Rock Surface Spillway Risk Assessment Using Logistic Regression

Johannes L. Wibowo

U.S. Army Engineer Research and Development Center (ERDC)

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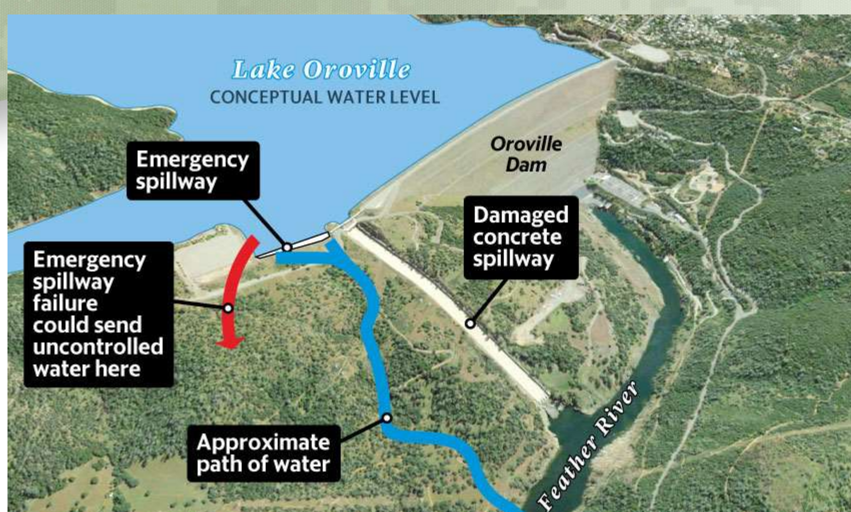
Rock Spillway Erosion



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Risk Assessment of Rock Spillway Erosion

Process of Answering Three Questions:

1. What can go wrong?
2. What is the likelihood it will go wrong?
3. What are the consequences if it does go wrong?

Rock Spillway Erosion

1 What Can Go Wrong?

Local Scouring

Headcut Erosion

Spillway Breach

Dam Breach

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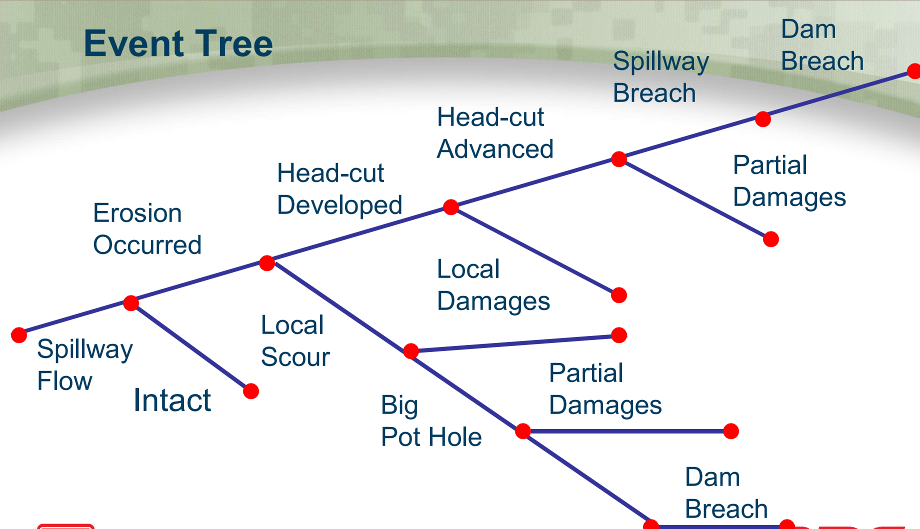
Rock Spillway Erosion

2 What Is The Likelihood It Will Go Wrong?

- Uncertainty of Flood Event
- Uncertainty of Material Parameters
- Uncertainty of Performance of the Unlined Spillway

Rock Spillway Erosion

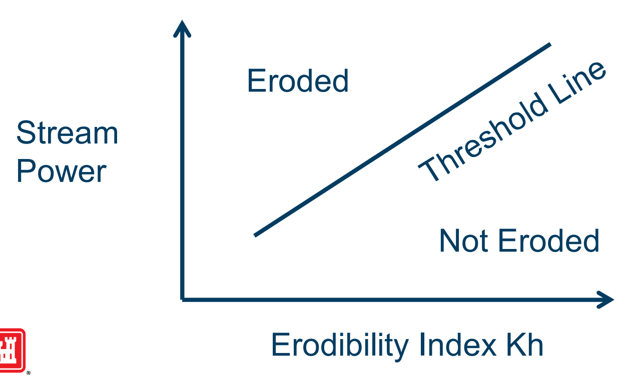
Event Tree



Several Spillway Erosion Methods

- USDA (Temple et al., 1994)
- Annandale (1995)
- REMR (WES, 1998)
- Bollaert (2002)

- Erosion Model - Threshold Line



Rock Spillway Erosion

- Erodibility Index (K_h)

- $K_h = M_s * K_b * K_d * J_s$

M_s = Material Strength Number
K_b = Block Size Number
K_d = Joint Shear Strength Number
J_s = Joint Orientation Number

Rock Spillway Erosion

- Stream Power

- $P = \gamma * U * h * S_f$

P = Stream Power
γ = Unit weight of water
U = flow velocity
h = water depth
S_f = Energy Slope

