Boska, John

From: Hubbard, Dean M <Dean.Hubbard@duke-energy.com>
Sent: Tuesday, April 23, 2013 10:50 AM
To: Boska, John
Subject: Non- Security Sensitive version of March 25th Presentation
Attachments: NRC Presentation March 25. 2013 FINAL Rev C (Non-security Sensitive).pdf

Follow Up Flag: Follow up
Flag Status: Completed

As discussed, slide 18 is now blank with a statement that the information was removed due to being security sensitive.

Thanks John

Dean

B-2

Fukushima -
Flooding Hazard Reevaluation

Upstream Dam Failure Analysis

NCR
Technical
Presentation

NRC Headquarters

One White Flint North

Rockville, MD

March 25, 2013

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Dave Baxter, VP, Regulatory Project Completion

Dean Hubbard, Oconee External Flood Licensing Manager

Ray McCoy, Principal Engineer, ONS Civil Design

Chris Ey, Civil Engineering Manager, HDR

Dana Jones, Oconee Fukushima Engineering Supervisor

Joe Ehasz, VP, URS Program Manager - Water Resources

Agenda

- Current Dam Failure Analysis - January 28, 2011
  - Breach Analysis Summary
  - Model Development
- Updated Dam Failure Evaluation – submitted March 12, 2013
  - Models Considered
  - Selection of Xu & Zhang
  - Update Breach Parameters
  - Sensitivity Analysis
  - Independent Review
  - Comparative Analysis - Large Modern Dam Failures
- Modifications Scope

2011 Breach Analysis Summary

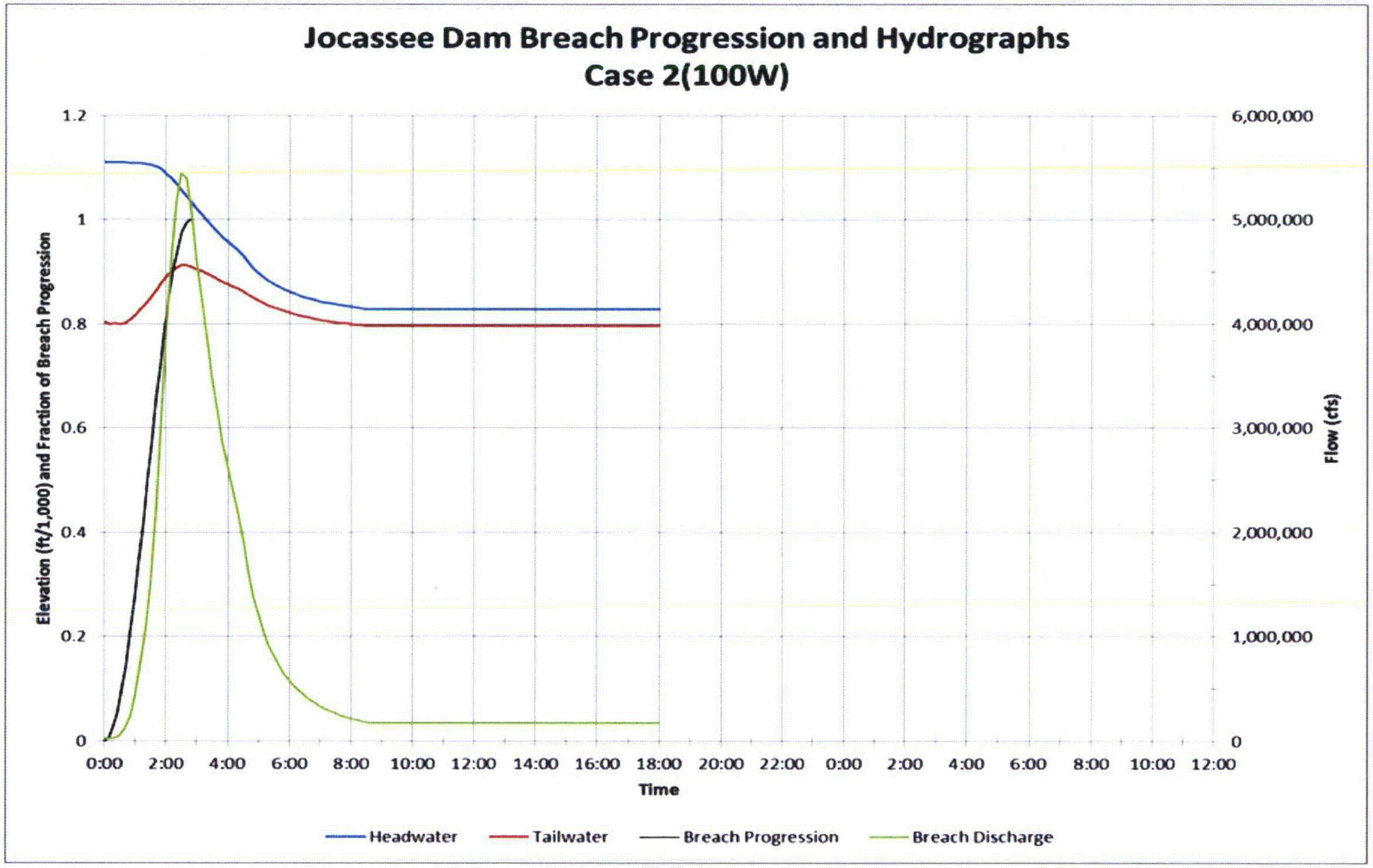
- Breach parameters developed using regression methodology and technical papers:
  - Froehlich 2008
  - Walder & O'Connor
  - MacDonald & Langridge-Monopolis
- Breach analysis focused on maximizing flooding levels to provide a very conservative and bounding analysis:
  - Breach dimensions maximized to assume loss of most of the dam embankment.
  - Froehlich breach time of 5 hours was reduced to 2.8
  - Maximum peak outflow was selected from all methods
  - Breach times of Keowee dams/dikes adjusted to maximize water directed at the site
  - Tailwater effect below Jocassee dam was not considered

2011 Breach Analysis Summary

Jocassee Dam (postulated dam failure)

- Initial breach derived primarily from Froehlich regression equations.
- Breach dimensions were adjusted based on physical constraints of natural valley
- Jocassee breach parameters:
  - Top Width - 1156 (64% of overall crest)
  - Bottom Width – 431 feet
  - Bottom Elevation – 800 msl
  - Breach Formation Time - 2.8 hrs,
  - Peak outflow 5,400,000 cfs

