

**EFFICIENCY OF TAILINGS CONSTRUCTION  
OPERATIONS**

**MT. POLLEY TAILINGS FACILITY**

Submitted To:

**MT. POLLEY MINING CORPORATION  
LIKELY, BRITISH COLUMBIA**

Submitted By:

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## **1.0 INTRODUCTION**

Mount Polley Mining Corporation (Mt. Polley) requested AMEC Earth & Environmental (AMEC) undertake a review of their tailings construction operations with the objective of providing recommendations to improve the efficiency of these operations. The work was commissioned by Mr. Ron Martel, Environmental Superintendent for Mt. Polley.

Mt. Polley's mine is located near Likely, central British Columbia. The mine produces a copper-gold concentrate from an alkalic porphyry ore obtained from three pits. The concentrate is produced with a grinding and flotation circuit. The tailings are sent by gravity to a valley-side impoundment formed by earthfill dams.

The review of Mt. Polley's tailings operations included a review of information provided by the mine and a two-day site visit. The site visit started with an initial meeting to discuss the key tailings planning issues encountered by Mt. Polley and a presentation by AMEC on principles and experiences in tailings operations. Most of the first day and the morning of the second day were spent in the field visiting the site, observing construction conditions and discussing the details of the operation with supervisory and operations personnel. The site supervisor for the off-shift was brought in by Mt. Polley thus there was opportunity for input from and discussion with both shift supervisors. A wrap-up meeting was held at the end of the site visit to present and discuss a summary of the conclusions and the main recommendations of the review exercise. A briefing document was prepared and handed out at the meeting; it is included in Appendix A. This report provides details substantiating the material presented in the briefing document.

## **2.0 DAM CONSTRUCTION REQUIREMENTS**

The tailings dam is a zoned compacted fill dam that is being built using a modified centreline method. It is formed by three components – the Main Dam, the Perimeter Embankment and the South Embankment that have their crests coalesce to a total length of approximately 4 km. The maximum dam height at the end of construction will be in the order of 53 m (El. 965 m). The dam crest along the three dams was approximately at El. 951 m at the time of the review.

The information on the dam available for review included Drawings 104, 115 and 215 (Stage 6) by Knight Piésold. References to drawings in this section are to those in Knight Piésold's Stage 6 design documentation. No reports were reviewed as part of this exercise though a summary document (Dam Safety Review, AMEC 2006) was used for historical background.

Drawing 215 shows Zone U as a "step-over" zone upstream of the clay till core, built in stages partly on previously built Zone U and partly on a tailings beach surface. The cross section shows a layer of rock (CBL, "coarse bearing layer") placed over the beach to bring it to El.951 m

(Stage 5) and to provide support for Zone U construction in the following stage. Stage 6 Zone U construction, the current cell construction, is shown as a 3 m lift (Stage 6a from El. 951 m to El.954 m). Dashed lines also indicate Stage 6b to El.958 m.

Stage 6a Zone U is shown in Drawing 215 as being 11 m wide at the base (El.951 m) and 10 m (minimum) wide at the top (El.954 m). Note 5 on the drawing indicates that these dimensions assume sand cell construction using tailings sand against the 1H:1V clay till core (Zone S) slope on the downstream side and a 1.3H:1V slope on the upstream (the beach side). It is our understanding that Zone U could cover a range of materials. The selected material was tailings sand placed by cell construction.

Drawing 104 "Material specifications" indicates that the material type for Zone U is "Select Fill" located on "the upstream toe" and states that the placement and compaction requirements are "to be determined based on material selection". Grain size curves under the heading of Zone U show gradation limits for "Zone S contact" and for "Zone CBL contact".

### 3.0 TAILINGS CHARACTERISTICS AND DEPOSITION SYSTEM

Mt. Polley operates three open pits and there is wide variability in the ore characteristics. Ore blending reduces this variability but the tailings characteristics are variable as the ore and the plant operation vary.

