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5.3.5 Groundwater Quantity

5.3.5.1 Introduction

Issues pertaining to the Groundwater Quantity Valued Component (VC) were identified, and potential Project-related effects on the Groundwater Quantity VC were assessed by using applicable regulatory, cultural, and scientific information and applying best practice analyses.

5.3.5.1.1 Applicable Guidelines and Regulations

Although Canadian federal legislation does not directly regulate groundwater quantity, federal legislation indirectly addresses groundwater issues with respect to the proposed Blackwater Gold Project (the Project).

- *Canadian Environmental Assessment Act, 2012* (*CEA Act*) (Government of Canada, 2012). The Project is a reviewable project, as defined by the *CEA Act*, and groundwater issues, including groundwater quantity, must be assessed under the *CEA Act*;
- *Canadian Environmental Protection Act, 1999* (*CEPA*) (Government of Canada, 1999). The *CEPA* regulates surface water chemical or physical quality, flow conditions, or water depth near the Project, which may be affected by Project-related activities pertaining to groundwater quantity;
- *Fisheries Act* (Government of Canada, 1985). Surface water chemical or physical quality, flow conditions, water depth, or benthic or riparian area conditions near the Project may be impacted by Project-related effects on groundwater quantity; and
- *Species at Risk Act* (*SARA*) (Government of Canada, 2002). Surface water chemical or physical quality, flow conditions, water depth, or benthic or riparian area conditions near the Project may be impacted by Project-related effects on groundwater quantity.

While groundwater flow is not directly regulated by British Columbia (BC) provincial legislation, groundwater quantity is indirectly regulated under a number of provincial acts and regulations.

- *Environmental Assessment Act* (BC *EAA*) (Government of BC, 2002). The Project is a reviewable project, as defined by this legislation, which requires groundwater issues (including groundwater quantity) to be assessed according to BC *EAA* criteria;
- *Mines Act* (Government of BC, 1996c). This legislation pertains to all mines that operate in BC;
- *Environment and Land Use Act* (Government of BC, 1996b). This legislation empowers Land Use Committees to ensure the preservation and maintenance of the natural environment, including groundwater, in administrating BC land use and resource development;

- *Environmental Management Act* (Government of BC, 2003), including the *Contaminated Sites Regulation* (Government of BC, 1996a), *Hazardous Waste Regulation* (Government of BC, 1988), and *Waste Discharge Regulation* (Government of BC, 2004b). This legislation regulates the chemical quality and management of substances, including substances that are released or discharged to the environment;
- *Water Act* (Government of BC, 1996d), including its *Ground Water Protection Regulation* (Government of BC, 2004a). This legislation regulates the diversion, extraction, use, and storage of surface water and the installation, use, and decommissioning of groundwater wells; and
- *Fish Protection Act* (Government of BC, 1997). This legislation regulates surface water chemical or physical quality, flow conditions, or water depth, as well as habitat conditions within or near surface waterbodies near the Project that may be affected by Project-related effects on groundwater quantity.

The *Mines Act* requires development of a reclamation and closure plan to support closure of the Project. The Reclamation and Closure Plan (**Section 2.6**) addresses the criteria of the *Mines Act* to support this assessment. Part 10 of the Health, Safety and Reclamation Code of Mines in British Columbia (BC Ministry of Energy, Mines and Petroleum Resources [BC MEMPR], 2008) also identifies reclamation and closure criteria applicable to BC mines.

5.3.5.1.2 Assessment Approach

Potential effects on the groundwater quantity VC from interaction with proposed Project components have been described in this section (for a more detailed description of the Assessment Approach, please refer to **Section 4**). The potential effects of the proposed Project were based on the findings of the groundwater quantity VC and Project component interaction analysis, which formed the basis for the effects assessment. For the assessment a MODFLOW groundwater model was constructed, the assimilation and calibration of this model has been described in **Section 5.1.2.3** and **Appendix 5.3.5A**. This section also discusses the construction of the Watershed Model, which was developed in tandem to calibrate stream flows in the MODFLOW model. After the construction of the MODFLOW model, and the model calibration, groundwater quantity simulations and particle tracking simulations were modeled to simulate the groundwater flow quantity, the groundwater path and timeline particles would take from key mine features. Following the potential effects Project activities might have on the groundwater quantity VC were determined and described, and proven best practice mitigation measures were identified and applied to minimize or offset the potential effect. Those effects remaining after the application of all mitigation measures were identified as residual effects.

5.3.5.2 Valued Component Baseline

5.3.5.2.1 Information Sources

This subsection provides detailed baseline information on the VC and the source of the information. Prior to commencement of environmental studies for the Project, no baseline groundwater data were available for the aquifers in the immediate area of the Project. Since 2012, groundwater baseline field programs were executed to fill this data gap. In these groundwater field programs the following activities were performed:

- Installation of groundwater monitoring wells and water flow and quality sampling;
- Determination of groundwater levels and seasonal variation; and
- Completion of hydraulic testing.

The following data were reviewed:

- Current groundwater use in the area;
- Published geology and hydrogeology reports;
- Geological maps, watershed maps, and aerial photography as described in e.g. KP 2013 Watershed modelling report, **Appendix 5.1.2.1B**;
- Geological conditions based on drill hole and test pit data as described in e.g. 2013 KP geotechnical characterization report, appendix A4; and
- Climate and hydrometeorology data as described in e.g. KP 2013 hydromet report, **Appendix 5.1.1.1A**.

The groundwater field program drilling, well installation and sampling related information has been outlined in the following reports, mainly in Knight Piésold Ltd. (Knight Piésold) Geotechnical Characterization Report (**Appendix 2.2A-4**); Reconnaissance Terrain and Terrain Stability Mapping (**Appendix 11A**); and Water Supply Feasibility – Well Drilling and Completion Report (Western Water Associates, 2013, **Appendix 5.3.6A**), which further characterize the geotechnical, terrain, hydrogeology and soils situation of the project area.

The groundwater quantity effects assessment is based on these site-specific baseline investigative results, available regional data, and groundwater quantity modelling conducted for the Project. Overall, the following groundwater-related models were prepared to assess baseline conditions:

- A watershed model to simulate monthly mean stream flows within the Local Study Area (LSA) and Regional Study Area (RSA) of the proposed mine. The model used historic climate records and stream flow records to develop monthly mean stream flows and groundwater flows from sub-catchments within the LSA and RSA over the period of record;
- A three-dimensional steady-state numerical groundwater quantity model using the MODFLOW-SURFACT computer modelling software. The groundwater model provides a broad LSA and RSA assessment of the baseline groundwater quantity VC (**Appendix 5.3.5A**). The conceptual hydrogeological model was developed from data collected in 2012 and 2013 (**Appendix 2.2A-4**). The three-dimensional numerical groundwater quantity (MODFLOW) model was calibrated to water levels measured during one of Knight Piésold's field visits (September 2012) and two of AMEC's field

visits (April 2013 and June 2013). **Section 5.1.1.2** provides a summary of the baseline model results. Once active tailings deposition has ceased, the TSF will be reclaimed by placing oxide tailings and OVB on the beaches and PAG waste rock and by constructing wetlands around the central pond margins, leaving a relatively small pond in the impoundment's low points. During closure, the open pit will be flooded to form a pit lake. When full, after an estimated 18 years from the end of mill operations, pit lake overflow will be routed to TSF Site D, where it will discharge to Davidson Creek together with TSF supernatant through a constructed channel. The ECD (Environmental Control Dam) will be removed, Tatelkuz Lake pumping will cease, and natural groundwater flows will resume. Surface water flows in Davidson Creek will be maintained following closure by a combination of impoundment surface water discharge and seepage. The East and West Dumps will be re-contoured as required and covered with approximately 30 centimetres (cm) of overburden and revegetated.

5.3.5.2.2 Spatial and Temporal Scope

Section 4 describes the rationale for temporal and spatial boundaries of the Project that are also relevant to the groundwater quantity effects assessment **Figure 5.3.5-1**.

5.3.5.2.2.1 Spatial Scope

The Project and associated facilities will be located in the headwaters of Davidson Creek, with the exception of the East Dump, which will be located in the headwaters of Creek 661. The LSA includes (as per **Table 4.3-1** in **Section 4**) the entire mine site and a 1 kilometer buffer around it to capture potential groundwater drawdown effects due to open pit excavation and seepage effects from mine waste management facilities. The RSA includes all of the watersheds that might potentially be involved with the Project: the entire watersheds of Davidson Creek, Creek 661, Turtle Creek; a portion of the watersheds of Chedakuz Creek, Laidman Lake, Creek 705, Blackwater River, and Fawnie Creek; and the tributaries flowing into the south side of Tatelkuz Lake. **Figure 5.3.5-2** shows the Project footprint and the groundwater LSA and RSA. The linear components of the Project (i.e., transmission line, airstrip, Kluskus-FSR, freshwater supply system, and mine access road) do not interact with the groundwater quantity valued component, therefore they have not been considered in the definition of the spatial scope.

In general, the includes all aquifers that have the potential to be measurably affected by the Project's development and operations. The RSA includes groundwater upstream and downstream of the Project that either potentially influences the LSA groundwater or could be indirectly influenced by the Project.

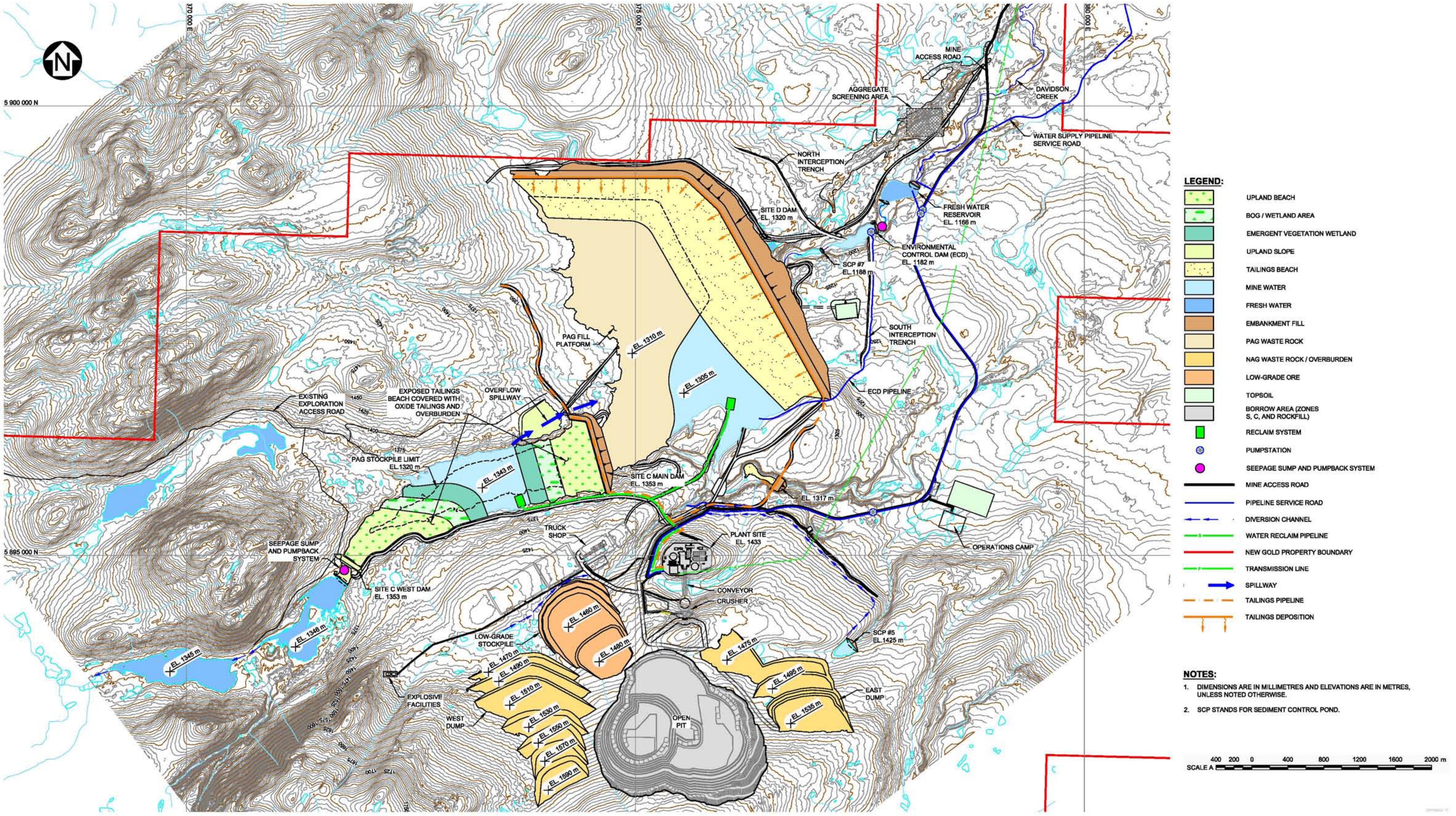

Figure from Knight Piésold Mine Waste and Water Management Design Report (VA101-457/6-11, Revision A) dated 22 November, 2013	CLIENT: newgold	DWN BY: KA	PROJECT: Blackwater Gold Project	DATE: January 2014
		CHK'D BY: MY		PROJECT NO: VE52277
	AMEC Environment & Infrastructure 4445 Lougheed, Suite 600, Burnaby, B.C., V5C 0E4 Tel. 604-294-3811 Fax 604-294-4664 — amec	DATUM: N/A	TITLE: Proposed Project Site Arrangement - Year 8	REV. NO.: A
		PROJECTION: N/A		FIGURE No. 5.3.5-1
		SCALE: N/A		

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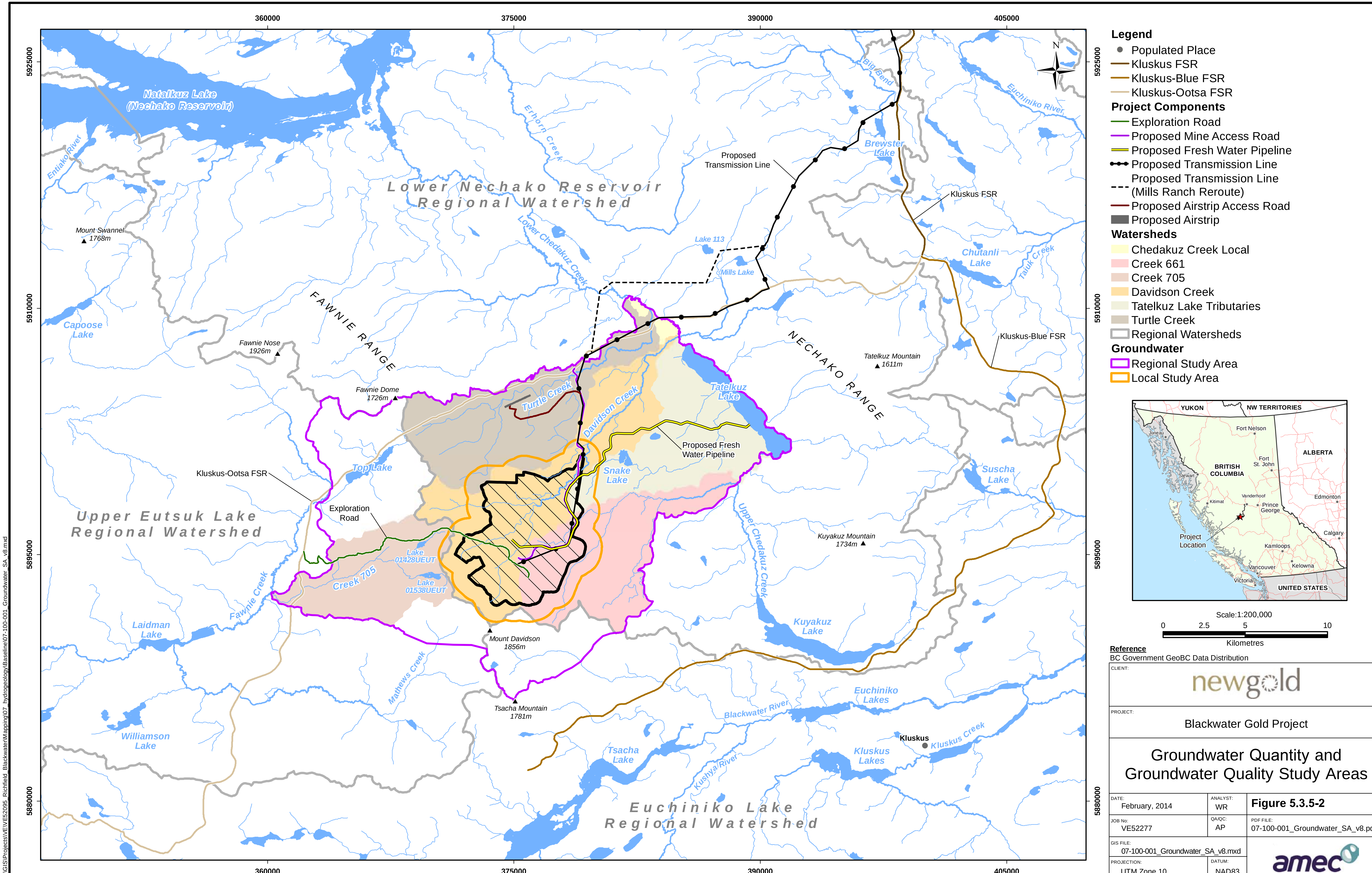


