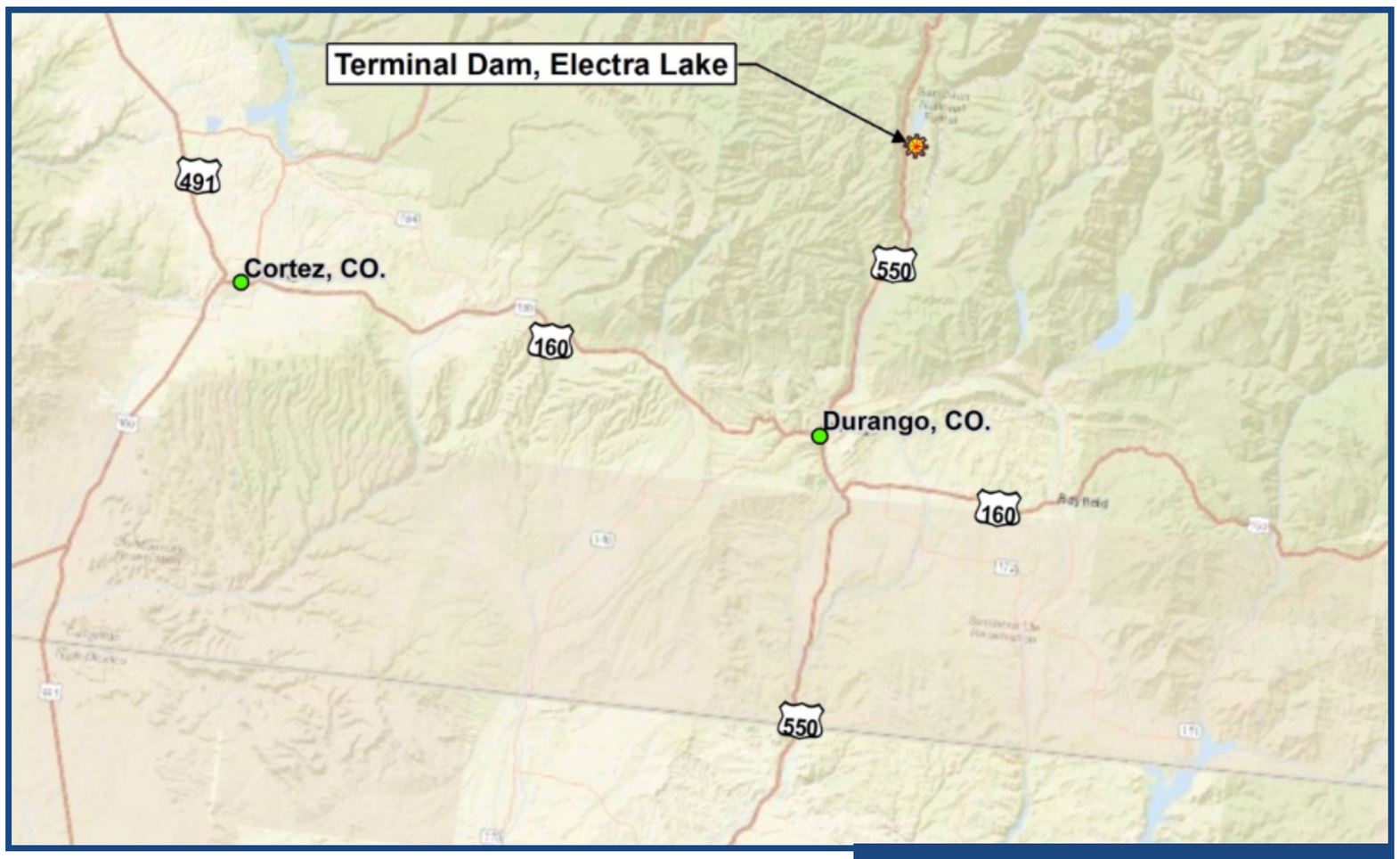
CASE STUDY: Understanding The Cause Of Seepage - Terminal Dam

GEOPHYSICAL INVESTIGATION TO IDENTIFY, MAP AND MODEL PREFERENTIAL SEEPAGE AROUND A DAM

Willowstick LLC - W.W. Wheeler & Associates, Inc.



