Final

Fiscal Year 2012 Site-wide Water Quality Modelling Report Faro Mine Remediation Project

Prepared for

Government of Canada as represented by Aboriginal Affairs and Northern Development Canada and the Government of Yukon

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CH2MHILL®

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The document contained herein should be considered Final as approved by the Government of Yukon on August 27, 2014 with no changes made since the draft submission.

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Acronyms and Abbreviations

AECOM	AECOM Canada Ltd.
AP	acidic potential
CVD	Cross Valley Dam
DES	Denison Environmental Services
DVT	Down Valley Tailings
ETA	Emergency Tailings Area
FCD	Faro Creek Diversion
FMC	Faro Mine Complex
FMRP	Faro Mine Remediation Project
FWMT	Faro Water Modelling Team
FY12	Fiscal Year 2012
GEEC	Gomm Environmental Engineering and Consulting
GHL	Lower Guardhouse
GHU	Upper Guardhouse
gpm	gallons per minute
GoldSim model	site-wide water quality model
GW	groundwater
HEP	hydrological effective precipitation
ICAP	*Anvil Range Mining Complex – Integrated Comprehensive Abandonment Plan*
ID Pond	Intermediate Dam Pond
IPRP	Independent Peer Review Panel
kg	kilogram(s)
L/sec	litres per second
LGSP A	low-grade stockpile A
LGSP C	low-grade stockpile C
m	metre(s)
m^2	square metre(s)
m^3	cubic metre(s)
MAR	mean annual runoff
mg/L	milligram per litre
mm	millimetre(s)
MP	Faro Main Pit
NA	not applicable

NFRC	North Fork Rose Creek
NP	neutralization potential
RCAA	Rose Creek Alluvial Aquifer
RCD	Rose Creek Diversion
RCTA	Rose Creek Tailings Area
RCV	Rose Creek Valley
RGC	Robertson GeoConsultants, Inc.
SFRC	South Fork Rose Creek
SIS	seepage interception system
SRK	SRK Consulting Engineers and Scientists
SW	surface water
UFC	Upper Faro Creek
v1	Version 1.0
v2	Version 2.0
WRD	waste rock dump
WTP	water treatment plant
X2	catchment that drains to the X2 monitoring location
Z2	Zone 2

SECTION 1
Introduction

The Government of Canada (as represented by Aboriginal Affairs and Northern Development Canada); Government of Yukon, Canada; and the Faro Water Modelling Team (FWMT) have recently developed computer models that simulate surface water (SW) flow, groundwater (GW) flow, and geochemical processes of interest in the Faro Mine Complex (FMC) and surrounding area. The development, calibrations, and applications of these models to support the ongoing development, refinement, and implementation of the Faro Mine Remediation Project (FMRP) are described in the *Draft Fiscal Year 2012 Water Modelling Analysis Report, Faro Mine Remediation Project* (CH2M HILL, 2013).

Several water quality models predate these more recent computer models. A variety of models were developed as early as 2005 to evaluate different aspects of the FMC. The first compiled FMC water quality model was developed by SRK Consulting Engineers and Scientists (SRK) (2009) by consolidating several different spreadsheet models aimed at estimating water quality within different portions of the FMC. The result was a single site-wide spreadsheet model developed in Microsoft Excel. A second model was then developed based on this consolidated Microsoft Excel model, including both water quality and water balance computations. This second model was developed using the GoldSim software platform and was described in *Faro Mine Complex Closure and Reclamation–Site Wide Water Quality Model* by Gomm Environmental Engineering and Consulting (GEEC) (2010). This version of the site-wide water quality model, hereafter referred to as GoldSim model Version 1.0 (v1), was developed to forecast trends in SW quality during and following the implementation of the FMRP, described in the *Faro Mine Complex Closure and Remediation Plan* (SRK, 2010).

This Fiscal Year 2012 Site-wide Water Quality Modelling Report describes the refinements made to the previous version of GoldSim model v1. This refined version is hereafter referred to as GoldSim model Version 2.0 (v2). The principal refinements of the GoldSim model v2 are as follows:

- Incorporates a more-accurate representation of the Rose Creek Tailings Area (RCTA), also referred as the Down Valley Tailings (DVT) Area.
- Incorporates stochastic variables to reflect uncertainty in individual seepage interception system (SIS) effectiveness, in addition to stochastic variables already present in GoldSim model v1, such as cover effectiveness and acid generation potential of each modelled waste rock dump (WRD). Formulating these variables stochastically in GoldSim model v2 allows water quality forecasts to be presented as a potential range rather than a single, deterministic forecast.
- Incorporates user friendly graphical user interfaces known as dashboards. The inclusion of dashboards provides intuitive menus, buttons, and descriptors that simplify the execution and manipulation of model simulations.

These and other enhancements included in GoldSim model v2 are described in this report, which is intended to complement the model documentation provided by GEEC (2010), which is provided in Appendix D.

The GoldSim model v2 was developed during Fiscal Year 2012 (FY12), which runs from April 1, 2012, until March 31, 2013. The GoldSim model will continue to be refined over time to reflect further development of geochemical, SW, and GW models, and respond to changes and understanding of the FMC environment and site engineering activities. As a result, information presented herein is a work in progress. Improvements to the GoldSim model will continue as additional site characterization, monitoring, and operational data become available; as knowledge of the FMC evolves; as supporting computer models are developed and applied; and as necessitated by the FMRP.

The GoldSim model files serve as companion files to this report. They contain additional details not addressed in this report, and are available on the project SharePoint site.

SECTION 2
Modelling Objectives

Site-wide water quality modelling is required to gain insight into potential outcomes to proposed actions associated with the FMRP. The GoldSim models v1 and v2 simulate the hydrologic system at the FMC where contaminated seepage from WRD sources are either reduced by implementation of covers or are intercepted by SISs. Intercepted seepage can be sent to treatment directly or stored within pits for treatment during seasonal treatment periods. The GoldSim models use selected meteorological, hydrological, and geochemical data to compute water quantity and water quality estimates at locations of interest throughout the modelled domain under assumed operational conditions. Because it is anticipated that this model and the supporting computer models that were recently developed (CH2M HILL, 2013) will evolve as knowledge of the FMC evolves and as FMRP needs change, the site-wide water quality modelling objectives are divided into near-term and potential longer-term objectives.

Near- and Long-term Modelling Objectives

The near-term modelling objectives described herein are associated with the current modelling effort, which focuses on developing GoldSim model v2. Specifically, the near-term modelling objectives are as follows:

- Add features and refinements to the model to facilitate its use by a wider range of stakeholders associated with the FMRP.
- Identify and, to the extent practical within the time and resource constraints in FY12, renovate the model to overcome oversimplified assumptions introduced in the predictive simulations.
- Incorporate a calibration check into the GoldSim model process to allow examination of the model's ability to replicate observations of interest in the FMC over a selected historical period.
- Gain insight into the receiving water locations that may be or may become impacted by mine-related contamination.
- Inform the Adaptive Management Plan.

The long-term objectives of the site-wide water quality modelling could include the following items, as necessitated by the implementation of the FMRP:

- Add additional functionality with the dashboards to further enhance the utility of the GoldSim model.
- Evaluate l alternative sequences and schedules of remedial actions to optimize implementation of the FMRP and decrease the threat to human health and the environment.
- Incorporate enhancements to make the model more accurate in the representation of physical processes, according to insights gained from the supporting computer models (CH2M HILL, 2013), in order to improve its predictive capabilities.
- Help inform subsequent phases of the Faro water treatment plant (WTP) design, Adaptive Management Plan, and other components of the FMRP, as needed.

