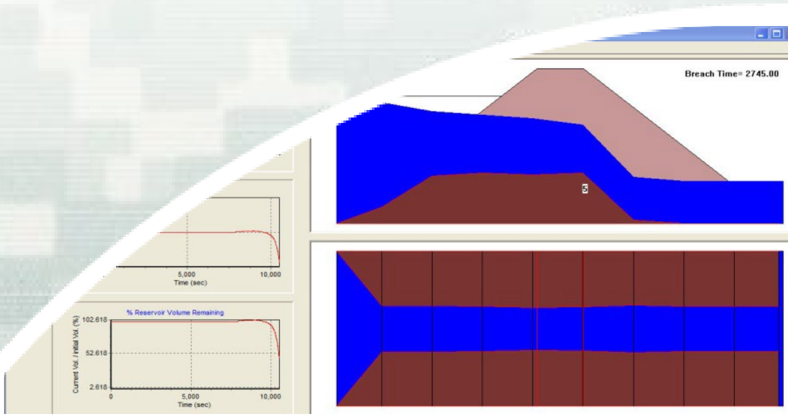
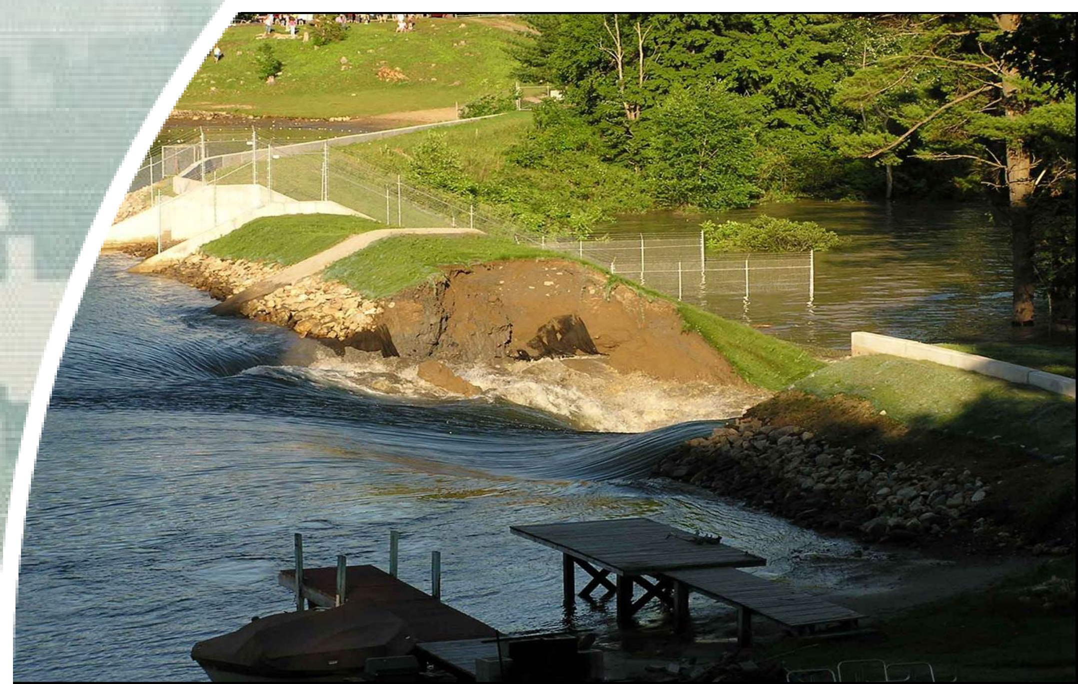
Determination of Dam Breach Parameters





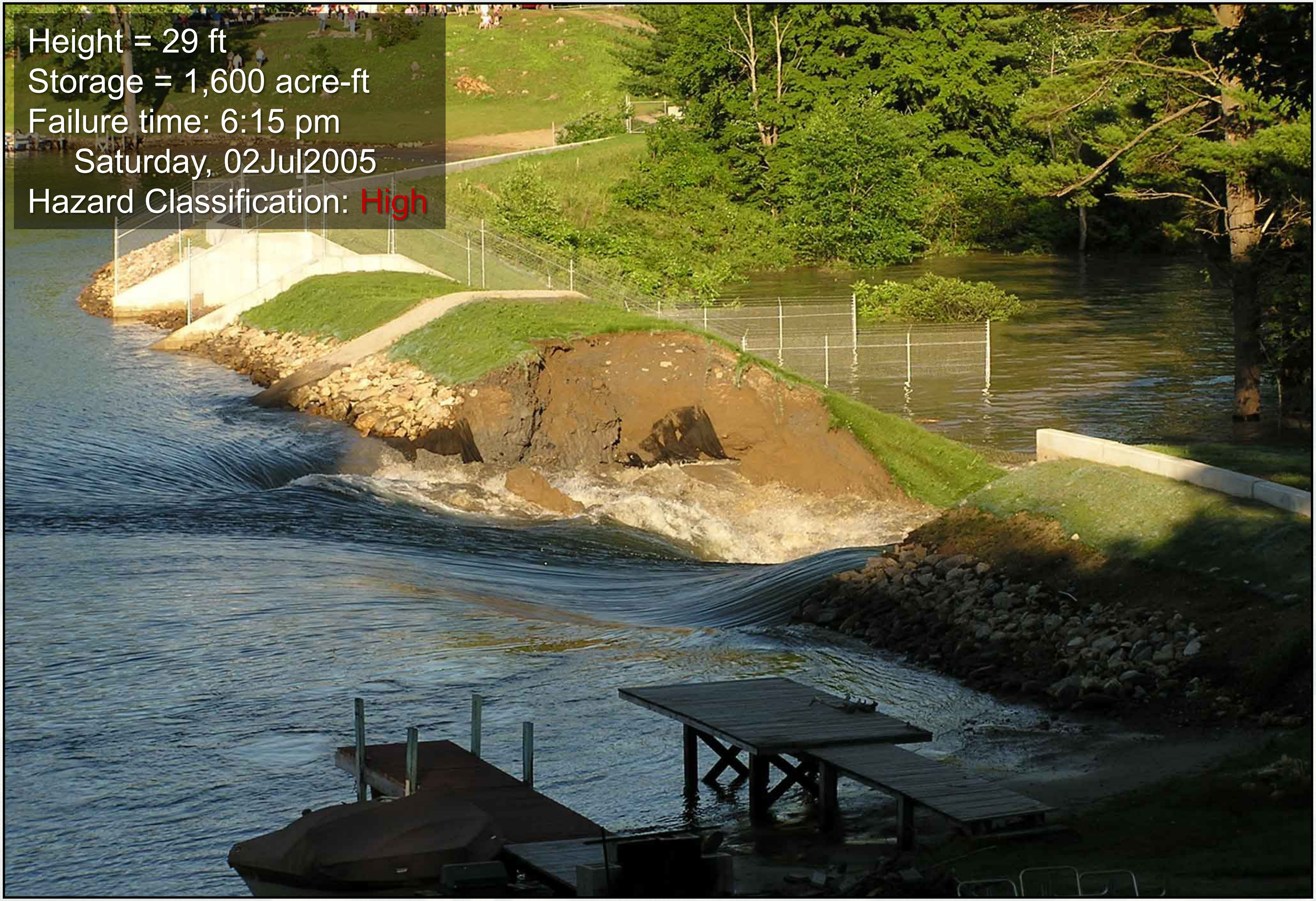
Mark Jensen

Hydrologic Engineering Center

NRCS Embankment Failure Research (SIMBA/WinDAMB model)

Temple, Darrel M., and Hanson, Gregory J., “Earth Dam Overtopping and Breach Outflow,” Presented at the ASCE World Water & Environmental Resources Congress 2005, EWRI, Anchorage, AK, 15-19 May 2005.

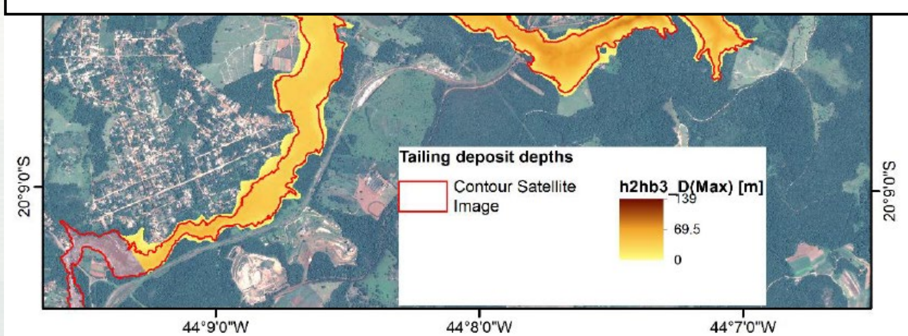
Hadlock Pond Dam New York



Taum Sauk Upper Dam, Missouri

Brazil Mine Tailings Failure

Modeling by Prof Leonardo Moura
University of Brasilia



Three Approaches

1. **User Entered Data**

   -Parameter Estimation

   User Entered Data

2. **Simplified Physical**

   Simplified Physical

3. **DL Breach**

   Physical Breaching (DLBreach)

User Entered Data
Simplified Physical
Physical Breaching (DLBreach)

