Golder Associates

TECHNICAL MEMORANDUM

DATE October 5, 2015 **REFERENCE No.** 1411734-047-TM-Rev2-11000

TO Lyn Anglin, Colleen Hughes
Mount Polley Mining Corporation

FROM Trish Miller
Suzanne Simard **EMAIL** trish_miller@golder.com
suzanne.simard@ubc.ca

FOREST CONDITIONS AND DIE BACK IN AREAS OF THICKER TAILINGS DEPOSITION

Mount Polley organized a site reconnaissance on July 8 and 9, 2015 to finalize sampling and analysis plans for the long term human health and ecological risk assessment following the 2014 tailings dam failure. Prior to and during the site reconnaissance it was observed that some trees located in the tailings/soil deposition area along Hazeltine Creek (referred to as the halo area) had died during the spring of 2015. Mount Polley wanted to know why the trees were dying, and if further losses could be expected. Subsequently, a more in-depth field assessment and sampling program was conducted between July 28 and August 4, 2015. By this time, most trees in the halo zone were dead or showing signs of decline. This memo provides perspectives on forest conditions and causes of tree die back in the halo zone where tailings were deposited on native soil in the forest along Hazeltine Creek.

The field study conducted between July 28 and August 4, 2015 was conducted to support the human health and ecological risk assessment of the effects associated with the tailings dam failure. The approach used for the terrestrial risk assessment was based on: i) field measurements of ecological impact, ii) laboratory evaluation of soil microbial communities, and iii) bioassays of the tailings mixture to determine causal factors for growth limiting conditions.

An ecosystem-based methodology was used to guide field measurements and describe the terrestrial ecosystem[1]. Data were collected from 21 plots located within the halo area and 8 plots located in local reference forests outside of the area of visual impact of the tailings material. Measurements were taken of chemical parameters in water and soil. Observations were made of plant root abundance and health, soil mycorrhizae and saprophytic fungi, among other parameters. A statistical analysis was used to compare these measurements and observations from the halo area to the reference forest plots.

[1] BC MFR "Field Manual for Describing Terrestrial Ecosystems" (https://www.for.gov.bc.ca/hfd/pubs/docs/lmh/.../LMH25_ed2_(2010).pdf)

Results available from the field program to date indicate that the pattern of tree mortality and subsequent sampling at Mount Polley was caused by the hypoxic or anaerobic environment of the tree roots created by the thick deposit of fine silty material over the forest floor (Photograph 1). This deposit would have immediately blocked soil pores and reduced oxygen reaching the roots of the trees. A distinct anaerobic odour was evident in the root zone for the plots excavated in the halo area. The plots in the halo zone were saturated leading to a perched water table; the cause was likely due to the small particle size of the deposited material that trapped water. Dissolved oxygen concentrations and the oxidation-reduction potential were lower, confirming a significant difference in the oxygen conditions in the root zone (Table 1).

Photograph 1: Site conditions and the pattern of tree mortality suggest that the mortality was caused by the anaerobic environment of the tree roots created by the thick deposit of fine silty material over the forest floor.

Table 1: Field measurements of soil chemistry using a soil and water slurry

	Background	Halo	P-Value
Dissolved Oxygen (mg/L)	8.5	5.1	0.02**
pH	5.7	7.0	<0.001**
Oxidation-reduction potential (mV)	241.9	91.9	0.001**
Specific conductivity (µS/cm)	39.5	217.4	<0.001**

Notes:
** - Significant difference
mg/L – milligrams per litre; mV – millivolts; µS/cm – microSiemens per centimetre

There were fewer roots in the soil plots in the halo zone (Table 2) and the roots that were present were associated with more saprophytic hyphae indicating that they were in a state of decay. Soil mycorrhizae were used as an indicator of the microbial community diversity and overall health. Soil mycorrhizae were absent from the roots in most of the plots in the halo area. At some outer edges and in isolated pockets where the tailings are sandy and shallow, the root zone has remained partially aerated and roots were in good condition.