Terminal Dam Location Map

Introduction

The following report delves into the findings of a comprehensive Willowstick® geophysical investigation conducted in September 2019 at the Terminal Dam of Electra Lake, situated near Durango, Colorado. Terminal Dam, a vital component of the Tacoma Hydropower Project owned by Xcel Energy, stands as a 1,270-foot long, 60-foot-high asphalt-faced zoned rockfill dam, overseeing the 22,364-acre-foot reservoir. The investigation aimed to identify, map, and model preferential electric current flow paths indicative of high-probability pathways for seepage beneath the right half of the dam structure. This pursuit was necessitated by a notable surge in seepage flows recorded in July 2018, with rates escalating from approximately 35 gallons per minute (gpm) to over 300 gpm, peaking at 450 gpm, prompting the initiation of draining procedures by Xcel Energy.

The sudden escalation in seepage flows underscored the urgency of identifying and rectifying potential leakage sources within the dam infrastructure. Our report delves into the intricate details of the geophysical survey methodologies employed, the reconstruction of electric current flow patterns to pinpoint preferential flow paths, and the implications of the findings in the context of mitigating seepage concerns and ensuring the structural integrity of the Terminal Dam.

SUMMARY

LOCATION

Colorado - USA

CHALLENGE

The tasks undertaken included initial dive exploration, dye testing, and a Willowstick geophysical survey to locate the leak, identified as a 12-inch diameter hole, necessitating temporary sealing until reservoir drainage.

SOLUTION

Efficient remediation of the seepage issue via diving, dye testing, and Willowstick exploration. Prompt repairs with hydraulic asphalt patching ensure dam integrity.

BENEFIT

Successful resolution bolsters dam stability, restores confidence, and enables uninterrupted hydropower operations. Assurance of long-term reliability.