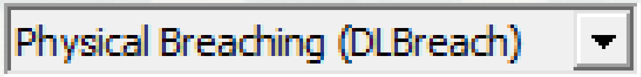
Three Approaches

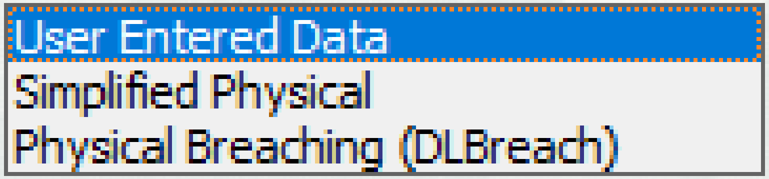
1. User Entered Data

   -Parameter Estimation

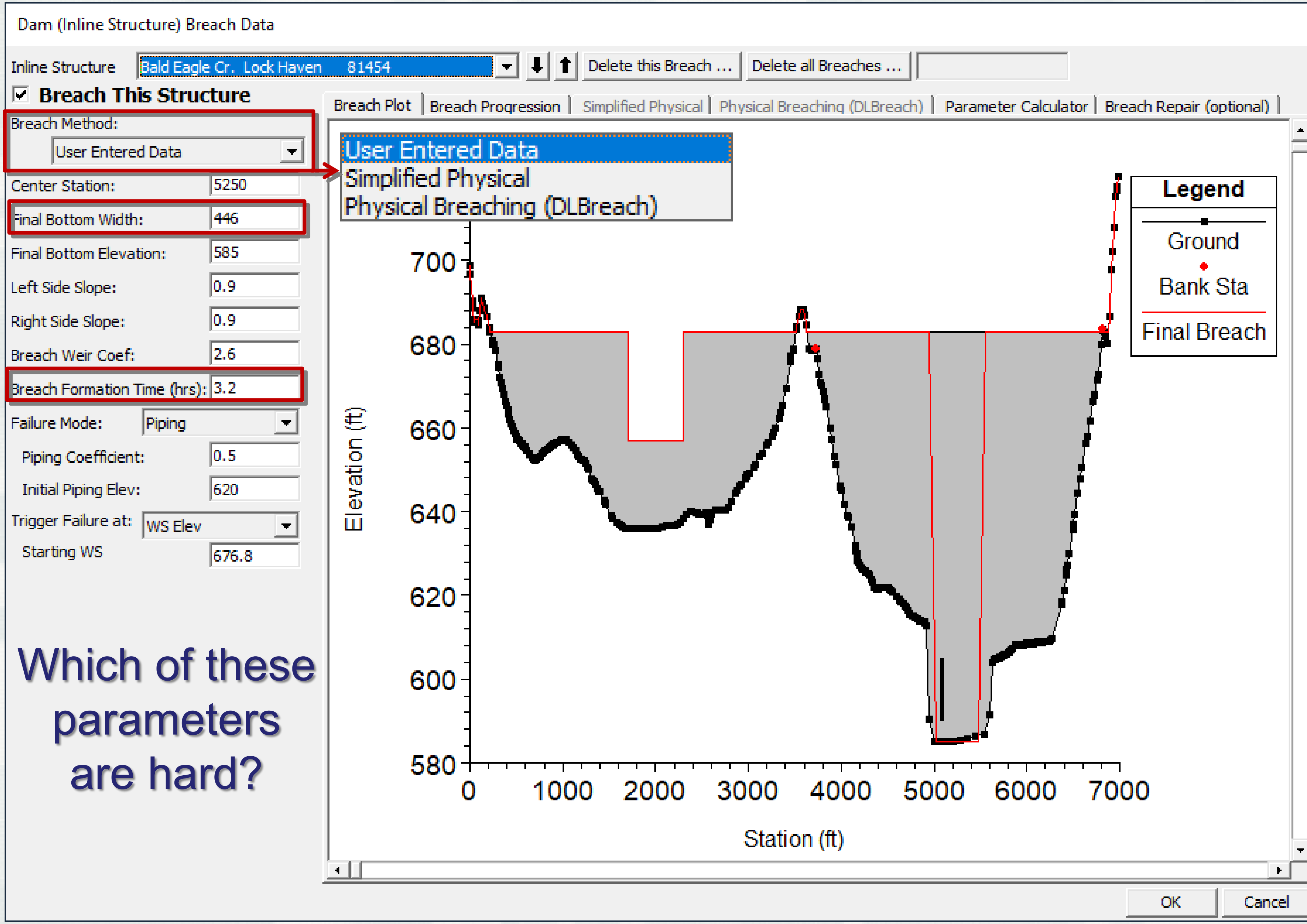
2. Simplified Physical

3. DL Breach





HEC-RAS Breach Data



Which of these parameters are hard?

HEC-RAS Breach Data Input

- **Location**: Centerline of breach
- **Type**: Overtopping or Piping
- **Size**: Bottom elevation, width and side slopes
- **Time:** to maximum size and progression type
- **Triggering situation**:
  - ✓ Pool elevation
  - ✓ Pool elevation + Duration
  - ✓ Clock time

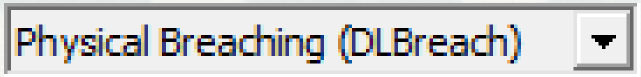
Three Approaches

1. **User Entered Data**

   -Parameter Estimation

2. **Simplified Physical**

3. **DL Breach**



Estimating the Breach Parameters

- **Literature And Guidance**
  - Existing COE guidance
  - Prediction of embankment dam breach parameters: *USBR (1998) Dam Safety Research Report*

- **Empirical** Methods -
  - MacDonald and Langridge-Monopolis (1984)
  - Froehlich (1995b)
  - Von Thun and Gillette (1990)
  - Xu and Zhang (2009)

Technology Review (1998)

Prediction of Embankment Dam
Breach Parameters

A Literature Review and Needs Assessment

DSO-98-004

DSO
DAM SAFETY OFFICE

Water Resources Research Laboratory

July 1998

Suggested Breach Parameters

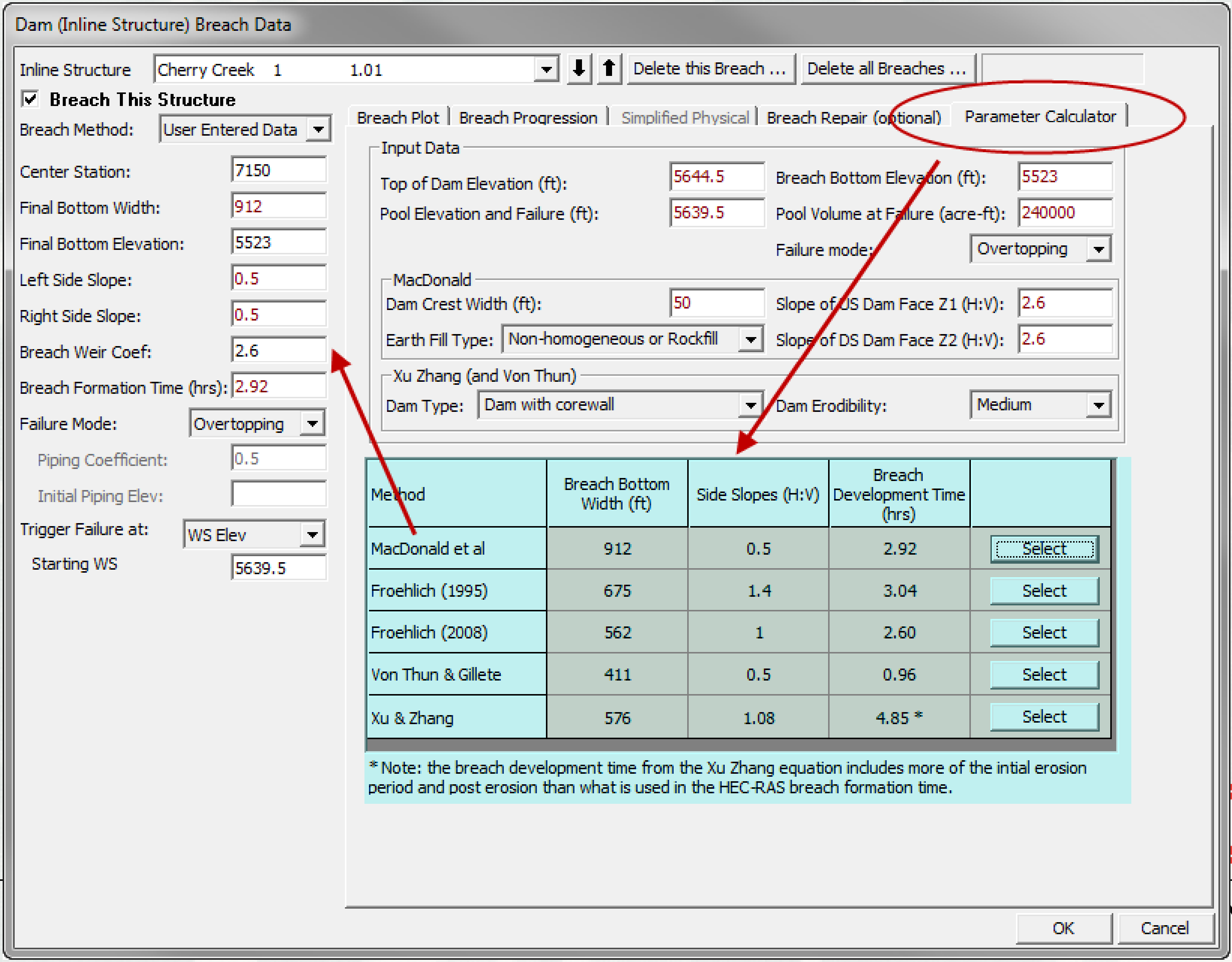
Dam Type	Average Breach Width (B_{ave})	Horizontal Component of Breach Side Slope (H) (H:V)	Failure Time, t_f (hours)	Agency
Earthen/Rockfill	(0.5 to 3.0) x HD	0 to 1.0	0.5 to 4.0	USACE 1980
	(1.0 to 5.0) x HD	0 to 1.0	0.1 to 1.0	FERC
	(2.0 to 5.0) x HD	0 to 1.0 (slightly larger)	0.1 to 1.0	NWS
	(0.5 to 5.0) x HD*	0 to 1.0	0.1 to 4.0*	USACE 2007
Concrete Gravity	Multiple Monoliths	Vertical	0.1 to 0.5	USACE 1980
	Usually ≤ 0.5 L	Vertical	0.1 to 0.3	FERC
	Usually ≤ 0.5 L	Vertical	0.1 to 0.2	NWS
	Multiple Monoliths	Vertical	0.1 to 0.5	USACE 2007
Concrete Arch	Entire Dam	Valley wall slope	≤ 0.1	USACE 1980
	Entire Dam	0 to valley walls	≤ 0.1	FERC
	(0.8 x L) to L	0 to valley walls	≤ 0.1	NWS
	(0.8 x L) to L	0 to valley walls	≤ 0.1	USACE 2007
Slag/Refuse	(0.8 x L) to L	1.0 to 2.0	0.1 to 0.3	FERC
	(0.8 x L) to L		≤ 0.1	NWS

***Note:** Dams that have very large volumes of water, and have long dam crest lengths, will continue to erode for long durations (i.e., as long as a significant amount of water is flowing through the breach), and may therefore have longer breach widths and times than what is shown in Table 3. HD = height of the dam; L = length of the dam crest; FERC - Federal Energy Regulatory Commission; NWS - National Weather Service

Where: HD = Height of the dam.

