Boardman Dam Breaching Risk Assessment

November 12, 2014
Traverse City, MI

URS Corporation
10850 Traverse Hwy. Suite 3365
Traverse City, MI 49684
Contents

Section One: Introduction .................................................................................................................. 4
  Objectives ........................................................................................................................................ 4
  Breaching Risk Assessment Meeting .......................................................................................... 4
  Participants .................................................................................................................................. 5

Section Two: Key Project Data ........................................................................................................ 5
  Project Description ......................................................................................................................... 5
  H&H Summary ............................................................................................................................... 10
  Geotechnical Summary ................................................................................................................ 12
  Proposed Dam Removal Scheme .................................................................................................. 13
  Geotechnical and Structural Analysis .......................................................................................... 18
  Channel Lining and Design ............................................................................................................ 18
  Downstream Dissipater Structure ................................................................................................ 19
  Lessons Learned from Brown Bridge Dam removal .................................................................... 19

Section Three: Potential Risks ....................................................................................................... 20
  Potential Breaching Risks Analysis ............................................................................................ 20
  Summary of Potential Breaching Risks Analysis ....................................................................... 20
    Risk No. 1: Overtopping of Embankment due to Debris ............................................................... 23
    Risk No. 2: Initial design of top cut off the dam is too low and may be overtopped by a significant flood event ........................................................................................................ 23
    Risk No. 3: Initial plan for the construction sequence of auxiliary spillway leaves downstream bank exposed ........................................................................................................ 23
    Risk No. 4: Decreased spillway flow capacity due to rough cut of core wall by contractor ......... 24
    Risk No. 5: Overtopping/Breaching in an uncontrolled location on the embankment ............... 24
    Risk No. 6: Core wall in deteriorated condition ........................................................................ 24
    Risk No. 7: Turbidity Downstream ............................................................................................ 24
    Risk No. 8: Cost Inflation .......................................................................................................... 25
    Risk No. 9: Slope Stability of the West valley wall .................................................................... 25
    Risk No. 10: Communication of an Emergency Dam Failure .................................................... 25
    Risk No. 11: Historic Stop Log Structure located within the core wall .................................. 25
    Risk No. 12: Slope Stability along the impoundment and upstream reaches of the river .......... 26
    Risk No. 13: Social impacts of construction .............................................................................. 26
    Risk No. 14: Unknown Infrastructure encountered within core wall or earthen embankment .... 26
    Risk No. 15: Contractor submitted design changes to breaching operation ......................... 27
    Risk No. 16: Artesian well conditions developing from excavation at the toe of the dam ......... 27

Section Four: Summary .................................................................................................................. 27
Appendices

Appendix A – Existing Boardman Dam Design Drawings
Appendix B – Geotechnical Investigation
Appendix C – Breaching Plans

Tables

Table 1 – List of participants
Table 2 – Project information
Table 3 – MDEQ flood discharge at Boardman Dam
Table 4 – Low discharges at Boardman Dam
Table 5 – Potential risks associated with breaching operation

Figures

Figure 1 – Aerial view of Boardman Dam
Figure 2 – Top of Boardman Dam inlet structure
Figure 3 – The Boardman Dam inlet structure from the north side of Cass Road
Figure 4 – Boardman Dam inlet structure from the south
Figure 5 – Boardman Dam earthen embankment and concrete corewall looking west
Figure 6 – Historical Boardman Dam engineering drawing from 1930 depicting cross section view of the existing earthen embankment
Figure 7 – Flow exceedance curve for annual and summer gage data
Figure 8 – Precipitation vs. flow and flow change at Boardman Dam for September 1961
Figure 9 – Precipitation vs. flow and flow change at Boardman Dam for August 1987
Figure 10 – Plan view of the Boardman Dam breaching operation
Figure 11 – Profile view of the Boardman Dam breaching operation
Figure 12 – Elevation view of the earthen dam breaching operation
Section One: Introduction

Objectives
The purpose of the Breaching Risk Assessment is to evaluate various risks and the possible scenarios associated with each for the Boardman Dam breaching and removal project. The Breaching Risk Assessment is intended to loosely follow the guidelines of the Potential Failure Mode Analysis (PFMA) developed by the Federal Energy Regulatory Commission (FERC). The knowledge obtained during the identification and evaluation of these risks is used to develop risk reduction measures and project-specific performance monitoring programs.

This report describes and documents the Breaching Risk Assessment conducted for the Boardman Dam, which is located on the Boardman River in Traverse City, Michigan. Included in this report are the identified risks to the project; major findings and understandings that resulted; potential risk reduction measures; and a summary of the process followed by the group.

Breaching Risk Assessment Meeting
The Breaching Risk Assessment Meeting for Boardman Dam was performed on November 12th, 2014. The agenda for the meeting is summarized below:

Wednesday, November 12, 2014
1:00 pm   Confirm that everyone has visited the Boardman Dam site and reviewed background information
2:00 pm   Summarize key project features
3:00 pm   Identify risks and possible scenarios
4:00 pm   Evaluate risks and risk reduction measures for each
5:00 pm   Closing thoughts
Participants

Table 1: List of participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Phone</th>
<th>Email</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dan DeVaun, PE</td>
<td>URS Corporation</td>
<td>231-922-4290</td>
<td><a href="mailto:dan.devaun@urs.com">dan.devaun@urs.com</a></td>
<td>Risk Assessment Facilitator</td>
</tr>
<tr>
<td>Troy Naperala, PE</td>
<td>URS Corporation</td>
<td>231-922-4301</td>
<td><a href="mailto:troy.naperala@urs.com">troy.naperala@urs.com</a></td>
<td>Project Engineer</td>
</tr>
<tr>
<td>Vik Gautam</td>
<td>URS Corporation</td>
<td>216-622-2447</td>
<td><a href="mailto:vik.gautam@urs.com">vik.gautam@urs.com</a></td>
<td>Geotechnical Engineer</td>
</tr>
<tr>
<td>Mike Damian, PG</td>
<td>URS Corporation</td>
<td>614-600-5827</td>
<td><a href="mailto:mike.damian@urs.com">mike.damian@urs.com</a></td>
<td>Sr. Dam Specialist</td>
</tr>
<tr>
<td>David Sawitzki, PE</td>
<td>URS Corporation</td>
<td>301-820-3594</td>
<td><a href="mailto:david.sawitzki@urs.com">david.sawitzki@urs.com</a></td>
<td>Sr. Dam Engineer</td>
</tr>
<tr>
<td>Janeen Stalder</td>
<td>URS Corporation</td>
<td>231-922-4292</td>
<td><a href="mailto:janeen.stalder@urs.com">janeen.stalder@urs.com</a></td>
<td>Risk Assessment Facilitator</td>
</tr>
<tr>
<td>Andy Selle</td>
<td>Inter-Fluve, Inc.</td>
<td>608-441-0342</td>
<td><a href="mailto:aselle@interfluve.com">aselle@interfluve.com</a></td>
<td>River Restoration Specialist</td>
</tr>
<tr>
<td>Frank Dituri</td>
<td>Grand Traverse Band of Ottawa &amp; Chippewa Indians</td>
<td>231-866-1851</td>
<td><a href="mailto:frank.dituri@gtbindians.com">frank.dituri@gtbindians.com</a></td>
<td>Project Partner</td>
</tr>
<tr>
<td>Kim Balke</td>
<td>Conservation Resource Alliance</td>
<td>231-946-6817</td>
<td><a href="mailto:kim@rivercare.org">kim@rivercare.org</a></td>
<td>Project Partner</td>
</tr>
<tr>
<td>Brett Fessell</td>
<td>Grand Traverse Band of Ottawa &amp; Chippewa Indians</td>
<td>231-218-2604</td>
<td><a href="mailto:brett.fessell@gtbindians.com">brett.fessell@gtbindians.com</a></td>
<td>Project Partner</td>
</tr>
<tr>
<td>Gregg Bird</td>
<td>Grand Traverse County Health Department</td>
<td>231-995-6100</td>
<td><a href="mailto:gbird@gtchd.org">gbird@gtchd.org</a></td>
<td>Emergency Management Coordinator</td>
</tr>
<tr>
<td>Bill Weihbrecht</td>
<td>URS Corporation</td>
<td>717-635-7901</td>
<td><a href="mailto:bill.weihbrecht@urs.com">bill.weihbrecht@urs.com</a></td>
<td>River Restoration Specialist</td>
</tr>
</tbody>
</table>

Section Two: Key Project Data

Project Description
The Boardman Dam removal project is part of a larger Boardman River Restoration project which encompasses the removal of three dams and restoration of more than 20 miles of the Boardman River. The Boardman Dam removal is the second of the three dams to be removed in this larger project. Special consideration is going into the Boardman Dam removal as there is a great deal of public attention and awareness associated with this project. The objectives of this project are to successfully remove the Boardman Dam in a controlled manner with minimal downstream transport of impounded sediments.

The Boardman Dam is a hydroelectric dam originally constructed in 1894 and then completely rebuilt in 1930. Power generation became uneconomical by the early 2000’s so operations were terminated and the dam decommissioned in 2005. Upon decommissioning, dam safety inspections were conducted in compliance with Michigan Department of Environmental Quality regulations. Boardman Dam was determined to have insufficient spillway capacity and impoundment water levels were required to be lowered approximately 16 feet where the water level has been maintained ever since.

The current configuration of the Boardman Dam has the river flowing through the intake channel into the powerhouse through the penstocks during normal flows, or overflowing into an auxiliary spillway during large floods. These features are located on the east side of the impoundment. The auxiliary spillway and powerhouse intake are regulated with gates. Along the west bank of the intake channel is an emergency
overflow spillway. In addition, the Cass Road Bridge spans the powerhouse intake works (Figures 2 and 3) and the bridge substructure is directly tied to the dam structure. An earthen embankment dam is approximately 700 feet to the west of the intake channel.

