

# Appendix G

Loss of Containment in Tailings Storage Facility (TSF)



## 1.0 LOSS OF CONTAINMENT IN TAILINGS STORAGE FACILITY (TSF)

The EIA Report (Section 8.17.2.1.1) did not consider a TSF embankment failure as a credible accident or malfunction scenario since, for the extensive reasons given in that section of the EIA Report, such an event is highly unlikely to occur. Nonetheless, the concern was still expressed by both governments and the public, and further information is provided below as responses to five basic questions:

- How might the TSF embankment fail?
- How likely is a TSF embankment failure?
- What would be the environmental effects of a TSF embankment failure and their significance?
- What mitigation measures will be employed to avoid a TSF embankment failure?
- What emergency response procedures will be implemented in the unlikely event of a TSF embankment failure?

### 1.1 HOW MIGHT THE TSF EMBANKMENT FAIL?

#### 1.1.1 The Value of Modelling

In the worldwide experience of Knight Piésold regarding TSF design and performance, there is very little precedent for dam breach modelling of tailings embankments. This type of modelling is currently being done by a small number of practitioners in North America, but the modelling approaches, failure mode assumptions, and interpretations of results vary greatly. There are consequently no industry standards or regulatory guidelines in North America for such modelling or, to our knowledge, elsewhere in the world.

The results of dam breach models are very dependent on input assumptions, particularly the size and shape of the breach, and the time that it takes for the breach to both initiate and then fully develop. Sensitivity analyses of some modelling attempts have shown that the peak discharge of a breach outflow hydrograph can vary by more than 100% depending on the breach parameters used, even if the parameters fall within recommended ranges. Furthermore, a review of the literature shows that numerous different relations with widely varying results have been proposed for estimating breach parameters and peak discharges (Wahl 1998)<sup>1</sup>. It must also be noted that almost all dam failure modelling work has been done for water storage embankments; tailings embankments have markedly different failure patterns and consequences because most of the material they contain is tailings solids, with comparatively little stored water.

It is thus not possible to accurately and reliably model either the size or the rate of the physical failure of a tailings storage facility, the volume of the solids and liquids that would escape as a result, at what rates, and how far they would travel downstream. Hence, more qualitative approaches must be employed. A conceptual assessment of a TSF slope failure can be developed to provide a general

<sup>1</sup> Wahl, T.L., 1998. Prediction of Embankment Dam Breach Parameters: A Literature Review and Needs Assessment. Dam Safety Research Report DSO-98-004, Water Resources Research Laboratory, U.S. Department of the Interior, Bureau of Reclamation, Dam Safety Office.

understanding of potential failure mechanisms, the probability of failure occurrence, and associated embankment safety considerations.

### 1.1.2 Nature, Mechanism, and Magnitude

The TSF embankments for the Sisson Project will be constructed in stages as a zoned rockfill structure. The final embankment height will vary along the embankment alignment according to the varying natural topography, with a maximum embankment height of approximately 76 m at the final crest elevation of 376 metres above sea level (masl), and a topographic low point of 300 masl.

The initial stage comprises starter embankments at topographic low points around the alignment that will include a geosynthetic (HDPE) liner on the upstream face to provide initial containment of fresh water for a start-up pond and, afterwards, the first two years of tailings deposition. Subsequent stages of the embankments will be progressively raised by the modified centerline construction method using quarried rockfill. Transition and filter zones will be constructed within the embankments between the tailings and coarse rockfill shell zone to ensure filter compatibility and internal stability of the embankment fill materials. Zoned rockfill embankments are inherently resistant to internal erosion or “piping” failure, and are also resistant to erosion of the downstream embankment face, in the unlikely event that over-topping of an embankment occurred.

In a highly unlikely, worst-case scenario, a slope failure could result in the breach of a TSF embankment. A slope failure could possibly result if an event occurred that was outside the facility’s design criteria. Such events include an earthquake larger than accounted for, or an extreme rainfall event greater than planned for, in the design undertaken by Knight Piésold according to guidance from external agencies including the Canadian Dam Association and ICOLD. A failure could also result if the design criteria were not followed during Construction or Operation.

