Houston Engineering Inc.

Fargo, ND | HEI No. 8675_001
March 9, 2017

PELICAN RIVER DAM ROCK MASONRY WALL FAILURE ASSESSMENT REPORT

Pelican Rapids, Minnesota

PELICAN RIVER DAM ROCK MASONRY WALL FAILURE ASSESSMENT REPORT

Pelican Rapids, Minnesota

March 9, 2017

Prepared for:
City of Pelican Rapids and Minnesota Department of Natural Resources – Dam Safety Division

Prepared by:
Houston Engineering, Inc.

HoustonEngineering Inc.

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision, and that I am duly Licensed Engineer under the laws of the State of Minnesota.

Houston Engineering, Inc.
1401 21st Ave. N
Fargo, ND 58102
Phone # 701.237.5065

Rick R. St. Germain

Rick R. St. Germain
MN #24613

3/9/17

Date

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1 INTRODUCTION

The purpose of this report is to provide the City of Pelican Rapids with an assessment of a collapsed stone masonry wall at the Pelican Rapids Dam and a plan for its rehabilitation. The scope of the study included a review of available information in addition to soil borings and piezometers to investigate any potential issues with stability or seepage. Plans with cost estimates to fix any deficiencies would be included. The work was partially funded by a grant from the Minnesota Department of Natural Resources (DNR) Dam Safety Division. The scope of work did not include an assessment of the concrete spillway or powerhouse.

2 DATA REVIEW AND FINDINGS

Masonry Rock Wall

Documents were collected to determine the history of the dam and the reason for failure of the masonry rock wall. The documents included the Final Construction Report prepared by Widseth, Smith, Nolting & Associates Inc. dated June 28, 1989. Much of the early history of the dam was gathered from this report and is summarized below.

The dam was initially constructed in the 1880s to provide waterpower for a sawmill and was later modified to power a grain mill. The dam was constructed of a timber crib and earth. In the early 1900s, the dam was raised and a rock wall was constructed on the downstream side. A timber sluiceway and spillway were also constructed during that period. In 1914-1915, the dam was raised again with “compacted local material;” a new grain mill was constructed downstream of the old one; and the timber sluiceway and spillway were replaced with concrete structures.

Fire subsequently destroyed the grain mill and in 1924, a concrete powerhouse with hydroelectric turbines was constructed at the end of the concrete sluiceway. During the 1930s, the hydroelectric turbines were scrapped out and the reservoir was drained. In 1957, the dam was repaired sufficiently to restore the reservoir.

During the period of 1987 to 1988, the dam underwent major structural rehabilitation to repair deficiencies and increase hydraulic capacity. The rehabilitation included: 1) driving sheet pile cutoff walls to refusal in dense glacial till along the axis of the dam; 2) repair and replacement of the existing spillway stoplogs with a sluicegate; 3) repair a cavity in the spillway floor; 4) resurfacing a portion of the spillway for aesthetics; 5) extending the downstream footing of the spillway; 6) addition of footings under a portion of the rock masonry wall; 7) grouting of the rock masonry wall; and 8) placement shoreline protection.

The first observance of a problem with the rock wall was a significant bulge noted on September 7, 2005, by the DNR. Recommendation at the time was for the City to monitor the bulge for movement. No records of any measurements could be found from either the City or DNR. The pictures in the dam inspection reports show the best evidence of the progression of the bulge and ultimate failure. The DNR Dam Safety

Division typically inspects the dam on an annual basis. The more recent inspection reports that address the rock wall are included in **Appendix B**.

The original plans for the dam and rock wall were not found. Some information was found in the record drawings dated June 28, 1989 for the 1987/1988 rehabilitation project. The rock wall was referenced in the chapter of the report describing changes that were made during construction. The report states "Dewatering the downstream face of the dam revealed that rock walls were without foundations. They were excavated in sections and filled with concrete." No details showing the dimensions and extent of the work were found. The pictures shown in **Appendix A** were taken from the construction report. The captions were also taken verbatim.

The forensic evidence shows that the wall does not meet common design practices. Retaining walls are typically built with a substantial foundation and reinforcement in the vertical portion of the wall to resist tension forces. The records of the 1987/1988 rehabilitation show that the rock wall did not have a foundation of any kind and that the rock wall did not have any sort of steel or concrete components that would provide resistance to tension forces. The grouted rock wall would provide little resistance to tension and would be very susceptible to cracking and failure. Another feature of retaining walls that is absent from this rock wall is a feature for drainage of water that would accumulate behind the wall. Typically, coarse aggregate, piping, and seep holes in the structure would be found in modern retaining walls. None of these features were included in the rock wall. Whether the intention of the rock wall was to be a structural component of the dam is unclear but it certainly would not meet today's design standards. It is pure speculation but perhaps the wall was constructed for aesthetic purposes.

It is likely the rock wall eventually failed due to soil and groundwater pressures and inadequate design.

Seepage

Part of the scope of work included an investigation into seepage that has been observed at the downstream toe of the dam north of the spillway. It's apparent from the design of the 1987/1988 rehabilitation that part of the purpose was to control seepage. A sheet pile/concrete wall was added to the upstream side of the dam. The sheet pile was driven to refusal in the dense glacial till underlying the site at an elevation estimated to be 1280. This is roughly 10 feet below the bottom of the downstream channel. One would reasonably assume that a sheet pile and concrete wall driven to refusal would alleviate any seepage showing at the ground surface. This was not the case. The 1989 Final Construction Report contains a letter from the design engineer to the City of Pelican Rapids summarizing comments from a DNR inspection done after the project was completed. The letter contains a paragraph documenting the existence of seepage after the construction. The paragraph reads:

> "The existing seepage…shall be confined and monitored: The water flow was not affected by the major rehabilitation of the dam. Removal of rocks indicates the flow comes from the north, the direction of the parking lot. The flow ceased when the dam was emptied during construction and when the dam was refilled, the initial flows were red with iron oxides." Therefore, the flow is

suspected to be an intercept drain to control ground water levels under the parking lot. The flow rate must be monitored."

Subsequent inspection reports by the DNR contain a common theme. The theme is that seepage was present and should be monitored. The most recent reports are included in **Appendix B** for more detailed description of the seepage.

It should be noted that seepage in dams is common, dams are typically designed to control and not eliminate seepage. Problems can occur if the seepage is excessive and soils are carried away with the water. This can lead to piping, increasing flow rates, erosion and ultimate failure of the dam. The evidence in this case shows that seepage downstream of the dam has existed since it was built. There has been no evidence of soils being suspended in the seepage. The rate of seepage has not been quantitatively measured but from pictures and observations it does not appear that the seepage has gotten worse over the years.

A geotechnical investigation of the potential for excessive seepage was done as part of the scope of work for this study. The results of this investigation can be found in the report by Braun Intertec in **Appendix C**.

The conclusion reached from the investigation is that seepage exists but the dam is not in danger of failing given the current conditions. Most importantly, the seepage should be monitored.

3 RECOMMENDATIONS

Review of the historic data and observations at the site show that the masonry rock wall is not adequately designed to ensure long-term stability. For this reason, it is our recommendation that it be removed and replaced with a system designed for stability. Two alternatives were looked at. The design criteria were the same for both alternatives. The main design criteria for the improvement is that number one, the dam embankment must be stable. Secondly, the improvement must be aesthetically pleasing. The site is a recreation area and landmark that is important to the City and its visitors.

Alternative 1 – Gravity Block Wall

Alternative 1 consists of a gravity block retaining wall. This alternative was chosen because the end result would look very similar to the original rock wall. The difference between the gravity block wall versus the masonry rock wall is that the gravity block wall is designed for long-term stability. A set of preliminary plans is included in **Appendix D** as a separate document. It should be made clear that the design of improvements to old structures such as the Pelican River Dam is often a dynamic process with unknowns that may be found once removal of the old features begins. Changes in design are common, along with the cost of construction. In this case, we believe we have taken a conservative approach and have assumed that the foundation for the rock wall that was constructed in the 1987/1988 rehab would not be salvaged and would need to be removed and reconstructed. Very little is known on the dimensions and lineal extent the constructed foundation. The only evidence of its existence was found in the pictures in the 1989 Final Construction Report. The new foundation would consist of concrete slurry poured between two sets of sheet piling. Details of the design can be seen on Sheets 4 and 5 of **Appendix D**. The concrete would be below frost depth and would be resistant to frost heaving. An advantage of this design is the sheet pile would serve as the forms for the concrete foundation and the work could be done in the

presence of groundwater. Another advantage is it would minimize the depth to which existing embankment materials would need to be removed.

Alternative 2 – Riprap Extension of the Downstream Toe

The second alternative is a much simpler design and is shown in Sheets 11 through 16 of the **Appendix D**. The design concept is that the existing rock masonry wall and the decorative landscaping walls above it would be removed to such an extent the rock riprap design section could be placed on the downstream side of the dam. This alternative would not require complete removal of the walls and concrete foundation. The riprap used in this design would not be the round field stone type but would be a crushed type which provides more stability and steeper slopes to minimize the volume and area required. This design may be a drawback to some in that the appearance of the dam will be changed substantially. Landscaping walls and plantings would not exist on the downstream face of the dam. There is an advantage in that maintenance would be minimal and the extension of the downstream toe of the dam would provide additional protection from seepage.

4 OPINION OF PROBABLE COSTS

The preliminary plans for both alternatives were used to develop quantities of materials needed for the construction. These quantities were used with unit pricing to develop the cost estimates shown in Table 1 and Table 2. Let it be known that this type of work is relatively specialized and the extent of the work could either increase or decrease depending on what is found once the removals begin. The estimated costs are subject to changes during the bidding and construction phases. We are confident that the level of detail we have provided is appropriate for budgeting and planning.

The estimated cost of the gravity block wall (Alternative 1) is $638,000.
The estimated cost of the riprap toe (Alternative 2) is $429,500.

Table 1: Alternative 1 – Gravity Block Retaining Wall Opinion of Probable Cost

Item No.	Description	Unit	Quantity	Unit Price	Amount
1	Mobilization	Lump Sum	1	$60,000	$60,000
2	Construction Entrance	Lump Sum	1	$5,100	$5,100
3	Water Control	Lump Sum	1	$8,000	$8,000
4	Temporary Shoring	Lump Sum	1	$2,300	$2,300
5	Remove Paver Sidewalk	Sq. Ft.	1,050	$4.50	$4,725
6	Remove Flowerbed	Lump Sum	1	$3,600	$3,600
7	Remove and Salvage Sign	Lump Sum	1	$450	$450
8	Remove and Salvage Flagpole	Lump Sum	1	$450	$450
9	Remove Metal Railing	Lin. Ft.	120	$14	$1,680
10	Remove Landscaping wall	Sq. Ft.	315	$6	$1,890
11	Remove Rock Wall	Sq. Ft.	1,000	$5	$5,000
12	Remove Rock Wall Foundation	Lin. Ft.	210	$26	$5,460
13	Common Excavation	Cu. Yd.	955	$23	$21,965
14	Sheet Piling	Sq. Ft.	2,775	$40	$111,000
15	Concrete Footing	Cu. Yd.	94	$500	$47,000
16	Modular Retaining Wall	Sq. Ft.	1,170	$90	$105,300
17	Select Granular Backfill - MN Class ___	Cu. Yd.	510	$20	$10,200
18	Clay	Cu. Yd.	35	$125	$4,375
19	Topsoil	Cu. Yd.	35	$130	$ 4,550
20	Install Sod	Sq. Yd.	1,200.00	$6	$ 7,200
21	Install Metal Railing	Lin. Ft.	135	$22	$2,970
22	Install Paver Sidewalk	Sq. Ft.	1,050	$21	$22,050
23	Install Salvaged Sign	Lump Sum	1	$1,100	$1,100
24	Install Salvaged Flagpole	Lump Sum	1	$4,100	$4,100
25	Construct Flowerbed	Lump Sum	1	$2,700	$2,700
				Construction Total	$443,165
	Contingencies (20%)				$ 88,633
	Bid Documents and Contractor Procurement				$15,000
	Construction Management				$76,000
	Permitting				$10,000
	Administration				$5,000
				Alternative 1 Total	$637,798

Table 2: Alternative 2 – Rock Riprap Opinion of Probable Cost

Item No.	Description	Unit	Quantity	Unit Price	Amount
1	Mobilization	Lump Sum	1	$60,000	$60,000
2	Construction Entrance	Lump Sum	1	$5,100	$5,100
3	Water Control	Lump Sum	1	$8,000	$8,000
4	Remove Paver Sidewalk	Sq. Ft.	1,050	$4.50	$4,725
5	Remove Flowerbed	Lump Sum	1	$3,600	$3,600
6	Remove and Salvage Sign	Lump Sum	1	$450	$450
7	Remove and Salvage Flagpole	Lump Sum	1	$450	$450
8	Remove Metal Railing	Lin. Ft.	120	$14	$1,680
9	Remove Landscaping wall	Sq. Ft.	315	$6.00	$1,890
10	Remove Rock Wall	Sq. Ft.	1,000	$5	$5,000
11	Common Excavation	Cu. Yd.	450	$23	$10,350
12	Geotextile Fabric - MNDOT Type VII	Sq. Yd.	700	$9	$6,300
13	Riprap - MN Class V	Cu. Yd.	1,450	$95	$137,750
14	Install Metal Railing	Lin. Ft.	135	$22	$2,970
15	Install Paver Sidewalk	Sq. Ft.	1,050	$21	$22,050
16	Install Salvaged Sign	Lump Sum	1	$1,100	$1,100
17	Install Salvaged Flagpole	Lump Sum	1	$4,100	$4,100
18	Install Sod	Sq. Yd.	1,200	$6	$7,200
19	Construct Flowerbed	Lump Sum	1	$2,700	$2,700
				Construction Total	$285,415
	Contingencies (20%)				$57,083
	Bid Documents and Contractor Procurement				$15,000
	Construction Management				$57,000
	Permitting				$10,000
	Administration				$5,000
				Alternative 2 Total	$429,498

5 CONSIDERATIONS FOR MOVING FORWARD/NEXT STEPS

It is my recommendation that after review and acceptance of this report that the City provide the DNR a copy for their reference.

