Hydromodification

Predicting & Mitigating Impacts Using the Four Factor Approach

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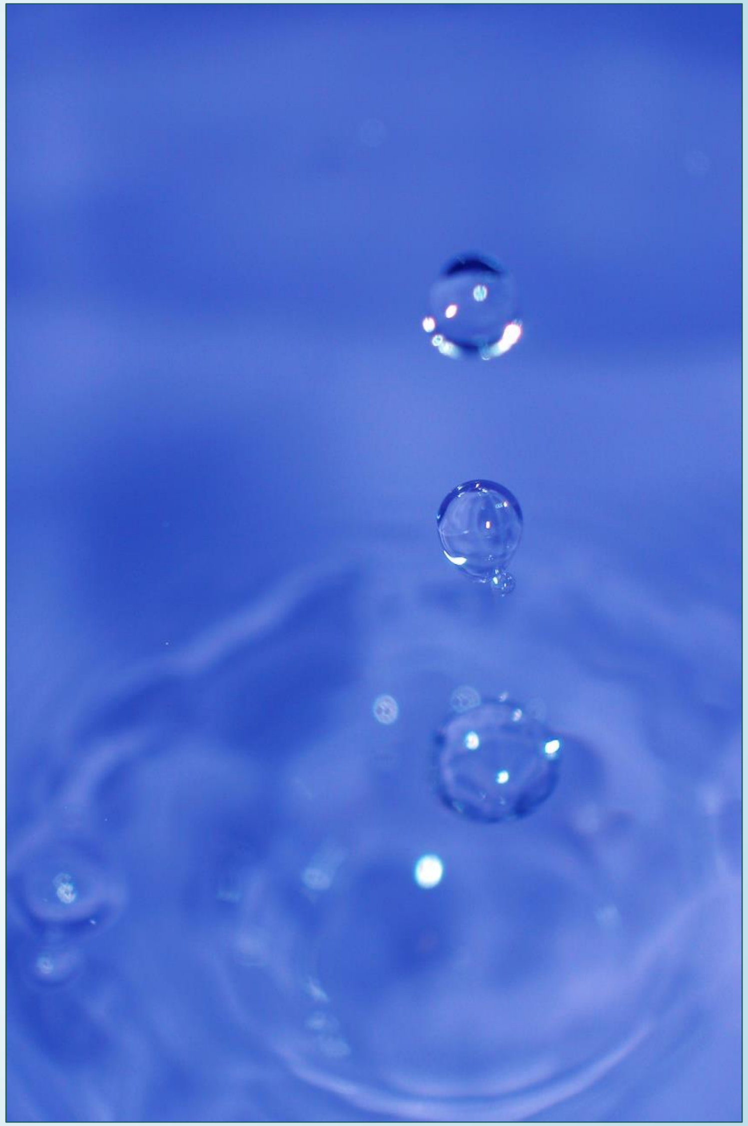
Hydromodification 101

- Definitions
- Impact Evaluation
- Management Strategies
- Stormwater BMP Sizing Sensitivities
- Questions



A Quick Poll…

What is your background?

a) Regulator

b) Municipality

c) Project Proponent

d) Consultant

e) Research Institution

Definitions

Restoration vs. Hydromodification Management

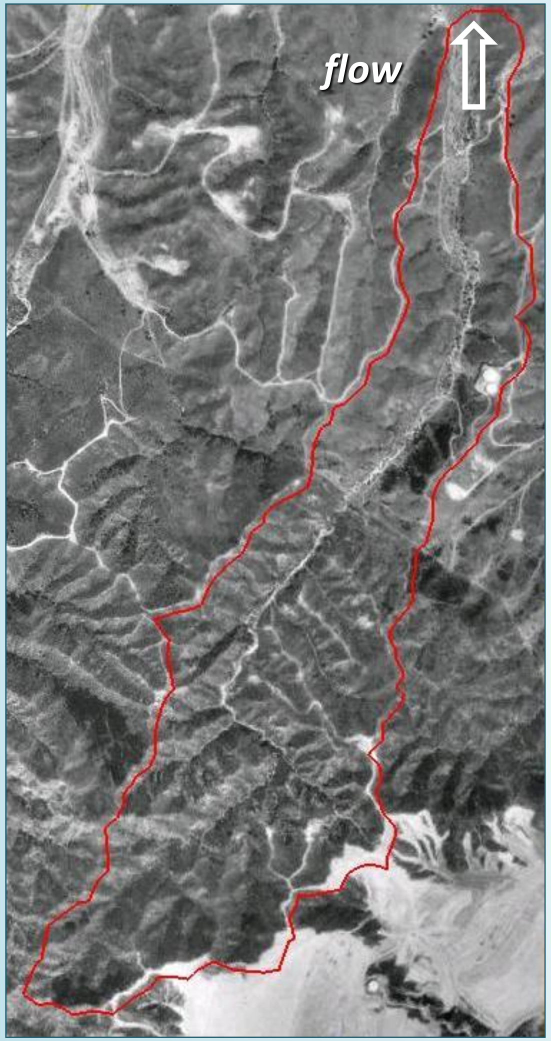
Hydromodification = Changes in runoff characteristics and in-stream processes caused by altered land use.

Restoration vs. **Hydromodification Management**

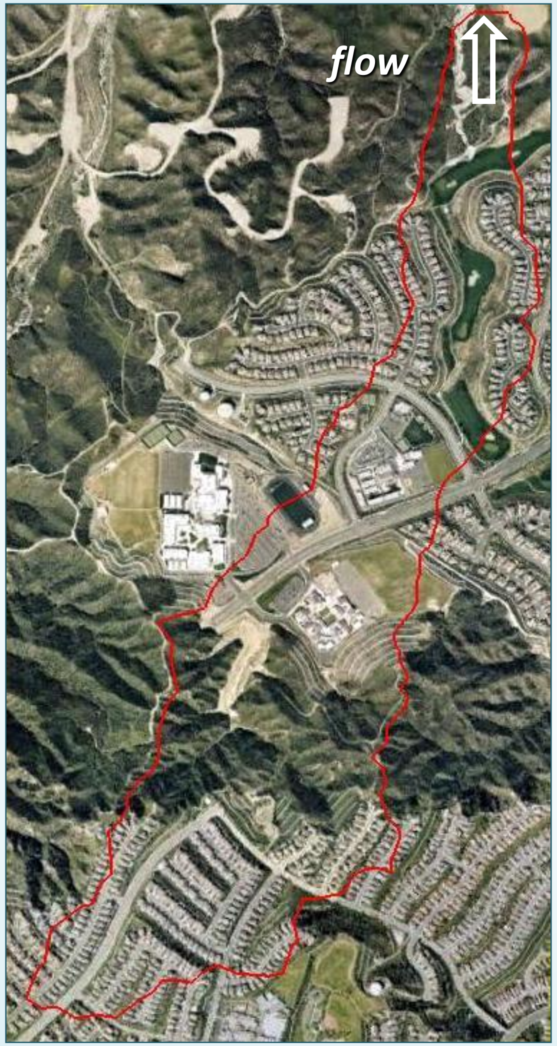
↓ ↓

Fix an existing geomorphic impact | Prevent a future geomorphic impact

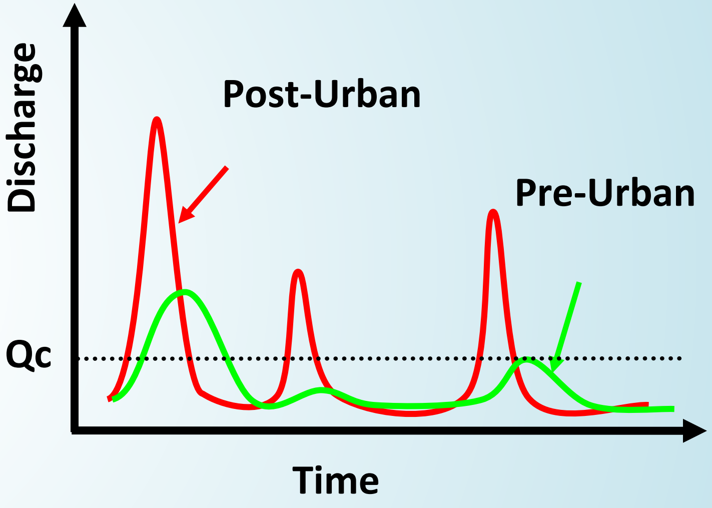
Example of Hydromodification



Pre-Development



Post-Development



Example of Hydromodification Impact

Pre-Development

Post-Development

Understanding the history of the stream's watershed and corridor provides clarity of impact due to hydromodification.

2/1990

3/1996

3/2002

A Quick Poll…

What is the primary driver for hydromodification related projects you are involved in?

a) Municipal Separate Storm Sewer System NPDES Permits

b) Clean Water Act Section 401 Water Quality Certification

c) Endangered Species Act

d) Environmental Review

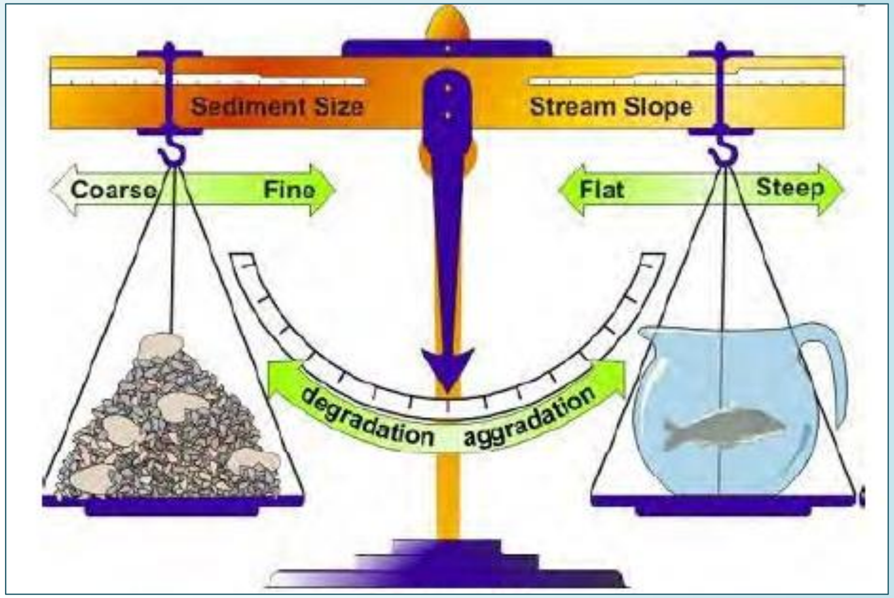
e) Voluntary: Threat to Infrastructure and Property

Impact Evaluation

How Are Hydromodification Impacts Modeled?

Qualitative: Lane (1955)

$Q_s D_{50} \propto Q_w S$



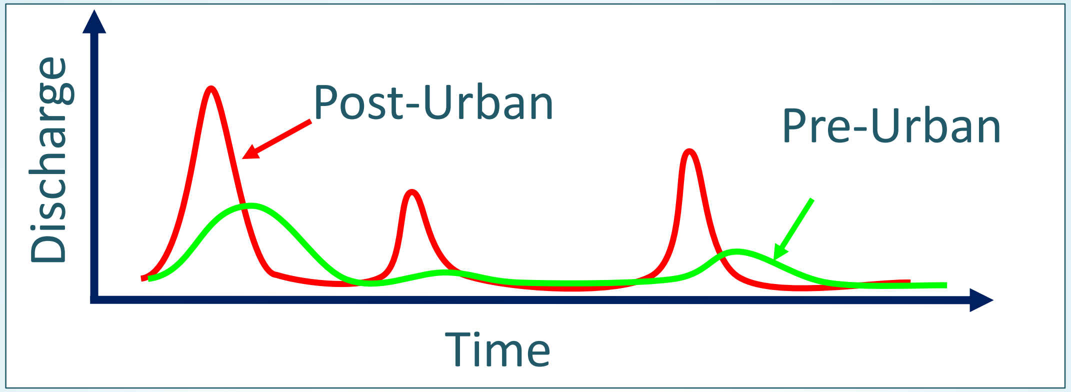
Source: Rosgen (1996), From Lane, 1955.

Quantitative:

Geomorphic Impact $= f($Δhydrology, Δchannel geometry, Δbed & bank material strength, Δsediment supply$)$

ΔHydrology

Simulate the hydrologic response of catchments under
pre- and post-developed conditions for a continuous period of record.



Input:

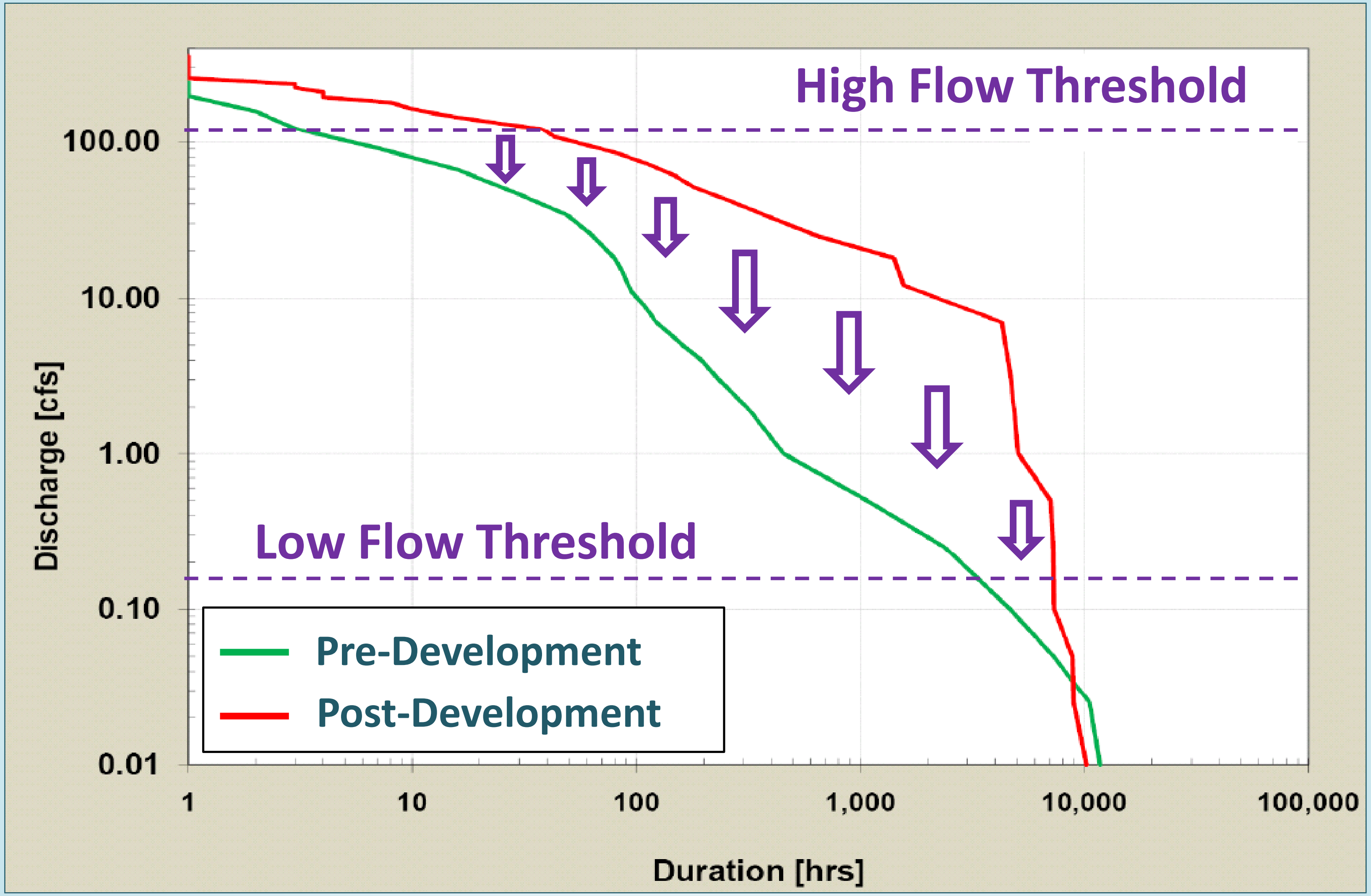
- Rainfall
- Catchment Delineation
- Soils
- **% Imperviousness**
- Lag Time
- In-stream Infiltration
- Evapotranspiration

Output:

- Flow

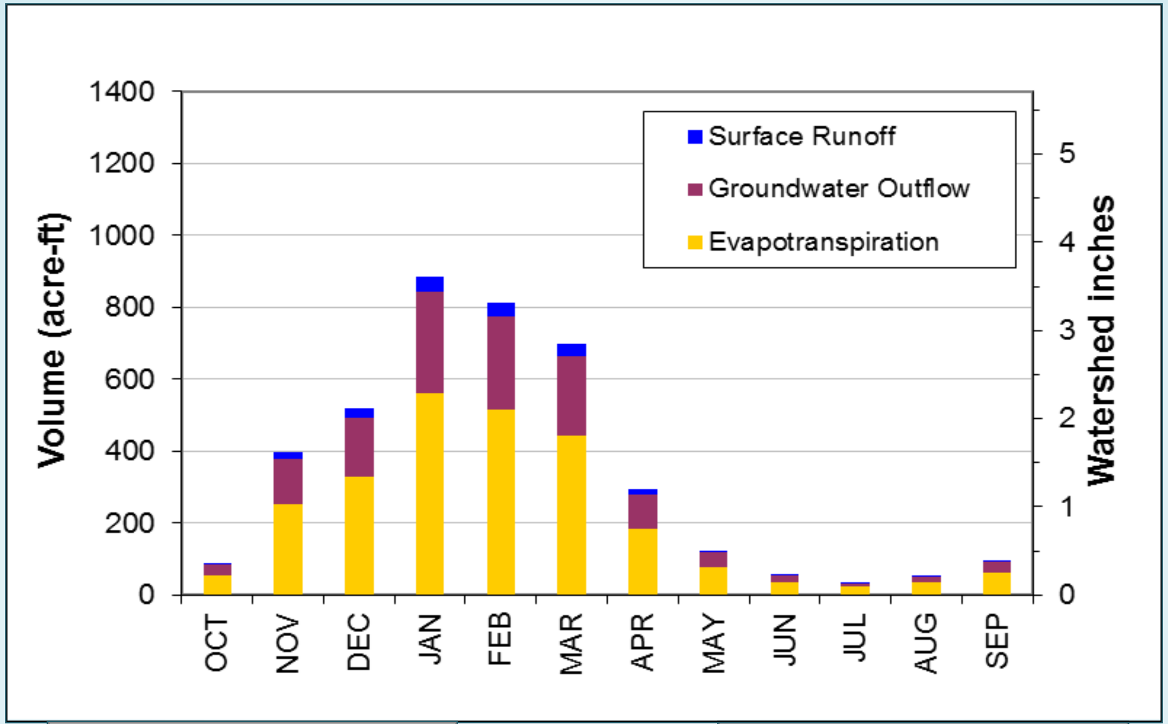
ΔHydrology

Flow output from hydrologic model is used to generate flow duration curves.

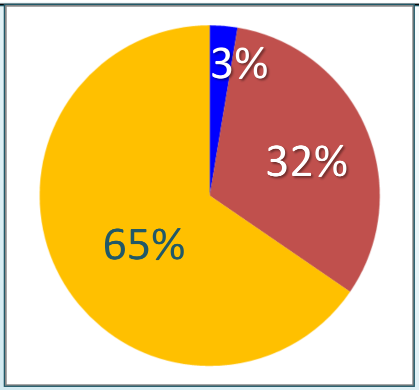


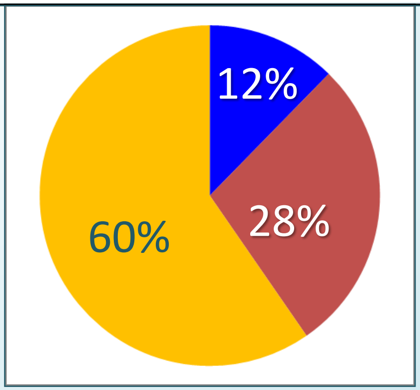
ΔHydrology

Output from hydrologic model can be used to evaluate water balance.



