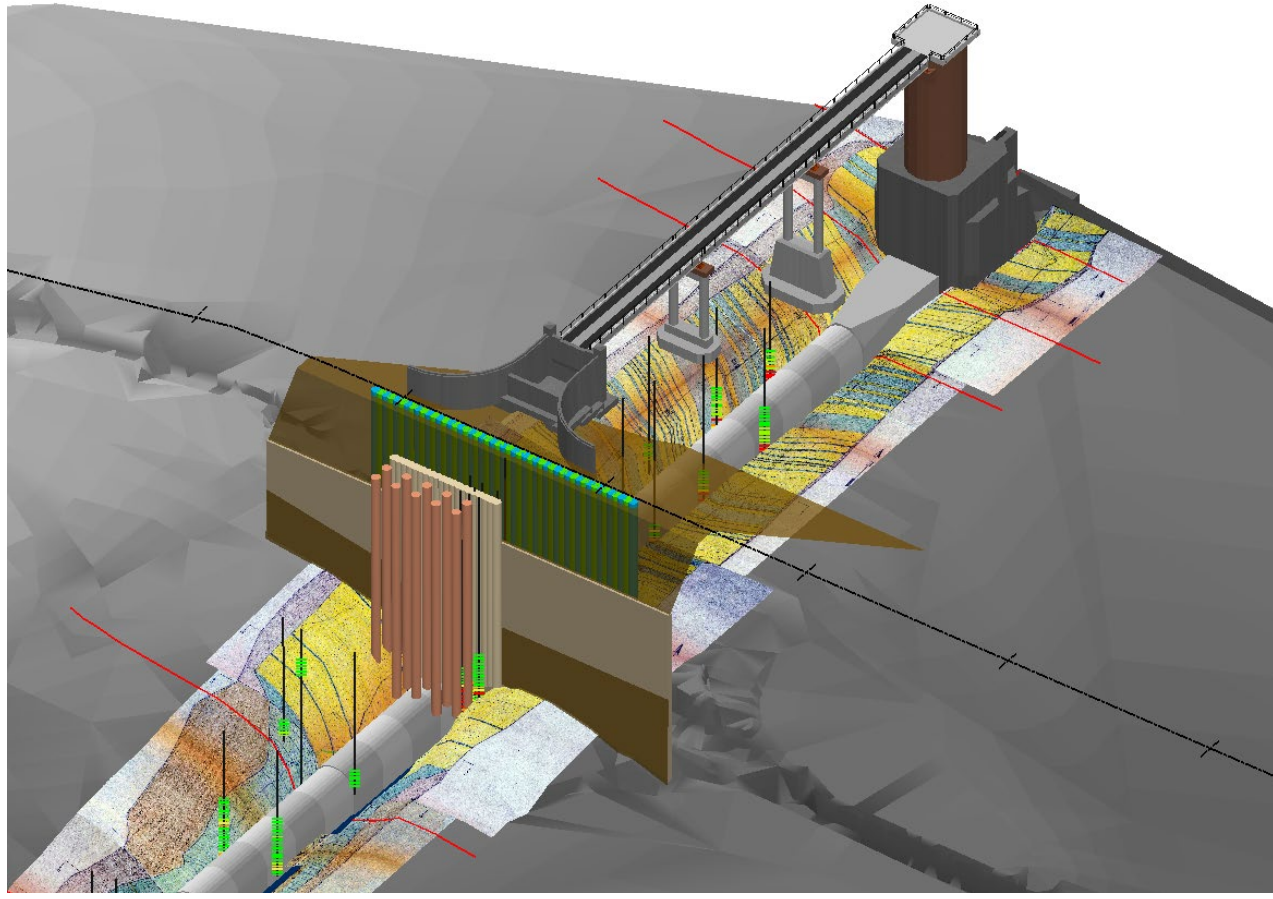
GEO-INSTITUTE
Nebraska Chapter

ASCE
NEBRASKA SECTION

US Army Corps of Engineers ®

Project Performance Monitoring & Data Driven Decisions



Georgette Hlepas, PhD, PE
US Army Corps of Engineers
10 Feb 2023

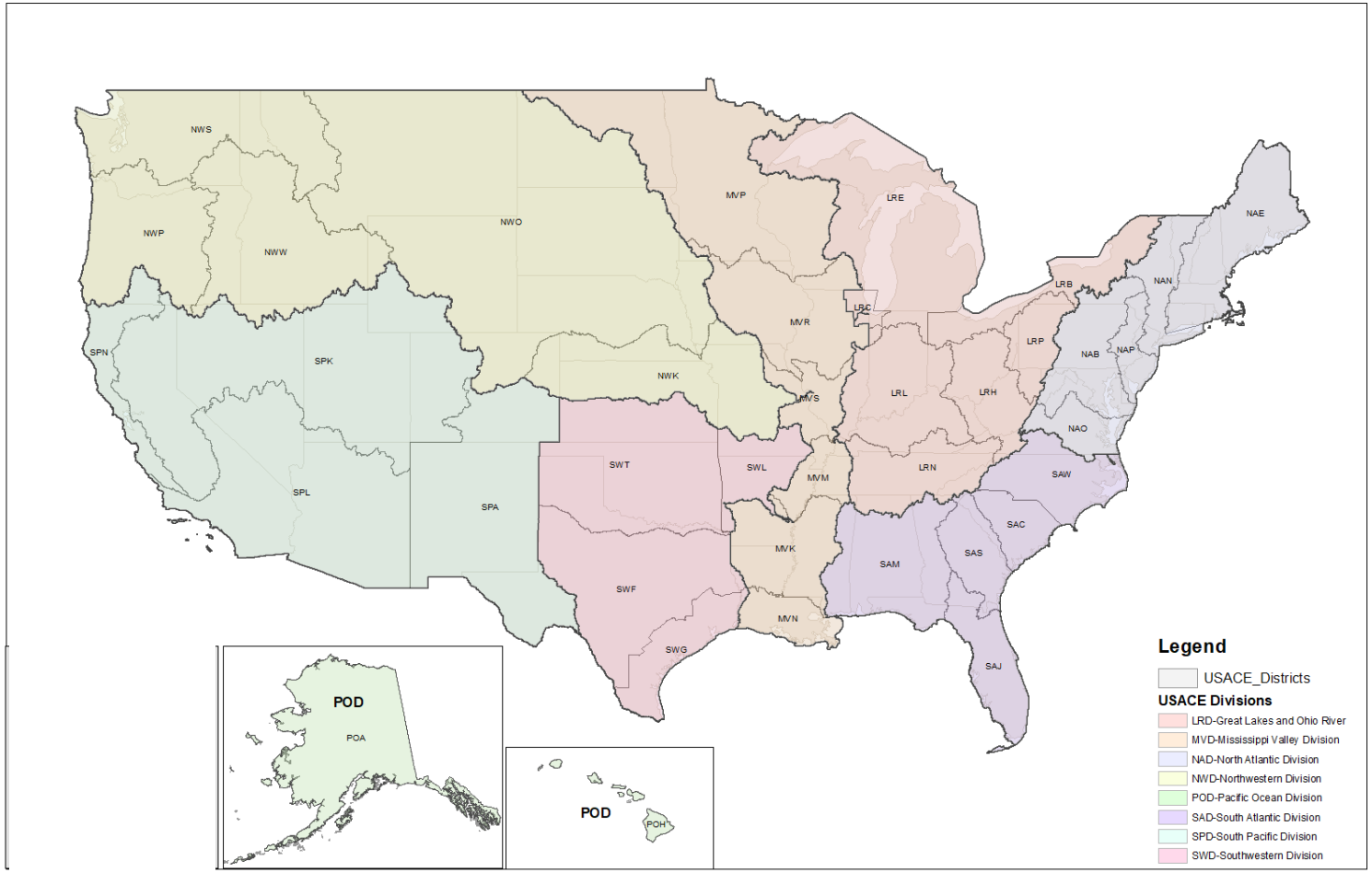
US Army Corp of Engineers

~32,000 employees

HQ in DC

9 Divisions

44 Districts



US Army Corps of Engineers

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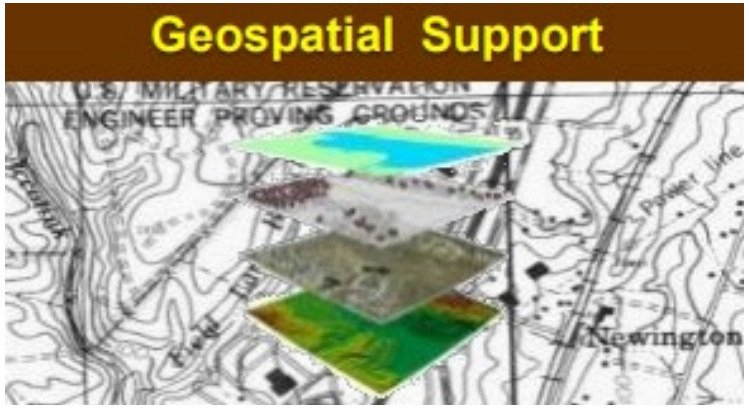
USACE Diverse Mission Set

~1,100 Geo-professionals



US Army Corps of Engineers

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Civil Works Mission Areas

- Navigation
- Flood Risk Management
- Ecosystem Restoration
- Hurricane & Storm Damage Reduction
- Hydropower
- Recreation
- Water Supply

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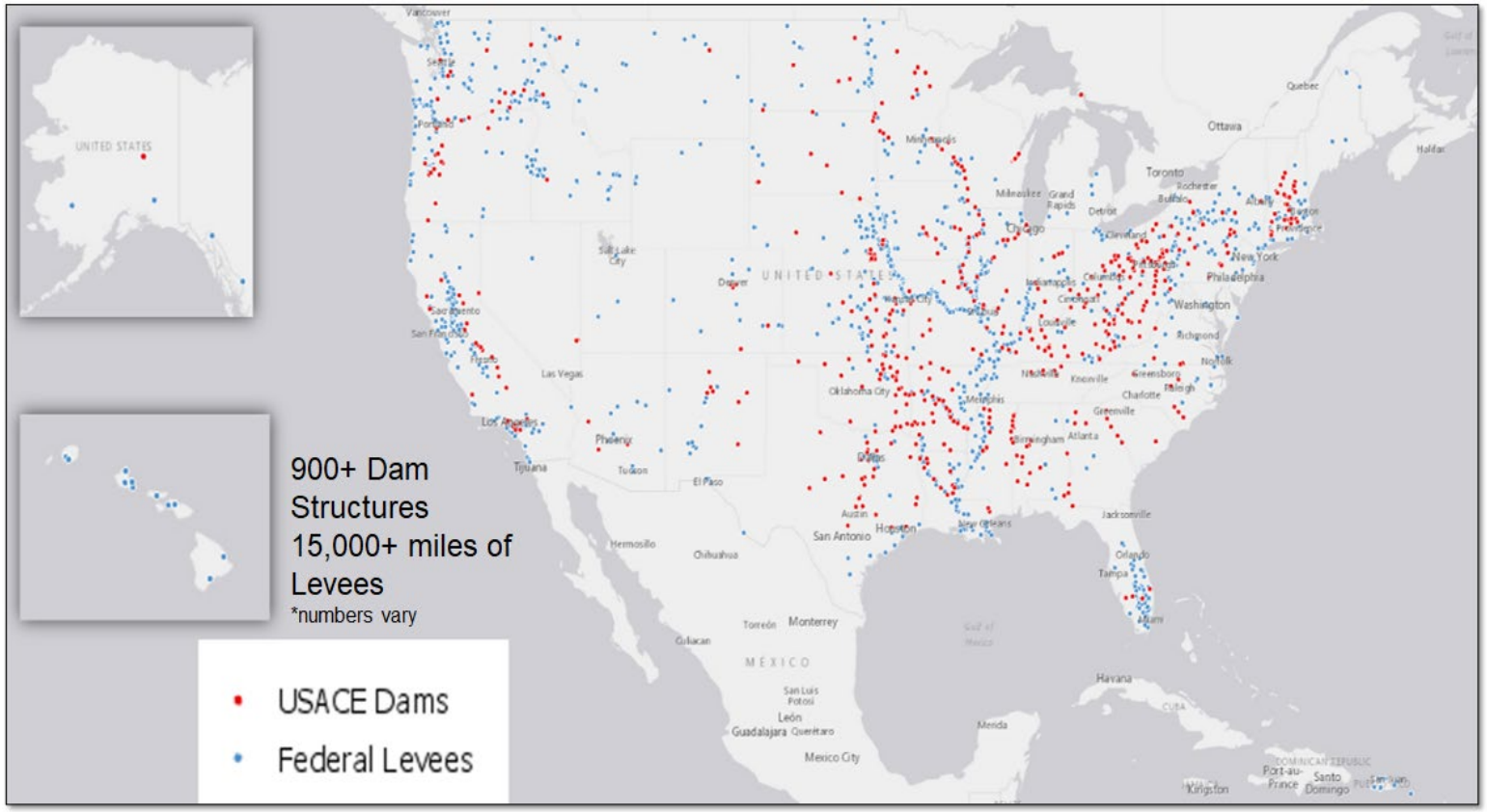
National Inventory of Dams and Levees



- **~716 Dams**
- Population at Risk +12.8M
- Property at risk = +1T
- Total length of 267 miles
- 80% earthen/20% concrete

- **~2,137 levee systems**
- Population at Risk +12M
- Property at risk = +1.3T
- Total length = 14,100 miles
- 97% earthen/3% floodwall

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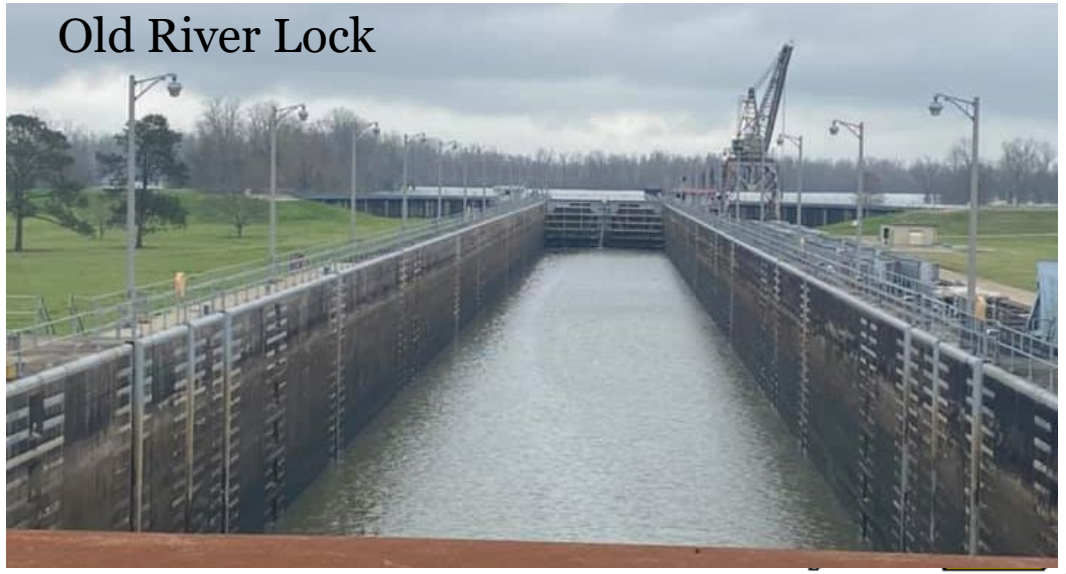
Navigation Structures

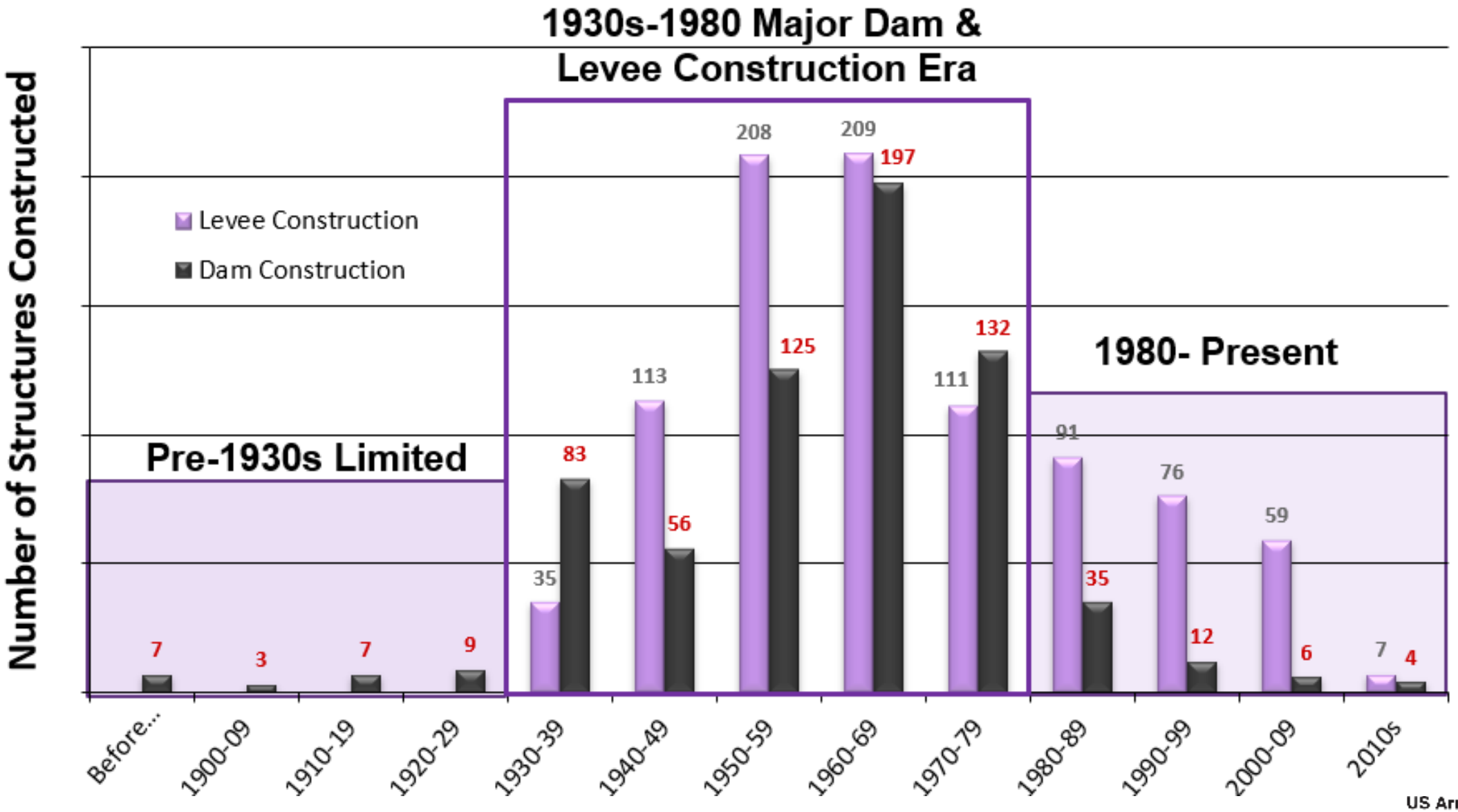
- 41 States served by Corps ports and waterways
- ~25,000 miles are operated and maintained for commerce
- 236 lock chambers at 191 lock sites on 41 waterways serve commerce
- 926 coastal, Great Lakes and inland harbors are maintained by the Corps
- Dredges over 210 million cubic yards of material each year


Chicago Harbor Lock


Old River Lock

Aging Infrastructure

Dams/Levees avg > 60 yrs old



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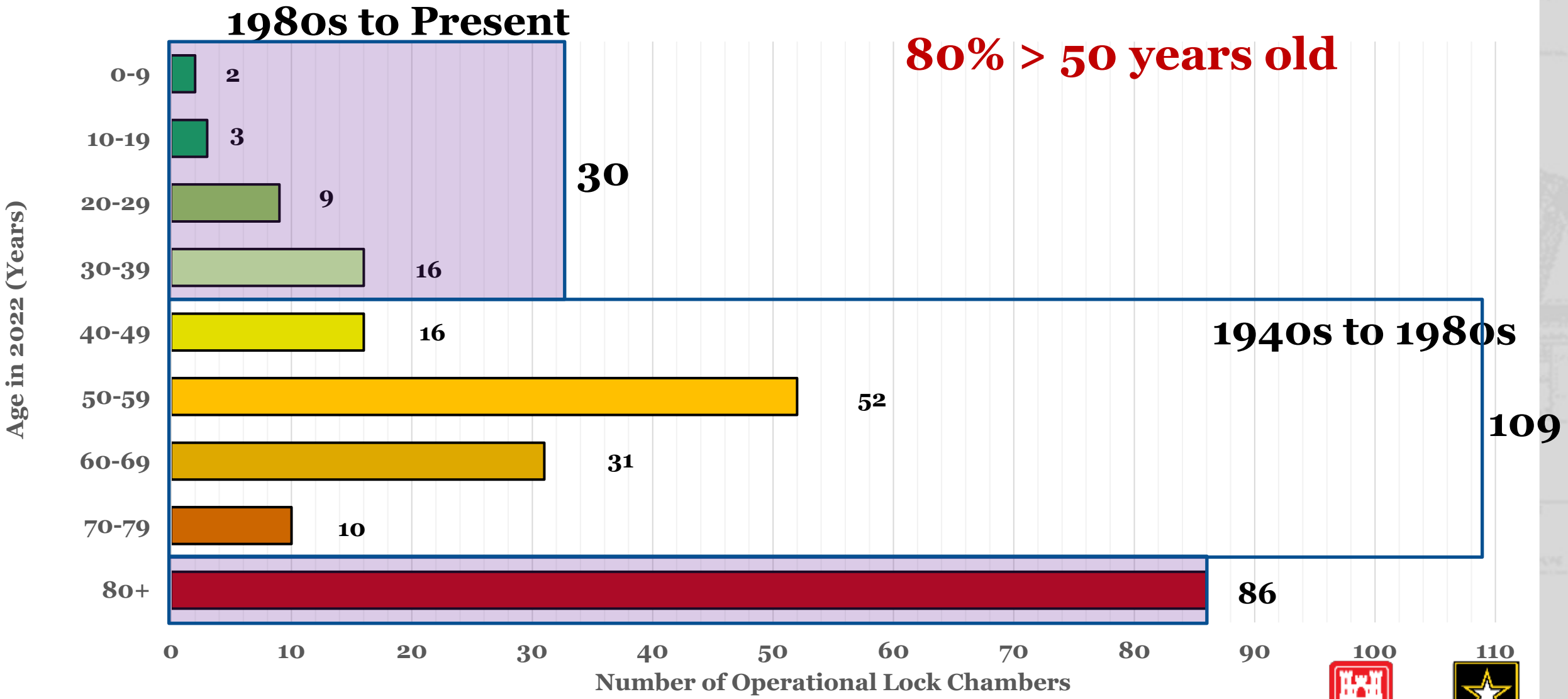
Aging Infrastructure – Navigation Locks



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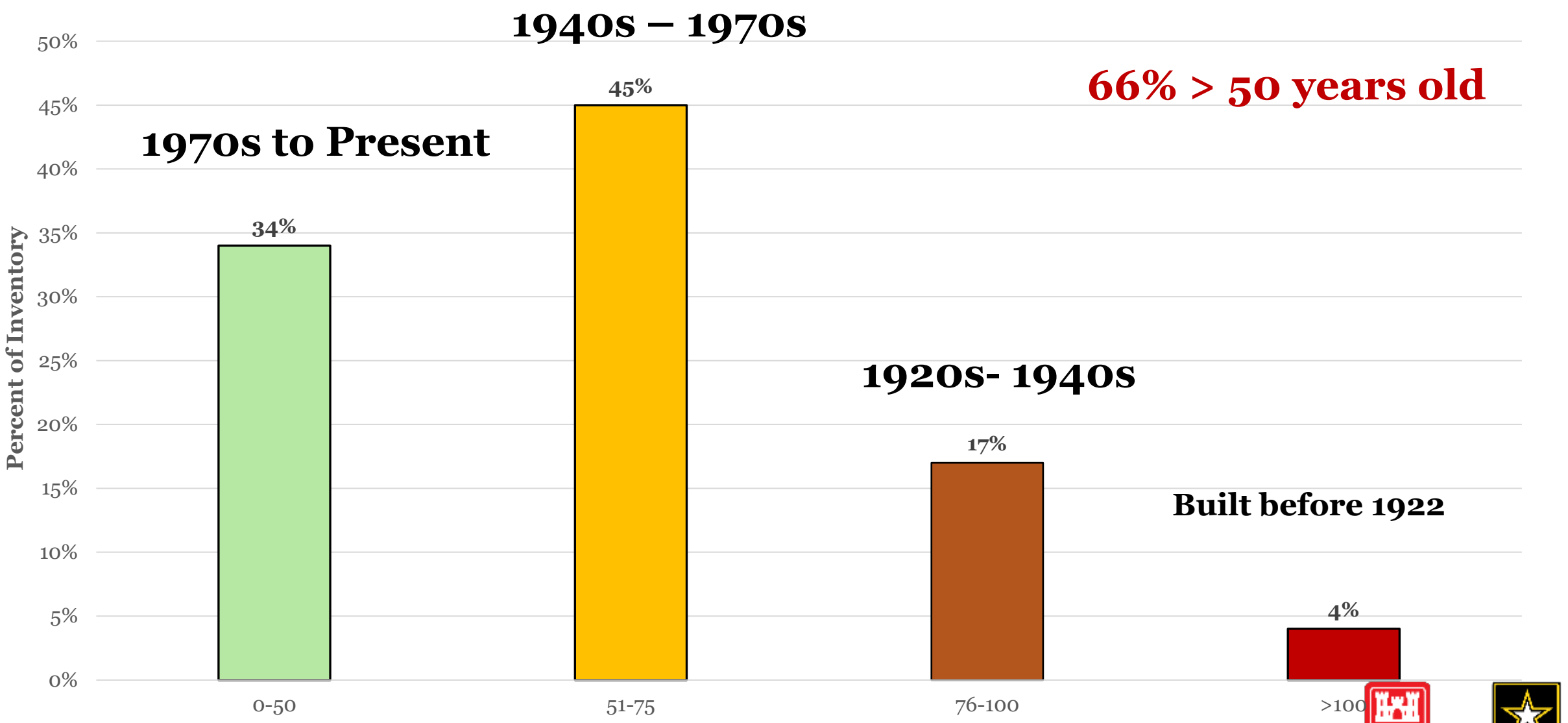
Aging Infrastructure - Bridges



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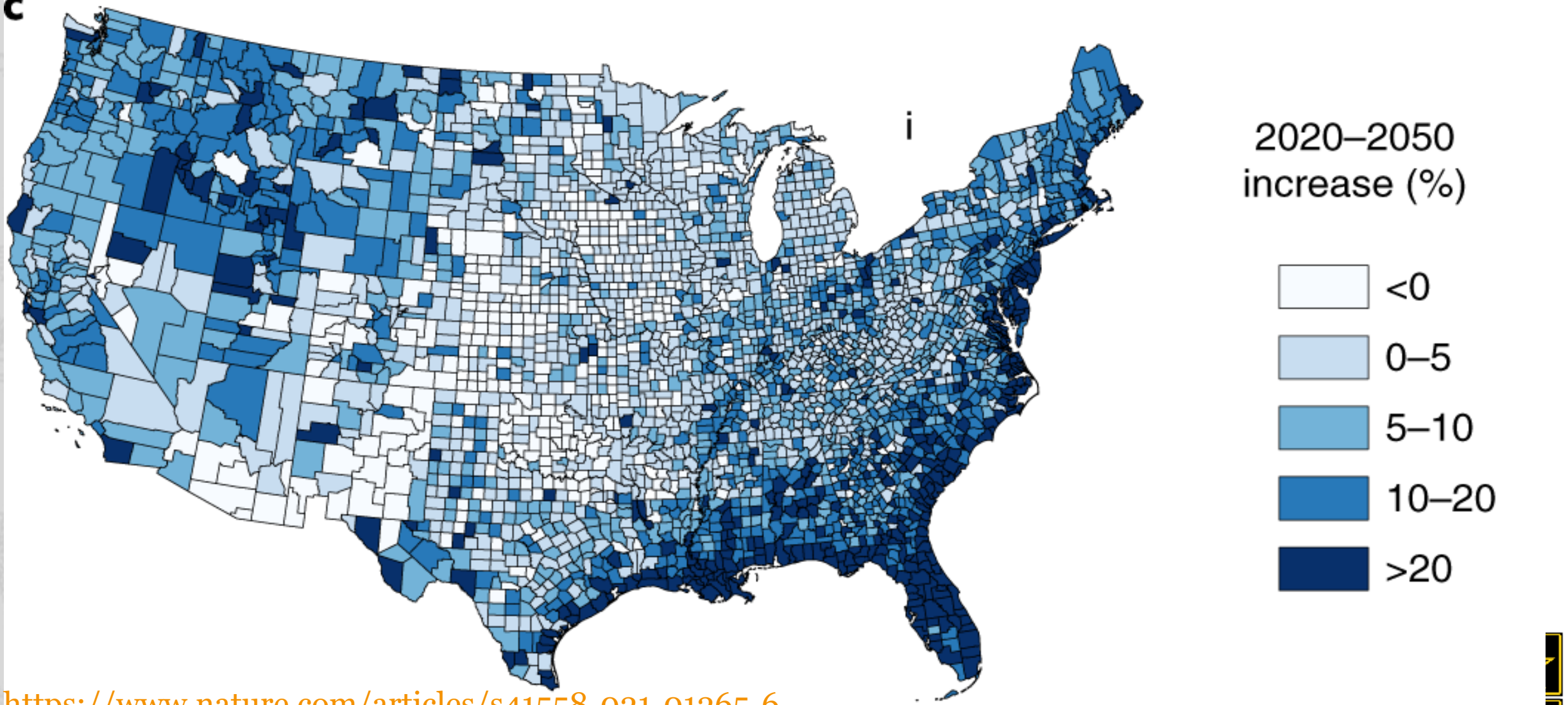
Data from CBIS: Corps Bridge Inventory System

Climate Change Impacts

Expected Increase in Average Annual Loss from Flooding the US due to



https://www.nature.com/articles/s41558-021-01265-6

Increasing Population Density

1957

Whittier Narrows Dam in 1957, just prior to completion | Photo: U.S. Army Corps of Engineers/Public Domain

~ 2015

United States Population

1980 ≈ 226,500,000

2021 ≈ 333,574,837

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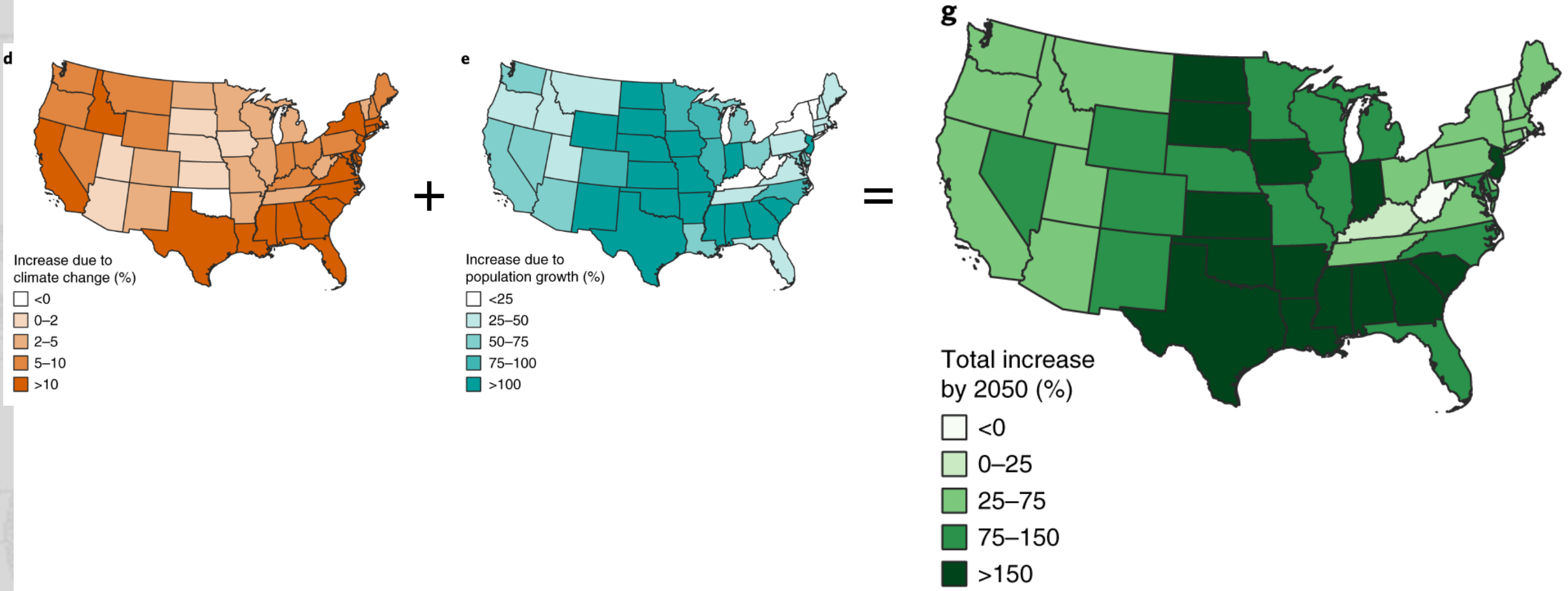
Climate Change and Population



Expected Increase in Average Annual Loss from Flooding in 2050

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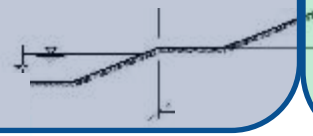
https://www.nature.com/articles/s41558-021-01265-6

Risk Assessment

Project Risk = f(Hazard, Performance, Consequences)

Load

What are the hazards and how likely are they to occur?

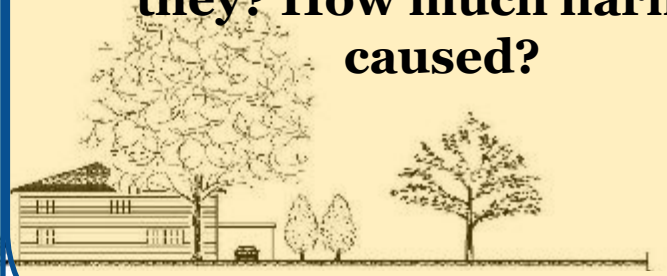


Aging Structure

How will the structure perform in the face of these hazards?

Growing Population

Who and what are in harms way?
How susceptible to harm are they? How much harm is caused?



