BARR

MILE POST 7 WEST RIDGE RAILROAD RELOCATION, DAM EXTENSIONS, AND STREAM MITIGATION PROJECT EAW
RECORD OF DECISION - FINDING OF FACT 28.d
2022 EAP

EMERGENCY ACTION PLAN

Milepost 7 Tailings Basin
Dams 1, 2, and 5 – Proposed 2023 Conditions

Owned By:	***Northshore Mining Company*** ***10 Outer Drive*** ***Silver Bay, MN 55614***
Immediate Downstream Community:	***Beaver Bay, MN***

April 2022

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Revisions

Revision	Description	Date
Original	Milepost 7 Tailings Basin Dam 1, 2, and 5	12/26/2012
1	Milepost 7 Tailings Basin Dam 1, 2, and 5 Proposed 2023 Conditions	4/1/2022

Emergency Action Plan
Milepost 7 Tailings Basin
Dams 1, 2, and 5
April 2022

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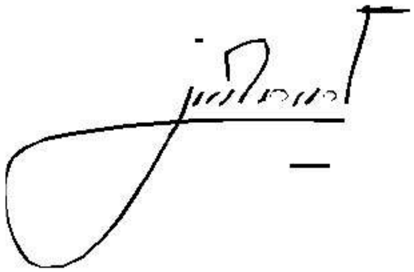
Certification

I hereby certify that this document was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of Minnesota.



Omid Mohseni

April 1, 2022 Reg. No. 26159

Abbreviations

Cliffs	Cleveland-Cliffs Inc.
EAP	Emergency Action Plan
FEMA	Federal Emergency Management Agency
HSEM	Homeland Security and Emergency Management
ICS	Incident Command System
MnDNR	Minnesota Department of Natural Resources
MP7	Milepost 7
MPCA	Minnesota Pollution Control Agency
MSHA	Minnesota Safety and Health Administration
NWS	National Weather Services
USACE	United States Army Corps of Engineers

1 Emergency Action Plan Summary

1.1 Statement of Purpose

The purpose of the emergency action plan (EAP) is to define responsibilities and provide procedures to be followed in the event of a flood, potential failure, or actual failure of the Milepost 7 Tailings Basin Dams 1, 2, or 5 (Dams 1, 2, or 5), located near Silver Bay, Minnesota, in Lake County. Note that the failure of these dams is a highly unlikely event, and the EAP outlines what actions are required in the event of an emergency. In an emergency situation, the majority of the EAP can be implemented by trained personnel using the Notification Flowcharts and other EAP documentation. Supporting detailed information is given in the following sections and appendices.

1.2 Notification Flowchart

The Notification Flowcharts (Figure 1-1 and Figure 1-2), on the following pages, summarize the sequence of notifications and actions required during an "actual/imminent failure" or "hydrologic event/potential failure" at Dams 1, 2, or 5. The Emergency Call List (Table 1-1) lists the current phone numbers for the staff included on the Notification Flowcharts.

The Notification Flowcharts apply to two conditions—imminent/actual failure and hydrologic event and/or potential failure—as defined in Section 2.2. A priority change may occur during a hydrologic event/potential failure. In this case, the mitigative actions may be initiated before warning and evacuation measures are taken to avoid a panic situation. The Tailings Basin Engineer is responsible for this judgment.

1.3 Site Description

Dams 1, 2, and 5 are perimeter dams that, along with natural topography, create the Milepost 7 (MP7) Tailings Basin embankments. The tailings basin is located west of the corporate limits of Beaver Bay, Minnesota. A breach in any of the dams would affect the [redacted]. The tailings basin is owned and operated by Northshore Mining Company (NSM).

Dams 1, 2, and 5 are primarily earth embankment dams with a proposed spillway to be built upon closure of the basin to handle runoff and protect the integrity of the dams. Additional information on the earthen embankments and spillway can be found in Appendix C.

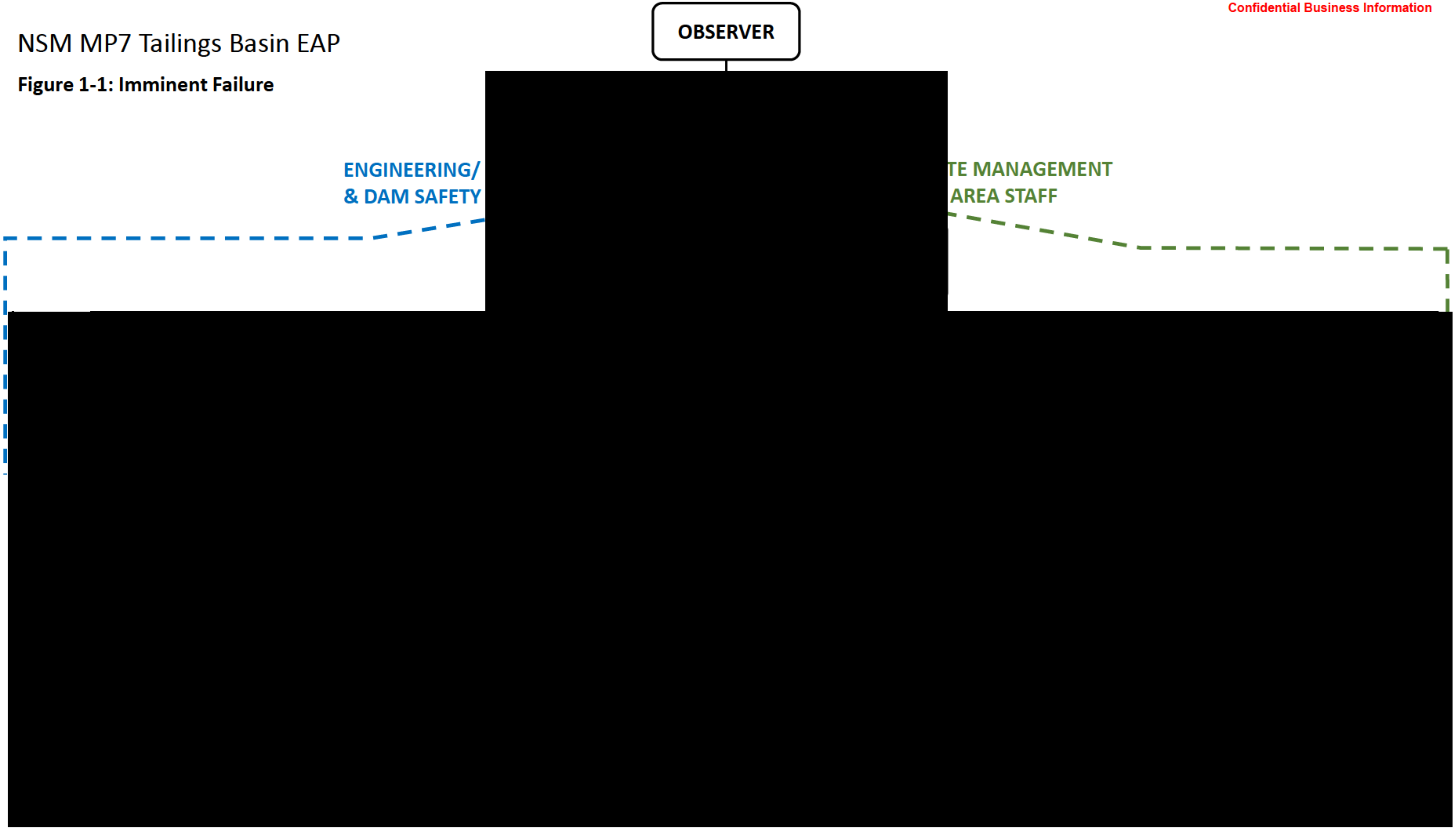
1.4 Supporting Documentation

Appendix A lists examples of typical notification devices that may be used by NSM or Lake County Emergency Management in the event of an emergency. Appendix B provides information on the emergency operating procedures for the dams, and Appendix C gives an overview of the dams.

Appendix D provides additional information regarding the purpose and requirements of the EAP. Appendix E includes the dam break analyses methodology, results summary, and the simulated inundation maps. Appendix F discusses potential training and testing of the EAP. Appendix G shows contact information and the EAP distribution list. Appendix H presents the rally points and the associated access points, and Appendix I provides the E-size inundation maps.

NSM MP7 Tailings Basin EAP

Figure 1-1: Imminent Failure



NSM MP7 Tailings Basin EAP

**Figure 1-2: Potential Hazard (*Situation at hand – no*[redacted]

OBSERVER

ENGINEERI[redacted]
& DAM SAF[redacted]

[redacted]NAGEMENT
[redacted]TAFF

[redacted]

Note: The grey shaded boxes will be contacted at the discretion of the responsible party

Table 1-1 Emergency Notification Contact List: Mil[redacted]

Tailings Basin Engineer **NSM**	[redacted]	
Area Manager – Railroad and Basin Operations **NSM**	[redacted]	
Area Manager Safety **NSM**	[redacted]	
Site General Manager **NSM**	[redacted]	
Area Manager Plant Operations **NSM**	[redacted]	
NSM Area Manager Environmental	[redacted]	
NSM Section Manager Safety	[redacted]	
Corporate Safety	[redacted]	
VP-Iron Ore Operations	[redacted]	
NSM/Cliffs Public Affairs Manager	[redacted]	
Procurement	[redacted]	
Corporate Environmental	[redacted]	
Area Manager - Maintenance and Asset Management	[redacted]	
Area Manager - Projects and Engineering	[redacted]	
Engineering Manager	[redacted]	
Cliffs Director Tailings Management	[redacted]	
Engineer of Record (Tailings Basin Consulting Engineer)	[redacted]	

Table. 1-1 *Continued* Emergency Notification Contact List: Milepost 7 Tailings Basin

Additional Resources	
MnDNR Dam Safety Jason Boyle 651-259-5715 (office) 651-917-1715 (home) Dale Homuth 651-259-5133 (office) 763-785-9052 (home)	**MN Division of the Homeland Security and Emergency Management** 651-201-7400
FEMA Regional V Manager 312-408-5500	**National Response Center** 800-424-8802
Lake County Emergency Management Office: 218-220-6277 Sheriff's Office: 218-834-8385	**MSHA Local Office** 218-720-5448 **MSHA National Office** 800-746-1553
MPCA MN Duty Officer 800-442-0798	**Northern Natural Gas** 888-367-6671
Ulland Brothers 218-262-3406 **Hoover Construction** 218-741-3280	**Beaver Bay Municipality** 218-226-3251 **Silver Bay Municipality** 218-226-4408
MN Power 800-228-4966	**Road Construction and State DOT** 800-657-3774
National Weather Service 952-361-3774	

2 Emergency Recognition Subplan

2.1 Emergency Level

It is important to determine the severity of the emergency before responding to an unusual event at a dam. Table 2-1 lists the events and the associated severity of the emergency to guide the dam Owner/Operator's actions during an emergency response. The emergency levels in Table 2-1 are explained at the bottom of the table, with Emergency Level 1 as nonemergency and Emergency Level 3 as urgent. Figure 1-1 and Figure 1-2 are the notification charts, and Table 1-1 is a list of all those who should be notified.

Table 2-1 Guidance for Determining the Emergency Level

Event	Situation	Emergency Level
Embankment overtopping	Reservoir level is 1.5 feet below the top of the dam	2
	Water from the reservoir is flowing over the top of the dam	3
Seepage	New seepage areas in or near the dam	1
	New seepage areas with cloudy discharge	2
	Seepage with cloudy discharge; increasing flow rate	3
Sinkholes	Observation of new sinkhole in reservoir area or on embankment	2
	Rapidly enlarging sinkhole	3
Embankment cracking	New cracks in the embankment greater than ¼-inch wide without seepage	1
	Cracks in the embankment with seepage	2
Embankment movement	Visual movement/slippage of the embankment slope	2
	Sudden or rapidly proceeding slides of the embankment slopes	3
[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]
	[redacted]	[redacted]
	[redacted]	[redacted]
	[redacted]	[redacted]

* Emergency Level 1: Nonemergency unusual event, slowly developing; high water
* Emergency Level 2: Potential dam failure situation, rapidly developing
* Emergency Level 3: Urgent; dam failure appears imminent or is in progress

2.2 Emergency Definitions

2.2.1 Imminent/Actual Failure

Description: Impending or actual sudden release of water caused by an accident or failure of project structures. Example: Failure of the perimeter earthen embankment.

2.2.2 Hydrologic Event/Potential Failure

Hydrologic Event Description: For the MP7 Tailings Basin, a hydrologic event is defined as conditions that result in significantly high water levels in the basin (i.e., a probable maximum precipitation event). A hydrologic emergency may result from higher-than-normal watershed yield over a prolonged period of time, a severe rainfall, snowmelt with a severe rainfall, or [redacted]

Potential Failure Description: This is the potential sudden release of water caused by an accident or other unusual occurrence. Actions taken during such potentially hazardous events may prevent or mitigate failure. Even if failure is inevitable, more time generally is available than in the situation of imminent/actual failure to issue warnings and/or take mitigative actions.

Examples of hydrologic event/potential failure:

- Advance warning or signs of significantly high water levels in the pond
- Erosion or uncontrolled seepage of earthen embankments
- Extensive movement, cracking, settlement, or leakage at the structure
- Something looks different from the normal conditions

2.3 Description and Maintenance of Detection and Monitoring Devices

2.3.1 Pond Water-Level Monitoring

Pond elevations are monitored daily by NSM staff to assess high water levels and/or changes in water levels that may impact the facility.

2.3.2 Dam Instrumentation Monitoring

Groundwater pressures are generally monitored on an approximate 4-hour basis. Deformation information is recorded at a minimum of twice a year.

2.4 Site and Flood Condition Surveillance

2.4.1 Hydrologic Surveillance

National Weather Service forecasts are monitored during times of high precipitation or snowmelt to evaluate the potential for extreme rainfall events. The pond water-level elevation of the tailings basin is monitored by NSM staff monthly; however, water surface levels should be monitored as often as possible during extreme storm events.

2.4.2 Informal Daily Inspections

During normal operation periods, on-site maintenance inspections are performed by NSM staff daily. The inspections consist of visually observing the dams and tailings basin embankments from the best available vantage points.

If unusual conditions are observed, the date and time of the observations, a description of the observed conditions, and a description of the actions taken will be recorded. Any unusual conditions will be [redacted]

2.4.3 Formal Inspections

Formal inspections of the MP7 Tailings Basin dams and embankments are conducted yearly by the engineer of record (Barr Engineering Co. personnel). A dam safety inspection report is submitted to NSM summarizing the inspection of the dams.

3 Emergency Notification Subplan

3.1 Incident Command System

[redacted]

3.2 Notification Sequence

The Notification Flowcharts (Figure 1-1 and Figure 1-2 in Section 1), summarize the sequence of notification and responsibilities for each participant in the EAP for Dams 1, 2, and 5. The chart applies to the two conditions—imminent/actual failure and hydrologic event (flood)/potential failure—as previously defined. If an individual cannot be reached, the next person on the list should be notified. If the flow of notification is altered, participants are encouraged to return to the order to ensure that every party is notified as needed.

The Notification Flowchart shows parties to be notified and the priority of notification for each participant in the EAP. Since the top priority is the protection of human life, participants are reminded that careful modifications to the order of notification or adaptations of the EAP may be necessary in unique circumstances. If failure is imminent or has occurred, warning and evacuation procedures are the top priority. For a potentially hazardous situation, mitigation efforts may be most important to avoid a panic situation. The Tailings Basin Engineer and his support team are responsible for this judgment.

[redacted]

3.3 Modes of Communication with Responsible Persons

The primary modes of communication with responsible persons are [redacted]

[redacted]

- [redacted]
- [redacted]

[redacted] for routine communication purposes. Other parties have equipment and personnel available to aid communication, such as the local police emergency manager, county emergency management, and federal organizations. [redacted]

3.4 Responsibilities

The following describes the chain of command and the responsibilities of the primary participants in the EAP.

3.4.1 [redacted]

[redacted].

The Tailings Basin Engineer, with the support of Lake County Emergency Management personnel, is also responsible for reviewing, updating, training, and testing the EAP as set forth in Appendix F. The Tailings Basin Engineer is responsible for ensuring that updated copies of the EAP are replaced when necessary.

3.4.2 Surveillance, Monitoring, and Initial Notification: NSM Staff

[redacted]

3.4.3 Warning and Evacuation: Lake County Dispatch

The top priority in an imminent/actual failure is the warning and evacuation of downstream areas. [redacted]

1) [redacted]

[redacted].

3.4.4 Coordinating Agency Communication: Tailings Basin Engineer

[redacted]

The NSM Safety Manager should contact the following staff and agencies listed in the notification flow chart

- Safety Section Manager
- Corporate Safety
- MSHA
- Federal Emergency Management Agency (FEMA)
- MPCA
- Minnesota Division of Homeland Security and Emergency Management (State Duty Officer)
- National Weather Service (Twin Cities Forecast Office and North Central River Forecast Center in Chanhassen, Minnesota)

Individual contacts are listed in the Notification Flowchart.

3.4.5 Mitigative Actions: Tailings Basin Engineer

[redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]

[redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

3.5 Public Warning Statements

Preparation of warning messages should begin as soon as the need is apparent so that these messages can be issued promptly upon declaration of an emergency condition. In some cases, an emergency condition may be declared with little or no advance notice. Warning messages should be considered for the following emergency conditions; example messages can be found in Appendix A:

- Imminent/Actual failure
- Hydrologic emergency (flood)/Potential Failure

3.6 Updates and End of Emergency Declaration

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Once the emergency is declared over, the dam Owner's Consulting Engineers will inspect the dam for any damage, hazardous or unsafe conditions, and assess near-term stability of structures. A post-disaster review of the inspection will be convened with the MnDNR Dam Safety Engineer to determine what actions may be needed to ensure that the dam complies with state standards. The review may result in formal orders issued to the dam Owner and may require the submittal of plans and specifications for repair.

4 Emergency Evacuation Subplan

4.1 Identification of Parties Responsible for Warning and Evacuation

[redacted]

4.2 Dam Breach Downstream Flow Paths

Risk to downstream roads and structures is dependent on which dam has failed. Individual flow paths were defined downstream of Dams 1, 2, and 5 to determine the boundaries of flood inundation downstream of each dam. It is important that the dam be identified during communication between NSM staff and Lake County Emergency Management so mitigation, warning, and evacuation efforts can be appropriately directed.

4.3 Dam Break Analyses and Inundation Maps

Inundation studies were done under fair-weather (sunny day) conditions, assuming a maximum pond elevation in the tailings basin and under probable maximum precipitation (PMP) storm-induced conditions. The dam break results and the impacts for the scenarios analyzed are summarized in Appendix E. The simulated inundation maps derived from the dam break analyses are presented in Appendix E. The inundation maps illustrate the approximate extent of the flooding and approximate flood wave travel time.

4.4 Effect of Dam Failure

[redacted]

4.5 Special Considerations

[redacted]

- [redacted]
  - [redacted]
  - [redacted]

    - [redacted]
    - [redacted]
    - [redacted]

- [redacted]
    - [redacted]
    - [redacted]
    - [redacted]
    - [redacted]
    - [redacted]

- [redacted]
    - [redacted]
    - [redacted]
    - [redacted]
    - [redacted]
    - [redacted]
    - [redacted]

[redacted]

Rally points and associated access routes in the basin for different dam break events considering the anticipated structure impacts are designated per the Access and Rally Point Plan (Appendix H).

5 Mitigation—Emergency Operations and Repair Subplan

5.1 General Emergency Response

The objective of emergency operations and repairs is to prevent or reduce the impact of an impending sudden release of water (see Section 2.2.1 and 2.2.2 for typical examples). It should be anticipated that this work may need to be performed during adverse conditions and will require various supplies and resources. The primary methods of mitigating the potential impact are the performance of emergency repairs and flood proofing, i.e., eliminating or reducing the potential for flood damage.

5.2 Hydrologic Emergencies

In the event of hydrologic emergencies, there are few additional actions available that could prevent or mitigate the effect of failure at Dams 1, 2, or 5. Pond levels should be monitored as often as possible during extreme events to prepare NSM staff for a possible hydrologic emergency.

[redacted]

5.3 Structural Emergencies or Potential Failure Conditions

In the event of structural emergencies or potential failure conditions, some repair options are available that could prevent or mitigate the effect of failure at Dams 1, 2, or 5. The services of a qualified engineer experienced in dam design and construction should be obtained before the performance of any repairs affecting dam safety. The one exception is if the services of an engineering firm cannot be obtained in time to prevent a failure. [redacted].

Potential emergency repairs that could be performed for some common deficiencies include:

- [redacted]

  [redacted]

- [redacted]

  [redacted]

[redacted]

[redacted] [redacted]

[redacted]

5.4 Emergency Supplies

[redacted]

5.5 Coordination of Flows

5.5.1 Advance Weather Runoff and Flow Forecasts

Advance weather runoff and flow forecasts/information are available from the National Weather Service. These forecasts and information can be extremely useful in the planning and timely implementation of mitigative measures. See the Notification Flowchart for telephone numbers.

5.5.2 Flow Regulation at the Milepost 7 Tailings Basin

[redacted]

5.5.3 Flow Regulation Upstream or Downstream

There is no flow regulation upstream or downstream along the Beaver River and its tributaries which could influence flows in the receiving waters at the time of a breach.

5.6 Maintenance Arrangements

5.6.1 Emergency Notification Contact List

The Emergency Notification Contact List (Table 1-1) should be replaced whenever there is a change in NSM or Cliffs personnel.

5.6.2 EAP Distribution List

The EAP distribution list is included in Appendix G and will be reviewed and updated at least annually by NSM. The purpose of an annual review of the EAP and training for dam owners and operators is to ensure that all contact information listed is accurate and that dam personnel are familiar with the EAP and understand their role in responding to a dam emergency.

5.6.3 Training

Personnel responsible for the implementation of portions of the EAP will be trained as outlined in Appendix F.

6 Post Emergency Action Subplan

6.1 Declaration of End of Emergency

The decision to declare the end of the emergency is left to the [redacted] After the threat of emergency has passed or the immediate consequences of a failure have been realized, it is important that the initiation of recovery or other post-emergency operations are based on a clearly defined decision. The declaration is to be transmitted through the notification chain as shown in the Notification Flowchart (Section 1).

6.2 Recovery

[redacted].

6.3 Inspection and Repair of the Dam

As soon as practicable following the emergency, irrespective of whether a failure actually occurred, the dam should be inspected by qualified engineers experienced in the design and inspection of dams. Appropriate notification of findings may be made to outside agencies. Repairs to the dam will be planned by experienced, technically competent personnel, and appropriate permits required by the regulatory agencies having jurisdiction over the project should be obtained.

However, if emergency conditions threatening life or property exist, NSM should, without special instructions, approvals, or permits, act at their discretion to prevent loss or injury.

6.4 Plan Critique

Soon after the emergency, a critique should be prepared, describing the events prior to, during, and following the emergency: significant actions taken by each participant; improvements for future emergencies; and all deficiencies found in procedures, materials, equipment, manpower, leadership, and funding. Throughout the process, it should be strongly emphasized that the purpose of the critique is not to assign credit or blame but to determine how future emergencies at this and other sites can be handled with the minimum loss of life and property.

A post-emergency report should be prepared and distributed to all organizations that participated in emergency response or have a direct interest in the emergency, including the Department of Natural Resources.

After a dam emergency has ended, a review of the event should take place as soon as practicable (if the review does not take place within 45 days of the dam emergency, valuable data may be lost). The review will determine what was done correctly during the EAP activation, what was done incorrectly, and what could be improved. Any needed changes to the EAP for the NSM MP7 Tailings Basin will be made or directed by the Owner.

An updated EAP, including updated Approval/Concurrence pages, will be provided to all holders of the EAP, including the Owner, Operator, the MnDNR State Dam Safety Engineer, and Lake County Emergency Management Officials.

The dam Owner/Operator should work with local emergency management to determine what opportunities exist to conduct or participate in dam-related EAP exercises.

7 List of Plan Revisions

Date	Section(s) Revised	Revision Description	Revisions by:

Appendices

Appendix A

Example Public Warning Statements

Appendix A

Example Public Warning Statements

Example warning statements suitable for broadcast over local radio channels or emergency broadcast systems are as listed below.

[redacted] [redacted]

[redacted]

[redacted] [redacted]

[redacted]

[redacted] [redacted]

[redacted]

Appendix B

Emergency Operating Procedures

Appendix B

Emergency Operating Procedures

Emergency operations are the procedures or operations that should be adhered to during conditions that represent an imminent danger to life and personal property or to the dam. The purpose of this section is to recommend emergency operating procedures that are designed to prevent or minimize property damage, injury, and/or loss of life as the result of emergency conditions.

Emergencies may arise as the result of natural forces such as unusually severe precipitation or may be the result of failure of some portion of the dam. In this section, some of the emergencies that may arise are discussed. However, forces or events that are not contemplated in this manual may precipitate an emergency. For this reason, it is extremely important that personnel charged with operation of the dam be fully aware of the nature of that responsibility and become thoroughly familiar with all aspects of dam maintenance and operation.

B.1 Hydrologic Emergency Operating Procedures

Unusually severe precipitation is considered to be that which could threaten the safety of the dam or require the implementation of special procedures to ensure dam safety. It is the intention of this manual to provide NSM staff with a conservative set of procedures for anticipating and reacting to severe precipitation events that may result in pond elevations near the minimum freeboard or flow rates that potentially exceed the discharge capacity of the proposed spillway.

To provide the time necessary to implement the emergency procedures required in the event of unusually severe precipitation, the NSM staff must first be aware of the potential development of such a flood and anticipate its severity. This means that emergency procedures may be initiated in situations when the ultimate emergency conditions do not develop. This possibility should not detract from the importance of the recommended procedures in all situations that have the potential for developing into emergency conditions.

During intense summer rainstorms, the NSM personnel should remain on-site to monitor pond levels and notify the [redacted] that there is potential for a hydrologic emergency. In the event of floods due to spring snowmelt or a combination of snowmelt and rainfall, the operator should prepare for a severe flood when floods in the area are predicted by the U.S. Weather Service flood forecaster. In addition to the flood predictions, the operator should monitor the daily and long-term forecasts. Forecasts predicting rapid warming trends in conjunction with rainfall should alert the operator to possible changes in the predictions of flood severity and timing. This procedure should continue until the snow cover is depleted.

B.2 Structural Emergency or Potential Failure Operating Procedures

[redacted]

[redacted]

[redacted]

- [redacted]
- [redacted]d

Appendix C

Description of Dams

Appendix C

Description of Milepost 7 Tailings Basin Dams

The Milepost 7 (MP7) Tailings Basin is an approximately 3-square-mile area used for deposition of tailings from Northshore Mining Company's mining operations. All the process water from plant operations and runoff from within the plant area is collected and pumped to the basin with the fine tailings. Once the tailings settle or are filtered out at the basin, clearer water is reclaimed and pumped back to the plant for process needs. Dams 1, 2, and 5, along with natural topography, create the embankments for the basin.

Dam 1 is on the southern end of the tailings basin. The dam is approximately 10,000 feet long and was initially constructed using a sand and gravel starter dam with an upstream clay face. Plant aggregate is used to increase the elevation of the dam, and the proposed maximum crest elevation for the 2019–2023 5YOP is 1,260 feet. The proposed dam downstream slope will be 6H:1V. The current dam crest is at 1,241 feet based on the lowest point on the filter berm in the fall of 2018, and the invert of the downstream flow path is approximately 1,130 feet. A seepage collection ditch is used to control seepage from Dam 1.

Dam 2 is on the northern end of the tailings basin. The dam is approximately 6,500 feet long. The dam was initially constructed using the glacial till cutoff, and plant aggregate is used to increase the dam elevation with the proposed maximum crest elevation of 1,260 feet for the 2019–2023 5YOP. The proposed downstream slope will be 6H:1V. The current dam crest is at 1,244 feet based on the lowest point in the filter berm in the fall of 2018 dam inspection, and the invert of the downstream flow path is approximately 1,154 feet. A seepage collection ditch is used to control seepage from Dam 2.

