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Memorandum

To:	Project File – 1CM014.02	**Date:**	May 10, 2004
cc:	Nathan Schmidt – Golder Associates Hugh Wilson – Miramar Hope Bay Limited Ben Hubert – Miramar Hope Bay Limited	**From:**	Maritz Rykaart
Subject:	Tail Lake water balance sensitivity analysis	**Project #:**	1CM014.02

This memorandum is in response to:

(1) A concern raised by Environment Canada during the Technical Sessions held in Yellowknife March 30 to April 1, 2004 and subsequent discussions between Chris Spence (Hydrologist with Meteorological Services of Canada) and Nathan Schmidt (Associate Senior Water Resources Engineer with Golder Associates), with respect to the Tail Lake water balance, specifically related to the fact that the Tail Lake tailings impoundment may not be suitably sized for the life of the project;

(2) A letter from Environment Canada dated April 26, 2004 in which EC reiterates their concerns regarding the water balance and the need for the proponent to provide contingency measures to manage the water balance uncertainty

1 Issues

Environment Canada (EC) had a number of specific concerns related to the Tail Lake tailings impoundment water balance, final impoundment volume and dam design height. Specifically these concerns were related to; (1) possible underestimation of mean annual runoff, (2) possible underestimation of mean annual precipitation, (3) intended impoundment lifespan, (4) dam crest height, (4) runoff factors in the water balance calculations, (5) lack of a water balance sensitivity analysis, and (6) mitigation measures to illustrate how uncertainties in the water balance will be managed.

The basis for all these concerns was related to the fact that if values of mean annual precipitation and mean annual runoff were underestimated, then the design capacity (i.e. the volume and dam height) of the Tail Lake impoundment was in question, and thus the entire water management strategy for Tail Lake was in question. EC acknowledged that the issue was not necessarily over the actual values of mean annual runoff or precipitation, since it would be extremely difficult to calculate these numbers precisely with the present baseline and regional data; however, EC requires a higher level of comfort on how the proponent is managing this uncertainty.

1.1 Underestimation of Mean Annual Precipitation

EC also commented that although they felt comfortable with the average annual precipitation (rainfall plus snow water equivalent) number of 207.3mm used by the proponent, they would expect the most anticipated average annual precipitation for the project area to be in the order of 225mm.

EC acknowledges that this value of 225mm cannot be defended rigourlesly, however as a minimum EC would prefer to see this value used in a sensitivity analysis.

1.2 Underestimation of Runoff (Water Yield)

EC is of the opinion that there is sufficient reliable regional data of similar sized catchments to confirm that the mean annual runoff (water yield) from Tail Lake should be in the order of 180mm as opposed the 111mm as used in the FEIS (MHBL, 2003). This constitutes an increase of 62% over the water yield used in the FEIS, and as such is expected to have a significant impact on the water balance calculations. EC would like to see that value be adopted in a sensitivity analysis for the Tail Lake water balance.

1.3 Consideration of Extreme Climatic Fluctuations in Water Balance

EC also felt that even though there is substantial uncertainty associated with the hydrological data, the Tail Lake water balance should include an evaluation of the impact of extreme climatic years. This would include the evaluation of the impact on the water balance on climatic years representing various recurrence intervals (i.e. 100-year wet or dry year).

1.4 Clarification of Runoff Numbers

SRK reported the use of a runoff factor of 29.6% in Supporting Document A5 (SRK, 2003a) of the FEIS. This number was an error. The mean annual precipitation used in the water balance was 207.3mm, and the mean annual water yield was 111mm, which should equate to a runoff factor of 53.5%. This runoff factor is applied to all precipitation falling on the catchment area, exclusive of the lake surface. The water balance is dynamic, and the lake surface area is recalculated after every month based on the Tail Lake stage curve.

This memorandum documents the findings of the Tail Lake water balance sensitivity analysis, using the revised mean annual precipitation and runoff numbers, suggested by EC. The runoff factors used in the sensitivity analysis are as follows:

- For a mean annual precipitation of 207.3mm and an associated mean annual water yield of 180mm, the runoff factor is 86.8%;
- For a mean annual precipitation of 225mm and an associated mean annual water yield of 180mm, the runoff factor is 80.0%.
- For any extreme climatic years, the runoff factor is calculated as the ratio of the proportionate water yield (runoff) to the specific recurrence interval annual precipitation.

1.5 Tailings Impoundment Design Life

EC expressed confusion as to the design lifespan of the tailings impoundment. It was their understanding that the Doris North Project was a two-year project. However, the Preliminary Tailings Impoundment Design (SRK, 2003a) documented in Supporting Document A5 of the FEIS, stated that the tailings impoundment has been designed to contain six years of tailings production, plus an additional four years of full containment.

SRK designed the Tail Lake tailings impoundment on the basis that the Doris North Project has confirmed ore reserves for a two-year mine life at a planned optimal production rate of 668 tonnes/day. However, in the selection of a suitable tailings disposal site, consideration was given to the potential for expansion of production from the Hope Bay belt, and, at the time of writing the FEIS the most likely expansion potential was the Doris Central and Doris Connector resources. If these reserves were to come on line it would add another four years of production (for a total mine life of six years) to the Doris North Project (*the proponent understands that this would be considered a new project and would be subject to a new permitting phase*). For this reason the Tailings Impoundment was designed for a six year mine life at an optimal production rate of 668 tonnes/day.

