Plum Creek Dam Rehabilitations

May 14, 2025

Agenda

Plum 14 Design

- Background (Existing Dam Condition / Site Constraints)
- Preliminary Design Submittals
- Environmental Studies – Identification of Forested Wetland
- Relocation of Structural Spillway
- Wetland Avoidance for Embankment Raise
- Supplemental Geotechnical Investigation (Phase 2)
- Wetland Avoidance Foundation Stability / Drainage System
- USACE Section 404 Permit Package

Plum 2 and Plum 21 Construction Highlight

- Revegetation challenges

Plum 21 Construction Highlight

- Improvement of Subgrade / Retained Backfill for RCC spillway

Plum 14
Background

- Constructed in 1968
- Class A (low hazard potential)
- Three upstream structures (Plum 10, 11, and 12)
- 42-inch PS conduit with low-level port
- Designed for 750-feet of spillway width; constructed with only 400-feet of spillway width

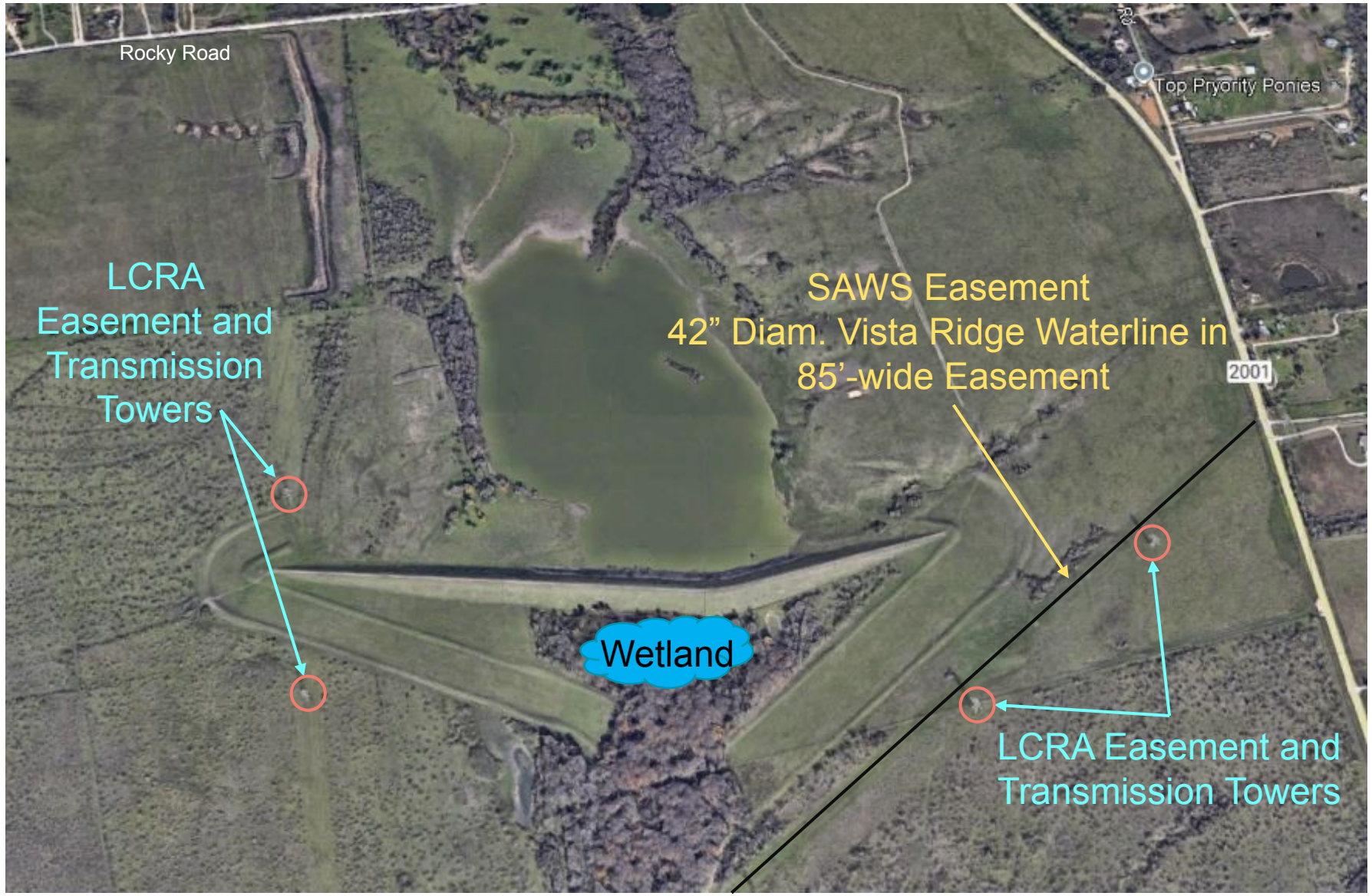
Item	Unit	12	14
Oralnags Ares	Sq.Mi.	3/ 3.62	1/15.11
Storage Capacity			
Sediment Pool (200 Ac. or 3css)	Ar.Ft.	199	393
Sediment Rcsetvc Bclow Rlser	Ac.Ft.	187	1,177
Scdlment In Oetentlon Pool	Ac.Ft.	58	161
Floodwater	Ar.Pt.	1,139	4,206
Tota3	Ac.Ft.	1,583	5,737
Surface Area			
Sedlment Pool 2/	Acre	89	177
Floodwater Pool	Acre	228	435
Volume of Flll	Cu.Yd.	105,600	319,000
Elevation Top of Oam	Foot	619.8	541.0
Maximum Helght of Dam	Foot	27	42
Emergency Spillway			
Crest Elevatioo	Foot	615.0	536.0
Bottom Wldth	Foot	400	750
Type	-	Veg.	Vcg.
Percent Chance of Use 3/	-	2.82	3.39

Plum 14
Background

- No internal drainage for seepage control
- Previous repairs
  - 1993 wave action erosion repaired with riprap installation on upstream slope
  - 2013 / 2014 plunge pool riprap replaced
  - October 2015 spillways engaged leaving minor erosion and gullies; woody debris
  - 2017 - Repair to right auxiliary spillway prepared by NRCS, approved by TCEQ, and completed shortly thereafter
- Previous modeling studies
  - 2016 Breach report (prepared by GBRA/Halff)
  - 2016 BLE San Marcos HUC-8 (Compass)

Plum 14

Site Constraints - Utility Conflicts and Wetland

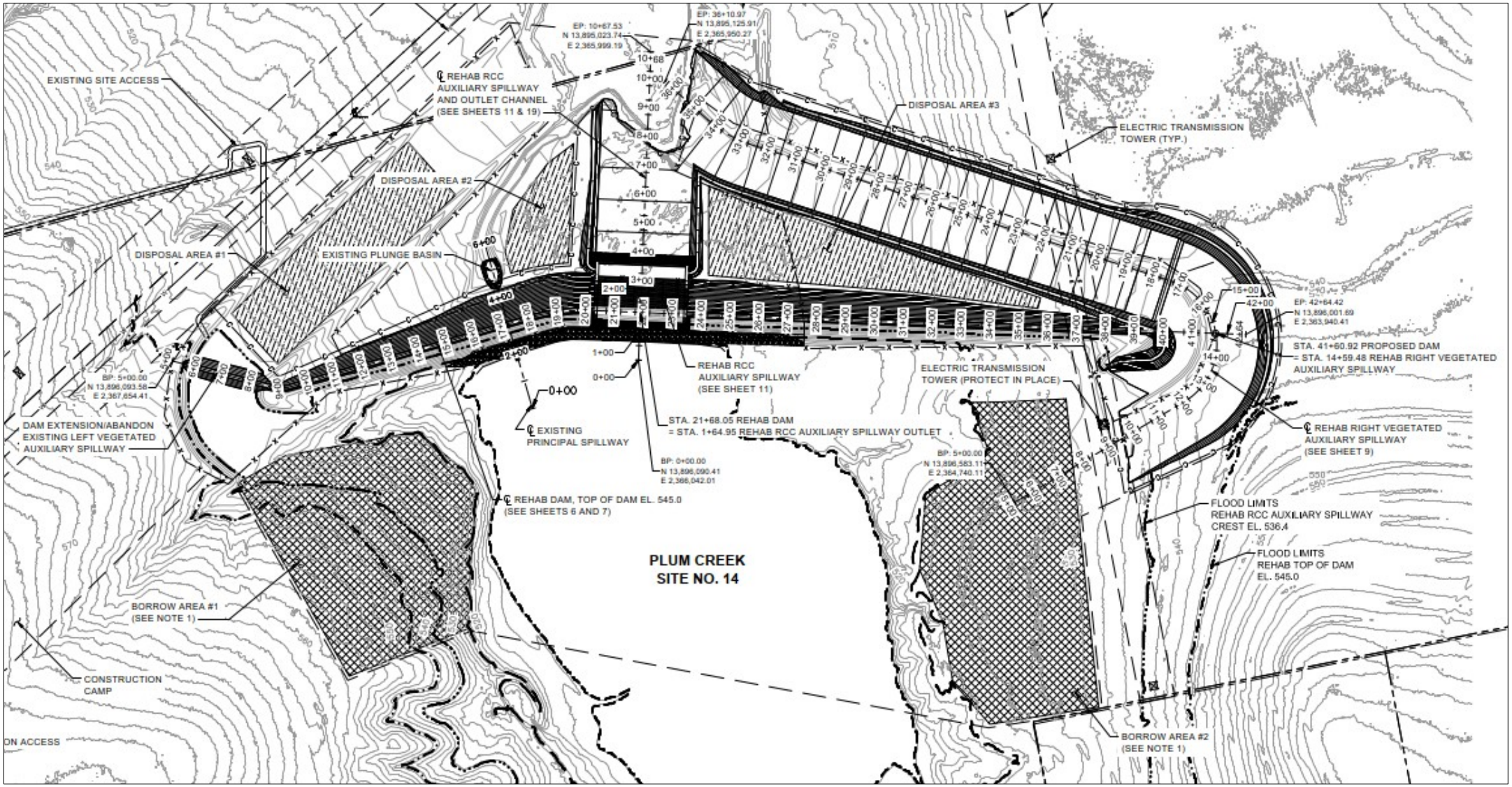


Plum 14
Concept Design to Initial 90% Submittal

- No available Plum 14 planning study performed prior to modernization design
- Two of three upstream dams were in concurrent design (Plum 10, Plum 12)
- Initial geotechnical investigation included borings at the following locations:
  - Embankment crest
  - Embankment US / DS toe
  - Along principal spillway alignment
  - Left and right auxiliary spillways
  - Embankment slope face (hand auger)
  - *Need for structural spillway was not identified during initial investigation*
- Initially proposed to keep existing PS riser
- RCC overtopping spillway to pass 75% PMF (*later updated to 80.3% PMF*)

