the third.

Example: The width and the discharge data of a small river are shown in the following table. Develop the Width-discharge relationship.

Discharge Q (m^3/sec)	0.2	5.9	23	39.6	74.4
Width (m)	8	12	16	18	20



From log-log plot: $W = 10.5\ Q^{0.15}$

If a second relationship is given:

$d = 0.4\ Q^{0.45}$

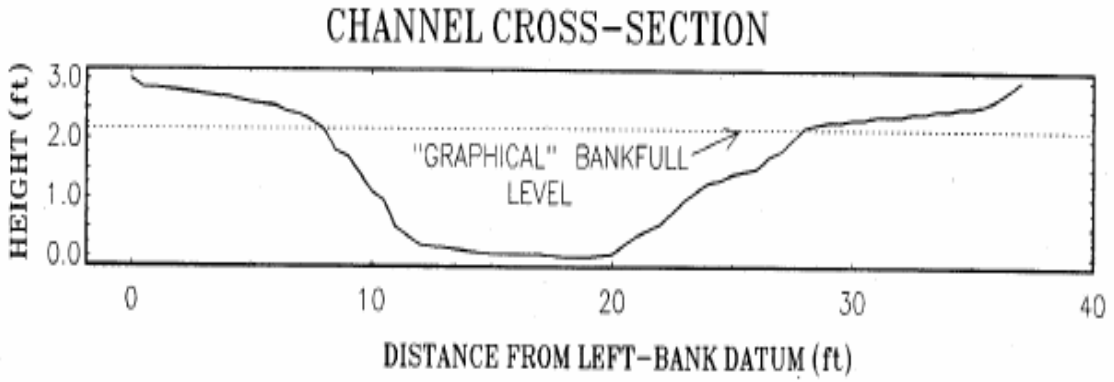
then the V – Q relationship can be developed(?)

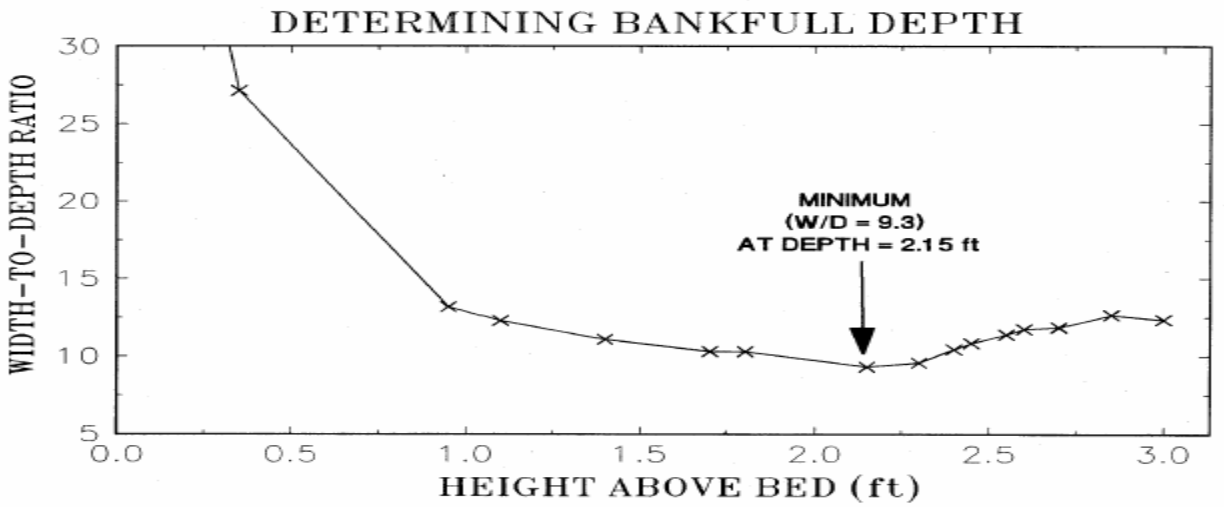
Bankfull Discharge

The surface at the top of the bankfull channel is the **floodplain,** which is inundated whenever the river or stream experiences a flow exceeding **bankfull discharge.**

It is determined by plotting depths against width-to-depth ratio of the channel where the ratio reaches a minimum value, or from the elevation at which a plot of cross sectional area vs. top width of the flow changes most abruptly.

Near the bed the flow is wide and shallow, so the width-to-depth ratio is high. At flood stages the flow spreads out across the floodplain and the width-to-depth ratio is also high. The bankfull discharge can be approximated by the flow depth that corresponds with the minimum width-to-depth ratio.

