Information Request 10

Responses to Information Request 10

IR 10 – Groundwater Interactions between Fish Lake and Open Pit.

References:

EIS, Section 2.7.2.4
EIS Appendix 2.6.1.4 D-A (Baseline Groundwater Hydrology Assessment)
EIS Appendix 2.7.2.4 A-A (Lake Level Fluctuation Predictions for Fish Lake)
EIS Appendix 2.7.2.4 A-B (Water Management Report)
EIS Appendix 2.7.2.4 A-C (Numerical Hydrologic Analysis)

Related Comments:

CEAR # 276 (BC Ministry of Mines, Energy and Natural Gas)
CEAR # 272 (Natural Resources Canada)

Rationale:

As part of site investigations for the original Prosperity Mine Project, the Proponent conducted a pump test in 1994 on wells immediately north of Fish Lake for the purpose of evaluating the use of wells for pit dewatering (Appendix 2.6.1.4D-A, p. 7). The test yielded estimates of hydraulic conductivity in hydrogeologic units between the proposed pit and Fish Lake that were considered unrealistically high, possibly due to problems with the testing procedure (Appendix 2.6.1.4D-A, Table C-5). Results from the test were therefore considered unreliable and discounted. Since that time, it appears that the Proponent has not undertaken any further site investigation work aimed at confirming the original pump test results or at better characterizing groundwater interactions between the proposed open pit and Fish Lake. Currently, for pre-development conditions, the Proponent estimates groundwater baseflow discharge to Fish Lake at 446-493 m3/day and lakebed seepage at 0 m3/day (Table 2.7.2.4A-14, p.642). The Panel notes that NRCan considers these estimates to be very low.

The Panel acknowledges that NRCan and the Proponent's consultant (BGC) have previously recommended the Proponent undertake further site investigations adjacent to Fish Lake aimed at better characterizing hydraulic conductivities in the area and thereby improving confidence in predictions of pit dewatering effects on groundwater interactions with Fish Lake (Appendix 2.7.2.4A-C, p.14).

The Panel recognizes the difficulty in undertaking new site hydrogeological studies. Nevertheless, given the importance in preserving Fish Lake in its present state during and after mining operations, the Panel believes that it is critical to have better data and understanding of the groundwater connection and the groundwater flow system between Fish Lake and the overburden and the permeable bedrock above the gypsum line at the proposed pit.

Information Requested:

The Panel requests that Taseko:

a. Undertake additional sensitivity analysis for modeling the hydraulic conductivity between the proposed pit and Fish Lake to assess the predicted effects of hydraulic conductivity on water quality in Fish Lake. This work should incorporate existing data, including data obtained from the 1994 pump test (discounted high flow results), and any new data collected. Specifically, Taseko should run a model based on the highest hydraulic conductivity values measured in the area.

b. Provide further rationale why the pump test data from wells 94-154, 94-157 and 94-159 were not relied on by BGC Engineering and were not used for the purposes of the Baseline Groundwater Hydrology Assessment (Appendix 2.6.1 4D-A).

Information Request #10a

Undertake additional sensitivity analysis for modeling the hydraulic conductivity between the proposed pit and Fish Lake to assess the predicted effects of hydraulic conductivity on water quality in Fish Lake. This work should incorporate existing data, including data obtained from the 1994 pump test (discounted high flow results), and any new data collected. Specifically, Taseko should run a model based on the highest hydraulic conductivity values measured in the area.

Response Summary

Several sensitivity scenarios were conducted, including a case where the hydraulic conductivity of all hydrogeologic units is increased by a factor of 5. Model calibration for the base case is good but poor model calibration results for the high conductivity scenario indicate that this high conductivity is unlikely to be encountered at the project (km) scale and that it would be of little value to carry these results forward to water balance modelling or water quality predictions.

Discussion

A thick sequence of relatively impervious Tertiary sediments overlie bedrock in the south area of the proposed open pit and act to confine groundwater in the bedrock. The early 1990s hydrogeological investigations intersected what was interpreted as a confined aquifer at the bedrock contact below the overburden sediments (approximately 80 m deep) in the south pit area. Hydraulic conductivity values measured in the Tertiary sediments are at least one order of magnitude less than those measured in the aquifer. Drilling and pump tests of the confined artesian aquifer indicated that artesian conditions are only present in the 1 to 2 m thick sand and gravel layer above the bedrock surface. This unit is projected to extend approximately 500 m across the south central area of the proposed open pit, pinching out against the rising bedrock surface to the south.