SECTION 3
Model Overview

The overall approach to the v2 modelling effort began with a comprehensive review of GoldSim model v1 and the associated documentation (GEEC, 2010). The model simulates changes in water quality at select locations within and downstream from the FMC as a function of changes in geochemistry and groundwater at key subareas including WRDs, the RCTA, and at existing and proposed SIS locations. The modelled WRD water quality is a function of the assumed WRD geochemical make-up and the type of cover proposed for installation in the closure plan (SRK, 2010).The RCTA is a significant driver of downstream SW quality because it is a major source of chemical loading to the Rose Creek Alluvial Aquifer (RCAA). GW in the RCAA eventually discharges to Rose Creek and other downgradient receiving waters.

The assumed effectiveness of each modelled SIS determines the quantity of mine-impacted GW that is intercepted and conveyed to the MP and Faro WTP. GW that is not intercepted in the modelled SIS locations is simulated to enter a downgradient receiving water node. Other components that influence SW quality in the GoldSim models are associated with managing site water storage, implementing WTP options, and assumptions related to the change in acid and metal-generating reactions within the WRDs.

Much of the structural logic of GoldSim model v1 developed by GEEC (2010) was retained in GoldSim model v2. Most of the changes are related to implementation assumptions, input hydrology calculations, routing flows through the system, and refinement of modelled elements, as described on Table 1[1]. Further, a calibration check that compared modelled results with selected historical data was implemented to examine the model's ability to replicate conditions of interest at the FMC over a selected historical period. Table 1 describes the model assumptions associated with GoldSim models v1 and v2, which are predictive models, along with the assumptions associated with the calibration check version of GoldSim model v2 (Historical Run).

This section provides the reader with an overview of the key components of the model based on GoldSim model v1. Section 4 describes the changes implemented in the GoldSim model v2.

3.1 Model Domain

The GoldSim models are currently reporting flows and water quality conditions for three areas: the Anvil Creek and Rose Creek drainages downstream of the FMC, the Vangorda Creek drainage downstream of the Vangorda/Grum area, and the Pelly River between its confluences with Vangorda Creek and Anvil Creek. The Pelly River downstream of the Anvil Creek confluence is the farthest downstream water quality compliance point and is presented on Figure 1[2], along with the site-wide stream network, key locations for which historical flow and water quality data are available, locations of the Faro and Vangorda/Grum mine areas, and names of the major streams considered in the model. The Faro Mine Area drains to the Pelly River via Rose Creek and then Anvil Creek, whereas the Vangorda/Grum Area drains to the Pelly River via Vangorda Creek.

Figures 2a and 2b provide more detail, showing the Faro and Vangorda/Grum mine areas, respectively, along with modelled catchment boundaries and the WRD configurations. Figure 2a shows eight catchment areas within the Faro Mine Area, and Figure 2b shows five catchment areas within the Vangorda/Grum Mine Area, all represented in the GoldSim models. The modelled catchments associated with the Faro Mine Area are as follows:

- Faro Main Pit (MP)
- North Fork Rose Creek (NFRC)
- Zone 2 (Z2)
- Catchment that drains to the X2 monitoring location (X2)
- Rose Creek Valley (RCV)

[1] Tables are located at the end of the section where first referenced.

[2] Figures are located at the end of the section where first referenced.

- Upper Guardhouse (GHU)
- Lower Guardhouse (GHL)
- RCTA, also referred to as DVT Area

The modelled catchments associated with the Vangorda/Grum Mine Area are as follows:

- Catchment that drains to the V1 monitoring location (V1)
- Catchment that drains to the V27 monitoring location (V27)
- Catchment that drains to the V8 monitoring location (V8)
- Vangorda Pit (VP)
- Grum Pit (GP_Area)

The modelled catchment delineations for the mine sites were originally based on the pre-mining topography and dictate how seepage and runoff are routed through the system. Because they are based on pre- mining conditions, they do not necessarily match surface water drainage catchments. Adjustments have been made to the WRDs and catchment boundaries throughout the life of the project, and it is expected that future adjustments will be made to adapt the boundaries to then-current site conditions.

3.2 Model Time Discretization

Time is continuous in the physical system, but the GoldSim models must describe the field problem at discrete time intervals. GoldSim model v1 was developed to run monthly time steps using annual input data and fixed monthly patterns, primarily because most of the input data for the site are available on an annual basis.

GoldSim model v1 was set to run for 200 years (total duration of the simulation) on monthly time steps (2,400 time steps), including 25 stochastic realizations. The duration of the simulation and number of stochastic realizations are adjustable and can vary depending on the user needs. The principal limitation in increasing the duration of the simulation and the number of stochastic realizations is the amount of simulation data that must be stored in system memory. One strategy to limit the amount of data stored in system memory and avoid excessive run times is to limit specific model outputs, especially the number of water quality constituents reported for each realization.

3.3 Model Core Equations

GoldSim model v1 includes more than 1,000 different GoldSim elements. Although it is impractical to describe all the elements, it is necessary for the user to understand the general logic of the model. Learning about the general logic and functions of the model is an important step in improving a user’s proficiency with the software and improving user insight into how the model conceptualizes the problem, without an exhaustive description of each element. On a fundamental level, the model can be separated into two parts:

- Generation of modelled seepage and runoff
- Routing and capture of flows though the modelled system

The main logic that needs to be understood is how precipitation generates seepage and runoff from each WRD and how the water quality loads are computed in the model. Figure 3 illustrates the general routing of flows through the system from the WRD or contaminated site to the downstream receiving environment. Ideally, all contaminated flows would be captured and treated before reaching the receiving environment, and all clean water would be kept from entering contaminated areas by installing diversions and cut-off walls. The following subsections describe the calculations for seepage, runoff, and loads from each WRD.

3.3.1 Seepage

Seepage is calculated as a function of WRD area, precipitation, and a factor that converts precipitation into seepage. Seepage volumes from each WRD in the GoldSim models v1 and v2 are computed according to Equation 1.

$$S_{w,c} = A_w * D_{w,c} * I_w * P \qquad (1)$$

where:

$S_{w,c}$ = total annual seepage for WRD "w" located in catchment "c" (cubic metres [m^3])
A_w = total area of WRD "w" (square metres [m^2])
$D_{w,c}$ = fraction of WRD "w" that drains to catchment "c"
I_w = infiltration factor for WRD "w" (unit less, 0 to 1)
P = annual precipitation (metres [m] entered as millimetres [mm] in the model)

Seepage volumes generated by the WRD sources are grouped by catchments, and a monthly factor is applied to the aggregated runoff to distribute the annual volumes into monthly flows. The seepage is then routed through the system as illustrated on Figure 3 and according to operational assumptions associated with the FMRP.

3.3.2 Runoff

The system runoff is computed as a function of the infiltration factor used in Equation 1 to compute seepage and the hydrological effective precipitation (HEP), which is the total annual precipitation minus losses to satisfy the soil moisture deficit and evapotranspiration (as defined by Younger et al. [2002]). The term "mean annual runoff" (MAR), used in previous reports, was changed to HEP to provide a more-accurate description of those flows. The term "runoff" is used by the technical community to define the rainfall excess that becomes flood runoff. Therefore, "runoff" is more appropriate for referring to overland flows only, and should not include infiltration. The runoff term included in GoldSim model v2 is computed according to Equation 2, as follows:

$$R_{w,c} = A_w * D_{w,c} * (HEP_c – I_w * P) \qquad (2)$$

where:

$R_{w,c}$ = total annual runoff for WRD "w" located in catchment "c" (m^3)
HEP_c = annual HEP for catchment "c" (m entered as mm in the model)

WRDs are then grouped by catchments and a monthly factor is applied to the aggregated runoff to distribute the annual flows into monthly flows. The total annual runoff for a WRD can also be described as the total annual HEP minus the total annual seepage computed for a specific WRD within a specific catchment.

The sum of the annual volumes from Equations 1 and 2, plus the boundary condition inflows described in Section 3.4, represent all the inflows to the modelled system and are balanced with all computed outflows, change in storage volume, or losses from the system for a given time step.