Plum 14

Concept Design through Initial 90% Submittal



Plum 14
Environmental Studies (August and November 2020)

- A Threatened and Endangered Species Habitat Assessment was completed
  - Results found that no effects to federally listed species are anticipated
- A Waters of the U.S. Delineation was completed
  - Results found that two stream features (one unnamed intermittent and Brushy Creek), the reservoir, and three wetland features (two fringe and one forested) are present

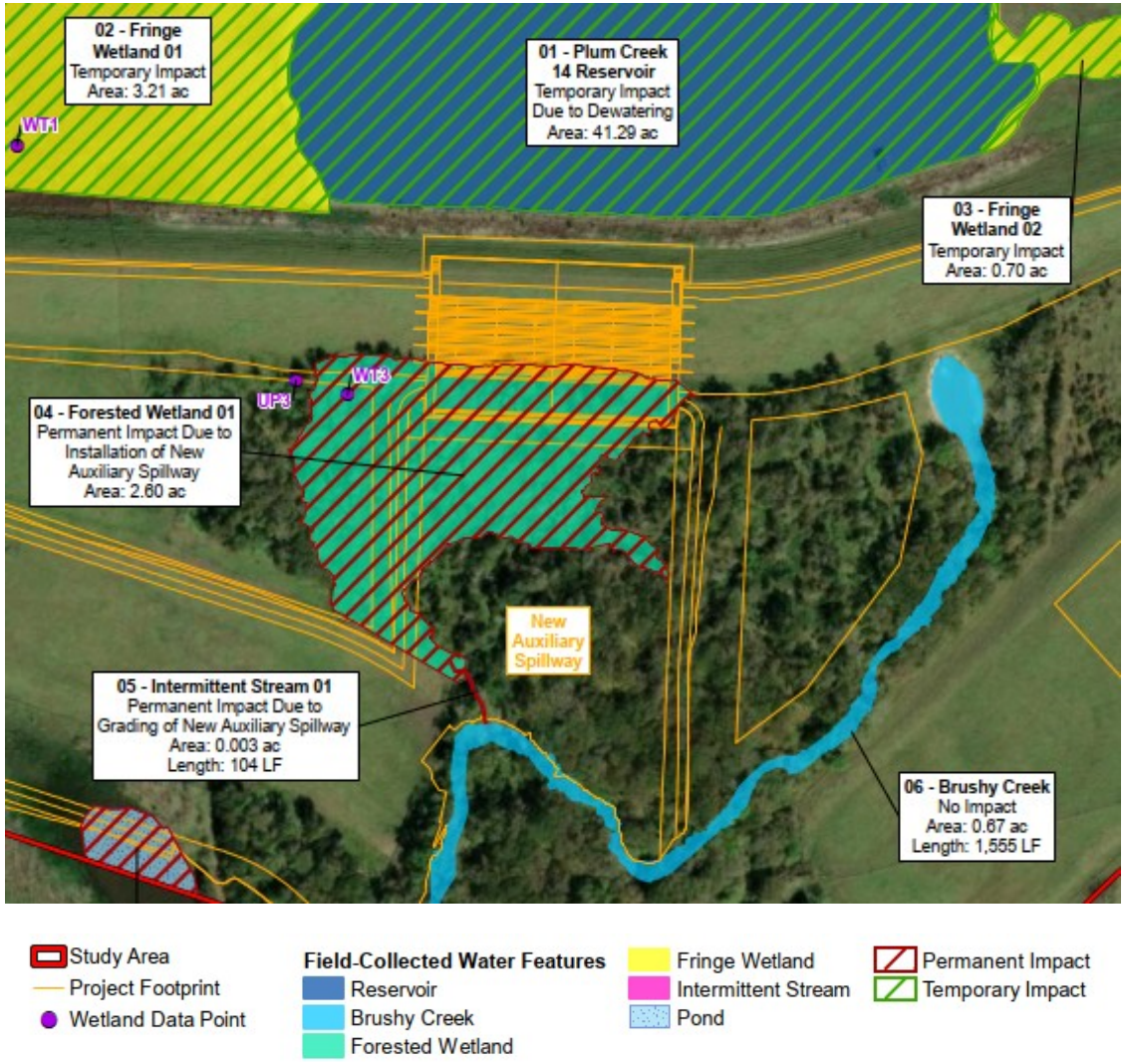
PFO Forested Wetland 01 is located on the toe of the downstream side of the dam (**Appendix A, Figure 6**). The forested wetland was approximately 2.60 acres in areal extent within the Study Area. Hydrophytic vegetation was dominated by black willow (*Salix nigra*), spike-rush, and cattail (*Typha latifolia*). The hydric soil indicator for this wetland was determined to be depleted matrix (F3). Wetland hydrology indicators included surface water and saturation. These features meet the criteria required by the USACE for wetlands: hydrophytic vegetation, hydric soils, and wetland hydrology; therefore, it is considered a wetland. This wetland is believed to receive hydrology from a leak in the dam structure. Water flows from the wetland to Intermittent Stream 01, a potentially jurisdictional water feature; therefore, can be considered potentially jurisdictional. Refer to **Appendix B, Photos 12-15** for conditions documented during the field investigation.

Plum 14
Forested Wetland Delineation Design Impacts

- Environmental Challenge:
  - Initial RCC spillway design conflicted with wetland preservation regulations.

- The forested wetland underwent multiple evaluations (regulatory changes) as well as avoidance considerations

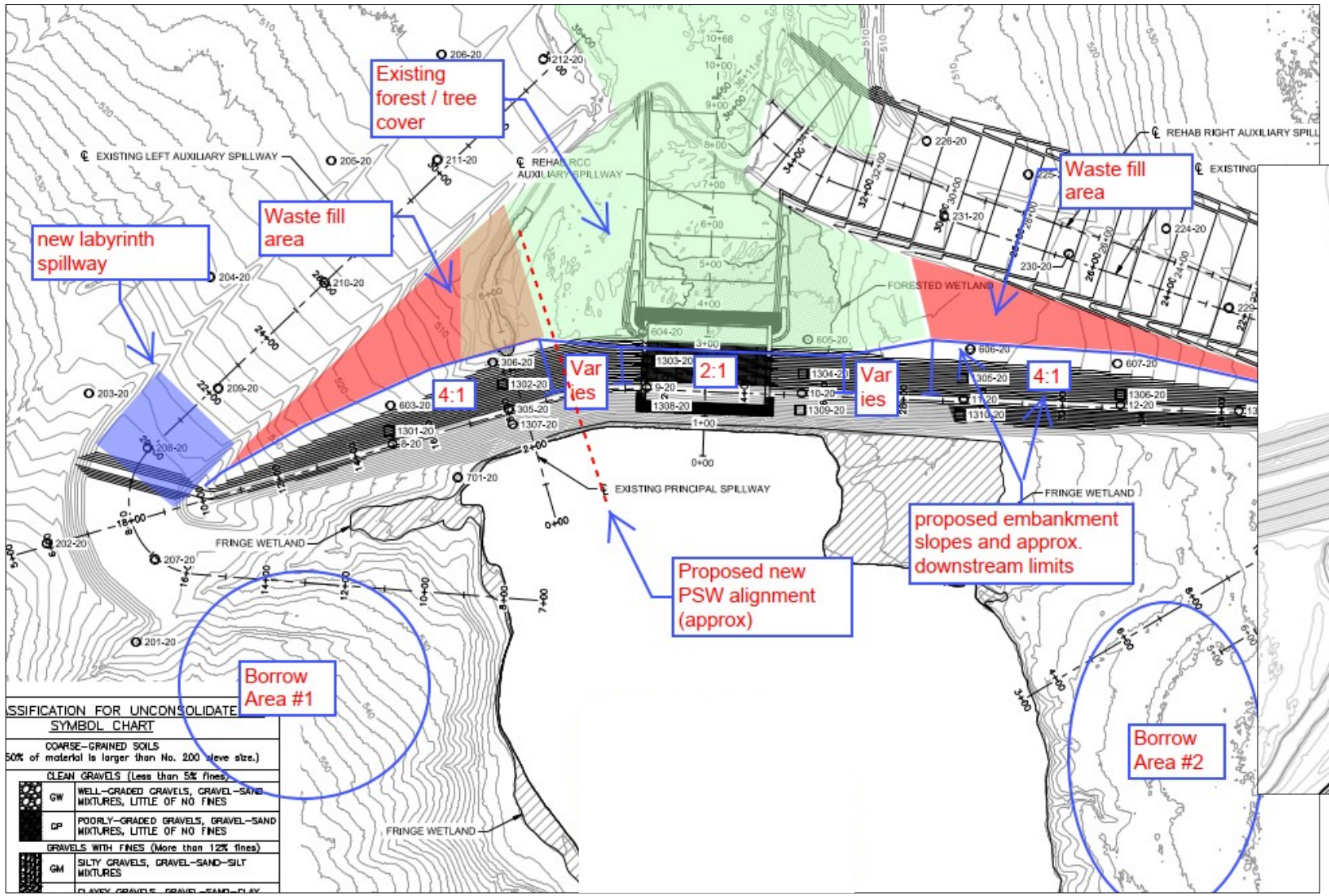
- Options after consultation with USACE:
  - USACE preference - avoidance
  - On-site mitigation (create/replace the 2.6 acres of forested wetlands)
  - Purchasing wetland credits from a mitigation bank

