

**Predictions of Groundwater Inflows  
to the Underground Mine Workings  
at the Idaho-Maryland Mine**

**Prepared  
for  
Rise Grass Valley Inc.**

**Prepared  
by  
Itasca Denver, Inc.  
143 Union Boulevard, Suite 525  
Lakewood, Colorado**

**#4091**

**March 2020**



## TABLE OF CONTENTS

|                                                                              | <u>Page</u> |
|------------------------------------------------------------------------------|-------------|
| LIST OF FIGURES.....                                                         | iii         |
| LIST OF TABLES.....                                                          | v           |
| LIST OF APPENDICES.....                                                      | vi          |
| LIST OF ABBREVIATIONS.....                                                   | vii         |
| CERTIFICATION .....                                                          | viii        |
| EXECUTIVE SUMMARY .....                                                      | ix          |
| 1.0 INTRODUCTION .....                                                       | 1           |
| 2.0 GENERAL HYDROGEOLOGIC CONDITIONS .....                                   | 3           |
| 2.1 CLIMATE AND GROUNDWATER RECHARGE .....                                   | 3           |
| 2.2 GEOLOGIC SETTING AND STRUCTURES.....                                     | 3           |
| 2.3 DEWATERING RATES FROM THE HISTORICAL MINES.....                          | 4           |
| 2.4 HYDRAULIC CONDUCTIVITIES AND GROUNDWATER LEVELS IN DOMESTIC WELLS.....   | 6           |
| 2.5 BASEFLOW RATES IN THE CREEKS .....                                       | 7           |
| 2.6 GROUNDWATER FLOW.....                                                    | 8           |
| 3.0 CONCEPTUAL HYDROGEOLOGIC MODEL .....                                     | 9           |
| 4.0 GROUNDWATER FLOW MODEL.....                                              | 11          |
| 4.1 MODEL DOMAIN AND DISCRETIZATION .....                                    | 11          |
| 4.2 MODEL BOUNDARIES .....                                                   | 13          |
| 4.3 SIMULATION OF HYDROLOGIC FEATURES .....                                  | 13          |
| 4.3.1 Simulation of Hydrostratigraphic Units.....                            | 13          |
| 4.3.2 Simulation of Rivers and Creeks.....                                   | 15          |
| 4.3.3 Simulation of Precipitation and Recharge .....                         | 15          |
| 4.4 SIMULATION OF UNDERGROUND MINE WORKINGS .....                            | 16          |
| 4.5 SIMULATION OF PRE-HISTORICAL-MINING CONDITIONS .....                     | 18          |
| 4.6 SIMULATION OF HISTORICAL MINING .....                                    | 19          |
| 5.0 PREDICTIVE SIMULATIONS.....                                              | 22          |
| 5.1 PREDICTED INFLOWS TO THE MINE .....                                      | 22          |
| 5.2 PREDICTED GROUNDWATER DRAWDOWN DUE TO MINING ACTIVITIES.....             | 23          |
| 5.3 PREDICTED EFFECTS TO CREEKS NEAR THE MINE DUE TO MINING ACTIVITIES ..... | 24          |
| 5.4 SENSITIVITY ANALYSES.....                                                | 25          |
| 6.0 CONCLUSIONS AND RECOMMENDATIONS .....                                    | 28          |
| 7.0 REFERENCES .....                                                         | 30          |
| FIGURES                                                                      |             |
| TABLES                                                                       |             |
| APPENDICES                                                                   |             |

## **LIST OF FIGURES**

|             |                                                                                                              |
|-------------|--------------------------------------------------------------------------------------------------------------|
| Figure 1-1  | Locations of the Historical Mines, Mineral Rights Boundary, and Surface Features                             |
| Figure 2-1  | Regional Surface Geology and Cross Section                                                                   |
| Figure 2-2  | Geologic Setting at the Idaho-Maryland Mine                                                                  |
| Figure 2-3  | Spatial Extents of the Historical Mines                                                                      |
| Figure 2-4  | Well Yield versus Depth of Wells                                                                             |
| Figure 2-5  | Estimated Hydraulic Conductivities at Boreholes along the Depth                                              |
| Figure 2-6  | Locations of Domestic Wells, Streamflow Monitoring, and Historical Mine Shafts and Drains                    |
| Figure 2-7  | Topography and Boundary of Hydrologic Study Area                                                             |
| Figure 3-1  | Main Components of the Conceptual Hydrogeologic Model – Current Conditions                                   |
| Figure 3-2  | Main Components of the Conceptual Hydrogeologic Model – Future Mining                                        |
| Figure 4-1  | Model Discretization and Simulated Geologic Units in Model Layer 4                                           |
| Figure 4-2  | Simulated Geologic Units in Cross Section                                                                    |
| Figure 4-3  | Model Boundary Conditions                                                                                    |
| Figure 4-4  | Simulated and Measured Groundwater Levels under Pre-Historical-Mining Condition                              |
| Figure 4-5  | Simulated Groundwater Contours under Pre-Historical-Mining Condition                                         |
| Figure 4-6  | Simulated and Measured Flow Rates for the Historical Mines                                                   |
| Figure 4-7  | Simulated and Measured Water Levels at the Union Hill Mine and New Brunswick Mine                            |
| Figure 4-8  | Water Levels at Selected Domestic Wells and Shaft in the Mine Area                                           |
| Figure 4-9  | Simulated and Measured Groundwater Levels under Current Condition (as of 2019)                               |
| Figure 4-10 | Comparison of Hydraulic Conductivities in Model Simulation with Estimated Hydraulic Conductivity Values      |
| Figure 5-1  | Plan View and Cross-Section View of the Future Mine Plan                                                     |
| Figure 5-2  | Predicted Inflow Rates to the Mine Workings during Future Mining                                             |
| Figure 5-3  | Simulated Drawdown of Groundwater Levels under Current Condition Relative to Pre-Historical-Mining Condition |

- Figure 5-4 Simulated Drawdown of Groundwater Levels at the End of Future Mining Relative to 2019 Water Level
- Figure 5-5 Simulated 10-Foot Groundwater Drawdown Contours at Different Times Relative to 2019 Water Level
- Figure 5-6 Simulated 5-Foot Groundwater Drawdown Contours at Different Times Relative to 2019 Water Level
- Figure 5-7 Change of Baseflow Rates in the South Fork of Wolf Creek and Wolf Creek over the Life of the Mine
- Figure 5-8 Predicted Groundwater Inflows to the Mine Workings under Sensitivity Scenarios
- Figure 5-9 Simulated 5-Foot Groundwater Drawdown Contours for Sensitivity Scenarios at the End of Mining Relative to 2019 Water Level
- Figure 5-10 Plan View and Cross-Section View of the Potential Expansion of the Future Mine Plan
- Figure 5-11 Predicted Groundwater Inflows to the Mine Workings of the Potential Expansion of Future Mining
- Figure 5-12 Simulated 5-Foot Groundwater Drawdown Contour at the End of the Potential Expansion of Future Mining Relative to 2019 Water Level

## **LIST OF TABLES**

|           |                                                                         |
|-----------|-------------------------------------------------------------------------|
| Table 2-1 | Elevations, Mine Lives, and Measured Flow Rates of the Historical Mines |
| Table 2-2 | Information and Average Measured Water Levels at Domestic Wells         |
| Table 2-3 | Measured Streamflow Rates and Discharge Rate from NID Canal             |
| Table 2-4 | Elevations of Drains and Mine Water Levels Estimated in 2019            |
| Table 4-1 | Elevations and Thicknesses of Model Layers in the Mine Area             |
| Table 4-2 | Calibrated Hydraulic Properties of Geologic Units                       |

## LIST OF APPENDICES

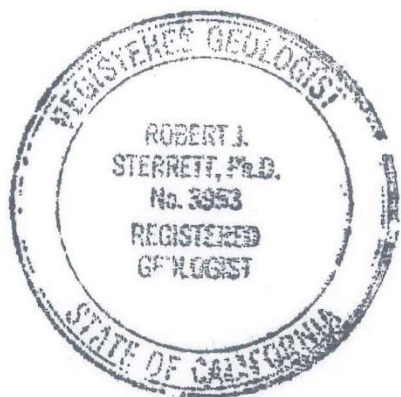
- A Introduction of *MINEDW*
- B Review of the *MINEDW* Groundwater Flow Modeling Code

## LIST OF ABBREVIATIONS

|                      |                                                                                    |
|----------------------|------------------------------------------------------------------------------------|
| 3-D                  | three-dimensional                                                                  |
| amsl                 | above mean sea level                                                               |
| bgs                  | below ground surface                                                               |
| cfs                  | cubic feet per second                                                              |
| ft                   | feet                                                                               |
| ft/day               | feet per day                                                                       |
| ft <sup>3</sup> /day | cubic feet per day                                                                 |
| gpm                  | gallons per minute                                                                 |
| HSA                  | hydrologic study area                                                              |
| $K$                  | hydraulic conductivity (L/t); the ability of a rock or soil unit to transmit water |
| $K_x$ and $K_y$      | horizontal hydraulic conductivity                                                  |
| $K_z$                | vertical hydraulic conductivity                                                    |
| LOM                  | life of the mine                                                                   |
| NID                  | Nevada Irrigation District                                                         |
| $S_s$                | specific storage                                                                   |
| $S_y$                | specific yield                                                                     |
| USGS                 | United States Geological Survey                                                    |

## CERTIFICATION

The work that is described in this report has been undertaken under the direction of the registered geologist whose stamp and signature appear below.

A handwritten signature in blue ink that reads "Robert J. Sterrett".

Robert J. Sterrett, Ph.D., R.G.  
California Registered Geologist #3953

## EXECUTIVE SUMMARY

Itasca Denver, Inc. (Itasca) prepared this report for Rise Grass Valley Inc. (Rise) to summarize the study related to groundwater flow modeling for the Idaho-Maryland Mine (the Mine). The main objectives of the groundwater flow model are to predict the following:

1. The inflow rates to the future mine workings based on the mine plan,
2. The potential effects of mining on groundwater levels, and
3. The potential reduction of baseflows of selected nearby creeks as the result of future mining.

The following tasks were conducted for the Mine:

1. Review and analyze available data;
2. Develop a conceptual hydrogeologic model based on the data analysis;
3. Construct a three-dimensional (3-D) groundwater flow model and calibrate the model to the available data;
4. Predict groundwater inflows to the underground mine workings, the drawdown of the water table, and potential reduction of baseflow of the key creeks due to pumping for mining; and
5. Perform sensitivity analyses of various input parameters to the model to assess their effects on the predicted inflow rates and drawdowns.

Based on the data analysis, Itasca developed a conceptual hydrogeologic model. The key hydrogeologic components and their relationships with future mining operations are summarized below:

1. Deep Groundwater Recharge: Because of the low hydraulic conductivities ( $K_s$ ) of the various rock units at the depths of future mining, the effect of recharge on the inflow rates to the deep mine workings is anticipated to be minor.
2. Geologic Setting: The main hydraulic parameter of the geologic units that controls the inflow rates to the mine workings is  $K$ . Because the  $K$  values decrease with depth, the inflow rates to the future mine workings are anticipated to be relatively low, given the size of the underground workings, as a result of mining in the low- $K$  rocks.

3. **Geologic Structures:** Past mining records and hydrogeologic investigations suggest that there are no permeable faults in the mining area and thus limited pathways for groundwater inflow.
4. **Mining:** Because the underground mining occurs in saturated rock, groundwater inflows to the mine workings will occur through groundwater seepage. The seepage to the mine workings in low-permeability rock can usually be managed by underground pumping.
5. **Regional Groundwater Flow:** Regional groundwater will be the main source of groundwater seepage into the Mine. Because of the low  $K$  of the rock units and the estimated low inflow rates to the mine workings (based upon the low  $K$  of the rock units), the effects of mining on regional groundwater flow are expected to be limited to the mining area.
6. **Surface Water:** The surface water within the mining area could provide recharge to the existing, shallow mine workings. Because the future mine workings are in deep, low- $K$  rock, the future contributions of surface water to mine inflows are estimated to be low.
7. **Seasonal Variation of Groundwater Inflow to Mine Workings:** Groundwater inflow rates to the historical Idaho-Brunswick Mine were reported to be low during the dry season and high during the rainy season. Itasca judges that the variations were likely due to surface-water inflows (surface-water runoff) through vertical workings (e.g., shafts). The seasonal variations of groundwater inflow to the mine workings are temporal and do not represent stable groundwater inflow conditions to future mining.

Using the hydrogeologic conceptual model and the available data, Itasca developed a 3-D finite-element numerical groundwater flow model of the Mine and the surrounding area. The model was calibrated to groundwater levels for the pre-historical-mining condition and during the historical mining operations. The model was further calibrated to the recovery of groundwater levels after the cessation of historical mining operations.

The calibrated model was used to predict the inflow rates to the future mine workings, the potential effects of mining on shallow groundwater levels, and the potential reduction of baseflows within selected creeks as the result of future mining. Sensitivity analyses were conducted to assess the sensitivity of predicted inflows and groundwater drawdowns to changes in values for the various input parameters that are used in the model. Such parameters include the  $K$  values of the key geologic units, the presence of faults, recharge, and potential change of mine plans.

Based on the analyses of the available data and the results of the groundwater flow model predictions, Itasca provides the following conclusions:

1. The groundwater flow model is reasonably calibrated to the measured inflow rates to the historical Idaho-Brunswick Mine, groundwater levels in the flooded Union Hill Mine and historical Idaho-Brunswick Mine, and baseflow rates at the South Fork of Wolf Creek and Wolf Creek. In addition, the calibrated model reasonably simulates groundwater levels in a variety of domestic wells, as well as the vertical hydraulic gradient from the shallow water-bearing zone to the historical mines.
2. The groundwater flow model predicts that the maximum and the stable mine-inflow rates are approximately 1,100 and 900 gallons per minute (gpm), respectively, based on the future mine plan that Rise provided, which is approximately 200 to 400 gpm in addition to the inflow rate of approximately 700 gpm to the historical Idaho-Brunswick Mine as measured in 1956. These predicted inflow rates are annual average rates.
3. The groundwater drawdown due to dewatering for future mining is largely confined to within the mineral rights boundary.
4. The reductions of the average baseflow rates in the South Fork of Wolf Creek and Wolf Creek are approximately 0.1 cubic feet per second (cfs) and 0.75 cfs, respectively, at the end of mining compared to the 2019 average baseflows.
5. The predicted inflow rates are not sensitive to the  $K$  values of the transition zone and faults. The transition zone is a zone that appears to have increased  $K$  values due to weathering and stress release but not as high of  $K$  as the shallower bedrock and alluvial units. The shallow units have increased  $K$  due to stress release as a result of erosion and weathering.
6. The recharge rate applied to the model has limited effect on the predicted inflow rate to future mining. But the recharge rate affects the extent of groundwater drawdown. Higher recharge would lead to a smaller area of drawdown.
7. The predicted inflow rates and groundwater drawdown are not sensitive to significant expansion of mining within the known mineralized system at depths greater than approximately 1,000 feet below ground surface.

Itasca has the following recommendations:

1. Rise should plan to collect hydrogeologic data according to the project stages. The key data are groundwater levels with depth and flow rates pumped from the Mine.
2. Prior to the dewatering of the Mine, monitoring wells and piezometers need to be installed for the measurement of water levels. The critical reason for the installation of piezometers

and monitoring wells prior to dewatering of the Mine is to measure the hydraulic responses over time at these monitoring points. As the Mine pumps groundwater from the mine workings, groundwater levels will decline in the surrounding rock, and the measurements of water levels in the wells/piezometers will document the groundwater-level changes.

3. The water-level data can be used to update the groundwater flow model to improve the confidence of the model.
4. It is expected that the actual mining areas will change from the modeled mining areas due to vein geometry and discoveries, which will only be known after extensive underground exploration is completed in the future. Itasca recommends that the groundwater flow model be updated periodically after dewatering commences. Updated modeling would incorporate changes to the long-term mining plan, data from monitoring wells, and measured pumping rates.

## 1.0 INTRODUCTION

Itasca Denver, Inc. (Itasca) prepared this report for Rise Grass Valley Inc. (Rise) to summarize the study related to groundwater flow modeling for the Idaho-Maryland Mine (the Mine). The main objectives of the groundwater flow model are to predict the following:

1. The inflow rates to the future mine workings based on the mine plan provided by Rise,
2. The potential effects of mining on groundwater levels, and
3. The potential reductions of baseflows of selected nearby creeks as the result of future mining.

The Mine is located in Nevada County, California, and is close to the city limits of the city of Grass Valley. The surface-land property of the Mine encompasses approximately 175 acres with two industrial sites for future mining: Centennial industrial site and Brunswick industrial site, as shown in Figure 1-1. Within the mineral rights boundary (as shown in Figure 1-1), there are five historical mines: Union Hill, Old Idaho, Old Brunswick, New Idaho, and New Brunswick. The maximum depth of the historical mines is approximately 3,300 feet (ft) below ground surface (bgs), or -530 ft above mean sea level (amsl). The historical mining produced a total of 2,414,000 ounces of gold from 1866 to 1955 (Rise 2019a). These mine workings are currently flooded by groundwater.

The output of the groundwater flow model will be used as input for the preparation of a use permit application for commencing full-scale underground mining activities (Rise 2019a). The tasks completed by Itasca include the following:

1. Review and analyze available data;
2. Develop a conceptual hydrogeologic model based on the data analysis;
3. Construct a three-dimensional (3-D) groundwater flow model and calibrate the model to the available data;
4. Predict groundwater inflows to the underground mine workings, the drawdowns of the water table, and potential reductions in baseflows of the key creeks due to mining; and

5. Perform sensitivity analyses of selected input parameters to the model to assess their effects on the calculated inflow rates and groundwater drawdowns.

## **2.0 GENERAL HYDROGEOLOGIC CONDITIONS**

Itasca received previous investigation reports on areas in or near the Mine area, which included surface geology, hydrogeologic investigations, operational reports of historical mines, and groundwater well completion information. The relevant information is summarized in this section.

### **2.1 CLIMATE AND GROUNDWATER RECHARGE**

The climate of the Mine area is temperate with moderate precipitation. Precipitation data have been recorded from 1893 to September 1966 for the Grass Valley 2 station based on data from the Western Regional Climate Center. The average annual precipitation (both as rain and snow) is approximately 53 inches, as reported on the Western Regional Climate Center website (<http://wrcc.dri.edu/Climate>) for Grass Valley, CA. Groundwater recharge in the area was estimated as 10 to 12 inches per year (Kopania 2019, pers. comm.).

### **2.2 GEOLOGIC SETTING AND STRUCTURES**

Based on the geologic map of the Chico quadrangle, California (Saucedo and Wagner 1992), as shown in Figure 2-1, the Mine site lies on the Sierra Nevada and is underlain by mafic intrusive and metamorphic rocks of Paleozoic and Mesozoic ages; metavolcanics, epiclastic, and ultramafic rocks of Jurassic age; granitic rocks of Jurassic and Cretaceous age; pyroclastic rocks of Tertiary age; and alluvium of Quaternary age (Clark 1976; Page et al. 1984). The granitic (igneous origin) and metamorphic rocks are hard and dense and yield little water to wells except when a wellbore intersects fractures or weathered portions of these geologic units. (Page et al. 1984). It should be noted that Figure 2-1 does not have a high graphic resolution because it is based on a figure from Saucedo and Wagner (1992). However, Figure 2-1 is sufficient for illustration purposes in this report.

Based on historical geological mapping of the underground mine workings and core drilling completed by Rise, the historical Brunswick and Union Hill mining areas occur within meta-andesite rocks (termed as “Brunswick Porphyrite Block”), and the historical Idaho and nearby Eureka and

Maryland Mines are mostly located within mafic intrusive and metamorphic rocks, including gabbro and serpentinite (Rise 2019a). In addition, fine-grained meta-sediments (slates, argillite) of the Mariposa Formation and Tertiary-aged andesite volcanic rocks are present to the east and southwest of the Brunswick Porphyry Block. The Tertiary-aged andesite deposits are typically less than a few hundred feet thick, forming a relatively thin mantle that obscures the underlying bedrock geology and faulting (Rise 2019a). These geologic units in the Mine area are presented in Figure 2-2.

As the cross sections in Figures 2-1 and 2-2 show, the geologic units were folded along sub-vertical directions. Both the volcanic and metamorphic rocks are more weathered and fractured in the shallow portion and competent below the weathered zone (Clark 1976; Todd 2007).

In the Mine area, geologic structures are poorly exposed on the surface but were intersected in the underground workings and drill holes (Rise 2019b, pers. comm.). As shown in Figure 2-2, two main faults, Fault 6-3 and the Morehouse Fault, generally have a strike direction of northwest-southeast. Both faults dip to the northeast, with Fault 6-3 dipping 70 degrees northeast and the Morehouse Fault dipping 40 degrees northeast (Rise 2019b, pers. comm.). Another fault, identified as the Idaho fault zone, generally follows the northern boundary of the Brunswick Porphyry Block (Rise 2019a). The Idaho fault zone was not delineated in the 3-D geologic model by Rise. The Idaho fault system is coincident with the mined Idaho veins that are incorporated into the model. On the left-hand side of Figure 2-2, the Morehouse Fault and Fault 6-3 are projected to the land surface; however, in cross section, these faults may not extend to the surface.

### **2.3 DEWATERING RATES FROM THE HISTORICAL MINES**

The Mine area had been mined intermittently from 1863 to 1956 under various operations. The elevations and estimated mine lives, along with the measured flow rates for the historical mines, are presented in Table 2-1. The spatial extents (both horizontal and vertical) of the historical mines are shown in Figure 2-3.

The Old Idaho Mine (Idaho #1) was mined from 1863 to 1914 to a depth of approximately 2,200 ft bgs, or 317 ft amsl. After the mine drifts reached the bottom of the Old Idaho Mine, the average groundwater pumping rate from the mine was approximately 290 gallons per minute (gpm), based on the pumping-rate record. The flow rate was 250 gpm for 10 months of the year and 500 gpm for the remaining two months during the rainy season (Mines and Mineral Resources of Nevada County 1920). This variation in pumping rates shows that surface-water inflows through shafts or other workings, along with shallow recharge through the shallow fractured rock units, is temporal.

The Old Brunswick Mine was mined intermittently between 1880 and 1915 (Rise 2019a). The only available estimated pumping rate was in 1933, when the mine was flooded. Therefore, the pumping rate in 1933 did not represent the average groundwater inflow rate to the mine during operation.

The New Brunswick Mine and the New Idaho Mine were expansions of the Old Brunswick and Old Idaho Mines, respectively, and were connected to the old mines. These two mines continued operation until 1956. The New Brunswick Mine drifts reached a bottom elevation of -530 ft amsl, and the New Idaho Mine had a bottom elevation of approximately -400 ft amsl. The two mines were connected in 1941 at the B2300 ft level (500 ft amsl). James Askew Associates (1991) reported that the average groundwater inflow rate to these historical mines was approximately 680 gpm, ranging from a low inflow rate of 500 gpm during the dry season to a high inflow rate of 1,200 gpm at the end of the rainy season. As mentioned above, these variations are more likely due to surface-water inflows through vertical workings along with shallow recharge through the higher hydraulic conductivity (K) surficial geologic materials.

South of the historical Idaho-Brunswick Mine, there was a small mine named the Union Hill Mine, which was closed in 1918 and has been flooded since then. The Union Hill Mine is not connected to the historical Idaho-Brunswick Mine but is in close proximity to the Brunswick Mine. In 1956, the water level at the Union Hill Mine was reported to be within 20 ft of the top of the shaft (Clark 2005), which suggested that the complete dewatering of the adjacent mine workings (historical Idaho-

Brunswick Mine) resulted in no more than 20 ft of water-level decline in the Union Hill Mine. The water level in the Union Hill Mine would not be higher than the surface elevation of the shaft. The top of the Union Hill Mine is at approximately 2,666 ft amsl with a measured water level of approximately 2,665 ft amsl in 2019 (Kopania 2019, pers. comm.). At the same time (as of 2019), the flooded New Brunswick shaft had a water level of approximately 2,497 ft amsl. The water level in the Union Hill shaft was approximately 160 ft higher than the water level in the historical Idaho-Brunswick Mine (Vector 1992), suggesting that there is a poor hydraulic connection between these two mines.

## **2.4 HYDRAULIC CONDUCTIVITIES AND GROUNDWATER LEVELS IN DOMESTIC WELLS**

The well completion reports provided well yields for the domestic wells in the vicinity of the Mine property. As illustrated in Figure 2-4, the yield of the wells generally decreases with depth, mainly as the result of decreasing fracture intensity with depth. In analyzing the yield of groundwater wells in southwestern Nevada County, Page et al. (1984) concluded that the fractured rocks generally occur above a depth of 215 ft bgs. Similarly, in the vicinity of the Mine property, the domestic wells with a depth shallower than 215 ft tended to produce more water, while the deeper wells generally produced less than 5 gpm (Vector 1992). Fractures tend to close with depth due to vertical loading stresses.

Figure 2-5 shows the estimated  $K$  with depth. The  $K$  values in Figure 2-5 demonstrate a decreasing trend with depth (Todd 2007; Kopania 2019, pers. comm.). Figure 2-5a is based on well completion reports from 334 wells that are within an area of 18 square miles in the vicinity of the Idaho-Maryland Mine. Figure 2-5b is derived from well completion reports near the Rise mineral rights boundary based on the estimated transmissivity values from Kopania (2019, pers. comm.) and the saturated thickness of each well. Though the units of  $K$  differ in these two figures (a  $K$  value of 1 ft/day is equal to a  $K$  value of 7.48 gpd/ft<sup>2</sup>), both figures show the decreasing trend with depth and the same order of magnitude of  $K$  values.

There are no estimated  $K$  values for the faults. Rise (2019b, pers. comm.) indicated that the faults did not show significant fractured zones, as observed in cores that were obtained by drilling and in historic mapping and reports (Bateman 1948), and may be less permeable than the surrounding rocks (Vector 1992; Todd 2007). The Idaho, 6-3, and Morehouse Faults are premineralized faults (Vector 1992; Todd 2007).

The relevant information from wells with groundwater-level measurements in the Mine area is summarized in Table 2-2. The wells that are listed under the “Todd 2007 Well ID” column in Table 2-2 have water-level measurements periodically from 1994 to 2007. The rest of the wells only have measured water levels during drilling or after well completion. The locations of wells with coordinates are presented in Figure 2-6. Analyses of water levels in the domestic wells suggested that shallower wells had higher water levels than the deeper wells (Todd 2007). In addition, the measured water levels in domestic wells near the historical Idaho-Brunswick Mine are more than 90 ft higher than the water level in the mine void (Sierra-Pacific 1995; Todd 2007; Rise 2019b, pers. comm.).

The measured water levels in Table 2-2 mostly reflect water levels measured more than 24 years after the cessation of historical mining operations. Only the water levels from those wells located outside of the historical mining area were used in the pre-historical-mining model calibration, as labeled in Table 2-2. Model calibrations will be discussed in Section 4.0.

## **2.5 BASEFLOW RATES IN THE CREEKS**

In the Mine area, streamflow rates were measured in April 2019 and August 2019 at the discharge location of the South Fork of Wolf Creek and at the Centennial Bridge culvert of Wolf Creek (or Wolf Creek), as shown in Figure 2-6. In addition to the natural creeks, there is the Nevada Irrigation District (NID) Canal in the mine area. The discharge rate from the NID Canal to Wolf Creek was available for the period of January 2018 to April 2019. Measured streamflow rates and the discharge rate from the NID Canal are listed in Table 2-3.

In August 2019, the measured flow rate in the South Fork of Wolf Creek at the discharge location was approximately 1.0 cubic foot per second (cfs). This flow rate is lower than the measured flow rate of 6.5 cfs in April 2019 because the April measured value may include the runoff contribution from snowmelt, rainfall, and overland flow. Because the baseflow is defined as the discharge from the groundwater system, the lower flow rate is considered to be closer to the groundwater discharge. Therefore, the baseflow rate in the South Fork of Wolf Creek is assumed to be approximately 1 cfs.

Measured streamflow rates in Wolf Creek and the NID Canal are only available in April 2019. The difference between the flow rate from the creek and that from the NID Canal (the measured flow rate in Wolf Creek deducts the flow rate released from the NID Canal) is 31.9 cfs. Because April is considered part of the snowmelt/rainy season, the baseflow of Wolf Creek should be lower than 31.9 cfs. Thus, without additional data available, Itasca assumed that the baseflow rate is lower than 31 cfs (Kopania 2019, pers. comm.).

## **2.6 GROUNDWATER FLOW**

The groundwater flow direction within the hydrologic study area (HSA) generally follows the topography from northeast to southwest (Figure 2-7). The HSA is described in Section 4.0. Due to the presence of the current flooded mine void, groundwater near the historical mine area flows toward the Mine area and discharges through the draining points in the west. The entire mine void is connected and has nearly the same water level, which is close to the elevation of the drains (e.g., East Eureka Shaft Drain, Eureka Drain) located at the west of the historical mine area. The locations of the historical mine shafts and drains are shown in Figure 2-6. Table 2-4 includes the estimated drain elevations in 2019 based on the LIDAR data and topographic map (Kopania 2019, pers. comm.).

### **3.0 CONCEPTUAL HYDROGEOLOGIC MODEL**

This section describes the main components of the conceptual hydrogeologic model that may affect the inflow rates to the future mine workings as well as the potential effects on groundwater levels. Because the underground mine workings are flooded under the current condition and will be pumped dry prior to the start of mining, it is beneficial to present the conceptual models under the current condition and the future mining condition, as shown in Figures 3-1 and 3-2, respectively. The key hydrologic components that may affect the inflow rates to the mine workings and have an effect on groundwater and surface-water resources at the conceptual level are the following:

1. Deep Groundwater Recharge: Because of the low  $K$ s of the various rock units at the depths of future mining, the effect of recharge on the inflow rates to the deep mine workings is anticipated to be minor.
2. Geologic Setting: The main hydraulic parameter of the geologic units that controls the inflow rates to the mine workings is  $K$ . Because the  $K$  values decrease with depth, the inflow rates to the future mine workings are anticipated to be relatively low, given the size of the underground workings, as a result of mining in the low- $K$  rocks.
3. Geologic Structures: Past mining records and hydrogeologic investigations suggest that there are no permeable faults in the mining area and thus limited pathways for groundwater inflow.
4. Mining: Because the underground mining occurs in saturated rock, groundwater inflows to the mine workings will occur through groundwater seepage. The seepage to the mine workings in low-permeability rock can usually be managed by underground pumping.
5. Regional Groundwater Flow: Regional groundwater will be the main source of groundwater seepage into the Mine. Because of the low  $K$  of the rock units and the estimated low inflow rates to the mine workings (based upon the low  $K$  of the rock units), the effects of mining on regional groundwater flow are expected to be limited to the mining area.
6. Surface Water: The surface water within the mining area could provide recharge to the existing, shallow mine workings. Because the future mine workings are in deep, low- $K$  rock, the future contributions of surface water to mine inflows are estimated to be low.
7. Seasonal Variation of Groundwater Inflow to Mine Workings: Groundwater inflow rates to the historical Idaho-Brunswick Mine were reported to be low during the dry season and high during the rainy season. Itasca judges that the variations were likely due to surface-water inflows (surface-water runoff) through vertical workings (e.g., shafts). The seasonal

variations of groundwater inflow to the mine workings are temporal and do not represent stable groundwater inflow conditions to future mining.

Figure 3-1 shows the schematic illustration of the conceptual hydrogeologic model of the Mine area (from northwest to southeast; the location is shown in Figure 2-3). The water level in the mine workings is lower than the water table of the shallow groundwater system as of the current condition (2019). With the given data set, it appears that the hydraulic connection between the shallow groundwater and the mine workings is relatively poor.

Figure 3-2 shows the conceptual groundwater flow conditions for future mining. Similar to Figure 3-1, inflows from the shallow groundwater system and regional groundwater to different mine workings will occur. The inflow rates will be controlled by the  $K_s$  of the various rock units. Water within the Mine will be removed by in-mine pumps to maintain dry working conditions.

## **4.0 GROUNDWATER FLOW MODEL**

The groundwater flow model that was constructed for this investigation utilizes the numerical code *MINEDW*, which was developed by Itasca (2012) to solve 3-D groundwater flow problems with an unconfined (or phreatic) surface using the finite-element method. *MINEDW* is a commercial software that was thoroughly reviewed by Sandia National Laboratories (Corbet et al. 1998) and is approved by the Nevada Division of Environmental Protection for use in permitting applications (NDEP 2018). *MINEDW* has been used successfully at more than 100 mine sites located throughout the world and in diverse hydrogeologic and climatic conditions. The code has been in use for approximately 30 years, and its predictions have been validated by field data collected over many years. Additional information regarding the code *MINEDW* is contained in Appendices A and B.

### **4.1 MODEL DOMAIN AND DISCRETIZATION**

Figure 2-7 shows the HSA for the groundwater flow model that was used for this project and forms the boundaries of the model. The HSA encompasses watershed boundaries and creeks. The primary reasons for selecting the boundaries of the HSA are as follows:

1. To link, if possible, the model boundaries to the natural hydrologic boundaries, such as watershed boundaries and rivers; and
2. To ensure that the model domain is sufficiently large in order to minimize potential artificial boundary effects on the numerical simulations and predictions. Stresses (water-level drawdowns), such as pumping from a mine, should not reach the boundaries of the model. Because the rock units have low permeability in this project, Itasca does not anticipate that the hydraulic effects induced by mining operations will reach the model boundaries.

The eastern boundary of the HSA is a watershed divide (Sierra crest), while the other three sides are rivers/creeks. The western boundary is the Feather River, the northern boundary is the North Yuba River and South Fork Feather River, and the southern boundary is the Rubicon River and Raccoon Creek. The dimensions of the HSA are approximately 40 miles from north to south and 60 miles from

east to west. The general topography, location of the Mine's mineral rights boundary, extent of the model domain, and creeks/rivers are shown in Figure 2-7.

The topographic elevations within the HSA are based on LIDAR data and United States Geological Survey (USGS) elevation data that were provided by Rise. The topographic elevations range from 24 to 8,595 ft amsl within the model domain, with the lowest elevation at the southwest corner and the highest at the southeast corner. The bottom elevation of the model in the Mine area is -3,445 ft amsl, which is approximately 1,200 ft below the future mine workings (Rise's future mine plan).

The groundwater model domain encompasses approximately 2,810 square miles, and the finite-element grid contains 324,448 nodes and 626,386 elements within 31 layers (Figures 4-1 and 4-2). The element grid is finely discretized in the Mine area to achieve the following objectives:

1. To refine the numerical solutions of hydraulic heads and flows near the area of flow convergence (for example, in the area of the Mine); and
2. To more accurately represent the detailed geologic settings of the mining area, the underground mine workings, and the future mine plan.

In addition, the model element grids have also been discretized to represent major rivers and creeks, geologic structures (e.g., faults), domestic wells, and the major features of the historical mines and mine plan (i.e., the shafts and drifts). As shown in Figure 4-1, in the immediate mining area, the minimal horizontal length of an element is about 20 to 25 ft. Within the area where detailed information for the mineral rights boundary (which includes the historical mine, surface land boundary, wells, and nearby creeks and canals) is available, the horizontal length of the element is approximately 50 ft. Within the local watershed area, the element size is up to 500 ft horizontally. Outside of these three refined areas, the element size is as large as 5,000 ft.