The monthly composite gradations of the tailings were provided by Mt. Polley (see Appendix B). The variability of the monthly gradations is shown on Figure 1. Based on these data, the gradation of the tailings solids has a mean grain size  $D_{50}$  of 50 microns with a percent passing the #200 sieve (75 microns) varying from 52 to 64% (average ~ 60%). The percentage of clay minerals (e.g. those exhibiting plasticity) in the tailings at this stage of mining is not known but past information notes non-plastic being the predominant nature of the tailings. There is approximately 40% fine sand (by weight) in the tailings. The mean specific weight of the solid particles is 2.7 g/cm<sup>3</sup>.

Variability of the solids content of the tailings slurry with time is shown on Figure 2. **Variability of solids content in a slurry has direct implications for how beach development proceeds and on how well potential cell construction may work for sand capture etc.** The level of variability indicated by the summary information provided on Figure 2 **is / is not** likely to be an issue for cell construction. **Ron will send data.**

The current mine throughput is **nominally 20,000 tons/day or an average of 833 tons/hour**. At an average slurry solids content of **35%**, that represents a total flow rate into the tailings facility of **0.516 m<sup>3</sup>/s or 8173 USgpm**. The tailings is discharged by gravity through a 24" HDPE DR11 pipeline from the plant (**El.1100 m**) to the tailings dam (currently approximately at El.951 m; final crest at El.965 m). The tailings line is in the order of **3 to 5km?** long from the plant site to the tailings facility. The total length of the dam, as noted above in Section 2, is in the order of 4 km.

#### **4.0 KEY ISSUES**

The site visit started with a meeting to discuss issues related to the tailings operations that had been identified by the site personnel. The meeting was attended by a cross section of Mt. Polley and Imperial Metals personnel. The key issues with the current tailings deposition plan brought up during the meeting included:

- Low efficiency / high costs for building cell for Zone U
- Too much wash out on cells (lack of sand capture)
- Too much time preparing cells (again, high costs)
- Costly to need to place CBL (rock on beach to support cell construction)
- Lack of beach

All of the above related to a lack of confidence in the current tailings operations methodology, as related to cell construction, to perform effectively or commensurately with the effort/costs invested. The ability to adjust the operating parameters to create more effective tailings deposition appears to be the overall goal based upon the key issues raised.

#### **5.0 FIELD OBSERVATIONS**

Cells are prepared for construction by building berms around the perimeter of each cell area (Photo 1) and by installing the tailings line such that in addition to the main tailings line going into the upstream end of the cell, there is also a by-pass line (Photo 1).

**Photo 1** – Preparation for cell construction

Cells are typically 10 m wide and approximately 150 m long. During the site visit, cell construction was occurring along the South Embankment. The cell observed (Photo 2) was likely a little narrower than 10 m. The flow observed during the first day of the site visit (Photo 2) was described as “typical”.

**Photo 2** - Cell construction (June 03, 2008)

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The flow during the morning of the second day (Photo 3) was probably of lower density. There seemed to be more water flowing on the cell surface and the operator reported that it was not “building well”.

**Photo 3 - Cell construction (June 04, 2008)**

The flow into the cell is the full tailings line (24” diameter), which flows partly full (Photo 4), however the flow velocity is high due to the significant head difference between the plant and the dam site.

**Photo 4 – Flow discharge into the cell**

The cell decant facility is provided by two 22” pipes (Photo 5) that discharge onto the beach. The pipes are installed across the berm by a backhoe. The pipes are installed approximately at the same elevation.

**Photo 5 – Cell decant system**

Due to the lower solids content of the decant flow, this flow can readily erode previously placed beach (e.g. Photo 5). When the decant pipe is at an elevation similar to the top of the beach, there isn't sufficient energy to erode the beach and the flow tends to channel next to the cell, which can, however, lead to erosion of the berm (Photo 6).