Furthermore, the Tail Lake water quality predictions confirmed that under a worst case scenario, if no decant was allowed during the six years of production, and decant was started in year seven, then by year ten, the water quality in Tail Lake should be of sufficiently good quality such that any water that flows into Tail Lake could be released, and thus no further containment capacity would be required. Therefore, the impoundment design allowed for an additional four years of full containment volume after the six years of production, for a total containment volume of ten years.

At the time of writing the FEIS, the proponent felt that this design allowed for ample conservatism, considering the fact that the FEIS is for the two-year Doris North Project. Essentially this design was adopted to ensure that the uncertainty was managed for the two-year project. The potential added benefit was that if additional production occurred at a later stage under a new project description, then additional tailings storage capacity would be available.

There is however no uncertainty about the lifespan of the Doris North Project; Doris Central and Doris Connector resources are not part of the Doris North Project. It will be a two-year life, and the tailings impoundment water balance sensitivity analysis presented in this memorandum covers that **two-year project only**.

1.6 Tailings Impoundment Crest Height and Freeboard

The tailings impoundment has been designed with both the North and South Dams at a crest elevation of **37.0m**. The full supply water level in Tail Lake, and the operational spillway elevation will be at **33.5m**. This allows for **3.5m** of freeboard which constitutes a **1m** settlement allowance and provides **2.5m** thermal protection. The 2.5m thermal protection freeboard requirement exceeded the 1.7m design freeboard requirement for wind induced waves, and therefore was selected as the critical parameter.

The maximum wave height was calculated resulting from a 160km/hr wind with a fetch of 3.2km. This would result in a wave height of 1.13m, which requires a 1.7m vertical freeboard height. Since the actual freeboard height is dominated by the thermal requirements, the dam can withstand waves as height as 1.67m, which exceeds the design requirement.

SRK documented dam crest heights in Supporting Document A5 of the FEIS, using the 1.7m hydraulic design freeboard, which resulted in the confusing, and incorrect crest elevation of 35.2m.

2 Precipitation and Water Yield Data Set

Subsequent to the Technical Sessions held in Yellowknife, March 30 to April 1, 2004, Golder Associates prepared two documents presenting the derived hydrological inputs for the Tail Lake water balance sensitivity analysis:

- Doris North – Water Yield Baseline, Sensitivity and Monitoring. Letter to Miramar Hope Bay Limited, dated April 22, 2004 (Attachment A); and
- Tail Lake Sensitivity Analysis – Derived Hydrological Inputs. Memorandum to Miramar Hope Bay Limited and SRK Consulting, dated May 5, 2004 (Attachment B).

These data were used to develop the Tail Lake water balance sensitivity analysis. Golder Associates presented synchronized monthly precipitation and water yield data. Under average annual conditions the water yield was set at 180mm and the average annual precipitation was kept at 207.3mm. This dataset was then further extrapolated to present data for wet and dry years with recurrence intervals of 10, 50 and 100 years.

3 Tail Lake Water Balance Sensitivity Analysis

3.1 Approach

The approach adopted in the Tail Lake water balance sensitivity analysis was to select a base case, and from that develop a number of scenarios illustrating how uncertainties could impact the water balance. The scenarios were developed based on probabilities of occurrence.

The water balance was calculated using the same basis as described in Supporting Document A5 of the FEIS, with the following changes adapted to the base case:

- The mean annual precipitation was 207.3mm.
- The mean annual water yield was 180mm.
- The runoff factor was calculated as: (mean annual water yield) / (mean annual precipitation) (i.e. 180mm/207.3mm = 86.8%).
- The mean annual lake evaporation is 220mm.
- The project life is two-years of tailings production at a constant rate of 668 tonnes/day.
- It was assumed that there would be no decanting from the tailings impoundment at any time – this is conservative and will add confidence to the results (*this is for the water balance sensitivity analysis only, since MHBL intends to decant whenever water quality allows*).
- Water for re-use in the mill will only be recovered for four months of the year.
- There will be no mine water pumped to the tailings impoundment (all Doris North ore resources are in confirmed permafrost and the mine temperature will be kept at -10^{o}C, so no mine water is expected – the number of 235m^3/day used in the FEIS was based on the fact that Doris Central and Doris Connector would come on-line; both reserves are located under Doris Lake which would be the source of the mine water. The proponent has subsequently confirmed that these reserves would not be mined).
- It was assumed that any seepage will be captured and returned to the tailings impoundment, therefore the water balance assumed zero seepage.
- The total sewage plant outflow volume of 68m^3/day is pumped to the tailings impoundment.

3.2 Results

The results of the Tail Lake water balance sensitivity analysis is presented in Tables 1 and 2. The “Case” column refers to the sequence of climatic events which was evaluated in terms of wet years with recurrence intervals of 10, 50 and 100 years. Since the primary water management issue associated with the Tail Lake tailings impoundment is containment of water, the sensitivity analysis was not run for extreme dry years. Extreme dry year results will show even longer water storage capacity, which implies greater safety margins in the design.

