Independent Expert Engineering Investigation and Review Panel

Report on Mount Polley Tailings Storage Facility Breach

Appendix G: Water Balance

January 30, 2015

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APPENDIX G: WATER BALANCE

1.0 INTRODUCTION

The mining activities and water management conditions for the Mount Polley Mine are summarized in Table 1.[1] A clear distinction can be made between the water balance actions and outcomes during the following three stages:

- Phase 1
- Care and Maintenance
- Phase 2

This terminology for the three distinct operational mine life Phases will be adopted in this Appendix.

TABLE G1: MOUNT POLLEY MINE LIFE

YEAR	ACTIVITY	MINE PITS	WATER MANAGEMENT OPERATING CONDITIONS
1995	Mill site construction		
1996	Logging and site stripping		
1997 - 2001	Phase 1 Active Mining	Cariboo and Bell	Deficit
2001 - 2005	Care and Maintenance		Neutral
2005 - 2014	Phase 2 Active Mining	Wight, Springer, Southeast Zone, Pond Zone	Surplus

2.0 PHASE 1 ACTIVE MINING

The initial water balance for the Mount Polley tailing storage facility (TSF) was developed during project development and design. This water balance was implemented during Phase 1 Active Mining. Only two pits, Cariboo and Bell, were mined during Phase 1.

In the 1995 Tailings Storage Facility Design Report, Knight Piésold (KP) states the following:

The tailings impoundment will be utilized as a water reservoir both prior to start-up and during operations, thus eliminating the need for a dam on Polley Lake. The water management plan has the following objectives:

- *To minimize the volume of fresh water extracted from Polley Lake.*
- *To limit the period of water removal from the Polley Lake/Hazeltine Creek system to high flow periods.*
- *To regulate additional surface water runoff into the tailings pond.*
- *To prevent the accumulation of excess water within the tailings impoundment so that the impoundment and open pit can be operated as a closed system with no surface water release.*
- *To supply make-up water for the milling process from within the project catchment area.*
- *To minimize the requirement for regulated discharges of surface runoff from the waste dumps.*[2]

[1] MP000212
[2] MP00001

A tailings water balance spreadsheet was developed that included all runoff entering the TSF from the upstream catchments, including mill, mine and waste dump areas. The water balance was run probabilistically by KP using @RISK, an approach that was not subsequently pursued by Mount Polley Mining Corporation (MPMC).

Design values used for the water balance were summarized[3] as follows:

- Average annual rainfall (based on three nearby weather stations) 451 mm.
- Average annual snowfall (water equivalent) 304 mm.
- Average annual lake evaporation (using the Thornthwaite model) 423 mm.
- Daily ore throughput 13,425 tpd.
- Tailings percent solids, 35%.

The first phase of the TSF was constructed to collect and store 1.5 million m^3 water for mill start up. The initial water balance was carried out for all 14 years of the initial mine life.

A tailings area filling schedule and staged construction sequence was developed for the TSF[4]. This schedule allowed for additional storage on top of the (assumed) flat tailings area for:

- 2 million m^3 of process (reclaim) water.
- Plus an emergency storage volume that could accommodate up to the 24-hour probable maximum precipitation (PMP) event with full inflow from upstream catchments.

After start of operations the water balance model was transferred to MPMC for operational implementation. MPMC assumed ownership of the water balance model in their submittal (1998 Water Management Plan) to the Ministry of Energy and Mines (MEM) as fulfillment of requirements under Permit M-200.[5] Changes were made to reflect the site conditions during operations, including the decision to withdraw 1 million m^3 of water annually from Polley Lake during the freshet for the first two years of operation. One activity that the mine incorporated in the water balance was to *"develop and maintain a detailed data base to allow water balances for site to be as accurate as possible, thereby becoming useful tools for predicting annual make-up water requirements, for scheduling associated construction activities and for scheduling releases of clean surface runoff water as appropriate"* (underlining added for emphasis). It was also recognized that the tailings tonnage and tailings solid content are mining and milling variables that would be updated monthly as the data became available.

