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HYDROGEOLOGICAL COMPUTER MODEL

1.0 INTRODUCTION AND OVERALL APPROACH

A preliminary numerical model of the groundwater flow system was used to estimate likely ranges of groundwater inflow to open pit and underground mines at Tyhee's Ormsby and Nicholas Lake sites. The model objectives and the overall approach are provided below. Sections 2 to 5 of the report provide:

- a description of the conceptual hydrogeologic model of the site;
- the assumptions and procedures used to prepare the model and sensitivity analysis;
- the scenarios modelled, model limitations and results; and
- recommendations for model refinement.

Estimated monthly flows, based on modeled daily flows and monthly precipitation data, are also provided for comparison to other mines in the area.

The Ormsby and Nicholas Lake models were established using guidelines published by the American Society for Testing and Materials (ASTM). Specifically, the following guidelines were used to direct and report the modelling study results:

- ASTM D5447-93 – Standard Guide for Application of a Groundwater Flow Model to a Site-Specific Problem.
- ASTM D5610-94 – Standard Guide for Defining Initial Conditions in Groundwater Flow Modelling.
- ASTM D5490-93 – Standard Guide for Comparing Groundwater Flow Model Simulations to Site-Specific Information.
- ASTM D5611-94 – Standard Guide for Conducting a Sensitivity Analysis for a Groundwater Flow Model Application.
- ASTM D5609-94 – Standard Guide for Defining Boundary Conditions in Groundwater Flow Modelling.

2.0 HYDROGEOLOGIC MODEL OF THE SITES

Initial hydrogeologic investigations were conducted at the Ormbsy and Nicholas Lake sites as part of ongoing geotechnical assessment and mineral exploration activities. This section provides the hydrogeological conditions and stratigraphical units observed as a result of the hydrogeological investigations conducted at both sites and used in the model development.

2.1 HYDROGEOLOGICAL CONDITIONS AND STRATIGRAPHIC UNITS

Site hydrogeology in both mine areas can be conceptualized as a thin layer of unconsolidated glacially-derived overburden above fractured bedrock. In general, hydrogeologic units present at Ormsby include country rock consisting of greywacke, the ore body generally consisting of amphibolite, and a thin but potentially vertically extensive shattered greywacke or fault zone situated along the ore body's eastern boundary. The hydrogeologic units present at Nicholas Lake include meta-sedimentary country rocks and the ore body within mineralized granite/granodiorite. Groundwater is held in storage within the bedrock fractures. The Ormsby/Nicholas Lake areas are also known for discontinuous permafrost which has not been mapped to date.

Local recharge in the Nicholas Lake and Ormsby areas likely occurs via direct precipitation onto surficial unconsolidated sediments or from runoff from exposed bedrock and upgradient surface water bodies. Recharge to deep groundwater likely occurs via open fractures and faults as slow-moving regional-scale lateral flow and also as vertically downward migration from shallow sediments and fractured bedrock. This observation is supported by vertically downward gradients observed in most nested well pairs. However, indications of vertically upward gradients were observed at both Ormsby and Nicholas Lake, with artesian flow conditions observed at Ormsby.

Shallow bedrock conductivities based on instantaneous displacement (slug) tests conducted in Ormsby and Nicholas Lake wells ranged from 8.2 E-06 to 1.2 E-07 m/sec. Deep bedrock hydraulic conductivities based on packer testing at Ormsby ranged from 1.0 E-13 m/sec (essentially impermeable) to 4.2 E-07 m/sec in the greywacke and amphibolite, with hydraulic conductivities ranging between 2.7 E-08 to 1.0 E-06 m/sec in the shattered argillite/fault zone. Conductivities in Nicholas Lake bedrock ranged between 4.5 E-09 to 3.9 E-08 m/sec. The measured hydraulic conductivities in both areas did not appear to decrease with depth, indicating relatively uniform fracture permeability. Packer test data are summarized in Table 1, and conductivities based on slug tests are included as Table 2.

Groundwater was found at generally shallow depths in all wells and piezometers including those screened at significant depths. Groundwater depths ranged from about 1.8 m to 24.8 m below ground surface (bgs). These depths to groundwater measurements are consistent with those expected for groundwater in hydraulic connection with unconsolidated sediments and near-surface fractured bedrock and adjacent surface water bodies. Well/piezometer construction details and depths to water are provided in Table 3.

2.2 HYDROGEOLOGICAL BOUNDARIES

Based on overall local topography regional groundwater inflow beneath the Ormsby modelled area was interpreted to flow from northwest to southeast towards the mining area and the fault zone situated along the ore body's eastern boundary. Therefore groundwater inflow for the Ormsby area was established along the northwest model boundary and the mining area and fault zone were considered as of the groundwater system outflows.

At Nicholas Lake the proposed underground mining area is beneath a local topographical high as compared to the surroundings and insufficient topographic information was available to establish local groundwater inflow and outflow directions beyond the proposed mining area.

2.3 GROUNDWATER RECHARGE

The only significant source of groundwater in mining areas is from recharge from precipitation. For preliminary modelling purposes, the average annual precipitation of 263.9 mm/year (from 2004 to 2009) measured at the Tyhee Meteorological Station was used to estimate groundwater recharge. At Ormsby, all precipitation was considered as recharge in the proposed open pit mine area and surrounding lakes including Winter Lake, Round Lake, Narrow Lake, Bruce Lake and Lux Lake while 10% of precipitation was considered as recharge the remaining area of the model domain. At Nicholas Lake, all precipitation was assigned as recharged at Nicholas Lake and with 10% of the precipitation included as recharged in the remaining area. Precise determination of seasonal infiltration and recharge to the groundwater flow system via migration through the unsaturated zone was beyond the scope of this preliminary work.

3.0 GROUNDWATER MODELLING PROCEDURES

The numerical groundwater model of the Ormsby and Nicholas Lake sites utilized readily available and commonly used commercial software.

The computer code used and its applicability to the project objectives is summarized in the Section E3.1. Construction of the model including selection of the mesh size, input parameters and boundary conditions, and sensitivity analysis are described in Sections 3.2 to 3.6.

3.1 NUMERICAL CODE SELECTION

Several numerical codes are available for simulating groundwater flow conditions. As stipulated in ASTM guidance, the following factors were considered:

- capability to simulate both physical flow and transport. At this stage only flow simulation capabilities were required; however future transport simulations may be required.
- three-dimensional capabilities to depict both vertical gradients and a variable horizontal gradient;
- broad acceptance within the industry and general recognition as a standard; and
- the model should be based upon a rigorous mathematical code.

The code best meeting these criteria was FEFLOW, as published by WASY Institute of Water Resources Planning and Systems Research Limited Berlin Germany. FEFLOW is interactive graphic based finite element simulation system designed for subsurface flow and transport processes.

FEFLOW can characterize the flow system at both mine areas using multiple hydrogeologic units accounting for heterogeneity for subsurface material, surface water bodies and by also varying boundary conditions between layers.

3.2 MODEL AREA AND MESH DESIGN

Site plans showing the major features of Ormsby and Nicholas Lake sites are provided in Figures P1 and P3, respectively. Figures P2 and P4 show depth profiles of the mining areas for Ormsby and Nicholas lake sites, respectively.

