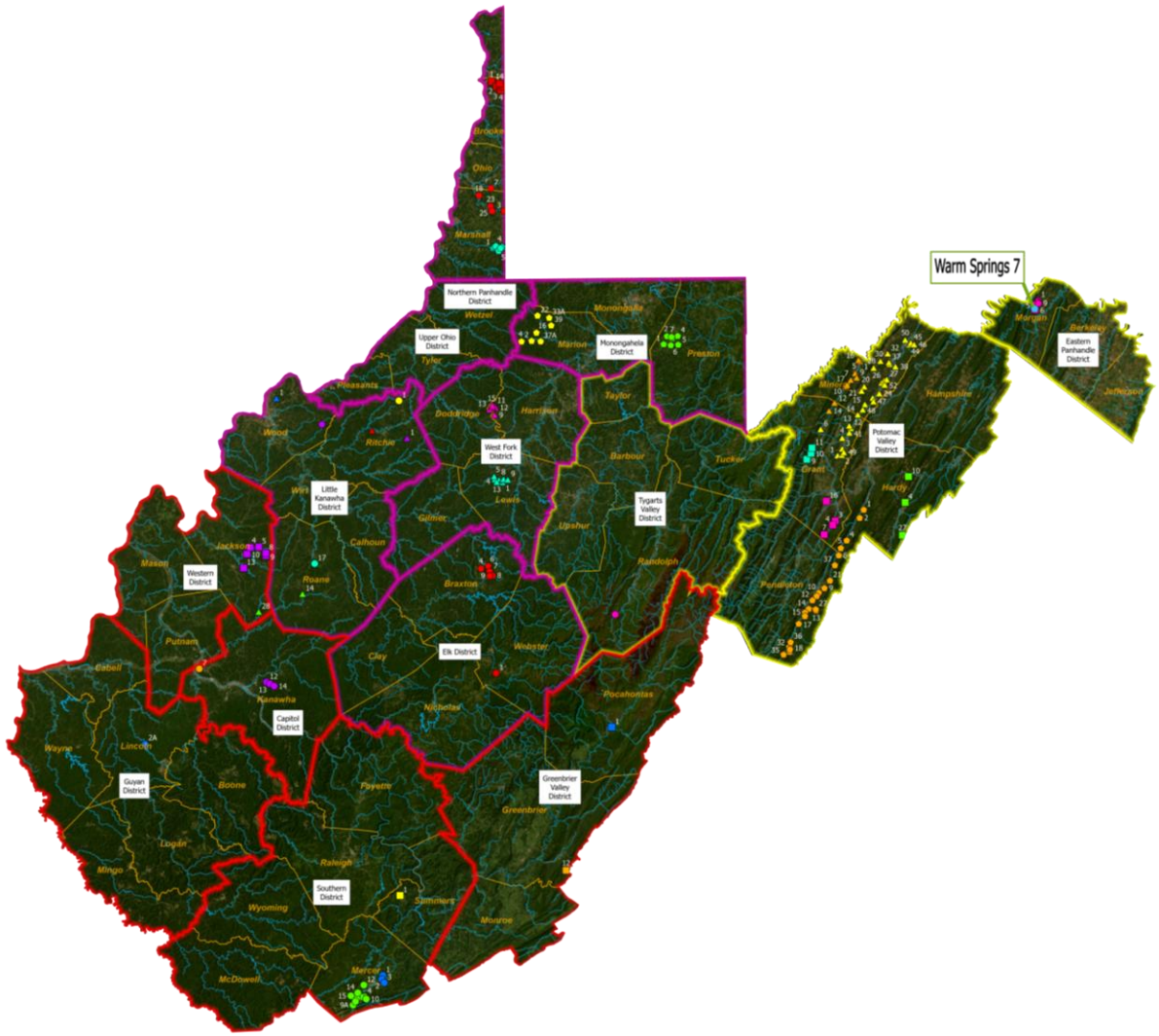
Warm Springs Run Site 7 Seepage Case History

Ben Wade (Engineer - WVCA)
Hunter Vance (Engineer - WVCA)
Bob Shusko, P.E. (Senior Principal Engineer - D'Appolonia)

