Appendix A

Mine Inflow Report

Inflow to the

Pogo Mine

Alaska

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Prepared for:

Teck Corporation
200 Burrard Street, Suite 600
Vancouver, BC Canada V6C 3L9

Prepared by:
Adrian Brown Consultants, Inc.

Adrian Brown, P.E., P. Eng

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Adrian**Brown**

Innovative Environmental Solutions

333 W. Bayaud Ave.
Denver, Colorado 80223-1801
303.698.9080 Fax 303.698.9241
www.abch2o.com

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List of Tables

ListofFigures

ListofPlates

Teck Corporation is proposing to develop the Pogo gold orebody near Fairbanks, Alaska. Ore extraction will be conducted by underground mining, currently proposed to start in 2003 and end in 2015. Inflow to the mine is a significant proportion of the total water inflow to the project, and is therefore an important component of project water management. This report presents the results of the evaluation of the inflow of water to the mine.

The mine inflow evaluation integrates a large amount of geological, meteorological, hydrological, and groundwater information obtained from the site to develop a model analog of the groundwater system at the mine site. Groundwater investigations comprised the following:

- Drilling, testing, completion, sampling, age dating, and monitoring of a large number of test wells in the vicinity of the orebody that provided areal geology, geohydrology and hydrogeochemistry information.
- Driving and drilling of the underground exploration facility, a 6,600-foot development that accessed the orebody area, and provided geology, flow, pressure, water quality, drawdown and permeability information, as well as a long-term dewatering test of the rockmass.
- Drilling of a 1,700 foot long pilot hole for the proposed 1875 Liese Creek Decline, that provided geology, hydraulic conductivity, and head information for the southeastern end of the orebody.

The geohydrology information was combined with the extensive topographic, meteorological, geologic, and structural information developed at the site to construct and calibrate a model of the groundwater system. This model was used to predict the inflow to the proposed underground development and mining operation, from 1999 to 2015, with the following results for the operational mining period:

	Average Inflow	Maximum Annual Inflow	Extreme Monthly Inflow
Expected Values	139 gpm	205 gpm	350 gpm
Maximum Values	175 gpm	245 gpm	350 gpm

The groundwater model of the Pogo Project is a valuable tool for evaluation of mine inflow. It is constrained by calibration against both static conditions and the effects of large-scale dynamic stresses on the system that occurred during the development of the exploration facility. However, the model makes certain assumptions, and the dataset used for construction and calibration of the model is always limited, so there remains some uncertainty in the results. The maximum values presented above appropriately bracket the upper values of mine inflow projections by quantifying the effect of the remaining uncertainty in the analysis, using the results of sensitivity analyses. The expected and maximal values form a reasonable basis for project planning.

The mine inflow estimates have increased over early estimates, primarily as a result of new information on the flow potential of faults in the mine area, in particular the Liese Creek fault zone. This feature has the potential to provide a conduit for flow to the mine from Liese Creek, the only water body that lies above or near the proposed mine. As the maximum reasonable inflow from this source has been included in the inflow projections, the expected inflow values are considered to be appropriate estimates for the proposed mining area and method.

1. Introduction

Teck Corporation (Teck) is developing the Pogo Project, a gold mine and processing facility located 90 miles east of Fairbanks, Alaska. The proposed project comprises an underground mine, a milling facility, and a surface dry-stack tailings storage facility. Mining will be by stoping, with backfill of mined voids with cemented tailings.

A significant component of the water management system for the proposed Pogo mine and mill complex is the amount of water that is produced by the mine. In recognition of this, Teck has undertaken an extensive and progressive evaluation of the groundwater conditions that exist at the mine site, and of the parameters that control groundwater flow to an underground mine at the site. This information been used to compute the expected inflow to the proposed mine under a range of mining scenarios. This report presents the results of these field evaluations, and the estimates of mine inflow that result from the analysis. It is the third evaluation and report on mine inflow at the Pogo site, and includes the results of all investigations performed to date at the site, and the results of detailed modeling of the inflow to the proposed mine using the currently proposed mine development plan.

The mine inflow estimates that are presented in this report are generally higher than the estimates in earlier evaluations, primarily as a result of the inclusion of recently collected information on the hydrogeology of the faulting system that occurs at the mine site. In particular, the results of investigations into flow characteristics of rocks in the vicinity of the Mid-Ridge and Liese Creek fault zones, which will be intersected by the proposed underground mine, have caused a re-evaluation of the contribution of those features to the overall mine inflow.

2. Setting

2.1 Topography

The Pogo orebody is located on the east flank of the valley of the Goodpaster River, between Liese Creek and Pogo Creek (Plate 1). Surface drainage from the orebody area is primarily to Liese Creek.

2.2 Climate

The climate of the project is cold and dry. The average maximum summer temperatures are 68°F to 77°F. Temperatures of less than -40°F occur on an average of 14 days per year.

Published USGS maps for the region indicate a value of approximately 19 inches on an annual average. Teck believes that site and regional data support a precipitation estimate of less than 19 inches. For the purpose of this evaluation, the 19-inch value will be used.

Evapotranspiration is highly seasonal, with a total annual evapotranspiration estimated to be 9.20 inches (EBA, 1998).

2.3 Geology

The geology of the orebody area has been evaluated in detail, based on surface mapping, test pits, surface drilling, installation of an underground exploration drift, and the drilling of in excess of 20,000 feet of underground exploration core holes.

The surficial material at the Pogo site is alluvium and colluvium. This material varies from a few inches thick to as much as an estimated 100 feet thick, depending on location. The thickest alluvial material exists in the Goodpaster Valley, in particular on the valley sides. Alluvial material in excess of 50 feet thick occurs beneath Liese Creek. The alluvial material is in general a mixture of silts and sands, with lenses of gravel, cobbles, and boulders.

The country rock at the site is a metamorphic rock package, comprising predominantly gneiss. The geologic system is complexly folded and faulted in the area of the orebody (Teck, 1999). The bedrock is less altered and faulted in the native diorite in upper Liese Creek (e.g. in the area of the tailings and water management facilities).

The gold-bearing ore is located in two approximately parallel tabular quartz vein systems, averaging approximately 15 feet thick, and separated by approximately 400 feet vertically. The upper vein is known as the L1 quartz vein, and contains the L1 orebody, and is located between 400 and 1000 feet below ground surface. The lower vein is known as the L2 quartz vein, and contains the L2 Orebody[1]. The extents of the quartz veins are indicated in Plate 2, and two sections through the orebodies are shown in Plate 3.

2.4 Structure

The geologic investigation and inspection of the development drift indicates that there are large-scale faults and fault zones located in the host rockmass. The faults in the vicinity of the orebodies and the ancillary structures that have been investigated for the project are shown in Plate 2.

The principal faults and structures have been identified by inference from drilling, in particular by identification of displacement of the quartz units that make up the tabular orebodies. In addition, drilling has been undertaken specifically to identify faults with significant groundwater carrying capacity. The faults and structures are grouped by their dip and trend.

2.4.1 Northwest Trending Faults

The group of northwest-trending faults includes the Liese Creek and Mid-Ridge faults.

1. Liese Creek Fault Zone. A fault system appears to run sub-parallel to Liese Creek, and may be the reason Liese Creek occupies its current location. The fault zone is generally identifiable in the subsurface by displacements in the orebody zone. It runs approximately NW-SE, is sub-vertical, and exhibits right-lateral strike-slip offset of a few hundred feet. Two long horizontal drill holes were drilled from the underground exploration drift to intersect this fault system

[1] A third quartz sill, which contains an ore target known as the L3 zone, is know to exist beneath the L2 ore zone. This lens is smaller than the L2 ore lens, and is not currently being considered for development.

(00U98C and 00U98D, indicated on Plate 7). Hole 00U98C passed beneath Liese Creek at approximately 700 feet from the collar. A 0.1-foot zone of broken material was reported in approximately the fault location (694 ft from the collar), but this was considered by the site geologist to be slough in the hole. At the location where the principal increase in water flow occurred during drilling (50 gpm increase at 683 feet from the collar), there were no reported faults, joints, fractures, or broken material. Hole 00U98D passed beneath Liese Creek at approximately 730 feet from the collar. The hole intersected a 75-foot zone containing graphite-rich gneiss, faulted material, gouge, and breccia between 646 feet and 721 feet from the collar. However, 00U98D did not intersect identifiable additional flow at or near the fault location.

2. Mid-Ridge Fault. This fault runs approximately NW-SE, is sub-vertical, and exhibits right-lateral strike-slip offset of a few hundred feet. The fault appears to be water bearing when intersected, although it also appears to act as a barrier to flow, resulting in high pressures being encountered when the structure was intersected by drilling performed in advance of underground development. The bulk hydraulic conductivity of this fault is considerably less than that observed in the high flow section of the Liese Creek fault zone.

2.4.2 Northeast-Trending Faults

The group of northeast-trending faults includes the Up-ramp, C, and Bypass faults, and two unnamed faults that cut the southern portion of the L1 vein. These are steep, sub-vertical faults that exhibit up to 200 ft of left-lateral offset. Measurable flow is not associated with these faults in drill holes or in the underground ramp system. Localized seeps were encountered where the footwall ramp intersected the Up-ramp fault and where the decline intersected the C fault. However, these seeps stopped after several months.

2.4.3 East-West Faults

The group of east-west faults includes the Basalt faults. These are vertical faults that exhibit evidence of left-lateral strike-slip motion of approximately 50 ft. The faults contain a swarm of discontinuous basalt dikes. No water is associated with these faults underground or in drillholes.

2.4.4 Low-Angle Faults

Several low angle faults are recognized at Pogo where they occur adjacent to mineralized quartz veins. They typically strike northeast with shallow to moderate dips to the northwest. The faults are defined by zones of fault gouge and mélange up to 4 feet thick that occur along the hangingwall and/or the footwall of the quartz veins. Measurable water flows have never been associated with these faults in drillholes or in the underground development.

2.5 Permafrost

Permafrost (perennially frozen soil and rock) is present to depths of approximately 300 feet below the surface on north- and west-facing slopes at the site. Discontinuous permafrost exists on the south-facing slopes to approximately the same depth. Locations beneath permanently flowing water (the Goodpaster River and the lower reaches of Liese Creek) are free of permafrost. The distribution of permafrost at the site is shown in Plate 6, which has been developed by reference to drilling observations, temperature measurement, vegetative cover, and field observation.

The temperature of the permafrost at the site has been measured by a number of thermistor strings in boreholes. In general, the temperature of the permafrost zones is between 30°F and 32°F (-1°C to 0°C) (Teck-Sumitomo, 2000). Accordingly, it is expected that the permafrost may be capable of transmitting groundwater flow, at least in some locations, as a result of heat flow from the surface during the summer (Andersen and Morgenstern, 1973).

2.6 Groundwater

Groundwater flow in the vicinity of the Pogo project is limited, due to the arid climate, low temperature, low hydraulic conductivity of the local rock suite, and presence of permafrost.

The piezometric surface in the site area prior to any site activity has been determined based on the available data, and is shown on Plate 4. The zone of saturation at the Pogo site appears to occur at a depth of approximately 300 feet below ground surface in the vicinity of the ridge between Liese Creek and Pogo Creek, grading to the land surface at the major topographic lows represented by the valleys of Liese Creek, lower Pogo Creek, and the Goodpaster River.

Information collected during drilling, and water levels in some completed wells, suggest the presence of a perched water table above the permafrost that exists on the north-facing slope of Liese Creek. At the ridge the depth to water of this feature appears to be in the order of 80 feet.

2.7 Surface Water

2.7.1 Streamflow

The site is located on the Goodpaster River. To the north of the orebody is Liese Creek, and to the south is Pogo Creek. Both creeks are considered to be perennial, although surface flow does not always occur in the stream channels, descending occasionally into the permeable valley fill sediments. Regional evaluations indicate that the flow in streams in the area is related to catchment area. Stream flow in streams and rivers in the vicinity of the site is summarized on a unit catchment area basis in Figure 2. Average stream flow is estimated to total the equivalent of 7.5 inches annual water depth over the catchment area (EBA, 1998; Teck-Sumitomo, 2000). Most of the runoff occurs in the spring freshet.

2.7.2 Baseflow

Baseflow in streams in the area has been evaluated using stream flows in the period December to March, when surface flow to the streams is at a minimum, and most of the stream flow is expected to be the result of emerging groundwater. Using the baseflow as a gauge of deep groundwater infiltration, stream baseflow is estimated to be equivalent to a production rate of 1 inch per year (Figure 2). This value may be an under-estimate of the actual baseflow in interior Alaska, as ice accumulation in the winter period is likely to be occurring, reducing the flow reporting to the rivers. Flow data from the four years of record available for the Goodpaster River (monitored at the Pogo Site) also indicate an estimated average baseflow of 1.0 inch per year (AMEC, 2000).

2.8 Water Quality

The quality of surface water in the project area is good. The water is calcium-sulfate dominated, with total dissolved solids content of approximately 100 mg/L. Dissolved trace metal concentrations in the surface water are generally below detection.

Groundwater in the valley sediments at the site area has a somewhat higher dissolved content, ranging from approximately 180 mg/L in wells close to the Goodpaster River, to approximately 650 mg/L in wells near the valley slopes. The water is predominantly calcium-magnesium-bicarbonate-sulfate water.

Groundwater in the gneiss rock is higher in dissolved solids with approximately 200-500 mg/L TDS in the vicinity of but outside the orebody. The water is calcium-magnesium-sulfate-bicarbonate water, and is hard. Arsenic is present in the water, at a concentration in the order of 0.1 mg/L. Other trace metals are predominantly below detection levels in this water. The quality of water in close proximity to fresh-water infiltration locations is generally better than this; TDS values in rock in the vicinity of Liese Creek is approximately 400 mg/L, based on inflow to a drill hole penetrating the Liese Creek fault zone.

Groundwater in and near the orebody displays the highest dissolved solids content of all project waters, with approximately 500-1600 mg/L TDS. The water is calcium-magnesium-sulfate-bicarbonate water, and is very hard. Arsenic is naturally elevated in this water, at concentrations ranging between 0.5 mg/L to 4 mg/L, and averaging around 2.5 mg/L. Some other trace metals including zinc are also present in the water at low levels.

3. Groundwater Evaluation

Groundwater parameters and the groundwater system behavior at the Pogo Site have been evaluated by a number of methods. Hydraulic conductivity has been directly measured from the surface in boreholes, and both directly measured and inferred from testing and monitoring of inflow and head response to the development of an exploration decline that was driven beneath the principal orebody at the site. This section summarizes the results of those investigations in developing hydrologic parameters for the mine inflow evaluation.

3.1 Surface Wells

3.1.1 Hydraulic Conductivity

Surface well tests have been conducted to identify groundwater head information, hydraulic conductivity information, and water quality information (Golder, 1998). During the drilling of the surface exploration program, a total of 41 hydrogeology tests were performed in vertical exploration coreholes. This testing comprised hydraulic conductivity testing using packer technology, and installation of permanent completions to allow measurement of groundwater pressure, in particular in the vicinity of the orebodies. The results are summarized in Table 1, and the distribution of the results is presented in Figure 1.

The median[2] hydraulic conductivity of the rock evaluated in these tests was 3 ft/yr[(3)], with values ranging from 0.01 ft/yr to 500 ft/yr. In general the higher values were encountered in the rock down to 300 feet below ground surface, and the lower values were encountered at deeper levels, in those tests that did not intersect the orebodies. The surface tests were in general undertaken in vertical holes, and so represent horizontal hydraulic conductivity. Many of the test sections included portions of the quartz orebody lenses, which are expected to be higher hydraulic conductivity than the surrounding rock, so the tests tend to over-estimate the hydraulic conductivity of the country rock.

3.1.2 Water Elevations

Water elevations in wells were measured prior to underground operations, and are reported in Table 9, and are plotted and contoured in Plate 4. This presentation indicates a number of features:

1. Groundwater flow in the vicinity of the orebodies is to the northwest, essentially down the spine of the ridge between Pogo Creek to the south, and Liese Creek to the north.
2. Groundwater is drawn to the topographic low areas, specifically Liese Creek valley, the Goodpaster River valley, and the Pogo Creek valley. This suggests that the rock conductivity is low compared with the infiltration; heads between these features are mounded.
3. Groundwater elevations are significantly below ground surface along the ridge that overlies the orebodies. This shows that the infiltration is insufficient to cause saturation of the rockmass beneath the ridge.

3.1.3 Water Quality

Water quality data for a wide range of parameters has been gathered from the surface holes, and also from some underground drill holes. These data are summarized in Table 6.

Two principal parameters of this dataset have been evaluated:

1. Total Dissolved Solids. TDS results are presented for the bedrock groundwater system in Figure 5. Details of the TDS concentration in the L1 orebody in the vicinity of the exploratory decline are presented in Figure 6. The concentration of TDS shows a significant elevation in the vicinity of the orebody, with a peak in excess of 1,000 mg/L, decreasing in all directions to the non-orebody background value of approximately 500 mg/L. TDS values in bedrock along the Liese Creek valley drop to approximately 250 mg/L, apparently as a result of infiltration of relatively fresh water from Liese Creek into the Liese Creek Fault Zone. This pattern consistent with lim-

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[2] The median is used here as a central measure, in that it is non-parametric, and distribution independent. In these datasets it has been found to be similar to the geometric mean, but not subject to influence by extreme but low-frequency values. The arithmetic average of the conductivity values was found to be considerably higher than most of the datasets from which they were computed, and it is not considered to be a reliable measure of central tendency.

[3] The units used for hydraulic conductivity in this report are feet per year (ft/yr). This is consistent with the use of the Imperial unit system for the report. Conversion to metric units can be made using the following factors:

1 ft/yr = 1.0×10^{-6} cm/sec
1 ft/yr = 1.0×10^{-8} m/sec

ited flow of groundwater from upgradient highland areas towards the Goodpaster River through the orebody, with dilution from infiltration vertically into the groundwater system.

2. Arsenic. The arsenic results are presented in Figure 7. Arsenic shows significant elevation in the heart of the orebody, with a peak in excess of 3,500 µg/L, and decreases in all directions to the general background value of approximately 25 µg/L. Groundwater monitoring wells were established downgradient of the core area at MW99-216 and MW99-213. These wells also support the conclusion that arsenic is not transported away from the orebody. The high concentration in the heart of the orebody appears to be due to release of arsenic by the orebody rocks. That this release continues to occur over geologic time suggests very slow movement of water laterally through the rockmass. The reduction in arsenic concentration as the water flows to the northwest away from the orebody is due in part to dilution, which explains a reduction by a factor of approximately three, as noted above. The remainder of the 100-fold decrease can only be explained by adsorption of arsenic by the country rock materials as groundwater from the orebody flows through them, resulting in the removal of arsenic from that water. This observation has significant implications for the fate of any arsenic that might be released from mine backfill after the closure of the mine.

Based on the groundwater quality data, it appears that flow in the groundwater system is very slow, allowing chemical interaction between the flowing groundwater and the rockmass. In locations where there may be surface inflow of water to drains, such as in the vicinity of Liese Creek (see quality of water for drain 00U098C), the groundwater quality is better than in other locations where inflow occurs to the orebody. This is consistent with an expectation that the inflowing water is a mixture of better quality surface water with the lower quality water in the orebody and country rock.

3.2 Dry Stack Tailings Area Tests

3.2.1 Hydraulic Conductivity

Testing of the hydrology of the Dry Stack Tailings Area has been conducted to determine water levels and hydraulic conductivity in this area (EBA, 1999; AMEC, 2000). The proposed dry stack tailings area to the southeast of the orebody has been tested for hydraulic conditions, using tests in a total of 14 drill holes. The hydraulic conductivity results are summarized in Table 2, and the cumulative distribution is plotted in Figure 1. The median hydraulic conductivity was 33 ft/yr. These tests were performed in relatively shallow vertical holes (to 100 feet), and are all in the base of the Liese Creek Valley. The median horizontal hydraulic conductivity is approximately an order of magnitude higher than test values obtained from greater depth, which is expected due to weathering and stress relief of the near-surface rockmass.

3.2.2 Water Levels

The water table in the groundwater system in the Liese Creek alluvium in the vicinity of the proposed Dry Stack is below creek level by as much as 20 feet. This is shown for well LD-005 in Figure 8. Water levels in the alluvium vary by up to 20 feet, due to seasonal inputs in the spring and summer. The water table is always below the creek level at this location. This indicates that the creek is perched above the water table in the alluvium, and water in general seeps from the creek into the alluvium, through the silty sands that make up the matrix of the near-surface materials in Liese Creek valley (AMEC, 2001).

3.3 Exploration Decline

An exploration decline has been constructed to provide access to the orebody area for the purposes of underground exploration of the orebody by drilling. Construction of the decline was initiated in early 1999. In mid-1999 the exploration decline entered the water table at the site, resulting in extraction of water from the groundwater system by this feature. Since that time the flow of groundwater to the decline has been measured, and the response of the groundwater system to the progress of the decline has also been monitored. More recently, the decline has been used as a platform for the drilling of exploration holes to evaluate the orebodies in the vicinity of the decline. This drilling has also provided an opportunity for hydrological investigation of the orebody and the surrounding materials in considerable detail. The results of the testing activities and the response of the groundwater system to the development of the decline are presented in this section.

3.3.1 Description of the Decline

The decline comprises approximately 6,600 feet of development drifting, beginning on the flank of Pogo Creek, and proceeding to the northeast. The drift begins with a decline, which drops from the collar elevation of 1525 feet to approximately 1,237 feet at the tail drift location. The drift then rises gently up to an elevation of 1267 feet. At this point the decline splits, with the northeastern arm descending beneath the orebody to an elevation of 1185 feet, and the eastern arm ascending to the orebody at an elevation of 1370 feet. The exploration then extends southwest and northeast along the orebody at this elevation for a total distance of approximately 500 feet. The decline and nearby monitor wells are shown on Plate 7.

During the period just after the drift entered the saturated portion of the bedrock there was localized grouting of the drift walls to control inflow. This grouting was successful, however after flows were observed to reduce rapidly after initially encountering water at any given location, the decision was taken to eliminate grouting of the rock around the drift to allow drainage of the rockmass to occur. The drift has been essentially ungrouted since, except for trial applications of foam grout materials, and grouting in the east heading of the ore drift to control flow from the vicinity of the Mid-Ridge Fault.

Since sinking the decline, exploration corehole drilling has been conducted from cutouts located approximately every 100 feet along the decline. These coreholes have generally been drilled along the 316-degree azimuth, and are angled from nearly horizontal to beyond vertical. The locations of the holes are shown on Plate 7. The holes have all been fitted with a packer plug arrangement, such that flow and/or water pressure can be measured or manipulated at the collar. In addition to the 316-degree azimuth holes, three holes have been drilled to establish the groundwater and geologic conditions to the east and northeast of the drift, towards Liese Creek. These holes were also flow- and pressure-tested.

The information collected from the decline and the exploration holes drilled from it comprises the following:

1. Flow data from the driving of the exploration decline.
2. Water level data from monitoring wells in the vicinity of the decline.

3. Flow and head data from drill holes drilled from the exploration decline.
4. Water quality data from the drill holes.

In addition, multi-hole response testing has been conducted in fans of holes drilled from the cutouts in the exploration adit, which has allowed the evaluation of the hydraulic behavior of relatively large volumes of rock adjacent to the exploratory decline.

3.3.2 Flow to the Decline

The flow to the decline is shown on Figure 3. The flow has increased fairly steadily since water was encountered in August 1999, and is currently controlled by shutting off inflow from some drain holes to limit mine inflow to approximately 70 gpm. The flow is to some extent controlled by the following activities:

1. There was grouting of the rock in the vicinity of the decline in the early period of decline development. However the inflow that was controlled by this grouting reduced after a few weeks, so the grouting was found to be unnecessary for inflow control in this location, and was discontinued.
2. Grouting also took place in the east end of the ore exploration drift, to control inflow from the vicinity of the Mid-Ridge Fault. This grouting was successful in restricting inflow to the mine, and allowing gradual drainage of the area through controlled drainholes. Subsequent drilling through this grouted area indicated that the water pressure was removed from this area, indicating that drainage took place despite the grouting.
3. A total of approximately fifty exploration holes have been drilled from the decline. These holes have served to draw water from the material in the vicinity of the decline when they are allowed to flow. All of them have been fitted with a packer and a control valve, which is in general closed after drilling, then opened to drain selected holes. The flow during drilling and subsequent drainage of the holes has in general increased the amount of flow that would otherwise enter the decline. The decline would have experienced a greater short-term inflow if these holes were allowed to drain freely[4]. All of the exploration holes except one (00U98C, drilled to the north east from the exploration facility into the Liese Creek fault zone) have been open and free draining since the end of 2000. Well 00U98C has been drained at a flow rate of approximately 25 gpm since the end of 2000.

The current length of drift below the original water table is approximately 3,000 feet. The flow from the entire drift can be used to compute an effective hydraulic conductivity, using the equation for radial flow to a drain:

$$Q = 2 \pi L K H / \ln(L/r)$$

[4] The peak instantaneous aggregate flow from all the holes if they had all been opened at the same time and were allowed to drain freely (based on the peak flow observed from each hole) is 399 gpm. It should be noted that there has been a significant decline in the flow from all holes over time (except 00U98C, which was drilled into the Liese Creek Fault beneath the creek), so that the flow to the decline that would have occurred had they been allowed to drain freely after being drilled would have been considerably less than this rate.

$K = Q \ln(L/r) / (2 \pi L H)$

where: Q = flow to the drain (70 gpm = 4,918,717 cu.ft/yr)
L = length of drain (3,000 ft)
K = hydraulic conductivity of material around drain
H = average head above drain (400 feet)
r = radius of drain (100 feet; equivalent to the radius created by the drill holes)

Thus, the average effective hydraulic conductivity of the material is:

$K = (4{,}918{,}717 \text{ cu.ft/yr}) * \ln(3000 \text{ ft} / 100\text{ft}) / (2 * \pi * 3000 \text{ ft} * 400 \text{ ft}) = 2.2 \text{ ft/yr}$

Note that this estimate is for an essentially horizontal opening in the groundwater system. The hydraulic conductivity therefore represents a mixture of both horizontal and vertical hydraulic conductivity. This is important because the modeling and the structural information suggest that the vertical hydraulic conductivity is greater than the horizontal hydraulic conductivity. As a result, the value here would be expected to be greater than the horizontal hydraulic conductivity, and less than the vertical hydraulic conductivity.

This value is also somewhat larger than would have been computed if the flow to the system had been allowed to equilibrate (the flow used was prior to drainage of the drains). Thus the head gradients to the underground workings were greater than would exist under steady state conditions.

3.3.3 Water Level Data

The water level in a number of surface drill holes has been monitored during the driving of the exploration decline, and the water levels recorded are shown in Figure 4. The locations of the wells are shown together with the outline of the decline in Plate 7. The following observations are made:

1. As the decline passed MW97-081, there was a small gradual reduction in water level in that well. The well is located approximately 75 feet southeast of the decline, and is completed below the elevation of the decline. At this location the decline only just intersects the water table in the rock, so the drawdown is the result of inflow to the decline further northeast along the decline.
2. As the decline passed very close to MW97-082 the water level in that well dropped rapidly. This well is completed with the open interval immediately adjacent to the decline, and within a few tens of feet of the decline. Thus the decline essentially intersected and drained the hole. The water level in the hole can only be measured to a depth of 750 feet below ground surface due to limitations in the sounder length; the actual water elevation is probably at decline level, which is at an approximate elevation of 1,330 feet at this location.
3. As the decline later passed by MW97-076, located approximately 100 feet east of the decline, the water level in this well also dropped rapidly (although less rapidly than MW97-082). A transducer has been placed in this hole to monitor the drawdown history, and the response is shown in Figure 4. The water level in this well has declined towards the drift elevation in this location, which is approximately 1257 feet.

4. Well MW-97-071 is located adjacent to the drift, just between the "split" between the ramp up to the orebody, and the final decline to the northeast. This well experiences problems with ice plugging, but a reading in late 2000 indicated that the water level in that well is now at approximately the elevation of the workings, having been drained by the development.
5. On the opposite side of the decline from MW97-076, and about 240 feet away from the decline is MW97-041. This well has slowly responded to the development of the decline adjacent to it, with a head reduction of approximately 40 feet. Eight coreholes have been drilled from the decline towards the area of MW97-041, and drained, without any major impact on the water level in the well. The closest of these coreholes passed within 100 feet of the well. Based on this information, it is concluded that the well is completed in a very low permeability zone of the bedrock; this well constitutes a direct indication of the presence of essentially vertical zones of very low permeability in the formation. It is probable that there are many such zones that segment the formation hydrogeologically.
6. To the southeast of the decline, along the approximate alignment of the Mid-Ridge Fault, well MW98-133 has drawn down in excess of 89 feet, MW99-204 has drawn down 60 feet, and MW99-202 has drawn down 31 feet since the driving of the drift. These water level reductions suggest that dewatering of the Mid-Ridge Fault has caused a propagation of drawdown to the southeast. There are no active monitoring wells in corresponding alignment to the northwest along the fault, so it is not known if this effect spreads in that direction also. This behavior is consistent with the observation that the Mid-Ridge fault zone is water bearing.