The probability of a case was simply calculated by assuming that if only mean annual climatic conditions occurred the probability would be 1:1. The probability of a scenario where at least one 100-yr wet year would occur prior to the impoundment reaching the full supply level of 33.5m was calculated as 1:100, and similarly the probability of two such events occurring during this period was calculated as 1:(100 x 100) or 1:10,000.

In all instances the water balance was run until the full supply level of **33.5m** in Tail Lake was reached. The “Total Time” column in Tables 1 and 2 reflect this time, and the “Post Operational Time” reflects the period of time after tailings deposition has stopped (i.e. “Total Time” less two years). The last column in Tables 1 and 2 reflect the volume of water stored in the tailings impoundment after tailings deposition has stopped, i.e. this is the incremental volume of water retained in the facility for the period after tailings deposition has stopped and before the full supply level of **33.5m** has been reached.

Table 1: Tail Lake water balance sensitivity analysis results assuming a mean annual precipitation of 207mm/yr.

Case	Probability	Total Time (years)	Post Operational Time (years)	Post Operational Volume (m^3)[a]
Base	1:1	9.08	7.08	3,481,014
1 x 10-yr	1:10	8.92	6.92	3,243,844
1 x 50-yr	1:50	8.75	6.75	3,057,414
2 x 10-yr	1:100	8.67	6.67	3,043,469
1 x 100-yr	1:100	8.75	6.75	3,026,145
3 x 10-yr	1:1,000	8.08	6.08	3,048,130
2 x 50-yr	1:2,500	7.75	5.75	2,658,840
2 x 100-yr	1:10,000	7.25	5.25	2,493,462
4 x 10-yr	1:10,000	7.75	5.75	3,106,028
1 x 100-yr; 1 x 50-yr; 1 x 10-yr	1:50,000	6.92	4.92	2,567,500
5 x 10-yr	1:100,000	7.08	5.08	3,022,041
3 x 50-yr	1:125,000	6.75	4.75	2,630,215
1 x 100-yr; 1 x 50-yr; 2 x 10-yr	1:500,000	6.67	4.67	2,556,063
3 x 100-yr	1:1,000,000	6.33	4.33	2,462,032
6 x 10-yr	1:1,000,000	6.83	4.83	3,090,919
1 x 100-yr; 2 x 50-yr; 1 x 10-yr	1:2,500,000	6.25	4.25	2,539,381
1 x 100-yr; 1 x 50-yr; 3 x 10-yr	1:5,000,000	6.25	4.25	2,572,145
4 x 50-yr	1:6,250,000	6.17	4.17	2,666,012

a. This water level in Tail Lake at this time in all cases will be 33.5m – the full supply level.

Table 2 presents selected results of the sensitivity analysis if the mean annual precipitation is increased to 225mm as suggested by EC. Only the results of the revised base case and the "worst" case, i.e. the case where the full supply level of the tailings impoundment is reached the quickest, are shown, since all the other scenarios follows the same trends as listed in Table 1.

Table 2: Tail Lake water balance sensitivity analysis results assuming a mean annual precipitation of 225mm/yr.

Case	Probability	Total Time (years)	Post Operational Time (years)	Post Operational Volume (m^3)
Base (225mm)	1:1	8.83	6.83	3,485,857
4 x 50-yr	1:6,250,000	6.00	4.00	2,656,432

It is clear from all the sensitivity runs that the time for the Tail Lake tailings impoundment to reach the full supply level of 33.5m is somewhere between 6 and 9 years, inclusive of the two-year operational period. This confirms that even under the most conservative assumptions, the earliest time at which the Tail Lake tailings impoundment will reach capacity would be after 6 years from the start of operation, which allows ample time to monitor the impoundment performance and water quality and to develop adaptive management type mitigative measures.

4 Impact on Water Quality Predictions

4.1 Principle

The water management approach for Tail Lake has been based on the principle that the only water that may be released from Tail Lake, would meet MMER guidelines, and a managed discharge strategy will be put in place to ensure that water is discharged into Doris Creek immediately above the 4.5m high waterfall where mixing would occur rapidly and the volume of discharge would be regulated to meet CCME guidelines downstream from the waterfall.

The predictive water quality modeling conducted for Tail Lake as documented in Supporting Document F8 (SRK, 2003b) of the FEIS, and subsequent supplemental information (MHBL, 2004a, 2004b) indicate that water quality in Tail Lake should meet MMER guidelines through natural degradation and dilution within Tail Lake itself. The predictive water quality results indicated that active discharge could be possible from year 1 of operations. As a contingency, the model also illustrated the net effect of only starting active discharge after all tailings deposition had ceased.

Furthermore, the predictive water quality model illustrated that copper would be the contaminant of concern after discharge to Doris Creek. Therefore the effects of the sensitivity calculations on copper concentrations for the revised water balance assumptions are discussed below.