**Photo 6 – Berm erosion by decant channel flow**

The cell is constructed by running a dozer along the length of the cell while the tailings line discharges the slurry (Photo 7). The dozer operator lowers the blade and pushes the sand deposited on the cell towards the downstream end of the cell (Photo 8) to liberate slimes (Photo 9) and facilitate their flow towards the decant pipes (Photo 10).

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**Photo 7** – Cell construction - discharge and dozer

**Photo 8** – Cell construction – pushing sand downstream

**Photo 9** – Cell construction – slimes

**Photo 10** – Slimes flowing into the decant pipes

The dozer then moves back towards the discharge point with the blade lowered to push some of the sand back up the cell (Photo 11).

**Photo 11** – Cell construction – pushing sand back

When the sand fill reaches approximately the level of the top of the decant pipe, the tailings flow is diverted from the cell to the by-pass line. A backhoe re-installs the decant pipes approximately half the pipe diameter above the previous location (Photo 12). The dozer uses the material placed in the cell to raise the berms (Photos 13 and 14).

**Photo 12** – Re-installed decant pipes

**Photo 13** – Raising berms



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**Photo 14 – Raising berms**

The dozer smoothes the bottom of the cell (Photo 15) before deposition and cell construction re-starts.

**Photo 15 – Bottom of newly prepared cell partially smoothed**

The elevation of the pond on June 02, 2008 was 949.39 m. Beaches formed by single point discharge were relatively flat and had an average slope estimated to be between 0.5 and 1% (Photos 16 and 17).

**Photo 16 – Typical beach formed by single point discharge of tailings – upstream and downstream view**

**Photo 17 – Typical beach formed by single point discharge of tailings – overview and detail**

## **6.0 DISCUSSION OF TAILINGS OPERATIONS - ISSUES AND CONDITIONS**

### **6.1 INTRODUCTION**

Compacted cell construction is a technology that facilitates the use of tailings for construction of structural fills that can be integral part of dam cross sections. It combines the hydrodynamic effects of the slurry flow with the mechanical effects of equipment (most typically a dozer) to distribute and compact the tailings. If adequately applied, the mechanical effort (and cost) is

minimized by taking full advantage of the hydrodynamic effects. Moreover, a well controlled system allows some selectivity on the percentage and gradation of the solid material retained in the cell. In the most effective applications, cell construction saves operations time and money by having the tailings play the role of earth fill in the dam cross-section versus more costly alternative borrow sources.

Beach placement does not tend to achieve the same level of fill density that can be obtained in cell construction, however it can also be an important element of the dam construction as it provides lateral support for construction as well as a base for stepping over with the construction of structural fill in the case of upstream or modified centerline construction methods. This is particularly the case if the beach can remain fully subaerial throughout the depositional process. There could be some control on the beach angle obtained by changing the hydraulic design of the discharge system and by controlling the slurry properties.

## **6.2 FLOWS THROUGH THE CELL**

The current cell operation at Mt. Polley involves the full tailings line discharging into an approximately 10 m wide, 150 m long cell. This operating norm leads to excessive flow depths and excessive flow velocities that do not produce optimal conditions for cell construction. Ideal flow conditions are such that the flow depth is typically less than a couple of inches and often only a fraction of an inch. Flow velocities that lead to the formation of back waves are excessive. It is recommended that the cell width be, as a start, doubled (to 20 m) to distribute the flow, which would contribute towards reducing both the flow velocity and depth.

This change in cell width may not be sufficient but it is considered to be an adequate first step based on experience and on a rough tailings balance discussed with the site staff. The optimum width for cell construction needs to be determined as a function of flow conditions, dozer operation requirements (see Section 6.3) and the availability of tailings for cell and beach construction. A very wide cell may consume too much tailings in cell construction, which would increase costs and may not leave sufficient tailings for construction of beaches required to support future Zone U construction. A detailed mass balance, considering both cell and beach construction, needs to be part of the site tailings plan to help determine the adequate width of cell required in this case.

If the change above does not produce adequate flow conditions, a wider cell (if compatible with the tailings balance) or changes to the inflow into the cell are recommended. One possibility would be to direct only a portion of the total flow into the cell.