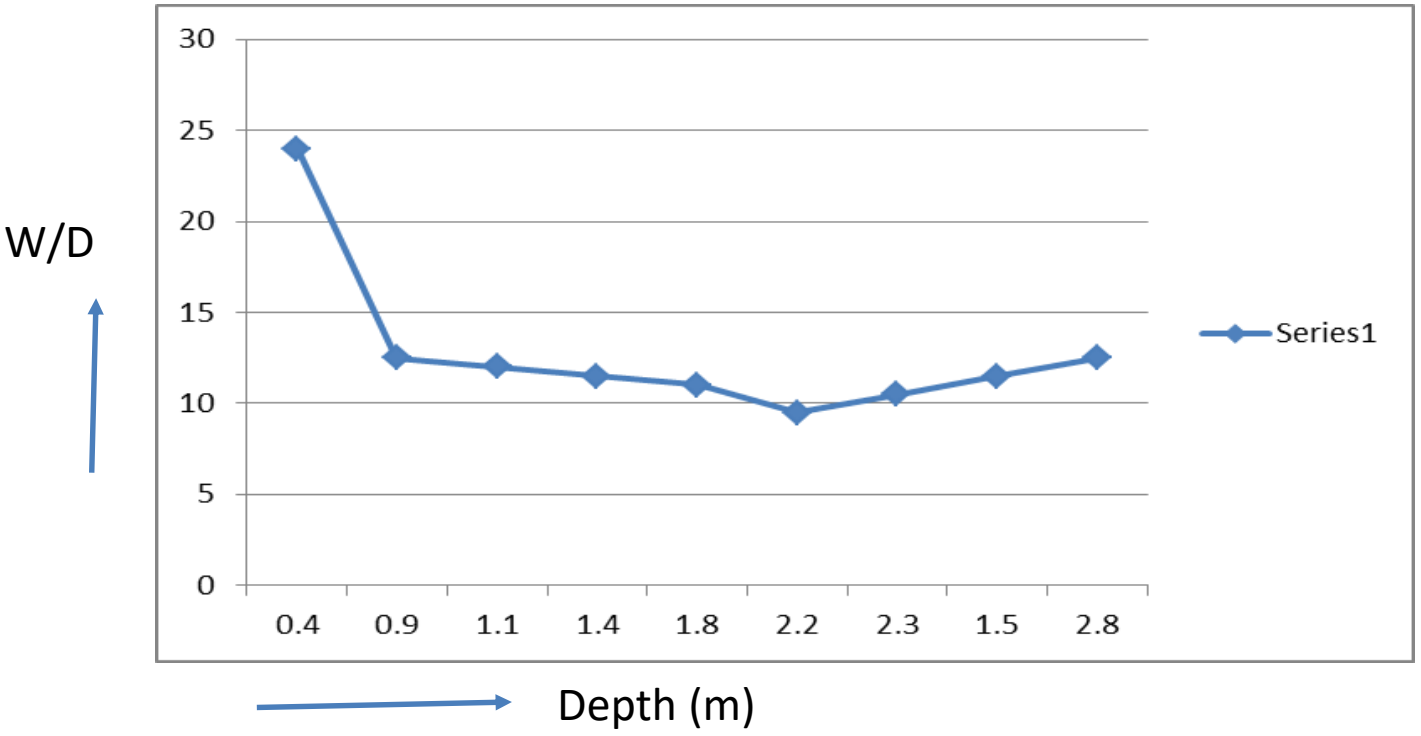




Example:

The widths and the corresponding depths of the cross-section of a river are shown in the following table. Calculate the depth of the bankfull discharge.

Depth (m)	0.4	0.9	1.1	1.4	1.8	2.2	2.3	2.5	2.8
Width (m)	9.6	11.3	13	16.1	19.8	20.9	24.2	28.8	35
W/D	24	12.6	11.8	11.5	11	9.6	10.5	11.5	



From the graph:
The discharge corresponding to the depth of 2.2m is the bankfull discharge.

Dominant Discharge

The wide variation is discharge of a river makes it difficult to study the discharge characteristics and select a representative discharge.

It has been suggested that bankfull discharge be considered as the dominant discharge.

It has also been suggested that dominant discharge is the discharge which is equaled or exceeded 50% of time (2-yr return period).

