APPENDIX 11.II

Effects of Freshwater Extraction on Lou Lake

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11.II.1 INTRODUCTION

During operation of the NICO Project, freshwater will be extracted from Lou Lake for plant operation, potable water, construction, and dust control. Under average operating conditions, withdrawals are expected to be approximately 112 000 cubic metres (m^3)/year but could increase to 146 000 m^3/year in a dry year and are as high as 179 000 m^3/year during the maximum possible requirement for construction; these discharges correspond to flow magnitudes ranging from 3.6 to 5.7 litres per second (L/s). Mean annual discharge from Lou Lake is approximately 97.1 L/s ranging from a low of 29.7 L/s in September to 371 L/s in June; however, discharge from Lou Lake has been observed to cease in the winter (Annex G).

The purpose of this appendix is to assess the potential effects to Lou Lake resulting from freshwater withdrawal for the NICO Project. The method used in this assessment is characterized by withdrawing storage volume from Lou Lake and examining the effect on outflow and water levels as a result of the withdrawal.

11.II.2 METHODS

11.II.2.1 Water Balance Model Setup

The water balance model operates on a monthly time step for a full water year beginning in November and ending the following October. The model takes into account inputs to and outputs from Lou Lake such as runoff from the local watershed, inflows from upstream sub-basins, precipitation, snow melt and lake outflow. During operations, the water balance model also incorporates extractions from the lake. As the point of reference for this analysis was water surface elevation on Lou Lake itself, any volumes presented in millimetres are assumed to be distributed evenly over the surface area of the lake (approximately 1.99 square kilometres [km^2]).

11.II.2.2 Water Balance Variables

11.II.2.2.1 Freshwater Extraction

As discussed above, the annual fresh water requirements for the NICO Project during the start up year will be 112 000 m^3 under average climatic conditions but could increase to 146 000 m^3 during a 1:25 year dry year (Appendix 3.III). In the end year of operations, the annual fresh water requirements will be 112 000 m^3 in both the average and 1:25 year dry climatic conditions. Freshwater will be extracted at a constant rate year round. Freshwater will also be extracted from Lou Lake during the construction phase.

The rate of freshwater extraction during the construction phase is anticipated to be approximately 6.28 L/s corresponding to a withdrawal volume of approximately 179 000 m^3/year where this is the maximum anticipated withdrawal for each year of the 2 year construction period. This withdrawal rate is based on construction phase requirements including potable water usage of 306 m^3/day, dust control and drilling requirements of 180 m^3/day and approximately 1250 m^3 for the cement plant. However, the maximum length of construction activities is anticipated to be approximately 12 months and it is likely that the withdrawal volume of 179 000 m^3/year is very conservative.

11.II.2.2.2 Lake Evaporation

From the 55 year record for monthly lake evaporation, E (mm), presented by Golder (Annex G) the monthly 1:25 year dry lake evaporation was estimated using a Gumble (Extreme Value Type I) distribution for maxima. For each month, monthly mean evaporation values were ranked from smallest to largest. The subset of values less than the mean were used with a Gumble distribution to calculate the 1:25 year monthly evaporation. The mean and 1:25 year maximum evaporation for each month are presented in Table 11.II.2-1.

Table 11.II.2-1: Monthly Mean Evaporation, E (mm), During Average Climatic Conditions and the 1:25 Year Dry Year

Month	Mean E (mm)	1:25 Year Dry E (mm)
November	0	0
December	0	0
January	0	0
February	0	0
March	0	0
April	0	0
May	0	0
June	119	145
July	155	183
August	121	147
September	67	82
October	18	26

11.II.2.2.3 Precipitation

The record for monthly total precipitation, P (mm), presented by Golder (Annex G) had a record for 55 years. From this record the 1:25 year dry precipitation was estimated using a Gumble (Extreme Value Type I) distribution for minima. The monthly averages were sorted by month. The population for each month was ranked from largest to smallest then split according to rank with the lower half of the population being used with a Gumbel distribution to estimate the 1:25 year minimum value for total precipitation. It is worth considering that this methodology creates a very conservative estimate of precipitation, lower than any year on record in the 55 year period of collection. However, as discussed below, it is observed that even under this significant drought condition the Project has little effect on Lou Lake beyond what occurs naturally. The values of precipitation used in this assessment are provided in Table 11.II.2-2.

