TECHNICAL MEMORANDUM

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HYDROGEOLOGICAL MODELLING TO ASSESS PROPOSED MINE PLAN – MCNAB VALLEY AGGREGATE PROJECT

1.0 INTRODUCTION

BURNCO Rock Products Ltd. (BURNCO) and 0819042 BC Ltd. are proposing to construct and operate the McNab Valley Aggregate Project ("the Project") on their 320 ha property in McNab Valley, which is located on the northern shore of Thornbrough Channel, immediately north of Gambier Island and northeast of the Town of Gibsons (Figure 1). Current Project plans include mining aggregate resources from an approximately 77 ha portion of the property situated approximately 500 m from the marine foreshore and extending northward approximately 600 m toward the southern banks of McNab Creek (Figure 2). The proposed extraction footprint will be positioned entirely within the gently sloping valley floor terrain and will be bounded to the west by a north-south aligned forest service road, to the south by a BC Hydro transmission corridor and to the east and north by McNab Creek. Terrain immediately west of the forest service road is comprised of steep, east-facing slopes that extend several hundred metres above the valley floor. Similarly steep and elevated, west-facing slopes are also positioned along the eastern margin of the valley floor, along the eastern shore of McNab Creek. All proposed property development components, including a marine load-out facility and processing operations, together with site geological, hydrologic, and hydrogeological setting are described in more detail in the separate documents (Golder, 2010; Golder, 2011, Golder 2014a, Golder 2014b).

This technical memorandum documents hydrogeological modelling and analysis that were conducted in support of project planning and permitting. The main objective of this work was to predict hydrogeological conditions that are expected to develop through the Project life. This was accomplished by first developing a numerical groundwater model that represented current hydrogeological conditions (Section 2) and then using this model to simulate the effects of mining progress on the groundwater regime (Section 3). Section 4 of this memorandum provides a summary of modelling results together with recommendations for monitoring during all stages of the Project to benchmark model predictions and to initiate mitigative measures if they are found to be necessary. The hydrogeological modelling presented in this memorandum adheres to the general guidelines outlined in Anderson and Woessner (1992) and guidelines that are specific for the Province of British Columbia (BCMOE, 2012).

2.0 MODEL CONSTRUCTION AND CALIBRATION

The numerical groundwater model that was used in this study was based on the conceptual site model, as presented in Golder 2014b. Following the selection of a suitable modelling code, the model mesh was constructed and initial values of hydrogeological parameters were assigned. The model was then calibrated to measured hydraulic heads and estimates of groundwater fluxes, such that it adequately represented pre-development groundwater conditions at the site and could simulate the groundwater conditions resulting from aggregate removal throughout the Project life including site closure.

2.1 Model Code Selection

The numerical code selected for simulation of the groundwater conditions for the Project must be able to reasonably represent these conditions before and during the Project life. Considering this, FEFLOW, a finite element numerical code from DHI-WASY Institute in Germany (Diersch, 2012) was selected for the project.

FEFLOW is capable of simulating groundwater, solute and heat flow in three dimensions in heterogeneous and anisotropic porous media. Its finite element mesh allows for accurate representation of hydrostratigraphy and hydrogeological boundaries, while boundary conditions and constraints permit representation of complex interaction between surface water and groundwater. In addition, FEFLOW is capable of varying material properties (e.g., hydraulic conductivity, porosity) during the course of model simulation, thus allowing for excellent representation of the aggregate extraction plan envisioned for the Project.

2.2 Model Construction

2.2.1 Finite Element Mesh

The overall extent of the numerical groundwater model for the project is presented on Figure 3. Laterally the model covers the entire footprint of the McNab Creek valley bottom, where the saturated thickness of the unconsolidated sediments is inferred to exceed approximately 5 m to 10 m, except in the south along the Howe Sound shore where the -10 m bathymetry contour was used to terminate the model domain. This lateral extent was selected based on bedrock elevation data inferred from geophysical surveys and bathymetry data, as presented in Attachment 1. Thus the model extends from the forest service road in the west to steep bedrock slopes adjacent to McNab Creek in the east (distance of approximately 1,200 m), and from the point approximately 500 m north from the bend in this creek to Howe Sound (distance of approximately 2,000 m). Vertically, the model extends from the inferred contact between the overburden and bedrock to the ground surface, with model thickness ranging from less than 10 m in the north to over 100 m in the south along the Howe Sound Shore.

The model domain was discretized into approximately 250,000 triangular elements (Figure 4). Laterally, uniform mesh spacing of 8 m to 10 m was used whereas vertically the model was subdivided into eight numerical layers ranging in thickness between 1 m and approximately 42 m. The bottoms of layers 1 to 6 were set flat in the area of proposed aggregate extraction at elevations of 0 m, -10 m, -20 m, -30 m, -35 m, and -45 m, respectively. This vertically discretization allowed accurate representation of the areas where aggregate would be extracted. Elsewhere, layer elevations was “draped” such that they conformed to the bedrock surface. The mesh design was considered to be appropriate for adequate representation of pre-development groundwater conditions and changes in these conditions during mining.

2.2.2 Boundary Conditions

Model boundary conditions provide the link between the model domain and surrounding hydrologic and hydrogeological systems. As presented on Figure 4, three types of boundary conditions were used in the site groundwater model: specified head, specified flux, and no-flow.

- **Specified head** boundaries were used to represent McNab Creek. These boundaries were assigned along the bottom of this creek in the top layer of the model. Surface water–groundwater exchange between the creek and the valley fill aquifer was assumed to be unimpeded by the creek bed sediments due to their coarse nature. Specified head boundaries were also used in the top model layer to represent the constructed groundwater-fed channel (WC 2) and the minor surface water features present adjacent to the Howe Sound shore. The boundary nodes used to represent McNab Creek, WC 2, and minor features were assigned head values based on corresponding geodetic elevations. Howe Sound was represented in the model by applying specified heads set to 0 m along the portion of the seabed within the model domain, between elevation contours 0 m and -10 m. Specified heads were also assigned along the north boundary of the model domain in all model layers to represent groundwater inflow from the portion of McNab Creek valley outside of the model domain, in the area where unconsolidated sediments are inferred to be relatively thin.
- **Specified flux** boundaries were used to represent recharge from direct precipitation everywhere in the top model layer, and infiltration of surface water runoff from the steep west slope onto a western portion of the Project l, as shown on Figure 4. The flux values assigned to these boundaries were adjusted seasonally, as discussed in Section 2.3. A specified flux boundary was also applied along the model bottom to represent groundwater inflow from bedrock. This boundary was assigned a flux of 2.5 x 10^{-8} m/s which was based on a two-dimensional analysis presented in Attachment 2. The significance of this flux was assessed during sensitivity analysis (Section 3.3).
- **No-flow** (zero-flux) boundaries were applied along the south edge of the model in model layers two to eight. This boundary type, together with specified head boundaries assigned along the seabed in model layer one, resulted in upward groundwater flow near the shoreline. The presence, at depth, of saltwater is expected to result in upward hydraulic gradients in this area. No-flow boundaries were also assigned along the east edge of model domain in all layers. This boundary reflected the assumption that groundwater inflow from the east has a negligible influence on groundwater flow conditions and consequently model predictions; a reasonable assumption considering the strong and overriding influence of McNab Creek which is located adjacent to this boundary.

2.2.3 Initial Model Parameters

Initial values of hydrogeological parameters applied in the numerical model were based on the values adopted in the site conceptual model (Golder, 2014b). The horizontal hydraulic conductivity of the valley fill aquifer, down to a depth of 20 m, was assigned a value of 7 x 10^{-4} m/s. At greater depth, the horizontal hydraulic conductivity was decreased by a factor of two from this value. In addition, the entire aquifer was assumed to be anisotropic, with vertical hydraulic conductivity five times less than the horizontal value. The till unit, which is inferred to be present in the northeast portion of model domain, was assigned a uniform and isotropic hydraulic conductivity value of 1 x 10^{-6} m/s.

In the absence of site specific information, aquifer storage properties were based on values published in the literature (Maidment, 1992). Specific yield and specific storage everywhere in the model were set to 0.3 and 1 x 10^{-4} 1/m, respectively.

Some values of initial model parameters discussed above were adjusted during model calibration (Section 2.3). The uncertainty of these parameters, and the effects of this uncertainty on model predictions, was assessed during model sensitivity analyses (Section 3.3).

2.3 Model Calibration

Calibration of a groundwater model is an essential part of model development, where the model is run repeatedly and model parameters are iteratively adjusted until model predicted values (hydraulic heads, groundwater fluxes) match observed values reasonably well, considering study objectives. The site groundwater model was calibrated in steady-state mode that represented near-static groundwater conditions at the end of summer, and transient mode that simulated hydrogeological response to heavy fall and winter precipitation. Calibration targets for steady-state calibration included a snapshot of hydraulic heads in early September 2010, when groundwater conditions were inferred to be at near-steady state, and estimates of the water loss from McNab Creek and discharge to WC 2 during dry conditions. For transient calibration well hydrographs for the period of September 2010 to January 2011 were considered. Steady-state and transient calibrations were conducted concurrently to provide consistency in adjustments to model input parameters. In addition, at the end of model calibration an independent check of model predictive capabilities was made by comparing model predicted heads for the dry season with the hydraulic heads measured in one year later in September 2011.

2.3.1 Steady-State Calibration – September 2010

The objective of the steady-state calibration was to reproduce groundwater conditions at the site that are typical of the late summer/early fall period. Figure 5 and Figure 6 present model predicted hydraulic heads and groundwater flow directions for these periods. In this simulation, recharge to groundwater from direct precipitation was set to a value of 17 mm/month, calculated as a difference between average dry-season precipitation and average dry-season evapotranspiration (Golder, 2014a), and assuming run-off of approximately 50%. Similarly, run-off and groundwater discharge from the slope west of the site of approximately 5,000 m^3/day was calculated as this difference in precipitation and evapotranspiration applied over the catchment area west of the Project contributing to the valley of McNab Creek (Golder, 2014a). This value was applied as a specified flux along the west model boundary.

Figure 7 shows the comparison of model predicted heads and those measured in site monitoring wells for the September 2010 dry season conditions. As presented on this graph, the calibrated model reproduced observed values reasonably well, with a mean error of approximately 0.4 m and mean absolute error of about 0.7 m. This suggests that, on average, the model predicted heads were slightly higher than the measured values and that on average the predicted heads were within 0.7 m of observed values. The root-mean-square error, normalized by the head difference measured across the site, was 5% which is considered a reasonable value in model calibration.

The loss from McNab Creek to the valley fill sediments was simulated by the calibrated model at approximately 22,000 m^3/day, which falls within the range of creek losses of 13,000 m^3/day to 66,000 m^3/day estimated based on available streamflow data for the dry season (Golder, 2014a). Similarly, the simulated discharge to WC 2 of approximately 2,100 m^3/day was within the range of measured discharge of 500 m^3/day to 6,900 m^3/day.

A qualitative check of the groundwater flow pattern produced by the calibrated numerical model indicates that this model simulates the relevant features of the groundwater regime as presented in the conceptual hydrogeological model reasonably well. That is, groundwater flow is directed from north to south, with the upper reaches of McNab

Creek acting as a recharge zone and WC 2 and Howe Sound being the discharge zones. At depth, the predicted hydraulic heads are generally higher at depth than near the water table, in agreement with upward hydraulic gradients observed in most monitoring wells installed at the site.

2.3.2 Transient Calibration – September 2010 to January 2011

The objective of transient model calibration was to reproduce the dynamic response of the groundwater regime to the increase in groundwater recharge in response to wet season precipitation. In this calibration, the model-predicted hydraulic heads were compared to the heads observed in site monitoring wells between September 2010 and January 2011. The following modifications were made to the groundwater model in order to facilitate this calibration:

- Initial values of hydraulic heads everywhere in the model domain were set to the dry season heads derived from the steady-state calibration;
- Specified hydraulic heads representing McNab Creek were varied over time to account for changes in creek's stage, as measured at McNab Creek monitoring stations;
- Recharge from direct precipitation was varied over time based on daily precipitation data for the site. It was assumed that 50% of precipitation infiltrates to the subsurface, with the remainder being lost to evapotranspiration and run-off; and
- Recharge originating as run-off and groundwater discharge from the bedrock slope west of the Project was varied over time based on site precipitation records. Daily flux values for this boundary were adjusted such that the average flux during the simulation period corresponded to the average wet season flux calculated for this catchment of approximately 33,000 m^3/day (Golder, 2014a).

Figure 8 presents the results of transient model calibration. The predicted hydraulic head fluctuations agree well with those observed in the monitoring wells in that the short-term variations in hydraulic heads predicted for monitoring wells located in the western portion of the site (i.e., MW05-1, DH10-01s,d; DH10-6s,d; DH10-07s,d) are significantly larger than in the remaining wells. As discussed in the hydrogeological characterization memorandum (Golder, 2014b) these fluctuations are associated with variations in recharge fluxes originating as run off from the western slope. In the eastern portion of the site, where measured and model predicted head fluctuation are smaller, groundwater conditions are primarily controlled by the creek stage and recharge from direct precipitation.

2.3.3 Steady State Evaluation – September 2011

An additional check on model calibration for dry season conditions was made by comparing the results of steady-state model calibration (without any modifications to model boundary conditions and parameters) with hydraulic heads measured in September 2011. This comparison was made independently of the calibration process, once all adjustments to model input parameters were finalized. As presented on Figure 9, model predictions match field observation reasonably well, with mean error and normalized root-mean-squared error between predicted and measured hydraulic heads of 0.2 m and 5%, respectively. Good results obtained from this comparison provided an additional measure of confidence in the model capabilities as a predictive tool.

2.3.4 Calibrated Model Parameters

Calibrated model parameters established during model calibration are presented on Figure 10. The adjustments that were made to the initial input parameters were as follows:

- Horizontal hydraulic conductivity in the shallow portion of the valley fill aquifer (above 20 m depth) was slightly lowered in the northern portion of the site (from the initial estimate of 7 x 10^{-4} m/s to 5 x 10^{-4} m/s), and slightly increased in the southern portion of the site (from 7 x 10^{-4} m/s to 8 x 10^{-4} m/s). These adjustments were necessary to improve the model match to the estimated seepage loss from McNab Creek and to improve hydraulic head predictions in the western portion of the aquifer.
- Horizontal hydraulic conductivity in the deeper portion of the valley fill aquifer (below 20 m depth) was lowered from 3.5 x 10^{-4} m/s to 2.5 x 10^{-4} m/s. This adjustment, in combination with the adjustment to aquifer anisotropy discussed in the next bullet, resulted in a better match of the observed upward hydraulic gradients at the site.
- Everywhere within the valley fill aquifer the ratio between horizontal and vertical hydraulic conductivity was increased from 5:1 to 20:1. Although vertical hydraulic conductivity has not been measured at the site, higher than originally assumed anisotropy is considered plausible based on borehole descriptions and considering the depositional nature of the aquifer materials.
- Two higher permeability features were introduced in the central and northern portions of the site. The first feature was a higher permeability 30 m wide zone parallel to WC 2, and extending to 20 m depth. Hydraulic conductivity of 1 x 10^{-2} m/s (isotropic) assigned to this feature is near the upper bound of hydraulic conductivities estimated based on grain size analyses of shallow soil samples, but appears to be consistent with the relatively coarse nature of sediments and sediment matrix exposed in the sides of WC 2. Introduction of this feature was necessary to improve the model the match to observed hydraulic heads and fluxes in the immediate vicinity of WC 2. The second feature was a higher permeability zone near the aquifer base in the northern portion of the aquifer with a hydraulic conductivity of 1 x 10^{-3} m/s (isotropic). The introduction of this feature, which could reflect a feature locally promoting additional discharge from bedrock and/or a pathway for additional recharge from McNab Creek, was required to improve the match of observed upward hydraulic gradients in the northern and central portion of the aquifer. The existence of each of these features is based on conjecture; therefore their influence on model prediction was further evaluated during model sensitivity analyses (Section 3.3).

Adjustment of the initial estimates of the parameter values and in many instances the addition of local zones with differing hydraulic conductivity, is expected during model calibration and is consistent with standard practice.

No other changes were made to model input parameters and boundary conditions. Considering the good results of the model calibration, the agreement between calibrated parameters with field data, and general agreement between predicated groundwater flow patterns and stream losses and gains, the calibrated numerical model is considered capable of simulating reasonably well future groundwater conditions resulting from aggregate extraction.

3.0 PREDICTED HYDROGEOLOGICAL CONDITIONS DURING MINING

Progress of aggregate extractions over a 16-year period was simulated in the calibrated groundwater model according to the proposed mine plan. The details of this mine plan are provided in Section 3.1 whereas the base case predictions of future hydrogeological conditions at the site are discussed in Section 3.2. Uncertainty in these predictions resulting from the uncertainty in the understanding of site groundwater conditions was assessed during model sensitivity analysis and is described in Section 3.3.

