

Non-Newtonian Validation and Verification in HEC-RAS



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Santa Barbara Mud-and-Debris Flow

Local News

A Year Ago, Montecito Debris Flows Brought 'Unfathomable Destruction' to Coastal Community

Residents and first responders recall and reflect on the fateful Jan. 9 events that reshaped their world



Santa Barbara County responders launched into rescue mode in the early-morning hours of Jan. 9, 2018 after debris flows devastated Montecito. (Ray Ford / Noozhawk photo)

1 > of 11

By Joshua Molina, Noozhawk Staff Writer | @JECMolina | January 8, 2019 | 10:02 p.m.

SECTIONS

SEARCH

Chicago Tribune

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NATION & WORLD

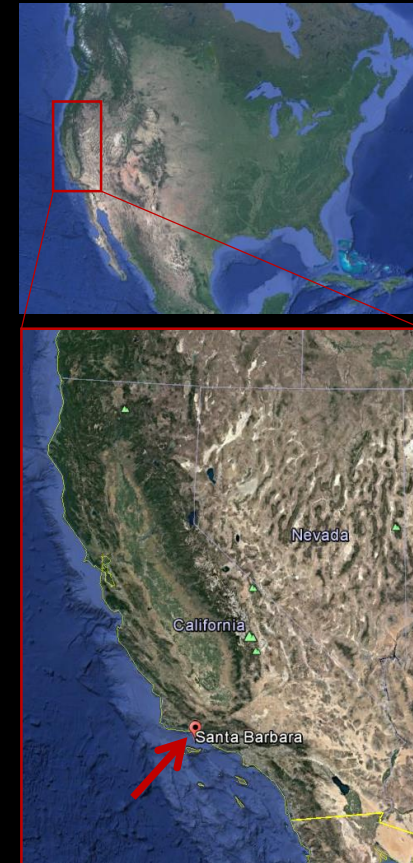
Mudslide-stricken California town is all but emptied out as residents ordered to leave

By KRYSTA FAURIA AND BRIAN MELLEY
ASSOCIATED PRESS | JAN 12, 2018 | 11:37 PM | MONTECITO, CALIF.

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A photograph showing a house surrounded by a large pile of rocks and debris, with a red 'X' marked on the house. The house is partially buried under the debris. The scene is a result of a mudslide or debris flow.

A house sits among boulders and mud along Glen Oaks Drive in Montecito after a major storm hit the burn area Wednesday. (Wally Skali / Los Angeles Times)



23 Fatalities
Damages:
\$200 Million (USD)

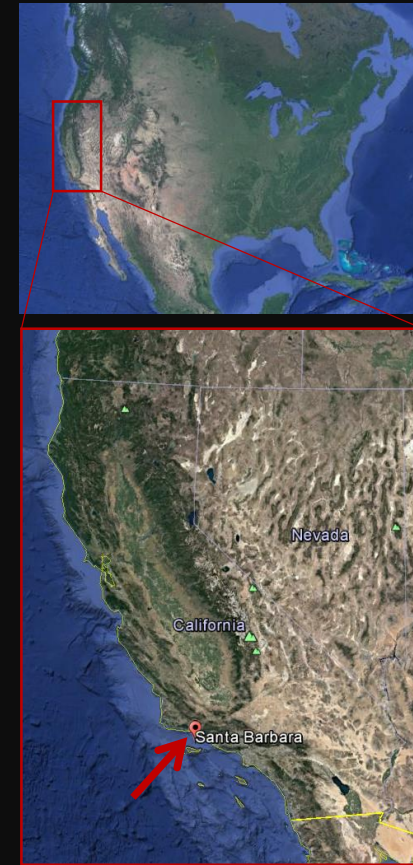
Santa Barbara Mud-and-Debris Flow



HEC-RAS
1&2D Hydraulic and
Morphodynamic Software

100,000 Downloads/Year
in 200 countries

Newtonian Assumptions



23 Fatalities
Damages:
\$200 Million (USD)

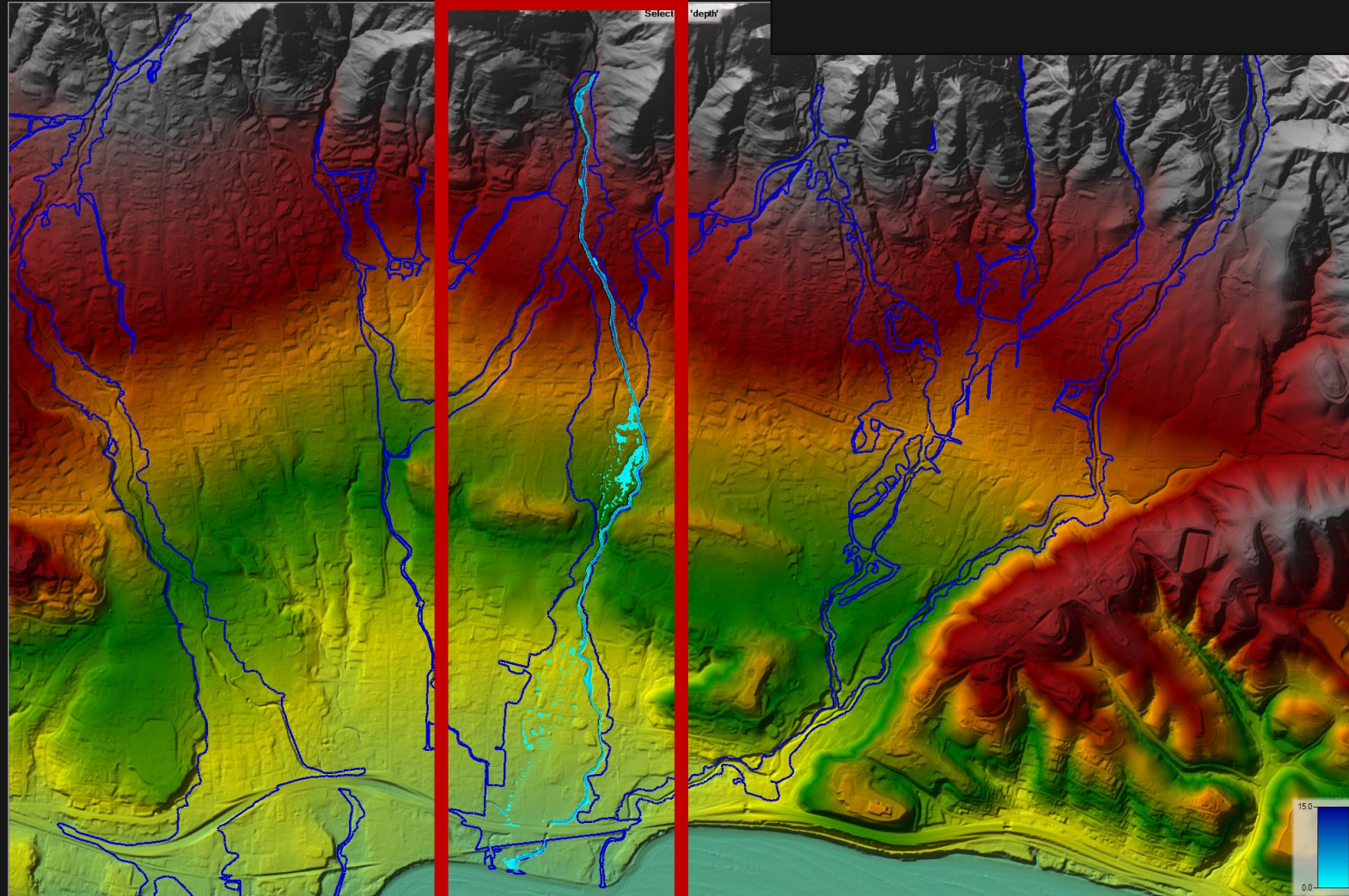
Santa Barbara Mud-and-Debris Flow



HEC-RAS
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Newtonian Assumptions



Non-Newtonian Validation and Verification in HEC-RAS

1.Non-Newtonian Closure in HEC-RAS

2.Laboratory and Meso-Scale Validation and Verification

3.Field Applications



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Non-Newtonian Validation and Verification in HEC-RAS

1.Non-Newtonian Closure in HEC-RAS

2.Laboratory and Meso-Scale Validation and Verification

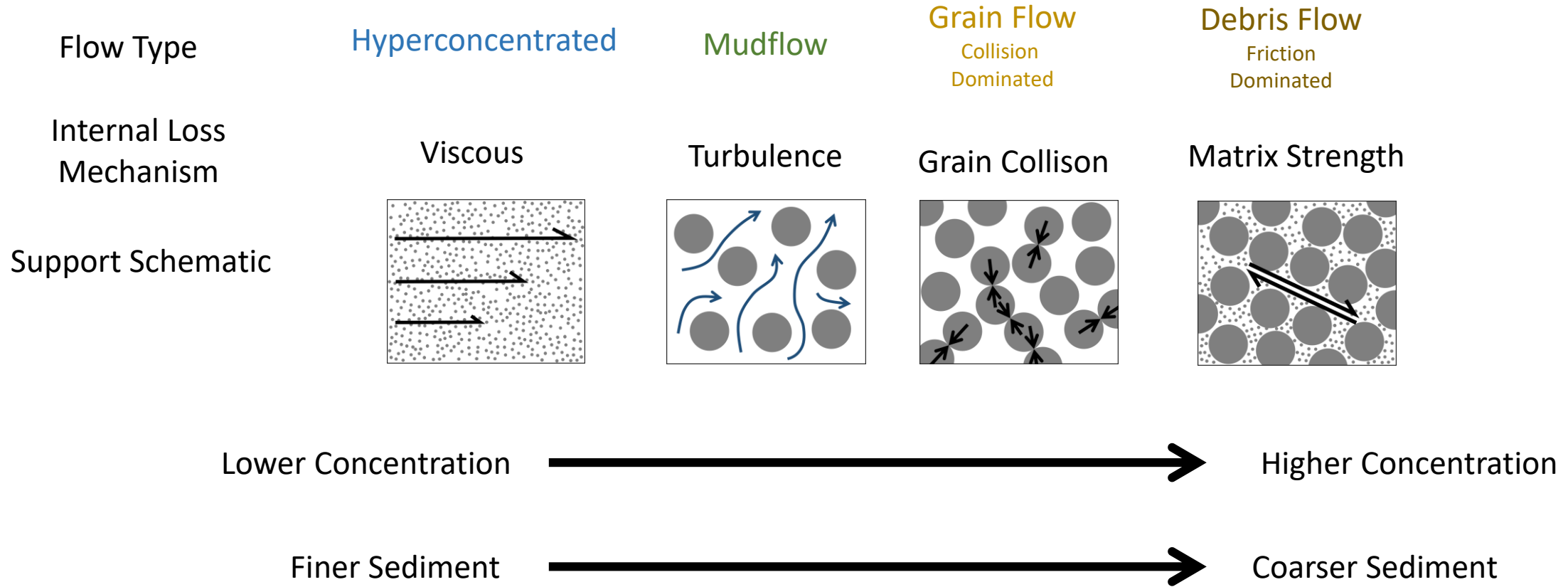
3.Field Applications



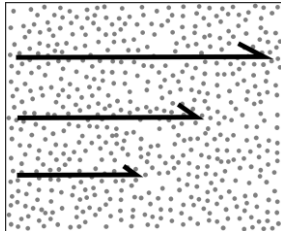
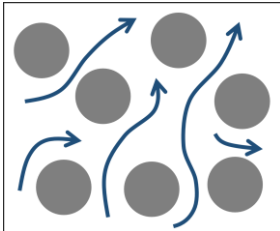
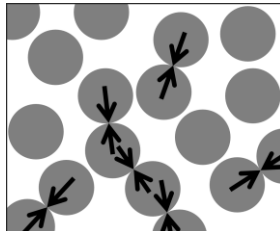
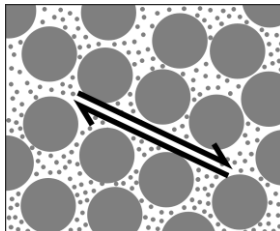
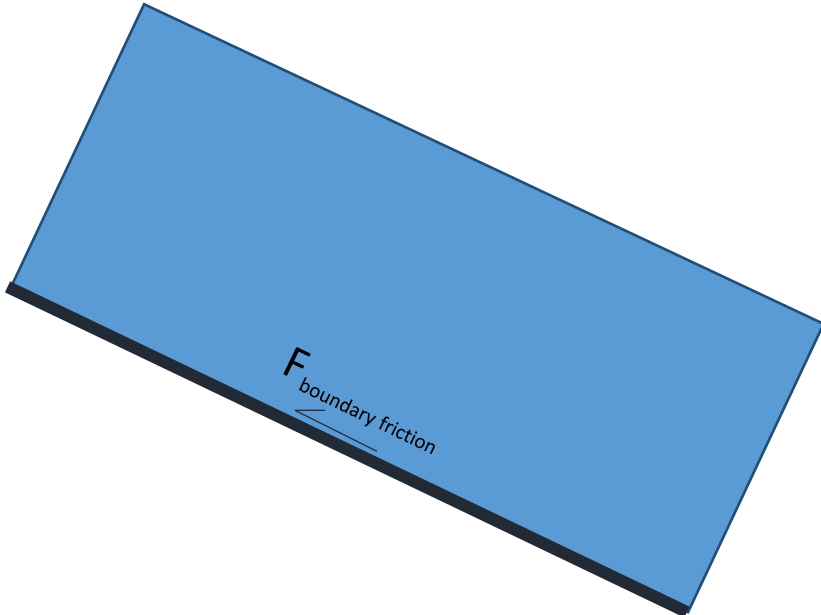