Pre-Development

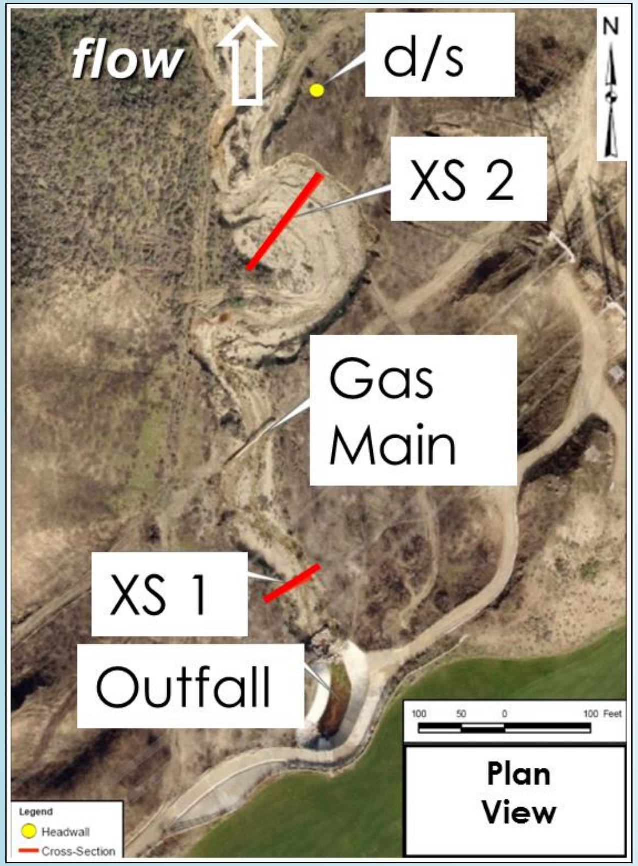


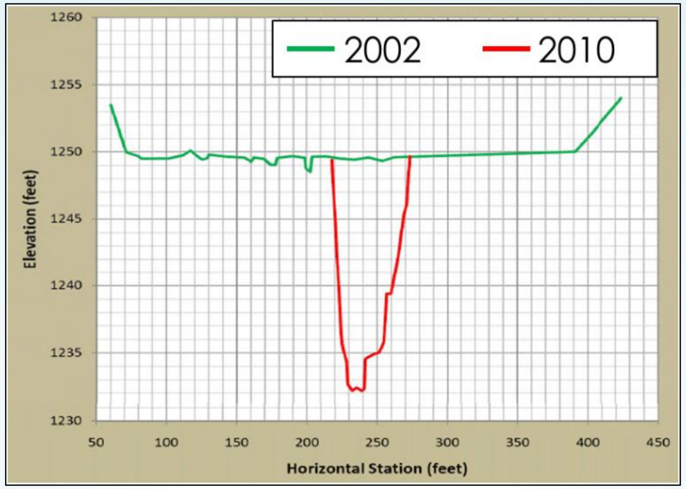


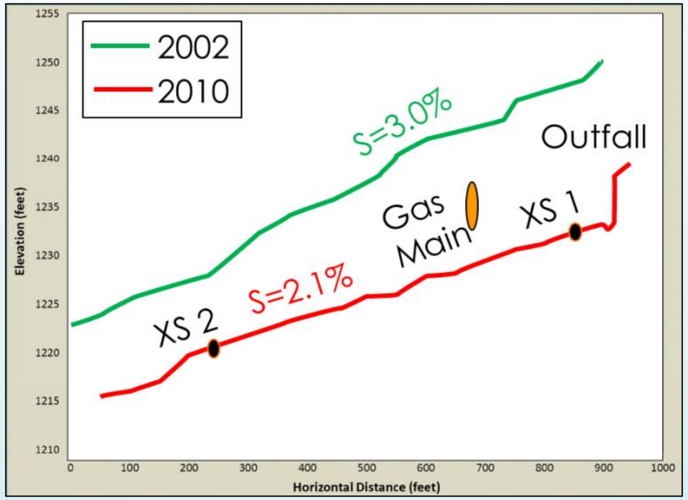
Post-Development

ΔChannel Geometry

Cross-sections, longitudinal profiles, and plan form
of the active channel are characterized at strategic locations.



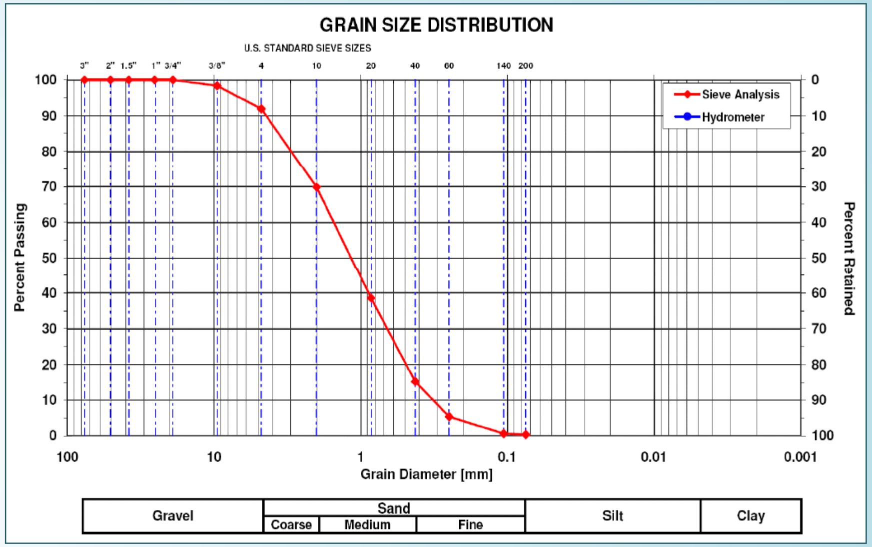




ΔBed & Bank Material Strength

For each reach surveyed, a measure of critical shear stress is based on the bed and bank material.

- **Non-Cohesive Bed:**
  - Wolman Pebble Count and / or Sieve Analysis
- **Cohesive Bed and Bank:**
  - Jet Test or Tables
- **Vegetated bank:**
  - Tables



Bank Material Type	τ_c (lbs/ft^2)
ASCE Manual No. 77	
Hardpans	0.67
Compacted Clays	0.50
Stiff Clays	0.32

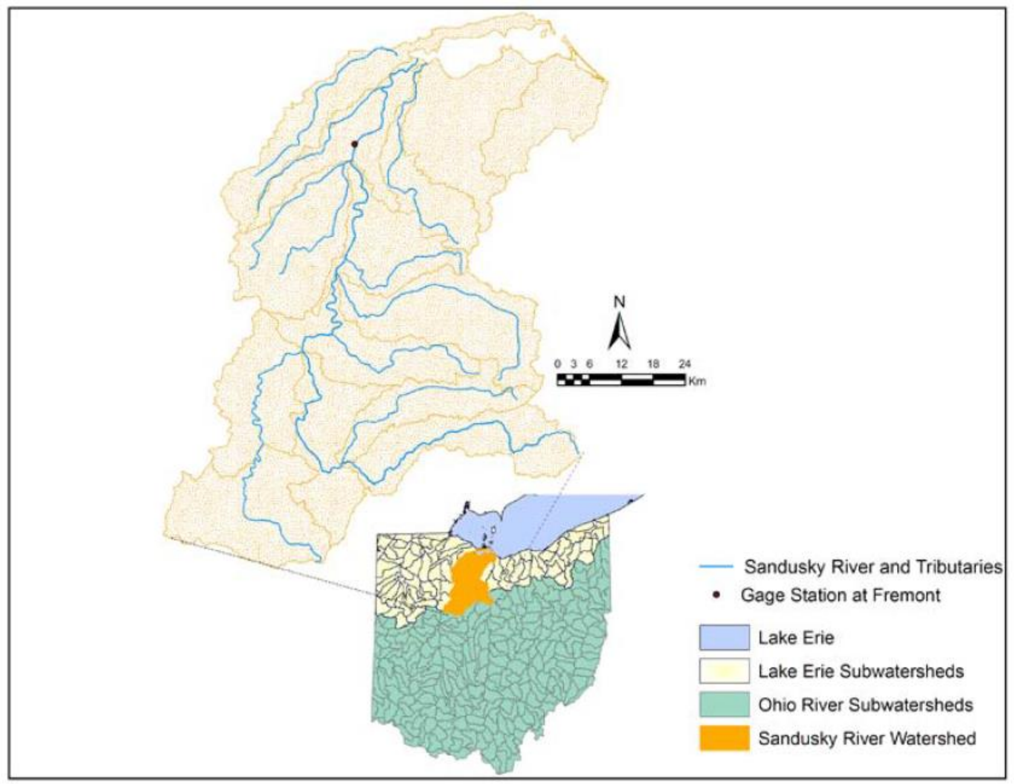
ΔBed & Bank Material Strength
ΔChannel Geometry

Geomorphic monitoring with field photogrammetry

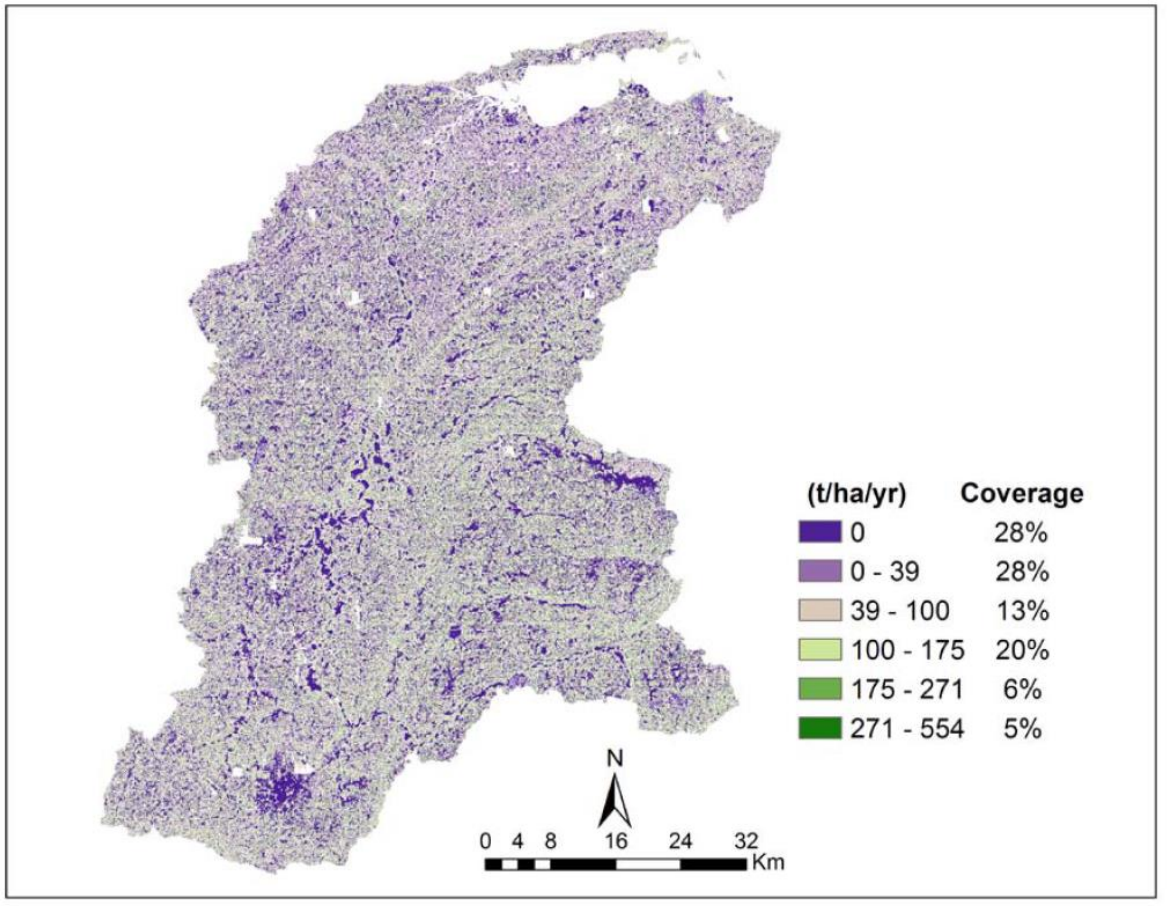
http://maps.google.com/help/maps/streetview/learn/cars-trikes-and-more.html#trekker

ΔSediment Supply

Bed sediment yields are estimated using field data and GIS analysis of hillslope gradient, geology, and land cover.



Source: SPATIAL VARIABILITY OF SEDIMENT DELIVERY IN THE SANDUSKY RIVER WATERSHED, OHIO
Hari P. Kandel, Dec 2010



ΔSediment Supply

Threshold Channel

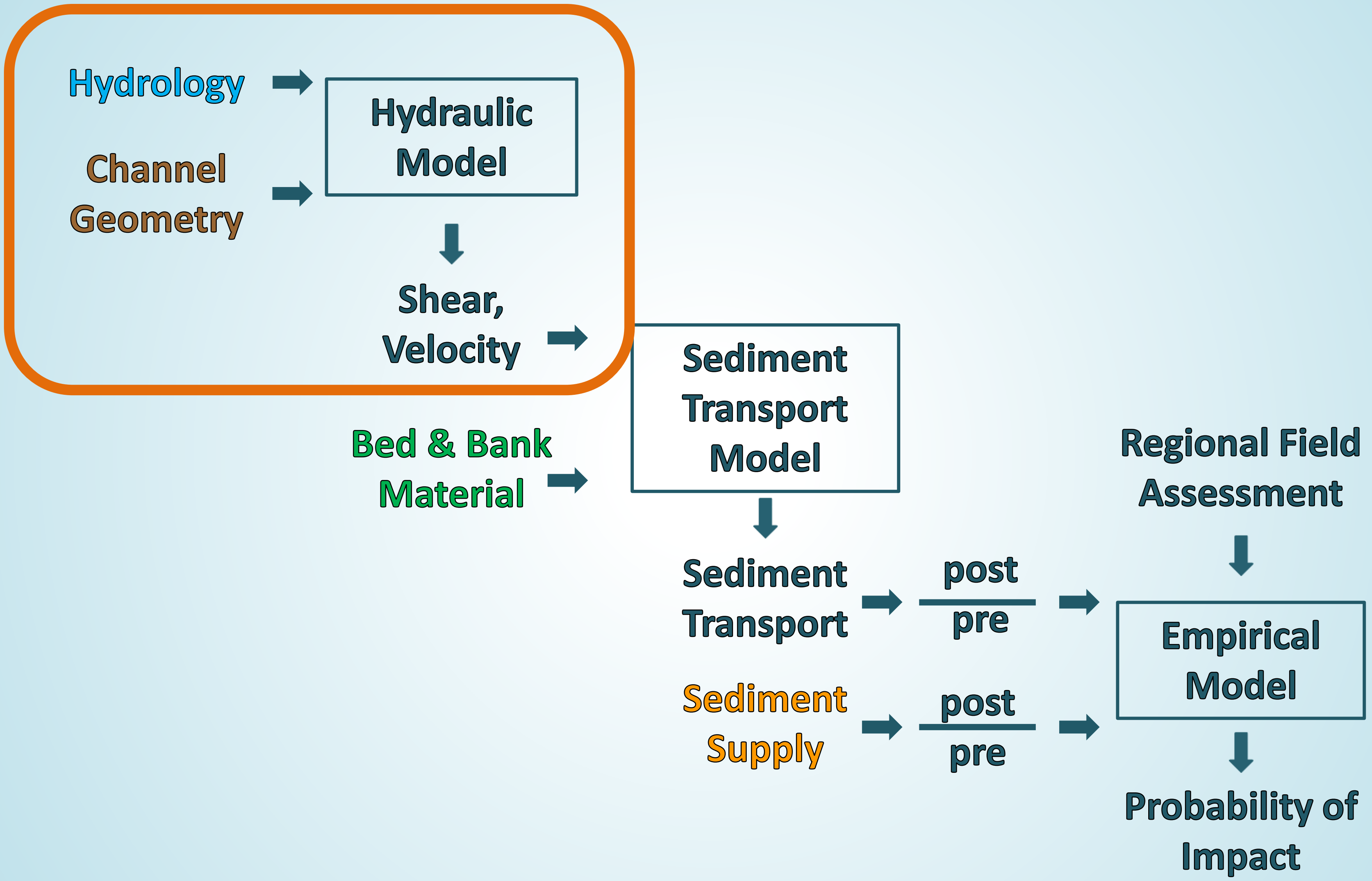
- Channel boundary material has no significant movement.
- Sediment supply **is not** a key factor

Source: NRCS, 2007 - Part 654 National Engineering Handbook

Alluvial Channel

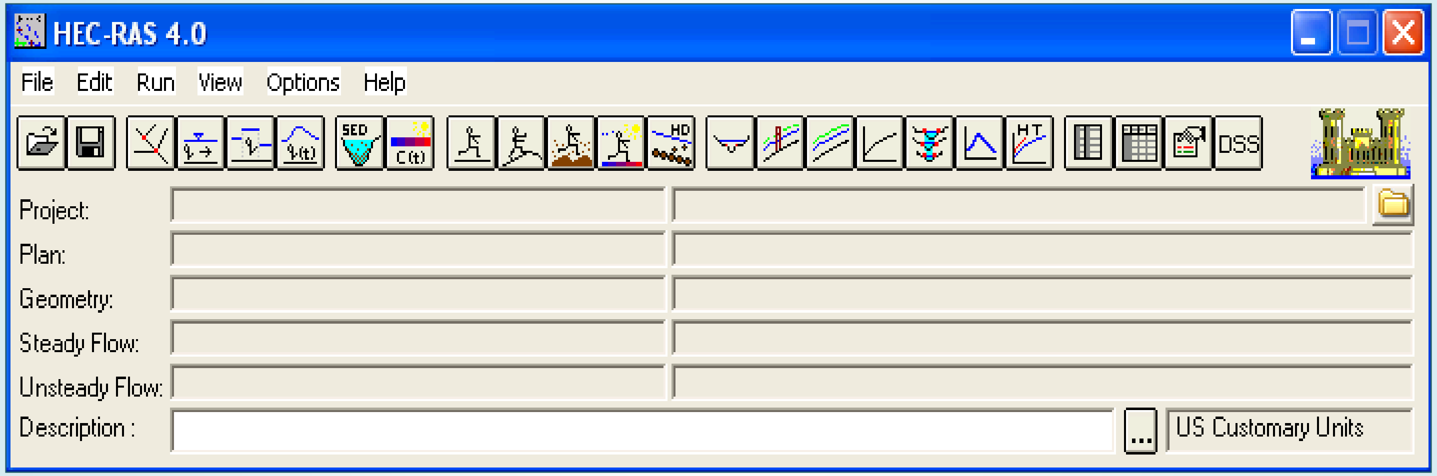
- Exchange of material between the inflowing sediment load and the bed and banks of the channel.
- Sediment supply **is** a key factor.

