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# POGO Project

## Documentation Series for Permitting Approval
February 2002

# 4 Water Management Plan

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**Documentation Series for Permitting Approval**
**March 2002**

# WATER MANAGEMENT PLAN
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# SECTION 1 | INTRODUCTION

## 1.1 The Pogo Project

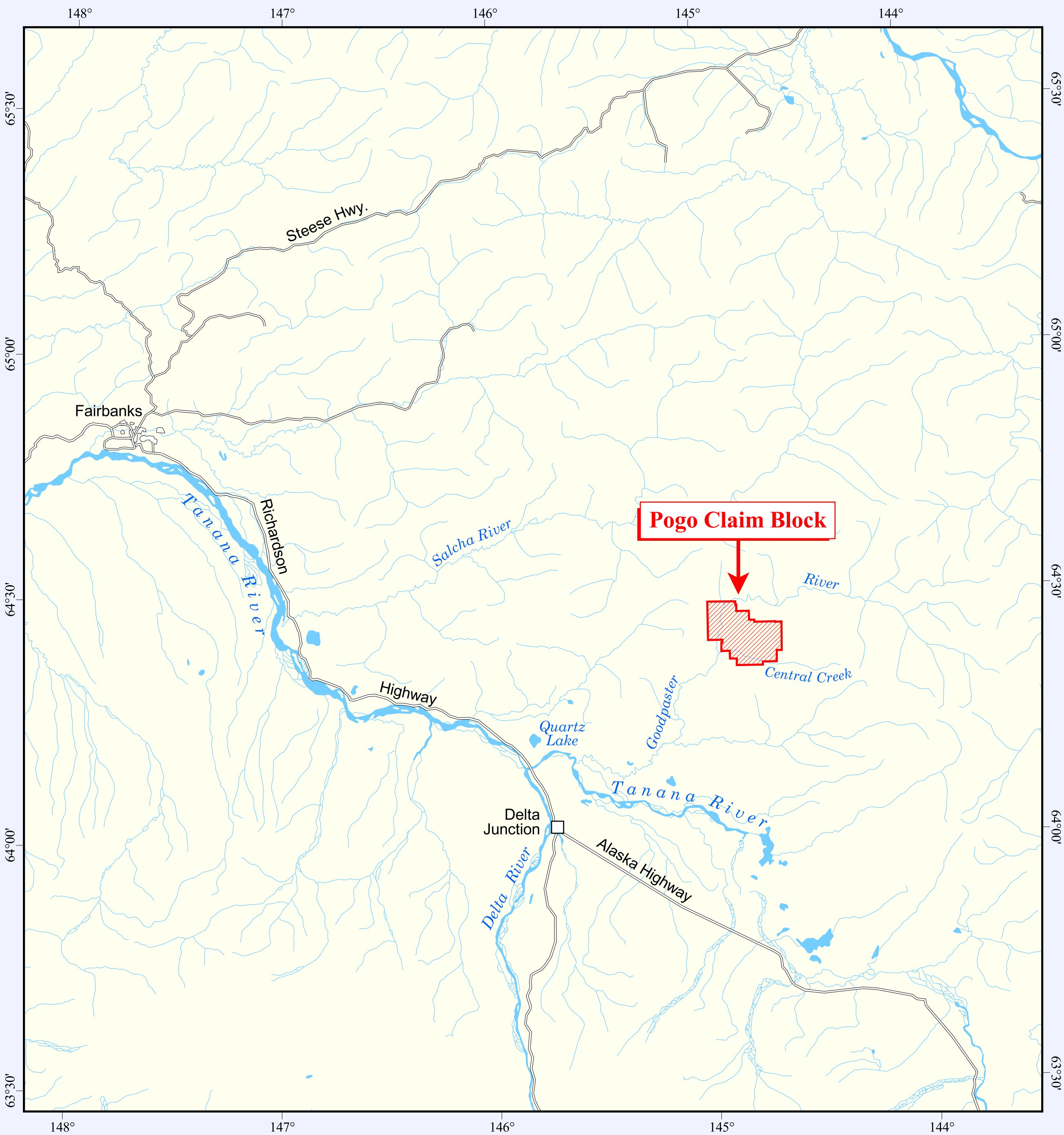
Teck-Pogo Inc. is proposing the development of the Pogo gold project located 38 miles northeast of Delta Junction, Alaska (see Figure 1.1). This report describes the water collection, treatment and disposal system for the Pogo project, and is part of a documentation series for permitting approval. Other documents in the series include “Introduction,” “Major Permits and Authorizations,” “Plan of Operations,” “Solid Waste Application,” ”Right-of-Way Application,” “Reclamation and Closure Plan,“ “Stormwater Pollution Prevention Plan” and “Appendices.”

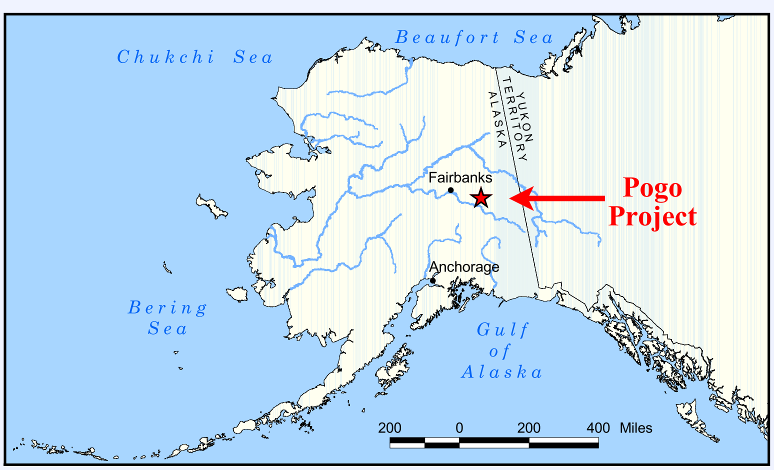
The project entails an underground mine designed to feed gold ore to the mill at an initial rate of approximately 2,500 tons per day (tpd), increasing to 3,500 tpd over time. The property will produce 350,000 to 550,000 ounces of gold annually.

As currently envisioned, the project will consist of the following major elements:

- underground drift-and-fill mine with a conveyor access for transfer of ore to the surface
- surface gold mill for gold recovery through gravity concentration, flotation and cyanide leaching
- tailings preparation facilities, including cyanide destruction and filtration, to produce paste backfill for the underground mine workings and dewatered tailings material suitable for storage in a drystack facility on the surface
- 250 person camp with recreation and catering facilities
- transmission line along the Shaw Creek Hillside route, and on-site electrical distribution system
- 49 mile all-season road constructed along the Shaw Creek Hillside route
- a water management system that maximizes recycling and treats all waters affected by the project in accordance with pertinent federal and state legislation.

A computer-generated view of the proposed project development is provided in Figure 1.2. Figure 1.3 shows the general configuration of the project facilities, followed by an illustration of site water flows in Figure 1.4.




10 0 10 20 30 40 50 Kilometers

5 0 5 10 15 20 25 30 Miles

Map base: US DMA DCW
Projection: UTM Zone 6;
Datum: NAD27
Map prepared by ABR, Inc.

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**Pogo Project**

Figure 1.1
General Location Map

18 Dec 2001 | ABR File: Water_Mgmt_Plan_Dec2001.apr

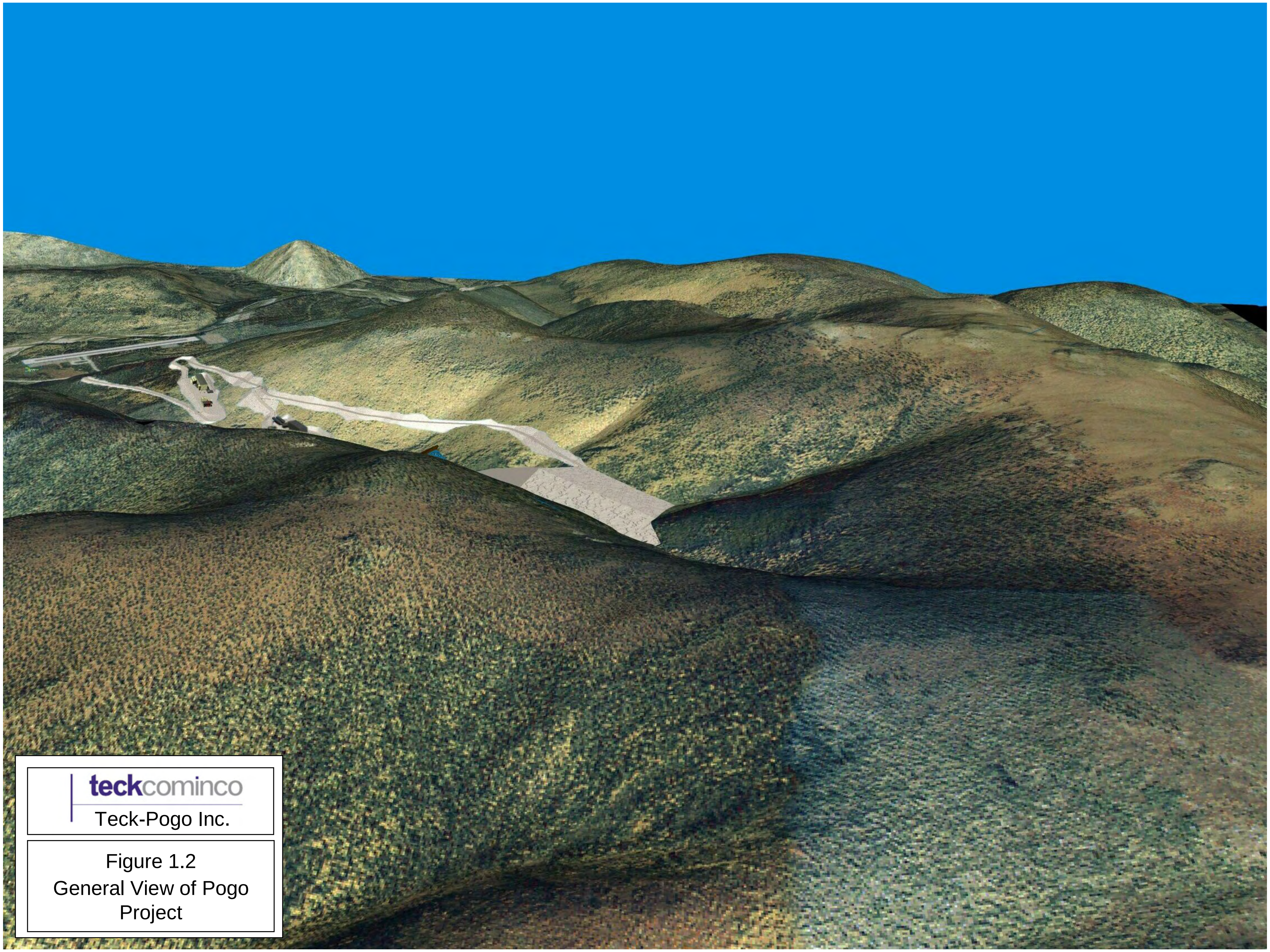
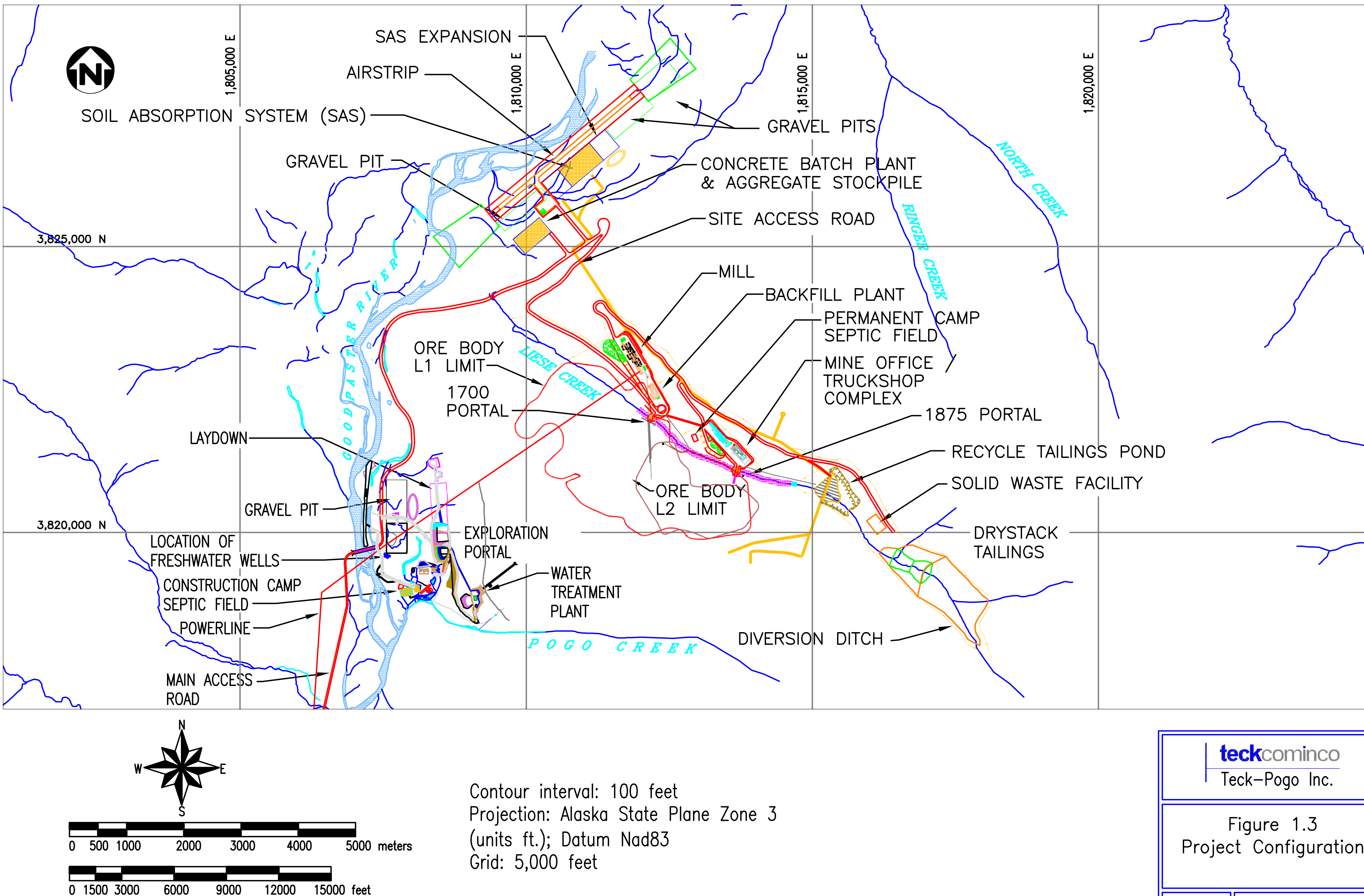



Figure 1.2
General View of Pogo Project




Contour interval: 100 feet
Projection: Alaska State Plane Zone 3
(units ft.); Datum Nad83
Grid: 5,000 feet

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Figure 1.3
Project Configuration

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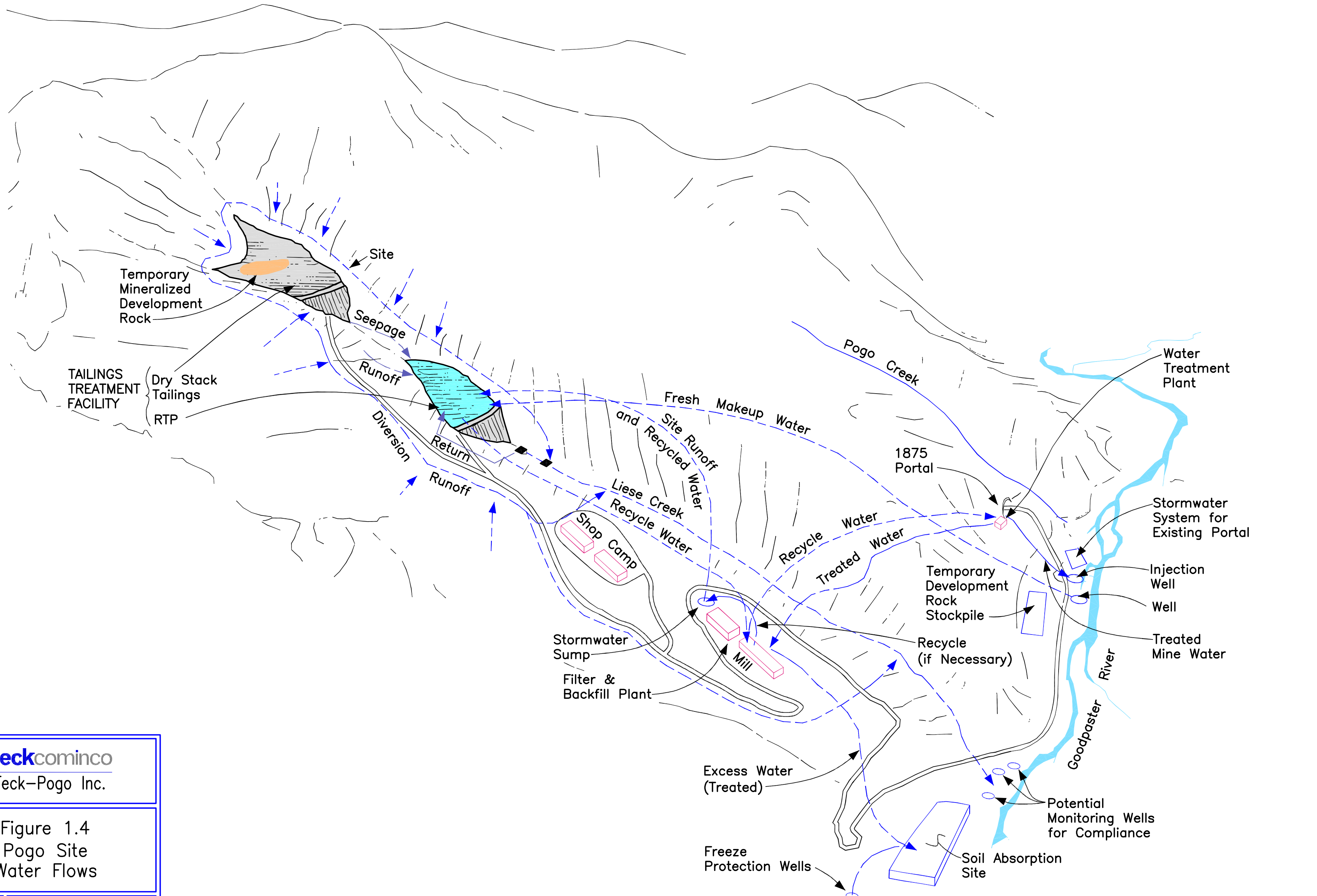


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Figure 1.4
Pogo Site
Water Flows

Teck submitted a permit application in August 2000 that triggered the preparation of a formal Environmental Impact Statement (EIS) for the Pogo project. It is expected that permits to construct the mine would be issued by the end of 2002. This would be followed by a 20 to 24 month construction period, depending on the date of project release.

The milling and tailings process has been specifically designed to allow the return of as much mineralized material as possible to the underground. After dewatering, approximately 50% of the tailings will be mixed with cement and placed as backfill in mined-out underground areas. The remaining 50% will be dewatered by a filtering process and placed in a tailings treatment facility on surface.

An all-season road will be constructed to provide access to the site from the existing highway system. Power to operate the mine will be obtained from the Golden Valley Electric Association by means of a new transmission line connecting to the existing grid. The transmission line will generally be constructed along the same corridor as the access road.

The Pogo project will have an operating life of 11 years based on current ore reserves. The capital cost of the project is estimated at between $200 million and $250 million.

The Pogo project is a joint venture between Teck-Pogo Inc. and the two subsidiary companies of Sumitomo Metal Mining Co. Ltd. and Sumitomo Corporation of Tokyo, Japan. Teck-Pogo Inc. is a wholly owned subsidiary of Teck Resources Inc., which itself is a wholly owned subsidiary of Teck Cominco Ltd. of Vancouver, Canada. Teck-Pogo Inc. is the operator of the project.

## 1.2 Purpose of this Document

The purpose of this document is to describe the water management for the Pogo project. Effective water management is integral to the project in order to:

- ensure the reliability of water supply for all process and potable needs
- protect the operations from flooding, erosion, interference from groundwater, precipitation and runoff
- control and treat water that comes into contact with project facilities in an environmentally sound manner.

To develop an integrated water management plan, all inflows and outflows must be identified and incorporated into an overall water balance to allow decisions to be made about the need for treatment and whether various flows should be combined or segregated. Estimates of water quality and quantity for the water balance are based on existing site data, test data and/or best engineering judgment.

The purpose of this report is to highlight the issues surrounding water management for the Pogo project, and to describe Teck's plans to achieve optimal results in terms of water quality and quantity.

This February 2002 update of the Water Management Plan has been prepared to incorporate the latest information and data developed from field investigations, testwork and engineering analyses as well as design decisions made in response to requests from the EIS team. The principle changes that have been made in the design and modeling assumptions since July 2001 are as follows:

- Reducing the RTP (recycle tailings pond) catchment area from 201 to 109 acres.
- Increasing the RTP dam size from 25 Mgal to 40 Mgal storage capacity.
- Including snowmelt in the RTP minimum size determinations.
- Relocating the mill and other plant facilities in the Liese Creek Valley.
- Adding two mine access portals in Liese Creek to accommodate the Liese Creek location of the mine facilities.
- Replacing the shaft and hoist arrangement with a conveyor access for removal of ore from the mine.
- Redesigning the mill flowsheet so as to regrind the intensive cyanidation unit tailings separately before feeding to the leach circuit, thereby achieving isolation of the flotation and cyanide circuits.
- Optimizing the water treatment system through the use of two treatment plants instead of three. The existing underground 100 gpm mine water treatment plant will treat mine drainage, while a new 400 gpm water treatment plant to be located on the surface near the exploration portal will treat both mine drainage and RTP water prior to discharge.

The updated site footprint significantly reduces the catchment area and the amount of stormwater that must be collected and treated. Combined with the larger RTP dam, the new configuration provides for retention for snowmelt and the 100-year/24-hour storm event, and reduces the risk of spillway use to very low levels. Elimination of the shaft also reduces the capital and operating costs of the project and shortens the project development schedule.

The water treatment system has been reconfigured to allow mine water and RTP water to be treated and released simultaneously, rather than first treating the mine water, pumping it to the RTP, then treating it again prior to release as had been proposed in the July 2001 plan. This will lower operating costs and improve system operability.

## 1.3 Organization of this Report

This document is organized into six sections: Section 1 consists of the introduction and summary of conclusions. Section 2 provides an overview of the site hydrological and meteorological conditions. The conceptual water management plan for the project is described in Section 3. Section 4 follows with a detailed analysis of the water balance model and calculations, including supply sources and requirements under various scenarios; available water quality data; and a description of the water collection, treatment and discharge system. Section 5 presents the predicted water quality during operations and a discussion of results. Section 6 describes the methods that will be used to monitor the performance of the water management plan during and after operations. Section 7 presents a contingency plan for addressing potential uncertainties in mine water inflows.

The appendices are included in a separate binder, and contain excerpts from studies and testwork undertaken by specialist consultants on behalf of Teck to evaluate the hydrologic setting and water management issues associated with the Pogo project.

All units of measure in this report are U.S. standard except water chemistry data, which by convention is expressed in metric units.

## 1.4 Summary & Conclusions

Key conclusions demonstrated by the analysis of water management for the Pogo project are as follows:

- Based on the proposed operating parameters and design criteria, the Pogo water management system will effectively maintain the water quality in the Goodpaster River under all reasonably foreseeable conditions.
- The water management plan has been developed to control and minimize the potential release of contaminants to the environment. The plan provides sufficient flexibility to deal with changes in operating conditions on a contingency basis during operations.
- The modeling shows there is a very low likelihood (22 events out of 1,000 years) of releasing stormwater over the RTP spillway.

- The design of the process flowsheet and operation minimizes the contaminant loading in the RTP. Monte Carlo modeling of precipitation and water quality parameters shows that RTP water will have relatively low levels of contaminants. In the very low likelihood of a stormwater discharge, modeling shows no adverse water quality impact to the Goodpaster River.
- Site hydrological investigations have been completed in sufficient detail to permit development of the water management plan. These investigations include detailed flow estimates for all inputs and outputs.
- The Pogo process is designed to maximize the use of recycle water. During normal operations, the only water discharged from the facility will be mine drainage and net precipitation collected from the plant site and tailings treatment facility.
- The water management plan incorporates two stages of water treatment. Primary treatment consists of a HDS (high-density sludge) system with ferric co-precipitation to remove dissolved metals and lime softening to reduce TDS (total dissolved solids). Secondary treatment is accomplished using an SAS (soil absorption system), which uses biological processes to reduce residual ammonia and cyanide, as well as absorption and precipitation to remove metals. These systems will ensure that applicable water quality standards will be met.
- The performance of the SAS has been demonstrated through a multi-phase laboratory program.
- Upon closure, modeling shows no measurable impact on water quality in the Goodpaster River.

Overall, the water management plan has been developed to ensure that during operation and at closure, the Pogo project will not have a significant adverse impact on the Goodpaster River. Specifically, discharge from the project will not interfere with the following:

- water quality uses
- the river's use as a source of public water supply
- the river's ability to protect and propagate fish, shellfish and wildlife
- recreational activities in and on the river.

# SECTION 2 | SITE HYDROLOGY

## 2.1 Regional Hydrology

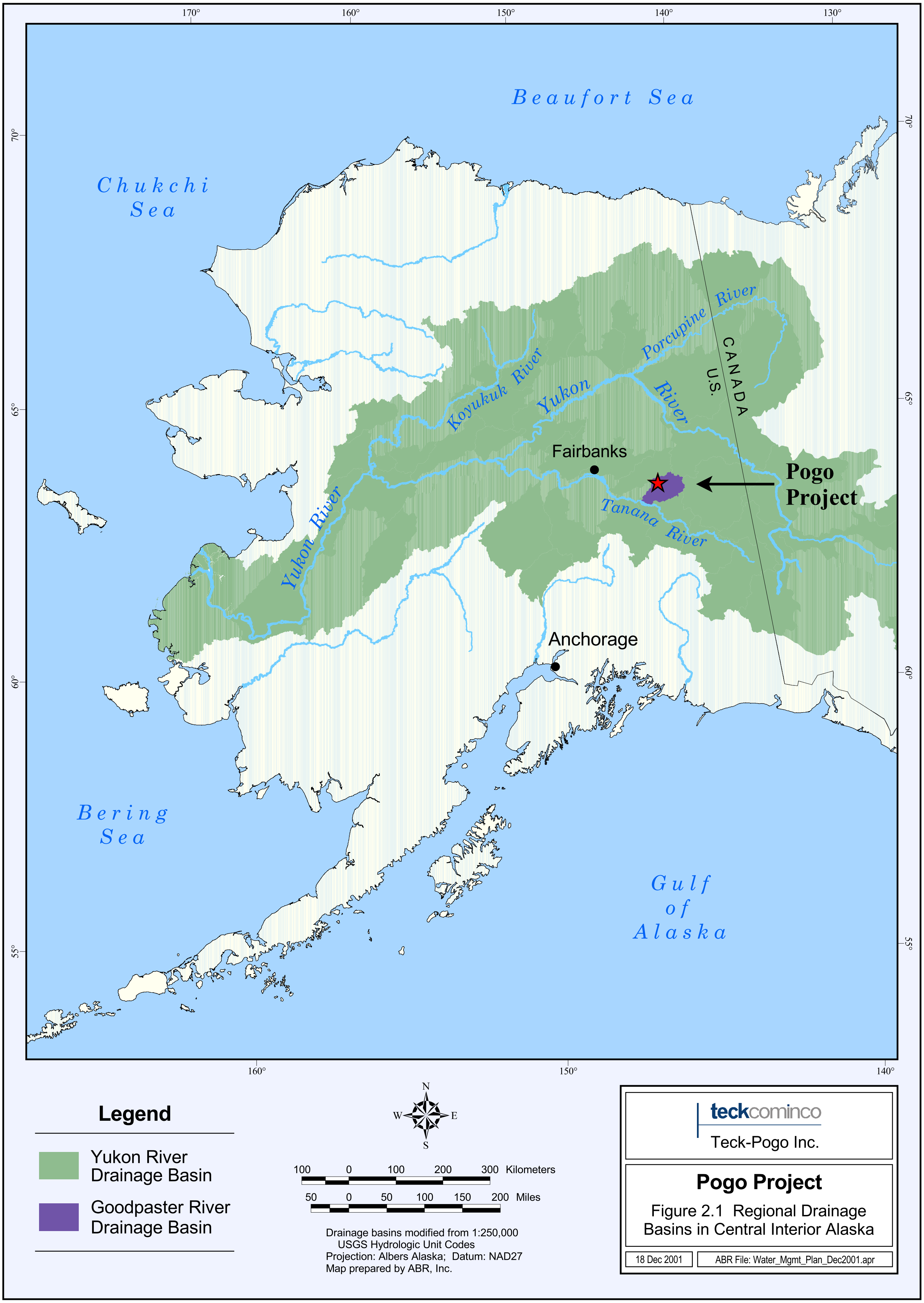
The Pogo project is located within the Goodpaster River and the Shaw Creek drainages, which are tributaries of the Tanana River (see Figure 2.1). The access road and powerline corridors are located within both drainages. The Pogo project facilities are contained within the Goodpaster Valley as well as the smaller Goodpaster drainage (see Figure 2.2) of Liese Creek. Runoff from surface mine facilities will report to the water treatment system within the upper Liese Creek basin as described in Section 4 of this report. Pogo Creek bounds the site to the south.

The Liese Creek basin is generally rectangular-shaped, with flows to the west-northwest. Liese Creek is an isolated, intermittent stream with no measurable flow during winter or in the lower portions of the drainage during dry summer periods. Due to the presence of a permeable alluvial fan at the mouth of Liese Creek, the creek seeps into the groundwater and does not resurface; thus, there is no surface connection between Liese Creek and the navigable waters of the Goodpaster River. Several minor, ephemeral streams drain the west-facing slope in the headwaters of the basin, and a single, minor stream drains the south-facing slope. Liese Creek is situated in a deep, V-shaped valley typical of non-glaciated terrain, with virtually no floodplain. There are low rates of sediment transport in the stream, particularly in the upper reaches of the creek where the proposed tailings and water storage facilities are located. The stream channel varies in width from 3 to 10 ft and is approximately 2 ft deep. The catchment area at the mouth of Liese Creek is approximately 1,500 acres.

Both regional and local information has been used to evaluate the site hydrology. Meteorological monitoring of precipitation, temperature, wind and snow cover has been conducted at site since 1997. Figure 2.3 shows the location of baseline monitoring stations within the region. Site and regional information from more than 30 monitoring stations is summarized in Appendix B.

Of the long-term regional data sites, Big Delta correlates most closely to the Pogo site with regard to precipitation records. Average annual precipitation for the Pogo site is estimated to be not more than 19", depending upon assumptions made about the use of the regional records. Records from Big Delta indicate that approximately 38% of the annual precipitation falls as snow. Site records to date confirm this ratio.

Hydrometric monitoring has been conducted on the Goodpaster River, Central Creek and Sonora Creek since 1997. The United States Geological Survey (USGS) assumed




**Pogo Project**

Figure 2.1 Regional Drainage Basins in Central Interior Alaska

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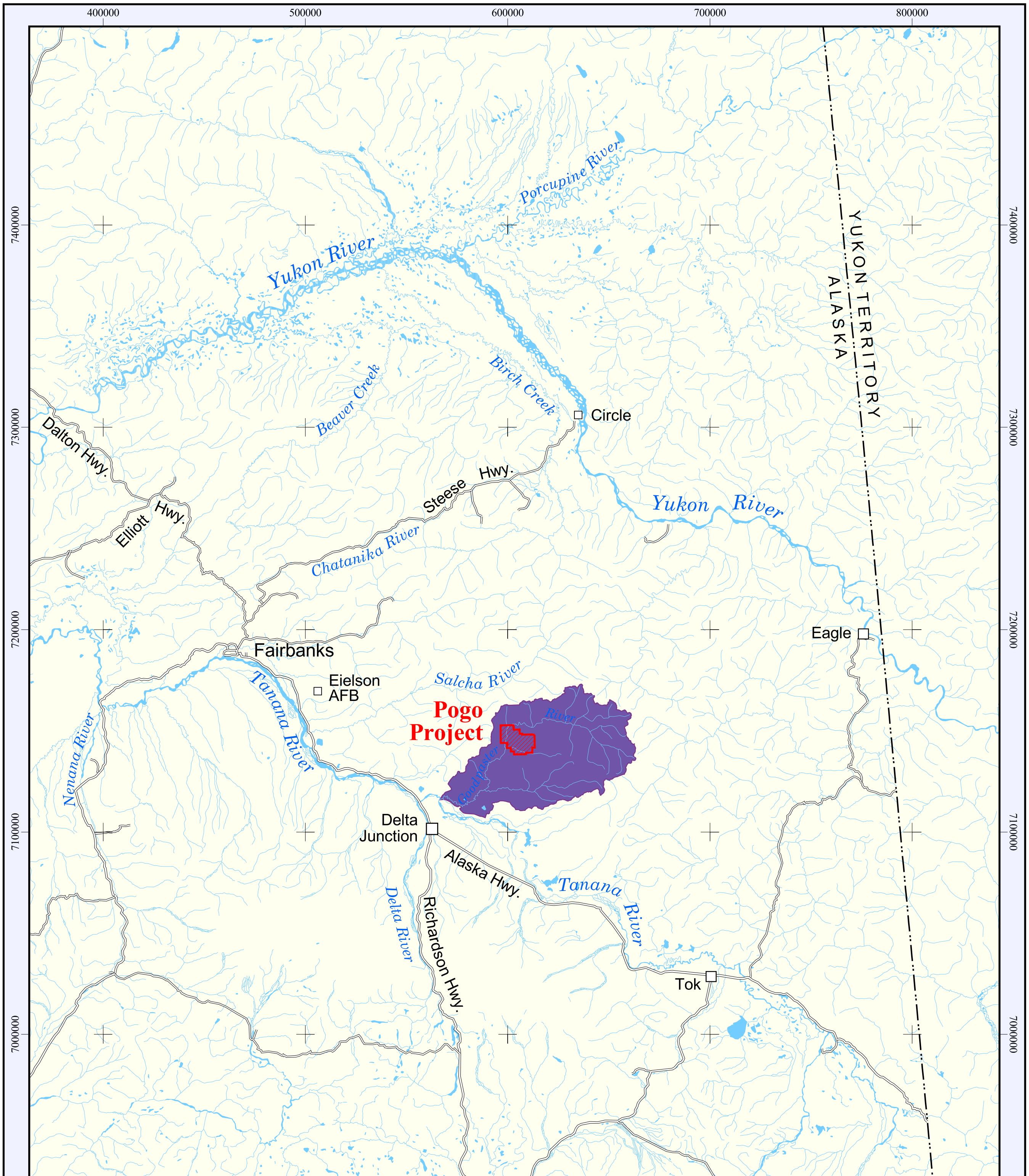


## Legend

Goodpaster River Drainage Basin

25 0 25 50 75 Kilometers

10 0 10 20 30 40 50 Miles

Goodpaster Basin modified from 1:250,000 USGS Hydrologic Unit Codes
Map base: US DMA DCW
Projection: UTM Zone 6; Datum: NAD27
Grid: 100,000 meters
Map prepared by ABR, Inc.