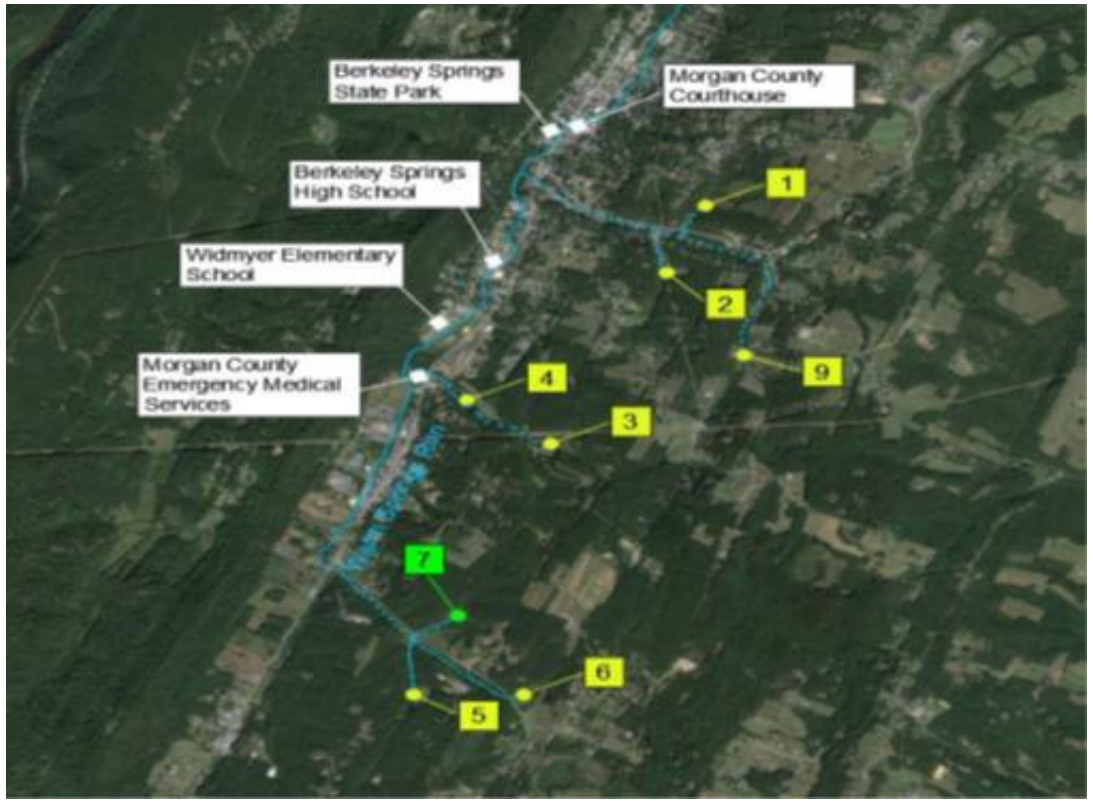
WVCA Dams

- 170 High Hazard Dams
- 115 Past Evaluated Life
- 2 RCC Dams
- 2 NRCS Rehabilitated Dams (Another currently starting construction)

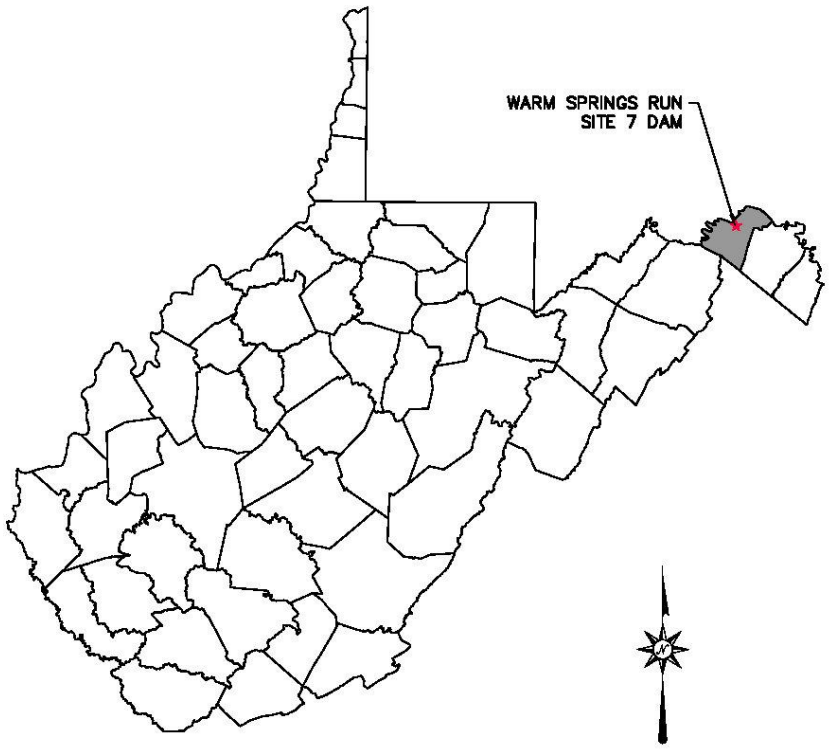


Warm Springs Run Dams

- Among the oldest in West Virginia
- Constructed between 1955-1961
- Designed to work in tandem to provide cumulative flood protection
- Nine were proposed – eight were built
- Located upstream of Berkeley Springs
- All eight dams are classified as "High Hazard"
- Exceeded their 50-year evaluated lives



Warm Springs Run Site 7



Warm Springs Run Site 7

- Construction Completed in 1958
- Dam height of 37-feet
- Dam length of 240-feet
- Two-stage intake riser with orifice at normal pool and weirs
- 30-feet wide vegetated auxiliary spillway
- 64 acre watershed
- Normal reservoir volume of 1.6 acre-feet
- Max design reservoir volume of 32 acre-feet