2011 SE Jocassee Dam Breach Progression and Stage-Discharge Hydrographs



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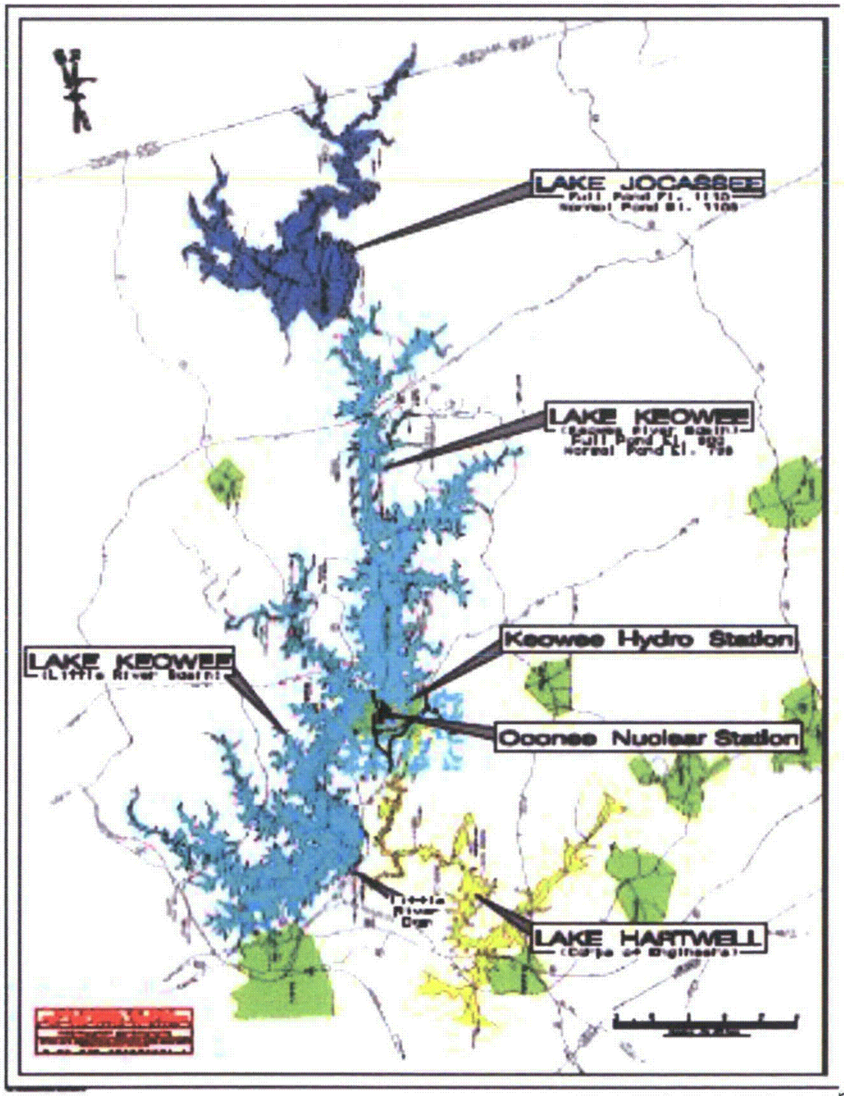
2011 Breach Analysis Summary

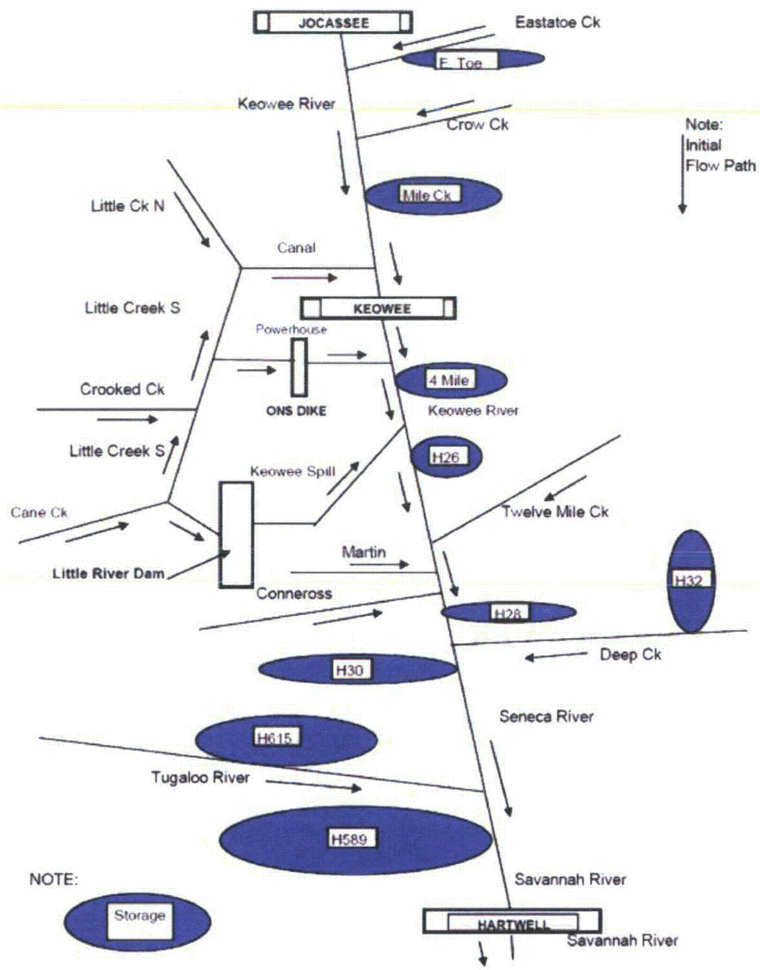
Keowee Dam/Dikes (postulated cascading dam failures)

- Overtopping failure trigger of two feet over the crest
- Cascading dam/dike failure on Keowee
  - Keowee main dam- 2.8 hrs
  - West Saddle Dam - 0.5 hrs
  - Intake Canal Dike- 0.9 hrs
  - Little River Dam – 1.9 hrs
- Conservative assumptions were made to maximize the water directed toward the power block