Hydromodification Impact Model



Hydraulic Model

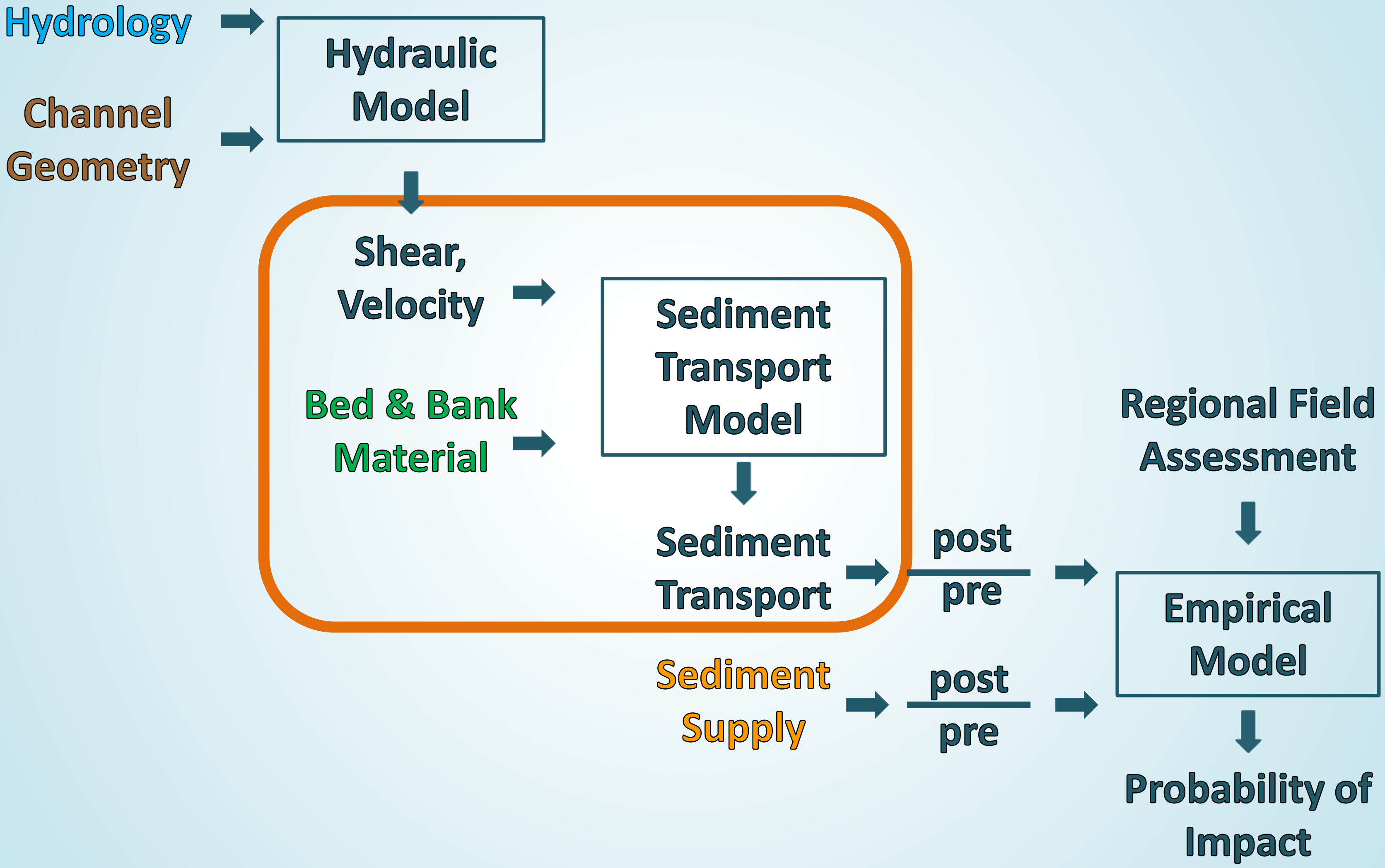
Stage, effective shear stress, and flow velocity are computed using **discharge** and **channel geometry** data as inputs to a hydraulic model.



$$\tau = \gamma R S$$

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

Hydromodification Impact Model

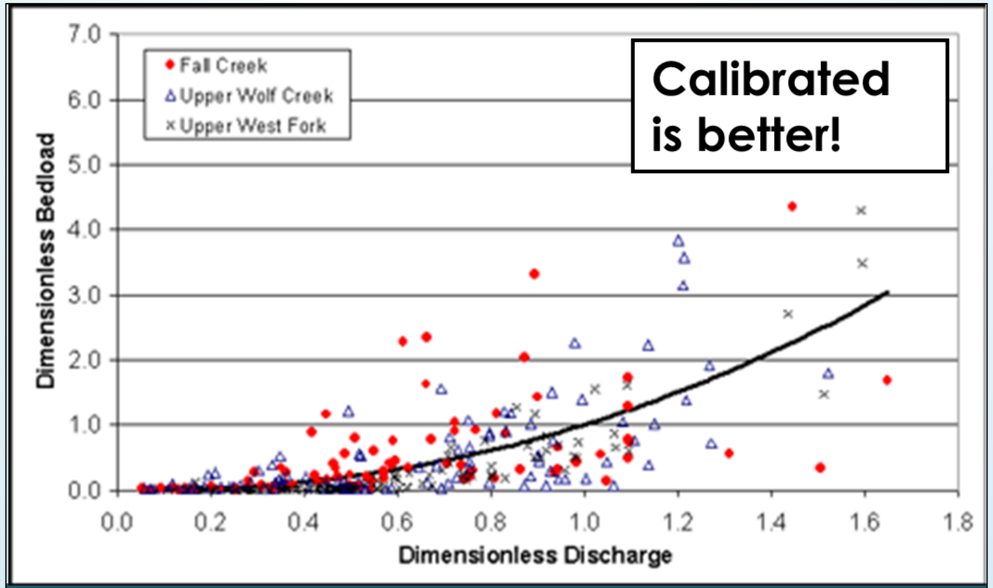


Sediment Transport Model

Stage, effective shear stress, flow velocity, and **critical bed / bank material strength** are input into the applicable work or sediment transport equation and summed over the period of record.

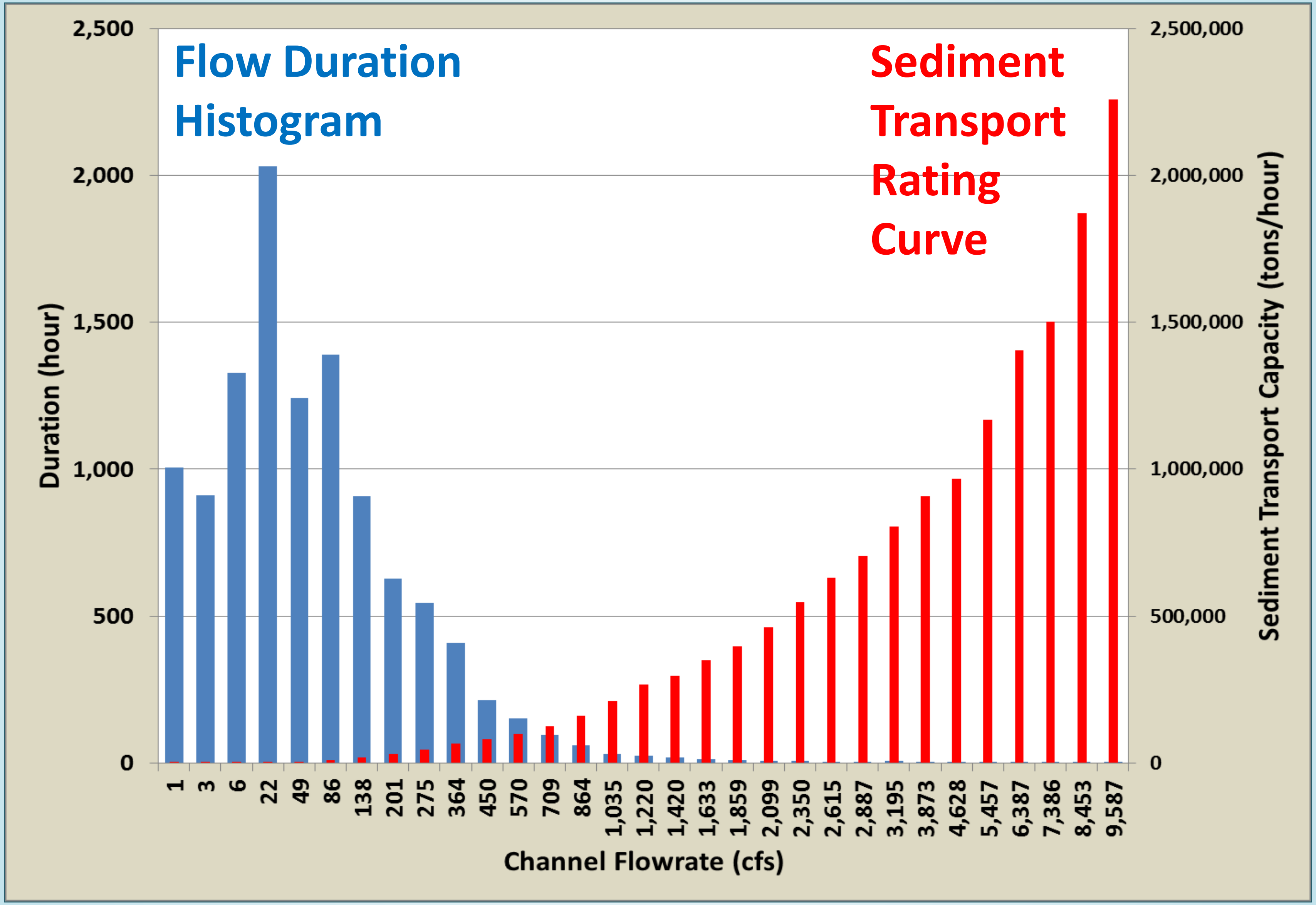
Work Equation:

$$W = \sum_{i=1}^{n} \left(\tau_i - \tau_c\right)^{1.5} \cdot V \cdot \Delta t_i$$