Historic Seep

- Seepage was observed shortly after construction was completed
- Flow was regularly about 1 gpm during inspections
- Inspections conducted monthly and after significant rainfall events that elevated the pool – seep continued to be monitored

Historic Seep

- Dye trace study conducted in 2019
- One dye placed in reservoir, one dye placed in principal spillway system
- Reservoir dye detected in the first 24 hours in receptor
- Visually observed flowing from seep on day of dye placement
- Design recommendation to install filter diaphragm, consider drainpipe and cradle replacement

Increased Seepage Volume

- The Berkeley Springs area received 3-4" of rain in 24-36 hours during the fall of 2021 (remnants of Hurricane Ida)
- The reservoir was approximately 1.5' below the low stage orifice (normal pool orifice) prior to the rain, but was elevated to approximately 6" above the invert of the low stage orifice following the rain
- Due to the added hydrostatic pressure, the seep became more visible and flowed at a higher rate (Estimated to exceed 10 gpm)
- Soil particles were deposited at the seep exit
  - Material resembled fine sand in its color, consistency, and texture
- Flow from the seep reduced in the days following the initial visit

Flow From Seep

Fine Material at Seep Outlet

Concern with the Seep

- A camera inspection of the principal spillway system revealed damaged concrete inside the intake riser which allowed water to flow into the principal spillway below normal pool
- The camera inspection also revealed disconnected joints in the reservoir drainpipe
- The fine sand and silt being deposited at the seep outlet indicated internal erosion of the dam
- Internal erosion can lead to piping which can create voids in the embankment
- Piping is the number one cause of non-flood related dam failures

Seep-Related Dam Failures

Big Bay Lake Dam

- 60-70' tall earth dam built in 1990
- A ½" diameter hole flowing 1 gpm became an 18" hole spouting 2-3' in the air in only an hour
- Just an hour and a half after the initial seep was discovered, the dam breached and an uncontrolled release of water started

Seep-Related Dam Failures

Bonasa Breaks Ranch Dam

- 19' tall, 414' wide stock pond dam with a 4.3 acre pool
- In 2010, a 5' deep depression near the future breach was regraded and no further action taken
- On April 13, 2017, the dam breached, causing flooding, erosion, and debris buildup downstream

Emergency Reservoir Drawdown

- In the week following the 2021 rain event, an onsite meeting was held with representatives from WVCA, WVDEP Dam Safety, NRCS, EPCD, and Morgan County
- Flow from the seep was recorded between 4 and 5 gpm with the pool level again below the low stage orifice
- Alternatives were discussed to temporarily and permanently mitigate or reduce seepage volume and particle migration
  - Filter blanket at the outlet of the seep designed by NRCS
  - Dewatering of the reservoir by EPCD and WVCA
  - Engineering investigation and design completed by EPCD's engineering firm with the assistance of WVCA

Emergency Reservoir Drawdown

- Following the onsite meeting, it was decided the best immediate action was to dewater the reservoir
  - Would reduce driving head on the seep
  - Allows more flood storage in the event of a major storm
- As-built drawings revealed the lack of a drawdown gate, so the reservoir had to be drawn down by pumps before the plate on the interior of the riser could be removed to open the low-level drainpipe
  - Dewatered using three 2" pumps at a controlled rate over 48 hours
  - Plate was then removed, but the drainpipe was separated and did not allow water to drain through it
- Flow from the seep significantly reduced during the first foot of dewatering
- The reservoir remains drawn down to this day

Drainpipe Repair/Replacement

- Immediately after the reservoir was dewatered, the existing 8" C.M.P. was sleeved with a 4" PVC pipe to the interior of the riser
- Since then, the 4" PVC pipe was replaced with an 8" pipe
- The reservoir end of the pipe was fitted with a vertical riser pipe with 1" holes around the perimeter and length of the pipe, and an open end for greater flows

Seep Investigation

- Drilling operations began January 2022
- Investigation revealed the dam was constructed from material with high gravel content
- Particle migration believed to be possible
- Samples from drilling revealed saturated regions within the dam embankment

Seep Investigation

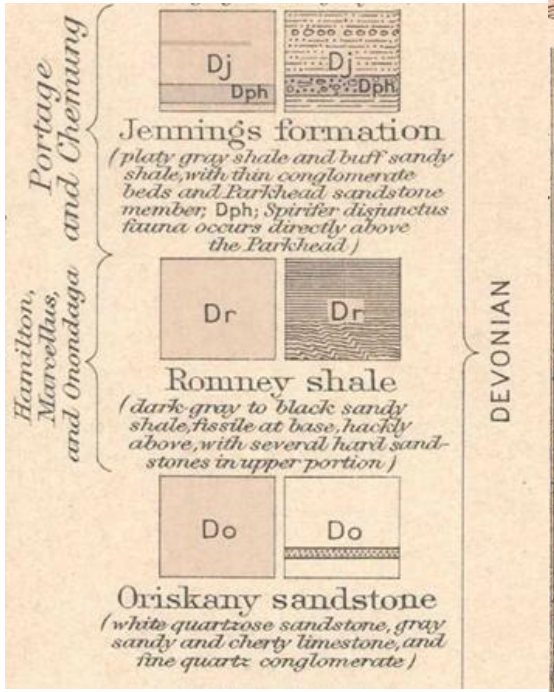
- Rock coring in hole B-04 and B-02 resulted in water flowing through the embankment and exiting around the PSW pipe
- Around 1 hour after coring began at B-04 water was observed