Model superelements around the lakes, ore body, mining area and the rest of the surrounding rocks were established with refined meshes within the lakes, ore bodies, mining area and fault as compared to the surrounding rocks at both sites. The mining area in both models and the fault zone at the Ormsby site were further refined. The element type set was six nodded triangle prism. The total number of nodes and meshes at the Ormsby site were 50,420 and 74,925, respectively and 4,866 and 6,046 respectively at Nicholas Lake site.

The preliminary Ormbsy model was established as a three-dimensional, steady state, finite element numerical model containing with four slices and three layers. Available digital ground surface elevations were imported into the model as the first slice. The second, third and fourth slice depths were set at 5 m, 20 m and 450 m, respectively below the first slice, which in turn created three layers of 5 m, 15m and 430m thickness. Figure P1 shows the dimensions of the Ormsby model domain and major features.

The preliminary Nicholas Lake model was set up a three-dimensional, steady state, finite element numerical model with three slices and two layers. Similar to the Ormsby model, surface elevations data was imported to the model as the first slice. The second and third slice was set at 5 m and 330 m respectively below the first slice, which in turn created two layers of 5 m, and 325 m thickness. Figure P2 shows the dimensions of the Nicholas Lake model domain and major features.

3.3 HYDRAULIC PARAMETERS

Hydraulic parameters applicable to the preliminary groundwater flow models are hydraulic conductivity and storativity.

At Ormbsy three hydraulic conductivity zones each with an average hydraulic conductivity of 7.35 x 10-9 m/sec, 6.6 x 10-10 m/sec and 3.0 x 10-7 m/sec for the greywacke (surrounding rock), amphibolite (ore body) and fault, respectively were assigned. At Nicholas Lake an average hydraulic conductivity of 2.06 x 10-8 m/sec for both surrounding rock and ore body was assigned. Detailed conductivity information is provided in Table 1 and summary conductivities used in the preliminary models are provided in Table 2.

As shown in Table 1, no significant patterns in measured conductivities was observed with rock type, location or depth. Therefore, the bedrock units and hydraulic conductivities within each zone were considered to be homogenous and isotropic with depth. Rock conductivities were revised during the sensitivity analysis as shown in Table 4 to account for possible natural variability and support estimates of potential or likely inflow ranges to the mining areas.

The model storativity was assigned as 2 x 10-4, which is typical for fractured bedrock.

3.4 BOUNDARY AND INITIAL HYDRUALIC CONDITIONS

Lateral, bottom and top boundaries to the preliminary models were based on available hydrogeological and topographic data for each site.

At Ormsby, a constant groundwater head boundary was assigned to the northwest side of the model domain. The constant head was set as 5 m below the ground elevation along a contour line of 320 m in the northwest side of the model area with an approximate hydraulic gradient of 0.03 m/m between constant head boundary in the northwest to the mining area and the fault zone. The Ormsby mining area and the fault zone were designed as groundwater system outflows and were simulated with an initial hydraulic head of 5 m below the ground elevation to allow water levels to draw down during mining.

At Nicholas Lake, the proposed underground mining area is beneath a local topographical high as compared to the surroundings and therefore groundwater inflow and outflow directions beyond the proposed mining area and a regional hydraulic gradient was difficult to establish. However constant head boundaries were assigned to the northwest and southeast of the model domain with an assumed hydraulic gradient of 10 m elevation difference between both constant head boundaries.

The initial hydraulic heads were established using limited groundwater elevations observed in monitoring wells and piezometers. The groundwater head distribution is generally shallower than that observed but provides a conservative estimate of inflows to the mining areas.

All the lakes in both models were simulated as water filled storage with infinite hydraulic conductivity and 100% porosity with initial heads equal to lake elevations. This allows for lake water levels to draw down resulting from mining activities.

The initial heads in the lakes were assigned by adding the best estimates of lake level changes from a study conducted by EBA to topographical elevations measured at the lakes.

At Bruce Lake and Lux Lake the lake level changes data was not available therefore the highest topographical elevations measured at the lakes were used as initial heads.

The initial heads at the Lakes were assigned as follows:

Lake	Topographic Elevation (m)	Best Estimate Lake Level Changes (m)	Assigned Initial Head (m)
Winter Lake	286	0.254	286.254
Round Lake	290	0.367	290.367
Narrow Lake	282	0.341	282.341
Lux Lake	318	-	318
Bruce Lake	317.1	-	317.1
Nicholas Lake	324	0.341	324.341

The bottom and the remaining sides of the model domain were assigned as no flow boundaries.

3.5 SENSITIVITY ANALYSIS

Although hydraulic conductivities measured in Ormsby and Nicholas Lake rocks were generally uniform, a sensitivity analysis of the preliminary model results was conducted using higher and lower hydraulic conductivities to account for potential heterogeneity in rock characteristics and potential zones of increased groundwater entry into the mines. The varied conductivities and sensitivity analysis results are presented in Table 4.

4.0 PRELIMINARY MODEL RESULTS

The following sections describe the modelled scenarios details for the predictive simulation results, the preliminary results, and the model assumptions and limitations. Estimated monthly flows for each mine site are also provided.

4.1 MODEL CONSTRUCTION

At Ormsby, inflows to the mining area were simulated by modeling water level drawdowns in the open pit using three depth intervals with a fourth depth interval to model drawdown from the bottom of the open pit to the bottom of underground mine. The water level depth intervals were as follows;

1. Initial head (5 m below ground level) to an elevation of 220 m
2. 220 m to 115 m elevation
3. 115 m to 10 m elevation
4. 10 m to -250 m elevation

Boundary conditions at all depth intervals were assigned with hydraulic heads equal to the bottom elevations of each depth interval, and flow constrained with flux to the outside of the mining area as zero. This feature along with the moveable top surface in FEFLOW allows simulation of boundary heads within the mining area as seepage faces and to estimate inflows due to continued decline in heads within each interval.

At Nicholas Lake, inflows to the underground workings were conservatively modeled using a vertical rectangular prism with horizontal and vertical dimensions approximately corresponding to the mapped ore body. Initial groundwater elevations were established as 5 m below ground elevation with drawdown to the bottom of the underground workings which is set at +5 m elevation.

As detailed mine plans were not available, the preliminary Ormsby and Nicholas Lake models were conservatively designed to incorporate full build-out and steady-state conditions and were assumed to predict the most groundwater flow. Model runs continued for approximately 20 years until an approximate steady state hydraulic conditions were assumed to be reached.

The preliminary model results can be refined as additional mining plans become available.

4.2 RESULTS

As shown in Table 4, groundwater flow into the Ormbsy open pit and underground mine based on average measured bedrock conductivities is estimated at approximately 787 m^3/day. This flow does not appear to be sensitive to rock hydraulic conductivity, with flows only potentially increasing to about 987 m^3/day with increased greywacke conductivity and flows only increasing to about 1,155 m^3/day with increased fault conductivity.

Groundwater flows into the underground workings at Nicholas Lake appear to be more sensitive to bedrock conductivities. Flows using the measured conductivity is estimated at 86 m^3/day, with potentially lower flows of approximately 8 m^3/day using one order of magnitude lower rock conductivity and increased flows of approximately 1,300 m^3/day using one order of magnitude higher bedrock conductivity. Additional sensitivity checks of the regional groundwater regime at Nicholas Lake, run by assigning variable heads both with and without the hydraulic gradient, did not significantly change the simulation results.

