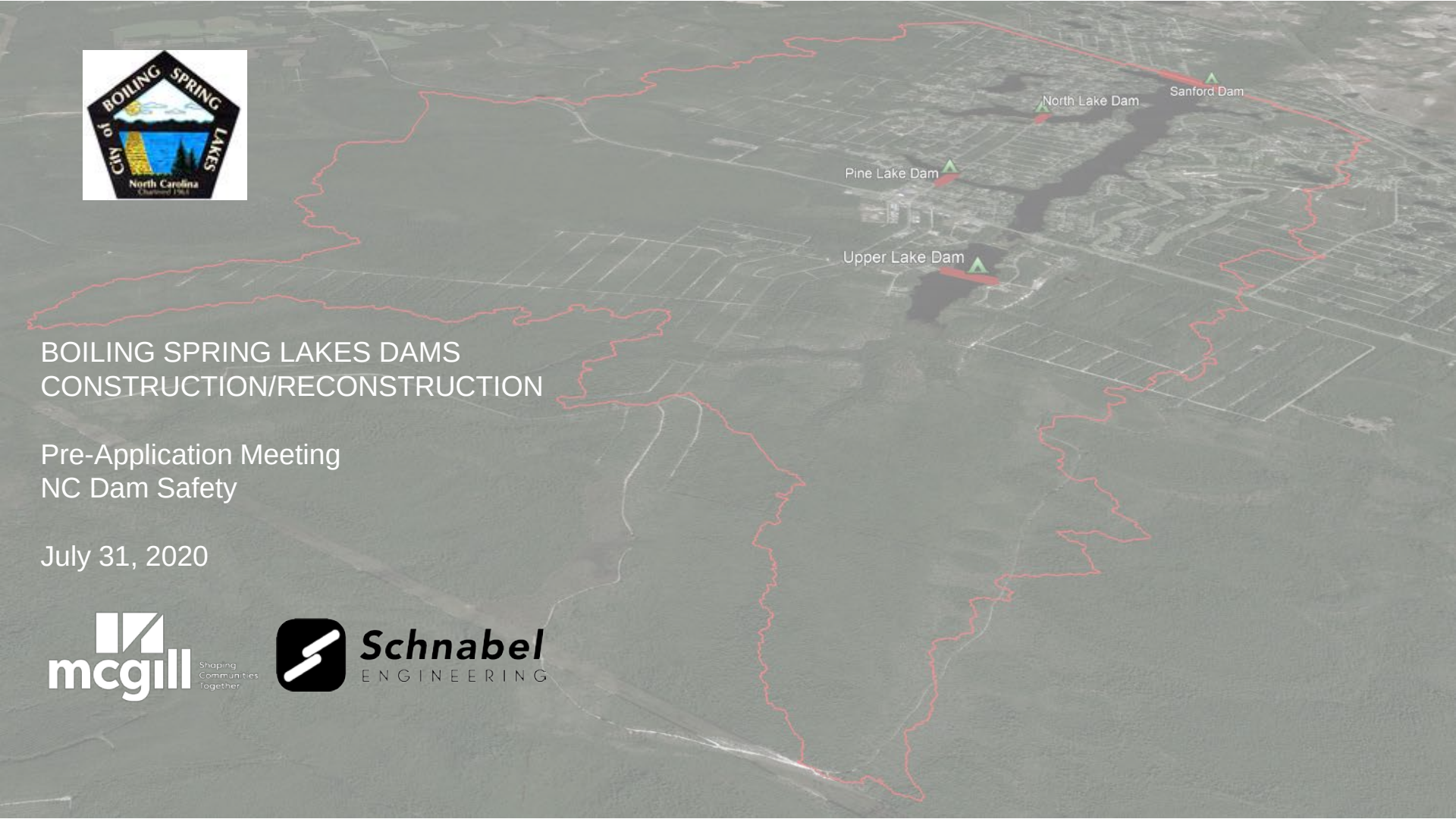


BOILING SPRING LAKES DAMS CONSTRUCTION/RECONSTRUCTION

Pre-Application Meeting
NC Dam Safety

July 31, 2020

mcgill Shaping Communities Together

Schnabel ENGINEERING

Agenda

- Hydrology/Hydraulics and spillways
- Control of water
- Roads and utilities
- Geotechnical exploration and evaluation

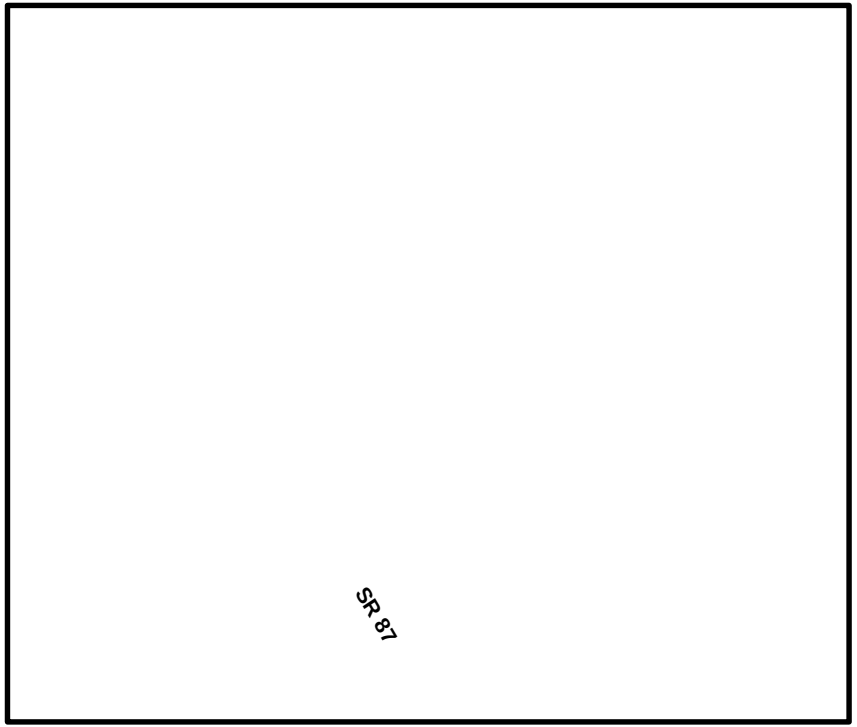
Proposed Spillway Design Flood (SDF):

Dam	State ID	Hazard Classification*	Design Storm
Sanford	BRUNS-003	High Hazard	½ PMP
North Lake	BRUNS-001	High Hazard	⅓ PMP
Pine Lake	BRUNS-002	High Hazard	⅓ PMP
Upper Lake	BRUNS-012	High Hazard	⅓ PMP

** Based on coordination with NC Dam Safety to in June 2019.*

BSLs H&H Study (Integrated Units - One System)

- Rainfall characterization
- Watershed configuration
- Rainfall-runoff modeling
- Dynamic hydraulic modeling
- Evaluation of proposed spillways
- Dam-breach risk analyses and inundation mapping
- Minimum Flow requirements?