Figure 4-2 displays the layout of the model layers in the Mine area in a cross-sectional view. The elevations of the model layers were generally set flat, based on the elevations of drifts/raises from

both the historical mines and the future mine plan. In total, there are 31 model layers, with the historical and future mine workings mainly being simulated from model layers 4 to 28. Outside of the Mine area, the elevations of the layers follow the variations of topography. The upper seven layers in the areas with higher ground-surface elevations have greater thickness than the areas with lower ground-surface elevations. The thickness and top elevation for each layer in the Mine area are listed in Table 4-1. The bottom three layers are assigned to represent the deep rock units below the future mine zone. These three thick layers were used to minimize the boundary effects from the no-flow model boundary condition assigned to the model bottom.

## **4.2 MODEL BOUNDARIES**

The boundary conditions and assigned specified-head values are presented in Figure 4-3. Model boundaries along the watersheds to the east (primarily the crest of the Sierra Nevada) were assumed to be no-flow boundary conditions. The nodes that are associated with the rivers located at the western (Feather River), southern (Rubicon River and Raccoon Creek), and northern (North Yuba River and South Fork Feather River) boundaries of the model were assigned with a specified-head (also referred to as constant-head) boundary condition that reflects the elevation of the river at that location. The constant-head elevations of the nodes along the Rubicon River and North Yuba River to the east (high-topographic-elevation area) were assigned to be lower than the river elevations based on the model calibration because the rivers at these high-topographic-elevation areas are most likely above the water table.

## **4.3 SIMULATION OF HYDROLOGIC FEATURES**

### **4.3.1 Simulation of Hydrostratigraphic Units**

In the finite-element method, hydraulic properties are assigned to the elements, and hydraulic heads and fluxes are associated with nodes; therefore, every element in the model was assigned to a hydrogeologic zone, as depicted in Figure 4-1 for Layer 4 (upper bedrock units) of the model. The top elevation of this layer is approximately 2,600 ft amsl in the Mine area. Each hydrogeologic zone

is assigned with horizontal ( $K_x$  and  $K_y$ , based on  $x$  and  $y$  axes) and vertical ( $K_z$ ;  $z$  axis) hydraulic conductivities, specific storage ( $S_s$ ), and specific yield ( $S_y$ ).  $S_y$  is only utilized when the water table is located within the element.

Itasca incorporated 103 hydrogeologic zones into the model; the assigned hydraulic properties after the model calibration are summarized in Table 4-2. Based on the model calibration, all of the geologic units were assigned with an anisotropy ratio (i.e., a  $K_x/K_z$  value) of 10. The description of the model calibration is provided in Sections 4-5 and 4-6.

As discussed in Section 2.4, the  $K$  values of the geologic units decrease with depth. Vertically, six main sub-units were assigned in the model for each geologic unit to simulate the decrease of the  $K$  values along the depth.

1. Fractured rocks – from the ground surface to 215 ft bgs;
2. Transition zone – from 215 to 300 ft bgs;
3. Upper bedrock – from 300 to 2,000 ft bgs;
4. Middle bedrock – from 2,000 to 4,000 ft bgs;
5. Lower bedrock – from 4,000 to 5,000 ft bgs; and
6. Deep bedrock – lower than 5,000 ft bgs.

Page et al. (1984) suggested that the rocks, except the alluvium and weathered top units, in the study area have similar hydraulic properties. The initial  $K$  values of the upper three sub-units (depths are less than 2,000 ft bgs) and lower three sub-units were assigned with reference values for fractured and unfractured igneous and metamorphic rocks, respectively (Freeze and Cherry 1979).

Because there is no measured storativity value, and the groundwater inflow rate in the long term (stable condition) is generally not sensitive to the storativity of the tight, hard-rock water-bearing zones, the same storativity values ( $S_s$  and  $S_y$ ) were assigned to different bedrock units in the model;

a  $S_s$  of  $5 \times 10^{-6} \text{ ft}^{-1}$  was assigned, and the  $S_y$  was 0.005 (Freeze and Cherry 1979). The alluvial unit and river-bed sediments were assigned with a  $S_s$  of  $5 \times 10^{-5} \text{ ft}^{-1}$  and a  $S_y$  of 0.05.

#### **4.3.2 Simulation of Rivers and Creeks**

In addition to the constant-head boundary representing the rivers along the model boundaries, all of the major rivers/creeks that are located within the HSA (Figure 4-3) were incorporated into the model and simulated in the stream-routing package within *MINEDW*. The elevations of riverbeds in the area were based on the LIDAR data or topographic elevations from the USGS via Rise. The stream-routing package simulates interactions between a routed river and an aquifer. The routed-river function uses Manning's equation to calculate the flow in an open channel. A given reach of the river is represented by a node and corresponding reach length. Each reach is connected to the next reach by sequencing the nodes from upstream to downstream. River-groundwater system interactions are simulated by comparing the head in the groundwater system to the head in the river over time and by transferring water across the riverbed accordingly (Itasca 2012). Besides riverbed elevations, the parameters for the stream-routing package also include riverbed  $K$  (based on the  $K$  values of the top hydrogeologic units in which streams are located), the length (calculated distance between model stream nodes) and width of the river/stream (assumed as 5 to 100 ft for the creeks and rivers roughly based on Google Earth measurements), and Manning's coefficient (0.02, a value for natural streams with an earth channel).

#### **4.3.3 Simulation of Precipitation and Recharge**

The long-term average precipitation for the Mine area was estimated to be 53 inches per year based on precipitation records summarized by the Western Regional Climate Center. Groundwater recharge was estimated to be 10 to 12 inches per year in the Grass Valley area (Kopania 2019, pers. comm.). In the HSA, the precipitation is high in the high-elevation areas to the east and low in the valley (west); however, due to the variation in geologic units and the depth of weathering, the proportion of the precipitation that recharges to the groundwater system is probably much higher to the west than that to the east, suggesting that the recharge is not directly proportional to the

precipitation. Therefore, in the groundwater flow model, a uniform rate of 12 inches per year was assigned to the entire model domain. The impact of precipitation on predicted inflows to future mining is discussed in Section 5.4.

The recharge to the groundwater system was applied to the first saturated node of the model. Though recharge does not occur over the entire year, Itasca simulated the recharge as a long-term average for the model simulations. Due to limited data available for calibration of seasonal variation, the semi-annual fluctuation (dry-wet seasons) of recharge was not incorporated into the model simulations.

#### **4.4 SIMULATION OF UNDERGROUND MINE WORKINGS**

The underground mine workings at the Mine include the historical Idaho-Brunswick Mine (including the Old Idaho, Old Brunswick, New Idaho, and New Brunswick Mines) and future mining. These workings comprise drifts, raises, and shafts. The extents are from the ground surface to a depth of 3,300 ft bgs. The vertical distance between levels is approximately 100 ft.

The historical mine workings were simulated using 9,344 drain nodes, and the future mining operation was simulated with 3,888 additional drain nodes. Drain nodes that were associated with the mine drifts and shafts remain numerically active until the end of mining. The starting times of the drain nodes were assigned gradually based on mine schedules and the elevations (from shallow to deep). Backfilling of the mined areas with cemented-paste backfill (CPB) was not simulated in the model. Based on Itasca's other project experience, the effect of backfilling using CPB will likely reduce the amount of seepage into the Mine. As such, Itasca's model could overestimate the amount of inflows and drawdowns.

Drain nodes were used to simulate the discharge of groundwater to the underground mine workings through the utilization of the following relationship:

$$Q = CL (H_s - H) \text{ if } H > H_s$$

and (1)

$$Q = 0 \text{ if } H \leq H_s$$

where:

$Q$  = groundwater discharge to the drain nodes [cubic feet per day (ft<sup>3</sup>/day)],

$H_s$  = specified elevation of a mine working node [ft],

$H$  = calculated hydraulic head [ft], and

$CL$  = the so-called leakance factor, assigned either an assumed value or one estimated from the following equation:

$$CL = \frac{f \cdot K \cdot D_2 \cdot D_3}{D_1} \quad (2)$$

where:

$K$  = hydraulic conductivity of the drain node material [feet per day (ft/day)],

$D_1, D_2, D_3$  = generic dimensions related to the size of the individual element to which any particular drain is associated [ft], and

$f$  = a factor that accounts for the effect of non-Darcian flow, the actual size of the excavation relative to the grid size, and the shape of the excavation.

The model simulated the historical Idaho-Brunswick Mine from the top to the bottom of the mine workings with the following mining-operational schedules:

- Old Idaho: 1863–1914
- Old Brunswick: 1880–1915
- New Brunswick: 1933–1956
- New Idaho: 1919–1956

The schedule was assumed based on the general mine sequence for the purposes of model calibration (Table 2-1). It should be noted that the schedule does not affect simulated groundwater inflows to the mine workings because the model simulation was focused on matching the inflow rates to the historical mines near the end of mining (e.g., flow rates to the Old Idaho Mine in 1919 and to the Idaho-Brunswick Mine in 1956), when the entire mines were near fully dewatered.

The horizontal and vertical extents of these historical mines are shown in Figure 2-3. Over the entire simulation period of the historical mining, the flooded Union Hill Mine area was simulated as a special geologic unit with high  $K$  (8,000 ft/day) and high porosity (50%). The assumed porosity value was based on the estimation of the mine void relative to the model element size in the Mine area. For example, the size of model elements is generally from 20 to 25 ft in the Mine area, while the mine workings had a width of approximately 10 ft; then an assumed porosity of 50% would normalize the ratio of the mine void relative to the size of the model elements with the consideration of mine-working connections.

#### **4.5 SIMULATION OF PRE-HISTORICAL-MINING CONDITIONS**

No groundwater levels are available for the model calibration of pre-historical-mining groundwater conditions. Itasca assumed that current water levels outside of the Mine area are close to those of the pre-historical-mining condition after more than 60 years of recovery. This assumption is supported by the available hydrographs from domestic wells (Todd 2007), which show that groundwater levels were generally stable from 1994 to 2007 with seasonal variations. The simulation of pre-historical-mining groundwater conditions was completed by calibrating the model to the observed water levels from the selected wells in Table 2-2. The model calibration focused on the wells with hydrographs (Todd 2007) because these wells were considered to have more reliable groundwater levels than the first water hits or reported water levels during drilling. Figure 4-4 shows the simulated and measured groundwater levels. The comparison between the simulated and measured hydraulic heads (groundwater levels) of the wells with hydrographs (blue squares) suggests that the simulated hydraulic heads reasonably agree with the measured hydraulic heads.

The simulated water levels deviate at some wells whose water levels were the first water hits measured during drilling or after well installation. For example, wells W76 (the very right dot in Figure 4-4) and W77 were in the same location; the first water hit of well W76 was 2,952 ft amsl, but the static water level for well W77 was 2,739 ft amsl, more than 210 ft lower. On the other hand, the static water level at well W70 of 2,769 ft amsl was 140 ft higher than its first water hit during drilling (2,629 ft amsl). These significant differences between the first-hit and static water levels at the same locations suggested that some of the reported water levels during drilling may not represent stable water levels of the water-bearing zone. Therefore, it is not possible for the model to match all the water levels from the first water hit.

The contours (500-ft contour interval) of the simulated water table are shown in Figure 4-5 in plan view. Water-table contours in this figure show that the shallow groundwater flow direction is toward the west/southwest, which is consistent with field observations and the conceptual model.

The baseflow rates at the South Fork of Wolf Creek and Wolf Creek were calibrated to the values that are summarized in Section 2.5. The simulated baseflow rates for the South Fork of Wolf Creek and Wolf Creek are 1.0 cfs and 21.9 cfs, respectively. The simulated baseflow rate for Wolf Creek is lower than the measured value because the measured value was obtained in April and thus may include surface-water runoff due to precipitation.

#### **4.6 SIMULATION OF HISTORICAL MINING**

Using the simulated groundwater levels from the pre-historical-mining simulation as the initial groundwater condition, Itasca conducted transient model calibrations by matching the change of groundwater levels at the Union Hill Mine and groundwater inflows to the historical mines. The simulations were conducted for the following two periods:

1. Mining Period: from 1918, when the Union Hill Mine ceased operation, to 1956, when the New Idaho and New Brunswick Mines ended operation; and
2. Recovery Period: from 1957 to 2019, during which the historical mines were flooded.

Figure 4-6 shows the simulated groundwater flow rates in comparison with the measured inflow rates to both the Old Idaho Mine (1919) and the Idaho-Brunswick Mine (1956). The simulated values are close to the average of the measured values and within the ranges of measured values. It should be noted that the reported high inflow rates were for the rainy season, which likely included the surface-water runoff into the mines.

In the recovery period, the simulated groundwater levels from the end of the mining period were used as the initial groundwater levels for the model simulation of the recovery of the groundwater system from 1957 to 2019. The historical mine openings were simulated with a zone with high  $K$  (8,000 ft/day) and high porosity (50%).

The simulated water levels in comparison with the limited measured water levels at both the Union Hill Mine and the New Brunswick Mine are shown in Figure 4-7. It should be noted that the assumed start date and actual excavation of different mines may not be accurate in the model; however, this minor difference in the mining schedule will not affect the model calibration result due to the long duration of mining activities and the long time period for groundwater recovery (since at least 1957). During the operation of the historical mines, the measured water level in the Union Hill Mine declined less than 20 ft to approximately 2,646 ft amsl (Clark 2005) when the Brunswick Mine was at the complete dewatering stage at a depth of approximately 1,500 ft below the measured water level in the Union Hill Mine. Such a large water-level difference could only be simulated by assigning the slate unit near the Morehouse Fault and the Union Hill Mine with a relatively smaller  $K$  value than the surrounding volcanic rocks based on the model calibration. Within the mineral rights boundary, the slate unit was only found in the Union Hill Mine area (Rise 2020, pers. comm.). Figure 4-7 shows that the model reasonably replicated the measured water levels at the mines during both the mining (one data point in 1956) and since the year 2003, when recovery had occurred.

As discussed in the previous sections, measured groundwater levels from the domestic wells are not available since 2007. However, it is reasonable to assume that these groundwater levels are

somewhat stable with the exception of seasonal fluctuations, as no major pumping (stresses) has occurred since 2007. The simulated water levels at the end of the recovery period were compared to the ranges of measured water levels in these wells from 1994 to 2007 (Todd 2007), as shown in Figure 4-8. The locations of the wells in Figure 4-8 are highlighted in Figure 2-6. The comparison between simulated and measured groundwater levels is shown in Figure 4-9, which shows that the simulated hydraulic heads in 2019 reasonably agree with the measured groundwater levels representing the recovered water levels (Table 2-2) after the cessation of the historical mining operations. Also presented in Figure 4-8 is the simulated water level and measured water level at the New Brunswick shaft, which represents the water level of the flooded mine. The following observations are made from Figure 4-8:

1. The simulated groundwater levels are within the ranges of measured water levels;
2. The simulated mine water level is essentially the same as the measured water level; and
3. The water levels in domestic wells are generally higher than the water level of the New Brunswick shaft. Because the underground mine workings are connected, the water level in the New Brunswick shaft is probably the same as in the underground workings.

The  $K$  values derived from the groundwater flow model calibration are summarized in Table 4-2. Figure 4-10 shows that the simulated horizontal  $K$  values of different geologic units are within the ranges of the estimated  $K$  values and literature values.

## **5.0 PREDICTIVE SIMULATIONS**

The predictive numerical simulations were conducted to assess the potential inflows to the mine workings, the effect on nearby domestic wells, and the potential effects on the creeks in the Mine area during mine development and production between the assumed years of 2020 and 2045 (Year 1 to Year 25), which is the current mine plan. The footprint of the mine workings is shown in Figure 5-1 for every 5 years of the 25-year mining plan.

### **5.1 PREDICTED INFLOWS TO THE MINE**

The simulation of future mining was assumed to start with the initial condition of when the underground mine workings were pumped dry, which would be similar to the hydraulic condition in 1956, when the historical Idaho-Brunswick Mine operation ended. Therefore, the simulated groundwater levels in 1956 were used as the initial condition for the predictive numerical model simulations. The average recharge used in the model calibrations was also assigned in the predictive model simulation. The pumping of existing mine-void water was not simulated with the model for the following reasons:

1. It can be better calculated using the analytical solution (volume/pumping rate = time to deplete current mine water); and
2. The groundwater flow model is only designed to simulate the groundwater flow through porous media based on Darcy's law, not the pipe flow in the mine workings during the dewatering of the flooded mine workings.

Using the calibrated groundwater flow model, Itasca simulated the future mine plan as drain nodes to predict the inflow rates to the future mine workings. The predicted inflow rates in Figure 5-2 suggest the following:

1. Total inflow to the entire Mine will reach a maximum value of approximately 1,100 gpm based on the future mine plan.
2. The stable predicted inflow rate is approximately 900 gpm.

3. The future mining will induce about 200 to 400 gpm of inflow in addition to that encountered during the historical mining operation, when the inflow rate was approximately 700 gpm to the historical Idaho-Brunswick Mine in 1956.

Figure 5-2 shows the instantaneous increase (or spike) of the predicted inflow rates. These “spikes” were the result of a combination of the following reasons:

1. The mining was simulated on a monthly interval instead of an hourly interval. Subsequently, all the drain nodes for the planned mined area of the respective month are numerically “turned on” instantaneously. This will numerically introduce the excessive release of groundwater from storage, which, in reality, would release gradually from the rock over the monthly interval.
2. The grid size of the model mesh, which is larger than the actual workings, may also result in a numerical effect.

The estimated stable flow rate of 900 gpm does not include seasonal increased flows that have been documented by Rise. As such, during the rainy season, total pumping would probably be in excess of 900 gpm, perhaps in the range of 1,400 to 1,500 gpm. This estimate is based on the observation that the rainy season flows would increase by approximately 500 gpm for the historical Idaho-Brunswick Mine. The additional pumping during the rainy season will have little effect on the average long-term predicted water levels, as the excess inflows are due to surface-water runoff and percolation.

## **5.2 PREDICTED GROUNDWATER DRAWDOWN DUE TO MINING ACTIVITIES**

Figure 5-3 shows the simulated drawdown of the water table under the current condition relative to the pre-historical-mining condition. The current condition is defined as the year 2019. As shown in Figure 5-3, because of the presence of the historical mine void, drawdown exists between the 2019 groundwater levels and pre-historical-mining water levels. Therefore, the assessment of the potential incremental effects on the groundwater levels should be relative to the 2019 water level, not the pre-historical-mining water levels.

Figure 5-4 shows the simulated drawdown of the groundwater levels by the end of future mining relative to the 2019 water levels. As shown in the figure, the drawdowns of the water table are generally within the mineral rights boundary. This is due to the low-*K* rocks where the deep mining will occur. One will note in this figure and in subsequent figures that the drawdown isopleths are contoured to 1-, 5-, and 10-ft intervals. The predicted contours are based upon the numerical groundwater flow model and the assumptions inherent in the model. Actual, in-field measured water levels may be different from the predicted water levels due to heterogeneities in the hydrogeologic system. The 10-ft drawdown isopleth has been widely used to predict a general area of hydrogeologic impact from mine dewatering and to recognize the uncertainties of groundwater flow modeling. The model is not designed to simulate seasonal or annual changes resulting from variations in groundwater recharge associated with variations in precipitation and groundwater recharge that would occur over the model simulation period. In addition, in many areas within the study area, changes in groundwater levels of less than 10 ft can be difficult to distinguish from natural seasonal and annual fluctuations in groundwater levels.

Figures 5-5 and 5-6 show the 10-ft and 5-ft drawdown extents, respectively, 10 years and 25 years after mining began relative to the 2019 water levels. Both figures illustrate that the extents of the 5-ft and 10-ft drawdown do not expand noticeably as the mining progresses. Again, this is mainly due to the low-*K* rocks where deep mining will occur.

### **5.3 PREDICTED EFFECTS TO CREEKS NEAR THE MINE DUE TO MINING ACTIVITIES**

The mining activities may lower the water table and may reduce the groundwater discharge to surface-water features such as creeks near the Mine. Figure 5-7 shows the predicted baseflow rates at the South Fork of Wolf Creek and Wolf Creek over the life of the mine (LOM). As shown in Figure 5-7, the baseflow rate in the South Fork of Wolf Creek is predicted to reduce by approximately 0.1 cfs at the end of future mining from the simulated current condition of 0.94 cfs (as of 2019). The baseflow in Wolf Creek is predicted to reduce by 0.75 cfs at the end of mining from the simulated flow rate of 21.9 cfs for the year 2019.

## 5.4 SENSITIVITY ANALYSES

Itasca conducted the following sensitivity analyses to assess the key parameters that would affect the inflow rates:

1. Scenario 1 – Increase the  $K$  values of the transition zones by 5 times;
2. Scenario 2 – Increase the  $K$  values of the faults (6-3 and Morehouse) by one order of magnitude (10 times);
3. Scenario 3 – Exclude the faults (6-3 and Morehouse) in the model;
4. Scenario 4 – Increase the recharge rate by 50% (18 inches per year); and
5. Scenario 5 – Extend the planned mining for an additional 40 years to mine additional ore.

Figure 5-8 shows the predicted potential inflow rates for Scenarios 1 through 4 in comparison with the Base-Case Scenario depicted in Figure 5-2. Figure 5-9 shows the extent of the 5-ft drawdown contour lines relative to the Base-Case Scenario for Scenarios 1 through 4. The following observations can be made from these figures:

1. In Scenario 1, the predicted stable total groundwater inflow to the mine workings would be approximately 970 gpm, which is approximately 8% higher than the predicted 900 gpm for the Base-Case Scenario. Therefore, the predicted inflow rate is not very sensitive to the  $K$  value of the transition zones because the mining occurs in the low- $K$  rock that is approximately 2,000 ft below the transition zones. The change of 5-foot drawdown extent is within 1,000 ft relative to the Base-Case Scenario.
2. Scenario 2 shows that increasing  $K$  values of the two faults by 10 times will increase the stable inflow rate to 1,100 gpm, which is approximately 20% higher than the inflow rate of the Base-Case Scenario. It should be noted that the lateral extents of the faults are limited to the mining area in the model. If the faults were extended through the entire model domain, the simulated inflow rates would be more sensitive to the  $K$  values of the faults than those presented in Figure 5-8. However, past mining and exploration operations did not encounter permeable faults. Similar changes of the 5-ft drawdown contour extent to those of Scenario 1 are observed for this scenario.
3. Scenario 3 shows that the simulated inflow rate will increase by approximately 6% to approximately 960 gpm without the inclusion of the faults. The increase is due to the increased  $K$  value in the upper layers (weathered rock, transition zone, and upper bedrock)

in the areas where the two faults are located. Figure 5-9 shows the effect of the exclusion of the faults on the extent of the 5-ft drawdown isopleth. The isopleth is within 800 ft of the Base-Case Scenario.

4. Scenario 4 shows that the simulated groundwater inflows to the mine workings will increase by approximately 3% to 925 gpm if the recharge rate in the model domain is increased by 50%. The extent of the 5-ft drawdown is much smaller than in the Base-Case Scenario by as much as 4,000 ft. The relatively low *K* of the deep bedrock limits the downward flow; recharge mainly affects the shallow groundwater table. The increase of recharge rate compensates for the drawdown of the water table due to the dewatering of the Mine and thus leads to smaller drawdown areas.

In Scenario 5, the groundwater flow model simulated an additional 40 years of mining, which accounts for the expansion of the mine workings. The additional mine plan is shown as “Potential Expansion of the Future Mine Plan” in Figure 5-10. The expansions in Scenario 5 would represent a major discovery of parallel veins, similar to those mined historically in the Brunswick Mine, within the known mineralized system. These expansions are modeled to depth below the Idaho and Brunswick Mines and below the “Mitchell Crosscut,” which extends past the main mine workings to the north on the 1,000-ft level.

The model simulated the additional mine plan with additional drain nodes in the mine plan area. These drain nodes were “turned on” gradually from Year 26 to Year 65 on a monthly basis from the bottom to the top. As shown in Figure 5-11, the predicted stable groundwater inflow rates to the mine workings increased to approximately 1,200 gpm and then decreased to approximately 1,000 gpm at the end of new mining (Year 65) from 900 gpm at the end of the original mine plan (Year 25). Figure 5-11 shows that the inflow rate reached as high as 1,600 gpm. The “numerical spike” in predicted groundwater inflow rate (from 1,000 gpm to 1,600 gpm within a month) to the Mine is due to the artifact of the release of groundwater storage from thick model layers that represent the additional mining zone. Because the initial model grid discretization did not anticipate the simulation of the deep mining interval of the potential future mine expansion, whose bottom elevation (approximately -3,154 ft amsl) is more than 900 ft lower than the lowest elevation of the original mine plan in the Base-Case Scenario, the numerical release of groundwater storage from

the thick model layers is greater than what would probably occur in the smaller mine workings. Therefore, the numerical spike of the inflow rate related to the thick model layers will not occur under field conditions. As also shown in Figure 5-11, the predicted inflow rate decreases from Year 50 to the end of mine life mostly due to the depletion of the groundwater storage. The predicted inflow at the end of potential future mining is likely the stable groundwater inflow rate to the mine workings. Hence, the potential expansion of the mine plan increases the stable inflow rate by approximately 12% compared to the Base-Case Scenario. Itasca judged that the current model discretization is adequate for the sensitivity analysis. However, the model discretization will be refined for the updated mine plan in the future if the deep mining as simulated in this sensitivity analysis occurs.

As shown in Figure 5-12, the 5-ft drawdown contour extent of Scenario 5 at the end of potential additional mining (to Year 65) relative to the 2019 water level expands less than 500 ft from that of the Base-Case Scenario. The drawdown contour of the Base-Case Scenario is at the end of the original planned future mining (Year 25) relative to the 2019 water level. The comparison of drawdown contours between Scenario 5 and the Base-Case Scenario suggests that the added potential mining will not lead to large incremental drawdowns as the mining progresses because the mining activities occur in deep, low- $K$  rocks.

## **6.0 CONCLUSIONS AND RECOMMENDATIONS**

Based on the data analyses, existing data, and groundwater flow model, Itasca provides the following conclusions:

1. The groundwater flow model is reasonably calibrated to the measured inflow rates to the historical Idaho-Brunswick Mine, groundwater levels in the flooded Union Hill Mine and historical Idaho-Brunswick Mine, and baseflow rates at the South Fork of Wolf Creek and Wolf Creek. In addition, the calibrated model reasonably simulates groundwater levels in a variety of domestic wells, as well as the vertical hydraulic gradient from the shallow water-bearing zone to the historical mines.
2. The groundwater flow model predicts that the maximum and the stable mine-inflow rates are approximately 1,100 and 900 gpm, respectively, based on the future mine plan that Rise provided, which is approximately 200 to 400 gpm in addition to the inflow rate of approximately 700 gpm to the historical Idaho-Brunswick Mine as measured in 1956. These predicted inflow rates are annual average rates.
3. The groundwater drawdown due to dewatering for future mining is largely confined to within the mineral rights boundary.
4. The reductions of the average baseflow rates in the South Fork of Wolf Creek and Wolf Creek are approximately 0.1 cubic feet per second (cfs) and 0.75 cfs, respectively, at the end of mining compared to the 2019 average baseflows.
5. The predicted inflow rates are not sensitive to the  $K$  values of the transition zone and faults. The transition zone is a zone that appears to have increased  $K$  values due to weathering and stress release but not as high of  $K$  as the shallower bedrock and alluvial units. The shallow units have increased  $K$  due to stress release as a result of erosion and weathering.
6. The recharge rate applied to the model has limited effect on the predicted inflow rate to future mining. But the recharge rate affects the extent of groundwater drawdown. Higher recharge would lead to a smaller area of drawdown.
7. The predicted inflow rates and groundwater drawdown are not sensitive to significant expansion of mining within the known mineralized system at depths greater than approximately 1,000 ft bgs.

Itasca has the following recommendations:

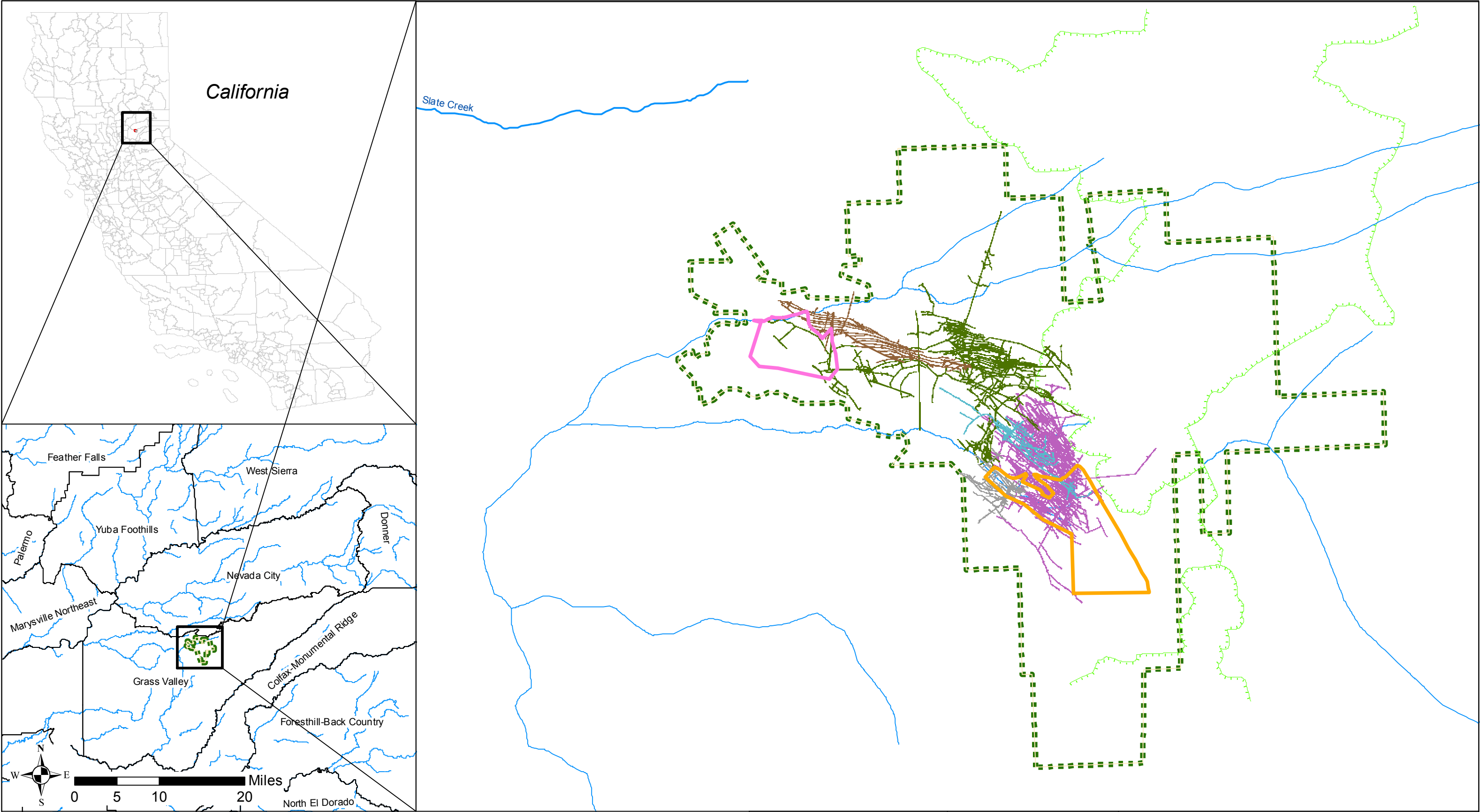
1. Rise should plan to collect hydrogeologic data according to the project stages. The key data are groundwater levels with depth and flow rates pumped from the Mine.

2. Prior to the dewatering of the Mine, monitoring wells and piezometers need to be installed for the measurement of water levels. The critical reason for the installation of piezometers and monitoring wells prior to dewatering of the Mine is to measure the hydraulic responses over time at these monitoring points. As the Mine pumps groundwater from the mine workings, groundwater levels will decline in the surrounding rock, and the measurements of water levels in the wells/piezometers will document the groundwater-level changes.
3. The water-level data can be used to update the groundwater flow model to improve the confidence of the model.
4. It is expected that the actual mining areas will change from the modeled mining areas due to vein geometry and discoveries, which will only be known after extensive underground exploration is completed in the future. Itasca recommends that the groundwater flow model be updated periodically after dewatering commences. Updated modeling would incorporate changes to the long-term mining plan, data from monitoring wells, and measured pumping rates.