3.1 Mine Plan

Figure 11 shows the mine plan that is proposed for the site. This mine plan envisions gradual extraction of the aggregate materials over a 16-year period using a “wet extraction” method. That is, aggregate would be extracted subaqueous without dewatering of the aggregate pit, thus allowing gradual formation of a pit lake as the mining progresses. In the mine plan aggregate extraction would start in the southwest portion of the site and would progress east and then north. In the first year of mining, the portion of WC 2 within the ultimate outline of the aggregate pit would be de-activated by constructing a plug immediately down-gradient of the pit. Concurrently, an approximately 670 m long extension would be constructed in the foreshore area and connected to the existing watercourse below the plug. At the end of mining, the pit would have horizontal dimensions of approximately 600 m in the east-west direction and 500 m in the north-south direction, with the pit bottom at -35 m elevation.

3.2 Base Case Prediction

3.2.1 Methodology

Simulation of aggregate extraction at the site required several modifications to the groundwater model to adequately represent the hydrogeological conditions associated with the “wet extraction” method. That is, the model had to account for the gradual removal of aggregate solids from the excavated area while accounting for the pore water that will drain from the aggregate and remain in the pit lake. In addition, adjustments had to be made to groundwater inputs along the model surface to account for the additional inputs of water from direct precipitation to the gradually expanding pit lake. Specifics of these modifications were as follows:

- The recharge rate to the valley fill aquifer outside of the aggregate extraction area was adjusted such that it represented average annual conditions. The rate along the top of the valley fill aquifer was revised to 1,200 mm/year, calculated as a difference between average annual precipitation and evapotranspiration and assuming 50% run-off (Golder, 2014a). Furthermore, input from run-off from the bedrock slope west of the site was adjusted such that it represented an estimate of average annual run-off of approximately 19,000 m^3/day (Golder, 2014a). These adjustments to model boundaries resulted in a model that represented average annual conditions for each year of mine life, which was considered sufficient for assessing overall changes in hydrogeological conditions during this time. Potential effects of wet winter conditions on water elevation in the pit lake were assessed separately, as discussed in Section 3.3.
- The model was run in the transient mode for a period of 16 years, and aggregate extraction was simulated according to the proposed plan (Section 3.1). This was accomplished in four phases, with each of the first three phases being 5 years long (Year 0 to 5, Year 5 to 10, Year 10 to 15), and the last phase being one year long (Year 16).

  During each phase hydraulic conductivity and porosity within the area where aggregate would be extracted were linearly increased from the values representing the valley fill aquifer to the values that represented the pit lake. Equivalent hydraulic conductivity of the pit lake was set to 0.1 m/s, which is considered sufficiently high in relation to the properties of the aquifer to allow the water level to equilibrate across the pit lake to within less than 0.1 m. Equivalent porosity of the pit lake was set to a value of 1 thus correctly representing the volume of the pit lake at the completion of each phase while preserving the volume of pore water that was initially stored in the aggregate. Each mining phase was divided into several time steps, with the length of each time step varied through the mining phases using automatic time-stepping routine available in FEFLOW.

- The specified flux boundary that represents recharge to groundwater from precipitation was automatically adjusted during model simulation in the area of the pit lake such that it accounted for additional input from direct precipitation to the lake surface at each phase of mine development. The flux value representing this input was set to 2,450 mm/year, which corresponds to the difference between average annual precipitation and evaporation (Golder, 2014a).
- In the first year of mining, the specified head boundaries representing WC 2 in the area of the aggregate pit and the plug were gradually removed to simulate deactivation of the watercourse. Concurrently, specified head boundaries representing the extension to WC 2 were gradually activated to simulate construction of this extension.
- Initial hydraulic heads for the transient simulation representing mining were set to the hydraulic heads representing average annual conditions. These heads were established by running the calibrated model to steady-state with the recharge rate reflecting average annual conditions, as discussed above.

3.2.2 Average Annual Conditions During Mining

Figures 12 to 14 present groundwater flow patterns that were predicted to develop during various phases of aggregate extraction at the site, whereas Figure 15 presents a cross-sectional view of the flow pattern predicted for Year 16 at the end of mining. As presented on these figures, after five years of mining a pit lake was predicted to form in the mined-out areas at initial elevation of approximately 5.5 m, which corresponds to the average water table elevation in the sediments along the west valley flank following the de-activation of WC 2. At Year 10 the pit lake level was predicted to decrease to approximately 4.5 m as the mining expands south towards the ocean shoreline where the water table elevations are lower. At later times the pit lake level was predicted to rise to approximately 5.0 m following expansion of the pit north where the water table elevation is primarily controlled by McNab Creek. This lake would act as a “flow through” lake, where groundwater would recharge the lake along its northern boundary and pit lake water would discharge to groundwater along its southern boundary. Overall, the presence of the pit lake would result in a gradually steepening of hydraulic gradients in the area between the McNab Creek and northern boundary of the pit lake; and between the southern boundary of the lake and Howe Sound. These changes in hydraulic gradients are related to predicted changes in water table elevation north and south of the pit lake. As illustrated by the drawdown contours presented on Figure 14 (right panel), at the end of mining (Year 16) the maximum drawdown (i.e., a decrease in water table elevation in relation to pre-development conditions) along the north boundary of the lake was predicted to be approximately 4 m; whereas, the maximum mounding (inverse of drawdown) along the south lake boundary was approximately 3 m.

Gradual removal of aggregate and concurrent development of the pit lake was also predicted to affect groundwater fluxes near the proposed development. As presented in Table 1, during aggregate removal the average annual loss from the McNab Creek to groundwater was predicted to decrease from the initial loss under current conditions of approximately 17,800 m^3/day to 10,900 m^3/day in Year 5 (about 39% decrease from the initial loss), and then gradually increase to 17,600 m^3/day in Year 16 at the end of mining (approximately a 1% decrease from the initial loss). This initial decrease in creek loss is related to the water table re-bound following deactivation of WC 2, at the time when the extent of the mined out area is relatively small. At later times, the creek loss was predicted to gradually increase as the north boundary of the pit lake gets closer to McNab Creek. Nevertheless, because of an increase in pit lake elevation and de-activation of WC 2, the predicted loss from the McNab Creek at the end of mining was predicted to be approximately 1% less than the loss estimated for the pre-development conditions.

Gradual development of the pit lake was also predicted to affect average annual groundwater discharge to WC 2 existing in the center of the valley fill aquifer. As presented in Table 1, average annual groundwater discharge to this watercourse in Year 5 of operation was predicted to decrease from the initial value of approximately 36,500 m^3/day to 23,100 m^3/day. This predicted decrease is attributed to the de-activation of the portion of WC 2 within the footprint of the mine area; this effect is partially offset by additional discharge to the watercourse extension that would be constructed south from this area in the first year of mining. At later time, as the pit lake elevation raises, groundwater discharge to WC 2 downgradient of the mine area was predicted to reach an average annual value of approximately 29,600 m^3/day, which represents an approximately 19% decrease relative to the pre-development discharge to the original watercourse configuration. As the pit lake elevation gradually rises throughout the mine life the average groundwater discharge to the watercourse and its extension downgradient of the mine area would also gradually increase.

Similarly, model results indicate that average annual groundwater discharge to the minor surface water features located along the southern pit lake boundary and the ocean shore would gradually increase throughout the Project life. The pre-development discharge to these features was estimated to be approximately 5,900 m^3/day and was predicted to increase to about 9,000 m^3/day at the end of mining in Year 16 (53% increase).

As presented in Table 1, the total groundwater discharge from the valley fill aquifer was predicted to remain relatively unchanged during mining. This total discharge, which represents groundwater outflow to groundwater-fed watercourse, minor stream, ocean shoreline, and lower portion of McNab Creek, was estimated to be approximately 57,900 m^3/day prior to mining and 58,800 m^3/day in Year 16 (approximately 2% increase).

3.3 End of Mining Average Winter Conditions

An additional model simulation was completed to estimate average winter (wet season) pit lake elevation. This analysis, together with the assessment of short-term precipitation inputs conducted concurrently as part of the hydrologic assessment, was needed for the evaluation of the height of impoundments structures that may be necessary along the perimeter of the pit lake. In this analysis, the model representing average precipitation conditions was modified such that it represents additional inputs from increased precipitation in winter. These modifications included: 1) an increase in recharge from direct precipitation outside of the pit lake to 2,400 mm/year, which represented a difference between average winter precipitation and evapotranspiration, and assuming 50% surface water run-off; 2) an increase in inputs from surface water run-off from the slopes west of the Project to 33,000 m^3/day as discussed in Section 2.3.2; and 3) an increase in the elevations of specified head boundaries representing McNab Creek and WC 2 by 0.5 m to account for an increase in water level in these water courses during the wet season. Following these modifications, the model was run in steady-state mode with values of hydraulic conductivity and porosity reflecting the pit lake configuration in Year 16.

This simulation approach was considered reasonable as the results of transient model simulations discussed in Sections 2.3.2 and 3.2 suggested that, due to the relatively high hydraulic conductivity of the aquifer and proximity to McNab Creek, near steady-state conditions would be reached over a shorter time frame than the duration of the wet season.

Figure 16 presents hydrogeological conditions that are predicted to develop at the end of mining during an average wet season. As expected, the predicted pit lake elevation during the wet season of approximately 6.2 m was higher than the elevation predicted for the average annual conditions at the end of mining. During the average wet season at the end of mining, the predicted water table decline near the north end of the lake was smaller, on the order of 3 m. However, during the wet season, higher water table mounding of approximately 4 m was predicted along the southern end of the pit lake adjacent to the area of WC 2.

3.4 Closure Pit Lake Level

At closure it is anticipated that the water level in the pit lake would be controlled by an outflow structure which would be in operation only at times of prolonged heavy precipitation. As discussed in Section 3.2, at the end of mining in Year 16 the pit lake water level was predicted to be approximately 5.0 m (average annual conditions). In the absence of any surface water outflow from the lake during normal operating conditions, this is also the level that would be expected after facility closure. Thus, the changes in average groundwater recharge and discharge predicted for Year 16, as described in Section 3.2 and presented in Table 1 are expected to remain the same during the closure period.

3.5 Sensitivity Analysis

The base case predictions described in the preceding section were based on the calibrated groundwater model for the site, and as such are considered to reflect the most likely conditions that could be encountered during aggregate extraction. Although an extensive amount of hydrogeological data were used to develop and calibrate the groundwater model, some uncertainty in model predictions exists due to uncertainty that is inherent in describing any subsurface environment. This inherent uncertainty is related to natural heterogeneity of subsurface materials that can never be fully characterized by investigations that rely on sparsely spaced boreholes and testing.

The assessment of uncertainty in model predictions was carried out by conducting a model sensitivity analysis. In this analysis, the model representing the average hydrogeological conditions during 16 years of aggregate extraction (Section 3.2) was run repeatedly while model input parameters were individually varied over ranges that reflected uncertainty in these values. Overall, 18 model sensitivity simulations were completed as follow:

- Hydraulic conductivity of the shallow portion of the valley fill aquifer (above 20 m depth) was increased and decreased by a factor of 2 from the base case value (2 simulations);
- Hydraulic conductivity of the deep portion of the valley fill aquifer was increased and decreased by a factor of 2 from the base case value (2 simulations);
- Hydraulic conductivity of the entire aquifer was assumed to be isotropic (1 simulation);
- Specific yield assigned to the valley fill aquifer was increased to 0.4 and decreased from 0.2 from the base case value of 0.3 (2 simulations);
- The first (shallow) permeable feature adjacent to WC 2 was removed by setting its hydraulic conductivity to the same value as the one assigned to the aquifer (1 simulation);
- The second (deep) permeable feature adjacent to WC 2 was removed by setting its hydraulic conductivity to the same value as the one assigned to the aquifer (1 simulation);

- Both permeable features were removed by setting their hydraulic conductivity to the same value as the one assigned to the aquifer (1 simulation);
- The flux representing groundwater discharge from bedrock to the valley fill aquifer was increased and decreased by a factor of 2 from the base case value (2 simulations);
- The flux representing infiltration of surface water run-off from the slope west of the site was increased and decreased by a factor of 2 from the base case value (2 simulations);
- The flux representing groundwater inflow from the slope west of the site was increased and decreased by a factor of 2 from the base case value (2 simulations); and
- The flux representing recharge from direct precipitation was increased and decreased by a factor of 2 from the base case value (2 simulations).

Figure 17 summarizes the results of sensitivity analyses for the average annual elevation of the pit lake in Year 16 at the end of mining. The results of this analysis indicate that the elevation of the pit lake was most sensitive to the hydraulic conductivity value assigned to the shallow portion of the aquifer. A decrease in this parameter resulted in an increase of the predicted pit lake elevation from the base case value of 5.0 m to 6.3 m, whereas an increase resulted in a decrease of the predicted lake elevation from 5.0 m to 4.0 m. A significant contribution of the hydraulic conductivity assigned to the shallow portion of the aquifer to the uncertainty in model predictions was expected, as this parameter is the dominant control on the groundwater outflow from the pit lake south towards Howe Sound. To a lesser degree, the predicted pit lake elevation was also sensitive to the flux representing surface water run-off from the west slope and anisotropy of the valley fill. In the remaining sensitivity simulations, the predicted pit lake elevation varied by less than 10% from the base case level, suggesting that the remaining model parameters had relatively small influence on predicted pit lake level.

Figure 18 presents the results of the sensitivity analysis for the predictions of average annual loss from McNab Creek, which would primarily be focused along the west-east portion of the watercourse north from the pit lake. Similar to that of the pit lake elevation, this loss was found to be most sensitive to the hydraulic conductivity of the shallow portion of the valley fill aquifer. An increase in this parameter by a factor of two resulted in an increase in the predicted loss to approximately 40,500 m^3/day from the base case value of about 17,600 m^3/day, and the predicted loss decreased to approximately 5,700 m^3/day when this parameter was decreased by a factor of two. McNab Creek loss was also sensitive to aquifer anisotropy, hydraulic conductivity of the deep portion of the aquifer, groundwater flux from bedrock, and flux originating from the surface water run-off from the west slope. The remaining model parameters were predicted to have a relatively small influence on the predicted creek loss.

4.0 SUMMARY AND RECOMMENDATIONS

A three-dimensional numerical hydrogeological model was developed for the Project area. The model was based on the site hydrogeological conceptual model that incorporated all hydrogeological data collected at the site to date. Following steady-state calibration to the near-static groundwater conditions observed in September 2010 and September 2011 and a transient model calibration using well hydrographs for the period from September 2010 to January 2011, the calibrated model was used to simulate aggregate extraction based on the 16-year long mine plan.

4.1 Summary

The results of model predictive simulation for the base case scenario, which is considered to represent the most likely conditions that could be encountered during mining, were as follows:

- A pit lake would form during mining and its elevation was predicted to reach approximately 5.5 m in Year 5, when the mined out area is relatively small and constrained to the western portion of the valley bottom. At later times, as the mine gradually expands south and then north, the pit lake level was predicted to first decrease to approximately 4.5 m (following expansion of the pit towards the south) and then increase to 5.0 m at the end of mining (following expansion of the pit towards the north). Predicted pit lake elevations reflect average precipitation conditions. This lake would act as a “flow through” lake, where groundwater would recharge the lake along its northern boundary and lake water would discharge to groundwater along its southern boundary.
- Aggregate extraction and gradual expansion of the pit lake was predicted to alter the water loss from McNab Creek to groundwater. During mining, the average annual loss from McNab Creek to groundwater was predicted to decrease from the initial loss under current conditions of approximately 17,800 m^3/day to 10,900 m^3/day in Year 5 (about 39% decrease from the initial loss), and then gradually increase to 17,600 m^3/day in Year 16 at the end of mining (about a 1% decrease from the initial loss). This initial decrease in creek loss is related to the water table re-bound following deactivation of WC 2, at the time when the extent of the mined out area is relatively small. At later times, the creek loss was predicted to gradually increase when the northern boundary of the pit lake gets closer to McNab Creek. Nevertheless, because of an increase in pit lake elevation and de-activation of WC 2, the predicted loss from the McNab Creek at the end of mining was predicted to be approximately 1% less than the loss predicted for the pre-development conditions.
- Gradual development of the pit lake was predicted to affect average annual groundwater discharge to WC 2 existing in the center of the valley fill aquifer. When the watercourse (including the extension) was considered, average annual groundwater discharge to this watercourse in Year 5 of operation was predicted to decrease from the initial value of approximately 36,500 m^3/day to 23,100 m^3/day following de-activation of the upstream portion of this watercourse. At later times, as the pit lake elevation raises, groundwater discharge to WC 2 and its extension down-gradient of the mine area was predicted to reach an average annual value of approximately 29,600 m^3/day, which represents an approximately 19% decrease from the pre-development discharge to the entire watercourse (including the de-activated portion).
- Model results indicate that average annual groundwater discharge to the minor surface water features located along the southern mine area and the ocean shore would gradually increase throughout the mine life. The pre-development discharge to these features was estimated to be approximately 5,900 m^3/day and was predicted to increase to about 9,000 m^3/day at the end of mining in Year 16 (53% increase).
- The total groundwater discharge from the valley fill aquifer was predicted to remain relatively unchanged during mining. This total discharge, which represents groundwater outflow to groundwater-fed watercourse, minor stream, ocean shoreline, and lower portion of McNab Creek, was estimated to be approximately 57,900 m^3/day prior to mining and 58,800 m^3/day in Year 16 (about 2% increase).
- The predicted pit lake elevation at the end of mining (Year 16) during the average wet season was approximately 6.2 m, which was 1.2 m higher than the level predicted for the average annual conditions.