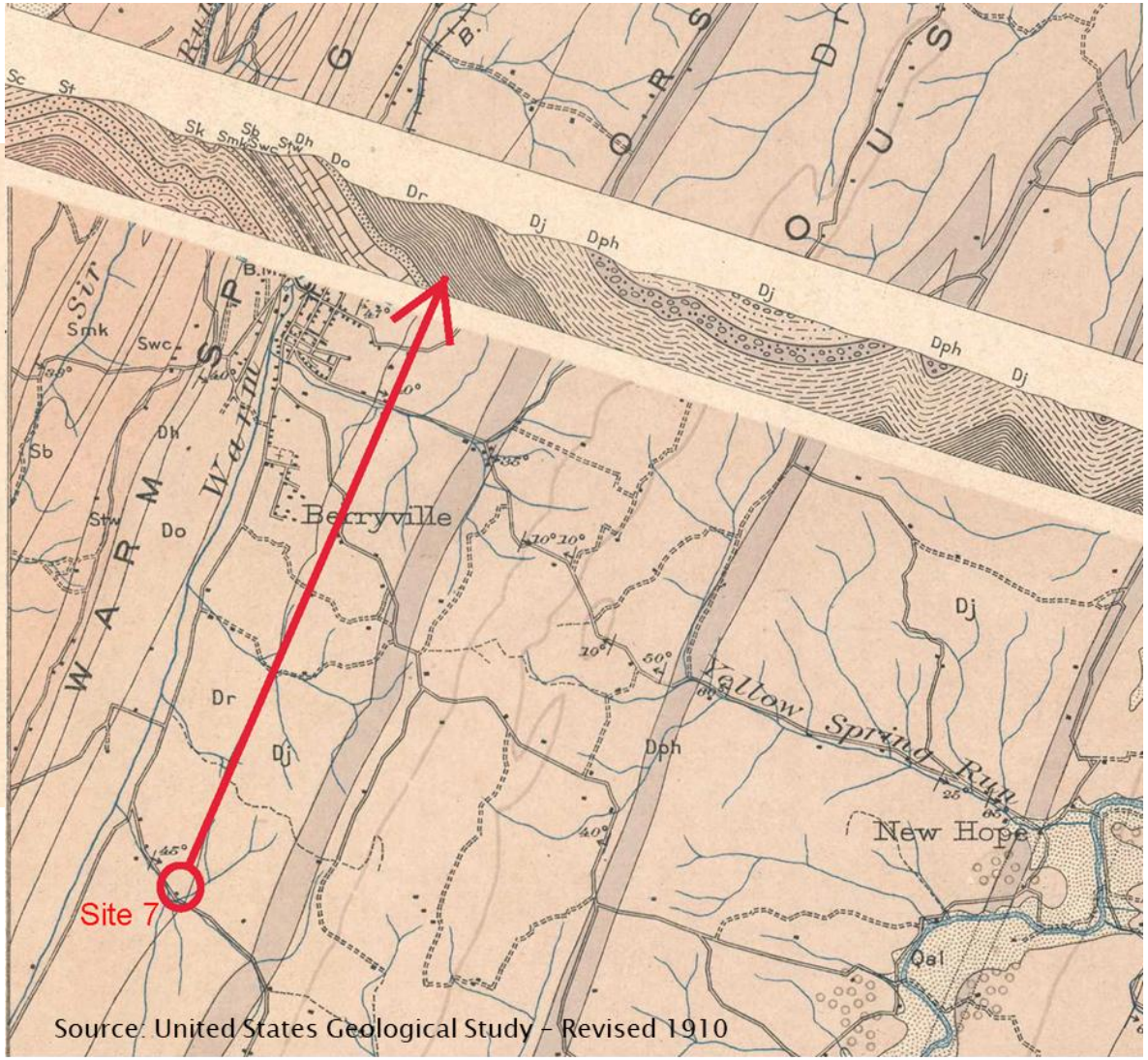
Proposed Rehabilitation Plan

- Research geology and perform a supplemental geotechnical investigation
- Develop rehabilitation design based on existing as-built and geotechnical data as well as recent inspection data
- Keep construction costs reasonable, especially considering the relatively small watershed size
- One construction season

Geology

- Bedrock at the site consists of the Romney Shale in the Middle Devonian Group.
- dark grey to black sandy shale with sandstone inclusions; weathers to yellowish green with reddish stains
- Rock dips nearly 45 degrees to the southeast; Synclinal axis plunges approximately 12-15 degrees to the north-northeast.