The combination of the water level data and the flow information allows an estimate of the drainable porosity[5] of the rock that is being dewatered by the passage of the decline, as follows. The width of the zone that the drift dewaters appears to be between 100 and 250 feet from the drift, or a total width of about 300 feet. The average depth of the original water table above the drift location was about 400 feet, and the length of the drift that intersects the water table in March 2000 was about 2,000 feet. The cumulative net flow from the drift to the end of March 2000 was approximately 4,900,000 gallons or 652,000 cubic feet of water. Thus the porosity can be computed by dividing the volume of water extracted into the volume of rock dewatered (which assumes that the infiltration to the rockmass is limited):

$$\begin{aligned} n &= \text{volume of water/volume of rock} \\ &= 652{,}000 \text{ cu.ft. water} / (300 \text{ ft} * 400 \text{ ft} * 2000 \text{ ft}) \\ &= 0.003 \end{aligned}$$

Thus the effective porosity of the rock appears to be in the order of 0.3%. This low porosity is consistent with the low hydraulic conductivity that has been identified in this rockmass.

3.3.4 Single Hole Hydraulic Conductivity Tests

All of the underground exploration holes have been tested for hydraulic conductivity. The test method was as follows:

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[5] The drainable porosity is the volume of water that will drain from a unit volume of rock when it changes from a saturated to an unsaturated condition.

1. Install a packer with a valve at the drift-end of the drill hole.
2. Close the valve for a minimum of 24 hours
3. Measure the shut-in head in the hole.
4. Open the valve and allow flow for an hour.
5. Measure the flow rate from the hole.
6. Close the valve and allow the head to recover.

This test provided a shut-in head and an open-hole flow rate, respectively.

The results of these tests are presented in Table 3, and the cumulative distribution of the test results is presented in Figure 1. This table shows the shut-in pressure and the open-hole flow for each hole. Hydraulic conductivity was computed for each hole using the steady-state radial flow equation. Pressure recoveries after the test were in general not accurately analyzable, as a result of the capture of air in the well bore during the flow period of the test. As a result, storage characteristics of the formation could not be determined from these tests.

In general three groups of results were obtained from these tests:

1. Drill holes that penetrated thick portions of the orebody generally produced relatively high hydraulic conductivity estimates. Typical values were in the order of 10 ft/yr to 100 ft/yr, averaged across the entire drill hole length.

2. Drill holes that penetrated relatively thin portions of the orebody, or did not penetrate the orebody, produced generally low hydraulic conductivity estimates, in the order of 0.1 ft/yr to 1 ft/yr, averaged across the entire drill hole length.

3. Drill holes that penetrated the Mid-Ridge and Liese Creek fault zones produced high hydraulic conductivity estimates for the relatively short portions of the hole where the fault zones were located (or inferred). Hydraulic conductivity values for these zones were in the order of 1000 ft/yr if the permeable zone was assumed to be 10 feet wide[6].

Based on these results, it is concluded that the orebody quartz zones and two major permeable fault zones comprise the principal permeable units in the formation, and that the remaining materials are of low hydraulic conductivity.

3.3.5 Liese Creek Fault Zone Hydraulic Conductivity

As discussed in Section 2.4.1 above and Section 3.3.2 above, two drill holes were extended to the northeast from the exploration adit to intersect the Liese Creek Fault zone. One of these holes (00U98C) is capable of producing approximately 150 gpm[7] of water from the fault and has exhibited a maximum his-

[6] In particular, one test of the Liese Creek fault zone indicated a one-foot wide intersection producing 50 gpm at a shut-in pressure of 116 psi. The computed hydraulic conductivity of that one-foot wide zone is 13,000 ft/yr.

[7] Note that when drilled, this hole produced approximately 10-15 gpm from the location of the Mid-Ridge fault zone, and an incremental 50 gpm from the location where the Liese Creek fault zone was expected to occur (no evidence of a fault was identified in the core recovered from this portion of the hole). The 150 gpm reported here is the peak flow ever recorded for the entire length of the drill hole, after it had been shut in for a considerable period of time. It is not considered that the hole could sustain this flow, but the data is used to pro-

toric shut-in pressure of 135 psi. Using these limiting values, the effective hydraulic conductivity of the fault assuming a 100-foot intersection[8] is 338 ft/yr. The other hole (00U98D) draws essentially no water from the fault, indicating a hydraulic conductivity of less than 10 ft/yr on the same basis[9]. Using these two holes as representative samplings of the fault zone hydraulic conductivity, the effective bulk hydraulic conductivity would be expected to be approximately 169 ft/yr[10].

Hole 00U98C was apparently partly plugged with (rock) debris from the wall of the hole at the time that the test presented in Table 3 was performed on June 13, 2000. As a result, this test data was not used to develop the hydraulic conductivity estimate of the portion of the hole that tapped the Liese Creek fault zone. The data that was used was the highest sustained flow ever measured (150 gpm, measured after cleaning the hole out on December 28, 2000) and the corresponding shut-in pressure immediately prior to the flow period (135 psi). All of the flow was ascribed to the fault zone, although during the drilling of the hole the flow from the hole was 30 gpm prior to entering the zone, and 80 gpm after passing through it, suggesting that perhaps only about half of the flow actually comes from the Liese Creek fault zone. Since that time, two further clean-outs and tests have been performed (September 10, 2001, and October 11, 2001). On all occasions, the transmissivity of the hole was computed:

Date	Pressure (psi)	Flow (gpm)	Trans-missivity (ft2/yr)	Length (ft)	Hydraulic Conductivity (ft/yr)	Comment
27-May-00		80				During drilling; rods in hole
13-Jun-00	125	16.5	4019	100	40	Partial blockage of hole; not used
28-Dec-00	135	150	33832	100	338	Cleaned out; value used
10-Sep-01	115	100	26478	100	265	Cleaned out; careful step test
11-Oct-01	115	100	26478	100	265	Cleaned out; careful step test

Accordingly, the transmissivity used in the analysis (from which the hydraulic conductivity of 338 ft/yr is computed) at the Liese Creek fault zone is considered to be conservative for this location. The testing that was relied upon was performed immediately after cleaning out the hole, and with full flow and pressure.

duce an upper bound to the effective conductivity of the fault material. Sustained flow from the hole after clearing of rock blockages and allowed to remain open was found to be approximately 100 gpm in September, 2001.

[8] Based on logging of core from the hole there is no observed fault intersection in the hole in the vicinity of the fault trace. The only broken material encountered in this area was 0.1-feet thick. However, in the modeling the faults are set to be 100 feet thick, so as to occupy a single cell. Accordingly the fault conductivity is computed assuming a 100-foot thickness, so that the computed effective conductivity matches the cell size in the model. The computed values are therefore lower than the actual conductivity in the fault zone itself.

[9] This assumes that the shut-in pressure is also 135 psi, and that the flow from the Liese Creek fault zone is less than 5 gpm, the limit of the ability to identify flow from the fault zone as distinct from the rest of the drill hole.

[10] The hydraulic conductivity values for the Liese Creek fault zone represent the effective mean hydraulic conductivity in the plane of the fault zone, reflecting the effect of both horizontal and vertical hydraulic conductivities.

3.3.6 Multiple Well Tests

A number of multiple well tests were performed in the underground holes to evaluate the groundwater flow system, and to obtain information about storage characteristics of the formation. The tests were performed as follows:

1. Install a packer with a valve at the drift-end of all drill holes in the vicinity of the test (with the valves closed), and install a pressure transducer at each collar.
2. Measure the shut-in head in each hole in the test.
3. Open the valve of the test hole, and allow flow from the hole for twelve hours. Measure the flow rate from the hole periodically.
4. Measure the pressure response in all monitored wells for the flow period.
5. Close the valve on the flowing well. Monitor the heads in all wells during the to recovery period.

The tests were analyzed using conventional pumping well analysis, with the monitor well locations being assumed to be the midpoint of the open portion of the hole being considered, and with drawdowns being measured relative to the initial water pressure measured at the collars of each hole.

The results of three tests are summarized in Table 4. Based on these results, the following observations are made:

1. The groundwater system in the vicinity of the exploration drift appears to be segmented, with moderately permeable and porous materials segmented from low permeable and porous materials.
2. The hydraulic conductivity of the materials tested is in the same range as the results obtained from the single-hole testing: from around 1 ft/yr to 100 ft/yr.
3. The storage characteristics of the materials vary from a drainable porosity of 0.04% to 0.3%, again indicating the variability of the material styles encountered by the drill holes.

These results are used in the development of the computer model of the groundwater system, by conditioning the hydraulic conductivity values that are used.

3.4 Liese Creek Decline Pilot Hole Tests

A 1,700-foot long geotechnical exploration corehole was drilled southwest from elevation 1875 ft on Liese Creek to provide a pilot hole for a proposed access decline at this location. The location of the drill hole is shown on Plate 4. Maximum flow from this hole was 3 gpm. The known fault structures were intersected very near the projected locations and no unanticipated water bearing fault structures were encountered. The entire hole was hydraulically tested using a straddle packer technology, with the packers spaced 100 feet apart. The testing was performed using low-pressure water injection.

3.4.1 Hydraulic Conductivity

The results of the testing are presented in Table 5, and are shown on a section through the pilot hole on Plate 5. The cumulative distribution of the hydraulic conductivity values is presented in Figure 1. In summary, the average hydraulic conductivity of the material encountered in the entire hole was 9 ft/yr, with values ranging from 1 ft/yr to 28 ft/yr. The higher conductivity values being associated with the Mid-Ridge fault zone and a more fractured area beyond the limits of proposed underground development in the final 300 feet of the hole. The testing provided information on the hydraulic conductivity in a vertical plane around the drill hole, combining horizontal and vertical hydraulic conductivity at the test locations. The conductivity of the testing was much more uniform than the conductivity values obtained from similar testing in vertical holes, suggesting that vertical fracturing is more ubiquitous and probably more continuous than horizontal fracturing.

3.4.2 Groundwater Pressure and Heads

The maximum shut-in pressure encountered in the testing was 31 psi (equivalent to an elevation head of 1,947 ft AMSL, at the end of the hole. The head at each test location has been computed, and is presented on Plate 5 for each test interval, interpreted as a water table. This head information has been incorporated into the pre-development groundwater levels shown in Plate 4.

3.5 Hydraulic Conductivity Summary

The results of analysis of all test data are presented in cumulative form in Figure 1, and are summarized below.

Test Location	Number	Hydraulic Conductivity (ft/yr)		
		Median	Geometric Mean	Arithmetic Mean
Surface holes	41	3	4	56
Underground	41	5	4	18
Dry Stack	14	33	22	49
1875 Liese Pilot Hole	15	5	7	10
Overall	111	5	5	35

These test results are in general from relatively long test intervals, and therefore represent an averaged value, including areas of lower permeability, and areas of higher permeability, in the tested section. The results suggest that the rockmass is in general of low hydraulic conductivity, with a median measured value of 5 ft/yr. The observation that there are some tests with significantly lower hydraulic conductivities measured, combined with the observation that the rockmass in the vicinity of the Pogo Deposit is intersected with a relatively large number of sills, dikes, and infilled faults, suggests that the overall effective rockmass hydraulic conductivity may be significantly less than the median hydraulic conductivity. This parameter is determined in this low conductivity rockmass by calibrating a model to the actual measured behavior of the flow system in the rockmass (see Section 5 below).

Most of the hydraulic conductivity tests include a contribution from the tabular, quartz orebodies. Based on observations of the orebody materials, and on the few tests that test it independently of the remainder of the rockmass, it appears that the ore materials are of significantly higher effective hydraulic conductivity than the surrounding country rock. Thus the results of the majority of the tests reported reflect the orebody, at least in part.

Based on the entire database of permeability testing, the most reasonable estimates of conductivities in the vicinity of the Pogo Project are:

Orebody	5 ft/yr
Country rock	0.5 ft/yr (1/10th the orebody conductivity)
Near-surface rock	50 ft/yr

3.6 Infiltration

Infiltration at the Pogo site is a complex process, controlled by a range of factors at the site, including slope aspect, slope angle, geology, presence of permafrost in the surface and subsurface, precipitation, runoff, temperature, and vegetation. A number of methods were used to estimate the overall infiltration to the ground surface at the Pogo site, and into permafrost at the site.

3.6.1 Infiltration into permafrost terrain

The rate of infiltration of precipitation into permafrost at the Pogo site has been estimated with the assistance of extensive investigation in central Alaska by Kane and Gieck at the University of Alaska at Fairbanks, in particular at a test area on Ester Dome near Fairbanks. They used a number of basic tools for the evaluation of infiltration into permafrost soils, with the following results:

1. Ring Infiltrometers. Infiltrometer tests on frozen soils show that the infiltration rate reduces by a factor of two when relatively dry soils are frozen, and by more than two orders of magnitude when relatively wet soils are frozen (Kane, 1980b; Kane and Stein, 1983b; Kane and Stein, 1983c).

2. Borehole infiltration. Borehole infiltration tests on frozen soils indicate that infiltration rate is a function of moisture content of the soil, and temperature. Kane (1980a) performed borehole tests in materials with high and low moisture content, and in frozen and unfrozen conditions. He concluded that infiltration rates approximately halve when a soil is (just) frozen, and that infiltration rate decreases by nearly an order of magnitude as the moisture content increases towards saturation for both frozen and unfrozen soils (Kane, 1980a).

3. Moisture profiles. Kane and Stein performed repeated test borings to depths of approximately 1 meter and measured moisture in soils during the winter each year from 1978-79 to 1981-1982 (Kane, 1980a; Kane and Stein, 1983c). They found that essentially no net moisture was lost from the top meter of natural or irrigated soil during the freezing and thawing processes that take place over the winter. Based on the tests performed, Kane and Stein conclude that "the majority of groundwater recharge occurs in permafrost-free areas during snowmelt, and no significant recharge occurs in permafrost areas of either continuous or discontinuous zones" (Kane and Stein, 1983b). During the snowmelt period, total recharge of between 0.9 and 3.6 inches was measured into dry loam when it is part of the frozen active layer (Gieck, 1986). However, this infiltration does not necessarily occur through frozen material, and does not necessarily proceed to depth in the groundwater system.

4. Darcy's Law. Computation of infiltration through permafrost requires the determination of hydraulic gradient and hydraulic conductivity for permafrost soils and rockmasses. Measurement of both of these parameters for frozen materials is difficult due to damage to the test equipment by freezing of the test fluid, and by disruption of thermodynamic equilibrium by the induced fluid flows in the test (Burt and Williams, 1976). Hydraulic conductivity reduces with temperature by a factor of two between 20°C and 0°C due to the reduction of water viscosity with temperature (Klock, 1972). Below freezing, soil hydraulic conductivity (and therefore the infiltration) reduces one to two orders of magnitude due to the reduction of the quantity of free water in the soil (Anderson and Morgenstern, 1973; Burt and Williams, 1976; Kane, 1980a). This reduction would also reduce infiltration by the same extent if infiltration were controlled by hydraulic conductivity.

5. Water Balance. Detailed water balance evaluation of areas containing permafrost is capable of identifying the magnitude of infiltration. In general, infiltration is computed in these studies by the difference between measured water inputs and outputs at the surface of a test area. Gieck (1986) performed a detailed water balance evaluation for two watershed basins and two runoff plots on Ester Dome, north of Fairbanks. In the test areas, the geology comprised approximately 20 cm of organic material and three meters of silty soil overlying metamorphic bedrock (schist). Water balances were performed for the 1983 and 1984 snowmelt periods (Gieck notes that there is essentially no infiltration apart from the snowmelt period). Infiltration to the silty soil in the shallow subsurface (overlying bedrock) in the snowmelt period was computed as follows:

Basin	Ester Creek		Happy Creek	
Year	1983	1984	1983	1984
Snowpack Water Equivalent (inches)	6.1	5.0	5.4	4.2
Computed Snowmelt Infiltration (inches)	3.6	2.6	1.2	0.9
Infiltration/Snowpack (%)	59%	52%	22%	21%
Permafrost cover (%)	21%	21%	57%	57%

Gieck concludes that "Much of the infiltration in the Happy Creek basin result(ed) in recharge to suprapermafrost groundwater, with recharge not reach(ing) the deeper groundwater. In comparison, Ester Creek watershed is dominated by well-drained, south-facing, permafrost-free soils" (Gieck, 1986, p. 62). If the two basins were considered to form a trend, then extrapolating to 100% permafrost cover would suggest a shallow infiltration of 0% of snowpack (0 inches per year), while extrapolating to 0% permafrost cover would suggest a shallow infiltration in the order of 75% of snowpack (or about 4 inches per year). It should be noted that this infiltration study was completed on unsaturated, shallow, silty soils overlying bedrock, a condition much different than the deep subsurface infiltration through the fractured and potentially frozen bedrock found at Pogo.

6. Groundwater Chemistry. Groundwater beneath continuous permafrost has been found to be non-potable, due to high dissolved solids content (Kane, 1980b). This suggests that the water has a very long subsurface residence time, and its quality has degraded as a result of dissolution of constituents from the soil or rock matrix. This in turn suggests much lower rates of infiltration of

precipitation to depth in continuous permafrost areas when compared with unfrozen locations, where groundwater is generally potable.

The conclusion of all available studies is that there is essentially no infiltration of precipitation through frozen soil or rock to the sub-permafrost groundwater system, although infiltration through the unsaturated zone is still possible through unfrozen conduits. The magnitude of the deep (sub-permafrost) infiltration that can occur in an Alaskan setting is not directly defined by the available literature, but appears to be substantially less than 1 inch per year.

3.6.2 Overall infiltration

Infiltration to basins in central Alaska involves infiltration through both permafrost and non-permafrost areas. A number of approaches have been used to evaluate the overall infiltration to basin areas, which can be applied to the Pogo project area.

1. Precipitation. Infiltration can often be estimated as being between 5% and 10% of precipitation. Using the value for precipitation of 19 inches per year (Section 2.2 above), expected infiltration would be 0.95 to 1.9 inches per year. However, at the Pogo Site infiltration will be affected by low permeability rock, permafrost, and steep slopes, which would be expected to reduce infiltration to levels lower than would occur in otherwise comparable sites without these conditions. Thus at Pogo the actual infiltration would be expected to less than the values obtained by this "typical" approach.
2. Baseflow. Baseflow in rivers (the flow which occurs when there is no surface runoff to streams) is the result of the emergence in rivers of deep-seated groundwater flow. Accordingly, in many situations infiltration can be estimated from the baseflow observed in rivers in the area. In the climatic system that occurs at Pogo, there is no surface runoff to streams in the winter, so this period provides a good basis for estimating baseflow. As presented in Section 2.7.2 above and Figure 2, winter baseflow in rivers in the region in which Pogo is located averages the equivalent of 1.0 inches per year. This value may be an underestimate of the actual infiltration, due to interception of emerging groundwater by ice formation in the winter months.

   Baseflow was measured in 1983 for the two basins studied by Gieck (1986). The baseflow is influenced by the amount of permafrost present in the basins. The baseflow rate (expressed as an equivalent annual areal yield) and the percentage permafrost in the two basins were as follows (Gieck, 1986):

Basin	Permafrost Cover	Total Precipitation	Snowpack Water Equivalent	Snowmelt Infiltration	Baseflow	Baseflow as % of Total Precipitation
Ester Creek	21%	15 inches	6.1 inches	3.6 inches	3.3 inches/yr	22%
Happy Creek	57%	12.5 inches	5.4 inches	1.1 inches	0.7 inches/yr	6%

   These results indicate that there is essentially no sub-permafrost infiltration in central Alaska; for a 100% permafrost covered basin, an infiltration rate in the order of 1% of total precipitation or 2.5% of snowpack water content is indicated. Gieck concludes in his study that "Infiltration into soils above the permafrost is isolated from the sub-permafrost water table and (is) unable to contribute to groundwater recharge" (Gieck, 1986, p. 56). The above information suggests that groundwater infiltration in non-permafrost areas of the Ester Dome area is in the order of 25% of total precipitation. Applied to the Pogo area, which is higher, colder, steeper, less soil covered, and has less southerly aspect, infiltration to non-permafrost areas would be expected to be lower. Flow data indicate an estimated average baseflow of 1.0 inch per year for the Goodpaster River Basin.(AMEC, 2000). If one assumes that 50% of the catchment area is non-permafrost, the infiltration to non-permafrost areas of the Goodpaster Basin would be approximately 2.0 inches per year (11% of precipitation, assuming 19 inches per year as the base for precipitation in the basin). This value is consistent with the findings of the University of Alaska at Fairbanks research.

3. Permeability. Infiltration to any location may be controlled by the permeability of the material near the ground surface. Based on both testing and model calibration (described below), the hydraulic conductivity of the country rock at Pogo (bedrock, excluding orebody materials and the principal fault zones) appears to be in the order of 0.3 ft/yr horizontally, and 1.5 ft/yr vertically. Under gravitational flow from a flooded surface, this material is capable of transmitting up to 18 inches per year of infiltration, and is not a major limitation to infiltration. However, when frozen, the rock hydraulic conductivity is expected to drop as much as a factor of 100 (Burt and Williams, 1976), reducing the infiltration of the rock to less than 1 inch per year. This may be a significant limitation to infiltration in the permafrost areas of the Pogo site.

In summary, infiltration to general areas in the Pogo area is expected to be between 0.5 and 1 inch per year. The non-permafrost infiltration portion of this baseflow is estimated to be between 1 to 2 inches per year, while the permafrost portion of this infiltration is expected to be substantially less than 1 inch per year.

3.7 Liese Creek Seepage

3.7.1 Surface flow

The quantity of water that is available for infiltration in the vicinity of Liese Creek is limited by the flow in the creek itself. Complete records of flow in the creek are not available, due to measurement difficulties particularly in the winter period. The flow in Liese Creek (taken to be made up of the sum of surface water flow and flow in the shallow alluvial material in the valley beneath the creek) has been estimated based on the monthly distribution of regional flow (Figure 2) applied to the Liese Creek catchment area above the potential mine interception point of approximately 900 acres. The monthly flow estimate for Liese Creek is shown in Table 7. The annual average flow at this point is computed to be 350 gpm, with a peak computed flow of 1063 gpm. These values compare well with the measured flow data for the stream in the summer and fall of 2000, which provides some verification of the reconstruction of flows presented in Table 7.

The fact that the flow at the gauging station on the creek is approximately equal to the expected yield of the basin at least in the summer indicates that the stream is not losing a large amount of flow to the subsurface, neither to the alluvium nor the underlying bedrock or fault. It therefore appears that the streambed has the ability to prevent large-scale exfiltration.

3.7.2 Subsurface flow

In addition to the surface water flow in Liese Creek, there is groundwater underflow in the alluvium beneath the creek. The quantity of this underflow has been estimated using Darcy's Law for a typical section of the valley, and hydraulic conductivity values developed from testing of the alluvium in the vicinity of the proposed dry-stack tailings facility (AMEC, 2001):

Width = 500 feet (measured at the dry stack location)
Thickness = 15 feet (average measured at the dry stack location)
Horizontal hydraulic conductivity = 5,000 ft/yr (bulk average value from in-situ testing[11])
Hydraulic gradient = 0.1 ft/ft (maximum measured at dry stack location)

Based on these values, the underflow is computed to be:

Q = K I A = K I W T = 5000 ft/yr x 0.1 ft/ft x (500 ft x 15 ft) = 3,750,000 cu.ft./yr = 53 gpm

Thus approximately 50 gpm of underflow is also conducted along the Liese Creek valley. This subsurface flow through the alluvium acts as a drain to conduct groundwater that flows towards Liese Creek from the bedrock downvalley towards the Goodpaster River.

In addition to this flow, it is possible that there is some flow of groundwater toward the Goodpaster River in the fault zone that maylie beneath the Liese Creek valley. An estimate of this flow can be made using the information obtained on the fault zone, and the geometry:

Width of fault zone = 100 feet (assumed; consistent with the computed conductivity)
Depth of fault zone = 3,000 feet (assumed maximum depth of circulating groundwater in model)
Hydraulic conductivity of fault zone = 168 ft/yr (from above; consistent with 100 ft width)
Hydraulic gradient = 0.1 ft/ft (measured from groundwater data)

Based on these assumptions, the pre-development groundwaterunderflow in the fault zone can be estimated:

Q = K I A = K I W T = 168 ft/yr x 0.1 ft/ft x (100 ft x 3,000 ft) = 5,040,000 cu.ft./yr = 71 gpm

Thus the total carrying capacity of the valley to remove groundwater towards the Goodpaster River is computed to be 124 gpm.

The water table in the groundwater system in the Liese Creek alluvium is below creek level, by as much as 20 feet. This is shown for well LD-005 in Figure 8. While the water levels change in the alluvium, the water table is always below the creek level at this location. This indicates that at this location (and all others where measurements are available) the creek is perched above the water table in the alluvium, and water in general seeps from the creek into the alluvium, through the silty sands that make up the matrix of the near-surface materials in Liese Creek valley (AMEC, 2001). To limit the infiltration flow to less than the above 124 gpm over the length of the stream requires that these materials have a vertical

[11] It is noted that the value used in Section 4.4.5 below for vertical hydraulic conductivity of the alluvium in Liese Creek is 1,000 ft/yr. The horizontal hydraulic conductivity value used here of 5,000 ft/yr represents the base of the alluvium below the water table, which tends to be coarser than the generally upper, silty layer, which is above the water table, and is the zone that limits the exfiltration from the creek.

hydraulic conductivity of approximately 200 ft/year, or less. This is computed from Darcy's Law, applied to vertical gravity flow through the creekbed materials as follows:

Seepage flow through creekbed = 124 gpm (5,040,000 cu.ft./yr)
Width of flowing creek = 5 feet (measured at the dry stack location)
Length of creekbed subject to seepage above Dry Stack area = 5,000 feet (from map)
Hydraulic gradient = 1 ft/ft (vertical gravity flow assuming creek depth is small)

Based on these values, the hydraulic conductivity of the creekbed material is computed to be:

$$K = Q / (I\ A) = Q / (I\ W\ L) = 5{,}040{,}000 \text{ cu.ft./yr} / (1 \text{ ft/ft} \times 5 \text{ ft} \times 5000 \text{ ft}) = 200 \text{ ft/yr}$$

This is a hydraulic conductivity consistent with that of silty sand, which is the material in the matrix of the streambed (in places there are also cobbles and boulders surrounded by this matrix). This evaluation provides some assurance that even if there were a highly permeable local conduit between the base of the alluvium and the proposed underground mine, it would not be capable of draining large flows from Liese Creek, because of the demonstrated creekbed leakage resistance.

Variation is observed in water levels measured in wells in the valley, as shown in Figure 8, for LD-005 located about 1000 feet upstream of the proposed mine location. This shows the following:

1. The water level in the alluvium is always at between 14 and 37 feet below ground surface. This shows that the creek flow is isolated from the alluvium, and that the drainage from the area in winter is insufficient to remove all of the water from the alluvium.
2. The data shows that the alluvium recharges mostly in July, and drains down in winter and spring. There appears to be a time lag for recharge. This demonstrates that there is only limited recharge of the alluvium from the stream flow in the valley; if recharge were rapid, stream flow would refill the alluvium in May, when it first occurs (see Table 7). This is direct support for the belief that the stream is perched, and that the flow in the stream cannot be directly drawn into the mine from the creek.
3. The cyclicity of the record does indicate drainage of the alluvium during the winter. The drainage is likely downgradient in the alluvium, and would continue throughout the year. This drainage would remove water from the alluvium all winter (when it is not being replenished very quickly as the entire surface is frozen), and it would be replenished in the spring.
4. The water level does not drain down to bedrock during the winter. This illustrates that there is no major drainage of alluvial water into the rock or downgradient to the Goodpaster River via the Liese Creek fault, or any other conduit. If there were, then the holes would drain during the winter (or in the more extreme case, be dry year-round).

When the surface and sub-surface flow to the valley center drops below approximately 50 gpm, the alluvium alone is sufficiently permeable to carry this flow, without surface flow occurring. It is computed that this occurs for approximately 3 months of the year. This provides some evidence that there is no continuous, highly conductive fault beneath the creek valley. If there were, then the alluvium would be rapidly drained, at least in the winter, which is not observed.

