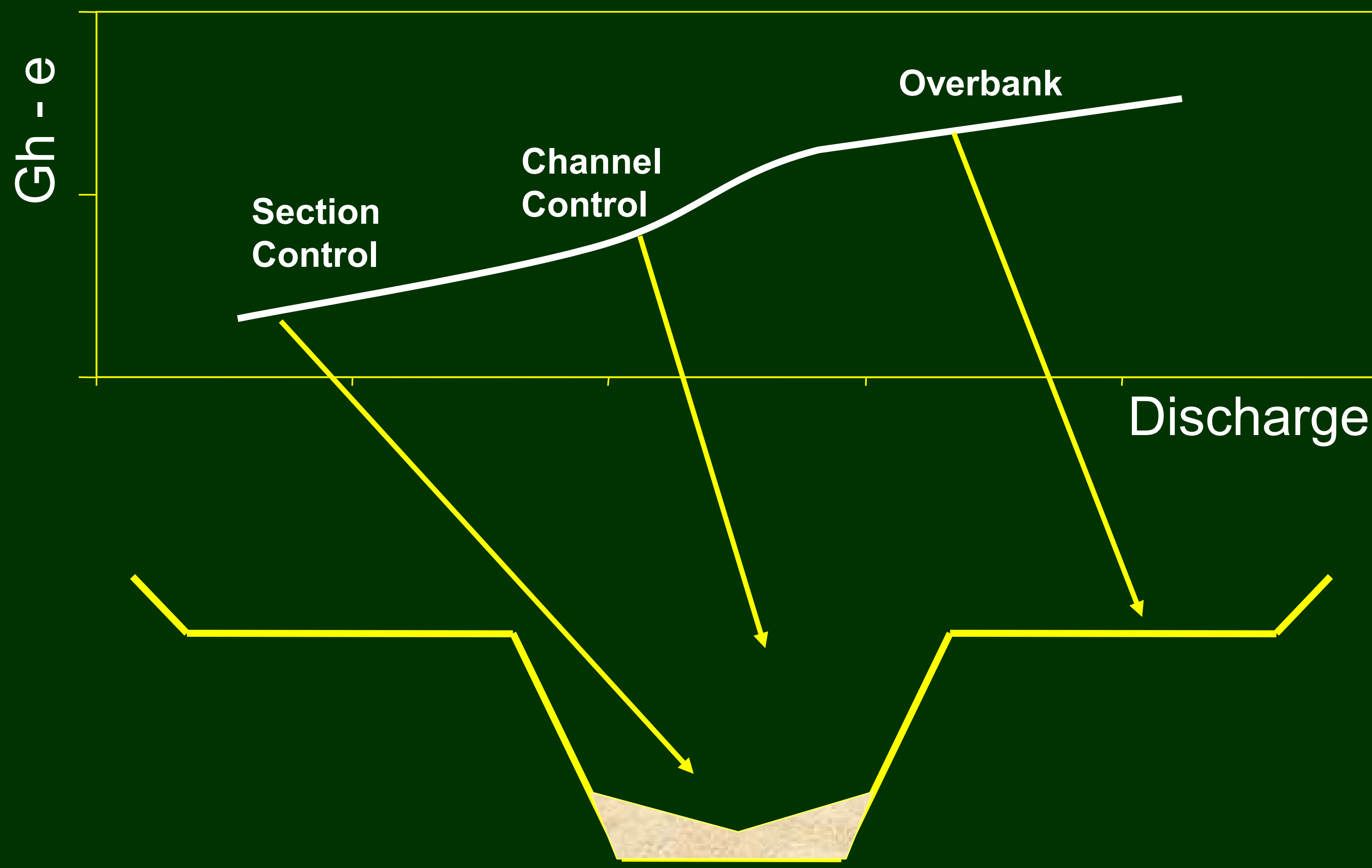
We will now move on to study rating curves for natural channels



The relation between stage and discharge in a natural channel can also be assumed to be a power function

Here is the power function that is often used to relate discharge and head under section control

$$Q = a(GH-e)^b$$

where:

a = coefficient

b = slope of the relation

(b is almost always greater than 2)

Here is the equation that is often used to relate discharge and head under channel control

Manning's equation:

$$Q = \frac{1.486}{n} A R^{2/3} S^{1/2}$$

Where:

A = cross section area

R = hydraulic radius (area/wetted perimeter)

S = energy slope

n = Manning's "n" (roughness coefficient)

Manning equation can be reduced to a simple power function

$$Q = \frac{1.486}{n} A R^{2/3} S^{1/2}$$

Can be reduced to:

$$Q = C\, d^{1.67} = C\, (GH\text{-}e)^{1.67}$$

Click here if you want to see how this is done.

Just to be sure we all know how to use exponents and how to compute basic hydraulic parameters we will go through a brief math primer

Weir equation:

$Q = CBH^{3/2}$

where

C = 2.5,

B = Top width = 20 ft

H = Average depth of flow = 2 ft

$$Q = 2.5 \times 20 \times 2^{1.50} = 141\ ft^3/s$$

Manning equation:

$$Q = \frac{1.486}{n} AR^{2/3} S^{1/2}$$

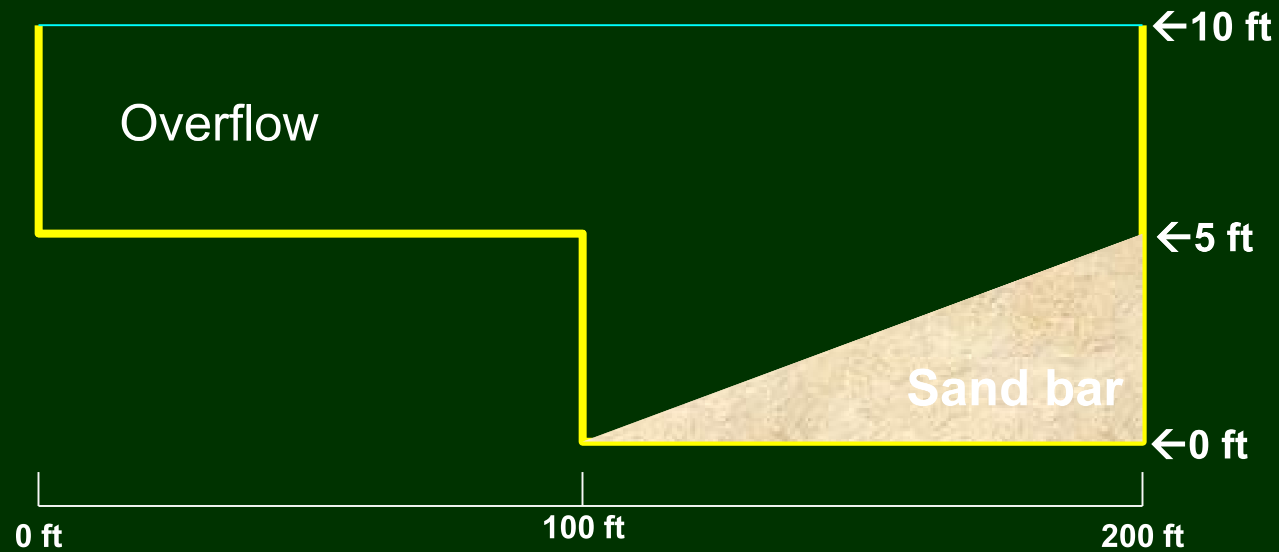
where:

- n = roughness coefficient = 0.05
- A = cross sectional area = 500 ft^2
- R = Hydraulic Radius (area / wetted perimeter) = 4.5 ft
- S = Energy slope (assume to be same as water surface slope = 0.002 ft/ft

$$\mathbf{Q = \frac{1.486}{0.05} \times 500 \times 4.5^{.667} \times 0.002^{1/2} = 1812\ ft^3/s}$$

Math Primer (cont).

Compute area for gh = 10 ft



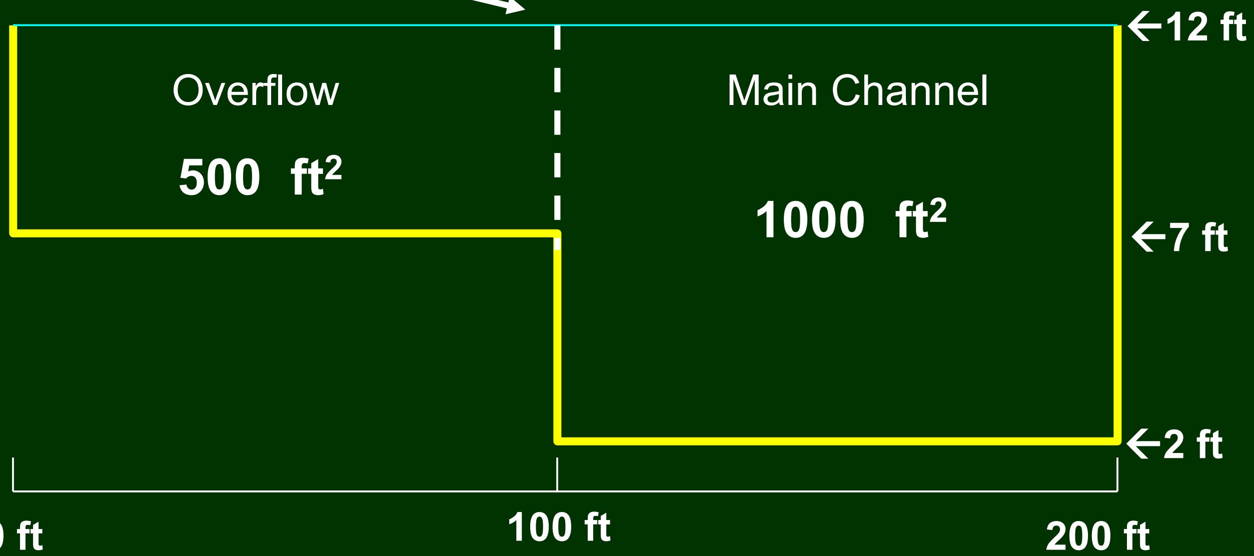
Area for main channel = $(10 \times 100) - ((5 \times 100)/2) = 750\ ft^2$

Area for overflow = $(5 \times 100) = 500\ ft^2$

TOTAL AREA = $1250\ ft^2$

Note: WP does not increase on main channel left bank above gh of 5 ft. There is no boundary friction there.