4.2 Results

The predictive water quality modeling showed that after two years of tailings production the total load of copper in the free standing water in Tail Lake would be 39.8kg (SRK, 2003b). For the base water balance sensitivity case (with a mean annual precipitation of 207.3mm), the total water volume in Tail Lake after two years is 4,07 million m^3, which results in a copper concentration in Tail Lake of 0.0098mg/L. Assuming the baseline copper concentration in Doris Creek is 0.0016mg/L, and the total water yield from Doris Lake is 15 million m^3/year (based on an increased yield from 134mm to 180mm as suggested by EC), then the allowable load of copper that can be introduced into Doris Creek to still meet the CCME guideline for copper of 0.002mg/L is 6.00kg/year. Under all cases, the total free standing volume of water in Tail Lake at the full supply level of 33.5m is 7.55million m^3, and the associated copper concentration in the lake at that time would be 0.0053mg/L. Assuming this concentration, a volume of 1.12 million m^3 of water can be released from Tail Lake at this time, based on the assimilative capacity of Doris Creek. This exceeds the net inflow of 580,000m^3/yr to Tail Lake, and therefore the tailings impoundment is adequately and conservatively sized.

Under the scenario where the background copper concentration in Tail Lake is 0.0018mg/L, the allowable discharge from Tail Lake when it reaches full supply level is approximately 570,000m^3/year, which is only fractionally less than the inflow.

5 Contingency Measures

EC requested that the proponent illustrate through the use of the water balance sensitivity analysis how the uncertainty in the water balance would be managed. The proponent feels that the sensitivity analysis clearly shows that the uncertainty is well covered by the design water capacity of the tailings impoundment. There are no reasonable climatic conditions (inclusive of increased precipitation and runoff numbers) under which the impoundment is not adequately sized. The only condition, during which there is a small risk of the tailings impoundment not being adequately sized, is if the background copper concentration in Doris Creek is at or above 0.0018mg/L. It should be noted that the proposed water management strategy requires that water be discharged from the start of operations if all water quality parameters are met. This would provide additional storage capacity and further reduce any uncertainty.

The proponent also will adopt an adaptive management plan to deal with the very limited risk associated with the tailing impoundment capacity. This plan would entail ongoing monitoring of the impoundment water levels, climatic parameters, and water quality. Annually a water balance review would be carried out and compared to the predicted estimates. The proponent believes that a trigger of three years is an appropriate timeframe to set for adopting mitigative measures, and therefore every year this trigger date will be re-established based on the expected “worst case scenario”, which in this sensitivity analysis is for the time to fill of six years. The trigger would thus be in year three of the life of the facility, unless the annual review requires this date to be moved up.

A three year trigger period allows sufficient time to develop design and implement mitigative strategies which could include:

- Raising of the impoundment wall to increase storage, or
- Construction of a water treatment plant.

6 Conclusion

The Tail Lake water balance sensitivity analysis shows conclusively that for the two-year Doris North Project, the tailings impoundment is adequately sized, to match even the most extreme cases.

7 References

Miramar Hope Bay Limited (2003). Final Environmental Impact Statement, Doris North Project. November 2003.

Miramar Hope Bay Limited (2004a). Final Environmental Impact Statement, Doris North Project – Supplemental Information for Technical Session Discussions March 30 – April 1, 2004.

Miramar Hope Bay Limited (2004b). Supplemental Information Requests, Doris North project. Submitted to NIRB April 30, 2004.

SRK Consulting Inc. (2003a). Hope Bay Doris North Project – Tailings Impoundment Preliminary Design, Nunavut, Canada. Report submitted to Miramar Hope Bay Limited, October 2003.

SRK Consulting Inc. (2003b). Hope Bay Doris North Project – Predictive Water Quality Modelling, Nunavut, Canada. Report submitted to Miramar Hope Bay Limited, October 2003.

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22 April 2004 04-1373-002.2000

Miramar Hope Bay Limited
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Attention: Mr. Hugh Wilson, Manager, Environmental. Affairs

RE: DORIS NORTH – WATER YIELD BASELINE, SENSITIVITY AND MONITORING

Dear Mr. Wilson,

Technical Sessions for the MHBL Doris North Project were held in Yellowknife in April 2004. During these sessions, the question was raised as to whether the Doris Lake watershed water yields presented in the baseline study (AMEC 2003) were accurate. This memorandum discusses the derived baseline water yields and compares it to monitoring data collected during the baseline study. It also discusses uncertainty in the baseline data and future monitoring to reduce this uncertainty.

Monitoring Data

Monitoring data for the Doris Lake Outlet was collected during the baseline study, including the years of 1996, 1997, 1998, 2000 and 2003. These data were presented by Rescan (2002), AMEC (2003) and Golder (2003). Only partial data were collected in 1996 and 2003 and portions of the full-year data for 1997, 1998 and 2000 were estimated based on other hydrometric data collected in the region.