Model Development HEC-RAS 1D Model



Jocassee-Keowee Dam Breach Study
Dam Breach Model Schematic



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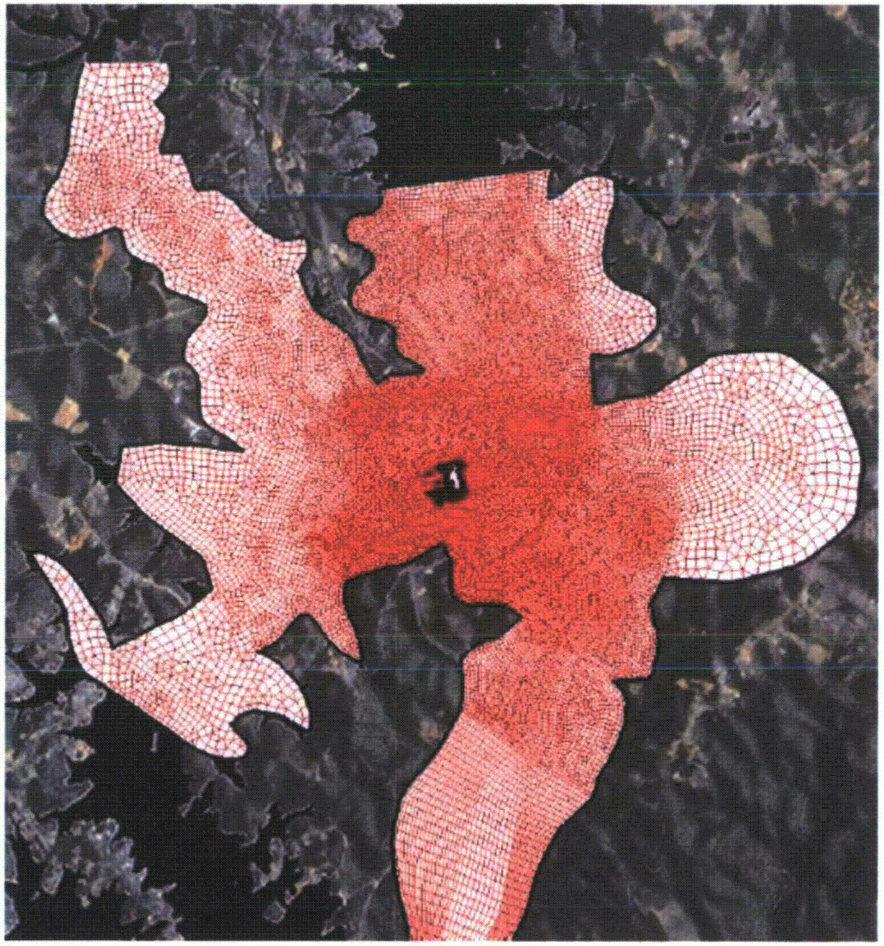
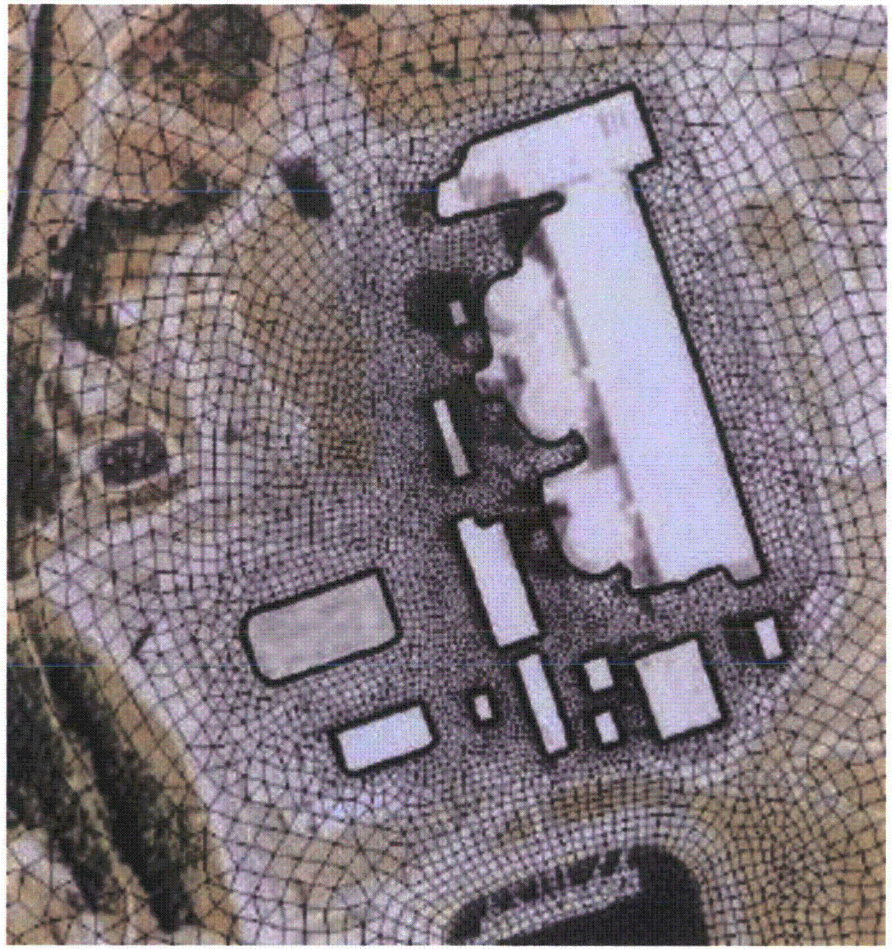
Model Development
SRH 2D Model

(57 thousand elements)

REVISED COMPUTATIONAL MESH





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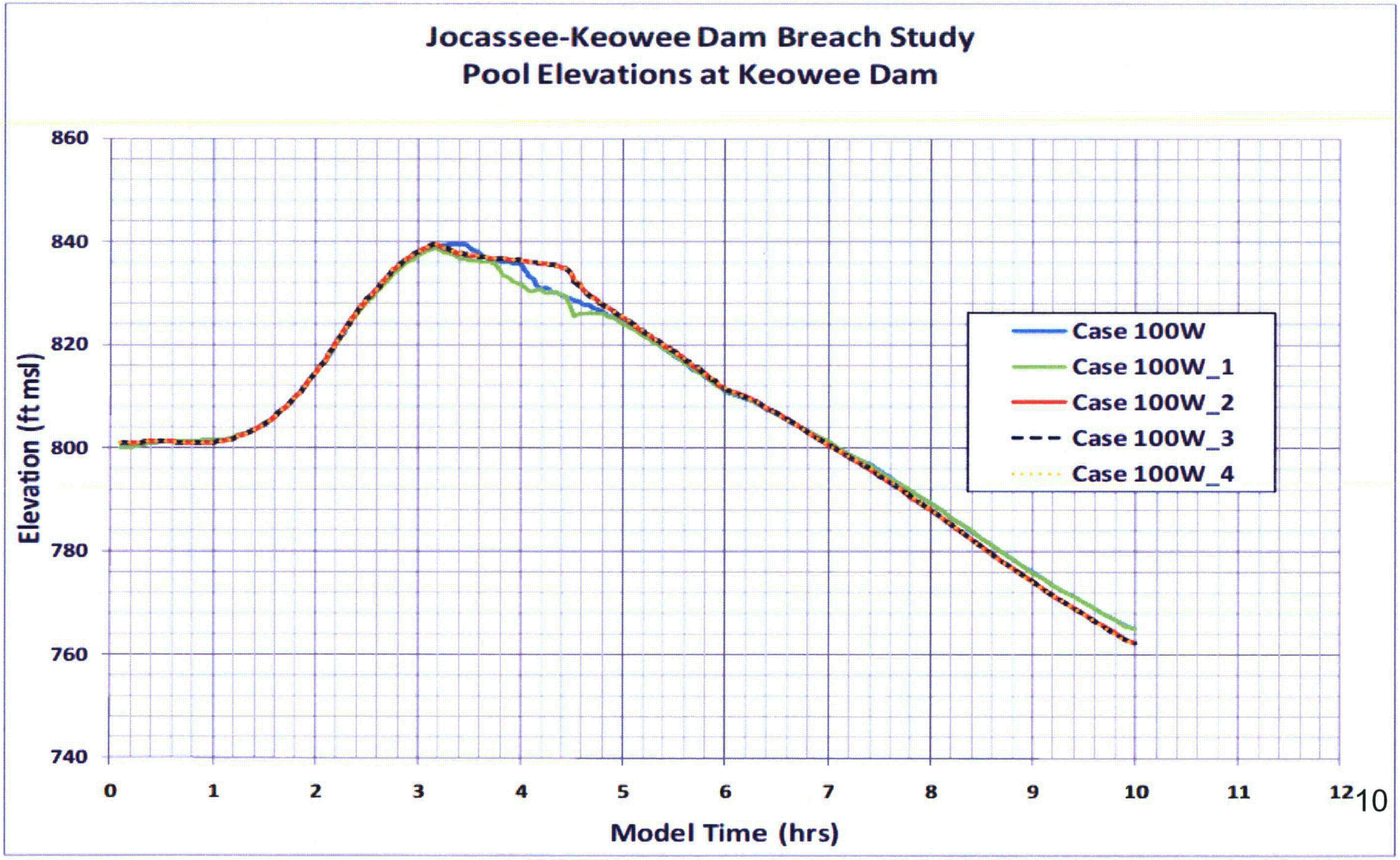
2011 Breach Analysis Summary
2D Model