Estimated monthly flows using approximate high and low flow ranges for each mine site are provided in Table 5. These values were estimated by multiplying the estimated daily flows by the number of days in each month, subtracting the model's estimated daily precipitation recharge, and by adding the estimated monthly precipitation recharge.

Monthly flows for Ormsby, assuming average daily flows ranging between 500 and 1500 m^3/day, were estimated to range between 13,444 and 49,691 m^3/mo. Monthly flows for Nicholas Lake, assuming average daily flows between 100 and 1200 m^3/day, were estimated to range between 2,800 and 42,336 m^3/mo. These values are similar to those observed at other comparable mine sites in NWT.

However, it is important to also note that zones of temporarily increased flow may be encountered during open pit and underground mining. These zones of increased flow may result from increased fracture density and/or openness, fault zone width or increased fault interconnectedness. The amount and duration of increased flow cannot be predicted with available data at this time.

4.3 MODEL ASSUMPTIONS AND LIMITATIONS

This preliminary model contains inherent limitations based on the fundamental assumptions needed to construct the model. One of the most significant assumptions, as discussed, is the potential range of bedrock hydraulic conductivity values. The modeled zones of hydraulic conductivities generally match the measured hydraulic conductivities at both sites however the possibility exists that zones with higher and lower conductivities may be present. The model assumes homogenous and isotropic conditions within each zone.

The Ormsby fault depth was also set to the model domain and its width was established as approximately 5 to 7m. Further information regarding the fault characteristics is unavailable, however current information suggests that the fault will likely be the major source of groundwater to the Ormsby mine.

There is quite a significant contrast between the hydraulic conductivities between the Ormsby ore body and the fault. The vertical gradient required in both models is extremely large i.e., from initial heads (5 m below ground elevation i.e., in the order of + 325 m elevation) to the bottom of excavation (-250 m). FEFLOW can reasonably estimate pit and underground workings inflows under these hydraulic conditions, with results reasonably corresponding to analytical results and the inflows measured in the surrounding areas however the wide difference in mine heads results in limitations to observable head changes distant from the mine areas.

Another assumption adopted for the model was the boundary head values. The head values and the gradient established at the boundaries were based upon the field observations and general topographical elevations. The topography is undulating and there is no detailed groundwater elevation map of the area to establish inflow and outflow boundaries or regional groundwater flow directions and gradients.

Similarly the initial groundwater head distribution is a conservative approach but no detailed data is available for head distributions. In addition, no temporal head elevation data is available to calibrate a transient model. The initial heads at the fault and within mining area are also assumed as conservative and accounts for the outflow of the groundwater flow system from northwest constant head boundaries.

The initial heads in the lakes are also a conservative estimate and assumed to account for the flow within the lakes due to streams connecting the lakes.

Although the area is known for discontinuous permafrost, no accounting for permafrost was included in the preliminary model as there is little quantitative difference between low bedrock conductivity and no-flow permafrost boundary.

Bedrock storativity assumed to be 2 x 10-4, which is typical for fractured bedrock.

4.4 MODEL VERIFICATION AND CALIBRATION

Numerical groundwater flow models are commonly calibrated by comparing simulated groundwater elevations at target wells/locations with actual water level measurements under different sets of aquifer stresses. If predicted changes in groundwater elevations reasonably match actual elevations, the model is considered to reasonably accurately represent actual hydrogeologic conditions in the modeled area. However, insufficient groundwater elevation and topographic data are available within the Ormsby and Nicholas Lake modeled areas to compare predicted drawdowns with actual data.

However, the estimated groundwater flow ranges are reasonably similar to those observed in other comparable open pit mines in the NWT area.

5.0 RECOMMENDATIONS

The estimated flows for both Ormsby and Nicholas Lake do not appear sufficient high to warrant installation and operation of dewatering wells. The flows should be manageable using sumps.

These are preliminary results and it is recommended that when a detailed mining plan and further hydrogeological data are available the model should be updated according to the mining plan, calibrated and precise results should be obtained prior to the execution of the mining plan.

Once the mining plan is available the model should be refined to estimate the inflow by drawdown of water levels at each mining stage and considering the results of first mining stage as initial conditions for the second mining stage. Other key recommendations include:

- Refine the model parameters to include permafrost areas and taliks;
- Refine the model parameters using more accurate deep and shallow geology characteristics;
- Refine the model parameters using more accurate and more extensive local topographic data;
- Improve knowledge of the fault's characteristics including location, thickness, and conductivity by additional drilling and packer testing;
- Characterize the fault zone hydrogeology and fracture interconnectedness by conducting long-term pumping tests;
- Improve understanding of shallow groundwater elevations and gradients by installing additional monitoring wells;
- Improve understanding of deep groundwater elevations including vertical gradients by installing additional VWP.

REFERENCES

ASTM D5610-94 – Standard Guide for Defining Initial Conditions in Groundwater Flow Modelling.

ASTM D5611-94 – Standard Guide for conducting a sensitivity analysis for a Groundwater Flow Model Application.

ASTM D5609-94 – Standard Guide for Defining Boundary Conditions in Groundwater Flow Modelling.

ASTM D5490-93 – Standard Guide for Comparing Groundwater Flow Model Simulation and Site-specific Information.

TABLES

TABLE 1a: SUMMARY OF HYDRAULIC PROPERTIES FROM PACKER TESTS AT NICOLAS LAKE

Borehole ID	Test	Lithology	Actual Interval Tested				Hydraulic Conductivity				
			From	To	Midpoint	Length of Interval	Min	Max	Average	Log(K)Average	$s_{Log(K)}$
			m bgs			m	m/s	m/s	m/s	---	
N 122	1	Granite	8.7	25.7	17.20	17.0	3.8E-08	1.0E-07	7.5E-08	-7.13	0.13
	2	ranite/Metase	38.7	55.7	47.20	17.0	2.1E-08	2.1E-08	2.1E-08	-7.68	0.01
	3	Metaseds	44.7	52.2	48.45	7.5	1.1E-08	5.2E-08	3.8E-08	-7.42	0.23
	4	Granite	68.7	85.7	77.20	17.0	5.2E-09	2.9E-08	1.6E-08	-7.81	0.21
	5	Granite	92.7	100.2	96.45	7.5	5.3E-08	1.0E-07	7.3E-08	-7.14	0.11
	6	Granite	98.7	115.7	107.20	17.0	7.0E-09	2.1E-08	1.5E-08	-7.82	0.11
	7	Metaseds	179.7	211.7	195.70	32.0	1.4E-08	2.6E-08	1.8E-08	-7.75	0.09
	8	Metaseds	194.7	211.7	203.20	17.0	2.3E-08	9.5E-08	4.0E-08	-7.39	0.26
N 123	1	Granite	14.7	31.7	23.20	17.0	1.6E-08	6.3E-08	2.7E-08	-7.57	0.15
	2	Granite	32.7	61.7	47.20	29.0	1.1E-10	7.5E-10	3.4E-10	-9.46	0.28
N 124	1	Granite	62.7	91.7	77.20	29.0	1.9E-09	1.4E-08	9.4E-09	-8.02	0.25
	2	Granite	173.7	187.7	180.70	14.0	1.4E-08	3.1E-08	2.1E-08	-7.69	0.14
	3	Granite	248.7	295.7	272.20	47.0	6.1E-09	1.1E-08	8.0E-09	-8.10	0.25
N 125	1	Granite	17.7	34.7	26.20	17.0	6.3E-09	7.7E-08	4.2E-08	-7.37	0.21
	2	Granite	38.7	55.7	47.20	17.0	1.0E-13	1.0E-13	1.0E-13	-13.00	0.00
	3	Granite	59.7	88.4	74.05	28.7	1.8E-08	3.5E-08	2.3E-08	-7.64	0.09
	4	Granite	101.7	118.7	110.20	17.0	3.2E-08	5.2E-08	4.1E-08	-7.38	0.06
	5	Granite	122.7	139.7	131.20	17.0	4.3E-08	7.1E-08	5.3E-08	-7.28	0.07
	6	Metaseds	140.7	154.7	147.70	14.0	6.2E-09	2.7E-08	2.1E-08	-7.67	0.15
	7	G.D/Metased	26.7	154.7	90.70	128.0	1.9E-08	2.6E-08	2.2E-08	-7.67	0.03

