



Oconee Nuclear Station External Flood NRC Technical Meeting Rockville, MD 10/28/09

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under 10 CFR 2.390~~



Duke Attendees

- Rich Freudenberger, Manager ONS Safety Assurance Manager
- Jeff Thomas, Corporate Regulatory Compliance Manager
- Tim Brown, ONS Project Manager
- Ray Mc Coy, ONS Principal Engineer
- Chris Ey, Manager Civil Engineering, HDR
- Andy Mc Coy, Ph.D., Water Resources Engineer, HDR

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Agenda

- Overview of Sensitivity Studies
- HEC-RAS Results
- HEC-RAS Model Confidence
- Selection & Justification of 2D Model Cases
- HEC-RAS Results and Input to Selected 2D Model Cases
- 2D Model Highlights & Results
- Summary

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Sensitivity Studies

➤ Jocassee

- Breach Size
- Time to Failure

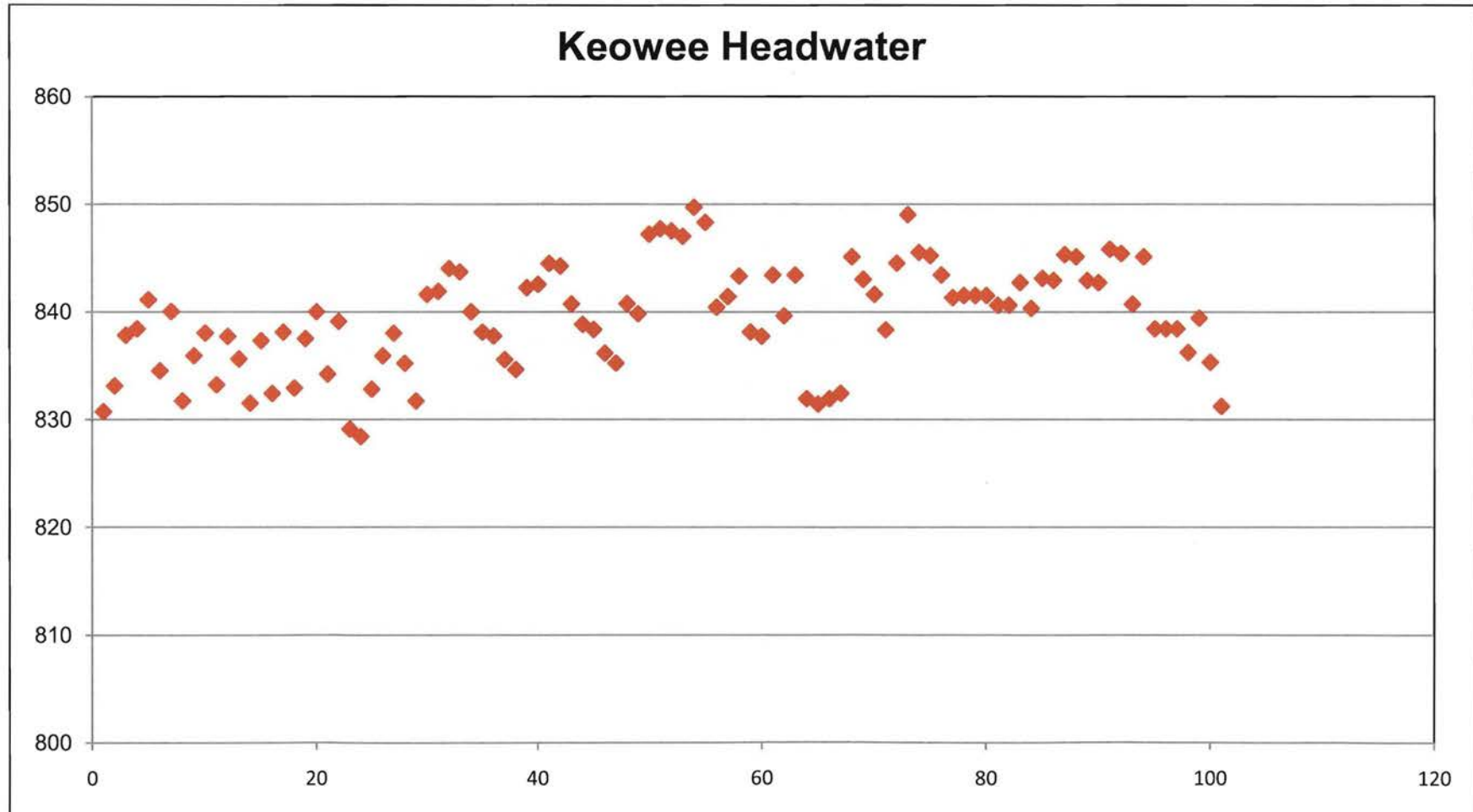
➤ Keowee

- Failure Sequence
- Breach Size
- Time to Failure
- West Saddle Dam Failure

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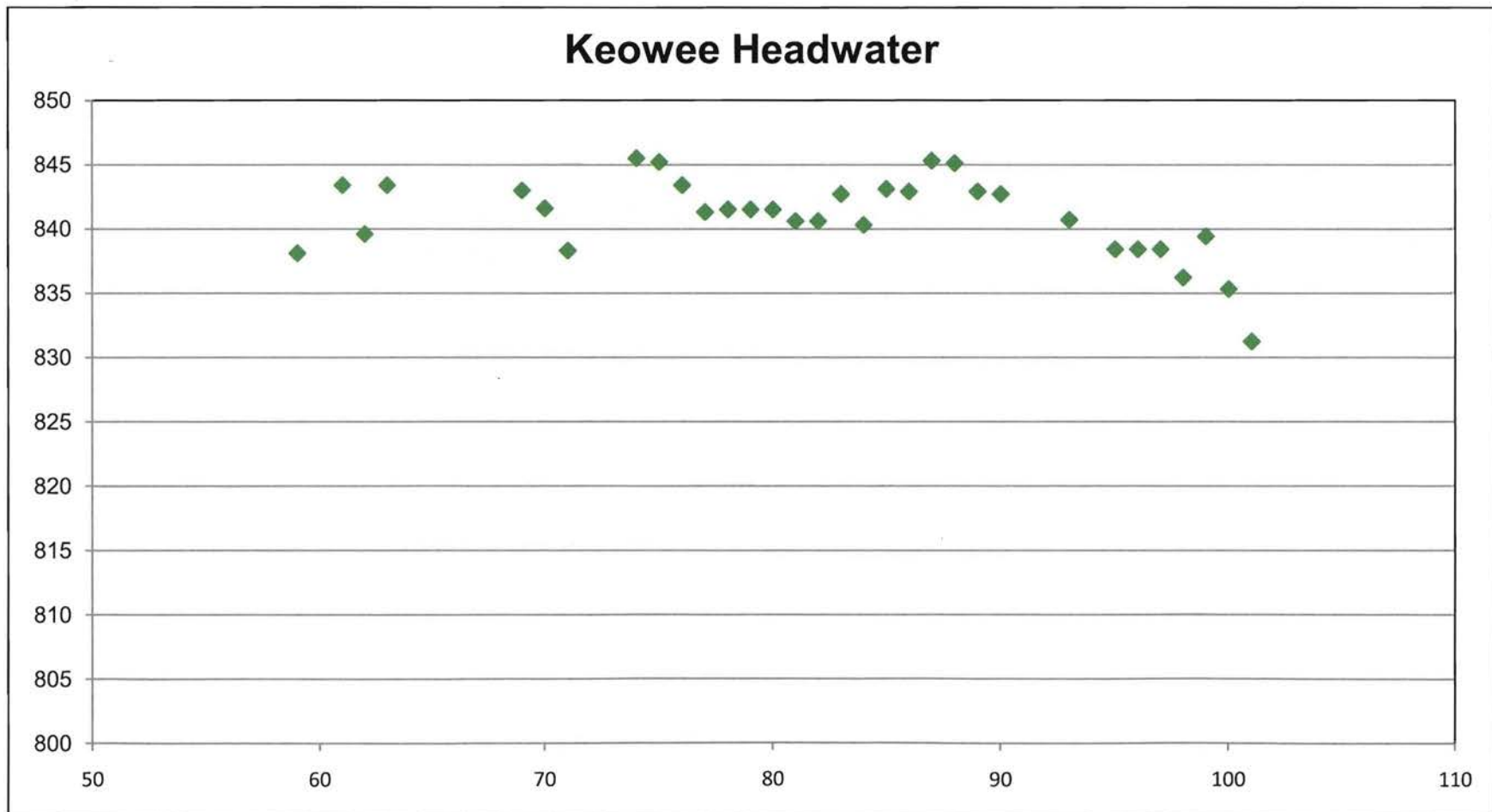
HEC-RAS Results