Comparison of Derived to Measured Water Yields

Derived and measured monthly and annual water yields for the Doris Lake outlet are shown in Table 1 and in Figure 1. In Figure 1, the blue band shows the range from mean to 10-year wet water yield and the red band shows the range from mean to 10-year dry water yield. These data show that, in general, the monitoring data fall within the band defined by the 10-year wet and dry water yields. This provides a comfort level, in that the derived baseline values are similar to measured data. However, it is not possible to definitively confirm the derived baseline values based on the data, due to a short period of record for the monitoring, the potential that measured data may not be clustered about the mean, and the fact that the data include incomplete years and estimated data.

Table 1 – Derived and Measured Monthly and Annual Water Yields for Doris Lake

Month	Derived Data[a]			Measured Data				
	10-Year Dry	Mean	10-Year Wet	1996	1997	1998	2000	2003
June	41.6	57.4	80.6	-	43.8	80.6	46.0	-
July	25.8	35.6	50.0	9.7	48.3	28.3	33.6	27.4
August	10.9	15	21.1	6.7	10.7	6.2	7.7	14.4
September	13.9	19.2	27.0	-	12.7	9.2	12.1	-
October	4.9	6.7	9.4	-	6.2	9.4	3.8	-
Annual	97	134	188	-	122	134	103	-

(a) Mean monthly, mean annual and extreme annual data were presented in the baseline study (AMEC 2003). Extreme monthly data are pro-rated based on mean monthly data.

Uncertainty in the Baseline Data

The derived mean annual water yield for the Doris Lake outlet (134 mm) is lower than those for other watersheds in western Nunavut, which are typically closer to 180 mm (Spence 2004). However, a water yield of 180 mm compares to a derived mean annual precipitation of 207 mm for the Doris North area (AMEC 2003), which would indicate a runoff coefficient of 87%. This is extremely high.

It is accepted that the water yield value of 180 mm represents the extreme upper limit of what might exist at the Doris North project, and that this incorporates uncertainty in runoff coefficient and precipitation. In discussions with Environment Canada personnel, it was agreed that this value would be used in a sensitivity analysis of the Tail Lake tailings facility. It was agreed that it would not be necessary to undertake a sensitivity analysis of the impact assessments of Doris Lake water level or decant into the Doris Lake outflow, since the existing analyses are conservatively based on the 134 mm value.

Future Monitoring

Monitoring of discharges from Doris Lake are planned for 2004 and subsequent years to provide additional baseline and operational data. This monitoring will include full open-water season data to further define baseline conditions and reduce the uncertainty of water yield estimates. Refined estimates will be incorporated into the operational plan for the Tail Lake tailings facility.

Conclusion

In response to questions regarding uncertainty in the derived values of mean annual water yield for the Doris North Project, a value of 180 mm was adopted as an extreme upper limit of what might be expected in the region. This was used in a sensitivity analysis of the Tail Lake tailings facility. Site-specific monitoring data are consistent with the derived baseline values, and data collection planned for 2004 and subsequent years will reduce the uncertainty of water yield estimates. The hydrology baseline data, impact analyses and sensitivity analyses are sufficient to move to the permitting phase for this project.

Yours very truly,

GOLDER ASSOCIATES LTD.

Nathan Schmidt, Ph.D., P. Eng.
Associate, Senior Water Resources Engineer

DOCUMENT1

References

AMEC 2003. Meteorology and Hydrology Baseline – Doris North Project. Prepared for Miramar Hope Bay Ltd. by AMEC Earth & Environmental Ltd., Burnaby, B.C., 20 p. + appendices.

Golder 2003. Doris North Project Aquatic Studies 2003. Prepared for Miramar Hope Bay Ltd. by Golder Associates, Edmonton, AB, 72 p. + appendices.

Rescan. 2002. Hope Bay Belt Project, 1993-2002 Data Compilation Report for Meteorology and Hydrology. Prepared for Hope Bay Joint Venture by Rescan Environmental Services Ltd., May 2002.

Spence, C. 2004. Personal communication between Nathan Schmidt, Golder Associates and Chris Spence, Environment Canada hydrologist, during meeting in Yellowknife, 1 April 2004.