Legend
Populated Place
Kluskus FSR
Kluskus-Blue FSR
Kluskus-Ootsa FSR
Project Components
Exploration Road
Proposed Mine Access Road
Proposed Fresh Water Pipeline
Proposed Transmission Line
Proposed Transmission Line (Mills Ranch Reroute)
Proposed Airstrip Access Road
Proposed Airstrip
Watersheds
Chedakuz Creek Local
Creek 661
Creek 705
Davidson Creek
Tatelkuz Lake Tributaries
Turtle Creek
Regional Watersheds
Groundwater
Regional Study Area
Local Study Area
Lower Nechako Reservoir Regional Watershed
Upper Eutsuk Lake Regional Watershed
Euchiniko Lake Regional Watershed
Natalkuz Lake (Nechako Reservoir)
FAWNIE RANGE
NECHAKO RANGE
Proposed Transmission Line
Kluskus FSR
Kluskus-Blue FSR
Kluskus-Ootsa FSR
Exploration Road
Proposed Fresh Water Pipeline
Mount Swannel 1768m
Fawnie Nose 1926m
Fawnie Dome 1726m
Mount Davidson 1856m
Tsacha Mountain 1781m
Tatelkuz Mountain 1611m
Kuyakuz Mountain 1734m
Kluskus
Capoose Lake
Top Lake
Laidman Lake
Williamson Lake
Tsacha Lake
Kluskus Lakes
Euchiniko Lakes
Kuyakuz Lake
Snake Lake
Tatelkuz Lake
Suscha Lake
Chutanli Lake
Brewster Lake
Lake 113
Mills Lake
Lake 01428UEUT
Lake 01538UEUT
Turtle Creek
Davidson Creek
Creek 705
Fawnie Creek
Mathews Creek
Erhorn Creek
Lower Chedakuz Creek
Upper Chedakuz Creek
Entiako River
Big Bend
Euchiniko River
Tatuk Creek
Blackwater River
Kluskus Creek
Kushya River
360000
375000
390000
405000
5925000
5910000
5895000
5880000
N
YUKON
NW TERRITORIES
BRITISH COLUMBIA
ALBERTA
UNITED STATES
Fort Nelson
Fort St. John
Juneau
Stewart
Kitimat
Vanderhoof
Prince George
Edmonton
Calgary
Kamloops
Kelowna
Vancouver
Victoria
Project Location
Scale:1:200,000
0 2.5 5 10
Kilometres
Reference
BC Government GeoBC Data Distribution
CLIENT:
newgold
PROJECT:
Blackwater Gold Project
Groundwater Quantity and Groundwater Quality Study Areas
DATE: February, 2014
ANALYST: WR
Figure 5.3.5-2
JOB No: VE52277
QA/QC: AP
PDF FILE: 07-100-001_Groundwater_SA_v8.pdf
GIS FILE: 07-100-001_Groundwater_SA_v8.mxd
PROJECTION: UTM Zone 10
DATUM: NAD83
amec
Y:\GIS\Projects\VE\VE52095_Richfield_Blackwater\Mapping\07_hydrogeology\Baseline\07-100-001_Groundwater_SA_v8.mxd

5.3.5.2.2.2 Temporal Scope

The temporal scale for the groundwater quantity effects assessment is from pre-construction (baseline) through post-closure (after the TSF discharges). Understanding of baseline groundwater quantity is required to determine whether effects could occur during the phases of the Project. During construction and operations and for a period of time after closure, there will be very limited groundwater seepage from the TSF into Davidson Creek. Approximately 18 years after the end of operations, the groundwater seepage from the TSF to Davidson Creek will increase somewhat as the ECD pumping system is removed. **Section 5.3.3** describes the potential effects of these seepage discharges on Davidson Creek water quality.

5.3.5.2.2.3 Administrative and Technical Boundaries

Administrative Boundaries are not applicable to this VC. Technical boundaries for the assessment are established by the groundwater model predictions used in the effects assessment. There is an uncertainty/margin of error associated with the use of groundwater models; however, standards for modeling were followed. Therefore, the groundwater model includes an acceptable level of uncertainty for an assessment.

5.3.5.2.3 Past, Present or Future Projects and Activities

The projects or activities identified in the Project Inclusion List (**Table 4.3-11** in **Section 4**) in the RSA do not affect groundwater quantity, because they do not involve pumping or diversion of groundwater.

No water licences related to groundwater use were found in the RSA, aside from drinking water wells for the exploration camp. There is one domestic water well at the Mills Ranch on Tatelkuz Lake. The well is very shallow and, at approximately 20 km downstream from the Project.

Due to the remote location of the mine site, current groundwater extraction near the Project is negligible, and previous mine exploration is negligible as well. The closest current off-site wells (Kluskus well and TTM Resources well) are registered on the provincial WELLS database (BC Ministry of Environment (BC MOE), 2013). One of these off site wells reportedly supplies the Kluskus First Nation village at Kluskus Lake, and the other is reportedly owned by a forest company. Both off-site wells are located more than 20 km from the Project.

5.3.5.2.4 Traditional Knowledge

Part C discusses traditional knowledge (TK) with respect to groundwater quantity and groundwater quality. Contamination of existing groundwater quantity is an important concern for local residents and Aboriginal groups, and members of these groups have expressed interest in the Project’s potential effects on groundwater quantity. Comments provided during the engagement and consultation process offered insight into traditional, ecological, or community knowledge (Lhoosk’uz Dene Nation and Saik'uz First Nation, pers. comm. 2013). This includes unique knowledge about the local environment, how it functions, and its characteristic ecological relationships.

Water is of great importance to First Nations that reside near the Project. In July 2013, interviews were conducted with residents of Indian Reserve (IR) #28 at the north end of Tatelkuz Lake. It was stated that “water is our life … it is the life for plants, trees, and animals” (interviews with Lhoosk’uz Dene Elders, pers. comm. 2013). Rainfall and spring water were also described as being important. One Elder noted that she prefers to fish for trout in surrounding lakes, as “trout caught in the rivers and creeks taste muddy.” According to one Elder, there is now Escherichia coli bacteria in lakes and streams near to Kuyakuz Lake and Kluskus Indian Reserve #1. The family residing at Indian Reserve #28 expressed concern that arsenic levels were high in nearby waterbodies. The family noted they used to get their drinking water from the well at the Mills Ranch but no longer do this because the water is now discoloured (interview with Lhoosk’uz Dene Nation and Saik'uz First Nation representatives, pers. comm. 2013). Based on tests conducted by AMEC in 2013, the water in the well was iron-stained but did not contain coliform bacteria. Bottled water for drinking purposes is now purchased in Vanderhoof or other communities.

Section 3 provides additional detail on comments and issues raised, as well as the public and Aboriginal issues tracking tables for the Project. **Section 14** through **Section 16** provides a summary of the Aboriginal background, rights, and interests for the Project.

5.3.5.2.5 Project Overview

Section 2.2 provides a detailed overview of the Project; mine water management is described in **Section 12.4.1.18.4.18**. A brief overview of the Project is documented here to provide context for the groundwater quantity effects assessment that follows.

Once active tailings deposition has ceased, the TSF will be reclaimed by placing oxide tailings and OVB on the beaches and PAG waste rock and by constructing wetlands around the central pond margins, leaving a relatively small pond in the impoundment’s low points. During closure, the open pit will be flooded to form a pit lake. When full, after an estimated 18 years from the end of mill operations, pit lake overflow will be routed to TSF Site D, where it will discharge to Davidson Creek together with TSF supernatant through a constructed channel. The ECD will be removed, Tatelkuz Lake pumping will cease, and natural groundwater flows will resume. Surface water flows in Davidson Creek will be maintained following closure by a combination of impoundment surface water discharge and seepage. The East and West Dumps will be re-contoured as required and covered with approximately 30 centimetres (cm) of overburden and revegetated.

The Project will be constructed over a two-year period, with some construction in the first operating year. Groundwater pumping wells will be installed around the pit perimeter at Year -2 in order to depressurize the pit area in preparation for mining.

Before construction, the Kluskus Forest Service Road (FSR) will be upgraded under a separate permit. The transmission line providing grid power to the Project will be built during the construction phase. The freshwater supply pipeline from Tatelkuz Lake will also be built, and an airstrip will be constructed three kilometres (km) north of the main Project site. Best management practices (BMPs) will be employed for all these linear facilities to limit, to the extent practical, any interaction with groundwater.

An open pit will feed ore to a gold processing plant that will use whole ore carbon-in-leach cyanidation process to extract gold and silver as dóre. Tailings will first be routed to an SO_2/air cyanide destruction circuit before disposal in the Tailings Storage Facility (TSF). This will significantly reduce concentrations of cyanide and residual metals; concentrations will further reduce in the TSF by natural degradation.

The TSF will be located in the Davidson Creek drainage and will permanently store tailings, potentially-acid generating (PAG) waste rock, and non–acid generating (NAG) waste rock with a high metal leaching potential produced during the operation of the mine. The TSF will have two cells (TSF Site C and TSF Site D). TSF Site C will be constructed first to provide storage capacity for start-up of the process plant and will contain the first two years of tailings and PAG and high metal leaching NAG waste rock. TSF Site D will be constructed to manage tailings and mine waste for the remainder of the operational life of the Project (Year 3 to Year 17). The TSF dams will consist of three zoned, water-retaining, earth-rockfill structures, referred to as the Site C Main Dam, Site C West Dam, and Site D Main Dam. Each TSF Site will include a tailings beach and supernatant water pond. The TSF will not discharge surface water during the operations and early closure phases of the Project.

The TSF will be constructed over materials that will potentially provide a groundwater pathway to receiving waters. The source of seepage will include the supernatant pond, infiltration of transport water and precipitation into the tailings beach, and tailings consolidation water. Limited seepage is expected through the dam and through the dam foundation materials. Extensive surficial sand and gravel materials might potentially contribute seepage from the TSF if no engineering controls are in place. However, engineered mitigation methods designed and to be incorporated into the Project will reduce the seepage lost to receiving streams through the groundwater flow system. In particular, a low-permeability core zone within each TSF embankment will extend to low-permeability subgrade (LPS) materials at depth to cut off potential seepage. An Environmental Control Dam (ECD) and groundwater interception trenches will be located approximately 1 km downstream of the Site D Main Dam to recover potential seepage from the TSF. Seepage interception trenches will be constructed on each side of Davidson Creek, excavated through the surficial sand and gravel terraces downstream of the Site D Main Dam. Seepage to the collection trenches will report to the ECD pond. Recovered water in the ECD will be pumped to TSF Site D.

Seepage from the Site C West Dam will be prevented from flowing to the west by a hydraulic barrier created by constructing a pond with a water level above the TSF Site C pond level.

To address stream flow reduction as a result of the TSF placement in the upper Davidson Creek watershed, water from Tatelkuz Lake will be pumped to Davidson Creek below the ECD to augment flows and maintain instream flow needs for aquatic resources.

NAG waste rock with low metal leaching potential and overburden will be placed in two dumps west and east (West Dump and East Dump) of the open pit. Engineered drainage ditches will be constructed downslope of the East Dump and West Dump to collect surface runoff and shallow groundwater seepage from the facilities and direct water to the TSF.

Low-grade ore (LGO) will be stored upslope of the TSF for processing during the last two years of milling. The LGO will be placed on an engineered compacted soil liner with a drainage collection system (**Section 2.2**), and all runoff and seepage will be treated with lime and directed to the TSF.

In general, all contact water from the mine site facilities will be directed to the TSF during operations and closure; non-contact water not required for processing will be diverted around the mine site by clean water ditches.

The existing exploration camp will initially be expanded for early construction activities and then a larger construction camp will be built to the east. A separate operations camp will be built adjacent to the larger construction camp and the latter removed when no longer required. Potable water will be provided by wells located near the camps. Sewage from the camps will be treated in a lagoon and discharged to a rapid infiltration basin down-gradient of the camps. Sewage from mine processing and support facilities during operations will be treated in a Rotating Biological Contactor and discharged to the TSF.

Once active tailings deposition has ceased, the TSF will be reclaimed by placing oxide tailings and OVB on the beaches and PAG waste rock and by constructing wetlands around the central pond margins, leaving a relatively small pond in the impoundment's low points. During closure, the open pit will be flooded to form a pit lake. When full, after an estimated 18 years from the end of mill operations, pit lake overflow will be routed to TSF Site D, where it will discharge to Davidson Creek together with TSF supernatant through a constructed channel. The ECD will be removed, Tatelkuz Lake pumping will cease, and natural groundwater flows will resume. Surface water flows in Davidson Creek will be maintained following closure by a combination of impoundment surface water discharge and seepage. The East and West Dumps will be re-contoured as required and covered with approximately 30 centimetres (cm) of overburden and revegetated.

5.3.5.3 Potential Effects of the Proposed Project and Proposed Mitigation

This subsection will identify and analyze potential adverse effects resulting from the proposed Project's construction, operations, closure and post-closure phases. The likelihood of different Project components having direct effects on the groundwater quantity VC is presented in the following sections, along with the nature of the expected effects and the likelihood of their occurrence. As well, the indirect interactions between effects are presented in the context of other VCs potentially affected.

There are no potential adverse effects on the VC from other known past, present, and reasonably foreseeable future projects or activities in the proposed Project area as described in **Section 5.3.5.2** above, which discusses the Valued Component Baseline.

Key and moderate interactions between project components and activities undertaken at the mine site and the groundwater quantity VC during the construction, operations, closure, and post-closure phases are presented in **Table 4.3-2** (Project Component and Activity Interaction Matrix) in **Section 4**. The linear components of the Project (i.e. transmission line, airstrip, Kluskus-FSR, freshwater supply system, and mine access road) do not interact with the groundwater quantity valued component, therefore they have not been considered in the scope of the assessment.

5.3.5.3.1 Potential Project Effects

Potential effects on groundwater quantity include groundwater table and flow regime changes due to mine pit dewatering, and changes in landscape features such as the construction of the TSF, Site C West Dam, dumps, and other mine related amenities.

5.3.5.3.1.1 Potential Direct Effects on Groundwater Quantity

The assessment of groundwater effects assumes that the Project-designed mitigation measures will be in place and effective. Mitigation measures include construction and operation of measures to reduce the potential impact of the mine site on its surrounding environment. From a groundwater perspective, mitigation methods are designed to minimize seepage and loss of contact water to the areas surrounding the mine site through the groundwater flow system. The mine site arrangement is such that virtually all groundwater within the mine site area flows into the TSF. Consequently, mitigation methods aimed at reducing and/or collecting seepage and contact water from the perimeter of the tailings dam were integral to the TSF design. Seepage and contact water collection is especially important where seepage could be lost to catchments with relatively low stream flows. As streams reach late winter low flows, seepage and background groundwater can represent the bulk of water flowing in the streams and could therefore be directly affected by the Project. The groundwater table changes will be mainly due to mine pit dewatering during operations and effects from changes in landscape features such as the construction of the TSF, Site C West Dam, dumps, and other mine related amenities. **Table 5.3.5-1** lists sources of direct effects on groundwater quantity by mine phase.

5.3.5.3.1.2 Potential Indirect Effects of Groundwater Quantity on other VCs

Based on the Project Description (**Section 2.2**), the change in baseline groundwater quantity could have potential indirect effects on freshwater aquatic resources, including fish and fish habitat, human health, groundwater quality, surface water quality, and environmental health.

Table 5.3.5-1: Potential Direct Effects on Groundwater Quantity by Mine Phase

Mining Phase	Potential Direct Effects Source	Link (Y/N)	Parameters/Comments
Construction			
Late Year -2 to end Year -1	Site clearing, grading, soil salvage, development of borrow pits, construction of main and ancillary facilities, water diversion/collection/treatment, storage and soil stockpiles, management of construction materials and waste, and workforce accommodation	Y	No operating TSF Groundwater flow patterns and water table changes(1)
Late Year -2 to end Year -1	Camp water supply and sewage treatment, plant-treated effluent	Y	Groundwater flow patterns and water table changes(1)
Year -2 and -1	Pit groundwater depressurization	Y	Cone of depression draws groundwater levels down around the pit(1)
Year -2 and -1	Plant site	Y	Groundwater flow patterns and water table changes
Operations			
Years 1 to 17	TSF	Y	TSF designed with interception systems(1)
Years 1 to 14 (decreases after mining ceases)	Pit area groundwater	Y	Cone of depression draws groundwater levels down around the pit(1) Groundwater flow patterns and water table changes
Years 1 to 17	Camp water supply and sewage treatment, plant-treated effluent	Y	Groundwater flow patterns and water table changes(1), (2)
Years 1 to 17	East Dump and West Dump and low-grade ore stockpile	Y	Groundwater flow patterns and water table changes
Years 1 to 17	Site C West Dam and seepage mitigation pond	Y	Groundwater flow patterns and water table changes
Years 1 to 17	Plant Site	Y	Groundwater flow patterns and water table changes
Closure			
Until no longer required	TSF supernatant pumping to pit	Y	TSF designed with downstream wetland system(1)
Until no longer required	TSF seepage	Y	TSF designed with downstream wetland system(1)
Until no longer required	Reclaimed East Dump runoff and seepage	Y	Captured by collection channel(3)
During early decommissioning; Years 17 to 19	Sewage treatment plant-treated effluent(2)	Y	Groundwater flow patterns and water table changes(1)
Post-Closure			
Indefinite	TSF seepage	Y	To Davidson Creek Groundwater flow patterns and water table changes
Indefinite	Residual East Dump, pit lake, and TSF seepage	Y	To Creek 661 Groundwater flow patterns and water table changes
Indefinite	West Dump seepage	Y	Captured by collection channel routed to TSF

Note: (1) Further discussion in the Mine Water Management Plan, **Section 12.2.1.18.4.18.**
(2) Further discussion in the Water Quality and Liquid Discharges Management Plan, **Section 12.2.1.18.4.10.**
(3) Should water quality meet BC guidelines and site-specific objectives, water will be discharged into Creek 661.
Y = yes; N = no; TSF = Tailings Storage Facility

5.3.5.3.1.3 Potential Combined Effects

Changes in baseline groundwater quantity could potentially affect other VCs such as wetlands, wildlife, and aquatic resources. During construction and operations, the potential combined Project effects include changes in groundwater quantity due to water management within the Project facilities footprint, seepage from the TSF, runoff from NAG waste rock and overburden dumps, or changes in the catchment areas of Project components.