KP provided input and review of the water balance on an annual basis, or at intervals required by the Mine. The tailings filling schedule and staged construction were updated monthly.[6] Tailings density estimates were also improved as the surface of the deposited tailings surface was surveyed above and below water.[7] Site-specific production, climate and disturbance area data were used to predict the fresh water needs from Polley Lake; the amount of water available for reclaim; and water stored on the TSF. This was effectively used as a calibration of the water balance.[8]

[3] MP00002
[4] MP00002
[5] MP00010
[6] MP00011
[7] MP00012
[8] MP00071

It was a significant decision to relate the stage construction timing and the height of the raise to the water balance, as indicated above and further emphasized by KP in the following statement in 1998: "*The Tailings Storage Facility will be closely monitored and the next embankment raise will be scheduled so that adequate freeboard is always maintained. Adjustments to the embankment construction schedule will be made as required.*"[9] It appears that beaching was problematic at the Main Embankment at this time (refer to section 5.4 of the main report).

Annual Water Management Plan reports were referenced, but not included, in the Annual Inspection Reports of the Engineers of Record (EOR). These Annual Water Management Plans were included in the Annual Environmental and Reclamation Reports submitted by MPMC to the appropriate agencies (in recent years the Ministry of Environment and the Ministry of Energy and Mines).

3.0 CARE AND MAINTENANCE

MPMC suspended operations from October 13, 2001 to February 2005 (refer to section 5.4 of the main report). During this period the mine was on standby and maintenance, and only a small number of employees were retained on site.[10] In the last annual inspection report before the shutdown KP concluded that: *"the Tailings Storage Facility has generally been operated in accordance with the objectives of the water balance. This includes maintaining a maximum of 2 to 2.5 million cubic meters of water in the impoundment as a supply for reclaim to the mill with certain freeboard allowances above this."*[11]

In the 2002 Annual Report KP indicated that[12] "water will need to be removed prior to the freshet next year. The projected increase in pond elevation will rise above the maximum allowable level." In June 2003 MEM subsequently requested details of the plan to remove water.[13]

KP stated the following in their 2004 Annual Inspection Report:[14] "The objectives for the water balance during the care and maintenance period have been to minimize the on-going accumulation of water within the TSF". In Appendix D of this report in a letter to Imperial Metals they state that: *"The water balance information … indicates that the pond elevation will increase above the maximum allowable level during the spring freshet of 2004. Therefore MPMC will be required to discharge water from the tailings prior to this period."*

These documents show that water balance and management reviews took place during the care and maintenance period, although few pool elevation measurements were taken. There were ongoing concerns about the TSF freeboard and KP recommended careful management of this aspect. However, further mine development also took place, which increased the mine footprint and led to higher water volumes in the TSF. This set the tone for the water balance and pond level management activities that followed the restart of operations.

[9] MP00011
[10] Panel Interview, December 12, 2014.
[11] MP00071
[12] MP00073
[13] MP00130
[14] MP00074

In 2005 KP issued a report entitled: "*Design of the Tailings Storage Facility to Ultimate Elevation*" as part of the planning for ongoing operations of the mine.[15] An updated water management plan was developed as part of the design for a seven year additional mine life. The objectives of the water balance were consistent with those stated in 1995:

- *Effectively manage the water to minimize the need for regulated discharges to surface water and prevent the need for water removal from Polley Lake.*
- *Capture and manage all water that has been affected by mine components.*
- *Divert runoff from undisturbed areas away from the mine site and tailings facility (TSF).*
- *Store some excess TSF water to be used to accelerate pit filling at closure.*
- *Drain the TSF at closure by routing water into the open pits.*

As a result of the new mine plan it was found that the water balance was moving from a deficit to a surplus condition, and that water would have to be stored on-site to meet the effluent permits in place. *"It is anticipated that the majority of the water will require storage in the TSF during operations, unless the effluent permit can be amended to discharge tailings supernatant."*[16]