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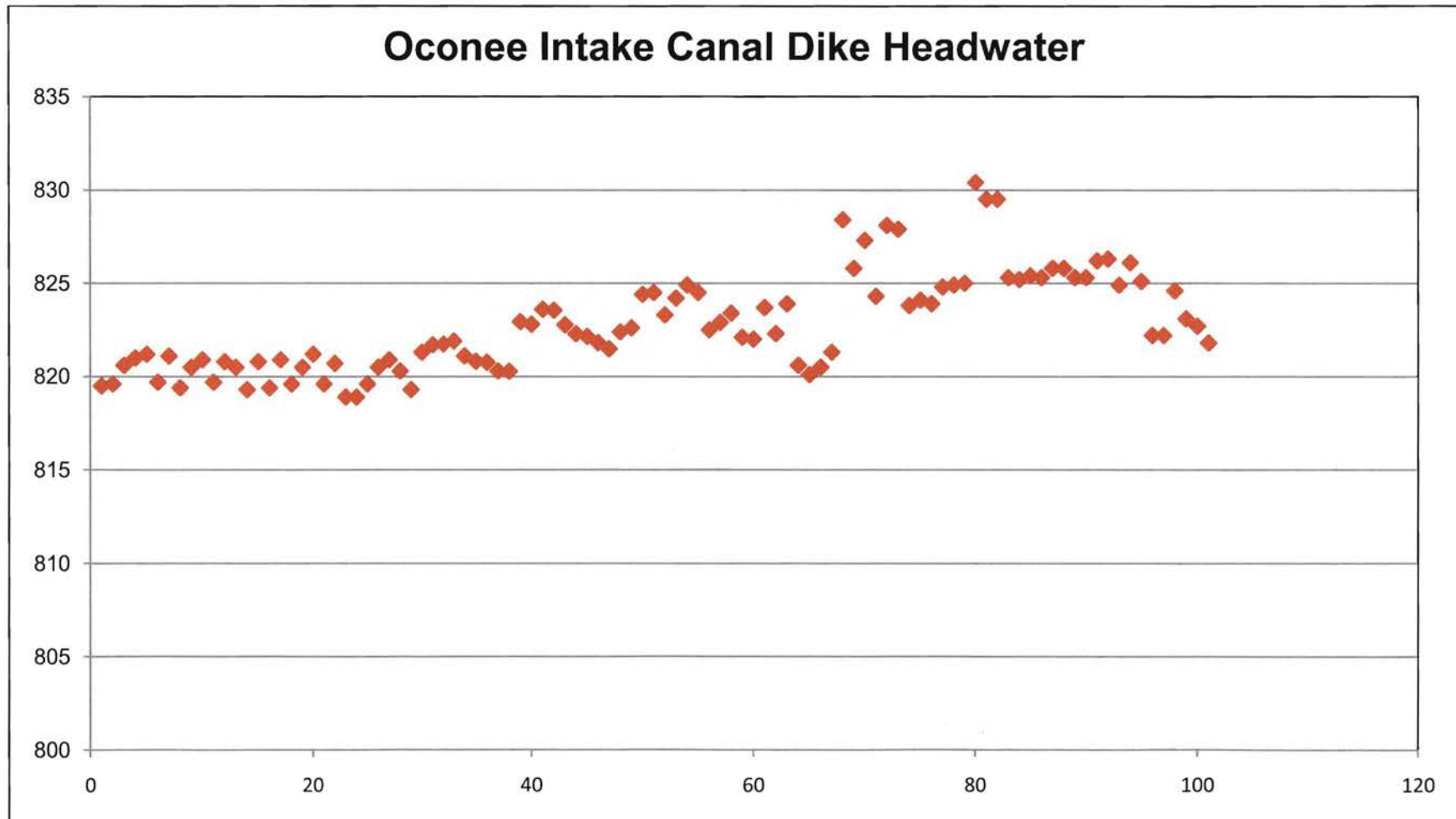
HEC-RAS Results w/ W. Saddle Dam Failure



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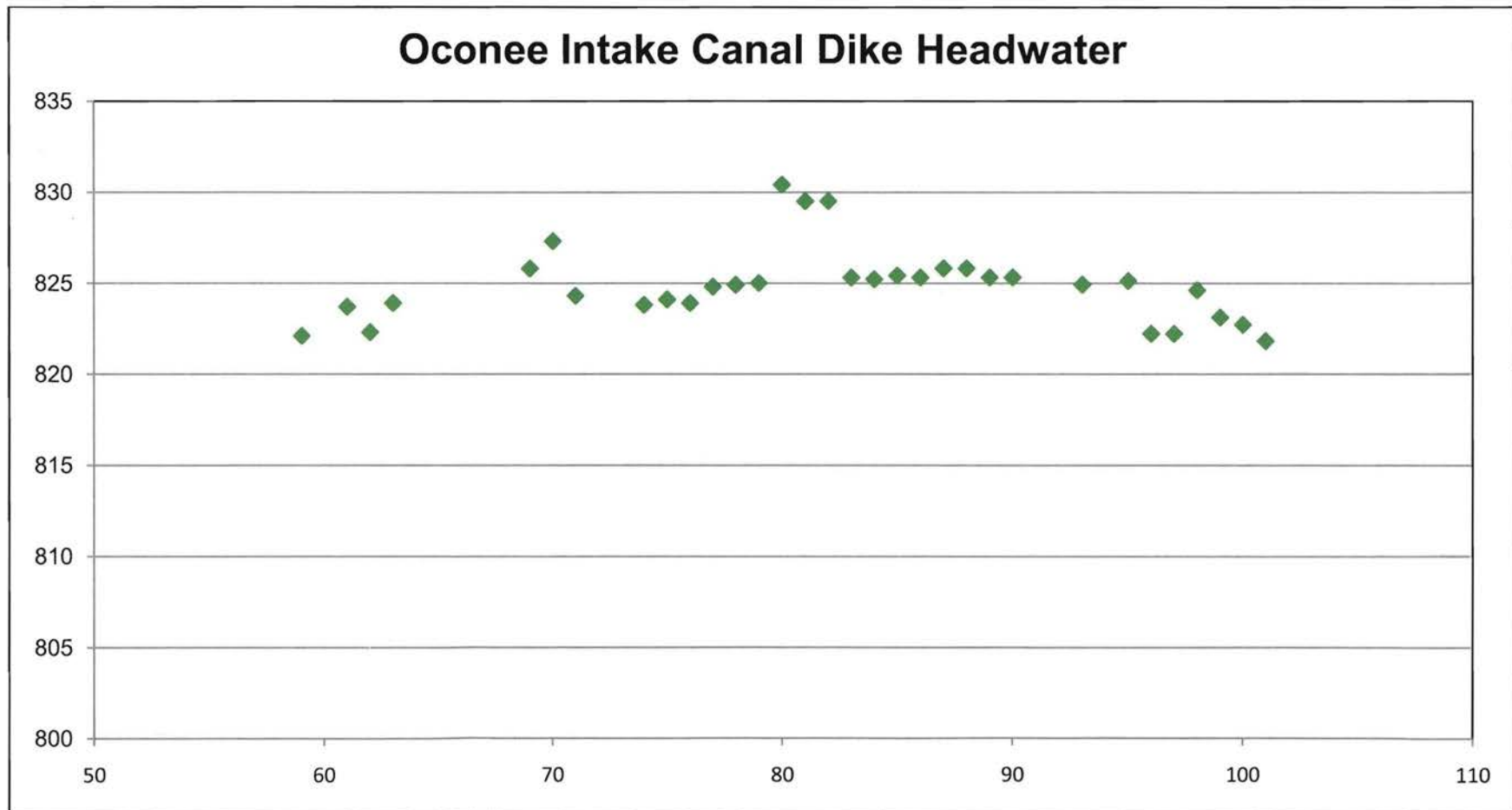
HEC-RAS Results



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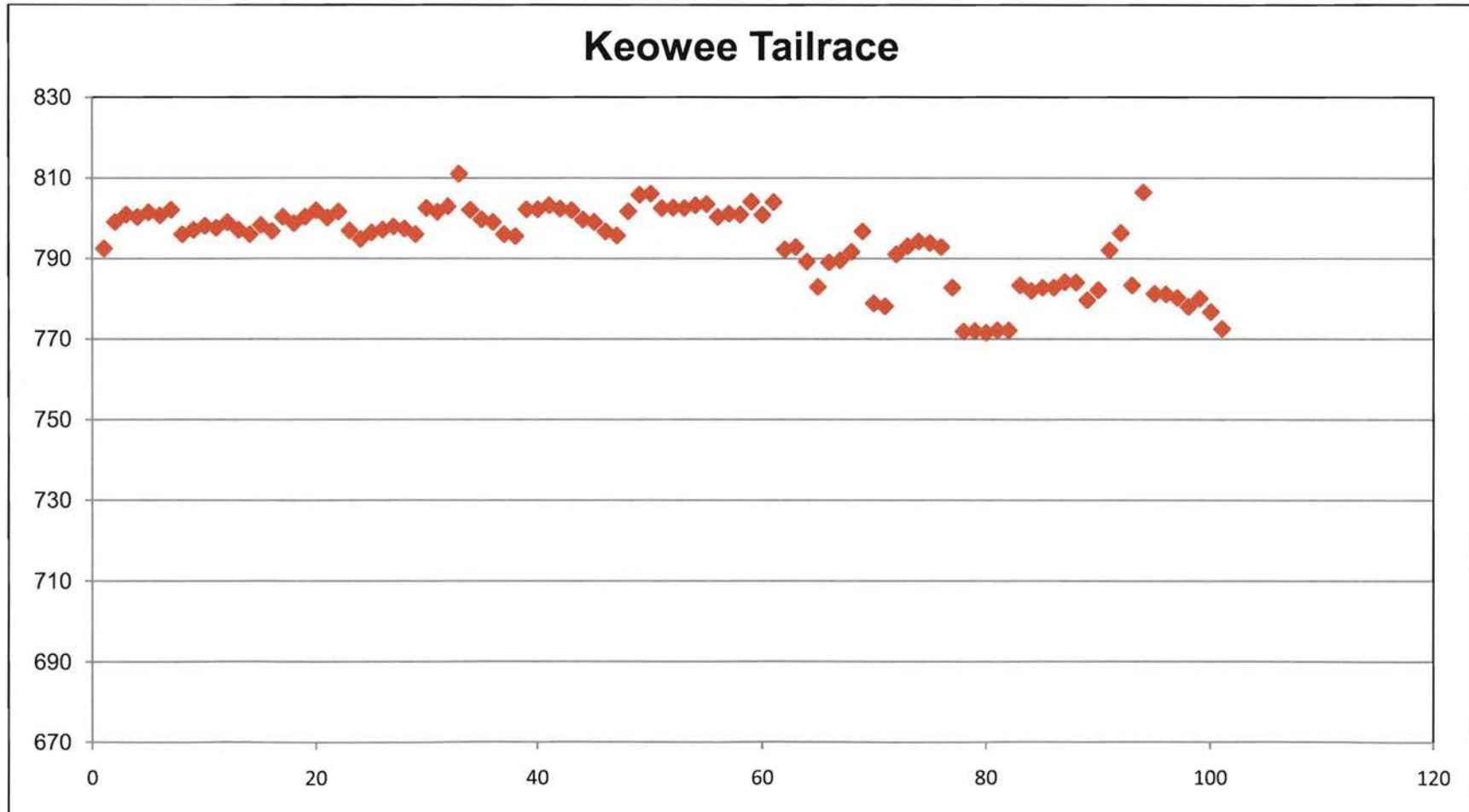
HEC-RAS Results w/ W. Saddle Dam Failure