Dam 5 is on the mid-eastern perimeter of the basin. The dam is approximately 3,000 feet long. The dam was initially constructed using a glacial till cutoff, and plant aggregate was used to increase the dam elevation with the proposed elevation of 1,265 feet for the 2019–2023 5YOP. The current minimum dam crest elevation is 1,235 feet based on fall 2018 conditions, and the dam toe is at approximately 1,165 feet. Seepage is controlled by a seepage pumping system consisting of a submersible sump pump and pipeline, which pumps to the Reclaim Pond.

As stated in the most recent MP7 Tailings Basin Five-Year Operations Plan (Years 2019–2023), the pond water level is controlled and water volume in the pond is kept to a minimum. The following processes are used to control the water volume in the pond:

1. [redacted]

2. [redacted]

[redacted]

[redacted]

Currently, there are no emergency spillways designed for the dams. Spillways will be designed upon permanent closure of the basin. The spillways will be built to handle runoff and protect the integrity of the dams.

Appendix D

Purpose of the Emergency Action Plan

Appendix D

Purpose of the Emergency Action Plan

The purpose of the Emergency Action Plan (EAP) is to document a workable plan of action to be followed in the event of failure of the Milepost 7 Tailings Basin dams or severe hydrologic conditions at the tailings basin. In 1980, the state of Minnesota promulgated rules regulating the operation and maintenance of dams; however, the dams are not currently regulated by the MnDNR. If the dams were to be classified as Class 1 by the MnDNR, then in accordance with Minnesota Rules 6115.0340, NSM would be required to prepare an emergency action plan. At this time NSM has initiated the creation of this plan for their own use, to be prepared in the event of an emergency situation at the dam.

A copy of Minnesota Rules Section 6115.0490 Warning Systems and Emergency Procedures is attached.

Minnesota Rules for Emergency Plans

Minnesota Rules 6115 Department of Natural Resources

6115.0490 WARNING SYSTEMS AND EMERGENCY PROCEDURES.

Class I dam owners shall prepare and file for approval a contingency plan for notifying any persons whose lives, property, or health may be endangered by failure, misoperation, or other circumstances or occurrence affecting the dam, identifying most practical and expeditious means for warning considering the time factor involved based on the proximity of the dam to affected parties. If there is no feasible or practical means to provide for adequate evacuation warning in sufficient time if a catastrophe occurs the owner shall be responsible for notifying affected downstream property owners of that fact.

STAT AUTH: MS s 105.535

Current as of 06/11/08

Appendix E

Dam Break Analyses Methodology and Results Summary

Appendix E - Dam Breach Analysis of the Northshore Milepost 7 Tailings Facility

April 2022

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Certifications

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

	April 1, 2022
Omid M. Mohseni, PhD, PE PE #: 26159	Date

Abbreviations

AEP	annual exceedance probability
Barr	Barr Engineering Co.
cfs	cubic feet per second
CDA	Canadian Dam Association
cfs	cubic feet per second
Cliffs/NSM	Cleveland-Cliffs Inc. - Northshore Mining Company
Cliffs	Cleveland-Cliffs Inc.
CSAH	County State Aid Highway
d_{50}	median grain size
EAP	Emergency Action Plan
FEMA	Federal Emergency Management Administration
FERC	Federal Energy Regulatory Commission
FOS	factor of safety
fps	feet per second
ft	feet
HEC-RAS	Hydrologic Engineering Center–River Analysis System
Milepost 7	MP7
MnDNR	Minnesota Department of Natural Resources
NAVD88	North American Vertical Datum of 1988
NSM	Northshore Mining Company
pcf	pounds per cubic foot
PMP	probable maximum precipitation
µm	micrometer
USGS	United States Geological Survey
VOF	volume of fluids
5YOP	5-Year Operations Plan

E1 Introduction

Cleveland-Cliffs Inc.-Northshore Mining Company (Cliffs/NSM) retained Barr Engineering Co. (Barr) to complete simulated dam breach analyses on the Milepost 7 (MP7) Tailings Basin in Lake County, Minnesota. The new dam breach analyses correspond to the projected 2023 conditions for the 2019–2023 5-Year Operations Plan (5YOP).

E1.1 Site Description

The Cliffs/NSM MP7 Tailings Basin is located approximately 3 miles to the northwest of the city of Beaver Bay at Lake Superior (Figure E1-1). The tailings basin is a two-cell tailings storage facility (TSF) with three perimeter dams, including Dams 1, 2, and 5. The two cells are connected with small culverts and have similar normal pool elevations. These dams, along with natural topography, impound fine tailings in the NSM MP7 Tailings Basin.

Dam 1 is located at the southern end of the MP7 Tailings Basin and is considered the highest dam (vertical distance from natural ground) at the facility (Figure E1-1). Dam 2 is located on the northern end of the Tailings Basin. Dam 5 is located on the mid-eastern perimeter of the basin. Currently, there is no emergency spillway for the dams as designed with the capability of storing stormwater runoff. The freeboard after a probable maximum precipitation (PMP) event is greater than 7 feet, as discussed in Section E3.2.

E1.2 Purpose

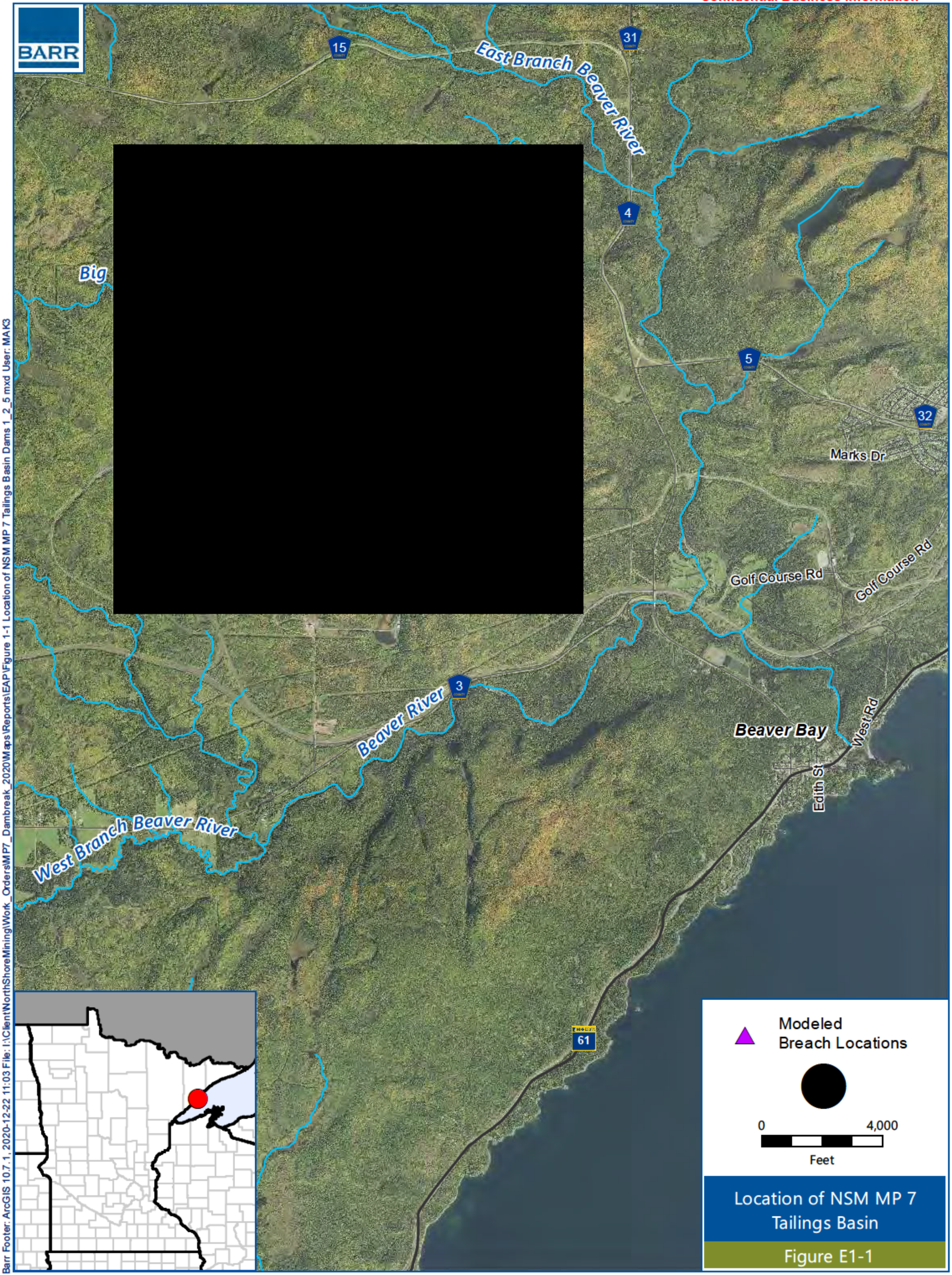
Previously, in 2012, Barr assisted Cliffs/NSM in completing the initial Emergency Action Plan (EAP) for the MP7 facility, which included dam break analyses of the three perimeter dams (Reference (1)). These analyses used the standard of the industry at the time as appropriate for the MP7 Tailings Basin, a one-dimensional (1D) version of the US Army Corps of Engineers Hydrologic Engineering Center-River Analysis System (HEC-RAS) software program. The analyses were performed considering the maximum estimated basin elevation and assumed no mobilization of fine tailings and only supernatant water (ponded water) runout during a hypothetical dam failure scenario.

NSM retained Barr to update the previous EAP for the projected 2023 conditions of the MP7 TSF, i.e., focusing on the time frame for the next 5-year operations plan (5YOP) (Reference (2)), which falls between the years of 2019 and 2023. The update to the EAP includes an assessment of mobilized tailings in a hypothetical dam failure by in-depth analyses and evaluations of site-specific material parameters, key geotechnical variables, credible failure modes, and by investigating potential deposition of plant aggregate and fine tailings as breach flood waves run out of the basin.

Organization of the current updated dam breach analyses closely follows the recommended approach provided in the *Canadian Dam Association (CDA) Draft Guidelines for Tailings Dam Breach Analysis* (version 12.1) (Reference (3)). As explained in Section E6, the runout analyses have been completed using FLOW-3D and HEC-RAS 2D software programs, which are both some of the most advanced software programs for this type of dam breach analysis.

This report describes the analyses and evaluations completed for the hypothetical failure of Dams 1, 2, and 5 during two hypothetical failure scenarios. It is organized as follows:

- Section E2: Describing the project data
- Section E3: Evaluating credible failure modes and defining failure scenarios
- Section E4: Defining breach parameters
- Section E5: Estimating volume of mobilized tailings
- Section E6: Introducing the hydraulic modeling approach
- Section E7: Model results and inundation maps
- Section E8: Summary and conclusion



Location of NSM MP 7 Tailings Basin

Figure E1-1

E2 Project Data

The project data includes the data necessary to (a) evaluate credible failure modes of the dams, (b) estimate the volume of runout during different failure scenarios, (c) develop the hydraulic model for routing the flood wave resulting from hypothetical breach scenarios, and (d) estimate the impact of hypothetical dam breach scenarios downstream of breach locations. The project data includes datum, topographic data, the tailings basin geometry, geotechnical data, hydrologic data, land cover data, road and rail crossings, and structures downstream of the potential failure locations.

E2.1 Datum

The project geospatial data referenced the NAD83 HARN (High Accuracy Reference Network) Minnesota Lake County coordinate system projection and NAVD88 vertical datum in feet.

E2.2 Topographic Data

The 2011 NE Minnesota Arrowhead Region 1-meter-resolution LiDAR was used as the basis for topographic data. Channel bathymetry data was incorporated from the 2012 HEC-RAS 1D model cross sections, as described in Section E6.2.

E2.3 Geometry of Dams

Dam 1 is approximately 10,000 feet long and was originally constructed using sand, gravel, and a clay face. Plant aggregate is used to raise the embankment elevation. The proposed maximum crest elevation for the 2019–2023 5YOP is 1,260 feet. The crest width is about 500 feet. The proposed dam raise has a downstream slope of 6H:1V. The bottom width of the embankment is approximately 1,200 feet. The normal pool elevation of the south cell is 1,250 feet, representing the year 2023 in the current 5YOP, with an estimated corresponding tailings beach elevation of 1,240 feet. The surface area corresponding to this normal pool elevation is approximately 1,015 acres.

Dam 2 is currently about 6,500 feet long and was originally constructed using a glacial till cutoff. Plant aggregate is used to raise the embankment, and similar to Dam 1, the proposed maximum crest elevation for the 2019–2023 5YOP is 1,260 feet. The crest width is about 350 feet. The proposed raise has a downstream slope of 6H:1V. The bottom width of the embankment is approximately 800 feet. The normal pool elevation is also 1,250 feet, representing the year 2023 in the current 5YOP, with an estimated corresponding fine tailings beach elevation of 1,240 feet. The surface area of the north cell at this normal operating pool elevation is approximately 795 acres.

Dam 5 is approximately 3,000 feet long and was constructed using plant aggregate with a glacial till cutoff. Plant aggregate is used to raise the dam, and the proposed maximum crest elevation for the 2019–2023 5YOP is 1,265 feet. The crest width is about 150 feet. Like Dam 1 and Dam 2, the proposed raise has a downstream slope of 6H:1V. The tailings beach is far upstream and is not up against the upstream face of Dam 5. As such, the tailings beach elevation is estimated to be approximately 1,200 feet in this area. Since the Dam 5 crest is planned to be at a maximum elevation of 1,265 feet during the same time frame that the maximum crest of Dam 1 and Dam 2 is 1,260 feet, the corresponding normal operating pool elevation is 1,250 feet.

E2.4 Geotechnical Data

The primary geotechnical data required for the dam breach analysis is the liquefied undrained shear strength and solids content of the fine tailings/slimes. Table E2-1 lists the fine tailings geotechnical data used in approximating the characteristics of the mixture of water and tailings as they flow out of the basin and the geotechnical analyses performed as part of this study.

Table E2-1 Fine Tailings Geotechnical Data Summary

Parameter	Value	Basis
Specific gravity	3.0–3.1	Available laboratory testing data
In-situ density (saturated)	130 pcf	Available laboratory and field testing data
Location of phreatic (pond) surface	1,250 feet	Estimated normal pool elevation relative to crest elevation from 2019–2023 5YOP
Median grain size	35 µm	Available laboratory testing data
Solids content	55 percent by volume	Estimated from field and laboratory testing data
Design liquefied undrained shear strength ratio (USSR)	0.10	Derived from available laboratory and field testing data evaluated as part of the most recent dam raise analysis for Dam 1
Post-liquefaction tailings slope	5.7 degrees	Estimated from the liquefied USSR

E2.5 Hydrologic Data

E2.5.1 Meteorological Data

PMP estimates for the project are derived from the Hydrometerological Report No. 51, 72-hour PMP for a 10-square-mile watershed (Reference (4)). For this part of Minnesota, the 6-hour and 72-hour, 10-square-mile PMP are 22 and 32 inches, respectively.

E2.5.2 Streamflow Data

There are no stream gages operating in the area of interest along the Beaver River. The United States Geological Survey (USGS) Stream Stats web-based tool (Reference (5)), which relies on regional regression equations to estimate flood magnitude and frequency relationships, was used to estimate the 1:25 annual exceedance probability (AEP) flow for the Beaver River at the confluence with the West Branch Beaver River and for the East Branch Beaver River at the confluence with the Beaver River. The 1:25 AEP flows were estimated to be 5,120 cfs and 3,080 cfs, respectively.

E2.6 Land Cover Data

The 2011 land cover data from the National Land Cover Database (Reference (6)) was used to estimate surface roughness in the hydraulic models downstream of NSM Railroad Bridge 1. The dataset includes 20 unique land-cover classifications using remote sensing technology. From these 20 classifications, Barr has developed an estimate for Manning's roughness coefficients appropriate for two-dimensional (2D) models in this region of Minnesota (Table E2-2).

Table E2-2 Manning's Roughness Values by Land Cover Type

Land Cover Type	1D Manning's n	2D Manning's n(1)
Barren land	0.04	0.036
Herbaceous	0.05	0.045
Mixed forest	0.10	0.090
Open water	0.03	0.027
Shrub/scrub	0.05	0.045
Woody wetlands	0.04	0.036
Cultivated crops	0.06	0.054
Deciduous forest	0.10	0.090
Developed, low-density	0.10	0.090
Developed, medium-density	0.12	0.108
Developed, open space	0.08	0.072
Emergent herbaceous wetlands	0.04	0.036
Evergreen forest	0.10	0.090
Hay/pasture	0.05	0.045

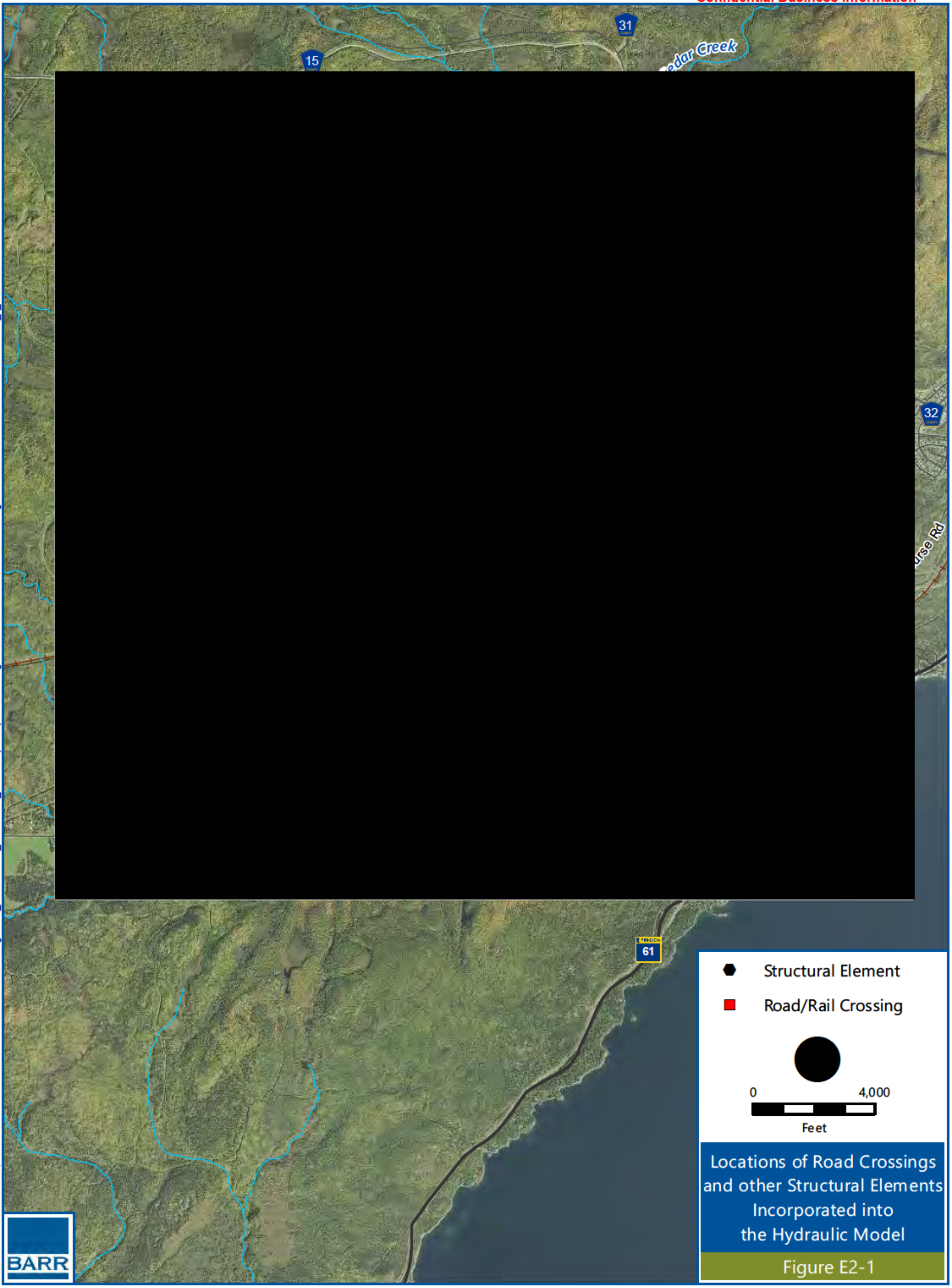
(1) Two-dimensional model roughness values assumed to be 90% of the one-dimensional model values for each cover type

E2.7 Road and Rail Crossings

There are five road and rail crossings over the Beaver River and in areas just downstream of Dam 1 and three road crossings downstream of Dam 2 and Dam 5 on the East Branch Beaver River. Bridge geometries were taken from the 2012 1D model for road crossings, including NSM Railroad Bridge 1 that was incorporated in the FLOW-3D model (Figure E2-1). Additional structures that were used inside the FLOW-3D model were a small dam (representing seepage recovery dam 1A), a road embankment crossing seepage recovery pond 1A, and a railroad embankment labeled in the models as Small Dam, Embankment 1 and Embankment 2, respectively, as shown in Figure E2-1. A culvert downstream of Bear Lake was incorporated into the breach analysis of Dam 5.

E2.8 Structures Identification

Habitable and non-habitable structures were identified by selecting building footprints within the study area from the Microsoft Open Data United States Building Footprints database (Reference (7)). This buildings dataset is freely available for download and use under the Open Data Commons Open Database License (ODbL). Microsoft created the building footprint polygons through an automated process that reviewed a composite of aerial imagery from multiple sources. The data vintage is circa 2018. Structure footprints were checked against aerial imagery to account for any new buildings since the creation of the dataset. High-resolution (6-inch) aerial imagery acquired by Lake County, Minnesota, in spring 2019 was reviewed, as well as the 2019 National Agriculture Imagery Program aerial imagery, for the maximum inundation extents of each structure. Structure locations were classified as habitable or non-habitable based on this desktop review of 2019 imagery as well as Lake County parcel classifications from May 2020. Additional structures were added to the final dataset, as needed, through the course of this review. Note that Barr did not undertake an on-site survey to verify the structure locations and classifications as of the date of the report.



Locations of Road Crossings and other Structural Elements Incorporated into the Hydraulic Model

Figure E2-1

E3 Dam Failure Modes and Failure Analyses

E3.1 Dam Failure Modes

The following subsections provide an overview of potential failure modes for the dams and identify the credible failure mode to be considered in the breach analyses of these dams. It is important to note that a credible failure mode is not indicative of any actual probability of the event occurring, but rather to aid engineers in simulating a hypothetical failure scenario for the development of an EAP.

E3.1.1 Overtopping Failure

An overtopping failure occurs when water rises unchecked and flows over the top of a dam, which can subsequently lead to erosion of the dam crest and downstream slope and, eventually, a dam breach. Overtopping generally occurs in one of two scenarios. The first scenario consists of a rise of the impounded pond to an elevation above the lowest point of the dam crest. The second scenario includes an impounded pool rise approaching, but not exceeding, the lowest point of the dam crest and then wind-driven waves in the pool runup and over the top of the dam.

[redacted]

E3.1.2 Liquefaction of Fine Tailings

Thorough analyses were performed to assess whether liquefaction failure is a credible failure mode for the MP7 Tailings Basin dams. It is anticipated that most of the time loading or change in loading within the fine tailings will be slow enough for the fine tailings to be sheared under drained conditions. However, there may be circumstances during which rapid changes in load and/or local stress may lead to undrained loading that changes the state of stress within the fine tailings over a short time period (e.g., trigger static liquefaction as a result of dam failure due to piping).

[redacted]

E3.1.3 Foundation Failure

The potential of failure of foundation materials was also reviewed. [redacted].

E3.1.4 Internal Erosion

Internal erosion is the mechanism where water moving through an earthen embankment dam carries soil particles, creating an elongated cavity or pipe. This pipe becomes a path of least resistance for water from the upstream pool to exit at the dam face, dam toe, and/or point beyond the dam toe. Continued erosion along this pipe subsequently results in a weak point within the dam materials and/or foundation and can lead to a dam breach.

[redacted]

E3.2 Dam Failure Scenarios

Two failure scenarios were considered for Dams 1, 2, and 5: a fair-weather failure scenario and a storm-induced failure scenario.

For the fair-weather dam failure scenario, the normal pool elevation in the tailings basin under the extreme hydrologic conditions in the 2019–2023 5YOP is expected to be about 1,250 feet. This normal pool elevation corresponds to a 5-year hydrologic condition with a probability of exceedance smaller than 1% according to the 2019–2023 water balance study, i.e., this is a very conservative estimate of normal pool elevation. During the fair-weather dam-failure scenario, it was assumed that the nearby streams and rivers exhibit the mean annual flow.

For the storm-induced failure scenario, the storm was assumed to be the 6-hour PMP event with a pool elevation of 1,245.1 in the tailings basin prior to the PMP event. A pool elevation of 1,245.1 feet corresponds to wet annual watershed net yield with a 1% probability of exceedance (i.e., a year with a number of extreme events). A probability of exceedance of 1% is based on the 2019–2023 water balance study (Reference (8)). This pool level condition is about 6.6 inches more than the annual average watershed net yield observed in the 2013–2017 period. Note that during a 72-hour PMP event, the low intensity of the rainfall during the first and last 24-hour periods will result in more infiltration in the watershed area, i.e., not all of the water from the 72-hour PMP event will become runoff. No calculation was performed to estimate the volume of infiltrated water during a 72-hour PMP event. Instead, a 6-hour PMP event was used with the assumption that some of the rain of the 72-hour PMP event would infiltrate and the entire 6-hour PMP event becomes runoff. Using a 6-hour PMP depth of 22 inches with the maximum pool elevation of 1,245.1 feet results in a pool elevation of about 1,252.2 feet. This corresponds closely to a 72-hour PMP event during average pool conditions in the MP7 Tailings Basin.

During the PMP-induced dam failure scenario, it was assumed that the nearby streams and rivers exhibit the 1:25 AEP flood. This assumption is based on the fact that the failure mode is [redacted].

E3.3 Modeled Failure Location

The failure location of Dam 1, [redacted] was set to the highest height (lowest toe) of Dam 1, [redacted]. The bottom elevation of the breach location was set equal to the [redacted] embankment—estimated from the LiDAR elevation data to be [redacted] (see Figure E1-1). This might be a very conservative assumption; however, due to lack of sophisticated models to determine the bottom of the breach location, it is a reasonable level of conservatism.

The assumed failure location of Dam 2 was similarly estimated as the area of greatest height, [redacted]. The base elevation of the breach location was set to a corresponding elevation of [redacted] for Dam 2, as estimated from LiDAR data. For Dam 5, the assumed failure location was also estimated in the area of greatest height, [redacted]. Due to the presence of Bear Lake downstream of the dam, the base of the failure was accordingly estimated as an [redacted]

E4 Breach Parameters

The breach parameters include breach width, breach side slope, and breach formation time. In some cases, the peak outflow may also be included in breach parameters if the software program does not simulate the outflow hydrograph. Herein, the breach parameters were estimated using Chapter 2 of the FERC Engineering Guidelines for Dam Safety and Inspections (Reference (9)). Note that all existing methods to estimate the dam breach parameters have been developed for water-retaining dams; therefore, these breach parameters, specifically the breach formation time, does not necessarily apply to tailings dams.

E4.1 Dam 1

The bottom elevation of the breach was set equal to the downstream toe of the embankment dam, estimated from the LiDAR elevation data to be [redacted] feet, as discussed in Section E3.3. According to the FERC Engineering Guidelines (Reference (9)), the ratio of average breach width to dam height in earthen dams varies from 1:1 to 5:1. To be on the conservative side, a ratio larger than 3:1 is usually selected. A ratio smaller than 3:1 is selected if there is adequate justification for a smaller breach width.