WATER SURFACE ELEVATIONS AT KEOWEE DAM



Updated Dam Failure Evaluation

Updated Dam Failure Evaluation
Fukushima 2.1

Attributes of updated and refined dam failure analysis

- Updated methodology and present day regulatory guidance
- Performed to meet NUREG CR/7046, 2011 & ANS 2.8, 1992
- Realistic but still conservative assumptions
- Physical characteristics of the dams/dikes recognized including materials and method/quality of construction
- Overtopping and Seismic are confirmed from the 2011 SE as not being credible failure modes

Updated Dam Failure Evaluation Fukushima 2.1

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Overtopping of the Jocassee dam was confirmed not to be a credible failure mode

- The Jocassee dam and dikes include 15 feet of freeboard
- The Jocassee watershed is small relative to storage capacity – 148 square miles
- The top of the spillways are located at 1110 (full normal level)
  - Four diverse methods of assuring spillway gate operation
  - Rigorous spillway gate maintenance and surveillance testing as required and monitored by FERC
- Lake management procedures require consideration of lower level to anticipate additional storage needs for significant storms
  - Weekly rain forecast are prepared by Duke Energy to project rainfall for the basin
  - Precipitation monitoring has assured that no overtopping of the spillway gates has occurred in 40 + years of operation
- PMF using current HRR-51,52 results in 3 feet of freeboard margin
- 2011 SE also concluded that overtopping was not credible

Updated Dam Failure Evaluation
Fukushima 2.1

Seismic Failure of the Dam was confirmed not to be a credible failure mode

- Seismic evaluation based on current FERC criteria using the 1989 EPRI Hazard Curves
  - The Jocassee dam is designed to a **0.12 g** horizontal ground acceleration (Oconee site is designed to a **0.1g** horizontal ground acceleration).
- 2007 Updated Fragility Analysis
  - High Confidence of a Low Probability of Failure (HCLPF) of the dam by sliding **0.305 g**
  - Evaluation was performed by Applied Research & Engineering Sciences (ARES) Corp., formerly EQE, a respected consulting firm in the area of seismic fragility
  - The ARES report concluded the median centered fragility value for failure of the dam is **1.64 g**.
  - Maximum Probabilistic Peak Ground Acceleration for a 2% probability of being exceeded within a 50 year period is **0.197** g (using the United States Geologic Service hazard maps applicable to Jocassee).
- Jocassee dam is included in the seismic model of the Oconee Probable Risk Assessment.
  - The combination of the updated seismic fragility with the seismic hazard curve results in a negligible risk contribution from seismic events.
  - In a letter dated 11/20/07 and in the 1/28/11 SE report, the NRC concluded that there is a negligible risk

Models Considered
Regression Analysis

- Froehlich 2008
- Walder & O'Connor
- MacDonald & Langridge-Monopolis 1984
- Xu & Zhang 2009

Selection of Xu & Zhang 2009
Basis

- Most current regression method developed and validated with the largest data base of dam failures:
  - 182 earth and rockfill dam failures compiled
  - 75 failures w/ sufficient info to develop breach regression models
- Empirical formulas that account for physical characteristics of dam/reservoir: dam type, failure mode, height, dam erodibility, reservoir shape/storage)
- 33 of the 75 failures were on large dams ($\geq$ 15 meters)
- Applies to multi-zoned dams
- Method yields realistic but conservative breach parameters
- Recognized by industry experts

Breach Parameters
Fukushima Update

- Jocassee Dam – Xu & Zhang
  - Starting reservoir elevation 1110 (normal full pond)
  - Rockfill dam with low erodibility classification
  - Piping failure initiating at 1020 feet msl (Sunny Day Failure)
  - Breach parameters:
    - ✓ Top Width - 701’ (39% of overall crest)
    - ✓ Bottom Width – 431’
    - ✓ Bottom Elevation – 870’
    - ✓ Breach Formation Time:
      - Xu & Zhang – 29.2 hrs.(13.2 hours piping +16.0 open weir)
      - Froehlich – 16.0 hours (open weir)
    - ✓ Peak outflow: 1,760,000 cfs

Jocassee Dam
Low Erodibility Classification

Diagram removed due to security sensitive information

Fukushima Model

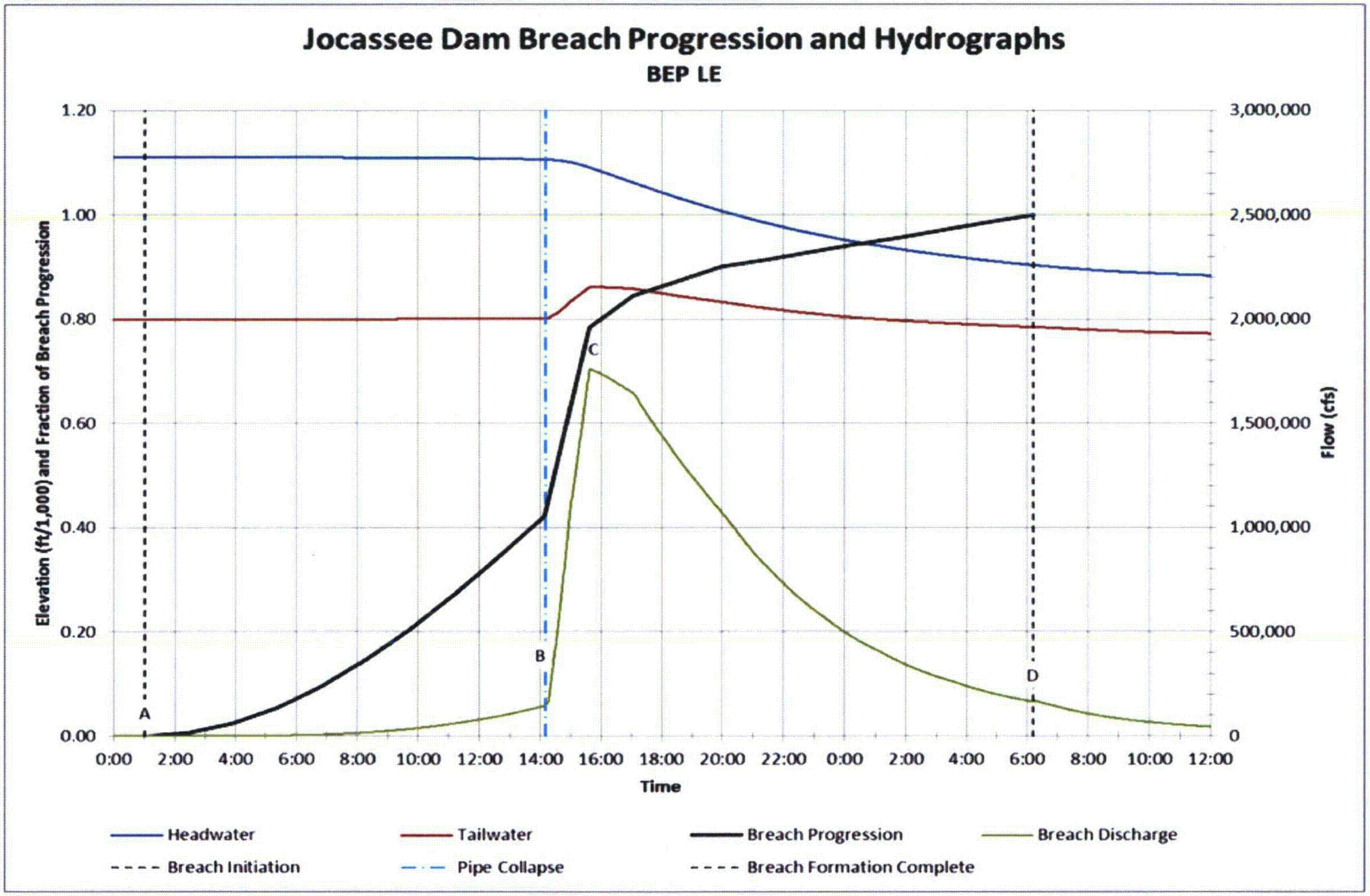
JOCASSEE DAM BREACH PARAMETERS												
Structure	Crest Elevation (ft msl)	Reservoir Starting Elevation (ft msl)	Failure Mode	Bottom Breach Elevation (ft msl)	Bottom Breach Width (ft)	Average Breach Width (ft)	Right Side Slope (Zr)	Left Side Slope (Zl)	Time to Failure (Hr)	Top of Breach Width (ft)	Breach Progression	Breach Initiation Elevation (ft msl)
Jocassee Dam	1125	1,110	Piping	870	431	566	0.53	0.53	29.2	701	Sine Wave	1,020

