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Memo

To:	Chris Hanks	**Date:**	November 4, 2011
Company:	Hope Bay Mining Limited	**From:**	Víctor Muñoz Saavedra, Maritz Rykaart
Copy to:	Lea-Marie Bowes-Lyon	**Project #:**	1CH008.049
Subject:	Tail Lake Water Cover Design: Motivation to Reduce Water Cover Thickness		

Tail Lake Water Cover Design – Summary

HBML would like to deposit more tailings in Tail Lake, while still maintaining the current closure plan for Tail Lake, and as such requested that SRK re-evaluate the design of the water cover, taking into consideration additional baseline data obtained since 2005, as well as re-evaluating some of the assumptions in the previous assessment. This technical memorandum documents the revised water cover design.

Tail Tahiq Imaqmik Qalliqhimania Hanatyuhiq - Nainaqhimayut

HBML-kut iliuqaqvikkumayat ilavaliqni uyagaktaqnikut talvunga Tail Tahiq, huli ihuaqhihimalugu tapkuat tatya umiknikhanut upalungaiyautit taphumunga Tail Tahiq, taimaittumiklu tukhigaqtut tapkuat SRK-kut naunaiyatqikhaqni tapkuat hanatyuhikhat imaqmut ulithimani, ihumagiqahiutilugit ilagiagutit huniumaittitlugu tuhagakhaliat piyauni taimangat 2005-mi, naunaiyatqikhaqnilu ilai ihumagiyauyut tapkunani hivuani naunaiyagaqni. Una piluaqnaqtuliqutinut tuhaqhit titiqagutai nutanguqni imaqmik qaliqhimania hanatyuhikhaq.

ᑕᓯᖅ ᐊᒃᑕᑯᖃᐅᑦ Tail Lake_ᒦᑦᑑᑉ ᖄᖓᓂ ᓴᓇᔭᐅᓯᒪᒐᔭᖅᑐᖅ _ ᑐᓴᒐᒃᓴᑦ ᓇᐃᓈᖅᓯᒪᔪᑦ

ᐅᑯᐊ Hope Bay ᐅᔪᕋᒃᑕᕆᐊᑦ ᓚᒪᑎᑦᑯᑦ ᐃᓕᐅᖃᐃᒃᑲᓐᓂᖃᑦᑕᕋᔪᕈᒪᖕᒪᑕ ᐊᒃᑕᑯᓂᒃ ᐅᔪᕋᒃᓴᓕᕆᔾᔪᑎᒥᓂᖅᓂᒃ ᐅᕗᖕᒐ Tail Lake−ᒧᑦ, ᓱᓕ ᐊᑐᖅᑕᐅᖃᑦᑕᕋᒪᑕ ᒫᓐᓇ ᒪᑐᓯᒍᑕᐅᔫᒥᖅᓂᐊᖅᑐᑦ ᐅᕗᖕᒐᖕᒐᔪᑦ Tail Lake−ᒧᑦ, ᑐᒃᓯᕿᓇᓯᒪᖕᒪᒋᑦᑐ ᐅᑯᐊ SRK−ᑯᑦ ᐱᒃᑯᔾᔨᕚᑦ ᕿᒥᕈᔭᐅᒃᑲᓐᓂᖅᑯᔭᖕᒋᑦ ᖃᓄᖅ ᓴᓇᔭᐅᓯᒪᓂᖕᒋᑦ ᖄᖓᓅᖅᑕᐅᒐᔭᖅᑐᑦ ᐃᒪᖕᒐᑕ ᐅᓕᒋᔭᐅᑐᑎᒃ, ᖃᓄᖅᑑᕈᑕᐅᔪᓄᑦ ᐃᓚᒋᔭᐅᒥᔪᑦ ᑕᒡᕗᖕᒐᖕᒐᔪᓕᒫᓅᖕᒐᔪᑦ ᓄᐊᑕᐅᓯᒪᔪᓄᑦ ᖃᐅᔨᒪᔾᔪᑎᒃᓴᒫᓄᑦ ᐱᔭᐅᓚᐅᖅᓯᒪᔪᑦ ᑕᐃᒪᖕᒐᓂᑦ 2005−ᖑᔪᒪᑦ, ᓱᓕᓗ ᖃᐅᔨᓴᖅᑕᐅᑲᓐᓂᕆᐊᖃᒪᑕ ᖃᐅᔨᓴᖅᑕᐅᓚᐅᖅᓯᒪᔪᓅᖕᒐᔪᑦ. ᐅᑯᐊ ᐱᓕᕆᐊᒃᓴᓕᕆᔾᔪᑎᑦ ᑎᑎᖃᑦ ᐊᓚᒃᓯᒪᔪᑦ ᐋᖅᑭᒋᐊᕈᑕᐅᒐᔭᖅᑐᑦ ᖄᖓᓅᖅᑕᐅᒐᔭᖅᑐᖅ ᐅᓕᒋᔭᐅᑐᓂ ᐋᖅᑭᒃᓯᒪᓂᕆᔭᖅᑕᖕᒐᓂᒃ.

1 Introduction

Hope Bay Mining Ltd. (HBML), a wholly owned subsidiary of the Newmont Mining Company (NMC) is currently constructing their Doris North Project (Project) in the Kitikmeot Region of Nunavut, Canada. Tailings for this Project will be sub-aqueously deposited in Tail Lake, which will be contained with the construction of two dams (North and South dams). At closure, the water level in Tail Lake will be lowered to its pre-mining level (28.3 m) and the North dam will be breached leaving a 4 m water cover over the tailings surface.

SRK Consulting (Canada) Inc. (SRK) completed a design of the minimum water cover needed at closure to prevent re-suspension of tailings with subsequent water quality effects (SRK 2005). That analysis concluded that the minimum water cover should be 2.42 m, a number which was defined by winter ice thickness. At the time the maximum amount of tailings planned for deposition in Tail Lake was about 458,200 tonnes, and based on bathymetric surveys, this would leave a final water cover of 4 m, a number that well exceeds the minimum required.

HBML would like to deposit more tailings in Tail Lake, while still maintaining the current closure plan for Tail Lake, and as such requested that SRK re-evaluate the design of the water cover, taking into consideration additional baseline data obtained since 2005, as well as re-evaluating some of the assumptions in the previous assessment. This technical memorandum documents the revised water cover design.

2 Background

The primary purpose of a water cover is to ensure that the covered mine waste, in this case tailings, is kept from oxidizing. Oxidizing will result in geochemical changes to the tailings, which in turn may result in water quality that exceed discharge standards. It is generally understood that a stagnant water column of 0.3 m is sufficient to prevent oxidization of the underlying waste; however, in nature the water column cannot be stagnant, and as a result the tailings bed stability is affected through physical processes such as wave action, seiching, seasonal lake turnover, currents, and ice entrainment. The general rule of thumb is therefore to ensure a water cover of at least 1 m, to counter these processes. Such rules of thumb are however only a guideline, and it is not appropriate to use that for an actual water cover design.