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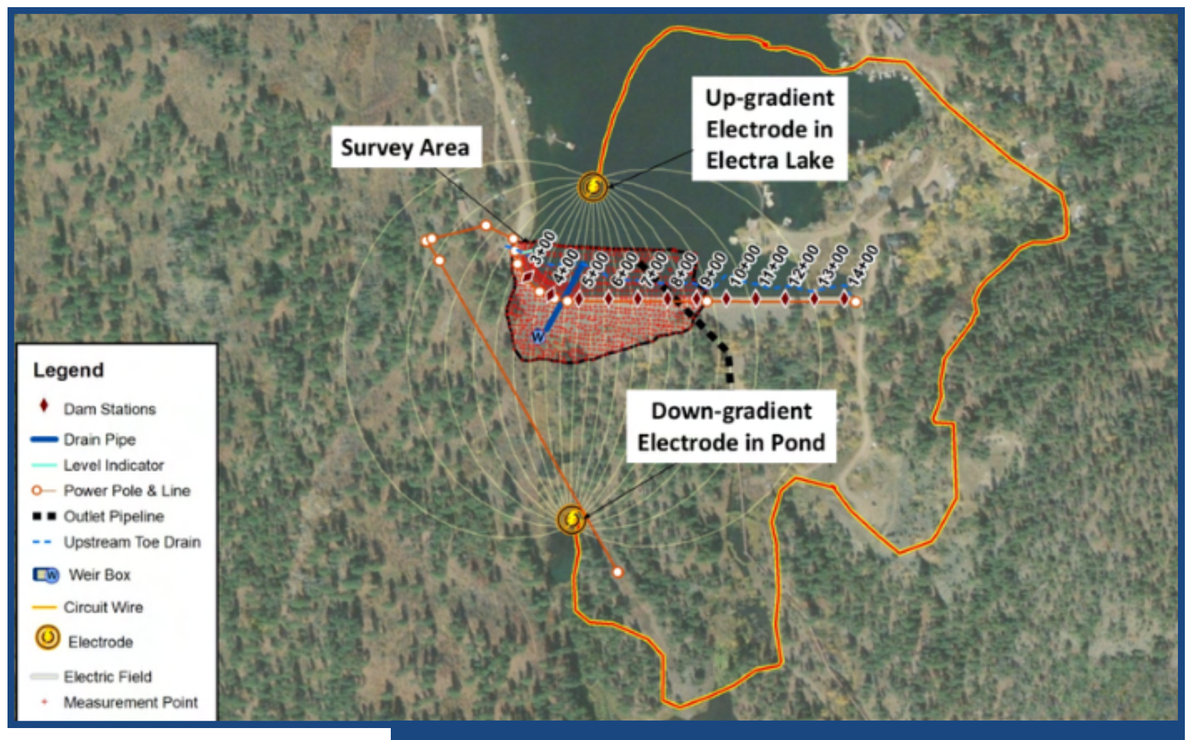
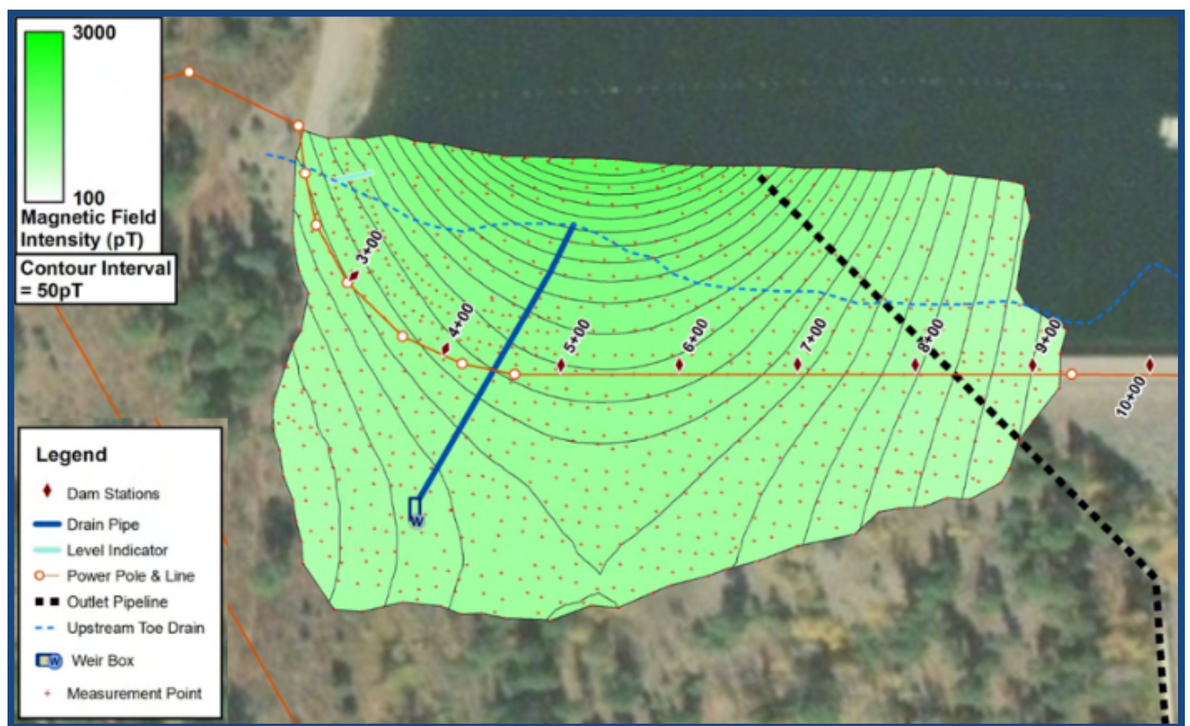
Investigative Approach

In geophysical terms, the "Willowstick" method, akin to Magnetometric Resistivity (MMR), diverges from traditional resistivity equations, instead employing potential field methods to visualize electric current flow in the ground. It offers advantages over DC Resistivity, including rapid measurements in free space, increased sensitivity to conductivity gradients, and ease in tracking buried conductive anomalies. The method applies by injecting electric current between electrodes strategically placed upstream and downstream of an embankment to detect preferential flow paths of seepage. This process leverages the fact that water with dissolved ions is a good conductor, concentrating current along seepage routes.



