Reservoir Sediment Management & Analysis for Engineers

Hydrosuction Sediment Removal Systems

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LEEP2 Building – Room G415
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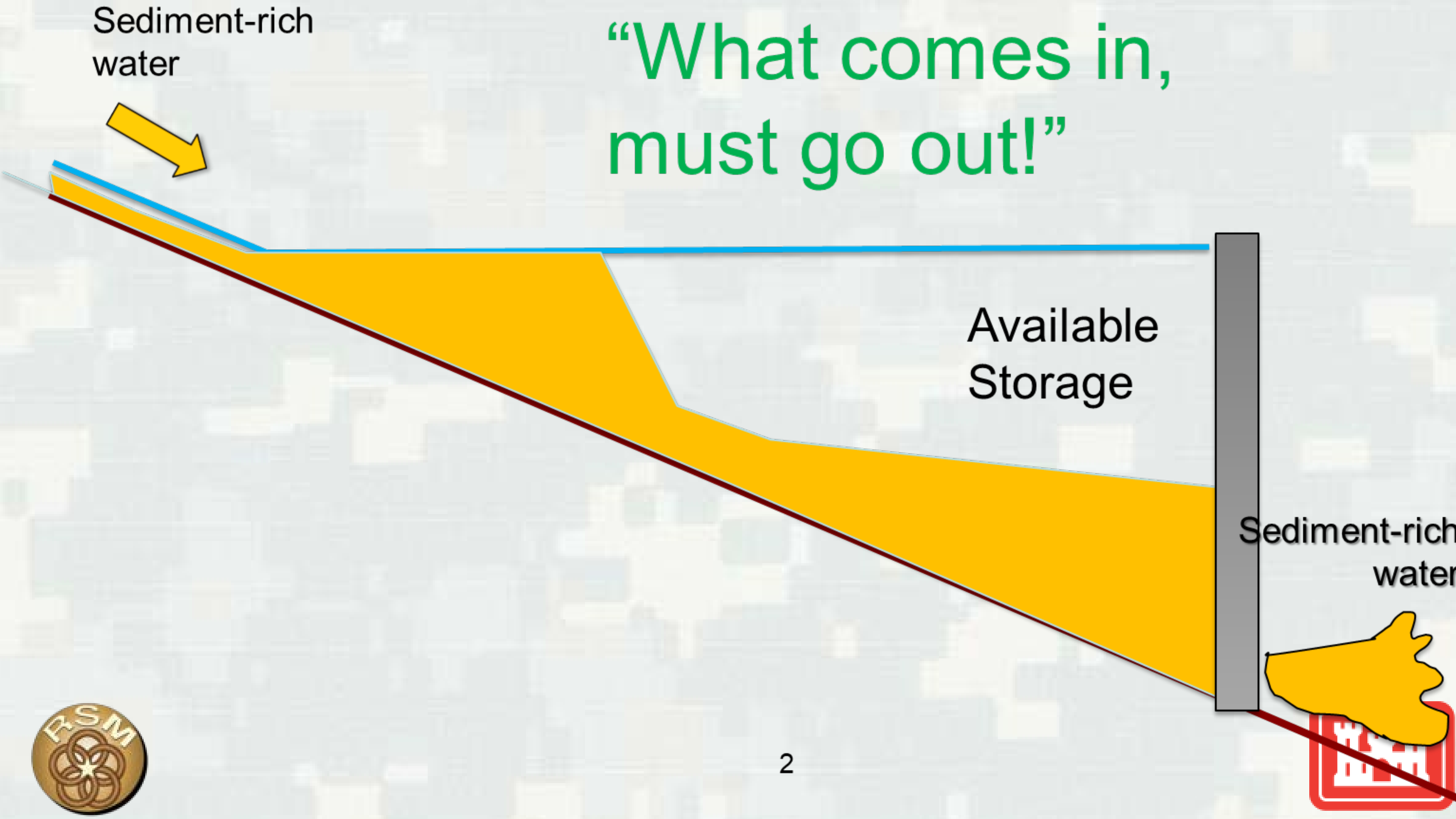
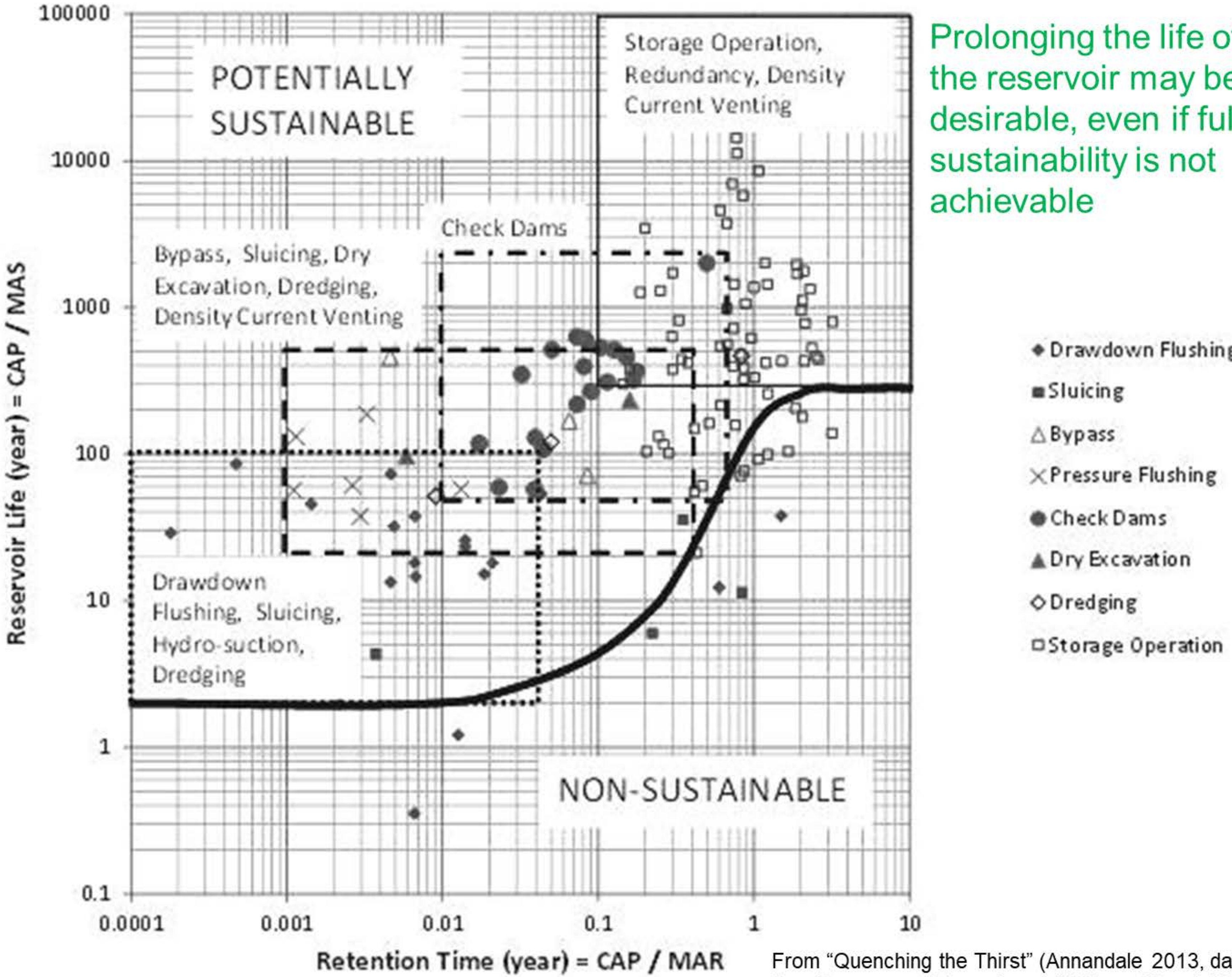
ERDC
Engineer Research and Development Center

Reservoir Sediment Sustainability

"What comes in, must go out!"





Prolonging the life of the reservoir may be desirable, even if full sustainability is not achievable

From "Quenching the Thirst" (Annandale 2013, data from Basson and Rooseboom 1999, and Sumi 2003)

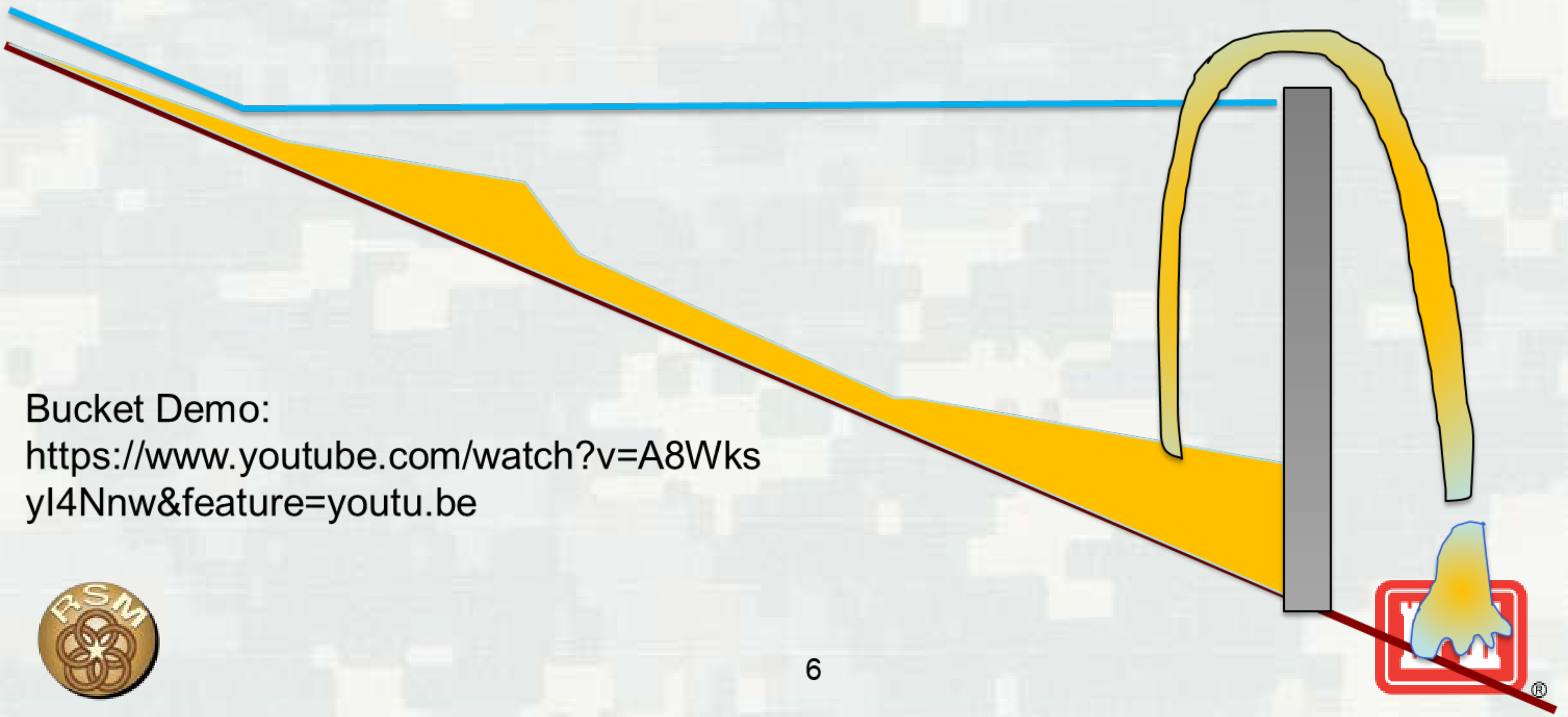
®

Lake Dredging Costs

- John Redmond: $6.7/cu yd
- Mission Lake: $6.5/ cu yd
- Lake Seminole: $27/ cu yd