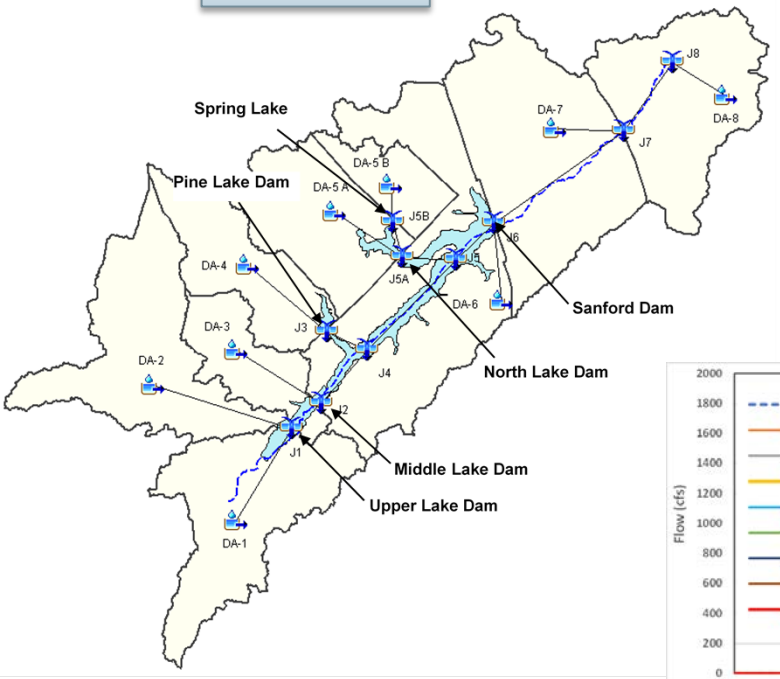


Rainfall Characterization

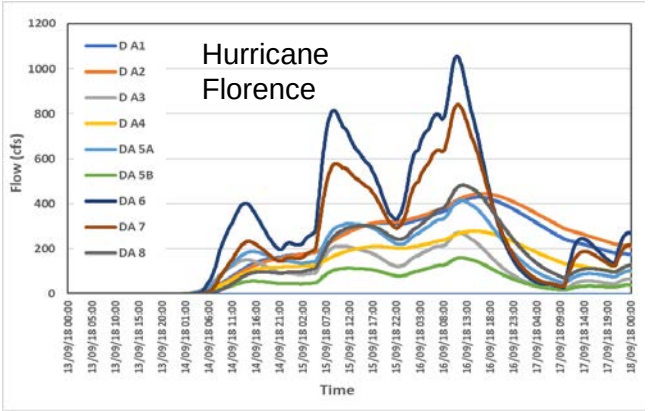
- Probable Maximum Precipitation (PMP):
  - Hydrometeorological Reports No. 51 and 52 (HMR 51 and 52)
  - Rainfall total: ≈ 50” in 72 hours with a peak of 9.5”
- 100-year Frequency Storm:
  - Predicted National Oceanic and Atmospheric Administration (NOAA) Precipitation Frequency Data Server (PFDS)
  - Rainfall total: 14.7” for a 48-hour storm
- Hurricane Florence Precipitation Data:
  - Recorded at the Cape Fear R at Lock #1 Nr Kelly, NC (02105769) station
  - Total recorded: 22” during 13 to 16 September 2018
  - 1000-year return storm

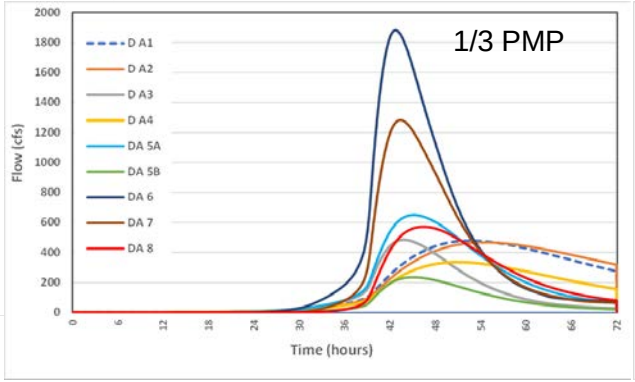
Rainfall-Runoff Modeling

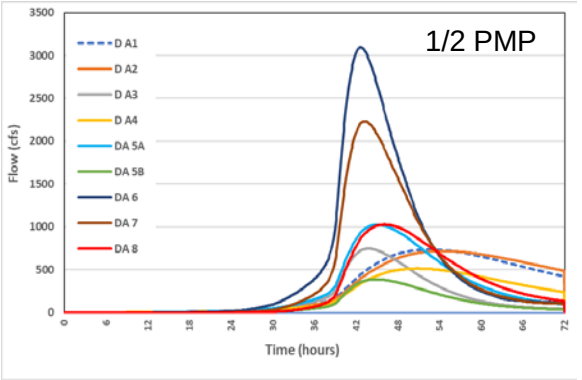
Model Setup



Runoff hydrographs







Dynamic Hydraulic Modeling

- Spillways consist of risers and culverts
- Maintained 2-ft freeboard
  - Upper Lake Dam will be raised to extent practical to increase freeboard
- Middle Lake Dam reconstructed is the worst-case scenario

