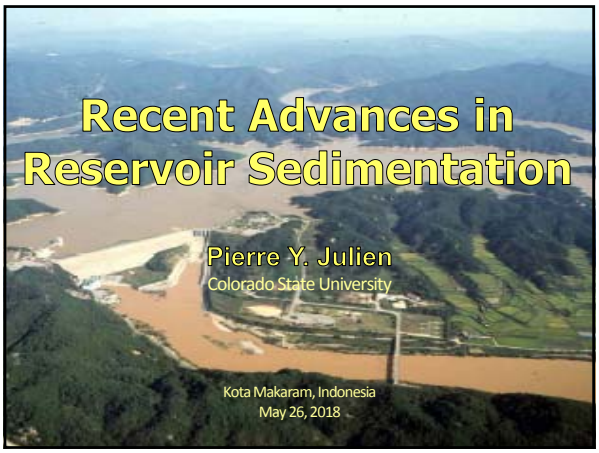
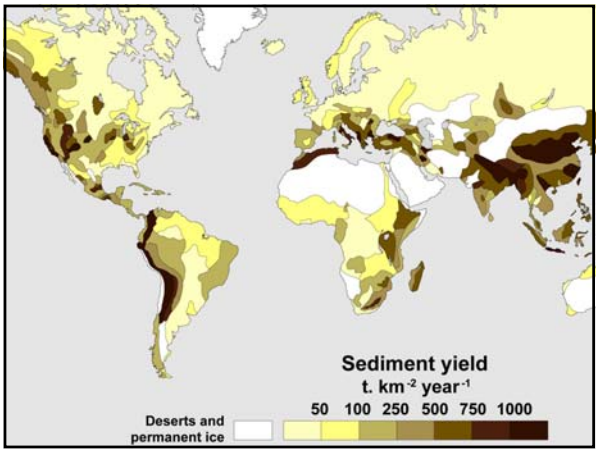
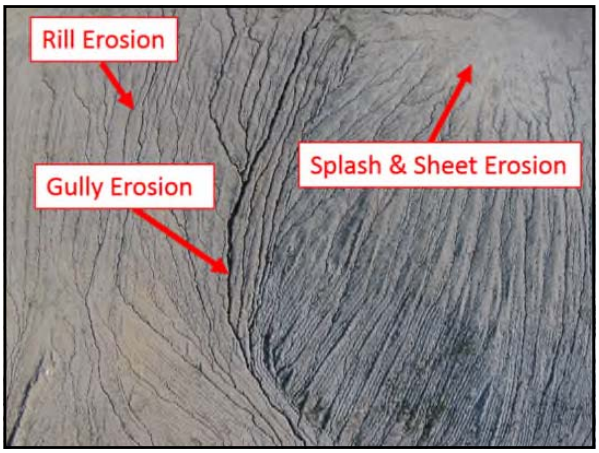


Reservoir Sedimentation

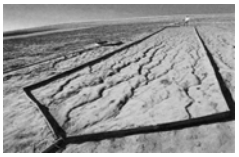
1. Sediment Sources and Yield
2. Dynamic Modeling
3. Density Currents
4. Dambreak Simulations
5. Multi-objective Decisions

2





Revised Universal Soil-Loss Equation (RUSLE)



E = R K L S C P

- E: mean annual soil loss
- R : rainfall erosivity
- K : soil erodibility
- L : slope length
- S : slope steepness
- C : cropping management
- P : conservation practice

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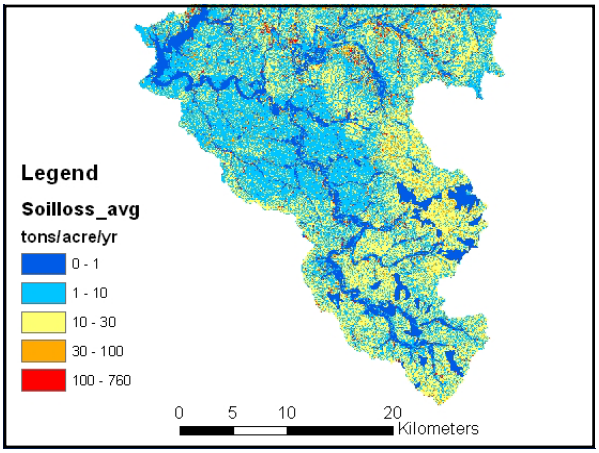
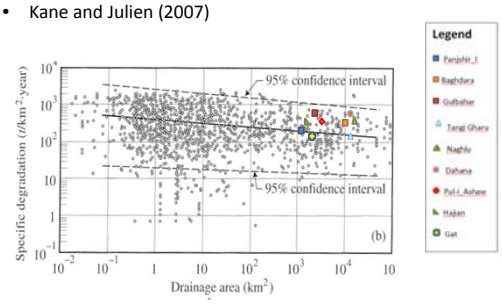