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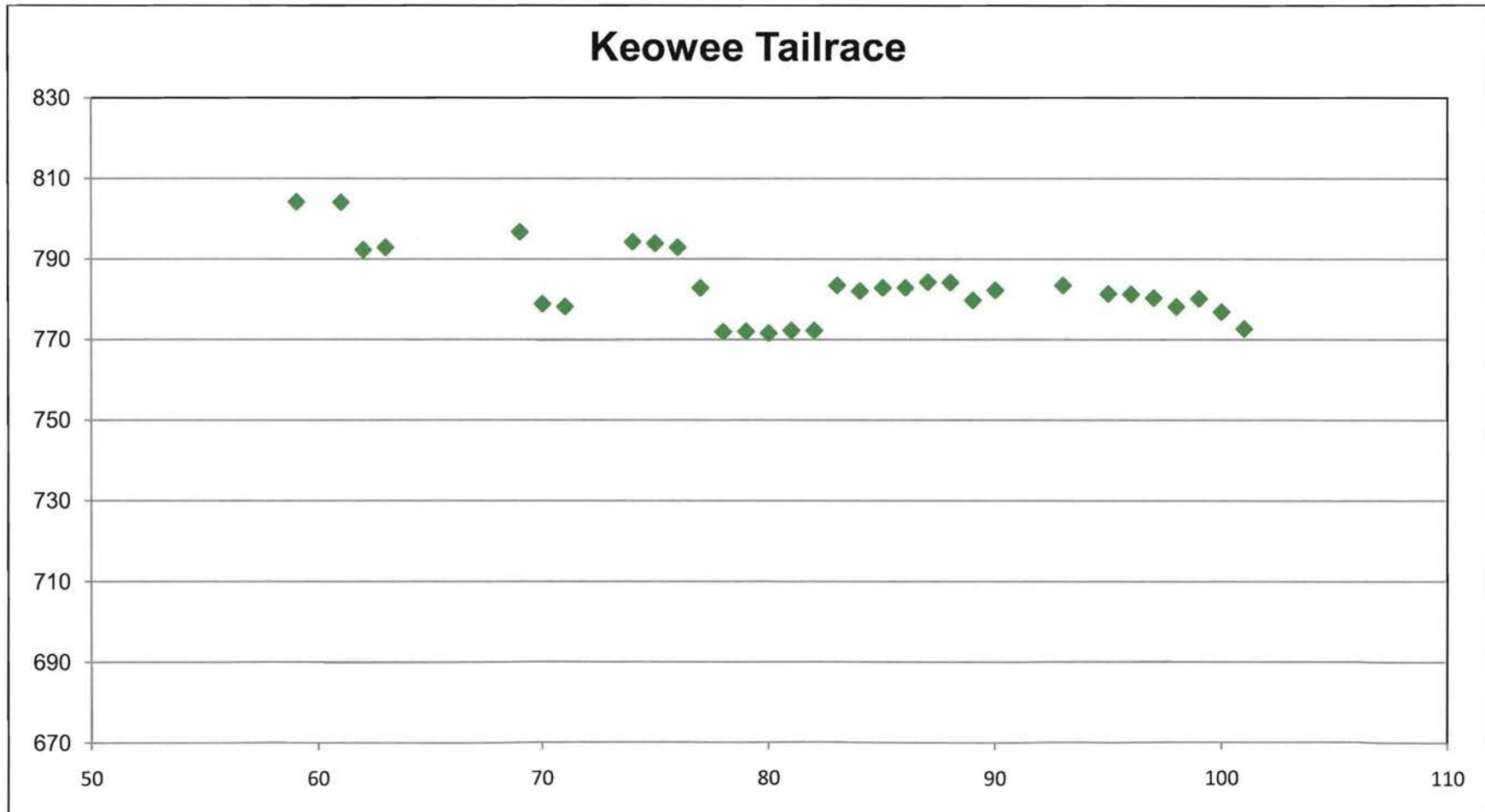
HEC-RAS Results



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HEC-RAS Results w/ W. Saddle Dam Failure



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HEC-RAS Model Confidence

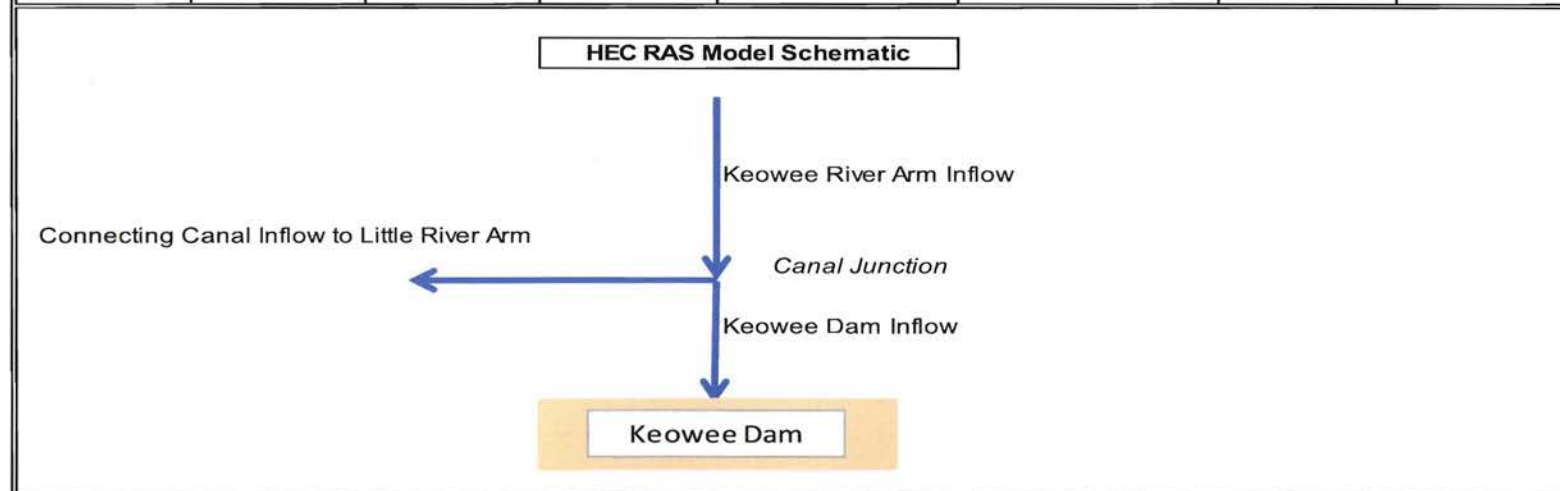
- Model confidence is measured by conservation of mass volume.
- A key area of interest is at the connecting canal confluence with the Keowee Arm of the reservoir.
- Mass volume calculated by integrating the discharge hydrographs for the various cases.
- Integration of the Keowee River inflow hydrograph should equal the summation of the integrated hydrographs for the Keowee Dam and the Connecting Canal.

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HEC-RAS Model Confidence

| Model | Hydrograph Volume (cfs-hrs) | | | | | Keowee Dam Flow % | Connecting Canal Flow % |
|--------|--------------------------------|-------------------|-------------------------|--------------------------------------|--|-------------------|-------------------------|
| | Keowee River Inflow (Upstream) | Keowee Dam Inflow | Connecting Canal Inflow | Keowee Dam & Connecting Canal Volume | Net Hydrograph Integration at Dam-River Junction | | |
| Case 1 | 18,695,218 | 11,618,099 | -7,077,118 | 18,695,218 | 0.7 | 62.1% | 37.9% |
| Case 2 | 18,791,578 | 11,680,136 | -7,111,442 | 18,791,578 | 0.1 | 62.2% | 37.8% |
| Case 3 | 18,804,194 | 11,848,448 | -6,955,747 | 18,804,195 | -1.1 | 63.0% | 37.0% |
| Mar-09 | 18,833,982 | 13,919,781 | -4,914,201 | 18,833,982 | -0.3 | 73.9% | 26.1% |



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Selection of 2D Model Cases

| Jocassee Dam | | | | | | |
|---|----------------------------------|--------------------------|-------------------------|-----------------------|-----------------------------------|--|
| Case | Bottom Breach Elevation (ft msl) | Bottom Breach Width (ft) | Side Slopes (ft per ft) | Time to Failure (hrs) | Initial Piping Elevation (ft msl) | Overtopping Breach Initiation Elevation (ft msl) |
| 1 | 800 | 250 | 1:1 | 2.6 | 1020 | NA |
| 2 | 800 | 425 | 1.55:1 & 0.7:1 | 2.8 | 1020 | NA |
| 3 | 800 | 600 | 1.55:1 & 0.7:1 | 3 | 1020 | NA |
| Keowee Dam Including West Saddle Dam Breach | | | | | | |
| Case | Bottom Breach Elevation (ft msl) | Bottom Breach Width (ft) | Side Slopes (ft per ft) | Time to Failure (hrs) | Initial Piping Elevation (ft msl) | Overtopping Breach Initiation Elevation (ft msl) |
| 1 | 670 | 500 | 1:1 | 2.8 | NA | 817 |
| 2 | 670 | 500 | 1:1 | 2.8 | NA | 817 |
| 3 | 670 | 500 | 1:1 | 2.8 | NA | 817 |
| ONS Intake Canal Dike | | | | | | |
| Case | Bottom Breach Elevation (ft msl) | Bottom Breach Width (ft) | Side Slopes (ft per ft) | Time to Failure (hrs) | Initial Piping Elevation (ft msl) | Overtopping Breach Initiation Elevation (ft msl) |
| 1 | 715.5 | 200 | 1:1 | 0.9 | NA | 817 |
| 2 | 715.5 | 200 | 1:1 | 0.9 | NA | 817 |
| 3 | 715.5 | 200 | 1:1 | 0.9 | NA | 817 |
| Little River Dam | | | | | | |
| Case | Bottom Breach Elevation (ft msl) | Bottom Breach Width (ft) | Side Slopes (ft per ft) | Time to Failure (hrs) | Initial Piping Elevation (ft msl) | Overtopping Breach Initiation Elevation (ft msl) |
| 1 | 670 | 290 | 1:1 | 1.9 | NA | 817 |
| 2 | 670 | 290 | 1:1 | 1.9 | NA | 817 |
| 3 | 670 | 290 | 1:1 | 1.9 | NA | 817 |