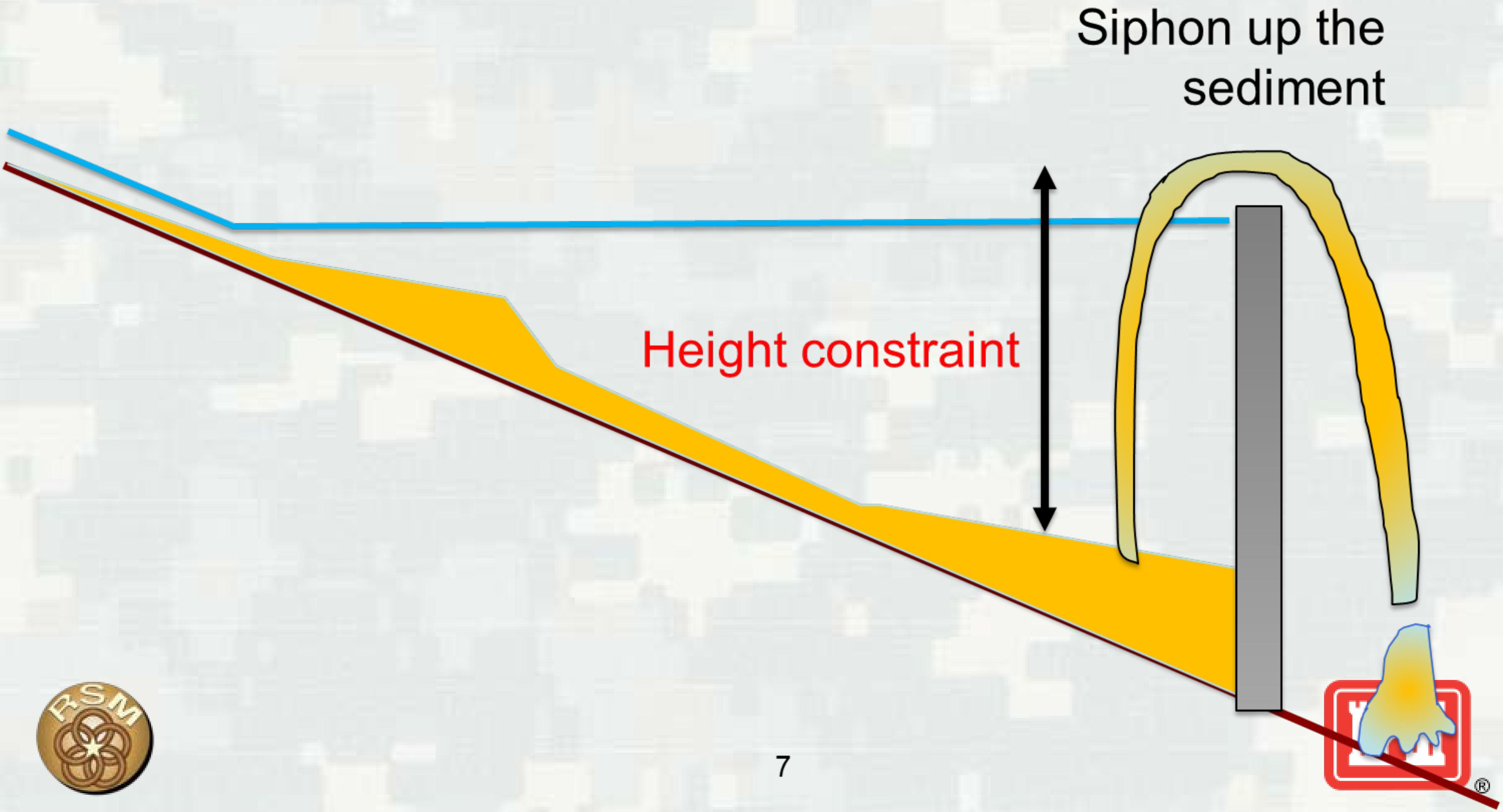
Hydrosuction

Hydrosuction

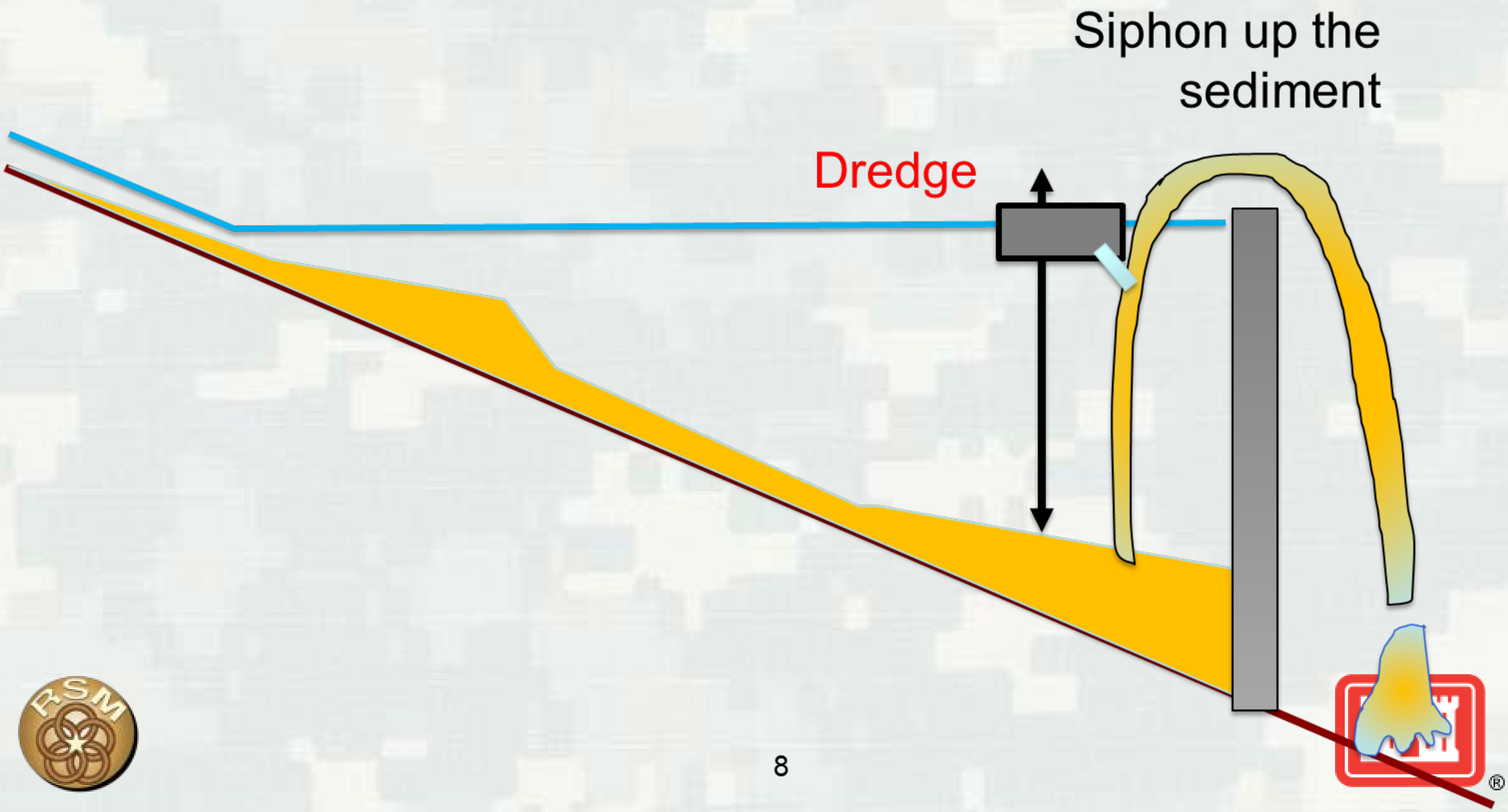


Bucket Demo:
https://www.youtube.com/watch?v=A8WksyI4Nnw&feature=youtu.be

Hydrosuction

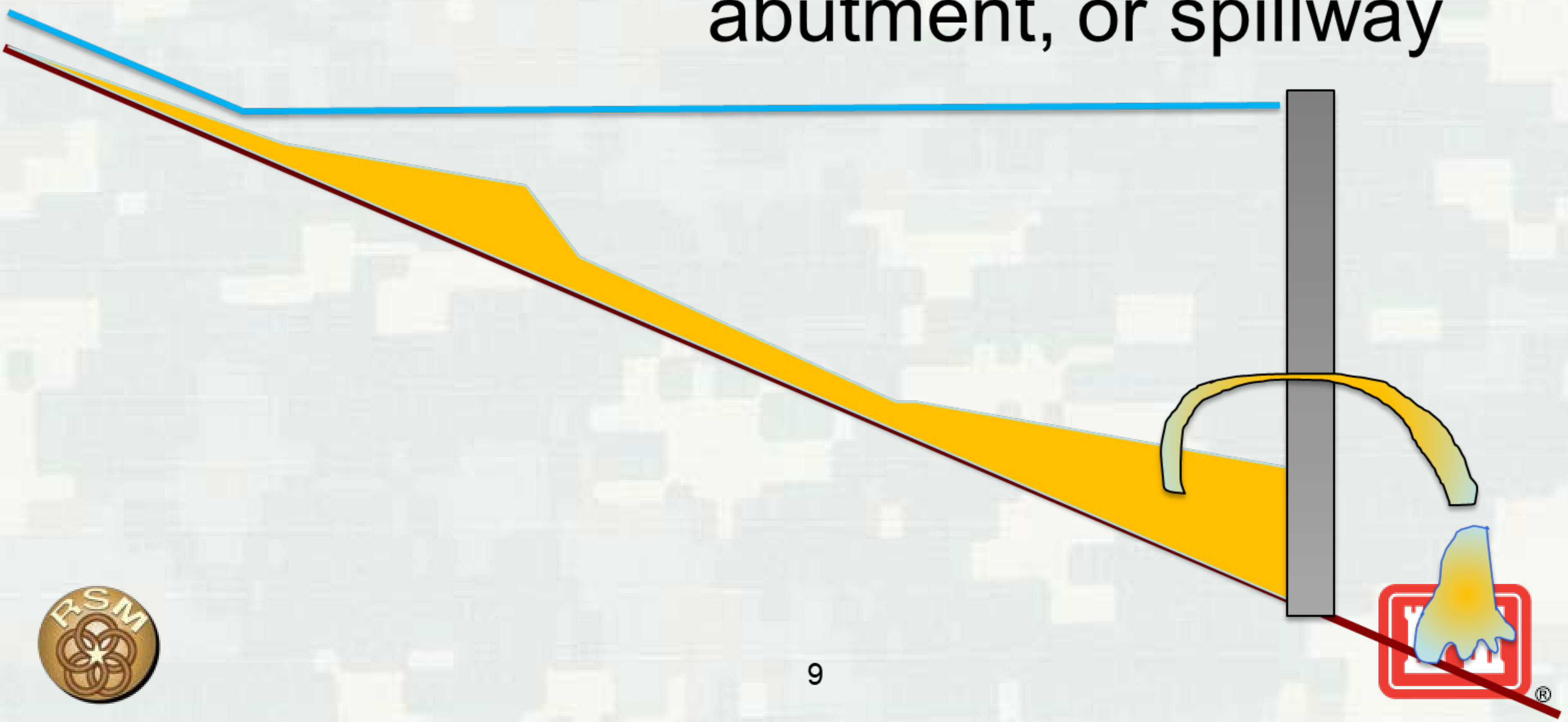


Dredging with Downstream Discharge of Sediments



Hydrosuction

Go through the dam, abutment, or spillway



Hydrosuction in the United States

- Experimental installation on Grove Lake, NE
  - 3,000 ft 6-inch PVC pipe
  - Sand balance restored for more than 5 years

