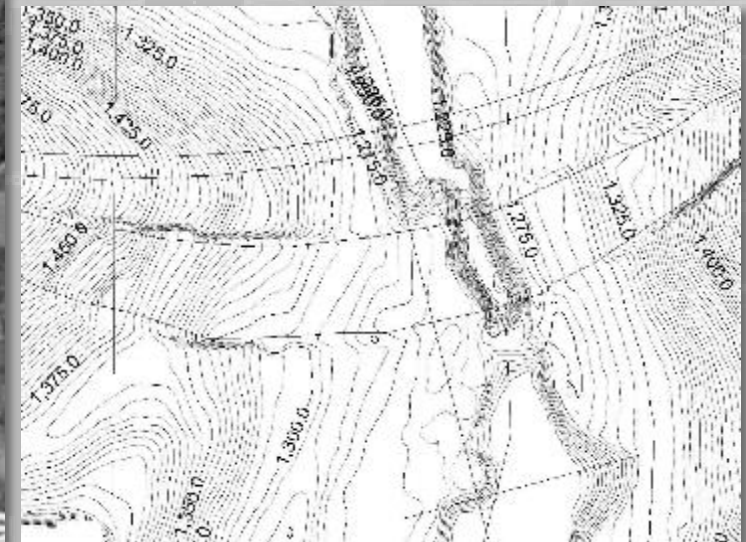


SITE CHARACTERIZATION FOR RISK ASSESSMENT OF COUGAR DAM, MCKENZIE RIVER, OREGON

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Date: 19 September 2019



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PRESENTATION OUTLINE



PRESENTATION OUTLINE



- Project Background
- Preliminary Risk Assessment
 - Key Questions for Phase II Issue Evaluation Risk Assessment
- Site Investigation Plan
 - Consolidate, Update Existing Data
 - New data



PROJECT BACKGROUND



PROJECT BACKGROUND

Located in the Willamette River Basin, NW Oregon

South Fork of the McKenzie River, 42 Miles East of Eugene/Springfield

Conservation Pool 189,000 acre-feet (summer) and 51,000 acre-feet (winter)

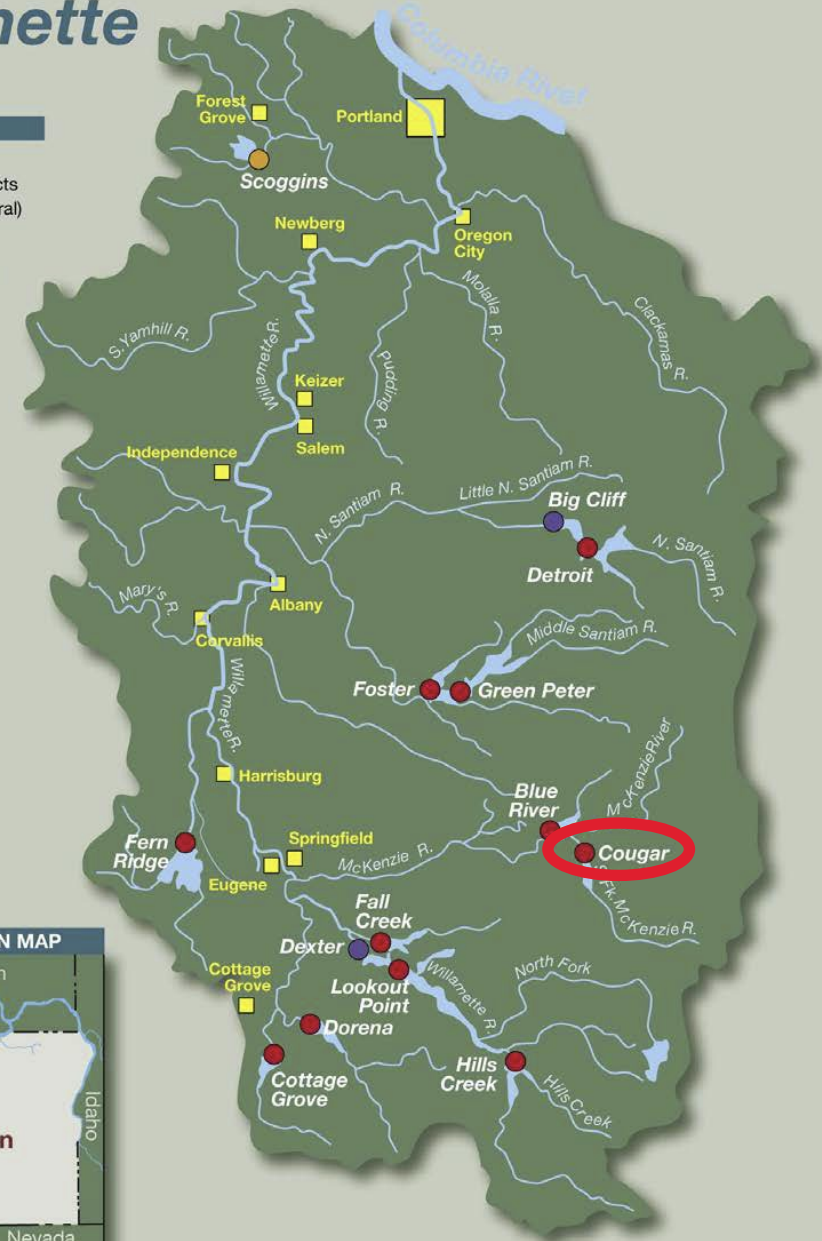
Purposes: Flood Risk Management, Hydropower, Water Quality, Water Supply

Constructed in 1963

The Willamette Basin

- LEGEND
- Re-regulating Dams
 - Multi-purpose Projects
 - Section 7 (non-Federal)

