APPENDIX A

DAM SAFETY INSPECTION REPORTS

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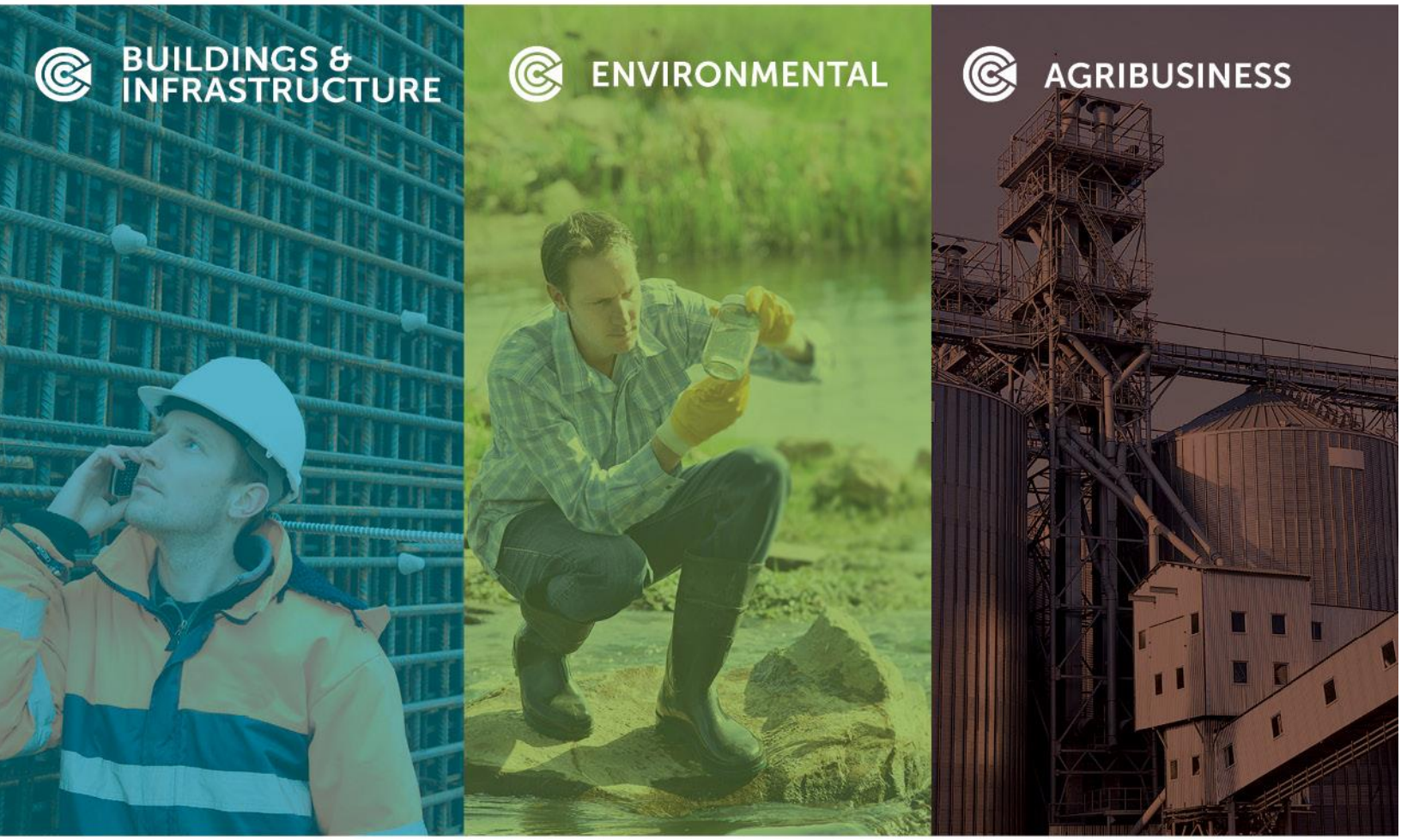

LAKE GERALDINE DAM
DAM SAFETY INSPECTION 2022 #1
IQALUIT, NUNAVUT

PRODUCED FOR: THE CITY OF IQALUIT
C/O COLLIERS PROJECT LEADERS

PRODUCED BY: CONCENTRIC ASSOCIATES INTERNATIONAL INCORPORATED

CONCENTRIC REFERENCE NUMBER: 21-9162

DATE: JUNE 30, 2022

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1. INTRODUCTION AND SCOPE OF WORK

This Dam Safety Inspection (DSI) of the Lake Geraldine Dam (LG Dam) has been prepared for the City of Iqaluit (City). As the owner and operator of the LG Dam, the City of Iqaluit is responsible for its safe management and operation. The intent of this DSI is to assist the City by identifying any visual changes in the condition of the LG Dam, identifying any new concerns, and making recommendations on maintenance, repairs, or further investigations.

1.1 Dam Safety Guidelines

The most recent Dam Safety Guidelines (DSG), published by the Canadian Dam Association, were first released in 2007 and further revised in 2013. The DSG applies, in general, to those structures that are at least 2.5 meters in height, and which have at least 30,000 cubic meters of storage capacity. The LG Dam exceeds these minimum requirements and therefore requires annual DSI's. The DSI is considered to be an Engineering Inspection which is recommended by the DSG to be performed annually or semi-annually by a professional engineer. A Dam Safety Review (DSR) is required at a minimum, every 5 years. The most recent DSR was performed in 2021.

This DSI forms part of the dam's permanent record documentation along with other documentation that make up the historical record of the dam (and berms). Section 3.6 "Surveillance" of the DSG recommends more frequent visual inspections be performed. Routine inspections performed by City staff trained in dam surveillance are recommended on a weekly basis to identify any conditions that might indicate a change in the dam's performance.

1.2 Description of Structure

The LG Dam is comprised of a concrete section with an integral concrete spillway, and three earthen berms: the north, center, and south berms. See below for a reference site plan and Appendix A for site photographs.

The 15.3 m wide spillway has an upper elevation of 111.1 m (representing the current maximum operating level of the reservoir), while the concrete dam sections on either side of the spillway have an elevation of 112.3 m. At the maximum operating level of the reservoir, the concrete dam has approximately 0.95 m of freeboard.

The southern section of the concrete dam extends approximately 39.1 m to the south rock abutment. The northern section of the concrete dam extends 13.3 m to the north of the spillway section, where it joins the center earth berm.

The center earth berm extends north approximately 75 m where it meets the access ramp and north access road. The north earth berm is located to the north of the access road ramp and extends 60m to the north rock abutment.

The south earth berm is a separate structure that is located in a valley to the south of the main concrete dam. The south berm is approximately 68.5 m long. The north and center berms incorporate a concrete cutoff wall which is reportedly founded in rock at the base of the berms.

Site Plan

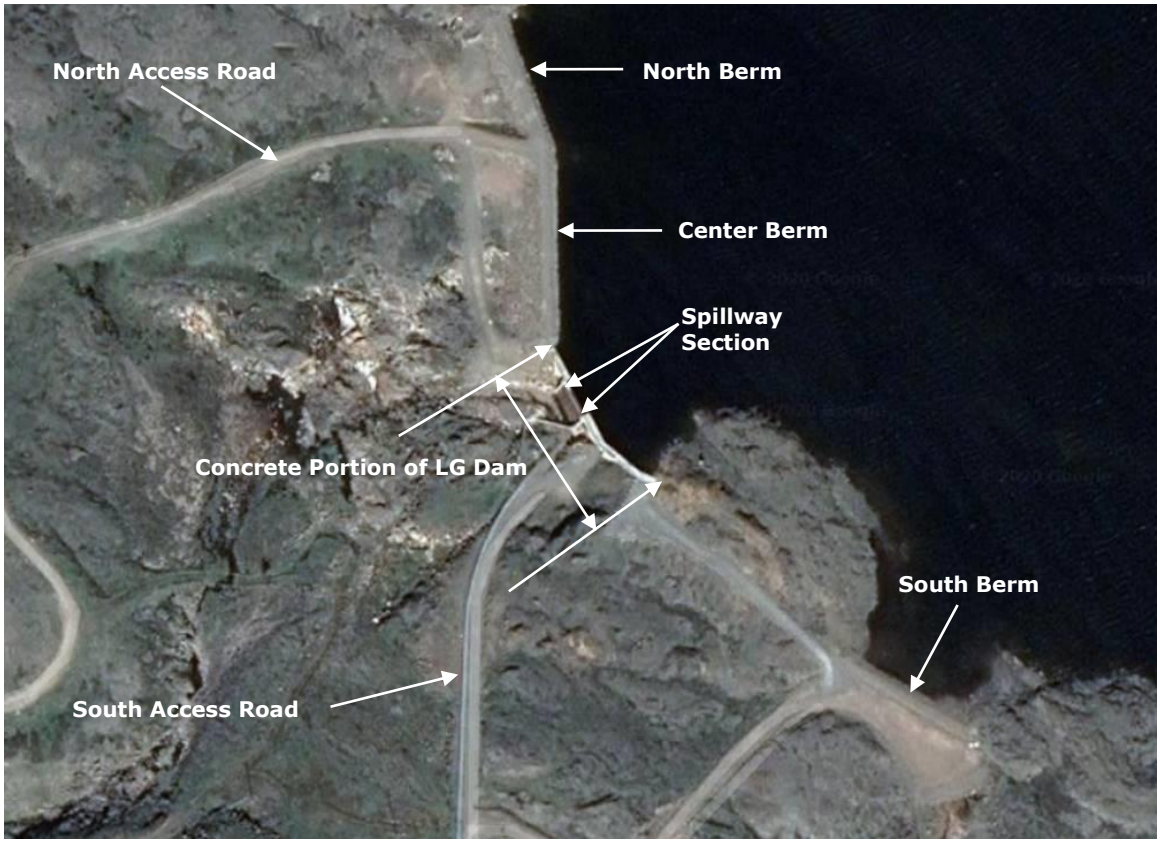

Table 1.1: Lake Geraldine Dam Summary*

Dam/Berm Segment	Length (m)	Crest Elevation	Base Elevation	Bedrock Elevation	Height of Dam/Berm (m)
North Berm	55.5	112.5	108.3	105.0	4.3
Center Berm	78.0	112.5	108.3	97.5	4.5
North Dam	13.3	112.3	102.6	97.5	11.0
Spillway	15.3	111.1	101.6	96	10.0
South Dam	39.1	112.3	102.6	67.5	11.0
South Berm	68.5	112.5	111.5	110.0	1.0

*Tabular data based upon Meco "Dam Safety Management Plan", July 2020

1.3 Scope of Work

As per the requirements of the Dam Safety Guide, the primary task of this DSI is to help identify any significant visual changes in the condition of the concrete dam and earthen berms based on a comparison with the previous inspections and reviews. A visual inspection can identify issues related to dam safety and provides the City of Iqaluit with the opportunity to mitigate any observed concerns or issues. This DSI report is the

primary deliverable and has been prepared in accordance with the Dam Safety Guide document.

The following is a summary of the scope of work for this assignment:

- Conduct a visual on-site assessment of the dam and berms above the water line;
- Prepare a photographic record documenting general and representative conditions;
- Identify, characterize, and risk-assess any significant visual changes in condition;
- Prepare a written report summarizing our observations, items of concern, and recommendations;
- Indicate any recommended repairs and outstanding recommendations from previous inspections and reviews;
- Submit final documents in electronic format.

2. HISTORY & BACKGROUND

2.1 Reservoir

The City of Iqaluit derives its water supply from Lake Geraldine, which is retained by a structure consisting of a cast in place concrete section incorporating an integral spillway, and three earthen berms. All concrete structures are reported to be founded on bedrock and engage the rock abutment at the south end of the concrete structure.

Lake Geraldine is a natural body of water in an irregularly shaped basin. It is fed by rainfall and snow/ice melt from a watershed with an area of approximately 385 hectares.

2.2 History

In the late 1950's, the demand for a reliable year-round source of water resulted in the construction of a cast in place concrete gravity dam and a section of earth berm with a central cast in place concrete cut off wall. The project was designed and built by the Department of National Defense. According to the literature, the original construction took place circa 1958.

Since that time, as the City has grown and water demands have risen, the dam has been raised four times to increase the storage capacity. In recent years, the City of Iqaluit has been pumping additional water into the reservoir in the fall of the year from a river located east of the reservoir.

The first height increase of the concrete dam and berms (0.3m) reportedly took place in 1979. This involved a concrete extension, which was dowelled into the existing structure.

The second height increase of the concrete dam and berms took place in 1985 and increased the height of the spillway structure by approximately 1.15m. The berm portion was widened and heightened as well to accommodate the increased storage capacity of the reservoir. The extension of the concrete dam was constructed of concrete dowelled into the existing structure and incorporated a steel formwork frame over the spillway section.

The third extension was undertaken in 1995 and increased the height of the concrete structures by a further 1.5m, with a corresponding increase in berm geometry. Based on analysis done prior to the extension, it was determined that the concrete structures would not have an adequate factor of safety against overturning if the extension was simply "dowelled-in" as before. The 1995 alteration therefore included an extensive rock-anchoring program for the concrete portions to provide the required stability to the structure.

The latest extension was completed in two phases over 2005/06. Additional rock anchors were installed thought the concrete structures in 2005 in preparation for a further height extension of 2 m in 2006. The existing berms were enlarged and the existing cut-of-walls within the north and center berms were extended in height. A new berm (south berm) and cut off wall were installed to the south of the main dam structure.

The last major repair program undertaken was completed in the summer of 2021, various repairs were undertaken to maintain the concrete structures, berms, and access roads. These repairs included:

- Placement of additional aggregate material and regrading of the north and south access roads.
- Installation of additional riprap/armor stone on the upstream face of the center and north berms.
- Installation of additional aggregate and regrading of the top of the center and north berms.
- Crack repair and sealing on the downstream face of the concrete structures.
- Concrete repair on the downstream face of the dam.

Replacement of the expansion joint sealant material on the downstream face of the concrete structures was not completed in 2021. This work is currently scheduled to be completed in June 2022.

In August 2019 various repairs were undertaken to repair the upstream face (below the water line) of the dam. These repairs included:

- Repair of the expansion joint.
- Polyurethane crack injection.
- Localized concrete repairs.

3. DAM SAFETY INSPECTION

3.1 Site Inspections and Staff Interviews

A visual site inspection of the LG Dam was performed on April 28-29, 2022 by Ryan Terpstra, B.Eng., of Concentric. The inspection was non-invasive in nature and did not include an underwater survey or assessment.

A summary of observed conditions is as follows:

- Ice had formed on Lake Geraldine and snow accumulation was present on and at the base the berms, concrete structures, and Lake Geraldine.

- The reservoir level (top of ice) was approximately 250 mm below the top of the spillway at the time of our review. The water level within the reservoir reported by Natural Resources Canada on April 29, 2022 was 108.657 m, approximately 2.4 m below the level of the spillway. For reference the water level within the reservoir on April 30, 2021 was 109.287 m, the water level this year (April 30, 2022) is approximately 0.63 m lower than this time in 2021.
- No significant changes were noted in the general condition of the concrete structures. No active seepage/leakage was observed within the visible portions of the concrete structures. Direct access to the base of the concrete structures and berms was obstructed by significant snow accumulation. Based upon our previous inspections and experience; water leakage/seepage is likely present at or near the base of the Gridline J5 expansion joint in the concrete structure.
- Although the majority of the north, center, and south berms were covered in snow and ice, no significant changes, such as sloughing, slides, bulging or displacement was noted in the earthen berms. No active seepage/leakage was observed within the visible portions of the berms however, based upon our previous inspections and experience; water leakage/seepage may be present.
- The aggregate stockpiles located on the downstream side of the north berm could not be verified due to the accumulation of snow and ice at this location. Stockpile levels will be verified during our next visit to the site.
- Examination of the access roads was undertaken, however; a detailed examination was not possible due to the accumulation of ice and snow. The roads will be re-examined during our next site visit.
- Members of the public continue to access the Dam, and Lake Geraldine (when iced over). Approximately 8 – 12 people were observed traveling across the lake during our site review (see photograph 6). There appears to be a trail that has been established that originates at the gap in the snow/wind fencing to the south of the south berm and continues across the lake.
- Ice accumulation within the valley on the downstream side of the dam (see photo 5). The timing of this visual inspection was called in part to reported ice buildup below the concrete dam and central earth berm, see photograph 5. Similar ice buildups have been reported over the years, usually reported to Concentric in spring time. Previous investigations have not concluded the source of the ice buildup, with further investigation in combination with additional monitoring have not been pursued by the City.
- The valve chamber adjacent to the south side of the concrete spillway was inaccessible due to heavy snow accumulation at this location. We did not inspect or exercise the valve controls. The 2015 DSI identified that the valve controls within the chamber appeared to be in an advanced state of corrosion and it remains unclear if this issue has been addressed and or the valves tested in recent years.

3.2 Dam Safety Analysis

A dam safety analysis was not completed as part of this inspection, however; there were no obvious indicators that the concrete structures have had significant changes since the last DSI in 2021. The deep snow and ice on and around the Lake Geraldine Dam at the time of our inspection may have obstructed visual indicators such as sloughing, slides, bulging or displacement.

3.3 Operation, Maintenance, and Surveillance

This DSI falls under the requirements of a visual inspection by an engineer as stated in Section 3.6 "Surveillance" of the Dam Safety Guide. The lack of a centralized repository of operational and maintenance records has been an ongoing issue. This, along with other issues regarding the operation and maintenance of the dam and reservoir, is noted within both the "Dam Safety Management Plan" dated July 16, 2020 prepared by MECO and the 2021 Dam Safety Review dated May 31, 2022 prepared by Concentric.

3.4 Recommendations and Required Action

Based on our inspection and review, we recommend the following:

1. Appoint a person or third party to control and update the Permanent Record File.
2. Updating of the permanent record file and its storage in a central location with an index that documents the date and contents of all records.

   The permanent record file needs to include:

   a) As-built drawings and specification for work undertaken at the dam.

   b) Weekly/monthly inspections completed by City staff.

   c) Dam Safety Inspections and Dam Safety Reviews generated by third parties on behalf of the City of Iqaluit.

   d) All maintenance records.

   e) Correspondence with regulatory agencies.

   f) Dam operation, maintenance and surveillance documents.

   g) Reports and documentation generated by third parties on behalf of the City of Iqaluit.
3. Appoint a person or third party to control and update the Emergency Preparedness Plan and Emergency Response Plan. Review EPP and ERP, issue to local authorities, and update the list of EPP document holders. Provide training to personnel and external responders.
4. Implement a public awareness program to educate and inform the public that:

   a) The dam and earthen berms are a no trespass area.

   b) Dog walkers should not allow their pets to travel atop and across the earthen berms due to the risk of (dog) fecal matter contamination of the potable water supply.

   c) ATV and skidoos should not be traveling atop the berms and across Lake Geraldine.
5. Implementation of a monitoring program to record data from the installed network of piezometers and thermistors used to monitor hydrogeologic and thermal environments within the backfill and foundations. This work is tentatively scheduled for implementation in summer of 2022.
6. The installation of video surveillance is tentatively scheduled for implementation in the fall of 2022 - summer of 2023.

7. Removal and replacement of the sealant installed within the expansion joints on the top and downstream face of the concrete dam (to be completed by Tower Construction in June 2022).
8. Exercising and testing of the valves within the valve chamber is required as part of preventative measures. The condition of the valves within the valve chamber at the base of the dam were previously identified as being in an advanced state of corrosion. To our knowledge no maintenance or testing has been completed on the controls valve in the last 5+ years. There is a significant potential for the valves to fail and not operate correctly when needed in an emergency.
9. Underwater survey of the concrete dam and spillway in 2022 - 2023.
10. Repair of cracks within the concrete dam, including crack injection. This work is tentatively scheduled for summer 2022.
11. Repair of spalled concrete within the concrete dam, this work is tentatively scheduled for summer 2022.
12. Install survey monuments and implement a biannual survey program as per the last DSR.
13. Install remote surveillance cameras as per the Last DSR.
14. The City should commit to determining the likely sources of ice buildup below the concrete dam and earth berms. This accumulation of ice is not seen in adjacent hills and valleys, it would be logical to believe that the ice accumulation is related to the water reservoir located directly up hill. We are aware of 3 potential sources of water; the north berm adjacent to the north road, the center berm at the low valley, and the south end of the concrete dam south of the spill way. Regular inspection and records of these locations should be included. Snow clearing may also be required to accommodate inspection and recording. The priority should be to identify the sources of water, and then determine if the water movement poses a threat to the stability of the dam and berm structures.

4. LIMITATIONS

This report was prepared for the sole use of the City of Iqaluit.

This report was prepared exclusively for the purposed project and site locations outlined in this report. The report is based on information provided to, or obtained by Concentric as indicated in the report, and applies solely to site conditions existing at the time of the site investigations.

The conditions of the site may change over time or may have already changed due to natural forces or human intervention, and Concentric takes no responsibility for the impact that such changes may have on the accuracy or validity of the observations, conclusions and recommendations set out in this report.

The report does not extend to any latent defect or other deficiency which could not have been reasonably discoverable or discovered within the scope of the report. Information supplied by the City of Iqaluit or third parties for use in this report has not been verified by Concentric unless stated otherwise.

Concentric's report represents a review of available information with an established work scope, schedule, and budget. The material in the report reflects Concentric's judgement in light of the information available to it at the time of preparation. Any uses that a third party makes of this report, or any reliance on decisions made based on it, are the responsibilities of such third parties.

Concentric accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made based on this report.

Should there be any questions, please contact the undersigned.

Yours sincerely,

CONCENTRIC

Ryan Terpstra, B.Eng.
Designer

Kathleen Perry-Theriault, P.Eng.
Project Manager

APPENDIX A
Site Photographs

Photograph 1 – Overview of concrete structure, center berm and north berm.

Photograph 2 – Typical center berm condition at the time of our review.

Photograph 3 – Typical north berm condition at the time of our review.

Photograph 4 – Typical snow and ice accumulation on the downstream face of the north and center berms.

Photograph 5 – Snow and ice accumulation within the valley downstream of the concrete dam and earthen berms.

Photograph 6 – Typical public access atop and over the dam and onto the reservoir.

Photograph 7 – Typical damage to the fencing atop the dam.

Photograph 8 – Typical concrete condition, south of the spillway.

APPENDIX B

Lake Geraldine Dam Inspection Checklist

Lake Geraldine Dam
Inspection Check List

Inspector Name:	Ryan Terpstra, Concentric	Reviewer:	-
Inspection Date:	April 28, 2022	Review Date:	-
Weather:	Cold, cloudy -10°C	Action Required:	None at this time (snow covered)

Sketch the deficiency, and note its important characteristics.
Measure the deficiency.
Photograph the deficiency or describe its characteristics in writing.
Locate the deficiency relative to a recognizable reference point.

