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Agricultural Research Service

Critical U.S. Sedimentation Issues & New Sediment Transport Model Advancements

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United States Department of Agriculture

Outline

- Critical sedimentation issues
- Technology needs & products
- HEC-RAS v5 new sediment features

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Subcommittee on Sedimentation (SOS)

The Subcommittee **promotes and supports development and standardization of equipment, methodologies, and calibration and performance criteria for the collection, analysis, interpretation, and interchange of fluvial-sediment data and related technical information**. Information and data about sediment transport or deposition rates and the physical and chemical qualities of sediment are important to understanding current resource conditions and trends. The Subcommittee evaluates this information and other relevant issues and facts, and drafts proposed position papers or recommendations for improving the availability, reliability, and interpretation of information and data about sediment conditions. The Subcommittee forwards the draft papers and recommendations to the ACWI for deliberation and approval as advice to the Federal Government. **With such information, decisions can be made by local, State, Tribal, and Federal entities on the direction of current and future programs for solutions to identified problems related to sediment**.

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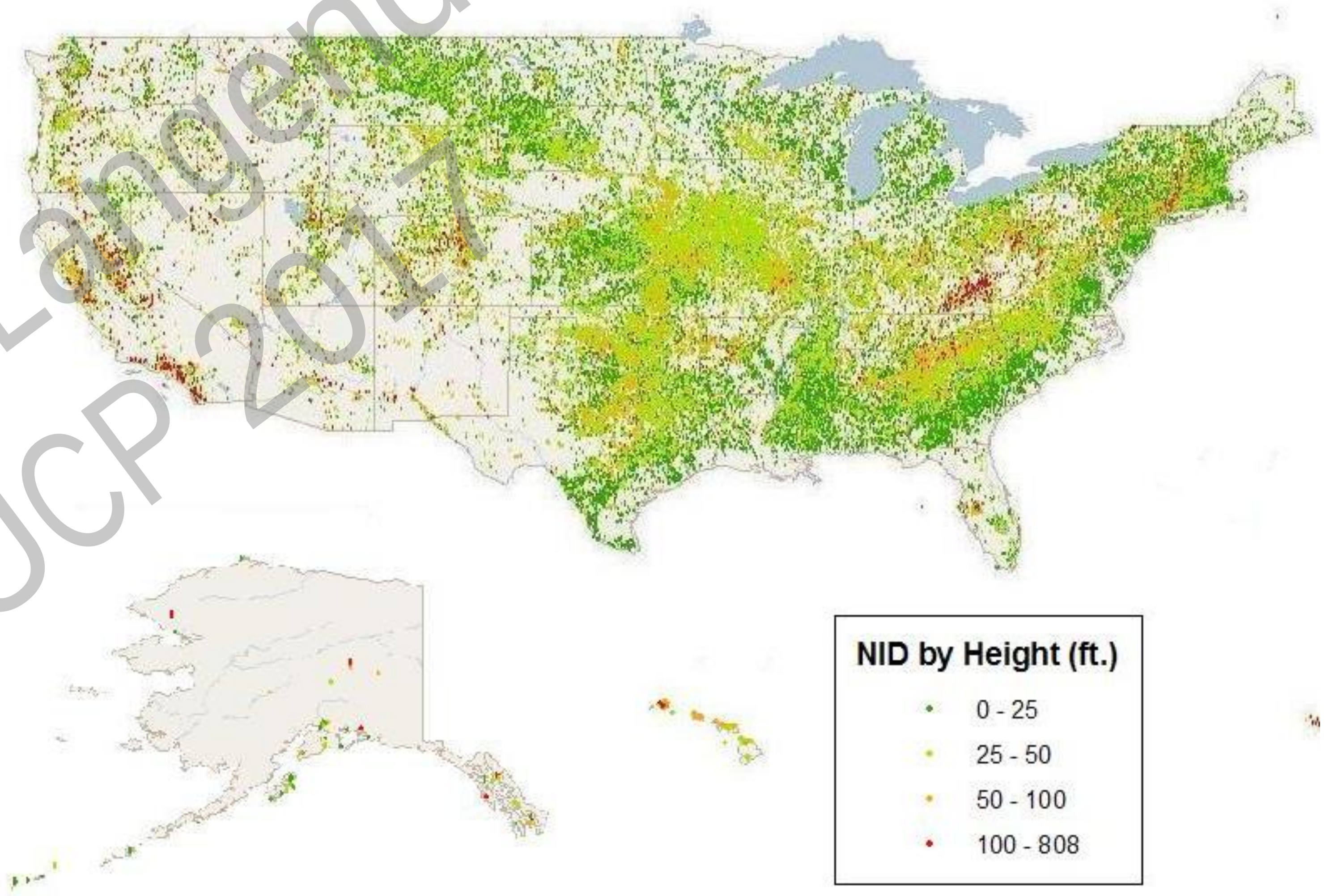
SOS Working Groups

- Dam removal guidelines
- Sustainable reservoir sediment management
- National stream morphology data exchange
- Infrastructure & environment
- Climate and sediment

- Federal interagency sedimentation project (FISP)

Dams and Reservoirs

- National Inventory of Dams (http://nid.usace.army.mil/)
- Lists > 90,000 dams
- Majority < 25 ft
- Majority completed between 1950-70
- Majority are earthen
- On average 1 dam/day has been constructed since the Declaration of Independence



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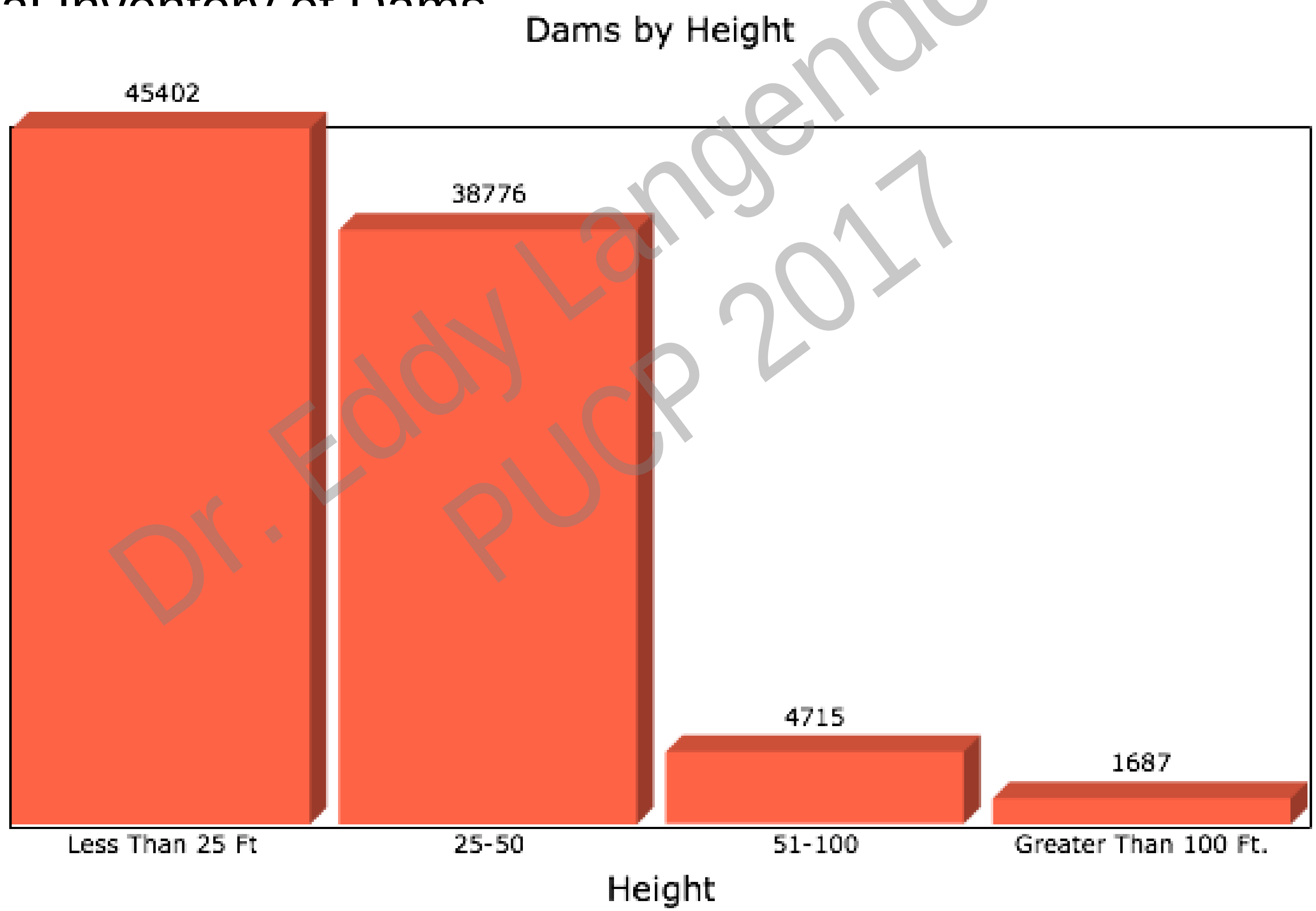

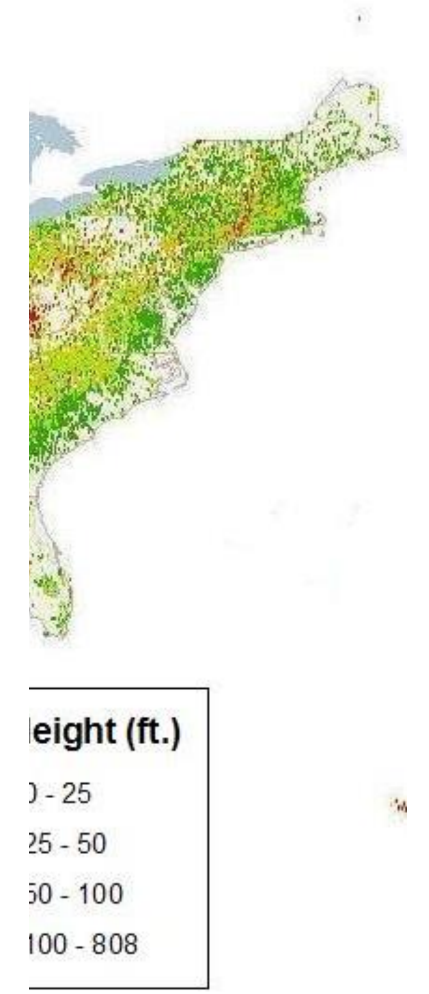

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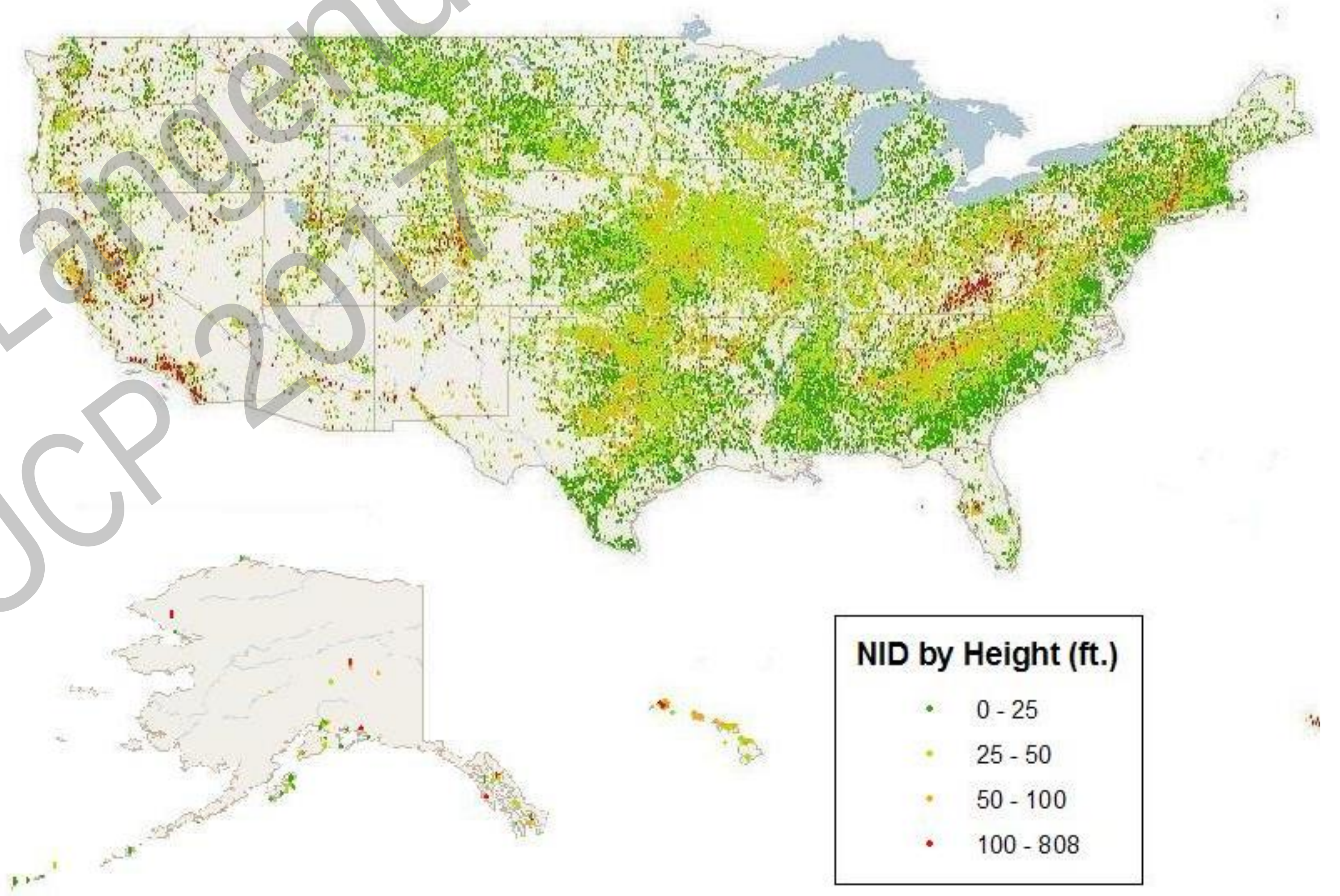

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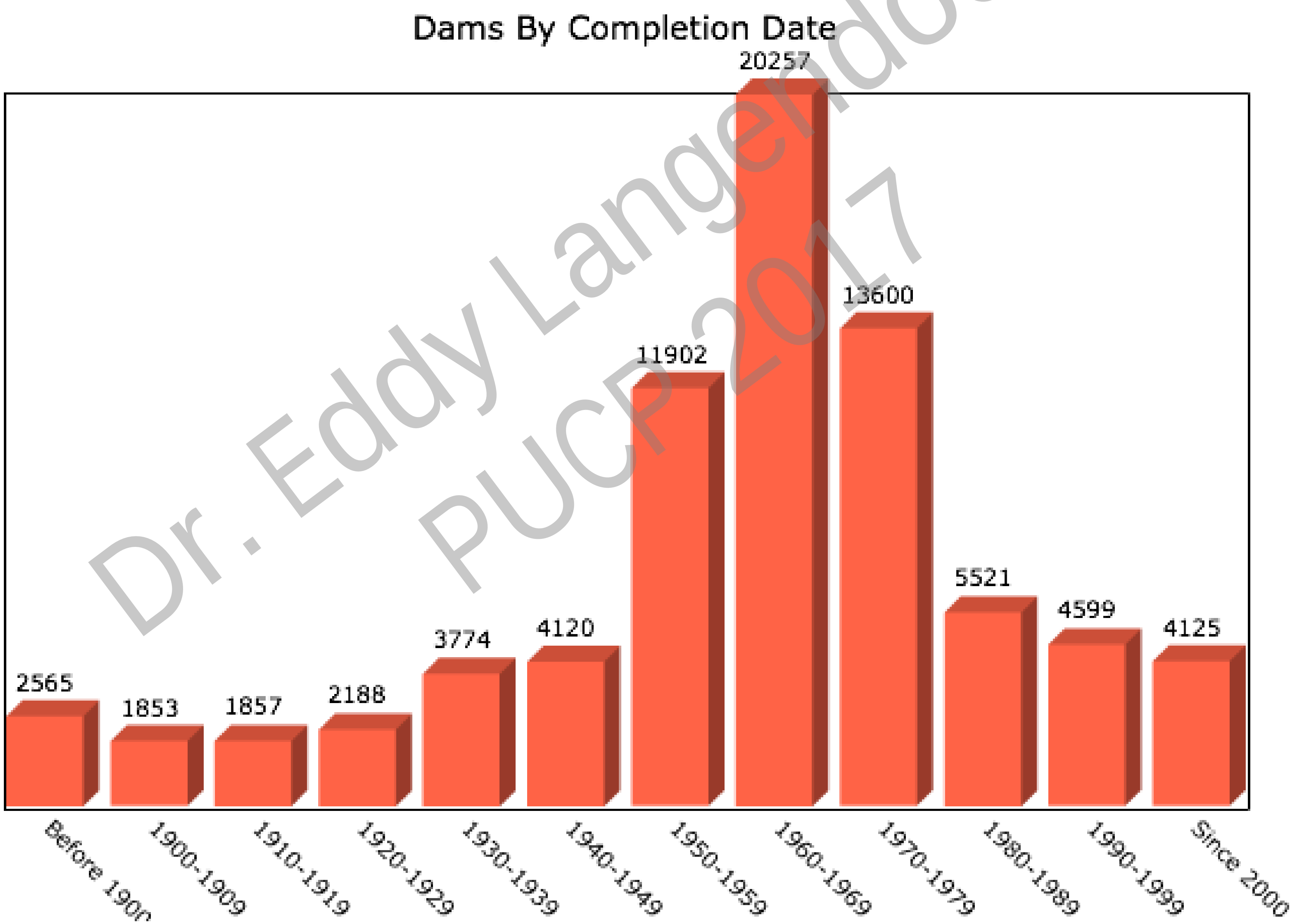

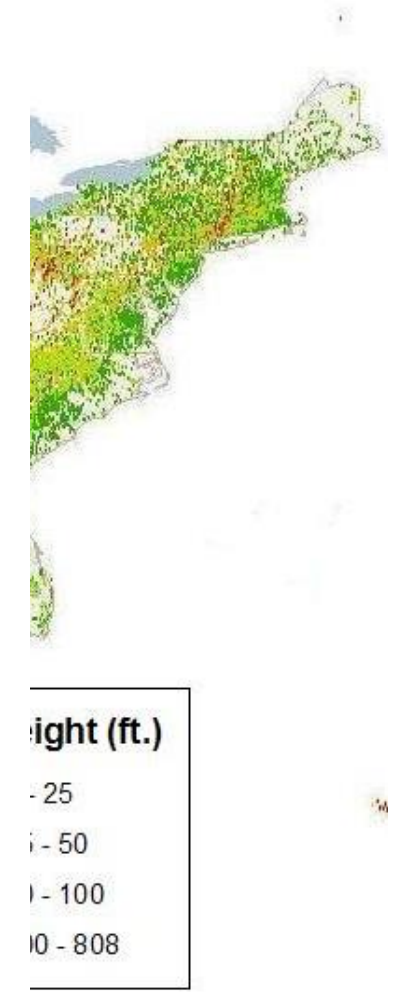

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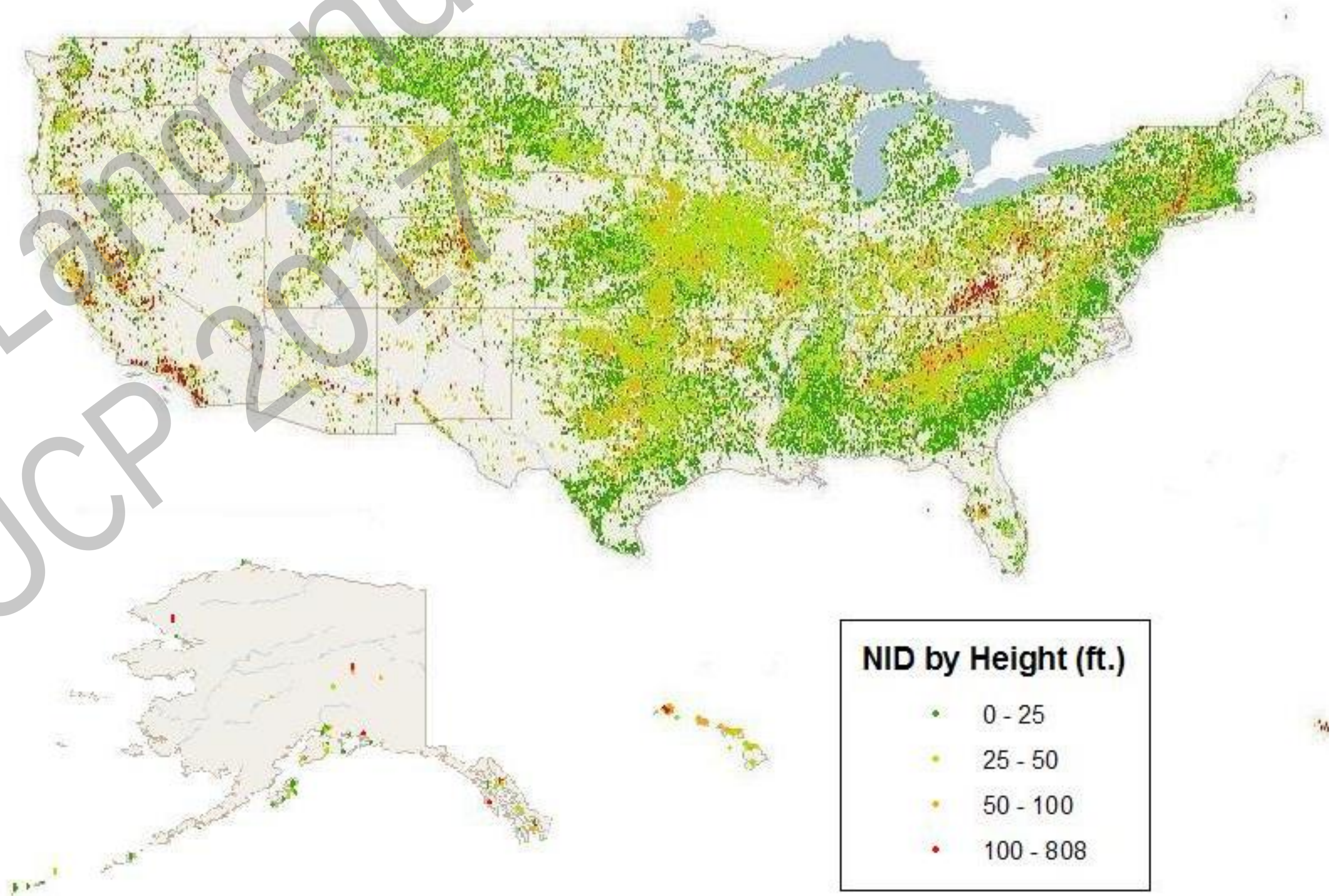

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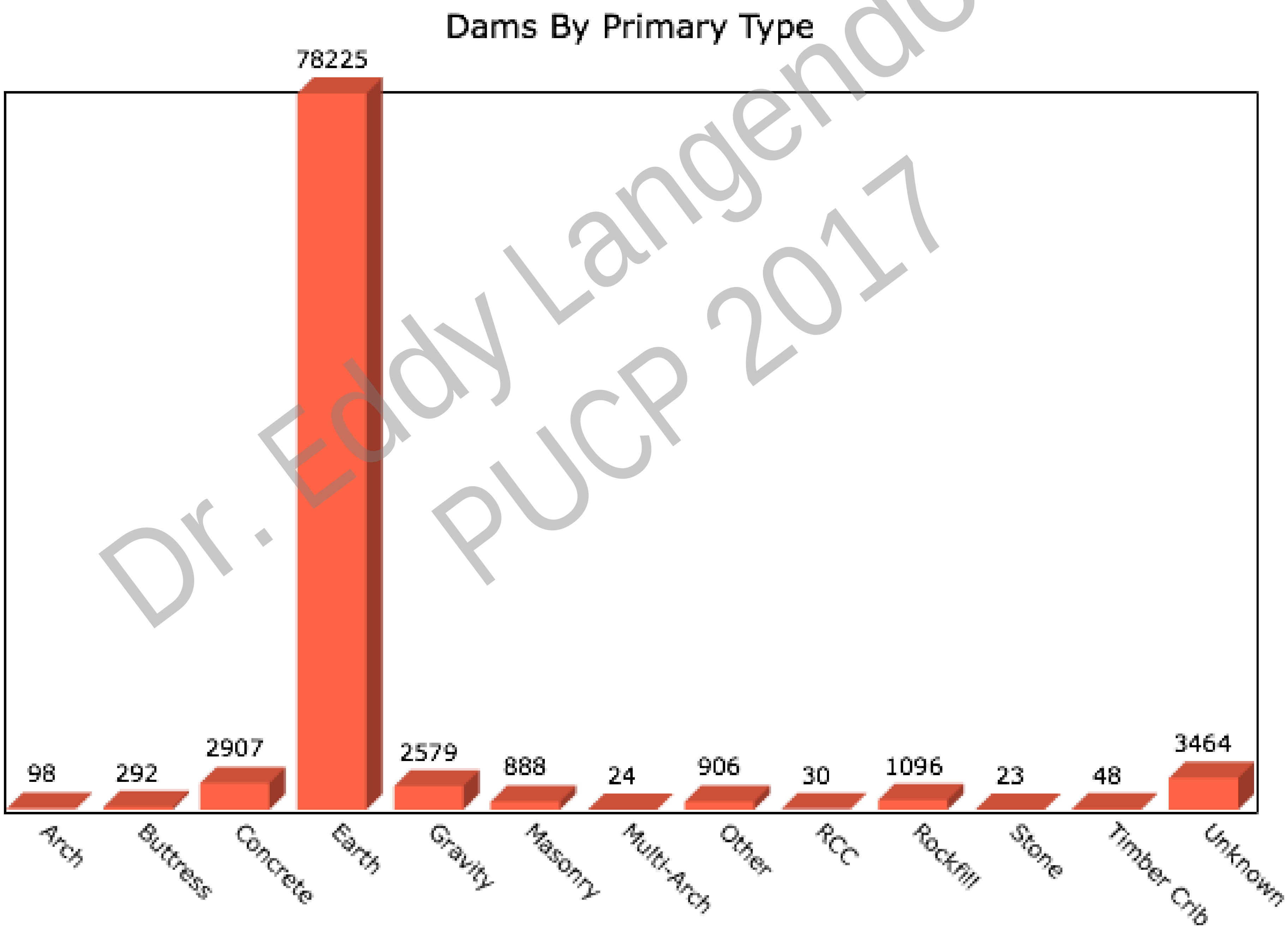

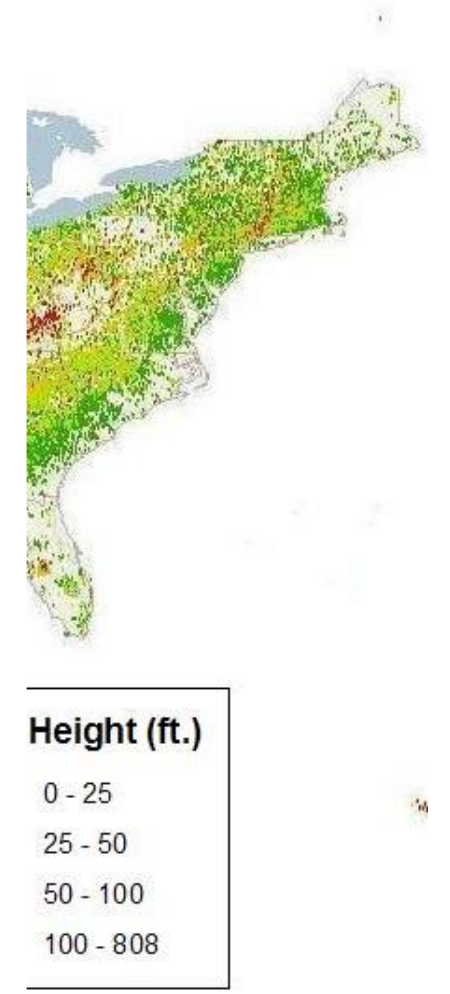

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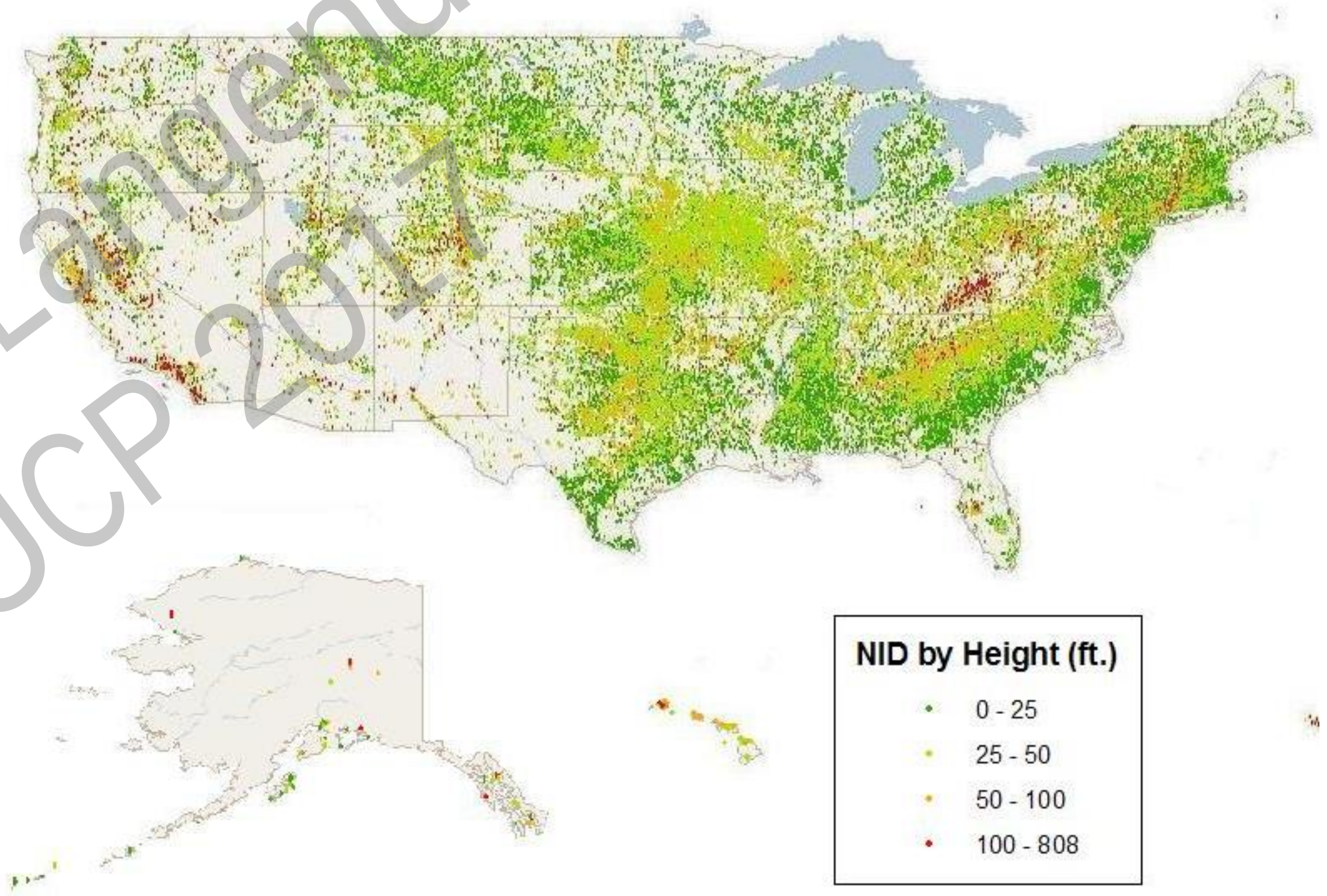
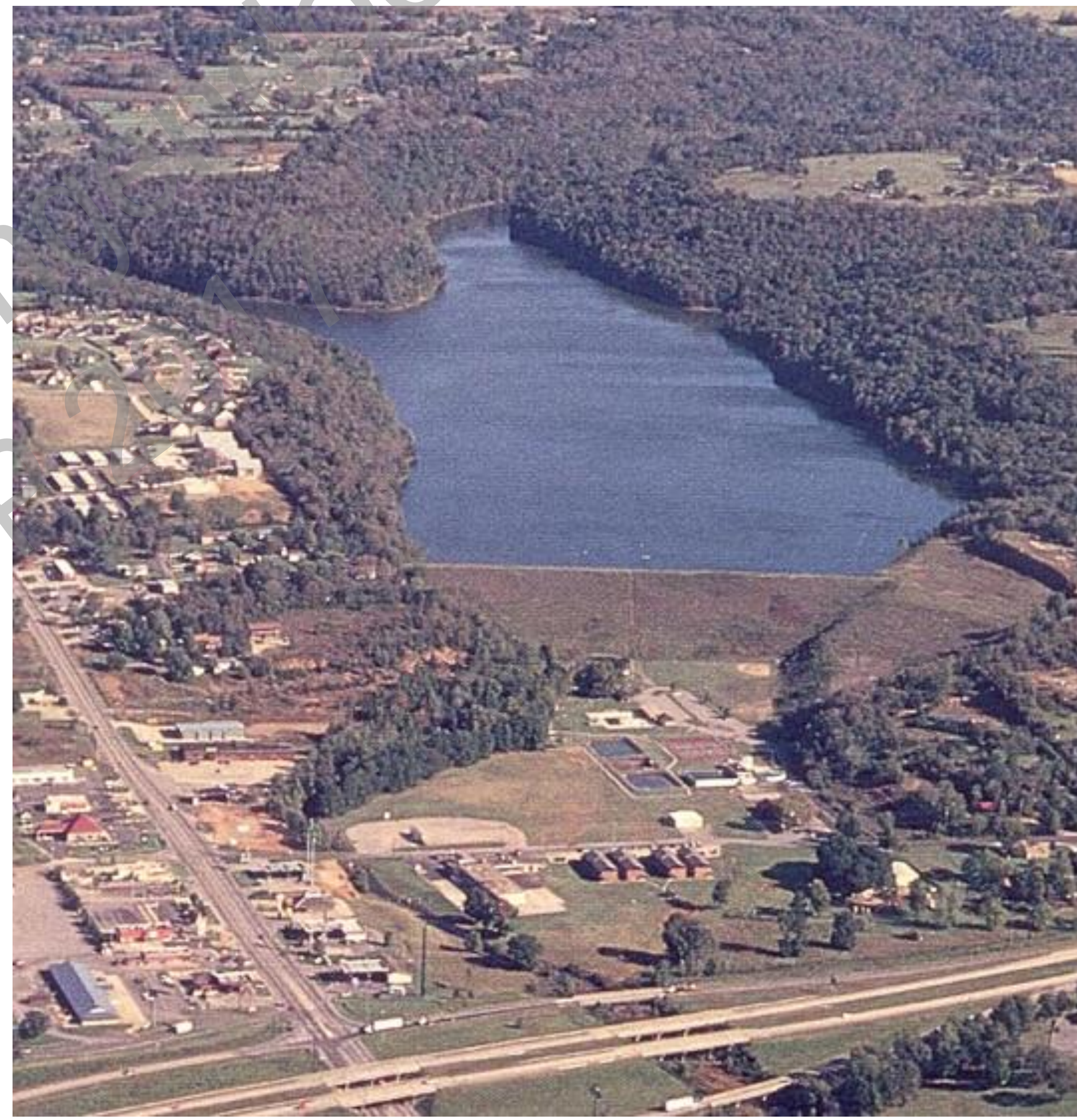


Dams and Reservoirs

- Earthen embankments have 50-yr (before 1960) or 100-yr design life (after 1960)
- U.S. Department of Agriculture dams
  - $14 billion infrastructure with $1 billion in benefits (1997 dollars)
  - ~2000 at end of design life
  - yr 2000 rehabilitation estimates > $550 million



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Dams and Reservoirs – Critical Issues

- Remaining storage capacity
- Hazard reclassification
- Increased environmental awareness
- Embankment integrity