TABLE 1b: SUMMARY OF HYDRAULIC PROPERTIES FROM PACKER TESTS AT ORMSBY

Borehole ID	Test	Lithology	Actual Interval Tested				Hydraulic Conductivity				
			From	To	Midpoint	Length of Interval	Min	Max	Average	Log(K)Average	$s_{Log(K)}$
			m bgs			m	m/s	m/s	m/s	---	
NDM 436	1	Amphibolite	74.5	79.0	76.75	4.5	1.0E-13	1.0E-13	1.0E-13	-13.00	0.00
	2	Greywacke	89.5	97.0	93.25	7.5	1.5E-07	1.8E-07	1.63E-07	-6.79	0.03
	3	Greywacke	104.5	112.0	108.25	7.5	4.2E-08	2.6E-07	1.59E-07	-6.80	0.17
NDM 439	1	Greywacke	51.5	56.0	53.75	4.5	0.0E+00	0.0E+00	1.0E-13	-13.00	0.00
	2	Greywacke	119.5	136.0	127.75	16.5	1.3E-08	4.6E-08	2.3E-08	-7.63	0.11
	3	Greywacke	128.5	136.0	132.25	7.5	9.8E-09	5.4E-08	2.3E-08	-7.64	0.14
NDM 440	1	Greywacke	24.5	32.0	28.25	7.5	1.0E-13	1.0E-13	1.0E-13	-13.00	0.00
	2	Greywacke	63.5	71.0	67.25	7.5	1.0E-13	1.0E-13	1.0E-13	-13.00	0.00
	3	Greywacke	123.5	128.0	125.75	4.5	2.2E-08	5.1E-08	3.1E-08	-7.51	0.15
	4	Greywacke	132.5	140.0	136.25	7.5	2.0E-08	2.6E-08	2.2E-08	-7.67	0.04
NDM 542	1	Greywacke	0.0	0.0	0.00	0.0	0.0E+00	0.0E+00			
		Test could not be completed due to a very large fracture.									
NDM 543	1	Greywacke	9.0	20.0	14.50	11.0	2.1E-06	3.2E-06			
		Test suspended due to excess flows									
NDM 544	1	Fault/Amphil	23.6	43.6	33.60	20.0	4.2E-07	6.0E-07	5.1E-07	-6.29	0.05
	2	Amphibolite	47.6	64.6	56.10	17.0	4.7E-08	1.6E-07	1.0E-07	-7.00	0.20
	3	Amphibolite	68.6	91.6	80.10	23.0	6.3E-09	7.6E-08	5.2E-08	-7.28	0.24
	4	Amphibolite	95.6	115.6	105.60	20.0	5.3E-08	1.3E-07	8.3E-08	-7.08	0.12
	5	Amphibolite	119.6	142.6	131.10	23.0	1.3E-07	1.7E-07	1.4E-07	-6.84	0.04
NDM 545	1	Greywacke	5.6	28.6	17.10	23.0	8.5E-07	1.0E-06	9.7E-07	-6.02	0.03
	1	Amphibolite	11.5	31.0	21.25	19.5	1.0E-13	1.0E-13	1.0E-13	-13.00	0.00

TABLE 1b: SUMMARY OF HYDRAULIC PROPERTIES FROM PACKER TESTS AT ORMSBY

Borehole ID	Test	Lithology	Actual Interval Tested			Length of Interval	Hydraulic Conductivity				
			From	To	Midpoint		Min	Max	Average	Log(K)Average	$s_{Log(K)}$
			m bgs			m	m/s	m/s	m/s	---	
NDM 558	2	Amphibolite	32.5	52.0	42.25	19.5	1.0E-13	1.0E-13	1.0E-13	-13.00	0.00
	3	Amphibolite	53.5	73.0	63.25	19.5	1.0E-13	1.9E-08	1.5E-10	-9.81	2.47
	4	Amphibolite	74.5	94.0	84.25	19.5	1.0E-13	2.8E-08	8.3E-10	-9.08	2.43
	5	Amphibolite	95.5	115.0	105.25	19.5	1.0E-13	2.5E-08	2.4E-09	-8.61	1.96
	6	Amphibolite	116.5	136.0	126.25	19.5	1.0E-13	4.4E-08	4.4E-11	-10.35	2.70
	7	Amphibolite	137.5	157.0	147.25	19.5	1.0E-13	6.6E-08	5.7E-09	-8.24	2.01
	8	Amphibolite	158.5	175.0	166.75	16.5	1.0E-13	6.8E-08	3.4E-10	-9.47	2.85
NDM 559	1	Greywacke	38.5	52.0	45.25	13.5	1.0E-13	3.4E-08	1.3E-10	-9.88	2.61
	2	Amphibolite	53.5	73.0	63.25	19.5	1.0E-13	1.3E-08	1.0E-12	-12.00	2.04
	3	Amphibolite	80.5	100.0	90.25	19.5	1.0E-13	2.7E-08	1.2E-12	-11.92	2.21
	4	Amphibolite	101.5	121.0	111.25	19.5	1.0E-13	2.1E-08	1.3E-11	-10.90	2.58
	5	Amphibolite	122.5	142.0	132.25	19.5	2.5E-08	5.1E-08	3.8E-08	-7.42	0.06
	6	Amphibolite	167.5	187.0	177.25	19.5	3.0E-08	6.1E-08	4.5E-08	-7.34	0.07
	7	Amphibolite	188.5	208.0	198.25	19.5	3.8E-08	8.2E-08	5.3E-08	-7.27	0.10
	8	Amphibolite	203.5	229.0	216.25	25.5	2.9E-08	7.2E-08	4.3E-08	-7.37	0.11
NDM 560	1	Greywacke	29.5	49.0	39.25	19.5	2.6E-07	4.2E-07	3.3E-07	-6.48	0.07
	2	Greywacke	50.5	70.0	60.25	19.5	6.3E-08	1.4E-07	8.6E-08	-7.06	0.12
	3	Greywacke	71.5	91.0	81.25	19.5	3.0E-08	8.7E-08	4.7E-08	-7.33	0.16
	4	Greywacke	92.5	112.0	102.25	19.5	2.2E-08	5.0E-08	3.2E-08	-7.50	0.10
	5	Greywacke	113.5	142.0	127.75	28.5	1.6E-08	2.9E-08	2.1E-08	-7.68	0.06
	6	Greywacke	143.5	164.0	153.75	20.5	6.3E-09	7.6E-08	4.7E-08	-7.33	0.21
	7	Greywacke	165.5	185.0	175.25	19.5	1.9E-08	5.8E-08	3.2E-08	-7.49	0.14
	8	Greywacke	186.5	206.0	196.25	19.5	1.0E-13	4.2E-08	8.3E-10	-9.08	2.37
	9	Greywacke	207.5	227.0	217.25	19.5	1.0E-13	4.4E-08	5.4E-10	-9.27	2.63
	10	Greywacke	228.5	248.0	238.25	19.5	2.9E-08	5.5E-08	4.1E-08	-7.39	0.07
	11	Greywacke	248.0	269.0	258.50	21.0	1.0E-13	4.2E-08	4.9E-10	-9.31	2.53
	12	Greywacke	270.5	305.0	287.75	34.5	1.9E-08	5.4E-08	3.1E-08	-7.51	0.11
	13	Greywacke	306.5	330.0	318.25	23.5	4.8E-08	7.3E-08	5.7E-08	-7.24	0.06
	14	Greywacke	335.0	365.0	350.00	30.0	3.8E-08	8.3E-08	5.2E-08	-7.29	0.11
	15	FLT/Amp	366.5	395.0	380.75	28.5	2.7E-08	7.8E-08	4.2E-08	-7.38	0.11
	16	Amphibolite	396.5	440.0	418.25	43.5	9.5E-09	5.8E-08	2.4E-08	-7.61	0.22
NDM 561	1	Greywacke	45.5	80.0	62.8	34.5	1.3E-07	1.7E-07	1.5E-07	-6.82	0.04
	2	Greywacke	81.5	110.0	95.8	28.5	2.3E-08	4.8E-08	3.9E-08	-7.41	0.07
	3	Greywacke	111.5	140.0	125.8	28.5	6.8E-09	5.9E-08	3.2E-08	-7.49	0.21
	4	Greywacke	141.5	173.0	157.3	31.5	4.5E-08	9.7E-08	6.0E-08	-7.22	0.11
	5	Greywacke	204.5	263.0	233.8	58.5	2.5E-09	3.0E-08	1.8E-08	-7.75	0.19
	6	Greywacke	264.5	305.0	284.8	40.5	5.1E-09	3.3E-08	2.2E-08	-7.65	0.18
	7	Greywacke	306.5	341.0	323.8	34.5	9.8E-08	1.5E-07	1.2E-07	-6.90	0.06
	8	reywacke/Fa	342.5	371.0	356.8	28.5	3.1E-07	6.4E-07	3.9E-07	-6.40	0.12
	9	Amphbolite	378.5	401.0	389.8	22.5	1.1E-08	7.5E-08	4.4E-08	-7.36	0.15