3.8 Water Dating

In order to obtain an understanding of the flow regime that exists at the Pogo site, a program of isotopic sampling and evaluation was performed in February 2001. Samples of water were taken from surface streams, shallow monitor wells, deep monitor wells, and from inflows to the underground exploration facility, and sent for chemical and isotopic analysis. The results are presented below (for species that showed significant differences between sample locations):

LOCATION	00U098C	00U098D	00U099	00U100	LT-009	SW-23
DESCRIPTION	Underground hole to Liese Creek Fault zone (high flow)	Underground hole to Liese Creek Fault zone (low flow)	Underground geology-drain hole near Mid-Ridge Fault	Underground geology-drain hole near Mid-Ridge Fault	Shallow alluvial well beside Liese Creek	Goodpaster River above Camp
DATE	26-Feb-01	26-Feb-01	26-Feb-01	26-Feb-01	25-Feb-01	28-Feb-01
Tritium	15.80	1.34	13.70	13.00	15.40	16.20
$\delta[^{18}$Oxygen](per mil)	-19.90	-19.45	-20.08	-19.90	-19.42	-20.22
$\delta[^{2}$Hydrogen](per mil)	-159.31	-155.04	-158.22	-158.56	-160.90	-160.49
Conductivity (µS/cm)	477	1540	503	521	267	140
pH (pH units)	7.93	7.78	7.91	7.96	7.94	7.84
Total Dissolved Solids (mg/L)	292	1150	315	311	167	82
Alkalinity (mg/L)	168	441	170	168	98	47
Sulfate (mg/L)	99	510	113	119	41	18
Nitrate (mg/L)	0.044	0.005	0.005	0.005	1.1	0.365
Calcium (mg/L)	51	148	40	41	40	16
Magnesium (mg/L)	24	113	33	35	8	4
Sodium (mg/L)	10	37	13	15	3	3
Arsenic (µg/L)	108	2930	150	217	3.8	0.1
Iron (mg/L)	0.14	2.48	0.22	0.38	0.03	0.03
Manganese (µg/L)	62	32	32	23	1	4
Strontium (µg/L)	978	7200	1250	1330	155	86.1

3.8.1 Chemical Analysis

The chemical analyses indicate that the concentration of constituents in the subsurface increase as the orebody is approached. The pre-drainage orebody groundwater had water quality that is indicated by the underground drain hole 00U98D, a low flow hole drilled into an undisturbed area northeast of the exploration development. This water is mineralized, with 1540 mg/L TDS, and a range of dissolved minerals.

The remainder of the water chemistry indicates that the water entering the underground through the exploration holes, which have in general been allowed to drain for the last year or more are relatively good quality, suggesting recent introduction of that water from the surface. This is consistent with the head information obtained in wells in the vicinity of the underground development, which shows that the water table near the underground workings has dropped to a level close to the elevation of the workings. This water level reduction would be expected to bring more recently infiltrated, lower residence-time water into contact with the drains, as this water would be located at the top of the zone of saturation. Accordingly, the water flowing from these drains would be expected to approach the quality of shallow groundwater.

Finally, the water in the alluvial well close to Liese Creek contains concentrations of dissolved solids that are intermediate between bedrock groundwater in the area and the expected surface water quality in Liese Creek (for which the Goodpaster River values are a surrogate, as Liese Creek was frozen at the time). This indicates that the groundwater in this location is derived predominantly from surface water, mixed with some deep bedrock groundwater discharge to the alluvium. Based on the groundwater piezometric surface, Liese Creek was in a groundwater discharge location prior to any underground development, so it was expected that in the winter period when the sample was taken, bedrock groundwater discharge would dominate the quality of the water in the alluvium, as there would be no surface water flow available to dilute the discharge to the alluvium from the bedrock. The results indicate that there is only limited outflow of groundwater from the bedrock system to the alluvium, which is consistent with the observed low inflow to the underground workings, the low hydraulic conductivities measured in the country rock at the site, the low computed infiltration to the bedrock system, and the low baseflow from the bedrock in the region.

3.8.2 Stable Isotopic Evaluation

The abundances of stable isotopes of hydrogen and oxygen were evaluated for each of the samples taken. The results are compared with the isotopic abundances from Standard Mean Ocean Water (SMOW), and are expressed as differences in parts per thousand (per mil). The data for both the hydrogen and oxygen isotopes of water indicate that the waters are of very similar origin, and have not been significantly altered differentially by evaporation or other processes that would alter the isotopic abundances of the water.

The only water that is somewhat different isotopically is the sample from the low flow underground hole, 00U98D. This water is somewhat isotopically lighter than the other samples, which may be consistent with it having been introduced into the groundwater system under different climatic conditions than exist at present. This difference suggests that this water may date from hundreds or thousands of years ago. This is consistent with the quality of the 00U98D water; it has a high TDS and high arsenic concentration, suggesting a long residence time in the vicinity of the orebody.

3.8.3 Tritium Evaluation

Tritium is an unstable isotope of hydrogen, which has a half-life of 12.4 years. It was introduced into the atmosphere in large quantity as a result of atmospheric testing of thermonuclear devices in 1952 to 1965. Tritium levels in precipitation peaked in the mid-1960s, at levels in excess of 1,000 tritium units (TU) worldwide. Today, tritium in precipitation varies worldwide, but ranges from 10 to 20 TU. Water that has been in the groundwater system for more than 50 years (i.e. pre-bomb water) has essentially no tritium, due to decay and the very low pre-bomb tritium levels (estimated at 5 TU, which if present in infiltration have decayed to below detection levels in the intervening period of more than 50 years).

The following inferences are drawn from the tritium testing results:

1. Surface water (and presumably precipitation) at the Pogo site has about 16.2 TU.
2. Water in the Liese Creek alluvium has about 15.4 TU, which suggests that it is approximately predominantly new (post-bomb) water.
3. Groundwater in the vicinity of the underground development, which has been subjected to drainage, has about 13.5 TU, which suggests that it is approximately 20% old water, and 80% new. This appears to be the result of removal of (old) stored water by the drainage, and vertical drawdown of relatively recent infiltration water into the drainage system.
4. Groundwater in the vicinity of the Liese Creek fault zone has about 15.8 TU, which is statistically indistinguishable from the tritium content of surface water and Liese Creek alluvial water. This result is consistent with this water being predominantly surface water that has been transported through the Liese Creek fault zone from the Liese Creek alluvium and Liese Creek to the drainhole. The result also suggests either that the water removed from the drain hole has been sufficient to remove the (old) pre-exploration water from the fault, or that water is naturally flowing from the creek alluvium into the fault and thence towards the Goodpaster River.

The tritium data suggests that the Liese Creek fault zone is sufficiently permeable to acts as a conduit for Liese Creek alluvial water to be drained to subsurface workings when they intersect the fault zone.

4. Inflow Model

Determination of the inflow to the proposed Pogo Mine requires simulation of the proposed mine development, operation, and closure. To perform this simulation a numerical model of the groundwater flow system at the Pogo site has been constructed and calibrated. This section of the report describes the model, and the results obtained from it[12].

4.1 Method

Evaluation of mine inflow was performed by use of a three-dimensional finite-difference numerical model of the Pogo project area. The code used was Visual MODFLOW, which is a commercially available version of the industry standard USGS MODFLOW groundwater analysis code (McDonald and Harbaugh, 1988). This code analyzes a three-dimensional orthogonal groundwater flow system. A variety of boundary conditions can be applied in the model, including fixed head, wells, drains, and rivers.

[12] Prior to development of the numerical model described in this report, a simple algebraic model and a more complex finite element method numerical model were created to estimate the inflow to the mine. These earlier models included significant aspects of the groundwater system analysis, in particular flow in fault zones, and detailed mine development. As the results have been superseded, the models are not presented.

4.2 Domain

The area modeled includes the surface catchments of Liese Creek and Pogo Creek, up to the respective mountain ridges surrounding these catchments, as shown in Plate 9. The modeled domain comprises the surface water drainages that contain the mine, and the outer slopes of Liese Creek and Pogo Creek.

A total thickness of 3000 feet below ground surface is analyzed; this is considered to be the limit of the circulating groundwater system in this area. This thickness was divided into 17 layers[13], in order to subdivide the model volume into discrete analysis portions. The layering is indicated in the east-west and north-south sections presented in Plate 10. The geometry subdivision was developed as follows:

1. The upper surface of the model is formed by the topography, which was input from the photoreconnaissance map provided by Teck. Elevations are accurate to approximately 5 feet.
2. The Goodpaster River and Liese Creek cut into the model, and are in direct communication with the uppermost layer of the model.
3. The upper layer of the model is 100 feet thick, to incorporate the Goodpaster River alluvium, the mountain talus, the top 100 feet of bedrock on the mountainsides, and the alluvium in the Liese and Pogo Creek valleys.
4. Immediately beneath the upper layer are five layers that represent the material between the surface and the quartz lens that contains the L1 orebody (L1 Quartz). These layers allow the simulation of approximately 300 feet of permafrost. Permafrost is observed to exist at the site area, to depths that of approximately 300 feet.
5. The geometry of the quartz veins that contain the orebodies is known, and was taken from the Draft Pre-Feasibility Study (Teck, 1999). This geometry is included in the model. The quartz sills form two discrete layers, each of approximately 15 feet thickness, and spaced approximately 400 feet apart. The upper quartz sill is denoted the L1 orebody, and is contained within the 6th layer of the model. The lower orebody is denoted the L2 orebody, and is contained within the 9th layer of the model[14]. Each layer extends beyond the quartz veins; a separate material type represents the different materials in the layers. The selection of the location of these two layers beyond the orebody extents is arbitrary.
6. Beneath the layer that contains the L2 orebody are a further 8 layers, which together with the layers above provide a total of 3000 feet of material thickness below ground surface[15].

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[13] The "layers" into which the modeled domain is divided are not necessarily geologically determined, but are created in order to subdivide the model domain to allow the three-dimensional flow to be analyzed. In this model, two layers are in part geologically determined: those containing the two orebodies. Most of the rest of the layering is not based on particular geological features, as the country rock is not "layered" geologically.

[14] The L3 quartz lens is not explicitly included in the model, due to its small size and minimal impact on the hydrology of the system.

[15] The 3,000 foot thickness is based on the assumed depth of circulating groundwater in this system.

The groundwater system is subdivided into cells within each layer; each cell is 100 feet on a side, and of varying thickness (determined by the layering). The entire model comprises over 300,000 cells, of which 199,818 are active.

4.3 Boundaries

The boundary conditions applied to the model are as follows (Plate 9):

1. Fixed Heads. Fixed head boundaries are applied to the model along the Goodpaster River. The heads in the uppermost cell in the stream location are fixed at stream elevation.
2. Lateral boundaries. All lateral boundaries are no-flow boundaries; heads are not fixed on those boundaries.
3. Lower boundary. The lower boundary of the model is also a no-flow boundary; head is not fixed on this boundary.
4. Mine. When they are developed, the exploration development, the mine access development drifts, and the mine are represented as a series of drains[16], one drain for each cell in the layer that will be mined. The elevation of the drain is set at the elevation of the mine. Water that flows to the "mines" during mining is collected in separate zones, and is removed from the model.
5. Liese Creek. The Liese Creek boundary is made up of drains with fixed elevations at the ground surface in the creek valley[17], together with infiltration injection of water equal to the total available average annual surface flow along the stream channel. This boundary system is described in more detail in Section 4.4.5 below.

4.4 Input Parameters

4.4.1 Hydraulic Conductivity

The hydraulic conductivity values that were used in the model were initially selected from within the range of hydraulic conductivity values measured for the materials in the model. The following conductivity values were selected:

1. Country Rock. The range of the effective average hydraulic conductivity appropriate for modeling relatively large volumes of country rock (as represented by each cell) was identified in the investigation process as 0.2 ft/yr to 2 ft/yr. Hydraulic conductivity was assumed to be isotropic in the horizontal plane, but is expected to be higher vertically, as a result of the strong vertical

[16] In the MODFLOW code, a "drain" is a feature that allows water to flow from a model cell to a fixed head sink, with the rate of flow being proportional to the elevation of the sink and the head at the node in the center of the cell. In the event that the water head in the node drops below the elevation of the node, no flow to the drain occurs.

[17] It is noted that the water in Liese Creek is perched up to 20 feet above the groundwater level that has been measured in the shallow subsurface. The model fixes the head in Liese Creek at ground surface, which may result in a slightly higher head at the creek than actually exists in some locations.

structure in the site rockmass. A ratio of vertical to horizontal hydraulic conductivity between 2:1 and 10:1 was considered reasonable for this anisotropy.

2. Orebodies. The test data for hydraulic conductivity of the orebody materials was found to range from 1 ft/yr to 100 ft/yr. The measured hydraulic conductivity appeared to depend on the thickness of the quartz orebody unit; thicker quartz bodies appeared to exhibit higher hydraulic conductivities. The effective ore hydraulic conductivity at a mine scale is expected to be lower, because the orebody is cut by a number of low permeability faults.

3. Faults. Fault traces have been evaluated for hydraulic conductivity in the underground testing program. Well flow tests produced the following hydraulic conductivities:

    a. Liese Creek Fault Zone. Flow and pressure measurements taken in intersections of the Liese Creek fault zone indicate an expected maximum average hydraulic conductivity of 168 ft/yr (Section 3.3.5).

    b. Mid-Ridge Fault. Flow and pressure measurements from drill holes advanced through the Mid-Ridge Fault indicate that it is of moderate hydraulic conductivity when compared with the Liese Creek fault zone. Based on flow measurements during drilling from underground, an expected hydraulic conductivity of 4 ft/yr to 40 ft/yr is computed.

    c. Basalt Faults. Two faults have been identified that are infilled with basalt. These faults are not water bearing, and appear to be less permeable than the country rock. Based on this observation, a hydraulic conductivity of 0.1 ft/yr was assumed.

    d. Other faults. There are a relatively large number of faults identified in the underground exploration, and in exploration coring of the Pogo area. These faults appear to have approximately the same hydraulic conductivity as the rest of the country rock.

4. Alluvium. Hydraulic conductivity values for alluvium were estimated from experience, and from pumping tests that were conducted in the Goodpaster River alluvium. A value of 1,000 ft/yr was selected and retained throughout[18].

5. Talus. The slopes beside the Goodpaster River are covered with a talus material, which is directly represented in the uppermost layer of the model. A hydraulic conductivity of 100 feet per year was selected for this material; no tests of this material were available[19].

6. Permafrost. For the areas of the rock that are within the permafrost zone, an isotropic hydraulic conductivity range of 0.1 ft/yr to 1 ft/yr was assumed, based on the evaluation presented in Section 3.6.1.

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[18] Note that as the Goodpaster River is a fixed head boundary and a location of groundwater discharge throughout the model runs, the results of the modeling were not sensitive to this hydraulic conductivity value. Accordingly, it was not verified or calibrated by this process, except to the extent that it was established that the value was high compared to the rock conductivity values.

[19] The value of hydraulic conductivity of the talus is not critical to the evaluation. However, the calibration does establish that its conductivity is high compared to the general rockmass. It is possible that the talus may be more permeable than the alluvium.

7. Mine Backfill. Hydraulic conductivity measurements for the paste backfill that will be placed in the mine voids have an average hydraulic conductivity as shown in the following table:

Flotation Tails: **CIP Tails:**	**100.0%** **0.0%**	**81.8%** **18.2%**
Cement: 0%	3.2 ft/yr	1.3 ft/yr
Cement: 2%	6.8 ft/yr	1.8 ft/yr

Based on the predominant use of cemented mixed tailings, the expected average hydraulic conductivity of the backfill is 1.8 ft/yr.[20]

8. Mine Back Rock. Stress relief in the roof rock during mining is expected to result in an increase in hydraulic conductivity in these materials. The expected conductivity of the roof rock is estimated to be 10 times the conductivity of the country rock[21].

The hydraulic conductivity values and ranges used in the modeling are presented in Table 8.

4.4.2 Drainable Porosity

The drainable porosity of the site materials provides stored water that reports as inflow to the mine when it is developed. Drainable porosity values used for the site materials were as follows:

1. Alluvium. The drainable porosity of the alluvium and the talus was assumed to be 10%, based on experience. This value has little impact on the analysis, as the alluvium in the model remains almost entirely saturated by the boundary conditions that were selected.
2. Rock. The drainable porosity of the country rock was set at 0.3%, based on back-analysis of the drainage that has accompanied the development of the decline and analyses of multiple hole tests performed underground (see Section 3.3.2 above).

4.4.3 Storativity

The specific storage[22] of the rockmass was set at 10^{-6} /ft. Storativity is the change in water storage in the rockmass caused by the changed effective stress caused by a water pressure change. The storage derives

[20] Substantially complete backfilling of the mine is considered by the mine-planning group to be achievable, and will minimize external disposal of tailings materials. The mining sequence will involve pumping a tailings paste (slurry) into each worked-out room, backfilling it up to the roof of the stope. The adjacent ore will then be mined. The process then repeats, resulting in essentially void-free backfill in the mined stopes.

[21] In the model, this transmissivity is applied to the mine backfill material, for convenience.

[22] The specific storage is the volume of water produced from a unit volume of saturated material (in this case rock) as a result of a unit water head change in that material. It is applied to all saturated rock in the model. In the Imperial system used in this report the units of specific storage are therefore cubic feet (of water) per cubic foot (of rock) per foot (of head change), which produces an overall Imperial unit of "per foot". This water storage can be significant; in the 3000 feet of rock considered in the model, a 1 foot head change would produce 0.003 cubic feet of water, which is the same amount of water as would be produced by desaturation of one foot of this same material.

from the combined effects of expansion of the water in the rockmass, and compression of the rock matrix when water pressure is reduced.

4.4.4 Infiltration

The boundaries of the model have been chosen to fall on locations that are expected to be no-flow boundaries, and have been treated as such. As a result, all water input to the model domain is provided by infiltration to the ground surface, and seepage from streams.

The infiltration to the model has been chosen as a range:

1. Non-permafrost areas. The range selected for infiltration to non-permafrost areas is 0.5 to 2.0 inches per year.
2. Permafrost areas. The range selected for infiltration to permafrost areas is 0.2 to 1.0 inches per year.
3. Bedrock areas. Infiltration to areas where bedrock outcrops at or within a few feet of ground surface may be controlled by rock conditions; in these areas the infiltration has been set to a high of 1.0 inches per year and a low of 0.5 inches per year.

The above values have been used as input to the calibration process for the modeling.

4.4.5 Liese Creek Recharge

The surface flow in Liese Creek creates a potential source of input of water to the groundwater system, by seepage out of the creek through the surficial alluvium, and into the bedrock beneath. This process was included in the model by computing the amount of exfiltration that could occur from the creek bed if the bedrock beneath was underdrained.

The amount of recharge that could occur from the creek to the Liese Creek fault zone can be computed from Darcy's Law, applied to flow out of the creek and through the alluvium beneath. Using the following parameters:

Width of flowing creek = 5 feet (measured at the dry stack location)
Length of creekbed above Liese Creek Fault Zone = 2,000 feet (from map)
Hydraulic gradient = 1 ft/ft (vertical gravity flow assuming creek depth is small)
Hydraulic conductivity of alluvium = 1,000 ft/yr (assumed maximum value[23])

Based on these values, the maximum exfiltration from the creek in the vicinity of the Liese Creek Fault zone is computed to be:

$$Q = K\,I\,A = K\,I\,W\,T = 1000 \text{ ft/yr} \times 1 \text{ ft/ft} \times (5 \text{ ft} \times 2{,}000 \text{ ft}) = 10{,}000{,}000 \text{ cu.ft./yr} = 142 \text{ gpm}$$

[23] This value is taken as 5 times higher than the value of 200 ft/yr, back-calculated in Section 3.7.2 above, to allow for the fact that there are no direct measurements of this parameter in the vicinity of the location where the creek flows across the Liese Creek Fault zone. This value is taken on the assumption that the entire outflow from the creek would occur over that portion of the creek; thus the length considered is shorter than the entire length of the creek.

This potential exfiltration from the creek was applied to the model as a recharge; if the head conditions in the bedrock were such as to allow this flow to enter the subsurface, then the infiltration to bedrock from the creek would be limited to 142 gpm. If the head conditions in the bedrock were at or above the elevation of the creek, then either none or a portion of this flow would infiltrate[24].

There are some times during the year when this flow exceeds the expected total flow in Liese Creek (surface flow plus alluvial flow). The total flow is presented in Table 7. Limiting the exfiltration from the creek on a monthly basis to either the creek flow or 142 gpm produces an average annual maximum exfiltration rate from the creek of 108 gpm (Table 7). This is the maximum creek contribution that is allowed in the model.

Finally, the creek exfiltration is applied to the model using the recharge package. Recharge is applied to the 20 cells in the model that are in the creek bed, and that lie above the Liese Creek Fault zone. The effective infiltration rate for these cells is computed from the cell geometry (100 feet x 100 feet) and the infiltration rate (5.4 gpm/cell), which produces an effective maximum infiltration rate of 455 inches per year for each of these cells.

5. Calibration

5.1 Method

Calibration of the model was achieved by adjustment of parameters within the ranges identified by field-testing to achieve the best fit between observed conditions and modeled conditions. Three datasets were used for this process in the Pogo Model:

1. Pre-Development Hydraulic Heads. The distribution of the pre-development water levels in the mine area provides a large-scale equilibrium condition against which the flow characteristics of the model can be calibrated. A total of 69 wells in which water levels have been taken were available for model calibration against pre-development head. Water levels in 26 of these monitor wells were used to define a pre-development head regime for the project area; where there were several wells in the same locality, one well was selected as representative to avoid bias in the calibration. Well completion information was available for all the wells, and the data were applied to the appropriate layer of the model for each calibration well. The calibration wells selected, and their locations, and their pre-development head elevations are presented in Table 9 and Plate 11.

2. Exploration Development Flow. The flow from the first two years of the exploration development was monitored and recorded, and is presented in Table 10 and Figure 3. The monitoring of these flows provides a large-scale inflow case against which to calibrate the flow characteristics

[24] The way that the model dealt with Liese Creek was to inject the total stream flow into the 20 cells that fell in the Liese Creek valley in those locations where the Liese Creek fault zone underlies the valley. This was achieved using MODFLOW's "Recharge" feature for those cells, with a recharge rate that equated to 455 inches per year. At each of these cells, a MODFLOW "Drain" was also installed, to remove water if the infiltration exceeded the infiltration capacity of the bedrock. The drains were all located within one model Flow Budget Zone, so that flow losses from the creek could be tracked.

of the model. Flows to the adit were restricted to some extent in that exploration drill holes extended into the orebody were initially packed off. As flow treatment capacity became available in the mine, these drains were opened, and relatively rapidly drained. To simulate this effect, the model incorporates these drain holes at the time when the valves were opened (rather than when they were drilled). In addition, measured flows to the exploration development do not include the significant flow from the Liese Creek fault zone area through drill hole 00U98C, as the drain hole that tapped that feature rapidly plugged with debris after drilling, reducing the flow to a small rate. The hole was subsequently (December, 2000) cleaned out and allowed to flow at a controlled rate of approximately 25 gpm; this flow is not included as it was beyond the period of the flow calibration.

3. Exploration Development Drawdown. The installation of the exploration decline has resulted in changes in groundwater pressure in the surrounding bedrock due to drainage of water to the decline. These changes have been monitored during the installation of the decline, and the results of this monitoring provide a basis for calibration of the transient characteristics of the groundwater model against a real, large-scale transient effect. The drawdowns that have been monitored are indicated in Figure 4. The changes in head at the wells in the vicinity of the exploration development from January 1999 to December 2000 are indicated in Table 11 and Plate 8.

The calibration process involved selection of a set of parameters, running of the model both at initial steady state and through the first two years of development, and comparing the results of the model with the three calibration datasets. Model parameters are adjusted to produce the best fit between computed and measured data.

5.2 Calibration Results

The calibration was performed to achieve the best fit against all three sets of information used for calibration. The calibration process required the performance of approximately 100 runs of the model, using parameters within the ranges developed for the Pogo project area, and described in Sections 2 and 3 above. In particular, infiltration to the uppermost layer and hydraulic conductivity in the upper 300 feet of the rockmass were conformed to the observed locations of permafrost at the site. However, the model could not be calibrated using higher infiltration and hydraulic conductivity in areas where there is no permafrost. The best calibration was obtained using the same infiltration rate and rockmass hydraulic conductivity, regardless of the reported presence or absence of permafrost[25].

Calibration required adjustment of horizontal hydraulic conductivity, infiltration, vertical hydraulic conductivity, and storativity. The parameter values that provided the best calibration to all the data are presented in Table 13, and summarized below:

[25] This conclusion was unexpected. It may be that infiltration at Pogo is restricted by the low hydraulic conductivity of the country rock to rates that are comparable with frozen soil or rock, so that the presence or absence of permafrost is not material to the actual infiltration rate.

Hydraulic Conductivity	**ft/yr**
Rock (horizontal)	0.29
Rock (vertical)	1.45
Orebody	2.9
Talus	110
Alluvium	1,095
Liese Creek Fault Zone	168
Mid-Ridge Fault	16.8
Other Faults	0.29
Liese Creek Alluvium	1,000
Infiltration	**in/yr**
Permafrost	0.75
Non-permafrost	0.75
Creekbed over LC fault	455
Specific Storage	**per ft**
Rock	1.00E-06
Specific Yield	**--**
Rock	0.003
Alluvium	0.3

The expected-case calibration is as follows:

1. Pre-Development Heads. Computed pre-development heads and the target, measured heads in wells at the site are presented in Table 9 and on Plate 11. The calibration achieved is shown in Figure 9; the mean difference between predicted and observed head values was 0.5 feet, the root mean square (RMS) difference was 61 feet, which represents 5% of the target data range. The RMS calibration difference was due in part to the lateral variability in the observed head data (wells close together have significantly different heads), and in part due to the complexity of the hydrology in the area near the orebody; in particular the calibration precision was reduced by levels in the center of the orebody being under-predicted by up to 151 feet, and levels at the south-east end of the orebody being over-predicted by up to 105 feet. These differences may result in part from incorrect identification of the actual depth from which the wells are measuring water pressure, as there appears to be a significant vertical head gradient in the upper portion of the flow regime between the ground surface and the orebodies.

2. Exploration Development Flow. The match between modeled and actual exploration development flow and is presented in Table 10 and Figure 10. Calibration is good; the mean error of the match is 1 gpm, and the RMS error is 2 gpm, which represents 8% of the flow range. Note that the modeled introduction of the exploration holes coincided with the time that the valves on the drainholes were opened, rather than when the holes were actually drilled. Thus the model was an analog of the entire drainage process that actually occurred in the mine. All of the holes except 00U98C drained down to minimal flow within a few months.

3. Exploration Development Drawdown. The match between modeled and exploration development drawdown is presented in Table 11 and Figure 11. The average error is 0 feet, and the RMS error

is 80 feet. While the overall average calibration error is small, the individual well calibration error is approximately 17% of the range of the data, which is fair agreement. Modeled drawdown in MW97-041 and MW97-066 were questionable, and were left out of the computation. The drawdown calibration is judged to be acceptable overall, as there is expected to be large variability in individual well responses to short-term localized drainage.

The calibrated model produces the simultaneous best fit against all three of these calibration measures: static heads (calibrates primarily infiltration and hydraulic conductivity), drawdown due to a major areal stress (calibrates primarily storativity and hydraulic conductivity), and inflow to the underground development (calibrates primarily hydraulic conductivity and to a lesser extent storativity). Based on the quality of the calibration fit, it is considered that the model provides adequate simulation of inflows to underground openings at the Pogo Project.

The effective hydraulic conductivity of the gneiss rocks was calibrated in the modeling process, and the average conductivity was found to be lower than the majority of the measured hydraulic conductivity values. For the best fit to the pre-development heads, development flows, and development drawdowns, the horizontal hydraulic conductivity was found to be 0.29 ft/yr, while the vertical hydraulic conductivity was found to be 1.45 ft/yr; the equivalent isotropic hydraulic conductivity was 0.87 ft/yr. For all hydraulic conductivity tests performed in rock materials in this project, the equivalent isotropic hydraulic conductivity was 5 ft/yr (Section 3.5 above).

There are several reasons to expect the calibrated large-scale effective hydraulic conductivity (which is the value obtained in the calibration of the model) to be toward the low end of the measured values:

1. The behavior of the overall rockmass (at a mine scale) is usually governed by the conductivity of the highest permeability extensive or large-scale features in the rockmass. At Pogo, the rockmass is intersected by a large number or faults, as well as a number of sills and dikes. These features are for the most part sub-vertical, and of low conductivity. Between these features, and apparently segmented by them, are higher hydraulic conductivity materials. While the analysis presented in this report explicitly models the principal faults, the more minor faults are not explicitly modeled, and are included by reducing the horizontal effective conductivity of the overall rockmass below the average value measured.
2. The majority of the measured test data for hydraulic conductivity comes from packer tests and single underground hole tests that straddle the L1 or the L2 orebody, which have relatively high hydraulic conductivity. Thus there are relatively few tests that are in the gneiss alone, which weights the database of hydraulic conductivity values heavily with orebody values.
3. The typical width of the extensive, continuous, low permeability features that segment the rockmass is in the order of 10 feet or less (based on observations in core and underground exposure). The typical test interval used for the hydraulic tests is 100 feet or more. Thus, most of the tests are dominated by the higher permeability materials between the low permeability features, and relatively few results reflect the low permeability features alone.