During the closure and post-closure phases, there is a potential for a combined Project effect on groundwater quantity due to changes in the Project's water management.

5.3.5.3.1.4 Potential Project Effects Carried Forward for Assessment

Changes in groundwater flow patterns and water levels may have an adverse effect on the performance of wells in the Project area (i.e., water supply). Moreover, those Project water supply wells may have an effect on local groundwater quantity. Some surface waterbodies could be affected through changes in groundwater quantity.

5.3.5.3.2 Specific Potential Project Effects

5.3.5.3.2.1 Information Sources and Methods

To assess the potential effects of mine site construction, operations, and closure on groundwater quantity, mine site elements were assessed using numerical models and analytical methods.

The baseline watershed model was modified to represent construction, operations, closure, and post-closure conditions. Monthly mean stream flows and groundwater flows were estimated for sub-catchments in the LSA and RSA for each phase of mine development. Each watershed model was constructed as a stand-alone model using historic climate records to estimate variability in monthly mean stream flows (**Appendix 5.1.2.1B**).

The MODFLOW model was modified to assess groundwater quantity associated with the phases of mine development. The MODFLOW model was used to produce groundwater quantity predictions with the representation of the TSF, East Dump and West Dump, LGO stockpile, freshwater reservoir, and seepage collection measures in the model (**Appendix 5.3.5A**). The MODFLOW model was modified to create three separate models representing construction, operations, closure, and post-closure phases of the Project to simulate mine workings and facilities and their associated seepage.

Knight Piésold developed the MODFLOW models, dividing the Project into three timeframes:

- A transient model to simulate construction through to the end of mine dewatering (end of Year 13);
- A transient model to simulate closure though to post-closure conditions; and
- A steady state model simulating post-closure conditions.

A two-dimensional SEEP/W model was used to estimate seepage from TSF Site C and TSF Site D to downstream of the TSF Site D Main Dam (**Appendix 2.2A-2**). Seepage estimates were completed for steady-state conditions based on the maximum TSF configuration at Year 17 of the mine life (i.e., end of process plant operations). Results of the SEEP/W modelling are considered representative estimates of potential TSF seepage and have been used in the environmental impact assessment.

A spreadsheet-based analytical model to estimate groundwater inflows to the pit was developed and provided a preliminary assessment of groundwater inflows and the estimated extent of drawdown associated with active mine dewatering (**Appendix 5.3.5A**).

Assumptions for the modelling described above, are provided in **Appendix 5.1.2.1B, Appendix 2.2A-2, and Appendix 5.3.5A.**

5.3.5.3.2.2 Watershed Model Results

The watershed model results provided estimates of monthly mean groundwater flows at the outlet of each modelled sub-catchment; therefore, only large-scale (coarse resolution) changes in the groundwater quantity system was estimated using the model. At this large scale, watershed model results indicated that groundwater flows were predicted to change from baseline conditions in headwater sub-catchments of Creek 705, Davidson Creek, and Creek 661 watersheds during mine development (**Appendix 5.1.2.1B)**. No change in groundwater flows in the Turtle Creek watershed was predicted to be associated with mine development.

Watershed model results indicated that potential effects on groundwater flows due to mine development will include the following:

- Altered groundwater flows in the headwaters of Creek 705 due to the construction of the pond west of the Site C West Dam (referred to as the "coffer dam at 11-DC" in the watershed model report), which will act as a hydraulic barrier to control seepage from TSF Site C. Watershed model results indicate that average annual groundwater flows leaving the headwater sub-catchments of Creek 705 (nodes 6-705 and 4-705 of the watershed model) were predicted to negligibly increase (<0.01 litres per second [L/s]), while the maximum increase in monthly mean groundwater flows at these nodes was predicted to be less than 1 L/s from baseline conditions. Groundwater flows leaving the lower sub-catchments of the Creek 705 watershed (nodes H7 and 1-705 of the watershed model) were predicted to be similar to baseline conditions. Therefore, effects on groundwater flows associated with the TSF Site C West Dam seepage control pond are predicted to remain localized to the headwater catchments of Creek 705. These effects on groundwater flows were predicted during all phases of mine development from construction through post-closure.
- Altered groundwater flows in Davidson Creek valley due to the construction and operation of the TSF and ECD interception trenches during operations and closure. The watershed model included a conservative assumption that no groundwater flow passes beneath the interception trenches during operations and closure. The watershed model results indicated that groundwater flows from sub-catchments downstream of the ECD

on Davidson Creek (at watershed model node H4B and downstream nodes) are at baseline conditions; therefore, effects on groundwater flows in the Davidson Creek watershed from the TSF and ECD are expected to remain localized to the area adjacent to the TSF. Pumping from Tatelkuz Creek to the freshwater reservoir during operations and closure will provide a source of water that will limit reductions in groundwater quantity along Davidson Creek. No change in groundwater quantity was predicted during the construction phase of mine development. Post-closure groundwater flows leaving sub-catchments downstream of H2 node in the watershed model (located immediately downstream of the ECD) were predicted to be similar to baseline conditions.

- Decreased groundwater flows in the headwater sub-catchments of Creek 661 due to inflows to the open pit. Predicted effects on the groundwater quantity system associated with development of the open pit were assessed with the MODFLOW model. Due to the coarse resolution of the watershed model, MODFLOW model results are considered to provide a more representative estimate of groundwater quantity conditions associated with development of the open pit. The MODFLOW model predictions are discussed in **Section 5.3.5.3.2.3.2**.
- Infiltration of surface water from the TSF spillway channel will potentially contribute to groundwater flows in adjacent catchments. The TSF spillway channel will be constructed and will route runoff within the local spillway catchment to Davidson Creek on closure. Surface water within this spillway channel may provide a source of infiltration to groundwater. Infiltration of surface water from the TSF spillway catchment was assumed in the watershed model to contribute groundwater flows to a sub-catchment beyond the extent of the watershed model (i.e., not Davidson Creek or Creek 661 watersheds). This assumption of infiltration from the spillway was included in the watershed model in order to provide a conservative estimate of stream flow impacts along Davidson Creek and Creek 661. However, since the TSF spillway channel traverses Creek 661 and Davidson Creek watersheds, the potential infiltration from the TSF spillway channel may contribute to groundwater quantity in these watersheds. The potential for infiltration of surface water from the spillway channel will increase during post-closure due to increased channel flows in the spillway from the TSF supernatant pond spilling water.
- Altered recharge to groundwater beneath the footprints of the East and West Dumps. The net effect on predicted recharge to groundwater beneath each dump footprint was a decrease in recharge during the spring and an increase in recharge during the low flow (winter) season.

5.3.5.3.2.3 MODFLOW Model Results

A summary of the MODFLOW seepage analysis results conducted using MODPATH particle tracking is presented below as it provides seepage estimates for all mine components (**Appendix 5.3.5A**). MODPATH particle tracking was implemented to delineate flow directions and estimate seepage travel times to discharge locations from key mine infrastructure. Further detail on the methodology of the seepage analysis is provided in the Numerical Groundwater Modelling Report (**Appendix 5.3.5A**). Subsequent sections discuss results from all the groundwater and seepage modelling according to Project component.

Table 5.3.5-2 shows the MODFLOW (MODPATH)-predicted future particle tracking and advective travel times for the selected Project-related features. Travel times are based on advective travel only and disregard the effects of dispersion and diffusion. Travel times are discussed in **Section 5.3.5.3.2.3** on specific Project-related features that follow.

Table 5.3.5-2: Results of MODFLOW MODPATH Particle Tracking and Advective Travel Times

Facility	MODPATH/ Seepage Discharge Location	Simulated Seepage Flux Rates		Travel Time to Discharge Location (Years)(1), (2), (3)			
		Discharge (L/s)	Discharge (% of Total)	Average	Median	Minimum	Maximum
Pit Lake							
Davidson Creek		0.01	1	809	781	424	1,334
Creek 661		0.5	42	290	218	28	1,037
TSF Main Embankment Drains		0.01	1	226	120	78	711
TSF Spillway		0.01	1	24	25	21	26
ECD System		0.03	2	364	279	122	1,313
Natural Channel Reporting to TSF		0.3	22	202	150	51	2,113
Channel to East Dump Drainage Ditches		0.4	31	103	102	12	227
	Total Seepage From Pit Lake	**1.3**	**100**	**-**	**-**	**-**	**-**
TSF Site C							
TSF Site D Pond		-	100	-	-	-	-
TSF Site D							
Davidson Creek		0.4	2	1,807	585	127	6,979(4)
Creek 661		0.2	1	365	254	97	1,037
TSF Main Embankment Drains		15	72	90	40	0.3	2,824(4)
TSF South Abutment Drains		0.4	2	21	15	1	84
TSF Spillway		0.1	<1	82	70	22	217
ECD System		5.0	24	224	129	13	2,492(4)
Natural Channel Reporting to TSF		0.1	<1	15	10	0.5	93
	Total Seepage From TSF Site D	**21.3**	**100**	**-**	**-**	**-**	**-**
East Waste Rock Dump							
Creek 661		1.7	56	424	405	47	1,288
Springs within East Dump Footprint		0.4	13	32	23	0.5	123
Channel to East Dump Drainage Ditches		0.7	22	109	88	2	297
Natural Channel Reporting to TSF		0.05	2	27	27	21	33
Lower East Dump Drainage Ditch		0.2	6	448	482	328	544
TSF Spillway		0.04	1	38	36	23	63
	Total Seepage From East Waste Rock Dump	**3.0**	**100**	**-**	**-**	**-**	**-**
West Waste Rock Dump							
Springs within West Dump Footprint		0.7	22	55	17	0.1	336
Natural Channel Reporting to TSF		2.4	74	198	160	0.5	558
TSF Site C Pond		<0.1	<1	-	-	159	-
Pit Lake		0.1	4	18	13	0.2	59

Facility	MODPATH/ Seepage Discharge Location	Simulated Seepage Flux Rates: Discharge (L/s)	Simulated Seepage Flux Rates: Discharge (% of Total)	Travel Time to Discharge Location (Years)(1), (2), (3): Average	Median	Minimum	Maximum
Total Seepage From West Waste Rock Dump		**3.3**	**100**	**-**	**-**	**-**	**-**
Plant Site							
Natural Channel Reporting to TSF		0.5	22	72	77	26	102
Lower East Dump Drainage Ditch		1.9	78	38	36	11	92
Total Seepage From Plant Site		**2.4**	**100**	**-**	**-**	**-**	**-**

Note: (1)Approximate seepage travel times from the stockpiles to the discharge locations were calculated using assumed effective porosities of 0.1% (0.001) for weathered bedrock, 0.01% (0.0001) for unweathered bedrock, and 15% (0.15) for alluvial materials.
(2) Travel times are provided for the steady-state post-closure model.
(3) Travel times are based on advective travel only, and disregard the effects of dispersion and diffusion.
(4) Particles with long travel times originate near the boundary of the TSF Site D Pond discharge zone. The proximity to this boundary may influence the modelled travel times.
L/s = litres per second; % = percentage; - = Not Applicable ; TSF = Tailings Storage Facility; ECD = Environmental Control Dam.

5.3.5.3.2.3.1 Tailings Storage Facility

The MODFLOW model was used to assess seepage flow paths, downstream discharge locations and travel times of potential seepage from the TSF facility. MODFLOW model results provided a coarse scale estimate of seepage rates from the foundation of the TSF facility compared to the SEEP/W analysis and excluded the contribution of seepage through the embankment (**Figure 5.3.5-3**). MODFLOW model results (**Figure 5.3.5-4**) showed that seepage originating from TSF Site D foundation only (not including embankment contribution) will be captured primarily by the TSF main embankment drains (15 L/s) and the ECD collection system (5 L/s). Travel time for seepage to arrive at the TSF embankment drains will be fast, with the minimum travel time estimated to be on the order of months or less. Lesser amounts of seepage are predicted to reach Creek 661 (0.2 L/s), Davidson Creek (0.4 L/s), the south abutment drains (0.4 L/s), and the TSF spillway (0.1 L/s). Some of the seepage flow paths that will discharge to Davidson Creek, the ECD system, and the TSF main embankment are predicted to have very long travel times, some in excess of 1,500 years. The estimated total foundation seepage rate leaving TSF Site D will be approximately 21 L/s.

As mentioned previously, the estimate only includes seepage through the foundation and does not include seepage through the TSF embankment. Embankment seepage cannot be simulated using the MODFLOW model construction due to the representation of the TSF using river boundaries and modified recharge rates to represent the pond and beach.

MODFLOW model results predict that all seepage from TSF Site C will discharge to the TSF Site D facility. Seepage travel times were not assessed for those seepage paths.

5.3.5.3.2.3.2 Open Pit

An understanding of hydrogeology in the deposit area was gained from data collected within the proposed open pit as part of a geomechanical site investigation and a hydrogeological study (including two pumping tests). Data from these programs were used to develop the conceptual hydrogeological model in the deposit area and were used to calibrate the baseline MODFLOW model.

Dewatering will be required to support excavating the open pit. Pit dewatering will lower the water table near the open pit. At the end of active dewatering (Year 13), water table drawdown of 1 m was predicted to extend an average distance of approximately 1,200 m from the pit edge. The predicted drawdown zone of influence is irregularly shaped and elongated beneath the topographic high at Mount Davidson. The 1 m drawdown contour will extend approximately 600 m from the pit edge in a southeastern direction towards the Blackwater River. Model simulation of the proposed open pit dewatering anticipates that the zone of influence, defined by the 1 m of groundwater drawdown, will eventually develop in the overburden and coalesce with the cone developed by the freshwater supply, as shown on **Figure 5.3.5-5.**

Reductions in groundwater quantity contributing to the Blackwater River catchment are predicted to be negligible at the end of active dewatering. Groundwater contribution (baseflow) to tributaries of the Blackwater River were a combined 5,585 cubic metres per day (m^3/d) in baseline conditions. Estimated reductions in average annual baseflow contribution to the Blackwater River tributary streams was predicted to be 20 m^3/d (0.25 L/s) at the end of active dewatering, which is equivalent to only a 0.4% decrease in average annual baseflows to Blackwater River tributaries and is within natural variation.

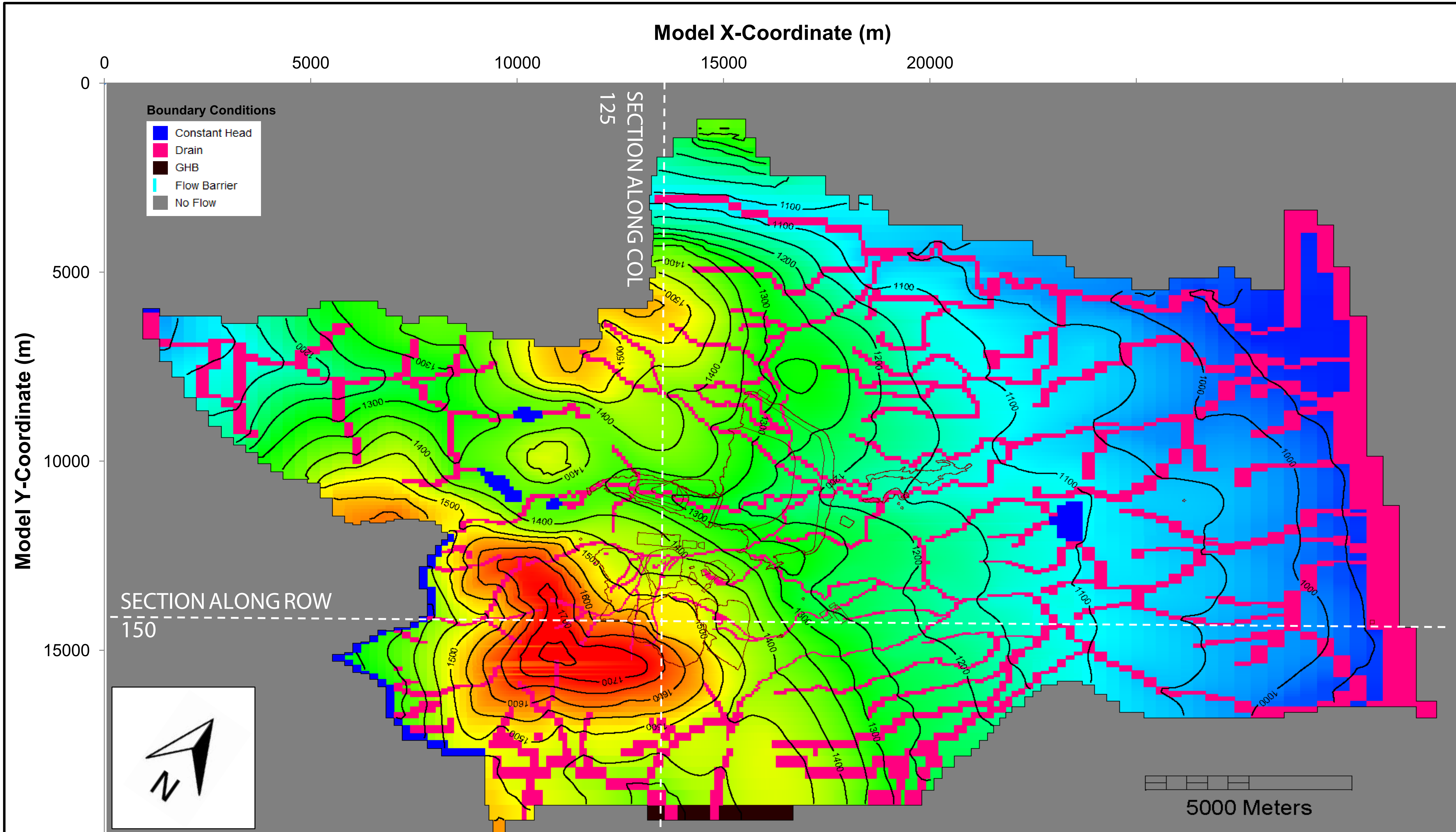
The MODFLOW model used drain cells specified within the void zone of the open pit to simulate dewatering. The results for pit dewatering indicate that simulated groundwater inflow rates to the proposed open pit will increase from the start of operations through Year 13, as the open pit increases in size and depth. Estimated annual average groundwater inflows to the open pit are estimated to be 50 L/s, with a maximum annual inflow rate of approximately 60 L/s. At the end of mine production the groundwater elevation predictions are shown on **Figure 5.3.5-6**. A comparison between MODLFOW model estimated pit inflows and Analytical model based predictions are shown on **Figure 5.3.5-7** (**Appendix 5.3.5A**).

