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MACRAES PHASE III - RESPONSE TO JUNE 1 2011 SECTION 92 REQUEST FOR INFORMATION

Dear Debbie

Below are responses prepared by Golder Associates (NZ) Limited (Golder) for Section 92 questions from the Otago Regional Council related to the proposed Macraes Phase III Project. Golder has only responded to specific questions as per your request.

Hydrogeology

10) *A blanket recharge rate of 32 mm per year is specified for the conceptual model (Appendix 12, Sections 2.4 and 4.0) and the numerical modeling (Appendix 12, Section 5.2) of the TTTSF and the Deepdell Creek catchments. This value of recharge is thought to be derived from a catchment water balance for Deepdell Creek, integrating recorded creek catchment yield and calculated riparian evapotranspiration. As such, the recharge rate may be highly averaged.*

   a. *What variability in recharge rate would be expected to result from variations in existing terrain or vegetation?*

Response to 10a
The recharge rate has been derived from the Deepdell Creek catchment yield and a riparian evapotranspiration assessment. It is correct that this outcome is highly averaged and will vary locally depending on topography, variations in local soil thicknesses and the nature of the soils.

Lower than average recharge could be expected under steep exposed rock conditions on the edge of deeply incised gullies. Under these conditions either the run-off exceeds the rates characteristic of the wider area or the infiltrating water seeps through fractures and joints in the shallow rock mass and discharges again to the gullies with relatively little delay. In effect, this shallow seepage water is not accounted as forming part of the base flow and therefore is not included in recharge calculations.

In other areas relatively thick layers of loess deposited on top of the peneplain surface have been weathered to clay. Trenches excavated to investigate foundation conditions for the proposed Top Tipperary Tailings Storage Facility (TTTSF) intersected several areas where thick clay layers cover the underlying weathered rock mass. It is expected that recharge through these clay soil horizons would be less than the regional average.

   b. *What changes to recharge rate would be expected to result from mining/infrastructure activities, and have these been incorporated within the model recharge (RCH) input layer?*

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Response to 10b
The simulation of recharge rates to groundwater from the existing and planned tailings storage facilities differs from the application of recharge across the wider site. The means of simulating the water levels in each of the tailings storage facilities also differs on a case by case basis.

The piezometric head within the tailings body during the operational period of the TTTSF has been maintained at an elevation equivalent to the final tailings surface elevation through the use of constant head cells. At closure of the TTTSF, the constant head cells are turned off and the water level within the tailings mass is allowed to gradually recover to an elevation appropriate for a recharge rate of 32 mm/year. This recharge rate is applied to the top of the tailings mass for the remainder of the simulation period. In effect, the recharge to groundwater through the TTTSF tailings mass is simply limited by the downward hydraulic gradient through the tailings mass. The reversion to a recharge to 32 mm/year following closure assumes the final tailings surface has a slope that encourages run-off and prevents surface ponding. In addition, it has been assumed that the tailings surface is rehabilitated with a soil or soil/tailings profile that provides for a similar soil moisture balance to the natural soils at the site.

The recharge to the Mixed Tailings Impoundment (MTI) and the Southern Pit Impoundment (SPI) has been simulated through applying a very large rate of recharge to these two areas and then removing the excess through the use of drainage cells to simulate the decant pond. As the MTI has been simulated as developing through the life of the mine, the extent and elevation of the tailings surface has changed through the simulated mine life. As with the TTTSF, it is expected that the closure plan for both the MTI and SPI is to include shaping the final tailings surface with a slope that encourages run-off and prevents surface ponding. It has also been assumed that the tailings surface is rehabilitated with a soil or soil/tailings profile that provides for a similar soil moisture balance to the natural soils at the site.

The waste rock stacks have been simulated with a recharge rate of 32 mm/year. This low rate takes into account the normal compaction of the upper surface of the stacks through mine traffic during the construction process. Although several of the waste rock stacks have been in place for in excess of 15 years there is no evidence that seepage flows from the base of these stacks have increased over time or exceed normal seepage and spring flows expected in this area. Underdrain discharges from beneath the Northern Gully waste rock stack remain small with no indication that the construction of the waste rock stack has led to a significant increase in seepage flows in this area.