3.3.3 Chemical Reactions and Loads

None of the GoldSim models developed for the FMC to date simulate chemical reactions. It is assumed that all loads are conservative and will be removed from the system as stream flow or by a water treatment process. The water quality concentrations (including pH) are simplified to a weighted average when different flows with different concentrations are mixed. The weighted average mass balance formulation was intended to provide conservative forecasts of water quality. IN FY12 the FWMT spent time examining the potential consequences of not including geochemical reactive mixing in the GoldSim models, and the results of that effort are described in CH2M HILL (2013). It is likely that future versions of the GoldSim model would benefit from inclusion of some type of geochemical reactive mixing process to avoid simulating water qualities that are unstable under natural conditions.

The following geochemistry assumptions could be changed during future refinement of the prediction of water quality for the FMC:

- Simulate geochemical reactions as dependent variables
- Estimate more-realistic WRD water quality for current and future conditions

- Refine the algorithm that calculates WRD water quality changes though time
- Estimate better initial amounts of acid-generating and acid-neutralizing minerals in each WRD
- Simulate geochemical reactions during the mixing of waters in the subsurface and within pit lakes

There are four principal sources of chemical loads in the model: the WRD loads, the RCTA loads, the WTPs effluent loads, and the background loads. These sources are described in the following subsections.

3.3.3.1 Waste Rock Dump Loads

The WRD chemical loads are derived from a mix of 18 different seepage water quality types (11 for the Faro Mine Area and 7 for the Vangorda/Grum Mine Area). These water quality types are the result of analyses conducted by SRK (described in GEEC, 2010) and are represented in the input spreadsheet contained in the GoldSim models. The input spreadsheet allows the user to update concentrations for the multiple water quality types and the mix of the water quality types that will dictate a specific WRD source water quality.

The specific steps used to develop individual WRD water quality estimates are as follows:

1) Select the water quality type statistic to use (that is, average or maximum).
2) Select the water quality composition of each WRD for neutral and acidic conditions. For example, if average water quality conditions are selected, the WRD Upper Northwest Dump water quality is represented by the composition of 70 percent of Faro Type 1 Waste (average) + 20 percent of Faro Type 2 Waste (average) +10 percent of Faro Type 3 Waste (average) for neutral conditions and 50 percent of Faro Type 2 Waste (average) and 50 percent of Faro Type 3 Waste (average) for acidic conditions. In past years, it was recognized that this approach would only be effective if there was tracking of any changes in the seepage results from different waste rock types, and if there was a recognition that the predictions would need to be updated if the averages or maximum values for certain seepage types changed over time. This update has been identified as a short-term objective, and will be implemented as additional seepage data become available.
3) Determine if the WRD is in a neutral, acidic, or transitional condition. The model assumes that each WRD's water quality changes through time from neutral to acidic conditions. The WRD condition is a function of its current neutralization potential (NP) and acidic potential (AP). The rate at which the NP is reduced through time is a function of the WRD cover type and initial values of NP and AP. A more-detailed description of the AP and NP logic and equations is available in GEEC (2010). The uncertainty regarding the NP values is covered with a stochastic parameter that multiplies the NP of each WRD according to a uniform distribution between 25 and 75 percent for each stochastic realization.
4) Use Equation 3 to compute constituent concentrations for each WRD based on how depleted the NP is during each time step. A target NP defined by the user is used to define a transition period. If the WRD NP is greater than the defined target NP, then the water quality concentration for that WRD would be based on the neutral condition. However, if the WRD NP is less than the defined target NP, then the water quality concentrations for that WRD would be a fraction of the neutral condition plus a fraction of the acidic condition, using Equation 3:

$$WQ_{i,w} = NC_{i,w}*(NP\_Rem_{i,w} \div NP\_TGT) + AC_{w}*(1 - [NP\_Rem_{i,w} \div NP\_TGT]) \quad (3)$$

where:

$WQ_{i,w}$ = water quality concentration for constituent " i" and WRD "w" (milligrams per litre [mg/L])
$NC_{i,w}$ = neutral concentration for constituent" i" and WRD "w" (mg/L)
NP_Rem_{w} = calculated remaining NP for WRD "w" (percentage of remaining NP)
NP_TGT = target NP (percentage of remaining NP)
AC_{w} = acidic concentration for constituent i and WRD "w" (mg/L)

Once the water quality is computed for each WRD with Equation 3, the annual load for each constituent and WRD is computed using Equation 4:

$$L_{i,w,c} = A_w * D_{w,c} * I_w * P * WQ_{i,w} \quad (4)$$

where:

$L_{i,w,c}$ = total annual Load for constituent" i" for WRD "w" located in catchment "c" (kilograms [kg])

The first four terms in Equation 4 equals the computed seepage from Equation 1.

3.3.3.2 Rose Creek Tailings Area Loads

The input loads associated with the RCTA are calculated differently than loads from the WRDs. The loads for the RCTA are input to the model as a fixed-time series of concentrations for zinc and sulphate, along with an associated flow rate through the tailings. Water quality for constituents other than zinc and sulphate are based on reference samples and are computed as a ratio of the sulphate concentration in a particular sample. The fixed-time series of zinc and sulphate concentrations are based on a Microsoft Excel model developed by SRK (2005) and are presented for average and maximum conditions.

3.3.3.3 Water Treatment Effluent Loads

The water quality effluent has fixed concentrations for the Faro and Vangorda/Grum mine areas for the following water quality constituents:

- pH
- alkalinity
- arsenic (As)
- silver (Ag)
- calcium (Ca)
- magnesium (Mg)
- sodium(Na)
- aluminum (Al)
- cadmium (Cd)
- cobalt (Co)
- copper (Cu)
- iron (Fe)
- lead (Pb)
- manganese (Mn)
- nickel (Ni)
- zinc (Zn)
- beryllium (Be)
- and boron (B)

Assumed zinc concentrations in the treatment plant effluent vary depending on whether a sand filter is installed. The zinc effluent is set to 0.1 mg/L without a sand filter, and 0.05 mg/L with a sand filter. Currently, none of the model scenarios have a sand filter.

Sulfate effluent concentrations are adjusted by Equation 5 when Ca influent concentrations are greater than 500 mg/L.

$$OUT_{SO4} = IN_{SO4} - [(WQ_{Ca} - 500) * 96 \div 40] \quad (5)$$

where:

OUT_{SO4}= Sulfate WTP effluent concentration
IN_{SO4}= Sulfate WTP influent concentration
WQ_{Ca}= Ca WTP influent concentration

Other constituents are assumed to have the effluent discharge equal to the WTP influent.

3.3.3.4 Background Water Quality

Two background water quality datasets were provided—one to reflect SW quality entering the Pelly River (Pelly Background) and another to define the SW quality entering the remaining portions of the system (that is, Faro, Vangorda, Rose, and Anvil creeks) and referred to here as Faro Background. The background water quality concentrations were developed by Minnow Environmental Inc. and AECOM Canada Ltd (AECOM), as described by GEEC (2010).

3.3.4 Other Calculations

Equations 1 through 4 are the core equations contained in the GoldSim models. Other important equations contained in the models relate to how NP within a given WRD decreases with time, how seepage is intercepted, and how water is routed through the modelled system.

The hydrologic conceptualization contained within the model governs the flows and loads that are routed to pit lakes, SISs, WTPs, or to receiving waters. Inflows to the model domain were evaluated to ensure they balance with the associated outflows from the model domain. The overall balance of the inflow and outflow components contained in the model is described in Section 4.2.