Slide Source: Rollin Hotchkiss

Hydrosuction Internationally

Sedicon

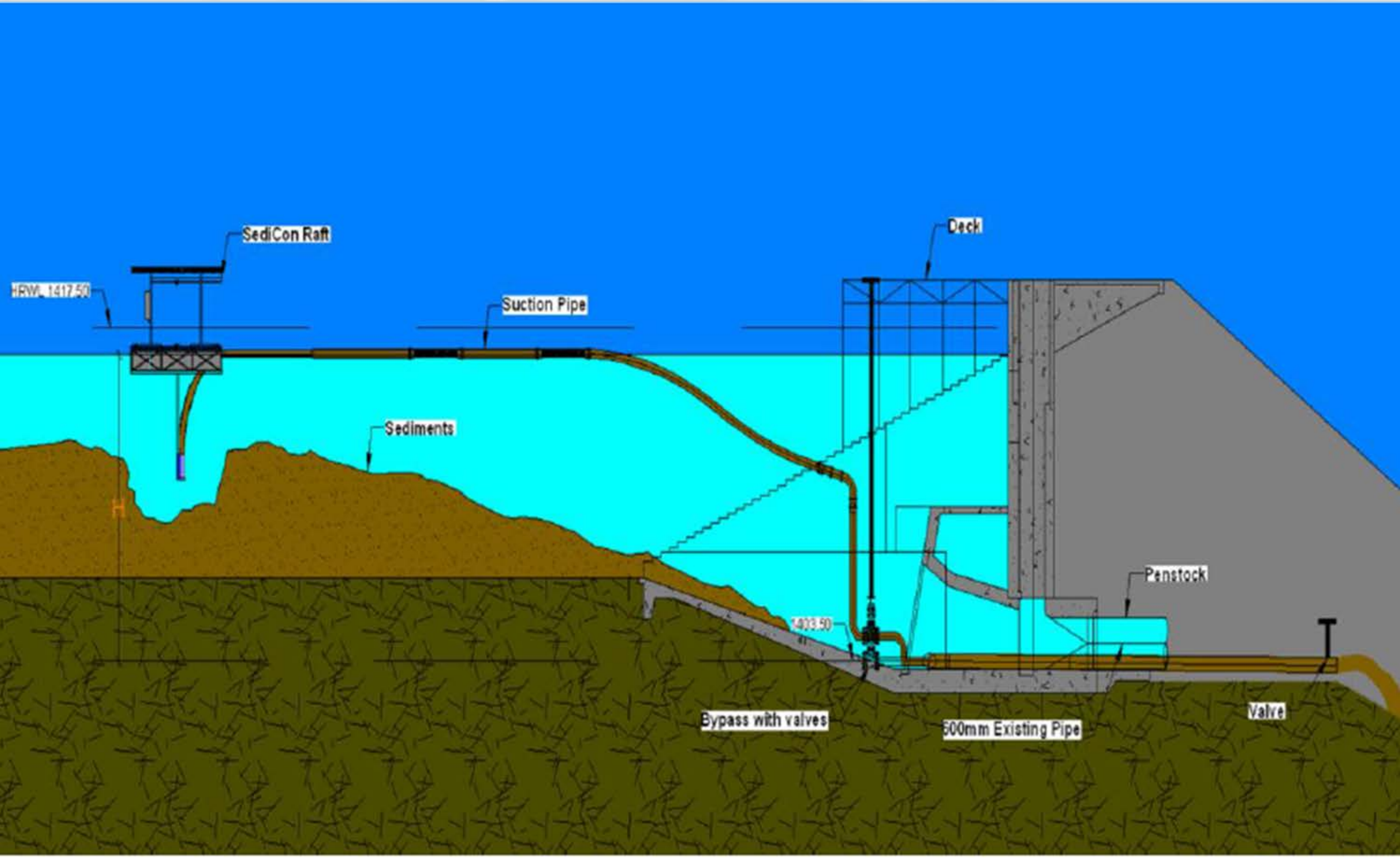

Santa Maria Dam
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
916 mi
Image Landsat / Copernicus


Santa Maria HPP, Guatemala

Santa Maria HPP, Guatemala


Santa Maria HPP, Guatemala

El Canada Hydrosuction

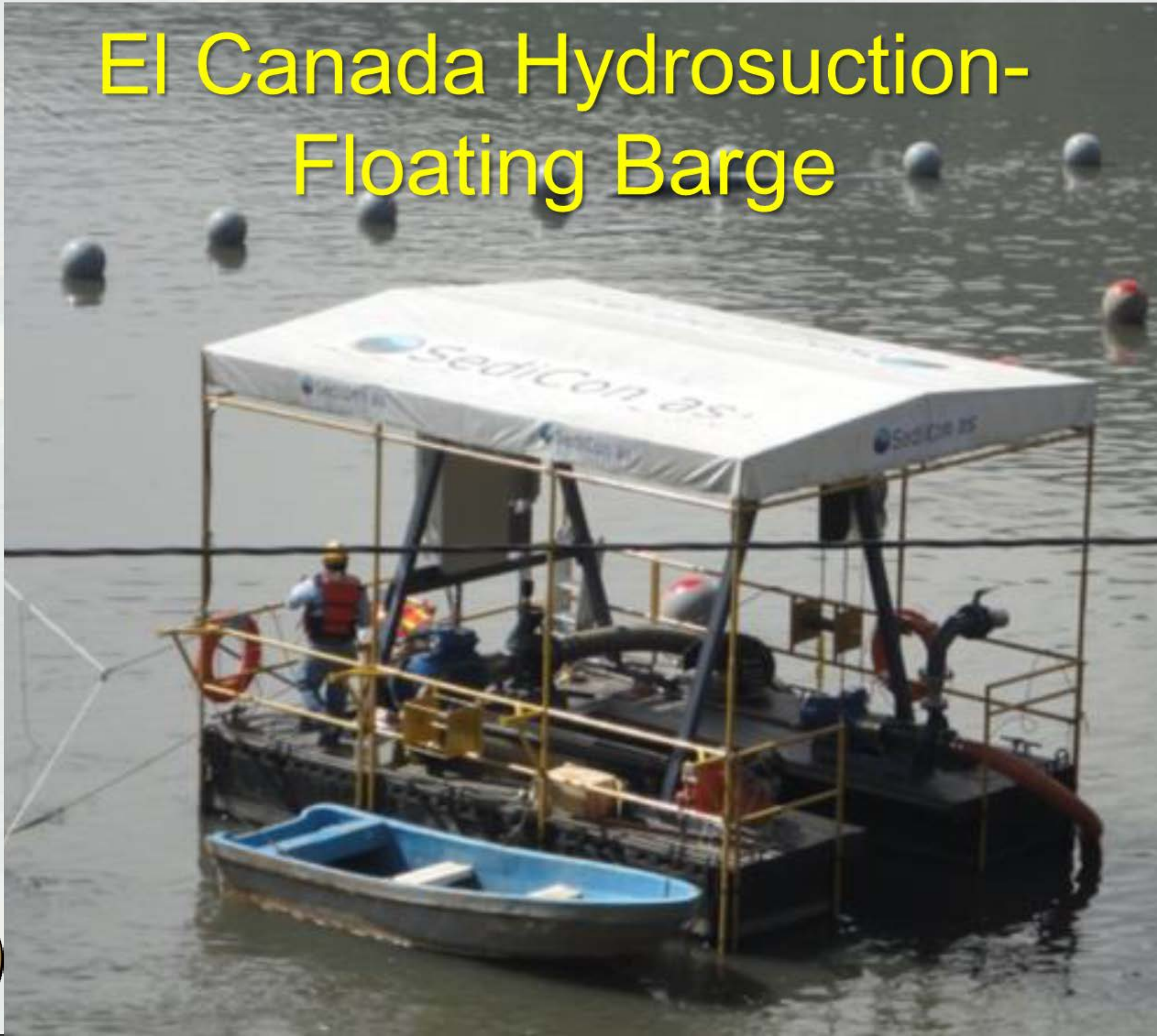


El Canada Hydrosuction-Connecting to Existing Conduit

Fig. 2.