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Justification for 2D Cases Selected

➤ Jocassee

- Case 1 – Modified Original Case (1992)
 - Bottom Breach width: 250 ft. (unchanged)
 - Bottom Breach elevation: 800 ft. MSL (unchanged)
 - Slope: 1:1 (unchanged)
 - Revised reservoir elevation from 1108 ft. to 1110 ft. MSL
 - Revised time to failure from 4 to 2.6 hours (Froehlich value –2.2 hours)
 - Piping elevation: 1020 ft (Captures probable failure initiation at West Abutment)
 - Failure Progression: Sine Wave (Conservative portrayal of material loss through breach)

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Justification for 2D Cases Selected

➤ Jocassee

- Case 2 – Conservative Case
 - Bottom Breach width: 425 ft (Average of Case 1 & 3)
 - Time to failure: 2.8 hours (Adopted value between Froehlich and Walder & O'Connor)
- Case 3 – Worst Case
 - Bottom Breach width: 600 ft. (Simulates maximum bottom breach width of dam fill)
 - West Slope: 1.55:1 (Captures probable failure initiation at West Abutment)
 - East Slope: 0.7:1 (Froehlich suggested value)
 - Time to failure: 3.0 hours (Walder & O'Connor)

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Justification for 2D Cases Selected

- Keowee – All parameters held constant for all three cases
 - Main Dam
 - Reservoir elevation: 800 ft. MSL
 - Bottom Breach elevation: 670 ft. MSL (Tailrace elevation)
 - Bottom Breach width: 500 ft (Site constraint)
 - Both side slopes: 1:1 (Froehlich suggested value)
 - Time to failure: 2.8 hours (Froehlich suggested value adjusted to size of dam)
 - Overtopping trigger: 817 ft. MSL – 2 ft above crest (Based on downstream slope velocity profiles and soils)
 - Failure Progression: Sine Wave (Conservative portrayal of material loss through breach)

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Justification for 2D Cases Selected

➤ Keowee

- West Saddle Dam
 - Bottom Breach elevation: 795 ft. MSL (Elevation of toe)
 - Bottom Breach width: 1680 ft (80% of total width-engineering judgment)
 - Both side slopes: Vertical (Facilitates model input)
 - Time to failure: 0.5 hours (Based on velocity studies)
- Intake Dike
 - Bottom Breach elevation: 715.5 ft. MSL (Elevation of toe)
 - Bottom Breach width: 200 ft (Site constraint)
 - Both side slopes: 1:1 (Froehlich suggested value)
 - Time to failure: .9 hr. (Proportional to Main Dam breach area)

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Justification for 2D Cases Selected

➤ Keowee

- Little River Dam

- Bottom Breach elevation: 670 ft. MSL (Elevation of toe)
- Bottom Breach width: 290 ft (Site constraint)
- Both side slopes: 1:1 (Froehlich suggested value)
- Time to failure: 1.9 hours (Proportional to Main Dam breach area)

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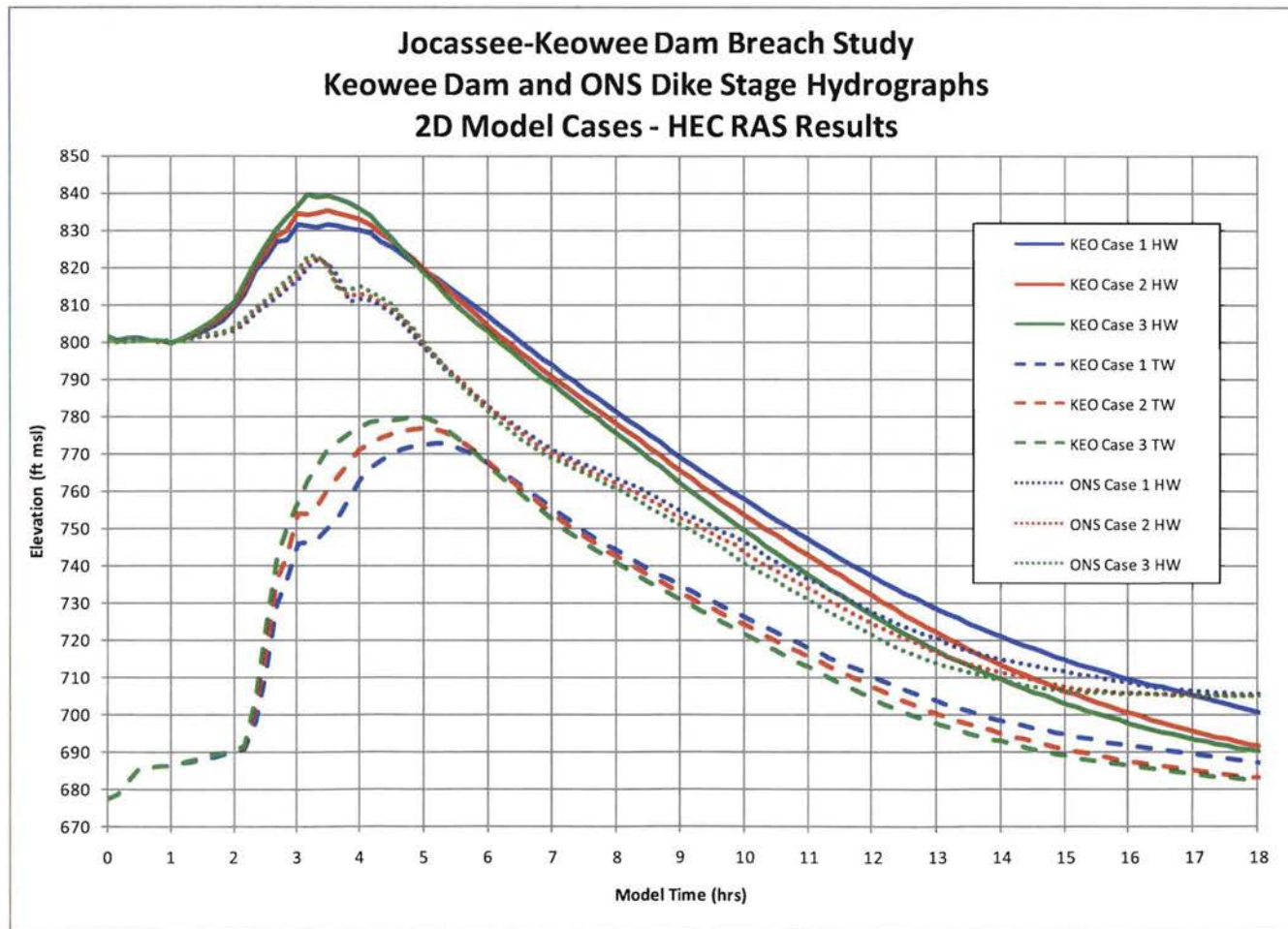


HEC-RAS Results for Selected 2D Cases

- Case 1 (Modified Original Case)
 - Keowee Headwater – 831.2 ft. MSL (16.2 ft. above dam crest)
 - Keowee Tailrace – 772.5 ft. MSL (2.5 ft. below TB basement)
 - Intake Dike Headwater – 821.8 ft. MSL (6.8 ft. above dike crest)
- Case 2 (Conservative Case)
 - Keowee Headwater – 835.3 ft. MSL (20.3 ft. above dam crest)
 - Keowee Tailrace – 776.7 ft. MSL (1.7 ft. above TB basement)
 - Intake Dike Headwater – 822.7 ft. MSL (7.7 ft. above dike crest)
- Case 3 (Worst Case)
 - Keowee Headwater – 839.4 ft. MSL (24.4 ft. above dam crest)
 - Keowee Tailrace – 780.0 ft. MSL (5.0 ft. above TB basement)
 - Intake Dike Headwater – 823.1 ft. MSL (8.1 ft. above dike crest)