Fish Lake does not have a direct hydraulic connection to this deep confined artesian aquifer. Low artesian pressures have been identified in the deep confined aquifer, which indicate that the local groundwater flow direction is upward and into the lake. This also suggests that the thick deposit of glacial till and glaciolacustrine silt would act as a significant barrier to groundwater flow between Fish Lake and the open pit.

For the base case calibrated numerical groundwater model, groundwater inflow into Fish Lake is predicted to range from 446 m^3/d in the Summer to 493 m^3/d in the Winter, with no lakebed seepage out of the lake. These results are consistent with Fish Lake being located at the valley bottom in a groundwater discharge area and the upward hydraulic gradients observed with several wells in the vicinity of Fish Lake (94-154, 94-157, 94-159).

For the operational scenario, the 3D groundwater model predicts that the groundwater baseflow into Fish Lake will be reduced by 7 – 9% to 413 – 450 m^3/d and that a small amount of lakebed seepage (15 m^3/d) will be induced by the nearby open pit dewatering.

BGC conducted several sensitivity scenarios documented in Appendix 2.7.2.4A-C of the 2012 EIS, including a case where the hydraulic conductivity of all hydrogeologic units is increased by a factor of 5. Table 10A-1 compares the base case 3D groundwater model results to the scenario which assumes that the hydraulic conductivity of all units is 5 times higher than the base case.

Table 10A-1: Summary of Average Annual Pre-Development, Base Case and High Conductivity Case Inflows/ Outflows for Fish Lake for the End of Operations (Open Pit at Lowest Level)

Simulation Details	Groundwater Baseflow (m^3/day)	Lakebed Seepage (m^3/day)
Pre-development scenario	470	0
Operational: Base Case	432	15
Operational: Hydraulic conductivity of all units increased by a factor of 5	1270	722

The results for the high conductivity case show that the effect of nearby open pit dewatering could induce up to 722 m3/d (8.3 L/s or 132 USgpm) of lakebed seepage from Fish Lake.

For the calibrated pre-development scenario, the normalized root mean square (NRMS) error was 9.9 % for piezometers only, and 11.9% for piezometers and shut-in tests (Appendix 2.7.2.4A-C of the 2012 EIS, Figure 10). A NRMS of less than 10% is usually considered good for many models (BC MOE 2012). For the high conductivity scenario, the NRMS for the pre-development model was 36.6% for piezometers only and 81.1% for piezometers and shut-in tests indicating poor calibration to available data. Poor calibration results indicate that this high conductivity case is unlikely to be encountered at the project (km) scale and that it would be of little value to carry these results forward to water quality or water balance modelling or water quality predictions.

At the local (10 – 100 m) scale, variability in hydraulic conductivity is expected and will need to be adaptively managed through the project lifetime. Specific to the Fish Lake and open pit interactions, this will include adapting depressurization techniques as needed during open pit development.

References

Taseko Mines Limited (2012). *New Prosperity Gold-Copper Mine Project Environmental Impact Statement*.

Information Request #10b

Provide further rationale why the pump test data from wells 94-154, 94-157 and 94-159 were not relied on by BGC Engineering and were not used for the purposes of the Baseline Groundwater Hydrology Assessment (Appendix 2.6.1 4D-A).

Response Summary

Pump test data from wells 94-154, 94-157 and 94-159 were not relied on by BGC Engineering because the pumping and observation wells are screened across multiple hydrogeological units, the pumping rate was not recorded throughout the test duration, and the observed pumping water levels suggest that a steady state pumping condition was not achieved.

Taseko and BGC believe that it would be inappropriate to place emphasis on the original 1994 results for the 3D numerical analysis given the uncertainty in the interpretation.