- At closure, the pit lake level is predicted to remain at an average annual elevation of approximately 5.0 m. At closure, changes in average groundwater recharge and discharge from the pre-development conditions are predicted to be the same as the ones predicted for the end of mining (Year 16).
- The uncertainty in model predictions was assessed during model sensitivity analysis. This analysis indicated that, considering the uncertainty in the model input parameters, the prediction of the average annual pit lake elevation at the end of mining ranges between approximately 4.0 m and 6.3 m in relation to the base case prediction of 5.0 m. Similarly, the prediction of the loss from McNab Creek ranges between 5,700 m^3/day and 40,500 m^3/day compared to the base case loss of about 17,600 m^3/day. The uncertainty in model predictions was primarily a function of the uncertainty in the hydraulic conductivity of the shallow portion of the valley fill aquifer.

4.2 Recommendations

Based on the findings of this study the following recommendations are made:

- The hydraulic head monitoring in the site monitoring wells should continue throughout the mine life, and the monitoring wells that will be destroyed during mining (HD10-07 in Year 3; DH10-02 in Year 10; and MW05-1 and DH10-01 in Year 15) should be replaced by new wells. These new wells should be located in the same vicinity as the destroyed wells but outside of the pit lake perimeter.
- Surface water monitoring in McNab Creek and in WC 2 should also continue throughout the mine life. In addition, the elevation of the pit lake should be recorded on the daily basis.
- Water quality samples should be collected from site monitoring wells on annual basis during mining. These samples should be analysed for the same chemical parameters as the ones in the 2012 sampling round (Golder, 2014b).
- Groundwater and surface water monitoring data collected as described in the above bullet points should be reviewed throughout the mine life on an annual basis. If at any time these reviews indicate that the changes in hydrogeological conditions during aggregate extraction are substantively different from the ones predicted using the groundwater model described in this memorandum, then the reasons for these differences should be evaluated and the model updated/re-calibrated. This updated model would then be used to provide revised predictions of future changes in groundwater flow conditions that will be necessary for site water management.

5.0 CLOSURE

We trust that the information presented in this technical memorandum is sufficient for your current requirements. Should you have any questions or require clarification, please do not hesitate to contact the undersigned at 604-296-4200.

GOLDER ASSOCIATES LTD.

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Principal

Leslie Smith

Leslie Smith, Ph.D.
External Reviewer

WZ/DWC/ES/jcc

Attachments: Table 1 – Predicted Changes in Groundwater Fluxes during Mining – Base Case

Figure 1 – Project Location
Figure 2 – Groundwater and Surface Water Monitoring Network
Figure 3 – Extent of Numerical Hydrogeological Model
Figure 4 – Model Mesh and Boundary Conditions
Figure 5 – Predicted Hydraulic Heads September 2010 Steady-State Calibration
Figure 6 – Predicted Hydraulic Heads September 2010 Steady-State Calibration – Section
Figure 7 – Predicted vs Measured Hydraulic Heads September 2010 Steady-State Calibration
Figure 8 – Predicted vs Measured Hydraulic Heads September 2010 to January 2011 Transient Calibration
Figure 9 – Predicted vs Measured Hydraulic Heads September 2011 Steady-State Calibration
Figure 10 – Calibrated Values of Hydrogeological Parameters Used in the Groundwater Model
Figure 11 – Proposed Conceptual Site Layout
Figure 12 – Predicted Hydrogeological Conditions during Mining Year 0 and Year 5
Figure 13 – Predicted Hydrogeological Conditions during Mining Year 10 and Year 15
Figure 14 – Predicted Hydrogeological Conditions during Mining Year 16
Figure 15 – Predicted Hydrogeological Conditions during Mining Year 16 – Section
Figure 16 – Predicted Hydrogeological Conditions – End of Mining Year 16 – Average Wet Season
Figure 17 – Results of Sensitivity Analysis Pit Lake Elevation at Year 16 – Average Annual Conditions
Figure 18 – Results of Sensitivity Analysis McNab Creek Loss at Year 16 – Average Annual Conditions

Attachment 1 – Bedrock and Bathymetry Data
Attachment 2 – Bedrock Flux Simulations

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6.0 REFERENCES

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Table 1

Predicted Changes in Groundwater Fluxes During Mining - Base Case

	Pit Lake Elevation	McNab Creek Loss		Groundwater-fed Watercourse 2 (WC 2) Gain*		Minor Stream Gain**		Ocean Gain***		TOTAL Groundwater Discharge****	
	m	m^3/day	% change from Year 0	m^3/day	% change from Year 0	m^3/day	% change from Year 0	m^3/day	% change from Year 0	m^3/day	% change from Year 0
Year 0	n/a	17800	n/a	36500	n/a	5900	n/a	8600	n/a	57900	n/a
Year 5	5.5	10900	-39%	23100	-37%	8400	42%	12000	40%	53300	-8%
Year 10	4.5	12500	-30%	25300	-31%	8200	39%	11600	35%	54200	-6%
Year 15	4.9	16900	-5%	28600	-22%	8800	49%	12300	43%	57400	-1%
Year 16	5.0	17600	-1%	29600	-19%	9000	53%	12600	47%	58800	2%

Note:

* The model assumes that portion of WC 2 within the mine area will be de-activated during Year 1, including construction of a plug that will extend to the access road.
The model also assumes that a extension south from the mine pit will be constructed at the same time.

** These values represent predicted discharge to minor streams between the mining area and ocean shoreline.

*** These values represent predicted discharge to the ocean shoreline, excluding minor streams.

**** These values represent total groundwater discharge at the site to WC 2, minor streams, ocean, and lower portion of McNab Creek.

n/a - not applicable

5 0 5

SCALE 1:150,000 KILOMETRES

LEGEND

▭ Project Area	— Highway
▨ Park / Protected Area	— Road
■ Sensitive Environmental Area	— Resource Road
■ Vegetation	┼ Railway
■ Indian Reserve	— Watercourse
■ Residential Area	- - Ferry
■ Waterbody	— Contour (250m)
	▲ Camp

REFERENCE

Parks/protected areas and sensitive areas from the Province of British Columbia. Elevation and indian reserves from Geobase. Base data from CanVec. Projection: UTM Zone 10 Datum: NAD 83

PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

LOCATION OF BURNCO AGGREGATE PROJECT

Golder Associates

PROJECT NO. 11-1422-0046			PHASE No.	
DESIGN	MD	02 Nov. 2012	SCALE AS SHOWN	REV. 5
GIS	DL	10 Mar. 2016	FIGURE 1	
CHECK	AS	10 Jun. 2014		
REVIEW	AC	10 Jun. 2014		

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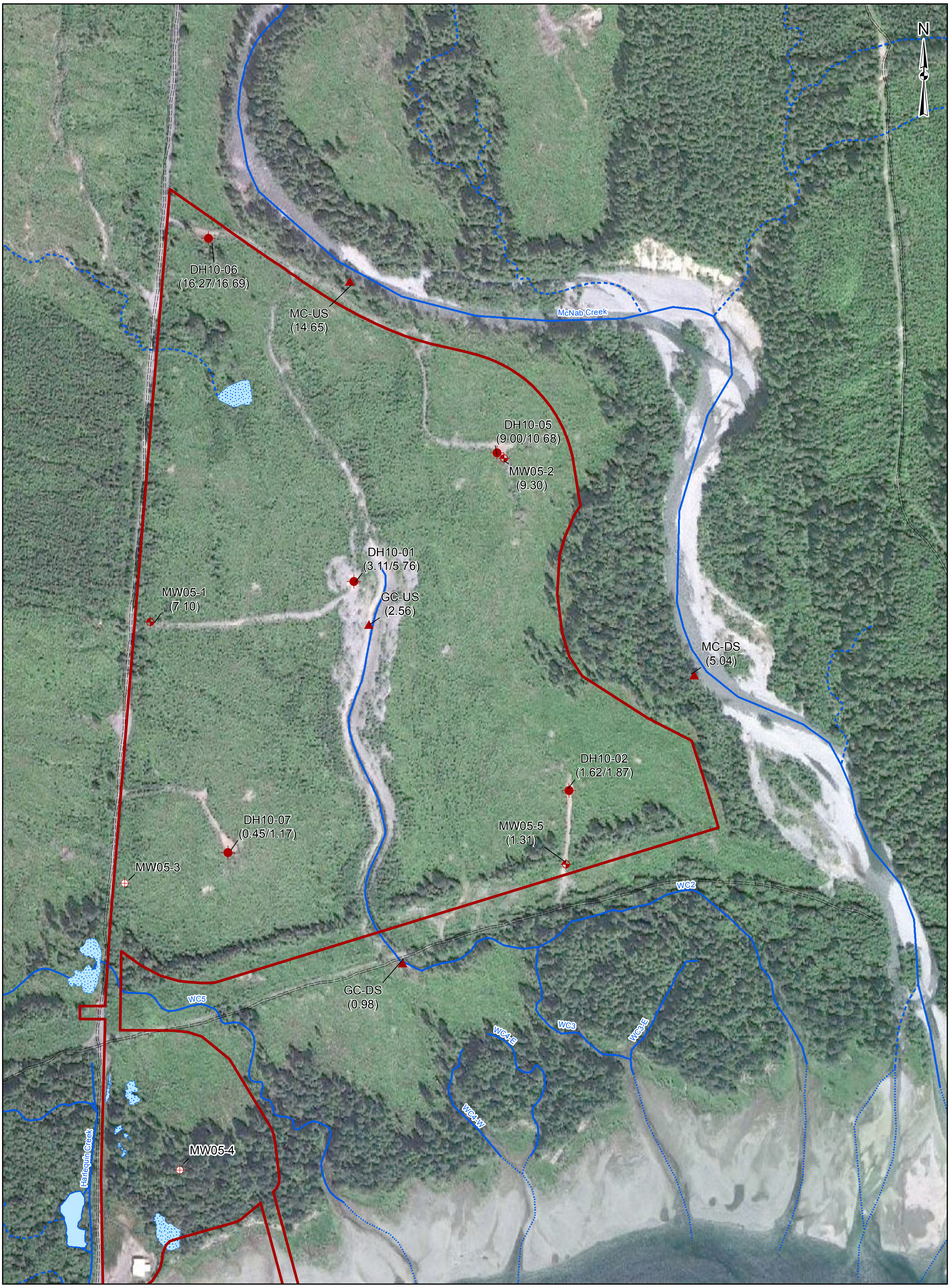

150 0 150

SCALE 1:5,000 METRES

LEGEND

● Monitoring Well with Two Nested Standpipe Piezometers (Golder, 2010)
▲ Surface Water Monitoring Station (Golder, 2010)
⊕ Monitoring Well with One Standpipe Piezometer (EBA, 2005)
⊕ Destroyed Monitoring Well (EBA, 2005) - Approximate location shown

DH10-01 — Well/Station Label
(3.11/5.76) — Deep Piezometer (if applicable)
— Shallow Piezometer

Water Elevations in Metres Recorded Aug. 11, 2010.

▭ Project Area
▨ Low Lying Wetted Area
▭ Beaver Impounded Wetted Area
— Permanent / Perennial Watercourse
--- Intermittent Watercourse
······ Intertidal Watercourse
=== Road (Existing)

REFERENCE

Watercourses from the Province of British Columbia and field data. Base features from the Province of British Columbia. Additional detailed site features provided by McElhanney. Well locations surveyed by Peter Gordon Surveys. Base Imagery from Google Maps 20100807. Projection: UTM Zone 10 Datum: NAD 83

PROJECT
BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

GROUNDWATER AND SURFACE WATER MONITORING NETWORK

Golder Associates

PROJECT NO. 11-1422-0046			PHASE No. 4600	
DESIGN	MM	05 Oct. 2010	SCALE AS SHOWN	REV. 1
GIS	DL	10 Mar. 2016	FIGURE 2	
CHECK	AM	07 Feb. 2013		
REVIEW	WZ	08 Feb. 2013		

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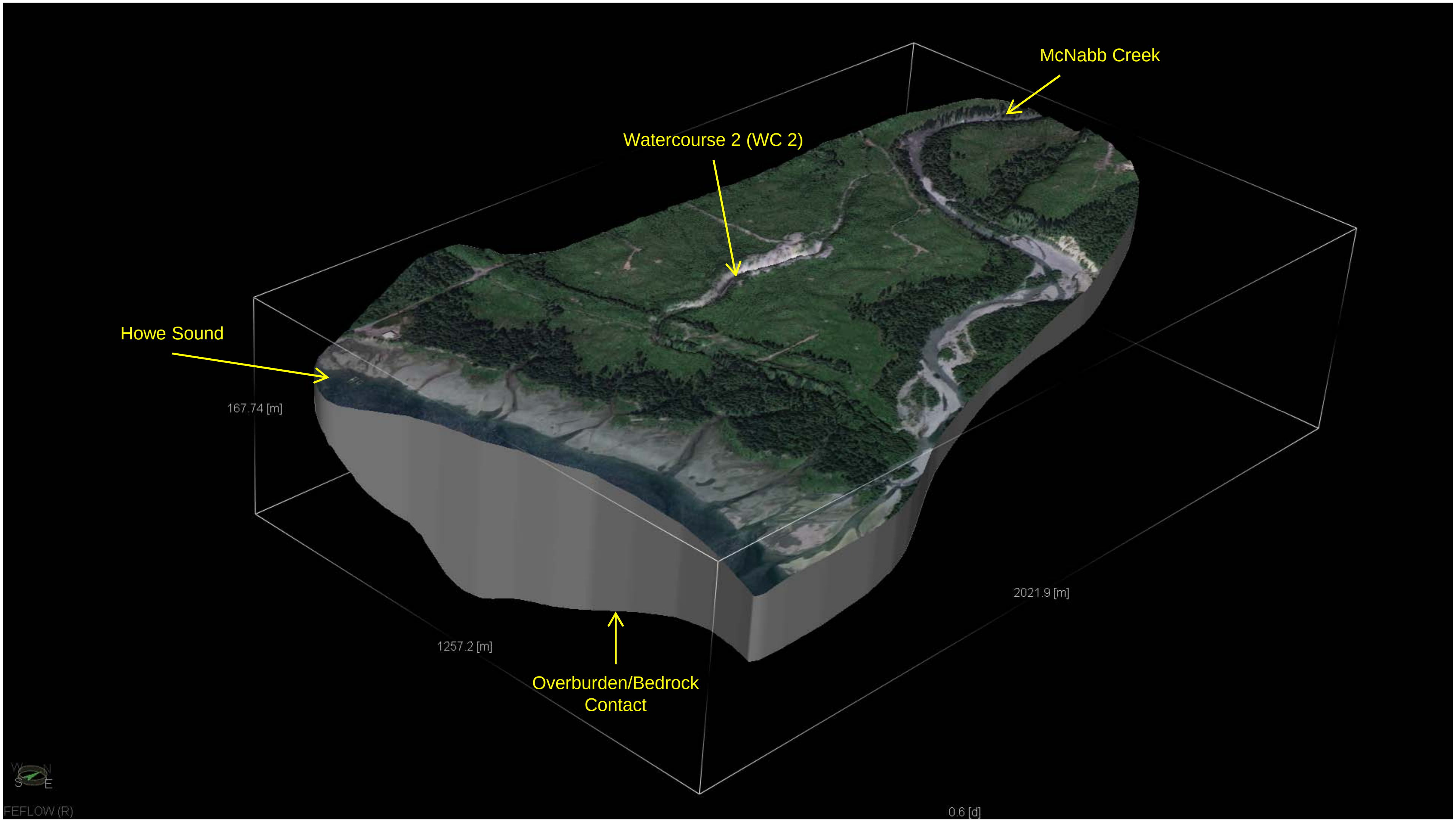

PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

EXTENT OF NUMERICAL HYDROGEOLOGICAL MODEL

Golder Associates

PROJECT No. 1114220046			PHASE No. 4600
DESIGN	WZ	22OCT14	SCALE As Shown REV.
CADD	WZ	22OCT14	FIGURE 3
CHECK	DWC	22OCT14	
REVIEW	DWC	22OCT14	