Table 2: Project information

<table>
<thead>
<tr>
<th>Project Location:</th>
<th>Michigan</th>
</tr>
</thead>
<tbody>
<tr>
<td>State</td>
<td>Michigan</td>
</tr>
<tr>
<td>County</td>
<td>Grand Traverse</td>
</tr>
<tr>
<td>River</td>
<td>Boardman River</td>
</tr>
<tr>
<td>Town</td>
<td>Traverse City</td>
</tr>
<tr>
<td>Dam:</td>
<td>Earthen Embankment with Concrete Core Wall</td>
</tr>
<tr>
<td>Type</td>
<td>Earthen Embankment with Concrete Core Wall</td>
</tr>
<tr>
<td>Hazard Classification</td>
<td>High Hazard with Height Under 40ft</td>
</tr>
<tr>
<td>Structural Height</td>
<td>43 feet</td>
</tr>
<tr>
<td>Hydraulic Height</td>
<td>Approx. 25 feet</td>
</tr>
<tr>
<td>Crest Elevation (top of embankment)</td>
<td>660 feet NAVD88</td>
</tr>
<tr>
<td>Base Elevation</td>
<td>Approx. 617 feet NAVD88</td>
</tr>
<tr>
<td>Crest Length</td>
<td>650 feet</td>
</tr>
<tr>
<td>Reservoir:</td>
<td></td>
</tr>
<tr>
<td>Drainage Basin Size</td>
<td>237 square miles</td>
</tr>
<tr>
<td>Normal Reservoir Level (Baseflow 250cfs)</td>
<td>El. 640.81 feet NAVD88</td>
</tr>
<tr>
<td>Normal Storage Capacity</td>
<td>103 acre-feet</td>
</tr>
<tr>
<td>10-yr Storm Flood Level</td>
<td>El. 644.61 feet NAVD88</td>
</tr>
<tr>
<td>Maximum Flood Level (200-yr) (1900cfs)</td>
<td>El. 646.44 feet NAVD88</td>
</tr>
<tr>
<td>Spillway:</td>
<td></td>
</tr>
<tr>
<td>Crest Elevation</td>
<td>El. 641.6 feet NAVD88</td>
</tr>
<tr>
<td>Spillway Gates:</td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>Sluice</td>
</tr>
<tr>
<td>Size</td>
<td>(2) at 9-feet wide by 9-feet tall</td>
</tr>
<tr>
<td>Top of Gates</td>
<td>El. 647 feet NAVD88</td>
</tr>
<tr>
<td>Bottom of Gates</td>
<td>El. 638 feet NAVD88</td>
</tr>
</tbody>
</table>
Figure 1: Aerial view of Boardman Dam

Figure 2: Top of the Boardman Dam inlet structure looking west; existing Cass Road bridge. Inlet is to the left and outlet is to the right
Figure 3: The Boardman Dam inlet structure from the north side of Cass Road looking south

Figure 4: Boardman Dam inlet structure from the south side of Cass Road looking northeast
When the Boardman Dam was used for power generation, water passed through the penstocks to the turbines in the powerhouse located north of Cass Road. Additional flow capacity was regulated through the auxiliary spillway to maintain water levels in the impoundment. During hydropower generation operations, the dam was maintained as a run-of-the-river dam, meaning that discharge from the dam was equal to inflow into the impoundment. After decommissioning the dam, the water level in the impoundment was lowered to the maximum extent possible through the intakes with all the gates left fully open.

The earthen embankment is constructed of sand and clay fill material and has a crest elevation of 660’. Within the embankment is a 10 inch thick, 33 foot high concrete core wall structurally reinforced with steel rebar. Sheet piling extends below the concrete wall into native clay soils. Figure 6 shows the cross section view of the earthen embankment and the extents of the core wall and sheet piling.
Figure 6: Historical Boardman Dam engineering drawings from 1930 depicting the cross section view of the existing earthen embankment including concrete core wall and underlying sheet piling.

See Appendix A for historic design drawings of the earthen embankment.

**H&H Summary**

The Boardman River watershed is comprised of glacially deposited sediments with the predominant soils being highly permeable loamy sands. Additionally, the majority of the watershed is undeveloped land. These two factors produce a highly stable river which is predominantly groundwater fed. This results in flood events with elongated hydrographs and muted peak flows.

Flood flow estimates on the Boardman River were evaluated by URS as part of a study to assess the hydrologic impacts of the dam removals. Two key findings were reached through this study: 1) the dams on the Boardman River were not capable of providing significant flood flow attenuation and based on operation records, did not appear to, 2) flood flow estimates based on distributions of the historic gage data downstream of Brown Bridge Dam were not impacted by the dam and are still valid post dam removal. The MDEQ maintains a flood discharge database for all major streams within the state. These estimates for the Boardman River are based on a Log Pearson Type III (LP3) distribution of the historic gage with a Drainage Area Ratio (DAR) applied to calculate the discharges at various locations on the river.

The MDEQ flood discharge estimates were assessed for validity by comparing our own LP3 calculations and utilizing an alternative USGS modeling system. It was determined that the MDEQ flood discharge estimates are sufficiently conservative for estimating flood discharges. For this reason we have chosen to utilize those flows in all modeling efforts that have been done for the H&H studies conducted on the Boardman River. And will utilize these flows in the designs for the Boardman Dam dewatering structure and pumping operation capacities.
Table 3: MDEQ flood discharge at Boardman Dam

<table>
<thead>
<tr>
<th>Recurrence Interval</th>
<th>Discharge (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50%</td>
<td>730</td>
</tr>
<tr>
<td>20%</td>
<td>1053</td>
</tr>
<tr>
<td>10%</td>
<td>1200</td>
</tr>
<tr>
<td>2%</td>
<td>1500</td>
</tr>
<tr>
<td>1%</td>
<td>1700</td>
</tr>
<tr>
<td>0.50%</td>
<td>1900</td>
</tr>
<tr>
<td>0.20%</td>
<td>2200</td>
</tr>
</tbody>
</table>

Table 4: Low discharges at Boardman Dam

<table>
<thead>
<tr>
<th>Month</th>
<th>Discharge (cfs) (50% frequency)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>250</td>
</tr>
<tr>
<td>February</td>
<td>250</td>
</tr>
<tr>
<td>March</td>
<td>280</td>
</tr>
<tr>
<td>April</td>
<td>390</td>
</tr>
<tr>
<td>May</td>
<td>310</td>
</tr>
<tr>
<td>June</td>
<td>270</td>
</tr>
<tr>
<td>July</td>
<td>240</td>
</tr>
<tr>
<td>August</td>
<td>230</td>
</tr>
<tr>
<td>September</td>
<td>240</td>
</tr>
<tr>
<td>October</td>
<td>250</td>
</tr>
<tr>
<td>November</td>
<td>270</td>
</tr>
<tr>
<td>December</td>
<td>270</td>
</tr>
</tbody>
</table>

Tables 3 and 4 were obtained from the Michigan Department of Environmental Quality based on a USGS gage (4127000) stationed upstream of the Boardman Dam. The shaded cells indicate the normal flows expected during the months of anticipated dam deconstruction.

An evaluation of the exceedance probability of the flows from 56 years of gage data for annual and summer flows was conducted and the resultant exceedance curves were obtained. From this curve it is evident that the river maintains a fairly even discharge with large spikes in flow being infrequent.

![Flow Exceedance Curve](image)

Figure 7: Flow exceedance curves for annual and summer gage data.

Hydrograph response time was also evaluated to adequately ensure on-site contractor responses would be facilitated in time. A comparison of local rain gage data and flow change at Boardman Dam showed that the rate of flow change in the river is slow and the river’s response to storm events tends to lag by
several days. See Figure 8 and 9 below. This would indicate that there should be adequate time (more than a day) available for the contractor to prepare the site for high flows.

![Figure 8: Precipitation vs. flow and flow change at Boardman Dam for September 1961](image)

![Figure 9: Precipitation vs. flow and flow change at Boardman Dam for August 1987](image)

**Geotechnical Summary**

Four soil borings were drilled in the vicinity of the Boardman Dam. The borings were located at the crest, mid-slope, and toe of the dam. The soil borings were advanced to depths ranging between 70 and 110 ft...
below existing ground surface. The subsurface information collected indicates that the earth embankment consists of medium dense, silty sand (SM) or sand with silt (SW-SM). Underlying the embankment soils are native interbedded layers of sands (SP), silty sands (SM), sands with silt (SP-SM to SW-SM), gravels (GW to GW-GM), silts (ML), silty clays (CL-ML) and lean clays (CL) extending to the bottom of the borings. The native coarse-grained soils have a generally medium dense apparent density, while the native fine-grained materials have a generally hard consistency. In general, a very stiff to hard lean clay or silty clay were encountered at elevations corresponding to the interface between the dam embankment and native ground, with coarser grained native soils below the clay.

Slightly artesian groundwater was encountered at the location of boring B-9 (the water level rose to approximately 2 ft above the ground surface). Based on piezometer water level data and observations made during drilling, the phreatic water level within the embankment drops relatively steeply between the shoreline and the corewall, but then remains relatively flat from midslope of the dam face to the toe.

Samples of concrete and reinforcing bars were obtained from the core wall. Concrete compressive strength was measured in pounds per square inch (psi) and was found to be on the order of 4 to 5,000 psi. The reinforcing consists of square steel bars, with yield strength measured in kilopound per square inch (ksi) of approximately 40 ksi. Spacing of vertical bars, as determined during the course of the exploration, corresponds very closely to that shown in the historical drawings. The configurations shown in the drawings are, therefore considered to be an accurate representation of field conditions.

See Appendix B for data generated during the geotechnical investigations.

**Proposed Dam Removal Scheme**

The Boardman Dam breaching operation is planned for the earthen embankment in the location of the pre-dam river alignment. The breaching operation will begin after the Cass Road Bridge has been constructed and a new channel is constructed through the footprint of the Cass Road fill embankment. The breaching operation will begin with the removal of the top of the embankment and core wall to an approximate elevation of 646', which is about 1.5 feet above the 10-yr water surface elevation within the impoundment. The dewatering will be accomplished by pumping the water over or otherwise past the earthen dam embankment and removing the earthen dam in the dry.