Infrastructure Safety Program Focused on: People, Performance, and Risks

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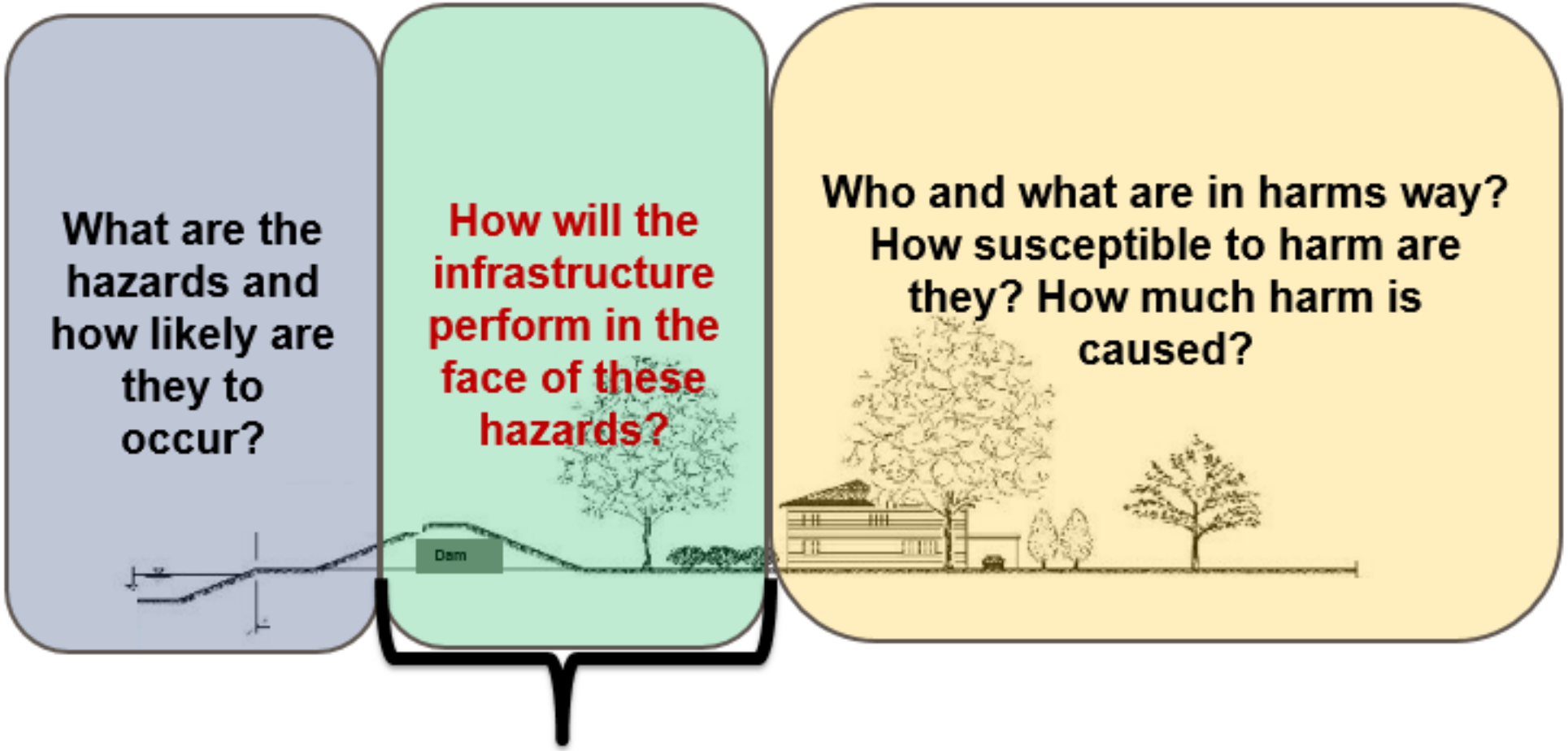
Instrumentation Informs Risk



Performance Monitoring

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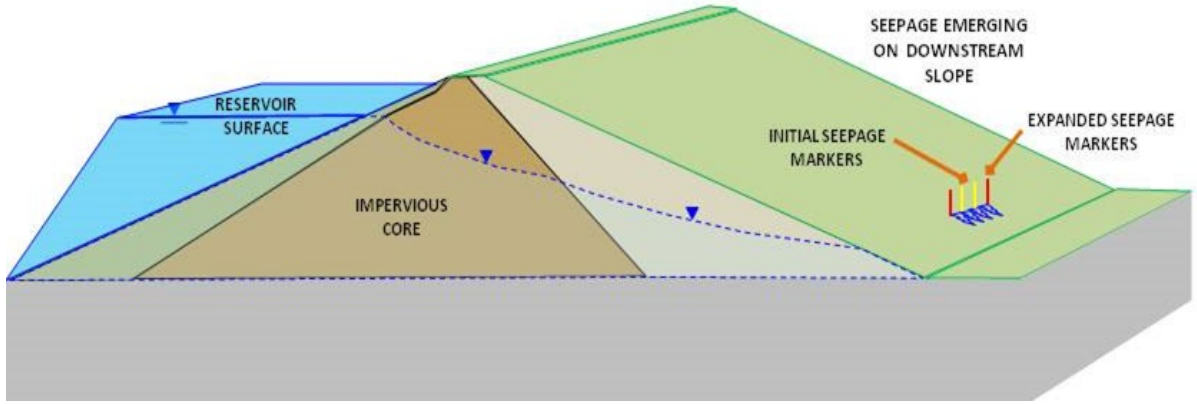
PERFORMANCE MONITORING

- Collected surface and subsurface information related to project performance



- Visual Monitoring
  - ✓Qualitative Information

- Instrumentation & Measurements
  - ✓ Quantitative Measurement of Performance over time
  - ✓ Informs Likelihood of Potential Failure Occurrence
  - ✓ Reduce Uncertainty in Risk Estimate
  - ✓ Provide early warning detection

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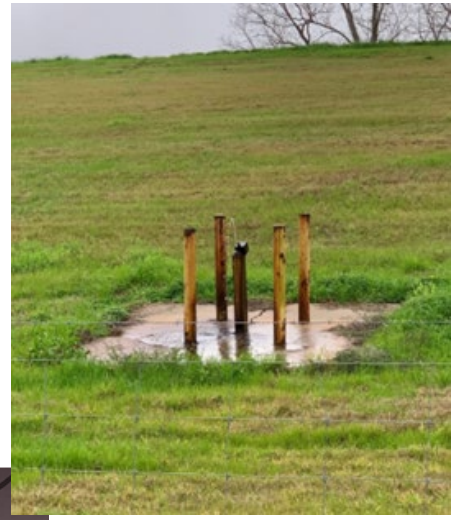
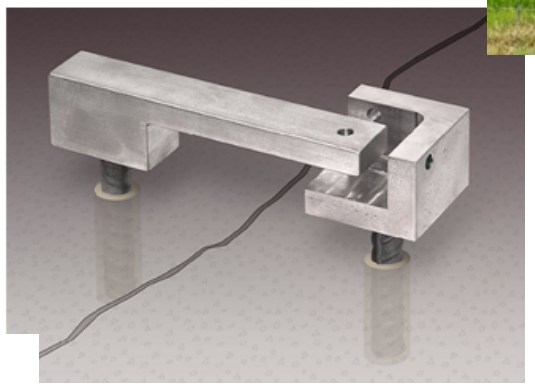
Variety of Tools for Monitoring

Surface Monitoring Point
Piezometer
Drain
Relief well
Joint Meter
Observation Well
Inclinometer
Crack meter
Settlement Plate
Earth Pressure Cell
Weir
Flowmeter
Strain Gauge

Extensometer
Flume
Staff Gauge/Water Level
Thermistor
Precipitation Gauge
Load Cell
Pendulum
Plumbline
Turbidity Meter
Liquid Level Gauge
Barometer
Tiltmeter
Seismic Monitoring Device
Stress Cell





Remote Sensing (LiDAR, InSAR)

There are many tools in our toolbox.

The trick is using the right tool for the job.

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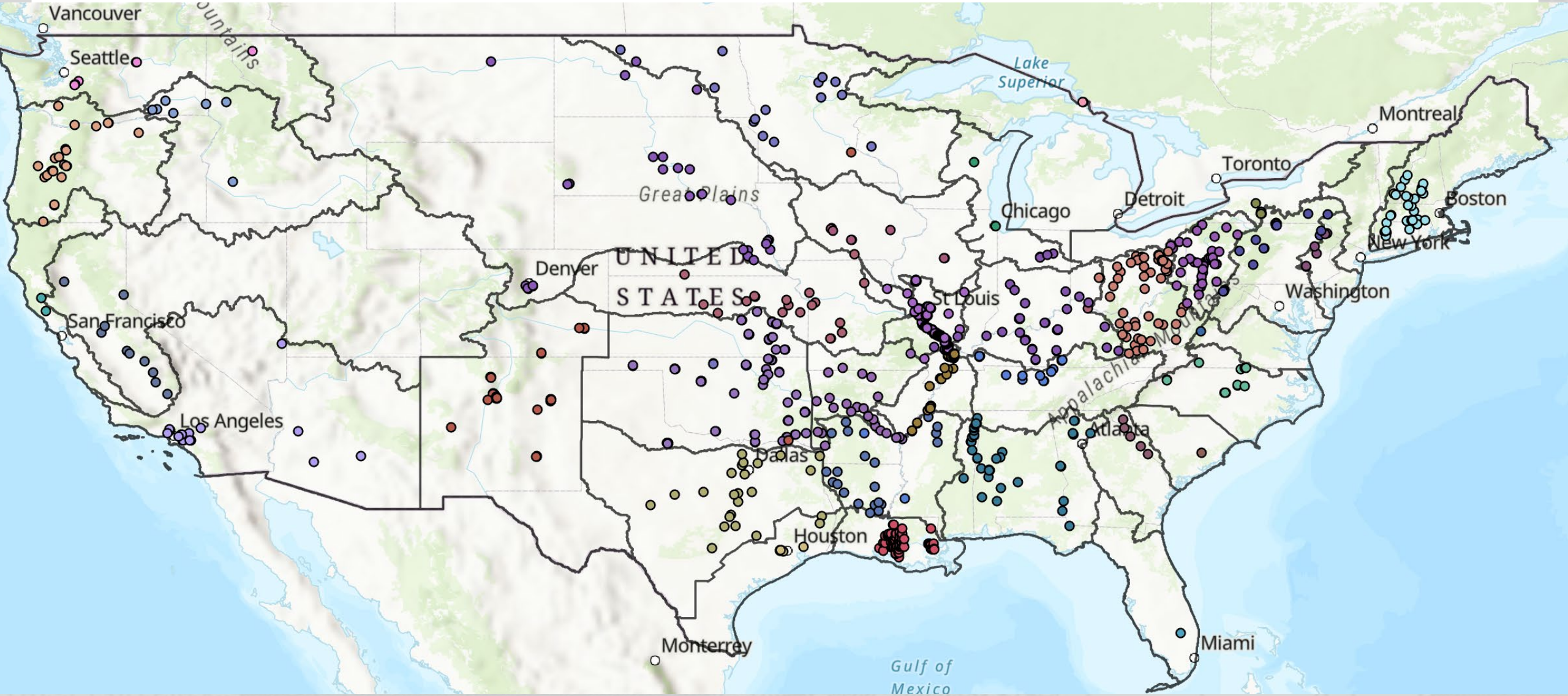
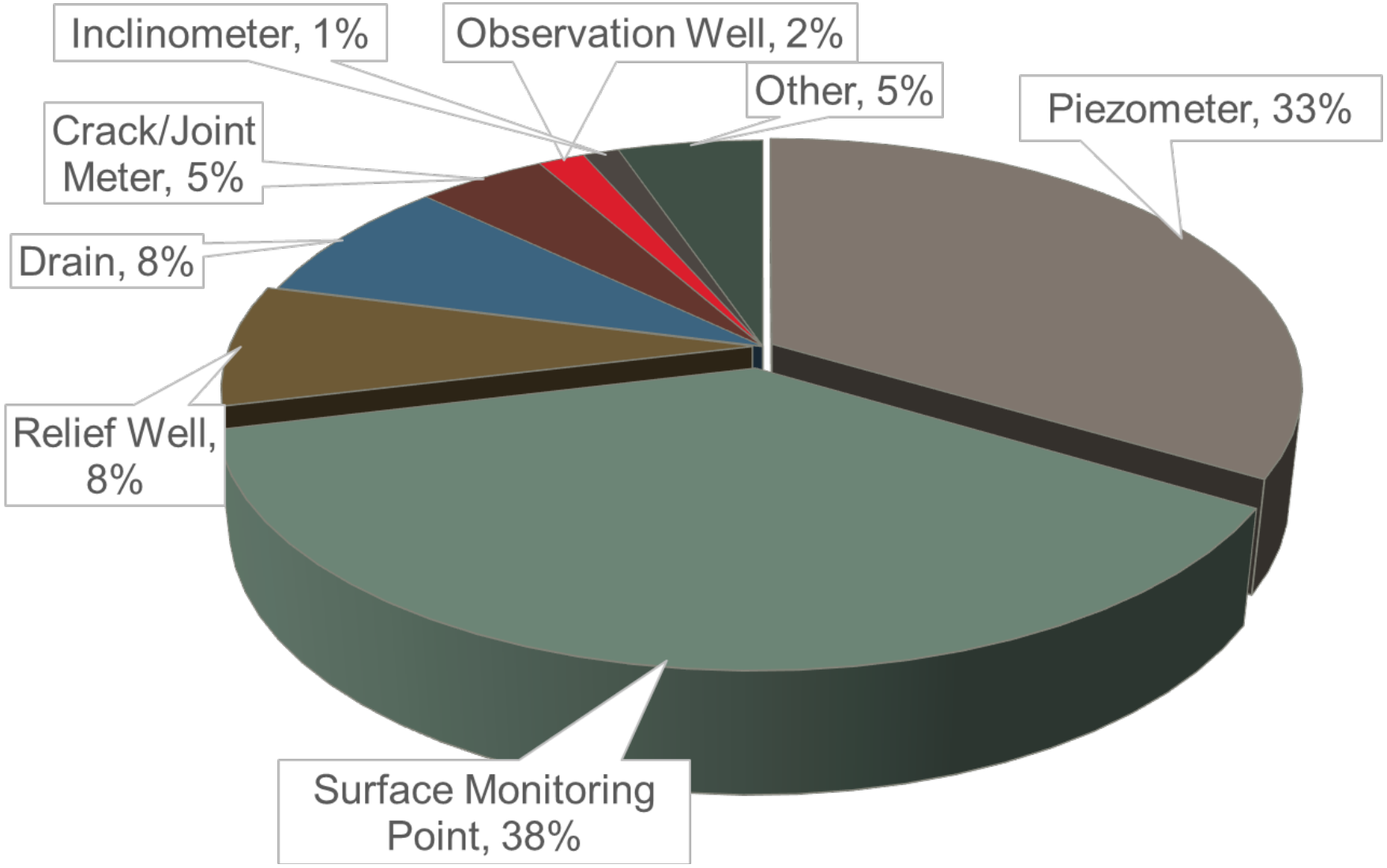
USACE has over 70,000 instruments across the dam & levee safety portfolio



USACE Dam Safety Instrument Types



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Instrumentation & Monitoring is great! …BUT

- Why were the instruments installed?
- Where do I install new instruments?
- What type do I install?
- How often do I collect/review data?
- When am I concern?

- How do I manage my data?
- When can I stop monitoring?
- What does the data mean?
- Is my program adequate?

A SATISFACTORY INSTRUMENTATION AND MONITORING PROGRAM SHOULD ADDRESS ALL THOSE QUESTIONS

…AND

Answer the Big Picture Question

- Is project performing as per design?
- Are there any concerning trends or behaviors?
- What are the recommended actions?

THAT IS NOT ALWAYS WHAT OUR PROGRAMS LOOK LIKE…

- ***We have legacy instruments that have served their purpose***

- ***We have areas we should be instrumenting but haven't***

"There is a danger that instrumentation may be discredited because of indiscriminate use"

--Ralph Peck

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Best Practice for an Effective Monitoring Program

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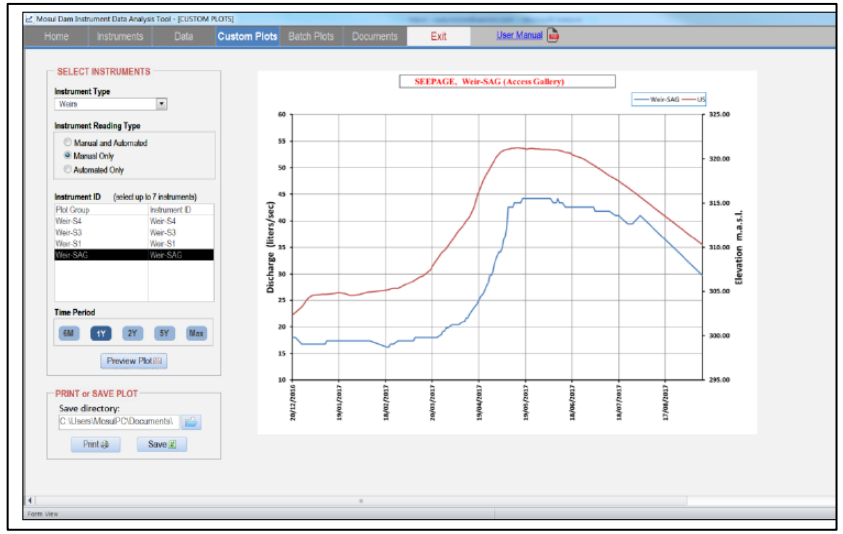
EM 1110-2-1908 and EM 1110-2-4300 Merger

- EM 1908 (1995) Instrumentation of Embankment Dams & Levees
  - **Published Feb 2021**
  - Vastly Expanded doc: RIDM, Evaluation, Data Management, New Technology

- EM 4300 (1987) Instrumentation for Concrete Structures
  - Re-release EM1908 with appropriate Concrete monitoring guidance
  - **95% Completion**



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Instrumentation Guide Specification

- New guide spec
  - for use with construction contracts where performance monitoring instrumentation is required
  - Includes furnishing all labor and equipment, installation and maintenance
  - Includes instrumentation data management and data interpretation requirements.

Publicly Released
May 2022 on WBDG

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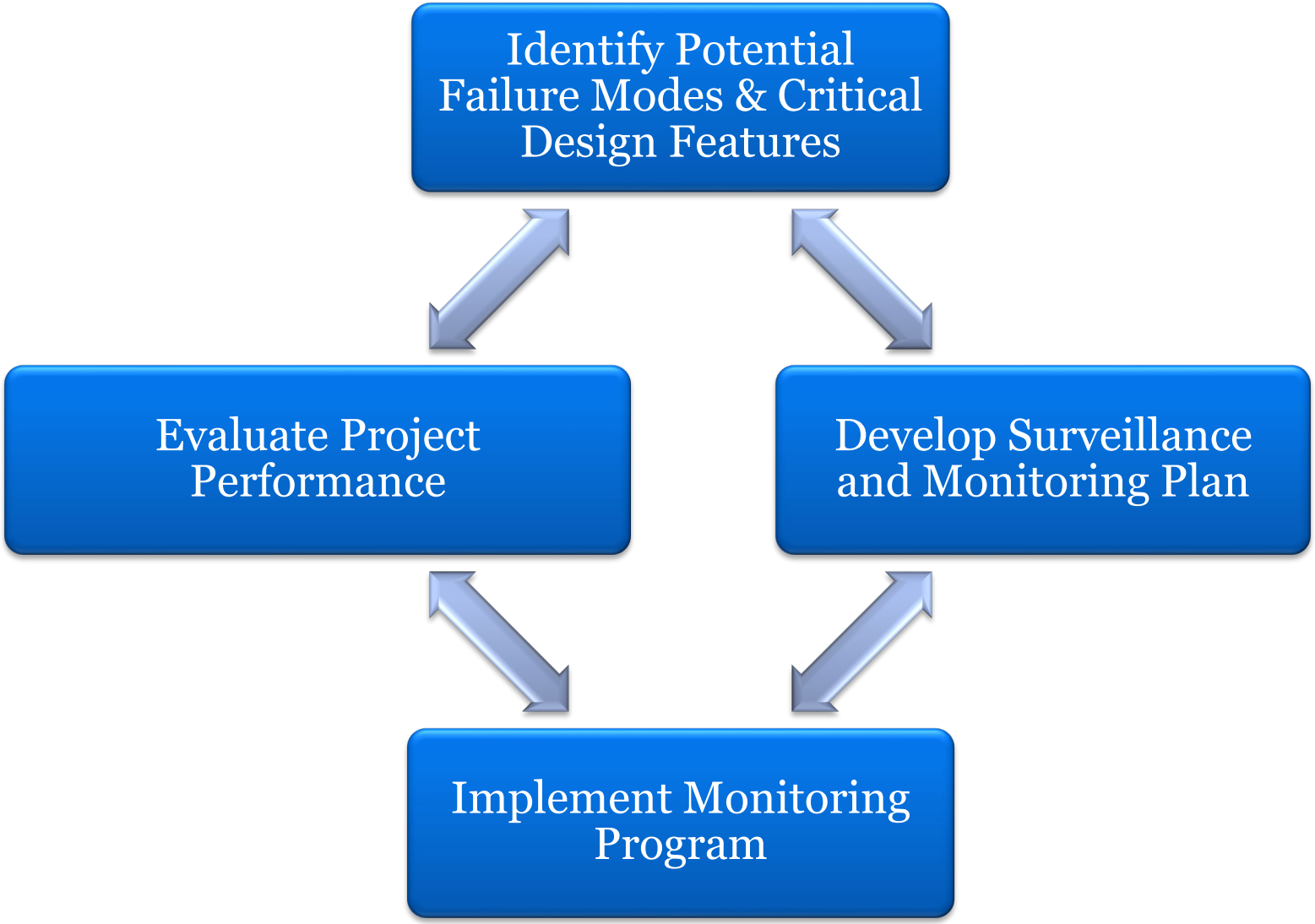
Best Practice for an Effective Monitoring Program



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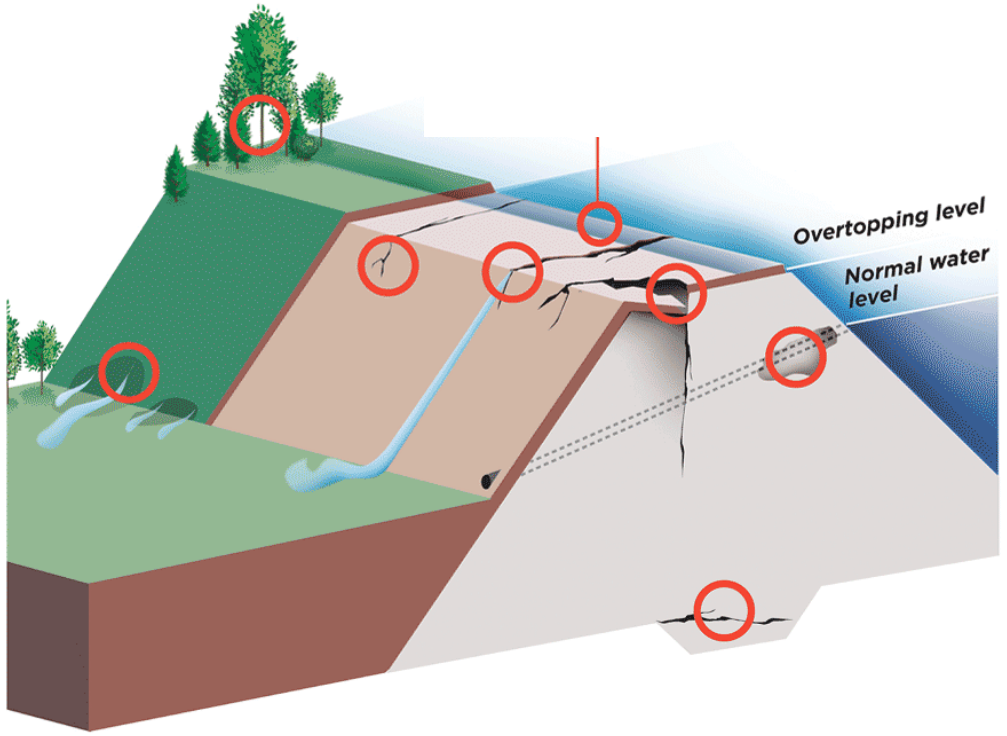
Identify Potential Failure Modes & Critical Design Features

- ✓ Project Specific Potential Failure Modes
  - ✓ Slope Instability
  - ✓ Uplift
  - ✓ Internal Erosion
  - ✓ Sliding/Overturning
  - ✓ Overtopping
- ✓ Project Specific Features
  - ✓ Seepage Barriers
  - ✓ Drains/Relief Wells



SOURCES: Association of State Dam Safety Officials, Federal Emergency Management Agency; Based on graphic by Jeff Colson, USACE Dam Safety Program

Michael Hogue/*DMN*

Focus data collection here!

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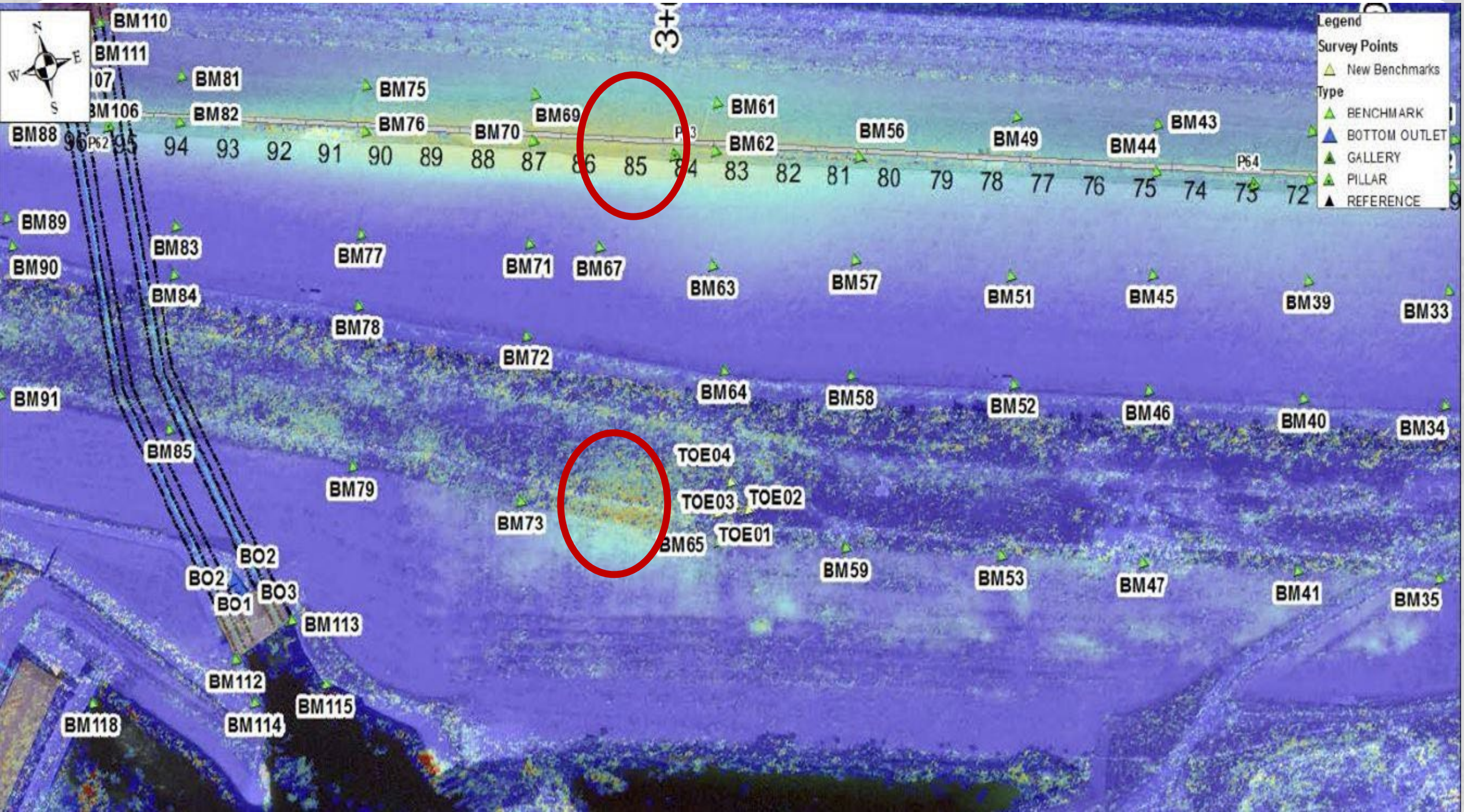
Historic Installations in Grid Patters
Intake
Guard Gate Chamber
Switchyard
Spillway

Areas of Highest Risk

-Internal Erosion Along Left Abutment Contact

-Internal Erosion Along Bottom Outlets


Legend
Survey Points
New Benchmarks
Type
BENCHMARK
BOTTOM OUTLET
GALLERY
PILLAR
REFERENCE
BM110
BM111
BM81
BM82
BM75
BM76
BM70
BM69
BM61
BM62
BM56
BM49
BM44
BM43
BM106
BM88
BM89
BM90
BM83
BM84
BM77
BM78
BM71
BM67
BM63
BM57
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BM33
BM72
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BM52
BM46
BM40
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BM85
BM79
BM73
TOE04
TOE03
TOE02
TOE01
BM65
BM59
BM53
BM47
BM41
BM35
BO2
BO2
BO3
BO1
BM113
BM112
BM115
BM114
BM118
P62
P63
P64
94
93
92
91
90
89
88
87
86
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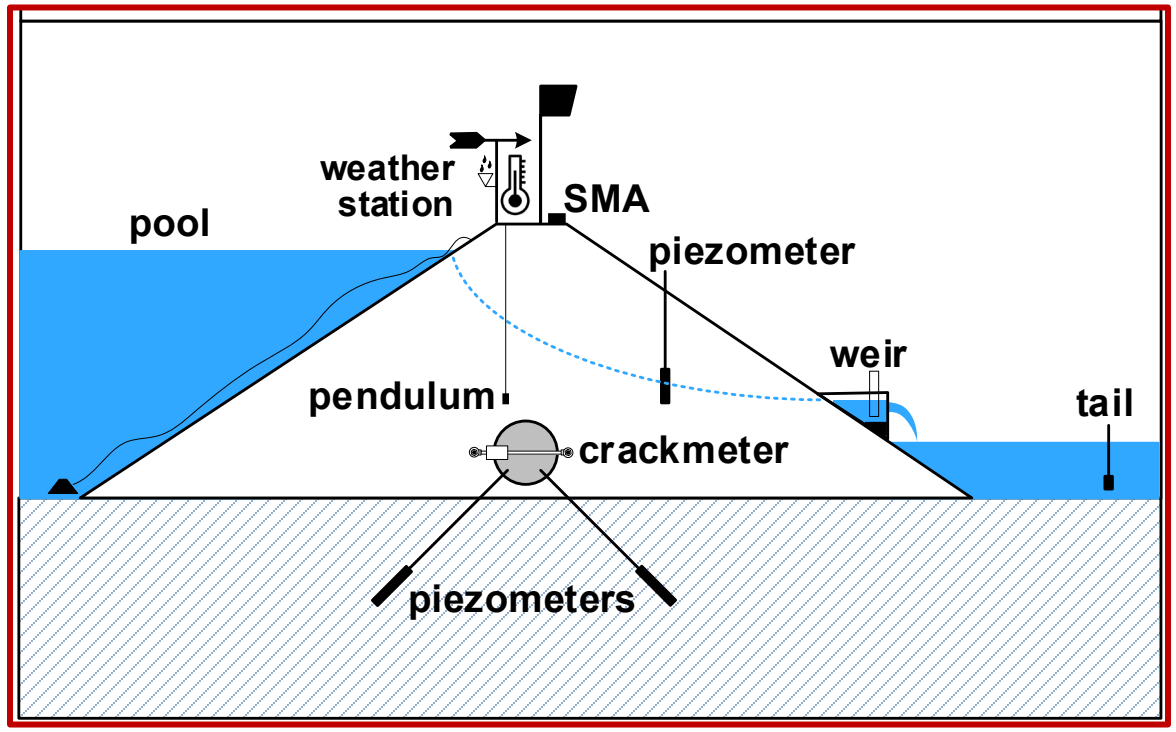
74
73
72

Develop Project Specific Surveillance & Monitoring Plans

- *Pertinent Plan Considerations*
  - Purpose of Instrumentation
  - Location of Instrument (x,y,**z**)
  - **Monitoring Frequency**
  - Thresholds and Action Levels
  - Roles and Responsibility
  - Program Maintenance Budget
  - Instrumentation Folio
  - **Data Management**
  - Quality Control



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Monitoring Frequency

Need to Move from:

"This is how we have always done it"

To: Monitoring Frequency Based on

- *Project Loading Conditions*
- *Monitored Failure Modes*
- *Risk Associated with the Project*
- *Engineering Judgment*

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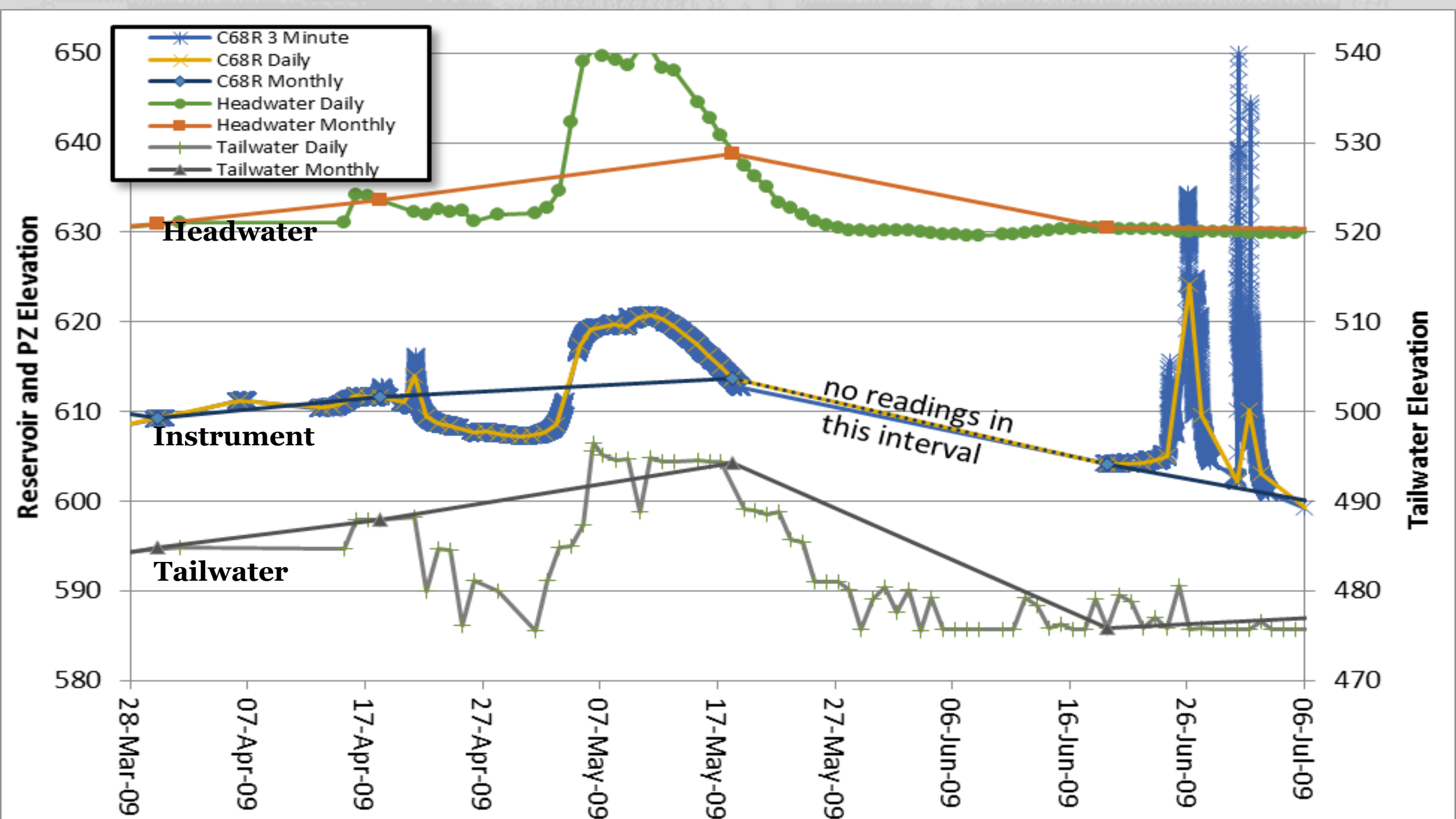
C68R 3 Minute
C68R Daily
C68R Monthly
Headwater Daily
Headwater Monthly
Tailwater Daily
Tailwater Monthly
Headwater
Instrument
Tailwater
no readings in this interval
Reservoir and PZ Elevation
Tailwater Elevation
650
640
630
620
610
600
590
580
540
530
520
510
500
490
480
470
28-Mar-09
07-Apr-09
17-Apr-09
27-Apr-09
07-May-09
17-May-09
27-May-09
06-Jun-09
16-Jun-09
26-Jun-09
06-Jul-09