Table 2 - Summary Bedrock Conductivities based on Slug Tests				
Location	Well Name	Date	Initial Depth to Water BTC (m)	Hydraulic Conductivity (m/s)
Ormsby	BH13	9/23/2009	7.79	9.50E-07
NL	N119	9/19/2019	1.881	2.22E-07
NL	N120	9/19/2009	4.68	8.20E-06
NL	N121	9/22/2009	3.425	1.21E-07

Table 3: Well Construction and Depth to Groundwater Summary – Ormsby and Nicolas Lake							
Well/ Piezometer	**EBA Hole ID**	**Depth – Installed (m)**	**Depth – Measured (m)**	**Inclination (Deg from Vert)**	**Diameter**	**Initial Depth to Water (m btoc)[a]**	**DTW 03/13/10 (m BGS)[b]**
Ormsby							
NDM 542	BH13	19.84	19.37	vert	2-inch	7.79	13.79
NDM 543	BH15	20	20.17	vert	2-inch		6.85
NDM 544	G03	27	24.4	-65			7.56
NDM 545	Redrill	28.6	28.5	-55	1-inch	6.83	7.9
NDM 558	5-Oct	163.5	VWP @163.5				9
NDM 561	3-Oct	N/A		-60	N/A	Artesian during drilling	
Nicolas Lake							
N119	BH-1	19.78	19.6	vert	2-inch	1.81	1.87[c]
N120	BH-4	19.81	20.9	vert	2-inch	4.68	7.12
N121	BH-3	19.63	16.85	vert	2-inch	3.425	4.68[b]
N122S	N01	85.5		-60	1-inch	6.47	10.63
N122D	N01	211.7		-60	2-inch	8.84	14.61
N123	N02	91.8		-60	2-inch	17.09	20.32
N124	N02A	298.5		-65	2-inch	23.79	24.86
N125	N03S	20?		-60	7/8-inch	10.3	16.4
N125	N03D	154.7		-60	2-inch	6.55	16.61

Table 4: Tyhee Groundwater Model Sensitivity Analyses Summary

Varied Parameter			Calculated Flows
Ormsby Rock Hydraulic Conductivity (m/sec)		Rationale	
Graywacke Amphibolite Fault Zone	Ave 7.3 E-09 m/s Ave 6.6 E-10 m/s Ave 3.0 E-07 m/s	Based on K's measured by packer tests in core holes	787 m^3/day
Sensitivity Adjustments			
High Greywacke Flow	1.8 E-08 m/s	Based on ave high Ks measured in packer tests	987 m^3/day
High Flow for Fault Zone	1.0 E-06 m/s	Account for potential geologic variability and for potential high volume flow from fault zone	1155 m^3/day

Nicholas Lake Rock Conductivity (m/sec)		Rationale	Calculated Flows
Granite/Metasediments	Ave 2.5 E-08 m/s	Ave K based on packer test results	80 m^3/day
Sensitivity Adjustments			
Low Flow both units	2.5 E-09 m/s	Account for potential lower permeability rocks	6 m^3/day
High Flow both units	2.5 E-07 m/s	Account for potential higher permeability rocks	1200 m3/day

Notes:
Analytical models using available Ks indicate very low flows from mine areas, thus most flow will be from seasonal recharge and/or from productive
Model insufficient to accept wide difference between fault K and country rock K, due narrow fault compared to size of pit, model
Model also has difficulty with large head differences between top and bottom of excavated area
Flow estimate based on constant head away from pit providing source of water, rock acting as slightly permeable porous media
Likely flow on lower end of these scale due to generally impermeable nature of country rock and ore bodies, and presently known limited fault
Nicolas Lake model - no significant variations by changing constant/not constant heads at model boundary, location of constant head boundary, changing from flat to slight gradient,

Calculation Worksheet - Estimate Monthly Flows from the Ormsby Mine Site

Tyhee Precipitation m/year	0.264 m/m^2				
Tyhee Precipitation m/day	0.00072 m/m^2				
		recharge/yr		recharge/day	
Approx Open Pit Area Recharge @100% Precip	2400 m^2	634	m^3/year	1.7	m^3/day
Approximate Model Area Recharge @10% Precip	1200000 m^2	31617	m^3/year	85	m^3/day
Model Calculated Recharge		32250	m^3/year	87	m^3/day