HEC-RAS Results for Selected 2D Cases

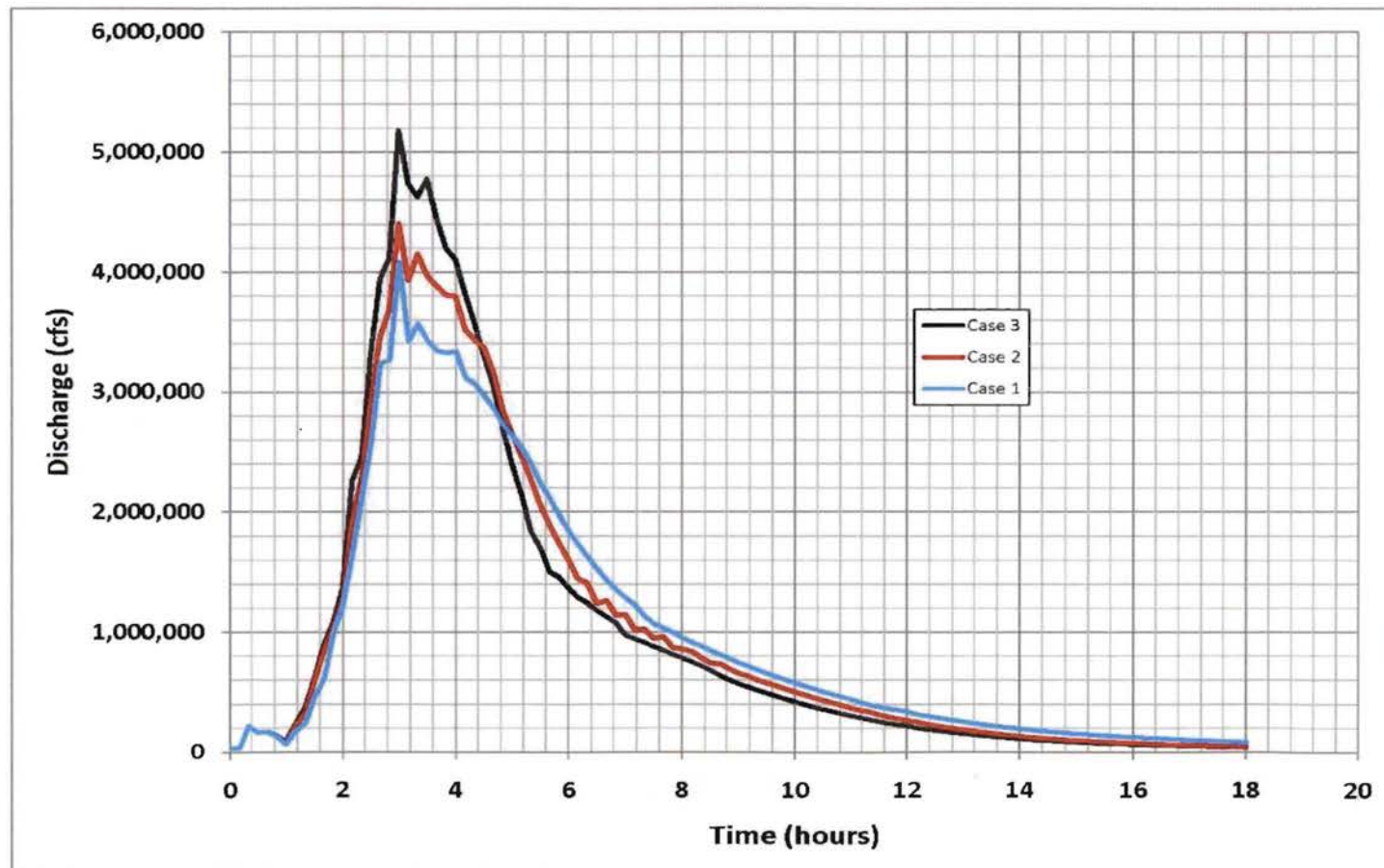


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HEC-RAS Input to Selected 2D Cases

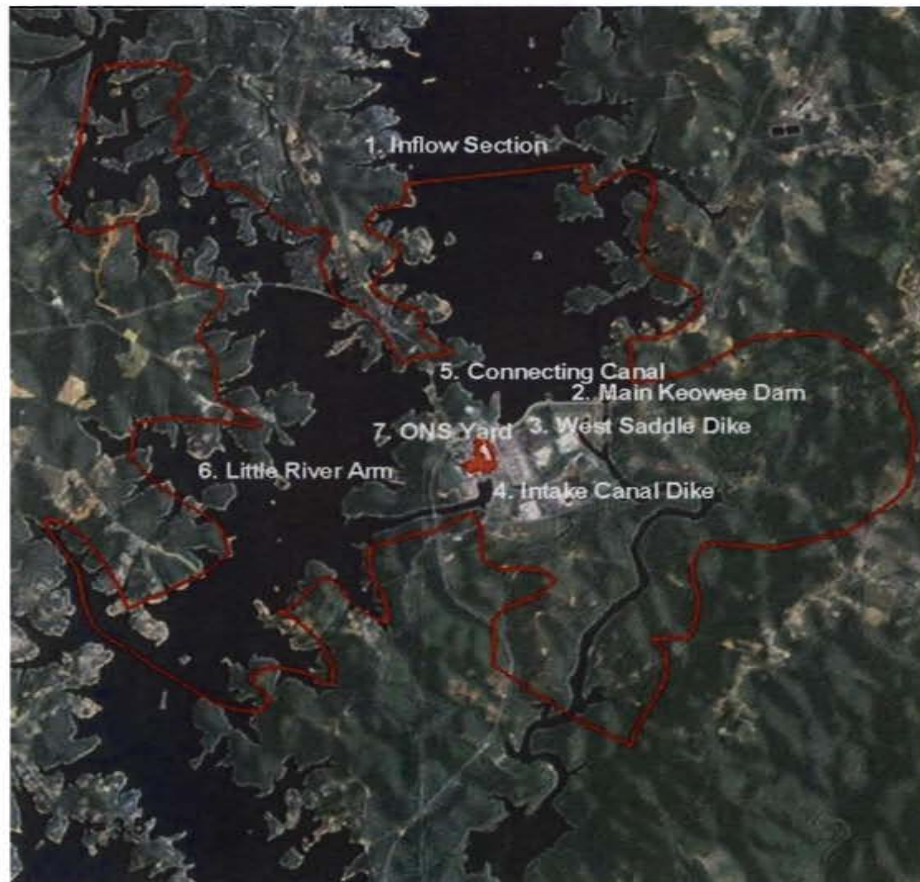
Input to
Keowee
Arm Inflow
Boundary
Condition



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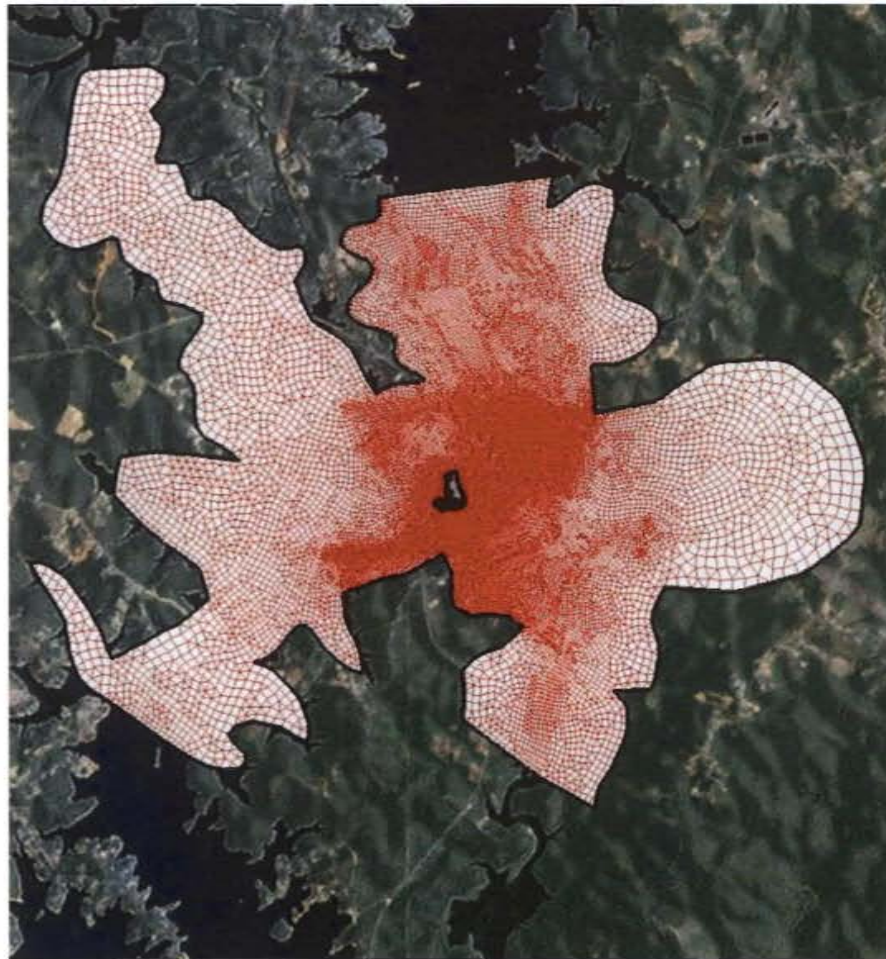
2D Model Highlights



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2D Model Highlights



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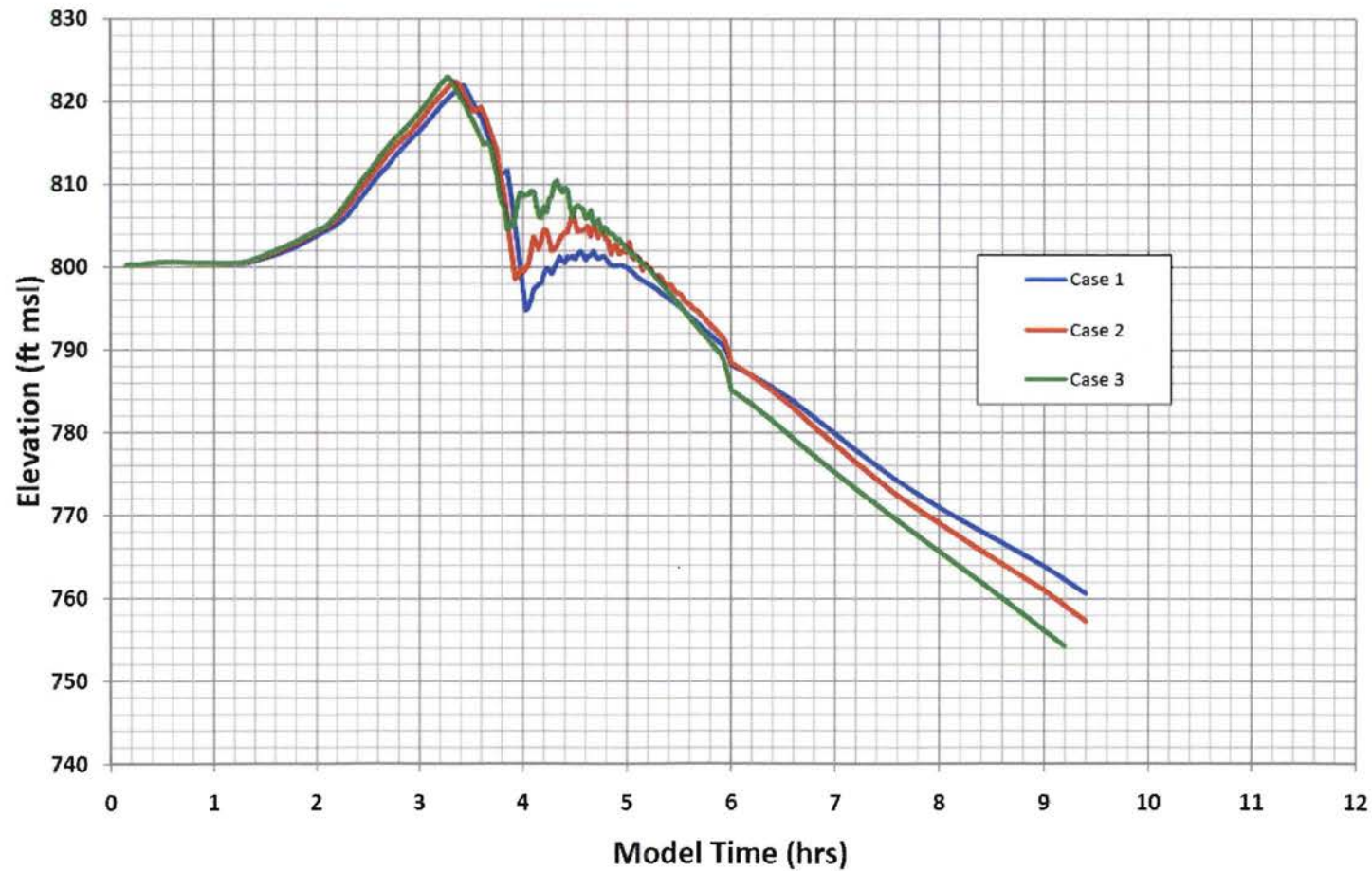