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Oroville Dam, California

United States Department of Agriculture

Oroville Dam, California

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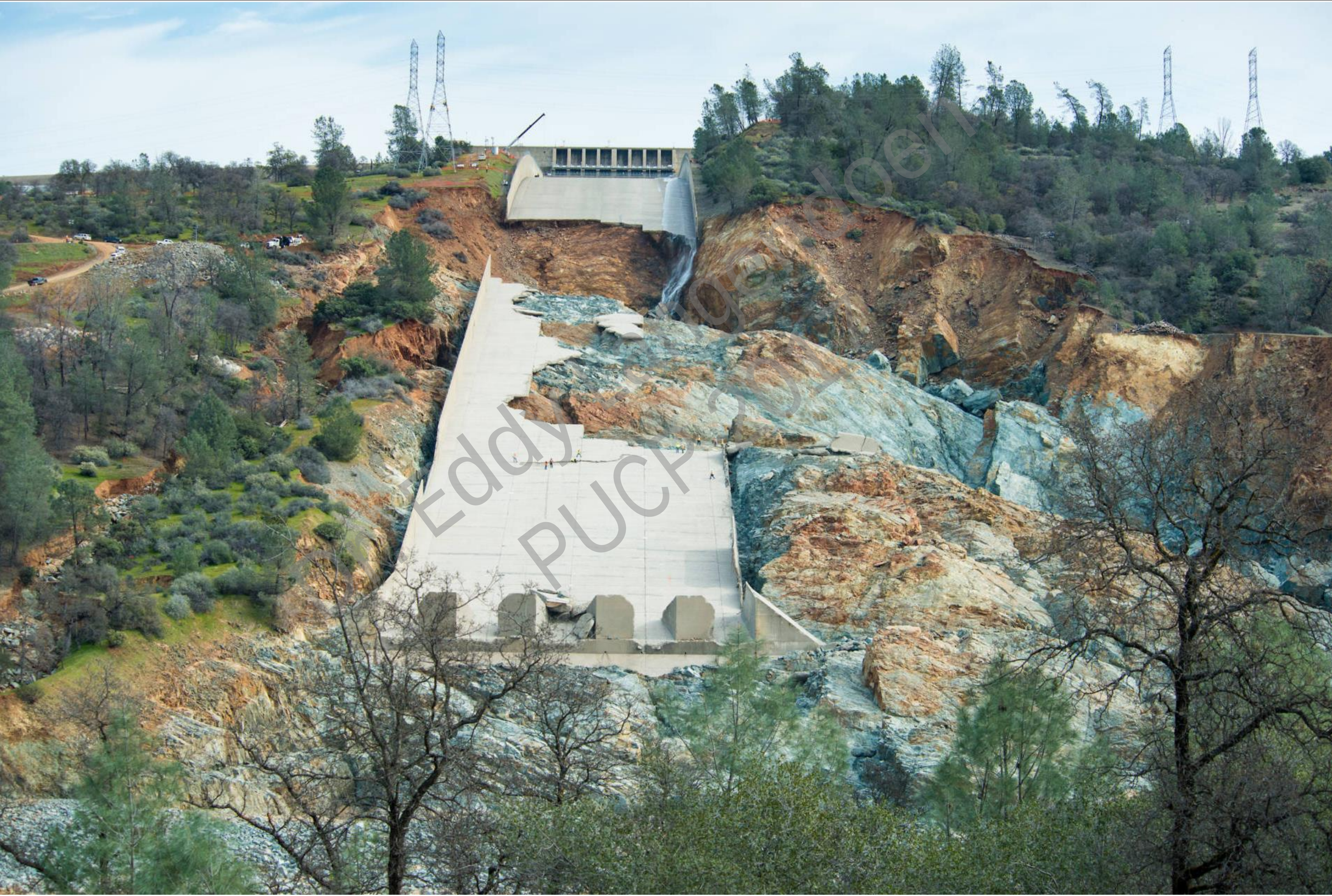

Embankments Incl. Levees

Flood Control Reservoir Sedimentation Rates

- Extensively surveyed between 1950 and 1970 by ARS, National Sedimentation Laboratory under the auspices of Subcommittee on Sedimentation
- These data are the foundation of the RESSED database (https://water.usgs.gov/osw/ressed/) and its successor RSI (U.S. Army Corps of Engineers)

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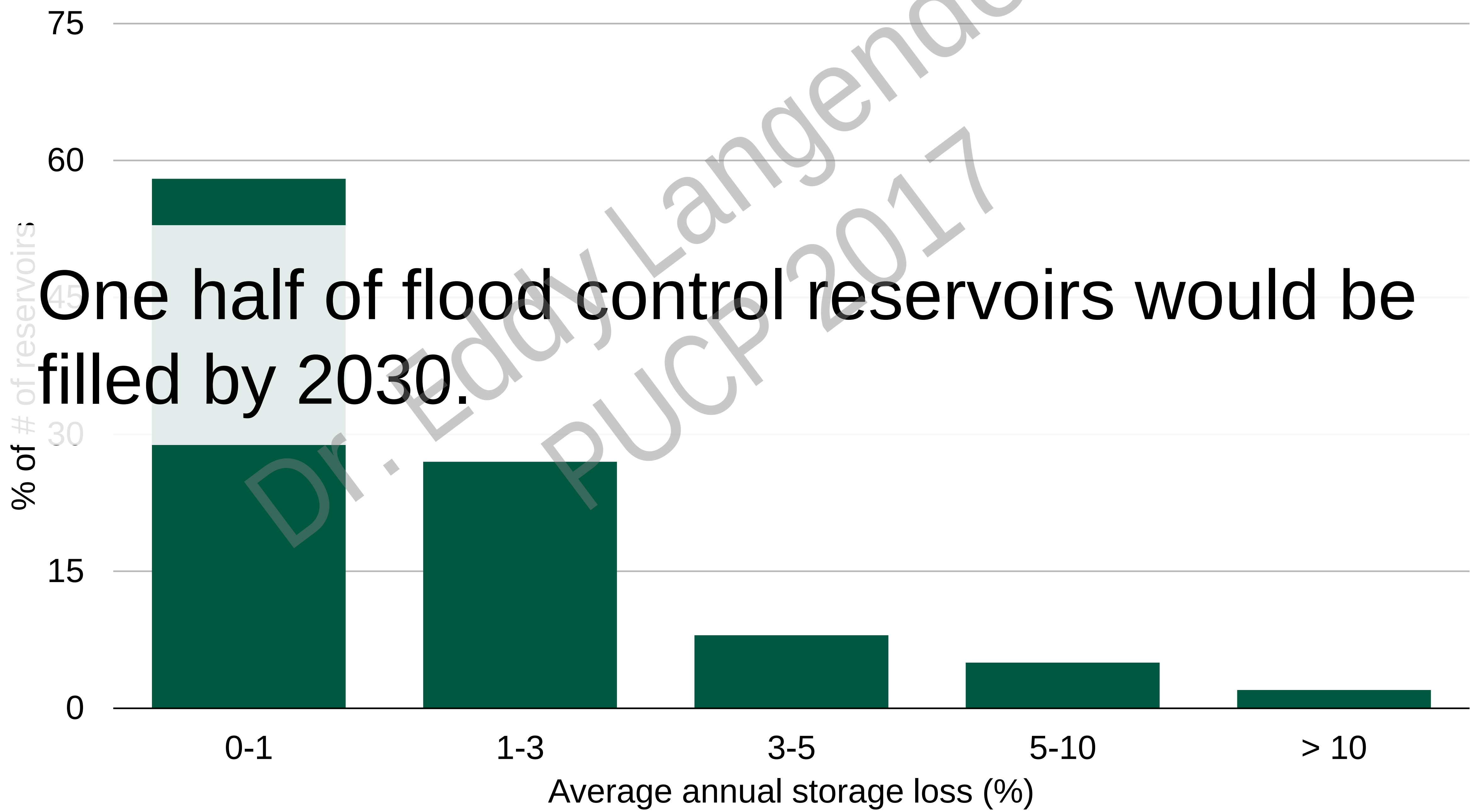
Reservoir Storage Depletion Rates

Reservoir capacity (acre-ft)	# of reservoirs	Annual depletion rate (%)		Mean depletion in 1967 (%)
		Mean	Median	
0 - 10	161	3.41	2.20	25.0
10 - 100	228	3.17	1.32	21.2
100 - 1000	251	1.02	0.61	17.2
1000 - 10000	155	0.78	0.50	11.0
10000 - 100000	99	0.45	0.26	9.92
100000 - 1000000	56	0.26	0.13	3.72
> 1000000	18	0.16	0.10	3.35
Total	968	1.77	0.72	16.7

1 acre-ft = 1233.5 m^3

From Dendy et al. (1967)

Reservoir Storage Depletion Rates



One half of flood control reservoirs would be filled by 2030.

From Dendy et al. (1967)

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THAT WAS 40 YEARS AGO. WHAT ABOUT NOW?

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Reservoir Storage Depletion Rates Studies

- No system-wide studies since the 1970s
- Some small studies funded by NRCS in early 2000s in Mississippi, Texas, Oklahoma, and Wisconsin (Baylor University and National Sedimentation Laboratory)
- State of Kansas a more systemwide study in 2011
- USBR and USACE are increasing their efforts to more frequently survey their reservoirs

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Dams & Reservoirs - Summary

- Embankment integrity
  - Dam strengthening
  - Dam removal
- Reservoir storage depletion
  - Dam removal
  - Sustainable reservoir sediment management

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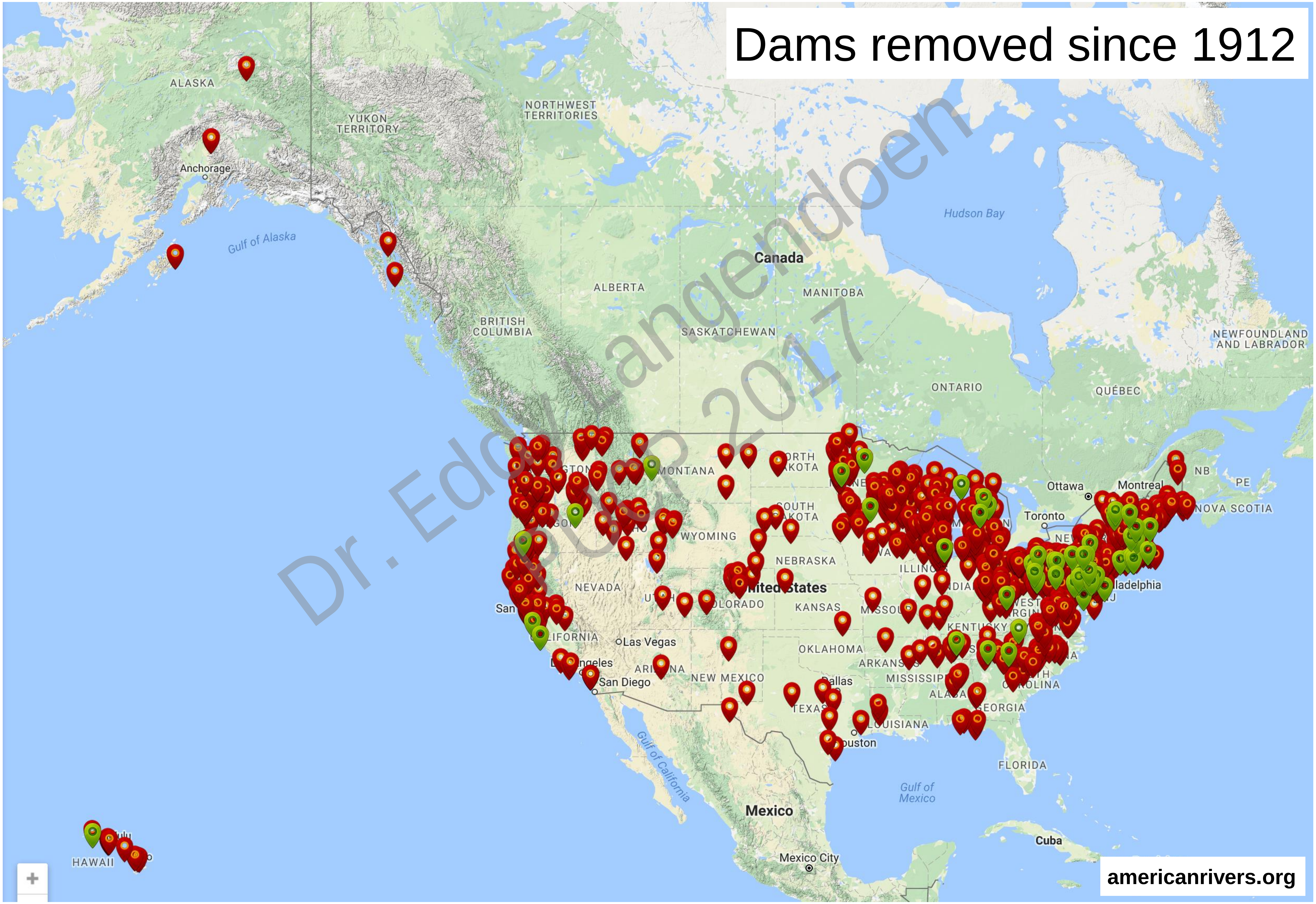
Dams removed since 1912



americanrivers.org

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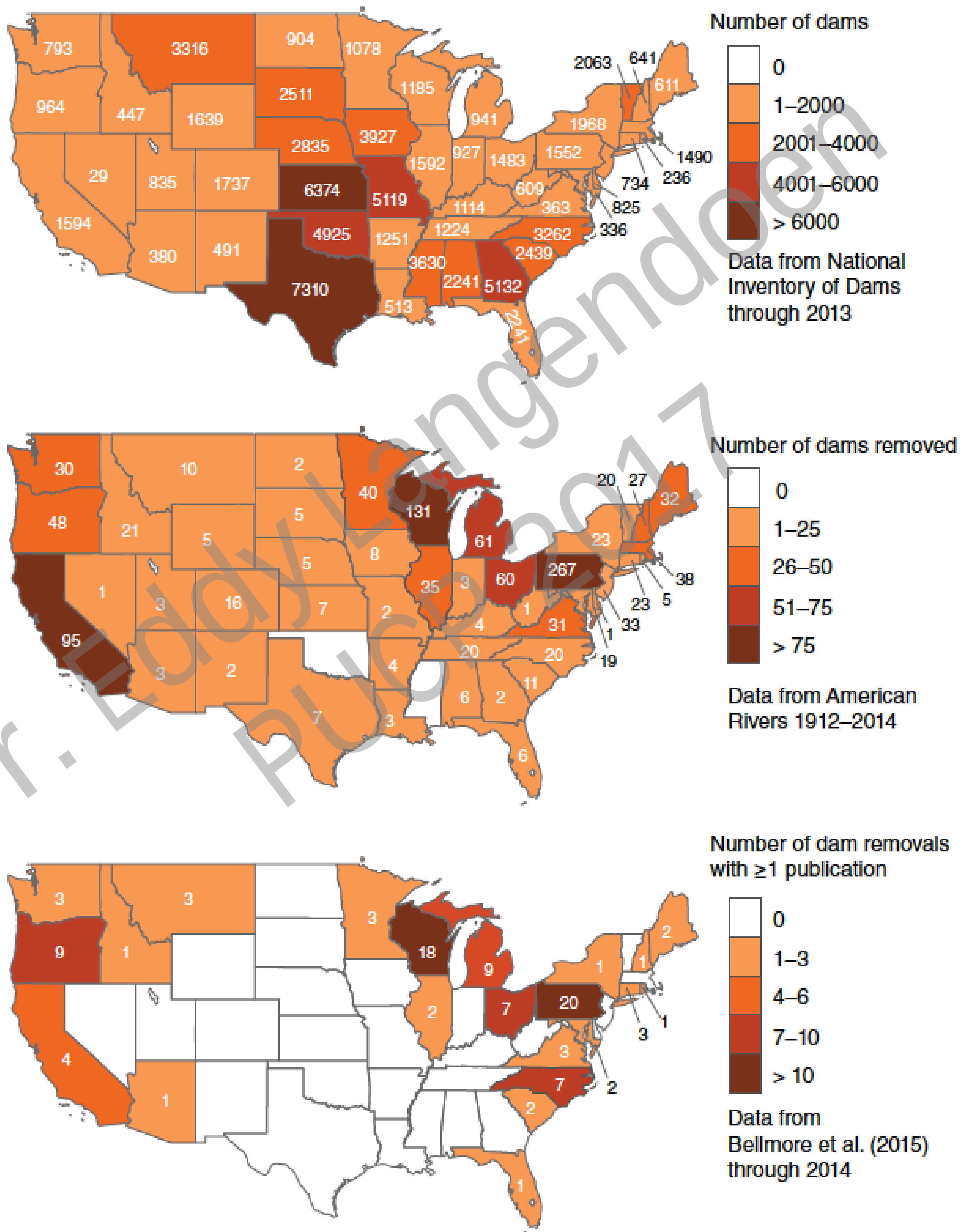

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Brewster Creek, Illinois

(a) Stream-channel evolution as of November 4, 2003

(b) After Notch 4 – November 20, 2003

(c) Stream-channel evolution as of December 29, 2003

(d) 2 weeks after Notch 5 – March 5, 2004

(e) Stream-channel evolution as of March 8, 2004

(f) Stream-channel evolution as of March 30, 2004

From Straub (2007), PhD Thesis, Colorado State University

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Evacuation of Reservoir Sediment?

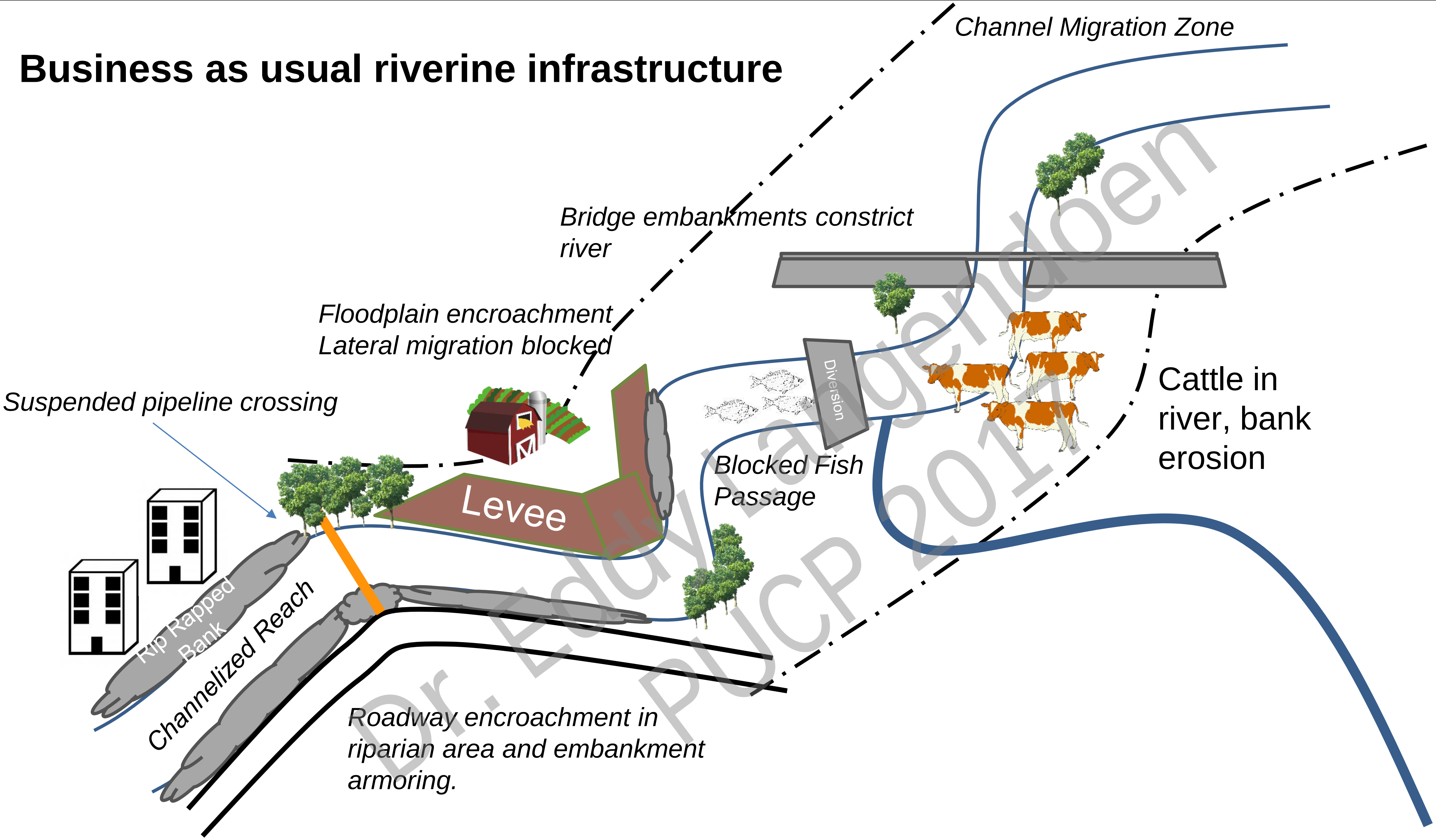
Lateral adjustment >> Vertical adjustment

&

Significant planform adjustment

Infrastructure and Stream Environment

Business as usual riverine infrastructure



Infrastructure Features:
- Bridge
- Diversion Structure
- Levee
- Parallel Roadway with riprap embankment
- Cattle/fencing
- Pipeline crossing

Processes / Habitat Features:
- Riparian Habitat
- Lateral Migration
- Longitudinal connectivity
- Sediment continuity
- Bank bioengineering

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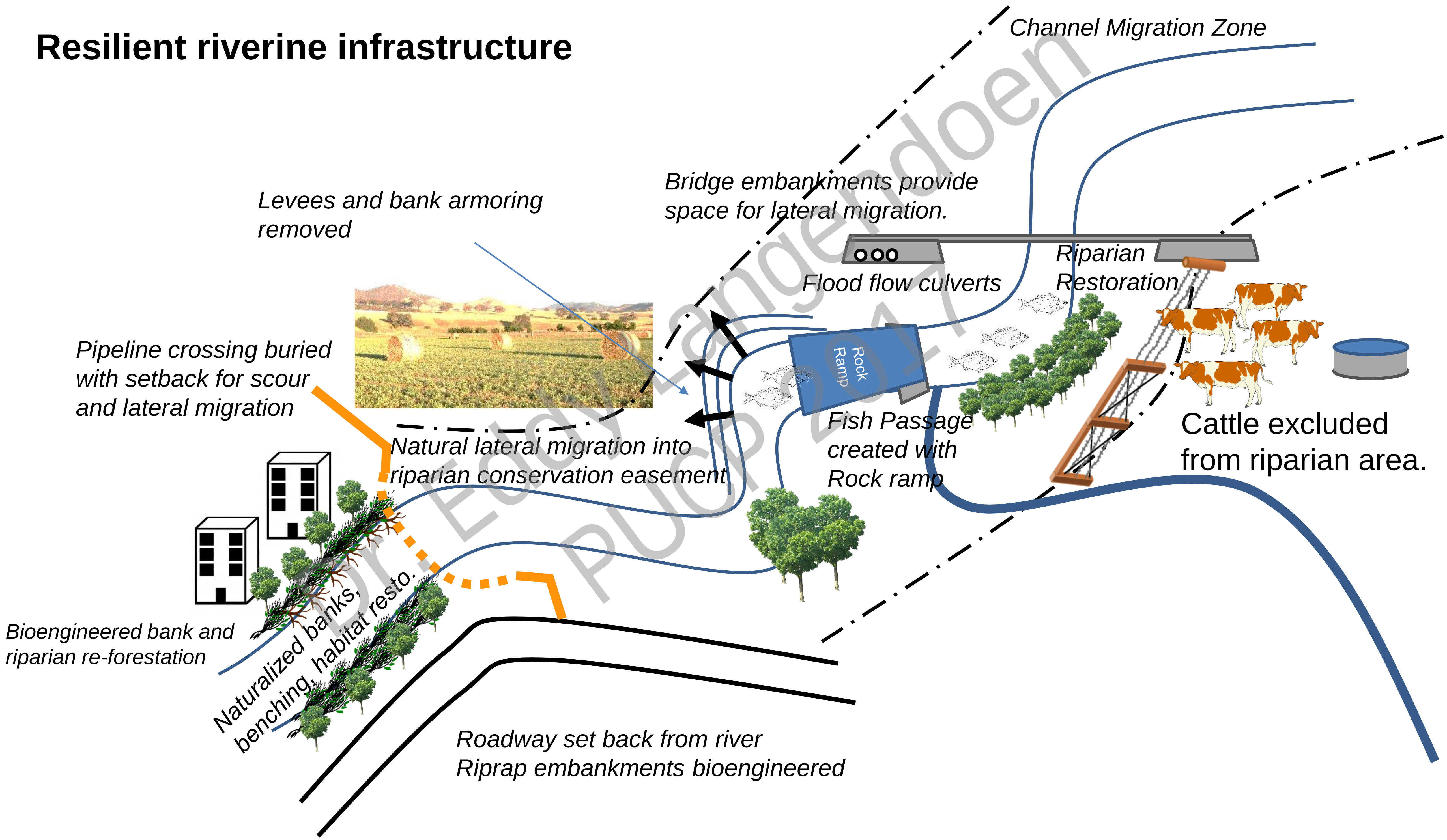
Infrastructure and Stream Environment

Resilient riverine infrastructure



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SOS Product Development

- Dam removal guidelines
- Workshops and FAQ on Reservoir Sedimentation and Sustainability
- White, briefing, & guidance papers
  - Infrastructure and the stream environment
  - Impact of climate change and extreme events on sediment delivery and landscape geomorphology
- Databases:
  - Reservoir sedimentation
  - Stream morphology data exchange

RECLAMATION
Managing Water in the West

DRAFT

Dam Removal Analysis Guidelines for Sediment - Version 3

Prepared for Subcommittee on Sedimentation
Federal Advisory Committee on Water Information

U.S. Department of the Interior
Bureau of Reclamation

February 2017

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U.S. Government 1D/2D/3D Sediment Transport Models*

- U.S. Army Corps of Engineers
  - HEC-RAS (1D/2D): http://www.hec.usace.army.mil/software/hec-ras/
  - ADH (2D/3D): https://chl.erdc.dren.mil/adh/main/index.html
- U.S. Bureau of Reclamation
  - SRH-1D (1D): https://www.usbr.gov/tsc/techreferences/computer%20software/models/srh1d/index.html
  - SRH-2D (2D): https://www.usbr.gov/tsc/techreferences/computer%20software/models/srh2d/index.html
  - U^2RANS (3D): https://www.usbr.gov/tsc/techreferences/computer%20software/models/u2rans/index.html
- U.S. Department of Agriculture
  - CONCEPTS (1D): https://drive.google.com/open?id=0B1sIOPn4amxWNFFUb2N5ZE9QTUk

* **Limited to physically- and process-based models only.**

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- U.S. Army Corps of Engineers
  - **HEC-RAS (1D/2D):** **http://www.hec.usace.army.mil/software/hec-ras/**
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- U.S. Bureau of Reclamation
  - SRH-1D (1D): https://www.usbr.gov/tsc/techreferences/computer%20software/models/srh1d/index.html
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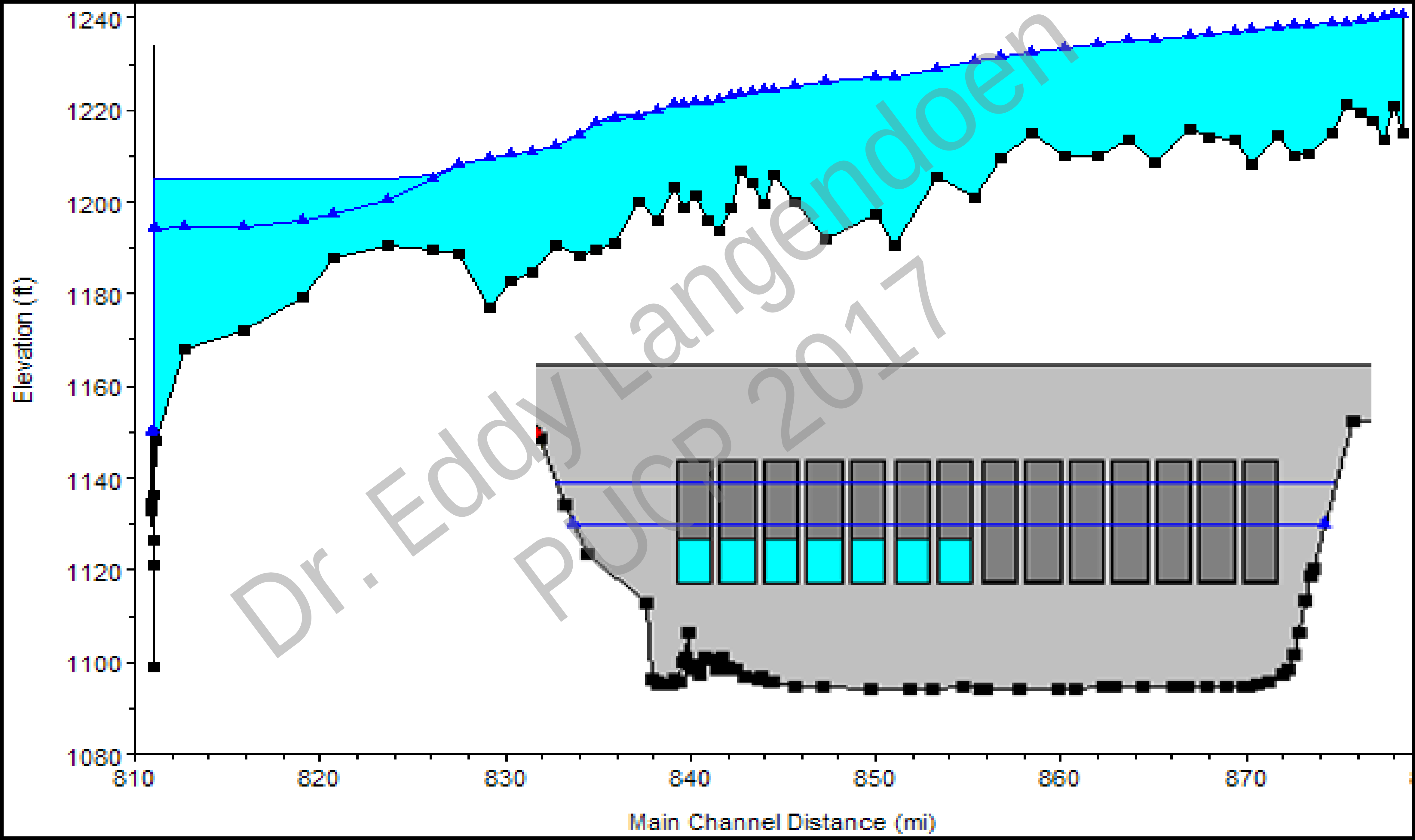
HEC-RAS v5 New Features

- Hydraulics
  - Two-dimensional and combined 1D/2D unsteady flow modeling
  - Mixed flow
  - Dam/levee breach analysis
- Sediment transport
  - Unsteady sediment transport
  - Reservoir sluicing and flushing (sustainable reservoir sediment management)
  - Bank erosion
- RAS Mapper

Advanced Reservoir Modeling and Unsteady Sediment Analysis with HEC-RAS



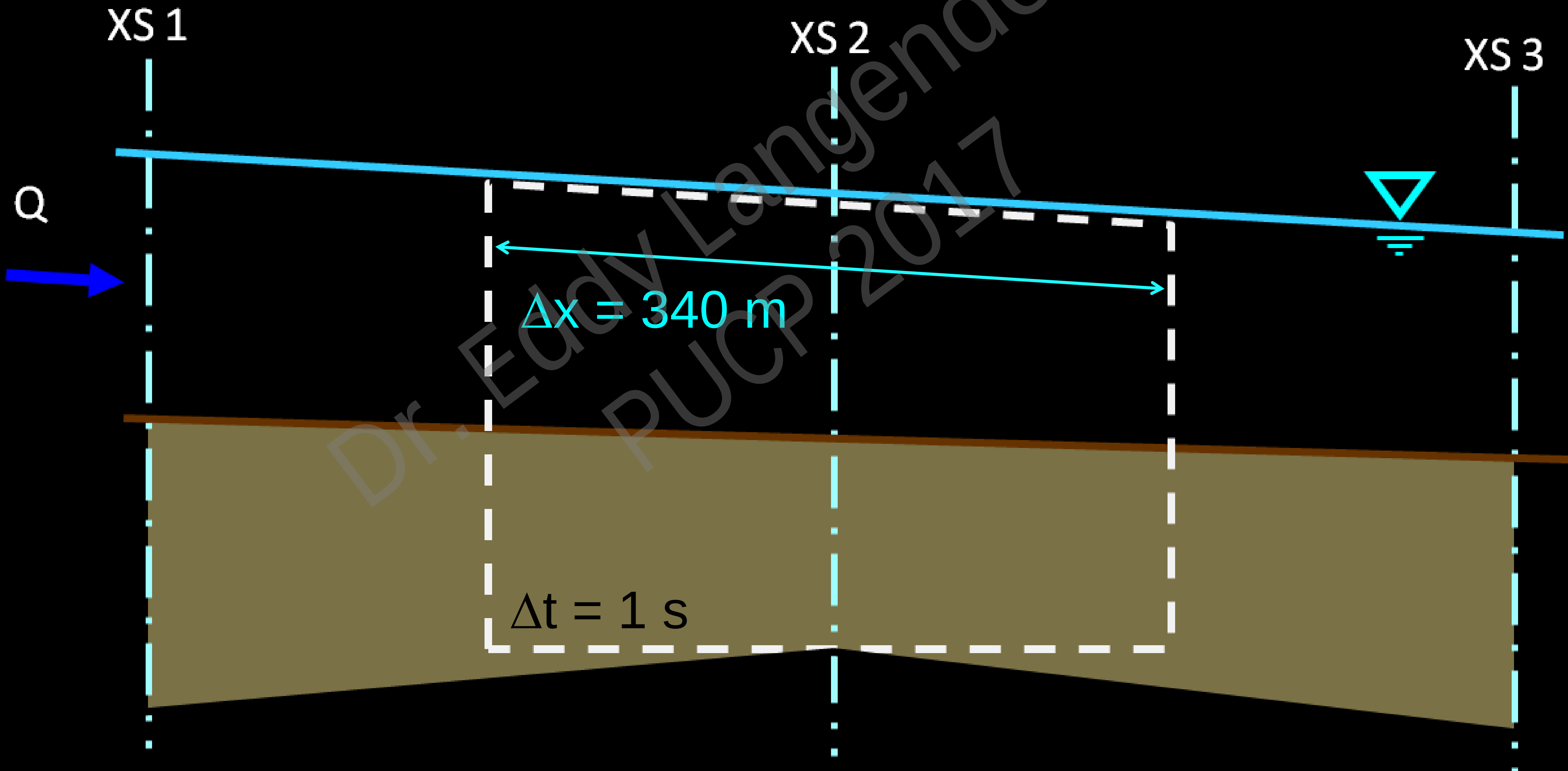
- Stanford Gibson, Phd
- Hydrologic Engineering Center, USACE

Advanced Reservoir Modeling and Unsteady Sediment Analysis with HEC-RAS

1. Principles of Reservoir Sedimentation
2. New Features for Reservoir Sediment Modeling
3. Limitations of the Quasi-Unsteady Assumption for Reservoir Sediment Analysis
4. Unsteady Sediment Transport Analysis