[redacted]

Regarding the breach formation time, the geometry of the dam was reviewed. As the crest width of the dam is quite large (the downstream side slope is 6H:1V, and the height is approximately 130 feet) and material behind the dam is both tailings and water, it is anticipated that breach formation [redacted] will occur over several hours. There is no recommendation or specific study of breach formation time for these types of large tailings dams in the literature. A number of parametric equations for predicting the breach formation time based on case studies were reviewed (Reference (10)). However, all dams in those case studies were water dams and not tailings dams. Using the parametric equations, the recommended breach formation time for Dam 1 ranges from 0.1–3.2 hours, with a median value of 1.0 hour. However, the relationship proposed by MacDonald and Landgridge-Monopolis (Reference (11)) is the only one that uses the volume of the embankment material eroded, so it will best account for the large size of the embankment. Using MacDonald and Landgridge-Monopolis (Reference (11)), the recommended breach formation time for Dam 1 is approximately 3.2 hours; hence, the breach formation time was set equal to [redacted]. Note that the calculated breach formation time is appropriate for water dams, which may erode faster than tailings dams.

A sensitivity analysis was completed by varying the breach formation time from 1 hour up to 3 hours, and the resulting changes to the inundation extent and impacts were determined to be minimal.

E4.2 Dam 2

The bottom elevation of the breach was set equal to the downstream toe of the embankment dam, which was estimated from the LiDAR data to be about [redacted]. The height of the dam is 100 feet; therefore, the average breach width was set equal to [redacted] (four times the height of the dam). [redacted]

Due to the massive size (width) of the Dam 2 embankment, but shorter and smaller geometry compared to Dam 1, and the fact that the dam holds both water and tailings, the time for breach formation was set equal to [redacted] hours using the relationship proposed by MacDonald and Landgridge-Monopolis (Reference (10)).

E4.3 Dam 5

The bottom elevation of the breach was set equal to the downstream toe of the dam, which is at [redacted] feet for Dam 5. However, the normal water elevation of Bear Lake at the toe of Dam 5 is at 1,202.7 feet, which is about 38 feet higher than the toe elevation. If Dam 5 breaches, the breach bottom elevation may never reach the elevation [redacted] feet because of Bear Lake. In addition, the flow through the breach will be a function of the difference between the head upstream in the basin and the water level of Bear Lake. As a result, the bottom elevation of the breach was set equal to [redacted] feet. This is also approximately equal to the assumed elevation far upstream of the dam. The height of breach was computed to be 32.3 feet; therefore, the average breach width was set equal to [redacted] feet (four times the height of the breach). [redacted]

Because of the height of the breach, the Dam 5 breach formation time was set equal to [redacted] hour.

Table E4-1 is a summary of breach parameters of all three dams.

Table E4-1 Selected Breach Parameter Values for Dam 1, Dam 2, and Dam 5

Dams	Average Breach Width (ft)	Bottom Breach Width (ft)	Breach Side Slope	Breach Formation Time (hours)
Dam 1	[redacted]	[redacted]	[redacted]	[redacted]
Dam 2	[redacted]	[redacted]	[redacted]	[redacted]
Dam 5	[redacted]	[redacted]	[redacted]	[redacted]

E5 Volume of Mobilized Tailings and Runout

E5.1 Localized Tailings Liquefaction near the Breach Area

The total volume of mobilized tailings is the sum of eroded tailings and liquefied tailings near the dam breach area due to a dam breach. Localized liquefaction of fine tailings was assumed to be the result of loss of confinement of the outer slope due to internal erosion and not a liquefaction failure of the embankment.

To estimate the volume of liquefied tailings, the dam geometry was used and the failure surface for static liquefaction was estimated, as explained in the following subsections.

E5.1.1 Dam Geometry

The dam geometry included in the breach-induced liquefaction evaluation consists of the anticipated crest elevation of each dam within the next 5 years. Dam 1 and Dam 2 are anticipated to be constructed up to elevation 1,260 feet in this timeframe. Dam 5 is anticipated to be constructed slightly higher, to a crest elevation of 1,265 feet. The upstream pond elevations were considered to be a maximum of 1,250 feet for normal operating conditions and 1,252.2 feet for flood conditions to accommodate 10 feet and 7.8 feet of freeboard relative to the lower crest elevation of Dam 1 and Dam 2.

E5.1.2 Failure Surface Estimation Approach

Failure surfaces following static liquefaction due to a hypothetical dam breach were evaluated for Dam 1 and Dam 2. Fine tailings are present far upstream of Dam 5; hence, fine tailings are not anticipated to flow if a breach of this dam were to occur.

The failure surfaces for a hypothetical breach of Dam 1 and Dam 2 were estimated considering potential slip surfaces for limiting scenarios from limit equilibrium analyses. The failure surface for each dam was estimated based on the approximate angle of repose of localized liquefied fine tailings of 5.7 degrees from horizontal and is the best available interpretation based on the current standard of practice and knowledge of dam breach conditions. This failure plane was then estimated to extend at this angle from the base of the limiting slip surface for each dam to the upstream pond, which represents the conservative situation where all the dam materials are eroded, sloughed, or piped from the initial limiting slip surface over to the adjacent tailings pond. For purposes of the hydraulic model, this final failure plane was considered to be the delineation between fine tailings that are washed away versus fine tailings that remain in place.

E5.2 Mobilized Tailings Volume

The localized liquefied tailings volume was based on the breach opening, the geometry of the basin in the proximity of the breach opening, and an equivalent slope angle of the failed tailings mass based on the post-liquefaction strength of the tailings (5.7 degrees). Figure E5-1 shows the schematic (plan view [a] and cross section [b]) used to approximate the volume of localized liquefied tailings, assuming a semi-conic shape for liquefied tailings. The hypothesized starting point of liquefaction is also shown. Volumes V1 and

V2, shown in Figure E5-1, were estimated using the semi-conic shape of V1 and the prism of V2. The eroded tailings were estimated by assuming that the weight of eroded fine tailings is equal to the weight of water in the tailings basin during each dam failure scenario.

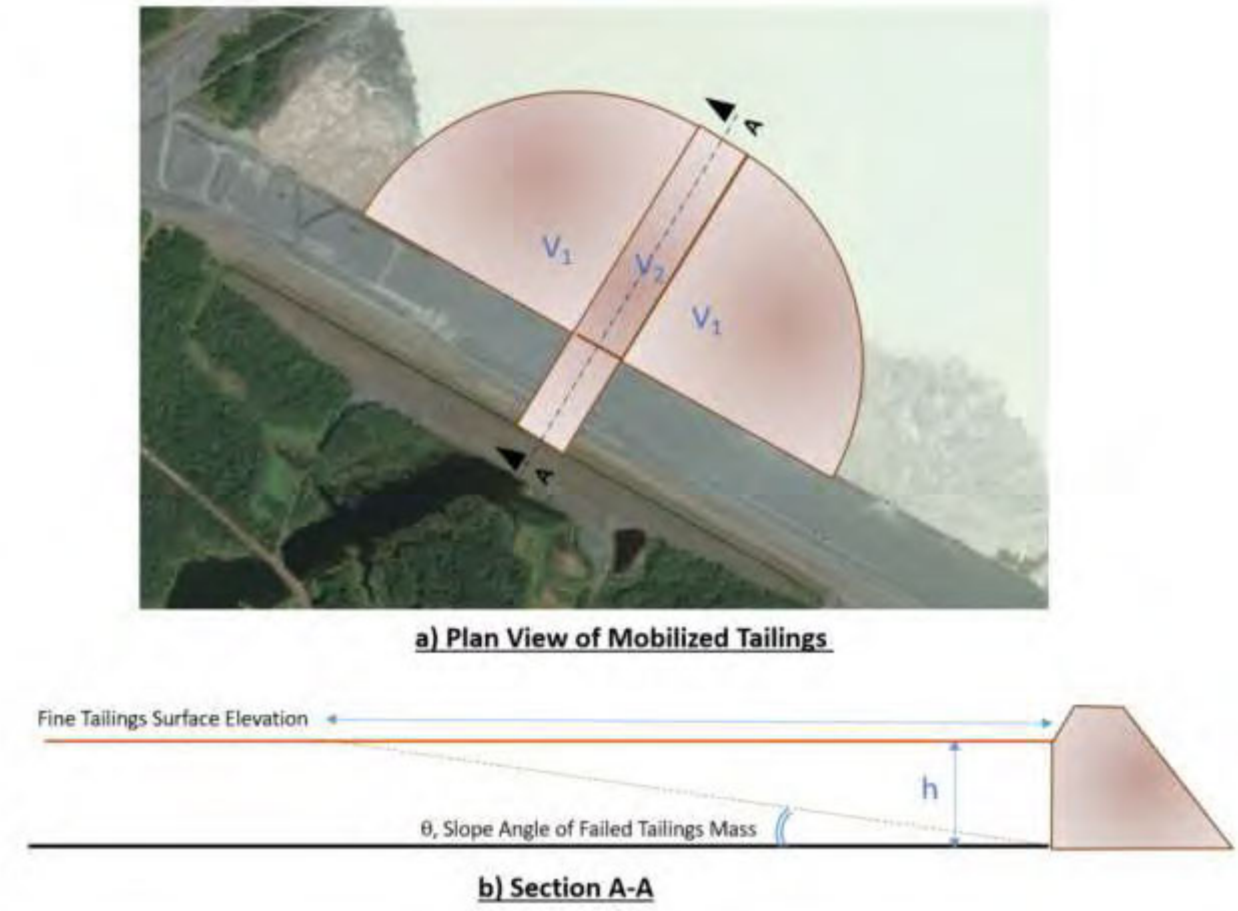


Figure E5-1 Schematic of the Geometry Used in Estimating the Volume of Mobilized Tailings

Table E5-1 lists the total volume of runout for Dam 1 based on the post-liquefaction slope angle of the fine tailings and the approach described above to estimate eroded fine tailings. The volume of eroded embankment was calculated based on the geometry of embankment and breach parameters and was determined to be about [redacted].

Note that for Dam 5, no fine tailings are present beneath or directly upstream of the dam to be liquefied. In addition, the fine tailings are situated far upstream of the dam and, therefore, the fine tailings will not be eroded following a breach of Dam 5. As a result, the failure of Dam 5 will be similar to a dam impounding only water with water in the south cell leaving through the breach location.

Table E5-1 Total Volume of Runout for the Failure of the Dams during the Two Failure Scenarios

Dams	Scenarios	Volume of Liquefied Tailings (CY)	Volume of Eroded Fine Tailings (CY)	Volume of Eroded Coarse Tailings (Embankment) (CY)	Pond Water Volume (CY)	Total Volume
Dam 1	Fair-weather	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	PMP-induced	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Dam 2	Fair-weather	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	PMP-induced	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Dam 5	Fair-weather	-	-	[redacted]	[redacted]	[redacted]
	PMP-induced	-	-	[redacted]	[redacted]	[redacted]

E5.3 Runout Characteristics

Fine tailings properties were used in the analysis to determine whether the fine tailings runout from a dam break may be mobilized as a Newtonian or non-Newtonian fluid. Characteristics were derived based on laboratory testing results of disturbed and undisturbed samples of fine tailings from the MP7 site. Based on test results from four samples, the average specific gravity of fine tailings is 3.06 (rounded to 3.1 for analysis), with overall values ranging from 3.02 to 3.12. Percent solids content was evaluated by weight and by volume, summarized in Table E5-2. The grain-size distribution of fine tailings is also summarized in Table E5-2. The results show that the solid content

Table E5-2 Fine Tailing Characteristics at the NSM MP7 Site

Statistics	Solids Content by Weight	Solids Content by Volume	Grain-Size Distribution				
			Gravel	Sand	P200	Silt	Clay
	%	%	%	%	%	%	%
Minimum	70.2	44.0	0.0	0.0	21.8	19.8	0.0
Maximum	98.2	94.9	11.0	78.2	100.0	98.3	11.0
Average	78.8	55.0	0.6	14.8	84.6	81.5	3.2

The solids content by volume of the fine tailings is about 0.55. Assuming full mixing of liquefied tailings, eroded tailings, and the supernatant pond, the solids content by volume of the runout mixture for the fair-weather dam failure scenarios for Dam 1 and Dam 2 are 0.22 and 0.18, respectively. Similarly, the solids content by volume of the runout mixture for the PMP-induced dam failure scenario is 0.2 and 0.17, respectively. According to O'Brien (Reference (12)), solids content by volume from 0.45 to 0.55 behaves as non-Newtonian fluids, and from 0.05 to 0.45 as hyper-concentrated flows. Solids content by volume less than 0.2 behaves as water (i.e., as Newtonian fluid).

E6 Hydraulic Modeling Approach

E6.1 General Description

As stated in Section E1.2, the purpose of this study was to perform the breach analyses of the MP7 Tailings Basin based on available cutting-edge tools and software programs as appropriate based on the characteristics of the MP7 Tailings Basin. As stated in Section E5.3, the runout characteristics lend themselves to use of a hydraulic model that routes the flood wave as a Newtonian fluid. However, the amount of solids and the presence of two road embankments, a small dam, and NSM Railroad Bridge 1 in the path of a flood wave resulting from the hypothetical failure of Dam 1 and a seepage pond downstream of Dam 2 will (1) cause ponding, lateral spread of flood waves, and development of quiescent areas near the dam that could enhance deposition of fine tailings, (2) decrease the runout volume downstream of NSM Railroad Bridge 1, (3) decrease the peak of flood wave, and (4) subsequently reduce the potential impact on downstream properties.

To meet the goals of this study, it was necessary to select software programs capable of simulating lateral flows, sediment transport, and above all, fine tailings deposition as stated in the CDA draft guidelines (Reference (3)). To simulate lateral flows a 2D hydraulic model was adequate, and to simulate sediment transport and deposition a 2D or 3D model with sediment transport modules was necessary. In the following subsections, model selection is further explored and described. The subsequent sections provide information on the hydraulic models used in this in-depth breach analysis of the MP7 Tailings Basin.

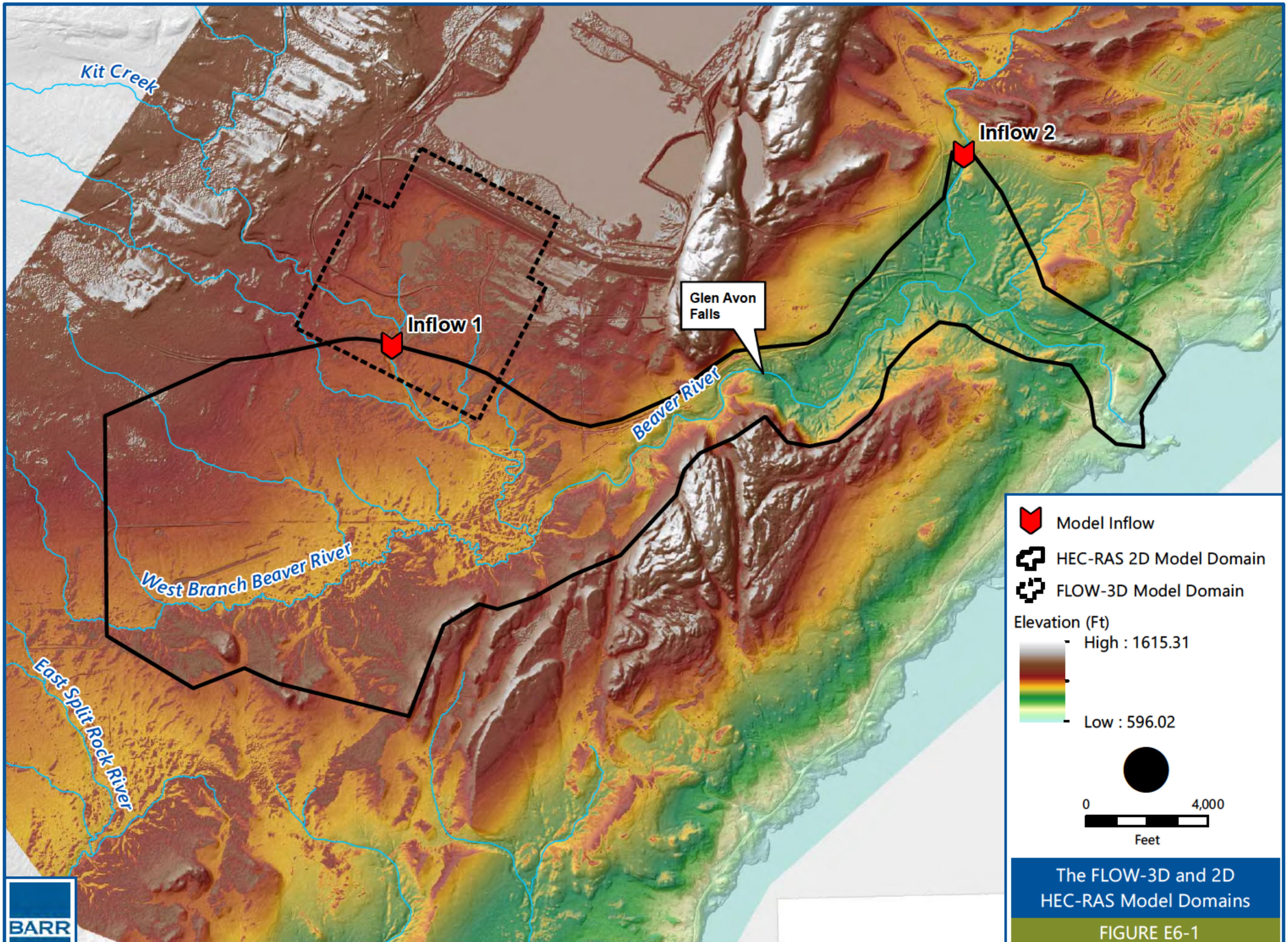
E6.1.1 Model Platform Selection

Three modeling platforms were considered for this analysis: FLOW-3D, FLO-2D, and HEC-RAS. FLOW-3D was selected because it is currently the only hydrodynamic software program with the capability of modeling runout of Newtonian and non-Newtonian fluids and simulating erosional and depositional processes. Running FLOW-3D for a large domain is not feasible because of the long run times. As a result, the selected approach was a hybrid model using an upstream FLOW-3D domain to capture sedimentation processes, specifically tailings deposition, and a downstream 2D model to route the flood wave along the Beaver River. Below are brief descriptions of the three model platforms.

FLOW-3D

FLOW-3D is a Computational Fluid Dynamics (CFD) software package developed by Flow Science Inc. It is capable of solving three-dimensional hydrodynamics on a structured orthogonal numerical mesh with a method called Fractional Area–Volume Obstacle Representation (FAVOR) and a modified volume of fluids (VOF) method called truVOF. It also includes several other modules to incorporate additional physics such as air entrainment, sediment transport, granular flow modeling, and non-Newtonian flow modeling. Because FLOW-3D solves the momentum, continuity, and sediment transport equation in a three-dimensional space, it is computationally impractical to run FLOW-3D for the entire domain and all dam failure scenarios. FLOW 3-D was used for modeling work in the upper reaches of the Dam 1 breach analysis. Figure E6-1 shows the model domains for the Dam 1 breach analysis. The FLOW-3D model domain was established as being from the dam embankment to NSM Railroad Bridge 1 to capture the potential fine tailings deposition upstream of Embankments 1 and 2 and the small dam (Figure E2-1) during a PMP-induced Dam 1 failure scenario.

Confidential Business Information



The FLOW-3D and 2D HEC-RAS Model Domains

FIGURE E6-1

HEC-RAS

HEC-RAS version 5.0.7 is the US Army Corps of Engineers Hydrologic Engineering Center hydraulic software program that can be developed as a 1D, 1D/2D, or fully 2D hydraulic model. For complex flood wave routing, fully 2D domains are used to capture complex flow patterns. While HEC-RAS has a sediment transport module, it cannot simulate sediment deposition. The current version of HEC-RAS is limited to routing water flood waves in a variety of terrains, i.e., it cannot simulate routing of non-Newtonian fluids. HEC-RAS is computationally reasonable and utilizes a subgrid bathymetry algorithm to allow for larger cells in the computational mesh with minimal loss of accuracy. HEC-RAS 2D was used for the area downstream of the NSM Railroad.

FLO-2D

FLO-2D is a pseudo-2D modeling platform that performs flood routing on a square grid in eight directions. FLO-2D is currently one of the very few modeling platforms capable of routing certain types of non-Newtonian fluids where relationships between solids content and both viscosity and yield stress are known. FLO-2D does not use subgrid bathymetry, and highly detailed modeling often requires small cell sizes which can result in moderately high computational demands. Because of the low solids content downstream of the NSM Railroad Bridge due to deposition of solids and, therefore, low viscosity levels of the flood wave, FLO-2D was not used in this study.

E6.1.2 Dam 1

Based on the capabilities of the three models, a FLOW-3D model was developed to simulate runout of the breach outflow hydrograph and tailings depositions in the area between Dam 1 and the NSM Railroad Bridge 1, and a HEC-RAS 2D model to was used to route the resulting flow hydrograph from NSM Railroad Bridge 1 to Lake Superior. In addition, as fine tailings deposition occurs in the area between Dam 1 and the railroad, the solids content of the flow hydrograph will further decrease such that the bulking of flow and its viscosity will have little-to-no effect on inundation of the downstream area, i.e., no depositional processes were simulated downstream of Railroad Bridge 1, as explained in Section E7. Note that the solids content of breach outflow at Dam 1 was estimated to be 20% by volume during the PMP-induced failure scenario (see Section E5.3). This is a relatively low solids content by volume, and as deposition occurs it is anticipated that the flow hydrograph at the railroad will have a solids content of about 15% by volume. Flows with solids content of 5% and above are considered hyper-concentrated flows, but the effect of solids content on viscosity and lateral spread of flow will be minimal along the valleys of the Beaver River.

E6.1.3 Dam 2

For Dam 2, only a HEC-RAS 2D model was developed. However, the results of the FLOW-3D model were used to adjust the breach outflow hydrograph at Dam 2. The adjustment represented the sediment deposition that would occur in the seepage pond downstream of Dam 2 and the area upstream of the County Road 31. Note that there are no structures or properties between the Dam 2 breach location and County Road 31; therefore, a reduction in outflow hydrograph will not have any impacts in properly simulating the inundated areas downstream of County Road 31.

E6.1.4 Dam 5

For the Dam 5 breach analyses, no tailings will be mobilized; rather, water would be routed behind the dam. It was assumed that the embankment breached materials would deposit in Bear Lake. As a result, a HEC-RAS 2D model was developed to route the breach outflow hydrograph through Bear Lake and from the areas downstream of Bear Lake to Lake Superior.

E6.2 Modeling Approach

As stated above, FLOW-3D, a CFD software package which is more suitable for smaller domains, is not feasible to run for large domains due to memory requirements and the model run time. As a result, FLOW-3D was selected for the PMP-induced failure scenario of Dam 1 to properly simulate the depositional processes of mobilized tailings upstream of NSM Railroad Bridge 1. The HEC-RAS 2D software program was selected for the area downstream of NSM Railroad Bridge 1 during the PMP-induced failure scenario of Dam 1. For the fair-weather failure scenario of Dam 1 and for both failure scenarios of Dam 2 and Dam 5, the HEC-RAS 2D software program was selected for developing the inundation maps. However, FLOW-3D results for the PMP-induced failure scenario of Dam 1 were incorporated in the breach outflows of all other scenarios. In the following subsection, the FLOW-3D and HEC-RAS 2D models of Dam 1 for the PMP-induced failure scenario are described. The modeling approach for HEC-RAS 2D is the same for all other breach scenarios.

The goal of the hydraulic model(s) was to obtain the inundation area and flood severity values for a scenario in which the mobilized tailings were fully mixed with water and routed downstream of the breach. Two models were used for this purpose: (1) a FLOW-3D model that was capable of predicting the amount of tailings deposition upstream of NSM Railroad Bridge 1 and (2) a HEC-RAS 2D model capable of routing the flow when the solids concentration is small enough to be treated as a Newtonian fluid. These two models were used for the PMP-induced Dam 1 failure scenario. It is expected that most of the deposition will occur upstream of NSM Railroad Bridge 1. For this reason, the FLOW-3D model domain extends from the Dam 1 breach location to about 1,000 feet downstream of NSM Railroad Bridge 1, whereas the HEC-RAS 2D model domain extends from NSM Railroad Bridge 1 to the outfall at Lake Superior. Figure E6-2 shows the workflow used to couple the FLOW-3D model and HEC-RAS 2D model simulations which consisted of:

1) Running HEC-RAS at the dam location to simulate the outflow hydrographs during the hypothetical failure of Dam 1.

2) Running a FLOW-3D simulation for which the upstream boundary condition is the Dam 1 embankment with the breach outflow hydrograph developed in Step 1. In this simulation the fluid is treated as a granular material in such a way that the solid volume fraction varies in space and time based on the hydrodynamics of flow.

3) Obtaining the water/tailings mixture hydrograph at NSM Railroad Bridge 1.

4) Using the hydrograph developed in Step 3 at NSM Railroad Bridge 1 as the upstream boundary condition for the HEC-RAS 2D model. The HEC-RAS 2D model is then used to route the flow

downstream of NSM Railroad Bridge 1 and simulate the inundation area, flow depths, and velocities.

E6.2.1 Flow 3D Model

FLOW-3D v12.0 was used to assess the volume of tailings deposited upstream of the road crossing structures downstream of the breach.

E6.2.1.1 Model Computation Mesh

The FLOW-3D model extent is shown in Figure E6-1. From north to south the model domain covers the area between the Dam 1 breach location and approximately 1,000 feet downstream of NSM Railroad Bridge 1. From east to west the model domain was set to contain the inundation area during the PMP-induced failure scenario. The computational mesh consisted of multiple mesh blocks. The largest mesh block consisted of average cell sizes of 10 feet in the horizontal direction and 2 feet in the vertical direction (see Figure E6-2).

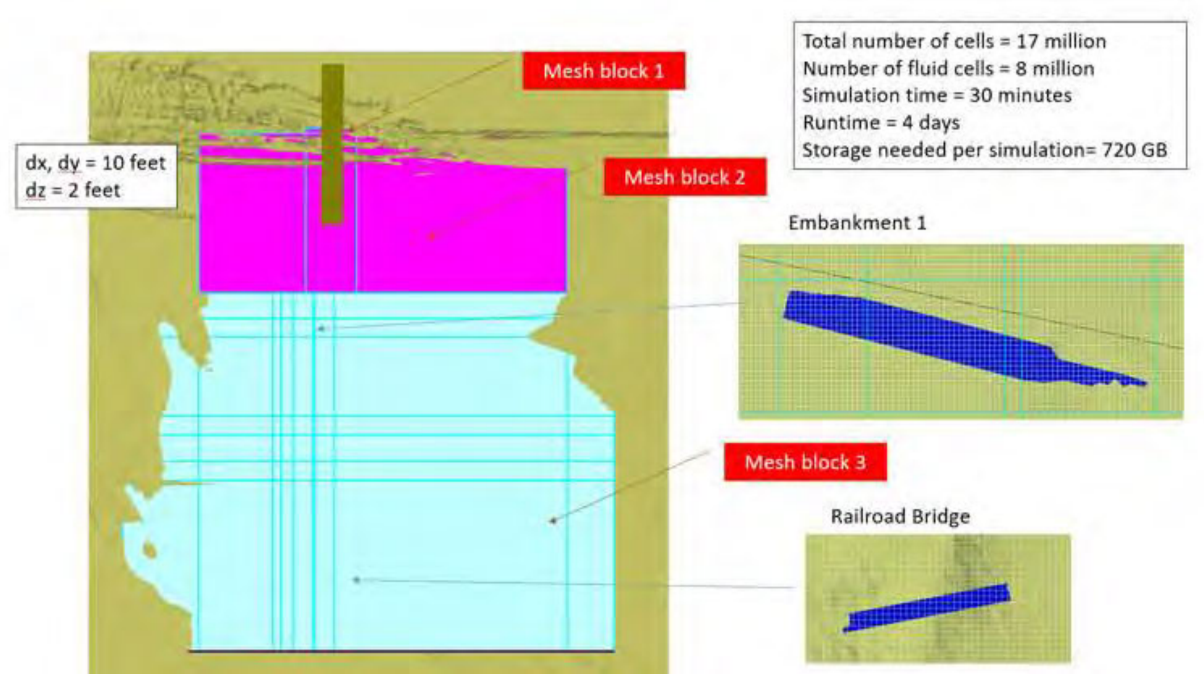


Figure E6-2 FLOW-3D Computational Mesh

E6.2.1.2 Terrain and Structures

The model geometry consisted of a terrain which was based on LiDAR information and three-dimensional CAD blocks to represent the road crossings. Inside the model domain, four crossings were identified and labeled Embankment 1 (road crossing seepage recovery pond 1A), Small Dam (seepage recovery dam 2), Embankment 2 (railroad embankment), and Railroad (i.e., NSM Railroad Bridge 1), as shown in Figure E6-3. The geometries of the embankment crossings were obtained from the 2012 HEC-RAS model. During development of the three-dimensional geometry, two 24-inch-diameter culverts extending through Embankment 1 and one 36-inch-diameter culvert extending through Embankment 2 were identified.