11) *In relation to GoldSim (Appendix 10, Section 2.1.5), the groundwater recharge rate is not explicitly referred to or accounted for. The GoldSim modelling project takes input from the MODFLOW modelling of seepage to surface water. Please confirm whether the GoldSim model also incorporates groundwater recharge of 32 mm per year?*

Response to 11
The GoldSIM model for the regional catchments does not incorporate a specific groundwater recharge rate. The GoldSIM model incorporating the AWBM does however generate a base flow component to the simulated hydrograph. All flow components of the hydrograph, including base flows and storm flows, are subject to a calibration process against measured flows from monitoring stations on Deepdell Creek and the Shag River. Surface water flows related to off-site catchments are entirely derived from the AWBM, including the groundwater derived base flow component.

The MODFLOW models used to assess groundwater flows and contaminant transport at the mine site only cover limited areas within the wider regional catchments simulated by the GoldSIM models. Consequently, the outputs from the MODFLOW models also only apply to these limited catchment areas. Within these subcatchment areas the baseflow component of the GoldSIM model has been turned off and replaced with the MODFLOW seepage rates. In effect, within these areas the baseflow from the AWBM has been replaced by discharges resulting from a steady state groundwater recharge of 32 mm/year together with localised flow contributions from the tailings storage facilities.

12) *As the AWBM is used for the hydrological simulation with the GoldSim model, a portion of catchment precipitation will be simulated as removed for evapotranspiration, interception and groundwater recharge. The groundwater recharge component is routed to the surface water system within the AWBM baseflow package (NEWBFLOW). Have the externalities and internal transfers been fully accounted for when including AWBM and MODFLOW groundwater exchanges?*

Response to 12

Within the GoldSIM subcatchment areas representing the Macraes Gold Project site, the baseflow component of the GoldSIM model has been turned off and replaced with the MODFLOW seepage rates. There is some inherent inaccuracy in this conversion of baseflow components from a daily simulation to a long term steady state seepage rate. The decline in surface flows over the dry summer periods are fully represented in the regional components of the model whereas this decline reaches a specific minimum flow from the mine site catchments based on the MODFLOW discharge rates.

The primary effect on the GoldSIM outcomes is to enforce a minimum base flow component onto each of the subcatchments originating from the mine site. This minimum flow does not actually occur, as Deepdell Creek has been observed to be ephemeral and it is expected that surface flows from each of the other main subcatchments intersecting the mine site would also be ephemeral. Once the water levels in the tailings storage facilities recovery to the long term steady state levels it is expected that the groundwater discharge flows from the mine site to most gullies and to the main regional drainage systems would also become ephemeral.

13) *It has been proposed that a sump be installed in the bed of the truncated Tipperary Creek near the downstream foot of the TTTSF impoundment wall. The intention is that the sump would attract the flow of groundwater from beneath the tailings deposited onto the land surface and capture this groundwater seepage for re-circulation within the mine tailings water system. The following questions arise:*

   a. *What extent and portion of groundwater emanating from beneath the TTTSF would become captured by the Tipperary Sump and why are other sumps proposed in the West Tipperary sub-catchment or Cranky Jims Creek headwaters abutting the TTTSF impoundment wall?*

Response to 13a

Modelled projections indicate that at closure of the TTTSF, groundwater flows (totalling approximately 46 m^3/day) could be captured at a modelled sump position approximately 300 m downstream from the toe of the TTTSF embankment and the TTTSF sump. This flow is approximately 30% of the water emanating from the base of the TTTSF at closure. This percentage however excludes discharges to the TTTSF drains, which collect approximately 1,800 m^3/day.