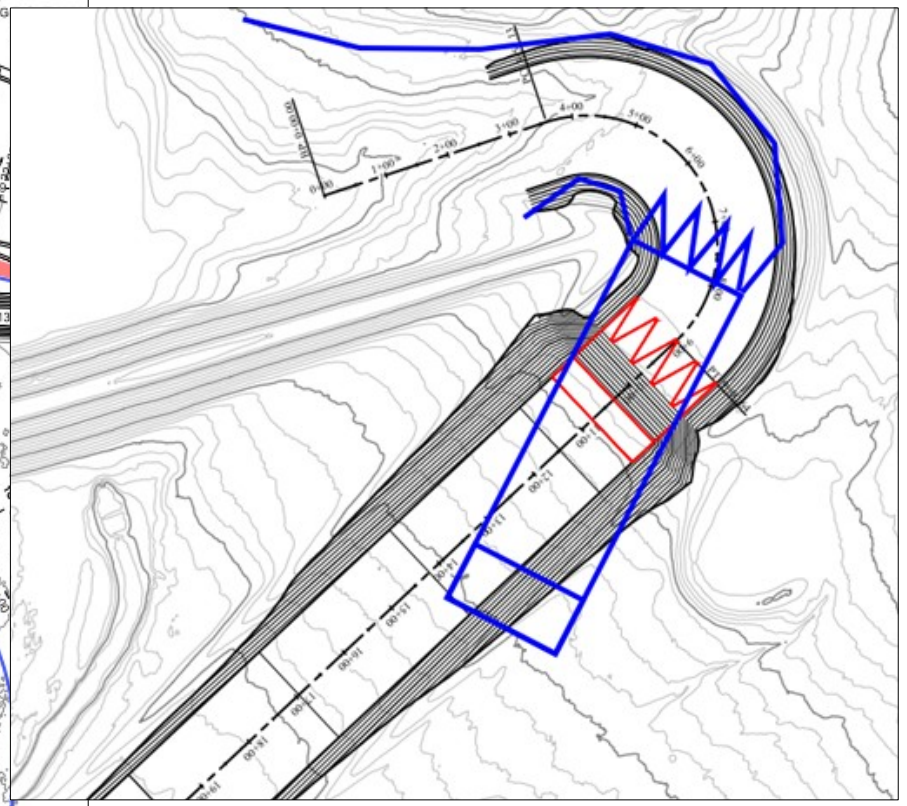


Plum 14
Forested Wetland Resolution

- Through ongoing coordination, a redesign of construction activities near the forested wetland was completed.
- The redesign was ultimately determined to be satisfactory to the USACE.

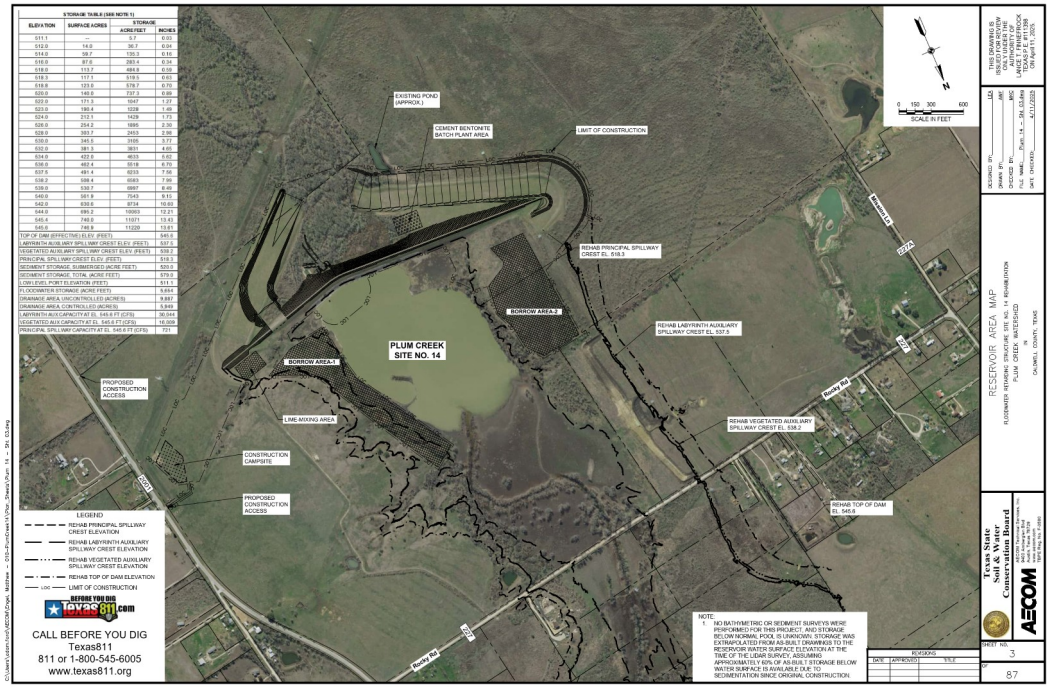
Plum 14
Relocate Structural Spillway

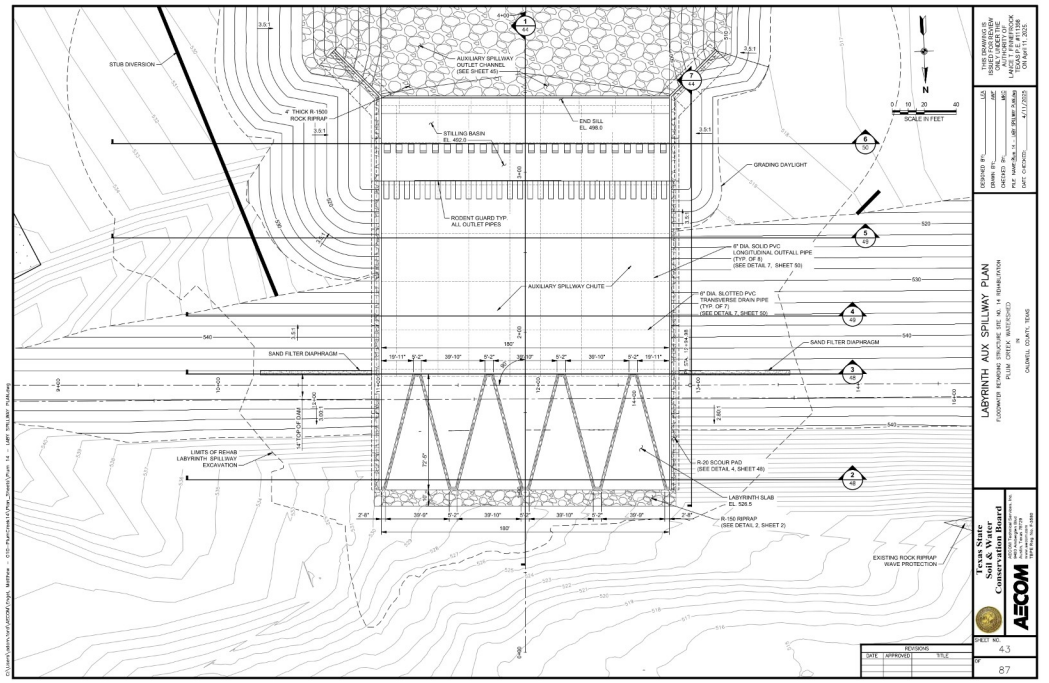




Plum 14
Labyrinth Weir Spillway Placement

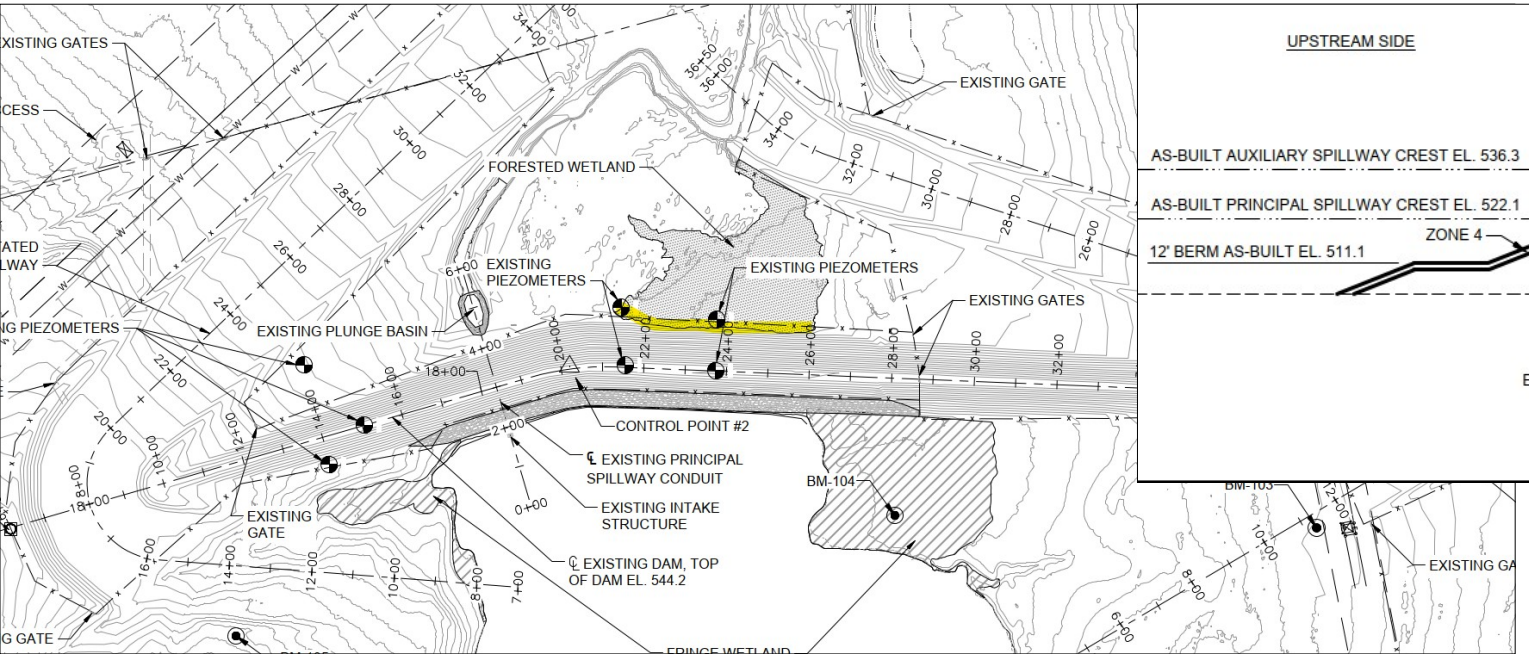
- Balanced Solution: Final design prioritized both dam safety and wetland preservation.
- Spillway Relocation:
  - Spillway moved from center of embankment to the left side of embankment
  - Ties in with existing vegetated exist channel
  - RCC-step replaced with a 4-cycle labyrinth weir.