Portable pumps will be installed on this newly created “work pad” on the west side of the embankment, where the proposed river channel will be constructed. Fused high density polyethylene (HDPE) pipes will be connected to the pumps for suction and discharge lines. The pumped discharge will outlet into a stilling basin as described below. The total capacity of the pumping system will be 400 cubic feet per second (cfs). This will provide ample capacity to meet the desired drawdown rate of one foot per day under mean flow conditions (approximately 270 cfs) (Prein and Newhof 2009). This flow rate also exceeds the 10 percent exceedance flow of 390 cfs (for the months of June, July, August, and September).

As a redundant safety measure, a 40 foot wide auxiliary spillway channel will be incrementally constructed through the embankment, in the event that the pumps fail or capacity is exceeded. The spillway will be lined with flexible hard armor mats (ArmorFlex). The first iteration of the spillway will be built at an elevation of 638’, with two additional 8 foot excavation iterations until a final spillway entrance elevation of 623’ is obtained. The final auxiliary spillway inlet elevation has been set by the bathymetry data obtained in the impoundment. The elevations within the impoundment are such that if
the inlet to the spillway is lowered further it will be below the impoundment adjacent to the spillway intake, causing issues with intake flow, sedimentation, and access.

A 40 foot by 55 foot stilling basin will be located at the downstream end of the spillway to alleviate any hydraulic jump associated with the discharging water. The stilling basin will incorporate heavy stone riprap material and will hold a 6 foot deep pool of water within the basin to dissipate the hydraulic energy coming off the spillway. The outlet of the stilling basin will be located on its northeast side, discharging to the proposed river channel approximately 200 feet upstream of the new Cass Road Bridge.

After the last iteration of the spillway is complete, the pumping operation will be stopped and the pumps removed. At this time the auxiliary spillway will be used as the sole outlet to pass river flows from the impoundment. Concurrently, the excavation of the proposed river channel will begin on the west side of the earth embankment, with a portion of this work to be done in the wet. The anticipated invert elevation of the restoration channel at the dam is 615’. This leaves approximately 7 feet between the proposed channel invert and the final spillway sill elevation.

During the pumping operation, the contractor shall always maintain a minimum of five feet of freeboard below the top of the concrete core wall. A float activated alarm system shall be installed on the upstream side of the impoundment to notify the contractor if the water level begins to rise. Figure 10 provides a plan view of the drawdown operation. Figures 11 and 12 illustrate the lowering of the earthen embankment in cross section view. Following restoration of the proposed river channel, the area around the breaching operation will be topsoiled, seeded, and restored.
Figure 10: Plan view of the Boardman Dam breaching operation
Figure 11: Profile of the Boardman Dam breaching operation

- First cut of excavation off the top of the dam
- First spillway excavation extent
- Second spillway excavation extent
- Final spillway excavation extent
Figure 12: Elevation view of earthen dam breaching operations
Sediment management during the breaching operation will be accomplished with a large sediment trap constructed at the end of the auxiliary spillway stilling basin. Initially when the drawdown and breaching begins, the impoundment itself will operate as a large sediment trap, with the majority of sediment settling in the impoundment. A secondary sand trap will be constructed immediately below the earthen embankment, downstream of the spillway stilling basin where the breach is occurring. Turbidity monitoring will be necessary downstream of the breaching operations throughout the duration of the project.

During the breaching operation, two construction roads will be required. The first will utilize the Boardman Dam public access parking lot and gravel entranceway located on the south side of Cass Road. The second would be constructed along an unnamed Grand Traverse Conservation trail running from Cass Road, south to the earthen embankment. Both construction roads are depicted on the overall site plan on Figure 10.

See Appendix C for concept design drawings of the proposed breaching operation.

**Geotechnical and Structural Analysis**

Geotechnical and structural analyses have been conducted on the Boardman Dam earthen embankment and core wall. Conclusions from the analyses are as follows:

- Geotechnical analysis focused on determining stable sideslopes for the temporary excavations that will be required to implement the breaching operations. Excavations sloped to 1.75H:1V on the dam have been found to be stable in terms of slope stability. Seepage below the subsurface groundwater flow is not anticipated to destabilize the slope excavations if drawdown of the pond is performed gradually. Overall embankment stability along the outlet channel opening is estimated to be adequate.

- Lateral response of the core wall to embankment removal was checked with a soil-structure interaction analysis. The concrete core wall is expected to have sufficient structural capacity to support approximately 10 feet of unbalanced earth and hydrostatic load. The incremental excavations to lower the dam (8 ft increments) have been specified based on this conclusion.

- Vibration and settlement monitoring along the impoundment slopes is recommended during the impoundment drawdown and breaching operation. Additionally, it is recommended to abstain from performing any mass excavations near the downstream toe of the dam until the pumping operation is complete and flow is diverted to the overflow channel.

**Channel Lining and Design**

The auxiliary spillway will be armored with articulated concrete blocks (ACB) and will be approximately 40 feet wide and 183 feet long. There are three iterations of the spillway planned. The first spillway weir invert will be at an elevation of 638’, the next at 630’, and the final spillway invert is proposed at 623’. Sheets of articulated block will line the channel and will be placed in 30 foot by 8 foot sections. These ACB sheets will be mechanically anchored into the channel and will also be connected with concrete seams between the sheets. The channel will have 2:1 side slopes, and the articulated concrete block will run up the slope to at least 1 foot above the 100-yr water surface elevation within the channel. The articulated block will armor the channel against erosion and undermining. The ACB armored spillway
will be temporarily removed and replaced at each dam removal sequence, reusing the ACB materials to the extent practical.

**Downstream Dissipater Structure**
Floodwaters through the spillway will flow down the north side of the earthen embankment into a 40 feet wide by 55 feet long riprap stilling basin. The stilling basin will be lined with Michigan Department of Transportation (MDOT) Class 4 and 5 rip rap material to dissipate energy at the toe of the letdown and to contain the hydraulic jump that will develop in the basin. Preliminary design of the basin has been to accommodate that portion of the 100-year flood discharge which exceeds the capacity of the proposed pumps.

The stilling basin will be constructed with earthen berms covered with a reverse graded filter and rip rap, and will utilize the existing topography on the northwest side of the basin. There will be a 35 foot outlet weir installed on the northeast side of the stilling basin. Due to high groundwater conditions at the toe of the dam, there is a need to limit the depth of the stilling basin below existing grades for constructability purposes. In order to establish sufficient tailwater to control the hydraulic jump in a shallow basin, an earthen control berm will be constructed downstream of the basin outlet. This will allow flow out of the basin into an additional stilling area confined by the existing topography and a downstream control berm acting as a check dam. The control berm will have four 36 inch diameter HDPE pipes to discharge smaller flows from the riprap stilling basin and an overflow weir above the HDPE pipes to discharge flows larger than the 50-year flood. Flows from the discharge from the downstream stilling area will discharge into the proposed river channel.

An additional smaller dissipater structure would be constructed at the discharge point of the pumping operation. This area would be directly west of the spillway stilling basin and would be designed to accommodate 400 cfs. This dissipater structure would utilize the same concepts discussed above, but to a smaller detail. Rip rap material would be used to line the bottom of the channel as well as earthen berms that would be constructed to create a tailwater condition at the discharge point. The area proposed for the pumping discharge is the same location as the historical river channel so this channel is already armored with cobble. This is also where the proposed channel through the dam embankment will be excavated, therefore, discharge into this area and any associated erosion would not be a significant concern.

**Lessons Learned from Brown Bridge Dam removal**
The Brown Bridge Dam, formerly located on the Boardman River in Grand Traverse County, MI was owned and operated by the City of Traverse City and originally constructed for the purpose of generating hydroelectricity. This dam was located approximately 12 miles upstream from Boardman Dam. In 2012, the City of Traverse City was granted a permit from the MDEQ to remove the Brown Bridge Dam and restore a natural river channel through the former Brown Bridge Pond impoundment. The project included a steel sheet pile walled diversion channel and drawdown structure constructed adjacent to the existing spillway structure.

On October 6, 2012 at first hydraulic loading of the temporary dewatering structure, a boil was noticed downstream of the concrete slab lining the bottom of the channel. Flow from the boil increased quickly, ultimately resulting in failure of the dewatering structure and collapse of the earthen embankment section between the dewatering structure and the Brown Bridge Dam spillway structure. The ensuing uncontrolled release of impounded water resulted in significant flooding along the Boardman River.
A series of post-failure investigations and subsequent geotechnical analyses found that the most likely failure mode of the temporary dewatering structure was internal erosion of the foundation material from underneath the water control structure within the dewatering structure. The hydraulic loading resulted in an unstable subsurface soil condition, which led to erosion of the foundation soils, release of water underneath of the control structure, collapse of the earthen embankment adjacent to the dewatering structure, and ultimately the uncontrolled release of water from the Brown Bridge Pond.

From the events of October 6, 2012, aspects of the Boardman Dam site investigation and the dewatering design have been adjusted to incorporate those lessons learned. Firstly, an intensive site investigation was conducted at the site of the Boardman Dam including groundwater and soils investigations. From these investigations the soil types below the dam were obtained and the capability of hydraulic movement within those soils was determined. Groundwater was noted around the downstream toe of the dam, therefore an investigation was completed to identify the locations of groundwater seeps and the likely source of that water flow. Both of these data items were included in the design of the dewatering process of Boardman impoundment. Groundwater is a concern at the beginning of the drawdown process, therefore, an ultra-conservative method of bypass siphoning and pumping has been established as the main form of impoundment water level drawdown until the water level reaches a depth of approximately 6 feet.

**Section Three: Potential Risks**

**Potential Breaching Risks Analysis**

A “round table” discussion was facilitated to identify possible risks for the Boardman Dam breaching. The group of participants was asked to list risks and their scenarios that could result in an unexpected dam breach during the controlled drawdown of the impoundment. During this discussion the events that would lead to the breach were clearly described.