However, since the culverts will be mostly clogged during the simulation it was decided to exclude them from model geometry. The terrain was constructed in ArcMap and exported as an ASCII file to be used in FLOW-3D. The embankment crossings were created in AutoCAD and imported in FLOW-3D as Standard Triangle Language (STL) files.

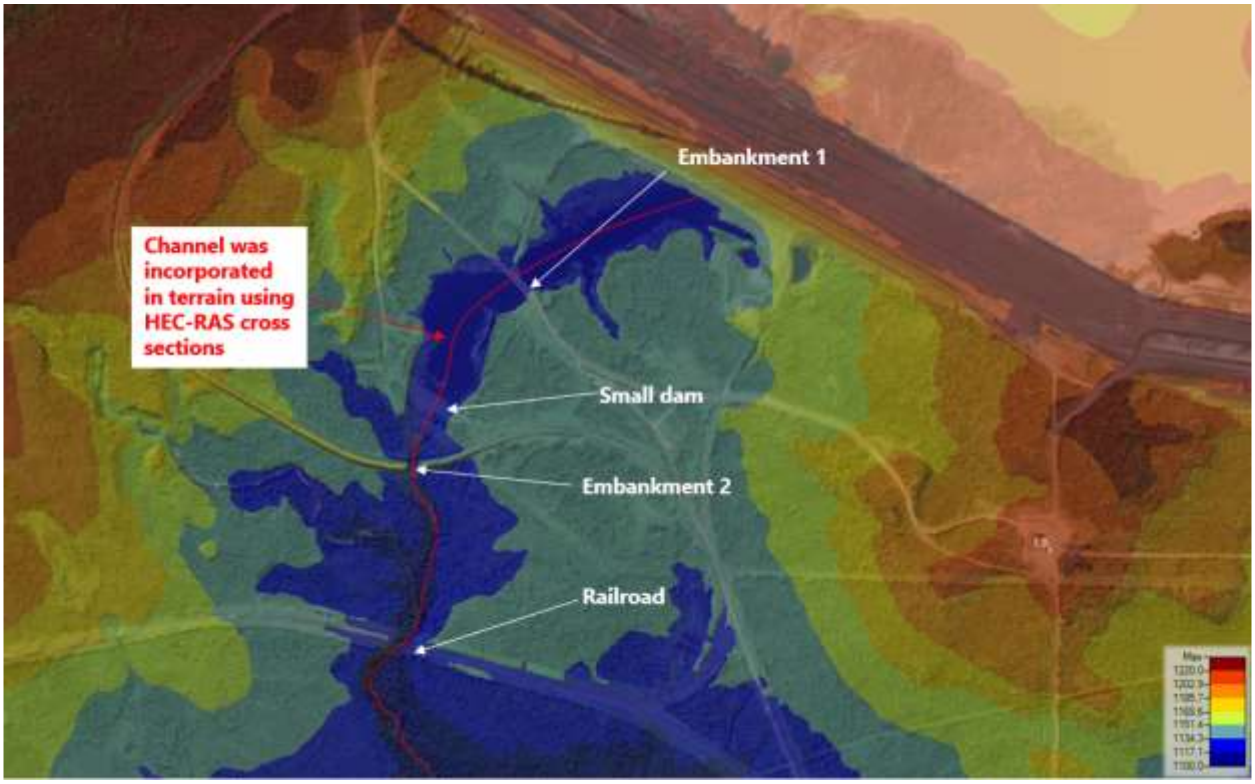


Figure E6-3 LiDAR Terrain and Structures Incorporated in FLOW-3D Model

E6.2.1.3 Initial Conditions

The model was initialized with zero velocities and water depth. The mixture of water and tailings was modeled as a granular flow material with properties listed in Table E6-1. As part of the breach process, the Dam 1 embankment material will be eroded and deposited downstream of Dam 1. The materials from the dam embankment will be much coarser than those from the fine tailings and, therefore, were separated from the total outflow hydrograph at the breach location. From the dam profile stratigraphy and the breach geometry, the total volume of the eroded dam embankment material was estimated to be [redacted] cubic yards. Note that in FLOW-3D, the solids of mobilized tailings will be simulated with a single size, which is the d_{50} of the fine tailings. Since the deposition of part of the embankment material is a likely scenario, it was assumed that all of the eroded embankment material would be deposited a short distance downstream of the breach location and would not be mobilized as the flood wave continues to move downstream. While this assumption is not fully accurate, it more accurately simulates the flow patterns downstream of the breach location compared to a scenario where all the mobilized tailings and embankment materials flow downstream with the characteristics of the fine tailings d_{50}. This assumption was implemented by running a precursor simulation through which [redacted] cubic yard of a coarser granular material was released into the model domain with no other flow at the breach location. This simulation allowed a new terrain to develop after the deposition of the dam embankment material downstream of the breach location. The new terrain is shown in Figure E6-4. This new terrain became the initial terrain for routing the breach outflow hydrograph.

Table E6-1 Material Properties Used in FLOW-3D for Tailings

Parameter	Description	Value
Close packing volume fraction (dry)	Fraction of a total volume that is physically occupied by the granular flow particles. Above this number particle velocity is zero. The value used in modeling was obtained from lab data.	0.72
Mechanical jamming volume fraction	Fraction of the total volume at which the granular flow enters the jamming transition. Above that fraction the flow experiences resistance due to grain-to-grain interaction. That is a transition from a liquid-like state to a rigid but disordered solid state.	0.7
Loose packing volume fraction (dry)	Lowest possible fraction of a total volume that is occupied by the granular material.	0.56
Average grain diameter	The values were obtained from historical site lab data.	35 μm
Grain density	Default values for sand were used.	3.12 slugs/ft^3
Friction angle	Drained lower bound and addresses the variability of the tailings based on historical lab testing data	24 degrees
Minimum volume fraction of granular phase	Minimum fraction of a volume to consider the fluid as granular. Using default value of zero, which means that all fluid will be simulated as a granular phase.	0

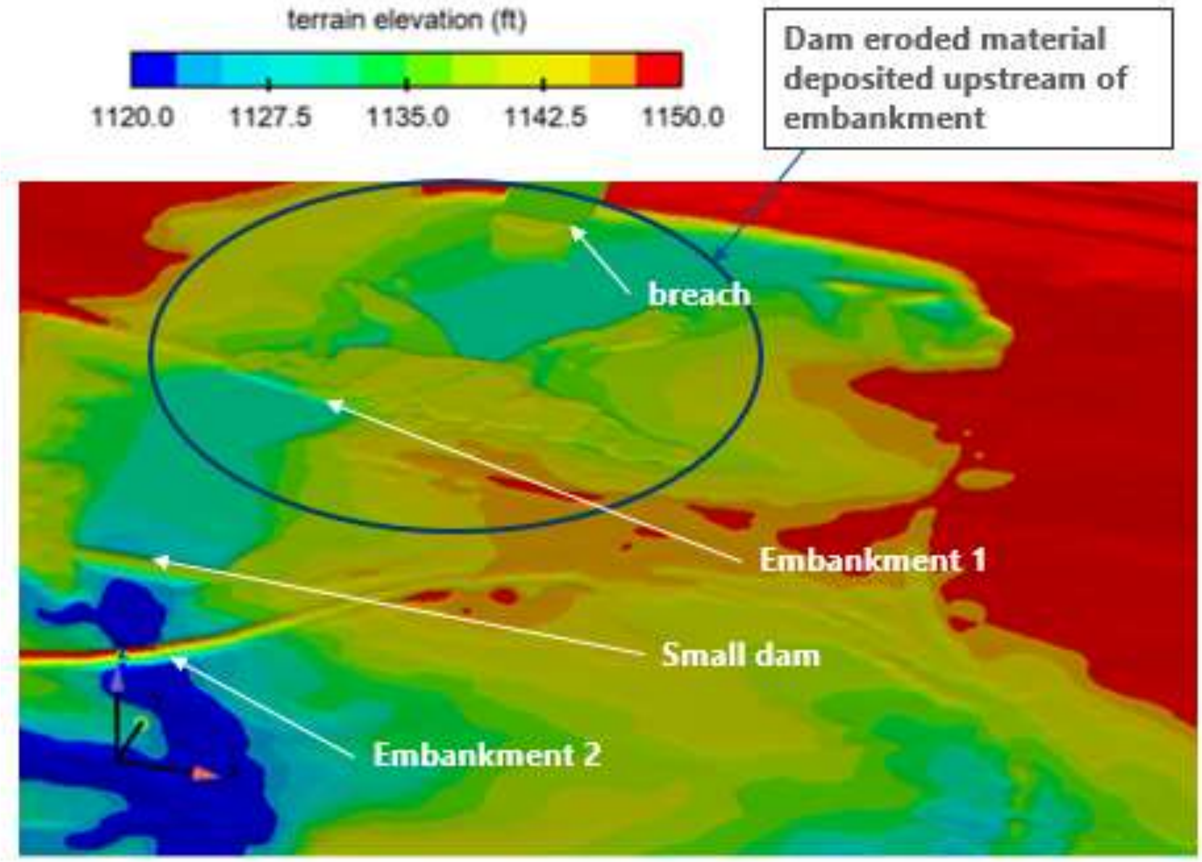


Figure E6-4 Terrain Used in FLOW-3D after Incorporating Eroded Dam Embankment Material

E6.2.1.4 Boundary Conditions

As explained above, the outflow hydrograph from the HEC-RAS model was used for the FLOW-3D model. However, since the outflow hydrograph included the eroded dam embankment material, which was already incorporated by adjusting the terrain, the breach outflow hydrograph was modified to reflect this. Figure E6-5 shows the outflow hydrograph generated by the HEC-RAS model using the breach parameters of Dam 1 (see Section E4). Figure E6-5 also shows the outflow hydrograph used in the model from which the eroded dam embankment material volume has been subtracted. Also, on the upstream end, a solids concentration of 20% was used based on the runout calculations, as explained in Section E5.3.

On the top of the model domain, an atmospheric pressure boundary condition was used; for the outlet, an outflow boundary condition (zero gradient pressure) was used. The rest of the mesh block boundary faces were set to symmetry boundary conditions. This is because FLOW-3D uses symmetry boundary conditions to connect blocks (either nested in a larger block or at an adjacent block) and/or simulate walls that are already blocked by the geometry elements.

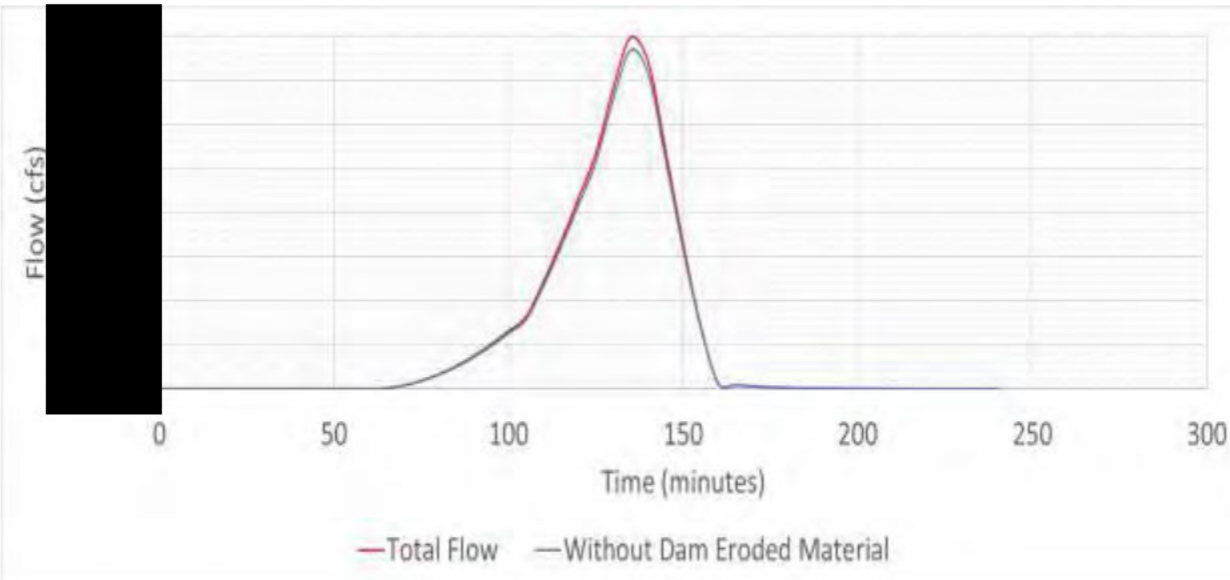


Figure E6-5 Dam 1 Breach Outflow Hydrograph Used in FLOW-3D Simulations

E6.2.2 HEC-RAS 2D Model

The hydrograph simulated from the FLOW-3D model just downstream of NSM Railroad Bridge 1 was used as input to the HEC-RAS 2D model, as described in the following sections. Based on the geometry of the Beaver River and its valley, it was expected that the majority of deposition/sedimentation would occur upstream of the NSM Railroad Bridge 1 embankment and that the resulting downstream flow would be fully mixed with a low solids content. A low solids content of the flow can be modeled as a Newtonian fluid with a viscosity close to the viscosity of water.

E6.2.2.1 Model Domain and Computation Mesh

The HEC-RAS 2D model domain starts from downstream of NSM Railroad Bridge 1 and follows the Beaver River to where it discharges to Lake Superior. The domain includes areas around the (former) airport to the southwest of the MP7 Tailings Basin, as well as the Silver Bay Golf Course, located near the East Branch Beaver River, just upstream of the confluence with the Beaver River. The computational domain is shown in Figure E6-1. The computational mesh is based on a 100-foot by 100-foot cell size. Use of breaklines allowed for further refinement of cell spacing and alignment to capture hydraulically significant features in the terrain. Breakline cell spacing along the banks of Beaver River was set to 50 feet.

E6.2.2.2 Terrain

The digital terrain data (LIDAR surveyed in 2011, Reference (13)) was obtained from the MnDNR for the Arrowhead Region of Northeast Minnesota as the basis for the model terrain since this was used in the 2012 HEC-RAS model. Bathymetry for Beaver River below the water level was imported from the 2012 HEC-RAS model cross sections and merged with the LIDAR terrain. To preserve the narrow channel and geometry of the surrounding rock outcropping (Figure E6-1) the channel of the area around Glenn Avon Falls was not added to the LiDAR data.

E6.2.2.3 Structures

The HEC-RAS 5.0.7 software does not allow bridge elements in a fully 2D model domain. Hydraulic structures were, therefore, represented in the model using storage area/2D connection elements. The conveyance area of bridges was approximated using culvert elements in the model. For primary bridge openings along the centerline of the Beaver River, the invert and low chord elevations were preserved. Conveyance area was preserved by adjusting the width of the culvert element. Secondary bridge openings preserved the low chord elevation and conveyance area. For triangular abutments, the invert elevation was set using two-thirds the distance from the low chord to the channel bottom. The width of the culvert element was adjusted to match the total conveyance area of the bridge opening.

E6.2.2.4 Surface Roughness

In the HEC-RAS model, surface roughness is modeled using Manning's n coefficient. Surface roughness is used to compute energy losses due to friction losses. Spatially distributed land-use classes from the 2011 National Land Cover Database (Reference (6)) were used to assign spatially variable n-values in the HEC-RAS 2D model domain. The association between land use and Manning's n-values is shown in Table E6-2.

Manning's n-values for each land-cover class in 1D models were obtained from the HEC-RAS Hydraulic Reference Manual. Associations between land-use class and 2D Manning's n-values are not yet published. Manning's n-values for 2D models are lower than 1D models because the n-value used in 1D modeling accounts for both friction losses and form losses. 2D models, however, simulate form losses; therefore, the n-value must be set lower to avoid double-counting head losses. Energy losses in overbank areas are mostly due to friction. Based on our experience with previously calibrated models, 2D model n-values are about 90% of the 1D model n-values, which were used in the HEC-RAS 2D model of this study.

Table E6-2 Manning's n Roughness Coefficients Used in the HEC-RAS 2D Model

Land Cover Type	2D Manning's n
Barren land	0.036
Herbaceous	0.045
Mixed forest	0.090
Open water	0.027
Shrub/scrub	0.045
Woody wetlands	0.036
Cultivated crops	0.054
Deciduous forest	0.090
Developed, low-density	0.090
Developed, medium-density	0.108
Developed, open space	0.072
Emergent herbaceous wetlands	0.036
Evergreen forest	0.090
Hay/pasture	0.045

E6.2.2.5 Boundary Conditions

Coincident flows with the 1:25 AEP were assumed for both the Beaver River and the East Beaver River as discussed in Section E3.2. An initial-conditions model with constant flows was run until a pseudo-steady state was reached (i.e., downstream outflow equaled upstream inflows and maintained a constant water surface elevation).

The upstream boundary for breach conditions was set downstream of NSM Railroad Bridge 1 and the associated railroad embankment. Based on the flow patterns obtained from the FLOW-3D model, the flow hydrograph into the HEC-RAS 2D model was broken into three segments, with 40% of the flow hydrograph assigned to each of the two outside segments and 20% of the flow assigned to the smaller, middle segment (Figure E6-6). The downstream boundary condition was set to normal depth with a friction slope of 0.005.

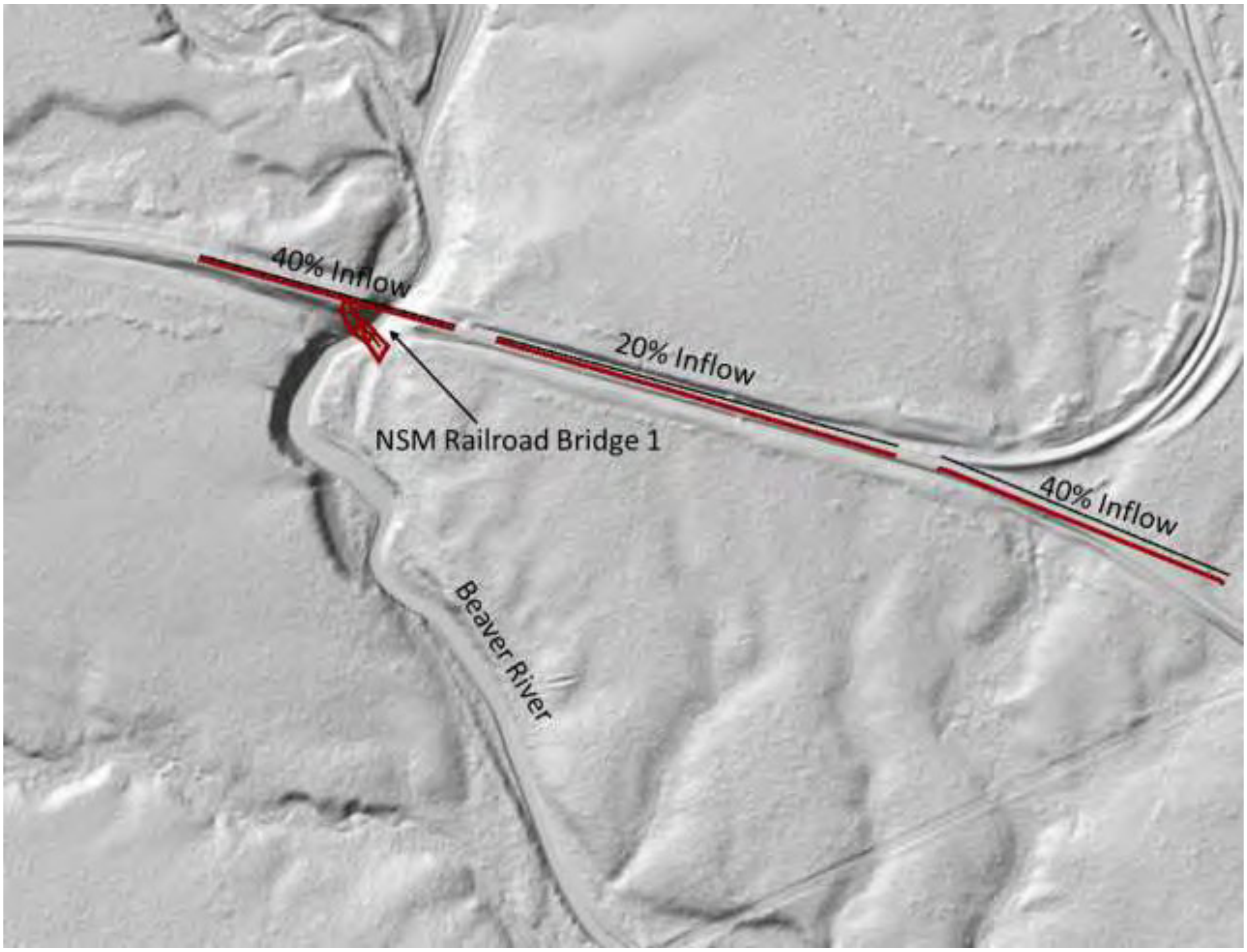


Figure E6-6 HEC-RAS Upstream Distributed Inflow Boundary Condition Lines

E7 Results

The results of dam breach analyses of Dam 1, Dam 2, and Dam 5 are presented in this section. The first subsection describes the results of the FLOW-3D and HEC-RAS 2D models for the PMP-induced breach of Dam 1. Subsequently, the results for the fair-weather failure scenario of Dam 1 and the results of both the PMP and fair-weather scenarios for Dam 2 and Dam 5 are provided.

Results include flood wave hydrographs at several locations (primarily at bridge locations), inundation maps, maps of maximum depths and velocities, and maps of maximum flood severity (where flood severity is categorized based on the maximum of depth x velocity). The Federal Emergency Management Administration (FEMA) has defined five categories for flood severity as listed in Table E7-1. The flood severities shown in the maps and tables are based on the ranges shown in Table E7-1.

Table E7-1 FEMA's Flood Severity Categories

Category	Flood Severity (ft^2/s)
Low	<2 2
Medium	>2 2 and <5.4
High	>5.4 and <16.1
Very high	>16.1 and <26.9
Extreme	>26.9

E7.1 PMP-Induced Dam 1 Failure Scenario

E7.1.1 FLOW-3D Results

Figure E7-1 shows velocity fields at four different time stamps throughout the simulation (50, 100, 300 and 400 seconds). These velocity fields show how quickly the flood wave spreads laterally upstream of Embankment 1 and that the flood wave arrives [redacted] after breach formation. Herein, the flood wave arrival time at a given location is the time difference between the start of breach formation time and when flow depth at that location increases by 0.2 feet. The velocities drop significantly upstream of Embankment 1 as the flood wave moves through the seepage pond. In general, the velocities varied from [redacted], with the highest values at the center of the flood wave and slower velocities in the recirculation areas in the east of the domain. The results also showed that, in general, the flow would be jammed upstream of each embankment or crossing structure and then released, as shown by the increase in viscosity at model observation points upstream of the embankments, the small dam, and NSM Railroad (Figure E7-2). These viscosity plots show that the fluid would become more viscous upstream of structures on which the fluid jams, such as Embankment 1 (see Figure E7-1) and NSM Railroad Bridge 1 (denoted as railroad in Figure E7-1). It is expected that downstream of such structures the fluid viscosity would decrease significantly.

Note that in Figure E7-2, the viscosity is significantly reduced downstream of Embankment 1 and the Small Dam, where significant jamming would occur upstream of these structures. Since significant jamming would occur upstream of NSM Railroad Bridge 1, the flow downstream of the bridge would be much lower in viscosity; therefore, a Newtonian fluid model (i.e., HEC-RAS 2D) can be used to simulate routing downstream of NSM Railroad Bridge 1.

Figure E7-3 shows the hydrograph simulated from FLOW-3D at NSM Railroad Bridge 1 compared to the breach outflow hydrograph. The peak flows of the two models and the volumes are different; the FLOW-3D simulated hydrograph volume is about 24 percent less than that of the breach outflow hydrograph. To estimate the amount of solids deposited upstream of the NSM Railroad, additional calculations were carried out in FlowSight (the FLOW-3D post-processing software package). The deposited volume of solids was estimated based on the volume fraction of cells upstream of the NSM Railroad, the fluid velocity of each cell, and the solid particle settling velocity, where the solid particle settling velocity was estimated to be $2.4x10^{-5}$ fps using the method developed by Dietrich (Reference (14)). The volume of deposited solids, including the embankment breach material, was determined to be about 730 acre-feet (i.e., 4% of the breach outflow volume). This indicates that approximately 18 percent of solids were deposited upstream of NSM Railroad Bridge 1 due to jamming and bulking of the fluid. In fact, this is the volume of tailings not leaving the NSM property.