I would also recommend that the City open a dialogue with the DNR to develop a plan to fund the improvements to the Pelican River Dam. It is our understanding that the State of Minnesota routinely funds 50% of the costs but would need approval from the state legislature. The dam is not in imminent danger of breaching, but the wall will likely continue to deteriorate and be a hazard to pedestrians. In my opinion, the biggest incentive to get the dam repaired is to regain its function as an attraction for the public.

6 ADDITIONAL COMMENTS

It should be noted that the scope of this study was narrowly defined to the repair of the rock wall. It was observed during our observations that some of the concrete components of the spillway are showing extreme deterioration and should be evaluated for soundness and remaining years of life. Before proceeding with the repair of the rock wall, the City may want a more holistic look at all the dam components before making a substantial investment.

Lastly, the DNR is quite interested in talking to the City regarding removal of the Pelican River Dam, and it would be remiss not to mention this alternative in this report. One of the benefits of this alternative is the 50% cost sharing that the State expects from the City on the other alternatives could be waived.

APPENDIX A

1989 Construction Report Photographs

This photograph shows the lack of foundation under the rock wall on the downstream end of the dam. This was excavated, one short distance at a time, and a footing was put in place.

The footing area being formed up under the rock wall.

The footing area is being filled. This footing was put in place under the rock wall for obvious reasons and was done in sections

The grout on the old rocks had severely degraded and lost its ability to bond. The old grout was air hammered out, the rock was sandblasted, and new grout was added.

This photograph shows the downstream end of the dam prior to letting water come back into the dam but after the rock walls were re-grouted and after the new foundation for the downstream end of the spillway was put in place.

APPENDIX B

DNR Dam Inspection Reports

Minnesota Department of Natural Resources
500 Lafayette Road • St. Paul, MN • 55155-40_

January 31, 2017

Mr. Don Solga
Pelican Rapids City Administrator
Pelican Rapids City Hall
PO Box 350
Pelican Rapids, MN 56572

RE: Pelican Rapids Dam, NID00190, Otter Tail County

Dear Mr. Solga;

Engineers from DNR Dam Safety inspected the Pelican Rapids Dam on 5/11/2016. Such inspections are conducted on a regular basis as required by Minnesota Rules. Due to it's "High Hazard" Classification, the Pelican Rapids Dam is inspected annually.

Over the past several years, Dam Safety has been concerned about the stability of the right retaining wall. During our May inspection, we noted that the wall continued to stand though the displacement in the stones appeared to be significant. Approximately two months later, during the night of July 11/12, the wall failed. However, the failure was primarily the masonry rock wall and much of the dam embankment remained intact. On August 10, 2016, MNDNR Dam Safety Funds were authorized for the design of the repair of the dam. It is unknown if the design has been completed as of this date. Please update us on the current status of this project.

In addition to the masonry rock wall, MNDNR Dam Safety noted that the downstream concrete spillway continues to deteriorate. The left downstream portions of the concrete spillway near the end of the concrete appears to be separating from the left masonry rock wall and a large crack with approximately 1 inch of separation has formed at the end of the spillway wall. Exposed rebar and a significant loss of concrete was noted in the left spillway concrete wall. The bed of the spillway was obscured by high velocity flows.

The concrete in the downstream right wall is crumbling and numerous small cracks were noted in the concrete. A slight separation and displacement of the concrete spillway abutment was noted in the right spillway.

MNDNR Dam Safety recommends the City of Pelican Rapids consult with their City Engineer for recommendations on repairing the spillway portion of the dam.

Dam Safety did not inspect the power house, conduits or the operation of the two lift gates, though we note the lift gates were actively controlling the pond elevation and outflow. MNDNR Dam Safety will perform its annual inspection of the dam in Spring, 2017.

If you have any questions, please feel free to contact me (651)-259-5663.

Sincerely,
DNR - Division of Ecological and Water Resources

Dana Dostert, P.E., P.G.
Senior Engineer - Dam Safety

ec: Jason Boyle, Minnesota State Dam Safety Engineer
Barry Stratton, EWR South District Manager
Emily Siira, MNDNR Area Hydrologist

Minnesota Department of Natural Resources
500 Lafayette Road • St. Paul, MN • 55155-40_

September 15, 2014

Mr. Don Solga
Pelican Rapids City Administrator
Pelican Rapids City Hall
PO Box 350
Pelican Rapids, MN 56572

RE: Pelican Rapids Dam, NID MN00190, Otter Tail County

Dear Mr. Solga;

Engineers from MNDNR Dam Safety inspected the Pelican Rapids Dam on August 22, 2014. Such Inspections are conducted on a regular basis as required by Minnesota Rules. "High Hazard" Dams, such as Pelican Rapids, are normally inspected annually.

On the day of the site visit, water levels in both the reservoir and the tailwater pool were much higher than normal. Water marks on the masonry rock wall indicate that tailwater levels had recently been approximately 6 to 12 inches higher. It was also noted that the lift gates were in the fully lowered (open) position.

The Dam Safety Unit found the Pelican Rapids dam to be in poor condition. The condition of the dam continues to degrade from what had been noted in past inspections.

A small void has begun to form behind the masonry rock wall, indicating the piping is occurring within the dam and that both water and soil are moving. We noted in past inspections that there is a known seepage exit point near the base of the masonry wall near the fence post. This area is approximately 10 to 12 feet below the location where the void is forming. Additional seepage exit points were noted at the base of the masonry rock wall in past years inspections, but these seepage points were obscured by high tailwater levels during our recent site visit.

The area of seepage in the grass on the lower right side of the dam, near the pelican, had visible seepage flowing. This area of seepage has been ongoing since at least 2000, and probably dates back to when the dam when rebuilt in the 1980's. The close proximity of this seepage point to the dam suggests that it may be seepage through the dam, but it is also possible that at least some of the seepage at this location is groundwater flowing from the high ground to the north and exiting near the river channel.

The cracks in the masonry rock wall continues to grow in size and noticeable shifting and displacement of individual stones was noted.

Dam Safety notes that a failure of the masonry rock wall may not result in a failure of the Pelican Rapids Dam due to the large concrete walls on the upstream side of the dam. However, if there was a large loss of soils with a failure of the masonry rock wall, the possibility exists that the upstream concrete walls could shift and potentially displace, resulting in a release of waters from the reservoir.

Dam Safety further noted that the concrete spillway remains in poor condition. Much of the concrete veneer on the spillway has broken away from the old concrete resulting in exposed rebar. The underlying concrete appears to be aged and additional spalls and cracks were noted.

No evidence of any shifting or movement was noted on the upstream components of the dam.

Dam Safety did not inspect the power house, conduits or the operation of the two lift gates, though we have noted in past inspections that the lift gates are actively adjusted to control water levels in the reservoir. We further note that the power house conduits may be used to lower water levels in the reservoir, if needed.

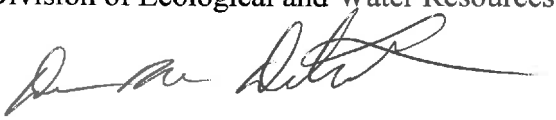
RECOMMENDATIONS:

1. Dam Safety recommends that the city continue to monitor the masonry wall weekly during normal flow conditions and daily during high water events.
2. We further recommend that the City of Pelican Rapids develop a plan in the next 90 days to repair and/or replace the masonry rock wall. We believe that a repair or replacement of this rock wall will be more cost effective than dealing with a wall or dam failure.
3. We further recommend that the city consult with an engineer specializing in concrete dams about the condition of the concrete spillway.

In June 2013, the U.S. Army Corps of Engineers was contacted to perform an inspection of the Pelican Rapids Dam. If that inspection was undertaken, please forward to DNR Dam Safety the results of that inspection. If that inspection was not undertaken, please also inform us to that affect.

If you have any questions or comments, please feel free to contact Jason Boyle at (651)-259-5715 or myself at (651)-259-5663. Dam Safety will inspect the dam again in 2015.

Sincerely,
Division of Ecological and Water Resources



Dana Dostert PE, PG
Senior Engineer - Dam Safety

ec: Jason Boyle, Minnesota Dam Safety Engineer
Julie Aadland, MNDNR Area Hydrologist
Barry Stratton, South District Manager

Photo 1 (8/22/2014) - Showing right downstream masonry rock wall. Location of void is below the red arrow. Seepage outlets at the base of the wall near the fence post and to the right.
Photo 2 (08/22/2014) - Close up of void forming behind masonry rock wall.

Minnesota Department of Natural Resources
500 Lafayette Road • St. Paul, MN • 55155-40_

Minnesota
DEPARTMENT OF NATURAL RESOURCES

Mr. Don Solga
Pelican Rapids City Administrator
Pelican Rapids City Hall
PO Box 350
Pelican Rapids, MN 56572

July 23, 2013

RE: Pelican Rapids Dam, NID00190, Otter Tail County

Dear Mr. Solga;

Engineers from DNR Dam Safety inspected the Pelican Rapids Dam on 6/13/2013. Such inspections a conducted on a regular basis as required by Minnesota Rules. Due to it's "High Hazard" Classification, the Pelican Rapids Dam is inspected annually.

The Dam Safety Unit found the Pelican Rapids Dam to be in fair condition. The condition of the dam has not changed significantly from what was noted in past inspections. On the date of the site visit, water levels in the pond were higher than normal and the lift gates were fully lowered. Seepage, which has been an ongoing concern, was observed from underneath the dam below the embankment, and in the rock retaining wall.

In general, cracks in the concrete rock wall appear to have gotten slightly larger, and there appears to be more separation than what was noted last year. The middle portion of the right rock retaining wall continues to show evidence of ongoing movement and displacement, though without instrumentation, it is difficult to determine a rate or the total amount of movement. The overall condition of the lower rock wall remains a concern.

Dam Safety did not inspect the power house, conduits or the operation of the two lift gates, though we note the lift gates were actively controlling the pond elevation and outflow.

Dam Safety recommends that the city continue monitoring the concrete rock wall weekly during normal flow conditions and daily during high water events for changes is seepage rates, and additional cracking and displacement in the concrete rock wall.

If any changes are observed in the Pelican Rapids Dam, or if you have any questions, please feel free to contact me (651)-259-5663. Dam Safety will inspect the Pelican Rapids Dam again in 2013.

Sincerely,
DNR - Division of Waters

Dana Dostert, P.E., P.G.
Senior Engineer - Dam Safety

ec: Jason Boyle, Minnesota State Dam Safety Engineer

Photo 1 - (6/13/2013) Seepage in the embankment below the right downstream rock wall.

Photo 2 - (6/13/2013) Seepage flowing out of the right downstream rock retaining wall.

Minnesota Department of Natural Resources

January 3, 2012

Mr. Don Solga
Pelican Rapids City Administrator
Pelican Rapids City Hall
PO Box 350
Pelican Rapids, MN 56572

RE: Pelican Rapids Dam, NID00190, Otter Tail County

Dear Mr. Solga;

Engineers from DNR Dam Safety inspected the Pelican Rapids Dam on 6/22/2011. Such inspections a conducted on a regular basis as required by Minnesota Rules. Due to it's High Hazard Classification, the Pelican Rapids Dam is inspected annually.

The Dam Safety Unit found the Pelican Rapids Dam to be in fair condition. The condition of the dam, including seepage, has not changed significantly from what was noted in the past two inspections. In general, cracks in the masonry rock wall and the concrete structure appear to be slightly larger than noted last year. Concrete spalling is an ongoing problem. The middle brick retaining wall continues to show evidence of ongoing movement and displacement, though without instrumentation, it is difficult to determine a rate of movement. The overall condition of the lower masonry rock wall remains a concern.