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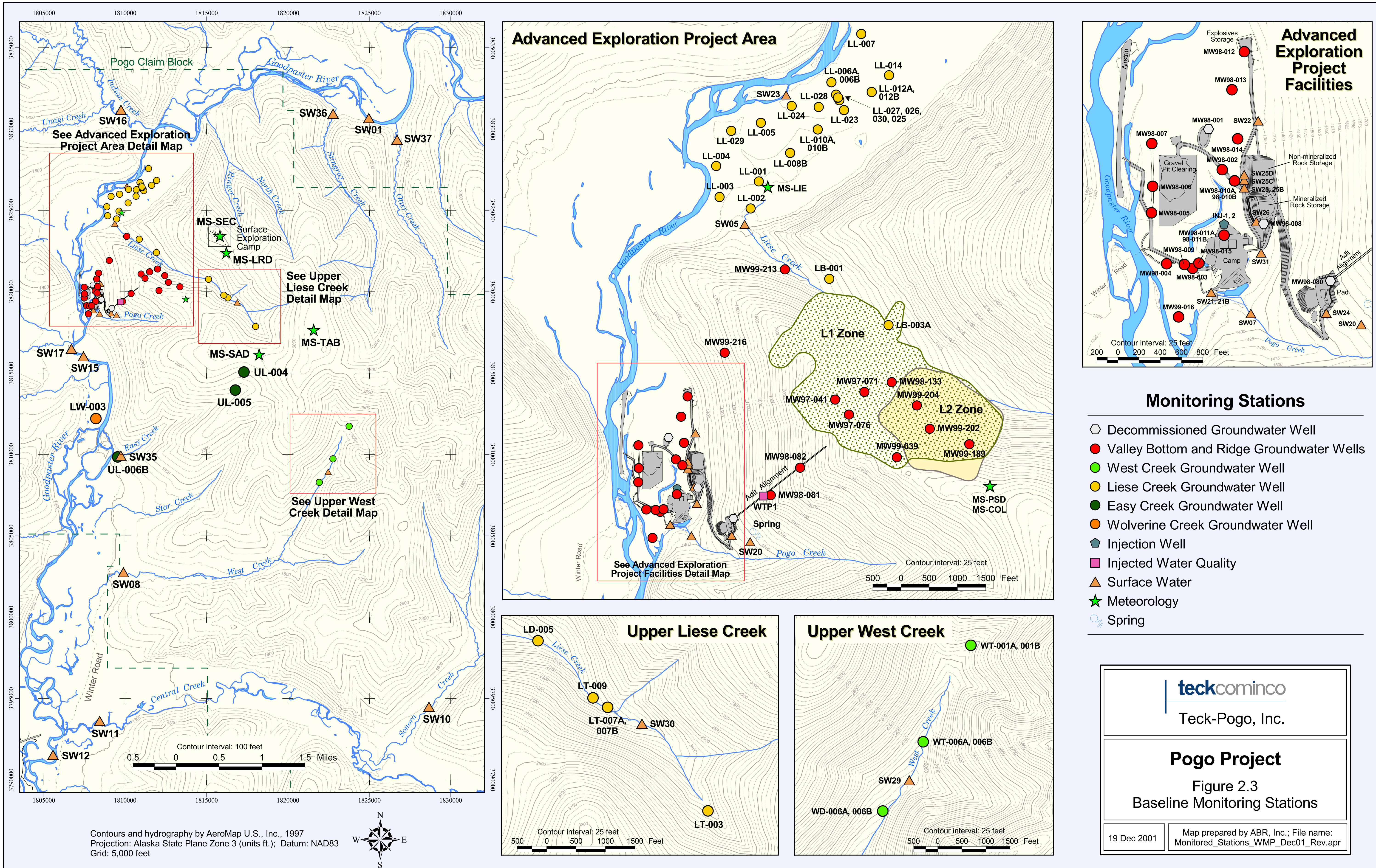
Figure 2.2 Goodpaster River Drainage Basin

18 Dec 2001 | ABR File: Water_Mgmt_Plan_Dec2001.apr



Pogo Claim Block
Goodpaster River
Indian Creek
Unagi Creek
SW16
SW36
SW01
SW37
See Advanced Exploration Project Area Detail Map
Liese Creek
Pogo Creek
Ringer Creek
North Creek
Shawnee Creek
Otter Creek
MS-SEC
Surface Exploration Camp
MS-LRD
See Upper Liese Creek Detail Map
MS-TAB
MS-SAD
UL-004
UL-005
SW17
SW15
LW-003
Easy Creek
SW35
UL-006B
Star Creek
See Upper West Creek Detail Map
West Creek
SW08
Winter Road
Central Creek
Sonora Creek
SW10
SW11
SW12
Contour interval: 100 feet
0.5 0 0.5 1 1.5 Miles
Contours and hydrography by AeroMap U.S., Inc., 1997
Projection: Alaska State Plane Zone 3 (units ft.); Datum: NAD83
Grid: 5,000 feet
N E S W
Advanced Exploration Project Area
LL-007
LL-014
LL-006A, 006B
LL-012A, 012B
SW23
LL-028
LL-027, 026, 030, 025
LL-024
LL-023
LL-029
LL-005
LL-010A, 010B
LL-004
LL-008B
LL-001
MS-LIE
LL-003
LL-002
SW05
MW99-213
LB-001
L1 Zone
LB-003A
MW99-216
MW97-071
MW98-133
MW97-041
MW99-204
L2 Zone
MW97-076
MW99-202
MW99-039
MW99-189
MW98-082
Adit Alignment
MW98-081
WTP1
Spring
MS-PSD
MS-COL
SW20
Pogo Creek
See Advanced Exploration Project Facilities Detail Map
Contour interval: 25 feet
500 0 500 1000 1500 Feet
Advanced Exploration Project Facilities
Explosives Storage
MW98-012
Airstrip
MW98-013
MW98-001
SW22
MW98-007
MW98-014
Gravel Pit Clearing
MW98-002
Non-mineralized Rock Storage
SW25D
SW25C
MW98-006
MW98-010A, 98-010B
SW25, 25B
Mineralized Rock Storage
MW98-005
INJ-1, 2
SW26
MW98-008
MW98-011A, 98-011B
MW98-009
MW98-015
Camp
SW31
MW98-004
MW98-003
Adit Alignment
MW98-080
Pad
SW21, 21B
MW99-016
SW07
SW24
SW20
Contour interval: 25 feet
200 0 200 400 600 800 Feet
Monitoring Stations
Decommissioned Groundwater Well
Valley Bottom and Ridge Groundwater Wells
West Creek Groundwater Well
Liese Creek Groundwater Well
Easy Creek Groundwater Well
Wolverine Creek Groundwater Well
Injection Well
Injected Water Quality
Surface Water
Meteorology
Spring
Upper Liese Creek
LD-005
LT-009
LT-007A, 007B
SW30
LT-003
Contour interval: 25 feet
500 0 500 1000 1500 Feet
Upper West Creek
WT-001A, 001B
WT-006A, 006B
SW29
WD-006A, 006B
Contour interval: 25 feet
500 0 500 1000 1500 Feet
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Figure 2.3
Baseline Monitoring Stations
19 Dec 2001
Map prepared by ABR, Inc.; File name: Monitored_Stations_WMP_Dec01_Rev.apr

operation of these monitoring stations in May 1999, at which time additional stations were established on Liese Creek and West Creek. Stream gauging has largely been confined to the summer months, except on the Goodpaster River, Central and Sonora Creeks, which have continuous flow records. The locations of hydrologic monitoring stations in the Pogo project area as well as discharge and runoff data from the hydrological analysis conducted to date are provided in Appendix B.

Groundwater exists at a depth of approximately 400 ft below surface at the orebody location. The gneissic rocks that characterize the site have generally low bulk hydraulic conductivity, as fracturing patterns do not tend to be laterally interconnected over significant distances. Permafrost is consistently present on north-facing slopes and ancient floodplain areas, and intermittent to non-existent on south-facing slopes. Details from testwork and hydrogeological analyses undertaken to assess potential mine inflows are provided in Appendix A.

## 2.2 Water Quality

The quality of surface water in the project area is generally good. The water is calcium-sulfate dominated, with a TDS (total dissolved solids) content of approximately 100 mg/l.

Groundwater in the Goodpaster Valley sediments near the mouth of Liese Creek generally has a total dissolved solids level ranging from 50 to 100 mg/l. Groundwater in the valley sediments near the existing portal has a somewhat higher TDS content ranging from approximately 180 to 650 mg/l, and is predominantly calcium-magnesium-bicarbonate-sulfate water. Groundwater in the gneissic rock has a TDS content of approximately 550 mg/l, and is hard, calcium-magnesium-sulfate-bicarbonate water. Arsenic is present at a concentration of around 0.1 mg/l. Other metals are predominantly near or below detection levels.

Groundwater in and near the orebody displays the highest range of TDS, from approximately 500 to 1,000 mg/l. The water is calcium-magnesium-sulfate-bicarbonate water and is very hard. Arsenic concentrations are elevated in this water, ranging between 0.5 and 4.0 mg/l, and averaging 2.5 mg/l.

## 2.3 Pogo Precipitation

Based on an analysis of all available regional precipitation data as well as four years of site data, total annual precipitation at the Pogo site is relatively low. Depending on which assumptions one uses, estimates for annual average precipitation can range up to 19".

The precipitation scenarios evaluated since project inception are summarized below. Numerical values are summarized in Table 2.1 and further described in Appendix B.

**Table 2.1: Range of Precipitation Scenarios**

| Average Precipitation Scenario | Rainfall (inches) | Snowpack (SWEQ) (inches) | Total Precipitation for Runoff (inches) |
|---|---|---|---|
| 1. EBA (1999) | N/A | N/A | 17.0[1] |
| 2. Pogo project (mid-2000)[2] | 10.6 | 6.5 | 17.1 |
| 3. Pogo project updated (late-2000) | 9.0 | 2.8 | 11.8[3] |
| 4. Published maps (2001)[4] | 11.8 | 6.7 | 18.5 |
| 5. Mean of regional data (2001)[5] | 9.2 | 5.6 | 14.8 |
| 6. Precipitation & runoff assessment (2002) | | | 15-17 |

**1.** Mean annual precipitation (deducting sublimation from this value would give estimate of total precipitation available for runoff). **2.** Precipitation was assumed to be 62% rainfall and 38% snowfall. **3.** Sublimation was assumed to be 0.5", giving 12.3" total precipitation. **4.** Based on USGS, 1994. **5.** This includes Munson Ridge data, which adds about 0.7" to rainfall and 0.2" to SWEQ (snow water equivalent).

1. EBA (1999). This was the intitial project scenario that incorporated both orographic and location trends.
2. Pogo project (mid-2000). Big Delta was determined to be the regional site with sufficient long-term records to allow storm events and long-term trends to be analyzed (30 years), and whose precipitation records closely tracked the Pogo site data. Since Big Delta is at elevation 1,270 and the Pogo mill site is at elevation 2,500, an orographic influence factor (increasing precipitation with higher elevation) was applied to adjust the Delta estimate based on published records from an area of similar topography in the Yukon (the Clearwater relationship).
3. Pogo project updated (late-2000). Regional data was further reviewed and site information was analyzed in more detail. This analysis showed no statistically significant orography trends in the regional data, site data or the combined data set. Consequently, the orographic influence factor may not be justified and the preciptiation record from Big Delta was used for the project model.
4. Published maps (2001). The mean annual precipitation value from the published U.S. Geological Survey map (USGS, 1994) could be used, although this data lacks any Pogo site-specific input. The values in this publication appear to be biased towards an orographic influence, which may be more applicable to the area west of the project than to the project site itself.
5. Mean of regional data (2001). Following discussions with the EIS team, regional information was reviewed. It was concluded that, with the exception of the Munson

Ridge station, there is only a tenuous relationship between precipitation and elevation. Thus by averaging all regional information without prejudice to elevation, an estimate of the mean annual precipitation that could be appropriate for the project site was produced.

6. Precipitation & Runoff Assessment (2002). An evaluation was completed to compare information from published reports with basin precipitation and basin runoff data (see Appendix B).

The site-specific observations of rainfall and snowpack, as well as Liese Creek and Goodpaster stream flows, do not appear to support the numbers from the published maps. However, as requested by the EIS team, Teck has agreed to use a 19" annual average for the purposes of this document. Detailed project engineering will evaluate the most recent site and regional data as it becomes available.

# SECTION 3 | CONCEPTUAL WATER MANAGEMENT PLAN

The water management plan balances operational water requirements and the need to manage all waters contacted by mining activity to minimize off-site impacts. The plan involves a number of interrelated underground and surface facilities that provide a high level of control over the operating environment. The plan includes measures to optimize either wetter-than-average or drier-than-average conditions to reduce potential impacts to receiving waters.

With 19" annual average precipitation and at 2,500 tpd, it is currently estimated that a net discharge in the order of 200 to 400 gpm will exist during mine life. The facilities have been designed to be protective of water quality in the Goodpaster River. The facilities have also been designed to limit the project footprint and facilitate post-mining reclamation.

## 3.1 Overall Water Collection, Treatment & Discharge Strategy

The major components of the overall water collection, treatment and discharge strategy for the Pogo project are shown in Figure 3.1. A new 400 gpm water treatment plant will be constructed on the surface near the existing 1525 portal. During mine development, the existing 100 gpm underground water treatment plant will continue to treat mine inflows and will discharge the treated water to the injection wells. Prior to completion of the 400 gpm plant (approximately 6 months), measures will be taken to limit mine inflows to the capacity of the existing water treatment plant (approximately 150 gpm). During completion of the development phase and after completion of the 400 gpm plant, mine drainage will be treated and discharged to the injection wells at up to 400 gpm.

Once operations begin, the availability of two water treatment plants provides a significant measure of flexibility. Both water treatment plants will be capable of either discharging to the injection wells, providing process water to the mill, or recycling to the RTP. Both plants will be capable of continuous monitoring of the treated effluent for pH, turbidity and conductivity. These parameters allow continuous monitoring of the performance of the plant and will allow automatic shutoff of any discharge during process problems. In this case, water would pump to the RTP for storage before re-treatment.

It is expected that the 100 gpm plant will continue to treat mine drainage and direct it to the mill for use in the process. Surface runoff and tailings seepage will be collected in the RTP and pumped to the 400 gpm plant, where it will be combined with any additional mine drainage, treated and discharged. During operations, it is expected that water will be discharged through the soil absorption system in order to take advantage of the additional treatment capabilities of that system. However, Teck would like to retain the

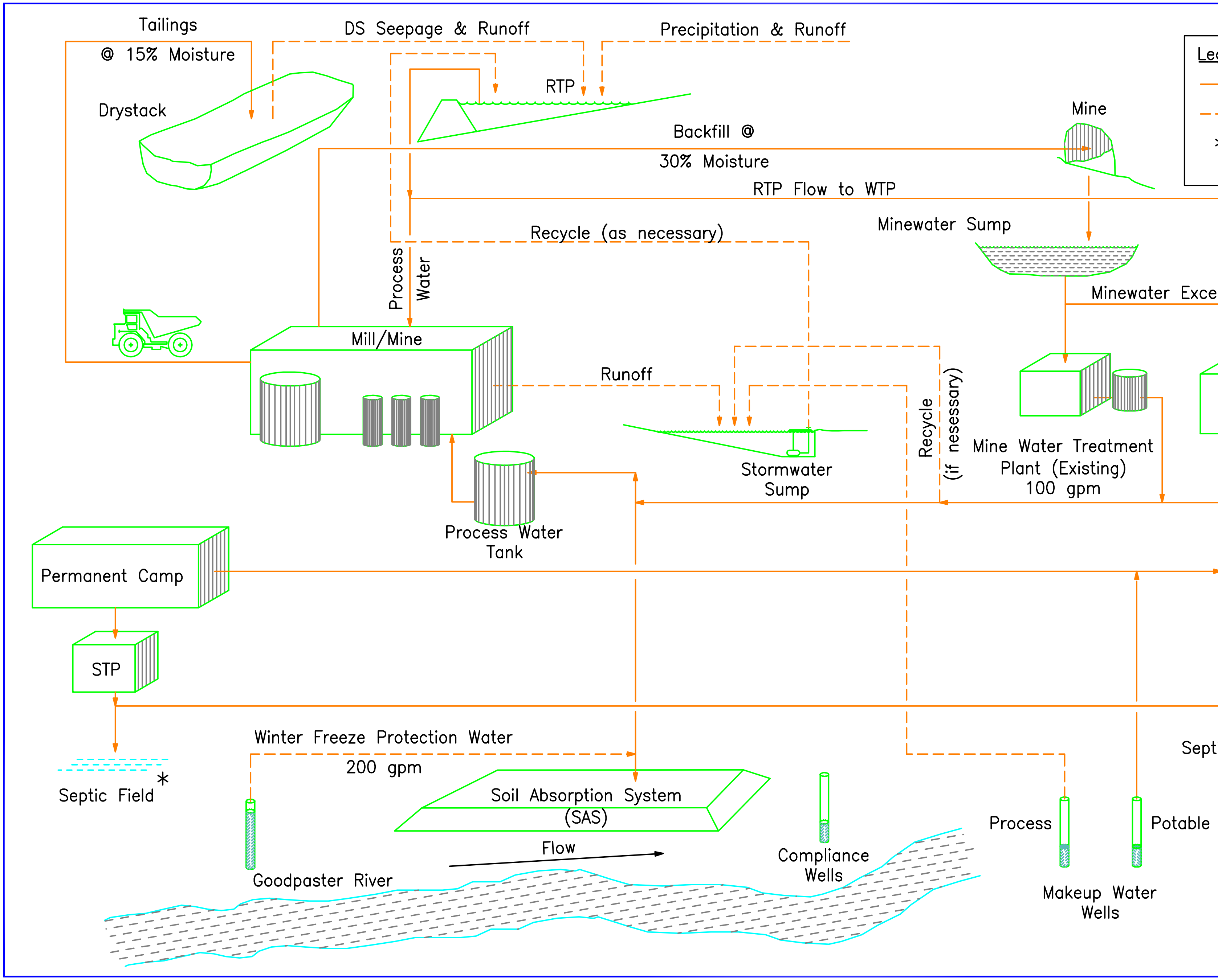


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Figure 3.1
Conceptual Water Management Flows

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flexibility to use the injection wells on an as needed basis if the treated water is of sufficient quality to meet the injection well influent limitations.

Additional details of the various flows that will occur in the system are described below.

## 3.2 Process Water

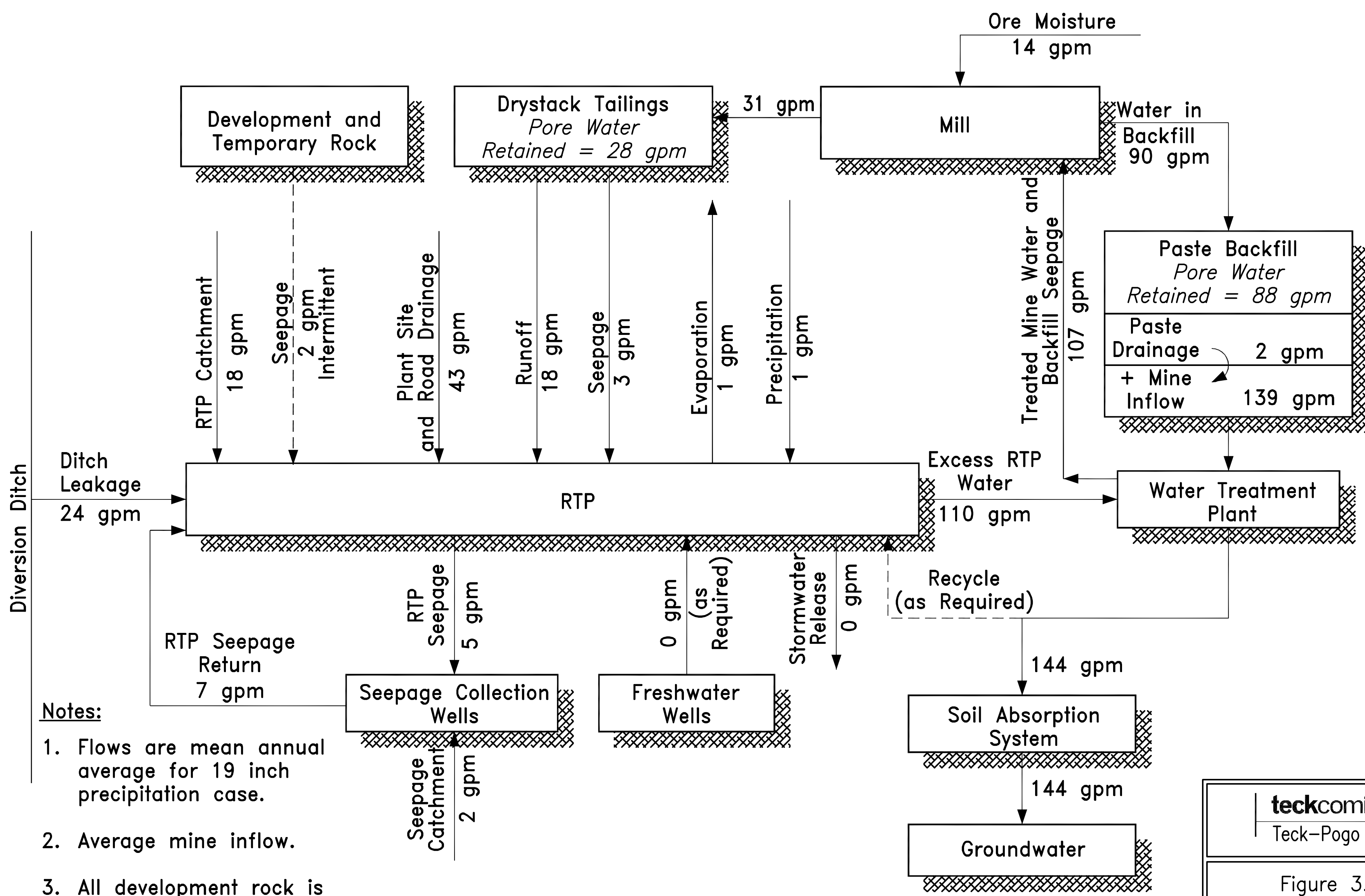
### 3.2.1 Supply Requirements & Sources

The Pogo process plant is designed to operate with a maximum recycle of water. The only water released from the process will be to the tailings as either part of the cemented backfill or as residual moisture in the surface drystack. The mill will require an estimated 1,174 gpm of water at a 2,500 tpd processing rate, increasing to 1,622 gpm at 3,500 tpd. This water will be used primarily for slurry preparation, for mixing with reagents, and for flotation. Most of this requirement will be met by recycling water in the process.

Of the total process water requirement, approximately 112 gpm at 2,500 tpd (156 gpm at 3,500 tpd) will be makeup water from external sources that will be used to replace the water entrained in the tailings material. In order of priority, mine drainage water, RTP water and fresh water will be used to satisfy the makeup requirement. The estimated amounts of water available for mill supply from the identified sources are as follows:

- Recycled process water: 1,107 gpm at 2,500 tpd, or 1,286 gpm at 3,500 tpd.
- Mine drainage water from the underground mine workings: this is expected to range between 60 and 205 gpm, depending on mine inflow conditions. This will vary depending on the mine development sequence.
- Recycle tailings pond: This water will consist of precipitation, stormwater and seepage that collect in the RTP immediately downstream of the tailings storage area. Modeling and data indicate that an average of approximately 100 gpm will be available, but this could vary from 0 to more than 190 gpm depending on annual precipitation.
- Fresh water from groundwater well sources: This will be used as required in the event that the above sources are inadequate to meet process needs.

The above process flows are annual average values. A block diagram of the site water balance is presented in Figure 3.2 (Figure 3.2a shows the site water balance at the 95$^{th}$ percentile). More detailed process block diagrams and mass balances for 2,500 tpd and 3,500 tpd are provided in Appendix I. It should be noted that the process has been designed to maximize the use of recycle water.




Notes:

1. Flows are mean annual average for 19 inch precipitation case.
2. Average mine inflow.
3. All development rock is incorporated in the drystack by year 6.

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Figure 3.2
Conceptual Site Water Balance at 2,500 tpd Average Case

CAD FILE NAME: P:\Figure Masters\Conceptual Site Water Balance at 2500 tpd Average Case.dwg
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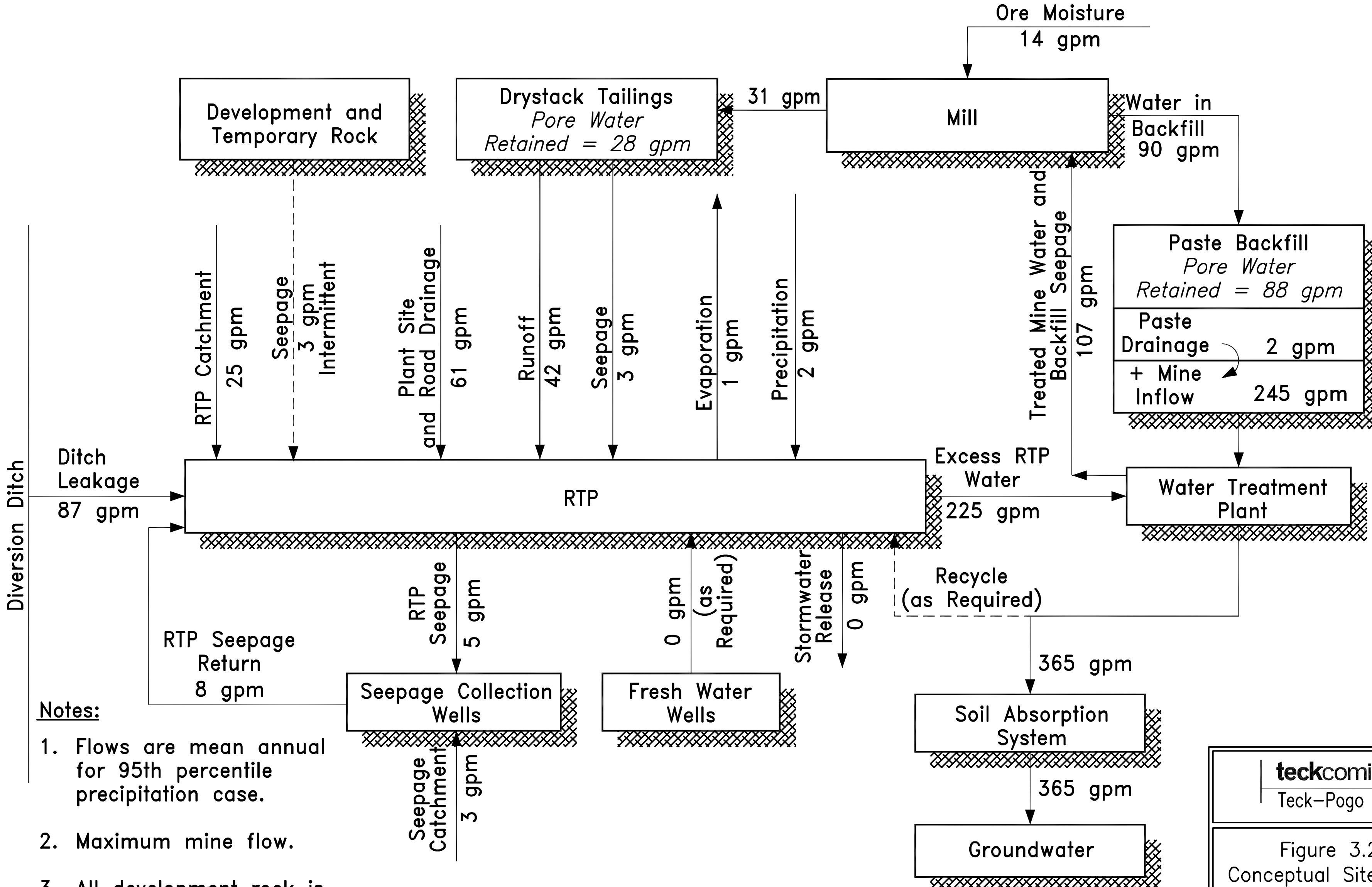


Notes:

1. Flows are mean annual for 95th percentile precipitation case.
2. Maximum mine flow.
3. All development rock is incorporated in the drystack year 6.

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Figure 3.2a
Conceptual Site Water Balance at 2,500 tpd 95th Percentile Case

CAD FILE NAME: P:\Figure Masters\Conceptual Site Water Balance at 2500 tpd 95th percentile Case.dwg
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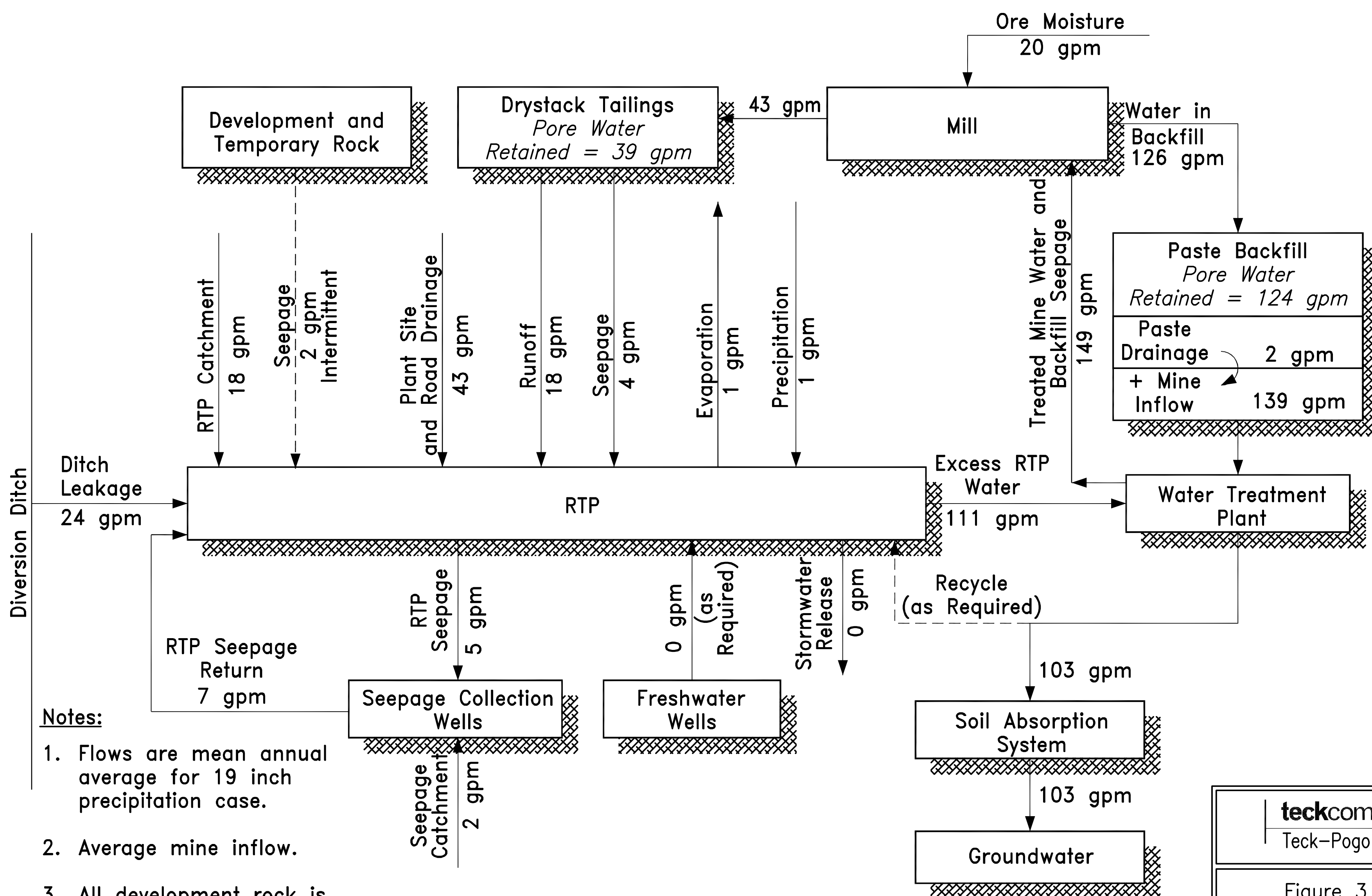


Notes:

1. Flows are mean annual average for 19 inch precipitation case.
2. Average mine inflow.
3. All development rock is incorporated in the drystack by year 6.

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Figure 3.2b
Conceptual Site Water Balance at 3,500 tpd
Average Case

CAD FILE NAME: P:\Figure Masters\Conceptual Site Water Balance at 3500 tpd Average Case.dwg
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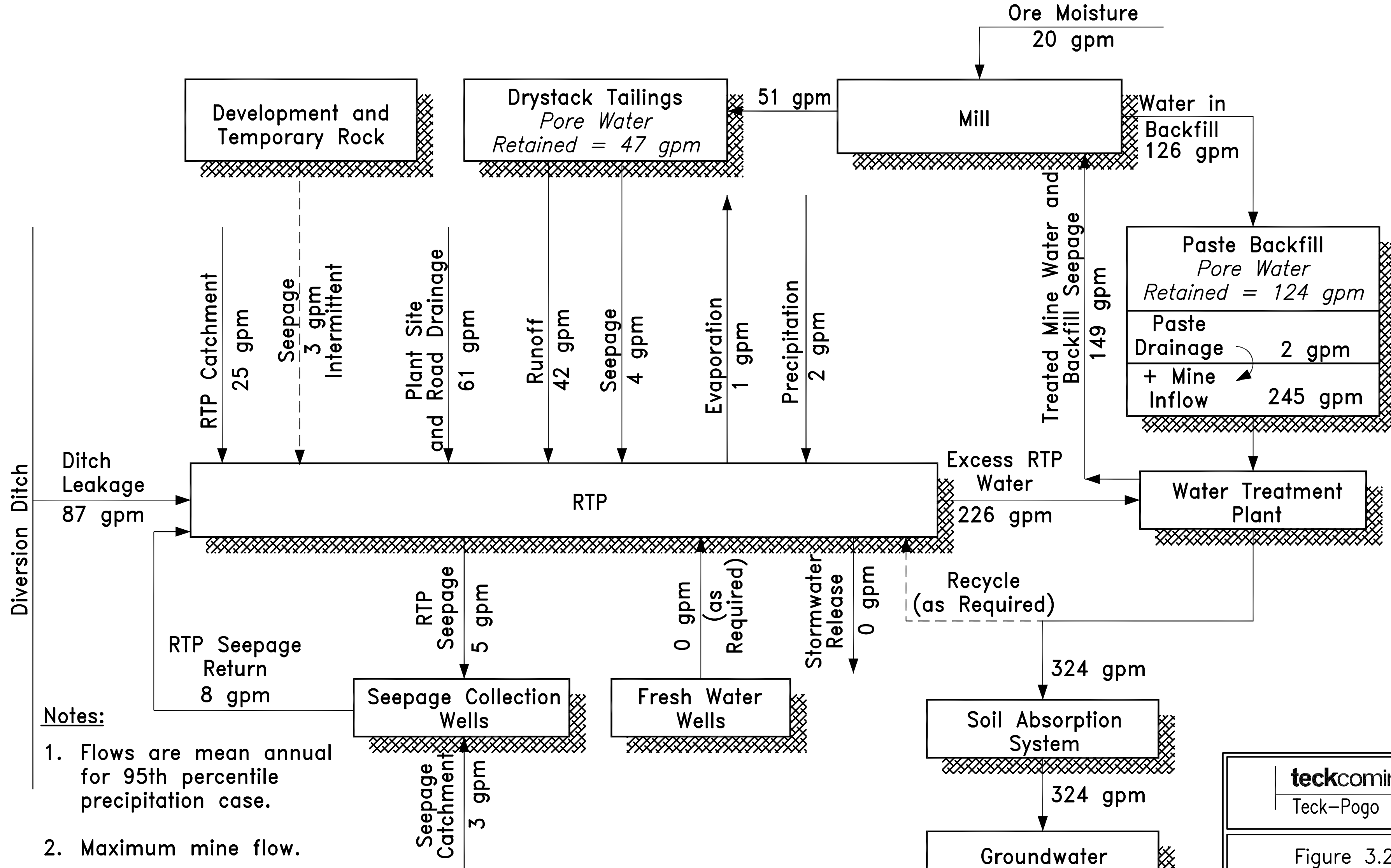


Notes:

1. Flows are mean annual for 95th percentile precipitation case.
2. Maximum mine flow.
3. All development rock is incorporated in the drystack year 6.

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Figure 3.2c
Conceptual Site Water Balance at 3,500 tpd 95th Percentile Case

LAST UPDATE: 02/04/18 2:48pm CAD FILE NAME: P:\Figure Masters\Conceptual Site Water Balance at 3500 tpd 95th percentile Case.dwg

### 3.2.2 Mill Water Flowsheet

The Pogo milling process has been selected and designed to minimize the use of fresh water and maximize the use of recycle water. Process water will essentially be recycled from the flotation and thickening circuits, stored in an internal recycle water tank and pumped to the grinding and flotation circuits.

Considerable effort has also been made in flowsheet design to minimize the exposure of grinding and flotation process water to cyanide. The main cyanide leach section of the process will operate in closed circuit. Waters affected by cyanide in this circuit will either be recycled to the head of the circuit or will remain in the thickened CIP (carbon-in-pulp) tailings after cyanide destruction for use as paste backfill for the mine. The small (2 gpm) tailings stream coming from the ICU (intensive cyanidation unit) will be directed to a dedicated regrind mill and then to the leach circuit instead combining this small stream with the flotation concentrate regrind mill as had been previously proposed. This will ensure that there will be no direct path for cyanide into the flotation tailings that will be placed in the surface drystack.

The following descriptions highlight the proposed water management strategy within the Pogo ore processing facility. Process flow diagrams illustrating the major water flows in the mill are provided in Figures 3.3 and 3.4.

#### Process Water Tank

The process water tank will receive and store water from two possible makeup sources: treated underground mine water and water from the RTP. This tank will contain the cleanest water available to the process.

The water will be used for reagent mixing (including flotation collectors, flocculant and sodium cyanide), slurry pump gland lubrication, and for the heat exchangers on the mill lube systems and carbon stripping circuit. Water from the process water tank will be discharged as required to the internal recycle water tank located in the mill building.

#### Internal Recycle Water Tank

The internal recycle water tank serves to modulate internal mill surges and to recycle process water from the flotation thickener, concentrate thickener, preleach thickener and from the tailings filter press. None of these streams have exposure to cyanide. Therefore with the exception of spills, there is no mechanism for cyanide to report to the grinding circuit or the internal recycle tank, thereby ensuring that the flotation tailings deposited in the tailings drystack facility will not have been contacted with cyanide.