## **7.0     REFERENCES**

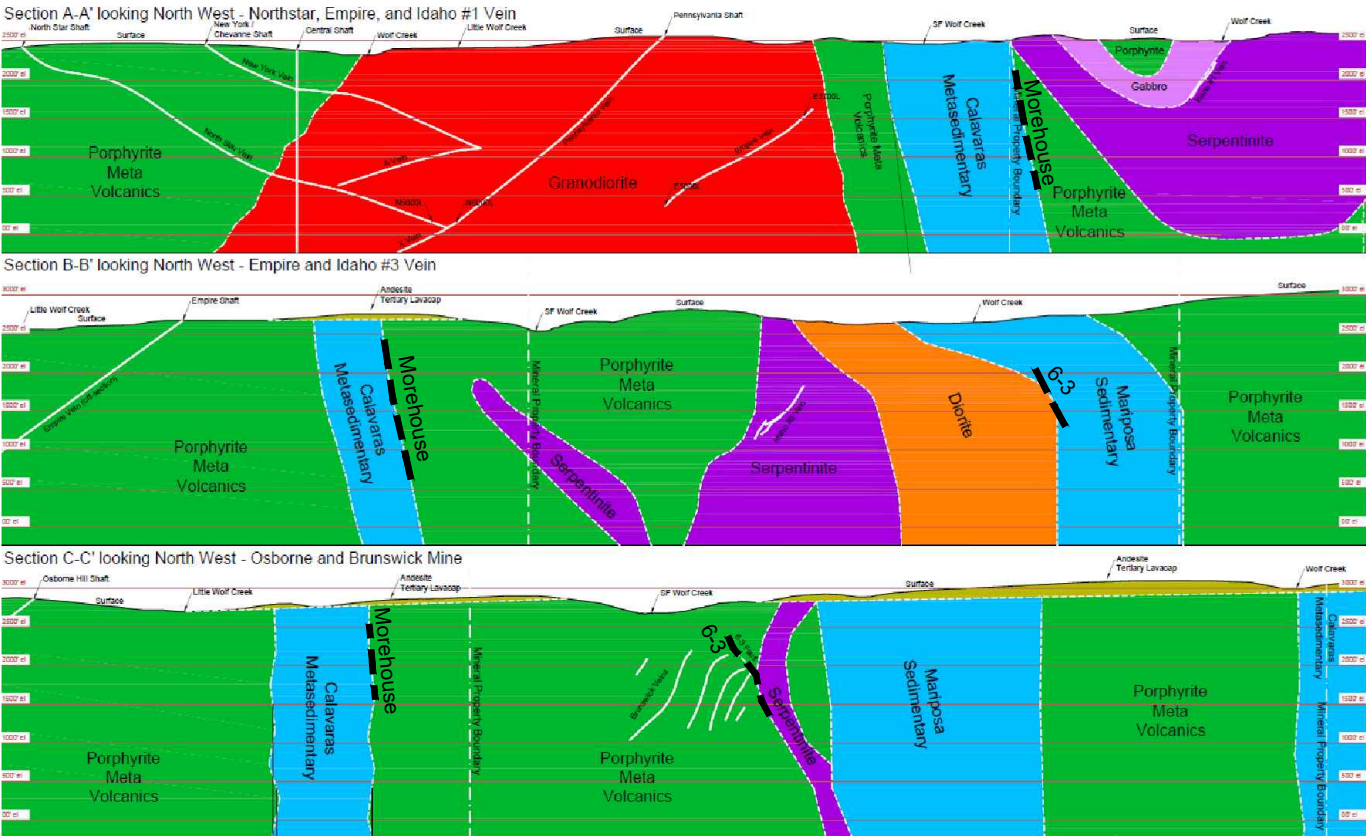
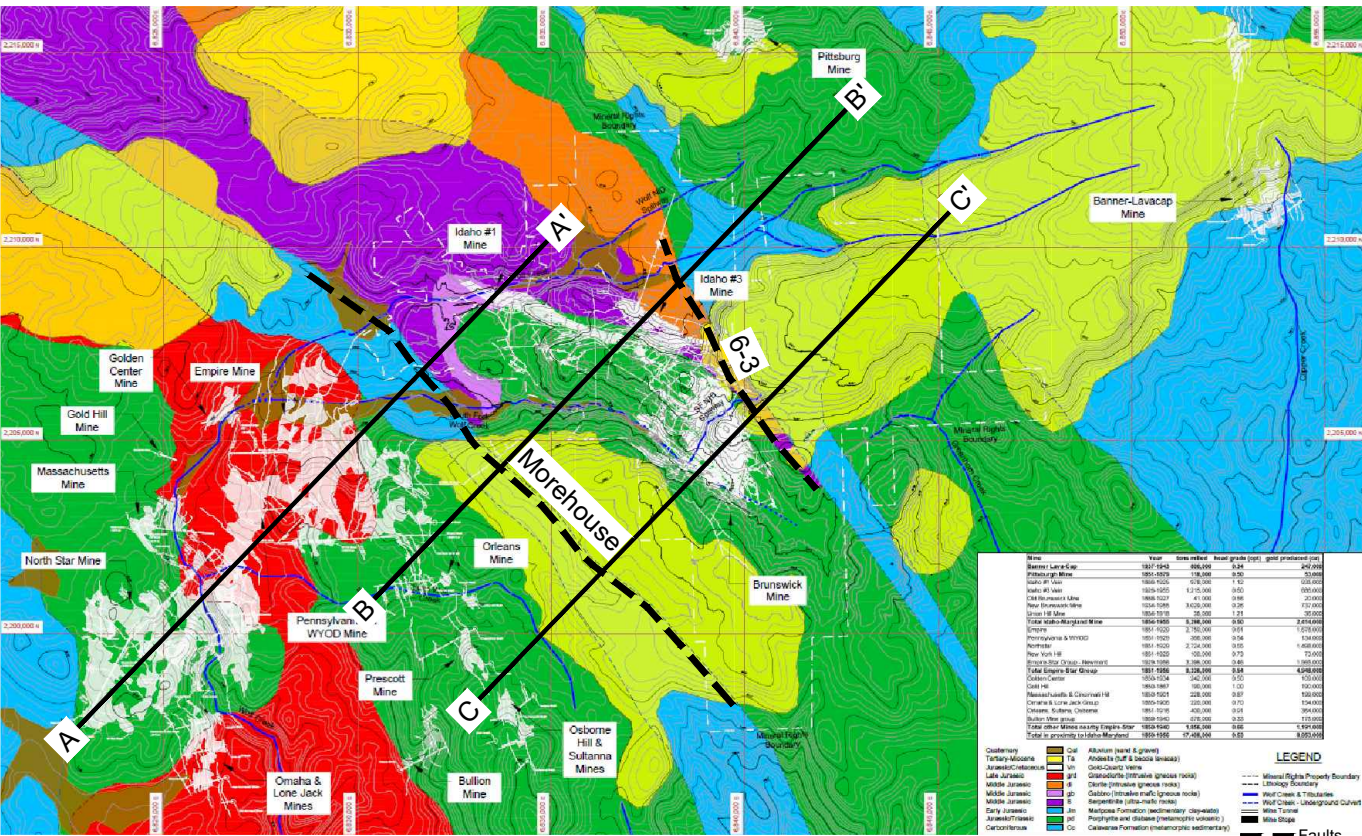
- Bateman, A.M. 1948. Report on geology and structure of Idaho-Maryland Mine, Grass Valley, California. August.
- Clark, J. 2005. *Gold in quartz: the legendary Idaho-Maryland Mine*. Grass Valley, CA: Comstock Bonanza Press.
- Clark, L.D. 1976. Stratigraphy of the north half of the western Sierra Nevada metamorphic belt, California. U.S. Geological Survey Professional Paper 923.
- Corbet, T., C. Ho, P. Knupp, and J. Ramsey. 1998. Review and verification of the MINEDW groundwater flow code. Sandia National Laboratories Report for Funds Agreement no. SNL-98FI-0610323.
- Freeze, R.A., and J.A. Cherry. 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice-Hall.
- Itasca. 2012. *MINEDW user manual*. Denver, CO: Itasca Denver, Inc.
- James Askew Associates. 1991. Technical assessment, Idaho-Maryland Mine, Nevada County, California.
- Kopania, A. 2019. Teleconference and email communication with Andrew Kopania (EMKO). December.
- Mines and Mineral Resources of Nevada County. 1920. Report of operations of the Idaho Maryland Mines Company from February 1<sup>st</sup>, 1919 to December 31<sup>st</sup>, 1919 by Fred G. Farish. 19 February.
- NDEP. 2018. Review of the MINEDW groundwater flow modeling code. From C. Newman to B. Hanna. 26 November.
- Page, R.W., P.W. Anttila, K.L. Johnson, and M.J. Pierce. 1984. Ground-water conditions and well yields in fractured rocks, southwestern Nevada County, California. U.S. Geological Survey Water-Resources Investigations Report 83-4262.
- Rise. 2019a. Scope of work groundwater modeling analysis. 9 September.
- Rise. 2019b. Email communication with Benjamin Mossman (Rise). 15 October.
- Rise. 2020. Email communication with Benjamin Mossman (Rise). 10 February.
- Saucedo, G.J., and D.L. Wagner. 1992. Geologic map of the Chico quadrangle. Scale 1:250,000. State of California Department of Conservation.
- Sierra-Pacific. 1995. Geologic and hydrogeologic background report for the Idaho-Maryland Gold Mine, Nevada County. Prepared by Sierra-Pacific Groundwater Consultants, Inc., March.
- Todd. 2007. Final report hydrogeologic assessment Idaho-Maryland Mine. Prepared by Todd Engineers for Idaho-Maryland Mining Corporation, August.

Vector. 1992. Hydrogeologic study for the Idaho-Maryland Mine, Grass Valley, Nevada County.  
Prepared by Vector Engineering, Inc. for James Askew Associates, Inc., January.



|                                                                                       |  |                                 |  |                                                                                       |  |                                                                                       |                                                                                             |  |                                      |
|---------------------------------------------------------------------------------------|--|---------------------------------|--|---------------------------------------------------------------------------------------|--|---------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|--|--------------------------------------|
| <b>Legend</b>                                                                         |  |                                 |  | <b>PROJECT NO.</b> 4091                                                               |  |  | <b>Locations of the Historical Mines,<br/>Mineral Rights Boundary, and Surface Features</b> |  |                                      |
| <b>Other Site Features</b>                                                            |  | <b>Historical Mine Workings</b> |  | <b>Surface Land Boundary</b>                                                          |  |                                                                                       |                                                                                             |  | <b>BY</b> DD                         |
| NID Canals                                                                            |  | New Brunswick                   |  | Old Idaho                                                                             |  |                                                                                       |                                                                                             |  | <b>CHECKED</b> HL                    |
| Creeks                                                                                |  | New Idaho                       |  | Union Hill                                                                            |  |                                                                                       |                                                                                             |  | <b>DRAWN</b> DD                      |
| Mineral Rights Boundary                                                               |  | Old Brunswick                   |  | Brunswick Industrial Site                                                             |  |                                                                                       |                                                                                             |  | <b>DRAWING NAME</b> Figure 1 Basemap |
|                                                                                       |  |                                 |  |                                                                                       |  | <b>DRAWING DATE</b> Feb. 26, 2020                                                     |                                                                                             |  |                                      |
|                                                                                       |  |                                 |  |                                                                                       |  | <b>REVISION DATE</b>                                                                  |                                                                                             |  |                                      |
|  |  |                                 |  |  |  |                                                                                       |                                                                                             |  |                                      |

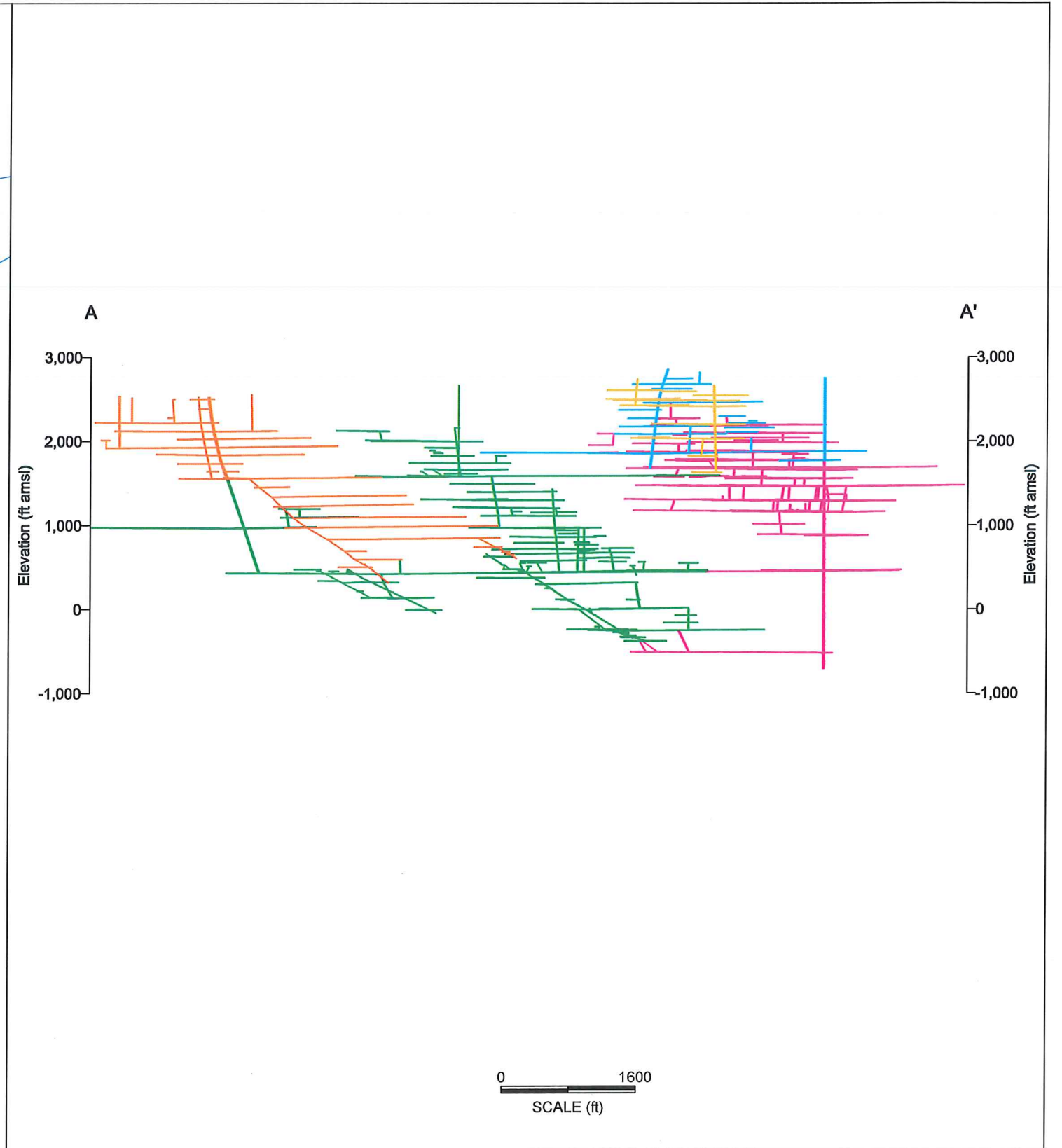
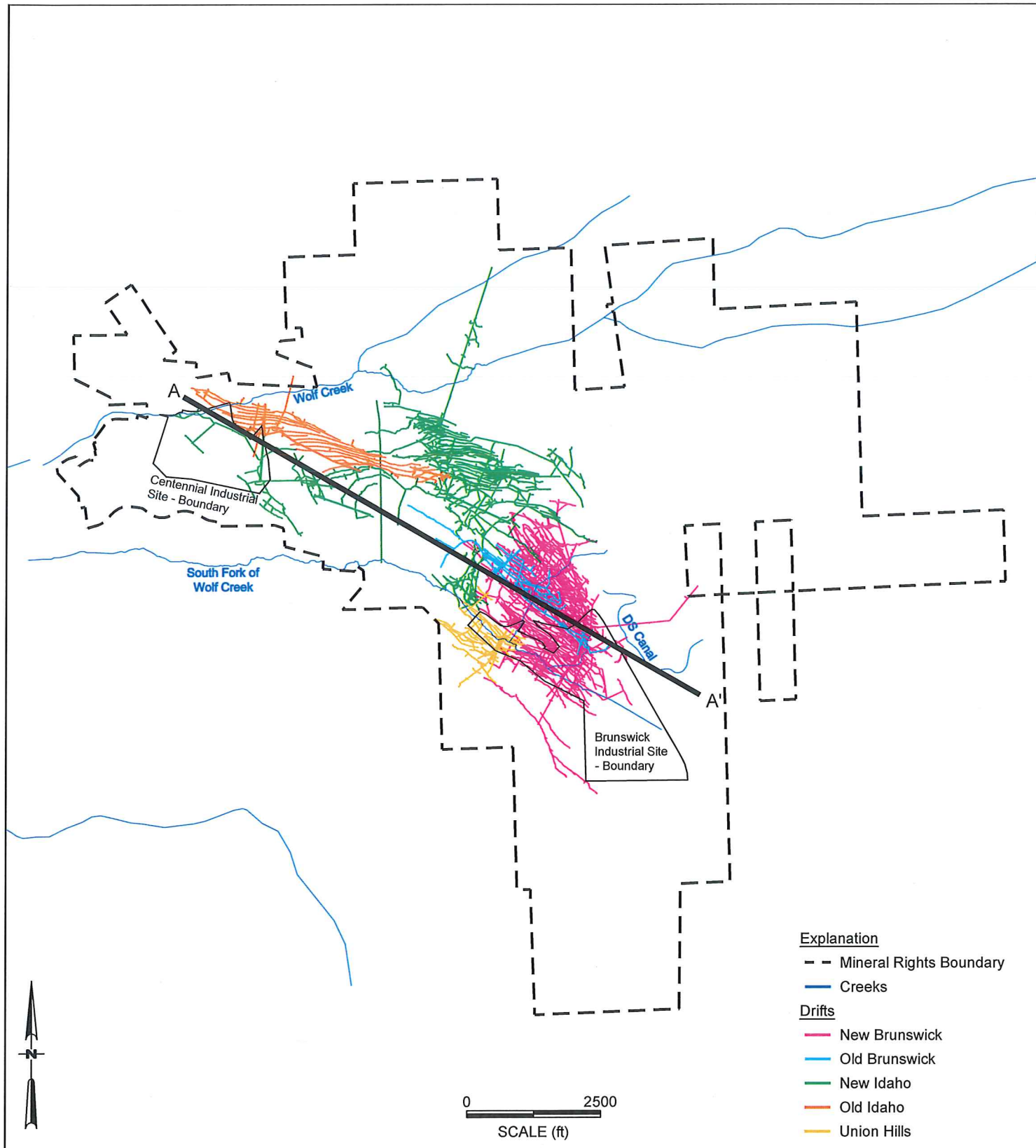




NOTE: The locations of the faults were approximately interpolated based on the 3-D geological model (Rise 2019a).

Source: Rise (2019a)

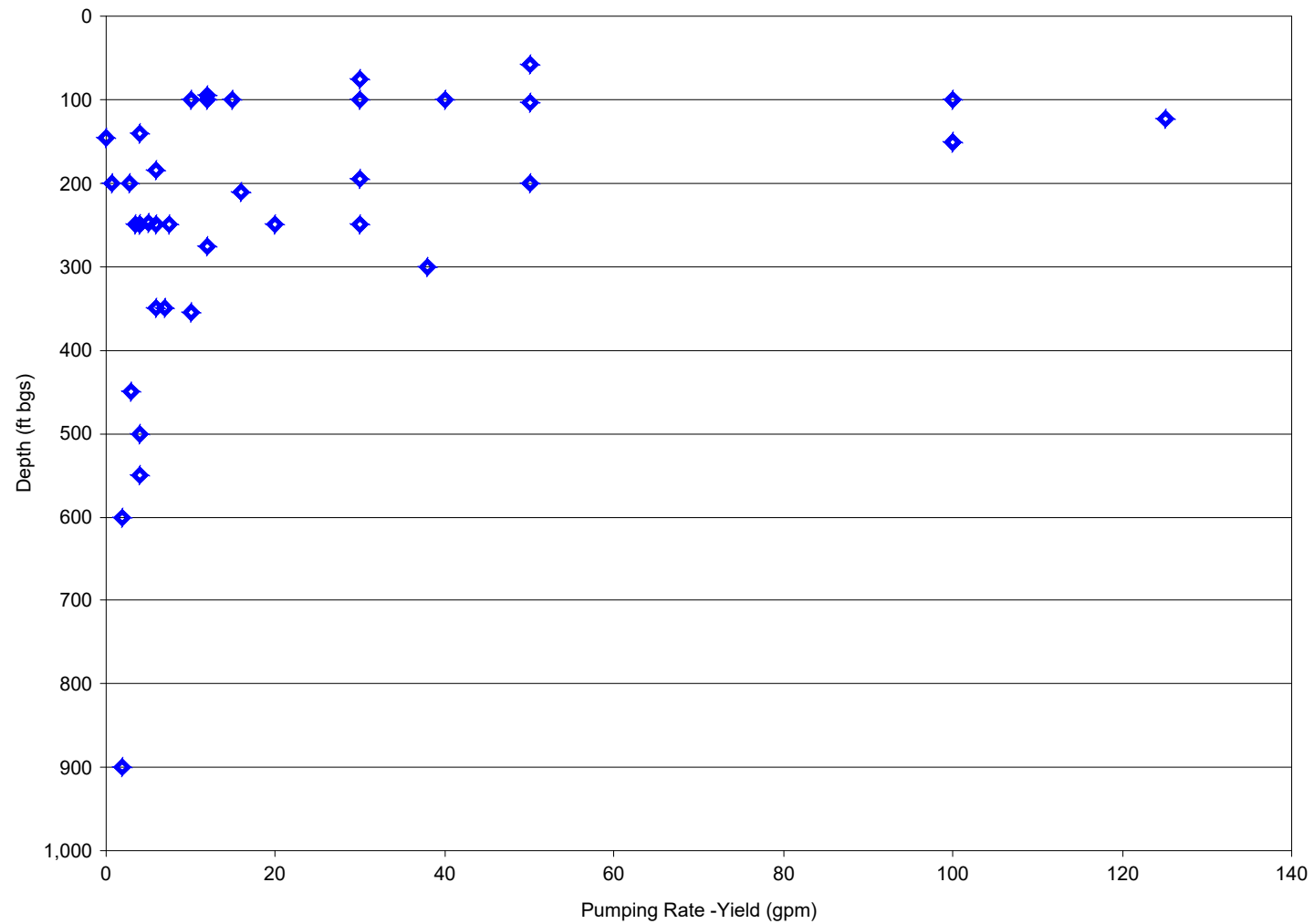
|               |             |                                                                                       |                                             |                   |
|---------------|-------------|---------------------------------------------------------------------------------------|---------------------------------------------|-------------------|
| PROJECT NO.   | 4091-19     |  | Geologic Setting at the Idaho-Maryland Mine |                   |
| BY            | DD          |                                                                                       |                                             |                   |
| CHECKED       | HL          |                                                                                       |                                             |                   |
| DRAWN         | RJN         |                                                                                       |                                             |                   |
| DRAWING NAME  | IMPIT       |                                                                                       |                                             |                   |
| DRAWING DATE  | 27 FEB 2020 |                                                                                       | CLIENT:<br>Rise Grass Valley Inc.           | FIGURE NO.<br>2-2 |
| REVISION DATE |             |                                                                                       |                                             |                   |



|               |             |
|---------------|-------------|
| PROJECT NO.   | 4091-19     |
| BY            | DD          |
| CHECKED       | HL          |
| DRAWN         | RJN         |
| DRAWING NAME  | MINES       |
| DRAWING DATE  | 27 FEB 2020 |
| REVISION DATE |             |

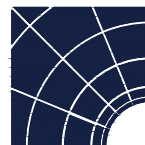


|                                         |                   |
|-----------------------------------------|-------------------|
| Spatial Extents of the Historical Mines |                   |
| CLIENT:<br>Rise Grass Valley Inc.       | FIGURE NO.<br>2-3 |



Source: Kopania (2019, pers. comm.)

|               |             |
|---------------|-------------|
| PROJECT NO.   | 4091-19     |
| BY            | DD          |
| CHECKED       | HL          |
| DRAWN         | RJN         |
| DRAWING NAME  | YIELD       |
| DRAWING DATE  | 27 FEB 2020 |
| REVISION DATE |             |

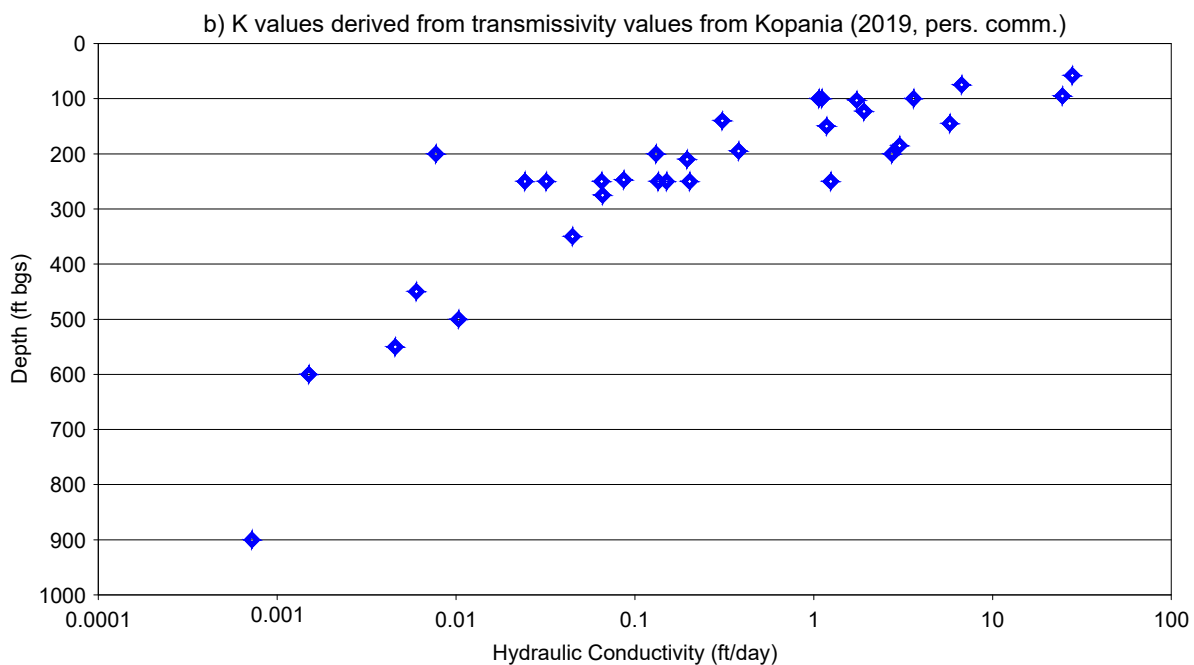
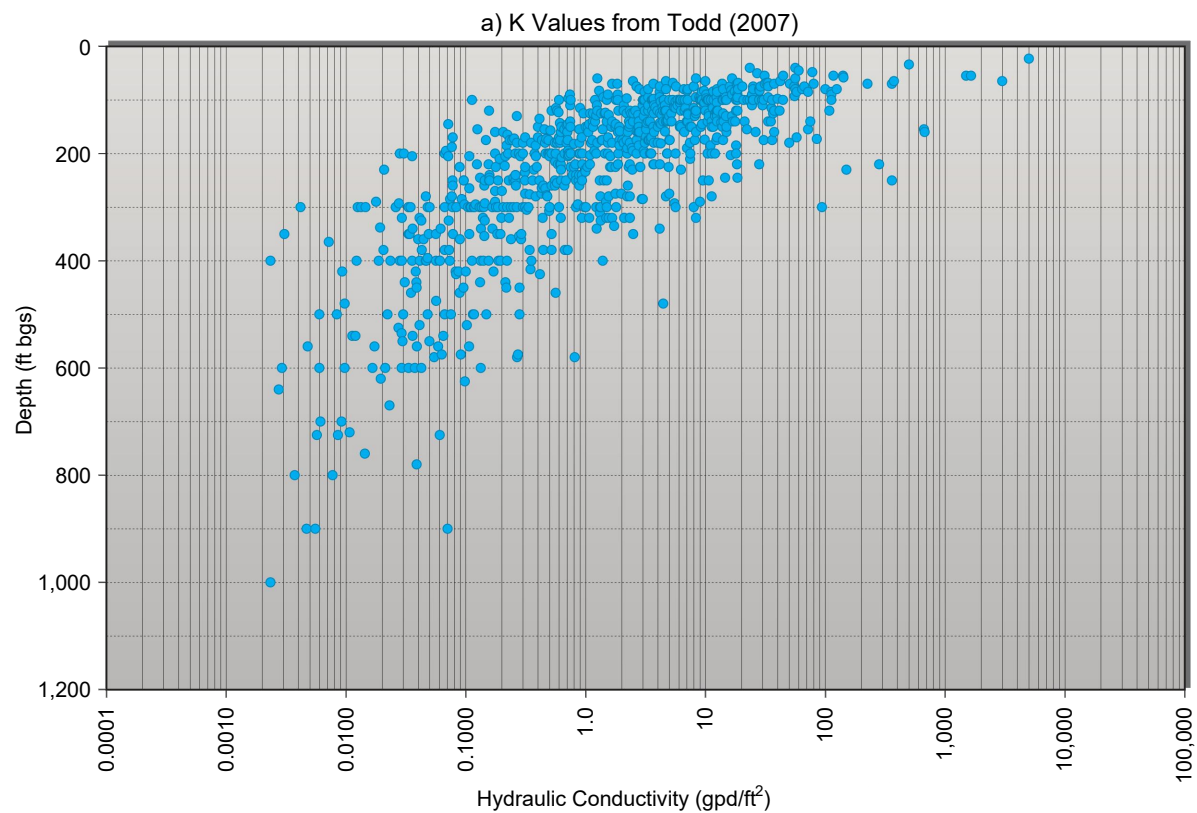


**ITASCA**<sup>TM</sup>  
Denver, Inc.

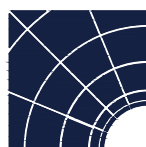
## Well Yield versus Depth of Wells

CLIENT:  
Rise Grass Valley Inc.

FIGURE NO.  
2-4



|               |             |
|---------------|-------------|
| PROJECT NO.   | 4091-19     |
| BY            | DD          |
| CHECKED       | HL          |
| DRAWN         | RJN         |
| DRAWING NAME  | COND        |
| DRAWING DATE  | 27 FEB 2020 |
| REVISION DATE |             |

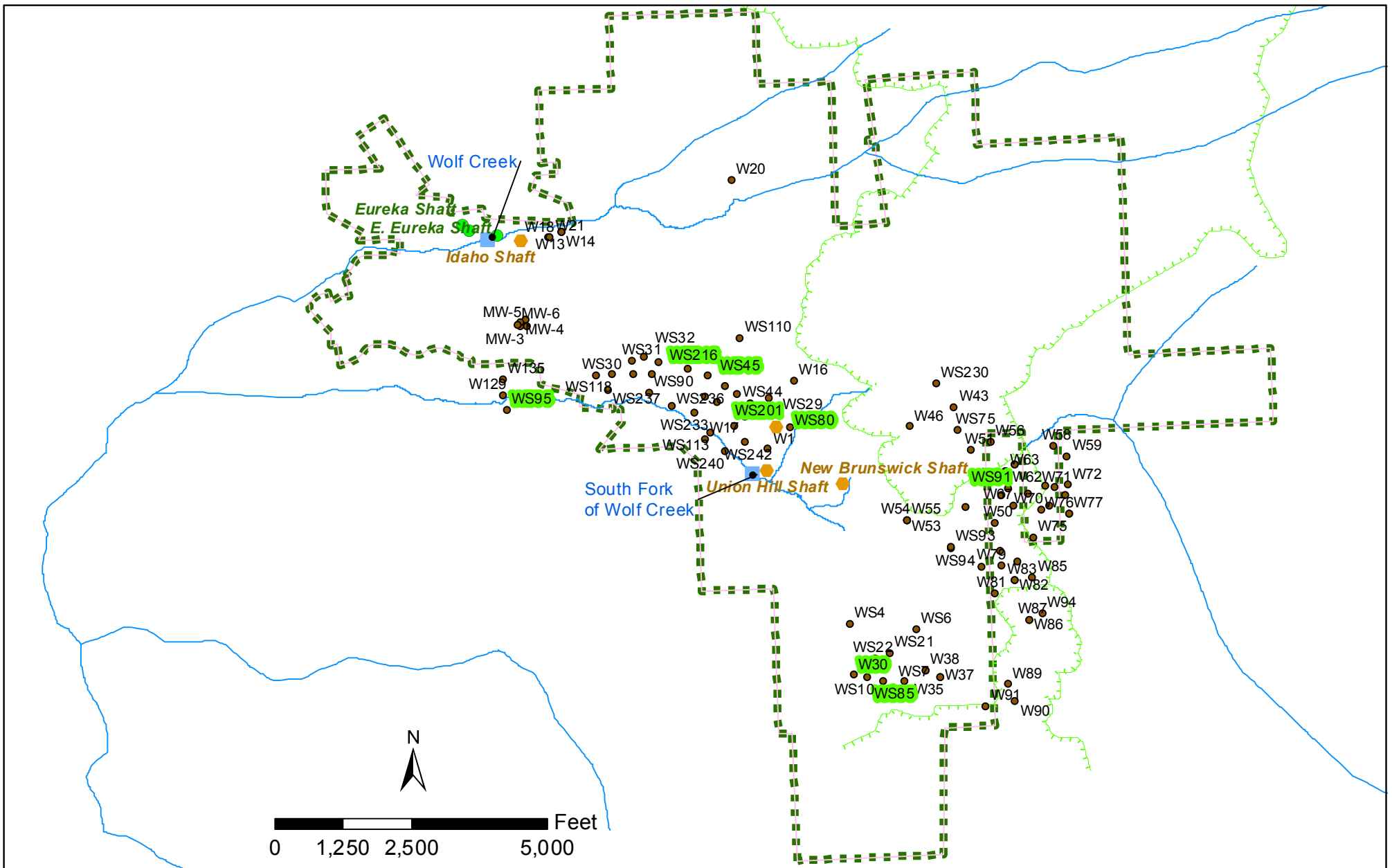


**ITASCA**<sup>™</sup>  
Denver, Inc.

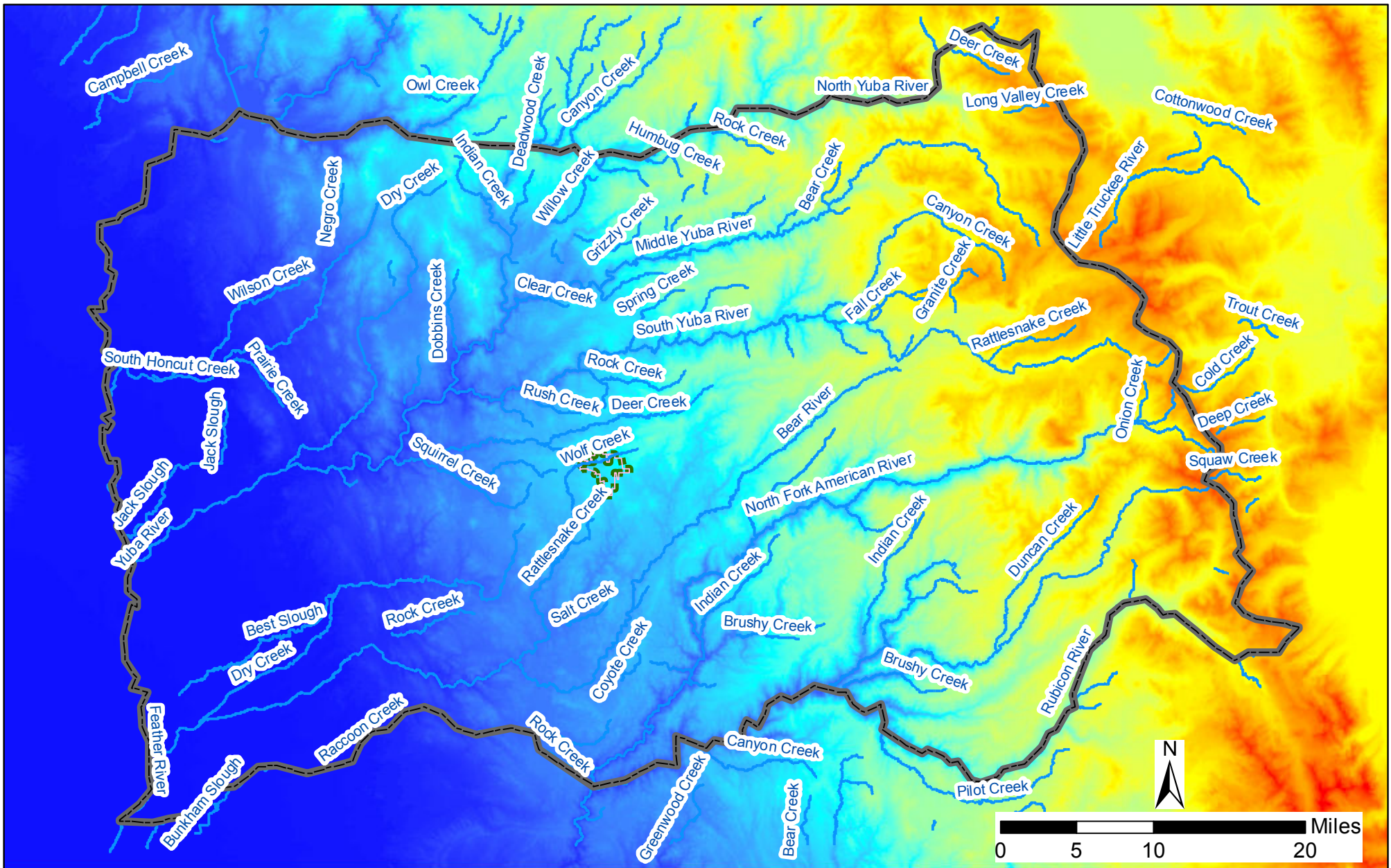
### Estimated Hydraulic Conductivities at Boreholes along the Depth

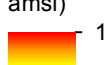
CLIENT:  
Rise Grass Valley Inc.