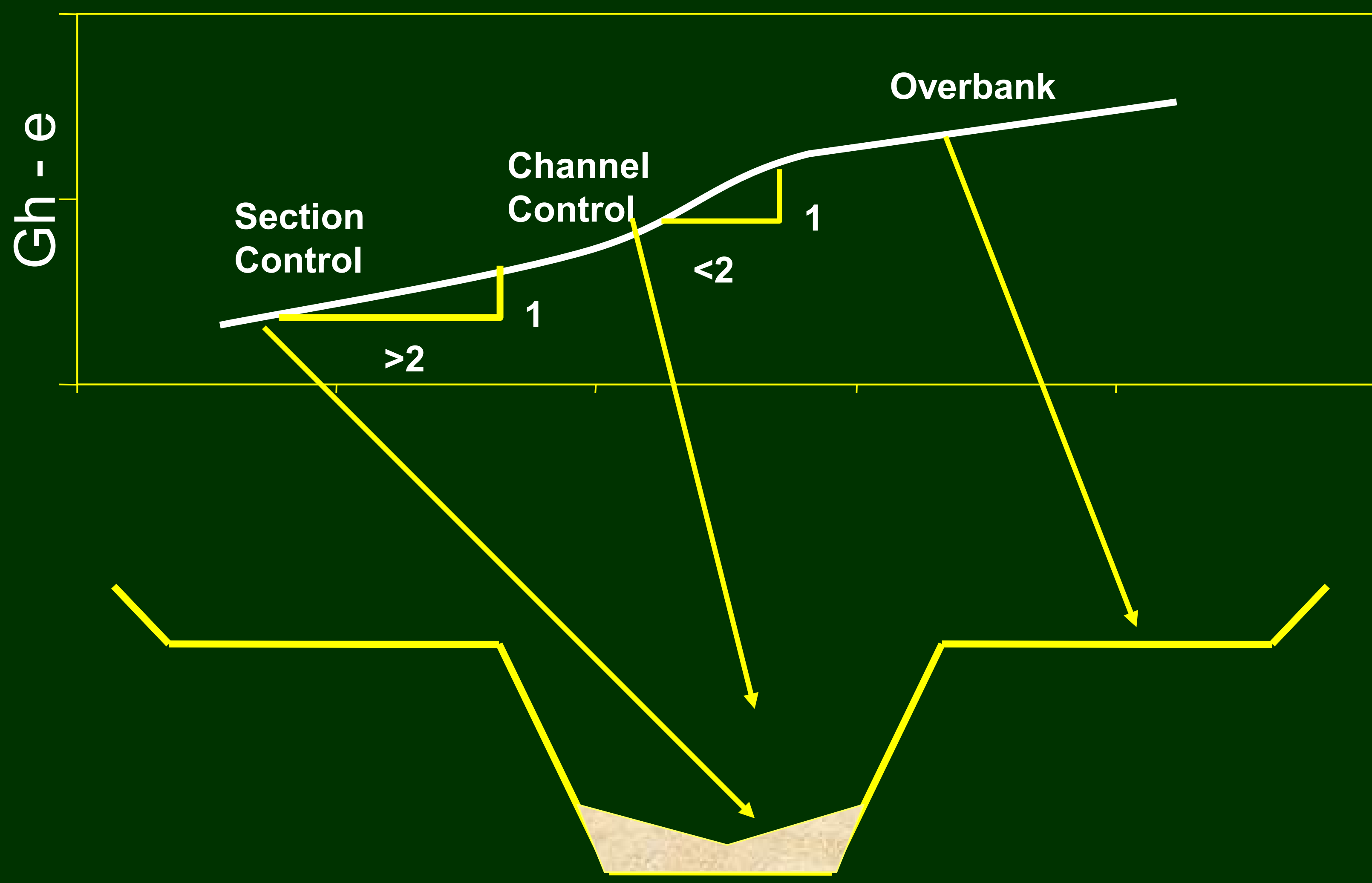
Compute WP, and R for gh = 12 ft



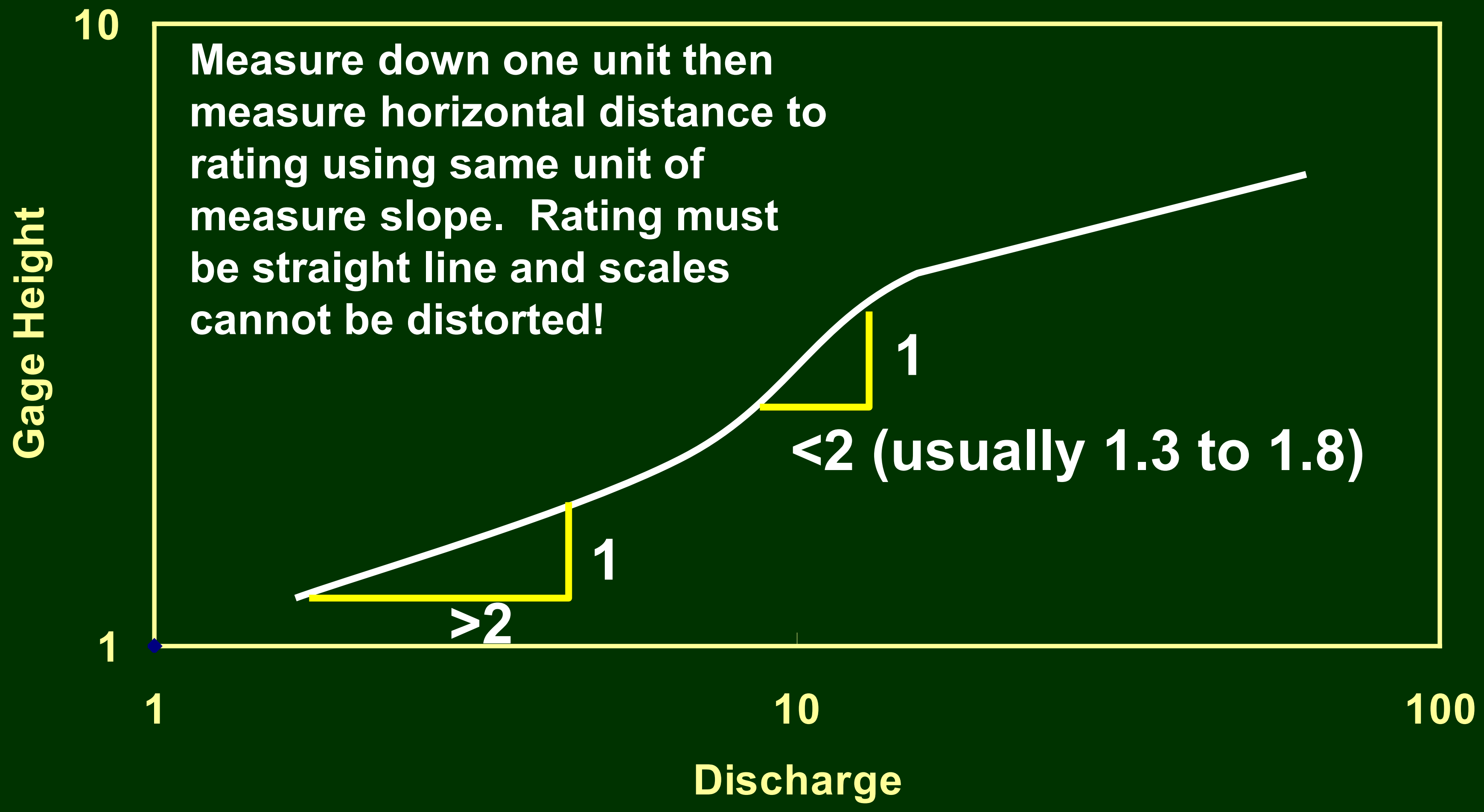
WP for main channel =	**10 + 100 + 5 =**	**115 ft**
WP for overflow =	**100 + 5 =**	**105 ft**
	TOTAL WP =	**220 ft**