Bypass connection to existing drainage pipe (a) side view (b) downstream view

El Canada Hydrosuction-Floating Barge



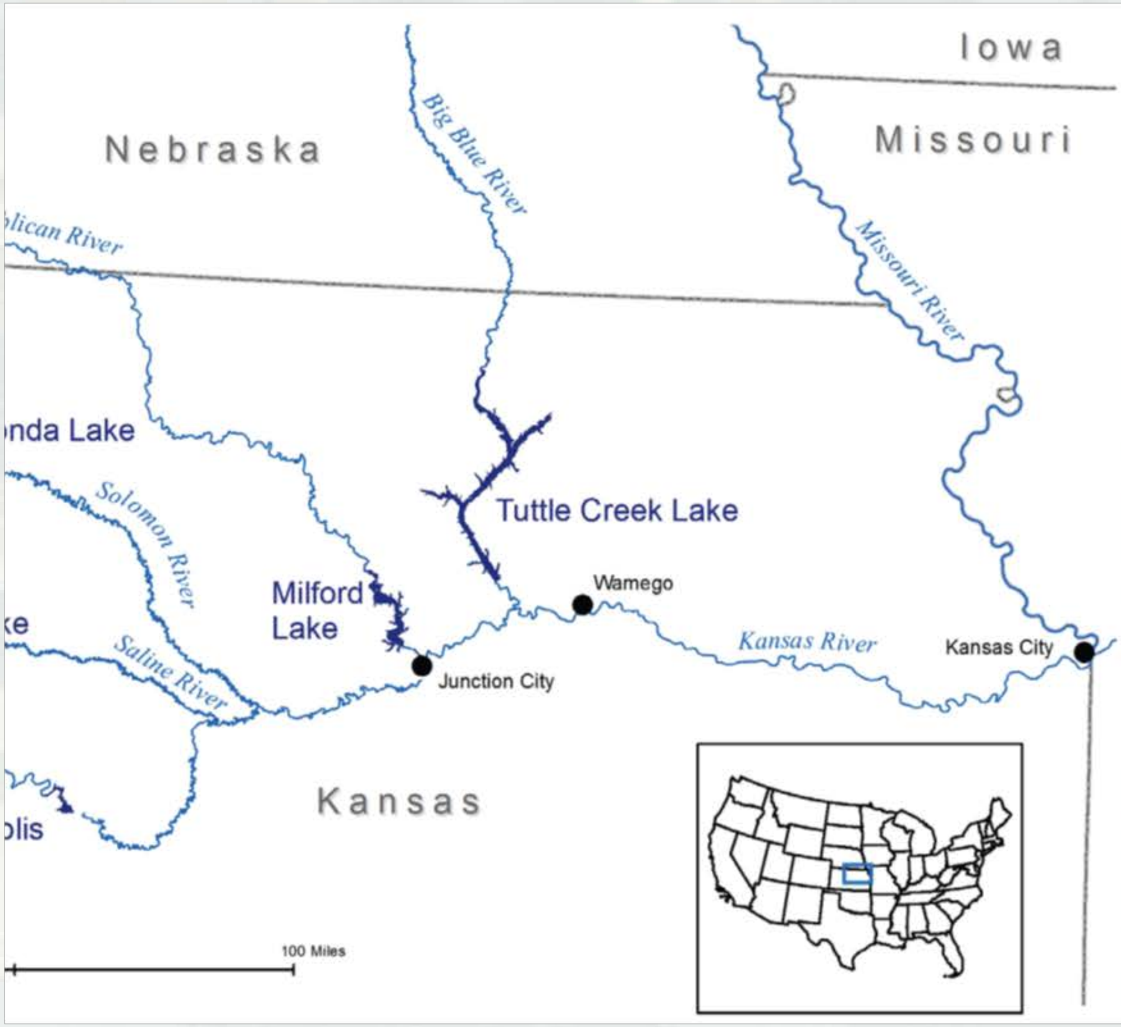
El Canada Hydrosuction-Discharge

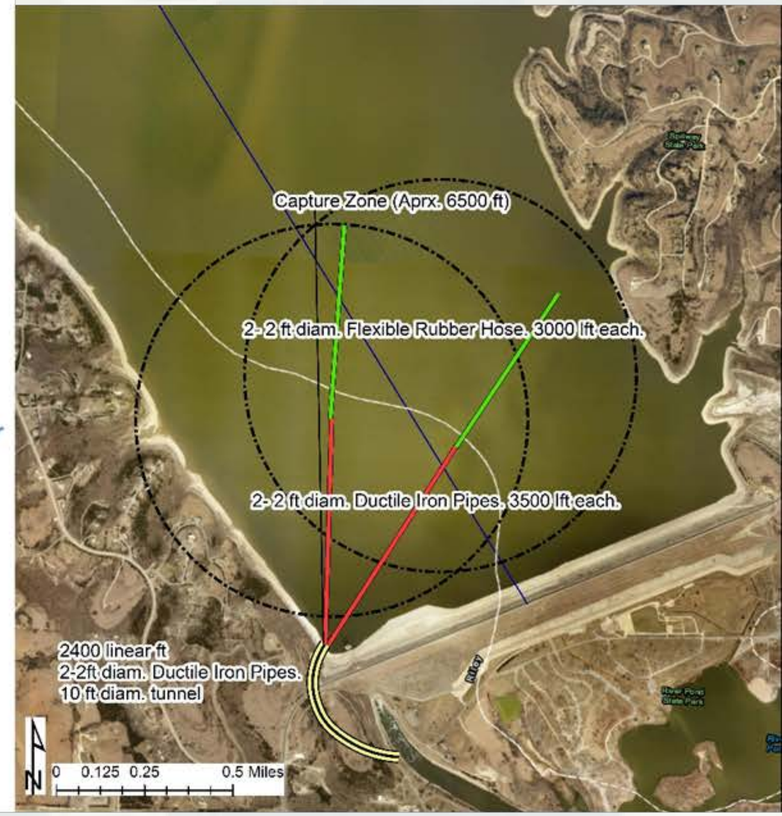
Results

- ≈ 157,000 cy in first 6 months

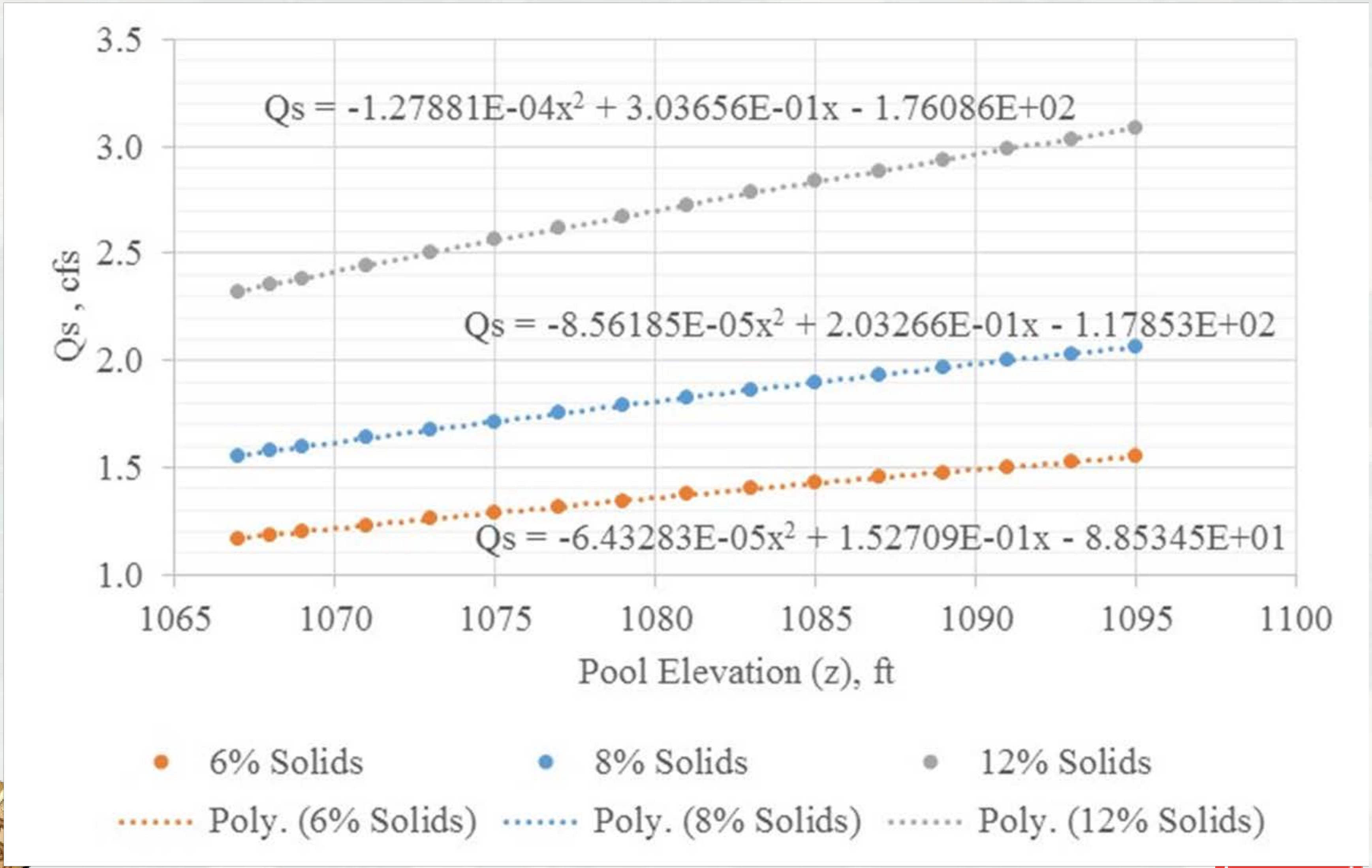
Year	Concentration	Availability
2012	12%	86%
2013	9%	98%
2014	8%	98%

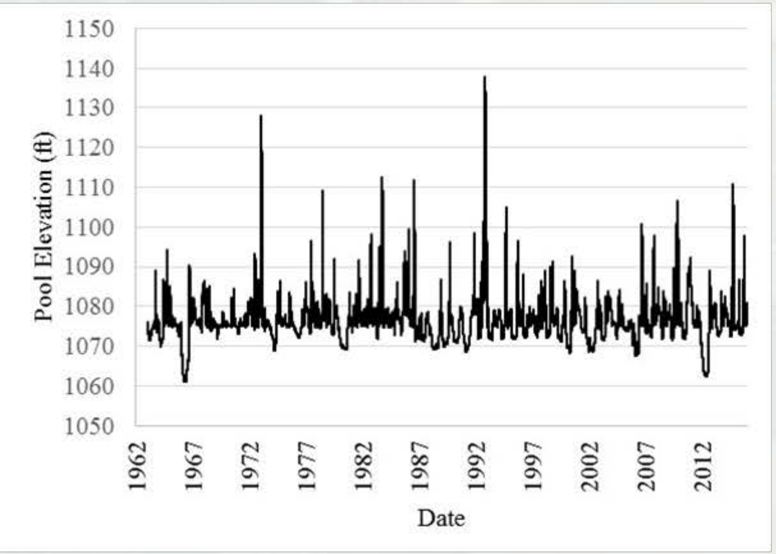
Tuttle Creek Lake Analysis





Hydrosuction Sediment Discharge Rating Curve Based on Pool Elevation





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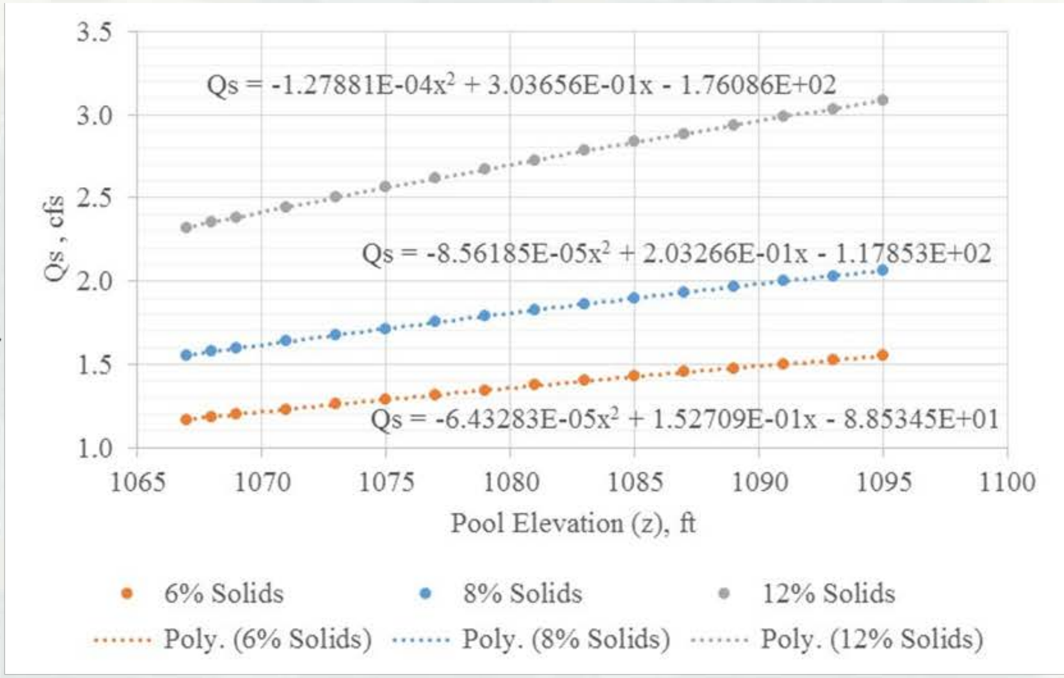
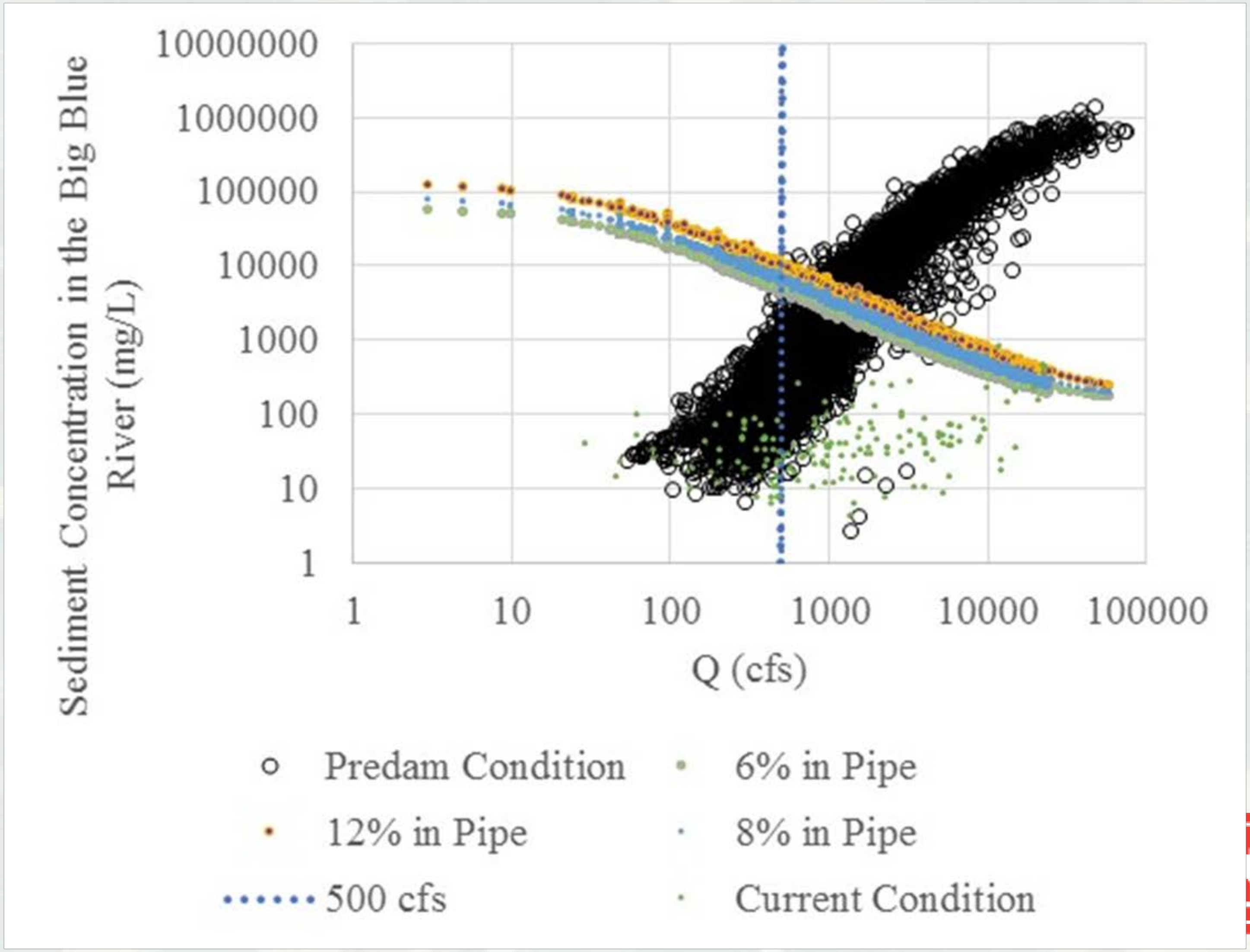