Each potential risk was discussed amongst the group, with discussion focused on risks that would result in an uncontrolled release of the impounded waters by the earthen embankment. Each risk scenario was discussed in detail. The summary of each scenario and the mitigating design features and or monitoring/instrumentation measures are detailed in the Table 5 in this section.

**Summary of Potential Breaching Risks Analysis**

The Breaching Risk Assessment identified 16 possible risks associated with the breaching operation at the Boardman Dam. Table 5 and the sections below detail each risk and the risk reduction measures recommended for each.
<table>
<thead>
<tr>
<th>Potential Risks</th>
<th>Name</th>
<th>Summary Description</th>
<th>Design Features</th>
<th>Monitoring/Instrumentation</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Debris</td>
<td>Debris at the Dam intake or bypass intake</td>
<td>1. Onsite equipment for cleaning. 2. Include as a pay item. 3. Bypass intake screening.</td>
<td>1. Daily observation. 2.</td>
<td>1. Have debris removal pay item. 2.</td>
</tr>
<tr>
<td>2</td>
<td>Flood</td>
<td>What is a safe flood event for initial cut?</td>
<td>1. 100-yr flood for initial cut. 2. Identify area in core wall where flood flows would breach first. 3.</td>
<td>1. Onsite water level monitoring equipment. 2. Immediate notification of rising impoundment waters to URS and contractor. 3.</td>
<td>2.</td>
</tr>
<tr>
<td>3</td>
<td>Initial Sequence</td>
<td>Construction sequence of auxiliary spillway</td>
<td>1. Construct spillway prior to full top cut. 2. Controlled overflow in single location. 3. Always construct downstream side first. 4. Include each spillway construction and articulated block installation as a pay item.</td>
<td>1. 2. 3.</td>
<td>4.</td>
</tr>
<tr>
<td>4</td>
<td>Spillway Crest Capacity</td>
<td>Impact to flow capacity due to roughness of core wall demolition</td>
<td>1. Specify overflow section to be cleanly cut by contractor.</td>
<td>1.</td>
<td>1. Stockpile broken concrete and/or rip rap. 2. 3.</td>
</tr>
<tr>
<td>5</td>
<td>Uncontrolled release plug</td>
<td>Overtopping/breaching in uncontrolled location</td>
<td>1. Keep core wall rubble on-site and nearby. 2. Notch core wall to guide breach location.</td>
<td>1.</td>
<td>1. Put notching in drawings and specs. 2. 3.</td>
</tr>
<tr>
<td>6</td>
<td>Core wall condition</td>
<td>What if the core wall is deteriorated?</td>
<td>1. Prepare conceptual repair measures. 2.</td>
<td>1. Observe as core wall is uncovered. 2.</td>
<td>1. Have pay item per SF to patch/repair core wall. 2.</td>
</tr>
<tr>
<td>8</td>
<td>Increased Project Cost</td>
<td>Cost inflation/management</td>
<td>1. Evaluate contract terms. 2. Unit price bid.</td>
<td>1. Prepare client with updated unit prices as project approaches. 2.</td>
<td>1. Reduce risk to bidders be effective contract measures and well defined pay items. 2.</td>
</tr>
<tr>
<td>9</td>
<td>Slope Stability</td>
<td>Slope stability of the West valley wall</td>
<td>1. Evaluate at interface with core wall.</td>
<td>1. Visually monitor and observe during construction. 2.</td>
<td>1. 2.</td>
</tr>
<tr>
<td>10</td>
<td>Emergency Communication</td>
<td>Communication of emergency situation such as overtopping of dam, dam failure, etc.</td>
<td>1. Contact EM, follow EMP for Boardman Dam.</td>
<td>1.</td>
<td>1. Make bidders aware of EMP.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td><strong>Historic Stop Log Structure in Core Wall</strong></td>
<td>Historic construction channel and stop log structure through corewall overlap with auxiliary spillway</td>
<td>1. Verify location and compare to planned location of auxiliary spillway and river channel.</td>
<td>1. As core wall is uncovered during auxiliary spillway construction, be aware of any signs of this structure.</td>
<td>1. Stipulate that the core wall patching/repair pay item (No. 6 above) also applies to old stop log structure.</td>
<td></td>
</tr>
<tr>
<td><strong>Impoundment Slope Stability</strong></td>
<td>Slope stability in the impoundment and upstream reaches of the river, private property, etc.</td>
<td>1. Stabilization measures.</td>
<td>1. Monitor slopes with instrumentation.</td>
<td>1. Put max. drawdown rate in the specifications.</td>
<td></td>
</tr>
<tr>
<td><strong>Citizen Perception and Cooperation</strong></td>
<td>Social impacts of Construction</td>
<td>1. Noise control during construction and with bypass pumping operation.</td>
<td>1. Press Release.</td>
<td>1. Put noise limits in the specs, to be measured at a specified location &amp; distance from the site.</td>
<td></td>
</tr>
<tr>
<td><strong>Unknown Infrastructure</strong></td>
<td>Unknown infrastructure within the core wall or earthen embankment</td>
<td>1. Scenario specific mitigation plans.</td>
<td>1. Protocol developed to contact owner/engineer in the case of discovery.</td>
<td>1. Consider putting a pay item for standby time in the bid package.</td>
<td></td>
</tr>
<tr>
<td><strong>Contractor Design Changes</strong></td>
<td>Contractor submitted design changes to breaching operation</td>
<td>1. Specifications will require all designs to be reviewed by URS and follow same protocols and processes followed for initial URS design.</td>
<td>1. Encourage value engineering by bidders.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sand Boil/artesian conditions</strong></td>
<td>If construction of stilling basin requires excavation, a sand boil could result from the unloading of soils.</td>
<td>1. Construct stilling basin at/above grade.</td>
<td>1. Visually monitor the area during and after construction for changes.</td>
<td>1. Put control of sand boils in the technical specifications.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.</td>
<td>2.</td>
<td>2. Pay item per ton for boil control filter aggregates.</td>
<td></td>
</tr>
</tbody>
</table>
Risk No. 1: Overtopping of Embankment due to Debris
A high flow event runs through the river system depositing significant debris in and around the dam intake structure and or bypass pumping intakes. The debris builds up resulting in decrease in flow discharge capacity from the intakes. Subsequent high flows occur resulting in significant rises in impoundment levels and possible overtopping of the embankment due to limited discharge capacity caused by debris clogging the inlets.

- Risk Reduction Actions:
  o Maintain equipment onsite for cleaning of intakes if necessary.
  o Include debris removal from intake structure and pumping intakes as a pay item.
  o Ensure bypass pumps have intake screening appropriate for the expected size of debris to be encountered.
  o Conduct daily observations of intakes.

Risk No. 2: Initial design of Dam Top Cut Too Low and May Be Overtopped by a Significant Flood Event
The initial design for the top cut excavation of the dam is based on the 10yr flood event. It is possible that a larger storm event could occur during the construction phase. If a 100yr or larger storm event were to occur shortly after the initial excavation of the top of the dam, it is possible that the dam could be overtopped. Although this has a very low probability of occurring, the additional stress on the earthen embankment and concrete core wall could result in failure of the dam.

- Risk Reduction Actions:
  o Change the construction design to use the 100-yr flood for the initial top excavation limits of the dam.
  o Identify an area in the core wall where flood flows would breach first by constructing a notch in the concrete core wall at this location, allowing for some control if the water surface elevations reached this level.
  o Maintain on-site water level monitoring equipment.
  o Set up immediate notification system to URS and contractor in the case of rising impoundment waters.
  o Monitor local and regional weather conditions and forecasts.

Risk No. 3: Initial Plan for the Construction Sequence of Auxiliary Spillway Leaves the Downstream Bank Exposed
The initial proposed sequence for the construction of the auxiliary spillway leaves the downstream side of the embankment exposed and vulnerable if an unexpected overtopping of the dam or spillway occurred.

- Risk Reduction Actions:
  o Construct the auxiliary spillway prior to the full top cut of the dam being complete.
  o Guide controlled overflow into the spillway at a single location to be selected by the Engineer.
  o For each iteration of the spillway, always construct the downstream side of the spillway first.
Plan for articulated block installation immediately after downstream spillway construction.
- Include each spillway construction and articulated block installation as a pay item.
- Stockpile concrete rubble or rip rap for emergency use during spillway excavation; stockpiling to be a pay item.

Risk No. 4: Decreased Spillway Flow Capacity Due to Rough Cut of Core Wall by Contractor
The spillway design capacity is critical to the safety of the dam breaching operation. The design of the spillway was determined under the assumption that the core wall would be removed to the approximate dimensions required to pass 1200 cfs. If the core wall is roughly cut the flow capacity into the spillway could be significantly reduced and could result in higher impoundment elevations than expected.

- Risk Reduction Actions:
  - Specify overflow section of the core wall to be removed cleanly by contractor during spillway construction.
  - Consider having a pay item for saw-cutting the concrete core wall, including its steel reinforcing bars, per L.F.

Risk No. 5: Overtopping/Breaching in an Uncontrolled Location on the Embankment
Overtopping of the earthen embankment in an uncontrolled location increases the risk of complete embankment failure. A breach in an uncontrolled location would also limit the ability of the contractor to stop the breach.

- Risk Reduction Actions:
  - Notch a section of the core wall approximately 2-feet lower than the rest during each construction sequence to designate where flood waters would overtop first.
  - Keep core wall rubble and extra super sacks on-site and nearby to plug the breach in case of overtopping. Set stockpiling and emergency placement of concrete rubble (or other rip rap) as contract pay items.

Risk No. 6: Core Wall in Deteriorated Condition
Initial observations and structural corings show that the core wall is in good condition. However, it is possible that after excavation of the earthen embankment surrounding the core wall some deterioration of the wall could be found. This could leave the embankment in an unstable state and poses a risk of an unexpected breach during the dam breaching operation.