1. Continuity (Exner) Equation

$$V_{\text{sed}} = \frac{\Delta x}{\Delta t}$$



Temporal Deposition Limiter

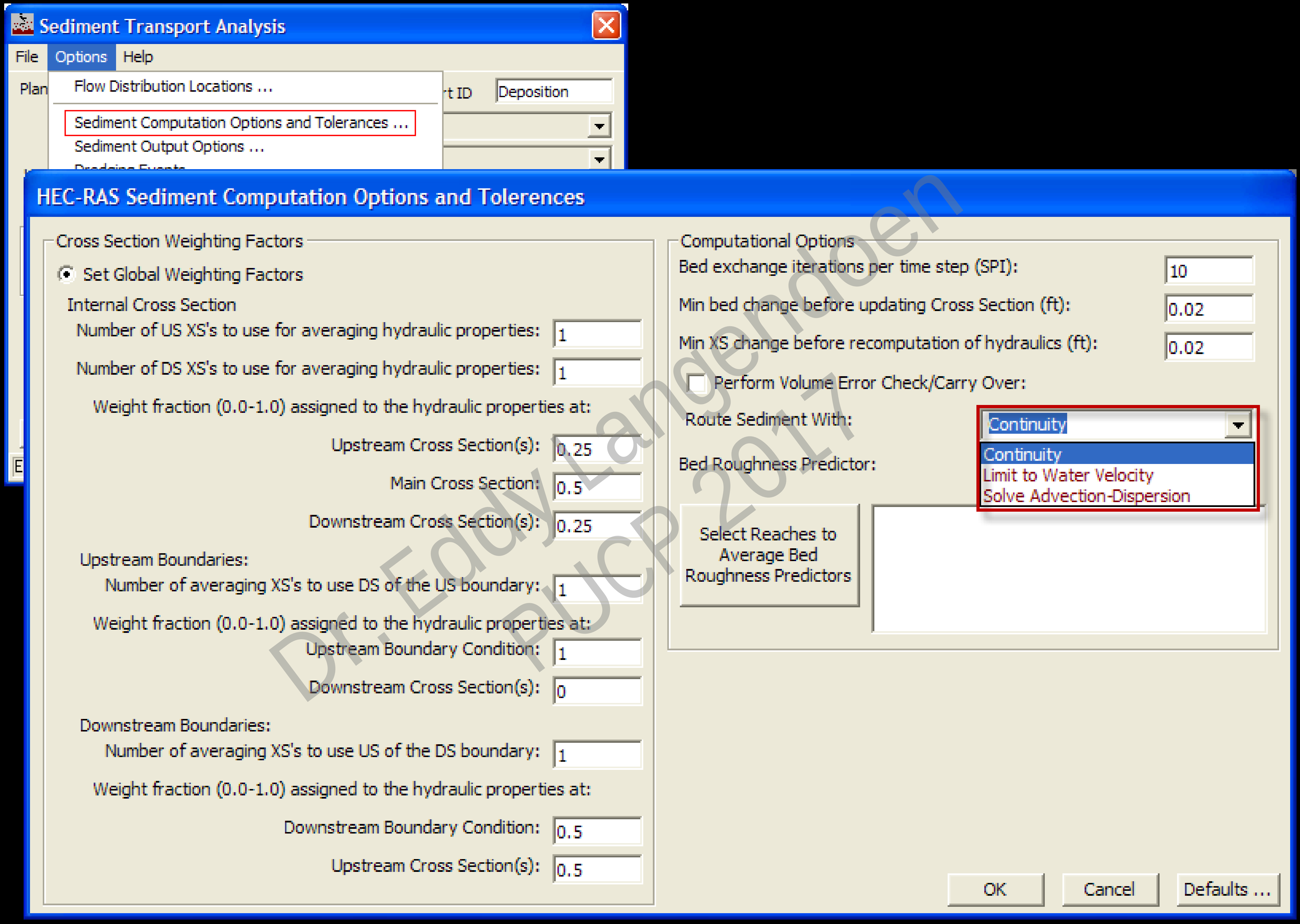
Deposition efficiency coefficient = $\dfrac{\omega_{s,i}\Delta t}{H_{e,i}}$

In a reservoir H_e is large

Therefore $H_e \gg \omega_s \Delta t$ if Δt is small

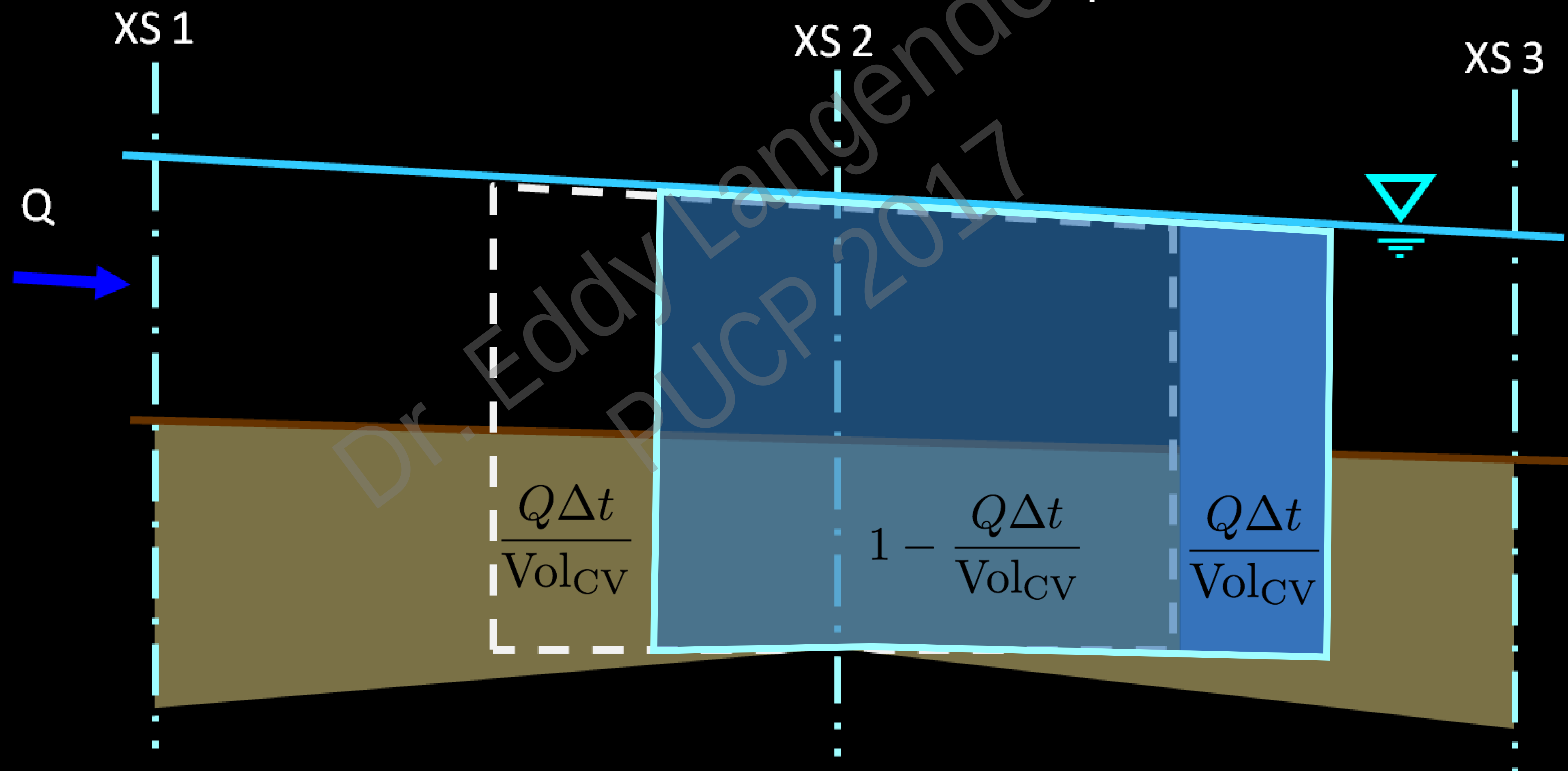
This will make the deposition efficiency coefficient very small for small time steps

If Δt does not reflect the travel time of the sediment, tying fall velocity to the time step rather than a residence time will over or under predict deposition.


Sediment Transport Analysis
File Options Help
Plan
Flow Distribution Locations ...
Sediment Computation Options and Tolerances ...
Sediment Output Options ...
rt ID
Deposition
HEC-RAS Sediment Computation Options and Tolerences
Cross Section Weighting Factors
Set Global Weighting Factors
Internal Cross Section
Number of US XS's to use for averaging hydraulic properties: 1
Number of DS XS's to use for averaging hydraulic properties: 1
Weight fraction (0.0-1.0) assigned to the hydraulic properties at:
Upstream Cross Section(s): 0.25
Main Cross Section: 0.5
Downstream Cross Section(s): 0.25
Upstream Boundaries:
Number of averaging XS's to use DS of the US boundary: 1
Weight fraction (0.0-1.0) assigned to the hydraulic properties at:
Upstream Boundary Condition: 1
Downstream Cross Section(s): 0
Downstream Boundaries:
Number of averaging XS's to use US of the DS boundary: 1
Weight fraction (0.0-1.0) assigned to the hydraulic properties at:
Downstream Boundary Condition: 0.5
Upstream Cross Section(s): 0.5
Computational Options
Bed exchange iterations per time step (SPI): 10
Min bed change before updating Cross Section (ft): 0.02
Min XS change before recomputation of hydraulics (ft): 0.02
Perform Volume Error Check/Carry Over:
Route Sediment With: Continuity
Continuity
Limit to Water Velocity
Solve Advection-Dispersion
Bed Roughness Predictor:
Select Reaches to Average Bed Roughness Predictors
OK
Cancel
Defaults ...
Dr. Eddy Langendoen
PUCP 2017

- $Vel_{sediment} = Vel_{water}$
- Limits sediment velocity to water velocity
- Increases residence time and deposition

$$\text{retention ratio} = 1 - \frac{Q\Delta t}{\mathrm{Vol}_{\mathrm{CV}}}$$



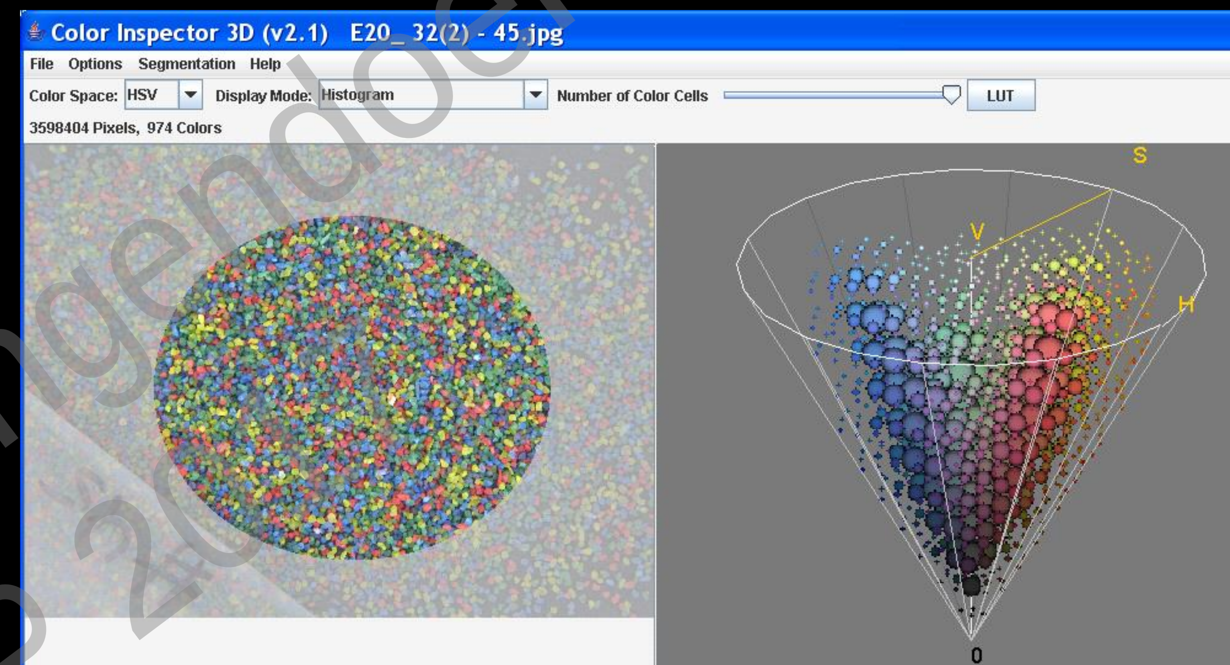
3. Advection Dispersion

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2} - \frac{\partial uC}{\partial x}$$

-Tracks the movement of sediment longitudinally
-We used the UNET Skyline solver
-Upwind first order for advection (1st derivative)
-Central difference scheme for dispersion (2nd derivative)

3. Advection Dispersion

$$C(X_2,t) = \int_{-\infty}^{\infty} C(X_1,\tau)\frac{\exp\left[\frac{-\{\bar{u}(\bar{t_2}-\bar{t_1}-t+\tau)\}^2}{4K(\bar{t_2}-\bar{t_1})}\right]}{\sqrt{4\pi K(\bar{t_2}-\bar{t_1})}}\bar{u}\,d\tau$$



Expected location of blue pulse based on time of introduction and average bed form celerity.

Actual expected spatial distribution of the blue sediment.

Advanced Reservoir Modeling and Unsteady Sediment Analysis with HEC-RAS

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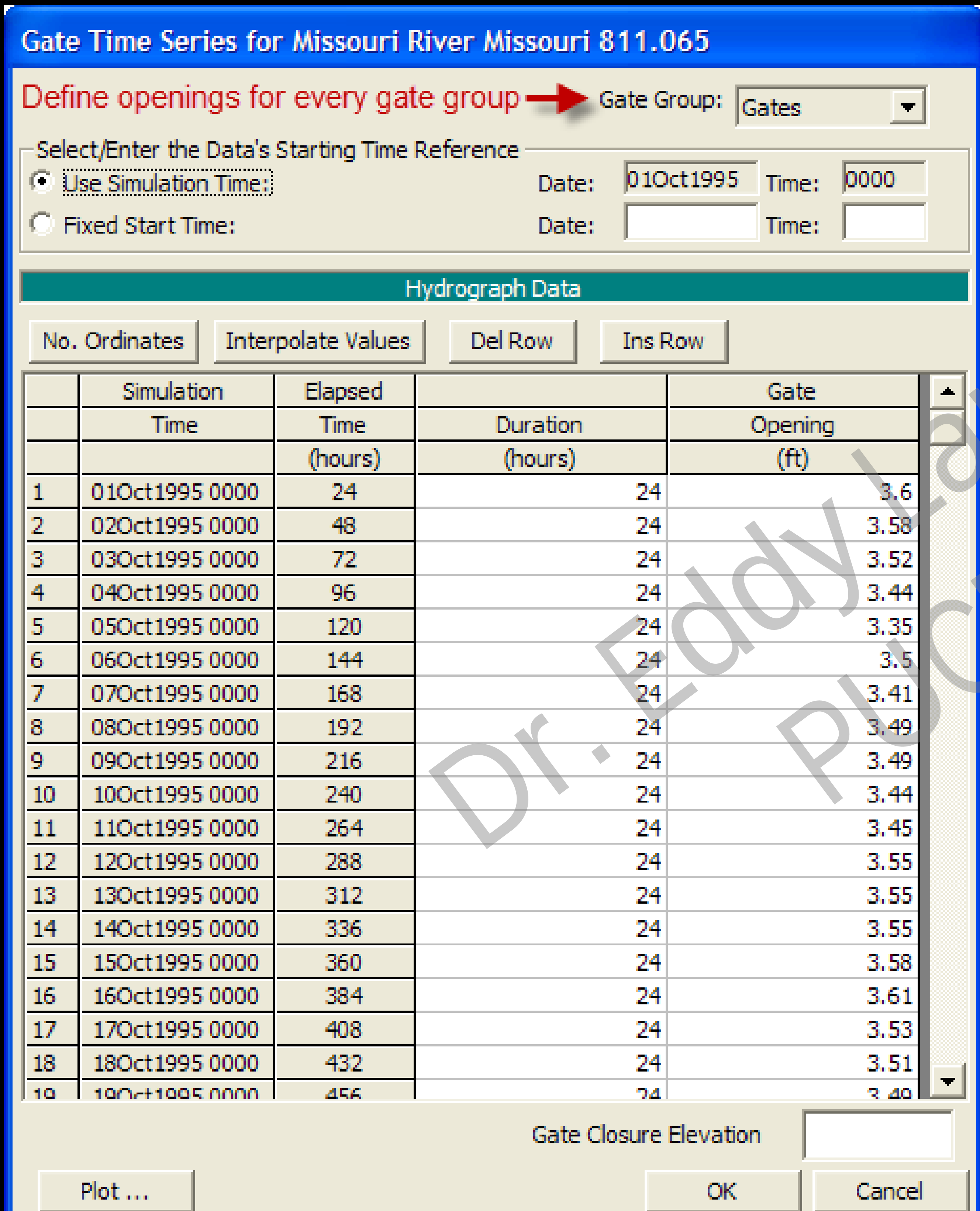
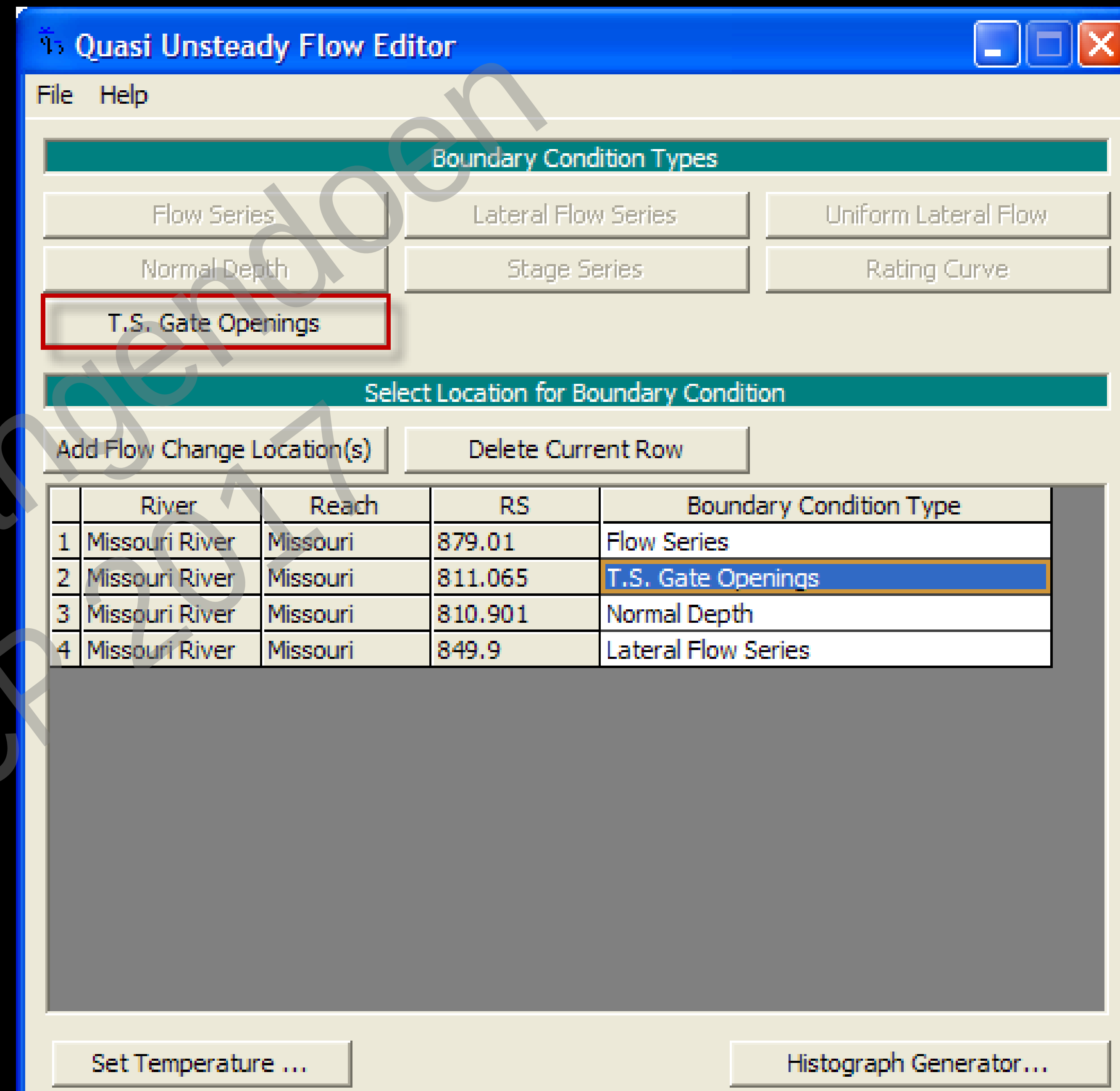
2. New Features for Reservoir Sediment Modeling
3. Quasi-Unsteady Reservoir Analysis and Limitations
4. Unsteady Sediment Transport Analysis

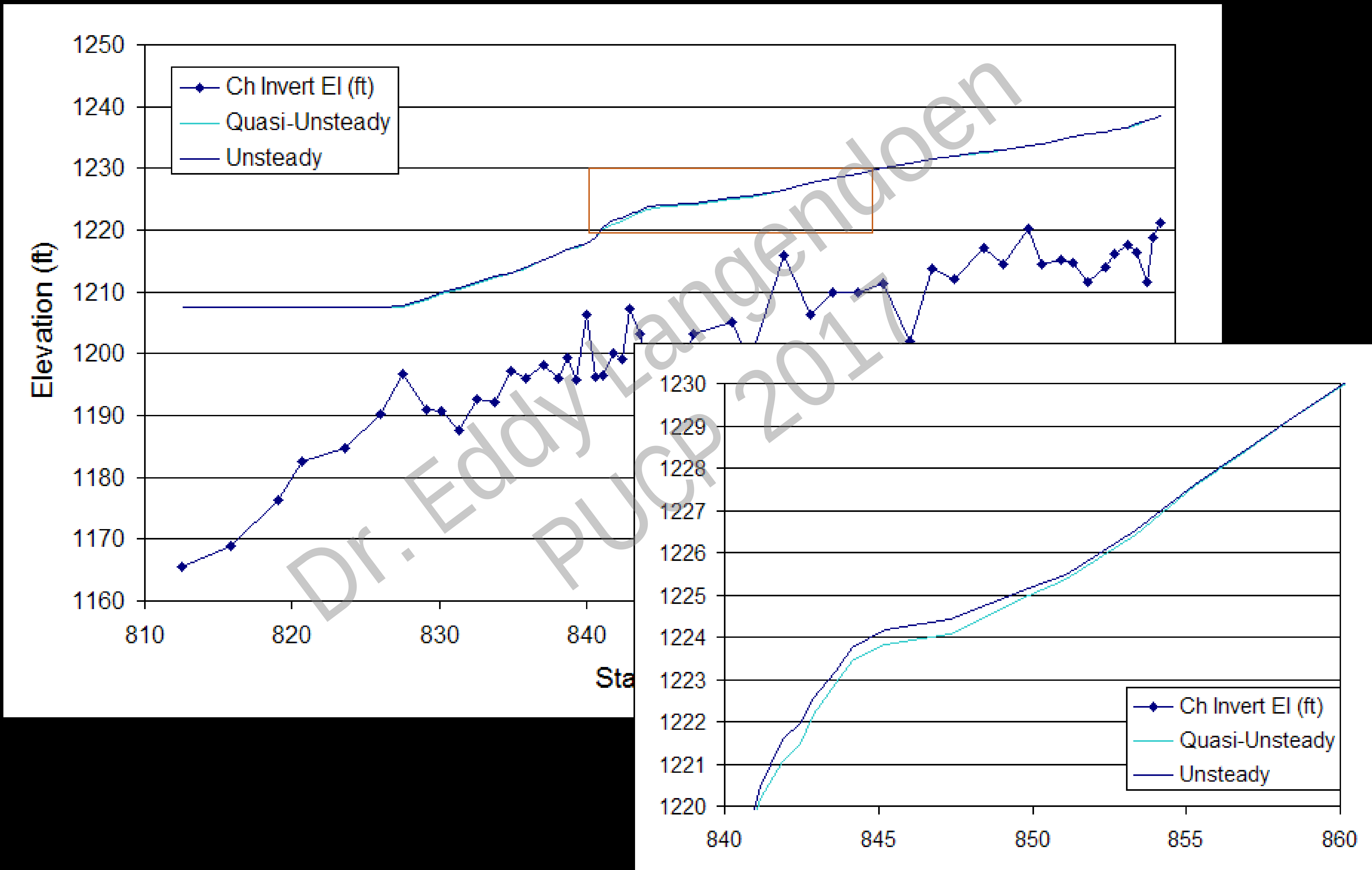
Quasi-Unsteady Gate Operations



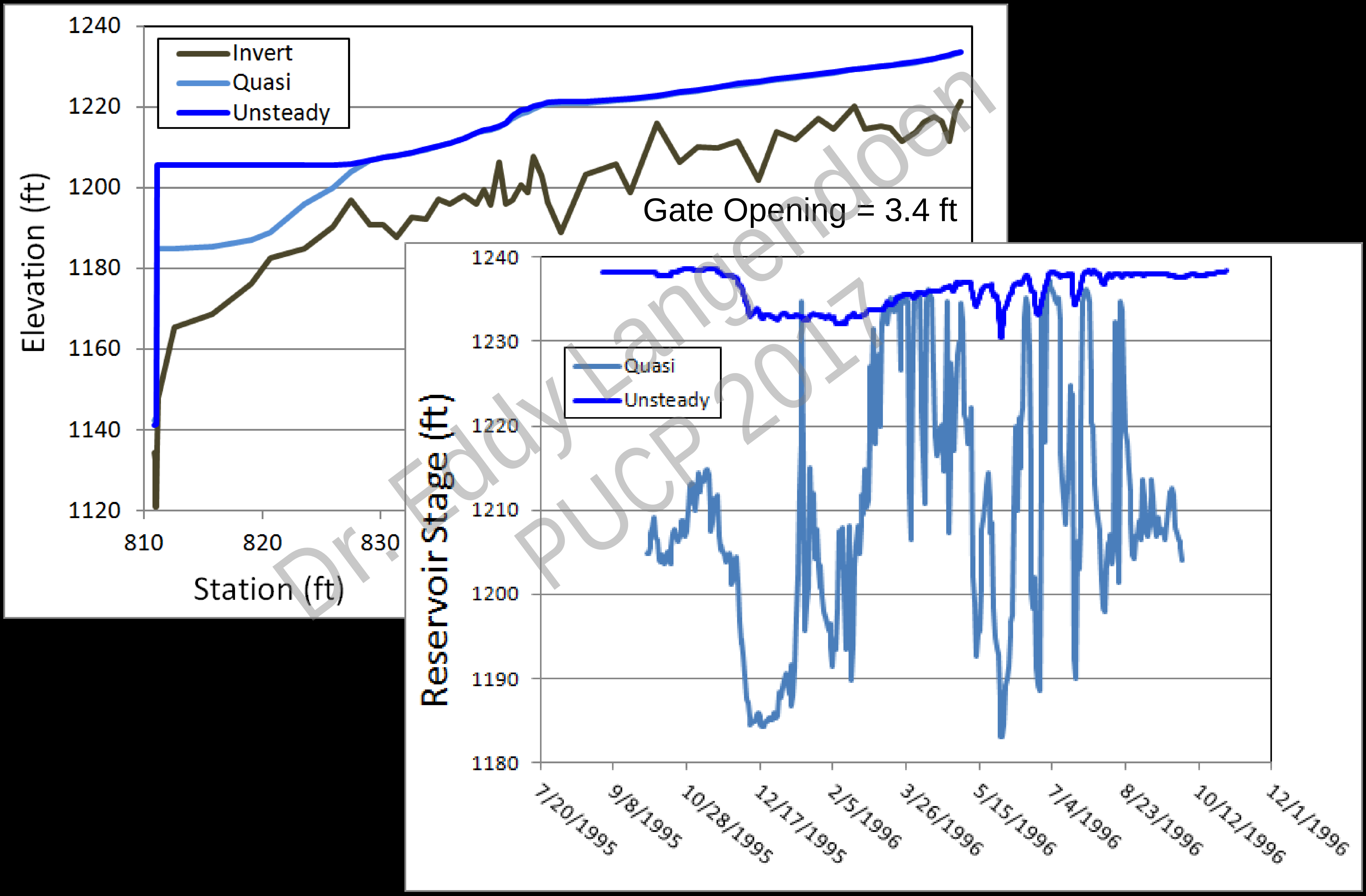


The only gate option in the quasi-unsteady version is the Time Series of Gate Openings.

Unsteady vs Quasi-Unsteady (DS Stage BC)



Unsteady vs Quasi-Unsteady (TS Gate BC)



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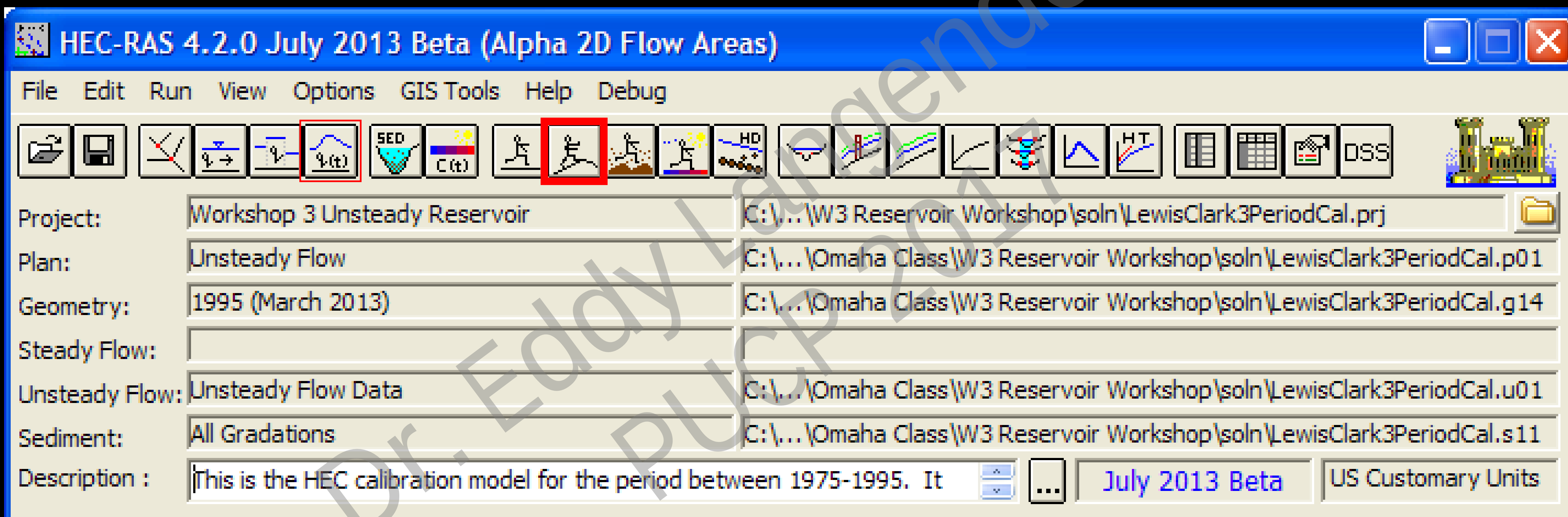
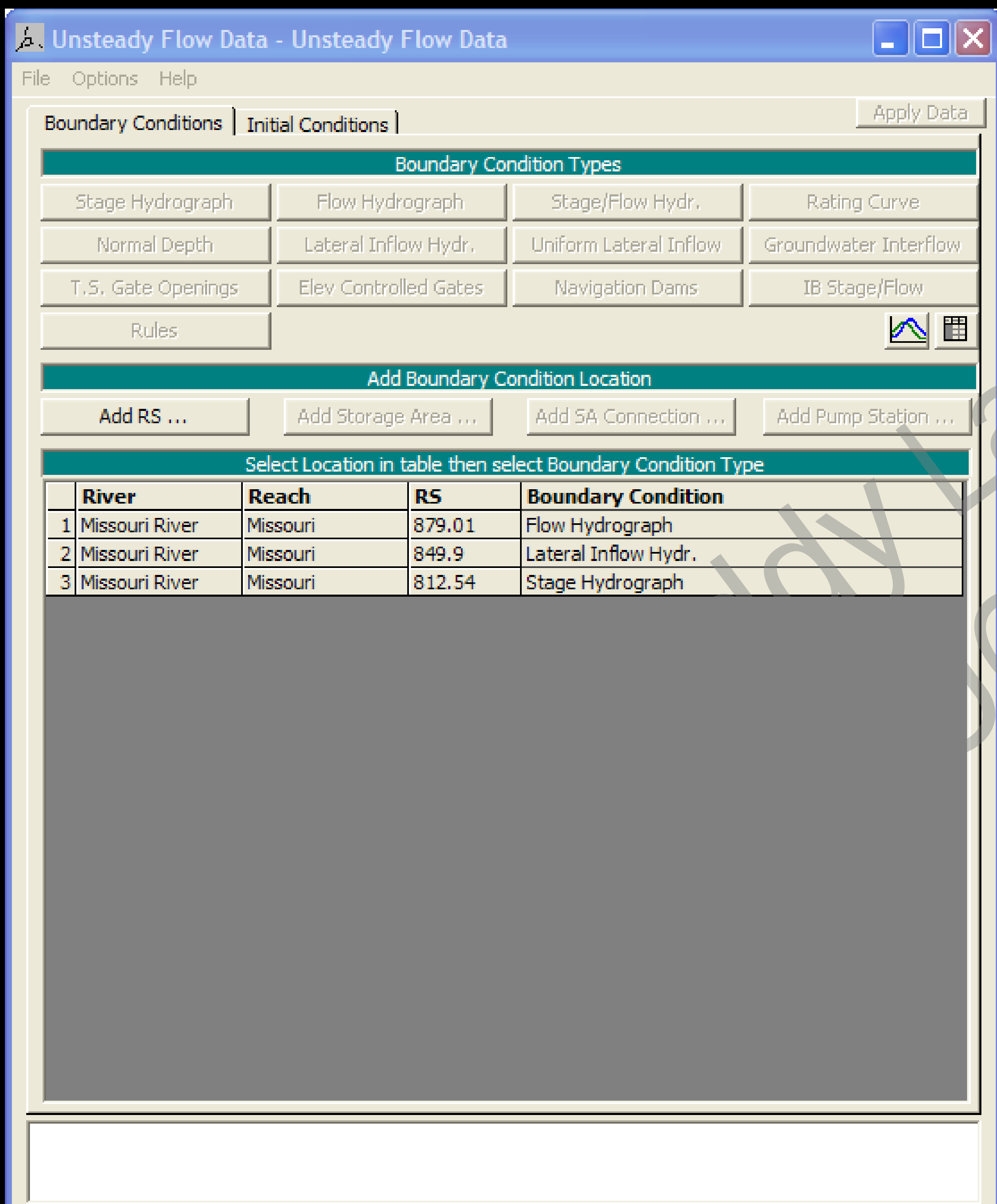
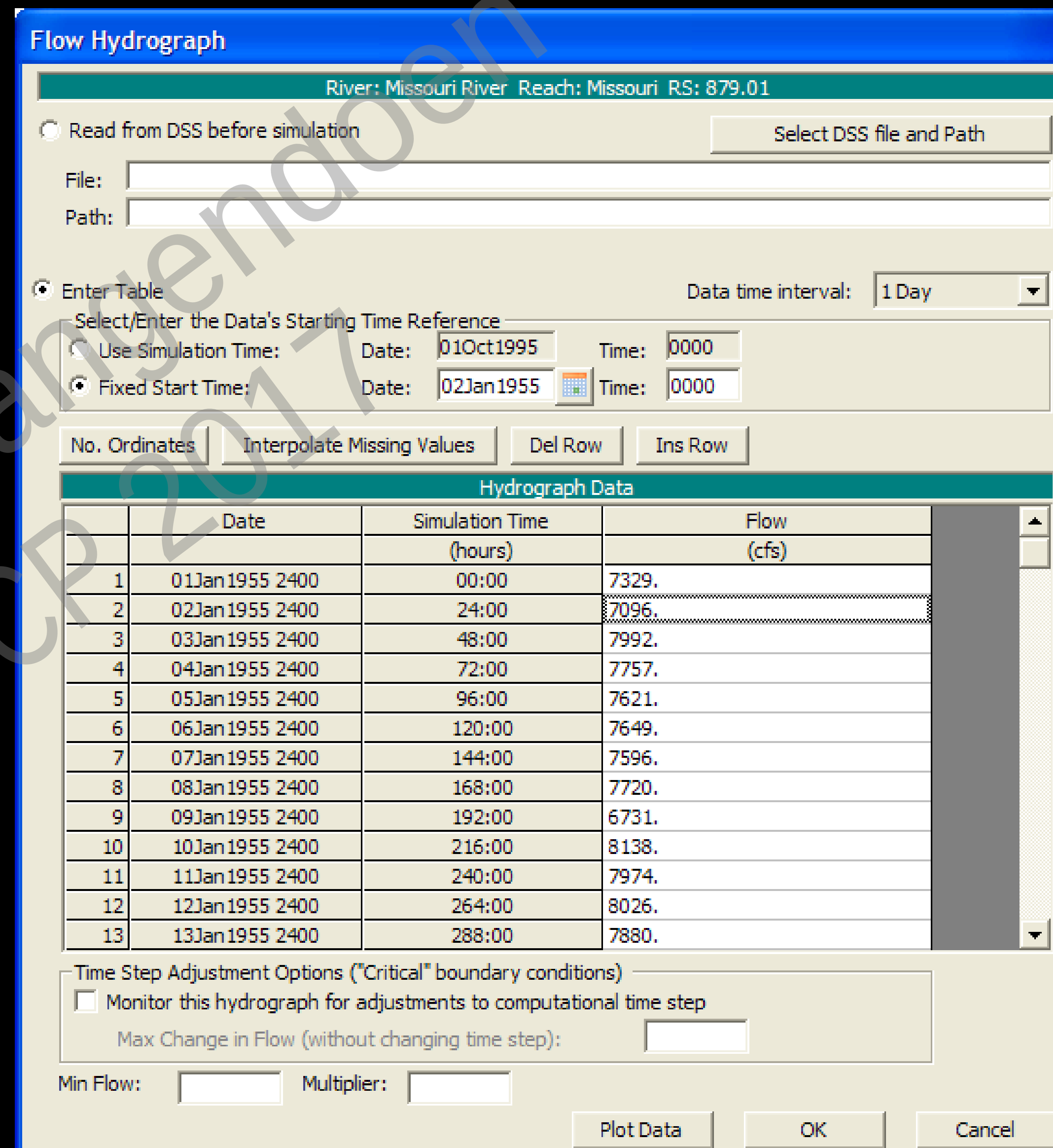
Unsteady Sediment Transport

