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Kate Parsons
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Dear Kate,

Re: Afton TSF – CDA Classification Review

INTRODUCTION

An assessment has been carried out to review and define appropriate dam classifications for the Afton Tailings Storage Facility (TSF) East and West Dams at the request of KGHM Ajax Mining Inc. (KGHM). An overview map showing the Afton TSF and the surrounding area is shown on Figure 1.



Figure 1 Afton TSF General Arrangement

The Afton TSF has been under care and maintenance since 1997 when operations at the Teck Resources Ltd. (Teck) Afton Mine were suspended. The last Dam Safety Review (DSR) for the facility was completed by Knight Piésold Ltd. (KP) in 2013 (KP 2014b). A Dam Safety Inspection was also completed by KP in 2014 (KP 2014c). The 2013 DSR included a review of the dam classifications for the East and West Dams and recommended

inundation maps be developed to show the potential impacted downstream areas in the event of a dam breach to confirm the dam classifications.

The Chief Mine Inspector's Orders for tailings dams in BC, dated August 18, 2014, also required dam breach inundation analyses be completed for all dams with a rating of 'High', 'Very High', or 'Extreme', per the Canadian Dam Association (CDA) "Dam Safety Guidelines" (CDA 2013) rating system. KP recently completed these studies (KP 2014a), and it is upon this new information that this dam classification review is based.

METHODOLOGY

The selection of appropriate design earthquake and flood events for dams in Canada is based on the dam hazard classification and recommended design values set out by the CDA. The hazard classification for a dam is carried out by considering the potential incremental consequences of a dam failure on human life, infrastructure, and the environment, defined as *"the total damage from an event with dam failure minus the damage that would have resulted from the same event had the dam not failed."*

The CDA dam classification criteria, are shown in Table 1 (CDA 2014)

Table 1 CDA Dam Classification

Dam Class	Population at Risk ¹	Incremental Losses		
		Loss of Life ²	Environmental and Cultural Values	Infrastructure and Economics
Low	None	0	Minimal short-term loss. No long-term loss.	Low economic losses; area contains limited infrastructure or services.
Significant	Temporary only	Unspecified	No significant loss or deterioration of fish or wildlife habitat. Loss of marginal habitat only. Restoration or compensation in kind highly possible.	Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes.
High	Permanent	10 or fewer	Significant loss or deterioration of <i>important</i> fish or wildlife habitat. Restoration or compensation in kind highly possible.	High economic losses affecting infrastructure, public transportation, and commercial facilities.
Very high	Permanent	100 or fewer	Significant loss or deterioration of <i>critical</i> fish or wildlife habitat. Restoration or compensation in kind possible but impractical.	Very high economic losses affecting important infrastructure or services (e.g., highway, industrial facility, storage facilities for dangerous substances).
Extreme	Permanent	More than 100	Major loss of <i>critical</i> fish or wildlife habitat. Restoration or compensation in kind impossible.	Extreme losses affecting critical infrastructure or services (e.g., hospital, major industrial complex, major storage facilities for dangerous substances).

NOTES:

1. Definitions for population at risk:

None - There is no identifiable population at risk, so there is no possibility of loss of life other through unforeseeable misadventure.
 Temporary - people are only temporarily in the dam-breach inundation zone (e.g., seasonal cottage use, passing through on transportation routes, participating in recreational activities). Permanent - the population at risk is ordinarily located in the dam-breach inundation zone (e.g., as permanent residents); three consequence classes (high, very high, extreme); three consequence classes (high, very high, extreme) are proposed to allow for more detailed estimates of potential loss of life (to assist in decision-making if the appropriate analysis is carried out).

2. Implications for loss of life:

Unspecified - the appropriate level of safety required at a dam where people are temporarily at risk depends on the number of people, the exposure time, the nature of their activity, and other conditions. A higher class could be appropriate, depending on the requirements.

However, the design flood requirement, for example, might not be higher if the temporary population is not likely to be present during the flood.

CDA DESIGN FLOOD AND EARTHQUAKE LEVELS

The CDA published a technical bulletin entitled “Application of Dam Safety Guidelines to Mining Dams” in October 2014 (CDA 2014). This bulletin provides an update to the recommended values for design flood and earthquake events, corresponding to the Dam Classifications in Table 1, for tailings dams in the active and passive closure phases. Table 2 provides the recommended design values for the active closure phase, and Table 3 provides the recommended design values for the passive closure phase.