2D Model Highlights





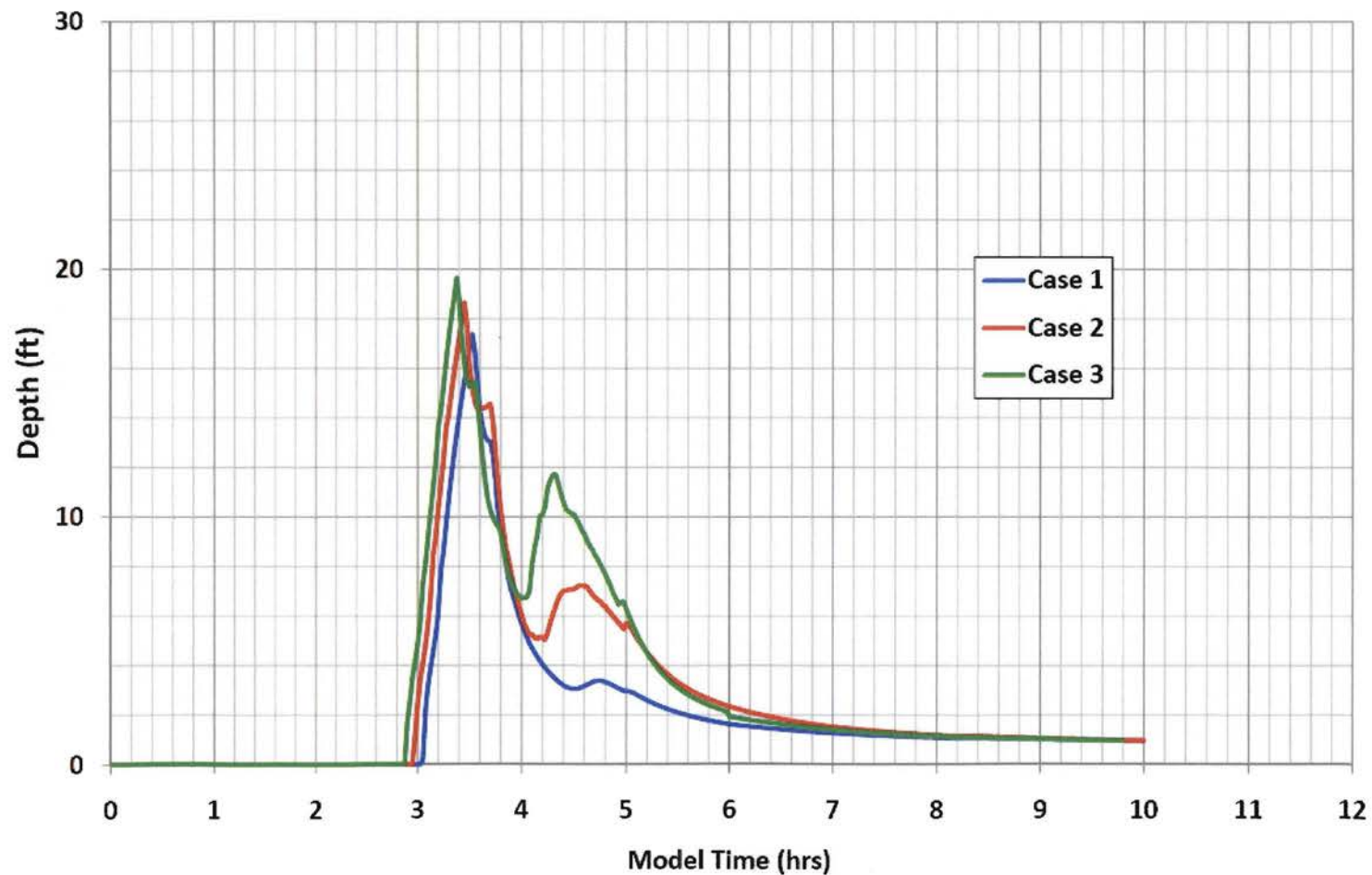
2D Model Draft Results at ONS Intake Canal Dike



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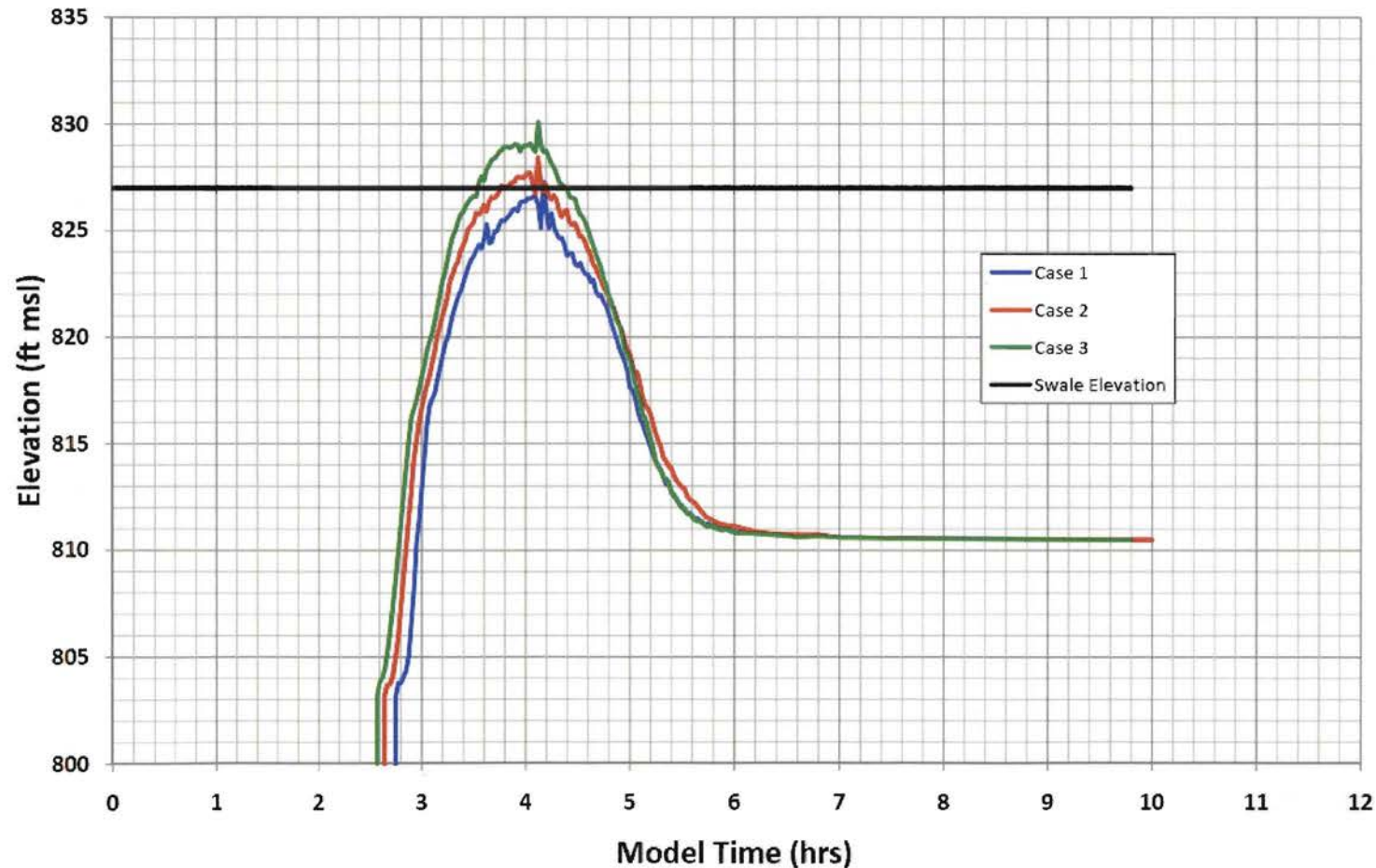
2D Model Draft Results at SSF



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2D Model Draft Results at WOE