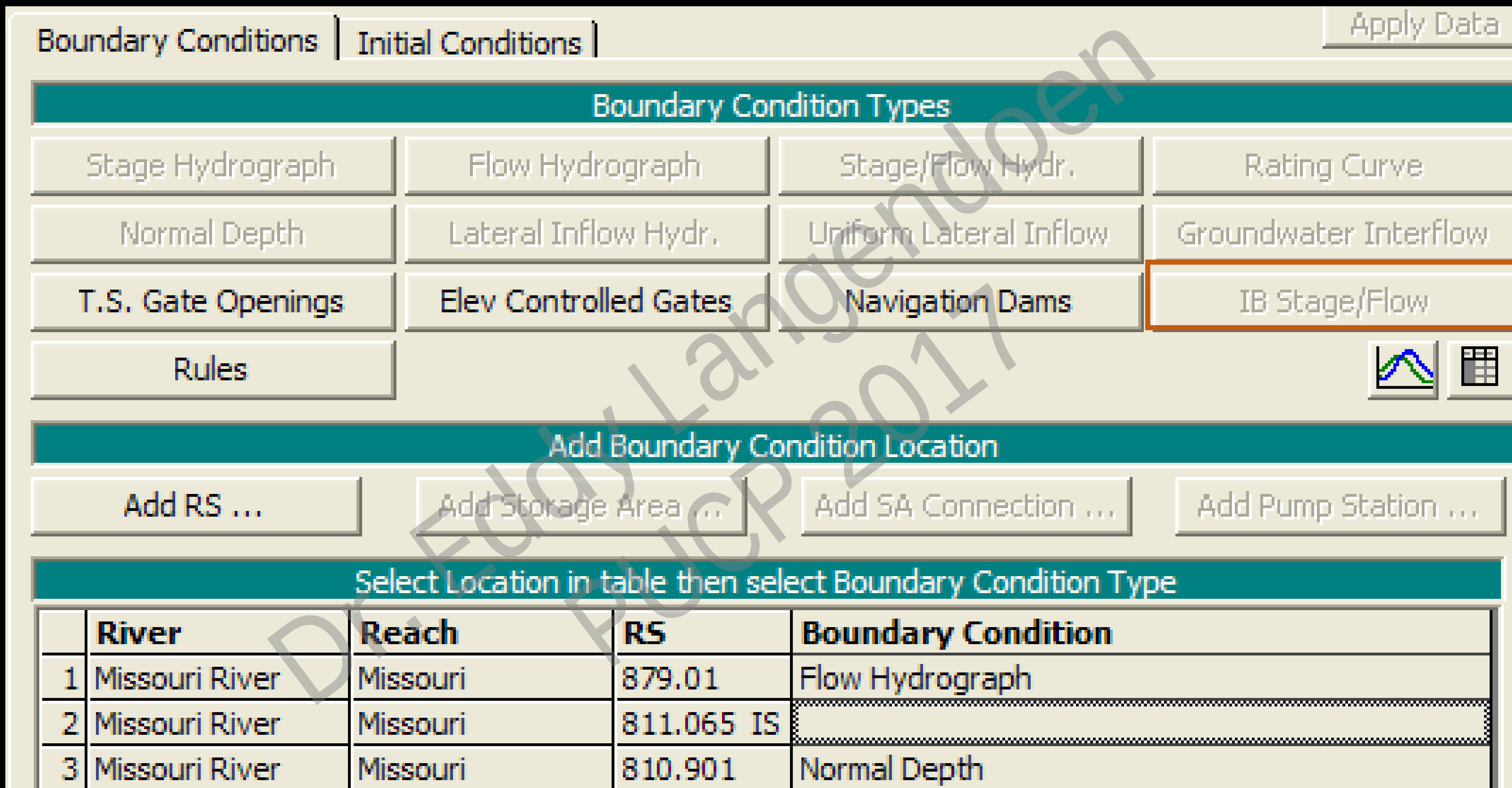


Unsteady Sediment Transport



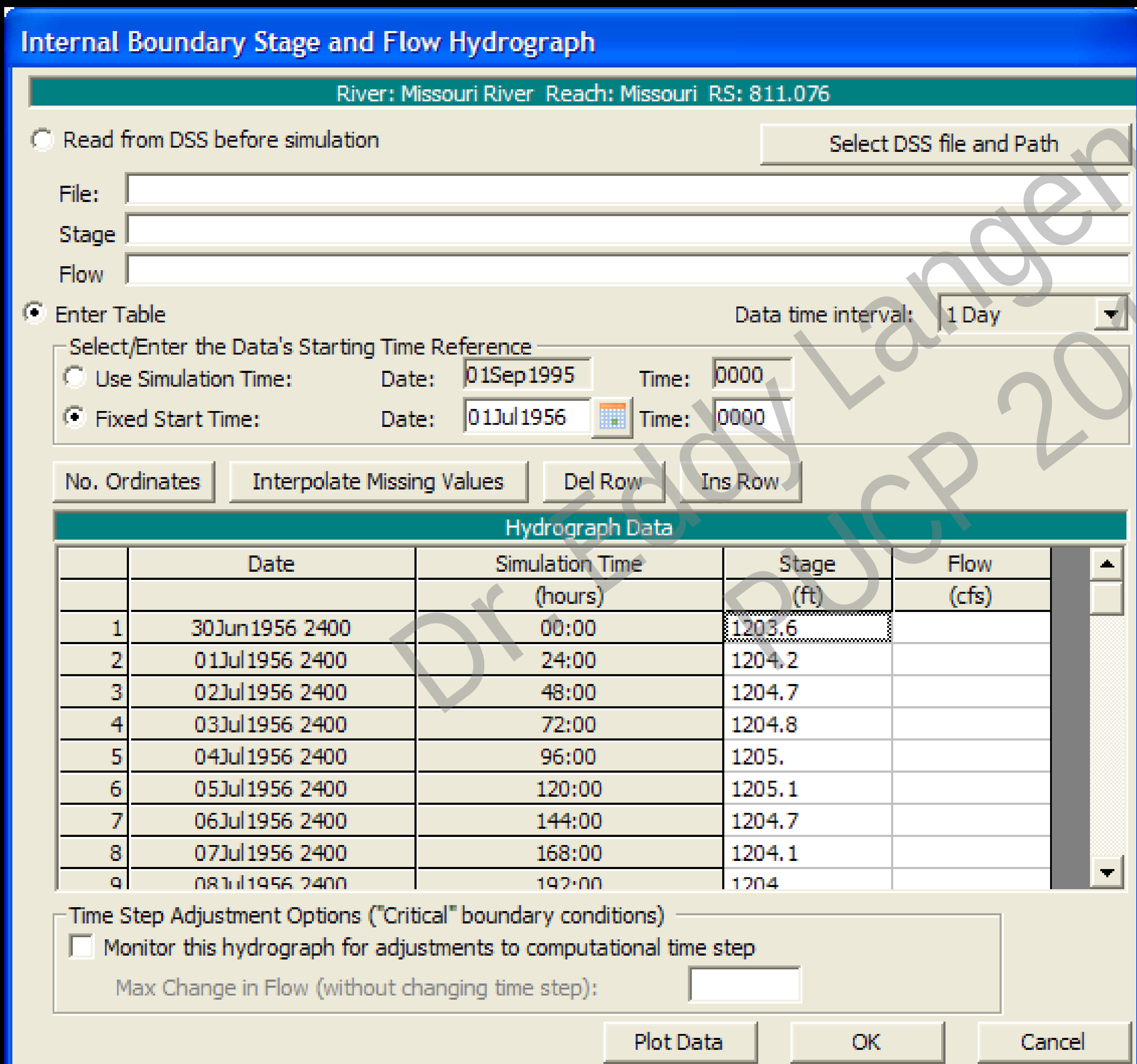


Unsteady Sediment Transport



-Structures in an unsteady sediment transport model have more simulation options

Internal Boundary Stage/Flow

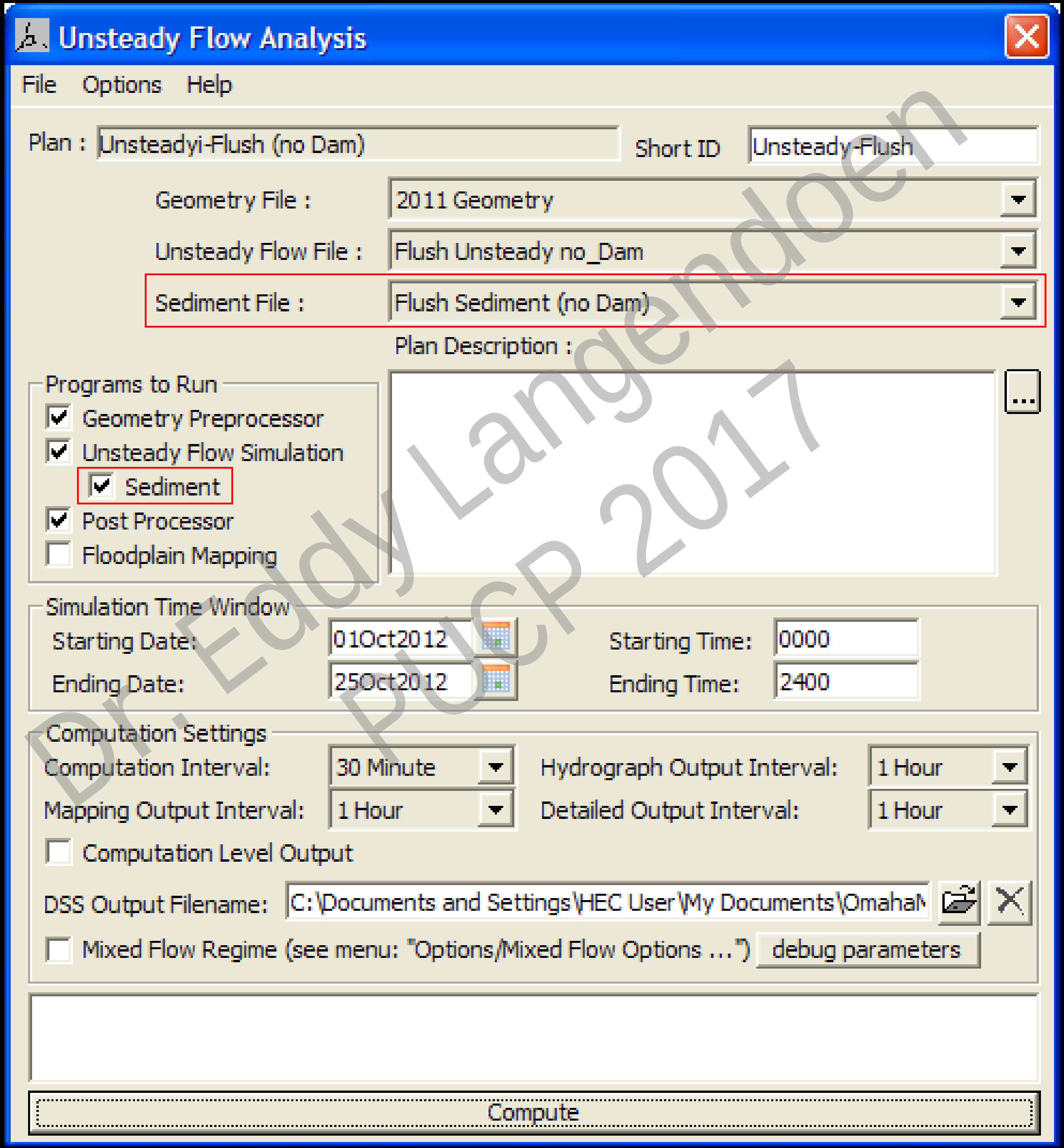


-Automatically opens gates to achieve either an upstream stage or a flow through the gates

-Define gate BCs which will be used in the first time step.

-Add the IB Stage/Flow BC to the XS upstream of the Inline Structure

Unsteady Sediment Transport



Reservoir Operation Situations

1. Know reservoir stage *a priori*?
   -Quasi-Unsteady Flow

2. Know Gate Operations *a priori*?
   -Unsteady Flow with Gate Operations

3. Know reservoir stage but want to compute gate flow?
   -Unsteady/IB Stage Flow

4. Don’t know gate ops. or reservoir stage but want to set flow through gates?
   -Unsteady with Rules

Reservoir Flushing and Unsteady Sediment Analysis with Operational Rules

Crosa *et al.* 2010

Stanford Gibson, Phd
Hydrologic Engineering Center

Advanced Reservoir Modeling and Unsteady Sediment Analysis with HEC-RAS

1. Principles of Reservoir Flushing and Sluicing

2. New Features for Sustainable Sediment Management Modeling

3. Modeling Sustainable Sediment Reservoir Operations with Unsteady Analysis and Rules

2. New Features for Sustainable Sediment Management Modeling

-Simplified Channel Evolution

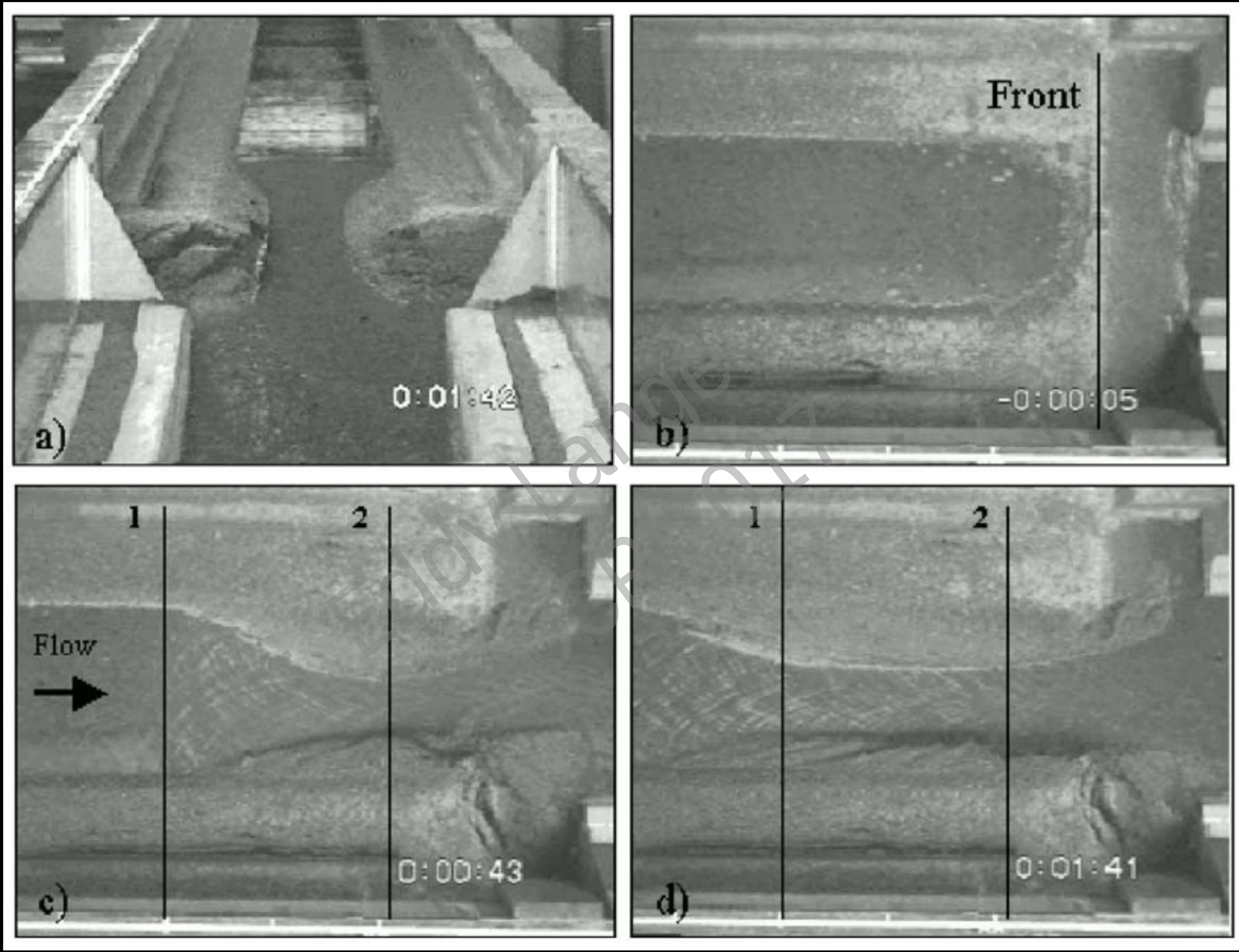
-Atkinson Width Calculator

-Multiple Erodible Channels

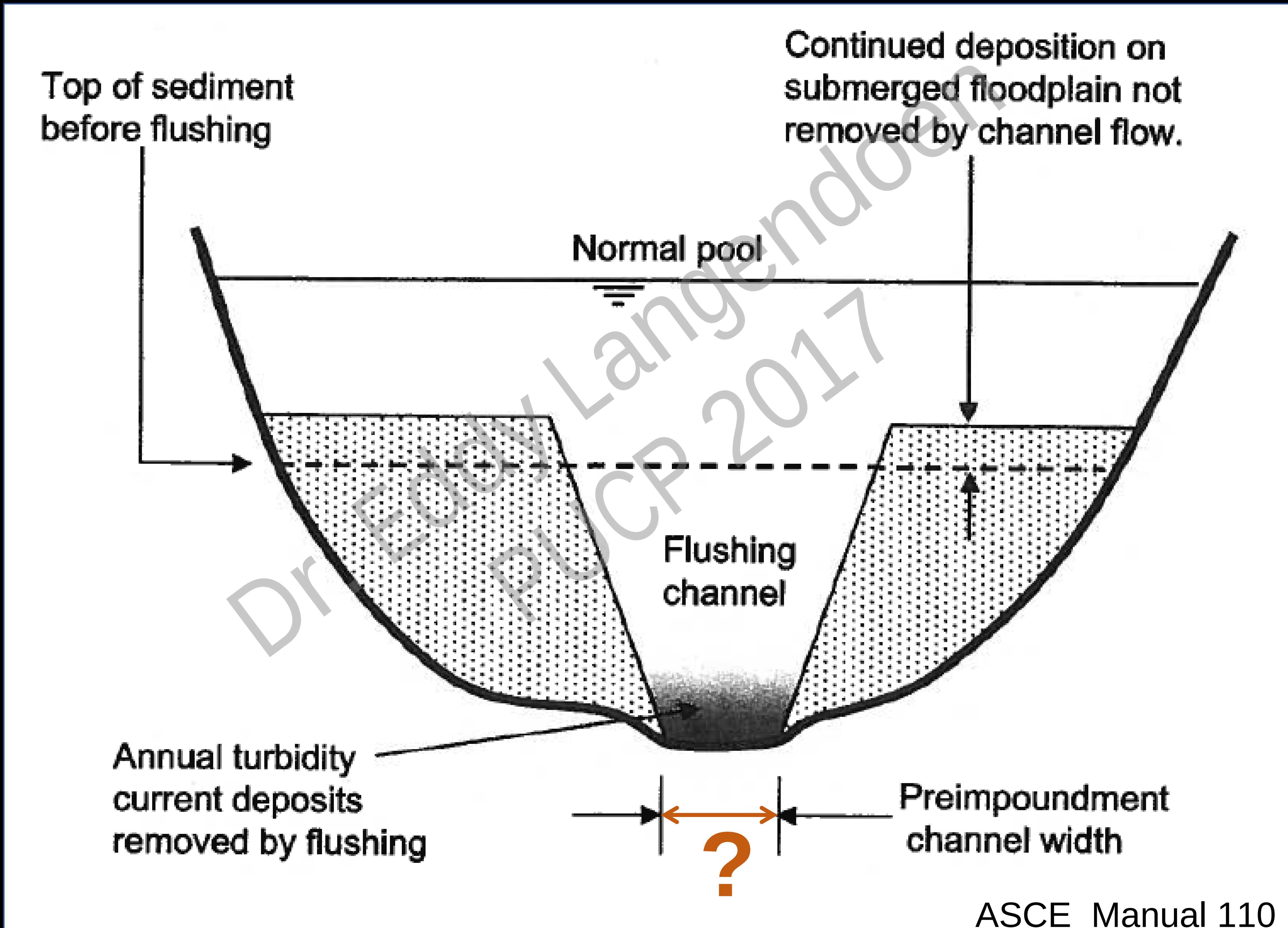
-Alternate Cohesive Erosion Methods

-Bed Stratigraphy

-Flocculation/Clod Erosion



Cantelli et al (2004) "Experiments on upstream-migrating erosional narrowing and widening of an incisional channel caused by dam removal," WATER RESOURCES RESEARCH, VOL. 40, W03304, doi:10.1029/2003WR002940.


Top of sediment
before flushing
Continued deposition on
submerged floodplain not
removed by channel flow.
Normal pool
Flushing
channel
Annual turbidity
current deposits
removed by flushing
Preimpoundment
channel width
?
ASCE Manual 110

'Channel Evolution' Erosion Model

Bed Change Options

Deposition

(•) No Bed Change Allowed Outside of the Movable Bed Limits

( ) Allow Deposition Outside of the Movable Bed Limits

Erosion

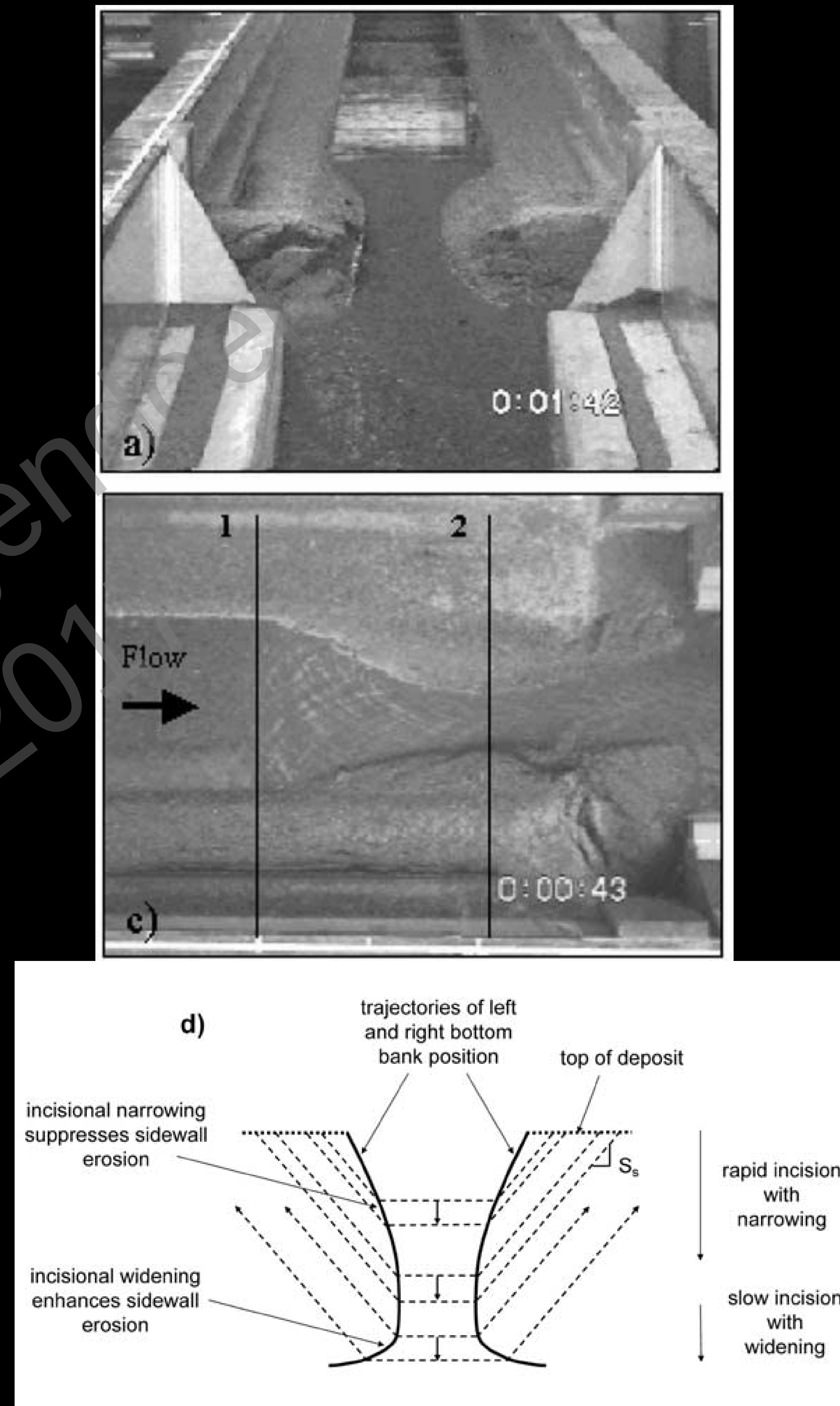
Erode Reservoir Sediments Using a Simplified Channel Evolution Model
Note: Standard bed change algorithms will be used for any XS left blank.

River: (All Rivers) Reset Trigger:

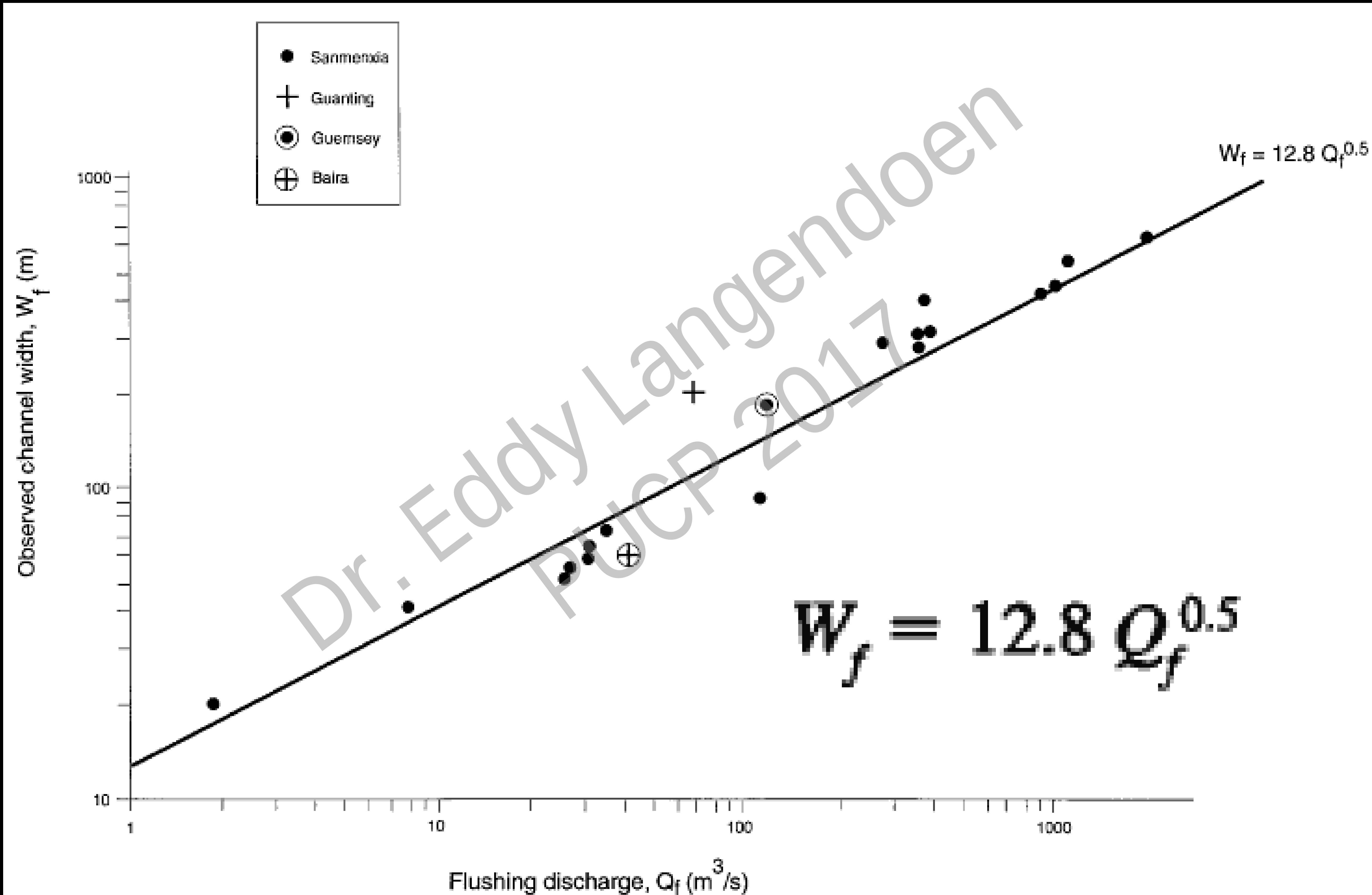
Reach: Width Calculator...

	River	Reach	RS	Max Width	Side Slope
1	Yang Flume	Yang Flume	1000	2000	0.5
2	Yang Flume	Yang Flume	980.*	2000	0.5
3	Yang Flume	Yang Flume	960.*	2000	0.5
4	Yang Flume	Yang Flume	940.*	2000	0.5
5	Yang Flume	Yang Flume	920.*	2000	0.5
6	Yang Flume	Yang Flume	900.*	2000	0.5
7	Yang Flume	Yang Flume	880.*	2000	0.5
8	Yang Flume	Yang Flume	860.*	2000	0.5
9	Yang Flume	Yang Flume	840.*	2000	0.5

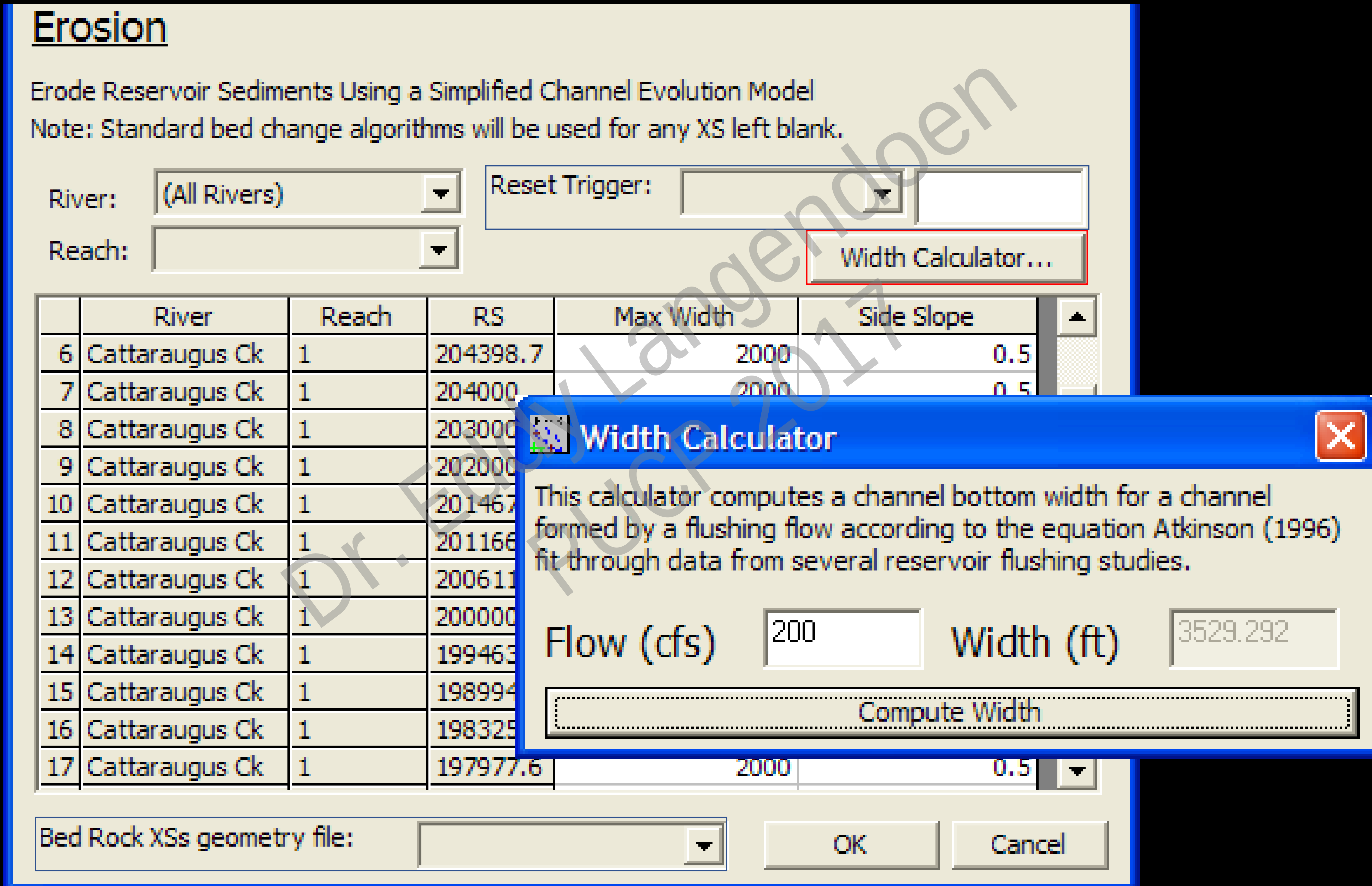
Bed Rock XSs geometry file: OK Cancel

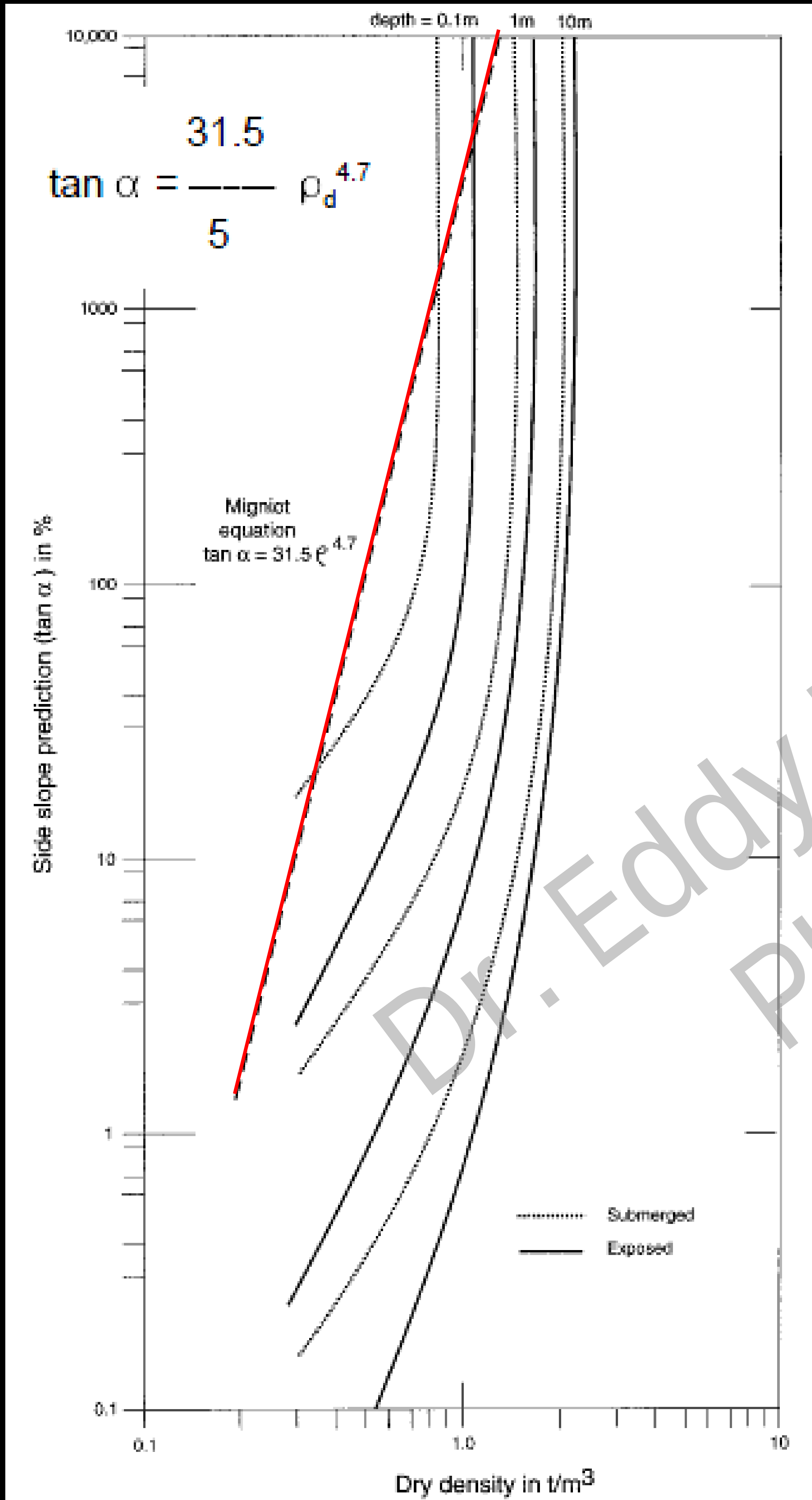


Atkinson (1996)



