

# Mine Waste and Water Management at the Mt. Milligan Project

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## Abstract

The Mt. Milligan Project is a recently permitted large tonnage open pit mine in British Columbia currently under construction. Permit approvals were achieved by integrating the complete mine life cycle into the mine waste planning and design process. Knight Piésold (KP), in close collaboration with Terrane Metals Corp. (Terrane), developed a long-term, scientifically sound and sustainable design for an integrated tailings, overburden, mine waste rock and water management facility.

Challenges in developing this state-of-the-art facility were numerous and included specific design measures to meet site specific environmental, geological, geotechnical and hydrogeological conditions, as well as geographic and economic factors. The storage of waste within the Tailing Storage Facility (TSF) has many advantages, including reduced environmental impacts, a reduced mine footprint, and economic savings while still ensuring secure and permanent engineered containment of mine waste solids during and after operations. The closure and reclamation initiatives will eventually return the TSF site to a self-sustaining facility with pre-mining usage and capability.

## Introduction

The Mt. Milligan Project is a large gold-copper deposit located in the Omineca Mining District in North Central British Columbia, approximately 150 km northwest of Prince George as shown on Figure 1.



**Figure 1: Project Location**

The Mt. Milligan Project has undergone numerous studies and economic evaluations since the project's discovery in 1987. Two separate pre-feasibility studies were completed in 1991 and 1996. Additional conceptual economic studies were completed in 1997 and 1998. A more recent pre-feasibility study was completed by AMEC in 2005-2006 for a previous project owner, Placer Dome Inc.

An Environmental Assessment (EA) was prepared and submitted to provincial and federal government agencies in early 1991. The provincial agencies issued a Mine Development Certificate (93-01) and Disposition Order in November 1993 that was amended to extend the expiry date through to November 2003. This Certificate expired and could not be renewed or revived.

Terrane Metals Corp. acquired the Mt. Milligan Project in 2006 and re-activated engineering and environmental work for the project with a feasibility study and new EA. Work required to obtain Provincial and Federal approval of an Environmental Assessment/Comprehensive Study was conducted in parallel with the engineering studies. Thompson Creek Metal Corp. purchased Terrane Metal Corp. in 2010. The project development concept currently consists of an open pit mine and a 60,000 tpd ore processing facility producing a gold and copper concentrate.

## **Site Conditions**

The Mt. Milligan Project site is situated on the Nechako Plateau, a region of flat to gently rolling terrain. Local relief is provided by a northwest trending ridge which rises approximately 300 to 500 m above the local plateau elevation of 1,000 m. The area was extensively glaciated during the last glacial period. A large north trending belt of glacial and glaciofluvial deposits, approximately 100 km long and 10 to 20 km wide, covers the area of interest with glacial deposits exceeding 100 m in thickness. Thinner till veneers and colluvium deposits frequently mantle the steeper slopes of hills. Isolated deposits of fine grained glaciolacustrine sand, silt and clay are found within topographic depressions. Drainages are typically dendritic with meandering stream courses that connect pothole lakes, ponds and swamps.

The regional climate is characterized by short cool summers and cold winters.

The project is located in the Rainbow Creek catchment area which drains in a northerly direction to the Nation River which drains eastward into Williston Lake and into the Peace River system.

Rainbow Creek and its tributary King Richard Creek (informal local name) are well incised creeks that control drainage patterns in the Mt. Milligan deposit area. Both creeks have several small lake chains at headwaters, and are commonly surrounded by swamps and marshes.

## **Review of Previously Permitted Mine Development Concept**

The mine development concept previously approved in January 1993 was based on transporting the ore approximately 7 km by conveyor to a more remote mill site for processing at a production rate of approximately 60,000 tpd. The mill site was situated adjacent to the TSF located at Limestone Creek. Two separate streams of tailing were to be produced and stored within a conventional storage facility impounded behind two major embankments designated the Main and South Embankments. A third Saddle Dam was to be constructed in a slight topographic depression during the later years to provide the design storage capacity.