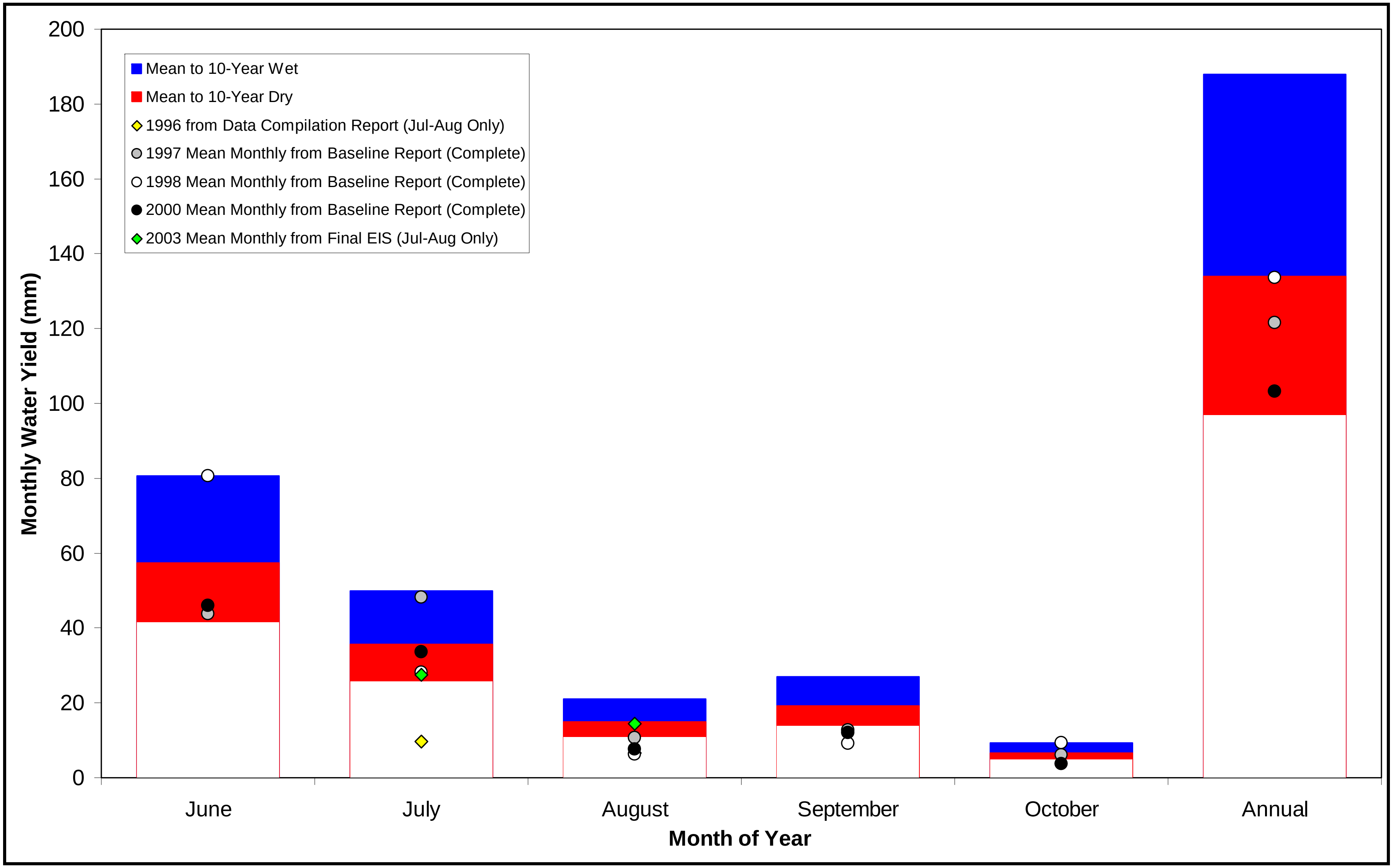

Figure 1 – Derived and Measured Water Yields at the Doris Lake Outlet

MEMORANDUM

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Golder Associates Ltd.
Telephone No.: 780-483-3499
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DATE: May 5, 2004 Proj No. 04-1373-002.2000

TO: Hugh Wilson (MHBL), Ben Hubert (Hubert & Associates), Maritz Rykaart (SRK Consultants)

FROM: Nathan Schmidt

RE: Tail Lake Sensitivity Analysis – Derived Hydrological Inputs

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Miramar Hope Bay Limited (MHBL) has requested that a monthly precipitation and water yield series be prepared for the Doris North project. This series will be used to simulate natural variation on the sensitivity analysis of the Tail Lake tailings facility. The sensitivity analysis has a specified mean annual water yield of 180 mm.

Natural variation of water yields is best characterized by examining long-term records from regional Environment Canada hydrometric stations. The stations considered in this analysis are presented in Table 1.

Table 1 – Regional Environment Canada Hydrometric Stations Considered for Analysis

Station Name	Station Number	Drainage Area	Period of Record	Years with Complete Data	Mean Annual Water Yield
Thelon River above Beverley Lake	06JC002	65,600 km^2	1970 – Present[a]	16	181 mm
Baillie River near the Mouth	10RA002	14,500 km^2	1978 – Present[a]	14	188 mm
Tree River near the Mouth	10QA001	5,810 km^2	1978 – Present	25	194 mm
Hood River near the Mouth	10QB001	15,600 km^2	1993 – Present	4	157 mm
Burnside River near the Mouth	10QC001	16,800 km^2	1976 – Present[a]	15	266 mm
Gordon River near the Mouth	10QC002	1,530 km^2	1977 – 1994	16	197 mm
Ellice River near the Mouth	10QD001	16,900 km^2	1971 – Present[a]	14	179 mm

(a) Data prior to 1984 are unreliable according to Environment Canada

From the stations listed in Table 1, the record from the Gordon River (Station 10QC002) was selected for derivation of a monthly water yield series, on the basis of close proximity to site, small drainage area and relatively long period of record with complete annual data set. Monthly water yields were calculated for the period 1978 – 1983 and 1985 – 1994 (16 years) by applying a factor of 0.914 to account for the difference in annual water yields (180 mm / 197 mm).