Breach Formation Time

Xu & Zhang definition: 29.2 (13.2 hours piping + 16.0 hours open weir)

Froehlich definition: 16.0 hours open weir

Fukushima Model Jocassee Dam Breach Progression and Stage-Discharge Hydrographs

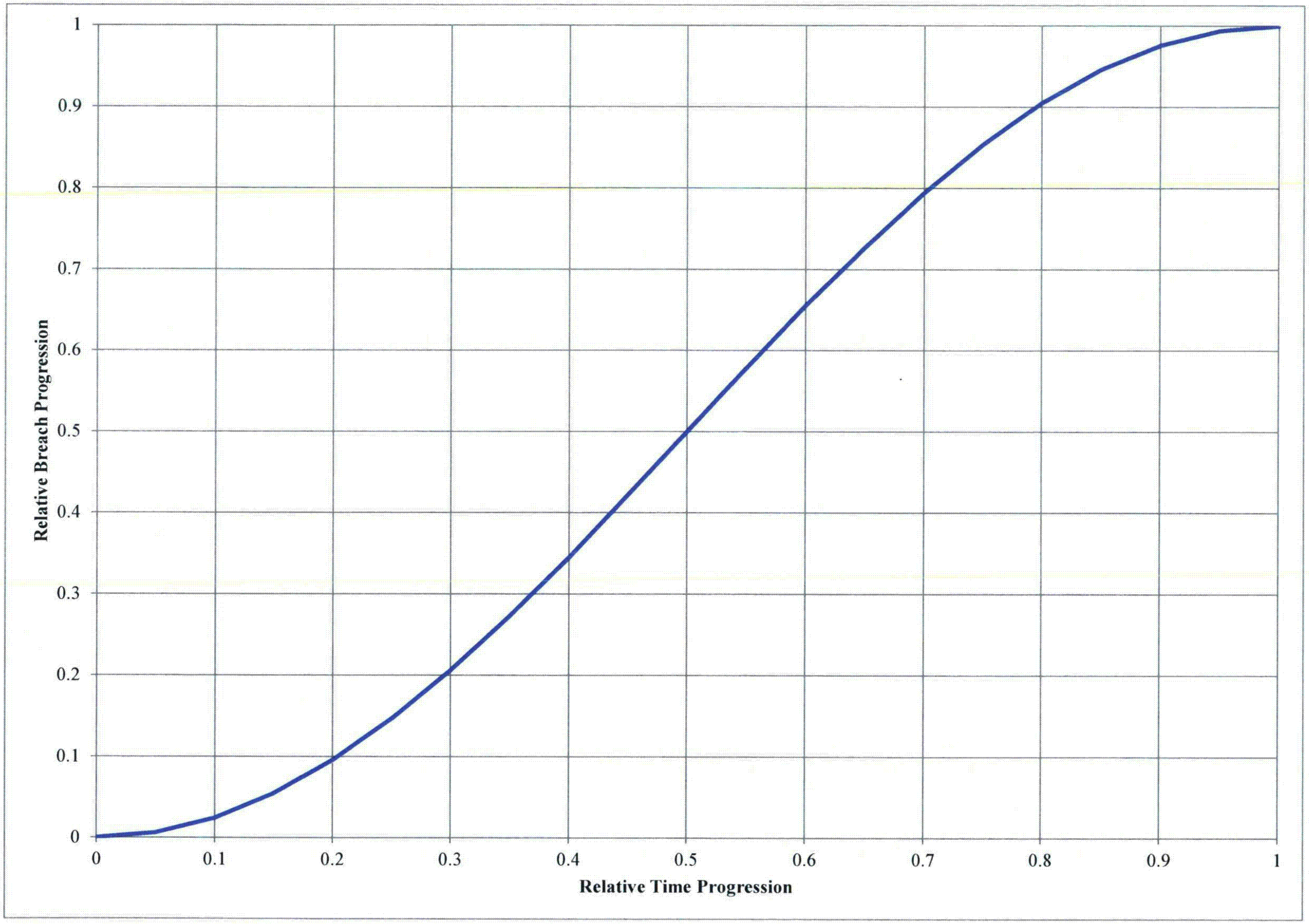


<u>Breach Formation Time</u>; Xu & Zhang definition: - 29.2 (13.2 hours piping + 16.0 hours open weir) **Froehlich definition**: -16.0 hours open weir

Breach Parameters
Fukushima Update

- Keowee Dam
  - Starting reservoir elevation 800 (normal full pond)
  - Homogeneous earth fill dam
  - Overtopping failure trigger of two feet over the crest at 817 msl by rapid rise of Keowee reservoir over the crest
  - Multiple simultaneous breach initiation formation points across the Keowee dam and West Saddle dam
- Cascading dam/dike failure on Keowee
  - Keowee main dam- 0.75 hrs
  - West Saddle Dam - 0.5 hrs (shorter than main dam, ratio of height)