Critical input parameters used to compute seepage, runoff, and loads from each modelled WRDs are summarized as follows:

- Precipitation per mining area (Faro and Vangorda/Grum)
- HEP per catchment
- Infiltration rate per WRD (a function of cover type)
- Area per WRD
- Percentage of WRD area in a given catchment
- Neutral and acidic water quality concentrations for a given WRD (based on a combination of water quality types for each WRD)
- AP and NP for a given WRD
- Calculated remaining NP

3.4 Model Initial and Boundary Conditions

GoldSim model v1 has fixed initial conditions reflective of January 2011 conditions. The model uses fixed average annual precipitation for the Faro and Vangorda/Grum mine areas and fixed average HEP values.

The HEP values for the various model catchments are used to calculate the monthly runoff and seepage flows for each of the WRD areas and are listed in Table 2. The HEP values on Table 2 were previously defined by AECOM (2009a) and GEEC (2010) as MAR. The SW flow boundary conditions are based on the catchment areas that are tributary to the model area and the associated HEP for each catchment area. The boundary conditions are summarized in Table 3 for the Faro and Vangorda/Grum mine areas. The boundary flows listed in Table 3 represent annual average flows that enter the modelled system.

The water quality parameters assigned to SW flows are the Faro Background water quality for Faro, except for (1) the Pelly River upstream V8 confluence with Pelly, which uses the Pelly Background, and (2) the alluvial inflows, which do not have any concentrations associated with the flows but eventually get mixed with the RCTA contaminated concentrations.

The water quality concentrations for each seepage water quality type, which were collected by SRK, are presented in Tables 4a through 4c and include average, median, and maximum values, respectively. The mix of water quality types for neutral conditions that represent each WRD seepage water quality is presented in Tables 5a and 5b for the Faro Mine Area and Vangorda/Grum Mine Area, respectively. Tables 6a and 6b present similar information, but for acidic conditions.

Table 7 normalizes the constituent concentrations around the average of concentrations across all water quality seepages. In other words, Table 7 presents a relative comparison of the water quality strength of the various seepage types as a percentage of the average for all types for each constituent. The table indicates which water types significantly deviate from the median of all types. For example, Type FD04 has concentrations of iron that are 786 percent higher than the average of all types. Also evident in the table is whether concentrations are evenly distributed across the water types or if specific types have significantly higher concentrations than others. For pH, zinc, cadmium, copper, and sulphate, the types Faro Type 3 Ore, FD04, FD37, and Vangorda Type 3 have significantly higher concentrations than the other seepage types. The data presented in Table 7 inform the user of the strength of the various water types and helps define the WRD water quality composition.

TABLE 1
Faro Mine Site Water Quality Model, Model Assumptions Sheet
Faro Mine Remediation Project

	Model Version/Alternative Model Version 1.0 (GEEC 2010)	(a) Model Version 2.0 Predictive Run	(b) Model Version 2.0 Historical Run
1 Hydrology			
Faro	Fixed annual precipitation of 357mm with fixed monthly pattern.	Monthly historical precipitation sequence. The historical data scales the HEP values as a percentage of the average (357mm). Monthly precipitation data was used from Faro Airport from Jan 1978 to Dec-2011. Data gaps were filled with the monthly average values. Precipitation was adjusted to be 20% greater than Faro Airport, but it is a user input and can be changed.	Historical precipitation starting Jan-2006 through Dec-2011, after that precipitation loops back to the first year of precipitation data, Jan-1978. Precipitation from Faro airport was increased by 20% to match historical flows in the current "in progress" version of the model.
Vangorda	Fixed annual precipitation of 369mm with fixed monthly pattern.	Same adjustment made for Faro with an extra 3.36% on historical precipitation and HEP.	Same as (a)
Evaporation/Evapotranspiration	Fixed annual value for evaporation from lake with monthly pattern. No evaporation for the Vangorda and Grum pits. No WRD evaporation. Evapotranspiration is not used.	The monthly pattern for lake evaporation is based on AECOM (2009) values in GoldSim model v2 and the same evaporation pattern is assumed to apply to all storage impoundments.	Same as (a)
2 Model Flows and Boundary Conditions			
DVT HEP	161mm	Version 1.0 values scaled based on historical precipitation.	Version 1.0 values scaled based on historical precipitation.
WRD above X2 (HEP)	202mm	Version 1.0 values scaled based on historical precipitation.	Version 1.0 values scaled based on historical precipitation.
WRD between X2 and X14 (HEP)	214mm	Version 1.0 values scaled based on historical precipitation.	Version 1.0 values scaled based on historical precipitation.
Faro Pit (HEP)	247mm	Version 1.0 values scaled based on historical precipitation.	Version 1.0 values scaled based on historical precipitation.
Upper Faro Creek	352mm	Version 1.0 values scaled based on historical precipitation.	Version 1.0 values scaled based on historical precipitation.
NFRC	325mm	Version 1.0 values scaled based on historical precipitation.	Version 1.0 values scaled based on historical precipitation.
Upper Anvil	325mm	Version 1.0 values scaled based on historical precipitation.	Version 1.0 values scaled based on historical precipitation.
Upper SFRC	342mm	Version 1.0 values scaled based on historical precipitation.	Version 1.0 values scaled based on historical precipitation.
Anvil Mouth	267mm	Version 1.0 values scaled based on historical precipitation.	Version 1.0 values scaled based on historical precipitation.
Rose Creek X14 mouth	255mm	Version 1.0 values scaled based on historical precipitation.	Version 1.0 values scaled based on historical precipitation.
SFRC	292mm	Version 1.0 values scaled based on historical precipitation.	Version 1.0 values scaled based on historical precipitation.
Z2	206mm (not used)	Version 1.0 values scaled based on historical precipitation.	Version 1.0 values scaled based on historical precipitation.
Vangorda Pit	206mm	Version 1.0 values scaled based on historical precipitation.	Version 1.0 values scaled based on historical precipitation.
Vangorda Dumps	206mm	Version 1.0 values scaled based on historical precipitation.	Version 1.0 values scaled based on historical precipitation.
Grum Pits	263mm	Version 1.0 values scaled based on historical precipitation.	Version 1.0 values scaled based on historical precipitation.
Grum Dumps	206mm	Version 1.0 values scaled based on historical precipitation.	Version 1.0 values scaled based on historical precipitation.
Grum Intercept	263mm	Version 1.0 values scaled based on historical precipitation.	Version 1.0 values scaled based on historical precipitation.
V1	374mm	Version 1.0 values scaled based on historical precipitation.	Version 1.0 values scaled based on historical precipitation.
V1 V27	193mm	Version 1.0 values scaled based on historical precipitation.	Version 1.0 values scaled based on historical precipitation.
V27 V8	193mm	Version 1.0 values scaled based on historical precipitation.	Version 1.0 values scaled based on historical precipitation.
Groundwater losses from Faro, Grum, and Vangorda pits are equal to 0	TRUE	TRUE	TRUE
Seepage from Z2 pit to NFRC	10%	Same as Version 1.0.	Same as (a)
Water storage in the WRD	No storage at WRD; all HEP that falls in a WRD report as seepage or runoff that same year.	Same as Version 1.0.	Same as (a)
FCD Seepage to Faro Pit	20%	26% (Based on ICAP water Balance.)	Same as (a)
RCD Seepage to RCTA area	NA	7% (Based on ICAP Water Balance.)	Same as (a)
Vangorda Creek Diversion seepage to Vangorda Pit	0%	0%	Same as (a)
Vangorda WRD surface runoff	65% of runoff to V27 (remainder to Shrimp Creek >V8)	Same as Version 1.0.	Same as (a)
Attenuation of seepage from waste rock or tailings	Not modelled.	not modelled	Not modelled
RCAA Alluvial Inflows	60 L/s	75 L/s based on more recent estimates (CH2M HILL, 2012)	Same as (a)

TABLE 1
Faro Mine Site Water Quality Model, Model Assumptions Sheet
Faro Mine Remediation Project