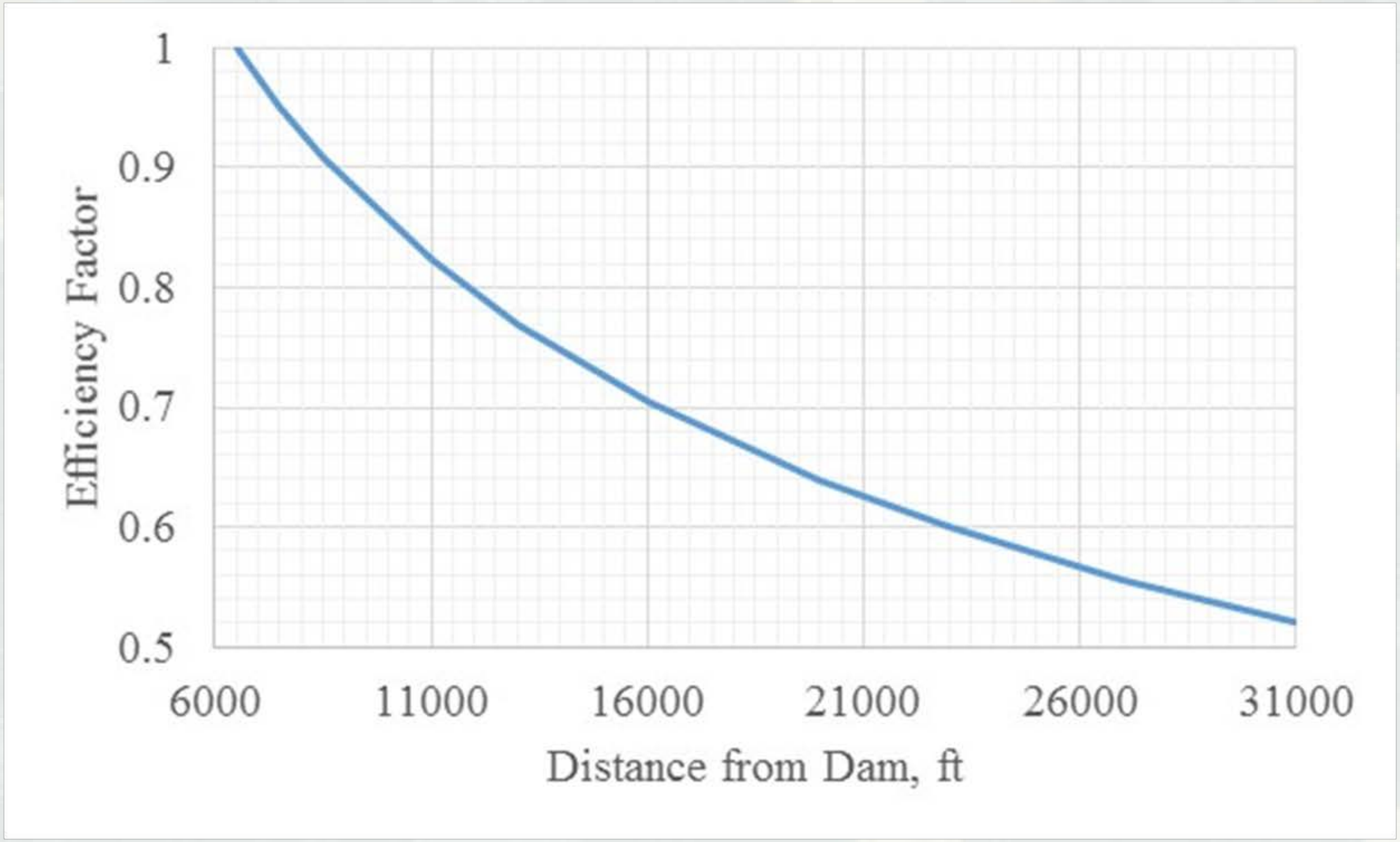
Table 4. Hydrosuction Effectiveness (Continuous Operation, 2 pipes)

Solids Fraction	Average Annual Sediment Discharge	
	M yd^3	% of Annual Accumulation
0.06	3.1	53%
0.08	4.1	70%
0.12	6.1	105%

Operating Within the Pre-dam Concentrations



Farther from dam = longer pipe = more friction = less sediment discharge



Example from Tuttle Creek Lake analysis. Loss in efficiency depends on project-specific features (pipe materials, head difference, etc.)

Hydrosuction for Sand

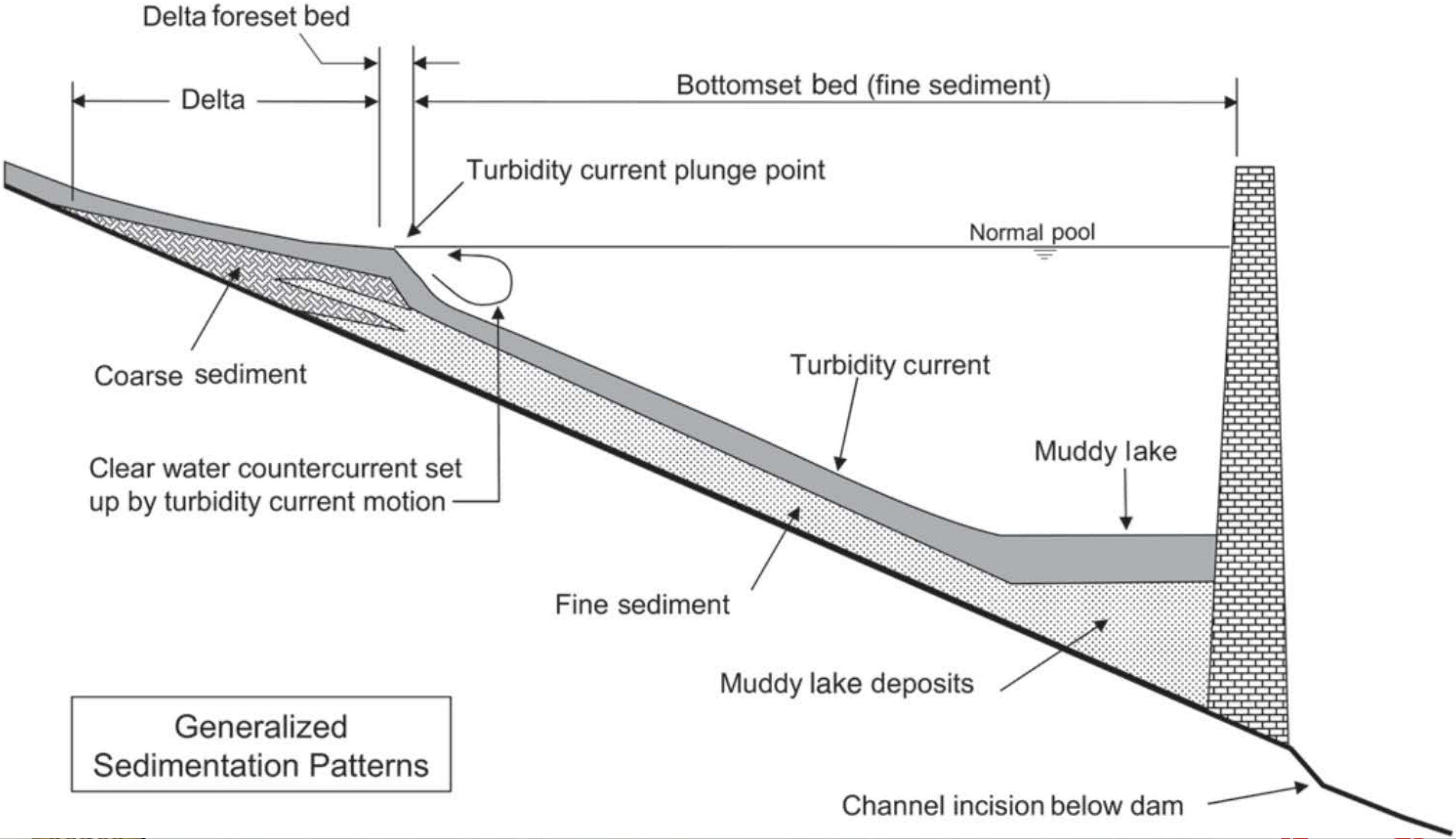
- Hotchkiss and Huang. 1995. "Hydrosuction Sediment-Removal Systems (HSRS): Principles and Field Test". *Journal of Hydraulic Engineering*, June 1995.