R = A / WP = **(1000 + 500) / 220 = 6.82 ft**

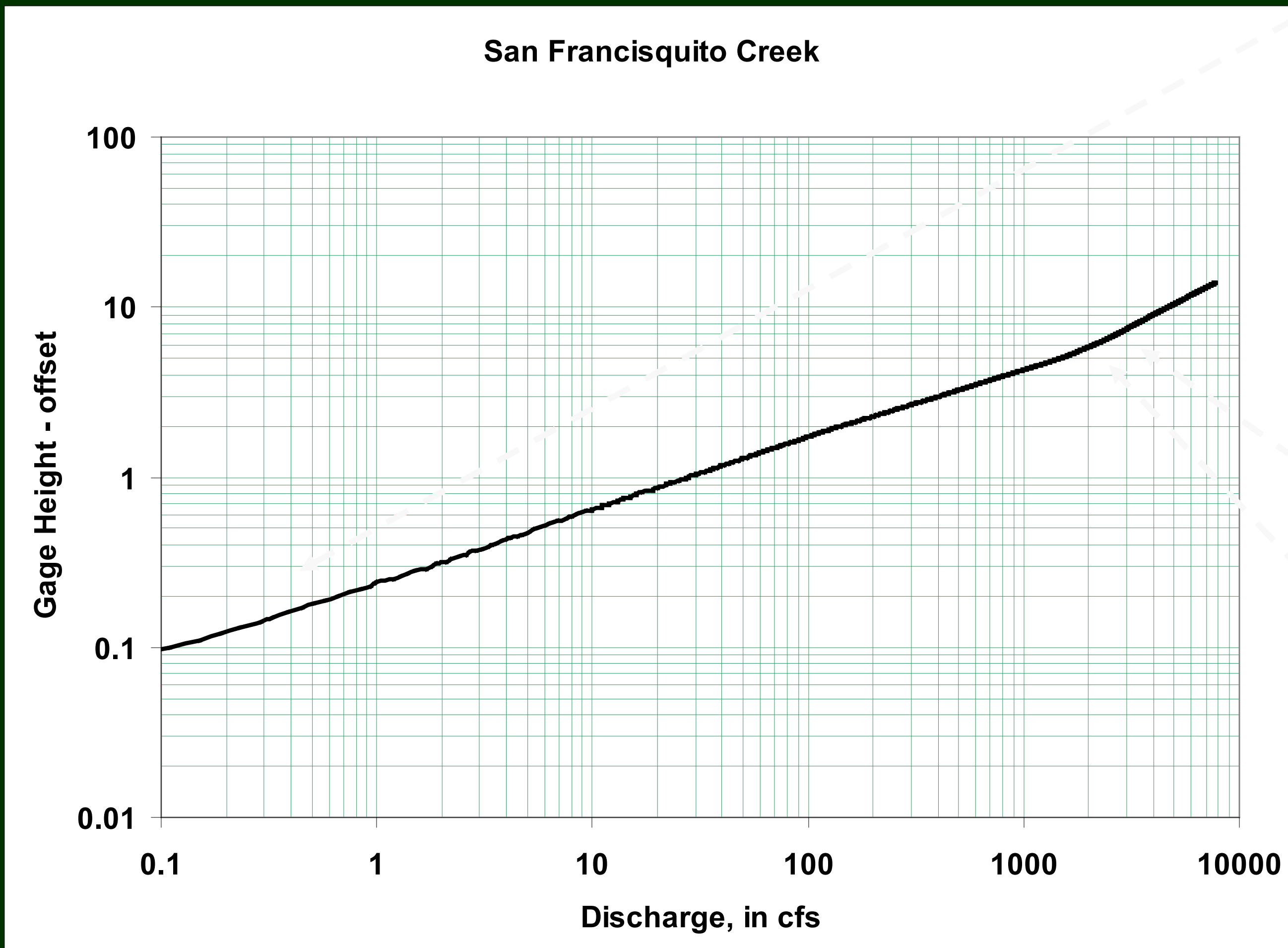
Rating curve slopes can provide insights to control conditions



Here is how to measure rating curve slopes



An example of a rating and controls



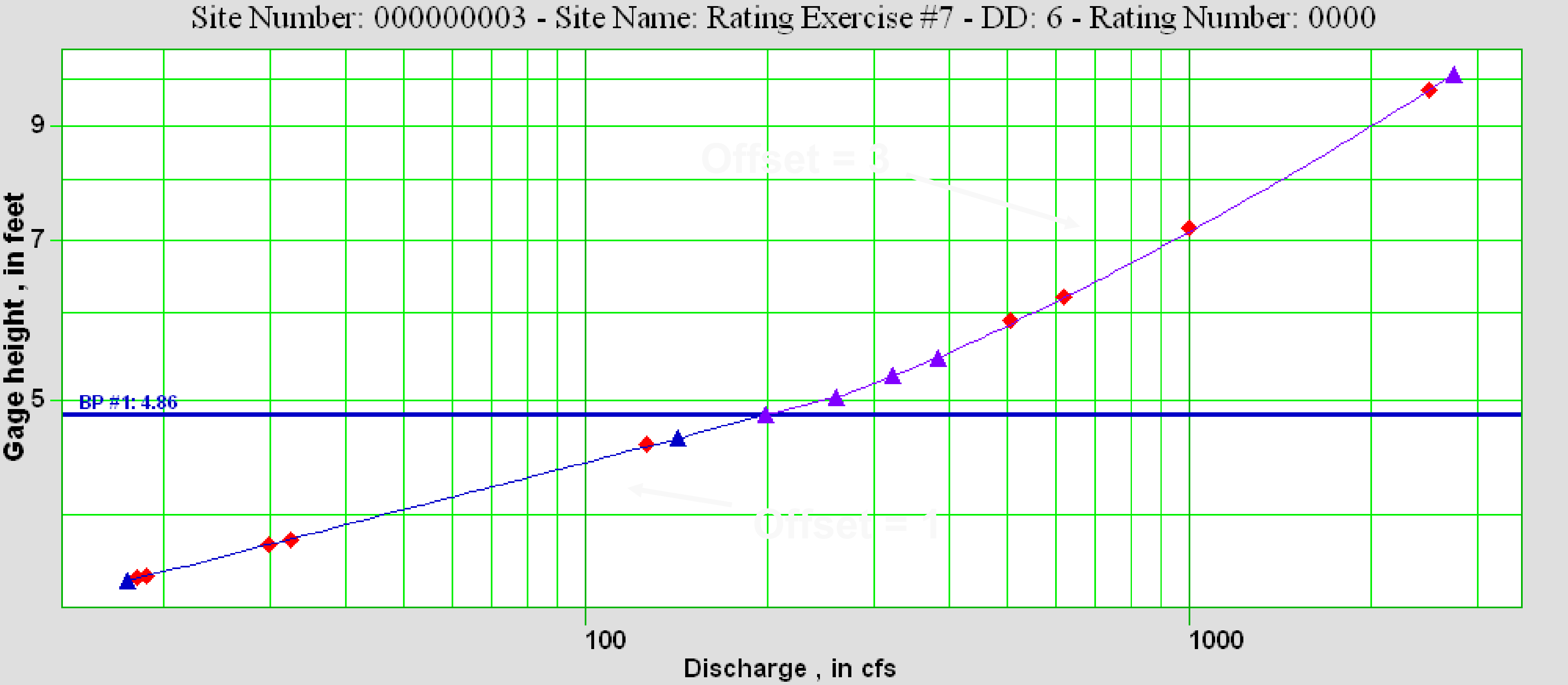
Click here to see video of control at high flow (1.2 MB file)