Table 2 Suggested Design Flood and Earthquake Levels – Active Closure Phase (CDA 2014)

Dam Class	Annual Exceedance Probability	
	Inflow Design Flood	Earthquake Design Ground Motion
Low	1/100	1/100
Significant	Between 1/100 and 1/1,000	Between 1/100 and 1/1,000
High	1/3 between 1/1,000 and PMF	1/2,475
Very High	2/3 between 1/1,000 and PMF	1/2 between 1/2,475 and 1/10,000 or MCE
Extreme	PMF ⁵	1/10,000 or MCE

Table 3 Suggested Design Flood and Earthquake Levels – Passive Closure Phase (CDA 2014)

Dam Class	Annual Exceedance Probability	
	Inflow Design Flood	Earthquake Design Ground Motion
Low	1/1,000	1/1,000
Significant	1/3 between 1/1,000 and PMF	1/2,475
High	2/3 between 1/1,000 and PMF	1/2 between 1/2,475 and 1/10,000 or MCE
Very High	PMF	1/10,000 or MCE
Extreme	PMF	1/10,000 or MCE

NOTES:

Acronyms: Annual Exceedance Probability (AEP); Earthquake Design Ground Motion (EDGM); Flow Design Flood (IDF); Probable Maximum Flood (PMF), Maximum Credible Earthquake (MCE).

- As defined in table 2.1: dam classification.
- Extrapolation of flood statistics beyond 1/1000 year flood (10^{-3} AEP) is discouraged.
- AEP levels for EDGM are to be used for mean rather than median estimates for the hazard.
- Selected on the basis of incremental flood analysis, exposure, and consequences of failure.
- PMF has no associated AEP. The flood defined as "1/3 between 1/1000 and PMF" or "2/3 between 1/1000 year and PMF" has no defined AEP.
- The EDGM value must be justified to demonstrate conformance to societal norms of acceptable risk. Justification can be provided with the help of failure modes analysis focused on the particular modes that can contribute to failure initiated by a seismic event. If the justification cannot be provided, the EDGM should be 1/10,000.

WEST DAM EVALUATION

2013 DSR Classification: 'Extreme'

Current Recommendation: 'Extreme'

The West Dam is a composite earthfill/rockfill dam, approximately 1,300 m long and 75 m in height at its highest point. The downstream rockfill zone of the West Dam was constructed to the full width associated with the ultimate tailings dam design elevation (732 m) which was not constructed, resulting in a wide, overbuilt dam. The crest width is in the order of 100 m at an elevation of 706 m.

Inundation studies considered two possible failure locations for the West Dam: one at the northwest section, above the Northwest Seepage Pond slightly south of the dam's highest location, and another at the southwest section, above the Southwest Seepage Pond at the highest location in this section (KP 2014a). The two failure conditions considered in these analyses were a "rainy day" scenario concurrent with downstream flood conditions, and a "Sunny Day" failure occurring without flood conditions, as per the CDA guidelines (CDA 2013). For both the "Sunny Day" and "Rainy Day" failure scenarios the downstream impacts associated with the failure of the northwest dam were predicted to govern.

The inundation analyses state that the incremental consequences of a West Dam failure are greater for the "Sunny Day" failure than for the "Rainy Day" failure scenario. This CDA classification review considers the "Sunny Day" failure scenario at the northwest section of the West Dam since it is the scenario with the largest incremental impacts.



Figure 2 West Dam, Northwest "Sunny Day" Failure – Inundation Map at Trailer Park

Figure 2 shows the inundation extents in the area of the trailer park downstream of the West Dam in the event of the "Sunny Day" northwest dam failure. It is estimated there is a permanent population in the order of 100 residents based on the number of homes and structures in this area. This is consistent with the estimates in both the 2009 DSR completed by BGC Engineering (BGC 2011) and the 2013 DSR completed by KP (KP 2014b). This dictates the CDA consequence rating of 'Extreme', without further consideration of the other classification categories.

In addition to the impacts to the trailer park, the dam failure could cause inundation of an approximately 1 km long stretch of Highway 1 (with associated risks to vehicle passengers) as well as numerous other homes/structures and farm property along the 11.3 km flow path to Kamloops Lake. The damages to properties and infrastructure may be environmentally and economically significant.

The influx of tailings solids (sediment) and water to Cherry Creek and Kamloops Lake may have adverse environmental impacts, particularly on fisheries and other aquatic life. The geochemical characteristics of the tailings and water in the Afton TSF as well as water quality modelling for the impacted downstream watershed resulting from a dam breach have not been completed.

The review of the West Dam classification indicates the current classification of 'Extreme' is appropriate.