Dam Safety did not inspect the power house, conduits or the operation of the two lift gates. It was noted that water levels were high on the date of the site visit, and the lift gates were in the fully lowered (open) position.

Dam Safety recommends that the city continue monitoring the masonry rock wall weekly during normal flow conditions and daily during high water events for changes is seepage rates, and additional cracking and displacement in the masonry wall.

If any changes are observed in the Pelican Rapids Dam, or if you have any questions, please feel free to contact me (651)-259-5663. Dam Safety will inspect the Pelican Rapids Dam again in 2012.

Sincerely,
DNR - Division of Waters

Dana Dostert, P.E., P.G.
Senior Engineer - Dam Safety

ec: Peter Buesseler, DNR Regional Manager
Julie Aadland, DNR Area Hydrologist
Jason Boyle, Minnesota State Dam Safety Engineer

Photo 1 (4/18/2007) - showing the middle brick retaining wall and the lower rock masonry wall. Note the straight condition of the wall. This photo was taken approximately 8 months after complection.

Photo 2 (9/5/2010) - showing the middle brick retaining wall and the lower rock masonry wall. Note the change from the original condition shown in photo 1.

Photo 3 (6/22/2011) - showing the middle rock retaining wall and the lower rock masonry wall.

Photo 4 (6/22/2011) - seepage flowing on downstream right side of dam. Additional seeps below the dam were obscured by high tailwater.

Photo 5 (6/22/2011) - Cracking around boulders. Note water flowing out of cracks and onto the boulders.

Photo 6 (6/22/2011) - Cracks and displacement in the masonry rock wall.

Minnesota Department of Natural Resources
500 Lafayette Road • St. Paul, MN • 55155-40_

April 20, 2012

Mr. Don Solga
Pelican Rapids City Administrator
Pelican Rapids City Hall
PO Box 350
Pelican Rapids, MN 56572

RE: Pelican Rapids Dam, NID00190, Otter Tail County

Dear Mr. Solga;

Engineers from DNR Dam Safety inspected the Pelican Rapids Dam on 4/13/2012. Such inspections a conducted on a regular basis as required by Minnesota Rules. Due to it's "High Hazard" Classification, the Pelican Rapids Dam is inspected annually.

The Dam Safety Unit found the Pelican Rapids Dam to be in fair condition. The condition of the dam has not changed significantly from what was noted in past inspections. In general, cracks in the concrete rock wall appear to be slightly larger, and appear to have more separation than what was noted last year. The middle portion of the right rock retaining wall continues to show evidence of ongoing movement and displacement, though without instrumentation, it is difficult to determine a rate or total amount of movement. The overall condition of the lower rock wall remains a concern.

Dam Safety did not inspect the power house, conduits or the operation of the two lift gates, though we note the lift gates were actively controlling the pond elevation and outflow. Water levels in the pond and flowing over the dam were significantly less than what is normal for April, reflecting the current dry conditions in the state. The seepage that is normally noted at the base of the right rock wall was not noted, most likely due to the lower water levels in the pond.

Dam Safety recommends that the city continue monitoring the concrete rock wall weekly during normal flow conditions and daily during high water events for changes is seepage rates, and additional cracking and displacement in the concrete rock wall.

If any changes are observed in the Pelican Rapids Dam, or if you have any questions, please feel free to contact me (651)-259-5663. Dam Safety will inspect the Pelican Rapids Dam again in 2013.

Sincerely,
DNR - Division of Waters

Dana Dostert, P.E., P.G.
Senior Engineer - Dam Safety

ec: Peter Buesseler, DNR Regional Manager
Julie Aadland, DNR Area Hydrologist
Jason Boyle, Minnesota State Dam Safety Engineer

Minnesota Department of Natural Resources
500 Lafayette Road • St. Paul, MN • 55155-40

Minnesota
DEPARTMENT OF
NATURAL RESOURCES

Mr. Don Solga
Pelican Rapids City Administrator
Pelican Rapids City Hall
PO Box 350
Pelican Rapids, MN 56572

June 2, 2010

RE: Pelican Rapids Dam, Otter Tail County, (NID MN00190)

Dear Mr. Solga:

The Minnesota DNR - Dam Safety Unit, inspected the Pelican Rapids Dam on May 5, 2010. Such inspections are conducted on a regular basis as required by state regulations.

The Dam Safety Unit found the Pelican Rapids Dam to be in fair condition. The condition of the dam, including seepage, has not changed significantly from what was noted in 2009. In general, cracks in the masonry wall and the concrete structure appear to be slightly larger than noted in 2009. Concrete spalling is an ongoing problem. We did not inspect the power house, conduits or the operation of the two lift gates. It was noted that water levels were high and the lift gates were in the fully lowered position.

I have included on the following page four photographs from the past four years showing the changes in the small retaining wall located above the masonry rock wall. DNR-Dam Safety has been monitoring the movement in this wall as we believe it also reflects the movement in the lower masonry wall, though we expect the total displacement in the brick wall to less than that of the masonry rock wall.

Dam Safety recommends that the city continue monitoring the masonry rock wall weekly during normal flow conditions and daily during high water events for continued seepage, and cracking and displacement in the masonry wall.

If any changes are observed in the Pelican Rapids Dam, or if you have any questions, please feel free to contact me (651)-259-5663. Dam Safety will inspect the Pelican Rapids Dam again in 2011.

Sincerely,
DNR - Division of Waters

Dana Dostert, P.E., P.G.
Dam Safety Engineer

CC: Dave Leuthe., DNR Technical Resources Section Administrator
Bob Bezek, DNR Regional Hydrologist
Terry Lejcher, DNR Area Hydrologist
Jason Boyle, P.E., Minnesota State Dam Safety Engineer

4/18/2007 – Photo of recently constructed block retaining wall over the masonry rock wall. Note that the wall is essentially straight.

7/31/2008 – Slight bulge noted in the brick masonry wall indicating some downstream movement.

8/13/09 – Continued movement of the brick retaining wall in the downstream direction. It is assumed that the lower masonry wall is also moving.

05/05/2010 – Conditions as of May 5, 2010. The device constructed for measuring the downstream movement of the masonry rock wall may not be recording the total movement as that device may also be moving. Running a tape between two points on the brock wall and measuring the offset of specific bricks may be a more accurate method of recording displacement and rate of movement.

Minnesota Department of Natural Resources

500 Lafayette Road • St. Paul, MN • 55155-4037

Mr. Don Solga
Pelican Rapids City Administrator
Pelican Rapids City Hall
PO Box 350 Pelican Rapids, MN 56572

October 5, 2009

RE: Pelican Rapids Dam, Otter Tail County, (NID MN00190)

Dear Mr. Solga:

The Minnesota DNR - Dam Safety Unit, inspected the Pelican Rapids Dam on September 13, 2009. Such inspections are conducted on a regular basis as required by state regulations.

The Dam Safety Unit found the Pelican Rapids Dam to be in fair condition. The condition of the dam has not changed significantly from what was noted in 2008. In general, cracks in the masonry wall and in the concrete structure appeared to be slightly larger than noted in 2008. Concrete spalling is an ongoing problem and several small pieces of the concrete facade have broken off since the 2008 inspection.

Seeps located downstream of the dam were observed to be actively flowing. However, it was not possible to observe all of the known seeps on the day of the site visit due to high tailwater conditions. We also noted that a small depression is forming next to the powerhouse. This is approximately the same location where a large sinkhole formed approximately ten years ago. We did not inspect the power house or the operation of the two lift gates.

Dam Safety recommends that the city continue monitoring the masonry rock wall weekly during normal flow conditions and daily during high water events for continued seepage, and cracking and displacement in the masonry wall. The small depression adjacent to the old powerhouse should be monitored. If this depression continues to grow, the area should be excavated to determine the cause, and then an appropriate repair made.

If any changes are observed in the Pelican Rapids Dam, or if you have any questions, please feel free to contact me (651)-259-5663. Dam Safety will inspect the Pelican Rapids Dam again in 2010.

Sincerely,
DNR - Division of Waters

Dana Dostert, P.E., P.G.
Dam Safety Engineer

CC: Dave Leuthe., DNR Technical Resources Section Administrator
Bob Bezek, DNR Regional Hydrologist
Terry Lejcher, DNR Area Hydrologist
Jason Boyle, P.E., Minnesota State Dam Safety Engineer

Minnesota Department of Natural Resources

500 Lafayette Road
St. Paul, Minnesota 55155-40__

January 2, 2008

Mr. Don Solga
Pelican Rapids City Administrator
Pelican Rapids City Hall
PO Box 350 Pelican Rapids, MN 56572

RE: Pelican Rapids Dam, Otter Tail County, (NID MN00190)

Dear Mr. Solga:

The Minnesota DNR - Dam Safety Unit, inspected the Pelican Rapids Dam on July 31, 2008. Such inspections are conducted on a regular basis as required by state regulations. Enclosed is a summary of our inspection for your records.

The Dam Safety Unit found the Pelican Rapids Dam to be in fair condition. We did not inspect the power house or the operation of the two lift gates. In addition, we were unable to inspect the left downstream embankment wall due to vegetation growing over the wall. We did note several deficiencies that warrant additional monitoring:

1. Seepage had been noted in past inspections and was observed again during the 2008 inspection. Seepage in dams is common. However, excessive seepage or seepage containing soil particles indicates a potentially serious condition.

2. A bulge in the downstream right (north) masonry/rock wall was first observed during the inspection of September 7, 2005. During the 2008 inspection, it was noted that the bulge seemed slightly larger than in past inspections. A brick wall was observed to be under construction on the upper portion of the dam during the 2006 inspection. It was noted during the 2008 inspection that this brick wall has bowed slightly in the downstream direction in the vicinity of the bulge.

3. It was noted that the cracking and displacement in the right mortar wall seemed greater than what was observed during the 2007 inspection.

4. Much of the concrete veneer over the old concrete dam is separating and falling into the river. This exposes older portions of the dam to weathering and erosion.

Dam Safety recommends that the city continue monitoring the masonry/rock wall weekly during normal flow conditions and daily during high water events for continued seepage, and cracking and displacement in the masonry wall. Dam Safety also recommends the city develop a

contingency plan to repair the masonry wall if it should fail suddenly.

Dam Safety noted that the residence just downstream of U. S. Highway 59 has been vacated. Dam Safety appreciates the actions taken by the city to purchase this property. The conversion of this property to non-residential significantly reduces the risks of personal injury if the Pelican Rapids Dam should fail. Dam Safety also appreciates the City's work in updating the Emergency Action Plan.

If any changes are observed in the Pelican Rapids Dam, or if you have any questions, please feel free to contact me (651)-259-5663. Dam Safety will inspect the Pelican Rapids Dam again in 2009.

Sincerely,
DNR - Division of Waters

Dana Dostert, P.E., P.G.
Dam Safety Engineer

CC: Dave Leuthe., DNR Technical Resources Section Administrator
Bob Bezek, DNR Regional Hydrologist
Terry Lejcher, DNR Area Hydrologist
Jason Boyle, P.E., Minnesota State Dam Safety Engineer

Minnesota Department of Natural Resources
500 Lafayette Road
St. Paul, MN 55155-4032

September 15, 2006

Mr. Don Solga,
Pelican Rapids City Administrator
Pelican Rapids City Hall
PO Box 350
Pelican Rapids, MN 56572

RE: Pelican Rapids Dam, Otter Tail County, (NID MN00190)

Dear Mr. Solga;

The Minnesota DNR - Dam Safety Unit, inspected the Pelican Rapids Dam on August 8, 2006. Such inspections are conducted on a regular basis as required by state regulations. Enclosed is a summary of our inspection for your records.

The Dam Safety Unit found the Pelican Rapids Dam to be in fair condition. Gates were adjusted by city workers to verify operation. We did not inspect the power house or the plunge pool area. We noted several deficiencies that warrant repairs or additional monitoring:

1. Low flows due to dry climatic conditions allowed for good inspection of the downstream face and spillway. Seepage had been noted in past years and was also observed during the 2006 inspection. Three areas of seepage are known and are shown in photos 1 though 4. However, the seepage below the bulge had not been noted in past inspections (photo 1, lower left red arrow). Seepage in dams is common. However, excessive seepage or seepage containing soils indicates a potentially serious condition. Personnel who operate the dam should be aware of these seepage sites and periodically monitor them for changing flows or an increase in soil content.

2. The rock face of the right (north) downstream side of the dam has a significant bulge. This bulge was first observed during the inspection of September, 7, 2005. A large tree existed in the embankment immediately upstream of the bulge. This tree was removed around 1995, leaving a large stump until 2005 or 2006. The development of this bulge is troublesome. The Dam Safety Unit plans to explore options to monitor this bulge to determine if movement has stopped or is ongoing.

The city should monitor the rock retaining wall weekly during normal flow conditions and daily during high water events for continued seepage, cracking and displacement While we are only requiring monitoring at this time, it may be necessary to repack the embankment and repair the rock wall in the future. (photos 2, 4 through 8).