Sediment Yield…

- Kane and Julien (2007)



Upland Degradation Problems

Reservoir Sedimentation

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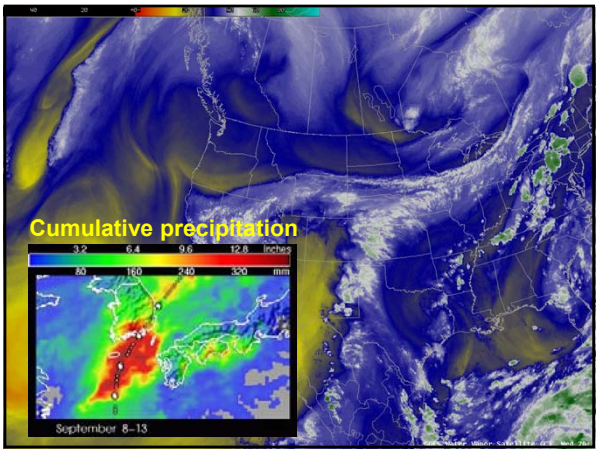
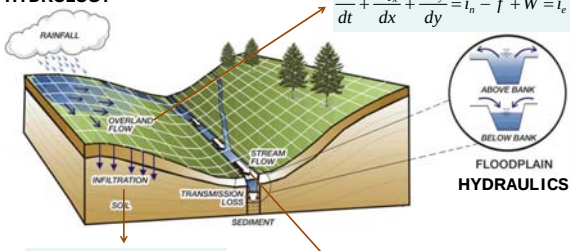


TREX: Two-dimensional Runoff Erosion and eXport

HYDROLOGY

$$\frac{\partial h}{dt} + \frac{\partial q_x}{dx} + \frac{\partial q_y}{dy} = i_n - f + \dot{W} = i_e$$