Terminal Dam Survey Layout and Coverage Map

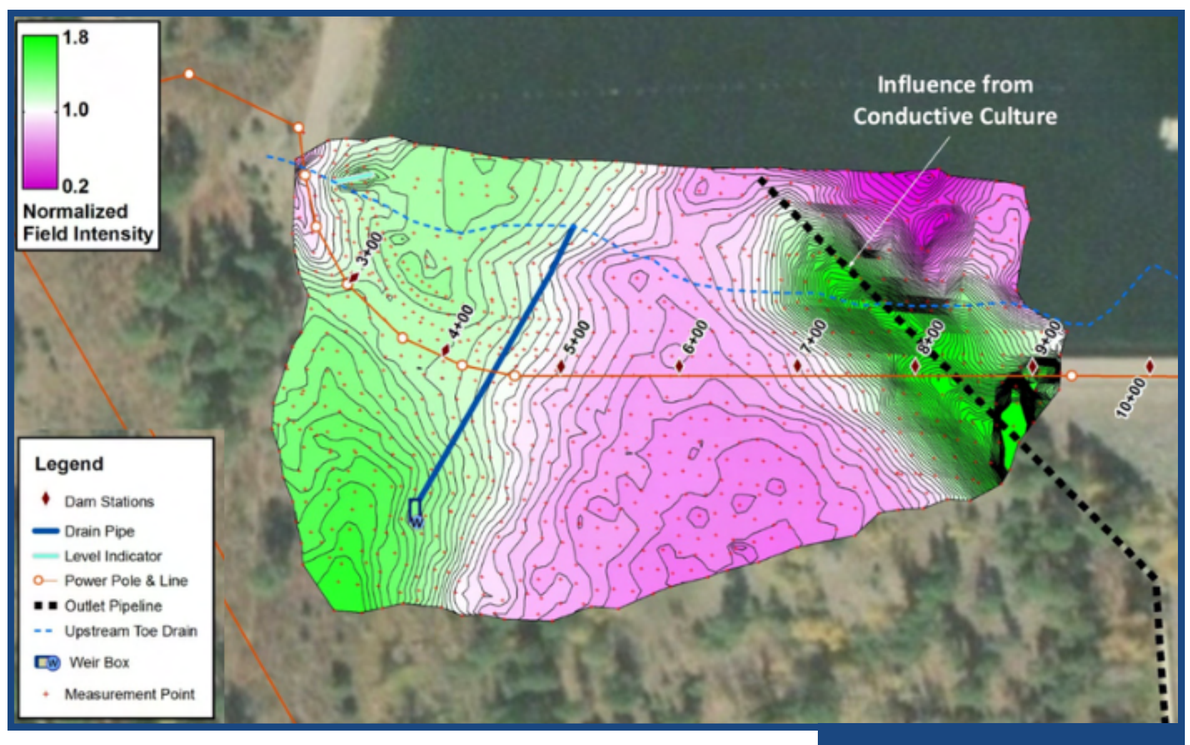
Initial investigations into increased seepage explored potential causes such as leakage through an asphalt liner or a foundation sinkhole. Dive explorations and dye testing narrowed the search to the lower part of the reservoir. Willowstick Technologies conducted a geophysical survey, pinpointing a hole in the liner near the upstream toe of the dam. Temporary stabilization measures were implemented, significantly reducing seepage losses and confirming the hole as the primary cause of increased flow.