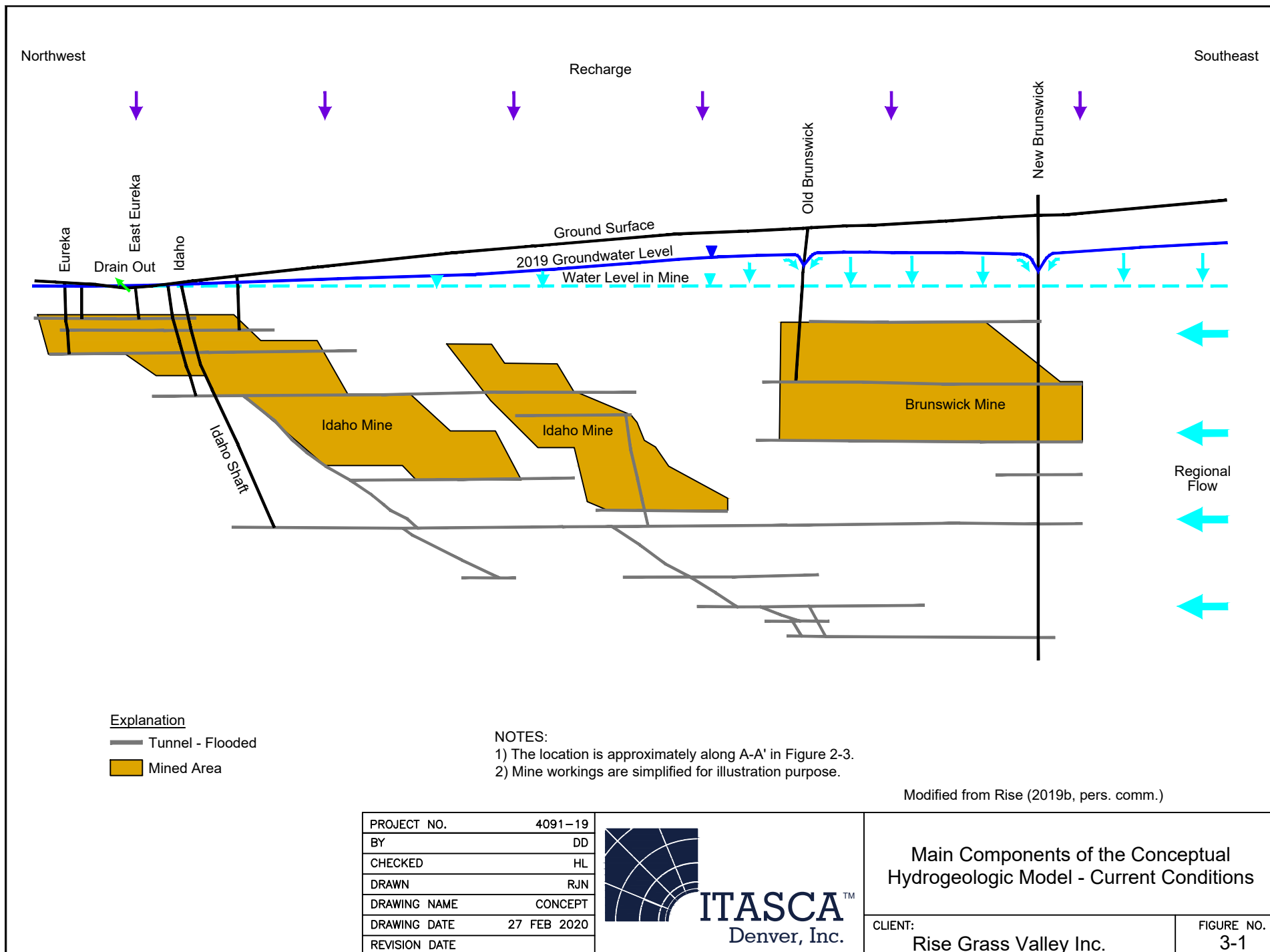
FIGURE NO.  
2-5

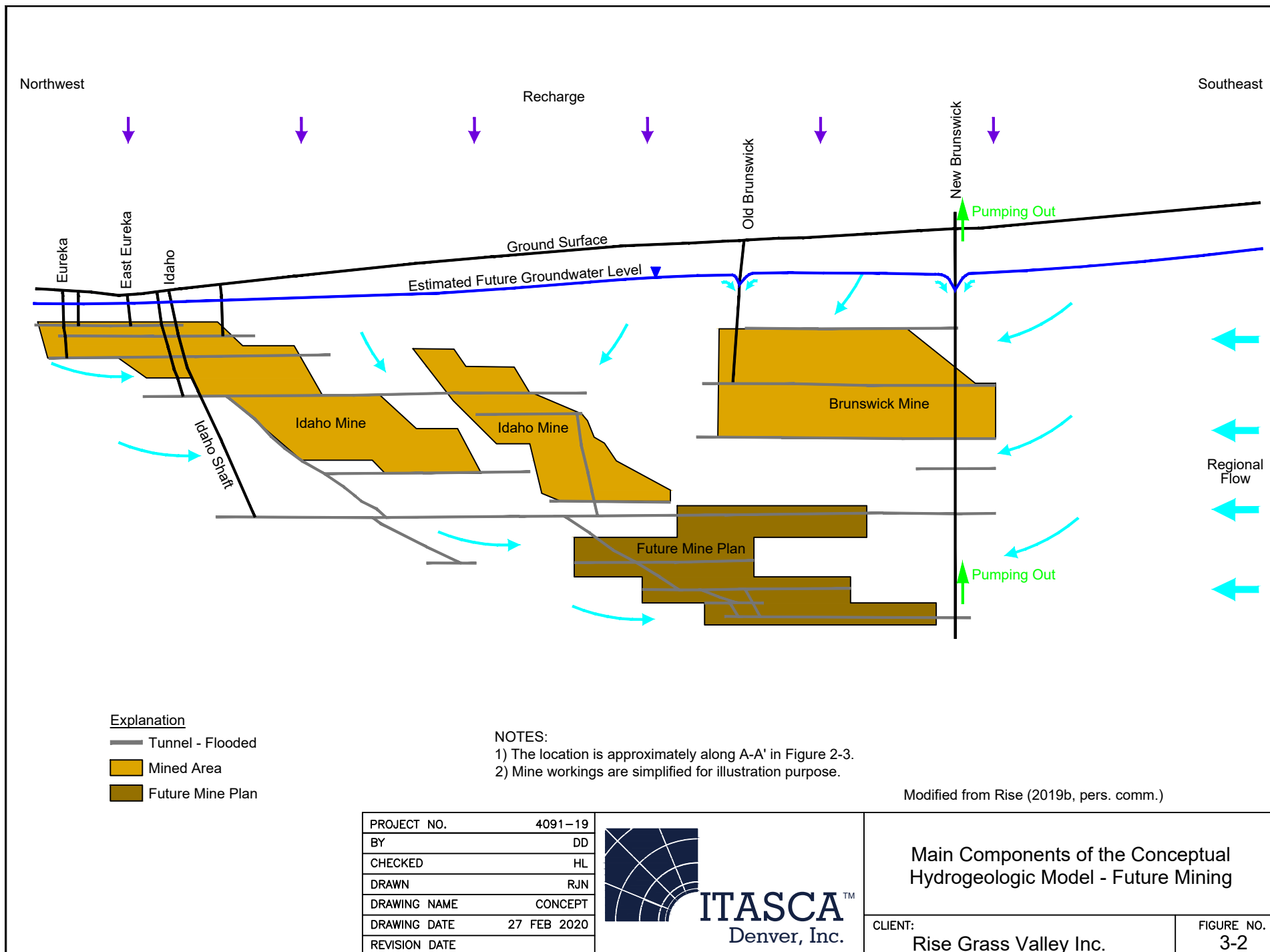


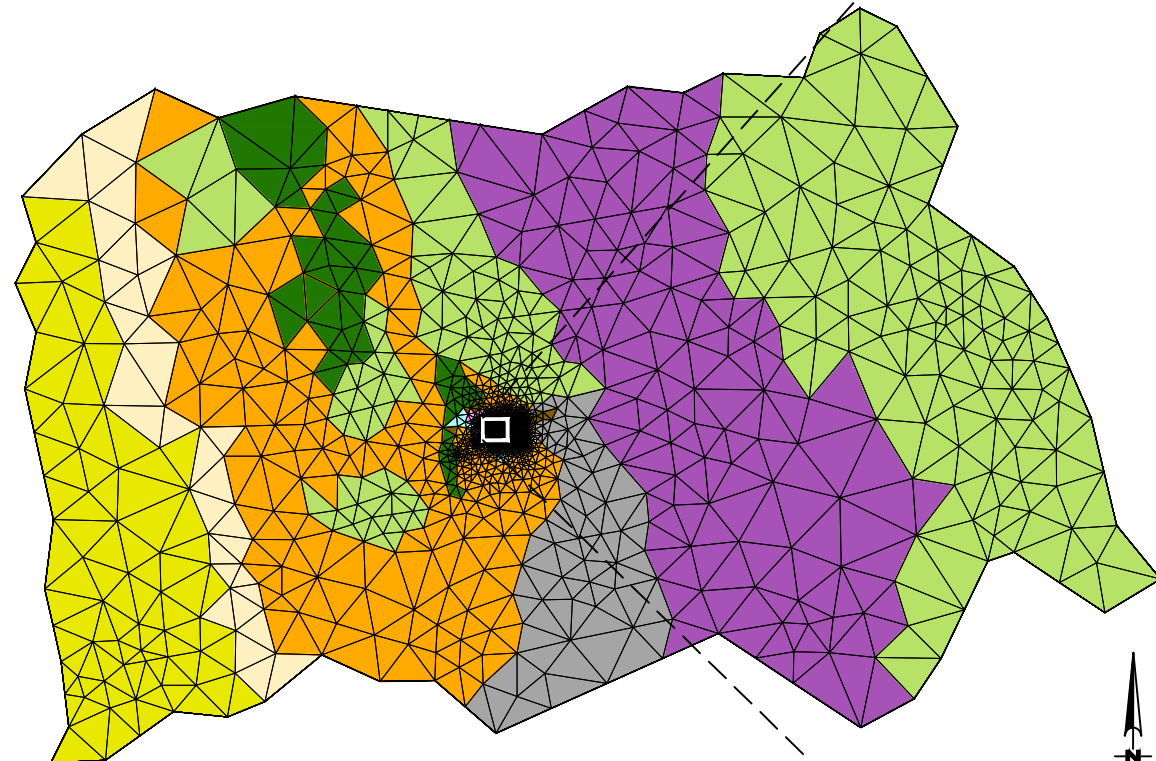
|                                                                                                            |                                                                                            |                               |                                |                                                                                                                                      |                                                                                           |  |
|------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|-------------------------------|--------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|--|
| <b>Legend</b>                                                                                              |                                                                                            | PROJECT NO. 4091              |                                | <br><b>ITASCA</b> <sup>TM</sup><br>Denver, Inc. | Locations of Domestic Wells, Streamflow Monitoring, and Historical Mine Shafts and Drains |  |
|  Streamflow              |  Drains | BY DD                         |                                |                                                                                                                                      |                                                                                           |  |
|  Monitoring Location     |  Shafts | CHECKED HL                    |                                |                                                                                                                                      |                                                                                           |  |
|  Mineral Rights Boundary |  Wells  | DRAWN DD                      |                                |                                                                                                                                      |                                                                                           |  |
|  NID Canals              | Note: Highlighted wells are shown in Figure 4-8.                                           | DRAWING NAME Figure 2-6 Wells |                                |                                                                                                                                      |                                                                                           |  |
|  Creeks                  |                                                                                            | DRAWING DATE Mar. 16, 2020    |                                |                                                                                                                                      |                                                                                           |  |
|                                                                                                            |                                                                                            | REVISION DATE                 | CLIENT: Rise Grass Valley Inc. |                                                                                                                                      | FIGURE NO. 2-6                                                                            |  |



|                                                                                                            |                     |                                    |      |                                                                                      |                                                  |            |
|------------------------------------------------------------------------------------------------------------|---------------------|------------------------------------|------|--------------------------------------------------------------------------------------|--------------------------------------------------|------------|
| <b>Legend</b>                                                                                              |                     | PROJECT NO.                        | 4091 |  | Topography and Boundary of Hydrologic Study Area |            |
|  Model Boundary          | Elevation (ft amsl) | BY                                 | DD   |                                                                                      |                                                  |            |
|  Mineral Rights Boundary | 10,440              | CHECKED                            | HL   |                                                                                      |                                                  |            |
|                         | -22                 | DRAWN                              | DD   |                                                                                      |                                                  |            |
|                                                                                                            |                     | DRAWING NAME Figure 2-7 Topography |      |                                                                                      | CLIENT:                                          | FIGURE NO. |
|                                                                                                            |                     | DRAWING DATE Feb. 10, 2020         |      |                                                                                      | Rise Grass Valley Inc.                           | 2-7        |
|                                                                                                            |                     | REVISION DATE                      |      |                                                                                      |                                                  |            |



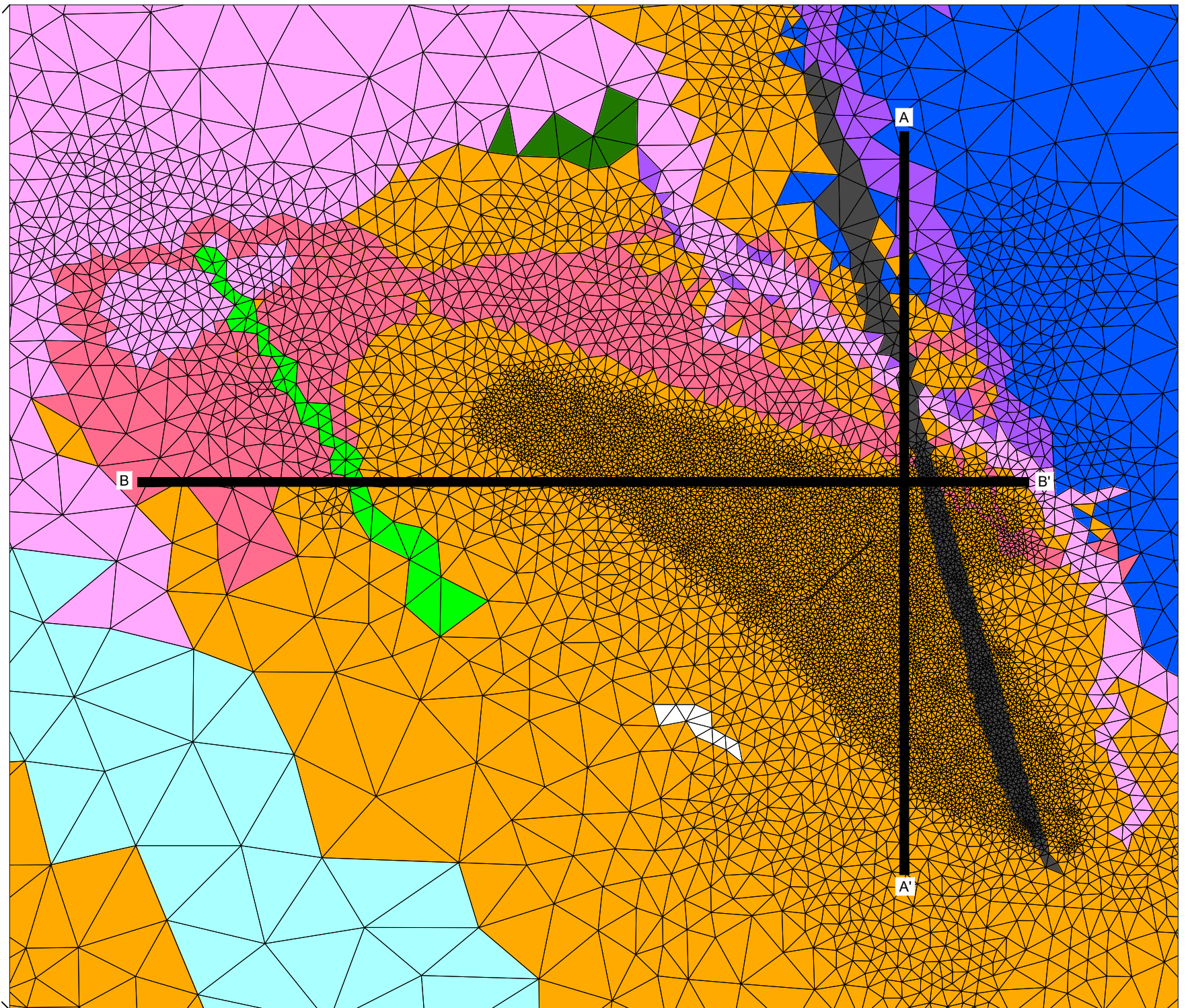




0 70000  
SCALE (ft)

Explanation

|                 |                   |
|-----------------|-------------------|
| Alluvium        | Gabbro            |
| Argillite       | Granodiorite      |
| Volcanic Rock   | Mariposa          |
| Brunswick       | Mine Void         |
| Calavaras       | Sandstone         |
| Delhi           | Schist            |
| Diorite         | Serpentinite      |
| Fault 6-3       | Tertiary Andesite |
| Morehouse Fault |                   |



NOTE: The top elevation is approximately 2,600 ft amsl in the Mine area.

0 1000  
SCALE (ft)

|               |             |
|---------------|-------------|
| PROJECT NO.   | 4091-19     |
| BY            | DD          |
| CHECKED       | HL          |
| DRAWN         | RJN         |
| DRAWING NAME  | MODEL       |
| DRAWING DATE  | 27 FEB 2020 |
| REVISION DATE |             |

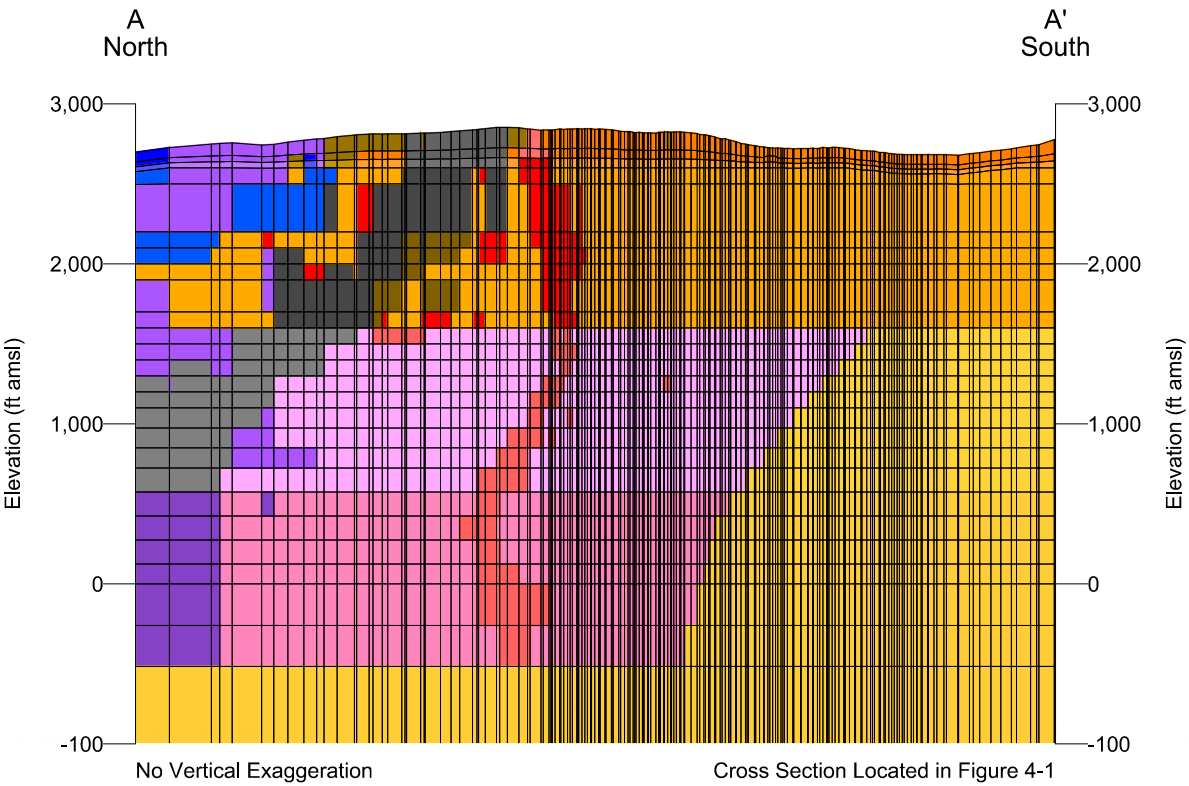


Model Discretization and Simulated  
Geologic Units in Model Layer 4

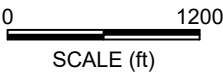
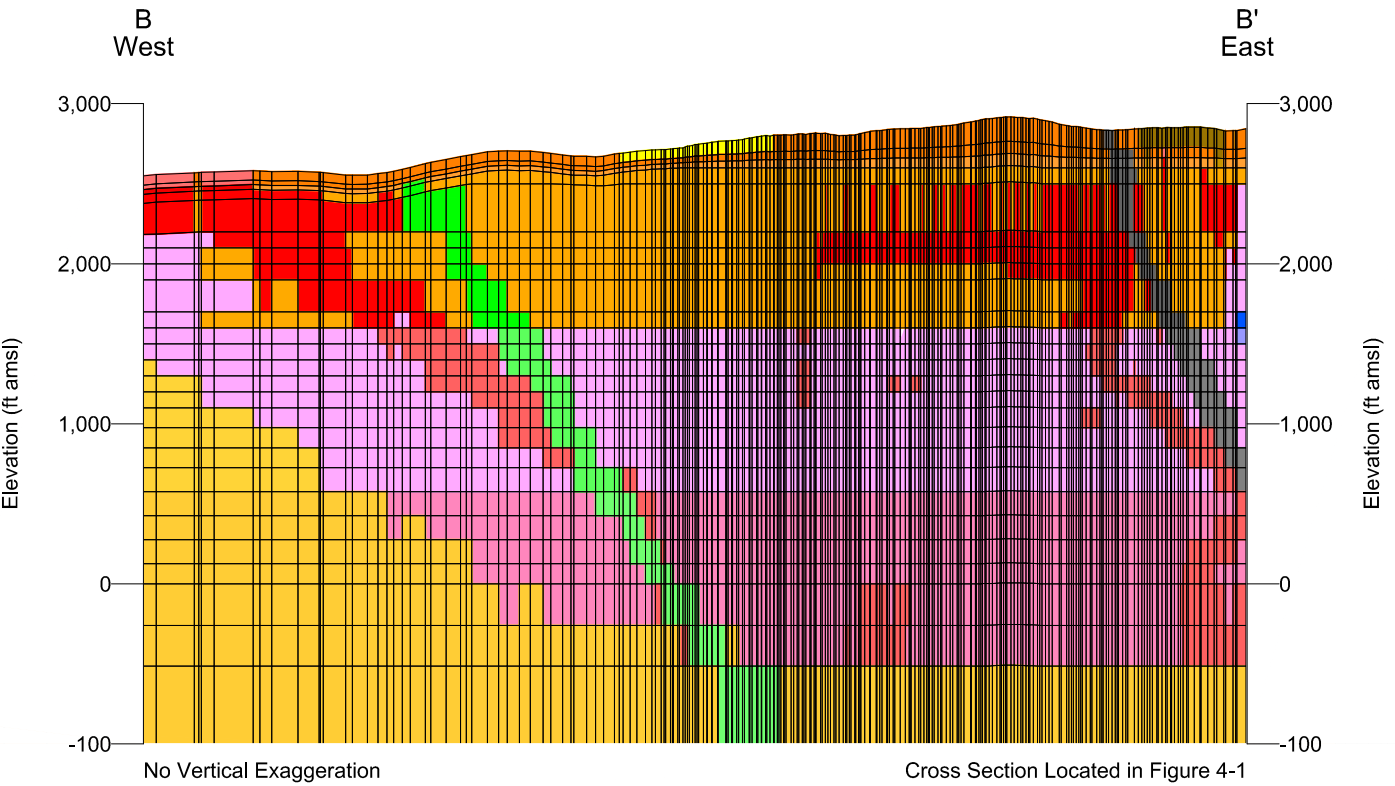
CLIENT:  
Rise Grass Valley Inc.

FIGURE NO.  
4-1

A) North-South



B) West-East



Explanation

| Tertiary Andesite | Volcanic Rock | Calavaras  | Delhi      | Schist       | Mariposa   | Diorite    | Sepentinite | Brunswick  | Fault 6-3  | Morehouse Fault | River Sediment |
|-------------------|---------------|------------|------------|--------------|------------|------------|-------------|------------|------------|-----------------|----------------|
| Fractured         | Fractured     | Fractured  | Fractured  | Fractured    | Fractured  | Fractured  | Fractured   | Fractured  | Fractured  | Transition      |                |
| Transition        | Transition    | Transition | Transition | Transition   | Transition | Transition | Transition  | Transition | Transition | Top             |                |
| Top               | Top           | Top        | Top        | Top          | Top        | Top        | Top         | Top        | Top        | Middle          |                |
|                   | Middle        | Middle     | Middle     | Middle       | Middle     | Middle     | Middle      | Middle     | Middle     | Deep            |                |
|                   | Deep          | Deep       | Deep       | Deep         | Deep       | Deep       | Deep        | Deep       | Deep       |                 |                |
|                   | Country Rock  |            |            | Country Rock |            |            |             |            |            |                 |                |

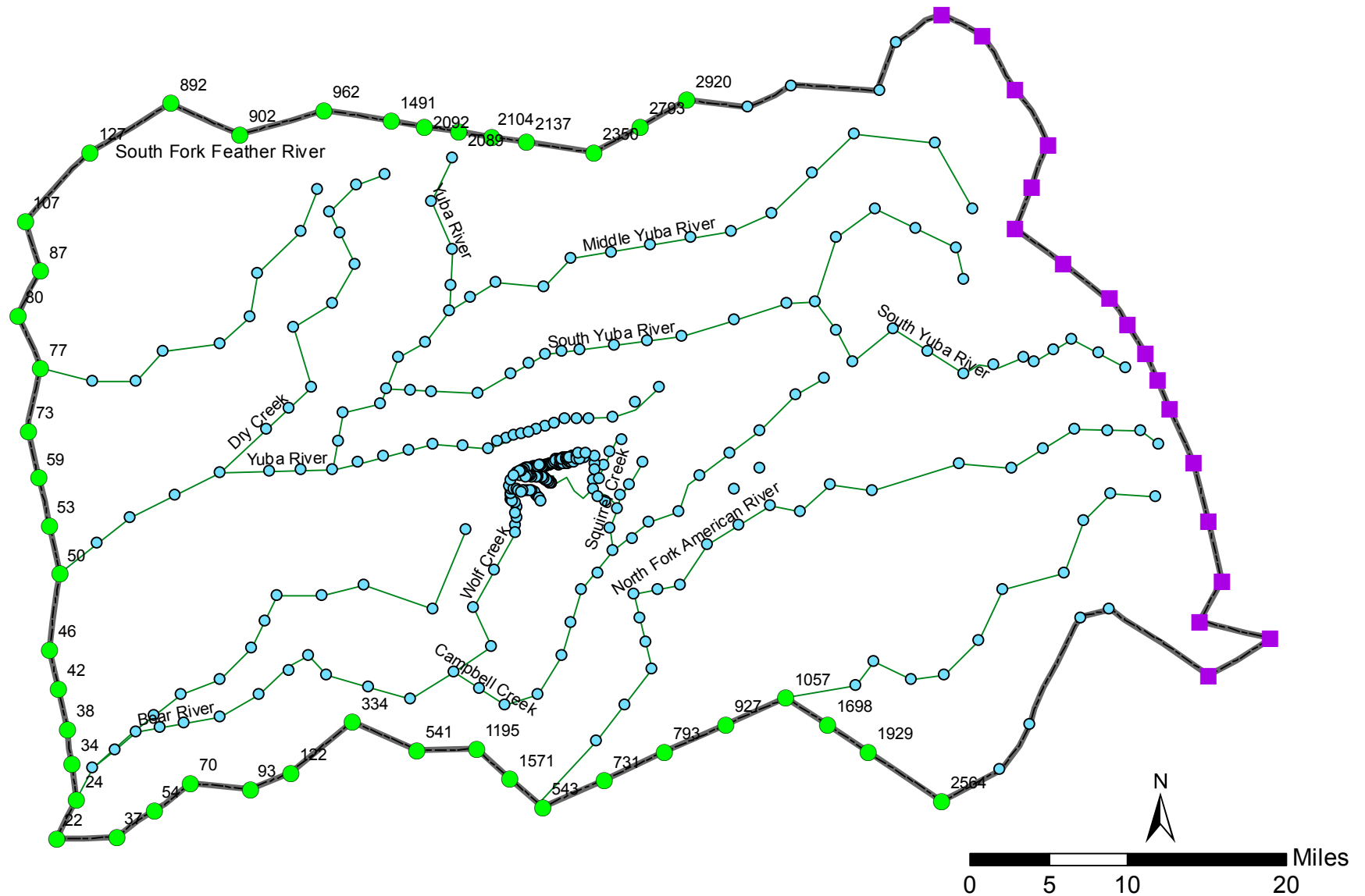
|               |             |
|---------------|-------------|
| PROJECT NO.   | 4091-19     |
| BY            | DD          |
| CHECKED       | HL          |
| DRAWN         | RJN         |
| DRAWING NAME  | XSEC        |
| DRAWING DATE  | 27 FEB 2020 |
| REVISION DATE |             |



Simulated Geologic Units in Cross Section

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 4-2



### Legend

- No Flow
- Constant Head (ft amsl)
- Simulated Stream
- Model Boundary

|               |                     |
|---------------|---------------------|
| PROJECT NO.   | 4091                |
| BY            | DD                  |
| CHECKED       | HL                  |
| DRAWN         | DD                  |
| DRAWING NAME  | Figure 4-3 Boundary |
| DRAWING DATE  | Feb. 21, 2020       |
| REVISION DATE |                     |



**ITASCA**  
Denver, Inc.

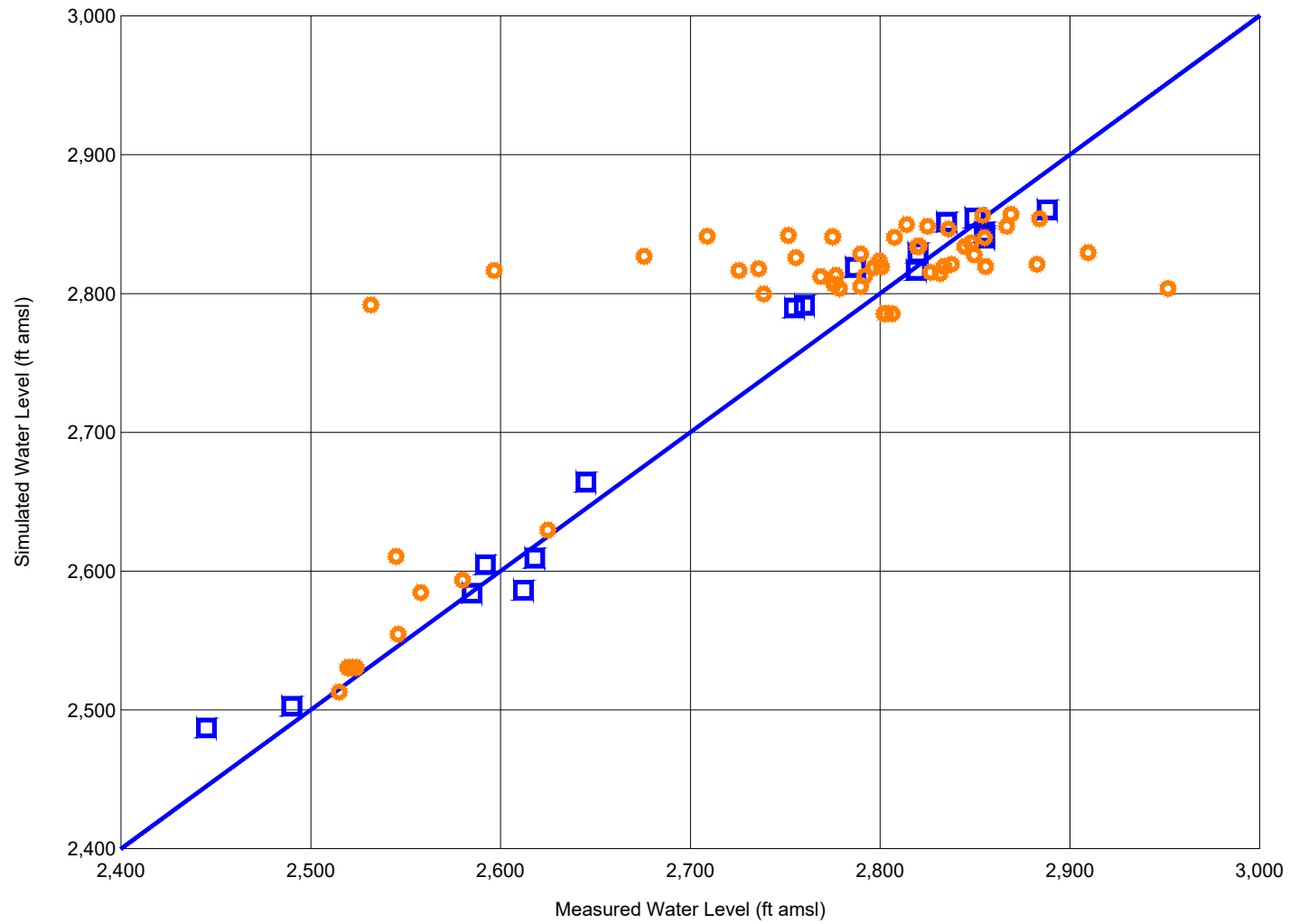
### Model Boundary Conditions

CLIENT:

Rise Grass Valley Inc.

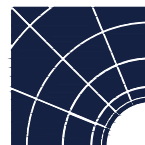
FIGURE NO.