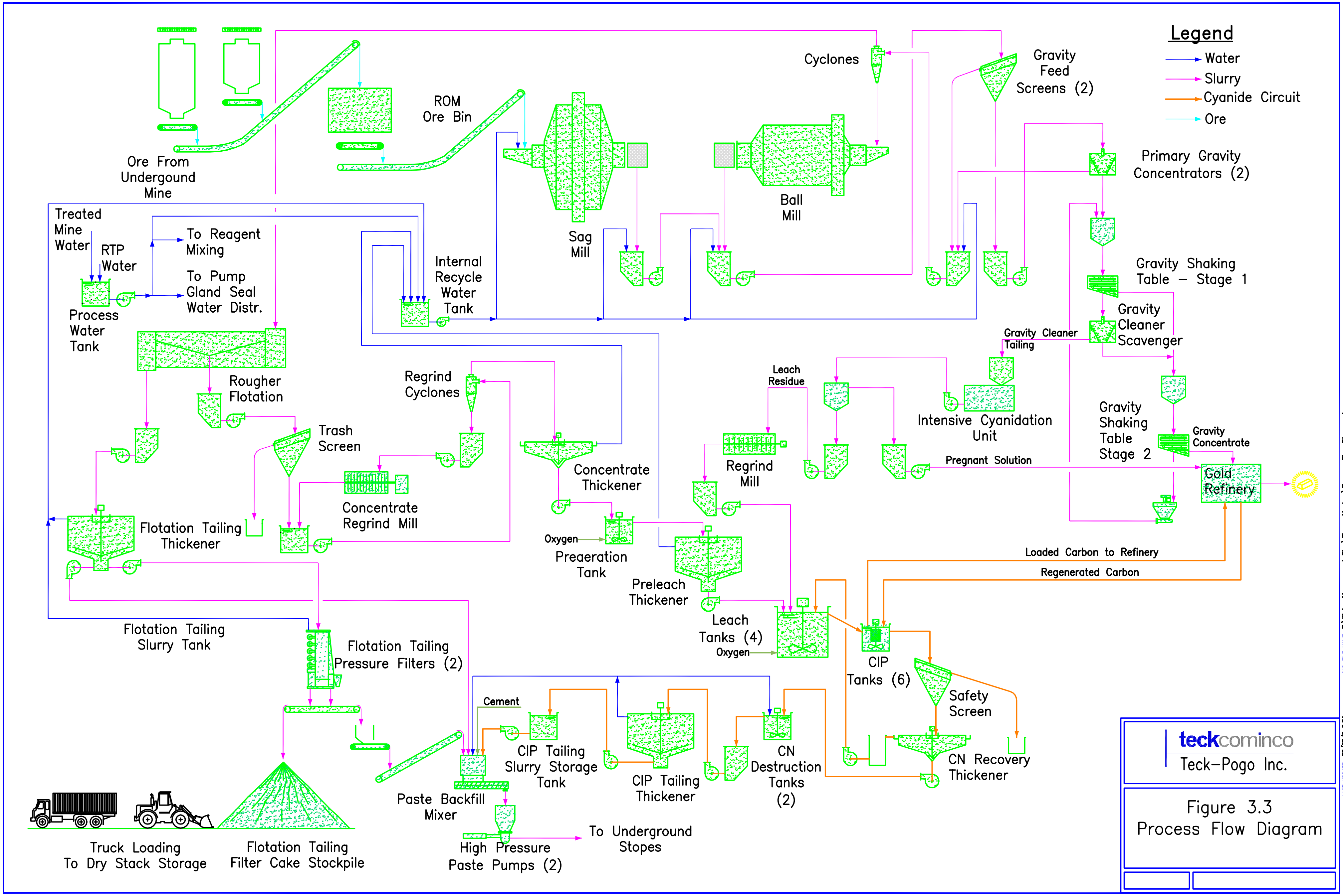


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Figure 3.3
Process Flow Diagram

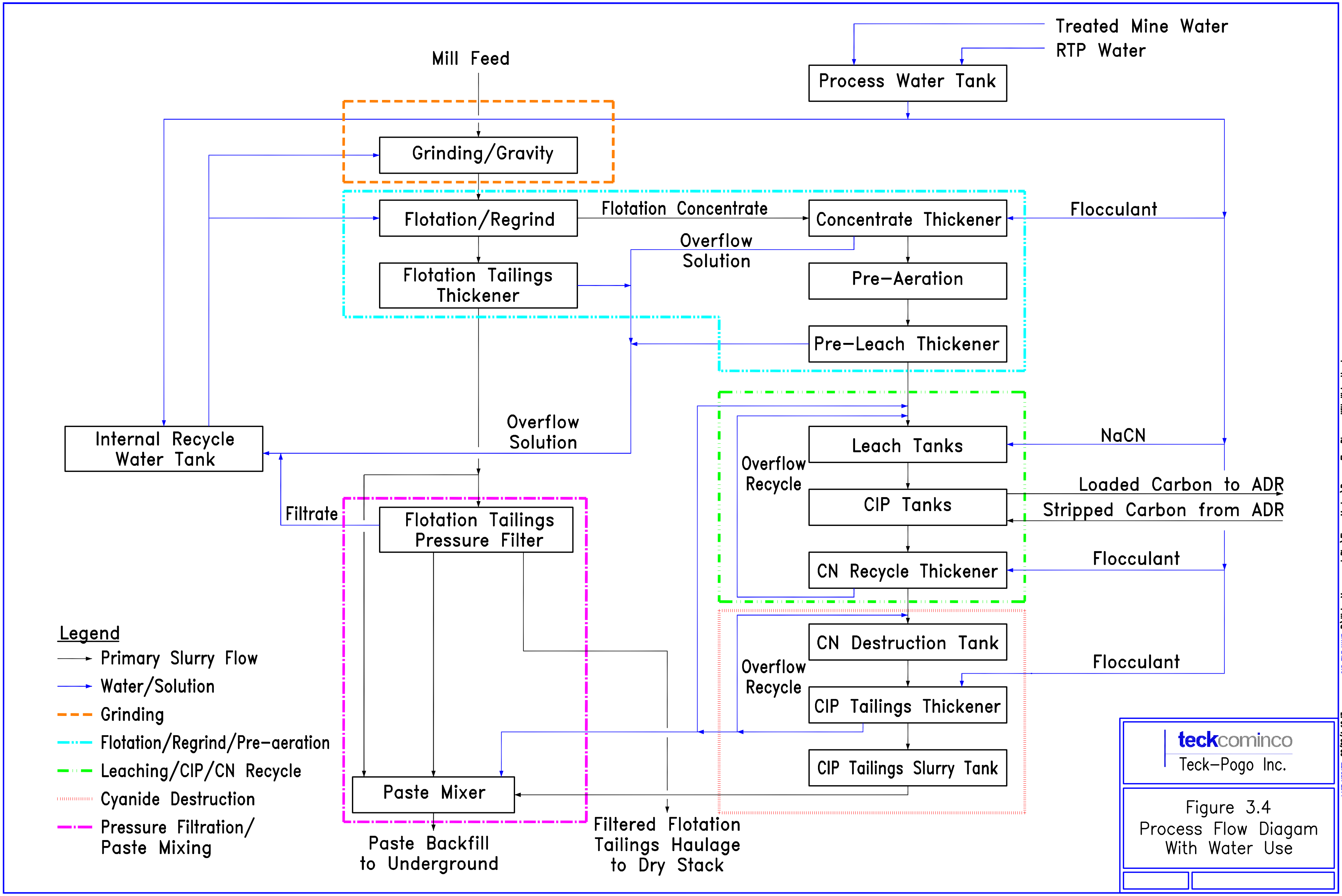



Figure 3.4
Process Flow Diagam
With Water Use

**Grinding Circuit**

The grinding circuit will receive water from the internal recycle water tank. Most of the water will be added to the SAG mill feed chute, with lesser amounts added to the ball mill discharge (cyclone feed) pump box, the SAG discharge screens and the gravity concentrators.

**Flotation/Regrind/Pre-aeration Circuit**

Internal recycle water will be used in the flotation concentrate launders and the rougher concentrate regrind mill. The final reground concentrate will be pumped to a dewatering thickener in preparation for pre-aeration. Thickener overflow will be recycled to the internal recycle tank, and thickener underflow will report to the pre-aeration tank ahead of the cyanide leach circuit. The concentrate will then be re-thickened in the pre-leach thickener, overflow will be returned to the internal recycle water tank, and underflow will pass to the cyanidation circuit.

Flotation tailings will report to a thickener, from which thickener overflow will be recycled to the internal recycle water tank and thickener underflow will be filtered using a pressure filter. The filtrate will be recycled to the internal recycle water tank, and a portion of the filter cake will be combined with CIP tailings to make paste backfill for the underground mine. The remainder of the flotation filter cake will be placed in the tailings drystack facility.

**Cyanide Leach/CIP Circuit**

The pre-leach thickener underflow will be leached using cyanide solution at ambient conditions to dissolve gold. After leaching, the dissolved gold will be adsorbed onto activated carbon granules in a conventional CIP circuit. The CIP circuit tailings will report to a thickener for the recovery of as much cyanide as possible to the overflow for recycling back to the leach tanks. The thickener underflow will be pumped to the cyanide destruction circuit.

**Cyanide Destruction Circuit**

Free cyanide and metallocyanide complexes in the thickened CIP tailings will be oxidized in a cyanide destruction tank by means of an $SO_2$/air process. The treated pulp will then be thickened, and the thickener overflow will be recycled to the cyanide destruction tank. Thickener underflow will be pumped into a CIP tailings holding tank.

The cyanide destruction process will reduce cyanide concentrations in the CIP tailings pore water to a concentration of less than 2 mg/l total cyanide. The CIP tailings will be mixed with flotation tailings on a 1:4 weight basis to make paste backfill for the mine.

## 3.3 Mine Water

### 3.3.1 Mine Drainage

Mine drainage water will have elevated metal levels and may have low but measurable levels of cyanide. This water will be collected in the mine sump and pumped to either the 100 gpm or the 400 gpm water treatment plant

The treated mine water will be similar in quality to the exploration adit drainage water currently being pumped to injection wells in the Goodpaster Valley. The low level of cyanide ($CN_T$ = 0.02 mg/l) that might occur in this flow would be the result of paste backfill drainage. At expected inflow conditions, it is anticipated mine water will supply the majority of process requirements, although this will vary over the life of the mine.

Mine water inflow for the Pogo mine has been studied by Adrian Brown, a specialist groundwater consultant. Brown's report describing the data collected, as well as his analysis and inflow forecasts, is provided in Appendix A.

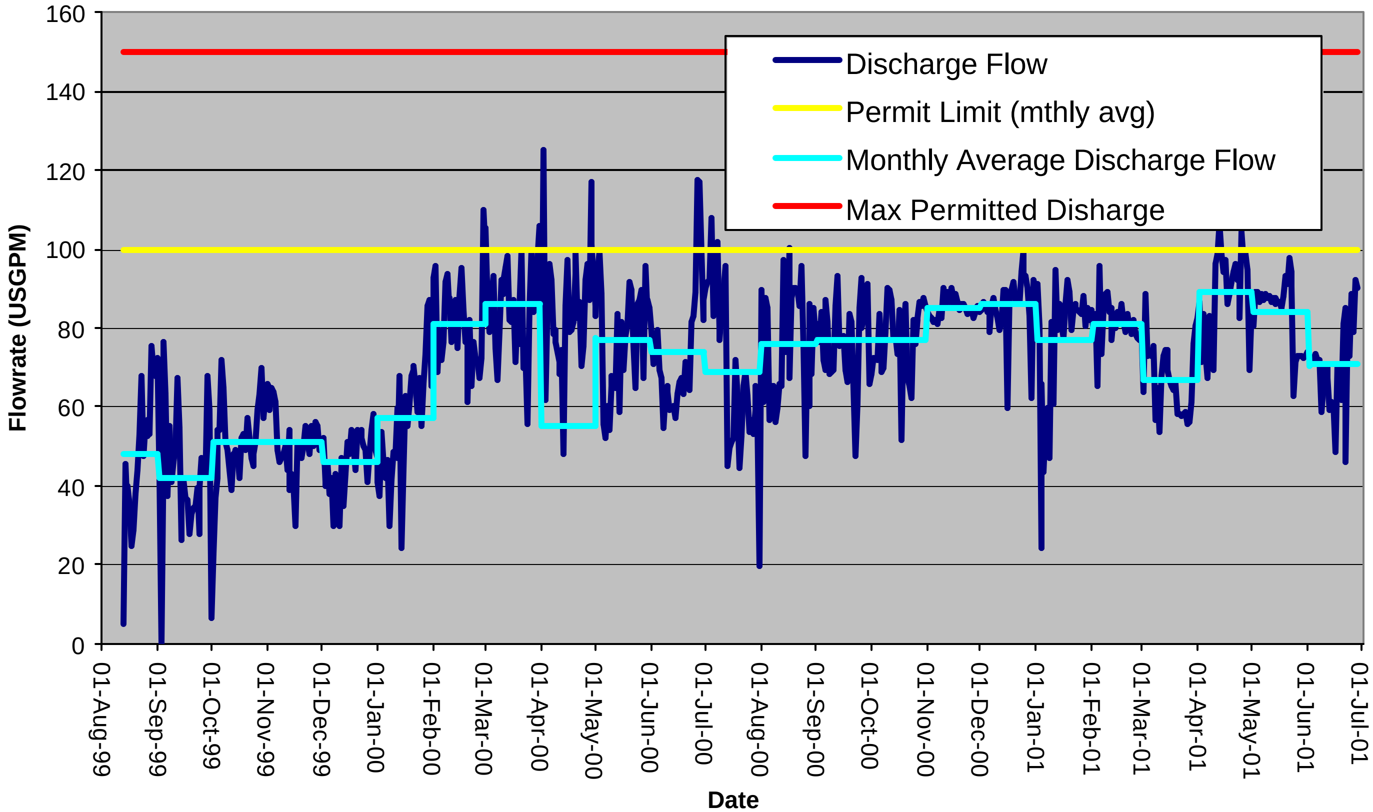
### 3.3.2 Mine Water Discharge during Development

In March 1999, the project was granted a five-year permit to conduct underground exploration. The goal was to collect data on the geotechnical aspects of the mineralized zone; to conduct additional closer-spaced diamond drilling, to assess water inflows into the mine opening; and to collect a bulk sample for metallurgical testing. Most of this work was accomplished during the winter of 1999 and spring of 2000.

The existing permit allows mine water to be discharged to an injection well in the Goodpaster Valley (near the camp) at a stipulated monthly maximum of 100 gpm and at site-specific water quality standards. The graph in Figure 3.5 shows the amount discharged over a 24 month period. The highest monthly discharge was 85 gpm, but peak flows reached 125 gpm. Grouting was performed on a number of occasions to reduce the inflows and ensure that the overall discharge quantity was kept below permit requirements.

It is proposed that the injection well technology be maintained to handle water discharge during the mine development and construction period prior to mill start-up and backfill placement underground. In his report (see Appendix A), Adrian Brown indicates the bulk

**Figure 3.5: Water Treatment Plant Discharge Flow**



of the water is confined to fractures in the rock and will dissipate over time. The expected average yearly inflow is approximately 139 gpm, but much higher instantaneous flows of up to 350 gpm are possible. While this quantity of water is not sustainable over the entire development period, strategies must be developed to anticipate and handle this eventuality over short periods. It is therefore proposed that the existing permit be amended to allow for a discharge of 400 gpm. During 2001, the site work and flow modeling that was conducted confirms that the aquifer characteristics are capable of supporting an injection well system at this 400 gpm rate (Appendix N).

This amendment will prevent having to delay development while waiting for water flows to dissipate, or having to rely on very costly grouting operations if such an event were to occur. Grouting may be used in the short run to mitigate peak mine water inflows; however, Teck prefers to limit the use of grouting because it may result in an increase in TDS levels in the mine drainage water.

During the advanced exploration phase, water inflows to the Pogo mine varied from below 10 gpm to over 150 gpm for short periods. Since its commissioning in August 1999, the water treatment plant has consistently accommodated these variations, operating within a design envelope of 50 to150 gpm and in compliance with the injection well influent limitations. A significant contributor to the success of the existing 100 gpm system has been the flexibility to manage the entire water system by pumping up to 50 gpm of makeup water from the gravel pit in support of underground operations, including the consistent and reliable operation of the water treatment plant.

During mine development, there will by many more working faces and water inflows will be even more variable. Total inflows ranging from 80 to 350 gpm are expected and a new 400 gpm (design range 200 to 600 gpm) water treatment plant will be constructed near the portal to assist the existing plant.

As determined by operations requirements, makeup water of up to 150 gpm will be pumped from the gravel pit as required in support of underground operations. Grouting will be used only where necessary to control inflows and limit the total flow to the injection wells to 400 gpm. At present, two injection wells (one operating/one standby) have been established in the floodplain. One to three additional wells will be needed to accommodate the possibility of increased flows (see Appendix N). Existing permitted water quality standards will be maintained.

One of the important functions of the RTP is to capture runoff and seepage from the drystack. Mitigative measures such as crowning the drystack and constructing armored channels down both perimeters of the drystack will be used to minimize sediment transport. However during high precipitation events, some physical transport of fine tailings to the RTP is expected. The Universal Soil Loss Equation is used to estimate the potential soil loss from the tailings area under the 19" annual average precipitation scenario of between about 6 and 20 tpy (tons per year), or an average of about 13 tpy.

In order to minimize the transport of the Pogo drystack tailings material, the following best management practices measures will be implemented:

- Drystack geometry – The majority of the highest erosion potential, on a per area basis, is on the drystack face. Instead of a single long slope, the Pogo stack will be broken up so that any given slope has a maximum height of 60 ft and a minimum 15 ft wide bench will be at the base of each slope segment to collect sediment runoff.
- Drystack compaction – The shell area of the tailings will be compacted to achieve at least 95% Standard Proctor Density in accordance with ASTM D-698. The general placement area will receive compactive effort as well, but it is the shell area that will gain most erosion resistance from compaction.
- Equipment operations – The drystack shell will be developed “cross slope” versus having placement and compaction equipment on the slopes which reduces the potential for equipment-induced erosion.

Management of runoff collection/routing areas – perimeter ditches that ring the drystack will have sedimentation traps for erosion control.

## 3.4 Surface Water & Runoff

All surface water and runoff from the plant site and tailings drystack area will be collected in the RTP immediately downstream of the tailings drystack facility. Under normal conditions, inflows to the pond will consist of:

- spring snowmelt
- stormwater runoff
- seepage from the tailings drystack
- excess treated mine water that cannot be used in the plant
- makeup fresh water to provide water during dry periods when precipitation and mine water inflows are insufficient for process plant needs.

To minimize the amount of precipitation and runoff that comes into contact with project facilities and drains to the RTP, a diversion ditch will be constructed along both sides of the Liese Creek basin uphill of the tailings drystack facility. This ditch will be developed during mine construction and will be operated and maintained throughout the life of the mine and during decommissioning.

A diversion ditch will also be constructed above the catchpoint of the road backslope along the haul road between the mill and the drystack tailings facility. This diversion ditch, termed a “detached ditch,” is different than the roadside ditch previously proposed. Construction of the detached ditch will allow all of the upslope runoff to be diverted around the facility without the risk of contacting tailings that might have been on the haul road. The runoff from the haul road will be collected in a separate roadside ditch and directed to the stormwater sump near the mill site, where it will be subsequently be pumped to the RTP.

The stormwater pumping system will have a small pump suitable for handling normal runoff and baseflows, as well as a large pump capable of handling a rate sufficient to accommodate a 5-year/6-hour storm. Both pumps will be connected to emergency standby power. In addition, the site layout has been planned so that in the event of a storm surge that cannot be handled by the pumping system, excess water will be directed over a weir and down the 1700 portal conveyor drift into the mine, where it can be stored as necessary.

### 3.4.1 Recycle Tailings Pond

Water that accumulates in the RTP will be used to fulfill all additional process makeup requirements that are not being met by mine water flow. In periods where precipitation inflows are inadequate, makeup fresh water will be added to the pond. RTP water will be routed to the plant and the process water tank. This system will ensure that water for process is always drawn from the RTP and that the entrainment of RTP contaminants in the backfill and tailings is maximized.

The RTP basin will be formed by excavating and constructing a dam downstream of the tailings drystack facility in the Liese Creek valley. The dam will be developed as a lined rockfill structure with expansion capability.

The criteria used to determine the appropriate size for the RTP dam was that the dam must meet or exceed the regulatory guidance for a stormwater exemption for facilities otherwise not permitted to discharge. The dam size was selected so as to result in an insignificant probability of stormwater release during the project life.

Published EPA guidance indicates that the treatment facility should be sized to contain the sum of the following two volumes:

1. The maximum volume of wastewater stored and contained by the facility during normal operating conditions without an increase in volume from precipitation.
2. The maximum volume of wastewater that would result from a 10-year/24-hour precipitation event, including runoff that is allowed to comingle with the treatment system.

Based on additional EPA guidance, Teck has assumed that the volume during normal operating conditions will include average water volume in the RTP, including snowmelt under the 19" precipitation scenario. The 10-year and 100-year event volumes[1] are based on 2.8" and 4.3", respectively. Based on this deterministic approach wherein average year precipitation and extreme precipitation events are superimposed, the resulting pond volume would be approximately 30 Mgal.

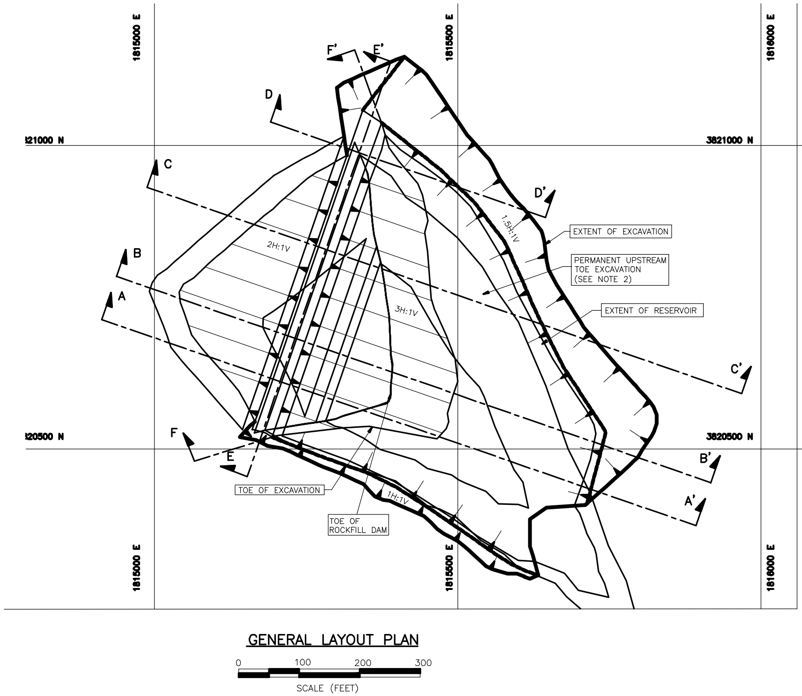
Teck also conducted Monte Carlo probabilistic modeling, however, that included a weekly precipitation model based on the 19" precipitation scenario. This model takes into consideration more "all-encompassing" weekly storm events as opposed to those that just occur daily. As a result of this analysis (see Section 4), a RTP pond volume of 40 Mgal was selected.

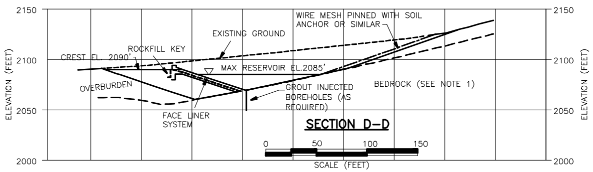
**Dam Construction**

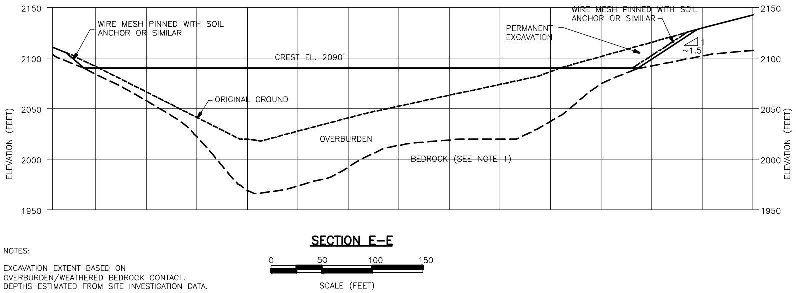
The dam will be constructed from local borrow and non-mineralized rock produced from underground mine development. Due to the absence of adequate fine-grained soils in the vicinity that could be used to develop a dam core of high integrity, a composite synthetic liner system will be placed on the upstream face of the dam. This liner system will be tied into a vertical seepage cut-off trench and/or extended in a sloping trench at the upstream toe. A plan and cross-section of the 40 Mgal dam is shown in Figure 3.6. Appendix M presents a summary of the design elements of the RTP dam.

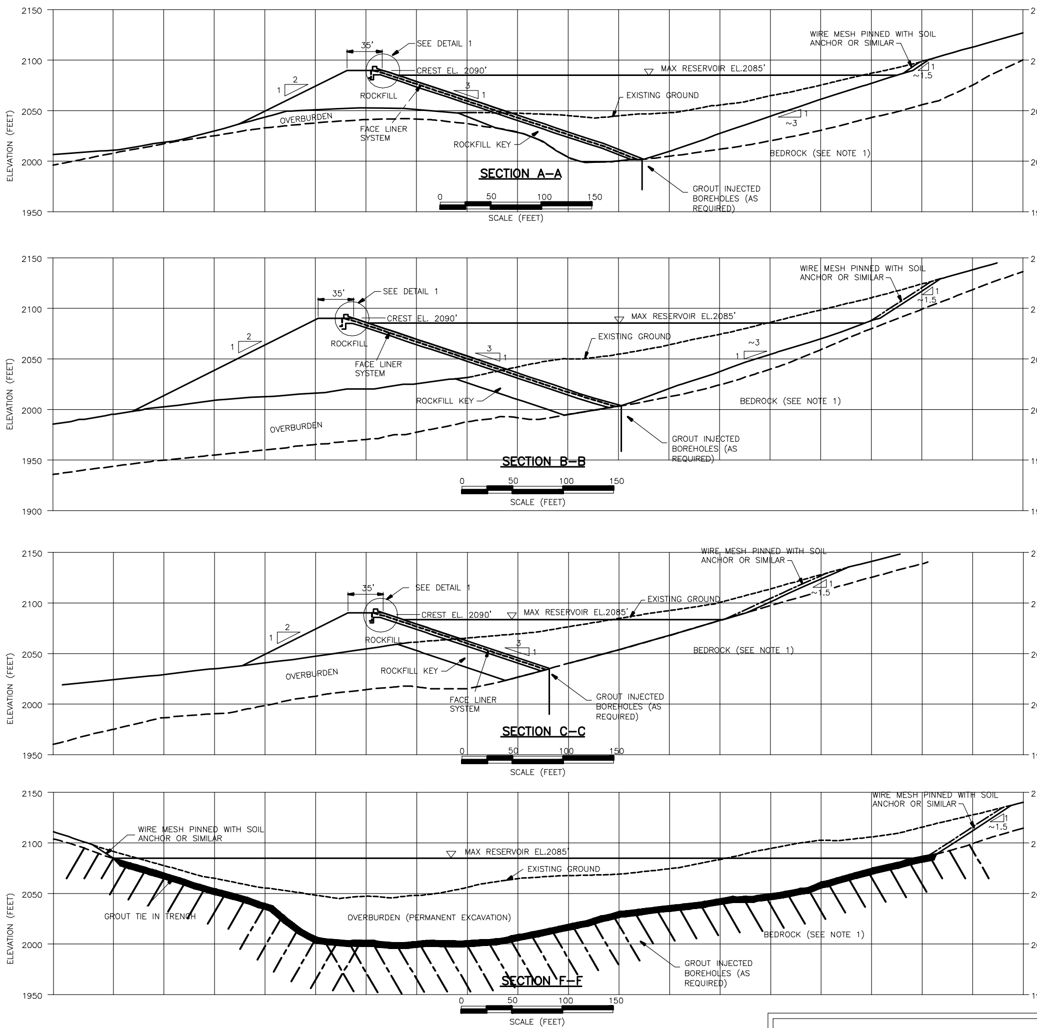
A system of seepage collection wells will be developed beyond the downstream toe of the RTP dam to collect seepage and runoff from the downstream face of the dam and return it to the RTP pond. The design of the seepage collection system and an analysis of the seepage potential are presented in Appendix M. This analysis indicates seepage volumes between 5 and 30 gpm. An outside review of the design assumptions and the seepage analysis was conducted by Robertson GeoConsultants and is also presented in Appendix M. This work confirmed the analysis and recommended the completion of three additional drillholes along the dam centerline to confirm assumptions (see Appendix M).

1. Technical Paper No. 47. "Probable Maximum Precipitation and Rainfall-Frequency Data for Alaska." US. Department of Commerce, Weather Bureau, John Miller, 1963.




NOTES:

1. EXCAVATION EXTENT BASED ON OVERBURDEN/WEATHERED BEDROCK CONTACT. DEPTHS ESTIMATED FROM SITE INVESTIGATION DATA.
2. UPSTREAM TOE EXCAVATION TO BE MAXIMUM 3H:1V CUT IN OVERBURDEN. WHERE BEDROCK INTERFACE IS STEEPER THAN 3H:1V, EXCAVATION SHOULD BE TO WEATHERED BEDROCK.

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Figure 3.6
40Mgal RTP Dam
Plan & Sections

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### 3.4.2 Runoff in the Tailings Treatment Area

All runoff in and around the tailings drystack facility will be directed to the RTP by means of a network of ditches and drains. “Flow-through” drains (coarse rockfill) will be constructed in the existing stream valleys (tributaries to Liese Creek) within the drystack area to augment the existing drainage courses and allow them to pass runoff under the stack. The rockfill used in the flow-through drains would be between 12" and 36". The rockfill should be covered with a geotextile separator to the drystack tailings. For practicality, it is unlikely the flow-through drains can be made smaller in height than twice the maximum particle size or narrower than three times the maximum particle size without restricting the void space between the rocks. As the rockfill would be placed at about 1H:1V, this would result in a flow-through drain with a base width of 21 feet, a crest width of 9 feet and a height of 6 feet. Based on this drain size and the proposed location of the drystack, it is estimated that the flow-through drains could pass approximately 120 times the existing daily average flow of 200 gpm measured at the United States Geological Survey gauge on Liese Creek. This capacity is approximately equivalent to a 1:10,000-year/24-hour storm event, with no credit taken for the diversion ditch and perimeter ditches.

At present, water flows in most of these channels are approximately 10 ft above the water table due to accumulated organic detritus in the bottom of the channel. The drainage courses would be prepared appropriately to remove this blinding layer. With this blinding layer removed and the diversion ditch and perimeter ditches in place, it is unlikely there would ever be any appreciable near-surface water in the existing drainage courses. Nonetheless, for additional security following mine closure, the flow-through drains have been designed to carry a significant capacity of water in comparison to previously measured flows in Liese Creek.

Any runoff from precipitation that falls on the access road or bypasses the major diversion ditch above the site will be collected along perimeter ditches at the edge of the stack or in the flow-through drains. After a season of winter tailings placement, the materials on the existing ground surface around the future perimeter of the tailings drystack footprint will be used as fill to create these ditches. In each successive year, this process will be repeated as the previous year’s ditch is simply incorporated into the drystack. The perimeter ditches provide a sufficient, and redundant, surface water handling system for the flow-through drains in case their performance becomes compromised during mine operations or following decommissioning. The flow-through drains are not required to function for assured drystack performance. Direct runoff from the tailings pile itself will flow to the perimeter ditches. All flows or seepage from the drystack will pass to the RTP and be collected and treated as necessary.

## 3.5 Fresh Water

Fresh water will be added to the RTP when other sources do not adequately meet process requirements. Potential sources of fresh water that could provide an adequate year-round supply for the project include surface water from either the Goodpaster River or excavated gravel pits, or groundwater from wells drilled into porous formations. In terms of adequate capacity and ease of operation, the best alternative is groundwater from the alluvial gravels. Bedrock water sources could be used if sufficient reserves and recharge capacity are available. Using water from the Goodpaster River is not desirable if there are other viable sources, and using surface water from the gravel pit would present operational difficulties due to winter freeze-up and icing.

It is proposed that two wells drilled to a depth of approximately 40 feet near the existing airstrip supply at least 100 gpm of fresh water for the project (see Figure 1.3). A freshwater supply pipeline will be routed from the wells through the plant site and on to the RTP. Investigations will be carried out to determine whether it is possible to supply this fresh water requirement from subsurface water wells above the plant site. This would be the preferred option as it would intercept the water flowing down-gradient to the mine, thereby reducing inflows and lowering overall costs.

## 3.6 Potable Water

### 3.6.1 Water for the Camp Complex

An average of 75 gpd of potable water will be required for each camp resident. As noted above, fresh water will be obtained from wells near the mine portal area, which should help ensure the safety of the potable water supply. Water for the camp will be pumped to a potable/fire water tank, from where it will flow to a 15 gpm potable water treatment plant and water storage tank.

### 3.6.2 Sewage Treatment

Lift stations will be located in each of the main buildings to pump sanitary sewage to a treatment plant. Package sewage treatment plants will be incorporated into both the construction camp and the permanent camp. Treated effluent from the construction camp will be discharged to the disposal field shown on Figure 1.3. During development, treated effluent from the permanent camp will be discharged into a disposal field shown on Figure 1.3. During operations, treated effluent from the permanent camp may be routed to the disposal field previously used for the construction camp.

# SECTION 4 | WATER BALANCE & MANAGEMENT

## 4.1 Introduction

The purpose of this water management plan is to evaluate the requirements for water collection, treatment and discharge at the Pogo project. A model using Monte Carlo simulation was developed to determine the probability distributions for various input and output events. The model was used to predict water flows and estimate discharge rates and water quality during various operating and shutdown conditions. The model shows that the water management system will be protective of water quality under a wide range of operating scenarios.

The following sections describe the water uses, qualities, balances, treatment and overall water management concepts for the Pogo project.

## 4.2 Water Inflows

To the greatest extent possible, the Pogo process plant is designed to operate on water collected from the immediate site disturbance area, including mine drainage. The requirement for additional water from wells is expected to be intermittent, occurring only in dry periods. Process flowsheets and water balances are included in Appendix I.

Water sources are classified as "contact" if the water has come into contact with mineralized or chemically processed rock. For project purposes, all contact water is assumed to possibly contain dissolved contaminants that may need treatment before being discharged.

### 4.2.1 Contact Water

As shown in Figures 1.4 and 3.1, the function of the RTP will be to gather seepage and runoff. The following will flow by gravity to the RTP:

- drystack runoff
- drystack seepage
- ditch leakage from diversion ditches up-gradient from the RTP
- road runoff from haulroad up-gradient from RTP
- runoff from temporary mineralized development rock stockpile.

The following will be collected in the mill site sump and then pumped to the RTP:

- ditch leakage from diversion ditches down-gradient from RTP
- road runoff from haulroad down-gradient from RTP
- mill site and camp/shop complex runoff.

The RTP will also receive treated mine water that is not either discharged or used in the process.

### 4.2.2 Non-contact Water

Non-contact runoff water will be captured in the site diversion ditch (see Figure 1.4) and rerouted to the existing Liese Creek drainage course below the facilities.

## 4.3 Water Balance & Model

A predictive model of Pogo site water flows and quality was developed to evaluate operating scenarios and the quality of the water released to the environment. This model incorporates the latest design concepts and utilizes Monte Carlo modeling in the evaluation of contaminant levels in the RTP and throughout the water management process.

The site water balance and water quality calculations have been set up as an Excel™ spreadsheet model running a Monte Carlo package, @Risk™ on top to calculate input probability distributions, and perform the simulations for determining output probability distributions.

Calculations are done on a weekly basis, with the net inflow or outflow being used to derive the pond volume, recycle flows and discharge flow. The model calculates the volumetric water balance first, then the water quality estimates for the input and output streams are used with the various flows to derive the a mass balance and calculate the water quality estimates for the various output flow streams.

Inflows, precipitation, and water quality parameters have been subjected to statistical analysis to derive their underlying probability distributions and have been incorporated into the model as probability functions from the Monte Carlo package, @Risk™. Snowpack, snowmelt, and rainfall precipitation have been analyzed and modeled on a weekly basis as Monte Carlo inputs. The resultant annual precipitation curve calibrates well with the selected annual precipitation data. Mine water inflow is based on yearly analysis and the model runs select years at random.

Water quality inputs have been derived as described in Section 4.3.

The model calculates the results by proceeding through the following stages:

- When a simulation year commences, the water quality values to be used throughout that year are selected from the input probability distributions.
- Then, weekly snowpack and rainfall precipitation is determined from the input probability distributions.
- Using the above weekly precipitation values, the precipitation water inflows are calculated from the appropriate catchment areas and runoff coefficients.
- The inflow volumes and qualities are combined as input to the model.
- Mine water inflow is then obtained from a lookup table and the mine inflow water quality is calculated and input to the model.
- These inflows are then accumulated in the model and mill consumptions and water treatment deducted to provide an overall weekly water balance.
- If the system is deficient in water, fresh water is input to the RTP to meet process requirements.
- The model then calculates the mass balance for various outflow streams by summing the mass inflows of the ions and parameters and dividing by the product volume to determine the product concentrations. The mass balance and water quality for the WTP (water treatment plant) feed water is determined in this manner.
- The Water Treatment Plant removal of ions and other parameters is then calculated and the resultant WTP discharge water quality determined.
- The model then examines the WTP discharge water quality and determines whether this water is suitable for discharge to the SAS. If it is not, the water is recycled to the RTP.
- For water discharged to the SAS, removal of ions and other parameters is then calculated.
- All of the above information is then used to calculate the mass balance for the RTP and to estimate the RTP water quality.

- The model balance calculation then determines whether a spillway release occurs and the consequent volume of water released.

The Monte Carlo model simulates actual conditions by randomly selecting inputs from the probability functions at the beginning of each simulation run. Typically the model runs are 1,000 simulations (equivalent to 1,000 years). @Risk™ collects all the data from the model runs and then allows the generation of frequency histograms and pdfs for selected flow streams and related quality parameters.

The model allows assessment of the requirements for environmental controls and water treatment. The expected discharge scenario contemplates treatment of all contact water in the water treatment plant and subsequent secondary treatment in the soil absorption system prior to release to the environment.

The water quantity and quality estimates for the balance are based on existing related site data, test data or best engineering judgment. The logic behind each input to the model is described below.

### 4.3.1 Water Quantity Estimates

The flow categories described below are shown schematically in Figure 3.1.

#### Plant Site, Road Drainage, Ditch Leakage & RTP Catchment

Water coming into contact with roads and travel areas around the mill, as well as the haul road between the mill and the tailings drystack, could become contaminated by ore and tailings. Runoff from these roads will therefore be routed to the mill area stormwater sump and thence pumped to the RTP.

Catchment ditches are planned above the highest elevation of tailings deposition. Upslope runoff will be intercepted by the diversions, managed as non-contact stormwater and rerouted to lower Liese Creek. Ditch leakage at a rate of 15% of ditch flow, to a maximum of 87 gpm during storm events, has been assumed to be contact water and has been added to precipitation in the tailings area and the RTP for the water balance. Ditch leakage will be minimized through appropriate design, operating and maintenance procedures.

Rainfall and snowmelt volumes over the RTP catchment area are totaled and then modified by the appropriate runoff coefficient (see Section 4.4.3, Table 4.2) to produce a RTP “run on” value. Similarly, the rainfall and snowmelt over the plant site and road area multiplied by the appropriate runoff coefficient are also added to this value, as is the infiltration quantity from the diversion ditches.

If the RTP impoundment experiences a limited bypass of water, the intercept pumpback system will capture this seepage and return the flow to the RTP (see Appendix M). Seepage is expected to be low in any case. Precipitation inflow captured by the pumpback system could range from 2 to 35 gpm, depending on the site rainfall and snowmelt rates. The net pumpback (total minus dam seepage return) has been added to the runoff volumes.

**Development & Temporary Rock Seepage**

The seepage flow is estimated by prorating the plant site, road drainage and ditch leakage flow for each week by the following catchment area ratio: (temporary rock storage area) / (RTP catchment area). The development rock stockpile will diminish in size over time as it is incorporated into the drystack, and will be gone by Year 6.

**Tailings Runoff**

Net runoff to the RTP is calculated as the rainfall and snowmelt on the drystack area.

**Tailings Seepage**

Flotation tailings placed in the drystack will have a residual moisture content of approximately 15%. At 15% and 2,500 tpd rated capacity, this will result in 36 gpm reporting to the tailings drystack facility. A small amount of seepage is expected from the unsaturated drystack. Because of the increase in size of the tailings drystack over the life of the mine, seepage will increase from initially very low levels to an estimated average of 3 gpm, with 6 gpm of flow just prior to mine closure at year 12. This seepage will be captured in the RTP.

Seepage flow from the drystack was estimated using several methods, including the finite element modeling program SEEP/W. Input parameters were derived from laboratory testing on tailings samples (triaxial hydraulic conductivity and Tempe cell moisture retention characterization). Details of the drystack seepage analyses are provided in Appendix D.

**RTP Direct Precipitation**

Direct precipitation (weekly rainfall and snowmelt) is used as input to the RTP.

**RTP Evaporation**

Weekly evaporation from the pond surface is estimated from the pan evaporation rate, the pond surface area and an evaporation coefficient. The calculated flow is subtracted from the pond input flow.