The model calibration process was performed using Liese Creek fault zone conductivities covering the possible range. The value selected in calibration is the average value of the two test values measured in the field. It is also close to the highest value that provides reasonable reproduction of heads in the vicinity of the project. While the available data do not identify the conditions in the entire Liese Creek fault zone, the calibration process did reasonably bound the possible range of fault hydraulic conductivity. If the fault is generally more permeable than the value used in the expected case calibrated model, it drains the water deep into the bedrock beneath Liese Creek even before mining, which is observed not to happen. Further, while it is possible that there could be a direct, local void connection from the creek to the mine, such a conduit has not been observed, and there is no obvious genetic reason for it existing. If it did exist, such a conduit would be relatively easy to address by grouting, isolation, or backfilling from surface, thus reducing or eliminating the inflow due to that feature. For this reason, such localized issues are not considered in the model.

6. Inflow Evaluation

6.1 Development of Mine

Inflow to the mine will occur as a result of the change of subsurface boundary conditions resulting from the creation of the mining development and ore extraction openings. The current development plan is to explore the mining area from underground in the four years before ore production and milling begins by installation of underground exploration drifts and associated exploration drill holes drilled into the orebodies from the exploration drifts. This exploration development work is expected to have the effect of accessing locations beneath the L1 mining area during the developmental period from the present to the end of the year 2003. Access to the L2 mining area will be completed by the year 2005. Actual mine production from the L1 orebody is expected to start at the beginning of the fifth year of the project, or 2003, while mine production from the L2 orebody will start two years later, in 2005. Mining is expected to be completed at the end of 2015.

The mining schedule used for the inflow simulation is summarized in Table 12. The locations of the current access development drives and the currently planned method of development of mining are shown in Plate 12 for the L1 orebody and Plate 13 for the L2 orebody.

Mining will take place in panels, approximately 250 feet along the orebody strike, and approximately 20 feet normal to the orebody strike. Each panel will be individually accessed from developmental workings in the footwall. Following mining, each panel will be backfilled with cemented paste tailings of low hydraulic conductivity. It is anticipated that multiple panels will be open at any time, with locations spread over the entire mine.

6.2 Expected Mine Inflow

The above mine development and mining schedule was applied to the calibrated model of the Pogo area, described in Section 5.2 above. The expected case has the following key parameters:

- Infiltration rate of 0.75 inches per year applied over the entire model domain (permafrost and non-permafrost)
- Average horizontal hydraulic conductivity of country rock of 0.29 feet per year
- Average hydraulic conductivity of the Liese Creek fault zone material of 168 feet per year
- Vertical hydraulic conductivity of the Liese Creek alluvium of 1,000 feet per year

Mining of the orebodies is simulated by extracting mining panels on an annual basis, with excavation assumed to take place at the beginning of each year, and backfilling of the mined panels taking place at the end of the same year. The results of the inflow evaluation are shown in Table 14 and Figure 12. The inflow to the mine during the operational mining period is expected to average 139 gpm. There is considerable variability in the inflow, depending on whether mine panels close to the Liese Creek fault zone are being worked. The maximum flow expected in any year is in 2007, when the inflow is expected to average 205 gpm.

The way in which inflow occurs to the mining system is identified in the results presented in Table 14. The subdivision of the inflow locations is as follows:

1. Inflow from Rock. The mine intersects saturated rock during exploration, development, and operation. The inflow from this rock to the mine occurs mainly in the exploration and underlying development drifts, and to a lesser extent to the orebodies as they are worked. This inflow averages approximately 67 gpm, or about half the operational period inflow.
2. Direct Flow from LCFZ. The mine intersects the Liese Creek Fault Zone (LCFZ) during operations. This causes significant expected inflow to the mine system, averaging 72 gpm over the operational period, or about half the total inflow. This component of inflow is highly variable, as the mined areas are backfilled, essentially eliminating flow to the mined stope at the end of each mining period.
3. Total Inflow to Mine. The total mine inflow is the sum of these inflows. The average inflow over the operational period is 139 gpm.

Short-term inrushes due to the mining suddenly encountering permeable, undrained materials was assessed by computing the inflow that would occur if the mining that was assumed to occur over a year actually occurred in a month. For the highest inflow month (2007), this resulted in an average inflow rate of 342 gpm. This is considered to be the highest credible inflow rate for the mine.

6.3 Post-Mining Period

During mine development and mine operation the water table in the overlying rockmass falls rapidly to close to mine level over those areas that are being mined. After mining, the water table and water pressures recover relatively rapidly, and return to approximately the original piezometric conditions in about 50 years. Groundwater flow is towards the mine from all directions during the exploration and mining operation, and for approximately 10 years thereafter. In later times, the generally northwest groundwater flow direction is re-established.

6.4 Uncertainty Evaluation

The calibrated model that was used for the evaluation of mine inflow comprises the geology and hydrology features and parameters that best reproduce the observed pre-mining heads, and the transient response to the exploratory development. This model comprises the best estimate of the actual system that could be developed using the information developed in the investigation process. However, many of the parameters and conditions in the model are not known with precision. Accordingly, the mine inflow predictions are correspondingly uncertain.

The sensitivity of inflow to the key variables in the evaluation was assessed by comparing the percentage change in the predicted flow to the percentage change in the parameter being evaluated. Using this approach, sensitivity of 100% indicates a direct linear relationship between mine inflow and the parameter varied; less than 100% sensitivity indicates a weaker relationship.

The variations that were performed were to the following parameters:

1. Hydraulic conductivity of the rockmass.
2. Infiltration at the ground surface.
3. Hydraulic conductivity of the Liese Creek fault zone.
4. Hydraulic conductivity of the Liese Creek alluvium.
5. Hydraulic conductivity of the mine backfill.

The sensitivity evaluation was performed in each case by the following process:

1. Changing (generally increasing) the parameter being evaluated.
2. Obtaining the best calibration to the pre-development head, the inflow to the exploration adit, and the drawdown due to the exploration adit.
3. Re-computing the mine inflow using the newly calibrated model, using the same mine development and ore extraction plans.
4. Comparing the change in the test parameter with the change in the inflow (both as percentages).

6.4.1 Country Rock Hydraulic Conductivity and Infiltration

The hydraulic conductivity of the rockmass was doubled from the expected value, that is to 0.58 feet per year, with all other parameters except infiltration held constant. The best calibration was obtained with an infiltration rate of 1.26 inches per year, which is greater than the infiltration rate that is expected to occur in the Pogo project area. The calibration fit degraded for all three measures, particularly with respect to inflow to the developmental mine:

Calibration Basis	Mean Error	RMS Error	Normalized RMS Error
Pre-development heads	-0.2 ft	71 ft	6%
Exploration drift flow	13 gpm	15 gpm	24%
Exploration drift drawdown	10 ft	101 ft	22%

Flow to the mine is affected by doubling the hydraulic conductivity (and approximately also doubling the infiltration); the computed average flow during the operational period increased by 47 gpm from 139 gpm to 186 gpm, an increase of 34% for a 100% change in hydraulic conductivity. This indicates a moderate sensitivity of flow to country rock hydraulic conductivity of 34%.

This sensitivity is for both the country rock hydraulic conductivity and the infiltration, as they are linked in the calibration process.

6.4.2 Liese Creek Fault Zone Hydraulic Conductivity

The majority of the inflow to the mine in the expected case is derived from the Liese Creek fault zone. As there is and will remain uncertainty about the value of hydraulic conductivity to be used to characterize that zone, an evaluation of the sensitivity of the mine inflow to this parameter has been conducted.

The sensitivity analyses were conducted by varying the hydraulic conductivity in the Liese Creek fault zone. A range of hydraulic conductivity values were used for these analyses, from eliminating the fault (that is setting its conductivity equal to that of country rock) to increasing its conductivity equal to 10 times the value used in the expected case. Each model was then re-calibrated (except the highest Liese Creek Fault Zone conductivity case, which could not be calibrated[26]), and the resulting models were used to compute the inflow to the mine. The results of these mine inflow analyses are presented below:

Liese Creek Fault Conductivity* (ft/yr)	3	37	168	1679
Percentage of Expected Liese Creek Conductivity	-98%	-78%	0%	900%
Average Operating Period Flow (gpm)	63	105	139	154
Percentage of Expected Case Operating Flow	-54%	-23%	0%	12%
Sensitivity of Flow to Liese Creek Conductivity	55%	30%	--	1%

*The hydraulic conductivity is for an assumed 100-foot wide fault zone

These results show that the mine inflow is not significantly sensitive to hydraulic conductivity estimates higher than the value used in the inflow analysis being used for the Liese Creek fault zone (168 ft/yr). Evaluation of the analysis results shows that this is due to two reasons:

1. At high conductivities, the fault zone acts as a drain along the creek, draining water northwest towards the Goodpaster River and "competing" with the mine for drainage.
2. At high conductivities, the resistance to flow of the Liese Creek alluvium controls the exfiltration of water from the creek. The amount of water that leaves the creek is not much affected by fault conductivities above the expected value.

6.4.3 Liese Creek Alluvium Conductivity

The Liese Creek alluvium acts as a limit to the amount of water that can flow from the creek into the underlying bedrock. The sensitivity of the mine inflow to the conductivity of the alluvium was investigated by increasing and reducing the conductivity in the expected case. The results of that evaluation are summarized below:

Liese Creek Alluvium Conductivity (ft/yr)	200	1000	7500
Percentage of Expected Alluvial Conductivity	-80%	0%	650%
Average Operating Period Flow (gpm)	109	139	181
Percentage of Expected Case Operating Flow	-21%	0%	31%
Sensitivity of Flow to Liese Creek Conductivity	26%	--	5%

[26] The model cannot be adequately calibrated if the LCFZ hydraulic conductivity is assumed to be higher than the expected case, because the alluvium beneath Liese Creek is drained, and the piezometric surface in the rock below the creek falls deep into the bedrock (which is not observed). The same parameters as the expected case were used for this analysis.

This sensitivity analysis shows that the mine inflow is not particularly sensitive to increases in Liese Creek alluvium above the value used in the expected case, but is somewhat sensitive to reductions in the alluvium conductivity.

6.4.4 Mine Backfill Hydraulic Conductivity

The mining method proposes complete backfilling of the mined-out stopes to obtain access to the next up-dip stope. The effective hydraulic conductivity of the backfilled mine and mine back material assumed in the model is 2.9 ft/yr[27]. The rate of groundwater flow through the backfilled mine after closure is not a strong function of the hydraulic conductivity of the backfill. The flow is limited by the infiltration and the country rock hydraulic conductivity, and the resistance offered by the backfill in the model is not a significant control. To test this dependence, an analysis was performed with the hydraulic conductivity of the mine backfill raised to 29 ft/yr, and then raised to 290 ft/yr (the functional equivalent of not backfilling the mine). The results of the flow through the L1 and L2 orebodies under both conditions are as follows:

Effective Hydraulic Conductivity of Backfill (ft/yr)	**2.9**	**29**	**290**
Post-closure Flow through L1 Orebody (gpm)	26	28	34
Post-closure Flow through L2 Orebody (gpm)	3	4	6
Post-closure Total Flow through Mined Material (gpm)	29	32	40

As can be seen, a two order of magnitude increase in transmissivity of the backfill/mine back system results in a 38% (11 gpm) increase in the flow through both orebodies after closure. This is a very low sensitivity to this parameter.

6.4.5 Inflow Uncertainty

The sensitivities of the Pogo mine inflow to the key parameters for which uncertainty remains has been evaluated using the above sensitivities, as follows:

[27] This assumption was made for convenience of computation; the conductivity of the post-mining orebody was assumed to be the same as for the pre-mining orebody material. The backfill conductivity is 1.8 ft/yr, and the post-mining mine back rock hydraulic conductivity is likely to be higher than the original country rock value of 0.29 ft/yr. An ensemble conductivity of 2.9 ft/yr (ten times the original bedrock conductivity, and equal to the original calibrated orebody conductivity, therefore seems reasonable. This parameter has little effect on the analysis.

Parameter	Inflow Increase for Maximum Parameter Value	Probability of Occurrence of Maximum Value	Expected maximum variability
Country Rock Hydraulic Conductivity/Infiltration	34%	Low; expected maximum infiltration value (1 in/yr) is half the increase	17%
Liese Creek Fault Zone Hydraulic Conductivity	12%	Low; expected value used is near highest reasonable value	6%
Liese Creek Alluvium Hydraulic Conductivity	31%	Low; value chosen is near highest reasonable number for materials	5%

The conclusions of the sensitivity evaluation are:

1. Mine inflow is moderately sensitive to infiltration and country rock hydraulic conductivity. These two parameters are linked by calibration; increasing one requires the increase of the other to maintain the best model calibration. Changes in infiltration and country rock hydraulic conductivity within the available range would result in a 17% maximum increase in inflow, or about 23 gpm.
2. Mine inflow is also weakly dependent on the hydraulic conductivity of the Liese Creek fault zone. The fault zone conductivity used in the expected analysis produces close to the maximum flow possible for variation of this parameter. The maximum expected change in inflow that would result from the credible maximum overall conductivity for the fault zone is 6%, or 8 gpm.
3. Mine inflow is moderately dependent on the hydraulic conductivity of the Liese Creek alluvium. The value used in the analysis is considered to be in the upper range of the possible values. Accordingly, the maximum additional inflow that is considered reasonable for variation of this parameter is 5%, or 7 gpm.

Based on these considerations, it appears that if each of the uncertain parameters turn out to be at their adverse maxima (which is unlikely), then the mine inflow would be approximately 28%40 gpm higher than the expected case mine inflow. This would result in a worst-case annual average flow to the mine during operation of approximately 175 gpm. With respect to the effect on the peak annual flow in 2007, this would be expected to increase at a lesser percentage, due to the lack of proportionality of the peak flow with infiltration. It is estimated that the peak annual flow would increase to approximately 245 gpm (from 205 gpm), an increase of 20%.

These results show that the principal uncertainty about flow to the mine is the extent to which the surface flow in Liese Creek can access the mine. This access is potentially limited by the presence of moderate permeability alluvium in the Liese Creek valley, and by the hydraulic conductivity of the fault zone materials themselves. Both of these barriers to Liese Creek flow into the mine may be absent locally, creating the possibility of a direct, open pathway from Liese Creek to the mine. Such a conduit cannot be proven not to exist prior to mining. If it did exist, and drained Liese Creek into the mine, the feature would be addressed during mining. Available engineered responses to an inrush of creek water on encountering such a feature would include:

- Collecting and discharging the discharge-quality creek water from the mine;
- Grouting or plugging the feature either from the ground surface or from the mine;
- Diverting the creek flow out of the valley thalweg in the vicinity of the conduit.

The first and second strategies have been demonstrated in the exploration development, and are standard underground mine water inrush control strategies. The third strategy is a commonly applied surface water control strategy, and is a standard method of preventing contact of water with sensitive locations in mining and civil engineering projects. Teck is providing additional details on these inrush response plans in the Water Management Plan of which this report is an Appendix.

6.5 Water Levels

The water levels that result from the mine development are presented in Plate 14 (which shows the water table at the end of mining in the expected case). The water level is drawn down to mine level in those panels where mining is being undertaken, and the water table is a muted reflection of this drawdown at mine level. Drawdown resulting from mining recovers relatively rapidly after mine closure, with levels returning to approximately the pre-mining condition in about 50 years after mining ceases.

7. Conclusions

Based upon the revised Pogo Mine inflow analysis, the inflow to the Pogo Mine is expected to be as follows:

1. Inflow to the mine will average approximately 139 gpm during the mining operational period, with a high flow of approximately 205 gpm that is expected in year 2007.
2. The computed inflow is relatively insensitive to the remaining uncertainties in the evaluation. The peak average flow computed by taking the maximum reasonable range of the uncertain variables is 175 gpm, and the corresponding peak average annual flow in 2007 is approximately 245 gpm.

The general mine inflow is not expected to be significantly seasonal; there may be a small peak in the summer due to a component of flow from Liese Creek. Short-term spikes of inflow (lasting less than a year) beyond the predicted average annual rates are to be expected due to encountering localized zones of higher permeability pressurized rock during mine development and operation. The maximum instantaneous (one month) inflow rate is estimated to be approximately 350 gpm, based on peak inflow from Liese Creek during the peak inflow year (2007).

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Table 1- Hydraulic Conductivity - Rock

Well	Test	Type	Collar (feet)	Top (feet)	Bottom (feet)	Kabc (ft/yr)	Kgol (ft/yr)
97-075	1	FHT	2265	1106	1309	160.00	63.07
97-076	1	FHT	2360	381	578	4.10	6.31
97-076	2	FHT	2360	571	798	3.45	0.63
97-077	1	FHT	2200	315	517	0.83	3.15
97-077	2	FHT	2360	507	764	0.81	3.15
97-078	1	FHT	2175	383	580	2.60	3.15
97-078	2	FHT	2175	226	304	5.25	3.15
97-079	1	FHT	2070	69	266	450.00	206.93
97-079	2	FHT	2070	420	588	500.00	10.35
97-079	3	FHT	2070	259	586	1.54	2.07
97-079	4	FHT	2070	574	671	430.00	413.86
97-079	5	FHT	2070	659	836	250.00	310.39
97-079	6	FHT	2070	827	964	270.00	310.39
98-080	1A	FHT	2070	195	390	3.40	3.12
98-080	1B	CIT	1590	195	390	4.14	4.10
98-080	2	FHT	2070	355	500	1.47	0.44
98-081	1	CIT	1841	195	359	13.29	14.51
98-081	2	CIT	1841	345	500	6.53	6.94
98-081	3	CIT	1841	485	769	5.58	5.99
98-081	4	FHT	1841	740	1000	5.20	4.42
98-082	1	FHT	2090	268	484	0.76	0.35
98-082	2	FHT	2090	468	740	0.28	0.08
98-082	3	FHT	2090	730	1000	0.32	0.20
98-104	1	CIT	2140	527	826	0.51	0.63
98-105	1	FHT	1696	490	807	1.08	0.38
98-105	2A	FHT	1696	433	807	11.50	9.15
98-105	2B	FHT	1696	433	490	57.50	47.30
98-107	1	FHT	2375	753	910	0.21	0.12
98-108	1	FHT	1708	510	667	4.80	6.62
98-109	1A	CIT	1696	470	647	13.13	14.19
98-109	1B	CIT	1696	470	510	46.19	50.46
98-109	2	FHT	1696	510	647	1.73	1.32
98-111	1	CIT	2140	297	504	0.09	0.09
98-112	1	CIT	1708	330	557	37.81	41.00
98-113	1	CIT	2375	478	525	3.37	3.78
98-113	2A	CIT	2375	418	525	1.21	1.39
98-113	2B	CIT	2375	418	478	1.97	2.27
98-113	3	FHT	2375	680	837	0.02	0.08
98-113	4	FHT	2375	981	1038	0.13	0.32
98-113	5A	CIT	2375	851	1038	1.89	2.30
98-113	5B	CIT	2375	851	981	2.59	3.12
98-114	1	FHT	1696	389	593	0.86	0.50

FHT = falling head test; CIT = constant flow injection test
K = hydraulic conductivity; abc = Adrian Brown Consultants; gol = Golder Associates

Table 2 - Hydraulic Conductivity - Tailings Area

Location	Hydraulic Conductivity (ft/yr)
LD3	104
LD5	13
LL2	3
LT7A	50
LT7B	57
WD3	158
WD6A	23
WD6B	0.5
WT1A	126
WT1B	8
WT2B	9
WT4	13
WT6A	43
WT6B	72
Geometric mean	22
Arithmetic mean	49
Minimum	0.5
Maximum	158

Table 3 - Hydraulic Conductivity - Underground

Hole	Location:	Collar Elevation (ft)	Azimuth (deg)	Dip (deg)	Length (ft)	Shut-in Pressure (ft water)	Shut-in Head (ft)	Flow rate (gpm)	Hydraulic conductivity (ft/yr)
00U021	1400NE	1256	316	19	458	0	1260	0	
00U022	1400NE	1256	316	33	387	0	1262	0	
00U024	1400NE	1256	316	75	308	0	1267	0	
00U026	1400NE	1256	136	71	390	0	1267	0	
00U033	1600NE	1262	316	19	448	162	1430	1.3	5
00U033	1600NE	1262	316	19	448	143	1412	1.2	2
00U034	1600NE	1262	316	37	324	0	1271	0	
00U034	1600NE	1262	316	37	324	118	1389	0.1	0.4
00U035	1600NE	1262	316	63	263	0	1274	0	
00U035	1600NE	1262	316	63	263	0	1274	0	
00U036	1600NE	1262	316	89	253	0	1273	0	
00U036	1600NE	1262	316	89	253	0	1273	0	
00U037	1600NE	1262	136	73	303	0	1273	0	
00U037	1600NE	1262	136	73	303	95	1368	0.2	2
00U038	1700NE	1265	316	21	299	150	1421	0.3	1
00U039	1700NE	1265	316	39	245	166	1441	0.1	0.1
00U040A	1700NE	1265	316	65	214	254	1530	0.1	0.1
00U040B	1700NE	1265	316	7	387	157	1426	8	7
00U041	1700NE	1265	136	89	233	249	1526	0.1	0.1
00U042	1700NE	1265	136	71	269	300	1576	3	10
00U043	1800NE	1269	316	21	307	162	1436	3	7
00U044	1800NE	1269	316	47	211	0	1280	0	
00U044	1800NE	1269	316	47	211	127	1407	0.1	0.4
00U045	1800NE	1269	316	84	211	0	1280	0	
00U045	1800NE	1269	316	84	211	203	1483	0.1	0.1
00U046A	1800NE	1269	316	6	426	173	1444	4	3
00U046A	1800NE	1269	316	6	426	88	1359	7	9
00U046B	1800NE	1269	136	70	257	0	1280	0	
00U051	2000NE	1273	316	23	250	69	1349	8	53
00U051A	2000NE	1273	316	6	359	83	1361	33	79
00U068	2300NE-N	1237	316	21	262	115	1353	60	128
00U069	2300NE-N	1237	316	47	191	125	1343	1.5	5
00U070	2300NE-N	1237	316	84	212	35	1253	0	<0.1
00U075	2400NE-N	1219	316	19	281	138	1357	21	32
00U083	2500NE-N	1216	316	22	253	145	1361	11	16
00U051	2000 NE	1280	316	23	250	14	1294	0.6	90
00U051A	2000 NE	1278	316	6	359	51	1329	10	34
00U055	2100 NE-N	1273	316	20	325	42	1314	1.2	18
00U061	2200NE-N	1256	316	21	221	106	1362	10	25
00U068	2300NE-N	1237	316	21	262	122	1360	50	97

Hole	Location:	Collar Elevation (ft)	Azimuth (deg)	Dip (deg)	Length (ft)	Shut-in Pressure (ft water)	Shut-in Head (ft)	Flow rate (gpm)	Hydraulic conductivity (ft/yr)
00U075	2400NE-N	1219	316	19	281	136	1355	20	30
00U083	2500NE-N	1216	316	22	253	145	1361	15	23
00U095B	2600NE-S	1378	316	17	268	115	1494	4	7
00U096A	2600NE-S	1381	316	37	228	102	1482	0.1	0.4
00U098A	2600NE-S	1378	316	10	303	60	1438	4	17
00U098B	2600NE-S	1376	0	5	313	78	1455	13	24
00U098C	2600NE-S	1376	35	-5	791	265	1665	100	33
00U098D	2600NE-S	1377	68	0	803	277	1653	13	3
00U098E	2600NE-S	1379	344	15	262	120	1499	13	22
00U098F	2600NE-S	1383	0	36	261	125	1507	0.1	0.3
00L302	2200NE-N	1248	316	-64	784	106	1354	13	2
00L306	2000 NE	1274	316	-77	510	46	1320	13	4
00L309	2400NE-N	1217	136	-69	576	132	1349	38	7
00L311	2400NE-N	1217	316	-62	485	145	1363	13	3

Table 4 – Hydraulic Parameters - Multiple Well Testing

WELL	Azimuth (deg)	Hole Dip (deg)	Hole Length (ft)	Hydraulic Conductivity (ft/yr)	Storage Coefficient	Comments
00U95B	316	17	268	5.9	3E-04	Partially within a high permeability block
00U98B	0	5	313	62.5	4E-03	High permeability block; Liese Creek hole
00U98E	344	15	262	1.4	8E-05	Largely within low permeability material

Table 5 - Hydraulic Conductivity - Liese Decline Pilot Hole

From (ft)	To (ft)	Average Hydraulic Conductivity (ft/yr)	Average Hydraulic Conductivity (cm/sec)	Shut-In Pressure at Collar (psi)	Open Valve Flow at Collar (gpm)	Elevation Head (ft AMSL)
110	210	No test performed				
210	310	8	8.2E-06	0	0	<1875
310	410	1	1.0E-06	0	0	<1875
410	510	4	4.1E-06	0	0	<1875
510	610	9	8.4E-06	0	0	<1875
580	680	5	4.5E-06	0	0	<1875
680	780	28	2.7E-05	1	0.6	1877
780	880	5	4.9E-06	11	0.5	1900
880	980	9	9.1E-06	18	0.8	1917
980	1080	4	3.4E-06	3	0.4	1882
1080	1180	4	3.5E-06	1	0.5	1877
1180	1280	5	4.5E-06	0.2	0.2	1875
1280	1380	5	4.9E-06	2	0.1	1880
1380	1480	14	1.3E-05	8	0	1893
1480	1580	25	2.4E-05	30	2.4	1944
1580	1680	30	2.9E-05	31	2.8	1947
210	1580	9	8.8E-06			

Table 6 - Groundwater Chemistry - Summary

SAMPLES	97-041	97-071	97-076	98-080	98-081	98-082	98-133	99-189	99-202	99-204	99-213	99-216	U98C	U98D
Cond (µS/cm)	1792	1103	960	629	778	927	1078	794	776	836	416	802	713	1700
DO-F (mg/L)	2.4	0.9	1.0	1.5	1.6	1.5	0.2	1.0	0.6	1.3	0.9	1.4		
EH-F (mV)	11	-41	37	-38	-33	-69	-186	107	97	105	46	103		
pH-F (s.u.)	7.58	7.78	8.20	7.98	8.04	7.84	7.66	7.81	7.94	8.23	7.62	8.16	7.60	7.20
pH-L (s.u.)	7.65	7.74	8.02	7.91	8.11	8.04	7.10	8.21	8.10	7.91	8.01	8.25	7.58	7.18
TDS (mg/L)	1622	853	666	427	547	684	932	507	512	631	285	501	449	1420
Temp (C)	8.8	5.2	7.1	6.3	8.1	7.2	6.4	7.5	6.9	7.4	5.9	10.7	3	3.4
TSS (mg/L)	83	26	12	17	90	459	45.2	10.3	5.5	51	3.2	43	20	39
Alk-T (mg/L)	345	340	313	207	285	320	519	300	168	212	171	294	211	473
Bicarb (mg/L)	275	361	352		311	370	519	300	168	212	170	293	211	473
Hard (mg/L)	1208	684	462	355	381	513	552	259	255	431	222	448		
Cl-T (mg/L)	1.1	0.51	0.64	0.64	0.8	0.59	9.6	2.1	1.6	1.2	0.33	0.8	1	1
F-T (mg/L)	0.11	0.4	0.47	0.4	1.42	1.38	0.4	0.56	0.9	0.2	0.38	0.62	0	0
SO4 (mg/L)	790	351	229	148	196	244	59	136	249	273	88	193	179	626
NH3 (mg/L)	0.2	0.1	0.2	0.1	0.1	0.1	0.7	0.6	0.1	3.5	0.1	1.5	0	0
NO3 (mg/L)	0.0	0.0	0.5	0.0	0.0	0.0	0.1	0.0	0.1	0.6	0.0	0.2	0	0
Ca (ug/L)	275	125	99	77	73	96	97	53	51	88	45	72	70	171
Fe (ug/L)	0.6	0.9	0.8	0.2	0.5	1.3	11.9	0.1	0.1	0.4	0.2	0.2	1	1
K (ug/L)	6	3	3	3	3	4	12	3	2	6	1	5	3	4
Mg (ug/L)	126	89	69	40	48	63	63	31	31	57	30	63	41	125
Na (ug/L)	29	14	19	10	39	37	51	82	76	25	9	23	20	46
Ag (µg/L)	0.03	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.06	0.01	0.02	-0.02	-0.04
Al (µg/L)	14	32	5	2	83	311	23	16	9	244	9	274	4	28
As (µg/L)	35	3109	3304	28	92	16	196	301	446	1283	26	21	505	1860
B (µg/L)	9	4	6	27	6	6	26	15	19	9	6	12	14	9
Ba (µg/L)	17	12	18	133	30	24	269	29	21	16	20	60	19	23
Be (µg/L)		0.9	0.6	0.4	0.4	0.5								
Bi (µg/L)	0.8	0.7	0.5	0.4	0.3	0.4	0.3	0.3	0.5	3.2	0.3	0.3	-0.5	-1
Cd (µg/L)	0.3	0.2	0.2	0.1	0.0	0.1	0.1	0.1	0.1	0.3	0.0	0.1	-0.02	-0.04
Co (µg/L)	24	2	5	1	12	18	3	1	1	12	0	2	0.3	1
Cr (µg/L)	5	4	2	1	2	2	14	5	3	6	2	3	2.5	1.7
Cu (µg/L)	2	1	1	1	1	1	1	1	1	16	0	2	0.3	1.6
Hg (µg/L)	0.013	0.018	0.018	0.005	0.016	0.013	0.080	0.022	0.026	0.034	0.019	0.019	-0.001	-0.001
Li (µg/L)		25	17	15	22	20								
Mn (µg/L)	729	181	95	129	418	249	798	60	35	300	53	87	75	25
Mo (µg/L)	5	3	43	31	1	5	1	5	4	4	1	3	2.8	1.3
Ni (µg/L)	5	2	35	25	3	14	7	6	3	20	1	12	2	8
P (ug/L)		0.2	0.2	0.2	0.2	0.2							180	580
Pb (µg/L)	0.1	0.1	0.2	0.2	0.7	1.0	0.1	0.1	0.1	1.0	0.1	0.3	-0.02	0.06
Sb (µg/L)	0	1	3	1	0	1	2	14	11	16	0	5	1	2
Se (µg/L)	1	2	1	1	1	1	1	1	1	3	1	10	-1	-2
Si (ug/L)		7	7	7	8	9								
Sn (µg/L)	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	-0.1	-0.2
Sr (µg/L)	4410	2324	3754	651	1478	1515	2860	3294	3822	1520	768	1669	2130	10400
Ti (µg/L)		5	5	5	5	5								
Tl (µg/L)	0.09	0.07	0.04	0.04	0.02	0.04	0.01	0.03	0.02	0.04	0.02	0.03	-0.02	-0.04
U (µg/L)	36	24	27	5	2	6	2	3	3	16	6	14	12	15
V (µg/L)	2	2	1	1	1	1	4	2	1	3	1	2	1	1
Zn (µg/L)	21	16	17	40	130	59	19	23	9	66	4	19	2	3