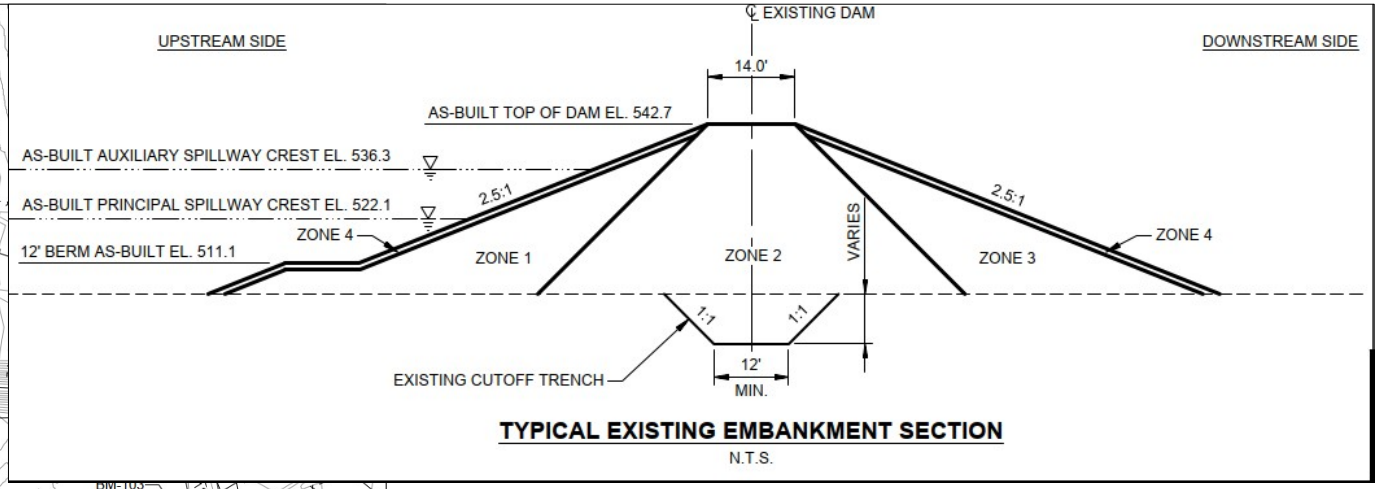




Plum 14
Wetland Avoidance for Embankment Raise

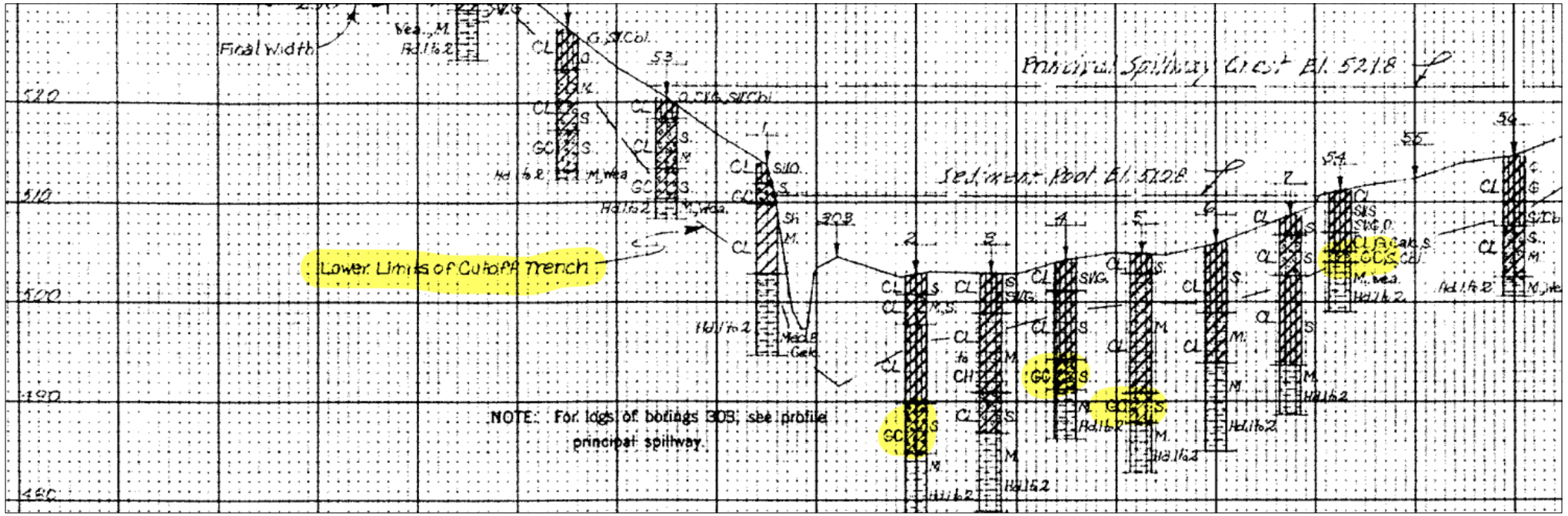
- Existing downstream toe of dam located directly on edge of wetland (constrained options and access)
- Proposed 2.9-ft raise of embankment crest would cause downstream slope of dam to extend too far into wetland and exceed 0.1-acre disturbance threshold.
- Design stability analyses found that flattening downstream slope from 2.5H:1V to 3.5H:1V was needed based on:
  - High-PI clays (LL=65-80, PI=40-55) w/ low long-term strengths comprising existing embankment & on-site borrow sources
  - Existing seepage in wetland based on observations of standing water and shallow groundwater
  - Foundation soils in wetland assumed as saturated, medium stiff, high-PI clays w/ low long-term strengths.





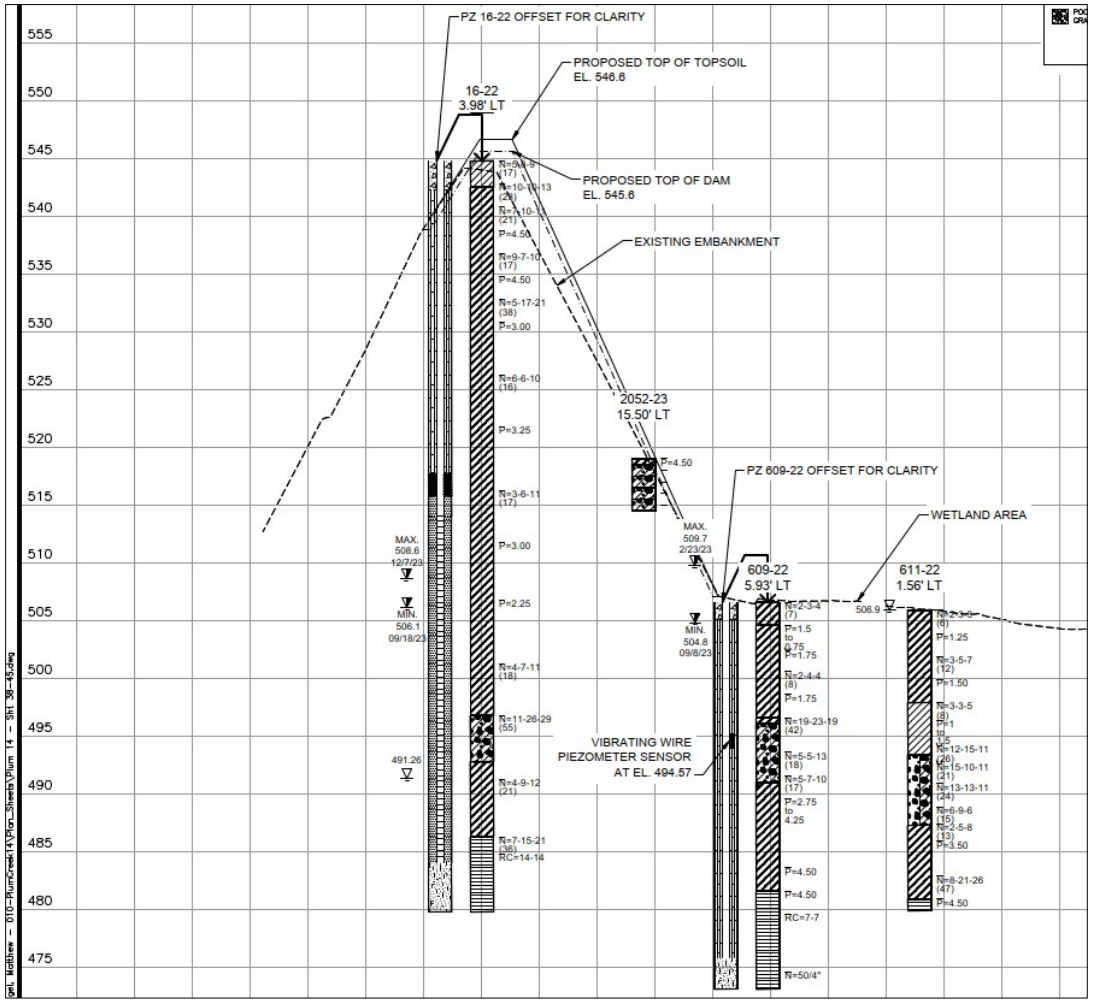
Plum 14
Wetland Avoidance for Embankment Raise

- Seepage interpreted as under-seepage below the dam cutoff trench. Per as-builts, cutoff trench did not penetrate through gravelly seams into shale in current wetland area.
- Initial investigation could not drill and sample wetland areas due to wetness and permitting issue.
- Performed supplemental geologic investigation to confirm assumed soil properties & seepage conditions to evaluate options for embankment wetland avoidance.