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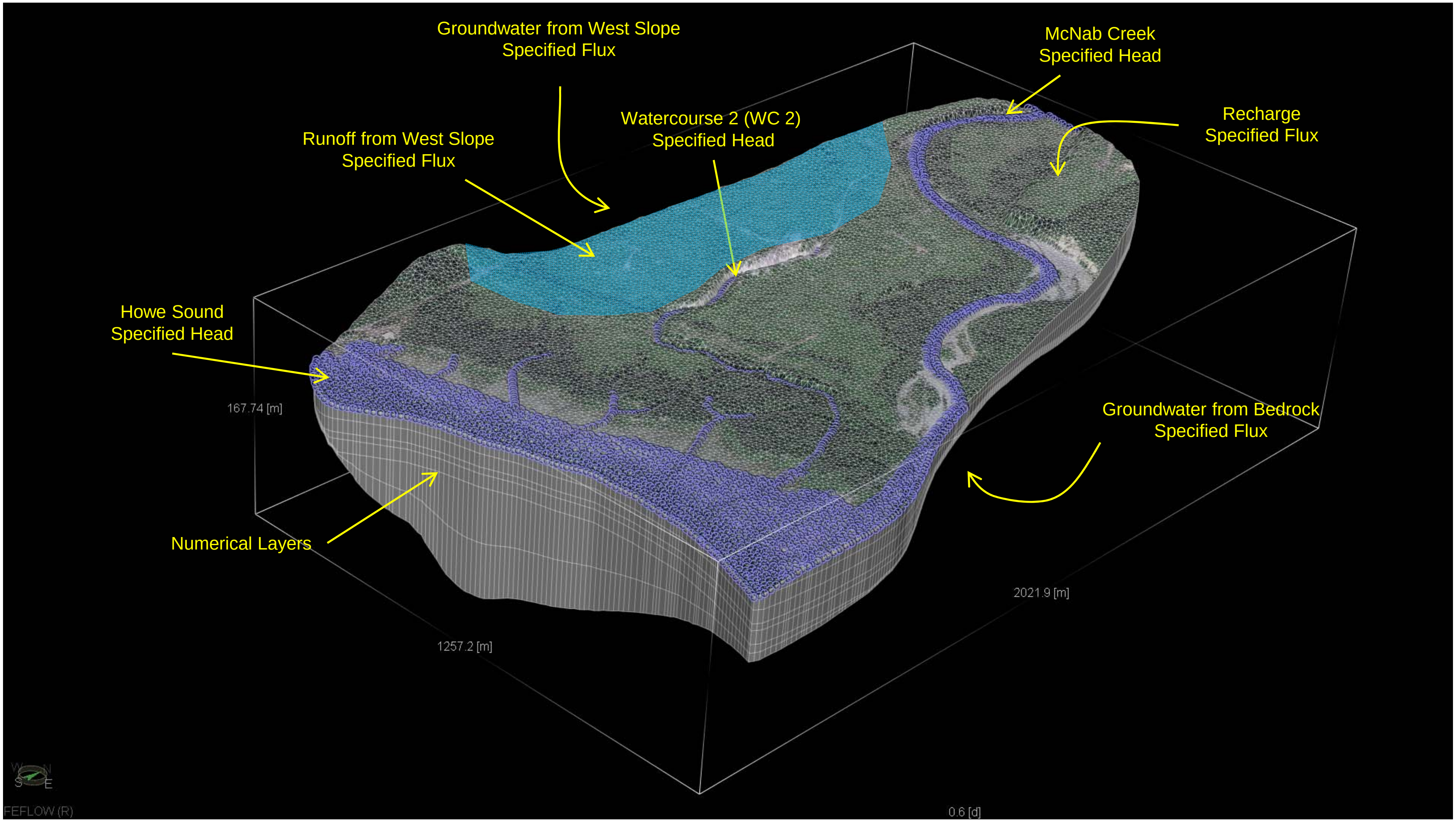

PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

MODEL MESH AND BOUNDARY CONDITIONS

Golder Associates

PROJECT No. 1114220046			PHASE No. 4600
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CADD	WZ	22OCT14	**FIGURE 4**
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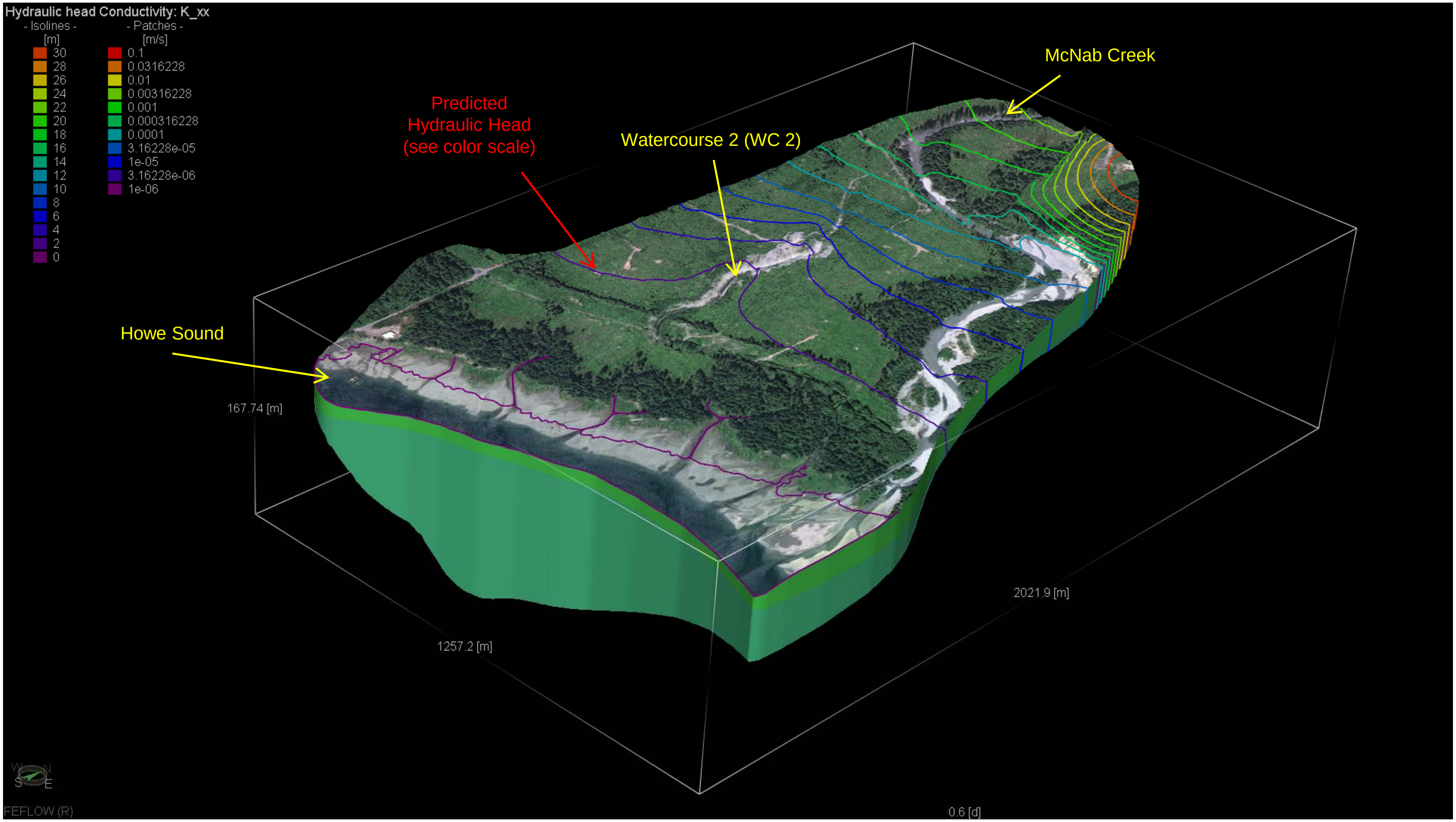
REVIEW	DWC	22OCT14	



PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

PREDICTED HYDRAULIC HEADS SEPTEMBER 2010 STEADY-STATE CALIBRATION

Golder Associates

PROJECT No. 1114220046			PHASE No. 4600	
DESIGN	WZ	22OCT14	SCALE As Shown	REV.
CADD	WZ	22OCT14	**FIGURE 5**	
CHECK	DWC	22OCT14		
REVIEW	DWC	22OCT14		

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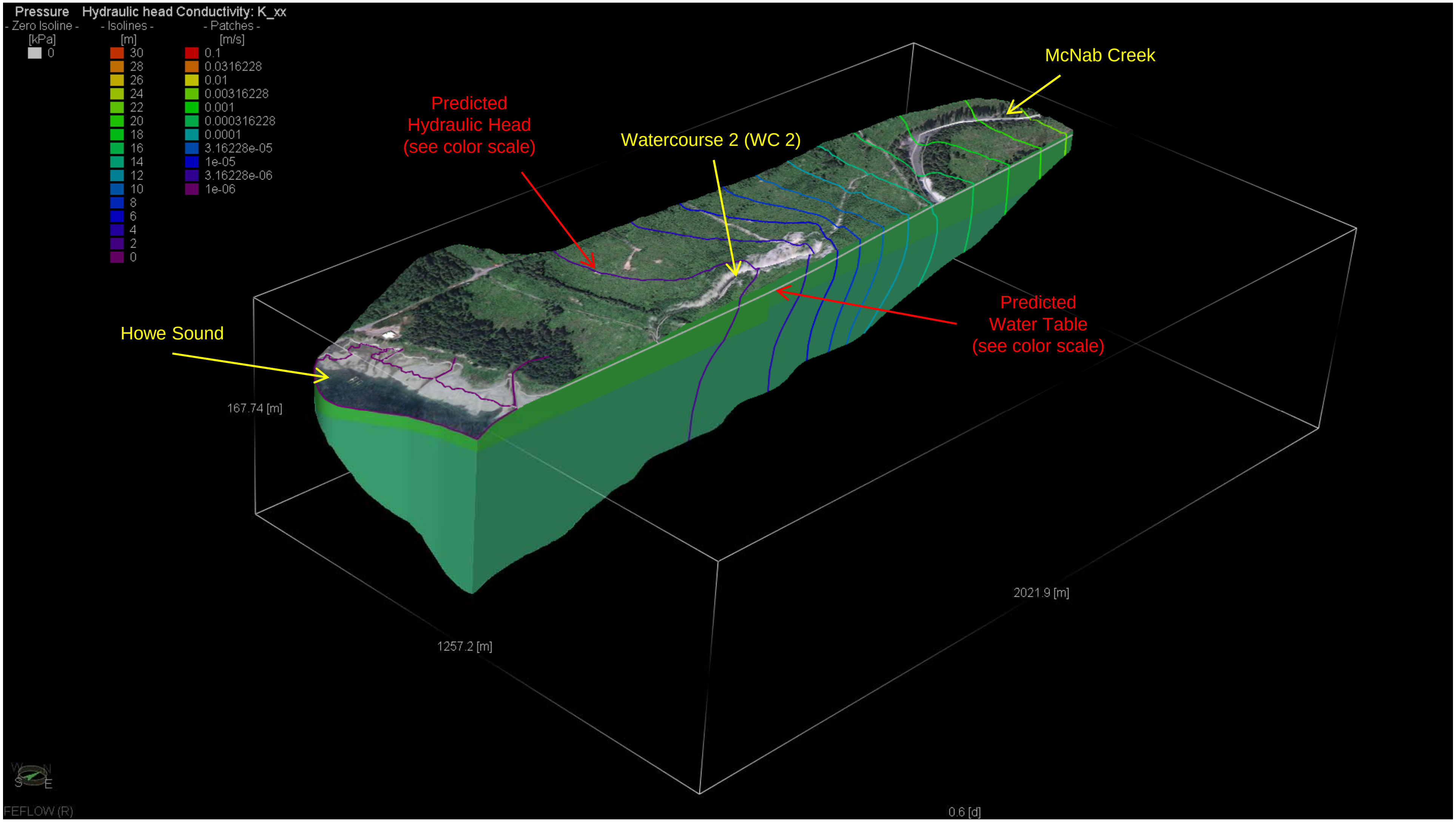

PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

PREDICTED HYDRAULIC HEADS
SEPTEMBER 2010 STEADY-STATE
CALIBRATION – SECTION

Golder Associates

PROJECT No. 1114220046			PHASE No. 4600
DESIGN	WZ	22OCT14	SCALE As Shown REV.
CADD	WZ	22OCT14	**FIGURE 6**
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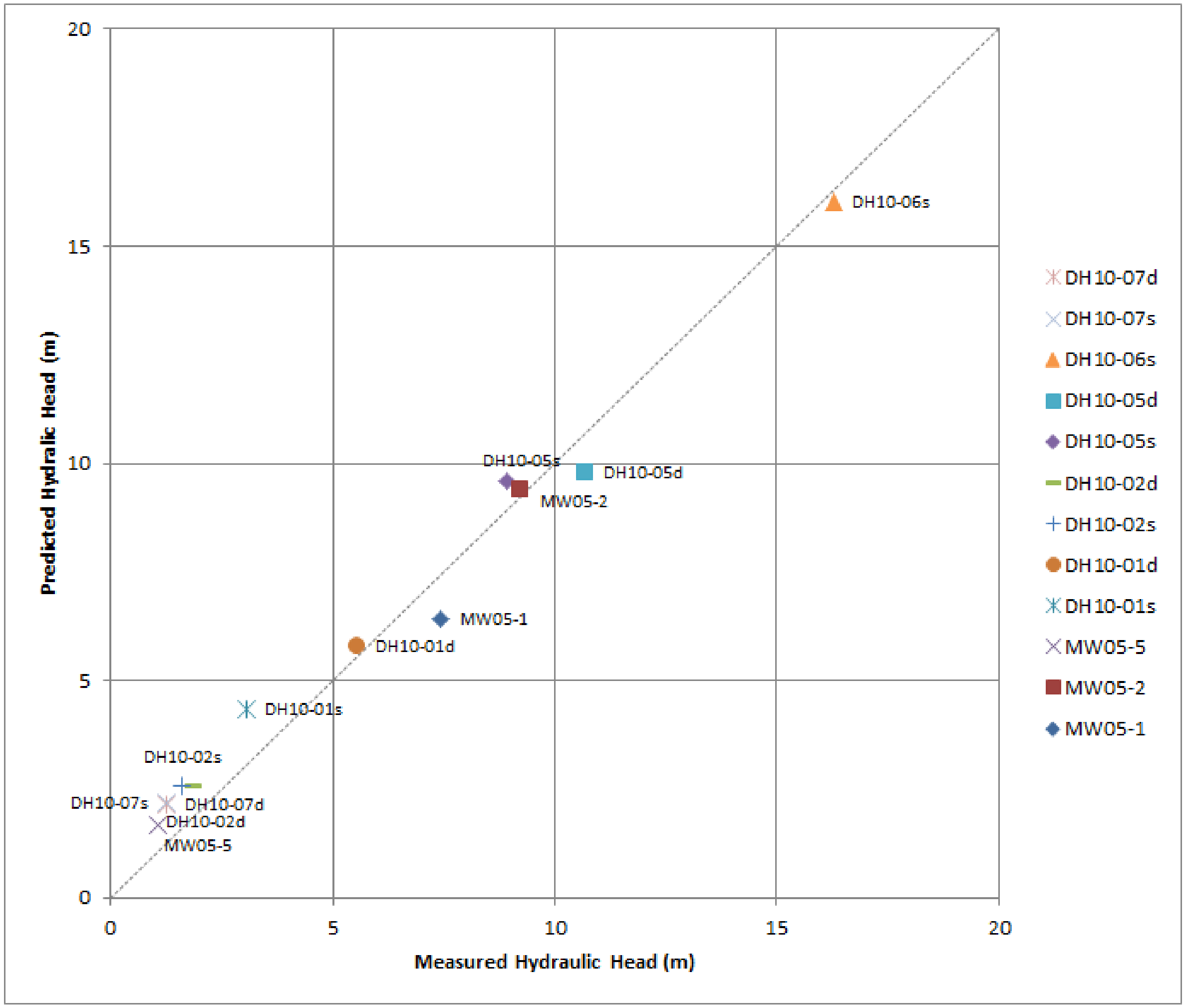
REVIEW	DWC	22OCT14	