- Risk Reduction Actions:
  - Prepare conceptual repair measures for as-needed use by the contractor.
  - Observe the core wall as it is uncovered.
  - Notify the owner/engineer upon observation of structural deterioration.

Risk No. 7: Turbidity Downstream
Turbidity from sediment movement during the drawdown of the impoundment could propagate downstream and change the color of the river, affecting the public perception of the project. Additionally, with excessive sediment movement downstream greater environmental impacts could occur, also affecting the overall success and public opinion of the project.
- **Risk Reduction Actions:**
  - Install sediment curtains to capture excess sediment moving downstream as needed.
  - Conduct regular turbidity monitoring downstream of the dam breaching operation.
  - Press release to notify the public of possible visual changes that could occur in the downstream reaches of the river during the breaching operation.

**Risk No. 8: Cost Inflation**
Increases in construction and management costs over the next few years could exceed the fundraising efforts of the project partners and could pose a risk to the successful completion of the project.

- **Risk Reduction Actions:**
  - Evaluate contract terms at the time of bid.
  - Evaluate unit price bids.
  - Prepare client with updated unit prices as project approaches.
  - Set realistic budgets with adequate contingencies.

**Risk No. 9: Slope Stability of the West valley wall**
The slope along the west side of the dam embankment and impoundment is steep and has the possibility to become unstable with the extensive construction activities occurring in the vicinity. This could compromise the construction site and its western access point and could negatively impact the stability of the earthen embankment.

- **Risk Reduction Actions:**
  - Evaluate the slope at the interface with the core wall.
  - Visually monitor and observe the slope during construction.

**Risk No. 10: Communication of an Emergency Dam Failure**
Swift communication and action if imminent failure is expected or following the initial unexpected breaching or failure of the dam embankment is critical in eliminating significant downstream damage and notifying anyone who might be in the path of flood waters.

- **Risk Reduction Actions:**
  - Contact the Grand Traverse County Emergency Manager.
  - Follow the Emergency Management Plan (EMP) for the Boardman Dam.
  - Communicate EMP to contractors at the time of bidding.

**Risk No. 11: Historic Stop Log Structure Located Within the Core Wall**
On historic design drawings there is a stop log structure and opening located within the core wall where the former river channel was allowed to pass through the dam until it neared completion. The stability of the core wall in this area is unclear and care should be taken during excavations in the vicinity of this structure. It will be imperative that the auxiliary spillway not be planned for excavation in the area of the stop log structure as this could significantly undermine the stability and effectiveness of the spillway.

- **Risk Reduction Plan:**
  - Verify the location of the stop log structure and compare this to the planned location of the auxiliary spillway and river channel through the embankment.
If the spillway is deemed to be too close to the structure, modify the auxiliary spillway placement.
- During excavation of the core wall and spillway construction, be aware of any signs of the stop log structure.
- Notify the owner/engineer if it is determined that the structure has been uncovered.

**Risk No. 12: Slope Stability along the Impoundment and Upstream Reaches of the River**
Unstable slopes along the river banks upstream of the Boardman Dam could affect construction access and safety, negatively impacting private property; and sloughing of slopes could result in increased turbidity and sediment within the river.

- **Risk Reduction Plan:**
  - Utilize stabilization measures on steep slopes identified prior to drawdown of the impoundment.
  - Evaluate providing slope stabilization and/or grading for bordering property owners to the impoundment.
  - Monitor slopes throughout the impoundment drawdown with slope stability instrumentation.

**Risk No. 13: Social Impacts of Construction**
Negative citizen impacts could affect the project progress and ultimate success. This project has a lot of public attention and is only part of a larger project. Noise control and construction traffic in and around the project site could result in complaints from adjacent property owners. Also, downstream changes to the river such as changes in turbidity could result in public complaint. Open communication with the public on what to expect during the construction phase, as well as proactive measures during construction to mitigate public concerns and complaints will be helpful in encouraging positive public reception to the project and its temporary impacts.

- **Risk Reduction Plan:**
  - Noise control during construction and with the bypass pumping operation to be included in the specifications.
  - Issue press releases prior to project start up and possibly during the project to keep the public informed of possible impacts they may experience and see.
  - Hold a public meeting prior to the start of the project to discuss any public concerns with the construction project and how those concerns are planned to be mitigated.

**Risk No. 14: Unknown Infrastructure encountered Within Core Wall or Earthen Embankment**
Construction crews could encounter unknown infrastructure contained within the concrete core wall or the earthen embankment. This could impact the timeline anticipated for construction and could result in unexpected costs to the client.

- **Risk Reduction Plan:**
  - Prepare scenario specific mitigation plans
  - Develop a protocol for contractor to contact the owner/engineer in the case of an unexpected discovery
Risk No. 15: Contractor Submitted Design Changes to Breaching Operation
As was seen during the Brown Bridge bidding and construction phase, the contractor can submit requested design changes to the proposed breaching operation plans. This is a risk as these design changes could overlook key items that were discussed and avoided during the initial design of the proposed breaching operation.

- **Risk Reduction Plan:**
  - Indicate in bid package and specifications that any contractor submitted design changes will require all designs to be reviewed by URS and follow the same protocols and processes followed for the initial URS breaching design.

Risk No. 16: Increase in Artesian Well Conditions from Excavation at the Toe of the Dam
During the geotechnical investigations conducted on the Boardman Dam, artesian well conditions were observed at the toe of the dam. These conditions occur in the same location as the proposed auxiliary spillway stilling basin. Any excavation of material in this location could result in sand boils and an increase in artesian flow, which could be connected to the hydrology of the impoundment. This could ultimately result in a weakening of the toe of the dam and could result in an unexpected dam failure.

- **Risk Reduction Plan:**
  - Construct the stilling basin at or above the current grade of the site
  - Visually monitor the area during and after the construction of the stilling basin specifically looking for boils in the soil or increased groundwater flow
  - Notify owner/engineer of any change in conditions at the toe of the dam during and after construction of spillway and stilling basin

Section Four: Summary
The risk assessment meeting for the Boardman Dam Breaching Operation identified and evaluated sixteen (16) potential risks to the dam breaching operations. Conclusions that were reached during the risk analysis include:

1. All sixteen (16) risks associated with the breaching operation and the dam removal project in general were evaluated and deemed to be possible and legitimate risks to the project.
2. Recommended Design Measures for Reduction of Risk
   - The recommended risk reduction measure for Risk No. 1, includes intake screening on bypass pumping operation. Without screening the pump pipes could become clogged by debris and result in decreased pumping capacity and inefficiencies in the operation.
   - The recommended risk reduction measure for Risk No. 2 is to design the initial top cut excavation of the dam to include 2 feet of freeboard above the 100-yr flood event instead of the 10-yr flood. This will allow an extra level of safety in the design.
   - The recommended risk reduction measure for Risk No. 6 is to provide conceptual repair measures for any instance where the core wall may be found to be damaged or deteriorated below the surface of the embankment in a critical area.
   - A recommended risk reduction measure for Risk No. 11, includes verifying the location of the historic stop log structure and comparing this to the planned location of the auxiliary spillway and river channel through the embankment. In conjunction with this,
if the location of the spillway conflicts with the location of the historic structure, the
design of the spillway will be modified.
• The recommended risk reduction measure for Risk No. 12, involves the active
stabilization of slopes identified to need extra stability in order to prevent excessive
sloughing of the banks.
• The recommended risk reduction measure for Risk No. 14 requires the creation of
scenario specific mitigation plans for any unknown infrastructure that may be
encountered within the concrete core wall and/or the earthen embankment.
• The recommended risk reduction measure for Risk No. 16, is to be mindful of the
artesian groundwater condition at the site of the proposed stilling basin and to reduce any
evacuation in that area. Therefore the stilling basin will be constructed at or above grade
so as to not increase the flow of the artesian water in that area.
• An additional recommended risk reduction measure requires 24-hr, on-site supervision
and lighting at the site to prevent pump failure and vandalism.

3. Recommended Monitoring Parameters:
• Daily observations of slopes with questionable stability (Risk Nos. 9 and 16)
• Daily observations for debris in the intake structures (Risk No. 1)
• Onsite water level monitoring equipment within the impoundment (Risk No. 2)
• Observation of core wall for deterioration as it is uncovered (Risk No. 6)
• Downstream monitoring of the river for turbidity during the breaching operation (Risk
No. 7)
• Slope stability monitoring where deemed applicable in the impoundment and upper
reaches of the river (Risk No. 12)
APPENDIX A – Existing Boardman Dam Design Drawings
APPENDIX B – Geotechnical Investigation
**MATERIAL DESCRIPTION**

- **Concrete**
  - Very loose, moist, brown medium to fine SAND (SP-SM) with silt, trace gravel [POSSIBLE FILL]
- **SAND**
  - Becomes loose, with dark gray organics, trace roots
  - Becomes tan, mostly fine SAND (SP) without gravel
  - Becomes loose, wet, medium to fine SAND (SP), without gravel
- **CLAY**
  - Becomes medium dense
  - Hard, moist, brown becoming gray, lean CLAY (CL), trace isolated coarse sand
- **SANDY CLAY**
  - Brown sandy lean clay
<table>
<thead>
<tr>
<th>Depth, feet</th>
<th>Elevation, feet</th>
<th>SAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>-605</td>
<td>SS-9</td>
</tr>
<tr>
<td>35.5</td>
<td>-600</td>
<td>SS-10</td>
</tr>
<tr>
<td>36.5</td>
<td>-595</td>
<td>SS-11</td>
</tr>
<tr>
<td>37</td>
<td>-590</td>
<td>SS-12</td>
</tr>
</tbody>
</table>

**MATERIAL DESCRIPTION**

- **Pocket Penetrometer (tsf)**
  - SS-9: 11, 13, 14, 18
  - SS-10: 8, 9, 12, 19
  - SS-11: 7, 13, 16, 19
  - SS-12: 7, 14, 18, 22

**REMARKS AND OTHER DETAILS**

- Becomes very stiff to hard, trace isolated gravel
- Becomes with interbedded sand seams up to 1-1/2"