Fukushima Model Keowee Dam Breach Progression HEC-RAS



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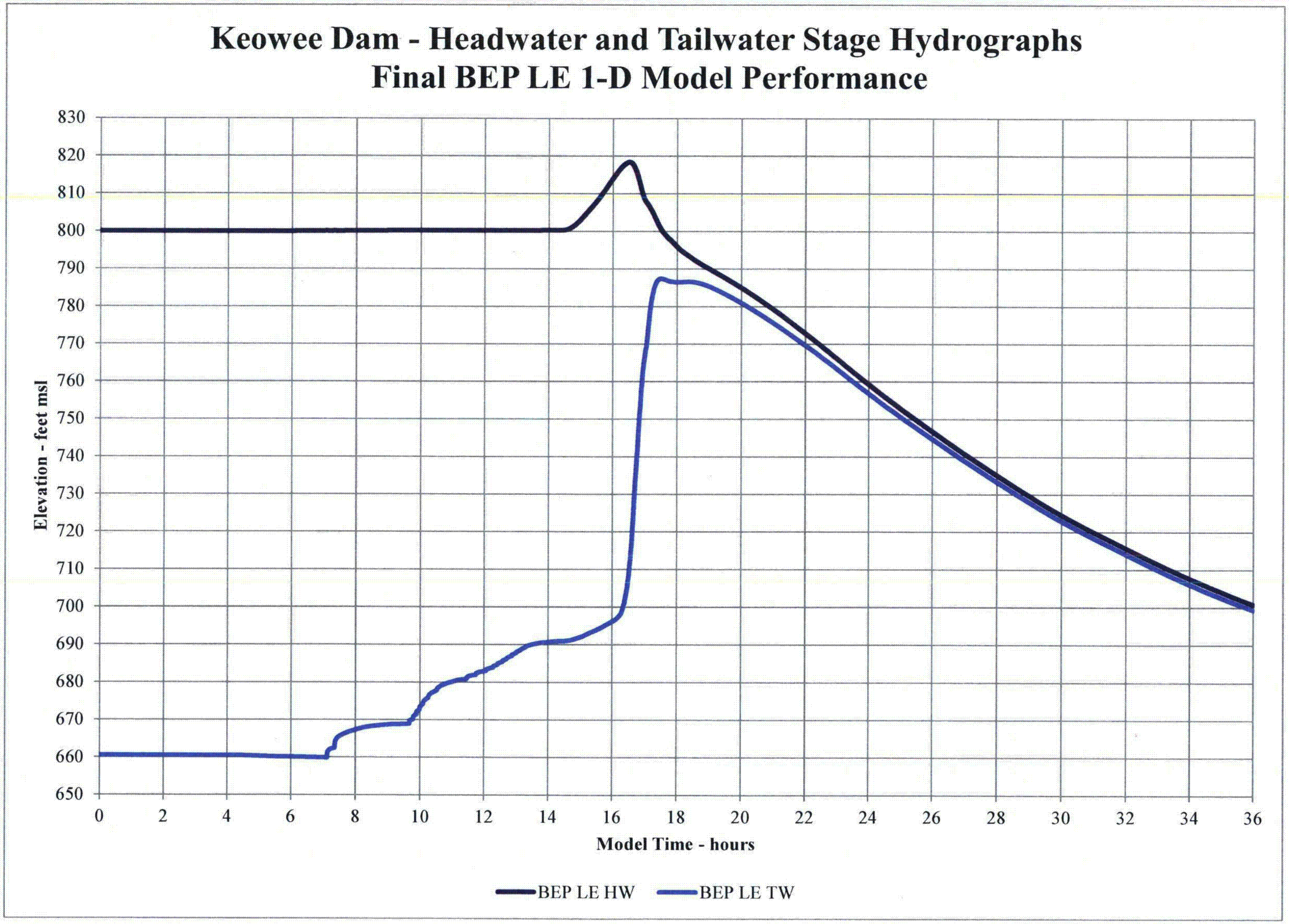
Fukushima 1D Modeling



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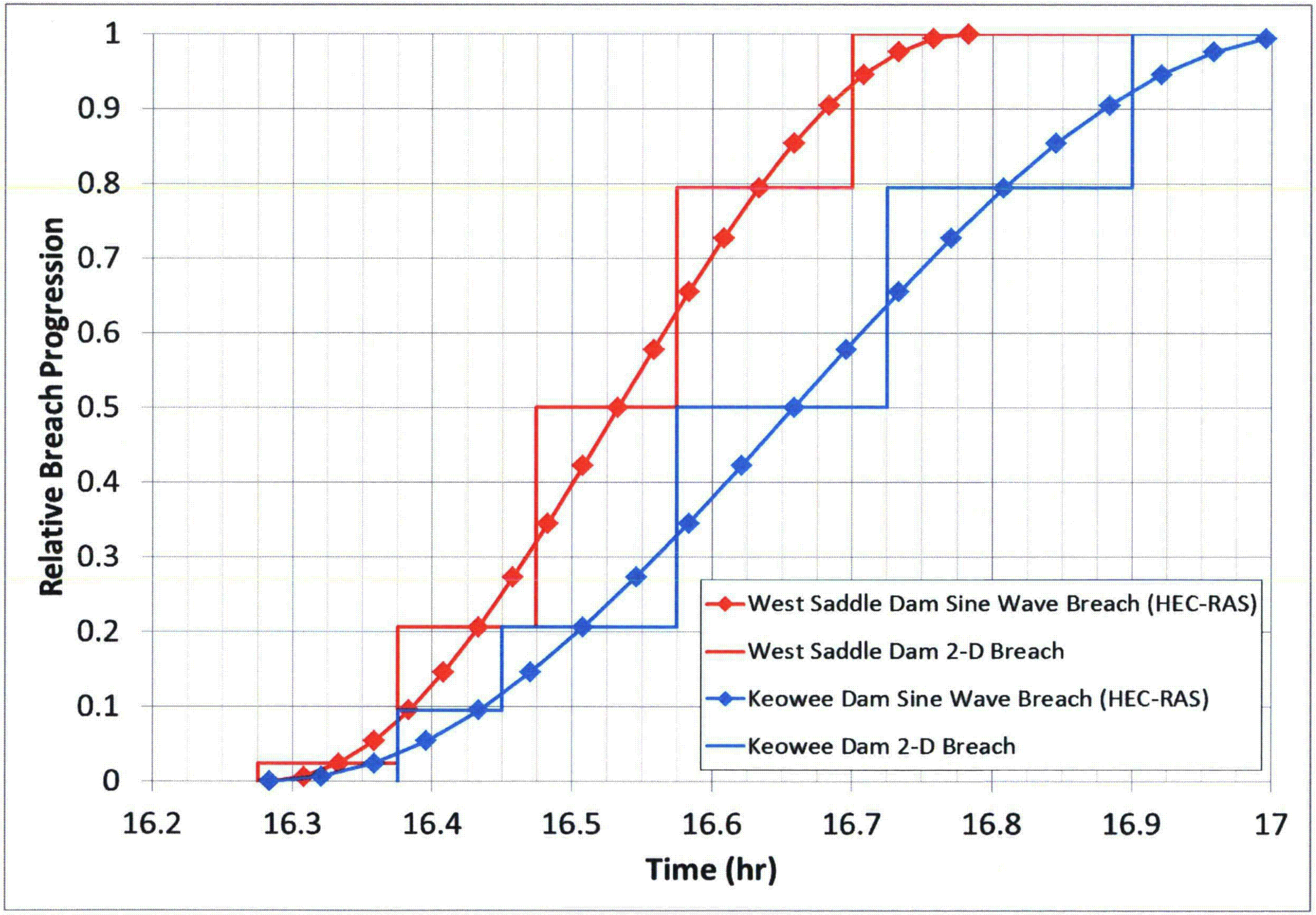
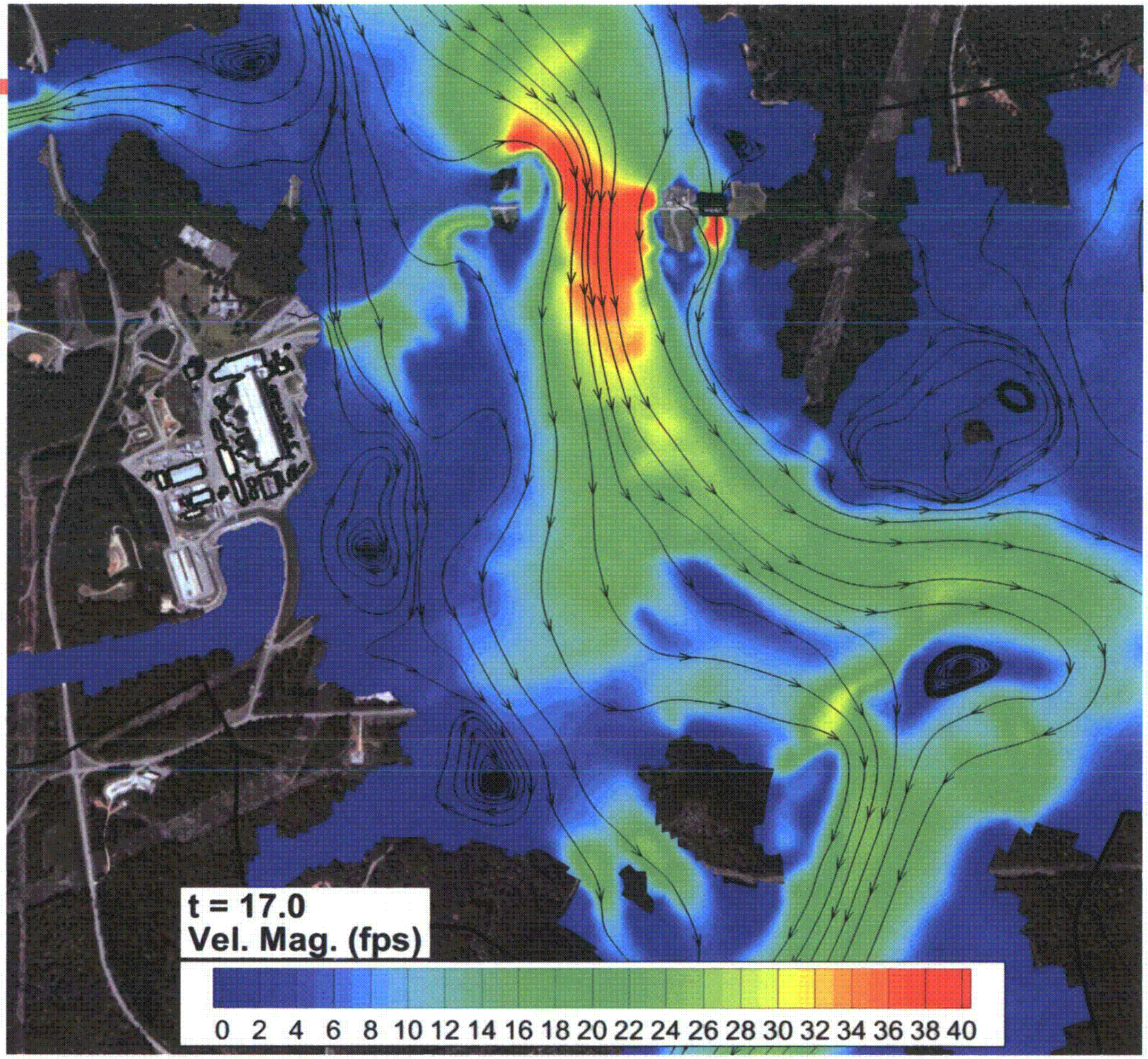
Fukushima 2.1 2D Modeling
Keowee Dam Breach Progression