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Taxonomy of Geologic Flows



Taxonomy of Geologic Flows

Flow Type	Hyperconcentrated	Mudflow	Grain Flow Collision Dominated	Debris Flow Friction Dominated
Internal Loss Mechanism	Viscous	Turbulence	Grain Collison	Matrix Strength
Support Schematic				
				
Clear Water Resisting Forces		Mud and Debris Flow Resisting Forces		

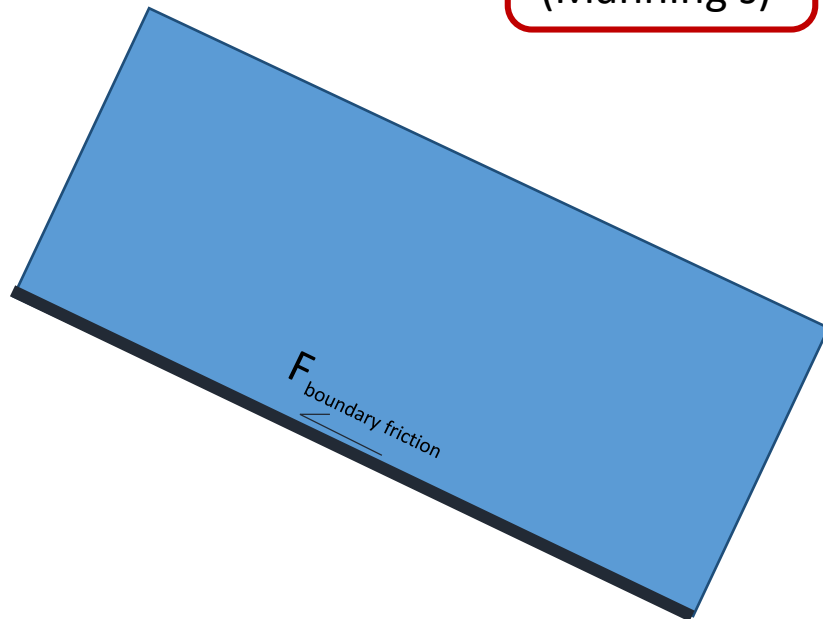
We Integrate These Effects in the Momentum Equation by Partitioning the Friction Slope

$$\frac{\partial Q}{\partial x} + \frac{\partial s_c (A + A_o)}{\partial t} - q = 0 \quad (\text{Conservation of Mass})$$

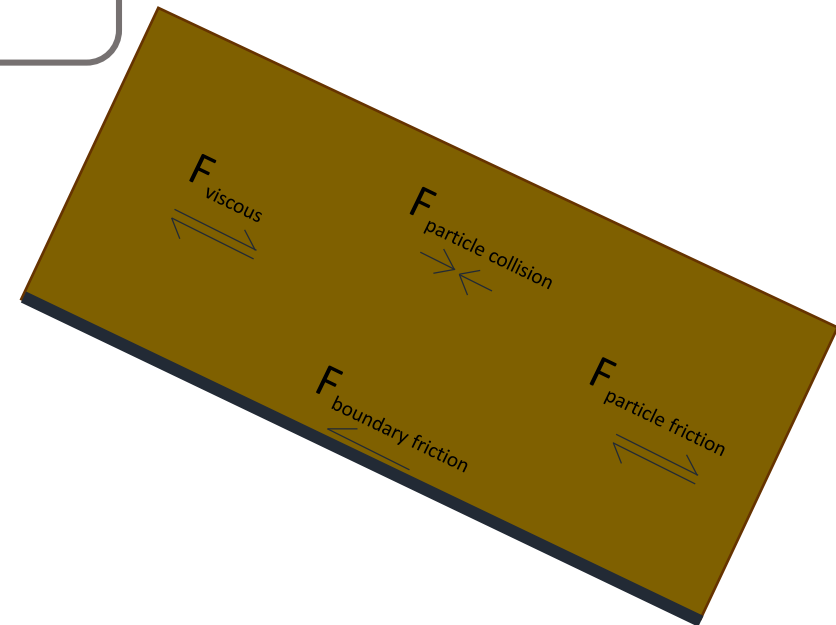
$$\frac{\partial (s_m Q)}{\partial t} + \frac{\partial (\beta Q^2 / A)}{\partial x} + gA \left(\frac{\partial h}{\partial x} + S_f + S_i \right) + L = 0 \quad (\text{Conservation of Momentum})$$

Friction Slope
(Manning's)

Viscous and
Inertial Internal
Losses



Clear Water Resisting Forces



Mud and Debris Flow Resisting Forces

We Integrate These Effects in the Momentum Equation by Partitioning the Friction Slope

$$\frac{\partial Q}{\partial x} + \frac{\partial s_c (A + A_o)}{\partial t} - q = 0 \quad (\text{Conservation of Mass})$$

$$\frac{\partial (s_m Q)}{\partial t} + \frac{\partial (\beta Q^2 / A)}{\partial x} + gA \left(\frac{\partial h}{\partial x} + S_f + S_i \right) + L = 0 \quad (\text{Conservation of Momentum})$$

Friction Slope
(Manning's)

Viscous and
Inertial Internal
Losses

Friction Slope is a Function
of Shear Stress

We Can Also Express Internal
Losses as a Stress

$$\tau_b = \gamma R S_f \sim \gamma D S_f$$

$$S_f = \left(\frac{\tau_b}{\gamma D} \right)$$

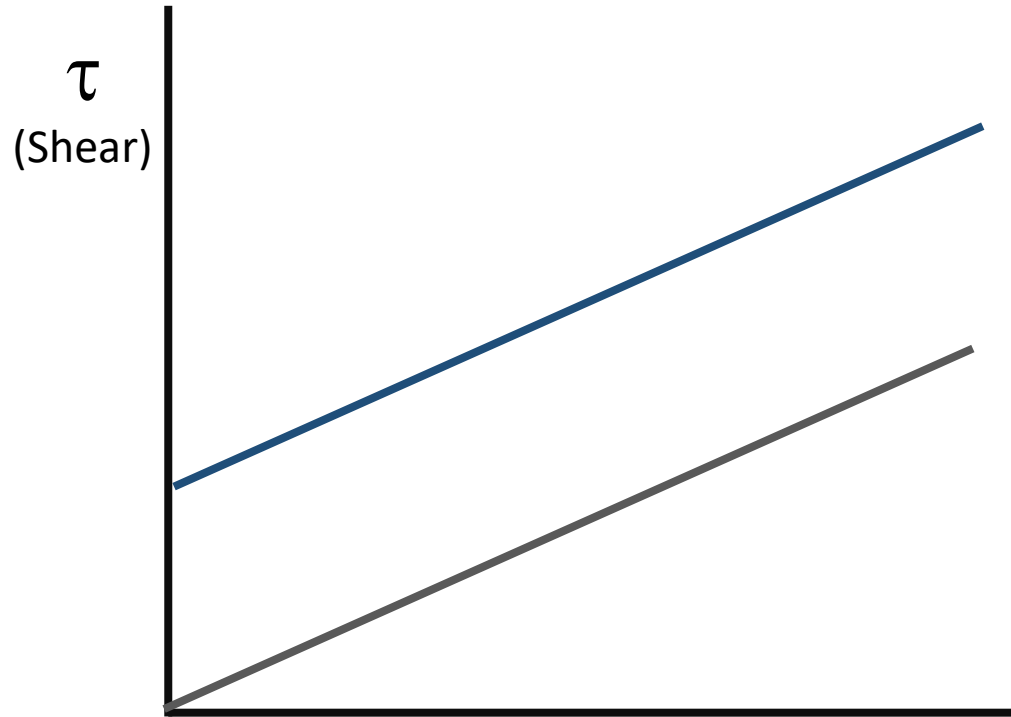
$$S_i = \left(\frac{\tau_i}{\gamma D} \right)$$

Which Allows Us To Quantify These Effects with Stress-Strain (Rheological) Models

Rheological Models

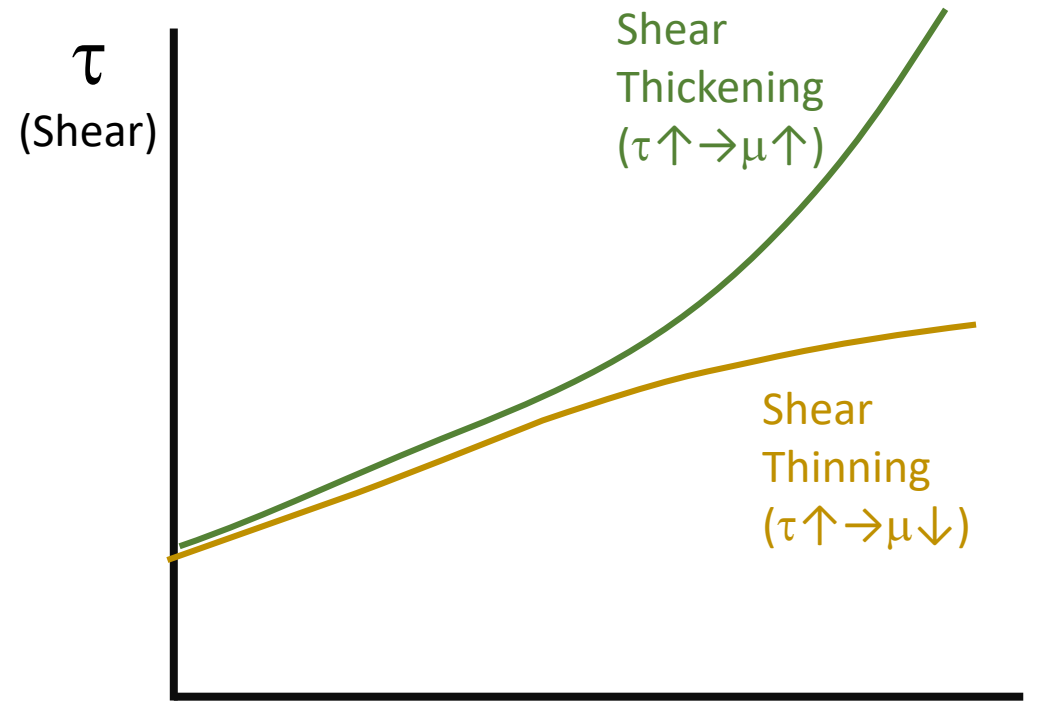
Deformational/Stress-Strain Relationships

$$\tau = \tau_y + \mu \left(\frac{dv_x}{dz} \right)$$

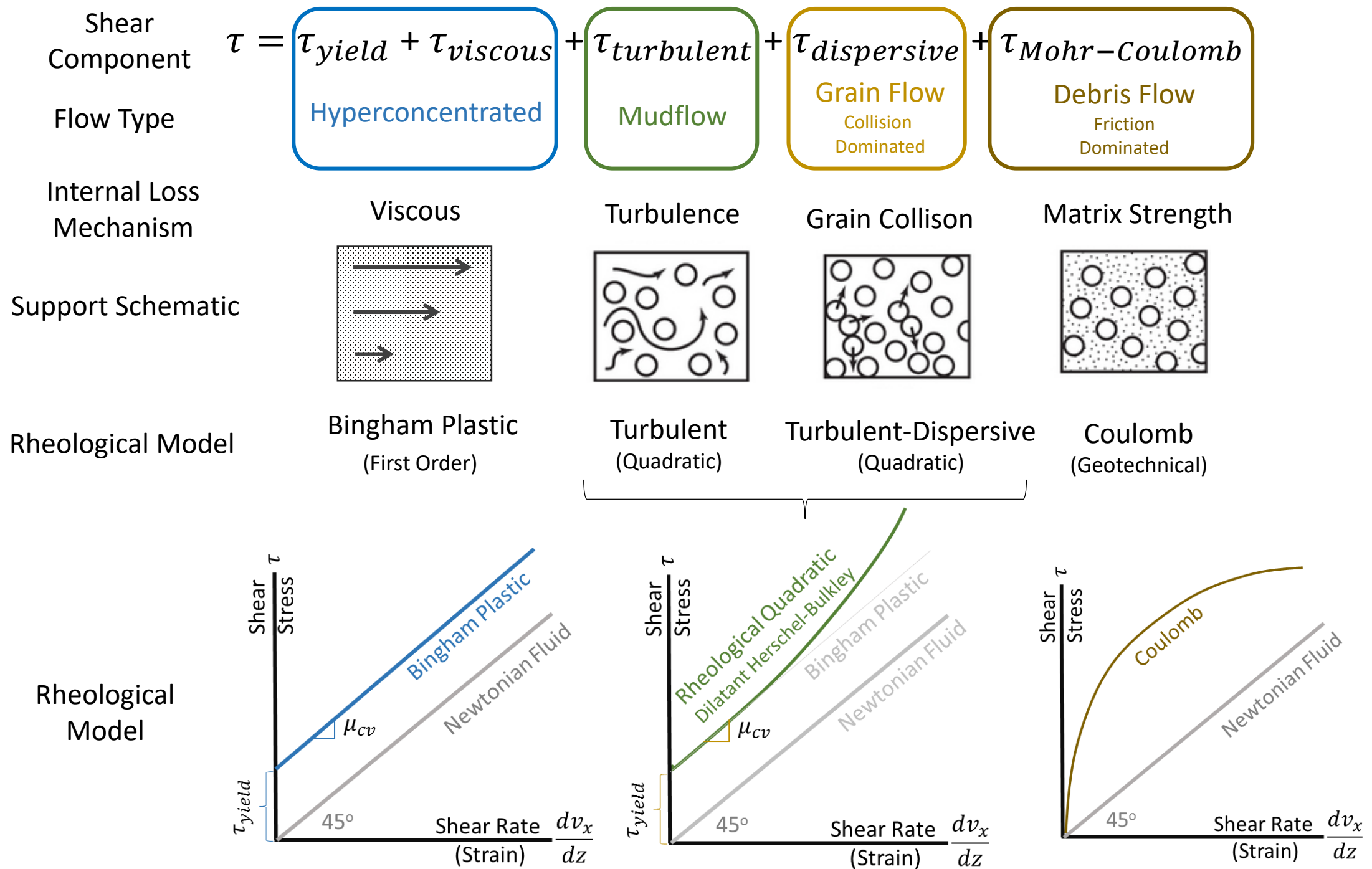


Linear: Newtonian
& Bingham Plastic

$$\tau = \tau_y + \mu \left(\frac{dv_x}{dz} \right) + \varphi \left(\frac{dv_x}{dz} \right)^2$$



Non-Linear:
Quadratic



Selecting a Non-Newtonian Method in HEC-RAS

Non-Newtonian Parameters are Unsteady Flow Variables

Unsteady Flow Data - Exp1a 2D (NN-Bing)

File Options Help

Initial Conditions | Meteorological Data |

Boundary Condition Types

Hydrograph	Flow Hydrograph	Stage/Flow Hydr.	Rating Curve
Depth	Lateral Inflow Hydr.	Uniform Lateral Inflow	Groundwater Interflow
Openings	Elev. Controlled Gates	Navigation Dams	IB Stage/Flow
Precipitation			

Add Boundary Condition Location

Add SA/2D Flow Area ... Add SA/2D Area Conn ... Add Pump Station ...