General Observations

Description	Yes	No	Observations	Action Required
Snow and ice present on dam & berms	X		Snow up to berms, top of berm exposed 50%	
Snow and ice present on the lake	X		Evidence of ice about 20' down from top of dam/berm	
North access road, gate secured (Any visible damage)	X		No damage	
South access road, gate secured (Any visible damage)		X	No gate present	Yes
Gates on the concrete dam locked (north and south ends on top of dam)	X		Yes locked	
Gates and fencing on top of dam intact or damaged		X	Damage to berm wire on top of north gate Damage to top of chain link of south fence next to gate	

Lake Geraldine Dam
Inspection Check List

Description	Yes	No	Observations	Action Required
Vandalism		X	None	
Debris on site or in the lake		X	No debris	
Dam signage intact or damaged	X		Intact, no damage	
Valve chamber condition and damage (Indicate if there is any cracking, displacement, physical damage, cover is in place, etc)		X	None that could be seen	
Uncontrolled breach in the concrete dam or earthen berms (embankments)		X		
Animal Activity:		X		

Additional Comments, Sketches or Observations

Concrete Dam and Spillway				
Description	Yes	No	Observations	Action Required
Water level relative to sill of spillway (measure from top of the concrete dam) Is there flow over the spillway		X	Ice observed about 15' below spillway wall	
Cracking / spalling present on top (surface) of the concrete dam (Indicate if new, existing, expanded, length, width, depth)		X	None present on north side	
Cracking / spalling present on upstream face (surface) of the concrete dam (Indicate if new, existing, expanded, length, width, depth)		X	Snow covered not visible	
Cracking / Spalling present on Downstream face (surface) of the concrete dam (Indicate if new, existing, expanded, length, width, depth)	X		Small areas of efflorescence on north face down stream side + same on south side Small minor areas of spalling	
Active seepage / leakage through dam Is there silt / sand within the leaking water (Indicate location and rate of leakage in liters per minute)		X	None visible	
Sealant Condition – Top of Dam	X		Fair to good	
Sealant Condition – Up stream face of Dam			Not visible	
Sealant Condition – Downstream face of Dam	X		Good from what is visible	
Active seepage / leakage at: - Interface between concrete and ground (bedrock) - Sealant joints		X	None visible	

Description	Yes	No	Observations	Action Required
Displacement, settlement or misalignment of sections of the dam		X	None visible	
Debris / blockage within the spillway and or drainage channel at base of dam		X	None visible	
Erosion at the base of the spillway	X		Not visible due to snow cover	
Monitoring stations (condition, damage, other)			Not is place yet	

Additional Comments, Sketches or Observations

North Berm				
Description	Yes	No	Observations	Action Required
Sloughing, slides, bulging, collapse or displacement within the earthen berm – Top of Berm		X	Snow covered	
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Upstream Face		X	Snow covered	
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Downstream Face		X	Snow covered	
Depressions or sink holes within the top (crest) of the berm		X	Not visible/snow covered	
Depressions or sink holes within the upstream face of the berm		X	Not visible/snow covered	
Depressions or sink holes within the downstream face of the berm		X	Not visible/snow covered	
Rock, gravel or aggregate displacement or washout (erosion) with the top of the berm	X		Minor erosion at downstream side of berm top	
Rock, gravel or aggregate displacement or washout (erosion) within the upstream face of berm		X	Not visible/snow covered	
Rock, gravel or aggregate displacement or washout (erosion) within the downstream face of berm		X	Not visible/snow covered	

Description	Yes	No	Observations	Action Required
Displaced rip-rap /armor stone on the upstream face of berm		X	Not visible/snow covered	
Displaced rip-rap /armor stone on the downstream face of berm		X	Not visible/snow covered	
Transverse / longitudinal cracking, within the Top / crest of the berm (Indicate if new, existing, expanded, length, width)		X	Not visible/snow covered	
Transverse / longitudinal cracking, within the Upstream face of the berm (Indicate if new, existing, expanded, length, width)		X	Not visible/snow covered	
Transverse / longitudinal cracking, within the Downstream face of the berm (Indicate if new, existing, expanded, length, width)		X	Not visible/snow covered	
Wet area or active leakage / seepage within the downstream side face of berm Is there silt / sand within the leaking water		X	Not visible/snow covered	
Ponding water at base of the berm (downstream), is there sand or silt suspended within the water		X	Not visible/snow covered	
Additional Comments, Sketches or Observations				

Center Berm				
Description	Yes	No	Observations	Action Required
Sloughing, slides, bulging, collapse or displacement within the earthen berm – Top of Berm		X	Not visible/snow covered	
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Upstream Face		X	Not visible/snow covered	
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Downstream Face		X	Not visible/snow covered	
Depressions or sink holes within the top (crest) of the berm		X	Not visible/snow covered	
Depressions or sink holes within the upstream face of the berm		X	Not visible/snow covered	
Depressions or sink holes within the downstream face of the berm		X	Not visible/snow covered	
Rock, gravel or aggregate displacement or washout (erosion) with the top of the berm		X	Not visible/snow covered	
Rock, gravel or aggregate displacement or washout (erosion) within the upstream face of berm		X	Not visible/snow covered	
Rock, gravel or aggregate displacement or washout (erosion) within the downstream face of berm	X		Minor erosion of side face of berm	

Description	Yes	No	Observations	Action Required
Displaced rip-rap /armor stone on the upstream face of berm		X	Not visible/snow covered	
Displaced rip-rap /armor stone on the downstream face of berm		X	Not visible/snow covered	
Transverse / longitudinal cracking, within the Top / crest of the berm (Indicate if new, existing, expanded, length, width)		X	Not visible/snow covered	
Transverse / longitudinal cracking, within the Upstream face of the berm (Indicate if new, existing, expanded, length, width)		X	Not visible/snow covered	
Transverse / longitudinal cracking, within the Downstream face of the berm (Indicate if new, existing, expanded, length, width)		X	Not visible/snow covered	
Wet area or active leakage / seepage within the downstream side face of berm Is there silt / sand within the leaking water		X	Not visible/snow covered	
Ponding water at base of the berm (downstream), is there sand or silt suspended within the water		X	Not visible/snow covered	
Additional Comments, Sketches or Observations				

South Berm				
Description	Yes	No	Observations	Action Required
Sloughing, slides, bulging, collapse or displacement within the earthen berm – Top of Berm		X	Not visible/snow covered	
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Upstream Face		X	Not visible/snow covered	
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Downstream Face		X	Not visible/snow covered	
Depressions or sink holes within the top (crest) of the berm		X	Not visible/snow covered	
Depressions or sink holes within the upstream face of the berm		X	Not visible/snow covered	
Depressions or sink holes within the downstream face of the berm		X	Not visible/snow covered	
Rock, gravel or aggregate displacement or washout (erosion) with the top of the berm		X	Not visible/snow covered	
Rock, gravel or aggregate displacement or washout (erosion) within the upstream face of berm		X	Not visible/snow covered	
Rock, gravel or aggregate displacement or washout (erosion) within the downstream face of berm		X	Not visible/snow covered	

Description	Yes	No	Observations	Action Required
Displaced rip-rap /armor stone on the upstream face of berm		X	Not visible/snow covered	
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Wet area or active leakage / seepage within the downstream side face of berm Is there silt / sand within the leaking water		X	Not visible/snow covered	
Ponding water at base of the berm (downstream), is there sand or silt suspended within the water		X	Not visible/snow covered	
Additional Comments, Sketches or Observations				

Lake Geraldine Dam Location Plan

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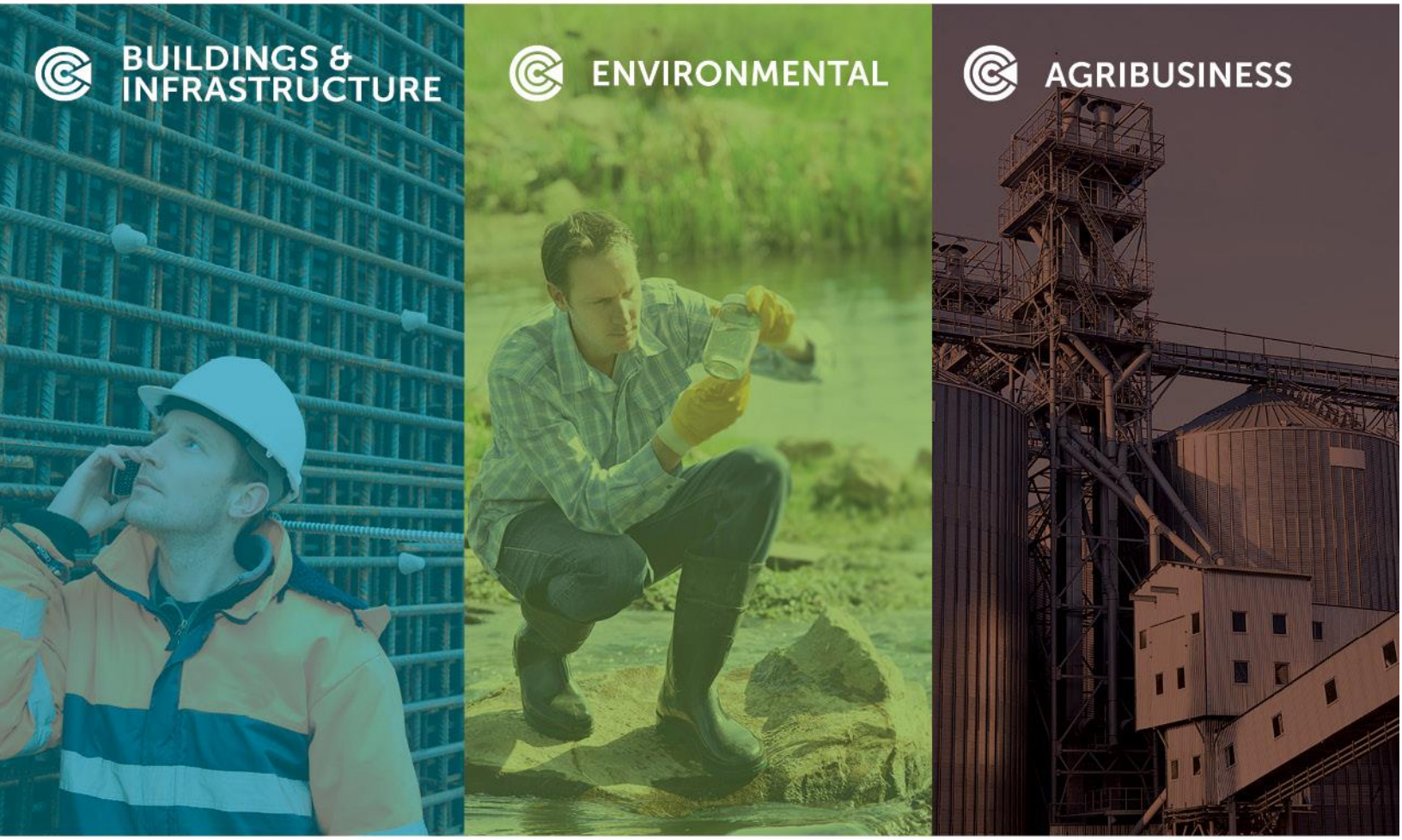

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1.2 Description of Structure

The LG Dam is comprised of a concrete section with an integral concrete spillway, and three earthen berms: the north, center, and south berms. See below for a reference site plan and Appendix A for site photographs.

The 15.3 m wide spillway has an upper elevation of 111.1 m (representing the current maximum operating level of the reservoir), while the concrete dam sections on either side of the spillway have an elevation of 112.3 m. At the maximum operating level of the reservoir, the concrete dam has approximately 0.95 m of freeboard.

The southern section of the concrete dam extends approximately 39.1 m to the south rock abutment. The northern section of the concrete dam extends 13.3 m to the north of the spillway section, where it joins the center earth berm.

The center earth berm extends north approximately 75 m where it meets the access ramp and north access road. The north earth berm is located to the north of the access road ramp and extends 60m to the north rock abutment.

The south earth berm is a separate structure that is located in a valley to the south of the main concrete dam. The south berm is approximately 68.5 m long. The north and center berms incorporate a concrete cutoff wall which is reportedly founded in rock at the base of the berms.

Site Plan

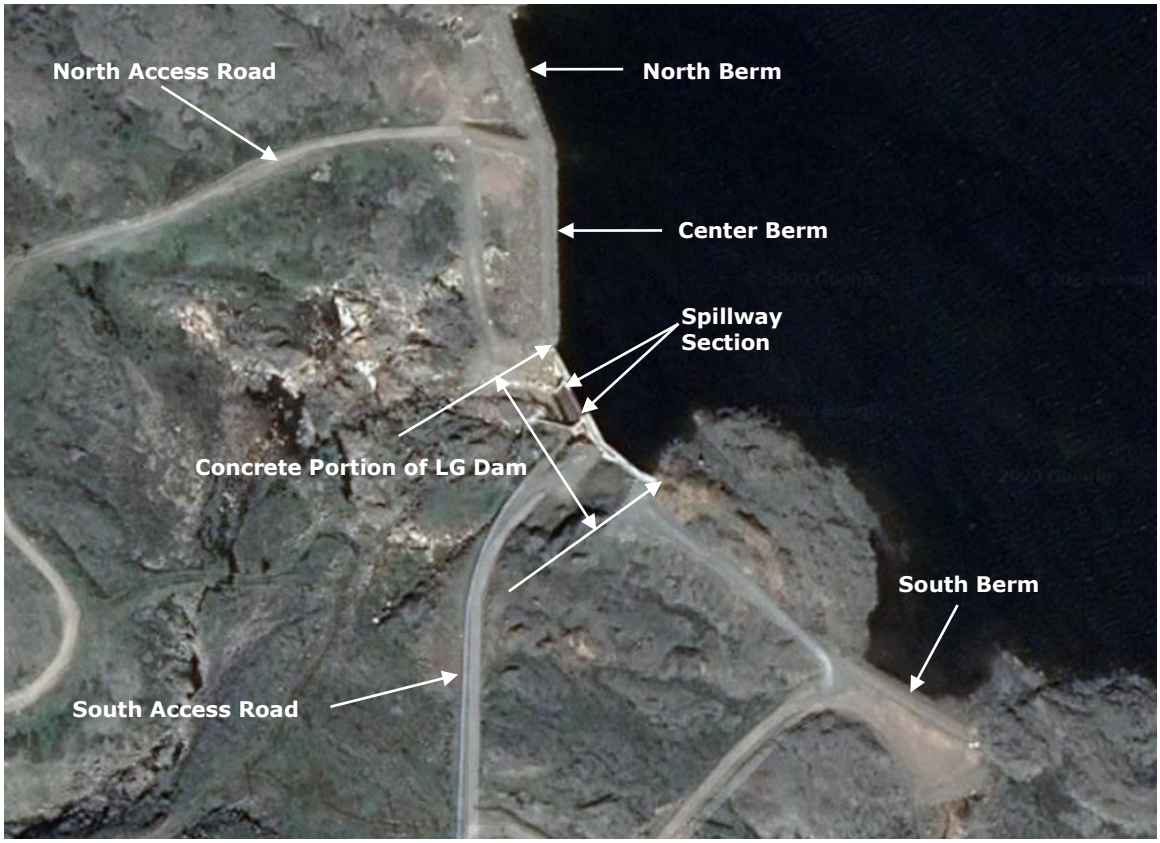


Table 1.1: Lake Geraldine Dam Summary*

Dam/Berm Segment	Length (m)	Crest Elevation	Base Elevation	Bedrock Elevation	Height of Dam/Berm (m)
North Berm	55.5	112.5	108.3	105.0	4.3
Center Berm	78.0	112.5	108.3	97.5	4.5
North Dam	13.3	112.3	102.6	97.5	11.0
Spillway	15.3	111.1	101.6	96	10.0
South Dam	39.1	112.3	102.6	67.5	11.0
South Berm	68.5	112.5	111.5	110.0	1.0

*Tabular data based upon Meco "Dam Safety Management Plan", July 2020

1.3 Scope of Work

As per the requirements of the Dam Safety Guide, the primary task of this DSI is to help identify any significant visual changes in the condition of the concrete dam and earthen berms based on a comparison with the previous inspections and reviews. A visual inspection can identify issues related to dam safety and provides the City of Iqaluit with the opportunity to mitigate any observed concerns or issues. This DSI report is the

primary deliverable and has been prepared in accordance with the Dam Safety Guide document.

The following is a summary of the scope of work for this assignment:

- Conduct a visual on-site assessment of the dam and berms above the water line;
- Prepare a photographic record documenting general and representative conditions;
- Identify, characterize, and risk-assess any significant visual changes in condition;
- Prepare a written report summarizing our observations, items of concern, and recommendations;
- Indicate any recommended repairs and outstanding recommendations from previous inspections and reviews;
- Develop a prioritized list of recommended repairs, upgrades, and improvements with Class D cost estimates;
- Submit final documents in electronic format.

2. HISTORY & BACKGROUND

2.1 Reservoir

The City of Iqaluit derives its water supply from Lake Geraldine, which is retained by a structure consisting of a cast in place concrete section incorporating an integral spillway, and three earthen berms. All concrete structures are reported to be founded on bedrock and engage the rock abutment at the south end of the concrete structure.

Lake Geraldine is a natural body of water in an irregularly shaped basin. It is fed by rainfall and snow/ice melt from a watershed with an area of approximately 385 hectares.

2.2 History

In the late 1950's, the demand for a reliable year-round source of water resulted in the construction of a cast in place concrete gravity dam and a section of earth berm with a central cast in place concrete cut off wall. The project was designed and built by the Department of National Defense. According to the literature, the original construction took place circa 1958.

Since that time, as the City has grown and water demands have risen, the dam has been raised four times to increase the storage capacity. In recent years, the City of Iqaluit has been pumping additional water into the reservoir in the summer and fall of the year from a river located east of the reservoir.

The first height increase of the concrete dam and berms (0.3m) reportedly took place in 1979. This involved a concrete extension, which was dowelled into the existing structure.

The second height increase of the concrete dam and berms took place in 1985 and increased the height of the spillway structure by approximately 1.15m. The berm portion was widened and heightened as well to accommodate the increased storage capacity of the reservoir. The extension of the concrete dam was constructed of concrete dowelled

into the existing structure and incorporated a steel formwork frame over the spillway section.

The third extension was undertaken in 1995 and increased the height of the concrete structures by a further 1.5m, with a corresponding increase in berm geometry. Based on analysis done prior to the extension, it was determined that the concrete structures would not have an adequate factor of safety against overturning if the extension was simply "dowelled-in" as before. The 1995 alteration therefore included an extensive rock-anchoring program for the concrete portions to provide the required stability to the structure.

The latest extension was completed in two phases over 2005/06. Additional rock anchors were installed thought the concrete structures in 2005 in preparation for a further height extension of 2 m in 2006. The existing berms were enlarged and the existing cut-of-walls within the north and center berms were extended in height. A new berm (south berm) and cut off wall were installed to the south of the main dam structure. A subsequent technical analysis of the dam and earth berms completed in 2020 indicated that the spillway structure is marginally compliant for stability with relying on rock anchors to resist overturning. CDA guidelines indicate that it is not recommended that passive rock anchors are relied on for stability.

The last major repair program undertaken was completed in the summer of 2021, various repairs were undertaken to maintain the concrete structures, berms, and access roads. These repairs included:

- Placement of additional aggregate material and regrading of the north and south access roads.
- Installation of additional riprap/armor stone on the upstream face of the center and north berms.
- Installation of additional aggregate and regrading of the top of the center and north berms.
- Crack repair and sealing on the downstream face of the concrete structures.
- Concrete repair on the downstream face of the dam.

Replacement of the expansion joint sealant material on the downstream face of the concrete structures was not completed in 2021. This work is currently scheduled to be completed in June 2022.

In August 2019 various repairs were undertaken to repair the upstream face (below the water line) of the dam. These repairs included:

- Repair of the expansion joint.
- Polyurethane crack injection.
- Localized concrete repairs.

3. DAM SAFETY INSPECTION

3.1 Site Inspections and Staff Interviews

A visual site inspection of the LG Dam was performed on June 22-23, 2022 by Randy Scott, of Concentric. The inspection was non-invasive in nature and did not include an underwater survey or assessment.

A summary of observed conditions is as follows:

- Ice remains within Lake Geraldine and snow was present on the downstream face of the north berm.
- The reservoir level (top of ice) was approximately 2.5 m below the top of the spillway at the time of our review. The water level within the reservoir reported by Natural Resources Canada on June 22, 2022 was 109.95 m, approximately 2.4 m below the level of the spillway.
- The temporary road access to the south berm has been blocked with concrete barriers. See Photograph 4.
- The area around the base of the power pole that supplies power to the temporary water treatment facility at the south berm has what appears to be some form of oil / creosote around the base of the pole. See Photograph 5.
- A sink hole was found within the south access road, approximately 40’ south of the access control gate. See Photographs 6 & 7.
- No significant changes were noted in the general condition of the concrete structures. Seepage was observed at two locations within the visible portions of the concrete structures. See Photograph 8.
- The metal enclosures installed atop the piezometer boreholes have been removed and some of the borehole tube designated for the installation of the piezometers have been obstructed with grave and sand. See Photographs 9 & 10.
- Portions of the galvanized metal enclosure that covers the pipe that supplies water from the dam to the water treatment plant have been removed for some unknown reason. See Photographs 12 & 13.
- A metal corner post (used to indicate the edge of the road) has been knocked over by vehicle traffic. See Photograph 11.
- The warning signs installed along the north side of the south access road were removed when the temporary water treatment plant was in operation at the south berm. This signage has not been re-installed now that the treatment plant is no longer in operation.
- The warning signage that is placed at the base of the access ramp to the center/north berms has been pushed over.
- A small rut was observed at the north end of the south berm (presumably from a vehicle).
- Leakage was observed at the base of the interface between the bedrock and the concrete dam. Leakage of water has been observed at this location during previous inspections; however, there appears to be a minor increase in the flow observed at this location.

- Several depressions within the rip-rap stone of the berm on the upstream face of the north and center berms were noted. This area of the berms is generally below the water line and is not visible.
- With the exception of the above noted, no significant changes, such as sloughing, slides, bulging or displacement, were noted in the earthen berms. No active seepage/leakage was observed within the visible portions of the berms; however, based upon our previous inspections and experience, water leakage/seepage may be present within the center berm that is being masked by melt water from the snow and ice.
- The aggregate stockpiles located on the downstream side of the north berm have been used, it is our understanding that this material was used when the temporary water purification plant was operating. These stockpiles are scheduled to be replaced in the summer of 2022.
- Members of the public continue to access the Dam structures and Lake Geraldine.

Minor leakage at the base of the concrete dam at the interface with the bedrock has been consistent over the last 10+ years however, during our most recent site review we noted a minor increase in the flow of water at this location. Leakage at this location is believed to be caused by water moving through the fractured bedrock below the dam and seepage of water between the base of the concrete dam and bedrock. We did not observe any changes or displacement of the bedrock at the base of the dam. As such, we do not believe that the underlying bedrock has changed or been disturbed.

3.2 Dam Safety Analysis

A dam safety analysis was not completed as part of this inspection; however, there were no obvious indicators that the concrete structures have had significant changes since the last DSI.