HYDROSUCTION SEDIMENT-REMOVAL SYSTEMS (HSRS): PRINCIPLES AND FIELD TEST

By Rollin H. Hotchkiss,[1] Member, ASCE, and Xi Huang,[2] Associate Member, ASCE

ABSTRACT: Hydrosuction sediment-removal systems (HSRS) remove deposited or incoming sediments from reservoirs using the energy represented by the difference between water levels upstream and downstream from a dam. HSRS are briefly described and compared to other reservoir-sediment management options. Hydraulic principles and design procedures are explained and applied to a field test carried out at Lake Atkinson, on the Elkhorn River, in Nebraska. The field study demonstrated that several different inlet shapes are capable of removing deposited sediment at the rate that it enters the reservoir on an annual basis. A ten-step procedure to determine the feasibility of using an HSRS is presented.

Hydrosuction for Fines



ASCE Manual 110, Fig 12.4

"…the infinite diversity of the slurries encountered by the dredgeman responds better to the extrapolation of actual test data and operating experience than to academic formulas. However, when data is lacking, formulas may represent the best information available, and indeed may be essential." (From *Fundamentals of Hydraulic Dredging*, Turner 1996)

Simplified Analysis Procedure

1. Collect system parameters
2. Select design parameters
3. Assume a percent solids
4. Compute slurry discharge via standard pipe flow equations
   - Take into account differences in viscosity and density due to solids
5. Multiply the slurry discharge by the assumed percent solids

What Percent Solids?

Table 2. Percent Solids in Documented Hydrosuction Projects

% Solids	Reservoir	Location	Sediment Type	Entrainment Mechanism	Reference
12	El Canada (Year 1)	Guatemala	Clay	Water-jetting	Jimenez, Figueroa, and Jacobsen, 2015
9	El Canada (Year 2)	Guatemala	Clay	Water-jetting	Jimenez, Figueroa, and Jacobsen, 2015
8	El Canada (Year 3)	Guatemala	Clay	Water-jetting	Jimenez, Figueroa, and Jacobsen, 2015
3	Djindiouia	Algeria	Silt and clay	Cutter-head powered by a turbine on the outlet pipe	Fan, 1985
15	Xiao Hua-shan	China		Water-jetting	Hotchkiss and Huang, 1995.

Simplified Analysis Procedure

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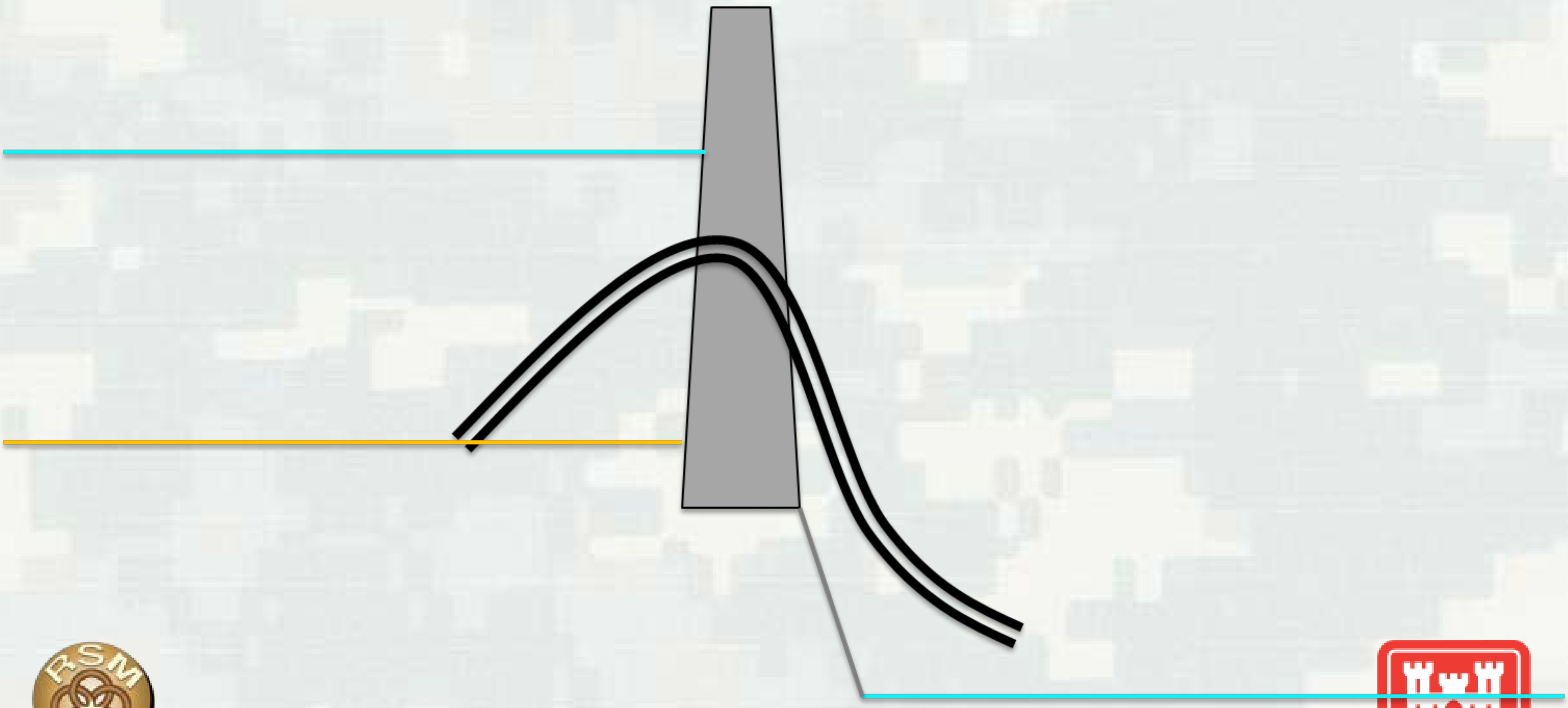
Pipe Flow Equations