The details of the updated water balance clearly demonstrated the dynamic nature of the mine plan that included the development of additional mine pits and increased waste rock dump footprints. One of the outcomes was the prediction of a requirement to store 7 million m^3 of water in the TSF by year seven after restart of operations. *"The increased pond level will result in a larger pond area with more of the beaches inundated by water. The beaches have an average slope of 1% so water will extend across the beach approximately 350 m horizontally as the pond rises 3.5 m. Sufficient beaches will be maintained upstream of the embankments to prevent stability concerns"*.[17]

Drawing G1 shows the TSF filling schedule and embankment stages from the start of operations to the end of the care and maintenance period. Only a few pond measurements were taken during this period and the pond level was quite high towards the end of 2004.

[15] MP00026
[16] MP00026
[17] MP00026

4.0 PHASE 2 ACTIVE MINING

Phase 2 active mining resumed on March 2, 2005 [18] and the footprint expanded to four more pits, Wight, Springer, Southeast Zone and Pond Zone. Drawing G1 shows the Phase 2 operations, TSF crest elevation, and pond as measured until the time of the breach.

As summarized by MPMC, "In 2004, a water balance was developed for the Mount Polley Mine site to aid in water planning and to predict water surplus or deficit volumes after the resumption of the operations in 2005. This water balance updates an earlier water balance by adding new development areas (including Springer Pit, Wight Pit and the Northeast Rock Disposal Site), updating precipitation estimates, and modifying other aspect of the water balance to match the new mine plan". [19]

This water balance model was updated monthly by MPMC with periodic reviews by KP. [20, 21]

Prior to start-up a geotechnical inspection was carried out by MEM on February 3, 2005. [22] The report states: *"There is currently no discharge from the tailings impoundment. Projected water balance indicates there will be a surplus water volume and a discharge permit will be required from the Ministry of Water, Land and Air Protection (WLAP), Plans for discharge from the TSF shall be submitted to MEM for review."*

MPMC responded as follows: [23] *"Since your inspection discussions and meetings were held with WLAP, they have since authorized the discharge of the Main embankment seepage collection pond for the operational phase. Also an application under section 8 and 9 of the Metal Mining Effluent Regulation (MMER) was made. Site Specific Water Quality Objectives are being developed for the Mount Polley Mine site. Plans for discharge will be submitted to MEM when they are developed."* This 2005 statement marks the first time that MPMC acknowledges the need for discharge from the TSF.

KP's 2005 Annual Inspection [24] indicated that the water balance was regularly updated based on periodic reviews. KP also noted that: *"The TSF is currently operating with a water budget surplus, as total inflows from precipitation and surface runoff exceed losses from evaporation and seepage removal. The Mount Polley Mine has undergone significant development in the last couple of years and it is very important that the Water Management Plan and site water balance be reviewed and updated as required to ensure that they stay current with the Mine Development Plan and that there is sufficient capacity in the TSF to store the increased site runoff associated with the expansion of the mine footprint. The water balance was reviewed by Knight Piésold in February 2006 and MPMC appears to be up to date with the Mine Development Plan."*

Based on the 2007 Annual TSF Inspection, KP again stated that: *"The TSF is currently operating with a water surplus…. MPMC is currently exploring ways to discharge water from the site to reduce ongoing storage requirements in the TSF, as all of the site surplus water is currently being stored in the TSF."* KP also recommended that 20 m wide beaches be maintained and found that this was not the case along approximately 200 m where water stood against the Main Embankment. [25]

[18] MP00172
[19] MPMC 2004 Annual Environmental and Reclamation Report
[20] MP00077
[21] MP10034
[22] MP00172
[23] MP00173
[24] MP00076
[25] MP00077

The 2009 Annual TSF Inspection [26] reviewed the water balance evaluations by MPMC and found a similar outcome as in the previous years: *"The mine site is currently operating with a water balance surplus…Site surplus is currently being stored in the TSF and the Cariboo Pit. MPMC is currently exploring ways to discharge water from the site to reduce the increasing site storage requirements in the TSF and Cariboo Pit."*

According to the 2010 Annual Inspection report KP did not review the site water balance that year. [27] The site was operating under a water surplus at the time and water was stored in the TSF, as well as the Cariboo and North East Zone pits.