**Mine Drainage**

The exploration workings have drained at an average rate of about 50 gpm. Groundwater drainage into the mine is expected to fluctuate widely as the workings expand during development and operations. Based on experience during exploration, the amount of water will vary as fractures and faults are intercepted but will rapidly diminish after the water in these features is drained. The highest average inflows will occur in mid project when mining approaches the Liese Creek fault.

Annual mine drainage projections are estimated by year and tabulated in the model based on Adrian Brown's "Mine Inflow" report (see Table 14, Appendix A). Mine inflows are segregated into Liese Creek Fault and Non-Liese Creek Fault Zone categories. The estimates provide a range of conditions from the lower to the upper bound of expected and maximum annual flows for the mine. All estimates are based on a calibrated model of the mine water inflow, where hydraulic conductivity, drainable porosity and infiltration have been adjusted to explain observed mine water inflows during the exploration phase.

**Paste Backfill Drainage**

The paste backfill will have an overall bulk moisture content of approximately 30% and will incorporate 89 gpm into the paste. Mine backfill will normally be mixed with cement before being placed underground. The cement hydration process will chemically fix the water and minimize any water release. Based on experience elsewhere, a minor amount of bleed water and flush water (between 1% and 2%) is anticipated during operations, with essentially all of the bleed occurring within the first days of backfill placement. The calculated backfill drainage flow (approximately 2 gpm) is based on the backfill placement rate. Experience at other mines shows that this flow is often not detectable or measurable. In the case of mine shutdown or closure, the paste drainage flow would diminish rapidly and is assumed to have ceased after week 10 of a shutdown.

**Makeup Fresh Water**

Fresh water will be added to the RTP if the inflow to the RTP is less than the process requirement. The fresh water would be added by pumping from wells located adjacent to the Goodpaster River near the existing airstrip (see Figure 1.3).

### 4.3.2 Water Quality Parameters

Based on preliminary screening work and feedback from regulatory agencies, the modeling work was conducted using the list of water quality parameters shown in Table 4.1.

**Table 4.1: Parameters Used in Water Quality Modeling**

| Parameter | Abbreviation |
|---|---|
| Total Suspended Solids | TSS |
| Total Dissolved Solids | TDS |
| Chloride | Cl |
| Sulfate | $SO_4$ |
| Total Kjeldahl Nitrogen | TKN |
| Nitrate | $NO_3$ |
| Total Cyanide | $CN_T$ |
| Arsenic | As |
| Cadmium | Cd |
| Chromium | Cr |
| Copper | Cu |
| Iron | Fe |
| Lead | Pb |
| Mercury | Hg |
| Manganese | Mn |
| Nickel | Ni |
| Selenium | Se |
| Silver | Ag |
| Zinc | Zn |

All modeling work was completed in dissolved values. It should be noted that $CN_T$ (a dissolved value) was used for modeling purposes — as opposed to CN free or CN WAD (weak acid dissociable) — because $CN_T$ most closely obeys a mass balance and can be tracked through the model without consideration of the solution chemistry. However, Teck believes that WAD cyanide is a more appropriate parameter to use for environmental monitoring purposes.

### 4.3.3 Water Quality Estimates

Once the volumetric flow from each source is determined, the water quality estimates for the input and output streams are superimposed on the flows to derive the model input and output water qualities.

**Input Data Sources**

Baseline water quality monitoring has been conducted on site since 1997. The sampling sites and periods of record are shown in Figure 2.3. The most source-specific data was used to develop the characteristics for specific project waters. This representative data was acquired from the following monitoring stations:

- Station SW05, Lower Liese Creek. Considered to be representative of runoff from lower Liese Creek.
- Station 98MW-005. Monitoring well considered to be representative of groundwater that will be pumped from wells in the valley and used as fresh water for the process plant.
- Station SW15, Goodpaster River.
- Station SW30, Upper Liese Creek. Considered to be representative of “undisturbed” site runoff from upper Liese Creek.
- Station SW31, Portal Haul Road Runoff. This station was used to monitor runoff from the haul road to the exploration portal and is therefore considered to be representative of disturbed sites, including diversion ditch leakage and runoff from the haul road and mill site.

The challenge was to predict the water quality of the following:

- flows that do not currently exist
- flows that may be modified by project activities
- flows resulting from processes and exposure to materials not readily available for testing.

For the water flows listed below, water quality projections were generated as input to the water balance model, based on relevant site data, laboratory testwork, Pilot Plant testing and information prepared by various consultants:

- site runoff from disturbed areas (ditches, pads, roads)
- seepage for waste rock storage areas
- runoff from the tailings drystack
- seepage from the tailings drystack
- mine drainage inflow
- drainage from cemented paste tailings placed underground.

The testwork included a series of metallurgical tests conducted by Lakefield Research Ltd. and paste backfill characterization by Golder Associates. The material used for metallurgical testing was selected from exploration samples considered to be representative of the ore body and standard milling feed. This testwork was based on Composite 4, a sample that was prepared based on extensive study of the geology and mineralogy of the orebody (see Appendix J). The material used for the Pilot Plant testing was taken from a bulk sample from the advance exploration program. Although the bulk sample material was not representative of the entire orebody, it was the only large sample available. The results from the Pilot Plant study were used to modify the water quality assumptions where appropriate. Memos and reports documenting the relevant analyses are appended as follows:

- inflow to the Pogo Mine (Adrian Brown, Appendix A)
- hydrology and precipitation (AMEC E&E, Appendix B)
- geochemical testwork and water chemistry predictions, including runoff and seepage water quality for the tailings and mineralized rock (SRK and AMEC, Appendices C and D)
- site water quality data (Appendix F)
- paste backfill characterization testwork (Golder, Appendix G)
- mine backfill drainage quality and cyanide destruction testwork (AMEC, Appendix H)
- environmental characterization of Pilot Plant test samples, phase I and phase II, Lakefield Research, available under separate cover.

The input data sources described below are summarized in Tables 4.2 and 4.3.

**Table 4.2: Model Input Data Sources – Quantity**

| | Plant Site Runoff | Development Rock Runoff | Tailings Runoff | Tailings Seepage | Precipitation on RTP | Mine Drainage | Backfill Drainage |
|---|---|---|---|---|---|---|---|
| **Data Source** | USGS contours, 1993, 19" annual average | USGS contours, 1993, 19" annual average | USGS contours, 1993, 19" annual average | Modeled hydraulic conductivity values from laboratory testing (triaxial & Tempe cells) | USGS contours, 1993, 19" annual average | Based on existing mine drainage data & groundwater modeling as per A. Brown | Estimated from testwork and operating experience from similar mines |
| **Rationale for Selection** | Suggested by EIS team | Suggested by EIS team | Suggested by EIS team | Modeled result using laboratory data & engineering judgment | Suggested by EIS team | Engineering judgment | Engineering judgment |
| **Expected Value** | Runoff coefficient 0.5 | Runoff coefficient 0.5 | Modeled with coefficient 1 | Range over life of mine from 0 at start-up to about 6 gpm at closure | USGS rainfall | Appendix A | (1% - 2% contained water, approximately 2 gpm) |
| **Presentation** | Appendix B | Appendix B | Appendix B | Appendix D | Appendix B | Appendix A | Report text |

**Table 4.3: Model Input Data Sources – Quality**

| | Plant Site & Road Runoff & Ditch Leakage | Development Rock Runoff | Tailings Runoff | Tailings Seepage | Precipitation on RTP | Mine Drainage | Backfill Drainage |
|---|---|---|---|---|---|---|---|
| **Data Source** | Station SW31 | Modeled | Modeled | Modeled | Available regional information. Testing of site samples | Based on existing mine drainage data | Composite 4 testwork & Pilot Plant |
| **Number of Samples** | 6 | Modeled result based on 19 humidity cells & columns, and 3 site samples | Modeled result based on 4 humidity cells | Modeled result based on 5 columns | 36 samples from National Atmospheric Deposition Program data | 23 influent samples from existing mine water treatment plant and 20 Liese fault samples (98C) | Composite 4 testwork & Pilot Plant |
| **Rationale for Selection** | Best available analogy to operating conditions | Appendix C | Appendix C | Appendix C & D | Values from available information | Best available analogy to operating conditions | Best available analogy to operating conditions |
| **Expected Value** | See Table 4.4 | See Table 4.4 | See Table 4.4 | See Table 4.4 | See Table 4.4 | See Table 4.4 | See Table 4.4 |
| **Present-ation** | Appendix I | Appendix C | Appendix C | Appendix C & D | Appendix B | Report text | Appendix H |

### 4.3.4 Model Input Details

The water quality estimates for the various sources of contact water are presented in Table 4.4. Please note that RWC represents “reasonable worst case”, a value that, based on field, lab, and theoretical data, is not likely to be exceeded. The “reasonable worst case” concentration is calculated using two primary assumptions.

The first assumption is that release of metal from a waste under field conditions is unlikely to be more rapid than in the laboratory. In the laboratory, sample is prepared and rinsed under warm conditions to maximize removal of weathering products.

The second assumption is that a mineral and its contained elements cannot dissolve in water without limit. If the element concentrations in the water exceed the concentrations imposed by saturation, the mineral will not dissolve. These saturation concentrations are “reasonable worst case” because in practice natural minerals dissolve very slowly. The low temperature of the water and hardness of the minerals slows down dissolution. These concentrations can be estimated using models and large site water chemistry databases. Therefore, the available lab data, site data and computed solubility concentrations were all evaluated and compared to arrive at the recommended RWC concentration (see Appendix C).

**Table 4.4: Water Quality Input Sheet (Sections A through I)**

**A. Plant Site, Road Drainage, Ditch Leakage**

| Parameter | Distribution | Selected Mean | Selected Std. Deviation | Reasonable Worst Case | Units |
|---|---|---|---|---|---|
| TSS | LogNormal | 109 | 315 | 417 | mg/l |
| TDS | LogNormal | 204 | 41.7 | 279 | mg/l |
| Cl | LogNormal | 8.49 | 6.53 | 20.6 | mg/l |
| $SO_4$ | LogNormal | 27.0 | 10.7 | 47.0 | mg/l |
| TKN | LogNormal | 1.73 | 0.160 | 2.01 | mg/l N |
| $NO_3$ | LogNormal | 4.70 | 7.83 | 16.1 | mg/l |
| $CN_T$ | Constant at RWC | | | 0.005 | mg/l |
| As | LogNormal | 0.0172 | 0.00832 | 0.0329 | mg/l |
| Cd | LogNormal | 5.9E-05 | 2.8E-05 | 0.000113 | mg/l |
| Cr | LogNormal | 0.00163 | 0.00054 | 0.00263 | mg/l |
| Cu | LogNormal | 0.00647 | 0.00214 | 0.0104 | mg/l |
| Fe | LogNormal | 1.03 | 0.320 | 1.62 | mg/l |
| Pb | LogNormal | 0.00036 | 0.00026 | 0.000838 | mg/l |
| Hg | LogNormal | 0.00809 | 0.00381 | 0.0153 | µg/l |
| Mn | LogNormal | 0.516 | 0.520 | 1.44 | mg/l |
| Ni | LogNormal | 0.00433 | 0.00062 | 0.00542 | mg/l |
| Se | LogNormal | 0.00067 | 0.00022 | 0.00108 | mg/l |
| Ag | LogNormal | 1.1E-05 | 1.6E-06 | 0.0000137 | mg/l |
| Zn | LogNormal | 0.0299 | 0.0170 | 0.0620 | mg/l |

**B. Development & Temporary Rock Seepage**

| Parameter | Distribution | Selected Mean | Selected Std. Deviation | Reasonable Worst Case | Units |
|---|---|---|---|---|---|
| TSS | LogNormal | 33.3 | 45.7 | 107 | mg/l |
| TDS | LogNormal | 435 | 117 | 772 | mg/l |
| Cl | Constant at RWC | 37.3 | 27.7 | 89 | mg/l |
| $SO_4$ | LogNormal | 634 | 295 | 386 | mg/l |
| TKN | LogNormal | 10 | 1.8 | 15 | mg/l N |
| $NO_3$ | Constant at RWC | | | 9 | mg/l |
| $CN_T$ | Constant at RWC | | | 0.02 | mg/l |
| As | LogNormal | 0.18 | 0.18 | 0.5 | mg/l |
| Cd | LogNormal | 0.0005 | 0.0014 | 0.005 | mg/l |
| Cr | LogNormal | 0.00258 | 0.00352 | 0.014 | mg/l |
| Cu | LogNormal | 0.004 | 0.002 | 0.03 | mg/l |
| Fe | LogNormal | 0.521 | 0.522 | 1.45 | mg/l |
| Pb | LogNormal | 0.0009 | 0.0025 | 0.005 | mg/l |
| Hg | LogNormal | 0.144 | 0.413 | 2 | µg/l |
| Mn | LogNormal | 0.235 | 0.666 | 0.98 | mg/l |
| Ni | LogNormal | 0.02 | 0.073 | 0.236 | mg/l |
| Se | LogNormal | 0.004 | 0.0165 | 0.03 | mg/l |
| Ag | LogNormal | 2.9E-05 | 2.4E-05 | 0.002 | mg/l |
| Zn | LogNormal | 0.05 | 0.335 | 0.699 | mg/l |

**C. Tailings Runoff**

| Parameter | Distribution | Selected Mean | Selected Std. Deviation | Reasonable Worst Case | Units |
|---|---|---|---|---|---|
| TSS | Constant at USLE Value | | | 400 | mg/l |
| TDS | Constant Mass | | | 523 | mg/l |
| Cl | Constant Mass | | | 164 | mg/l |
| $SO_4$ | Constant Mass | | | 302 | mg/l |
| TKN | Constant at RWC | | | 0.5 | mg/l |
| $NO_3$ | Constant Mass | | | 19.8 | mg/l |
| $CN_T$ | Constant at RWC | | | 0.02 | mg/l |
| As | Constant Mass | | | 0.4 | mg/l |
| Cd | Constant Mass | | | 0.0004 | mg/l |
| Cr | Constant Mass | | | 0.0011 | mg/l |
| Cu | Constant Mass | | | 0.003 | mg/l |
| Fe | Constant Mass | | | 0.0003 | mg/l |
| Pb | Constant Mass | | | 0.0004 | mg/l |
| Hg | Constant Mass | | | 0.2 | µg/l |
| Mn | Constant Mass | | | 0.38 | mg/l |
| Ni | Constant Mass | | | 0.02 | mg/l |
| Se | Constant Mass | | | 0.006 | mg/l |
| Ag | Constant Mass | | | 0.0002 | mg/l |
| Zn | Constant Mass | | | 0.06 | mg/l |

**D. Tailings Seepage**

| Parameter | Distribution | Selected Mean | Selected Std. Deviation | Reasonable Worst Case | Units |
|---|---|---|---|---|---|
| TSS | Constant at RWC | | | 5 | mg/l |
| TDS | LogNormal | 600 | 610 | 3000 | mg/l |
| Cl | LogNormal | 12.2 | 12.3 | 34 | mg/l |
| $SO_4$ | LogNormal | 57.4 | 125 | 2002 | mg/l |
| TKN | LogNormal | 1 | 1 | 17.8 | mg/l N |
| $NO_3$ | Constant at RWC | | | 4 | mg/l |
| $CN_T$ | Constant at RWC | | | 0.05 | mg/l |
| As | LogNormal | 1.6 | 2 | 5.1 | mg/l |
| Cd | LogNormal | 0.00035 | 0.002 | 0.005 | mg/l |
| Cr | LogNormal | 0.00251 | 0.0034 | 0.014 | mg/l |
| Cu | LogNormal | 0.004 | 0.007 | 0.034 | mg/l |
| Fe | LogNormal | 2 | 22 | 29.6 | mg/l |
| Pb | LogNormal | 0.0009 | 0.0025 | 0.005 | mg/l |
| Hg | LogNormal | 0.189 | 0.376 | 2 | µg/l |
| Mn | LogNormal | 0.108 | 0.182 | 4.75 | mg/l |
| Ni | LogNormal | 0.025 | 0.12 | 0.24 | mg/l |
| Se | LogNormal | 0.013 | 0.05 | 0.13 | mg/l |
| Ag | LogNormal | 6.9E-05 | 6.4E-05 | 0.002 | mg/l |
| Zn | LogNormal | 0.05 | 0.335 | 0.699 | mg/l |

**E. Precipitation on RTP**

| Parameter | Distribution | Selected Mean | Selected Std. Deviation | Reasonable Worst Case | Units |
|---|---|---|---|---|---|
| TSS | Constant at RWC | | | 0 | mg/l |
| TDS | Constant at RWC | | | 10 | mg/l |
| Cl | Constant at RWC | | | 0.056 | mg/l |
| $SO_4$ | Constant at RWC | | | 0.185 | mg/l |
| TKN | Constant at RWC | | | 0.03 | mg/l N |
| $NO_3$ | Constant at RWC | | | 0.1525 | mg/l |
| $CN_T$ | Constant at RWC | | | 0 | mg/l |
| As | Constant at RWC | | | 0 | mg/l |
| Cd | Constant at RWC | | | 0 | mg/l |
| Cr | Constant at RWC | | | 0 | mg/l |
| Cu | Constant at RWC | | | 0 | mg/l |
| Fe | Constant at RWC | | | 0 | mg/l |
| Pb | Constant at RWC | | | 0 | mg/l |
| Hg | Constant at RWC | | | 0 | µg/l |
| Mn | Constant at RWC | | | 0 | mg/l |
| Ni | Constant at RWC | | | 0 | mg/l |
| Se | Constant at RWC | | | 0 | mg/l |
| Ag | Constant at RWC | | | 0 | mg/l |
| Zn | Constant at RWC | | | 0 | mg/l |

**F. RTP Evaporation**

| Parameter | Distribution | Selected Mean | Selected Std. Deviation | Reasonable Worst Case | Units |
|---|---|---|---|---|---|
| TSS | Constant at RWC | | | 0 | mg/l |
| TDS | Constant at RWC | | | 0 | mg/l |
| Cl | Constant at RWC | | | 0 | mg/l |
| $SO_4$ | Constant at RWC | | | 0 | mg/l |
| TKN | Constant at RWC | | | 0 | mg/l N |
| $NO_3$ | Constant at RWC | | | 0 | mg/l |
| $CN_T$ | Constant at RWC | | | 0 | mg/l |
| As | Constant at RWC | | | 0 | mg/l |
| Cd | Constant at RWC | | | 0 | mg/l |
| Cr | Constant at RWC | | | 0 | mg/l |
| Cu | Constant at RWC | | | 0 | mg/l |
| Fe | Constant at RWC | | | 0 | mg/l |
| Pb | Constant at RWC | | | 0 | mg/l |
| Hg | Constant at RWC | | | 0 | µg/l |
| Mn | Constant at RWC | | | 0 | mg/l |
| Ni | Constant at RWC | | | 0 | mg/l |
| Se | Constant at RWC | | | 0 | mg/l |
| Ag | Constant at RWC | | | 0 | mg/l |
| Zn | Constant at RWC | | | 0 | mg/l |

**G. Mine Drainage**

| Parameter | Distribution | Selected Mean | Selected Std. Deviation | Reasonable Worst Case Untreated | Units |
|---|---|---|---|---|---|
| TSS | Constant at RWC | | | 1500 | mg/l |
| TDS (Fault Water) | Constant at RWC | | | 300 | mg/l |
| TDS (Mine Water) | Constant at RWC | | | 649 | mg/l |
| Cl | Constant at RWC | | | 5 | mg/l |
| $SO_4$ (Fault water) | Constant at RWC | | | 85 | mg/l |
| $SO_4$ (Mine water) | Constant at RWC | | | 283 | mg/l |
| TKN | Constant at RWC | | | 10 | mg/l N |
| $NO_3$ | Constant at RWC | | | 10 | mg/l |
| $CN_T$ | Constant at RWC | | | 0.02 | mg/l |
| As | Constant at RWC | | | 5.36 | mg/l |
| Cd | Constant at RWC | | | 0.0005 | mg/l |
| Cr | Constant at RWC | | | 0.013 | mg/l |
| Cu | Constant at RWC | | | 0.02 | mg/l |
| Fe | Constant at RWC | | | 4.27 | mg/l |
| Pb | Constant at RWC | | | 0.07 | mg/l |
| Hg | Constant at RWC | | | 0.25 | µg/l |
| Mn | Constant at RWC | | | 0.717 | mg/l |
| Ni | Constant at RWC | | | 0.03 | mg/l |
| Se | Constant at RWC | | | 0.002 | mg/l |
| Ag | Constant at RWC | | | 0.0001 | mg/l |
| Zn | Constant at RWC | | | 0.021 | mg/l |

**H. Backfill Drainage**

| Parameter | Distribution | Selected Mean | Selected Std. Deviation | Reasonable Worst Case Untreated | Units |
|---|---|---|---|---|---|
| TSS | Constant at RWC | | | 250 | mg/l |
| TDS | Constant at RWC | | | 13682 | mg/l |
| Cl | Constant at RWC | | | 27 | mg/l |
| $SO_4$ | Constant at RWC | | | 6803 | mg/l |
| TKN | LogNormal | 15 | 13 | 64 | mg/l N |
| $NO_3$ | Constant at RWC | | | 2.39 | mg/l |
| $CN_T$ | Constant at RWC | | | 1.01 | mg/l |
| As | Constant at RWC | | | 5.59 | mg/l |
| Cd | Constant at RWC | | | 0.01 | mg/l |
| Cr | Constant at RWC | | | 0.02 | mg/l |
| Cu | Constant at RWC | | | 1 | mg/l |
| Fe | Constant at RWC | | | 3 | mg/l |
| Pb | Constant at RWC | | | 0.03 | mg/l |
| Hg | Constant at RWC | | | 3 | µg/l |
| Mn | Constant at RWC | | | 10.11 | mg/l |
| Ni | Constant at RWC | | | 0.37 | mg/l |
| Se | Constant at RWC | | | 0.43 | mg/l |
| Ag | Constant at RWC | | | 0.0024 | mg/l |
| Zn | Constant at RWC | | | 0.43 | mg/l |

**I. Makeup Fresh Water**

| Parameter | Distribution | Selected Mean | Selected Std. Deviation | Reasonable Worst Case | Units |
|---|---|---|---|---|---|
| TSS | Constant at RWC | | | 12.9 | mg/l |
| TDS | Constant at RWC | | | 106 | mg/l |
| Cl | Constant at RWC | | | 0.96 | mg/l |
| $SO_4$ | Constant at RWC | | | 20.2 | mg/l |
| TKN | Constant at RWC | | | 0.33 | mg/l N |
| $NO_3$ | Constant at RWC | | | 0.45 | mg/l |
| $PO_4$ | | | | | |
| $CN_T$ | Constant at RWC | | | 0 | mg/l |
| As | Constant at RWC | | | 0.00040 | mg/l |
| Cd | Constant at RWC | | | 0.000053 | mg/l |
| Cr | Constant at RWC | | | 0.00367 | mg/l |
| Cu | Constant at RWC | | | 0.0017 | mg/l |
| Fe | Constant at RWC | | | 0.026 | mg/l |
| Pb | Constant at RWC | | | 0.00023 | mg/l |
| Hg | Constant at RWC | | | 0.058 | µg/l |
| Mn | Constant at RWC | | | 0.0403 | mg/l |
| Ni | Constant at RWC | | | 0.00144 | mg/l |
| Se | Constant at RWC | | | 0.00070 | mg/l |
| Ag | Constant at RWC | | | 0.000016 | mg/l |
| Zn | Constant at RWC | | | 0.0047 | mg/l |

Sections A through I of Table 4.4 are explained below.

*Plant Site Drainage, Road Drainage & Ditch Leakage (Section A)* – Water quality for these RTP sources has been estimated using the SW31 database. The values used were calculated by fitting a log normal distribution based on six samples taken during 2000, including those taken during spring runoff. The RWC was selected at the 95$^{th}$ percentile.

*Development & Temporary Rock Seepage (Section B)* – SRK conducted testwork and geochemical modeling based on humidity cells and columns to predict average and reasonable worst case predictions of the water quality of runoff and seepage from the development rock (see Appendix C).

SRK did not provide estimates for cyanide species. Cyanide concentration is based on a reported value of 0.02 mg/l $CN_T$ for seepage from the mineralized development rock pile at station SW26, even though no cyanide has been used on site. The reported value is believed to be a lab interference due to high TDS values.

*Tailings Runoff (Section C)* – Water quality predictions are based on humidity cell testwork and geochemical modeling by SRK and AMEC (see Appendices C and D). It is assumed that contaminants will be transported from the drystack at a constant mass flowrate, with the runoff concentration for each parameter calculated by dividing the estimated mass flow quantity by the quantity of drystack runoff for each week. Cyanide concentration is assumed to be the same as for the mineralized rock pile, at 0.02 mg/l.

*Tailings Seepage (Section D)* – Water quality predictions are based on humidity cell testwork and geochemical modeling by SRK (see Appendix D). Cyanide ($CN_T$) concentration is assumed to be 0.05 mg/l. based on a reasonable worst case scenario.

*Precipitation on RTP (Section E)* – The hydrology section of the "Environmental Baseline Document" (Appendix B) illustrates the normal pattern of precipitation in the project area by month and provides details on site precipitation estimates. Precipitation falling directly on the RTP is accounted for separately, and has been assigned high range chemistry (90%) based on National Atmospheric Deposition Program data for dustfall and rainout of airborne particulate.

*RTP Evaporation (Section F)* – This is the RTP evaporation factor.

*Mine Drainage (Section G)* – The mine water quality data used in the model for most parameters is based on samples of untreated mine water collected in the feed sump for the existing water treatment plant. The values used to represent mine water consist of the maximum total values from a set of 23 samples collected over a 10 day period from

22 March to 1 April 2000. Values for some of the parameters were adjusted as described below:

- TDS and $S0_4$ – As shown on Figures 4.1 and 4.2, the TDS values in the drainage from the existing underground workings have declined over time as the high TDS groundwater near the orebody has been drained. This trend applies not only to the combined drainage, but to each of the individual boreholes that flowed for any significant period (see Figure 4.3). Similar trends for $S0_4$ are shown on Figure 4.2 and 4.4. While this trend also applies to many other parameters, the water treatment plant is more capable of treating those other parameters than TDS and $S0_4$, so an improved estimate was needed for these parameters. TDS and SO4 projections have thus been made for two categories of mine drainage: Liese Creek Fault zone inflows and Non-Liese Creek Fault zone inflows. The TDS and $S0_4$ for these inflows have been estimated based on the trended data from borehole 98C (Figures 4.3 and 4.4) and from the overall inflow by backing out the dilutive effect of the current 98C inflow, normalizing the resulting data for the period of June 2000 to present to derive a mean and standard deviation. The values used in the model (Table 4.4 G) represent the mean plus two standard deviations.
- TKN – 10 mg/l as N (based on experience at other operations (see Appendix H); the maximum measured value of the 23 samples noted above was 0.6 mg/l as N).
- Arsenic (As) – 5.36 mg/l (maximum value from the original drill core samples; maximum measured value of the 23 samples noted above was 0.803 mg/l).
- Cyanide ($CN_T$) – 0.02 mg/l (equivalent to SW26 value).

*Backfill Drainage (Section H)* – The water quality predictions for paste backfill drainage are based on the analysis by AMEC (see Appendix H). Predictions were partially made using the testwork from samples of CIP tailings pulp following $SO_2$/air treatment. The testwork was successful in reducing cyanide and dissolved metals to low concentrations.

However, to reflect expected conditions during operation, maximum total values were increased from measured results for some parameters. The Pilot Plant cyanide destruction circuit reduced residual cyanide ($CN_T$) levels in the tailings to between 0.3 to 1.0 mg/l. However, due to concerns about the volatility of cyanide gases in the Pilot Plant, the $SO_2$/air dosage rates were higher than normal for a commercial operation. Based on this factor and experience at other operations, the cyanide level is assumed to be 2 mg/l. The concentrations of copper, iron and zinc were increased to reflect the increased concentration of cyanide to 2 mg/l due to the assumed presence of metal cyanide complexes.

**Figure 4.1: Pogo Mine Drainage Volume & TDS**

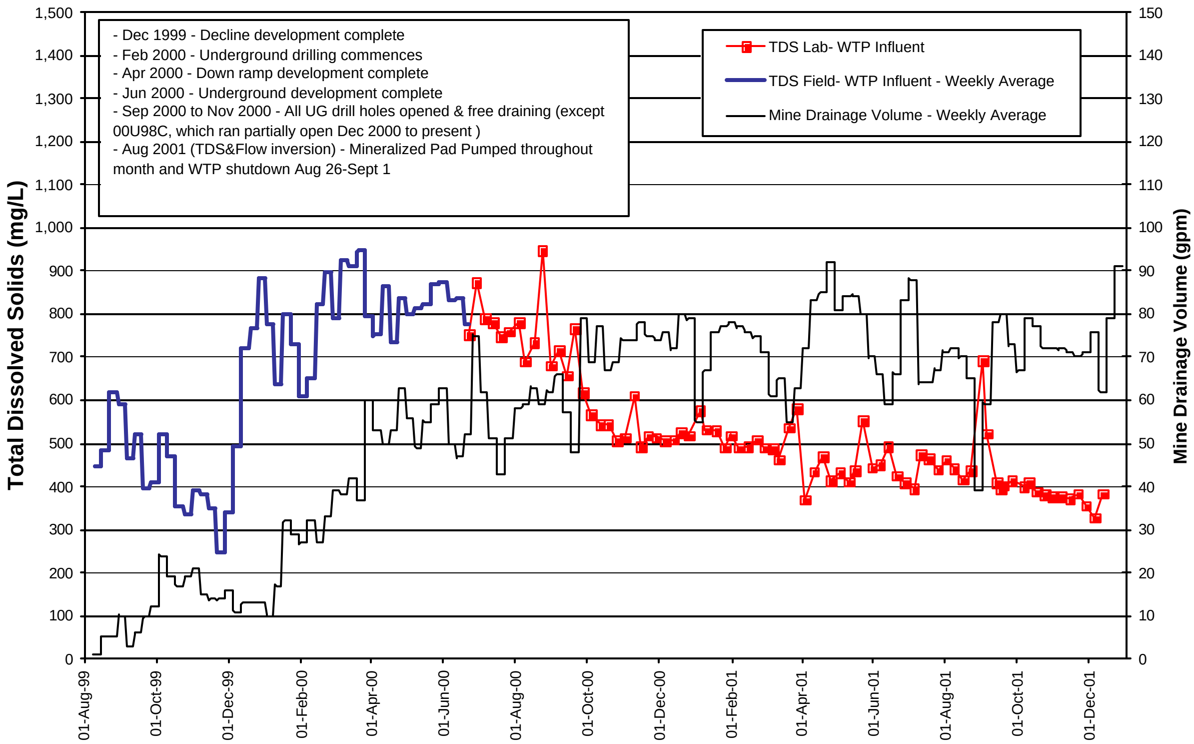


**Figure 4.2: WTP Feed Water Chemistry**

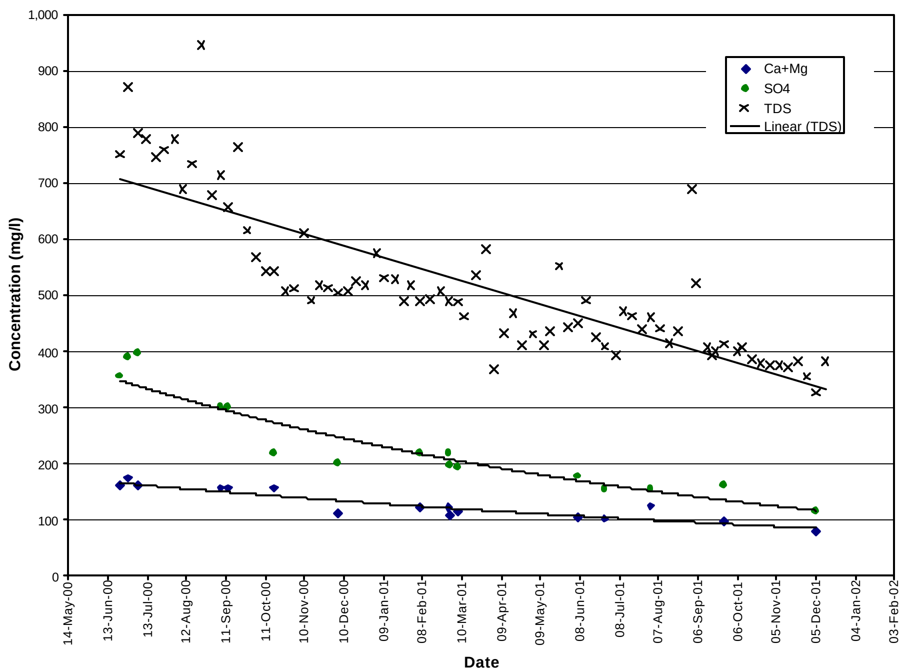



**Figure 4.3: Underground Drillhole TDS vs. Time**

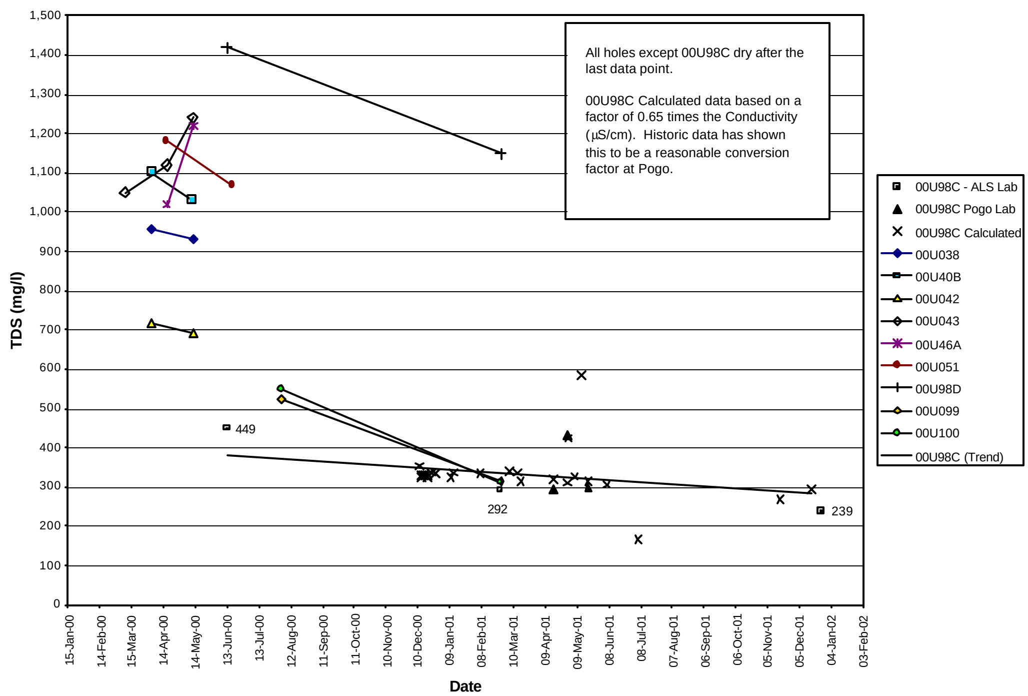
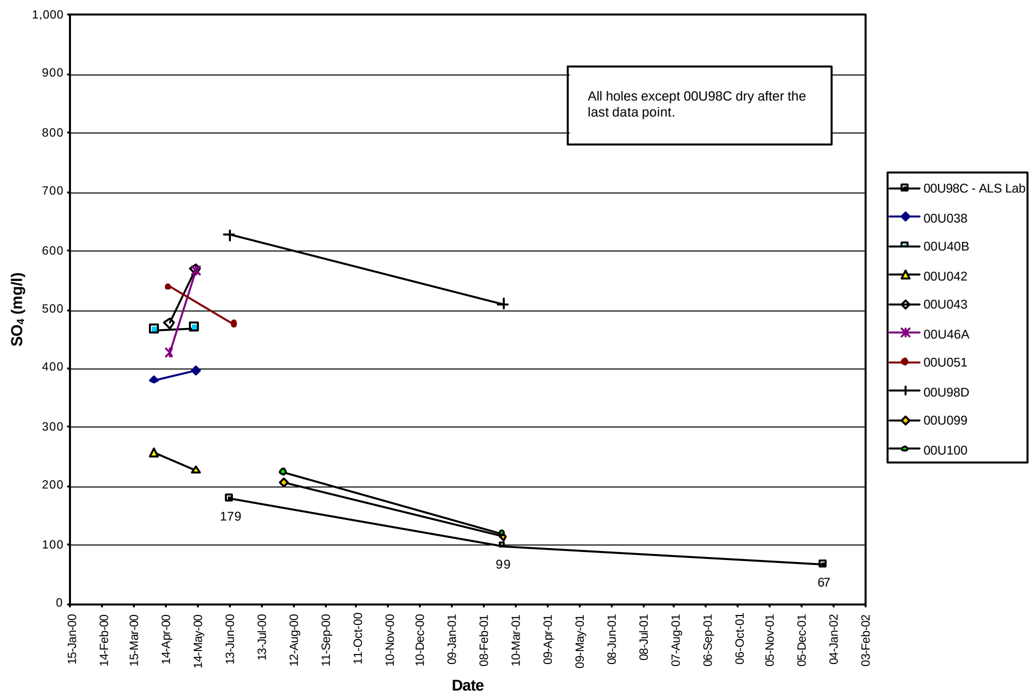


**Figure 4.4: Underground Drillhole $SO_4$ vs. Time**




*Makeup Fresh Water (Section I)* – Fresh makeup water will be pumped into the RTP when water levels are low and accumulated precipitation is insufficient for process plant operation. The fresh water quality has been characterized by the MW98-005 data and is used in the RTP water balance. The supporting data is provided in Appendix F.

**RTP Pumpback**

If some seepage should occur through the RTP composite liner system the intercepting wells and pumpback system will capture this seepage along with runoff from the dam face and return the flow to the RTP. It is assumed that any seepage will be of the same quality as the RTP water.

**Process Water**

Neither the flotation water nor the cyanide destruct water will directly enter the RTP. Only the water associated with the drystack tailings and paste backfill tailings will leave the mill circuit. As noted previously, the CIP tailings slurry stream will be treated for cyanide destruction prior to combination with flotation tailings and placement in the mine.

Pilot Plant testwork indicates that the process will operate solely with water removal through the tailings and paste backfill and does not require a process bleed. The quantity of recycle solution, however, is quite high and if a bleed should become necessary in operations, a treatment plant would be installed on that bleed stream prior to the treated water being discharged to the RTP.

Process water demands will be satisfied on a hierarchical basis: first treated mine drainage will be used and then secondly RTP water. If no other water is available, fresh water will be added to the RTP to meet the process requirement. This allows the process to continue to consume and entrain RTP contaminants in the tailings even during low inflow periods when the process must use fresh water. The seasonal operating strategy will be based on on-going forecasts of supply and demand, with the goal that sufficient water remains in the RTP to supply process needs over the winter.