Depending on when and where the TSF embankment slope failure occurred, some process water and tailings solids stored in the TSF could be released to the surrounding environment (to both land and watercourses). The theoretical maximum volume of water that could be stored in the TSF impoundment is approximately 23 million cubic metres ( $Mm^3$ ) at the end of the mine life (with lesser amounts during earlier years of Operation) which includes the maximum operating pond volume, plus the Probable Maximum Flood (PMF) volume selected as the Inflow Design Flood (IDF) for the TSF. The maximum volume of tailings solids that could be stored in the TSF is approximately  $247 Mm^3$  at the end of mine life (again, with lesser amounts during earlier years of Operation). The amount of solids that could be released during an embankment breach would be dependent on the geometry of the breach and the rate of outflow. Given the size and configuration of the TSF, and the consolidation characteristics of the tailings, it is extremely unlikely that most or all of the solids contained in the TSF would be released during a breach of the TSF embankment; rather, only a portion of the unconsolidated tailings that are directly in contact with the outflowing water near the location of the breach would be transported in such an event. Thus, in a worst-case scenario, the breach could involve a relatively small portion, likely less than one fifth of the contained tailings and pore water being released to the environment (Azam and Li 2010)<sup>2</sup>.

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<sup>2</sup> Azam, Sahid and Li, Qiren. 2010. Tailings Dam Failures: A Review of the Last One Hundred Years, Geotechnical News, December.

After the end of Operation, the potential volume of water and solids that could be released as a result of a dam breach would be more limited than if it occurred during Operation. A smaller surface pond will be maintained that will be remote from the embankments and passively managed by an overflow spillway discharging the ponded water to the open pit. If a breach occurred following the end of Operation, it would result in the slumping of a small volume of relatively dry tailings solids that becomes fluidized through direct contact with the lesser volume of water released, over the outside face of an embankment. The spatial extent of any environmental effects would be limited to the natural angle of repose of the tailings solids.

## 1.2 HOW LIKELY IS A TSF EMBANKMENT FAILURE?

The probability of a TSF slope failure is very low, especially with the proposed rockfill embankment design and modified centerline construction method for the TSF. The primary mitigation strategies associated with the prevention of a TSF slope failure are the use of suitably conservative design criteria, construction quality control and quality assurance, regulatory oversight, and strict operating procedures. As is described in Section 3.2.4.3.3 of the EIA Report, the TSF embankments have been designed in consideration of a specific severe Inflow Design Flood (IDF and a Maximum Design Earthquake (MDE) to meet and/or exceed the requirements of the Canadian Dam Safety Guidelines (CDA 2007)<sup>3</sup>.

Specifically, the design for the TSF embankments provides for the construction of massive rockfill structures that exceed the prescribed factor of safety (FOS) stability requirements. The static analysis indicates that the TSF design exceeds the minimum FOS requirements under all conditions; minor deformation of the embankments, such as crest settlement, would be inconsequential to the safety of the facility during the maximum design earthquake. To further minimize the risk of embankment failure, the operating TSF will be constructed and managed with a minimum of two metres of freeboard above the storage requirement for the IDF volume to ensure the PMF will be contained. To ensure that required factors of safety are maintained, the TSF embankment raises will be completed under the supervision of a licensed professional geotechnical engineer, and qualified geotechnical engineers will be required to complete regular as-built slope and stability surveys throughout the mine life.