FLOODPLAIN HYDRAULICS

$$f = K_h \left(1 + \frac{H_c (1 - S_e)\theta_e}{F}\right)$$

$$\frac{\partial A}{dt} + \frac{\partial Q}{dx} = q_l + \hat{W}$$

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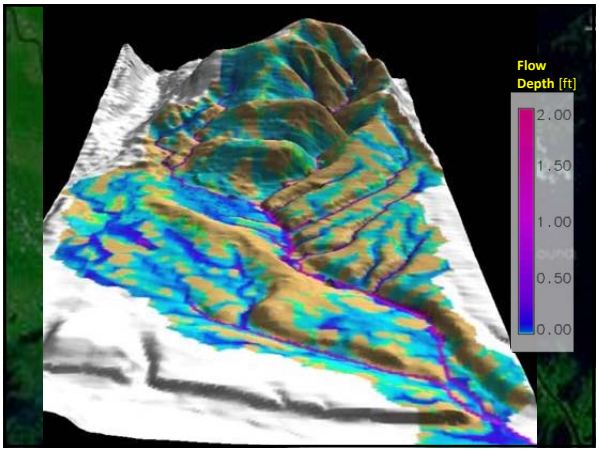
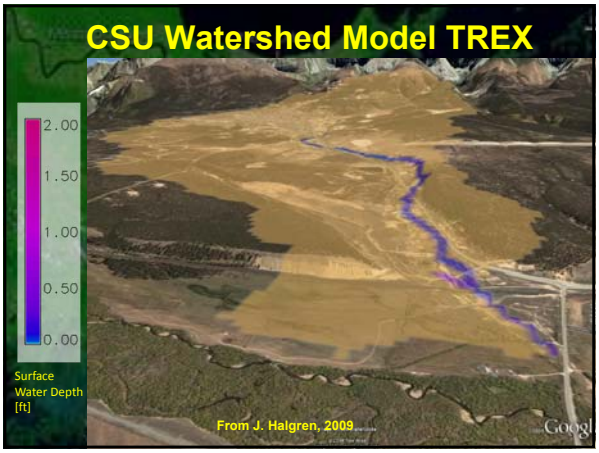
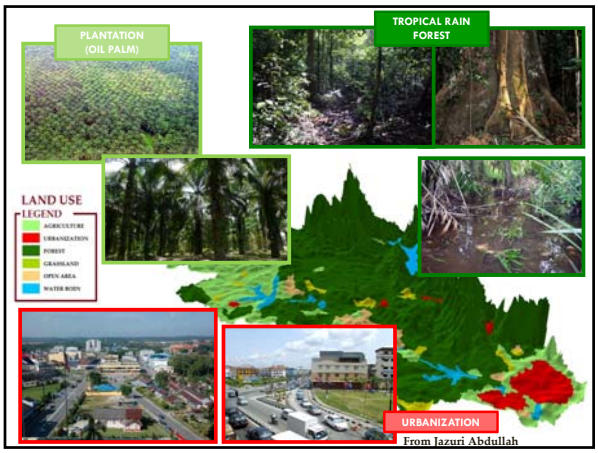
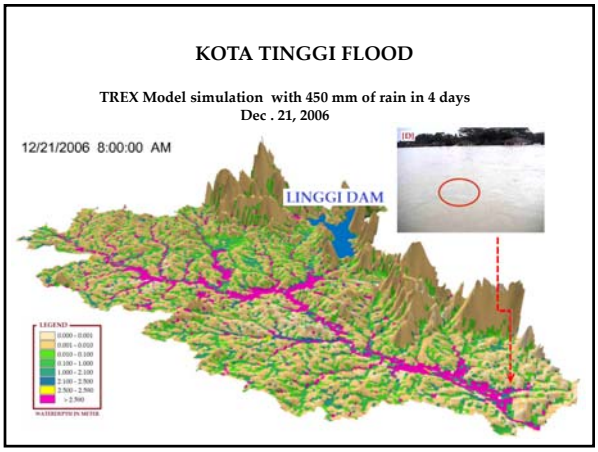


CSU Watershed Model TREX

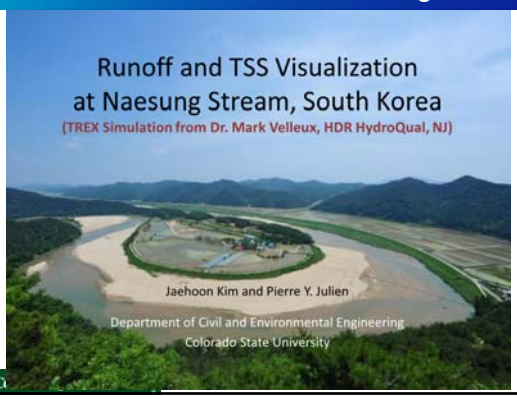




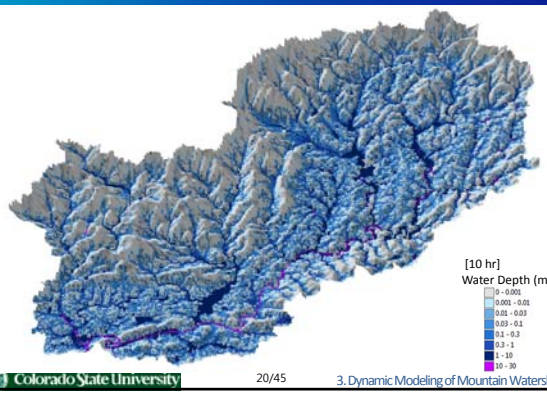
From Jazuri Abdullah



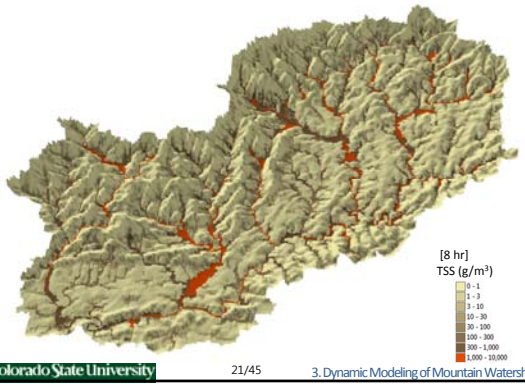
Runoff and TSS Visualization at Naesung Stream