## 4.4 Net Allowable Discharge Calculation for Model Input

Excess water that will need to be discharged includes site precipitation in excess of evaporation and mine drainage not consumed in the process.

For the purposes of this report, the mine drainage and precipitation flows have been combined to represent the net allowable discharge (NAD). The NAD has been selected based on the $95^{th}$ percentile probability for mine water inflow and precipitation at the Pogo site. This equates to 247 gpm mine drainage and 215 gpm from precipitation runoff, for a total of 462 gpm. It is anticipated that approximately 112 gpm will be consumed by the process, leaving 365 gpm as the high end of the annual quantity to be discharged.

The average quantity to be discharged, under the 19" precipitation scenario and average mine inflows is 148 gpm. To provide adequate operational flexibility and to be able to draw the RTP pond down after storm events, the water treatment plant has been sized to treat 400 gpm, which is the treatment rate that has been used in the model. This is also the discharge rate that Teck will seek to permit.

## 4.5 Water Balance & Quality Calculations

The Pogo water balance and quality model was used to examine the major variables that affect water management, water quality and discharge characteristics under different operating scenarios. These variables and the water quantity and quality modeling are described below.

The modeling was completed using Monte Carlo techniques to vary the inputs according to appropriate probability density functions. Thus, iterations of the water balance were calculated to reflect the various possible combinations of the inputs, including those combinations of statistically infrequent events that could influence the overall design.

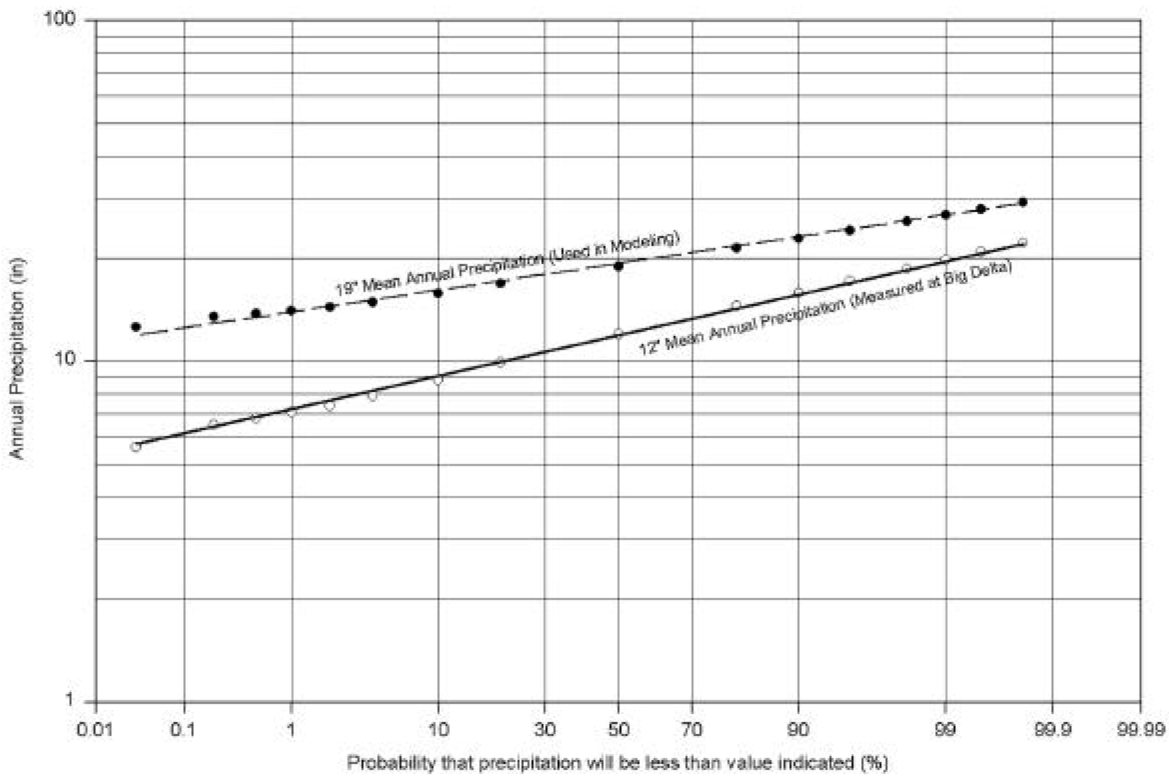
The purpose of the Monte Carlo analysis was to evaluate RTP water quality, the mine drainage quality, predict treatment performance, and to evaluate the likelihood of a release of excess stormwater through the RTP dam spillway.

### 4.5.1 Monte Carlo Model

The model incorporates the following inputs, assumptions, and features:

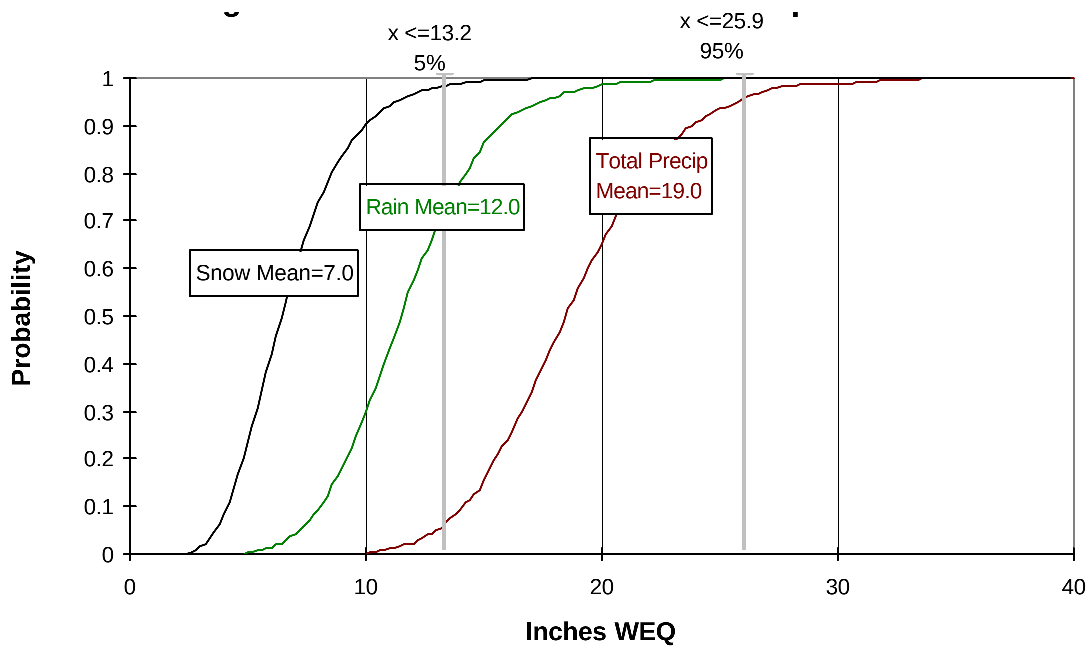
- Water inflows from precipitation are variable depending on climatic cycles and random variations in weather patterns. As described in Appendix B, precipitation events are typically characterized by logNormal probability distributions. As explained in Section 2, the Big Delta data is the best available for determining the frequency of storm events for the Pogo site. Figure 4.5 presents the data developed for the Pogo project as a logNormal probability plot. The curve with the 12" annual average is the Big Delta record. The curve with the 19" annual average has been used for modeling for the purposes of this report. The model input precipitation PDFs are shown in Figure 4.6.
- Weekly precipitation increments from the historical record at Delta Junction have been shown to be statistically independent, so probability functions for weekly precipitation have been developed for the period from breakup until freeze-up and are used to model precipitation on a weekly basis. The Delta long term record was scaled up to reflect the 19" precipitation scenario. The Monte Carlo simulation of weekly probability functions yields an annual precipitation frequency distribution that closely correlates with the actual precipitation annual frequency distribution from historical records.

**Figure 4.5: Mean Annual Precipitation Frequency Analysis**




(Source: Big Delta FAA, 1941-1989 & 1994-1998)

**Figure 4.6: Distribution for Annual Precipitation**




- Based on the 19" precipitation scenario, snowpack was assumed to follow the distribution shown in Figure 4.6, with a mean of 7" and a standard deviation of 2.4. In order to compare this snowpack assumption against regional and site snowpack measurements, the evaluation presented in Appendix B was conducted, which showed an expected mean of 3.2", with a standard deviation of 0.8. The modeled inputs thus appear to be conservative.
- The snow is modelled to melt on a declining balance basis during the month of May according to the distribution described in Table 4.5.
- The diversion ditch flow and Liese basin hydrology were estimated from fixed runoff coefficients, appropriate catchment areas and the randomly selected precipitation for each week. Diversion water quality for SW30 is presented in Table 4.6.

**Table 4.5: Probability Density Function Input Parameters for the Monte Carlo Model**

| Parameter | Distribution | Selected Mean | Selected Standard Deviation | Selected Limits | | Units |
|---|---|---|---|---|---|---|
| Weekly rainfall | Cumulative observed at Big Delta | Prorated Big Delta[1] | Prorated Big Delta[1] | 0 | Prorated Big Delta[2] | inches |
| Starting snowpack | LogNormal | 7 | 2.4 | 0 | none | inches |
| Potential snowmelt | Triangular | 3 | | 0.6 | 7.4 | inches/ week |
| Mine operating year | Integer Uniform | | | 1 | 12 | years |
| Mine shutdown start week | Integer Uniform | | | 1 | 52 | week |
| Mine shutdown duration | Triangular | 9 | | 1 | 20 | weeks |
| Mine shutdown occurrence | Discrete yes or no, with probability input | | | | | |

**1**. Big Delta mean prorated by (desired annual rainfall) / (Big Delta annual rainfall).
**2**. Prorated Big Delta 1:500 event x 1.5.

- Goodpaster flow during storm events was estimated at 700 ft$^3$/s, the approximate average of open water season flows for the 1998 and 1999 hydrologic years. This flow estimate would likely be conservative (low) when compared to the actual storm flows that would accompany any spillway use event. A reasonable low flow estimate of 50 ft$^3$/s was assumed for all non-storm periods. Goodpaster River water quality is presented in Table 4.6.
- Mine inflow water modeling by Adrian Brown ("Pogo Mine Inflow," January 2002) was used as the basis of inflows for the mine water. During normal operations, most of this water will be pumped to the mill, where it will be absorbed as interstitial water in the tailings. The model assumes that excess mine drainage, either during normal operations or during a potential mine shutdown, will be treated and if it of acceptable water quality, can be discharged. However, if it is not of acceptable quality, it will need to be pumped to the RTP pond. This water would be stored in the RTP for subsequent use in the process or re-treatment and disposal through the soil absorption system (SAS).
- Operating year – The site footprint and mine inflows vary according to year. An equal probability was given to each year (see Table 4.5).

### Table 4.6: Surface Water Quality (SW30, SW05 & SW15)

**Diversion Water (SW30)**

| Parameter | Distribution | Selected Mean | Selected Std. Deviation | Reasonable Worst Case | Units |
|---|---|---|---|---|---|
| TSS | LogNormal | 8.67 | 2.08 | 12.8 | mg/l |
| TDS | LogNormal | 81.5 | 24.7 | 131 | mg/l |
| Cl | LogNormal | 0.333 | 0.231 | 0.795 | mg/l |
| $SO_4$ | LogNormal | 3.47 | 0.666 | 4.80 | mg/l |
| TKN | LogNormal | 0.467 | 0.351 | 1.17 | mg/l N |
| $NO_3$ | LogNormal | 0.867 | 0.153 | 1.17 | mg/l |
| $CN_T$ | Constant at RWC | | | 0.01 | mg/l |
| As | LogNormal | 0.00396 | 0.00083 | 0.00561 | mg/l |
| Cd | LogNormal | 3.2E-05 | 1.6E-05 | 0.0000648 | mg/l |
| Cr | LogNormal | 0.00182 | 0.00189 | 0.00560 | mg/l |
| Cu | LogNormal | 0.00158 | 0.00024 | 0.00206 | mg/l |
| Fe | LogNormal | 0.191 | 0.117 | 0.425 | mg/l |
| Pb | LogNormal | 0.0001 | 5.6E-05 | 0.000211 | mg/l |
| Hg | LogNormal | 0.01 | 0.00552 | 0.0210 | µg/l |
| Mn | LogNormal | 0.00346 | 0.00201 | 0.00748 | mg/l |
| Ni | LogNormal | 0.00048 | 0.00036 | 0.00121 | mg/l |
| Se | Constant at RWC | | | 0.001 | mg/l |
| Ag | LogNormal | 1.6E-05 | 5.5E-06 | 2.70E-05 | mg/l |
| Zn | LogNormal | 0.0008 | 0.00019 | 0.00117 | mg/l |

**Lower Liese Creek (SW05)**

| Parameter | Distribution | Selected Mean | Selected Std. Deviation | Reasonable Worst Case | Units |
|---|---|---|---|---|---|
| TSS | Constant at RWC | | | 6 | mg/l |
| TDS | Constant at RWC | | | 128 | mg/l |
| Cl | Constant at RWC | | | 0.1 | mg/l |
| $SO_4$ | Constant at RWC | | | 9.6 | mg/l |
| TKN | Constant at RWC | | | 0.8 | mg/l N |
| $NO_3$ | Constant at RWC | | | 1 | mg/l |
| $CN_T$ | Constant at RWC | | | 0.02 | mg/l |
| As | Constant at RWC | | | 0.005 | mg/l |
| Cd | Constant at RWC | | | 0.0069 | mg/l |
| Cr | Constant at RWC | | | 0.00003 | mg/l |
| Cu | Constant at RWC | | | 0.0025 | mg/l |
| Fe | Constant at RWC | | | 0.0023 | mg/l |
| Pb | Constant at RWC | | | 0.283 | mg/l |
| Hg | Constant at RWC | | | 0.00012 | µg/l |
| Mn | Constant at RWC | | | 0.01 | mg/l |
| Ni | Constant at RWC | | | 0.0083 | mg/l |
| Se | Constant at RWC | | | 0.0013 | mg/l |
| Ag | Constant at RWC | | | 0.0005 | mg/l |
| Zn | Constant at RWC | | | 0.00001 | mg/l |

**Goodpaster River (SW15)**

| Parameter | Distribution | Selected Mean | Selected Std. Deviation | Reasonable Worst Case | Units |
|---|---|---|---|---|---|
| TSS | Constant at RWC | | | 46 | mg/l |
| TDS | Constant at RWC | | | 59 | mg/l |
| Cl | Constant at RWC | | | 0.1 | mg/l |
| $SO_4$ | Constant at RWC | | | 9.5 | mg/l |
| TKN | Constant at RWC | | | 0.6 | mg/l N |
| $NO_3$ | Constant at RWC | | | 0.2 | mg/l |
| $CN_T$ | Constant at RWC | | | 0.005 | mg/l |
| As | Constant at RWC | | | 0.0013 | mg/l |
| Cd | Constant at RWC | | | 0.00003 | mg/l |
| Cr | Constant at RWC | | | 0.0025 | mg/l |
| Cu | Constant at RWC | | | 0.0019 | mg/l |
| Fe | Constant at RWC | | | 1.46 | mg/l |
| Pb | Constant at RWC | | | 0.00085 | mg/l |
| Hg | Constant at RWC | | | 0.01 | µg/l |
| Mn | Constant at RWC | | | 0.06 | mg/l |
| Ni | Constant at RWC | | | 0.002 | mg/l |
| Se | Constant at RWC | | | 0.0005 | mg/l |
| Ag | Constant at RWC | | | 0.00001 | mg/l |
| Zn | Constant at RWC | | | 0.0041 | mg/l |

- Probability of an occurrence of a mine shutdown (5% probability in any year starting in any week and having a possible duration of 1 to 20 weeks, with a nine week mean. See Table 4.5)

- The model incorporates a control for TDS and sulfate ($SO_4$) which evaluates the level of TDS and sulfate in the water being discharged and if this water is higher than the either 500 or 250 respectively, the water is recycled to the RTP. This water is stored in the RTP until it can be mixed with other flows to achieve acceptable levels.

The input probability density functions are defined by the parameters in Tables 4.4 and 4.5. For illustration, representative frequency distribution plots for chemical inputs are shown in Figures 4.7 and 4.8.

The model was run 1,000 times, with each run representing one year of operation. Input parameters were sampled from the probability distributions at the beginning of each iteration. Output values were compiled weekly during each run.

A schematic of the model is presented in Figure 4.9 and a sample input sheet is presented in Table 4.7.

**Figure 4.7: Distribution for Development & Temporary Rock Seepage As**

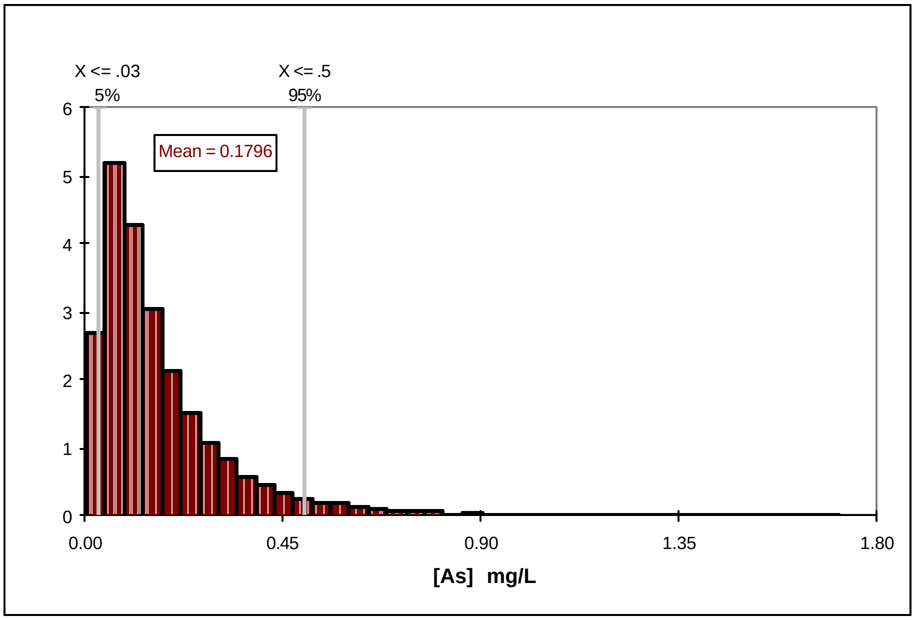
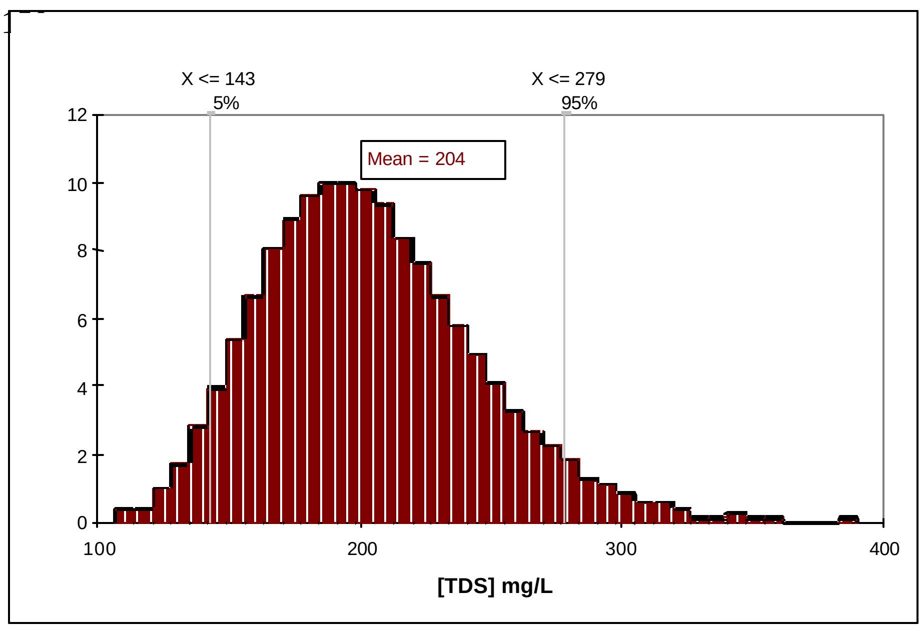
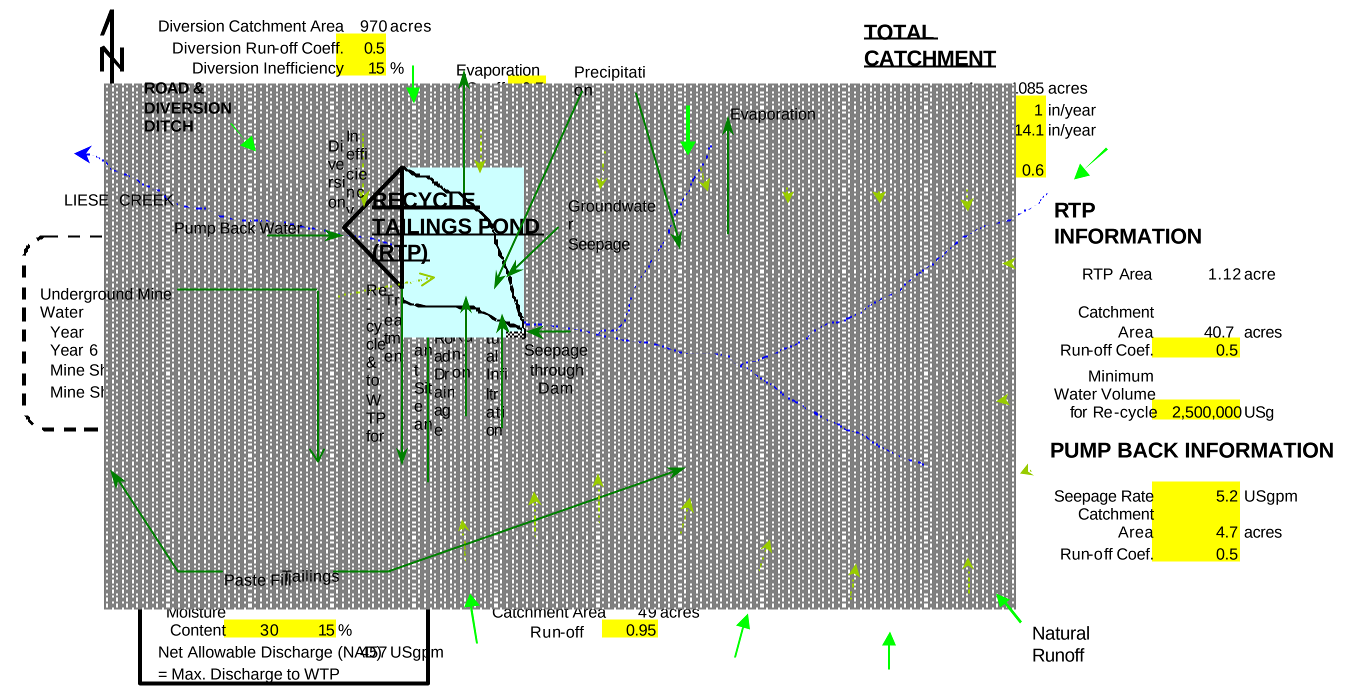



**Figure 4.8: Distribution for Plant Site, Road, & Ditch Drainage TDS**






TECK CORPORATION **Pogo Project**

## LEISE CREEK TAILINGS FACILITY WATER BALANCE

**LEGEND:**

Hydrological Input/Outputs

Input Parameters which can be edited

Not to Scale

**Water Balance Output**

| | |
|---|---|
| **Starting Snowpack - Water Equivalent (WEQ)** | **6.99 inches** |
| **End of Year Pond Storage** | **2,716,245 USg** |
| **Total Required Make-up** | **0 USg** |
| **Make-up Water flow** | **0.0 USgpm** |
| **Overall Water Balance** | **0.0 USgpm** |
| **Annualized Average Discharge** | **125.6 USgpm** |
| **Maximum Pond Volume** | **16,899,328 USg** |

**Figure 4.9 Graphic Input Sheet**

## Table 4.7: Input and Balance Sheet
## Pogo Tailings Facility Monte Carlo Water Balance Model

**Starting Snowpack - Water Equivalent (WEQ) 7.0 inches SWEQ**
**Mine Operating Year Varies Mine Shutdown Probability is 5.0%**

| | | |
|---|---|---|
| **End December Pond Storage** | **2,716,245** | **USg** |
| **Annual Make-up Water** | **0** | **USg** |
| **Make-up Water flow** | **0.0** | **USgpm** |
| **Overall Water Balance** | **0.0** | **USgpm** |
| **Annual Precipitation Inflow** | **125.6** | **USgpm** |
| **Maximum Pond Volume** | **16,899,328** | **Usg** |
| **Maximum Pond Level** | **2,081** | **ft** |

**List of Inputs from Input Sheet and Other Inputs**

| | | | | |
|---|---|---|---|---|
| Starting Snowpack - Water Equivalent (WEQ) | **6.99** | in | | |
| RTP Storage Equation A | 0.409 | | | |
| B | 13.06 | | | |
| NAD Case | **7** | | | |
| Net Allowable Discharge | **462** | USgpm | | |
| Water Treatment Plant Capacity | **400** | USgpm | | |
| Alternate factor on storage for WT flow | 0.00001 | | | |
| Apply after | 22-Jun-01 | | | |
| Threshold for summer treatment | - | USg | | |
| Apply after | 01-Jun-01 | | | |
| and before | 01-Aug-01 | | | |
| Ratio of maximum precip to 1:500 year | **1.5** | | | |
| NAD Option | **5** | | | |
| Pan Evaporation Rate | 14.1 | in/year | | lookup |
| Total RTP Contrib. Catchment Area | **1084.7** | acre | | |
| DS Tailings Production | 1250 | T/d | | lookup |
| DS Tailings Moisture Content | 15 | % | | |
| Insitu DS Tailings Density | 0.0468 | T/cf | | |
| DS Tailings Area | 19.2 | acres | | |
| Paste Tailings Production | 1250 | | | |
| Seepage from DS | 3.0 | USgpm | | |
| Paste Fill Moisture Content | 30 | % | | |
| RTP Area | 1.12 | acres | | |
| RTP Catchment Area | 40.7 | acres | | |
| RTP Catchment Run-off Coef. | 0.5 | | | |
| Plant Site & Road Catchment Area | 49.0 | acres | | |
| Plant Site and Road Run-off Coef. | 0.95 | | | |
| Area J Catchment Area | 4.7 | acres | | |
| Area J Run-off Coef. | 0.50 | | | |
| Diversion Catchment Area (A, B, and F) | 970.0 | acres | | |
| Diversion Run-off Coef. | 0.5 | | | |
| Diversion Inefficiency | 15 | % | | |
| Maximum inefficiency flow | **87** | USgpm | | |
| Pond starting storage | **2,500,000** | Usg | | |
| Min. water required in Pond | **2,500,000** | USg | | |
| Evaporation Coefficient from DS Surface | 0.1 | | | |
| Evaporation Coefficient from Pond Surface | 0.70 | | | |
| Pumping back seepage rate | 5.2 | usgpm | | |
| Pumping back local drainage area | 15.6 | acres | | |
| Pumping back drainage area runoff coef | 0.5 | | | |
| Ore in-situ moisture content | **3** | % | | |
| Mine Operating Year | **6** | | | |
| U/G Mine Water Flow Rate | 56.2 | USgpm | | |
| U/G Fault Water Flow Rate | 73.5 | USgpm | | |
| Mine Shutdown from week to week | **0** | | **0** | |
| Duration of Mine Shutdown | **0** | weeks | | |

**Rainfall Probability Function for Big Delta**

| | **Dist** |
|---|---|
| | Min |
| | 20.0% |
| | 50.0% |
| | 80.0% |
| | 90.0% |
| | 95.0% |
| | 98.0% |
| | 99.8% |
| | Max |
| **Operating ?** | |
| **Week** | # |
| **Starting** | |
| Number of Days | |
| **CLIMATE** | |
| Month | |
| Rainfall | in |
| % of Annual Evaporation | |
| Starting snowpack (WEQ) | in |
| Potential snowmelt (WEQ) | in/week |
| Actual snowmelt (WEQ) | in/week |
| Runoff coefficient | |
| **TAILINGS** | |
| **Dry Stack (DS)** | |
| Monthly DS Tailings Inputs | Tons |
| Monthly DS Tailings Inputs | cf |
| Cumulative DS Tailings Volume | cf |
| **Paste (P)** | |
| Paste Tailings Inputs | Tons |
| **WATER BALANCE** | |
| **Dry Stack (DS)** | |
| ***Inputs flows to DS*** | |
| DS Tailings Water | USg |
| Direct Rainfall | USg |
| Direct Snowmelt | USg |
| Evaporation of Precip. from Dry Stack | USg |
| *Total Inputs to Dry Stack* | USg |
| *Net Runoff Reporting to RTP* **C.** | USg |
| ***Outputs from DS*** | |
| Seepage from Dry Stack **D.** | USg |
| Water Retained in Dry Stack | USg |
| *Total Outputs* | USg |
| *Net Water Reporting to RTP* | USg |
| **Recycle Tailings Pond (RTP)** | |
| ***Inputs*** | |
| Direct Rainfall **E.** | USg |
| Snowmelt E. | USg |

### 4.5.2 Evaluation of Dam Size Based on Model

The RTP dam has been sized to retain snowmelt as well as the 100-year/24-hour event. Monte Carlo modeling allows evaluation of many precipitation and mine drainage scenarios to assess the likelihood of a release of stormwater from the RTP. Modeling shows that there is an insignificant chance that stormwater will be released over the dam spillway, with predicted spillway use of 22 times in 1,000 years. Figure 4.10 presents the probability distribution for stormwater release under the full distribution of precipitation shown in Figure 4.6.

**Figure 4.10: Distribution for Stormwater Release Volume**

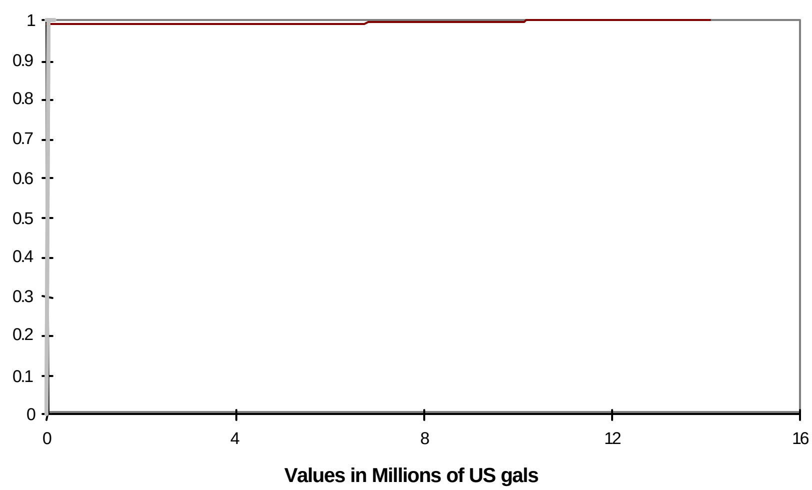
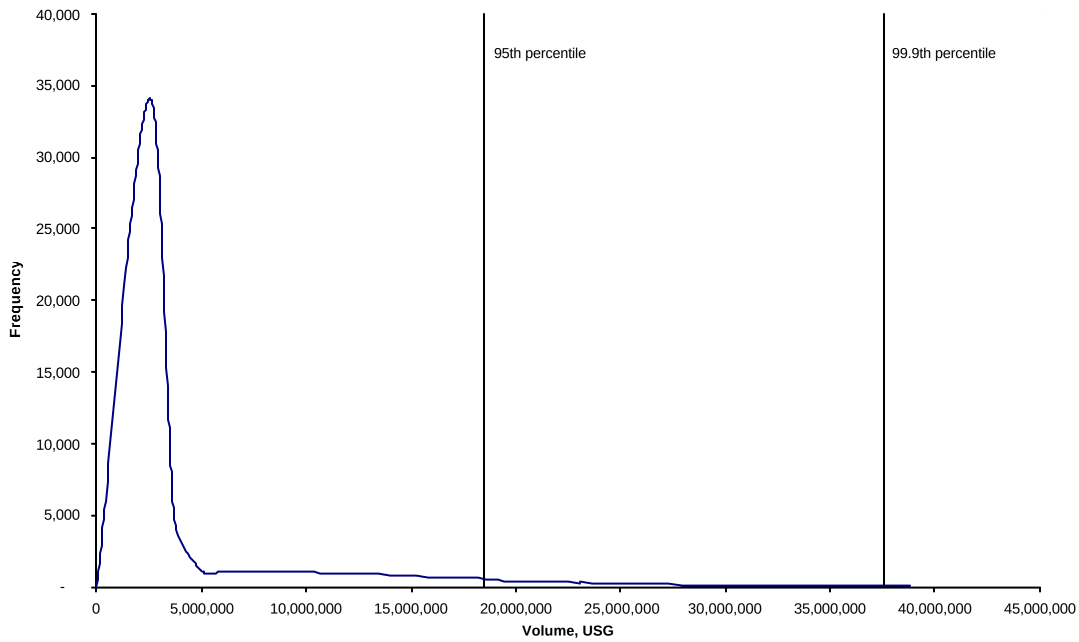



Figure 4.11 below shows that most of the time there is less than 5 Mgal of water in the RTP pond and there is a very low probability that the pond volume will exceed the 40 Mgal dam size. Given that the Monte Carlo modeling considers all snowfall and stormwater inflow events, this analysis provides a high degree of confidence that the dam sizing is adequate and is an appropriate basis for completion of the remainder of the modeling.

**Figure 4.11: Distribution for Maximum Pond Volume, Base Case**




Despite the low probability that such an event would occur, an evaluation of the potential impact on the Goodpaster River of such a stormwater release is presented in Table 4.8 below. The following provides details on the headings of each column in the table.

**RTP**

*95$^{th}$ Percentile of Annual Maxima During Stormwater Discharge* – This is the 95$^{th}$ percentile of the highest value modeled each year during the1,000 iterations.

**Goodpaster**

*Goodpaster (SW15) During Storm Events* – This represents the water quality at SW15 shortly after the peak of the August 2000 storm event.

*95$^{th}$ Percentile of Annual Maxima During Stormwater Discharge* – This is the 95$^{th}$ percentile of the highest valued modeled each year in the Goodpaster during a storm event and after the stormwater from the RTP has mixed with the Goodpaster.

It should be noted that under all cases, the modeling shows there would be no significant adverse effect on the Goodpaster River.

**Table 4.8: Monte Carlo Simulation Results for Maximum Stormwater Discharge Concentrations**

| | RTP | Goodpaster | |
|---|---|---|---|
| Parameter | 95% of Annual Maximum during Stormwater Discharge | Goodpaster (SW15) during Storm Event | 95% of Annual Maximum during Stormwater Discharge |
| TSS (mg/l) | 162 | 46.0 | 45.9 |
| TDS (mg/l) | 407 | 59.0 | 62.0 |
| Cl (mg/l) | 73.6 | 0.100 | 0.262 |
| $SO_4$ (mg/l) | 179.1 | 9.50 | 9.56 |
| TKN (mg/l) | 3.33 | 0.600 | 0.603 |
| $NO_3$ (mg/l) | 13.64 | 0.200 | 0.275 |
| $CN_T$ (mg/l) | 0.01295 | 0.00500 | 0.00517 |
| As (mg/l) | 0.117 | 0.00130 | 0.00178 |
| Cd (mg/l) | 0.000255 | 0.0000300 | 0.0000308 |
| Cr (mg/l) | 0.00534 | 0.00250 | 0.00252 |
| Cu (mg/l) | 0.00741 | 0.00190 | 0.00191 |
| Fe (mg/l) | 4.22 | 1.46 | 1.46 |
| Pb (mg/l) | 0.001529 | 0.000850 | 0.000848 |
| Hg (µg/l) | 0.0851 | 0.0100 | 0.0102 |
| Mn (mg/l) | 0.861 | 0.0600 | 0.0599 |
| Ni (mg/l) | 0.00776 | 0.00200 | 0.00200 |
| Se (mg/l) | 0.00247 | 0.000500 | 0.000518 |
| Ag (mg/l) | 0.000164 | 0.0000100 | 0.0000103 |
| Zn (mg/l) | 0.0682 | 0.00410 | 0.00411 |
| Mean Annual Stormwater Release Volume 2.8 M | 2.8 M | | |

### 4.5.3 Evaluation of Dissolved vs. Total Assumption for Model

Total suspended solids (TSS) will be removed from all flows through the water treatment plant by coagulation, flocculation, settling, and filtration, with expected effluent values for TSS of 20 mg/l or less. For these flows, the use of dissolved values for modeling purposes is appropriate as there will be not be a significant TSS component.

The only flows not going through the water treatment plant will be those that occur during the extremely infrequent stormwater release over the dam spillway. Modeling shows that the 95$^{th}$ percentile of these values, if they were to occur, would be 162 mg/l (Table 4.8) and would not result in a measurable adverse effect on the Goodpaster River.

These results support the assumption that it is appropriate for the water model to focus on dissolved metals concentrations.

### 4.5.4 Monte Carlo Model Overestimates Contaminant Inflows

It should be noted that the manner in which the Monte Carlo model operates probably results in an overstatement of contaminant values during storm events. The Monte Carlo model selects single input values for all input water quality variables at the beginning of each model year. If an extreme high value is randomly selected, this high value is carried forward all year as the quality for a given flow. As the weekly precipitation values are varied, the same quality is applied to the flow. This does not accurately reflect actual conditions, as at high precipitation levels, the mass of contaminants available for leaching and flow into the RTP will tend to remain fixed. The model thus overstates contaminant levels because it does not consider this constant mass effect. A more accurate representation would consider the dilution effect of higher levels of precipitation holding the mass of contaminants constant for flows above a given level or percentile of normal water inflow.

When the random selection of extreme high values for RTP inputs of TDS and $SO_4$ occurs, the control of TDS and $SO_4$ by the model results in recycling all water to the RTP for the year until it is sufficiently mixed to allow it to be discharged. This does not probably reflect true conditions, as the elevated RTP values would most likely not occur for a full year due to the dilution effects described above. Thus the model consequently derives high pond volumes that lead to predicting spill events that would not actually occur. Constructing a model to reflect these condition would add additional complexity and we have chosen to continue modeling as discussed, with appropriate recognition of its limitations.

It should also be noted that the model inputs have used measurements of $CN_T$ with a 10 µg/l detection limit, and that results less than this have been considered as 10 µg/l. This places a strong upward bias on the modeled values for $CN_T$. WAD cyanide levels would be lower (probably 5% to 10% of $CN_T$) than the $CN_T$ represented in the modeling, depending on the particular solution chemistry.