It is important to note that it is incorrect to imply that any particular proposed or actual dam structure is more or less likely to fail based solely on the extrapolation of general dam failure statistics. Much of the analyses of water and tailings dam failures have been carried out by the International Commission on Large Dams (ICOLD 2001)<sup>4</sup> which stated that *“many factors influence the behavior of tailings impoundments; accidents and other incidents are often the result of inadequate site investigation, design, construction, operation, or monitoring of the impoundment, or a combination of these. Every site and dam is unique so direct application from one to another is seldom possible. However, there are a number of common principles and the lessons learned from incidents at one dam can be applied in general terms to other situations.”*

<sup>3</sup> Canadian Dam Association. 2007. Dam Safety Guidelines 2007 (previously published 1999). Available online at: [http://www.imis100ca1.ca/cda/CDA/Publications\\_Pages/Dam\\_Safety\\_Guidelines.aspx](http://www.imis100ca1.ca/cda/CDA/Publications_Pages/Dam_Safety_Guidelines.aspx).

<sup>4</sup> International Commission on Large Dams (ICOLD). 2001. Tailings Dams Risk of Dangerous Occurrences, Lessons Learnt from Practical Experiences. Bulletin Number 121.

There are accepted methodologies to estimate the failure probabilities associated with a particular tailings facility. In particular, Silva, Lambe, and Marr (2008)<sup>5</sup> present a risk assessment methodology that uses a semi-empirical relationship between factor of safety and annual probability of failure. This allows geotechnical engineers to provide a quantified risk assessment for a given structure. The assessment for the Sisson Project TSF embankment is based on:

- the level of investigation, testing, analysis and documentation that will be carried out prior to Construction;
- the construction quality control, quality assurance, and documentation required for best engineering practice; and
- the operating and monitoring criteria required both by law and as needed to adhere to Northcliff's commitment to its *Principles of Responsible Mineral Development*.

Following this established assessment methodology, the proposed TSF for the Sisson Project would have an annual probability of failure of between 1-in-1 million to 1-in-10 million. This supports the conclusions of the EIA Report that a major failure of the tailings embankment is a not a credible accident or malfunction scenario and that it is highly unlikely to occur.

### **1.3 WHAT WOULD BE THE ENVIRONMENTAL EFFECTS OF A TSF EMBANKMENT FAILURE?**

The potential environmental effects of a major failure of the TSF embankment are considered here, despite the extremely low likelihood of occurrence (annual probability of failure of between 1-in-1 million to 1-in-10 million). It is a non-credible accident scenario that is being considered in response to many requests for its consideration.

The mechanism for a failure of the embankment would be the occurrence of a flood beyond the probable maximum flood (PMF) or an earthquake that exceeds the Maximum Design Earthquake (MDE). Both mechanisms could be considered an effect of the environment on the Project with consequential environmental effects which are best characterized as an accident or unplanned event.

Table 1.1 below provides a description of this scenario, a description of the potential environmental effects and the VECs potentially affected in a manner consistent with the approach employed in the assessment of accidents, malfunctions and unplanned events.

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<sup>5</sup> F. Silva, T.W. Lambe, W.A. Marr. December 2008. Probability and Risk of Slope Failure. Journal of Geotechnical and Geoenvironmental Engineering, ASCE.

**Table 1.1 Non-Credible Accidents, Malfunctions and Unplanned Events and Scenarios**

Accident/ Malfunction/ Unplanned Event	Description of Scenario	Description of Potential Environmental Effects	VECs Potentially Affected
Loss of Containment in the TSF	This non-credible accident is very unlikely to occur and would involve a breach of the tailings embankment. The triggering mechanism would be an extreme earthquake or flood event outside of the very conservative design criteria for the facility. In the very unlikely event that it occurred, it could result in the loss of up to 23 Mm <sup>3</sup> of contaminated water and a portion of a maximum of 247 Mm <sup>3</sup> of stored tailings.	The potential environmental effects would be related to the uncontrolled loss of a relatively large volume of tailings pond water, and some lesser volume of tailings and other sediment into Napadogan Brook, and possibly into the Nashwaak River. The release would likely result in or contribute to flooding in Napadogan Brook, and possibly the Nashwaak River. The release of tailings and other sediment would likely affect the channel and flood plain of Napadogan Brook, and possibly Nashwaak River. The erosion and deposition of natural material eroded by the flood and tailings would likely cover and infill the channel and floodplains, affecting Water Resources, Aquatic Environment, Terrestrial Environment, Vegetated Environment, and Wetland Environment. The flooding and deposition may interfere with bridge crossings and related infrastructure, and would like interfere with various land uses. Public Health and Safety might be affected through contamination of Water Resources or through hazardous conditions associated with land use and activities or transportation.	<ul style="list-style-type: none"> <li>• Water Resources</li> <li>• Aquatic Environment</li> <li>• Terrestrial Environment</li> <li>• Vegetated Environment</li> <li>• Wetland Environment</li> <li>• Public Health and Safety</li> <li>• Land and Resource Use</li> <li>• Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons</li> <li>• Transportation</li> </ul>