Select Location in table then select Boundary Condition Type

River	Reach	RS	Boundary Condition
Storage/2D Flow Areas			
1	Parson 1a	BCLine: US	Flow Hydrograph
2	Parson 1a	BCLine: DS	Normal Depth

Non-Newtonian fluid properties have been specified

Non-Newtonian Options and Parameters

Non-Newtonian Method: Bingham

Yield Strength: Obrian a 1.1 b 3.

Sediment Laden Viscosity: User Defined K K 0

Generalized Herschel-Bulkley Parameters: K 22.5 n 0.45

Clastic Methods: Voellmy ϕ 0

Hindered Settling Method: No Hindered Settling

Hydraulics Only

Representative Grain Size - d_s (mm): 0.2

Volumetric Concentration (C_v) (%): 65.

Select Bulking Method: Do Not Bulk

OK Cancel

1D, Unsteady, FD (Working)
2D, Unsteady, FV (Working)
1D, Unsteady, FV (coming soon)
1D/2D Mobile Bed (coming later)
-Not in Steady or Quasi-Unsteady

Non-Newtonian Validation and Verification in HEC-RAS

1.Non-Newtonian Closure in HEC-RAS

2.Laboratory and Meso-Scale Validation and Verification

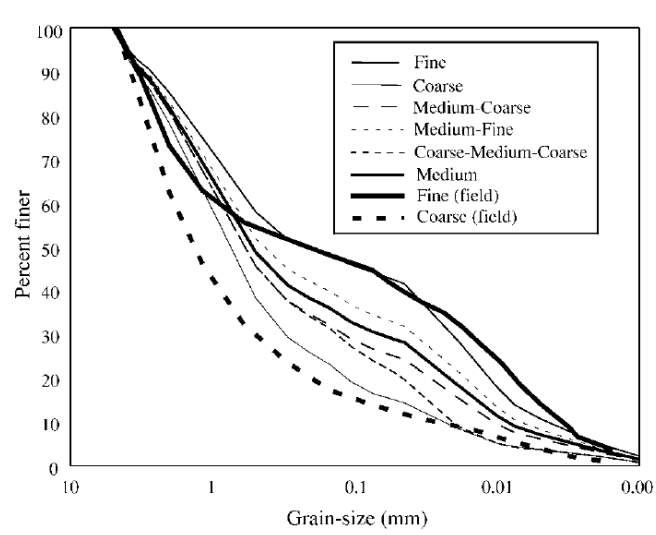
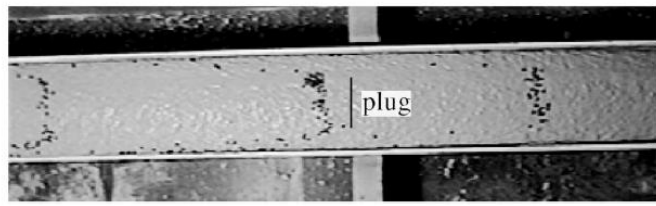
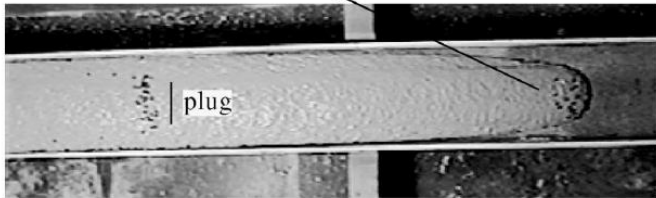
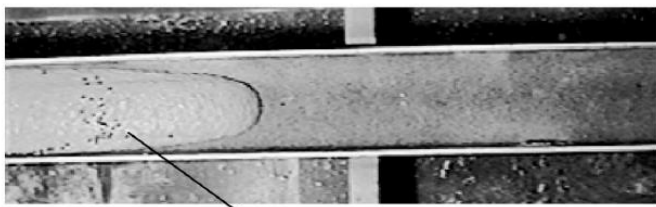
3.Field Applications



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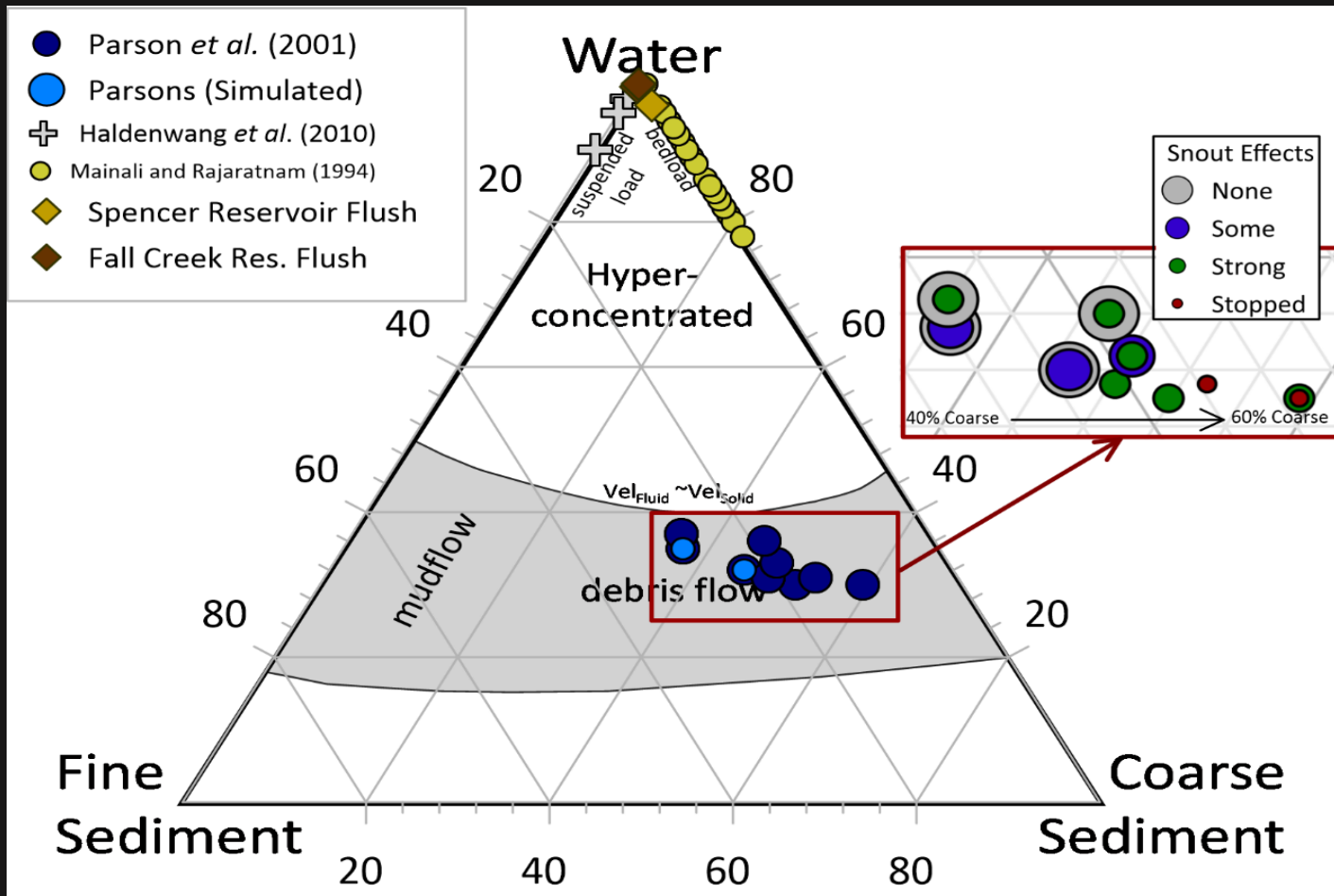


1. Parson et al – Mudflow and Debris Flow

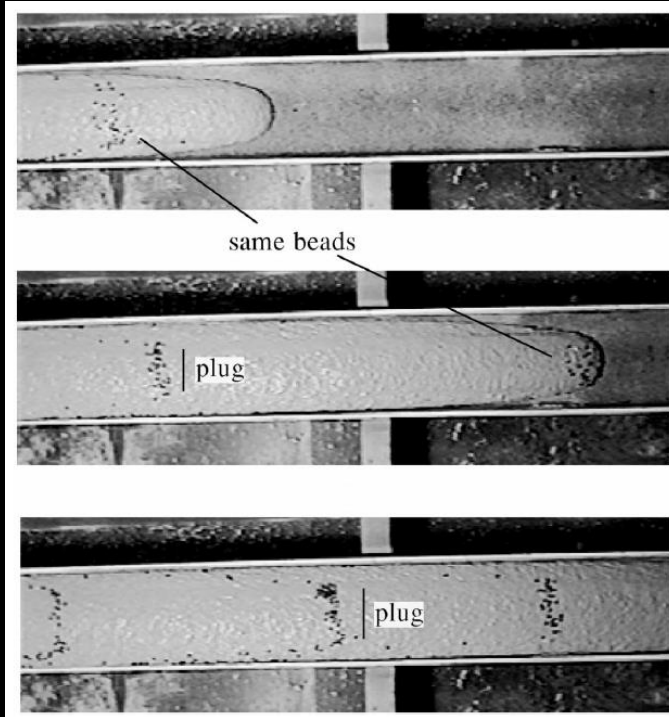


Experimental Study of the Grain-Flow, Fluid-Mud Transition in Debris Flows

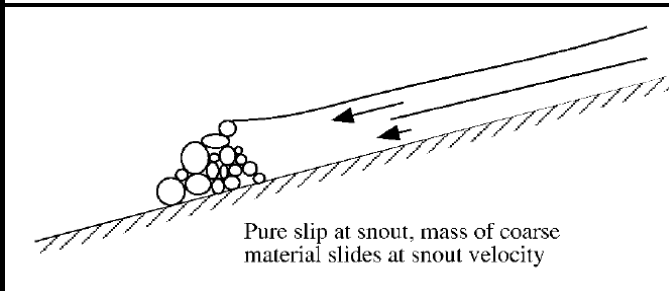
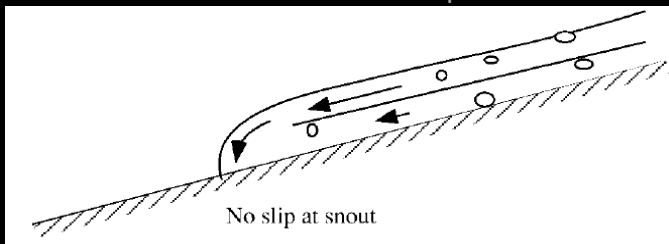
Jeffrey D. Parsons,¹ Kelin X. Whipple, and Alessandro Simoni²