Upon closure, the open pit will be flooded, creating a pit lake. Total water contributing to the pit void in the model was specified as a combination of groundwater inflows and water pumped from TSF Pond D. A separate, transient closure model run estimated the length of time for the pit lake to fill to the open pit spillway elevation to be 20 years after the end of operational dewatering. This prediction assumed that water will be pumped to the pit lake from TSF Site D at a rate of 362 L/s to assist groundwater and to direct precipitation and runoff inflows in rapid pit filling. During closure and after pit filling, it is expected that groundwater elevations directly surrounding the pit lake will recover to the elevation of the pit lake water surface, as shown on **Figure 5.3.5-8**.

The steady-state MODFLOW post-closure simulations show a predicted groundwater inflow to the pit lake of 4.5 L/s, when the pit lake will be at its maximum elevation. After closure, predicted seepage from the pit lake will be approximately 1.3 L/s. MODFLOW model results predict that seepage from the pit lake will contribute to the Davidson Creek and Creek 661 watersheds but not to the Blackwater River catchment, as shown on **Figure 5.3.5-9**. A large proportion of the seepage originating from the pit lake will discharge to drainages that ultimately report to the TSF, including natural channels upstream of the East Dump drainage ditches (0.4 L/s) and drainages reporting to the TSF Site D (0.3 L/s). Seepage to the East Dump drainage ditches will follow shallow flow paths, primarily through the overburden. Seepage to Creek 661 (0.5 L/s) will travel though the upper layers of bedrock and reach Creek 661 with a predicted median travel time of approximately 220 years. Negligible seepage (0.01 L/s) will discharge to Davidson Creek, with a median travel time of 780 years. Results of the seepage analysis indicated that seepage flow paths originating from the pit lake and the TSF Site D converge toward the TSF spillway and Creek 661 via local groundwater flow paths. Seepage flow paths originating from the pit lake will travel to Davidson Creek via deeper (regional) groundwater flow paths within the competent bedrock.

No changes to average annual baseflows or groundwater flows to the Blackwater River catchment were predicted in post-closure.

Precipitation on the upper pit walls and runoff from the surrounding slopes across the pit walls will be in contact with mineralized rock. After closure, the pit lake will flood much of the pit walls and floors, thereby reducing the rock surface area exposed to weathering and consequent metal leaching.



Notes:
The contour lines shown above are of model simulated water table elevation (masl).

Proposed Mine facility outlines are shown for spatial reference only and are not simulated in the baseline model.

Figure from Knight Piésold Numerical Groundwater Modelling Report (VA101-457/6-13, Revision 0) dated 16 January, 2013

Water Table Contours (masl)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900

CLIENT: newgold

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DWN BY:	AA
CHK'D BY:	MY
DATUM:	N/A
PROJECTION:	N/A
SCALE:	N/A

PROJECT
Blackwater Gold Project

TITLE
Baseline Calibrated Groundwater Elevation Map

DATE:	January 2014
PROJECT NO:	VE52277
REV. NO.:	A
FIGURE No.	5.3.5-3

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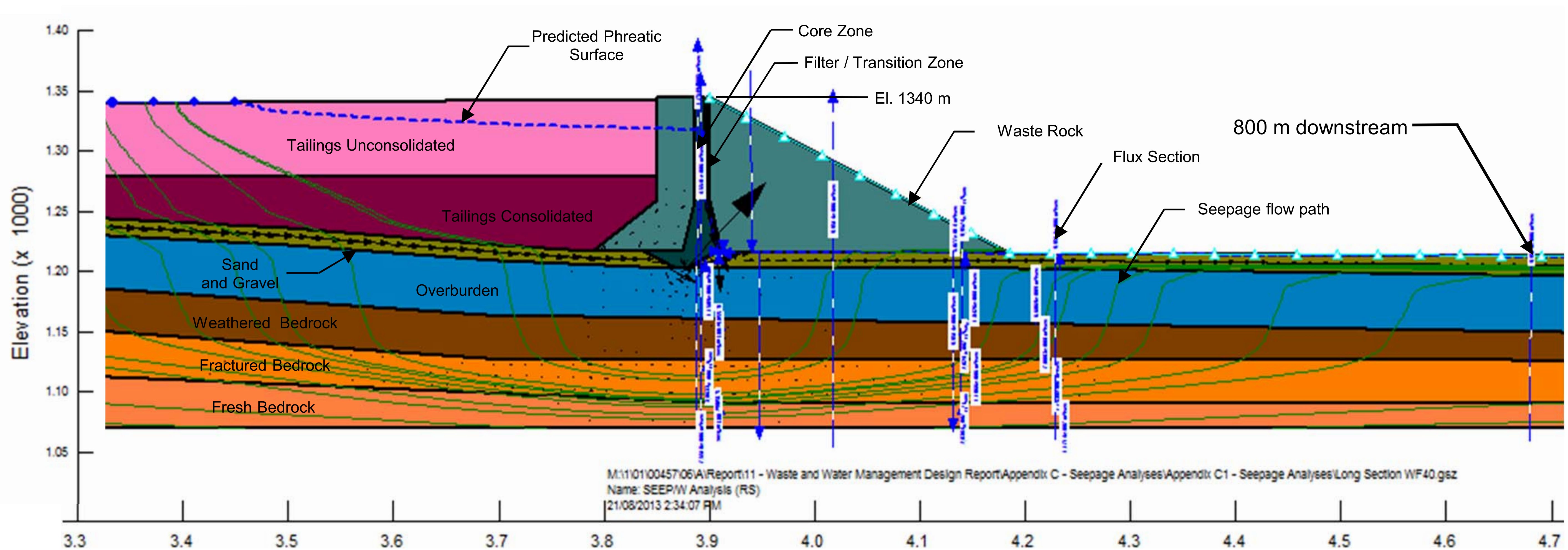
Material	Saturated Hydaulic Conductivity (K_{sat} = m/s)	Anisotropy Ratio (K_v:K_h)
Waste Rock (Zone C)	1.0E-04	1.0
Core Zone (Zone S)	1.0E-08	1.0
Filter (Zone F) / Transition (Zone T)	1.0E-05 / 1.0E-04	1.0
Sand and Gravel	1E-04	1.0
Overburden / Weathered Bedrock	5.0E-08	1.0
Fractured / Fresh Bedrock	4.0E-07 / 1.0E-7	1.0
Tailings Unconsolidated	5.0E-08	0.1
Tailings Consolidated	5.0E-08	0.1



NOTES:

1. LOCATION OF PHREATIC SURFACE PREDICTED FROM STEADY STATE SEEPAGE ANALYSIS.

Figure from Knight Piésold Mine Waste and Water Management Design Report (VA101-457/6-11, Revision A) dated 22 November, 2013 (Appendix C-1).

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DATUM:	N/A
PROJECTION:	N/A
SCALE:	N/A

PROJECT: Blackwater Gold Project

TITLE: **Tailings Storage Facility**
TSF Site D Main Dam

DATE:	January 2014
PROJECT NO:	VE52277
REV. NO.:	A
FIGURE No.	5.3.5-4

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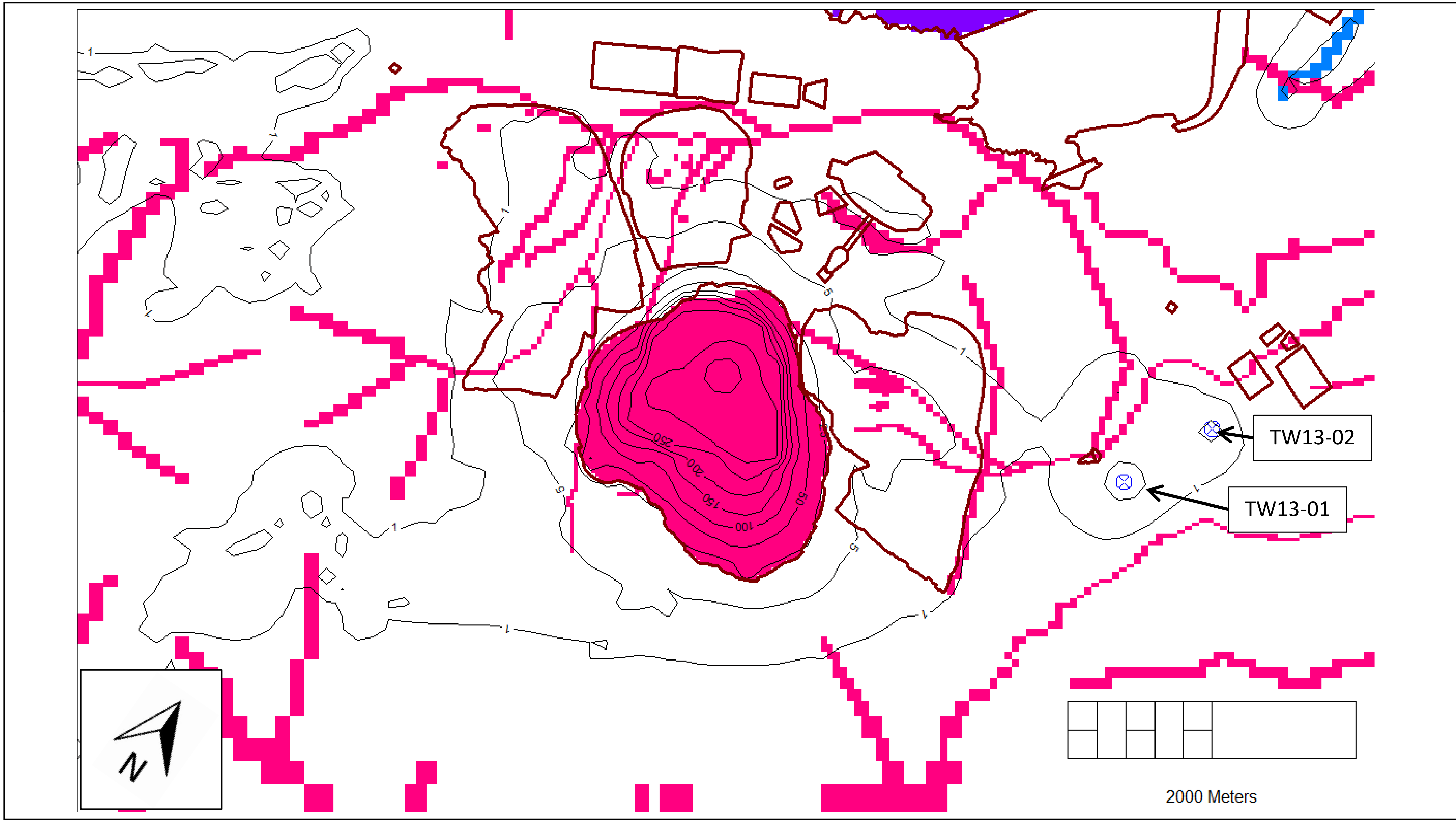

Boundary Conditions

- Constant Head
- River
- Drain
- GHB
- Flow Barrier
- No Flow

Groundwater Extraction Well

NOTES:

1. CONTOURS INDICATE PREDICTED WATER TABLE DRAWDOWN (meters) FROM PRE-DEVELOPMENT CONDITIONS.

Reference
Figure from Knight Piésold Numerical Groundwater Modelling Report (VA101-457/6-13, Revision 0) dated 16 January, 2013.

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DATUM:	N/A
PROJECTION:	N/A
SCALE:	N/A

PROJECT: Blackwater Gold Project

TITLE: Predicted Open Pit Drawdown

DATE:	January 2014
PROJECT NO:	VE52277
REV. NO.:	A
FIGURE No.	5.3.5-5

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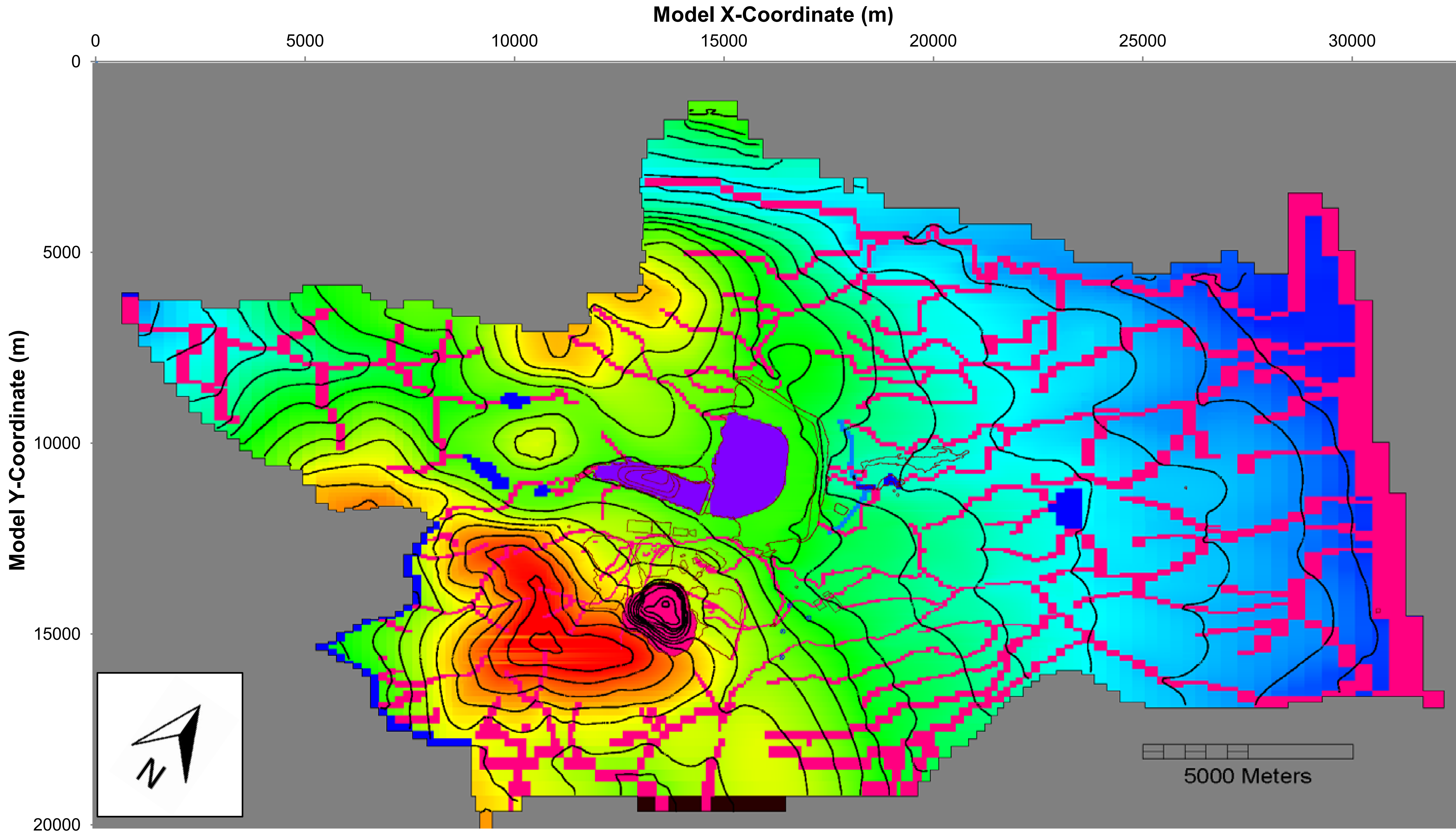

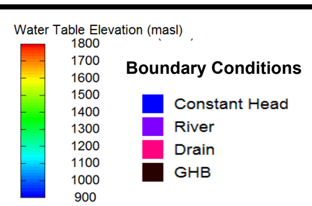

NOTES:

1. CONTOUR INDICATE MODEL SIMULATED WATER TABLE ELEVATION (masl).

2.THE ECD SYSTEM (DRAIN BOUNDARY CONDITIONS) ARE HIGHLIGHTED IN LIGHT BLUE DOWNSTREAM FROM THE MAIN TSF EMBANKMENT.