3. There are two depressions in the embankment that should be filled, reseeded and monitored for continued subsidence. (photo 10). These depressions were noted as far back as 1995. As these depressions were larger in past photographs, it is likely that they had been filled in past years.

4. While the viny vegetation on the dam improves the aesthetics of the dam, the vegetation makes it difficult to inspect and monitor the condition of the concrete. (Photos 3, 11, 12). This vegetation should be cut back annually.

5. As it was not possible to completely observe the left downstream rock wall, that wall should be inspected once the vegetation has been removed. (photo 11).

6. The close proximity of businesses and residences to the Pelican Rapids Dam, as well as the lower elevation of those properties, make this a High Hazard Dam. A High Hazard Dam is defined by Minnesota Rules as one that will likely result in the loss of life if the dam should fail.

   Over the next 90 days, the Dam Safety Unit will complete a dam break analysis of the Pelican Rapids Dam. The results of this dam break analysis should then be incorporated into an updated Emergency Action Plan.

If any changes are observed in the Pelican Rapids Dam, or if you have any questions, please feel free to contact me (651)-259-5663.

Sincerely,
DNR Waters

Dana Dostert, P.E., P.G.
Dam Safety Unit

CC: Mel Sinn, P.E., DNR Technical Resources Section Administrator
Larry Kramka, DNR Regional Hydrologist
Terry Lejcher, DNR Area Hydrologist
Dana Gauthier, P.E. DNR Dam Safety Engineer
Dan Zwilling, P.E., DNR Dam Safety Engineer
Brian Rongitsch, P.G., DNR Supervisor, Technical Analysis and Engineering
Judy Boudreau, DNR Hydrologist, Information, Mapping and Publications.
Glen Yakel, DNR Supervisor, Monitoring and Database Management

Photo 1 (08/08/2006) - Face of north side of Pelican Lake Dam. Note bulge near the center of the rock structure. Historic photos show a large tree above the bulge site. Photos from 1995 to 2005 show a large stump.

Seepage was observed in three locations, at the base of the downstream left embankment, below the bulge, and in the soil approximately10 feet downstream of the dam (see red arrows). Seepage is shown in photos 2, 3 and 4.

Photo 2 (08/08/2006) - Seepage below bulge in downstream retaining wall. This seepage is often obscured by high tailwater conditions. In the rock face, note the cracking of the concrete.

Photo 3 (08/08/2006) - Seepage on left downstream face of the rock retaining wall near the powerhouse. Vegetation made it difficult to inspect condition of retaining wall.

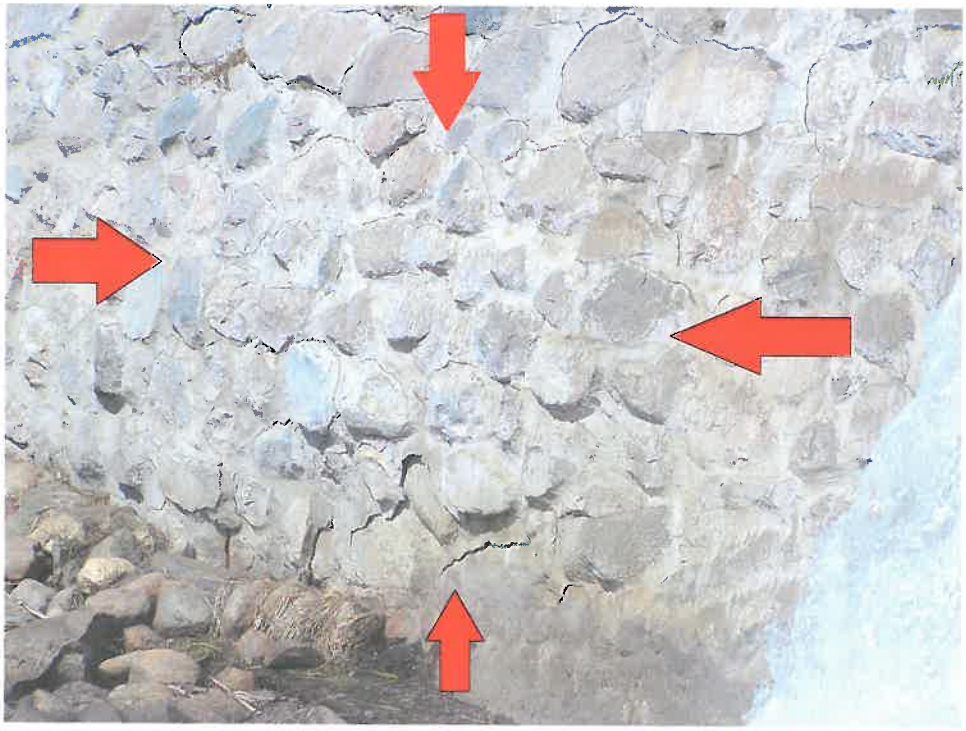


Photo 4 (08/08/2006) - Bulge in rock face on right downstream face. Note seepage at base of bulge. Note separation and displacement of concrete from boulders. The bulge is approximately the area inside the red arrows.

Photo 5 (08/08/2006) - Close up of rock wall separation and displacement.

Photo 6 (08/08/2006) - Photo of crack and displacement in rock wall. This picture is in the bulge on the right downstream side of the retaining wall.

Photo 7 (08/08/2006) - In the bulge, 1-inch crack, displacement and separation of boulder from concrete. Note vegetation growing in crack.

Photo 8 (08/08/2006) - In the bulge. 1.5-inch displacement of boulder and concrete from base of rock wall.

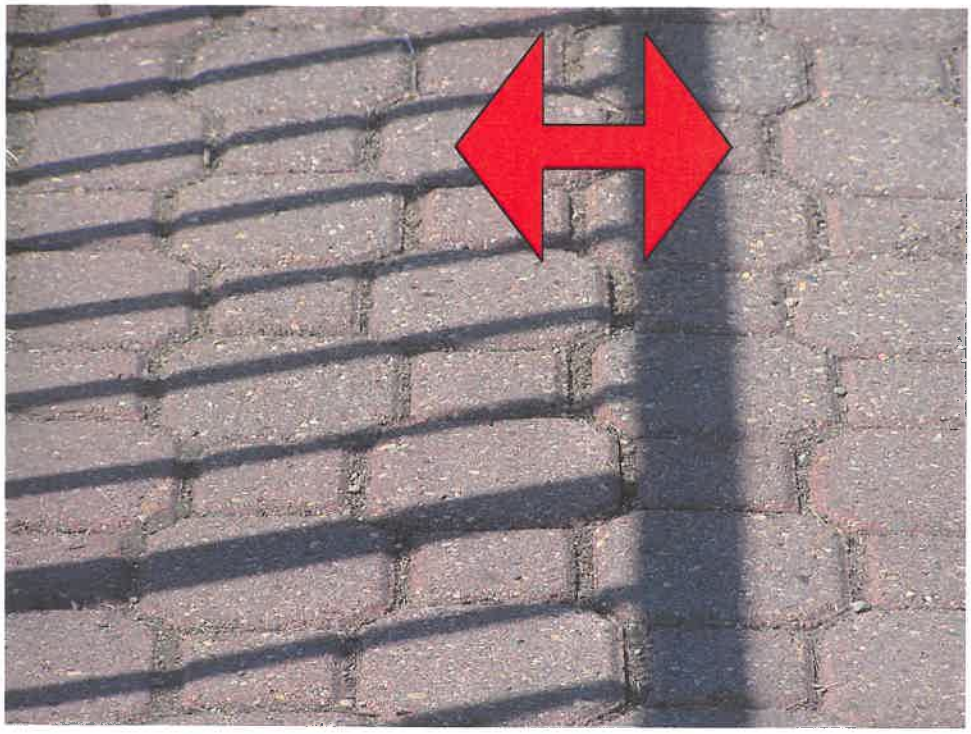


Photo 9 (08/08/2006) - Above the bulge on the brick walkway. The bricks on the right (upstream) side are tightly packed and generally flat. The bricks on the left (downstream)side have a slight dip in the downstream direction. Note the joint in the bricks between the arrows and the change in joint size and material in the joint. Compare to the flush bricks on the right with some soil on the beveled edge. The bricks on the right are stable while the bricks on the left indicate a creep in the downstream direction

Photo 10 (08/08/2006) - Subsidence / loss of material on the left upstream side of embankment. Downstream of this site, the left wall is separating from the embankment (photo 11) and seepage is occurring at the base of the wall.

The subsidence in this area has existed for at least 10 years. It has been filled and leveled at least on one other occasion. This area should be filled agin, leveled and watched for continued subsidence.

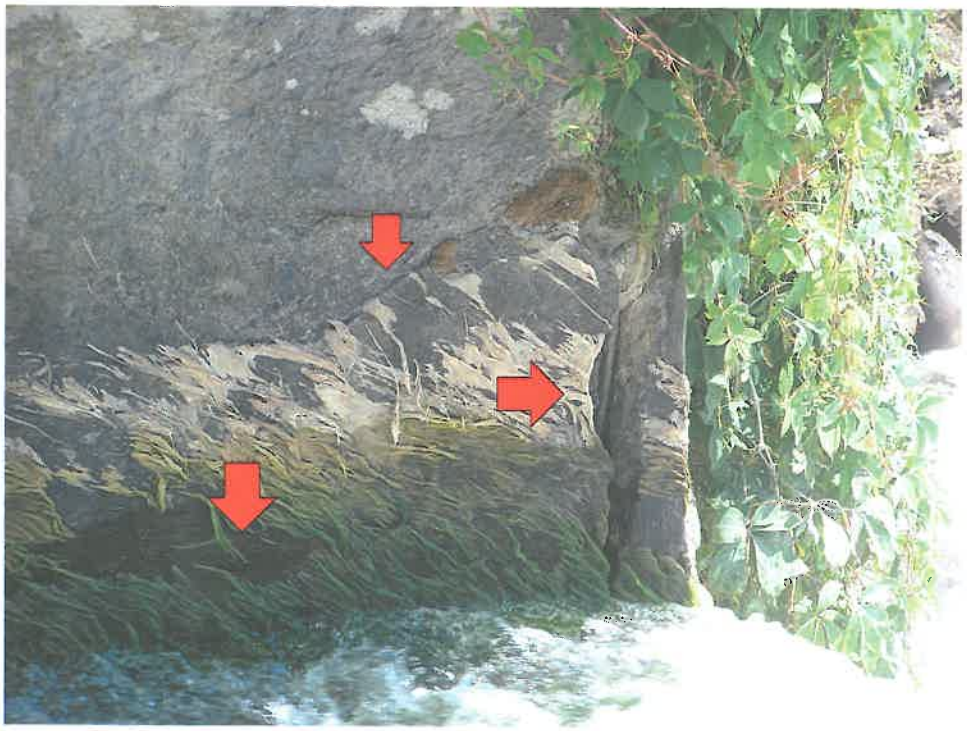


Photo 11 (08/08/2006) - Left Spillway wall (trending east-west) is shown on the left side of the photo. Left embankment wall (trending north-south) is to the immediate left of the vegetation. Note the separation of the left embankment wall from the left spillway wall.

The red arrows show fractures in the spillway wall.

The seepage shown in photo 3 is at the base of this embankment wall.

Vegetation prevented viewing of most of the left embankment wall.

Photo 12 (08/08/2006) - Looking at left spillway wall showing additional fractures in the left spillway wall.

INSPECTION REPORT

Dam Name: Pelican Rapids
County: Otter Tail
NID #: MN00190
Owner: City of Pelican Rapids
Hazard Class: Significant

Inspected by: Dan Zwilling
Date: 9/7/05
Contact: Donald Solga, City Admin
Address: 315 N Broadway 56572-0350
Phone Number: (218) 863-6571

General Condition of Dam (circle two): (Good) Fair Poor (Stable) Unstable
Estimated Discharge or Lake gage level: _____

Repairs and Maintenance Needed: __

1. Three items to keep a watch on are listed below. The embankment subsidence on the northwest side of dam appears new and should be monitored quarterly. Please send the DNR a report in September 2006 of your observations.
2. Implement procedures to open the powerhouse spillway for emergency flows.