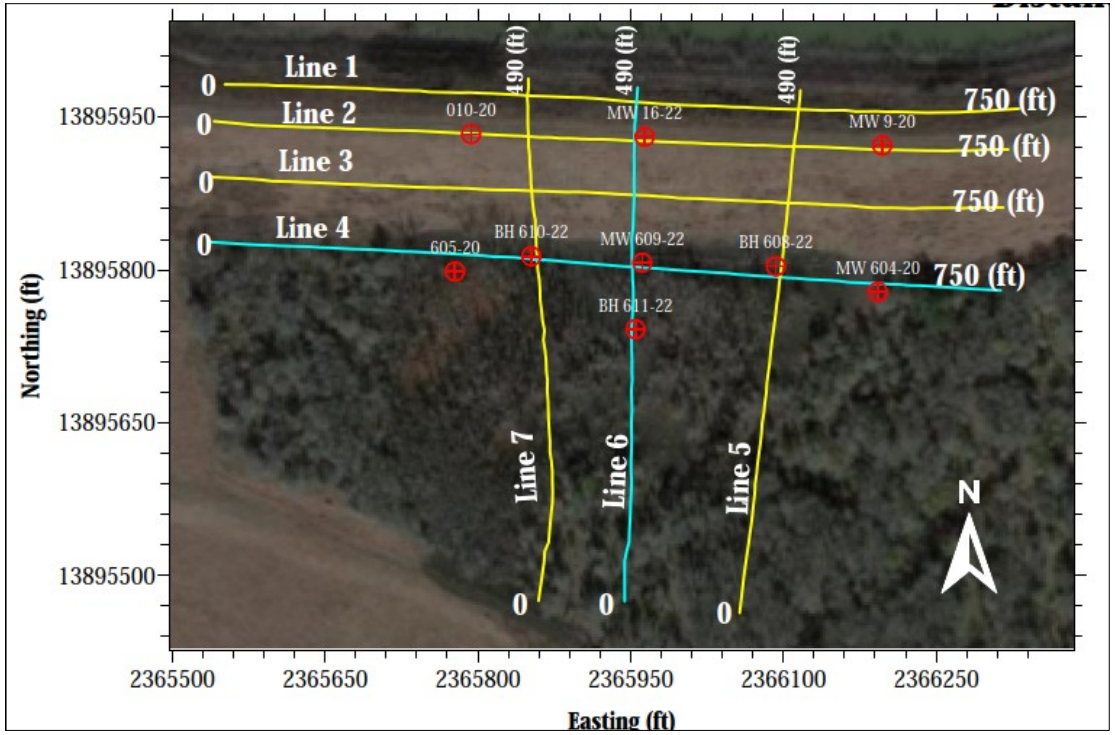
Plum 14
Supplemental Geologic Investigation (Phase 2)

- **Supplemental Borings**:
  - Drilling and sampling in / around wetland (and also in labyrinth weir footprint)
  - Standpipe and vibrating wire piezometer install to measure groundwater and monitor fluctuations
  - Advanced lab testing
  - Special measures for wetland drilling (permit, timber matting access, mud rotary drilling methods)
- **Findings**:
  - Encountered gravelly seams under the embankment extending into wetland
  - Groundwater generally at or above ground surface, with artesian groundwater a few feet above ground surface in some areas due to seepage
  - Foundation clays were softer in wetland due to saturation
  - Lab testing confirmed long-term shear strengths (foundation and embankment) assumed for initial design, which controlled design



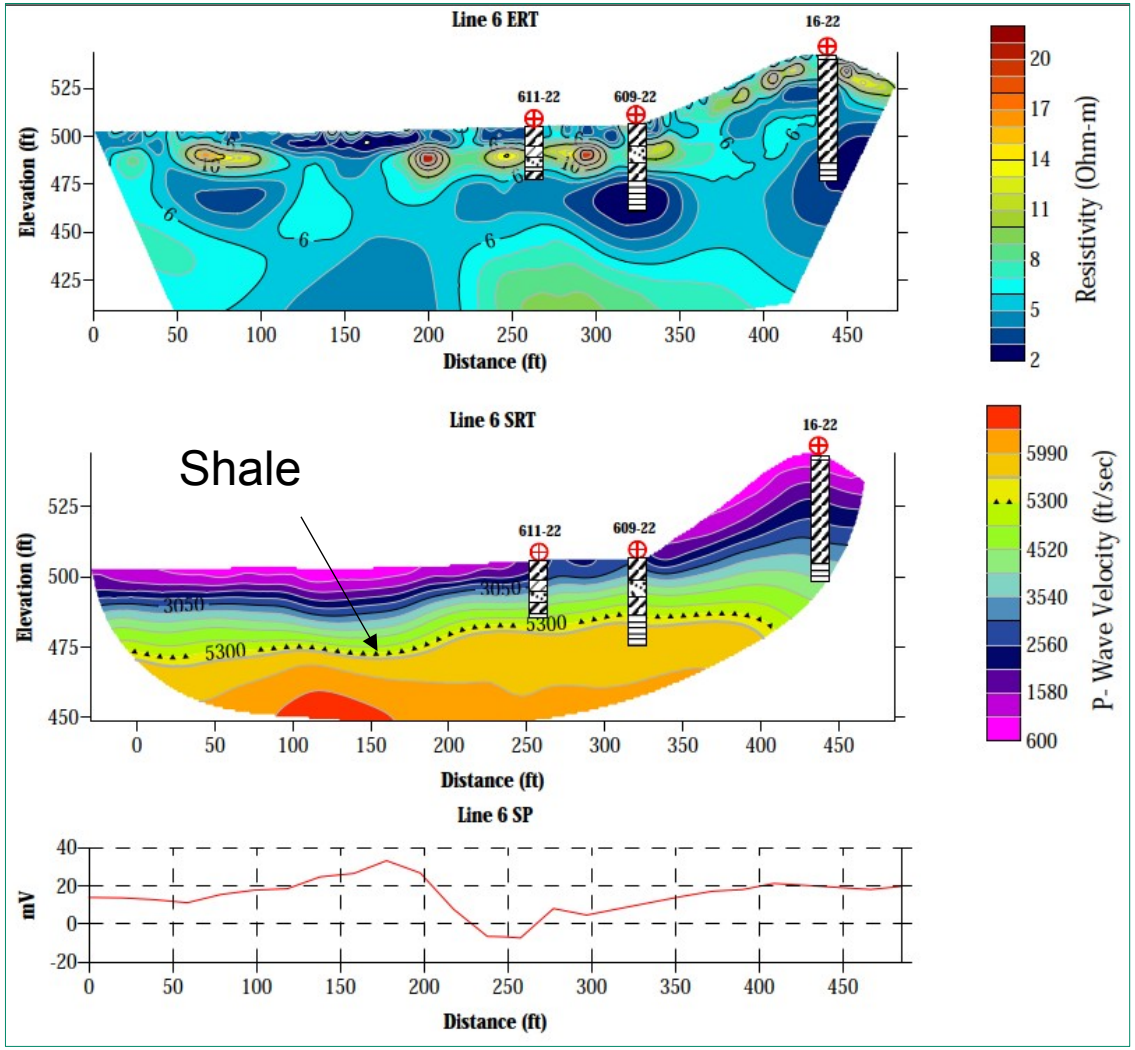
Plum 14
Supplemental Geologic Investigation (Phase 2)

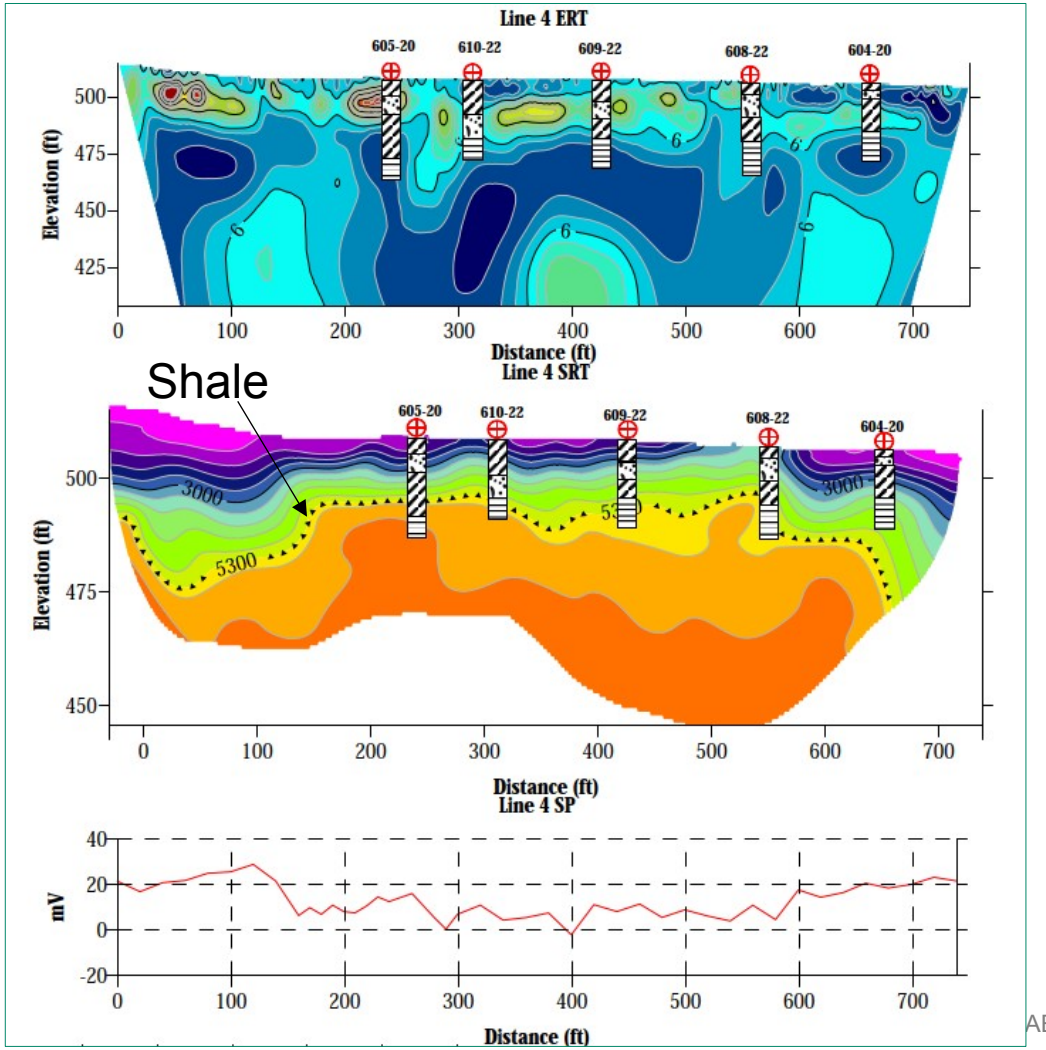
- Geophysical Investigation: Surface-based methods included Seismic Refraction Tomography (SRT), Electrical Resistivity Imaging (ERI), Self Potential (SP), and Frequency-Domain Electromagnetics (FDEM)
- Purposes: to map inferred elevations of shale bedrock and soil stratigraphy, groundwater/saturated zones, and seepage patterns between discrete boring locations