Artificial controls can also have compound shapes

Artificial section control

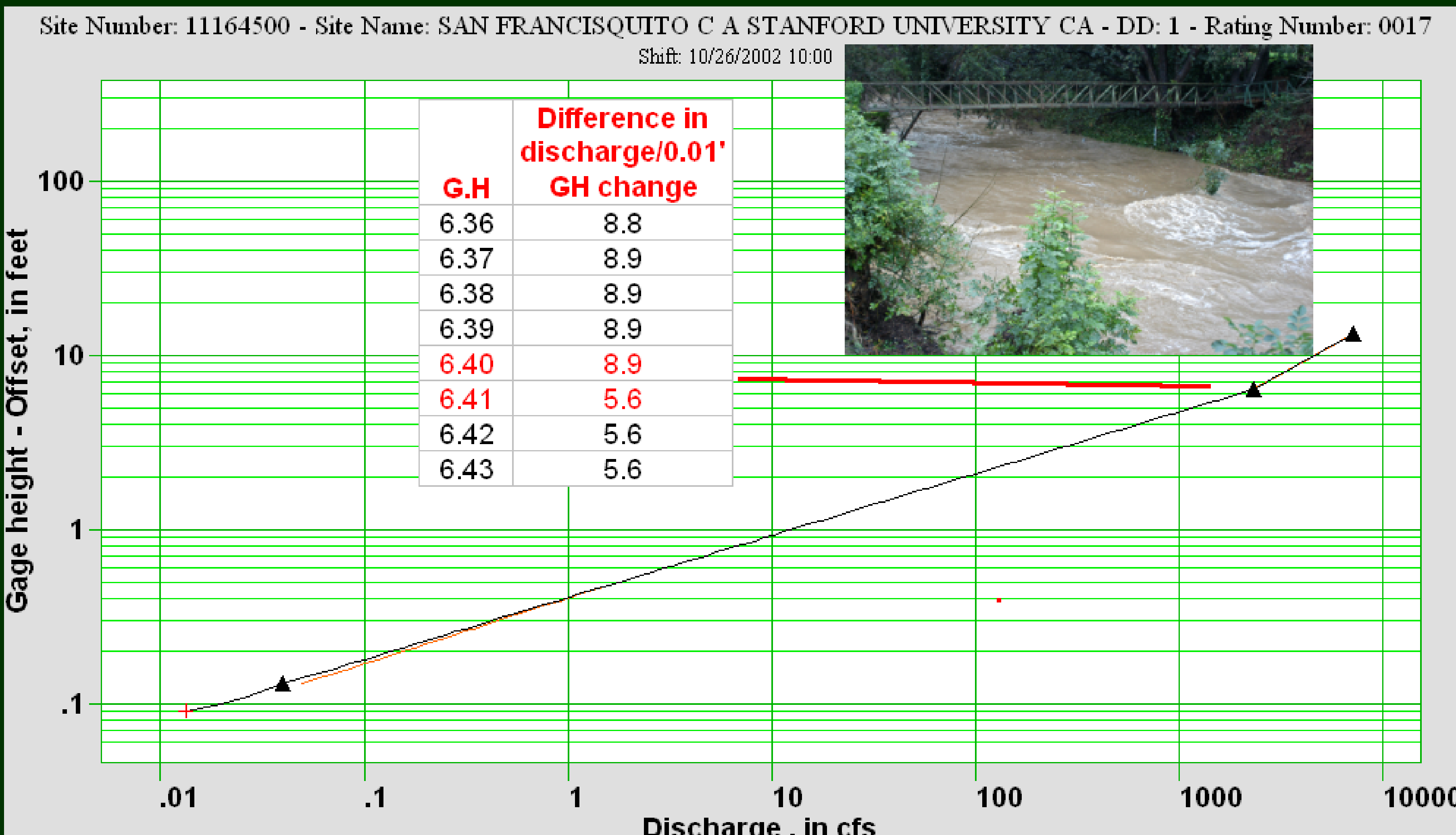
Multiple offsets can be used to straighten different parts of ratings

- Use of multiple offsets makes sense for many ratings
- GRSAT making working with multiple offsets easy!



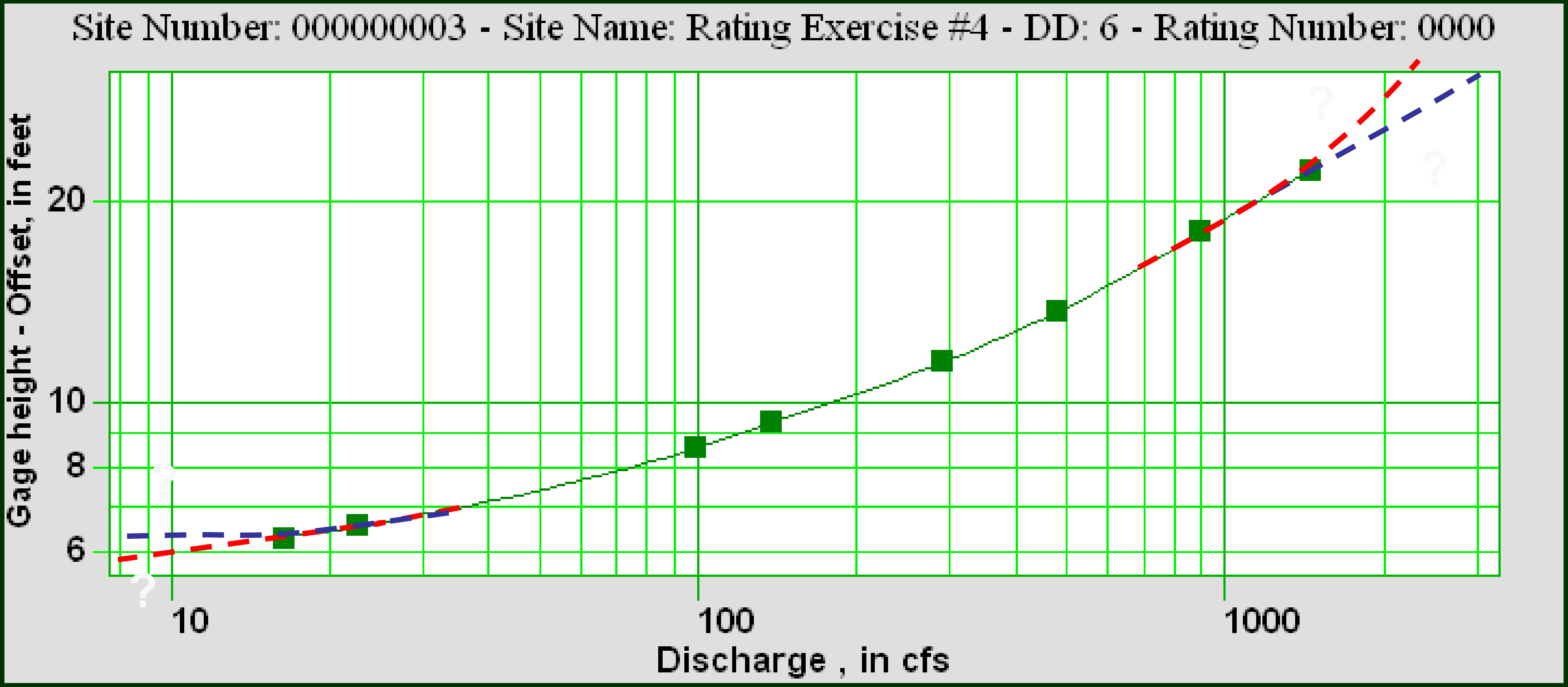
You must smooth the transition between rating segments when multiple offsets are used!