4-3



○ From Well Completion Reports    □ Wells with Hydrographs from Todd (2007)

|               |             |
|---------------|-------------|
| PROJECT NO.   | 4091-19     |
| BY            | DD          |
| CHECKED       | HL          |
| DRAWN         | RJN         |
| DRAWING NAME  | HIST        |
| DRAWING DATE  | 27 FEB 2020 |
| REVISION DATE |             |

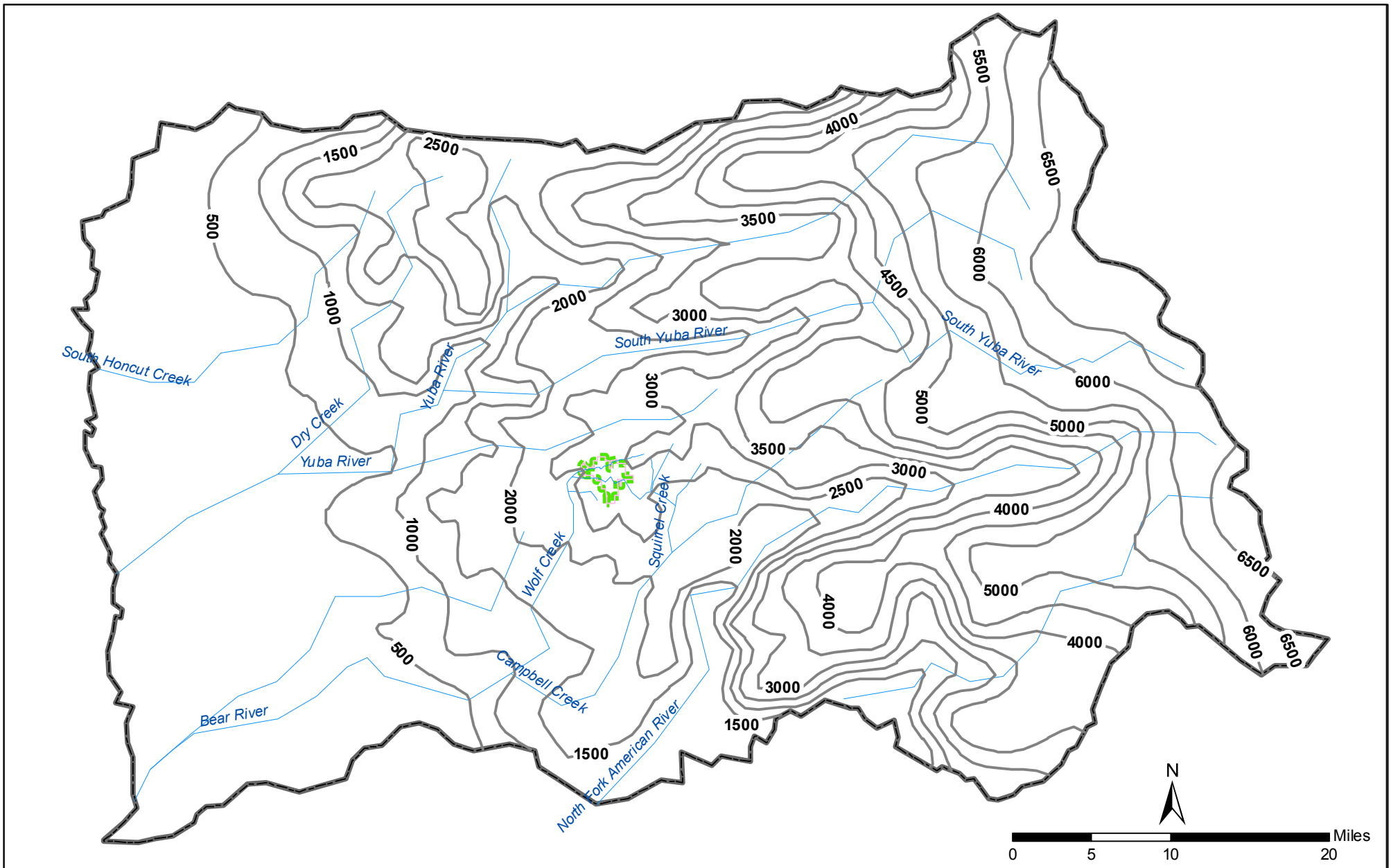


**ITASCA**<sup>™</sup>  
Denver, Inc.

Simulated and Measured Groundwater  
Levels under Pre-Historical-Mining Condition

CLIENT:  
Rise Grass Valley Inc.

FIGURE NO.  
4-4



### Legend

-  Groundwater Contour (ft amsl)
-  Mineral Rights Boundary
-  Model Boundary
-  Simulated Streams

|               |                       |
|---------------|-----------------------|
| PROJECT NO.   | 4091                  |
| BY            | DD                    |
| CHECKED       | HL                    |
| DRAWN         | DD                    |
| DRAWING NAME  | Figure 4-5 SS Contour |
| DRAWING DATE  | Feb. 28, 2020         |
| REVISION DATE |                       |



**ITASCA**  
Denver, Inc.

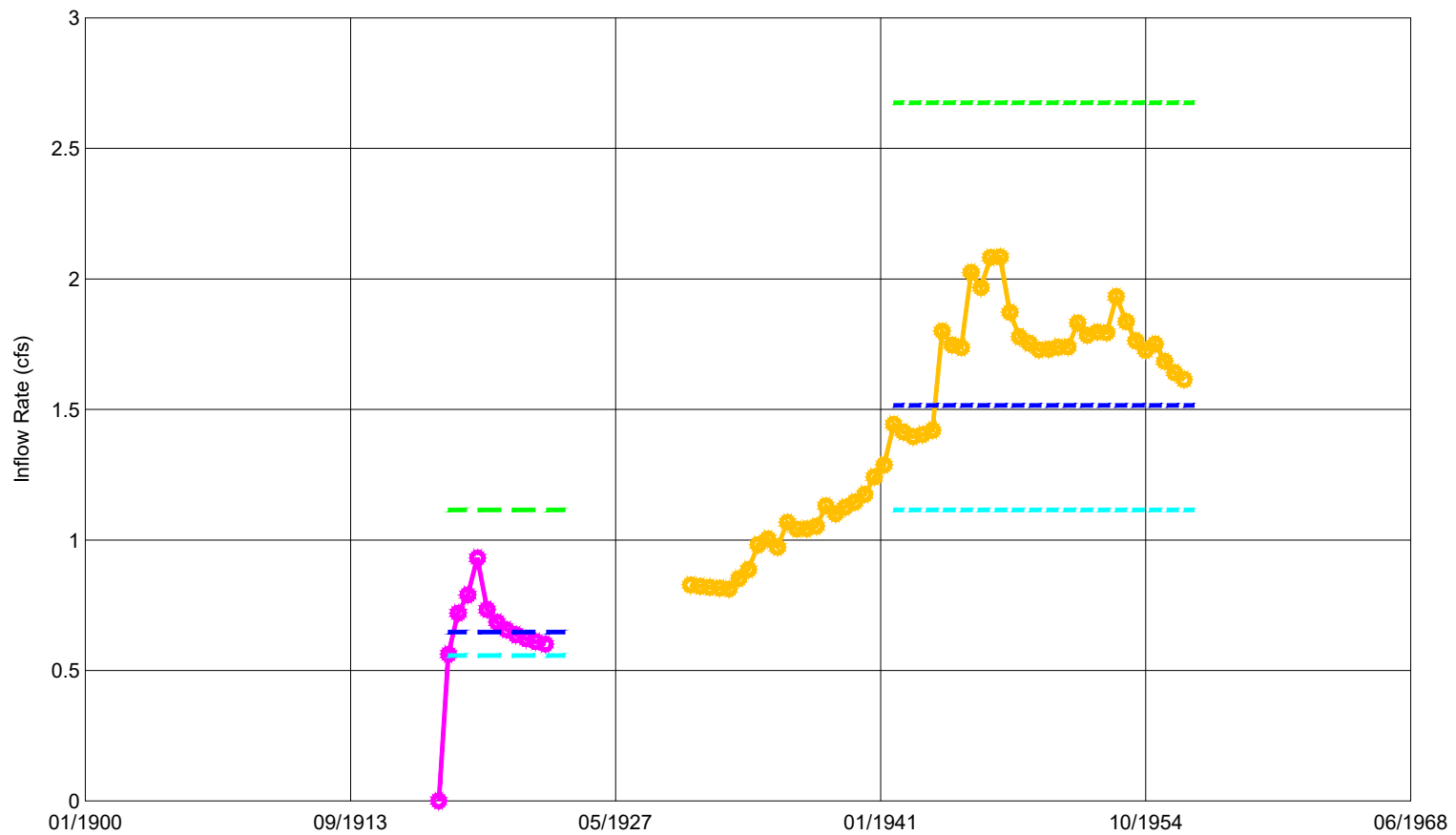
### Simulated Groundwater Contours under Pre-Historical-Mining Condition

CLIENT:

Rise Grass Valley Inc.

FIGURE NO.

4-5



Date

|                       |                             |
|-----------------------|-----------------------------|
| <u>Old Idaho Mine</u> | <u>Idaho-Brunswick Mine</u> |
| ● Simulated           | ● Simulated                 |
| ● Measured            | ● Measured                  |
| --- High              | --- High                    |
| --- Low               | --- Low                     |
| --- Average           | --- Average                 |

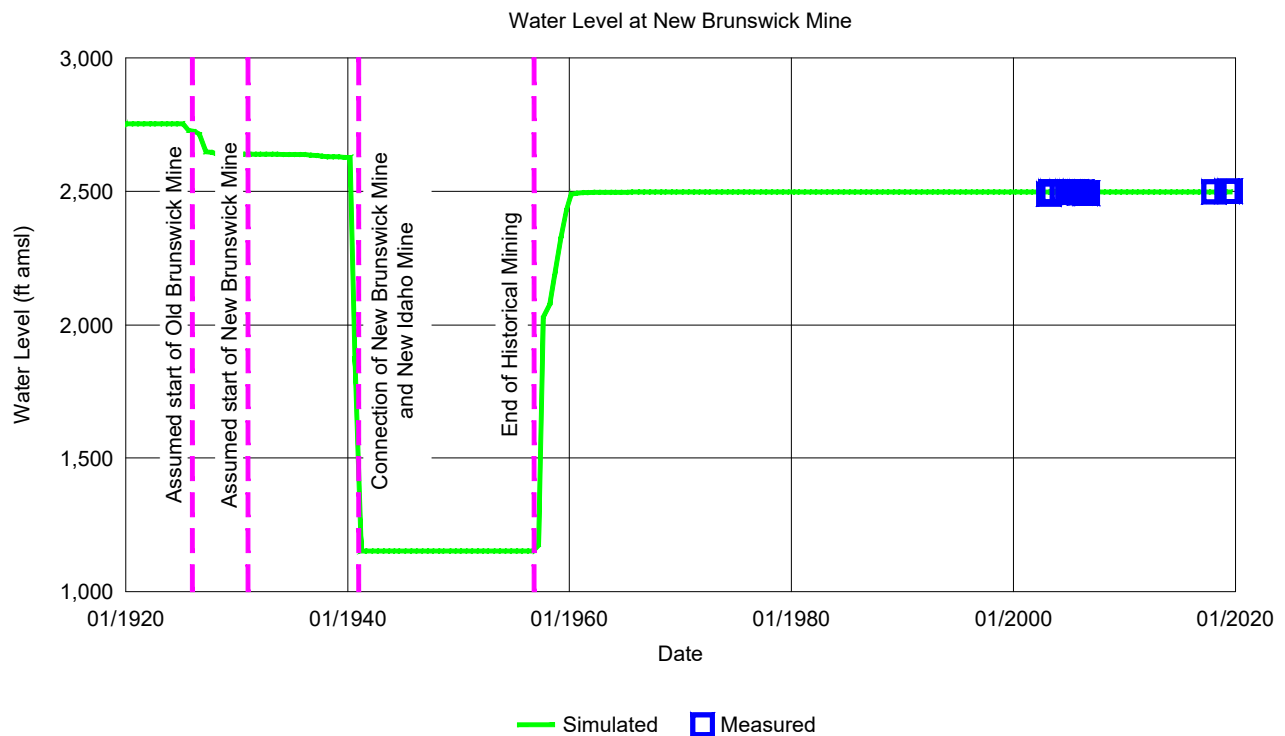
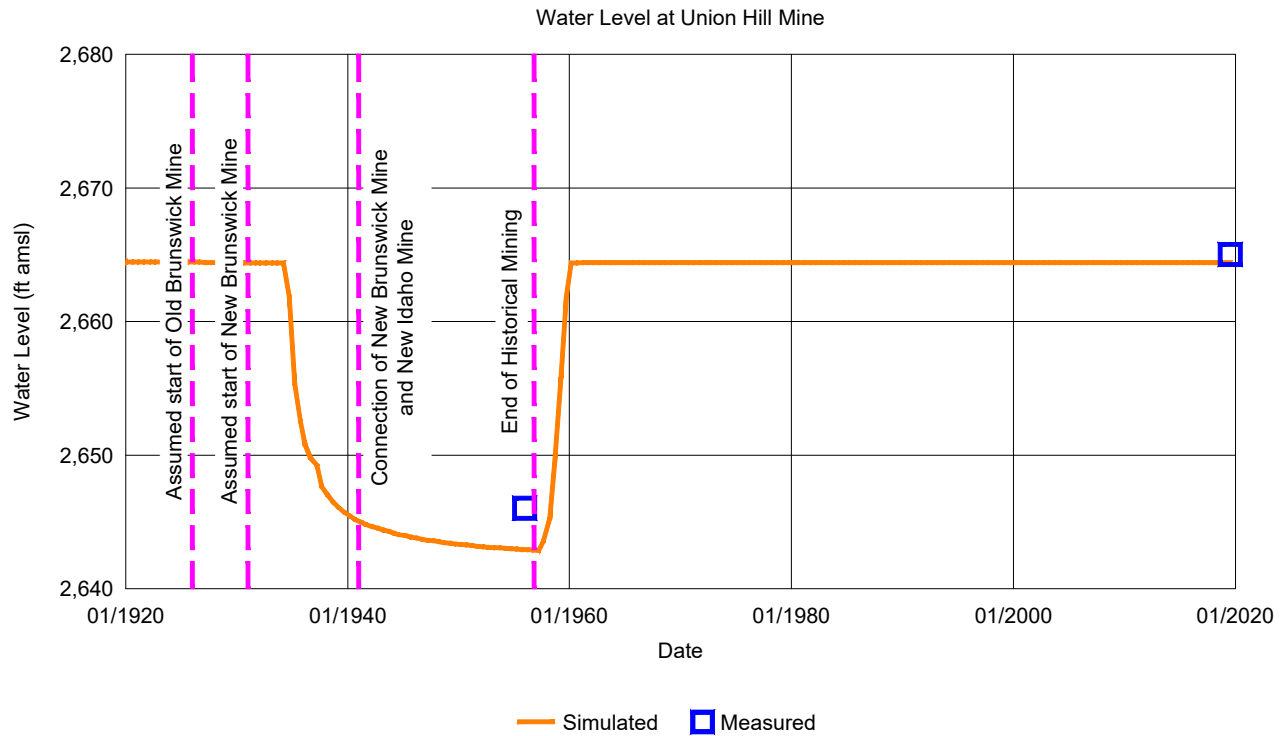
|               |             |
|---------------|-------------|
| PROJECT NO.   | 4091-19     |
| BY            | DD          |
| CHECKED       | HL          |
| DRAWN         | RJN         |
| DRAWING NAME  | FLOW        |
| DRAWING DATE  | 27 FEB 2020 |
| REVISION DATE |             |



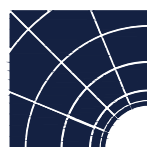
Simulated and Measured Flow Rates  
for the Historical Mines

CLIENT:  
Rise Grass Valley Inc.

FIGURE NO.  
4-6



|               |             |
|---------------|-------------|
| PROJECT NO.   | 4091-19     |
| BY            | DD          |
| CHECKED       | BTH         |
| DRAWN         | RJN         |
| DRAWING NAME  | UNION       |
| DRAWING DATE  | 27 FEB 2020 |
| REVISION DATE |             |

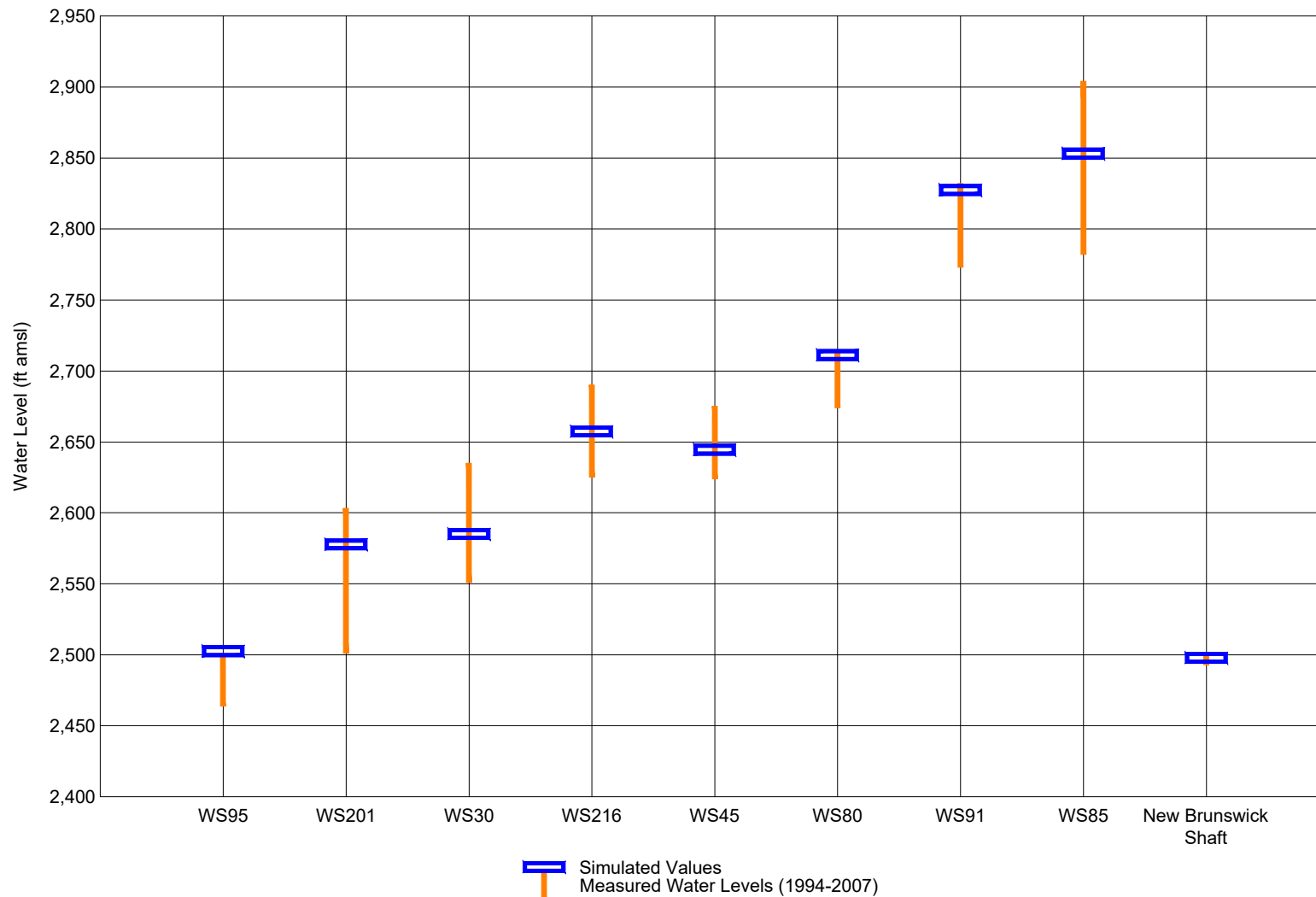


**ITASCA**<sup>™</sup>  
Denver, Inc.

### Simulated and Measured Water Levels at the Union Hill Mine and New Brunswick Mine

CLIENT:  
**Rise Grass Valley Inc.**

FIGURE NO.  
**4-7**



NOTE:

- 1) Measured water levels in the New Brunswick Shaft are from 2003-2019.
- 2) Locations of wells are shown in Figure 2-6.

|               |             |
|---------------|-------------|
| PROJECT NO.   | 4091-19     |
| BY            | DD          |
| CHECKED       | HL          |
| DRAWN         | RJN         |
| DRAWING NAME  | DOMESTIC    |
| DRAWING DATE  | 27 FEB 2020 |
| REVISION DATE |             |

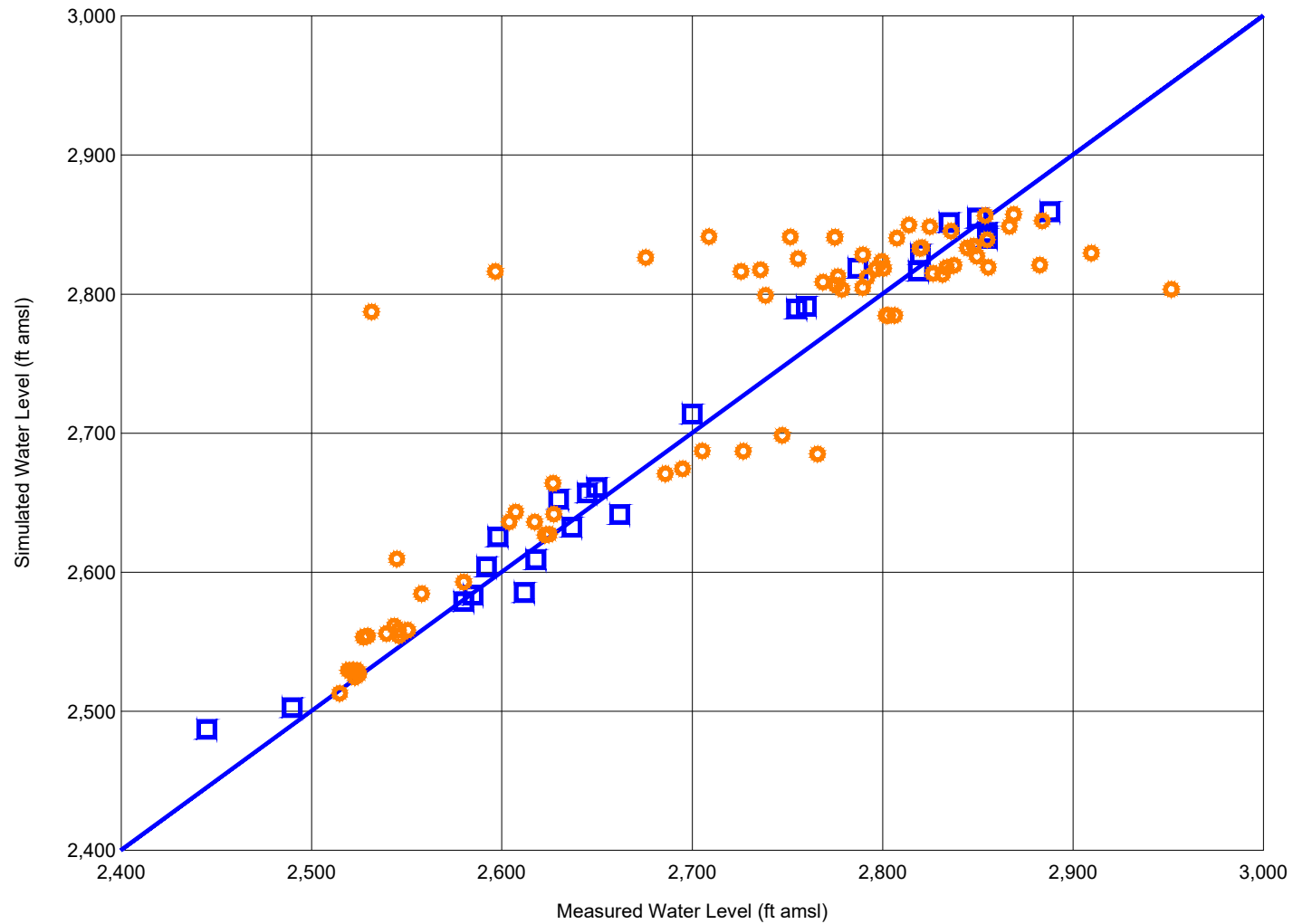


**ITASCA**<sup>TM</sup>  
Denver, Inc.

### Water Levels at Selected Domestic Wells and Shaft in the Mine Area

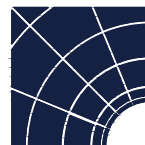
CLIENT:  
Rise Grass Valley Inc.

FIGURE NO.  
4-8



○ From Well Completion Reports    □ Wells with Hydrographs from Todd (2007)

|               |             |
|---------------|-------------|
| PROJECT NO.   | 4091-19     |
| BY            | DD          |
| CHECKED       | HL          |
| DRAWN         | RJN         |
| DRAWING NAME  | HIST        |
| DRAWING DATE  | 27 FEB 2020 |
| REVISION DATE |             |

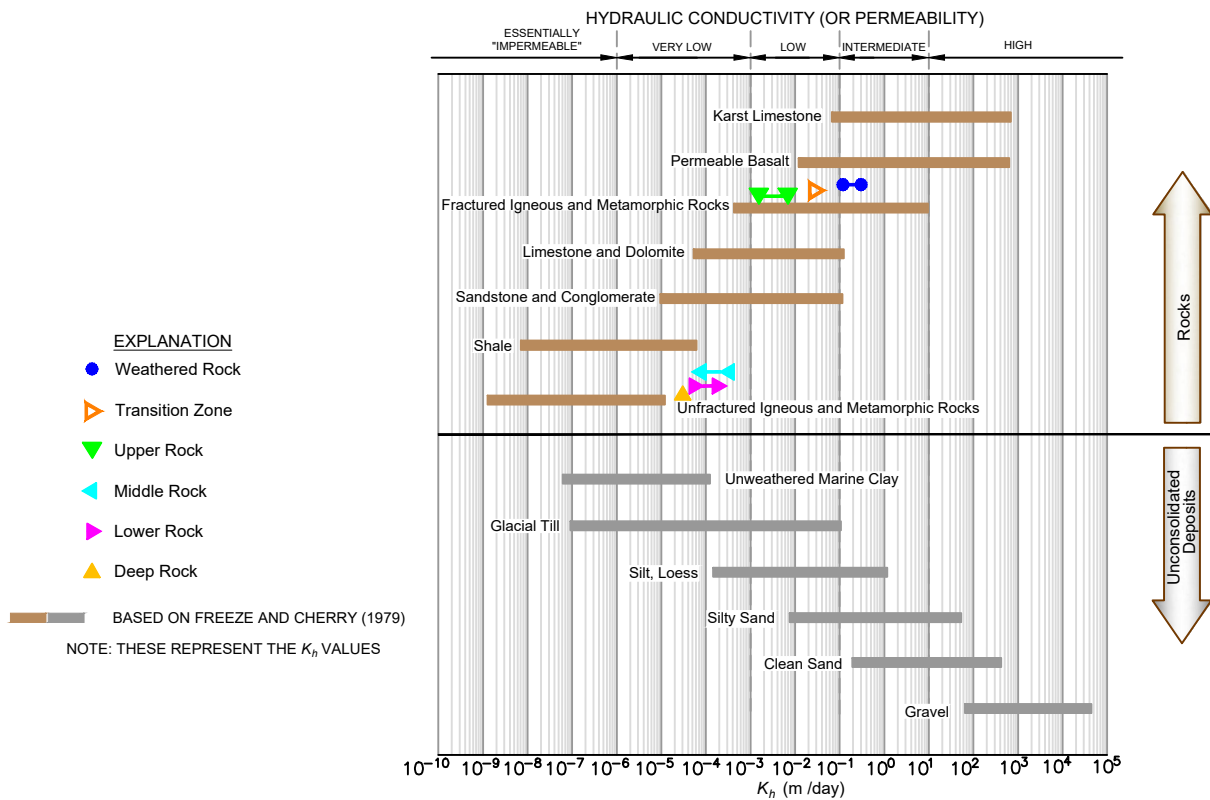


**ITASCA**<sup>™</sup>  
Denver, Inc.

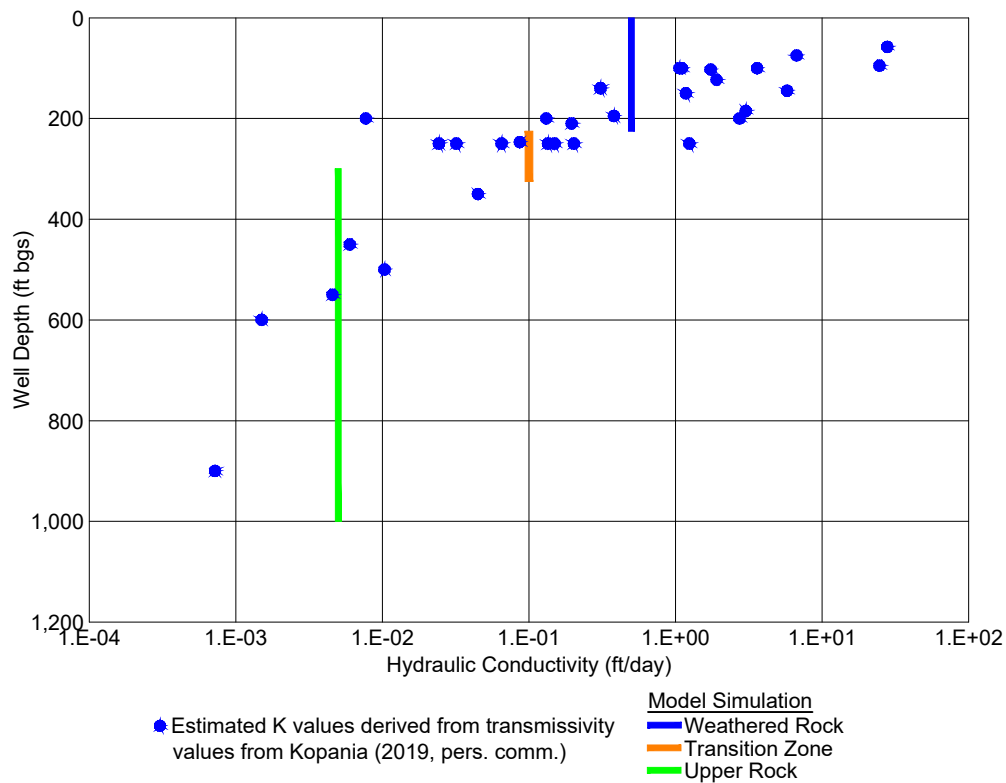
Simulated and Measured Groundwater Levels  
under Current Condition (as of 2019)

CLIENT:  
Rise Grass Valley Inc.

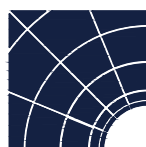
FIGURE NO.  
4-9



Source: Freeze and Cherry (1979)



|               |             |
|---------------|-------------|
| PROJECT NO.   | 4091-19     |
| BY            | DD          |
| CHECKED       | HL          |
| DRAWN         | RJN         |
| DRAWING NAME  | COMP        |
| DRAWING DATE  | 27 FEB 2020 |
| REVISION DATE |             |

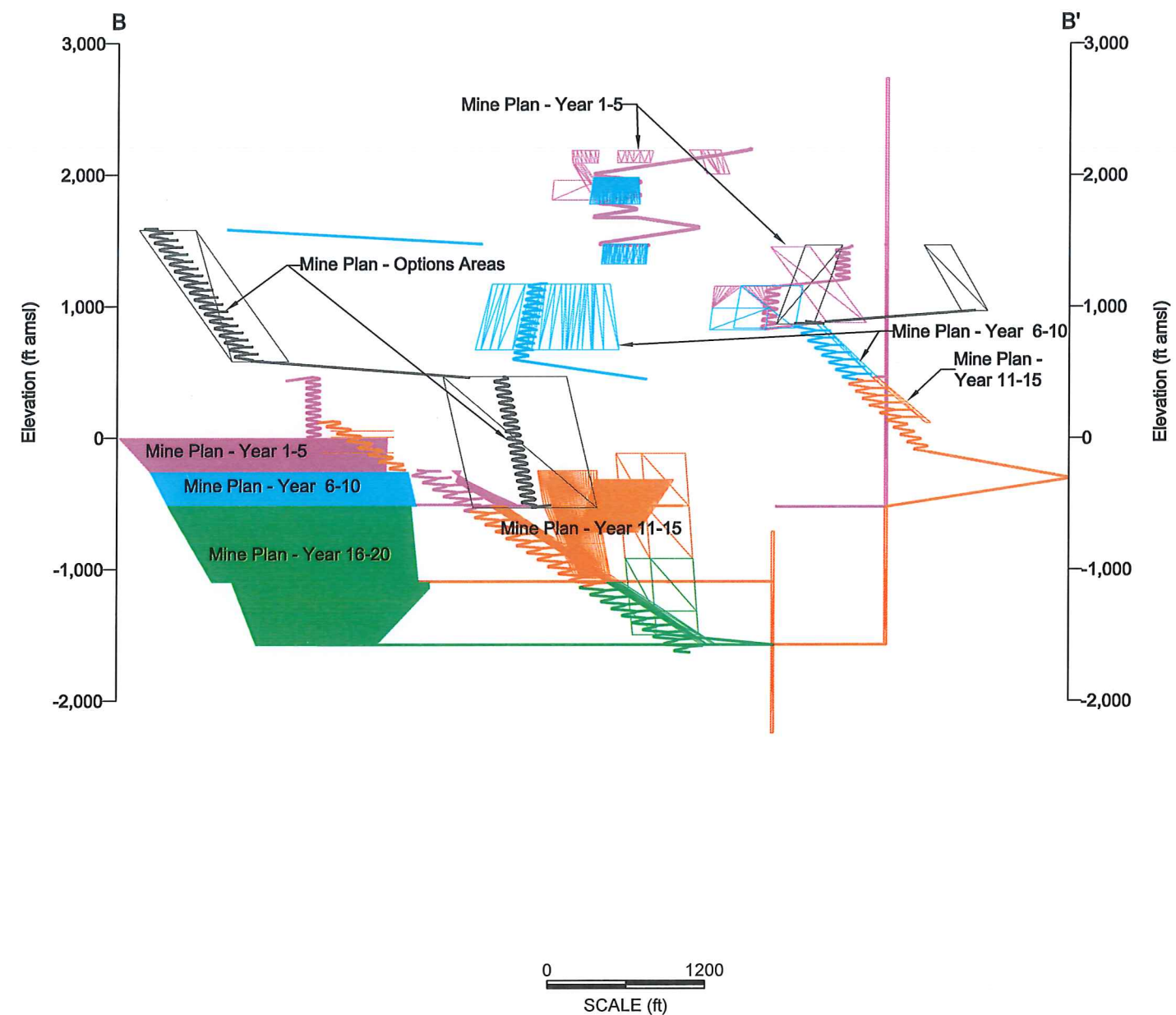
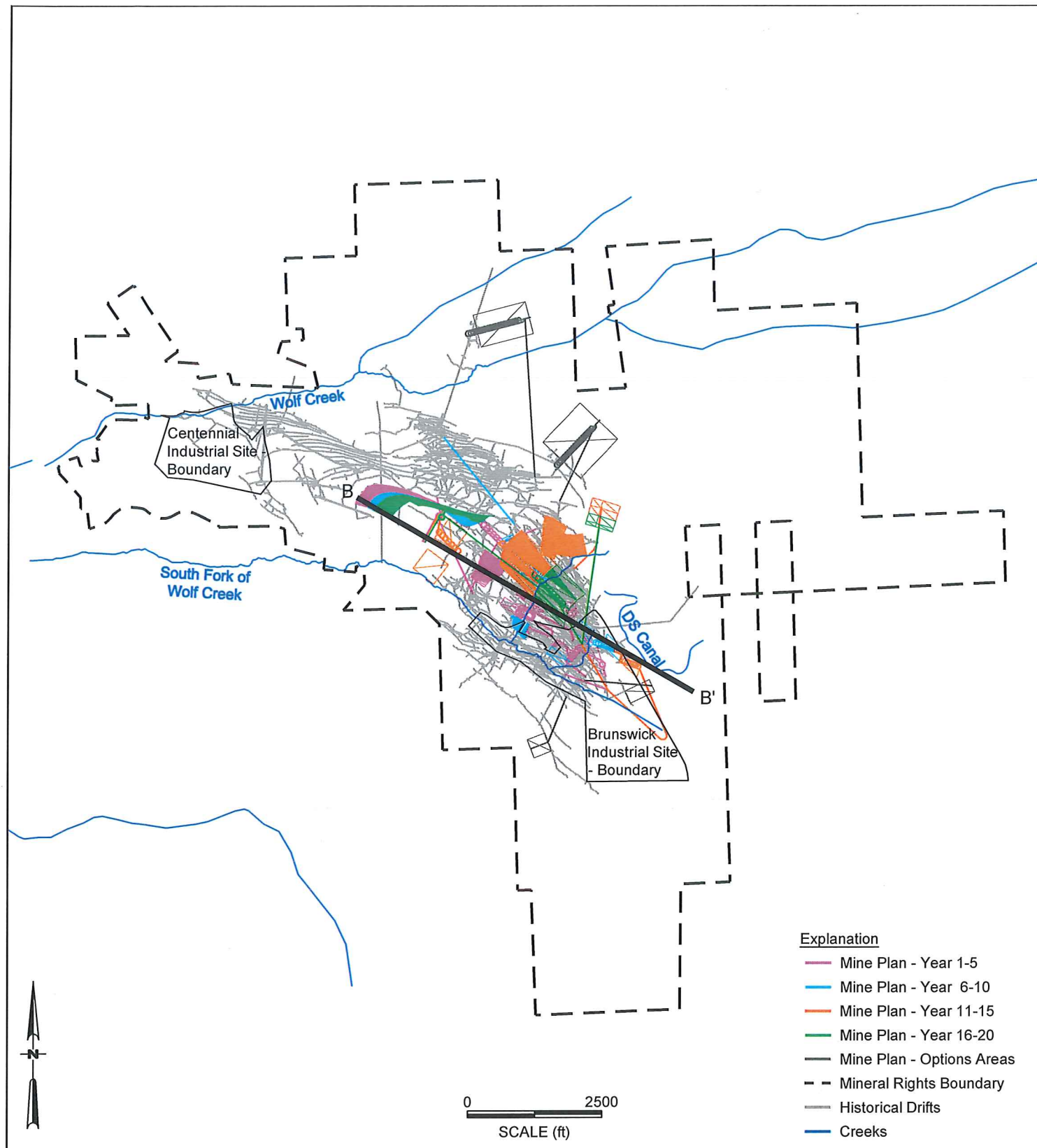


**ITASCA**<sup>™</sup>  
Denver, Inc.

Comparison of Hydraulic Conductivities in  
Model Simulation with Estimated Hydraulic  
Conductivity Values

CLIENT:  
Rise Grass Valley Inc.