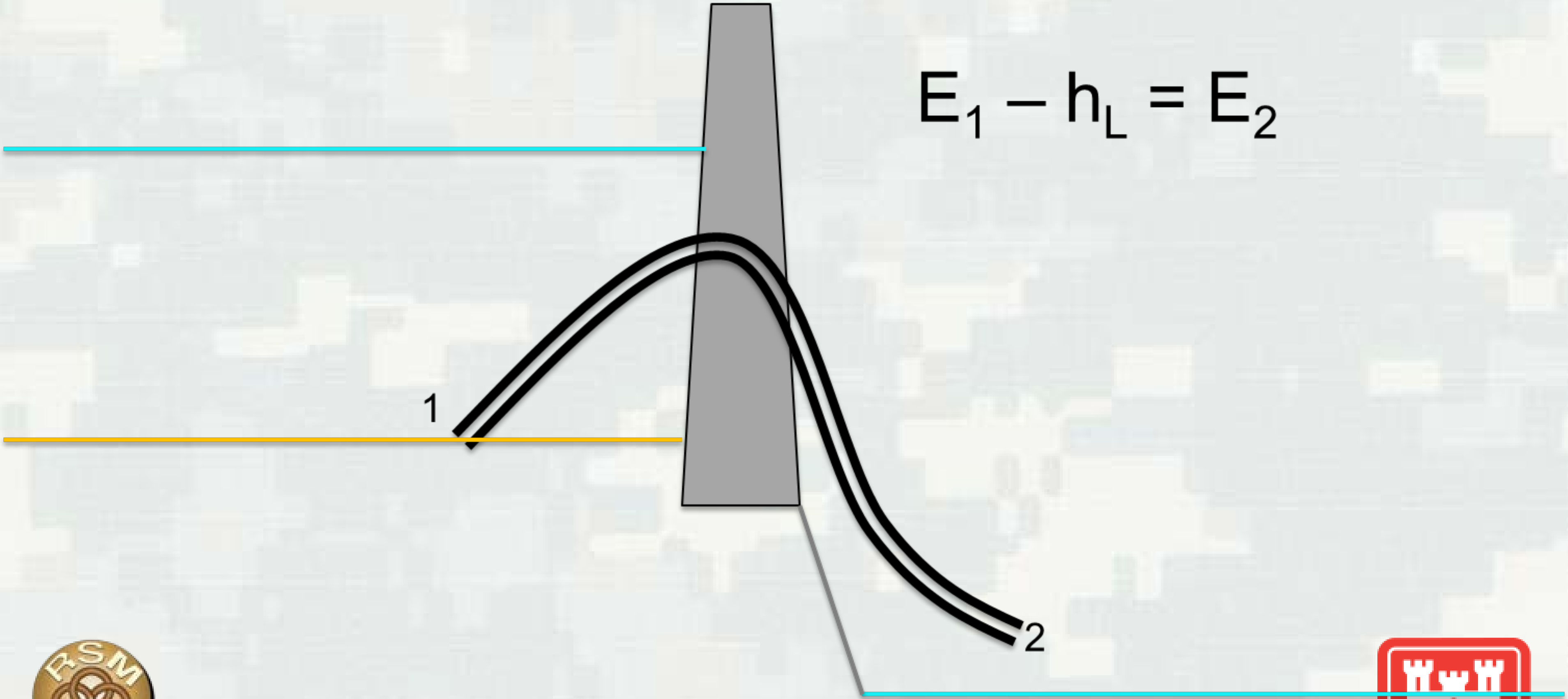
1. Energy equation

2. Headloss equation

Energy Equation



Energy Equation

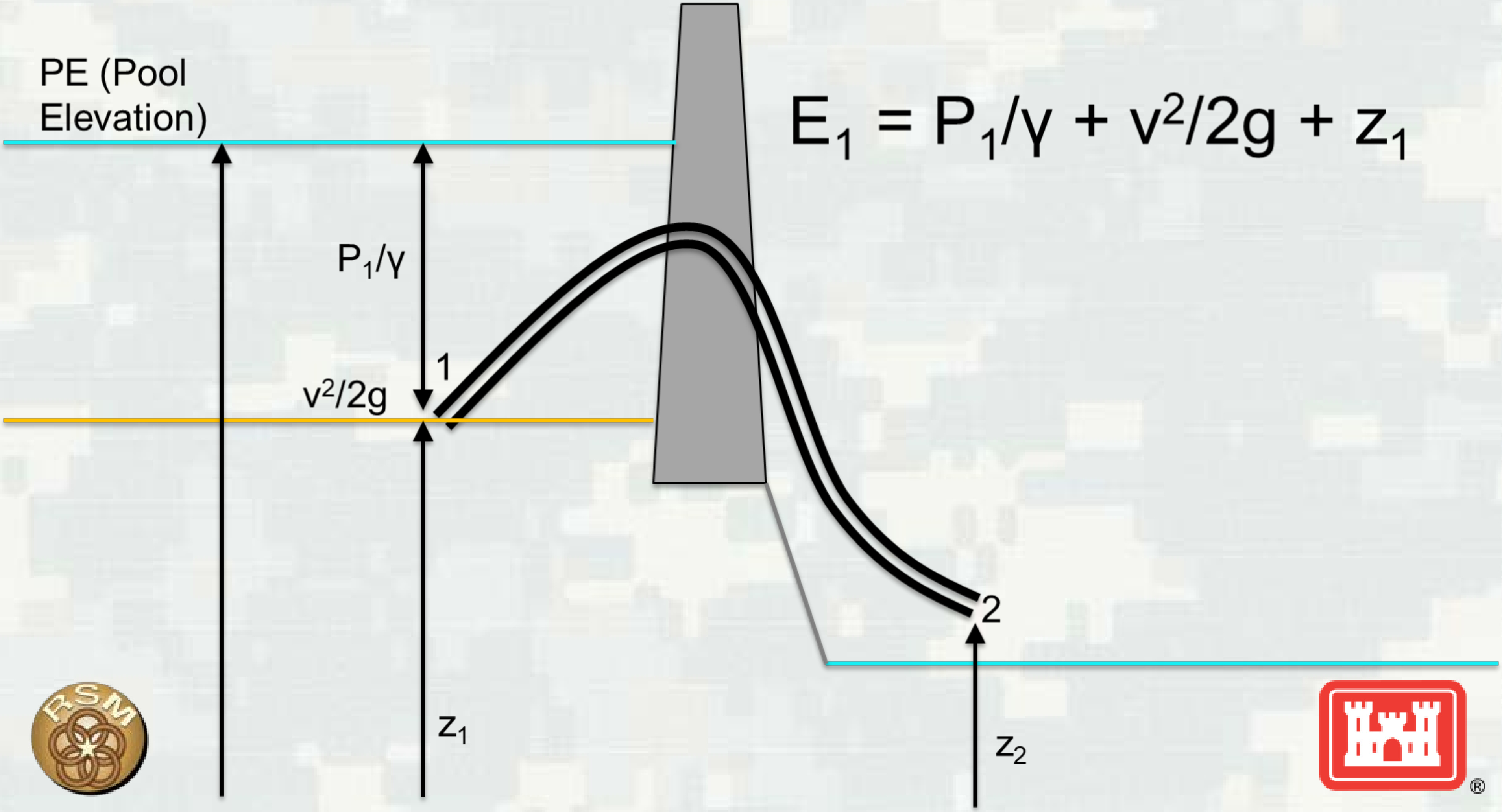


$$E_1 - h_L = E_2$$

Pipe Flow Equations

$$E_1 - h_L = E_2$$

$$E_1 = P_1/\gamma + v^2/2g + z_1$$

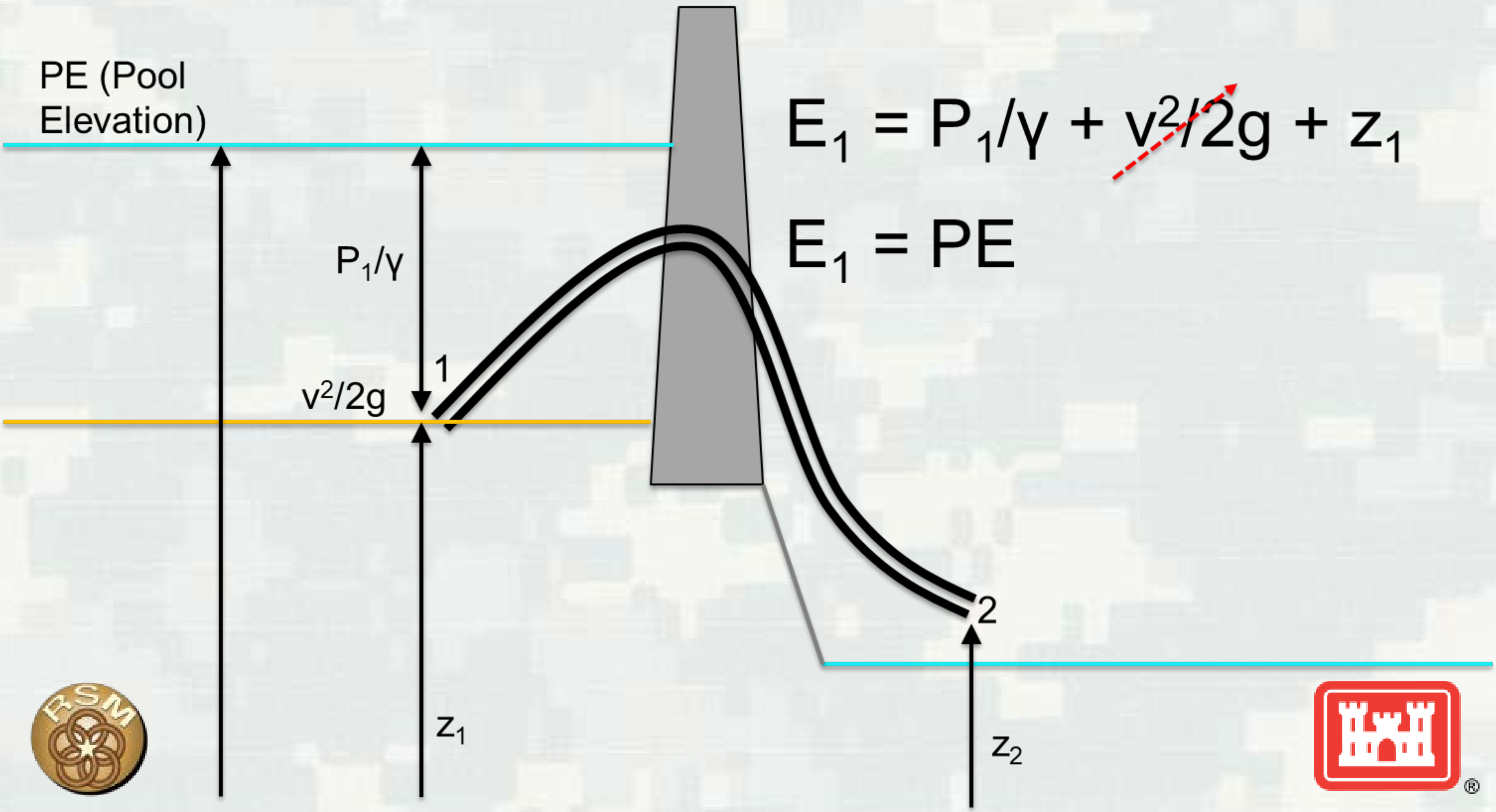


Energy Equation

$$E_1 - h_L = E_2$$

$$E_1 = P_1/\gamma + \cancel{v^2/2g} + z_1$$

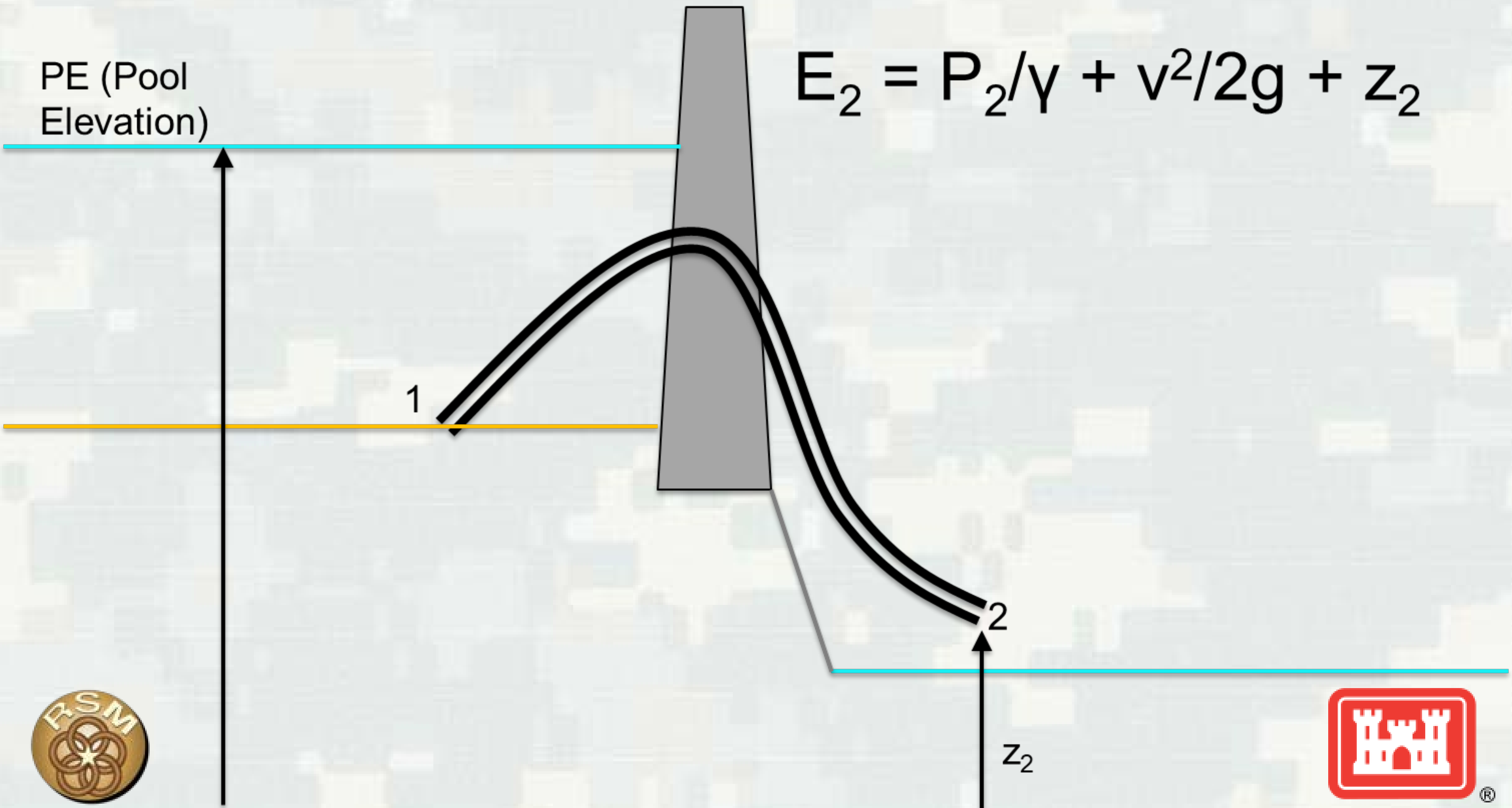
$$E_1 = PE$$



Energy Equation

$$E_1 - h_L = E_2$$

$$E_2 = P_2/\gamma + v^2/2g + z_2$$

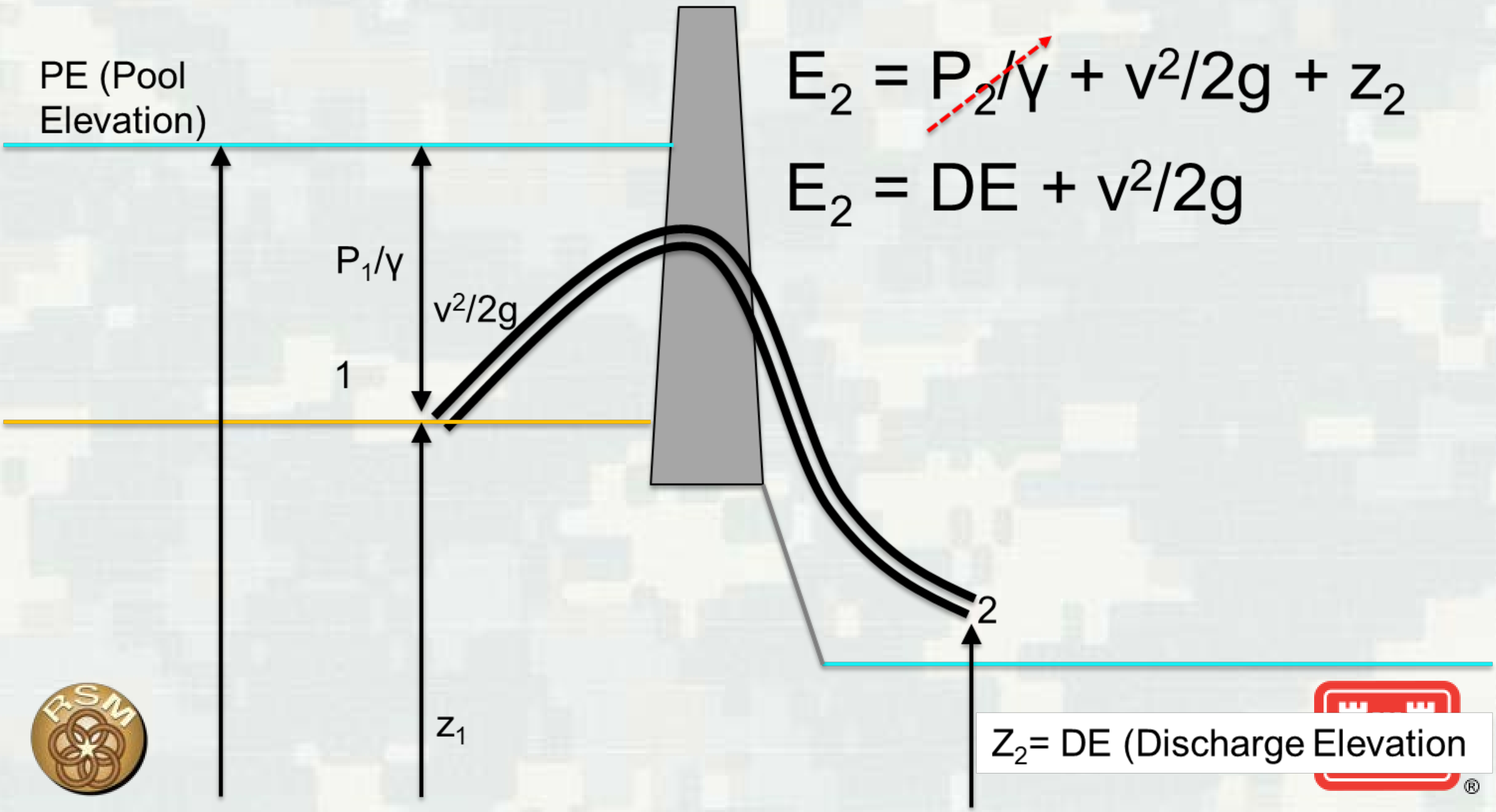


Pipe Flow Equations

$$E_1 - h_L = E_2$$

$$E_2 = P_2/\gamma + v^2/2g + z_2$$

$$E_2 = DE + v^2/2g$$



Energy Equation

$$E_1 - h_L = E_2$$

$$PE - h_L = DE + v^2/2g$$

$$v^2/2g = PE - DE - h_L$$

$$v = [2g(PE - DE - h_L)]^{0.5}$$

Headloss Equation

h_L = f (fluid properties, velocity, pipe dimensions and properties)

$$h_L = \frac{V_t^2}{2g}\left[M + f_1\left(\frac{L_1}{D}\right) + f_2\left(\frac{L_2}{D}\right) + \cdots f_n\left(\frac{L_n}{D}\right)\right]$$