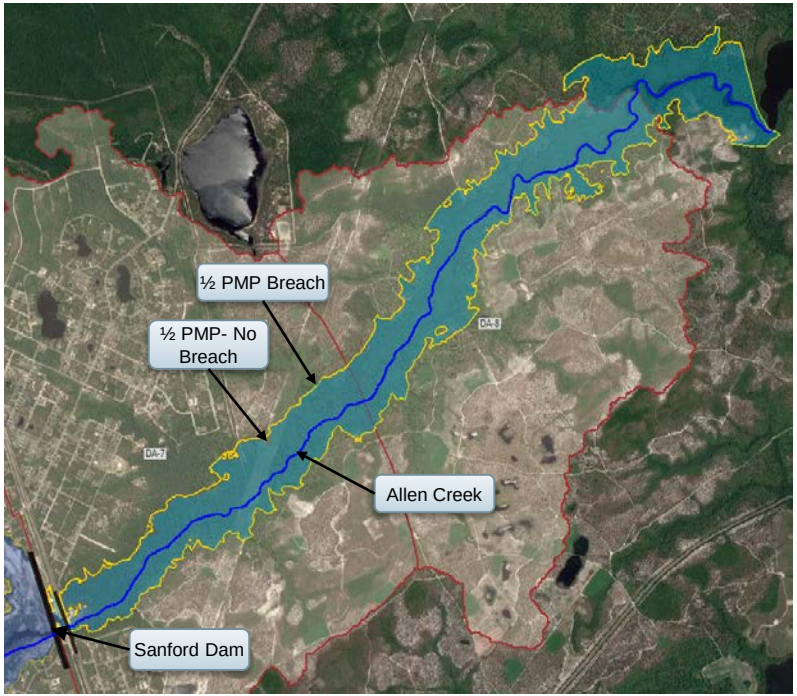
	Top of Dam or road (ft NAVD88)	Spillway Design Flood	Peak Flow (cfs)	Peak Water Surface Elevation (ft NAVD88)	Freeboard (ft)	Riser Structure		
						Weir Length (ft)	Culvert Size (span x rise) (ft)	No. of Culverts
Sanford Dam	38.2	½ PMP	5385.	35.11	3.09	140	7.5 x 6.5	6
North Lake Dam	40	⅓ PMP	848.9	37.9	2.1	55	6 x 6	2
Pine Lake Dam	44	⅓ PMP	316.9	40.69	3.31	14	5 x 4	1
Upper Lake Dam	41.3	⅓ PMP	941.3	40.08	1.22	94	6 x 5	5
SR 87	33.67	100 Yr	1033.8	33.54	--	--	--	--

Dam-Breach and Inundation Mapping

- Breach Setting:
  - Bottom elevation set at the bottom of each lake or downstream normal tailwater for the breach condition, whichever is greater.
  - Bottom width set equal to three times the breach height
  - 2:1 side slopes.
- Spillway Design Flood (SDF) Breach
  - Each Dam individually (SD, NLD, PLD, ULD) to evaluate individual inundation
  - Concurrent breach of all upstream dams (including Middle) during ½ PMP to evaluate effect on Sanford Dam Spillway
  - Concurrent Breach of all dams (including Middle) during ½ PMP to evaluate inundation extent
- Sunny Day Breach
  - Each Dam individually (SD, NLD, PLD, ULD) to evaluate individual inundation
  - Concurrent Breach of all dams (including Middle) to evaluate inundation extent

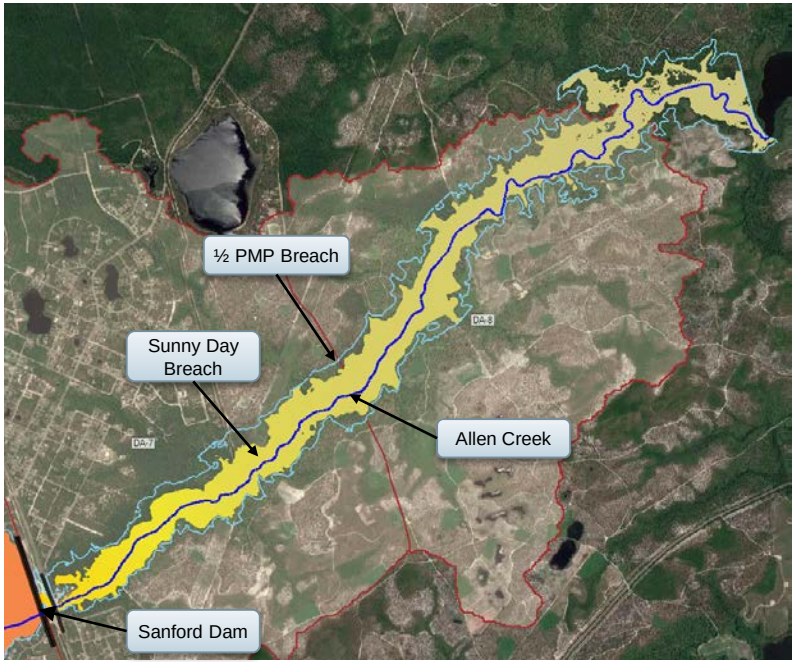
Dam-Breach and Inundation Mapping

- Concurrent breach of all dams during ½ PMP
    - No noticeable difference in inundation zones between breach and no-breach conditions



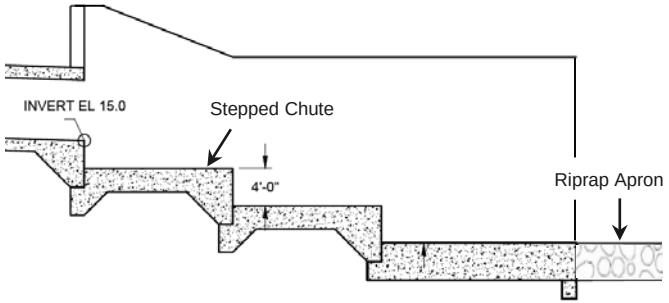
Dam-Breach and Inundation Mapping

- Concurrent breach of all dams – Sunny Day
  - Noticeable difference in inundation between Sunny Day and ½ PMP
- Emergency Action Plan
  - One EAP for all dams
  - Concurrent ½ PMP and Sunny Day breach inundation mapping