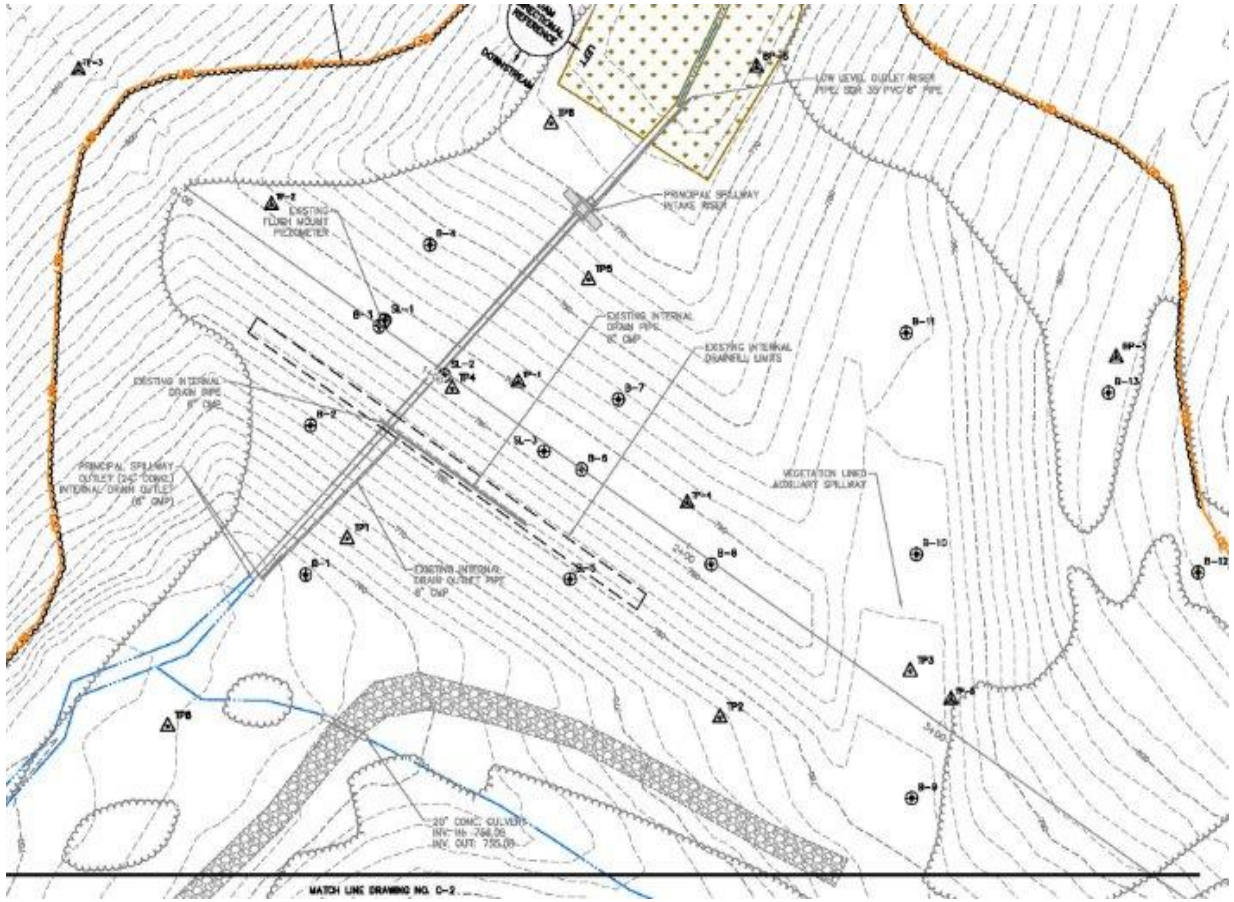


Geology

- Extent of Thick Shale Formation, Difficult to Escape from the Conditions.
- Highly Variable/Unpredictable Weathering
- Varying Permeability
- 45° to Near Vertical Varying Bedding of Rock
- Variable Embankment Fill Composition
- Evidence of Water Passing Through Competent and Weathered Rock
- Shale Conditions Present Difficulties in Treating Bedrock With Confidence

Supplemental Geotechnical Investigation

- Borings were performed by others after the 2021 storm event
- 8 test Ppts at dam and 6 test pits at borrow areas were performed in 2025
- Geotechnical laboratory testing
- Embankment fill had appreciable amounts of coarse particles (GC-GM and GP-GM)
- Similar materials encountered at borrow areas
- The bedrock and coarse material is likely a factor causing the observed seepage



Supplemental Geotechnical Investigation

- Embankment material's fines are the same as the fines observed at the seepage location