Table 11.II.2-2: Monthly Total Precipitation, P (mm), During Average Conditions and the 1:25 Year Dry Year

Month	Average Conditions (mm)	1:25 year dry (mm)
November	19	5
December	15	5
January	21	2
February	25	1
March	40	0
April	44	5
May	36	5
June	39	1
July	37	6
August	27	6
September	22	9
October	20	9

11.II.2.2.4 Runoff

The treatment of runoff was split into 2 cases, one case to account for runoff resulting from rainfall, and the second to account for runoff from the melt of accumulated snow in spring. When precipitation fell as rainfall, runoff from the terrestrial portion of sub-basin LL5 was calculated as a ratio of total monthly precipitation. The runoff ratios used are those in Table 11.II.2-3 under the Natural Ground Surface Runoff Coefficients column. Precipitation reporting to the lake surface is expected to report entirely to the lake without losses. The column identified as accumulation of runoff allows for the accumulation of snowfall and discrete proportioning of runoff such that 50% of the snowmelt occurs in May and the remainder accumulation occurs in June. Similarly, 50% of precipitation in October is accumulated as snowfall while the remainder reports immediately as runoff.

Table 11.II.2-3: Runoff Coefficients

Month	Natural Ground Surface Runoff Coefficients	Water Surface Runoff Coefficients	Accumulation of Runoff
November	0.6	1.0	0
December	0.6	1.0	0
January	0.6	1.0	0
February	0.6	1.0	0
March	0.6	1.0	0
April	0.6	1.0	0
May	0.5	1.0	50
June	0.4	1.0	100
July	0.3	1.0	100
August	0.3	1.0	100
September	0.3	1.0	100
October	0.4	1.0	50

11.II.2.2.5 Inflows from Upstream

Lou Lake receives inflow from approximately 33.5 km^2 of upstream watershed consisting of sub-basins LL1, LL2, LL3, and LL4. Inflow from upstream, $Q_{in,upstream}$ (m^3/month), was defined as the sum of the mean monthly flow at LL2 and LL3, Q_{LL2} and Q_{LL3} respectively. Mean monthly values for $Q_{in,upstream}$ were derived from the flow record (Golder 2010). During the 1:25 year dry period, inflow from upstream is based on percentile ranking of the monthly values in the flow record. The average upstream inflow and 1:25 year dry inflow monthly volumes are presented in Table 11.II.2-4.

Table 11.II.2-4: Upstream Inflow to LL5

Month	Average Inflow to LL5 (m^3)	1:25 Year Dry Inflow to LL5 (m^3)
November	141 031	62 505
December	146 271	80 915
January	128 965	88 648
February	112 369	80 932
March	121 838	113 539
April	110 786	98 378
May	449 512	155 649
June	559 043	224 470
July	176 900	88 921
August	131 128	65 960
September	98 970	60 106
October	135 206	62 335
Total	**2 312 017**	**1 182 356**

m^3 = cubic metres

11.II.2.2.6 Storage

Initial storage was calculated based on bathymetry data collected on 16 July 1998 by Golder (2005). The bathymetry data was used to create a relationship between Lou Lake Stage at station L-A, $z_{w.s.}$ meters above local datum (mald), and total storage, S (m^3) for the upper 2 m of the lake. The initial condition for total storage was calculated using Equation (1) evaluated at the initial condition for lake level assumed to be approximately 96.730 mald. Subsequent calculations of storage and elevation were also evaluated using Equation (1).

$$S = \frac{z_{w.s.} - 89.042}{5.9699(10^{-7})} \quad (1)$$

Starting at the initial condition, the monthly change in storage, ΔS (m^3), was calculated as the residual of the monthly water balance.