Fukushima 2D Modeling Velocity and Flow Pattern at 17 hrs.



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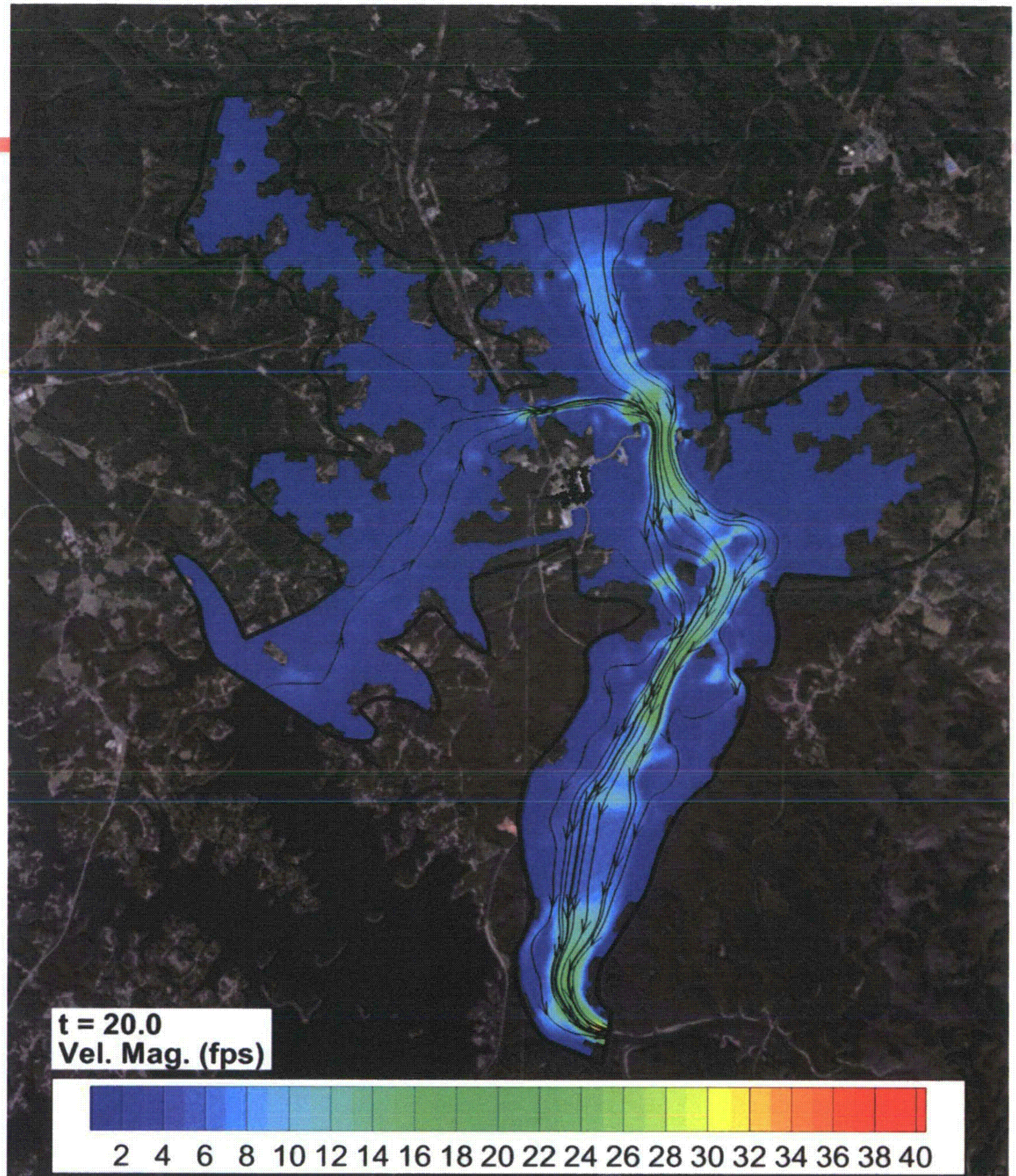
Fukushima 2D Modeling Velocity and Flow Pattern at 20 hrs.