Plum 14
Supplemental Geologic Investigation (Phase 2)

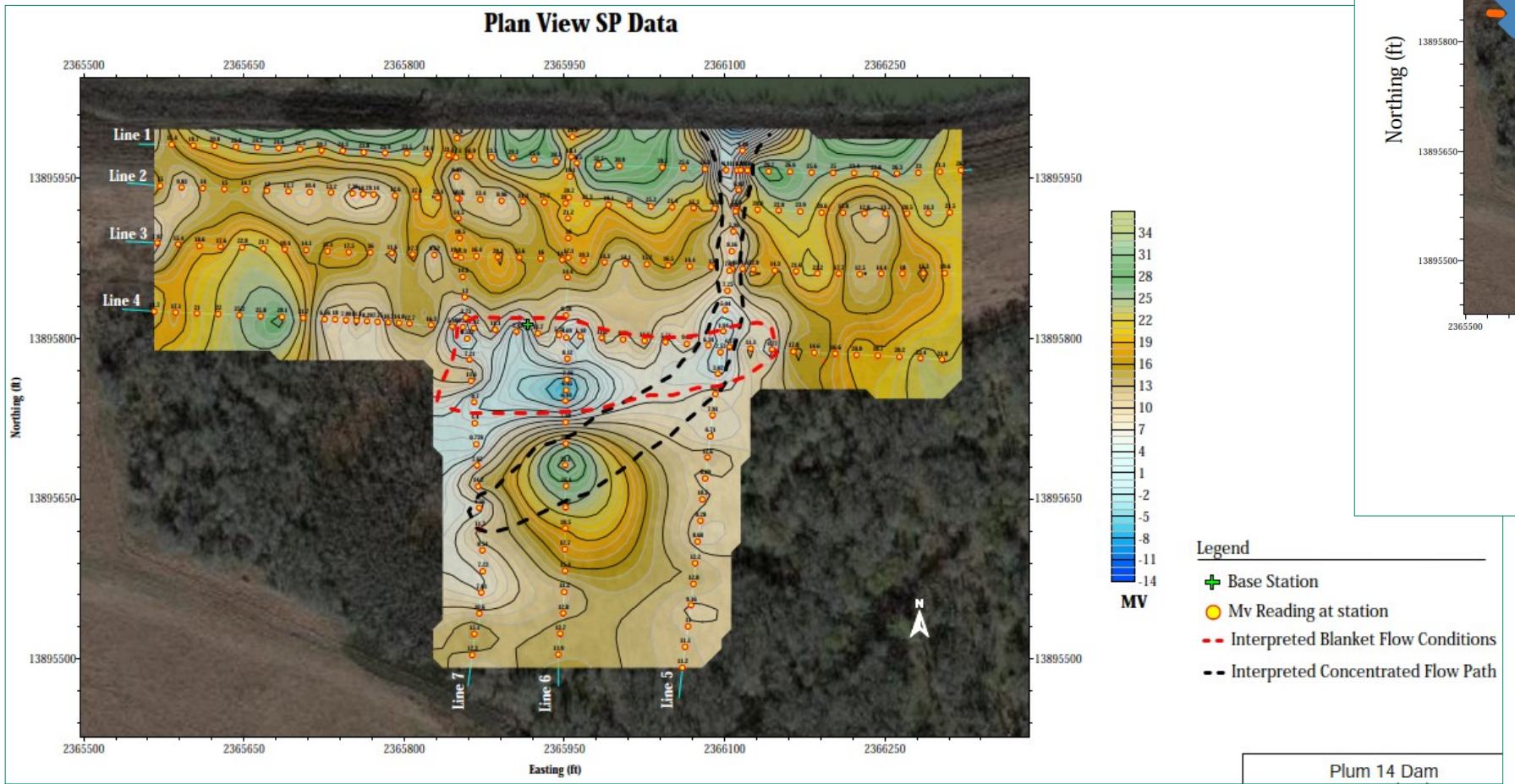
- Representative geophysical results for ERT, SRT, and SP:

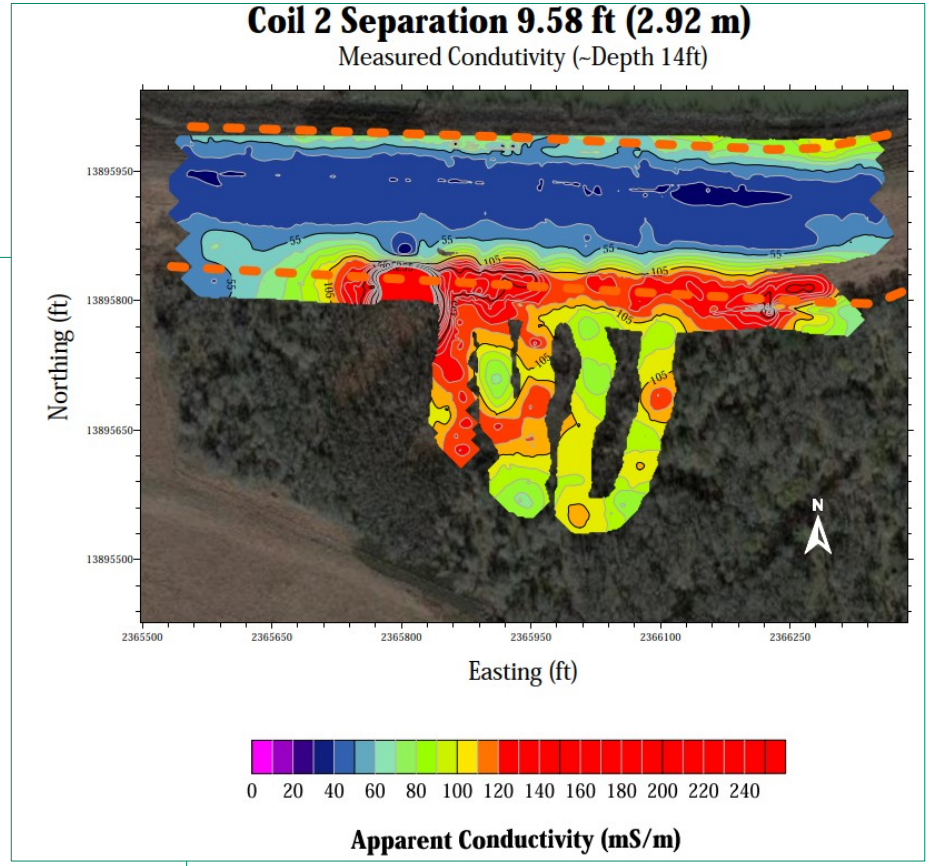




Plum 14
Supplemental Geologic Investigation (Phase 2)

- Representative geophysical results for SP and FDEM:





Plum 14
Wetland Avoidance Constraints

- Challenges:
  - The embankment slope at STA 23+00 must be steepened to 2.25H:1V to minimize wetland disturbance to below threshold 0.1 acre.

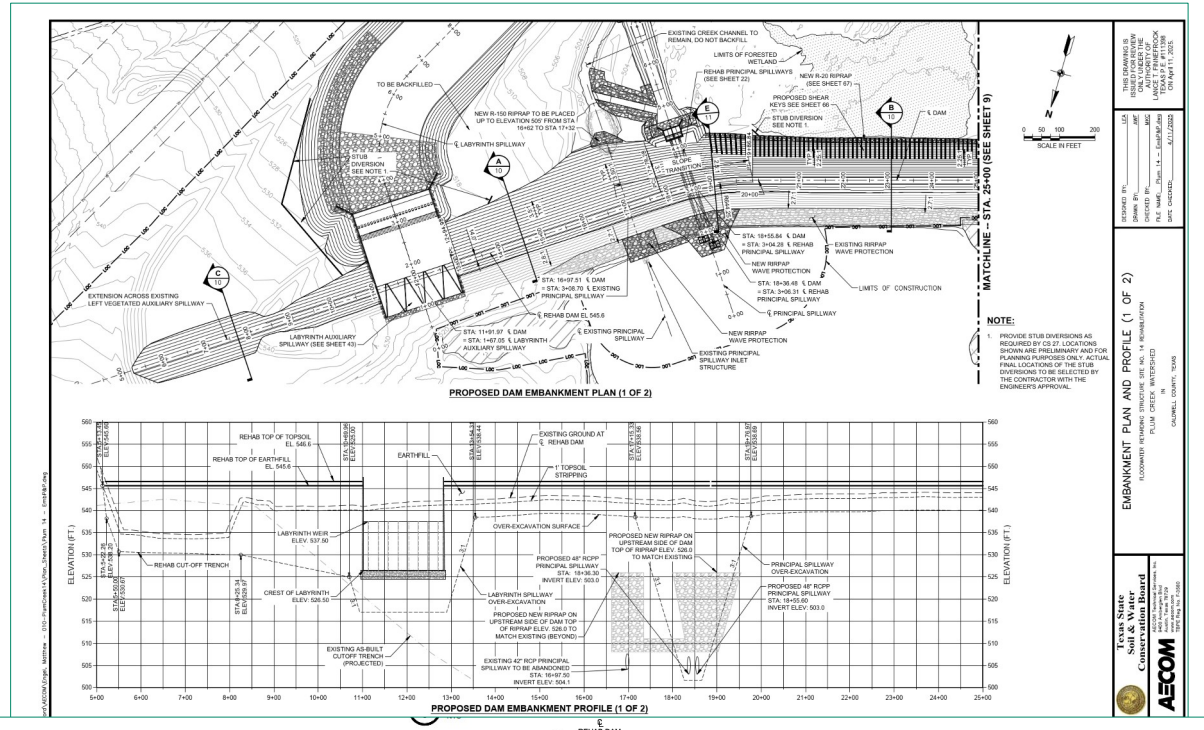
  - Gravity drainage options to control seepage (e.g., typical toe drain with outlet pipes to creek channel) were not effective due to relatively flat site gradients and inability to significantly drawdown water table / reduce seepage pressures.