## 4.6 Excess Water Management, Treatment & Discharge

Before final release to the environment, the excess water from the RTP and the mine drainage will be treated by two methods: first, a water treatment plant will remove suspended solids, arsenic and other metals; then a soil absorption system will remove residual ammonia (TKN) and cyanide and provide some polishing reduction of metals. The water treatment plant and soil absorption system are described in Sections 4.7 and 4.8.

## 4.7 Chemical Treatment Process System (Water Treatment Plant)

The water treatment plant for Pogo will utilize two processes to remove contaminants from the water before discharge. These processes are:

- High-Density Sludge (HDS) process to achieve enhanced co-precipitation of metals, including arsenic.
- Lime Softening and Recarbonation to remove calcium and magnesium and thereby reduce TDS.

A third process, sulfide precipitation, will be available as a contingent measure if additional treatment is necessary in order to achieve the expected metals concentrations.

### High Density Sludge (HDS)

The water treatment plant will utilize the high-density sludge (HDS) process to achieve enhanced co-precipitation of metals, mainly arsenic. This process uses ferric hydroxide, which is generated by a combination of ferric chloride and lime. The HDS process includes sludge recycle to maximize solids inventory, sludge density and settling rates.

The process provides high solids inventories, which result in a large surface area to promote the removal of metals such as arsenic and zinc to low concentrations via co-precipitation with iron. An organic polymer or polyelectrolyte is added to flocculate the ferric hydroxide precipitate prior to clarification.

In the first stage, the excess water is dosed with ferric chloride solution. Calcium hydroxide is then added as a milk-of-lime slurry to raise the pH and cause the iron to precipitate. At the elevated pH, ferric iron reacts with the dissolved arsenic to precipitate ferric arsenate:

$$FeCl_3 + H_3AsO_4 \Rightarrow FeAsO_4 + 3HCl$$

The remaining iron is hydrolyzed and precipitates as an amorphous ferric hydroxide having a high surface area:

$$2FeCl_3 + 3Ca(OH)_2 \Rightarrow 2Fe(OH)_3 + 3CaCl_2$$

This surface is capable of adsorbing arsenic, cyanide and key metals so that the treatment achieved may exceed that predicted by thermodynamic equilibrium models. At the elevated pH, other metals (M) are also hydrolyzed and precipitate as hydroxides:

$$M(HCO_3)_2 + 2Ca(OH)_2 \Rightarrow 2CaCO_3 + M(OH)_2 + 2H_2O$$

The ferric and metal hydroxides are highly hydrated and of low density. To separate them from the treated water by settling, they must be formed into flocs that will settle in a clarifier within a reasonable time. To achieve this, long-chain organic molecules are added to the process. These molecules have ionized groups attached at intervals, and these groups adsorb onto the precipitate surface. In this way, these molecules bind the precipitate particles into much larger flocs, which will settle successfully. The iron precipitate will surround and incorporate the suspended solids and other precipitates that are formed in the process, so that a clear solution overflows the clarifier.

The thickened sludge taken from the bottom of the clarifier is mostly recycled to the point of iron addition. Doing so produces a high solids density sufficient for the flocculant molecules to bridge the precipitate particles and work effectively. It also provides a large surface area on which the various precipitates can form, discouraging their formation as scale on the surfaces of the process equipment. When the precipitates deposit in this way, the solid particles grow in size, improving the settling performance in the clarifier.

**Lime Softening & Recarbonation**

The lime softening process involves the addition of hydrated lime ($Ca(OH)_2$) to increase pH through the addition of hydroxyl ion (OH-) and subsequently remove hardness through the precipitation of calcium and magnesium as $CaCO_3$ and $Mg(OH)_2$. The increase in pH converts $CO_2$ and $HCO_3^{-2}$ to $CO_3^{-2}$ which in turn reacts with $Ca^{+2}$ ion to precipitate $CaCO_3$. A reduction in TDS occurs primarily due to the removal of $Ca^{+2}$, $Mg^{+2}$ and $CO_3^{-2}$ ion from solution. The individual reactions associated with the lime softening process are illustrated below:

$$Ca(OH)_2 \Leftrightarrow Ca^{+2} + 2OH-$$

$$Ca^{2+} + 2OH^- + 2CO_2 \Leftrightarrow Ca(HCO_3)_2$$

$$Ca(OH)_2 + Ca(HCO3)2 \Leftrightarrow Ca\ CO_3\mathbf{?} + H_2O$$

$$Mg^{+2} + Ca(OH)_2 \Leftrightarrow Mg(OH)_2\mathbf{?} + Ca^{+2}$$

The lime softening process is conducted in the pH range of 9.8 to 11.2 depending on the degree of hardness removal required and the chemistry of the water. Therefore final pH adjustment is required prior to discharge and can be managed to optimize the effectiveness of the soil absorption system. Neutralization after lime softening can be carried out using carbon dioxide ($CO_2$) gas to avoid the addition of TDS to the water. There are a number of potential mechanisms involved, depending on the chemistry of the water, but the primary mechanism responsible for pH adjustment is the reaction of carbon dioxide with hydroxyl ion to produce bicarbonate ion. Assuming the water contains some residual Ca and Mg the neutralization reaction using $CO_2$, can be summarized by the following mechanisms;

$$Ca^{2+} + 2OH^- + 2CO_2 \Leftrightarrow Ca^{2+} + 2HCO_3^-$$

$$Mg^{2+} + 2OH^- + 2CO_2 \Leftrightarrow Mg^{2+} + 2HCO_3^-.$$

The above combined lime softening and $CO_2$ neutralization process is described as single stage lime softening since Ca remaining in solution after lime addition and solids separation is not subsequently removed but is re-dissolved and converted to soluble $CaHCO_3$ during $CO_2$ neutralization. The testwork and field trials carried out at the Pogo water treatment plant indicate that a removal of 17% of the influent TDS can be expected for the water chemistry seen at the mine (see Appendix L).

**Sulfide Precipitation**

The precipitation process can be enhanced by utilizing a second stage reactor to allow for addition of sodium hydrosulfide (NaHS) or other reagents, to reduce metals such as mercury and silver prior to release to the soil absorption system. Sulfide precipitation takes advantage of the extremely low solubility of these metal sulfides to achieve low levels in the discharge stream.

**Filtration**

The final stage of the treatment system will include a multi-media pressure filter to polish the treated water for removal of residual suspended solids prior to release to the soil absorption system. Excess sludge generated by the process will be dewatered using a filter press to produce a cake for disposal with tailings backfill.

Experience with other HDS systems has indicated that this final filtration step is critical to meeting very low discharge limits. With respect to metals, the proposed treatment system will not be sensitive to variations in feed chemistry.

**System Performance**

Subject to proper design, process optimization and operation, the proposed treatment scheme can typically treat feeds containing metals at concentrations several orders of magnitude greater than the RTP water characteristics predicted by modeling (see Appendix L). Therefore, it should be noted that water treatment plant performance with respect to metals is not sensitive to the accuracy of the water quality estimates for the RTP.

It is important to note, however, that the proposed treatment system will be not be as effective at removing elevated levels of more complex ionic species, such as cyanide and ammonia, as is the case with cations (metals). We know that at other similar treatment plants, the cyanide is typically present as metal complexes. From this fact and based on our experience, the water treatment plant is expected to remove a portion of the cyanide in the feed. Ammonia levels will not be materially affected by the proposed treatment process.

Under short-term upset conditions, ammonia and cyanide concentrations may increase above the projections. Under these conditions, the water treatment plant will not be able to effectively reduce cyanide and ammonia. In this case, the soil absorption system, as described in Section 4.8, would help to reduce these contaminants. The soil absorption system has a demonstrated ability to remove ammonia and cyanide and would also be able to remove residual dissolved metals.

## 4.8 Soil Absorption System & Discharge

### 4.8.1 General

The soil absorption system (SAS) facility is designed to be the final step in a two-step water treatment process. Use of the soil absorption system would be preceded by chemical treatment in the water treatment plant as described above. The entire water treatment system is designed to ensure that the system is protective of the water quality in the Goodpaster River.

The soil absorption system consists of a distribution pipe network placed above an engineered soil column. The system will deliver water at up to 400 gpm from the water treatment plant as required. The water will flow down through the absorption system and into the near-surface alluvium material of the Goodpaster Floodplain. Appendix E describes the preliminary flow modeling for the system.

During its passage through the soil, residual metals will be removed through absorption onto the soil particles and by biological oxidation. Cyanide metal complexes will be removed through absorption, complexation and biological degradation. Ammonia will be removed by biological degradation in a manner analogous to a septic leach field. Diffusion and travel time will result in the attenuation of the treated water producing a clean effluent.

### 4.8.2 Design Criteria

The soil absorption system was designed based on the principles and guidelines published for leach fields. The soil absorption system must be able to accept flows of up to 400 gpm and should have sufficient expansion capability so that a portion of the system can be offline for maintenance without disabling the entire system. The system should also be capable of operating year-round without freezing.

### 4.8.3 Site Selection

Three locations were originally identified as potential sites for a soil absorption facility:

- Goodpaster Valley adjacent to the proposed airstrip.
- Lower Liese Creek hillside (on the north side of Liese Creek).
- Saddle area east of the mill site (upper Liese Creek at the southeast end of Pogo Ridge).

Site investigations were carried out at each of the three potential soil absorption locations. In all boreholes, SPT samples were gathered every 5 ft to a 30 ft depth and every 10 ft thereafter. Selected SPT samples were then chosen for laboratory gradation and Atterberg limits testing.

Conditions at the lower Liese Creek site were not favorable for a soil absorption field for several reasons. Discontinuous permafrost was encountered throughout the area, with zones of visible segregated ice. Also, the soil profile along the bench varied dramatically. In some draws, there were significant amounts of silt and organics encountered and bedrock elevation varied from 17 to 65 ft. These characteristics are not conducive to operating a soil absorption system that requires soils of relatively high permeability to accept the flow of water being introduced.

The remaining two sites both appear to be suitable locations for a soil absorption facility. The upper and lower sites lie on unfrozen ground, which is underlain by overburden materials likely to have relatively high hydraulic conductivities.

The Goodpaster site has a thick overburden layer of up to 80 to 90 feet of rounded, sandy gravels and cobbles. The water table is located at a depth of approximately four to six feet within the alluvial sediments. Pump tests have indicated that the saturated bulk hydraulic conductivities of this material are in the order of $10^{-3}$ to $10^{-4}$ fps. The relatively high bulk hydraulic conductivity of the alluvium is favorable for designing a soil absorption system.

The upper Liese Creek site is located southeast of the plant site on top of Pogo Ridge in close proximity to the water treatment plant. This site would allow for a long flowpath down the Easy Creek basin prior to discharge into the river systems. Overburden at the upper Liese Creek site typically varies between 5 and 15 ft, and consists of silty sand, colluvium and fractured rock. The hydraulic conductivity in this area appears to be in the $10^{-4}$ to $10^{-5}$ fps range in the upper siltier portions of the overburden. Should the site be located in this area, more extensive sampling or in-situ testing should first be done.

In order to make use of gravity feed and the predictable soil conditions, the Goodpaster site has been selected.

### 4.8.4 Column Testing

Laboratory testing was carried out to assess the absorption and degradation properties of the soil readily available at the Pogo site. The testing program was designed and managed by AGRA Simons and carried out at Process Research Associates Ltd. (see Appendix E for details). A brief summary of the program is presented below.

The testing program was designed to evaluate the impact of variations in organic content and feed composition on the removal efficiency of major ions (cyanide, ammonia and thiocyanate) and metals. Two soil mixtures were created from blending coarse sand, aeolian silt and surficial organic peat samples obtained from Pogo. At a rate of approximately 7 gpd/ft$^2$, three different feed solutions were passed through soil column samples that were 4" in diameter and 36" deep. The two soil samples differed in organic content, with a low organic content sample containing 10% organics, 10% silt and 80% sand, and a high organic content sample containing 20% organics, 10% silt and 70% sand.

The removal and polishing capacity of the soil samples was then assessed by running a synthetic mine water solution (domestic water with chemical reagents added) through the samples. When the soil absorption process was selected as a treatment route, the ability of the soils to remove complex ions was further investigated by feeding actual mine water with complex ions into the soil system. This process removed the possibility of a chemical interaction between species contained in domestic water that would not be present in the mine water. Finally, the effect of elevated metals on the removal/polishing capacity of the soils was examined by adding mine water with elevated metals content.

The findings of the study indicated that cyanide was effectively removed providing the feed solution did not initially contain unusually high levels of cyanide. It appeared that biological degradation processes effectively removed thiocyanate in the low organic content soil system, but the higher organic content soil did not offer sufficient oxygen to allow these processes to occur. Once the biological cultures became established in the soil columns (within one to two weeks), ammonia was effectively removed in all scenarios, although the high organic content soils took longer to stabilize.

The soil columns also indicated relatively high capacities for the removal of arsenic, cadmium, selenium, lead, mercury and silver, even when subjected to feed solutions with elevated concentrations of these metals. It also appeared that once immobilized, the metals were not available for re-leaching. The soil columns were generally found to have a slightly acidic environment ranging from pH 6.0 to 6.8, and an oxidation reduction potential of +200 to +300 mV. There were no discernable trends with regard to the removal of nitrates, sulfates or total dissolved solids.

Additional information on the use of soil infiltration systems to polish mine effluent is discussed in “Soil Effluent Treatment by Land Application” in Appendix E.

### 4.8.5 Design Features

**General**

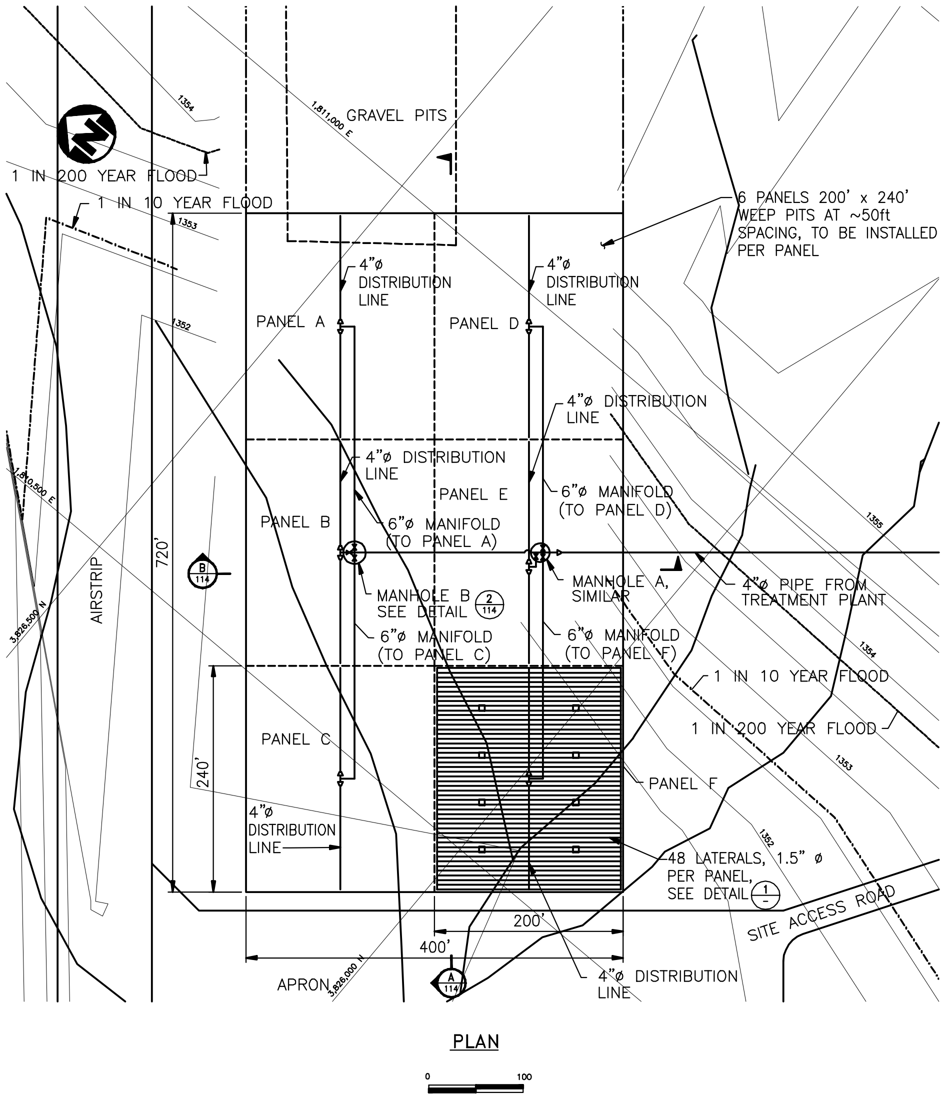
The soil absorption system will consist of a piping distribution network that discharges water from the water treatment plant to a soil layer designed to remove residual metals, cyanide/metal complexes, ammonia, nitrate and other cyanide degradation products. The system will be underlain by the relatively highly permeable alluvium or colluvium typical of the Pogo site.

**Facility Configuration**

The soil absorption system will be a 720 x 400 ft area that will be divided into six, 200 x 240 ft panels, allowing for an average application rate of 2.0 gpd/$ft^2$. The natural ground below the soil absorption system will be stripped of organics and mixed to create an appropriate soil media. Based on the results of the column study, it is recommended that thoroughly mixing a three foot layer of the existing soil column will provide suitable treatment. Based on the column study results, optimal results will be obtained by not blending in additional organic material and by operating with influent at a slightly elevated pH of 9.0. Nitrification processes in the SAS soil column are expected to reduce the pH by 0.5 to 1 unit. The hydraulic conductivity of the material was estimated as $2 \times 10^{-5}$ m/s based on constant head permeability tests. Conforming to the design guidelines for highly treated effluent streams, an application rate of 2.0 gpd/$ft^2$ has been chosen for the soil absorption system design. If necessary, coarse-grained material will be added to increase the permeability of the material.

A buried, insulated three inch diameter pipeline will transport water from the water treatment plant at the plant site to the bottom of Liese Valley. The small diameter of the pipe will dissipate most of the energy from the 1,350 ft drop in elevation. The pipe will then change to a buried, insulated four inch diameter PVC pipe. The four inch pipe will discharge into a six inch distribution manifold. For 60 minutes every six hours, one of six electronically actuated valves will open, distributing flow to the 40, 1.5" laterals in one of the panels. The panels will be dosed in a sequence to spread out the impact and promote proper treatment and operation of the soils absorption system. The soil absorption system field will be covered with mulched organics to provide an insulating layer approximately 3.5 feet thick. Thermal modeling shows that this insulating layer, together with the continuous circulation of 200 gpm of groundwater through the system during cold weather periods, will prevent freezing of the distribution laterals and the soil column, so that the system is available if needed for discharge during the winter or early spring. The mulched organics will ultimately provide a rich source of organics for reclamation and closure activities. The sides will be sloped at 3H:1V to help prevent against erosion and sloughing of the insulating material. Figures 4.12 and 4.13 show the location, arrangement and details of the proposed soil absorption system. Appendix E provides details on the recommended location of the wells for the circulation system, as well as the thermal analysis.

In the event of a problem with the SAS, the flow from the water treatment plant would be halted until the system could be put back into operation. Three-dimensional flow modeling of the soil absorption system indicated that under the base case soil conditions, dissipating the input flows within the floodplain appeared feasible (see Appendix E). The most notable difference between the scenarios was the variation in flowpath. Modeling a permafrost zone east of the soil absorption system and applying a 400 gpm flow resulted in a change in the hydraulic head distribution, causing the water to take a more direct path to the river. Sensitivity analyses indicated that if the hydraulic conductivity were significantly lower than assumed and the K-ratio was significantly higher than assumed, a soil absorption system input of 400 gpm may be too high to ensure that all flow will report to the floodplain aquifer without producing some surface flow. To address this potential concern, a series of weep trenches will be placed within the footprint of the system. These weep trenches will be 10 to 20 ft deep and backfilled with drain rock.



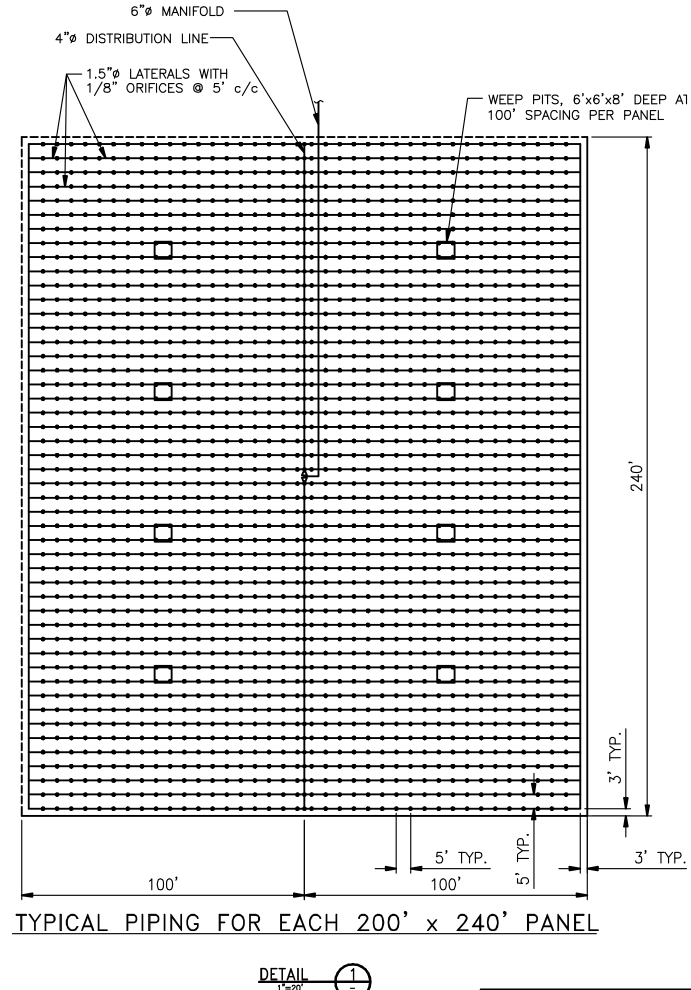




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Figure 4.12
Goodpaster
Soil Absorption System
G.A. & Details

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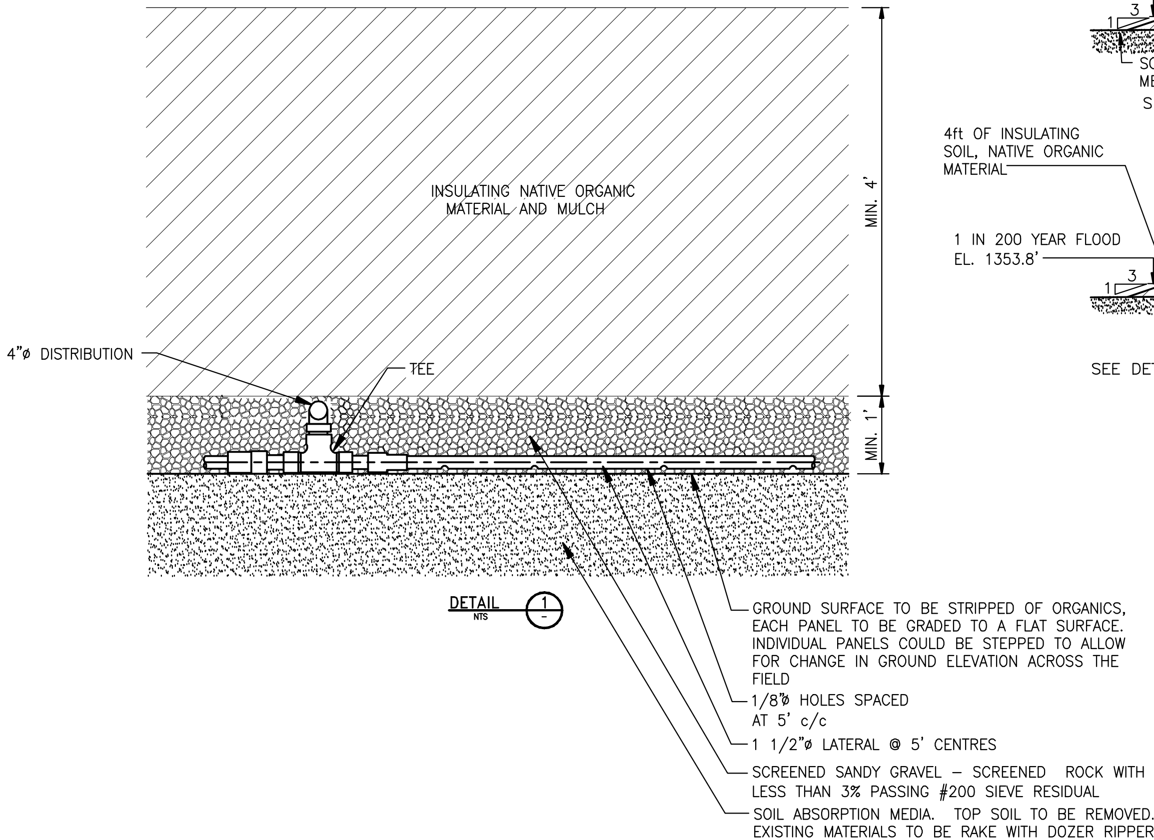
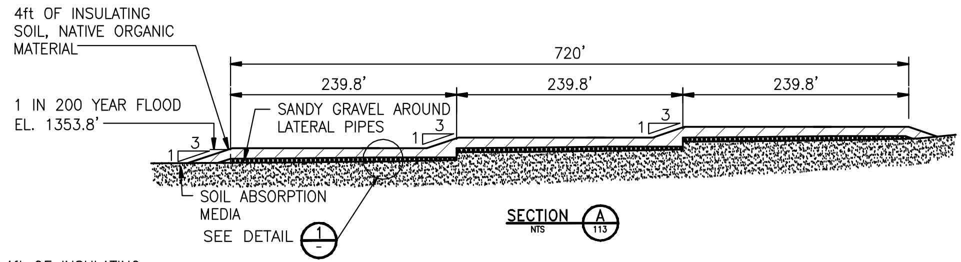
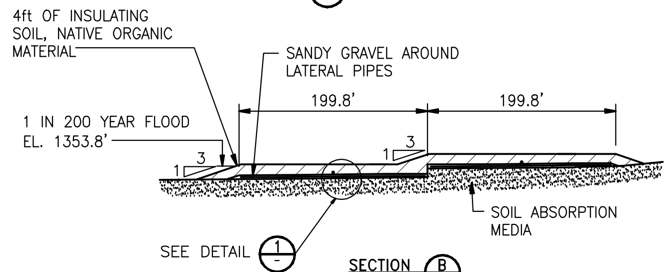



DETAIL 1 – NTS




SECTION A 113 – NTS

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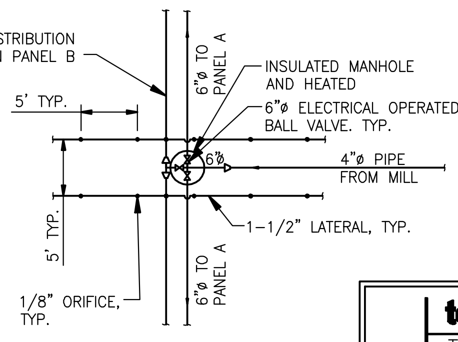


DETAIL 2 113 – NTS

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Figure 4.13
Goodpaster
Soil Absorption System
Sections & Details

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## 4.9 Stormwater

An application will be made for coverage under the general stormwater permit. Well-defined practices known as "BMPs" (best management practices) will be used for stormwater management to control runoff water quality. The primary parameter that will need to be controlled is sediment. Care will be exercised to control oils and greases at their sources to ensure stormwater does not become contaminated with these materials.

In accordance with national standards, stormwater BMPs will adhere to the following design criteria:

- design and construct drainage ditches as required
- provide spill planning, spill control materials and response teams to rapidly control oil, chemical or other spills that may affect stormwater
- reclaim disturbed areas as soon as practicable after disturbance; this will include regrading, topsoil establishment, revegetation with approved seed mixes and plantings, and maintenance of reclaimed areas to help establish the program
- maintain roads and traveled areas to minimize erosion
- grade roads and disturbed areas so that flows are directed to appropriate control facilities; maintain grading frequently.

Stormwater BMPs will be detailed in a "Stormwater Pollution Prevention Plan" as part of project operation planning.

## 4.10 Closure Water Management Concept

Upon closure, the site will be completely reclaimed. This will include removing all buildings and structures, and recontouring and revegetating all disturbed areas. The tailings drystack will have been contoured during development to match surrounding landforms and will be capped appropriately upon closure to limit infiltration and promote revegetation. The mine will have been backfilled with cemented mill tailings as a standard operating procedure during active mining and processing. The RTP dam will be breached, recontoured and revegetated.

Surface runoff will initially be managed as stormwater with appropriate BMPs. After reclamation has been in place and has proven successful, no additional runoff treatment will be performed. The only two other potential closure water sources will be mine drainage and tailings stack seepage.

Due to the low hydraulic conductivity of the rock, no long-term effect on Goodpaster River water quality is expected. Seepage from the tailings drystack will be small during operations and will diminish to even lower values while reclamation and revegetation are being completed.

### 4.10.1 Water Characteristics on Closure

Closure water will include runoff from reclaimed sites and a small flow of dry tailings seepage. The runoff from reclaimed sites would ultimately be of natural background quality. Runoff water will be managed using stormwater BMPs. As reclamation becomes more established, sediment will be increasingly controlled by the revegetation process. BMPs would be eliminated gradually as water quality improves and stabilizes.

Tailings seepage is expected to exhibit the water quality outlined in Table 4.4, Section D. Seepage flow has been modeled using SEEP/W and is expected to be about 6 gpm at its peak in year 12, just prior to closure. This peak flow would diminish as the pile drains and is capped and reclaimed. The anticipated seepage rate is based on an assumed moisture content of 15% in the pressure filtered tailings material.

### 4.10.2 Closure Water Management

The following activities would be completed before mine closure:

- The mine will be sealed by use of a combination of select paste backfill placement and hydraulic plugs in all portals, vent raises, and internal development workings as appropriate. The objective will be to prevent mine drainage out of the mine openings and to re-establish a groundwater regime near the mine that is hydrogeologically discontinuous, as is the existing groundwater regime.
- Evaluate the need for a continued RTP dam. Seepage from the drystack tailings is estimated to decline over the long term. As such, it may be logical to combine Liese Creek base flows within an engineered attenuation/absorption system within the Liese Creek drainage. Modeling of the seepage quantity and quality from the drystack is summarized in Appendices C and D.
- Decommission the diversion ditch and armor the drystack appropriately to provide long-term protection against surficial erosion.

Modeling for closure of the underground hydrogeologic regime indicates that the mine will flood and return to an equilibrium flow condition over a period of approximately 50 years. Due to the low bulk hydraulic conductivity of the rock mass, movement of water down-gradient towards the Goodpaster floodplain will be very slow. Adrian Brown has provided an analysis of the post-mining groundwater chemistry (see Appendix K), which shows small and generally undetectable changes in water quality in the Goodpaster River upon closure. With respect to the closure requirement for the RTP dam, preliminary modeling indicates that recombining closure tailings seepage of about 6 gpm with Liese Creek base flows near the site of the RTP will result in water quality similar to that of the pre-development Liese Creek water. Runoff from the drystack tailings facility will be monitored and evaluated to determine the timing of RTP dam removal.

# SECTION 5 | WATER TREATMENT & DISCHARGE

## 5.1 Treatment Predictions

This section presents the results of the modeling described in Section 4, and develops appropriate conclusions based on this work. The Monte Carlo water balance and quality model described in Section 4 has been used to generate predicted water quality for the various streams of interest for the Pogo project.

The results are presented in Table 5.1 for the base case Monte Carlo modeling of both inflows and water quality chemistry. Table 5.2 presents the results when the inflows are varied according to the Monte Carlo simulation but all water quality inputs are set to the reasonable worst case values. Table 5.3 presents the results for the case of a mine shutdown (Monte Carlo modeling of inflows and chemistry).

The table columns and content are explained as follows.

**RTP Quality** – This is the water quality in the RTP pond.

*RTP Mean Annual Average* – Weekly results for each annual iteration are averaged over the year and the mean of the 1,000 iterations is reported.

*RTP 95$^{th}$ Annual Average* – Weekly results for each annual iteration are averaged and the 95$^{th}$ percentile of the 1,000 iterations is reported.

*RTP 95$^{th}$ Annual Maxima* – Weekly results for each annual iteration is compiled, the maxima is selected, and the 95$^{th}$ percentile of the 1,000 iterations is reported.

**WTP Feed Quality** – This is water quality of feed to the water treatment plant, including water from the RTP, mine drainage and backfill drainage.

*WTP Feed Mean Annual Average* – Weekly results for each annual iteration are averaged over the year and the mean of the 1,000 iterations is reported.

*WTP Feed 95$^{th}$ Annual Average* – Weekly results for each annual iteration are averaged and the 95$^{th}$ percentile of the 1,000 iterations is reported.

*WTP Feed 95$^{th}$ Annual Maxima* – Weekly results for each annual iteration are compiled, the maxima is selected, and the 95$^{th}$ percentile of the 1,000 iterations is reported.

**WTP Treatment** – This describes the predicted effectiveness of the chemical water treatment plant during normal operations (see Appendix L).

**SAS Feed Quality** – After consideration of the WTP feed quality and the WTP treatment effectiveness, this is the water quality of the feed to the soil absorption system. WTP feed values that are lower than the treatment limits report through the water treatment plant unchanged.

*SAS Feed Mean Annual Average* – Weekly results for each annual iteration are compiled, with the mean of the 1,000 interations reported.

*SAS Feed 95% Annual Average* – Weekly results for each annual iteration are averaged and the 95th percentile of the 1,000 iterations is reported.

*Upset* – This is the value that could occur if short-term process upsets in the operations or water treatment plant are not detected and corrected. For the metals, the upset condition was assumed to be two times the water treatment plant effluent. For anions, TSS and TDS, this was taken as two times the WTP 95% annual average. For CN, the value was assumed to be 0.2 mg/l.

**SAS Treatment** – This is the amount, based on testwork and engineering judgment, by which the soil absorption system is expected to remove contaminants. These factors reflect the fact that the removal efficiency of the SAS is expected to be lower at lower influent concentrations.

**After SAS Treatment** – Given the removal efficiencies of the SAS, this is the water quality after the water passes through the SAS soil column.

**Groundwater Mixing, Attenuation & Dispersivity** – After the water passes through the SAS soil column, there is an additional thickness of unprepared soil that will provide further treatment. Following passage through this basal soil layer, natural groundwater processes will further attenuate and reduce the contaminant levels, including dilution of the advective portion of the flow, diffusion and dispersion. Natural groundwater flow in the area is estimated to be approximately equal to the SAS effluent volumes. Furthermore, the flow from the SAS will pass through a considerable saturated soil column that will provide additional conditioning of the mixed flow. Taken together, these elements are difficult to quantify, but will certainly be a significant factor in mitigating the potential effect of the SAS effluent on the Goodpaster River. To represent the combined effects of these processes, an assumption of 1:1 mixing with the groundwater has been assumed.

**Potential Water Quality in Goodpaster River** – This is water quality in the Goodpaster River, assuming the SAS flow would directly enter the Goodpaster River. As shown in Appendix E, this is not expected to be the case, as flow modeling indicates that a portion of the flow will continue down-gradient at depth. For this analysis, an assumed flow of 800 gpm (1:1 mixing with the groundwater as noted above) at the quality indicated after mixing, attenuation and dispersivity, is assumed to mix with the Goodpaster River with Goodpaster River flowing at 50 cfs, which based on observed conditions, is a reasonable winter low flow estimate.

*Goodpaster Quality* – This is the average Goodpaster water quality, reported as total recoverable, as reflected by SW15.

*Dissolved to Total Translator* – This is the translator used to convert the results of the model from dissolved to total recoverable so that they can be compared to the total recoverable standard (see Appendix L).

*Annual Average* – Annual Goodpaster water quality in total recoverable.

*95$^{th}$ Percentile* – 95$^{th}$ Percentile Goodpaster water quality in total recoverable.

*Upset Condition* – Upset water quality in total recoverable.

*Goodpaster Criteria* – Assumed existing water quality standard in the Goodpaster River, calculated at 5$^{th}$ percentile hardness of 27.

**Water Treatment and Quality Predictions**

Table 5.1 shows the results of the evaluation with chemical input concentrations varied according to the probability functions as described in Table 4.4 and flows varied according to their probability density functions or predicted values as described in Section 4.

Table 5.2 shows the results of the evaluation with chemical inputs held constant at the reasonable worse case concentrations and inflows varied according to their probability density functions.

Table 5.3 above shows the results of an evaluation under an assumed mine shutdown case. This case assumed that a mine shutdown would occur for the full 52 weeks of the model year, with the 1,000 iterations run to examine the effects of varying the other inputs. Based on the way the model is constructed, the predicted result is applicable for mine shutdowns of any extended duration, including 1, 3 or 5 years. It should be noted that the other cases included a 5% chance of a short-term mine shutdown of 1 to 20 weeks' duration.

These tables show that under the given scenarios, the combined treatment provided by the water treatment plant and the soil absorption system will ensure that the release of treated effluent has no significant adverse effect on the Goodpaster River.