L = Length of the dam crest.

Breach Parameter Calculator



MacDonald and Langridge-Monopolis (1984)

Earthfill

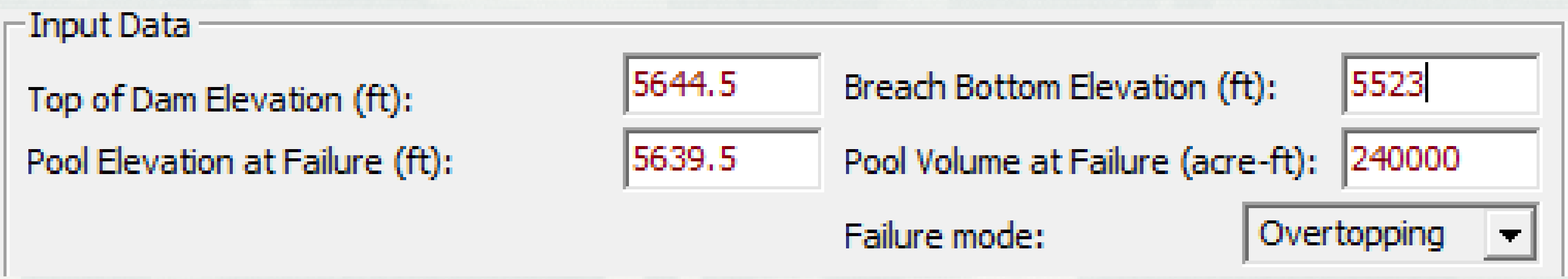
$$V_{eroded} = 0.0261(V_{out} * h_w)^{0.769}$$

$$t_f = 0.0179\,(V_{eroded})^{0.364}$$

$$BREACH_{size} = f(V_{eroded})$$

Non-earthfill

$$V_{eroded} = 0.00348(V_{out} * h_w)^{0.852}$$



h_w = Pool Elev – Breach Bottom Elev

V_{out} = Pool Volume at Failure

(but is total flow volume – including inflow)

Von Thun & Gillette (1990)

$$B_{avg} = 2.5h_w + C_b$$

$$t_f = 0.02h_w + 0.25$$ (erosion resistant)

$$t_f = 0.015h_w$$ (easily erodible)

Reservoir Size, m^3	C_b, meters
$< 1.23*10^6$	6.1
$1.23*10^6$ - $6.17*10^6$	18.3
$6.17*10^6$ - $1.23*10^7$	42.7
$> 1.23*10^7$	54.9

Reservoir Size, acre-feet	C_b, feet
< 1,000	20
1,000-5,000	60
5,000-10,000	140
>10,000	180

Input Data

Top of Dam Elevation (ft): 5644.5

Breach Bottom Elevation (ft): 5523

Pool Elevation at Failure (ft): 5639.5

Pool Volume at Failure (acre-ft): 240000

Failure mode: Overtopping

h_w = Pool Elev – Breach Bottom Elev

V_{out} = Pool Volume at Failure

Froehlich (1995)

$$B_{ave} = 0.1803\,K_o\,V_w^{0.32}\,h_b^{0.19}$$

$$t_f = 0.00254\,V_w^{0.53}\,h_b^{-0.90}$$

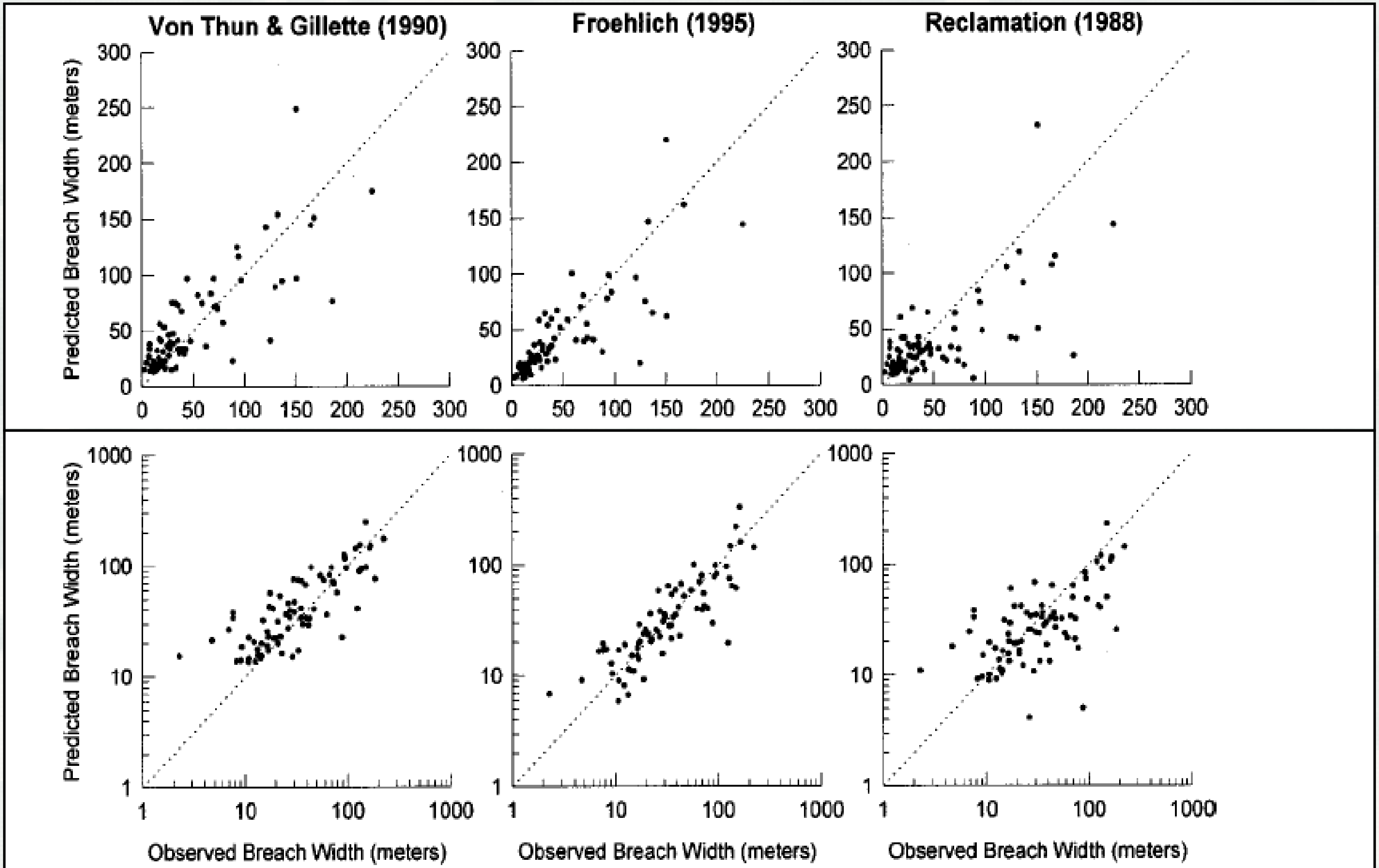
Froehlich (2008)

$$B_{ave} = 0.27\,K_o\,V_w^{0.32}\,h_b^{0.04}$$

$$t_f = 20.18\,V_w^{0.5}\,h_b^{-1.0}$$

Volume of water at h
MLM Volume of water thr

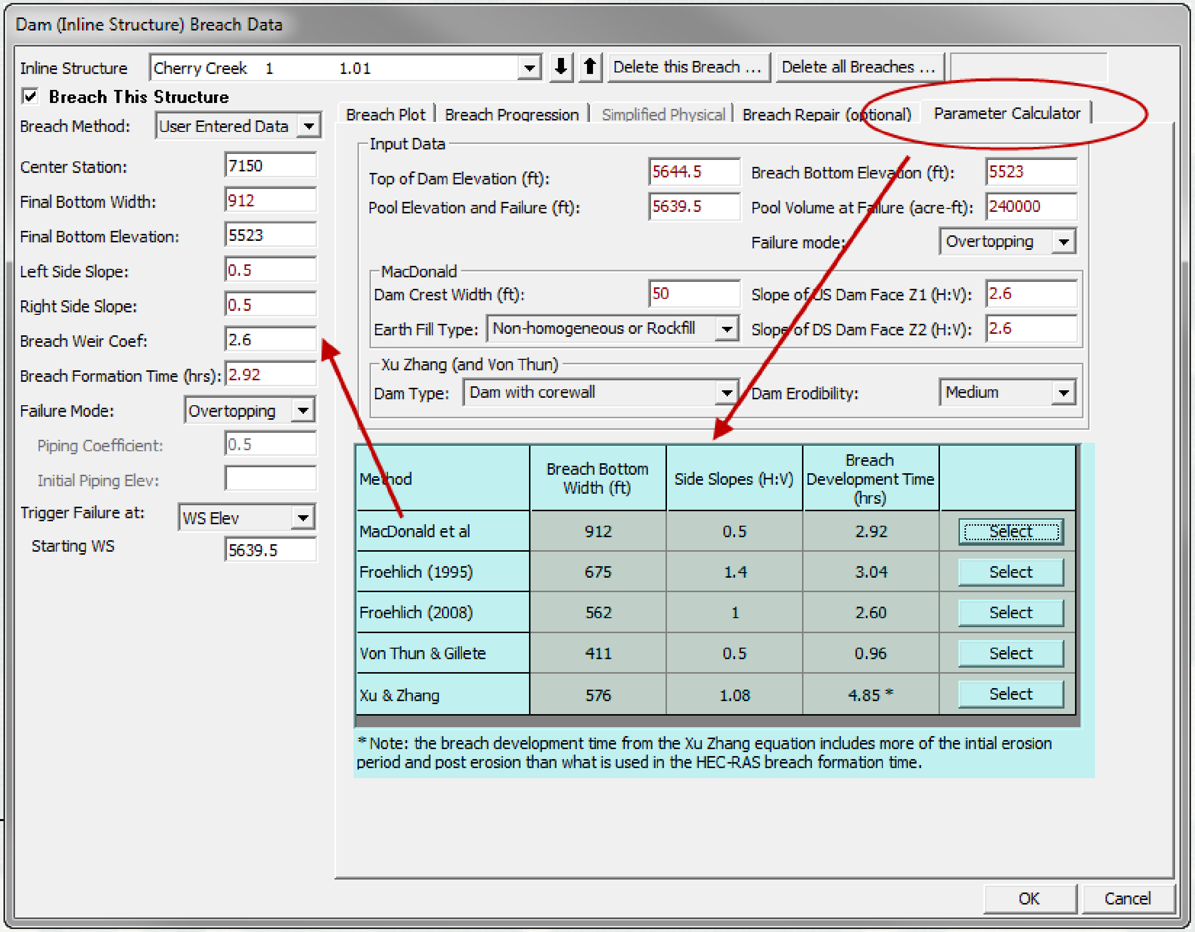
Width Comparison



Predicted and observed breach widths (Wahl 1998), plotted arithmetically (top) and on logarithmic scales (bottom)