Click on the photo below to view an animation of changing controls



G.H	Difference in discharge/0.01' GH change
6.36	8.8
6.37	8.9
6.38	8.9
6.39	8.9
6.40	8.9
6.41	5.6
6.42	5.6
6.43	5.6

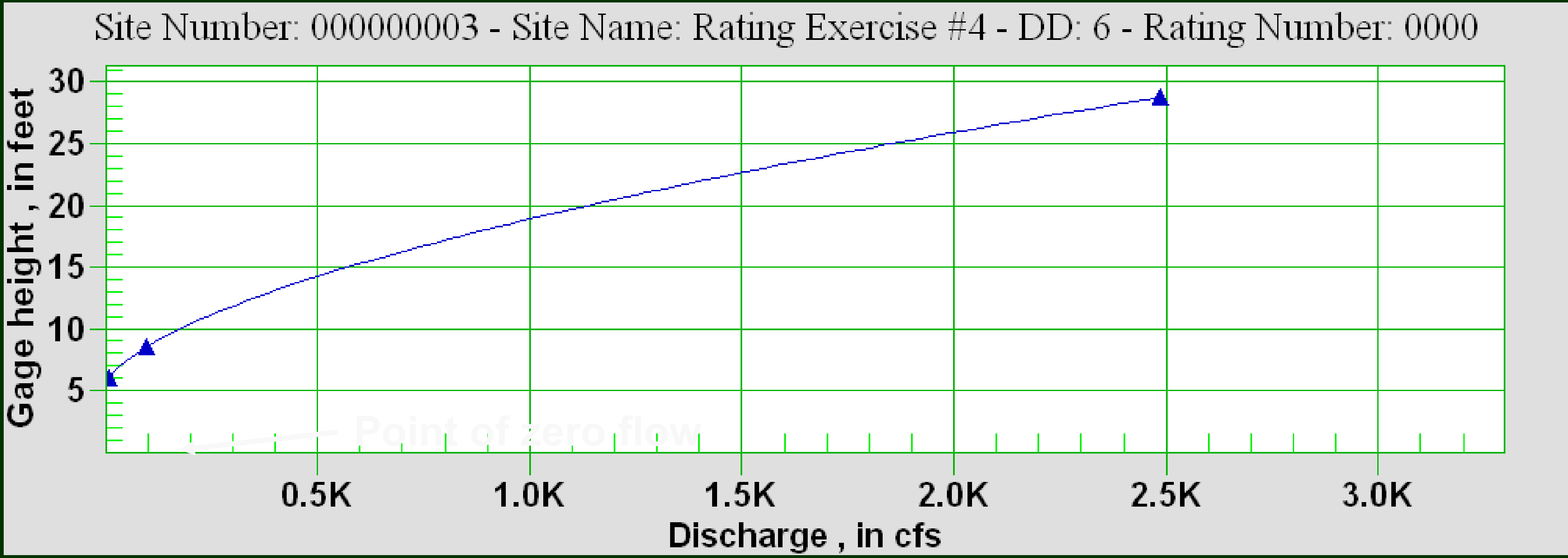
It is often necessary to extend ratings to stages above or below where measurements have been made



USGS

Ratings can be extended to low stages by:

1. Using arithmetic-scale graph and the PZF as a guide.
2. Using knowledge of the control
3. Using hydraulic equations



USGS

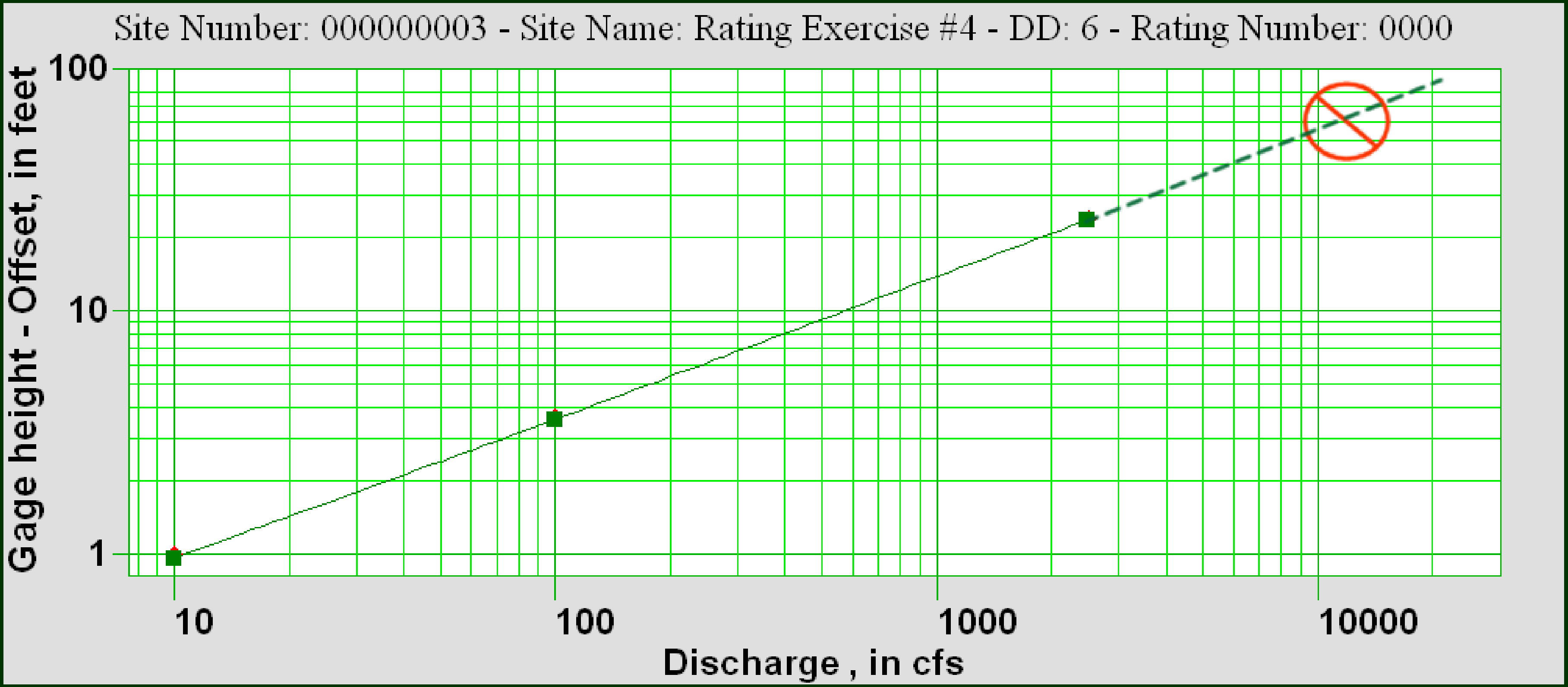
Ratings can be extended to high stages by:

1. Plotting techniques
   - Use straight line, knowledge of control.
2. Slope-conveyance
3. Step-backwater model
4. Areal comparison of peak runoff rates
5. Flood routing

USGS

Here is a rule of thumb to keep in mind when extending ratings

- Rule of Thumb -- Do **NOT** extend beyond twice the highest measured discharge (this may be a direct or indirect measurement)



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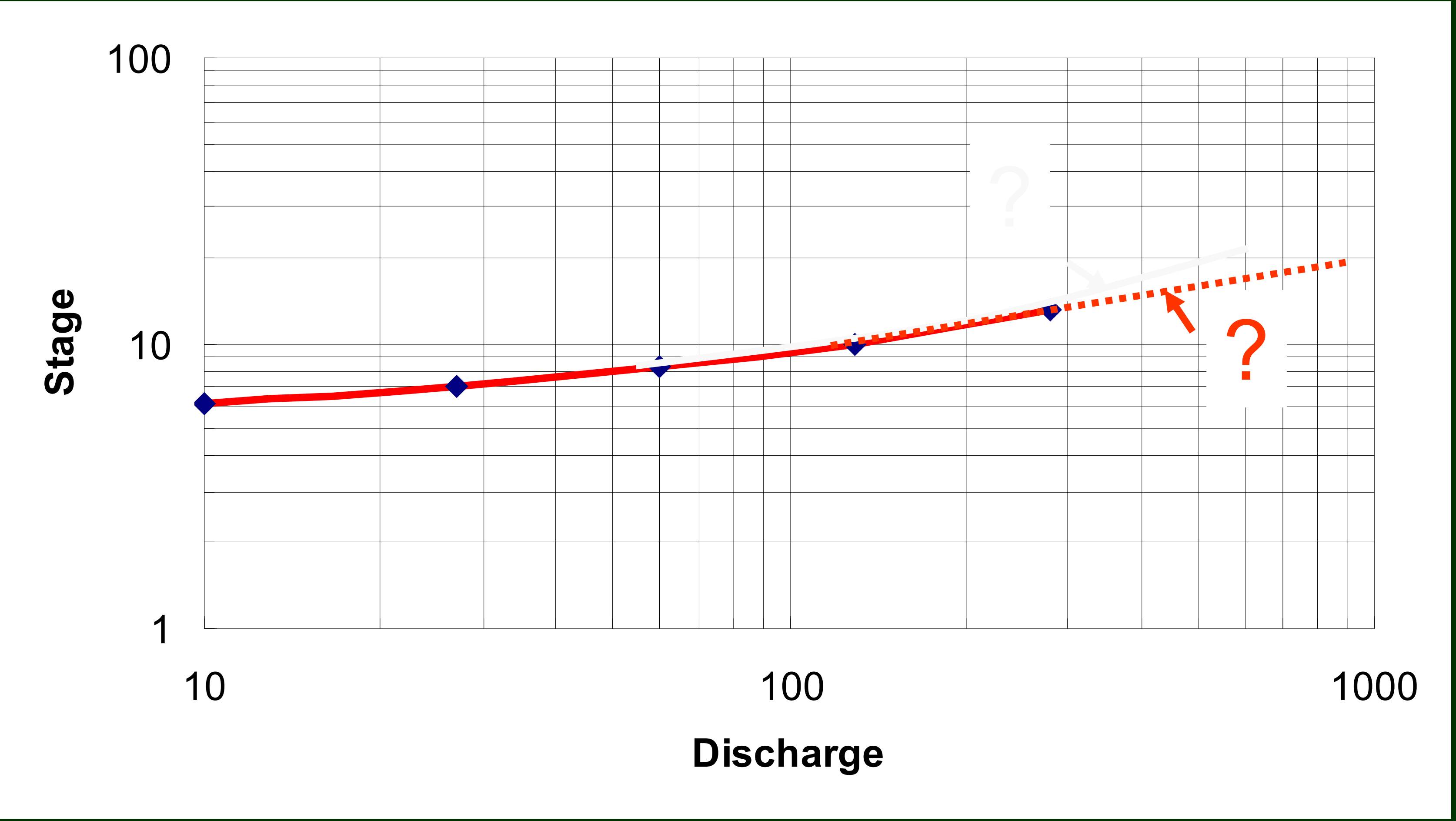
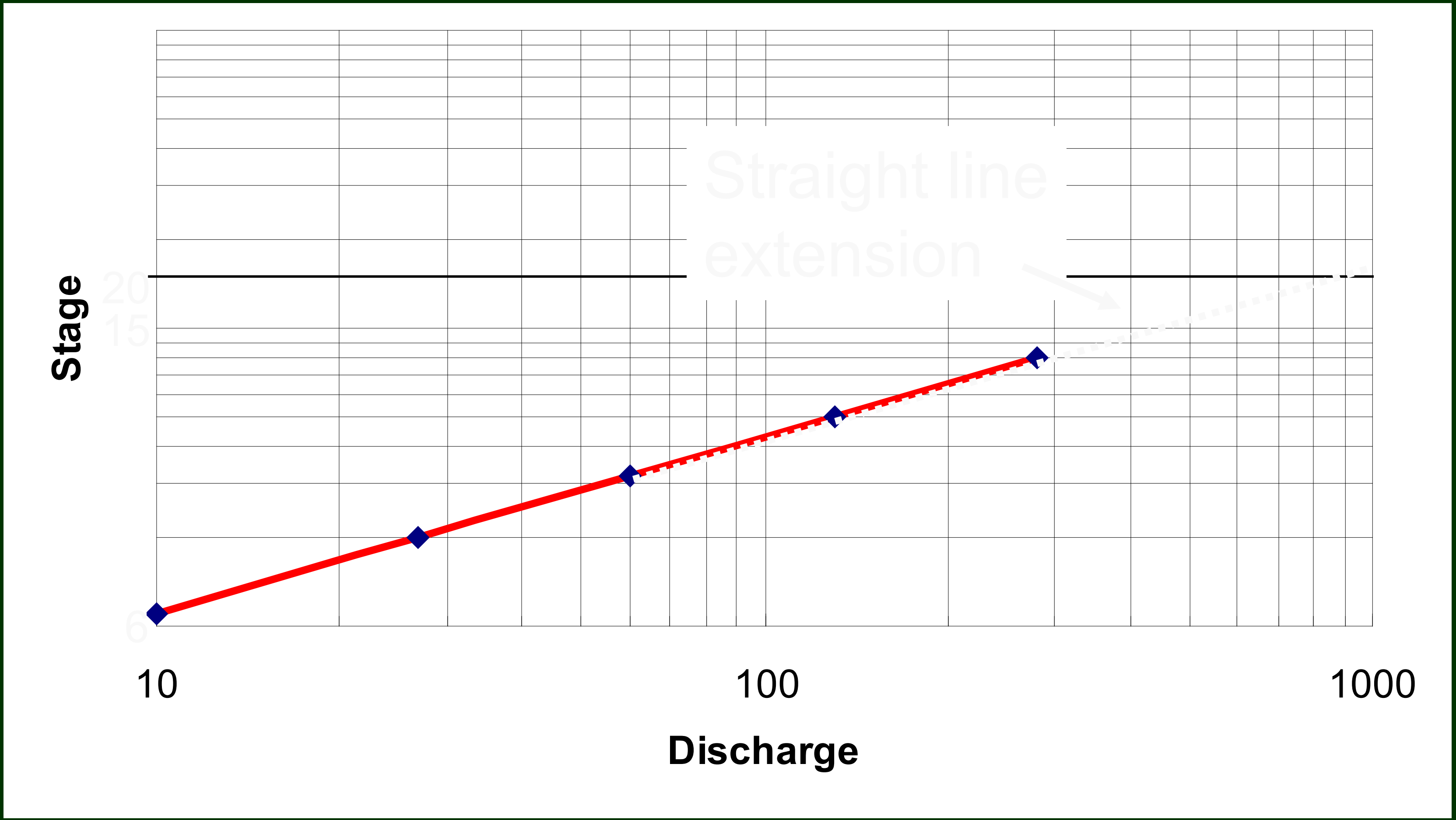
The wrong offset can increase uncertainty when extending ratings