2. Parson et al – Mudflow and Debris Flow

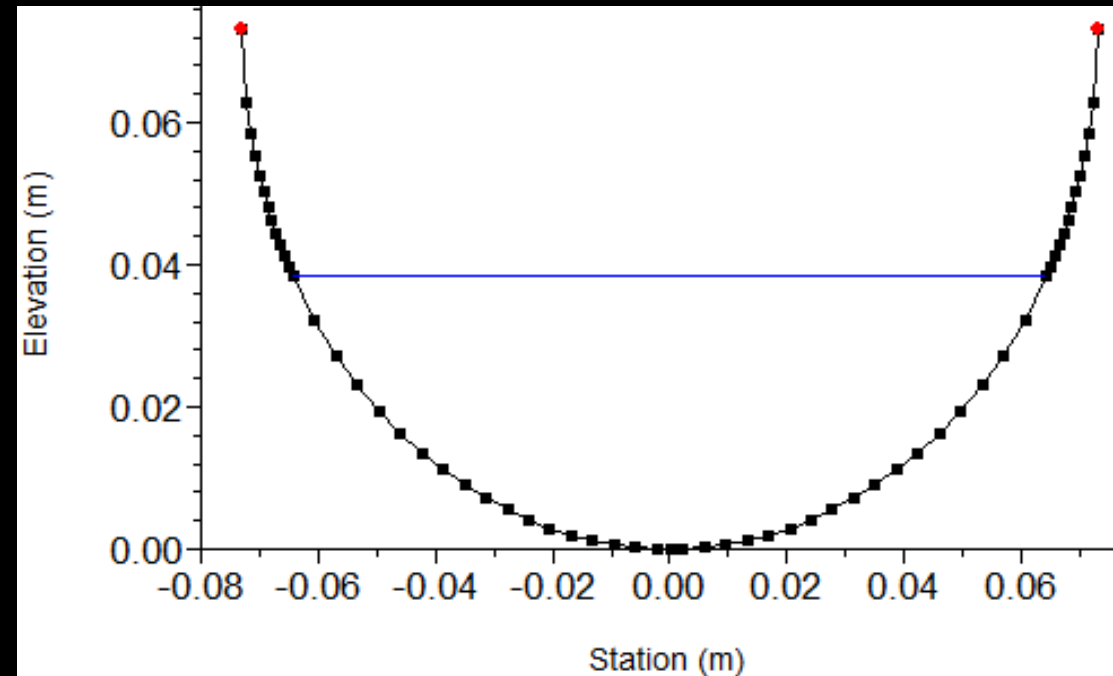


Start with non-snout effect experiments



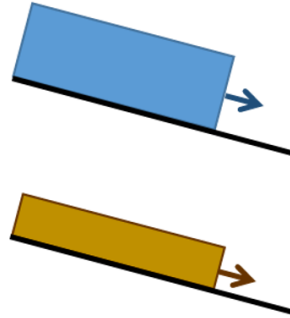
Fine 1D Simulations:

Experiment	Material	w	R	Slope (θ)	Snout effect?	U_p	U_{snout}	Q
1a	F	16.8	.073	10.7	None	.24 (8.3)	.22 (1.8)	.00189 (1.8)
1b	$C_m=83.2\% \rightarrow C_v=65\%$.073	15.2	None	1.17 (10.2)	.87 (1.0)	.00692 (1.3)
1c			.05	15.2	Some	.26 (7.8)	.16 (1.7)	.00061 (.4)
2a	MF	14.8	.073	10.7	None	.83 (4.8)	.57 (.9)	.00391 (.6)
2b	$C_m=85.2\% \rightarrow C_v=68\%$.073	13.7	None	1.69 (2.3)	1.22 (.7)	.00988 (3.7)
2c			.05	13.7	Some	.30 (8.3)	.16 (.3)	.00096 (.4)

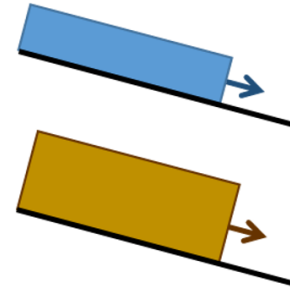


3. A steady state debris flow will be deeper/shallower than a water flow of the same volume?

a) $D_{\text{water}} > D_{\text{debris}}$

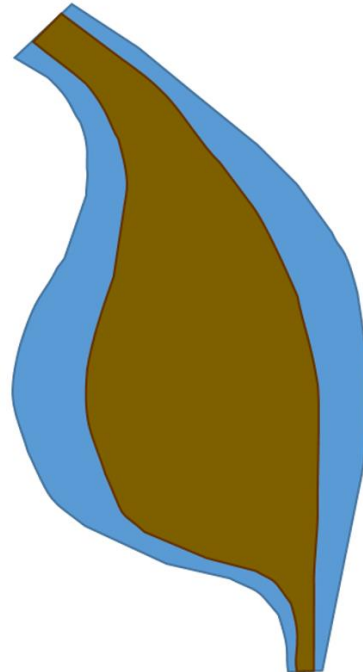


b) $D_{\text{debris}} > D_{\text{water}}$

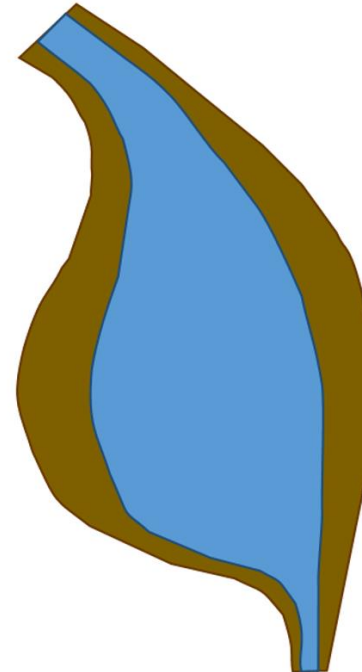


4. A debris flow will have a bigger/smaller floodplain area than a water flow of the same peak volume?

a) $A_{\text{water}} > A_{\text{debris}}$

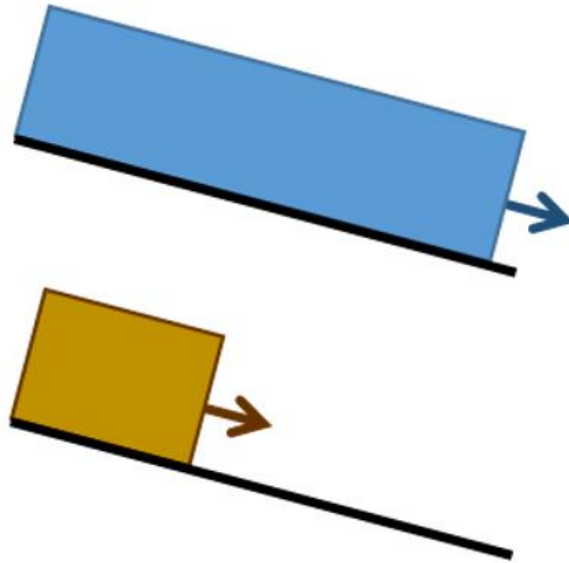


b) $A_{\text{debris}} > A_{\text{water}}$

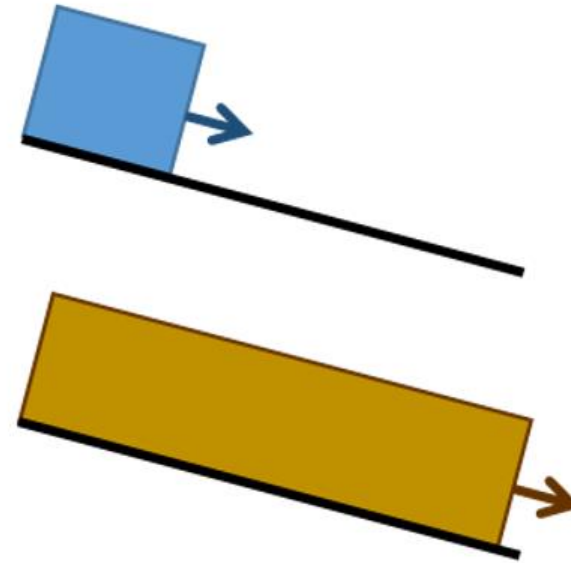


2. A debris flow will be faster or slower than a water flow of the same volume?

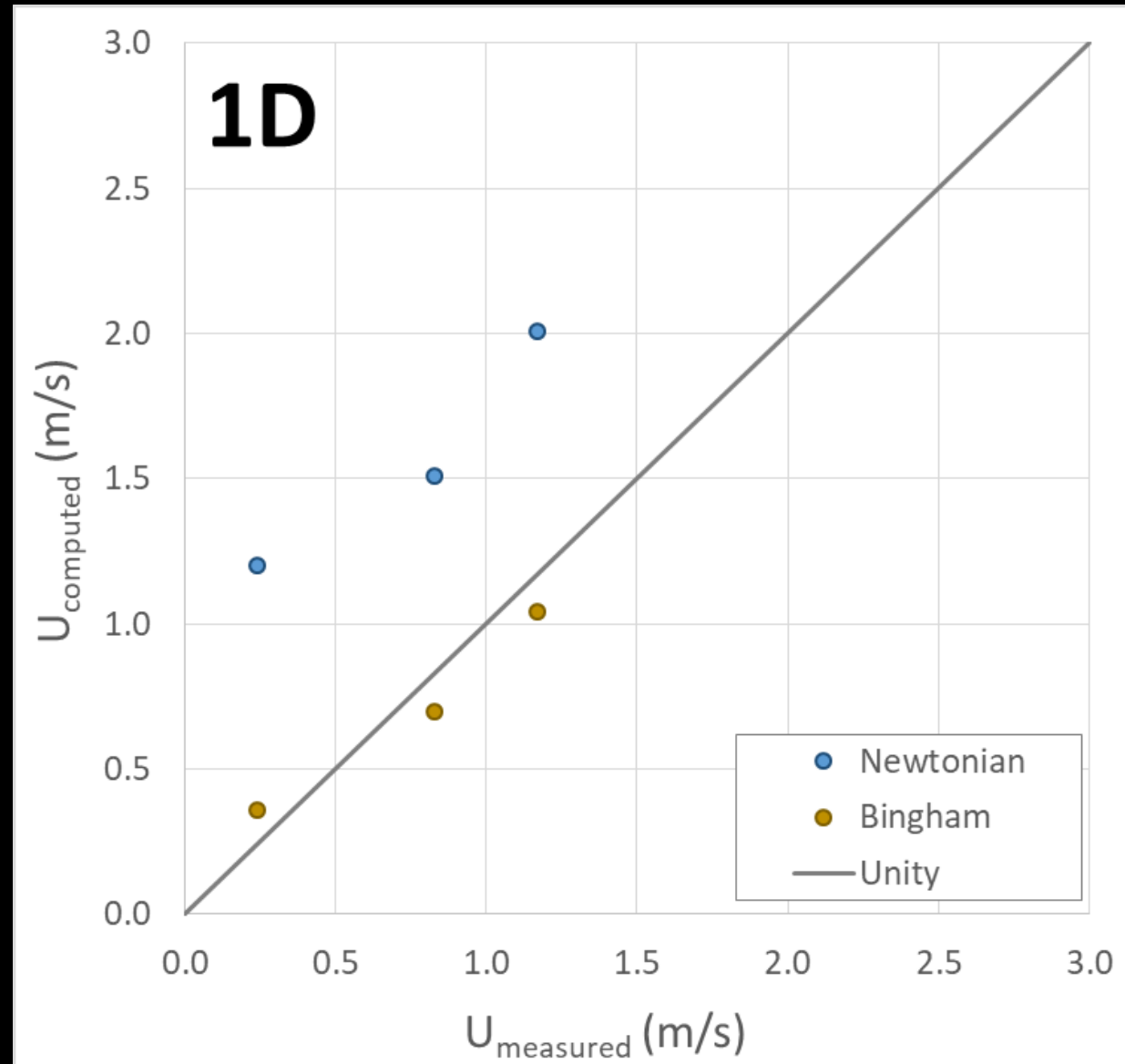
a) $V_{\text{water}} > V_{\text{debris}}$