$$f = \frac{0.25}{\left[\log\left(\frac{\varepsilon}{3.7D}\right) + \left(\frac{5.74}{Re^{0.9}}\right)\right]^2}$$

$$Re = \rho V_t D/\mu$$

$$\mu = \mu_w(1 + 2.5\varphi + 14.1\varphi^2)$$

$$\rho = [(1 - \varphi) + 2.64\varphi](62.4)(0.031081)$$

Φ = percent solids

Pipe Flow Solution Procedure

- Select a trial velocity
- Compute h_L from fluid and pipe properties
- Solve for velocity from the energy equation
- Compare and adjust the trial velocity

Simplified Analysis Procedure

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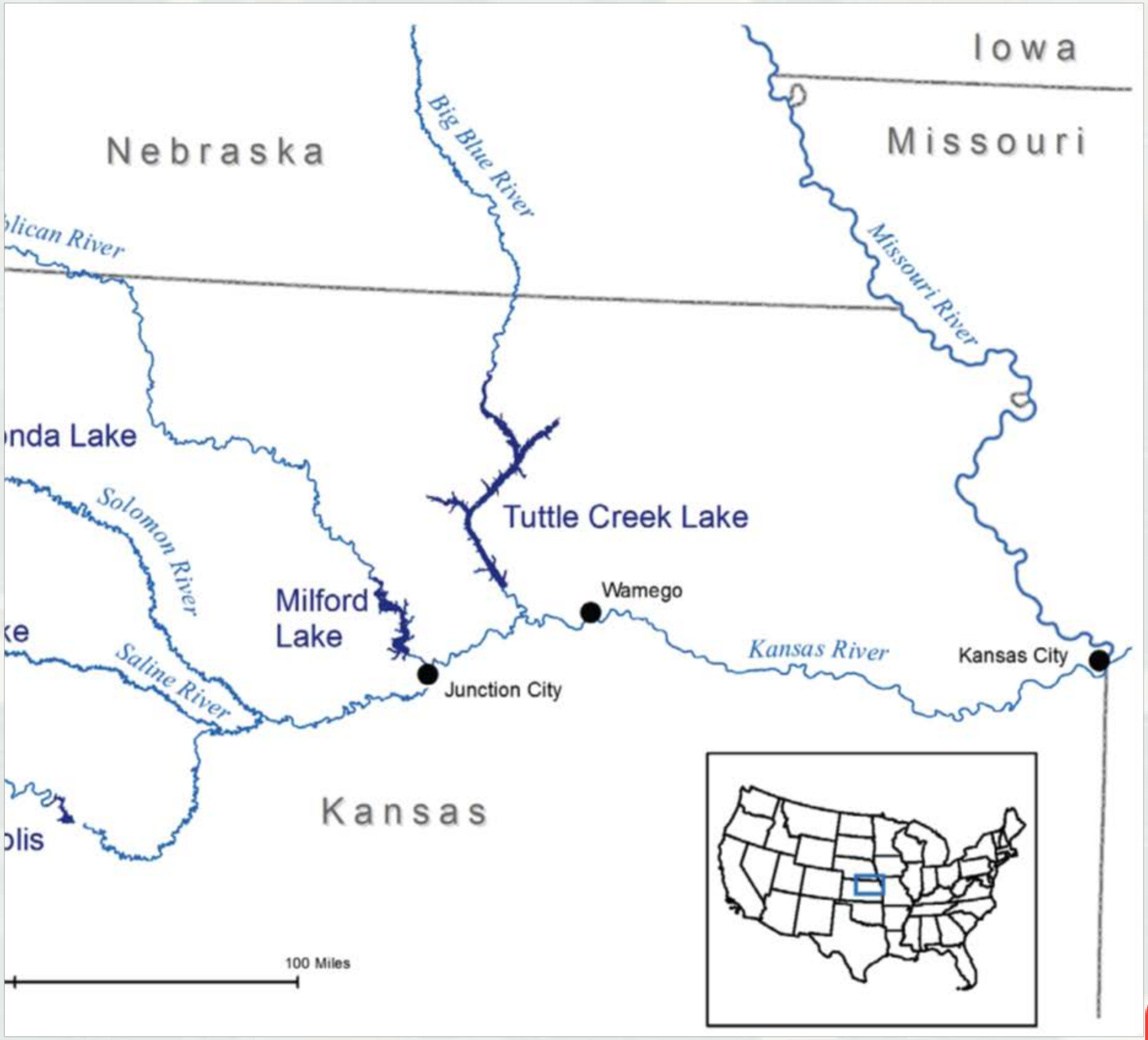
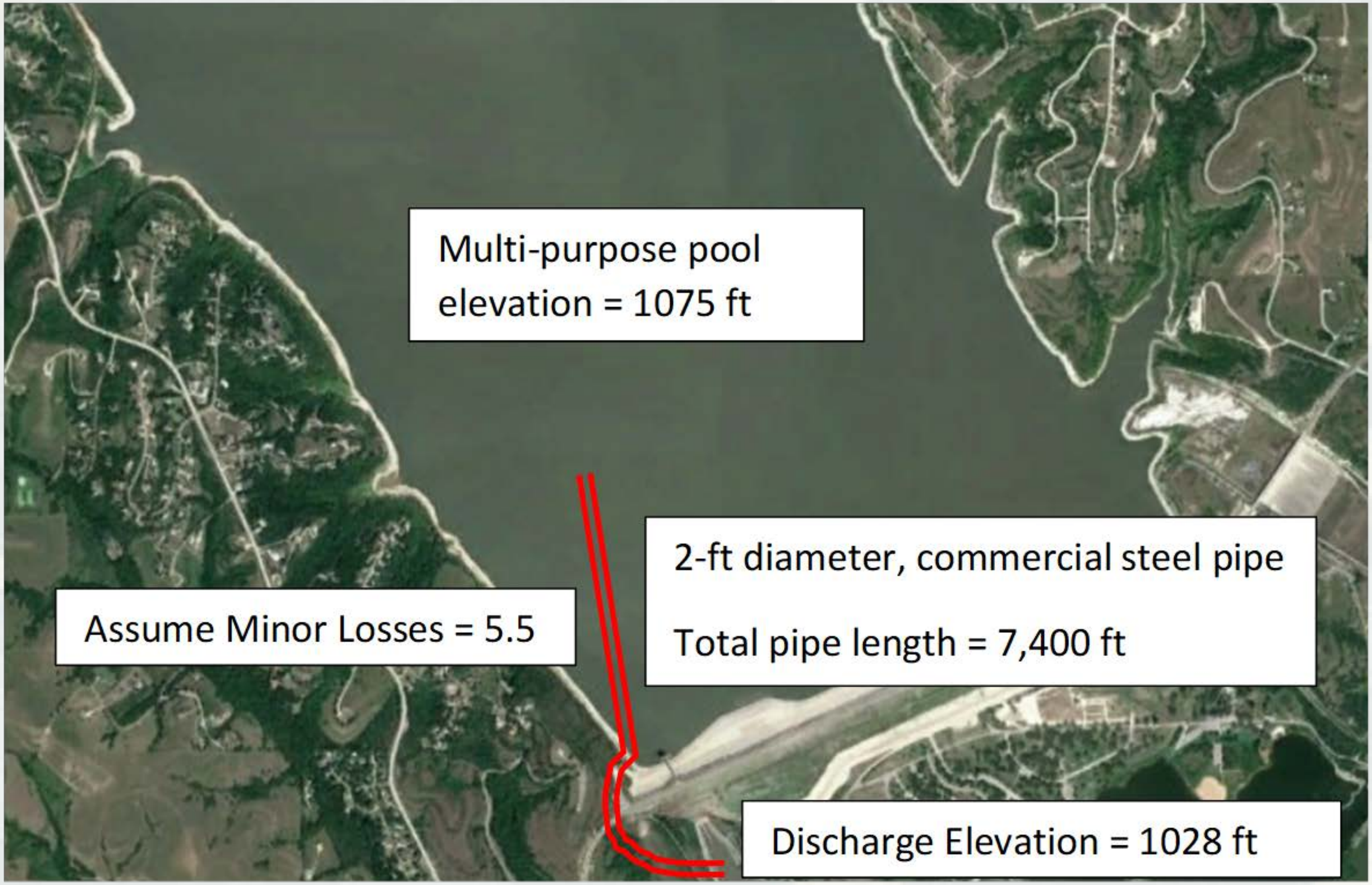
Workshop: Tuttle Creek Lake



Workshop: Tuttle Creek Lake



Steps

- Follow the document: “How to Perform a Basic Hydrosuction Analysis for Cohesive Material”

- Skip steps related to assessing multiple pool levels or multiple pipe materials (step 1, 12, 18 - 21)