PROJECT

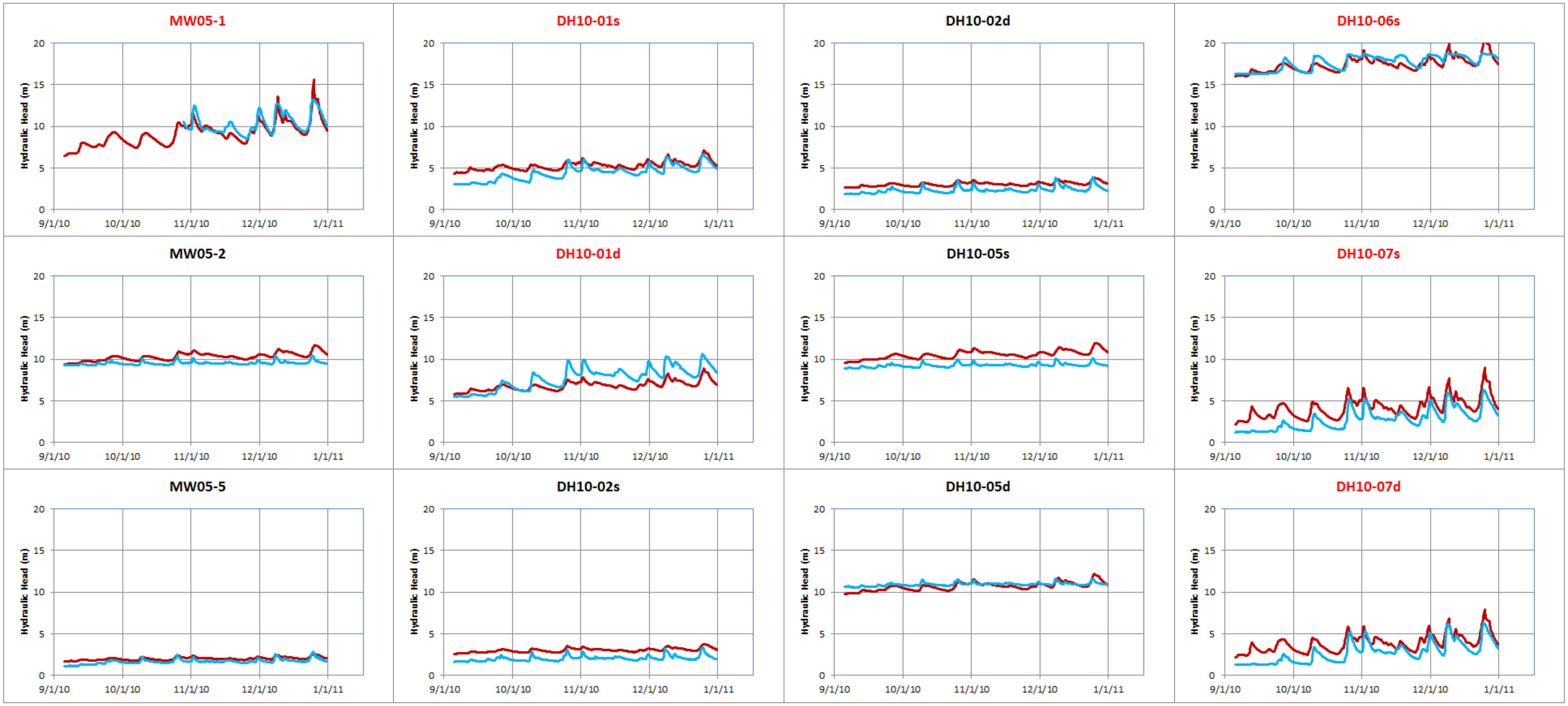
BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

PREDICTED VS MEASURED HYDRAULIC HEADS SEPTEMBER 2010 STEADY-STATE CALIBRATION

Golder Associates

PROJECT No. 1114220046			PHASE No. 4600	
DESIGN	WZ	22OCT14	SCALE As Shown	REV.
CADD	WZ	22OCT14	**FIGURE 7**	
CHECK	DWC	22OCT14		
REVIEW	DWC	22OCT14		



Note:

Blue lines represent measured hydraulic heads.

Red lines represent predicted hydraulic heads.

PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

PREDICTED VS MEASURED HYDRAULIC HEADS SEPTEMBER 2010 TO JANUARY 2011 TRANSIENT CALIBRATION

Golder Associates

PROJECT No. 1114220046			PHASE No. 4600
DESIGN	WZ	22OCT14	SCALE As Shown REV.
CADD	WZ	22OCT14	**FIGURE 8**
CHECK	DWC	22OCT14	
REVIEW	DWC	22OCT14	

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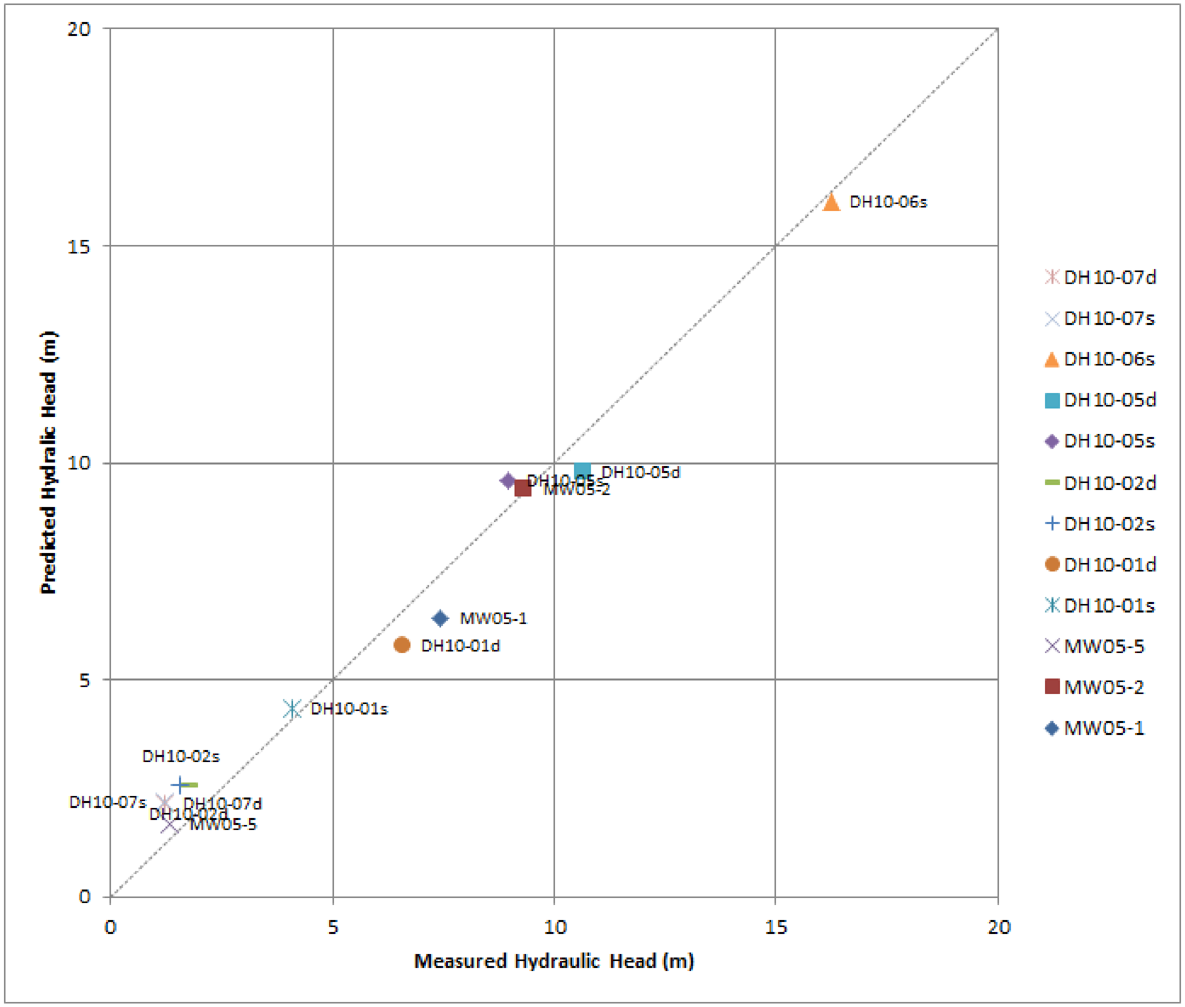

PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

PREDICTED VS MEASURED HYDRAULIC HEADS SEPTEMBER 2011 STEADY-STATE CALIBRATION

Golder Associates

PROJECT No. 1114220046			PHASE No. 4600
DESIGN	WZ	22OCT14	SCALE As Shown REV.
CADD	WZ	22OCT14	**FIGURE 9**
CHECK	DWC	22OCT14	
REVIEW	DWC	22OCT14	

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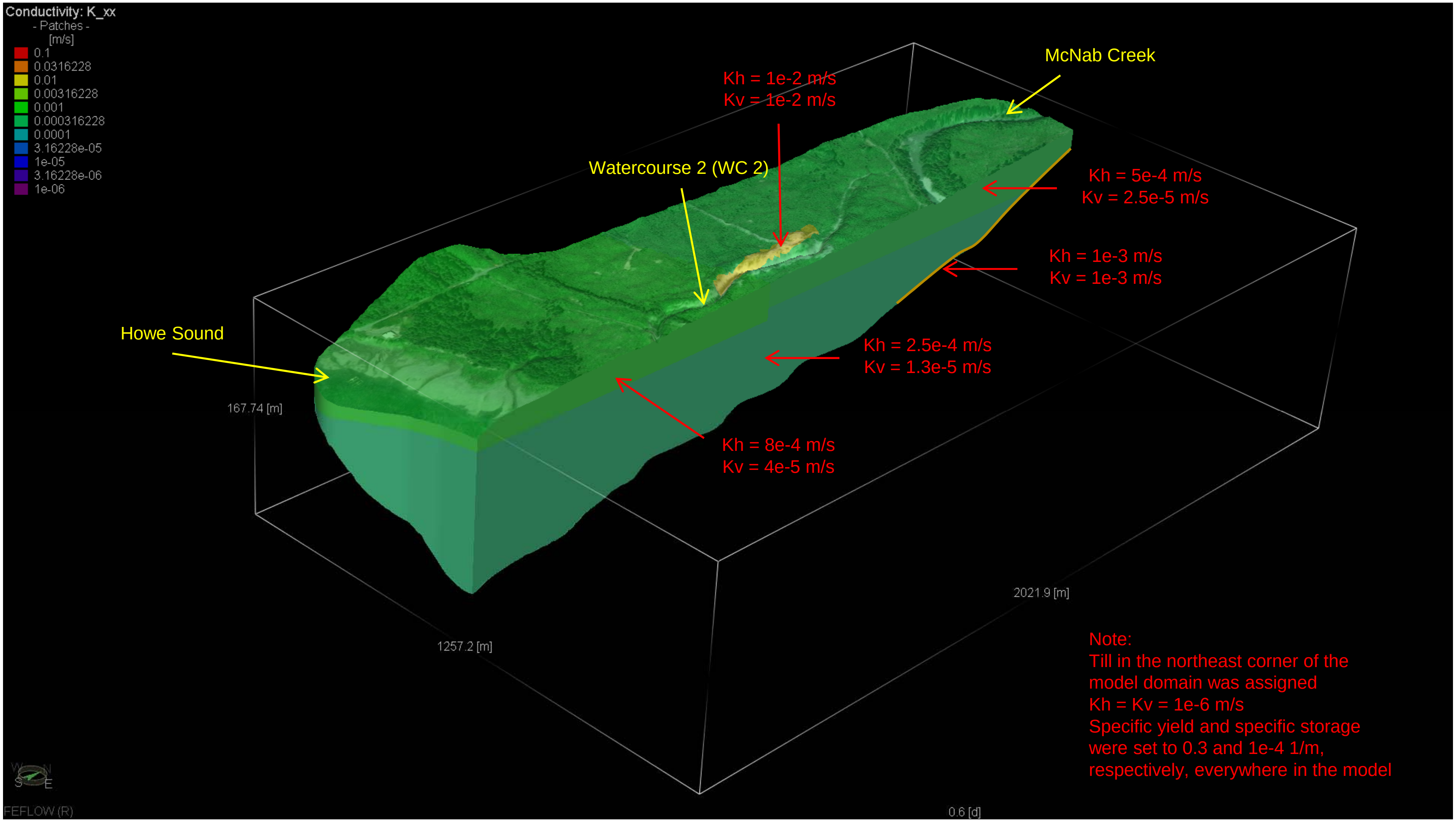

Note:
Till in the northeast corner of the model domain was assigned Kh = Kv = 1e-6 m/s
Specific yield and specific storage were set to 0.3 and 1e-4 1/m, respectively, everywhere in the model

PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

CALIBRATED VALUES OF HYDROGEOLOGICAL PARAMETERS USED IN THE GROUNDWATER MODEL

Golder Associates

PROJECT No. 1114220046			PHASE No. 4600	
DESIGN	WZ	22OCT14	SCALE As Shown	REV.
CADD	WZ	22OCT14	**FIGURE 10**	
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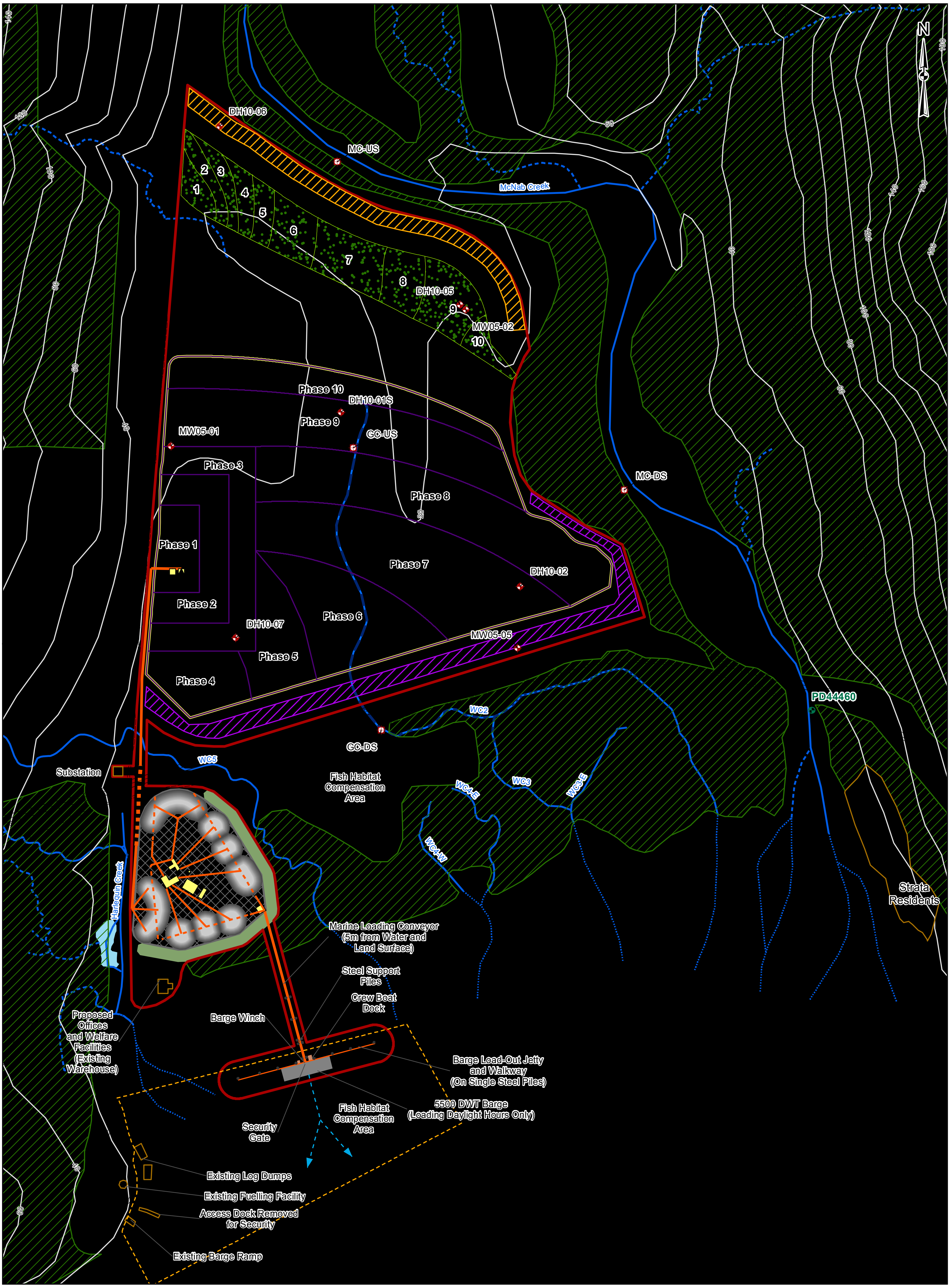
REVIEW	DWC	22OCT14		



LEGEND

- ✚ Monitoring Well (Golder 2012)
- ⊕ Surface Water Monitoring Station (Golder 2012)
- ● Current Water Licence (POD)
- ▭ Project Area
- ▭ Proposed Aggregate Pit Phase
- ▭ Final Pit Lake Outline
- ⊠ Processing Area
- ▭ Product Stockpile
- ▨ Fines Storage Area
- ▭ Existing Feature
- ▭ Existing Log Tenure Area
- ▭ Possible Processing Plant Configuration