3.3 Operation, Maintenance, and Surveillance

This DSI falls under the requirements of a visual inspection by an engineer as stated in Section 3.6 "Surveillance" of the Dam Safety Guide. The lack of a centralized repository of operational and maintenance records has been an ongoing issue. This, along with other issues regarding the operation and maintenance of the dam and reservoir, is noted within both the "Dam Safety Management Plan" dated July 16, 2020 prepared by MECO and the 2021 Dam Safety Review dated May 31, 2022 prepared by Concentric.

3.4 Recommendations and Required Action

Based on our inspection and review, we recommend the following:

1. Items deemed to be of an urgent need include:
    a. Repair the sink hole in the south access road.
    b. The contaminated soil around the base of the hydro pole adjacent to the south berm should be removed.
2. Updating of the permanent record file and its storage in a central location with an index that documents the date and contents of all records. The permanent record file needs to include:

a) As-built drawings and specification for work undertaken at the dam.

b) Weekly/monthly inspections completed by City staff.

c) Dam Safety Inspections and Dam Safety Reviews generated by third parties on behalf of the City of Iqaluit.

d) All maintenance records.

e) Correspondence with regulatory agencies.

f) Dam operation, maintenance, and surveillance documents.

g) Reports and documentation generated by third parties on behalf of the City of Iqaluit.

3. Implement a public awareness program to educate and inform the public that:

   a) The dam and earthen berms are a *no trespass* area.

   b) Dog walkers should not allow their pets to travel atop and across the earthen berms due to the risk of (dog) fecal matter contamination of the potable water supply.

   c) ATV and skidoos should not be traveling atop the berms and across Lake Geraldine.

4. The protective galvanized metal enclosure installed over the pipeline from the dam to the water treatment plant should be re-instated.

5. The metal posts / markers that were installed along the north side of the south access road to should be re-instated.

6. The warning signage at the base of the access ramp to the center – north berms should be repaired.

7. The aggregate stockpiles maintained at the west side of the north berm should be replenished.

8. Implementation of a monitoring program to record data from the installed network of piezometers and thermistors used to monitor hydrogeologic and thermal environments within the backfill and foundations. This work is tentatively scheduled for implementation in summer of 2022.

9. The installation of video surveillance is tentatively scheduled for implementation in the fall of 2022 - summer of 2023.

10. Exercising and testing of the valves within the valve chamber is required as part of preventative measures. The condition of the valves within the valve chamber at the base of the dam was previously identified as being in an advanced state of corrosion. To our knowledge no maintenance or testing has been completed on the controls valve in the last 5+ years. There is a significant potential for the valves to fail and not operate correctly when needed in an emergency.

11. Underwater survey of the concrete dam and spillway in 2023.

12. Undertake a test opening on the downstream side of the concrete dam and center berm in late January – early February 2023 to ascertain the source of the water that forms large ice sheets within the valley in the winter months.

13. Repair of cracks within the concrete dam, this work is tentatively scheduled for summer 2022.
14. Repair of spalled concrete within the concrete dam, this work is tentatively scheduled for summer 2022.

4. LIMITATIONS

This report was prepared for the sole use of the City of Iqaluit.

This report was prepared exclusively for the purposed project and site locations outlined in this report. The report is based on information provided to, or obtained by Concentric as indicated in the report, and applies solely to site conditions existing at the time of the site investigations.

The conditions of the site may change over time or may have already changed due to natural forces or human intervention, and Concentric takes no responsibility for the impact that such changes may have on the accuracy or validity of the observations, conclusions and recommendations set out in this report.

The report does not extend to any latent defect or other deficiency which could not have been reasonably discoverable or discovered within the scope of the report. Information supplied by the City of Iqaluit or third parties for use in this report has not been verified by Concentric unless stated otherwise.

Concentric's report represents a review of available information with an established work scope, schedule, and budget. The material in the report reflects Concentric's judgement in light of the information available to it at the time of preparation. Any uses that a third party makes of this report, or any reliance on decisions made based on it, are the responsibilities of such third parties.

Concentric accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made based on this report.

Should there be any questions, please contact the undersigned.

Yours sincerely,

CONCENTRIC

Randy Scott
Designer

Steve Parker, P.Eng.
Lead Project Manager

APPENDIX A
Site Photographs

Photograph 1 – Overview of concrete structure.

Photograph 2 – Typical south berm condition at the time of our review.

Photograph 3 – Typical north and center berm condition at the time of our review.

Photograph 4 – The temporary road to south berm has been blocked with a concrete barrier to limit public access to the dam and reservoir.

Photograph 5 – Oil residue on the ground around the base of the hydro pole, south berm.

Photograph 6 –Sink hole within the south access road, approximately 40’ south of the access gate.

Photograph 7 –Sink hole within the south access road, approximately 40’ south of the access gate.

Photograph 8 – Typical expansion joint seepage (concrete dam).

Photograph 9 – Borehole tube for piezometer (open).

Photograph 10 – Borehole tube for piezometer blocked with aggregate material.

Photograph 11 – Corner marker at the junction of the south access road and the road to the south berm has been knocked over.

Photograph 12 – Section of the supply pipe from the dam with the corrugates metal enclosure removed.

Photograph 13 – Section of the supply pipe from the dam with the corrugates metal enclosure removed.

APPENDIX B

Lake Geraldine Dam Inspection Checklist

CONCENTRIC

Lake Geraldine Dam
Inspection Check List

Iqaluit

Inspector Name: Randy Scott
Inspection Date: June 22/23, 2022
Weather: Clear & Sunny

Reviewer:
Review Date:
Action Required:

Sketch the deficiency, and note its important characteristics.
Measure the deficiency.
Photograph the deficiency or describe its characteristics in writing.
Locate the deficiency relative to a recognizable reference point.
https://wateroffice.ec.gc.ca/report/real_time_e.html?stn=10UH013

General Observations

Description	Yes	No	Observations	Action Required
Snow and ice present on dam & berms	✓		- Snow present on the down stream face of the north berm.	
Snow and ice present on the lake	✓		- Ice present within the reservoir.	
North access road, gate secured (Any visible damage)	✓			
South access road, gate secured (Any visible damage)		✓	- Sink hole found approx. 40' from gate - Warning signage along side of road damaged/missing	✓ Repair
Gates on the concrete dam locked (north and south ends on top of dam)	✓		- Sink hole observed approx. 40' south of gate, Recommend that it is repaired as soon as possible.	✓ Repair
Gates and fencing on top of dam intact or damaged		✓	- Minor damage to fence, no action required.	

CONCENTRIC

Lake Geraldine Dam Inspection Check List

Iqaluit

Description	Yes	No	Observations	Action Required
Vandalism		✓		
Debris on site or in the lake		✓	- NONE OBSERVED	
Dam signage intact or damaged		✓	- SIGNAGE AT BASE OF RAMP ACCESS TO BERMS PUSHED OVER	✓
Valve chamber condition and damage (Indicate if there is any cracking, displacement, physical damage, cover is in place, etc)	✓		- NO DAMAGE OBSERVED	
Uncontrolled breach in the concrete dam or earthen berms (embankments)		✓		
Animal Activity:		✓		

Additional Comments, Sketches or Observations

- SIGNAGE AT BASE OF RAMP ACCESS TO BERMS TO BE REPAIRED
- A SINK HOLE WAS NOTED APPROX. 40' SOUTH OF GATE IN THE SOUTH ACCESS ROAD, RECOMMEND THIS IS REPAIRED AS SOON AS POSSIBLE.
- THE TEMPORARY ROAD TO THE SOUTH BERM HAS BEEN CLOSED OFF WITH THE INSTALLATION OF A CONCRETE BARRIER
- WARNING SIGNAGE ALONG SIDE OF SOUTH ACCESS ROAD MISSING AND DAMAGED.

Concrete Dam and Spillway

Description	Yes	No	Observations	Action Required
Water level relative to sill of spillway (measure from top of the concrete dam) Is there flow over the spillway			- WATER LEVEL IS APPROX. 1.4M BELOW SPILLWAY	
Cracking / spalling present on top (surface) of the concrete dam (Indicate if new, existing, expanded, length, width, depth)		✓		
Cracking / spalling present on upstream face (surface) of the concrete dam (Indicate if new, existing, expanded, length, width, depth)		✓		
Cracking / Spalling present on Downstream face (surface) of the concrete dam (Indicate if new, existing, expanded, length, width, depth)	✓		- NO NEW CRACKING - MINOR SEEPAGE NOTED AT TWO LOCATIONS	✓ MONITOR
Active seepage / leakage through dam Is there silt / sand within the leaking water (Indicate location and rate of leakage in liters per minute)	✓		- MINOR SEEPAGE NOTED AT TWO LOCATIONS, SEE SKETCH	✓ MONITOR
Sealant Condition – Top of Dam	/	/	- POOR, TO BE REPLACED IN 2022	
Sealant Condition – Up stream face of Dam	/	/	- GOOD	
Sealant Condition – Downstream face of Dam	/	/	- POOR, TO BE REPLACED IN 2022	
Active seepage / leakage at: - Interface between concrete and ground (bedrock) - Sealant joints	✓		- LEAKAGE NOTE AT BASE OF CONCRETE DAM ALONG INTERFACE WITH BEDROCK, SEE SKETCH	✓ MONITOR

CONCENTRIC

Lake Geraldine Dam
Inspection Check List

Iqaluit

Description	Yes	No	Observations	Action Required
Displacement, settlement or misalignment of sections of the dam		✓		
Debris / blockage within the spillway and or drainage channel at base of dam		✓		
Erosion at the base of the spillway		✓	- RIP-RAP IN SPILLWAY NEED TO BE SPREAD OUT EVENLY	✓
Monitoring stations (condition, damage, other)	/		- NOT INSTALLED AT THIS TIME, SOME OF THE BOREHOLES FOR THE PIEZOMETERS HAVE GRAVEL IN THE TUBES.	

Additional Comments, Sketches or Observations

- LEAKAGE AT BASE OF CONCRETE DAM (SOUTH END) NEEDS TO BE MONITORED

- THE BOREHOLE CAPS AT THE PIEZOMETER LOCATIONS HAVE BEEN REMOVED (BY PERSONS UNKNOWN) AND GRAVEL HAS ENTERED INTO THE BOREHOLES, THIS MAY OBST

North Berm				
Description	Yes	No	Observations	Action Required
Sloughing, slides, bulging, collapse or displacement within the earthen berm – Top of Berm		✓		
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Upstream Face	✓		- THE LOW WATER LEVELS HAVE REVEALED SEVERAL POCKETS (FROM WAVE ACTION) IN THE RIP-RAP. RECOMMEND THIS IS REPAIRED ASAP.	✓
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Downstream Face		✓		
Depressions or sink holes within the top (crest) of the berm		✓		
Depressions or sink holes within the upstream face of the berm	✓		- SEE ABOVE	
Depressions or sink holes within the downstream face of the berm		✓		
Rock, gravel or aggregate displacement or washout (erosion) with the top of the berm		✓		
Rock, gravel or aggregate displacement or washout (erosion) within the upstream face of berm	✓		- SEE ABOVE	
Rock, gravel or aggregate displacement or washout (erosion) within the downstream face of berm		✓		

CONCENTRIC

Lake Geraldine Dam
Inspection Check List

Iqaluit

Description	Yes	No	Observations	Action Required
Displaced rip-rap /armor stone on the upstream face of berm	✓		- LOW WATER LEVELS REVEALED SEVERAL AREAS WHERE THE RIP-RAP HAS BEEN DISPLACED AND DEPRESSIONS ARE PRESENT	✓ REPAIR
Displaced rip-rap /armor stone on the downstream face of berm		✓		
Transverse / longitudinal cracking, within the Top / crest of the berm (Indicate if new, existing, expanded, length, width)		✓		
Transverse / longitudinal cracking, within the Upstream face of the berm (Indicate if new, existing, expanded, length, width)		✓		
Transverse / longitudinal cracking, within the Downstream face of the berm (Indicate if new, existing, expanded, length, width)		✓		
Wet area or active leakage / seepage within the downstream side face of berm Is there silt / sand within the leaking water		✓	- SNOW MELT STILL UNDERWAY	
Ponding water at base of the berm (downstream), is there sand or silt suspended within the water	✓		- LARGE PONDING AREA ON THE NORTH SIDE OF THE ACCESS RAMP TO BERMS, LIKELY MELT WATER	
Additional Comments, Sketches or Observations				

Center Berm

Description	Yes	No	Observations	Action Required
Sloughing, slides, bulging, collapse or displacement within the earthen berm – Top of Berm		✓		
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Upstream Face		✓		
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Downstream Face		✓		
Depressions or sink holes within the top (crest) of the berm		✓		
Depressions or sink holes within the upstream face of the berm	✓		- DEPRESSIONS NOTED AT BASE OF BERM WITHIN THE RIP-RAP	
Depressions or sink holes within the downstream face of the berm		✓		
Rock, gravel or aggregate displacement or washout (erosion) with the top of the berm		✓		
Rock, gravel or aggregate displacement or washout (erosion) within the upstream face of berm		✓		
Rock, gravel or aggregate displacement or washout (erosion) within the downstream face of berm		✓		

CONCENTRIC

Lake Geraldine Dam
Inspection Check List

Iqaluit

Description	Yes	No	Observations	Action Required
Displaced rip-rap /armor stone on the upstream face of berm		✓		
Displaced rip-rap /armor stone on the downstream face of berm	✓		- LOW WATER LEVEL IN RESERVOIR REVEALED SEVERAL DEPRESSIONS IN RIP-RAP, LIKELY FROM EROSION/WAVE ACTION	✓
Transverse / longitudinal cracking, within the Top / crest of the berm (Indicate if new, existing, expanded, length, width)		✓		
Transverse / longitudinal cracking, within the Upstream face of the berm (Indicate if new, existing, expanded, length, width)		✓		
Transverse / longitudinal cracking, within the Downstream face of the berm (Indicate if new, existing, expanded, length, width)		✓		
Wet area or active leakage / seepage within the downstream side face of berm Is there silt / sand within the leaking water	✓		- LIKELY MELT WATER	
Ponding water at base of the berm (downstream), is there sand or silt suspended within the water	✓		- LIKELY MELT WATER	

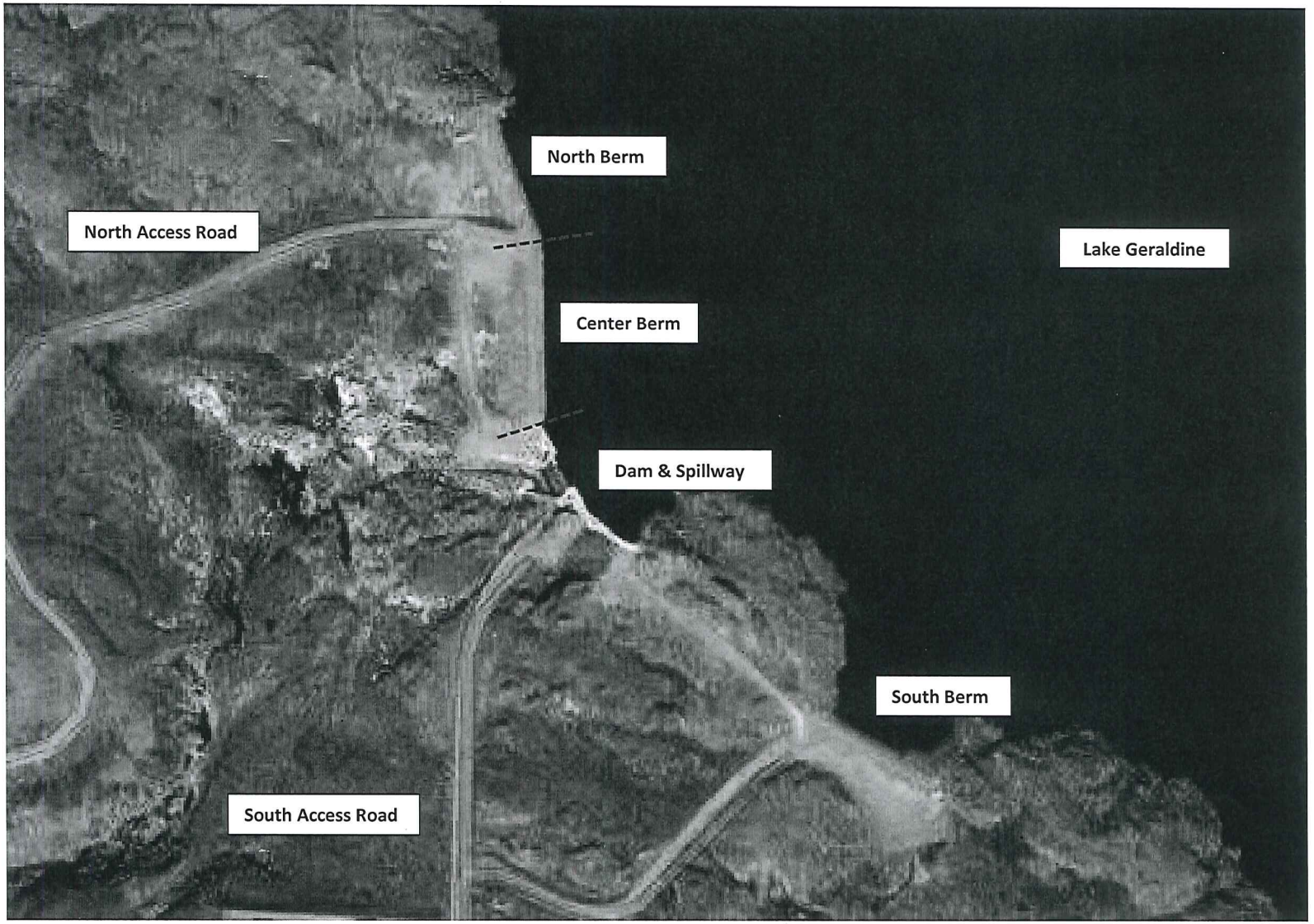
Additional Comments, Sketches or Observations

- DEPRESSIONS IN RIP-RAP ON UPSTREAM FACE OF BERM SHOULD BE REPAIRED BEFORE WATER LEVEL IS RESTORED IN RESERVOIR.

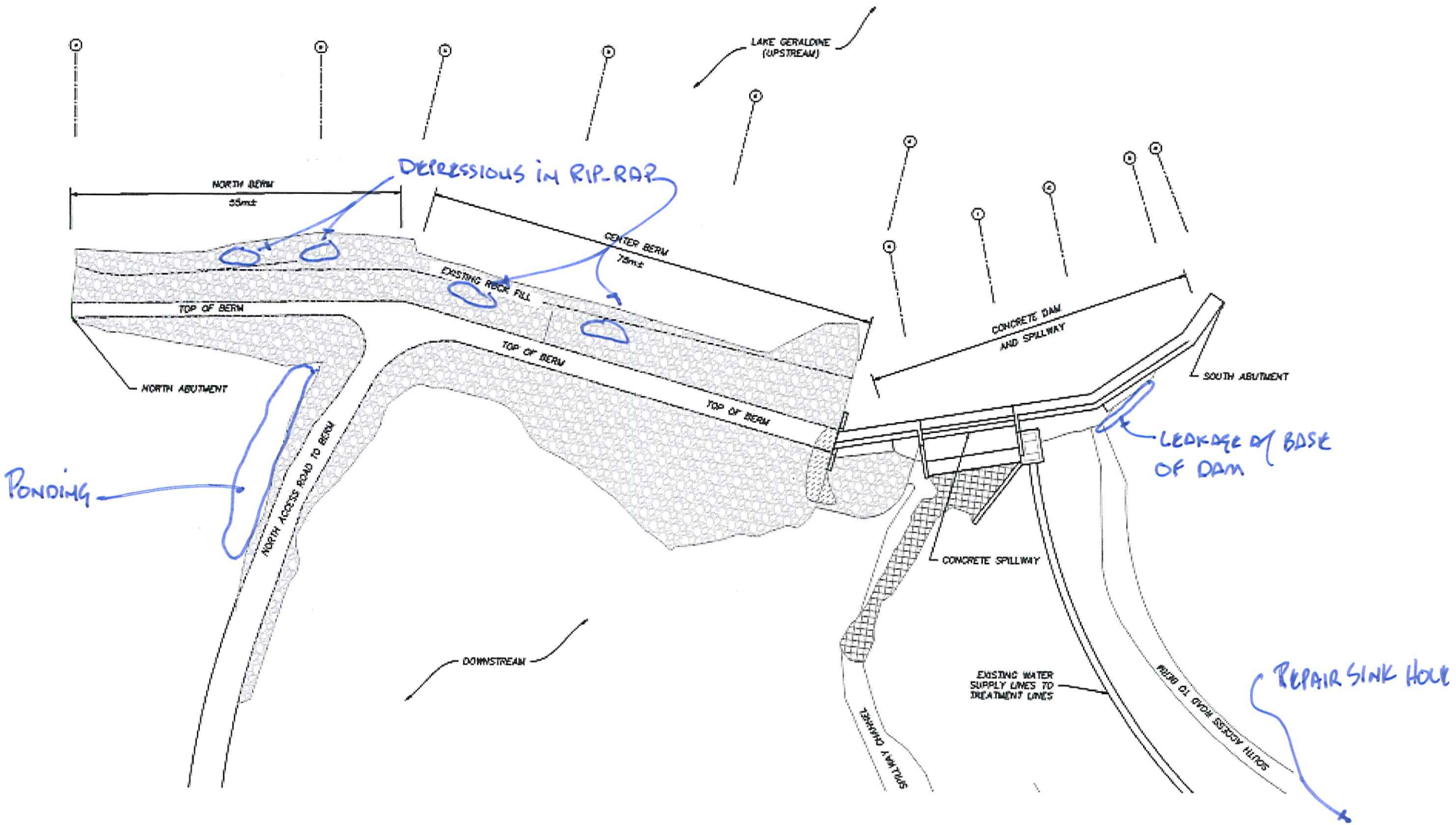
South Berm				
Description	Yes	No	Observations	Action Required
Sloughing, slides, bulging, collapse or displacement within the earthen berm – Top of Berm		✓		
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Upstream Face		✓		
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Downstream Face		✓		
Depressions or sink holes within the top (crest) of the berm		✓		
Depressions or sink holes within the upstream face of the berm		✓		
Depressions or sink holes within the downstream face of the berm		✓		
Rock, gravel or aggregate displacement or washout (erosion) with the top of the berm	✓		- RUT IN TOP OF BERM, LIKELY FROM A VEHICLE ↑ SMALL	
Rock, gravel or aggregate displacement or washout (erosion) within the upstream face of berm		✓		
Rock, gravel or aggregate displacement or washout (erosion) within the downstream face of berm		✓		

Description	Yes	No	Observations	Action Required
Displaced rip-rap /armor stone on the upstream face of berm		✓		
Displaced rip-rap /armor stone on the downstream face of berm		✓		
Transverse / longitudinal cracking, within the Top / crest of the berm (Indicate if new, existing, expanded, length, width)		✓		
Transverse / longitudinal cracking, within the Upstream face of the berm (Indicate if new, existing, expanded, length, width)		✓		
Transverse / longitudinal cracking, within the Downstream face of the berm (Indicate if new, existing, expanded, length, width)		✓		
Wet area or active leakage / seepage within the downstream side face of berm Is there silt / sand within the leaking water		✓		
Ponding water at base of the berm (downstream), is there sand or silt suspended within the water		✓		
Additional Comments, Sketches or Observations				