$$\Delta S = P - E - X - Q_{out} + Q_{in} + R \quad (2)$$

$$S_t = S_{t-1} + \Delta S \quad (3)$$

An interim $z_{w.s.}$ for month, t, was derived for use in calculating outflow from S_t using Equation (1). Monthly average detention storage, S_{det} (m), was calculated as the height of the water surface above the outlet invert by subtracting the estimated invert elevation, z_{outlet} (mald) from the monthly average lake stage, $z_{w.s.}$ (mald). The invert elevation of the outlet is assumed to be approximately 96.509 m. To provide context the lowest observed elevation on Lou Lake was 96.585 mald in the fall of 2006.

$$S_{\det} = z_{w.s.} - z_{outlet} \quad (4)$$

11.II.2.2.7 Outflow

Information on the shape of Lou Lake's outlet and resulting rating curve were not available. To fill this gap a trapezoidal outlet was assumed and an iterative solution was used to establish the outlet dimensions. The outlet was taken to have a 24 centimetres (cm) wide base with a side slope of 0.05. Lou Lake outflow, Q_{LL5} (m^3/s) was calculated as a function of S_{det}. A synthetic rating curve was developed to simplify a critical flow condition out of a trapezoidal outlet with a 24 cm base with side slopes of 0.05.

11.II.2.2.8 Lake Level

A monthly average lake level adjusted for losses from outflow was calculated by subtracting monthly outflow from total storage and calculating lake level using Equation 2. The initial condition for the Lou Lake level was set at 96.730 mald during average climatic conditions. This was the average lake level calculated from the LL5 flow record using Equations 2 and 5 and the geometry assumed for the outlet.

11.II.3 RESULTS

The water balance model was run to evaluate the influence of the NICO Project operations on average monthly lake levels during average and 1:25 year dry climatic conditions. Each model was assessed for any of the possible withdrawal rates.

11.II.3.1 Model Performance

The validity of the model was evaluated relative to the monthly average streamflow at LL5 (Annex G). The model performed well, generally accounting for the timing of the peak and magnitude of outflow (Figure 11.II.3-1). It slightly overestimated discharge during the summer and fall and slightly underestimated flows through the winter months. The modelled discharge differed from the flow record discharge by approximately 159 000 m^3 or 5.1% of total outflow throughout the course of the year.

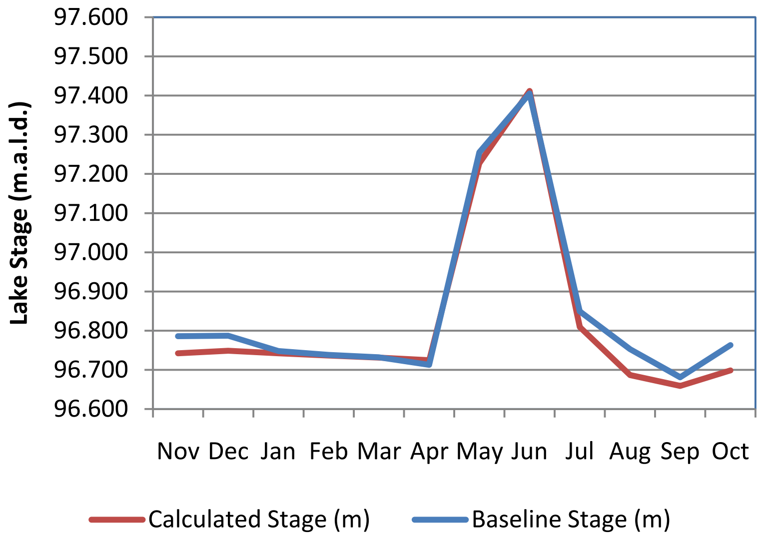

Figure 11.II.3-1: Modelled and Baseline Monthly Average Lake Stage for Lou Lake

11.II.3.2 Water Balance Results

11.II.3.2.1 Average climate conditions

Under the average climate conditions, lake stage was modelled for Lou Lake under four scenarios: No withdrawal (or the baseline condition), average annual withdrawal, 1:25 year dry withdrawal and the maximum annual construction withdrawal. The results of the four scenarios are presented in Figure 11.II.3-2. As observed from Figure 11.II.3-2, the net effect to Lou Lake as a result of freshwater withdrawal for the NICO Project is not anticipated to have a measureable effect on lake stage.