In 2011, after the change of EOR, AMEC also reported that they did not review the water balance. Information in their Annual Inspection report was supplied by MPMC. The site was still operating under a surplus. The design engineer reviewed the dam filling schedule and used that to plan the embankment raises. The 2011 Annual Review report recommended that a comprehensive review and update of the site water balance be undertaken. [28]

BGC performed the 2012 Annual Review and also did not review the MPMC water balance. [29]

In its 2013 Annual Review, AMEC made the same comments as in 2011 about the water balance not being reviewed by the design engineer as well as the surplus water conditions. The 2014 embankment raise was planned to crest El. 967.5 m and the target completion date was the end of June 2014. [30]

At the end of May 2013 the TSF was storing approximately 7.6 million m^3 of water. [31] From August 2012 to August 2013 the water volume in the TSF, as estimated from bathymetric surveys, increased by about 1.4 million m^3. [32]

BGC noted in early June 2014 that: [33] *"As of the end of May 2014, following what is understood to have been an abnormally high snowpack runoff and significant multi-day rainfall event, the pond volume was estimated to be between 8 and 9 million m^3. This is significantly more water than is required to maintain a viable process water reclaim pond – in 2010, for example, the estimated volume of water in the TSF was only about 900,000 m^3".*

In the 2014 review of the water balance model used during the Phase 2 period since 2005 BGC noted: [34] *"The Excel-based monthly water balance model developed by MPMC considers average, dry and wet year scenarios"*. This review found a few errors and it was recommended that the mine should attempt to calibrate the model using actual past performance and measured input and output.

Figure 5.6.1 in the main report illustrates the accelerating accumulation of water over time. At the time of failure on August 4, 2014 MPMC estimated that the pond contained 10,192,931m^3.

[26] MP10034
[27] MP00037
[28] MP00041
[29] BGC00001
[30] MP00044
[31] MPMC00105
[32] MPMC00108
[33] MPMC00111
[34] MPMC00110

5.0 WATER TREATMENT

In 2009 MPMC prepared a report entitled: *Mount Polley Mine Technical Assessment Report for a Proposed Discharge of Mine Effluent*. In this report the TSF water balance is described as follows: *"At the time of re-opening in 2005, the Mount Polley Mine had a substantial accumulation of water in the TSF. Despite the careful management of water at the Mount Polley Mine through the application of best management practices (e.g., water recycling, storage in mined-out pits, use in dust suppression), the current and future Mount Polley water balance for the mine indicates surplus water of roughly 1.4 million cubic metres per year. Accordingly, the Mount Polley Mine has a need to eliminate excess water to maintain optimal geotechnical performance of the TSF."* [35]

The following strategy is assessed in this report: *"In seeking the best option, the Mount Polley Mine is assessing an alternate strategy for water discharge which includes plans for passive treatment and subsequent discharge to Hazeltine Creek to the east of the TSF."*

A permit amendment was granted on November 7, 2012 that allowed discharge of up to 1.4 million m^3 per year of filtered water to Hazeltine Creek. The maximum discharge was 35% of flow in the Creek and the window was April to October. In April of 2014 it was estimated that only 170,500 m^3 total discharge was possible due to constraints of "dam filtered water": [36] this appears to be a restriction related to solids content.

SRK Consulting (Canada) Inc. commented in 2013: *"Runoff from progressively larger areas has been diverted to the TMF since it re-opened in 2005, and will increase over next few years as runoff from the northwest portion of the site is diverted to the TMF. The annual site-wide free water volume generated on site is expected to increase to 1.7 million m^3 of water under average hydrologic conditions, or 3.2 million m^3 under a wet hydrologic year with similar precipitation as was measured in 2008 (621 mm), because of expanded footprint."* [37]

Permitting of a water treatment plant was pursued in late 2013 and the Terms of Reference for Discharge was issued by the Ministry of Environment on March 26, 2014. Completion of treatment plant construction was expected later in 2014. This plant would allow total annual discharge of 3 million m^3.