Table 5a: Estimated Monthly Flows from the Ormsby Mine Site

		Month	Jan	Feb	March	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec		
Average Precip/Month per Tyhee Met Station		m/m^2	0.0153	0.0153	0.0094	0.014	0.0098	0.0265	0.0346	0.0481	0.0447	0.0175	0.0202	0.0086	0.264	m/m^2
Approx Excavation Area @ 100% prec	2400 m^2	m^3/mo	37	37	23	34	24	64	83	115	107	42	48	21	634	m^3/year
Approx Recharge to Model Area @10% Precip	1200000 m^2	m^3/mo	1832	1832	1126	1677	1174	3174	4144	5760	5353	2096	2419	1030	31617	m^3/year
Actual Total Monthly Recharge		m^3/mo	1869	1869	1148	1710	1197	3237	4227	5876	5461	2138	2468	1051	32250	m^3/year
Low End of Likely GW Inflow at	**500 m^3/day**	m^3/mo	15500	14000	15500	15000	15500	15000	15500	15500	15000	15500	15000	15500	182500	m^3/year
GW Inflow, no model recharge	*413 m^3/day*	m^3/mo	*12815*	*11575*	*12815*	*12401*	*12815*	*12401*	*12815*	*12815*	*12401*	*12815*	*12401*	*12815*	*150883*	m^3/year
Add Actual Recharge - **Estimated Monthly Flows**		**m^3/mo**	**14684**	**13444**	**13963**	**14112**	**14012**	**15639**	**17041**	**18691**	**17862**	**14953**	**14869**	**13865**	**183134**	**m^3/year**
High End of Likely GW Inflow at	**1500 m^3/day**	m^3/mo	46500	42000	46500	45000	46500	45000	46500	46500	45000	46500	45000	46500	547500	m^3/year
GW Inflow only, subtract model recharge	*1413 m^3/day*	m^3/mo	*43815*	*39575*	*43815*	*42401*	*43815*	*42401*	*43815*	*43815*	*42401*	*43815*	*42401*	*43815*	*515883*	m^3/year
Add Actual Recharge - **Estimated Monthly Flows**		**m^3/mo**	**45684**	**41444**	**44963**	**44112**	**45012**	**45639**	**48041**	**49691**	**47862**	**45953**	**44869**	**44865**	548134	**m^3/year**

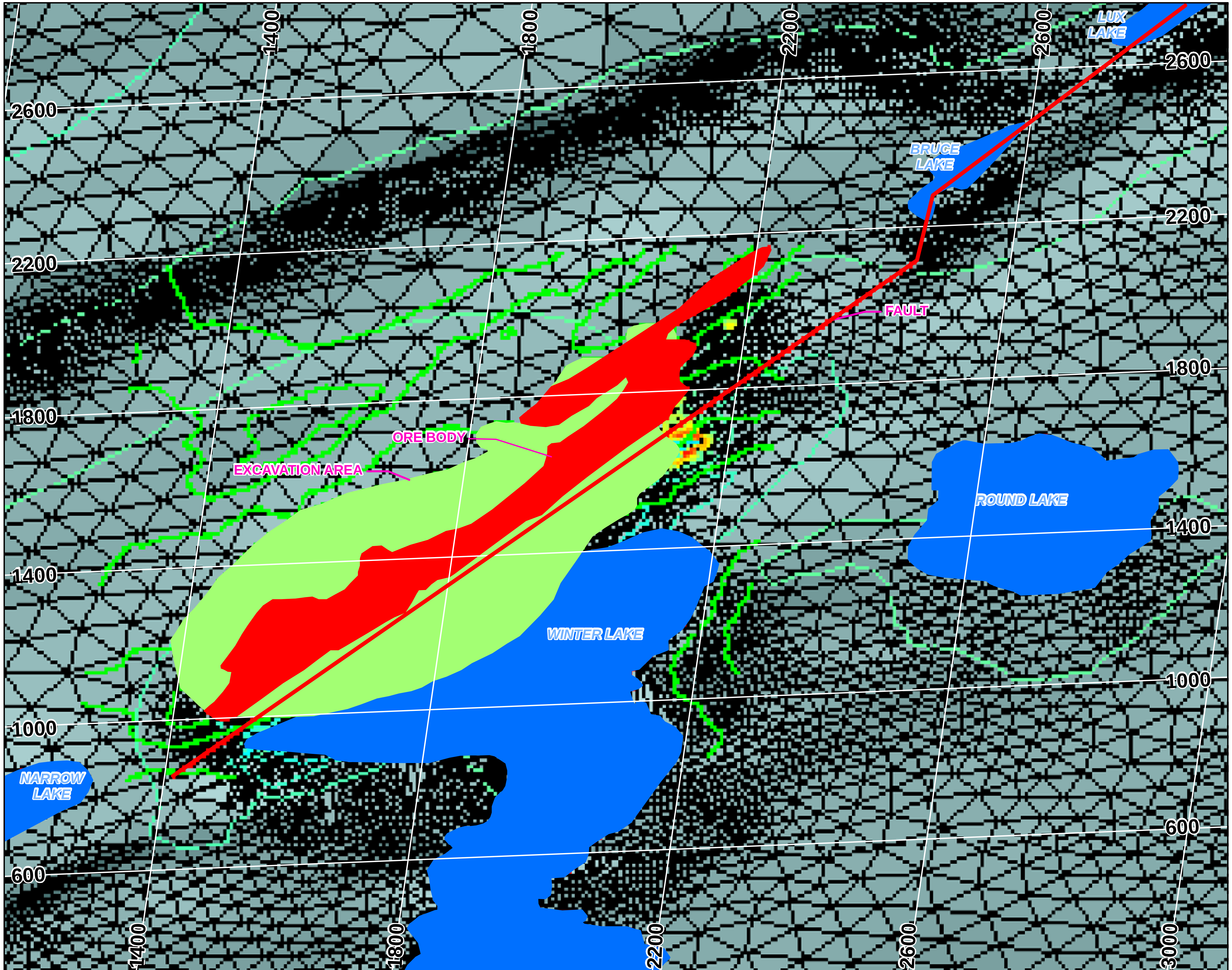
Calculation Worksheet - Estimate Monthly Flows from the Nicolas Lake Mine Site

Tyhee Precipitation m/year	0.264 m/m^2				
Tyhee Precipitation m/day	0.00072 m/m^2				
		recharge/yr		recharge/day	
Approximate Nicolas Lake Model Area Recharge @10%	2000000 m^2	52800	m^3/year	145	m^3/day

Table 5b: Estimated Monthly Flows from the Nicholas Lake Mine Site

		Month	Jan	Feb	March	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec		
Average Precipitation/Month per Tyhee Met Station		m/m^2	0.0153	0.0153	0.0094	0.014	0.0098	0.0265	0.0346	0.0481	0.0447	0.0175	0.0202	0.0086	0.264	m/m^2
Approx Recharge to Model Area @10% Precip	2000000 m^2	m^3/mo	0	0	0	0	0	0	0	0	0	0	0	0	0	m^3/year
Likely GW Inflow - Minimal or No Recharge from Surfa	**100 m^3/day**	**m^3/mo**	**3100**	**2800**	**3100**	**3000**	**3100**	**3000**	**3100**	**3100**	**3000**	**3100**	**3000**	**3100**	36500	m^3/year
High End of Likely GW Inflow at	**1200 m^3/day**	m^3/mo	37200	33600	37200	36000	37200	36000	37200	37200	36000	37200	36000	37200	438000	m^3/year
GW Inflow only, subtract model recharge	*1055 m^3/day*	m^3/mo	*32716*	*29550*	*32716*	*31660*	*32716*	*31660*	*32716*	*32716*	*31660*	*32716*	*31660*	*32716*	*385200*	m^3/year
Add Actual Recharge - **Estimated Monthly Flows**		**m^3/mo**	**32716**	**29550**	**32716**	**31660**	**32716**	**31660**	**32716**	**32716**	**31660**	**32716**	**31660**	**32716**	**385200**	**m^3/year**

FIGURES



LEGEND
- Ore Body
- Excavation Area

Groundwater Modeling for Estimation of Inflows to Mining Areas

Site plans showing the model block, mesh, mining area and other major features at Ormsby site

PROJECTION	DATUM
UTM Zone 12	NAD83

FILE NO.
Figure E1.mxd

PROJECT NO.	DWN	CKD	REV
V13101438	BM	AS	0

OFFICE	DATE
EBA-RIV	April 26, 2010

EBA Engineering Consultants Ltd.