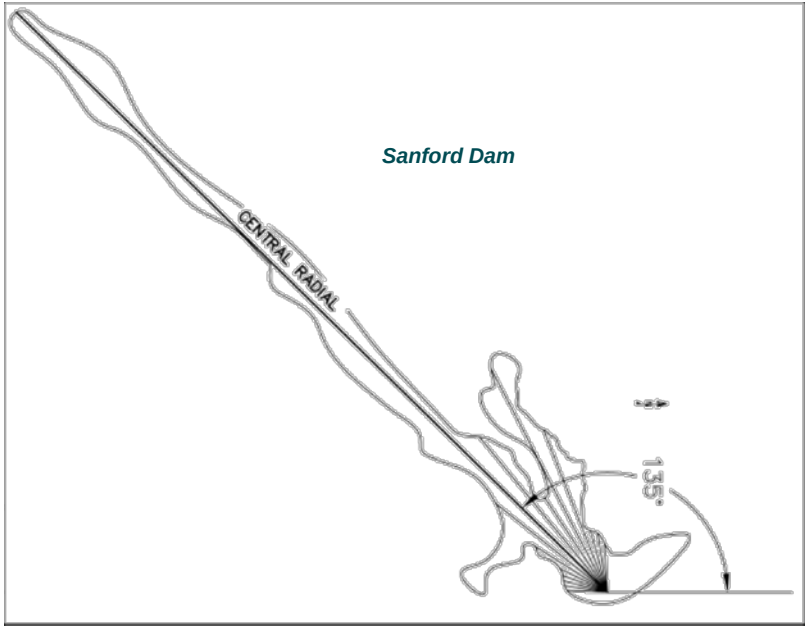
Energy Dissipators

- Design for Sanford Dam:
  - Stepped chute
  - Riprap apron



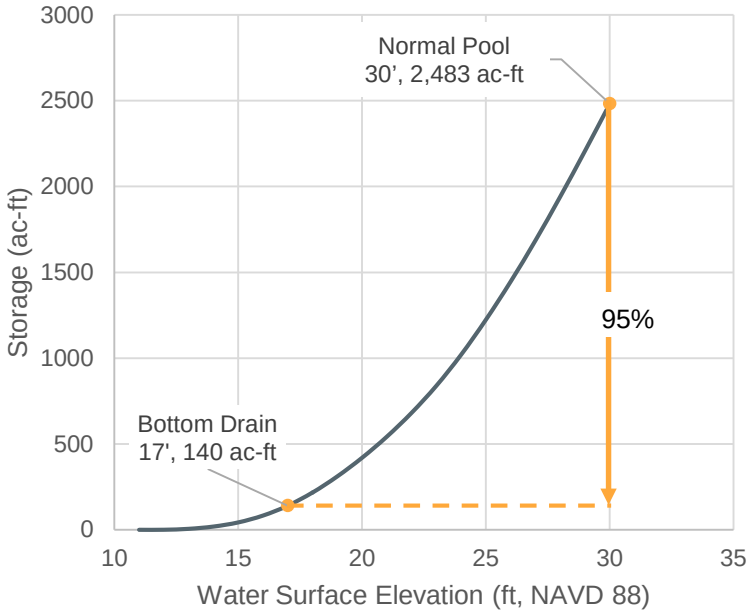
Wave Protection

- Wave protection evaluation was performed based on the fetch distance
- Riprap is provided for the upstream faces of all dams
- Limited fetch on downstream faces, no protection provided
    - SR 87 and MLD limit fetch on downstream face of ULD



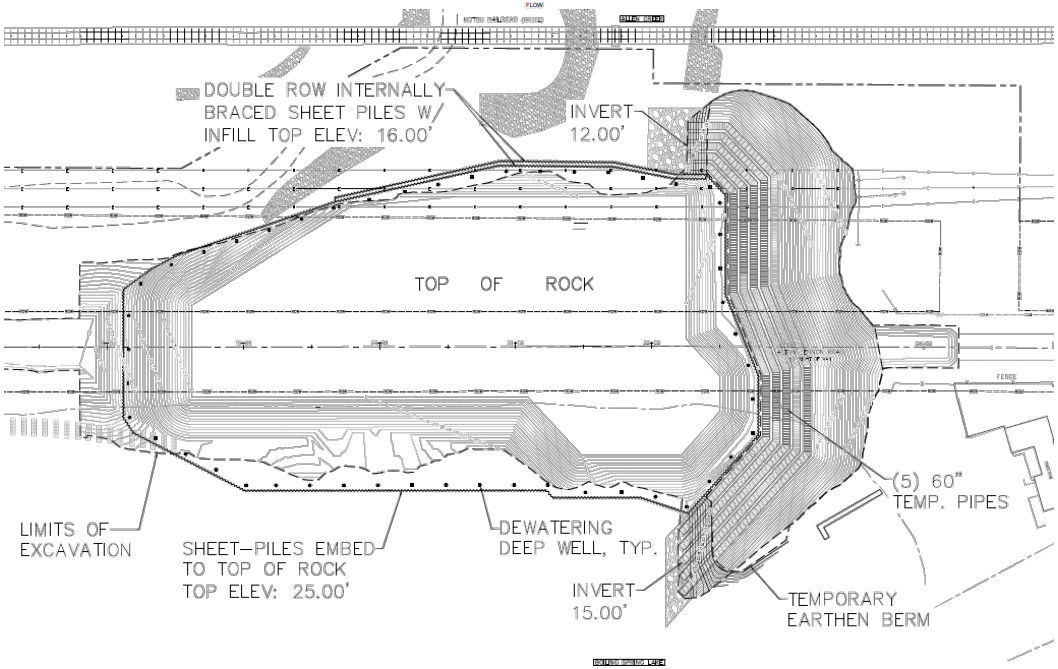
Low Level Drains

- Target drawdown rate ≈ 1 ft / day
- Storage-volume relationship for each lake was computed in GIS using the site-specific LiDAR and bathymetric survey
- Sanford Dam bottom drain is about 4 ft above bottom of channel in lake



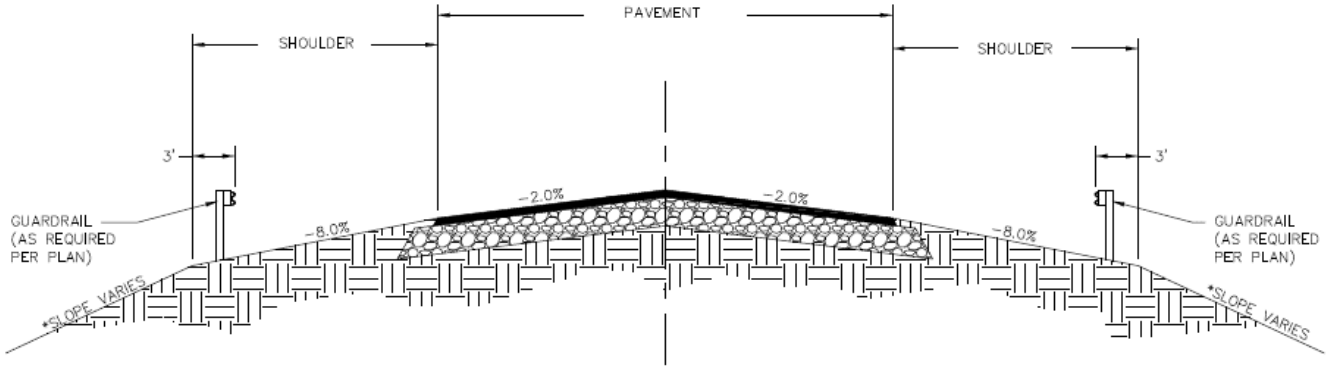
Control of Water

- Bypass the 10-year storm peak flow around construction area
- Cofferdams used to divert flow through temporary culverts