The higher sulphide containing tailing (cleaner tailing) were to be stored upstream of the lower non-sulphide containing tailing (scavenger tailing) confined in Limestone Creek Valley by the cleaner tailings dam. The cleaner tailings were to be continuously submerged to prevent oxidation and acid generation. Upstream of the cleaner TSF and bounded by an additional upstream dam, the water

storage dam was the water reservoir to capture and store make-up water. The design of the Main and South embankments utilized cycloned sand for ongoing construction.

The waste dump layouts included a North and South waste dump. The dumps were designed with shallow 30-degree slopes to facilitate re-vegetation. Overburden and waste rock were segregated within the dumps. The potentially acid generating (PAG) material was to be placed in the south dump. Pit backfilling was included in the mine plan once portions of the pit became available.

## **Mine Waste Planning**

Following reactivation of engineering studies in 2006, a completely new mine waste management plan was developed. The mine waste management criteria for the various site materials are outlined below:

### **Topsoil**

- Temporary stockpiles for use in reclamation.

### **Overburden**

- Construction material for TSF, where practical and cost-effective.
- Surplus to overburden dumps.
- Re-grade and re-vegetate at closure.

### **Non-acid generating (NAG) waste rock:**

- Construction material for TSF, where practical and cost effective.
- Surplus to NAG dumps.
- Cover with loose till and topsoil at closure.

### **Low NAG, oxide and weathered waste rock:**

- Place in designated areas within the TSF for subaqueous storage.
- Possible use as a construction material in the shell zone upstream of the embankment core zone.

### **Low and High PAG waste rock:**

- Requires sub aqueous storage.
- Place in causeway to separate cleaner and scavenger tailing.
- Place in cleaner tailing facility.
- Place in open pit.

### **Cleaner tailings:**

- Requires sub aqueous storage.
- Place in separate cell in tailing facility to allow for progressive encapsulation by scavenger tailing.
- Place in open pit.
- At closure cap with scavenger tailing.

### **Scavenger tailings:**

- Place in tailing facility.

- Place in open pit.
- Used for capping material to encapsulate cleaner tailing.

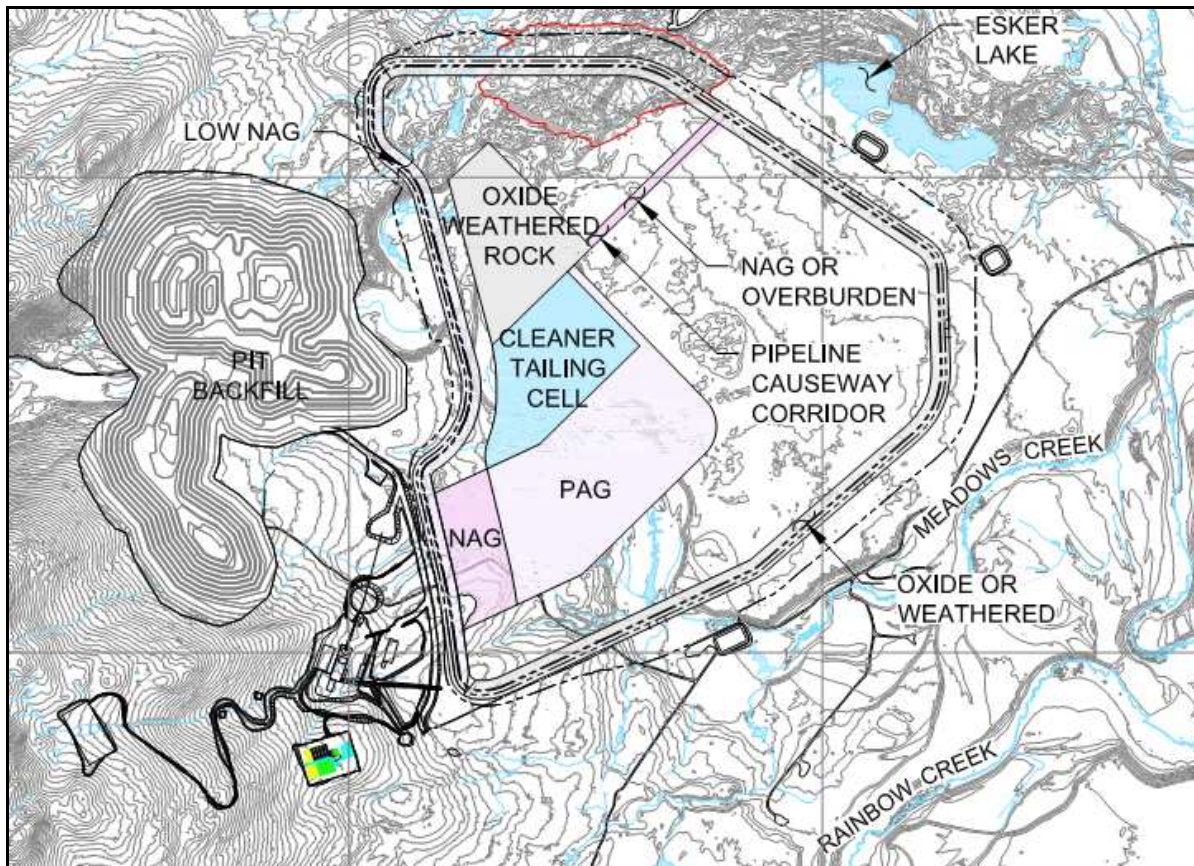
## **Mine Waste Rock Management Planning**