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HEC-RAS Results vs. 2D Model Results

| Scenario | Breaching | | | | | | | |
|----------|------------------------|--------------|-----------|--------------|-------------|--------------|-----------|--------------|
| | Keowee Dam | | | | Intake Dike | | | |
| | HEC-RAS | | 2D | | HEC-RAS | | 2D | |
| | Elevation | Decimal Time | Elevation | Decimal Time | Elevation | Decimal Time | Elevation | Decimal Time |
| Case 1 | 817 | 2.28 | 817 | 2.13 | 817 | 3.03 | 817 | 3.05 |
| Case 2 | 817 | 2.25 | 817 | 2.11 | 817 | 2.93 | 817 | 2.97 |
| Case 3 | 817 | 2.20 | 817 | 2.08 | 817 | 2.87 | 817 | 2.89 |
| Scenario | Maximum Water Surfaces | | | | | | | |
| | Keowee Dam | | | | Intake Dike | | | |
| | HEC-RAS | | 2D | | HEC-RAS | | 2D | |
| | Elevation | Decimal Time | Elevation | Decimal Time | Elevation | Decimal Time | Elevation | Decimal Time |
| Case 1 | 831.2 | 3.50 | 834.7 | 3.05-3.50 | 821.8 | 3.33 | 821.9 | 3.43 |
| Case 2 | 835.3 | 3.50 | 837.7 | 3.05-3.50 | 822.7 | 3.33 | 822.5 | 3.35 |
| Case 3 | 839.4 | 3.17 | 841.6 | 3.05-3.50 | 823.1 | 3.17 | 823.0 | 3.28 |
| Scenario | Maximum Water Surfaces | | | | | | | |
| | Swale | | | | Tailwater | | | |
| | HEC-RAS | | 2D | | HEC-RAS | | 2D | |
| | Elevation | Decimal Time | Elevation | Decimal Time | Elevation | Decimal Time | Elevation | Decimal Time |
| Case 1 | 826.6 | 4.00 | 826.6 | 4.08 | 772.3 | 5.33 | 799.7 | 4.63 |
| Case 2 | 828.6 | 4.00 | 827.7 | 4.05 | 776.7 | 5.00 | 803.2 | 4.48 |
| Case 3 | 830.8 | 3.83 | 829.0 | 3.93 | 780.0 | 4.83 | 807.2 | 4.25 |

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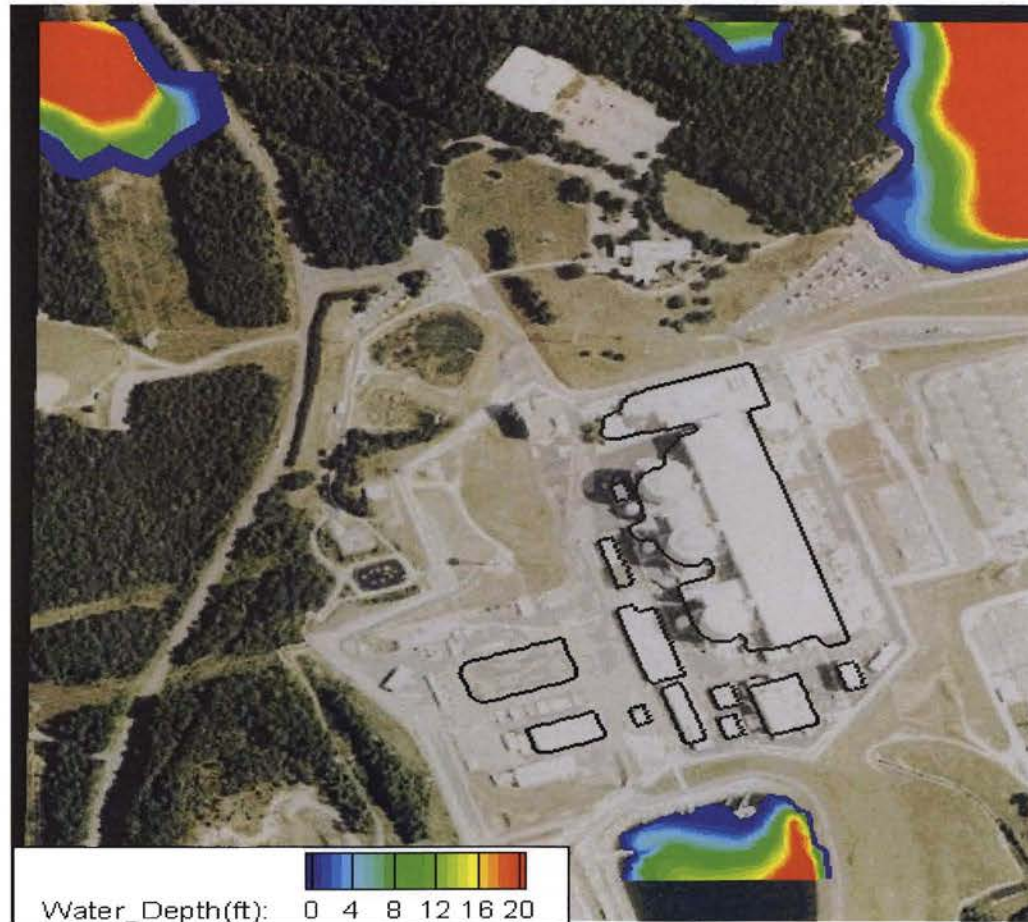
HEC-RAS Results vs. 2D Model Results

| Scenario | Total Volume Calculations Through Boundaries Over 10-hr(acre-ft) | | | | | |
|----------|--|-----------|---------|-----------|-----------|---------|
| | Inflow | | Percent | Outflow | | Percent |
| | HEC-RAS | 2D | | HEC-RAS | 2D | |
| Case 1 | 1,328,806 | 1,364,320 | 2.67 | 1,424,010 | 1,536,862 | 7.92 |
| Case 2 | 1,370,834 | 1,369,540 | -0.09 | 1,477,262 | 1,589,787 | 7.62 |
| Case 3 | 1,394,457 | 1,393,885 | -0.04 | 1,506,357 | 1,624,993 | 7.88 |

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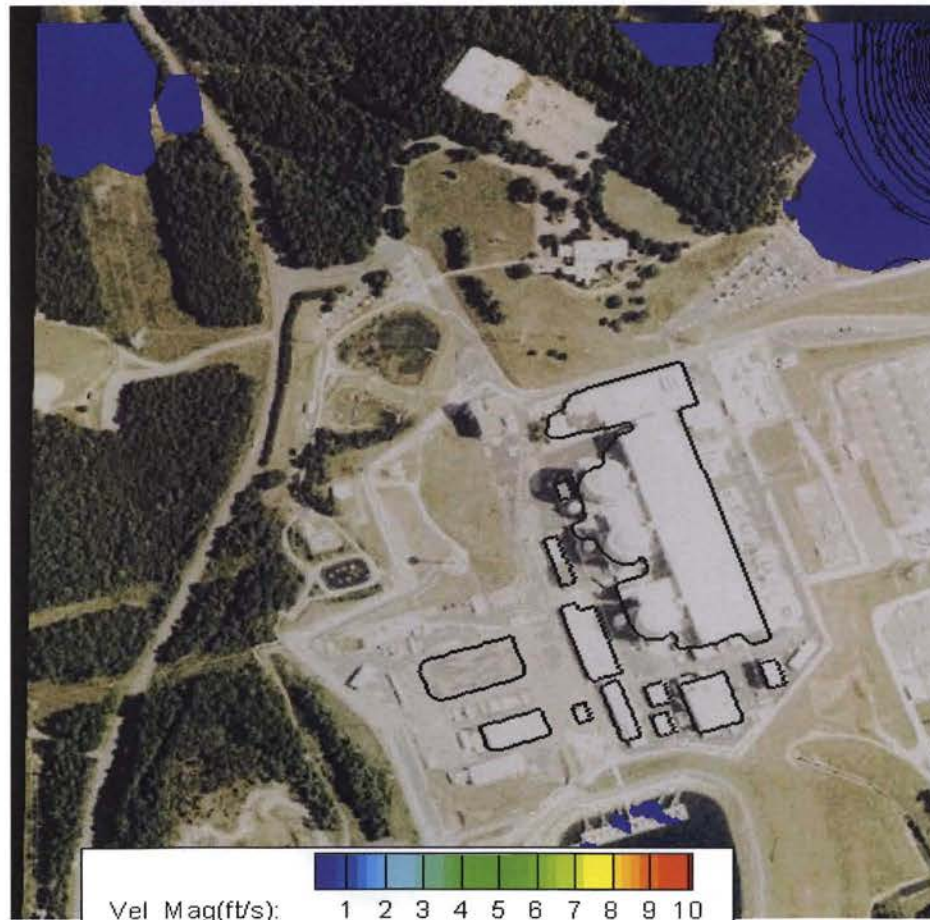
2D Model Draft Results Case 1



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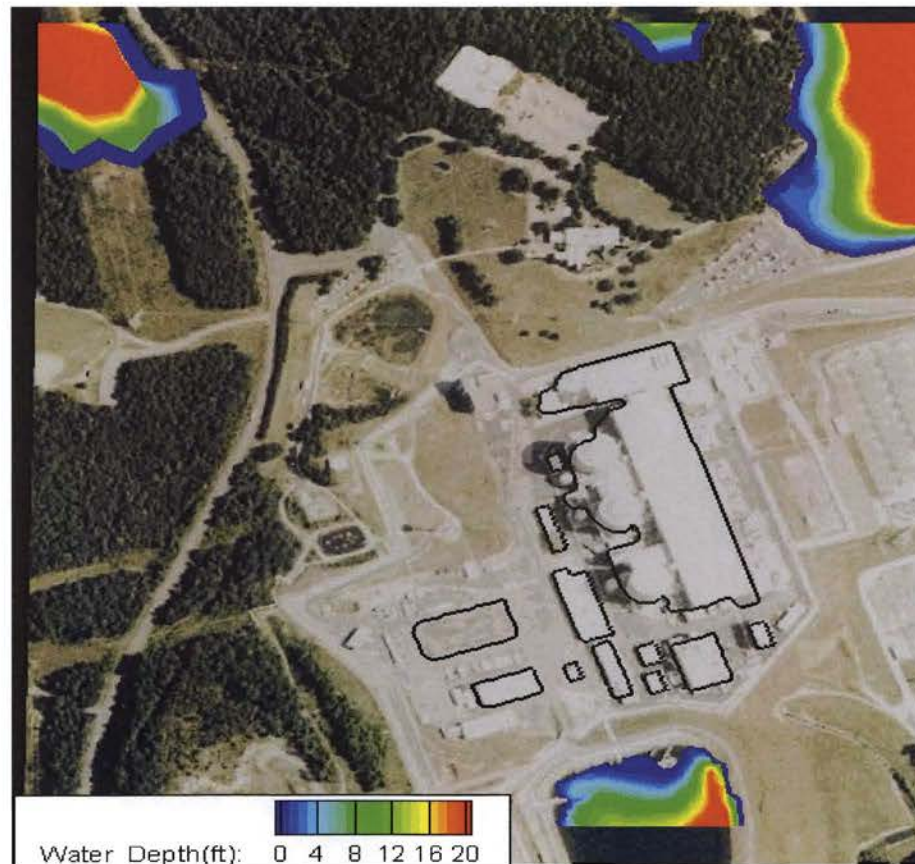
2D Model Draft Results Case 1