3. EMBANKMENT DRAINS ARE NOT ASSIGNED WITHIN THE FOOTPRINTS OF THE TSF EMBANKMENTS.

Reference
Figure from Knight Piésold Numerical Groundwater Modelling Report (VA101-457/6-13, Revision 0) dated 16 January, 2013.

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DWN BY: MY	PROJECT	Blackwater Gold Project	DATE: January 2014
CHK'D BY: JK			PROJECT NO: VE52277
DATUM: N/A	TITLE	Groundwater Elevation Map at the End of Production	REV. NO.: A
PROJECTION: N/A			FIGURE No. 5.3.5-6
SCALE: N/A			

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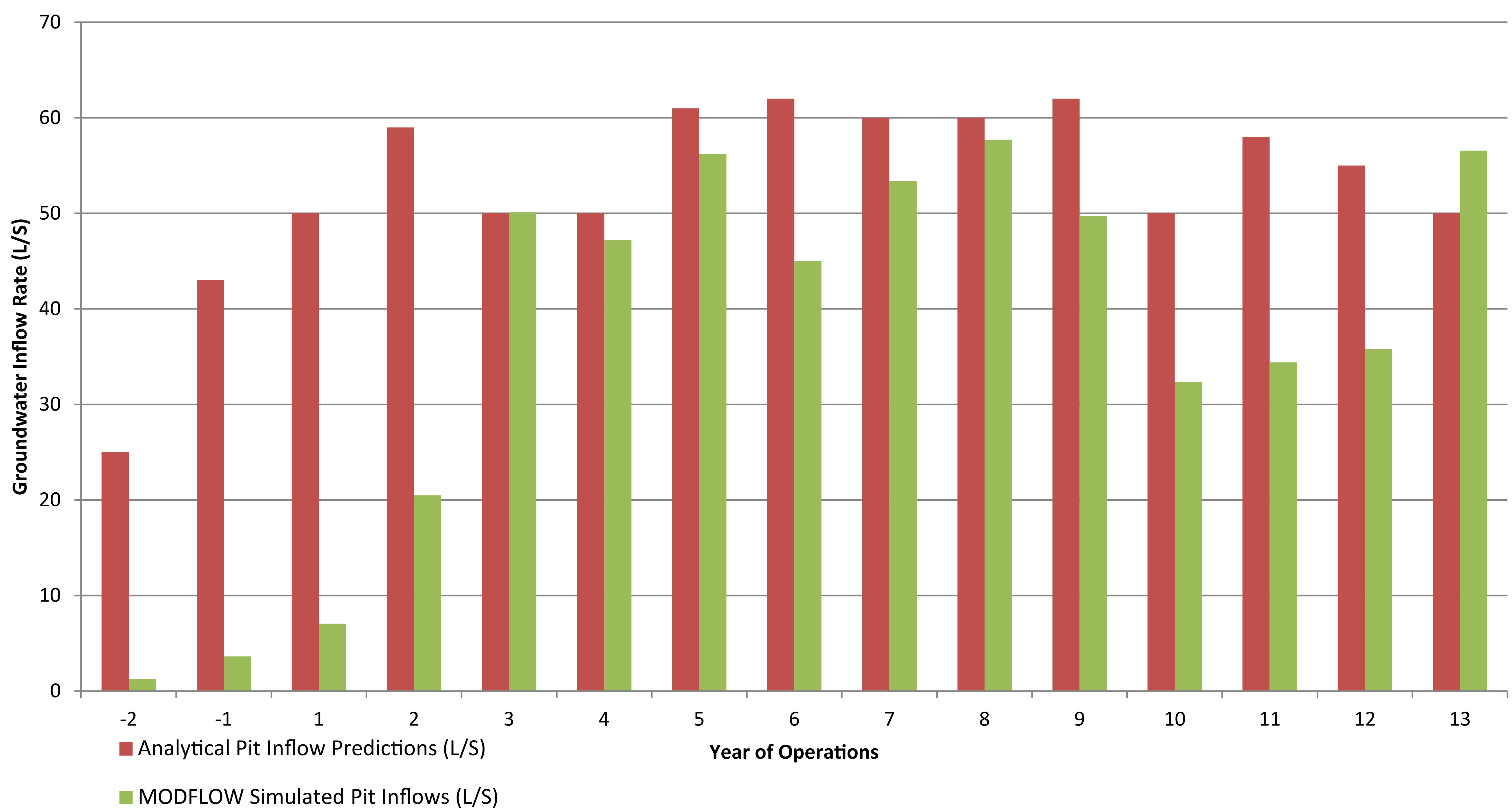

NOTES:

1. PIT INFLOW RATES PREDICTED FOR YEARS -2 THROUGH 2 USING THE ANALYTICAL METHOD ARE HIGHER THAN THOSE PREDICTED USING THE NUMERICAL MODEL. THE ANALYTICAL METHOD CONSIDERS THE GROUNDWATER PUMPING REQUIREMENTS FOR PIT DEWATERING AND PIT WALL DEPRESSURIZATION. THE NUMERICAL MODEL SIMULATIONS DO NOT INCLUDE PUMPING REQUIREMENTS TO ACHIEVE DEPRESSURIZATION.

Reference
Figure from Knight Piésold Numerical Groundwater Modelling Report (VA101-457/6-13, Revision 0) dated 16 January, 2013.

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CHK'D BY:	JK
DATUM:	N/A
PROJECTION:	N/A
SCALE:	N/A

PROJECT: Blackwater Gold Project

TITLE: Predicted Pit Inflow Rates: Numerical Model and Analytical Calculation

DATE:	January 2014
PROJECT NO:	VE52277
REV. NO.:	A
FIGURE No.	5.3.5-7

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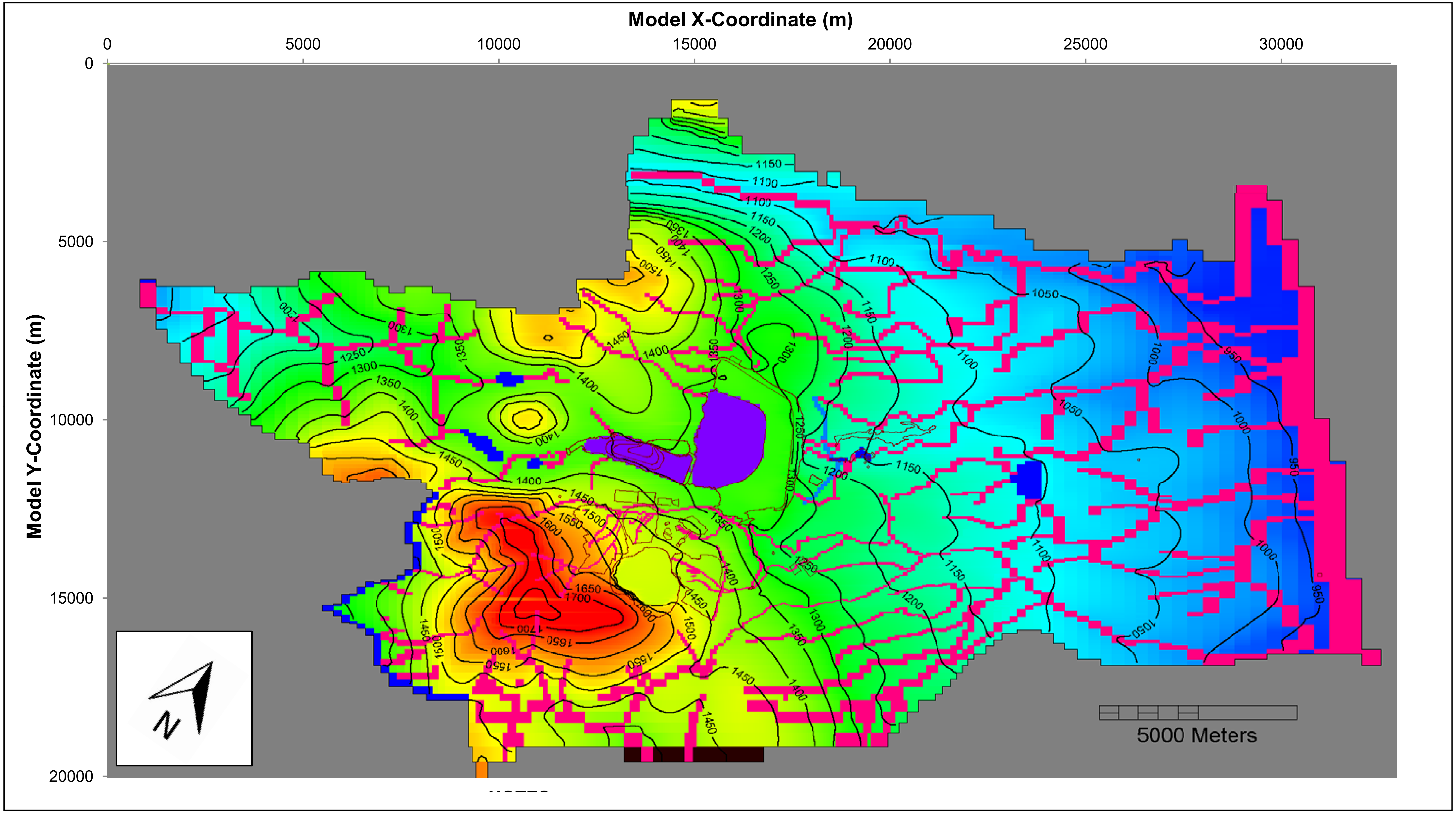

Water Table Elevation (masl)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900

Boundary Conditions
- Constant Head
- River
- Drain
- GHB
- Flow Barrier
- No Flow

NOTES:

1. THE CONTOUR LINES SHOWN ABOVE ARE OF MODEL SIMULATED WATER TABLE ELEVATION (masl).

2.THE ECD SYSTEM (DRAIN BOUNDARY CONDITIONS) ARE HIGHLIGHTED IN LIGHT BLUE DOWNSTREAM FROM THE MAIN TSF EMBANKMENT.

3. THE ULTIMATE PIT LAKE ELEVATION ASSIGNED TO THE MODEL WAS 1475 masl.

3. EMABKMENT DRAINS ARE NOT ASSIGNED WITHIN THE FOOTPRINTS OF THE TSF EMBANKMENTS.

Reference
Figure from Knight Piésold Numerical Groundwater Modelling Report (VA101-457/6-13, Revision 0) dated 16 January, 2013.

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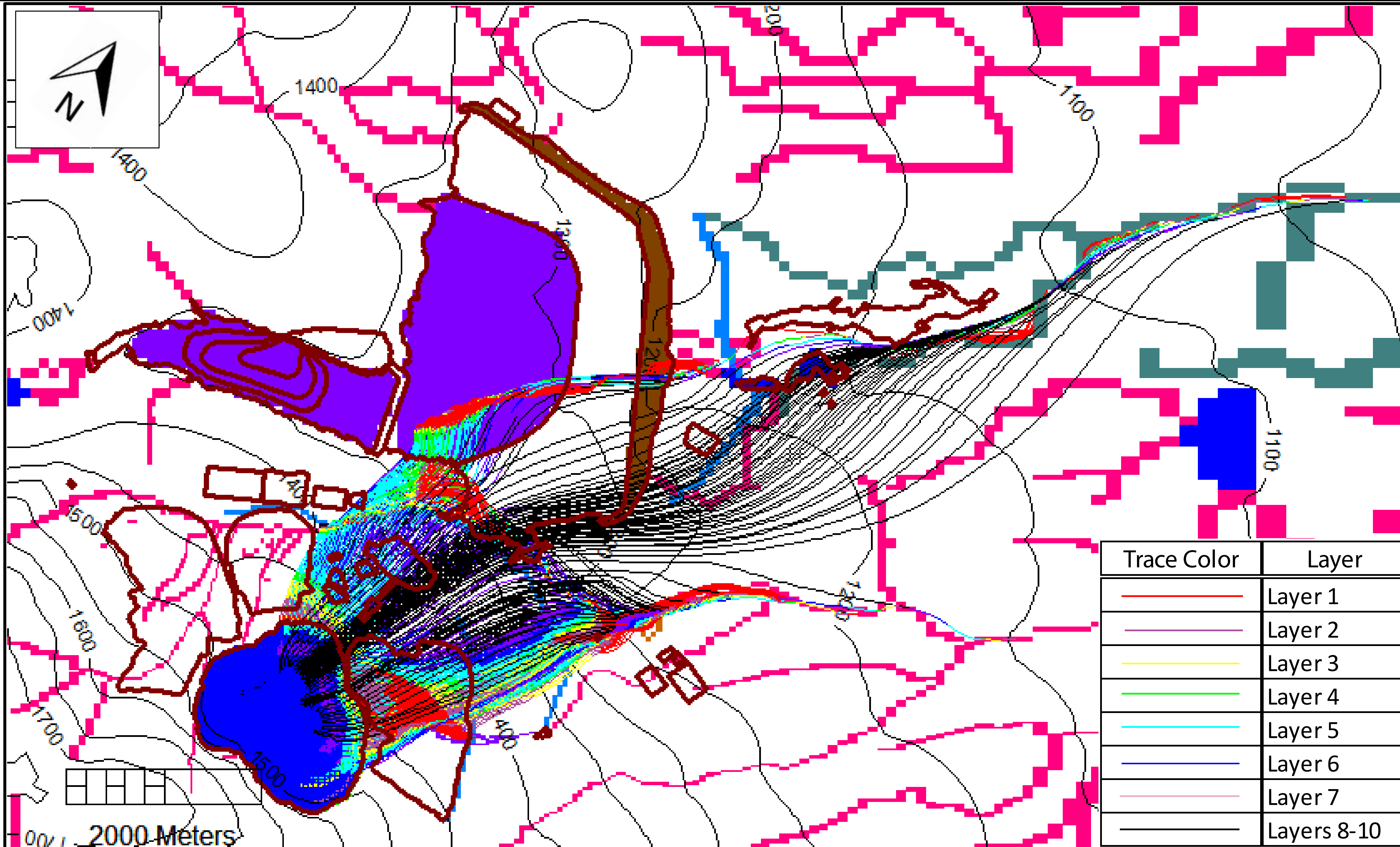
DWN BY:	MY
CHK'D BY:	JK
DATUM:	N/A
PROJECTION:	N/A
SCALE:	N/A

PROJECT: Blackwater Gold Project

TITLE: Post-Closure Model Groundwater Elevation Map

DATE:	January 2014
PROJECT NO:	VE52277
REV. NO.:	A
FIGURE No.	5.3.5-8



Notes:
Particle Traces are coloured according to the model layer it is travelling in.
Particles were inserted into layers 1 through 8.
The contours shown above are of water table elevation (masl).

Figure from Knight Piésold Numerical Groundwater Modelling Report (VA101-457/6-13, Revision 0) dated 16 January, 2013 (Appendix D).

CLIENT: newgold	DWN BY: AA	PROJECT	Blackwater Gold Project	DATE: January 2014
	CHK'D BY: MY			PROJECT NO: VE52277
AMEC Environment & Infrastructure 4445 Lougheed, Suite 600, Burnaby, B.C., V5C 0E4 Tel. 604-294-3811 Fax 604-294-4664	DATUM: N/A	TITLE	**Post Closure Pit Lake Model Particle Track Analysis**	REV. NO.: A
amec	PROJECTION: N/A			FIGURE No. 5.3.5-9
	SCALE: N/A			

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5.3.5.3.2.3.3 West Dump

According to the MODFLOW modelling, approximately 3.3 L/s of seepage will originate from the West Dump. Of that amount, 0.7 L/s and 2.4 L/s will flow to springs within the dump footprint and to a natural channel reporting to the TSF Site D, respectively. The springs will be captured in a perimeter collection ditch and also report to the TSF Site D. Minimal seepage (<0.1 L/s) will report to TSF Site C and 0.1 L/s to the pit lake. Therefore, all the seepage from the West Dump will be captured by mine facilities. **Figure 5.3.5-10** shows the MODFLOW-predicted travel pathways for particles originating from the West Dump.

5.3.5.3.2.3.4 East Dump

The MODFLOW model predicted approximately 3 L/s of seepage will originate from the East Dump. Only NAG5 waste rock and overburden will be placed in the East Dump and thus only waste rock with the best geochemical qualities will be used in its construction. Seepage from the East Dump at a rate of approximately 1.7 L/s will discharge primarily to Creek 661 after a median travel time of more than 400 years. Particle traces indicate that seepage will travel to Creek 661 along local groundwater flow paths in the overburden and shallow bedrock. Approximately 1.3 L/s of the seepage will discharge primarily via local springs within the East Dump footprint and hence by engineered drainage ditches and natural channels routed to TSF Site D. A trace portion of seepage (<1%) will discharge to the TSF spillway. **Figure 5.3.5-11** shows the MODFLOW-predicted travel pathways for particles originating from the East Dump.

5.3.5.3.2.3.5 Plant Site

All seepage from the footprint of the plant site is predicted to discharge to engineered drainage ditches and natural channels that flow to TSF Site D. Seepage of approximately 2.4 L/s will originate from the footprint of the plant site and flow to TSF Site D with a median travel time of 40 years. **Figure 5.3.5-12** shows the MODFLOW-predicted travel pathways for particles originating from the plant site.

5.3.5.3.2.3.6 LGO Stockpile

An LGO stockpile will be placed between the East Dump and the West Dump. Engineered drainage ditches will be constructed downslope of the LGO stockpile to collect surface runoff and shallow groundwater seepage from facilities for the relatively short time the stockpiles are in place (up to a maximum of 17 years). The collected water will be treated with lime due to the expected acidic drainage with elevated metals. The drainage ditch will direct treated water to the TSF. This stockpile will be fully removed and processed by the end of milling in Year 17. Therefore, it is predicted that there will be no short- or long-term effects.