b) $V_{\text{debris}} > V_{\text{water}}$

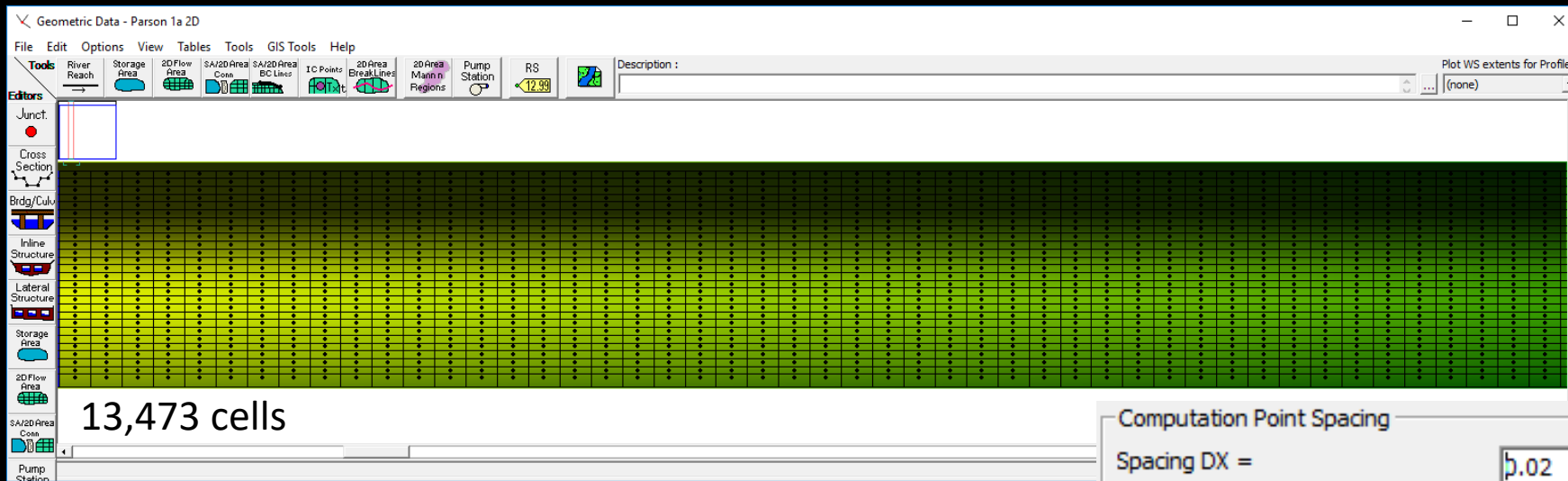
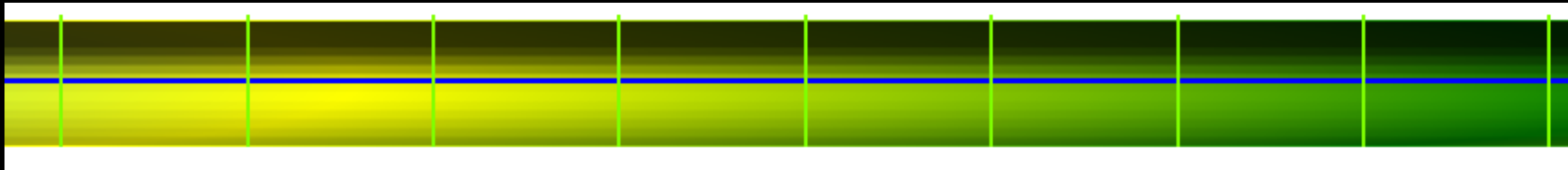
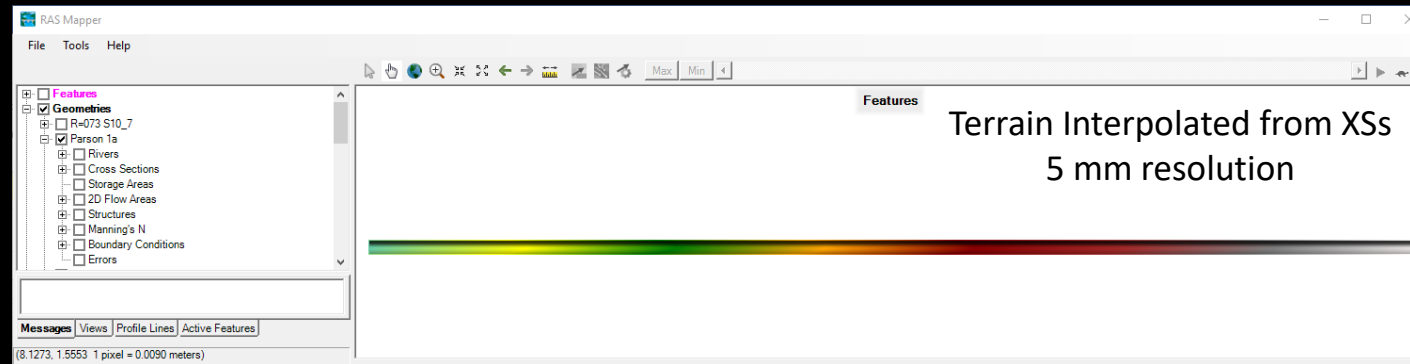


2. Parson et al – Mudflow and Debris Flow



2. Parson et al – Mudflow and Debris Flow

Fine 2D Simulations:



Computation Point Spacing

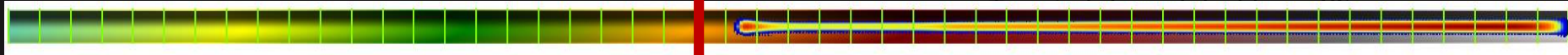
Spacing DX = 0.02

Spacing DY = 0.005

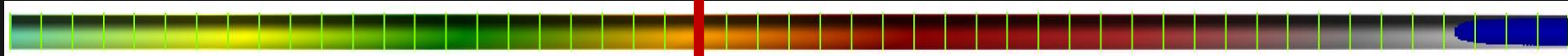
2. Parson et al – Mudflow and Debris Flow (2D)

Fine 2D Simulations:

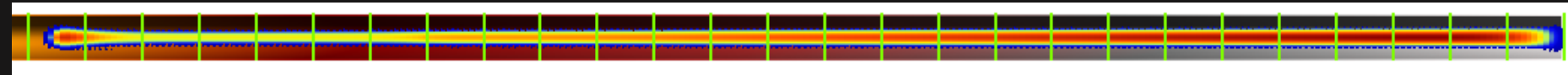
Newtonian (t=10s)



Bingham (t=10s)



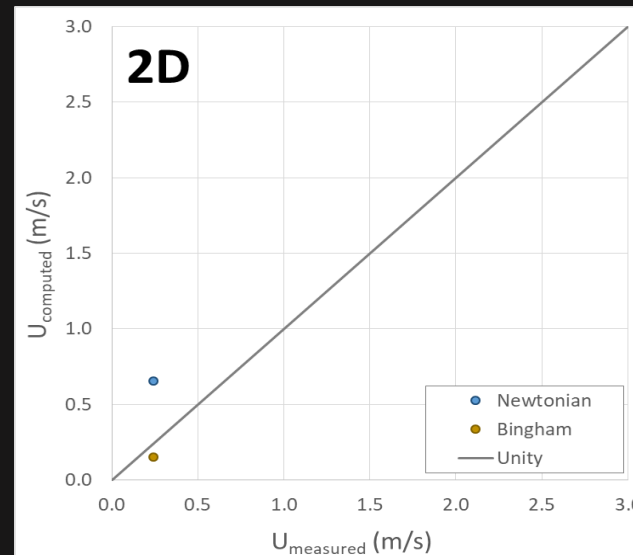
Newtonian (t=10s)



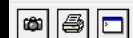
Bingham (t=10s)



13,473 cells

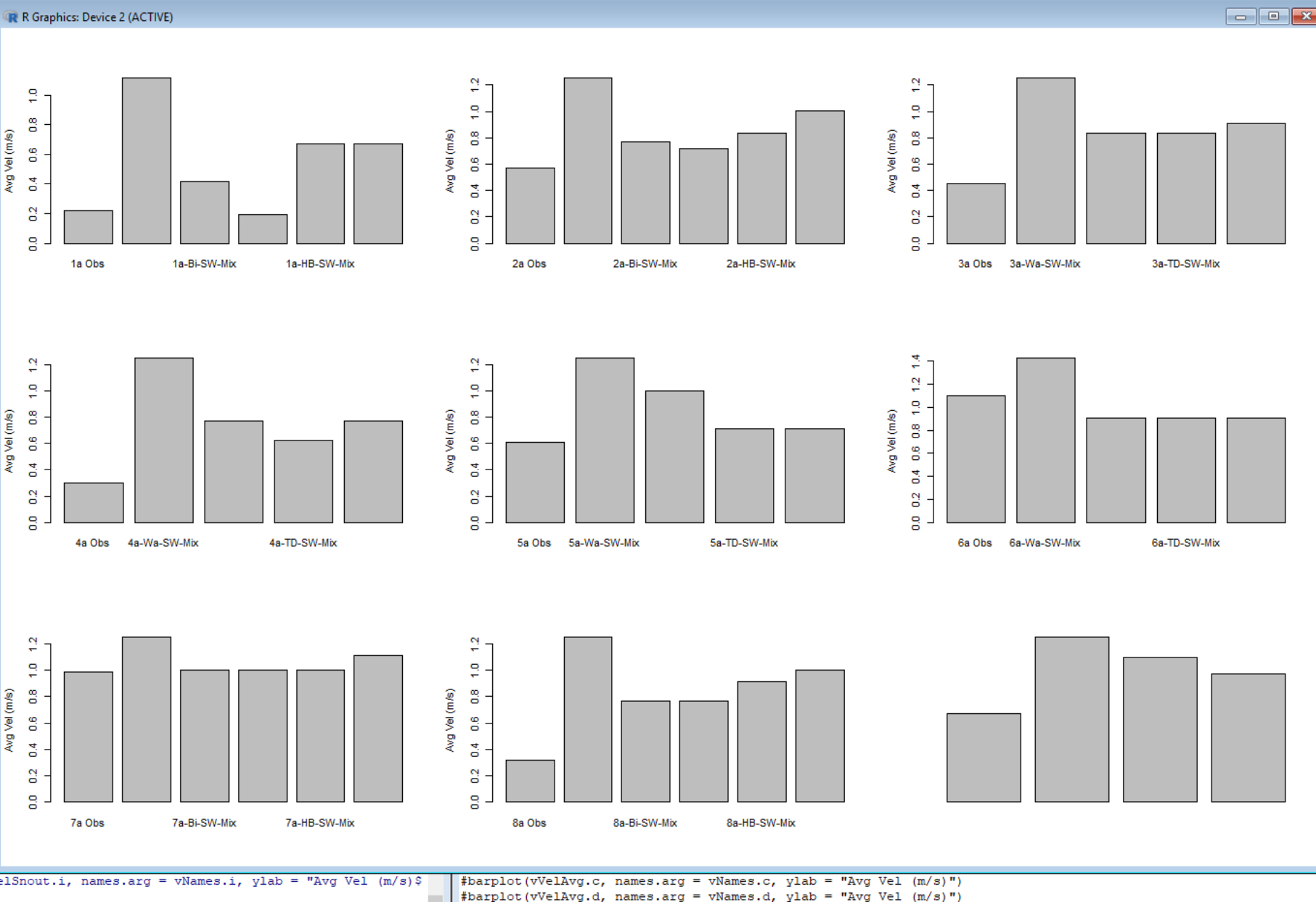


I'm working on a video on how to interact with the RAS HDF5 Results in R



R Console

```
[1] "u"
[1] "u"
[1] "u"
[1] "u"
[1] "u"
[1] "u"
[1] "u"
>
> #par(mfrow=c(2,2))
> #barplot(vVelAvg.a, names
> #barplot(vVelAvg.b, names
> #barplot(vVelAvg.c, names
> #barplot(vVelAvg.d, names
>
> # This plots avg Velocity
> par(mfrow=c(2,2))
> barplot(vVelSnout.a, name
> barplot(vVelSnout.b, name
> barplot(vVelSnout.c, name
Error in barplot.default(vVelSnout.d, name
incorrect number of names
> barplot(vVelSnout.d, name
Error in barplot.default(vVelSnout.d, name
incorrect number of names
>
> # this shows all in a by-
> #layout(matrix(c(1,1,2,3)
> #NN.Data <- rbind(vNN.Yie
> #barplot(NN.Data, names.e
> #plot(vNN.Visc,vNN.Visc.c
> #plot(vNN.Yield,vNN.Yield
>
> #layout(matrix(c(1,1,2,3)
> #NN.HB.Data <- rbind(vNN.
> #barplot(NN.HB.Data, name
> #plot(vNN.HB.Visc, vNN.HB
> #plot(vNN.HB.Yield,vNN.HB
>
> par(mfrow=c(2,2))
> barplot(vVelSnout.a, name
> barplot(vVelSnout.b, name
> barplot(vVelSnout.c, name
> barplot(vVelSnout.d, name
>
> # This plots avg Velocity
> par(mfrow=c(3,3))
> barplot(vVelSnout.a, name
> barplot(vVelSnout.b, name
> barplot(vVelSnout.c, name
> barplot(vVelSnout.d, name
> barplot(vVelSnout.e, name
> barplot(vVelSnout.f, name
> barplot(vVelSnout.g, name
> barplot(vVelSnout.h, name
> barplot(vVelSnout.i, name
Error in barplot.default(vVelSnout.i, names.arg = vNames.i, ylab = "Avg Vel (m/s)"
incorrect number of names
```



Series/2D Flow Areas/Parson 1a/
Series/2D Flow Areas/Parson 1a/F
Series/2D Flow Areas/Parson 1a/F
Series/2D Flow Areas/Parson 1a/F

Series/2D Flow Areas/Parson 1a/
Series/2D Flow Areas/Parson 1a/F

3. Hungr et al – Non-Newtonian Dam Breach

30.5 m Dam Breach

1,000+ m Runout

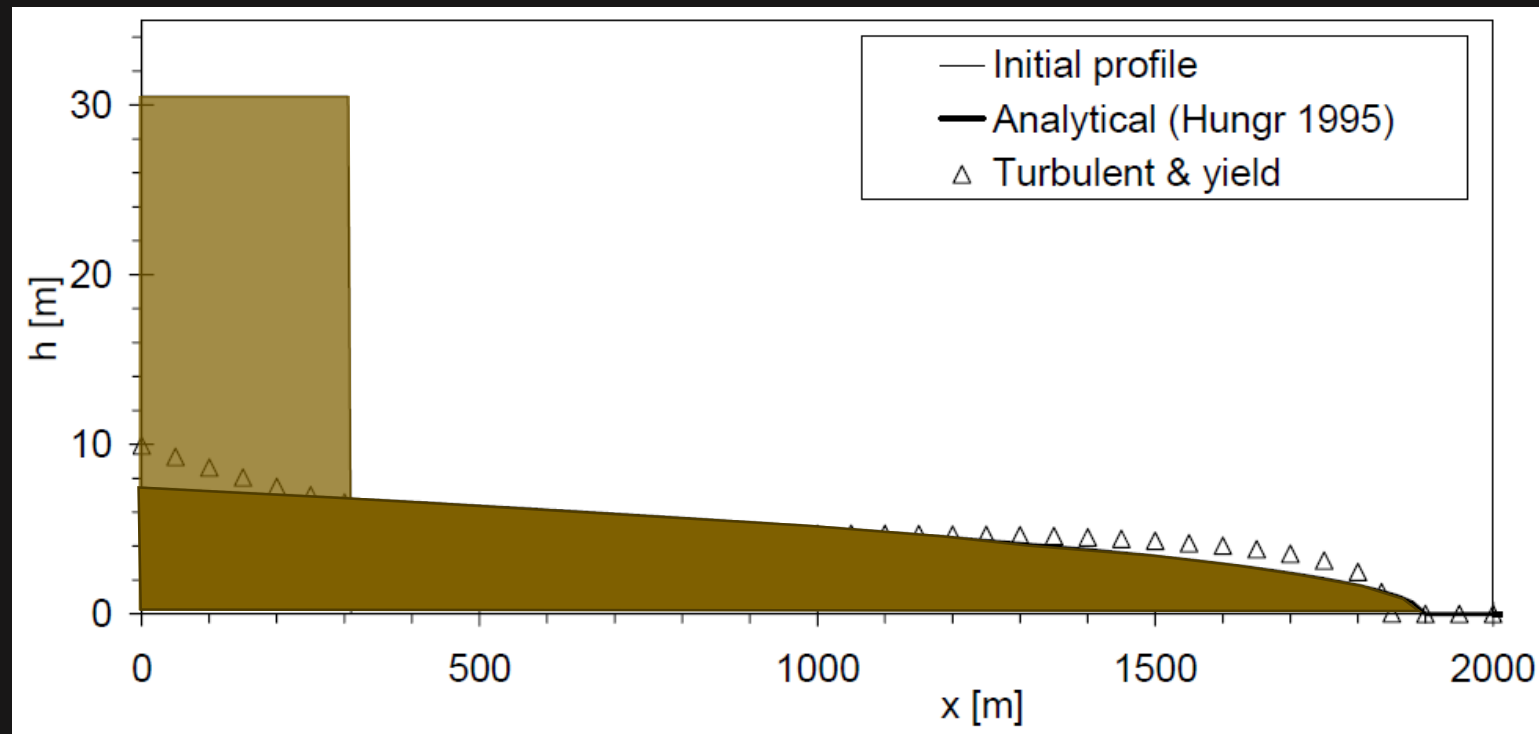
$\rho=1,835 \text{ kg/m}^3$

Bingham:

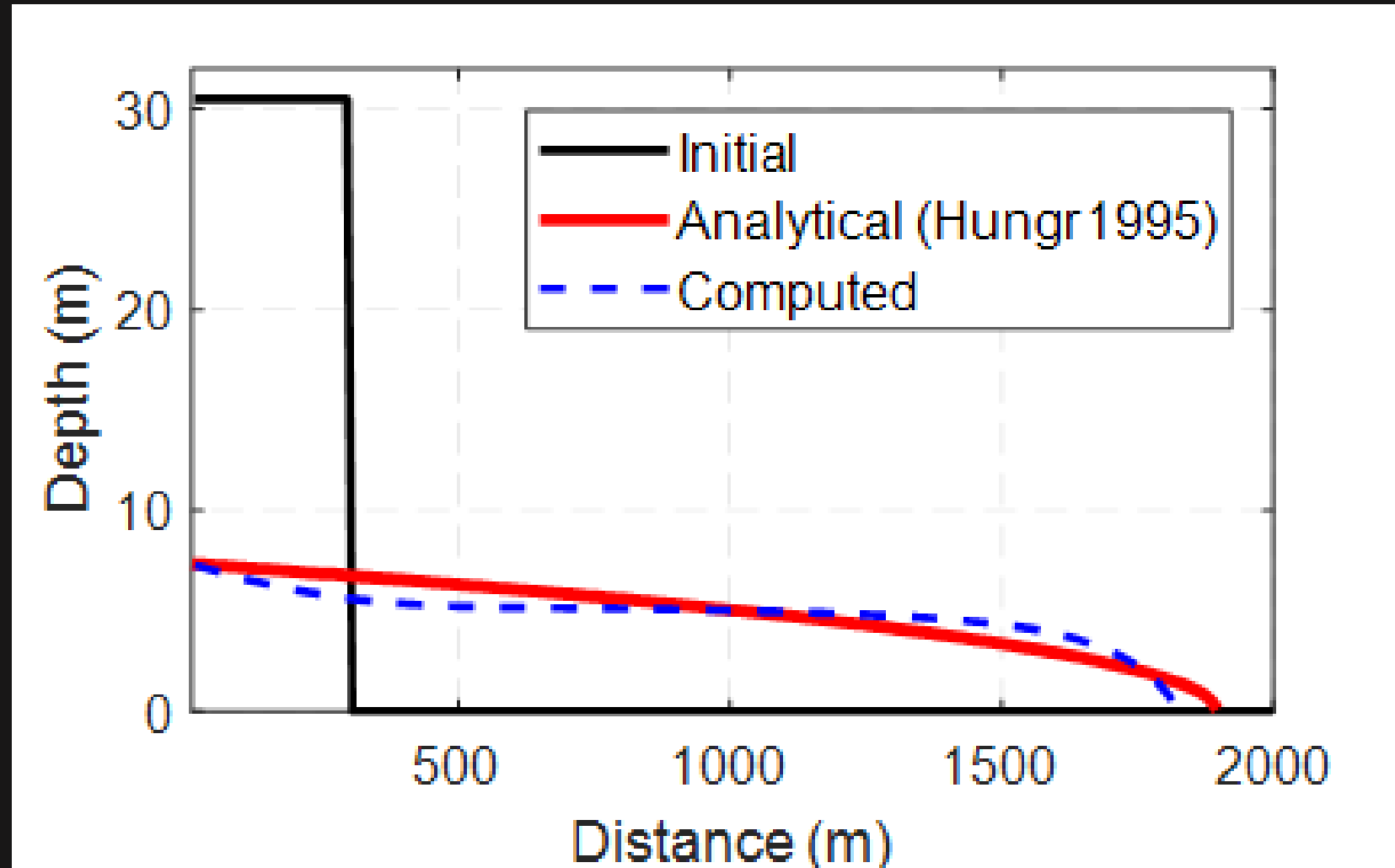
$$\tau_y = 1,500 \text{ N/m}^2$$

$$\mu_B = 100 \text{ Pa-s}$$

$$\tau = \tau_y + \mu_B \left(\frac{dv_x}{dz} \right)$$



3. Hungr et al – Non-Newtonian Dam Breach



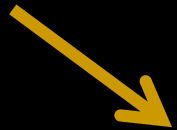
HEC-RAS
1D Finite Difference
2D Finite Volume
Fortran Code

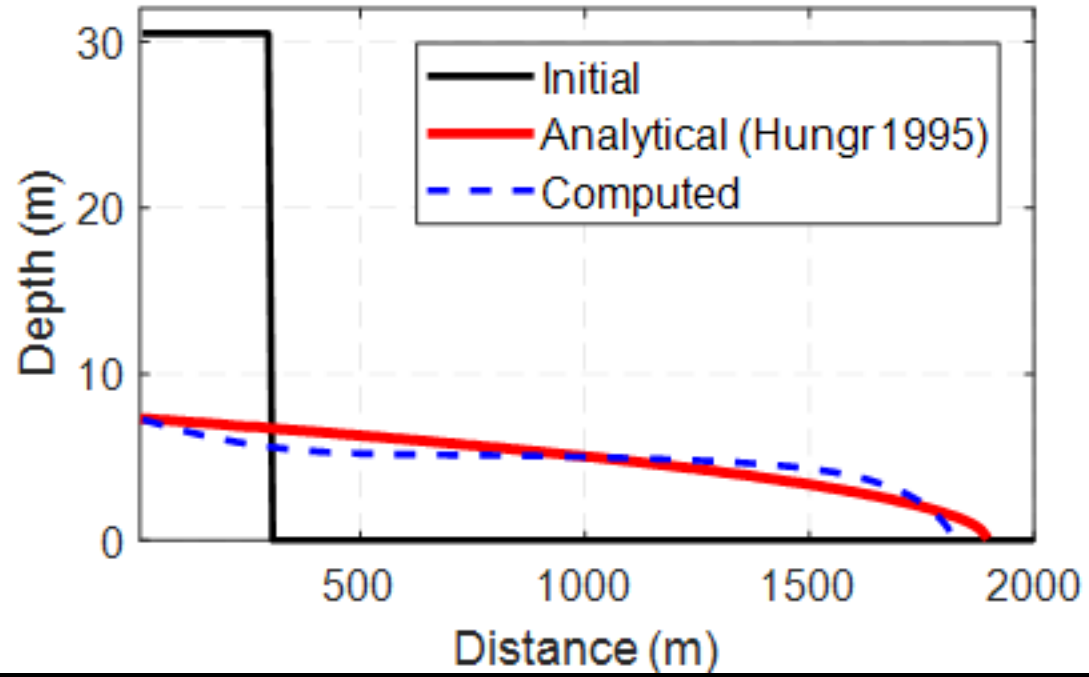


Adaptive Hydraulics
2D Finite Area
C++ Code

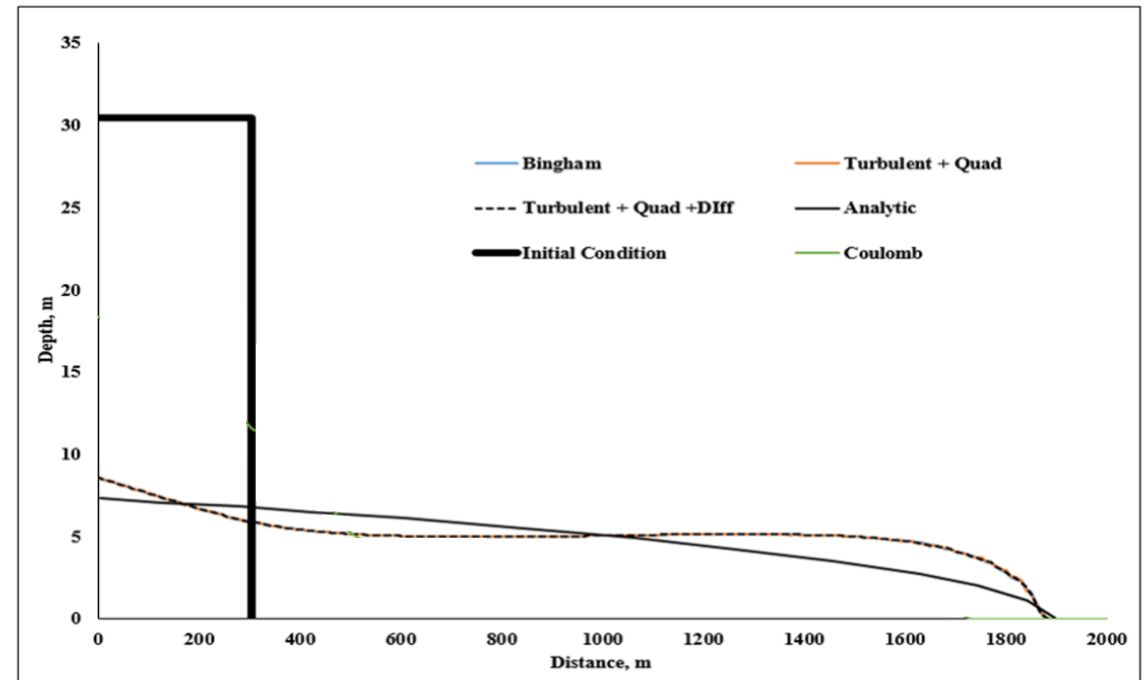



DebrisLib





2D Adaptive Hydraulics

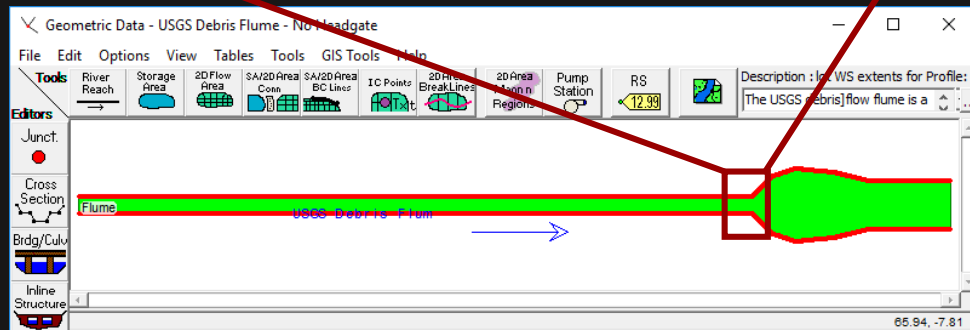
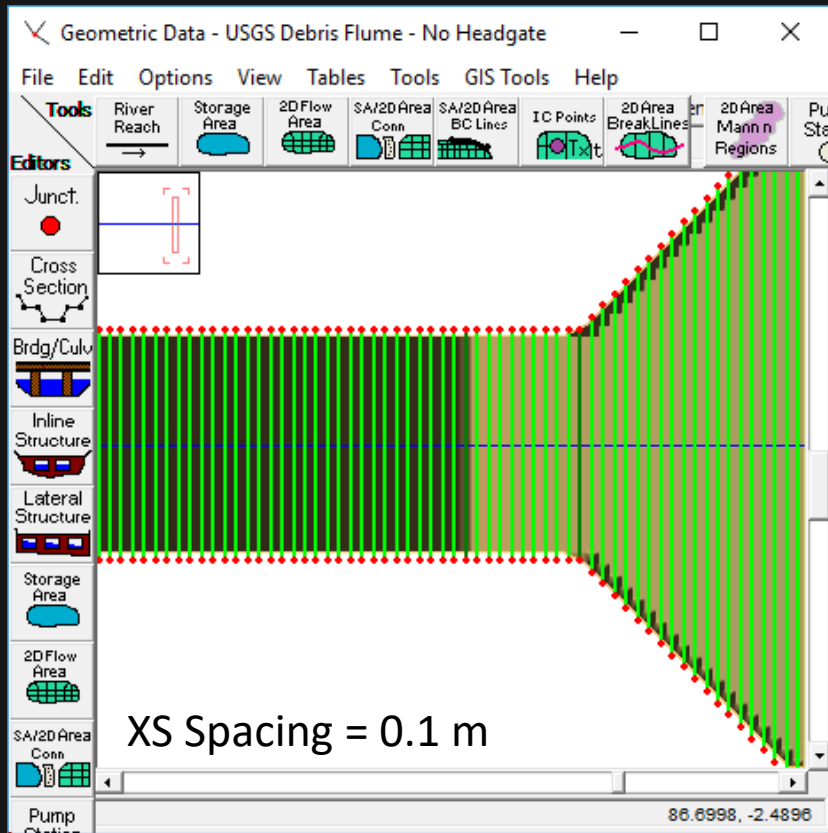