Table 7 - Liese Creek Flow Reconstruction

Month	Runoff Rate (inch/month)	Computed Flow (gpm)	Measured Flow (2000) (gpm)	Alluvial Exfiltration* (gpm)
Jan	0.1	58		58
Feb	0.07	42		42
Mar	0.08	47		47
Apl	0.18	101		101
May	1.88	1064	763	142
Jun	1.6	906	1033	142
Jul	0.97	550	180	142
Aug	0.97	551	943	142
Sep	0.83	467		142
Oct	0.42	239		142
Nov	0.2	114		114
Dec	0.14	78		78
Average	**7.46 in/yr**	**352**		**108**
Average (May-August)		**768**	**730**	

*Exfiltration limited to 142 gpm (see text)

Table 8 - Material Hydraulic Conductivities

Material	Horizontal Hydraulic Conductivity (ft/yr)			Vertical Hydraulic Conductivity
	Minimum	Mean	Maximum	
Goodpaster River Alluvium		1000		=horizontal
Goodpaster Valley Talus		100		=horizontal
Country Rock	0.2	0.4	2	= 2 to 10 x horizontal
Permafrost	0.1	0.3	1	= 2 to 10 x horizontal
Ore	1	10	100	= horizontal
Liese Creek fault zone	0.4	36	168	=horizontal
Mid-Ridge Fault	4	16.8	40	=horizontal
Basalt Faults		0.1		=horizontal
Other Faults	0.2	0.4	2	=horizontal
Mine backfill	0.1	1.8	10	= horizontal

Table 9 - Calibration Against Pre-Mining Heads

Well	Easting (ft)	Northing (ft)	Pre-Development Head (ft AMSL)	Best Fit Estimate Calculated (ft)	Best Fit Estimate Error (ft)
MW98-003	1807875	3819087	1321	1320	-1
MW98-004	1807629	3819130	1321	1318	-3
MW98-015	1807875	3819087	1321	1320	-1
MW98-005	1807487	3819613	1322	1319	-3
MW98-006	1807498	3819863	1322	1319	-3
MW98-011A	1808171	3819400	1322	1321	-1
MW99-016	1807742	3818627	1322	1318	-4
MW98-010A	1808271	3819914	1323	1322	-1
MW98-013	1808247	3820775	1326	1323	-3
MW99-216	1809022	3821910	1330	1432	102
MW98-080	1809175	3818970	1337	1332	-5
MW99-213	1810090	3823389	1456	1403	-53
MW98-081	1809836	3819386	1530	1595	65
MW97-066	1811421	3821703	1659	1764	105
MW98-082	1810357	3819873	1701	1761	60
MW98-133	1811980	3821387	1764	1785	21
MW99-202	1812654	3820563	1781	1881	100
MW99-189	1813356	3820289	1825	1899	74
MW99-204	1812425	3820976	1857	1827	-30
MW97-071	1811492	3821214	1915	1804	-111
MW97-041	1810974	3821077	1921	1770	-151
MW97-076	1811218	3820813	1927	1816	-111
LD-003	1815329	3820673	2023	2002	-21
LT-007B	1816305	3819615	2178	2175	-3
LT-007A	1816303	3819616	2179	2175	-4
LT-003	1818009	3817853	2466	2462	-4
Count				26	
Mean Error (ft)				0.5	
Mean Absolute Error (ft)				40	
Root Mean Squre Error (ft)				61	
Standard Error of the Estimate (ft)				12	
Normalized Root Mean Square Error				5%	

Table 10 - Calibration Against Adit Flow

CASE	Actual	Best	High
Rock Hydraulic Conductivity (ft/yr)		0.29	0.56
Infiltration (in/yr)		0.75	1.35
Fault Hydraulic Conductivity (ft/yr)		168	168
Time (yr)	Flow (gpm)	Flow (gpm)	Flow (gpm)
0	0	0	0
0.1	0	0	0
0.2	8	2	3
0.8	13	9	15
1	31	21	35
1.2	43	45	52
1.3	55	66	83
1.4	62	61	74
1.7	63	65	77
1.8	71	69	79
2	71	66	79
Count		11	11
Mean Error (gpm)		-1	7
Mean Absolute Error (gpm)		4	8
Root Mean Squre Error (gpm)		5	11
Standard Error of the Estimate (gpm)		2	2
Normalized Mean Error		-2%	11%
Normalized Root Mean Square Error		8%	16%

Table 11 - Calibration Against Drawdown in Wells

Location	Measured Drawdown (ft)	Computed Drawdown (ft)	Drawdown Difference (ft)
LD-003	11*	0	-11
LT-003	-5*	0	5
LT-007A	4*	0	-4
LT-007B	4*	0	-4
MW98-003	0	0	0
MW98-004	0	0	0
MW98-005	0	0	0
MW98-006	-1	0	1
MW98-010A	-2	0	2
MW98-011A	-1	0	1
MW98-013	1	0	-1
MW98-015	-1	0	1
MW99-016	2	0	-2
MW97-041	31	406	n/a
MW97-066	0	277	277
MW97-071	>457	411	-46
MW97-076	515	325	-190
MW98-080	1	4	3
MW98-081	15	74	59
MW98-082	>351	174	-177
MW98-133	>87	256	n/a
MW99-189	0	15	15
MW99-202	31	30	-1
MW99-204	60	97	37
MW99-213	-1	1	2
MW99-216	-8	0	8
Count			**24**
Mean Error (ft)			**0**
Mean Absolute Error (ft)			**35**
Root Mean Squre Error (ft)			**80**
Standard Error of the Estimate (ft)			**19**
Normalized Root Mean Square Error			**17%**

*Drawdown for January 1999 to December 2000

Table 12 - Expected Development and Mining

Year	Adit	L1 Dev	L2 Dev	L1 Mining	L2 Mining
1999	X				
2000	X				
2001		X			
2002		X			
2003		X	X	Pre-Prod	
2004			X	X	
2005				X	X
2006				X	X
2007				X	X
2008				X	X
2009				X	X
2010				X	X
2011				X	X
2012				X	X
2013				X	X
2014				X	X
2015				X	X

Table 13 - Model Parameters for Expected Case

Material	Hydraulic Conductivity (ft/yr)		Storage	Storativity (/ft)	Infiltration (in/yr)
	Horizontal	Vertical			
Goodpaster River Alluvium	1095	1095	3%	1E-06	0.75
Talus	110	110	3%	1E-06	0.75
Rock	0.29	1.45	0.3%	1E-06	0.75
Ore	2.9	2.9	0.3%	1E-06	
Liese Creek Fault Zone	168[a]	168[a]	0.3%	1E-06	0.75
Liese Creek Alluvium	1,000	1,000	3%		455[b]
Mid-Ridge Fault	17	17	0.3%	1E-06	0.75
Basalt Fault	0.29	1.45	0.3%	1E-06	0.75
Other Faults	0.29	1.45	0.3%	1E-06	0.75
Mine Back Rock/Backfill	2.9	2.9	0.3%	1E-06	

[a]Maximum value that can produce an acceptable calibration against heads and flows in the creek valley.
[b]Liese Creek infiltration is for the approximately 2,000 feet of creek that lies over Liese Creek Fault Zone

Table 14 - Mine Inflow Analysis Results

Year	Activity	Direct Inflow from LCFZ (gpm)	Non-LCFZ Mine Inflow (gpm)	Total Inflow to Mine (gpm)
1999	Development	0	6	6
2000	Development	0	59	59
2001	Development	0	55	55
2002	Development	0	79	79
2003	Pre-Production	0	75	75
2004	Mine Operation	0	108	108
2005	Mine Operation	91	84	174
2006	Mine Operation	67	77	145
2007	Mine Operation	138	67	205
2008	Mine Operation	120	53	172
2009	Mine Operation	73	56	130
2010	Mine Operation	0	76	76
2011	Mine Operation	150	52	201
2012	Mine Operation	153	42	195
2013	Mine Operation	54	52	105
2014	Mine Operation	17	62	80
2015	Mine Operation	0	72	72
Statistics of Mine Operation Period Flows	**Minimum**	**0**	**42**	**72**
	Average	**72**	**67**	**139**
	Maximum	**153**	**108**	**205**
	Std Deviation	**59**	**18**	**50**
	95% UCL	**188**	**102**	**237**