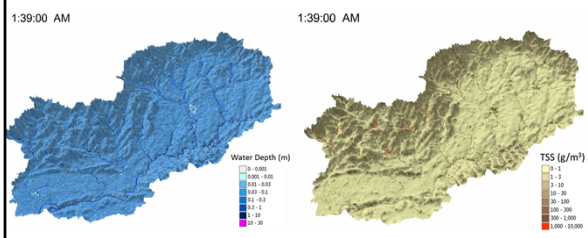
Water Depth



Total Suspended Solids



Runoff and TSS Visualization at Naesung Stream



Colorado State University 22/45 3. Dynamic Modeling of Mountain Watersheds

Reservoir Sedimentation

1. Sediment Sources and Yield
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5. Multi-objective Decisions

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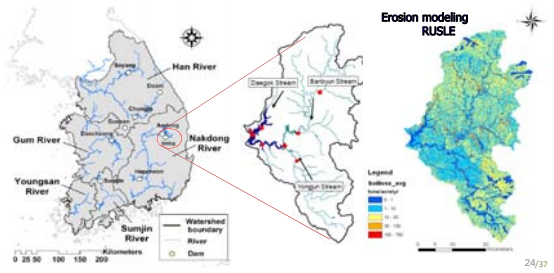
Example

Imha Reservoir has suffered from turbidity problems since 2002.

- Watershed area covers 1,361 km^2
- Three major tributaries



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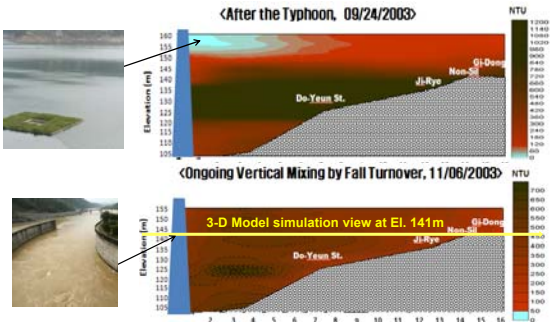
Turbidity Measurements



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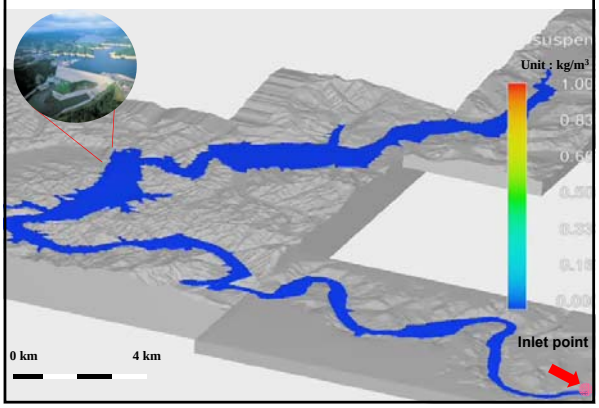
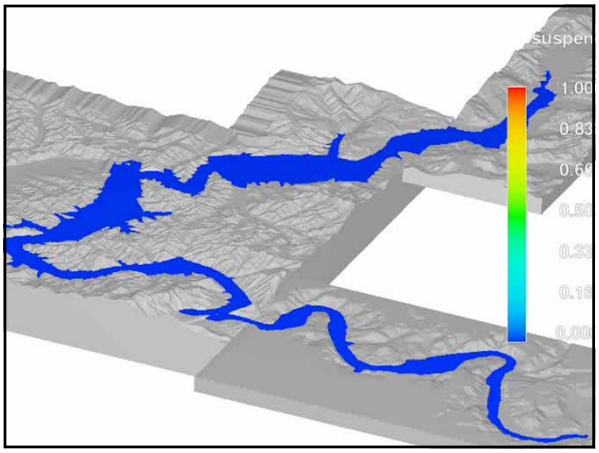
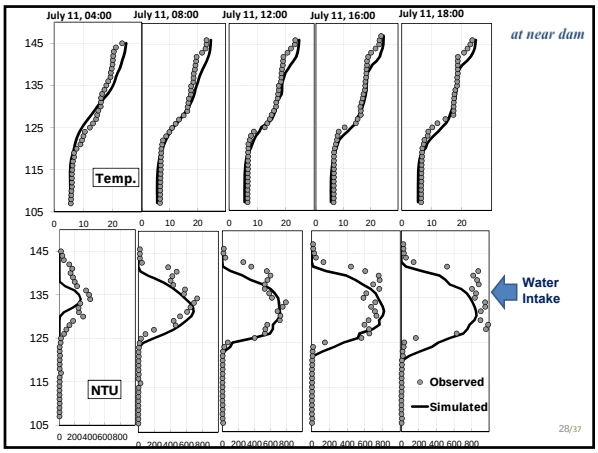
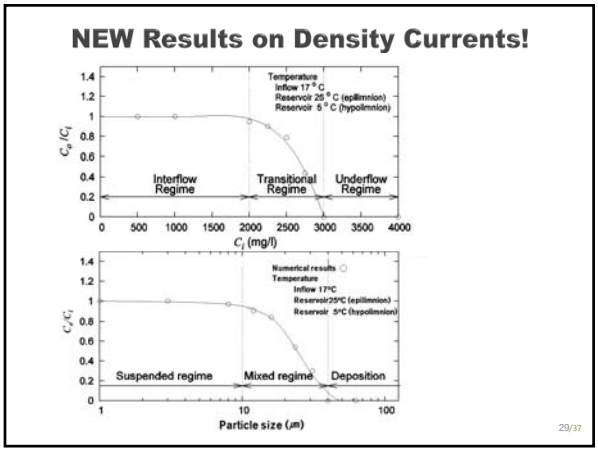
Numerical animation with bird's-eye viewpoint at EL. 141m