In the worst case, a large volume of tailings pond water (23 Mm<sup>3</sup>) would be lost over a very short period of time, possibly in a matter of hours. This would likely result in stream flows that would be outside of the natural range of those experienced in Napadogan Brook, and possibly the Nashwaak River, at least immediately below its confluence with the Napadogan Brook. It is not possible to predict with any certainty the extent of flooding that would result from this increase in stream flow, but it would be severe in Napadogan Brook in the worst case.

Should the resultant flood arise due to a storm exceeding the IDF for the TSF, the release of tailings water would likely be only a relatively minor contributor to what would otherwise be quite catastrophic natural flow conditions in receiving waters arising from such a catastrophic and non-credible storm. The area of the TSF comprises only 6% of the Napadogan Brook watershed area, and 0.4% of the Nashwaak River watershed area. It must be recognized that the Inflow Design Storm (IDF) would result in a 60 cm rise in the TSF pond level at the final stage based on current design. By way of comparison, the large storm of December 2010 (equivalent to about a 1-in-100 year return period) would have resulted only in a 15 cm rise in the pond level. The current design has, in addition to the capacity to retain the IDF, a two metre freeboard; overtopping the embankments would require a storm that generated more than four times the IDF. Such an IDF event is not only implausible, but would also in itself be catastrophic for the Napadogan and Nashwaak watersheds, perhaps even the Saint John River watershed, thus greatly reducing any environmental effects attributable to the loss of containment of the TSF.

In the event of an earthquake exceeding the MDE for the TSF, the resultant downstream flood due to a release from the TSF would be attributable to the unplanned event, except in the extraordinarily unlikely event that it coincided with a storm exceeding the IDF. A flood from this circumstance may represent the worst case scenario from an environmental effects perspective, as it would be under circumstances where dilution of contaminated water would be less than under the catastrophic flood scenario, with water quality environmental effects likely extending to Napadogan Brook, and possibly into the Nashwaak River.

It is possible that the fine particulate load associated with the liquid phase of the release (*i.e.*, the formerly ponded water and the fine-grained tailings solids particles that are suspended within the water through erosion as the water is released to the environment) could be considerable, and the settling of this fine material could result in smothering of bottom habitats, both aquatic and terrestrial.

If such an extremely unlikely loss of containment did occur, the environmental effects would undoubtedly be substantial and, for at least for some VECs, could be significant, particularly the Aquatic Environment. Qualitatively, the environmental effects could include:

- Direct mortality of fish and aquatic plants and animals;
- Smothering of downstream aquatic habitat with fine tailings solids in Napadogan Brook and perhaps further downstream;
- Degradation of water quality in Napadogan Brook and perhaps further downstream;
- Loss of fish productivity where habitat is smothered or water quality becomes not conducive to fish health;
- Health environmental effects to wildlife exposed to degraded water quality;
- Prohibitions on fishing, hunting, using affected surface waters for drinking, recreational use of affected waters, to protect human health;
- Loss of access to land and resources for traditional use purposes by Aboriginal people for some distance down Napadogan Brook and perhaps further downstream;
- Loss of access to land for various land use activities;
- Loss of transportation infrastructure and interruption of traffic and access;
- A decline of water quality that may affect downstream users of Water Resources; and
- Loss of wetland, vegetation, and other terrestrial habitat due to the flooding, erosion and/or deposition of tailings and other sediment.