According to the MEND 1998 guidelines (MEND 1998), the objective of water cover design is: *"…to provide an adequate depth of water to ensure the consolidated bed of tailings is not entrained or remobilized during operation and after closure of the pond."* The water cover must be deep enough that the tailings do not become re-suspended due to wind generated waves and currents. Re-suspension occurs when the resistance of the bed of tailings is overcome by action of overlying water. The resistance of the bed is dependent on particle size, density, and cohesion. The action of the overlying water-wave action is dependent on:

- fetch length, i.e. the maximum distance of water over which waves may be generated;
- wind speed for a maximum (design) return period; and
- wind direction and duration.

This technical memorandum presents the design calculations for a minimum water cover thickness to prevent re-suspension from occurring, and supersedes the analysis completed in 2005 (SRK 2005).

3 Water Cover Design Approach

3.1 Current State-of-the Art

The current state-of-the art in water cover design is the procedure documented in MEND (1998). According to this guideline, there are five processes that affect bed stability; seiching, seasonal lake turnover, currents, wave action and ice entrainment. The guideline suggest that for *small tailings impoundments* (less than 5 km^2 water body area), and a water depth of 0 to 10 m, that only wave action and ice entrainment need to be accounted for in the design. During operation Tail Lake will vary in size between 81 and 130 ha (0.8 to 1.3 km^2), and its depth will range between 2.3 and 9.2 m (this is based on the water level in Tail Lake ranging between 28.3 m and 33.5 m). At closure the Tail Lake water surface will be 0.76 km^2, and the water depth will be 2.3 m. Clearly Tail Lake falls within the definition of a "*small tailings impoundment*" as defined in MEND (1998).

Note that the surface areas quoted for Tail Lake in the technical memorandum is based on the engineering stage curve for Tail Lake which includes the areas leading up to the North and South dams. The actual body of water in Tail Lake at the normal water elevation of 28.3 m is 76.6 ha in size; however, if the surface leading up to the dams are included, the area increases to about 81 ha.

3.2 Wave Action

For re-suspension due to wave action, the MEND (1998) guideline uses the method proposed by Lawrence *et al*. (1991) to determine minimum water cover depth, but couples his approach with a critical bed velocity computation derived from the work of Komar and Miller (1975). Since the modification adopted by MEND (1998) is less conservative than the original Lawrence *et al*. (1991) method, SRK have selected to use both methods in calculating a safe water cover thickness for Tail Lake. Both of these methods provide a way of calculating the minimum water cover depth at which no tailings re-suspension will occur, i.e. if the minimum water cover depth requirement is satisfied, and then there will be no re-suspension of tailings.

Mian and Yanful (2001) and Bennet and Yanful (2001) has been documenting their research on water covers, and suggest that the procedures for water cover design, such as those proposed by Lawrence *et al*. (1991) and MEND (1998) are perhaps too conservative, and that water cover design should be based on an allowable re-suspension value, i.e. the water cover can be designed to allow some re-suspension provided that that amount of re-suspension would not result in exceedence of water quality criteria. This research has culminated in the development of a proposed new design methodology for selecting an optimum water cover depth (Samad and Yanful 2005). This method calculates the bed erosion for any specific water cover depth, using a similar wave theory approach as Lawrence *et al*. (1991), but refines it to account for shallow water waves and counter current flow.

Furthermore, Samad and Yanful (2005) suggest that the tailings impoundment should be divided into a grid, and a minimum water cover depth requirement at each grid point should be calculated. This refinement accounts for changes in fetch distance and bathymetry at each grid point, and generally results in reduced minimum water cover depth requirement. The grid method proposed by Samad and Yanful (2005) is therefore less conservative than the methods described by MEND (1998) and Lawrence *et al*. (1991).

3.3 Ice Entrainment and Ice Scouring

The presence of an ice cover prevents direct atmospheric exchange on the water surface, and specifically eliminates the interaction of wind on the water surface. There is however two other processes whereby the presence on an ice cover may impact the design of a water cover, i.e. ice entrainment and ice scouring.
Ice entrainment occurs when the ice layer is sufficiently thick that it freezes to the bed (or the tailings surface) of the water body (MEND 1998). This is also called grounded ice. As the ice thaws, sediment entrained in the ice is released into the water column.

Ice scouring is the product of a decrease in the flow area due to the presence of ice. This results in increased underwater flow velocities around constricted zones. When ice grounds, the influence of ice scouring on the tailings surface becomes increasingly significant (Peinerud 2003).

MEND (1998) recommends that to prevent ice entrainment and scouring from impacting the water column, the minimum water cover should be at least 10% deeper than the maximum ice thickness at any time during the winter months.

4 Water Cover Design Assumptions

4.1 Wind

4.1.1 Wind Direction

Site specific baseline wind data (2005 to 2009) at Doris Lake, confirms that the predominant summer wind direction is NWN (Rescan 2009).

4.1.2 Wind Speed

The site specific baseline wind data record at Doris Lake is not sufficiently long to allow a proper statistical analysis of wind speed. Golder (2005) carried out a correlation analysis and concluded that it is appropriate to use wind speed data from the Cambridge Bay weather station as a substitute for long term data at the Project site. SRK subsequently used the entire Cambridge Bay database (1953 to 2010) (Environment Canada 2010) to develop a probability distribution of wind speed to determine summer month (June to September) wind return periods. These return periods are listed in Table 1.

Table 1: Calculated Summer Month Wind Speed Return Periods for Cambridge Bay

Return Period (years)	Hourly Average Wind Speed (m/s)
2	17.6
5	20.2
10	21.9
25	24.0
50	25.6
100	27.1

MEND (1998) does not provide guidance as to what wind speed data should be used in the water cover assessment, leaving it open to interpretation by the designer. Lawrence *et al*. (1991) use a wind return period of 10 years, while Samad and Yanful (2005) use a design wind return period of 100 years.

4.2 Fetch

Fetch for Tail Lake was based on the predominant NWN direction at the closure water elevation of 28.3 m. Even though fetch is clearly a function of the lake geometry and surrounding topography and thus not constant, MEND (1998) recommends that the maximum fetch distance be used for water cover design. Samad and Yanful (2005) argue that using the single maximum fetch would overestimate wind-induced wave growth at places where the fetch is shorter than the maximum. They therefore suggest that a more realistic estimation of fetch can be made by dividing the lake into square parcels measuring 25 m x 25 m, and the fetch calculated individually for every parcel. Adopting this approach for Tail Lake results in 1,187 parcels with a cumulative fetch distribution as illustrated in Figure 1. Using this approach, the maximum fetch for Tail Lake is 626 m.