Key Factors for Design

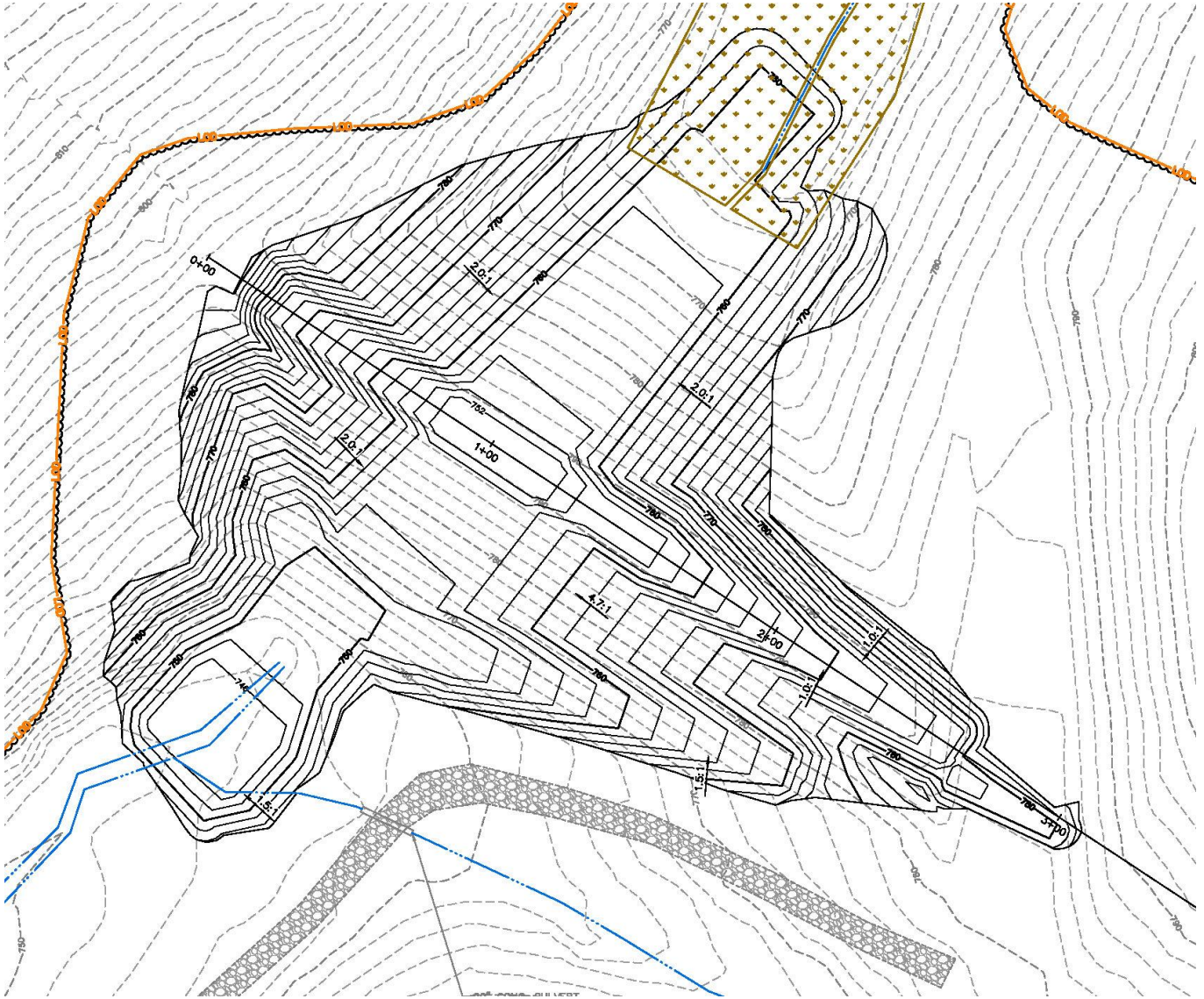
- Occurrence of seepage and difficult geology.
- The existing internal drainage system is not consistent with current dam safety design criteria .
- The principal spillway conduit is undersized and has anti-seep collars within the embankment.
- The dam overtops during the Probable Maximum Flood (PMF) storm event.
- The downstream slope of the dam embankment does not meet minimum factors of safety against slope failure
- Earthen auxiliary spillway is subject to headcut erosion during the design storm event
- The reservoir drain does not have a valve and is embedded in the embankment which inhibits maintenance or repair