FIGURE NO.  
4-10



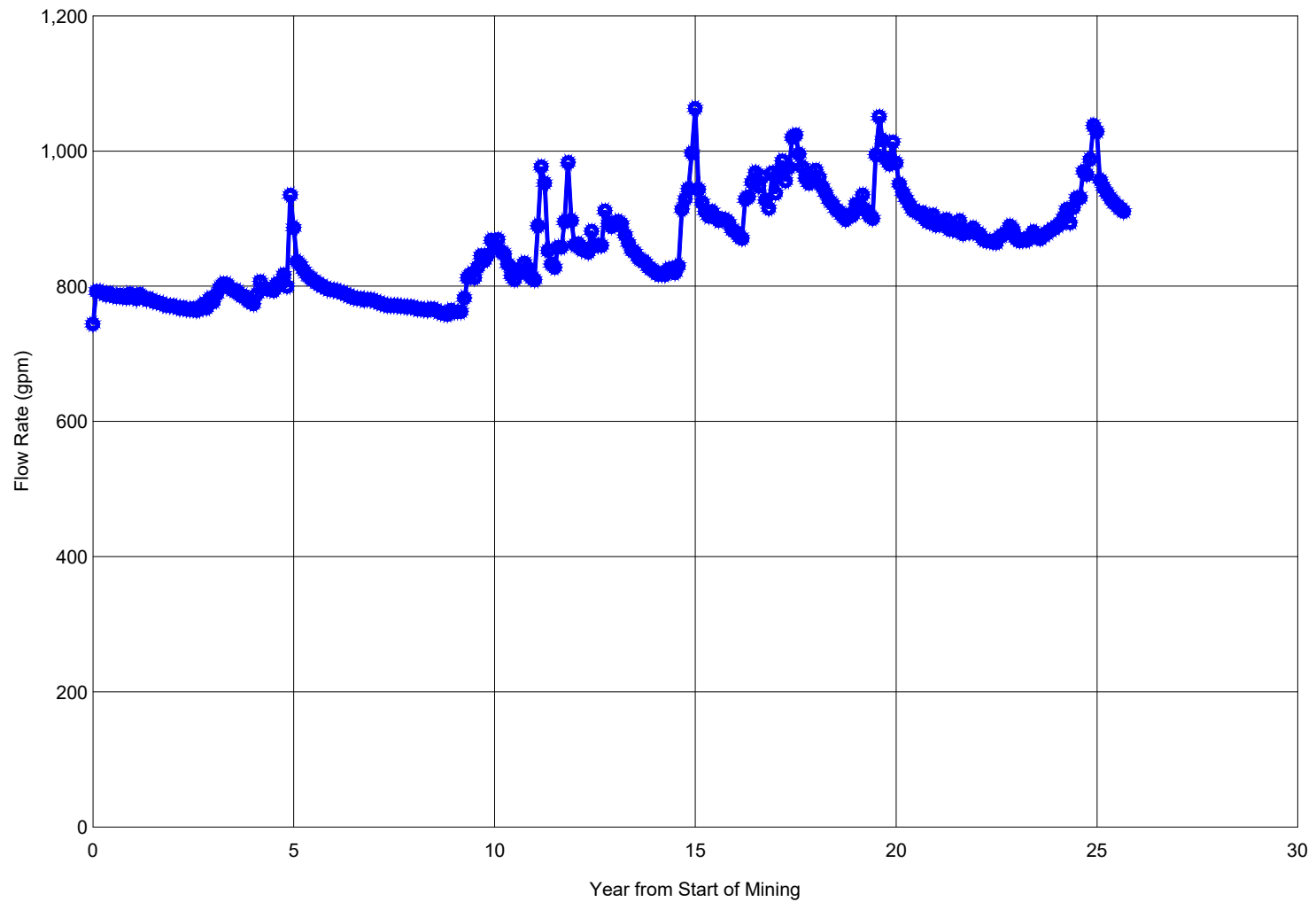
|               |             |
|---------------|-------------|
| PROJECT NO.   | 4091-19     |
| BY            | DD          |
| CHECKED       | HL          |
| DRAWN         | RJN         |
| DRAWING NAME  | EXTENT      |
| DRAWING DATE  | 27 FEB 2020 |
| REVISION DATE |             |



Plan View and Cross-Section View of the  
Future Mine Plan

CLIENT:  
Rise Grass Valley Inc.

FIGURE NO.  
5-1



|               |             |
|---------------|-------------|
| PROJECT NO.   | 4091-19     |
| BY            | DD          |
| CHECKED       | HL          |
| DRAWN         | RJN         |
| DRAWING NAME  | INFLOW      |
| DRAWING DATE  | 27 FEB 2020 |
| REVISION DATE |             |

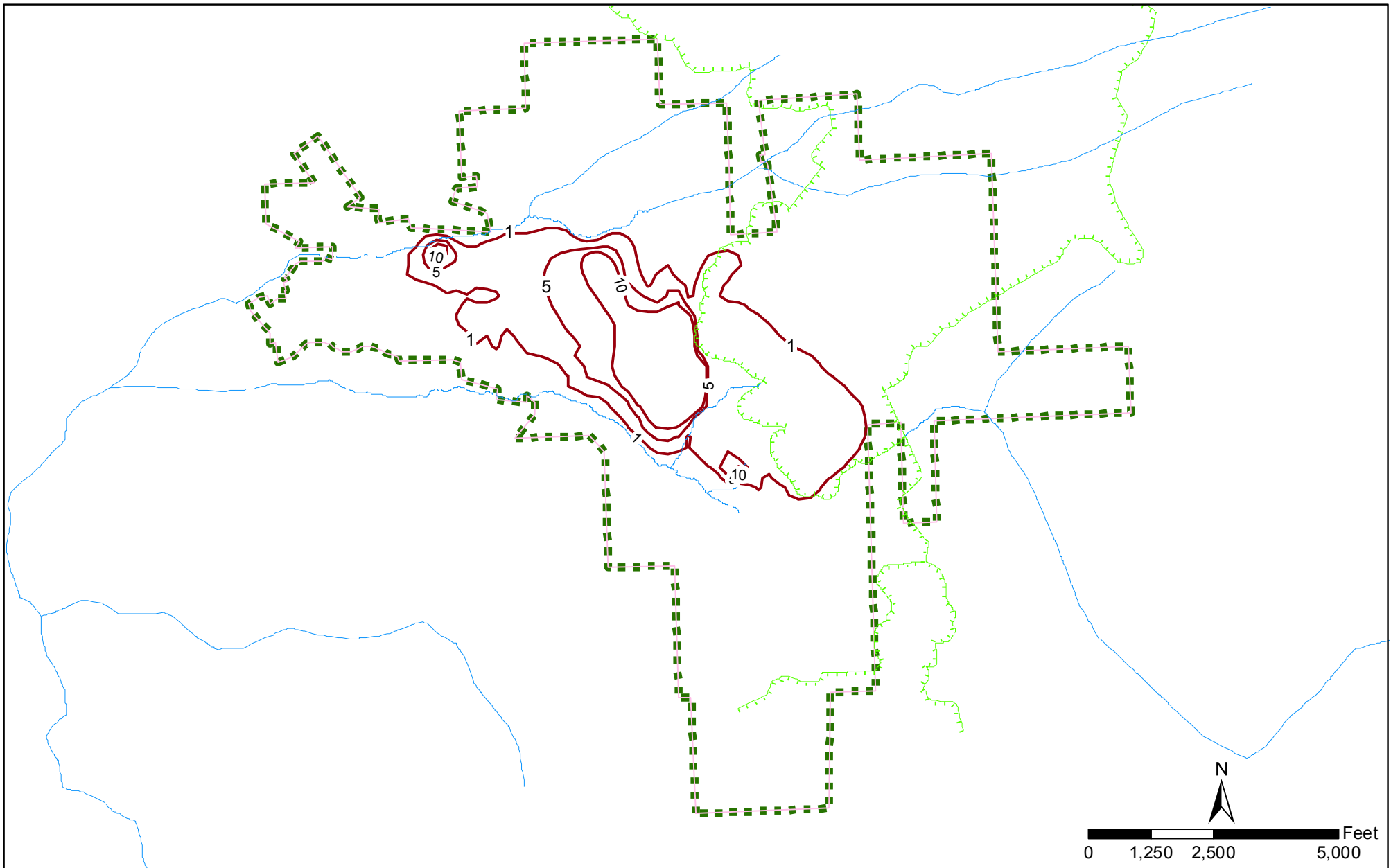


**ITASCA**<sup>™</sup>  
Denver, Inc.

Predicted Inflow Rates to the Mine Workings  
during Future Mining

CLIENT:  
Rise Grass Valley Inc.

FIGURE NO.  
5-2



### Legend

- NID Canals
- Creeks
- Drawdown as of 2019 (ft)
- Mineral Rights Boundary

|               |                        |
|---------------|------------------------|
| PROJECT NO.   | 4091                   |
| BY            | DD                     |
| CHECKED       | HL                     |
| DRAWN         | DD                     |
| DRAWING NAME  | Figure 5-3 2019 Impact |
| DRAWING DATE  | Feb. 26, 2020          |
| REVISION DATE |                        |



**ITASCA**  
Denver, Inc.

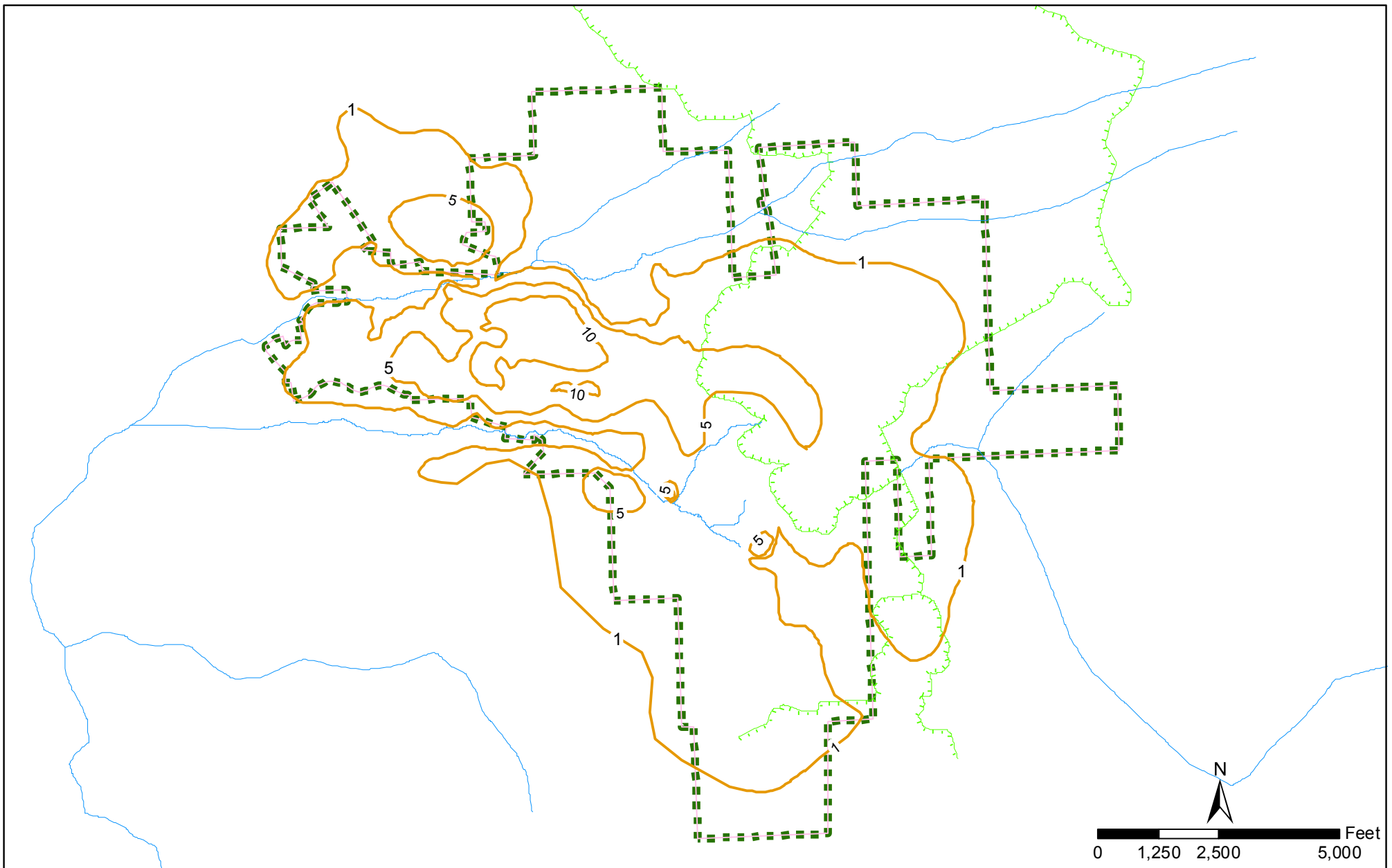
### Simulated Drawdown of Groundwater Levels under Current Condition Relative to Pre-Historical-Mining Condition

CLIENT:

Rise Grass Valley Inc.

FIGURE NO.

5-3



### Legend

- Drawdown (ft) - End of Future Mining
- - - NID Canals
- Creeks
- - - Mineral Rights Boundary

|               |                     |
|---------------|---------------------|
| PROJECT NO.   | 4091                |
| BY            | DD                  |
| CHECKED       | HL                  |
| DRAWN         | DD                  |
| DRAWING NAME  | Figure 5-4 EOM-2019 |
| DRAWING DATE  | Feb. 26, 2020       |
| REVISION DATE |                     |



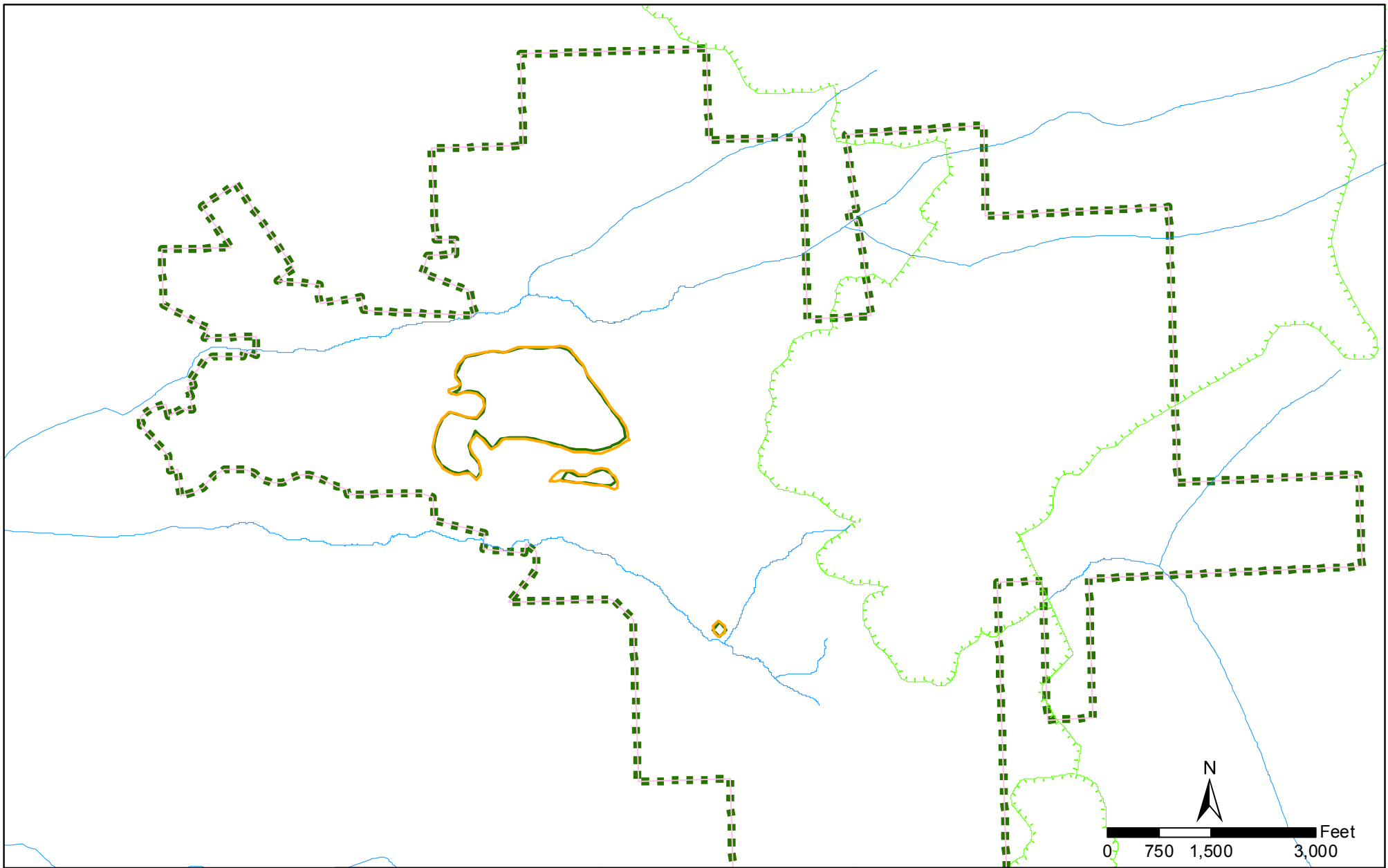
### Simulated Drawdown of Groundwater Levels at the End of Future Mining Relative to 2019 Water Level

CLIENT:

Rise Grass Valley Inc.

FIGURE NO.

5-4



- Legend**
- After 10 Years of Future Mining
  - End of Future Mining (25 Years)
  - ⋯ NID Canals
  - Creeks
  - - - Mineral Rights Boundary

|               |                  |
|---------------|------------------|
| PROJECT NO.   | 4091             |
| BY            | DD               |
| CHECKED       | HL               |
| DRAWN         | DD               |
| DRAWING NAME  | Figure 5-5 10-ft |
| DRAWING DATE  | Feb. 26, 2020    |
| REVISION DATE |                  |



**ITASCA**  
Denver, Inc.

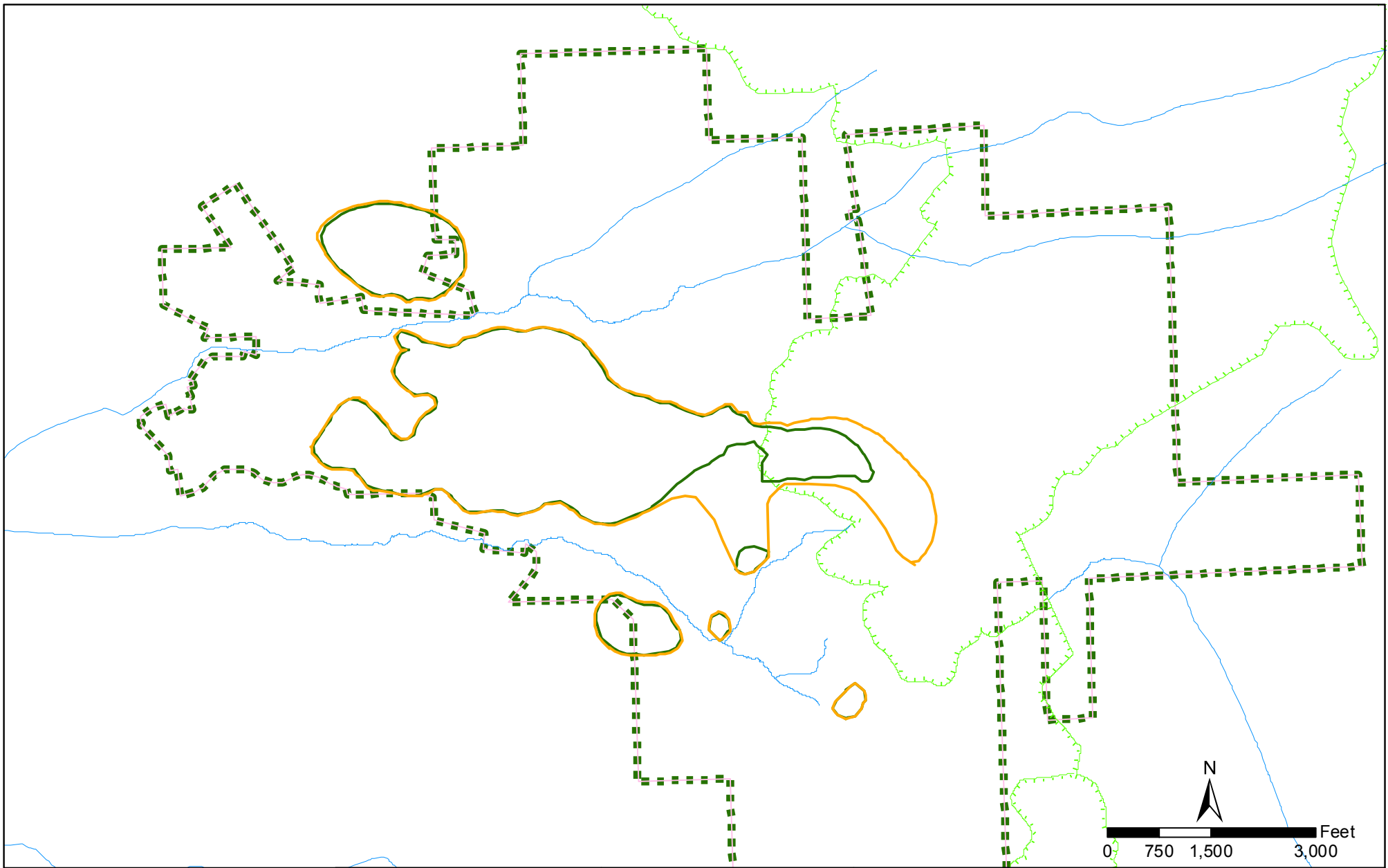
### Simulated 10-Foot Groundwater Drawdown Contours at Different Times Relative to 2019 Water Level

CLIENT:

Rise Grass Valley Inc.

FIGURE NO.

**5-5**



- Legend**
- After 10 Years of Future Mining
  - End of Future Mining (25 Years)
  - ⋯ NID Canals
  - Creeks
  - - - Mineral Rights Boundary

|               |                 |
|---------------|-----------------|
| PROJECT NO.   | 4091            |
| BY            | DD              |
| CHECKED       | HL              |
| DRAWN         | DD              |
| DRAWING NAME  | Figure 5-6 5-ft |
| DRAWING DATE  | Feb. 26, 2020   |
| REVISION DATE |                 |



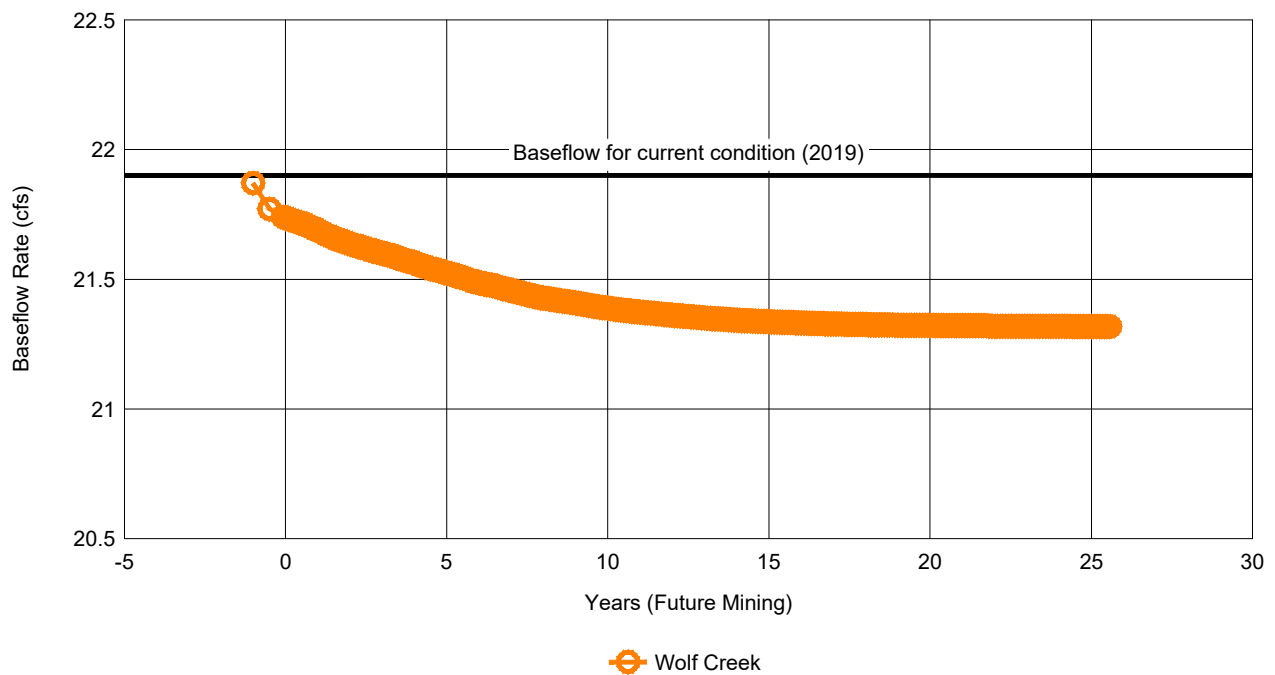
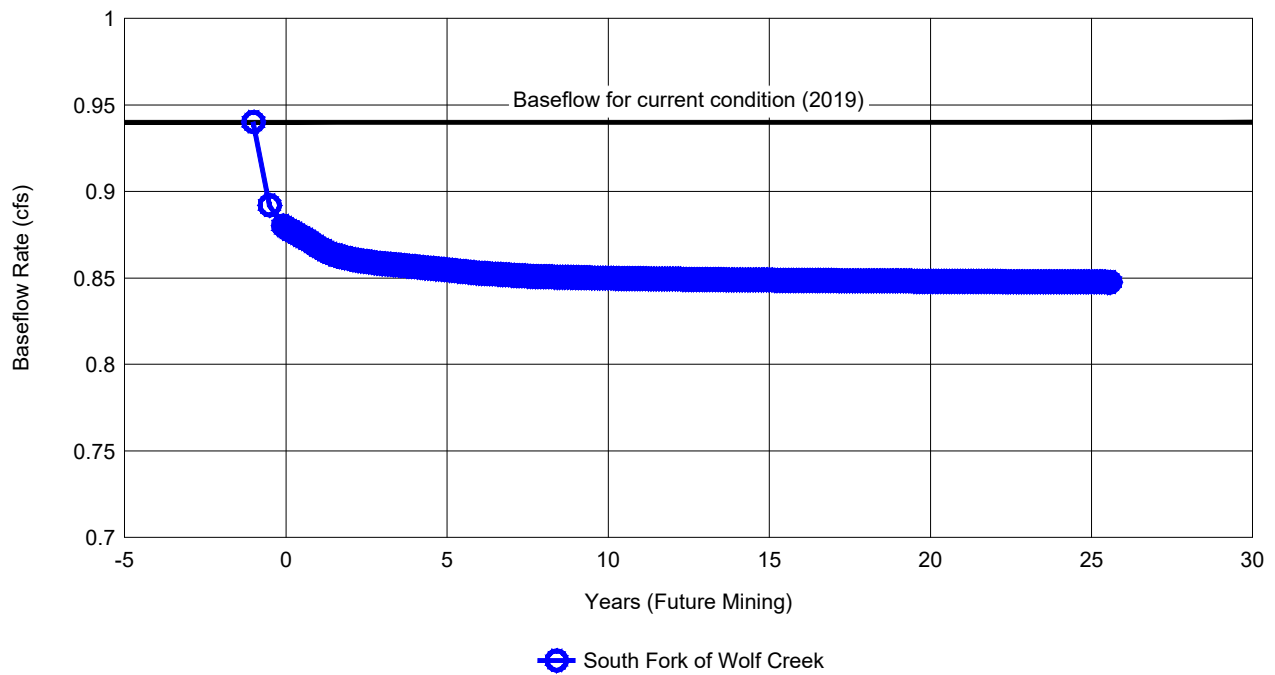
# Simulated 5-Foot Groundwater Drawdown Contours at Different Times Relative to 2019 Water Level

CLIENT:

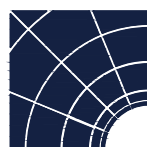
Rise Grass Valley Inc.

FIGURE NO.

5-6



|               |             |
|---------------|-------------|
| PROJECT NO.   | 4091-19     |
| BY            | DD          |
| CHECKED       | HL          |
| DRAWN         | RJN         |
| DRAWING NAME  | BASE        |
| DRAWING DATE  | 27 FEB 2020 |
| REVISION DATE |             |

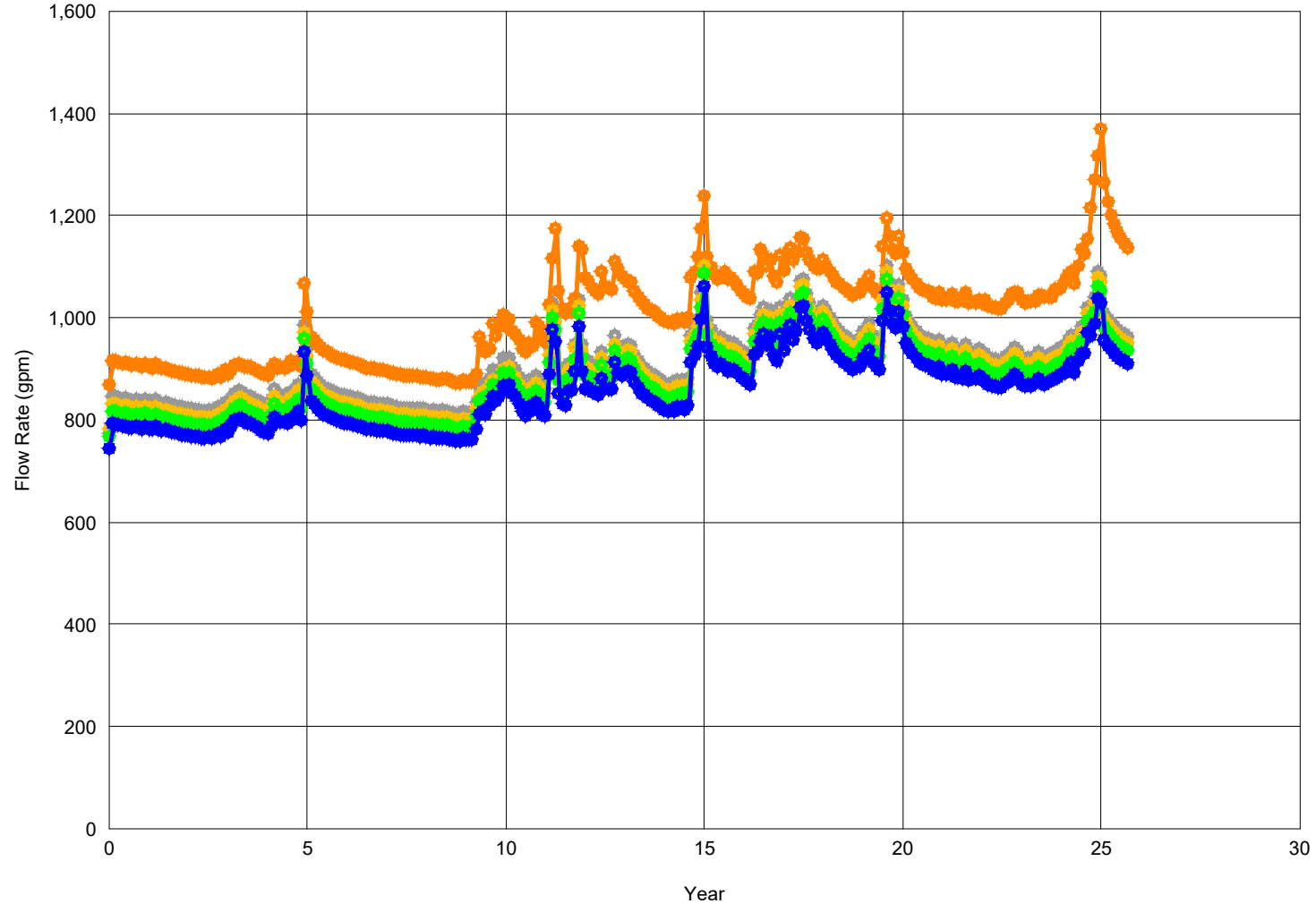


**ITASCA**<sup>TM</sup>  
Denver, Inc.

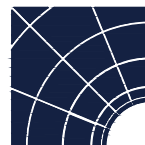
Change of Baseflow Rates in the South Fork of  
Wolf Creek and Wolf Creek over the  
Life of the Mine

CLIENT:  
Rise Grass Valley Inc.