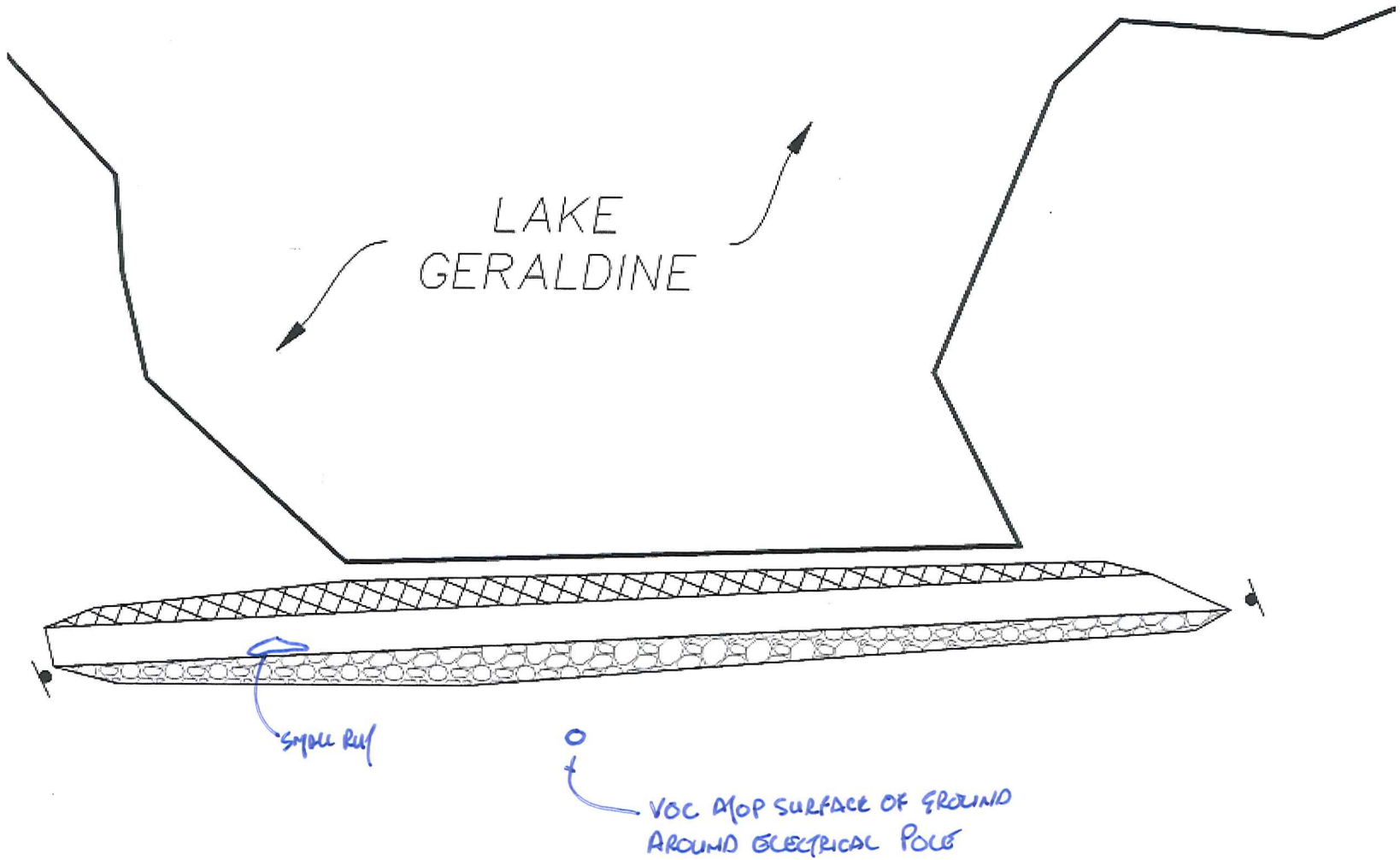
Lake Geraldine Dam Location Plan



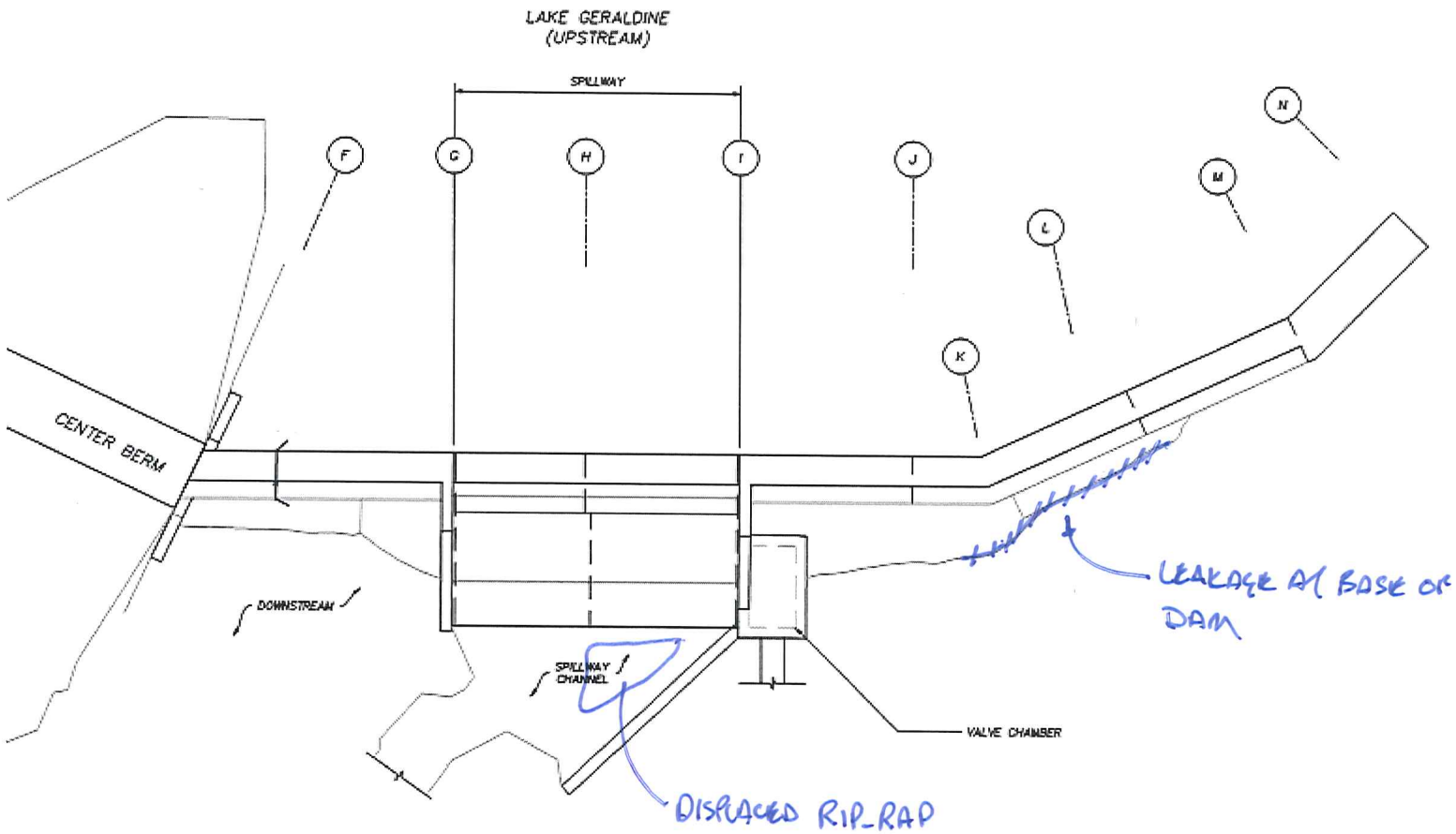
Site Plan – Concrete Dam, Center and North Berms



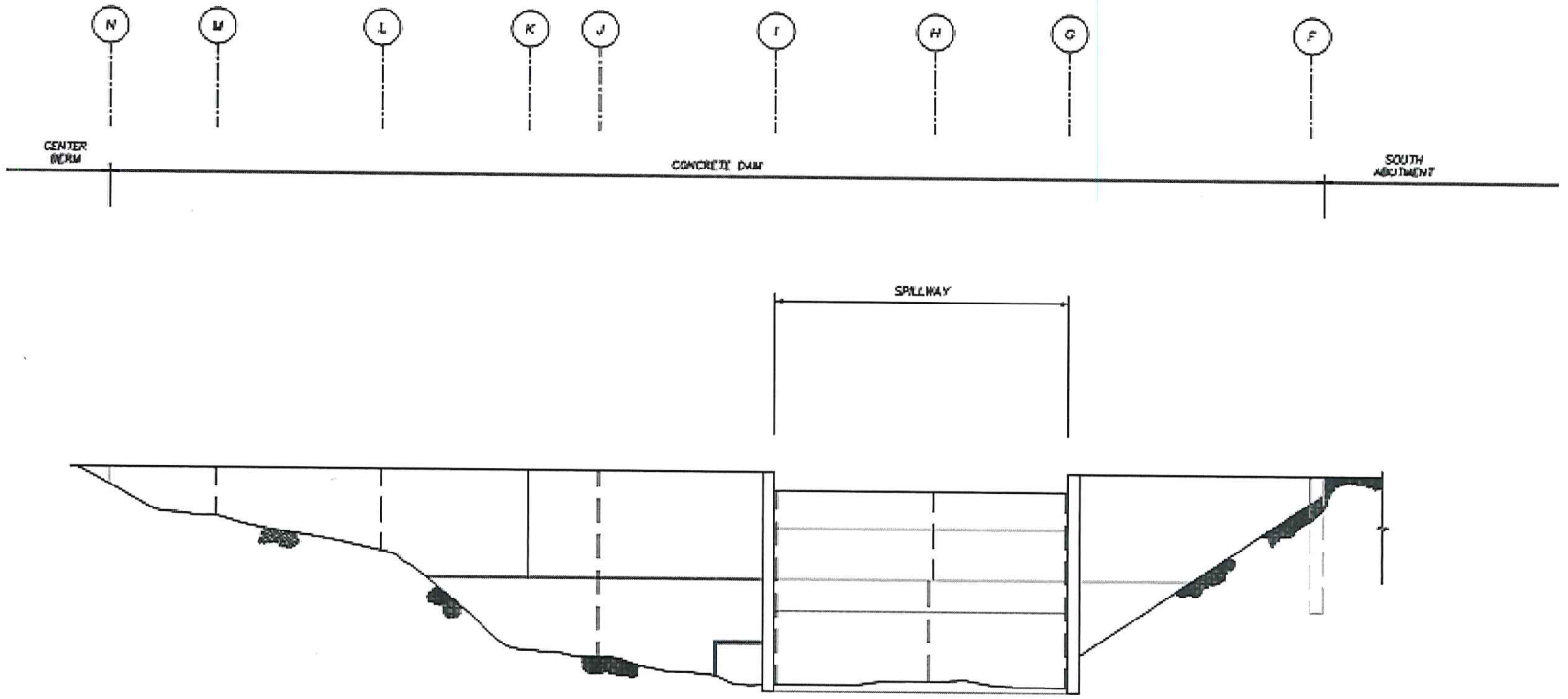
Site Plan – South Berm



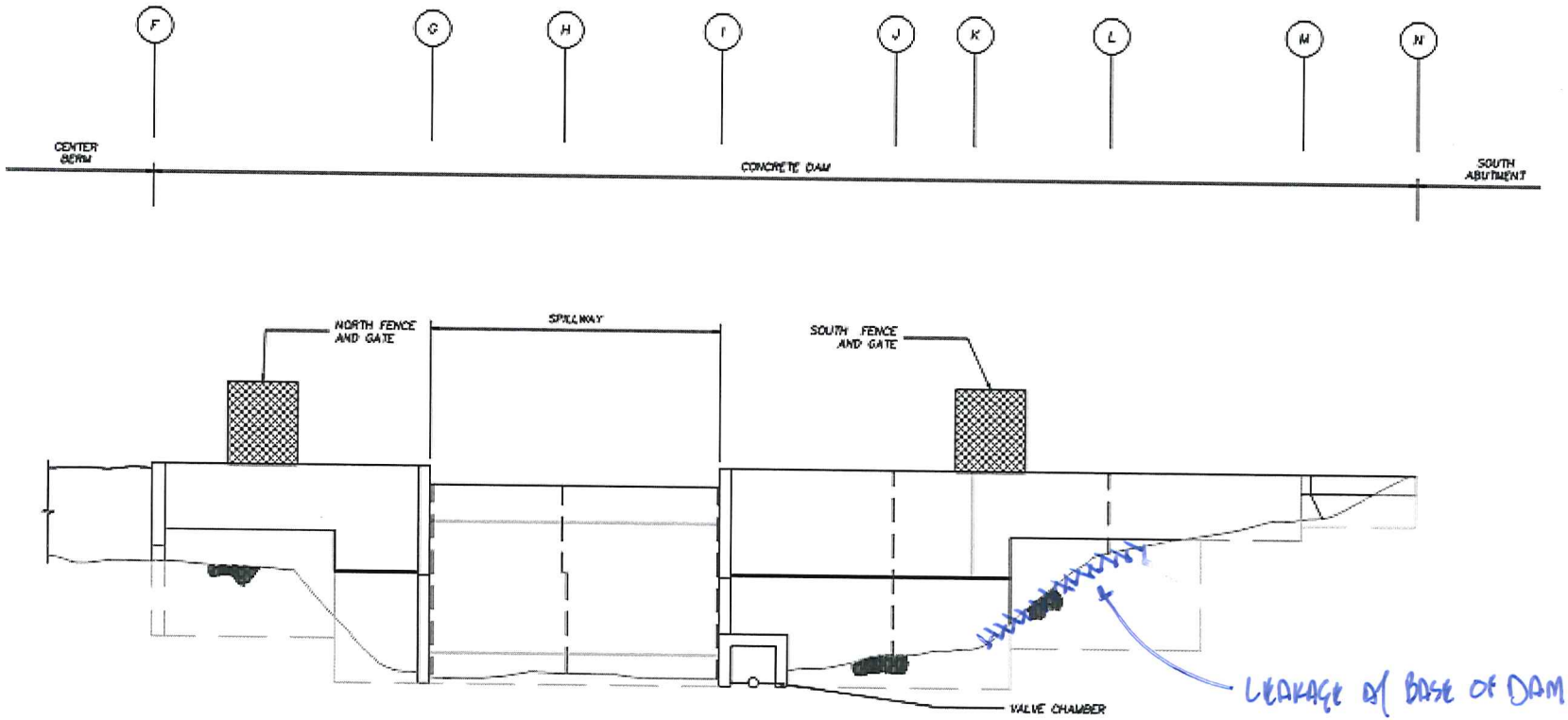
Plan View – Concrete Dam and Spillway



Elevation – Upstream Face, Concrete Dam and Spillway



Elevation – Downstream Face, Concrete Dam and Spillway



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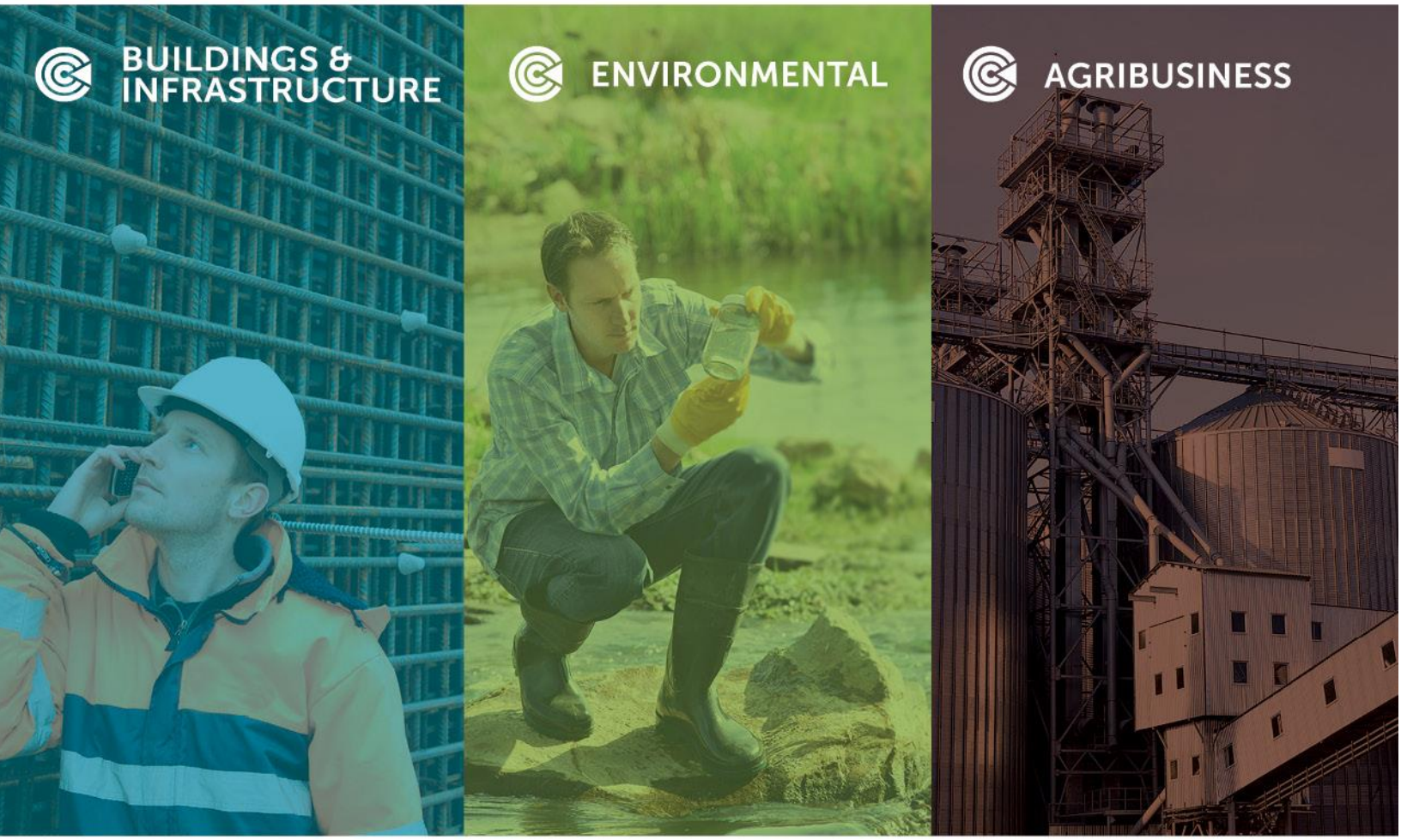

LAKE GERALDINE DAM
DAM SAFETY INSPECTION 2022 #3
IQALUIT, NUNAVUT

PRODUCED FOR: THE CITY OF IQALUIT
C/O COLLIERS PROJECT LEADERS

PRODUCED BY: CONCENTRIC ASSOCIATES INTERNATIONAL INCORPORATED

CONCENTRIC REFERENCE NUMBER: 21-9162

DATE: AUGUST 4TH, 2022

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LIST OF APPENDICES

1. INTRODUCTION AND SCOPE OF WORK

This Dam Safety Inspection (DSI) of the Lake Geraldine Dam (LG Dam) has been prepared for the City of Iqaluit (City). As the owner and operator of the LG Dam, the City of Iqaluit is responsible for its safe management and operation. The intent of this DSI is to assist the City by identifying any visual changes in the condition of the LG Dam, identifying any new concerns, and making recommendations on maintenance, repairs, or further investigations.

1.1 Dam Safety Guidelines

The most recent Dam Safety Guidelines (DSG), published by the Canadian Dam Association, were first released in 2007 and further revised in 2013. The DSG applies, in general, to those structures that are at least 2.5 meters in height, and which have at least 30,000 cubic meters of storage capacity. The LG Dam exceeds these minimum requirements and therefore requires annual DSI's. The DSI is considered to be an Engineering Inspection which is recommended by the DSG to be performed annually or semi-annually by a professional engineer. A Dam Safety Review (DSR) is required, at a minimum, every 5 years. The most recent DSR was performed in April 2022.

This DSI forms part of the dam's permanent record documentation along with other documentation that make up the historical record of the dam (and berms). Section 3.6 "Surveillance" of the DSG recommends more frequent visual inspections be performed. Routine inspections performed by City staff trained in dam surveillance are recommended on a weekly basis to identify any conditions that might indicate a change in the dam's performance.

1.2 Description of Structure

The LG Dam is comprised of a concrete section with an integral concrete spillway, and three earthen berms: the north, center, and south berms. See below for a reference site plan and Appendix A for site photographs.

The 15.3 m wide spillway has an upper elevation of 111.3 m (representing the current maximum operating level of the reservoir), while the concrete dam sections on either side of the spillway have an elevation of 112.3 m. At the maximum operating level of the reservoir, the concrete dam has approximately 0.95 m of freeboard.

The southern section of the concrete dam extends approximately 39.1 m to the south rock abutment. The northern section of the concrete dam extends 13.3 m to the north of the spillway section, where it joins the center earth berm.

The center earth berm extends north approximately 75 m where it meets the access ramp and north access road. The north earth berm is located to the north of the access road ramp and extends 60m to the north rock abutment.

The south earth berm is a separate structure that is located in a valley to the south of the main concrete dam. The south berm is approximately 68.5 m long. The north and center berms incorporate a concrete cutoff wall which is reportedly founded in rock at the base of the berms.