The tailings water balance also requires a monthly precipitation series as input. The rainfall and snowfall series derived in the hydrology baseline report (AMEC 2003) were examined and initially it was thought that this series would be appropriate for use. However, the series of annual precipitation-to-runoff (annual rainfall, snowfall from January to October, and snowfall from November and December of the preceding year) was compared to the derived runoff series, and was found to be poorly correlated. Therefore, this alternative was not selected.

To derive a precipitation series consistent with the water yield series, the following method was used:

- The annual precipitation was taken as the sum of corrected rainfall plus snowfall, as derived in the baseline study was adopted (207.3 mm);
- The mean monthly distributions of rainfall and snowfall (Table 8 in the baseline study) were adopted;
- Natural variation was incorporated by assuming that the difference between annual precipitation and annual water yield is constant and represented by the mean annual values (207.3 mm – 180 mm = 27.3 mm);
- Precipitation was derived based on the derived annual water yield. The annual water yield was added to the 27.3 mm value derived in the previous to derive annual precipitation-to-runoff. The mean monthly distribution of precipitation was then applied to derive the January-to-October precipitation for that year and the November-December precipitation for the previous year.

The derived water yield and precipitation series are presented in Table 2. Note that the incomplete year of 1984 has been skipped.

The issue of whether the derived precipitation series is representative of local conditions was discussed with Chris Spence (Environment Canada Hydrologist) on May 3, 2004. He indicated a level of comfort with the mean annual value of 207.3 mm, but suggested that a value of 225 mm might be the most anticipated at the project site. The sensitivity to this value could be examined by adding an extra 17.7 mm of direct precipitation to the lake for each year of the water balance.

A frequency analysis on the annual water yield and precipitation series has been undertaken and the results are presented in Table 3.

The derived water yield series is representative of the requested mean value to be applied in the sensitivity analysis and of long-term natural variation in a regional watershed. The derived precipitation series differs from the derived series presented in the baseline report, but is consistent with the water yield series and is representative of the annual mean and mean monthly variation presented in the baseline report. This water yield and precipitation series is provided solely for the purpose of incorporating natural variation into a sensitivity analysis for the Tail Lake water balance.

Table 2 – Derived Water Yield and Precipitation Series for Tail Lake Water Balance Sensitivity Analysis