Higher Frequency = More Data

Reading Frequency	Readings per Instrument per Year
Monthly	12
Weekly	52
Daily*	365
Hourly	8,760
Every 15 min**	35,040
Every 3 min	175,200

* Practical Limit for Manual Instruments

** Common for many ADAS (consider data transmission and data needs)

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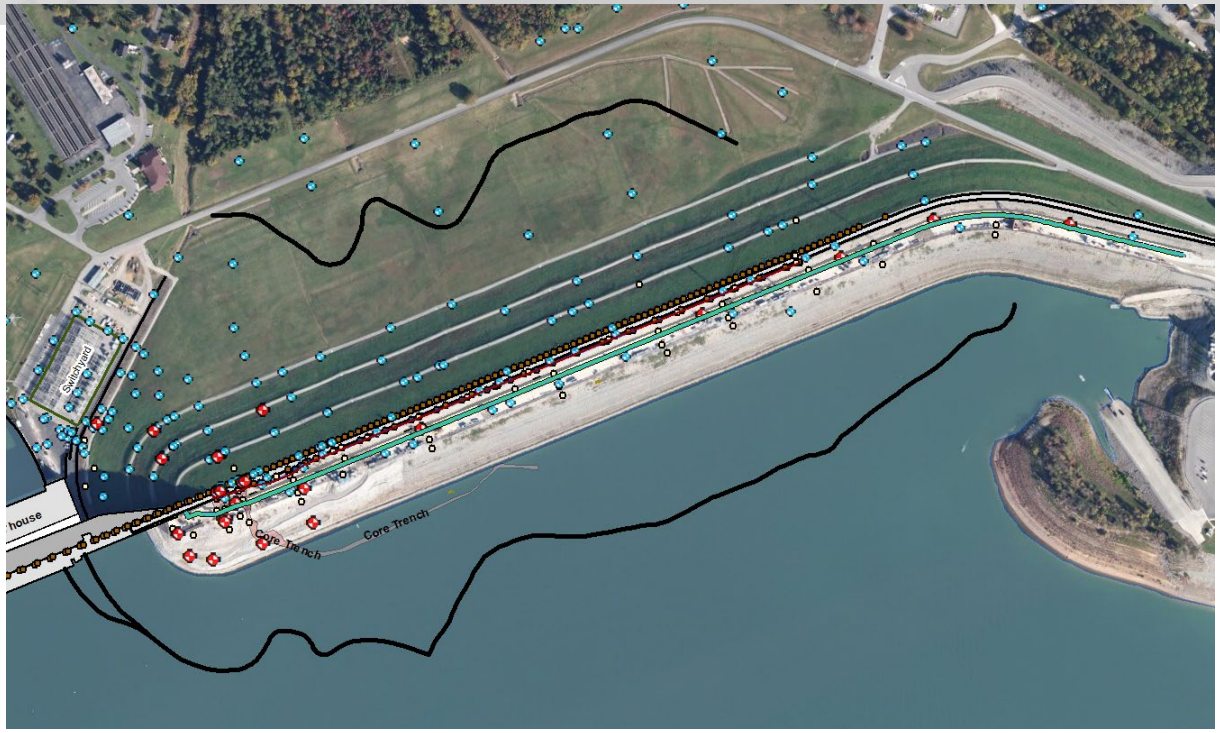
DATA VOLUMES

Wolf Creek Dam

247	Piezometers	+6.7 million readings
74	Inclinometers	+360k readings/yr
164	Monuments	719MB; 40MB/yr



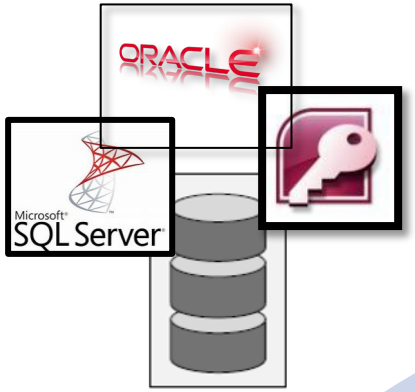
J. Percy Priest Dam

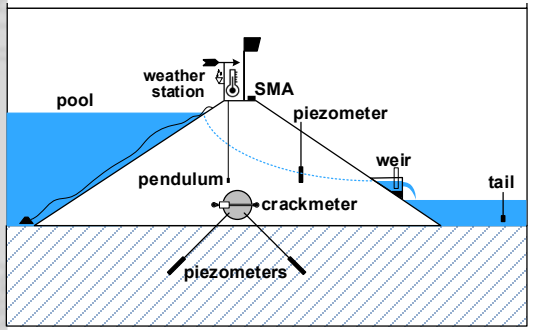
130 Active Instruments
+4.3M readings total / ~0.5M readings/yr
423 MB since 1982 / 51 MB last year

DATA MANAGEMENT

Data Transfer

Data Access



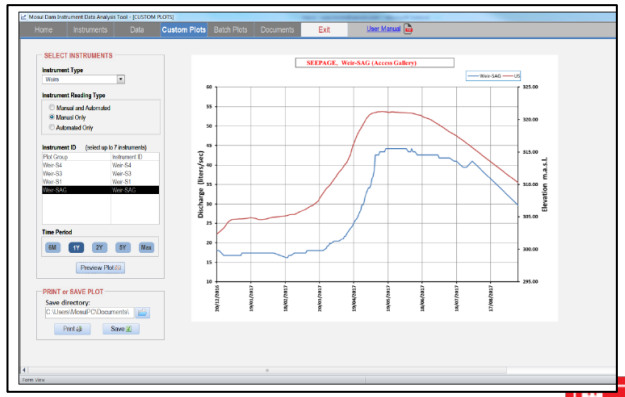


Data Evaluated

Data Processed & Plotted

Data Storage

Field Measurement



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USACE Enterprise Instrumentation Data Management

	Instrument Count	Instrument Group Cou
g Station - Instrumentation Browser	4	0
g Station - Instrumentation Browser	4	0
ientation Browser	96	0

- ✓ USACE owned, developed, managed
- ✓ Meets USACE cyber security requirements
- ✓ Maintain inventory of instrumentation across USACE
- ✓ Upload and store manual and automated data
- ✓ Access and visualize data for design and evaluation purposes
- ✓ Instrumentation program quality control
- ✓ Thresholds and alerts

https://midas.rsgis.dev

Apps _USACE AIS Fee for Service GGM TEN cms My Drive - Google... CHRTAS Mail - Hlepas,

Monitorin

INSTRUMENTS
68513

INSTRUMENT GROUPS
122

Filter...

Project Name		
10th Street Pumping Station - Instrumentation Browser		
28th Street Pumping Station - Instrumentation Browser		
Aberdeen - Instrumentation Browser		
Abiquiu Dam - Instrumentation Browser	213	0
Above Cairo, II Parcel 2 - Instrumentation Browser	6	0
Addicks Dam - Instrumentation Browser	27	0

Herbert Hoover Dike

Herbert Hoover Dike
Instrumentation Browser

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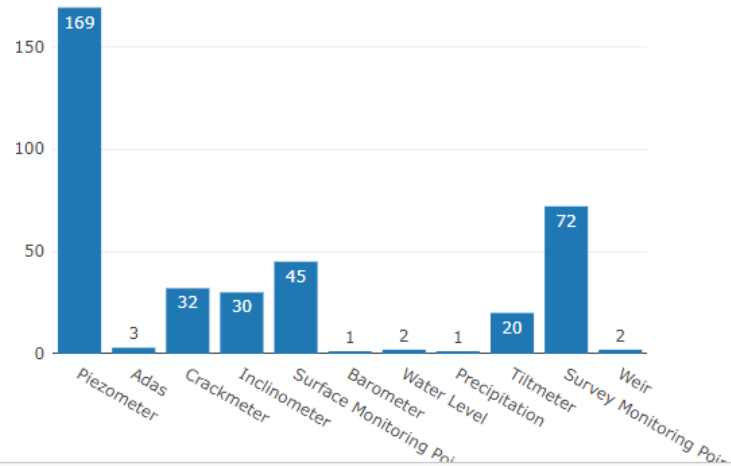
Instrument Groups 15

Name	Instrument Count	Timeseries Count	Tools
Crackmeters M20-30	8	1	
Crackmeters M30-40	11	0	
Crackmeters M40-50	5	0	
Crackmeters M10-20	8	4	
H&H - Environmental	4	4	
Other	3	3	
Tiltmeter M12-30	12	0	
Tiltmeter M30-64	8	0	

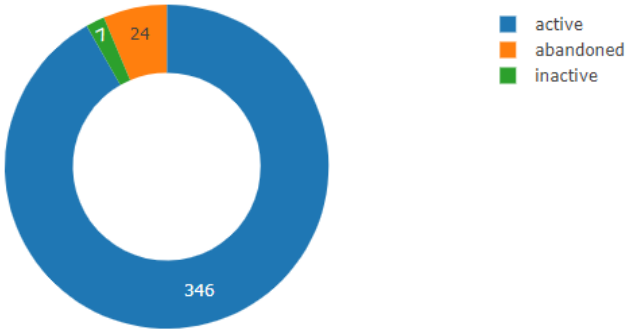
Collection Groups 1

Name	Tools
Test	

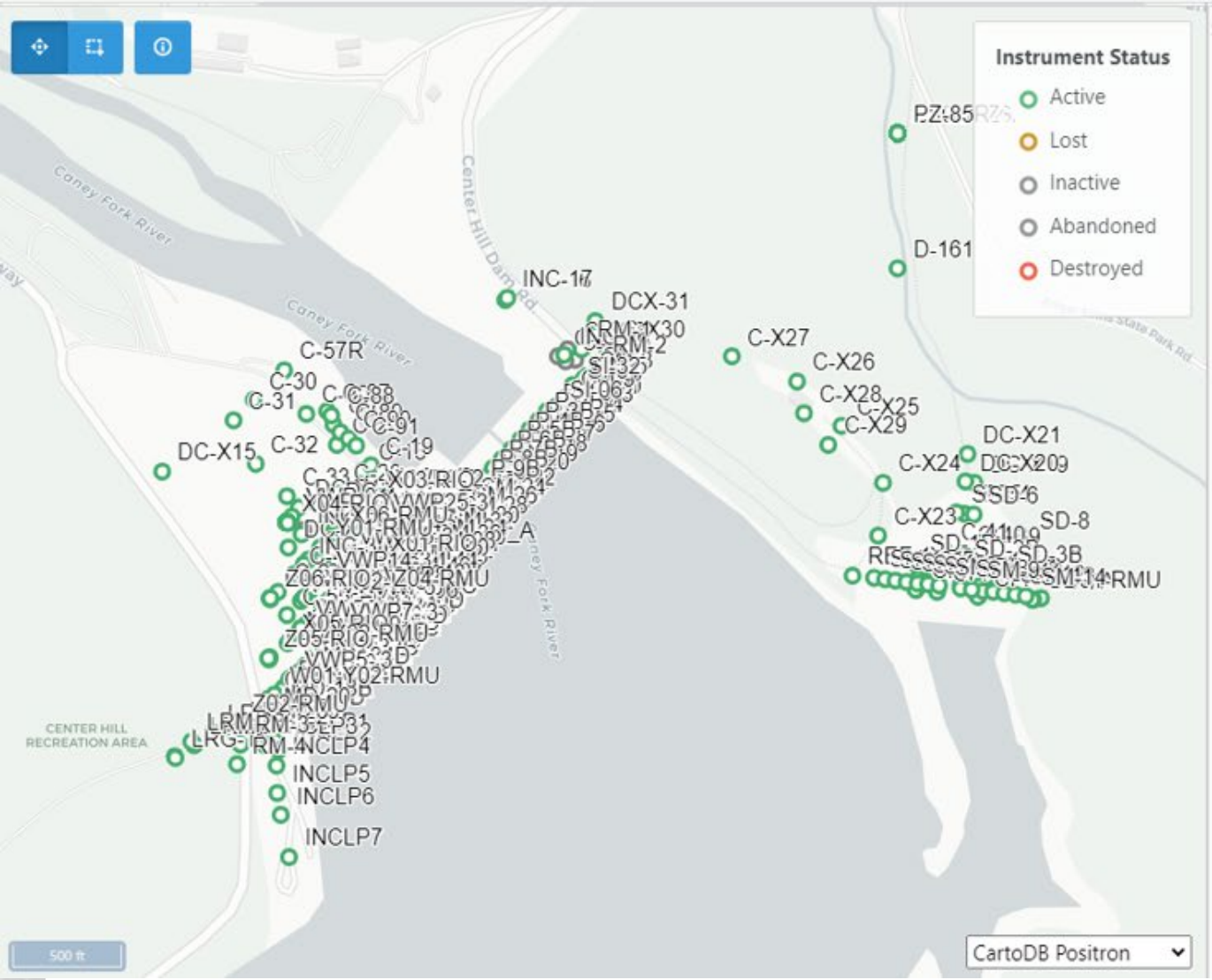
Instrument Types



Instrument Status

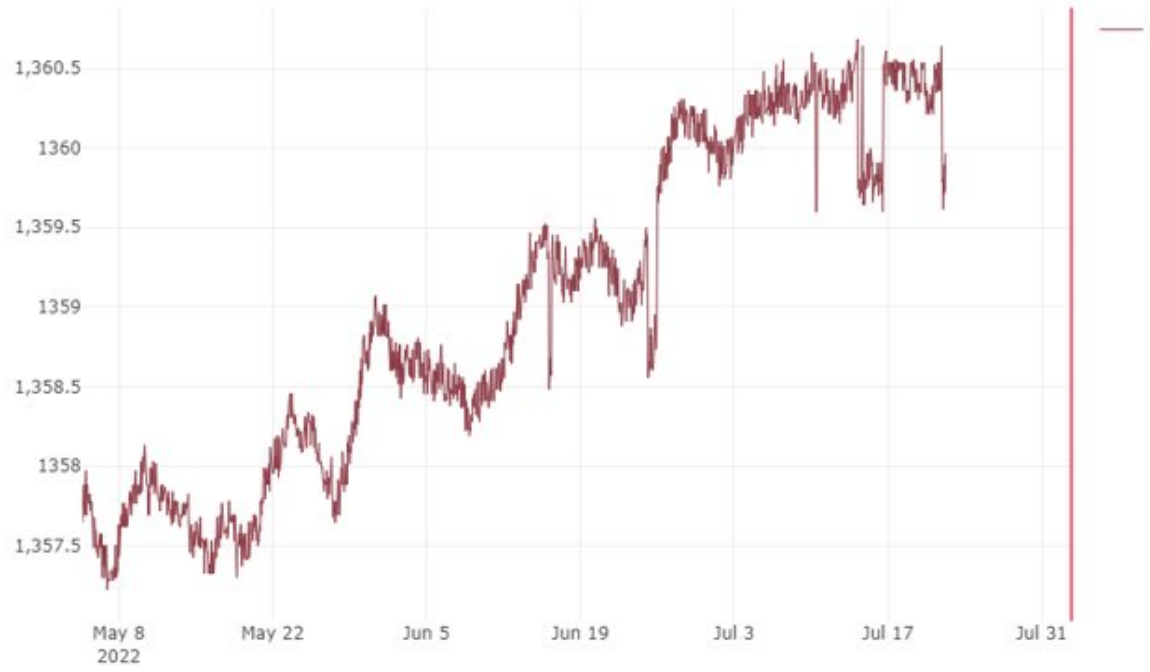


Dashboard | Explorer | All Instruments | Uploader | Batch Plotting | Admin



Date From: 05/04/2022 | Date To: 08/02/2022 | Presets: 7 day | 30 day | 60 day | 90 day | Lifetime

Elevation



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DATA ANALYSIS

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Evaluation Definition

e·val·u·a·tion

[əˌvalyəˈwāSH(ə)n]

NOUN

evaluations *(plural noun)*

the making of a judgment about the amount, number, or value of something; assessment.
"the evaluation of each method" · "an initial evaluation of the program"
synonyms: assessment · appraisal · judgment · gauging · rating · estimation · ranking · weighing up · summing up · consideration · assay · analysis · opinion · sizing up

COMPREHENSIVE ANALYSIS OF PROJECT PERFORMANCE BASED ON INSTRUMENTATION RESPONSE AND VISUAL OBSERVATION

…NOT JUST PLOTTING AND IDENTIFYING TRENDS

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Additional Data Required!

It's the Cumulative information that informs our understanding

It's the Visualization of the data that facilitates Communication

Aids In Emergency Response & Rapid Decision Making

Aids in Partnering for Complete Multi-discipline Picture

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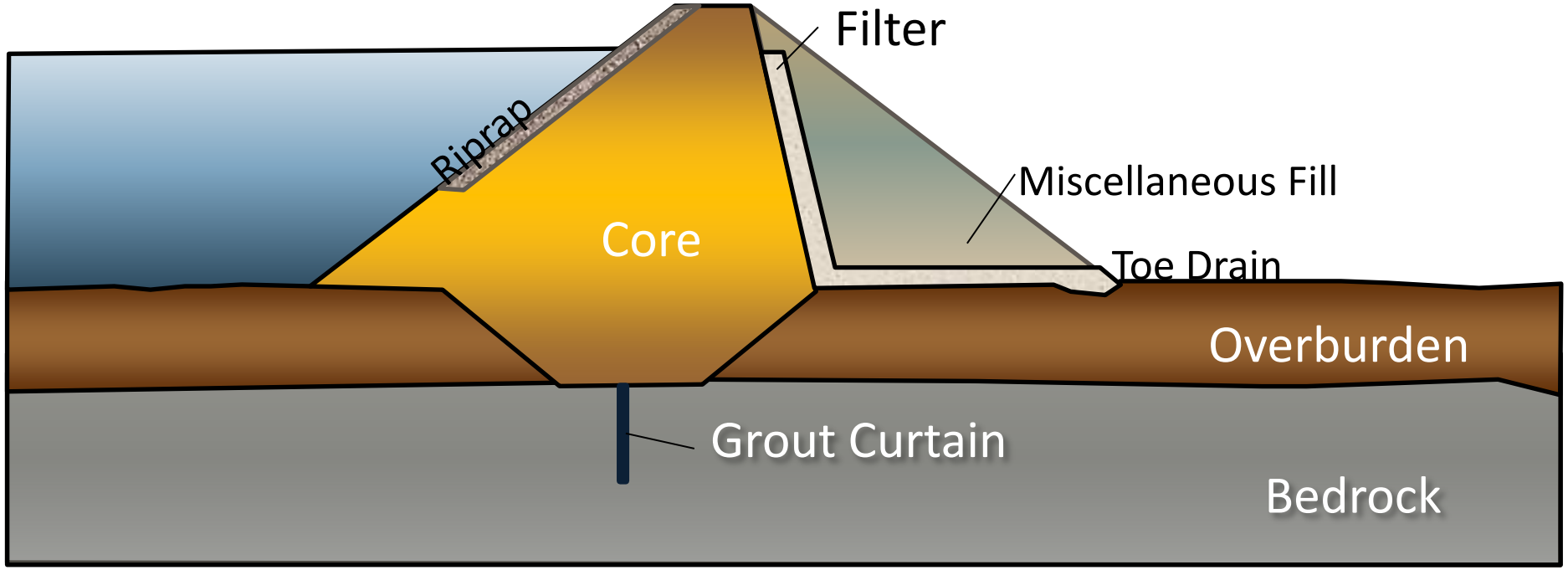
Site Specific Potential Failure Modes

Design, Construction & Operation



Project Purpose

Design Features

Operational Details

Construction Details

Loading History

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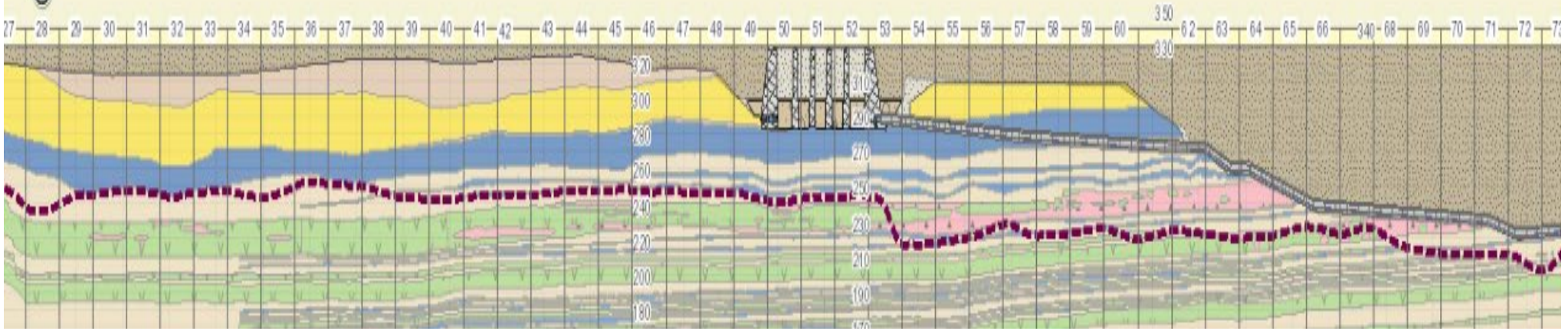
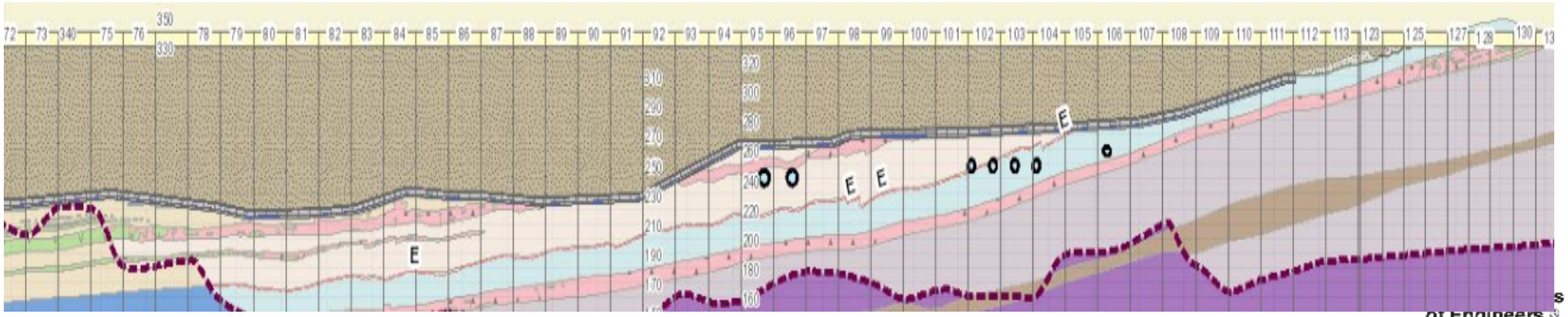
Sometimes Relatively Complex Construction Details



- Varying Embankment Zone Height
- Structural Features (Tunnels, Gallery, Spillway)
- Varying Filter and Drainage Zone and Extents
- Varying Excavated/Fill Zones, Weighted Berm Dimensions

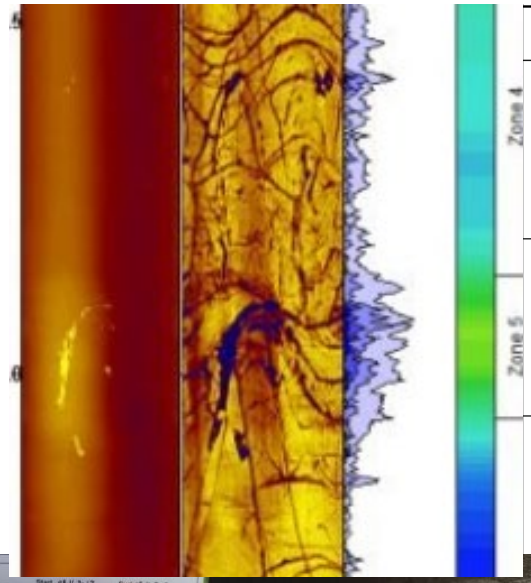


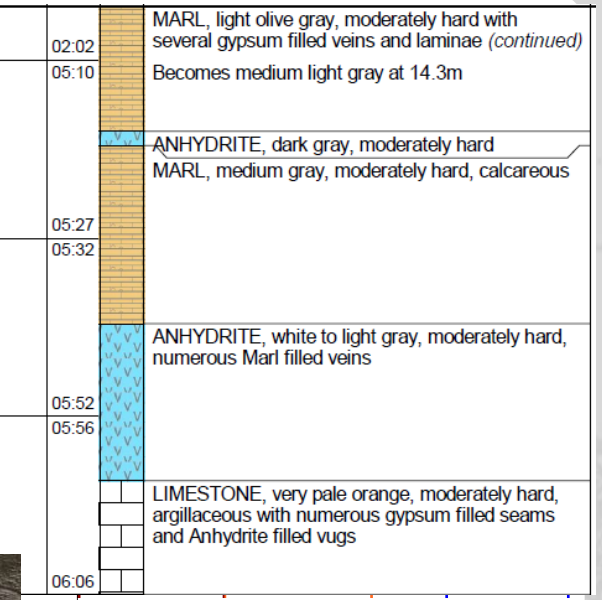
Site Specific Geology

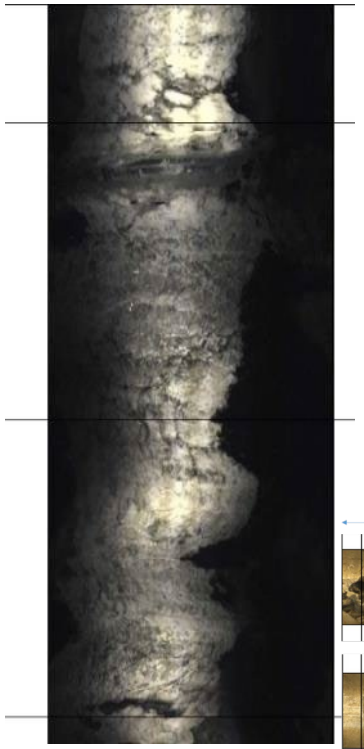
- Topography
- Foundation/abutment material
- Geologic Structure
- Groundwater
- Earthquake potential

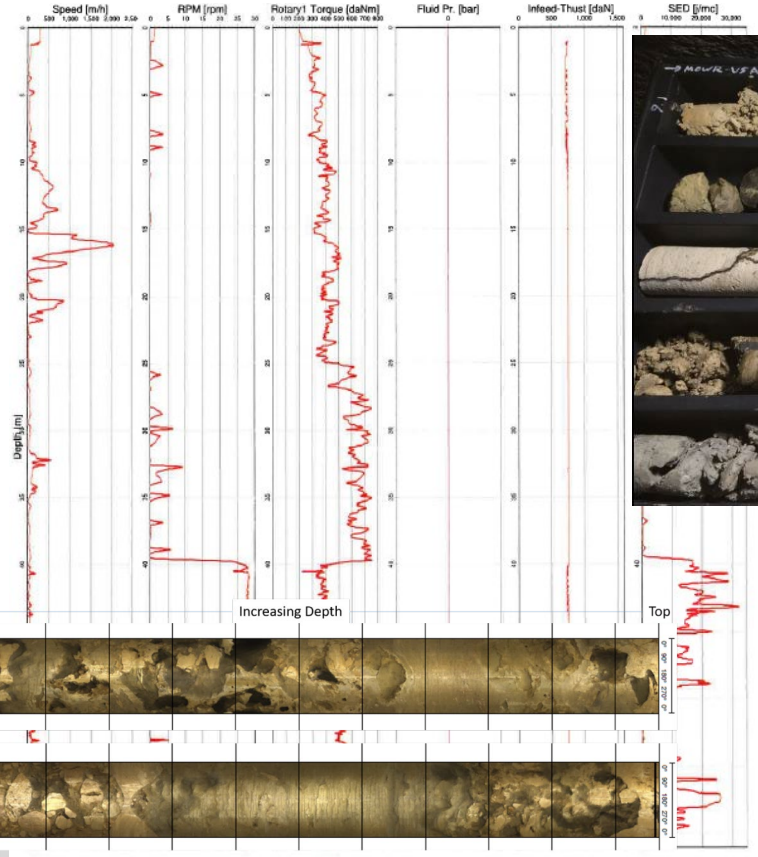
Subsurface Investigation Data

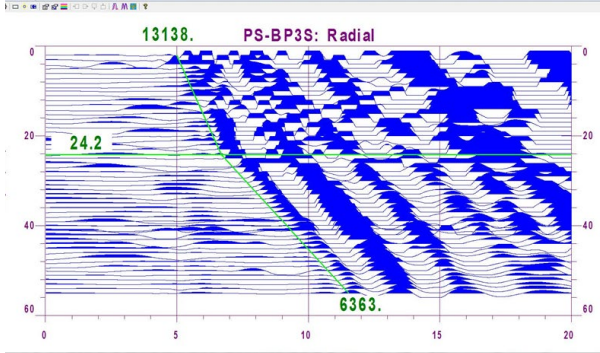
- Borehole Hole Logs & Photos
- Downhole Imaging & Geophysics
- Drilling Parameter Records
- Water Pressure Tests

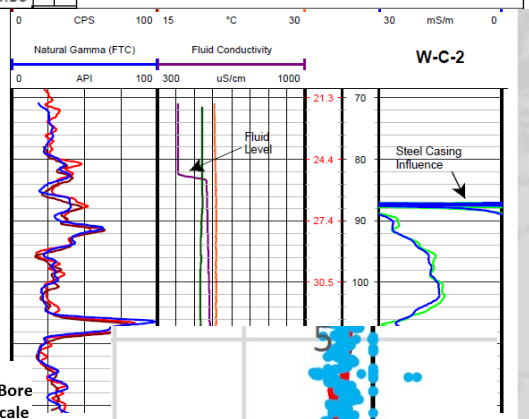


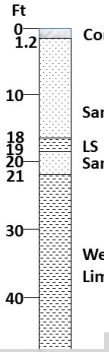


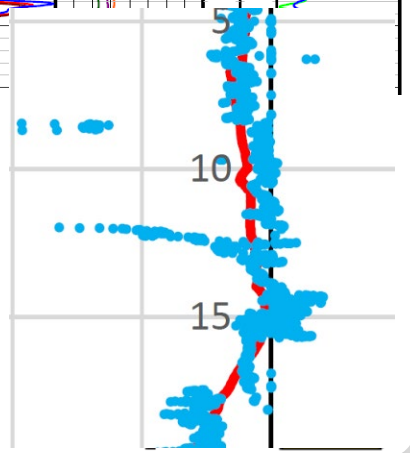













Visual Observation
Wet Area
March 2015

ENVIRONMENTAL INFLUENCES/IMPACTS

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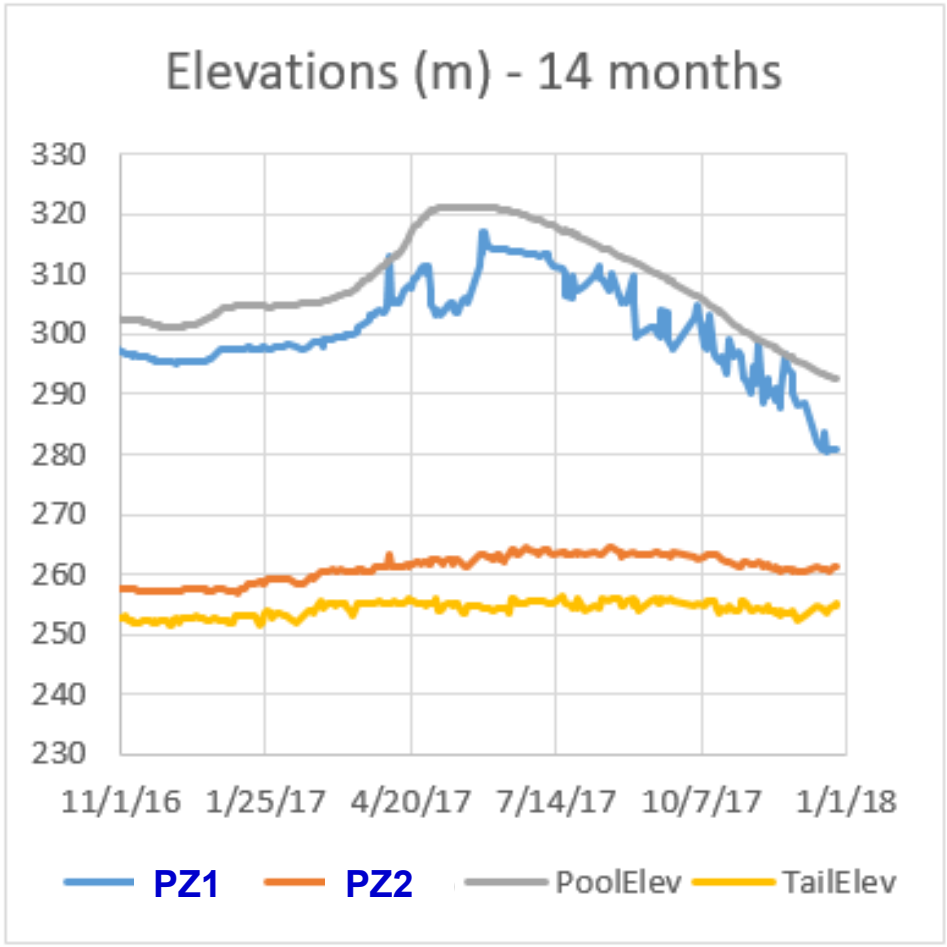
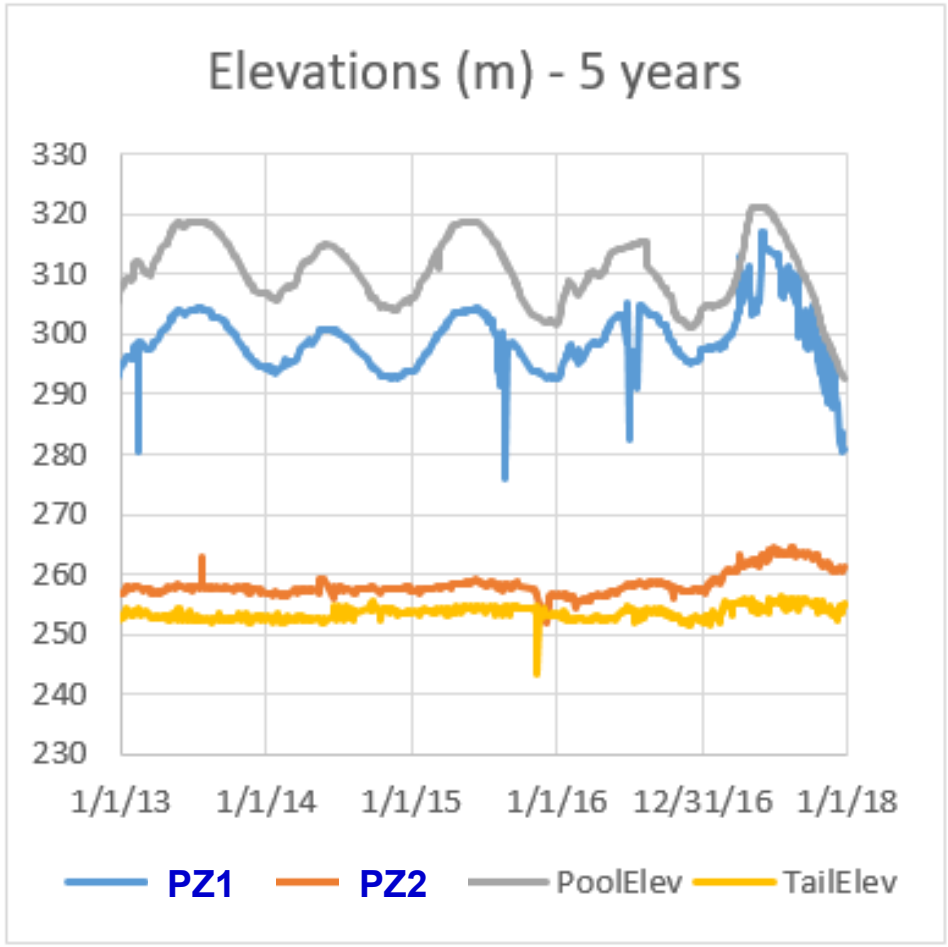
Past Performance
Expected Future Performance