0 5 10 15 20 25 30
APPROXIMATE MILES

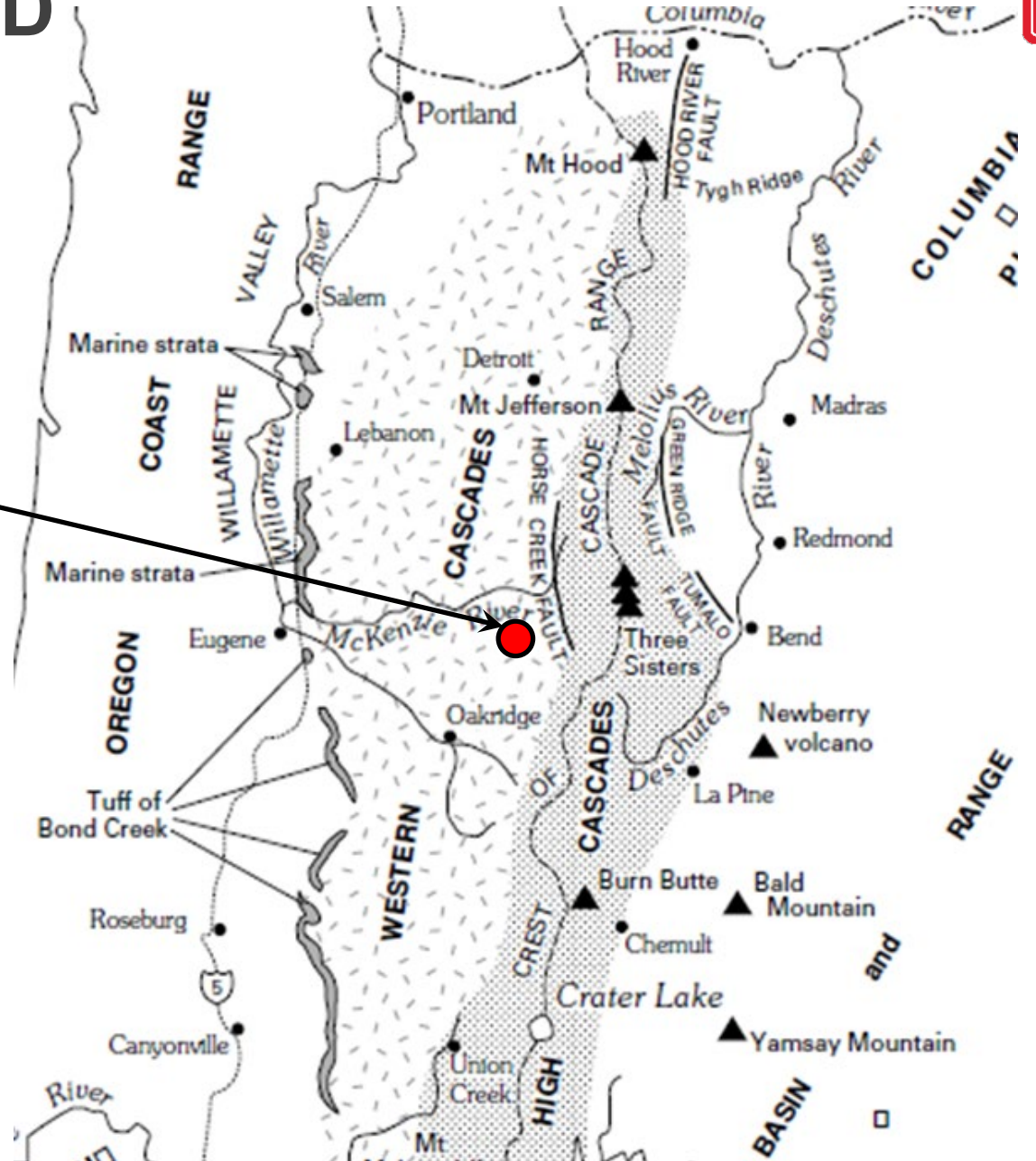




PROJECT BACKGROUND

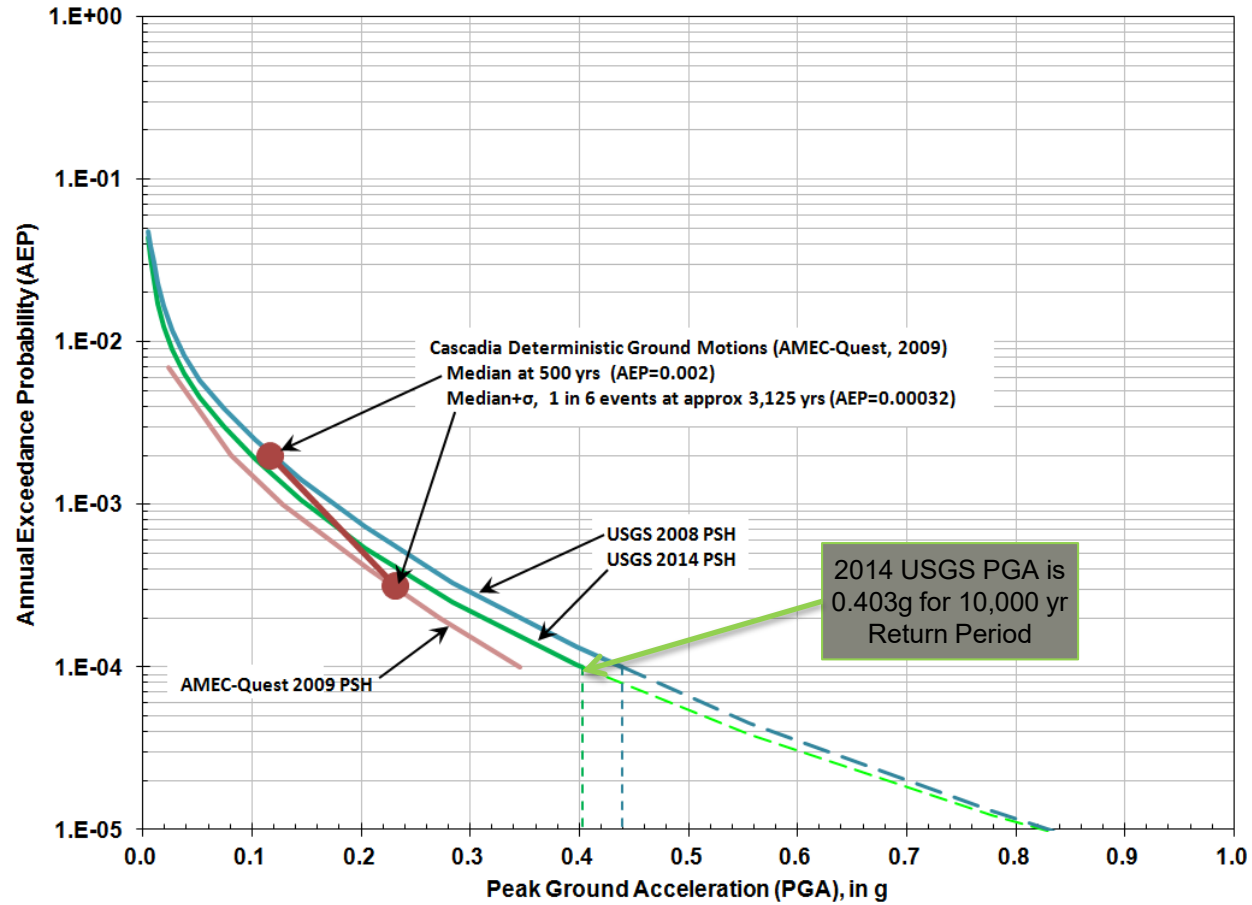
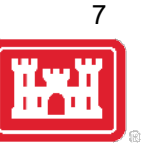


Cougar Dam



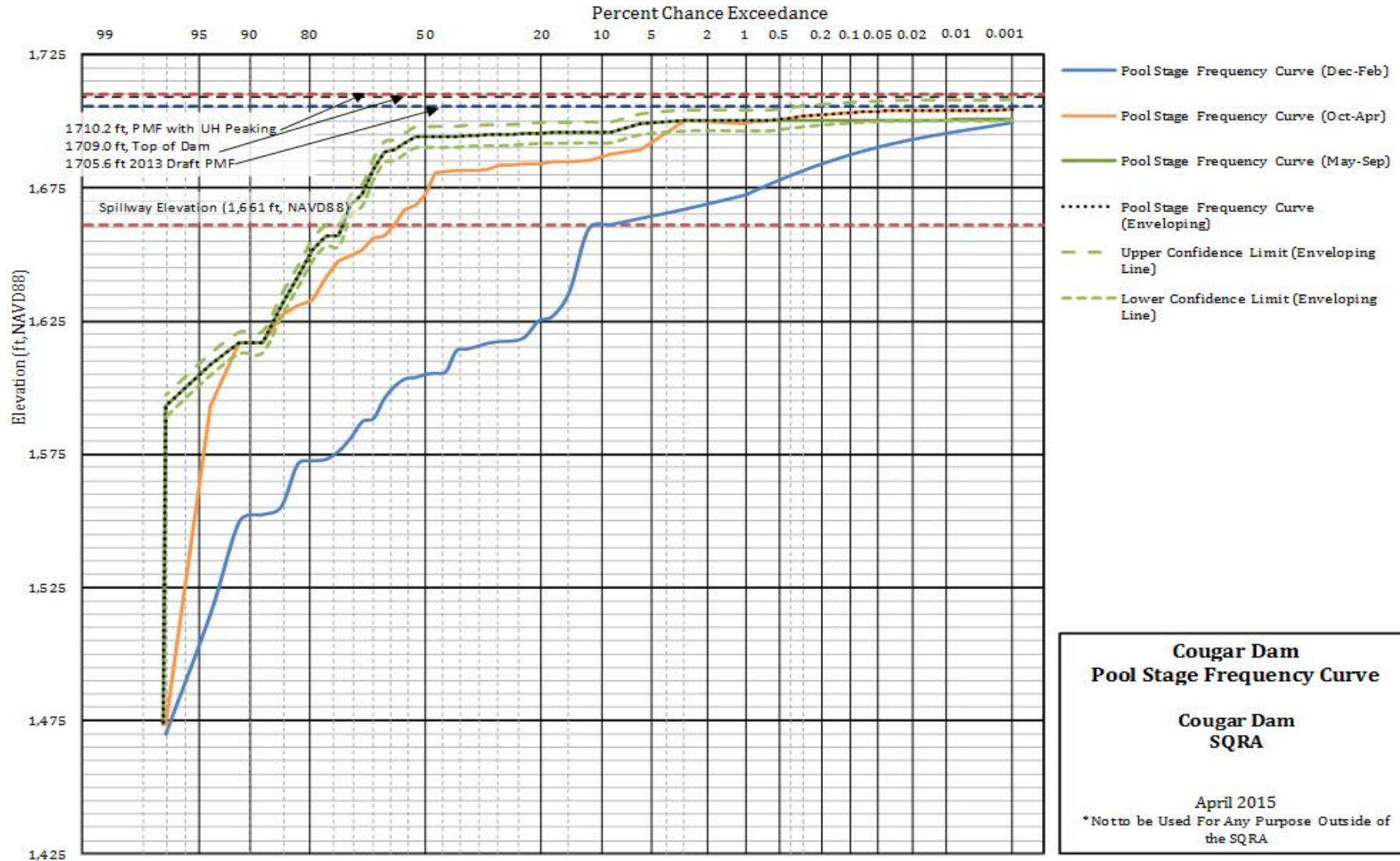
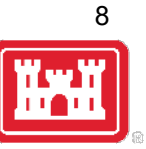