- ▨ McNab Creek Flood Protection Dyke
- ▨ Pit Lake Containment Berm
- ▭ Processing Area Berm
- ▨ Mature Forest
- ▭ Waterbody
- ▨ Intertidal Zone
- — Elevated Conveyor
- ‒ ‒ Underground Conveyor
- — Barge Load-out
- — Transmission Line
- === Road (Existing)
- — Contour (20m)

- — Permanent / Perennial Watercourse
- - - Intermittent Watercourse
- ······ Intertidal Watercourse

Constructed Watercourse

- Phase 1 (1985)
- Phase 2 (1998)
- Phase 3 (2001 - 2003)
- → Barge Route
- ● Pile

REFERENCE

DEM from Geobase. Watercourses from the Province of British Columbia and field data. Base data from the Province of British Columbia. Contours from TRIM positional data. Additional detailed site features provided by McElhanney.
Projection: UTM Zone 10 Datum: NAD 83

200 0 200

SCALE 1:6,000 METRES

PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

PROPOSED CONCEPTUAL SITE LAYOUT

PROJECT NO. 11-1422-0046			PHASE No.
DESIGN	MJ	02 Nov. 2012	SCALE AS SHOWN REV. 1
GIS	DL	10 Mar. 2016	
CHECK	AS	10 Jun. 2014	**FIGURE 11**
REVIEW	AC	10 Jun. 2014	

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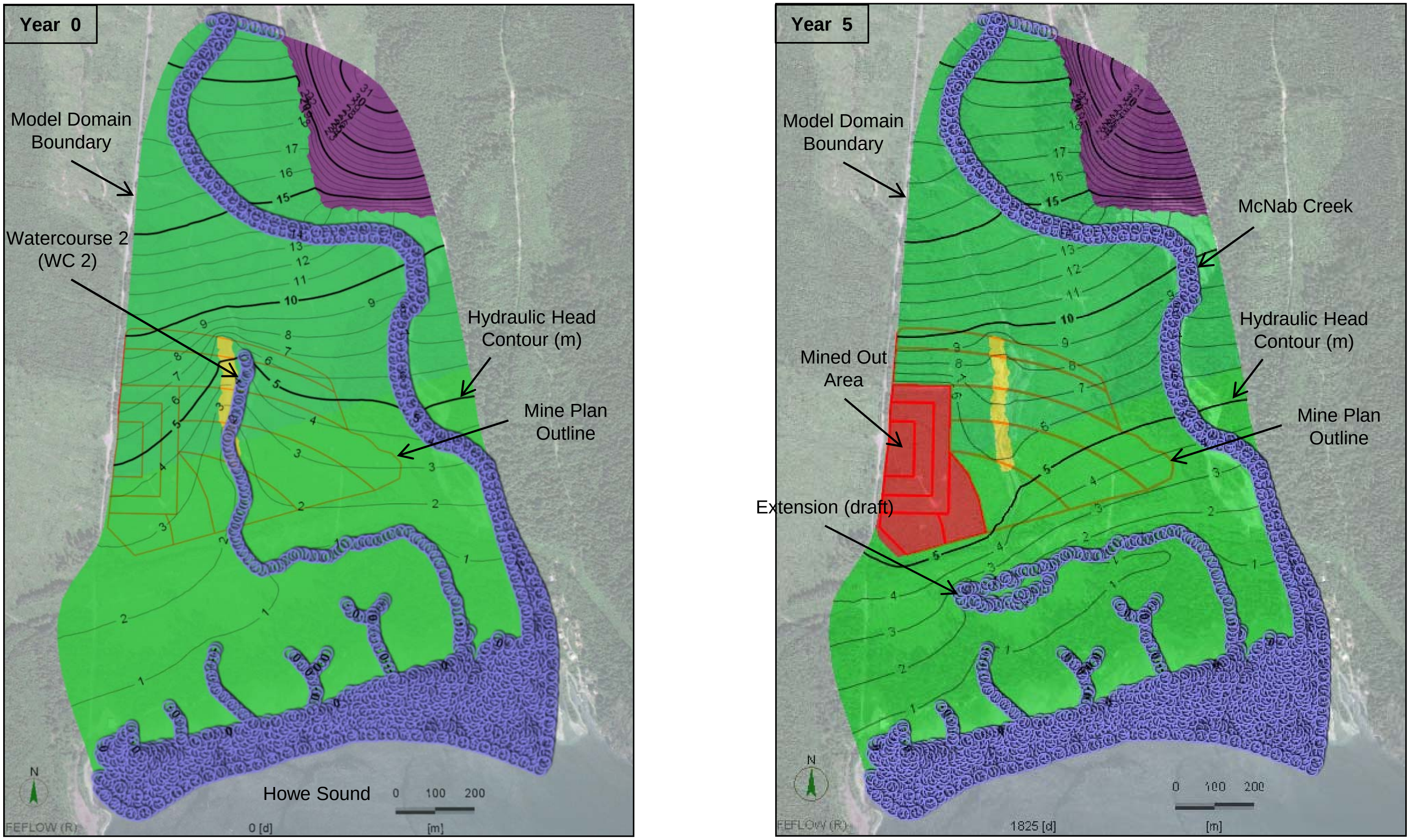

PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

PREDICTED HYDROGEOLOGICAL CONDITIONS DURING MINING YEAR 0 AND YEAR 5

Golder Associates

PROJECT No. 1114220046			PHASE No. 4600	
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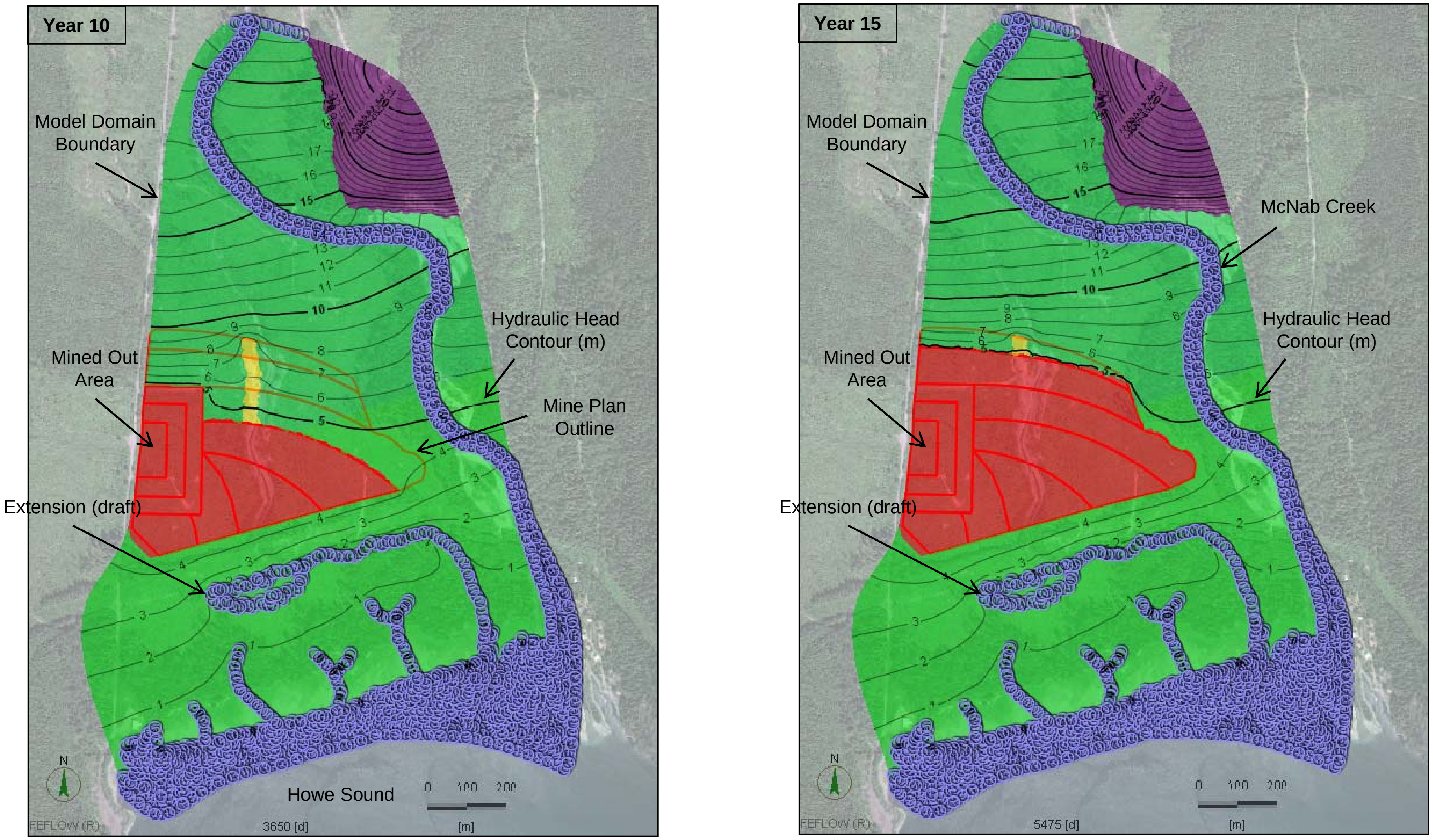
REVIEW	DWC	22OCT14		



PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

PREDICTED HYDROGEOLOGICAL CONDITIONS DURING MINING YEAR 10 AND YEAR 15

Golder Associates

PROJECT No. 1114220046			PHASE No. 4600	
DESIGN	WZ	22OCT14	SCALE As Shown	REV.
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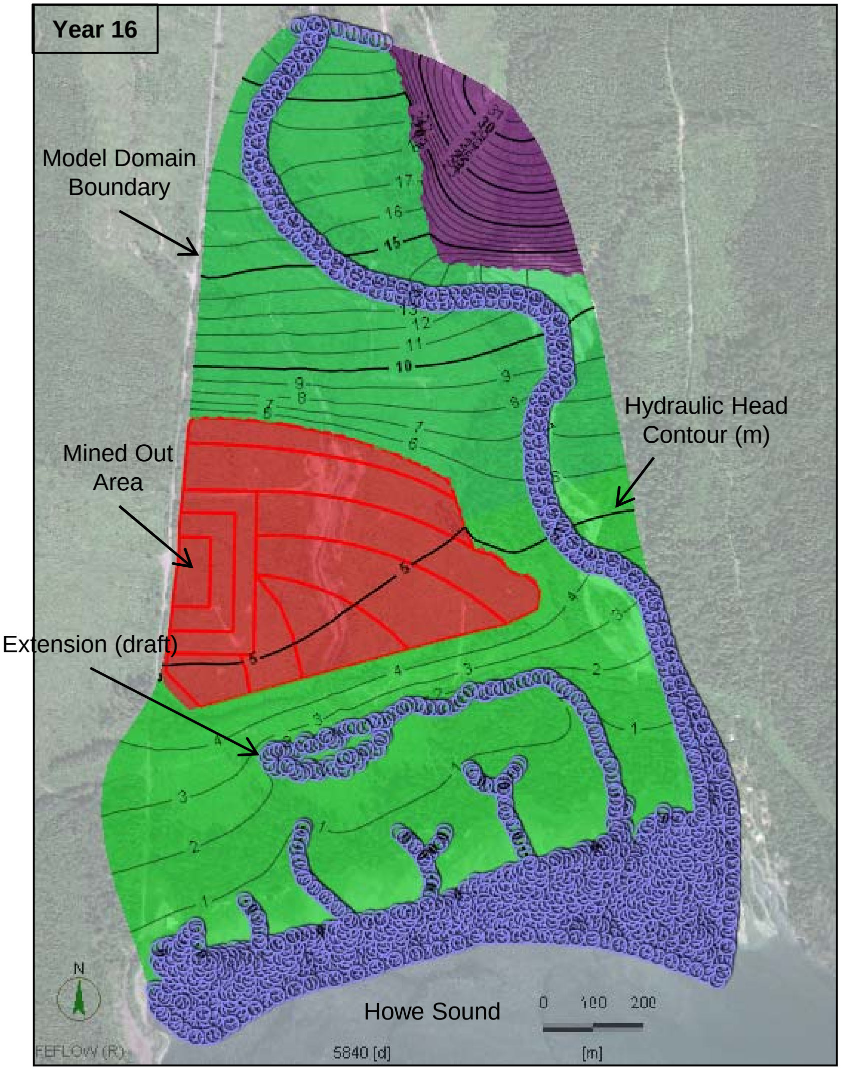
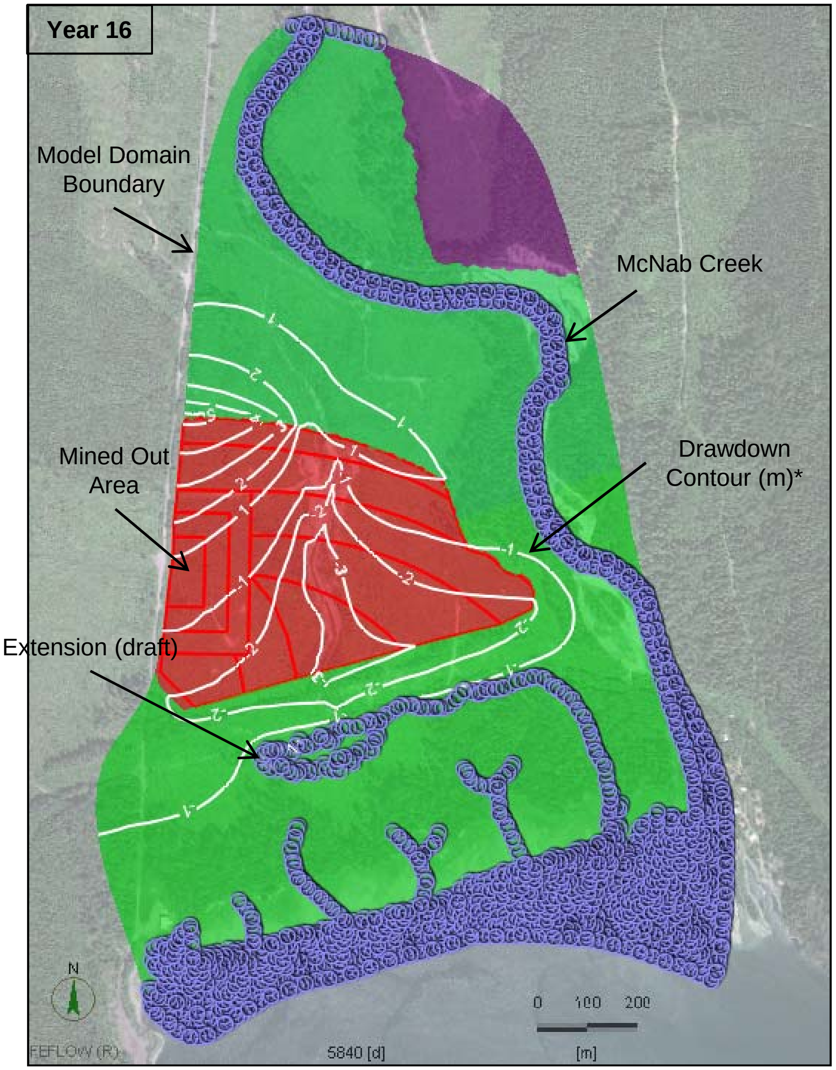
REVIEW	DWC	22OCT14		





Notes

* Drawdown was calculated as a difference between hydraulic heads predicted for Year 16 and Year 0. Positive values indicate decrease in hydraulic heads from the pre-development conditions.