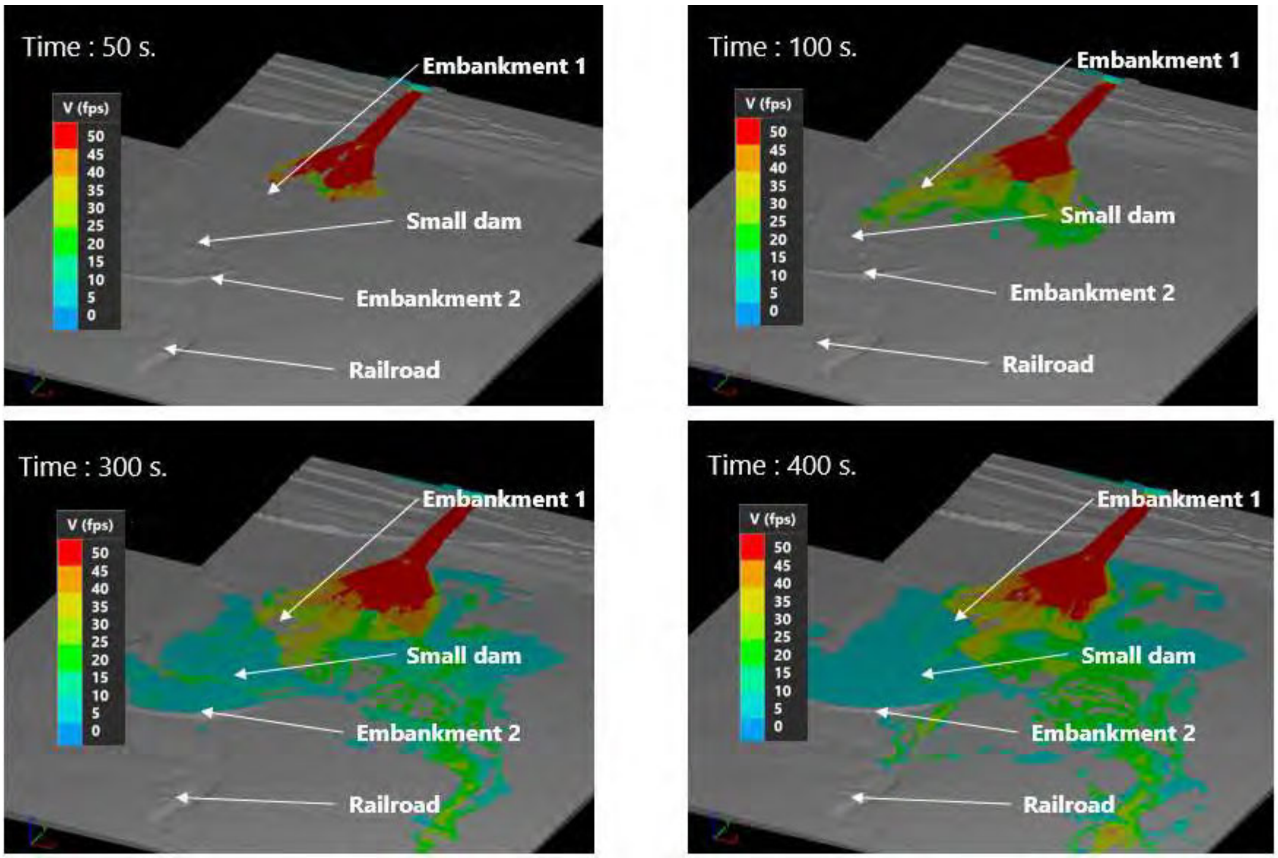


Figure E7-1 Velocity Field at Four Different Time Stamps of Simulation

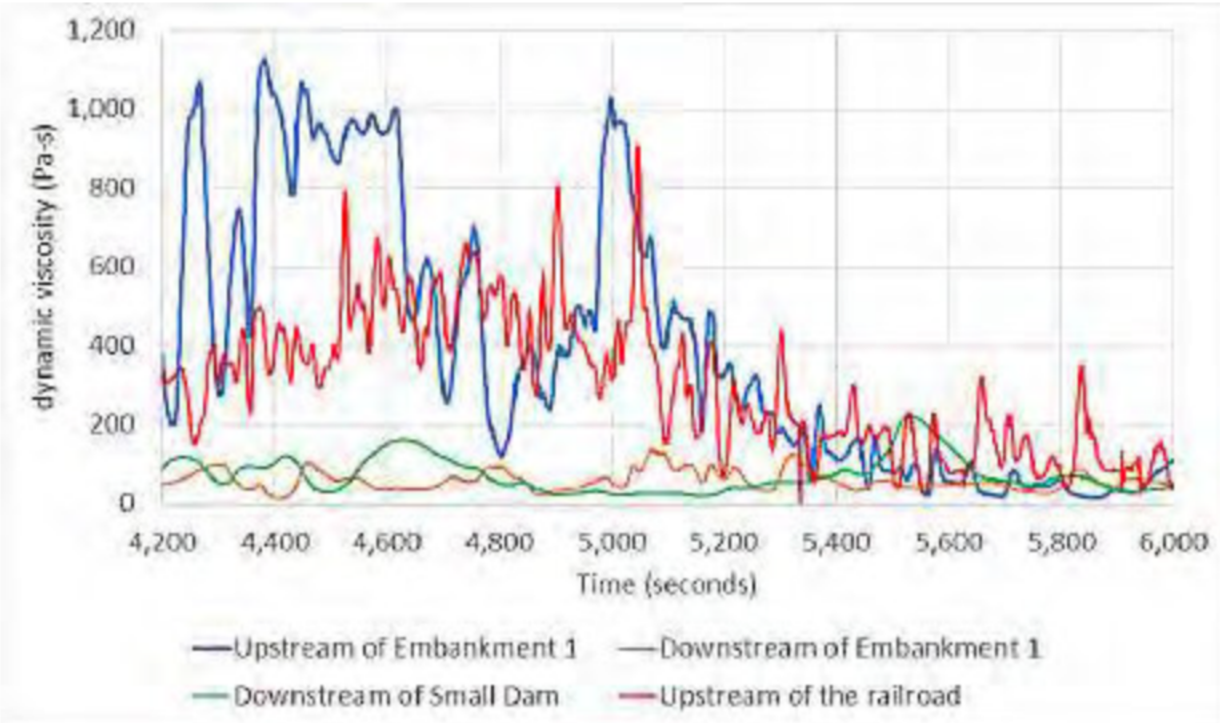


Figure E7-2 **Simulated Viscosity Values for Multiple Locations in the Model**

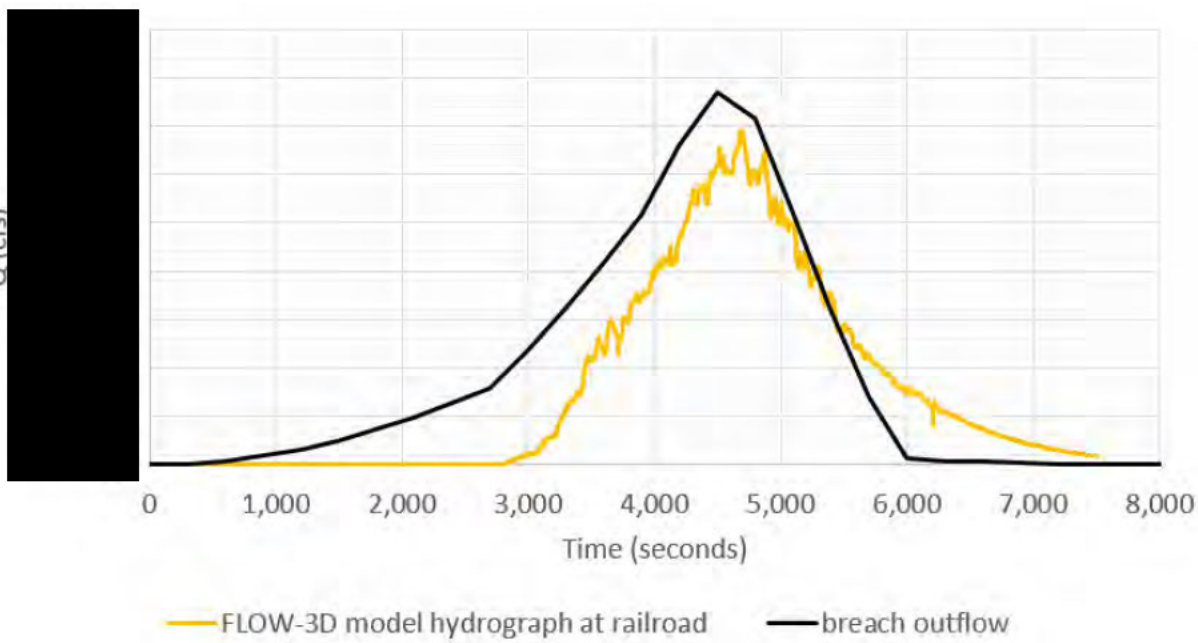


Figure E7-3 **Dam 1 Breach Outflow Hydrograph and the flow hydrograph at NSM Railroad Bridge 1 during the PMP-Induced Failure Scenario**

E7.1.2 HEC-RAS 2D Results

The flow hydrographs along the Beaver River, resulting from the PMP-induced failure of Dam 1 with 1:25 AEP coincidental flows, are shown in Figure E7-4 (the locations of the hydrographs are shown in the Map Book in Exhibit 1). Attenuation of the peak flow is seen at each subsequent cross section to where the peak flow at the downstream end of the model is approximately 24% of the peak flow at NSM Railroad Bridge 1.

The maximum inundation extent and maximum flow depths are shown in Figure E7-5 and Figure E7-6, respectively. [redacted] The last column of Table E7-2 is color coded from dark blue (extreme) to white (low) to show flood severity for every structure. As listed in Table E7-2, [redacted] Exhibit 1 is the Map Book for this scenario, showing the detailed model results.

A maximum velocity of about [redacted] fps would occur at the toe of the dam. Velocities in excess of [redacted] fps are seen in some of the steeper, more channelized areas of the floodplain. A maximum velocity of [redacted] fps occurs at the upstream side of the Highway 61 Bridge near Lake Superior.

Impacts would additionally be seen at [redacted] Note that the outlines of bridges in these figures are from the 2012 HEC-RAS 1D model with the current simulated HEC-RAS 2D model water surface elevations superimposed on those drawings.

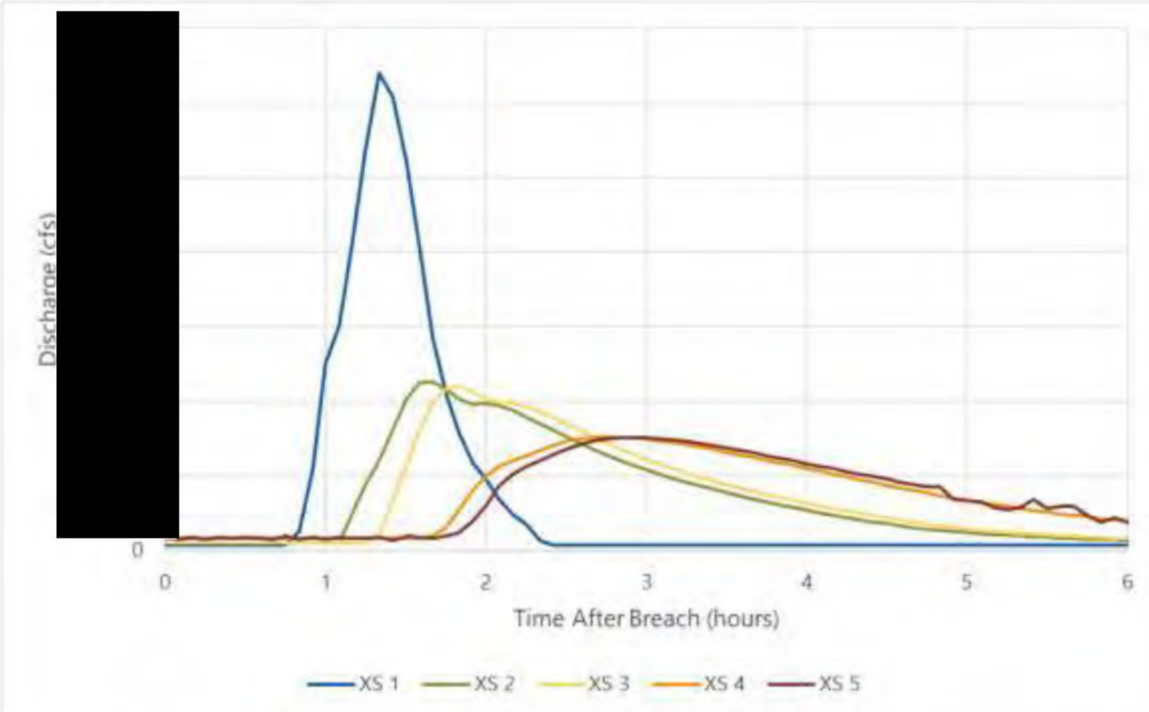


Figure E7-4 Hydrographs along the Beaver River during the PMP-Induced Dam 1 Failure Scenario

[redacted]

may show watercourses that no longer exist.

[redacted]

Model Cross Section

Dam1 Modeled Breach Location

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Public Waters Inventory (PWI) Watercourses[1]

National Hydrography Dataset (NHD) Rivers and Streams[2]

N

2,500 0 2,500

Feet

Figure E7-5

PMP, BREACH INUNDATION EXTENTS, DAM 1

2023 Tailings Basin Dam 1 Breach Analysis

Northshore Mining
Lake County, Minnesota

[redacted]

may show watercourses that no longer exist.

- [redacted]
- Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Dam1 Modeled Breach Location

Public Waters Inventory (PWI) Watercourses[1]

National Hydrography Dataset (NHD) Rivers and Streams[2]

Maximum Depth

- 0 - 2 Feet
- 2 - 5 Feet
- 5 - 10 Feet
- 10 - 15 Feet
- 15 - 20 Feet
- > 20 Feet

2,500 0 2,500

Feet

Figure E7-6

PMP, BREACH
MAXIMUM DEPTH, DAM 1

2023 Tailings Basin Dam 1 Breach Analysis

Northshore Mining
Lake County, Minnesota

Table E7-2 Structure Impacts during the PMP-Induced Dam 1 Failure Scenario

Tables are color coded from dark blue (high) to white (low) to show flood severity.

Structure Type	Parcel ID	Parcel Address	Map Book Page	Affected during No-Breach	Arrival Time (hrs)	Arrival Time of Max Depth (hrs)	Max Inundation Depth (ft)	Velocity (fps)	Flood Severity (ft^2/sec)
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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* NA stands for not applicable because these structures are impacted prior to the dam breach, and the flood wave arrival time depends on the timing of the storm

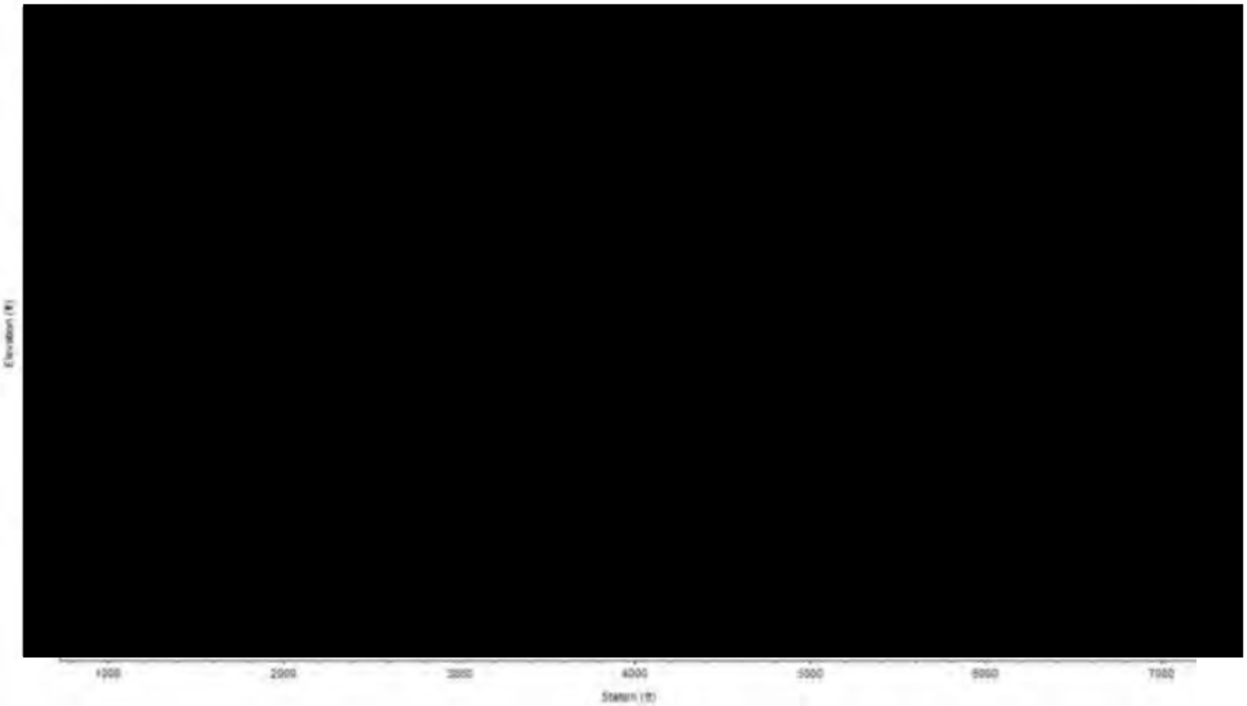

Figure E7-7 Water Surface Elevation at CSAH3 Bridge during the PMP-Induced Failure of Dam 1

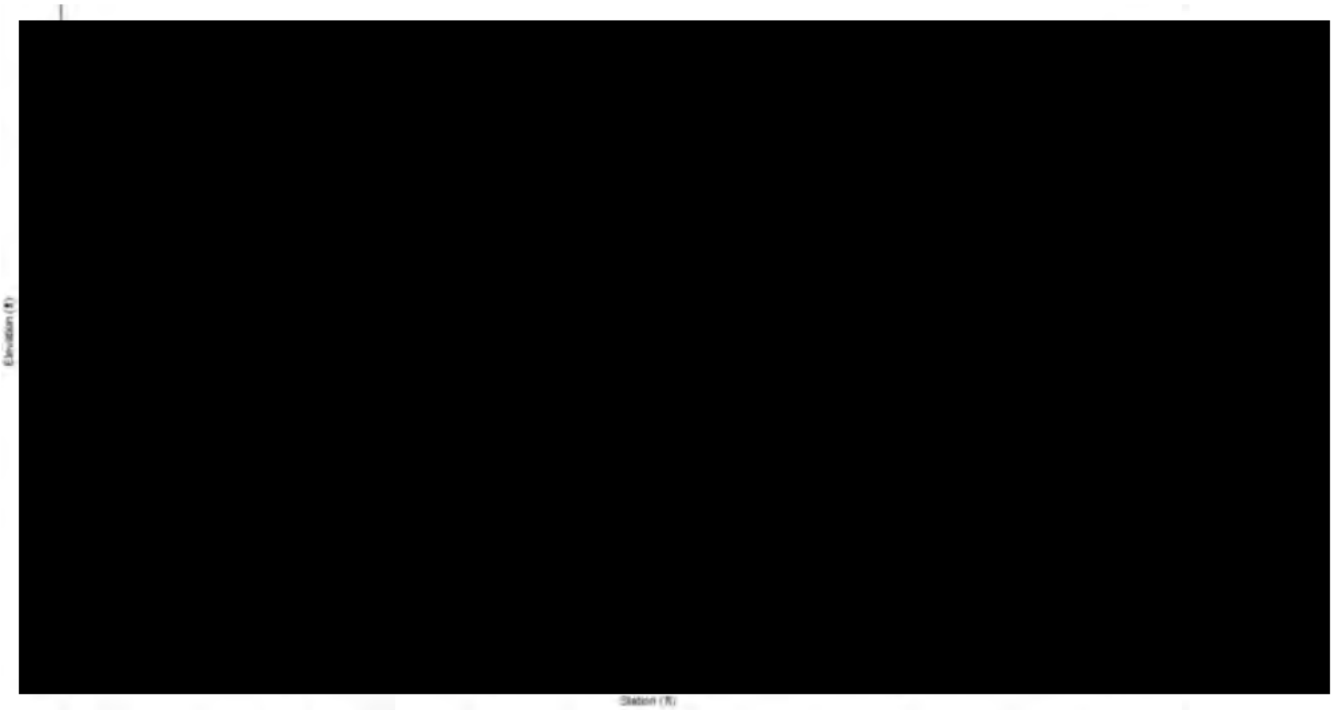

Figure E7-8 Water Surface Elevation at CSAH4 Bridge during the PMP-Induced Failure of Dam 1

[redacted]

Figure E7-9 Water Surface Elevation at Highway 61 Bridge during the PMP-Induced Failure of Dam 1

E7.2 Fair-Weather Dam 1 Failure Scenario

The breach outflow hydrograph during the fair-weather Dam 1 failure scenario is shown in Figure E7-10. This hydrograph was generated by the HEC-RAS 1D model using the breach parameters and the volume of the mobilized tailings and supernatant pond in the NSM Tailings Basin in the same way as the Dam 1 PMP-induced breach hydrograph. The HEC-RAS 2D model was used to route the hydrograph from the Dam 1 breach location and NSM Railroad Bridge 1. Assuming all embankment coarse materials will be deposited just downstream of the breach location, and approximately 18% of solids will be deposited upstream of NSM Railroad Bridge 1, the resulting hydrograph downstream of the railroad was adjusted by the corresponding volumes, as shown in Figure E7-10. The adjusted hydrograph was then routed from NSM Railroad 1 through the Beaver River to Silver Lake with the same 2D HEC_RAS model used in the Dam 1 PMP-induced failure scenario (Figure E7-11). An initial flow of 500 cfs was assumed as mean annual flow in both Beaver River and East Beaver River.

The flow hydrographs along the Beaver River resulting from the fair-weather failure of Dam 1 are shown in Figure E7-4 (the locations of the hydrographs are shown in the Map Book in Exhibit 2). Attenuation of the peak flow is seen at each subsequent cross section to where the peak flow at the downstream end of the model is just over 20% of the breach peak flow at Dam 1.

The maximum inundation extent and maximum flow depths are shown in Figure E7-12 and Figure E7-13, respectively. [redacted] The last column is color coded from dark blue (extreme) to white (low) to show flood severity for every structure. As shown in Table E7-3, [redacted] Exhibit 2 is the Map Book for this scenario, showing the detailed model results.

A maximum velocity of about [redacted] fps occurs at the toe of the dam. Velocities in excess of [redacted] fps are seen in some of the steeper, more channelized areas of the floodplain. A maximum velocity of [redacted] fps occurs at the upstream side of the Highway 61 Bridge near Lake Superior.

In addition, [redacted]. Note that the outlines of bridges in these figures are from the 2012 HEC-RAS 1D model with the current simulated HEC-RAS 2D model water surface elevations superimposed on those drawings.

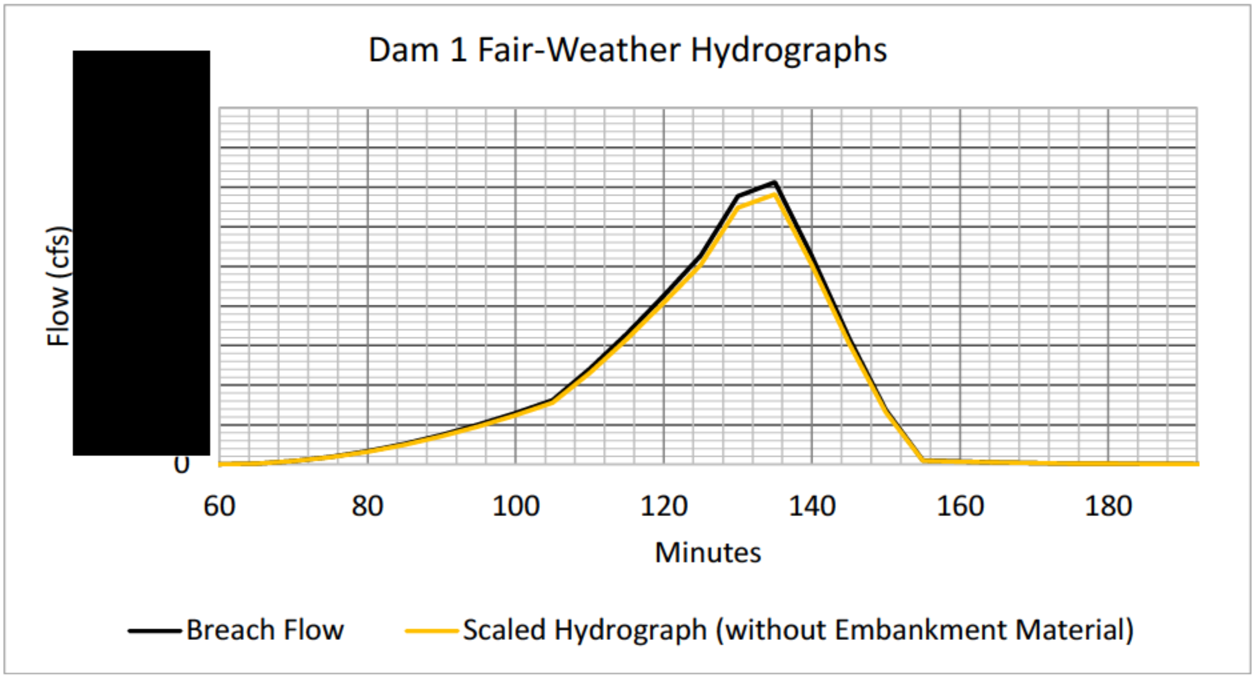

Figure E7-10 **Dam 1 Breach Outflow Hydrograph and at NSM Railroad Bridge 1 during the Fair-Weather Failure Scenario**

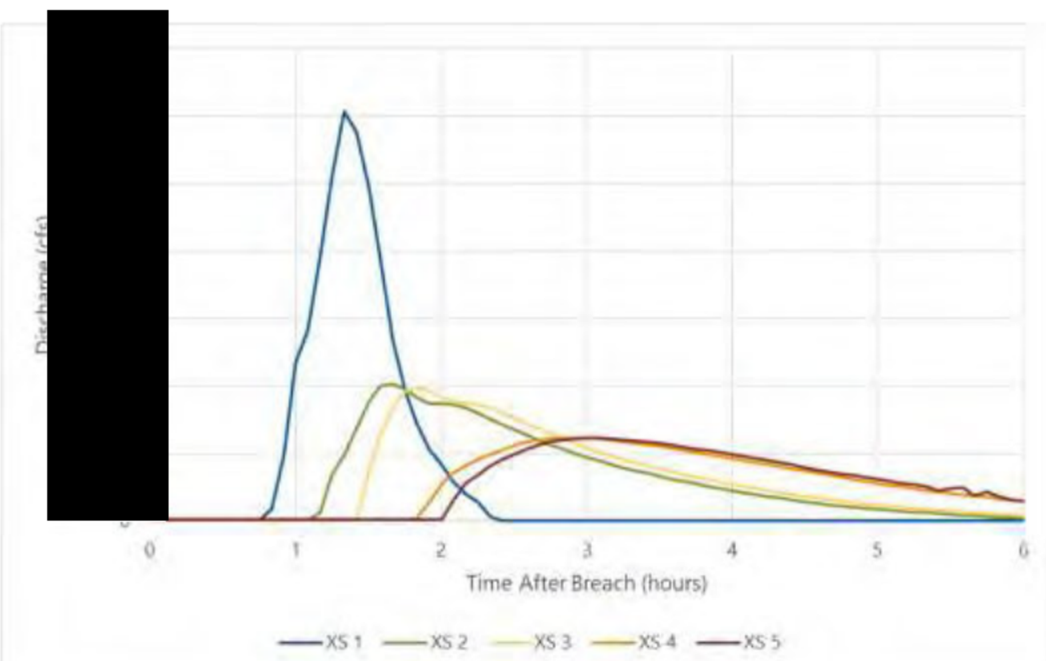

Figure E7-11 **Hydrographs along the Beaver River during the Fair-Weather Dam 1 Failure Scenario**

[redacted]

[redacted]

Model Cross Section

Note: No structures are impacted during no breach scenario.

Dam1 Modeled Breach Location

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Public Waters Inventory (PWI) Watercourses[1]

National Hydrography Dataset (NHD) Rivers and Streams[2]

2,500 0 2,500

Feet

Figure E7-12

FAIR WEATHER, BREACH INUNDATION EXTENTS, DAM 1

2023 Tailings Basin Dam 1 Breach Analysis

Northshore Mining

Lake County, Minnesota

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Dam1 Modeled Breach Location

Public Waters Inventory (PWI) Watercourses[1]

National Hydrography Dataset (NHD) Rivers and Streams[2]

Maximum Depth

- 0 - 2 Feet
- 2 - 5 Feet
- 5 - 10 Feet
- 10 - 15 Feet
- 15 - 20 Feet
- > 20 Feet

N

2,500 0 2,500

Feet

Note: No structures are impacted during no breach scenario.

Figure E7-13

FAIR-WEATHER, BREACH MAXIMUM DEPTH, DAM 1

2023 Tailings Basin Dam 1 Breach Analysis

Northshore Mining
Lake County, Minnesota

Table E7-3 Structure Impacts during the Fair-Weather Dam 1 Failure Scenario

Tables are color coded from dark blue (high) to white (low) to show flood severity.

Structure Type	Parcel ID	Parcel Address	Map Book Page	Affected during No-Breach	Arrival Time (hrs)	Arrival Time of Max Depth (hrs)	Max Inundation Depth (ft)	Velocity (fps)	Flood Severity (ft²/sec)
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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

Figure E7-14 Water Surface Elevation at CSAH3 Bridge during the Fair-Weather Failure of Dam 1

[redacted]

Figure E7-15 Water Surface Elevation at CSAH4 Bridge during the Fair-Weather Failure of Dam 1

[redacted]

Figure E7-16 Water Surface Elevation at Highway 61 Bridge during the Fair-Weather Failure of Dam 1

E7.3 PMP-induced Dam 2 Failure Scenario

The breach outflow hydrograph during the PMP-induced Dam 2 failure scenario is shown in Figure E7-17. The breach hydrograph was generated by HEC-RAS based on the breach parameters and the volume of the mobilized tailings and supernatant pond in the NSM Tailings Basin. Assuming all embankment coarse materials will be deposited in the seepage pond and upstream of CSAH4, and approximately 18% of solids will be deposited upstream of CSAH4, the breach outflow hydrograph at Dam 2 was adjusted, as shown in Figure E7-17. The adjusted hydrograph was then routed from the railroad through the Beaver River to Silver Lake. Note that there is only one normally unoccupied NSM structure in the area between Dam 2 and CSAH4, and this adjustment to the breach hydrograph has no effect on the consequence assessment upstream of CSAH4 as a result of a hypothetical failure of Dam 2.