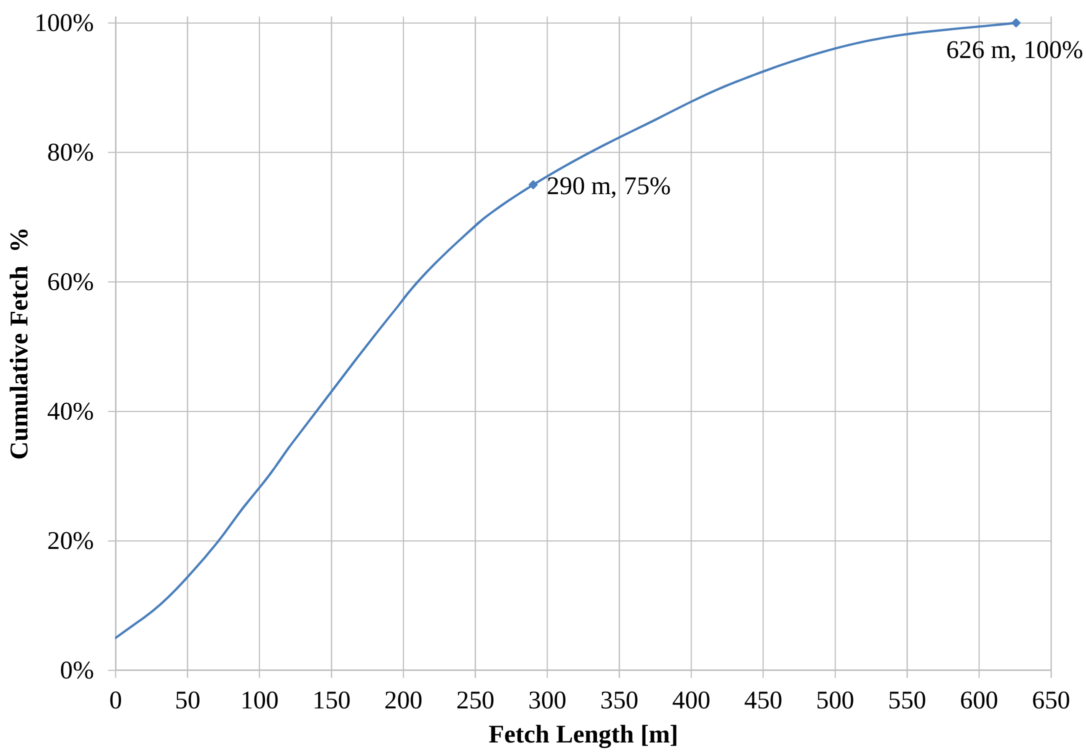

Figure 1: Calculated Fetch Distribution for Tail Lake Based on Method Proposed by Samad and Yanful (2005)

4.3 Sediment (Tailings) Properties

4.3.1 Particle Size

Additional tailings characterization testing has been carried out since the water cover design was first prepared in 2005 (SRK 2005; SRK 2009). Figure 2 presets grain size distribution curves for two representative tailings test samples. According to these tests the median particle size (D_{50}) of the tailings to be deposited in Tail Lake is between 0.076 and 0.080 mm.

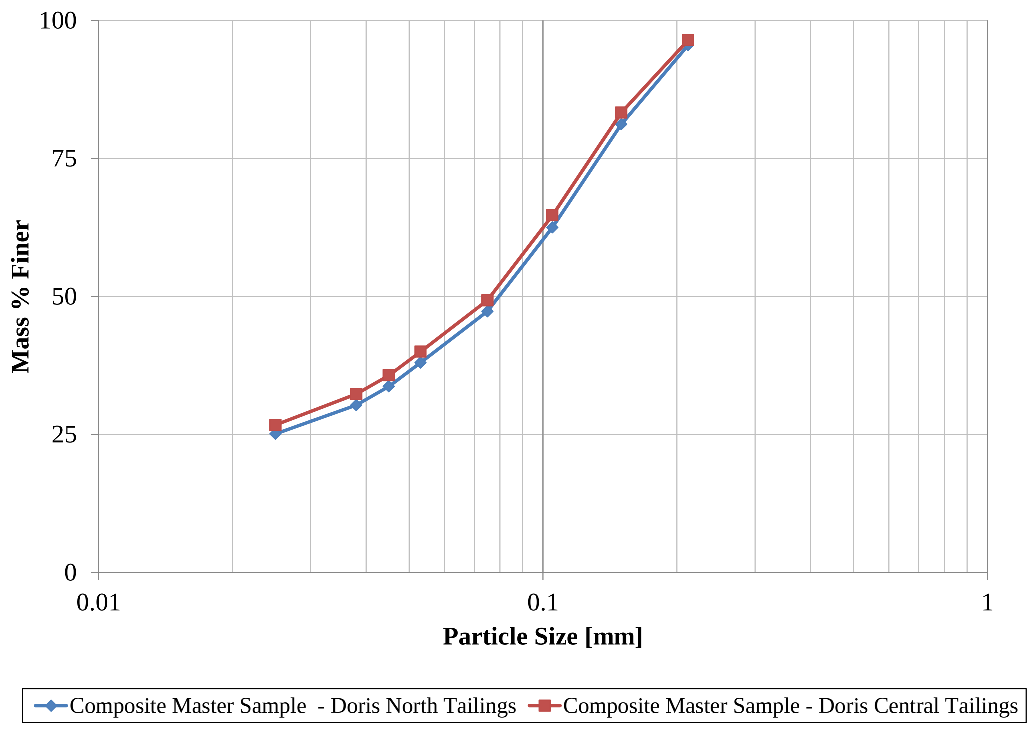

Figure 2: Typical particle size distribution range for tailings to be deposited in Tail Lake

4.3.2 Density

Table 2 summarizes typical range of tailings solids density for the Project as determined through testing (SRK 2009). Tail Lake will receive either flotation tailings only, alternately a combined stream of flotation and detoxified tailings. Since the volume of detoxified tailings, relative to the flotation tailings is very small (less than 10%), the blended product exhibit a solids density close to that of the flotation tailings.

Table 2: Typical Range of Solids Density for Tailings to be Deposited in Tail Lake

Tailings Type	Density (kg/m³)
Flotation tailings	2,760
Flotation tailings mixed with detoxified tailings	2,850
Detoxified tailings	3,460

4.4 Threshold Velocity

There are different empirical methods to estimate threshold velocities in fine particles under oscillatory waves (Komar and Miller 1975; Madsen and Grant 1975; Dingler 1979; MEND 1998). Lawrence *et al.* (1991) and MEND (1998) suggest that none of these methods may be directly applicable due to the thixotropic behaviour of tailings, and they stipulate that the only way to precisely determine the threshold velocity is through laboratory testing. Lawrence *et al.* (1991) does however comment that threshold velocity is relatively insensitive to water depth, and MEND (1998) therefore conceded that the use of these empirical methods is reasonable. Table 3 list threshold velocities calculated for Tail Lake, with the selected value being the lowest velocity, and thus the most conservative.