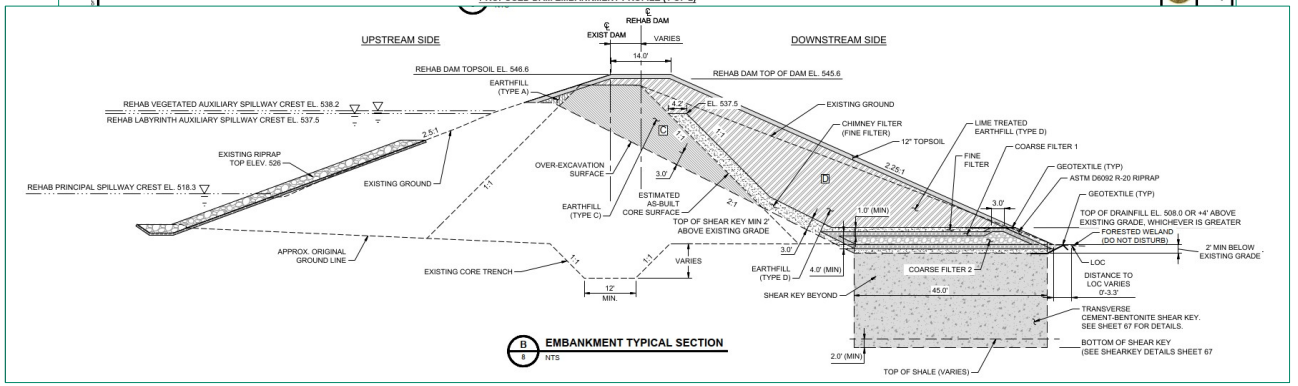
  - Wetland must be maintained. Design options to cut-off seepage under the dam and/or to significantly reduce seepage under the dam for the purposes of dam safety were not acceptable per USACE.

Plum 14

Innovative Solutions: Wetland Avoidance Foundation Stability / Drainage System

- Embankment Slope: Lime-treated clays will be used to reconstruct the steepened downstream slope of the dam embankment. Increased strength allows steeper slope angles.
- Internal Drainage: Chimney and blanket drain added to provide seepage control, and stabilizes downstream toe of dam. Collected seepage is filtered and discharges directly to wetland to maintain seepage flows to wetland as required by USACE permit.
- Ground improvement (GI): Strength of saturated foundation clays needs to be increased to accommodate steepened downstream slope angle. Cement-bentonite transverse shear keys selected for ground improvement.

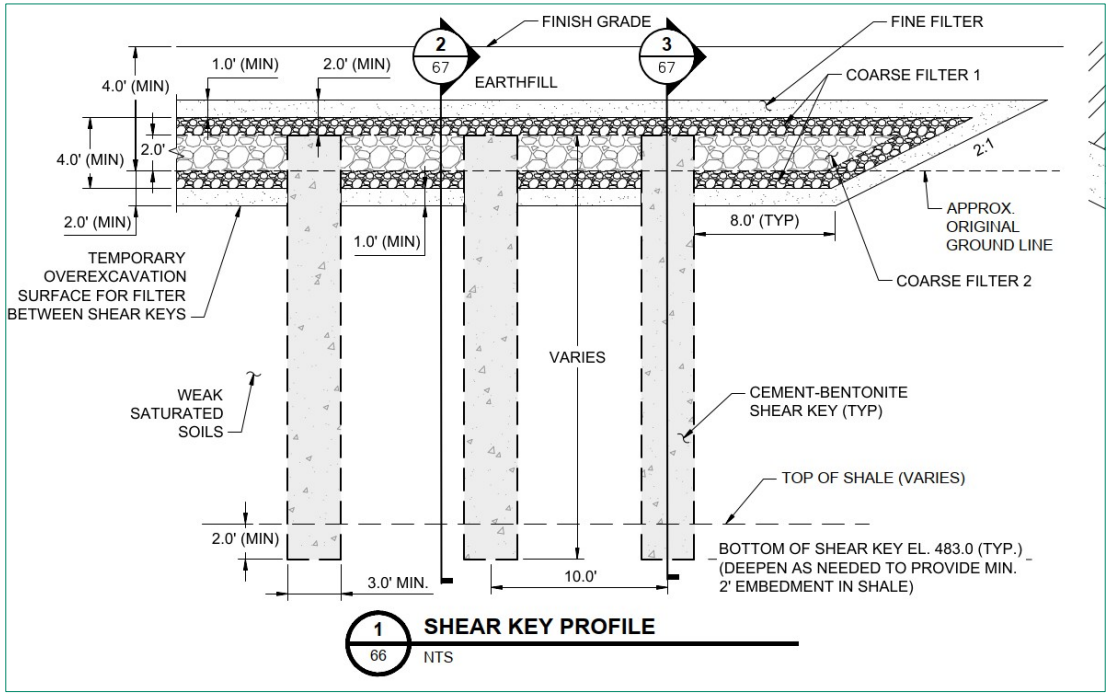




Plum 14

Innovative Solutions: Wetland Avoidance Foundation Stability / Drainage System

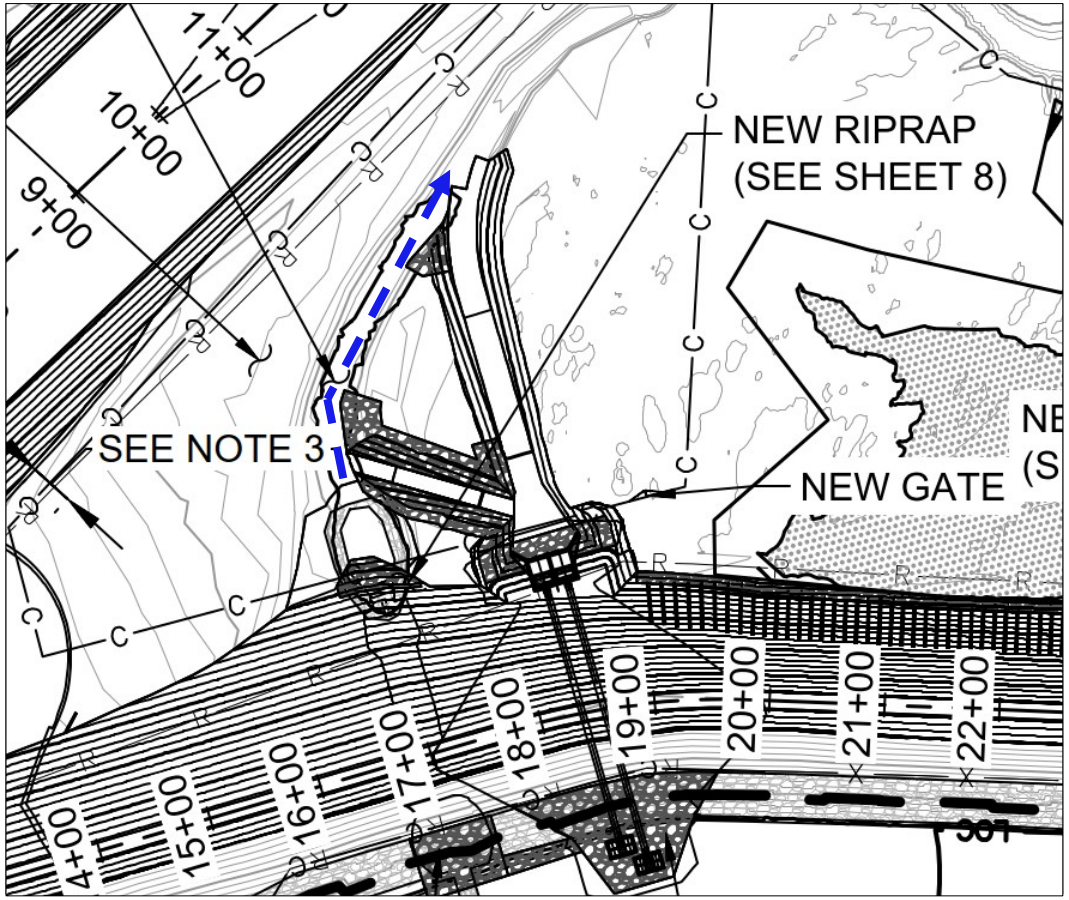
- The cement-bentonite shear keys consist of 3-foot-wide keys spaced 10 feet on center, extending 2 feet into shale. Discontinuous nature of shear keys allows maintenance of seepage flow to the wetland as per USACE permit requirement.
- Cement-bentonite transverse shear keys to be constructed using slurry trench methods and temporary berm work platform to accommodate shallow groundwater. Clamshell excavation methods are planned to accommodate limited access work area. Reservoir level to be lowered before construction to reduce groundwater levels and seepage pressures.
  - Selected over stone column method due to concerns about filter compatibility and stability of open-hole excavations.
  - Selected over deep soil-cement mixing method due to difficulty in thoroughly mixing fat clays and layers of large gravel / cobbles at the site with cement.
- The blanket drain is integrated above and between shear keys to provide continuity with the downstream slope and filtering function, without incorporating drain pipes due to gravity drainage limitations.



Plum 14

USACE Section 404 Permit Package

- Pre-application meeting with new USACE project manager (3rd Corps PM assigned).
- Additional USACE coordination Brushy Creek below the PS spillway impact basin was required, resulting in a small redesign.
- A bypass channel was added to avoid cutting off surface flow from the portion of Brushy Creek between the old PS channel plunge pool and the new stream connection with the relocation of the principal spillway.