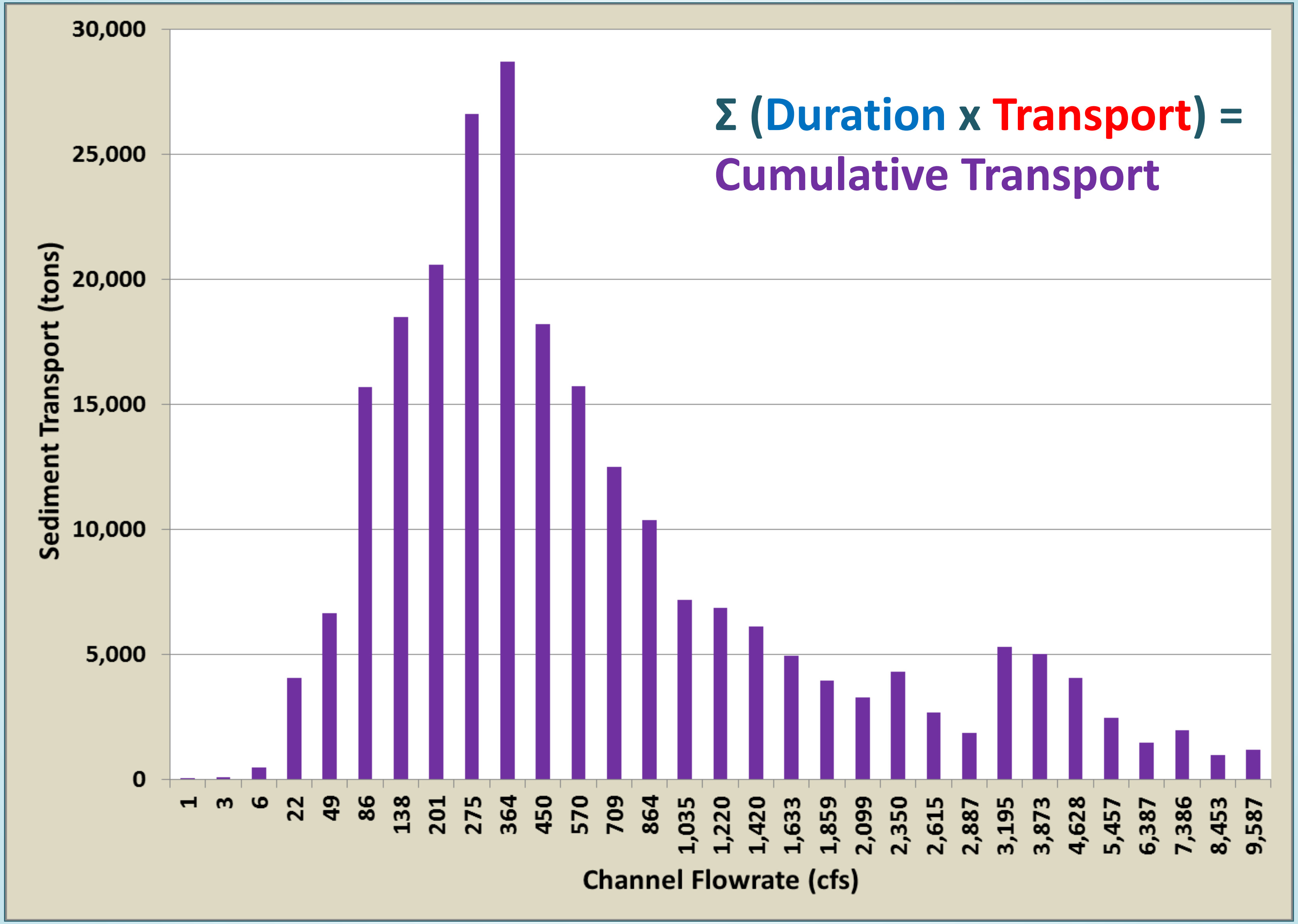


http://water.epa.gov/scitech/datait/tools/warsss/dimless.cfm

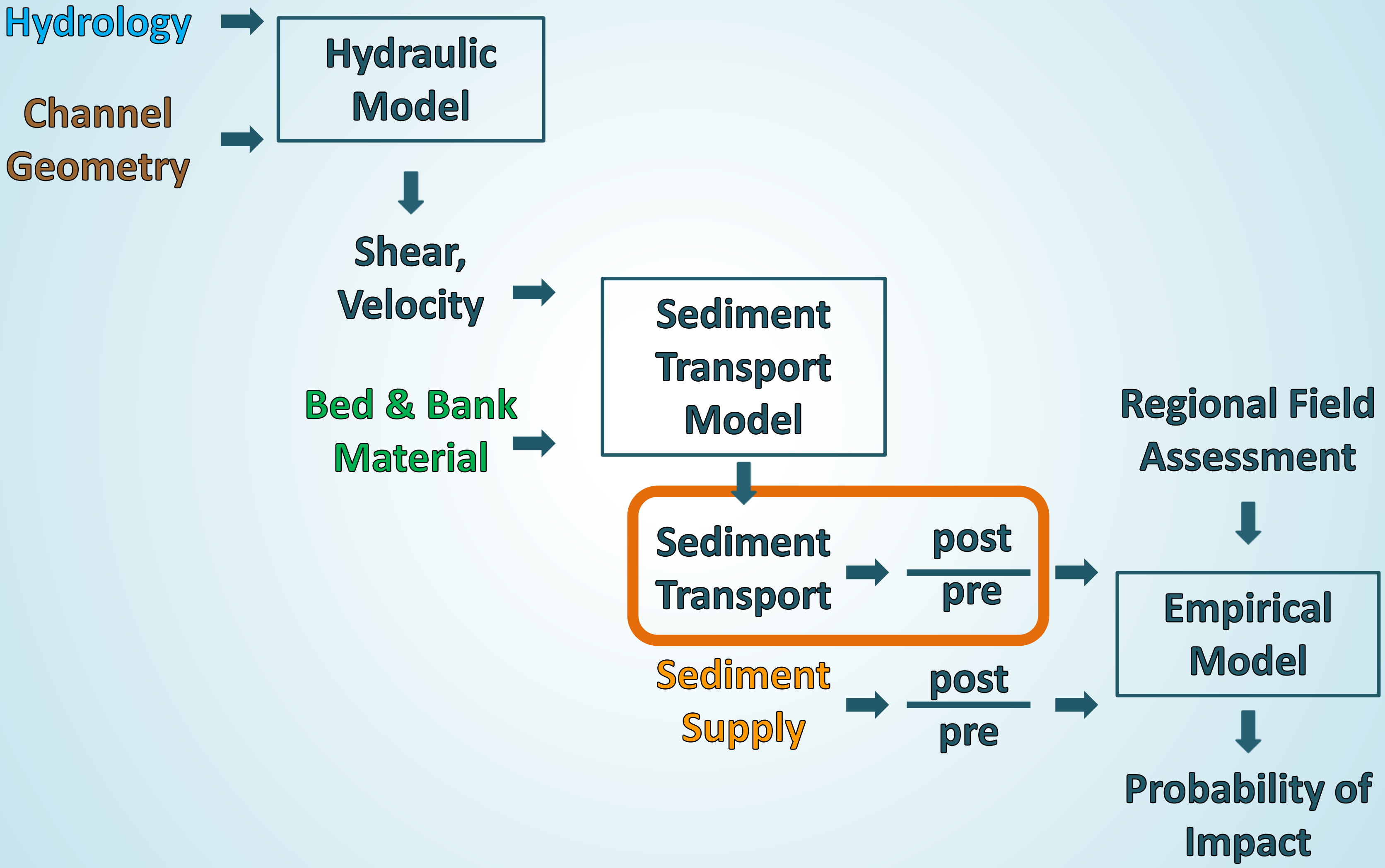
Sediment Transport Model



Sediment Transport Model



Hydromodification Impact Model

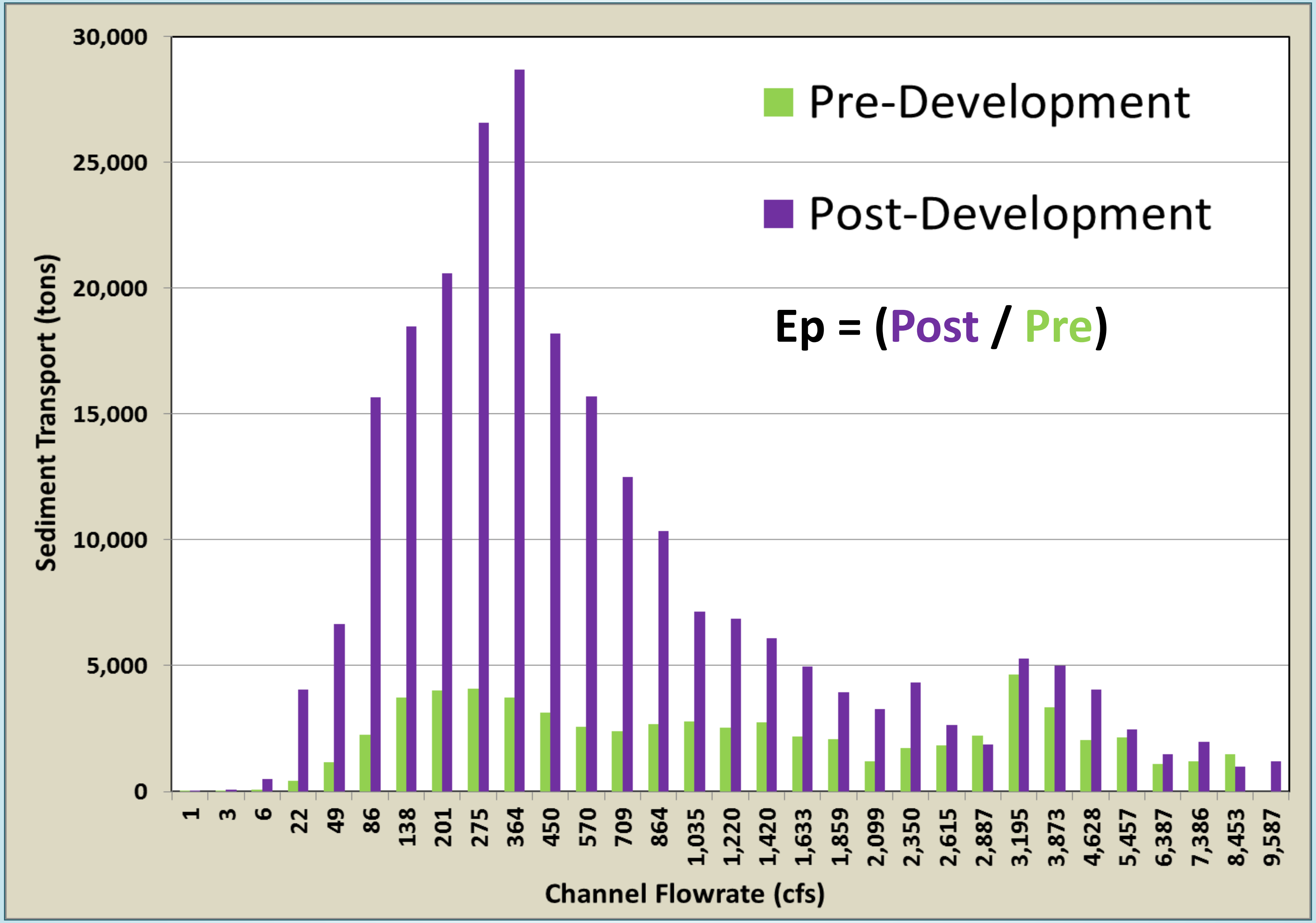


Erosion Potential

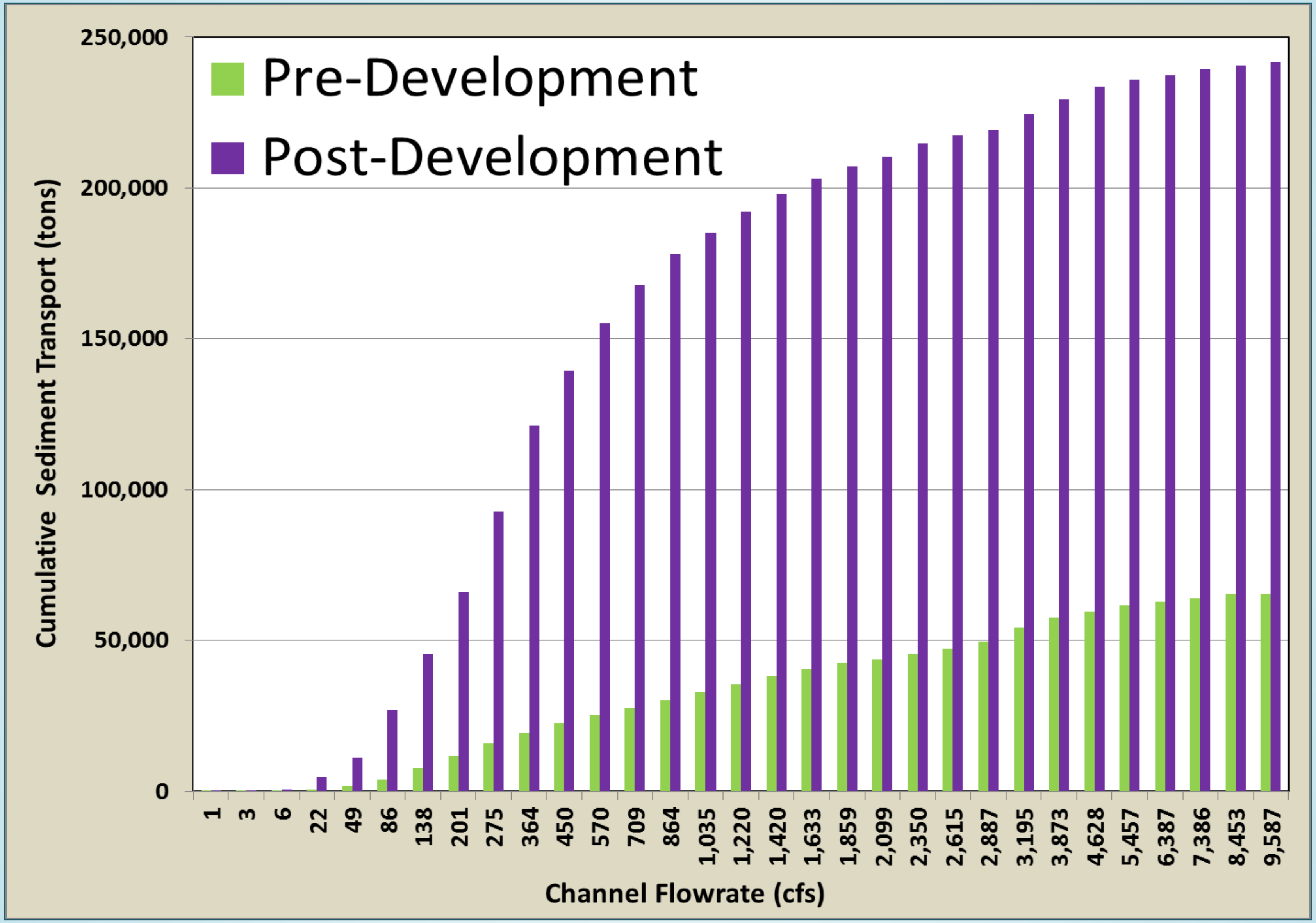
Erosion Potential (Ep) is calculated by comparing relative change in cumulative sediment transport capacity in the pre- and post-development conditions.

$$Ep = \frac{\text{Sediment Transport}_{\text{Post}}}{\text{Sediment Transport}_{\text{Pre}}}$$

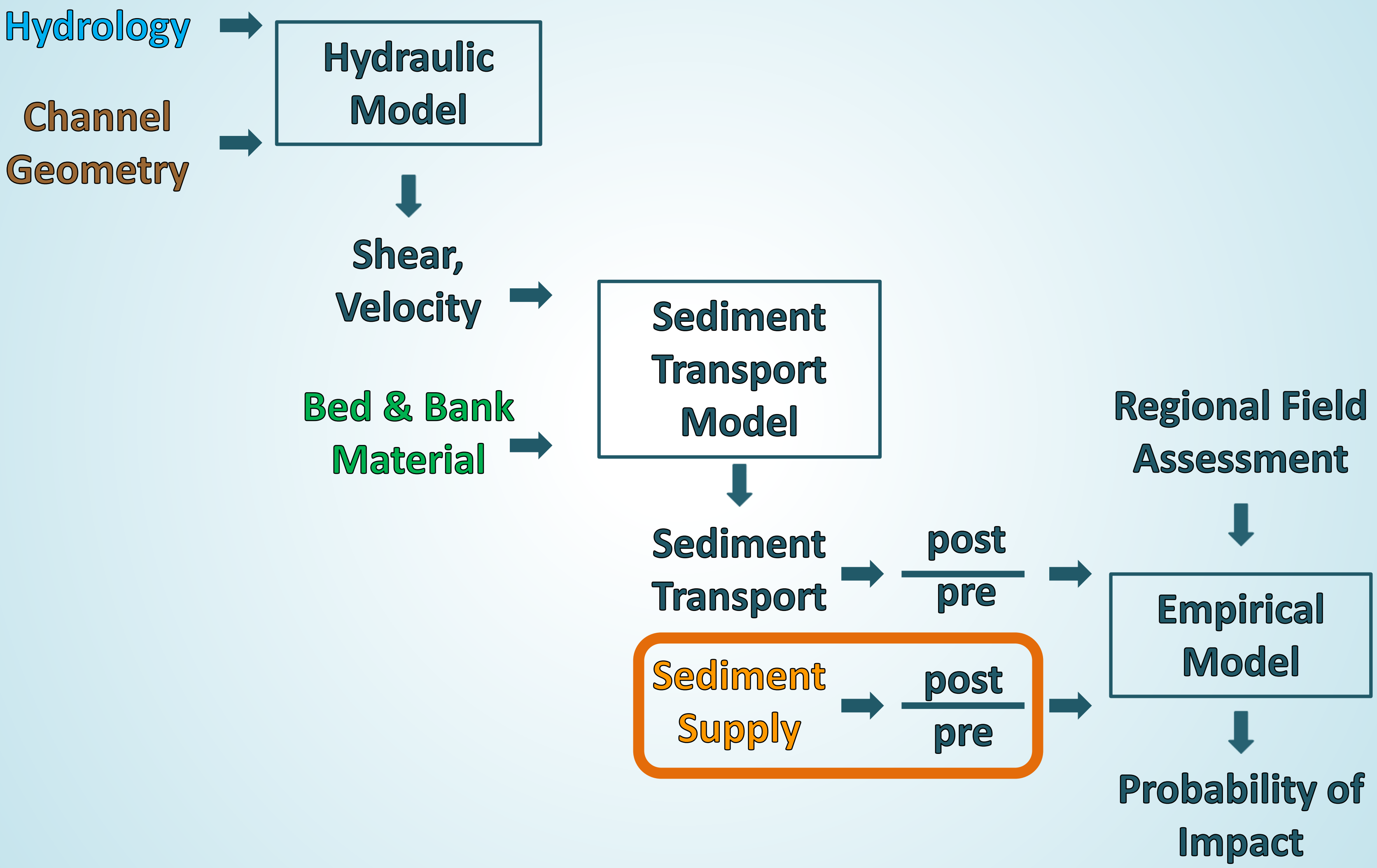
Erosion Potential



Erosion Potential



Hydromodification Impact Model

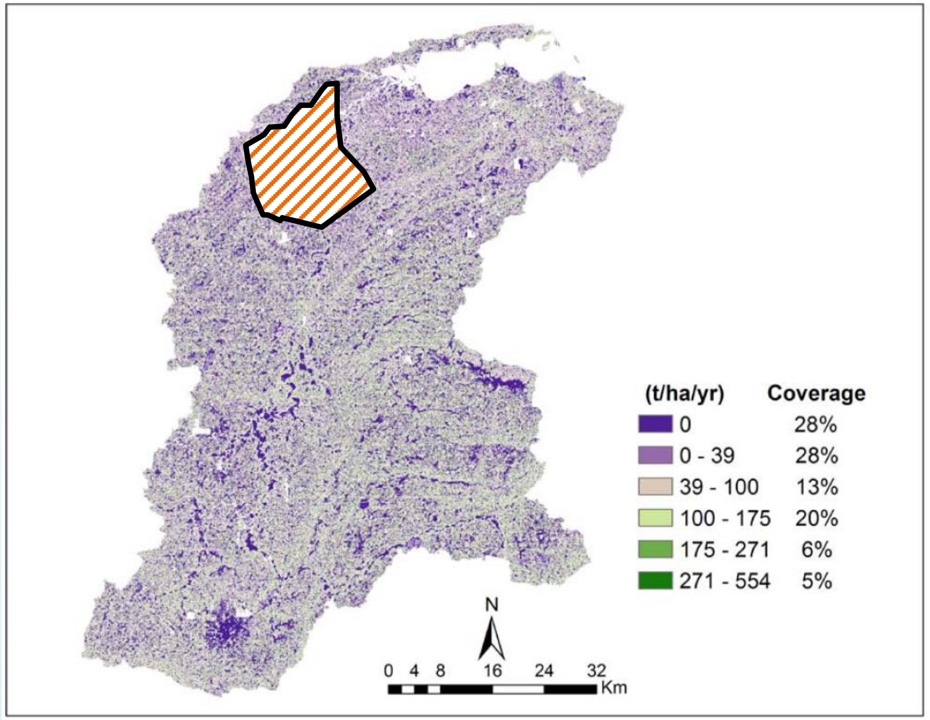


Bed Sediment Supply

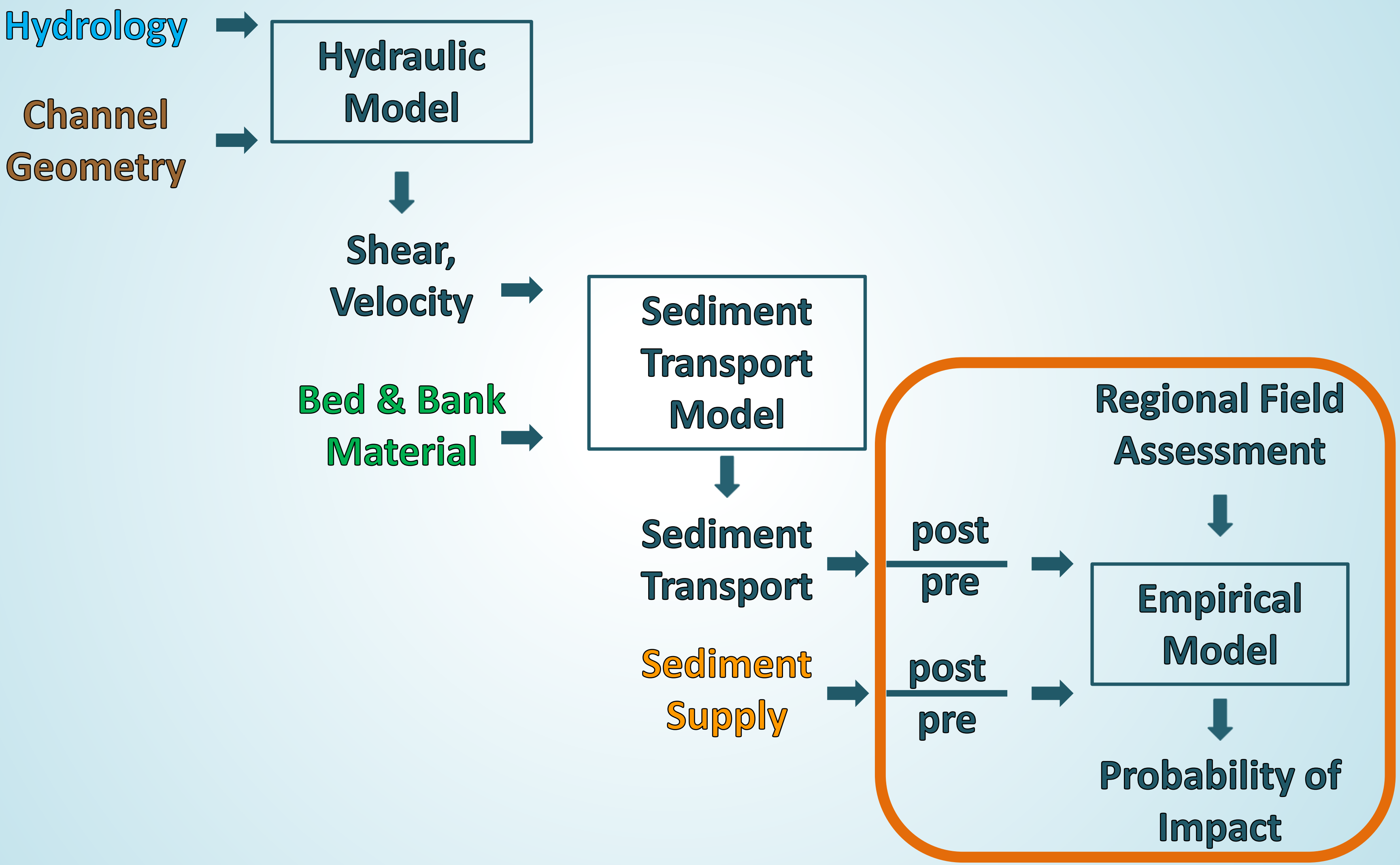
Sediment supply loss can be accounted for by reducing the Target Ep by the ratio of bed sediment supply (Sp) to that computation point.

Post
Pre

$$Sp = \frac{\text{Sediment Supply}_{\text{Post}}}{\text{Sediment Supply}_{\text{Pre}}}$$

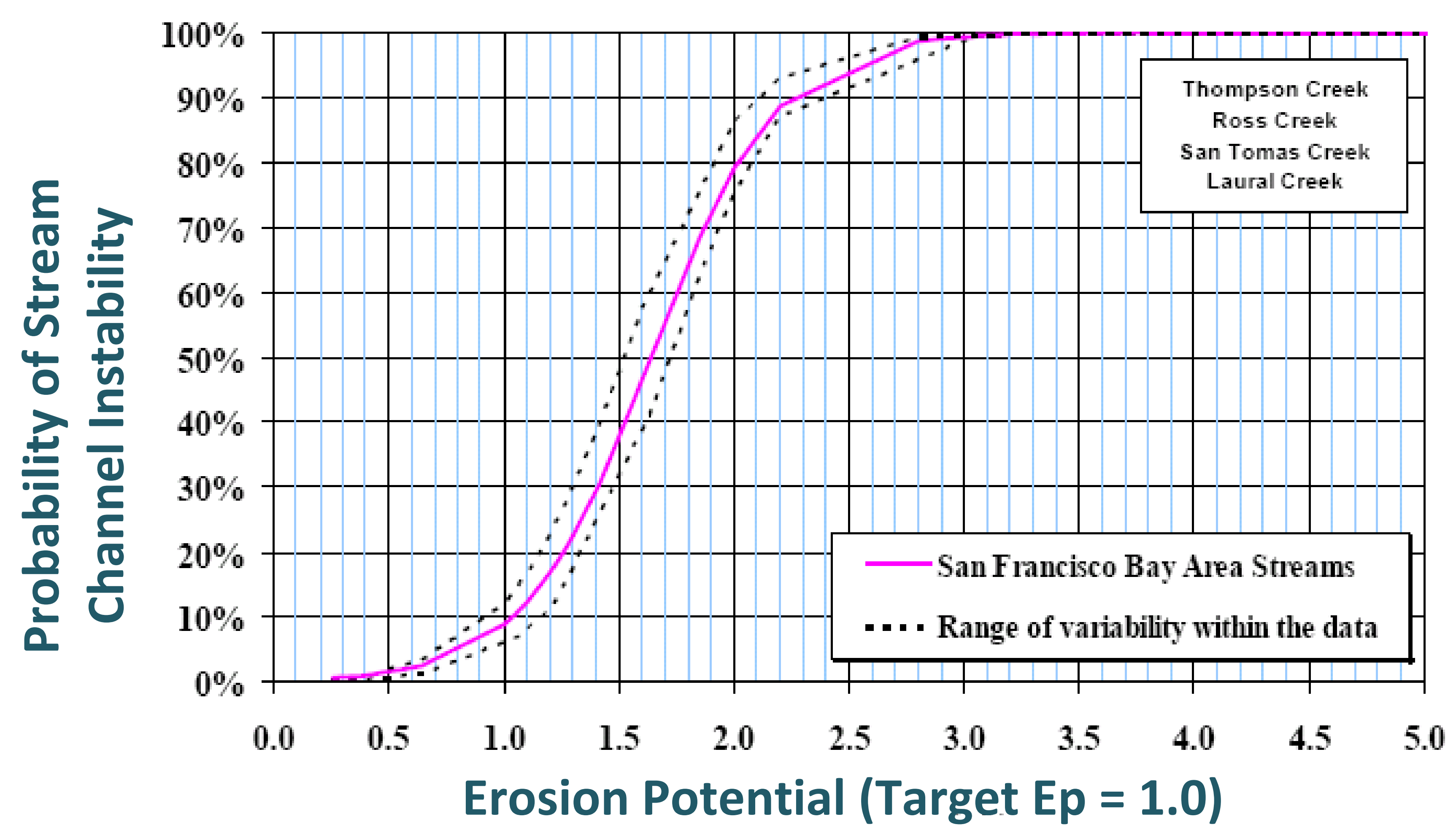


Hydromodification Impact Model



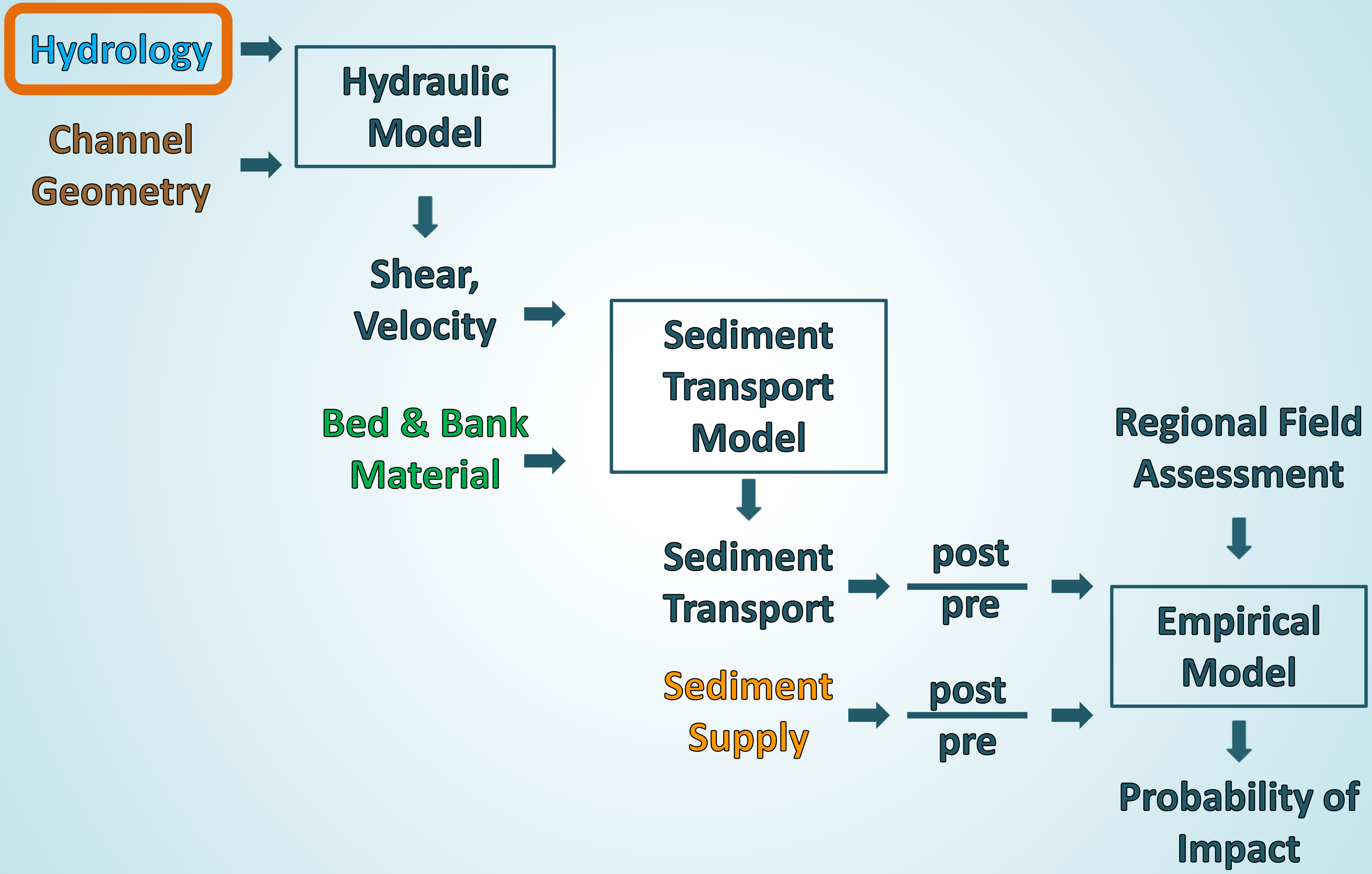
Empirical Model

Ep is compared to the Target Ep (Sp)
to get a Probability of Channel Instability.