Rehabilitation Design

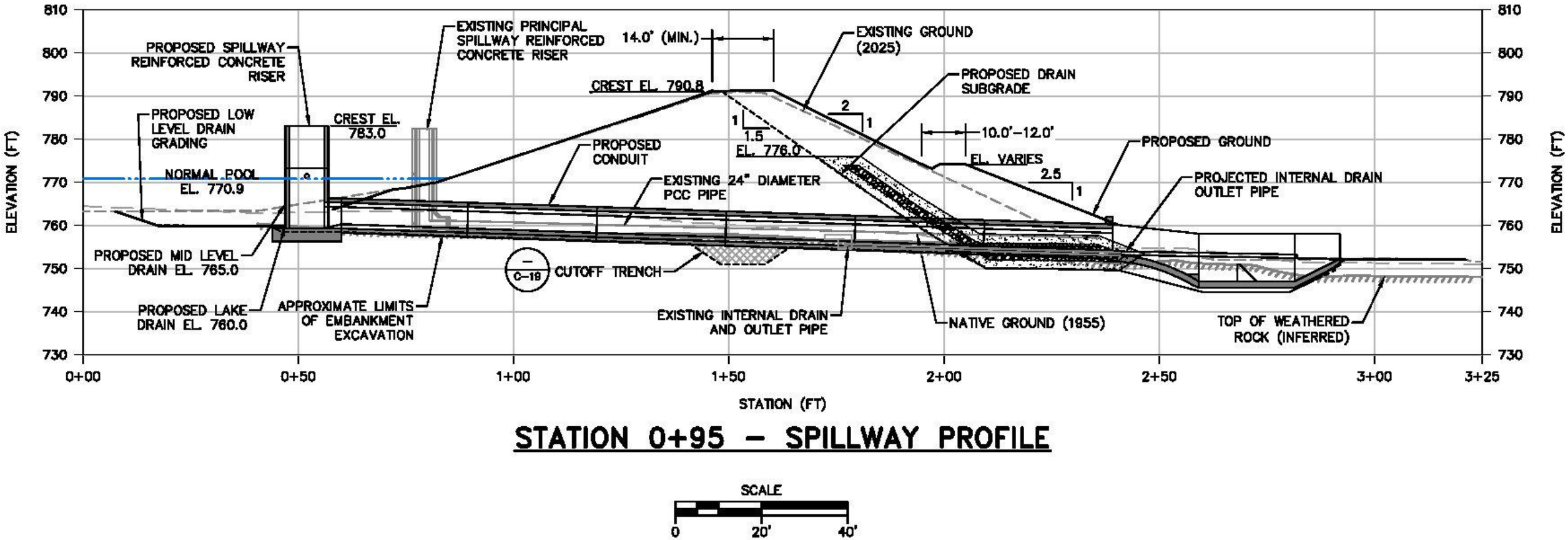
- Backfill the existing earth-lined auxiliary spillway to top of dam elevation.
- Construct a two-stage filtered chimney and toe drain on the downstream slope of the dam and within the backfilled auxiliary spillway.
- Construct a seepage cutoff trench along the dam crest alignment that extends into weathered rock and backfill with low permeability flowable fill.
- Construct a combined principal/auxiliary spillway intake riser within the reservoir with a low-level dewatering orifice, a mid-level orifice, and a normal pool orifice. All orifices will have gate valves
- Install a new 8-foot by 8-foot principal spillway outlet conduit.
- Construct a stilling basin downstream of the principal spillway outlet conduit.
- Excavation of sediment and debris in the reservoir directly upstream of the existing intake riser.
- Construct a 2.5 Horizontal to one (1) vertical (2.5H:1V) buttress and bench on the downstream slope of the dam embankment