Feature	Yes	No	Remarks	Photos
I. OUTLET STRUCTURES				
A. Accumulation of debris		X		
B. Cracked or eroded concrete		X		
C. Abnormal leakage		X		
D. Separated joints		X		
E. Settlement	minor		This settlement was noted in early inspections in 1998 and 2002. Appears stable but keep monitoring.	5
F. Erosion at outlet				
G. Faulty gates or stop logs			None	
H. Other problems				
II. EMBANKMENT SLOPE				
A. Wave erosion		X		
B. Cracks		X		
C. Slides or sloughs	watch		Embankment on the northwest side of the dam is subsiding slightly. This needs to be monitored quarterly since this appears to be a recent development.	3, 4
D. Subsidence	minor		See above	
E. Damage to slope protection		X		
F. Inadequate vegetation		X		
G. Tree brush growth		X		
H. Animal burrows		X		
I. Seepage, leakage, boils	minor		This leakage was noted in previous inspections starting in 1996. No apparent change in rate. Keep monitoring.	1,2

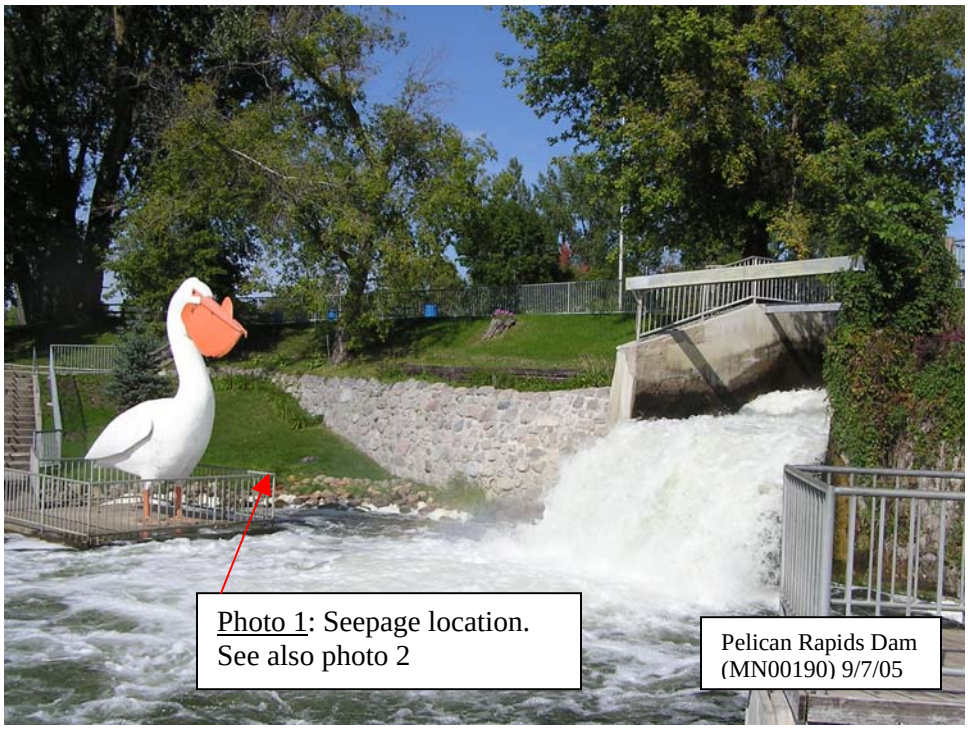


Photo 1: Seepage location. See also photo 2

Pelican Rapids Dam (MN00190) 9/7/05

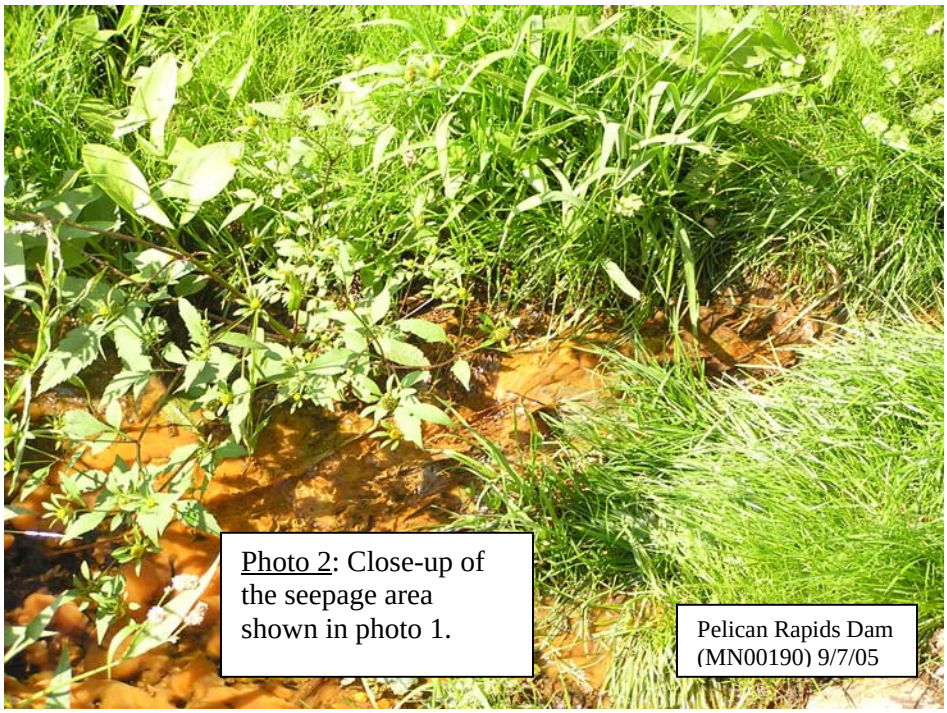


Photo 2: Close-up of the seepage area shown in photo 1.

Pelican Rapids Dam (MN00190) 9/7/05

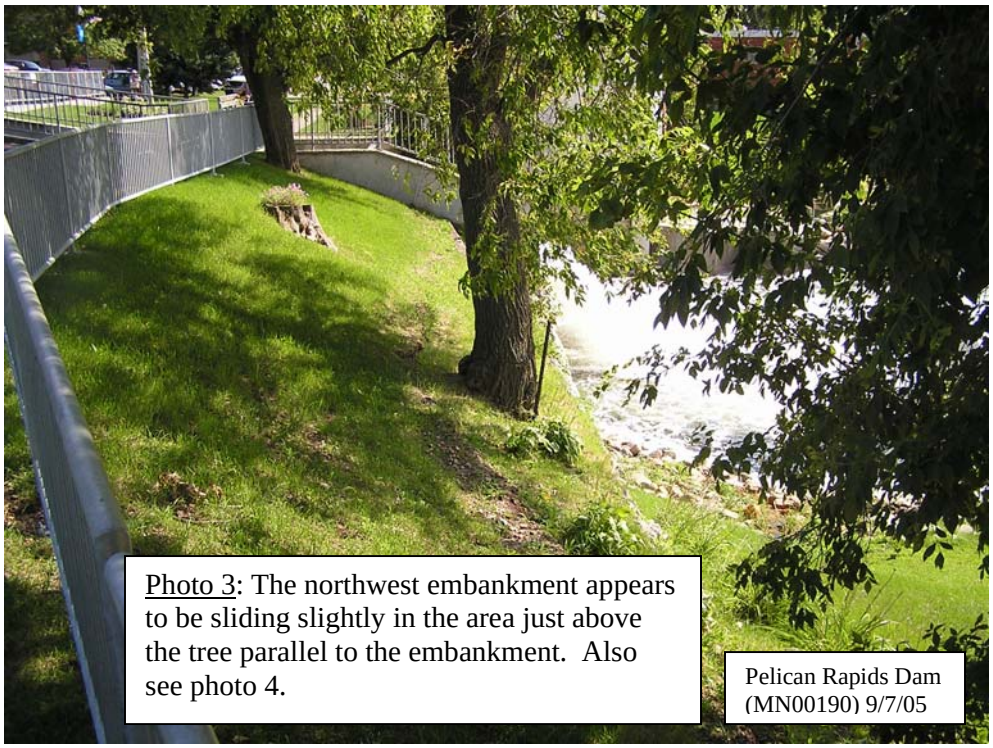


Photo 3: The northwest embankment appears to be sliding slightly in the area just above the tree parallel to the embankment. Also see photo 4.

Pelican Rapids Dam (MN00190) 9/7/05

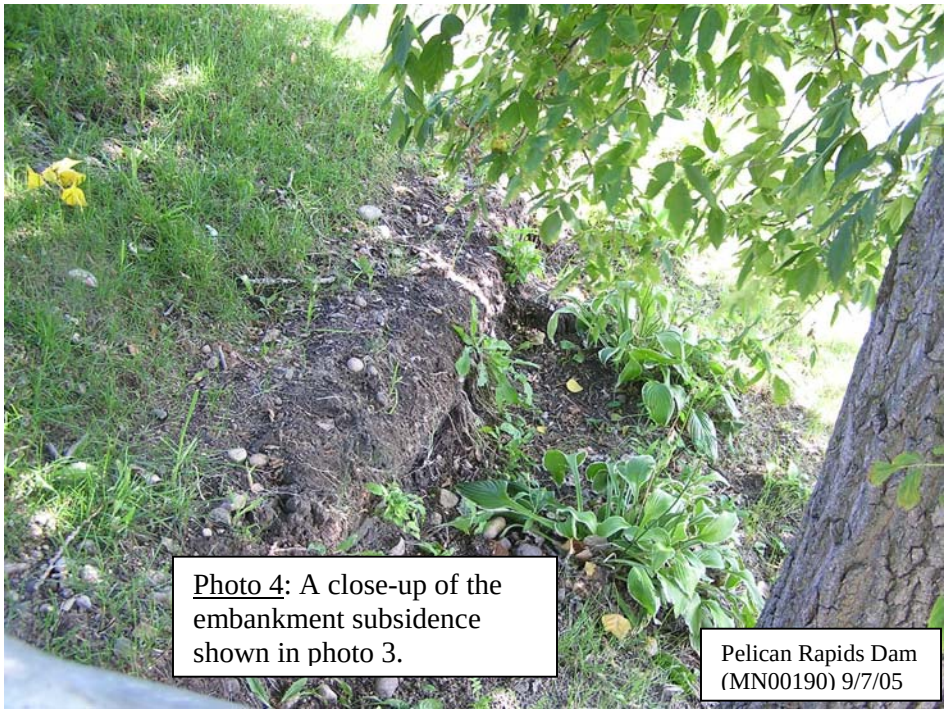


Photo 4: A close-up of the embankment subsidence shown in photo 3.

Pelican Rapids Dam (MN00190) 9/7/05

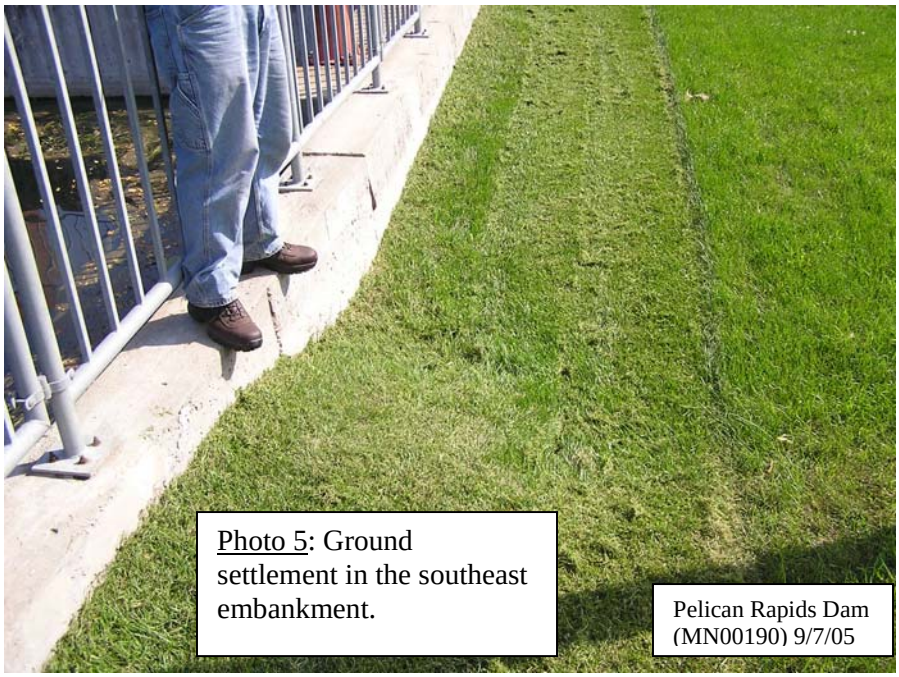


Photo 5: Ground settlement in the southeast embankment.

Pelican Rapids Dam (MN00190) 9/7/05

APPENDIX C

Geotechnical Report

Braun Intertec Corporation
526 10th Street NE, Suite 300
P.O. Box 485
West Fargo, ND 58078

Phone: 701.232.8701
Fax: 701.232.7817
Web: braunintertec.com

February 14, 2017 Project B1610289

Rick St. Germain, PE
Houston Engineering, Inc.
1401 21st Avenue North
Fargo, ND 58102

Re: Piezometer Installation and Monitoring
Pelican Rapids Dam
Pelican Rapids, Minnesota

Dear Mr. Germain:

Braun Intertec Corporation respectfully submits this report pertaining to the installation of piezometers with associated monitoring for the existing dam within the City of Pelican Rapids, Minnesota.