	Model Version/Alternative Model Version 1.0 (GEEC 2010)	(a) Model Version 2.0 Predictive Run	(b) Model Version 2.0 Historical Run
Groundwater Collection Efficiency	Uniform stochastic parameter varying from 95% to 99.9%, multiplying collection of groundwater; universal for all collection systems.	Efficiencies were updated: Zone 2 Outwash: 70-90 percent S-Wells: 70-90 percent ETA: 90-95 percent CVD: 90-95 percent SIS1, SIS2, SIS3,SIS4: 95-99.9 percent	Same as (a)
Faro Pit Load	NA	2012 values based on historical measured concentrations and pit volumes.	2006 values based on historical measured concentrations and pit volumes.
Vangorda Pit Load	NA	2012 values based on historical measured concentrations and pit volumes.	2006 values based on historical measured concentrations and pit volumes.
ID Load	NA	2012 values based on historical measured concentrations and pit volumes.	2006 values based on historical measured concentrations and pit volumes.
CVD Load	NA	2012 values based on historical measured concentrations and pit volumes.	2006 values based on historical measured concentrations and pit volumes.
Grum Load	NA	2012 values based on historical measured concentrations and pit volumes.	2006 values based on historical measured concentrations and pit volumes.
3 Implementation/Timing			
Stochastic/Deterministic	Stochastic run with 25 realizations.	Stochastic run with 100 realizations.	Deterministic run from 2006 to 2011
Start of the simulation (year)	2011	2012	2006
Upgrade S-Wells	year 0	Same as Version 1.0.	Same as (a)
Upgrade Z2 pumping well to year round operation	year 0	Same as Version 1.0.	Same as (a)
Faro WTP Capacity and implementation year	Unlimited capacity /year 1	5000 gpm maximum flow at year 0 changes to 6,000 gpm at year 5.	5000 gpm maximum flow
Cover WRD Oxide Fines (OXSP)	year 1	year 11	Same as (a)
Cover WRD - Low Grade Stock Piles (MGSP,CHSP,LGSPA,LGSPC)	year 1	year 11	Same as (a)
Cover WRD -Sulphide Cells (MESC, NELS, IDSC)	year 2	year 12	Same as (a)
Cover WRD - Mt. Mungly and South West Pit Wall Dumps	year 3	year 13	Same as (a)
Partial Relocation of North West Dumps	year 3	year 13	year 13
Implement Lower GHC water management system, intercept runoff and seepage from WRDs in Lower GHC catchment and direct to ETA SIS	year 3	year 10. same as ETA upgrades.	Same as (a)
Cover Remaining Faro WRD	year 9	year 19	Same as (a)
Upgrade of FCD Channel stopping seepage to Faro Pit	year 7. FCD seep to Faro Pit goes from 20% to 0%.	Assumed that Seepage does not stop	Same as (a)
Upgrade ETA SIS	Efficiency is upgraded from 70% to stochastic efficiency in year 8.	Efficiency is upgraded from 70% to stochastic efficiency in year 10.	Same as (a)
Cover Tailings	year 6	year 15	Same as (a)
Install other collection systems along NFRC (Zone II outwash SIS)	year 9	year 10	Same as (a)
Install CVD SIS	year 13	year 10	Same as (a)
Line NFRC	year 13	year 20	Same as (a)
Infiltration for Uncovered Areas	Infiltration is set as 45% of the precipitation.	Same as Version 1.0.	Same as (a)
Infiltration Rudimentary Cover	Uniform stochastic parameter from uniform distribution, from 15% to 25%, multiplying precipitation	Same as Version 1.0.	Same as (a)
Infiltration (low Infiltration cover)	Uniform stochastic parameter from uniform distribution, from 3% to 8%, multiplying precipitation	Same as Version 1.0.	Same as (a)
Infiltration (very low Infiltration cover)	Infiltration is set as 0.5% of the precipitation.	Same as Version 1.0.	Same as (a)
Cover WRD Grum Sulphide Cell (G1_S)	year 0	Same as Version 1.0.	Same as (a)

TABLE 1
Faro Mine Site Water Quality Model, Model Assumptions Sheet
Faro Mine Remediation Project

	Model Version/Alternative **Model Version 1.0 (GEEC 2010)**	**(a)** **Model Version 2.0 Predictive Run**	**(b)** **Model Version 2.0 Historical Run**
Upgrade Vangorda Creek Diversion	year 0	Same as Version 1.0.	Same as (a)
Cover WRD - Ore Transfer Pad (OTP)	year 2	year 19	Same as (a)
Cover WRD - Vangorda Dumps (V1_S, V1_B, V2, V3_O) and Vangorda In-Pit Dumps (VPL_1, VPL_2, VPL_3)	year 10	year 19	Same as (a)
Cover WRD - remaining Grum Dumps (G1_B, G2)	year 12	year 19	
Install Vangorda SIS (capture drainage to Main stem Vangorda Creek)	year 12	year 15 for V27 catchment year 15 for V8 catchment	Same as (a)
Grum Intercept of Runoff	Year 7	Year 15	Same as (a)
Vangorda/Faro Crossover Pipeline	NA	Year 13	Same as (a)
Pump Grum Outflows to WTP (Vangorda or Faro)	FALSE	Year 3	FALSE
Install Grum SIS (capture drainage to Main stem Vangorda Creek)	year 12	year 12 for V27 catchment Never implemented for V8 catchment.	Same as (a)
4 Water Quality			
Faro Pit	Pit concentration equals inflows plus pit walls loads.	The inclusion of the Faro Pit storage makes possible a mix in the pit so the pit outflow concentration is not the same of the inflows. Start water quality Load estimated from observed data concentrations and water elevation. Faro Pit wall loads estimated from SRK Model.	Same as (a)
Vangorda Pit	Pit concentration equals inflows plus pit walls loads.	The inclusion of the Vangorda Pit storage makes possible a mix in the pit so the pit outflow concentration is not the same of the inflows. Start water quality Load estimated from observed data concentrations and water elevation.	Same as (a)
Grum Pit	Biological treatment	Option to turn Biotreatment ON or OFF. Water quality for Biotreatment OFF was estimated from historical data. This Run has Biotreatment OFF	Same as (a)
Intermediate Dam	NA	Starting water quality load estimated from 2012 observed data concentrations and water elevation.	Starting water quality load estimated from 2006 observed data concentrations and water elevation.
CVD	NA	Starting water quality load estimated from 2012 observed data concentrations and water elevation.	Starting water quality load estimated from 2006 observed data concentrations and water elevation.
WRD	Maximum and average seepage conditions	Same as Version 1.0. Average seepage conditions used. Input Water quality adjusted for As, Pb, Se and Tl (CH2M HILL, 2012).	Same as (a)
AP/NP	Each WRD has an initial value for AP and NP, assumed to be for 2011.	Same as Version 1.0.	Same as (a); however this should be changed to better represent the current WRD acid status.
WRD change from Neutral to Acid	WRD transition from Neutral to Acid conditions when the remaining NP reaches 30% of the initial value. The initial NP value is multiplied by a uniform stochastic value (25%-75%).	Same as Version 1.0.	Same as (a)
RCTA	From SRK model for S04 and Zn; remaining elements are scaled based on S04. Data starts in 2011.	Same as Version 1.0. Extended the dataset for S04 and Zn average conditions used	Time series from SRK model starting in 2006, average conditions used
WRD Runoff	Water quality of runoff from WRD surfaces is set to 10% of what the seepage water quality concentration is before the cover and is assumed to be the same as background after the covers. Model does not have collection systems for runoff.	Same as Version 1.0.	Same as (a)
5 Operations			
Faro Pit	No Storage Element; flows are accumulated during non-treatment season then evenly discharged during treatment season.	Releases are based on a user-defined monthly rule curve optimized for 7 month WTP operation (April-October). The pit is allowed to fluctuate between 1,144 and 1,139 m based on the barge limitations.	Rule curve based on average historical operation
Vangorda Pit	No Storage Element; non-WTP season flows are accumulated to next season.	Target Elevation at the end of September.	Based on historical elevations
Grum Pit	Runoff is discharged to V27.	Target Elevation at the end of September. Grum Inflows are pumped to WTP	Based on historical elevations