Note: LCFZ = Liese Creek Fault Zone

Figure 1 - Hydraulic Conductivity Distributions

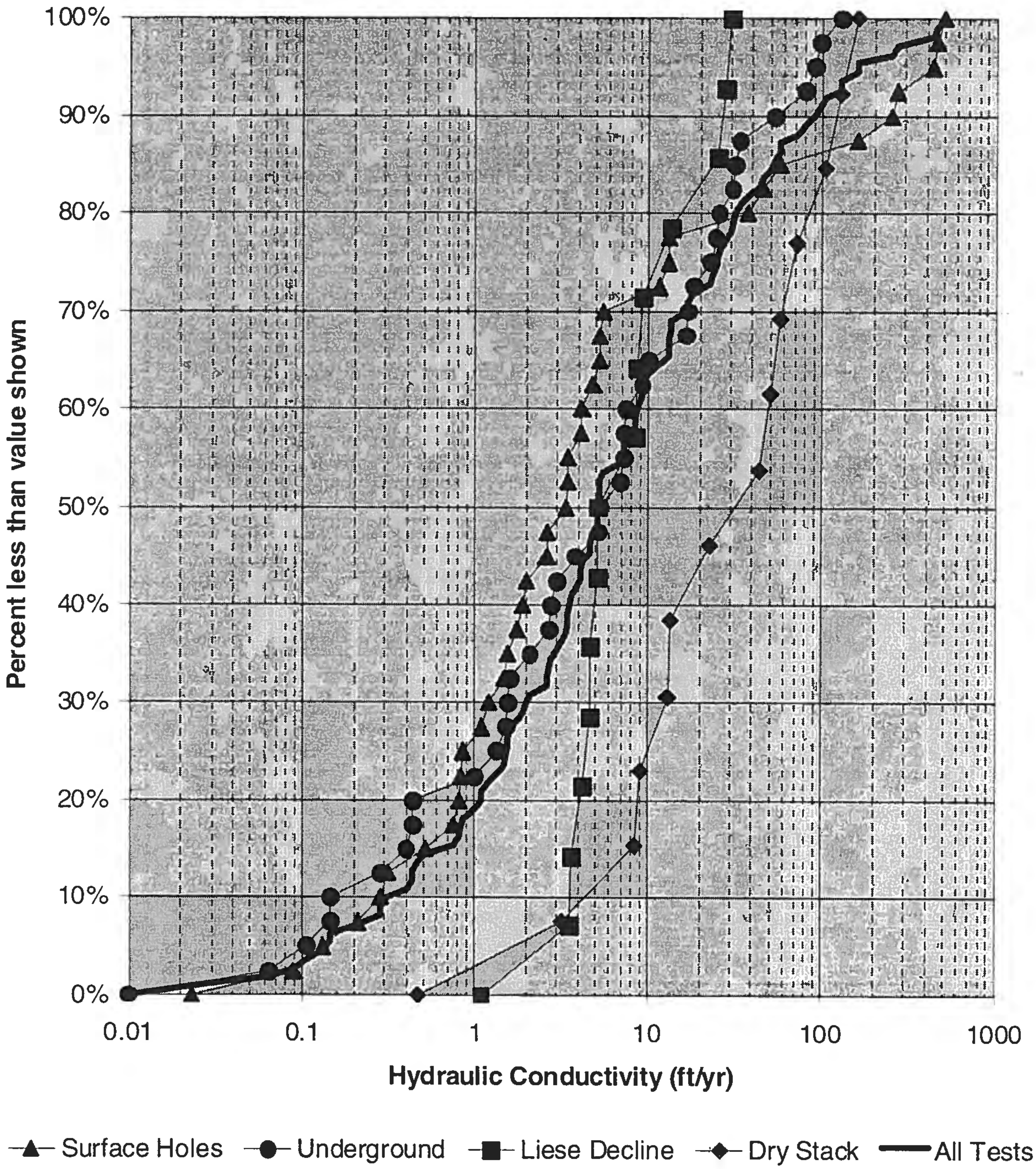


Figure 2 - Alaskan River Streamflows

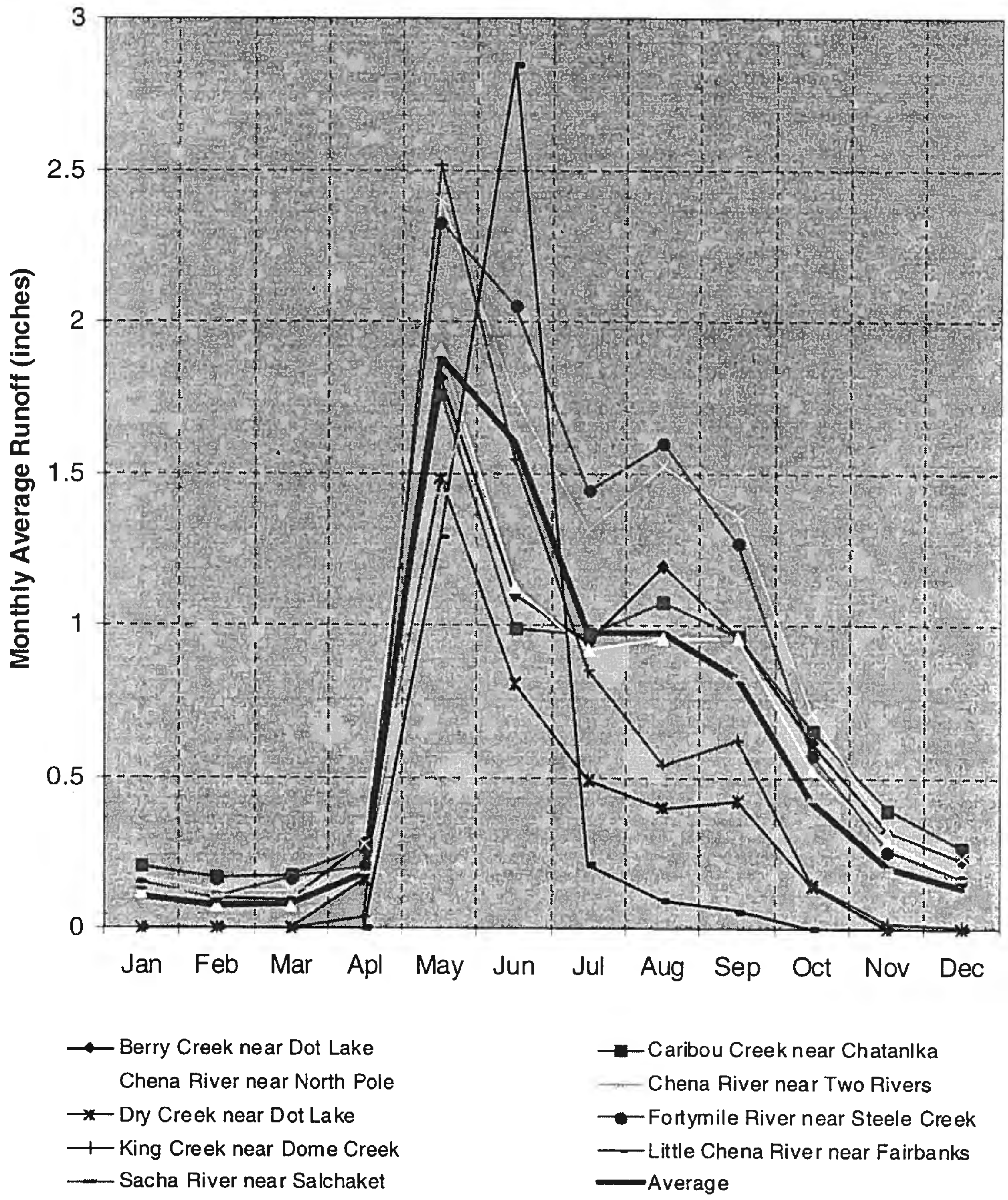


Figure 3 - Exploratory Adit Inflow

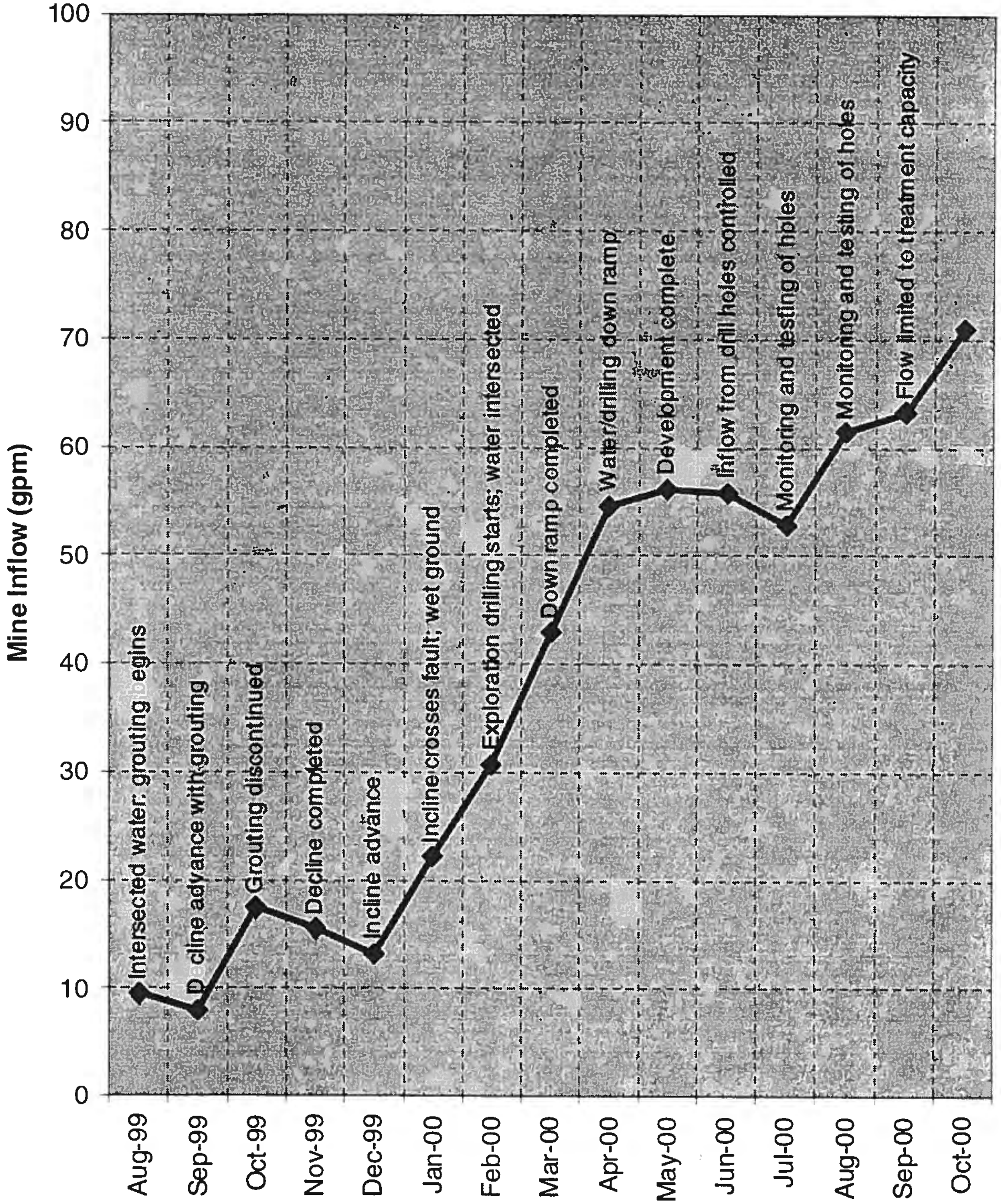


Figure 4 - Water Elevations - Surface Wells

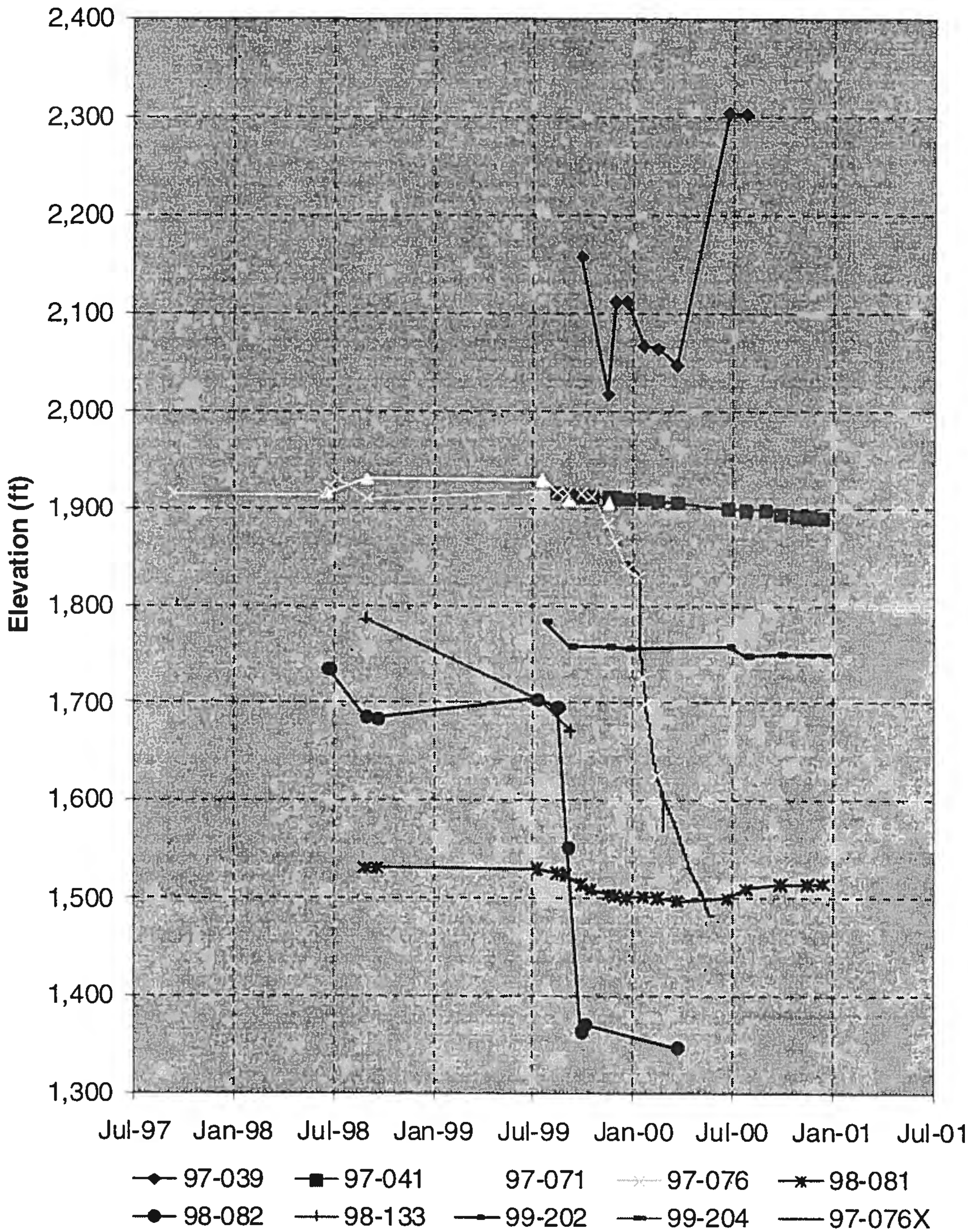


Figure 5 – Total Dissolved Solids in Groundwater

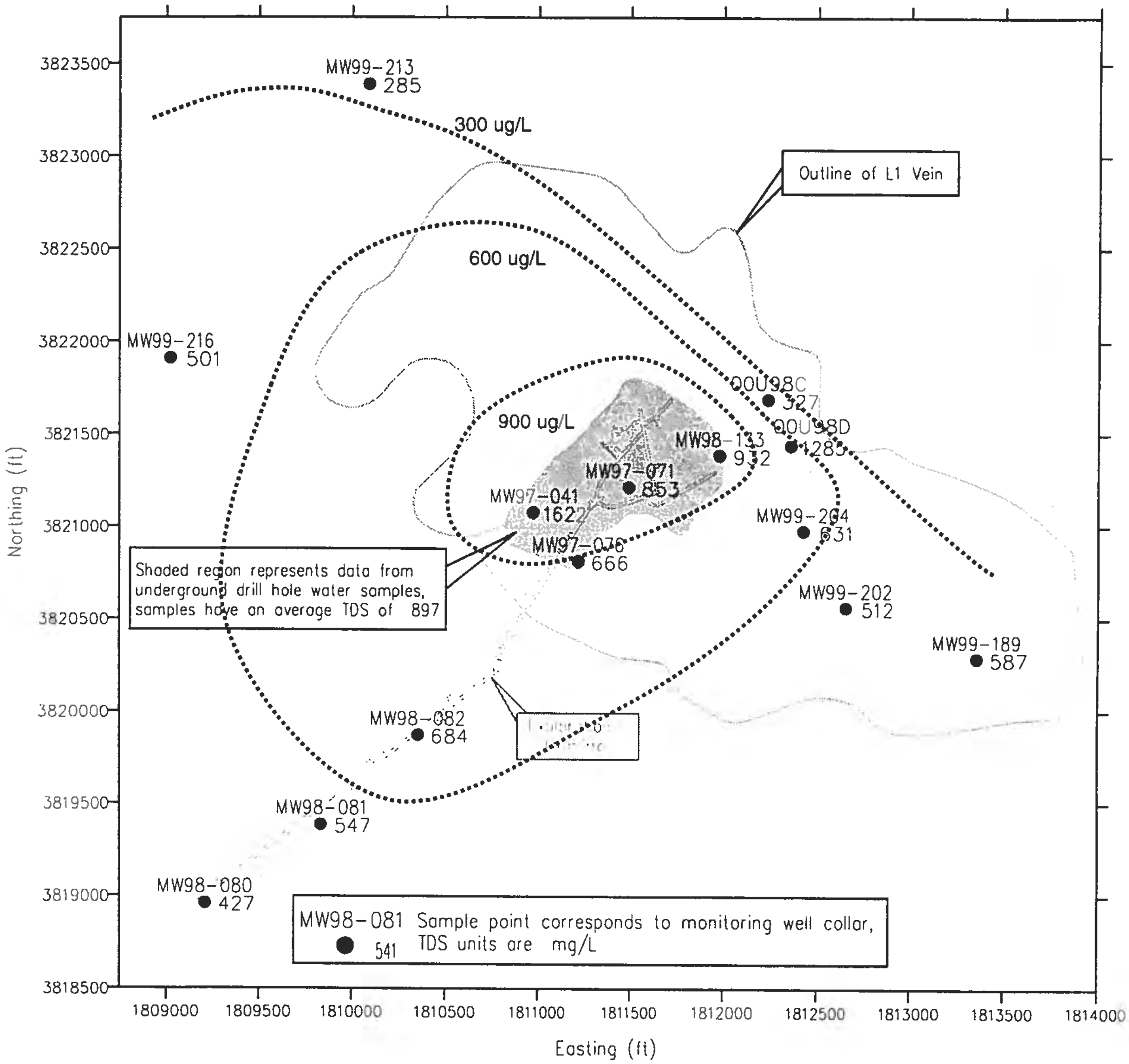


Figure 6 – TDS of L1 Orebody - Detail

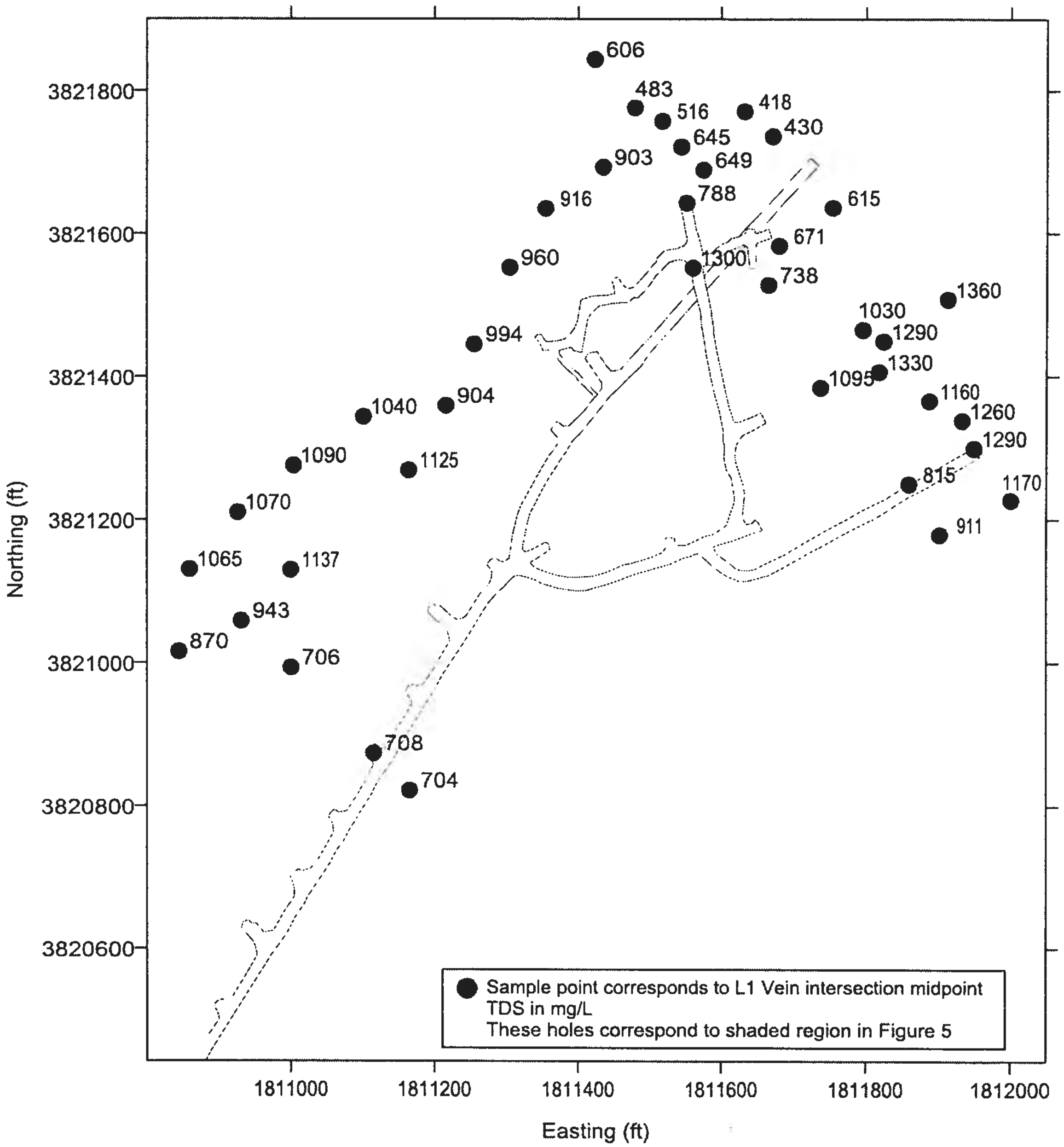


Figure 7 - Arsenic in Groundwater

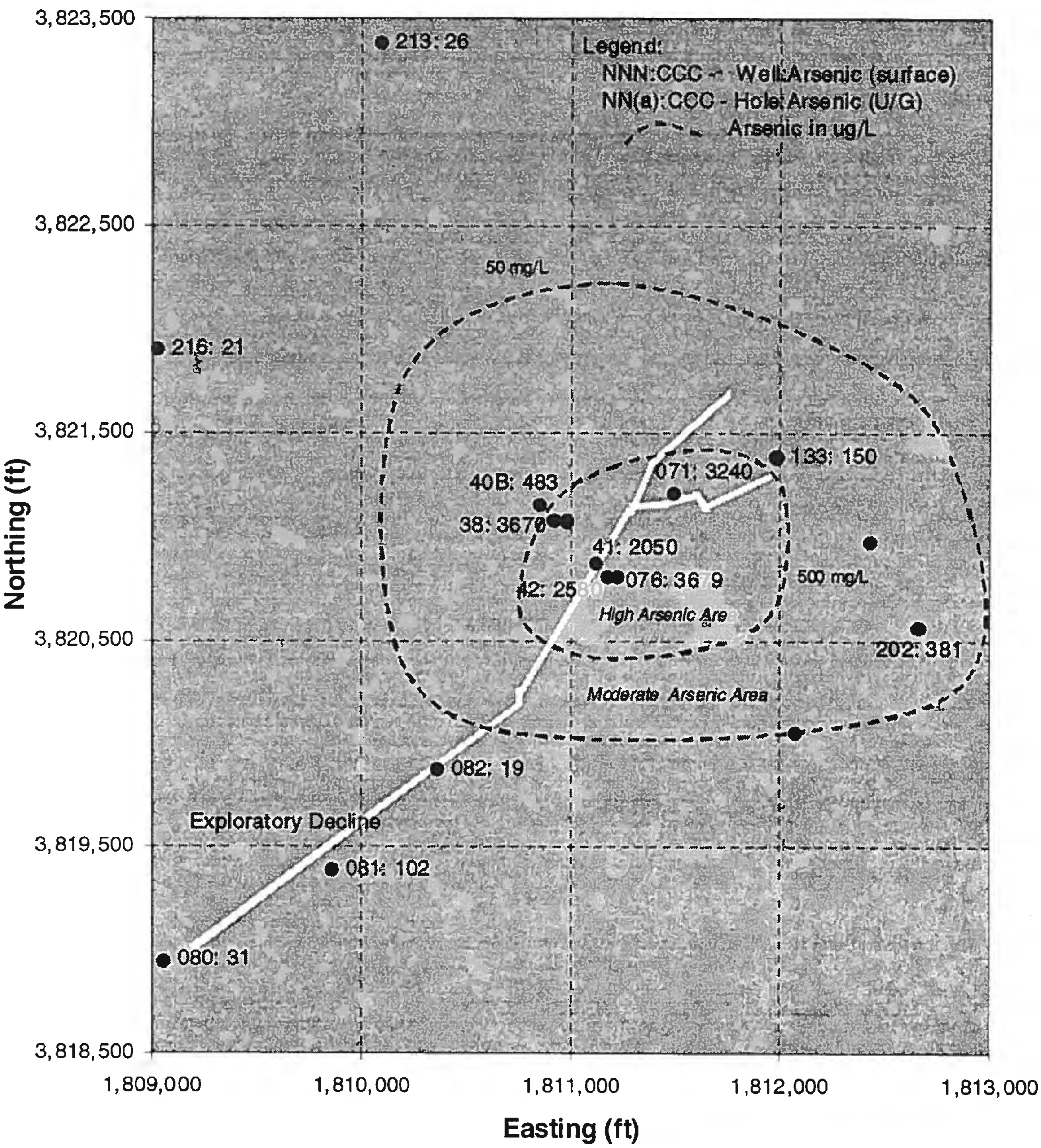


Figure 8 - Liese Creek Groundwater Levels - LD-005

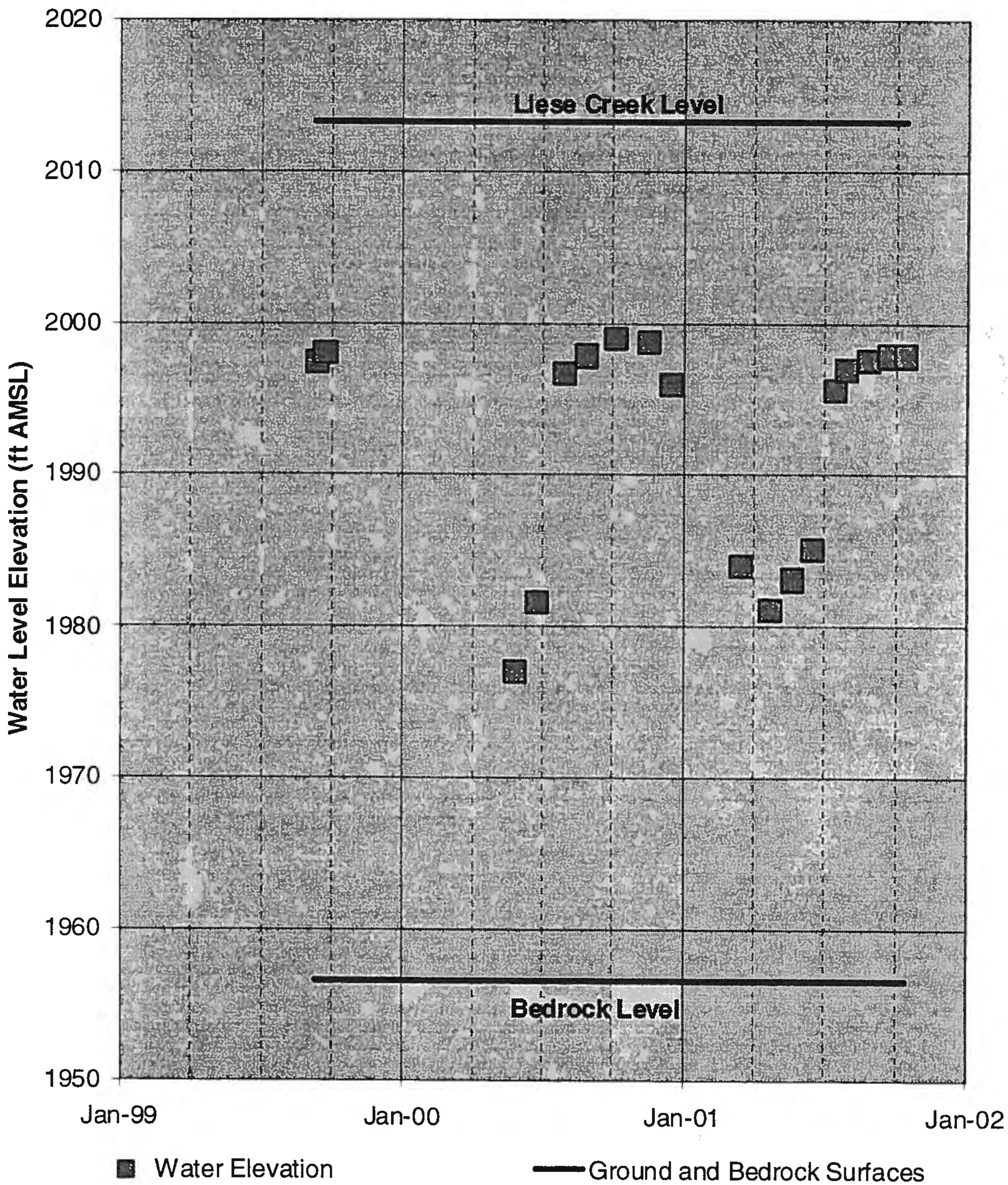


Figure 9 - Calibration Against Pre-Mining Heads

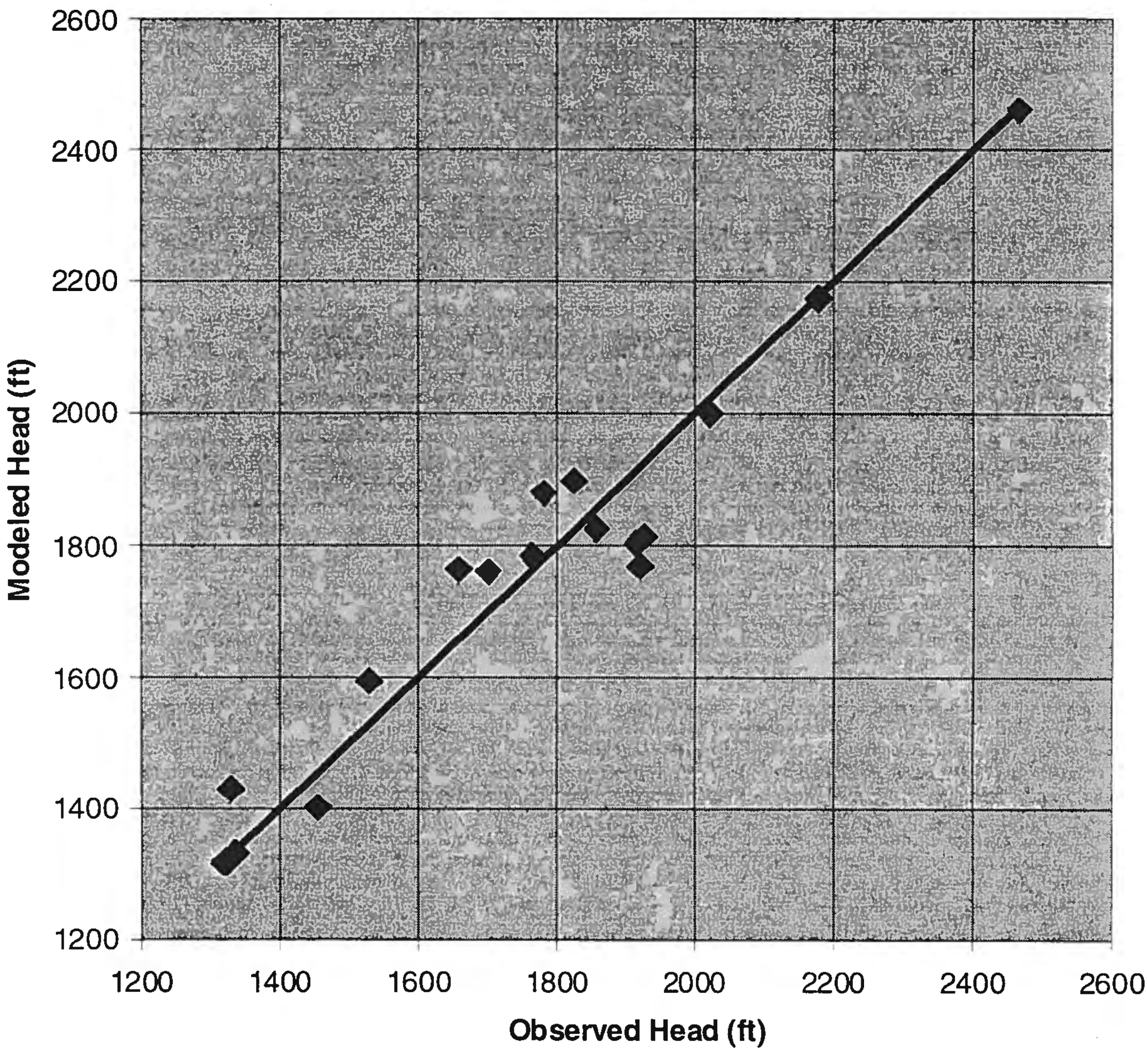


Figure 10 - Calibration Against Exploration Adit Inflow

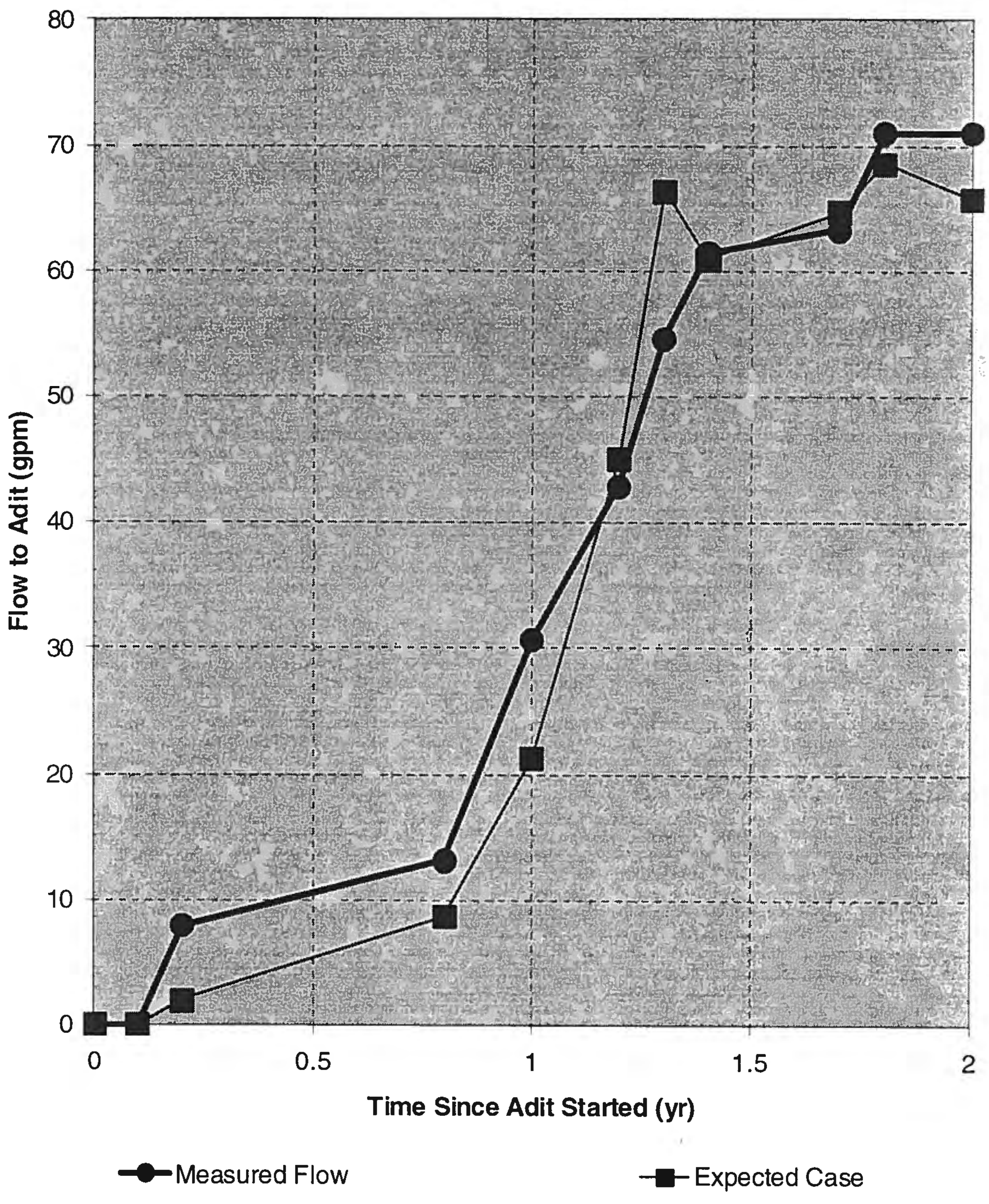


Figure 11 - Calibration Against Adit Drawdowns

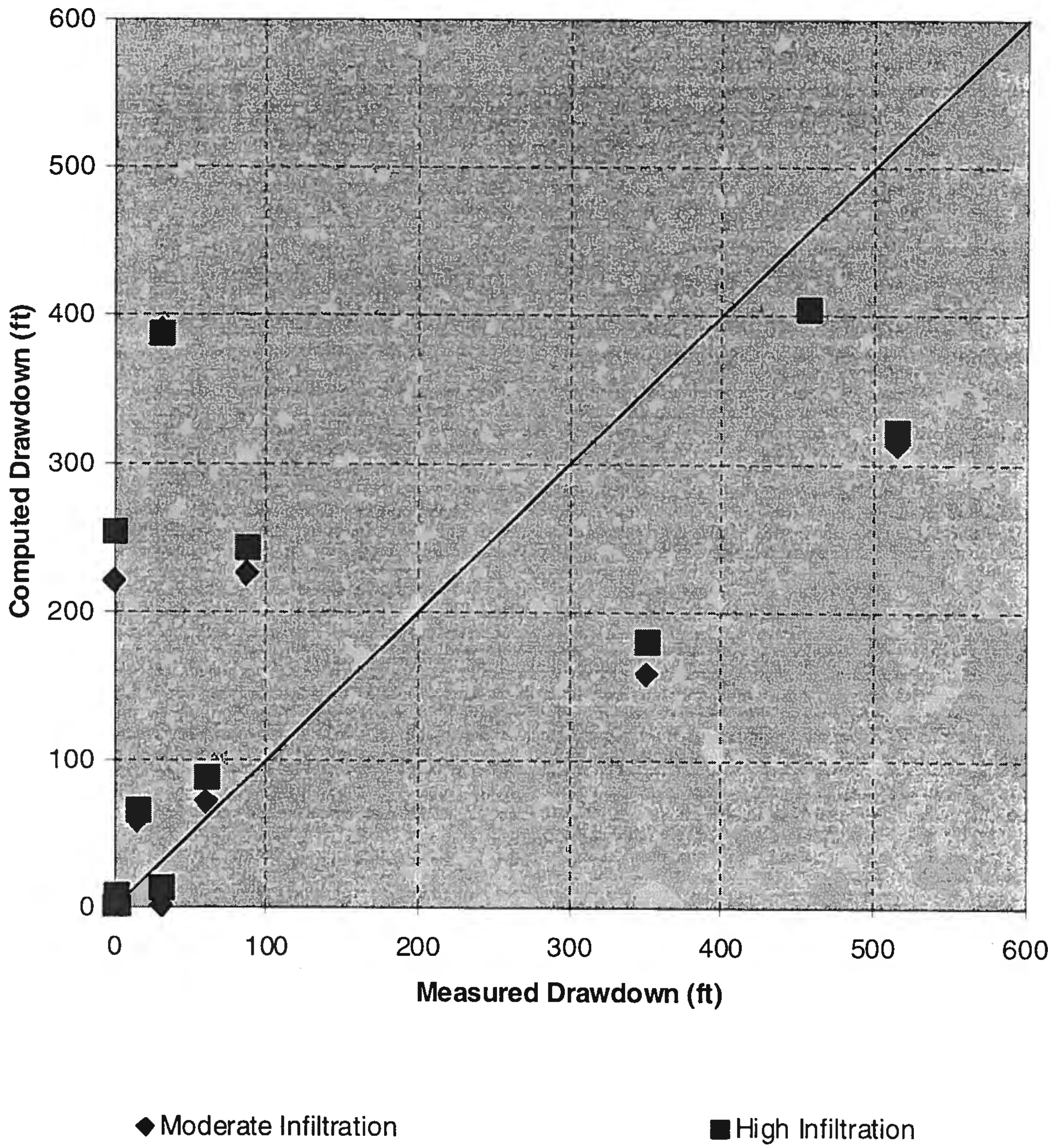
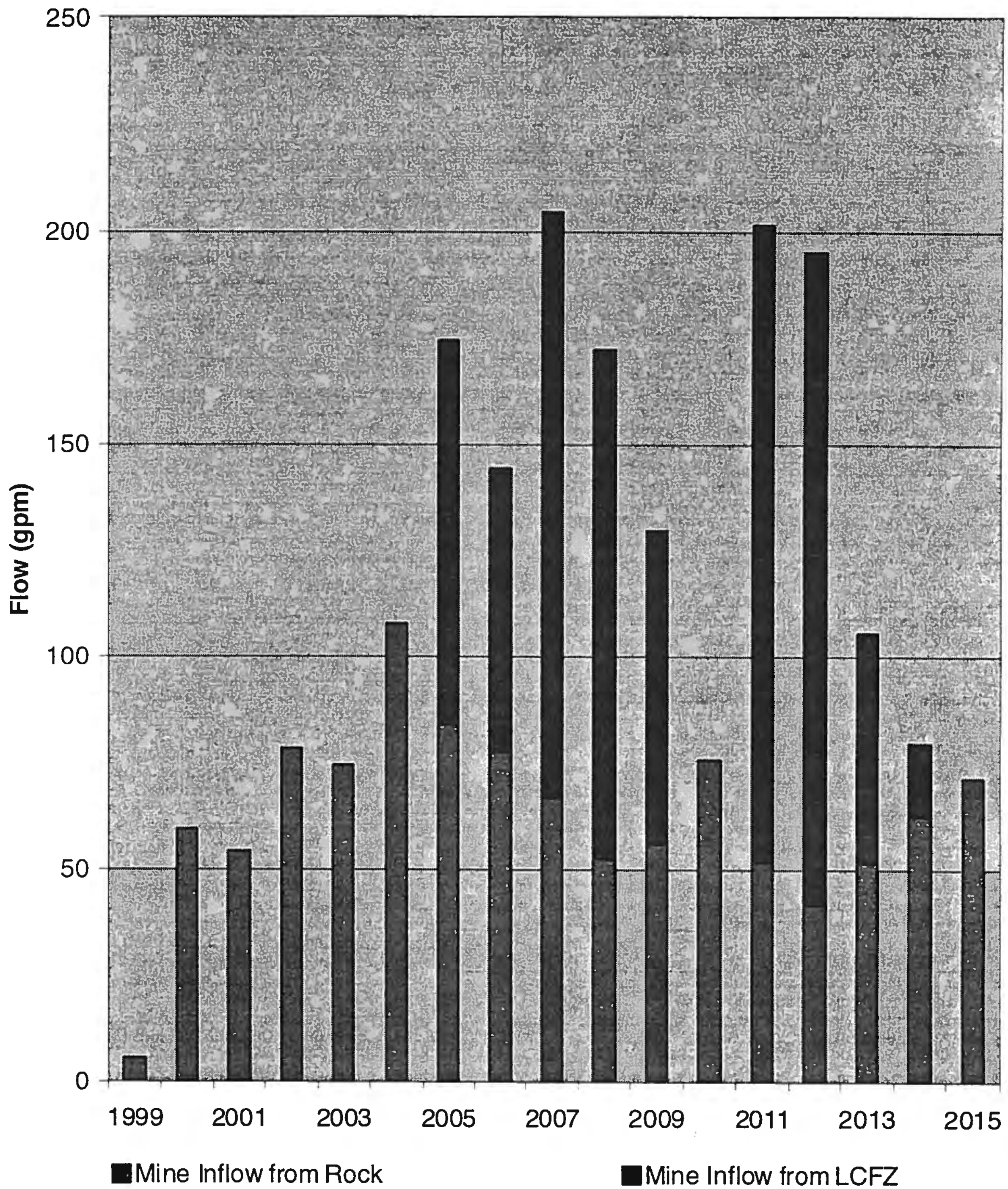
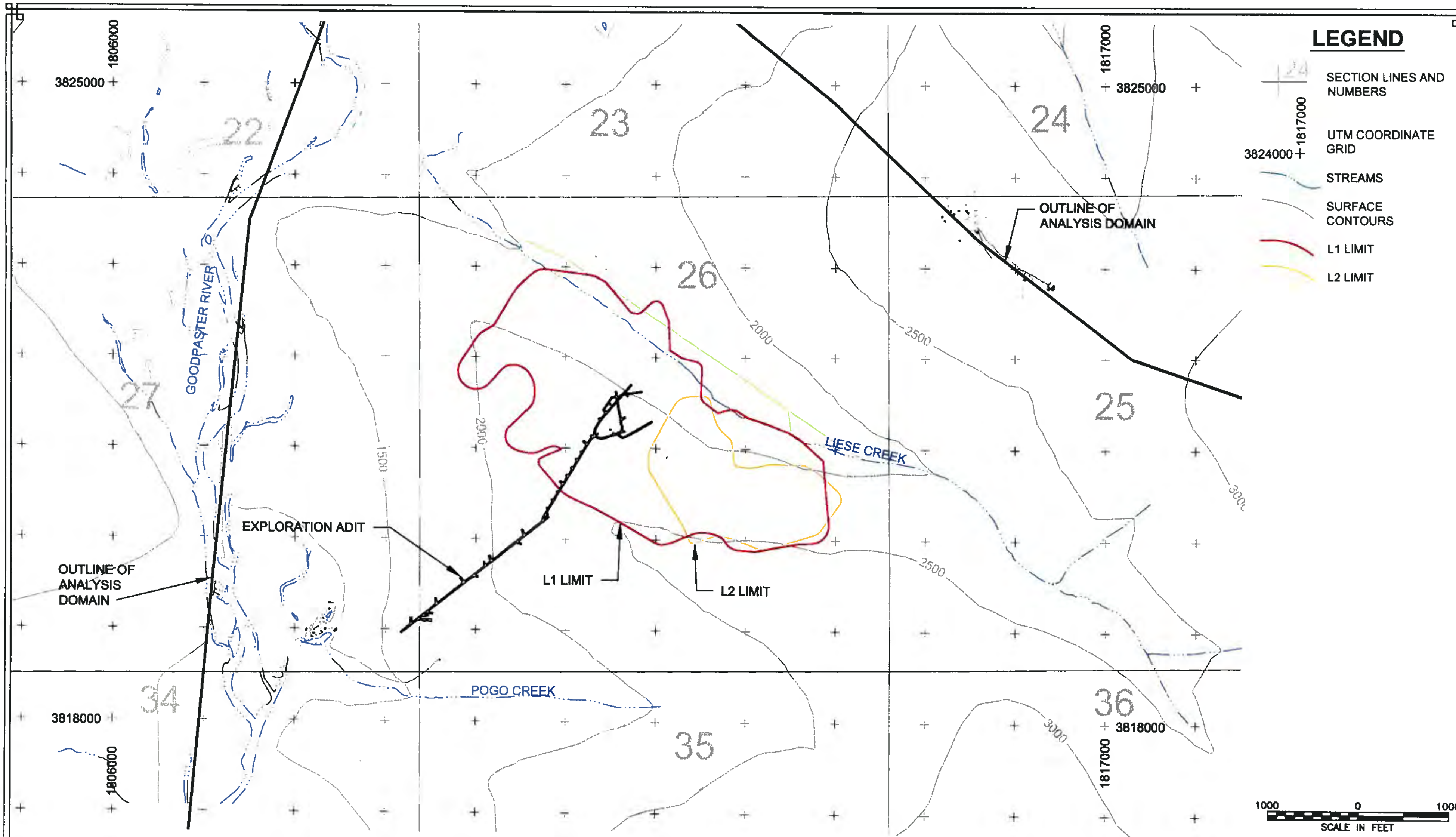