FIGURE NO.  
5-7



|               |             |
|---------------|-------------|
| PROJECT NO.   | 4091-19     |
| BY            | DD          |
| CHECKED       | HL          |
| DRAWN         | RJN         |
| DRAWING NAME  | SENS        |
| DRAWING DATE  | 27 FEB 2020 |
| REVISION DATE |             |

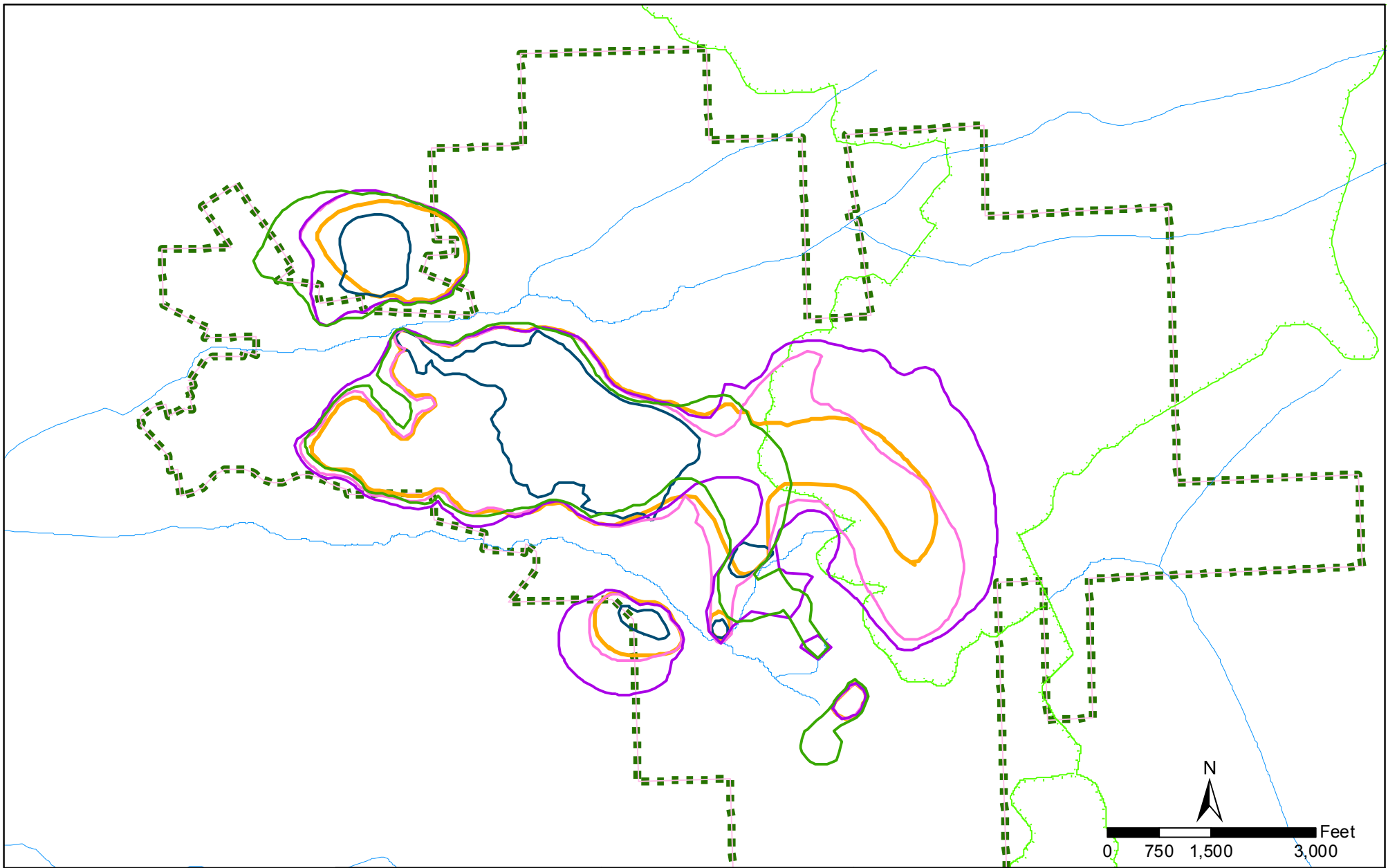


**ITASCA**<sup>™</sup>  
Denver, Inc.

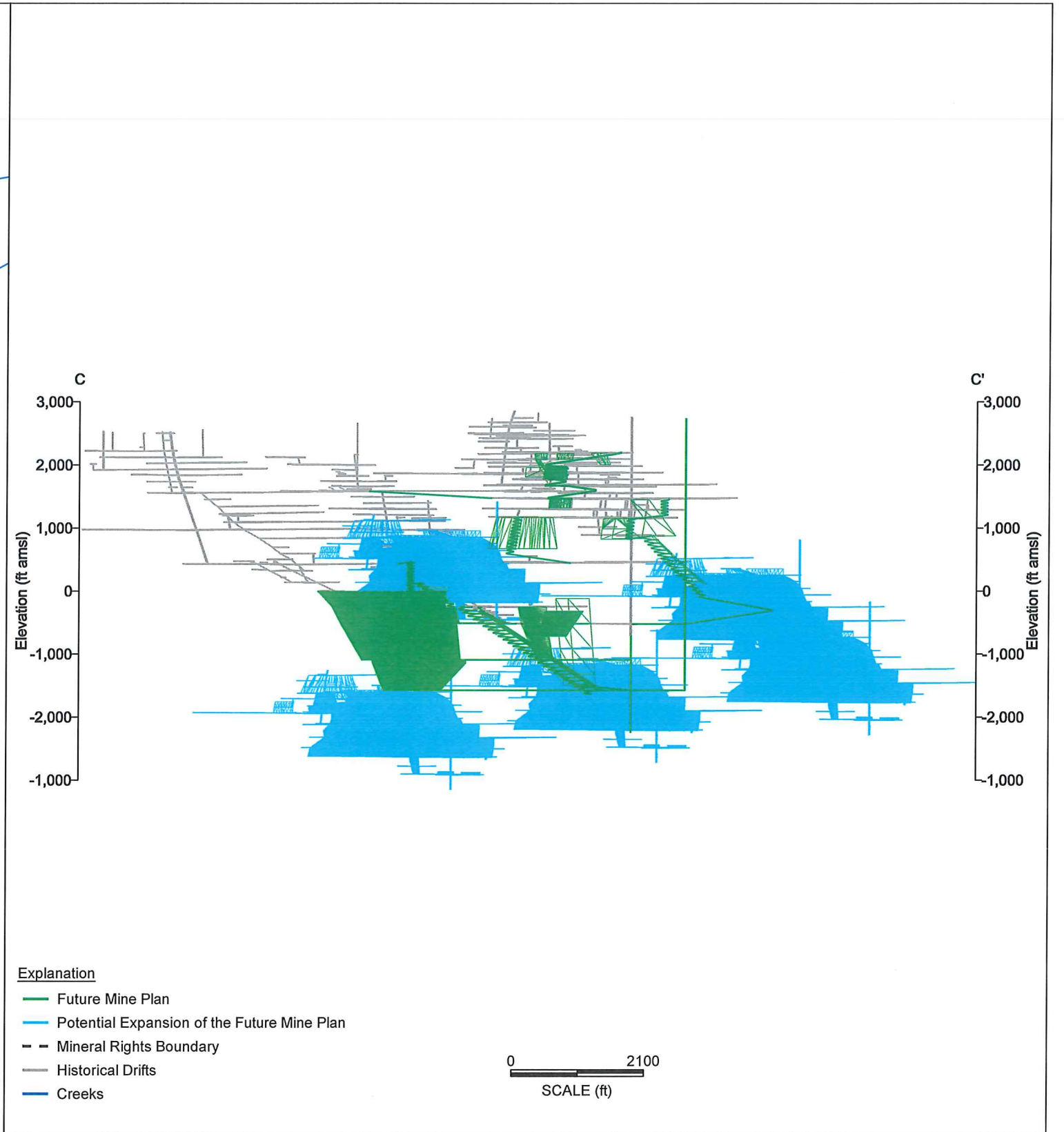
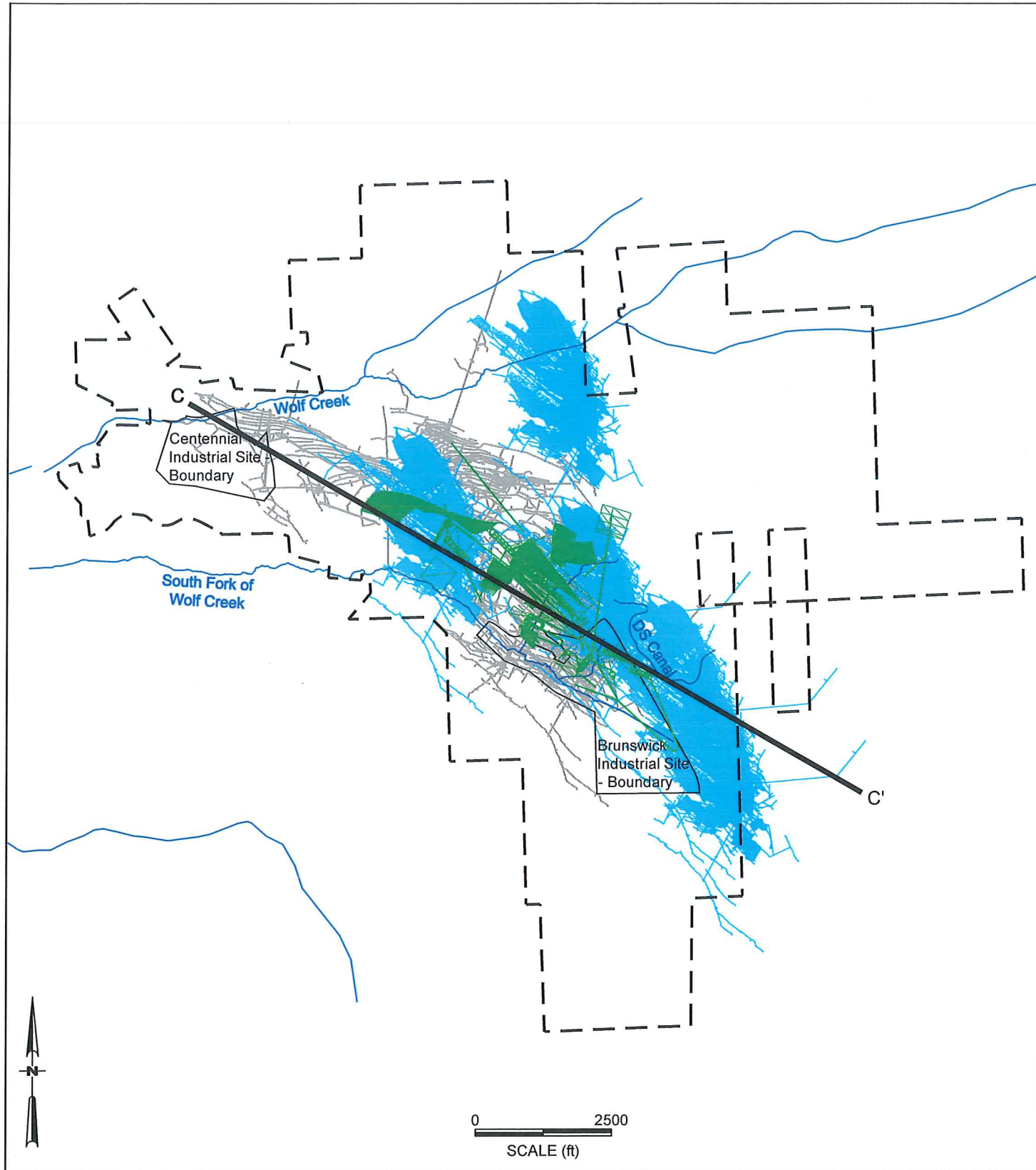
### Predicted Groundwater Inflows to the Mine Workings under Sensitivity Scenarios

CLIENT:  
Rise Grass Valley Inc.

FIGURE NO.  
5-8



|                                                                                                                                                                                                                                        |               |                 |                                                                                      |                                                                                                                                   |  |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|-----------------|--------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|--|
| <b>Legend</b><br><br><div> <div>Scenario 1</div> <div>Scenario 2</div> <div>Scenario 3</div> <div>Scenario 4</div> <div>Base-Case</div> </div> <div> <div>NID Canals</div> <div>Creeks</div> <div>Mineral Rights Boundary</div> </div> | PROJECT NO.   | 4091            |  | <b>Simulated 5-Foot Groundwater Drawdown Contours for Sensitivity Scenarios at the End of Mining Relative to 2019 Water Level</b> |  |
|                                                                                                                                                                                                                                        | BY            | DD              |                                                                                      |                                                                                                                                   |  |
|                                                                                                                                                                                                                                        | CHECKED       | HL              |                                                                                      |                                                                                                                                   |  |
|                                                                                                                                                                                                                                        | DRAWN         | DD              |                                                                                      | CLIENT:                                                                                                                           |  |
|                                                                                                                                                                                                                                        | DRAWING NAME  | Figure 5-9 Sens |                                                                                      | Rise Grass Valley Inc.                                                                                                            |  |
|                                                                                                                                                                                                                                        | DRAWING DATE  | Feb. 26, 2020   |                                                                                      | FIGURE NO.                                                                                                                        |  |
|                                                                                                                                                                                                                                        | REVISION DATE |                 |                                                                                      | 5-9                                                                                                                               |  |



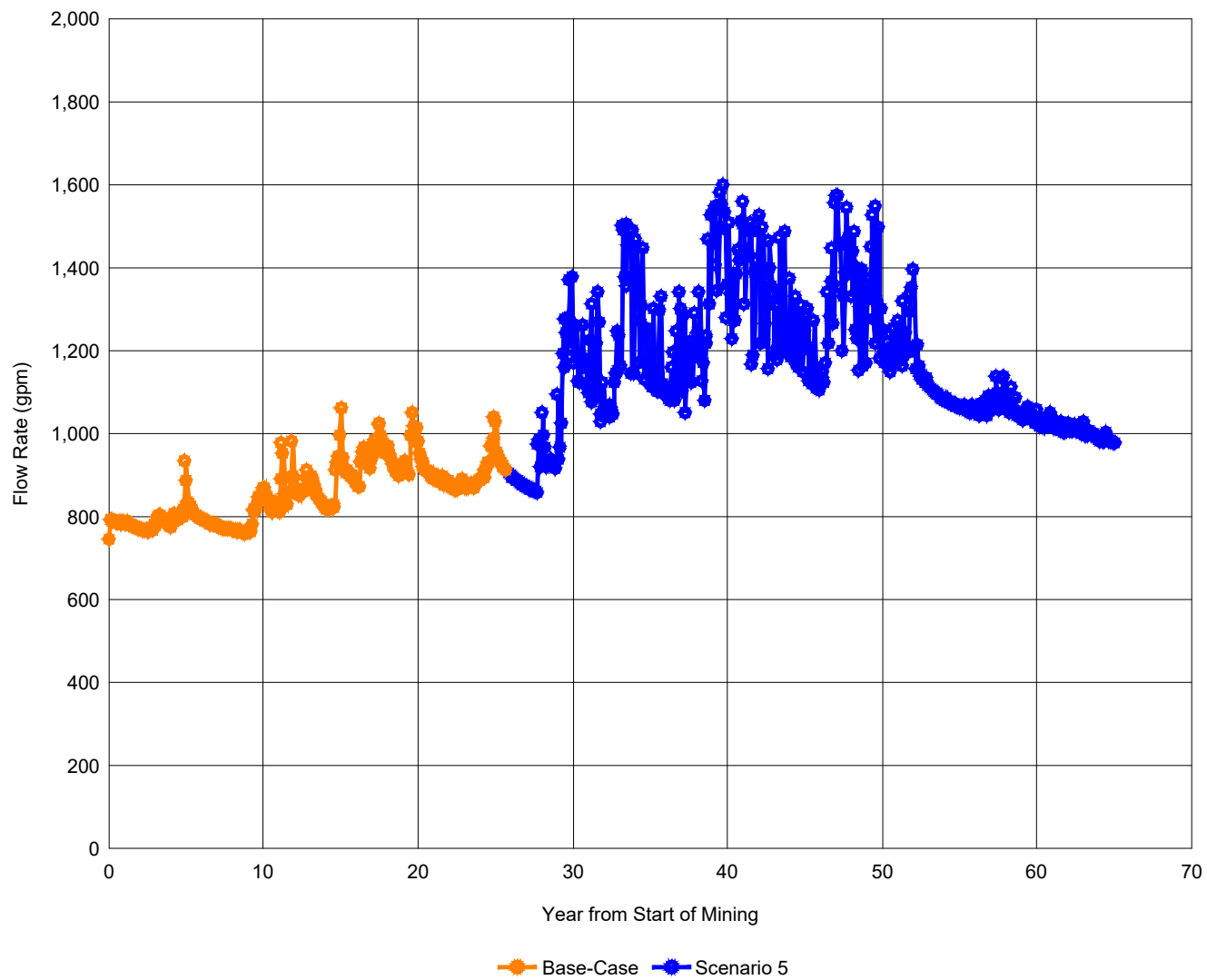
**Explanation**

- Future Mine Plan
- Potential Expansion of the Future Mine Plan
- - Mineral Rights Boundary
- Historical Drifts
- Creeks

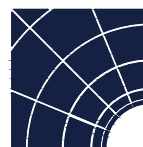
|               |             |
|---------------|-------------|
| PROJECT NO.   | 4091-19     |
| BY            | DD          |
| CHECKED       | HL          |
| DRAWN         | RJN         |
| DRAWING NAME  | MINEPLAN    |
| DRAWING DATE  | 27 FEB 2020 |
| REVISION DATE |             |



|                                                                                     |                 |
|-------------------------------------------------------------------------------------|-----------------|
| Plan View and Cross-Section View of the Potential Expansion of the Future Mine Plan |                 |
| CLIENT: Rise Grass Valley Inc.                                                      | FIGURE NO. 5-10 |



|               |             |
|---------------|-------------|
| PROJECT NO.   | 4091-19     |
| BY            | DD          |
| CHECKED       | HL          |
| DRAWN         | RJN         |
| DRAWING NAME  | S5          |
| DRAWING DATE  | 27 FEB 2020 |
| REVISION DATE |             |

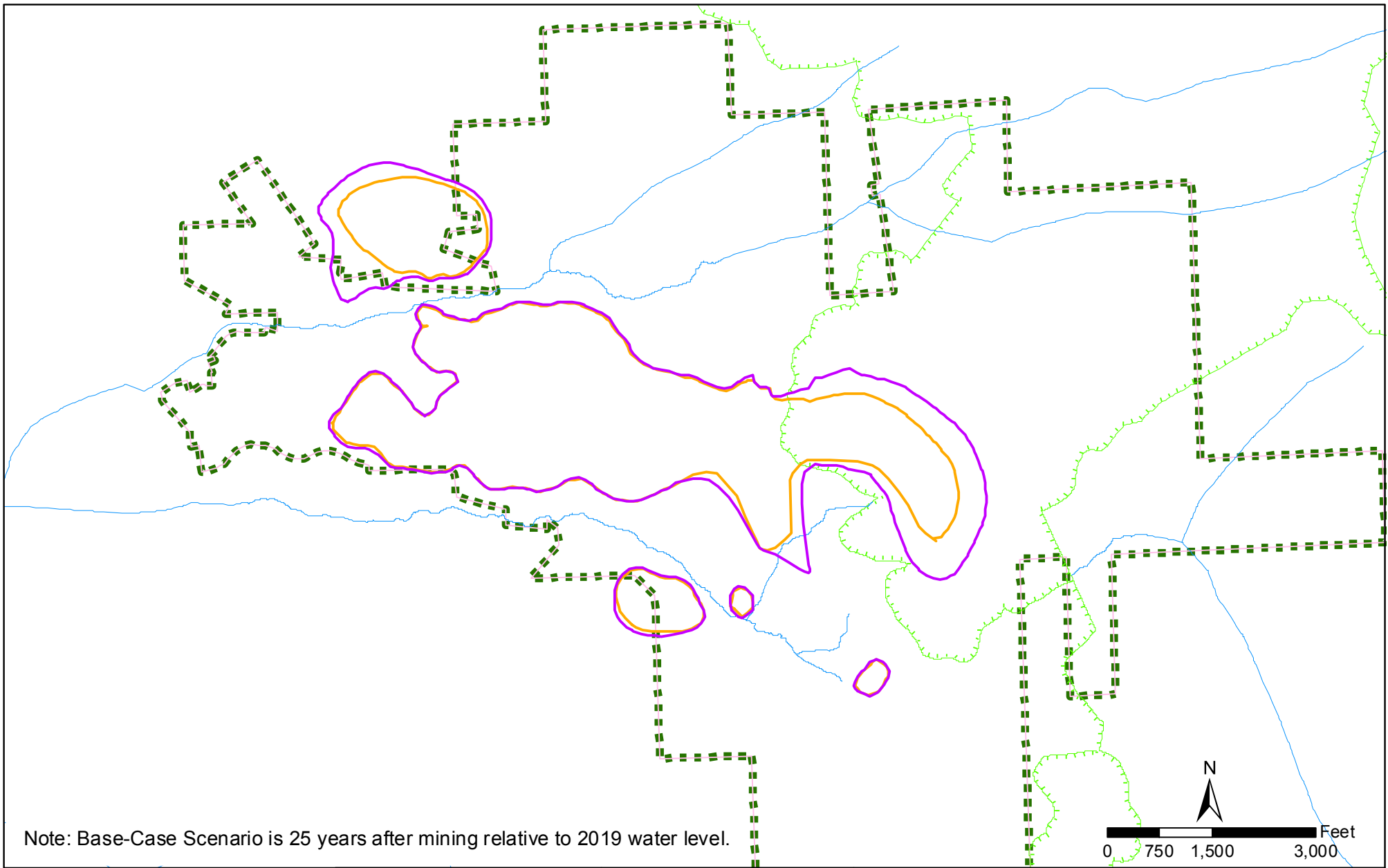


**ITASCA**<sup>TM</sup>  
Denver, Inc.

Predicted Groundwater Inflows to the Mine  
Workings of the Potential Expansion of  
Future Mining

CLIENT:  
Rise Grass Valley Inc.

FIGURE NO.  
5-11



Note: Base-Case Scenario is 25 years after mining relative to 2019 water level.

- Legend**
- Scenario 5
  - Base-Case
  - NID Canals
  - Creeks
  - Mineral Rights Boundary

|               |                  |
|---------------|------------------|
| PROJECT NO.   | 4091             |
| BY            | DD               |
| CHECKED       | HL               |
| DRAWN         | DD               |
| DRAWING NAME  | Figure 5-12 S5-5 |
| DRAWING DATE  | Feb. 27, 2020    |
| REVISION DATE |                  |



Simulated 5-Foot Groundwater Drawdown Contour  
at the End of the Potential Expansion of Future  
Mining (Year 65) Relative to 2019 Water Level

CLIENT:

Rise Grass Valley Inc.

FIGURE NO.

5-12

TABLE 2-1

**Elevations, Mine Lives, and Measured Flow Rates of the Historical Mines**

| Mine          | Elevation<br>(ft amsl) |       | Mine Life<br>(Year) |       | Flow Rate<br>(gpm) |       |         |
|---------------|------------------------|-------|---------------------|-------|--------------------|-------|---------|
|               | Bottom                 | Top   | Start               | Close | From               | To    | Average |
| Union Hill    | 1,619                  | 2,737 | NA                  | 1918  | NA                 | NA    | NA      |
| Old Idaho     | 317                    | 2,557 | 1863                | 1914  | 250                | 500   | 290     |
| Old Brunswick | 1,675                  | 2,855 | 1880                | 1915  | NA                 | NA    | NA      |
| New Brunswick | -709                   | 2,452 | 1933                | 1956  | 500                | 1,200 | 680     |
| New Idaho     | -384                   | 2,665 | 1919                | 1956  |                    |       |         |

Note:

NA = not available

TABLE 2-2

**Information and Average Measured Water Levels at Domestic Wells**  
(Page 1 of 2)

| Rise Well ID | EIR 1995 Well ID | Todd 2007 Well ID <sup>1</sup> | Easting (ft) | Northing (ft) | Top Elevation of Well (ft amsl) | Well Depth (ft bgs) | Screen From (ft bgs) | Screen To (ft bgs) | Measured Water Level (ft amsl) | Measurement Date/Year | Used for Pre-Historical-Mining Simulation <sup>2</sup> |
|--------------|------------------|--------------------------------|--------------|---------------|---------------------------------|---------------------|----------------------|--------------------|--------------------------------|-----------------------|--------------------------------------------------------|
| W129         |                  | WN0323                         | 6833687.6    | 2205996.0     | 2,515.0                         | 140.0               | 120.0                | 140.0              | 2,445.0                        | 2007                  | ✓                                                      |
| W130         | WS95             | WN0095                         | 6833754.9    | 2205729.1     | 2,510.0                         | 100.0               | 60.0                 | 100.0              | 2,490.0                        | 1994-2007             | ✓                                                      |
|              | WS90             | WN0090                         | 6836366.8    | 2206037.8     | 2,590.0                         | 72.0                |                      |                    | 2,585.0                        | 1994-2007             | ✓                                                      |
|              | WS125            | WN0125                         | 6836407.3    | 2206372.2     | 2,670.0                         | 120.0               |                      |                    | 2,592.0                        | 1994-2007             | ✓                                                      |
| W5           | WS30             | WN0030                         | 6835379.4    | 2206357.5     | 2,644.0                         | 230.0               |                      |                    | 2,612.0                        | 1995-2007             | ✓                                                      |
|              | WS236            | WN0236                         | 6836771.2    | 2205795.5     | 2,635.0                         | 199.0               |                      |                    | 2,618.0                        | 1994-2007             | ✓                                                      |
|              | WS216            | WN0216                         | 6837070.2    | 2206475.2     | 2,770.0                         | 199.0               |                      |                    | 2,645.0                        | 1995-2007             | ✓                                                      |
| W49          | WS93             | WN0093                         | 6841882.2    | 2203215.6     | 2,801.0                         | 400.0               | 42.0                 | 62.0               | 2,755.0                        | 1995-2007             | ✓                                                      |
| W48          | WS94             | WN0094                         | 6841891.5    | 2203199.1     | 2,801.0                         | 400.0               | 95.0                 | 115.0              | 2,760.0                        | 1995-2007             | ✓                                                      |
| W34          | WS6              | WN0006                         | 6841253.6    | 2201705.4     | 2,877.0                         | 250.0               | 0.0                  | 140.0              | 2,787.0                        | 1994-2006             | ✓                                                      |
| W47          | WS221            | WN0221                         | 6842139.7    | 2203948.8     | 2,818.0                         | 90.0                | 50.0                 | 90.0               | 2,819.0                        | 1995-2007             | ✓                                                      |
| W65          | WS91             | WN0091                         | 6842916.5    | 2204295.0     | 2,866.7                         | 500.0               | 160.0                | 180.0              | 2,820.0                        | 1996-2007             | ✓                                                      |
| W32          | WS7              | WN0007                         | 6841020.3    | 2200747.7     | 2,948.0                         | 350.0               | 110.0                | 130.0              | 2,835.0                        | 1994-2006             | ✓                                                      |
| W40          | WS85             | WN0085                         | 6840637.1    | 2200763.5     | 2,945.0                         | 175.0               | 40.0                 | 175.0              | 2,850.0                        | 1995-2007             | ✓                                                      |
| W31          | WS4              | WN0004                         | 6840027.6    | 2201813.2     | 2,932.0                         | 295.0               | 80.0                 | 150.0              | 2,855.0                        | 2006-2007             | ✓                                                      |
| W36          | WS21             | WN0021                         | 6840752.6    | 2201268.8     | 2,916.0                         | 325.0               | 90.0                 | 150.0              | 2,855.0                        | 1995-2007             | ✓                                                      |
| W39          | WS25             | WN0025                         | 6841421.9    | 2200961.7     | 2,899.0                         | 350.0               | 50.0                 | 70.0               | 2,855.0                        | 1994-2007             | ✓                                                      |
| W44          | WS230            | WN0036                         | 6841616.3    | 2206213.9     | 2,966.0                         | 175.0               | 135.0                | 175.0              | 2,888.0                        | 1995-2007             | ✓                                                      |
|              | WS201            | WN0201                         | 6838535.8    | 2205950.5     | 2,860.0                         | 425.0               |                      |                    | 2,720.0                        | 1995-2007             | x                                                      |
|              | WS233            | WN0233                         | 6837178.6    | 2205676.3     | 2,640.0                         | 90.0                |                      |                    | 2,598.0                        | 1994-2007             | x                                                      |
|              | WS113            | WN0113                         | 6837482.4    | 2205319.4     | 2,645.0                         | 55.0                |                      |                    | 2,637.0                        | 1995-2007             | x                                                      |
|              | WS242            | WN0242                         | 6838104.2    | 2205145.9     | 2,695.0                         | 155.0               |                      |                    | 2,650.0                        | 1995-2007             | x                                                      |
| W8           | WS45             | WN0045                         | 6837427.5    | 2206358.9     | 2,769.0                         | 300.0               | 200.0                | 300.0              | 2,662.0                        | 1994-2007             | x                                                      |
| W7           | WS80             | WN0080                         | 6838933.7    | 2205394.6     | 2,797.0                         | 100.0               |                      |                    | 2,700.0                        | 1994-2007             | x                                                      |
|              | WS240            | WN0240                         | 6837746.0    | 2204970.2     | 2,650.0                         | 199.0               |                      |                    | 2,630.0                        | 1995-2007             | x                                                      |
| W19          | WS122            | WN0122                         | 6838119.4    | 2205610.1     | 2,779.0                         | 220.0               | 180.0                | 220.0              | 2,863.0                        | 1994-2007             | x                                                      |
| W6           | WS31             |                                | 6836048.6    | 2206624.5     | 2,685.0                         | 320.0               |                      |                    | 2,545.0                        | Aug-1981              | ✓                                                      |
| W9           | WS32             |                                | 6836524.8    | 2206608.7     | 2,747.0                         | 400.0               |                      |                    | 2,377.0                        | Oct-1987              | ✓                                                      |
| W10          |                  |                                | 6834750.5    | 2208982.9     | 2,528.0                         | 20.0                |                      |                    | 2,520.0                        | Nov-1991              | ✓                                                      |
| W11          |                  |                                | 6834750.5    | 2208982.9     | 2,528.0                         | 19.0                |                      |                    | 2,519.5                        | Nov-1991              | ✓                                                      |
| W13          |                  |                                | 6834750.5    | 2208982.9     | 2,528.0                         | 11.0                | 3.0                  | 11.0               | 2,524.0                        | Jun-1996              | ✓                                                      |
| W14          |                  |                                | 6834750.5    | 2208982.9     | 2,528.0                         | 14.0                | 4.0                  | 14.0               | 2,522.0                        | Jun-1996              | ✓                                                      |
| W29          | WS10             |                                | 6840336.8    | 2200825.5     | 2,949.0                         | 250.0               | 95.0                 | 135.0              | 2,854.0                        | Sep-1985              | ✓                                                      |
| W30          |                  |                                | 6840095.1    | 2200869.8     | 2,949.0                         | 400.0               | 80.0                 | 135.0              | 2,869.0                        | Jul-1985              | ✓                                                      |
| W33          | WS22             |                                | 6840499.2    | 2201182.8     | 2,919.0                         | 300.0               | 100.0                | 120.0              | 2,814.0                        | Jan-1985              | ✓                                                      |
| W35          |                  |                                | 6841687.3    | 2200839.9     | 2,865.0                         | 125.0               | 90.0                 | 125.0              | 2,775.0                        | Sep-1985              | ✓                                                      |
| W37          |                  |                                | 6841687.3    | 2200839.9     | 2,865.0                         | 125.0               | 90.0                 | 125.0              | 2,775.0                        | Sep-1985              | ✓                                                      |
| W38          |                  |                                | 6841421.9    | 2200961.7     | 2,899.0                         | 250.0               |                      |                    | 2,709.0                        | Nov-1983              | ✓                                                      |
| W43          |                  |                                | 6841935.6    | 2205767.6     | 2,924.0                         | 175.0               | 95.0                 | 175.0              | 2,884.0                        | Mar-1980              | ✓                                                      |
| W45          | WS75             |                                | 6842006.2    | 2205360.8     | 2,896.0                         | 140.0               | 80.0                 | 140.0              | 2,836.0                        | Dec-1989              | ✓                                                      |
| W46          |                  |                                | 6841130.4    | 2205417.9     | 2,883.0                         | 110.0               | 70.0                 | 110.0              | 2,848.0                        | Jan-2011              | ✓                                                      |
| W50          |                  |                                | 6842674.2    | 2203651.1     | 2,846.0                         | 160.0               | 120.0                | 160.0              | 2,736.0                        | Aug-1989              | ✓                                                      |
| W51          |                  |                                | 6842237.2    | 2204998.2     | 2,870.0                         | 105.0               | 40.0                 | 100.0              | 2,855.0                        | Aug-1998              | ✓                                                      |
| W52          |                  |                                | 6842780.4    | 2203150.2     | 2,842.0                         | 240.0               | 220.0                | 240.0              | 2,792.0                        | Sep-1999              | ✓                                                      |
| W53          |                  |                                | 6841070.4    | 2203697.3     | 2,819.0                         | 24.0                |                      |                    | 2,806.5                        | Nov-2006              | ✓                                                      |
| W54          |                  |                                | 6841070.4    | 2203697.3     | 2,819.0                         | 25.0                | 15.0                 | 25.0               | 2,803.0                        | Nov-2006              | ✓                                                      |
| W55          |                  |                                | 6841070.4    | 2203697.3     | 2,819.0                         | 25.0                |                      |                    | 2,802.0                        | Nov-2006              | ✓                                                      |
| W135         |                  |                                | 6833681.6    | 2206277.6     | 2,535.0                         | 200.0               | 45.0                 | 65.0               | 2,515.0                        | Mar-2003              | ✓                                                      |
| W56          |                  |                                | 6842608.0    | 2205149.5     | 2,871.7                         | 300.0               |                      |                    | 2,751.7                        | Jan-1986              | ✓                                                      |
| W58          |                  |                                | 6843742.3    | 2205071.3     | 2,841.7                         | 175.0               | 20.0                 | 175.0              | 2,826.7                        | May-1982              | ✓                                                      |
| W59          |                  |                                | 6844007.0    | 2204866.3     | 2,879.7                         | 175.0               | 40.0                 | 180.0              | 2,789.7                        | Mar-1981              | ✓                                                      |
| W61          |                  |                                | 6843056.1    | 2204728.6     | 2,869.7                         | 125.0               | 85.0                 | 125.0              | 2,844.7                        | Dec-1997              | ✓                                                      |
| W62          |                  |                                | 6843056.1    | 2204728.6     | 2,869.7                         | 150.0               |                      |                    | 2,819.7                        | Nov-1990              | ✓                                                      |
| W63          |                  |                                | 6842878.0    | 2204606.0     | 2,865.7                         | 125.0               | 105.0                | 125.0              | 2,820.7                        | May-1996              | ✓                                                      |
| W66          |                  |                                | 6842796.5    | 2204170.0     | 2,859.7                         | 150.0               | 110.0                | 150.0              | 2,849.7                        | Apr-2003              | ✓                                                      |
| W67          |                  |                                | 6843018.9    | 2203966.2     | 2,895.7                         | 155.0               | 135.0                | 155.0              | 2,755.7                        | Jul-1988              | ✓                                                      |
| W68          | WS81             |                                | 6843289.7    | 2204192.3     | 2,905.7                         | 300.0               | 140.0                | 300.0              | 2,675.7                        | May-1990              | ✓                                                      |
| W70          |                  |                                | 6843603.1    | 2204343.2     | 2,918.7                         | 380.0               | 340.0                | 380.0              | 2,768.7                        | Apr-2004              | ✓                                                      |
| W71          |                  |                                | 6843781.8    | 2204303.1     | 2,935.7                         | 230.0               | 170.0                | 230.0              | 2,725.7                        | Oct-1988              | ✓                                                      |
| W72          |                  |                                | 6844021.3    | 2204351.0     | 2,960.7                         | 250.0               | 210.0                | 250.0              | 2,775.7                        | Nov-1986              | ✓                                                      |
| W73          |                  |                                | 6843688.1    | 2203976.8     | 2,953.7                         | 247.0               | 127.0                | 247.0              | 2,833.7                        | Aug-1994              | ✓                                                      |
| W75          |                  |                                | 6843387.3    | 2203397.3     | 2,937.7                         | 130.0               | 50.0                 | 130.0              | 2,837.7                        | Jun-2001              | ✓                                                      |
| W76          |                  |                                | 6844050.6    | 2203818.7     | 2,993.7                         | 100.0               | 40.0                 | 100.0              | 2,951.7                        | Mar-1984              | ✓                                                      |
| W77          |                  |                                | 6844050.6    | 2203818.7     | 2,993.7                         | 340.0               | 320.0                | 340.0              | 2,738.7                        | Aug-2001              | ✓                                                      |