Discussion

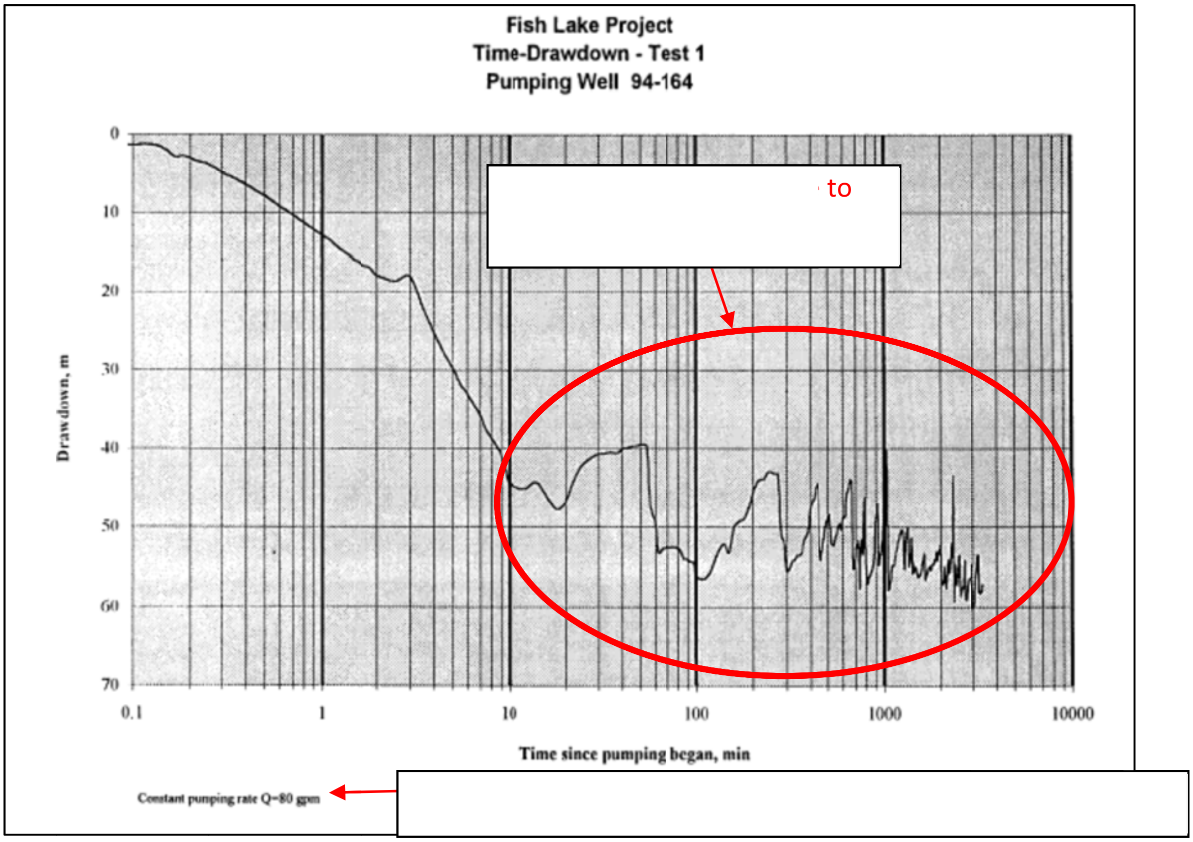
As part of the 1995 open pit investigations, KP conducted two pumping tests in the vicinity of the proposed open pit by pumping from well 94-164 and observing drawdown at three nearby wells (94-154, 94-157, and 94-159). A detailed review of the well logs, pumping test methods and data indicates the following problems with obtaining reliable hydraulic conductivity data from the tests:

1) The pumping and observation wells are screened across multiple hydrogeological units (quaternary overburden, tertiary overburden and basalt, and cretaceous bedrock).

   The pumping and observation wells used for these tests (94-164, 94-154, 94-157 and 94-159) are screened across over 160 m of quaternary alluvium and glacial till, tertiary basalt and glacial lacustrine sediments (silts, sands, gravels) and cretaceous bedrock. Most likely, the pumped water is coming from thin interlayers of coarser sands and gravels within the tertiary and to a lesser extent the quaternary deposits. KP used an arbitrary aquifer thickness of 35 m to interpret the pumping test results. Although a useful approach for confirming the practicality of open pit dewatering, this approach is not well suited to evaluating the hydraulic conductivity of individual hydrostratigraphic units, as only an average hydraulic conductivity over the entire well screen is obtained. Instead, packer and piezometer permeability tests were relied upon as the primary source of information for determining the hydraulic conductivity of individual units, with less emphasis placed on the pumping test results.

2) The pumping rate was not recorded throughout the test duration, and the observed pumping water levels suggest that a steady state pumping condition was not achieved, as shown on Figure 10B-1.