PROJECT BACKGROUND - SEISMIC LOADING





PROJECT BACKGROUND - HYDROLOGIC LOADING





PROJECT BACKGROUND - STRUCTURES

Rockfill Embankment Dam

Elevation Top of Dam, feet (NGVD29)	1,705 + Overbuild
Length, feet	1,600
Maximum Height, feet	519

Outlet Works (Tunnel)

Type	13.5-ft tunnel
Size of Gates (Vertical Slide x2), feet	6.5 x 12.5
Design Discharge at Max Pool, cfs	12,050

Spillway (Gated Chute)

Size of Gates (Tainter x2), feet	40 x 43.3
Design Discharge, ft ³ /s	76,140
Gross Crest Length, feet	89
Crest Elevation, feet (NGVD29)	1,656.75

Power Plant

Penstock (x1) Diameter, feet	10.5
Number of Generating Units	2
Rated Capacity, MW	25

Reservoir

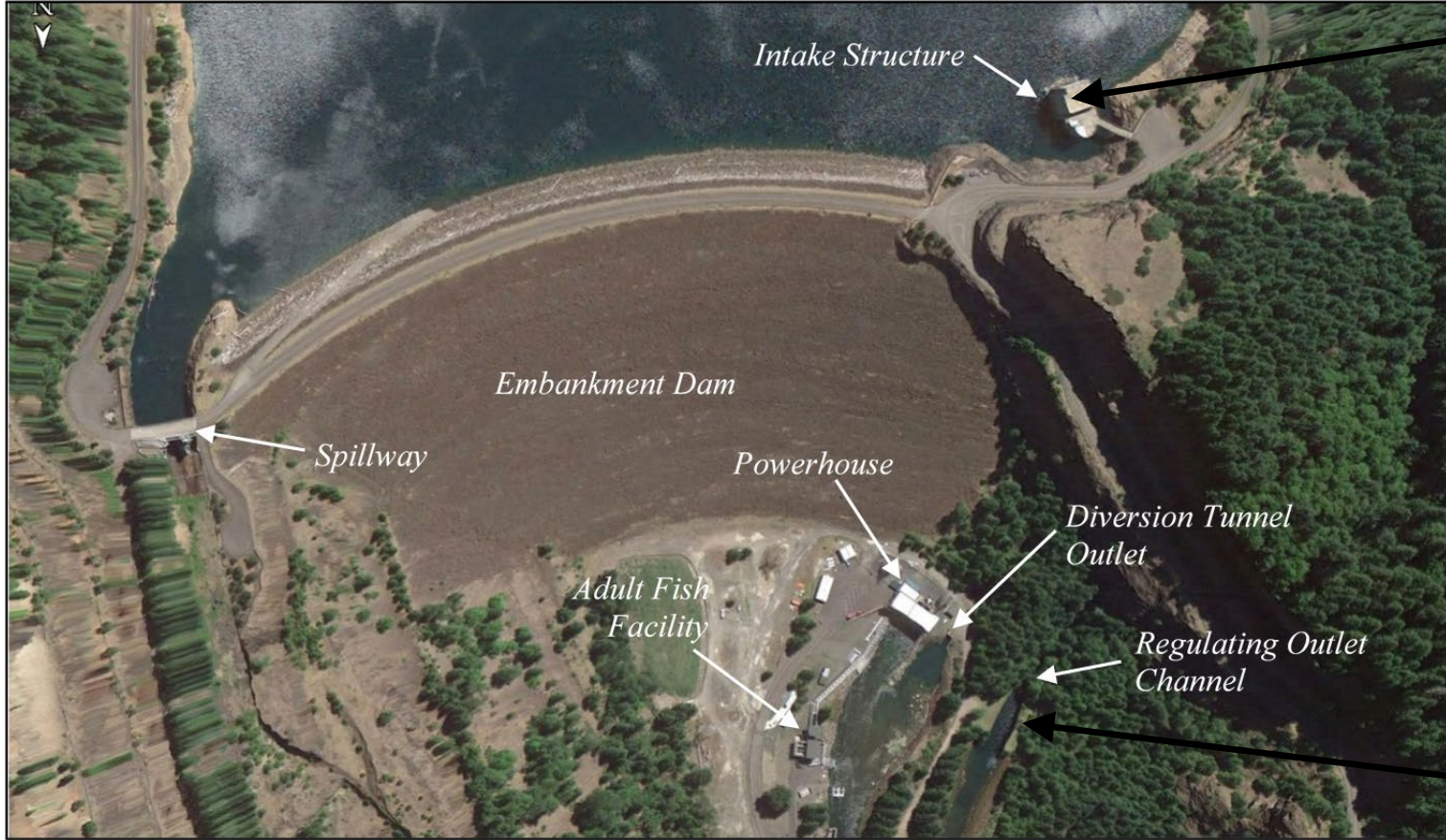
Minimum Power Pool, feet (NGVD29)	1,516
Minimum Flood Control Pool, feet (NGVD29)	1,532
Maximum Conservation Pool, feet (NGVD29)	1,690
Maximum Pool, feet (NGVD29)	1,699