Period of Performance



~1 yr Plot



~5 yr Plot

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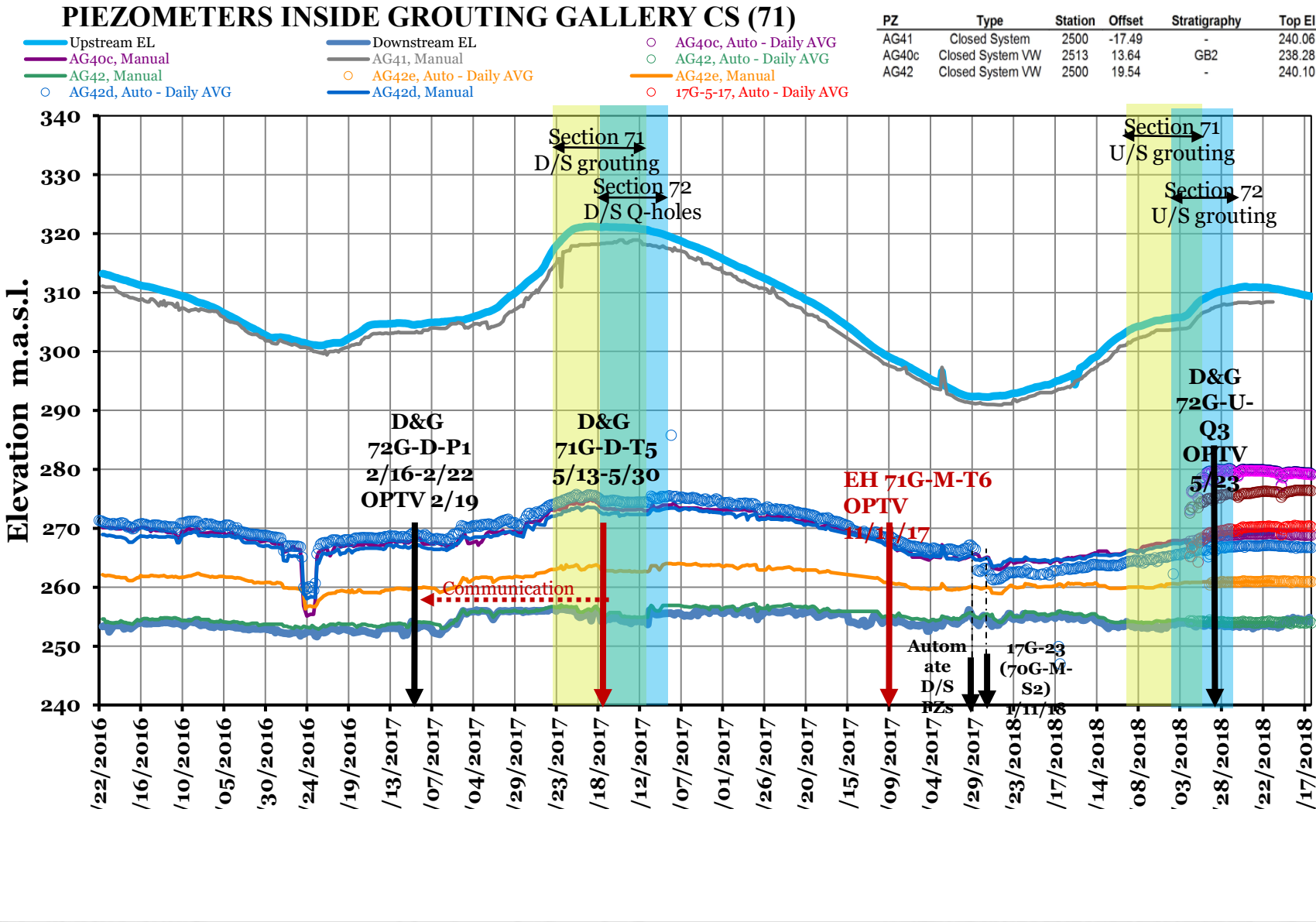
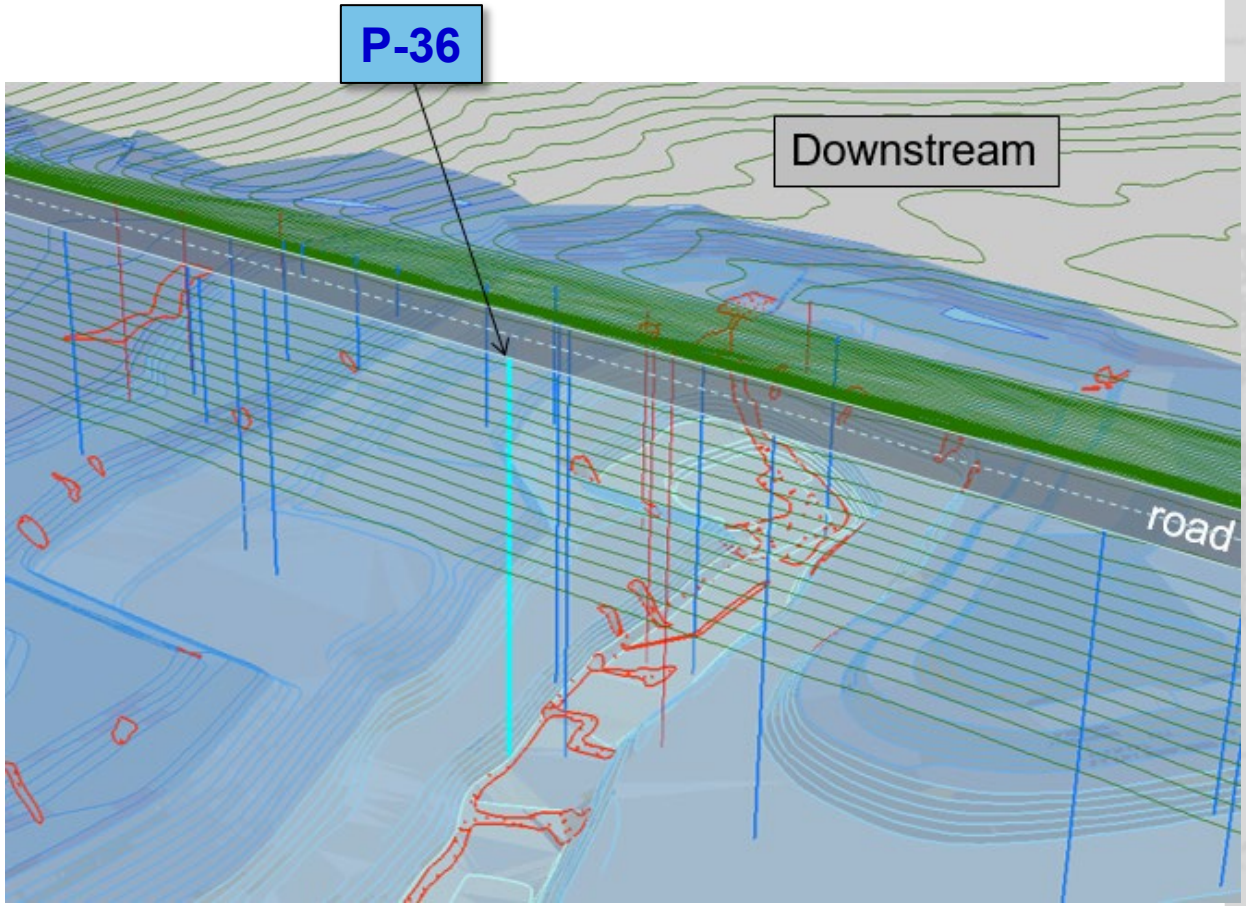
Construction Activity



PZ	Type	Station	Offset	Stratigraphy	Top El	Bott
AG41	Closed System	2500	-17.49	-	240.06	22
AG40c	Closed System VW	2513	13.64	GB2	238.28	23
AG42	Closed System VW	2500	19.54	-	240.10	22

Instrument Location Details



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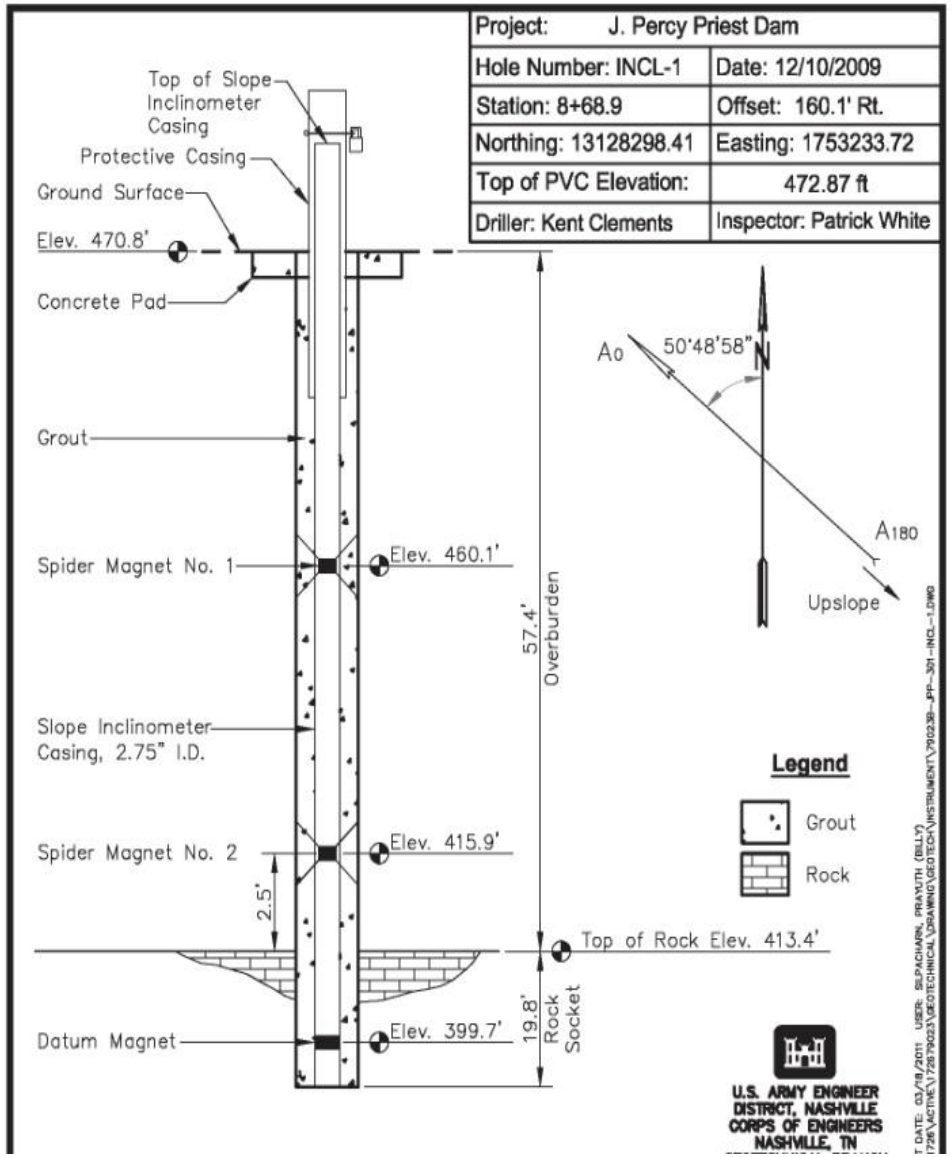
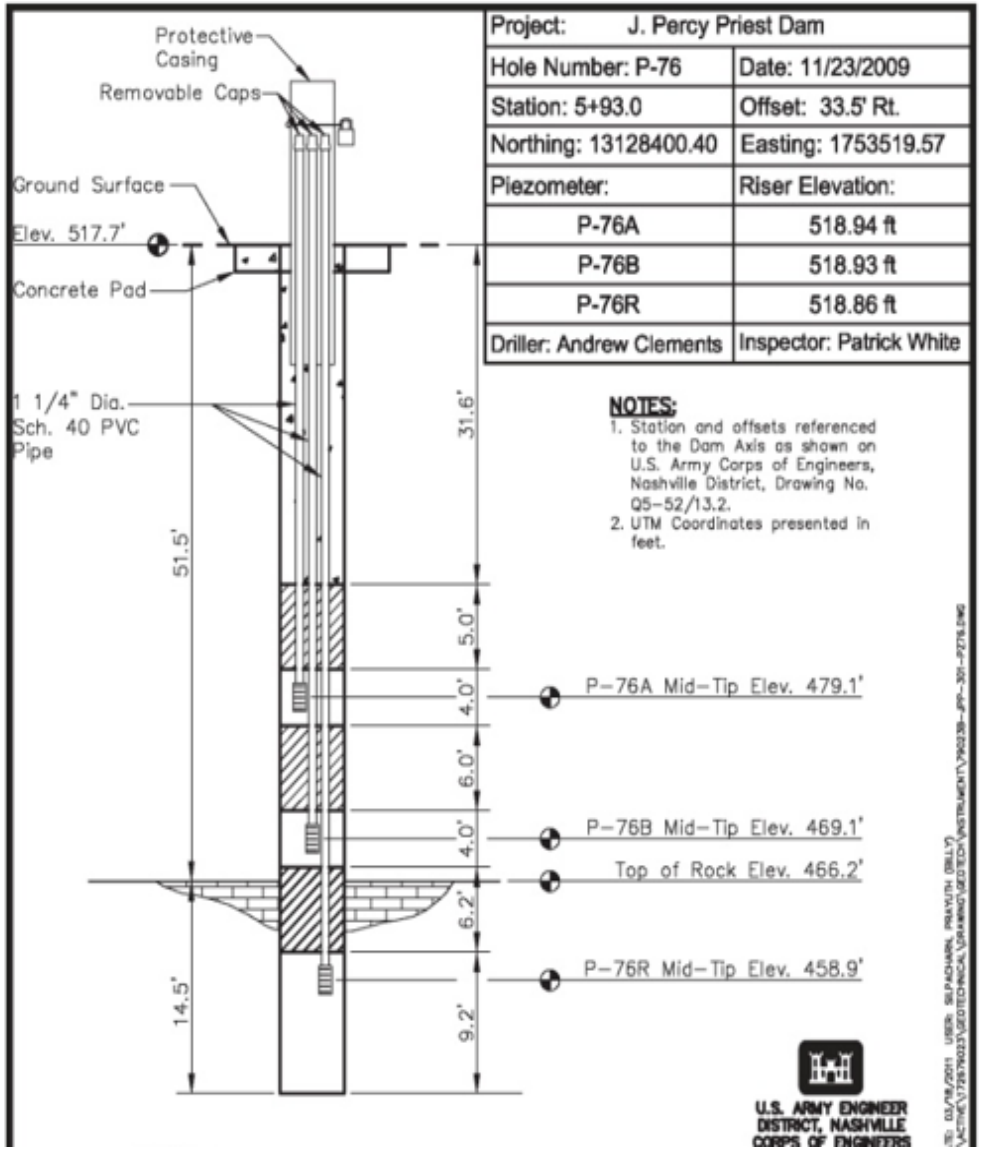
Instrument Installation Details





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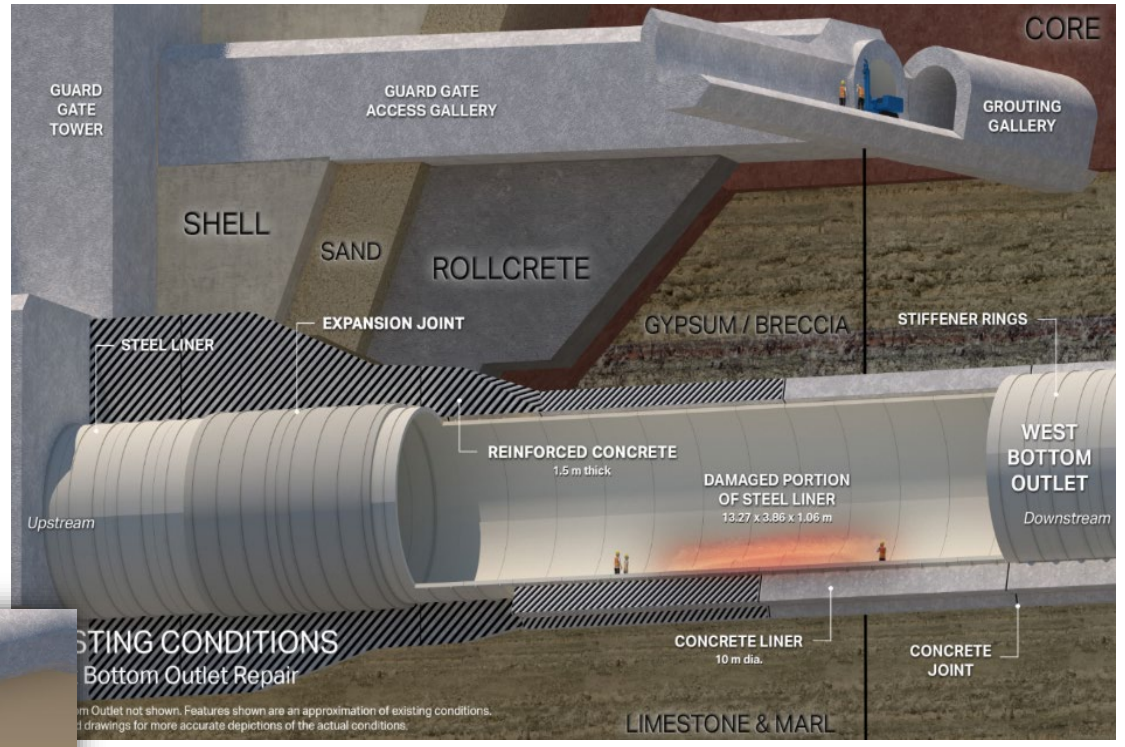
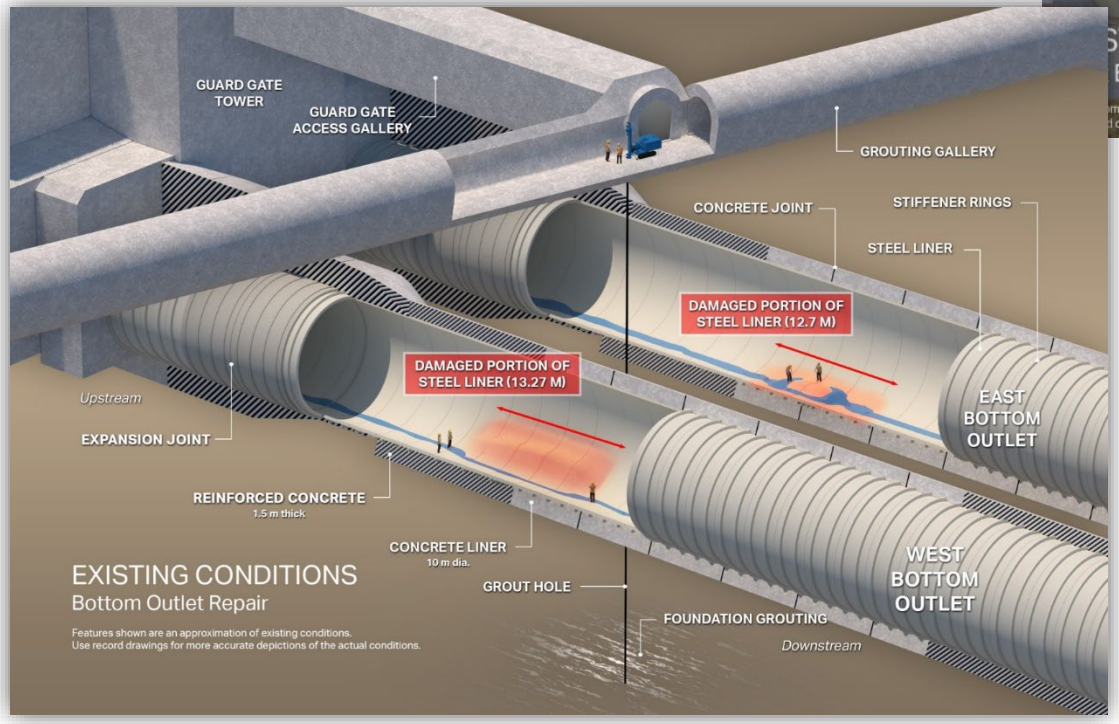
Construction Photos, Drawings and Rendering

- These can be invaluable

Sometimes need 3D to understand project feature relationships





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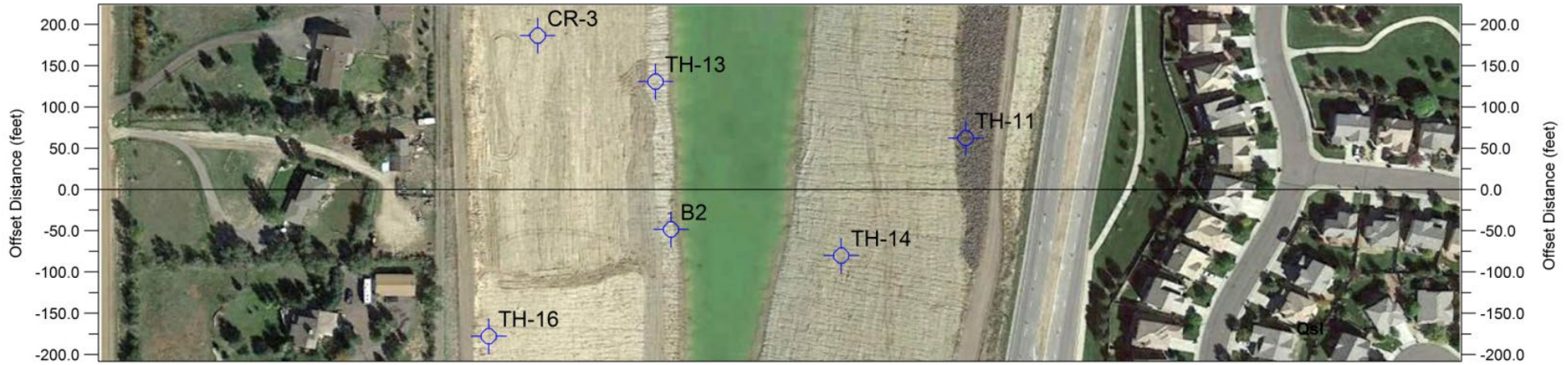
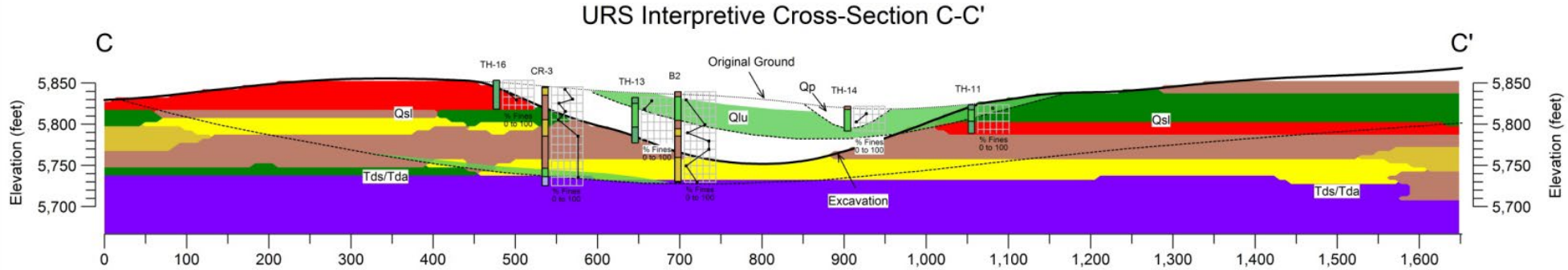
That’s a lot of Data…

Use of Folio Static Reports



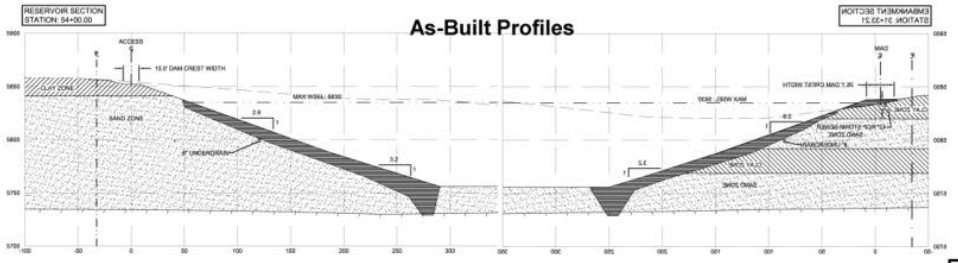


Lithology

- 1_Clay
- 2_Sandy Clay
- 3_Clayey Sand
- 4_Sand and Clay
- 5_Silty Sand
- 6_Sand and Gravel
- 7_Conglomerate
- 8_Sandstone
- 9_Claystone

Test Hole Legend

- Clay
- Sandy Clay
- Silty Sand
- Sand and Gravel
- Claystone
- Conglomerate



NOTES

1. Geologic contacts are approximate.
2. As-Built Profiles taken from Chambers Dam Reservoir Grading Plan, As-Builts dated 5/12, Sheet 6A.

PROJECT NO. 22244278	CHAMBERS RESERVOIR DOUGLAS COUNTY, COLORADO CROSS SECTION C - C'
PREPARED BY: DNG	
DATE: 11-21-14	

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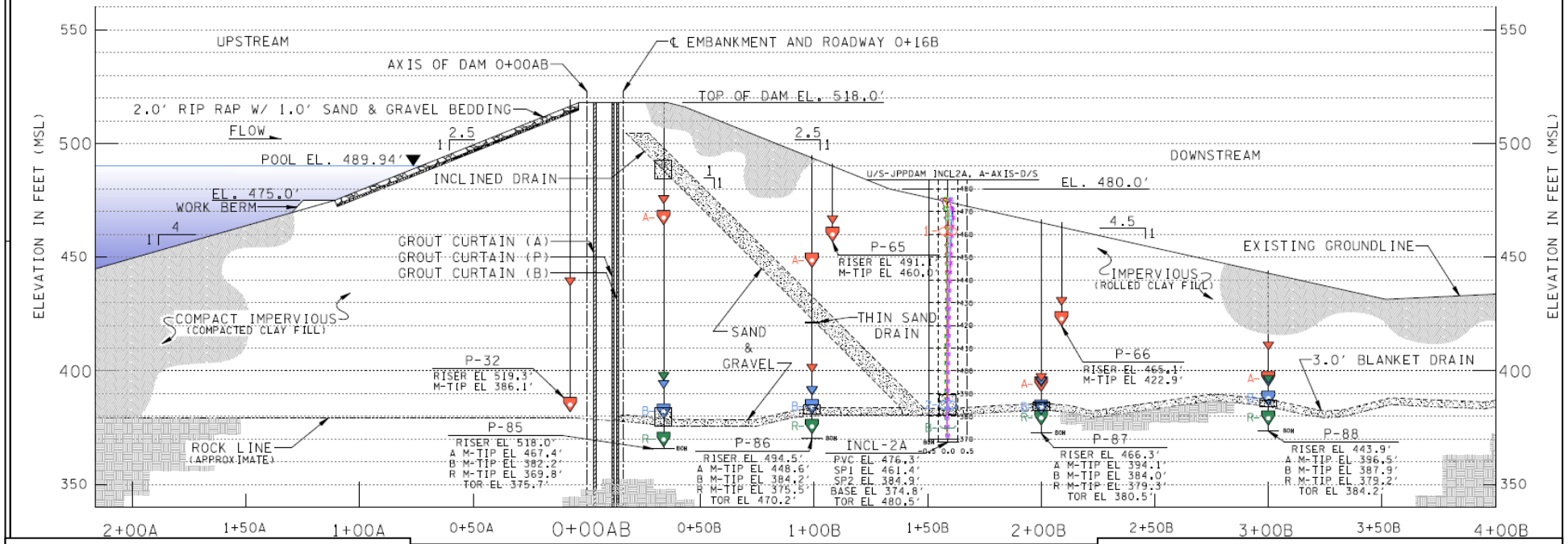
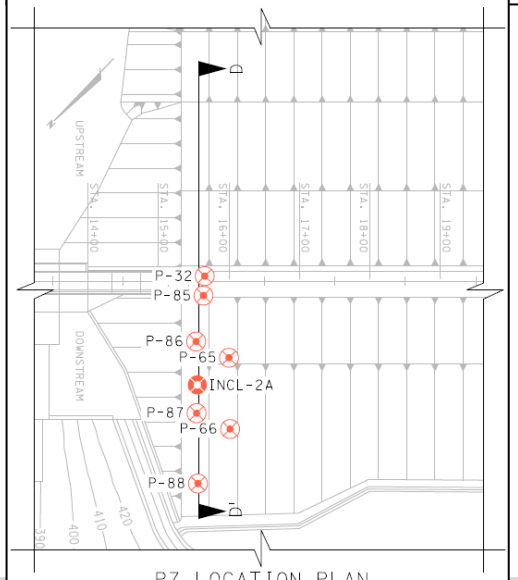
Static Section Templates





PZ LOCATION PLAN
N.T.S.

PZ-ID	LOCATION NORTHING	EASTING	STATION	OFFSET	TOP OF PVC ELEVATION	TOP OF CONCRETE PAD ELEVATION	MID-TIP ELEVATION	PIEZOMETER LOCATION
P-85A	13127722.62	1752824.35	15+63.96	33.76 (+)	518.02	516.53	467.4	EMBANKMENT
P-85B					518.02		382.2	BLANKET DRAIN
P-85R					518.03		369.8	BEDROCK
P-86A	13127776.70	1752786.27	15+53.46	99.07 (+)	494.45	492.86	448.6	EMBANKMENT
P-86B					494.49		384.2	BLANKET DRAIN
P-86R					494.48		375.5	BEDROCK
P-87A	13127848.31	1752715.04	15+54.44	200.07 (+)	466.25	464.65	394.1	EMBANKMENT
P-87B					466.30		384.0	BLANKET DRAIN
P-87R					466.23		379.3	BEDROCK
P-88A	13127918.94	1752644.62	15+55.54	299.80 (+)	443.89	442.23	396.5	EMBANKMENT
P-88B					443.90		387.9	BLANKET DRAIN
P-88R					443.91		379.2	BEDROCK
P-32	13127692.34	1752852.21	15+65.16	7.37 (-)	519.28	516.44	386.1	EMBANKMENT
P-65	13127751.07	1752746.97	15+99.49	108.15 (+)	491.13	488.50	460.0	EMBANKMENT
P-66	13127822.14	1752675.45	16+01.06	208.97 (+)	465.08	462.10	422.9	EMBANKMENT

NOTES:
ALL MEASUREMENTS ARE PRESENTED IN FEET.
(+) INDICATES OFFSETS RIGHT OF DAM AXIS (DOWNSTREAM).
UTM COORDINATES, ELEVATIONS ARE BASED ON BENCH MARK RM-2=518.109'.