TABLE 1
Faro Mine Site Water Quality Model, Model Assumptions Sheet
Faro Mine Remediation Project

	Model Version/Alternative Model Version 1.0 (GEEC 2010)	(a) Model Version 2.0 Predictive Run	(b) Model Version 2.0 Historical Run
ID	NA	Rule Curve is used. Releases are based on a user defined monthly Rule Curve. Pumping from ID before CVD SIS implementation is based on ID rule curve.	Same as (a)
CVD	NA	Rule Curve is used. Releases are based on a user defined monthly Rule Curve.	Same as (a)
Faro WTP Season	5-month treatment season (May-September).	7-month treatment season (April-October) with the option to extend treatment season to December if Faro Pit water surface elevation is above monthly target.	Same as Version 1.0.
Vangorda WTP Season	5-month treatment season (May-September).	7-month treatment season (April-October) until year 13 when Vangorda flows will start to go to the Faro mine area.	Same as Version 1.0.
Vangorda/Faro Crossover Pipeline	NA	Vangorda WTP stops operating when Crossover is implemented.	NA
S-wells pumping	Seepage is collected and pumped based on global efficiency of the SIS.	Seepage is collected and pumped based on the SIS efficiency.	Historical monthly values were used. The SIS efficiency parameter will be adjusted to match historical flows.
Z2 Pumping	90% of the Z2 flows are pumped to Faro Pit.	Same as Version 1.0.	Historical Z2 assumes all the Z2 flows are replaced by historical time series of Pumping *1/0.9 to account the pumping is only 90% of total Z2 Area.
ETA Pumping	Seepage is collected and pumped based on global efficiency of the SIS.	Seepage is collected and pumped based on the SIS efficiency. ETA flows are sent to ID Pond.	Historical ETA assumes that the pumped amount to WTP will be fixed to historical; the balance between the historical and the ETA monthly collected by the model will go to ID Pond.
6 Seepage Collection Assumptions			
ETA SIS	Not explicitly specified.	ETA flows to WTP during treatment season and to ID outside treatment season until year when tailings covers are implemented, then it flows to WTP during treatment season and to Faro Pit outside treatment season. Collects flows from the following WRDs: CHSP, FTE, FTW, LGSPA_X23, LGSPC_X23, MDE_X23, MDW, MESC, MGSP, MME, MMW, NWL_X23, NWM_X23, NWU_X23, OHRW_X23, OXSP, RD_X23, SPB, SWPWD_X23, MDE_RCV, OHRW_RCV, NWM_GHU, NWU_GHU, LPL, NWL_GHL, NWM_GHL, NWU_GHL, UPL. Assumed efficiency in collecting catchment seepage - 70-95%.	ETA flows into ID until 2011 when it starts to flow to WTP during treatment season and to ID out of the treatment season
CVD SIS	Not explicitly specified.	Uncollected WRD from the site that drains to DVT. Assumed efficiency in collecting catchment seepage - 90-95%.	Same as (a)
S-Wells	Not explicitly specified.	Always goes to the pit. X2 contributions: ID_X2, IDSC, MDE_X2,OHRE,OHRW_X2,RZD_X2. Assumed efficiency in collecting catchment seepage - 70-90%.	Same as (a)
Z2 Outwash (NFRC)	Not explicitly specified.	WRDs assumed to contribute to Z2 Outwash: NEL_NFRC,NELS_NFRC,NEU_NFRC,Z2E_NFRC. Assumed efficiency in collecting catchment seepage - 90-95%.	Same as (a)
Z2 Area	No Z2 pit. 90% of the Z2 WRDs flows go to Faro Pit, 10% is directed to groundwater to NFRC area.	Same as Version 1.0.	Same as (a)
Main Pit Catchment	Always goes to the pit.	Always goes to the pit.	Same as (a)

Notes:

GEEC. 2010. *Faro Mine Complex Closure and Reclamation. Site Wide Water Quality Model. Draft 1*. April.

% = percent
CVD = Cross Valley Dam
ETA = Emergency Tailings Area
gpm = gallons per minute
ICAP = *Anvil Range Mining Complex – Integrated Comprehensive Abandonment Plan*
ID = Intermediate Dam
NA = not applicable
RCD = Rose Creek Diversion
SIS = Seepage Interception System
SFRC = South Fork Rose Creek
WTP = Water Treatment Plan

TABLE 2
Hydrologically Effective Average Precipitation Values and the Areas They are Applied to
Faro Mine Remediation Project

Description/Applied Area	Model Abbreviation	HEP)
RCAA or DVT Hydrologically Effective Precipitation	DVTI_HEP	161mm
WRDs above X2, including NFRC, Z2, and X2 catchments	WR_aboveX2_HEP	202mm
WRDs between X2 and X14, including RCV, X23, GHL, and GHU catchments	WR_btwn_X2_X14_HEP	214mm
MP	FP_HEP	247mm
Upper Faro Creek (UFC)	UFC_HEP	352mm
NFRC	NFRC_HEP	325mm
Upper Anvil	Upper_Anvil_HEP	325mm
Upper South Fork Rose Creek	Upper_SFRC_HEP	342mm
Anvil Mouth	Anvil_Mouth_HEP	267mm
Rose Creek X14 mouth	Rose_X14_Mouth_HEP	255mm
SFRC	SFRC_HEP	292mm
Z2 area	Z2_HEP	206mm (not used)
Vangorda Pit	VP_HEP	206mm
Vangorda Dumps	VD_HEP	206mm
Grum Pits	GP_HEP	263mm
Grum Dumps	GD_HEP	206mm
Grum Intercept	GR_intercept_HEP	263mm
Catchment V1, upstream of V27	V1_HEP	374mm
Catchment between V1 and V27 flow points	V1_V27_HEP	193mm
Catchment between V27 and V8 flow points	V27_V8_HEP	193mm

TABLE 3
Model Boundary Conditions
Faro Mine Remediation Project

Boundary Condition Description	Model Abbreviation	Average HEP (mm)	Area (km^2)	Average Annual Flow Volume (m^3)
Faro Mine Area				
Faro Pit Lake Surface Inflows	FP_HEP	247	0.7	172,900
Faro Pit Catchment WRD inflows	FP_HEP	247	1.29	319,391
UFC inflows	UFC_HEP	352	15.3	5,385,600
NFRC inflows	NFRC_HEP	325	103.9	33,767,500
Upper SFRC inflows	Upper_SFRC_HEP	342	74.3	25,393,500
Alluvial Inflow	IN_Alluvial_Inflow	N/A	N/A	1,893,415
FCD Seepage	FC_Div_Leakage	N/A	N/A	% of UFC_HEP inflows
SFRC inflows	SFRC_HEP	292	102.1	29,813,200
Rose Creek X14 mouth inflows	Rose_X14_Mouth_HEP	255	105	26,775,000
Upper Anvil inflows	Upper_Anvil_HEP	325	322	104,650,000
Anvil Mouth (minus Upper Anvil) inflows	Anvil_Mouth_HEP	267	321	85,707,000
RCAA inflows	DVTI_HEP	161	4.1	660,100
WRDs above X2, including NFRC, Z2, and X2 catchments	WR_aboveX2_HEP	202	1.75	354,349
WRDs between X2 and X14, including RCV, X23, GHL, and GHU catchments	WR_btwn_X2_X14_HEP	214	3.31	707,624
Vangorda Mine Area				
Grum Pits	GP_HEP	263	2.26	594,380
V1 Area or undisturbed Catchment V1 upstream of V27	V1_HEP	374	20.2	7,554,800
Area between V1 and v27 Flows, locations V1 to V27	V1_V27_HEP	193	3	579,000
V27 to V8 Area; includes the drainage area between V8 and v27, including Shrimp Creek	V27_V8_HEP	193	59.6	11,502,800
Pelly River				
Pelly River Upstream V8 confluence with Pelly	Pelly_US_V8	N/A	N/A	6,125,170,000