5.3.5.3.2.3.7 Camp Wells

Groundwater extraction wells that will supply potable water to the mine construction and operations camps were included in the MODFLOW model using the analytical Fracture Wells (FWL4) package. The well locations and screened intervals were obtained from well drillers' reports

(Western Water Associates Ltd., 2013). Pumping rates were assigned to the wells to meet the estimated 382 m^3/d (70 gallons per minute (gpm)) water required to supply the camp during the construction phase of the Project (**Table 5.3.5-3**). The water demand during construction will exceed the estimated requirements during operations (127 m^3/d). **Figure 5.3.5-5** shows the groundwater cone of depression from these wells combining with the pit drawdown cones. During operations, closure, and post-closure, no seepage from the mine facilities is expected to reach these supply wells since the MODFLOW model shows the groundwater flow paths are not expected to intersect the well screens of these wells. In addition, the predicted travel times for groundwater seepage to reach the supply wells will be, on average, in excess of 400 years. The MODFLOW model shows minor drawdown effects on the groundwater from these two supply wells; therefore, no significant influence from these wells is expected on flows in Davidson Creek or Creek 661.

***Table 5.3.5-3*: Groundwater Extraction Well Details**

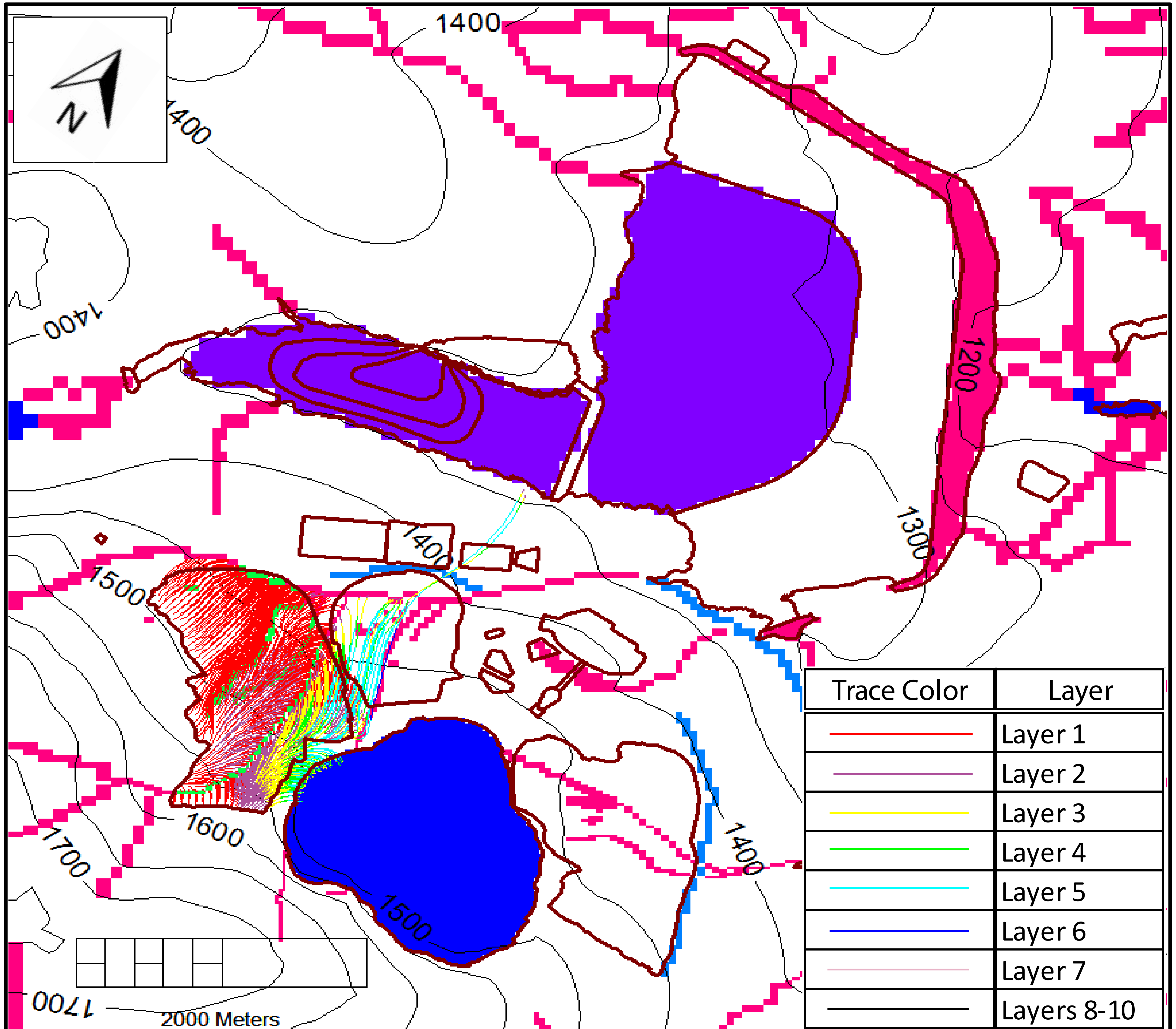
Well	Pumping Rate		Elevation (masl)	Screen Depth (m)	Bottom of Well (masl)	Layers Screened
	(gpm)	(m^3/d)				
TW13-01	40	218	1,402	27	1,375	1
TW13-02	30	164	1,333	58	1,275	1

Note: gpm = gallons per minute; m = metre; masl = metres above sea level; m^3/d = cubic metres per day.

5.3.5.3.2.4 SEEP/W Model Results

Separate base case and sensitivity analyses of the seepage from the TSF Site C and TSF Site D structures were carried out using modelling software SEEP/W in support of the feasibility design (**Appendix 2.2A-2**). Seepage estimates were completed for steady-state conditions based on the maximum TSF configuration at Year 17 of the mine life (i.e., end of process plant operations).

The material parameters of each of the subsurface units modelled in the seepage analysis were based on published values and were supported by site investigations, including lab testing, to derive a reasonable best estimate value. Hydraulic conductivity functions for partially saturated soils were estimated based on material type, using functions available in the analysis software package. The estimated material parameters were compared to in situ and laboratory permeability test results of samples obtained from site investigations wherever possible. **Table 5.3.5-4** presents the material property values used in the SEEP/W model.



Notes:
Particle traces are coloured according tot he model layer it is travelling in.
The contours shown above are of water table elevation (masl).
Figure based on Knight Pieshold drawing January 2014

CLIENT: newgold		DWN BY: AA	PROJECT	Blackwater Gold Project	DATE: January 2014
		CHK'D BY: MY			PROJECT NO: VE52277
AMEC Environment & Infrastructure 4445 Lougheed, Suite 600, Burnaby, B.C., V5C 0E4 Tel. 604-294-3811 Fax 604-294-4664	amec	DATUM: N/A	TITLE	**West Dump Modflow MODPATH Particle Analysis**	REV. NO.: A
		PROJECTION: N/A			FIGURE No. 5.3.5-10
		SCALE: N/A			

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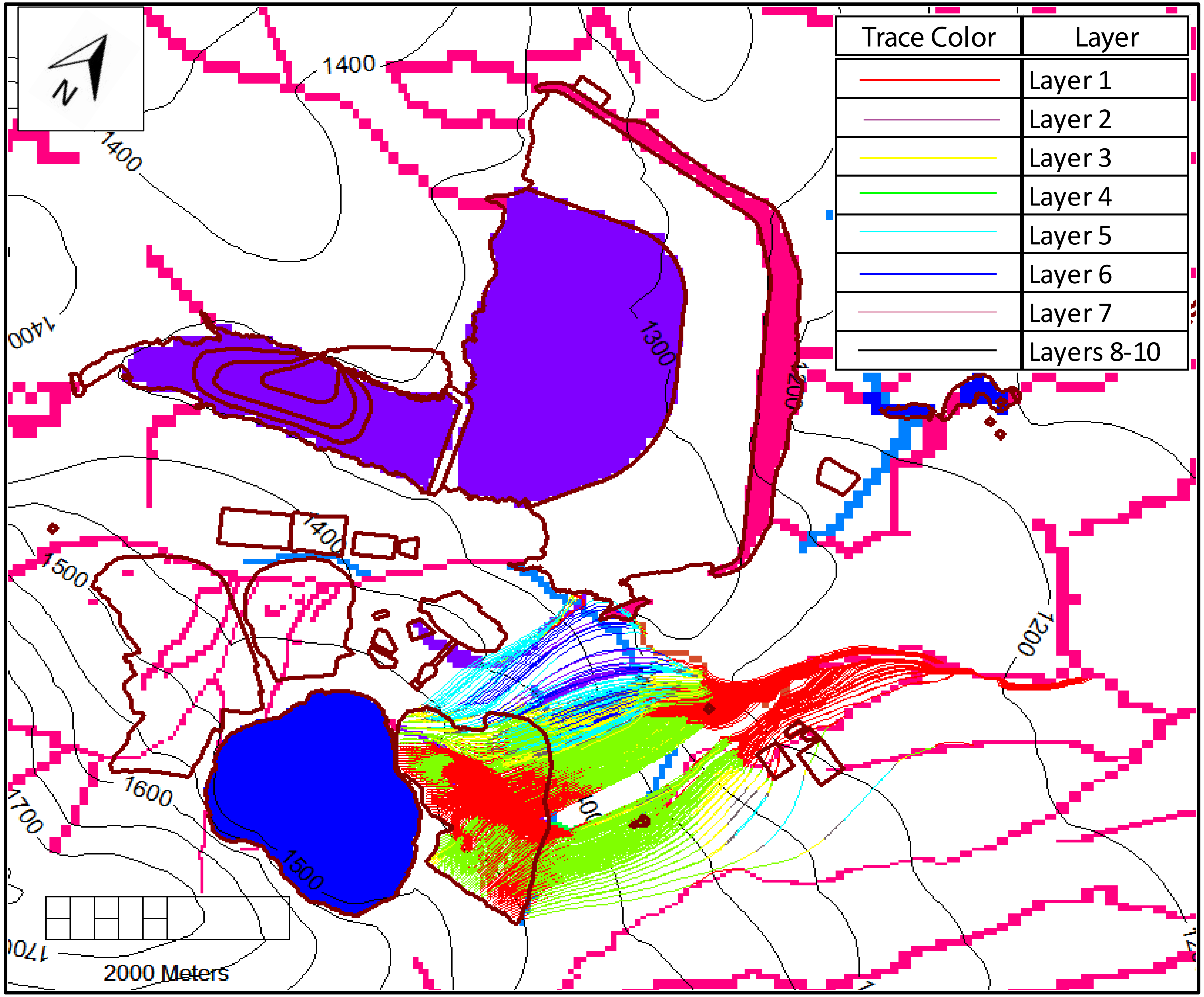

Notes:
Particle traces are coloured according to the model layer it is travelling in.
Contours indicate water table elevation (masl).

Figure from Knight Piésold Numerical Groundwater Modelling Report (VA101-457/6-13, Revision 0) dated 16 January, 2013 (Appendix D)

CLIENT:	newgold
	AMEC Environment & Infrastructure 4445 Lougheed, Suite 600, Burnaby, B.C., V5C 0E4 Tel. 604-294-3811 Fax 604-294-4664
DWN BY:	AA
CHK'D BY:	MY
DATUM:	N/A
PROJECTION:	N/A
SCALE:	N/A
PROJECT	Blackwater Gold Project
TITLE	**East Dump Modflow MODPATH Particle Analysis**
DATE:	January 2014
PROJECT NO:	VE52277
REV. NO.:	A
FIGURE No.	5.3.5-11

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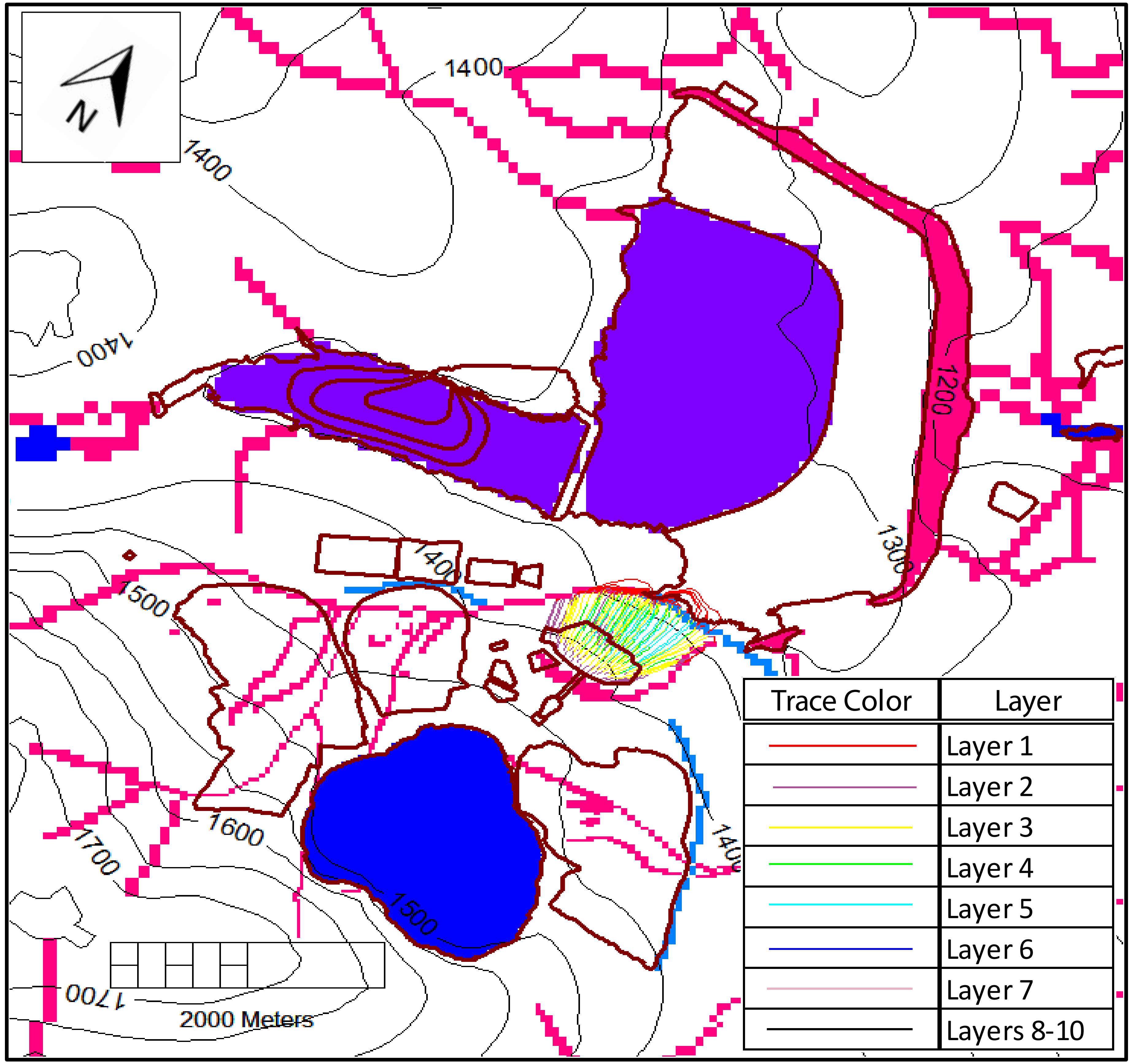

Notes:
Particle traces are coloured according to the model layer it is travelling in.

Figure from Knight Piésold Numerical Groundwater Modelling Report (VA101-457/6-13, Revision 0) dated 16 January, 2013 (Appendix D).

CLIENT:	newgold
AMEC Environment & Infrastructure 4445 Lougheed, Suite 600, Burnaby, B.C., V5C 0E4 Tel. 604-294-3811 Fax 604-294-4664	amec
DWN BY:	AA
CHK'D BY:	MY
DATUM:	N/A
PROJECTION:	N/A
SCALE:	N/A
PROJECT	Blackwater Gold Project
TITLE	**Plant Site MODFLOW MODPATH Particle Analysis**
DATE:	January 2014
PROJECT NO:	VE52277
REV. NO.:	A
FIGURE No.	5.3.5-12

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Table 5.3.5-4: Material Parameters Used in the Base Case Seepage Estimate

Material Type	Saturated or Unsaturated	Saturated Hydraulic Conductivity (Ksat, m/s)	Anisotropy Ratio (KV:KH)	Remark
Sand and Gravel	Saturated or Unsaturated	1E-04	1.0	In Situ Material
Overburden (Glaciofluvial, Till, and Lacustrine)	Saturated	5E-08	1.0	In Situ Material
Completely Weathered Bedrock	Saturated	5E-08	1.0	In Situ Material
Fractured Bedrock	Saturated	4E-07	1.0	In Situ Material
Fresh Bedrock	Saturated	1E-07	1.0	In Situ Material
Zone S (Core Zone)	Saturated or Unsaturated	1E-08	1.0	Embankment Fill Material
Zone F	Saturated or Unsaturated	1E-05	1.0	Embankment Fill Material
Zone T	Saturated or Unsaturated	1E-04	1.0	Embankment Fill Material
Zone C (Waste Rock)	Saturated or Unsaturated	1E-05	1.0	Embankment Fill Material
Consolidated Tailings	Saturated or Unsaturated	5E-08	0.1	Tailings
Unconsolidated Tailings	Saturated or Unsaturated	5E-08	0.1	Tailings

Note: K_{sat} = saturated hydraulic conductivity; KV:KH = ratio of vertical versus horizontal permeability; m/s = metres per second

The base case seepage estimate was undertaken by dividing the TSF into three sections: north abutment, main embankment, and south abutment. **Figure 5.3.5-4** shows a representative cross-section of the TSF Site D Main Dam embankment.