**Table 5.1: Water Treatment & Water Quality Predictions – Base Case**

| Parameter | RTP Quality | | | WTP Feed Quality | | | WTP Treatment | SAS Feed Quality | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | RTP Mean Annual Average Dissolved | RTP 95% Annual Average Dissolved | RTP 95% Annual Maximum Dissolved | WTP Feed Mean Annual Average Dissolved | WTP Feed 95% Annual Average Dissolved | WTP Feed 95% Annual Maximum Dissolved | Estimate for Treated Effluent | SAS Feed Mean Annual Average Dissolved | SAS Feed 95% Annual Average Dissolved | Upset Dissolved |
| TSS (mg/l) | 32.4 | 89.4 | 262 | 462 | 1,064 | 1,483 | 20 | 19.2 | 20 | 40 |
| TDS (mg/ l) | 281 | 396 | 559 | 352 | 465 | 640 | 85% | 317 | 402 | 930 |
| Cl (mg/ l) | 85.1 | 228 | 573 | 52.6 | 139 | 546 | Note1 | 99.0 | 139 | 279 |
| $SO_4$ (mg/ l) | 102.0 | 168 | 230 | 132 | 200 | 269 | Note1 | 139 | 201 | 401 |
| TKN (mg/ l) | 2.31 | 4.86 | 8.94 | 4.39 | 7.55 | 10.12 | Note1 | 4.49 | 7.55 | 15.1 |
| $NO_3$ (mg/l) | 7.04 | 13.8 | 18.1 | 7.60 | 12.3 | 16.9 | Note1 | 8.4 | 13.1 | 24.6 |
| $CN_T$ (mg/l) | 0.0125 | 0.0172 | 0.0303 | 0.0164 | 0.0227 | 0.0327 | Note1 | 0.0163 | 0.0227 | 0.200 |
| As (mg/ l) | 0.184 | 0.488 | 1.136 | 1.68 | 3.79 | 5.36 | 0.03 | 0.0300 | 0.0300 | 0.0600 |
| Cd (mg/ l) | 0.00017 | 0.00027 | 0.00035 | 0.00029 | 0.00046 | 0.00062 | 0.0003 | 0.00022 | 0.00029 | 0.00060 |
| Cr (mg/ l) | 0.00314 | 0.00600 | 0.0116 | 0.00587 | 0.00967 | 0.0131 | 0.03 | 0.00561 | 0.00967 | 0.06000 |
| Cu (mg/ l) | 0.00513 | 0.00767 | 0.00985 | 0.0122 | 0.0219 | 0.0319 | 0.005 | 0.00483 | 0.00500 | 0.0100 |
| Fe (mg/ l) | 0.678 | 1.23 | 1.66 | 1.71 | 3.26 | 4.25 | 0.30 | 0.300 | 0.300 | 0.600 |
| Pb (mg/ l) | 0.00052 | 0.00090 | 0.00115 | 0.0207 | 0.0488 | 0.0695 | 0.001 | 0.00075 | 0.00100 | 0.00200 |
| Hg (µg/l) | 0.0731 | 0.104 | 0.170 | 0.129 | 0.212 | 0.283 | 0.10 | 0.0797 | 0.100 | 0.200 |
| Mn (mg/l) | 0.364 | 0.885 | 1.32 | 0.492 | 0.884 | 1.25 | 0.20 | 0.197 | 0.200 | 0.400 |
| Ni (mg/ l) | 0.00588 | 0.0144 | 0.0297 | 0.0133 | 0.0239 | 0.0341 | 0.03 | 0.0125 | 0.0226 | 0.0600 |
| Se (mg/ l) | 0.00252 | 0.00504 | 0.00979 | 0.00354 | 0.00494 | 0.00779 | 0.002 | 0.00193 | 0.00200 | 0.00400 |
| Ag (mg/ l) | 0.00006 | 0.00008 | 0.00010 | 0.00007 | 0.00010 | 0.00013 | 0.0001 | 0.00007 | 0.00009 | 0.00020 |
| Zn (mg/ l) | 0.0304 | 0.0541 | 0.0789 | 0.0286 | 0.0438 | 0.0669 | 0.015 | 0.0150 | 0.0150 | 0.0300 |

*Table 5.1: Water Treatment & Water Quality Predictions – Continued*

| | SAS Treatment | | | After SAS Treatment | | | Groundwater Mixing, Attenuation & Dispersivity | | | | Potential Water Quality in Goodpaster River | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Treatment for Mean %** | **Treatment for 95th Percentile** | **Treatment for Upset** | **Mean Annual Average Dissolved** | **95th Percentile Annual Average Dissolved** | **Upset Dissolved** | **Ground-water Quality** | **Mean Annual Average Dissolved** | **95th Percentile Annual Average Dissolved** | **Upset Dissolved** | **Goodpaster Quality Total** | **Dissolved to Total Xlator** | **Annual Average Goodpaster** | **95th Percentile Goodpaster** | **Upset Goodpaster** | **Goodpaster Criteria** |
| TSS (mg/l) | 0% | 0% | 0% | 19.2 | 20.0 | 40.0 | 7.65 | 13.42 | 13.8 | 23.8 | 5.70 | 1.00 | 5.97 | 5.98 | 6.32 | 30 |
| TDS (mg/l) | 0% | 0% | 0% | 317 | 402 | 930 | 88.8 | 203 | 246 | 509 | 75.0 | 1.00 | 79.4 | 80.9 | 90.0 | 100 |
| Cl (mg/l) | 0% | 0% | 0% | 99.0 | 139.3 | 279 | 0.388 | 49.7 | 69.8 | 139.5 | 0.340 | 1.00 | 2.04 | 2.7 | 5.13 | 230 |
| $SO_4$ (mg/l) | 0% | 0% | 0% | 139 | 201 | 401 | 27.5 | 83.5 | 114 | 214 | 16.7 | 1.00 | 19.0 | 20.1 | 23.5 | 250 |
| TKN (mg/l) | 30% | 30% | 60% | 3.14 | 5.28 | 6.04 | 0.117 | 1.63 | 2.70 | 3.08 | 0.200 | 1.00 | 0.249 | 0.286 | 0.299 | 10 |
| $NO_3$ (mg/l) | 0% | 0% | 0% | 9.8 | 15.4 | 33.7 | 0.148 | 4.28 | 6.65 | 19.9 | 0.232 | 1.00 | 0.371 | 0.453 | 0.910 | 10 |
| $CN_T$ (mg/l) | 30% | 30% | 60% | 0.01143 | 0.0159 | 0.0800 | 0.00250 | 0.00697 | 0.00920 | 0.0413 | 0.00430 | 1.00 | 0.00439 | 0.00447 | 0.00557 | 0.0052 |
| As (mg/l) | 40% | 40% | 80% | 0.0180 | 0.0180 | 0.0120 | 0.00073 | 0.00936 | 0.00936 | 0.00636 | 0.00029 | 0.87 | 0.00065 | 0.00065 | 0.00053 | 0.05 |
| Cd (mg/l) | 0% | 0% | 0% | 0.00022 | 0.00029 | 0.00060 | 0.0003 | 0.00012 | 0.00016 | 0.00032 | 0.00002 | 0.92 | 0.00003 | 0.00003 | 0.0003 | 0.0004 |
| Cr (mg/l) | 40% | 40% | 80% | 0.00337 | 0.00580 | 0.01200 | 0.00036 | 0.00187 | 0.00308 | 0.00618 | 0.00089 | 0.68 | 0.00095 | 0.00102 | 0.00117 | 0.071 |
| Cu (mg/l) | 5% | 5% | 10% | 0.00459 | 0.00475 | 0.00900 | 0.00063 | 0.00261 | 0.00269 | 0.00481 | 0.00088 | 0.92 | 0.00095 | 0.00095 | 0.00103 | 0.0039 |
| Fe (mg/l) | 25% | 25% | 50% | 0.225 | 0.225 | 0.300 | 0.102 | 0.163 | 0.163 | 0.201 | 0.147 | 0.32 | 0.160 | 0.160 | 0.164 | 0.30 |
| Pb (mg/l) | 0% | 0% | 0% | 0.00075 | 0.00100 | 0.00200 | 0.00015 | 0.00045 | 0.00057 | 0.0011 | 0.00048 | 0.75 | 0.00048 | 0.00049 | 0.000151 | 0.0006 |
| Hg (µg/l) | 0% | 0% | 0% | 0.0797 | 0.100 | 0.200 | 0.00519 | 0.0424 | 0.0526 | 0.103 | 0.00660 | 0.87 | 0.0081 | 0.0085 | 0.01043 | 0.012 |
| Mn (mg/l) | 0% | 0% | 0% | 0.197 | 0.200 | 0.400 | 0.0323 | 0.1145 | 0.116 | 0.216 | 0.0101 | 0.89 | 0.0142 | 0.0143 | 0.0181 | 0.050 |
| Ni (mg/l) | 40% | 40% | 80% | 0.00751 | 0.0135 | 0.01200 | 0.00024 | 0.00387 | 0.00689 | 0.00612 | 0.00062 | 0.94 | 0.00074 | 0.00085 | 0.00082 | 0.052 |
| Se (mg/l) | 40% | 40% | 80% | 0.00116 | 0.00120 | 0.00080 | 0.00050 | 0.00083 | 0.00085 | 0.00065 | 0.00060 | 0.76 | 0.00062 | 0.00062 | 0.00061 | 0.005 |
| Ag (mg/l) | 0% | 0% | 0% | 0.00007 | 0.00090 | 0.00020 | 0.00001 | 0.00004 | 0.00005 | 0.00010 | 0.00001 | 0.39 | 0.00001 | 0.00001 | 0.0002 | 0.00012 |
| Zn (mg/l) | 30% | 30% | 60% | 0.01050 | 0.01050 | 0.0120 | 0.00117 | 0.00583 | 0.00583 | 0.00658 | 0.00107 | 0.95 | 0.00124 | 0.00124 | 0.00127 | 0.035 |

**Notes**: **1**. WTP not effective at treatment for these parameters. **2**. Goodpaster flow taken as 50 cfs. **3**. Standard is 1.33 times background.

**Table 5.2: Water Treatment & Water Quality Predictions – RWC Chemistry Inputs**

| Parameter | RTP Quality | | | WTP Feed Quality | | | WTP Treatment | SAS Feed Quality | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | RTP Mean Annual Average Dissolved | RTP 95% Annual Average Dissolved | RTP 95% Annual Maximum Dissolved | WTP Feed Mean Annual Average Dissolved | WTP Feed 95% Annual Average Dissolved | WTP Feed 95% Annual Maximum Dissolved | Estimate for Treated Effluent | SAS Feed Mean Annual Average Dissolved | SAS Feed 95% Annual Average Dissolved | Upset Dissolved |
| TSS (mg/l) | 83.7 | 101 | 288 | 379 | 897 | 1,483 | 20 | 20.0 | 20.0 | 40 |
| TDS (mg/l) | 439 | 760 | 1,512 | 446 | 760 | 1,512 | 85% | 345 | 392 | 1,519 |
| Cl (mg/l) | 104 | 318 | 788 | 86.1 | 297 | 751 | Note1 | 93.3 | 108 | 595 |
| $SO_4$ (mg/l) | 229 | 409 | 947 | 219 | 409 | 947 | Note1 | 146 | 175 | 817 |
| TKN (mg/l) | 4.12 | 5.85 | 10.2 | 5.32 | 7.89 | 10.6 | Note1 | 4.40 | 7.66 | 15.8 |
| $NO_3$ (mg/l) | 12.4 | 14.2 | 16.7 | 11.6 | 13.8 | 16.7 | Note1 | 13.9 | 15.9 | 27.6 |
| $CN_T$ (mg/l) | 0.0129 | 0.0173 | 0.0292 | 0.0160 | 0.0224 | 0.0314 | Note1 | 0.0140 | 0.0215 | 0.200 |
| As (mg/l) | 0.342 | 0.935 | 2.34 | 1.36 | 3.12 | 5.36 | 0.03 | 0.0300 | 0.0300 | 0.0600 |
| Cd (mg/l) | 0.00050 | 0.00097 | 0.00233 | 0.00050 | 0.00097 | 0.00233 | 0.0003 | 0.00029 | 0.00030 | 0.00060 |
| Cr (mg/l) | 0.00507 | 0.00714 | 0.0125 | 0.00666 | 0.00971 | 0.0131 | 0.03 | 0.00555 | 0.00954 | 0.0600 |
| Cu (mg/l) | 0.00875 | 0.0126 | 0.01996 | 0.0128 | 0.0200 | 0.0310 | 0.005 | 0.00498 | 0.00500 | 0.0100 |
| Fe (mg/l) | 2.44 | 5.93 | 13.94 | 2.70 | 5.93 | 13.94 | 0.30 | 0.300 | 0.300 | 0.600 |
| Pb (mg/l) | 0.00103 | 0.00143 | 0.00263 | 0.0152 | 0.0401 | 0.0695 | 0.001 | 0.00094 | 0.00100 | 0.00200 |
| Hg (µg/l) | 0.188 | 0.376 | 0.927 | 0.200 | 0.376 | 0.927 | 0.10 | 0.0977 | 0.100 | 0.200 |
| Mn (mg/l) | 1.02 | 1.74 | 2.73 | 0.953 | 1.74 | 2.73 | 0.20 | 0.200 | 0.200 | 0.400 |
| Ni (mg/l) | 0.0149 | 0.0234 | 0.0595 | 0.0181 | 0.0249 | 0.0595 | 0.03 | 0.0118 | 0.0219 | 0.0600 |
| Se (mg/l) | 0.00895 | 0.0233 | 0.0595 | 0.00791 | 0.0233 | 0.0595 | 0.002 | 0.00200 | 0.00200 | 0.00400 |
| Ag (mg/l) | 0.00018 | 0.00037 | 0.00092 | 0.00016 | 0.00037 | 0.00092 | 0.0001 | 0.00010 | 0.00010 | 0.00020 |
| Zn (mg/l) | 0.0846 | 0.164 | 0.344 | 0.0694 | 0.164 | 0.344 | 0.015 | 0.0150 | 0.0150 | 0.0300 |

*Table 5.2: Water Treatment & Water Quality Predictions – Continued*

| | SAS Treatment | | | After SAS Treatment | | | Groundwater Mixing, Attenuation & Dispersivity | | | | Potential Water Quality in Goodpaster River | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | Treatment for Mean % | Treatment for 95th Percentile | Treatment for Upset | Mean Annual Average Dissolved | 95th Percentile Annual Average Dissolved | Upset Dissolved | Ground-water Quality | Mean Annual Average Dissolved | 95th Percentile Annual Average Dissolved | Upset Dissolved | Goodpaster Quality Total | Dissolved to Total Xlator | Annual Average Goodpaster | 95th Percentile Goodpaster | Upset Goodpaster | Goodpaster Criteria |
| TSS (mg/l) | 0% | 0% | 0% | 20.0 | 20.0 | 40.0 | 7.65 | 13.83 | 13.8 | 23.8 | 5.70 | 1.00 | 5.98 | 5.98 | 6.32 | 30 |
| TDS (mg/l) | 0% | 0% | 0% | 334 | 392 | 1,519 | 88.8 | 217 | 241 | 804 | 75.0 | 1.00 | 79.9 | 81 | 100 | 100 |
| Cl (mg/l) | 0% | 0% | 0% | 93.3 | 108.1 | 595 | 0.388 | 46.9 | 54.3 | 297.7 | 0.340 | 1.00 | 1.94 | 2.20 | 10.57 | 230 |
| $SO_4$ (mg/l) | 0% | 0% | 0% | 146 | 175 | 817 | 27.5 | 86.8 | 101 | 422 | 16.7 | 1.00 | 19.1 | 19.6 | 30.7 | 250 |
| TKN (mg/l) | 30% | 30% | 60% | 3.08 | 5.36 | 6.31 | 0.117 | 1.60 | 2.74 | 3.21 | 0.200 | 1.00 | 0.248 | 0.287 | 0.304 | 10 |
| $NO_3$ (mg/l) | 0% | 0% | 0% | 15.2 | 18.2 | 37.0 | 0.148 | 7.03 | 8.02 | 21.7 | 0.232 | 1.00 | 0.466 | 0.500 | 0.972 | 10 |
| $CN_T$ (mg/l) | 30% | 30% | 60% | 0.00977 | 0.0151 | 0.0800 | 0.00250 | 0.00613 | 0.00879 | 0.0413 | 0.00430 | 1.00 | 0.00436 | 0.00445 | 0.00557 | 0.0052 |
| As (mg/l) | 40% | 40% | 80% | 0.0180 | 0.0180 | 0.0120 | 0.00073 | 0.00936 | 0.00936 | 0.00636 | 0.00029 | 0.87 | 0.00065 | 0.00065 | 0.00053 | 0.05 |
| Cd (mg/l) | 0% | 0% | 0% | 0.00029 | 0.00030 | 0.00060 | 0.00003 | 0.00016 | 0.00017 | 0.00032 | 0.00002 | 0.92 | 0.00003 | 0.00003 | 0.00003 | 0.0004 |
| Cr (mg/l) | 40% | 40% | 80% | 0.00333 | 0.00573 | 0.01200 | 0.00036 | 0.00185 | 0.00305 | 0.00618 | 0.00089 | 0.68 | 0.00095 | 0.00101 | 0.00117 | 0.071 |
| Cu (mg/l) | 5% | 5% | 10% | 0.00474 | 0.00475 | 0.00900 | 0.00063 | 0.00268 | 0.00269 | 0.00481 | 0.00088 | 0.92 | 0.00095 | 0.00095 | 0.00103 | 0.0039 |
| Fe (mg/l) | 25% | 25% | 50% | 0.225 | 0.225 | 0.300 | 0.102 | 0.163 | 0.163 | 0.201 | 0.147 | 0.32 | 0.16 | 0.160 | 0.164 | 0.30 |
| Pb (mg/l) | 0% | 0% | 0% | 0.00094 | 0.00100 | 0.00200 | 0.00015 | 0.00054 | 0.00057 | 0.0011 | 0.00048 | 0.75 | 0.00048 | 0.00049 | 0.00051 | 0.0006 |
| Hg (µg/l) | 0% | 0% | 0% | 0.0977 | 0.100 | 0.200 | 0.00519 | 0.0515 | 0.0526 | 0.103 | 0.00660 | 0.87 | 0.00841 | 0.00845 | 0.0104 | 0.012 |
| Mn (mg/l) | 0% | 0% | 0% | 0.200 | 0.200 | 0.400 | 0.0323 | 0.1161 | 0.116 | 0.216 | 0.0101 | 0.89 | 0.0143 | 0.0143 | 0.0181 | 0.050 |
| Ni (mg/l) | 40% | 40% | 80% | 0.00706 | 0.0131 | 0.01200 | 0.00024 | 0.00365 | 0.00669 | 0.00612 | 0.00062 | 0.94 | 0.00073 | 0.00084 | 0.00082 | 0.052 |
| Se (mg/l) | 40% | 40% | 80% | 0.00120 | 0.00120 | 0.00080 | 0.00050 | 0.00085 | 0.00085 | 0.00065 | 0.00060 | 0.76 | 0.00062 | 0.00062 | 0.00061 | 0.005 |
| Ag (mg/l) | 0% | 0% | 0% | 0.00010 | 0.00010 | 0.00020 | 0.00001 | 0.00005 | 0.00005 | 0.00010 | 0.00001 | 0.39 | 0.00001 | 0.00001 | 0.00002 | 0.00012 |
| Zn (mg/l) | 30% | 30% | 60% | 0.0105 | 0.0105 | 0.0120 | 0.00117 | 0.00583 | 0.00583 | 0.00658 | 0.00107 | 0.95 | 0.00124 | 0.00124 | 0.00127 | 0.035 |

**Notes**: **1**. WTP not effective at treatment for these parameters. **2**. Goodpaster flow taken as 50 cfs. **3**. Standard is 1.33 times background.

## Table 5.3: Water Treatment & Water Quality Predictions – Mine Shutdown Case

| | RTP Quality | | | WTP Feed Quality | | | WTP Treatment | SAS Feed Quality | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | RTP Mean Annual Average Dissolved | RTP 95% Annual Average Dissolved | RTP 95% Annual Maximum Dissolved | WTP Feed Mean Annual Average Dissolved | WTP Feed 95% Annual Average Dissolved | WTP Feed 95% Annual Maximum Dissolved | Estimate for Treated Effluent | SAS Feed Mean Annual Average Dissolved | SAS Feed 95% Annual Average Dissolved | Upset Dissolved |
| TSS (mg/l) | 26.4 | 63.7 | 248.5 | 678 | 1,102 | 1,479 | 20 | 20.0 | 20.0 | 40 |
| TDS (mg/ l) | 351 | 427 | 518 | 478 | 594 | 917 | 85% | 392 | 439 | 1,098 |
| Cl (mg/ l) | 94.0 | 159.0 | 277 | 62.4 | 129.2 | 229 | Note1 | 86.5 | 99.4 | 258 |
| $SO_4$ (mg/ l) | 166.0 | 250 | 390 | 217 | 296 | 417 | Note1 | 184 | 218 | 591 |
| TKN (mg/ l) | 4.13 | 5.82 | 9.89 | 6.99 | 7.98 | 10.22 | Note1 | 5.92 | 7.86 | 16.0 |
| $NO_3$ (mg/l) | 8.39 | 13.9 | 17.1 | 9.23 | 12.3 | 15.1 | Note1 | 9.1 | 13.4 | 24.6 |
| $CN_T$ (mg/l) | 0.0179 | 0.0253 | 0.0417 | 0.0250 | 0.0296 | 0.0422 | Note1 | 0.0208 | 0.0238 | 0.0.200 |
| As (mg/ l) | 0.129 | 0.302 | 0.750 | 2.44 | 3.98 | 5.33 | 0.03 | 0.0300 | 0.0300 | 0.0600 |
| Cd (mg/ l) | 0.00021 | 0.00027 | 0.00035 | 0.00039 | 0.00048 | 0.00069 | 0.0003 | 0.00029 | 0.00030 | 0.000600 |
| Cr (mg/ l) | 0.00515 | 0.00744 | 0.0128 | 0.00896 | 0.01026 | 0.0131 | 0.03 | 0.000749 | 0.010111 | 0.06000 |
| Cu (mg/ l) | 0.00547 | 0.00752 | 0.00958 | 0.0174 | 0.0227 | 0.0408 | 0.005 | 0.00500 | 0.00500 | 0.0100 |
| Fe (mg/ l) | 0.652 | 1.09 | 1.55 | 2.23 | 3.36 | 4.24 | 0.30 | 0.300 | 0.300 | 0.600 |
| Pb (mg/ l) | 0.00064 | 0.00091 | 0.00109 | 0.0313 | 0.0512 | 0.0692 | 0.001 | 0.00100 | 0.00100 | 0.00200 |
| Hg (µg/l) | 0.0766 | 0.098 | 0.131 | 0.169 | 0.219 | 0.299 | 0.10 | 0.0997 | 0.100 | 0.200 |
| Mn (mg/l) | 0.366 | 0.772 | 1.272 | 0.571 | 0.812 | 1.101 | 0.20 | 0.200 | 0.200 | 0.400 |
| Ni (mg/ l) | 0.01195 | 0.0179 | 0.0301 | 0.0226 | 0.0254 | 0.0359 | 0.03 | 0.0179 | 0.0238 | 0.0600 |
| Se (mg/ l) | 0.00233 | 0.00319 | 0.00588 | 0.00443 | 0.00499 | 0.01152 | 0.002 | 0.00200 | 0.00200 | 0.00400 |
| Ag (mg/ l) | 0.00007 | 0.00009 | 0.00010 | 0.00010 | 0.00011 | 0.00015 | 0.0001 | 0.00009 | 0.0000100 | 0.00020 |
| Zn (mg/ l) | 0.0305 | 0.0504 | 0.0751 | 0.0273 | 0.0360 | 0.0545 | 0.015 | 0.0150 | 0.0150 | 0.0300 |

*Table 5.3: Water Treatment & Water Quality Predictions – Continued*

| | SAS Treatment | | | After SAS Treatment | | | Groundwater Mixing, Attenuation & Dispersivity | | | | Potential Water Quality in Goodpaster River | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Treatment for Mean %** | **Treatment for 95th Percentile** | **Treatment for Upset** | **Mean Annual Average Dissolved** | **95th Percentile Annual Average Dissolved** | **Upset Dissolved** | **Ground-water Quality** | **Mean Annual Average Dissolved** | **95th Percentile Annual Average Dissolved** | **Upset Dissolved** | **Goodpaster Quality Total** | **Dissolved to Total Xlator** | **Annual Average Goodpaster** | **95th Percentile Goodpaster** | **Upset Goodpaster** | **Goodpaster Criteria** |
| TSS (mg/l) | 0% | 0% | 0% | 20.0 | 20.0 | 40.0 | 7.65 | 13.83 | 13.8 | 23.8 | 5.70 | 1.00 | 5.98 | 5.98 | 6.32 | 30 |
| TDS (mg/l) | 0% | 0% | 0% | 392 | 439 | 1,908 | 88.8 | 240 | 264 | 593 | 75.0 | 1.00 | 80.7 | 81.5 | 92.8 | 100 |
| Cl (mg/l) | 0% | 0% | 0% | 86.5 | 99.4 | 258 | 0.388 | 43.4 | 49.9 | 129.4 | 0.340 | 1.00 | 1.823 | 2.046 | 4.78 | 230 |
| $SO_4$ (mg/l) | 0% | 0% | 0% | 184 | 218 | 591 | 27.5 | 105.8 | 123 | 309 | 16.7 | 1.00 | 19.8 | 20.4 | 26.8 | 250 |
| TKN (mg/l) | 30% | 30% | 60% | 4.14 | 5.50 | 6.38 | 0.117 | 2.13 | 2.81 | 3.25 | 0.200 | 1.00 | 0.266 | 0.290 | 0.0305 | 10 |
| $NO_3$ (mg/l) | 0% | 0% | 0% | 10.9 | 15.8 | 34.1 | 0.148 | 4.65 | 6.79 | 20.3 | 0.232 | 1.00 | 0.384 | 0.458 | 0.924 | 10 |
| $CN_T$ (mg/l) | 30% | 30% | 60% | 0.0145 | 0.0167 | 0.0800 | 0.00250 | 0.00851 | 0.00959 | 0.0413 | 0.00430 | 1.00 | 0.00445 | 0.00448 | 0.00557 | 0.0052 |
| As (mg/l) | 40% | 40% | 80% | 0.0180 | 0.0180 | 0.0120 | 0.00073 | 0.00936 | 0.00936 | 0.00636 | 0.00029 | 0.87 | 0.00065 | 0.00065 | 0.00053 | 0.05 |
| Cd (mg/l) | 0% | 0% | 0% | 0.00029 | 0.00030 | 0.00060 | 0.00003 | 0.00016 | 0.00017 | 0.00032 | 0.00002 | 0.92 | 0.00003 | 0.00003 | 0.00003 | 0.0004 |
| Cr (mg/l) | 40% | 40% | 80% | 0.00449 | 0.00606 | 0.01200 | 0.00036 | 0.00243 | 0.00321 | 0.00618 | 0.00089 | 0.68 | 0.00098 | 0.00124 | 0.00117 | 0.071 |
| Cu (mg/l) | 5% | 5% | 10% | 0.00475 | 0.00475 | 0.00900 | 0.00063 | 0.00269 | 0.00269 | 0.00481 | 0.00088 | 0.92 | 0.00095 | 0.00095 | 0.00103 | 0.0039 |
| Fe (mg/l) | 25% | 25% | 50% | 0.225 | 0.225 | 0.300 | 0.102 | 0.163 | 0.163 | 0.201 | 0.147 | 0.32 | 0.160 | 0.160 | 164 | 0.30 |
| Pb (mg/l) | 0% | 0% | 0% | 0.00100 | 0.00100 | 0.00200 | 0.00015 | 0.00057 | 0.00057 | 0.0011 | 0.00048 | 0.75 | 0.00049 | 0.00049 | 0.00051 | 0.0006 |
| Hg (µg/l) | 0% | 0% | 0% | 0.0997 | 0.100 | 0.200 | 0.00519 | 0.0524 | 0.0526 | 0.103 | 0.00660 | 0.87 | 0.00845 | 0.00845 | 0.01043 | 0.012 |
| Mn (mg/l) | 0% | 0% | 0% | 0.200 | 0.200 | 0.400 | 0.0323 | 0.1161 | 0.116 | 0.216 | 0.0101 | 0.89 | 0.0143 | 0.0143 | 0.0181 | 0.050 |
| Ni (mg/l) | 40% | 40% | 80% | 0.0108 | 0.0143 | 0.0120 | 0.00024 | 0.00550 | 0.00726 | 0.00612 | 0.00062 | 0.94 | 0.00080 | 0.00086 | 0.00082 | 0.052 |
| Se (mg/l) | 40% | 40% | 80% | 0.00120 | 0.00120 | 0.00080 | 0.00050 | 0.00085 | 0.00085 | 0.00065 | 0.00060 | 0.76 | 0.00062 | 0.00062 | 0.00061 | 0.005 |
| Ag (mg/l) | 0% | 0% | 0% | 0.00009 | 0.00010 | 0.00020 | 0.00001 | 0.00005 | 0.00005 | 0.00010 | 0.00001 | 0.39 | 0.00001 | 0.00001 | 0.00002 | 0.00012 |
| Zn (mg/l) | 30% | 30% | 60% | 0.0105 | 0.0105 | 0.0120 | 0.00117 | 0.00583 | 0.00583 | 0.00658 | 0.00107 | 0.95 | 0.00124 | 0.00124 | 0.00127 | 0.035 |

**Notes**: **1**. WTP not effective at treatment for these parameters. **2**. Goodpaster flow taken as 50 cfs. **3**. Standard is 1.33 times background.

## 5.2 Discussion of Model Results

The average weekly RTP pond volume computed under a scenario of annual precipitation of 19" and maximum mine water inflow is shown in Figure 5.1. The volume surge in early May is a result of snowpack melting. If one assumes that a 100-year/24-hour precipitation event is concurrent with the snowmelt peak in week 4, the combined volume approaches 30 Mgal. The water treatment plant begins operating as soon as water is available, and continues at 400 gpm until the pond volume returns to the minimum pool volume of 2.5 Mgal. A chart of discharge volumes vs. time under this scenario is shown in Figure 5.2.

Frequency distribution plots for select water quality parameters under average conditions in the RTP are presented in Figures 5.3 through 5.6.

Sensitivity analyses for RTP water quality for arsenic and TDS are shown in Figures 5.7 and 5.8. These show the strongest positive correlation with tailings seepage inputs.

Sensitivity analyses for Water Treatment Plant feed concentrations for select parameters are shown in Figures 5.9 through 5.13. Many of these show a negative correlation with mine operating year, which reflects the influence of the mine drainage on the WTP feed. Note that in Figure 5.13, there is a negative correlation between mine operating year and Non-Liese Creek Fault Zone mine inflows, which is believed to be the link to the correlations with mine operating year.