It is worth noting that, even without a TSF embankment failure, the naturally occurring exceptionally severe storm or violent shaking from an earthquake assumed above would have environmentally negative effects on the natural and human environment. For example, such a severe storm and flooding would cause high levels of erosion and hence sediment transport into all of the regional



watercourses, with potentially similar environmental effects as listed above (*i.e.*, smothering of downstream aquatic and terrestrial habitat with gravel/sand/silt/clay) as for a release of tailings. And such a severe earthquake would be devastating for buildings, infrastructure and perhaps human life in New Brunswick.

In conclusion, the environmental effects of such a major failure of containment in the Sisson Project TSF embankment would be substantive and significant, especially for Aquatic Environment, but they are extremely unlikely to occur, with an annual probability of occurrence of 1-in-1 million to 1-in-10 million.

#### **1.4 WHAT MITIGATION MEASURES WILL BE EMPLOYED TO AVOID A TSF EMBANKMENT FAILURE?**

As described above and in the EIA Report, the primary mitigation strategies associated with the prevention of a TSF slope failure are the rigorous design and operating procedures incorporated into the proposed TSF design. Furthermore, embankment construction will include technical oversight and implementation of quality assurance and quality control programs by geotechnical engineers.

Detailed operations manuals prepared during detailed design will include operating procedures to ensure that the TSF is operated in a manner consistent with the design principles. Application of these procedures, along with annual embankment safety inspections by a qualified engineer, and embankment safety reviews of the facility every five years by a qualified professional geotechnical engineer, will mitigate the risk of conditions occurring that could lead to a TSF slope failure.

Embankment safety inspections by a qualified geotechnical engineer will be required following closure in accordance with the proposed Decommissioning, Reclamation and Closure Plan and CDA guidelines. These safety inspections will provide the opportunity to identify early warning signs in the unlikely event that stability issues were to arise following Closure. Substantial design freeboard will also be maintained between the maximum ponded water level (controlled by the spillway to the open pit) and the TSF embankment crest elevation at Closure.

In the exceptionally unlikely event that such a scenario was experienced, Northcliff would be able to undertake measures to assess the consequences of the failure, and develop a plan for restitution to the extent possible that could include a wide array of restorative, rehabilitative and compensatory measures to mitigate the environmental effects. Such actions would be undertaken in close consultation with regulatory authorities and affected parties.

#### **1.5 WHAT EMERGENCY RESPONSE PROCEDURES WILL BE IN PLACE IN CASE THERE IS A TSF EMBANKMENT FAILURE?**

Emergency response procedures will be developed for and contained in the Emergency Preparedness and Response Plan (Section 3.4 of Appendix D in the EIA Report). Briefly, in the highly unlikely event of a TSF embankment failure during Operation, tailings deposition to that area would cease, and site personnel would be dispatched to the location to conduct a safety and preliminary damage assessment. Government agency personnel and community representatives would be contacted promptly. Northcliff will have its own trained personnel on-site to undertake immediate containment activities using the heavy equipment needed for everyday mining operations. If during detailed Project

planning it is considered to be warranted, Northcliff could retain the services of a third-party environmental response and remediation contractor who would be available to assist Northcliff in responding promptly to a TSF failure, if required. In the short-term, steps would be taken to restore safe working conditions in the area. Personnel and equipment would be dispatched to contain any potential threats to the public, the environment, and to any damaged areas as appropriate. The medium and longer term plan for the embankment failure area and any damaged areas off-site would be developed in concert with government agencies and other stakeholders, as appropriate.

If a slope failure was to occur during the Closure or Post-Closure phases, a similar course of action would be taken. That is, once the failure was identified, the short-term goal would be to contain the loss to mitigate any ongoing threats to public safety and the environmental or other damage to adjacent off-site areas. The medium to long-term goal would be developed in concert with government agencies and other stakeholders, as appropriate.