Figure P1

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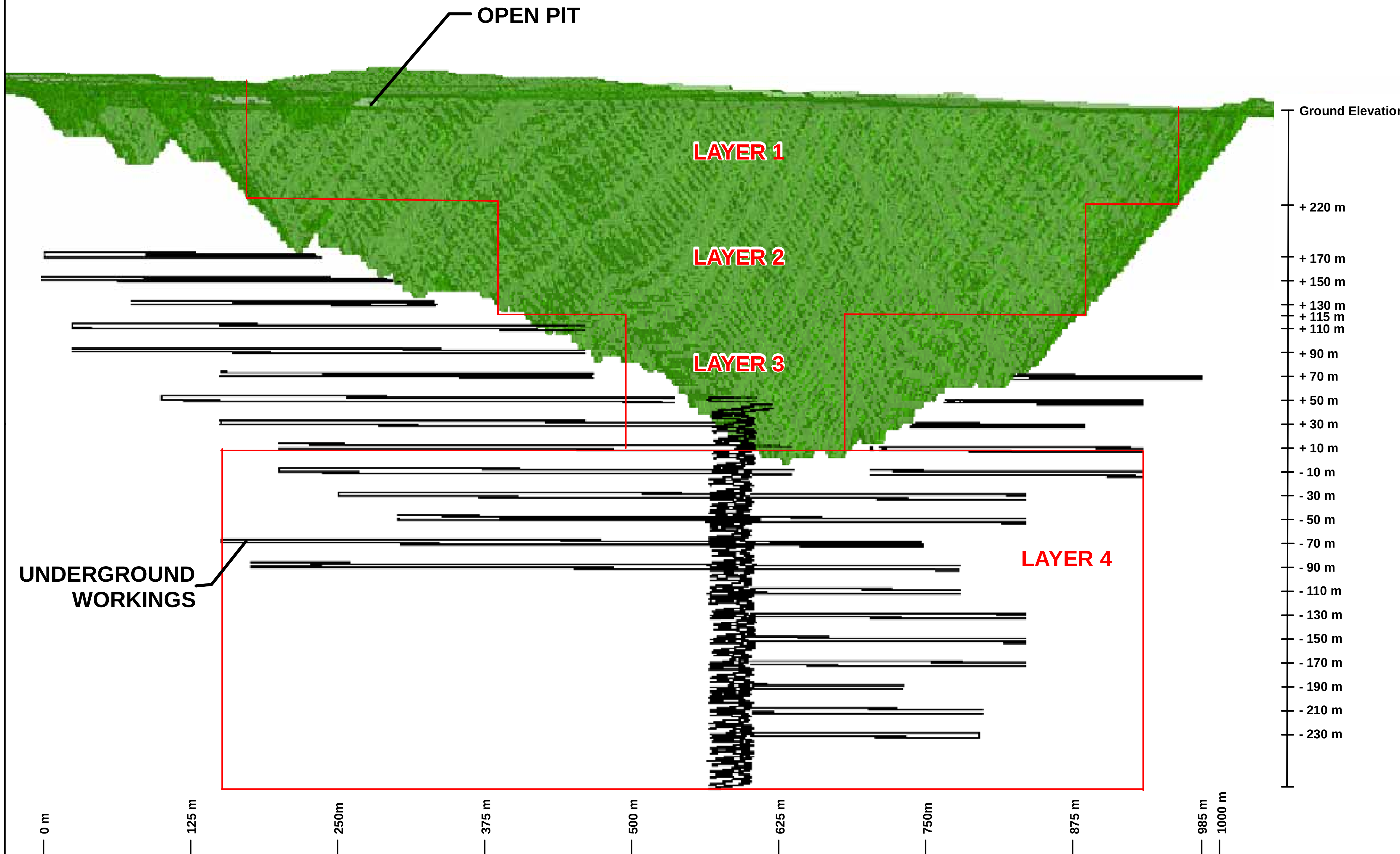

LEGEND

Layer 1 to Layer 4 - Modeled Layers

NOTES

Ground elevations are variable at the proposed mining area. For this figure ground elevation was referenced as + 325 m approximate at the center of mining area.

GROUNDWATER MODELING FOR ESTIMATION OF INFLOWS TO MINING AREAS

Depth Profile of Open Pit, Underground Workings and Modeling Layers - Ormsby Site

PROJECTION	DATUM
UTM Zone 12	NAD83

FILE NO.
EBA_11x17_l-side_Template

EBA Engineering Consultants Ltd.