---

**End of Boring at 50.5' bgs**

---

**Project:** Cass Rd. Bridge  
**Project Location:** Traverse City, Michigan  
**Project Number:** 13653531  
**Log of Boring:** B-07  
**Sheet:** 2 of 2
**Material Description**

- **SS-1**
  - Number: 3
  - Recovery: 75%
  - Description: 4” Sandy vegetative soil with organics, trace gravel

- **SS-2**
  - Number: 5
  - Recovery: 83%
  - Description: Medium dense, moist, coarse to fine SAND (SP to SP-SM), trace gravel

- **SS-3**
  - Number: 14
  - Recovery: 71%
  - Description: Medium dense, moist, dark gray and oxidation staining, coarse to fine SAND (SP to SP-SM), trace gravel

- **SS-4**
  - Number: 3
  - Recovery: 71%
  - Description: Becomes tan

- **SS-5**
  - Number: 4
  - Recovery: 79%
  - Description: Becomes moist to wet

- **SS-6**
  - Number: 3
  - Recovery: 71%
  - Description: Becomes wet, trace clay, trace gray staining

- **SS-7**
  - Number: 5
  - Recovery: 83%
  - Description: Medium dense, wet, brown and gray, sandy GRAVEL (GW to GW-GM)

- **SS-8**
  - Number: 6
  - Recovery: 54%
  - Description: Becomes gravelly

**Remarks and Other Details**

- Stickup rises to +2.8 ft
- Concrete
- Sand cuttings
- Bentonite chips
- Cuttings
- Schedule 40 PVC riser, 2” ID
- Hole collapse
- 6 bags #20-#30 sand
- 0.010” Slotted well screen
- Collapse/cuttings
### Material Description

**SS-9**
- Hard, moist, gray lean CLAY (CL) with silt and sand
- Becomes medium dense with gravel

**SS-10**
- Hard, moist, lean CLAY (CL) with interbedded silt laminae and fine sand laminae/seams
- Stiff to hard, moist, gray lean CLAY (CL) with interbedded silt laminae and fine sand laminae/seams

**SS-11**
- Medium dense to dense, wet, tan, POORLY GRADED SAND with SILT (SP-SM)
- Hard, moist, gray lean CLAY (CL) with interbedded silt laminae and fine sand laminae/seams
- Dense, wet, tan medium to fine SAND (SP) becomes very stiff, interbedded with medium dense, wet, tan, medium to fine SAND (SP), clay beds are 3” to 9” thick and spaced 6” to 12”

**SS-12**
- Hard, moist, gray lean CLAY (CL) with interbedded silt laminae and fine sand laminae/seams
- Becomes very stiff to hard

**SS-13**
- Very dense, wet, tan, medium to fine SAND (SP)

**SS-14**
- *Note: Information not clearly visible*

**SS-15**
- 2” lean CLAY (CL) seam

---

**Remarks and Other Details**

- Collapse/cuttings

---

**Well Details**

- PL=NP, LL=NP, PI=NP
- %G=0, %S=94, %M=6
- %C=0, %F=6

---

**Log of Boring/Well B-08**

**Project:** Cass Rd. Bridge  
**Project Location:** Traverse City, Michigan  
**Project Number:** 13653531  
**Report:** GEO_CR_WELL; File K:\PROJECTS\U\URS TRAVERSE CITY\13653531\DOCS\LOGS\GINT\BOARDMAN DAM_BORINGS.GPJ; 11/4/2014 12:40:11 PM
becomes dense, interbedded with hard, moist, gray lean CLAY (CL) with interbedded fine sand laminae and seams, and silt laminae

Dense, wet, gray SILT (ML), with fine sand laminae

End of Boring at 70’ bgs
Project: Cass Rd. Bridge
Project Location: Traverse City, Michigan
Project Number: 13653531

Log of Boring/Well
B-09
Sheet 1 of 2

Date(s) Drilled: 8/26/2014
Logged By: T. George
Checked By: 40.0 feet

Drilling Method: Hollow Stem Auger with Water Added
Drill Rig Type: Acker Renegade
Drill Bit Size/Type: 4-1/4" ID/ 8-1/2" OD HSA

Total Depth of Borehole: 40.0 feet
Surface Elevation: 616.9 ft above msl

Borehole Backfill: Well set, then abandoned due to artesian water
Sampling Method(s): Split Spoon

Groundwater Level(s): Encountered @ 1' bgs ATD. Water level rose to 1.8' above ground.

MATERIAL DESCRIPTION

<table>
<thead>
<tr>
<th>Depth, feet</th>
<th>Water Content, %</th>
<th>Well Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>616.9 Topsoil</td>
<td>97</td>
<td>Very loose, wet, brown with oxidation staining, coarse to fine SAND (SP-SM to SP), trace gravel, root fibers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>becomes with less oxidation staining, less root fibers</td>
</tr>
<tr>
<td>Medium dense, wet, gray and brown, sandy coarse GRAVEL (GW-GM) and sand, gravel diameter up to 1.5&quot;</td>
<td>69</td>
<td></td>
</tr>
<tr>
<td>Hard, moist, gray lean CLAY (CL)</td>
<td>94</td>
<td>Medium dense, moist to wet, tan fine SAND (SP), trace gravel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>becomes moist, coarse to fine sand</td>
</tr>
<tr>
<td>becomes moist, fine sand, no gravel</td>
<td>15.5</td>
<td>Hard, moist, gray, lean CLAY (CL), silt laminae, fine sand laminae</td>
</tr>
<tr>
<td>Medium dense, wet, tan POORLY GRADED SAND with SILT (SP-SM)</td>
<td>23.2</td>
<td></td>
</tr>
<tr>
<td>3rd Hard, lean clay (CL) with silt laminae</td>
<td>17.0</td>
<td>1&quot; Lean clay (CL)</td>
</tr>
</tbody>
</table>

REPORT AND OTHER DETAILS

Plugged well with bentonite chips
#20-#30 silica sand
Schedule 40 PVC riser, 2" ID
#20-#30 silica sand
0.010" Slotted well screen
Borehole collapse
<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Sampling Resis.</th>
<th>Blows/6” OR CORE RQD</th>
<th>Recovery, %</th>
<th>Pocket Penetrometer (kg)</th>
<th>Graphic Log</th>
<th>MATERIAL DESCRIPTION</th>
<th>Water Content</th>
<th>Well Details</th>
<th>REMARKS AND OTHER DETAILS</th>
</tr>
</thead>
<tbody>
<tr>
<td>585</td>
<td>35</td>
<td>SS-9</td>
<td>3</td>
<td>13</td>
<td>23</td>
<td>75</td>
<td></td>
<td></td>
<td>becomes dense</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>580</td>
<td>40</td>
<td>SS-10</td>
<td>3</td>
<td>16</td>
<td>22</td>
<td>63</td>
<td></td>
<td></td>
<td>becomes medium dense</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

End of Boring at 40’ bgs

Pocket Penetrometer (tsf)

Borehole collapse

2’ Lean clay (CL) with oxidation staining

End of Boring at 40’ bgs

Project: Cass Rd. Bridge
Project Location: Traverse City, Michigan
Project Number: 13653531

4" Topsoil

- Loose, moist, brown, WELL-GRADED SAND with SILT (SW-SM)
- becomes medium dense
- becomes trace gravel
- becomes with gravel
- becomes with sandstone fragments
- becomes dense, increasing silt content, some gravel

3' Stickup

Bentonite

Cuttings

Sand
### Material Description

<table>
<thead>
<tr>
<th>Elevation (feet)</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Sampling Res.</th>
<th>Blow/6&quot; OR CORE% ROD</th>
<th>Recovery, %</th>
<th>Pocket Penetrometer (ft)</th>
<th>Graphic Log</th>
<th>Water Content %</th>
<th>Well Details</th>
<th>Remarks and Other Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>625</td>
<td>35</td>
<td>SS-9</td>
<td>6</td>
<td>19</td>
<td>14</td>
<td>78</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Started to add water.</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>SS-9</td>
<td>14</td>
<td>18</td>
<td>25</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.010&quot; Slotted well screen</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>SS-11</td>
<td>7</td>
<td>12</td>
<td>20</td>
<td>94</td>
<td></td>
<td></td>
<td>PL=NP LL=NP PI=NP</td>
<td></td>
<td>%G=9 %S=81 %M=8 %C=2 %F=10</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>SS-12</td>
<td>4</td>
<td>5</td>
<td>15</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cuttings</td>
</tr>
<tr>
<td></td>
<td>55</td>
<td>SS-13</td>
<td>11</td>
<td>15</td>
<td>19</td>
<td>100</td>
<td>4.5+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>ST-1</td>
<td>5</td>
<td>5</td>
<td>9</td>
<td>56</td>
<td></td>
<td></td>
<td>PL=10 LL=16 PI=6</td>
<td></td>
<td>%G=6 %S=42 %M=36 %C=16 %F=52</td>
</tr>
<tr>
<td></td>
<td>65</td>
<td>SS-14</td>
<td>10</td>
<td>13</td>
<td>22</td>
<td>100</td>
<td>4.5+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Pocket Penetrometer (ft):**
- 607.7: Hard, moist to wet, gray SANDY SILTY CLAY (CL-ML)
- 607.7: Medium dense, wet, gray silty SAND (SM), trace gravel
- 594.0: Hard, moist, gray CLAY (CL-ML) with sand

**MATERIAL DESCRIPTION:**
- Becomes wet, less silt
- Becomes trace gravel
- Becomes medium dense, gray, trace wood fragments

**Log of Boring/Well
B-10**

**Sample Type:**
- SS-9
- SS-10
- SS-11
- SS-12
- SS-13
- ST-1
- SS-14
- SS-15
### Samples

<table>
<thead>
<tr>
<th>Type</th>
<th>Number</th>
<th>Sampling Reservoir</th>
<th>Recovery,</th>
<th>Pocket Penetrometer (lb)</th>
<th>Graphic Log</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST-2</td>
<td>46</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SS-16</td>
<td>20</td>
<td></td>
<td>67</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Material Description**