Operations

Operated remotely from Lookout Point Dam approx. 55 miles or 1.25 hrs away



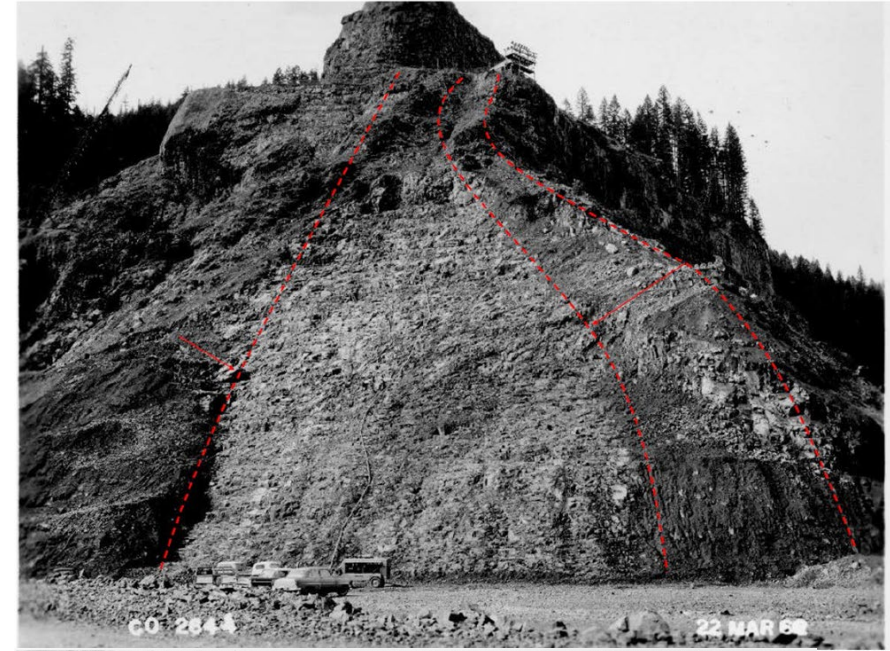
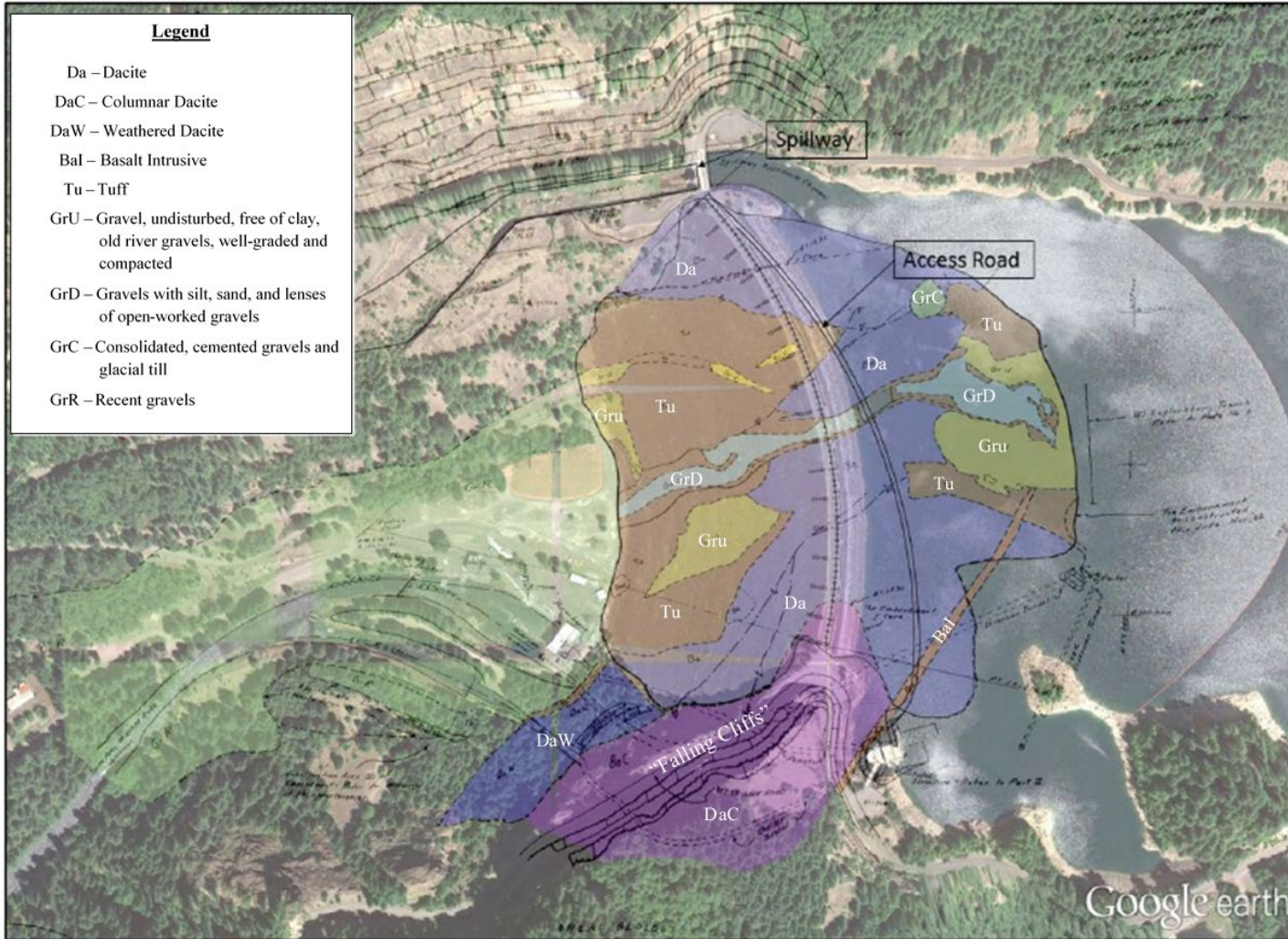
PROJECT BACKGROUND





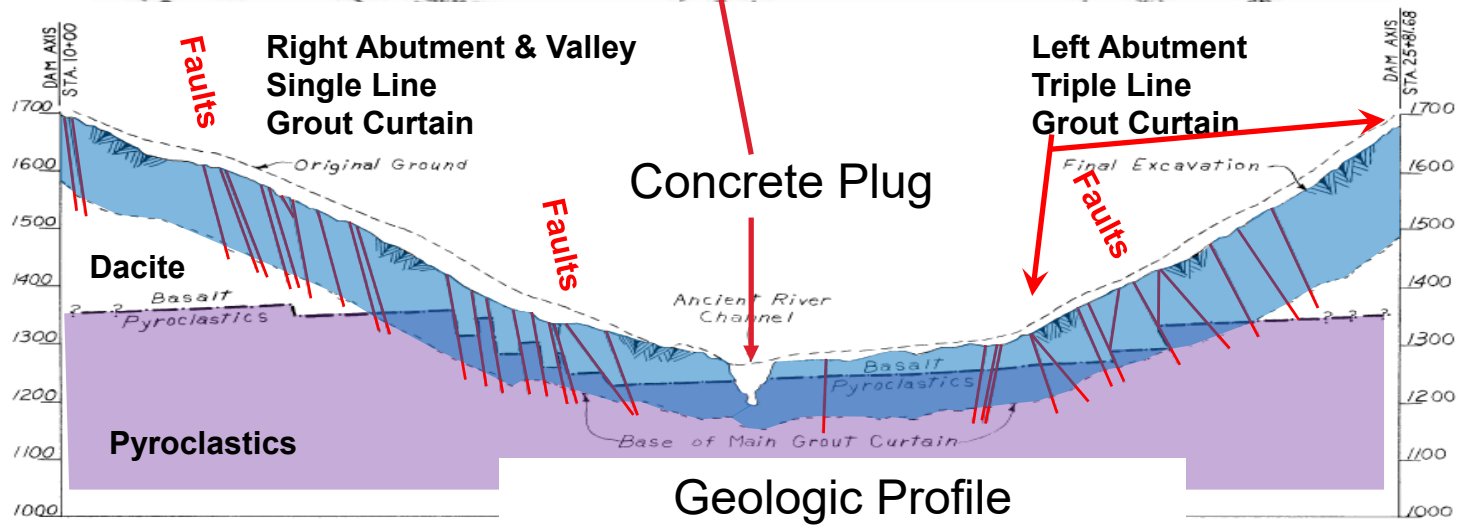
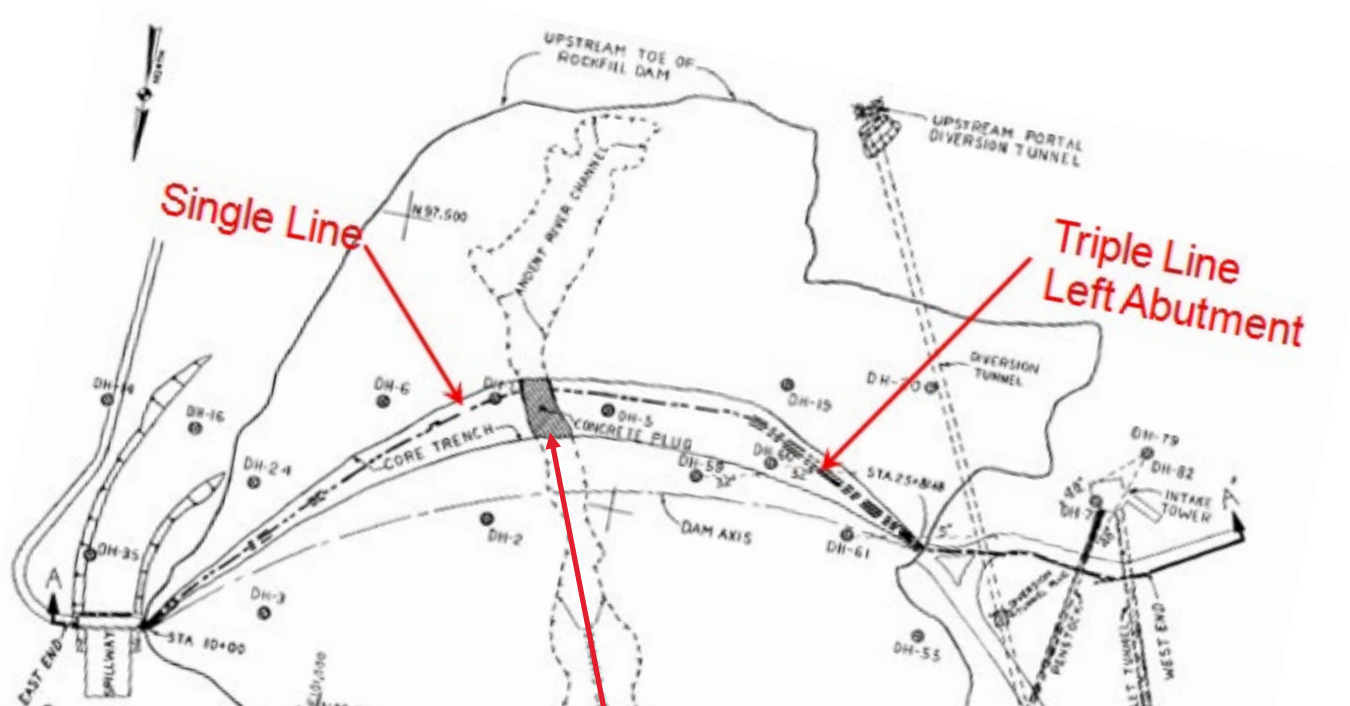