Waste dump areas had been previously identified in the various prefeasibility studies and economic evaluations. The waste dump areas have been subsequently refined and optimized to minimize surface water control requirements. A range of options are available for disposal of non-acid generating (NAG) waste materials including:

- Disposal in external waste rock dumps; and
- Use as a construction material at the TSF or other locations.

The 1991 EA contemplated segregating and constructing a PAG waste rock dump upslope of the open pit where any drainage would flow into the pit. The dump was to be covered by a compacted till cover at closure to reduce oxidation and acid generation. This option was rejected in the current studies as it posed increased risks of acid production during mine operation and closure.

A lower risk alternative was selected involving disposing all PAG/Low PAG mine waste rock in a sub-aqueous manner in order to control oxidation, metal leaching and acid generation. Placement of PAG/low PAG waste rock will be within the TSF, as shown below on Figure 2. The PAG/Low PAG waste rock will be placed such that it will be submerged relatively quickly during impoundment filling and covered by the final tailings surface. The PAG/low PAG waste materials in the later years of mining are scheduled for backfill within mined out areas of the open pit and then capped with scavenger tailings and flooded at closure by a pit lake.



**Figure 2: Overall Waste Management Site Plan**

## **Tailing Storage Facility Design Features**

The TSF has been designed to permanently store tailing, potentially acid generating, low potentially acid generating, and low non-acid generating waste rock materials in the PAG/Low PAG area of the TSF. The low NAG, oxide and weathered rock material types will also be stored in separate areas within the TSF.