The seepage model provided an estimate of the unit seepage rate (per linear metre of embankment) through each representative cross-section of the TSF embankment. Results indicate that approximately 55 L/s of seepage will potentially pass through the embankment and foundations of the Site D Main Dam at the maximum extent of the TSF in Year 17. The majority of the embankment seepage (53 L/s) will flow through the main section of the dam that faces downstream along Davidson Creek; this seepage will be recoverable. Most of the seepage is predicted to daylight to surface or within the surficial sand and gravel zone upstream of the ECD. Approximately 2 L/s of seepage will be unrecoverable without additional engineering measures. This seepage is predicted to discharge up to 1 km down Davidson Creek and up to 2 km down Creek 661 from the planned engineered facilities.

Embankment seepage from TSF Site C Main Dam of approximately 21 L/s during Years 1 and 2 will be captured at the downstream construction sediment control pond and recycled back to the TSF Site C pond with the exception of a small portion of seepage that will be captured in TSF Site

D. This capture and pump-back system will be decommissioned in Year 3 and all subsequent seepage will be captured by TSF Site D.

A sensitivity analysis was undertaken as a component of the SEEP/W studies. A description of the sensitivity study and results are provided in the Tailings Storage Facility Seepage Sensitivity Analysis Report (**Appendix 5.3.5B**). The analysis evaluated the sensitivity of the seepage estimate by individually varying the saturated hydraulic conductivity of the foundation materials and the Zone S (Core Zone) embankment material. Maximum and minimum (upper and lower bound) saturated hydraulic conductivities for each unit were chosen based on the possible variability in each unit, based on published values and available laboratory and in situ permeability test data. **Table 5.3.5-5** summarizes the selected values for the sensitivity analyses.

Table 5.3.5-5: Upper and Lower Bound Material Parameters used in Sensitivity Analyses

Material Type	Saturated Hydraulic Conductivity (K_{sat}, m/s)		
	Lower Bound	**Base Case**	**Upper Bound**
Sand and Gravel	1E-05	1E-04	5E-04
Overburden	1E-09	5E-08	1E-06
Completely Weathered Bedrock	1E-09	5E-08	1E-07
Fractured Bedrock	1E-07	4E-07	1E-06
Fresh Bedrock	1E-08	1E-07	1E-07
TSF Dam Zone S (Core Zone)	1E-08	1E-08	1E-07

Note: K_{sat} = saturated hydraulic conductivity; m/s = metres per second; TSF = Tailings Storage Facility

The sensitivity analyses indicated that the total seepage estimate was most sensitive to variation in the saturated hydraulic conductivity of the overburden unit and, to a lesser extent, the Zone S (core zone) unit. The total seepage estimate was found to be slightly sensitive to variation in the saturated hydraulic conductivity of the bedrock profile and sand and gravel unit. **Table 5.3.5-6** presents a summary of the results of the sensitivity analyses.

Table 5.3.5-6: ***Upper and Lower Bound and Base Case Seepage Estimates***

Sensitivity Analyses	Lower Bound	Base Case	Upper Bound
Unit	Total Seepage (L/s)		
Sand and Gravel	27	55	68
Overburden	27	55	200
Completely Weathered Bedrock	45	55	57
Fractured Bedrock	50	55	65
TSF Dam Zone S	55 [1]	55	120
Unit	Unrecoverable Seepage (L/s)		
Sand and Gravel	<2	2	2
Overburden	3	2	8
Completely Weathered Bedrock	3	2	2
Fractured Bedrock	<3	2	4
TSF Dam Zone S	2	2	5
Unit	Unrecoverable Seepage as a Percentage of Total (%)		
Sand and Gravel	5	4	3
Overburden	12	4	4
Completely Weathered Bedrock	7	4	4
Fractured Bedrock	5	4	6
TSF Dam Zone S	4	4	4

Note: [1] The lower bound was set as equal to the base case; however, it is possible to have a lower saturated hydraulic conductivity in the core zone, depending on material quality and compaction.
L/s = litres per second; TSF = Tailings Storage Facility; % = percentage.

Overall, the unrecoverable seepage was generally less sensitive than the total seepage estimate to variation in the saturated hydraulic conductivity. Similar to total seepage, unrecoverable seepage was most sensitive to the saturated hydraulic conductivity of the overburden unit and, to a lesser extent, the Zone S unit.

The worst case (upper bound) total seepage estimate for the sensitivity runs was 200 L/s, with approximately 8 L/s unrecoverable (4%), compared to the best case (lower bound) estimate of 27 L/s total seepage, with less than 2 L/s total unrecoverable seepage (5%). The worst case estimate of 200 L/s was an outlier compared to the other estimates and was based on a hydraulic conductivity for the overburden that is inconsistent with the geotechnical characterization of the site (**Figure 5.3.5-13**).

The unrecoverable seepage percentage is a useful metric to evaluate the effectiveness of the water management features, such as the interception trenches and ECD. These robust seepage management features are relatively unaffected by a reasonable range of hydrogeological variability. A reasonable sensitivity case was not encountered that would prevent the majority of total seepage to be captured downstream in the ECD and recycled to the TSF.

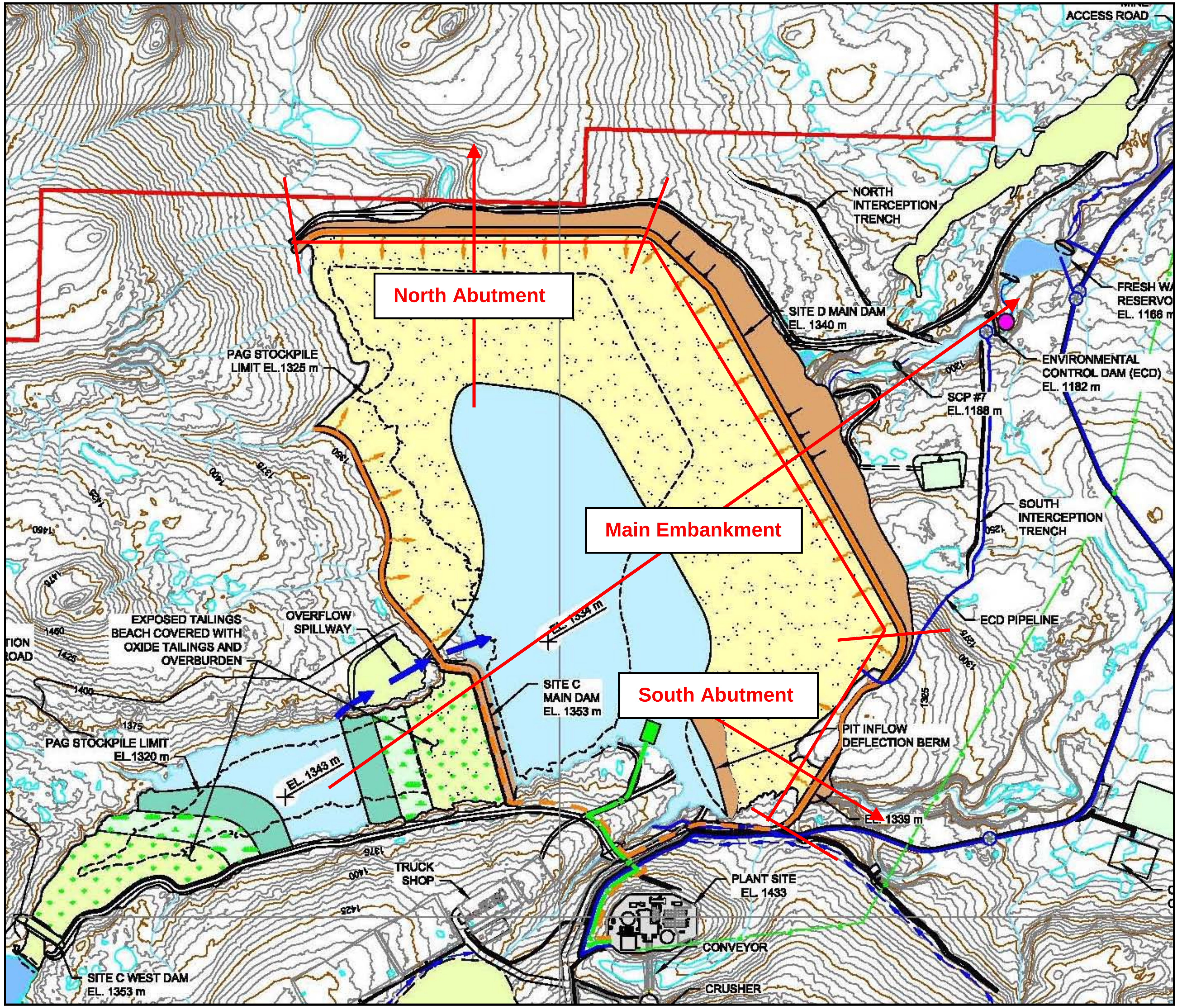

Figure from Knight Piésold Mine Waste and Water Management Design Report (VA101-457/6-11, Revision A) dated 22 November, 2013 (Appendix C-1)

CLIENT: newgold	DWN BY: AA	PROJECT: Blackwater Gold Project	DATE: January 2014
	CHK'D BY: MY		PROJECT NO: VE52277
AMEC Environment & Infrastructure 4445 Lougheed, Suite 600, Burnaby, B.C., V5C 0E4 Tel. 604-294-3811 Fax 604-294-4664	DATUM: N/A	TITLE: **Tailings Storage Facility Seepage Analysis Arrangement**	REV. NO.: A
amec	PROJECTION: N/A		FIGURE No. 5.3.5-13
	SCALE: N/A		

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5.3.5.3.2.5 Pit Inflow Analytical Model Results

An additional spreadsheet-based analytical method was used to estimate inflows into the pit (**Appendix 5.3.5A**). A comparison of year-to-year pit inflow volumes calculated by the MODFLOW model and by the analytical method is shown on **Figure 5.3.5-7** The discrepancy in pit inflow rates results during the initial few years is due to the analytical method used to design the dewatering system and includes groundwater pumping rates required to achieve slope depressurization during the first few years of pit dewatering.

5.3.5.3.3 Summary of Groundwater Quantity Predictions

The following summarizes the results of the numerical groundwater quantity models based on the data analysis, model calibration, and model simulations.

Results of the base case SEEP/W model showed that approximately 55 L/s of seepage will pass through the TSF Dam D embankment and foundations at the maximum extent of the TSF in Year 17. The majority of this seepage (53 L/s) will be recoverable and is predicted to daylight to surface or within the surficial sand and gravel zone upstream of the ECD. Approximately 2 L/s of the total seepage will be unrecoverable without additional engineering measures. Sensitivity analysis of the SEEP/W seepage estimates did not find a case that would prevent the majority of total seepage to be captured downstream in the ECD and recycled to the TSF. The base case SEEP/W results provide the most reasonable estimate of total and “unrecoverable” seepage from the facility and were used in the surface water quality effects assessment.

MODPATH particle tracking and mass balance analysis showed that the majority (72%) of foundation seepage originating from the TSF Site D will discharge to the TSF embankment drains and to the seepage collection system at the ECD (24%). Approximately 2% of the foundation seepage originating from TSF Site D will bypass seepage collection measures and discharge to Davidson Creek. Approximately 1% of the foundation seepage will discharge to Creek 661 and less than 1% discharge to the TSF spillway.

The maximum groundwater inflow rates to the pit predicted using the MODFLOW numerical groundwater model were approximately 60 L/s, with an average inflow rate of 50 L/s. Numerical model results generally compare well with estimates using an analytical calculation.

Water table drawdown of 1 m was predicted to extend an average distance of approximately 1,200 m from the pit edge at the end of active pit dewatering (Year 13). The predicted zone of influence is irregularly shaped and elongated beneath the topographic high at Mount Davidson. The 1 m drawdown contour extends approximately 600 m from the pit edge in a southeastern direction towards Blackwater River. The estimated average annual baseflow contribution to these Blackwater River tributary streams will be 20 m^3/d (0.4%) lower than baseline conditions at the end of active pit dewatering (Year 13), within natural baseline variation. Contributions to baseflow in the post-closure phase will be the same as in baseline. Therefore, predicted reductions in groundwater quantity contributing to the Blackwater River catchment will be negligible.

The maximum groundwater drawdown zone of influence for the open pit, as defined by 1 m drawdown contours, was predicted to merge with the drawdown zone of influence from the two planned camp potable water wells. The assessment was conducted using a camp water demand expected for the construction phase, which is approximately three times greater than the predicted water demand during operations and is therefore considered conservative. The MODFLOW model showed minor drawdown effects on the groundwater from these two supply wells; therefore, no significant influence from these wells is expected on flows in Davidson Creek or Creek 661.

The pit lake will take an estimated 20 years to fill to its maximum volume at the spillway elevation following the cessation of dewatering. This analysis assumed that water will be pumped to the pit lake from TSF Site D at a rate of 362 L/s to assist in rapid pit filling.

About 1.3 L/s of seepage from the pit lake will flow towards the Davidson Creek and Creek 661 catchments. Seepage from the pit lake is not expected to flow towards the Blackwater River catchment. A large proportion of the pit lake seepage will discharge to drainages that flow to TSF Site D (0.7 L/s). About 0.5 L/s of seepage will travel along local groundwater flow paths, through the upper bedrock, and discharge to Creek 661. A trace amount of seepage (0.01 L/s) will discharge to Davidson Creek, following travel paths though deep bedrock.

Approximately 1.3 L/s of seepage from the East Dump will discharge to springs and natural channels and be directed to engineered drainage ditches that convey runoff and toe discharge to the TSF. About 1.7 L/s of seepage from the East Dump will flow within the overburden gravel and shallow bedrock under the engineered drainage ditches and discharge to Creek 661.

Seepage flow paths originating from TSF Site D, the pit lake, and the East Dump were found to converge beneath the TSF spillway and Creek 661. These local groundwater flow paths will discharge to the overlying drainages. Seepage flow paths originating from the pit lake were modelled to travel via deeper (regional) groundwater flow paths within the competent bedrock to Davidson Creek.

Seepage originating from the West Dump will discharge primarily to drainage channels routed to the TSF. Seepage from this facility is not expected to reach the downstream environment.

Seepage originating from the process plant site will flow to natural and engineered drainages that are routed to the TSF. Seepage from this facility is not expected to reach the downstream environment.

5.3.5.3.4 Mitigation of Potential Effects

Conceptual management of mine water is discussed in **Section 2.2** and in the Mine Water Management Plan (MWAMP), **Section 12.2.1.18.4.18**. Mitigation methods to reduce the potential impact of seepage and groundwater extraction from the Project on the surrounding environment are included in the previous discussion. This section consolidates the measures.

Mitigation measures will include but are not limited to:

- Clustering of facilities around TSF (surface water and groundwater capture);
- Collection and diversion ditches (surface water and groundwater capture);
- TSF dam cut-off trench and downstream seepage collection ditches;
- ECD;
- Seepage collection and pump-back systems;
- Pumping water from Tatelkuz Lake to Davidson Creek (maintain stream flows due to reduction of surface water and groundwater);
- Hydraulic barrier (West Dam – Creek 705); and
- Constructed wetlands in TSF, ECD, and water reservoir in post-closure.

Mitigation methods are designed to reduce impact on groundwater and stream flow rates and to reduce the seepage and other contact water that may be lost to the areas surrounding the mine site through the groundwater quantity system. Consequently, mitigation methods will focus on maintaining flows and reducing and collecting seepage throughout the mine site.

Mitigation includes any action taken to avoid, minimize, restore, compensate, or offset the adverse effects of a project or activity. The following sections describe mitigation measures developed for the TSF, open pit, waste dumps, process plant site, and stockpiles.

5.3.5.3.4.1 Tailings Storage Facility Mitigation

Seepage from the TSF will primarily be controlled by the low-permeability core zone constructed prior to the development of the tailings beach, the cut-off trenches, and the low-permeability subgrade materials (**Appendix 2.2A-2**). Special design provisions incorporated into the tailings dam design to minimize seepage losses include the development of extensive tailings beaches (which isolate the supernatant pond from the dam), hydraulic barriers, embankment drainage collection systems, and toe drains at the downstream toe of the dams to reduce seepage gradients. Additional seepage collection ditches constructed along the toe of the embankments will collect seepage and surface runoff and direct the flow to pump-back systems.

Secondary seepage collection at the ECD will be achieved by constructing a collection dam approximately 1 km downstream at a topographic low point in Davidson Creek. This location was established based on a hydrogeology assessment where potential seepage paths were projected to daylight. A pump-back system will manage seepage and stormwater inflows. Recovered water will be pumped to the TSF Site D and the collection pond will be maintained in a dewatered condition to the maximum extent practical. Seepage through this dam will be captured in an embankment drain system and sump and pumped back to the ECD pond.

Two seepage interception trenches (one on each side of Davidson Creek) will be excavated through the surficial sand and gravel terraces downstream of the Site D Main Dam and will report to the ECD pond. The seepage interception trenches (North and South) are located based on the results of geotechnical drilling along the proposed alignments. The trenches will be excavated and keyed into the low-permeability subgrade and will be approximately 3.3 km long with a depth ranging from 5 m to 15 m.