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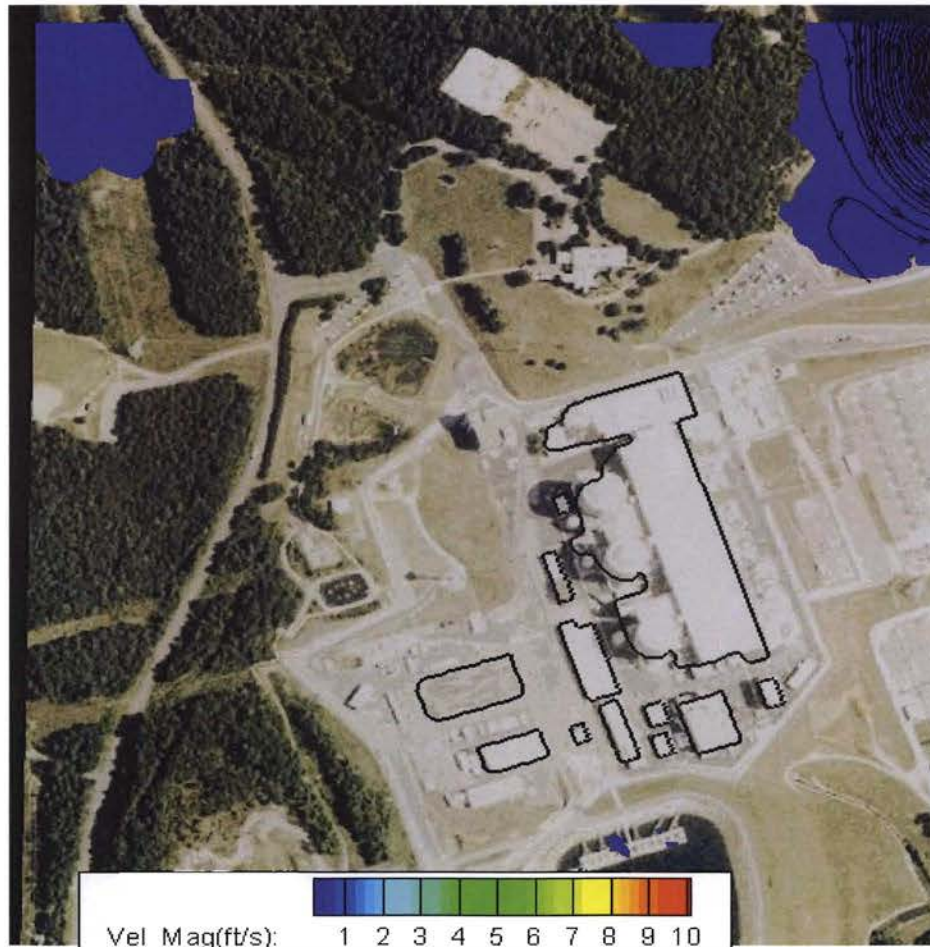
2D Model Draft Results Case 2



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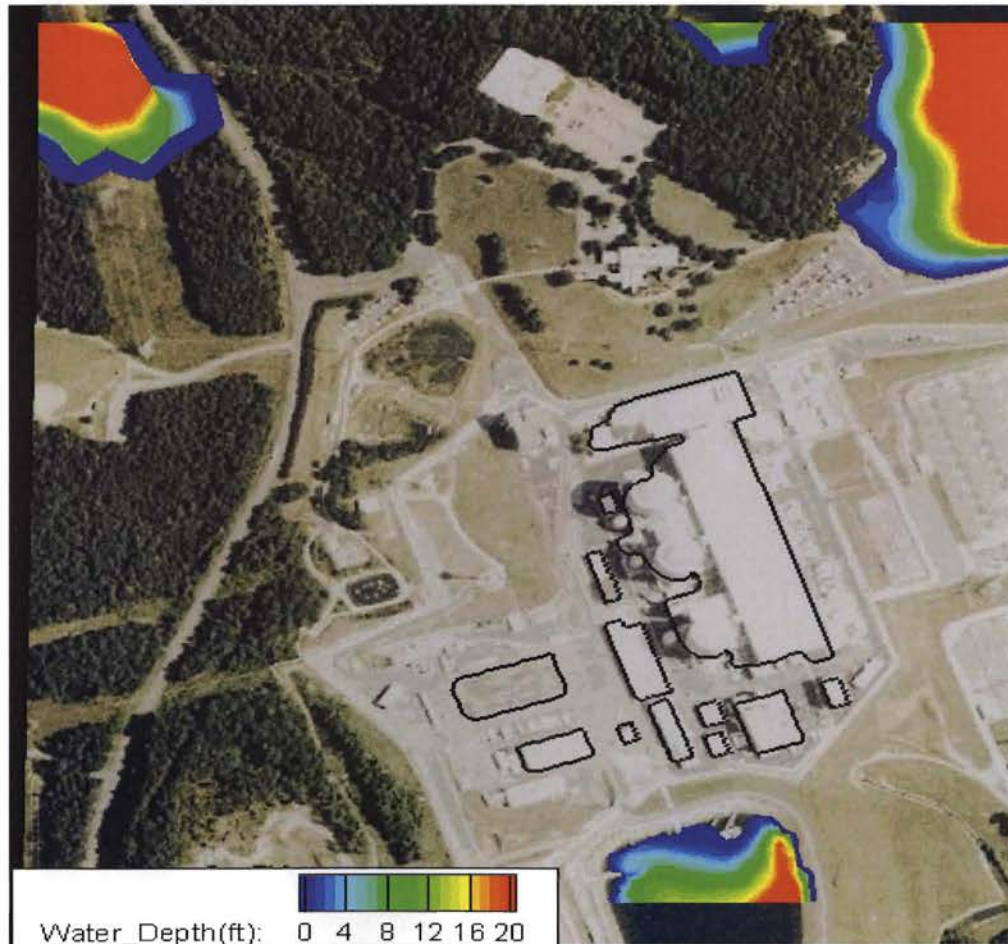
2D Model Draft Results Case 2



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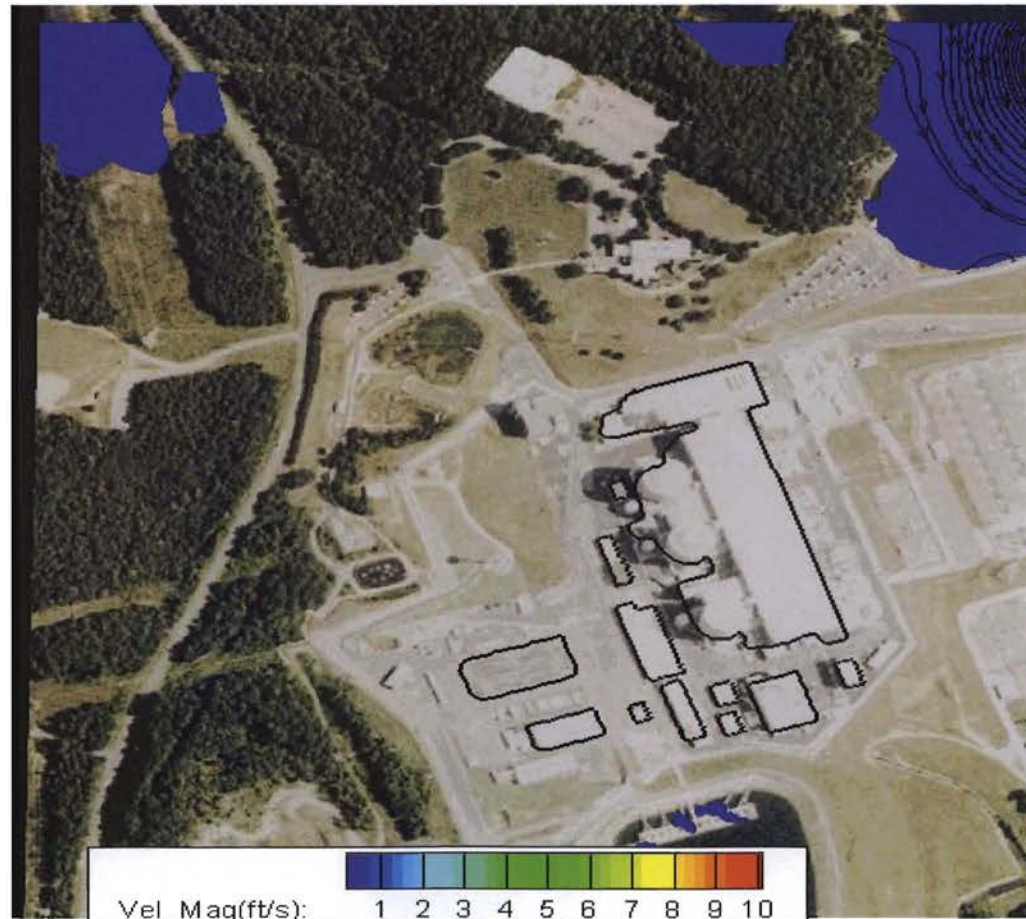
2D Model Draft Results Case 3



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2D Model Draft Results Case 3



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Summary

- 101 HEC-RAS Sensitivity cases evaluated.
- Confidence in HEC-RAS model is high, based on mass volume integration of inflow vs. outflow at the model boundaries.
- 2D model created, incorporating the Oconee site, model has over 40,000 elements.
- Cases selected for 2D model encompass a reasonable range of pertinent parameters.
- 2D model results compare favorably to the HEC-RAS results, except for Keowee tailrace elevation.

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