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Fukushima 1D-2D Modeling Results

Breaching							
Keowee Dam				Intake Dike			
HEC-RAS		2-D		HEC-RAS		2-D	
Elevation	Decimal Time	Elevation	Decimal Time	Elevation	Decimal Time	Elevation	Decimal Time
817	16.28	817	16.24	n/a	n/a	n/a	n/a

Maximum Water Surfaces							
Keowee Dam				Intake Dike			
HEC-RAS		2-D		HEC-RAS		2-D	
Elevation	Decimal Time	Elevation	Decimal Time	Elevation	Decimal Time	Elevation	Decimal Time
818.4	16.53	820.1	16.58	810	17.17	807.2	17.67

Maximum Water Surfaces							
Swale				Tailwater			
HEC-RAS		2-D		HEC-RAS		2-D	
Elevation	Decimal Time	Elevation	Decimal Time	Elevation	Decimal Time	Elevation	Decimal Time
817.5	16.55	815.5	16.53	787.4	17.52	790.4	18.41

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Sensitivity Analysis

Model	Peak Outflow (cfs)
McDonald & Langridge-Monopolis 1984	1,566,381
Costa, 1985	1,634,480
Xu & Zhang, 2009	1,760,000
Evans, 1986	1,803,331
SCS, 1981	2,647,711
Bureau of Reclamation, 1982	3,046,462
McDonald & Langridge-Monopolis 1984	5,093,603 (upper envelope)
Froehlich (with additional conservatism), 2008	5,440,000

Data in this table based on Wahl 2004, January 28, 2011 SE and updated Xu & Zhang data

100+ HEC-RAS studies performed with varied breach parameters and control variables

Erodiblity was the most significant factor influencing the breach parameters for Xu & Zhang 2009

Bias of conservatism with realism

Independent Review Breach Parameters

- **Independent Peer Review**

  Joe Ehasz, P.E.

  David Bowles, Ph. D P.E. P.H.

- **FERC Board of Consultant Review**

  Gonzalo Castro, Ph.D., P.E.

  James Michael Duncan, Ph.D., P.E.

  James F Ruff, Ph.D., P.E.

  Gabriel Fernandez, Ph.D., P.E.

Comparative Analysis
Large Modern Dam Failures

- **Taum Sauk**
  - Overtopping failure initiated by human error (previous overtopping events had occurred)
  - Random rockfill embankment supporting the inner concrete liner loosely placed by end dumping the material without compaction except for the top 16' of 84' height
  - The embankment was constructed on a very steep downstream slope of 1.3H to 1V with a 10 high concrete parapet wall along the crest of the dam
  - Embankment was highly erodible and contained over 45% sand sized material (also evident in unusual level of surface erosion from rain events)
- **.Teton**
  - earthen dam with majority of dam constructed of highly erodible windblown silt (infant mortality event)
  - No transition zones (sand and/or fine filters) were included between the silt core and the sand & gravel
  - Thin layer of small rock fill on both up and downstream faces with a majority of protection relied upon mix of sand, gravel and cobble
  - Piping failure at 130' below the crest due to inadequate protection of impervious core trench material
  - Breach top width 781' (~25% of overall crest)
- **Hell Hole**
  - True rockfill dam,with upstream sloping impervious core with massive rock fill sections up and down stream to support and protect the core.
  - Failure caused by overtopping during construction due to an intense rain event that could not be passed through the construction diversion tunnel
  - After overtopping of the core started, the dam took 26 hours to complete the breach and empty the upstream reservoir

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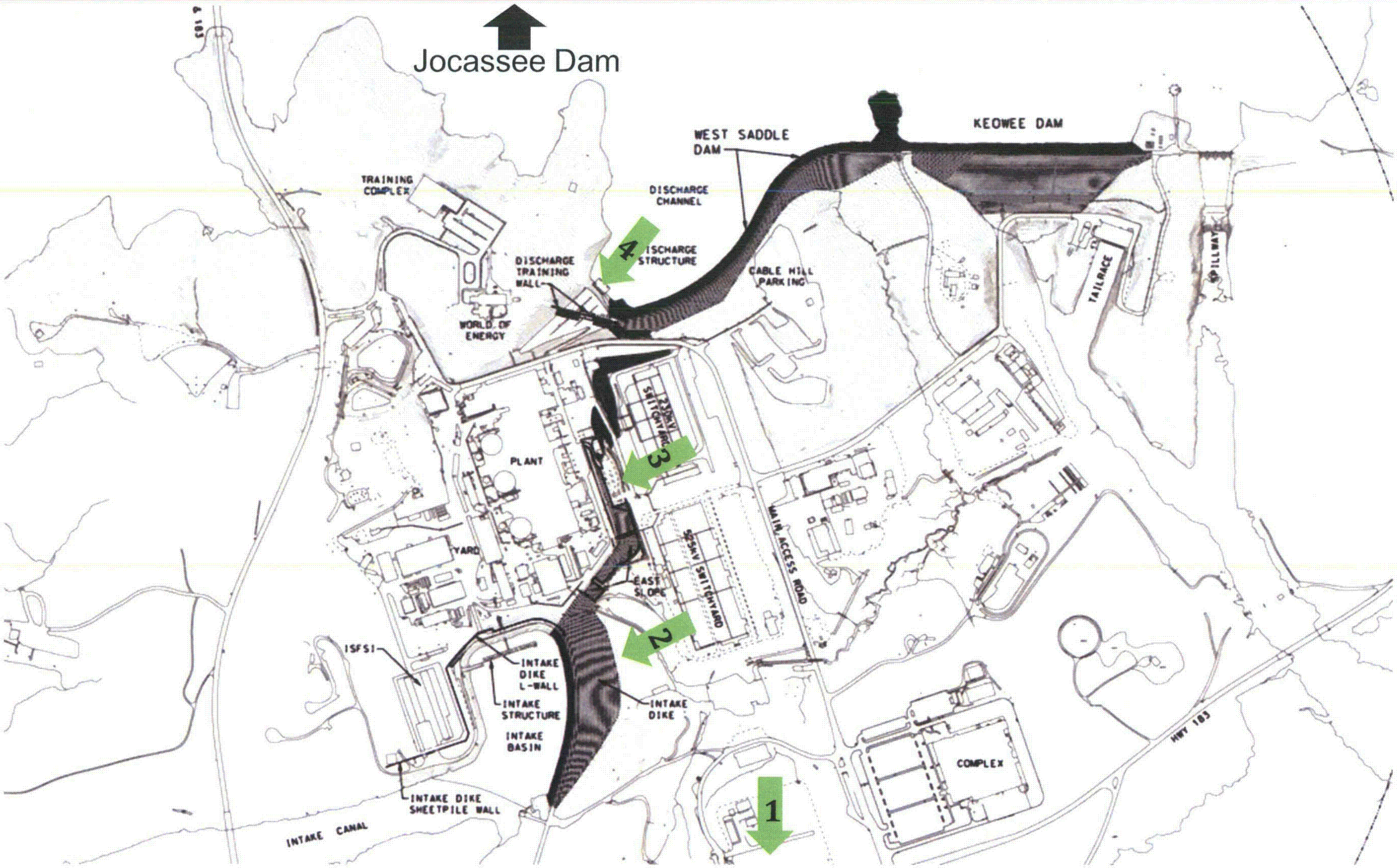
Modification Scope Updated

- Modifications for protection from dam failure (under review):
  1. Relocation of external backup power transmission line
  2. Intake Dike embankment protection
  3. East embankment protection
  4. Discharge Diversion wall
- Modifications for Local Intense Precipitation (under review):
  - Transformer relocation
  - Diversion walls and drainage canals
  - Aux building and Turbine building protection

Modification Options



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Questions and Feedback