Rehabilitation Design

Rehabilitation Design



Rehabilitation Design

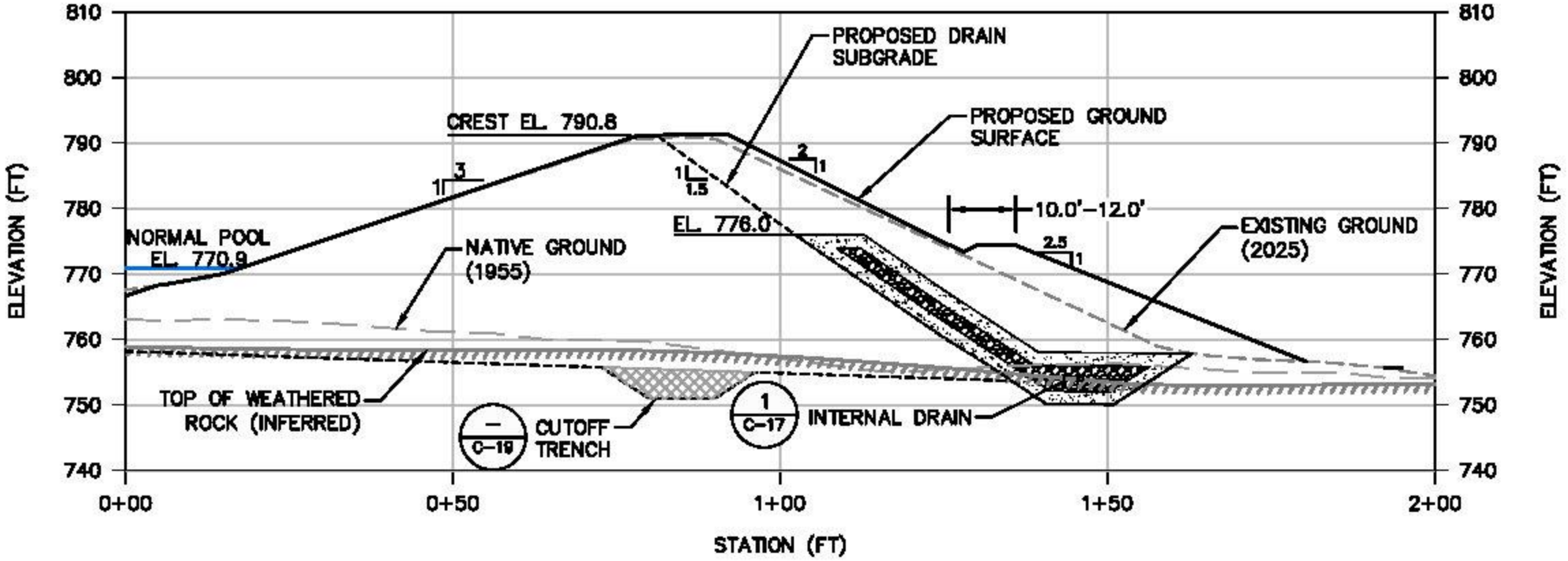


STATION 0+95 – SPILLWAY PROFILE

SCALE

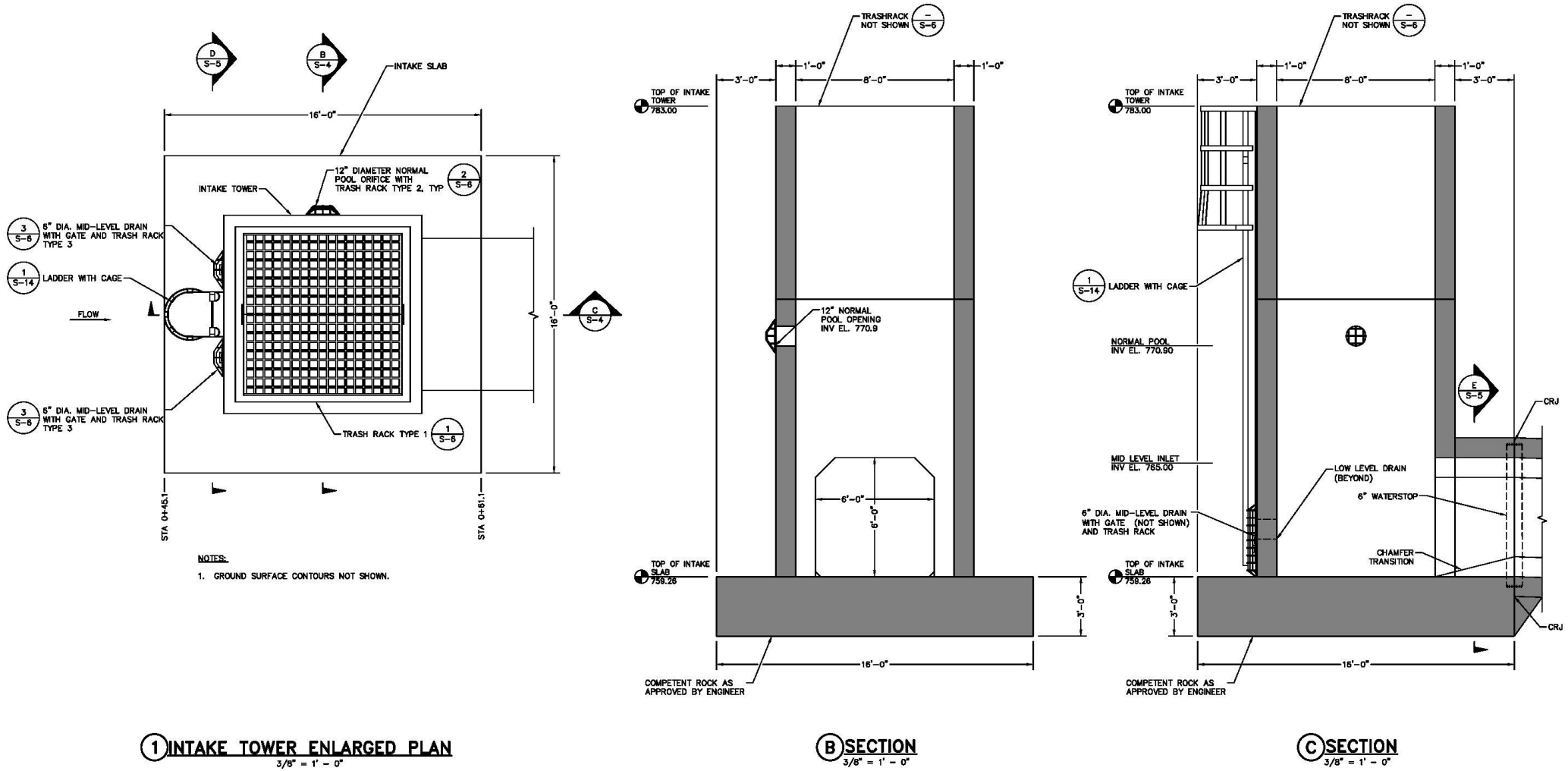
0 20' 40'

Rehabilitation Design



STATION 1+10

Rehabilitation Design



1 INTAKE TOWER ENLARGED PLAN
3/8" = 1' - 0"

B SECTION
3/8" = 1' - 0"

C SECTION
3/8" = 1' - 0"

Questions?