PROJECT BACKGROUND – FOUNDATION





EMBANKMENT CORE PLAN AND FOUNDATION PROFILE

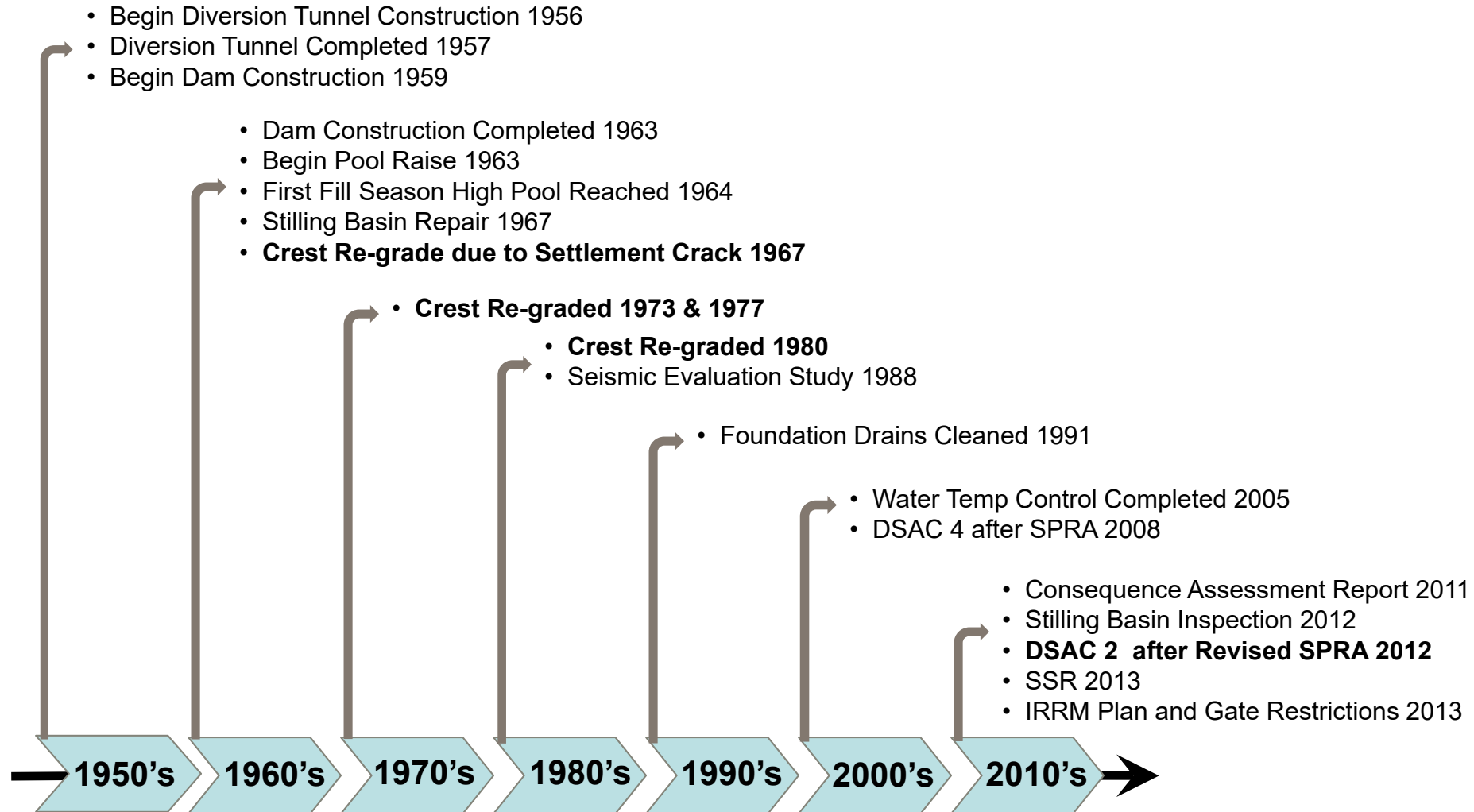


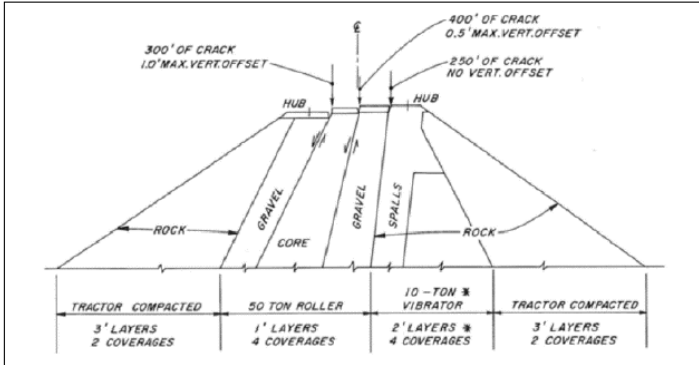


PROJECT BACKGROUND - PERFORMANCE



Timeline 1956 - 2015

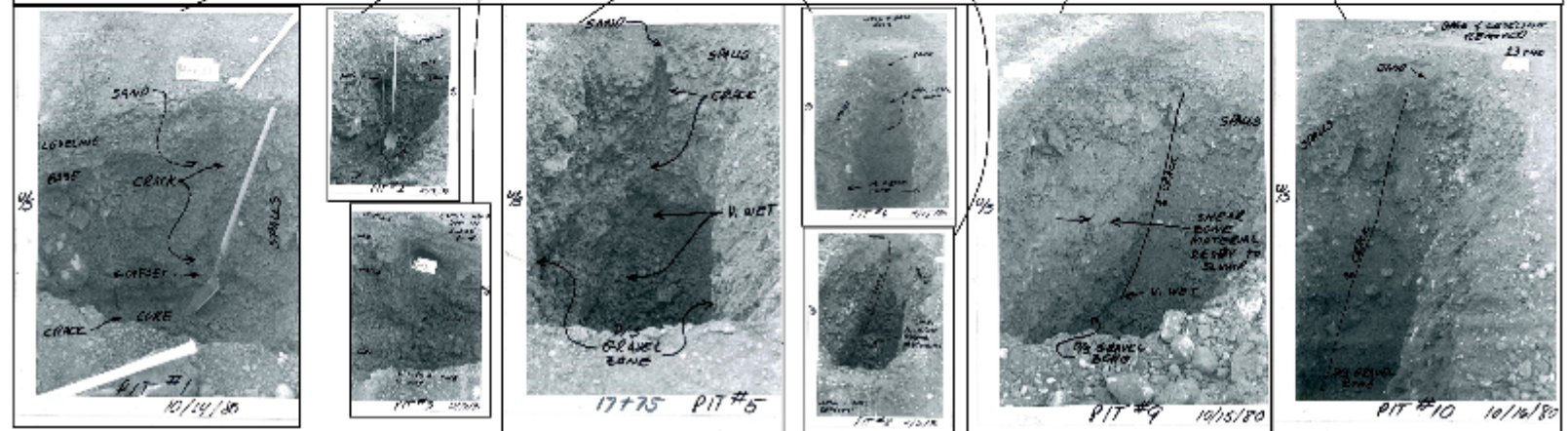
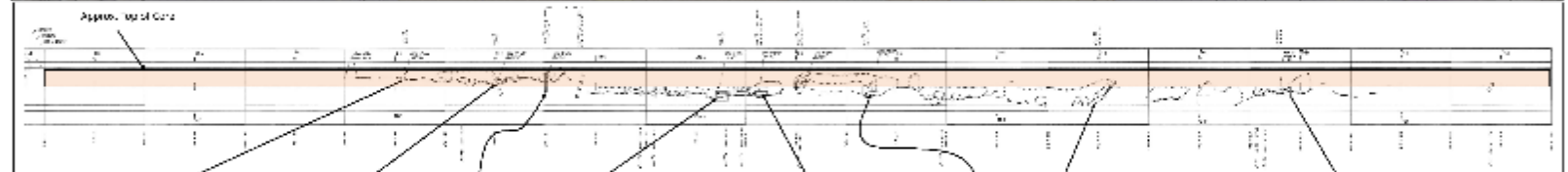
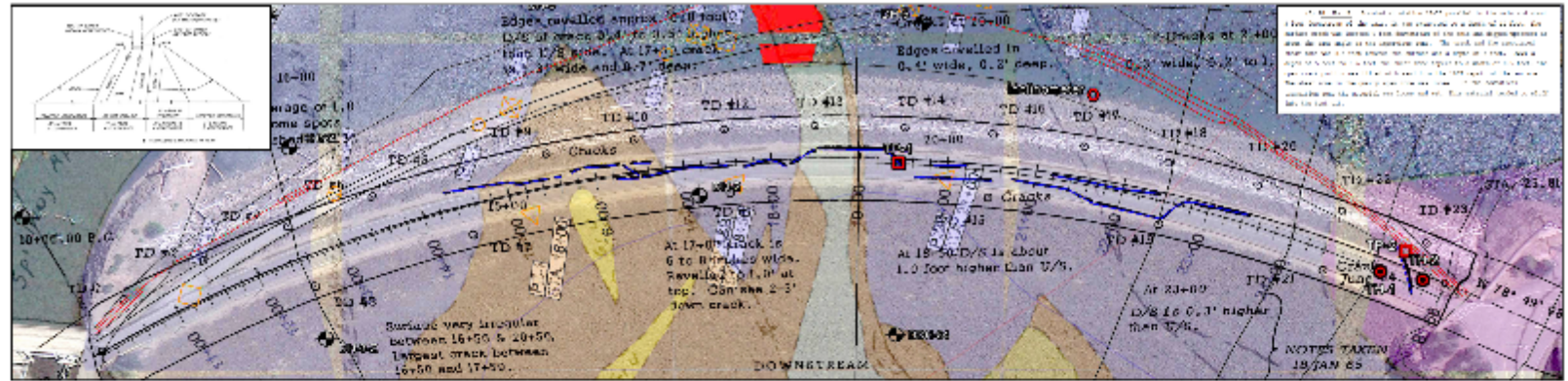




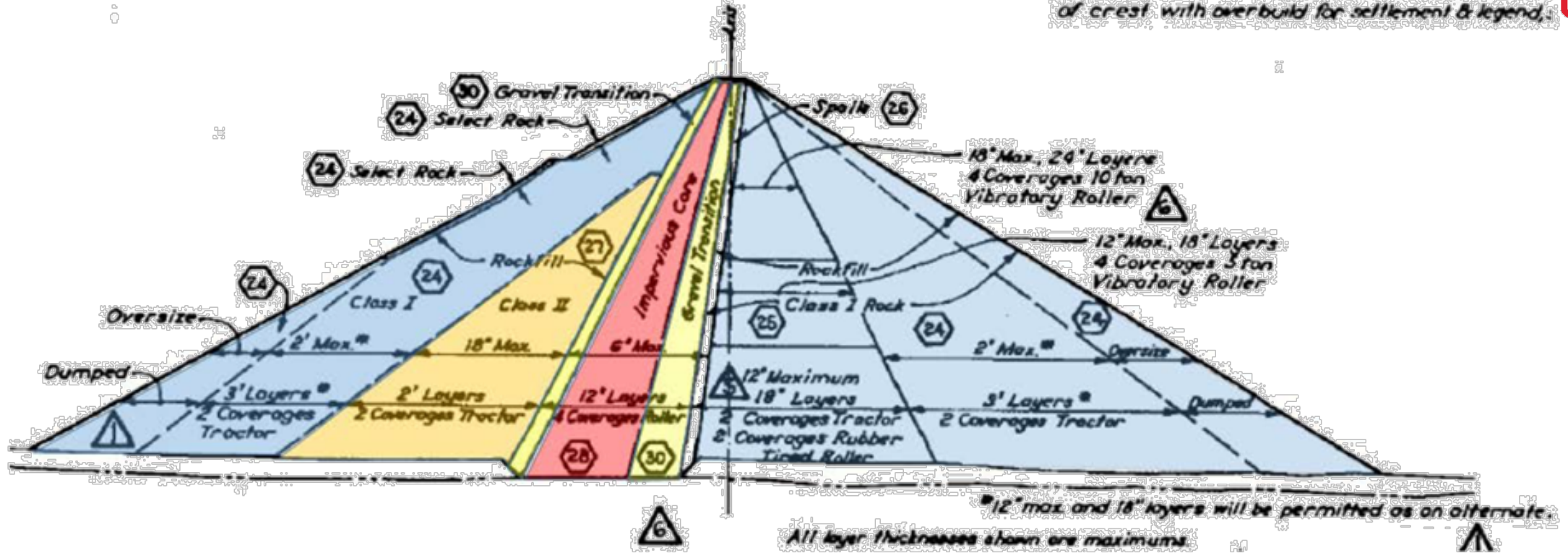
(Pope, 1967)

A number of test pits investigated cracks in the crest over the years.

- Cracks extend thru core into spalls
- Cracks primarily longitudinal
- Some upstream of core, some downstream of core, some cross core upstream-downstream
- Transverse cracks are present
- Crest stair-steps down towards reservoir (Pope 1967)
- Most shallow, but >1"-open cracks have been confirmed to extend to depths greater than 15 feet below the crest (total depth unknown)



TYPICAL CROSS SECTION



Class I rockfill: unweathered basalt or andesite rock fragments with max diameter of 24" & ≤15% passing the No. 4 sieve.

Class II rockfill: similar to Class I with ≤ 25% passing No. 4

Impervious core: rock fragments or gravel with sandy clay or sandy silt binder. Max size 6" (≤40% retained on 3" screen & ≥25% passing No. 4)

Gravel transition: sandy gravel or silty sandy gravel with a max size of 6"

Spalls: max size 6 inches no more than 15% passing No. 4

Note: Test pits in crest of dam have documented cracks through core, gravel transition, and spalls