Figure 12 - Expected Mine Inflow





Adrian Brown

TECK CORPORATION

LOCATION PLAN

POGO GOLD PROJECT, ALASKA

N

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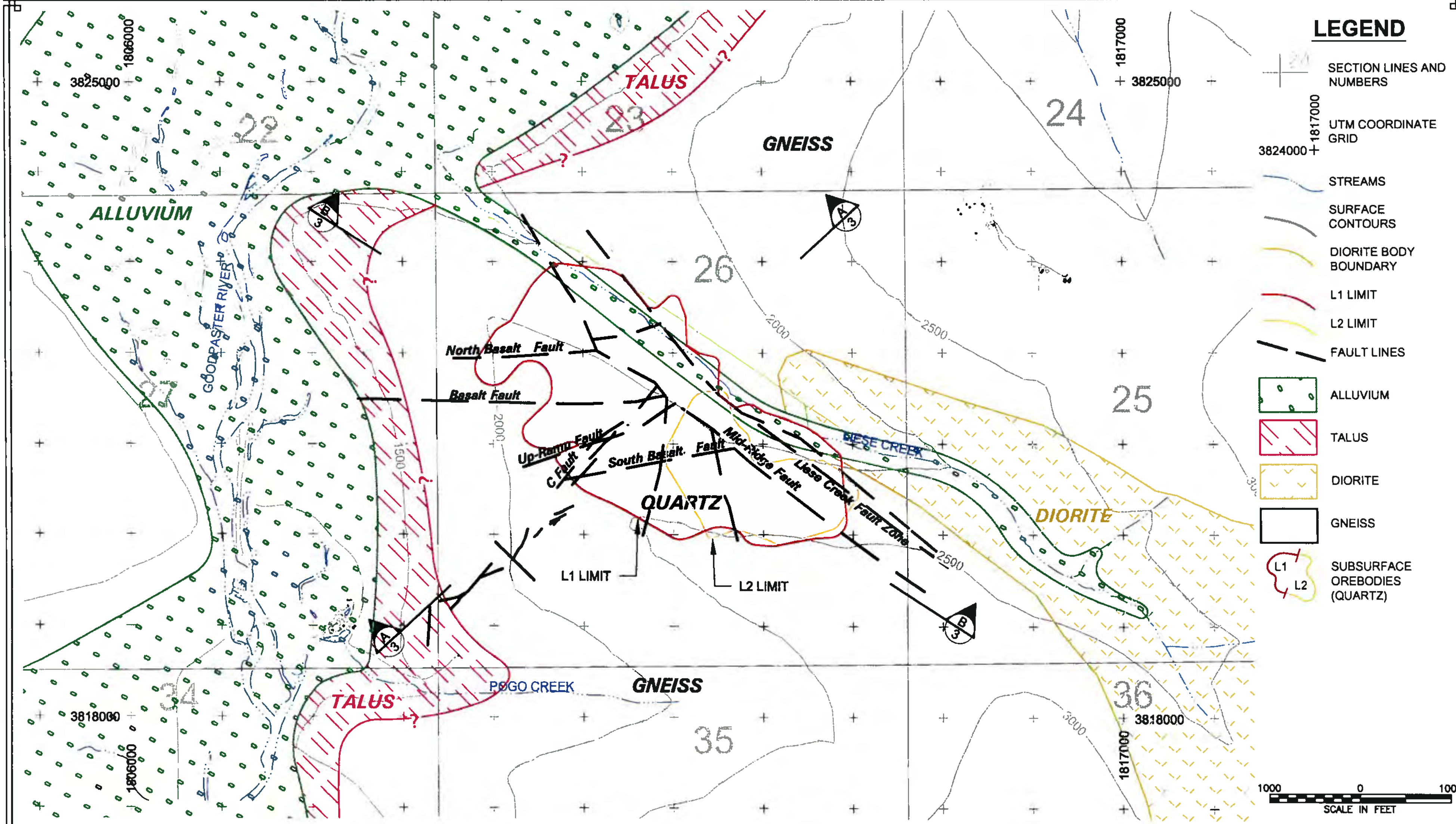
DRAWN D.B	DATE 3 JAN 2002	1
CHECKED A.B	DATE 3 JAN 2002	



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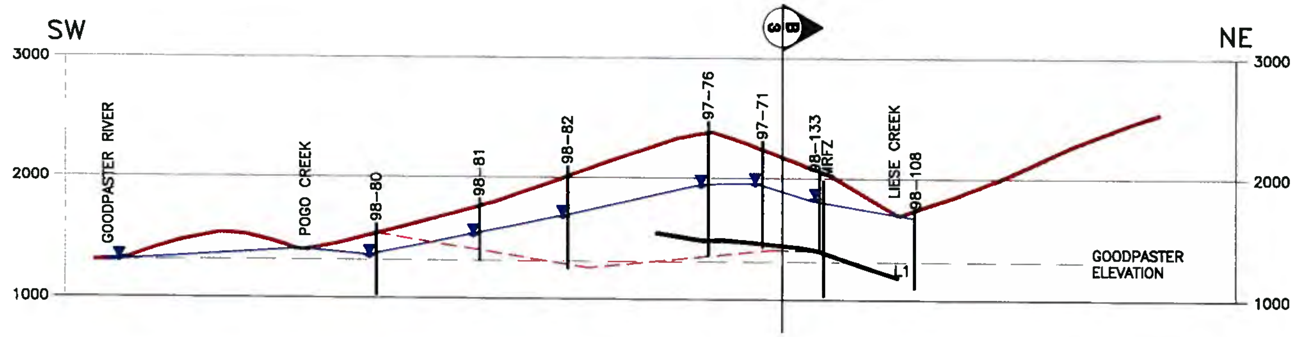
TECK CORPORATION

GEOLOGY AND STRUCTURE

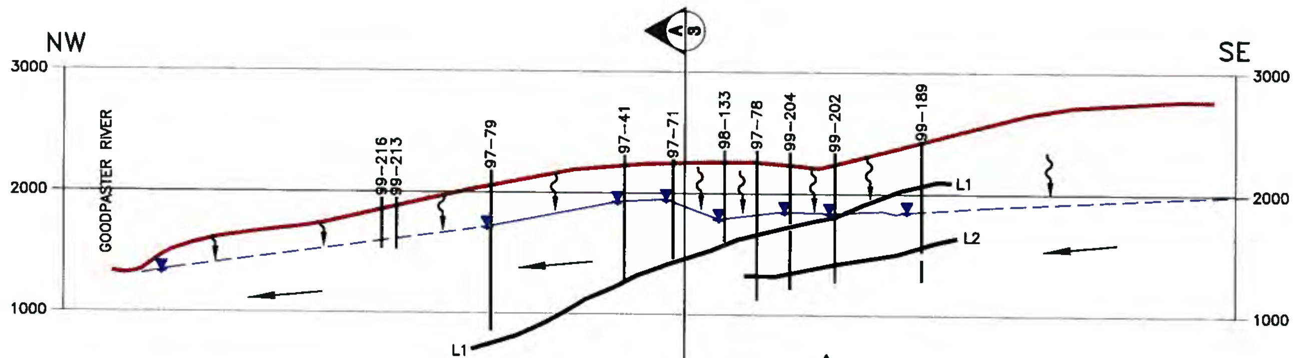
POGO GOLD PROJECT, ALASKA

DESIGNED: A.B.	DATE: 3 JAN 2002	FILE	PLATE NUMBER
DRAWN: D.B.	DATE: 3 JAN 2002		2
CHECKED: A.B.	DATE: 3 JAN 2002		



CROSS SECTION A 3

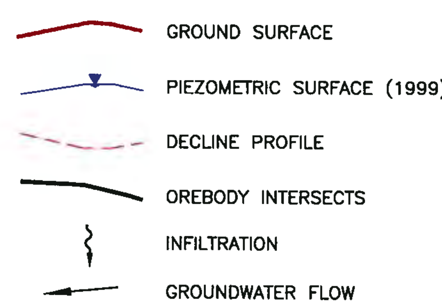
NO VERTICAL EXAGGERATION



CROSS SECTION B 3

NO VERTICAL EXAGGERATION

LEGEND



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SCALE IN FEET

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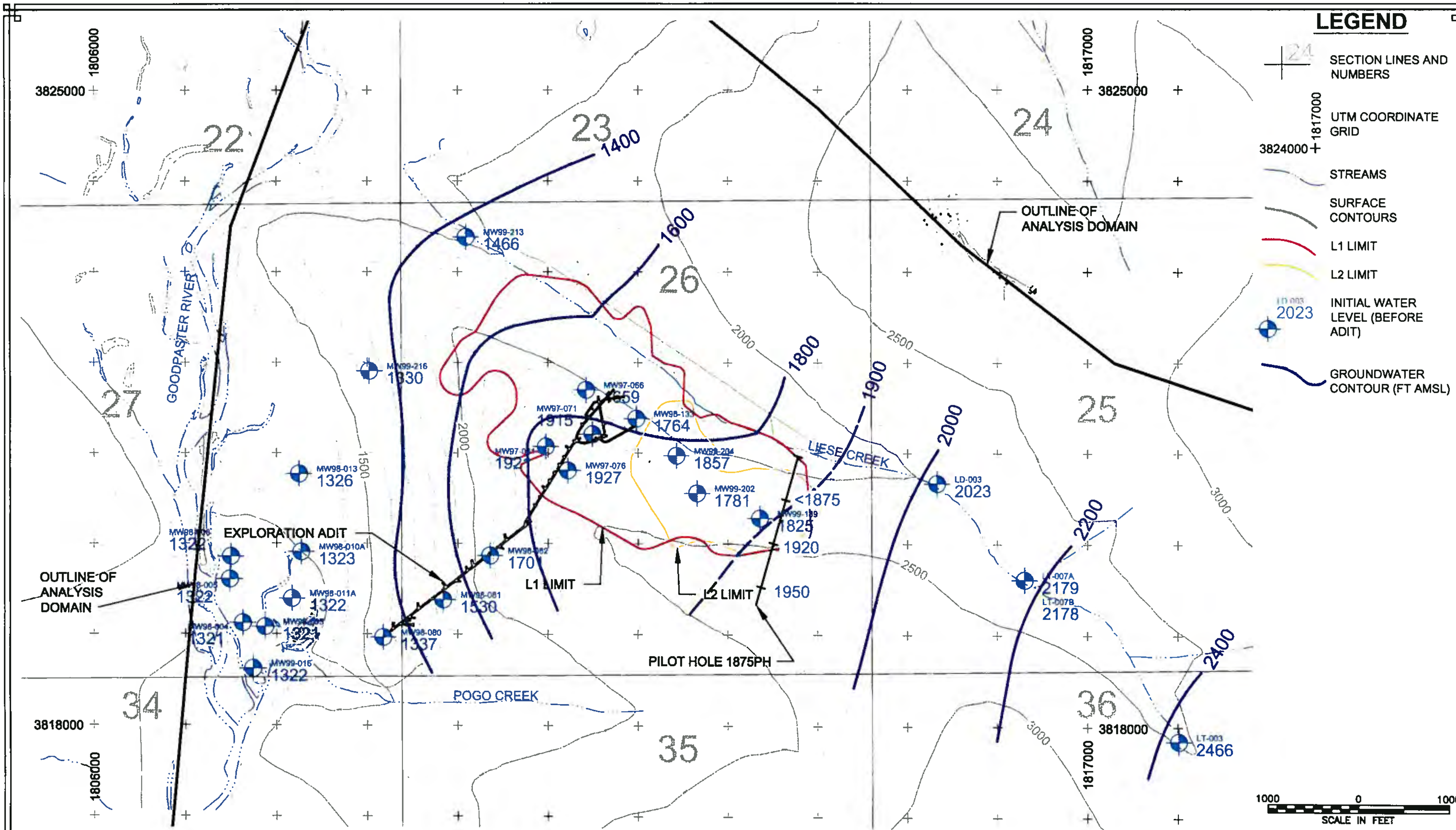
Innovative Environmental Solutions

TECK CORPORATION

GEOLOGIC CROSS SECTIONS

POGO GOLD PROJECT, ALASKA

DESIGNED A.B	DATE 3 JAN 2002	FILE #1543a1 1543a-005 DWG. X-Sections Date 3 JAN 2002	PLATE NUMBER 3
DRAWN D.B	DATE 3 JAN 2002		
CHECKED A.B	DATE 3 JAN 2002		



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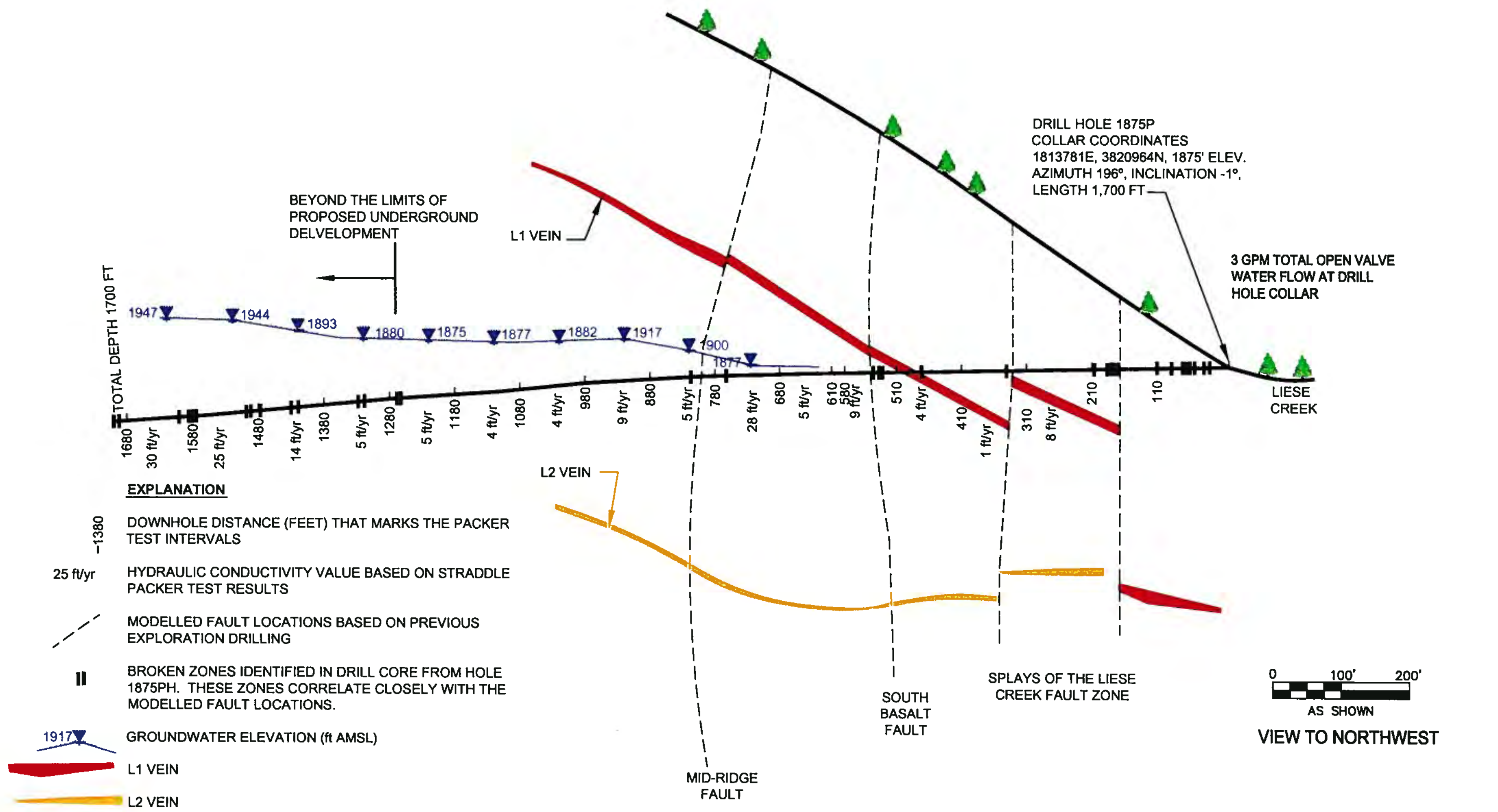
TECK CORPORATION

PRE-DEVELOPMENT GROUNDWATER LEVELS

POGO GOLD PROJECT, ALASKA

DESIGNED A.B.	DATE 3 JAN 2002	
DRAWN D.B.	DATE 3 JAN 2002	
CHECKED A.B.	DATE 3 JAN 2002	

PLATE NUMBER 4



Adrian Brown

TECK CORPORATION

LIESE CREEK PILOT HOLE 1875PH

POGO GOLD, ALASKA

N

DESIGNED: A.B.	DATE 3 JAN 2002	FILE #1543a\ 1543a-008 DWG 1875PH-pdf Date 3 JAN 2002 18:30:00	PLATE NUMBER 5
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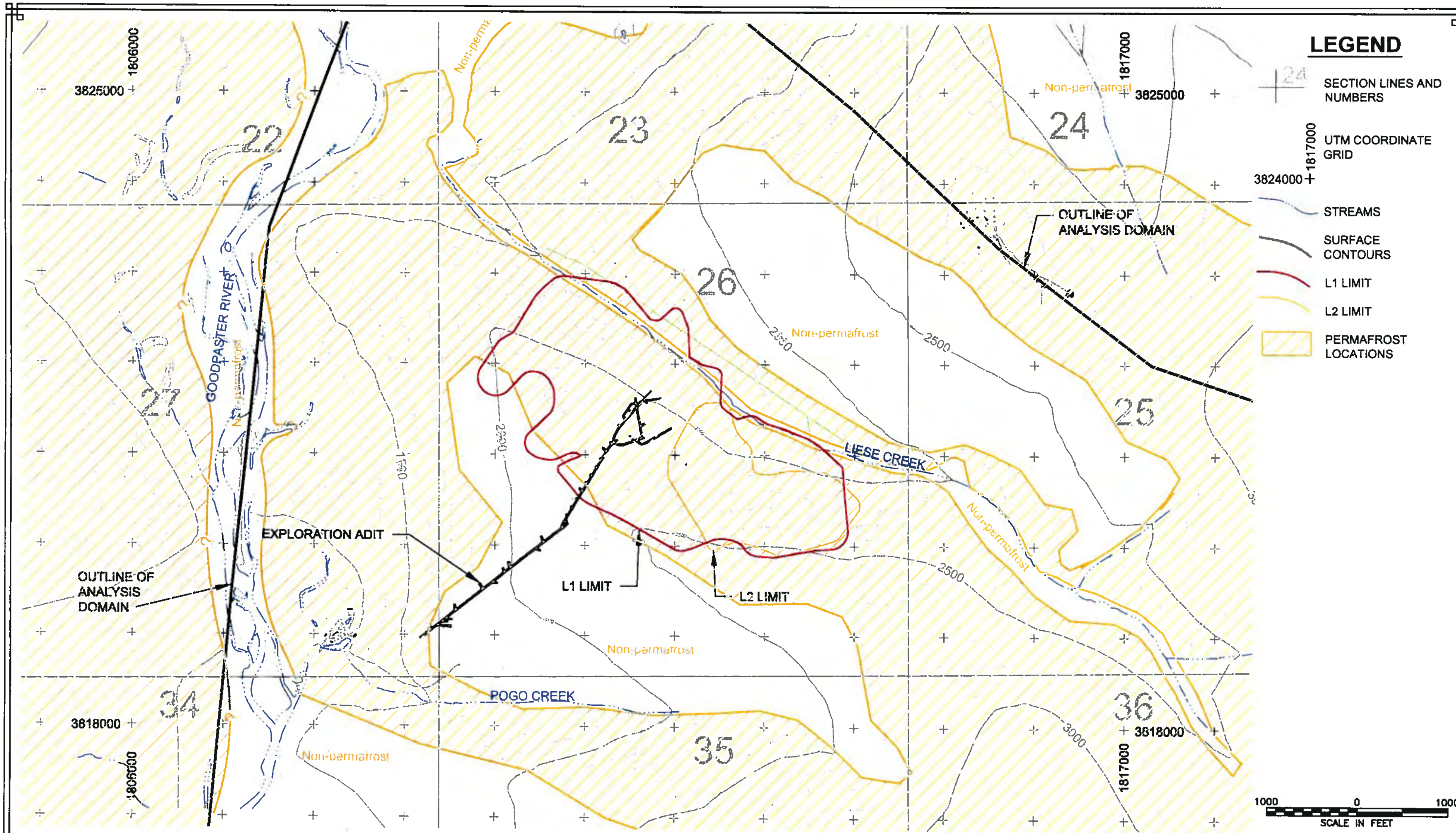
CHECKED: A.B.	DATE 3 JAN 2002		

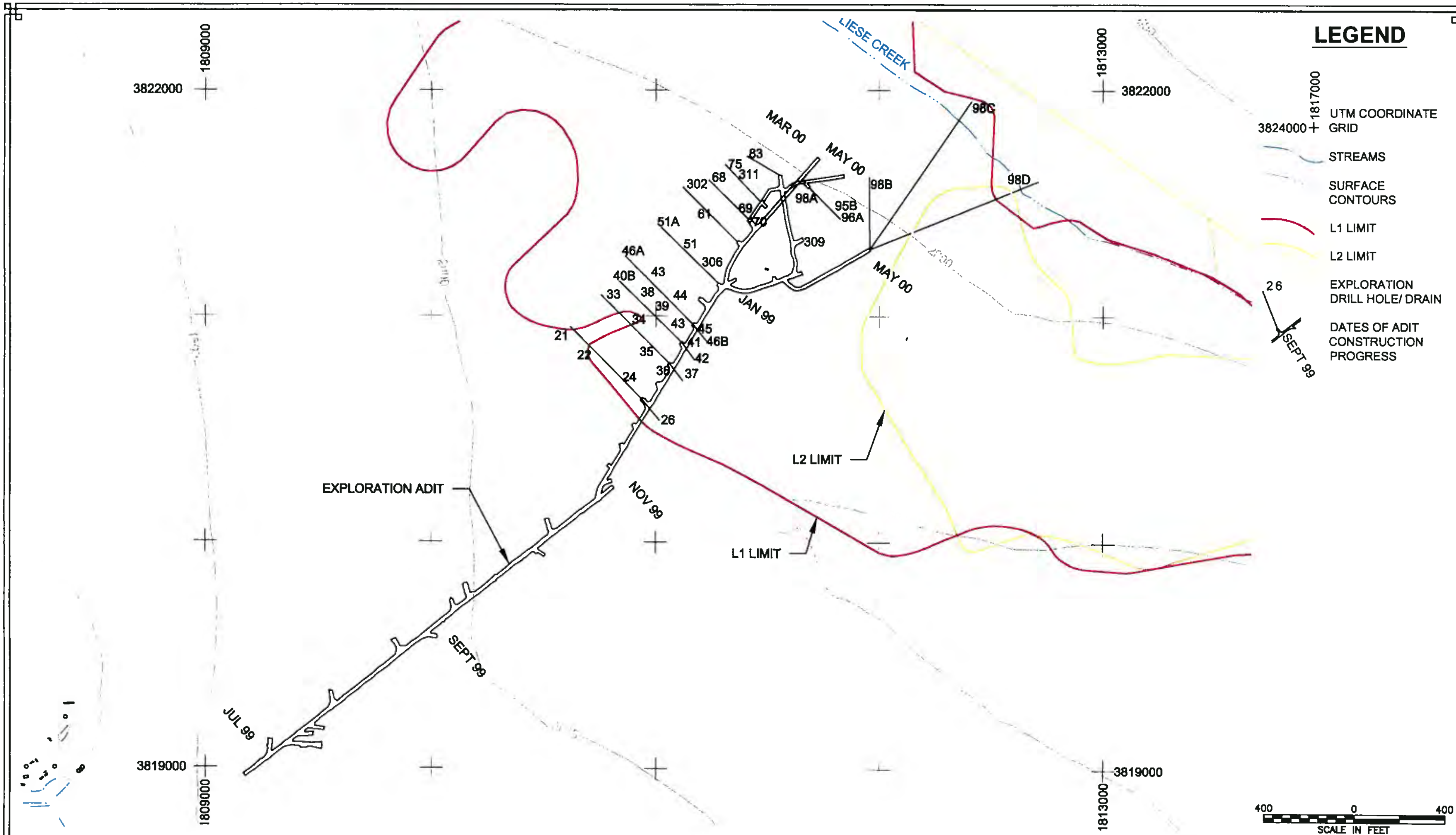


TECK CORPORATION

PERMAFROST

POGO GOLD PROJECT, ALASKA

DESIGNED: A.B.	DATE: 3 JAN 2002	FILE:	PLATE NUMBER
DRAWN: D.B.	DATE: 3 JAN 2002		6
CHECKED: A.B.	DATE: 3 JAN 2002		



Adrian

TECK CORPORATION

EXPLORATION ADIT

POGO GOLD PROJECT, ALASKA

DESIGNED A B	DATE 3 JAN 2002	FILE #1543a1 1543a-005 DWG Ade Date 3 JAN 2002 08 15 00	PLATE NUMBER 7
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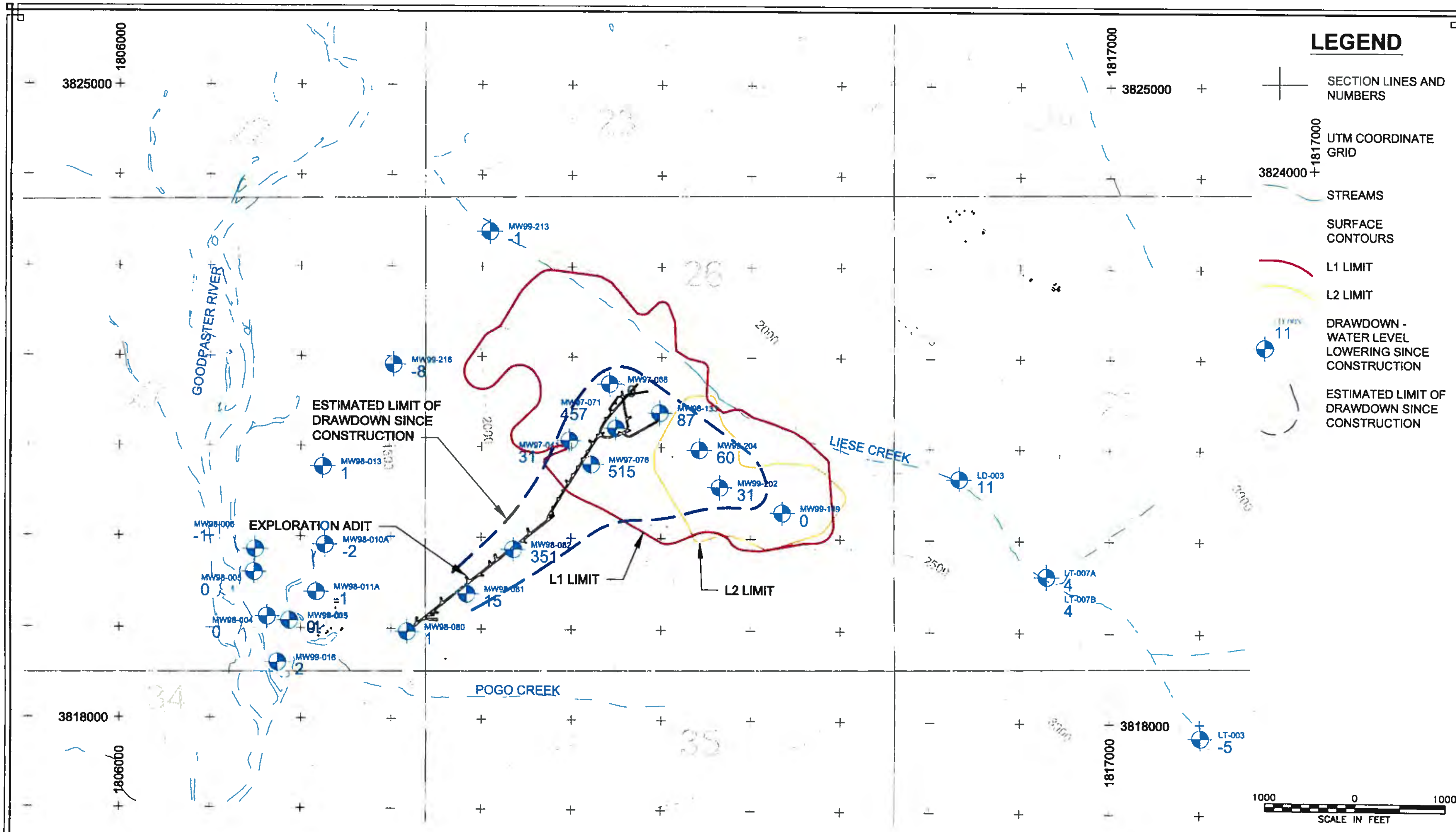