PROJECT NO.	DWN	CKD	REV
V13101438	BM	AS	0

OFFICE	DATE
EBA-RIV	April 27, 2010

Figure P2

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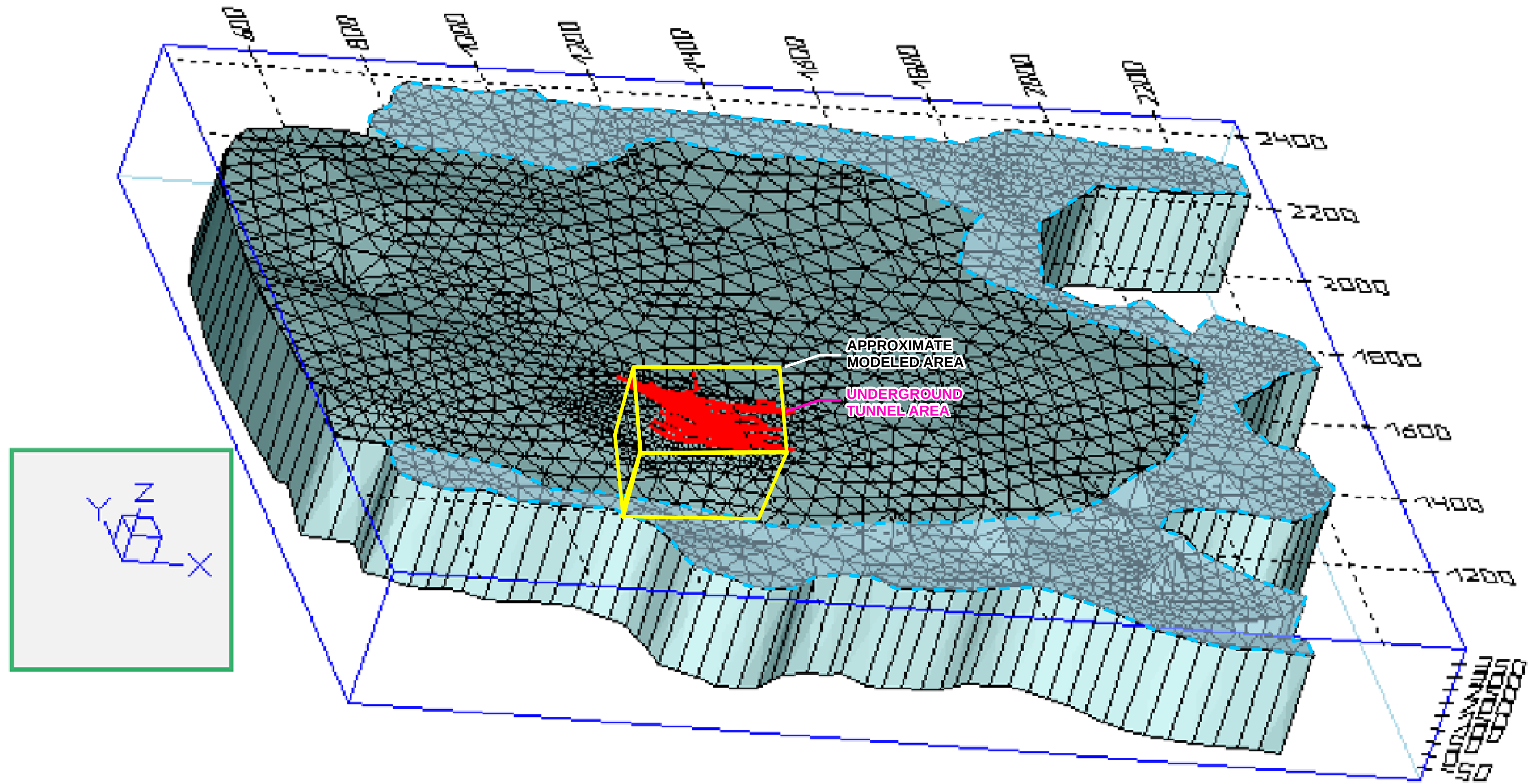

LEGEND

- Approximate Nicholas Lake Boundary
- Approximate Modeled Area

Groundwater Modeling for Estimation of Inflows to Mining Areas

Site plans showing the model block, mesh, mining area and other major features at Ormsby site

PROJECTION: UTM Zone 12	DATUM: NAD83
FILE NO.: Figure E3.mxd	
PROJECT NO.: V13101438	DWN: BM · CKD: AS · REV: 0
OFFICE: EBA-RIV	DATE: April 26, 2010

EBA Engineering Consultants Ltd.

Figure P3

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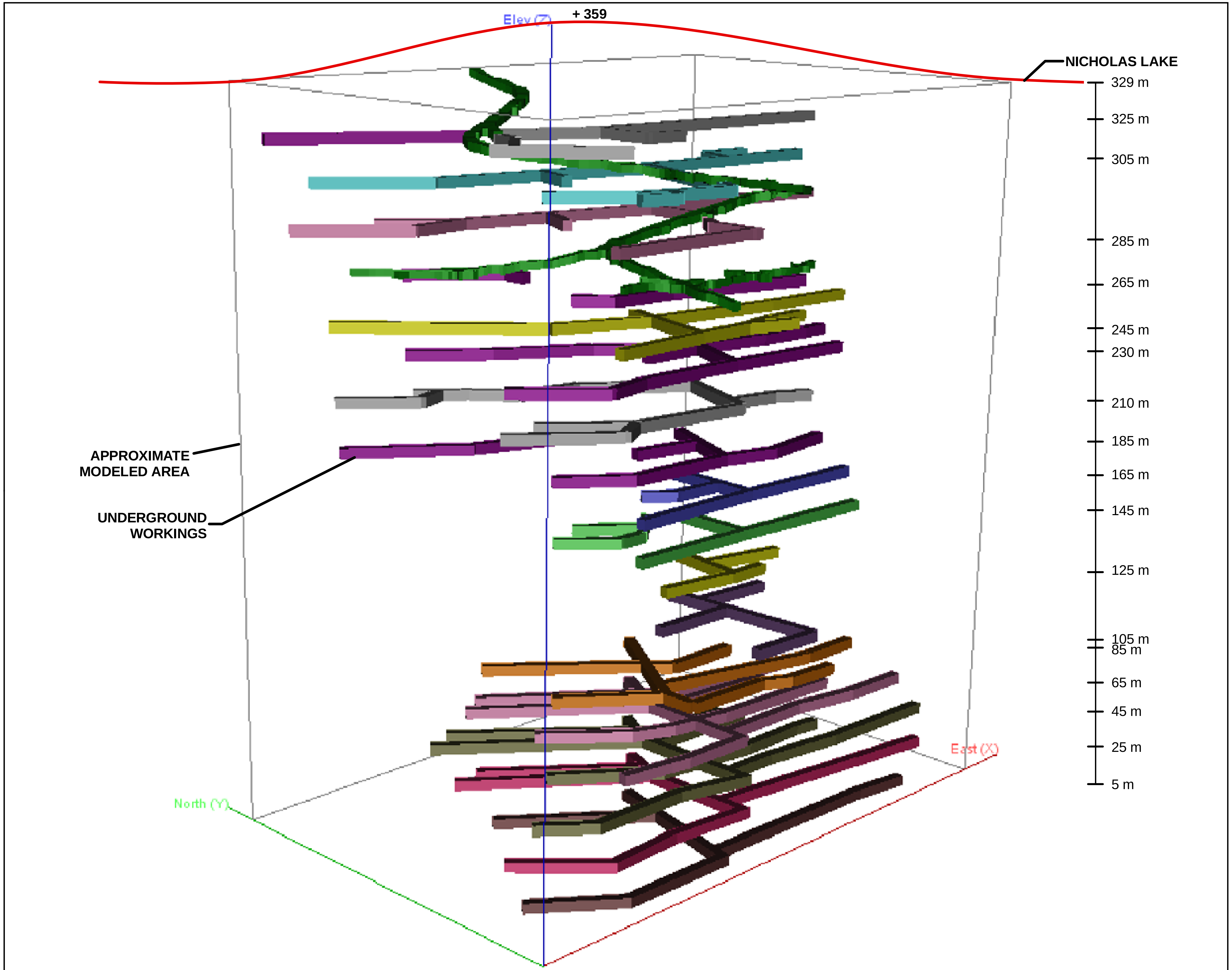

LEGEND

Approximate Ground Elevation

NOTES

1. Ground elevations are variable above the proposed underground mine workings. For this figure ground elevation was referenced as + 359 approximate at the center of the proposed mining area.

2. Elevations on the vertical scale were obtained as the bottom elevations of each underground workings from a digital file provided.

Groundwater Modeling for Estimation of Inflows to Mining Areas

Depth Profile of Underground Workings and Modeling Depth - Nicholas Lake Site

PROJECTION: UTM Zone 12	DATUM: NAD83
FILE NO.: EBA_11x17_l-side_Template	

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PROJECT NO.	DWN	CKD	REV
V13101438	BM	AS	0

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Figure P4

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