[35] MOE00001
[36] MP00212
[37] MPMC00109

6.0 MAY 2014 INCIDENT

On Saturday May 24, 2014 a potential "dam breach" event occurred at the TSF following a large rainfall (approximately 24 mm in 24 hours) and it was still raining on Tuesday May 27, 2014 at the time of the internal MEM report relating to the incident.[38] The dam freeboard was reported as 0.7 m or less. Although no overtopping was observed, further observations were being made. Actions included raising of the core at low spots, including Corner 3 where overtopping might have occurred. No additional surface water was directed to the TSF. The mine completed an "Advice of Geotechnical Incident".[39, 40]

Prior to this incident, in 2013 AMEC report that *"Zone S was completed to a minimum elevation of 967.0 m with Zone F (filter) and Zone T (transition) completed to a minimum elevation of 966.1 m."*[41]

Notes in report drawings indicated 2013 as-built crest elevation varies (see also Drawing F6). AMEC found the following in their review of site conditions following the incident:[42]

- On Monday May 26 the water level was at El. 966.3 m, which resulted in a freeboard of 0.7 m to the top of Zone S (at El. 967.0 m). This freeboard was lower than 0.9 m minimum outlined in the OMS Manual.
- Zone S was also found to have a few low spots at 966.3 m (Corner 3), 966.4 m (Corner 2), 965.5 m (Corner 5) and 966.2 m (at the pipe crossing on the Perimeter Embankment). This indicates that the water was at the crest in Corner 3 and over the crest at the pipe crossing.
- Wet spots and standing water were observed at Corner 3 and the pipe crossing but no major erosion or direct seepage.

All the low areas were addressed by Thursday May 29, when the pool water level increased to El. 966.45 m. The top of the Perimeter Embankment was increased to EL. 967.3 m.

The July 1, 2013 OMS Manual states:[43] *"the normal and maximum operating pond levels are as follows:*

- *Normal Operating Level – Water level at least 1.3m below the embankment crest;*
- *Maximum Operating Level – Water level is 0.9m below the embankment crest, which also means the loss of storage capacity for a 24-hour PMP event.*

Tailings deposition will cease if the pond level reaches maximum operating level and the removal of water from the pond will commence using the reclaim barge."

At this time, despite having less freeboard than the Maximum Operating Level specified in the OMS, tailings deposition continued. However, all water collection systems were diverted from the TSF and water was routed for storage in the Cariboo Pit.[44]

[38] MP00188
[39] MP00189
[40] MP00190
[41] MP00044
[42] MP00192
[43] AMEC00216
[44] MP00195

MPMC submitted weekly follow-up reports to MEM On June 6,[45] June 13,[46] June 20,[47] June 27,[48] and July 4.[49] During June the pond elevation remained at 966.4 m and on July 3 increased to 966.6 m. The embankment height was increased to El. 967.6 m by July 3, 2014.

MPMC provided a Water Management Plan as a follow-up to MEM on July 18, 2014. At that time the pool was at El. 966.6 m and the freeboard ranged from 1.3 m to 2.5 m on the TSF embankments.[50] The Normal Operating Level freeboard (1.3 m) was re-established at the TSF on July 4, 2014.

On July 14, 2014 MPMC proposed to pump out the Cariboo pit adding still more water to the TSF.[51] AMEC approved this plan two days later subject to MEM agreement to a reduction in freeboard to 1.1 m and subsequent modification of the OMS manual.[52]

On August 3, 2014, the day before the failure, the water level in the Mount Polley TSF was El. 966.83 m, an increase of 0.23 m since July 18.

Appendix G: Drawings

- **Drawing G1**: TSF Crest and Pond Elevations

[45] MP00195
[46] MP00196
[47] MP00198
[48] MP00200
[49] MP00202
[50] MP00204
[51] AMEC00330
[52] AMEC00334