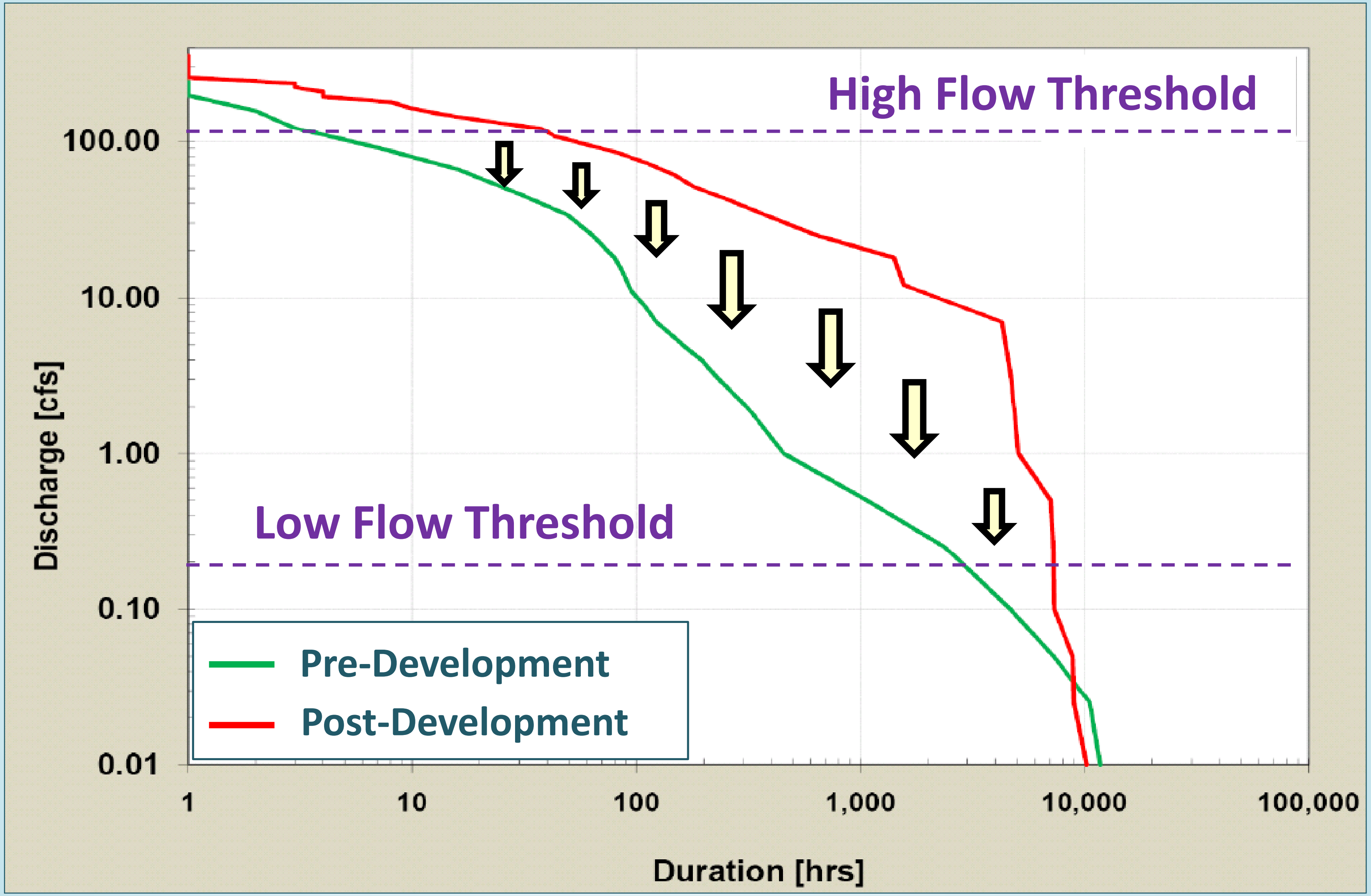


Management Strategies

Out-of-Stream Management

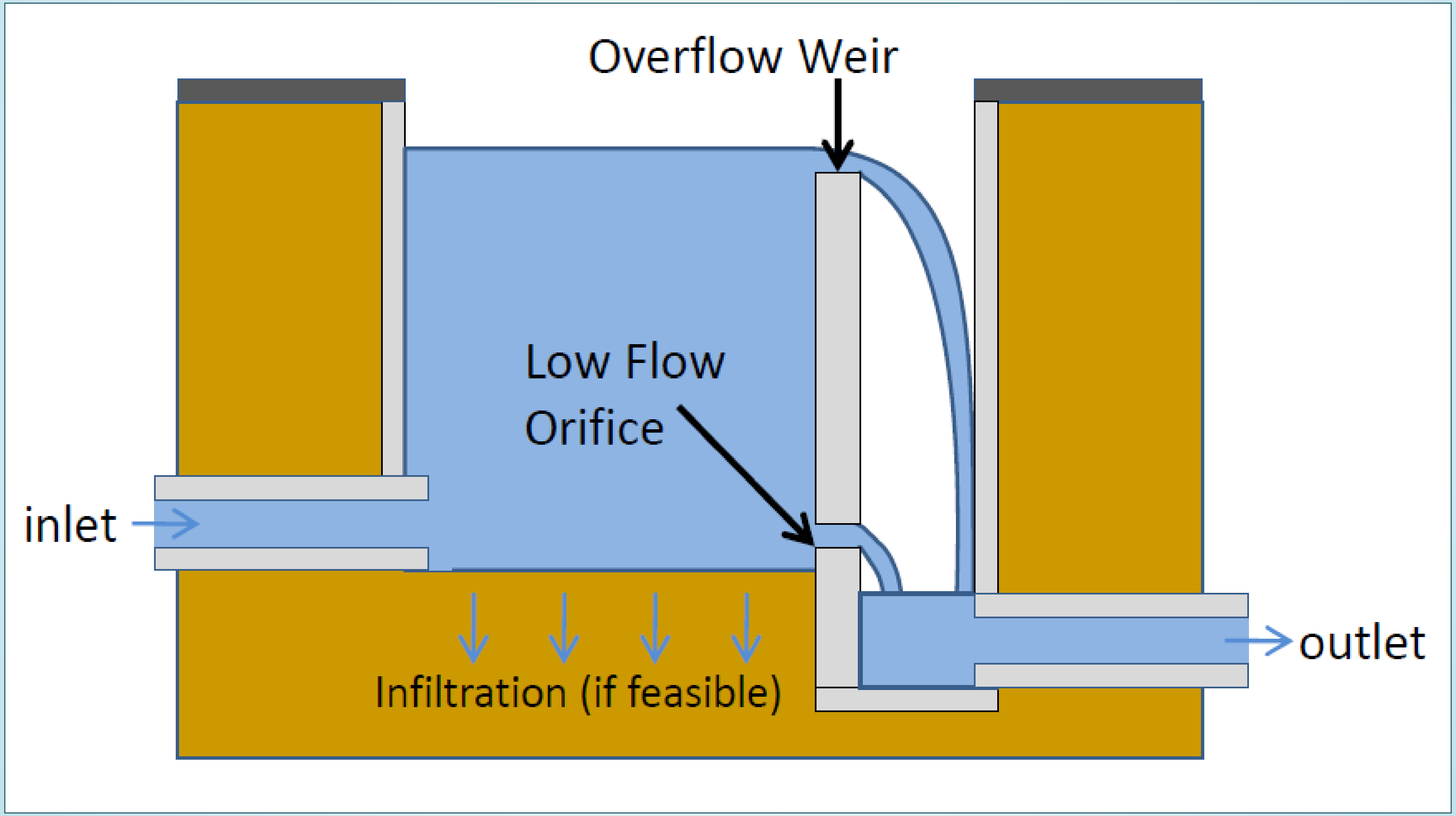


Out-of-Stream Management



Out-of-Stream Management

Route post-development runoff through stormwater BMPs
to mimic pre-development hydrology.



Out-of-Stream Management

The need to retrofit prior development

Out-of-Stream Management

Example of retrofitting prior development

Out-of-Stream Management

Onsite Bioretention

Underground Detention/Retention

Regional Detention

In-Stream Management

Hydrology

Channel Geometry

Hydraulic Model

Shear, Velocity

Bed & Bank Material

Sediment Transport Model

Sediment Transport

post / pre

Sediment Supply

post / pre

Regional Field Assessment

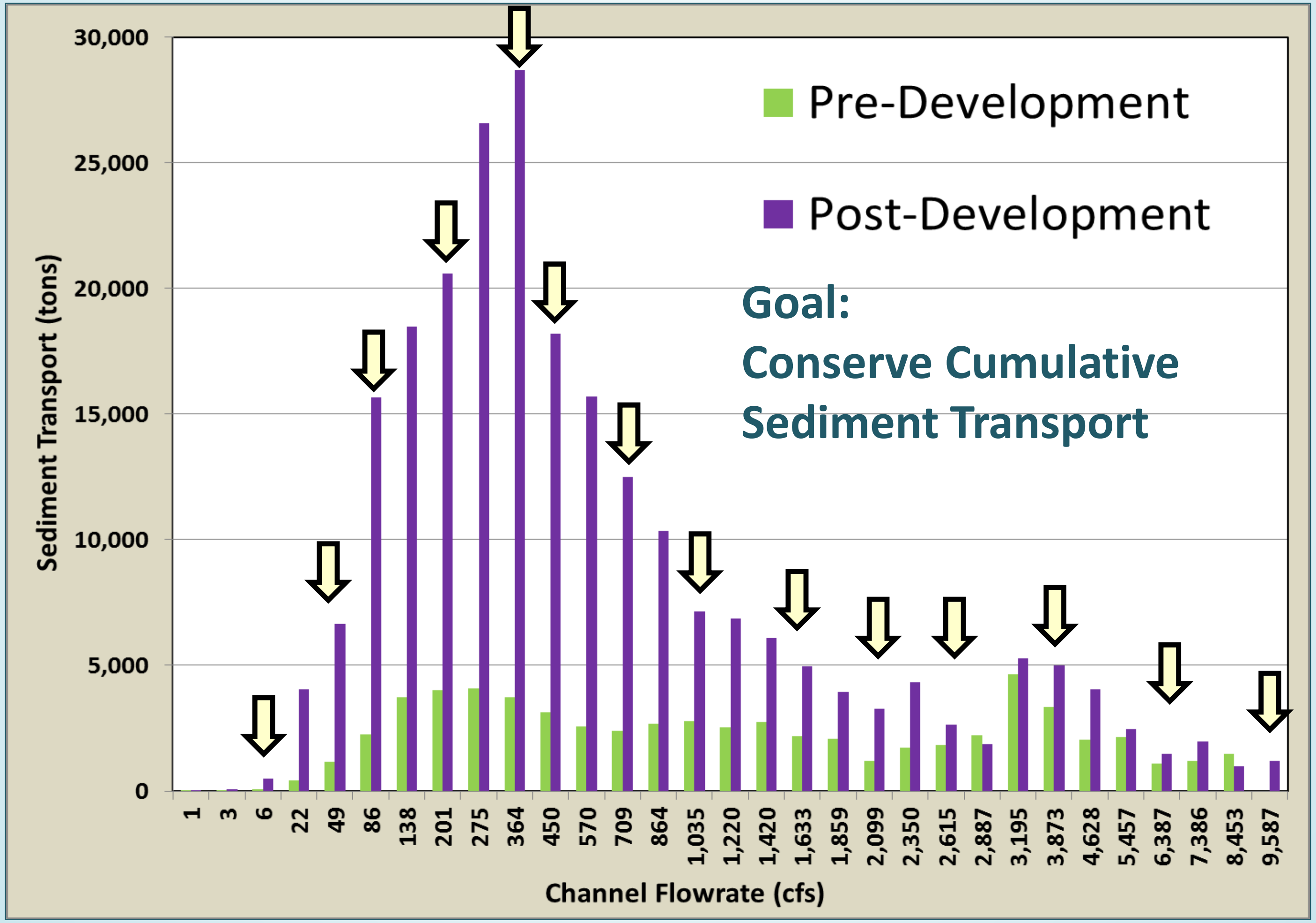
Empirical Model

Probability of Impact

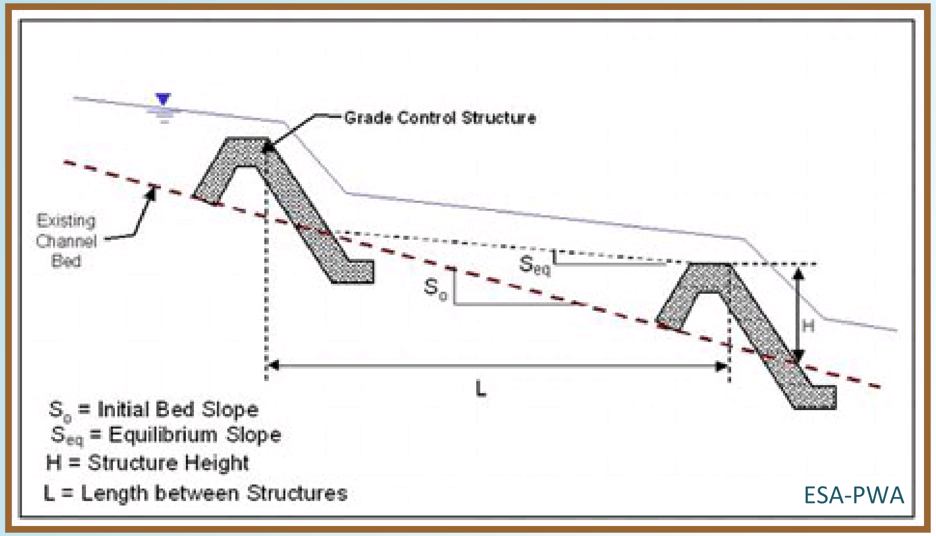
In-Stream rehabilitation is typically appropriate where hydromodification impacts already exist, not pristine streams.

In-Stream Management

Modify the stream morphology
to mimic pre-development sediment transport.