Table 3: Calculated Threshold Velocity for Tail Lake using Various Empirical Methods

Method	Realistic Case				Conservative Case			
	Median Particle Size (mm)	Fetch (m)	Max. Wind Speed (m/s)	Particle Density (kg/m³)	Median Particle Size (mm)	Fetch (m)	Max. Wind Speed (m/s)	Particle Density (kg/m³)
	0.080	290	21.9	2,850	0.076	626	27.1	2,760
Komar and Miller (1975)	0.741				0.785			
Dingler (1979)	0.471				0.519			
MEND (1998)	0.063				0.065			
Suggested Design Value (Minimum of Above Values)	0.063				0.065			

4.5 Ice Thickness

Ice thickness in Tail Lake for 1996, 2004 and 2006 through 2008 has been measured (Adly 2010). Based on this dataset the maximum recorded ice thickness in Tail Lake ranged between 1.4 and 2 m. Given the limited size of the dataset, ice growth (U.S. Army Corps of Engineers 2005) and decay models (Bilello 1980) was used to develop a long-term record of ice thickness estimations for Tail Lake and thereby reduce uncertainty. These models use daily average air temperature data to estimate how thick an ice layer would develop over time.

A correlation plot was developed to compare average daily air temperatures between the site specific weather station at Doris Lake (six years of data), to the long term dataset at Cambridge Bay (62 years of data). The analysis suggest that temperatures at Doris are slightly warmer than Cambridge Bay, and therefore using Cambridge Bay temperature data for ice thickness modeling will result in slightly conservative values. Figure 3 presents the daily average air temperature at Cambridge Bay compared to the simulated dataset for the Project site.

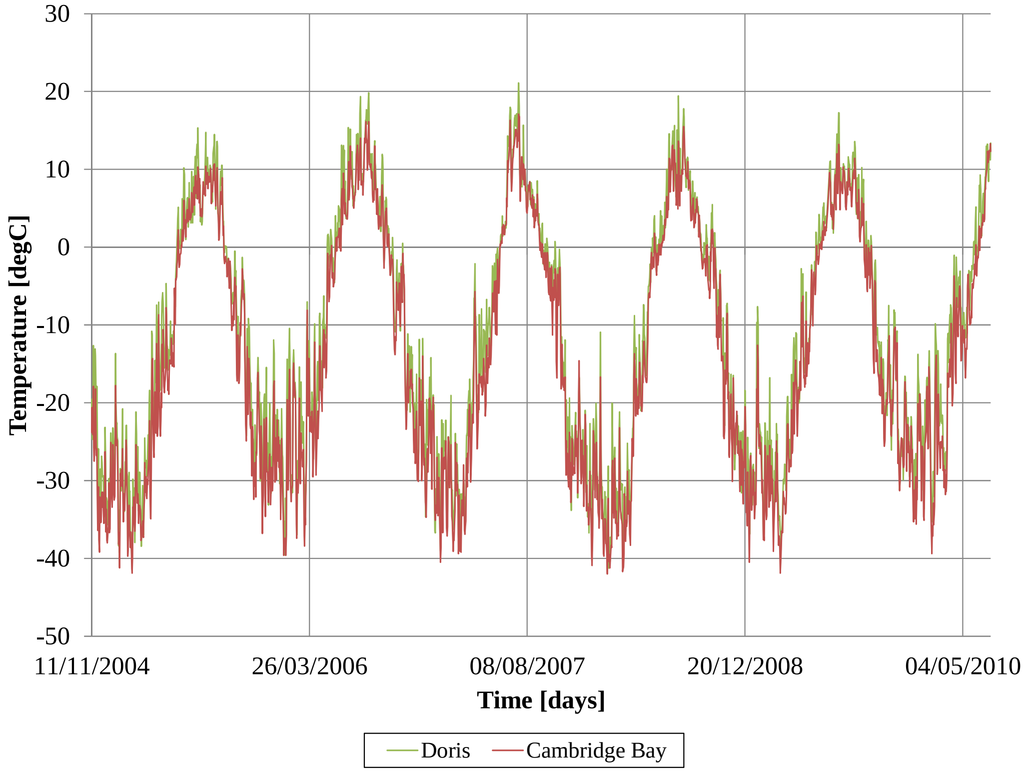

Figure 3: Measured Daily Average Air Temperature at Cambridge Bay Compared to Simulated Dataset for Project Site

The ice growth model includes an empirical factor α, which takes into consideration factors that typically influence ice growth such as physical and environmental characteristics of the lake (U.S. Army Corps of Engineers 2005). This parameter was calibrated (α = 2.53) using the measured ice thicknesses for Tail Lake, with the results presented in Table 4.

Table 4: Calibration of Tail Lake Ice Growth Model

Date	Measured Ice Thickness (m)	Modeled Ice Thickness (m)	
		@ Measurement Date	Seasonal Maximum
24-Apr-96	2.0	1.9	2.0
6-Jun-04	2.0	2.0	2.0
31-May-06	2.0	1.8	1.8
22-May-07	1.4	1.8	1.9
25-May-08	2.0	2.0	2.0

The modelled maximum seasonal ice thickness in Tail Lake over the period 1948 to 2009 is presented in Figure 4. Extrapolation of the probabilistic trend line suggests that the maximum ice thickness associated with 10 and 100 year recurrence intervals are about 2.01 m and 2.05 m respectively.