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Logistic Regression

- Regression for Binary Outcomes
  - Occurrence (Erosion)
  - Non-Occurrence (No Erosion)
- User of Logistic Regression Method
  - Medical
  - Business
- Probabilistic Liquefaction Analysis (Liao et al, 1988)

Logistic Regression

- Odds ratio $$\frac{p}{1-p}$$
- Logit transformation

$$Ln\left[\frac{p}{1-p}\right] = b_0 + b_1 x$$

$$p = \frac{1}{1+\exp[-(b_0 + b_1 x)]}$$

p = probability of occurrence

b_0, b_1 = regression parameters

x = independent variable

Logistic Regression

Multiple Logistic Regression

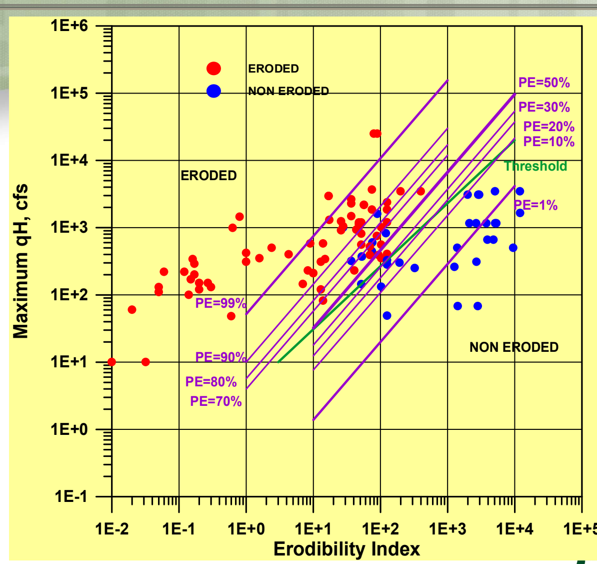
$$p = \frac{1}{1 + \exp\left[-\left(b_0 + b_1 x_1 + b_2 x_2 + .. + b_n x_n\right)\right]}$$

p = probability of occurrence

b_0, b_1, b_2, .., b_n = regression parameters

x_1, x_2, .., x_n, = independent variables

Logistic Regression of USDA Data



Logistic Regression

Multiple Logistic Regression for Spillway Erosion

$$p = \frac{1}{1 + \exp\left[-\left(b_0 + b_1 \; K_h g\left(SP\right) SP\right)\right]}$$

K_h = Erosion Index, Material Resistance
SP = Stream Power

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Logistic Regression

Multiple Logistic Regression for Annandale's Chart

$$p = \frac{1}{1 + \exp\left[-\left(-1.859 - 7.029 \; \log\left(K_h\right) + 9.798 \; \log\left(SP\right)\right)\right]}$$

K_h = Erosion Index, Material Resistance
SP = Stream Power
Nagelkerke's R^2 = 0.908

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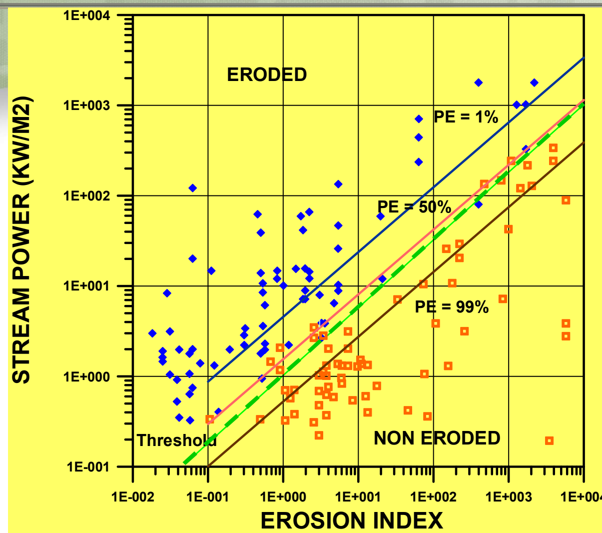
Annandale's Threshold Lines



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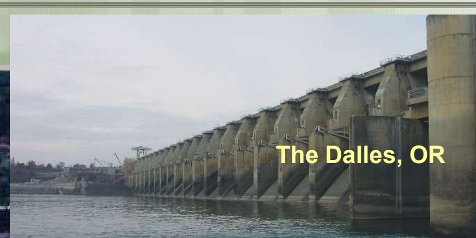
Logistic Regression



	The Dalles, OR Q=2,290,000 cfs	Bluestone. WV Q=430,000 cfs
Erosion Index (Kh)	1960	2734
Stream Power (Kw/m2)	125.4	22.3
Probability of Erosion	0.012	0.000

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Ordinal Logistic Regression

Sj = F (Material, Peak Discharge, Flow Duration, Spillway Geometry)

Data: Case Histories (USDA and COE)

Damage Levels:

No Damage	0 - 0.05%
Lightly Damage	0.06 – 15%
Moderately Damage	16 – 40%
Severely Damage	41 – 75%
Breach	76 – 100%

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Conclusions and Recommendations

- Rock Spillway Erosion analysis need to be done on unlined rock spillways as well as on rock underneath the concrete spillway
- Logistic regression analysis is a powerful tool to analyze probability of erosion of the rock spillways
- Seismic velocity is a good tool to assess the Rock Erodibility Index
- Coupling Discrete Elements and Computational Fluid Dynamic (CFD) will be the next generation method for analyzing rock spillway erosion

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Questions???

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