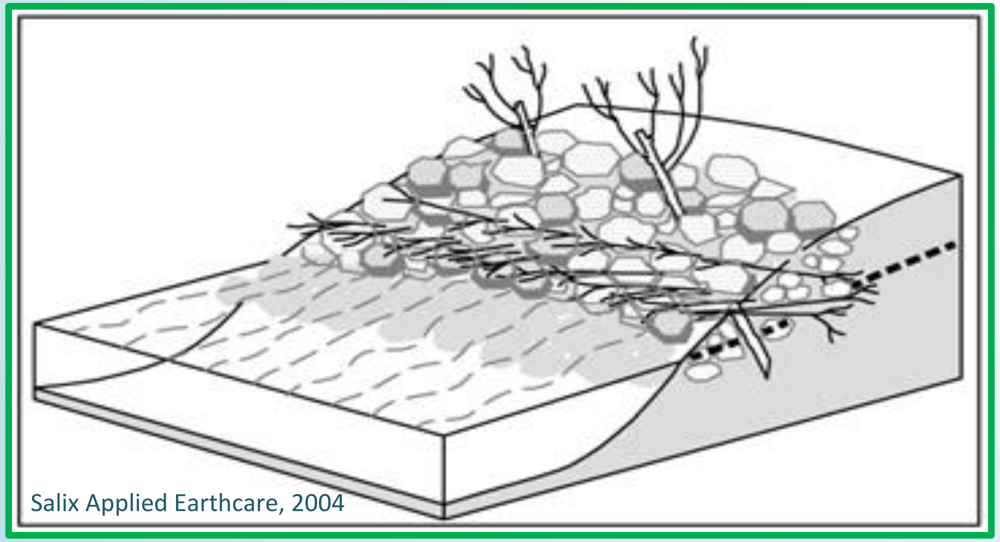


In-Stream Management

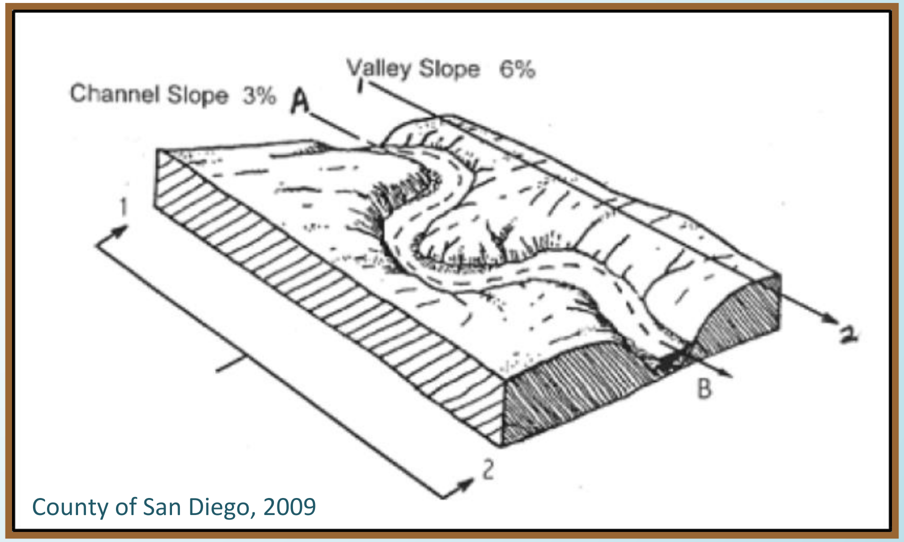


Grade Control

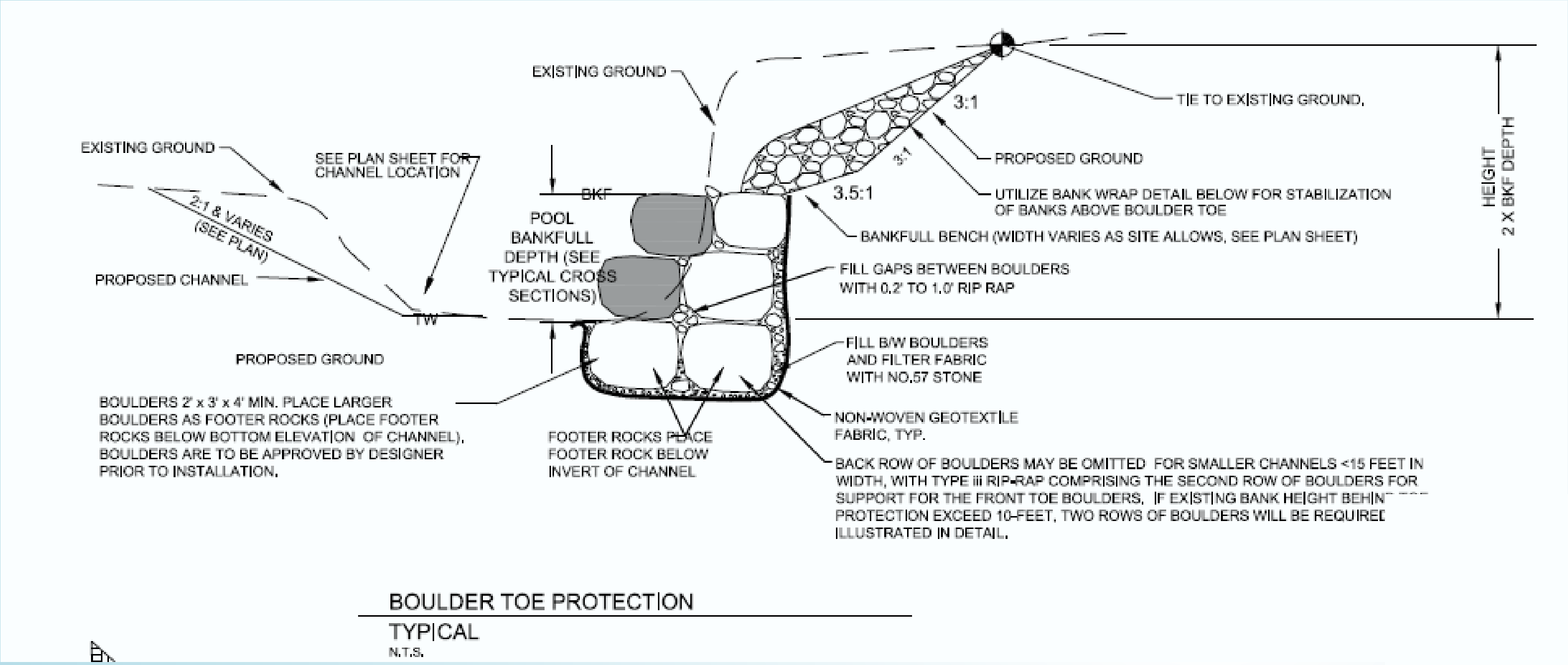
Channel Reinforcement

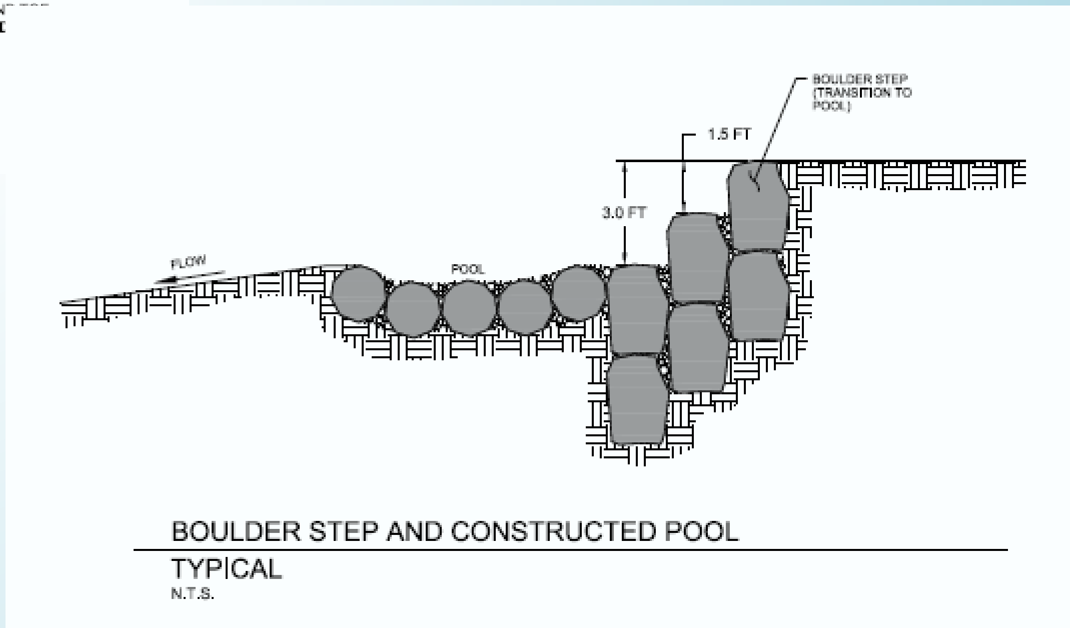


Sinuosity



In-Stream Management Techniques



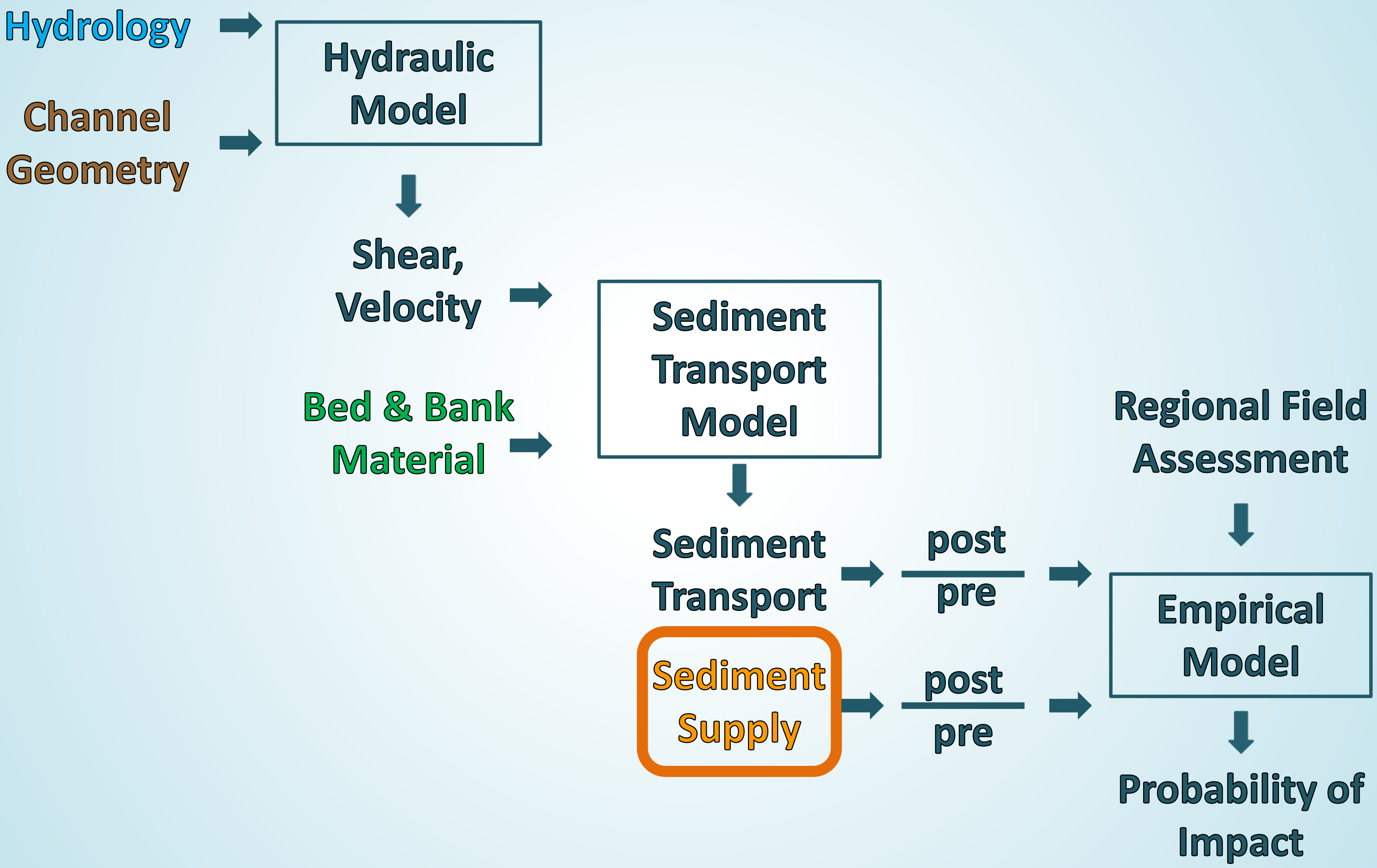


(Pre) In-Stream Management

- Severe erosion
- Excessive down cutting
- Sediment load impacting sewers & basins
- Stream within private property

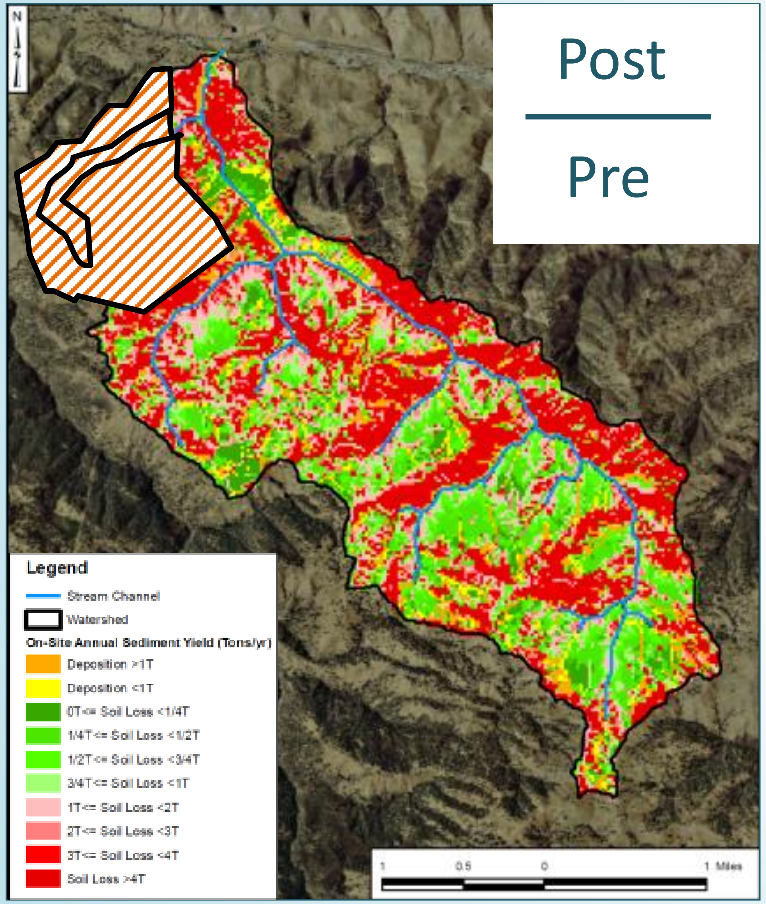
(Post) In-Stream Management

Sediment Supply Management



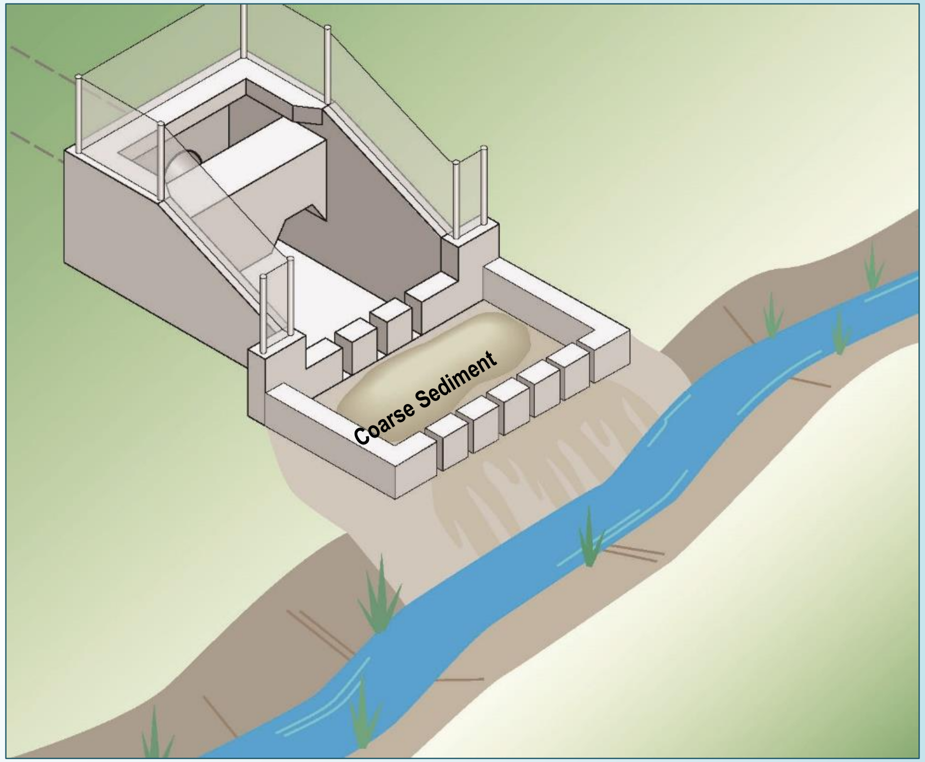
Sediment Supply Management

Avoid / Pass Through Bed Sediment Sources



$$\frac{\text{Post}}{\text{Pre}}$$

Replace Bed Sediment Sources



$$Sp = \frac{\text{Sediment Supply}_{\text{Post}}}{\text{Sediment Supply}_{\text{Pre}}} \uparrow$$

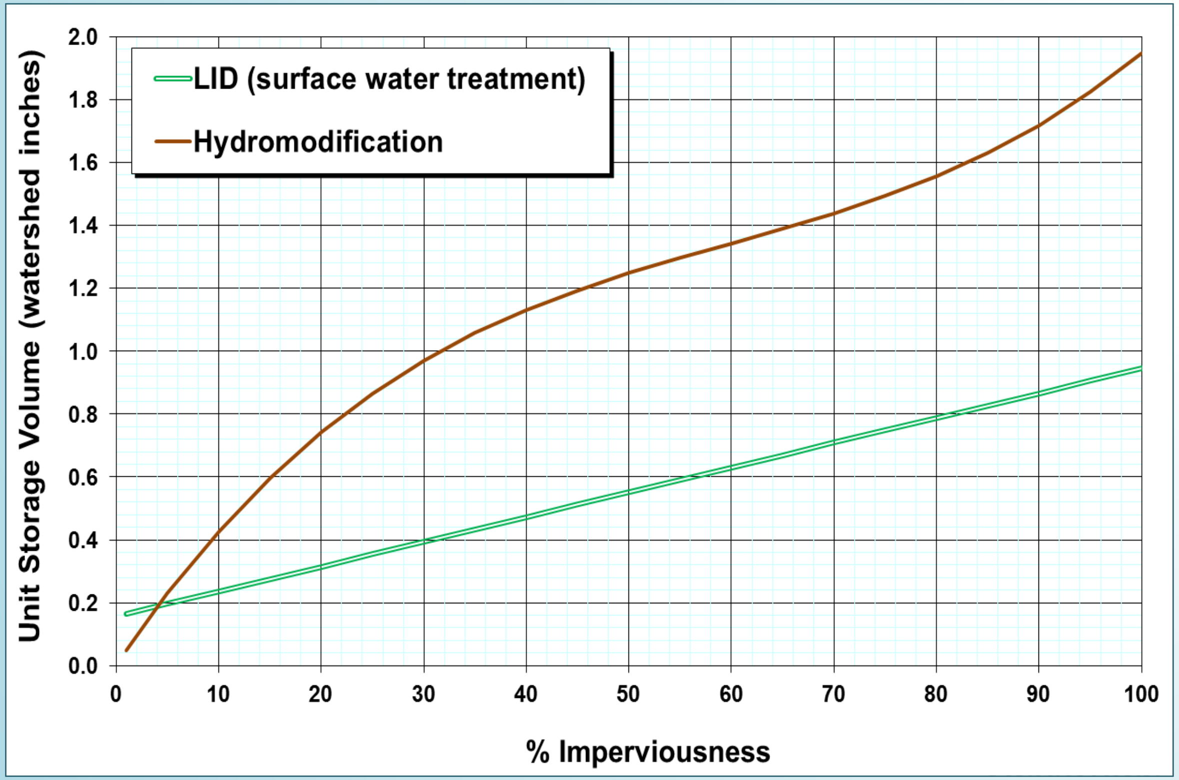
Management Scales

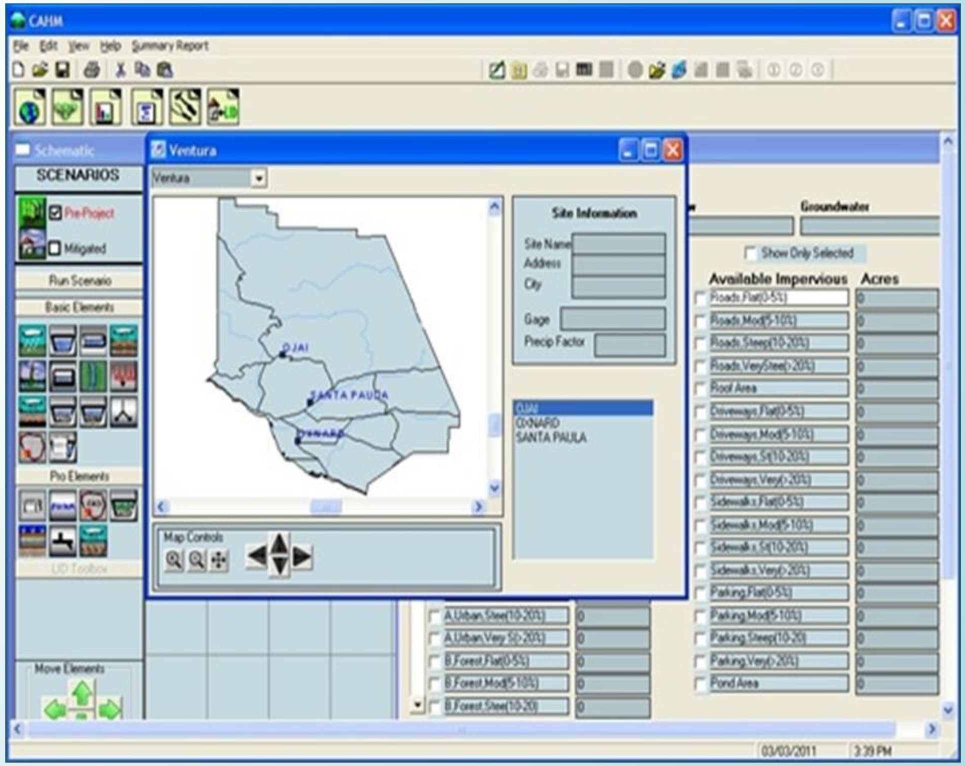
A watershed perspective allows for consideration of land use planning (credit for open space).