EAST DAM EVALUATION

2013 DSR Classification: 'High'

Current Recommendation: 'Very High' during New Afton Mine operations; 'Significant' post New Afton Mine closure

The East Dam is a composite earthfill/rockfill structure, approximately 860 m long and 65 m in height at its highest point. It is buttressed by a mine rock dump on the downstream (east) side and the Spillway is located at its north end. The Spillway traverses a portion of the New Gold Inc. (New Gold) New Afton Mine property on its course towards the historic Afton Open Pit.

Inundation studies considered one possible failure location for the East Dam, at the Spillway near the north end of the dam (KP 2014a). The rest of the dam is buttressed by a large mine rock dump where no failure mode is credible. In both "Sunny Day" and "Rainy Day" failure scenarios that were modelled, all water and tailings solids released from the Afton TSF were contained in the Afton Open Pit, as shown on Figure 3. This assumes there is sufficient capacity in the Afton Pit to contain the breached volume when the failure occurs.



Figure 3 East Dam Failure – Inundation Map

The New Afton Mine is a block cave mining operation that extends at depth from the historic Afton Open Pit to the southwest. Production at the New Afton Mine began in 2012, with a projected mine life of 12 years (www.newgold.com). Initially the pit was dewatered and the underground mine was accessed through a decline ramp at the bottom of the pit. A new access decline was established outside of the Afton Open Pit in 2014, and the original access was double bulkheaded. The plug is not considered to be water tight and is a potential flow path to the underground mine. An additional potential flow path to the underground mine may occur should the surface expression of the block cave mining activities break through into the pit.

With an East Dam failure being fully contained in the Afton Open Pit, environmental impacts are expected to be low. No natural streams or waterbodies are anticipated to be affected by surface water discharge, although some groundwater impacts may occur. There is also minimal risk to surface infrastructure, with no expected damage to Highway 1, New Gold’s plant and (surface) equipment, or any other downstream infrastructure.

The main concern related to failure of the East Dam is the risk to underground mine workers during the operation of the New Afton Mine. Water and/or tailings inflow to the Afton Open Pit may subsequently enter the underground mine workings, posing potential risks to the underground mine infrastructure and mine workers. It is reported that roughly 80 workers are underground at any given time. This is assumed to be true for a permanent basis during the New Afton Mine operating life.

With reference to Table 1, a population at risk of between 10 and 100 dictates a dam safety rating of ‘Very High’, and as a conservative measure it is recommended this rating be assigned to the East Dam during the New Afton Mine operating life. In reality, the “Sunny Day” failure at the East Dam is highly improbable, and the “Rainy Day” failure would take a number of hours of prolonged and extreme rainfall to occur, during which time the New Afton Mine could be evacuated.

Risks to human life in the event of a dam failure are reduced after closure of the New Afton Mine. This, coupled with the minimal environmental and economic risks noted above, may warrant a reduction in the CDA classification of the East Dam to ‘Significant’. This should be re-evaluated closer to the end of the New Afton Mine operating life to confirm if the downstream conditions have changed.

SUMMARY OF RECOMMENDED DESIGN VALUES

An assessment has been carried out to review the dam classifications for the Afton TSF East and West Dams in accordance with the CDA “Dam Safety Guidelines”. The results are summarized in Table 4.

Table 4 Afton TSF East and West Dams – CDA Classification Summary


	Current CDA Classification	Recommended CDA Classification
West Dam	Extreme	Extreme
East Dam during New Afton Mine Operations	High	Very High
East Dam post New Afton Mine Closure	n/a	Significant

The recommended design flood and earthquake values for the East and West Dams are provided in Tables 2 and 3. It is important to note that the ‘Extreme’ consequence rating for the West Dam dictates the design flood for the Afton TSF which is the Probable Maximum Flood.

We trust this letter adequately summarizes the CDA dam classification review that has been completed. Please contact the undersigned should you have any questions or comments.

Yours truly,
KNIGHT PIESOLD LTD.

Signed:

for 


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Reviewed:



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Approved:



Ken Brouwer, P.Eng.
President

/sr

References

- BGC (BGC 2011) Dam Safety Review - East and West Dams. Afton Mine, Kamloops. B.C. Final
- Canadian Dam Association (CDA 2013) - Canadian Dam Association, Dam Safety Guidelines 2007 (revised 2013)
- Canadian Dam Association (CDA 2014) - Canadian Dam Association, "Technical Bulletin: Application of Dam Safety Guidelines to Mining Dams
- Knight Piésold Ltd (2014a) - Afton Tailings Storage Facility, Dam Breach Inundation Study, VA101-246/41-1
- Knight Piésold Ltd (2014b) – Dam Safety Review, Afton Tailings Storage Facility, VA101-246/16-2
- Knight Piésold Ltd (2014c) - Report on 2014 Annual Inspection, Afton Tailings Storage Facility, VA101-246/41-1