Table 2: Root, microbial community and fungi health

	Background	Halo	P-Value
Rooting depth (cm)	30.3	15.7	0.03**
Root restricting water layer (% of plots)	0	52	0.01**
% live roots			
Ah horizon	38	3	<0.001**
B horizon	40	0	<0.001**
Live mycorrhizae on roots (% of roots)	16	1	<0.001**
Saprophytic hyphae on roots (% of roots)	8	22	0.14

Notes:
** - Significant difference
cm - centimetre

When oxygen becomes limiting to roots, trees can change metabolic and biochemical processes to survive temporarily, but prolonged oxygen starvation leads to death. Following the tailings dam breach on August 4, 2014, the trees likely survived the remainder of the summer by adjusting their metabolism to the hypoxic (low oxygen) conditions and entering winter dormancy early. In spite of these metabolic switches, roots and soil organisms would have soon started to die. This slow root death and induced dormancy can help explain why the trees were green and living in the months following the breach.

In the spring of 2015, the trees in the deeper deposits of the outflow area rapidly turned brown and died. Two factors likely contributed to their death at this time. First, snow melt and spring rains would have increased the water content of the deposits, thus creating fully saturated and anoxic (oxygen depleted) soil conditions. The shift from hypoxic to anoxic conditions would have amplified root mortality. Second, the dying tree roots would have been unable to acquire sufficient water to meet demands for photosynthesis and transpiration at the time winter dormancy broke in spring. As trees flushed and soils warmed, the foliage would have continued to transpire while dead roots were incapable of acquiring and transporting sufficient water to the crown via the xylem. Without sufficient water conductance to the crowns, the trees died rapidly over a period of 1-2 months.

By early August, 2015, trees whose roots were subject to prolonged or temporary anaerobic conditions following the breach were dead or dying. Core samples of affected trees also revealed sap rot (decay) initiating in many stems. The fine deep deposits in most areas have remained saturated well into the summer, resulting in a perched water table that continues to block gas exchange with the soil. This saturation, combined with the dead root systems and sap rot, indicate that the dead trees are at risk of blowing over in a wind. In other areas, coarser textured tailings are drying quickly as the summer progresses, but unfortunately the anoxia damage to the trees has already occurred and is irreversible. The dead trees in these conditions will eventually blow over or collapse. Harvesting of the dead trees will remove the risk of blowdown and create more suitable site conditions for rapid reclamation of the forest. The felled trees, along with planting of native species, can be used to create ecological structure and function as part of the reclamation strategy. Golder has made area-specific recommendations with assigned priorities for falling trees and Mount Polley is acting on these recommendations.

The higher concentrations of copper in the tailings may lead some to hypothesize that the tree mortality was due to copper toxicity. Copper toxicity retards root elongation by damaging the plasma membrane in root cells. In plants, copper toxicity is indicated by reduced root growth and foliar interveinal chlorosis with eventual browning of needle tips, ultimately leading to slower growth rates. The rapid death of the trees observed in the spring of 2015 at Mt. Polley does not fit the pattern of copper toxicity effects, which would have involved slowly declining growth rates with more gradual mortality.

Mount Polley organized field studies and follow-up analyses to provide the data needed to explain and document the forest conditions in the area where tailings have deposited as part of the Ecological Risk Assessment. This study results will become available later in 2015 and in early 2016.

We trust the above meets your present requirements. If you have any questions or requirements, please contact the undersigned.

GOLDER ASSOCIATES LTD.

Trish Miller, M.Sc., R.P.Bio.
Principal, Senior Environmental Scientist

Suzanne Simard, Ph.D., RPF
Professor of Forest Ecology, University of British Columbia

TAM/SS/pn

o:\final\2014\1421\1411734\1411734-047-tm-rev2-11000\1411734-047-tm-rev2-mp csr remediation 5oct_15.docx