Stormwater BMP Sizing

Sizing Method	Onsite	Regional	In-Stream
Nomographs or Sizing Factors	X		
Regional Models	X	X	
System-Specific Analysis	X	X	X

Complexity

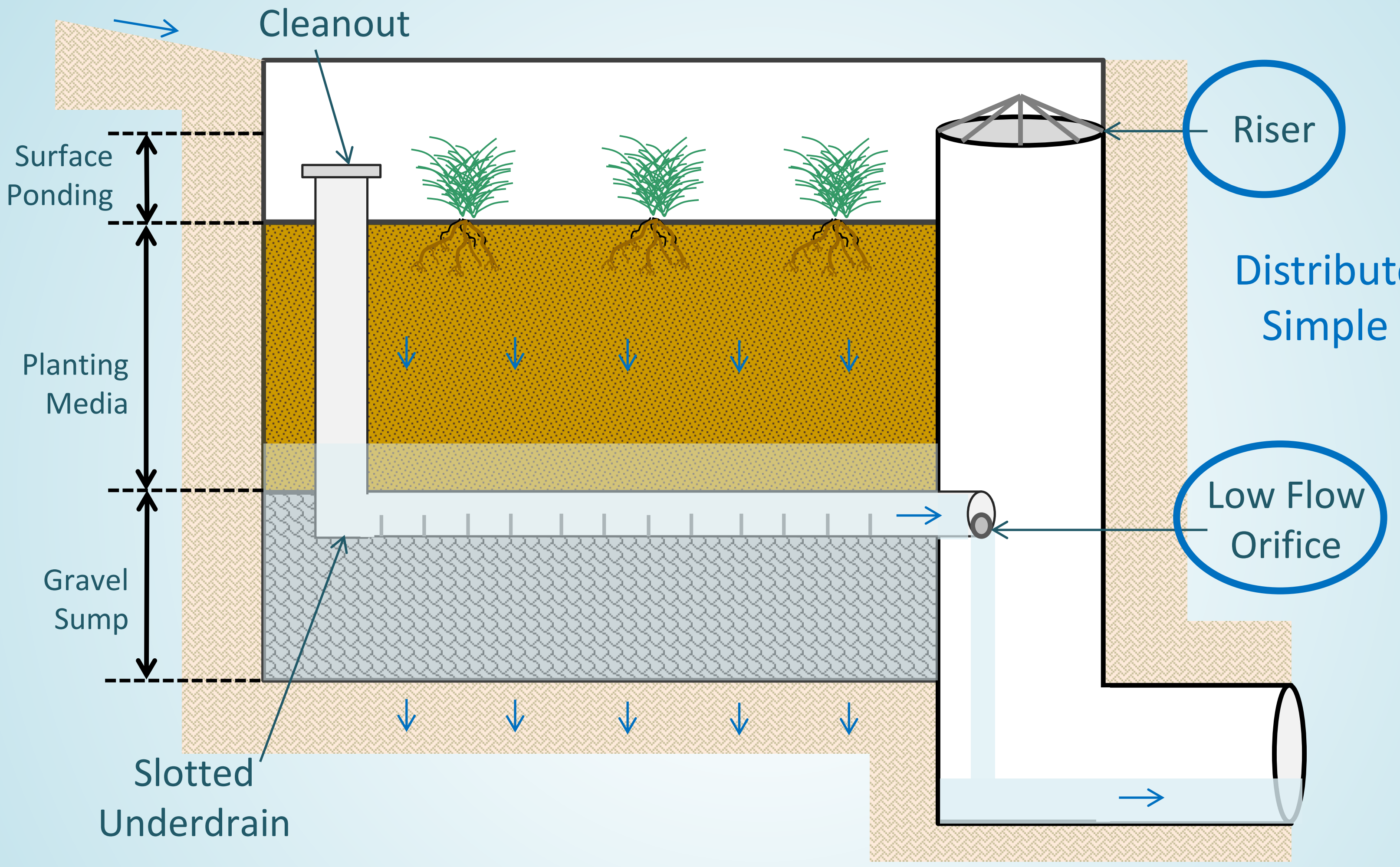




Clear Creek Solutions

Stormwater BMP Sizing Sensitivities

LID BMPs



Distributed LID = Simple Outlet

Hydromodification LID BMPs look the same as for surface water quality, except they are larger!

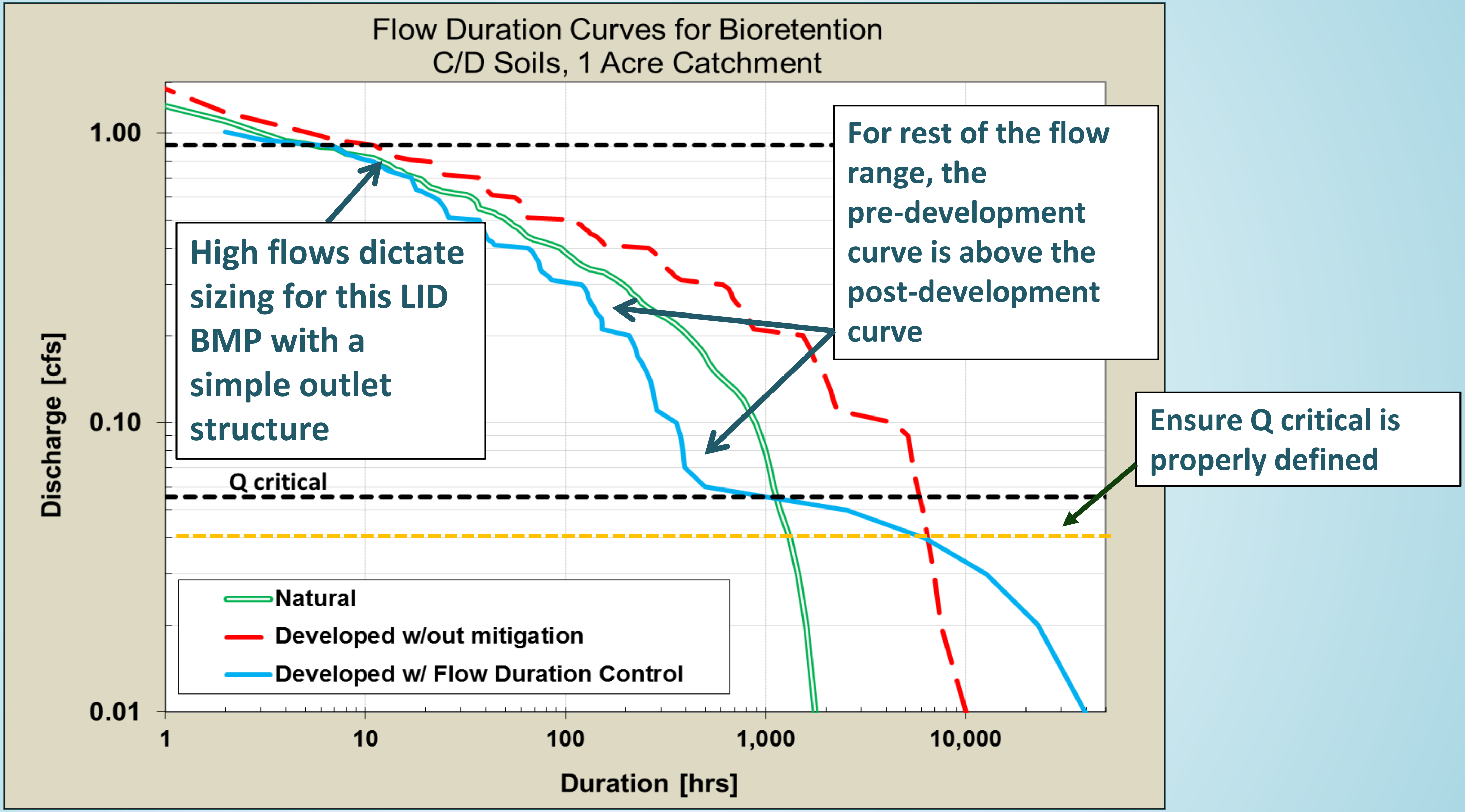
Performance Standard

Flow Duration Control (FDC)

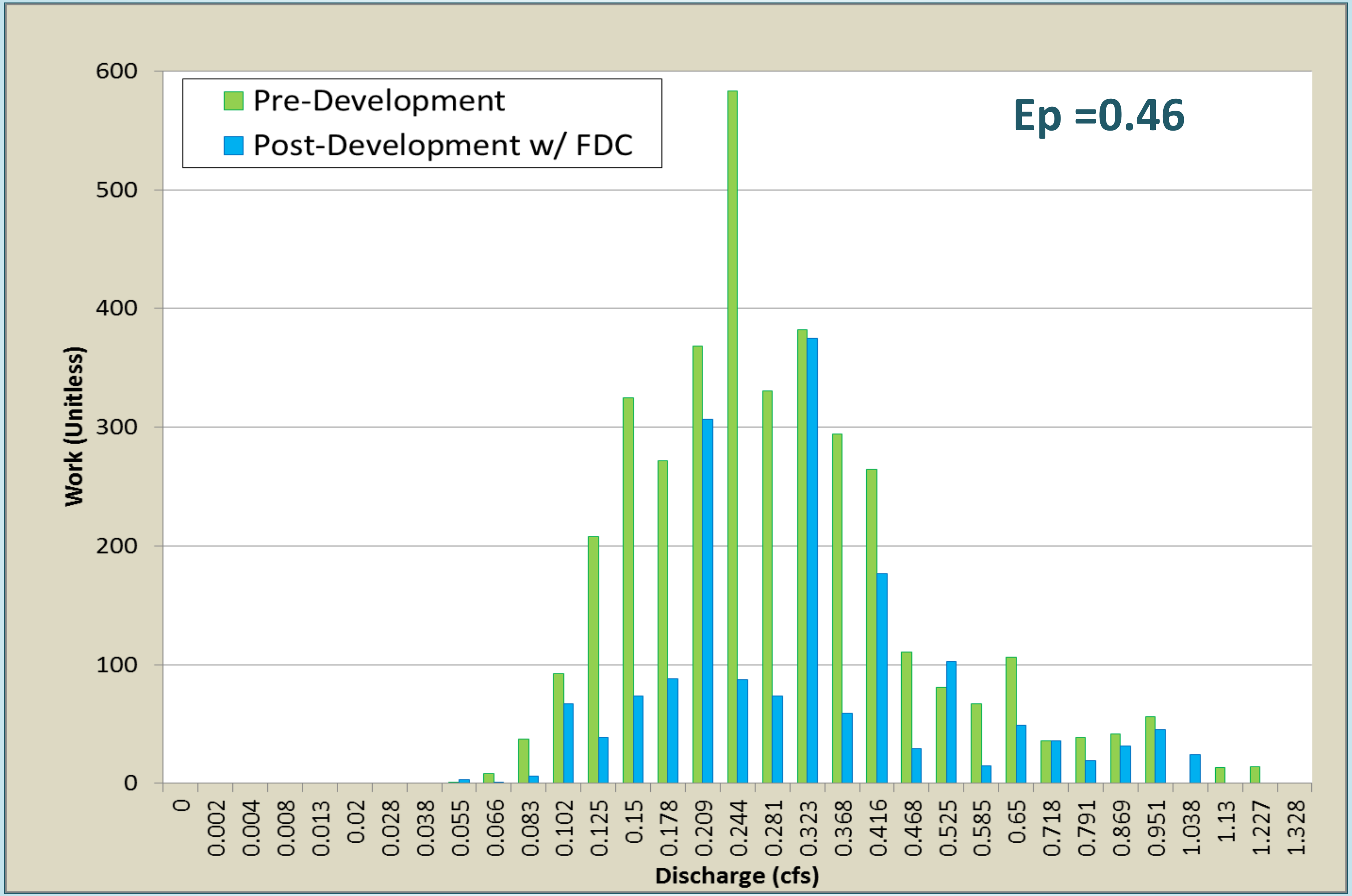
vs.

Erosion Potential (Ep)

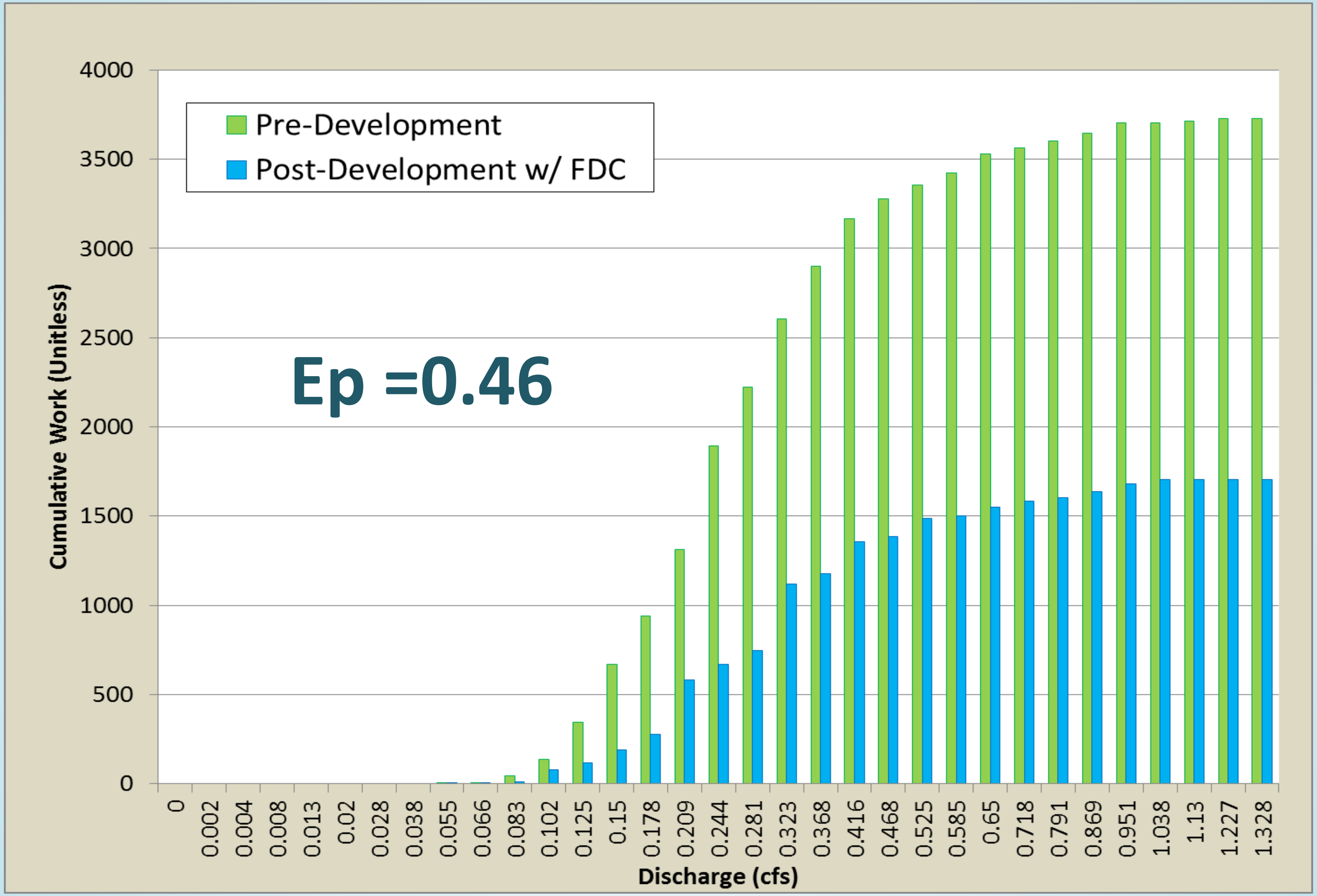
Performance Standard



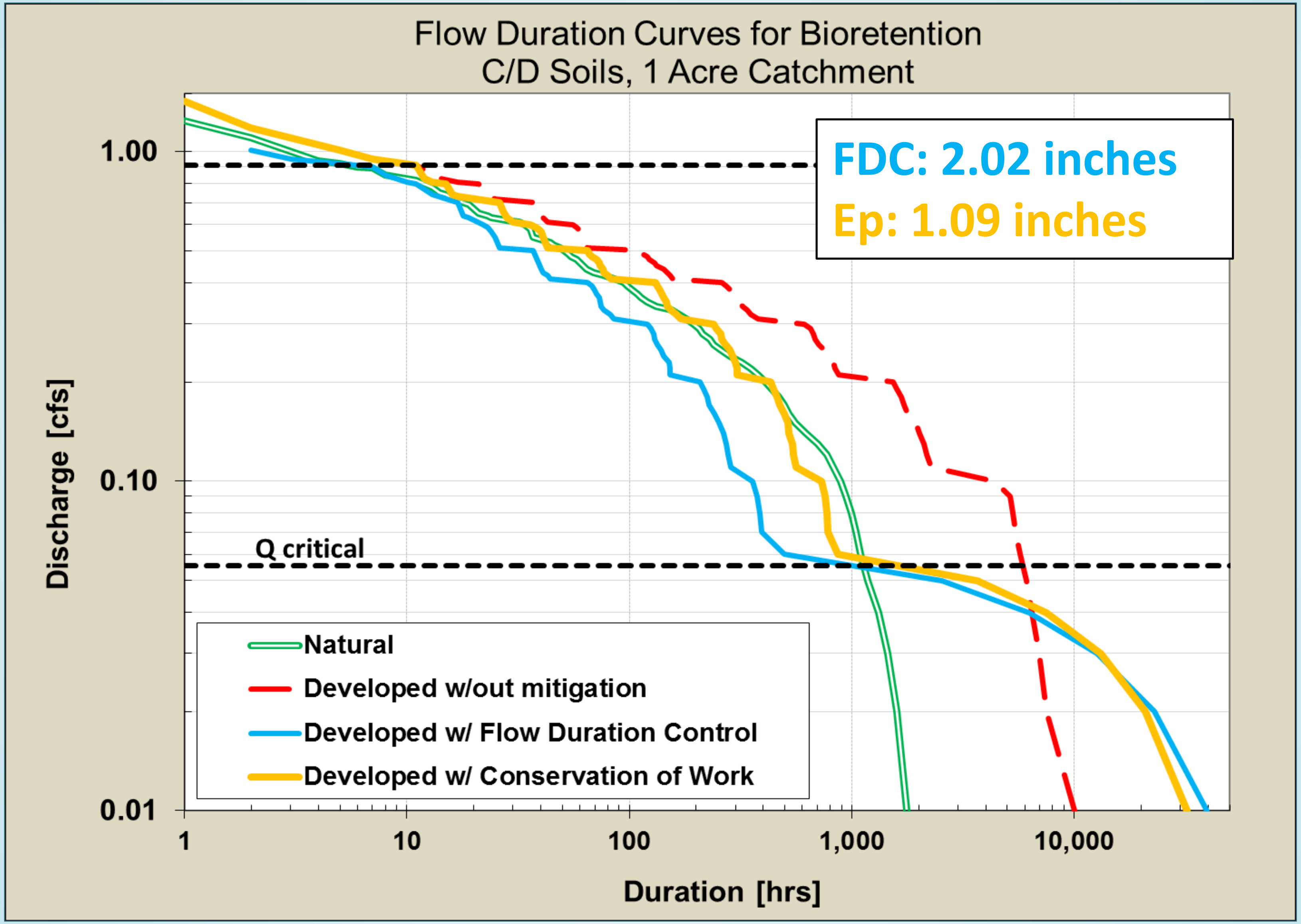
Performance Standard



Performance Standard

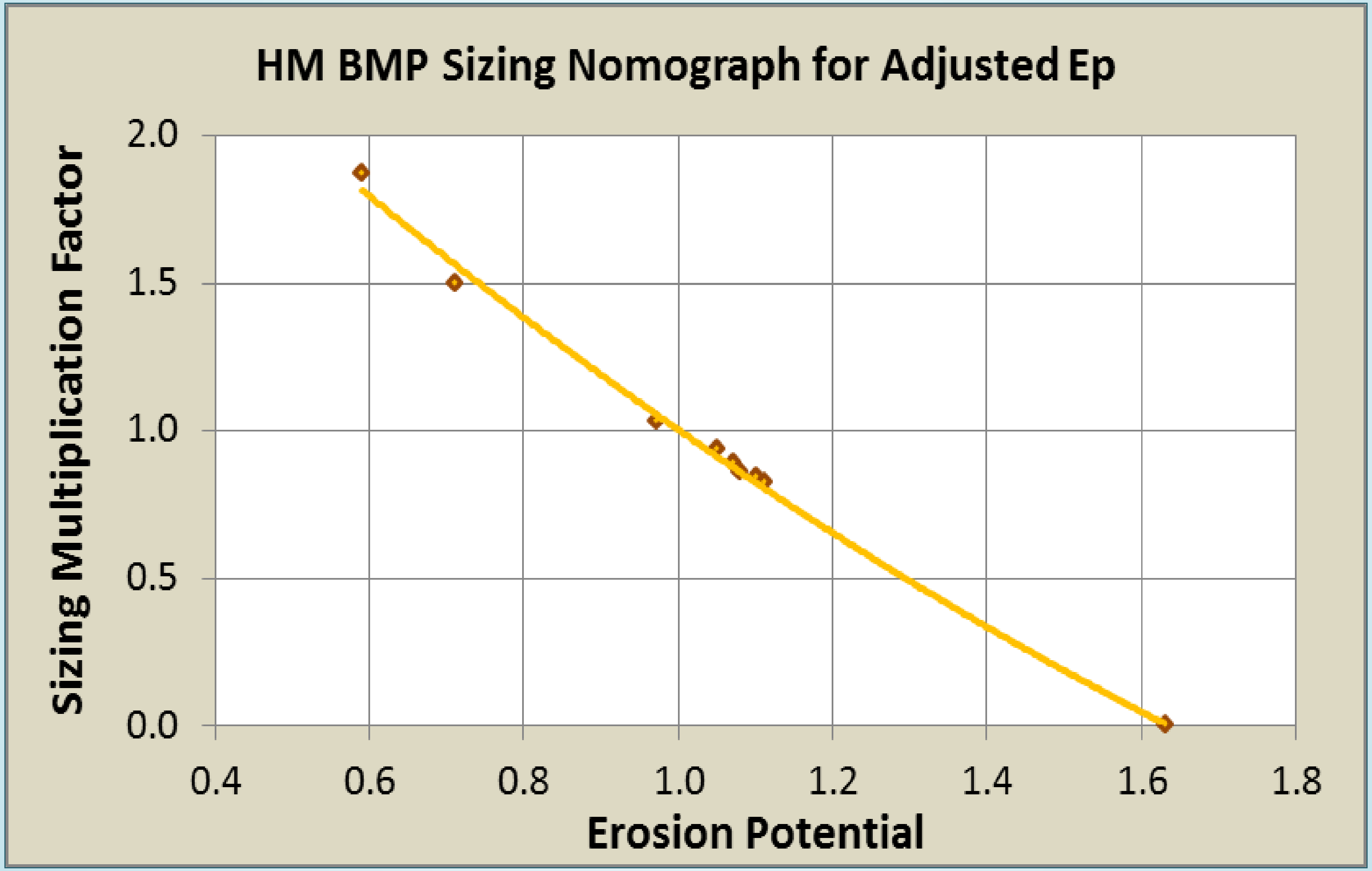


Performance Standard



Performance Standard

Ep lends itself to incorporating changes in sediment supply.