Width Calculator





"No reasonably reliable general purpose relationship could be found for predicting flushing channel side slopes." -Atkinson (1996)

2. New Features for Sustainable Sediment Management Modeling

-Simplified Channel Evolution

    -Atkinson Width Calculator

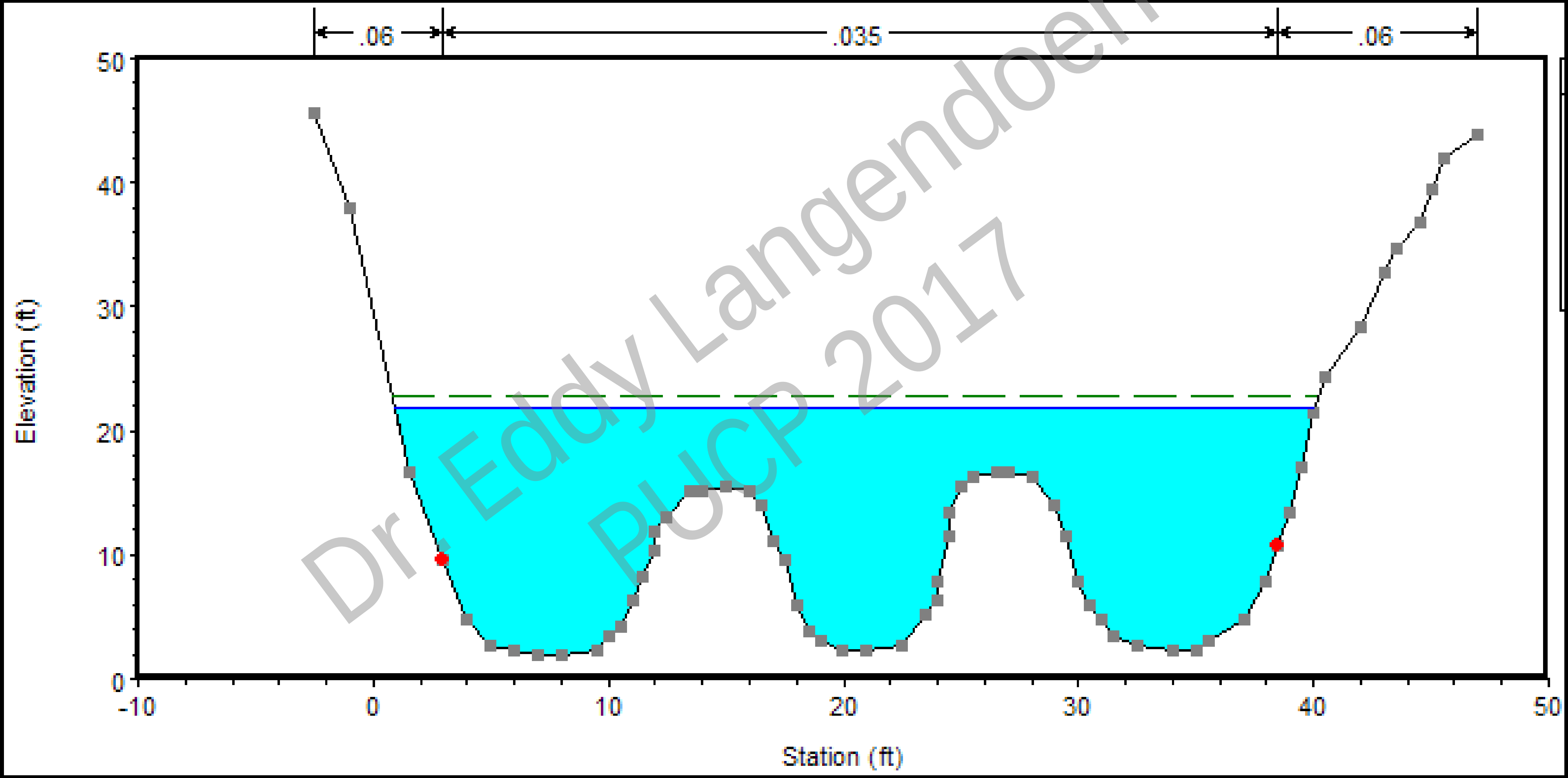
-Multiple Erodible Channels

-Alternate Cohesive Erosion Methods

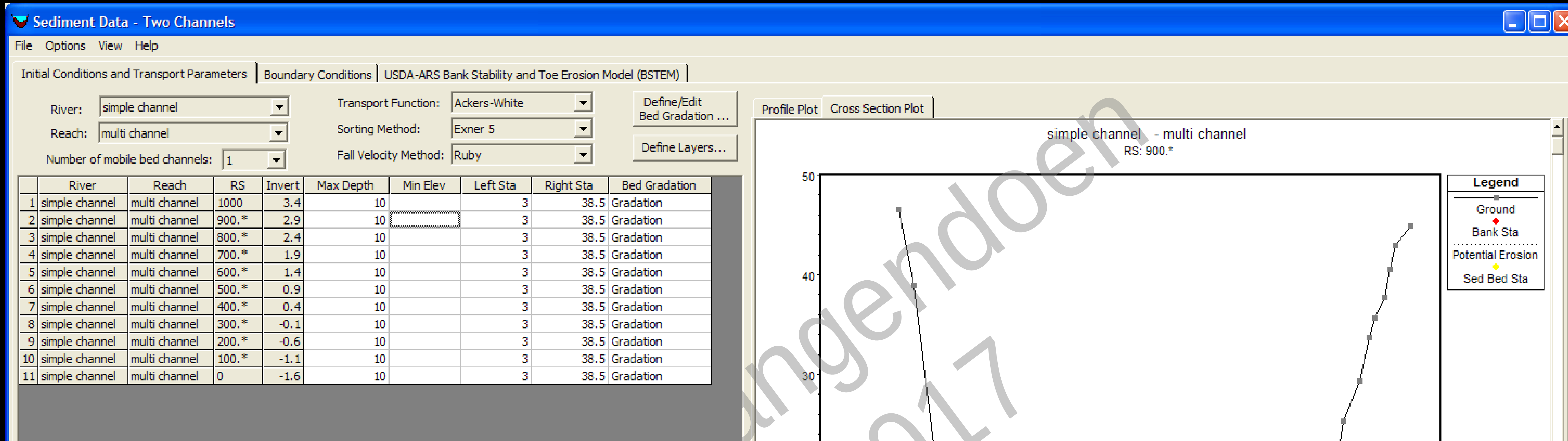
-Bed Stratigraphy

-Flocculation/Clod Erosion

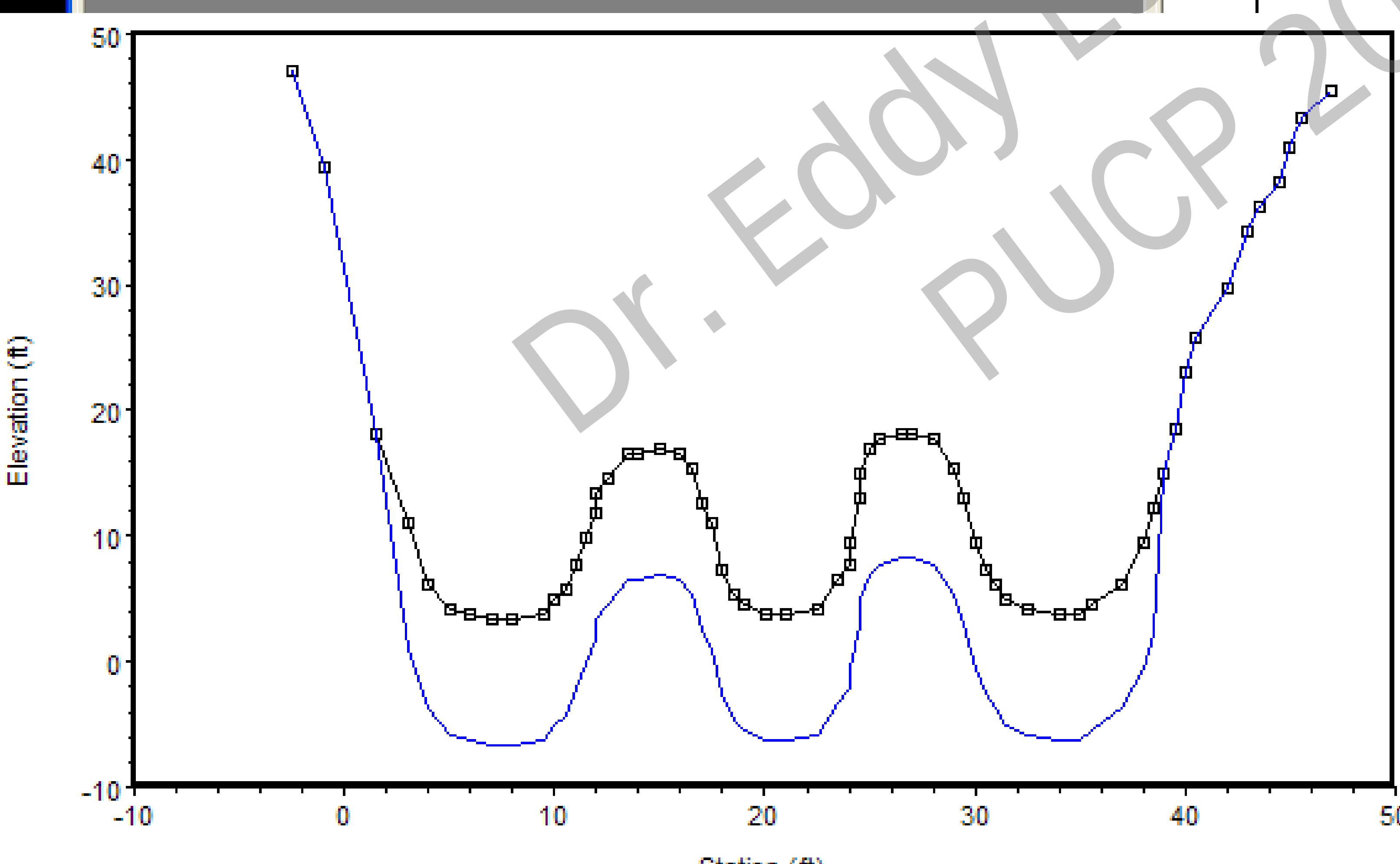
Multiple Erodible Channels



Multiple Erodible Channels



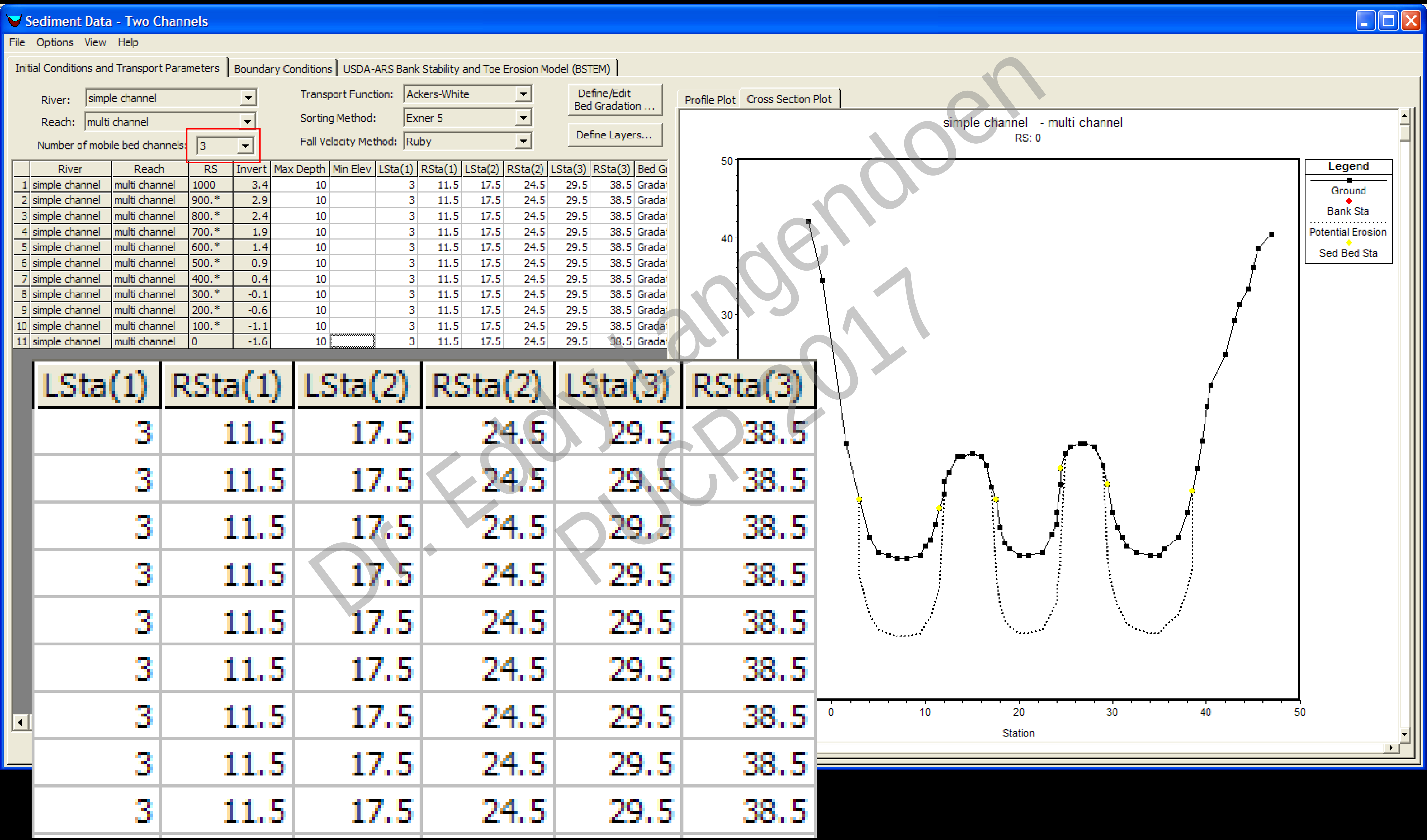
	River	Reach	RS	Invert	Max Depth	Min Elev	Left Sta	Right Sta	Bed Gradation
1	simple channel	multi channel	1000	3.4	10		3	38.5	Gradation
2	simple channel	multi channel	900.*	2.9	10		3	38.5	Gradation
3	simple channel	multi channel	800.*	2.4	10		3	38.5	Gradation
4	simple channel	multi channel	700.*	1.9	10		3	38.5	Gradation
5	simple channel	multi channel	600.*	1.4	10		3	38.5	Gradation
6	simple channel	multi channel	500.*	0.9	10		3	38.5	Gradation
7	simple channel	multi channel	400.*	0.4	10		3	38.5	Gradation
8	simple channel	multi channel	300.*	-0.1	10		3	38.5	Gradation
9	simple channel	multi channel	200.*	-0.6	10		3	38.5	Gradation
10	simple channel	multi channel	100.*	-1.1	10		3	38.5	Gradation
11	simple channel	multi channel	0	-1.6	10		3	38.5	Gradation



Multiple Erodible Channels

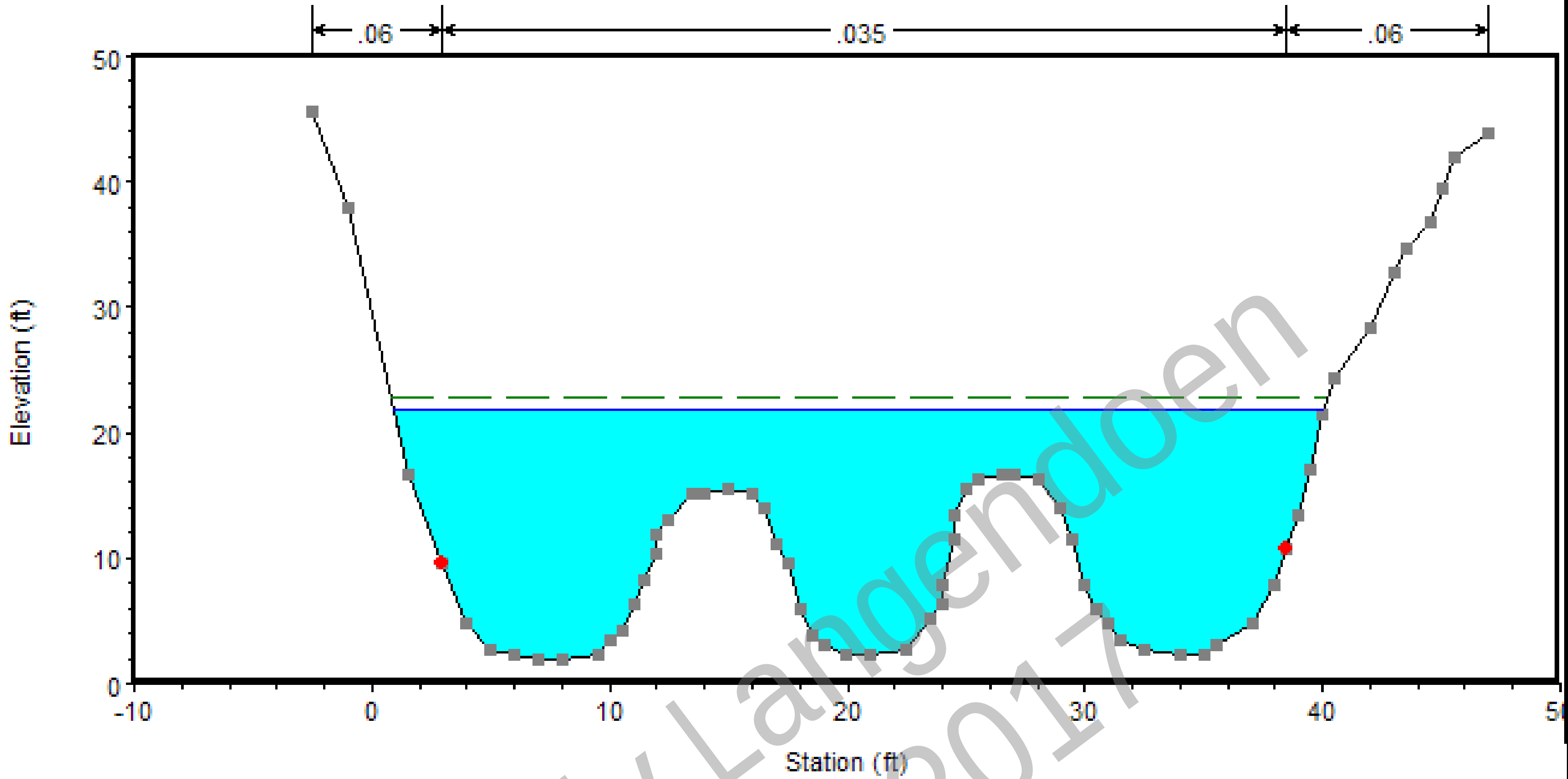
Figure 1.4 Bars due to deposition (vegetated – previous deposition)

Multiple Erodible Channels

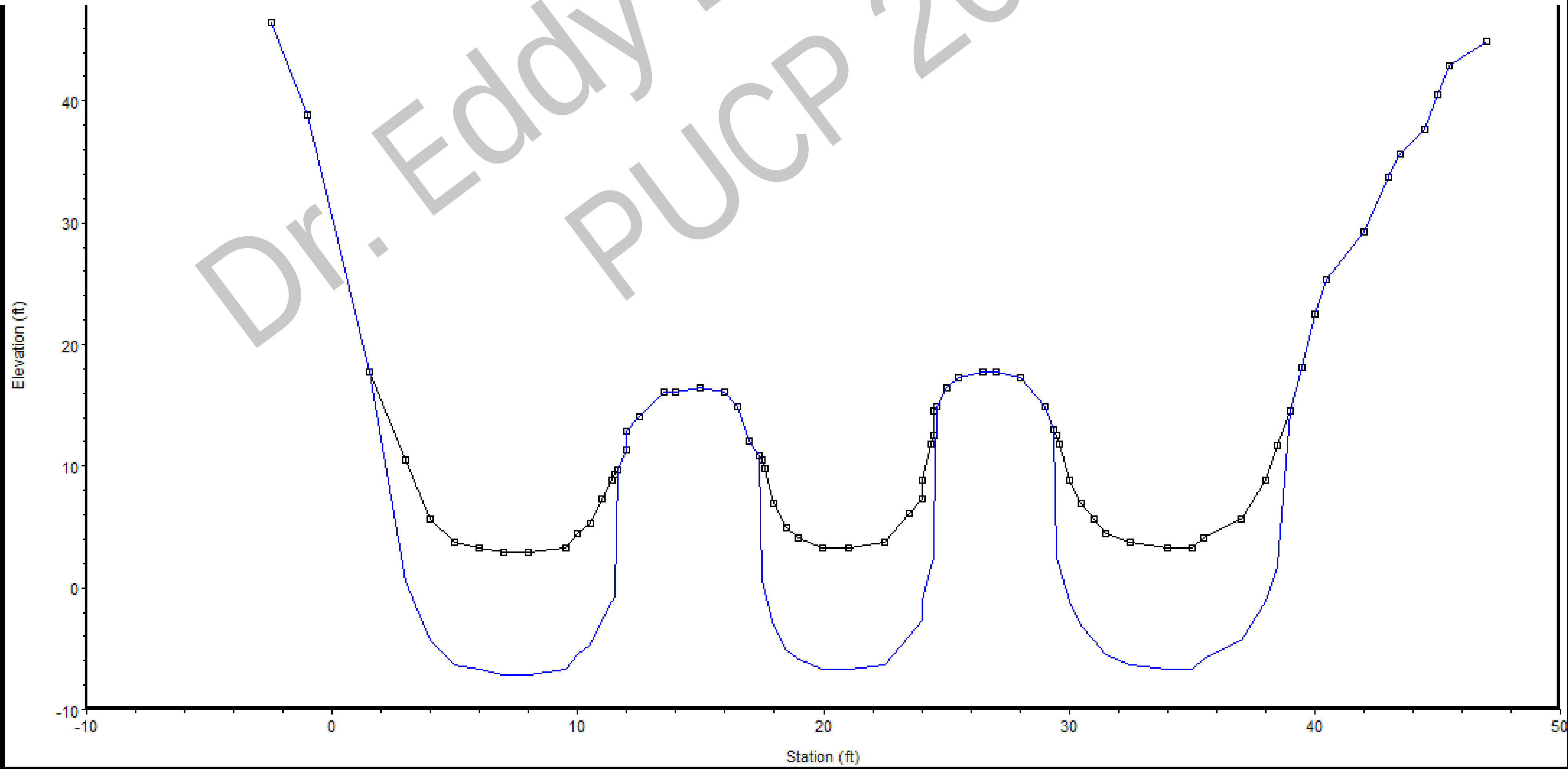


	River	Reach	RS	Invert	Max Depth	Min Elev	LSta(1)	RSta(1)	LSta(2)	RSta(2)	LSta(3)	RSta(3)	Bed Gr
1	simple channel	multi channel	1000	3.4	10		3	11.5	17.5	24.5	29.5	38.5	Grada
2	simple channel	multi channel	900.*	2.9	10		3	11.5	17.5	24.5	29.5	38.5	Grada
3	simple channel	multi channel	800.*	2.4	10		3	11.5	17.5	24.5	29.5	38.5	Grada
4	simple channel	multi channel	700.*	1.9	10		3	11.5	17.5	24.5	29.5	38.5	Grada
5	simple channel	multi channel	600.*	1.4	10		3	11.5	17.5	24.5	29.5	38.5	Grada
6	simple channel	multi channel	500.*	0.9	10		3	11.5	17.5	24.5	29.5	38.5	Grada
7	simple channel	multi channel	400.*	0.4	10		3	11.5	17.5	24.5	29.5	38.5	Grada
8	simple channel	multi channel	300.*	-0.1	10		3	11.5	17.5	24.5	29.5	38.5	Grada
9	simple channel	multi channel	200.*	-0.6	10		3	11.5	17.5	24.5	29.5	38.5	Grada
10	simple channel	multi channel	100.*	-1.1	10		3	11.5	17.5	24.5	29.5	38.5	Grada
11	simple channel	multi channel	0	-1.6	10		3	11.5	17.5	24.5	29.5	38.5	Grada

LSta(1)	RSta(1)	LSta(2)	RSta(2)	LSta(3)	RSta(3)
3	11.5	17.5	24.5	29.5	38.5
3	11.5	17.5	24.5	29.5	38.5
3	11.5	17.5	24.5	29.5	38.5
3	11.5	17.5	24.5	29.5	38.5
3	11.5	17.5	24.5	29.5	38.5
3	11.5	17.5	24.5	29.5	38.5
3	11.5	17.5	24.5	29.5	38.5
3	11.5	17.5	24.5	29.5	38.5
3	11.5	17.5	24.5	29.5	38.5



.06
.035
.06
Elevation (ft)
Station (ft)



Elevation (ft)
Station (ft)

Multiple Erodible Channels

Sediment Data - Two Channels

File | Options | View | Help

Initial Conditions and Transport Parameters | Boundary Conditions | USDA-ARS Bank Stability and Toe Erosion Model (BSTEM)

River: simple channel
Reach: multi channel
Number of mobile bed channels: 3

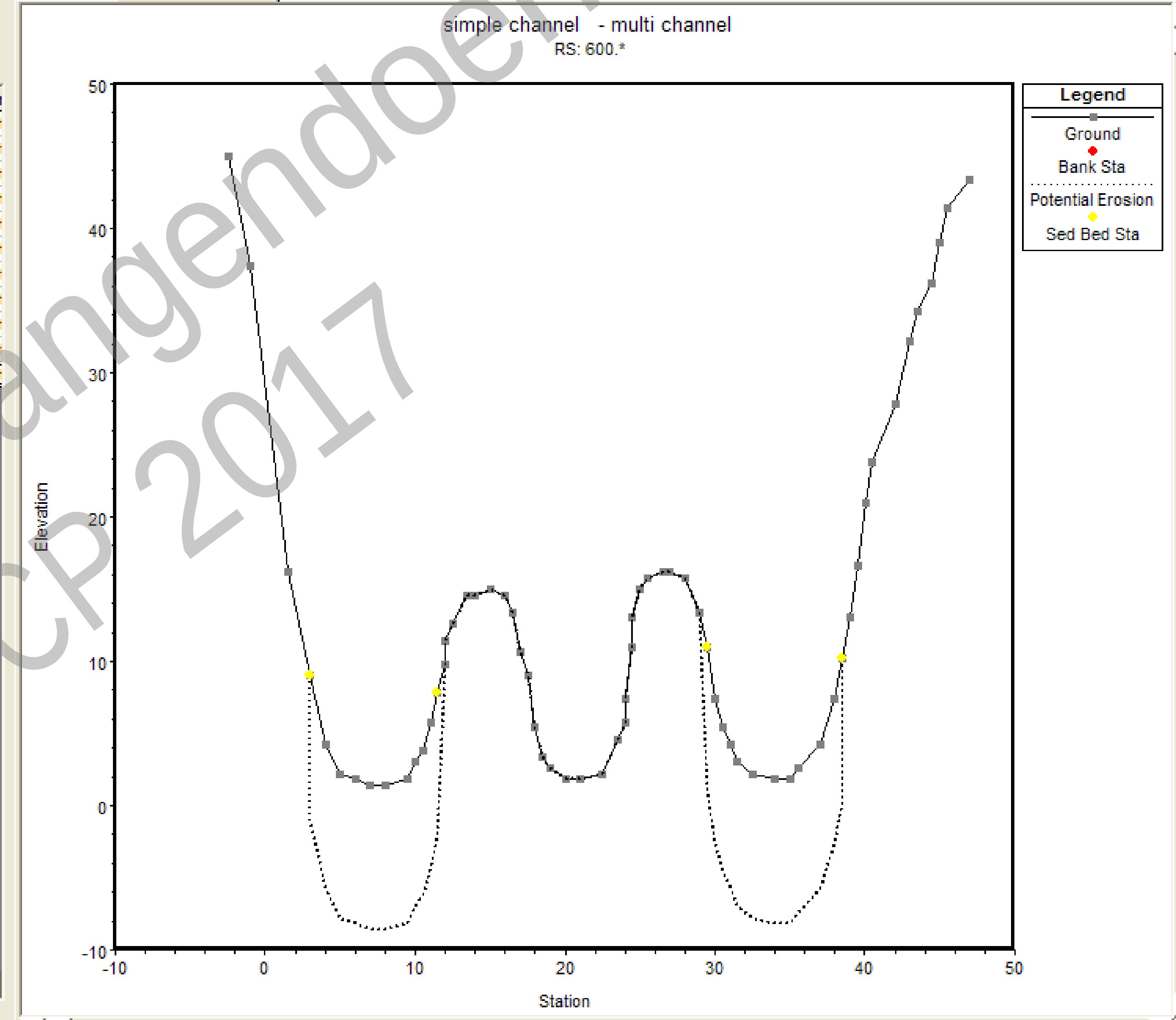
Transport Function: Ackers-White
Sorting Method: Exner 5
Fall Velocity Method: Ruby

Define/Edit Bed Gradation ...
Define Layers...

	River	Reach	RS	Invert	Max Depth	Min Elev	LSta(1)	RSta(1)	LSta(2)	RSta(2)	LSta(3)	RSta(3)	Bed Gr
1	simple channel	multi channel	1000	3.4	10		3	38.5					Grada
2	simple channel	multi channel	900.*	2.9	10		3	38.5					Grada
3	simple channel	multi channel	800.*	2.4	10		3	38.5					Grada
4	simple channel	multi channel	700.*	1.9	10		3	38.5					Grada
5	simple channel	multi channel	600.*	1.4	10		3	11.5	29.5	38.5			Grada
6	simple channel	multi channel	500.*	0.9	10		3	11.5	29.5	38.5			Grada
7	simple channel	multi channel	400.*	0.4	10		3	11.5	17.5	24.5	29.5	38.5	Grada
8	simple channel	multi channel	300.*	-0.1	10		3	11.5	17.5	24.5	29.5	38.5	Grada
9	simple channel	multi channel	200.*	-0.6	10		3	11.5	17.5	24.5	29.5	38.5	Grada
10	simple channel	multi channel	100.*	-1.1	10		3	11.5	17.5	24.5	29.5	38.5	Grada
11	simple channel	multi channel	0	-1.6	10		3	11.5	17.5	24.5	29.5	38.5	Grada

LSta(1)	RSta(1)	LSta(2)	RSta(2)	LSta(3)	RSta(3)
3	38.5				
3	38.5				
3	38.5				
3	38.5				
3	11.5	29.5	38.5		
3	11.5	29.5	38.5		
3	11.5	17.5	24.5	29.5	38.5
3	11.5	17.5	24.5	29.5	38.5
3	11.5	17.5	24.5	29.5	38.5
3	11.5	17.5	24.5	29.5	38.5
3	11.5	17.5	24.5	29.5	38.5

Profile Plot | Cross Section Plot



2. New Features for Sustainable Sediment Management Modeling

-Simplified Channel Evolution

-Atkinson Width Calculator

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-Alternate Cohesive Erosion Methods

-Bed Stratigraphy

-Flocculation/Clod Erosion

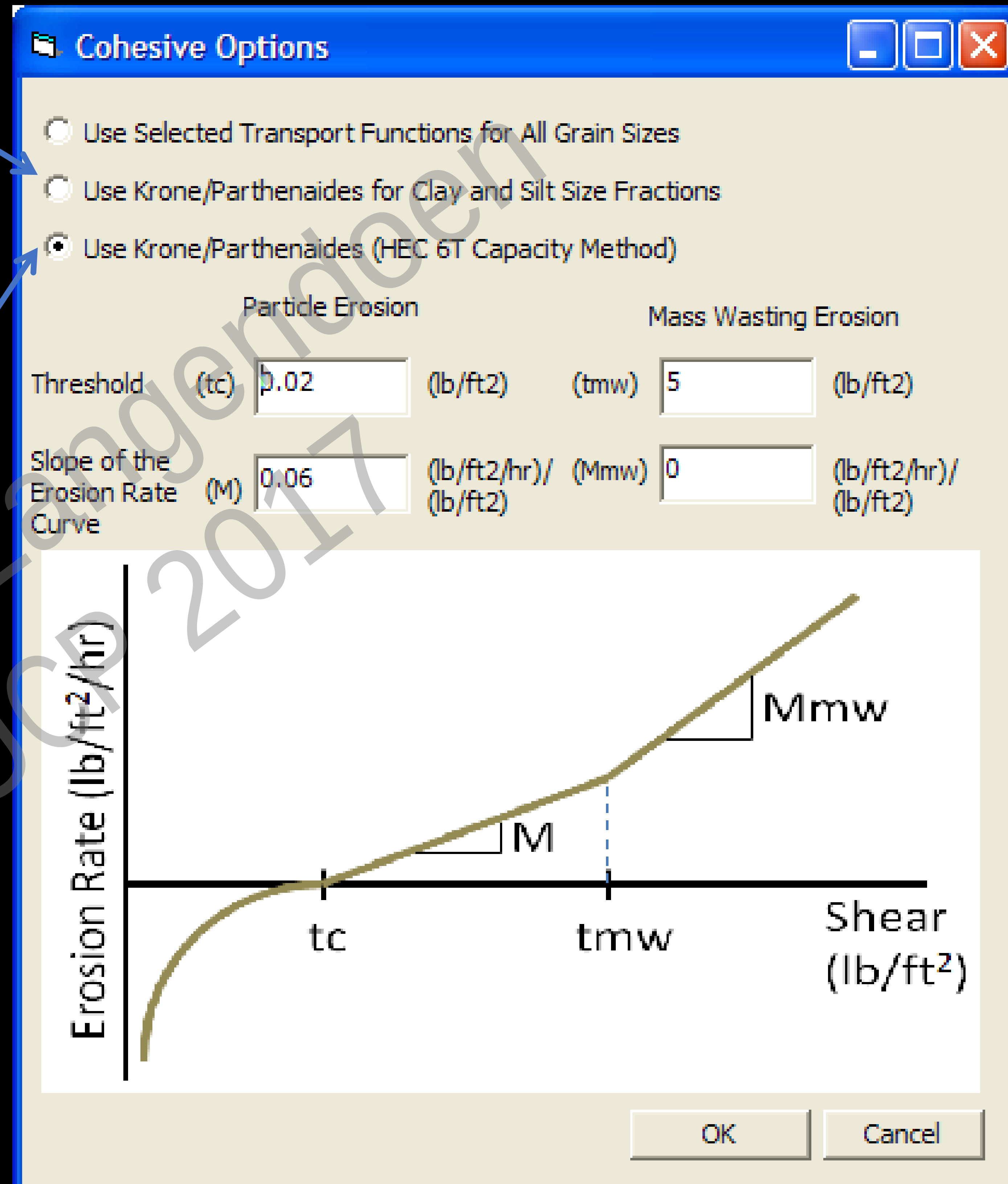
Cohesive Erosion Methods

HEC-RAS KP Method

-Apportions M between available fine grain classes in bed.
-Assumes infinite wash load – If fine sediment can be scoured it can be transported

HEC 6T KP Method

-Considers fine capacity – Inflowing fines decrease the amount of fines that can be scoured.
-Removes Total M (reduced by inflowing sediment) from each grain class