Site Plan

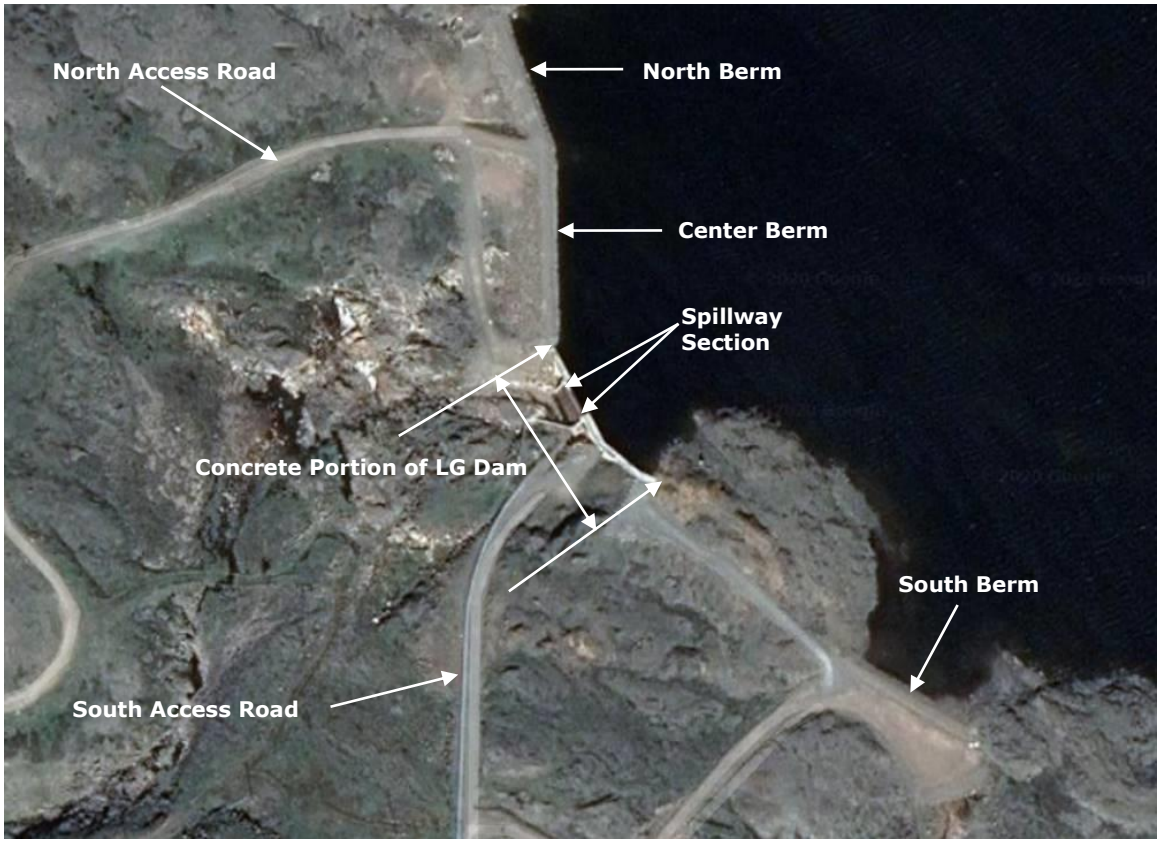

Table 1.1: Lake Geraldine Dam Summary*

Dam/Berm Segment	Length (m)	Crest Elevation	Base Elevation	Bedrock Elevation	Height of Dam/Berm (m)
North Berm	55.5	112.5	108.3	105.0	4.3
Center Berm	78.0	112.5	108.3	97.5	4.5
North Dam	13.3	112.3	102.6	97.5	11.0
Spillway	15.3	111.3	101.6	96	10.0
South Dam	39.1	112.3	102.6	67.5	11.0
South Berm	68.5	112.5	111.5	110.0	1.0

*Tabular data based upon Meco "Dam Safety Management Plan", July 2020

1.3 Scope of Work

As per the requirements of the Dam Safety Guide, the primary task of this DSI is to help identify any significant visual changes in the condition of the concrete dam and earthen berms based on a comparison with the previous inspections and reviews. A visual inspection can identify issues related to dam safety and provides the City of Iqaluit with the opportunity to mitigate any observed concerns or issues. This DSI report is the

primary deliverable and has been prepared in accordance with the Dam Safety Guide document.

The following is a summary of the scope of work for this assignment:

- Conduct a visual on-site assessment of the dam and berms above the water line;
- Prepare a photographic record documenting general and representative conditions;
- Identify, characterize, and risk-assess any significant visual changes in condition;
- Prepare a written report summarizing our observations, items of concern, and recommendations;
- Indicate any recommended repairs and outstanding recommendations from previous inspections and reviews;
- Develop a prioritized list of recommended repairs, upgrades, and improvements with Class D cost estimates;
- Submit final documents in electronic format.

2. HISTORY & BACKGROUND

2.1 Reservoir

The City of Iqaluit derives its water supply from Lake Geraldine, which is retained by a structure consisting of a cast in place concrete section incorporating an integral spillway, and three earthen berms. All concrete structures are reported to be founded on bedrock and engage the rock abutment at the south end of the concrete structure.

Lake Geraldine is a natural body of water in an irregularly shaped basin. It is fed by rainfall and snow/ice melt from a watershed with an area of approximately 385 hectares.

2.2 History

In the late 1950's, the demand for a reliable year-round source of water resulted in the construction of a cast in place concrete gravity dam and a section of earth berm with a central cast in place concrete cut off wall. The project was designed and built by the Department of National Defense. According to the literature, the original construction took place circa 1958.

Since that time, as the City has grown and water demands have risen, the dam has been raised four times to increase the storage capacity. In recent years, the City of Iqaluit has been pumping additional water into the reservoir in the summer and fall of the year from a river located east of the reservoir.

The first height increase of the concrete dam and berms (0.3m) reportedly took place in 1979. This involved a concrete extension, which was dowelled into the existing structure.

The second height increase of the concrete dam and berms took place in 1985 and increased the height of the spillway structure by approximately 1.15m. The berm portion was widened and heightened as well to accommodate the increased storage capacity of the reservoir. The extension of the concrete dam was constructed of concrete dowelled

into the existing structure and incorporated a steel formwork frame over the spillway section.

The third extension was undertaken in 1995 and increased the height of the concrete structures by a further 1.5m, with a corresponding increase in berm geometry. Based on analysis done prior to the extension, it was determined that the concrete structures would not have an adequate factor of safety against overturning if the extension was simply "dowelled-in" as before. The 1995 alteration therefore included an extensive rock-anchoring program for the concrete portions to provide the required stability to the structure.

The latest extension was completed in two phases over 2005/06. Additional rock anchors were installed thought the concrete structures in 2005 in preparation for a further height extension of 2 m in 2006. The existing berms were enlarged and the existing cut-of-walls within the north and center berms were extended in height. A new berm (south berm) and cut off wall were installed to the south of the main dam structure. A subsequent technical analysis of the dam and earth berms completed in 2020 indicated that the spillway structure is marginally compliant for stability with relying on rock anchors to resist overturning. CDA guidelines indicate that it is not recommended that passive rock anchors are relied on for stability.

The last major repair program undertaken was completed in the summer of 2021, various repairs were undertaken to maintain the concrete structures, berms, and access roads. These repairs included:

- Placement of additional aggregate material and regrading of the north and south access roads.
- Installation of additional riprap/armor stone on the upstream face of the center and north berms.
- Installation of additional aggregate and regrading of the top of the center and north berms.
- Crack repair and sealing on the downstream face of the concrete structures.
- Concrete repair on the downstream face of the dam.

Replacement of the expansion joint sealant material on the downstream face of the concrete structures was started in 2021 but unable to be completed due to local weather and site conditions. This work was completed in July 2022.

In August 2019 various repairs were undertaken to repair the upstream face (below the water line) of the dam. These repairs included:

- Repair of the expansion joint.
- Polyurethane crack injection.
- Localized concrete repairs.

3. DAM SAFETY INSPECTION

3.1 Site Inspections and Staff Interviews

A visual site inspection of the LG Dam was performed on August 4, 2022 by Cameron McDonald, of Concentric. The inspection was non-invasive in nature and did not include an underwater survey or assessment. For general overview photographs see photograph 1-3 in Appendix A.

A summary of observed conditions is as follows:

- Ice was observed in the spillway approximately 200m downstream of the Dam. No ice present in Lake Geraldine.
- The water level within the reservoir reported by Natural Resources Canada on August 4, 2022 was 110.m, the level of the spillway is 111.3m.
- The temporary road access to the south berm is still blocked with concrete barriers.
- The area around the base of the power pole that supplies power to the temporary water treatment facility at the south berm has what appears to be some form of oil / creosote around the base of the pole. See Photograph 4. This was reported in the last DSI report, no corrective measures have been taken to address this issue.
- The sink hole identified in the previous report, located within the south access road, approximately 40’ south of the access control gate has been repaired.
- No significant changes were noted in the general condition of the concrete structures.
- The metal enclosures installed atop the piezometer boreholes have been removed and some of the borehole tube designated for the installation of the piezometers have been obstructed with gravel and sand. See Photographs 6 & 7.
- No change in condition to the metal corner post (used to indicate the edge of the road) identified to have been knocked over by vehicle traffic in the previous report. See Photograph 8.
- Portions of the galvanized metal enclosure that covers the pipe that supplies water from the dam to the water treatment plant are still missing. See Photograph 9.
- No change in condition to the blizzard markers installed along the north side of the south access road identified in the previous report. See Photograph 10.
- The warning signage that is placed at the base of the access ramp to the center/north berms has been corrected. Signage was noted to have been bent in previous report.
- The warning signage at the south end of the south berm has not yet been installed. This item is part of a capital project that Tower Arctic Limited was engaged to install.
- No change in condition to the small rut identified in the previous report at the north end of the south berm (presumably from a vehicle).
- Leakage was observed at the base of the interface between the bedrock and the concrete dam. Leakage of water has been observed at this location during previous inspections. This leakage is steady and constant.

- A steady flow of water was observed at the toe of the road which leads from the North access road to the base of the concrete Dam. The source of this water is difficult to identify since this is the low point for the entire North and Centre earthen berms.
- A number of depressions within the rip-rap stone of the berm on the upstream face of the north and center berms were identified. This area of the berms is generally below the water line and is not always visible.
- The rip rap at the base of the concrete dam, within the spillway, needs to be adjusted. The rip rap has been displaced and is no longer covering all portions of the base of the dam. Miscellaneous deleterious materials were observed in the spillway.
- Depression noted in the rip rap lip on the south berm in line with the GN's mobile water treatment plant units. It appears rip rap may have been displaced to accommodate intake hoses. This should be corrected. See photograph 12.
- With the exception of the above noted, no significant changes, such as sloughing, slides, bulging or displacement, were noted in the earthen berms. No active seepage/leakage was observed within the visible portions of the berms; however, based upon our previous inspections and experience, water leakage/seepage may be present within the center berm that is being masked by melt water from the snow and ice.
- The aggregate stockpiles located on the downstream side of the north berm have been used, it is our understanding that this material was used when the temporary water purification plant was operating. These stockpiles are scheduled to be replaced in the summer of 2022.
- Members of the public continue to access the Dam structures and Lake Geraldine. Bungee cords were installed to suppress the barbed wire on top of the fence on the North Side of the Concrete Dam. See photograph 11.

Minor leakage at the base of the concrete dam at the interface with the bedrock has been consistent over the last 10+ years however, during our most recent site review we noted a minor increase in the flow of water at this location. Leakage at this location is believed to be caused by water moving through the fractured bedrock below the dam and seepage of water between the base of the concrete dam and bedrock. We did not observe any changes or displacement of the bedrock at the base of the dam. As such, we do not believe that the underlying bedrock has changed or been disturbed.

3.2 Dam Safety Analysis

A dam safety analysis was not completed as part of this inspection; however, there were no obvious indicators that the concrete structures have had significant changes since the last DSI.

3.3 Operation, Maintenance, and Surveillance

This DSI falls under the requirements of a visual inspection by an engineer as stated in Section 3.6 "Surveillance" of the Dam Safety Guide. The lack of a centralized repository of operational and maintenance records has been an ongoing issue. This, along with other issues regarding the operation and maintenance of the dam and reservoir, is noted

within both the "Dam Safety Management Plan" dated July 16, 2020 prepared by MECO and the 2021 Dam Safety Review dated May 31, 2022 prepared by Concentric.

3.4 Recommendations and Required Action

Based on our inspection and review, we recommend the following:

1. Items deemed to be of an urgent need include:
   a. Repair the sink hole in the south access road.
   b. The contaminated soil around the base of the hydro pole adjacent to the south berm should be removed.
2. Updating of the permanent record file and its storage in a central location with an index that documents the date and contents of all records. The permanent record file needs to include:
   a) As-built drawings and specification for work undertaken at the dam.
   b) Weekly/monthly inspections completed by City staff.
   c) Dam Safety Inspections and Dam Safety Reviews generated by third parties on behalf of the City of Iqaluit.
   d) All maintenance records.
   e) Correspondence with regulatory agencies.
   f) Dam operation, maintenance, and surveillance documents.
   g) Reports and documentation generated by third parties on behalf of the City of Iqaluit.
3. Implement a public awareness program to educate and inform the public that:
   a) The dam and earthen berms are a *no trespass* area.
   b) Dog walkers should not allow their pets to travel atop and across the earthen berms due to the risk of (dog) fecal matter contamination of the potable water supply.
   c) ATV and skidoos should not be traveling atop the berms and across Lake Geraldine.
4. The protective galvanized metal enclosure installed over the pipeline from the dam to the water treatment plant should be re-instated.
5. The metal posts / markers that were installed along the north side of the south access road to should be re-instated.
6. The warning signage at the base of the access ramp to the center – north berms should be repaired.
7. The aggregate stockpiles maintained at the west side of the north berm should be replenished.
8. Implementation of a monitoring program to record data from the installed network of piezometers and thermistors used to monitor hydrogeologic and thermal environments within the backfill and foundations. This work is tentatively scheduled for implementation in summer of 2022.

9. The installation of video surveillance is tentatively scheduled for implementation in the fall of 2022 - summer of 2023.
10. Exercising and testing of the valves within the valve chamber is required as part of preventative measures. The condition of the valves within the valve chamber at the base of the dam was previously identified as being in an advanced state of corrosion. To our knowledge no maintenance or testing has been completed on the controls valve in the last 5+ years. There is a significant potential for the valves to fail and not operate correctly when needed in an emergency.
11. Underwater survey of the concrete dam and spillway in 2023.
12. Undertake a test opening on the downstream side of the concrete dam and center berm in late January – early February 2023 to ascertain the source of the water that forms large ice sheets within the valley in the winter months.
13. Repair of cracks within the concrete dam, this work is tentatively scheduled for summer 2022.
14. Repair of spalled concrete within the concrete dam, this work is tentatively scheduled for summer 2022.

4. LIMITATIONS

This report was prepared for the sole use of the City of Iqaluit.

This report was prepared exclusively for the purposed project and site locations outlined in this report. The report is based on information provided to, or obtained by Concentric as indicated in the report, and applies solely to site conditions existing at the time of the site investigations.

The conditions of the site may change over time or may have already changed due to natural forces or human intervention, and Concentric takes no responsibility for the impact that such changes may have on the accuracy or validity of the observations, conclusions and recommendations set out in this report.

The report does not extend to any latent defect or other deficiency which could not have been reasonably discoverable or discovered within the scope of the report. Information supplied by the City of Iqaluit or third parties for use in this report has not been verified by Concentric unless stated otherwise.

Concentric's report represents a review of available information with an established work scope, schedule, and budget. The material in the report reflects Concentric's judgement in light of the information available to it at the time of preparation. Any uses that a third party makes of this report, or any reliance on decisions made based on it, are the responsibilities of such third parties.

Concentric accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made based on this report.

Should there be any questions, please contact the undersigned.

Yours sincerely,

CONCENTRIC

Cameron McDonald
Designer

Steve Parker, P.Eng.
Lead Project Manager

APPENDIX A
Site Photographs

Photograph 1 – Overview of concrete structure.

Photograph 2 – Typical south berm condition at the time of our review.

Photograph 3 – Typical north and center berm condition at the time of our review.

Photograph 4 – Oil residue on the ground around the base of the hydro pole, south berm.

Photograph 5 – Typical expansion joint (concrete dam).

Photograph 6 – Borehole tube for piezometer (open).

Photograph 7 – Borehole tube for piezometer blocked with aggregate material.

Photograph 8 – Corner marker at the junction of the south access road and the road to the south berm has been knocked over.

Photograph 9 – Section of the supply pipe from the dam with the corrugates metal enclosure removed.

Photograph 10 – Blizzard markers knocked over

Photograph 11 – Bungee cord suppressing barbed wire

Photograph 12 – Displaced rip rap in South Berm

APPENDIX B

Lake Geraldine Dam Inspection Checklist

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Lake Geraldine Dam
Inspection Check List

Iqaluit

Inspector Name: Cameron McDonald
Inspection Date: August 4, 2022
Weather: Sunny 10° (Rained in the morning)

Reviewer:
Review Date:
Action Required:

Sketch the deficiency, and note its important characteristics.
Measure the deficiency.
Photograph the deficiency or describe its characteristics in writing.
Locate the deficiency relative to a recognizable reference point.

General Observations

Description	Yes	No	Observations	Action Required
Snow and ice present on dam & berms		X	Snow & ice in the spillway downstream	
Snow and ice present on the lake		X		
North access road, gate secured (Any visible damage)	X			
South access road, gate secured (Any visible damage)	X			
Gates on the concrete dam locked (north and south ends on top of dam)	X			
Gates and fencing on top of dam intact or damaged	X		Bungee chord supressing barbed wire was in place on the North Gate. Bungee chord was removed	

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Lake Geraldine Dam
Inspection Check List

Iqaluit

Description	Yes	No	Observations	Action Required
Vandalism		X		
Debris on site or in the lake		X		
Dam signage intact or damaged	X		Dam signage intact, still missing sign on south end of South berm	
Valve chamber condition and damage (Indicate if there is any cracking, displacement, physical damage, cover is in place, etc)	—		No damage	
Uncontrolled breach in the concrete dam or earthen berms (embankments)	—		None	
Animal Activity:	—		None	

Additional Comments, Sketches or Observations

Concrete Dam and Spillway

Description	Yes	No	Observations	Action Required
Water level relative to sill of spillway (measure from top of the concrete dam) Is there flow over the spillway	—		1.5m freeboard on spillway, no flow over spillway	
Cracking / spalling present on top (surface) of the concrete dam (Indicate if new, existing, expanded, length, width, depth)		X		
Cracking / spalling present on upstream face (surface) of the concrete dam (Indicate if new, existing, expanded, length, width, depth)		X		
Cracking / Spalling present on Downstream face (surface) of the concrete dam (Indicate if new, existing, expanded, length, width, depth)	X		Regular cracking & spalling, same places as previous reports, not noticeably larger	
Active seepage / leakage through dam Is there silt / sand within the leaking water (Indicate location and rate of leakage in liters per minute)		X		
Sealant Condition – Top of Dam	—		Good	
Sealant Condition – Up stream face of Dam	—		Good	
Sealant Condition – Downstream face of Dam	—		Good - Recently Replaced	
Active seepage / leakage at: - Interface between concrete and ground (bedrock) - Sealant joints	X		Interface at Gridline L	

Description	Yes	No	Observations	Action Required
Displacement, settlement or misalignment of sections of the dam		X		
Debris / blockage within the spillway and or drainage channel at base of dam		X	Some garbage / deleterious materials in drainage channel	
Erosion at the base of the spillway	X		Rip rap needs to be adjusted	
Monitoring stations (condition, damage, other)	—		No damage	
Additional Comments, Sketches or Observations				

North Berm				
Description	Yes	No	Observations	Action Required
Sloughing, slides, bulging, collapse or displacement within the earthen berm – Top of Berm		X		
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Upstream Face		X		
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Downstream Face		X		
Depressions or sink holes within the top (crest) of the berm		X		
Depressions or sink holes within the upstream face of the berm		X		
Depressions or sink holes within the downstream face of the berm		X		
Rock, gravel or aggregate displacement or washout (erosion) with the top of the berm		X		
Rock, gravel or aggregate displacement or washout (erosion) within the upstream face of berm		X		
Rock, gravel or aggregate displacement or washout (erosion) within the downstream face of berm		X		

Description	Yes	No	Observations	Action Required
Displaced rip-rap /armor stone on the upstream face of berm	X		Same locations as previously identified, See markups on site layout plan	
Displaced rip-rap /armor stone on the downstream face of berm		X		
Transverse / longitudinal cracking, within the Top / crest of the berm (Indicate if new, existing, expanded, length, width)		X		
Transverse / longitudinal cracking, within the Upstream face of the berm (Indicate if new, existing, expanded, length, width)		X		
Transverse / longitudinal cracking, within the Downstream face of the berm (Indicate if new, existing, expanded, length, width)		X		
Wet area or active leakage / seepage within the downstream side face of berm Is there silt / sand within the leaking water		X		
Ponding water at base of the berm (downstream), is there sand or silt suspended within the water		X		
Additional Comments, Sketches or Observations				

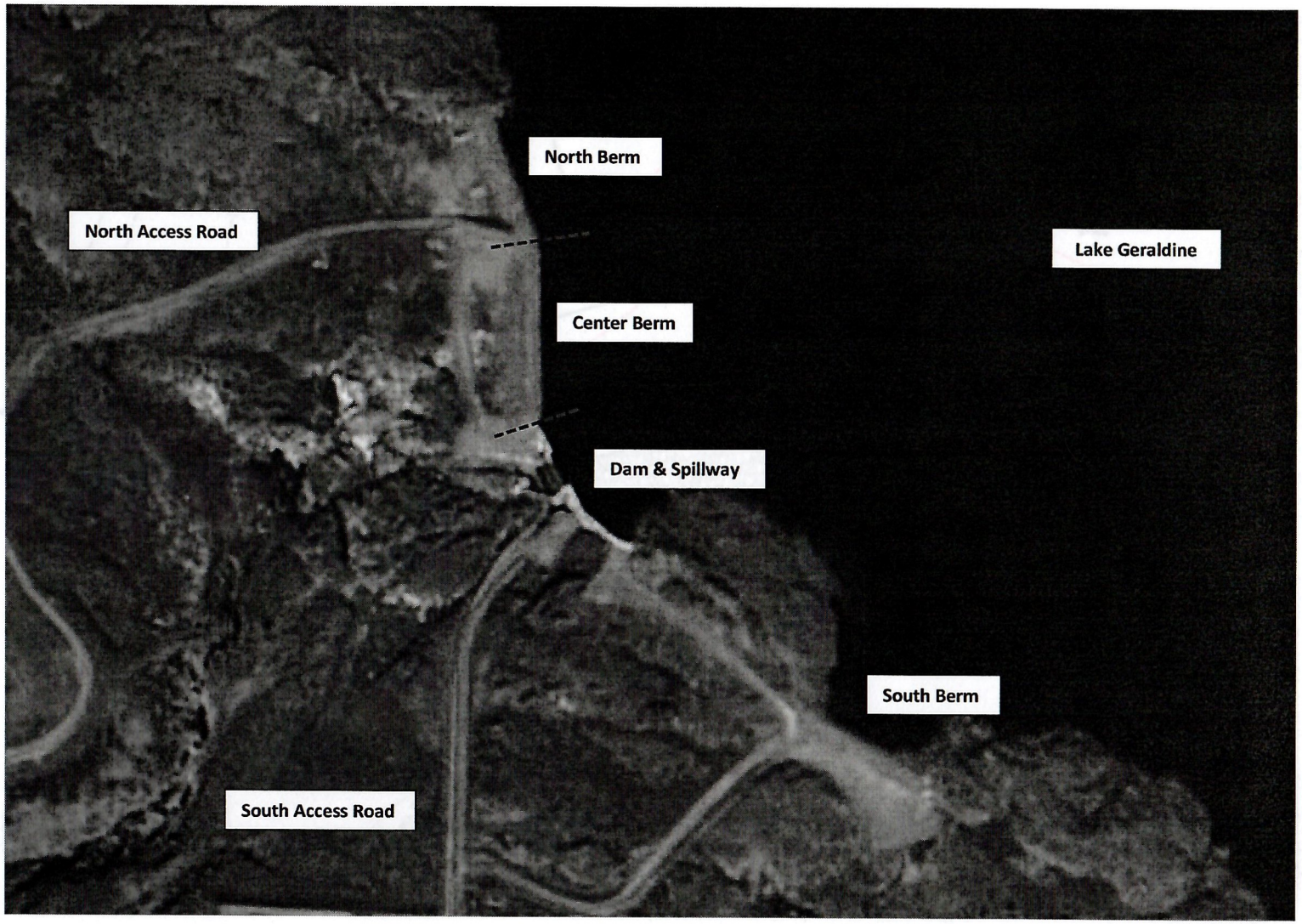
Center Berm				
Description	Yes	No	Observations	Action Required
Sloughing, slides, bulging, collapse or displacement within the earthen berm – Top of Berm		X		
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Upstream Face		X		
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Downstream Face		X		
Depressions or sink holes within the top (crest) of the berm		X		
Depressions or sink holes within the upstream face of the berm		X		
Depressions or sink holes within the downstream face of the berm		X		
Rock, gravel or aggregate displacement or washout (erosion) with the top of the berm		X		
Rock, gravel or aggregate displacement or washout (erosion) within the upstream face of berm		X		
Rock, gravel or aggregate displacement or washout (erosion) within the downstream face of berm		X		