Reservoir Sedimentation

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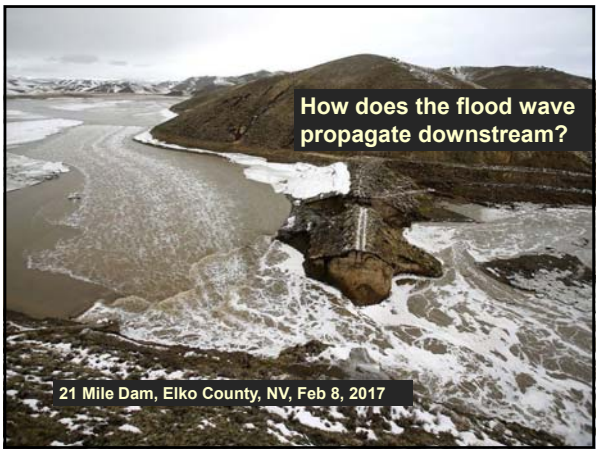
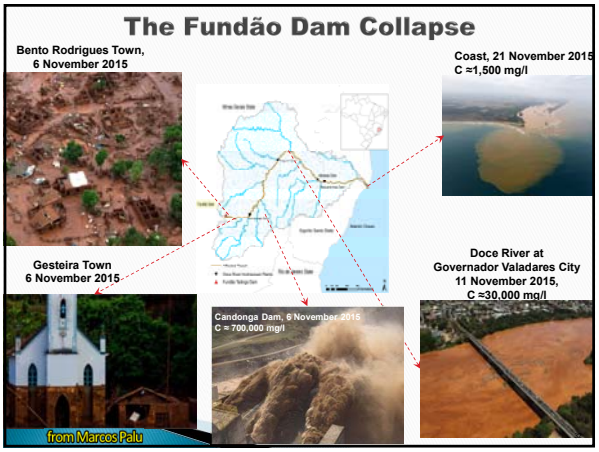
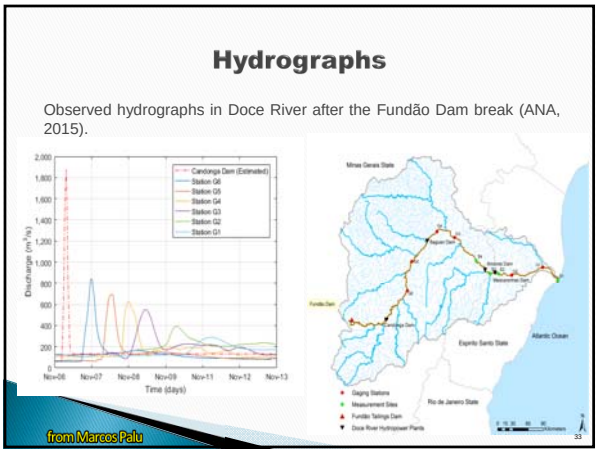
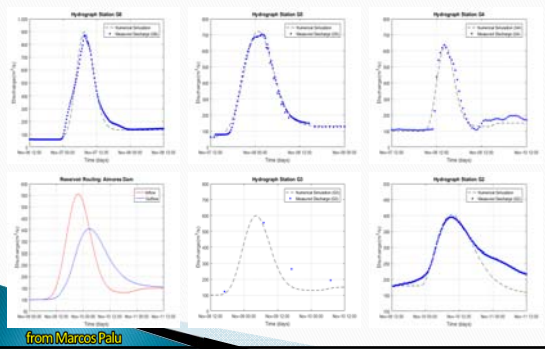