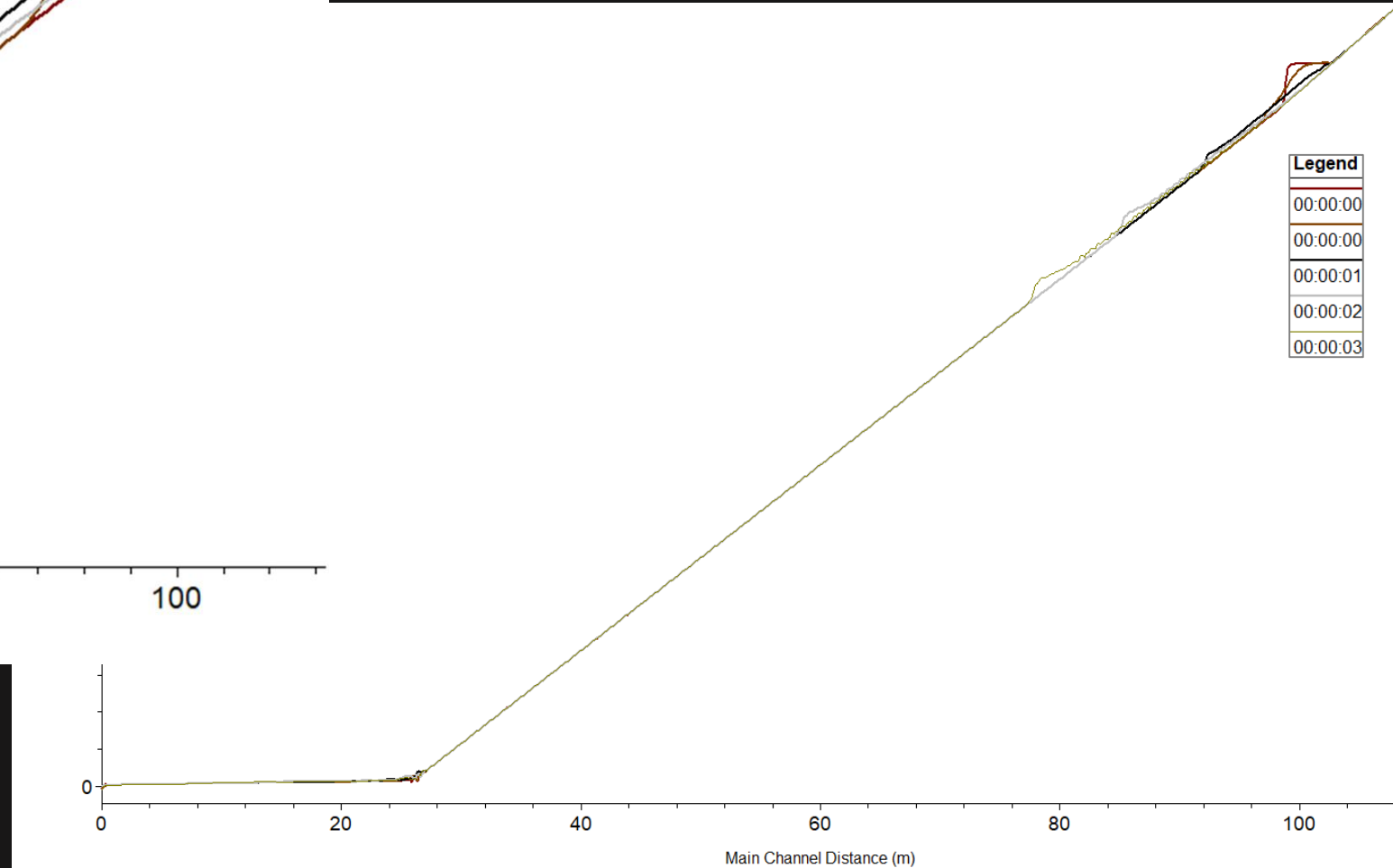
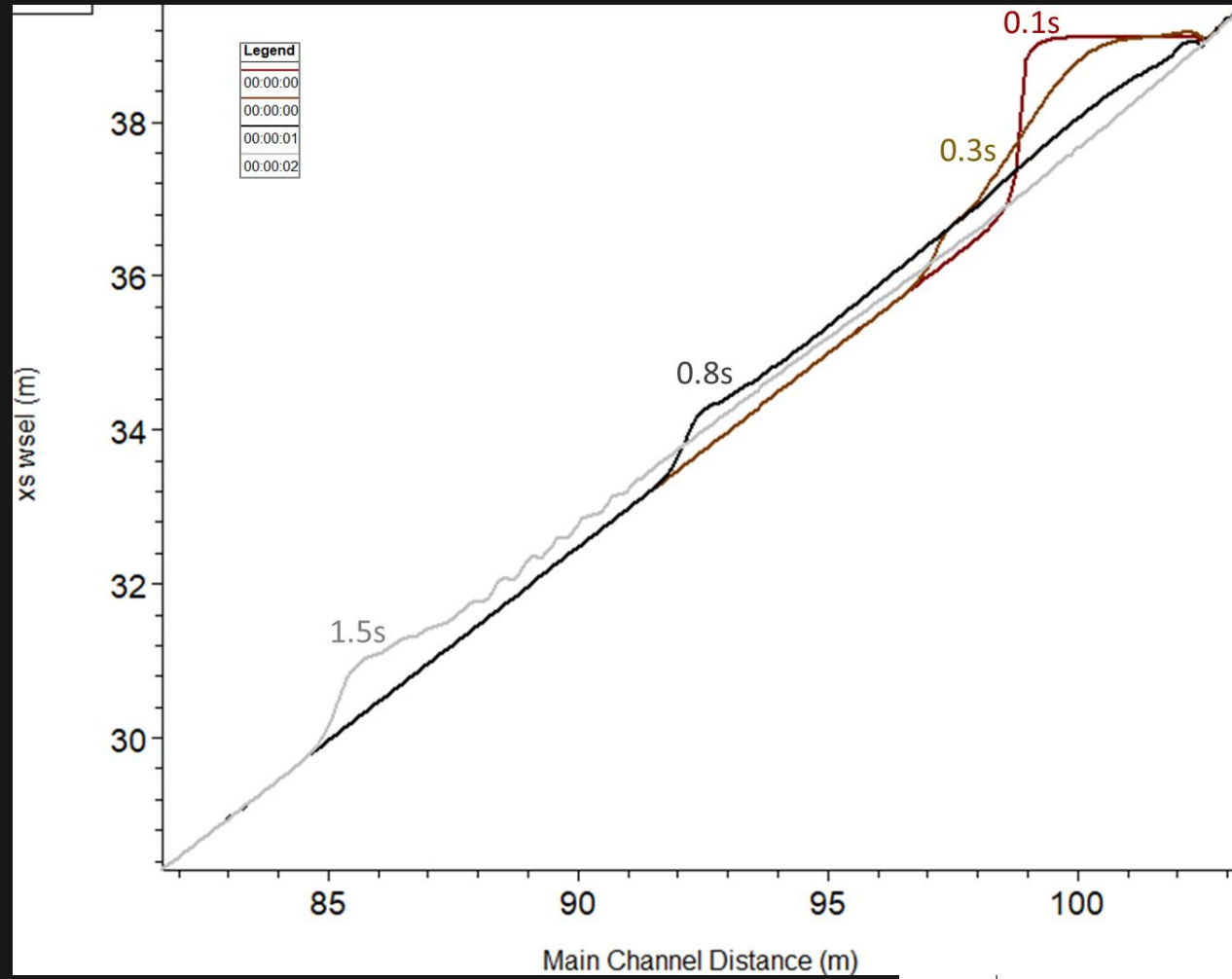
NON-NEWTONIAN FLOWS

ADH

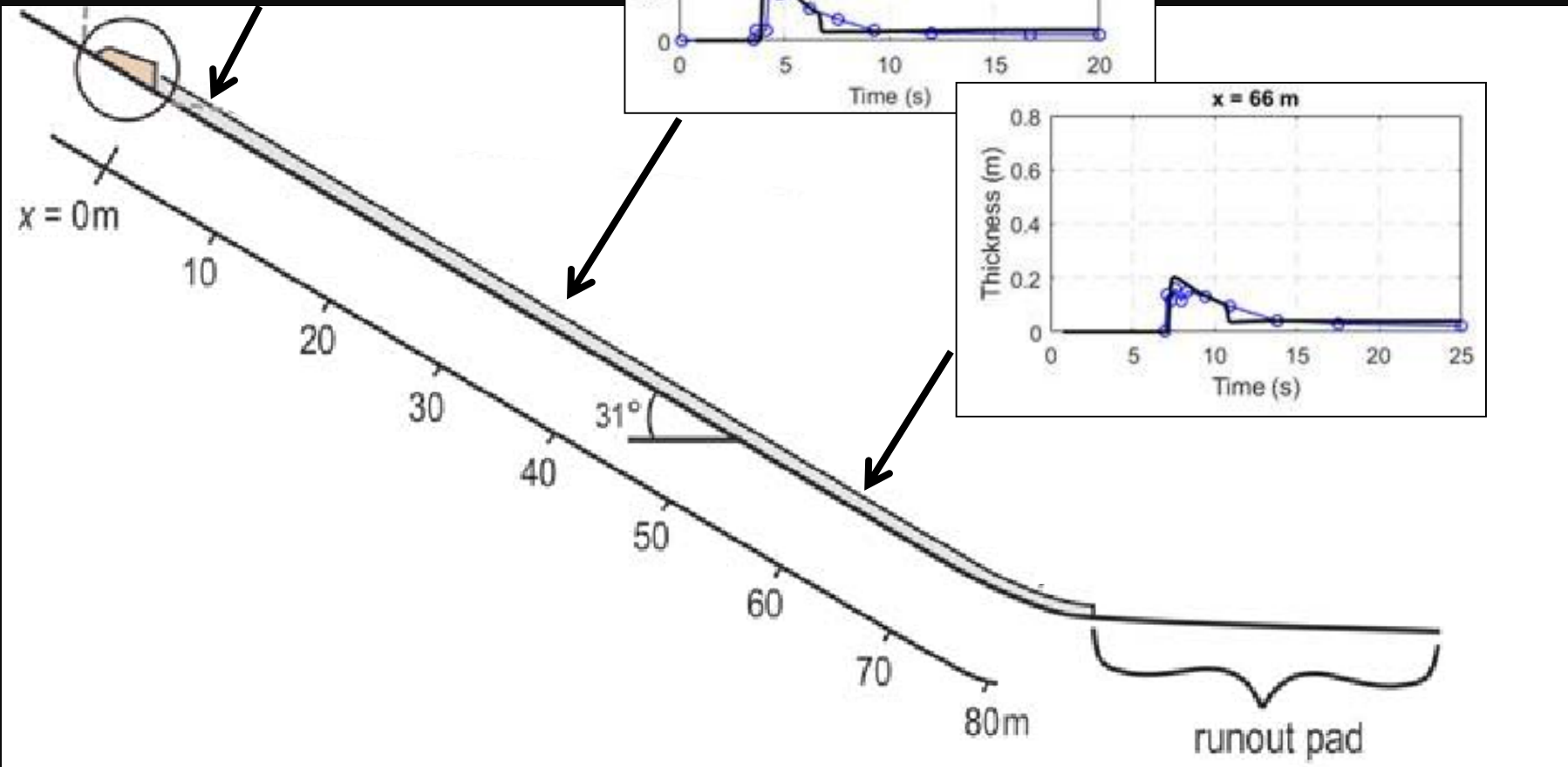
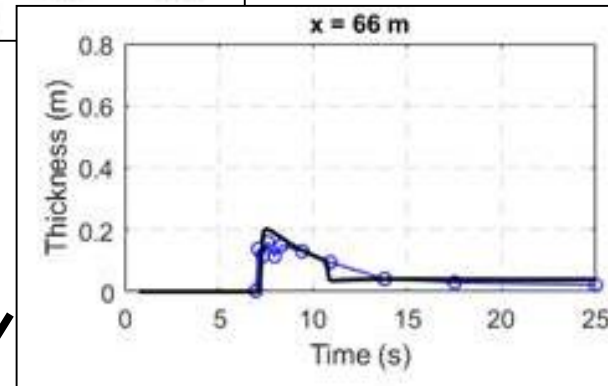
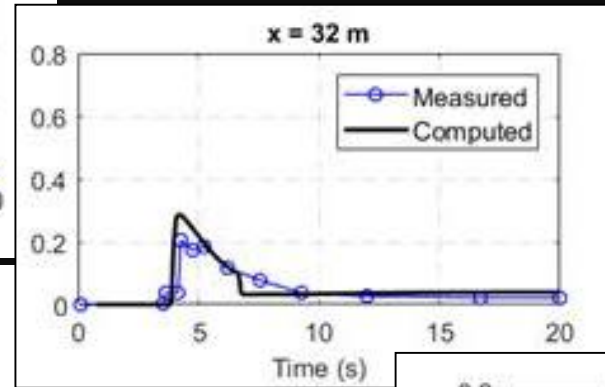
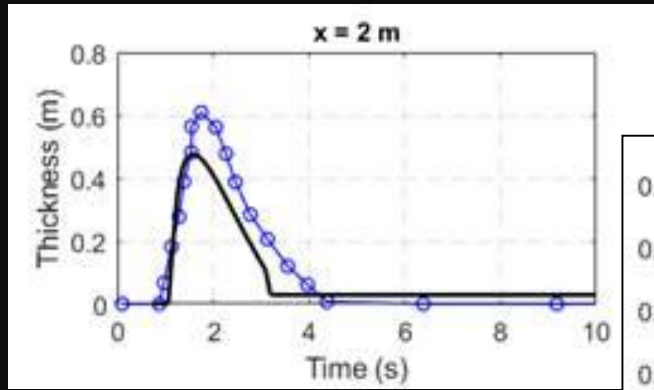
4. USGS Debris Flume