TABLE 2-2

**Information and Average Measured Water Levels at Domestic Wells**  
(Page 2 of 2)

| Rise Well ID | EIR 1995 Well ID | Todd 2007 Well ID <sup>1</sup> | Easting (ft) | Northing (ft) | Top Elevation of Well (ft amsl) | Well Depth (ft bgs) | Screen From (ft bgs) | Screen To (ft bgs) | Measured Water Level (ft amsl) | Measurement Date/Year | Used for Pre-Historical-Mining Simulation <sup>2</sup> |
|--------------|------------------|--------------------------------|--------------|---------------|---------------------------------|---------------------|----------------------|--------------------|--------------------------------|-----------------------|--------------------------------------------------------|
| W78          |                  |                                | 6842446.4    | 2202845.2     | 2,808.7                         | 100.0               | 40.0                 | 100.0              | 2,778.7                        | Sep-1981              | √                                                      |
| W79          |                  |                                | 6842809.5    | 2202877.1     | 2,841.7                         | 100.0               | 5.0                  | 95.0               | 2,831.7                        | Dec-1990              | √                                                      |
| W80          | WS217            |                                | 6843101.8    | 2202955.5     | 2,870.7                         | 100.0               |                      |                    | 2,855.7                        | Aug-1990              | √                                                      |
| W81          |                  |                                | 6842687.1    | 2202376.3     | 2,868.7                         | 300.0               | 200.0                | 300.0              | 2,776.7                        | Sep-1990              | √                                                      |
| W82          |                  |                                | 6843049.3    | 2202618.4     | 2,896.7                         | 720.0               |                      |                    | 2,796.7                        | Sep-1996              | √                                                      |
| W83          |                  |                                | 6843049.3    | 2202618.4     | 2,896.7                         | 560.0               | 280.0                | 300.0              | 2,596.7                        | Aug-1996              | √                                                      |
| W85          |                  |                                | 6843374.6    | 2202660.2     | 2,892.7                         | 100.0               |                      |                    | 2,882.7                        | Dec-1990              | √                                                      |
| W86          |                  |                                | 6843304.1    | 2201888.2     | 2,969.7                         | 350.0               | 80.0                 | 100.0              | 2,909.7                        | May-2002              | √                                                      |
| W87          |                  |                                | 6843304.1    | 2201888.2     | 2,969.7                         | 350.0               | 150.0                | 350.0              | 2,789.7                        | May-1995              | √                                                      |
| W89          |                  |                                | 6842917.2    | 2200701.1     | 2,957.7                         | 420.0               | 280.0                | 420.0              | 2,807.7                        | Sep-1995              | √                                                      |
| W90          |                  |                                | 6843055.3    | 2200403.3     | 2,966.7                         | 600.0               |                      |                    | 2,866.7                        | Aug-2000              | √                                                      |
| W91          |                  |                                | 6842522.6    | 2200305.3     | 2,900.0                         | 110.0               | 70.0                 | 110.0              | 2,825.0                        | Dec-1986              | √                                                      |
| W94          |                  |                                | 6843565.0    | 2202004.3     | 2,979.7                         | 480.0               |                      |                    | 2,799.7                        | Dec-2005              | √                                                      |
| W100         |                  |                                | 6843964.0    | 2204168.2     | 2,966.7                         | 780.0               | 420.0                | 440.0              | 2,531.7                        | Aug-2005              | √                                                      |
| W101         |                  |                                | 6843523.8    | 2203897.1     | 2,950.7                         | 450.0               | 250.0                | 450.0              | 2,800.7                        | Feb-2006              | √                                                      |
|              | WS124            |                                | 6836264.5    | 2206687.2     | 2,730.0                         | 208.0               |                      |                    | 2,625.0                        | NA                    | √                                                      |
|              | WS243            |                                | 6836071.2    | 2206374.7     | 2,640.0                         | 131.0               |                      |                    | 2,558.0                        | NA                    | √                                                      |
|              | WS118            |                                | 6835671.2    | 2206380.5     | 2,665.0                         | 200.0               |                      |                    | 2,580.0                        | 1979                  | √                                                      |
|              | WS237            |                                | 6835594.3    | 2206079.7     | 2,620.0                         | 200.0               |                      |                    | 2,546.0                        | 1979                  | √                                                      |
| W1           |                  |                                | 6838534.1    | 2205005.8     | 2,747.0                         | 420.0               |                      |                    | 2,727.0                        | Aug-1999              | x                                                      |
| W16          |                  |                                | 6839015.6    | 2206259.9     | 2,826.0                         | 140.0               |                      |                    | 2,766.0                        | May-1994              | x                                                      |
| W17          |                  |                                | 6837373.5    | 2205180.8     | 2,684.0                         | 150.0               | 130.0                | 150.0              | 2,604.0                        | May-2000              | x                                                      |
| W18          |                  |                                | 6834516.2    | 2208874.4     | 2,530.0                         | 560.0               | 140.0                | 160.0              | 2,525.0                        | Mar-2011              | x                                                      |
| W20          |                  |                                | 6837861.6    | 2209933.7     | 2,648.0                         | 100.0               | 60.0                 | 100.0              | 2,623.0                        | Jun-2006              | x                                                      |
| W21          |                  |                                | 6834546.0    | 2208888.9     | 2,530.0                         | 15.0                |                      |                    | 2,523.0                        | Jun-1996              | x                                                      |
|              | WS116            |                                | 6837379.7    | 2205958.4     | 2,700.0                         | 208.0               |                      |                    | 2,617.4                        | 1975                  | x                                                      |
|              | WS114            |                                | 6837592.6    | 2205870.6     | 2,710.0                         | 208.0               |                      |                    | 2,627.4                        | NA                    | x                                                      |
|              | WS119            |                                | 6837743.5    | 2206166.2     | 2,780.0                         | 145.0               |                      |                    | 2,695.0                        | 1989                  | x                                                      |
|              | WS44             |                                | 6838216.9    | 2205847.2     | 2,810.0                         | 225.0               |                      |                    | 2,627.0                        | 1982                  | x                                                      |
|              | WS29             |                                | 6838719.2    | 2205632.4     | 2,788.0                         | 425.0               |                      |                    | 2,705.4                        | 1986                  | x                                                      |
|              | WS235            |                                | 6837967.0    | 2206024.5     | 2,805.0                         | 200.0               |                      |                    | 2,686.0                        | NA                    | x                                                      |
|              | WS121            |                                | 6837921.3    | 2205424.0     | 2,690.0                         | 155.0               |                      |                    | 2,607.4                        | 1978                  | x                                                      |
|              | WS110            |                                | 6838024.3    | 2207045.2     | 2,830.0                         | 208.0               |                      |                    | 2,747.4                        | NA                    | x                                                      |
| MW-1         |                  |                                | 6834073.0    | 2207317.0     | 2,569.9                         | 24.0                |                      |                    | 2,545.9                        | 2007                  | x                                                      |
| MW-2         |                  |                                | 6834101.0    | 2207375.0     | 2,569.9                         | 19.2                |                      |                    | 2,550.7                        | 2007                  | x                                                      |
| MW-3         |                  |                                | 6834127.0    | 2207265.0     | 2,571.6                         | 34.4                |                      |                    | 2,543.6                        | 2007                  | x                                                      |
| MW-4         |                  |                                | 6834003.0    | 2207259.0     | 2,572.1                         | 50.0                |                      |                    | 2,539.6                        | 2007                  | x                                                      |
| MW-5         |                  |                                | 6833993.0    | 2207319.0     | 2,569.1                         | 48.4                |                      |                    | 2,529.6                        | 2007                  | x                                                      |
| MW-6         |                  |                                | 6833950.0    | 2207286.0     | 2,569.7                         | 55.0                |                      |                    | 2,527.4                        | 2007                  | x                                                      |

## Notes:

NA = not available

Blank cell = no information or not available

- The 26 wells labeled with "Todd 2007 Well ID" had hydrographs; the measured water levels are the stable values visually obtained from the hydrographs with consideration of seasonal changes.
- The wells highlighted in green are outside of the footprint of the historical mining area and were used for the simulation of the pre-historical-mining condition.  
√ = Yes; x = No

TABLE 2-3

**Measured Streamflow Rates and Discharge Rate from NID Canal**

| Stream                   | Coordinate   |               | Flow Rate (cfs) |          |                    |
|--------------------------|--------------|---------------|-----------------|----------|--------------------|
|                          | Easting (ft) | Northing (ft) | Apr-2019        | Aug-2019 | Estimated Baseflow |
| South Fork of Wolf Creek | 6838228      | 2204566       | 6.5             | 1.0      | 1.0                |
| Wolf Creek               | 6833389      | 2208847       | 51.3            | 74.6     | <31                |
| NID Canal                | NA           | NA            | 19.4            | NA       | NA                 |

Note:

NA = not available

**TABLE 2-4**

**Elevations of Drains and Mine-Water Levels Estimated in 2019**

| <b>Location</b>                  | <b>Elevation<br/>(ft amsl)</b> |
|----------------------------------|--------------------------------|
| Eureka Drain                     | 2,502                          |
| East Eureka Shaft Drain          | 2,497                          |
| East Eureka Shaft                | 2,501                          |
| New Brunswick Shaft <sup>1</sup> | 2,499                          |

Note:

1. Water level in the historical mine.

TABLE 4-1

## Elevations and Thicknesses of Model Layers in the Mine Area

| Node Layer | Elevation<br>(ft amsl) | Thickness<br>(ft) |
|------------|------------------------|-------------------|
| 1          | 2,900                  |                   |
| 2          | 2,800                  | 100               |
| 3          | 2,700                  | 100               |
| 4          | 2,600                  | 100               |
| 5          | 2,500                  | 100               |
| 6          | 2,200                  | 300               |
| 7          | 2,100                  | 100               |
| 8          | 2,000                  | 100               |
| 9          | 1,900                  | 100               |
| 10         | 1,700                  | 200               |
| 11         | 1,600                  | 100               |
| 12         | 1,500                  | 100               |
| 13         | 1,400                  | 100               |
| 14         | 1,300                  | 100               |
| 15         | 1,200                  | 100               |
| 16         | 1,100                  | 100               |
| 17         | 975                    | 125               |
| 18         | 850                    | 125               |
| 19         | 725                    | 125               |
| 20         | 575                    | 150               |
| 21         | 425                    | 150               |
| 22         | 275                    | 150               |
| 23         | 125                    | 150               |
| 24         | 0                      | 125               |
| 25         | -260                   | 260               |
| 26         | -515                   | 255               |
| 27         | -1,095                 | 580               |
| 28         | -1,575                 | 480               |
| 29         | -2,245                 | 670               |
| 30         | -2,445                 | 200               |
| 31         | -2,845                 | 400               |
| 32         | -3,445                 | 600               |

TABLE 4-2

## Calibrated Hydraulic Properties of Geologic Units

| Zone                  | Horizontal Hydraulic Conductivity<br>(ft/day) <sup>1</sup> |            |                    |        |        |        | Storativity<br>(ft <sup>-1</sup> ) | Specific Yield<br>(-) |
|-----------------------|------------------------------------------------------------|------------|--------------------|--------|--------|--------|------------------------------------|-----------------------|
|                       | Weathered                                                  | Transition | Upper              | Middle | Lower  | Deep   |                                    |                       |
| Mariposa              | 1                                                          | 0.1        | 0.005              | 0.001  | 0.0008 | 0.0001 | 5.00E-06                           | 0.005                 |
| Calavaras             | 0.5                                                        | 0.1        | 0.005              | 0.001  | 0.0008 | 0.0001 | 5.00E-06                           | 0.005                 |
| Tertiary              | 0.5                                                        | 0.1        | 0.005              | 0.001  | 0.0008 | 0.0001 | 5.00E-06                           | 0.005                 |
| Diorite               | 0.5                                                        | 0.1        | 0.01               | 0.001  | 0.0008 | 0.0001 | 5.00E-06                           | 0.005                 |
| Sepentini             | 1                                                          | 0.1        | 0.02               | 0.001  | 0.0008 | 0.0001 | 5.00E-06                           | 0.005                 |
| Delhi                 | 0.5                                                        | 0.1        | 0.01               | 0.001  | 0.0008 | 0.0001 | 5.00E-06                           | 0.005                 |
| Fault 6-3             | 0.001                                                      | 0.001      | 0.001              | 0.001  | 0.0008 | NA     | 5.00E-06                           | 0.005                 |
| Fault Morehouse       | 0.001                                                      | 0.001      | 0.001              | 0.001  | 0.0008 | NA     | 5.00E-06                           | 0.005                 |
| Argillite             | 1.5                                                        | 0.1        | 0.01               | 0.0005 | 0.0008 | 0.0001 | 5.00E-06                           | 0.005                 |
| Volcanic Rocks        | 0.4                                                        | 0.1        | 0.005 <sup>2</sup> | 0.0002 | 0.0002 | 0.0001 | 5.00E-06                           | 0.005                 |
| Andesite              | 0.5                                                        | 0.1        | 0.01               | 0.001  | 0.0008 | 0.0001 | 5.00E-06                           | 0.005                 |
| Granodior             | 2.5                                                        | 0.1        | 0.01               | 0.002  | 0.0008 | 0.0001 | 5.00E-06                           | 0.005                 |
| Schist                | 1.5                                                        | 0.1        | 0.01               | 0.0005 | 0.0005 | 0.0001 | 5.00E-06                           | 0.005                 |
| Sandstone             | 0.5                                                        | 0.3        | 0.05               | 0.004  | 0.004  | 0.0001 | 5.00E-06                           | 0.005                 |
| Gabbro                | 1                                                          | 0.1        | 0.01               | 0.0005 | 0.0005 | 0.0001 | 5.00E-06                           | 0.005                 |
| Brunswick             | 1                                                          | 0.1        | 0.01               | 0.0005 | 0.0005 | 0.0001 | 5.00E-06                           | 0.005                 |
| Alluvium <sup>3</sup> | 2.5                                                        | 0.5        | 0.25               | 0.005  | 0.005  | 0.001  | 1.00E-05                           | 0.05                  |
| Riverbed Sediments    | 10                                                         | NA         |                    |        |        |        | 1.00E-05                           | 0.05                  |
| Mine Void             | 8000                                                       |            |                    |        |        |        | 1.00E-05                           | 0.5                   |

Notes:

NA = not simulated in the model

1. Anisotropic ratio  $K_x/K_y = 10$ ,  $K_x = K_y$ .

2. Hydraulic conductivities of slate unit along the Morehouse Fault and Union Hill Mine were assumed as 0.0015 ft/day.

3.  $K$  values in the area with alluvium on the surface were assigned to decrease with depth. The weathered rock and transition zone do not apply to this unit.

## **APPENDIX A**

### **Introduction of *MINEDW***

## APPENDIX A

### INTRODUCTION OF *MINEDW*

***MINEDW*** is a three-dimensional (3-D) finite-element groundwater modeling code developed specifically for mining and civil engineering applications. This white paper outlines the mathematical basis of the groundwater flow code, boundary conditions, and features, such as the ones listed below, developed specifically for simulating common mining scenarios. The information in this white paper is supplemented by the ***MINEDW*** manual, which gives in-depth information about how to construct a groundwater model using ***MINEDW***.

Itasca Denver, Inc. (Itasca) developed ***MINEDW***, a 3-D finite-element groundwater flow code. The core of the code is based on algorithms previously developed by Durbin and Berenbrock (1985) for the United States Geological Survey (USGS) code *FEMFLOW3D*. As of early 2018, ***MINEDW*** had been used successfully at more than 75 mines located throughout the world and in diverse hydrogeologic and climatic conditions. The code has been in use for approximately 30 years, and its predictions have been validated by field data collected over many years and the Sandia National Laboratory (Corbet et al. 1998). Moreover, ***MINEDW*** was reviewed by the Nevada Division of Environmental Protection (NDEP 2018; Appendix 2) and approved for regulatory use.

The ***MINEDW*** software includes special features that facilitate the 3-D simulation of dewatering operations in open-pit and underground mines. Some of these features are as follows:

- A groundwater flow problem is simulated as saturated-unsaturated groundwater flow based on Darcy's law. This allows the finite-element mesh to remain fixed with time (except for excavations) and the saturated flow domain to adjust with time in accordance with changes in the position of the water table. The fixed mesh, in contrast to a deforming mesh, facilitates the representation of the spatial hydrogeologic variability of a groundwater system by the finite-element mesh.

- **MINEDW** provides 3-D graphic representations of geology, model domain, pit geometry, groundwater heads, groundwater flux, recharge and evaporation zones, particle tracking, and pore pressures.
- Specified-head boundary conditions can be imposed using heads that are either invariable with time or variable with time. In the latter case, the boundary heads are specified in terms of tables representing a hydrograph of the heads.
- Specified-flux boundary conditions and internal source-sink terms are defined by a group of data sets that can be combined in different configurations for each time step.
- Variable-flux boundary conditions can be imposed to simulate time-variant boundary fluxes in response to changing boundary heads. This boundary condition allows the finite volume of the modeled flow domain to be “extended” to infinity by “attaching” the analytical solution for a semi-infinite, linear aquifer to the boundary of the flow domain.
- The interaction between the groundwater system and river networks can be realistically simulated. Streams are simulated as a river network (or networks) that consists of a main river channel and tributary channels. The model accounts for streamflow depletions or additions by simulating the exchange of water between the stream and the groundwater system.
- In addition, evapotranspiration of groundwater from vegetated areas or evaporation from bare-soil areas can be simulated. The evapotranspiration rate is assumed to be inversely proportional to the depth from the ground surface to the water-table elevation. **MINEDW** uses the maximum evaporation rate and the extinction depth as constraints.
- Spatial and temporal variation in precipitation across the model domain can be simulated. In areas with steep relief, **MINEDW** has the capability to simulate orographically controlled precipitation.
- Open-pit excavation, open-pit backfilling, and pit-lake formation can be efficiently simulated within a **MINEDW** model.
- **MINEDW** can efficiently simulate the formation of a zone of relaxation (ZOR) around a pit excavation or underground mining operation through time according to the mining schedule.
- Outputs of pore-pressure distribution can be seamlessly used in both two-dimensional (2-D) and 3-D geomechanical models using Itasca’s geomechanical codes.

In addition, when predicting inflows to both open-pit and underground mines and to help design mine dewatering and depressurization systems, **MINEDW** overcomes limitations in model discretization inherent in finite-difference codes:

1. The discretization used in a numerical model can strongly affect the predictions of inflow and the shape of the water table near an open-pit or underground excavation. Not only must discrete features, such as faults and contacts between significantly different hydrogeologic materials, be included in the discretization, but predicting the essentially radial flow toward an excavation is more accurately performed by using small, approximately logarithmic horizontal and vertical grid spacing.
2. The seepage face—the surface of the open-pit highwall through which lateral flow occurs—is difficult to estimate using finite-difference codes (i.e., *MODFLOW*). The height of the seepage face affects both the amount of lateral inflow and the height of the water table behind the highwall. A poor estimate of the height of the seepage face can introduce significant errors to the predicted inflows and pore-pressure distribution.

The following list indicates some of the mining hydrogeology projects in which **MINEDW** was used for groundwater modeling of dewatering system design and impact analyses:

- Anglo American – Sishen and Kolomela Mines, South Africa;
- Aurora Mining Company – Aurora Mine, Guyana;
- Cameco Corporation – McArthur River, Cigar Lake, and Millennium Mines, Canada;
- De Beers Canada – Victor, Snap Lake, Gahcho Kué, and Fort à la Corne Mines, Canada;
- De Beers Consolidated Mines – Premier, Finsch, Venetia, Voorspoed, AK6, and Mulepe Mines, South Africa;
- Debswana – Orapa, Letlhakane, Jwaneng, and Damtshaa Mines, Botswana;
- Eurasian Resource Group – Frontier Mine, Democratic Republic of Congo;
- Goldcorp – Éléonore Mine, Canada;
- Kinross Gold Corporation – Fruta del Norte Project, Ecuador;
- Newmont Mining Corporation – Lone Tree, Twin Creeks, Gold Quarry, and Leeville Mines, U.S.A.;

- Rio Tinto – Resolution Mine, Arizona, U.S.A.; and
- Alrosa - Mir Mine, Mirny, Russia.

## **APPENDIX B**

### **Review of the *MINEDW* Groundwater Flow Modeling Code**



26 November 2018

Mr. Braden Hanna  
Principal Geochemist  
Itasca Denver, Inc.

**VIA EMAIL**

Re: Review of the *MINEDW* Groundwater Flow Modeling Code

Dear Mr. Hanna:

The Nevada Division of Environmental Protection (Division) – Bureau of Mining Regulation and Reclamation (BMRR) is in receipt on 2 May 2018 of a request from Itasca Denver, Inc. (Itasca) for BMRR to review the finite-element groundwater flow modeling code *MINEDW*. For code review to progress it was necessary for project-specific groundwater modeling to be completed with *MINEDW* and submitted to the Division. Groundwater modeling files and an associated report were submitted in reference to the Lone Tree project (NEV0090058). The Lone Tree groundwater model review will be addressed under separate cover to Newmont Mining Corporation. The Lone Tree groundwater flow model project files were used to test the *MINEDW* code. Testing and approval of commercially available and non-open source codes is required per the Division's Guidance for Hydrogeologic Groundwater Flow Modeling at Mine Sites ([https://ndep.nv.gov/uploads/documents/201803\\_CPN\\_Hydro\\_Guidance\\_revision01.pdf](https://ndep.nv.gov/uploads/documents/201803_CPN_Hydro_Guidance_revision01.pdf)). The purpose of the testing is not to evaluate the mathematical methods or the programming structure of the code. Testing is simply designed to determine if Division personnel could reasonably use the code to evaluate sensitivity of any models submitted using *MINEDW*. Testing therefore focuses on simple aspects of the code such as reproducibility of a simple steady-state model, reasonable modification of hydraulic properties, and implementation of specialized and useful tools such as particle tracking.

The Division has determined that *MINEDW* is acceptably transparent for regulatory use, and may therefore be applied to predictive groundwater flow modeling studies to be submitted to BMRR. The review and approval of the code were greatly streamlined by the inclusion of the draft user's manual (Itasca, 2016) and the previous rigorous assessment of the code (Corbet et al., 1998). This approval does not necessarily extend to other state or Federal regulatory agencies, such as the Nevada Division of Water Resources (NDWR) or the U.S. Bureau of Land Management (BLM). Itasca is encouraged to contact each specific agency to determine appropriate guidelines.

## **I. Code Testing**

Detailed below are several tests that were conducted using the Lone Tree groundwater model in comparison to analytic element solutions (AEM; Hunt, 2006), or other tests conducted to evaluate code transparency and usability.

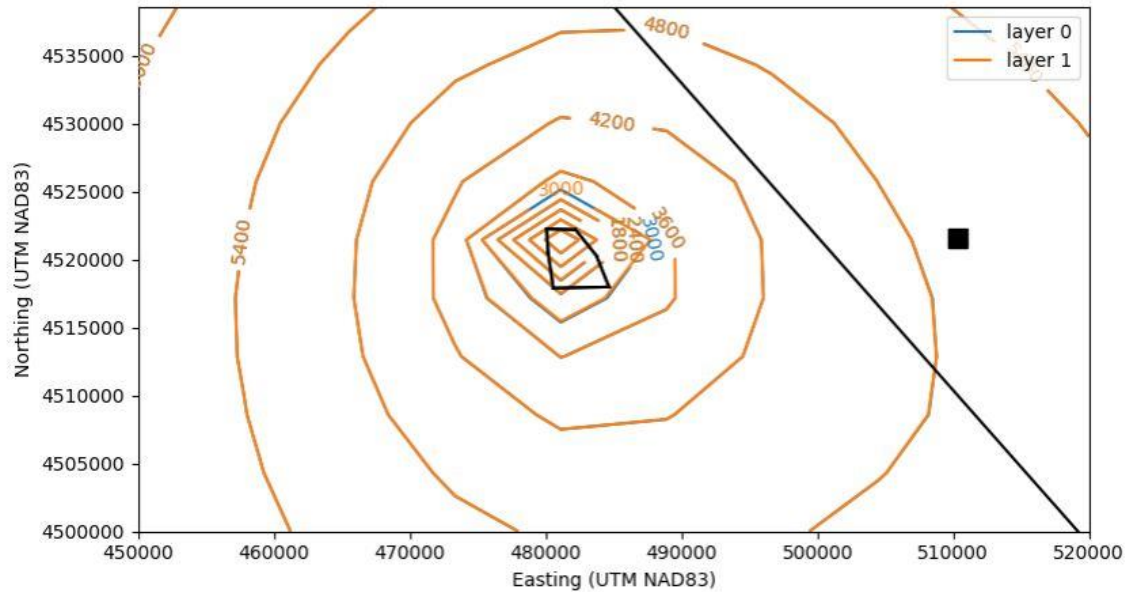
1. **Steady-state simulation.** The Division used *MINEDW* to extract potentiometric surface contours from the first and second layers of the Lone Tree groundwater model (Figure 1). These potentiometric surface contours were then compared to two AEM simulations using the Tim<sup>ML</sup> application (Bakker, 2010). The simulations used hydraulic parameter values extracted from the *MINEDW* model.

The first AEM simulation created a single inhomogeneity representing the area of the Lone Tree pit (with increased hydraulic conductivity [K] values), included the same constant head boundary on the eastern side of the model domain as in the Lone Tree model (black square on figures), and included a line sink to represent the Humboldt River (northwest-southeast trending line on figures). Results of this simulation are illustrated in Figure 2. The second AEM simulation included the same features of the first, but added an additional inhomogeneity to account for K contrasts between alluvium in the vicinity of the Humboldt River and at greater distances. Results of this simulation are shown in Figure 3.

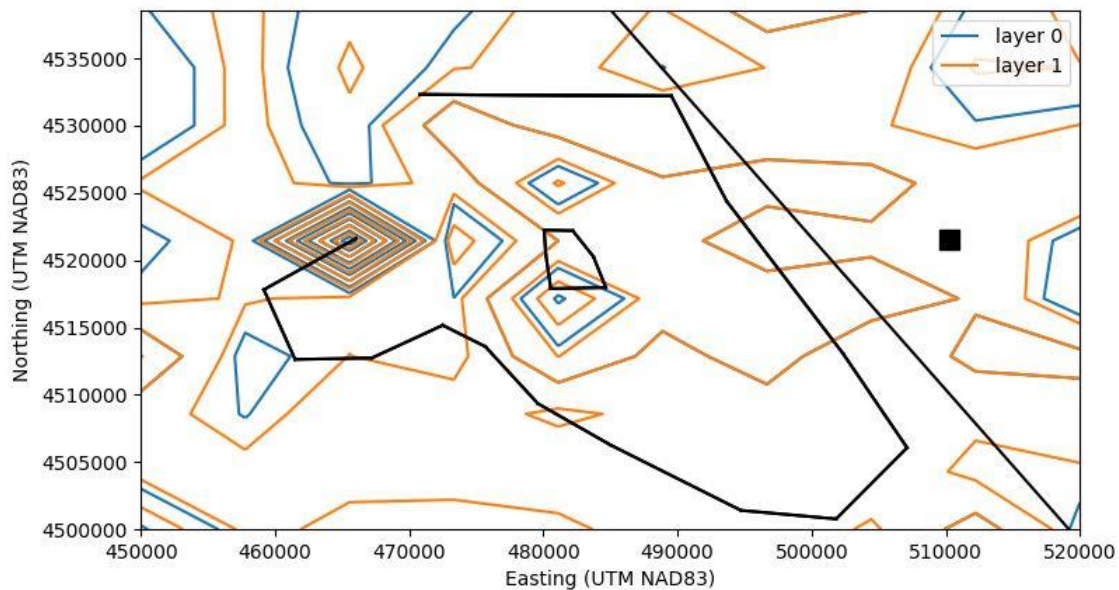
Overall, the AEM simulations arrive at similar (but clearly simplified) results when compared to the *MINEDW* simulation. The three simulations all indicate generally lower water levels in the vicinity of the mine and the river, and the second AEM simulation produces some of the complexity in water levels observed to the east of the Lone Tree pit. The AEM simulations indicate acceptable overall reproducibility in comparison to the *MINEDW* code.



**Figure 1.** Head isolines extracted from the steady-state Lone Tree simulation.



**Figure 2.** Predicted potentiometric surface of AEM simulation one.



**Figure 3.** Predicted potentiometric surface of AEM simulation two.

2. **Modification of parameter values.** The Division commonly encounters submitted model reports with questionable or unverified parameter values (e.g.,  $K$ , specific storage [ $S_s$ ], specific yield [ $S_y$ ]). It is therefore important for BMRR to be able to test scenarios by modifying some parameter values. For the MINEDW testing, the  $K$  values of the FAUL-PIT zone were modified to be 0.1 ft/day, and the Havallah (HAVA-PIT) were modified to be 10, 10, and 2 ft/day respectively for the x, y, and z dimensions. All modifications were made to the steady-state model. This allowed the Division to test the ability to modify input parameters in the code and run the

model. The model ran to completion and the Division was able to evaluate the resultant changes in the predicted steady-state potentiometric surface.

3. **Particle Tracking.** The final test completed by the Division was activation of particle tracking capabilities. This was completed in the transient model. Both forward and reverse particle tracking were completed. The results suggest that the code was able to create the particle tracks, but the visualization functions were not functioning according to the user's manual. See item II.3 below.

## II. Issues Identified

Although *MINEDW* is approved for use for BMRR permitting studies, included below are several issues that may require action in the future.

1. **Mesh generator.** The Division was unable to use the mesh generator function, despite multiple attempts and checking common errors. Itasca (2016) notes that the mesh generator function is a separate program with a different graphical user interface (GUI). It is possible that this program was not installed appropriately on the computer utilized by the Division during review, or was not included on the software license key supplied by Itasca. Although this is troubling from a model design standpoint, the Division has determined that generating meshes would not be imperative for model review purposes. This problem has therefore not affected model approval.
2. **Solvers.** As noted in the 2 May 2018 correspondence from Itasca, one proprietary solver (the Algebraic Multigrid Methods for Systems [SAMG]) was not included in the software distribution provided to the Division. BMRR assumes that this would not affect the ability of BMRR to review submitted models.
3. **Particle tracking visualization.** As described above, the particle tracking capabilities appear to be functional. The Division was able to review the results of the particle tracking (as a .DAT file) using a standard text editor. These particle tracks could be visualized using a plotting routine based on the x-y-z location of the particle tracks through time. However, the functionality of the *MINEDW* GUI did not appear to be as stated in the user's manual, because no particle tracks appeared when the workflow was followed as detailed in the user's manual. This does not require additional attention at this time, but in the future correspondence may be required as to the potential causes for this discrepancy.

In conclusion, BMRR has determined that *MINEDW* may be utilized for future predictive modeling applications in support of mining regulatory permitting. Itasca should contact other agencies however to evaluate their specific needs and requirements. It is imperative that BMRR maintains the ability to review submitted *MINEDW* models. Therefore the software license key supplied by Itasca (serial number 303-001-0005-53369) must remain active to allow the software to run on BMRR computers.

Thank you for the opportunity to review the *MINEDW* groundwater flow modeling code. The listing of accepted codes (available at <https://ndep.nv.gov/land/mining/regulation/guidance-policies-references-and-requirements>) will be updated shortly to reflect this approval.

Finally, in the initial request for review, Itasca requested that key serial number 303-001-0005-53369 would be provided specifically for use by myself. However, I will be leaving the Division in the near future. The provided software key will be retained by the Division for future use by the Closure Branch.

Sincerely,

Connor Newman  
Environmental Scientist – Hydrology and  
Geochemistry, Closure Branch  
Bureau of Mining Regulation and Reclamation  
Nevada Division of Environmental Protection

## References

- Bakker, M., 2010, TimML: A multiaquifer analytic element model, version 3.4, [www.bakkerhydro.org/timml](http://www.bakkerhydro.org/timml), pp. 44.
- Corbet, T., Ho, C., Knupp, P., and Ramsey, J., 1998, Review and verification of the MINEDW groundwater flow code, Sandia National Laboratories Report for Funds Agreement no. SNL-98FI-0610323, pp. 30 plus figures and appendices.
- Hunt, R.J., 2006, Ground water modeling applications using the analytic element method, *Groundwater*, vol. 44, no. 1, pp. 5–15, DOI: 10.1111/j.1745-6584.2005.00143.x
- Itasca, 2016, Draft MINEDW User Manual, version 3.0, pp. 144.

ec: Joe Sawyer, P.E., Bureau Chief, BMRR  
Tom Gray, Supervisor, Closure Branch, BMRR  
Rob Kuczynski, P.E., Supervisor, Regulation Branch, BMRR  
Dan Erbes, Hydrogeologist, U.S. BLM, Nevada State Office  
Jon Benedict, Hydrologist, NDWR  
Dan Stone, Ph.D., Principal Hydrogeologist, Itasca  
Steve Meyerhoff, Ph.D., Senior Project Hydrogeologist, Itasca  
Joel Donalson, P.E., Senior Environmental Manager, Newmont Mining