Cell length seems adequate for now, however it should also be re-assessed once the other more immediate changes discussed here are implemented.

### **6.3 DOZER OPERATION**

Dozer operation should be carried out perpendicular to the length of the cell. Ridges on the sand surface created by the dozer in this case (Photo 18) help spread the flow across the cell, reduce the flow velocity and promote deposition of the coarser fraction (while the fluid and the slimes flow downstream).

**Photo 18** – Dozer operation perpendicular to cell length

The dozer running back and forth perpendicular to the cell can gradually raise the berms while compacting the fill. This would reduce the downtime required to build the berms – an initial berm can be built when the cell is prepared for construction and then maintained and raised by the dozer during construction. The dozer should also maintain a gradual slope on the cell surface from the discharge (upstream end) to the decant (downstream end) to promote flow of the slimes to the decant, creating a better deposit. This method makes better use of the hydraulic conditions to spread the sand along the cell and avoids significant amounts of material being pushed down the cell by the dozer.

### **6.4 DECANT FACILITY**

The current decant system requires the cell construction operation to stop at every foot of construction to move the decant pipes up. It is reported that it typically takes 1.5 hrs to raise the decant pipes. This system can be optimized by the installation of a spillbox system that allows better control of the flow and an almost continuous cell operation for a few feet of placed fill (depending on the size and number of spillboxes). Some examples are shown on Photo 19. Other options have been discussed with site personnel.

**Photo 19** – Spillbox examples

As the cell construction proceeds, an additional board can be easily placed by the dozer operator in less than 10 minutes or by a second person in the area.

## 6.5 IMPACT OF FEED VARIABILITY

Variability of the feed properties – flow rate, solids content, gradation or chemistry – is detrimental to both cell and beach construction. Operations that rely upon tailings for construction purposes perform better when the feed parameters stay relatively constant because equilibrium flow conditions and slopes can be achieved, maximizing production. However, feed variability can be unavoidable depending on plant feed (ore variability) and plant operations.

Feed variability, if significant, could be at least in part managed by adding a few spigots upstream of the cell construction operations. In this case, spigots could be used to draw from the upper part of the flow (assuming it is stratified) and increase the solids content of the flow delivered to the cell.

Construction management could also be optimized by good communications between plant and construction personnel. For example, if warned by the plant that the feed will be poor, the construction personnel may select to operate spigots as discussed above or even to temporarily suspend cell construction (in case of very poor feed or added lime in the slurry).

## 6.6 OPTIMIZATION OF CELL OPERATIONS

Cell construction could be optimized by having two cells on each side of the dam so one cell can be operated while the other one is being prepared (construction of initial berms, installation of spillboxes, installation of discharge pipe). This also allows drainage to occur in a cell that was recently built while the other cell is under construction.

Downward drainage is an important part of the success of cell construction both in terms of resulting material properties and in terms of ease of dozer operations. By having four cells (2 on each side of the dam), drainage is enhanced by increasing the “rest” time between two construction events in the same cell and down time is reduced.

Based on experience, it is expected that to build the 3 m lift required for Stage 6A according to the design of the dam, it would take 2 “passes”: built 1.5m in one cell, come back over with an additional 1.5m. However, this can be better determined as experience in cell construction for the site specific conditions is developed. It is recommended that the footprint of the cells of the second pass is staggered from the first pass cells, so spillbox locations do not lined up on any particular vertical. The fill in the area near the spillbox tends to incorporate more fine tailings (slimes) and therefore not have the same properties as the fill closer to the discharge point.

Cell construction is more labour intensive than beach deposition and requires light for the operator to be able to see the fill and the flow conditions. Therefore it is recommended that cell construction be the focus of the summer operations while the winter time is used for beach deposition. The cost of cell construction in the winter is typically higher than during the summer.