Predicted Magnetic Field Map

Data Processing

To effectively integrate ECD results with pertinent site information, both 2D and 3D models are constructed which greatly aid the interpretation process. To facilitate data analysis and interpretation, ECD model slices were embedded in both the 2D and 3D site models and carefully analyzed to identify preferential seepage flows through and beneath the dam.
With the aid of data from the ratio response map, ECD inversion results, and site models for context, an interpretation was made considering all the information together with relevant site features to produce the best interpretation possible. Similar to the Ratio Response Map which provides the “footprint” of anomalous..



Ratio Response Map

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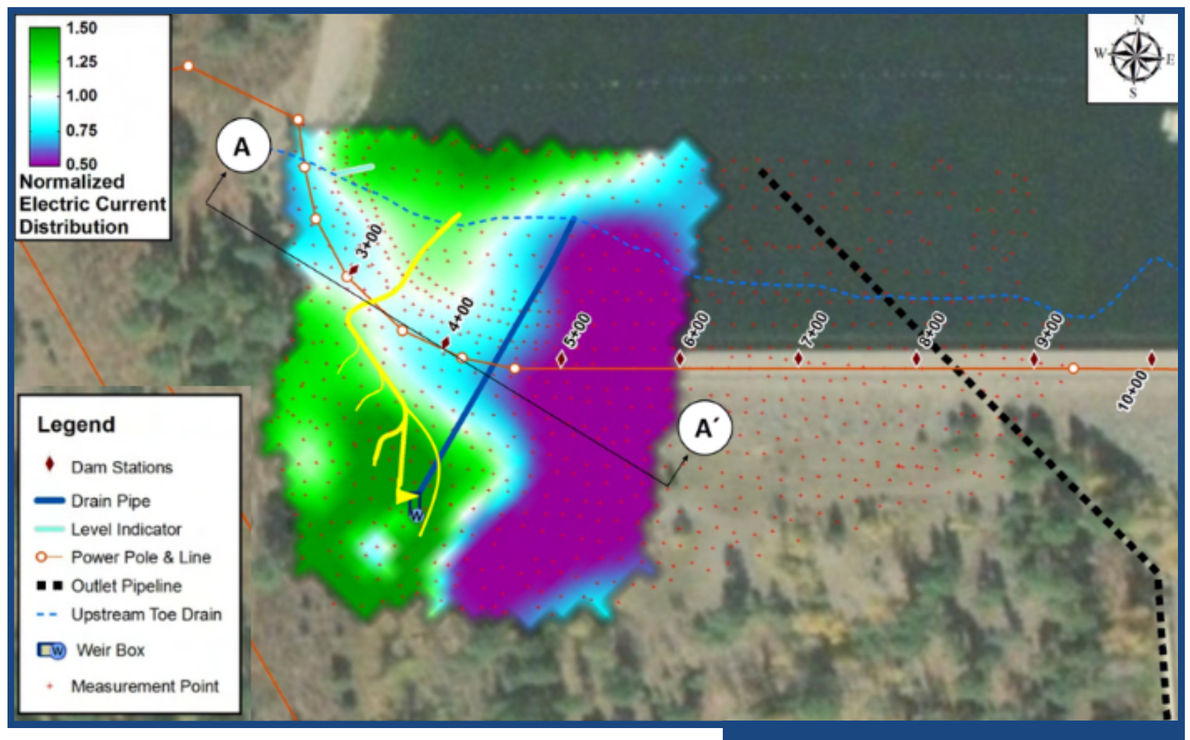
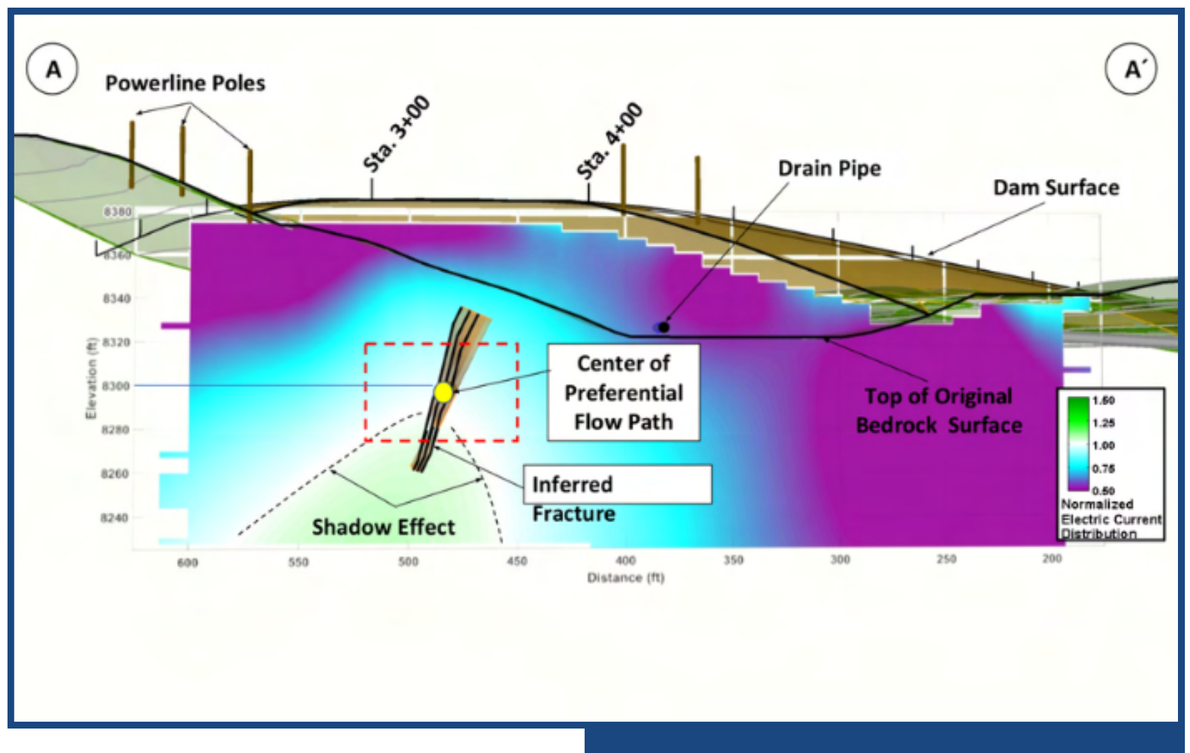
Data Processing Cont...