Roadway

- Return to pre-breach condition
- Guardrails will be placed on SD, NLD, PLD
- Crowned road with sheet flow to shoulders for NLD and PLD
- Crowned road with gutters and flumes on both sides of SD



Utilities

- Sanford Dam
    - No underground utilities on SD
    - Power/telecommunication pole bracing in MOTSU

- North Lake and Pine Lake Dams
    - Buried water and telecommunication lines

Geotechnical Exploration

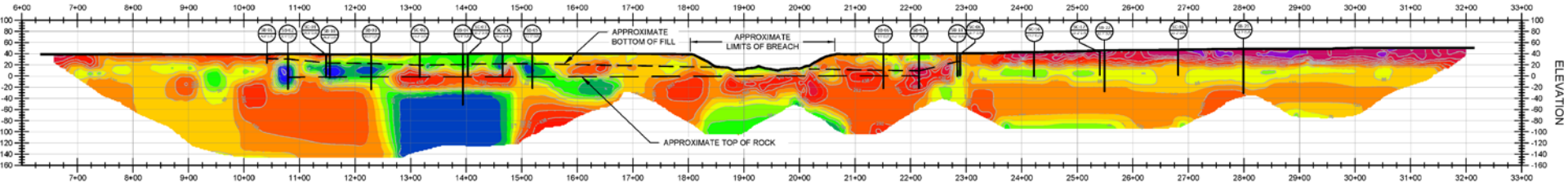
- Drilling and sampling, In-situ testing, soil and rock laboratory testing

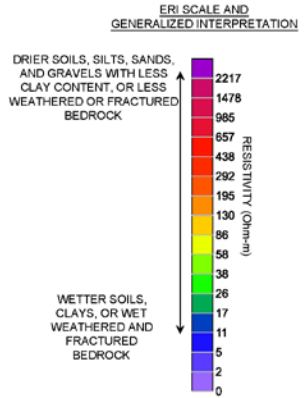
		Sanford Dam	North Lake Dam	Pine Lake Dam	Upper Lake Dam
Test Borings	Number	26	4	4	3
	Depth	15’ – 90’	25’ – 27’	25’	25’
CPT	Number	17	3	3	3
	Depth	22’ – 42’	25’ – 44’	25’ – 59’	12’ – 59’
Rock/Refusal		Rock at El. 0’	Refusal at El. 0’	Refusal at El. 0’	--