Month	WY (mm)	Precip (mm)	Month	WY (mm)	Precip (mm)	Month	WY (mm)	Precip (mm)	Month	WY (mm)	Precip (mm)
Nov-77		12.9	Dec-81	0.0	10.5	Jan-87	0.0	11.1	Feb-91	0.0	6.8
Dec-77		10.4	Jan-82	0.0	7.3	Feb-87	0.0	11.6	Mar-91	0.0	8.8
Jan-78	0.0	7.2	Feb-82	0.0	7.6	Mar-87	0.0	15.0	Apr-91	0.0	9.7
Feb-78	0.0	7.5	Mar-82	0.0	9.8	Apr-87	0.0	16.5	May-91	7.1	12.8
Mar-78	0.0	9.7	Apr-82	0.0	10.8	May-87	0.1	21.7	Jun-91	52.4	14.1
Apr-78	0.0	10.7	May-82	0.0	14.2	Jun-87	95.9	24.0	Jul-91	33.6	19.9
May-78	0.3	14.1	Jun-82	20.4	15.7	Jul-87	61.1	33.8	Aug-91	16.9	25.1
Jun-78	37.1	15.5	Jul-82	42.0	22.1	Aug-87	45.4	42.8	Sep-91	19.5	21.9
Jul-78	79.8	21.9	Aug-82	48.7	28.0	Sep-87	37.6	37.3	Oct-91	8.7	22.0
Aug-78	27.0	27.7	Sep-82	37.2	24.4	Oct-87	17.8	37.4	Nov-91	3.1	14.5
Sep-78	11.0	24.1	Oct-82	11.1	24.5	Nov-87	1.8	14.4	Dec-91	0.0	11.7
Oct-78	2.7	24.2	Nov-82	1.2	12.0	Dec-87	0.0	11.6	Jan-92	0.0	8.0
Nov-78	0.5	13.3	Dec-82	0.1	9.6	Jan-88	0.0	8.0	Feb-92	0.0	8.4
Dec-78	0.1	10.7	Jan-83	0.0	6.6	Feb-88	0.0	8.4	Mar-92	0.0	10.9
Jan-79	0.0	7.4	Feb-83	0.0	7.0	Mar-88	0.0	10.8	Apr-92	0.0	12.0
Feb-79	0.0	7.8	Mar-83	0.0	9.0	Apr-88	0.0	11.9	May-92	0.2	15.8
Mar-79	0.0	10.0	Apr-83	0.0	9.9	May-88	0.0	15.7	Jun-92	111.9	17.4
Apr-79	0.0	11.0	May-83	0.0	13.0	Jun-88	74.0	17.3	Jul-92	47.6	24.5
May-79	0.3	14.5	Jun-83	44.3	14.4	Jul-88	34.1	24.4	Aug-92	12.9	31.1
Jun-79	79.0	16.0	Jul-83	33.9	20.3	Aug-88	24.3	30.9	Sep-92	5.7	27.0
Jul-79	57.5	22.5	Aug-83	27.8	25.7	Sep-88	26.2	26.9	Oct-92	2.8	27.1
Aug-79	12.3	28.5	Sep-83	26.3	22.3	Oct-88	19.9	27.0	Nov-92	0.0	18.6
Sep-79	9.3	24.8	Oct-83	11.8	22.4	Nov-88	1.4	14.5	Dec-92	0.0	15.0
Oct-79	4.1	24.9	Nov-83	0.8	18.1	Dec-88	0.0	11.7	Jan-93	0.0	10.4
Nov-79	1.2	9.9	Dec-83	0.0	14.5	Jan-89	0.0	8.1	Feb-93	0.0	10.9
Dec-79	0.2	8.0	Jan-85	0.0	10.0	Feb-89	0.0	8.5	Mar-93	0.0	14.0
Jan-80	0.0	5.5	Feb-85	0.0	10.5	Mar-89	0.0	10.9	Apr-93	0.0	15.4
Feb-80	0.0	5.8	Mar-85	0.0	13.5	Apr-89	0.0	12.0	May-93	0.0	20.3
Mar-80	0.0	7.4	Apr-85	0.0	14.9	May-89	0.1	15.9	Jun-93	132.7	22.4
Apr-80	0.0	8.2	May-85	3.7	19.7	Jun-89	107.7	17.5	Jul-93	75.4	31.6
May-80	3.2	10.8	Jun-85	75.7	21.7	Jul-89	43.8	24.6	Aug-93	13.8	40.0
Jun-80	41.1	11.9	Jul-85	54.1	30.6	Aug-89	17.5	31.2	Sep-93	12.5	34.8
Jul-80	21.1	16.8	Aug-85	32.0	38.7	Sep-89	7.8	27.2	Oct-93	6.5	35.0
Aug-80	19.7	21.2	Sep-85	49.4	33.7	Oct-89	4.5	27.3	Nov-93	0.2	16.3
Sep-80	24.7	18.5	Oct-85	15.9	33.9	Nov-89	0.6	13.4	Dec-93	0.0	13.1
Oct-80	4.5	18.5	Nov-85	1.8	15.2	Dec-89	0.0	10.8	Jan-94	0.0	9.0
Nov-80	0.6	12.6	Dec-85	0.0	12.3	Jan-90	0.0	7.5	Feb-94	0.0	9.5
Dec-80	0.0	10.1	Jan-86	0.0	8.5	Feb-90	0.0	7.8	Mar-94	0.0	12.2
Jan-81	0.0	7.0	Feb-86	0.0	8.9	Mar-90	0.0	10.1	Apr-94	0.0	13.4
Feb-81	0.0	7.3	Mar-86	0.0	11.4	Apr-90	0.0	11.1	May-94	42.3	17.7
Mar-81	0.0	9.4	Apr-86	0.0	12.6	May-90	0.0	14.6	Jun-94	81.4	19.5
Apr-81	0.0	10.4	May-86	0.2	16.6	Jun-90	69.7	16.1	Jul-94	19.4	27.6
May-81	4.4	13.7	Jun-86	88.8	18.3	Jul-90	44.8	22.7	Aug-94	18.1	34.9
Jun-81	66.8	15.1	Jul-86	62.3	25.8	Aug-90	15.9	28.8	Sep-94	32.3	30.4
Jul-81	27.7	21.3	Aug-86	15.9	32.7	Sep-90	21.4	25.1	Oct-94	11.9	30.5
Aug-81	11.9	27.0	Sep-86	16.4	28.4	Oct-90	12.9	25.2	Nov-94	1.4	
Sep-81	29.1	23.5	Oct-86	7.4	28.5	Nov-90	1.1	11.7	Dec-94	0.0	
Oct-81	11.8	23.6	Nov-86	0.8	19.9	Dec-90	0.0	9.4			
Nov-81	2.3	13.1	Dec-86	0.0	16.1	Jan-91	0.0	6.5			

Table 3 – Derived Annual Water Yield and Precipitation for Tail Lake Water Balance Sensitivity Analysis

	Derived Annual Water Yield (mm)	Derived Annual Precipitation[a] (mm)
1978	158.4	185.7
1979	164.0	191.3
1980	115.0	142.3
1981	154.0	181.3
1982	160.8	188.1
1983	144.9	172.2
1985	232.6	259.9
1986	191.7	219.0
1987	259.8	287.1
1988	180.0	207.3
1989	182.1	209.4
1990	165.9	193.2
1991	141.4	168.7
1992	181.1	208.4
1993	241.1	268.4
1994	206.8	234.1
Maximum	259.8	287.1
Mean	**180.0**	**207.3**
Minimum	115.0	142.3

(a) Precipitation expressed over hydrologic year November to October

Table 3 – Results of Frequency Analysis of Derived Annual Water Yield and Precipitation

Return Period	Annual Water Yield (mm)	Annual Precipitation (mm)
100-Year Wet	295	322
50-Year Wet	277	304
10-Year Wet	232	259
Mean	180	207
10-Year Dry	131	158
50-Year Dry	105	132
100-Year Dry	97	124