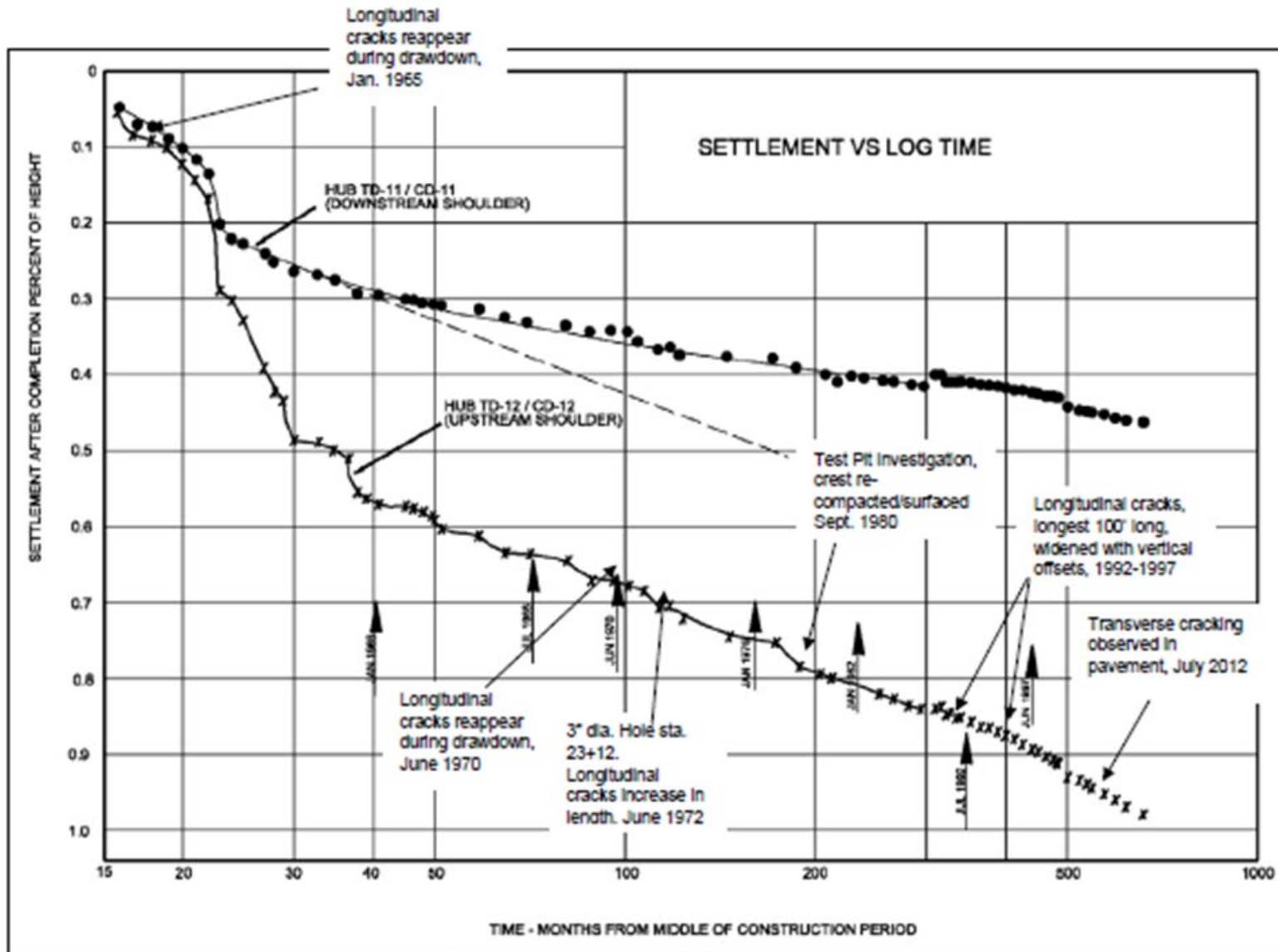


Figure 4-8: Embankment Settlement vs. log time

- Settlement as percent of height-
- Downstream Shoulder (top)
 - Upstream Shoulder (bottom)

Continuing, and sometimes rapid settlement of upstream shoulder and ongoing incidence of cracks

Important questions: is the deformation concentrated along pre-existing planes, have they experienced strain softening, and what is their geometry?



SETTLEMENT HISTORY



How will the dam respond to seismic loading, given its performance under static loads?



IES RISK ASSESSMENT

- Initiates with a Semi-Quantitative Risk Assessment (May 1, 2015) to update previous PFMA/SPRA Risk Assessments
- Will complete Quantitative Risk Assessment (IES) after Phase 1 and Phase 2 Field Investigations are Complete, and Inclinometer Data is Available



PRELIMINARY RISK ASSESSMENT



- 72 Potential Failure Modes Evaluated During 2015 Potential Failure Modes Analysis
 - 9 Overtopping Failure Modes
 - 15 Internal Erosion Failure Modes
 - 12 Spillway Gate Failure Modes
 - 5 Spillway Chute Failure Modes
 - 8 Spillway Operational Failure Modes
 - 14 Regulating Outlet Works Failure Modes
 - 2 Diversion Tunnel Failure Modes
 - 7 Powerhouse Failure Modes

- 7 Potential Risk-Driving Failure Modes Remained After Initial Screening



SEMI-QUANTITATIVE RISK ASSESSMENT: KEY QUESTIONS FOR PHASE I SITE INVESTIGATION



- PFM 1: Overtopping
- PFM 4: Seismic instability of the embankment
- PFM 5: Liquefaction of the foundation
- PFM 6 & 19: Concentrated Leak Erosion (CLE) through Seismic or Static induced transverse cracks
- PFM 11: CLE at an abutment contact
- PFM 29: Trunnion friction Tainter gate failure
- PFM 31, 32, 38: Seismic spillway gates structural failure
- PFM 1: What is the probability that a peak pool will exceed the dam crest elevation, with and without debris? How much overtopping can the embankment take before failure?
- PFM 4: What ground motions might be expected, and how will the embankment respond to seismic loading?
- PFM 5: Is the as-built foundation prone to liquefaction?
- PFM 6&19: Which is the controlling loading condition; static or seismic? How continuous, deep, and wide might differential settlement cracks be within the embankment materials?
- PFM 11: Are there asperities in the foundation, how well were the abutments prepared to receive embankment materials, was the embankment well compacted at the abutments, why is there an increase in seepage when the pool exceeds a certain elevation?
- PFM 29: Were the gates designed for adequate trunnion friction?
- PFM 31, 32, 38: Are the gates & spillway pier stable for all seismic failure modes?



SITE INVESTIGATION PLAN



SITE INVESTIGATION PLAN (PHASE I)



1. Structural Analysis

- Screening-level assessment first, and if necessary more advanced analysis (more advanced analysis was not needed).
- Gates were not adequately designed for anticipated trunnion friction, gate modifications were subsequently approved (one of the two gates has been upgraded, the other gate is scheduled to be upgraded)

2. Seismic and Seepage Assessments

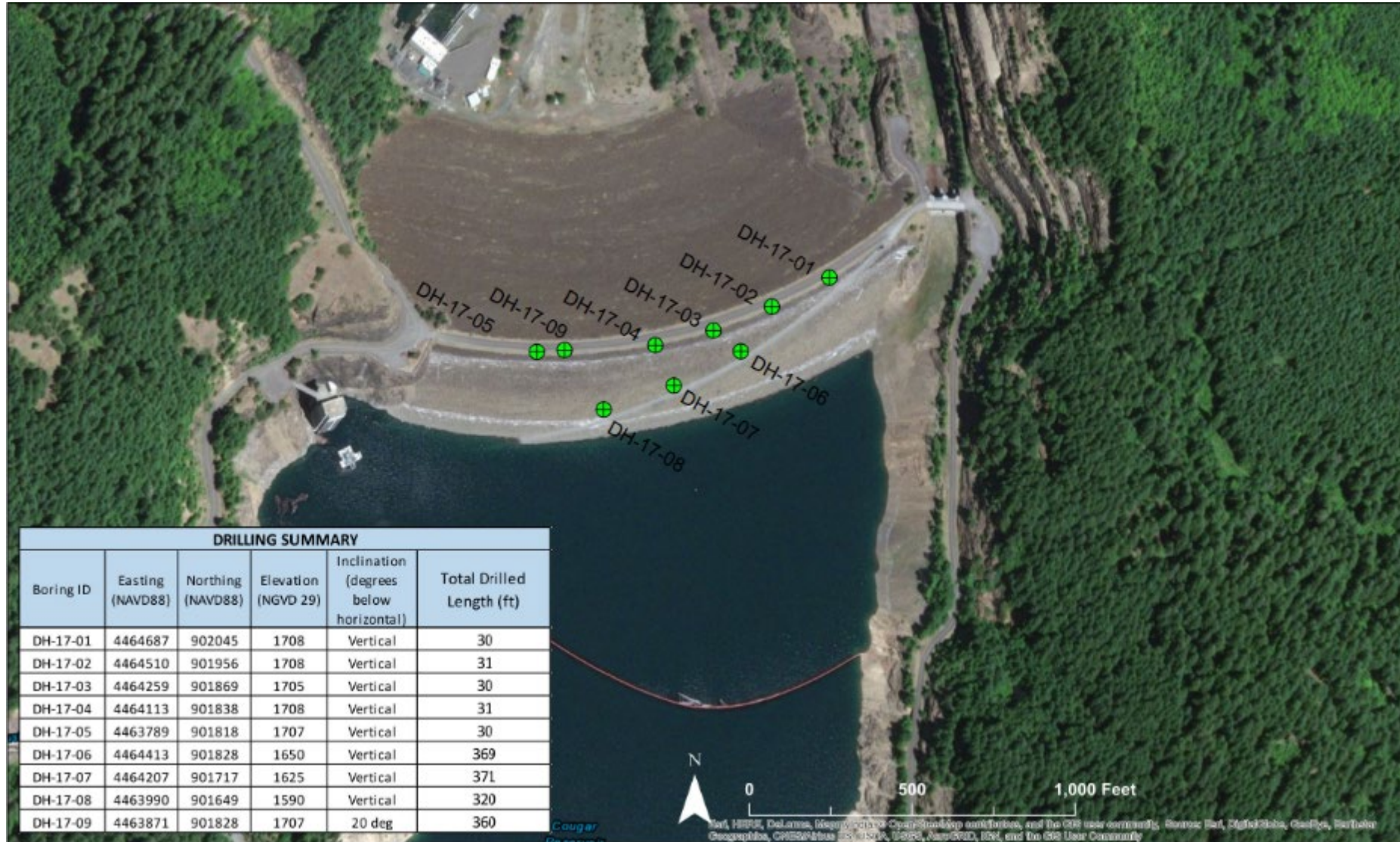
- A Field Investigation Plan and Drilling Plan were prepared to;
 - » Establish field controls and methods for safe acquisition of the subsurface information
 - » install inclinometers to define pre-existing shear planes in the upstream slope
 - » perform down-hole shear wave velocity tests to inform deformation models (Newmark, and FLAC analyses were conducted)
 - » collect soil samples for further characterization of the embankment materials
 - » Conducted interview of project engineer present during construction and collected available data