LEGEND:

- SAND DRAIN LAYERS ENCOUNTERED DURING DRILLING.
- SAND DRAIN LAYERS AND ESTIMATED ROCKLINE TAKEN FROM DRAWINGS PROVIDED BY U.S. ARMY CORPS OF ENGINEERS, NASHVILLE DISTRICT.
- PZ PIPE, MID-TIP LOCATION & AUG 2011 WATER LEVEL
- 2-⊗ MAGNET EXTENSOMETER
- TOP OF ROCK ENCOUNTERED DURING DRILLING
- WATER LEVELS REFLECT LATEST 2011 READINGS

SCALE: 1" = 20'
20' 0 20'
Graphic Scale

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U.S.ARMY

Project Information Models

- Interactive Features and Attributes
- Comprehensive Data Visualization
- Improve Data Evaluation
- Data Driven Decisions
- Facilitate Communication

Data Analysis

Evaluation

Recommendation

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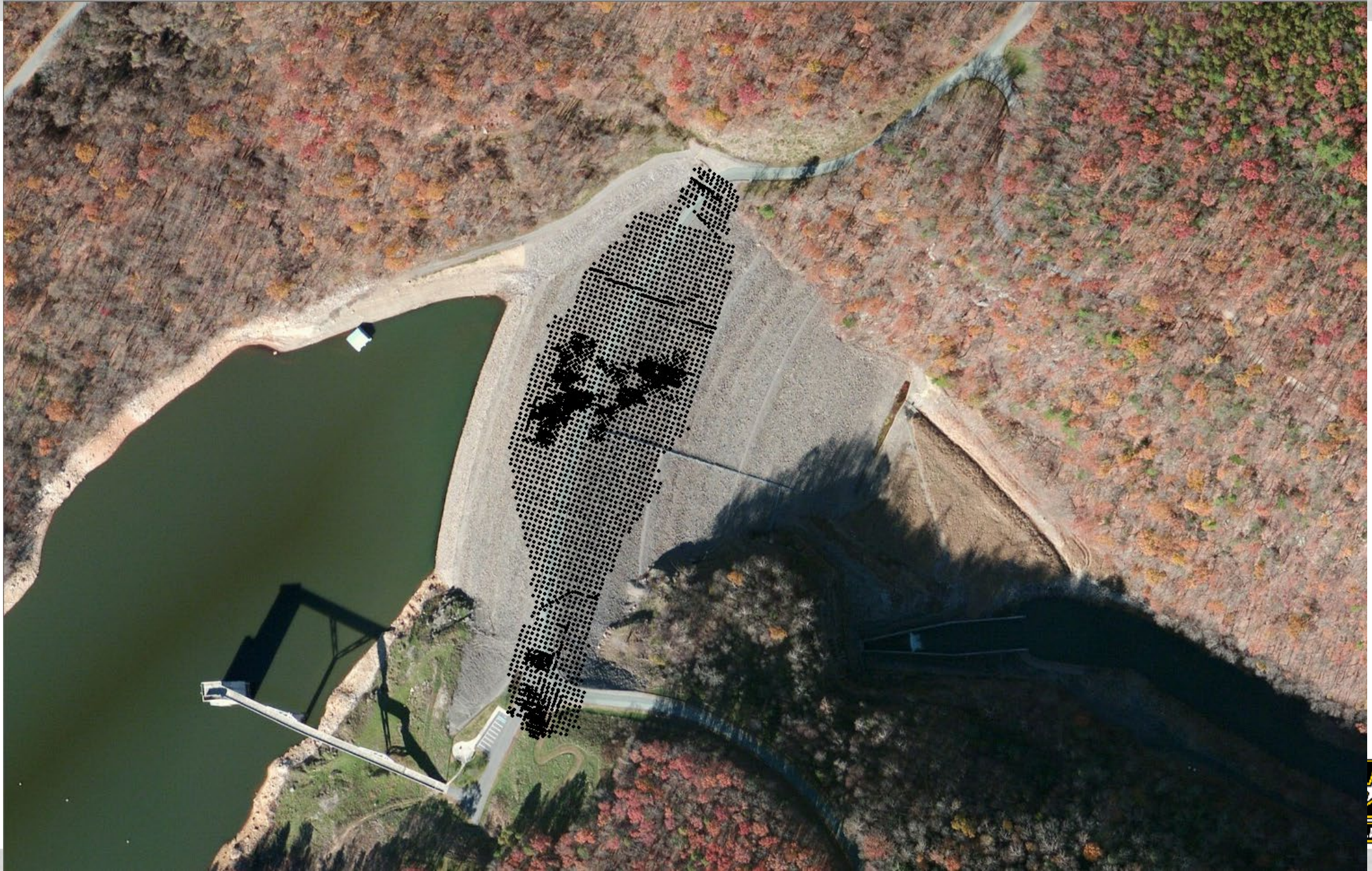
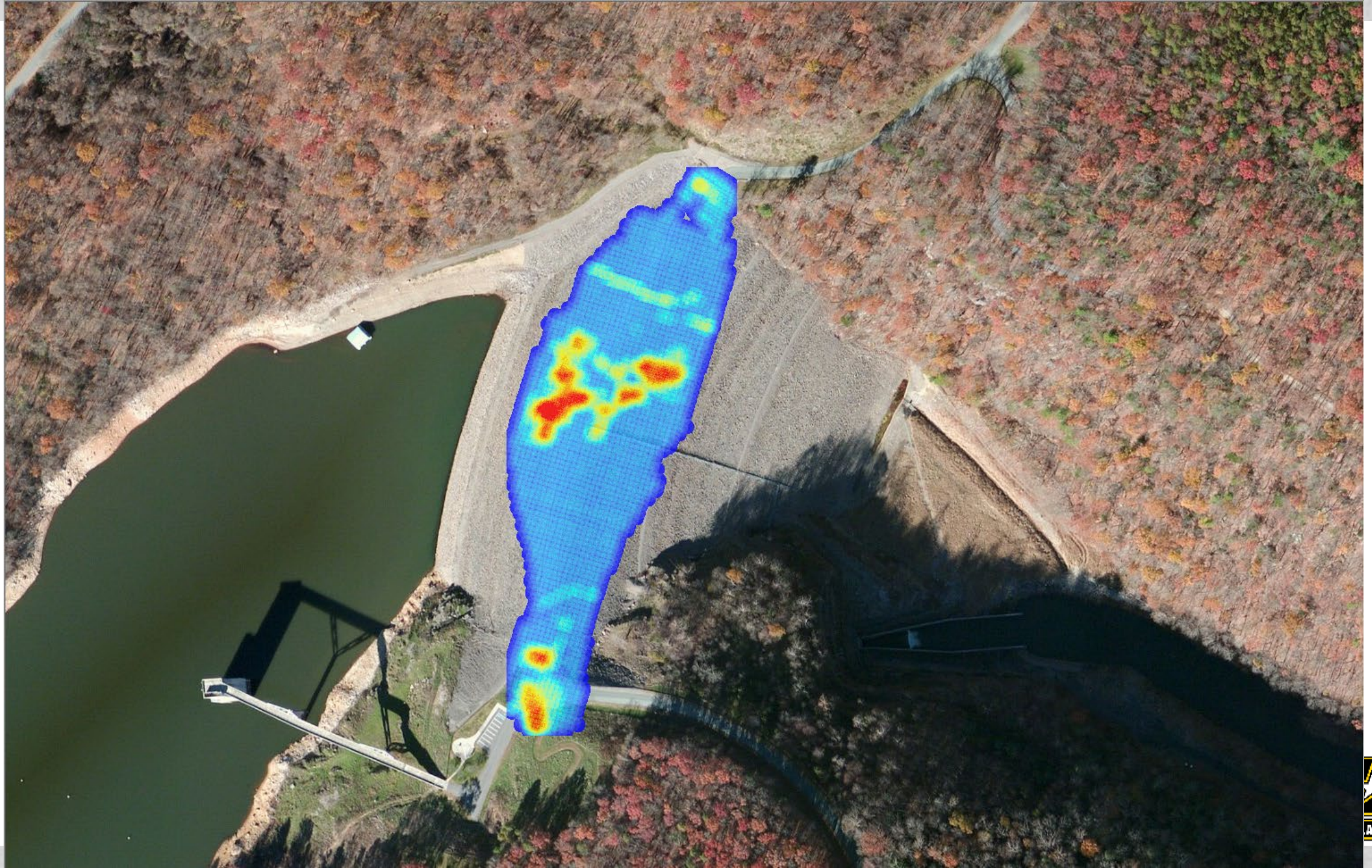
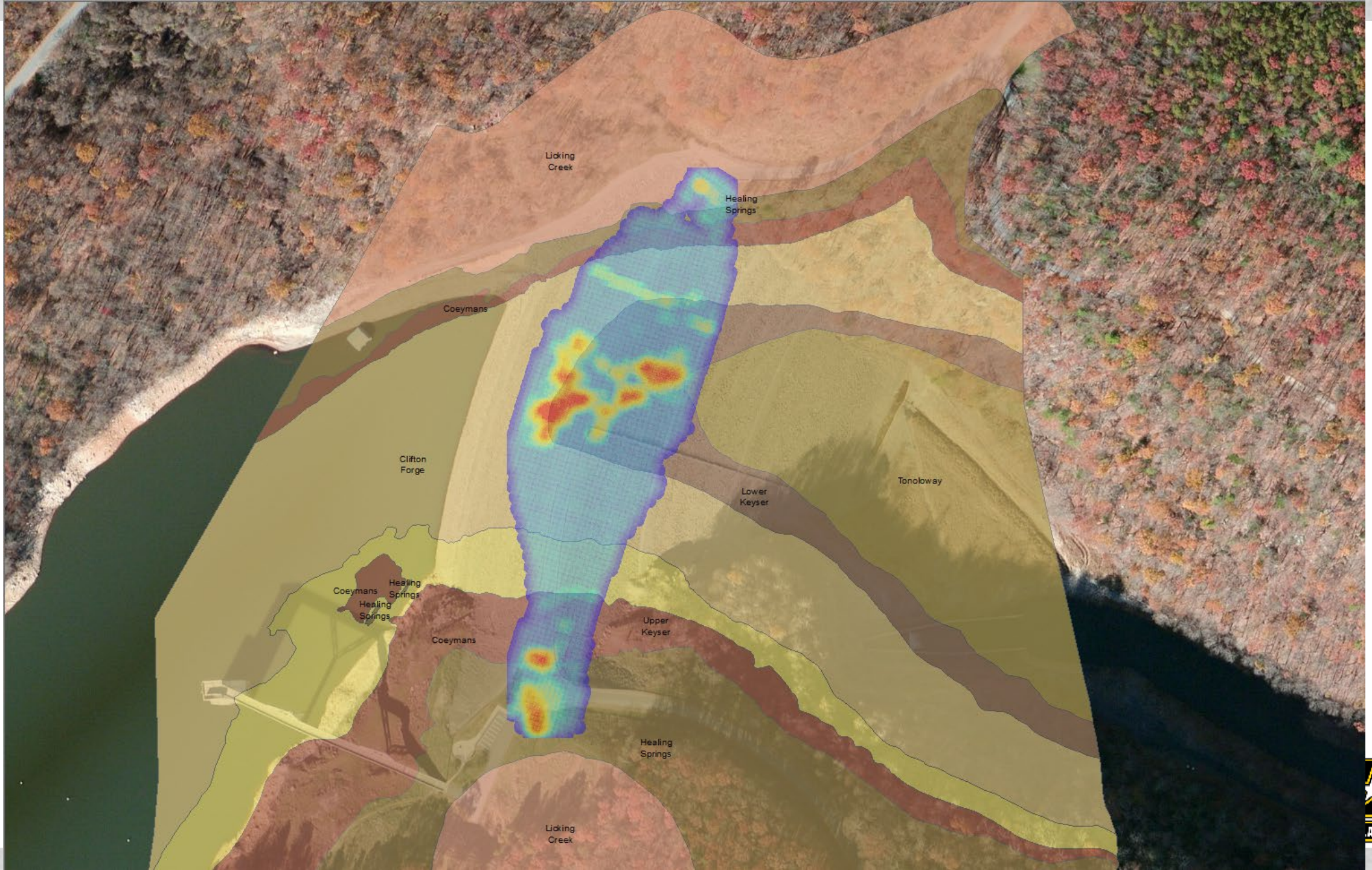
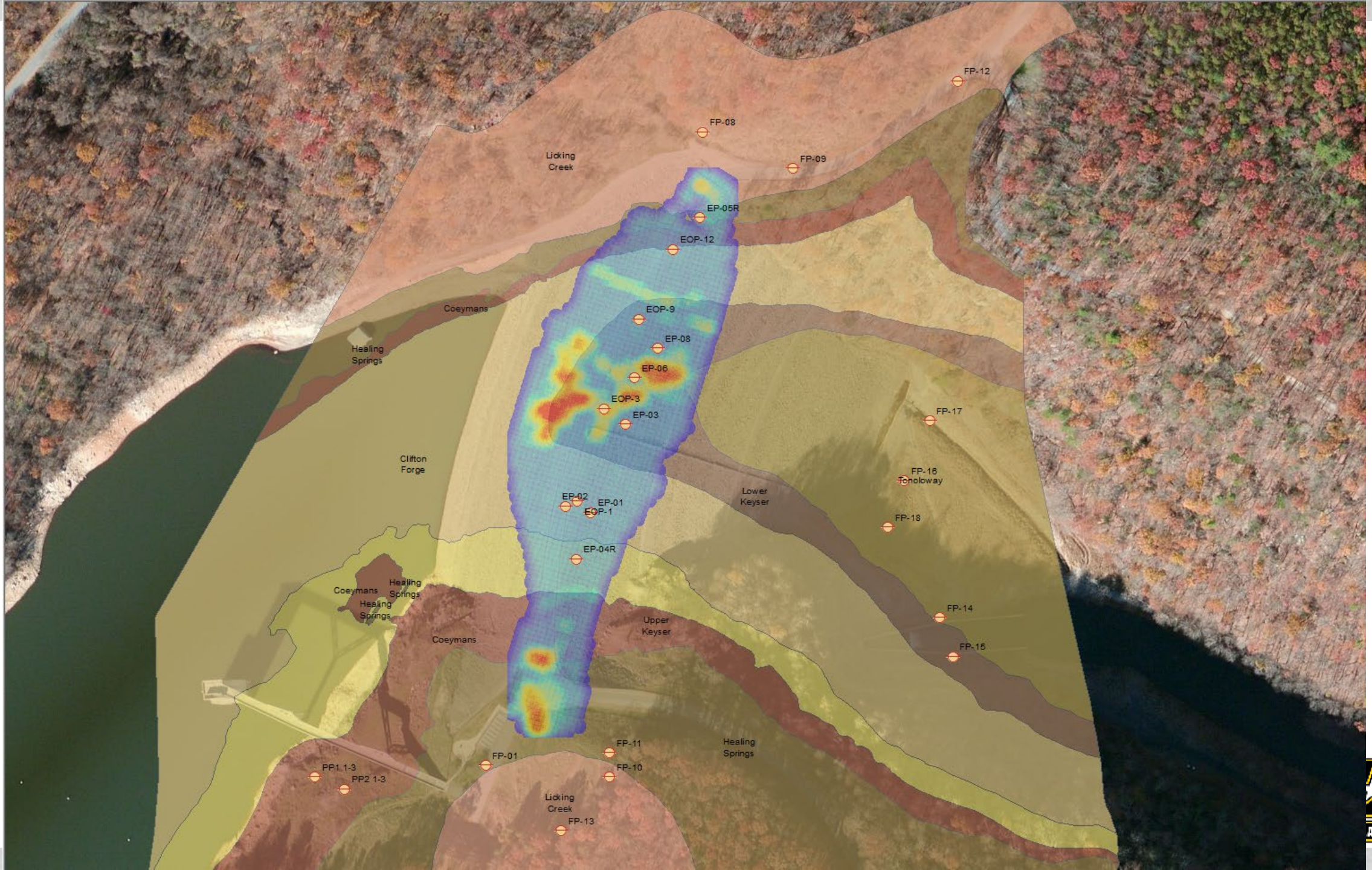
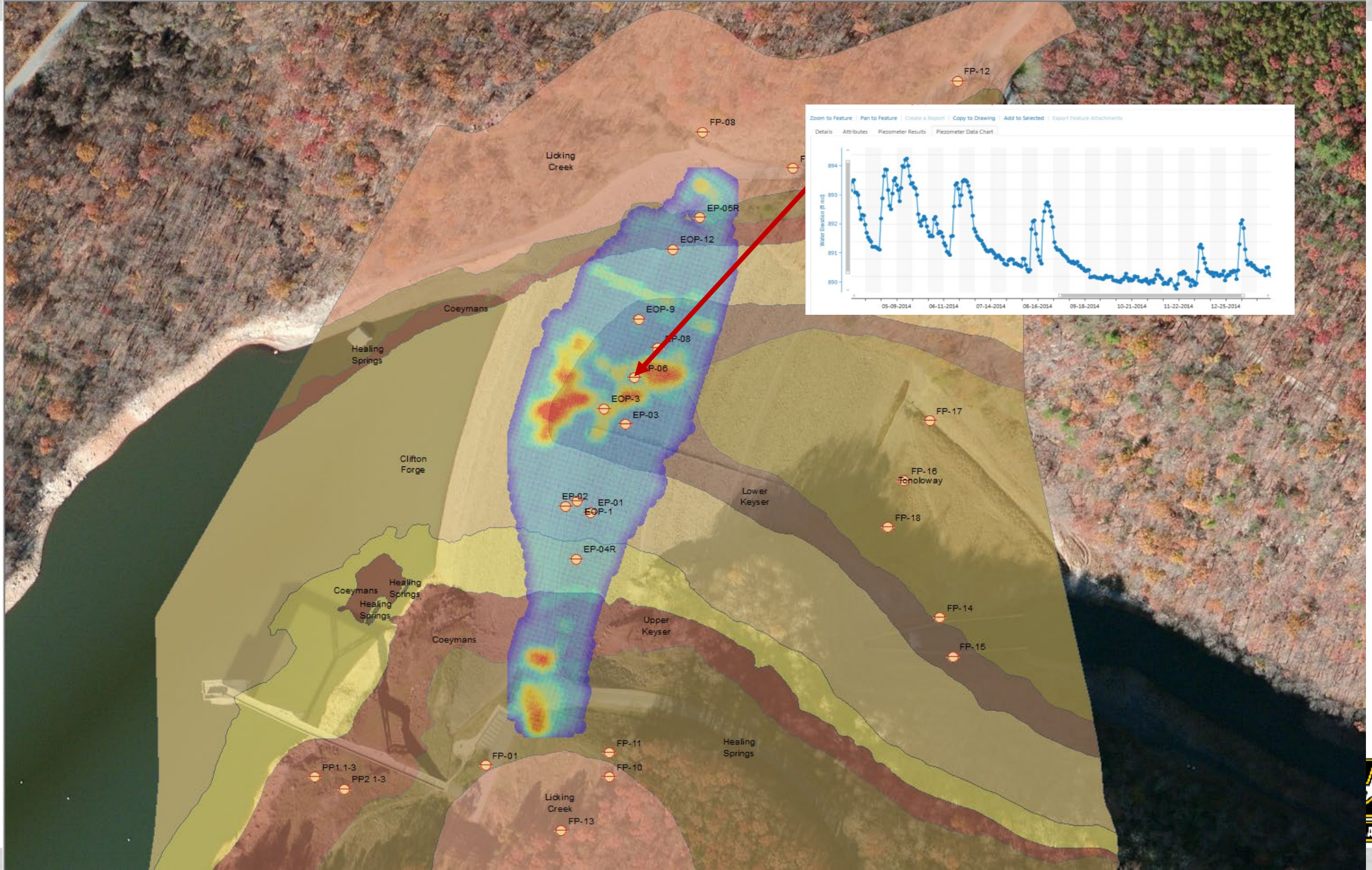
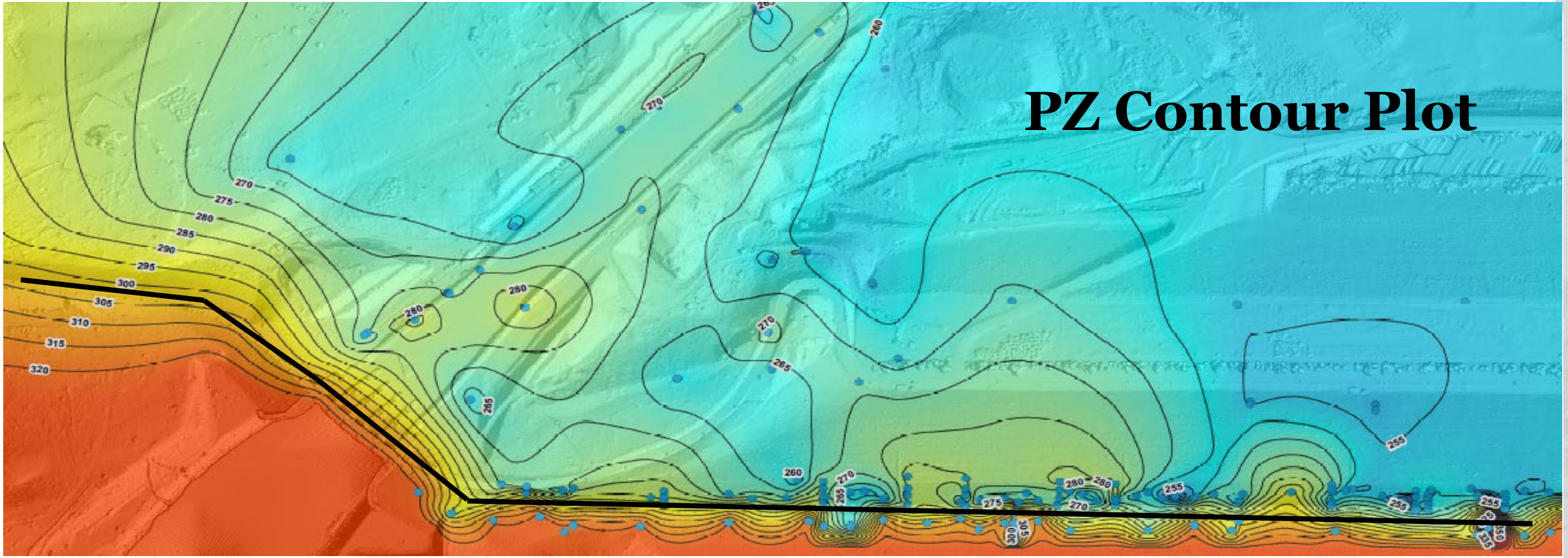


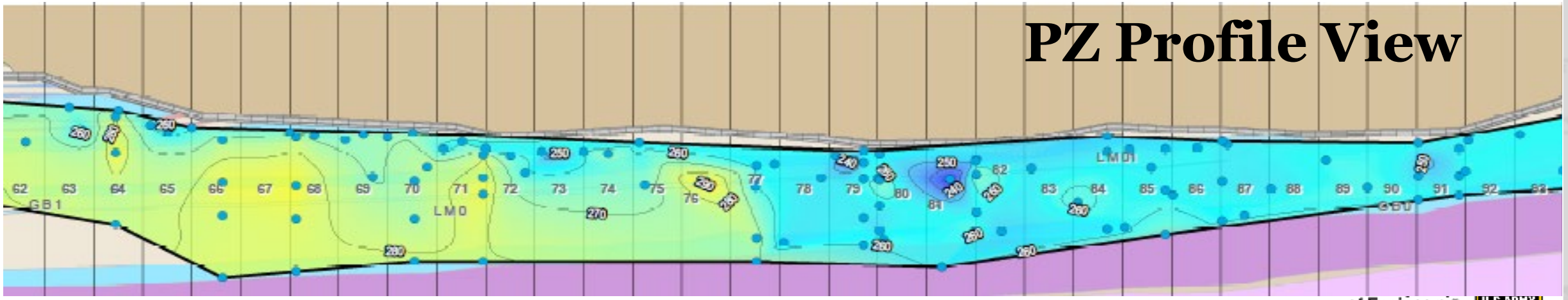



Licking Creek
Healing Springs
Coeymans
Clifton Forge
Lower Keyser
Tonoloway
Coeymans
Healing Springs
Coeymans
Healing Springs
Upper Keyser
Coeymans
Healing Springs
Licking Creek


FP-12
FP-08
Licking Creek
FP-09
EP-05R
EOP-12
Coeymans
EOP-9
Healing Springs
EP-08
EP-06
EOP-3
EP-03
FP-17
Clifton Forge
FP-16
Tonoloway
Lower Keyser
EP-02
EP-01
EOP-1
FP-18
EP-04R
Coeymans
Healing Springs
Coeymans
Healing Springs
FP-14
Upper Keyser
Coeymans
FP-15
FP-11
Healing Springs
FP-01
PP1 1-3
FP-10
PP2 1-3
Licking Creek
FP-13


FP-12
FP-08
Licking Creek
EP-05R
EOP-12
Coeymans
EOP-9
EP-08
Healing Springs
EP-06
EOP-3
EP-03
FP-17
Clifton Forge
FP-16
Tonoloway
Lower Keyser
EP-02
EP-01
EOP-1
FP-18
EP-04R
Coeymans
Healing Springs
Coeymans
Healing Springs
Upper Keyser
FP-14
FP-15
FP-11
FP-01
Healing Springs
PP1 1-3
FP-10
PP2 1-3
Licking Creek
FP-13
Zoom to Feature
Pan to Feature
Create a Report
Copy to Drawing
Add to Selected
Export Feature Attachments
Details
Attributes
Piezometer Results
Piezometer Data Chart
Water Elevation (ft msl)
894
893
892
891
890
05-09-2014
06-11-2014
07-14-2014
08-16-2014
09-18-2014
10-21-2014
11-22-2014
12-25-2014





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Grout Take Volumes

- Low
- Medium Low
- Medium
- Medium High
- High

Rock Type

- Marl
- Limestone
- Gypsum Breccia
- Gypsum/Anhy

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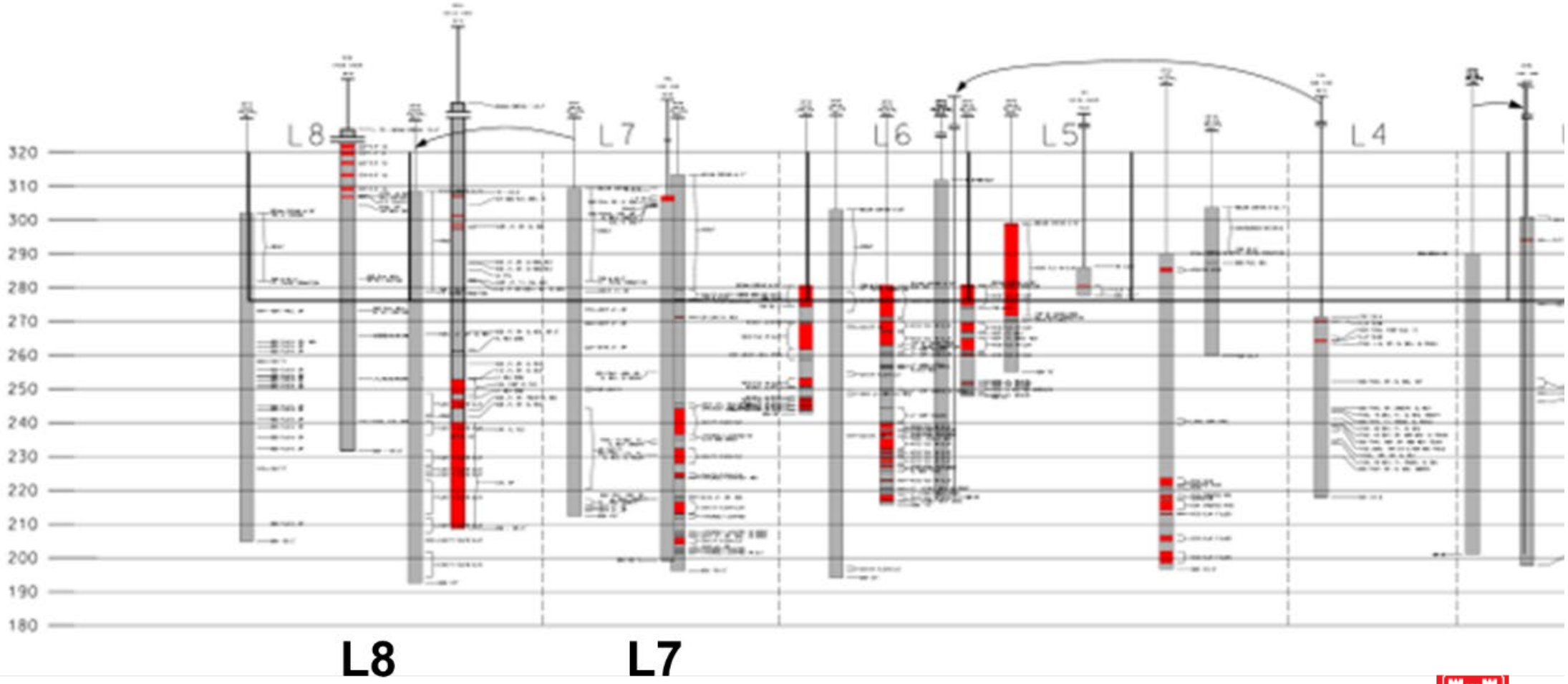
Sometimes 2D is not enough



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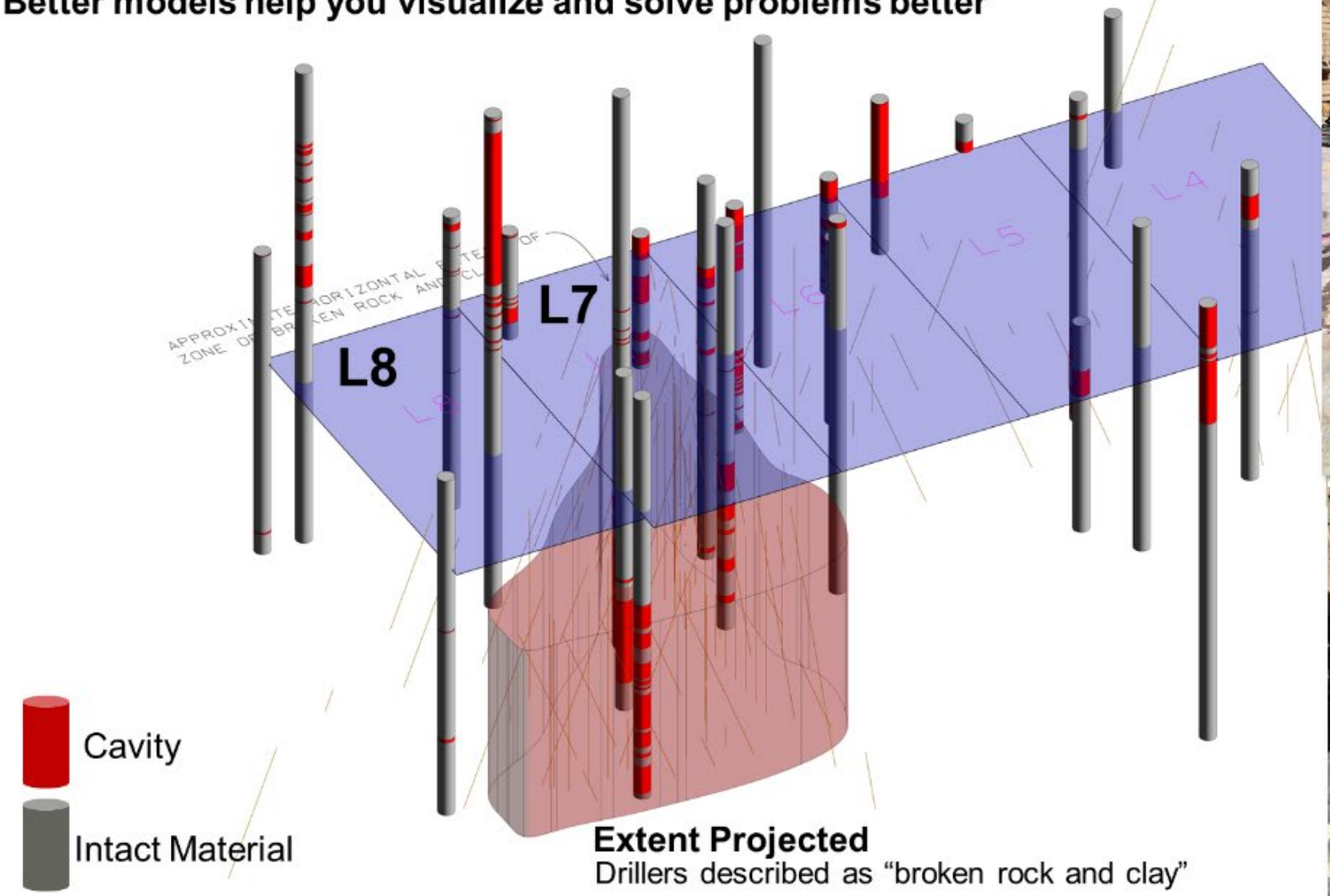
Better models help you visualize and solve problems better



Extent Projected
Drillers described as “broken rock and clay”

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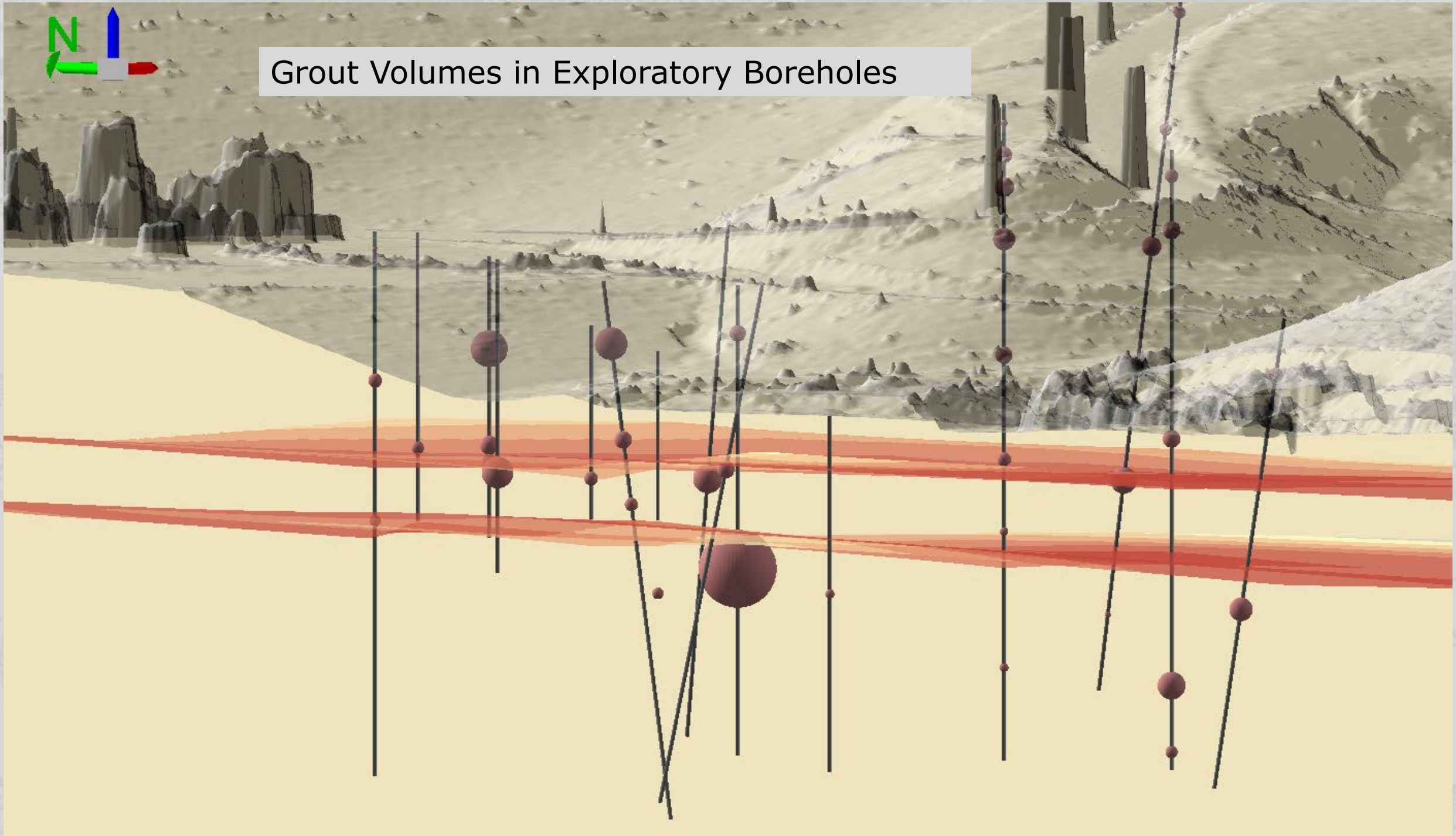
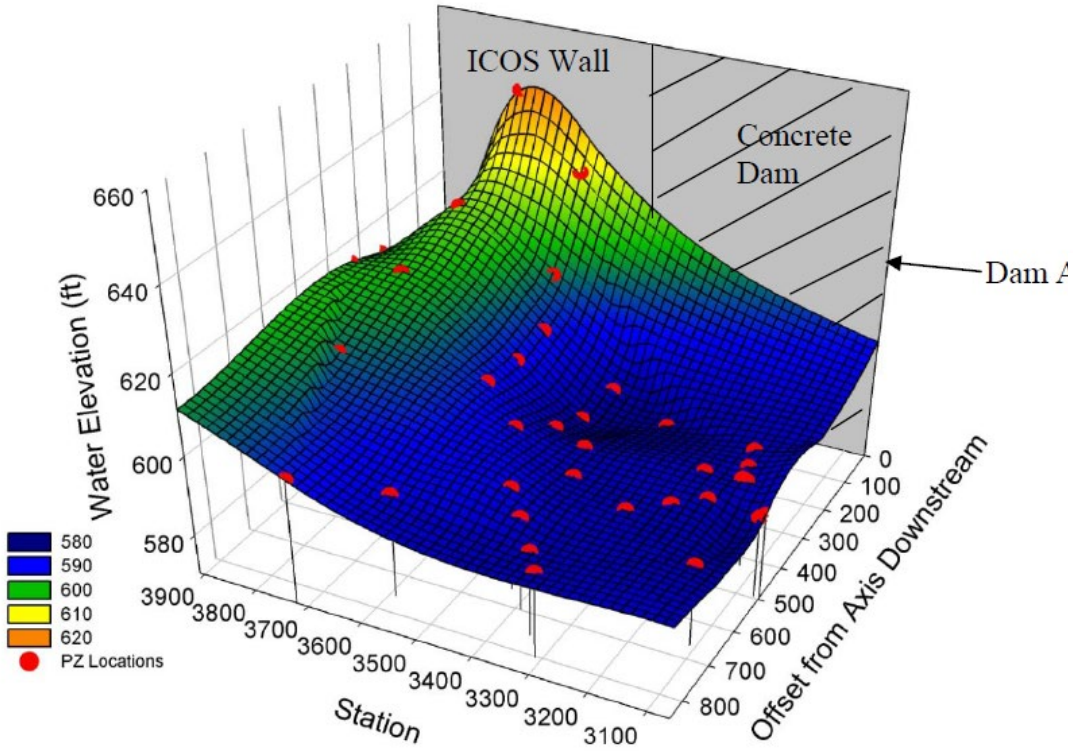
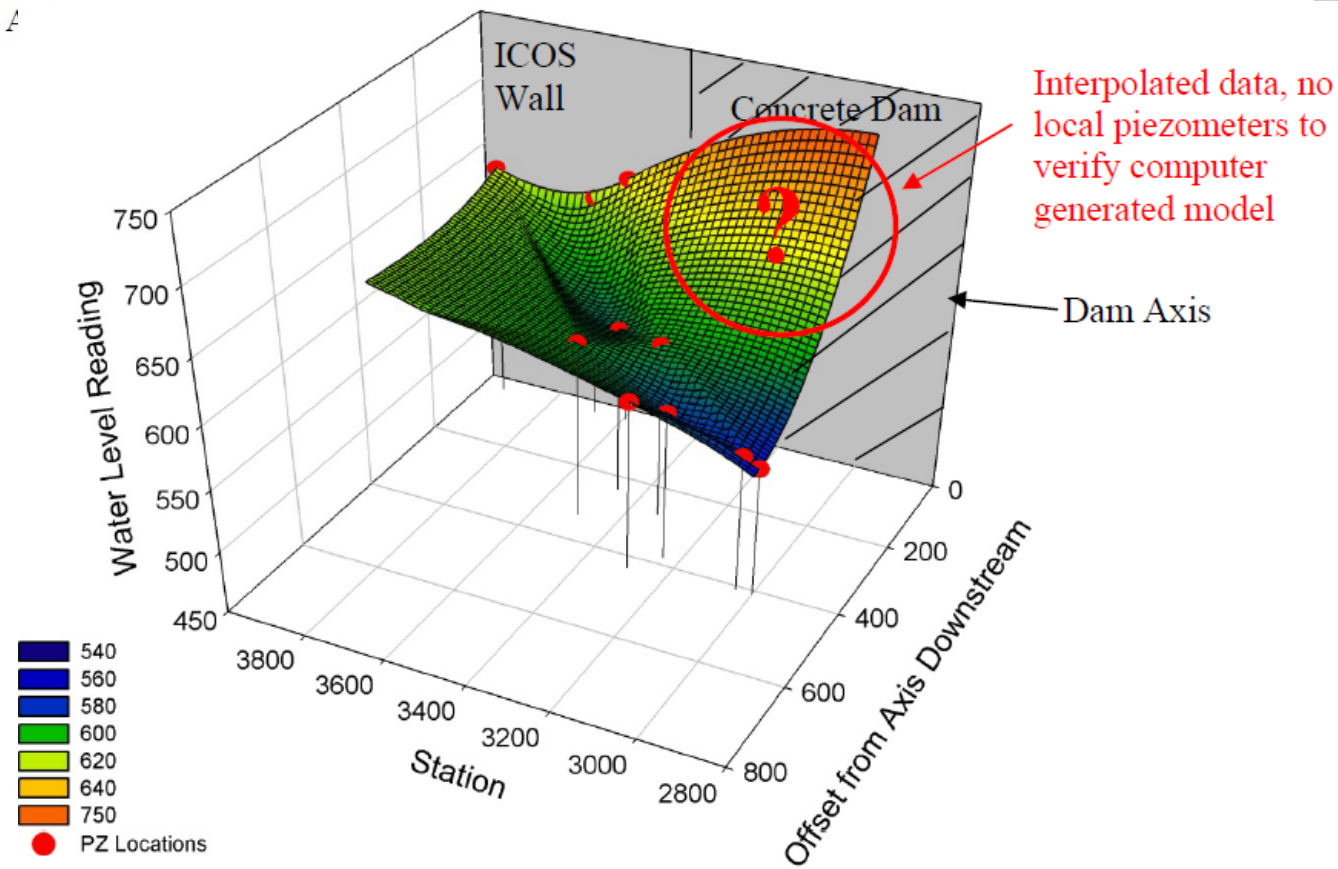