FourImportant Ideas

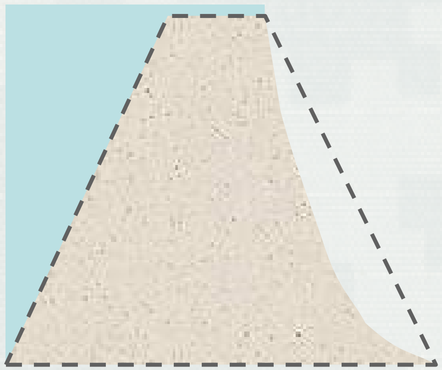
1. Do not mix-and-match width and breach time.
2. Xu & Zang has a different breach development time.



Thought Experiment

When does the clock start for “breach time” in HEC-RAS?

1.)



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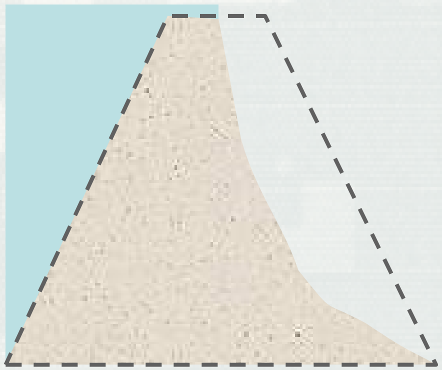
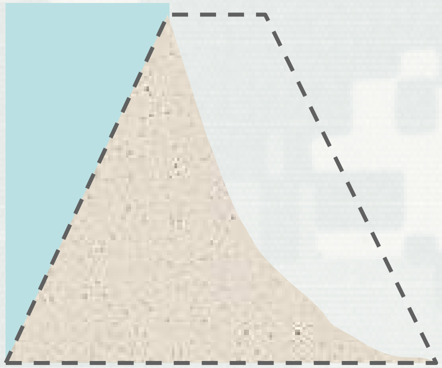
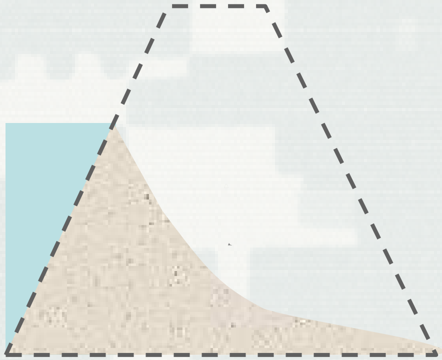


3.)



4.)



Four Important Ideas

3. Do the breach parameters make physical sense hydraulically?

    -Is it still eroding with now water
    -Does it stop eroding with high head and velocity

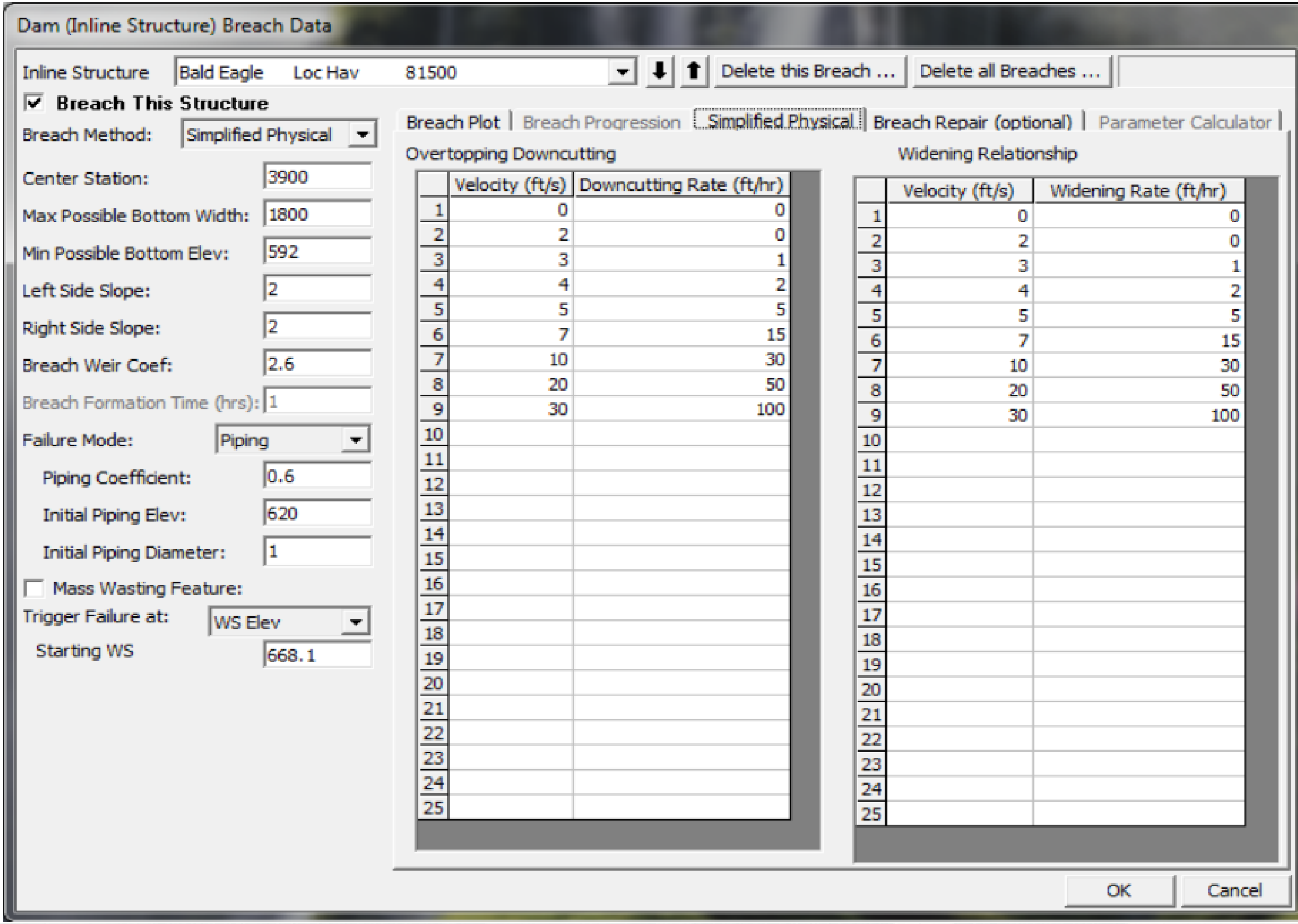
4. Sensitivity

Three Approaches

1. User Entered Data — User Entered Data
   -Parameter Estimation

2. Simplified Physical — Simplified Physical

3. DL Breach — Physical Breaching (DLBreach)



Dam (Inline Structure) Breach Data

Inline Structure: Bald Eagle Loc Hav 81500

Delete this Breach ... | Delete all Breaches ...

☑ **Breach This Structure**

Breach Method: Simplified Physical

Center Station: 3900

Max Possible Bottom Width: 1800

Min Possible Bottom Elev: 592

Left Side Slope: 2

Right Side Slope: 2

Breach Weir Coef: 2.6

Breach Formation Time (hrs): 1

Failure Mode: Piping

Piping Coefficient: 0.6

Initial Piping Elev: 620

Initial Piping Diameter: 1

☐ Mass Wasting Feature:

Trigger Failure at: WS Elev

Starting WS 668.1

Breach Plot | Breach Progression | Simplified Physical | Breach Repair (optional) | Parameter Calculator

Overtopping Downcutting

	Velocity (ft/s)	Downcutting Rate (ft/hr)
1	0	0
2	2	0
3	3	1
4	4	2
5	5	5
6	7	15
7	10	30
8	20	50
9	30	100
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		

Widening Relationship

	Velocity (ft/s)	Widening Rate (ft/hr)
1	0	0
2	2	0
3	3	1
4	4	2
5	5	5
6	7	15
7	10	30
8	20	50
9	30	100
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		

OK | Cancel

Where do these rates come from?