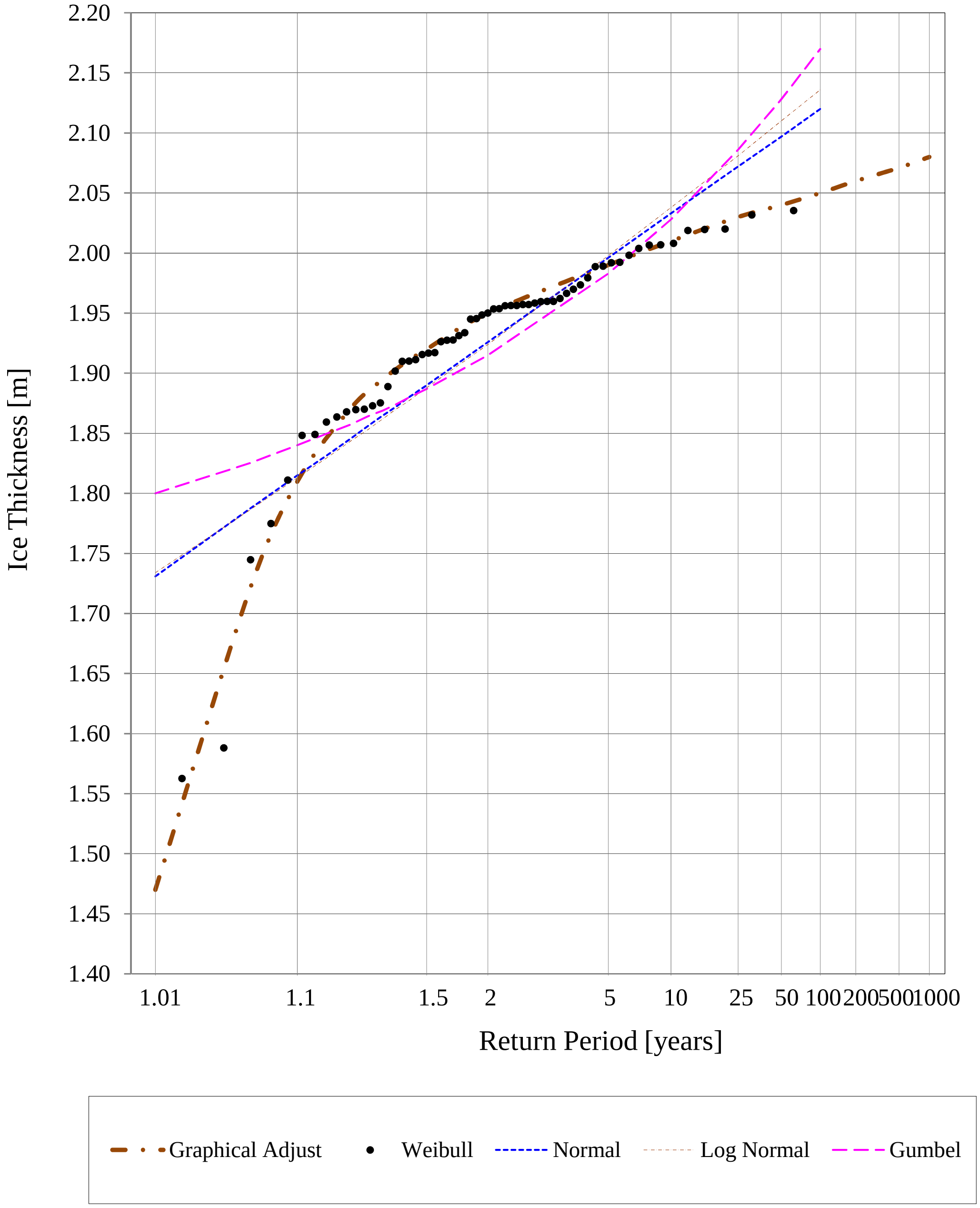

Figure 4: Modelled Maximum Seasonal Ice Thickness in Tail Lake

4.6 Summary of Water Cover Design Criteria

Table 5 present a summary of the primary design criteria used to calculate the Tail Lake water cover in accordance with the methods proposed by MEND (1998) and Lawrence *et al.* (1991). Two cases were evaluated; (1) the most “realistic” case, and (2) the “conservative” case. The “realistic” case represents the mostly likely set of design parameters, while the “conservative” case presents the most conservative range of all the individual design parameters.

Table 5: Summary of Tail Lake Water Cover Design Criteria

Parameter	Realistic Case (Case 1)	Conservative Case (Case 2)
Fetch (m)	290	626
Maximum Wind Speed (m/sec)	21.9	27.1
Median Particle Size (mm)	0.080	0.076
Threshold Velocity (m/s)	0.063	0.065
Particle Density (kg/m³)	2,850	2,760
Wave Height Ratio (dimensionless)	1.0	1.0
Ice Thickness	2.01	2.05

5 Water Cover Design Analysis

5.1 Wave Action Analysis

Results of the water cover design calculations are presented in Figures 5 through 8. Each of these figures show the minimum water cover as calculated using both the conservative Lawrence *et al*. (1991) and the less conservative MEND (1998) methods for Cases 1 and 2.

Figure 5 demonstrates the sensitivity of the calculation to fetch distance. As the fetch distance increases, the minimum water cover depth increases. The effect of wind speed on the water cover is illustrated in Figure 6. With increasing wind speed, the minimum water cover increases.

The MEND (1998) method uses the median particle size as a variable to account for bed shear stress, whilst the Lawrence *et al*. (1991) method uses the particle threshold velocity to account for bed shear stress. Figures 7 and 8 present the effect that different values of these properties have on the minimum water cover. As can be seen in Figure 7, as the median particle size increase, the required water cover decreases. Similarly, as the threshold velocity increases, the water cover reduces as illustrated in Figure 8.

As illustrated by Figures 5 through 8, using the MEND (1998) method results in a water cover thickness range between 0.12 m and 0.34 m, while the Lawrence *et al*. (1991) method, yields a range in water cover thickness from 0.85 m to 1.78 m. Therefore, for the chosen design parameters as listed in Table 5, the minimum water cover, depending on the Case or method of analysis used, ranges between 0.12 m and 1.78 m.