2. New Features for Sustainable Sediment Management Modeling

-Simplified Channel Evolution

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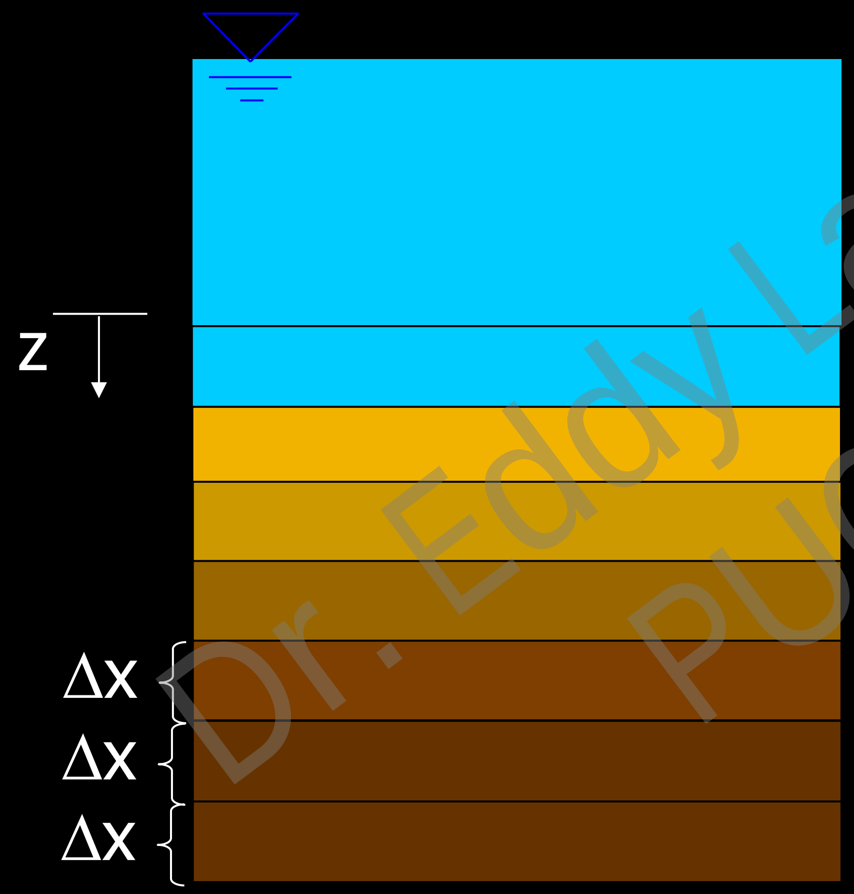
-Bed Stratigraphy

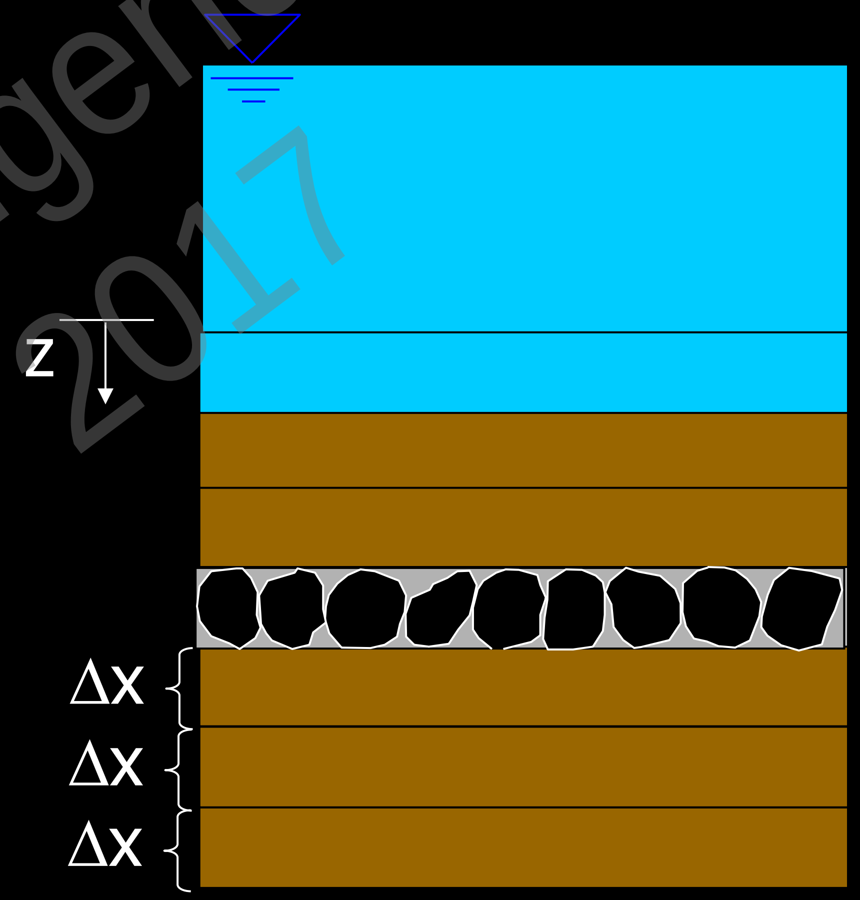
-Flocculation/Clod Erosion

Eulerian Multi-Layer Bed Accounting

Advantageous for: Reservoir Flushing, Dam Removal, Glacial Lacustrian or Outwash Substrates, Cohesive Substrates with Depth/ Density Dependent Erodibility

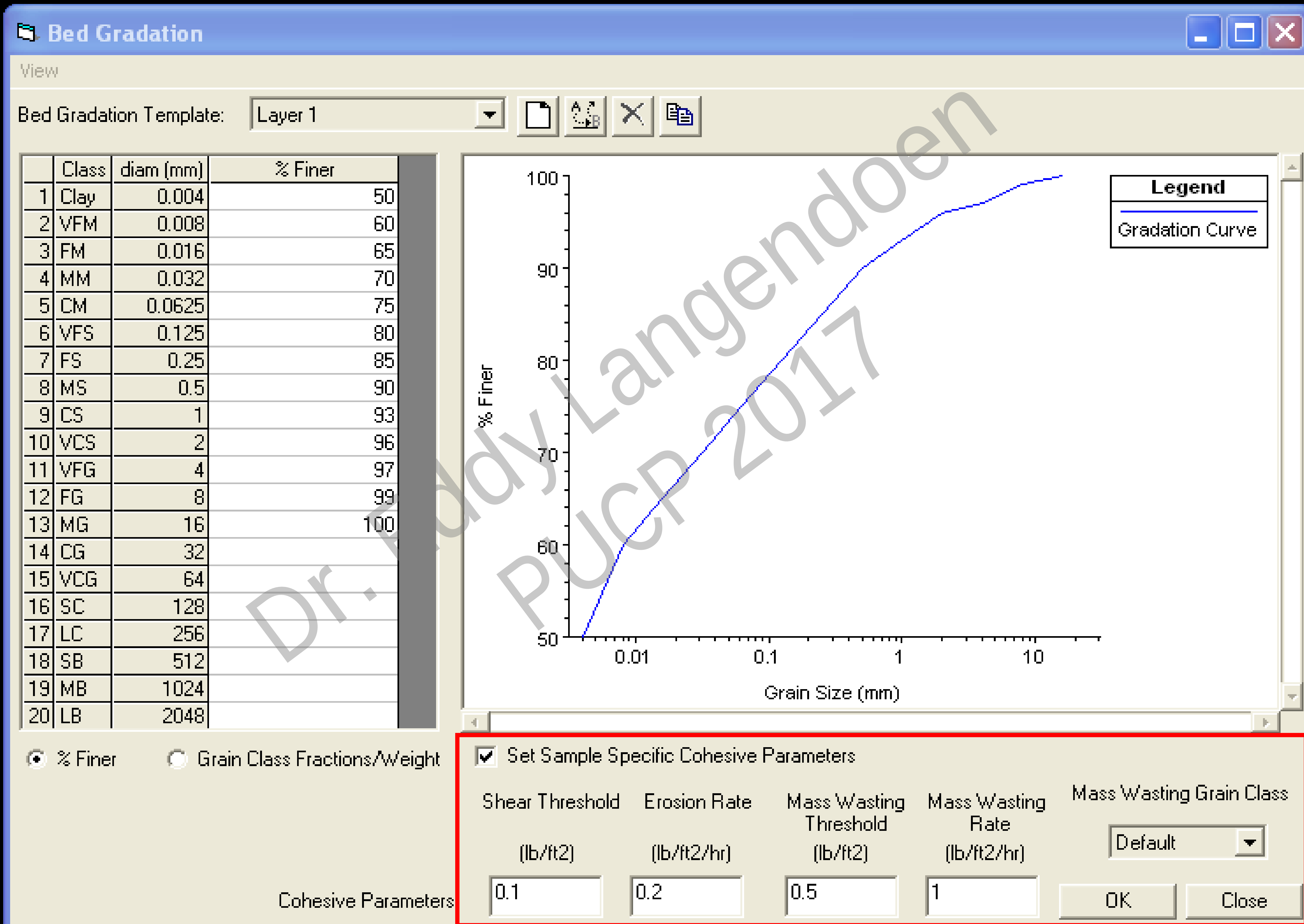


Erodibility=f(Density)
Density=f(Depth)

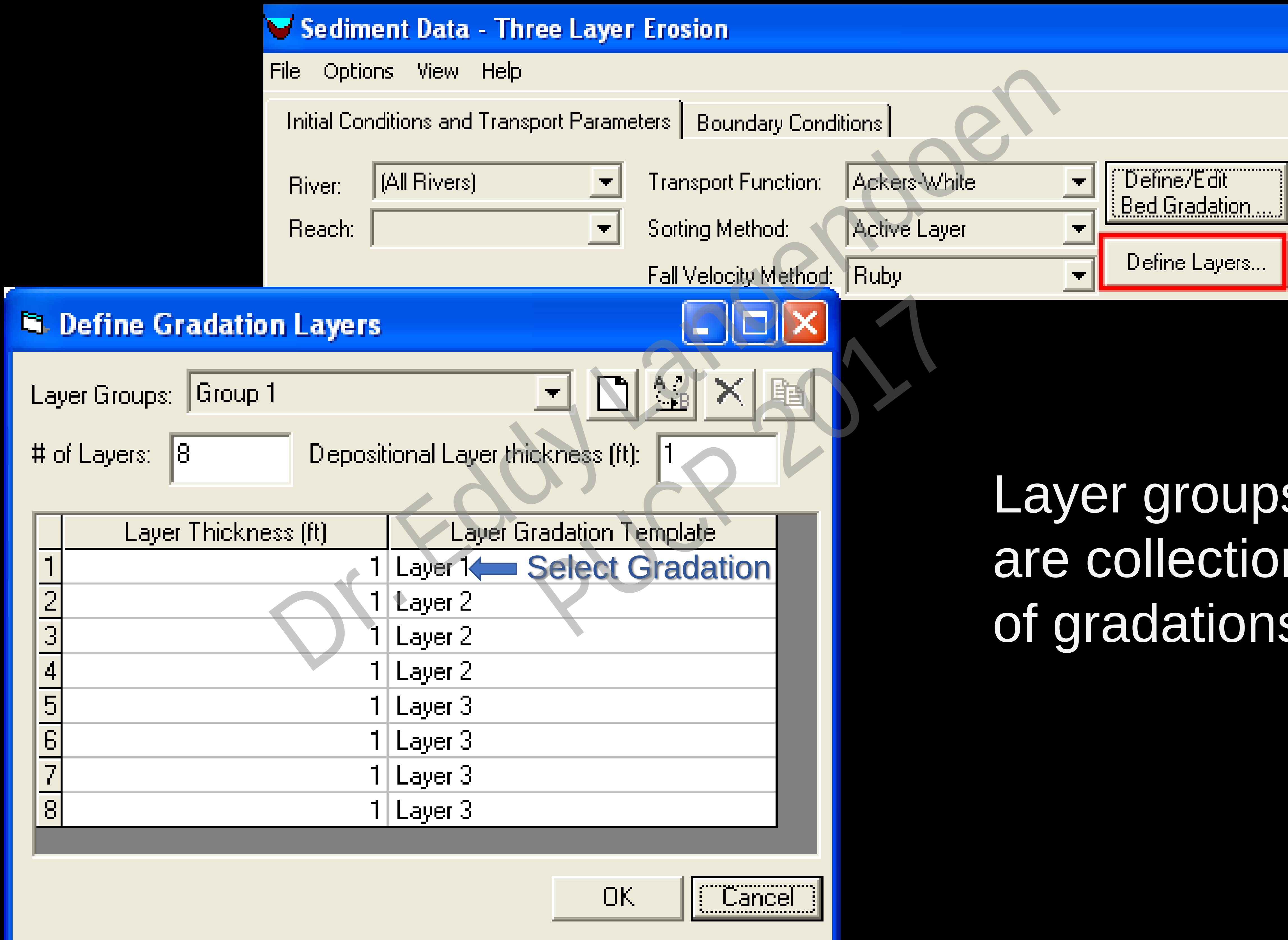


Resistant Reservoir Layer
Lacustrian Glacial Strata
Glacial Outwash Strata

Eulerian Multi-Layer Bed Accounting

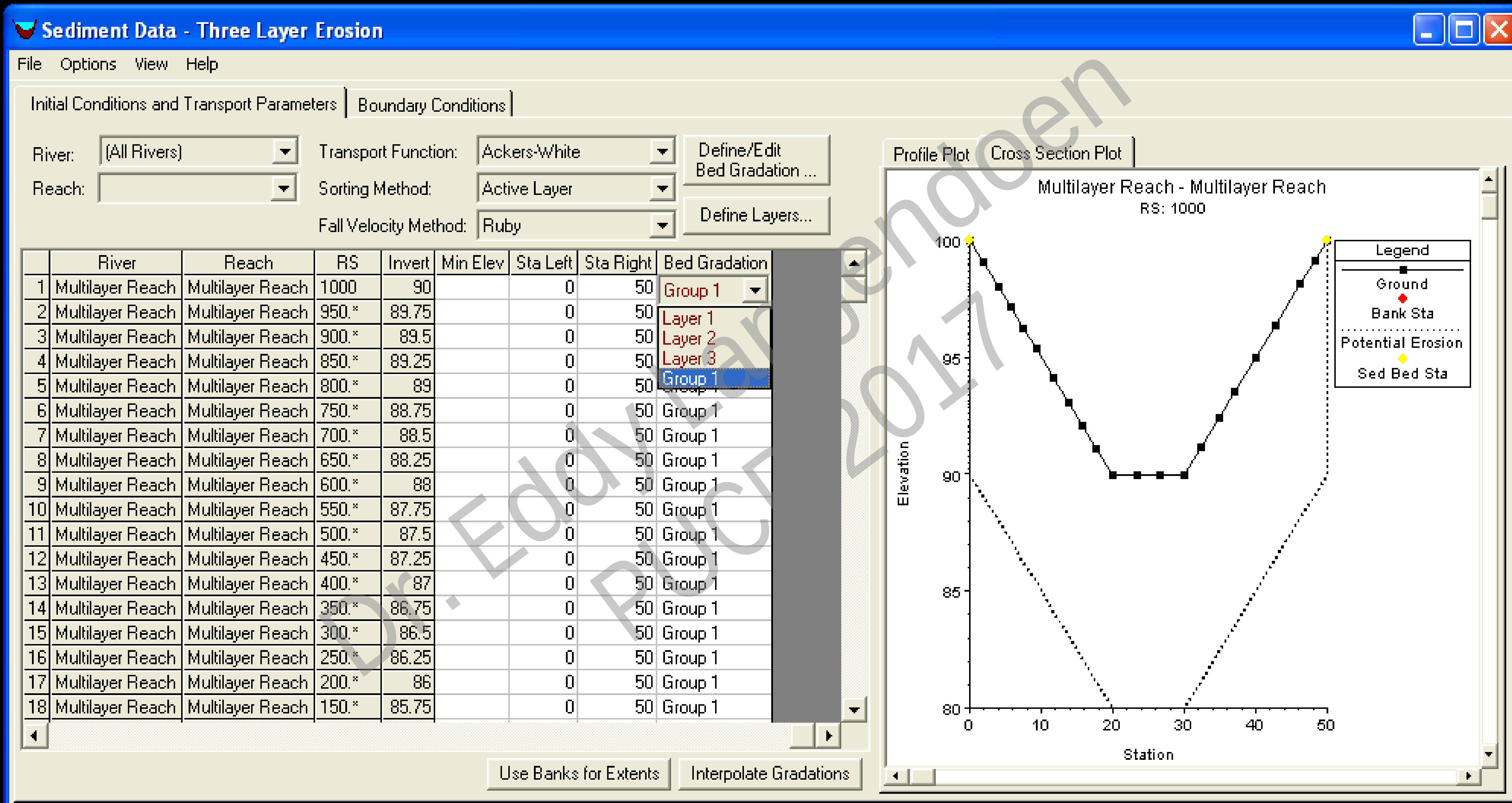


Eulerian Multi-Layer Bed Accounting



Layer groups are collections of gradations

Eulerian Multi-Layer Bed Accounting



Groups show up at the bottom of the list of gradations. If a layer group is selected, the multi-layer method is used.

2. New Features for Sustainable Sediment Management Modeling

-Simplified Channel Evolution

-Atkinson Width Calculator

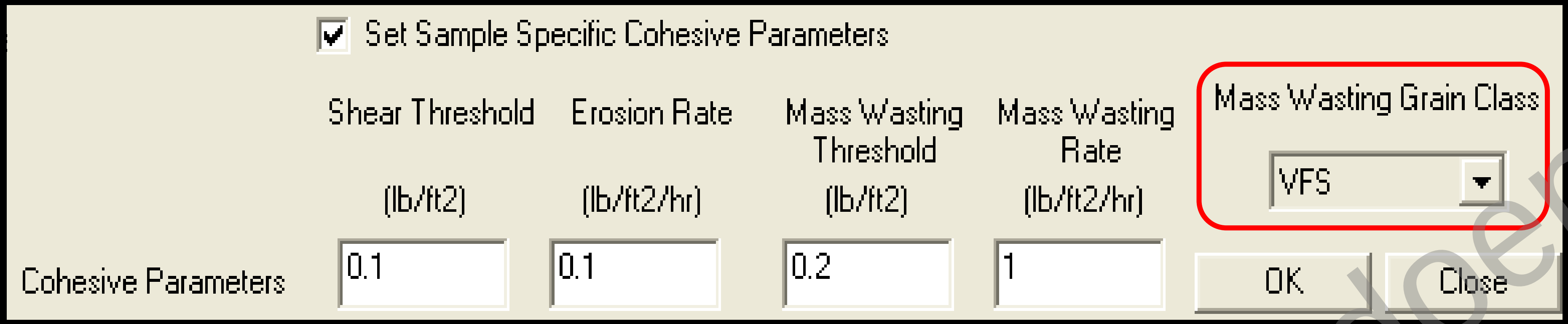
-Multiple Erodible Channels

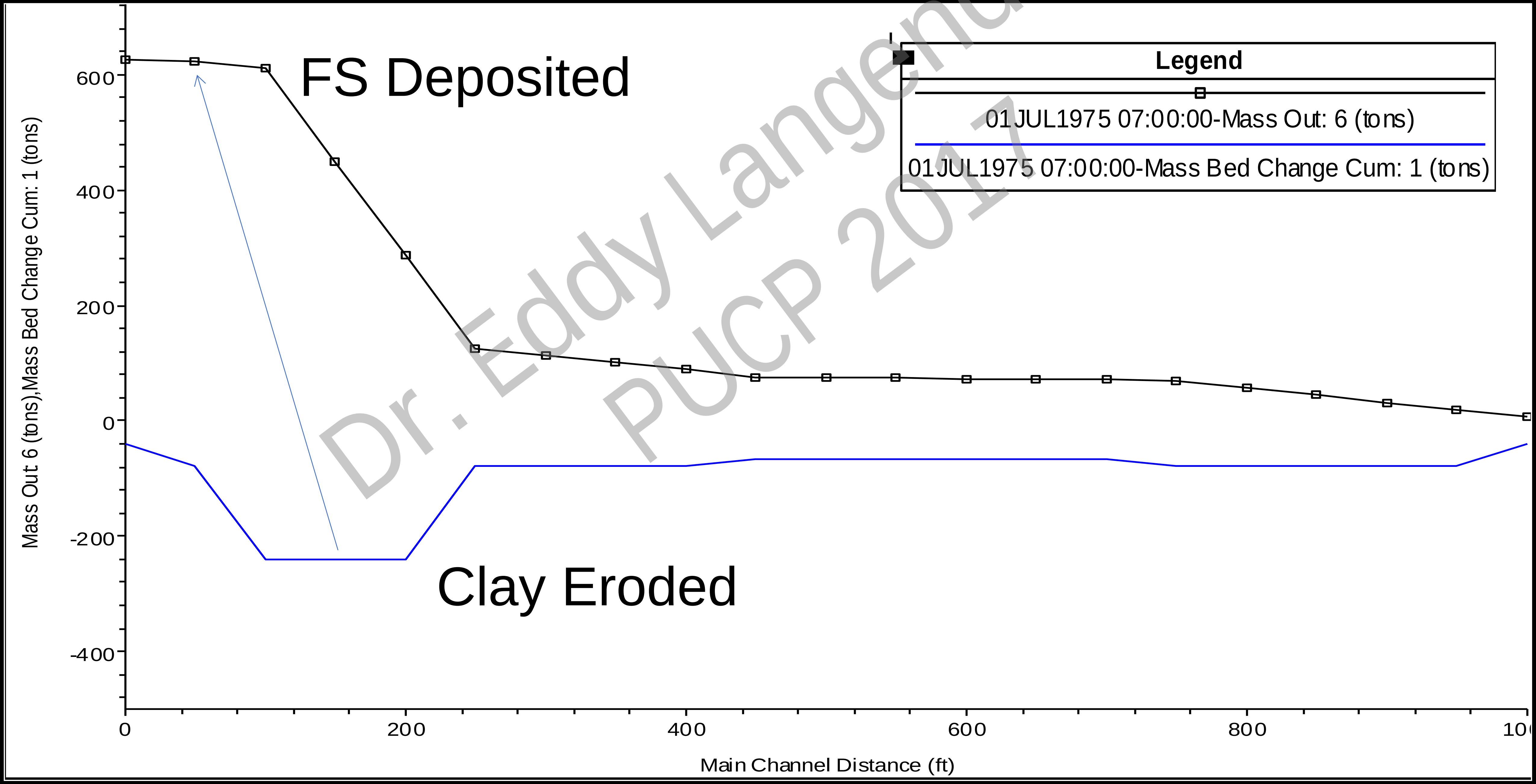
-Alternate Cohesive Erosion Methods

-Bed Stratigraphy

-Flocculation/Clod Erosion

Clod Erosion and Flocculation





Advanced Reservoir Modeling and Unsteady Sediment Analysis with HEC-RAS

1. Principles of Reservoir Flushing and Sluicing

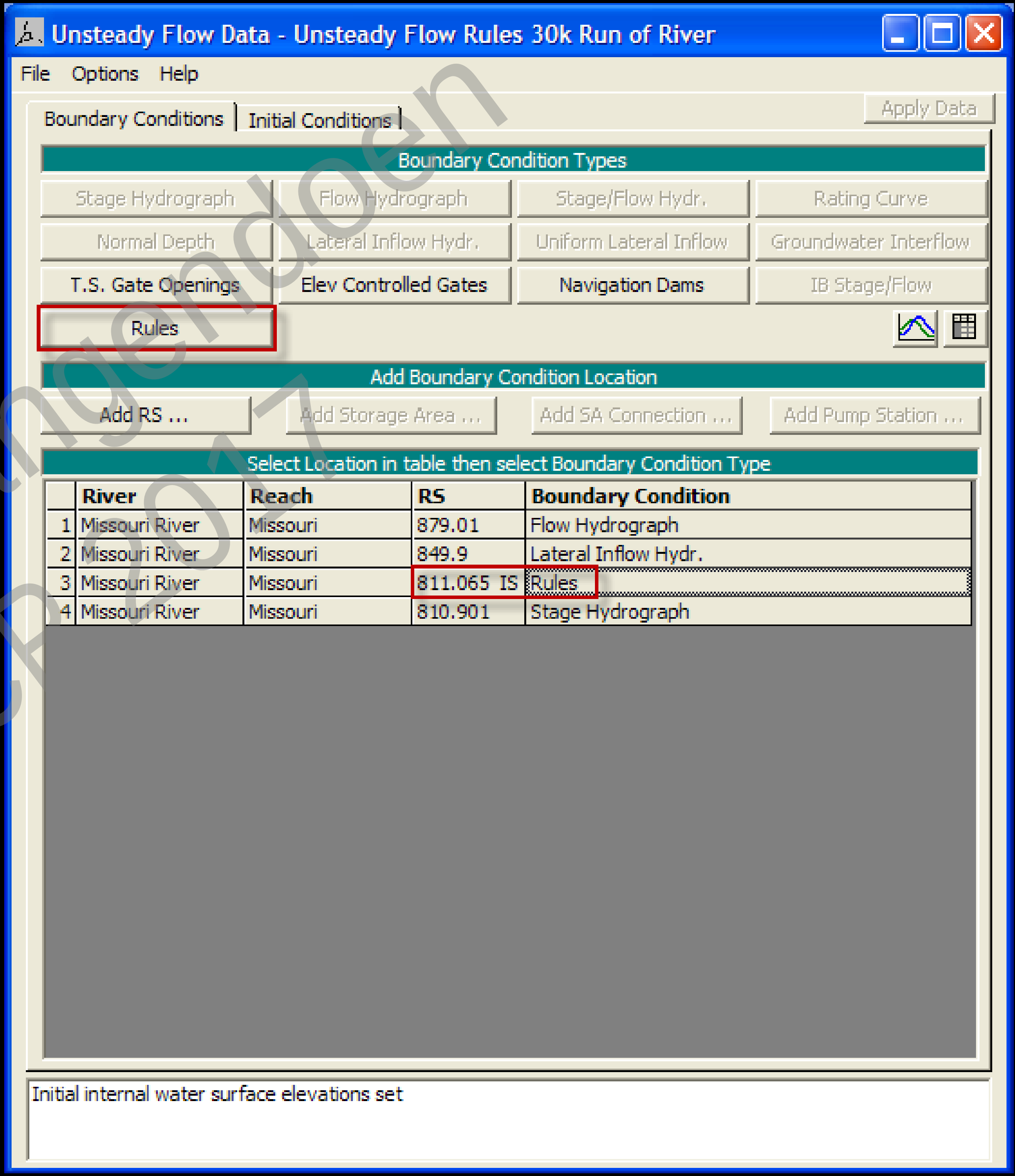
2. New Features for Sustainable Sediment Management Modeling
   - -Multiple Erodible Channels
   - -Simplified Channel Evolution (and width calc)
   - -Bed Stratigraphy

3. Modeling Sustainable Sediment Reservoir Operations with Unsteady Analysis and Rules

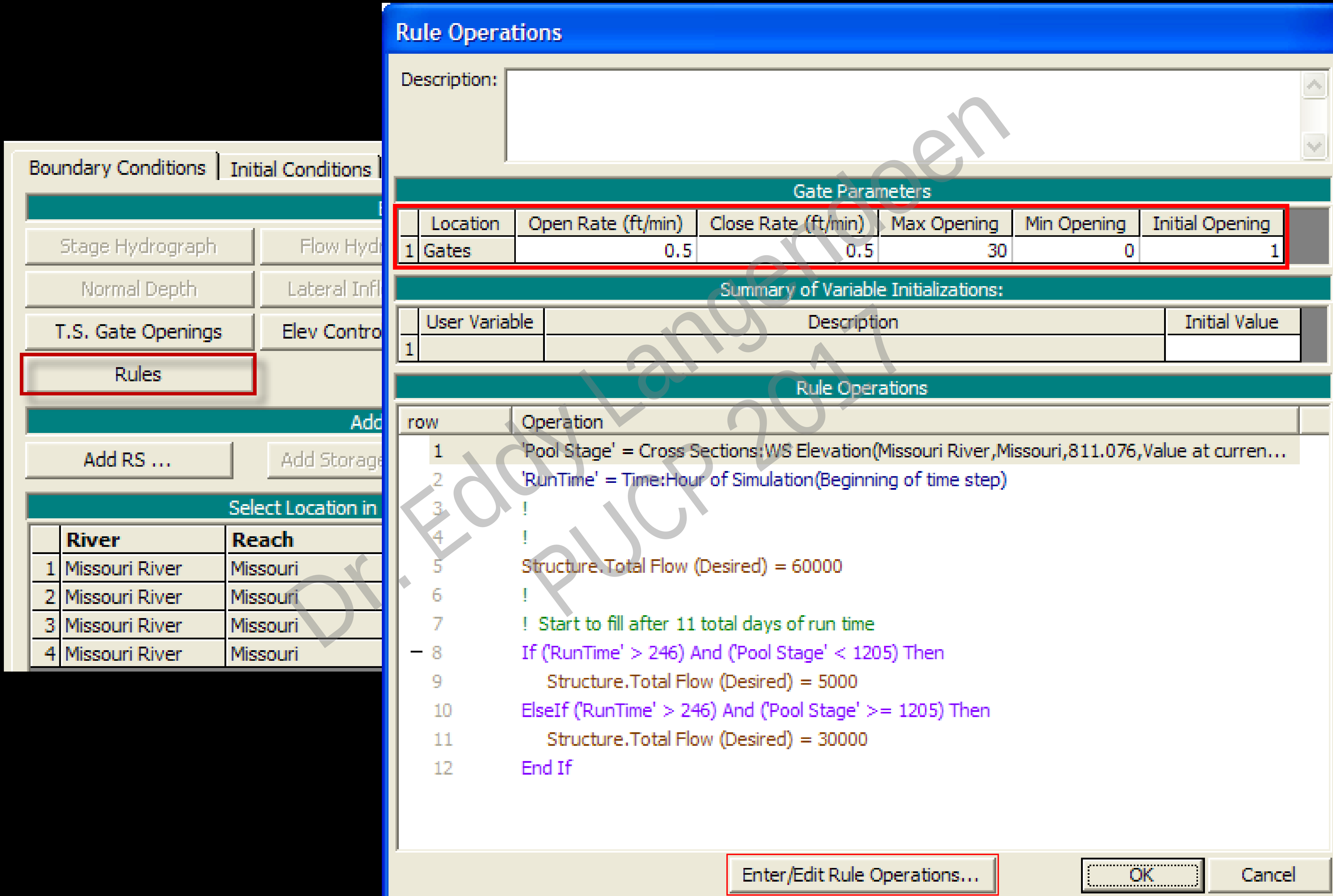
Rules

The advanced rules allow sophisticated automated control of hydraulic structures
(e.g. inline structures, lateral structures, storage area connectors, and, pumps).

Fully integrated with unsteady sediment transport
(i.e. gates can be operated with rules as sediment is routed through the model and aggradation and degradation are computed).

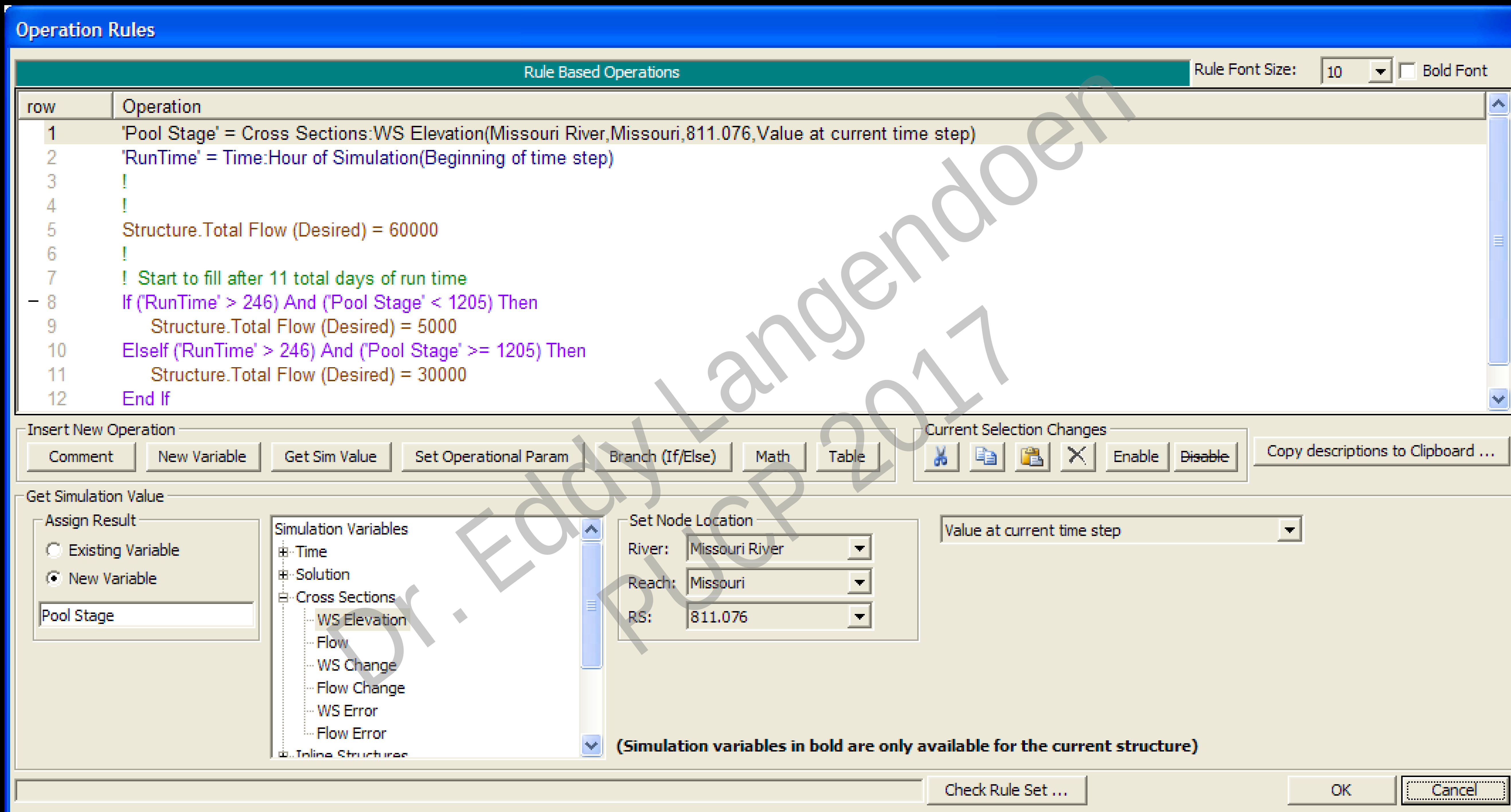


Rules



Rule Operations
Description:
Gate Parameters
Location | Open Rate (ft/min) | Close Rate (ft/min) | Max Opening | Min Opening | Initial Opening
1 Gates 0.5 0.5 30 0 1
Summary of Variable Initializations:
User Variable | Description | Initial Value
Rule Operations
row | Operation
1 'Pool Stage' = Cross Sections:WS Elevation(Missouri River,Missouri,811.076,Value at curren...
2 'RunTime' = Time:Hour of Simulation(Beginning of time step)
3 !
4 !
5 Structure.Total Flow (Desired) = 60000
6 !
7 ! Start to fill after 11 total days of run time
8 If ('RunTime' > 246) And ('Pool Stage' < 1205) Then
9 Structure.Total Flow (Desired) = 5000
10 ElseIf ('RunTime' > 246) And ('Pool Stage' >= 1205) Then
11 Structure.Total Flow (Desired) = 30000
12 End If
Enter/Edit Rule Operations...
OK
Cancel
Boundary Conditions
Initial Conditions
Stage Hydrograph
Normal Depth
T.S. Gate Openings
Rules
Add RS ...
Select Location in
River | Reach
1 Missouri River Missouri
2 Missouri River Missouri
3 Missouri River Missouri
4 Missouri River Missouri

Rules


Operation Rules
Rule Based Operations
Rule Font Size: 10
Bold Font
row
Operation
1 'Pool Stage' = Cross Sections:WS Elevation(Missouri River,Missouri,811.076,Value at current time step)
2 'RunTime' = Time:Hour of Simulation(Beginning of time step)
3 !
4 !
5 Structure.Total Flow (Desired) = 60000
6 !
7 ! Start to fill after 11 total days of run time
8 If ('RunTime' > 246) And ('Pool Stage' < 1205) Then
9 Structure.Total Flow (Desired) = 5000
10 ElseIf ('RunTime' > 246) And ('Pool Stage' >= 1205) Then
11 Structure.Total Flow (Desired) = 30000
12 End If
Insert New Operation
Comment
New Variable
Get Sim Value
Set Operational Param
Branch (If/Else)
Math
Table
Current Selection Changes
Enable
Disable
Copy descriptions to Clipboard ...
Get Simulation Value
Assign Result
Existing Variable
New Variable
Pool Stage
Simulation Variables
Time
Solution
Cross Sections
WS Elevation
Flow
WS Change
Flow Change
WS Error
Flow Error
Set Node Location
River: Missouri River
Reach: Missouri
RS: 811.076
Value at current time step
(Simulation variables in bold are only available for the current structure)
Check Rule Set ...
OK
Cancel
Dr. Eddy Langendoen
PUCP 2017