N
Grout Volumes in Exploratory Boreholes

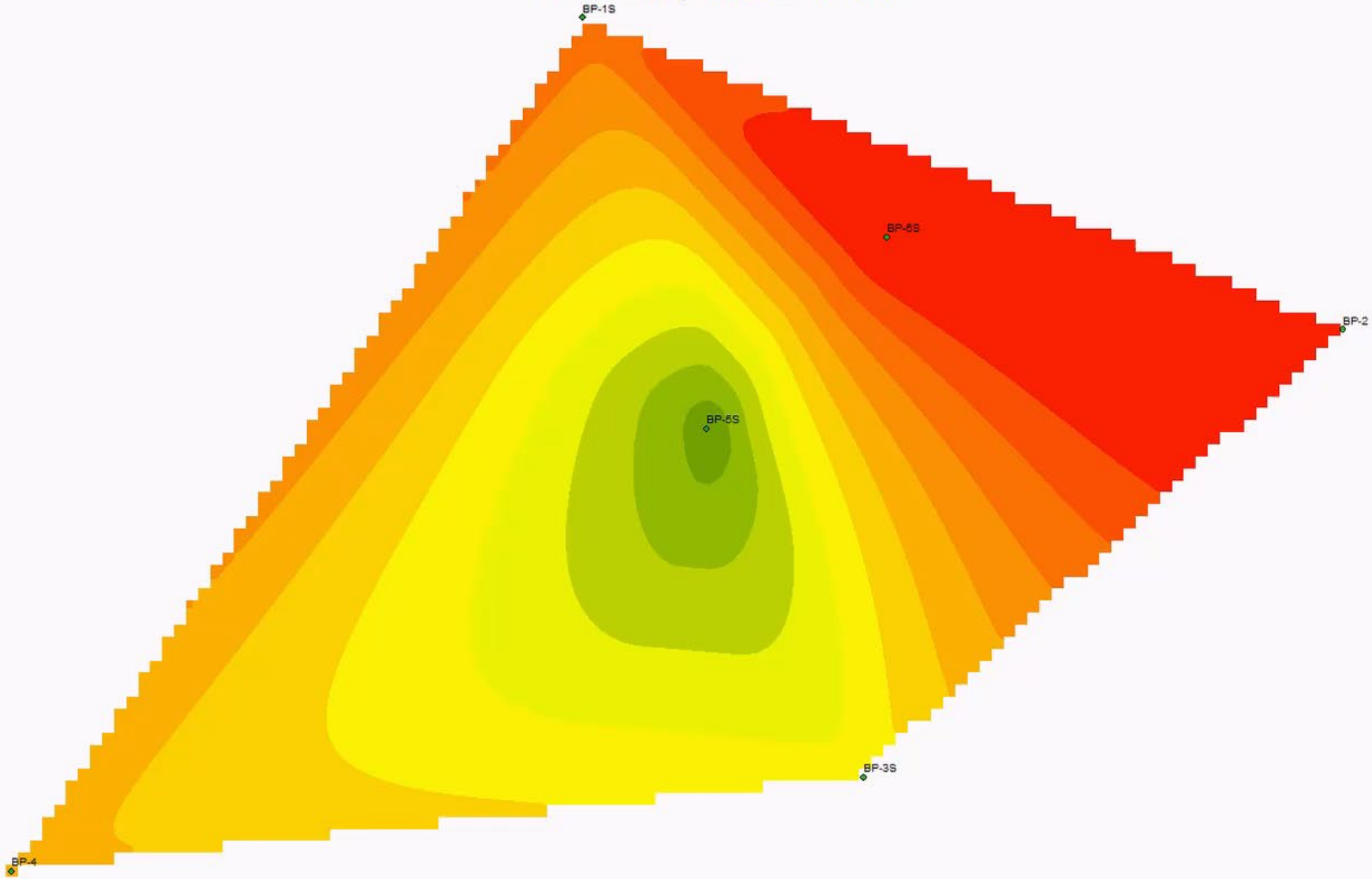
3D Plots



All PZ's in Alluvium

All PZ's in Rock




Max PZ Reading: 11/10/2021 12:15 AM
BP-1S
BP-6S
BP-2
BP-5S
BP-3S
BP-4

That's great for long-term monitoring and evaluation…
…but what about monitoring during Construction??


Center Hill


Chickamauga Lock


Wolf Creek Da

LOTS!!!! of Construction equipment comes with automated monitoring.

Your project is changing fast

(Are you looking at that data?)

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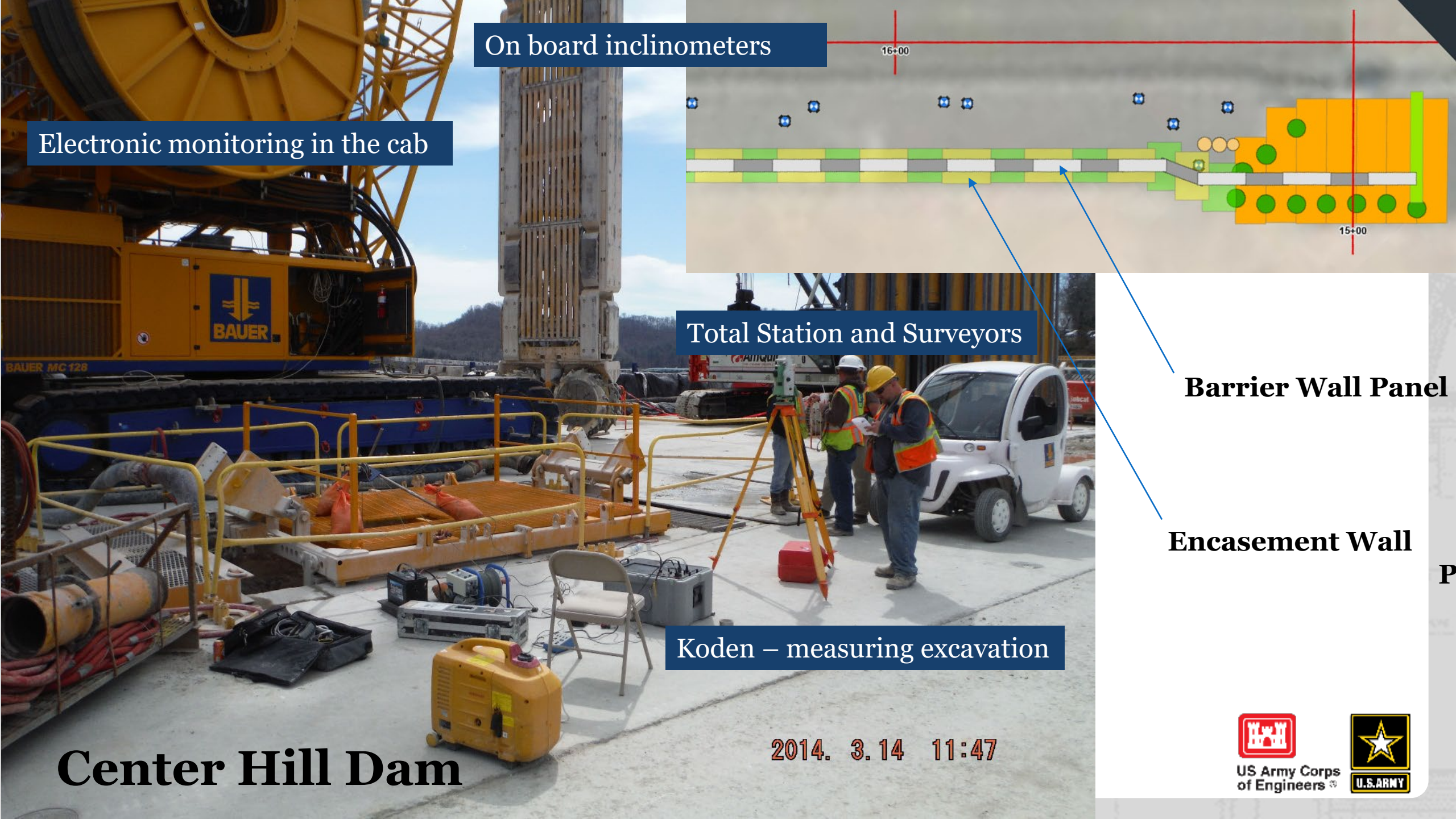

Center Hill Dam

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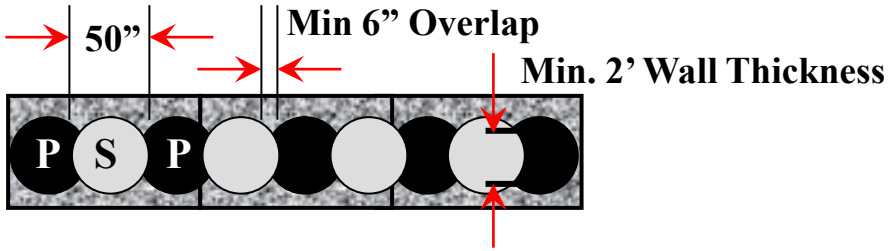

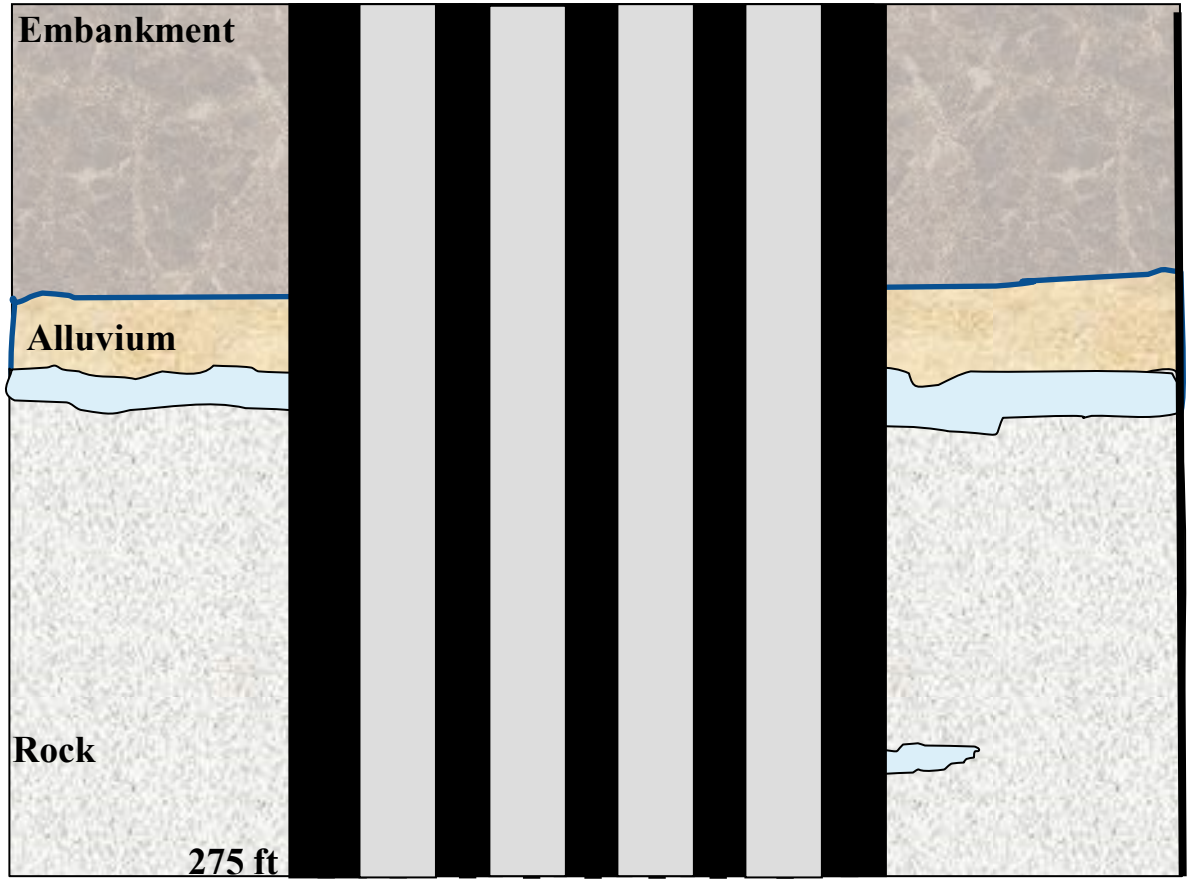

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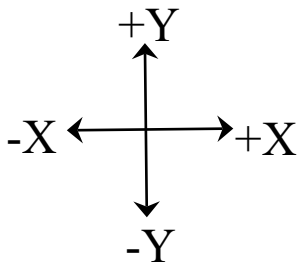
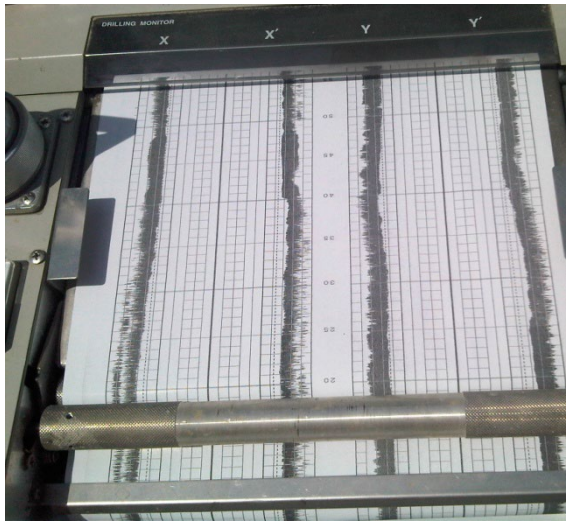
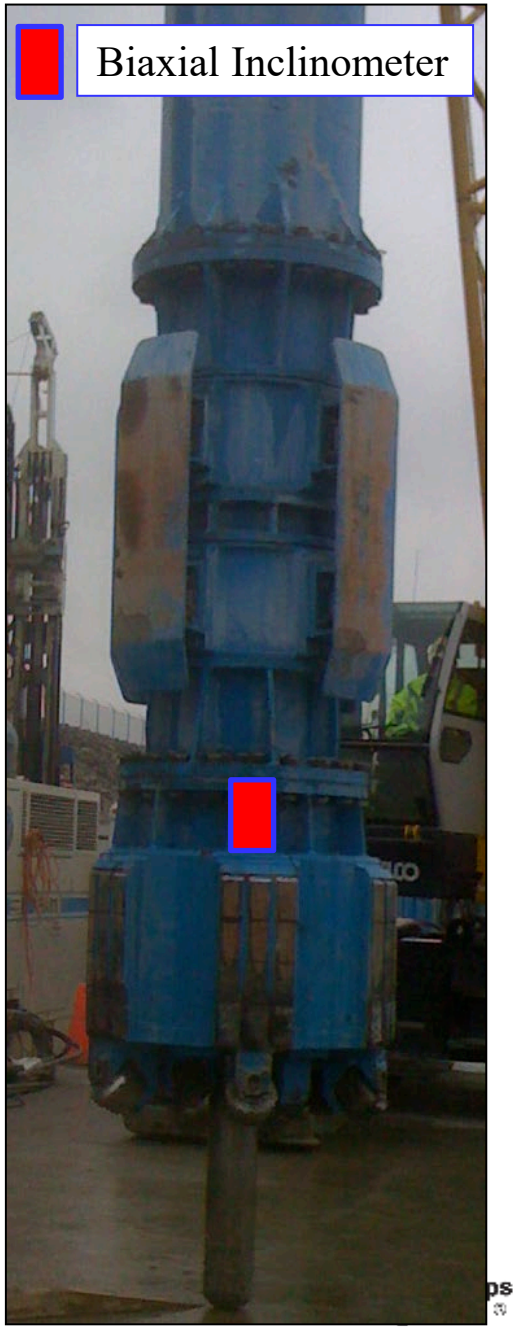
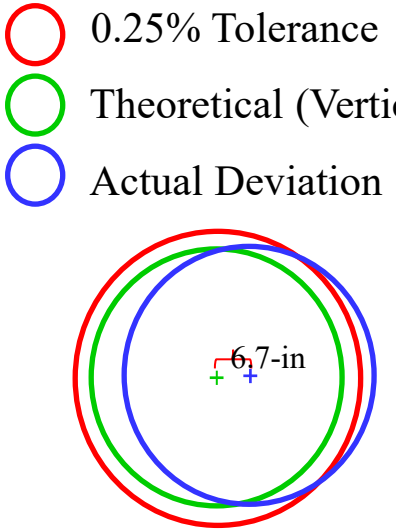
Secant Pile Verticality

- Biaxial Inclinometer
  - ▶ Multiple Shots to Reduce Error
- KODEN
  - ▶ Dimensions of Final Excavation

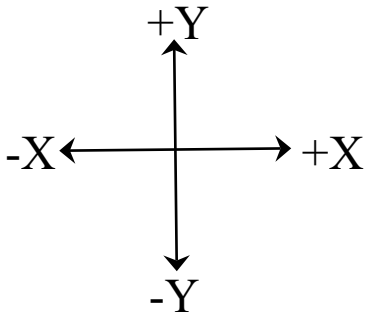








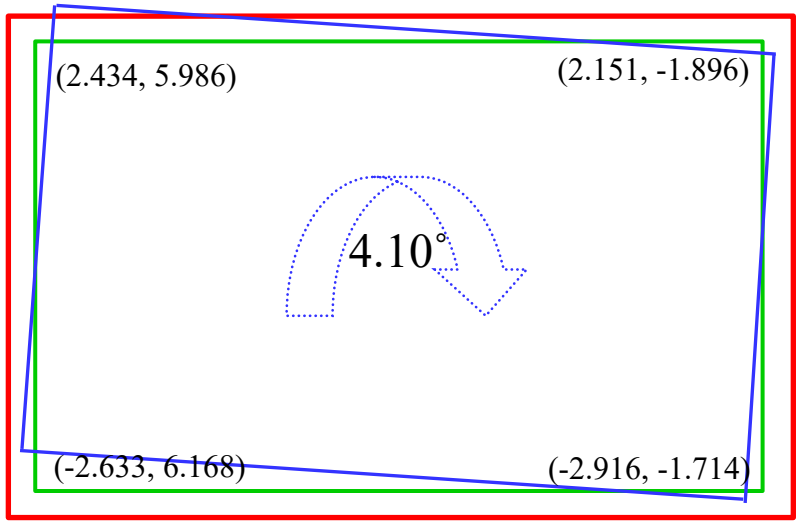
Panel Verticality



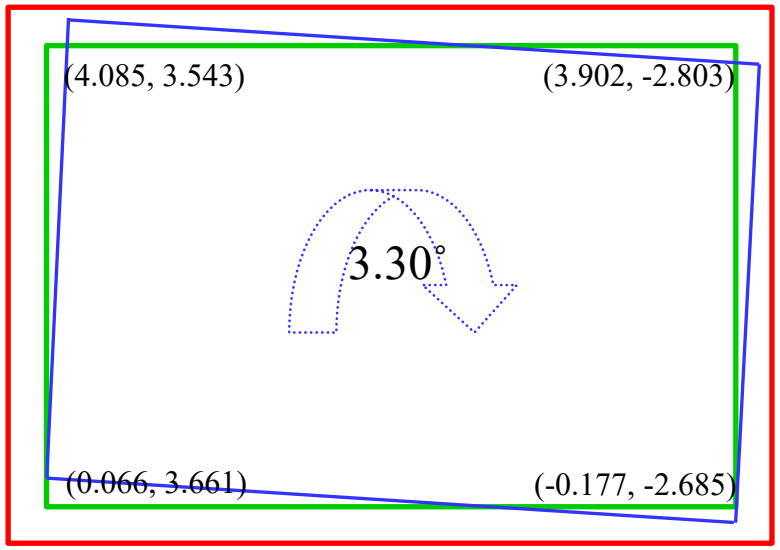
0.25% Tolerance

Theoretical (Vertical)

Actual Deviation



Section Cut @ 120-ft



Section Cut @ 166-ft

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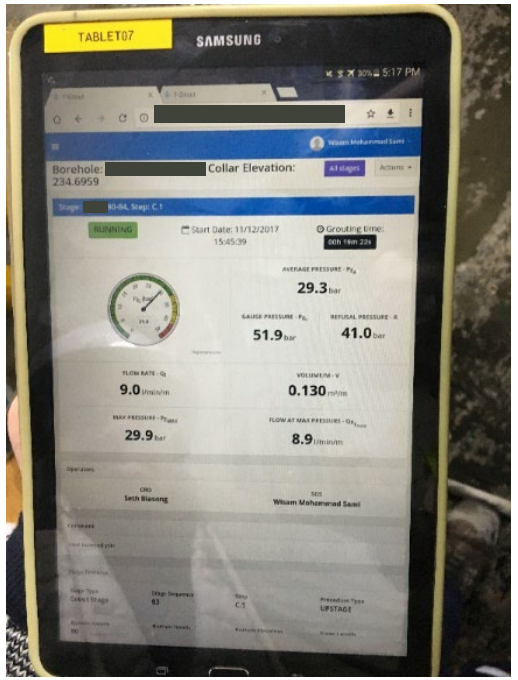
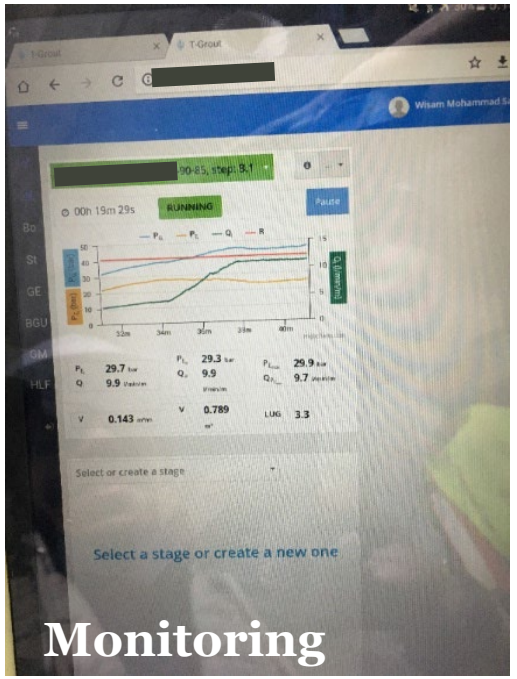
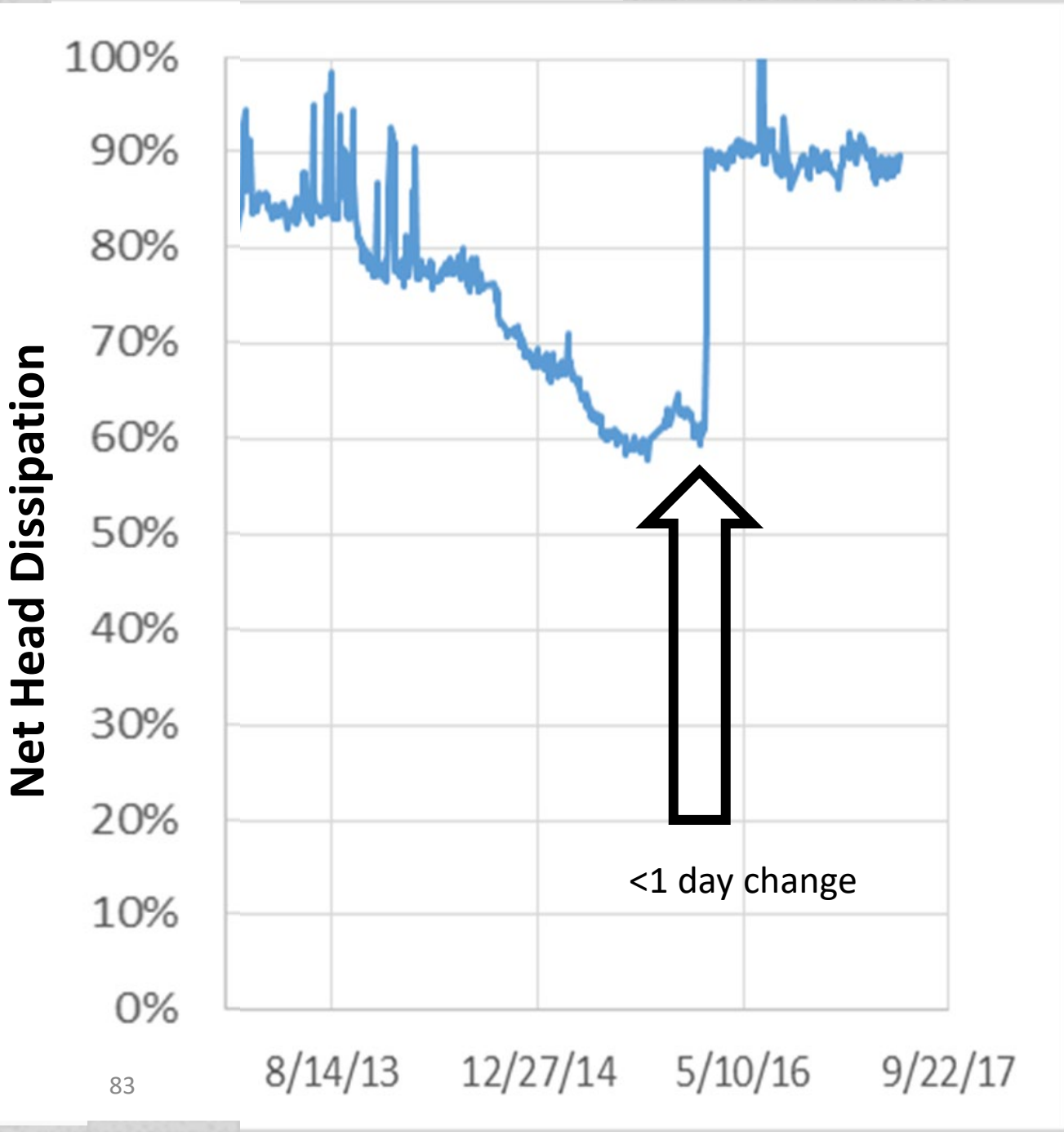
Drilling


TABLET07
SAMSUNG
Borehole:
Collar Elevation:
234.6959
RUNNING
29.3
51.9
41.0
9.0
0.130
29.9
8.9


Select a stage or create a new one
Monitoring


Grouting
Mosul Dam Grouting Project


LIVE
Mosul Dam
We need information at the speed of relevance

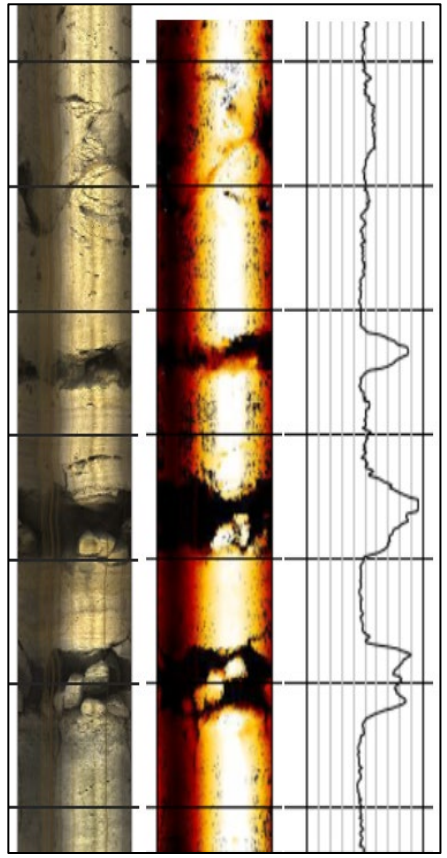

Net Head Dissipation
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
8/14/13
12/27/14
5/10/16
9/22/17
<1 day change


Wolf Creek Dam
We are generating a huge amount of data FAST

We are gathering data in so many ways

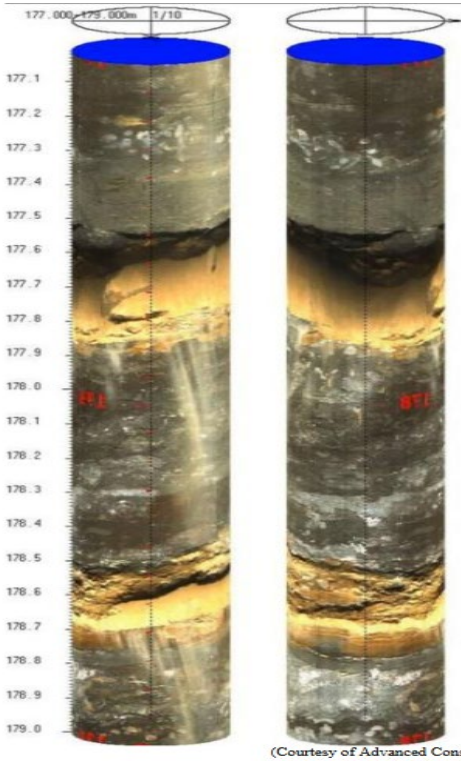
200208-A-BO243-1046

Brooke Hubbard, a civil engineer from the Unmanned Aerial Vehicle (UAV) section with the Jacksonville District explains technology used to U.S. Army Corps of Engineers' South Atlantic Division senior enlisted adviser Command Sgt. Maj. Chad C. Blansett during a recent visit Feb. 8, 2021. (USACE photo by Mark Rankin)



Mosul Dam

Wolf Creek



Optical Televiewer

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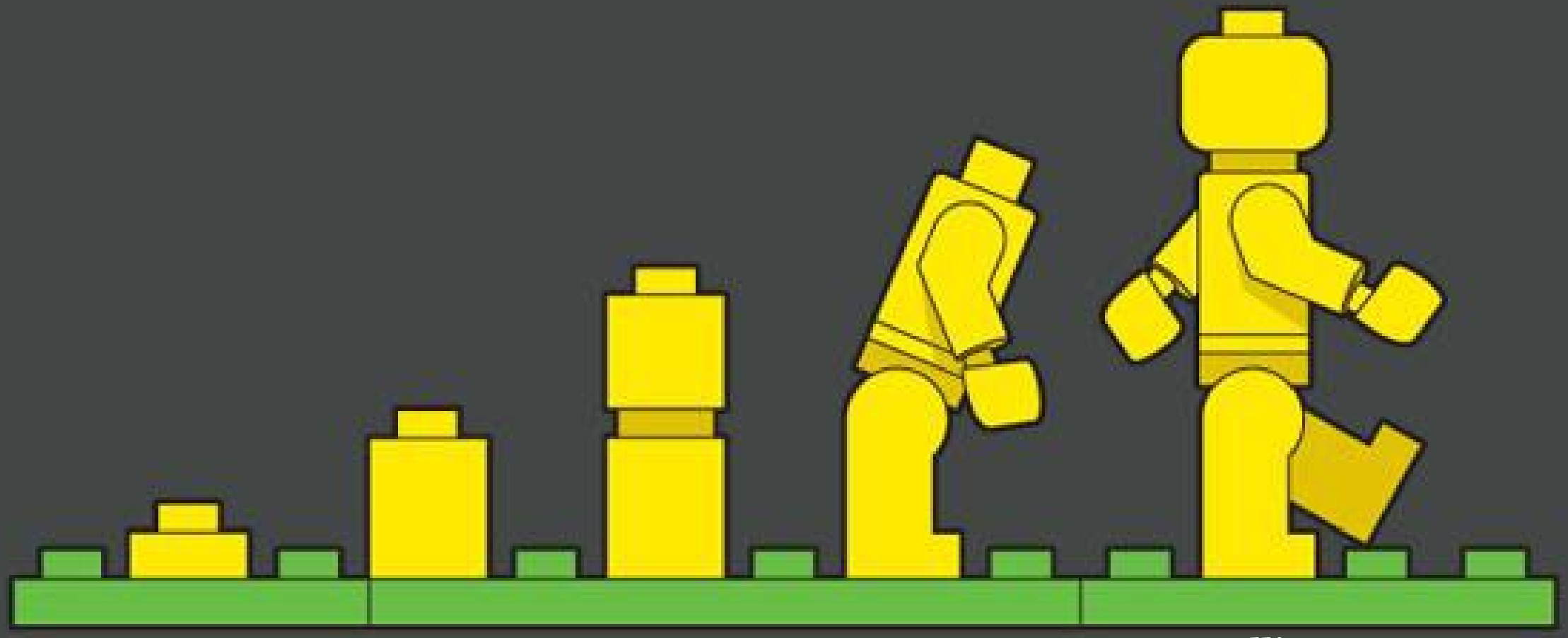
EXPECT!!! To Change with Technology



Plumb Bob
& Paper

Satellite Imagery
Smart Phones
Databases & GIS
Automation!