Geotechnical Exploration

- Electrical Resistivity Imaging (ERI) on Sanford Dam

Centerline Profile

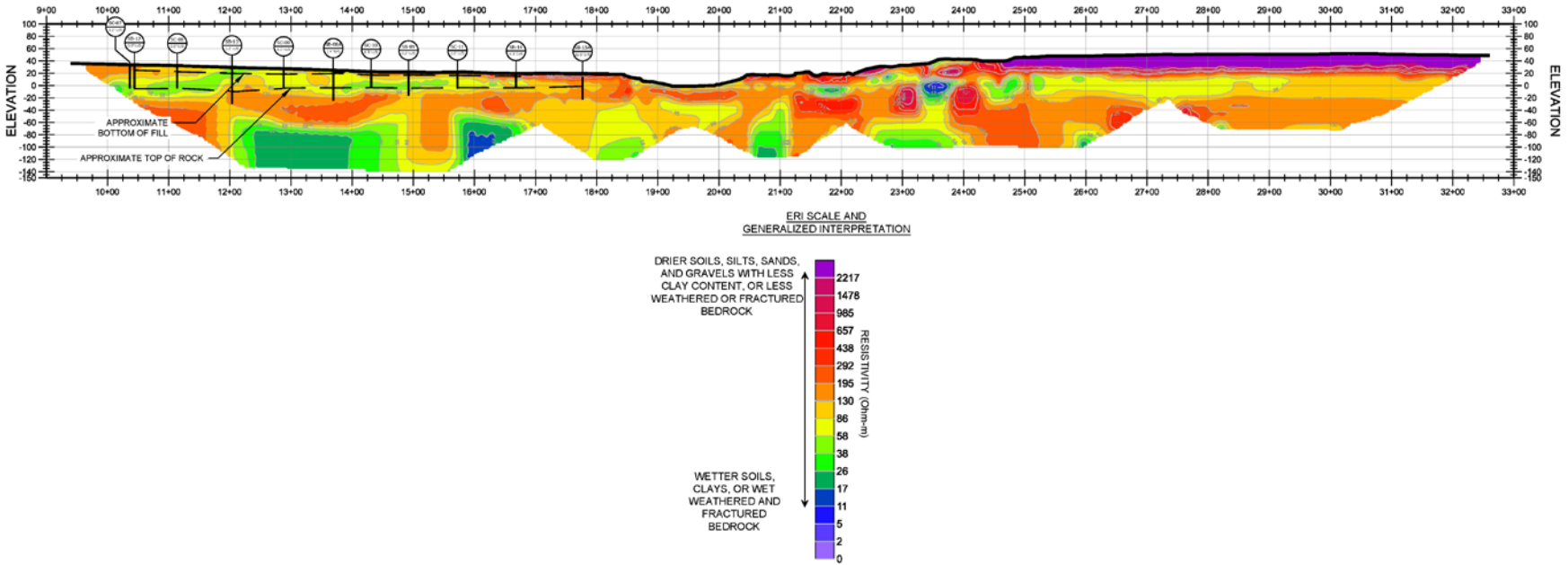




Geotechnical Exploration

- Electrical Resistivity Imaging (ERI) on Sanford Dam

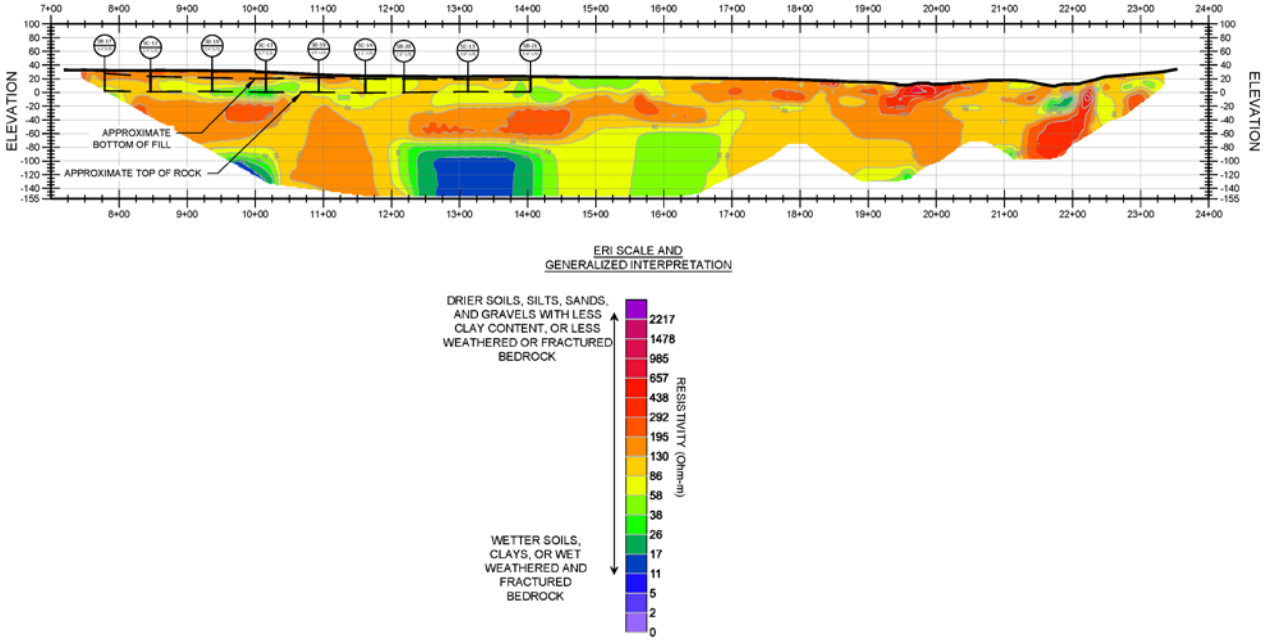
Downstream Profile



Geotechnical Exploration

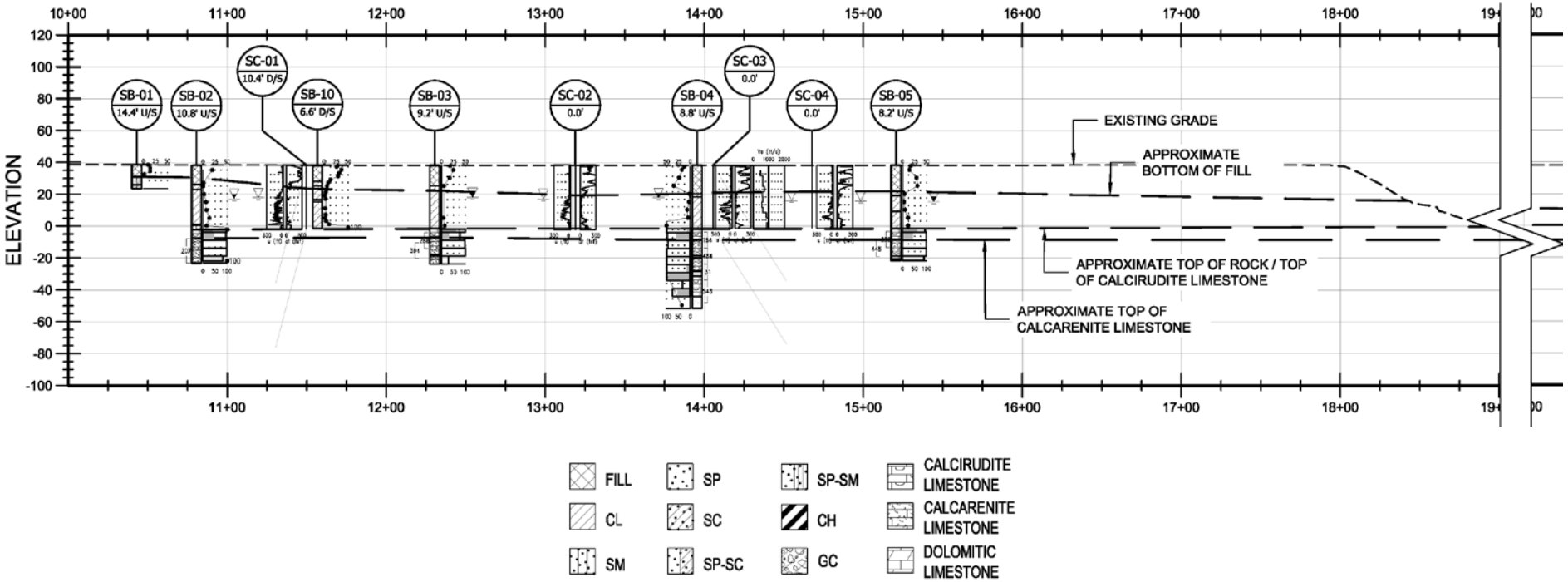
- Electrical Resistivity Imaging (ERI) on Sanford Dam