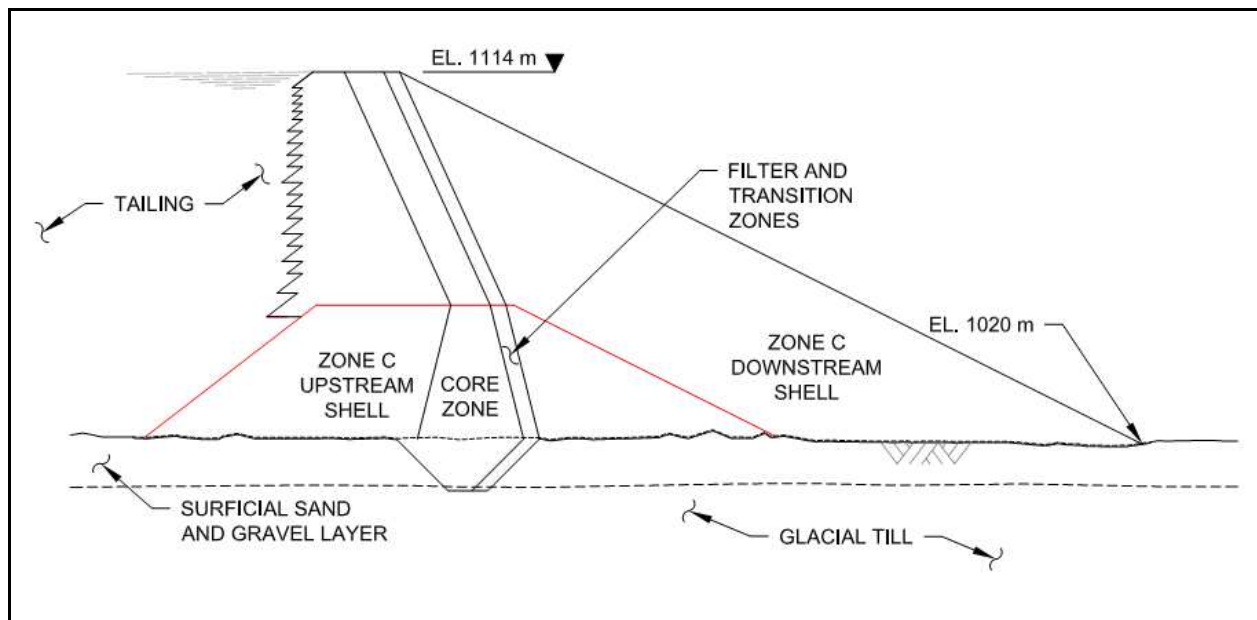
Specific overall features of the TSF are listed below.

- A zoned water retaining earth-rockfill dam approximately 10.7 km enclosed peripheral length and averages 75 to 90 m high with a maximum height of 100 m
- Cleaner tailing will be stored within a separate cell within the larger scavenger tailing basin
- Diversion ditches and sediment ponds that direct water to the TSF
- Tailing distribution system
- Reclaim water system
- High PAG, low PAG, Low NAG, oxide and weathered rock waste storage areas (located within TSF)
- Portion of low NAG, oxide and weathered materials used in construction of the upstream shell zones
- Tailing beaches, and

- Supernatant water pond.

The Main Embankment will be constructed from low permeability glacial till, overburden and waste rock materials from stripping operations at the open pit and borrow areas within using annual raises throughout the life of the Project for a total of 21 construction stages. The overall embankment length has been subdivided into the South, Southeast, Northeast and North Dam. The South Dam will be expanded in stages across the King Richard Creek Valley, and the Southeast/Northeast Dams will be constructed along the eastern plateau towards the Esker lakes. The North Dam will extend through the esker deposit after regrading of the eskers to allow for excavation of the cutoff trench. The maximum tailing embankment height will be at the South Dam in King Richard Creek valley at 100 m.

The Main Embankment will be constructed and operated as a water-retaining structure. The Main Embankment will comprise of a zoned structure that will have a low permeability glacial till core zone with appropriate filter and transition zones to prevent downstream migration of the tailing. The core zone will be keyed into the low permeability glacial till in the foundation. A typical section illustrating the staging of the embankment is shown below on Figure 3.



**Figure 3: Typical Main Embankment Cross-Section**

A total of 70 Mm<sup>3</sup> of fill will be used over the life of the tailings dam construction for the cutoff trench and embankment zones.