Some of the downward seepage out of the TTTSF indicated above is likely to return to the underdrain or embankment drainage systems. The drains offer the path of least resistance for seepage flows to discharge to the surface and consequently also collect seepage water from the underlying rock mass. This process of seepage through the underlying rock mass toward the underdrains leads to a certain amount of double counting of flows. The volumes involved are however generally small and do not lead to replication of water flows or contaminant mass loads at the receiving points.

The downstream sump is not expected to be constructed prior to the start of tailings deposition in the TTTSF, even though this is how it has been modelled. Seepage losses through the in-situ rock mass to Tipperary Creek are expected to take some time to eventuate. The progress of the expected plume can be tracked using monitor wells. The sump at the downstream site can be constructed once monitoring indicates it is becoming necessary.

No other sumps are proposed for the purposes of managing tailings water losses from the TTTSF. Silt bunds are however planned to be constructed in the headwaters of the West Tipperary and Cranky Jims Creek catchments. These structures are to ensure sediment losses from the embankments are managed during the construction and operational period of the mine.

b. *Figures show groundwater flow directions in the vicinity of the TTTSF. However, these tend to primarily obey gradients defined by topography and relative hydraulic head. To what extent were lateral and vertical anisotropy in hydraulic conductivity considered in the MODFLOW simulations?*

Response to 13b

Differences in vertical and lateral hydraulic conductivity applicable to the schist rock mass at Macraes are documented in Table 6 of the TTTSF groundwater modelling report. This table is replicated as Table 1 below. Calibration and sensitivity analyses undertaken on groundwater models covering the existing Macraes mine site indicate the models are most sensitive to the hydraulic conductivity applied parallel to the X axis of the models (K_x). On that basis the hydraulic conductivity applied as K_y has generally been increased to allow for the relatively common but small scale faults that intersect the mine site parallel to the model north (Y) axis. The ratio of K_y/K_x is generally between 2 and 5. In effect, groundwater flow from the TTTSF is preferentially toward the south, all other factor being equal.

The groundwater flow directions across the site generally appear to be controlled by topographic gradients, both in the simulations and in actuality. This characteristic is mainly a consequence of the deeply incised gullies that form the main receiving water channels and their relative spacing.

Vertical hydraulic conductivity values applied to the modelling are lower than lateral values, mainly to allow for the effects of the schist foliation parallel partings. Investigations into the permeability of the crushed, shattered and weathered rock mass of the Macraes Fault have not indicated that the hydraulic conductivity of this material is greater than that of the intact rock mass, as is documented in Appendix B of the TTTSF groundwater report. On that basis, the hydraulic conductivity applied to the rock mass beneath the TTTSF has not been varied in the simulation to take into account the Macraes Fault. Although the rock mass of the Macraes Fault Zone is less likely to be anisotropic than that of the surrounding schist, this factor was not considered crucial to the simulation outcomes.

Table 1: Hydraulic conductivity values applied to groundwater model.

Geological feature (1)	K_X	K_Y	K_Z
Highly weathered schist	3.5×10^{-7}	1.0×10^{-6}	2.5×10^{-7}
Moderately weathered schist	1.0×10^{-7}	2.5×10^{-7}	6×10^{-8}
Slightly weathered schist	5.0×10^{-9}	9.0×10^{-9}	1.0×10^{-9}
Unweathered schist	1.0×10^{-9}	5.0×10^{-9}	5.0×10^{-10}
Embankment Zone A	1.0×10^{-7}	1.0×10^{-7}	1.0×10^{-7}
Embankment body – Zone B	5.0×10^{-6}	5.0×10^{-6}	5.0×10^{-6}
Embankment body – Zone C and WRS	1.0×10^{-6}	1.0×10^{-6}	1.0×10^{-6}
Fine tailings	2.0×10^{-7}	2.0×10^{-7}	2.0×10^{-7}
Coarse tailings	5.0×10^{-6}	5.0×10^{-6}	5.0×10^{-6}

Notes: 1) All units in m/s.

c. *If anisotropy was incorporated in model simulations, how were the absolute or relative values of contributions from schist foliation, jointing, shears, crush zones or other rock defects included in the hydraulic conductivity field?*

Response to 13c

As discussed in response to question 13b above.