Description	Yes	No	Observations	Action Required
Displaced rip-rap /armor stone on the upstream face of berm	X		See site plan	
Displaced rip-rap /armor stone on the downstream face of berm		X		
Transverse / longitudinal cracking, within the Top / crest of the berm (Indicate if new, existing, expanded, length, width)		X		
Transverse / longitudinal cracking, within the Upstream face of the berm (Indicate if new, existing, expanded, length, width)		X		
Transverse / longitudinal cracking, within the Downstream face of the berm (Indicate if new, existing, expanded, length, width)		X		
Wet area or active leakage / seepage within the downstream side face of berm Is there silt / sand within the leaking water	X		Leakage noticed near the access road to the concrete Dam, see site plan, no silt in water	
Ponding water at base of the berm (downstream), is there sand or silt suspended within the water		X		
Additional Comments, Sketches or Observations				

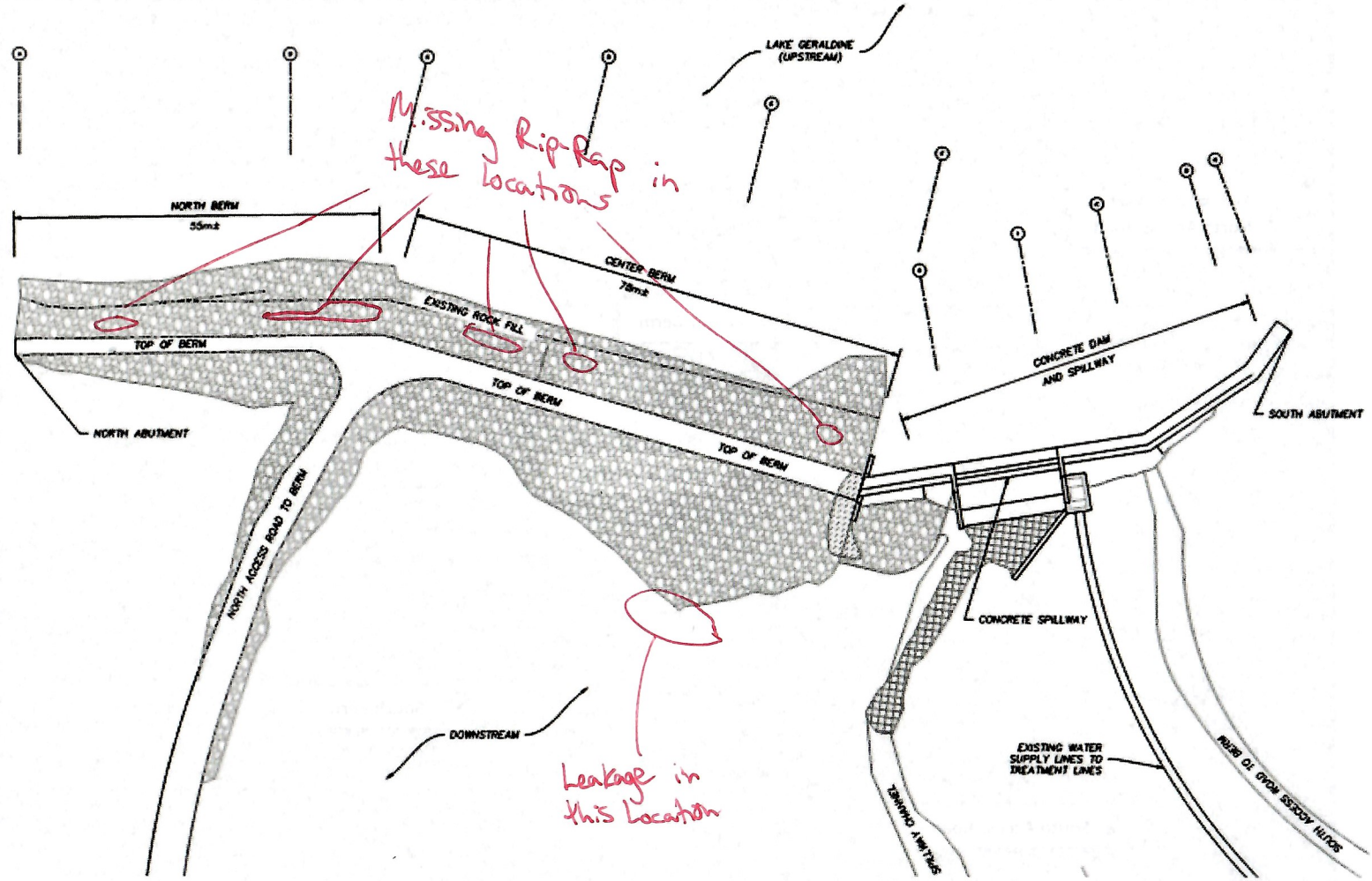
South Berm				
Description	Yes	No	Observations	Action Required
Sloughing, slides, bulging, collapse or displacement within the earthen berm – Top of Berm		X		
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Upstream Face	X		In line with the GN mobile water treatment unit, rip rap lip is depressed. Was likely to allow their hoses to lie flat across the berm.	X
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Downstream Face		X		
Depressions or sink holes within the top (crest) of the berm		X		
Depressions or sink holes within the upstream face of the berm		X		
Depressions or sink holes within the downstream face of the berm		X		
Rock, gravel or aggregate displacement or washout (erosion) with the top of the berm		X		
Rock, gravel or aggregate displacement or washout (erosion) within the upstream face of berm		X		
Rock, gravel or aggregate displacement or washout (erosion) within the downstream face of berm		X		

Description	Yes	No	Observations	Action Required
Displaced rip-rap /armor stone on the upstream face of berm	X		See note above	
Displaced rip-rap /armor stone on the downstream face of berm		X		
Transverse / longitudinal cracking, within the Top / crest of the berm (Indicate if new, existing, expanded, length, width)		X		
Transverse / longitudinal cracking, within the Upstream face of the berm (Indicate if new, existing, expanded, length, width)		X		
Transverse / longitudinal cracking, within the Downstream face of the berm (Indicate if new, existing, expanded, length, width)		X		
Wet area or active leakage / seepage within the downstream side face of berm Is there silt / sand within the leaking water		X		
Ponding water at base of the berm (downstream), is there sand or silt suspended within the water		X		
Additional Comments, Sketches or Observations				

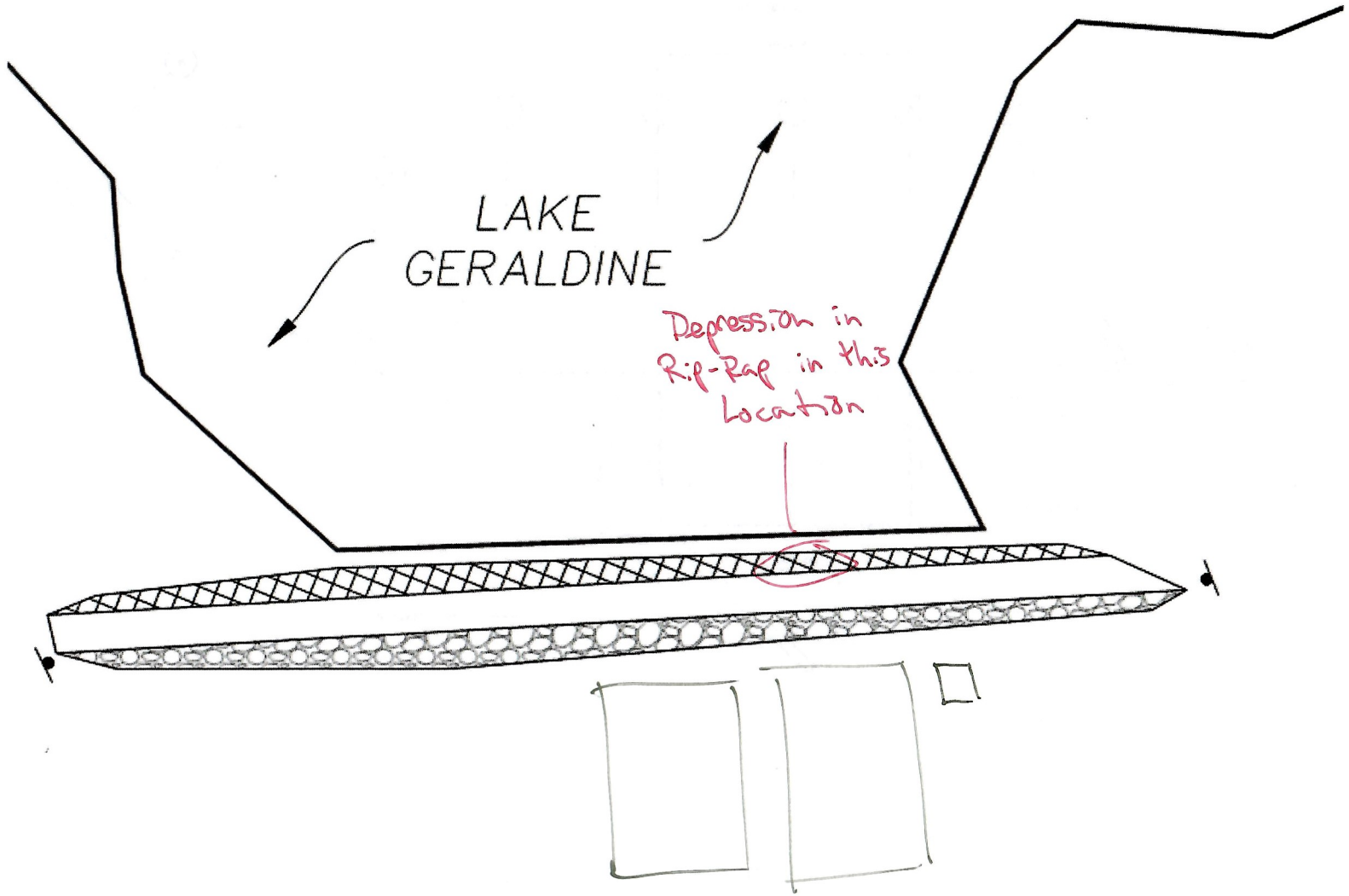
Lake Geraldine Dam Location Plan



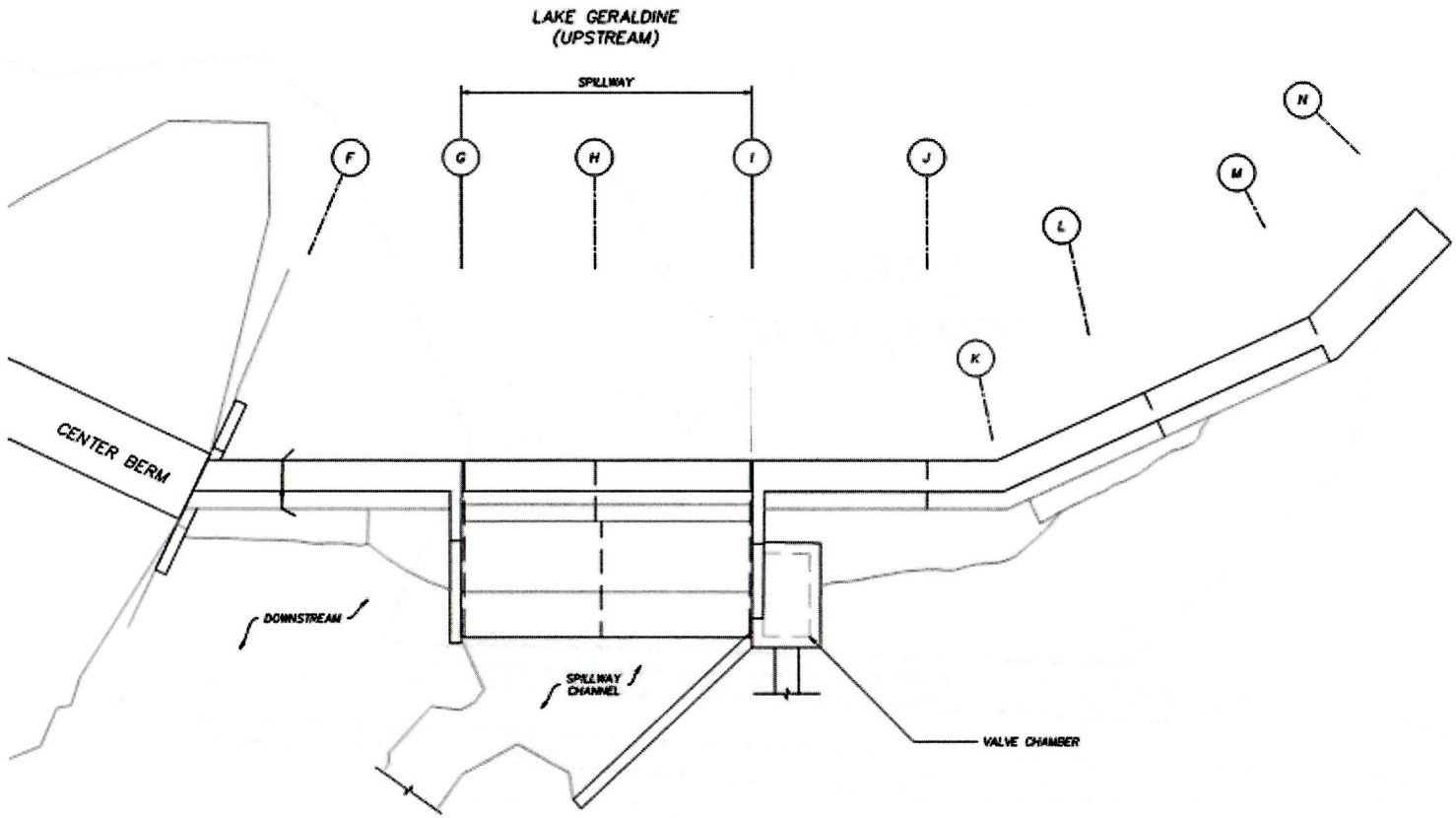
Site Plan – Concrete Dam, Center and North Berms



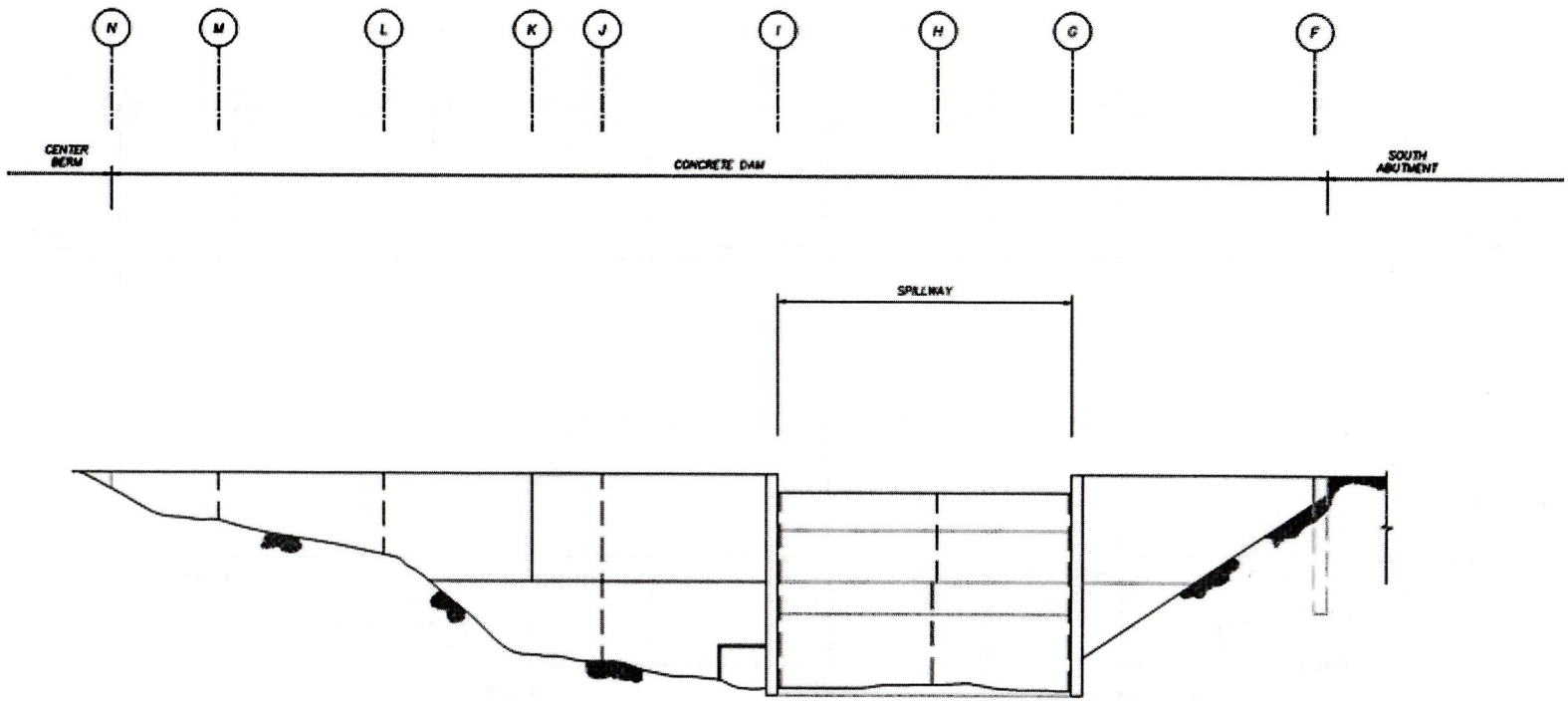
Site Plan – South Berm



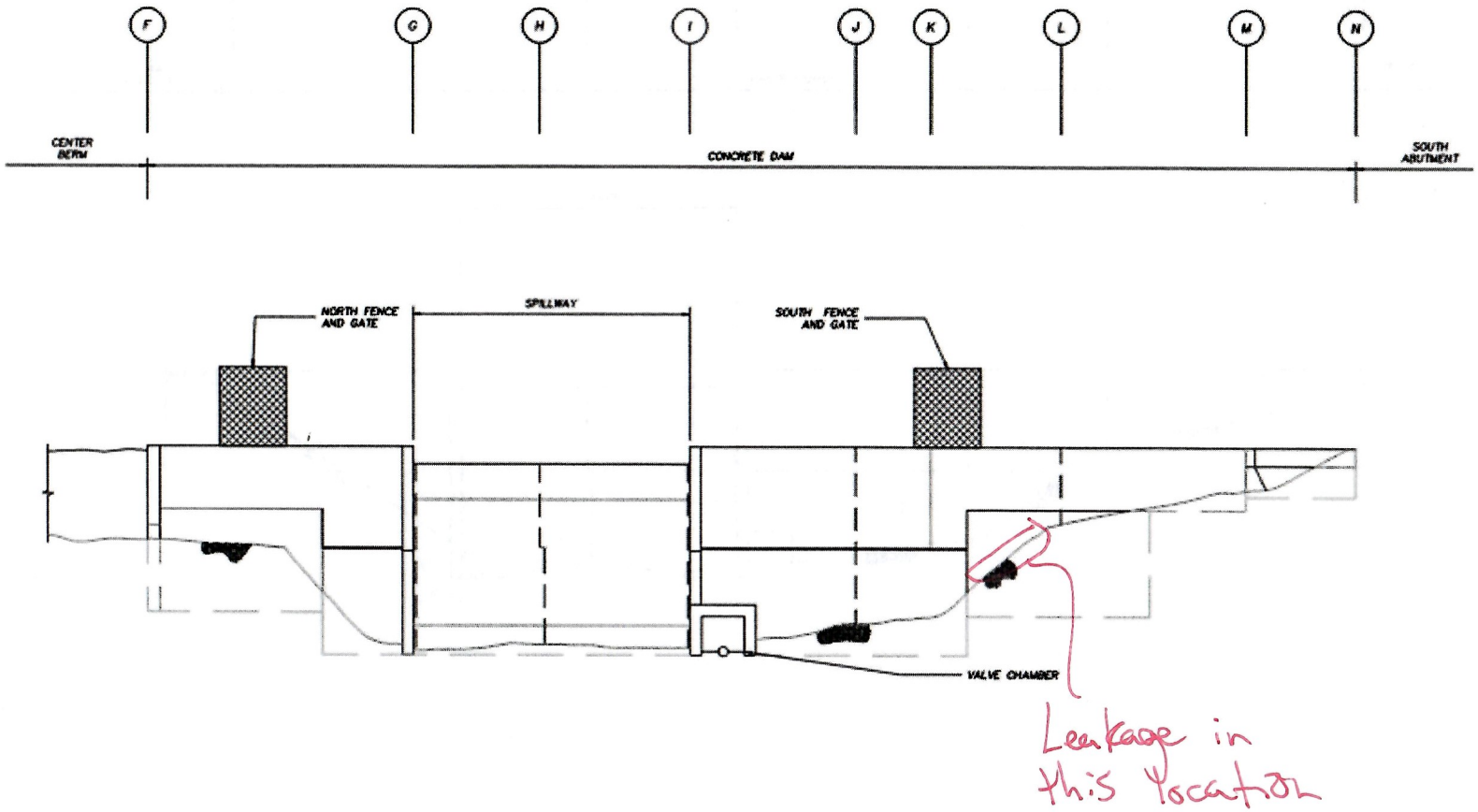
Plan View – Concrete Dam and Spillway



Elevation – Upstream Face, Concrete Dam and Spillway



Elevation – Downstream Face, Concrete Dam and Spillway



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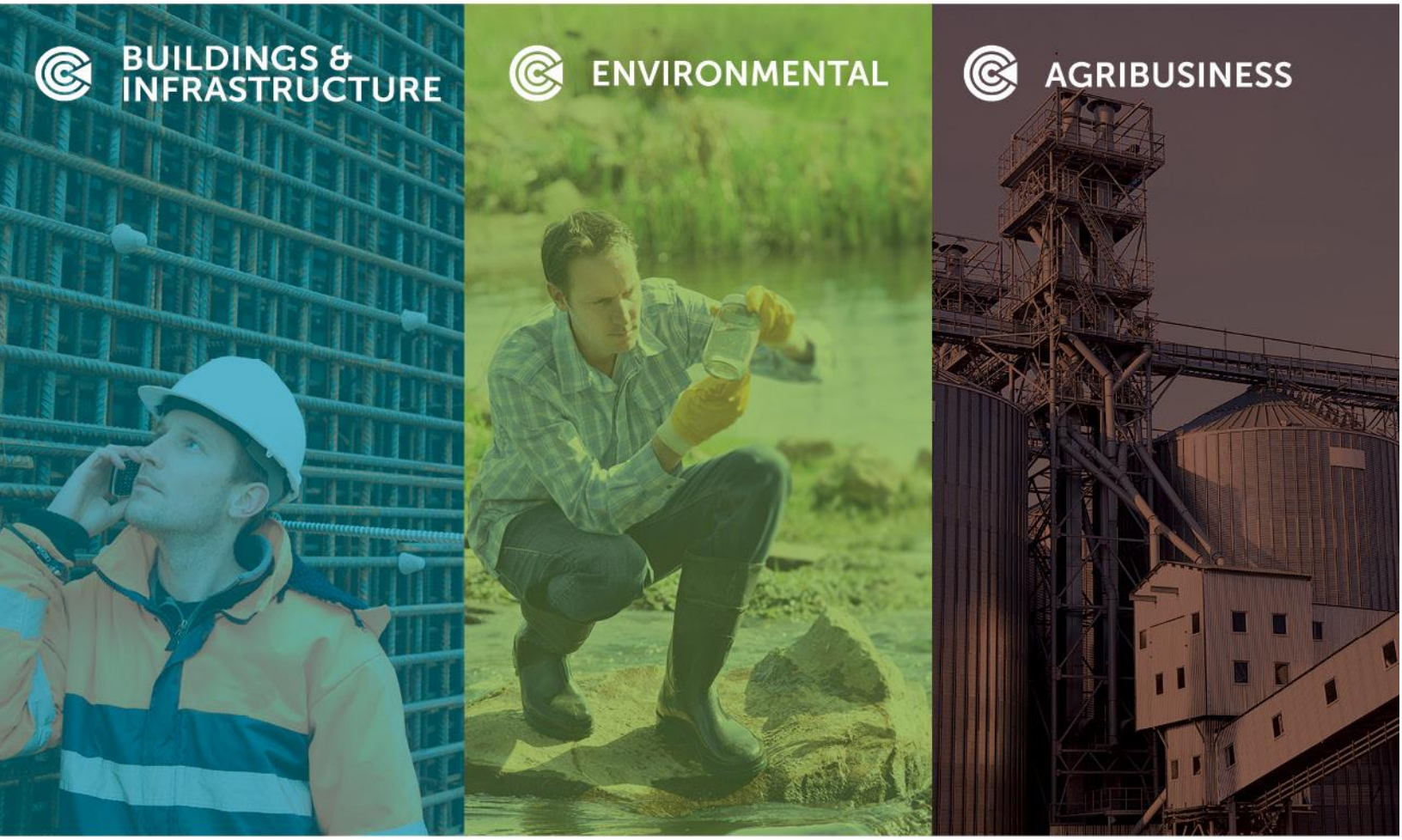