The Pipeline Corridor Causeway (PCC) will be developed concurrently throughout the life of the Project as the embankments are raised annually using 9.1 Mt of weathered – oxide and low NAG rock and 13.5 Mt of High NAG rock and overburden from the open pit. The elevation of the PCC stages will generally follow the staged embankment construction elevations. A veneer of glacial till will be placed beneath the PCC towards the Northeast Embankment to provide a hydraulic barrier between the PCC and the Basin Underdrainage system. The PCC will be constructed to provide pipe benches for routing the scavenger and cleaner tailing pipelines as well as provide access for the haul trucks to the North, Northeast and Southeast Dams. The minimum required width of the PCC will be 50 meters but

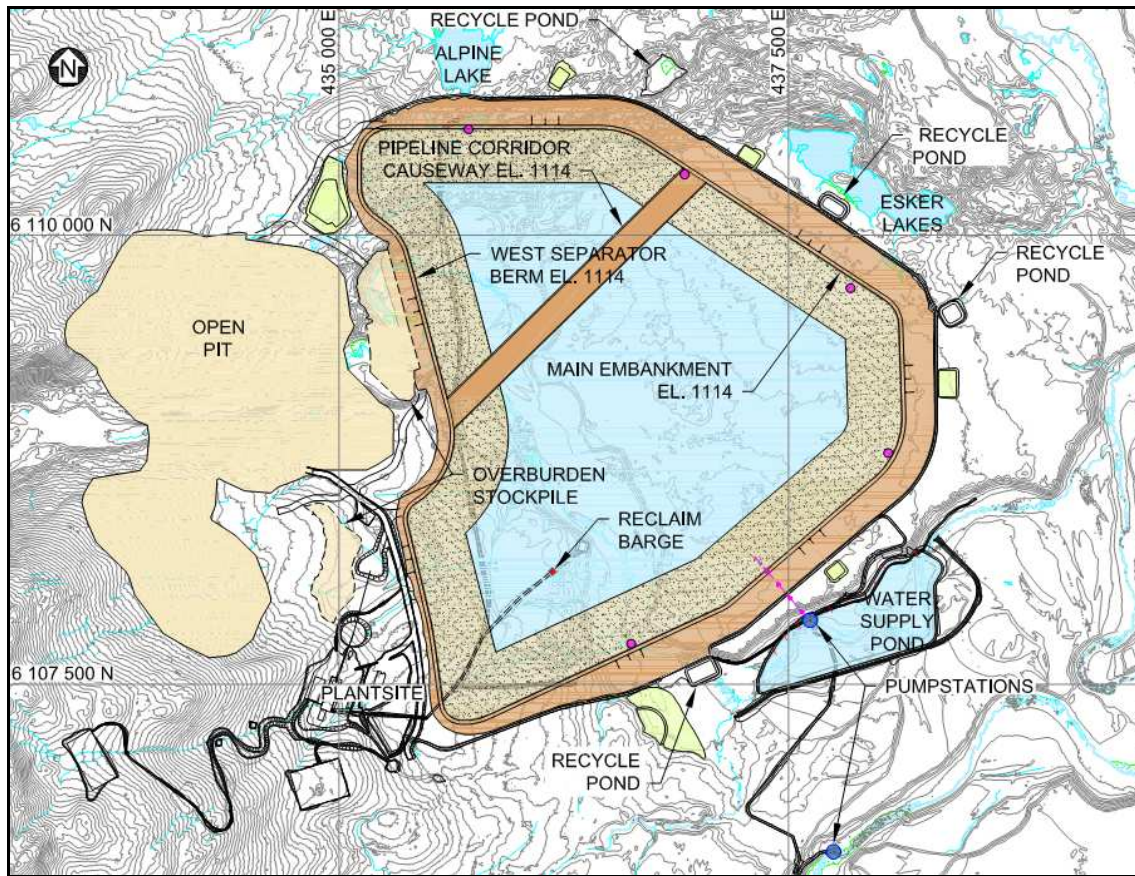
it will be much wider at times based on the production of material from the pit. The east side of the PCC will be constructed from overburden and NAG waste rock while the west side of the PCC will be constructed using oxide-weathered material and low NAG waste rock.

A berm is required along the western edge of the impoundment across King Richard Creek to provide containment between the TSF and the Open Pit. The West Separator Berm (WSB) will be constructed using 11.6 Mt of overburden and 10.6 Mt of rock from the open pit; it will be operated as a water-retaining structure. The WSB will be designed and constructed using the same techniques developed for the Main Embankment. The WSB will comprise a zoned structure that will have a low permeability glacial till core zone with appropriate filter and transition zones to prevent downstream migration of the tailing. The WSB will be extended towards the south and north until it ties into the Main Embankment creating a four sided impoundment. Downstream of the WSB, surplus overburden fill will be placed to develop a laydown area and to direct runoff into the TSF.