Adrian Brown

TECK CORPORATION

ADIT DRAWDOWN

POGO GOLD PROJECT, ALASKA

N

DESIGNED A B	DATE 3 JAN 2002	FILE #1543a	PLATE NUMBER
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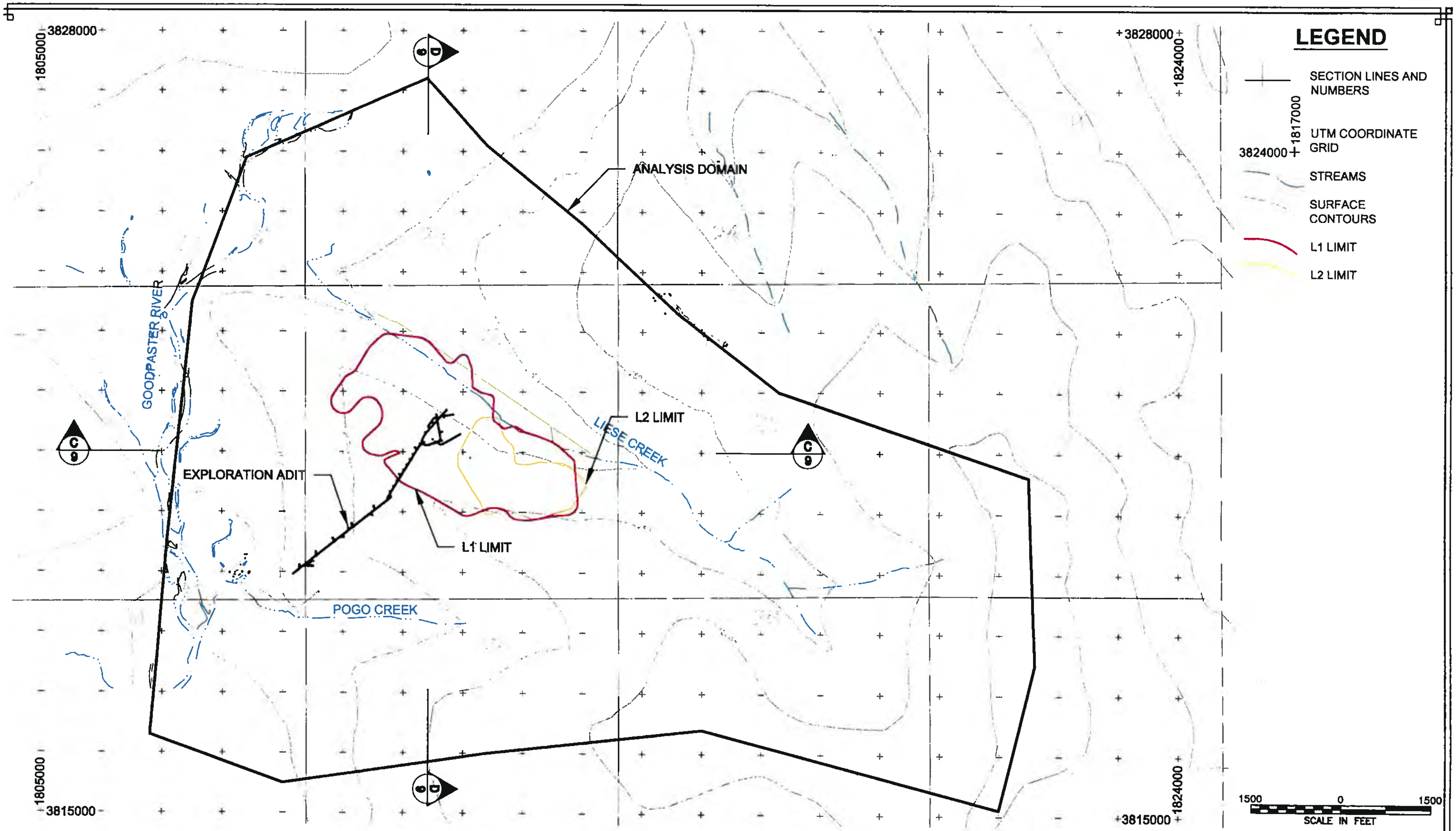

AdrianBrown

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ANALYSIS DOMAIN

POGO GOLD PROJECT, ALASKA

N

DESIGNED A B	DATE 3 JAN 2002	FILE #1543A\ 1543a-005.DWG Domain Date 3 JAN 2002 08 25 00	PLATE NUMBER 9
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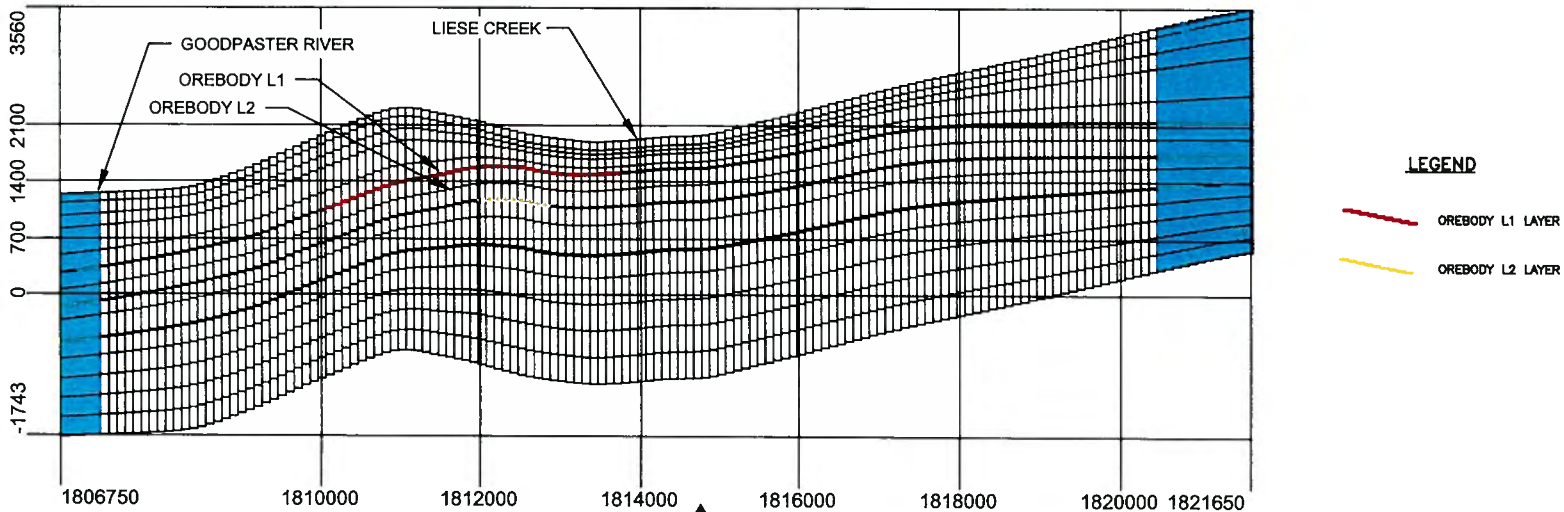
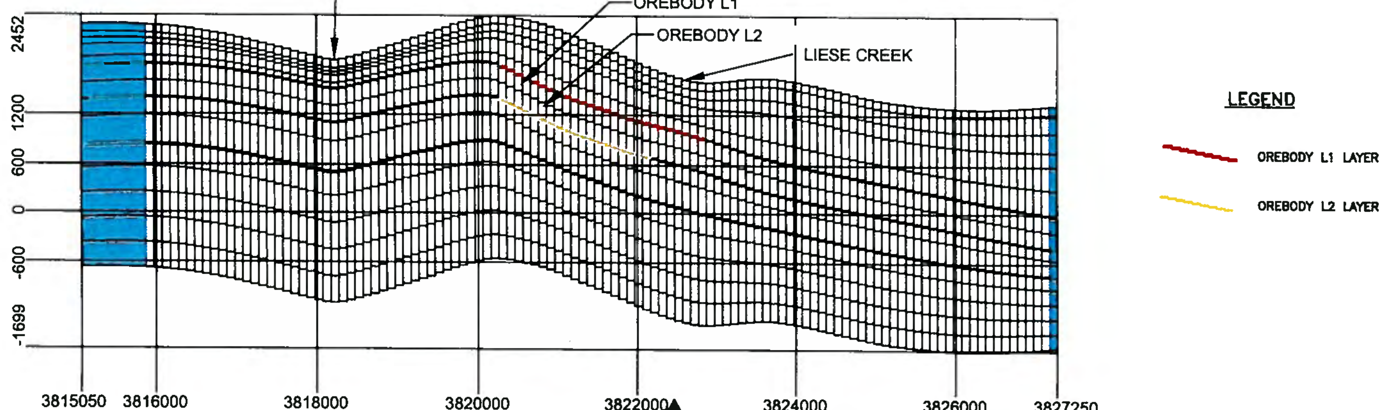
CHECKED A B	DATE 3 JAN 2002		



CROSS SECTION C/8

NO VERTICAL EXAGGERATION



CROSS SECTION D/8

NO VERTICAL EXAGGERATION

1500 0 1500

SCALE IN FEET

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MODEL SECTIONS

POGO GOLD PROJECT, ALASKA

DESIGNED A B	DATE 3 JAN 2002	FILE #1543a\ 1543a-005 DWG Sect c&d Date 3 JAN 2002 08 30 00	PLATE NUMBER 10
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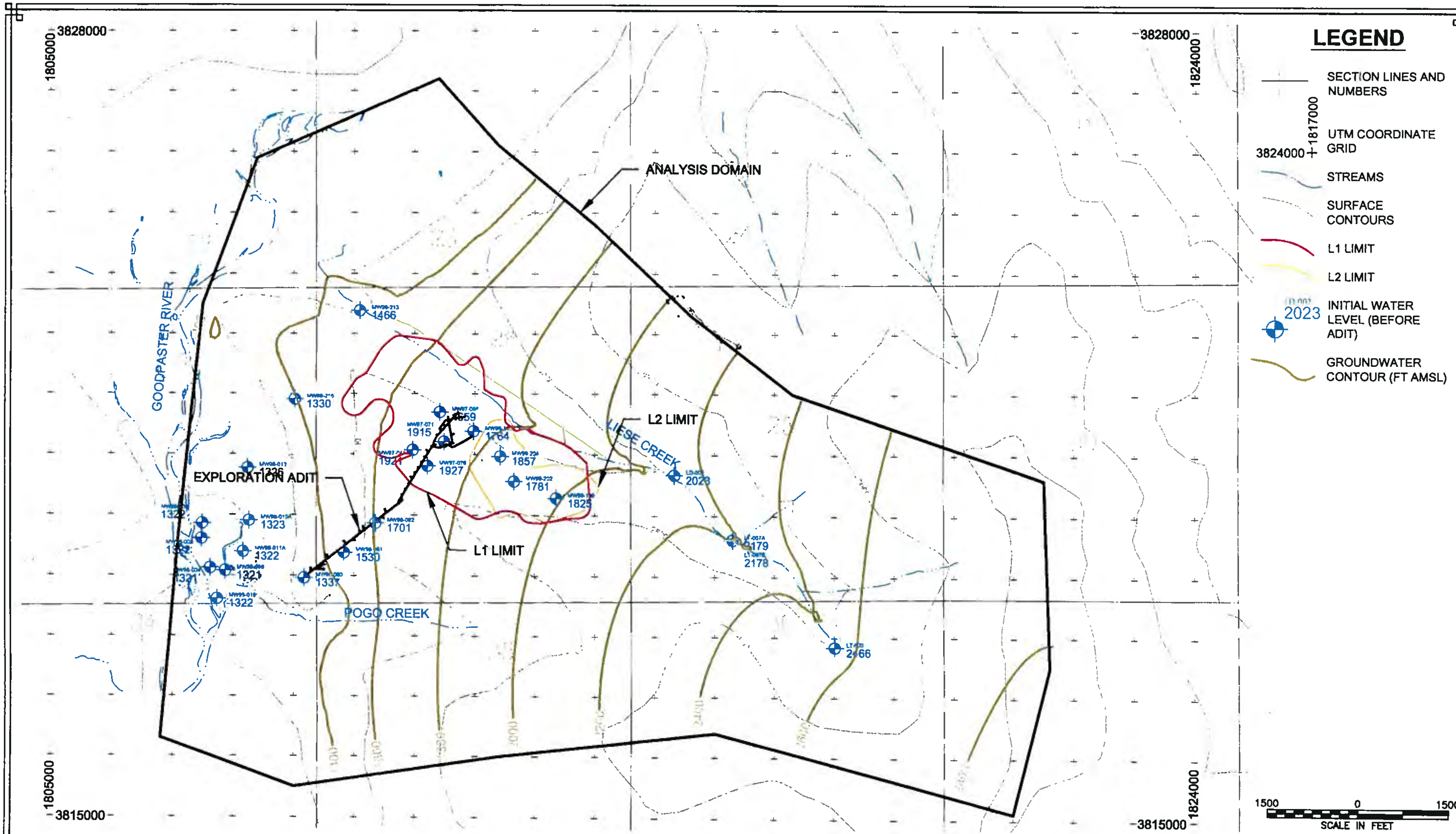
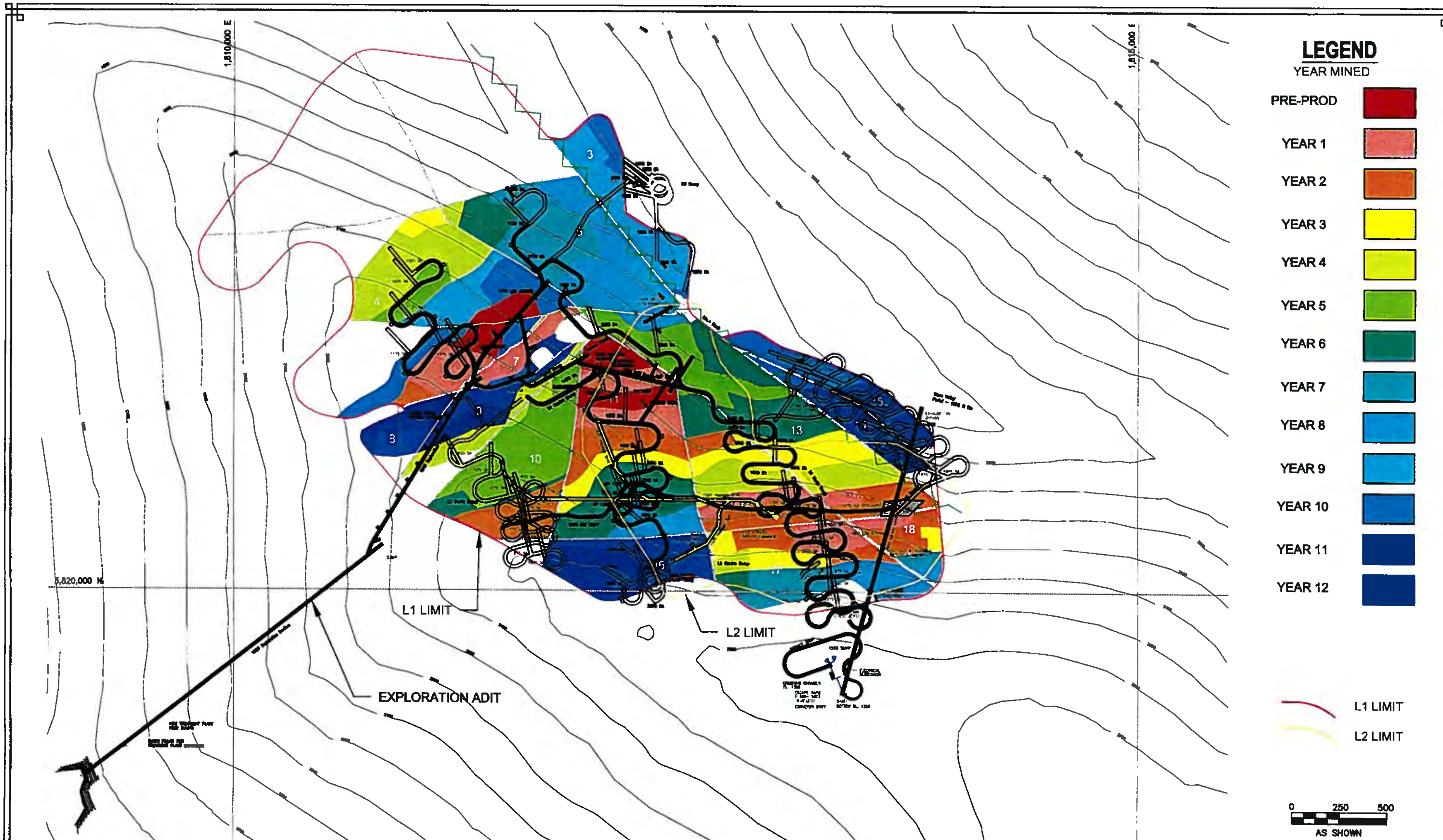


Adrian Brown	TECK CORPORATION	PRE-DEVELOPMENT MODELED HEADS	POGO GOLD PROJECT, ALASKA	N

DESIGNED A B	DATE 3 JAN 2002	FILE #1543a1	PLATE NUMBER
DRAWN D B	DATE 3 JAN 2002	1543a-005 DWG Pre-Heads	11
CHECKED A B	DATE 3 JAN 2002	Date 3 JAN 2002 08 25 00	

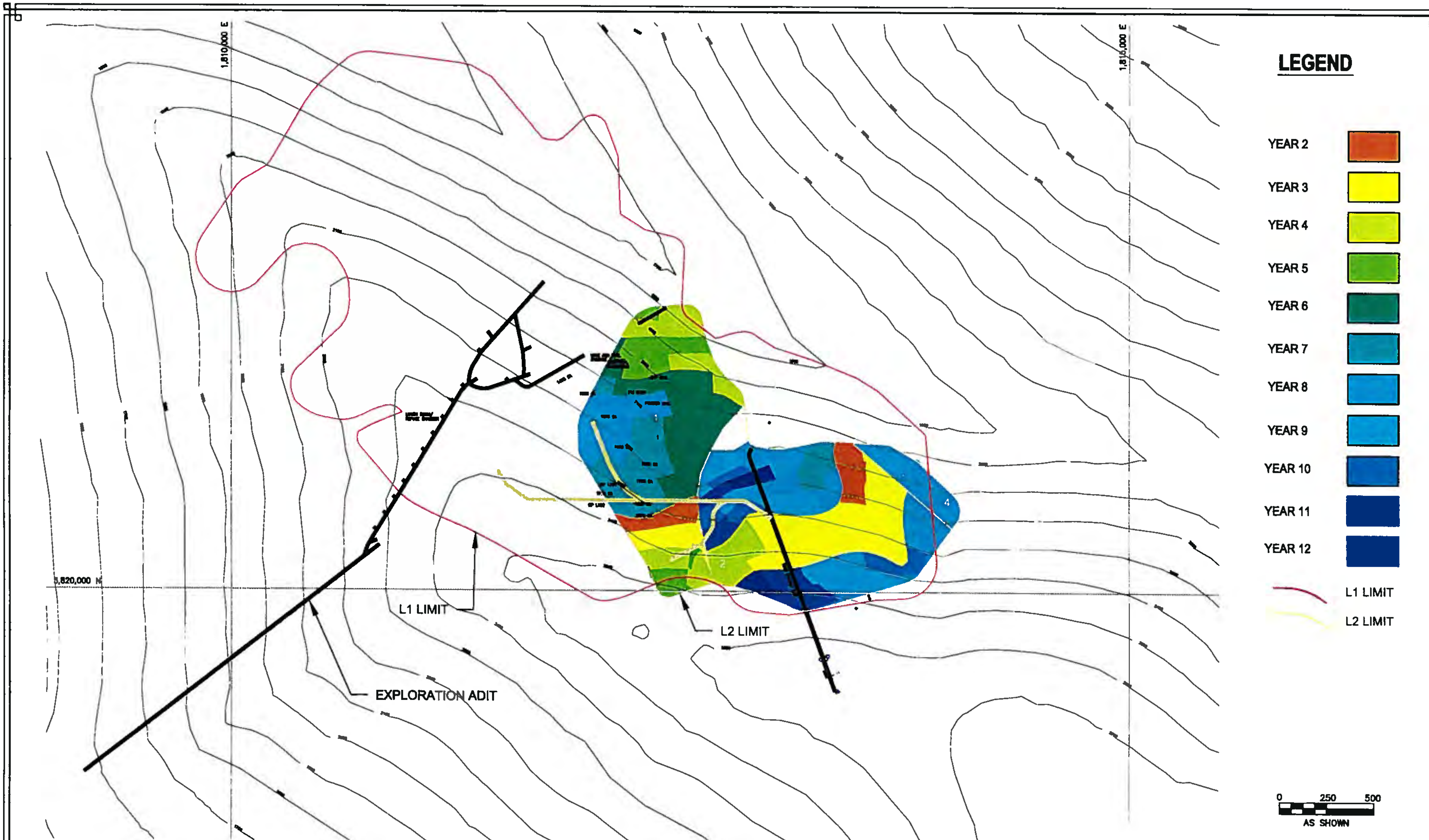


TECK CORPORATION

L1 OREBODY DEVELOPMENT AND MINING

POGO GOLD, ALASKA

DESIGNED A B	DATE 3 JAN 2002	PLATE NUMBER
DRAWN D B	DATE 3 JAN 2002	12
CHECKED A B	DATE 3 JAN 2002	



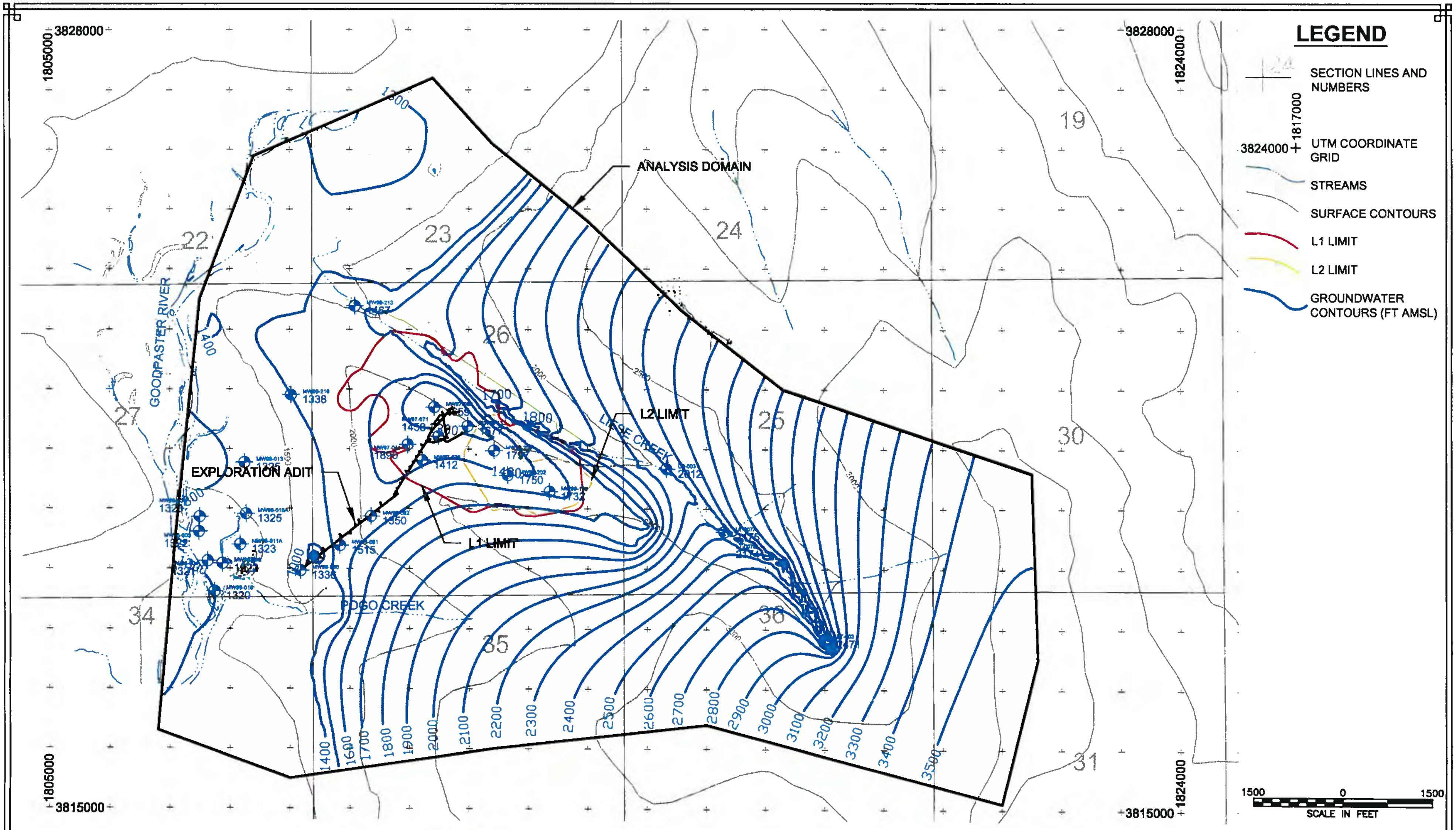
TECK CORPORATION

L2 OREBODY DEVELOPMENT AND MINING

POGO GOLD, ALASKA

N

DESIGNED A B	DATE 3 JAN 2002	FILE #1543a\1543a-006 DWG	PLATE NUMBER
DRAWN D B	DATE 3 JAN 2002	L2-pdf plate12	13
CHECKED A B	DATE 3 JAN 2002	Date 3 JAN 2002 09 45	



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TECK CORPORATION

MODELED HEADS AT END OF MINING

POGO GOLD PROJECT, ALASKA

DESIGNED A.B.	DATE 3 JAN 2002	FILE #1543a1 1543a-005 DWG. Post-Heads Date 3 JAN 2002 08 25 00
DRAWN D.B.	DATE 3 JAN 2002	
CHECKED A.B.	DATE 3 JAN 2002	

PLATE NUMBER 14