The flow hydrographs along the final reach of the Beaver River, i.e., at cross-sections 4 and 5, resulting from the PMP-induced Dam 2 failure scenario are shown in Figure E7-18 (the locations of the hydrographs are also shown in the Map Book in Exhibit 3). Attenuation of the peak flow is seen at each subsequent cross section to where the peak flow at the downstream end of the model is just over 20% of the peak flow at the Dam 2 breach location.

The maximum inundation extent and maximum flow depths are shown in Figure E7-19 and Figure E7-20, respectively. [redacted] The last column is color coded from dark blue (extreme) to white (low) to show flood severity for every structure. [redacted] Exhibit 3 is the Map Book for this scenario, showing the detailed model results.

A maximum velocity of about [redacted] fps occurs at the toe of the dam. Velocities in excess of [redacted] fps are seen in some of the steeper, more channelized areas of the floodplain. A maximum velocity of [redacted] fps occurs at the upstream side of the Highway 61 Bridge near Lake Superior.

In addition, [redacted] Note that the outlines of culverts and bridges are from the 2012 HEC-RAS 1D model with the current water surface elevations superimposed at those crossings. It should also be noted that the water surface elevation of the inundated area to the south [redacted]

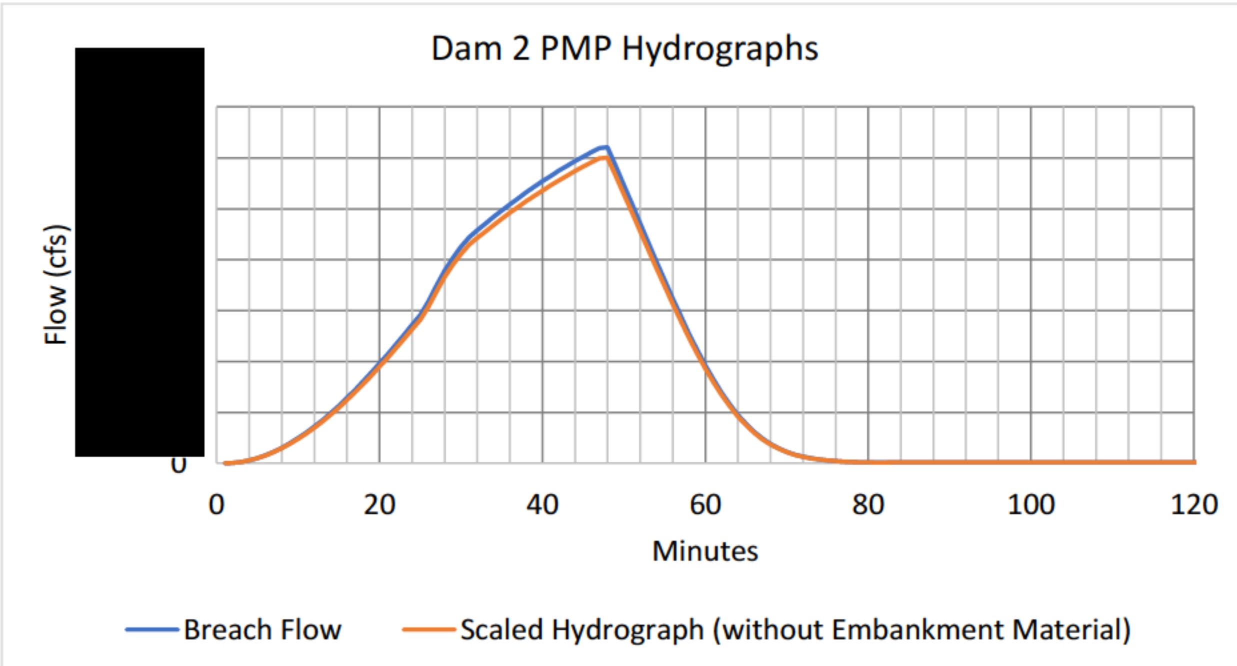

Figure E7-17 Dam 2 Breach Outflow Hydrograph during the PMP-Induced Failure Scenario

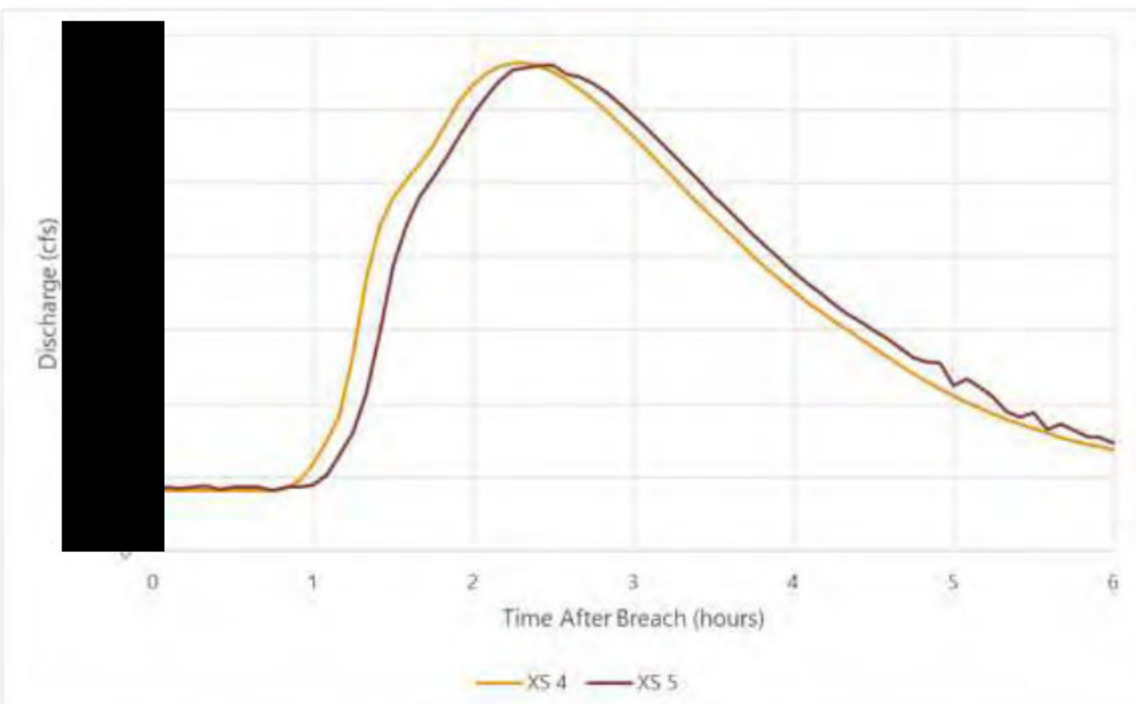

Figure E7-18 Hydrographs along the Downstream Reach of the Beaver River during the PMP-Induced Dam 2 Failure Scenario

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Model Cross Section

Dam 2 Modeled Breach Location

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Public Waters Inventory (PWI) Watercourses[1]

National Hydrography Dataset (NHD) Rivers and Streams[2]

N

2,500 0 2,500

Feet

Figure E7-19

PMP, BREACH
INUNDATION EXTENTS, DAM 2

2023 Tailings Basin Dam 2 Breach Analysis

Northshore Mining
Lake County, Minnesota

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Dam 2 Modeled Breach Location

Public Waters Inventory (PWI) Watercourses[1]

National Hydrography Dataset (NHD) Rivers and Streams[2]

Maximum Depth

- 0 - 2 Feet
- 2 - 5 Feet
- 5 - 10 Feet
- 10 - 15 Feet
- 15 - 20 Feet
- > 20 Feet

2,500 0 2,500

Feet

Figure E7-20

PMP, BREACH
MAXIMUM DEPTH, DAM 2

2023 Tailings Basin Dam 2 Breach Analysis

Northshore Mining
Lake County, Minnesota

Table E7-4 Structure Impacts during the PMP-Induced Dam 2 Failure Scenario

Tables are color coded from dark blue (extreme) to white (low) to show flood severity.

Structure Type	Parcel ID	Parcel Address	Map Book Page	Affected during No-Breach	Arrival Time (hrs)	Arrival Time of Max Depth (hrs)	Max Inundation Depth (ft)	Velocity (fps)	Flood Severity (ft^2/sec)
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

* NA stands for not applicable because these structures are impacted prior to the dam breach, and the flood wave arrival time depends on the timing of the storm

[redacted]

Figure E7-21 Water Surface Elevation at CSAH4 Culvert during the PMP-Induced Failure of Dam 2

[redacted]

Figure E7-22 Water Surface Elevation at CSAH5 Culvert during the PMP-Induced Failure of Dam 2

[redacted]

Figure E7-23 Water Surface Elevation at Pipeline Access Road Bridge during the PMP-Induced Failure of Dam 2

[redacted]

Figure E7-24 Water Surface Elevation at CSAH4 Bridge during the PMP-induced Failure of Dam 2

[redacted]

Figure E7-25 Water Surface Elevation at NSM Railroad Bridge 2 during the PMP-induced Failure of Dam 2

[redacted]

Figure E7-26 Water Surface Elevation at Highway 61 Bridge during the PMP-Induced Failure of Dam 2

E7.4 Fair-Weather Dam 2 Failure Scenario

The breach outflow hydrograph during the fair-weather Dam 2 failure scenario is shown Figure E7-27. The breach hydrograph was generated by HEC-RAS based on the breach parameters and the volume of the mobilized tailings and supernatant pond in the NSM Tailings Basin. Assuming all embankment coarse materials will be deposited in the seepage pond and upstream of CSAH4, and approximately 18% of solids will be deposited upstream of CSAH4, the breach outflow hydrograph at Dam 2 was adjusted, as shown in Figure E7-27. The adjusted hydrograph was then routed from the railroad through the Beaver River to Silver Lake. Note that there is only one NSM structure in the area between Dam 2 and CSAH4, and this adjustment to the breach hydrograph has no effect on the consequence assessment upstream of CSAH4 as a result of a hypothetical failure of Dam 2.

The flow hydrographs along the final reach of the Beaver River, i.e., at cross-sections 4 and 5, resulting from the fair-weather Dam 2 failure scenario, are shown in Figure E7-28 (the locations of the hydrographs are also shown in the Map Book in Exhibit 4). Attenuation of the peak flow is seen at each subsequent cross section to where the peak flow at the downstream end of the model is just under 20% of the peak flow at the Dam 2 breach location.

The maximum inundation extent and maximum flow depths are shown in Figure E7-29 and Figure E7-30, respectively. Note that there would be no impact during the no-breach flow conditions, i.e., mean annual flow. [redacted] The last column is color coded from dark blue (extreme) to white (low) to show flood severity for every structure. [redacted]. Exhibit 4 is the Map Book for this scenario, showing the detailed model results.

A maximum velocity of about [redacted] fps occurs at the toe of the dam. Velocities in excess of [redacted] fps are seen in some of the steeper, more channelized areas of the floodplain. A maximum velocity of [redacted] fps occurs at the upstream side of the Highway 61 Bridge near Lake Superior.

In addition, [redacted] Note that the outlines of culverts and bridges are from the 2012 HEC-RAS 1D model with the current water surface elevations superimposed at those crossings. [redacted]

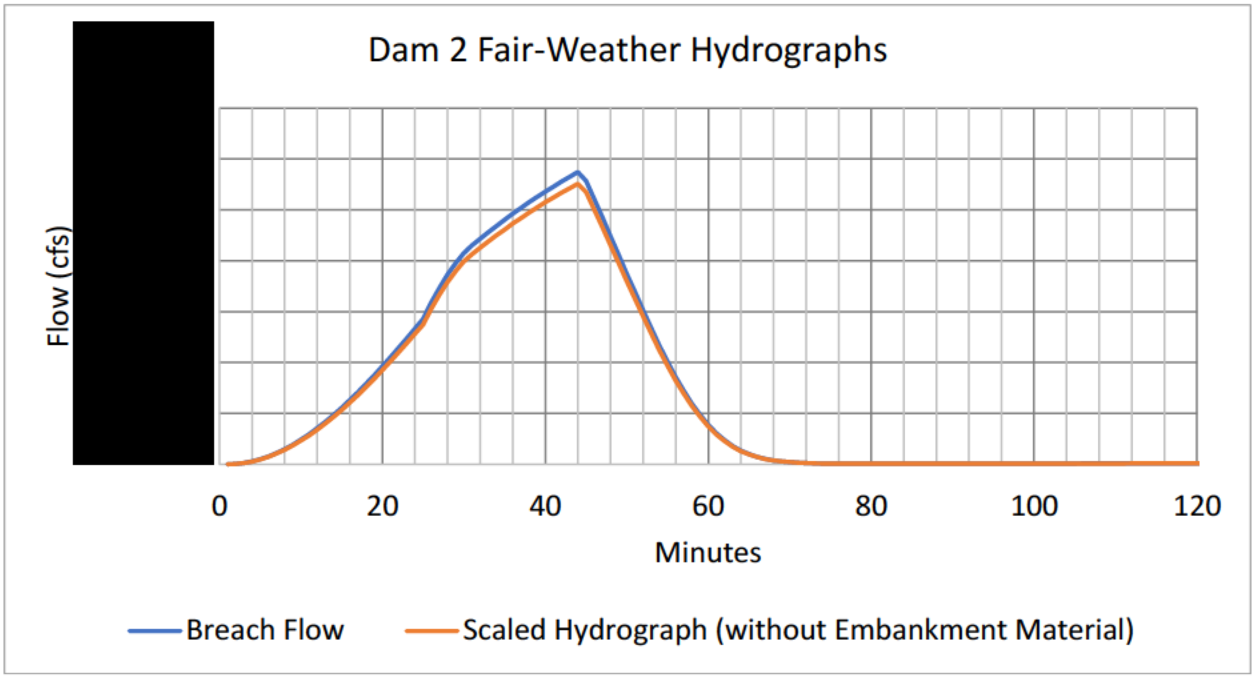

Figure E7-27 Dam 2 Breach Outflow Hydrograph during the Fair-Weather Failure Scenario

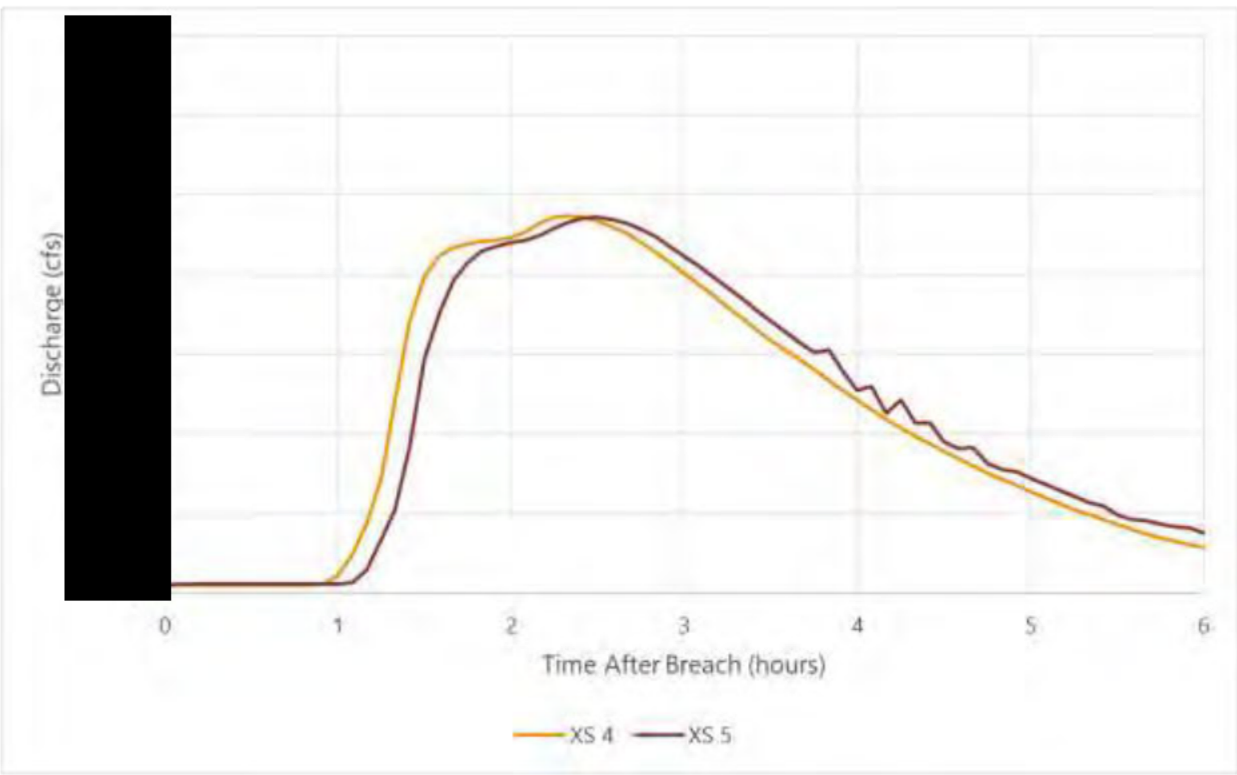

Figure E7-28 Hydrographs along the Downstream Reach of the Beaver River during the Fair-Weather Dam 2 Failure Scenario

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Model Cross Section

Note: No structures are impacted during no breach scenario.

Dam 2 Modeled Breach Location

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Public Waters Inventory (PWI) Watercourses[1]

National Hydrography Dataset (NHD) Rivers and Streams[2]

N

2,500 0 2,500

Feet

Figure E7-29

FAIR-WEATHER,BREACH INUNDATION EXTENTS, DAM 2

2023 Tailings Basin Dam 2 Breach Analysis

Northshore Mining
Lake County, Minnesota

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Dam 2 Modeled Breach Location

Public Waters Inventory (PWI) Watercourses[1]

National Hydrography Dataset (NHD) Rivers and Streams[2]

Maximum Depth

- 0 - 2 Feet
- 2 - 5 Feet
- 5 - 10 Feet
- 10 - 15 Feet
- 15 - 20 Feet
- > 20 Feet

2,500 0 2,500

Feet

Note: No structures are impacted during no breach scenario.

Figure E7-30

FAIR-WEATHER,BREACH MAXIMUM DEPTH, DAM 2

2023 Tailings Basin Dam 2 Breach Analysis

Northshore Mining
Lake County, Minnesota

Table E7-5 Structure Impacts during the Fair-Weather Dam 2 Failure Scenario

Tables are color coded from dark blue (extreme) to white (low) to show flood severity.

Structure Type	Parcel ID	Parcel Address	Map Book Page	Affected during No-Breach	Arrival Time (hrs)	Arrival Time of Max Depth (hrs)	Max Inundation Depth (ft)	Velocity (fps)	Flood Severity (ft^2/sec)
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

Figure E7-31 Water Surface Elevation at CSAH4 Culvert during the Fair-Weather Failure of Dam 2

[redacted]

Figure E7-32 Water Surface Elevation at CSAH5 Culvert during the Fair-Weather Failure of Dam 2

[redacted]

Figure E7-33 Water Surface Elevation at Pipeline Access Road Bridge during the Fair-Weather Failure of Dam 2

[redacted]

Figure E7-34 Water Surface Elevation at CSAH4 Bridge during the Fair-Weather Failure of Dam 2

[redacted]

Figure E7-35 Water Surface Elevation at NSM Railroad Bridge 2 during the Fair-Weather Failure of Dam 2

[redacted]

Figure E7-36 Water Surface Elevation at Highway 61 Bridge during the Fair-Weather Failure of Dam 2

E7.5 PMP-induced Dam 5 Failure Scenario

The breach outflow hydrograph during the PMP-induced Dam 5 failure scenario is shown in Figure E7-37. The breach hydrograph was generated by HEC-RAS based on the breach parameters and supernatant pond in the NSM Tailings Basin. Note that the fine tailings will not be mobilized during the breach of Dam 5. It was assumed that all embankment coarse materials will be deposited in Bear Lake. The outlet of Bear Lake at its southern corner was recently reconstructed by adding a weir and a 36-inch pipe upstream of the 36-inch culvert under the basin pipeline access road. The new pipeline and the culvert were incorporated into the HEC-RAS 2D model.

The HEC-RAS 2D model shows that if Dam 5 breaches, the flood wave [redacted] (the locations of the hydrographs are also shown in the Map Book in Exhibit 5). Attenuation of the peak flow is seen at each subsequent cross section to where the peak flow at the downstream end of the model is just under 40% of the peak flow at the Dam 5 breach location.

The maximum inundation extent and maximum flow depths are shown in and Figure E7-39 and Figure E7-40Figure E7-40, respectively. [redacted]. The last column is color coded from dark blue (extreme) to white (low) to show flood severity for every structure. [redacted] Exhibit 5 is the Map Book for this scenario, showing the detailed model results.

A maximum velocity of about [redacted] fps occurs at the toe of the dam. Velocities in excess of [redacted] fps are seen in some of the steeper, more channelized areas of the floodplain. A maximum velocity of [redacted] fps occurs at the upstream side of the Highway 61 Bridge near Lake Superior. [redacted]. Note that the outlines of culverts and bridges are from the 2012 HEC-RAS 1D model with the current water surface elevations superimposed at those crossings.

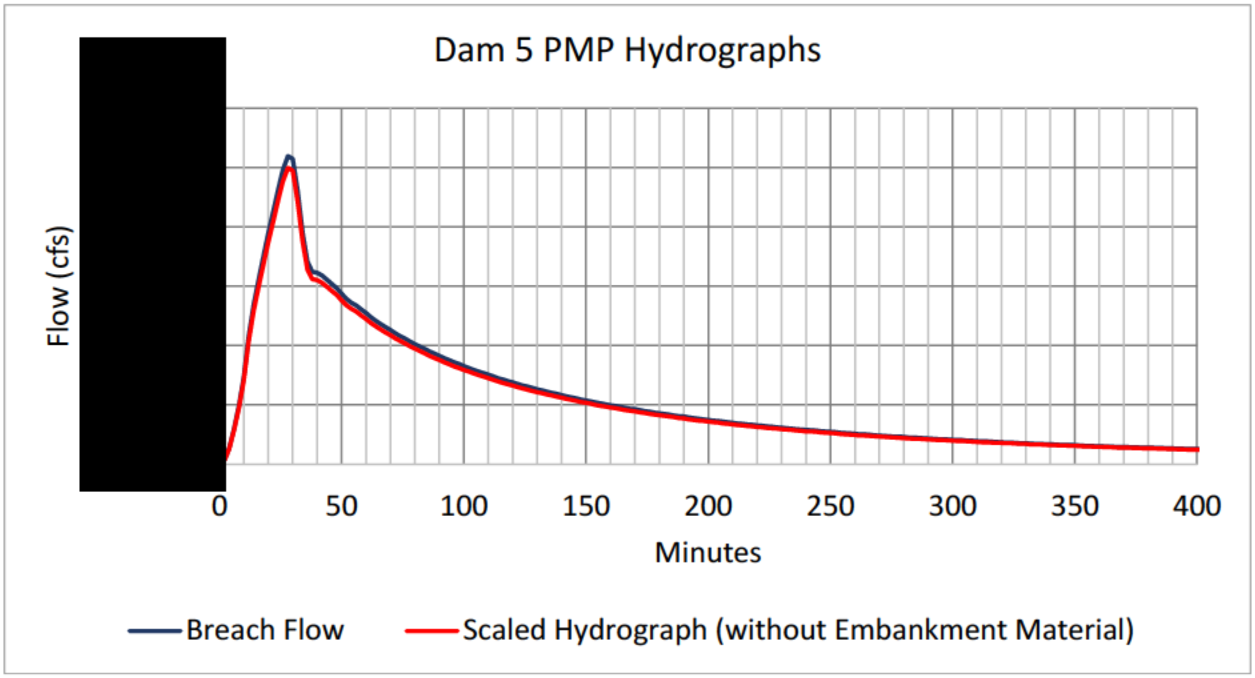

Figure E7-37 Dam 5 Breach Outflow Hydrograph during the PMP-Induced Failure Scenario

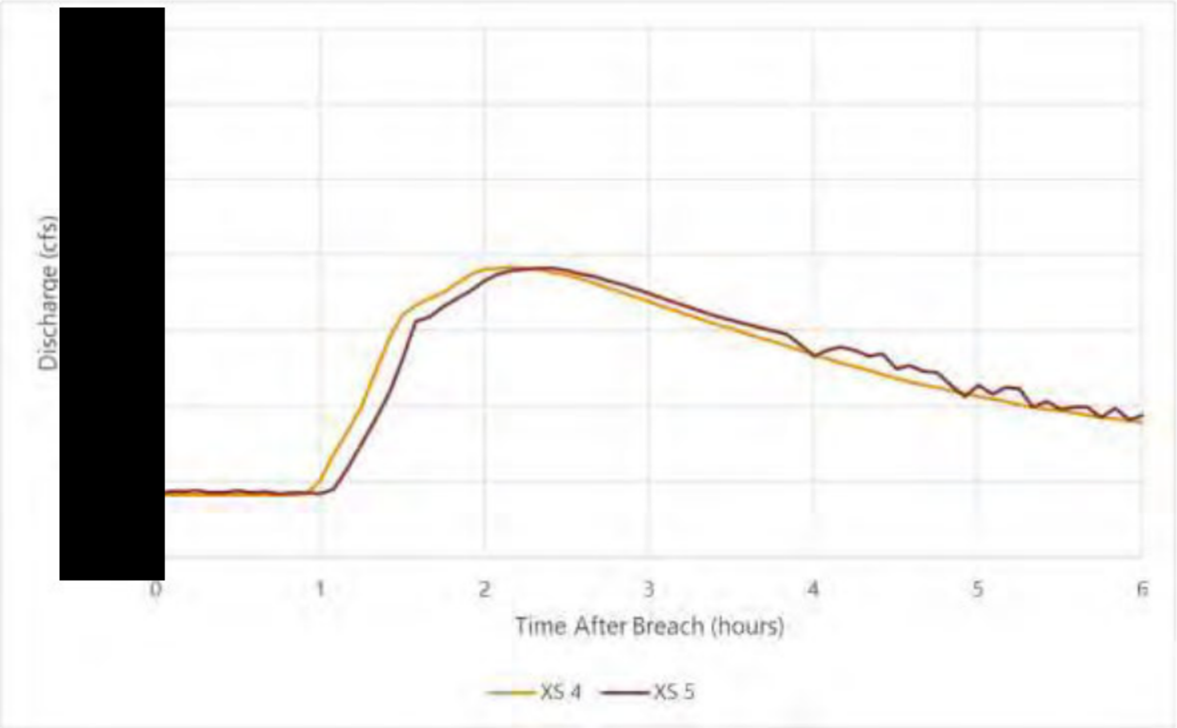

Figure E7-38 Hydrographs along the Downstream Reach of the Beaver River during the PMP-Induced Dam 5 Failure Scenario

[redacted]

[redacted]

- Model Cross Section
- Dam 5 Modeled Breach Location
- No Breach Scenario Inundation Extent
- Dam Breach Scenario Inundation Extent
- Public Waters Inventory (PWI) Watercourses[1]
- National Hydrography Dataset (NHD) Rivers and Streams[2]

2,500 0 2,500

Feet

Figure E7-39

PMP,BREACH
INUNDATION EXTENTS,DAM 5

2023 Tailings Basin Dam 5 Breach Analysis

Northshore Mining
Lake County, Minnesota

[redacted]

[redacted]

Dam 5 Modeled Breach Location

Public Waters Inventory (PWI) Watercourses[1]

National Hydrography Dataset (NHD) Rivers and Streams[2]

Maximum Depth

- 0 - 2 Feet
- 2 - 5 Feet
- 5 - 10 Feet
- 10 - 15 Feet
- 15 - 20 Feet
- > 20 Feet

N

2,500 0 2,500

Feet

Figure E7-40

PMP, BREACH
MAXIMUM DEPTH, DAM 5

2023 Tailings Basin Dam 5 Breach Analysis

Northshore Mining
Lake County, Minnesota

Table E7-6 Structure Impacts during the PMP-Induced Dam 5 Failure Scenario

Tables are color coded from dark blue (extreme) to white (low) to show flood severity.