- **End of Boring at 70’ bgs**
- Shelby tube refusal at 66 feet; 11-inch recovery
- Cuttings

**Remarks and Other Details**

- Project Number: 13653531
- Project: Cass Rd. Bridge
- Project Location: Traverse City, Michigan
- Report: GEO_CR_WELL; File K:\PROJECTS\U\URS TRAVERSE CITY\13653531\DOCS\LOGS\GINT\BOARDMAN DAM_BORINGS.GPJ; 11/4/2014 12:40:15 PM

**Log of Boring/Well**

B-10

Sheet 3 of 3
**MATERIAL DESCRIPTION**

<table>
<thead>
<tr>
<th>Depth, ft</th>
<th>Recovery, %</th>
<th>Water Content, %</th>
<th>Remarks and Other Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>92</td>
<td>0.5</td>
<td>65°-68° Topsoil</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Medium dense, moist, brown silty SAND (SM), trace gravel</td>
</tr>
<tr>
<td>5</td>
<td>58</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Medium dense, moist, brown fine SAND (SP), trace gravel</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>becomes loose</td>
</tr>
<tr>
<td>10</td>
<td>79</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Medium dense, moist, brown silty SAND (SM), some gravel</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>becomes loose, light brown, trace gravel</td>
</tr>
<tr>
<td>15</td>
<td>41</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>becomes medium dense, trace sandstone fragments</td>
</tr>
<tr>
<td>20</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>becomes medium dense to dense, with sandstone fragments</td>
</tr>
<tr>
<td>25</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>becomes wet, trace gravel</td>
</tr>
<tr>
<td>Depth, feet</td>
<td>Recovery, %</td>
<td>Water Content, %</td>
<td>Remarks and Other Details</td>
</tr>
<tr>
<td>------------</td>
<td>-------------</td>
<td>------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>-620</td>
<td>61</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td>-620</td>
<td>61</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td>-625</td>
<td>56</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>-625</td>
<td>56</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>-615</td>
<td>56</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>-615</td>
<td>56</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>-610</td>
<td>50</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>-610</td>
<td>50</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>-605</td>
<td>50</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>-605</td>
<td>50</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>-600</td>
<td>83</td>
<td>83</td>
<td></td>
</tr>
<tr>
<td>-600</td>
<td>83</td>
<td>83</td>
<td></td>
</tr>
<tr>
<td>-595</td>
<td>39</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>-595</td>
<td>39</td>
<td>39</td>
<td></td>
</tr>
</tbody>
</table>

**MATERIAL DESCRIPTION**

- **Medium dense, wet, brown POORLY GRADED SAND with SILT and GRAVEL (SP-SM)**

- **Medium dense, wet, gray SILT (ML) with sand, some clay**

- **Medium stiff, wet, gray CLAY (CL-ML) with sand**

**Plastic Limit = NP, Liquid Limit = NP, Plasticity Index = NP**

- $\%G = 33$
- $\%S = 60$
- $\%M = 6$
- $\%C = 1$
- $F = 7$

**No recovery in Shelby tube**
Medium dense, wet, gray, fine SILTY SAND (SM), trace gravel, clay

REMARKS AND OTHER DETAILS

End of Boring at 70' bgs

PL=NP LL=NP PI=NP
%G=8 %S=74 %M=12
%C=6 %F=18
## GRAIN SIZE DISTRIBUTION

**Project:** Traverse City Cass Rd & Boardman Dam

**Location:**

**CTL Project Number:** 14050036CLE

### Specimen ID: B-08 SS-11, BOT

**Classification:** POORLY GRADED SAND with SILT (SP-SM)

<table>
<thead>
<tr>
<th>Specimen ID</th>
<th>Sample</th>
<th>Classification</th>
<th>%MC</th>
<th>LL</th>
<th>PL</th>
<th>PI</th>
<th>Cc</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-08</td>
<td>SS-11, BOT</td>
<td>POORLY GRADED SAND with SILT (SP-SM)</td>
<td>18</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
<td>1.06</td>
<td>2.52</td>
</tr>
</tbody>
</table>

### Specimen ID: B-08 SS-11, BOT

<table>
<thead>
<tr>
<th>D100</th>
<th>D60</th>
<th>D50</th>
<th>D30</th>
<th>D10</th>
<th>%Gravel</th>
<th>%Sand</th>
<th>%Silt</th>
<th>%Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.75</td>
<td>0.285</td>
<td>0.249</td>
<td>0.185</td>
<td>0.113</td>
<td>0</td>
<td>94</td>
<td>6</td>
<td>0</td>
</tr>
</tbody>
</table>

**Grafco Ltd.**

3085 Interstate Parkway
Brunswick, Ohio 44212

Telephone: 330-220-8900
Fax: 330-220-8944
Email: ctl@ctleng.com

**Grafco Ltd.**

3085 Interstate Parkway
Brunswick, Ohio 44212

Telephone: 330-220-8900
Fax: 330-220-8944
Email: ctl@ctleng.com

**Grafco Ltd.**

3085 Interstate Parkway
Brunswick, Ohio 44212

Telephone: 330-220-8900
Fax: 330-220-8944
Email: ctl@ctleng.com
Unconfined Compressive Strength
of Intact Rock Core Specimens (ASTM D 7012-04)

Rock Description: Concrete

Boring No.: V-2       Average Length: 5.205 in
Sample No.: NA         Average Diameter: 2.484 in
Depth (ft): 2.5'       Length to diameter ratio: 2.10
Moisture condition: As received  Cross Sectional Area: 4.844 in²

Rate of Loading: 120 lbs/sec  Failure Load: 33,800 lbs
Testing Time: 280 sec       Axial Strain at Failure: 0.005 in/ln
(Rate 2-15 minutes to failure) Stress: 6,978 psi

Unconfined Compression Test

Axial Strain, in/in

Before Testing

After Failure

REMARKS:
Unconfined Compressive Strength
of Intact Rock Core Specimens (ASTM D 7012-04)

Rock Description: Concrete

- Boring No.: V-2
- Sample No.: NA
- Depth (ft): 8.5'
- Moisture condition: As received

- Average Length: 5.063 in
- Average Diameter: 2.485 in
- Length to diameter ratio: 2.04
- Cross Sectional Area: 4.848 in²

- Rate of Loading: 120 lbs/sec
- Testing Time: 251 sec
  (Rate 2-15 minutes to failure)

- Failure Load: 30,098 lbs
- Axial Strain at Failure: 0.004 in/in
- Stress: 6,209 psi

Unconfined Compression Test

Before Testing

After Failure

REMARDS:
RESOURCE INTERNATIONAL, INC.  
Engineering Consultants

Unconfined Compressive Strength  
of Intact Rock Core Specimens (ASTM D 7012-04)

6350 Presidential Gateway  9885 Rockside Road  4480 Lake Forest Drive  
Columbus, OH 43231  Cleveland, OH 44125  Cincinnati, Ohio 45242  
Phone (614) 823-4949  Phone (216) 573-0955  Phone (513) 769-6998  
Project: Boardman Dam  Project No.: N-14-032  Date of Testing: 9/24/2015  
Test Performed by: E.M.

Rock Description: Concrete

Boring No.: V-2  Average Length: 5.135 in  
Sample No.: NA  Average Diameter: 2.487 in  
Depth (ft): 10.6'  Length to diameter ratio: 2.06  
Moisture condition: As received  Cross Sectional Area: 4.855 in²  
Rate of Loading: 120 lbs/sec  
Testing Time: 300 sec  
(Rate 2-15 minutes to failure)

Failure Load: 36,261 lbs  
Axial Strain at Failure: 0.0055 in/in  
Stress: 7,468 psi

Unconfined Compression Test

Before Testing

After Failure

REMARKS:
**Unconfined Compressive Strength of Intact Rock Core Specimens (ASTM D 7012-04)**

**Project:** Boardman Dam  
**Project No.:** N-14-032  
**Date of Testing:** 9/24/2015  
**Test Performed by:** E.M.

**Rock Description:** Concrete

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boring No.:</td>
<td>H-2</td>
</tr>
<tr>
<td>Sample No.:</td>
<td>NA</td>
</tr>
<tr>
<td>Depth (ft):</td>
<td>4.5’ from top</td>
</tr>
<tr>
<td>Moisture condition:</td>
<td>As received</td>
</tr>
<tr>
<td>Average Length:</td>
<td>7.699 in</td>
</tr>
<tr>
<td>Average Diameter:</td>
<td>3.743 in</td>
</tr>
<tr>
<td>Length to diameter ratio:</td>
<td>2.06</td>
</tr>
<tr>
<td>Cross Sectional Area:</td>
<td>10.998 in²</td>
</tr>
<tr>
<td>Rate of Loading:</td>
<td>120 lbs/sec</td>
</tr>
<tr>
<td>Testing Time:</td>
<td>420 sec</td>
</tr>
<tr>
<td>(Rate 2-15 minutes to failure)</td>
<td></td>
</tr>
</tbody>
</table>

**Failure Load:** 51,510 lbs  
**Axial Strain at Failure:** 0.0045 in/in  
**Stress:** 4,684 psi

**Remarks:**

**Unconfined Compression Test**

**Before Testing**

**After Failure**
URS Corporation  
1375 Euclid Avenue Suite 600  
Cleveland OH  44115  

Job No.:  B4-281-743  
Date:  10-14-14  
Cust. PO:  Verbal-Tom George

Description:  2 samples  1" Sq. Rebar

Spec:  ASTM A615

<table>
<thead>
<tr>
<th>ID#</th>
<th>Tensile, ksi</th>
<th>Yield, .2% ksi</th>
<th>Elong., % in 8'</th>
<th>Red. of Area, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>62.6</td>
<td>41.0</td>
<td>22</td>
<td>36</td>
</tr>
<tr>
<td>2</td>
<td>63.5</td>
<td>41.5</td>
<td>27</td>
<td>50</td>
</tr>
</tbody>
</table>

Test Method:  ASTM A370-13

Authorized Agent:  [Signature]

This Report May Not Be Reproduced Except In Full
This report represents Tensile Testing interpretation of the results obtained from the test and is not to be construed as a Guaranty or Warranty of the condition of the materials tested. Tensile Testing shall not be held liable for misinterpretation of conditions, loss, damage, injury or death arising from or attributable to delay preceding a test or subsequent to performance of a test.
SITE RECONNAISSANCE REPORT

This report summarizes URS’s site reconnaissance of the Boardman Dam and Keystone Pond shoreline on 10/25/2014 and 10/28/2014. It should be used with the general location map and photo log which are both attached.