The PAG Separator Dyke, comprised of high and low PAG waste rock, will confine the cleaner tailing with 9.5 Mt of PAG waste rock plus 1.9 Mt of overburden (for the early stages when PAG rock is not available) from the open pit and has been designed in step with the mine production schedule. It will be developed at the same or similar rate of rise as the tailing but will be several meters higher to provide a dry, stable placement surface and allow for installation of the cleaner tailing pipeline and for truck traffic. The maximum elevation of the waste storage area will remain at an elevation where it can be flooded by the supernatant pond in the case of premature closure. At closure, this waste storage area will be covered by non-acid generating scavenger tailing and submerged below the final closure tailing elevation.

The PAG separator dyke will extend outwards to the east as a large lobe or causeway in order to allow development of tailing beaches along the embankments. This zone of tailing beach will provide a low permeability transition zone between the coarse, permeable reactive waste rock and the tailing embankments, and will function as a seepage control measure. The PAG Separator Dyke will be constructed and managed so that only one reclaim water system to the plant site will be required.

The Mt. Milligan general arrangement at the end of operations is shown on Figure 4.



**Figure 4: General Arrangement – End of Operations**

## **Water Management Planning**

Water will be controlled in a manner that minimizes erosion in areas disturbed by construction activities and prevents the release of construction water, which could adversely affect the water quality of receiving waters (namely Meadows Creek, Rainbow Creek, Alpine Lake and Creek and Esker Lakes). This includes the collection and diversion of surface water runoff, temporary groundwater dewatering and the use of holding ponds and pump back systems.

Mt Milligan's operational water management system is designed as a closed system to minimize the use of external fresh surface water or groundwater sources through maximizing recycle of process water. Only limited deep seepage would be discharged from the mine site during operations (i.e., through the inter-till sand and gravel aquifer). Process water will be stored on site within the TSF and any additional water requirements will be made up from the Meadows Creek watershed as necessary using an off channel pumpstation to recover water during high flow periods. In the case of extreme dry periods (e.g., two consecutive 1 in 10 year return period dry years) a contingency off channel pumpstation on Rainbow Creek will be used to supply process water during freshet and higher flow periods.

Seepage through the embankments will be collected in the embankment filter and seepage collection system and recycled back into the tailing facility. The embankment will be constructed with toe drains to collect seepage and reduce seepage gradients. Seepage collected in the embankment drainage systems will be transferred to the seepage collection and recycle ponds located at topographic low points at the downstream toe. Additional collection ditches constructed along the toe of the

embankments will be used to collect seepage and surface run-off and direct the flow to the seepage collection and recycle ponds, from where it will be pumped back to the TSF.