Upstream Profile



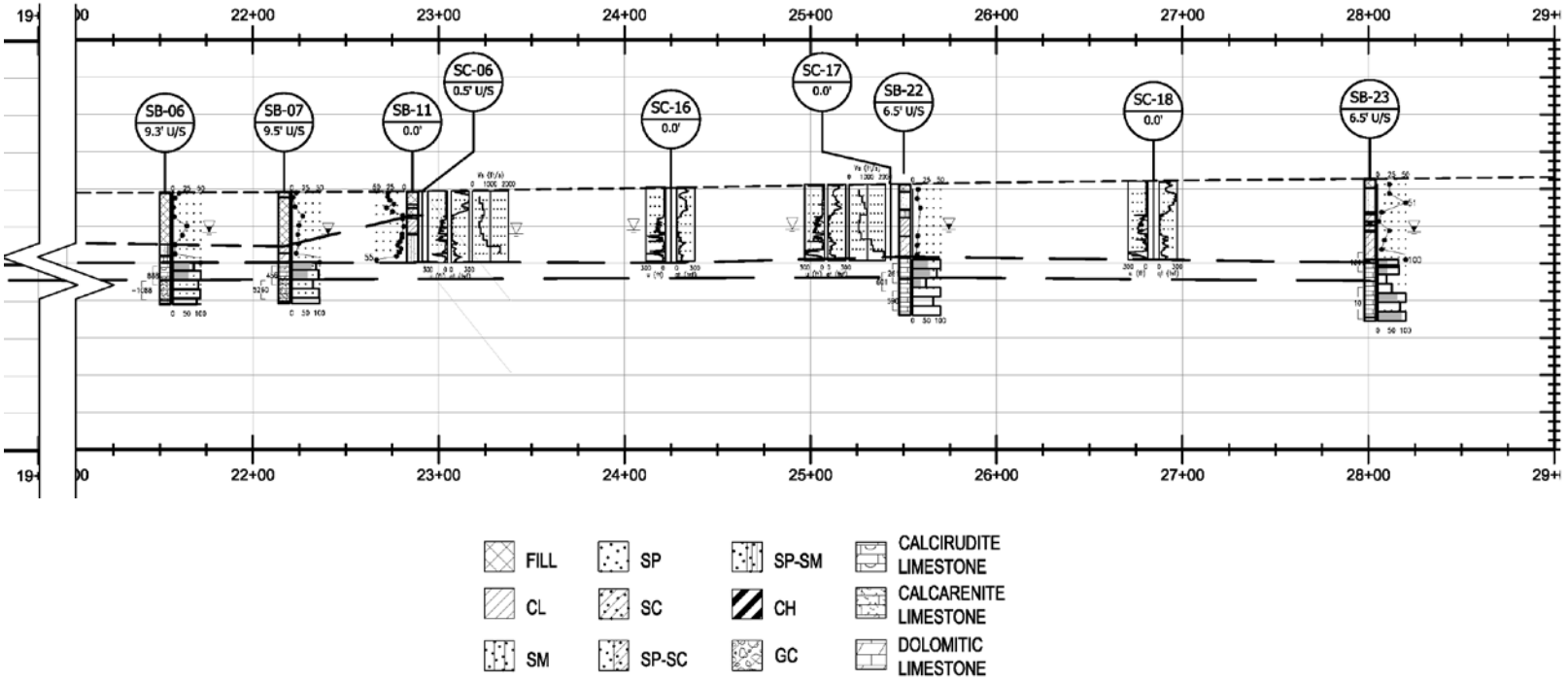
Geotechnical Exploration

- Centerline geotechnical Profile (1 of 2)



Geotechnical Exploration

- Centerline geotechnical Profile (2 of 2)