LAKE GERALDINE DAM
DAM SAFETY INSPECTION 2022 #4
IQALUIT, NUNAVUT

PRODUCED FOR: THE CITY OF IQALUIT
C/O COLLIERS PROJECT LEADERS

PRODUCED BY: CONCENTRIC ASSOCIATES INTERNATIONAL INCORPORATED

CONCENTRIC REFERENCE NUMBER: 21-9162

DATE: SEPTEMBER 29TH, 2022

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LIST OF APPENDICES

1. INTRODUCTION AND SCOPE OF WORK

This Dam Safety Inspection (DSI) of the Lake Geraldine Dam (LG Dam) has been prepared for the City of Iqaluit (City). As the owner and operator of the LG Dam, the City of Iqaluit is responsible for its safe management and operation. The intent of this DSI is to assist the City by identifying any visual changes in the condition of the LG Dam, identifying any new concerns, and making recommendations on maintenance, repairs, or further investigations.

1.1 Dam Safety Guidelines

The most recent Dam Safety Guidelines (DSG), published by the Canadian Dam Association, were first released in 2007 and further revised in 2013. The DSG applies, in general, to those structures that are at least 2.5 meters in height, and which have at least 30,000 cubic meters of storage capacity. The LG Dam exceeds these minimum requirements and therefore requires annual DSI's. The DSI is considered to be an Engineering Inspection which is recommended by the DSG to be performed annually or semi-annually by a professional engineer. A Dam Safety Review (DSR) is required, at a minimum, every 5 years. The most recent DSR was performed in April 2022.

This DSI forms part of the dam's permanent record documentation along with other documentation that make up the historical record of the dam (and berms). Section 3.6 "Surveillance" of the DSG recommends more frequent visual inspections be performed. Routine inspections performed by City staff trained in dam surveillance are recommended on a weekly basis to identify any conditions that might indicate a change in the dam's performance.

1.2 Description of Structure

The LG Dam is comprised of a concrete section with an integral concrete spillway, and three earthen berms: the north, center, and south berms. See below for a reference site plan and Appendix A for site photographs.

The 15.3 m wide spillway has an upper elevation of 111.3 m (representing the current maximum operating level of the reservoir), while the concrete dam sections on either side of the spillway have an elevation of 112.3 m. At the maximum operating level of the reservoir, the concrete dam has approximately 0.95 m of freeboard.

The southern section of the concrete dam extends approximately 39.1 m to the south rock abutment. The northern section of the concrete dam extends 13.3 m to the north of the spillway section, where it joins the center earth berm.

The center earth berm extends north approximately 75 m where it meets the access ramp and north access road. The north earth berm is located to the north of the access road ramp and extends 60m to the north rock abutment.

The south earth berm is a separate structure that is located in a valley to the south of the main concrete dam. The south berm is approximately 68.5 m long. The north and center berms incorporate a concrete cutoff wall which is reportedly founded in rock at the base of the berms.

Site Plan

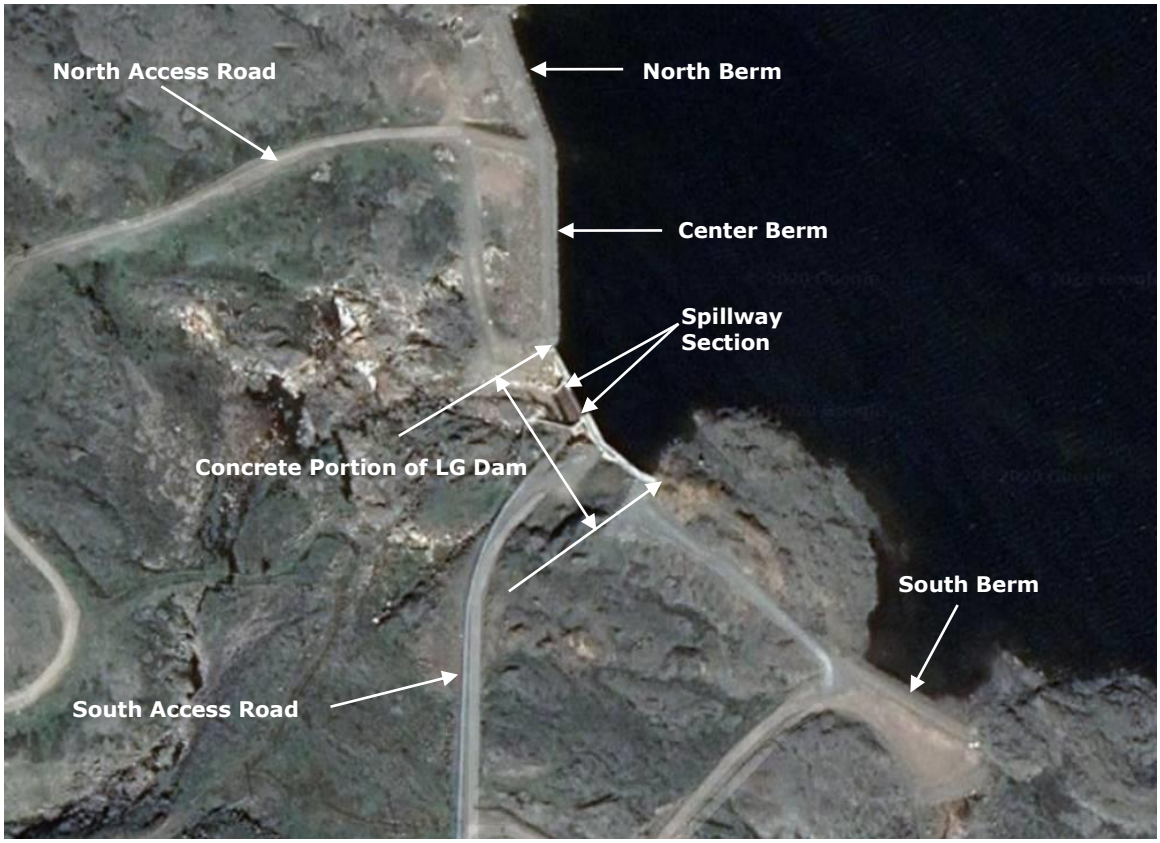


Table 1.1: Lake Geraldine Dam Summary*

Dam/Berm Segment	Length (m)	Crest Elevation	Base Elevation	Bedrock Elevation	Height of Dam/Berm (m)
North Berm	55.5	112.5	108.3	105.0	4.3
Center Berm	78.0	112.5	108.3	97.5	4.5
North Dam	13.3	112.3	102.6	97.5	11.0
Spillway	15.3	111.3	101.6	96	10.0
South Dam	39.1	112.3	102.6	97.5	11.0
South Berm	68.5	112.5	111.5	110.0	1.0

*Tabular data based upon Meco "Dam Safety Management Plan", July 2020

1.3 Scope of Work

As per the requirements of the Dam Safety Guide, the primary task of this DSI is to help identify any significant visual changes in the condition of the concrete dam and earthen berms based on a comparison with the previous inspections and reviews. A visual inspection can identify issues related to dam safety and provides the City of Iqaluit with the opportunity to mitigate any observed concerns or issues. This DSI report is the

primary deliverable and has been prepared in accordance with the Dam Safety Guide document.

The following is a summary of the scope of work for this assignment:

- Conduct a visual on-site assessment of the dam and berms above the water line;
- Prepare a photographic record documenting general and representative conditions;
- Identify, characterize, and risk-assess any significant visual changes in condition;
- Prepare a written report summarizing our observations, items of concern, and recommendations;
- Indicate any recommended repairs and outstanding recommendations from previous inspections and reviews;
- Develop a prioritized list of recommended repairs, upgrades, and improvements with Class D cost estimates;
- Submit final documents in electronic format.

2. HISTORY & BACKGROUND

2.1 Reservoir

The City of Iqaluit derives its water supply from Lake Geraldine, which is retained by a structure consisting of a cast in place concrete section incorporating an integral spillway, and three earthen berms. All concrete structures are reported to be founded on bedrock and engage the rock abutment at the south end of the concrete structure.

Lake Geraldine is a natural body of water in an irregularly shaped basin. It is fed by rainfall and snow/ice melt from a watershed with an area of approximately 385 hectares.

2.2 History

In the late 1950's, the demand for a reliable year-round source of water resulted in the construction of a cast in place concrete gravity dam and a section of earth berm with a central cast in place concrete cut off wall. The project was designed and built by the Department of National Defense. According to the literature, the original construction took place circa 1958.

Since that time, as the City has grown and water demands have risen, the dam has been raised four times to increase the storage capacity. In recent years, the City of Iqaluit has been pumping additional water into the reservoir in the summer and fall of the year from a river located east of the reservoir.

The first height increase of the concrete dam and berms (0.3m) reportedly took place in 1979. This involved a concrete extension, which was dowelled into the existing structure.

The second height increase of the concrete dam and berms took place in 1985 and increased the height of the spillway structure by approximately 1.15m. The berm portion was widened and heightened as well to accommodate the increased storage capacity of the reservoir. The extension of the concrete dam was constructed with concrete and steel

reinforcement, dowelled into the existing structure and incorporated a steel formwork frame over the spillway section.

The third extension was undertaken in 1995 and increased the height of the concrete structures by a further 1.5m, with a corresponding increase in berm geometry. Based on analysis done prior to the extension, it was determined that the concrete structures would not have an adequate factor of safety against overturning if the extension was simply "dowelled-in" as before. The 1995 alteration therefore included an extensive rock-anchoring program for the concrete portions to provide the required stability to the structure.

The latest extension was completed in two phases over 2005/06. Additional rock anchors were installed thought the concrete structures in 2005 in preparation for a further height extension of 2 m in 2006. The existing berms were enlarged and the existing cut-of-walls within the north and center berms were extended in height. A new berm (south berm) and cut off wall were installed to the south of the main dam structure. A subsequent technical analysis of the dam and earth berms completed in 2020 indicated that the spillway structure is marginally compliant for stability with relying on rock anchors to resist overturning. CDA guidelines indicate that it is not recommended that passive rock anchors are relied on for stability. The geotechnical investigation completed in 2019 concluded that the bedrock below the concrete dam appeared to be fractured and that the loading capacity of the rock bolts (installed in 2006) would not meet the design expectations. Additional information on this investigation is available within the report produced by Meco and titled, "Technical Analysis & Risk Assessment, Lake Geraldine DSMP", dated 16 July 2020.

In August 2019 various repairs were undertaken to repair the upstream face (below the water line) of the dam. These repairs included:

- Repair of the expansion joint.
- Polyurethane crack injection.
- Localized concrete repairs.

The last major repair program undertaken was completed in the summer of 2021, various repairs were undertaken to maintain the concrete structures, berms, and access roads. These repairs included:

- Placement of additional aggregate material and regrading of the north and south access roads.
- Installation of additional riprap/armor stone on the upstream face of the center and north berms.
- Installation of additional aggregate and regrading of the top of the center and north berms.
- Crack repair and sealing on the downstream face of the concrete structures.
- Concrete repair on the downstream face of the dam.

Replacement of the expansion joint sealant material on the downstream face of the concrete structures was started in 2021 however, the work could not be completed due to local weather and site conditions. This work was completed in July 2022.

Additional improvements were undertaken in the summer of 2022. These repairs included:

- Installation of eight survey monuments.
- Installation of water pressure (piezometer) and temperature data monitoring stations.
- Re-establishment of aggregate stock piles on site.

This work was currently underway at the time this report was prepared.

3. DAM SAFETY INSPECTION

3.1 Site Inspections and Staff Interviews

A visual site inspection of the LG Dam was performed on September 29, 2022 by Cameron McDonald, of Concentric. The inspection was non-invasive in nature and did not include an underwater survey or assessment. For general overview photographs see photograph 1-3 in Appendix A.

A summary of observed conditions is as follows:

- No ice present surrounding the concrete portion of the dam. Snow began to fall midway through the inspection. No ice present in Lake Geraldine.
- The water level within the reservoir reported by Natural Resources Canada on September 29, 2022 was 111.108m.
- Concrete barriers remain in place to block access to the bypass road to the southern berm.
- The area around the base of the power pole that supplies power to the temporary water treatment facility at the south berm has what appears to be some form of oil / creosote around the base of the pole. See Photograph 4. This was reported in the previous DSI report, no corrective measures have been taken to address this potential issue.
- No significant changes were noted in the general condition of the concrete structures.
- Nunavut Excavating has completed the installation of the monitoring stations along the downstream face of the North and South Berms. The metal enclosures installed atop the piezometer boreholes have been removed and some of the borehole tube designated for the installation of the piezometers are obstructed with gravel and sand. See Photographs 3, 6 & 7.
- No change in condition to the metal corner post (used to indicate the edge of the road) identified to have been knocked over by vehicle traffic in the previous report. See Photograph 8.
- Portions of the galvanized metal enclosure that covers the pipe that supplies water from the dam to the water treatment plant are still missing. See Photograph 9.
- No change in condition to the blizzard markers installed along the north side of the south access road identified in the previous report. See Photograph 10.

- The warning signage at the south end of the south berm has been installed. Signage is not installed in a suitable manner. See Photograph 13.
- No change in condition to the small rut identified in the previous report at the north end of the south berm (presumably from a vehicle).
- Leakage was observed at the base of the interface between the bedrock and the concrete dam. Leakage of water has been observed at this location during previous inspections. This leakage is steady and constant.
- The rip rap at the base of the concrete dam, within the spillway, needs to be adjusted. The rip rap has been displaced and is no longer covering all portions of the base of the dam. Miscellaneous materials were observed in the spillway.
- Depression noted in the rip rap lip on the south berm in line with the GN's mobile water treatment plant units. It appears rip rap may have been displaced to accommodate intake hoses. This should be corrected. See photograph 12.
- With the exception of the above noted, no significant changes, such as sloughing, slides, bulging or displacement, were noted in the earthen berms. No active seepage/leakage was observed within the visible portions of the berms; however, based upon our previous inspections and experience, water leakage/seepage may be present within the center berm that is being masked by melt water from the snow and ice.
- The aggregate stockpiles located on the downstream side of the north berm were replenished in early September, however Nunavut Excavating used some of the material to replace aggregate when they installed the monitoring stations.
- Members of the public continue to access the Dam structures and Lake Geraldine.
- Minor leakage at the base of the concrete dam at the interface with the bedrock has been consistent over the last 10+ years however, during our most recent site review we noted a minor increase in the flow of water at this location. Leakage at this location is believed to be caused by water moving through the fractured bedrock below the dam and seepage of water between the base of the concrete dam and bedrock. We did not observe any changes or displacement of the bedrock at the base of the dam. As such, we do not believe that the underlying bedrock has changed or been disturbed.
- Several depressions within the upstream face of the dam were noted when the water level was low in June 2022, these depressions should be corrected in the spring – summer of 2023 when the water level is low in the dam.

3.2 Dam Safety Analysis

A dam safety analysis was not completed as part of this inspection; however, there were no obvious indicators that the concrete structures have had significant changes since the last DSI.

3.3 Operation, Maintenance, and Surveillance

This DSI falls under the requirements of a visual inspection by an engineer as stated in Section 3.6 "Surveillance" of the Dam Safety Guide. The lack of a centralized repository of operational and maintenance records has been an ongoing issue. This, along with other issues regarding the operation and maintenance of the dam and reservoir, is noted

within both the "Dam Safety Management Plan" dated July 16, 2020 prepared by MECO and the 2021 Dam Safety Review dated May 31, 2022 prepared by Concentric.

3.4 Recommendations and Required Action

Based on our inspection and review, we recommend the following:

1. Items deemed to be of an urgent need include:
   a. The contaminated soil around the base of the hydro pole adjacent to the south berm should be removed.
   b. Replace stockpile material that Nunavut Excavating used.
2. Updating of the permanent record file and its storage in a central location with an index that documents the date and contents of all records. The permanent record file needs to include:
   a) As-built drawings and specification for work undertaken at the dam.
   b) Weekly/monthly inspections completed by City staff.
   c) Dam Safety Inspections and Dam Safety Reviews generated by third parties on behalf of the City of Iqaluit.
   d) All maintenance records.
   e) Correspondence with regulatory agencies.
   f) Dam operation, maintenance, and surveillance documents.
   g) Reports and documentation generated by third parties on behalf of the City of Iqaluit.
3. Implement a public awareness program to educate and inform the public that:
   a) The dam and earthen berms are a *no trespass* area.
   b) Dog walkers should not allow their pets to travel atop and across the earthen berms due to the risk of (dog) fecal matter contamination of the potable water supply.
   c) ATV and skidoos should not be traveling atop the berms and across Lake Geraldine.
4. The protective galvanized metal enclosure installed over the pipeline from the dam to the water treatment plant should be re-instated.
5. The metal posts / markers that were installed along the north side of the south access road to should be re-instated.
6. The aggregate stockpiles maintained at the west side of the north berm should be replenished by Nunavut Excavation.
7. The installation of video surveillance should be considered with a scheduled implementation in the summer of 2023.
8. Exercising and testing of the valves within the valve chamber is required as part of preventative measures. The condition of the valves within the valve chamber at the base of the dam was previously identified as being in an advanced state of corrosion. To our knowledge no maintenance or testing has been completed on the

controls valve in the last 5+ years. There is a significant potential for the valves to fail and not operate correctly when needed in an emergency. A study to address this issue is currently underway.

9. Underwater survey of the concrete dam and spillway in 2023.
10. Undertake a test opening on the downstream side of the concrete dam and center berm in late January – early February 2023 to ascertain the source of the water that forms large ice sheets within the valley in the winter months.
11. Repair of cracks within the concrete dam, this work is tentatively scheduled for summer 2023.
12. Repair of spalled concrete within the concrete dam, this work is tentatively scheduled for summer 2023.

4. LIMITATIONS

This report was prepared for the sole use of the City of Iqaluit.

This report was prepared exclusively for the purposed project and site locations outlined in this report. The report is based on information provided to, or obtained by Concentric as indicated in the report, and applies solely to site conditions existing at the time of the site investigations.

The conditions of the site may change over time or may have already changed due to natural forces or human intervention, and Concentric takes no responsibility for the impact that such changes may have on the accuracy or validity of the observations, conclusions and recommendations set out in this report.

The report does not extend to any latent defect or other deficiency which could not have been reasonably discoverable or discovered within the scope of the report. Information supplied by the City of Iqaluit or third parties for use in this report has not been verified by Concentric unless stated otherwise.

Concentric's report represents a review of available information with an established work scope, schedule, and budget. The material in the report reflects Concentric's judgement in light of the information available to it at the time of preparation. Any uses that a third party makes of this report, or any reliance on decisions made based on it, are the responsibilities of such third parties.

Concentric accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made based on this report.

Should there be any questions, please contact the undersigned.

Yours sincerely,

CONCENTRIC

Cameron McDonald
Designer

Steve Parker, P.Eng.
Lead Project Manager

APPENDIX A
Site Photographs

Photograph 1 – Overview of concrete structure.

Photograph 2 – Typical south berm condition at the time of our review.

Photograph 3 – Typical north and center berm condition at the time of our review. New monitoring stations installed.

Photograph 4 – Oil residue on the ground around the base of the hydro pole, south berm.

Photograph 5 – Typical expansion joint (concrete dam).

Photograph 6 – Borehole tube for piezometer (open).

Photograph 7 – Borehole tube for piezometer blocked with aggregate material.

Photograph 8 – Corner marker at the junction of the south access road and the road to the south berm has been knocked over.

Photograph 9 – Section of the supply pipe from the dam with the corrugates metal enclosure removed.

Photograph 10 – Blizzard markers knocked over.

Photograph 12 – Displaced rip rap in South Berm.

Photograph 13 – Warning signage installed in the wrong location at the South end of the South Berm.