Plum 21 and Plum 2 Construction

Role and Importance of Revegetation in Dam Rehabilitation

- **Challenges Faced:**
  - Impact of dry weather periods on revegetation processes.
  - Specific issues such as seed germination and water availability.

- **Plum 2 Solution**
  - TCEQ coordination for irrigation water withdrawal from Lake Kyle via TCEQ temporary permit

- **Plum 21 Solution**
  - Contractor irrigated via TCEQ temporary permit
  - Waited for rain
  - PCCD then applied for a second permit

Plum 21 and Plum 2 Construction

Role and Importance of Revegetation in Dam Rehabilitation

- **Lessons Learned:**
  - Importance of aligning revegetation schedules with optimal environmental conditions.
  - Strategies to mitigate similar challenges in future projects.

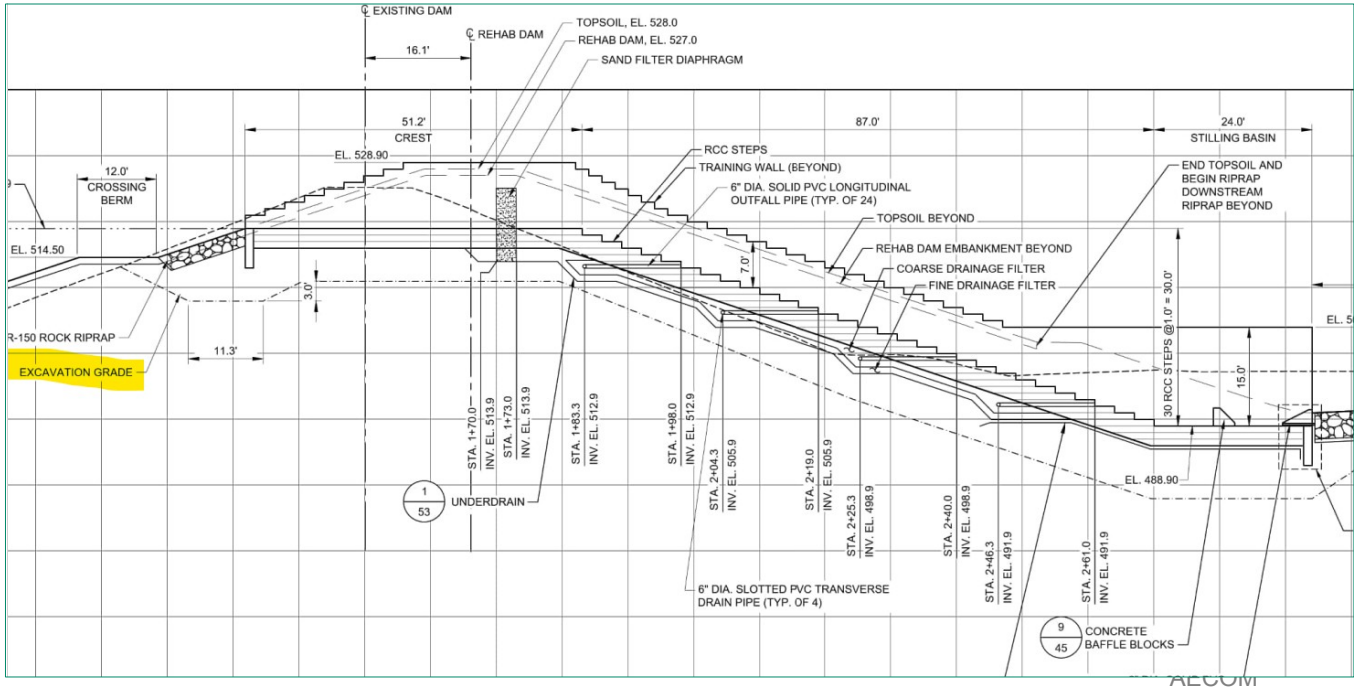
- **Recommendations for future projects:**
  - Seasonal Alignment
  - Optimal Germination Periods
  - Weather Forecasting
  - Buffer Periods
  - Pre-Construction Soil Preparation
  - Adaptive Management

Plum 21 Construction

Improvement of Subgrade / Retained Backfill for RCC Spillway

- Issues:
  - On-site soils (embankment, foundation, and borrow sources) are high-PI clays (PI 30-50) and exhibit shrink/swell behavior during natural wetting and drying cycles
  - Shrink/swell behavior introduces risk of differential movement and associated cracking of the RCC spillway, particularly for the lightly-loaded RCC chute slab
  - High bearing pressures of RCC spillway walls introduce consolidation settlement risk

- Solution: Over-excavate and replace with non-expansive soil under/adjacent to RCC spillway. Depth based on lab swell testing.
  - Conventional approach: Use imported fill in replacement zone ($$)
  - Innovative approach: Use lime-treated on-site borrow



Plum 21 Construction

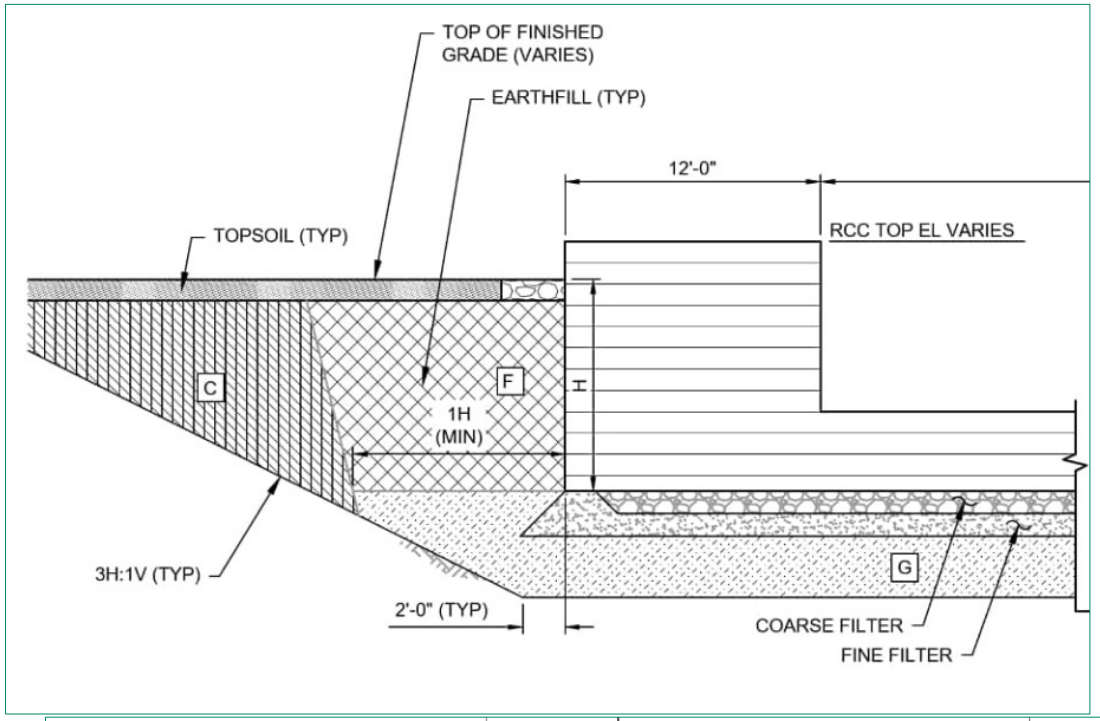
Improvement of Subgrade / Retained Backfill for RCC Spillway

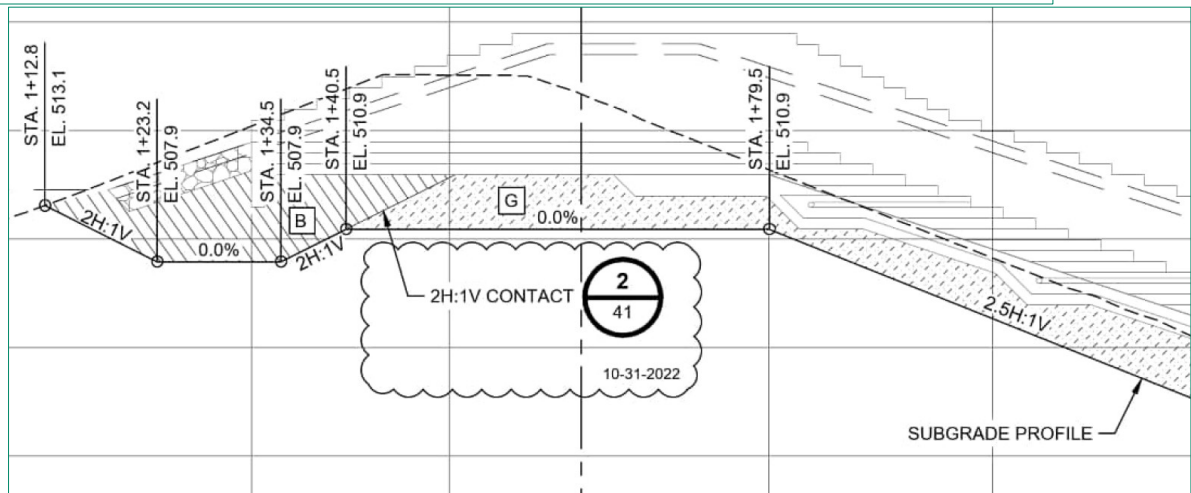
Benefits of lime-treated earthfill:

- Reduced soil plasticity
- Decreased shrink-swell under unreinforced RCC slab
- Higher strength and increased bearing capacity under RCC walls
- Reduced earth pressures on RCC walls
- Reduced structure settlement
- Filter compatible with adjacent untreated clay
- Cost reduction by reducing volumes of import fill and excavation waste

Mitigation measures:

- Design-phase lab treatability study performed to confirm lime compatibility with on-site soil (sulfates, organics), and estimate minimum % lime to provide permanent chemical reaction to maintain long-term properties
- Minimum mellowing time of soil-lime mixture before placement to mitigate isolated instances of elevated sulfates and risk of sulfate-induced heave
- Small zone of imported soil on upstream side of lime-treated fill to compensate for slightly-higher permeability of lime-treated fill
- Robust field and lab CQC testing program in specifications to confirm adequacy





Conclusion

Thank you.

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Plum 14

Relocate Structural Labyrinth Spillway