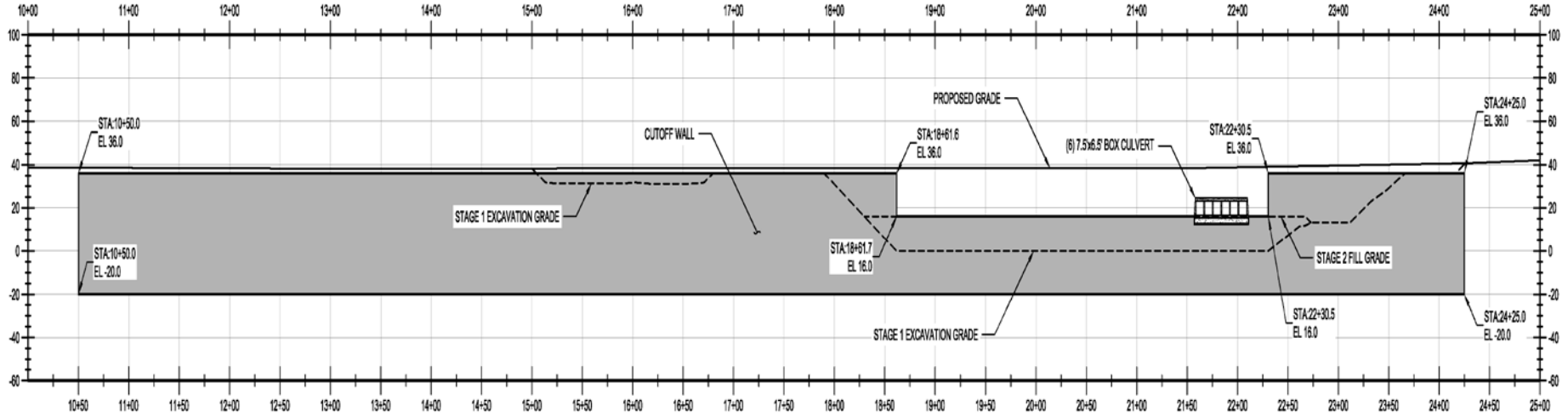
Geotechnical Exploration

Summary of findings at Sanford Dam

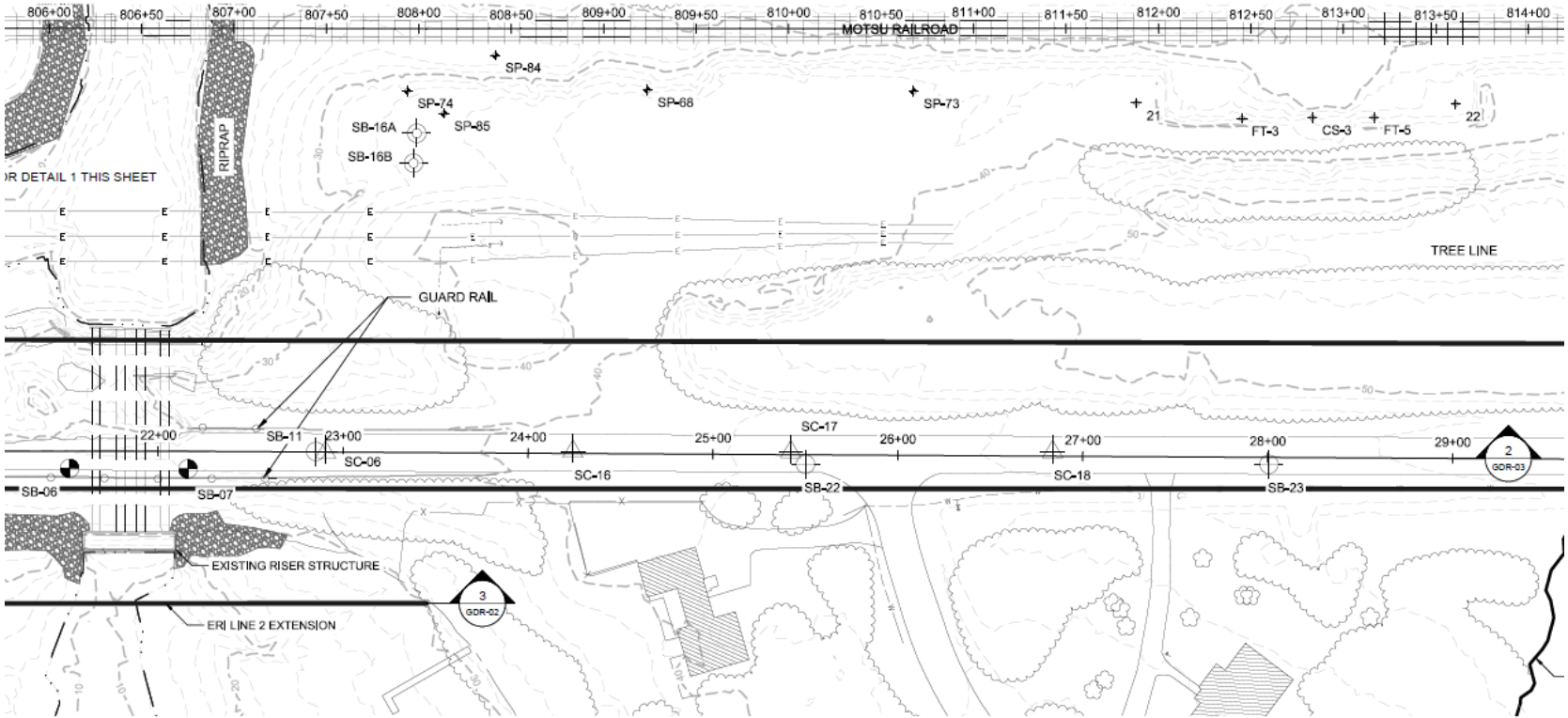
- Top of rock at Elevation 0’ NAVD88
- Thirteen borings more than 8’ in rock
- Four piezometers in rock
- Top layer of rock (calcirudite limestone) described as vuggy, fossiliferous, weak (700 to 2,200 psi)
- Underlain by fossiliferous, fine-to-medium-grained, very weak (600 psi) calcarenite limestone
- The top calcirudite limestone layer provides for a preferential seepage path between the reservoir and the rock layer

Sanford Dam Foundation

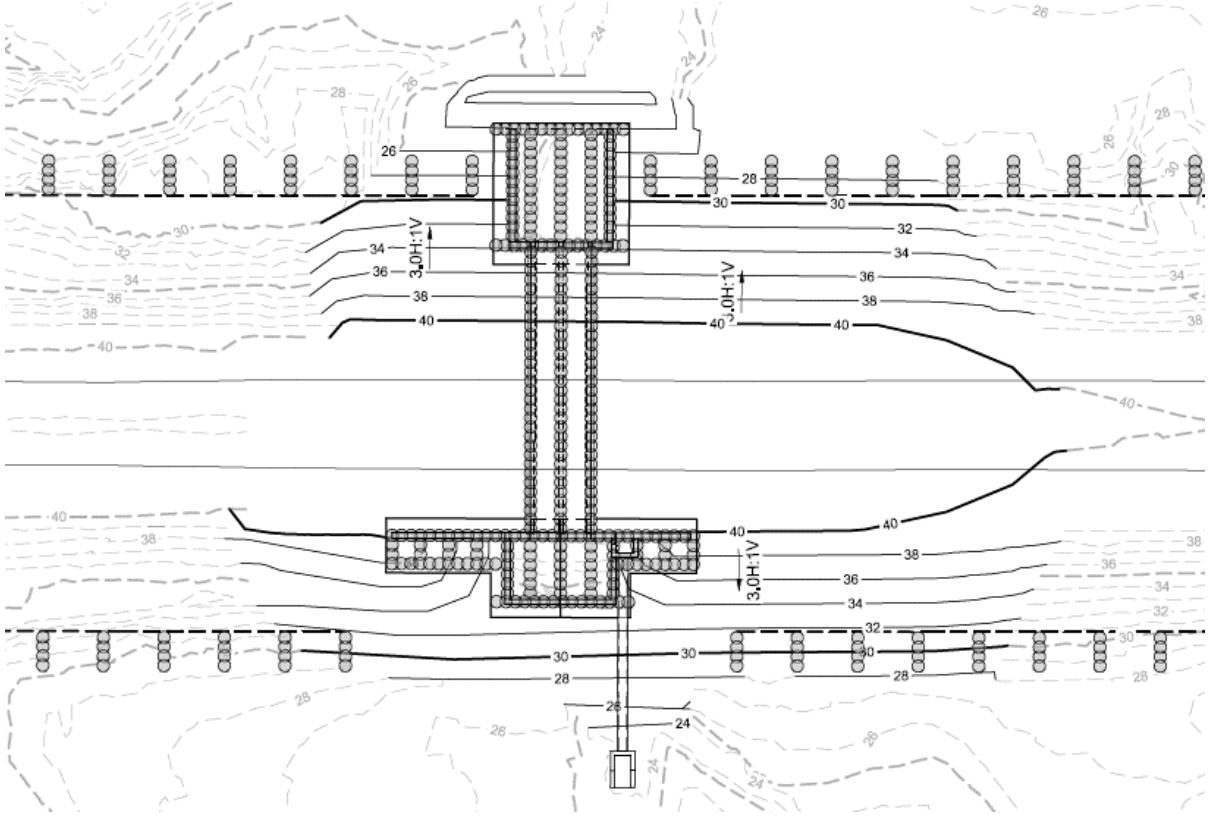
- Cutoff wall constructed using a mix-in-place method along the length of the dam
- Bottom elevation of EL -20, which is about a depth of 8 to 10 feet below the bottom of the calcirudite limestone layer



Area Right of Sanford Dam



Foundation Soil Conditions



Geotechnical Instrumentation

- Vibrating wire piezometers
- Additional measures will be included with permit application