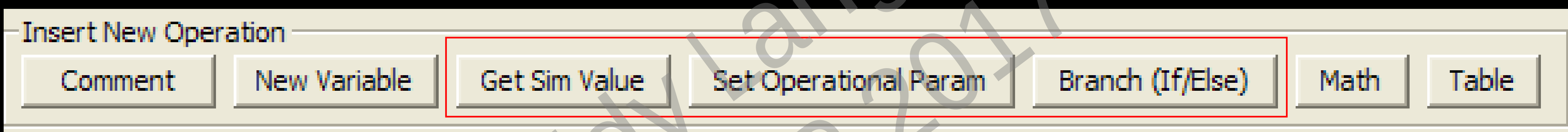
Rules

“HEC-RAS Output”
WSE/Q/Time

Turn Simulation Results
into a Variable

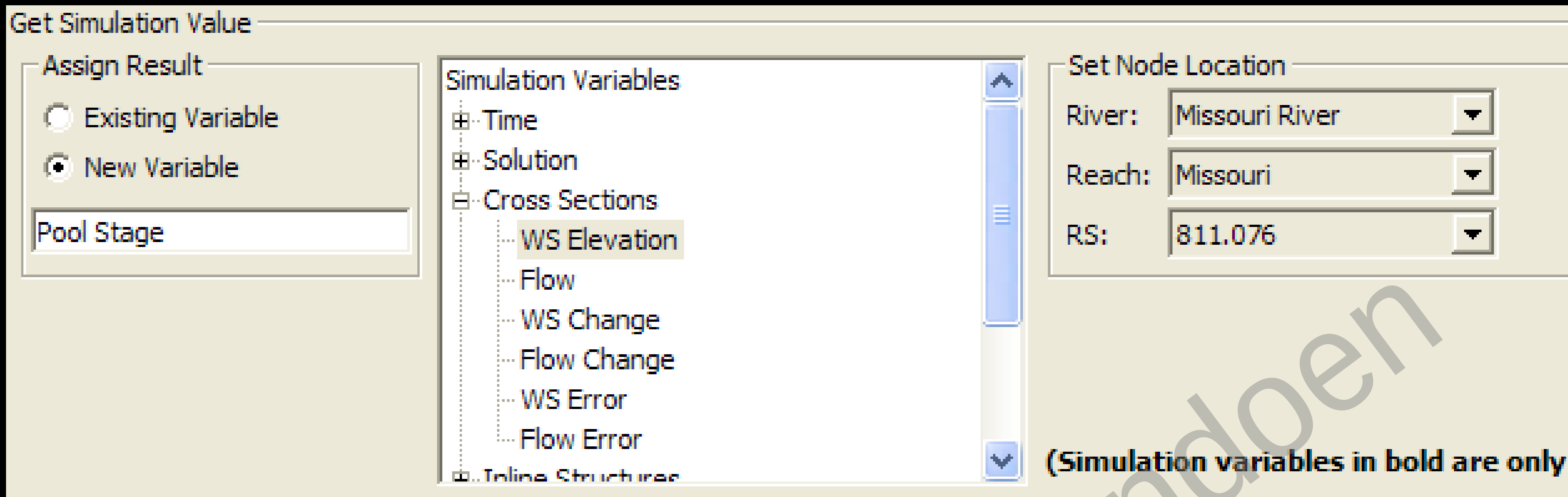
If/Then/Else
And/Or

Programming
Logic



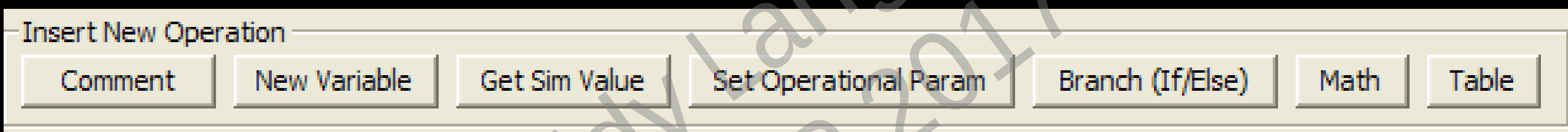
Set a Target to
Base Operations on

“Target Variable”
“Operational Goal”
“Specified Parameter”



Document
Document

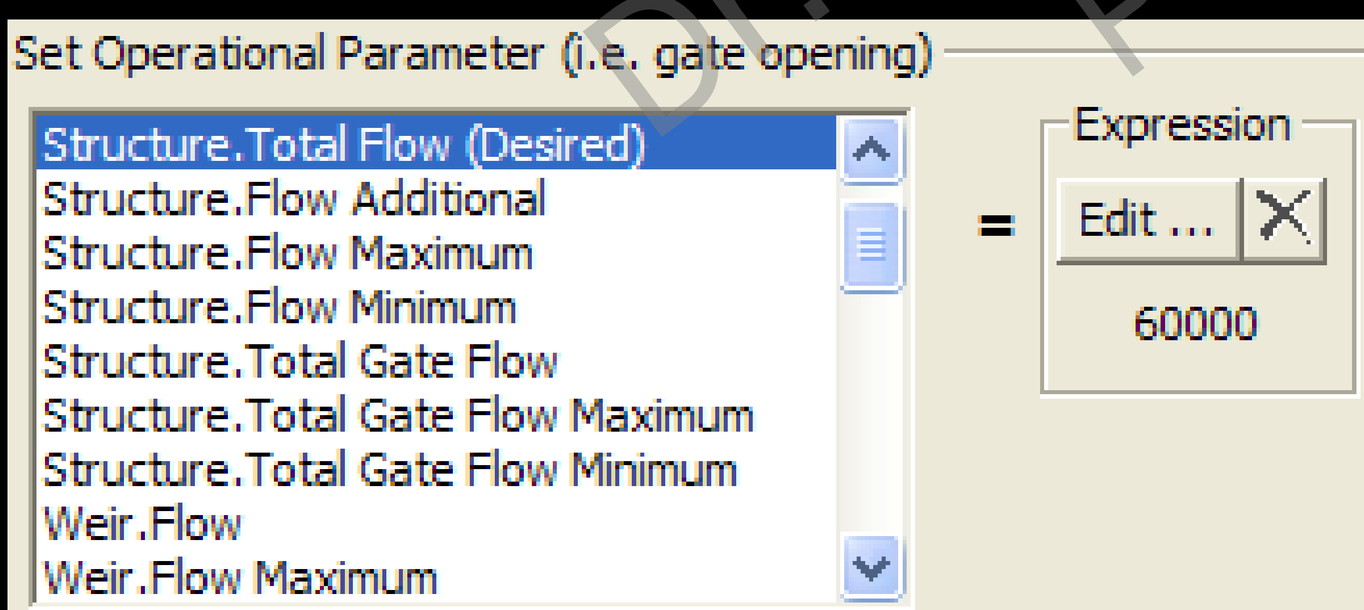
Turn Simulation Results
into a Variable

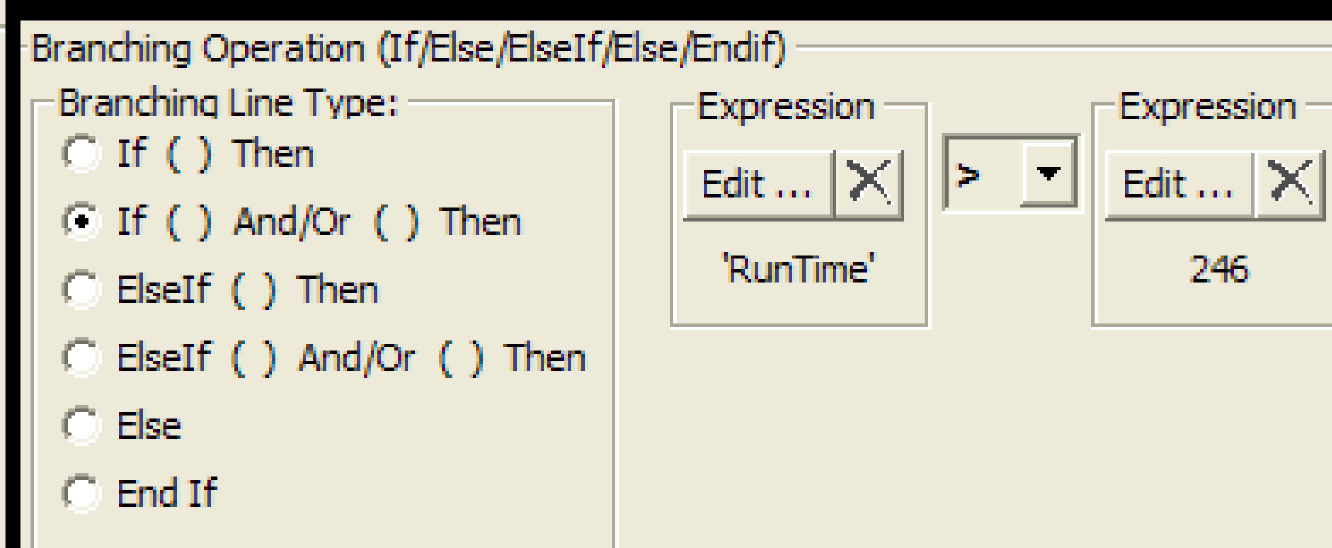


Set a Target to
Base Operations on

Programming
Logic

Complex
Equations





Rules

```
'Pool Stage' = Cross Sections:WS Elevation(Missouri River,Missouri,811.076
'RunTime' = Time:Hour of Simulation(Beginning of time step)
!
!
Structure.Total Flow (Desired) = 60000
!
!  Start to fill after 11 total days of run time
If ('RunTime' > 246) And ('Pool Stage' < 1205) Then
    Structure.Total Flow (Desired) = 5000
ElseIf ('RunTime' > 246) And ('Pool Stage' >= 1205) Then
    Structure.Total Flow (Desired) = 30000
End If
```

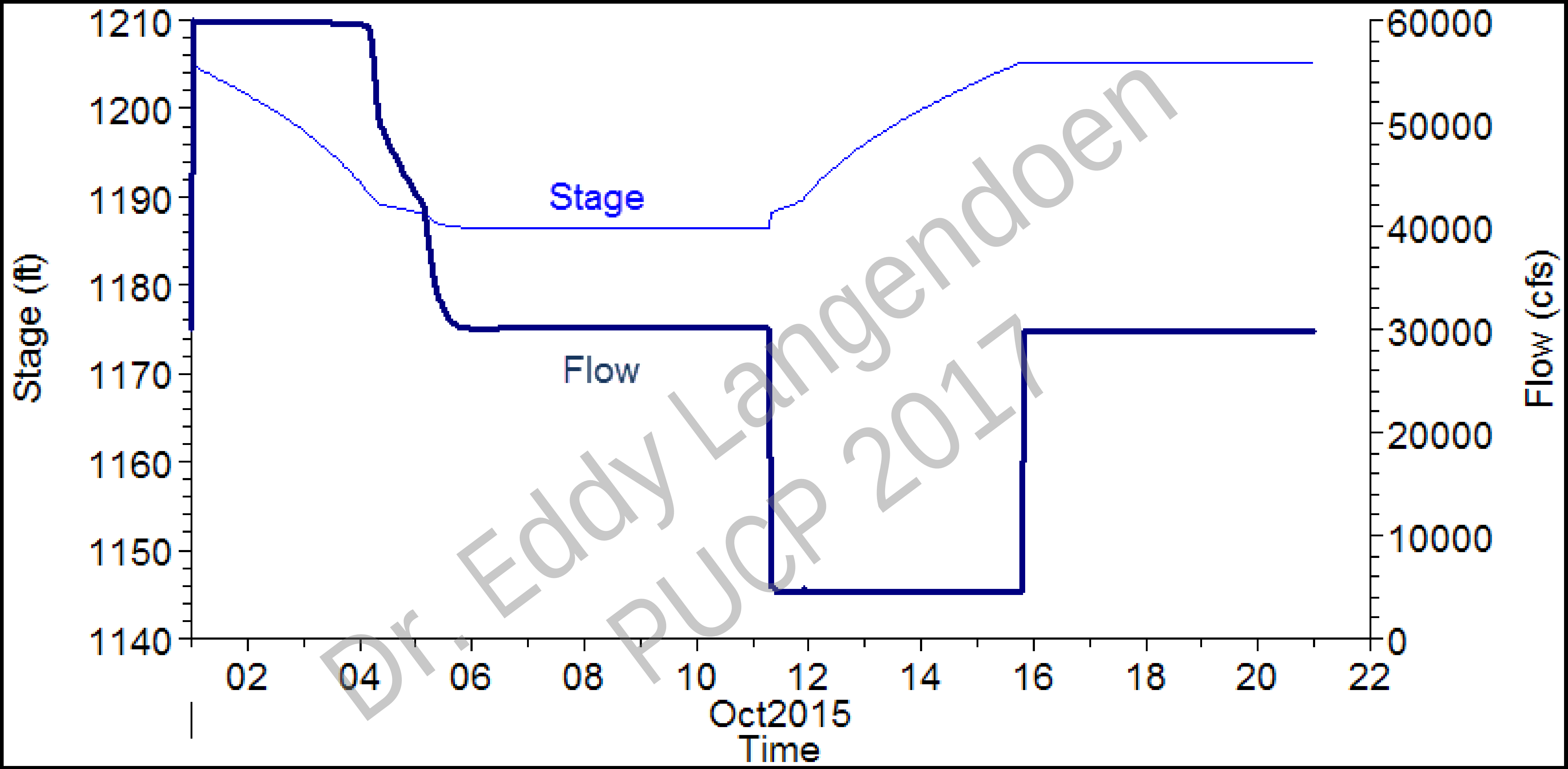
Get Sim Value

Set Operational Param

Comment

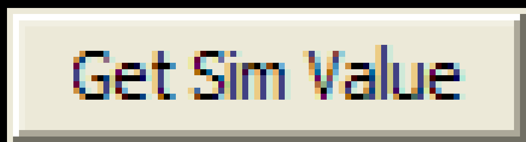
Branch (If/Else)

Rules



-The relatively simple rule set in the previous slide generated this draining/flushing/refilling hydrograph.

Rules: What's Next



= Sediment Variables

Sediment output as Simulation Variables will allow automated gate operation based on:

-Release Concentrations

-Delta aggradation or advancement

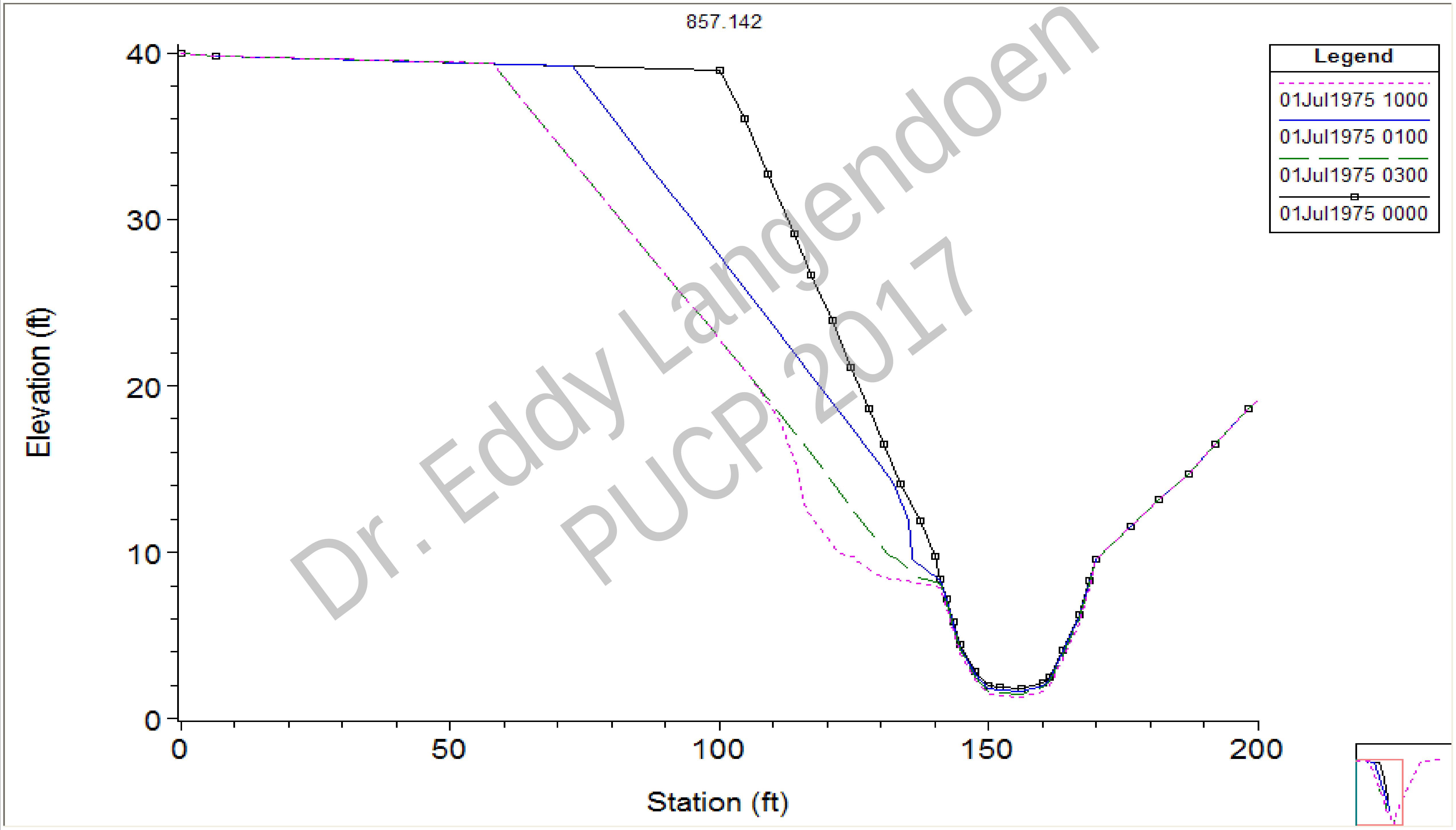
-Inflowing sediment concentrations (e.g. for sluicing/pass through analysis)

= Dredging Schedules

Will target dredging operations to bed changes

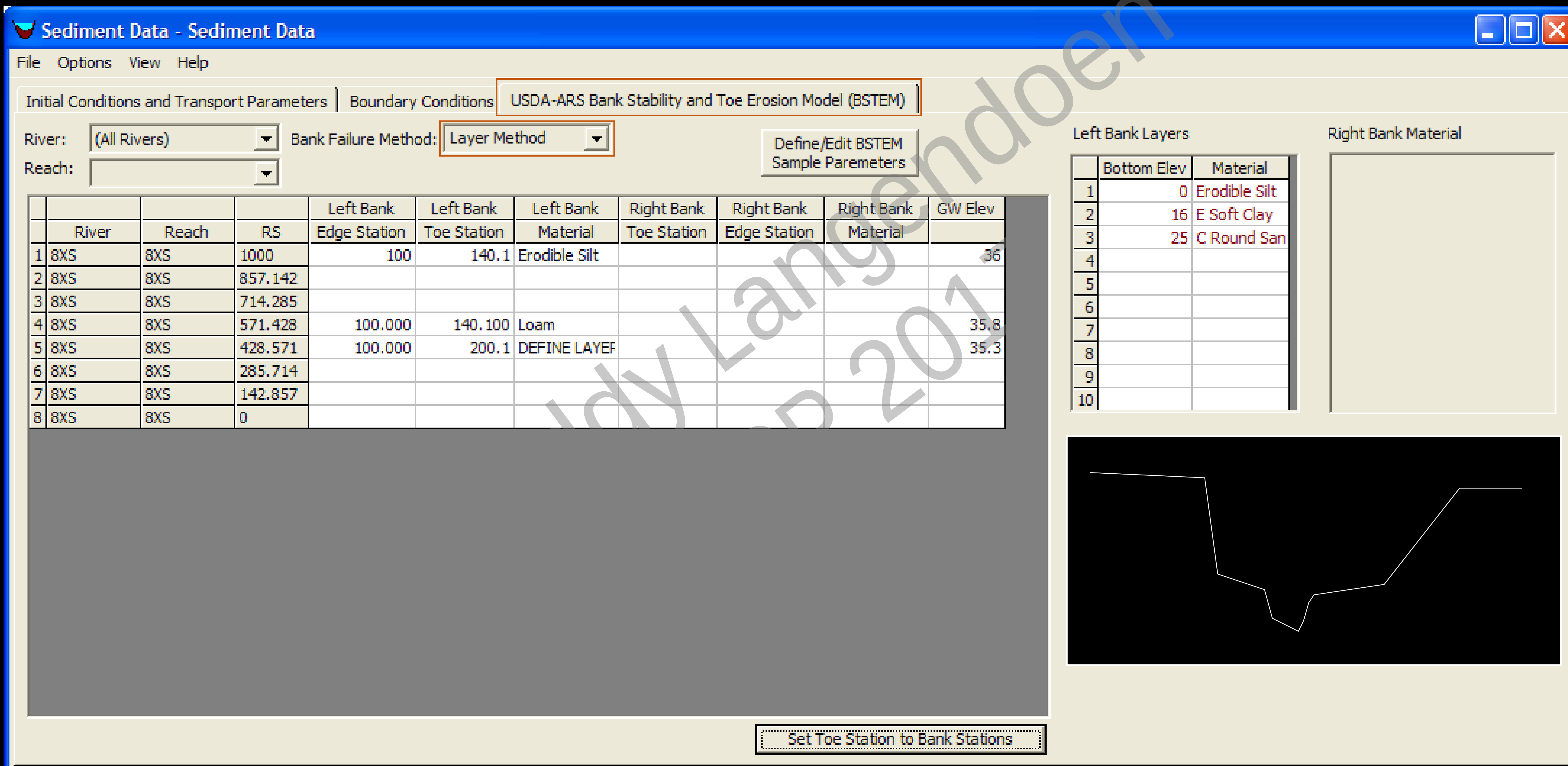
-(e.g. if Mass Δ at XS 849>+100,000 tons → Dredge)

Using the USDA-ARS Bank Failure and Toe Scour (BSTEM) Routines in HEC-RAS



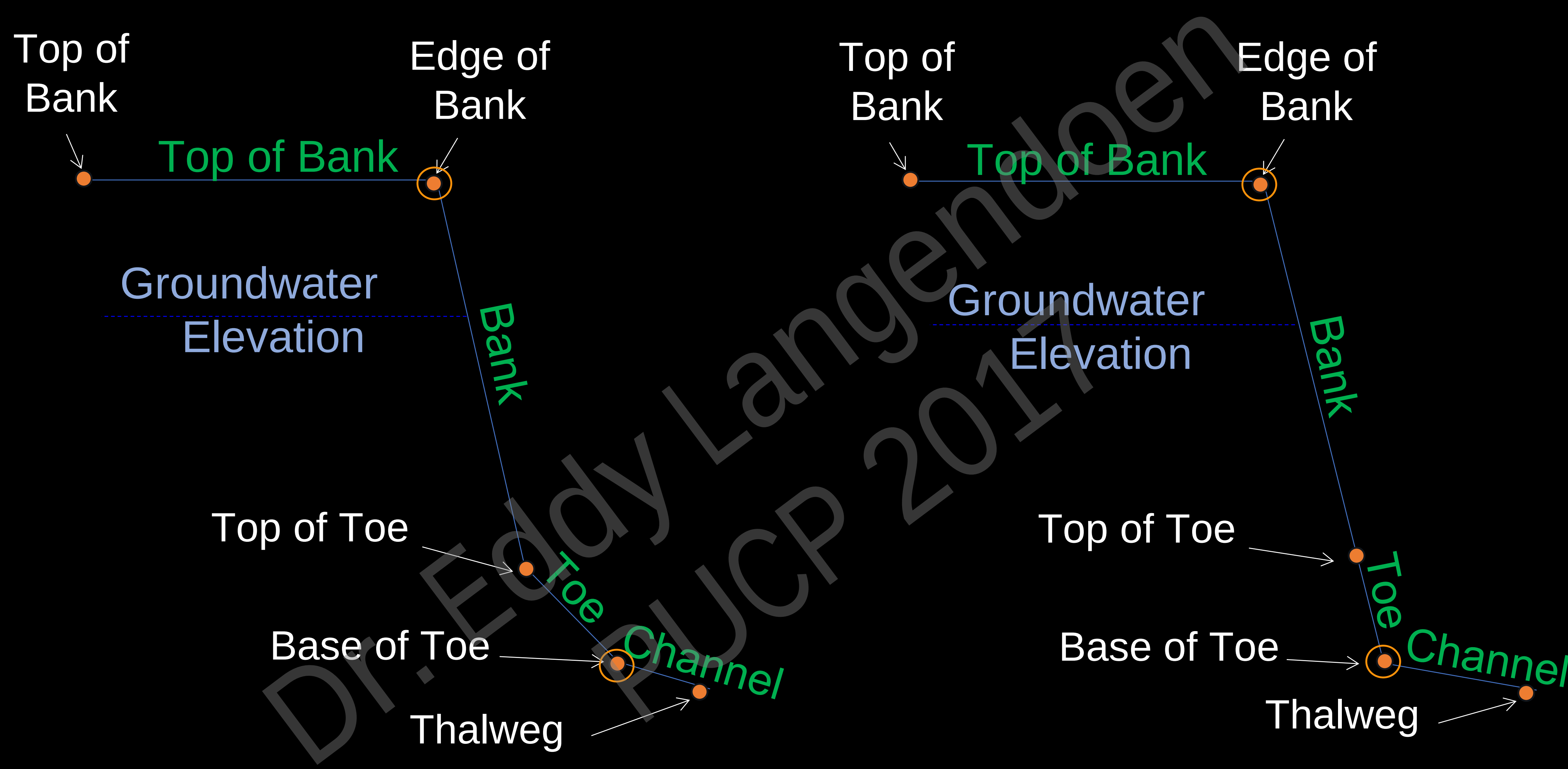
Stanford Gibson, PhD
Hydrologic Engineering Center

USDA-ARS BSTEM Interface



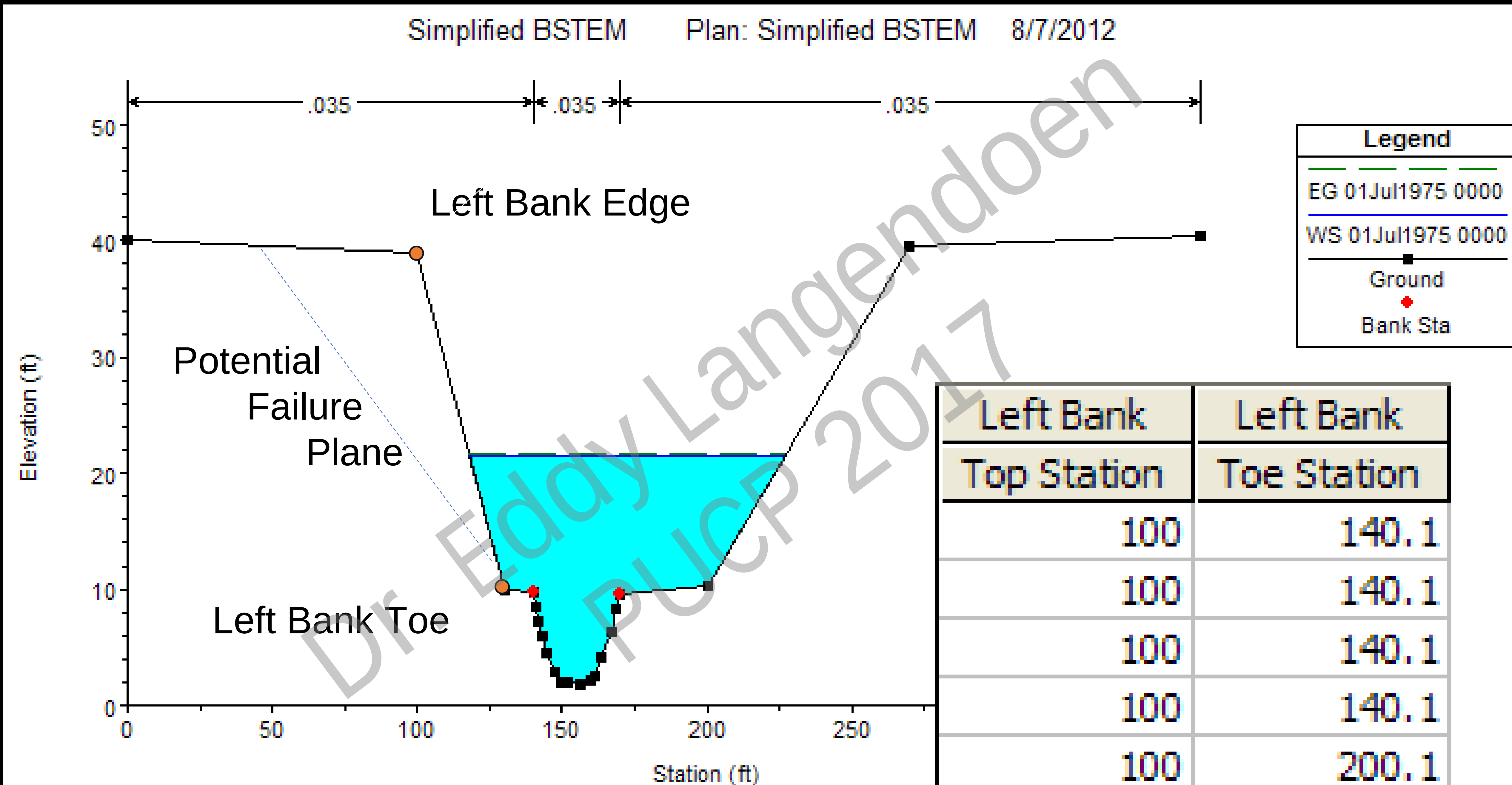
-A third optional tab in the Sediment Data Editor

BSTEM Bank Schematic



HEC-RAS simplifies this to two important points: Edge of Bank and Toe

Defining top of Bank and Toe



Left Bank Top Station	Left Bank Toe Station
100	140.1
100	140.1
100	140.1
100	140.1
100	200.1
100	140.1
100	140.1

Set Toe Station to Bank Stations

Defining Bank Material

Three Methods:

1. Pre-Defined Default Parameters
2 .Single Set of User Defined Material
3. Layers of Unique Material at a Bank

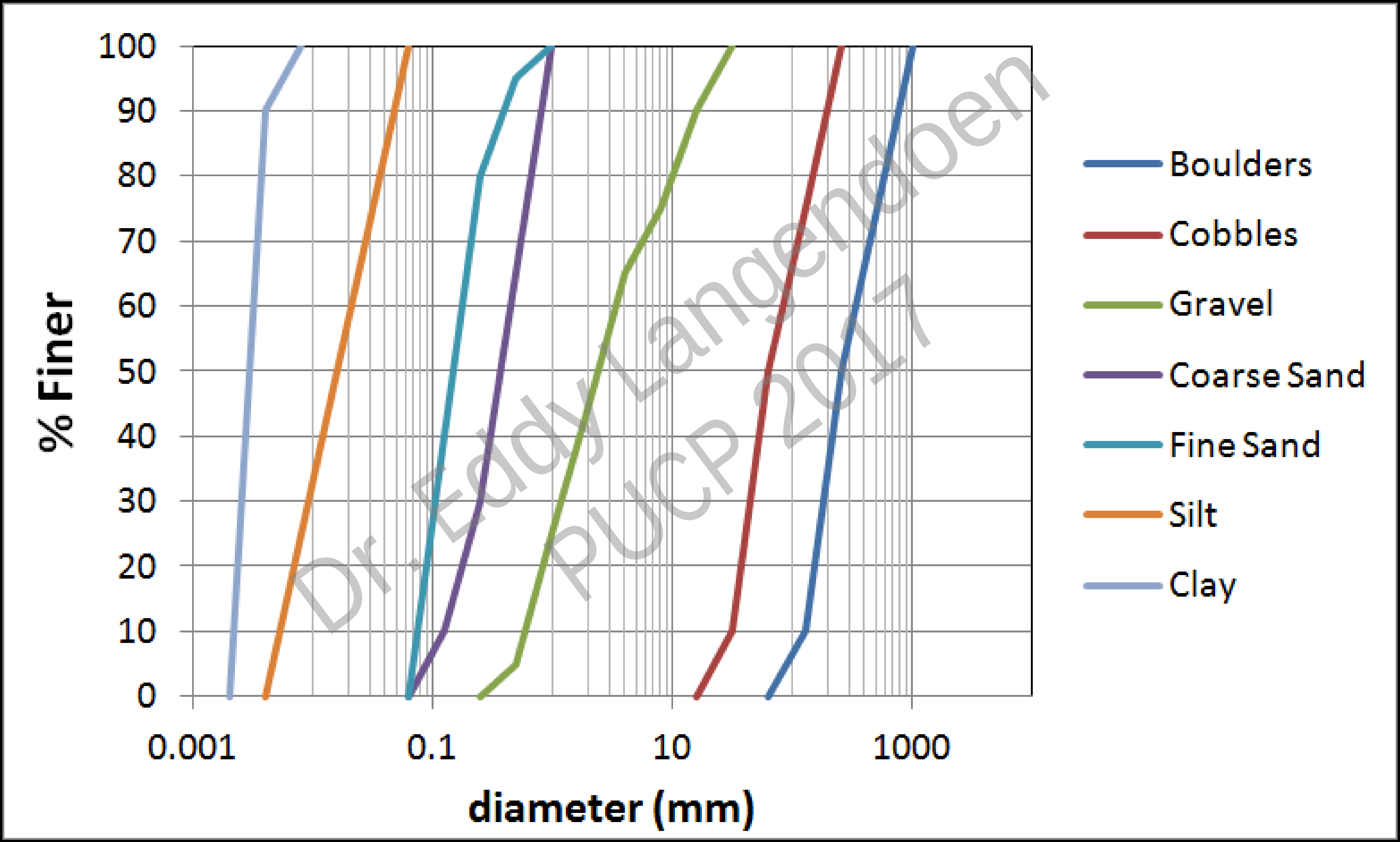
	River	Reach	RS	Left Bank Edge Station	Left Bank Toe Station	Left Bank Material
1	8XS	8XS	1000	100	140.1	Erodible Silt
2	8XS	8XS	857.142			
3	8XS	8XS	714.285	100	140.1	Loam
4	8XS	8XS	571.428			
5	8XS	8XS	428.571	100.000	200.1	
6	8XS	8XS	285.714			
7	8XS	8XS	142.857			
8	8XS	8XS	0			

Boulders
Cobbles
Gravel
C Angular
C Round S
F Angular
F Round S
Erodible Sil

Default Material Parameters

Default Material Type	Saturated Unit Weight (lbf/ft^3)	Friction Angle (ϕ')	Cohesion (lb/ft2)	ϕ^b	Critical Shear (lb/ft2)	Erodibility ($ft^3/lbf\text{-}s$)
Boulders	127.3	42	0	15	10.4	7.04E-07
Cobbles	127.3	42	0	15	2.59	1.41E-06
Gravel	127.3	36	0	15	0.23	4.74E-06
Coarse Angular Sand	117.8	32.3	8.354	15	0.0106	2.21E-05
Coarse Round Sand	117.8	28.3	8.354	15	0.0106	2.21E-05
Fine Angular Sand	117.8	32.3	8.354	15	0.00267	4.40E-05
Fine Round Sand	117.8	28.3	8.354	15	0.00267	4.40E-05
Erodible Silt	114.6	26.6	89.81	15	0.00209	4.94E-05
Moderate Silt	114.6	26.6	89.81	15	0.1044	7.07E-06
Resistant Silt	114.6	26.6	89.81	15	1.0443	2.20E-06
Erodible Soft Clay	112.7	26.4	171.26	15	0.00209	4.94E-05
Moderate Soft Clay	112.7	26.4	171.26	15	0.1044	7.07E-06
Resistant Soft Clay	112.7	26.4	171.26	15	1.0443	4.94E-05
Erodible Stiff Clay	112.7	21.1	263.16	15	14.6	4.94E-05
Moderate Stiff Clay	112.7	21.1	263.16	15	0.1044	7.07E-06
Resistant Stiff Clay	112.7	21.1	263.16	15	1.0443	4.94E-05