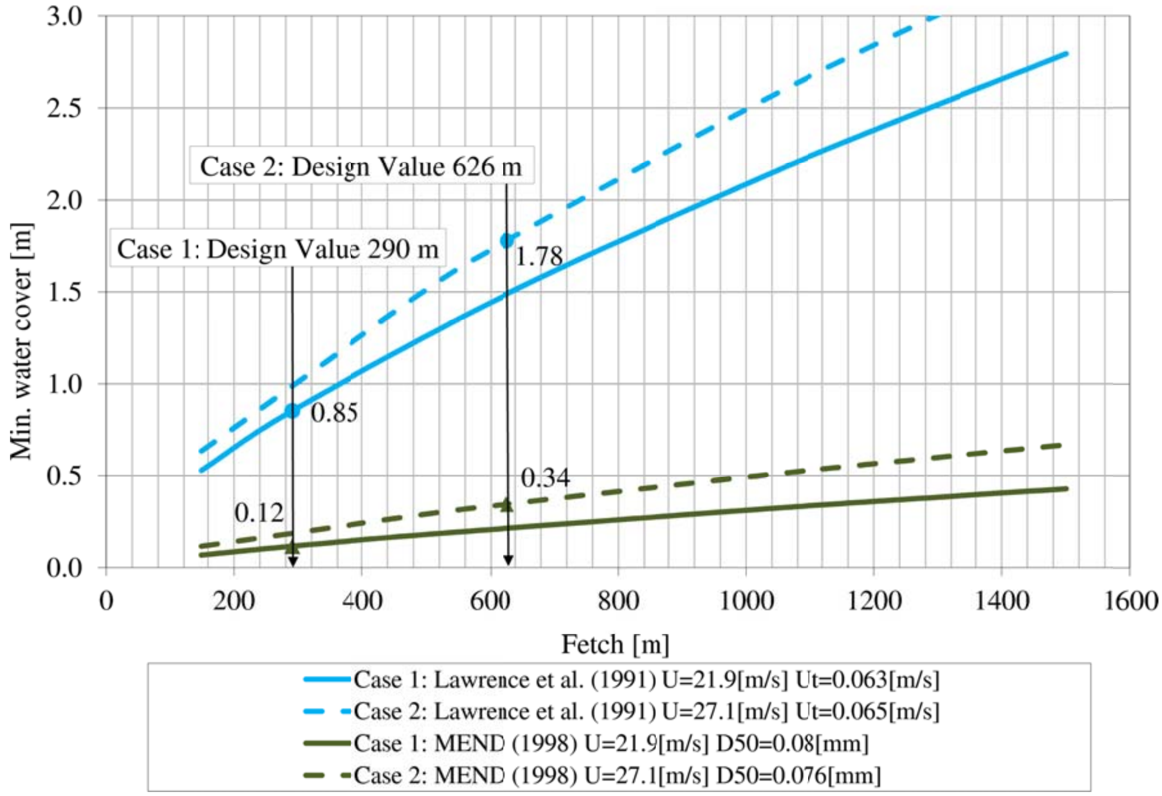

Figure 5: Water Cover Thickness as a Function of Fetch Distance

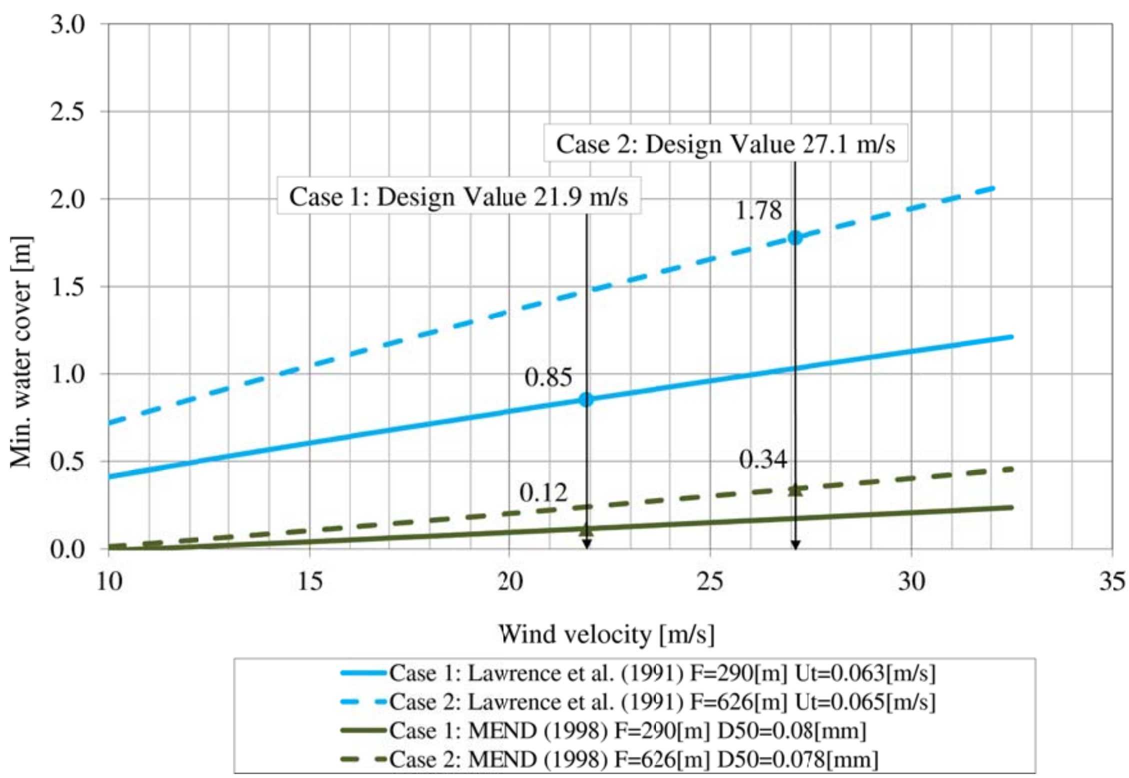

Figure 6: Water Cover Thickness as a Function of Wind Velocity

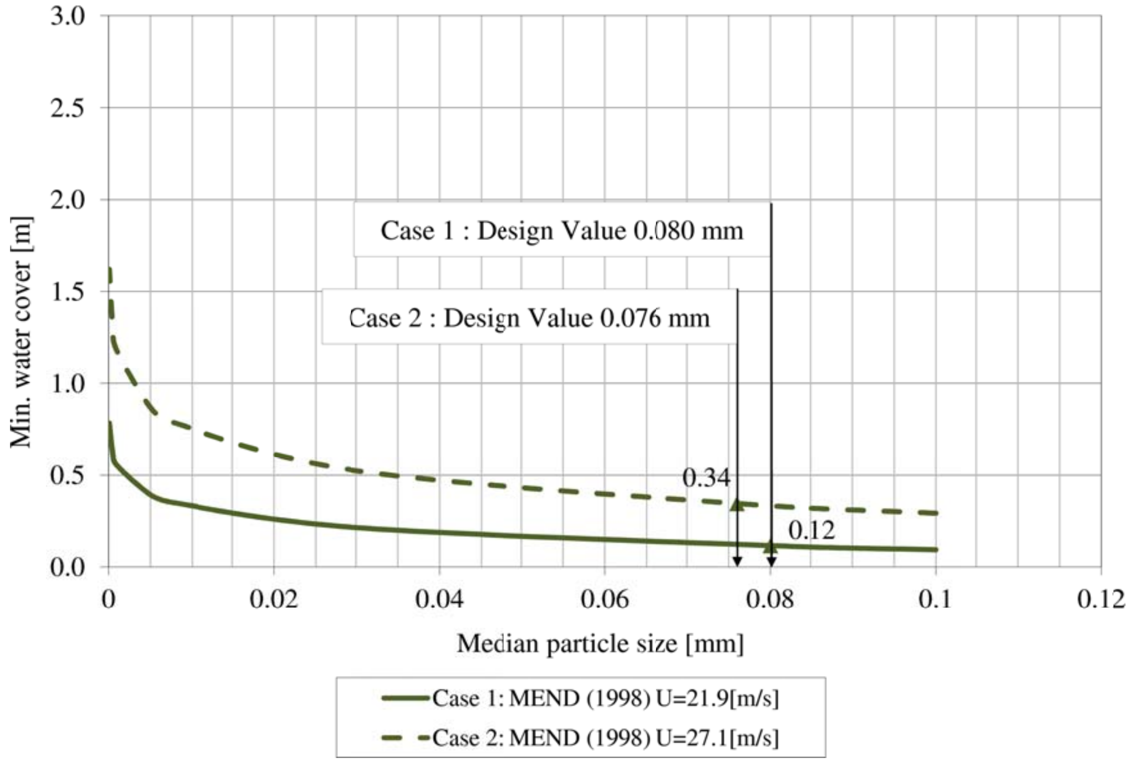

Figure 7: Water Cover Thickness as a Function of Tailings Median Particle Size

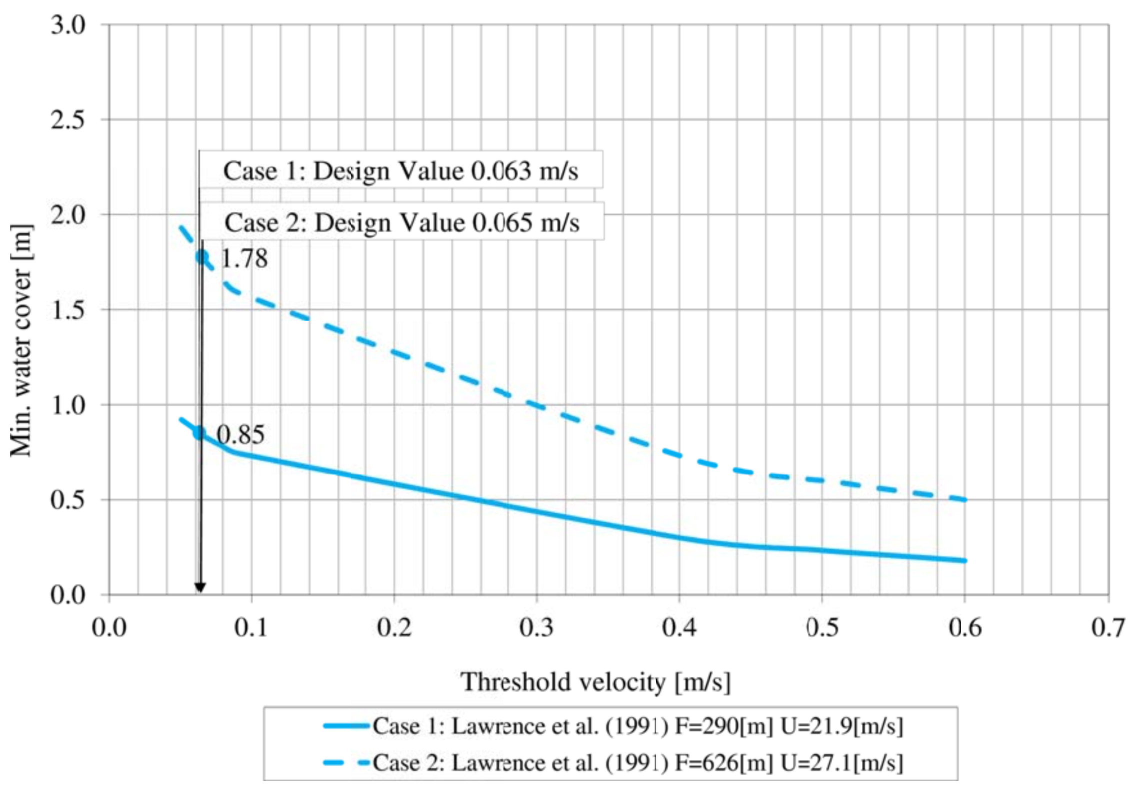

Figure 8: Water Cover Thickness as a Function of Threshold Velocity

The water covers calculated using the Lawrence *et al*. (1991) and MEND (1998) procedures assumes that wave development is consistent with deep water wave theory. Deep water wave theory applies when the ratio of water depth over wavelength is less than 0.5, which is a condition which is typically not met for shallow water covers (typically less than 5 m deep). Under such circumstances, shallow water wave theory must be applied, which results in calculating smaller significant wave heights and shorter significant wave periods.

Both Lawrence *et al*. (1991) and MEND (1998) design procedures acknowledge that the water cover design does not apply if the deep water wave condition cannot be met; however, they do not propose a solution to overcome this problem. The Shore Protection Manual of the U.S. Army Coastal Engineering Research Center (CERC 1984) does provide a procedure to calculate the significant wave height and period using shallow wave theory, and SRK conducted a sensitivity analysis on the range of input parameters evaluated for Tail Lake to determine how much the significant wave height and significant wave period would vary if the appropriate wave theory was applied. In this procedure was assumed that the wind speed is equal to the wind stress factor (Lawrence *et al.* 1991; Atkins *et al*. 1997; Yanful and Catalan 2002).