MMC PRODUCTION CENTER
Modeling | Mapping | Consequences

Prepared by:
MMC MCX

Appendix 3.X.X – Application of Simplified Physical Breach Method in HEC-RAS

FY17 MMC Technical Manual SOP

July 2018

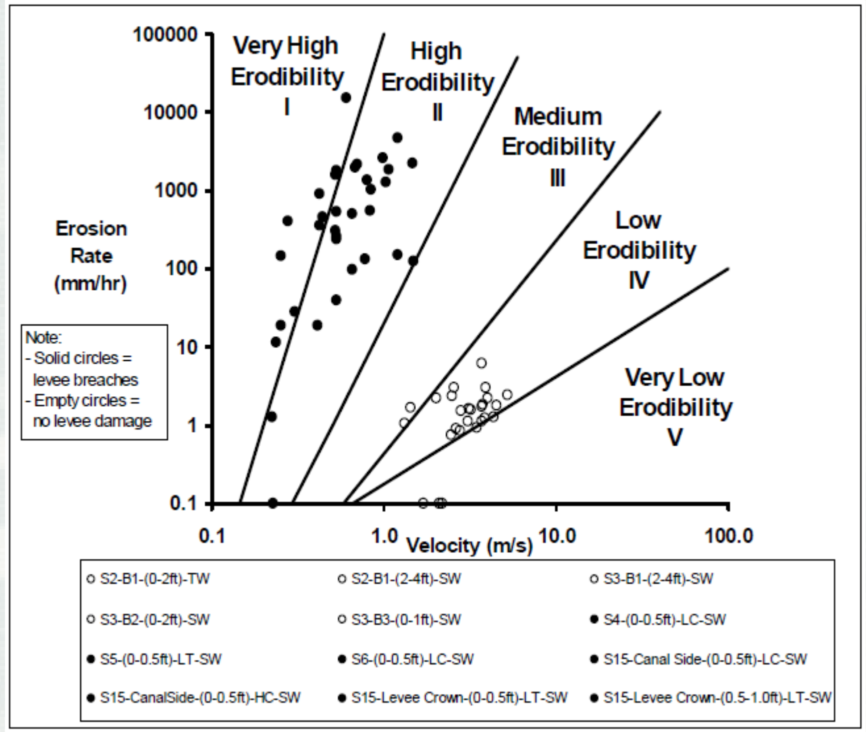
Draft

Technical Memorandum for Record

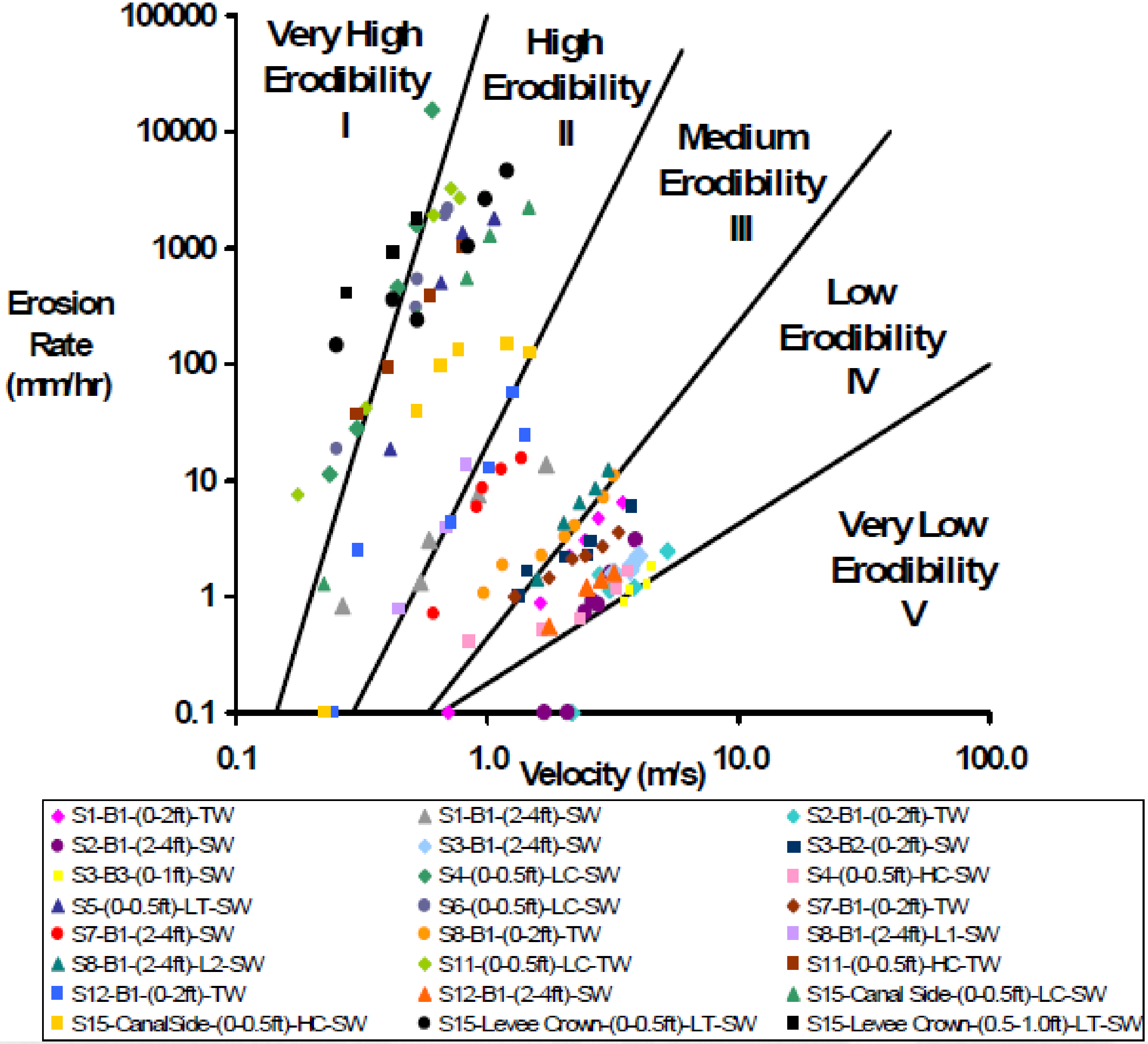
Date: May 31, 2013 (Revised July 2, 2013)

From: Chris Bahner, P.E., D. WRE

Subject: Updated Levee Breach Characteristics for MMC SOP



The guidance is under development.
There are some historic values that can help.


Very High Erodibility I
High Erodibility II
Medium Erodibility III
Low Erodibility IV
Very Low Erodibility V
Erosion Rate (mm/hr)
100000
10000
1000
100
10
1
0.1
0.1
1.0
10.0
100.0
Velocity (m/s)
S1-B1-(0-2ft)-TW
S1-B1-(2-4ft)-SW
S2-B1-(0-2ft)-TW
S2-B1-(2-4ft)-SW
S3-B1-(2-4ft)-SW
S3-B2-(0-2ft)-SW
S3-B3-(0-1ft)-SW
S4-(0-0.5ft)-LC-SW
S4-(0-0.5ft)-HC-SW
S5-(0-0.5ft)-LT-SW
S6-(0-0.5ft)-LC-SW
S7-B1-(0-2ft)-TW
S7-B1-(2-4ft)-SW
S8-B1-(0-2ft)-TW
S8-B1-(2-4ft)-L1-SW
S8-B1-(2-4ft)-L2-SW
S11-(0-0.5ft)-LC-TW
S11-(0-0.5ft)-HC-TW
S12-B1-(0-2ft)-TW
S12-B1-(2-4ft)-SW
S15-Canal Side-(0-0.5ft)-LC-SW
S15-CanalSide-(0-0.5ft)-HC-SW
S15-Levee Crown-(0-0.5ft)-LT-SW
S15-Levee Crown-(0.5-1.0ft)-LT-SW

Three Approaches

1. **User Entered Data** — User Entered Data

   -Parameter Estimation

2. **Simplified Physical** — Simplified Physical

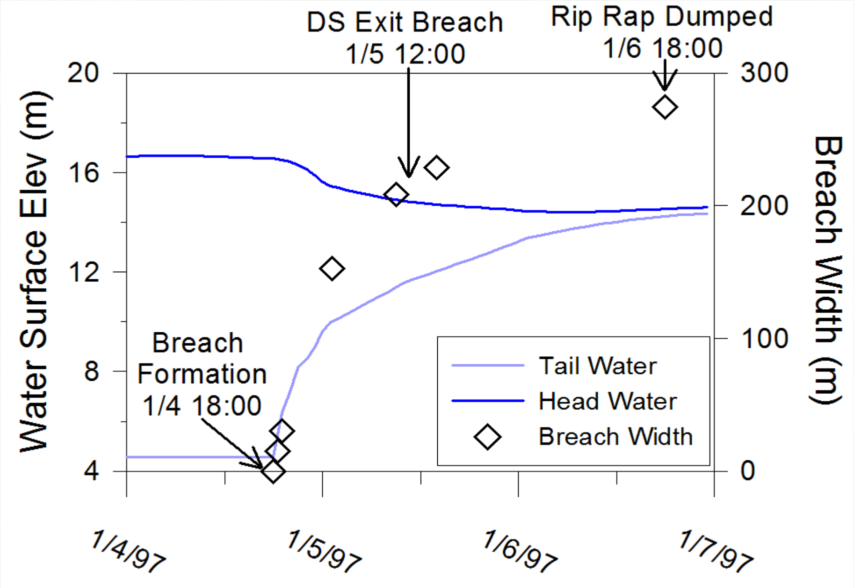
3. **DL Breach** — Physical Breaching (DLBreach)

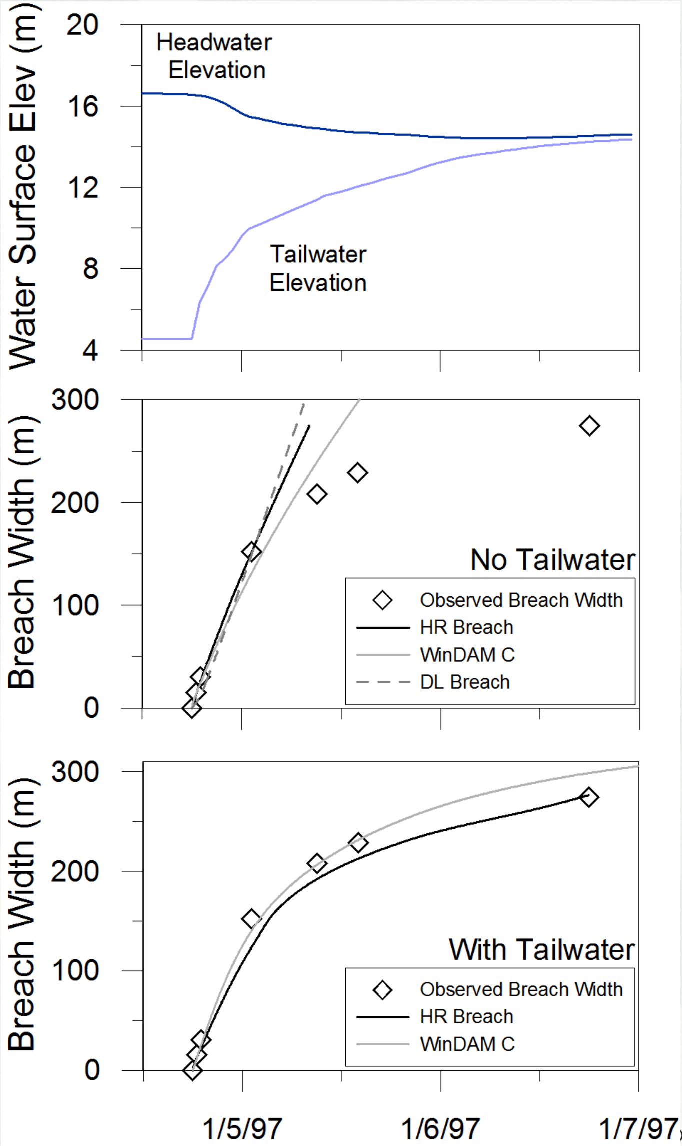
Estimating the Breach Evolution

Process Models

- ►ARS SIMBA/WinDAMB
- ►HR-BREACH (HR Wallingford)
- ►DL Breach (Dr Weiming Wu)