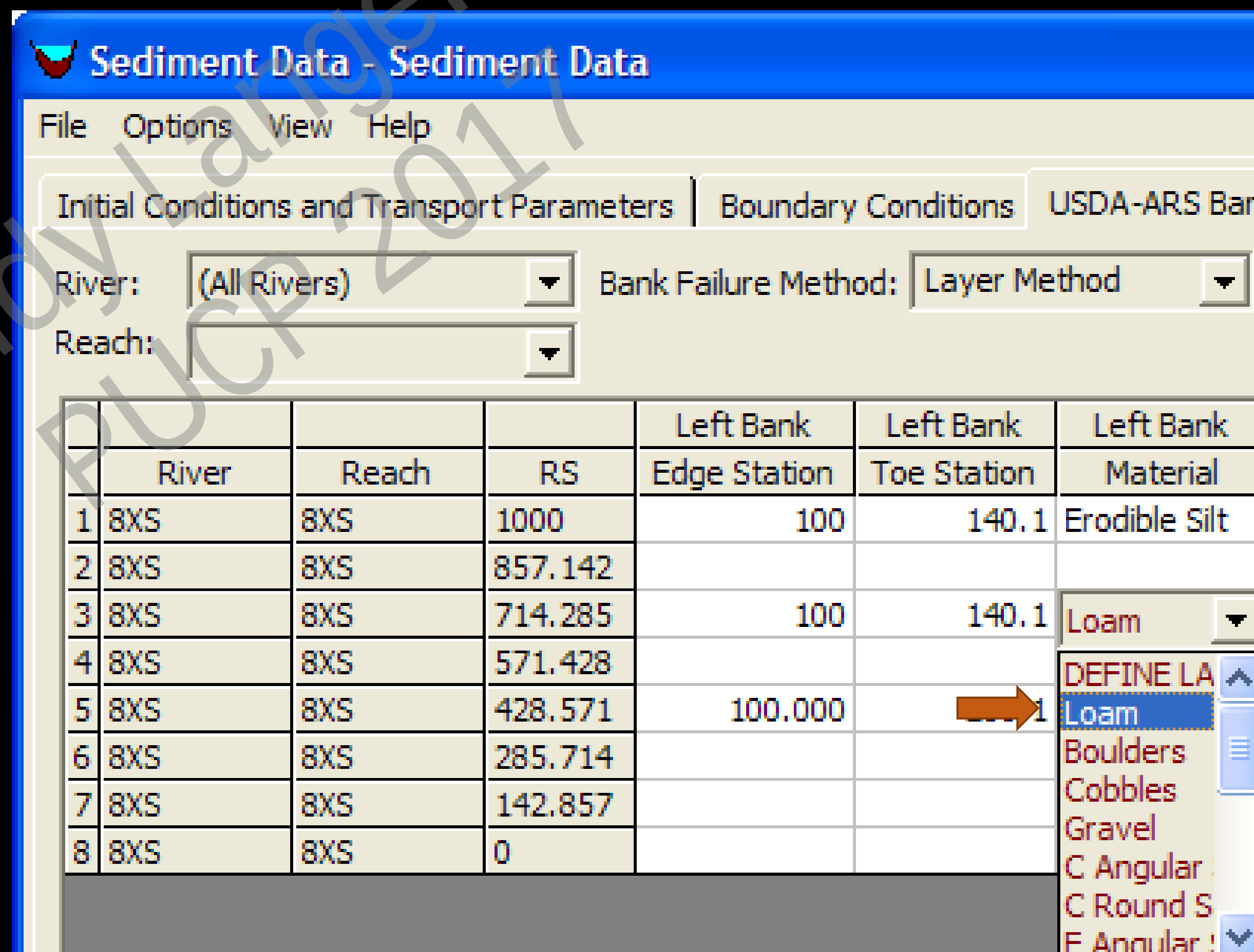
Default Material Gradations



Defining Bank Material

Three Methods:

1. Pre-Defined Default Parameters
2. **Single Set of User Defined Material**
3. Layers of Unique Material at a Bank

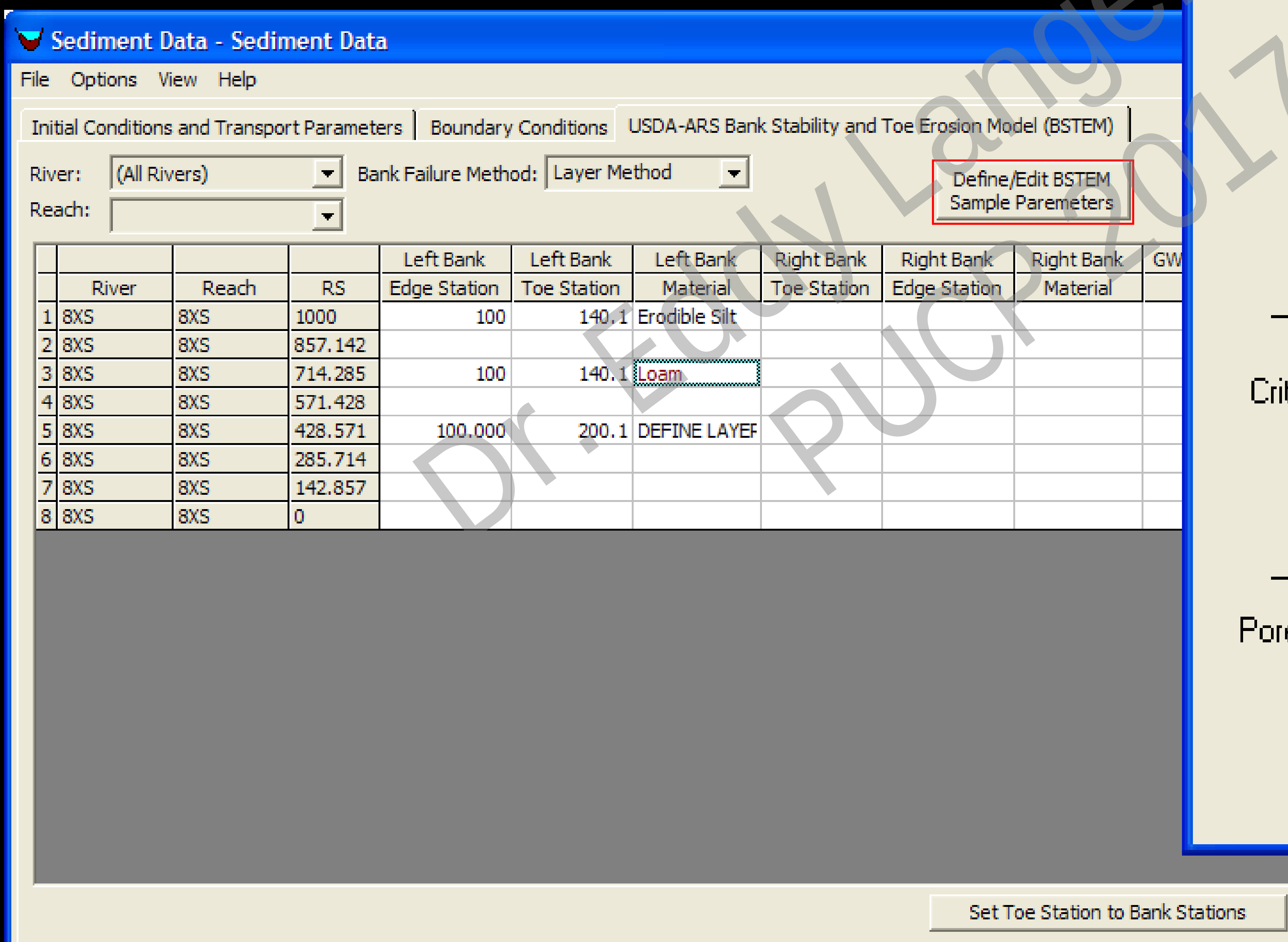


User defined materials will appear between the "DEFINE LAYERS" method and the default materials

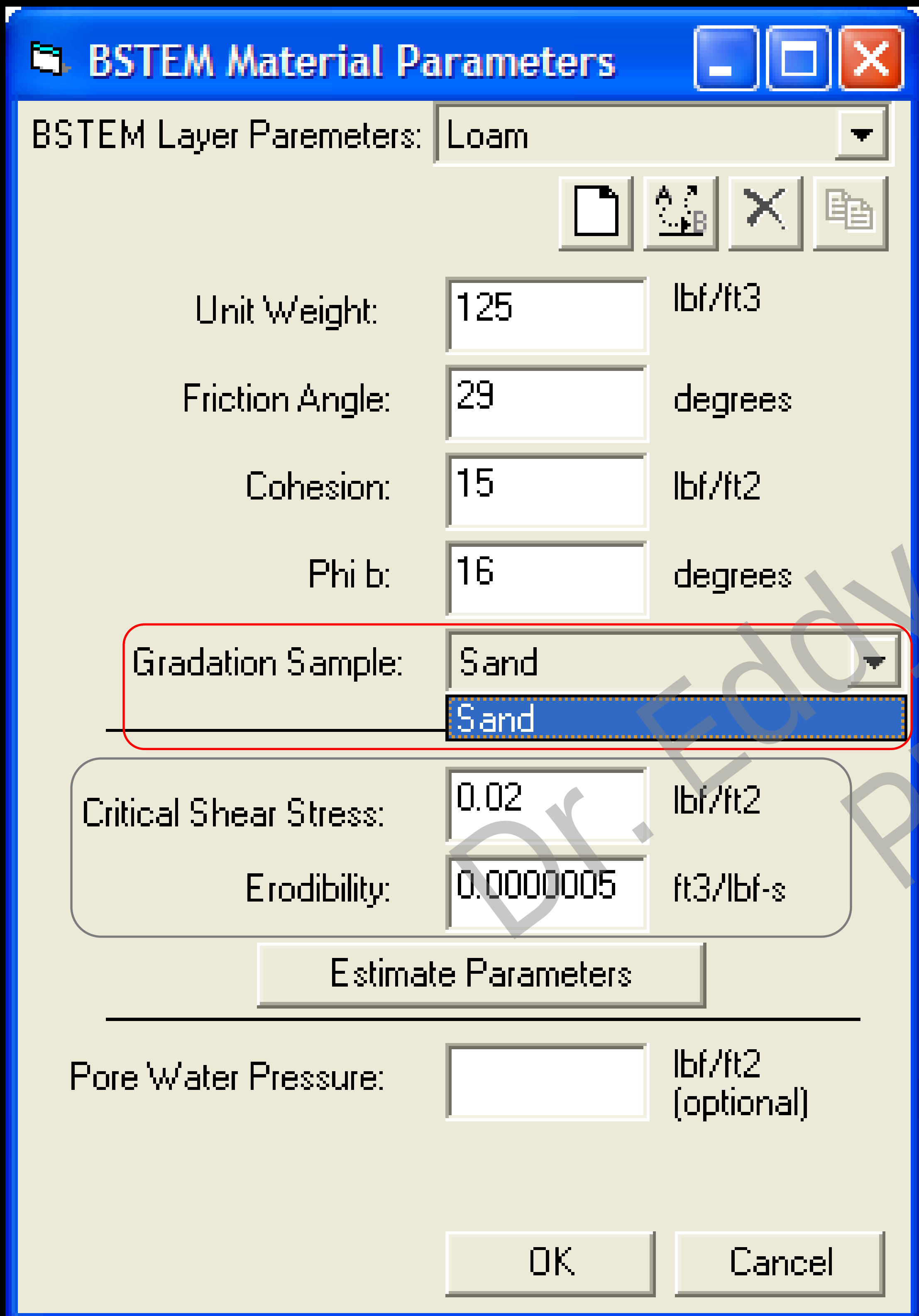
Defining Bank Material

Three Methods:

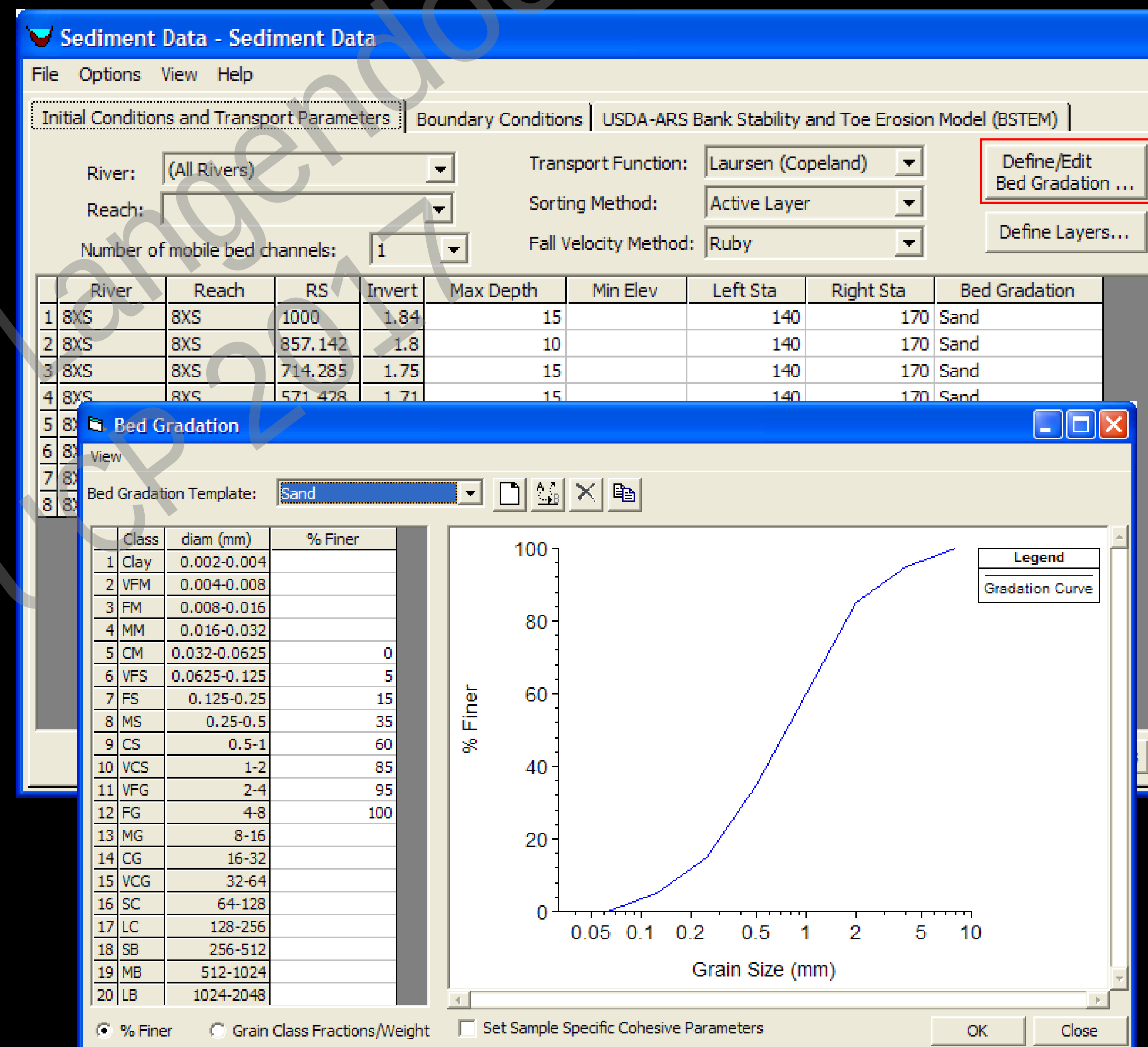
1. Pre-Defined Default Parameters
2. **Single Set of User Defined Material**
3. Layers of Unique Material at a Bank



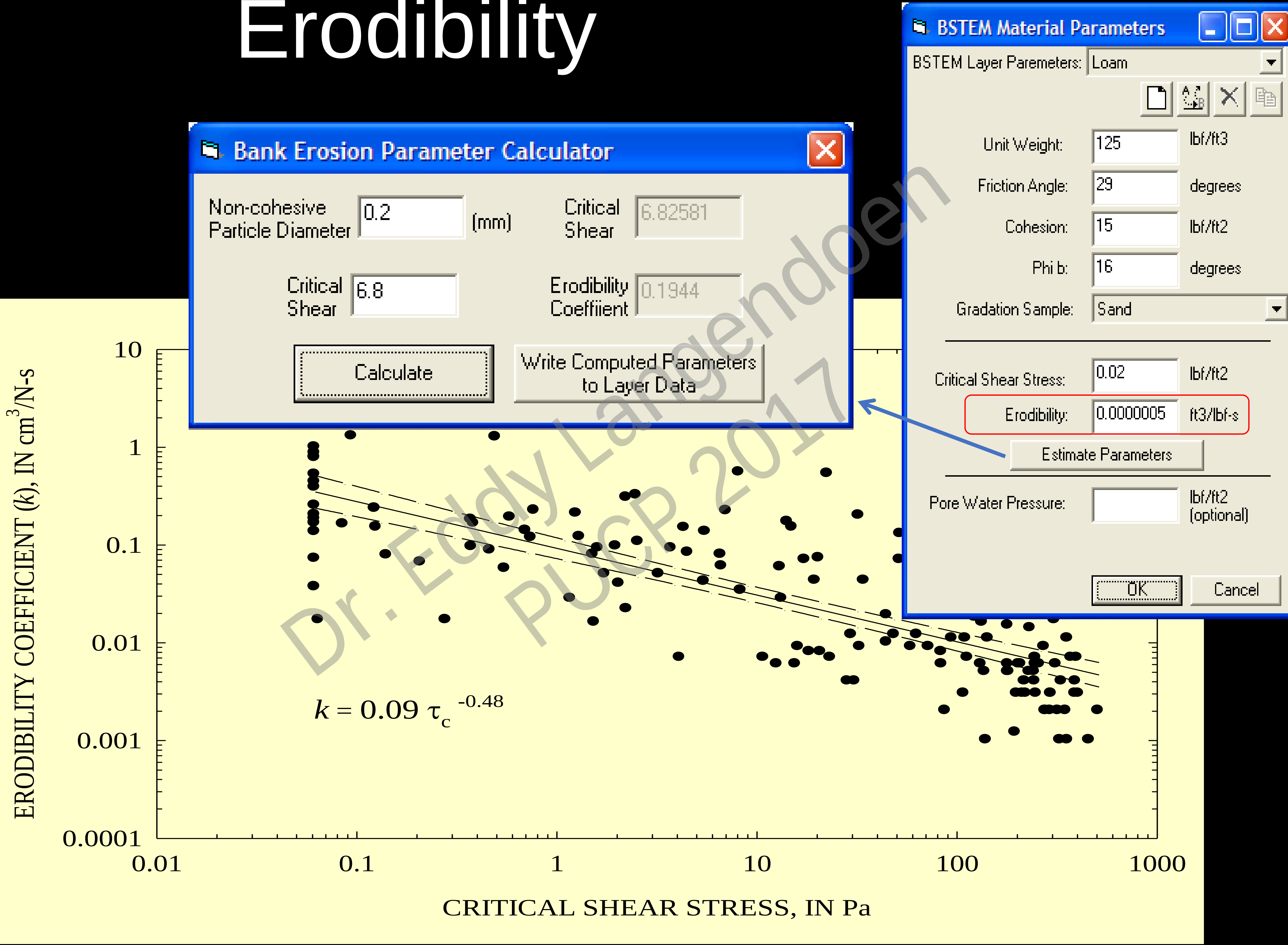
Gradation of the Failure Material



- The gradation drop down is populated with the gradations from the main menu.
- Affects the toe scour method and results.



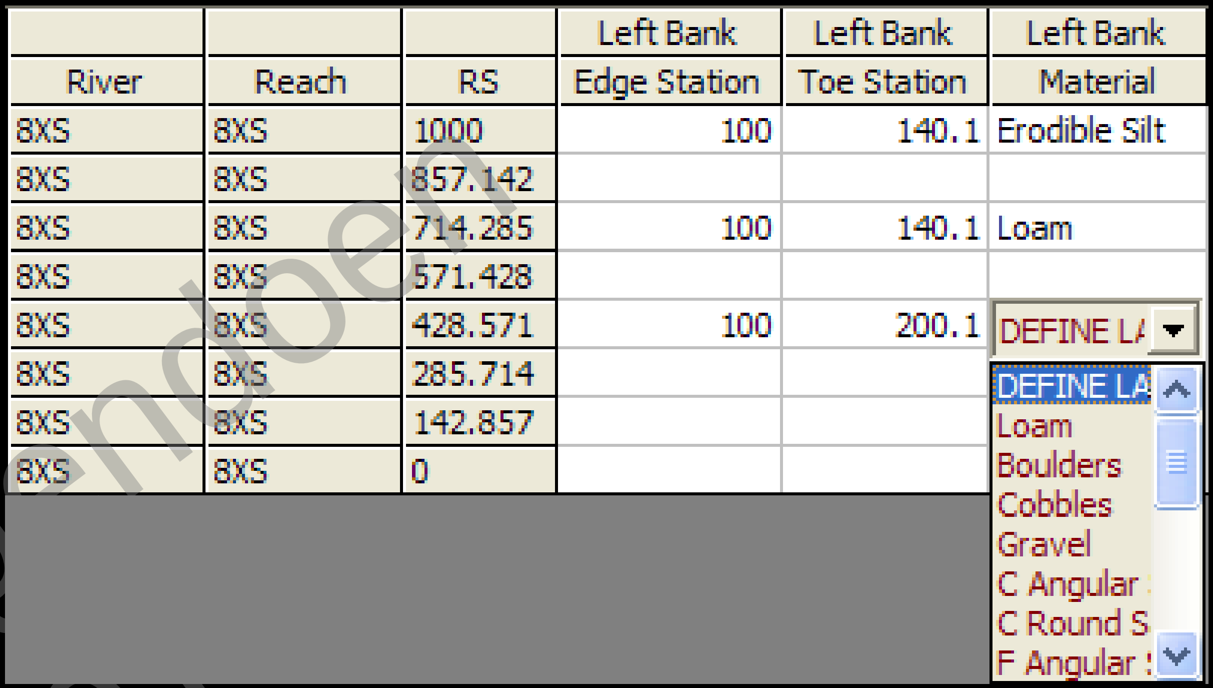
Erodibility



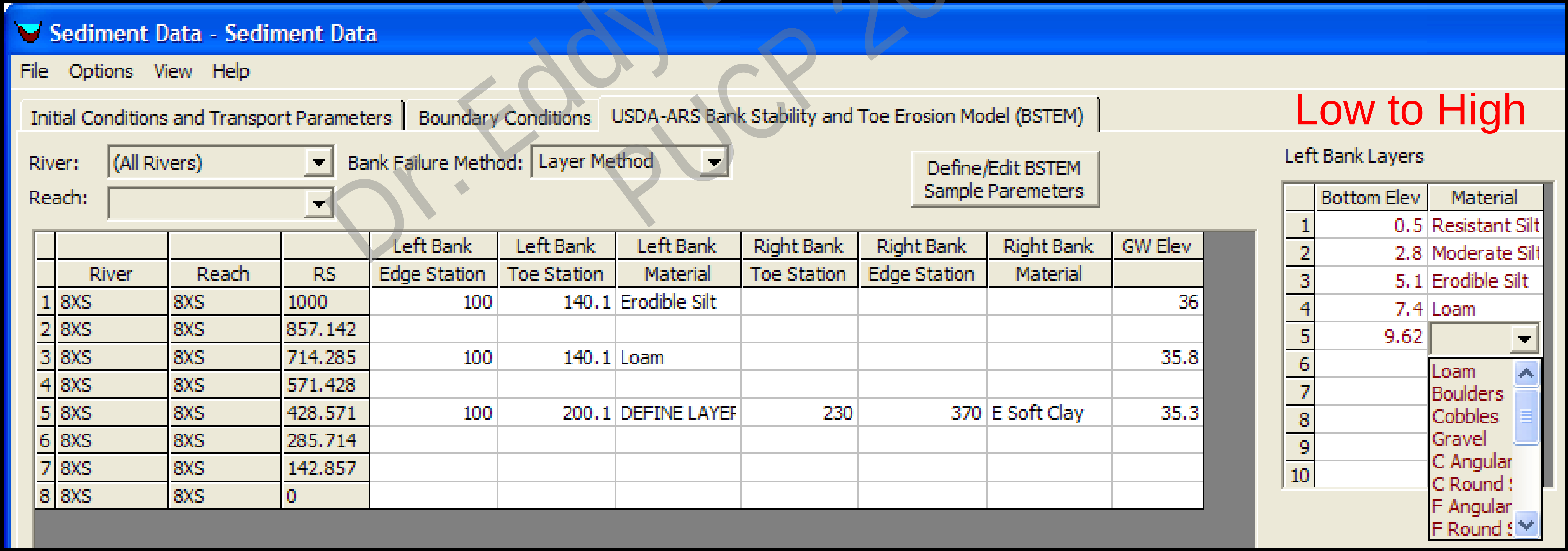
Defining Bank Material

<u>Three Methods</u>:

1. Pre-Defined Default Parameters
2. Single Set of User Defined Material
3. **Layers of Unique Material at a Bank**



River	Reach	RS	Left Bank Edge Station	Left Bank Toe Station	Left Bank Material
8XS	8XS	1000	100	140.1	Erodible Silt
8XS	8XS	857.142			
8XS	8XS	714.285	100	140.1	Loam
8XS	8XS	571.428			
8XS	8XS	428.571	100	200.1	DEFINE LA
8XS	8XS	285.714			
8XS	8XS	142.857			
8XS	8XS	0			



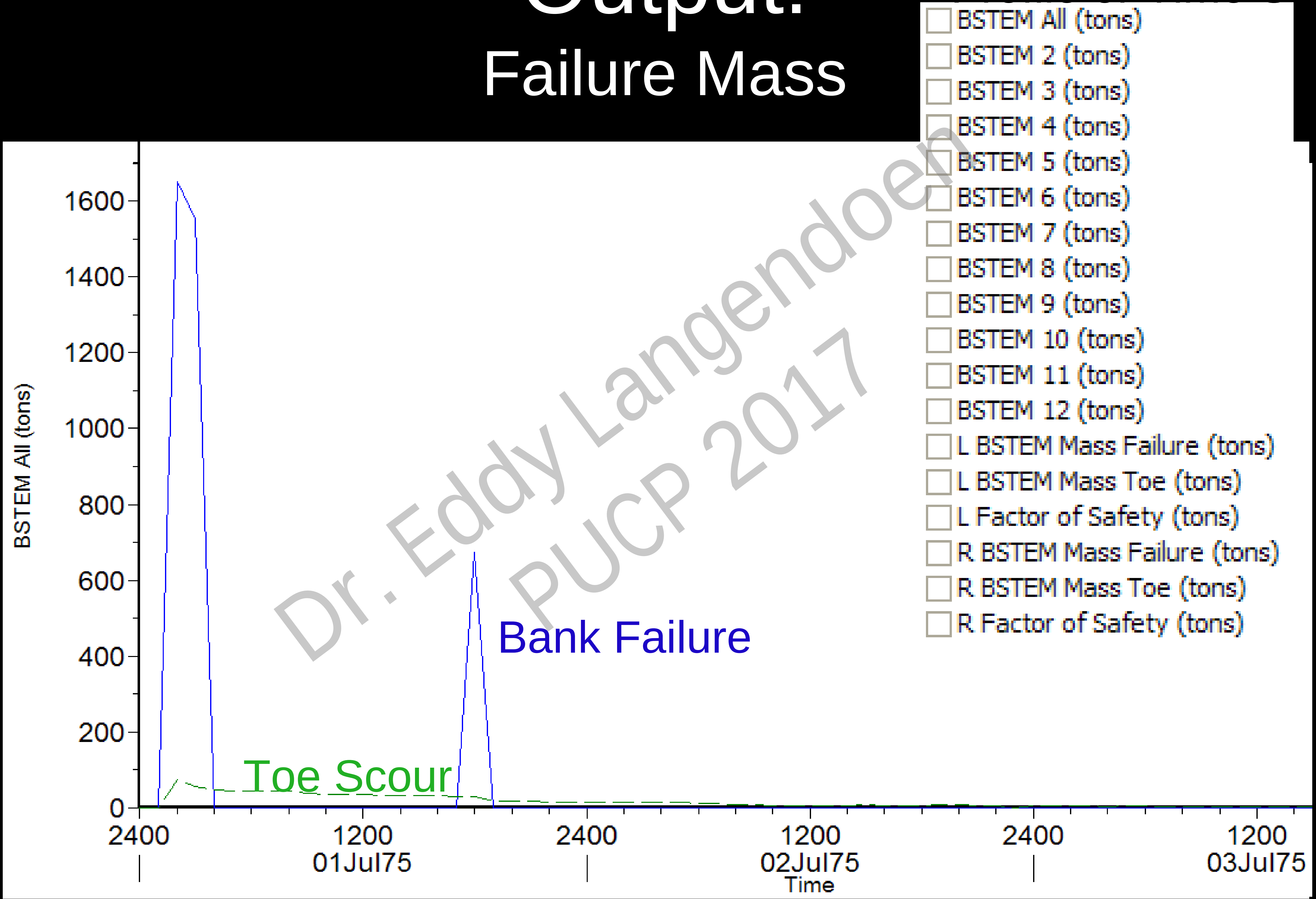
	River	Reach	RS	Left Bank Edge Station	Left Bank Toe Station	Left Bank Material	Right Bank Toe Station	Right Bank Edge Station	Right Bank Material	GW Elev
1	8XS	8XS	1000	100	140.1	Erodible Silt				36
2	8XS	8XS	857.142							
3	8XS	8XS	714.285	100	140.1	Loam				35.8
4	8XS	8XS	571.428							
5	8XS	8XS	428.571	100	200.1	DEFINE LAYEF	230	370	E Soft Clay	35.3
6	8XS	8XS	285.714							
7	8XS	8XS	142.857							
8	8XS	8XS	0							

Low to High

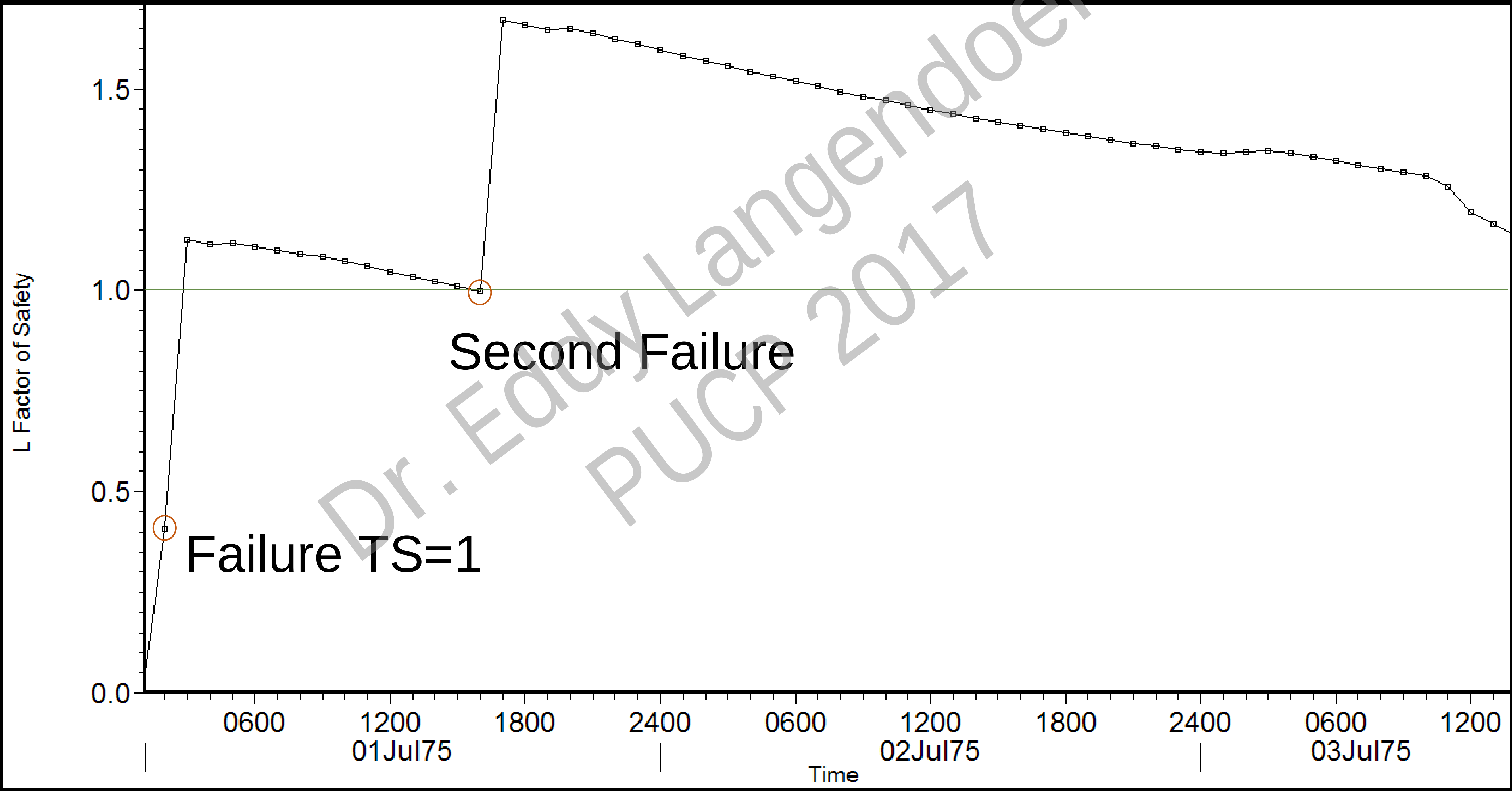
Left Bank Layers

	Bottom Elev	Material
1	0.5	Resistant Silt
2	2.8	Moderate Silt
3	5.1	Erodible Silt
4	7.4	Loam
5	9.62	
6		
7		
8		
9		
10		

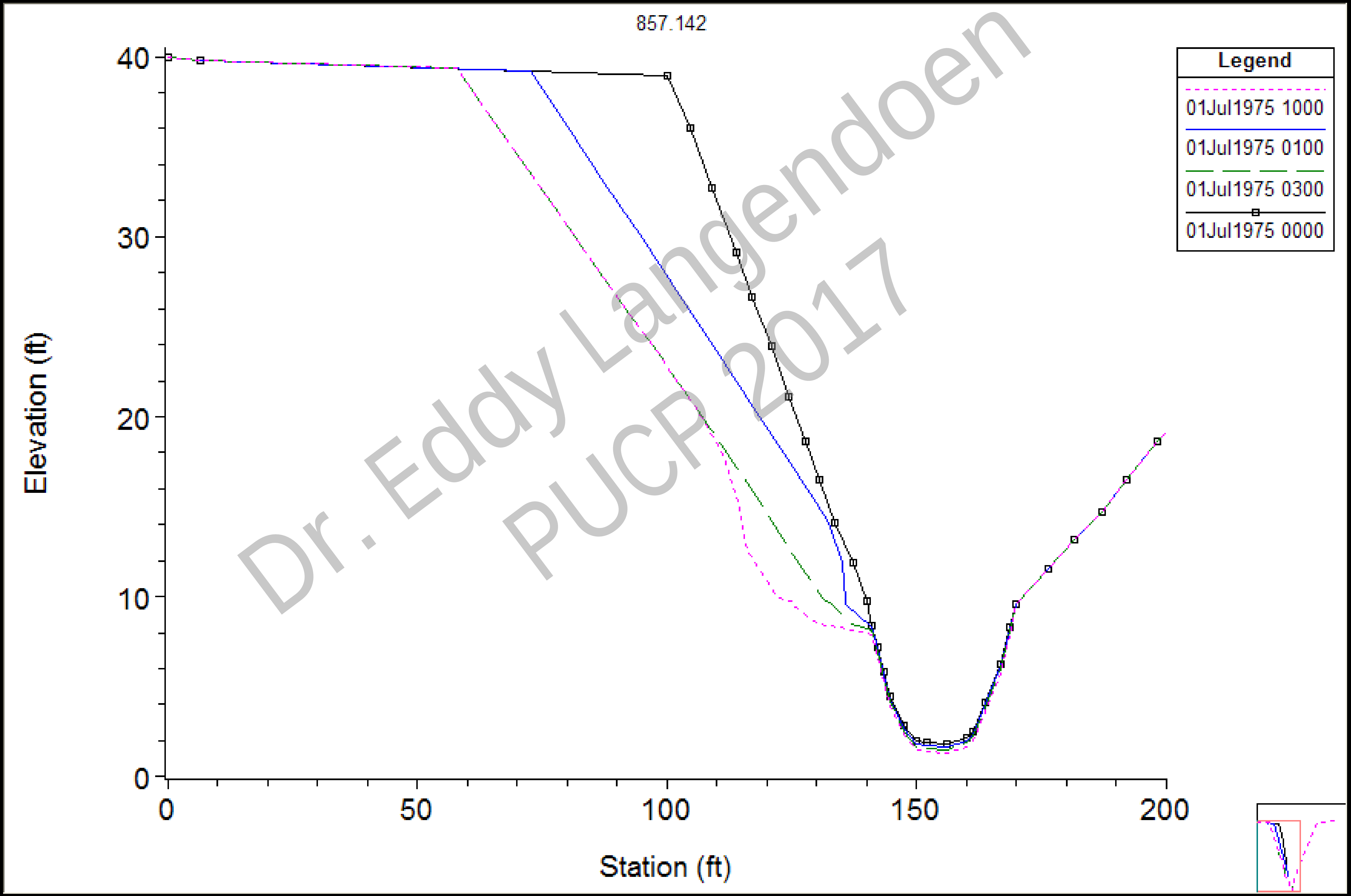
Output:
Failure Mass



Output:
Factor of Safety



Output:
Cross Section



United States Department of Agriculture

THANK YOU.

QUESTIONS?