How does the flood wave propagate downstream?
21 Mile Dam, Elko County, NV, Feb 8, 2017


The Fundão Dam Collapse
Bento Rodrigues Town, 6 November 2015
Coast, 21 November 2015 C ≈1,500 mg/l
Gesteira Town 6 November 2015
Doce River at Governador Valadares City 11 November 2015, C ≈30,000 mg/l
Candonga Dam, 6 November 2015 C ≈ 700,000 mg/l
from Marcos Palu


Hydrographs
Observed hydrographs in Doce River after the Fundão Dam break (ANA, 2015).
Discharge (m³/s)
Time (days)
Nov-06
Nov-07
Nov-08
Nov-09
Nov-11
Nov-12
Nov-13
Minas Gerais State
Espirito Santo State
Atlantic Ocean
Rio de Janeiro State
from Marcos Palu

Floodwave Propagation Modeling



from Marcos Palu

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Sediment Routing NEW Development!

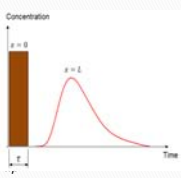
The one-dimensional advection-dispersion equation is applied on the evaluation of transport of suspended load in open channels (Fischer et al., 1979; Julien, 2010).

$$\frac{\partial C}{\partial t} + U\frac{\partial C}{\partial x} = K_d\frac{\partial^2 C}{\partial x^2} - kC$$

C is the concentration;
U is the flow averaged velocity;
κ_d is the longitudinal dispersion coefficient;
k is the settling rate.

Analytical solution for a constant spill in finite time interval is given by (Chapra, 2008):

$$C(x,t) = \frac{C_0}{2}\begin{cases} e^{\frac{Ux}{2K_d}(1-\Gamma)}\left[erfc\left(\frac{x-Ut\Gamma}{2\sqrt{K_d t}}\right) - erfc\left(\frac{x-U(t-\tau)\Gamma}{2\sqrt{K_d(t-\tau)}}\right)\right] \\ + e^{\frac{Ux}{2K_d}(1+\Gamma)}\left[erfc\left(\frac{x+Ut\Gamma}{2\sqrt{K_d t}}\right) - erfc\left(\frac{x+U(t-\tau)\Gamma}{2\sqrt{K_d(t-\tau)}}\right)\right] \end{cases}$$



Where: $\Gamma = \sqrt{1+4\eta}$ and $\eta = \frac{kK_d}{U^2}$

The error function complement, *erfc*, is equal to:

$$erfc(b) = 1 - erf(b) = 1 - \frac{2}{\sqrt{\pi}}\int_0^b e^{-\beta}$$

from Marcos Palu

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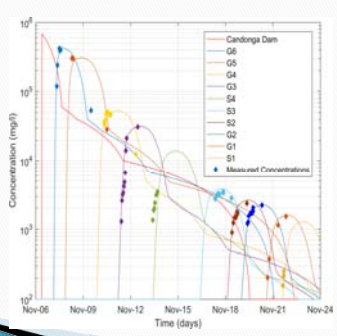
Sediment Concentration Modeling



from Marcos Palu

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Reservoir Sedimentation

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Other Issues besides sedimentation

- It is hard to change reservoir operation rules for sedimentation problems because we have many other issues to deal with.