Our Understanding of Project

The dam was initially constructed in the 1880s to provide waterpower for a sawmill and was later modified to power a grist mill. The dam was supposedly constructed of timber crib and earth. In the early 1900s, the dam was raised and a rock wall was constructed on the downstream side and a timber sluiceway and a timber spillway were also constructed during that period. In 1914-1915, the dam was raised again with “compacted local material”; a new grist mill was constructed downstream of the old one; and the timber sluiceway and spillway were replaced with concrete structures.

Fire subsequently destroyed the grist mill and in 1924, a concrete powerhouse with hydroelectric turbines were constructed at the end of the concrete sluiceway. During the 1930s, the hydroelectric turbines were scrapped out and the reservoir was allowed to drain. In 1957, the dam was repaired sufficiently to restore the reservoir. The sluiceway was filled in, and the spillway was repaired, including replacing the stoplogs.

During the period of 1987 to 1988, the dam underwent major structural rehabilitation to repair deficiencies and increase hydraulic capacity. The rehabilitation included: driving sheetpile cutoff walls to refusal in “dense glacial till” along the axis of the dam, repair and replacement of the existing spillway stoplogs with a sluicegate, repair of the existing rockwall and placement of shoreline protection. This sheetpile is apparently attached to a concrete wall which is currently seen along the upstream portion of the dam.

As early as 2006, a bulge in the rock wall north (right) of the existing spillway was documented by the Minnesota Department of Natural Resources as result of their annual inspection. Subsequent annual inspection reports documented the presence of the bulge and its progressive enlargement. By mid-July of 2016, the rock wall had failed but the dam did not breach. As a result the City of Pelican Rapids has decided to take action in order to repair the wall.

Purpose and Scope

The purpose of our work was to provide better insight on the seepage paths in and around the dam as well as the function of the sheet pile wall. To do this we installed several piezometers and monitored the groundwater levels at each select location. Based upon what we found during the installation and monitoring of the piezometers, we have presented our interpretations of the data collected as well as its effects on mitigation alternatives. The following tasks were conducted to achieve the stated purpose.

Field Exploration

Penetration Test Borings

We drilled 2 standard penetration test borings (ST-01 and ST-02) along the axis of the dam downstream of the concrete wall and its supposed sheet pile wall extension. Penetration tests were performed at 2 1/2-foot vertical intervals to 30 feet and at 5-foot intervals to the boring termination depths of 41 feet. In each of these borings, a standpipe piezometer with a sand filter-pack was installed within the dam embankment depth. The remainder of the borings were backfilled with bentonite chips. Each piezometer was placed in a protective post with a lockable lid.

We also drilled 1 standard penetration test boring (ST-03) downstream of the dam crest and adjacent to the paved/stamped concrete parking area. Penetration tests were performed at 2 1/2-foot vertical intervals to 20 feet and at 5-foot intervals to the boring termination depth of 31 feet. In this boring, a standpipe piezometer with a sand filter-pack was installed within the upper 10 feet. The remainder of the boring was backfilled with bentonite chips. As with the other piezometers, it was placed in a protective post with a lockable lid.

Because of the materials encountered, thin-wall tube samples were not obtained.

Groundwater is encountered in all of the boreholes, the depth where it is observed was recorded on the boring logs during or immediately after completion of drilling. In addition to groundwater measurements during the exploration, we read each of the installed piezometers twice.

Hand Auger Borings

We drilled 2 hand auger borings on the right side of the tailwater basin next to the pelican statue (ST-04 and ST-05) to explore immediately downstream of the dam. In addition, we drilled 1 hand auger boring (ST-06) in the embankment slope to explore near the sloughed area. These hand auger borings extended to maximum depths of 10 feet. In Boring ST-4, we installed a temporary piezometer consisting of a 1-inch diameter PVC pipe with a screen interval between 3 1/2 and 8 feet below grade. The piezometer was placed in a protective post with a lockable lid underlain by a bentonite chip plug.

Borehole Abandonment

Because we installed piezometers in most of the borings, sealing of the boreholes was not performed. However, the shallow abandoned hand auger Borings ST-05 and ST-06 were backfilled with cuttings.

Staking and Surveying

The borings were originally staked by Braun Intertec and later surveyed by Houston Engineering. Locations of the borings are presented on the Borings Location Sketch in the appendix.

Sample Review and Laboratory Testing

Samples were returned to our laboratory where they were visually classified and logged by a geotechnical engineer. After classification, we then set up a laboratory testing schedule to establish the necessary engineering properties for a potential stability and engineering analyses.

We conducted the following tests:

- 26 Moisture Content Tests
- 1 Atterberg Limit Tests
- 2 Passing 200 Sieve Tests
- 2 Mechanical Sieve Tests

Because of the difficulty of obtaining thin-wall tube samples, no unconfined compression or moisture/density tests were performed.

The results of the tests are included on the Log of Boring sheets and in the *Laboratory Test Reports* appendix.

Results

Geology

Based on the materials encountered in the borings, our review of the available historic documents and the Geologic Map of Minnesota, Quaternary Geology; the soils downstream of the concrete wall are soil fill which overlie glacial outwash sands which, in turn, overlie glacial clay till. The fill was apparently

placed for construction of the dam and the glacial soils were deposited from the Des Moines Lobe during the Late Wisconsin Glaciation.

The boring logs presented in the appendix identify and describe the materials penetrated, and present the results of groundwater observations and laboratory testing of samples. Strata boundaries shown on the logs do not reflect visible textural or geologic origin-related changes in the samples but mark the depths between which the split spoon samples were advanced. Textural, geologic origin-related and other types of in-situ boundaries, where observed, are noted in the Description of Materials column on the logs.

Embankment Stratigraphy

As indicated by the boring logs for Borings ST-01, ST-02, ST-03 and ST-06, the surficial 2 feet consists of topsoil. Underlying the topsoil, we found a fill mixture of brown sandy lean clay, silty clay with sand, clayey sand, silty sand and poorly graded sand. A one-foot thick layer of buried topsoil was encountered underlying the fill at Boring ST-01. The fill and topsoil thickness ranged from 18 feet in Boring ST-01 to 9 feet at ST-03; Boring ST-06 was terminated in the fill at 10 feet. The glacial outwash sand that we found underlying the fill and topsoil consisted of poorly graded sand with silt and gravel to silty sand. This thickness of the glacial outwash sand ranged from 2 1/2 feet in Boring ST-03 to greater than 23 feet in Boring ST-01, which was terminated in the outwash sand at 41 feet. Borings ST-02 and ST-03 encountered glacial till consisting of gray sandy lean clay at depths of 11 to 30 feet. Both of these borings were terminated in the glacial till at depths of 31 and 41 feet.

Terrace/Floodplain Stratigraphy

Hand-augered Borings ST-04 and ST-05 were drilled in the low-lying area immediately downstream of the dam and right of the tailwater basin. Both borings encountered 1 to 2 feet of topsoil overlying glacial outwash consisting of poorly graded sand to silty sand. Boring ST-04 was terminated at 10 feet, and Boring ST-05 was terminated on a rock obstruction at 6 feet.

SPT N-Values

For the embankment fill, the SPT N-values ranged from 2 to 16 blows per foot (BPF) (very loose to medium dense granular soil and very soft to stiff cohesive soil) with typical values of 8 to 11 BPF. The underlying glacial outwash had N-values of 6 to 28 BPF (loose to dense granular soil) with typical values of 8 to 12 BPF. N-values for the glacial till ranged from 9 to 24 BPF (rather stiff to very stiff cohesive soil) with typical values of 12 to 22 BPF.

Groundwater

All of the borings encountered free groundwater during drilling, except Boring ST-06. The elevations of the groundwater levels measured on November 1 through 3, 2016, ranged from 1293 to 1296 feet. The

water levels surveyed at the reservoir and tailwater basin on November 2, 2016 were at 1308.8 and 1294.2 feet respectively. Subsequently, readings were taken at the piezometers at Borings ST-01 through ST-04 and the open hole at Boring ST-05 on November 7, 2016. The piezometers were read again on December 6, 2016 but the open hole at ST-5 caved and was backfilled prior to this reading; we understand that the water levels of the reservoir and tailwater basin had not fluctuated significantly from the November 2 levels. The piezometer measurements are as follows:

Table 1. Groundwater Readings

Boring	11/07/16	12/06/16
ST-1	1296.4	1296.3
ST-2	1296.6	1296.8
ST-3	1294.8	1294.7
ST-4	1296.2	1296.3
ST-5	1295.0	No Reading

Conclusions

Based upon the data collected from the borings and the piezometer readings, we conclude that the concrete wall and sheetpile located upstream of the borings is currently acting as an effective groundwater barrier and that the sheetpile is socketed in the glacial till. Although glacial till was not found in Boring ST-01, it is reasonable to interpret from the groundwater readings that the sheetpile does extend into the glacial till within this portion of the dam. Therefore, methods of mitigating the failed portion of the embankment can be designed as earth retaining structures without the seepage component most commonly associated with water-retaining structures, such as dam embankments.

Qualifications

Variations in Subsurface Conditions

Material Strata

Our evaluation, analyses and recommendations were developed from a limited amount of site and subsurface information. Strata boundaries and thicknesses have been inferred to some extent. Strata boundaries can also vary in depth, elevation and thickness away from the exploration locations.

Variations in subsurface conditions present between exploration locations may not be revealed until additional exploration work is completed, or construction commences. If any such variations are

revealed, our recommendations should be re-evaluated. Such variations could increase construction costs, and a contingency should be provided to accommodate them.

Groundwater Levels

Groundwater measurements were made under the conditions reported herein and shown on the exploration logs, and interpreted in the text of this report. It should be noted that the observation periods were relatively short, and groundwater can be expected to fluctuate in response to rainfall, flooding, irrigation, seasonal freezing and thawing, surface drainage modifications and other seasonal and annual factors.

Use of Report

This report is for the exclusive use of the parties to which it has been addressed. Without written approval, we assume no responsibility to other parties regarding this report. Our evaluation, analyses and recommendations may not be appropriate for other parties or projects.

Standard of Care

In performing its services, Braun Intertec used that degree of care and skill ordinarily exercised under similar circumstances by reputable members of its profession currently practicing in the same locality. No warranty, express or implied, is made.

General Remarks

We trust this is the information you require for designing concepts for mitigating the failure of the downstream face of the embankment. To have questions answered or schedule a time to meet and discuss our findings and conclusions, please call Bryan Ripp at 952.995.2236.

Sincerely,

BRAUN INTERTEC CORPORATION

Professional Certification:
I hereby certify that this plan, specification or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

Bryan J. Ripp, PE, CFM
Senior Geotechnical Engineer
License Number: 40232
February 14, 2017

Nathan L. McKinney, PE
Principal - Senior Engineer

Appendix:
Boring Location Sketch
Boring Logs (ST-01 through ST-06)
Descriptive Terminology of Soil
Grain Size Accumulation Curve (ASTM)

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DENOTES APPROXIMATE LOCATION OF STANDARD PENETRATION TEST BORING

N

30' 0 60'

SCALE: 1" = 60'

Sheet: of

Fig:

Project No:	B1610289
Drawing No:	B1610289
Scale:	1" = 60'
Drawn By:	BJB
Date Drawn:	2/13/17
Checked By:	BR
Last Modified:	2/13/17

SOIL BORING LOCATION SKETCH

GEOTECHNICAL EVALUATION
PELICAN RAPIDS DAM
NEAR 1ST STREET NORTHEAST AND EAST MILL STREET
PELICAN RAPIDS, MINNESOTA

BRAUN INTERTEC
The Science You Build On.
11001 Hampshire Avenue S
Minneapolis, MN 55438
PH. (952) 995-2000
FAX (952) 995-2020

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LOG OF BORING

Braun Project B1610289
Piezometer Installation and Monitoring
Pelican Rapids Dam
Near 1st Street Northeast & East Mill
Pelican Rapids, Minnesota

BORING: **ST-01**

LOCATION: 3 feet E of sidewalk pavers, 18 feet N of original location. See sketch.

DRILLER: Interstate Drilling | METHOD: 3 1/4" HSA, Autohammer | DATE: **11/1/16** | SCALE: **1" = 4'**

(See Descriptive Terminology sheet for explanation of abbreviations)

Elev. feet	Depth feet	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
1312.0	0.0	FILL	FILL: Lean Clay, black, moist. (Topsoil)	11		28	
1310.0	2.0	FILL	FILL: Silty Clay with Sand, with Gravel, brown, moist.	7		13	LL=23, PL=16, PI=7
			-black and brown at 5 feet.	8		8	
1304.0	8.0	FILL	FILL: Poorly Graded Sand with Silt, fine- to coarse-grained, trace Gravel, brown with iron-staining, moist.	7		5	
				11*			*Minimal recovery.
			-black, 2 inch Clay seam at 13 feet. -with Gravel below 13 feet.	8		7	
				3*			*Minimal recovery.
1295.0	17.0				▽		
1294.0	18.0	CL	LEAN CLAY, trace roots, black and gray, moist. (Buried Topsoil)	5			
		SP-SM	POORLY GRADED SAND with SILT, coarse-grained, with Gravel, gray, moist to wet, loose to medium dense. (Glacial Outwash)	18			
			-waterbearing at 21 feet.				
1289.0	23.0	SM	SILTY SAND, fine- to medium-grained, trace gravel, gray, waterbearing, loose to medium dense. (Glacial Outwash)	11			
			CLAYEY SAND layer at 25 feet.	12			
				9			
			CLAYEY SAND layer at 30 feet.	7			

*An open triangle in the water level (WL) column indicates the depth at which groundwater was first observed while drilling. A solid triangle indicates the groundwater level in the boring on the date indicated. Groundwater levels fluctuate.