Figure 10B-1. Pumping Test #1: Pumping Well Drawdown (KP 1995)



Based on BGC's experience, the drawdown fluctuations observed in this test are likely due to fluctuations in the pumping rate. This can often happen in lower producing wells if the test pump is not constantly adjusted for the declining water level in the pumping well. As pumping test analysis methods generally rely on the assumption of a constant pumping rate, the results obtained from these tests are uncertain.

KP interpreted aquifer transmissivity from these tests using several methods, assuming a constant pumping rate of 80 GPM and an assumed aquifer thickness of 35 m. The hydraulic conductivity results interpreted from this test ranged from 6.0 x 10-6 to 9.0 x 10-6 m/s with a geometric mean of 6.9 x 10-6 m/s. These results are likely an overestimation of the bulk hydraulic conductivity due to the assumed constant pumping rate of 80 GPM which is uncertain (and likely much lower). Additionally, these results represent the bulk conductivity of the multiple units (quaternary till/ tertiary glacial lacustrine sediments and basalt flows and cretaceous bedrock) which these wells are screened across and the aquifer thickness of 35 m is arbitrary.

As part of this IR response, BGC re-interpreted the aquifer pumping test results using reasonable ranges in pumping test flow rates and aquifer thickness. The pumping well used for these tests was well 94-164 which is a 168 mm diameter well screened through overburden, and completed open hole in bedrock. The entire well screen interval consists of 10.5 m of perforated screen in overburden and 32 m of open hole in bedrock.

The pumping well drawdown plot indicates that during the pumping test the well water level was around 60 mbgl. BGC has attributed the fluctuations in drawdown to fluctuations in the reported pumping rate of 80 USgpm. Based on BGC's experience conducting pumping tests with similarly constructed bedrock wells, they estimate the pumping rate could have fluctuated between as low as 20 USgpm (4 times less than the reported rate) and as high as 160 USgpm (2 times higher than the reported rate). It is unlikely that the well pumping rate was much higher than 160 USgpm, as that would be a much higher pumping rate than the capability of a submersible pump which could fit in the 168 mm well.

BGC has also re-examined the pumping well and monitoring well drillhole logs and completion details and re-interpreted the aquifer thickness as potentially ranging from 30 to 180 m. The pumping and observation wells are all screened across a combination of quaternary sediments and tertiary basalt and lacustrine sediments. Examination of the logs suggests that the majority of groundwater water is likely coming from the upper bedrock interface, and from isolated sand and gravel seams interlayered within the tertiary and to a lesser extent the quaternary sediments. These interlayered sand and gravel seams are generally thin, and are not interpreted to be continuous across the site. As such, BGC has interpreted the entire sequence of tertiary silt and interlayered sand and gravel as a single aquifer with a thickness up to 180 m.

Applying these potential ranges in pumping test flow rate and in the interpreted aquifer thickness gives a potential range in pumping test results from 2.1E-07 to 1.6E-05 m/s. With the lowest values resulting from an interpreted low pumping rate and thick aquifer, and the high conductivity values resulting from a combination of a high pumping rate and a thin aquifer.