Notes:
km^2 = square kilometre(s)

TABLE 4A
Average Values for Seepage Water Quality Types
Faro Mine Remediation Project

	Type																	
Water Quality Parameter	**Faro Type 1**	**Faro Type 2 Ore**	**Faro Type 2 Waste**	**Faro Type 3 Ore**	**Faro Type 3 Waste**	**FD04**	**FD05/06**	**FD14**	**FD19**	**FD37**	**FD40**	**Grum Type 1a**	**Grum Type 1b**	**Grum Type 2**	**Grum Type 3 (Faro 3w)**	**Grum Type WGD**	**Vangorda Type 2**	**Vangorda Type 3**
pH	8	7	7	3	4	2	8	8	8	3	4	8	8	7	4	8	7	4
Acidity mg/L	12	419	72	16,894	1,348	30,970	11	9	125	29,738	300	11	25	93	1,348	13	637	11,016
Alkalinity mg/L	182	203	134	4	10	1	199	113	375	1	9	320	509	302	10	334	131	22
Ag mg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Al mg/L	0	0	1	223	27	502	0	0	0	309	13	0	0	0	27	0	0	108
As µg/L [a]	0	3	5	1,074	678	136	0	0	1	291,000	4	1	3	3	678	4	0	109
B µg/L	33	10	17	500	37	0	30	35	10	500	10	23	30	10	37	23	42	50
Be µg/L	0	2	0	18	22	0	0	0	1	31	8	0	1	0	22	0	7	31
Ca mg/L	144	474	284	318	172	378	121	178	569	289	65	156	336	307	172	183	331	429
Cd µg/L	5	115	41	11,913	1,359	9,645	2	10	28	27,713	3,689	0	2	44	1,359	0	131	4,631
Cl mg/L	1	10	1	87	3	342	2	1	2	2	1	1	2	2	3	1	1	2
Co µg/L	7	399	85	5,722	564	10,620	1	9	86	9,801	227	4	10	142	564	4	1,766	12,825
Cr µg/L	0	11	0	499	82	740	0	0	0	753	21	0	0	0	82	0	10	185
Cu mg/L	0	0	0	154	3	249	0	0	0	345	1	0	0	0	3	0	0	12
Fe mg/L	0	37	3	2,618	223	6,748	0	0	0	3,896	44	0	0	9	223	0	91	1,568
K mg/L	6	12	8	5	6	0	4	15	10	0	1	3	7	7	6	3	9	10
Mg mg/L	125	497	322	594	252	1,655	93	229	601	614	74	78	246	260	252	102	481	2,532
Mn µg/L	158	37,541	7,708	310,378	20,717	936,000	85	175	20,879	356,625	4,086	105	134	2,249	20,717	64	135,965	1,484,300
Mo µg/L	1	4	1	9	1	0	0	2	2	18	0	1	1	2	1	1	8	158
Na mg/L	26	43	11	37	9	10	6	90	20	3	3	3	11	7	9	4	8	6
NH3 mg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ni µg/L	54	571	262	5,104	927	7,700	44	69	407	9,200	177	90	401	664	927	90	2,724	10,875
No2 mg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NO3 mg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pb µg/L [a]	3	6	18	670	604	96	0	7	14	4,090	334	1	2	8	604	0	3	318
Sb µg/L	0	0	0	483	1	0	0	1	0	722	0	0	1	1	1	0	0	37
Se µg/L [a]	1	3	1	15	1	10	3	3	13	250	1	1	2	10	1	3	1	2
Sn µg/L	0	136	0	7	1	0	0	0	0	13	0	26	22	0	1	26	82	2,027
SO4 mg/L	732	3,667	2,066	20,647	2,533	35,523	448	1,559	3,839	35,900	755	384	1,367	1,723	2,533	518	3,589	24,776
Sr mg/L	1	3	1	1	1	0	1	2	3	0	0	1	1	1	1	1	1	2
T_p mg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tl µg/L [a]	0	1	1	6	4	1	0	0	0	25	1	0	0	2	4	0	1	3
U µg/L	31	7	6	692	126	0	9	86	14	1,370	27	18	31	13	126	18	16	604
V µg/L	8	47	9	48	19	0	0	17	24	90	1	1	11	1	19	1	17	524
Zn mg/L	3	226	38	7,309	275	6,930	3	4	66	15,759	69	0	4	44	275	0	310	4,660

Notes:
[a] Values changed from GEEC 2010 report.
µg/L = microgram(s) per litre

TABLE 4B
Median Values for Seepage Water Quality Types
Faro Mine Remediation Project

	Type																	
Water Quality Parameter	**Faro Type 1**	**Faro Type 2 Ore**	**Faro Type 2 Waste**	**Faro Type 3 Ore**	**Faro Type 3 Waste**	**FD04**	**FD05/06**	**FD14**	**FD19**	**FD37**	**FD40**	**Grum Type 1a**	**Grum Type 1b**	**Grum Type 2**	**Grum Type 3 (Faro 3w)**	**Grum Type WGD**	**Vangorda Type 2**	**Vangorda Type 3**
pH	8	7	7	3	4	2	8	8	8	3	4	8	8	8	4	8	7	4
Acidity mg/L	12	417	62	8,725	216	34,300	8	8	114	31,000	145	9	22	83	216	12	312	5,900
Alkalinity mg/L	190	219	57	1	2	1	206	118	403	2	2	336	540	290	2	390	150	2
Ag mg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Al mg/L	0	0	0	94	9	497	0	0	0	277	8	0	0	0	9	0	0	29
As µg/L [a]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
B µg/L	35	10	10	500	50	0	20	35	10	500	10	10	30	10	50	10	50	50
Be µg/L	0	1	0	9	9	0	0	0	1	35	7	0	0	0	9	0	7	24
Ca mg/L	131	494	218	332	126	424	115	176	590	283	68	165	348	321	126	173	393	444
Cd µg/L	4	47	35	6,305	115	10,700	2	8	14	25,800	70	0	1	25	115	0	80	1,600
Cl mg/L	1	13	1	2	1	159	1	1	2	1	1	1	2	2	1	1	1	1
Co µg/L	3	435	60	3,075	239	10,550	0	12	62	9,740	175	2	4	63	239	2	906	7,670
Cr µg/L	0	0	0	345	20	900	0	0	0	820	23	0	1	0	20	0	1	105
Cu mg/L	0	0	0	8	1	132	0	0	0	324	1	0	0	0	1	0	0	1
Fe mg/L	0	23	1	1,170	27	5,295	0	0	0	3,225	29	0	0	1	27	0	8	1,030
K mg/L	4	13	8	4	6	0	4	15	10	0	1	3	7	7	6	3	11	10
Mg mg/L	97	629	159	379	136	1,610	86	221	582	601	61	71	237	253	136	96	398	1,990
Mn µg/L	81	48,850	3,710	146,500	6,300	629,500	5	79	18,150	362,000	3,190	7	56	1,470	6,300	34	45,000	1,090,000
Mo µg/L	0	5	0	9	0	0	0	2	2	18	0	1	1	1	0	1	2	21
Na mg/L	8	45	6	17	4	10	6	120	21	3	3	3	11	5	4	4	9	5
NH3 mg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ni µg/L	55	630	179	3,170	312	7,500	31	63	383	8,965	123	87	350	501	312	87	2,370	6,610
No2 mg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NO3 mg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pb µg/L [a]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sb µg/L	0	0	0	408	0	0	0	1	0	530	0	0	1	1	0	0	0	2
Se µg/L [a]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Sn µg/L	0	30	0	7	0	0	0	0	0	13	0	26	0	0	0	26	36	2,550
SO4 mg/L	513	4,150	1,270	11,600	1,340	37,800	399	1,435	3,835	34,500	612	413	1,345	1,700	1,340	502	2,880	17,500
Sr mg/L	1	3	1	0	0	0	0	2	3	0	0	1	1	1	0	1	2	1
T_p mg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tl µg/L [a]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
U µg/L	11	7	1	552	23	0	10	86	14	1,370	27	18	28	4	23	18	16	489
V µg/L	0	34	0	48	1	0	0	1	24	90	1	0	1	1	1	0	1	68
Zn mg/L	2	2.17E+02	30	5,515	59	7,795	2	3	53	14,350	44	0	3	17	59	0	129	2,760

Note:
[a] Values changed from GEEC 2010 report.