## **6.7 BEACH OPERATION**

Beach placement will occur by:

1. single point discharge – when the entire tailings line is directed to the pond, which is recommended to be the main operation mode in the winter.
2. cell decant – the outflow of cell construction will contribute material to beach formation; it will form a relatively flat beach that will tend to erode steeper beaches formed by single point discharge.
3. spigots placed upstream of cell construction, if used.

Beach operation needs to focus on providing sufficient beaches to support cell construction and the required raises of the dam in each construction season according to the design. This can be determined by a well prepared tailings plan.

## **6.8 TAILINGS PLAN**

A tailings plan needs to be developed based on a detailed mass balance. It needs to be consistent with the water balance that it is understood to have already been developed by Mt. Polley. The objectives of the tailings plan would include:

- confirming that there is availability of material to build the dam as required by the dam design and the water balance
- determining the required schedule of cell construction (length of construction period, need to work night shift, need to run concurrent cells, etc)
- determining whether the beach construction will be acceptable to support the next period of cell construction (or whether there is a need to re-assess the methodology).

The developed tailings plan would be based on data that includes: plant production, sustainable productivity of cell construction, typical fill densities for cell and beach, achievable summer and winter beach angles, etc. It should also recognize the clear goals of mine closure so that as the tailings facility develops, ease of transition from final operating configuration to the approved closure configuration is as simple as possible.

## **6.9 DATA COLLECTION**

Continuous optimization of tailings operations requires an in-depth understanding of these operations. Therefore it is recommended that key data are collected and appropriately evaluated to allow further improvement of the operations. These data would include (some, if not most, of these data are already collected by Mt. Polley):

- Slurry density (solids content) and its variability with time
- Tailings gradation and its variability with time
- Tailings gross mineralogy (at least plasticity, if any) and its variability with time
- Plant production and its variability with time
- Cell fill density at various locations
- Cell fill gradation at various locations
- Percent of solids retained in the cell
- Average beach angle – during cell operation and single point discharge (summer and winter operation if so selected)
- Actual water balance data (precipitation, evaporation, etc)
- Man-hours and equipment for cell construction including cell preparation
- Down-time for cell construction and reasons

Analyses of the data would be used to calibrate the tailings plan to make it more reliable and to allow improvements on the planning of the operations. These data would also be valuable to improve productivity and quality of the fills built using cell construction. The dam designers may be consulted on potential design optimization opportunities afforded by wider cells built with high quality fills, should these be achieved.

#### **6.10 PERSONNEL TRAINING**

Efficient cell construction is as much due to an appropriate system design as it is due to skilled operators who understand and commit to the technique. The dozer operators and the supervisors need to have a good understanding of the technical objectives of cell construction and the desired outcome so they can work towards achieving it. Dozer operators need to be skilful to react appropriately to feed variability. Operators and supervisors also need to develop good communications with the plant personnel, who also need to be sensitized to the impact of feed properties to cell construction and its implications to dam construction and cost. Knowing when to beach versus place of cell, adding a stoplog to a spillbox, changing out a spigot etc. etc. are but a few of the key items under the control of the operators and supervisors that can really make the difference between a good tailings plan and an optimal one.

#### **7.0 SUMMARY AND RECOMMENDATIONS**

A review of Mt. Polley's tailings operation was conducted with the objective of providing recommendations to improve the efficiency of these operations. The review was based on a two-day site visit, observation of the construction conditions and discussions with supervisory and operations personnel. The conclusions and the main recommendations to improve the efficiency and reliability of tailings operations were presented at a closure meeting on site and are reiterated below.