Structure Type	Parcel ID	Parcel Address	Map Book Page	Affected during No-Breach	Arrival Time (hrs)	Arrival Time of Max Depth (hrs)	Max Inundation Depth (ft)	Velocity (fps)	Flood Severity (ft^2/sec)
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

* NA stands for not applicable because these structures are impacted prior to the dam breach, and the flood wave arrival time depends on the timing of the storm.

[redacted]

Figure E7-41 Water Surface Elevation at CSAH4 Bridge during the PMP-Induced Failure of Dam 5

[redacted]

Figure E7-42 Water Surface Elevation at Highway 61 during the PMP-Induced Failure of Dam 5

E7.6 Fair-Weather Dam 5 Failure Scenario

The breach outflow hydrograph during the fair-weather Dam 5 failure scenario is shown in Figure E7-43. The breach hydrograph was generated by HEC-RAS based on the breach parameters and supernatant pond in the NSM Tailings Basin. Note that the fine tailings will not be mobilized during the breach of Dam 5. It was assumed that all embankment coarse materials will be deposited in Bear Lake.

Similar to the PMP-induced failure scenario of Dam 5, if Dam 5 breaches during a fair-weather failure scenario, the flood wave [redacted] (the locations of the hydrographs are also shown in the Map Book in Exhibit 6). Attenuation of the peak flow is seen at each subsequent cross section to where the peak flow at the downstream end of the model is just under 30% of the peak flow at the Dam 5 breach location.

The maximum inundation extent and maximum flow depths are shown in Figure E7-45 and Figure E7-46, respectively. [redacted] The last column is color coded from dark blue (extreme) to white (low) to show flood severity for every structure. [redacted]. Exhibit 6 is the Map Book for this scenario, showing the detailed model results.

A maximum velocity of about [redacted] fps occurs at the toe of the dam. Velocities in excess of [redacted] fps are seen in some of the steeper, more channelized areas of the floodplain. A maximum velocity of [redacted] fps occurs at the upstream side of the Highway 61 Bridge near Lake Superior.

[redacted].
Note that the outlines of culverts and bridges are from the 2012 HEC-RAS 1D model with the current water surface elevations superimposed at those crossings.

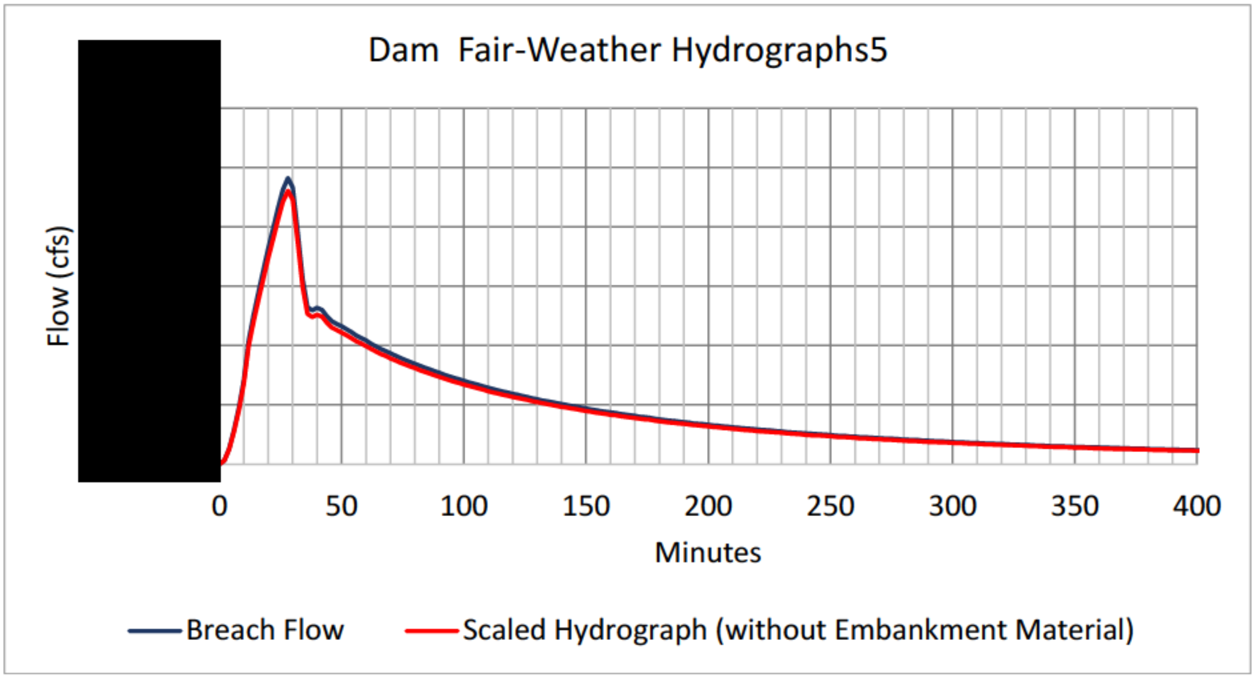

Figure E7-43 Dam 5 Breach Outflow Hydrograph during the Fair-Weather Failure Scenario

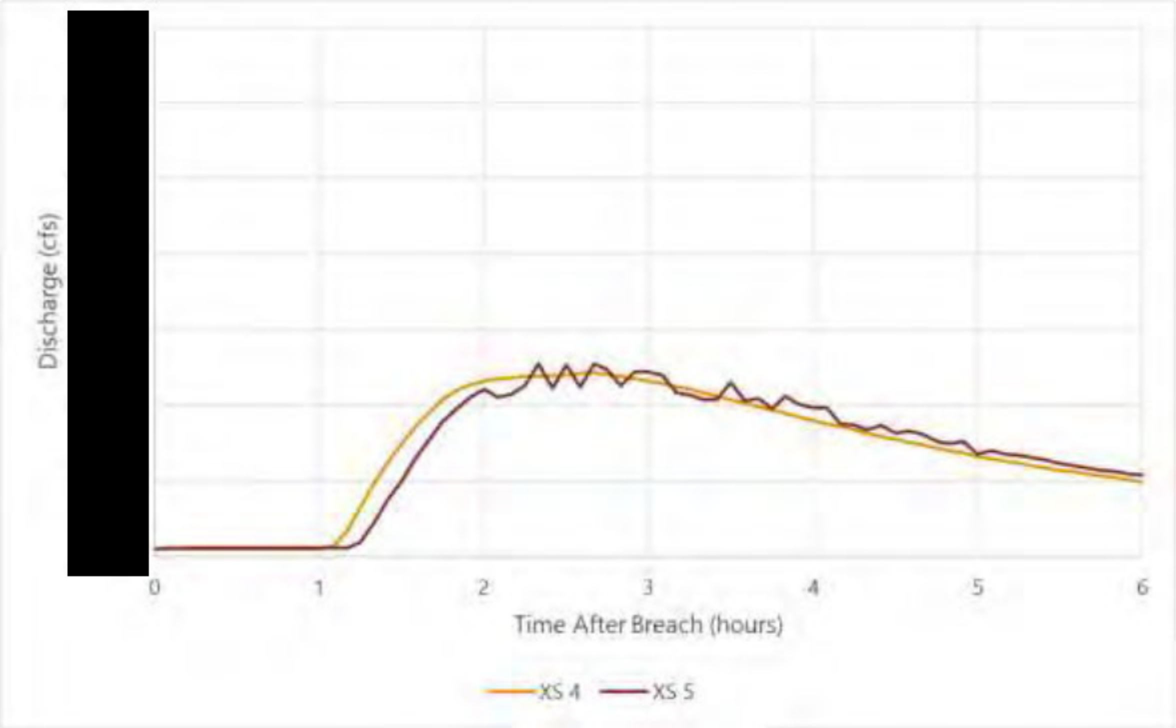

Figure E7-44 Hydrographs along the Downstream Reach of the Beaver River during the Fair-Weather Dam 5 Failure Scenario

[redacted]

[redacted]

Model Cross Section

Note: No structures are impacted during no breach scenario.

Dam 5 Modeled Breach Location

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Public Waters Inventory (PWI) Watercourses[1]

National Hydrography Dataset (NHD) Rivers and Streams[2]

2,500 0 2,500

Feet

Figure E7-45

FAIR-WEATHER,BREACH INUNDATION EXTENTS, DAM 5

2023 Tailings Basin Dam 5 Breach Analysis

Northshore Mining

Lake County, Minnesota

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Dam 5 Modeled Breach Location

Public Waters Inventory (PWI) Watercourses[1]

National Hydrography Dataset (NHD) Rivers and Streams[2]

Maximum Depth

0 - 2 Feet

2 - 5 Feet

5 - 10 Feet

10 - 15 Feet

15 - 20 Feet

> 20 Feet

2,500 0 2,500

Feet

Note: No structures are impacted during no breach scenario.

Figure E7-46

FAIR-WEATHER,BREACH
MAXIMUM DEPTH, DAM 5

2023 Tailings Basin Dam 5 Breach Analysis

Northshore Mining
Lake County, Minnesota

Table E7-7 Structure Impacts during the Fair-Weather Dam 5 Failure Scenario

Tables are color coded from dark blue (extreme) to white (low) to show flood severity.

Structure Type	Parcel ID	Parcel Address	Map Book Page	Affected during No-Breach	Arrival Time (hrs)	Arrival Time of Max Depth (hrs)	Max Inundation Depth (ft)	Velocity (fps)	Flood Severity (ft^2/sec)
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Figure E7-47 Water Surface Elevation at CSAH4 Bridge during the Fair-Weather Failure of Dam 5

Figure E7-48 Water Surface Elevation at Highway 61 during the Fair-Weather Failure of Dam 5

E7.7 Sensitivity Analysis

It is important to note that the breach parameters used in breach analyses of the NSM MP7 Tailings Basin were obtained from the FERC Engineering Guidelines (Reference (9)), which have been developed for water-retaining dams and not for tailings dams. The FERC Guidelines are appropriate in this case because there are not recommended breach parameters for tailings dams. Based on current understanding in the industry, it is also very likely that the breach parameters, i.e., average breach width and time to failure, usually used for water-retaining dams are relatively conservative estimates when used for tailings dams for the same failure modes. Nonetheless, a sensitivity analysis was performed for Dam 1 during the PMP-induced failure scenario. In this sensitivity analysis, the peak outflow at the breach location of Dam 1 was raised by more than 20%, i.e., increased from [redacted] cfs. The ordinates of the outflow hydrograph shown in Figure E7-3 were also scaled by the ratio of [redacted]. This change in the outflow hydrograph represents not only a 22% increase in the peak outflow but also more than a 30% increase in the average breach width, or a significant decrease in breach formation time. The results of the sensitivity analysis showed that during the PMP-induced Dam 1 failure scenario no additional structure would be impacted as a result of a significant increase in the outflow peak and volume. Figure E7-49 shows the inundation extent for this sensitivity analysis.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Model Cross Section

Dam1 Modeled Breach Location

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Sensitivity Run Extent

Public Waters Inventory (PWI) Watercourses[1]

National Hydrography Dataset (NHD) Rivers and Streams[2]

2,500 0 2,500

Feet

FIGURE E7-49

PMP, BREACH AND SENSITIVITY INUNDATION EXTENTS, DAM 1

2023 Tailings Basin Dam 1 Breach Analysis

Northshore Mining
Lake County, Minnesota

E8 Summary and Conclusions

A total of six hypothetical dam breach analyses were performed on the NSM TSF near Silver Bay, Minnesota. The analyses were performed on Dam 1, Dam 2, and Dam 5 for the projected 2023 conditions under fair-weather and PMP-induced failure scenarios. Maps from these analyses can be used for emergency planning purposes.

The results of this study showed that during the hypothetical failure of Dam 1 at its highest location, a total of [redacted]

For Dam 2, [redacted]

During both failure scenarios of Dam 5 [redacted]

In all hypothetical failure scenarios of the NSM MP7 Tailings Basin, [redacted].

E9 References

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Exhibit 1

Map Book of PMP-Induced Dam 1 Failure Scenario

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Road/Railroad Impacted in Breach Scenario Only

Road/Railroad Impacted in Breach and No-Breach Scenario

Dam1 Modeled Breach Location

Model Cross Section

Public Waters Inventory Watercourse

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

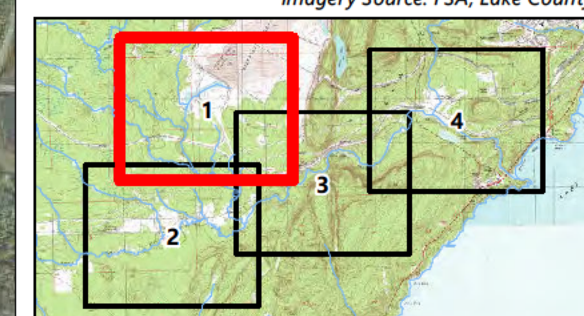
Dam Breach Scenario Flood Severity Category

- Low
- Medium
- High
- Very High
- Extreme
- Main Channel
- Upstream Channel

Approximate Impact Distance

- 1 Mile
- 2 Miles
- 3 Miles
- 4 Miles
- 5 Miles
- 6 Miles

Imagery Source: FSA, Lake County, 2019



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Feet

Exhibit 1 - Page 1

SIMULATED PMP BREACH, INUNDATION MAPBOOK DAM 1

2023 Dam 1 Breach Analysis

Northshore Mining

Lake County, Minnesota

Confidential Business Information

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Road/Railroad Impacted in Breach Scenario Only

Road/Railroad Impacted in Breach and No-Breach Scenario

Dam1 Modeled Breach Location

Model Cross Section

Public Waters Inventory Watercourse

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

- Low
- Medium
- High
- Very High
- Extreme

Main Channel

Upstream Channel

Superior Hiking Trail

Recreational Trail

Mile

4760 HWY 3
Water Surface: 1067.7 ft
Ground Surface: 1057.5 ft
Max. Velocity: 4.7 ft/s
Arrival Time: 1.3 hr
Max. Depth Arrival Time: 1.6 hr
Flood Severity: Extreme

Approximate Impact Distance

- 1 Mile
- 2 Miles
- 3 Miles
- 4 Miles
- 5 Miles
- 6 Miles

Imagery Source: FSA, Lake County, 2019

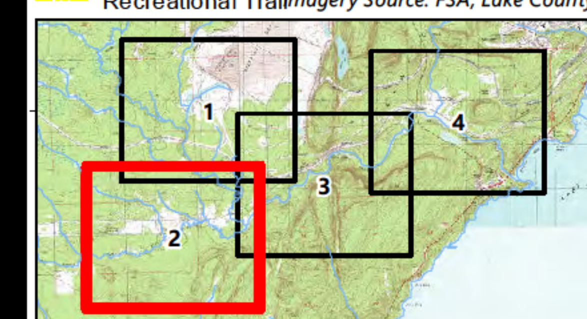

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Exhibit 1 - Page 2

SIMULATED PMP BREACH, INUNDATION MAPBOOK DAM 1

2023 Dam 1 Breach Analysis

Northshore Mining
Lake County, Minnesota

[redacted]

Confidential Business Information

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Road/Railroad Impacted in Breach Scenario Only

Road/Railroad Impacted in Breach and No-Breach Scenario

Dam1 Modeled Breach Location

Model Cross Section

Public Waters Inventory Watercourse

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

Low

Medium

High

Very High

Extreme

Main Channel

Upstream Channel

Superior Hiking Trail

Recreational Trail

Approximate Impact Distance

1 Mile

2 Miles

3 Miles

4 Miles

5 Miles

6 Miles

Imagery Source: FSA, Lake County, 2019

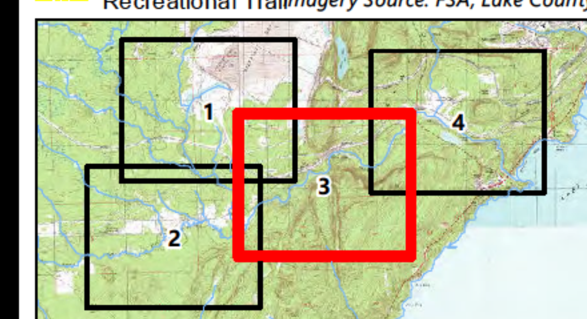

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Exhibit 1 - Page 3

SIMULATED PMP BREACH, INUNDATION MAPBOOK DAM 1

2023 Dam 1 Breach Analysis

Northshore Mining

Lake County, Minnesota

[redacted]

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Road/Railroad Impacted in Breach Scenario Only

Road/Railroad Impacted in Breach and No-Breach Scenario

Dam1 Modeled Breach Location

Model Cross Section

Public Waters Inventory Watercourse

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

Low

Medium

High

Very High

Extreme

Main Channel

Superior Hiking Trail

Recreational Trail

Approximate Impact Distance

1 Mile

2 Miles

3 Miles

4 Miles

5 Miles

6 Miles

Imagery Source: FSA, Lake County, 2019

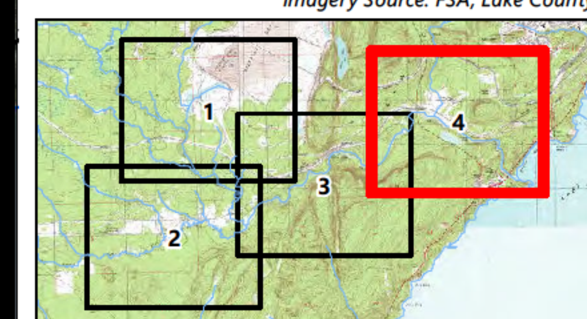

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Exhibit 1 - Page 4

SIMULATED PMP BREACH, INUNDATION MAPBOOK DAM 1

2023 Dam 1 Breach Analysis

Northshore Mining

Lake County, Minnesota

Exhibit 2

Map Book of Fair-Weather Dam 1 Failure Scenario

[redacted]

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Dam1 Modeled Breach Location

Road/Railroad Impacted in Breach Scenario Only

Model Cross Section

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

- Low
- Medium
- High
- Very High
- Extreme

Main Channel

Upstream Channel

Approximate Impact Distance

- 1 Mile
- 2 Miles
- 3 Miles
- 4 Miles
- 5 Miles
- 6 Miles

Imagery Source: FSA, Lake County, 2019

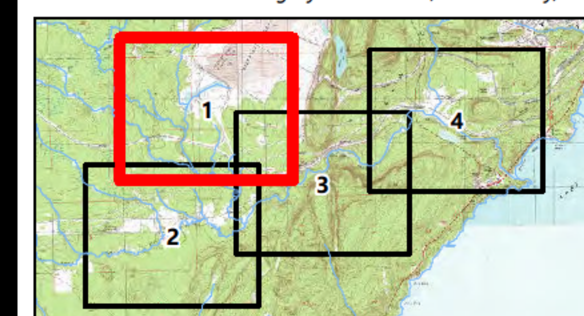

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Exhibit 2 - Page 1

SIMULATED FAIR-WEATHER BREACH, INUNDATION MAPBOOK DAM 1

2023 Dam 1 Breach Analysis

Northshore Mining

Lake County, Minnesota

Confidential Business Information

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Dam1 Modeled Breach Location

Road/Railroad Impacted in Breach Scenario Only

Model Cross Section

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

- Low
- Medium
- High
- Very High
- Extreme

Main Channel

Upstream Channel

Superior Hiking Trail

Recreational Trail

4760 HWY 3
Water Surface: 1065.4 ft
Ground Surface: 1057.6 ft
Max Velocity: 4.4 ft/s
Arrival Time: 1.4 hr
Max. Depth Arrival Time: 1.6 hr
Flood Severity: Very High

Approximate Impact Distance

- 1 Mile
- 2 Miles
- 3 Miles
- 4 Miles
- 5 Miles
- 6 Miles

Imagery Source: FSA, Lake County, 2019

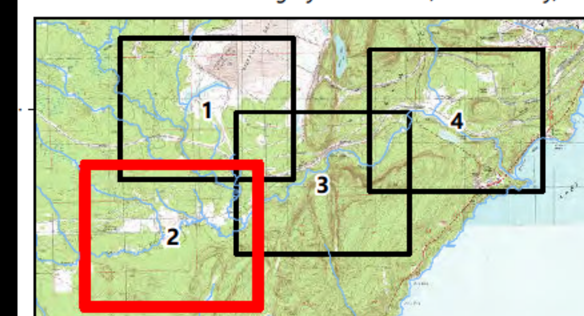

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Exhibit 2 - Page 2

SIMULATED FAIR-WEATHER BREACH, INUNDATION MAPBOOK DAM 1

2023 Dam 1 Breach Analysis

Northshore Mining
Lake County, Minnesota

[redacted]

[redacted]

[redacted]

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Dam1 Modeled Breach Location

Road/Railroad Impacted in Breach Scenario Only

Model Cross Section

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

- Low
- Medium
- High
- Very High
- Extreme

Main Channel

Upstream Channel

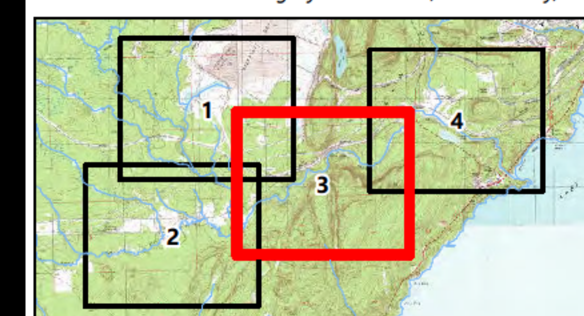
Superior Hiking Trail

Recreational Trail

Approximate Impact Distance

- 1 Mile
- 2 Miles
- 3 Miles
- 4 Miles
- 5 Miles
- 6 Miles

Imagery Source: FSA, Lake County, 2019



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Feet

Exhibit 2 - Page 3

SIMULATED FAIR-WEATHER BREACH, INUNDATION MAPBOOK DAM 1

2023 Dam 1 Breach Analysis

Northshore Mining
Lake County, Minnesota

[redacted]

[redacted]

[redacted]

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Dam1 Modeled Breach Location

Road/Railroad Impacted in Breach Scenario Only

Model Cross Section

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

- Low
- Medium
- High
- Very High
- Extreme

Main Channel

Upstream Channel

Superior Hiking Trail

Recreational Trail

Approximate Impact Distance

- 1 Mile
- 2 Miles
- 3 Miles
- 4 Miles
- 5 Miles
- 6 Miles

Imagery Source: FSA, Lake County, 2019

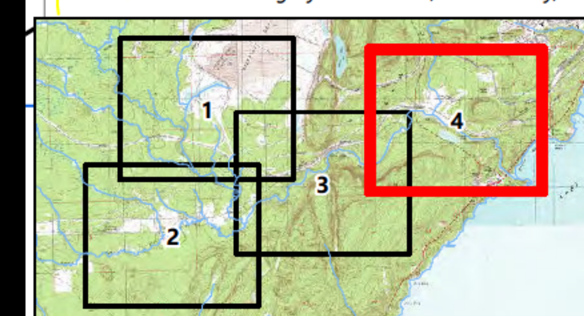

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Exhibit 2 - Page 4

SIMULATED FAIR-WEATHER BREACH, INUNDATION MAPBOOK DAM 1

2023 Dam 1 Breach Analysis

Northshore Mining

Lake County, Minnesota

Exhibit 3

Map Book of PMP-Induced Dam 2 Failure Scenario

[redacted]

Confidential Business Information

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Dam 2 Modeled Breach Location

Road/Railroad Impacted in Breach Scenario Only

Model Cross Section

Public Waters Inventory Watercourse

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

- Low
- Medium
- High
- Very High
- Extreme

Approximate Impact Distance

- 1 Mile
- 2 Miles
- 3 Miles
- 4 Miles
- 5 Miles
- 6 Miles

Superior Hiking Trail

Recreational Trail

Imagery Source: FSA, Lake County, 2019

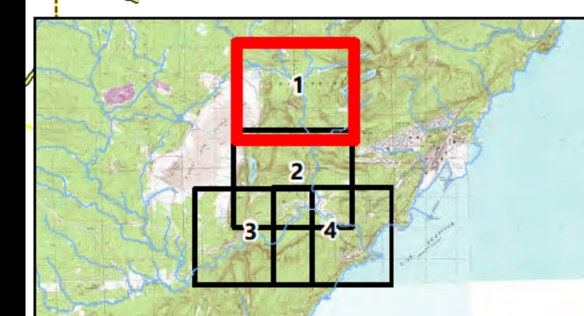

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Exhibit 3- Page 1

SIMULATED PMP BREACH,
INUNDATION MAPBOOK DAM 2

2023 Dam 2 Breach Analysis

Northshore Mining
Lake County, Minnesota

[redacted]

Confidential Business Information

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Dam 2 Modeled Breach Location

Road/Railroad Impacted in Breach Scenario Only

Model Cross Section

Public Waters Inventory Watercourse

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

- Low
- Medium
- High
- Very High
- Extreme

Superior Hiking Trail

Recreational Trail

Approximate Impact Distance

- 1 Mile
- 2 Miles
- 3 Miles
- 4 Miles
- 5 Miles
- 6 Miles

Imagery Source: FSA, Lake County, 2019

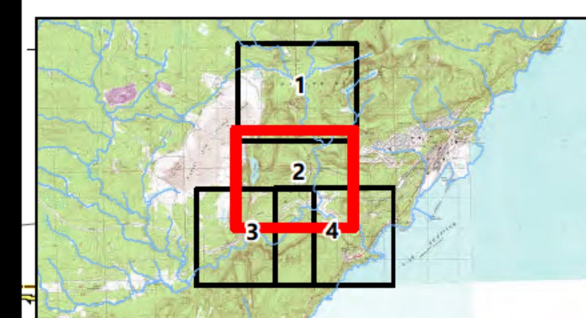

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Exhibit 3- Page 2

SIMULATED PMP BREACH, INUNDATION MAPBOOK DAM 2

2023 Dam 2 Breach Analysis

Northshore Mining

Lake County, Minnesota

[redacted]

Confidential Business Information

[redacted]

[redacted]

[redacted]

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Dam 2 Modeled Breach Location

Road/Railroad Impacted in Breach Scenario Only

Model Cross Section

Public Waters Inventory Watercourse

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

Low

Medium

High

Very High

Extreme

Superior Hiking Trail

Recreational Trail

Approximate Impact Distance

1 Mile

2 Miles

3 Miles

4 Miles

5 Miles

6 Miles

Imagery Source: FSA, Lake County, 2019

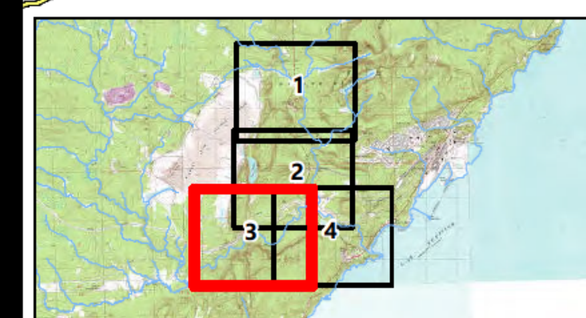

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Exhibit 3- Page 3

SIMULATED PMP BREACH, INUNDATION MAPBOOK DAM 2

2023 Dam 2 Breach Analysis

Northshore Mining

Lake County, Minnesota

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Dam 2 Modeled Breach Location