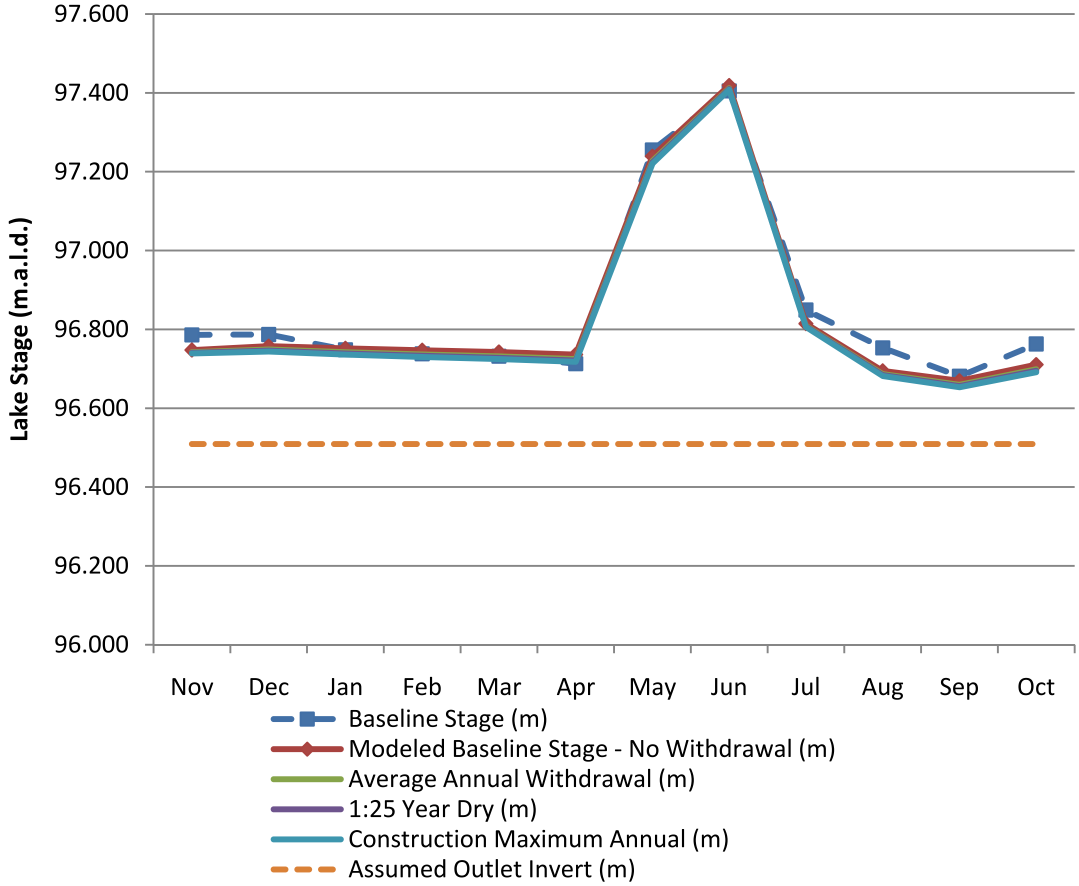

Figure 11.II.3-2: Average Climate Condition Withdrawal Scenario Effects on Lou Lake

11.II.3.2.2 1:25 Year Dry Climate Conditions

For the 1:25 Year Dry Climate Condition the four withdrawal scenarios were assessed for the effect on lake stage. As observed in Figure 11.II.3-3, the baseline condition of the 1:25 Year Dry period naturally draws the lake level down below the invert elevation of the outlet of the lake. The subsequent three withdrawal scenarios further lower the elevation of the water surface by a maximum of 4.7 cm.