The results of this sensitivity analysis are presented in Figures 9 and 10 for Cases 1 and 2 respectively. SRK then substituted the appropriate shallow water wave theory significant wave height and wave period values into the Lawrence *et al*. (1991) and MEND (1998) formulations to allow a comparison of the results as presented in Table 6. The difference in calculated water cover thickness based on deep versus shallow water wave theory is so small (0.01 to 0.03 m) for Tail Lake that SRK is satisfied that the methods proposed by Lawrence *et al*. (1991) and MEND (1998) are acceptable.

Table 6: Water Cover Design Comparison using Deep Versus Shallow Water Wave Theory

Method		Deep Water Wave Theory	Shallow Water Wave Theory	Difference
Lawrence *et al*. (1991)	Case 1	0.85 m	0.83 m	0.02 m
	Case 2	1.78 m	1.75 m	0.03 m
MEND (1998)	Case 1	0.12 m	0.13 m	0.01 m
	Case 2	0.34 m	0.36 m	0.02 m

The analysis and sensitivity analysis has confirmed that the minimum water cover thickness due to wave action for Tail Lake will be between 0.85 and 1.78 m. Adopting the most conservative value therefore suggest that the minimum design water cover thickness due to wave action in Tail Lake should be 1.78 m.

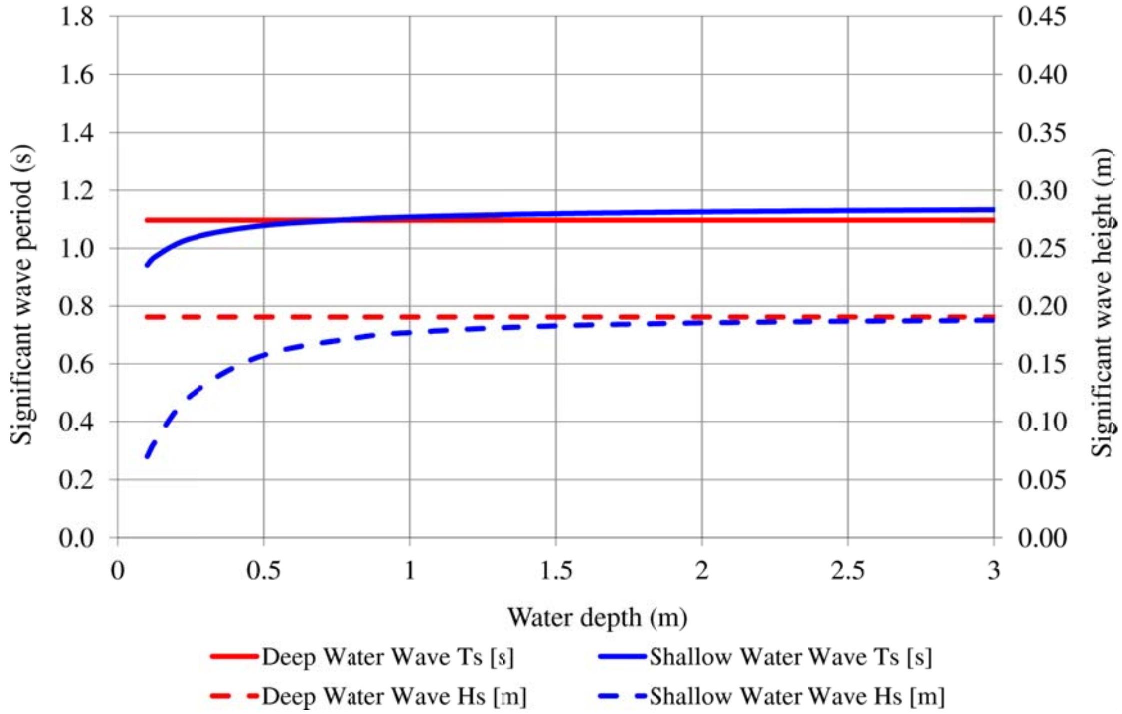

Figure 9: Variation of the Significant Wave Period and Wave Height over Different Water Covers using Both Shallow and Deep Water Wave Theory (Case 1)