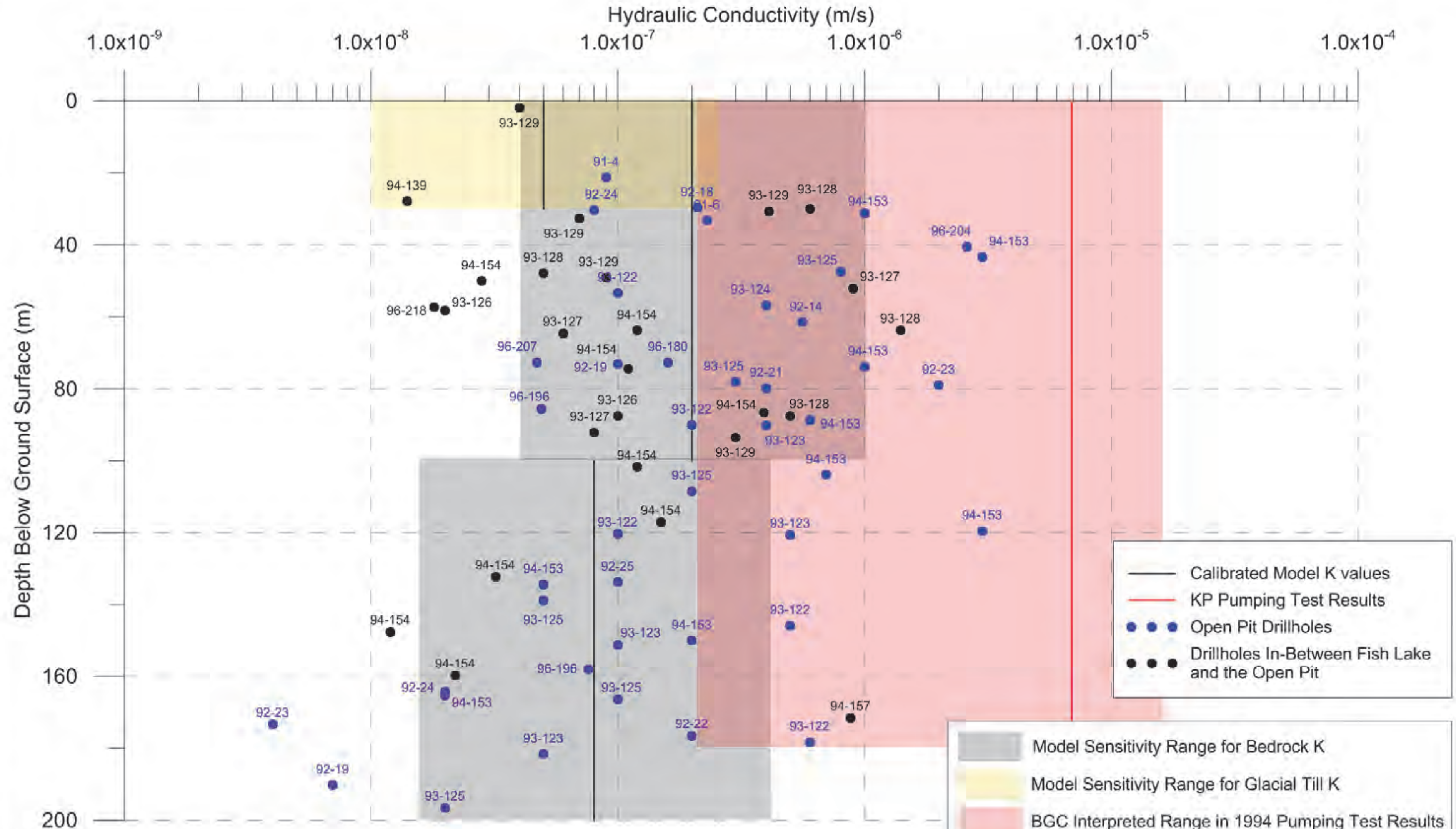
These results are shown graphically on Figure 10B-2. Also included on Figure 10B-2 are the individual packer and slug test results from drillholes and piezometers within the immediate vicinity of Fish Lake and the Open Pit.

In BGC's experience, it's unusual for hydraulic conductivity results from pumping tests to be substantially different than results from packer and slug tests in the same hydrogeologic units. They also believe that the actual pumping test hydraulic conductivity results are on the lower end of the re-interpreted range in results. Figure 10B-2 shows that this low range interpretation of the pumping test has been reasonably captured within the sensitivity simulations presented in Appendix 2.7.2.4A-C of the 2012 EIS.

Although the panel requests that the 1994 pumping test results be included in the sensitivity scenarios evaluated, BGC believes that it would be inappropriate to place emphasis on the original 1994 results for the 3D numerical analysis given the uncertainty in the interpretation.

References

Taseko Mines Limited (2012). *New Prosperity Gold-Copper Mine Project Environmental Impact Statement*.



Notes:
1) See BGC 2012a, Figure 2 (Appendix 2.7.4.2 A-C of 2012 EIS) for drillhole locations

SCALE: N/A	DESIGNED: KSJ	BGC ENGINEERING INC. AN APPLIED EARTH SCIENCES COMPANY	PROJECT: NEW PROSPERITY GOLD-COPPER PROJECT
DATE: FEB 2013	CHECKED: TWC		TITLE: HYDRAULIC CONDUCTIVITY MEASUREMENTS FOR DRILLHOLES IN THE VICINITY OF THE OPEN PIT AND FISH LAKE
DRAWN: KSJ	APPROVED: TWC	CLIENT: Taseko New Prosperity	PROJECT No.: 0499-002-60 DWG No.: 10B-2 REV.:

N:\BGC\Projects\0499 Knight Piesold\002 - New Prosperity\60 CEAA Response Effort\02 Tech Memo Responses\Figure_Source_Files\K_data\K_Data_Open_Pit_Fish_Lake_200mDepth.grf