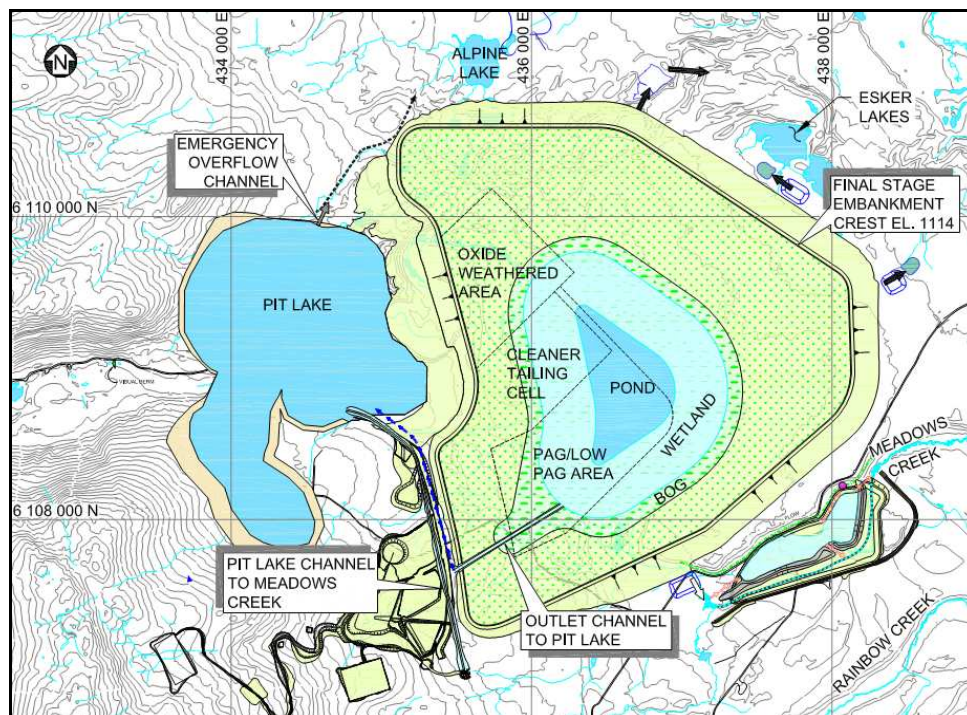
## **Closure and Reclamation**

The primary objective of the closure and reclamation initiatives will be to eventually return the TSF site to a self-sustaining facility with pre-mining usage and capability. The TSF will be required to maintain long-term stability, protect the downstream environment and manage surface water.

Upon mine closure, surface facilities will be removed in stages and full reclamation of the TSF will be initiated. General aspects of the closure plan include:

- Selective discharge of scavenger tailing around the facility during the final years of operations to establish a final tailing beach that will facilitate surface water management and reclamation.
- Dismantling and removal of the tailing and reclaim delivery systems and all pipelines, structures and equipment not required beyond mine closure.
- Construction of overflow channels. This full closure scenario will also work well in the event of premature closure of the mine.
- Removal of the seepage collection system at such time that suitable water quality for direct release is achieved.
- Removal and regrading of all access roads, ponds, ditches and borrow areas not required beyond mine closure.
- Long-term stabilization of all exposed erodible materials.

The Mt. Milligan Project general arrangement plan after closure is shown below on Figure 5.



**Figure 5: General Arrangement – At Closure**

## **Conclusion**

The TSF has been designed to permanently store tailing, potentially acid generating, low potentially acid generating and low non-acid generating waste rock materials in the PAG/Low PAG area of the TSF. The low NAG, oxide and weathered rock material types will also be stored in separate areas within the TSF. Knight Piésold's design of the Mt. Milligan Tailings Storage Facility resulted in a significant reduction in the mine footprint which in turn reduces environmental impacts during construction, operations and closure. This subsequently will improve the sustainability of the project and allow for simple and effective water management at closure. A closed water system enables minimal use of supplemental water sources further reducing environmental impacts. The use of overburden and non-acid generating waste rock for embankment construction minimizes the need for conventional waste rock dumps and borrow development required for construction.

The design of a tailing and waste rock co-disposal facility reduces risk associated with potentially acid-generating and oxide/weathered waste rock as it is placed in its final location and saturated relatively rapidly to minimize the potential for the material to become reactive and problematic. The proximity of the TSF to the open pit provides a simple closure plan as the final tailing pond supernatant can be routed into the adjacent mined out pit to form a pit lake. The Environmental Assessment team conducted detailed water quality modelling and confirmed this concept was technically and environmental feasible.

## **References**

- Knight Piésold Ltd., 2010a, *Terrane Metals Corp. Mt. Milligan Project, Tailing, Overburden and Waste Rock Management, Design Basis Report, Ref. No VA101-141/3-2*, January 21, 2010.
- Knight Piésold Ltd., 2010b, *Terrane Metals Corp. Mt. Milligan Project, Tailing Storage Facility, Stage 1 Detailed Design Report, Ref. No VA101-141/3-4*, July 7, 2010.