14) *The underground panels are being dewatered. The panels once mined, will ultimately collapse into the mined void. This is known from examples of deep underground metalliferous mining overseas which has caused a zone of enhanced artificial hydraulic conductivity in the overlying rock. The combination of enhanced permeability and secondary porosity, and the continuing need for dewatering of the operational workings would produce additional desaturation of the southern parts of the MGP. The Fraser Pit is to be expanded and pit base dewatering is to be maintained for the operational life of the*

pit. Time lags in the effects of dewatering of the Fraser Underground, Fraser Pit and others like such as Innes Mills III, could take years to fully exert themselves through the buffering effects of storage coefficients in the groundwater system. The following questions arise:

a. *In view of the likelihood of a future deepened centre of desaturation of the schist, has a full analysis of the future groundwater hydrology considered the effects of desaturation in terms of shifting flow divides?*

Response to Question 14a

As discussed in the assessment of the groundwater system related to the proposed TTTSF, the Frasers Underground mine was specifically excluded from the assessment. The construction of the underground mine and eventual collapse of the mine panel roofs clearly results in an extended area of schist dewatering. These workings are primarily located within the Tipperary Creek catchment with the shallower workings being in the North Branch Waikouiti River catchment.

Long term dewatering of the schist rock mass to the underground workings would lead to seepage reaching the underground workings from the overlying waste storage areas. These areas include both the Frasers East Waste Rock Stack and the TTTSF. It is not expected that the long term dewatering of the rock mass above the underground workings would extend laterally past the TTTSF tailings footprint.

The underground workings clearly change the position of the deep groundwater catchment divide. This shift has been utilised in the proposed mitigation measures for Tipperary Creek, as water collected from the TTTSF drainage systems and at the Tipperary sump is to be injected to the underground workings under gravity flow.

b. Have the changed desaturation conditions been considered in the bulk system hydraulic conductivity of either the conceptual model or numerical groundwater model simulations?

Response to Question 14b

The changes in hydraulic conductivity resulting from underground mine roof collapse and desaturation of the roof areas has not been taken into account in the groundwater simulations. The roof zones are not expected to extend to the surface. Although some downward seepage of water from the TTTSF could be expected, this seepage would be controlled by the existing mine water management system. Following closure, the drainage water from the TTTSF is to be pumped or injected to the underground workings. Seepage through the intact rock from the TTTSF to the underground workings effectively has the same result.

15) Evidence of arsenic concentration reduction between the MTI and groundwater monitoring wells is provided in Section 3.5.1 of Appendix 12. It is stated that this is one of the lines of evidence for the attenuation of arsenic in groundwater seepage. Currently, a groundwater plume of conservative contaminants is observed in monitoring down-gradient of the MTI. The following questions arise:

a. *To what extent did the authors of Appendix 12 consider the alternative possibility of simple arsenic retardation in seepage?*

Response to Question 15a

The transport of contaminants from the MTI in a groundwater plume down Maori Tommy Gully is well documented. The plume of dissolved arsenic in Maori Tommy Gully has been retarded in comparison to the plumes of conservatively transported contaminants, including sulphate. The extent of the retardation of the arsenic plume has not been identified from direct observation, as a breakthrough curve has not yet been recorded at the closest row of monitor wells.

Retardation of arsenic generally is due to a combination of sorption and co-precipitation processes. Iron oxides in particular have significant capacity for attenuation of arsenic. The only process to have been experimentally evaluated for this study is that of adsorption onto the host rock and soil. Other processes that may attenuate arsenic, such as co-precipitation, aqueous complexation, and sorption onto substrates such as organics, have not been taken into account. As it is likely that other processes are contributing to the retardation of the arsenic plume, the actual breakthrough curve for arsenic in the groundwater is likely to be observed later than the modelled curve would suggest.

b. *Could the transport of arsenic down-gradient of the MTI and TTTSF areas reach a geochemical threshold whereby a secondary break-through of groundwater-borne arsenic could eventuate?*

Response to Question 15b
The outcomes for laboratory testing of soil and rock samples obtained from the Macraes Gold Project were documented in Appendix C of the TTTSF hydrogeological assessment. Laboratory tests into the adsorption of arsenic (III) onto the rocks and soils present at the Macraes Gold Project site indicated the maximum adsorption capacities of the materials tested are at least:

- 510 mg/kg for loess.
- 460 mg/kg for weathered schist.
- 270 mg/kg for unweathered schist.