Performance Standard

- FDC is the status quo, but Ep can result in smaller BMPs for simple outlets.
- Ep alone does not mimic the distribution of erosive flows.
- Ep can account for sediment supply loss, but FDC cannot.

Low Flow Threshold

5% Q_2

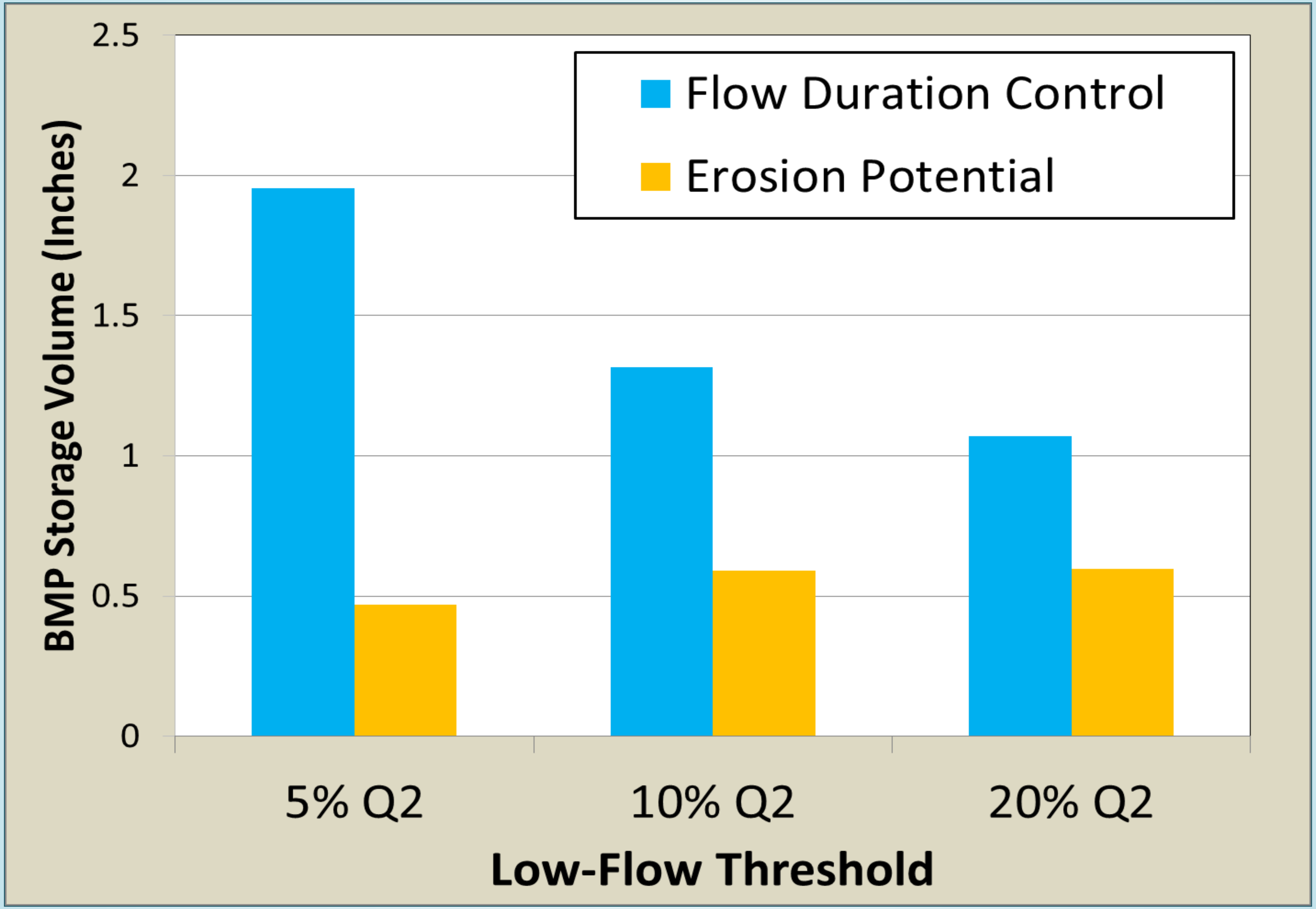
vs.

10% Q_2

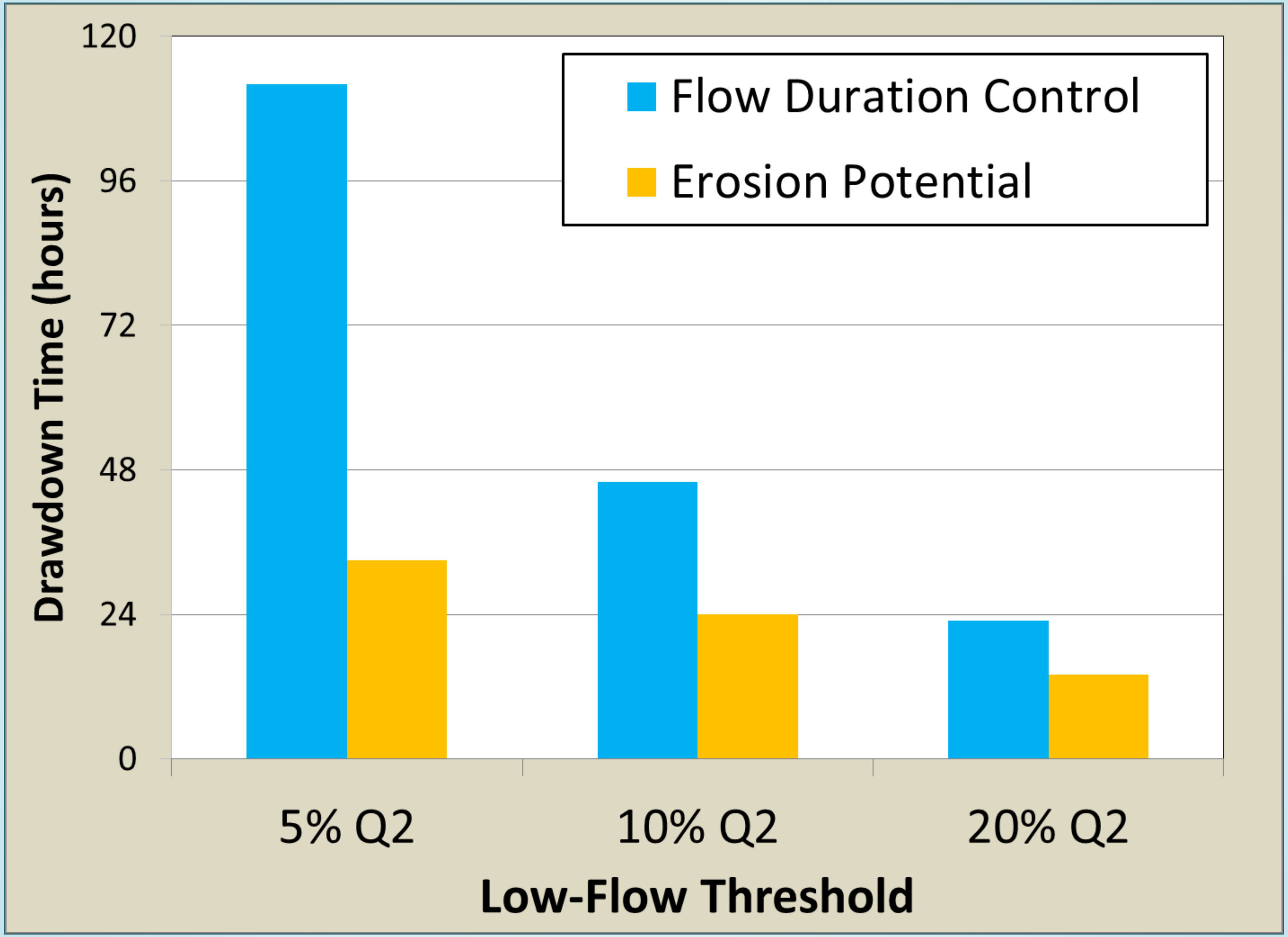
vs.

20% Q_2

Low Flow Threshold



Low Flow Threshold



Low Flow Threshold

- FDC
  - BMP size & drawdown time decrease with increased low flow threshold.
- Ep
  - BMP size is not as sensitive to low flow threshold.
  - BMP drawdown time decreases with increased low flow threshold.

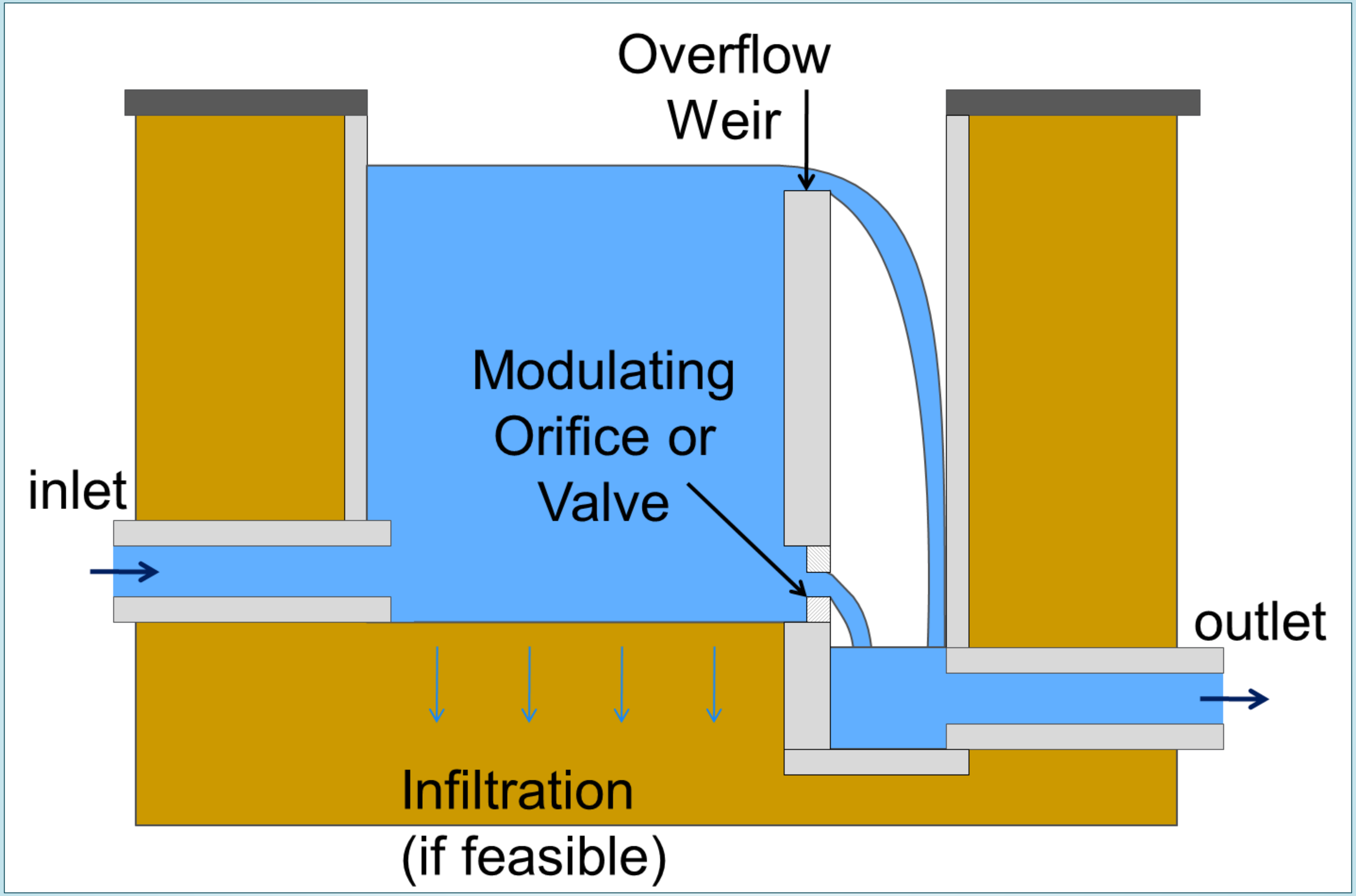
Outlet Design

Passive Controls

vs.

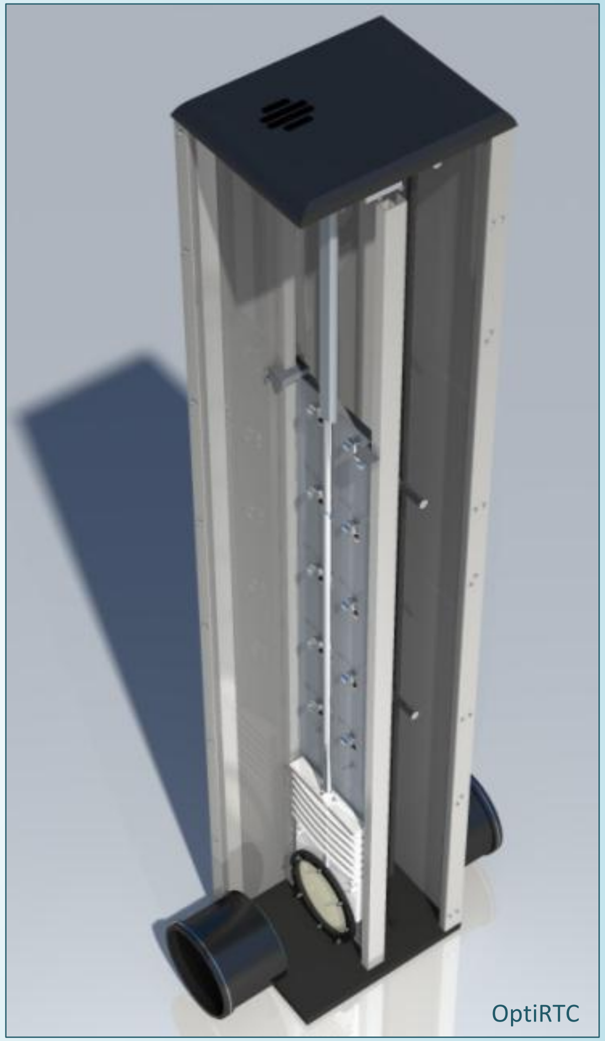
Active Controls

Outlet Design



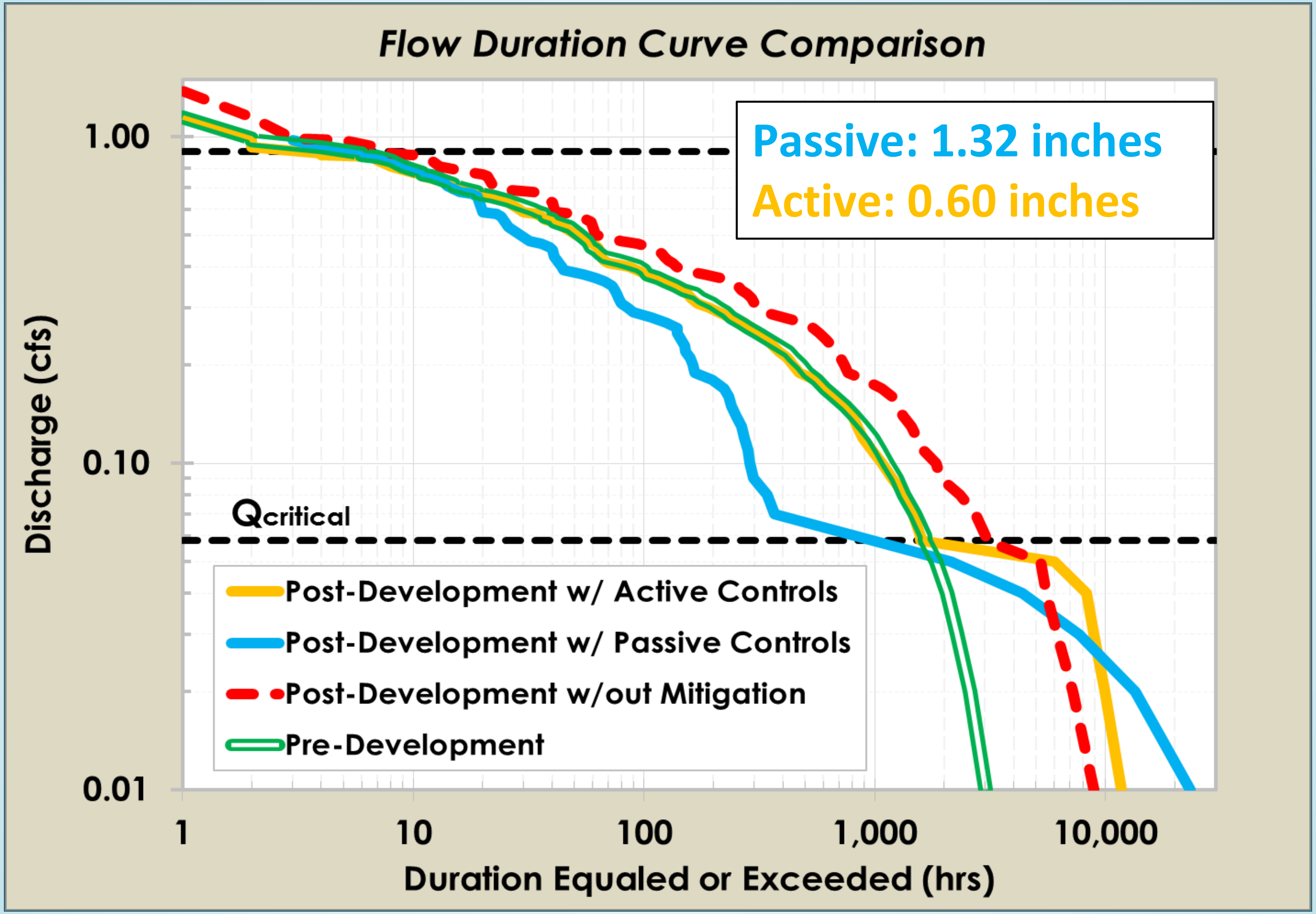
Outlet Design

Active Controls



OptiRTC

Outlet Design



Outlet Design

Benefits of Active Controls

- Retrofit
  - Existing flood control basins can provide hydromod control
- New Development
  - BMP size decreases, making hydromod management feasible
- Adaptive Management
  - Data available in real-time
  - Adjust flow releases without physical retrofit
  - Flow monitoring and calibration

Conclusion

Takeaways

- Four Keys Factors that Affect Stream Morphology

$$\text{Geomorphic Impact} = f\left(\begin{array}{l}\Delta\text{hydrology},\\ \Delta\text{channel geometry},\\ \Delta\text{bed \& bank material strength},\\ \Delta\text{sediment supply}\end{array}\right)$$

- Erosion Potential (Ep) relates to probability of impact

$$Ep = \frac{\text{Sediment Transport}_{\text{Post}}}{\text{Sediment Transport}_{\text{Pre}}}$$

- Hydromodification Management Strategies
  - Out-of-Stream
  - In-Stream
  - Sediment Supply

Questions?

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