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LOG OF BORING

Braun Project B1610289
Piezometer Installation and Monitoring
Pelican Rapids Dam
Near 1st Street Northeast & East Mill
Pelican Rapids, Minnesota

BORING: **ST-01 (cont.)**

LOCATION: 3 feet E of sidewalk pavers, 18 feet N of original location. See sketch.

DRILLER: Interstate Drilling | METHOD: 3 1/4" HSA, Autohammer | DATE: **11/1/16** | SCALE: **1" = 4'**

(See Descriptive Terminology sheet for explanation of abbreviations)

Elev. feet	Depth feet	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
1280.0	32.0		SILTY SAND, fine- to medium-grained, trace gravel, gray, waterbearing, loose to medium dense. (Glacial Outwash) *(continued)*				
				6			
				8			
1271.0	41.0		END OF BORING.				
			Water observed at a depth of 17 feet with 31 feet of hollow-stem auger in the ground.				
			A piezometer with a screen depth interval of 8 to 18 feet was set in the borehole.				

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LOG OF BORING

Braun Project B1610289
Piezometer Installation and Monitoring
Pelican Rapids Dam
Near 1st Street Northeast & East Mill
Pelican Rapids, Minnesota

BORING: **ST-02**

LOCATION: See sketch.

DRILLER: Interstate Drilling | METHOD: 3 1/4" HSA, Autohammer | DATE: **11/1/16** | SCALE: **1" = 4'**

(See Descriptive Terminology sheet for explanation of abbreviations)

Elev. feet	Depth feet	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
1312.8	0.0	FILL	FILL: Sandy Lean Clay, trace roots, black, moist. (Topsoil)	8		21	
1310.8	2.0	FILL	FILL: Silty Sand, fine- to medium-grained, trace Gravel, brown, moist.	2		7	
1308.8	4.0	FILL	FILL: Sandy Lean Clay, trace Gravel, brown, moist.	9		12	
			-black and brown, trace roots below 7 1/2 feet.	5		13	
			-Poorly Graded Sand with Silt from 9 to 10 feet.	16		9	
1299.8	13.0			24		6	
		SP	POORLY GRADED SAND with Gravel, medium- to coarse-grained, brown with iron-staining, wet to waterbearing, loose to medium dense. (Glacial Outwash)	28			
			-gray below 16 1/2 feet.	12	▽		
				12			
				5			
				8			
				7			
1282.3	30.5			11			
		CL					

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LOG OF BORING

Braun Project B1610289
Piezometer Installation and Monitoring
Pelican Rapids Dam
Near 1st Street Northeast & East Mill
Pelican Rapids, Minnesota

BORING: **ST-02 (cont.)**
LOCATION: See sketch.

DRILLER: Interstate Drilling | METHOD: 3 1/4" HSA, Autohammer | DATE: **11/1/16** | SCALE: **1" = 4'**

(See Descriptive Terminology sheet for explanation of abbreviations)

Elev. feet	Depth feet	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
1280.8	32.0		SANDY LEAN CLAY, trace Gravel, gray, moist, rather stiff to very stiff. (Glacial Till) *(continued)*				
				24		18	
				22		12	
1271.8	41.0		END OF BORING.				
			Water observed at a depth of 17 feet with 21 feet of hollow-stem auger in the ground.				
			A piezometer with a screen depth interval of 6 to 16 feet was set in the borehole.				

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LOG OF BORING

Braun Project B1610289
Piezometer Installation and Monitoring
Pelican Rapids Dam
Near 1st Street Northeast & East Mill
Pelican Rapids, Minnesota

BORING: **ST-03**

LOCATION: See sketch.

DRILLER: Interstate Drilling | METHOD: 3 1/4" HSA, Autohammer | DATE: **11/2/16** | SCALE: **1" = 4'**

(See Descriptive Terminology sheet for explanation of abbreviations)

Elev. feet	Depth feet	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
1303.4	0.0						
		FILL	FILL: Sandy Lean Clay, dark brown and black, moist. (Topsoil)	3		21	
1301.4	2.0						
		FILL	FILL: Sandy Lean Clay, brown, moist. -6 inches of Poorly Graded Sand with Silt, reddish brown, at 3 feet.	2		42	
1299.4	4.0						
		FILL	FILL: Clayey Sand, trace roots and Gravel, black, moist.	4			P200-8%
1296.9	6.5						
		FILL	FILL: Sandy Lean Clay, trace Gravel, black, moist.	10		18	
1294.4	9.0						
		SP-SM	POORLY GRADED SAND with SILT, fine- to coarse-grained, trace Gravel, brown, moist, loose. (Glacial Outwash) -gray, with Gravel, wet below 10 1/2 feet.	8	▽		
1291.9	11.5						
		CL	SANDY LEAN CLAY, trace Gravel, gray, moist to wet, rather stiff to very stiff. (Glacial Till)	10		15	
				10		19	
				12		21	
				19		20	
1278.4	25.0						
		ML	SANDY SILT, trace Gravel, gray, wet, medium dense.	15			
1275.4	28.0						
		CL	SANDY LEAN CLAY, trace Gravel, gray, moist, rather stiff. (Glacial Till)	9		10	
1272.4	31.0						
			END OF BORING.				

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LOG OF BORING

Braun Project B1610289
Piezometer Installation and Monitoring
Pelican Rapids Dam
Near 1st Street Northeast & East Mill
Pelican Rapids, Minnesota

BORING: **ST-03 (cont.)**
LOCATION: See sketch.

DRILLER: Interstate Drilling | METHOD: 3 1/4" HSA, Autohammer | DATE: **11/2/16** | SCALE: **1" = 4'**

Elev. feet 1271.4	Depth feet 32.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
			Water observed at a depth of 10 1/2 feet with 13 1/2 feet of hollow-stem auger in the ground. A piezometer with a screen depth interval of 5 to 10 feet was set in the borehole.				

(See Descriptive Terminology sheet for explanation of abbreviations)

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LOG OF BORING

Braun Project B1610289
Piezometer Installation and Monitoring
Pelican Rapids Dam
Near 1st Street Northeast & East Mill
Pelican Rapids, Minnesota

BORING: **ST-04**

LOCATION: See sketch.

DRILLER: M. Haugstad | METHOD: Hand Auger | DATE: **11/3/16** | SCALE: **1" = 4'**

(See Descriptive Terminology sheet for explanation of abbreviations)

Elev. feet	Depth feet	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
1298.8	0.0						
1297.8	1.0	CL	SANDY LEAN CLAY, black, moist. (Topsoil)			27	
		SP-SM	POORLY GRADED SAND with SILT, fine- to coarse-grained, with Gravel, black and brown, moist. (Glacial Outwash)			11	
1295.8	3.0				▽		
		SM	SILTY SAND, fine- to medium-grained, with Gravel, gray, waterbearing. (Glacial Outwash) -trace Gravel below 5 feet.				
1288.8	10.0						P200=8%
			END OF BORING. A piezometer with a screen depth interval of 3 1/2 to 8 1/2 feet was set in the borehole. Water observed at a depth of 3 feet while drilling. Boring then backfilled.				

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LOG OF BORING

Braun Project B1610289
Piezometer Installation and Monitoring
Pelican Rapids Dam
Near 1st Street Northeast & East Mill
Pelican Rapids, Minnesota

BORING: **ST-05**

LOCATION: See sketch.

DRILLER: M. Haugstad | METHOD: Hand Auger | DATE: **11/3/16** | SCALE: **1" = 4'**

Elev. feet	Depth feet	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
1298.2	0.0	CL	SANDY LEAN CLAY, trace Gravel, black, moist. (Topsoil)			22	
1296.2	2.0	SP-SM	POORLY GRADED SAND with SILT, fine- to coarse-grained, trace Gravel, brown, moist. (Glacial Outwash)		▽	16	
1293.7	4.5		-hit rock at 4 1/2 feet.				
			END OF BORING.				
			Water observed at a depth of 3 1/2 feet while drilling.				
			Boring then backfilled.				

(See Descriptive Terminology sheet for explanation of abbreviations)

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LOG OF BORING

Braun Project B1610289
Piezometer Installation and Monitoring
Pelican Rapids Dam
Near 1st Street Northeast & East Mill
Pelican Rapids, Minnesota

BORING: **ST-06**

LOCATION: See sketch.

DRILLER: M. Haugstad | METHOD: Hand Auger | DATE: **11/3/16** | SCALE: **1" = 4'**

(See Descriptive Terminology sheet for explanation of abbreviations)

Elev. feet	Depth feet	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
1307.1	0.0	FILL	FILL: Sandy Lean Clay, trace Gravel, black, moist.			26	
1305.1	2.0	FILL	FILL: POORLY GRADED SAND with SILT, fine- to medium-grained, trace Gravel, black and brown, moist.				P200=6%
			-brown below 4 1/2 feet.				P200=6%
1297.1	10.0		END OF BORING.				
			Boring then backfilled.				
			Water not observed within 10 feet hand auger boring.				

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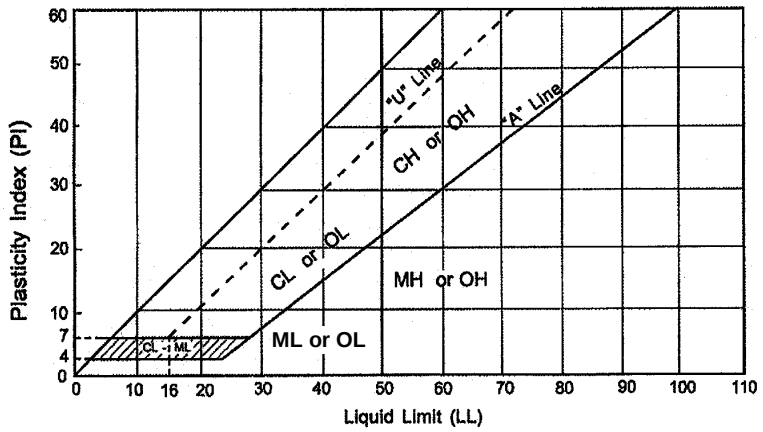
Descriptive Terminology of Soil

Standard D 2487
Classification of Soils for Engineering Purposes
(Unified Soil Classification System)

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [a]				Soils Classification	
				Group Symbol	Group Name [b]
Coarse-grained Soils more than 50% retained on No. 200 sieve	Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines [e]	$C_u \geq 4$ and $1 \leq C_c \leq 3$ [c]	GW	Well-graded gravel [d]
			$C_u < 4$ and/or $1 > C_c > 3$ [c]	GP	Poorly graded gravel [d]
		Gravels with Fines More than 12% fines [e]	Fines classify as ML or MH	GM	Silty gravel [d f g]
			Fines classify as CL or CH	GC	Clayey gravel [d f g]
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines [i]	$C_u \geq 6$ and $1 \leq C_c \leq 3$ [c]	SW	Well-graded sand [h]
			$C_u < 6$ and/or $1 > C_c > 3$ [c]	SP	Poorly graded sand [h]
		Sands with Fines More than 12% [i]	Fines classify as ML or MH	SM	Silty sand [f g h]
			Fines classify as CL or CH	SC	Clayey sand [f g h]
Fine-grained Soils 50% or more passed the No. 200 sieve	Silts and Clays Liquid limit less than 50	Inorganic	PI > 7 and plots on or above "A" line [j]	CL	Lean clay [k l m]
			PI < 4 or plots below "A" line [j]	ML	Silt [k l m]
		Organic	Liquid limit - oven dried / Liquid limit - not dried < 0.75	OL	Organic clay [k l m n]
				OL	Organic silt [k l m o]
	Silts and clays Liquid limit 50 or more	Inorganic	PI plots on or above "A" line	CH	Fat clay [k l m]
			PI plots below "A" line	MH	Elastic silt [k l m]
		Organic	Liquid limit - oven dried / Liquid limit - not dried < 0.75	OH	Organic clay [k l m p]
				OH	Organic silt [k l m q]
Highly Organic Soils	Primarily organic matter, dark in color and organic odor			PT	Peat

a. Based on the material passing the 3-inch (75mm) sieve.
b. If field sample contained cobbles or boulders, or both, add "with cobbles or boulders or both" to group name.
c. $C_u = D_{60}/D_{10}$ $C_c = \frac{(D30)^2}{D_{10} \times D_{60}}$
d. If soil contains ≥15% sand, add "with sand" to group name.
e. Gravels with 5 to 12% fines require dual symbols:
   GW-GM well-graded gravel with silt
   GW-GC well-graded gravel with clay
   GP-GM poorly graded gravel with silt
   GP-GC poorly graded gravel with clay
f. If fines classify as CL-ML, use dual symbol GC-GM or SC-SM.
g. If fines are organic, add "with organic fines: to group name.
h. If soil contains ≥15% gravel, add "with gravel" to group name.
i. Sand with 5 to 12% fines require dual symbols:
   SW-SM well-graded sand with silt
   SW-SC well-graded sand with clay
   SP-SM poorly graded sand with silt
   SP-SC poorly graded sand with clay
j. If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.
k. If soil contains 10 to 29% plus No. 200, add "with sand" or "with gravel" whichever is predominant.
l. If soil contains ≥ 30% plus No. 200, predominantly sand, add "sandy" to group name.
m. If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.
n. PI ≥ 4 and plots on or above "A" line.
o. PI < 4 or plots below "A" line.
p. PI plots on or above "A" lines.
q. PI plots below "A" line.