On 10/25/2014, URS walked the south facing Boardman dam shoreline and the west shoreline (referred to herein as Area 1) approximately to a point approximately 1600-feet south of the NW corner of Boardman Dam. On 10/28/2014, URS walked the area northwest of the northwest corner of the dam, from the dam to the railroad tracks to Cass Road (Area 2). Additionally, a portion of the area located on the north side of Cass Road (Area 3) was also observed. Lastly the north side of the dam (Area 4) was inspected.

The areas were inspected for signs of instability, seepage, slope angle, and soil type when visible. Other observations were made that may better help understand lake mechanisms. Itemized observations at each of the four areas are listed below.

Area 1: South facing Boardman Dam shoreline and west shoreline approximately 0 to 1600-feet south of the NW corner of Boardman Dam

- Along the south face of the dam, slopes consisted of mostly sand with gravel and cobbles.
  - Near the upper portion of the slope, a folding rule was used to estimate slopes at 3 to 1. (Photo 1)
  - Near the lower portion of the slope angles, similarly, slope angles were measured at approximately 2 to 1. (Photo 2)
- Near the toe of the slope, several minor terraces were observed in the sand shoreline representing former higher lake levels. (Photo 3)
- Along the west shoreline at a distance of approximately 100-feet south of the NW corner of Boardman Dam, a bare sandy slope was observed at 29-33 degrees as measured with a Brunton Compass. Sand slides were easily mobilized by the weight of one’s foot on the slope surface. (Photo 4)
- Along the west shoreline at a distance of approximately 400-feet south of the NW corner of Boardman Dam, an elliptical culvert approximately 24-inches wide by 15-inches tall was
observed discharging water from a source above near the railroad tracks which were located to the west. The slope area surrounding the outfall was eroded and over steepened. (Photo 5)

- Along the west shoreline at a distance of approximately 600-1600-feet south of the NW corner of Boardman Dam, numerous seepage areas were observed and were concentrated within concave shaped shoreline areas. Some of the water was observed to emanate from an above source then fan out across the slope to the lake. (Photo 6)

- Clay seams were observed within this portion of slope and were visible at portions of the shoreline which protruded into the lake.
  - Also along this area, several terrace levels were observed several feet above the present water level indicating former higher lake levels. (Photo 7)

**Area 2: From northwest corner of Boardman Dam westward to Railroad track and northward to Cass Road**

- Upper portion of slopes along this area measured up to 34-degrees with Brunton compass. Large straight hardwood trees observed on slope in this area indicating stable soils when present. (Photo 8)

- Lower portions near toe measured up to 42-degrees. Outward-Tilting trees and slightly bent trees were observed indicating possible over-steepened conditions near the toe. (Photo 9)

- Seepage stream observed flowing southward. Source of seepage appeared to be from near side of railroad, underneath railroad or from opposite side of railroad. (Photo 10)
  - Peaty surficial soils observed near toe of railroad gravel embankment indicating possible seasonally wet and possibly ponded water conditions.

- Railroad embankment gravel slopes measured 38 to 40 degrees with Brunton compass. (Photo 11)

**Area 3: North of Cass Road near the south shoreline of the wetland ponded area formed by the Boardman River (Grand Traverse Natural Education Reserve)**

- On the north side of Cass Road near boring B-3 and near where the wetland area is close to Cass Road, slope creep was observed as evidenced by bent trees. Slope angles were measured at 35-degrees and indicate possible over steepened conditions. (Photo 12)

**Area 4: Boardman Dam north slope**

- The north slope of the Boardman Dam was grass covered and appeared stable. A bench was present midway down the slope where Boring B-8 was drilled. (Photo 13)

- No seepage zones were observed through the slope. Wetness at the toe may have been influenced by the adjacent wetland.
• While drilling at B-9 near the toe of slope, artesian water was encountered while setting a monitoring well. After the well was completed with a 2.55-ft stickup, approximately 2.5 gpm of water flowed out of the top of the casing. The water may have originated from beneath the dam. The well was abandoned immediately after setting by placing bentonite hole plug chips inside the well. Then on the following day the well was removed and bentonite chips were compacted with the drill rig augers into the borehole.

• Visible portions of the concrete cutoff wall and sheet wall on the west side of the concrete cutoff wall, both appeared in good condition. (Photo 14)
Figure 1. General location map of site reconnaissance areas.
<table>
<thead>
<tr>
<th>Photo No.</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8/25/14</td>
</tr>
<tr>
<td>2</td>
<td>08/25/14</td>
</tr>
</tbody>
</table>

**Client Name:**
The Grand Traverse Band of Ottawa and Chippewa Indians

**Site Location:**
Boardman Dam, Traverse City, Michigan

**Project No.:**
13653531
<table>
<thead>
<tr>
<th>Photo No.</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>08/25/14</td>
</tr>
<tr>
<td>4</td>
<td>08/28/14</td>
</tr>
<tr>
<td>Photo No.</td>
<td>Date</td>
</tr>
<tr>
<td>-----------</td>
<td>------------</td>
</tr>
<tr>
<td>5</td>
<td>08/25/14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Photo No.</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>08/25/14</td>
</tr>
<tr>
<td>Photo No.</td>
<td>Date</td>
</tr>
<tr>
<td>----------</td>
<td>------------</td>
</tr>
<tr>
<td>7</td>
<td>08/25/14</td>
</tr>
<tr>
<td>8</td>
<td>08/28/14</td>
</tr>
</tbody>
</table>

Client Name: The Grand Traverse Band of Ottawa and Chippewa Indians

Site Location: Boardman Dam, Traverse City, Michigan

Project No. 13653531
<table>
<thead>
<tr>
<th>Photo No.</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>08/28/14</td>
</tr>
<tr>
<td>10</td>
<td>08/28/14</td>
</tr>
<tr>
<td>Photo No.</td>
<td>Date</td>
</tr>
<tr>
<td>----------</td>
<td>------------</td>
</tr>
<tr>
<td>11</td>
<td>08/28/14</td>
</tr>
<tr>
<td>12</td>
<td>08/28/14</td>
</tr>
<tr>
<td>Photo No.</td>
<td>Date</td>
</tr>
<tr>
<td>----------</td>
<td>------------</td>
</tr>
<tr>
<td>13</td>
<td>08/28/14</td>
</tr>
<tr>
<td>14</td>
<td>08/28/14</td>
</tr>
<tr>
<td>Photo No.</td>
<td>Date</td>
</tr>
<tr>
<td>----------</td>
<td>-----------</td>
</tr>
<tr>
<td>1</td>
<td>08/25/14</td>
</tr>
<tr>
<td>2</td>
<td>08/25/14</td>
</tr>
<tr>
<td>Photo No.</td>
<td>Date</td>
</tr>
<tr>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>3</td>
<td>08/25/14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Photo No.</th>
<th>Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>08/25/14</td>
<td>View of Keystone pond and existing Boardman Dam, looking from south to north. Top of concrete core wall can be seen protruding from the earthen embankment in left portion of image.</td>
</tr>
<tr>
<td>Photo No.</td>
<td>Date</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>----------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>5</td>
<td>08/26/14</td>
<td>Drilling of soil boring B-07 adjacent to spillway, powerhouse, and intake structure. Intake structure is concrete structure behind drill rig. Powerhouse is brick building to the left of the drilling rig.</td>
</tr>
<tr>
<td>6</td>
<td>08/26/14</td>
<td>Existing hydroelectric powerhouse emptying to existing Boardman River channel.</td>
</tr>
<tr>
<td>Photo No.</td>
<td>Date</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>7</td>
<td>08/26/14</td>
<td>Existing spillway adjacent to hydroelectric powerhouse.</td>
</tr>
<tr>
<td>8</td>
<td>08/26/14</td>
<td>Well set at soil boring B-09 at base of downstream side of existing Boardman Dam embankment. Artesian water was encountered at this boring location, so well was abandoned and hole sealed.</td>
</tr>
<tr>
<td>Photo No.</td>
<td>Date</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>----------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>9</td>
<td>08/27/14</td>
<td>Location of boring B-09 after abandoning and sealing of well.</td>
</tr>
<tr>
<td>10</td>
<td>08/27/14</td>
<td>View of downstream side of existing Boardman Dam embankment, looking uphill from location of boring B-09. Pickup truck is at crest of embankment.</td>
</tr>
<tr>
<td>Photo No.</td>
<td>Date</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>11</td>
<td>08/28/14</td>
<td>View of downstream side of existing Boardman Dam embankment, looking downhill towards location of boring B-09, marked by stake with orange streamer.</td>
</tr>
<tr>
<td>12</td>
<td>08/28/14</td>
<td>View of downstream side of existing Boardman Dam embankment, looking downhill to the northeast from location of boring B-10.</td>
</tr>
</tbody>
</table>
SUMMARY OF EXCAVATION VOLUMES:

EXCAVATION REQUIRED TO LOWER
OVERALL DAM HEIGHT TO ELEVATION 845.0
8,954 CUBIC YARDS

EXCAVATION REQUIRED FOR SPILLWAY
CHANNEL TO ELEVATION 523.0
13,150 CUBIC YARDS
SUMMARY OF EXCAVATION VOLUMES

EXCAVATION REQUIRED FOR NEW RIVER CHANNEL THROUGH DAM SWIRL CUBIC YARDS