Changes in Data Management

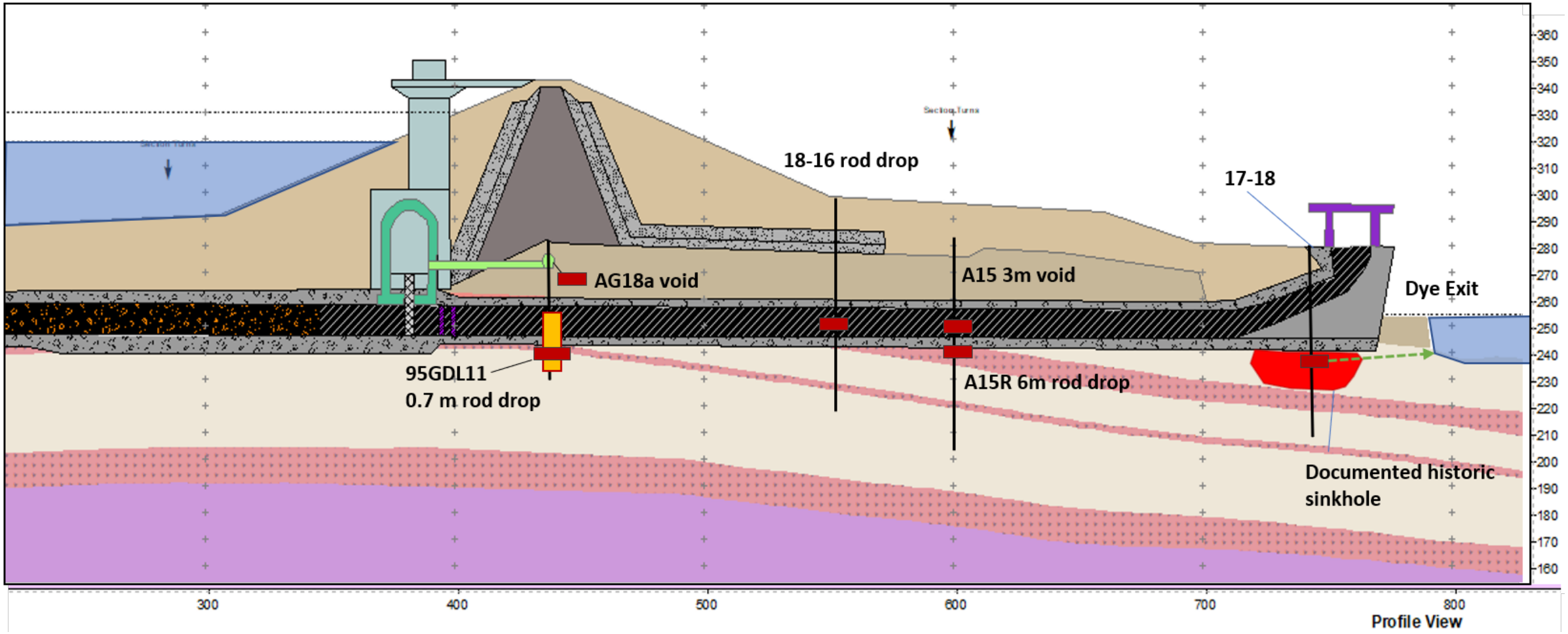
Imagine Getting the data for all these instruments

And all the construction data

- **4,850 holes** drilled & grouted to completion
- **348,652 m** length of drilling
- **39,227 m³ of grout** (22,177 tons of solids)
  - 1.3 Washington Monuments by Volume

- Pore Pressure Cells
- Earth Pressure Cells
- Extensometers
- Inclinometers
- Pendulums
- Accelerometers
- Manual Water Level Gauges
- Survey Monitoring Points
- Weirs

While Simultaneously building and updating the subsurface information – including still finding historical data



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Unified Facilities Guide Specifications

[01 31 20 Project Technical Data Management and Visualization]

3.2.2.1 Raw Data

Provide digital raw and appended raw data files of the automated grouting control and data collection system in .csv format and load to the appropriate location of the SFTP site within 12 hours for raw data and 24 hours for appended raw data. Format raw data files, or appended data files if not an option for raw data, such that the field headers have names that allow the user to understand what date they contain.

3.2.2.2 Processed Data

Provide grouting and water pressure testing data to all required fields of the EDB as detailed in the data dictionary, provided in the Volume [_____] attachments. Differentiate water pressure testing records in the naming convention and in the EDB records in accordance with the provided data dictionary.

3.2.2.3 Reports

Furnish records of pay quantities to the [COR][ACO] within 24 hours for the previous day's activities. Submit daily records in the form of drilling and grouting reports with the daily log of construction.

Include in the drilling report:

(1) The location and station/offset of each hole drilled;
(2) The date;
(3) Drill rig identification;
(4) Inclination and azimuth;
(5) Time drilling was started and stopped;
(6) Rock type and condition if core is logged;
(7) Any unusual drilling conditions encountered;

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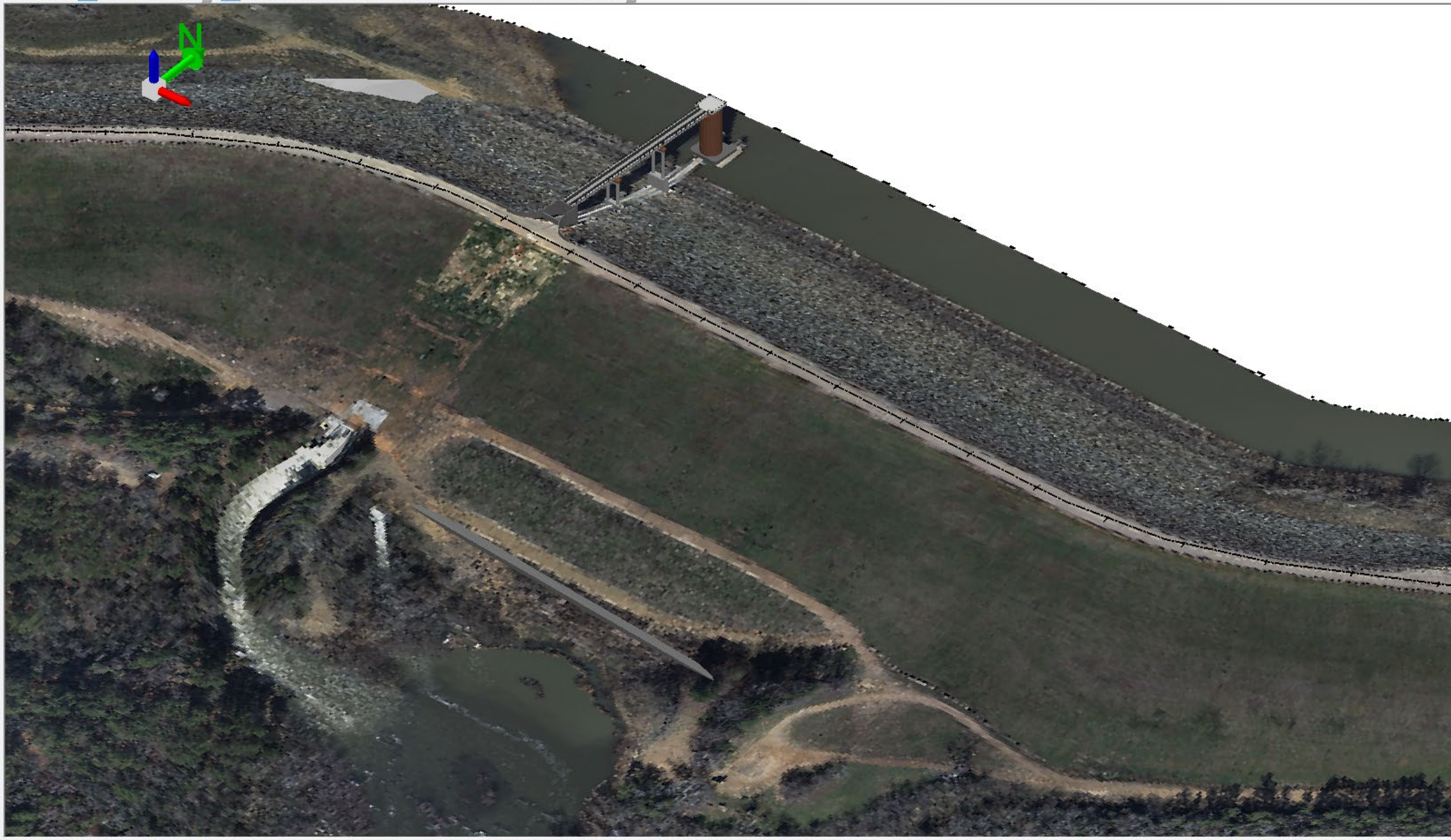
simdam-pine_creek.sxd - ArcScene

File Edit View Bookmarks Selection Geoprocessing Customize Windows Help

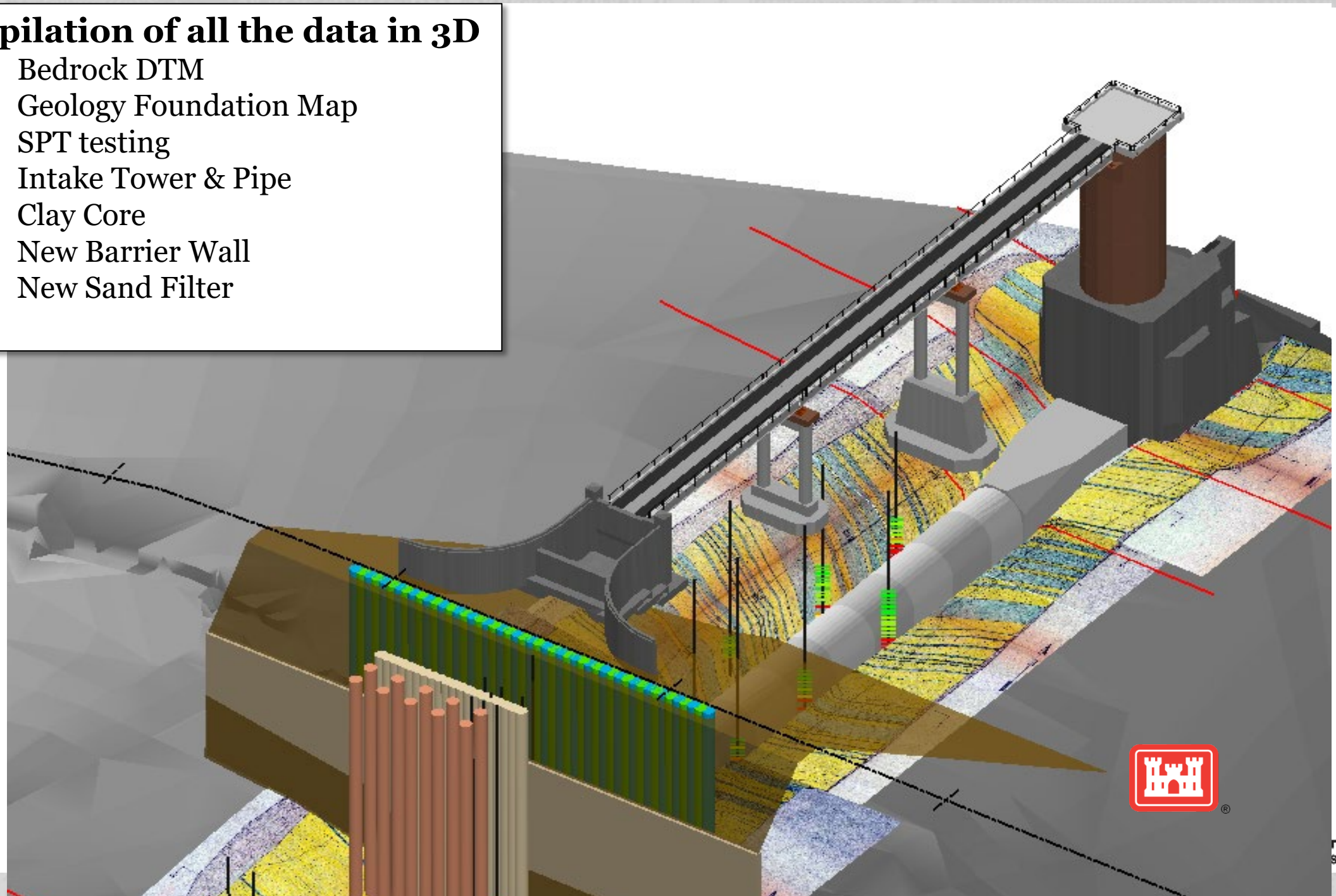
Table of Contents

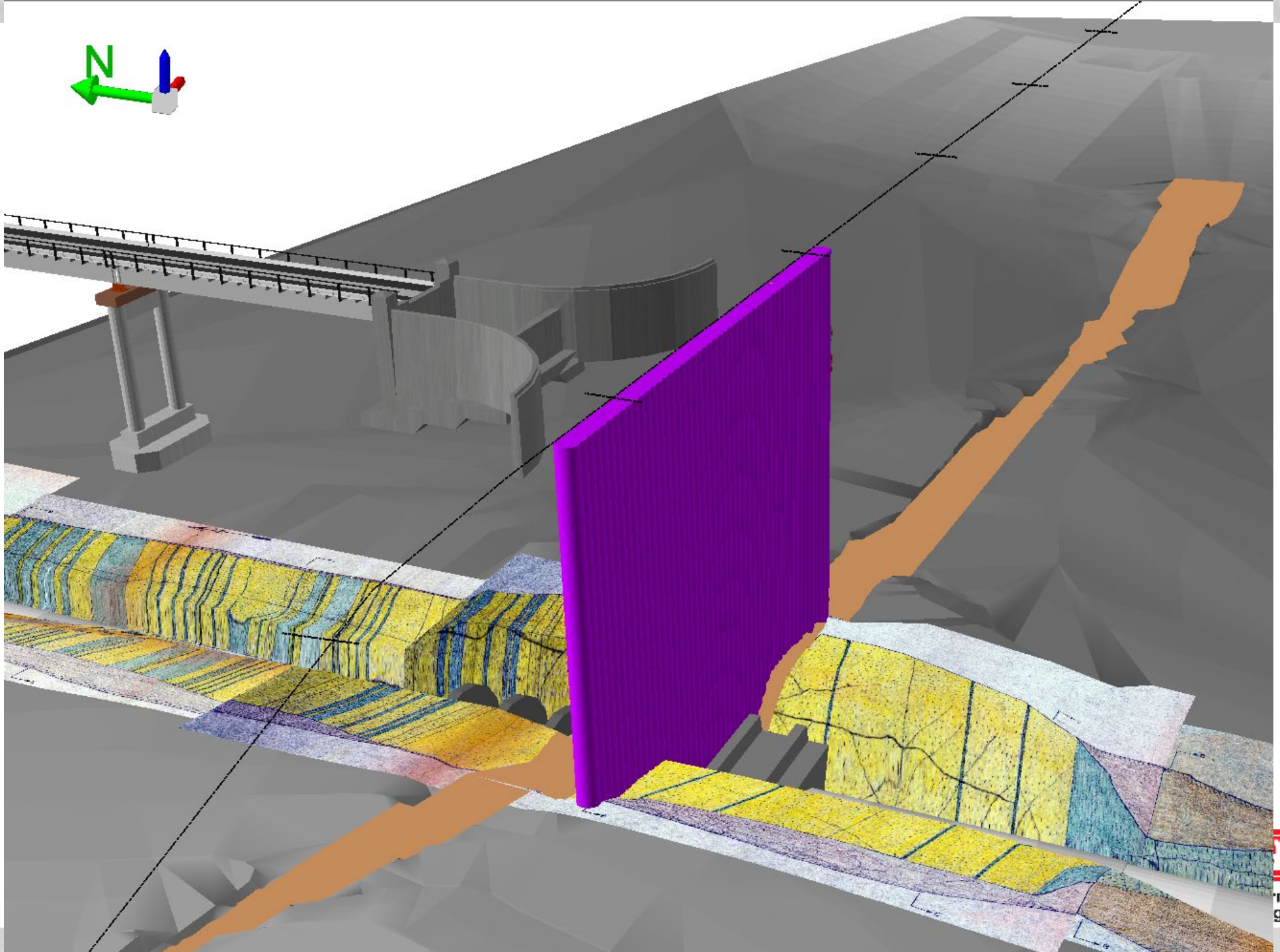
Scene layers
- Geotechnics
- Geologic Foundation Maps
- Instruments
- Construction Features
- Construction Limits
- fromcontours
- Dam Features
- Site Features
- PineCreekMosaic.sid



Compilation of all the data in 3D

- Bedrock DTM
- Geology Foundation Map
- SPT testing
- Intake Tower & Pipe
- Clay Core
- New Barrier Wall
- New Sand Filter

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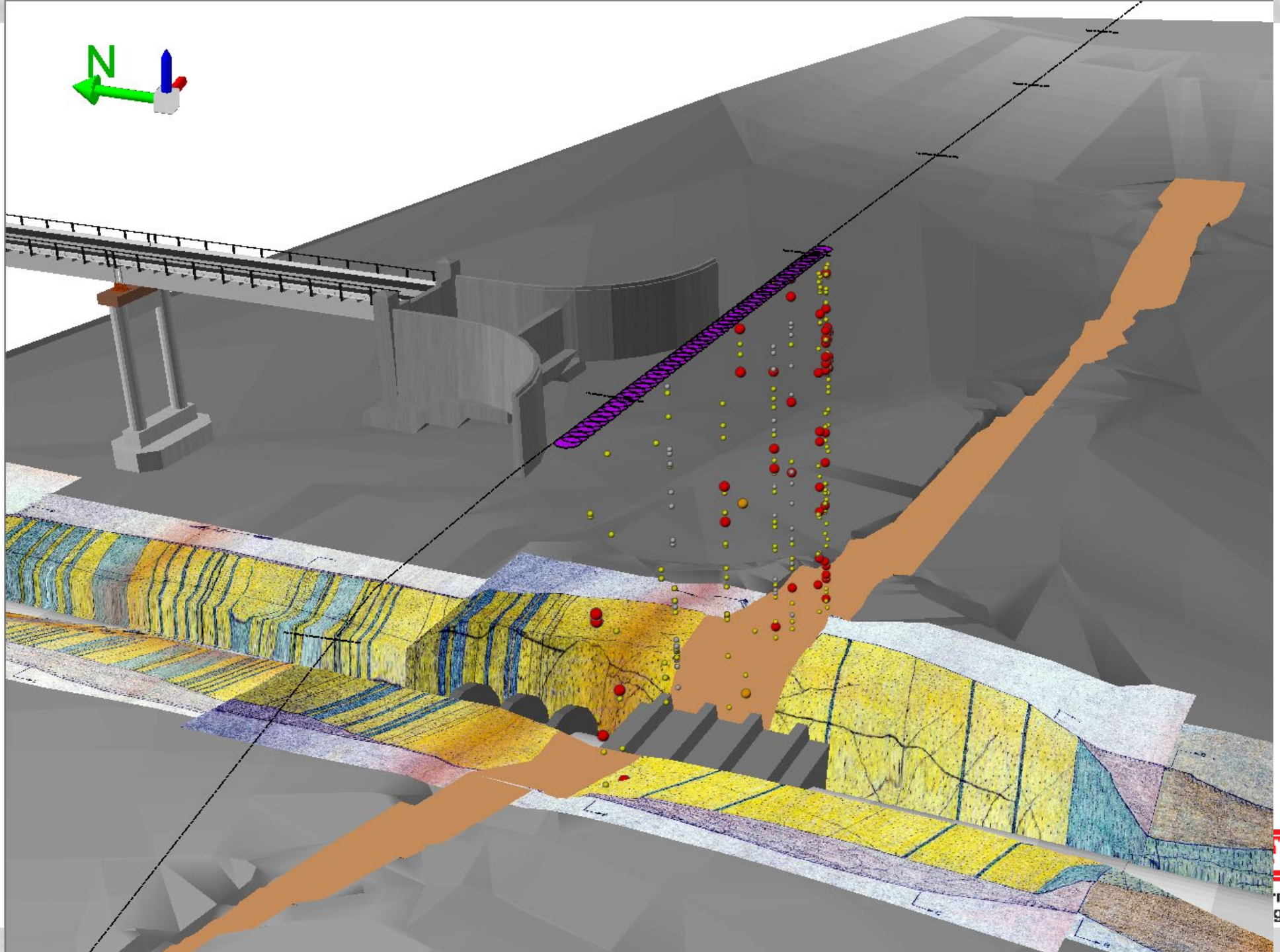

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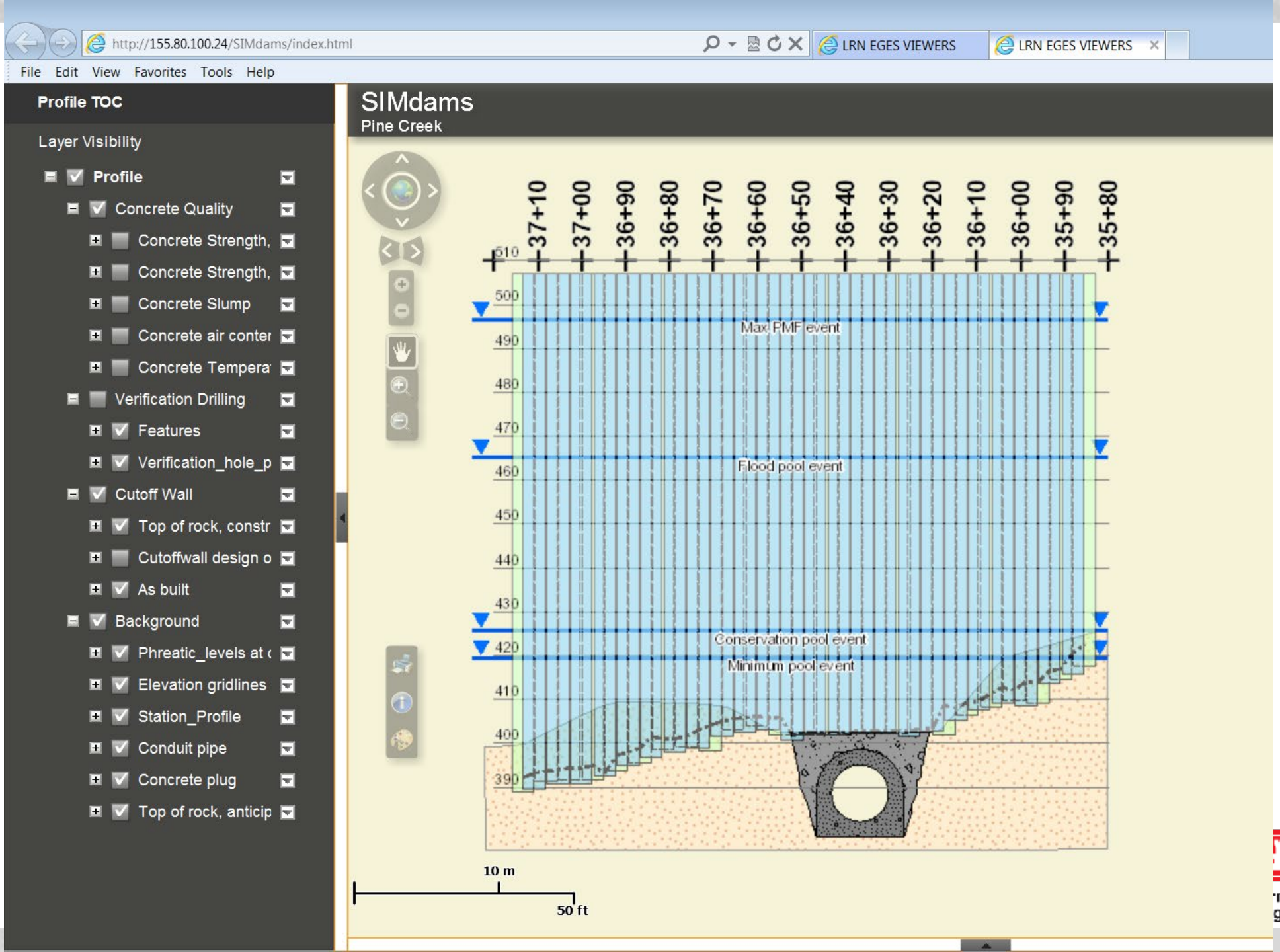
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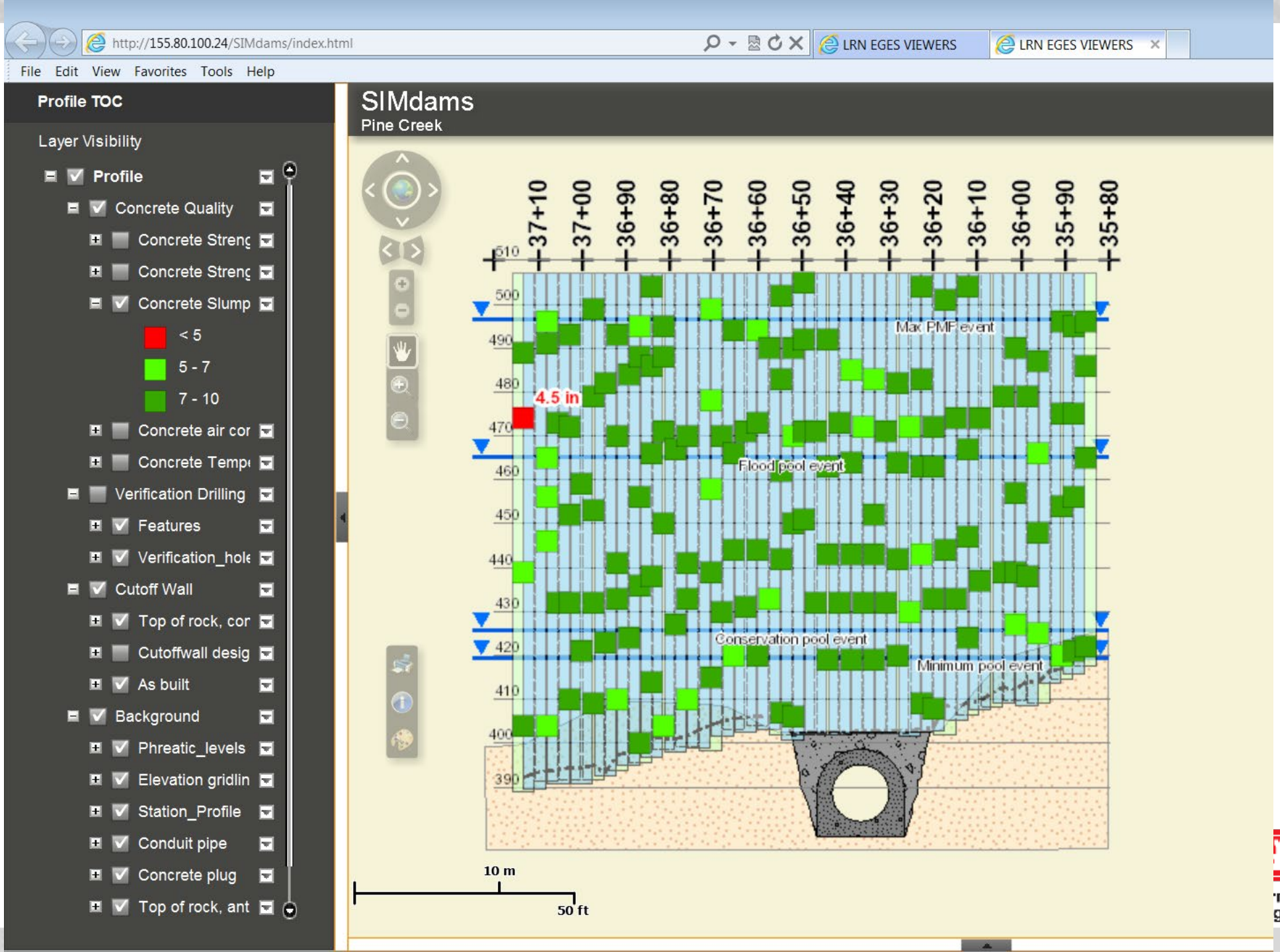
Max PMF event
Flood pool event
Conservation pool event
Minimum pool event
10 m
50 ft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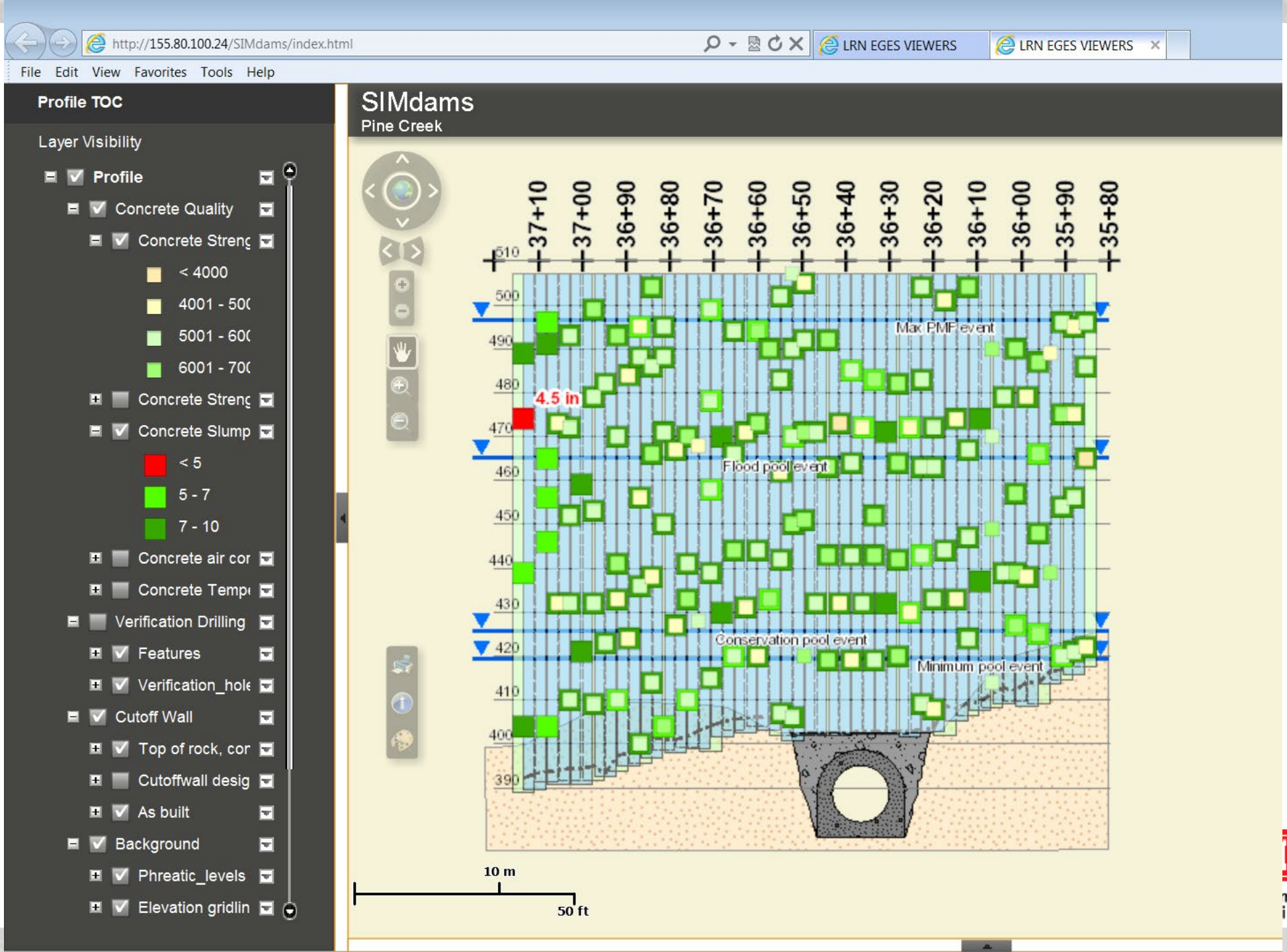
4.5 in
Max PMF event
Flood pool event
Conservation pool event
Minimum pool event
10 m
50 ft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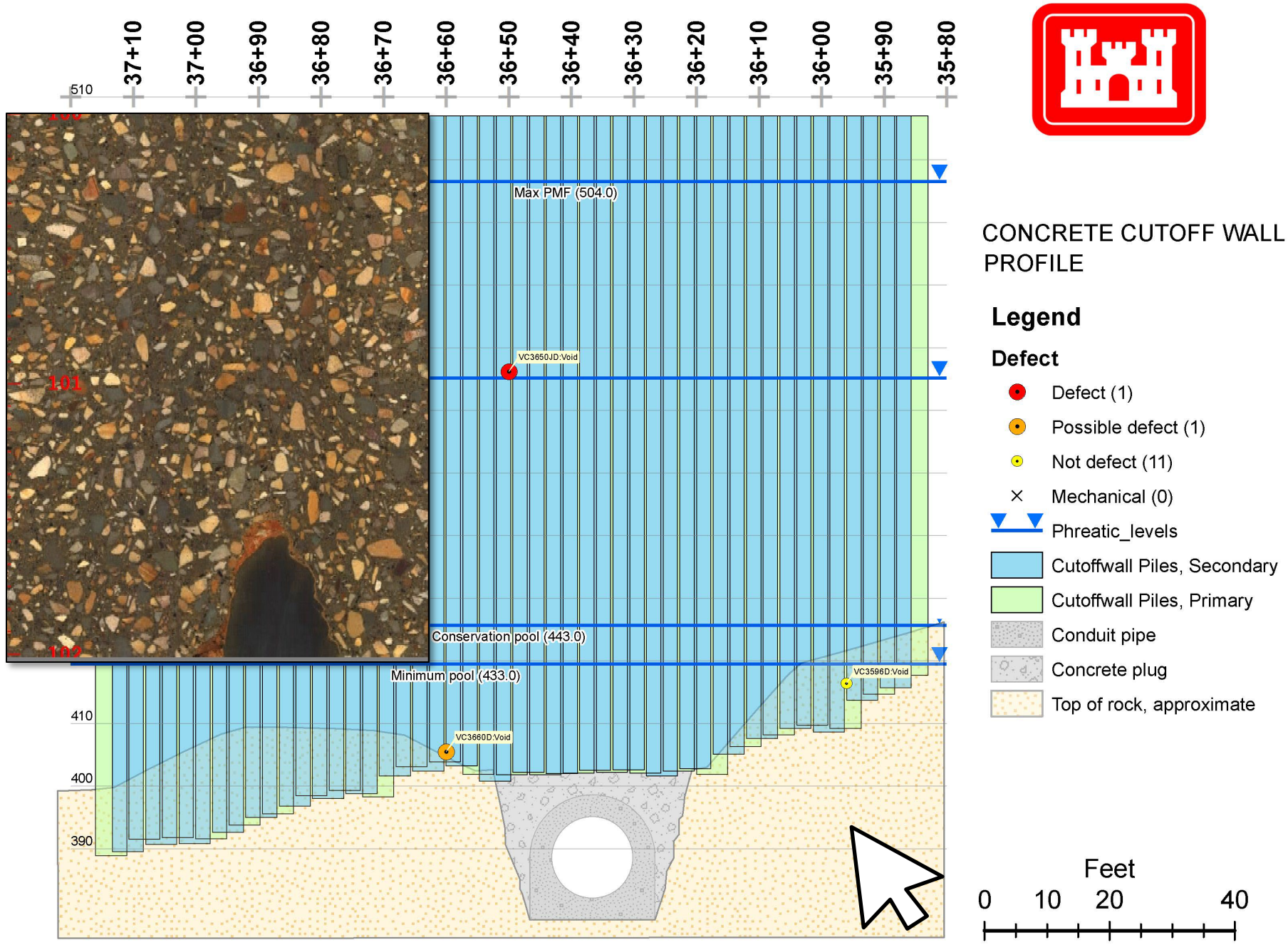
4.5 in
Max PMF event
Flood pool event
Conservation pool event
Minimum pool event
10 m
50 ft

Verification drilling: Voids



CONCRETE CUTOFF WALL PROFILE

Legend

Defect

- Defect (1)
- Possible defect (1)
- Not defect (11)
- Mechanical (0)
- Phreatic_levels
- Cutoffwall Piles, Secondary
- Cutoffwall Piles, Primary
- Conduit pipe
- Concrete plug
- Top of rock, approximate