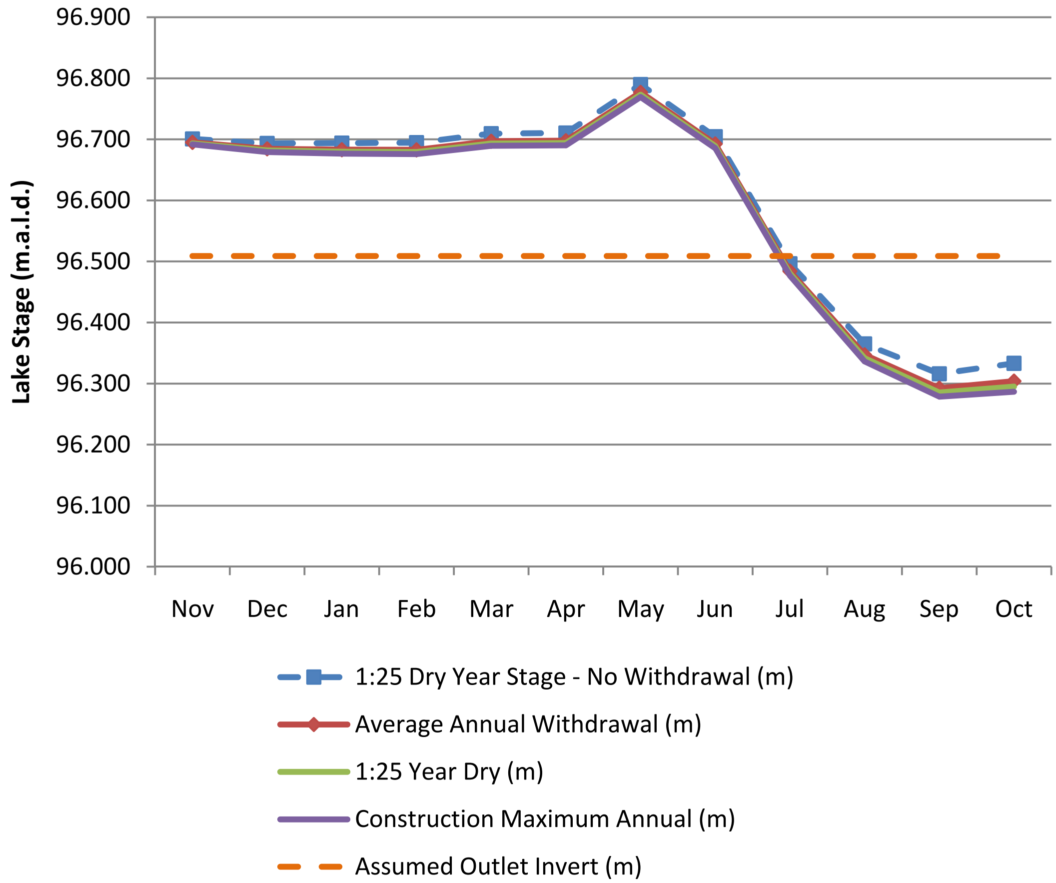

Figure 11.II.3-3: 1:25 Year Dry Climate Condition Withdrawal Scenario Effects on Lou Lake

11.II.4 UNCERTAINTY AND MITIGATION MEASURES TAKEN

The parameters and context presented here represent a statistical likelihood. The values presented may not actually ever occur. To be conservative, the 1:25 year extreme values were used for the primary drivers of the water balance model, total precipitation and lake evaporation. As there is uncertainty in statistically predicting any one climate parameter, there is added uncertainty in the likelihood that these circumstances will coincide. That is, a minimum total precipitation does not necessarily coincide with an increase in evaporation. To be conservative, it was assumed that the 1:25 year minimum precipitation will coincide with the 1:25 year maximum evaporation. Also, it was assumed that all months in the year will experience their 1:25 extreme values for precipitation and evaporation consecutively.

11.II.5 CLOSURE

It is expected that this appendix has provided a conservative estimate of how the level of Lou Lake may fluctuate in an exceptionally dry year. The maximum predicted change in Lou Lake relative to the natural, or baseline, condition of the lake is approximately 4.7 cm in a 1:25 year dry period coinciding with maximum required water withdrawal which occurs during construction. In general, it is anticipated that the average freshwater withdrawal condition in Lou Lake would not exceed 3.7% of the mean annual discharge and that the resultant effect on lake stage would not likely be a measurable.

11.II.6 REFERENCES

Golder (Golder Associates Ltd.). 2005. Draft Report on Environmental Surveys at Fortune Minerals NICO Property. Report No. 03-1117-029, January, 2005.

Golder. 2011. NICO construction water management. Report No. 10-1118-0046 (5900). February 2011.