3. Hydrologic and Consequences Updates

- » Updated PMF, Hydraulic Load Frequency Curve, Dam Breach and LifeSim 2.0



SITE INVESTIGATION PLAN (PHASE 1)



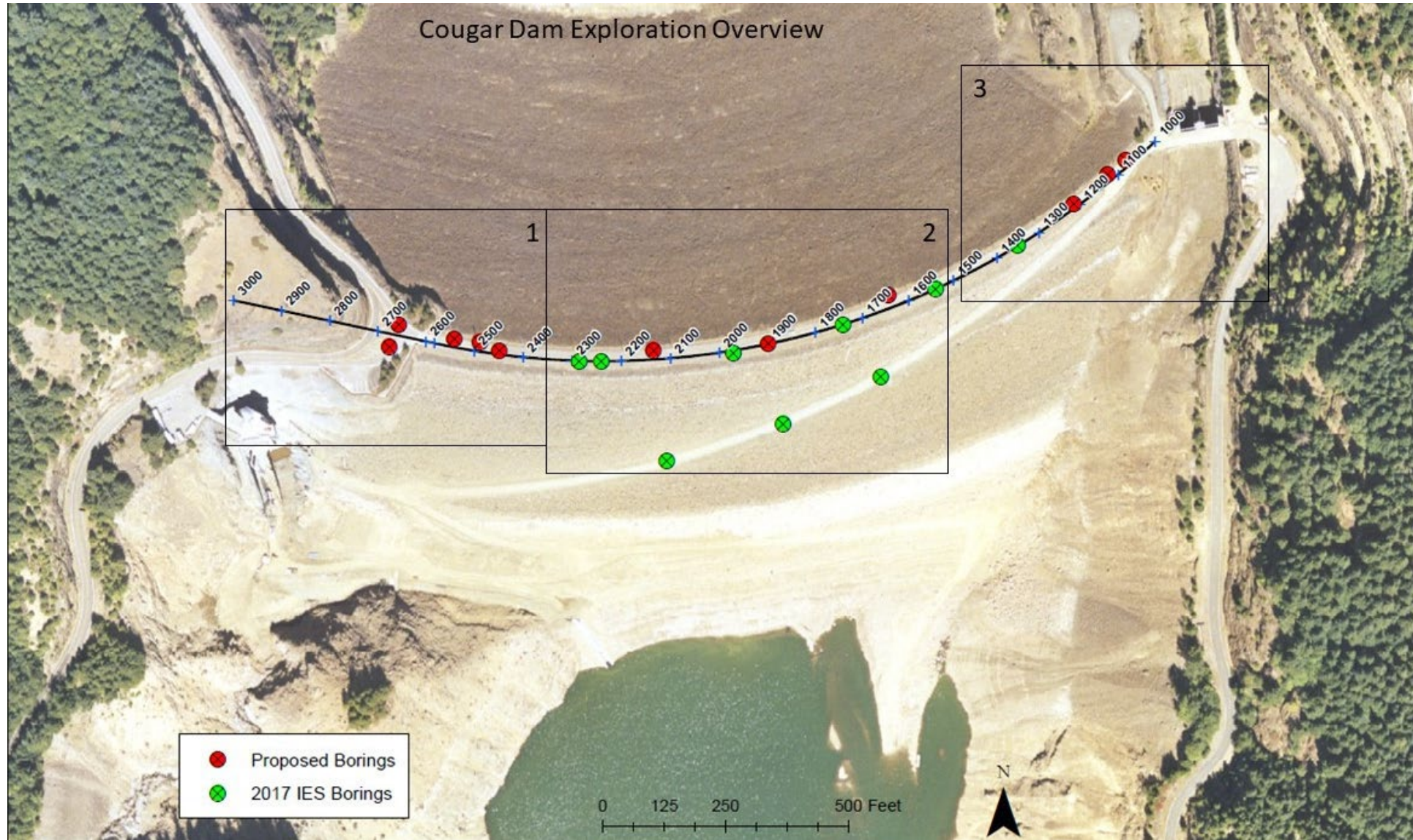


SITE INVESTIGATION PLAN (PHASE 1- COMPLETED)



- 9 boreholes were drilled (5 shallow holes, <30 ft, terminating in the core and 4 deep holes terminating in bedrock)
- Inclinator casing was installed in all holes to answer questions about location and geometry of existing deformations. Movements of less than 0.25 inch have been detected in the upper 80 feet of the Class I Rockfill on the upstream side of the embankment. Continued monitoring should be able to determine if this represents a pattern of progressive movement. No discernible movement has been detected in the impervious core.
- Vibrating wire piezometers and extensometers were installed in 3 of the boreholes on the outside of the inclinometer casing.
- No significant soft or loose zones were encountered during drilling.
- Limited Torsional Ring Shear testing indicates that the core material may experience up to a 15 percent strength loss during an earthquake.
- Hole Erosion Testing (HET) indicates that the core material has a moderate to high level of erosion resistance
- Downhole geophysics was performed by USBR to determine shear velocity, which was used to inform preliminary deformation modeling

SITE INVESTIGATION PLAN (PHASE 2)





SITE INVESTIGATION PLAN (PHASE 2- OCT 2019)



- 8 borings drilled to depths of 60 feet
- 1 boring drilled to depth of 250 feet (will be new inclinometer to monitor downstream slope)
- The 8 60-ft borings will be completed as observation wells
- Majority of the borings target the spalls zone downstream of the dam crest
- Samples will be collected for sieve analysis and filter compatibility and cracking susceptibility evaluations
- 2 of the 9 borings will target sampling gravel transition zone for same purpose



CLOSING



1. Previous site characterization and performance data were compiled, reviewed, and consolidated into a new Site Characterization Report
2. Previous risk assessments were updated with a PFMA and Semi-quantitative characterization of the risk utilizing latest methodology and tools.
3. A site investigation plan for Phase I investigation was prepared (and executed) to fill data gaps and help to answer key questions related to the specific risk driving failure modes identified for this project.
4. After completion of the Phase I work, a quantitative risk assessment was completed and additional site investigation plan developed to close out any remaining issues.
5. Results from the quantitative risk assessment and the path forward will be discussed in the next Cougar Dam presentation.