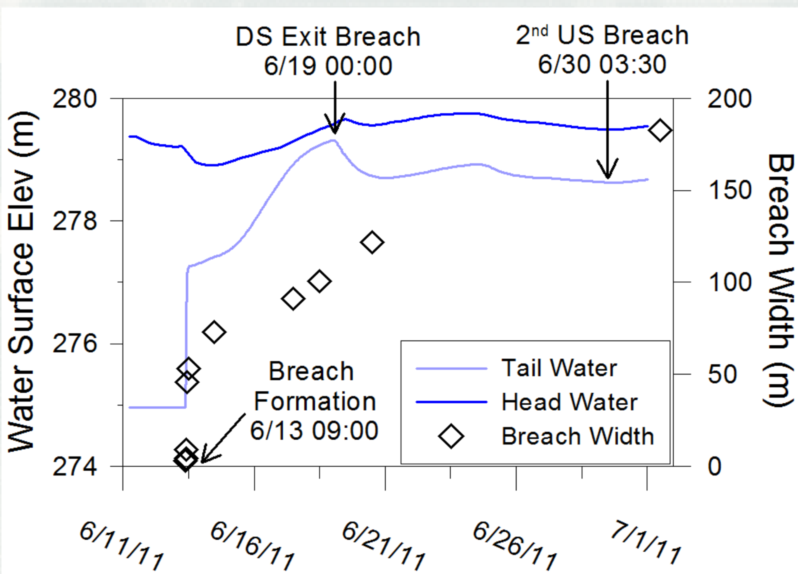
Sutter Bypass Levee Breach

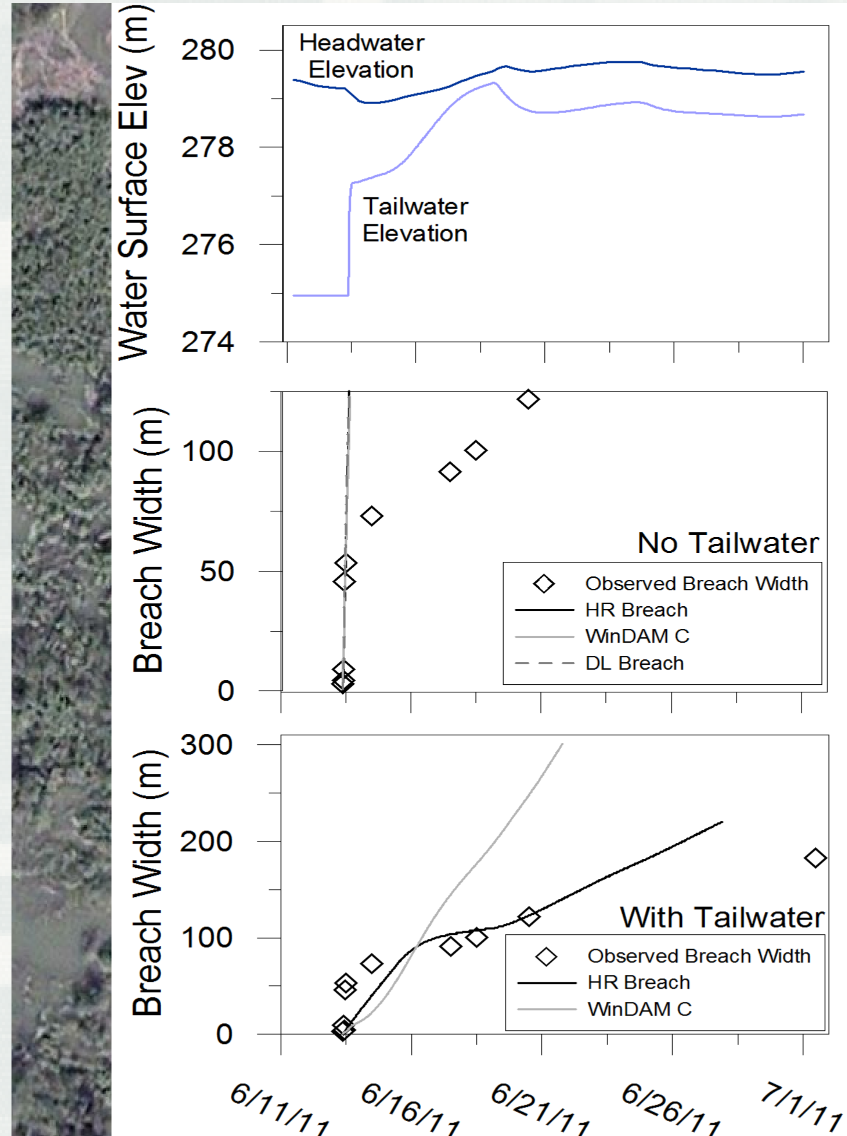




From: Risher, P. and Gibson, S. (2016) “Applying Mechanistic Dam Breach Models to Historic Levee Breaches,” Proceedings FloodRisk 2016.

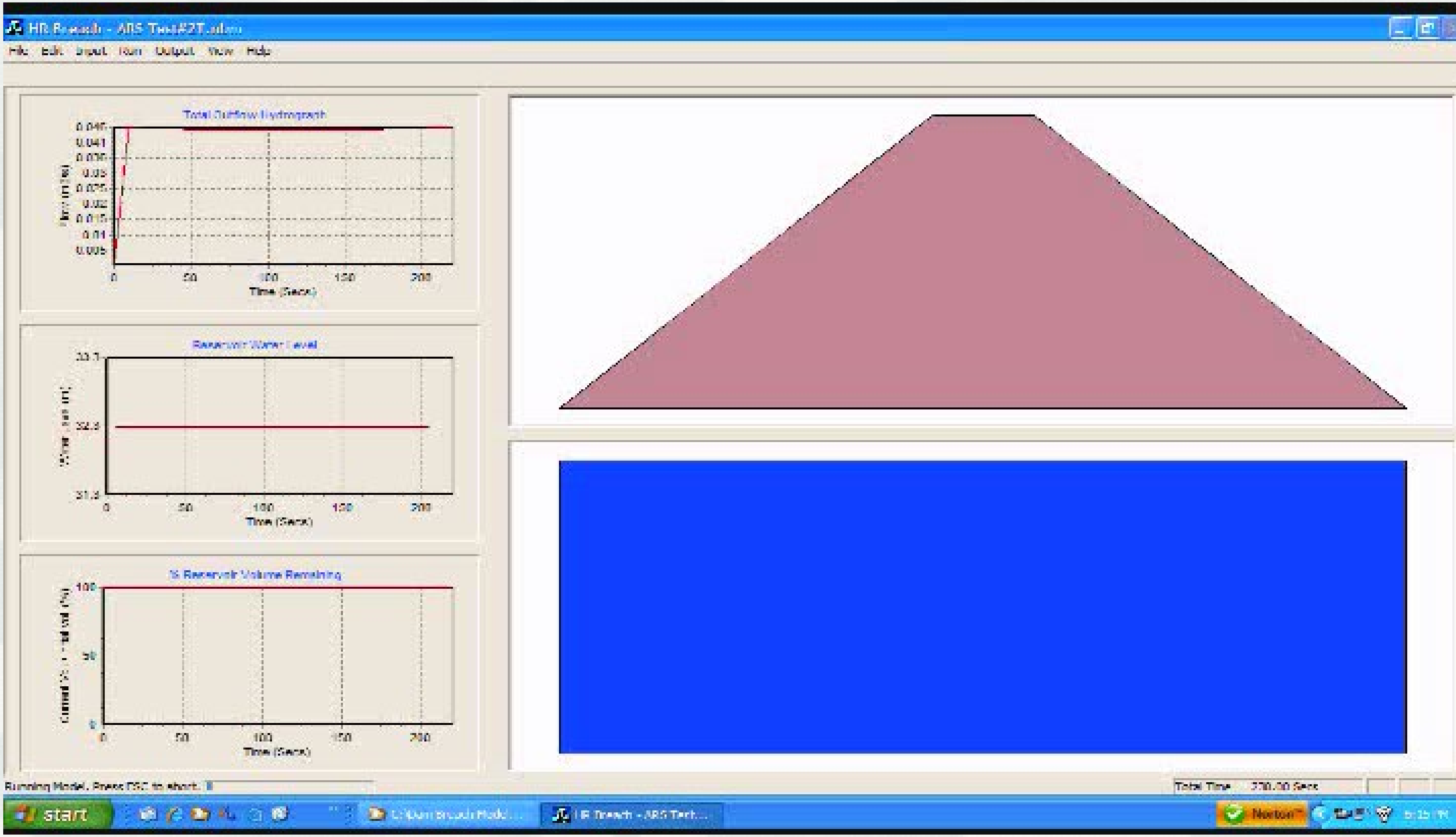
Hamburg Breach (Missouri River)





From: Risher, P. and Gibson, S. (2016) "Applying Mechanistic Dam Breach Models to Historic Levee Breaches," Proceedings FloodRisk 2016.