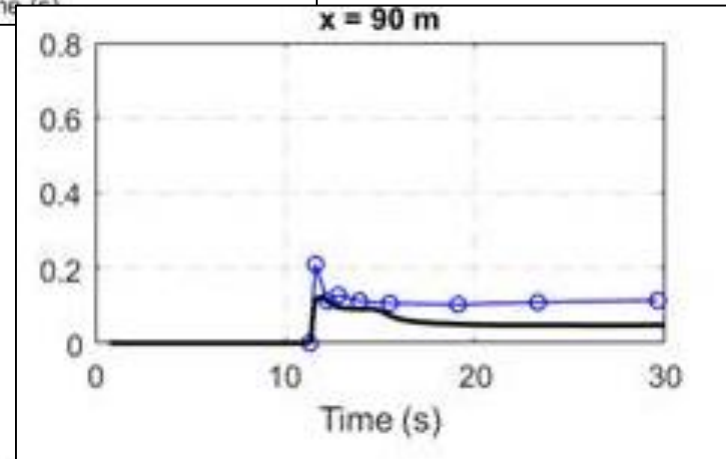
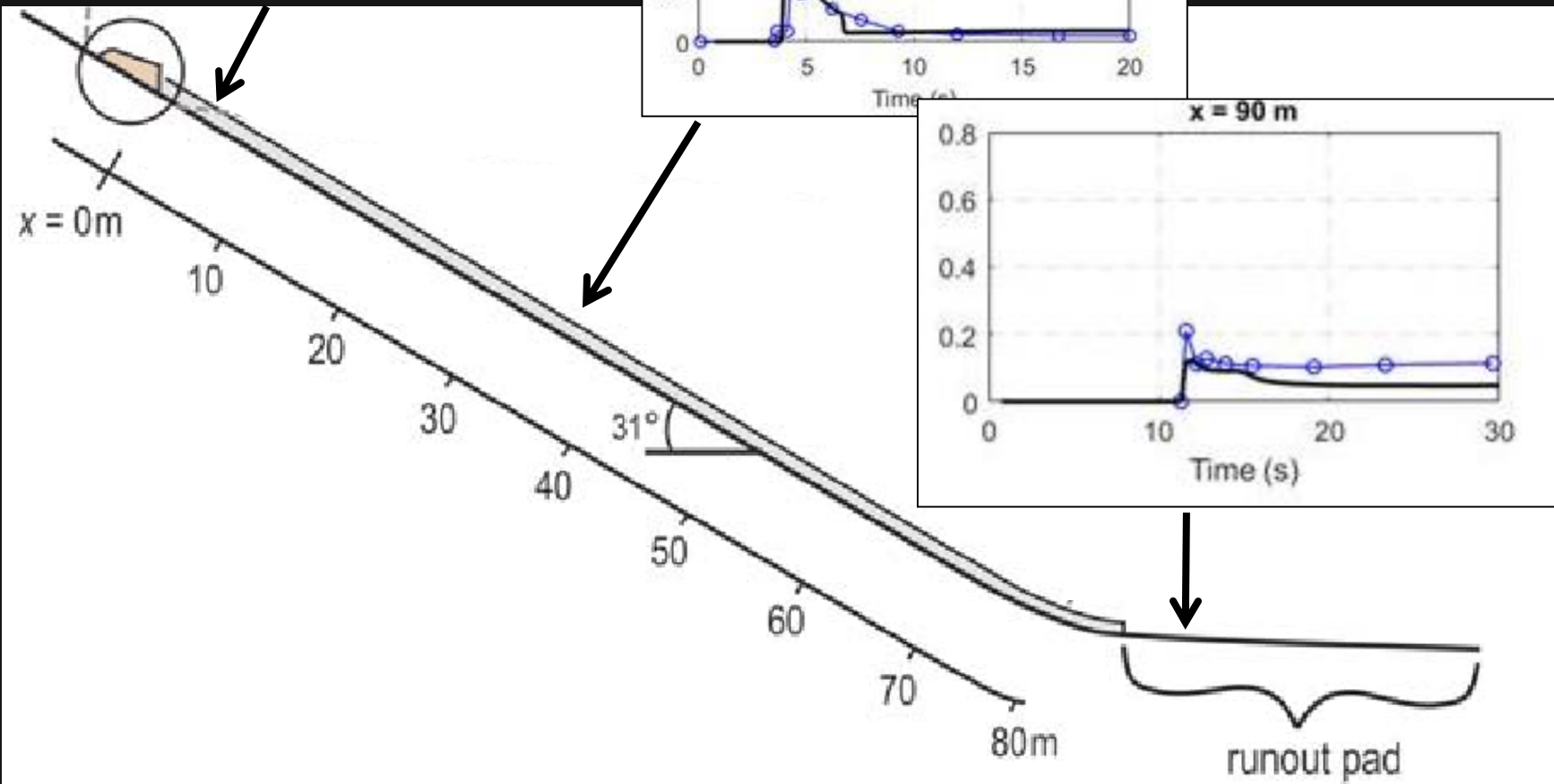
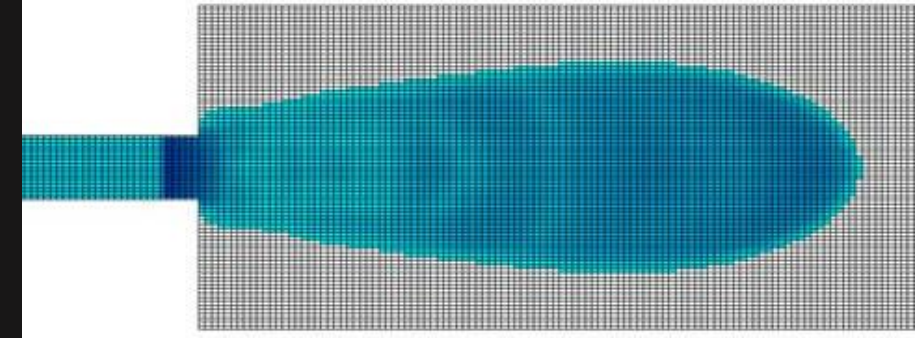
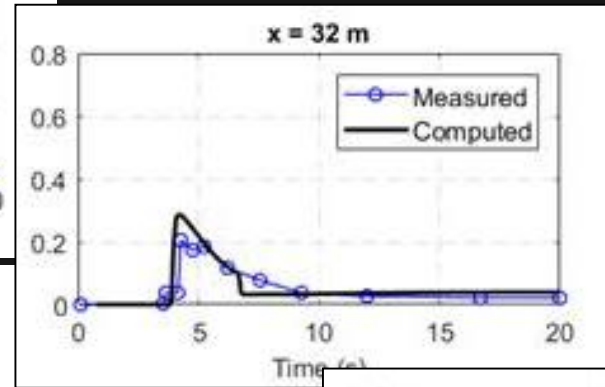
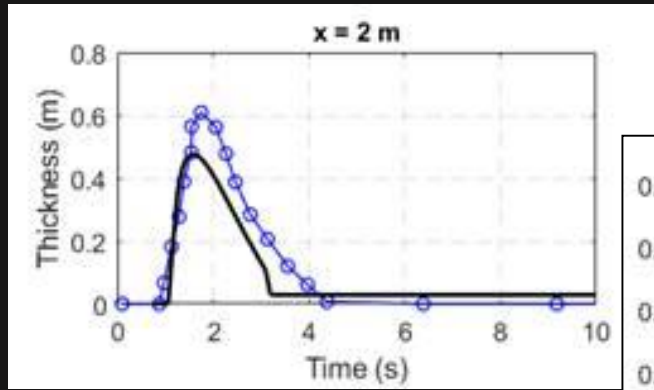
US Geological Survey - Debris Flume



US Geological Survey - Debris Flume



US Geological Survey - Debris Flume



Non-Newtonian Validation and Verification in HEC-RAS

1.Non-Newtonian Closure in HEC-RAS

2.Laboratory and Meso-Scale Validation and Verification

3.Field Applications



**US Army Corps
of Engineers®**



Santa Barbara Mud-and-Debris Flow

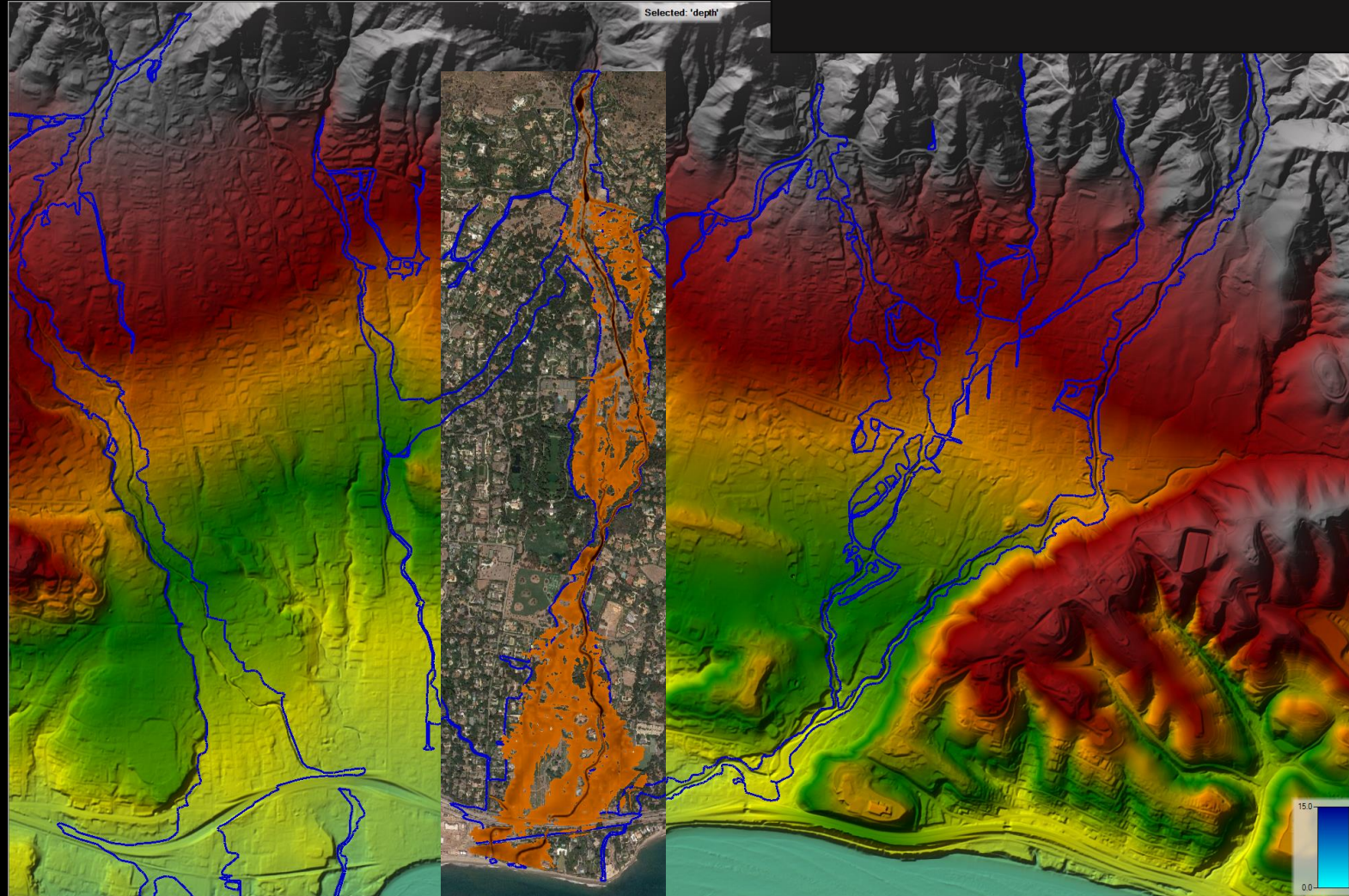


HEC-RAS

1&2D Hydraulic and
Morphodynamic Software

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in 200 countries

Newtonian Assumptions



This work was funded by:
USACE Flood and Coastal R&D
Post-Wild Fire Work Unit
PI: Ian Floyd



1. Next Steps. What Non-Newtonian approaches would you like to see?
2. Non-Newtonian (and 2D sediment transport) will be available for testing in a pre-Beta that will be available shortly. Email me if you want to test:
stanford.gibson@usace.army.mil