...features in a 2D sense, the ECD model identifies in a 3D sense where electric current flow is stronger (green) or weaker (purple) than the background model—within the volume of subsurface directly beneath the survey area. Results are analyzed and presented by extracting one or more 2D slices and placing them in site context.

The flow path manifested itself strongly both upstream and downstream of the crest, but it manifested only subtly beneath the crest—for two reasons. First, many of the crest measurements were impacted by the power line along the crest. The data required some filtering which helped the overall processing, but it still resulted in a zone along the crestline where it is more difficult to see at a glance, due to some interference. Secondly, the signal from the deepest part of the flow path (beneath the crest) is naturally weaker than the signal from the electric current at the upstream and downstream locations, both because it is deeper and because the overlying surface measurements are at the same time higher in elevation (top of crest).



ECD Model Slice at 8330 ft.

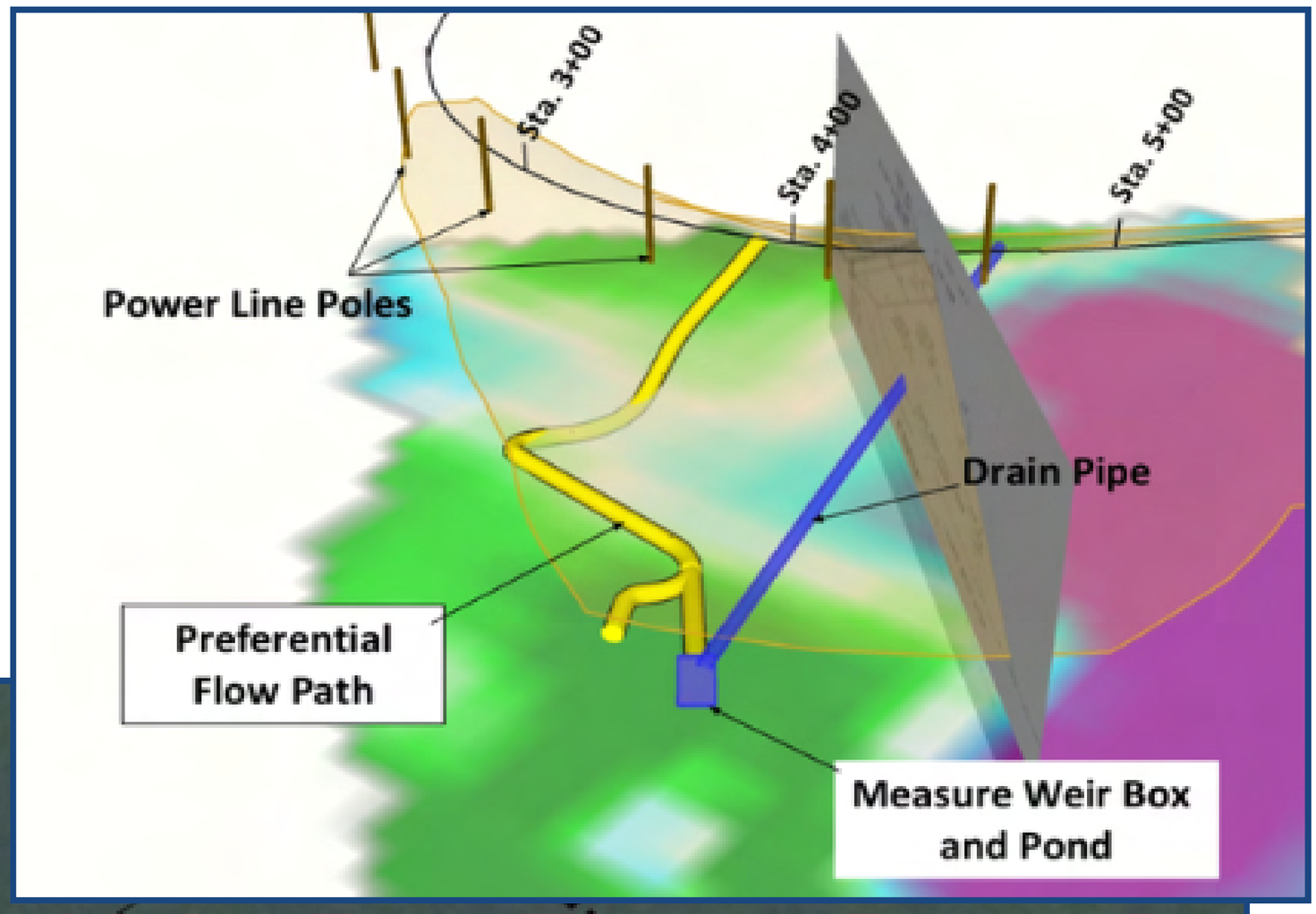