Road/Railroad Impacted in Breach Scenario Only

Model Cross Section

Public Waters Inventory Watercourse

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

Low

Medium

High

Very High

Extreme

Superior Hiking Trail

Recreational Trail

Approximate Impact Distance

1 Mile

2 Miles

3 Miles

4 Miles

5 Miles

6 Miles

Imagery Source: FSA, Lake County, 2019

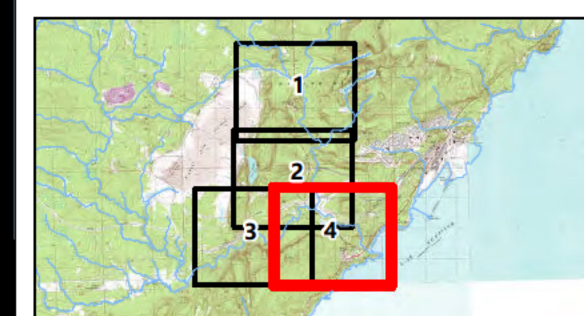

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Exhibit 3- Page 4

SIMULATED PMP BREACH, INUNDATION MAPBOOK DAM 2

2023 Dam 2 Breach Analysis

Northshore Mining

Lake County, Minnesota

Exhibit 4

Map of Fair-Weather Dam 2 Failure Scenario

[redacted]

[redacted]

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Dam 2 Modeled Breach Location

Road/Railroad Impacted in Breach Scenario Only

Model Cross Section

Public Waters Inventory Watercourse

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

- Low
- Medium
- High
- Very High
- Extreme

Superior Hiking Trail

Recreational Trail

Approximate Impact Distance

- 1 Mile
- 2 Miles
- 3 Miles
- 4 Miles
- 5 Miles
- 6 Miles

Imagery Source: FSA, Lake County, 2019

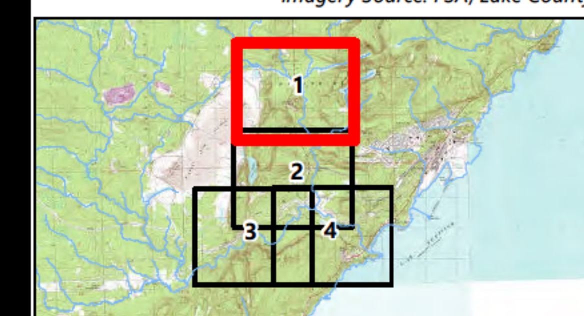

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Exhibit 4 - Page 1

SIMULATED FAIR-WEATHER BREACH, INUNDATION MAPBOOK DAM 2

2023 Dam 2 Breach Analysis

Northshore Mining
Lake County, Minnesota

[redacted]

Confidential Business Information

[redacted]

[redacted]

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Dam 2 Modeled Breach Location

Road/Railroad Impacted in Breach Scenario Only

Model Cross Section

Public Waters Inventory Watercourse

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

- Low
- Medium
- High
- Very High
- Extreme

Superior Hiking Trail

Recreational Trail

Approximate Impact Distance

- 1 Mile
- 2 Miles
- 3 Miles
- 4 Miles
- 5 Miles
- 6 Miles

Imagery Source: FSA, Lake County, 2019

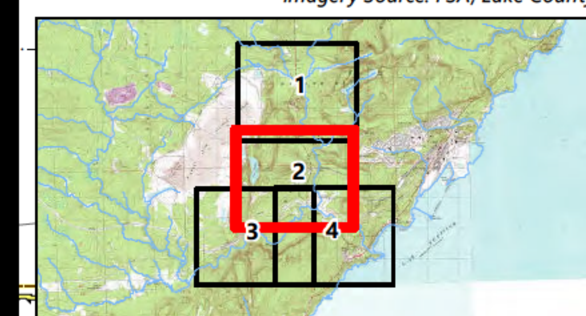

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Exhibit 4 - Page 2

SIMULATED FAIR-WEATHER BREACH, INUNDATION MAPBOOK DAM 2

2023 Dam 2 Breach Analysis

Northshore Mining

Lake County, Minnesota

[redacted]

Confidential Business Information

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Dam 2 Modeled Breach Location

Road/Railroad Impacted in Breach Scenario Only

Model Cross Section

Public Waters Inventory Watercourse

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

- Low
- Medium
- High
- Very High
- Extreme

Superior Hiking Trail

Recreational Trail

Approximate Impact Distance

- 1 Mile
- 2 Miles
- 3 Miles
- 4 Miles
- 5 Miles
- 6 Miles

Imagery Source: FSA, Lake County, 2019

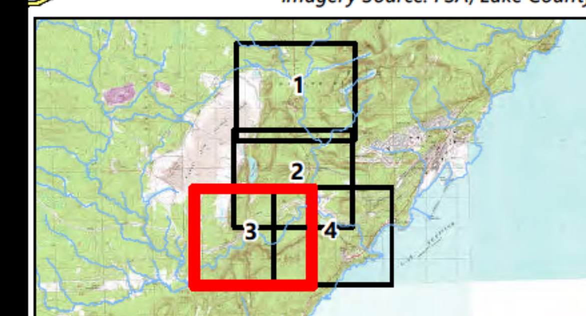

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Exhibit 4 - Page 3

SIMULATED FAIR-WEATHER BREACH, INUNDATION MAPBOOK DAM 2

2023 Dam 2 Breach Analysis

Northshore Mining

Lake County, Minnesota

[redacted]

Confidential Business Information

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Dam 2 Modeled Breach Location

Road/Railroad Impacted in Breach Scenario Only

Model Cross Section

Public Waters Inventory Watercourse

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

- Low
- Medium
- High
- Very High
- Extreme

Superior Hiking Trail

Recreational Trail

Approximate Impact Distance

- 1 Mile
- 2 Miles
- 3 Miles
- 4 Miles
- 5 Miles
- 6 Miles

Imagery Source: FSA, Lake County, 2019

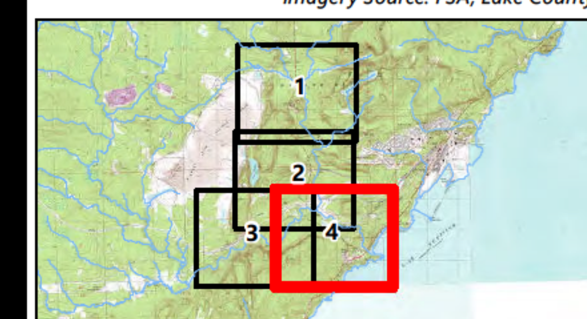

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Exhibit 4 - Page 4

SIMULATED FAIR-WEATHER BREACH, INUNDATION MAPBOOK DAM 2

2023 Dam 2 Breach Analysis

Northshore Mining

Lake County, Minnesota

Exhibit 5

Map of PMP-Induced Dam 5 Failure Scenario

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Dam 5 Modeled Breach Location

Road/Railroad Impacted in Breach Scenario Only

Model Cross Section

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

- Low
- Medium
- High
- Very High
- Extreme

Superior Hiking Trail

Recreational Trail

Approximate Impact Distance

- 1 Mile
- 2 Miles
- 3 Miles
- 4 Miles

Imagery Source: FSA, Lake County, 2019

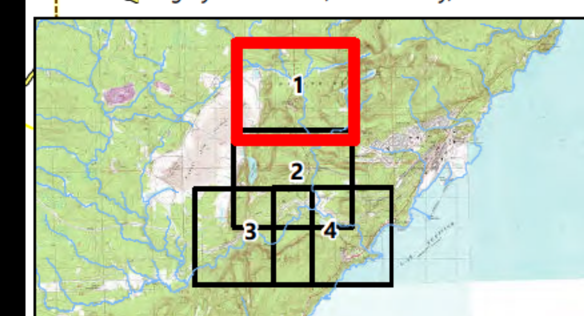

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Exhibit 5 - Page 1

SIMULATED PMP BREACH, INUNDATION MAPBOOK DAM 5

2023 Dam 5 Breach Analysis

Northshore Mining

Lake County, Minnesota

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Dam 5 Modeled Breach Location

Road/Railroad Impacted in Breach Scenario Only

Model Cross Section

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

- Low
- Medium
- High
- Very High
- Extreme

Superior Hiking Trail

Recreational Trail

Approximate Impact Distance

- 1 Mile
- 2 Miles
- 3 Miles
- 4 Miles

Imagery Source: FSA, Lake County, 2019

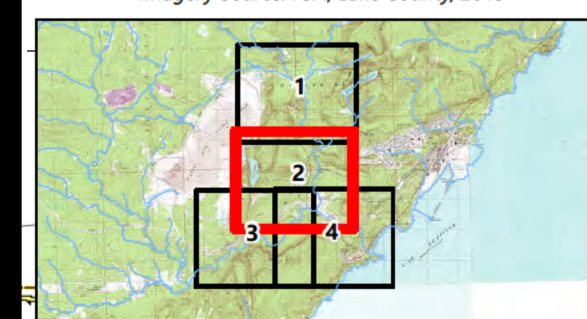

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Exhibit 5 - Page 2

SIMULATED PMP BREACH, INUNDATION MAPBOOK DAM 5

2023 Dam 5 Breach Analysis

Northshore Mining
Lake County, Minnesota

[redacted]

Confidential Business Information

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Dam 5 Modeled Breach Location

Road/Railroad Impacted in Breach Scenario Only

Model Cross Section

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

Low

Medium

High

Very High

Extreme

Superior Hiking Trail

Recreational Trail

Approximate Impact Distance

1 Mile

2 Miles

3 Miles

4 Miles

Imagery Source: FSA, Lake County, 2019

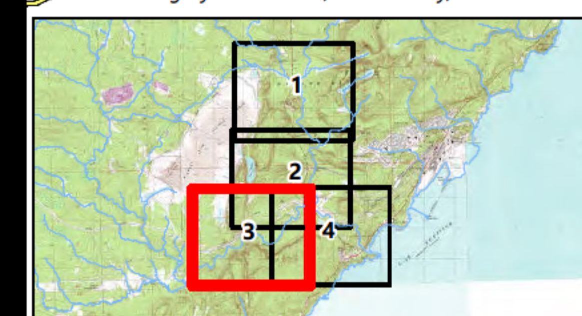

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Exhibit 5 - Page 3

SIMULATED PMP BREACH, INUNDATION MAPBOOK DAM 5

2023 Dam 5 Breach Analysis

Northshore Mining

Lake County, Minnesota

Confidential Business Information

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Dam 5 Modeled Breach Location

Road/Railroad Impacted in Breach Scenario Only

Model Cross Section

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

- Low
- Medium
- High
- Very High
- Extreme

Superior Hiking Trail

Recreational Trail

Approximate Impact Distance

- 1 Mile
- 2 Miles
- 3 Miles
- 4 Miles

Imagery Source: FSA, Lake County, 2019

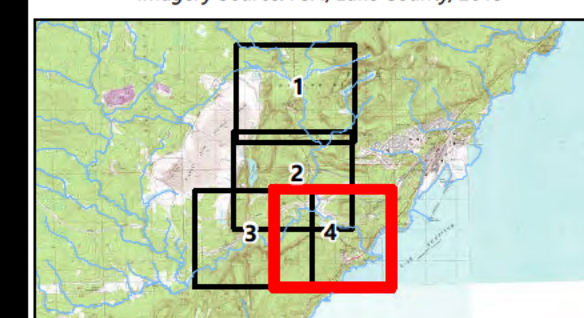

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Exhibit 5 - Page 4

SIMULATED PMP BREACH, INUNDATION MAPBOOK DAM 5

2023 Dam 5 Breach Analysis

Northshore Mining
Lake County, Minnesota

Exhibit 6

Map Book of Fair-Weather Dam 5 Failure Scenario

Confidential Business Information

[redacted]

- [redacted]
- [redacted]
- [redacted]
- Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario
- Dam 5 Modeled Breach Location
- Road/Railroad Impacted in Breach Scenario Only
- Model Cross Section
- Mapbook Page Extent
- No Breach Scenario Inundation Extent
- Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

- Low
- Medium
- High
- Very High
- Extreme

Approximate Impact Distance

- 1 Mile
- 2 Miles
- 3 Miles
- 4 Miles

- Superior Hiking Trail
- Recreational Trail

Imagery Source: FSA, Lake County, 2019

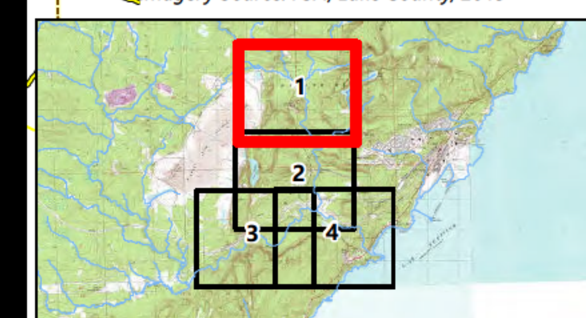

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Exhibit 6 - Page 1

SIMULATED FAIR-WEATHER BREACH, INUNDATION MAPBOOK, DAM 5

2023 Dam 5 Breach Analysis

Northshore Mining
Lake County, Minnesota

[redacted]

Confidential Business Information

[redacted]

[redacted]

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Dam 5 Modeled Breach Location

Road/Railroad Impacted in Breach Scenario Only

Model Cross Section

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

Low

Medium

High

Very High

Extreme

Superior Hiking Trail

Recreational Trail

Approximate Impact Distance

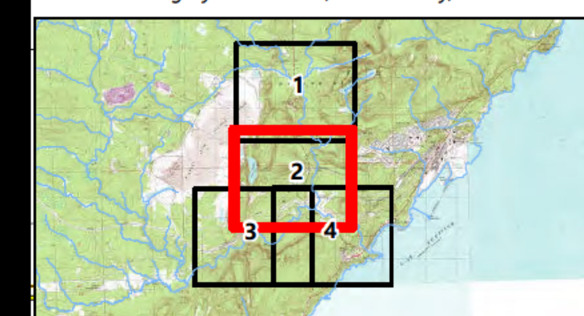
1 Mile

2 Miles

3 Miles

4 Miles

Imagery Source: FSA, Lake County, 2019



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Feet

Exhibit 6 - Page 2

SIMULATED FAIR-WEATHER BREACH, INUNDATION MAPBOOK, DAM 5

2023 Dam 5 Breach Analysis

Northshore Mining

Lake County, Minnesota

[redacted]

Confidential Business Information

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Dam 5 Modeled Breach Location

Road/Railroad Impacted in Breach Scenario Only

Model Cross Section

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

- Low
- Medium
- High
- Very High
- Extreme

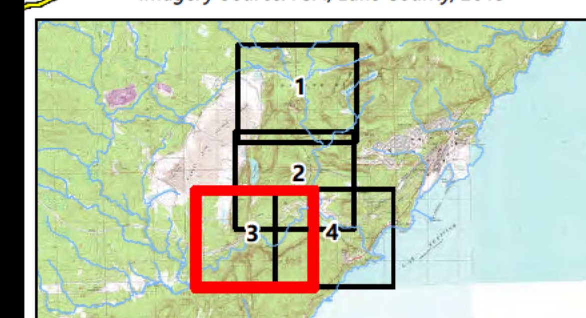
Approximate Impact Distance

- 1 Mile
- 2 Miles
- 3 Miles
- 4 Miles

Superior Hiking Trail

Recreational Trail

Imagery Source: FSA, Lake County, 2019



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Feet

Exhibit 6 - Page 3

SIMULATED FAIR-WEATHER BREACH, INUNDATION MAPBOOK, DAM 5

2023 Dam 5 Breach Analysis

Northshore Mining

Lake County, Minnesota

[redacted]

[redacted]

[redacted]

[redacted]

Habitable/Non-Habitable Structure, Not Impacted in Breach and No-Breach Scenario

Dam 5 Modeled Breach Location

Road/Railroad Impacted in Breach Scenario Only

Model Cross Section

Mapbook Page Extent

No Breach Scenario Inundation Extent

Dam Breach Scenario Inundation Extent

Dam Breach Scenario Flood Severity Category

- Low
- Medium
- High
- Very High
- Extreme

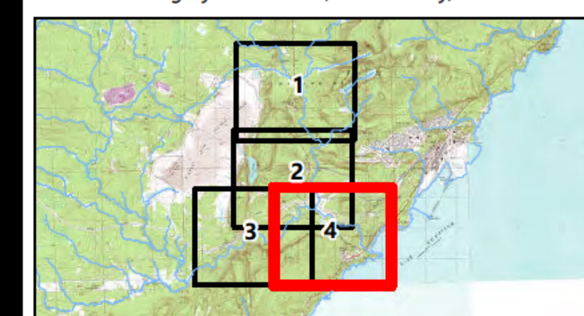
Superior Hiking Trail

Recreational Trail

Approximate Impact Distance

- 1 Mile
- 2 Miles
- 3 Miles
- 4 Miles

Imagery Source: FSA, Lake County, 2019



1,000 0 1,000

Feet

Exhibit 6 - Page 4

SIMULATED FAIR-WEATHER BREACH, INUNDATION MAPBOOK, DAM 5

2023 Dam 5 Breach Analysis

Northshore Mining

Lake County, Minnesota

Appendix F

Emergency Action Plan Review, Updating Training, and Testing

Appendix F

Emergency Action Plan Review, Updating, Training, and Testing

F.1 Emergency Action Plan Review and Updating

Review and update of the Emergency Action Plan (EAP) should be targeted every 5 years as part of the operating plan updates or as Cleveland-Cliffs determines is necessary. Review and updating should also include adjustments that are found to be necessary through experience gained as a result of practice sessions or emergencies that occur at other sites. The telephone numbers and persons listed in the Notification Flowchart are of primary importance.

F.2 Training

Anyone assuming significant responsibilities in the EAP, and their alternates, must review the elements of the EAP and conduct appropriate training every 3 years.

F.3 Testing

Testing of the EAP may be carried out as a part of the training session. Testing the EAP familiarizes the responsible parties with the EAP, gives the community a good idea of the real time needed for evacuation, and helps make evident any EAP deficiencies. Simulation drills may be conducted as a means of preparation, training, and testing the EAP. The Notification Flowchart and emergency equipment/ procedures should be reviewed annually.

Appendix G

Emergency Action Plan Storage Location and Distribution Lists

Appendix G

Emergency Action Plan Storage Location and Distribution Lists

The storage location and distribution lists are provided to ensure that each participant has a copy of the EAP and that copies of the EAP are easily accessible. The lists will also assist with distribution of updated EAPs when necessary.

A copy of the EAP document will be stored in the following location:

- [redacted]

In addition to the NSM and Cliffs Technology Group staff listed in the emergency notification contact list, the following is a distribution list for the EAP document.

Matt Pollmann
Director
Lake County Emergency Management
99 Edison Blvd
Silver Bay, MN 55647
Office: 218-220-6277
Matt.Pollmann@co.lake.mn.us

Jason Boyle
State Dam Safety Engineer
Division of Ecological and Water Resources
Minnesota Department of Natural Resources
500 Lafayette Rd.
St. Paul, Minnesota 55155-4032
Phone: 651-259-5715
jason.boyle@dnr.state.mn.us

Engineering Support
Barr Engineering Co.
4300 MarketPointe Drive
Minneapolis, MN 55435
phone: 952-832-2600

Aaron Grosser
Senior Geotechnical Engineer
Barr Engineering Company
Direct: 952-832-2609
agrosser@barr.com

Sara Leow
Geotechnical Engineer
Barr Engineering Company
Direct: 218-529-7125
sleow@barr.com

Appendix H

Rally Points and Associated Access Routes

onfidential Business Information

[redacted]

Gate

Rally Point

Access route to rally point for Dam 1 event

Alternative access route to rally point for Dam 1 event if traveling to basin from south of Beaver Bay

Access route to rally point for Dam 2 or Dam 5 event
if traveling to basin from north of Beaver Bay

Access route to rally point for Dam 2 or Dam 5 event
if traveling to basin from south of Beaver Bay

Beaver Bay Municipal Boundary

0 2,200
Feet

ACCESS AND RALLY POINT PLAN
MP 7 Dambreak Analysis
Silver Bay, Minnesota

FIGURE H-1

Supplement to Figure H-1: Access and Rally Point Plan Description

Traffic routes depicted on Figure H-1 and described below should be used for traffic within the basin.

[redacted]

[redacted]

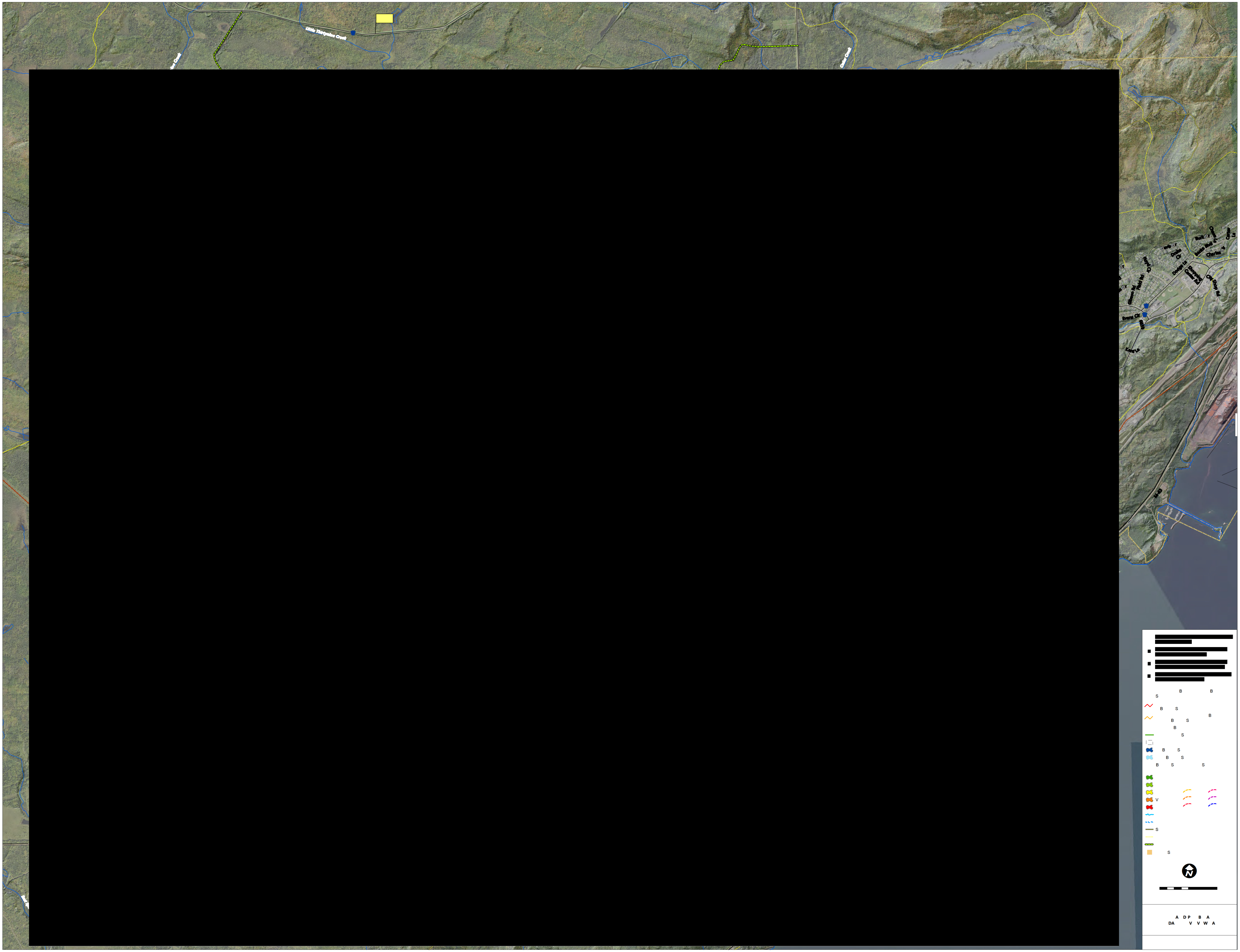
[redacted]

Upon emergency designation, basin personnel will be dispatched to open then secure entry points until replaced.

Appendix I

Comprehensive Inundation Maps

[redacted]



[redacted]

[redacted]

[redacted]

[redacted]
Lake Superior
Note: No structures are impacted during no breach scenario.

[redacted]

Cleveland-Cliffs - *Cliffs Technical Group - Tailings Engineering*

Transmittal Letter

CLIFFS

Suite 202
10 Outer Drive
Silver Bay, MN 55614

PHONE (218)226-6023

TO:

Jason Boyle
State Dam Safety Engineer
500 Lafayette Road
Saint Paul, MN 55155-4025

Attention:

Reference

Date: 07/21/23
Project: Northshore Mining - EAP
CMSC Job#:
Reference: As Noted
By: Dean Korri - Director Civil Engineering
email: Dean.Korri@Clevelandcliffs.com
Copies:

We are sending the following Item(s).

- [ ] Print(s)
- [ ] Diskette(s)
- [x] Attached
- [ ] Mylar(s)
- [ ] Other
- [ ] Under separate cover via

for the following purposes:

- [ ] Approved
- [ ] For Approval
- [ ] For Your Information and File
- [ ] For Review and Comment
- [ ] As Requested
- [x] Follow Up Submittal

Number of Copies	Document Ref or Number	Rev.	Date	Drawing Title/Description
1	EAP Errata Submittal			Northshore 2022 EAP - Appx. D Errata
				Changes to Purpose statement not changed from 2012 ed.

Remarks:

Cliff's Representative: **D.Korri**

Cleveland-Cliffs Technical Group
Suite 202
10 Outer Drive
Silver Bay, MN 55614
(218) 226-6023

Notice of Errata

To: Jason Boyle
MnDNR Dam Safety

From: Dean Korri
Cleveland-Cliffs Inc.

Date: July 21, 2023

Subject: Northshore MilePost-7 Emergency Action Plan Notice of Errata

Dean Korri of Cleveland-Cliffs Inc. ("Cliffs") hereby provides notice of a correction to the Northshore MP07 Emergency Action Plan ("EAP") submitted to the Minnesota Department of Natural Resources on 04/18/2022. For any further inquiries, please contact Dean Korri at dean.korri@clevelandcliffs.com.

Title	Section	Page	Now Reads	Should Read
Emergency Action Plan Milepost 7 Tailings Basin Dated (Apr. 2022)	Appendix D: Purpose of the Emergency Action Plan	D-1 Lines 3-6 (of original)	The purpose of the Emergency Action Plan (EAP) is to document a workable plan of action to be followed in the event of failure of the Milepost 7 Tailings Basin dams or severe hydrologic conditions at the tailings basin. In 1980, the state of Minnesota promulgated rules regulating the operation and maintenance of dams; however, the dams are not currently regulated by the MnDNR. If the dams were to be classified as Class 1 by the MnDNR, then in accordance with Minnesota Rules 6115.0340, NSM would be required to prepare an emergency action plan. At this time NSM has initiated the creation of this plan for their own use, to be prepared in the event of an emergency at the dam. A copy of Minnesota Rules Section 6115.0490 Warning Systems and Emergency Procedures is attached.	The purpose of the Emergency Action Plan (EAP) is to document a workable plan of action to be followed in the event of failure of the Milepost 7 Tailings Basin dams or severe hydrologic conditions at the tailings basin. In 1979, the state of Minnesota enacted rules regulating the operation and maintenance of dams. Being classified as Class 1 by the MnDNR, then in accordance with Minnesota Rules 6115.0340, NSM is required to prepare an emergency action plan. A copy of Minnesota Rules Section 6115.0490 Warning Systems and Emergency Procedures is attached.

Appendix D

Purpose of the Emergency Action Plan

The purpose of the Emergency Action Plan (EAP) is to document a workable plan of action to be followed in the event of failure of the Milepost 7 Tailings Basin dams or severe hydrologic conditions at the tailings basin. In 1979, the state of Minnesota enacted rules regulating the operation and maintenance of dams. Being classified as Class 1 by the MnDNR, then in accordance with Minnesota Rules 6115.0340, NSM is required to prepare an emergency action plan.

A copy of Minnesota Rules Section 6115.0490 Warning Systems and Emergency Procedures is attached.