On the west side of the TSF, a dam and seepage recovery sump will be constructed within the Davidson Creek watershed, designed to prevent seepage from this dam flowing into the headwaters of Creek 705. Seepage will be monitored and pumped back from this sump to the TSF. The Site C West Dam seepage will be controlled in the long term by constructing a freshwater pond upstream of the TSF with an elevation higher than the TSF supernatant pond. The freshwater pond level upstream of the TSF will create a hydraulic barrier establishing a freshwater seepage hydraulic gradient towards the TSF. The elevation of the supernatant pond in Site C will be passively controlled by the closure spillway for the facility.

Around Year 3 of operations, TSF Site C will be partially reclaimed. Seepage from Site C will be naturally captured in Site D.

During post-closure, several wetlands will be constructed at or near the former ECD site to capture groundwater seepage originating from the reclaimed TSF Site D. Given the results of the SEEP/W and MODFLOW modelling, minimal seepage might bypass these wetlands.

Stream flows and groundwater levels in Davidson Creek below the ECD will be maintained during operations and early closure by pumping water from Tatelkuz Lake. Flows will be maintained post-closure by the discharge of TSF supernatant and seepage to Davidson Creek.

Groundwater monitoring wells will be installed in the downstream areas below the TSF Site D. Additional monitoring wells will be installed prior to commissioning TSF Site D and during operations, as required.

5.3.5.3.4.2 Open Pit Mitigation

During operations, the open pit dewatering system will consist of a combination of three subsystems: in-pit groundwater depressurization system; perimeter depressurization system; and surface water dewatering system, to minimize runoff from entering the pit. Surface water dewatering systems were designed to manage surface water inflows from rainstorm events and associated snowmelt. A combination of in-pit and perimeter pumping wells will be implemented to achieve acceptable dewatering requirements. The flow from both the surface and groundwater systems will be combined and conveyed via an open channel ditch to TSF Site D.

At closure, pit filling will begin to create a post-closure pit lake. To increase the speed of the pit filling and augment the groundwater inflow, excess TSF supernatant and water pumped during operations for mill freshwater (i.e., pump gland and reagent mixing) from Tatelkuz Lake will be redirected during closure to the open pit. Pit filling will take approximately 20 years (18 years after the cessation of mill operations), upon which the pit lake level will have reached its maximum capacity, will flow over the spillway, and will discharge towards the TSF.

5.3.5.3.4.3 West Dump Mitigation

The West Dump layout was designed to minimize water control requirements. Foundation drains will be installed in areas of existing drainage courses or where excessive seeps or springs are encountered. Shallow discharge from the dump will be collected in ditches near the toe of the dump and routed to a sedimentary basin, prior to being directed to the TSF. During operations, pit dewatering efforts are expected to influence and capture much of the seepage from the West Dump with residual seepage flowing towards the TSF.

At closure, the West Dump will be re-contoured as required and covered with up to 30 cm of overburden and revegetated. Such reclamation will reduce infiltration and seepage.

5.3.5.3.4.4 East Dump Mitigation

The East Dump layout was designed to minimize water control requirements. Foundation drains will be installed in areas of existing drainage courses, or where excessive seeps or springs are encountered. Water that will infiltrate through the dump (comprising NAG5 waste rock and overburden) will be collected in two collection ditches, one at the toe of the dump and one further downstream of the East Dump. The ditches will be constructed to capture runoff and shallow seepage from the dump and route it to the TSF, thus preventing any surface contact water reaching the headwaters of Creek 661. During operations, pit-dewatering efforts are expected to influence and capture some of the seepage from the East Dump. At closure, the East Dump will be recontoured as required and covered with up to 30 cm of overburden and revegetated. The reclamation will reduce infiltration and seepage.

5.3.5.3.4.5 Process Plant Site Mitigation

During operations, a perimeter ditch along the process plant site will intercept seepage from the site. After operations, the process plant site will be reclaimed and revegetated.

5.3.5.3.4.6 Low-Grade Ore Stockpile Mitigation

During operations, perimeter drains will divert natural drainage around the LGO stockpile. Foundation drains overlain by a 0.5 m thick compacted soil liner will collect seepage from the stockpile. The seepage will report to a sump for monitoring flow and quality of the foundation drainage and collected seepage. The foundation drainage and seepage will report to a ditch around the stockpile that will discharge to the TSF. Potential seepage bypassing the ditch will follow natural flow gradients towards the TSF. The LGO stockpile will be fully removed by the end of ore processing in Year 17, the former stockpile liner and collection system will be removed, and the site will be reclaimed.

5.3.5.3.4.7 Effectiveness of Mitigation

Table 5.3.5-7 provides ratings for effectiveness of mitigation measures to avoid or reduce potential effects on groundwater quantity during mine site development. Mitigation measures will be based on site-specific information and construction engineering and are therefore preliminary at this stage.

Table 5.3.5-7: Mitigation Measures and Effectiveness of Mitigation to Avoid or Reduce Potential Effects on Groundwater Quantity during Mine Site Development

Likely Environmental Effect	Project Phase	Mitigation/Enhancement Measure	Effectiveness of Mitigation Rating
Impact of seepage and groundwater extraction on the surrounding environment	Construction, Operations, Closure, Post-closure	Clustering of facilities around TSF (surface water and groundwater capture)	High
		Collection and diversion ditches (surface water and groundwater capture)	High
		Minimize seepage from TSF dam by constructing cut-off trench and downstream seepage collection ditches	High
		ECD to capture most seepage for pump back to the TSF	High
		Seepage collection and pump-back systems	High
		Pumping water from Tatelkuz Lake into Davidson Creek to maintain stream flows to offset reduction in surface water and groundwater downstream of the ECD	High
		Low-permeability core zone in dams to control seepage from the TSF	High
		Monitor seepage, groundwater, and surface water downstream of the TSF and waste dumps. Establish trigger levels to implement contingency measures described in the Application to protect downstream receiving waters quality and aquatic resources.	High
		Construct a hydraulic dam west of the West Dam to create a hydraulic barrier forcing groundwater back toward the dam and away from Fawnie Creek drainage.	High
	Post-closure	Constructed wetlands in TSF, ECD, and water reservoir.	High

Note: ECD = Environmental Control Dam; TSF = Tailings Storage Facility

In summary, low success rating means mitigation has not been proven successful, moderate success rating means mitigation has been proven successful elsewhere, and high success rating means mitigation has been proven effective. The effectiveness of mitigation measures was rated to be high, because the proposed mitigation measures are technologies that are widely used in mining and other industries and have a long-term proven record to be effective in mitigating groundwater quantity effects.

5.3.5.3.5 Additional Mitigation – Triggers for Adaptive Management

Any additional mitigation will be completed in response to monitoring and will be integrated into adaptive management practices at the site.

The developed model predictions will be compared against actual site groundwater pumping, seepage flows, and monitoring well piezometric levels. Seepage from the TSF Site D embankment drains and inflows to the ECD will be monitored and compared to predicted values. Monitoring wells down-gradient of TSF Site D will be used to monitor possible unrecoverable seepage rates.

Triggers related to groundwater quantity will also include groundwater and seepage quality indicators since changes in quality may be related to increased seepage rates. Triggers could include increasing trends in groundwater quality concentrations that begin to approach predicted concentrations or applicable guidelines/site-specific water quality objectives. Sulphate (from SO_2/air treatment and sulphide mineral oxidation) and sodium (from use of sodium cyanide (NaCN) for ore processing) will be useful tracers for seepage.

The measured volumes of mine water pumped from the open pit will be compared to the predicted values, and the model will be updated if required to reflect these differences. The predicted propagation of the cone of depression will be compared against measured groundwater levels in monitoring wells. If groundwater drawdown surrounding the pit is greater than anticipated, the potential for the increased drawdown to result in stream flow reductions will be assessed. In addition, monitoring will be conducted in streams to assess potential for reduced stream flows, and measurements will be compared against baseline measurements to assess potential for impact. If required, additional flows for the tributaries will be provided.

MODFLOW model predictions show that seepage leaving the East Dump may migrate downstream and discharge to Davidson Creek and/or Creek 661. Monitoring wells will be located as close as possible down-gradient of the East Dump to provide early warning of possible seepage quantity or quality concerns. However, the East Dump will comprise low sulphur and metals NAG5 waste rock and overburden. Should observed conditions indicate higher seepage flows or poorer quality than those modelled and predicted, contingency activities will be implemented as required, as discussed below, to address potential downstream effects before they occur. Such activities will include updating and improving the understanding of groundwater conditions along the seepage pathway to best define the necessary contingency measures.

5.3.5.3.6 Contingencies

Several contingency measures can be considered if adaptive management strategies are required for the Project:

- Groundwater source reduction contingencies:
  - Post-closure, lower the pit lake level so that some or all of the pit lake seepage and some of the East Dump seepage is routed towards the pit, rather than to downstream sites;
- Groundwater interception contingencies:
  - Recovery wells are a common method for reducing migration of seepage away from the mine operations. Recovery wells can include conventional pumping wells, well points, and relief wells; and
  - Deep trenches are a method for intercepting groundwater. Two ditches for the TSF are provided in the current mine plan. Observations during operations and closure

may identify additional or alternative locations for ditches to reduce the quantity of seepage migrating downstream;

- Groundwater treatment contingencies:
  - o Wetlands constructed at or near groundwater discharge areas in Davidson Creek and Creek 661 to improve the quality of water as it emerges from the groundwater regime into the surface water regime. Natural wetlands are present in Davidson Creek and Creek 661 downstream, and these may also provide contaminant reduction in seepage.

5.3.5.4 Residual Effects and Their Significance

5.3.5.4.1 Definition of Effects Criteria and Certainty of Predictions

This subsection identifies and describes any residual effects after mitigation. If and where residual adverse effects are identified, an assessment is provided of the significance of those residual effects considering context, magnitude, geographic extent, duration, reversibility, frequency. This section:

- Assesses the likelihood of the effect;
- Assesses the significance of the residual effects; and
- Assesses/discusses the level of confidence and risk in the determination of significance and likelihood of the residual effect.

Residual effects refer to changes in groundwater quantity after mitigation that can reasonably be ascribed to the Project and are not a result of natural flow variations. Groundwater data were collected over the previous two years. Several models were employed to predict effects on groundwater quantity, and model results are generally consistent. Some uncertainty exists with projections of site groundwater quantity. However, conservative assumptions were included and, taken together, represent an unlikely scenario. The Project design involves routing groundwater and contact water to the TSF during operations, with no surface water discharge during operations or early closure.

Seepage estimates are based on extensive geotechnical investigations and assessment. It is assumed that all seepage predicted to travel within the deep overburden and bedrock layers at a distance of 1 km downstream of the TSF Site D Main Dam will ultimately discharge to Davidson Creek. While seepage can be monitored close to mine sources to confirm flow and quality predictions, most of the seepage discharges to Davidson Creek will not occur until well after mine closure, providing ample time to confirm predictions and implement contingency measures, as required.

5.3.5.4.2 Construction

No residual effects are expected during the construction phase, given the mitigation and management measures to be implemented (**Section 2.2** and **Section 5.3.3**). Construction camp wells will be installed and operated during the construction and operation phases of the Project. However, because the amount of water that will be pumped is insignificant relative to the dewatering of the mine pit the effects of pumping these wells was not considered in the effects assessment.

5.3.5.4.3 Operations and Closure

Effects on groundwater quantity due to the mine development are predicted to be localized (within 1 km of TSF Dam D) and essentially restricted to the mine footprint. For example, the piezometric surface in the TSF will be raised over 100 m compared to baseline conditions. Groundwater quantity passing Dam D will be reduced by the cut-off wall and seepage interception system. However, effects on groundwater quantity beyond the ECD are not predicted to be significant as water will be pumped to Davidson Creek during operations and closure, maintaining surface water flows and groundwater levels below the water reservoir. Seepage flows to Davidson Creek from the TSF foundation and dam embankment drains during post-closure are predicted to be similar to baseline groundwater inflows to the Creek.

Residual unrecovered seepage rates from mine facilities to Davidson Creek and Creek 661 are predicted to be low, and the potential effects on surface water quality is assessed in **Section 5.3.3**.

5.3.5.4.4 Post-Closure

It is expected that groundwater quantity will return to, or very close to, pre-mining flow patterns. Groundwater levels immediately adjacent to the TSF will be increased above baseline levels, resulting in a localized alteration to groundwater flows in the Davidson Creek watershed; however, this is predicted to have a very limited residual effect. Moreover, monitoring conducted during the operations and closure phases will be used to verify these predictions.

Groundwater levels around the pit will recover to the elevation of the pit lake after the lake is full. The piezometric surface beyond the East Dump drainage ditch during post-closure is predicted to be similar to baseline conditions.

5.3.5.4.5 Significance of Residual Project Effects

Limited residual effects are predicted for groundwater quantity given mitigation is built into the design of the Project. Residual effects relate to localized changes (up to 1 km in Davidson Creek and up to 2 km down Creek 661 beyond collection facilities) in groundwater quantity and are TSF-specific. While there are changes predicted according to the groundwater modelling work, they are minor residual effects and not significant.

The context for groundwater quantity is low since the VC has strong resilience to stress. The magnitude of predicted effects is negligible (not measurable) during construction phase and low (5% to 10 % change in contribution to surface water flow from baseline conditions or 1% to 10% reduction in wetland area from baseline) during operation, closure and post-closure phase. The geographic extent is local (confined within the LSA). The duration is chronic for post closure, and reversibility is possible. The likelihood is high, and the significance is negligible during construction phase and minor during operation, closure and post-closure phases. The confidence in the significance assessment of no residual Project effects is high since an extensive effort was made to gather site data, model both the groundwater quantity and the geochemistry of Project related activities and assess the predicted outcomes.

Table 5.3.5-8 presents the significance of residual Project effects on groundwater quantity. Categories are defined in **Section 4.3.6**.

Table 5.3.5-8: Significance of Residual Project Effects on Groundwater Quantity

Categories for Significance Determination	Project Phase		
	Construction	**Operations/Closure**	**Post-Closure**
Context	Low	Low	Low
Magnitude	Negligible	Low	Low
Geographic Extent	Local	Local	Local
Duration	Short term	Long term	Long term
Reversibility	Reversible	Reversible	Reversible
Frequency	Continuous	Continuous	Continuous
Likelihood Determination	High	High	High
Statement of the level of Confidence for Likelihood	High	High	High
Significance Determination	Not Significant - negligible	Not Significant – minor	Not Significant – minor
Statement of the Level of Confidence for Significance	High	High	High

5.3.5.5 Cumulative Effects

This section determines the need for assessing cumulative effects, assess potential cumulative effects, and if applicable, assess cumulative effects and evaluate these effects. To produce a cumulative effect, a residual effect of the Project must act in combination with the residual effects of one or more other human activities.

Exploration activities for the Project resulted in land disturbance, with moderate interactions potentially affecting groundwater quantity on a very limited and local scale, for instance from pumping tests or exploration water supply needs. The Proponent developed approved environmental management plans for its exploration licence and has successfully implemented these plans. Access trails and drill pads require reclamation under the licence, and these have been carried out, usually within a year or less of completion of site disturbance. Reclamation activities have been periodically inspected by BC MEMPR and have been found to be satisfactory. It is unlikely that there will be any groundwater quantity–related cumulative effects from exploration activities that pre-date Project construction. All drill holes advanced by Knight Piésold for geotechnical purposes in the facility footprints were backfilled with grout if a standpipe or instrument was not installed. The two pumping wells installed within the open pit have been capped.

Pacific Northern Gas Ltd. is proposing a natural gas transmission pipeline between Summit Lake, BC, and Kitimat, BC. Based on the information provided in the pre-Application, the gas line will be located well away from the groundwater RSA, and therefore no cumulative effect is expected from the proposed pipeline.

There is high confidence that the residual effects of the Project on groundwater quantity are not significant. No other possible sources within the LSA or RSA contribute to cumulative effects through interactions to groundwater quantity therefore cumulative effects are not expected.

5.3.5.6 Limitations

This subsection will present assumptions and limitations relative to the assessment of Project effects and the assessment of cumulative effects. The assessment of groundwater quantity potential effects was based on empirical data and quantitative modelling results. All sources derived from empirical data were subject to some uncertainty. Several models were used to provide insights into site conditions and provide predictions for the future site assessment. These models included:

- SEEP/W for tailings seepage;
- MODFLOW for general groundwater flows at the mine site and RSA;
- Site-wide watershed model for watershed water balance; and
- Pit inflow analytical model to predict groundwater inflow to the pit.

Models were based on extensive baseline information and employed conservative assumptions and best practices. Ongoing monitoring of groundwater piezometric levels and flow trends will be conducted to verify the accuracy of predictions.

5.3.5.7 Conclusion

This subsection will provide a conclusion regarding the significance of residual effects and cumulative effects if applicable. Several models were constructed, calibrated using site groundwater and surface water data, and run for the baseline and operations, closure, and post-closure mine phases. The models found that only localized changes in groundwater quantity would occur due to the Project, primarily around the TSF. While there are predicted changes in groundwater quantity, the residual effects are predicted to be negligible or minor and not significant. There are no other possible sources in the LSA or RSA contributing residual effects. Thus, there will be no cumulative effects on groundwater quantity from the Project and other sources.

Several levels of groundwater quantity and seepage control mitigation measures will be implemented for the Project. A program of monitoring site drainages, receiving waters, and groundwater quantity and chemistry will be conducted, commencing at mine construction, to verify predictions. Should monitoring results indicate unexpected mine facility seepage rates or down-gradient groundwater quantity changes, adaptive management will be implemented to address potential effects or reverse trends. Additional contingency measures are discussed in the MWAMP (**Section 12.2.1.18.4.18**). Taken together, the proposed mitigation, monitoring, and contingency measures provide a high level of environmental protection for groundwater quantity.