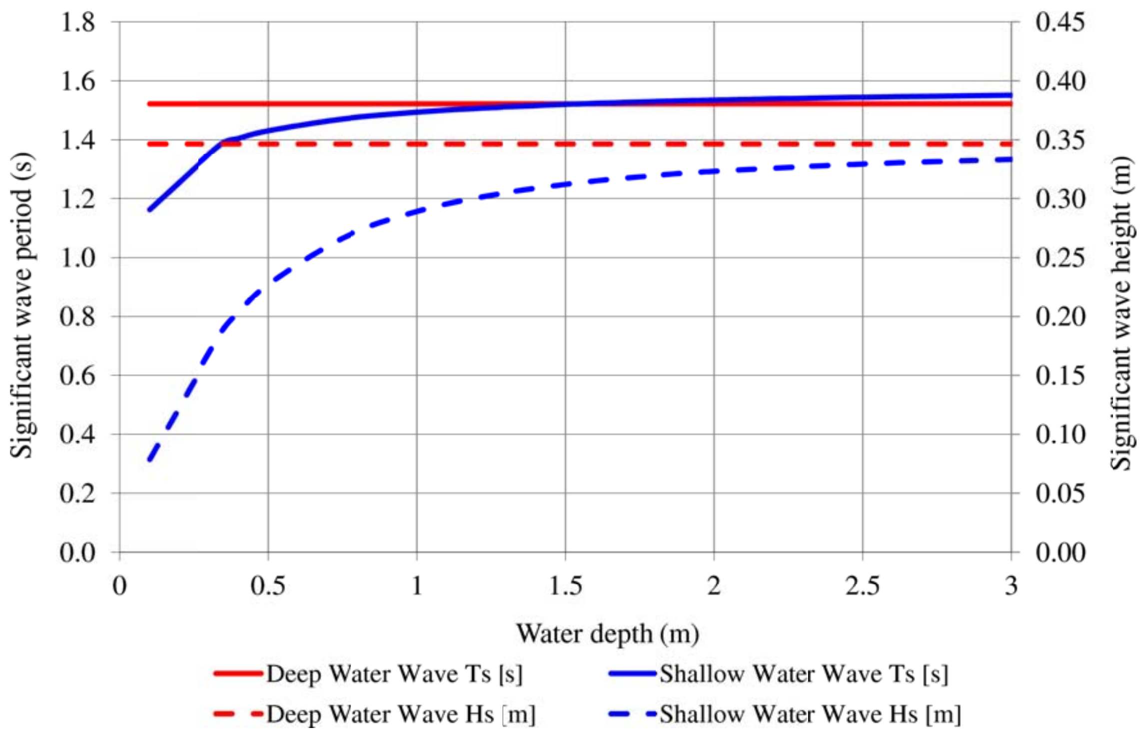

Figure 10: Variation of the Significant Wave Period and Wave Height Over Different Water Covers using Both hallow and Deep Water Wave Theory (Case 2)

5.2 Ice Entrainment Analysis

MEND (1998) recommends: "*The recommendation for the minimum water cover in a pond is that it should be at least 10% deeper than the maximum ice thickness at any time during winter months.*" The basis for this rule of thumb approach is that the 10% buffer provides a factor of safety against grounding of the ice. This factor of safety approach is used rather than suggesting development of complicated ice growth models to predict the maximum ice thickness.

As discussed in Section 4.5, SRK did produce an ice growth model for Tail Lake and calibrated it against measured ice thickness over a number of years. Based on this model the maximum ice thickness in Tail Lake based on a 100 year recurrence interval is predicted to be 2.05 m.

5.3 Severe Drought Analysis

The design guideline by MEND (1998) state that the water cover should be designed taking into account standard water balance principles; however, it does not provide any procedure for taking into account drought conditions. Yanful (2005) documents a detailed procedure to account for drought conditions in the evaluation of a minimum water cover design.

A drought analysis for Tail Lake was completed by introducing a 1:100 year drought following multiple years of average climatic conditions and evaluating how that would affect the total water cover thickness. The evaluation was done using the comprehensive site wide water and load balance model for Tail Lake (SRK 2011). The conclusion was that during all years of the analysis, including the drought conditions the annual inflows to Tail Lake are greater than the outflows. This implies that even with the drought conditions simulated, the lake water level will not drop below 28.3 m and therefore the minimum water cover thickness can be maintained during a severe drought.

5.4 Uneven Tailings Placement

While the water cover analysis assumes a struck level for the tailings surface, it is recognized that this is not practical. Given the shallow depth of Tail Lake, HBML would have to implement operational controls for tailings deposition to minimize these undulations. SRK recommends that a safety factor be built into the minimum water cover design to allow for some undulations. The recommended allowable tolerance should be 0.25 m.

6 Conclusion

The minimum water cover requirements for Tail Lake can be summarized as follows:

- Minimum water cover required to account for wave action is 0.12 to 1.78 m.
- Minimum water cover required to prevent ice scour is 2.05 m.
- Allowance required allowing for undulations in tailings surface is 0. 25m.
- Allowance required to allow for severe drought conditions is 0 m.

Therefore the overall minimum water cover for Tail Lake should be 2.3 m. A literature search was completed which confirmed that the typical range of water cover thicknesses at arctic mines in Canada and Sweden are between 0.2 and 2.5 m thick (Lawrence *et al.* 1991; Samad and Yanful 2003; Yanful 2002; Manlagnit 2008; Bjelkevik 2005; Julien *et al*. 2005; Peacey and Yanful 2002; Bennet and Yanful 2001; Mian and Yanful 2001; Atkins and Hay 1997). The recommended water cover for Tail Lake falls within the higher end of this range providing confidence that it is appropriate.

With the closure water elevation in Tail Lake set at 28.3 m, that means that the maximum level of tailings in Tail Lake would be 26.0 m. Therefore the total available capacity within Tail Lake for tailings is about 1,100,000 m^3. Assuming a tailings density of 1.293 t/m^3, and a daily production rate of 800 tpd, that means there is sufficient capacity in Tail Lake for about 1.4 Mt of tailings, or 58 months of operation while maintaining a 2.3 m water cover in Tail Lake.

Regards

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