Feet
0 10 20 40

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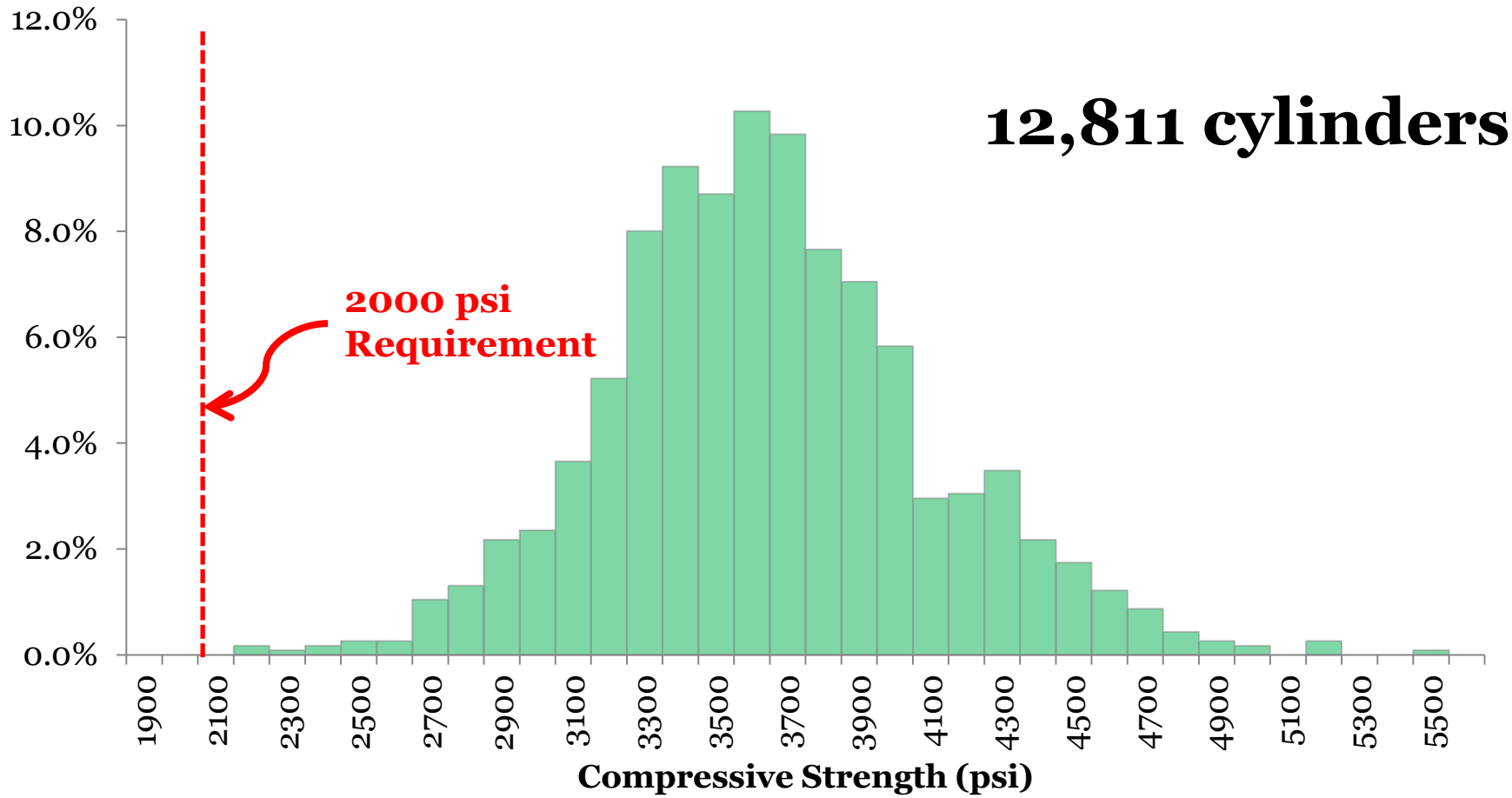
28 Day Strength Test



Min (psi)	Max (psi)	Avg (psi)	Spec (psi)
2157	5443	3601	2000

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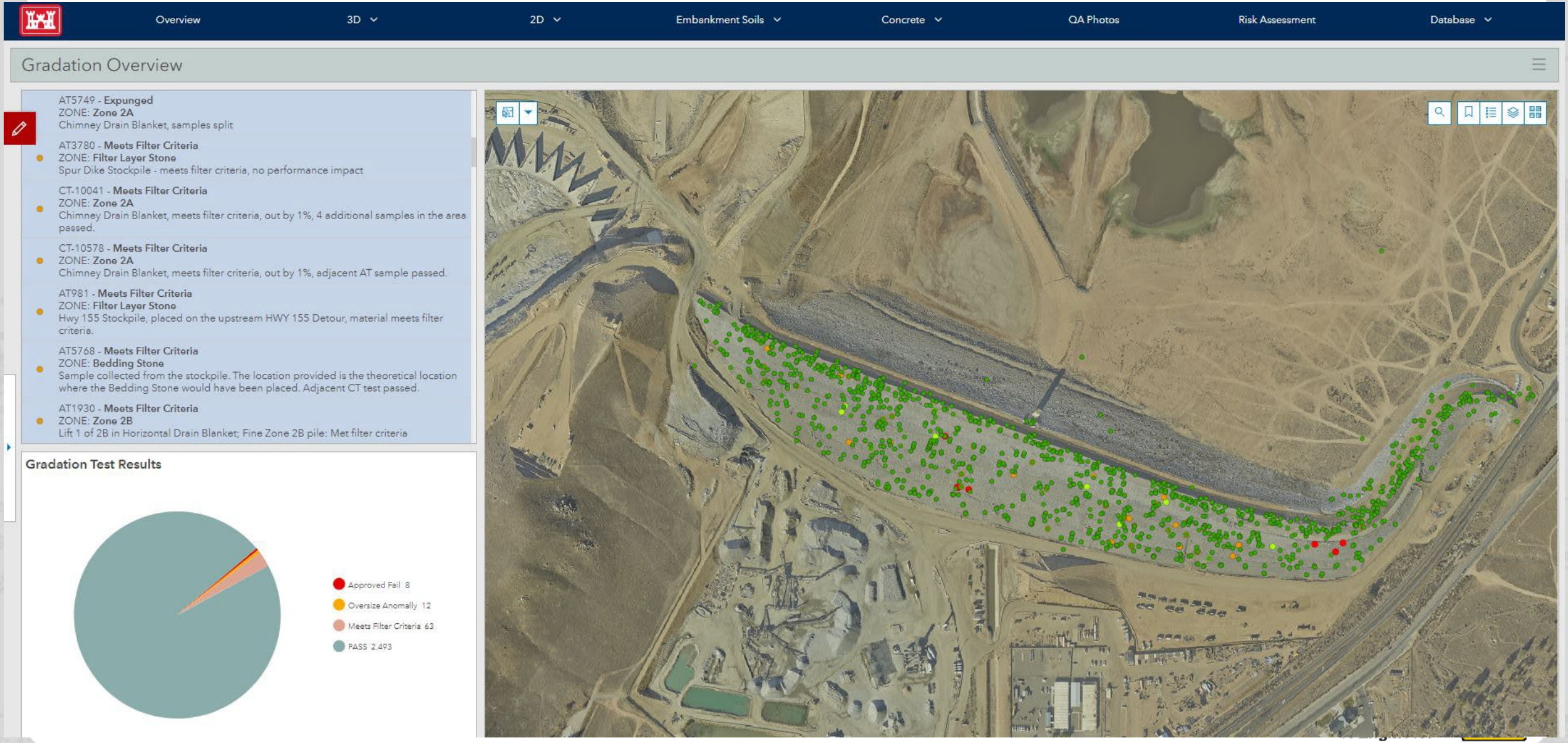
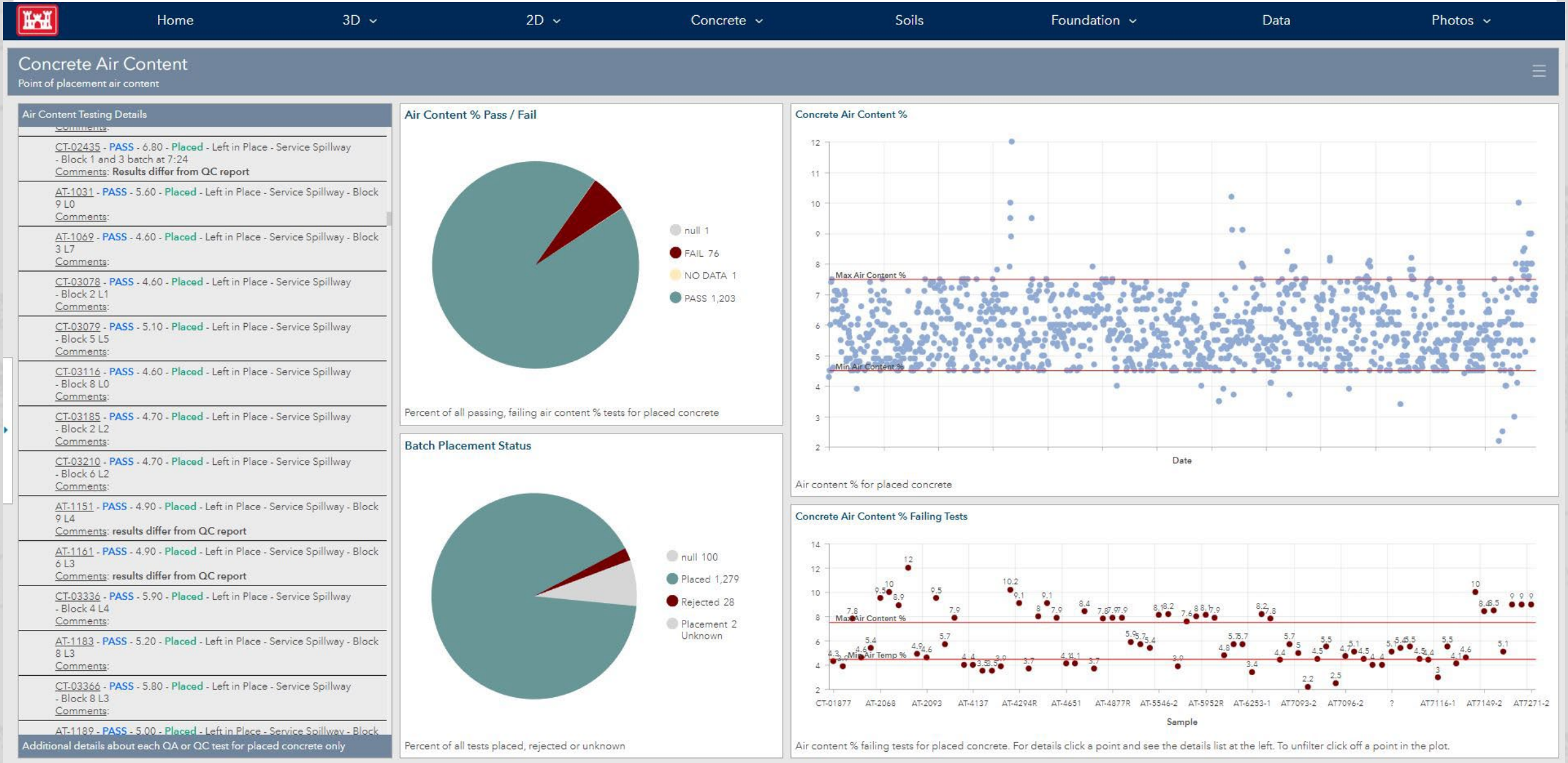
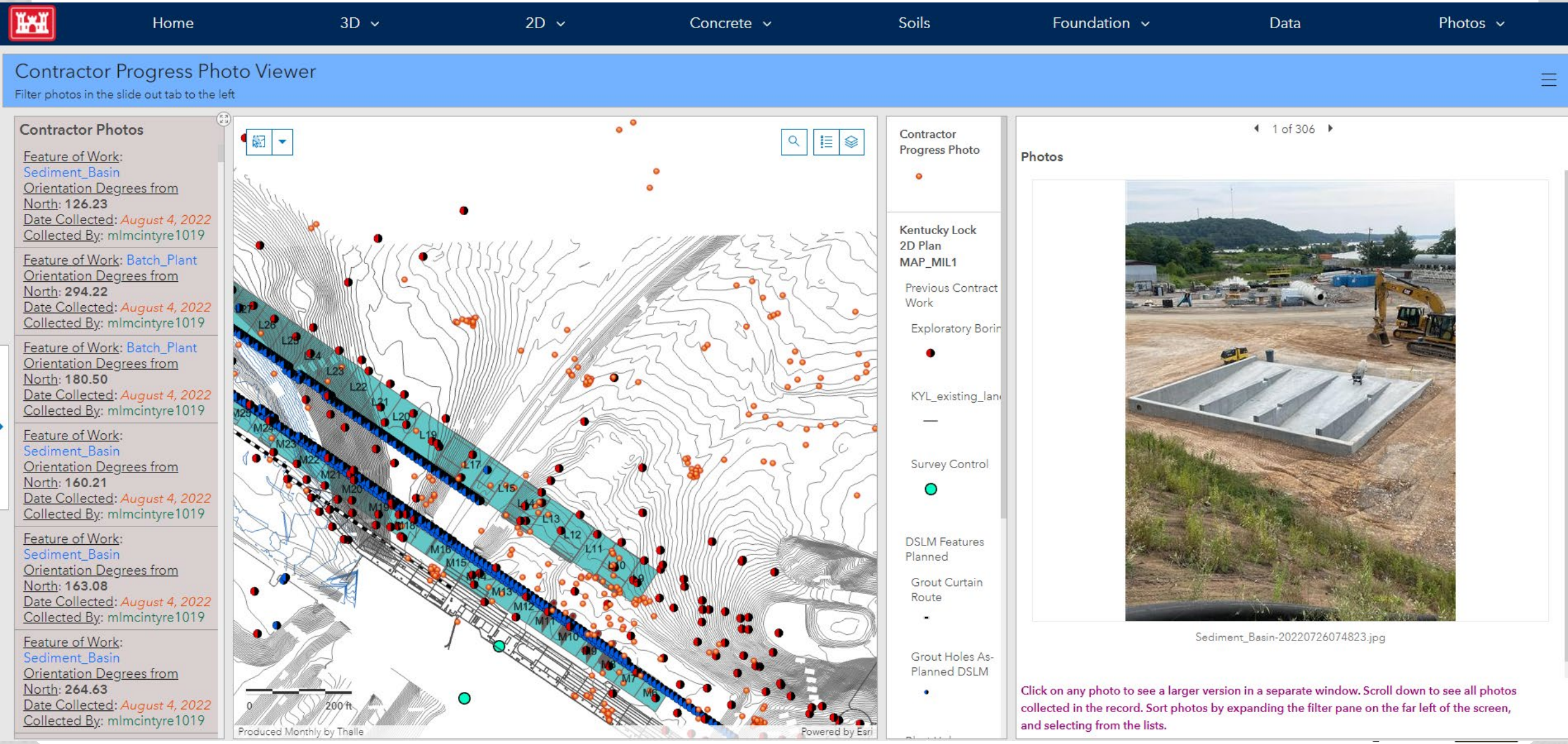
Tracking Material Gradation Testing and Results



Tracking Concrete Air Content Test Results



Access Construction Progress Photos & their Locations



Access Blast Plans and Reports

Home | 3D | 2D | Concrete | Soils | Foundation | Data | Photos

Individual Blast Plans and Reports

Blast Details Report (Cut Sheet)

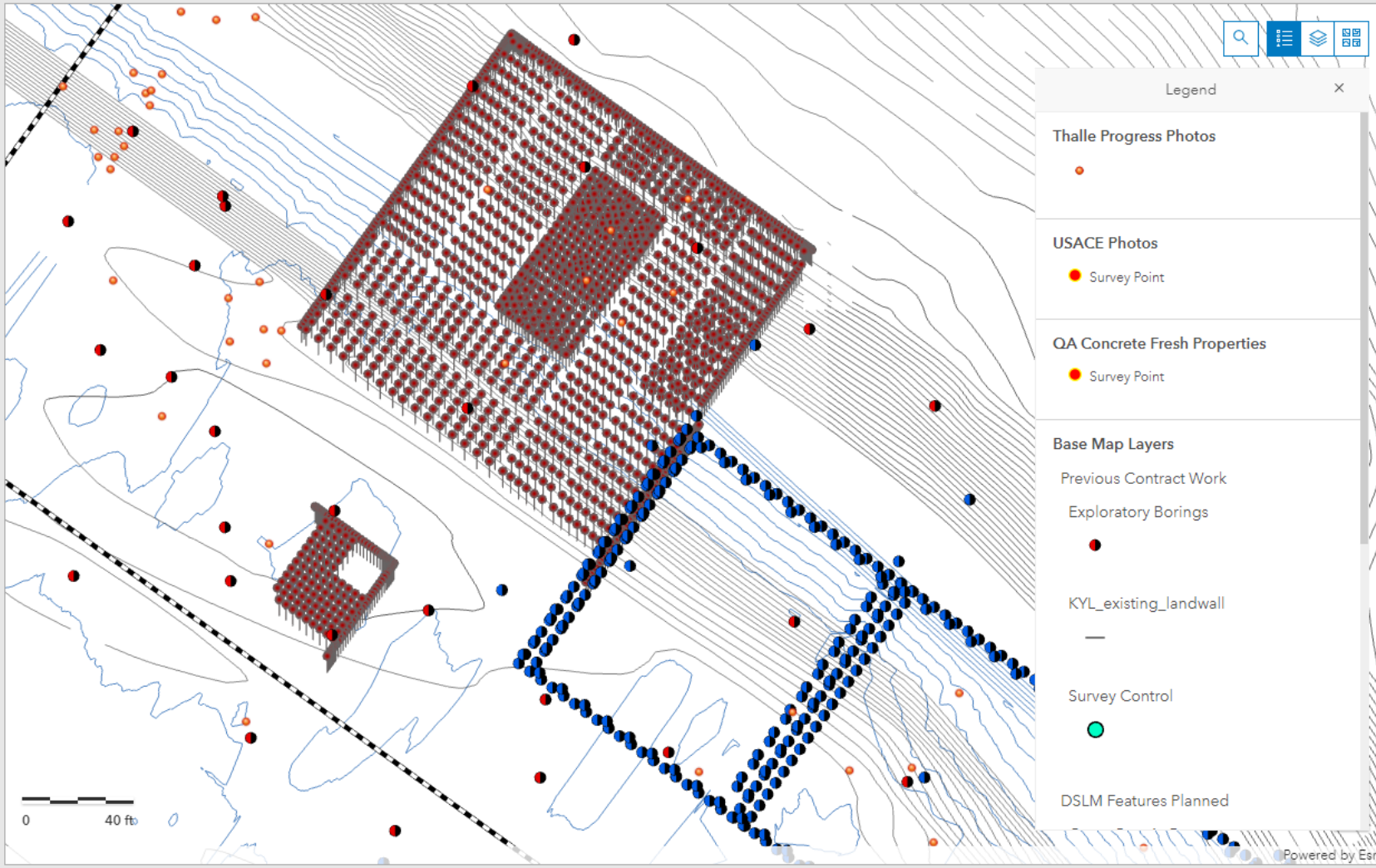
Blast #1 PS Test
Blast Date: 9/7/2022 12:00:00 AM
Number of Holes: 39
Drilled Feet: 1297.900000
Contractor's Burden:
Contractor's Stiffness Ratio:
Min Hole Spacing: 1.500000
Maximum Hole Spacing: 1.500000
Top Stemming Minimum: 2.000000
Top Stemming Maximum: 2.000000
Stemming Material: sand
Max Subdrill: 0.000000
Total Primer Weight: 6.300000
Minimum Hole to Hole Delay:
Max Hole to Hole Delay:
Max lbs per Delay:
Max Holes per Delay:
Powder Factor KTR:
Min Hole Diam(in):
Max Hole Diam(in):
Min Hole Depth (ft):
Max Hole Depth (ft):
Minimum lbs explosives per hole:
Maximum lb explosives per hole:
Expected Volume: 0.000000
Volume per Length:
Total Explosive Weight:

Blast #2 Sinking Cut Test
Blast Date: 9/13/2022 12:00:00 AM
Number of Holes: 125
Drilled Feet: 1482.600000
Contractor's Burden: 3.000000
Contractor's Stiffness Ratio: 4.000000
Min Hole Spacing: 3.000000
Maximum Hole Spacing: 3.000000
Top Stemming Minimum: 3.000000
Top Stemming Maximum: 3.000000
Stemming Material:
Max Subdrill: 0.000000
Total Primer Weight: 838.000000
Minimum Hole to Hole Delay:
Max Hole to Hole Delay:

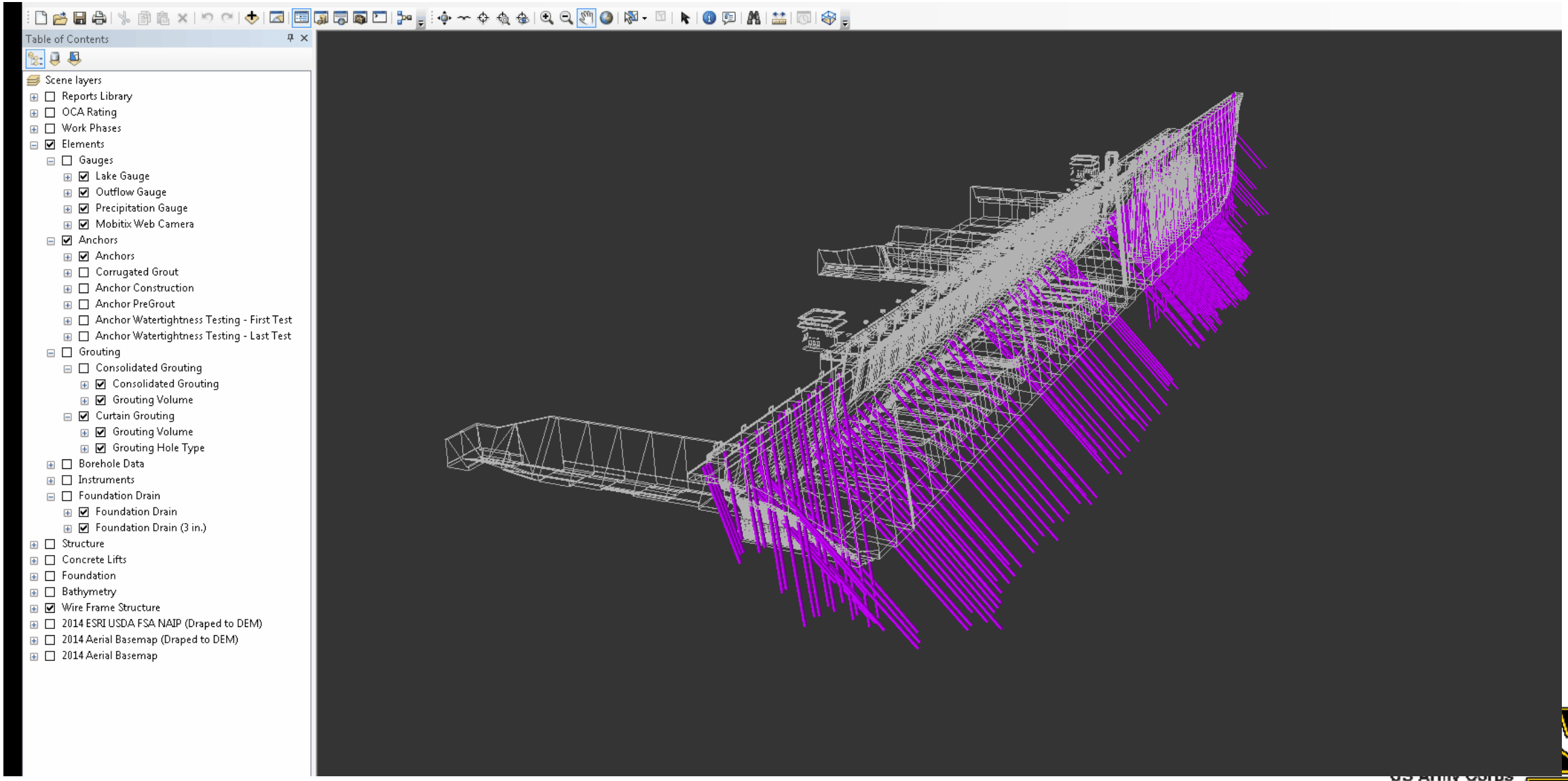
Blast Details (Cut Sheet)

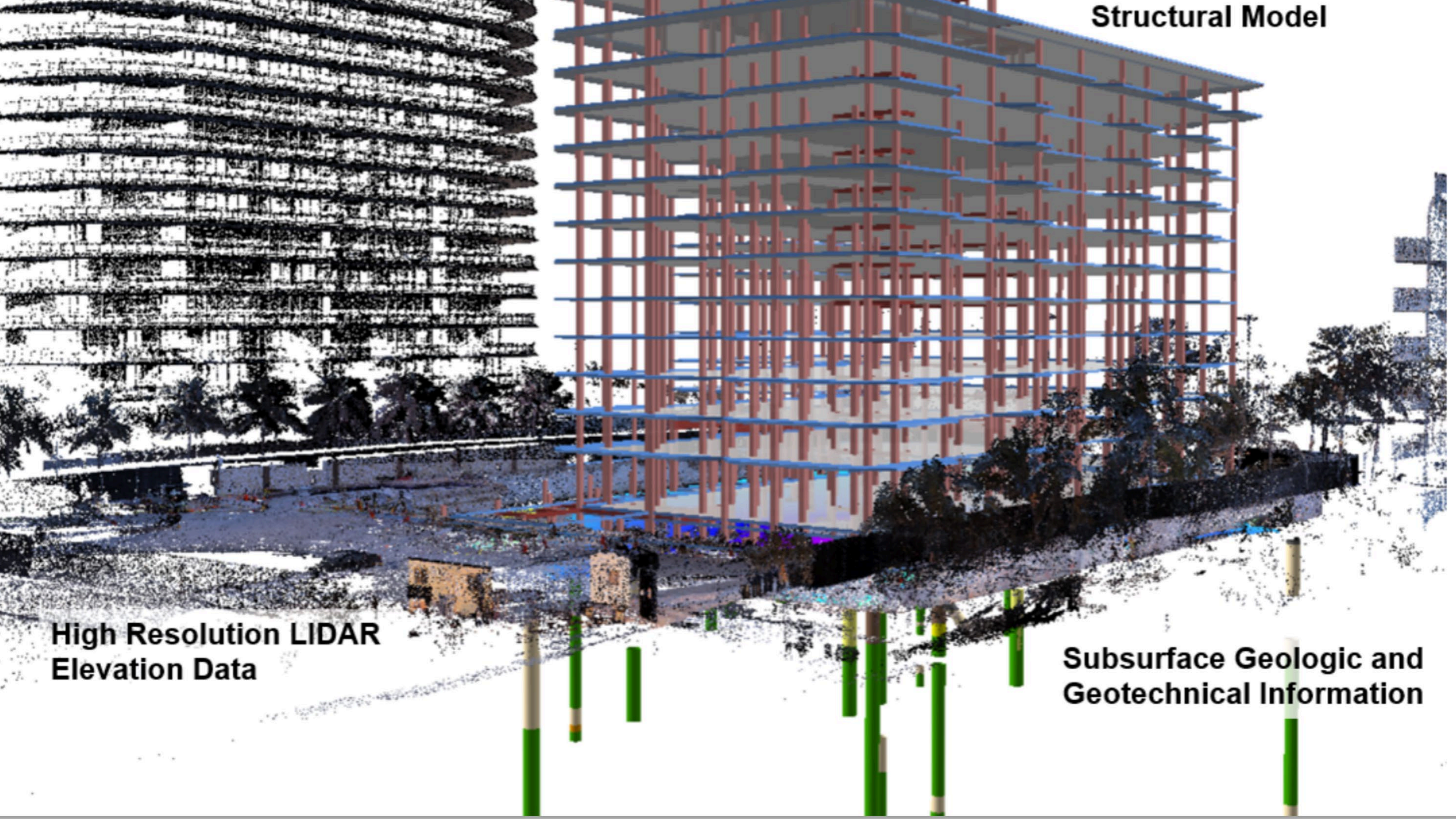
Blast #8 Prod_EL 270
Blast Date: 10/10/2022 12:00:00 AM
Number of Holes: 112
Drilled Feet: 1,222.00
Contractor's Burden: 3.50
Contractor's Stiffness Ratio: 3.10
Min Hole Spacing: 5.50
Maximum Hole Spacing: 5.50
Top Stemming Minimum: 3.00
Top Stemming Maximum: 3.00
Stemming Material: aggregate
Max Subdrill: 0.00
Total Primer Weight: 652.00
Minimum Hole to Hole Delay: 25.00
Max Hole to Hole Delay: 500.00
Max lbs per Delay: 13.50
Max Holes per Delay: 2
Powder Factor KTR: 0.70
Min Hole Diam(in): 2.25
Max Hole Diam(in): 2.25
Min Hole Depth (ft): 10.30
Max Hole Depth (ft): 11.80
Minimum lbs explosives per hole: 4.50
Maximum lb explosives per hole: 6.50
Expected Volume: 883.50
Volume per Length:
Total Explosive Weight: 652.00

Blast #9 Prod _EL 270
Blast Date: 10/11/2022 12:00:00 AM
Number of Holes: 112
Drilled Feet: 1,184.60
Contractor's Burden:
Contractor's Stiffness Ratio: 3.00
Min Hole Spacing: 4.50
Maximum Hole Spacing: 5.50
Top Stemming Minimum: 3.00
Top Stemming Maximum: 3.00
Stemming Material: aggregate
Max Subdrill: 0.00
Total Primer Weight: 624.00
Minimum Hole to Hole Delay: 25.00



Bluestone 3D Site Information Model




Structural Model
High Resolution LIDAR
Elevation Data
Subsurface Geologic and
Geotechnical Information

Some Lessons Learned along the way…

1. GET YOUR DATA in a non-proprietary/digital format (.csv, .txt)
2. KEEP YOUR DATA ORGANIZED – Digital chaos happens quickly
3. You need a DATA MANAGEMENT System – Not just a database
4. A DATA MANAGER is Needed, especially for large/complex project
5. Geo-Professionals and GIS specialists need to work together

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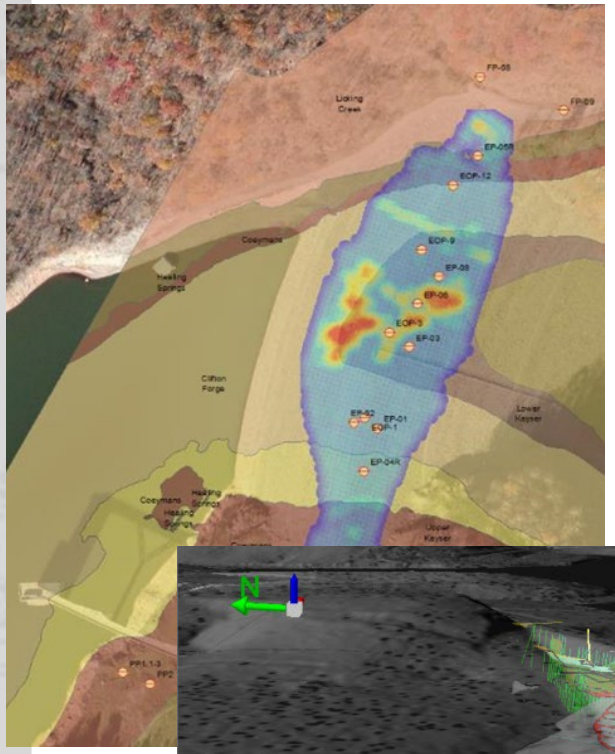
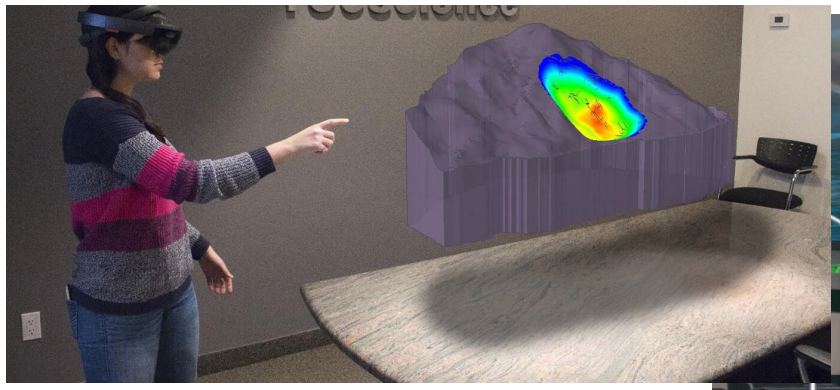
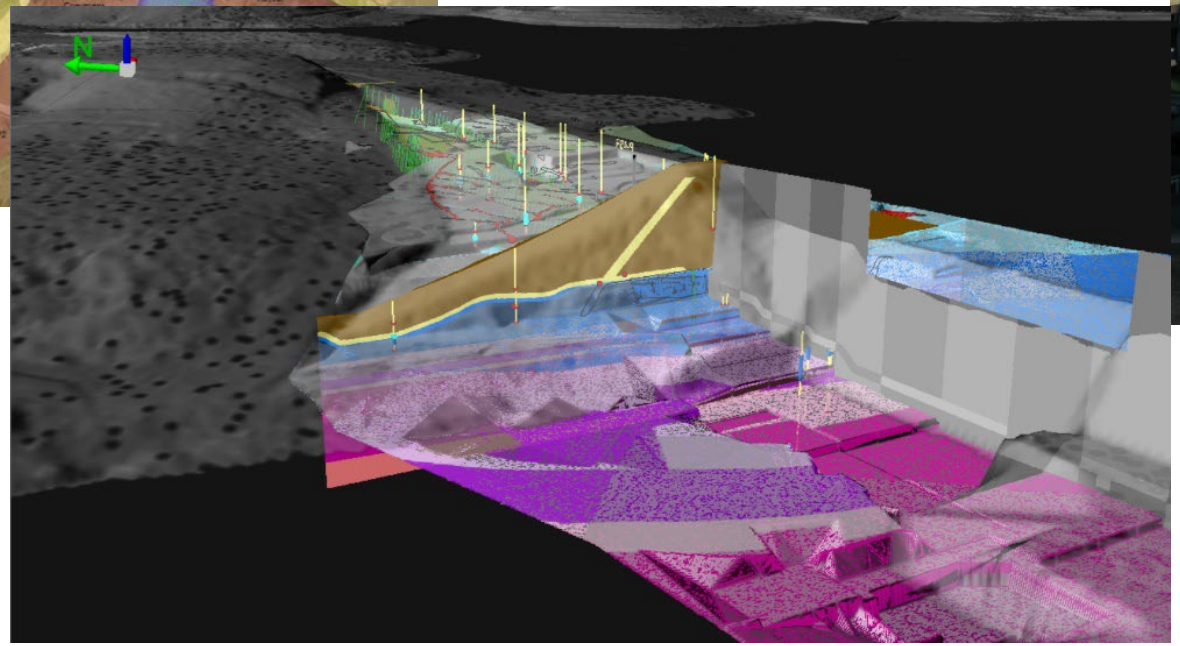
Future Vision of Data Management







Advanced 3D Data Visualization
Virtual Communication
Advanced Modeling for Design and Risk Assessment

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Key Take Aways

- ✓ **Instrumentation is key in monitoring project performance**
- ✓ **Target monitoring program using Risk Informed Decisions**
- ✓ **Monitoring frequency matters**
- ✓ **Performance evaluation requires consideration of a variety of information (both historic and new)**
  - ✓ It's the Cumulative information that informs our understanding
  - ✓ It's the Visualization of the data that facilitates Communication
  - ✓ Aids In Emergency Response & Rapid Decision Making
  - ✓ Aids in Partnering for Complete Multi-discipline Picture
- ✓ **Databases should to be leveraged for all data types to streamline project information modeling**

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Acknowledgements:

Laurel Robison (DSMMCX, USACE)
Nashville District
Sacramento District
Norfolk District

THANK YOU!