River Slope

The longitudinal slope of a river shows continuous decrease. The reduction in slope corresponds to a longitudinal profile which is concave upwards. As the river flow is due to gravity, the flow is from higher to lower elevation (decreasing slope). The reduction in slope is expressed as:

$S = S_0 e^{- \alpha x}$

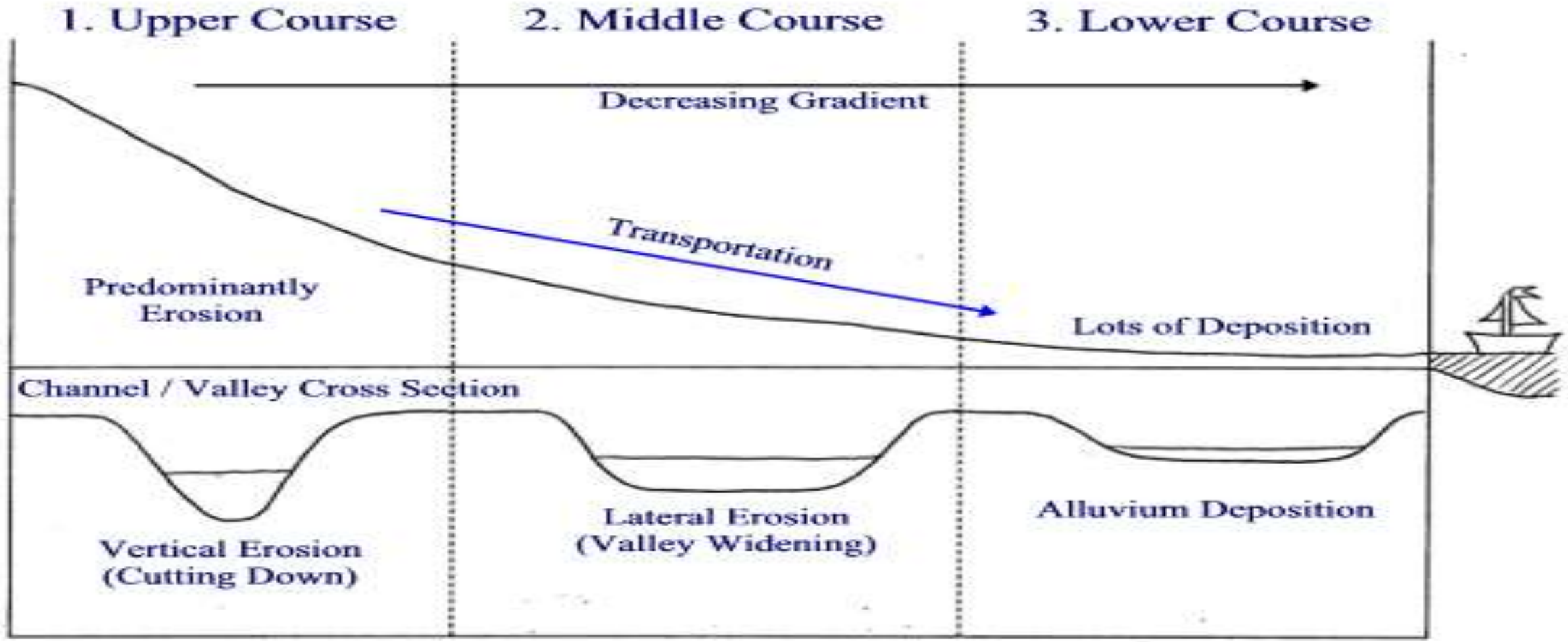
where: S_0 and S are the slopes x = 0 and at any x downstream and α is a constant.

If slope S is dy/dx then: $dy/dx = S_0 e^{- \alpha x}$

Integrating, gives the equation of the longitudinal profile as:

$$Y = (e^{- \alpha x} - 1) S_0 / \alpha$$

Longitudinal Profile of Rivers



There are several other reasons for such a profile:

1. The size (mass) of the sediment load decreases continuously due to abrasion (reduction in sediment size due to rubbing, grinding and crushing of particles against each other) and hence the stream requires a flatter slope to transport the sediment as the river moves downstream.
2. The upper part of the drainage basin is the main source of sediment (zone of erosion) and as the river reaches the valley, the sediment concentration decreases (due to deposition) which results in a decrease in slope.
3. As the river flows downstream, the discharge increases due to inflow from the tributaries but not the sediment load (not in same proportion). The river reduces the slope to the extent required for the increased water and sediment discharges.

Sediment Size

The median size of sediment is found to decrease continuously along the length of the river as discussed earlier. If W is the weight of the sediment particle at a distance x then:

$$W = W_0 e^{-\beta x}$$

Where W_0 is the weight of the sediment at x = 0 and β is a constant.

If weight is replaced by particle diameter (d), then: $d = d_0 e^{-cx}$