You can be much more certain of how to extending the rating when the correct offset is used!



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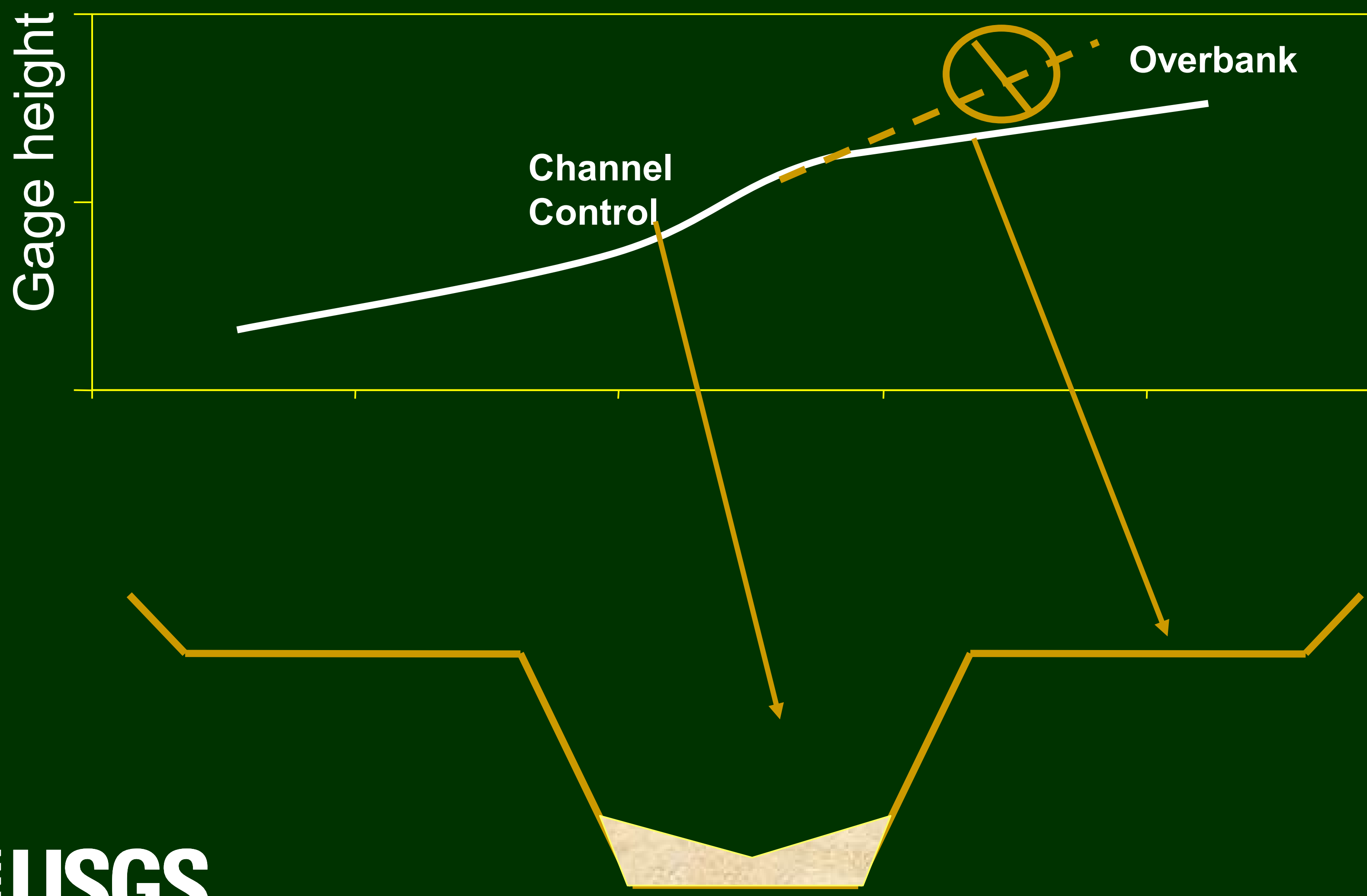
Rating extensions must consider channel geometry



USGS

When to Draw a New Rating?

- When measurements indicate a significant, consistent, and permanent departure from the current rating, especially on the upper end.
- When the shape of the shift diagrams departs significantly from the shape of the rating.