For sorption modelling it was considered inappropriate to apply linear or Freundlich isotherms due to the implied lack of an upper limit on the adsorption capacity of the rock mass. Languir isotherms were therefore derived to represent the observations from the adsorption tests taking into account the maximum adsorption capacities of the rock mass. The process of developing the Langmuir isotherms is documented in the appendix identified above.

The maximum adsorption capacity for arsenic (III) is less than that for arsenic (V) because the latter is a much more effective sorbant. As the maximum adsorption capacity of the materials was not actually exceeded within the range of arsenic concentrations tested, these values are considered to represent minimum outcomes. The arsenic transport modelling for the site was therefore undertaken applying the above values, corrected for the likely fraction of the rock mass actually in contact with seepage water. This correction is documented in the same appendix.

The outcomes incorporating the correction that were applied to the modelling are:

- Upper 20 m of the combined weathered schist and loess - 230 mg/kg of soil/rock.
- Rock between 20 m and 60 m below the ground surface - 46 mg/kg.
- Conservative transport of arsenic at greater depths.

The simulated concentrations of arsenic adsorbed onto the host rock and soil did not reach the maximum potential concentrations over the time period modelled (150 years). As the simulation of sorption by definition involves a dynamic balance between dissolved and adsorbed contaminants, the simulated maximum adsorbed concentrations were approximately proportional to the dissolved concentrations in the groundwater in each cell of the model. The modelled dissolved tailings seepage water and groundwater concentrations were not high enough to lead to adsorbed concentrations approaching the potential maximum.

<u>Tailings Static and Kinetic Geochemical Assessment</u>

16) *The following comments, questions and further information requests have arisen from a preliminary review of Appendix 13:*

a. *Please provide a detailed description of how tailings are deposited into the tailings impoundments. Please discuss where the sampling points are in relation to the discharge spigots, and whether there is any segregation of tailings particles upon discharge.*

b. *Please provide a map of the sampling locations, and also discuss the spatial variation for sulphate, arsenic, iron and other metals within the tailings impoundments.*

c. *Please provide assurance that the sampling sites chosen provided samples that were representative of tailings disposed at the site.*

d. *Please confirm whether the ores from which the "Macraes Tails" and "Reefton Tails" samples were derived had been subject to pressure oxidation.*

e. *Please confirm whether flotation only tailings were present in the impoundments from which the* *samples were collected.*

f. *There is no kinetic testing for sulphate, iron and other metals in the leachate. There is also no testing of material of higher sulphide content e.g. flotation tailings. Please discuss.*

g. *Not all the data were provided with the kinetic testing e.g., the solids data, mineralogy. Please provide this data where available.*

h. *Please discuss variations in the composition of the ore that has been processed to date and will be processed in the future, and how this effects likely tailings composition i.e., if the ore has been subjected to pressure oxidation it will be a source of sulphate, arsenic and other metals, whereas non-pressure oxidation tailings will have the same but will also potentially have acid forming properties is sulphides are allowed to oxidise.*

i. *Please discuss the likely composition of tailings in the future i.e. will it be similar to that sampled (low sulphides either from low sulphide ore due to pressure oxidation processing), or will it be more similar to the "Macraes Tails" sample?*

j. *The kinetic testing has presumably been selected to test the leachability of arsenic, however, if tailings are to be sulphidic it would be appropriate to undertake some leaching tests on this type of material. Please provide data from such testing, or provide explanation as to why this is not required.*

Response to 16a to 16j

The reviewer has asked a series of questions to discern whether variations in mineral processing and tailings deposition practices will affect water quality discharges from the proposed TSF. Factors which could affect tailings water composition include, but are not limited to:

- Geochemical composition of ores likely to be processed
- Process methods, such as whether pressure oxidation will be used or not
- Deposition of flotation versus concentrate tails
- Methods for tails deposition
- Management of decant water

When planning for a new mine, gathering reliable information on these factors is typically challenging as only limited information is generally available for estimating effects on water quality. On the contrary, at the Macraes Gold Project, 20 years of surface water and groundwater data are available from two substantial TSFs (MTI and SPI) which have received tailings associated with a variety of mine processes and ore from two locations (Macraes and Reefton). The water quality data are from multiple drains and also from groundwater wells down-gradient of the TSFs.

Therefore, water quality trends from the existing TSFs provide the most relevant information for projecting water quality into the future. To reduce uncertainly regarding the characteristics of tailings likely to be placed in the TTTSF, leach testing of current Macraes and Reefton tails was undertaken to identify if there is significant variations in geochemical composition. Further, samples from 50 m of drill cores from deposited tails in the two existing TSFs representing over 10 years of processing also underwent leach testing. This period included ore from both Macraes and Reefton. The tailings samples also represents a mixture of concentrate and flotation tailings that is considered to be representative of the materials deposited in the impoundments over the past 10 years.

As discussed in Section 5.3 of Appendix 13, review of the 20 years of surface water and groundwater data, plus more recent but limited mineralogy testing, laboratory leach testing, and kinetic testing for arsenic, suggests the following:

- The mineralogical compositions of the current tailing streams from the two mines are comparable to that of the historic tails in the TSFs.
- Leach testing results (including arsenic, sulphate and other metals) for the current tailings and the placed tailings in the MTI and SP11 are comparable.

- A comparison of laboratory data with measured water quality data from the site shows that the kinetic column and the SPLP leach methods provide arsenic leachate data that are in good agreement with arsenic concentrations in seepage reporting from the deepest MTI underdrains.
- The sulphate data from the SPLP testing are also in agreement with sulphate concentrations in tailings impoundment decant and seepage for early periods in the life of the mine.
- Trends in the long-term water quality record from the deepest MTI underdrains do not show distinct changes in water quality corresponding to changes in mining, mineral processing, or tailings deposition methods. This is likely due to the fact that tailings decant and seepage quality reflects the bulk properties and conditions of the materials in the TSFs.

The observation that the water quality in some of the TSF drains does not correlate with leach testing results appears to relate to the gradual change in decant water quality over time, likely due to the ongoing recycling of the decant water, evaporation, dilution, and changes to the process and water management methods over the 20 years of mine operation. Whereas there are some drains with water quality that is in good agreement with laboratory data, there are other drains reporting seepage from the MTI and the SP11 with substantially higher concentrations of parameters such as arsenic and sulphate. These higher concentrations are likely to result from tailings above these drains being leached with decant water that contains elevated concentrations of these parameters to begin with.

To provide further clarification to the requestor, the drill bores for collection of tailings samples were located in transects starting at the edge of the TSF and moving inward, limited by drill rig accessibility but away from the TSF boundary to get core samples of tailings to a depth of 50 m. Over time, the discharge outlet for tails into the TSF moves to allow even filling of the TSF. Therefore, the drill core samples, which correspond to more than 10 years of filling, represent a variety of mine processes and tails sources and a map showing the precise locations is not likely to provide useful information in terms of assessing the presence of specific tailings types.

As demonstrated by the above, identifying relationships between micro-scale changes within the TSF and tailings water quality is likely to be of significantly less value than the macro-scale evidence provided by the long-term water quality record, including the observation that there is little variation in geochemical composition between the tested tails and their discharges. Detailed responses to the questions above, therefore, are not considered likely to provide additional conclusive and useful information that would support development of estimates of future water quality that are more refined than those that have been presented thus far.

We hope the responses to these questions are sufficient to resolve the uncertainty expressed by the Otago regional Council reviewers.

Yours sincerely

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