1. The current operation leads to flow depths and flows velocities that seem too high to allow effective cell construction to occur. It is recommended that the width of the cells be increased, tentatively to 20 m with the objective of decreasing flow velocity and flow depth. Cell length seems adequate for now but it could be re-evaluated later.
2. Track-pack the cell perpendicular to the flow (as opposed to working the dozer up and down the cell). Berms (dry dykes) could be raised as cell compaction proceeds. This is expected to reduce downtime, improve efficiency and improve flow patterns.
3. Build and install spillboxes for the cell decant to improve ability to manage the flow and to reduce downtime during construction thus improving efficiency. When a cell is complete, the spillbox is simply moved to the next cell.
4. If the measures above are not sufficient to meet objectives, or if feed variability is an issue, spigots could be installed upstream of the cell to improve feed (by reducing water and slimes), and/or manage feed consistency, and/or decrease volumes/velocities into the cell.
5. Prepare a tailings plan / mass balance consistent with the water balance.
  - a. The tailings plan needs to verify availability of sand to build the required cell and beach to support the dam raises at all stages of construction.
  - b. The tailings plan could include a focus on cell construction in the summer and on beach placement during the winter.
  - c. Cell construction could be optimized by having two cells on each side of the dam. One cell could be prepared while the other one is being built; one side of the dam can be draining while the other is being built/prepared. Night shift might be considered during the cell construction (late spring, summer, fall) season.
  - d. Cell construction would likely take two "passes": built 1.5 m in one cell, come back over with an additional 1.5 m to achieve the full 3 m lift. The second pass should be staggered relative to the first pass to avoid locating all spillboxes on the same vertical.
6. Collect data on material parameters (gradation, cell deposit density, beach angles, etc), mill operation (gradation, slurry solids content) and cell operation (volumes, time, cost, etc). Data would be used to calibrate (and improve) the tailings plan to actual performance and to develop performance improvement changes in the field.
7. Train field supervisors and operators. They need a full understanding of the technical objectives of cell construction and its desired outcome. This understanding will lead to commitment and innovation from these experienced individuals.

## 8.0 CLOSURE

This report has been prepared for the exclusive use of Mt. Polley for specific application as described within this report. Any use which a third party makes of this report, or any reliance on

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or decisions made based on it, are the responsibility of such third parties. No other warranty, expressed or implied is made.

We sincerely appreciate the opportunity to provide our services to Mt. Polley. We would be pleased to discuss any aspects of this proposal at your convenience. Please do not hesitate to contact the undersigned if you have any questions.

Respectfully submitted,

**AMEC Earth & Environmental**

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**APPENDIX A**  
**Briefing Document**

## Efficiency of Tailings Sand Cat Operations – June 04, 2008

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### Key Issues

- Low efficiency / high costs building cell for Zone U
- Too much wash out on cells
- Too much time preparing cells + need to place CBL (rock on beach to support cell construction)
- Lack of beach

### Main recommendations:

1. Increase the width of the cells. Tentatively increase the cell width to 20 m with the objective of decreasing flow velocity and flow depth. Cell length seems adequate for now.
2. Track pack the cell perpendicular to the flow (as opposed to working the cell up and down). Berms (dry dykes) could be raised as cell compaction proceeds – reduce downtime
3. Build and install a spillbox to reduce downtime
4. Potential for installing spigots upstream of the cell to improve feed (by reducing water and slimes) or manage feed consistency into the cell - decrease volumes/velocities.
5. Prepare a tailings plan / mass balance consistent with the water balance.
  - a. Tailings plan needs to verify availability of sand to build the required cell and beach to support the cell raises.
  - b. Tailings plan could include planning for focus on cell construction in the summer and beach placement in the winter.
  - c. Cell construction could be optimized by having 2 cells on each side of the dam and possibly night shift; one cell could be prepared while the other one is being built; one side of the dam can be draining while the other is being built/prepared.
  - d. Cell construction would likely take 2 “passes”: built 1.5m in one cell, come back over with an additional 1.5m.
6. Collect data on material parameters (gradation, cell deposit density, beach angles, etc), mill operation (gradation, slurry solids content) and cell operation (volumes, time, cost, etc). Data would be used to calibrate (and improve) tailings plan to actual performance and to develop performance improvement changes in the field.
7. Train field supervisors and operators. Bring them up to speed with the technical objectives of the cell construction and the desired outcome.

**APPENDIX B**

**Tailings Gradation Data**

## **APPENDIX C**

### **Production and Slurry Density Data**