HR BREACH

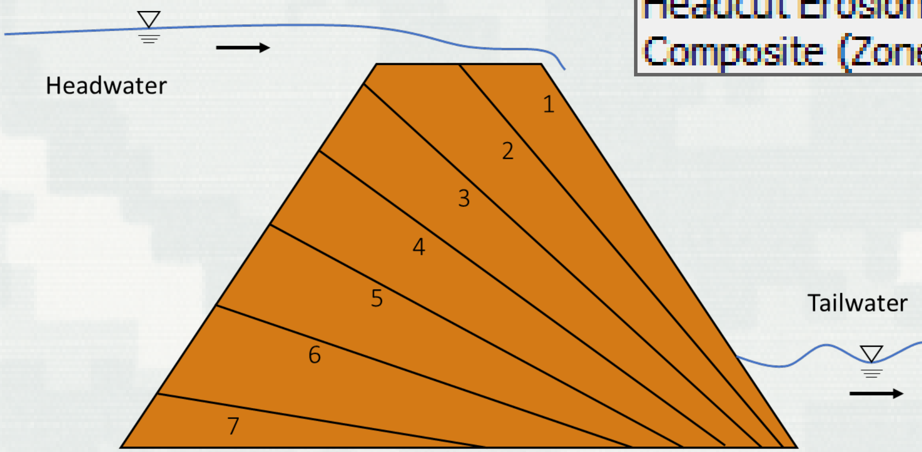


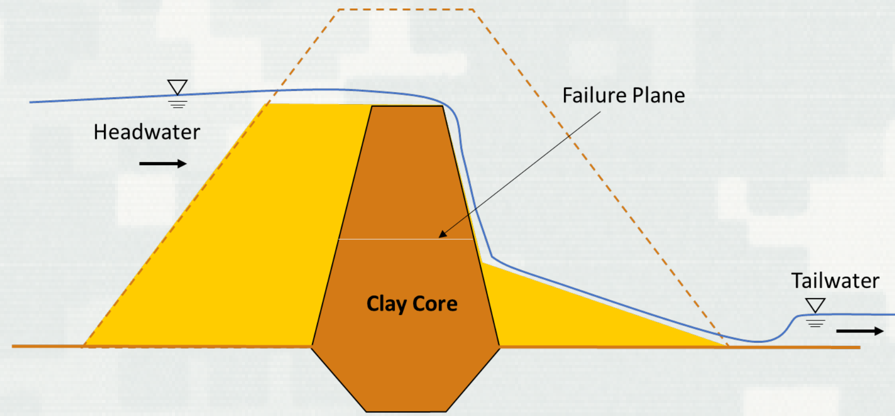
- Erosion thru homogeneous or simple composite dams
- Channel erosion, headcutting and side slope instability + piping
- Storage routing with quasi-steady hydraulics thru the breach

DLBreach

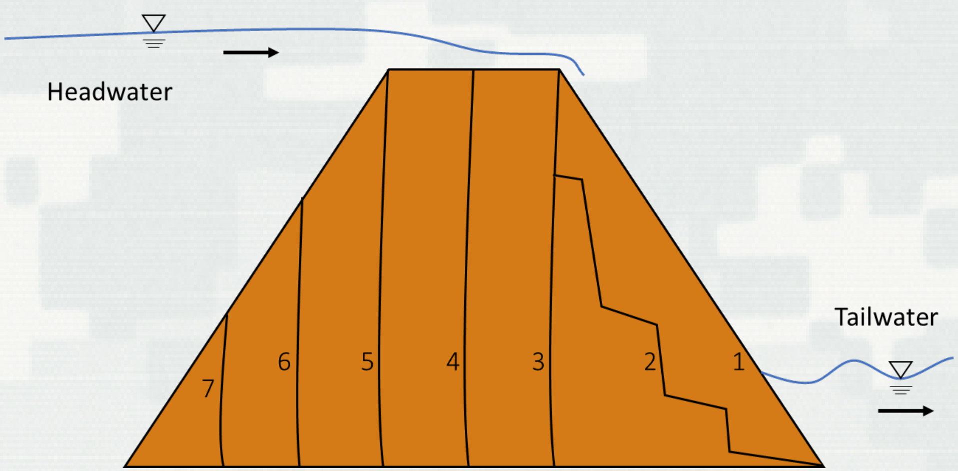
Surface Erosion
Headcut Erosion
Composite (Zoned) Structure