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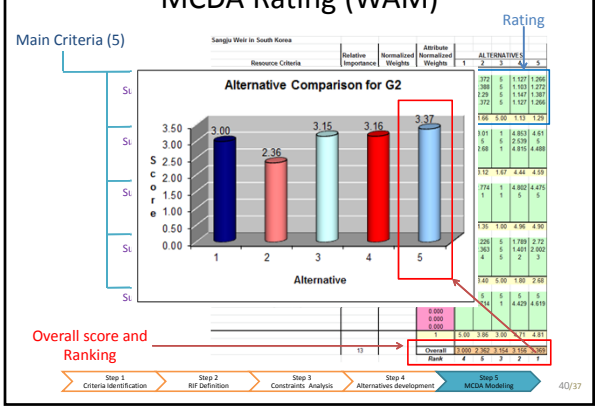
MCDA Rating (WAM)



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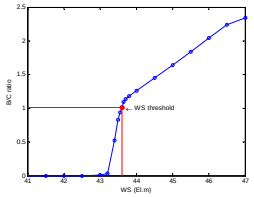
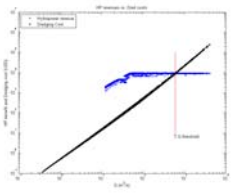
Hydraulic Thresholds

Operate the dam above
H threshold = EL. 43.6 m

Open the gates above
Q threshold = 620 m³/s





from H. Kim and Julien ASCE, 2018

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Summary and Conclusions

1. Sediment Sources and Yield

Erosion mapping locates problem source areas

2. Dynamic Modeling

Dynamic models like TREX can simulate extreme floods

3. Density Currents

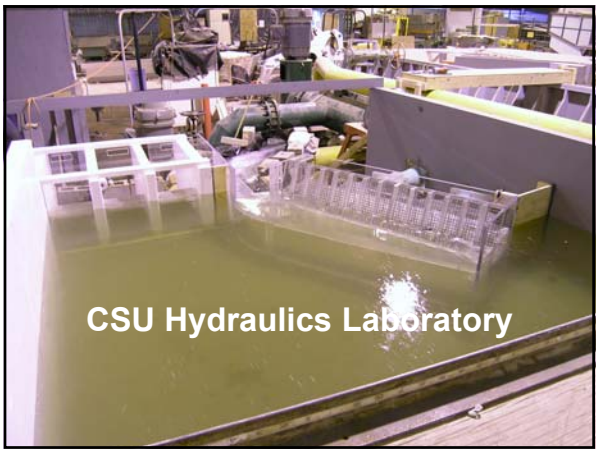
Turbidity problems from density currents can be modeled

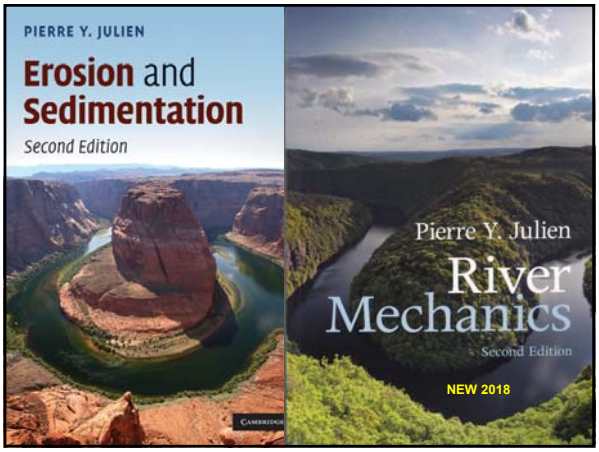
4. Dambreak Simulations

New models for flood and sediment wave propagation from dam break

5. Multi-objective Decisions

Base dam operations on hydraulic thresholds and MCDA


CSU Hydraulics Laboratory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ACKNOWLEDGMENTS
Sangdo An (KICT, South Korea)
Mark Velleux, HDR, USA
Marcos Palu, Brazil
Hwayoung Kim, K-Water, South Korea
James Halgren (CSU)
Aaron Orechwa, Tetratech, USA
Shukran Sahaar, Afghanistan
A. Fuad Embi (DID, Malaysia)
Atikah Sharie (DID, Malaysia)
Jazuri Abdullah (UiTM, Malaysia)
Shazwani N. Muhammad (UKM, Malaysia)
Djoko Legono, Gadjah Mahda, Indonesia
Neil Andika, Indonesia
Un Ji, KICT, South Korea
Patrick O'Brien, USACE, USA
Carmen Bernedo, Stantec, USA
Terima Kasih atas Perhatian Anda!