APPENDIX B

Lake Geraldine Dam Inspection Checklist

Lake Geraldine Dam
Inspection Check List

Inspector Name:	Cameron McDonald	Reviewer:	
Inspection Date:	September 29, 2022	Review Date:	
Weather:	-1°C, Overcast with periods of snow	Action Required:	

Sketch the deficiency, and note its important characteristics.
Measure the deficiency.
Photograph the deficiency or describe its characteristics in writing.
Locate the deficiency relative to a recognizable reference point.
https://wateroffice.ec.gc.ca/report/real_time_e.html?stn=10UH013

General Observations

Description	Yes	No	Observations	Action Required
Snow and ice present on dam & berms	X		Snowfall began during DSI. Some photos in the report will show snow on the berms and concrete dam, and others will not. Water on the downstream face of the concrete dam was not from snow melt.	
Snow and ice present on the lake		X		
North access road, gate secured (Any visible damage)	X			
South access road, gate secured (Any visible damage)		X	Gate was not locked and secured.	
Gates on the concrete dam locked (north and south ends on top of dam)	X			
Gates and fencing on top of dam intact or damaged	X		Fencing is intact, however there are areas that appear to be bent out of shape due to trespassers climbing around the fence and over top of the barbed wire.	

Lake Geraldine Dam
Inspection Check List

Description	Yes	No	Observations	Action Required
Vandalism		X		
Debris on site or in the lake		X		
Dam signage intact or damaged			Dam signage in place, signage at the North Berm is knocked over. Signage for the South Berm is installed in the wrong location.	
Valve chamber condition and damage (Indicate if there is any cracking, displacement, physical damage, cover is in place, etc)			No visible change.	
Uncontrolled breach in the concrete dam or earthen berms (embankments)		X		
Animal Activity:		X		

Additional Comments, Sketches or Observations

Concrete Dam and Spillway				
Description	Yes	No	Observations	Action Required
Water level relative to sill of spillway (measure from top of the concrete dam) Is there flow over the spillway		X	6-8” of freeboard.	
Cracking / spalling present on top (surface) of the concrete dam (Indicate if new, existing, expanded, length, width, depth)		X		
Cracking / spalling present on upstream face (surface) of the concrete dam (Indicate if new, existing, expanded, length, width, depth)		X		
Cracking / Spalling present on Downstream face (surface) of the concrete dam (Indicate if new, existing, expanded, length, width, depth)	X		Pre existing spalling. Surface level, spalling does not appear to be expanding.	
Active seepage / leakage through dam Is there silt / sand within the leaking water (Indicate location and rate of leakage in liters per minute)	X		See diagram	
Sealant Condition – Top of Dam	——	——	Sealant has been picked out of expansion joints.	
Sealant Condition – Up stream face of Dam	——	——	Good.	
Sealant Condition – Downstream face of Dam	——	——	Good.	
Active seepage / leakage at: - Interface between concrete and ground (bedrock) - Sealant joints	X		See diagram.	

Lake Geraldine Dam
Inspection Check List

Description	Yes	No	Observations	Action Required
Displacement, settlement or misalignment of sections of the dam		X		
Debris / blockage within the spillway and or drainage channel at base of dam		X		
Erosion at the base of the spillway			Rip rap needs to be adjusted to be uniformly distributed along the toe of the dam.	
Monitoring stations (condition, damage, other)			Monitoring stations have been installed. South berm monitoring station was installed in the wrong location. Nunavut Excavating to correct this.	X

Additional Comments, Sketches or Observations

North Berm				
Description	Yes	No	Observations	Action Required
Sloughing, slides, bulging, collapse or displacement within the earthen berm – Top of Berm		X		
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Upstream Face		X		
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Downstream Face		X		
Depressions or sink holes within the top (crest) of the berm	X		Tire marks along top of berm from construction activities related to monitoring station installation.	
Depressions or sink holes within the upstream face of the berm		X		
Depressions or sink holes within the downstream face of the berm		X		
Rock, gravel or aggregate displacement or washout (erosion) with the top of the berm		X		
Rock, gravel or aggregate displacement or washout (erosion) within the upstream face of berm		X		
Rock, gravel or aggregate displacement or washout (erosion) within the downstream face of berm		X		

Description	Yes	No	Observations	Action Required
Displaced rip-rap /armor stone on the upstream face of berm	X		Locations previously identified. New material was not placed this year.	
Displaced rip-rap /armor stone on the downstream face of berm		X		
Transverse / longitudinal cracking, within the Top / crest of the berm (Indicate if new, existing, expanded, length, width)		X		
Transverse / longitudinal cracking, within the Upstream face of the berm (Indicate if new, existing, expanded, length, width)		X		
Transverse / longitudinal cracking, within the Downstream face of the berm (Indicate if new, existing, expanded, length, width)		X		
Wet area or active leakage / seepage within the downstream side face of berm Is there silt / sand within the leaking water		X		
Ponding water at base of the berm (downstream), is there sand or silt suspended within the water		X		
Additional Comments, Sketches or Observations				

Center Berm				
Description	Yes	No	Observations	Action Required
Sloughing, slides, bulging, collapse or displacement within the earthen berm – Top of Berm		X		
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Upstream Face		X		
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Downstream Face		X		
Depressions or sink holes within the top (crest) of the berm	X		Tire marks along top of berm from construction activities related to monitoring station installation.	
Depressions or sink holes within the upstream face of the berm		X		
Depressions or sink holes within the downstream face of the berm		X		
Rock, gravel or aggregate displacement or washout (erosion) with the top of the berm		X		
Rock, gravel or aggregate displacement or washout (erosion) within the upstream face of berm		X		
Rock, gravel or aggregate displacement or washout (erosion) within the downstream face of berm		X		

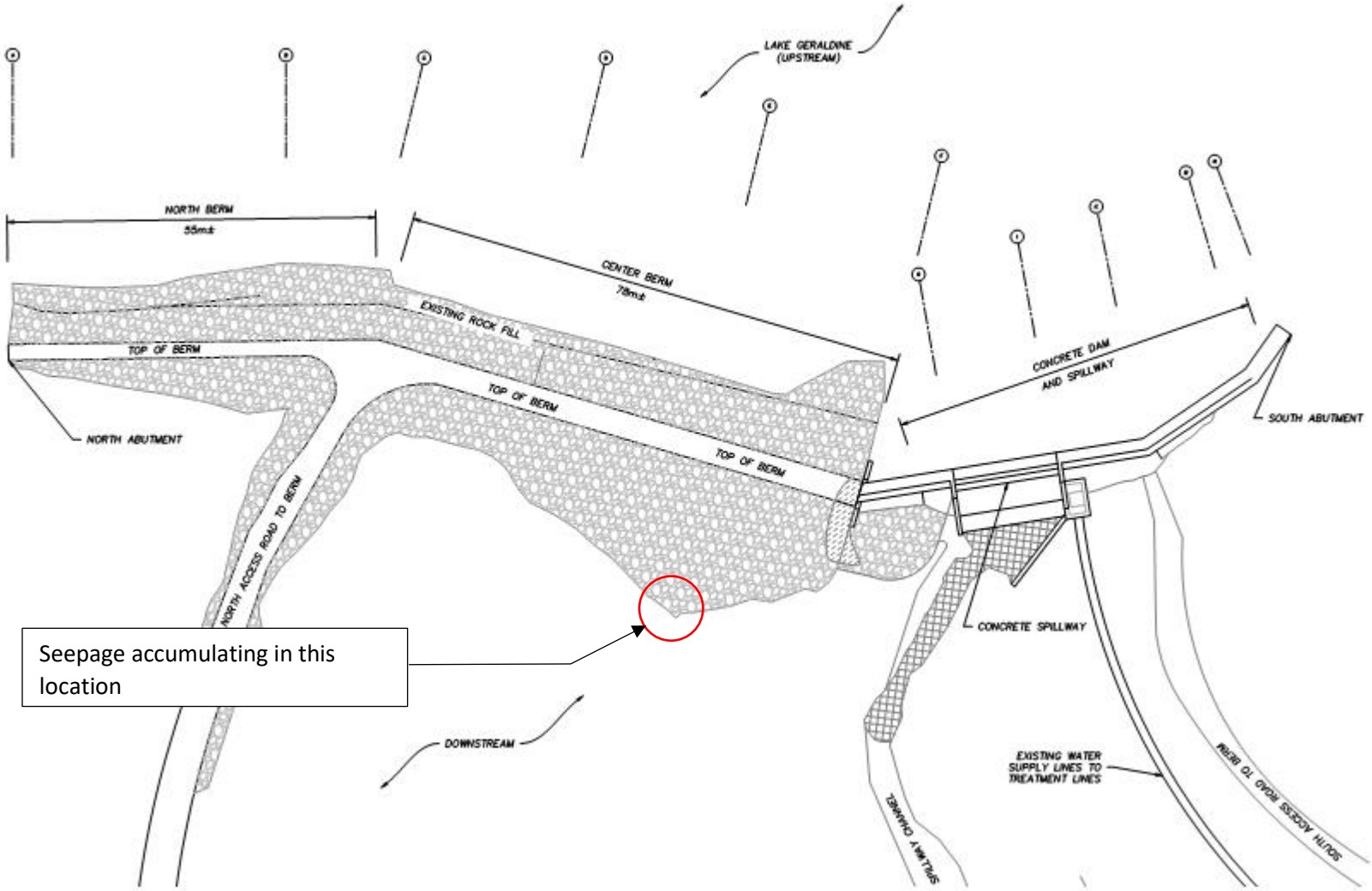
Description	Yes	No	Observations	Action Required
Displaced rip-rap /armor stone on the upstream face of berm	X		Locations previously identified. New material was not placed this year.	
Displaced rip-rap /armor stone on the downstream face of berm		X		
Transverse / longitudinal cracking, within the Top / crest of the berm (Indicate if new, existing, expanded, length, width)		X		
Transverse / longitudinal cracking, within the Upstream face of the berm (Indicate if new, existing, expanded, length, width)		X		
Transverse / longitudinal cracking, within the Downstream face of the berm (Indicate if new, existing, expanded, length, width)		X		
Wet area or active leakage / seepage within the downstream side face of berm Is there silt / sand within the leaking water	X		Slow stream of water at the low point of the berm. No silt or sediment being scoured. See diagram.	
Ponding water at base of the berm (downstream), is there sand or silt suspended within the water	X		See diagram.	
Additional Comments, Sketches or Observations				

South Berm				
Description	Yes	No	Observations	Action Required
Sloughing, slides, bulging, collapse or displacement within the earthen berm – Top of Berm		X		
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Upstream Face		X		
Sloughing, slides, bulging, collapse or displacement within the earthen berm - Downstream Face		X		
Depressions or sink holes within the top (crest) of the berm		X		
Depressions or sink holes within the upstream face of the berm		X		
Depressions or sink holes within the downstream face of the berm		X		
Rock, gravel or aggregate displacement or washout (erosion) with the top of the berm		X		
Rock, gravel or aggregate displacement or washout (erosion) within the upstream face of berm		X		
Rock, gravel or aggregate displacement or washout (erosion) within the downstream face of berm		X		

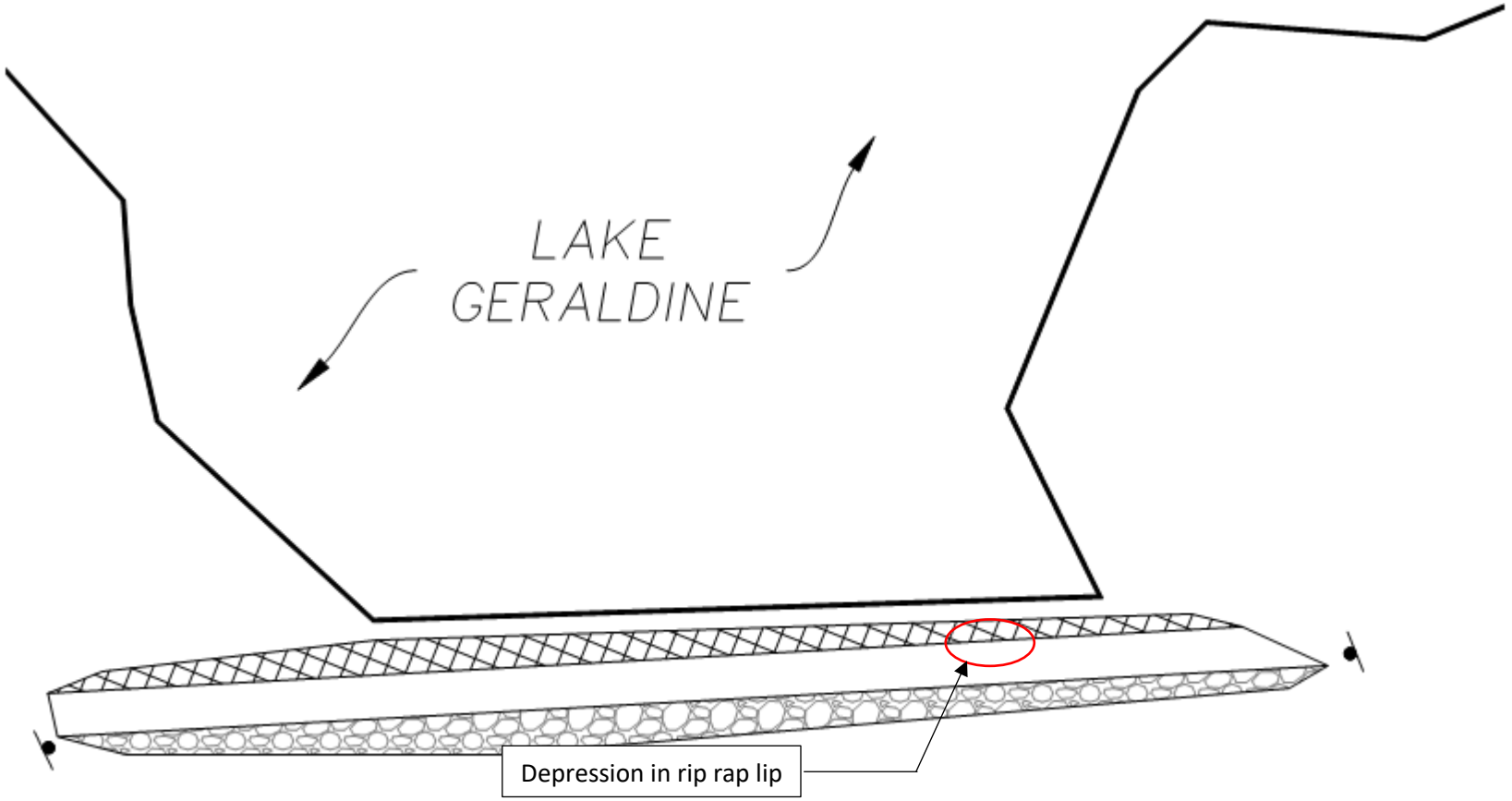
Description	Yes	No	Observations	Action Required
Displaced rip-rap /armor stone on the upstream face of berm	X		Rip rap lip has been displaced where the GN's mobile water treatment plant was located. See diagram.	X
Displaced rip-rap /armor stone on the downstream face of berm		X		
Transverse / longitudinal cracking, within the Top / crest of the berm (Indicate if new, existing, expanded, length, width)		X		
Transverse / longitudinal cracking, within the Upstream face of the berm (Indicate if new, existing, expanded, length, width)		X		
Transverse / longitudinal cracking, within the Downstream face of the berm (Indicate if new, existing, expanded, length, width)		X		
Wet area or active leakage / seepage within the downstream side face of berm Is there silt / sand within the leaking water		X		
Ponding water at base of the berm (downstream), is there sand or silt suspended within the water		X		
Additional Comments, Sketches or Observations				

Lake Geraldine Dam Location Plan

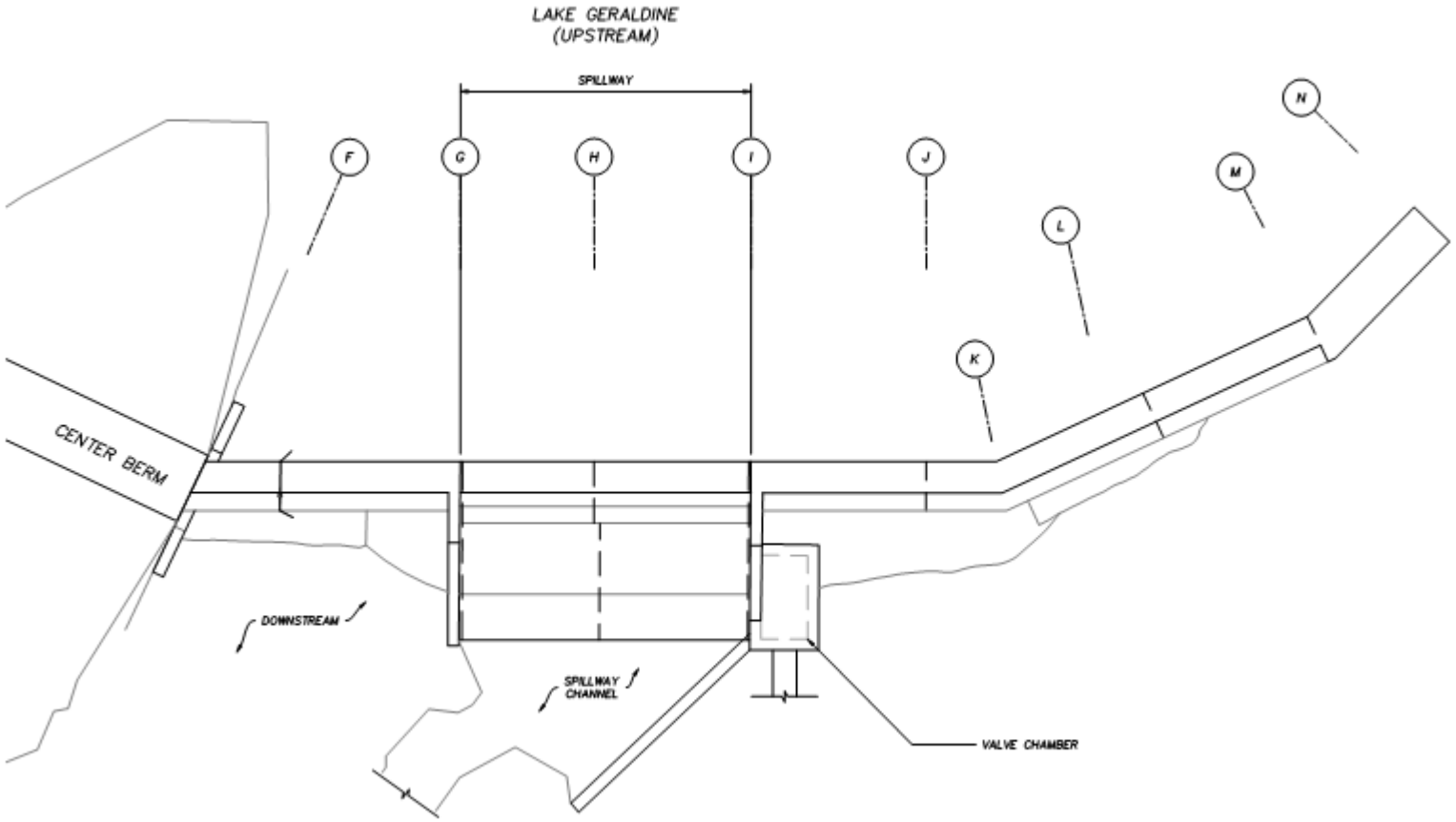
Site Plan – Concrete Dam, Center and North Berms



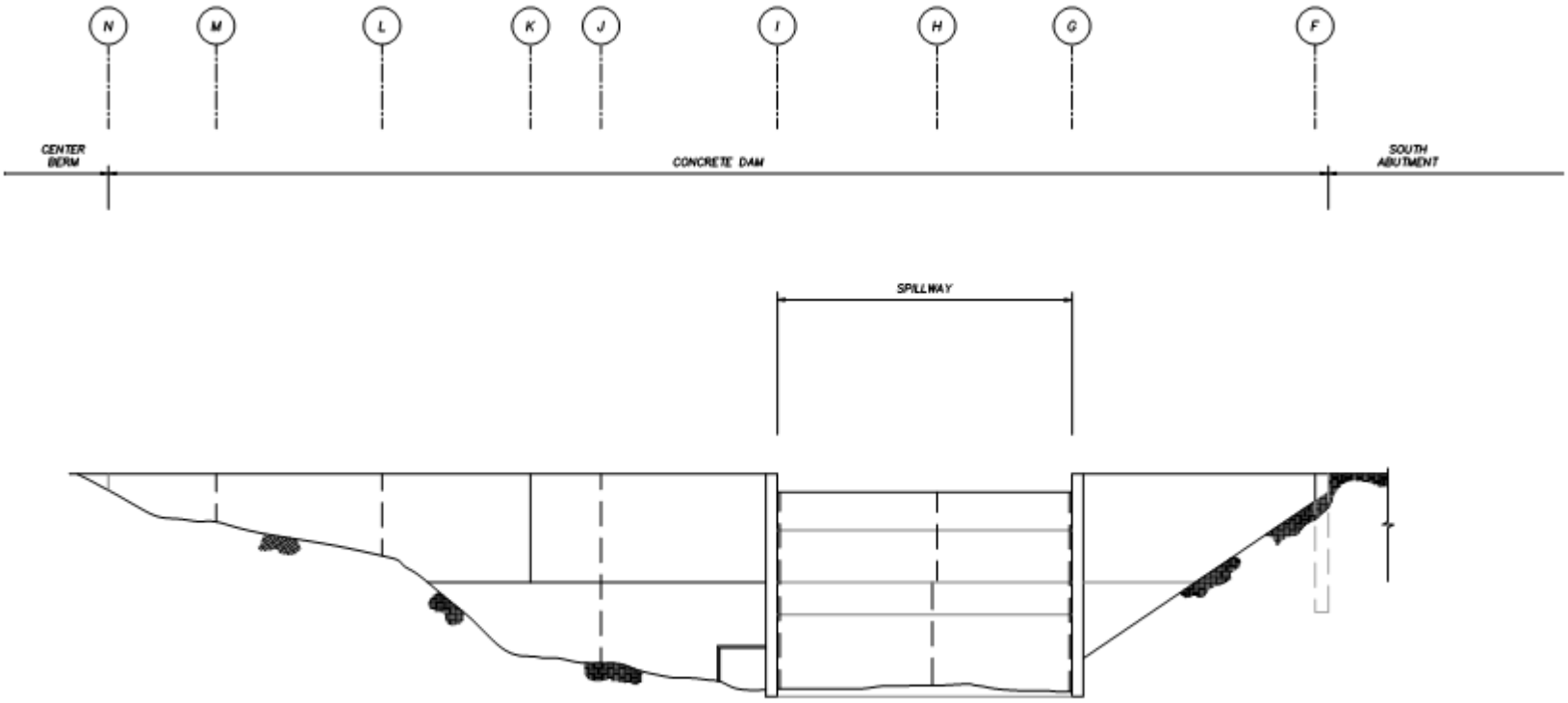
Site Plan – South Berm



Plan View – Concrete Dam and Spillway



Elevation – Upstream Face, Concrete Dam and Spillway



Elevation – Downstream Face, Concrete Dam and Spillway