PROJECT

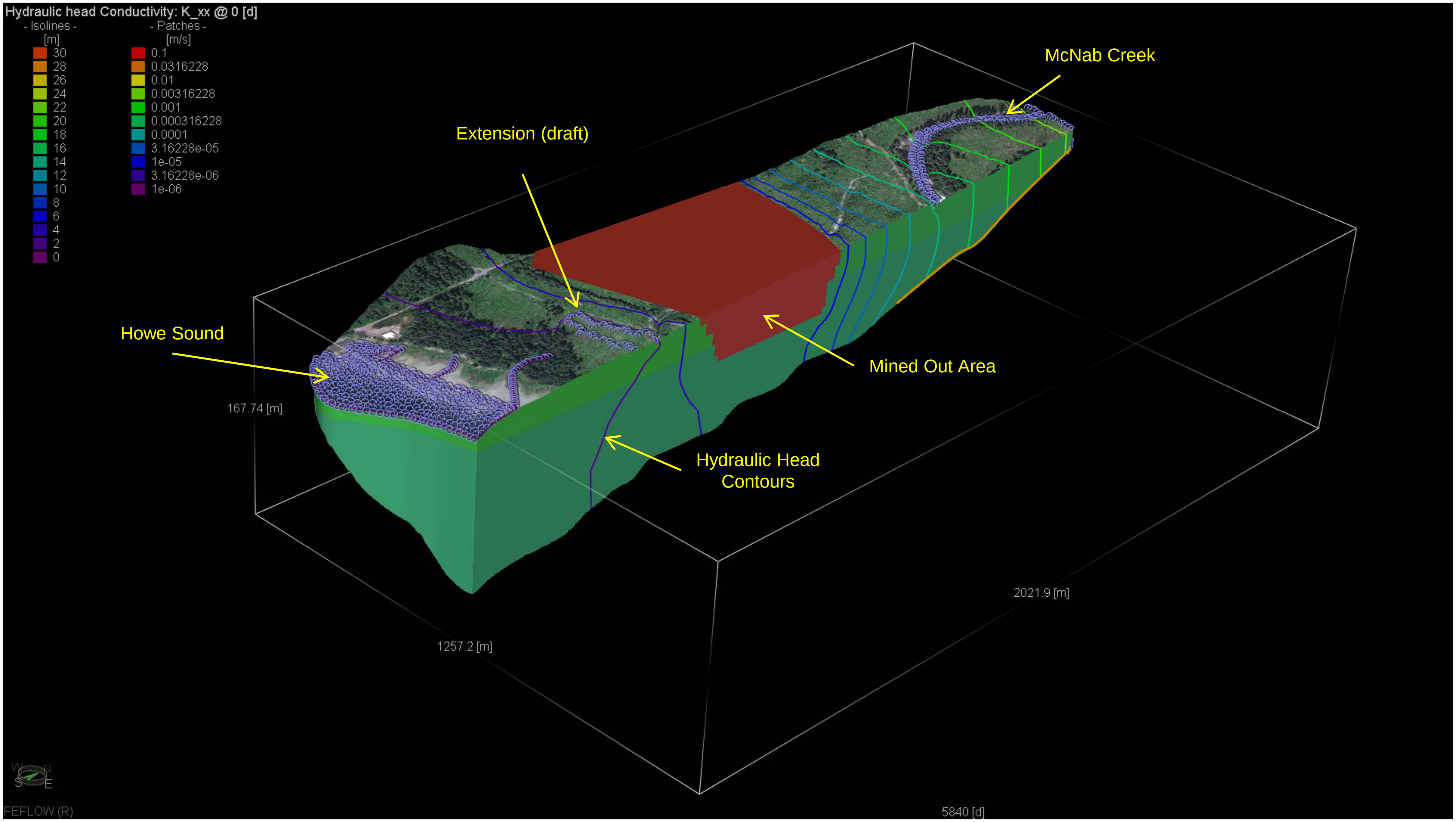
BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

PREDICTED HYDROGEOLOGICAL
CONDITIONS DURING MINING
YEAR 16

Golder Associates

PROJECT No. 1114220046			PHASE No. 4600
DESIGN	WZ	22OCT14	SCALE As Shown REV.
CADD	WZ	22OCT14	**FIGURE 14**
CHECK	DWC	22OCT14	
REVIEW	DWC	22OCT14	



PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

PREDICTED HYDROGEOLOGICAL CONDITIONS DURING MINING YEAR 16 – SECTION

Golder Associates

PROJECT No. 1114220046			PHASE No. 4600
DESIGN	WZ	22OCT14	SCALE As Shown REV.
CADD	WZ	22OCT14	**FIGURE 15**
CHECK	DWC	22OCT14	
REVIEW	DWC	22OCT14	

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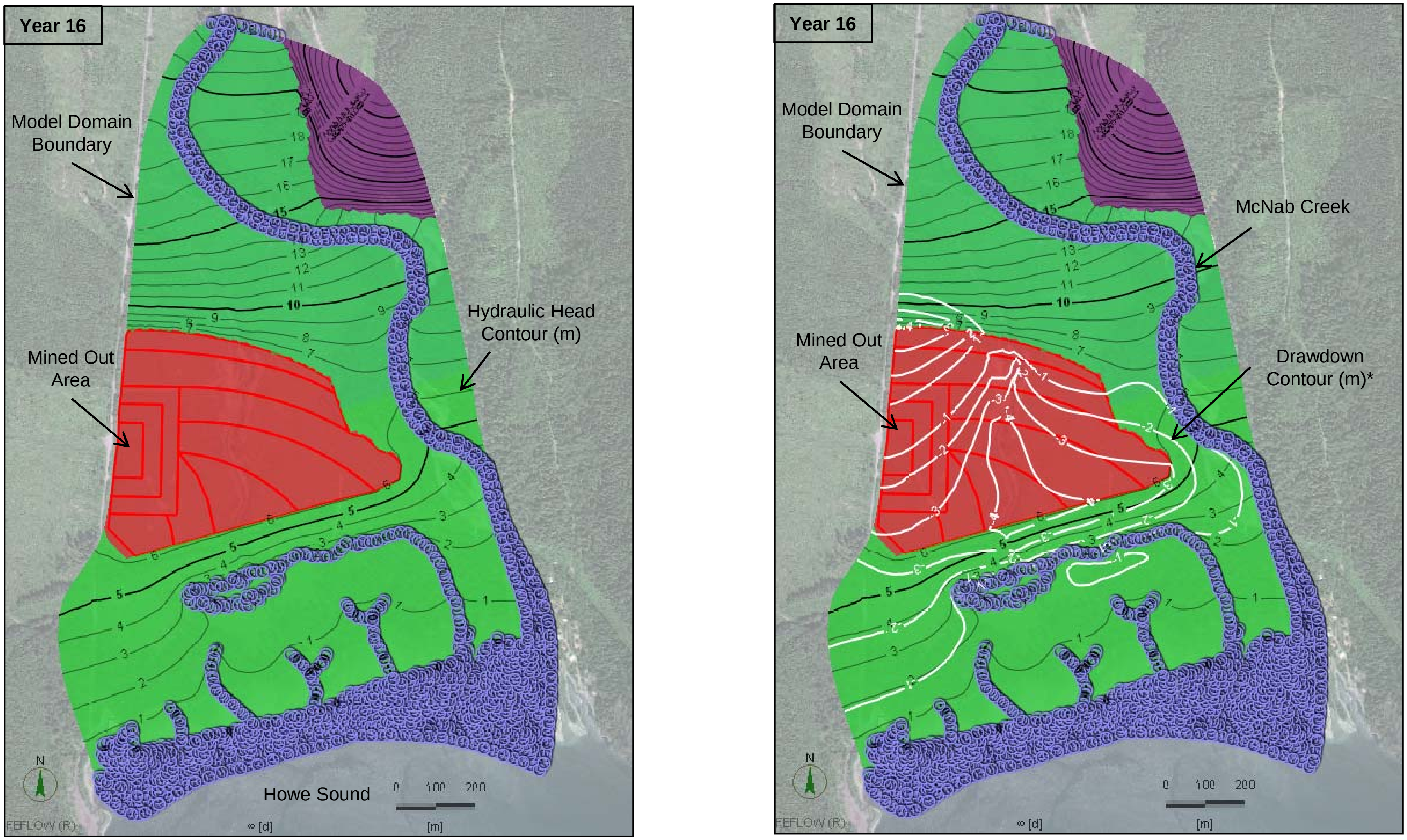

Notes

* Drawdown was calculated as a difference between hydraulic heads predicted for Year 16 and Year 0. Positive values indicate decrease in hydraulic heads from the pre-development conditions.

PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

PREDICTED HYDROGEOLOGICAL
CONDITIONS – END OF MINING YEAR 16
AVERAGE WET SEASON

Golder Associates

PROJECT No. 1114220046			PHASE No. 4600	
DESIGN	WZ	22OCT14	SCALE As Shown	REV.
CADD	WZ	22OCT14	**FIGURE 16**	
CHECK	DWC	22OCT14		
REVIEW	DWC	22OCT14		

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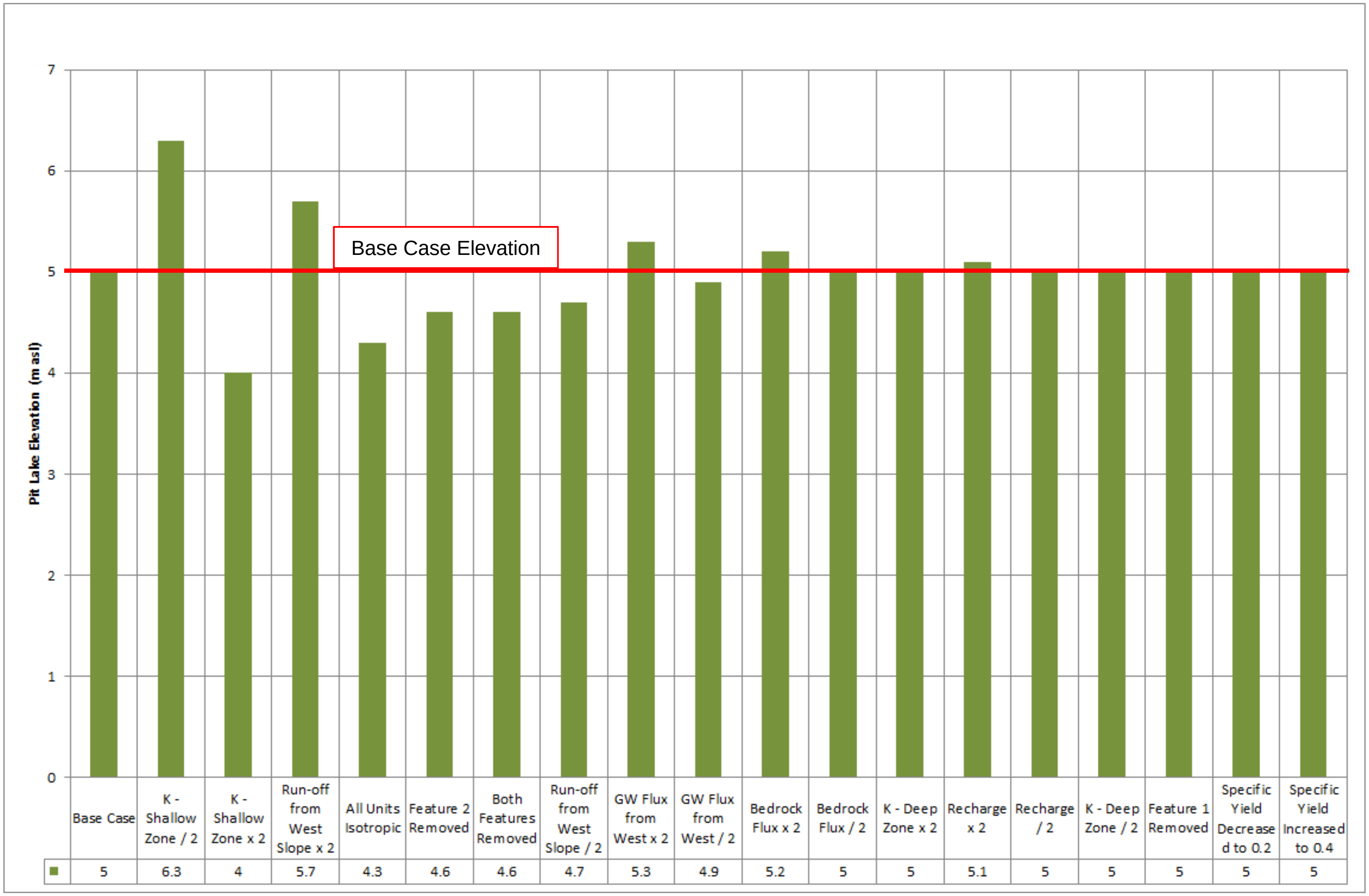


PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

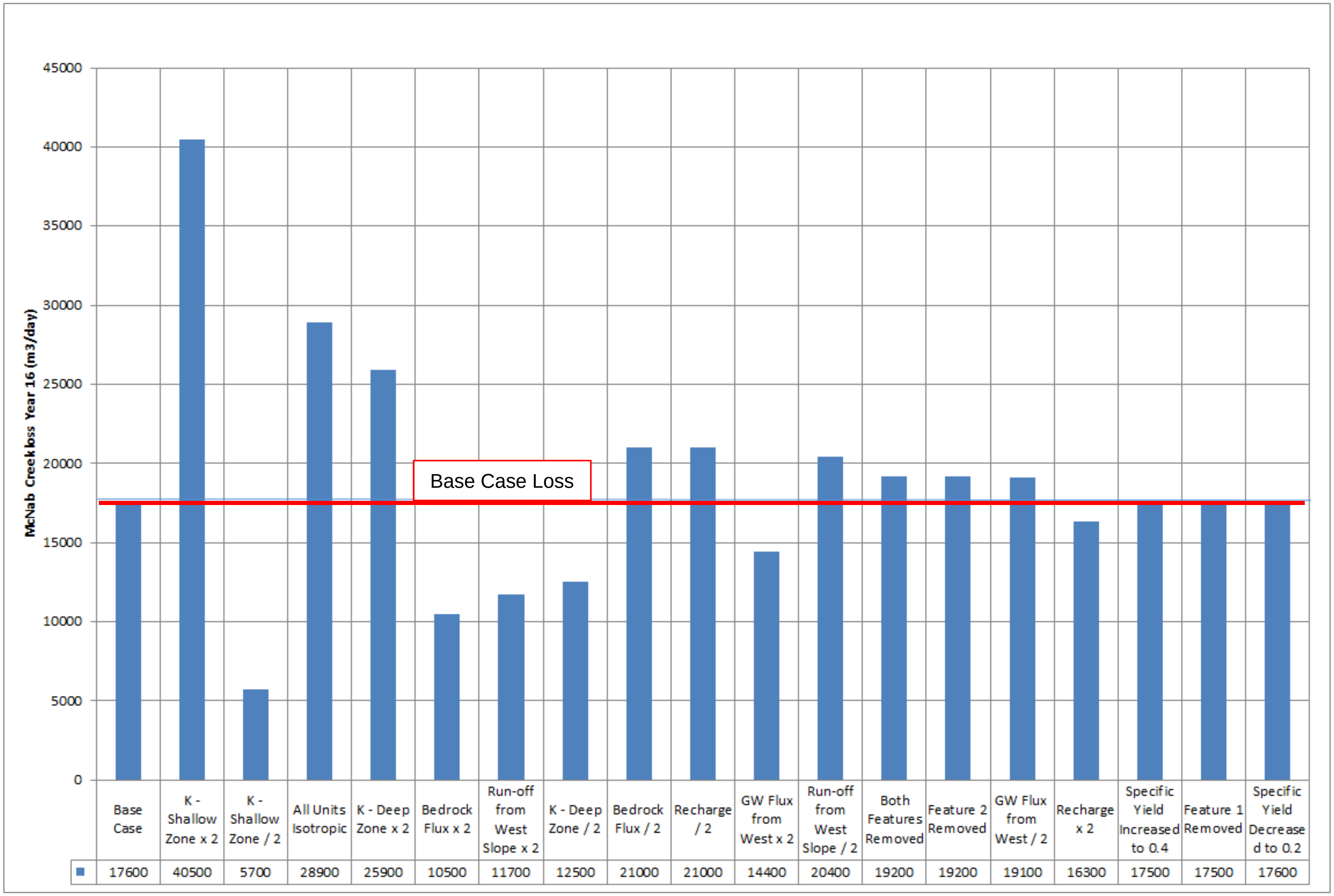
TITLE

RESULTS OF SENSITIVITY ANALYSIS
PIT LAKE ELEVATION AT YEAR 16
AVERAGE ANNUAL CONDITIONS

Golder Associates

PROJECT No. 1114220046			PHASE No. 4600
DESIGN	WZ	22OCT14	SCALE As Shown REV.
CADD	WZ	22OCT14	**FIGURE 17**
CHECK	DWC	22OCT14	
REVIEW	DWC	22OCT14	

O:\Active_2011\1422\11-1422-0046 Burnco McNab Creek EA\Phase 4600 Groundwater Resources\Hydrogeology\Tech Memo 201302 Modelling\Figures\Figures-revised rev 2.pptx



	Base Case	K - Shallow Zone x 2	K - Shallow Zone / 2	All Units Isotropic	K - Deep Zone x 2	Bedrock Flux x 2	Run-off from West Slope x 2	K - Deep Zone / 2	Bedrock Flux / 2	Recharge / 2	GW Flux from West x 2	Run-off from West Slope / 2	Both Features Removed	Feature 2 Removed	GW Flux from West / 2	Recharge x 2	Specific Yield Increased to 0.4	Feature 1 Removed	Specific Yield Decreased to 0.2
■	17600	40500	5700	28900	25900	10500	11700	12500	21000	21000	14400	20400	19200	19200	19100	16300	17500	17500	17600

PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

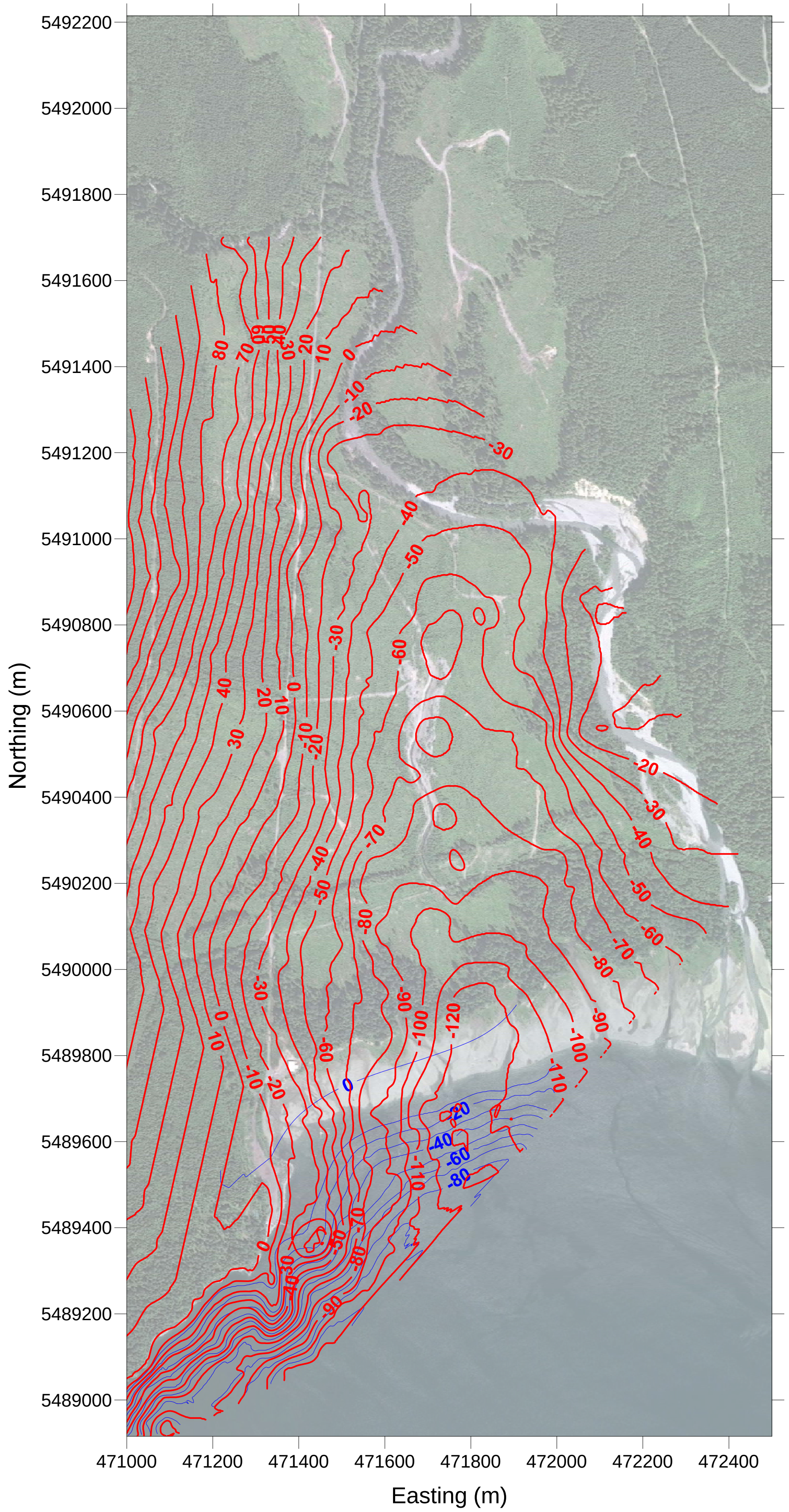
RESULTS OF SENSITIVITY ANALYSIS
MCNAB CREEK LOSS AT YEAR 16
AVERAGE ANNUAL CONDITIONS

Golder Associates

PROJECT No. 1114220046			PHASE No. 4600	
DESIGN	WZ	22OCT14	SCALE As Shown	REV.
CADD	WZ	22OCT14	**FIGURE 18**	
CHECK	DWC	22OCT14		
REVIEW	DWC	22OCT14		

ATTACHMENT 1

Bedrock and Bathymetry Data



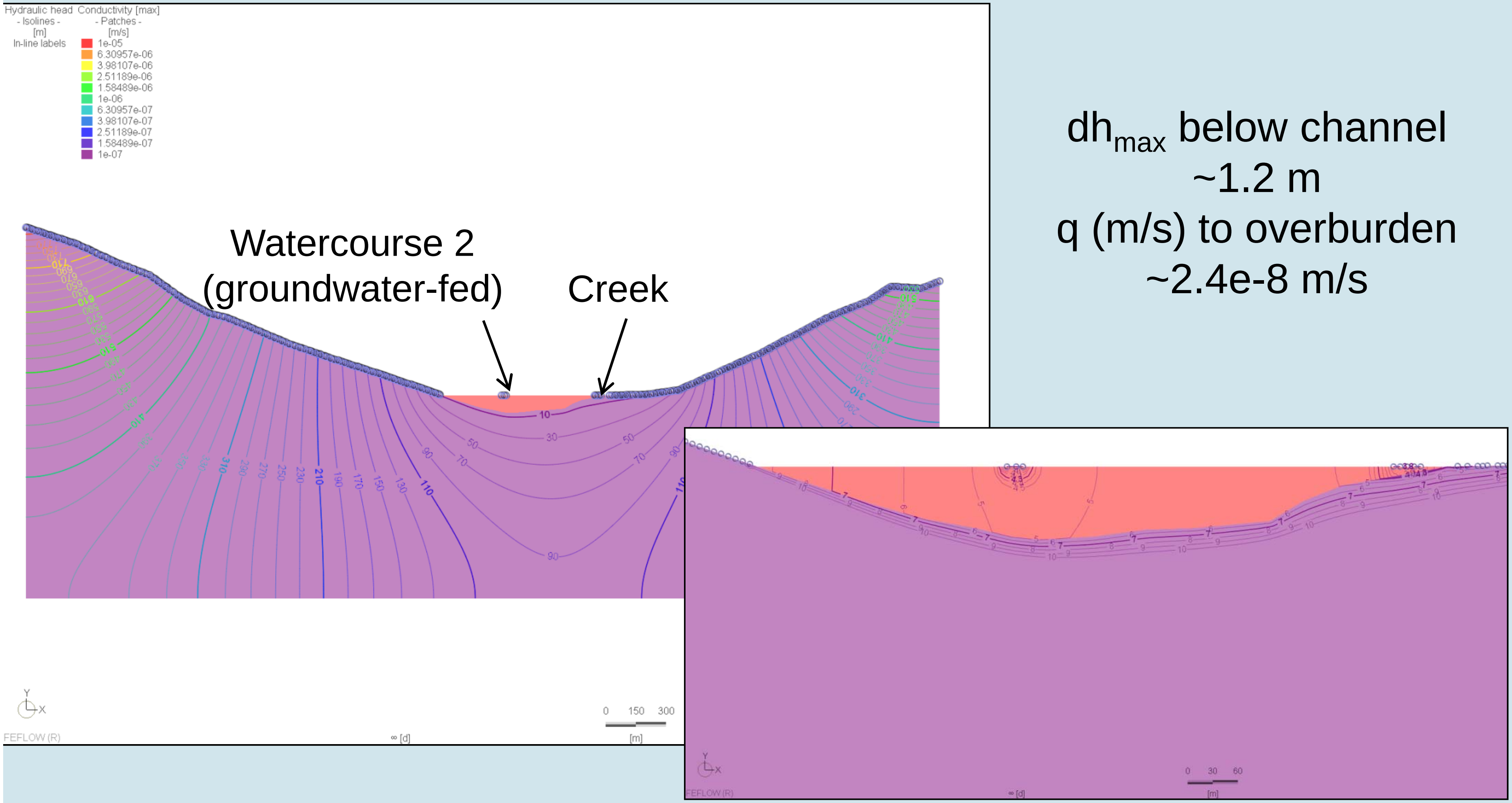
NOTE:
Red contours represent bedrock elevation (m) inferred by Frontier based on their 2009 and 2011 surveys.
Blue contours represent bathymetry data (m).

Q:/11-1422-0046 McNab/Data
20130208

ATTACHMENT 2

Bedrock Flux Simulations

McNab Bedrock Flux – Case 1
Bedrock K 1e-7 m/s; Overburden K 1e-5 m/s

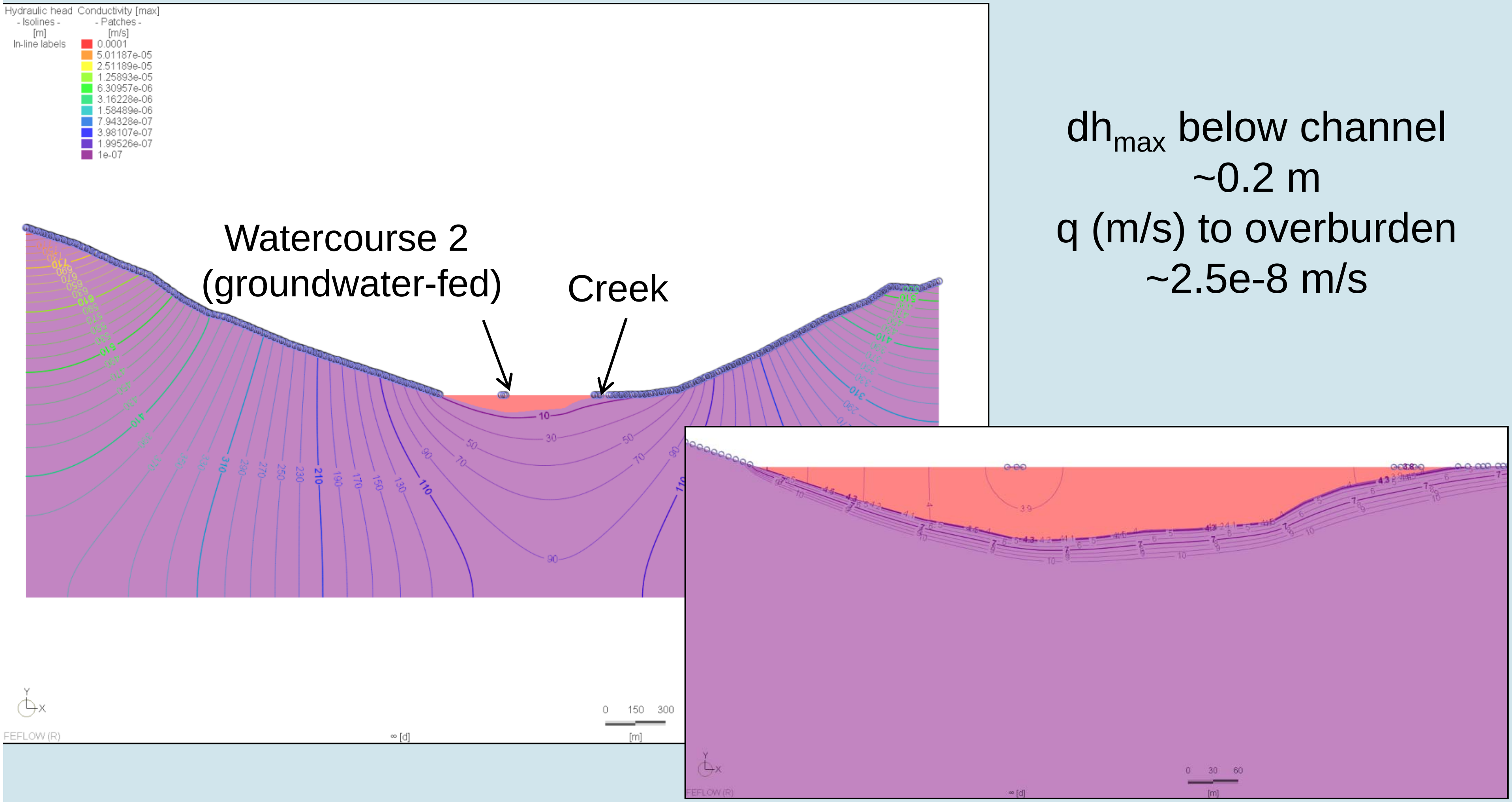


Watercourse 2
(groundwater-fed)

Creek

dh$_{max}$ below channel
~1.2 m
q (m/s) to overburden
~2.4e-8 m/s

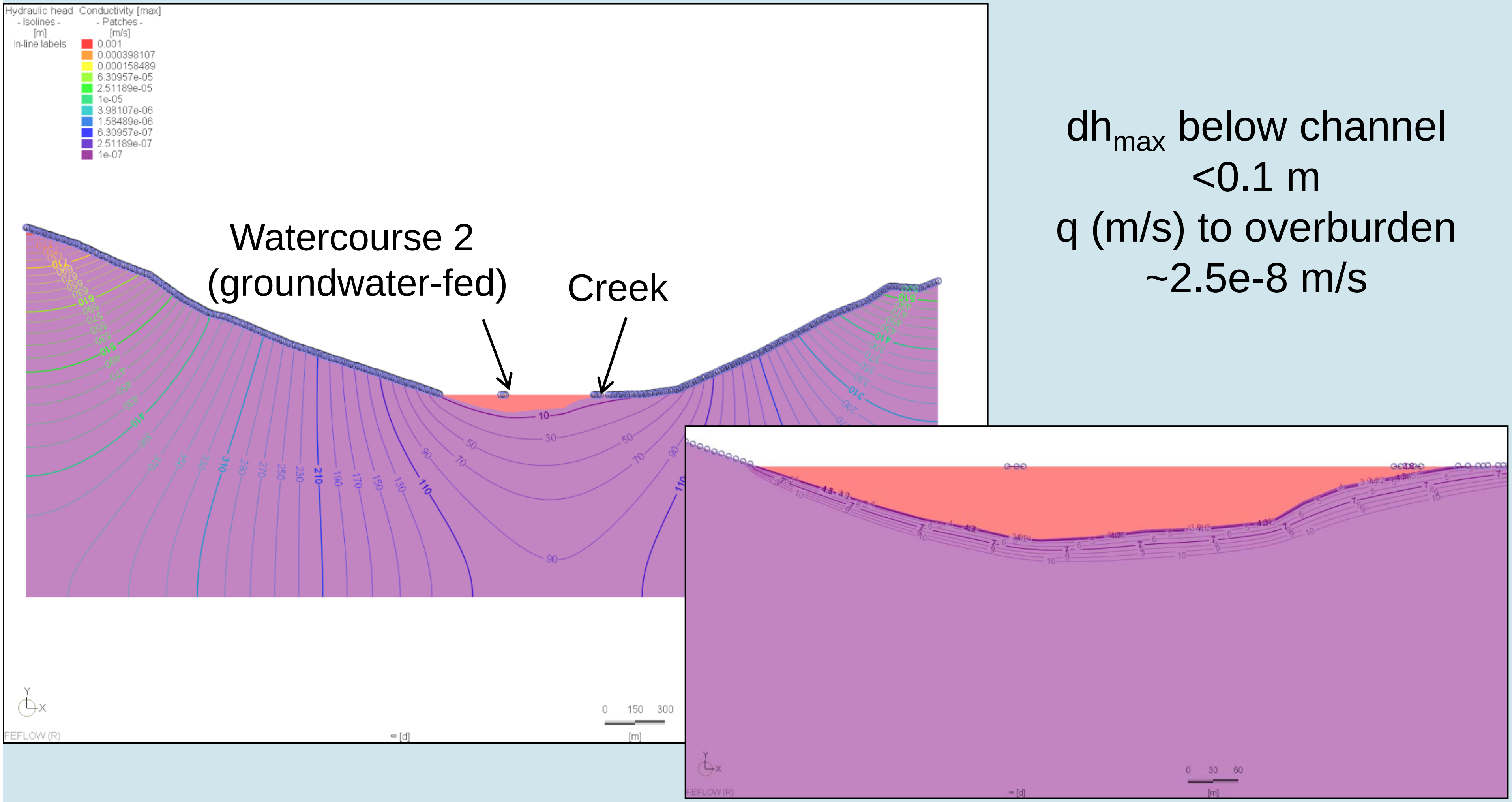
McNab Bedrock Flux – Case 2
Bedrock K 1e-7 m/s; Overburden K 1e-4 m/s



dh$_{max}$ below channel
~0.2 m
q (m/s) to overburden
~2.5e-8 m/s

Golder Associates

McNab Bedrock Flux – Case 3
Bedrock K 1e-7 m/s; Overburden K 1e-3 m/s



Watercourse 2 (groundwater-fed)

Creek

dh_{max} below channel
<0.1 m
q (m/s) to overburden
~2.5e-8 m/s

Golder Associates