**Figure 5.1: Water Volume in RTP, Maximum Expected Mine Inflow – 19" Precipitation**

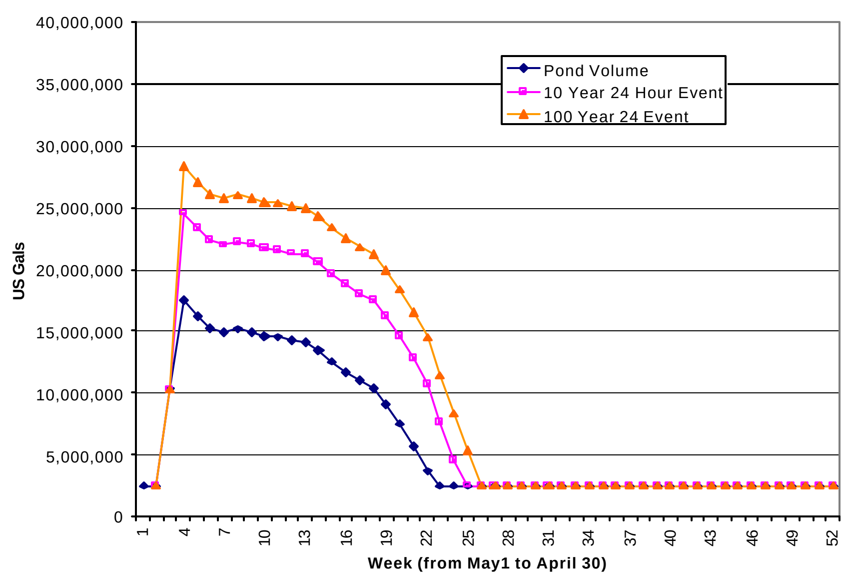


**Figure 5.2: Water Treated & Pumped to SAS for Maximum Expected Mine Inflow & 19" Precipitation**

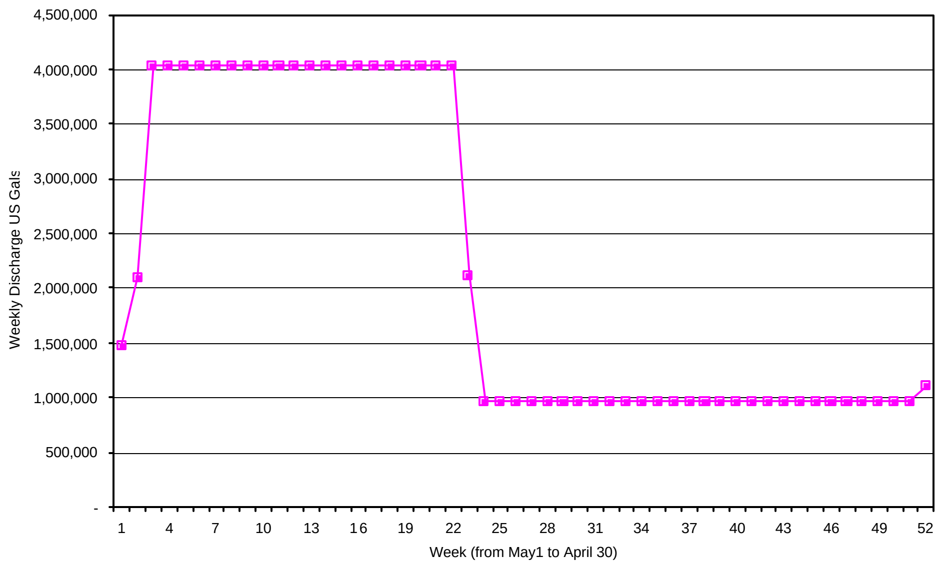



**Figure 5.3: Distribution for Average RTP TDS Concentrate**

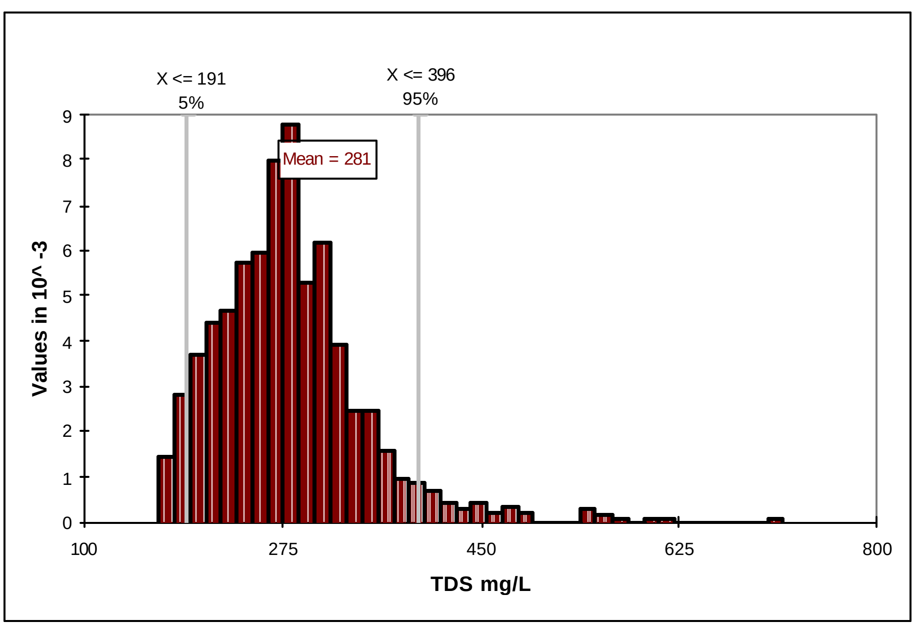


**Figure 5.4: Distribution for Average RTP CN Concentrate**

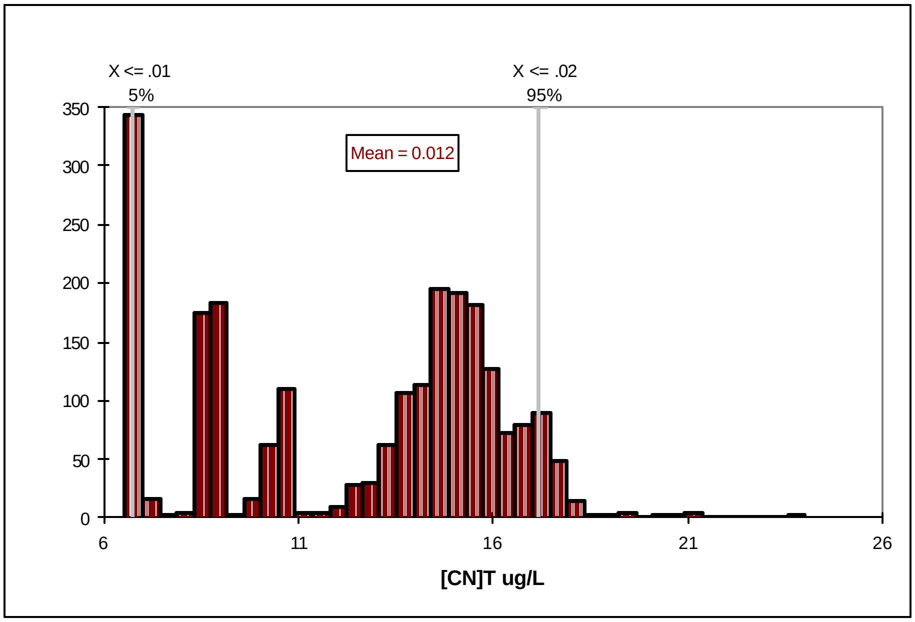



**Figure 5.5: Distribution for Average RTP Zn Concentrate**

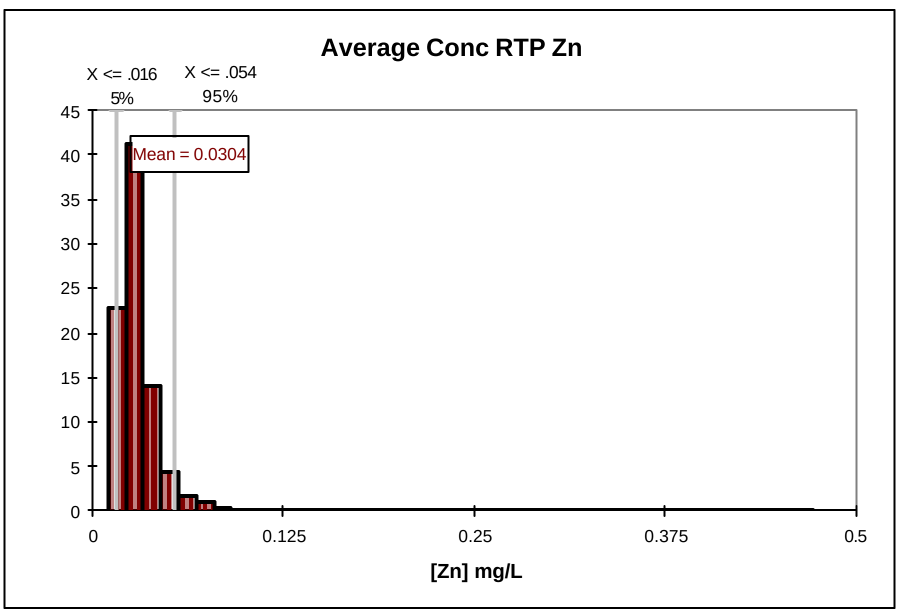


**Figure 5.6: Distribution for Average Concentrate RTP Zn**

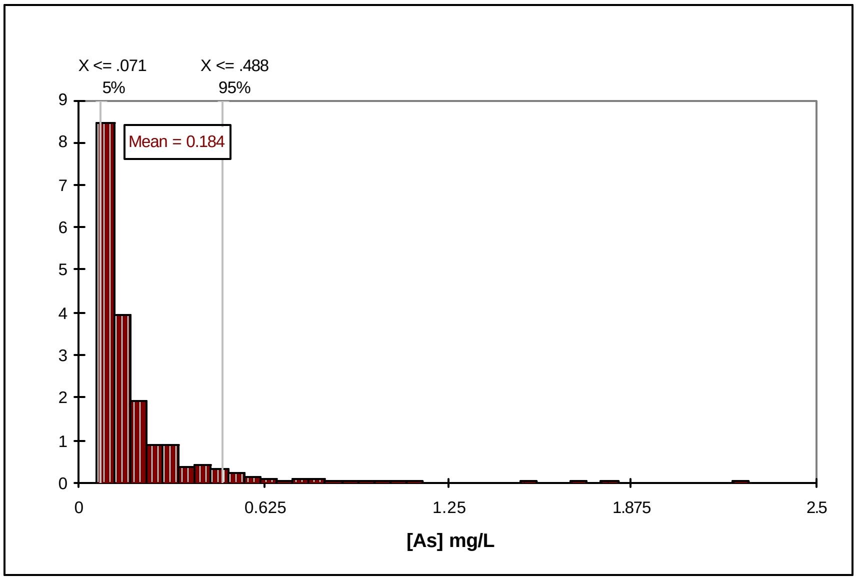



**Figure 5.7: Regression Sensitivity for Average Concentrate RTP As/BK299**

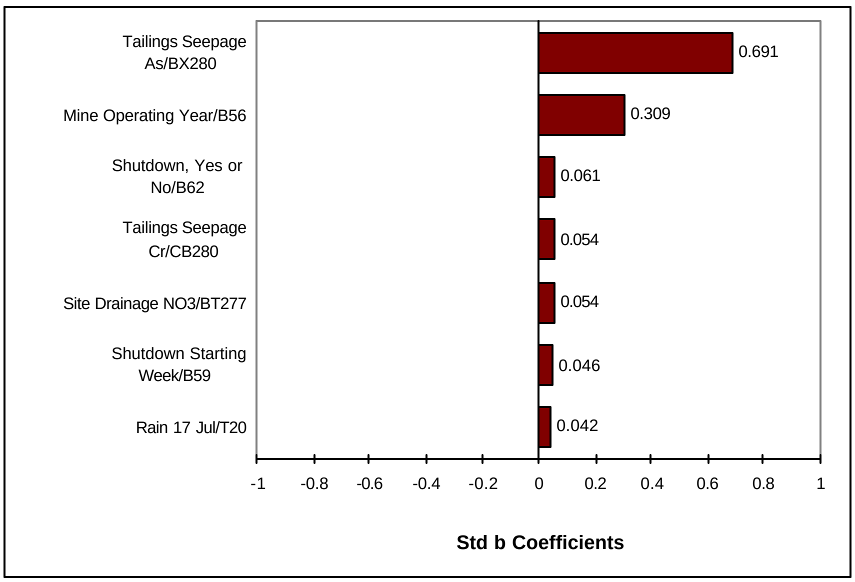


**Figure 5.8: Regression Sensitivity for Average Concentrate RTP TDS/BK291**

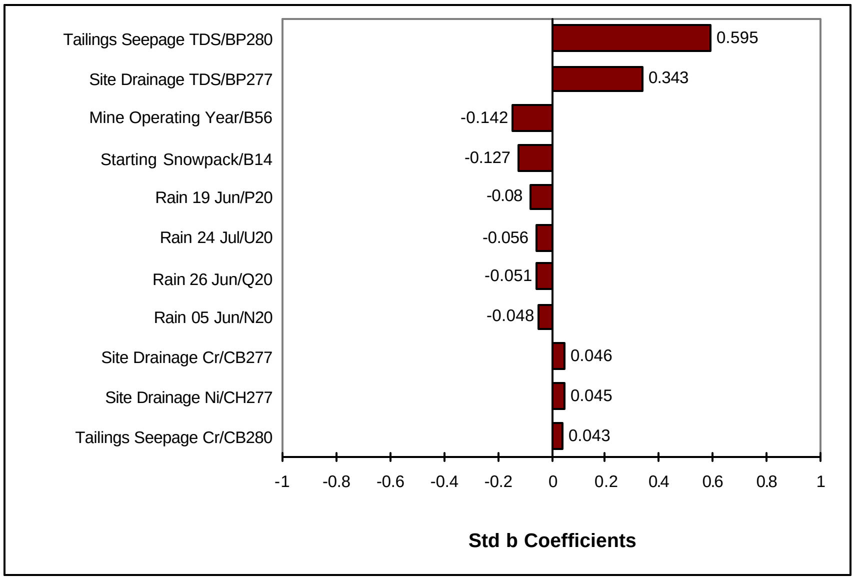



**Figure 5.9: Regression Sensitivity for Average WTP Feed TDS/ BK125**

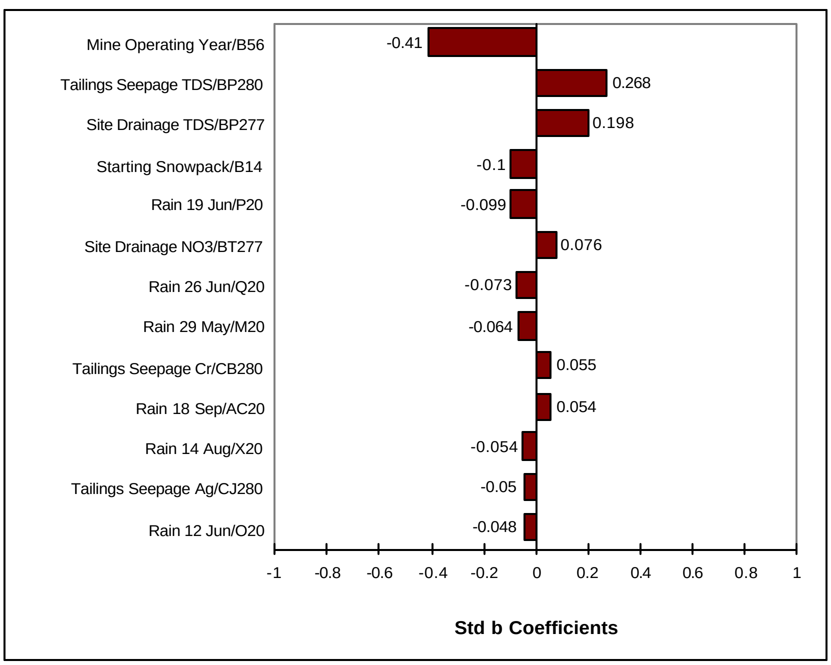


**Figure 5.10: Regression Sensitivity for Average WTP Feed $NO_3$ /BK129**

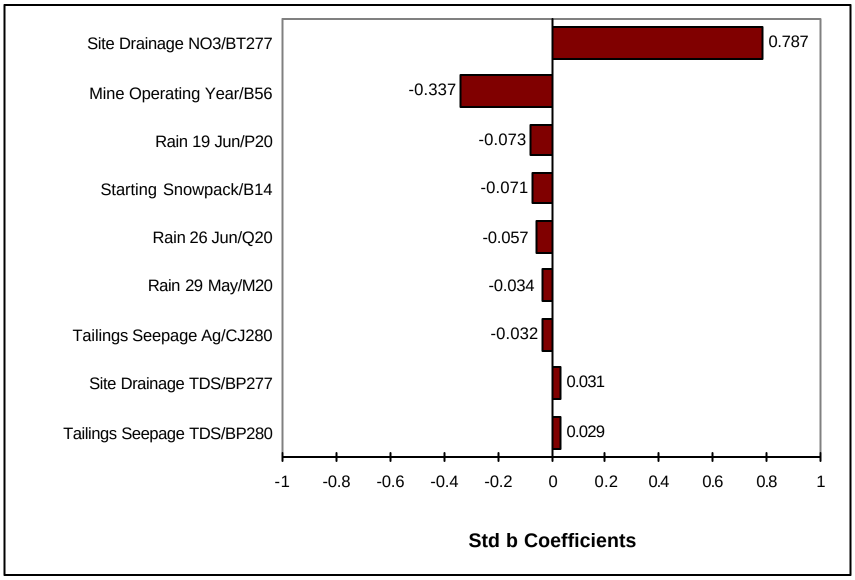



**Figure 5.11: Regression Sensitivity for Average WTP Feed CN/ BK131**

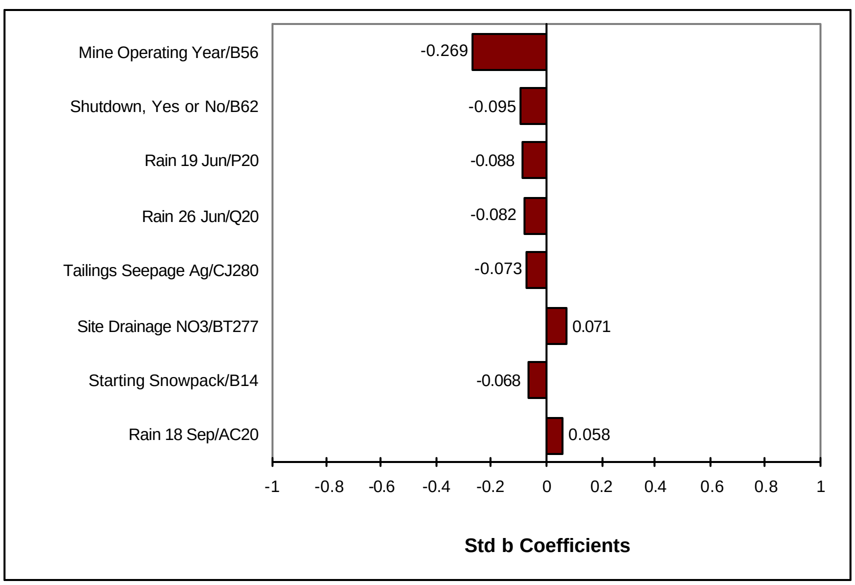


Figure 5.12: Regression Sensitivity for Average WTP Feed As/BK133

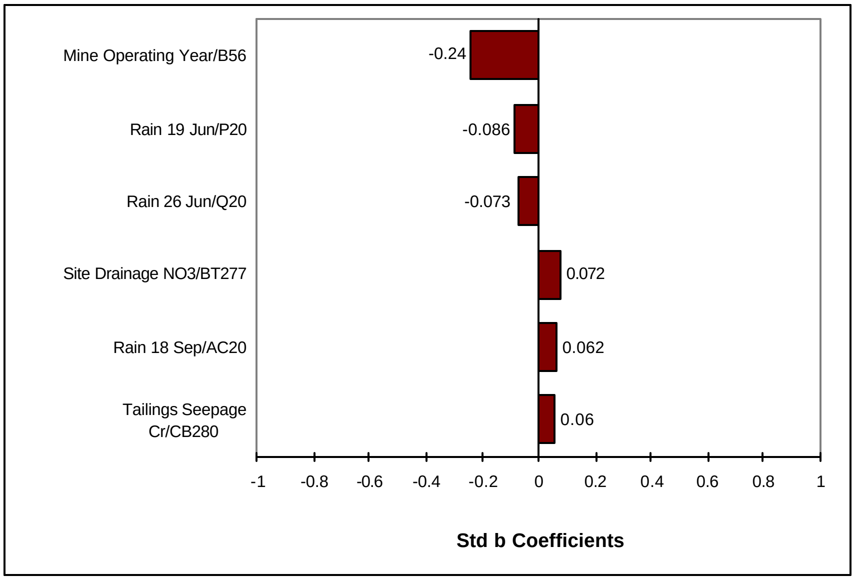
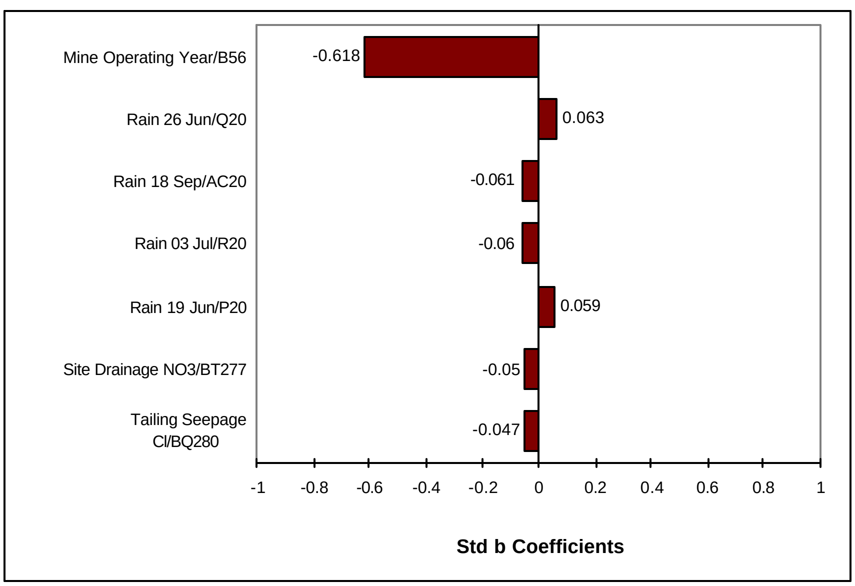



Figure 5.13: Regression Sensitivity for Mine Inflow Mine/BJ572



### 5.3 Summary of Water Management System & Water Quality Impacts

This Water Management Plan presents an updated analysis in response to agency comments on the previous plan (July 2001) and reflects changes made to the project design. The observations and conclusions summarized below are drawn from the testwork and modeling completed to date for the water management system.

- The Monte Carlo modeling demonstrates that the proposed Pogo water management system will be effective in maintaining the water quality in the Goodpaster River.
- The water treatment and discharge rate of 400 gpm provides adequate reserve capacity as compared to the average expected discharge volume of 138 gpm.
- The reduced catchment area and the 40 Mgal RTP dam will ensure there is a very low likelihood of stormwater releasing over the RTP spillway. The dam size provides significant freeboard over and above the expected snowmelt and the 100-year/24-hour storm volumes.
- In the very low likelihood event of a stormwater discharge, modeling shows no adverse water quality impact to the Goodpaster River. Under normal operating conditions, the RTP water will have relatively low levels of contaminants.
- Runoff and seepage from tailings are the primary sources of contaminants into the RTP.
- Mine drainage has a high contaminant loading and will be treated prior to being discharged, used in the process, or stored in the RTP.
- The incorporation of cyanide destruction on the CIP tailings prior to their use in the paste backfill, as well as the internal recirculation of water in the cyanide circuit results in no direct path for cyanide into the RTP water.
- When production increases to 3,500 tpd, water usage in the mill will increase, as will the amount of water entrained in the tailings, thus the amount of water being discharged will decrease. This will improve RTP water quality and lower the total amount of water discharged over the life of mine.
- Upon closure, modeling shows no measurable impact to water quality in the Goodpaster River.

The water management system provides considerable flexibility and will incorporate a monitoring and control system to detect and correct water treatment plant upsets. The soil absorption system provides an additional measure of safety by means of its adsorptive and biological capabilities. The mill site, site roads, drystack tailings areas and RTP pond are all located within the Liese Creek drainage. The Liese Creek drainage naturally exits into an attenuating environment between the mouth of Liese Creek and the Goodpaster River. Consequently, the Goodpaster River will be further protected from potential impacts by this additional natural water treatment.

# SECTION 6 | MONITORING PLAN

## 6.1 Monitoring Objective

The objective of the monitoring plan will be to ensure that the water quality of the Goodpaster River is protected. The three major components of the plan will be monitoring the operating performance of the SAS; monitoring the water that is near, but has not reached, the Goodpaster River; and monitoring the water in the Goodpaster River.

## 6.2 Monitoring Plan

Teck will sample wells on the perimeter of the SAS to monitor its performance. These samples will provide early feedback, enabling response and mitigation as needed before there is a compliance problem at down-gradient wells. Teck will also sample monitoring wells down-gradient of the SAS on a monthly basis to determine water quality and elevation trends and to sample the water before it reaches the river. (For example, sample locations LL-3 and LL-4 and LL-29 would be monitored, as shown in Appendix E). In addition, a groundwater well located up-gradient of the absorption field will be monitored. Background sampling is underway at these sites and will continue as discharge to the soil absorption area commences.

The details of the monitoring plan and the physical and chemical parameters that will be measured will be developed in consultation with the agencies. Test procedures will follow EPA or other approved methods. The QA/QC (Quality Assurance/Quality Control) program in place for the advanced exploration program will be continued and expanded as necessary. A more detailed monitoring plan will be included with the State of Alaska Solid Waste Application for the drystack tailings area, RTP pond and soil absorption area. The results from compliance monitoring will be reported to the appropriate agencies on a quarterly basis following discharge to the soil absorption area. If there is an anomalous value of concern, it will be addressed as outlined in the monitoring plan.

## 6.3 Monitoring & Compliance Issues

Regardless of the monitoring plan that is developed to ensure protection of the Goodpaster River, there are some monitoring and compliance issues that deserve special discussion with respect to the application of good science to the project. These are described briefly below.

*Total vs. dissolved criteria* – In 1999, the EPA adopted new criteria for many parameters, replacing old total recoverable criteria with dissolved criteria. Some of the numeric values were increased, while some were decreased. The important issue is that the EPA recognized that the dissolved criteria are those that are most environmentally relevant. The State of Alaska should adopt the updated dissolved criteria.

*Cyanide* – Current Alaska water quality standards are 0.0052 mg/l free cyanide. Since there are no EPA approved methods to measure free cyanide at these levels, the EPA has, in the past, recommended applying the standard as total cyanide. However, based on a large body of evidence, the measurement of total cyanide at these low levels is not scientifically defensible and places a project proponent unjustifiably at risk for false positive results during compliance monitoring. Teck believes that a more appropriate technique is to measure WAD (weak acid dissociable cyanide). In other permit actions in the United States, the EPA has allowed the use of WAD cyanide for compliance monitoring. Teck is in the process of compiling a technical document that will demonstrate that the use of WAD cyanide can be both technically defensible and protective of the environment. In the near future, Teck intends to present this document to the agencies for their consideration. It should also be noted that free cyanide is significantly less than WAD cyanide levels in typical gold mill solutions due to the presence of metals such as copper, which reports as a cyanide complex. Similarly, WAD cyanide levels would normally be lower than the $CN_T$ represented in the modeling, primarily due to iron cyanide complexes, which report as $CN_T$ but not WAD.

*Manganese* – The criteria for manganese have been developed based on organoleptic (taste and odor) considerations. The rationale for the manganese criteria states the following:

> "Very large doses of ingested manganese can cause some disease and liver damage but these are not known to occur in the United States. Only a few manganese toxicity problems have been found throughout the world and these have occurred under unique circumstances, i.e., a well in Japan near a deposit of buried batteries… Consumer complaints arise when manganese exceeds a concentration of 150 ug/l in water supplies. These complaints are concerned primarily with the brownish staining of laundry and objectionable tastes in beverages. It is possible that the presence of low concentrations of iron may intensify the adverse effects of manganese. Manganese at concentrations of about 10 to 20 ug/l is acceptable to most consumers. A criterion for domestic water supplies of 50 ug/l should minimize the objectionable qualities."
>
> — EPA Gold Book, 1986

McKee and Wolf (1963) summarized data on the toxicity of manganese to freshwater aquatic life and determined that "[i]ons of manganese are found rarely at concentrations above 1 mg/l. The tolerance values reported range from 1.5 mg/l to over 1,000 mg/l. Thus, manganese is not considered to be a problem in fresh waters."

Modeling for manganese was done because baseline data collection had shown it could be naturally elevated in the Pogo project area. However, given that there are no expected public drinking water supplies originating in the area of Pogo discharge, careful consideration must be given as to whether a manganese standard is appropriate for the Pogo project, and if so, how and where it should be applied.

*Mercury* – The current Alaska water quality standard is 0.012 µg/l Hg total. In 1999, the EPA adopted a criteria of 0.77 µg/l Hg dissolved. The State of Alaska should adopt the new criteria so as to apply the best available science to the project.

*Iron* – Like manganese, the criteria for iron of 0.3 mg/l is based on organoleptic considerations. The most recent EPA criteria document (1999) lists 1.0 mg/l as the chronic criterion for freshwater aquatic life, as according to the 1976 Red Book. Therefore, careful consideration must be given as whether an iron standard is appropriate for the Pogo project, and if so, how and where it should be applied.

# SECTION 7 | MINE INFLOW CONTINGENCY PLAN

## 7.1 Introduction

Water management will be an important component of the operation of the Pogo underground gold mine. Collection, treatment and disposal of both surface and underground waters in an environmentally responsible manner will be required. During development and operation of the mine, groundwater will drain into the mine workings. Based on the 2½ years of experience gained from the existing underground exploration workings and the detailed hydrogeological investigations and analyses completed to date (Adrian Brown, January 2002), the expected inflows to the mine without mitigative measures can be reasonably estimated and are summarized in Table 7.1.

**Table 7.1: Expected Mine Inflows**

| | Non-Liese Creek Fault Zone | Liese Creek Fault Zone | Total |
|---|---|---|---|
| Average annual inflow | 67 | 72 | 139 gpm |
| Peak annual inflow | 108 | 153 | 205 gpm [1] |

**1**. Columns are not additive because peak annual inflows for each category do not occur in same year.

Even with the site data that is available, there is still some uncertainty in these estimates. In order to minimize the risk of large unexpected inflows that would exceed the capability of the treatment and disposal system, Teck-Pogo Inc. proposes to follow this Groundwater Inflow Investigation and Contingency Plan to manage groundwater inflow to Pogo Mine. For the purposes of this plan, the mine inflows will be divided into two major categories, Non-Liese Creek Fault Zone inflows, and Liese Creek Fault Zone inflows. The appropriate contingency planning measures will be somewhat different depending upon the potential source of the mine inflows.

## 7.2 Non-Liese Creek Fault Zone Inflows

Non-Liese Creek Fault Zone Inflows are those where recharge of water bearing structures and strata is expected to be limited to infiltration of annual precipitation. Due to the 2½ years of experience with the underground exploration workings and the density of drill information in the area near the orebody, there is a reasonable degree of confidence in the Non-Liese Creek Fault Zone inflow estimates.

## 7.3 Liese Creek Fault Zone Inflows

Liese Creek Fault Zone Inflows are those associated with the Liese Creek fault zone, where recharge potentially could be influenced by surface and subsurface flow in the Liese Creek catchment. There is more uncertainty in the Liese Creek Fault inflow estimates. The inflow estimates include the assumption that the Liese Creek fault has the physical characteristics, rock quality, degree of fracturing, etc., identified by the two cored holes that were drilled from underground and extended beneath Liese Creek. Further, the fault zone is assumed to have the flow properties measured in permeability tests conducted in these two holes. The estimates also assume that mining has proceeded without the use of contingency measures to manage groundwater inflows.

It is recognized, however, that the information from the two holes may not be representative of the Liese Creek fault zone more generally. The quality of the rock may be poorer and the fault may be more permeable than indicated by these holes.

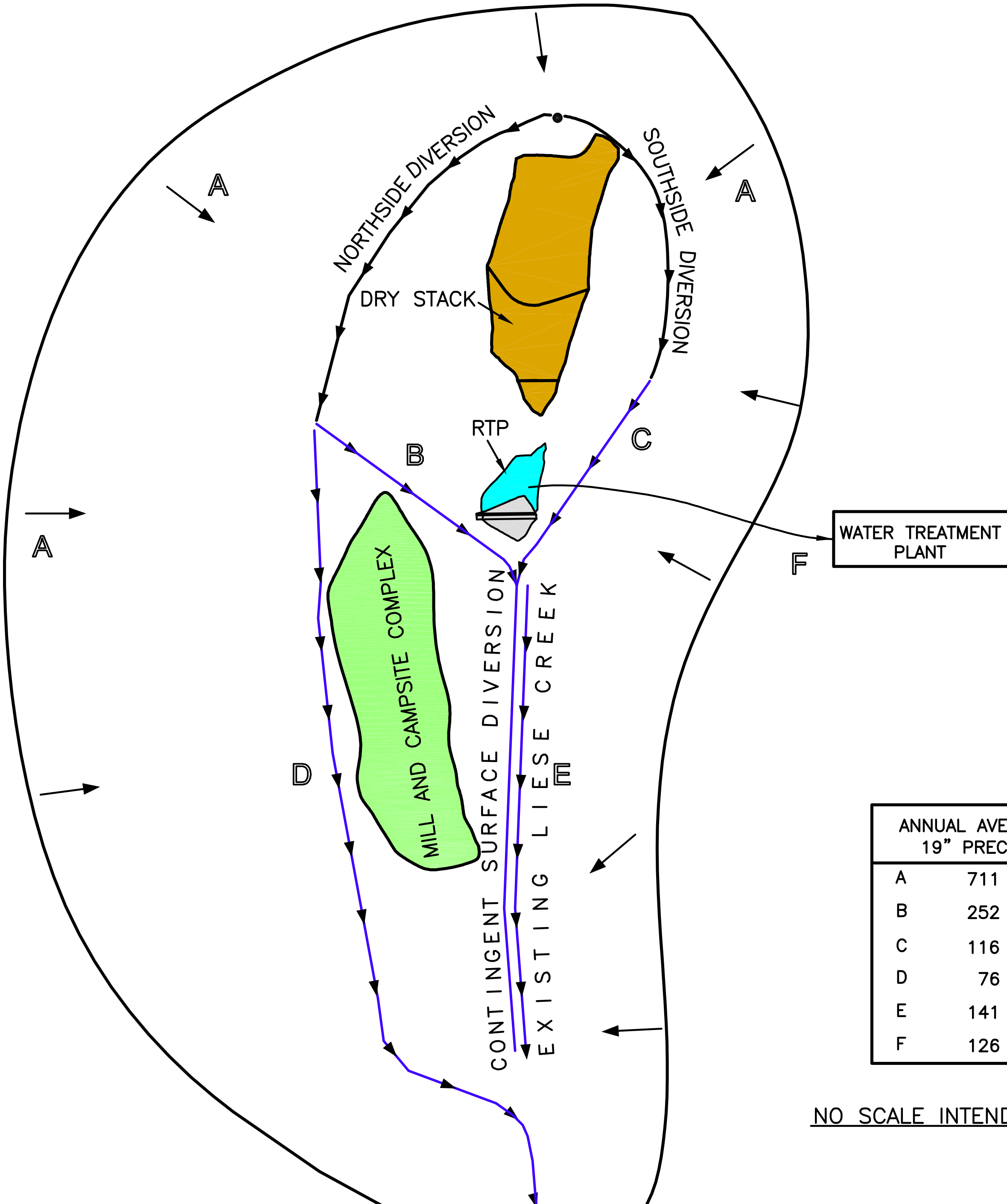
Prior to mining, the estimated flows in Liese Creek and the underlying alluvium are summarized in Table 7.2.

**Table 7.2: Liese Creek Flows**

| | Pre-mining Condition[1] | Operating Condition[2] |
|---|---|---|
| Average annual flow | 350 gpm (computed) | 711 gpm |
| Winter flows | <50 gpm | Not estimated |
| Peak avg. monthly flow (in spring) | 1,063 gpm (computed) | Not estimated |
| Underflow in the alluvium beneath the creek | 53 gpm (estimated) | Not estimated |
| Peak monthly flow, creek plus alluvium | 1,116 gpm | Not estimated |
| Flow remaining in Liese Creek basin after RTP dam and all contingent diversions constructed | – | 141 gpm |

**1**. Liese Basin catchment above orebody (from Appendix A). **2**. Entire Liese Basin catchment (see Figure 7.1).

Thus in a worst case scenario under pre-mining conditions, the upper conceivable limit of inflows to the mine from the Liese Creek fault is approximately 1,100 gpm. The probability of this extreme inflow occurring underground is considered very remote. First, present day Liese Creek is elevated above the groundwater in the Liese Creek colluvium, indicating that there is not always a direct connection between the surface flow and the near-surface groundwater. Even without active control measures, it is not likely that the extreme surface flow would ever report into the mine. Second, the actual basin runoff available for infiltration through the Liese Creek fault zone will be less than the pre-mining conditions reported in Column 1 of Table 7.2 due to the construction of




| ANNUAL AVERAGES FOR 19" PRECIPITATION | | |
|---|---|---|
| A | 711 | gpm |
| B | 252 | gpm |
| C | 116 | gpm |
| D | 76 | gpm |
| E | 141 | gpm |
| F | 126 | gpm |

NO SCALE INTENDED

LEGEND

1. FLOWS ARE ANNUAL AVERAGES
2. ANNUAL TOTAL PRECIPATION ASSUMED = 19".
3. TOTAL BASIN FLOW, A, IS EQUAL TO B+C+D+E+F.
4. FLOW B COULD BE COMBINED WITH D OR SURFACE DIVERTED.
5. FLOW C COULD BE SURFACE DIVERTED.
6. CONTINGENCY PLAN COULD LIMIT SURFACE COMPONENT AVAILABLE TO UNDERGROUND TO E.

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Figure 7.1
Liese Basin
Schematic Flows

the mine facilities, including the RTP dam. Once this dam is constructed, all of the basin precipitation from the catchment above the dam and runoff from the drystack, plant site, and roads will be collected in the RTP and routed to the water treatment plant before being discharged.

With active control measures, such as construction of all diversion ditches, including rerouting of Liese Creek through the contingent surface diversion, a significant portion of the runoff from the upper basin could be diverted around the area of concern. This would reduce the runoff potentially available for infiltration into the Liese Creek Fault Zone to approximately 140 gpm.

## 7.4 Groundwater Inflow Investigation & Management Plan

The flow control measures that will be considered and implemented if necessary, either singly or in combination, are detailed below. In summary, the goals of the program will be to:

- Evaluate groundwater conditions in advance of penetrating an area with development.
- If the groundwater from the Liese Creek Fault Zone is of suitable quality that it can be discharged directly without treatment, collect and discharge this drainage to surface water in lower Liese Creek at the inflow rate.
- If treatment is required, use contingency measures so as to not exceed the capacity of the treatment and disposal system.

### 7.4.1 Mine Inflow Investigation Program

The most important tool available to control and manage mine inflows is advance investigation and monitoring of groundwater conditions so that adequate time is available to develop and implement an appropriate plan. The measures described below will be taken to investigate and monitor groundwater conditions.

#### All Areas

A 1,000 foot long pilot hole will be drilled from surface along the alignment of the 1700 conveyor drift. Pilot holes have been drilled along alignments of the 1525 and the 1875 portal and are a proven method for evaluation ground conditions well in advance of development.

Definition drilling will be done in advance of stope development. During the mine development, stope definition drilling of the orebody will be completed on 100 foot centers. This drilling will generally be completed from development workings below the orebody and will provide information about groundwater conditions generally two years in advance of mining.

Longhole drilling will be completed into major water bearing blocks and structures in advance of development. Geologic investigation shows that the area is composed of relatively large blocks of low permeability gneiss that that is segregated into discrete blocks by higher permeability generally steeply dipping fault structures and the gently dipping orebody. The primary aquifers are associated with the orebody and the structures. Although the level of detailed knowledge about these structures will be continually increasing through the mine life, the work to date has shown that there is sufficient current knowledge to be able to predict when development workings will be advancing toward potential major water bearing structures. The longhole drilling will be completed prior to advancing into these areas and will provide information needed to manage inflows.

Packers will be installed on all underground drill holes as needed to control inflow. Experience to date shows that this is an effective way of controlling mine inflows.

Periodic testing of major water bearing structures will be conducted to monitor water quality, static pressures, and inflow rates. Systematically observing the response of the aquifer will provide the data needed to make management decisions.

**Liese Creek Fault Zone**

Long holes will be drilled from Ramp L1C across the Liese Creek fault zone in advance of any development that would occur across the fault. The portion of the L1 orebody that lies on the north side of the Liese Creek fault zone will be accessed by specific development workings in year six of the mine. The portion of the L2 orebody that lies near the Liese Creek fault zone and is below Liese Creek will be accessed in year six of the mine. This provides several years during which the hydrogeologic conditions of the Liese Creek Fault Zone can be evaluated. The development workings on the south side of the fault will be completed in Year 2 of the mine and will thereby provide a suitable drilling platform for completion of the long holes necessary to obtain more information about the Liese Creek fault. The layout of the proposed drill program to investigate the Liese Creek Fault zone is shown in Figure 7.2.

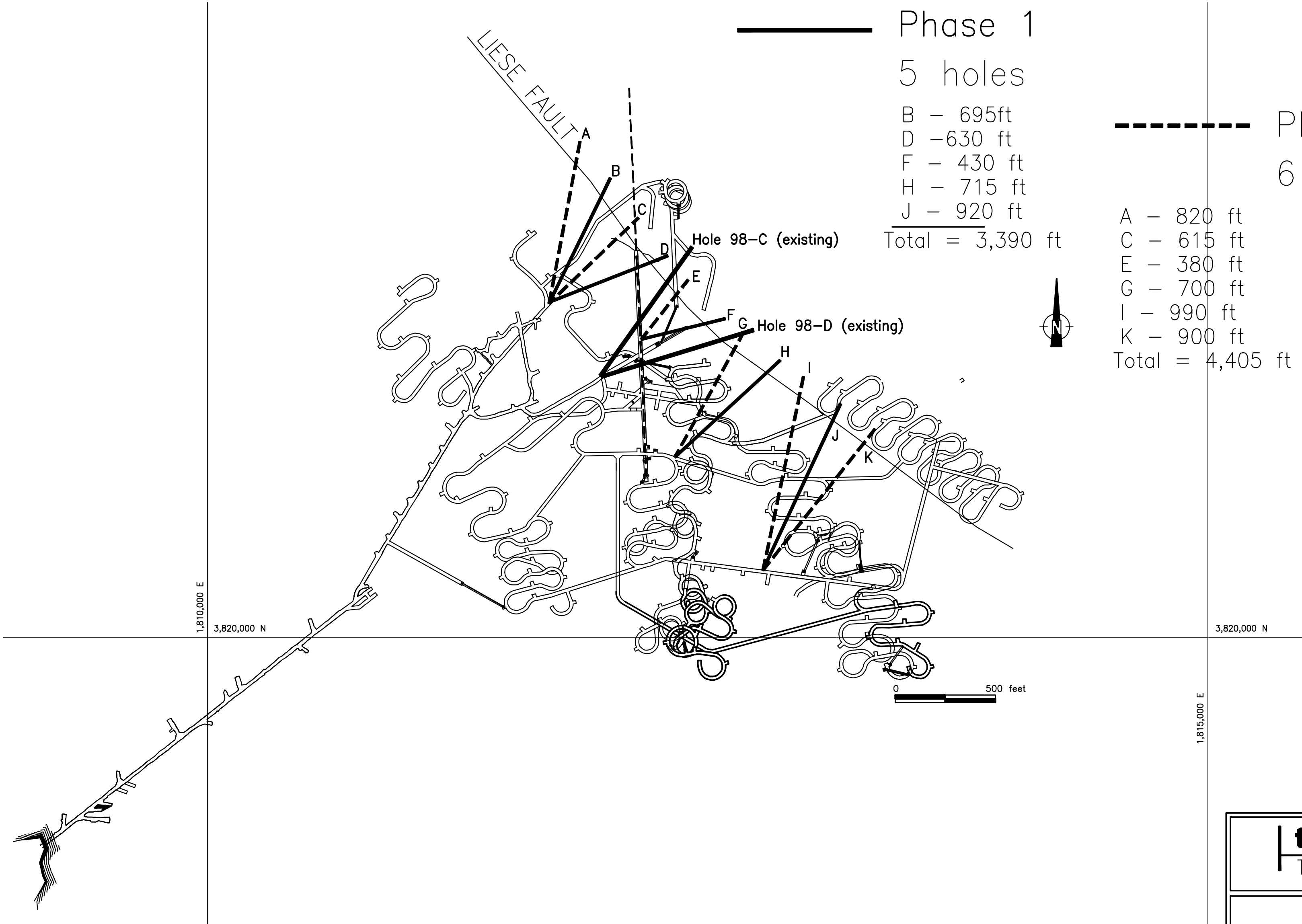


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Figure 7.2
Proposed Drill Progam
in Liese Fault

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## 7.5 Contingency Plans

Based on the results of the investigation program outlined above, the following flow control measures for the Liese Creek Fault Zone will be considered and implemented as necessary. These measures will be implemented singly or in combination, as appropriate to achieve the desired level of inflow control.

*Collect & Discharge* – If the groundwater is of suitable quality, the water will be collected either from drain holes drilled into permeable sections of the fault zone or from separate mine sumps and would be discharged to lower Liese Creek surface water at the inflow rate. If the water is not of suitable quality, this control measure will not be implemented.

*Collect, Treat & Discharge* – If the water can be treated to a suitable quality, the water will be collected from drain holes or sumps, treated and discharged at a maximum rate of 400 gpm via the injection wells.

*Grouting to Control Inflows* – These may entail grouting parts of the Liese Creek fault zone itself, and/or the ore that it is deemed necessary to leave in place between the fault and the rest of the mine workings. The fault may be grouted ahead of an advancing drift that then provides isolated access through to the other side of the fault, or the fault may be grouted using inclined holes drilled from adjacent development openings. In the latter case, the grouting is designed to reduce the permeability of the fault above the mine workings prior to mining the ore in and around the fault.

It is expected that grouting can successfully address the various hydrogeologic characteristics that might exist in the Liese Creek fault zone. If the zone is a discrete, small, high permeability zone, it can be successfully grouted. If the zone is a wider assemblage of smaller water-bearing structures that may not respond well to grouting, a portion of the ore adjacent to the fault zone could be grouted and left in place.

*Revise the Mining Layout* – Designing and implementing a revised mining layout, as well as possibly revising the mining methods used locally for areas in and around the fault, may be used to control inflows. This may include leaving some ore in place as pillars and grouting all or some of this ore. The revised mining approach used will depend on factors such as whether the issue being addressed is one of the stability of openings in and around the fault or the permeability of the structural features identified.

*Surface Flow Control* – Implementing control measures on surface to reduce or remove communication of the flow in Liese Creek with the Liese Creek fault zone would be effective to reduce inflows into this zone. This measure would divert Liese Creek around the area of interest via a pipe or flume constructed adjacent to Liese Creek. At closure, the pipe or flume would be removed and the flow returned to the original channel.