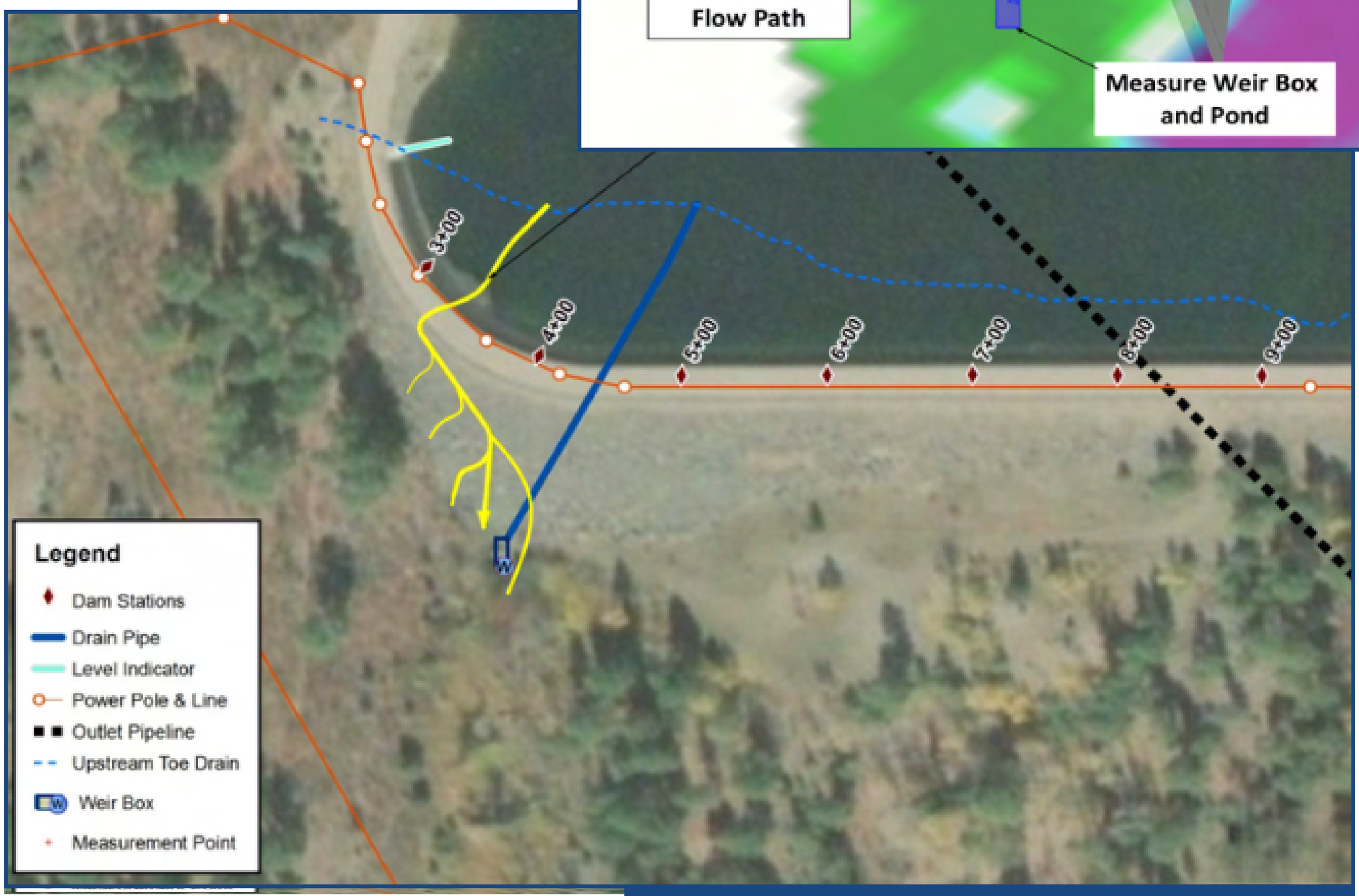
Cross Section “A” of Above ECD Map

CONCLUSION ON NEXT PAGE

Conclusion

The single defect causing a sudden increase in seepage flows in the right valley section of the dam was successfully pinpointed through a combination of diving, dye testing, and Willowstick geophysical exploration, proving highly effective in locating the hole. General findings from the comprehensive investigation of the upstream liner and foundation substantiated that the two discovered defects were similar and localized, likely stemming from construction-related issues. Despite being over 40 years old, the asphalt liner was found to be in good condition, with no other defects detected. The hole repairs were successfully implemented, utilizing state-of-the-art methods and a specialized contractor for asphalt liner construction and repairs. As the reservoir slowly returns to its maximum operating level, seepage flows in the right valley section have returned to their original ranges prior to the 2018 spike.





Conclusion Showing 2D And 3D Maps Of The Discovered Preferential Flow Path

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