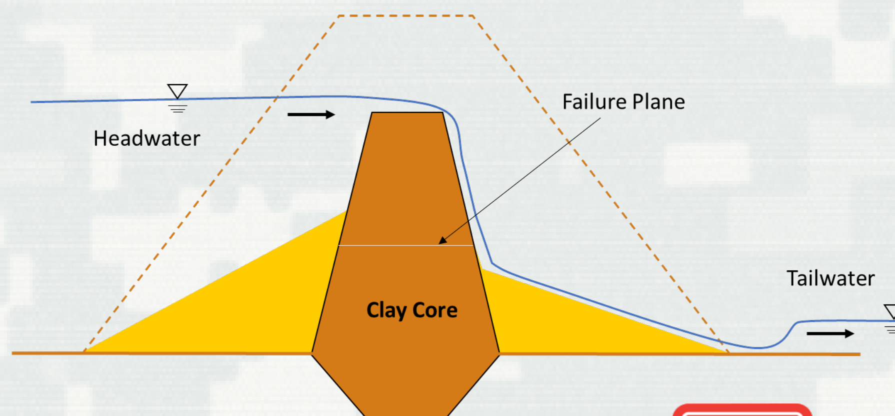
Surface





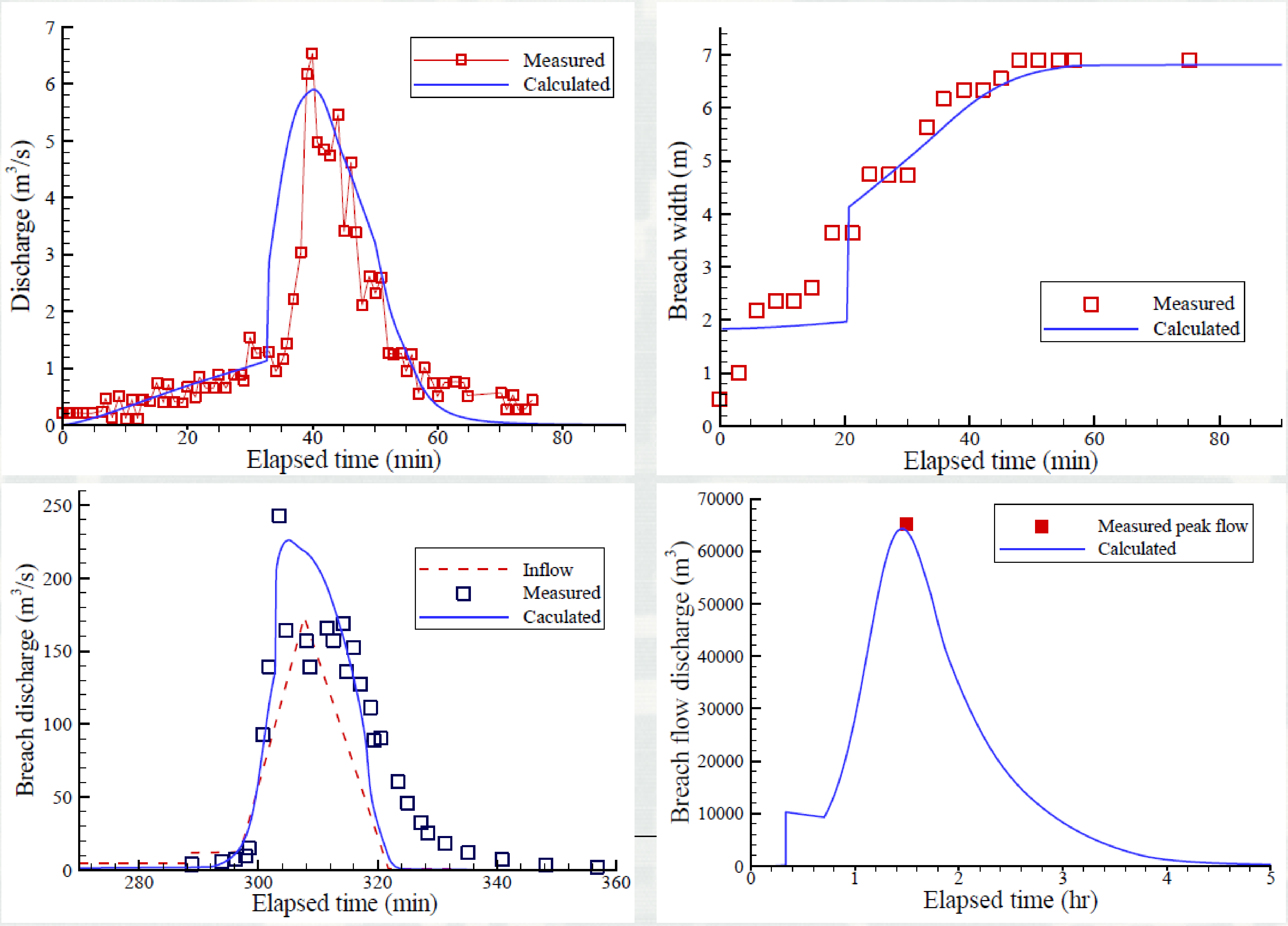
Headcut





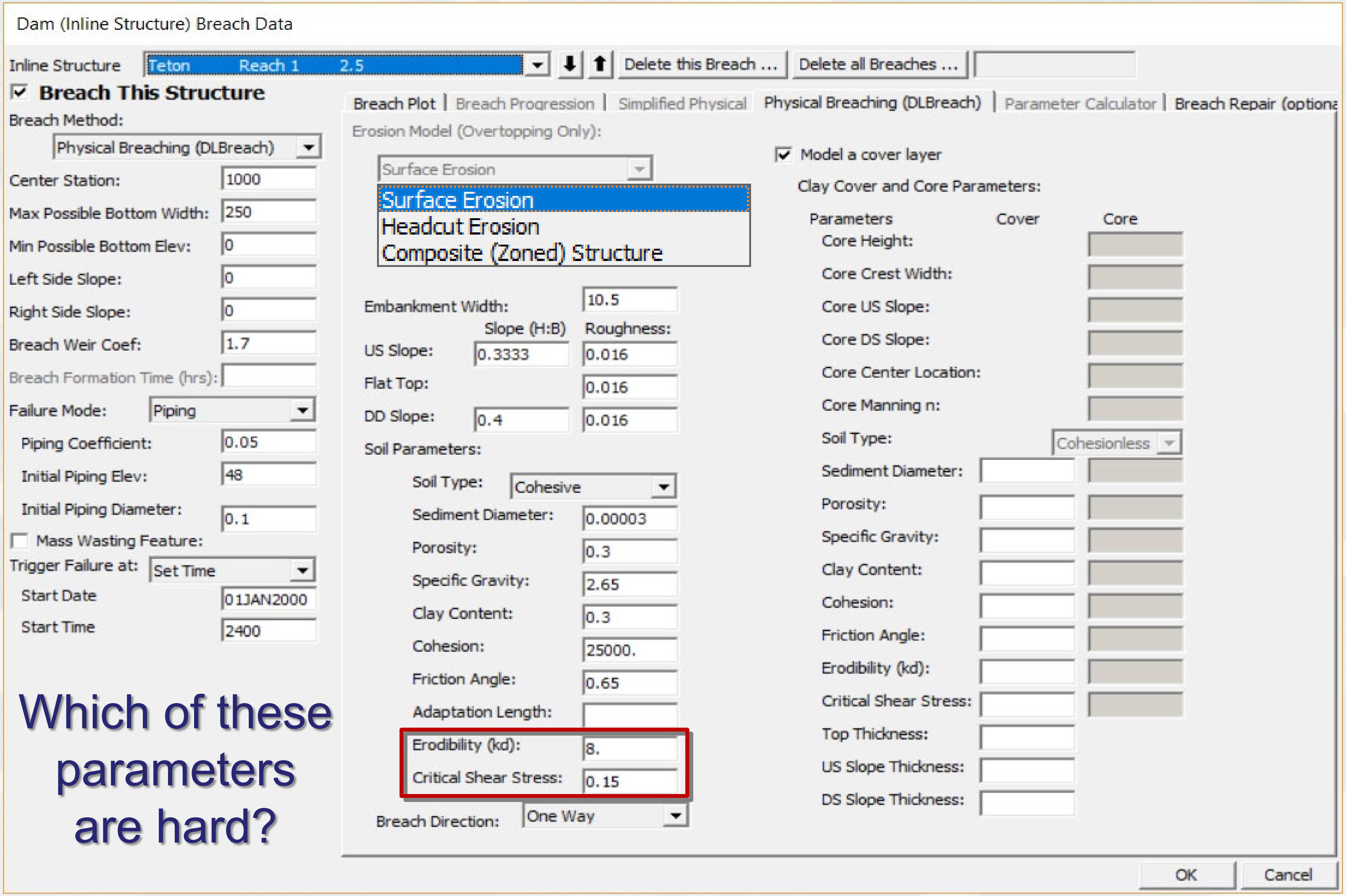
Composite

DLBreach



Measured
Calculated
Discharge (m³/s)
Elapsed time (min)
Breach width (m)
Elapsed time (min)
Inflow
Measured
Caculated
Breach discharge (m³/s)
Elapsed time (min)
Measured peak flow
Calculated
Breach flow discharge (m³)
Elapsed time (hr)

DLBreach



Which of these parameters are hard?

US Army Corps
of Engineers
Hydrologic Engineering Center

Using HEC-RAS for Dam Break Studies

August 2014

https://www.hec.usace.army.mil/publications/TrainingDocuments/TD-39.pdf

Approved for Public Release. Distribution Unlimited.

TD-39

References

ASCE/EWRI Task Committee on Dam/Levee Breaching, “Earthen Embankment Breaching”, Journal of Hydraulic Engineering, December 2011.

Colorado State Department of Natural Resources, Division of Water Resources, Office of the State Engineer, Dam Safety Branch, “Guidelines for Dam Breach Analysis,”, 10 Feb. 2010.

Colorado State University, “Predicting Peak Outflow from Breached Embankment Dams,” prepared for the National Dam Safety Review Board Steering Committee on Dam Breach Equations by M.W. Pierce, C.I. Thornton and S.R. Abt, June 2010.

FERC (1988), USA Federal Regulatory Commission – Notice of Revised Emergency Action Plan Guidelines, February 22, 1988.

Fread, D. L., (1988) (revised 1991), BREACH: An Erosion Model for Earthen Dam Failures, National Weather Service, Office of Hydrology, Silver Spring, MD.

Froehlich, D. C. (1987), “Embankment Dam Breach Parameters,” Hydraulic Engineering, Proc. 1987 ASCE National Conference on Hydraulic Engineering, New York, 570-575.

Froehlich, D. C. (1995a), “Embankment Dam Breach Parameters Revisited,” Water Resources Engineering, Proc. 1995 ASCE Conf. on Water Resources Engineering, New York, 887-891.

Froehlich, D. C. (1995b), “Peak Outflow from Breached Embankment Dam,” J. Water Resour. Plan. Management Div. , ASCE 121(1), 90-97.

Froehlich, David C. (2008), “Embankment Dam Breach Parameters and Their Uncertainties,” Journal of Hydraulic Engineering, ASCE, Vol. 134, Issue 12, pp 1708-1721, Dec. 2008.

Gee, D. Michael and Brunner, Gary W., 2007. “Comparison of Breach Predictors,” Association of State Dam Safety Officials (ASDSO), Dam Safety 2007, Austin, TX, 9-13 September 2007.

References (cont)

Gee, D. Michael, 2010. "Dam Breach Modeling with HEC-RAS using Embankment Erosion Process Models," World Environmental and Water Resources Congress 2010, ASCE-EWRI, Providence, R.I., 16-20 May 2010.

HR BREACH Model http://www.floodsite.net/html/HR_Breach_Model.htm

MacDonald, T. C., and Langridge-Monopolis, J. (1984), "Breaching Characteristics of Dam Failures," ASCE J. Hydraulic Engineering, 110(5), 567-586,

Temple, Darrel M., and Hanson, Gregory J., "Earth Dam Overtopping and Breach Outflow," Presented at the ASCE World Water & Environmental Resources Congress 2005, EWRI, Anchorage, AK, 15-19 May 2005.

U.S. Army Corps of Engineers, Hydrologic Engineering Center, "Flood Emergency Plans – Guidelines for Corps Dams," RD-13, June 1980.

U.S. Army Corps of Engineers, Hydrologic Engineering Center, "Numerical Simulation of Mudflows from Hypothetical Failures fo the Castle Lake Debris Blockage near Mount St. Helens, WA", HEC-PR-14, October 1990.

Von Thun, J. L., and Gillette, D. R. (1990), "Guidance on Breach Parameters," Internal Memorandum, U.S. Dept. of the Interior, Bureau of Reclamation, Denver, March 13, 1990, 17p.

References (cont)

Wahl, Tony L., “Prediction of Embankment Dam Breach Parameters – A Literature Review and Needs Assessment,” DSO-98-004, Dam Safety Research Report, U.S. Department of the Interior, Bureau of Reclamation, Dam Safety Office, July 1998.

Wahl, Tony L., “Uncertainty of Predictions of Embankment Dam Breach Parameters,” ASCE Journal of Hydraulic Engineering, May 2004.

Wahl, Tony L., et al., 2008. “Development of Next-Generation Embankment Dam Breach Models,” United States Society on Dams, 28th Annual USSD Conference, Portland, OR, April 28-May 2, 2008, pp. 767-779.

Washington State Dept. of Ecology, Dam Safety Guidelines, Tech. Note 1 Dam Break Inundation Analysis and Downstream Hazard Classification, Water Resources Program, Dam Safety Office, P.O. Box 47600, Olympia, WA 98504-7600, July 1992, http://www.ecy.wa.gov/programs/wr/dams/Images/pdfs/technote_1.pdf

Xu, Y., and Zhang, L.M., 2009. “Breaching Parameters for Earth and Rockfill Dams.” J. Geotech. Geoenviron. Eng. 135(12), 1957-1969.

USBR Levee Breach Lab Studies

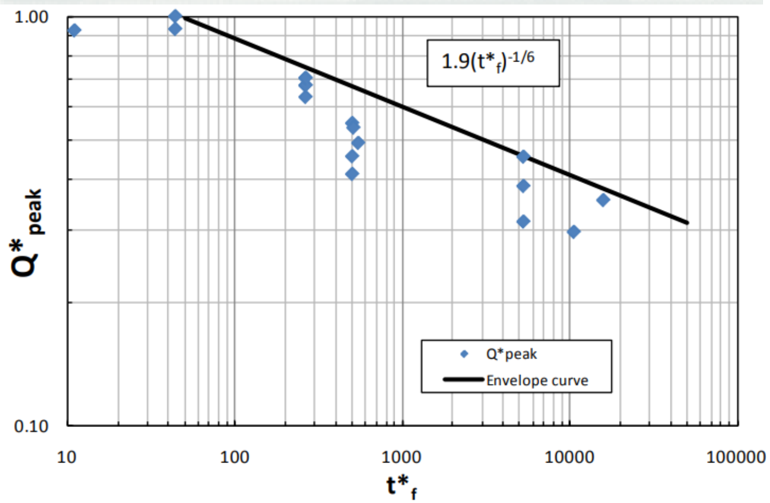


Figure 28. — Dimensionless peak discharge as a function of dimensionless breach development time.

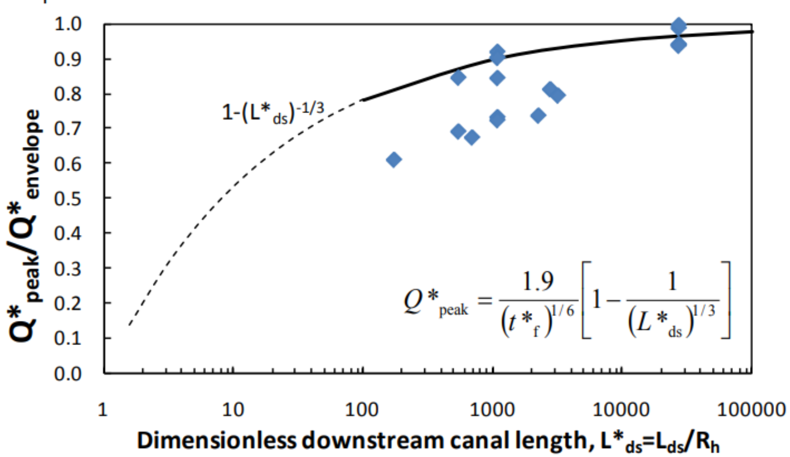


Figure 29. — Effect of downstream canal reach length on peak breach outflow.

RECLAMATION

Managing Water in the West

Hydraulic Laboratory Report HL-2011-09

Physical Hydraulic Modeling of Canal Breaches

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
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