Geophysical Evaluation of Dam Seepage to Support Rehabilitation Efforts

AEG2020 Virtual Conference
September 18, 2020

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Presentation Outline

- Dam and Lake History
- Geophysical Survey Methods
- Characterization Results
- Rehabilitation Efforts
- Lessons Learned
Estimate Levee Toe Groundwater Levels From River Flood Stage Conditions

Correlate Groundwater Levels to River Levels

Luzerne Lake Dam
Greenville, Muhlenberg County, Kentucky
Historical Factoids
-Constructed in the 1920s
-1200 ft long, 20 ft height
-Excessive seepage on dry side face
-Series of grouting programs at 3 locations
-Continued seepage post grouting
-No site investigation/borings
-Geophysical surveys proposed to locate preferential flow pathways
Dam Erosion and Seepage
Regional Geology

Middle Pennsylvanian Carbondale Formation

*Mixed clastics, coal, limestone, sandstone, shale*

**Upper:** well-cemented sandstone, locally cross-bedded.

**Middle:** interbedded coal, micaceous sandstone and carbonaceous shale

**Base:** sandstone interbedded with carbonaceous clay shale and siltstone.
Proposed Geophysical Survey Methods
- 2D Electrical Resistivity Imaging (2D-ERI)
- Frequency Domain Electromagnetic Terrain Conductivity (FDEM) and SP Profiling
- Ground Penetrating Radar (GPR)
FDEM Survey
- Geophex GEM-2 multi-frequency sensor
- Profile lines spaced 10 ft apart parallel to the crest
- Data collected at 3 frequencies (47.01, 13.50 and 3.93 kHz)
- Processed, gridded, contoured and interpreted using Surfer 13 as color-filled maps
**Terrain Conductivity Survey**

**47.01 KHz**

**FDEM Survey Purpose**

- Map variations in dam embankment materials (granular vs. fine-grained soil fill)
- Possible utility conduits and shallow foundation soils
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Spontaneous Potential (SP) Survey

- Nonpolarizable Electrodes
- Reference electrode on wetside at water line
- Moving electrodes along dryside toe at 2 ft intervals
- Plot self potential values measured, observe trends and anomalies expected based on flow (inflow, outflow)
SP Response from Flows into and out of Dams
2D-ERI Survey
- Data collected with an AGI SuperSting R8 earth resistivity meter
- Dipole-dipole array of 56 electrodes at a spacing of 3 ft along one long profile line of about 1100 ft in length along the crest of the dam.
- Data downloaded and inverse-modeled using the software Advanced EarthImager2D
2D-ERI Survey

- Data collected with an AGI SuperSting R8 earth resistivity meter
- Dipole-dipole array of 56 electrodes at a spacing of 3 ft along one long profile line of about 1100 ft in length along the crest of the dam.
- Data downloaded and inverse-modeled using the software Advanced EarthImager2D
Resistivity and Self Potential Profile Line 1
**GPR Survey Purpose**

Mapping subsurface heterogeneities including utility trenches, pits, granular backfill, voids and below-grade structures.

**GPR Survey**

GSSI SIR4000 System with a shielded 400-megahertz (MHz) antenna; processed with RAdar Data Analyzer (RADAN) Version 7.4
GPR Survey Purpose
Mapping subsurface heterogeneities including utility trenches, pits, granular backfill, voids and below-grade structures.

GPR Profile Line 1

GPR Profile Line 1

GPR Profile Line 1
Table 1. Summary of Potential Seepage Areas from Geophysical Data Evaluation

<table>
<thead>
<tr>
<th>Distance Along Profile Line, ft</th>
<th>FDEM</th>
<th>2D-ERI Soils</th>
<th>2D-ERI Bedrock</th>
<th>SP</th>
<th>GPR</th>
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<tr>
<td>30 to 60</td>
<td>X</td>
<td>X</td>
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<tr>
<td>60 to 90</td>
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<td>90 to 100</td>
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<td>120 to 130</td>
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<td>145 to 160</td>
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\(^a\)Observed either as low resistivity weathered bedrock zones or greater depth to bedrock.
Dam Remediation Alternatives

- Embankment soils seepage
- Foundation bedrock seepage
- Shallow seepage zone removal versus additional grouting
- Removal of upper soils/historic roadway and replace soil/increase crest and flatten dam slope.
Middle Pennsylvanian Carbondale Formation

**Upper:**
- well-cemented sandstone, locally cross-bedded.

**Middle:**
- interbedded coal, micaceous sandstone and carbonaceous shale

**Base:**
- sandstone interbedded with carbonaceous clay shale and siltstone.

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**Dam Remediation**

- Dry-side slope flattened
- Removal of dam down below historical road, raised again with crest widening
Conclusions

- Geophysical profiles were able to map an undulating variably-weathered bedrock surface beneath fine-grained clayey dam embankment materials.

- Several zones of decreased resistivity present within dam embankment soils, could indicate increased soil moisture contents and seepage zones.
Conclusions

- Areas of anomalous Spontaneous Potential (SP) readings correlate well with several areas of lower resistivity within the soil and bedrock, providing another line of evidence for increased seepage.

- Some evidence that the 3 former grout areas remain locations of increased seepage.
Conclusions

- Some evidence of remaining seepage to the northwest and southeast of the water intake structure where erosion washout is currently observed.
- Geophysical surveys led to understanding of potential seepage pathways and selection of remedial alternative.