Laboratory Tests

DD	Dry density, pcf	**OC**	Organic content, %
WD	Wet density, pcg	**S**	Percent of saturation, %
MC	Natural moisture content, %	**SG**	Specific gravity
LL	Liquid limit, %	**C**	Cohesion, psf
PL	Plastic limits, %	**Ø**	Angle of internal friction
PI	Plasticity index, %	**qu**	Unconfined compressive strength, psf
P200	% passing 200 sieve	**qp**	Pocket penetrometer strength, tsf

Particle Size Identification

Boulders..... over 12"
Cobbles ..... 3" to 12"
Gravel
  Coarse ..... 3/4" to 3"
  Fine..... No. 4 to 3/4"
Sand
  Coarse ..... No. 4 to No. 10
  Medium..... No. 10 to No. 40
  Fine..... No. 40 to No. 200
Silt ..... <No. 200, PI< 4 or below "A" line
Clay ..... <No. 200, PI ≥ 4 and on or about "A" line

Relative Density of Cohesionless Soils

Very Loose..... 0 to 4 BPF
Loose..... 5 to 10 BPF
Medium dense ..... 11 to 30 PPF
Dense ..... 31 to 50 BPF
Very dense..... over 50 BPF

Consistency of Cohesive Soils

Very soft..... 0 to 1 BPF
Soft..... 2 to 3 BPF
Rather soft ..... 4 to 5 BPF
Medium..... 6 to 8 BPF
Rather stiff ..... 9 to 12 BPF
Stiff ..... 13 to 16 BPF
Very stiff..... 17 to 30 BPF
Hard..... over 30 BPF

Drilling Notes

Standard penetration test borings were advanced by 3 1/4" or 6 1/4" ID hollow-stem augers, unless noted otherwise. Jetting water was used to clean out auger prior to sampling only where indicated on logs. All samples were taken with the standard 2" OD split-tube samples, except where noted.

Power auger borings were advanced by 4" or 6" diameter continuous flight, solid-stern augers. Soil classifications and strata depths were inferred from disturbed samples augered to the surface, and are therefore, somewhat approximate.

Hand auger borings were advanced manually with a 1 1/2" or 3 1/4" diameter auger and were limited to the depth from which the auger could be manually withdrawn.

BPF: Numbers indicate blows per foot recorded in standard penetration test, also known as "N" value. The sampler was set 6" into undisturbed soil below the hollow-stem auger. Driving resistances were then counted for second and third 6" increments, and added to get BPF. Where they differed significantly, they are reported in the following form: 2/12 for the second and third 6" increments, respectively.

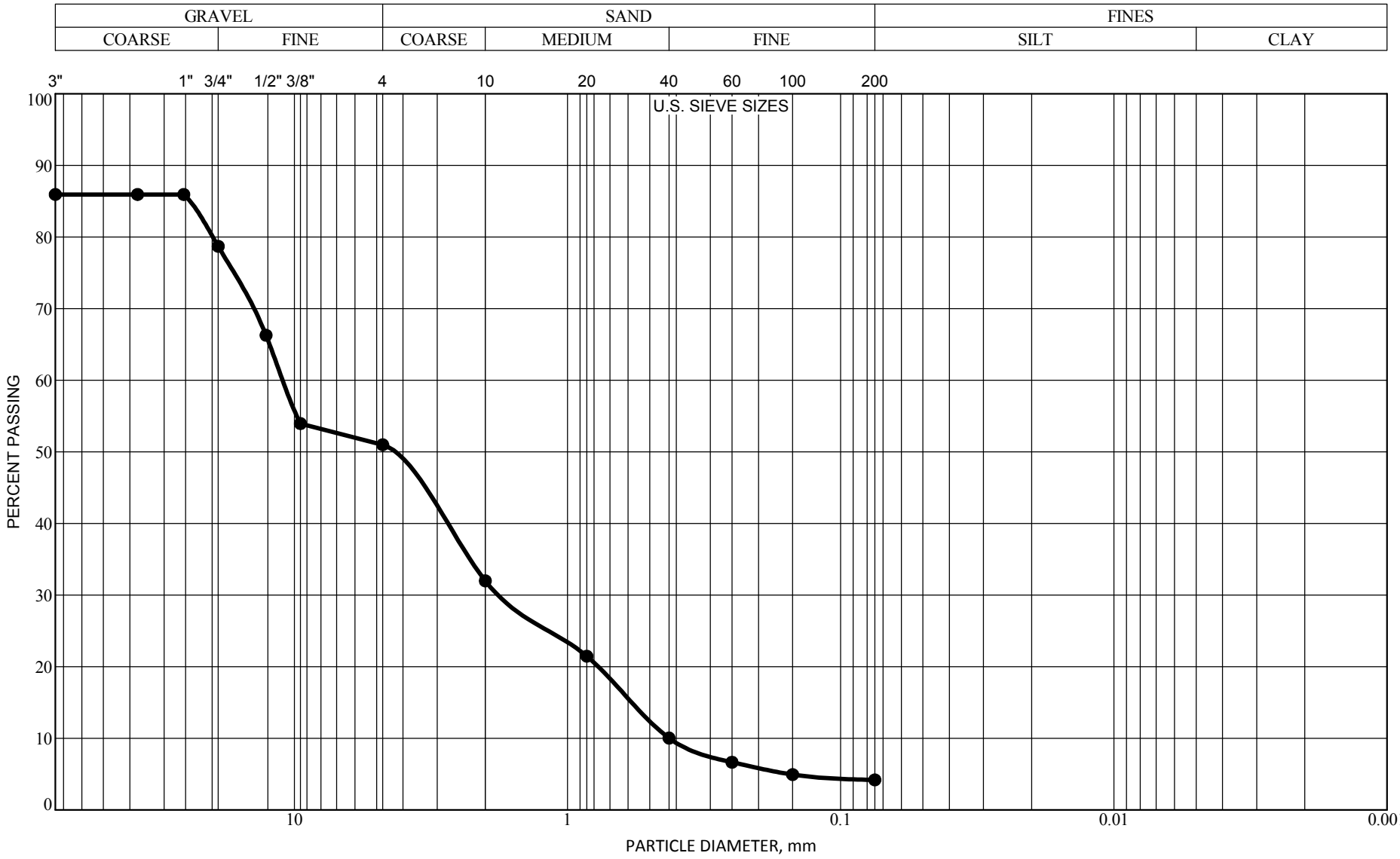
WH: WH indicates the sampler penetrated soil under weight of hammer and rods alone; driving not required.

WR: WR indicates the sampler penetrated soil under weight of rods alone; hammer weight, and driving not required.

TW: TW indicates thin-walled (undisturbed) tube sample.

Note: All tests were run in general accordance with applicable ASTM standards.

GRAIN SIZE ACCUMULATION CURVE (ASTM)



BRAUN INTERTEC

Braun Project B1610289
Piezometer Installation and Monitoring
Pelican Rapids Dam
Near 1st Street Northeast & East Mill
Pelican Rapids, Minnesota

BORING: ST-02 DEPTH: 15.0'-16.0'

GRAVEL	35.0%
SAND	46.8%
FINES	4.2%

D60=10.954
D30=1.701
D10=0.423

Cu=25.9
Cc=0.6

CLASSIFICATION:
POORLY GRADED SAND with GRAVEL(SP)

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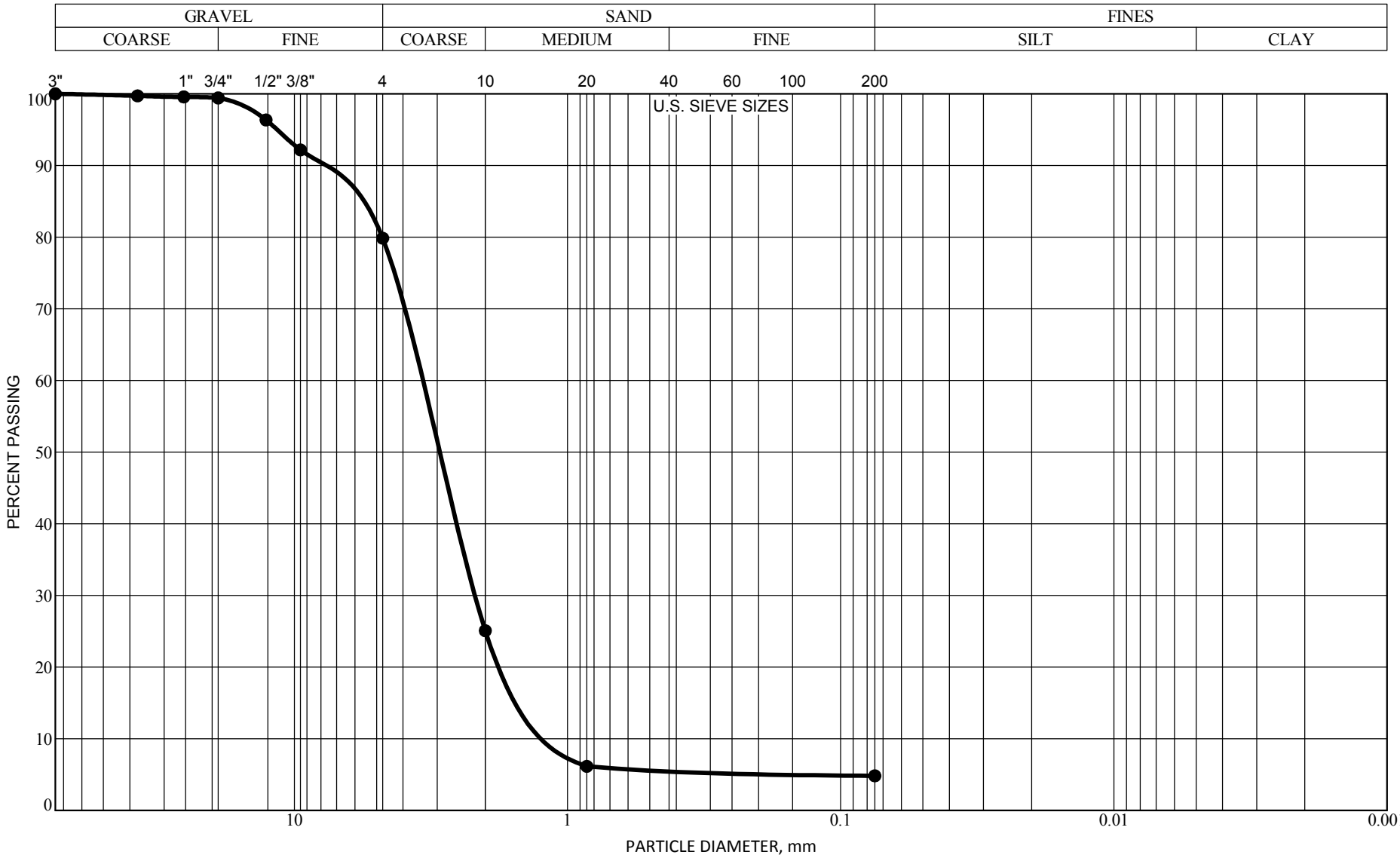
GRAIN SIZE ACCUMULATION CURVE (ASTM)



BRAUN INTERTEC

Braun Project B1610289
Piezometer Installation and Monitoring
Pelican Rapids Dam
Near 1st Street Northeast & East Mill
Pelican Rapids, Minnesota

BORING: ST-02 DEPTH: 20.0'-21.0'

GRAVEL	20.2%
SAND	75.0%
FINES	4.8%

D60=3.472
D30=2.162
D10=1.012

Cu=3.4
Cc=1.3

CLASSIFICATION:
POORLY GRADED SAND with GRAVEL(SP)

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APPENDIX D

Preliminary Plans (separate document)