TABLE 4C
Maximum Values for Seepage Water Quality Types
Faro Mine Remediation Project

	Type																	
Water Quality Parameter	**Faro Type 1**	**Faro Type 2 Ore**	**Faro Type 2 Waste**	**Faro Type 3 Ore**	**Faro Type 3 Waste**	**FD04**	**FD05/06**	**FD14**	**FD19**	**FD37**	**FD40**	**Grum Type 1a**	**Grum Type 1b**	**Grum Type 2**	**Grum Type 3 (Faro 3w)**	**Grum Type WGD**	**Vangorda Type 2**	**Vangorda Type 3**
pH	8	8	8	7	8	3	8	8	8	3	7	8	9	8	8	8	8	7
Acidity mg/L	34	2.16E+03	281	53,100	19,800	49,500	31	24	281	53,100	1,220	40	69	238	19,800	30	6,230	41,600
Alkalinity mg/L	40	1.30E+01	2	1	1	1	85	40	259	1	1	108	255	659	92	108	351	127
Ag mg/L	0	0.00E+00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Al mg/L	0	0	4	986	405	986	0	0	0	578	39	0	0	0	405	0	0	687
As µg/L [a]	0	3	10	2,030	5,130	136	0	0	1	291,000	4	6	4	5	5,130	8	0	306
B µg/L	50	1.00E+01	50	500	50	0	50	50	10	500	10	50	50	10	50	50	50	50
Be µg/L	0	7	1	50	210	0	0	0	1	50	17	0	6	0	210	0	14	82
Ca mg/L	279	6.19E+02	675	508	468	504	201	279	675	348	124	286	477	462	468	286	534	603
Cd µg/L	20	645	104	56,700	46,700	15,500	6	20	82	56,700	46,700	0	5	178	46,700	0	1,070	23,200
Cl mg/L	3	2.50E+01	3	1,050	48	1,050	3	3	3	5	3	3	3	1	0	3	0	1
Co µg/L	29	1,060	560	20,000	6,320	20,000	3	20	290	16,900	652	12	50	696	6,320	12	10,300	38,300
Cr µg/L	1	33	0	1,180	521	1,100	0	1	0	1,180	42	1	1	1	521	1	29	573
Cu mg/L	0	2	1	559	61	559	0	0	0	559	5	0	0	2	61	0	0	180
Fe mg/L	1	135	20	15,100	4,320	15,100	0	1	3	9,440	162	0	1	46	4,320	0	1,070	8,350
K mg/L	24	29	25	11	20	0	5	24	12	0	2	4	12	20	20	4	14	28
Mg mg/L	397	873	2,040	3,210	2,090	3,210	213	397	765	1,100	178	179	438	570	2,090	179	2,790	8,410
Mn µg/L	687	84,900	35,700	2,360,000	315,000	2,360,000	493	495	35,700	656,000	13,400	1,920	1,008	7,520	315,000	608	1,200,000	4,830,000
Mo µg/L	2	8	2	18	3	0	0	2	2	18	0	2	3	4	3	2	28	434
Na mg/L	150	79	65	216	114	10	9	150	26	3	5	6	18	15	114	6	16	15
NH3 mg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ni µg/L	135	1,430	1,840	15,800	11,600	15,000	121	135	676	15,800	477	132	1,420	2,650	11,600	132	7,200	38,000
No2 mg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NO3 mg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pb µg/L [a]	10	8	94	1,420	1,120	96	0	7	14	4,090	334	2	4	34	1,120	0	3	955
Sb µg/L	1	0	0	1,530	9	0	0	1	0	1,530	0	1	4	3	9	1	0	108
Se µg/L [a]	1	3	3	15	1	10	4	3	13	250	1	2	4	24	1	5	1	3
Sn µg/L	0	313	0	13	3	0	0	0	0	13	0	51	99	0	3	51	256	3,000
SO4 mg/L	2,667	6,290	10,920	67,200	27,930	59,000	1,160	2,667	5,100	67,200	2,000	836	2,496	4,100	27,930	836	18,600	88,800
Sr mg/L	4	4	4	2	2	1	1	4	4	1	0	1	2	2	2	1	2	6
T_p mg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tl µg/L [a]	0	2	4	10	20	1	0	0	0	25	1	0	0	5	20	1	1	8
U µg/L	149	11	15	1,660	589	0	11	149	15	1,660	45	18	52	33	589	18	21	1,720
V µg/L	49	122	48	90	81	0	0	49	48	90	1	1	59	1	81	1	114	2,580
Zn mg/L	14	655	166	34,800	4,480	10,900	14	11	166	34,800	199	0	17	139	4,480	0	2,580	16,700

Note:
[a] Values changed from GEEC 2010 report.

TABLE 5A
Faro Neutral Conditions
Faro Mine Remediation Project

	Faro Type 1	Faro Type 2 Ore	Faro Type 2 Waste	Faro Type 3 Ore	Faro Type 3 Waste	FD04	FD05/06	FD14	FD19	FD37	FD40
WRD	**F1**	**F2W**	**F2O**	**F3W**	**F3O**	**FD04**	**FD05_06**	**FD14**	**FD19**	**FD37**	**FD40**
Crusher Stockpile (CHSP)	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
Faro Valley North (FVN)	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
Faro Valley South (FVS)	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
Fuel Tank Dump E (FTE)	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Tank Dump W (FTW)	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
Intermediate Dump (ID)	50%	0%	30%	0%	20%	0%	0%	0%	0%	0%	0%
Intermediate Dump Sulphide Cell (IDSC)	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
Low Grade Stockpile A (LGSPA)	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
Low Grade Stockpile C (LGSPC)	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
Lower Northeast Dump (NEL)	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
Lower Northeast Sulphide Cell (NELS)	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
Lower Northwest Dump (NWL)	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
Lower Parking Lot Dump (LPL)	90%	0%	10%	0%	0%	0%	0%	0%	0%	0%	0%
Main Dump East MDE (MDE)	40%	0%	40%	0%	20%	0%	0%	0%	0%	0%	0%
Main Dump West (MDW)	0%	0%	90%	0%	10%	0%	0%	0%	0%	0%	0%
Main East Sulphide Cell (MESC)	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
Medium Grade Stockpile (MGSP)	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
Middle Northwest Dump (NWM)	70%	0%	20%	0%	10%	0%	0%	0%	0%	0%	0%
Mt. Mungly East (MME)	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
Mt. Mungly West (MMW)	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
Outer Haul Road East (OHRE)	40%	0%	60%	0%	0%	0%	0%	0%	0%	0%	0%
Outer Haul Road West (OHRW)	50%	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%
Outer Northeast Dump (NEO)	50%	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%
Oxide Fines Stockpile (OXSP)	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
Ramp Zone Dump (RZD)	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Ranch Dump RD (RD)	50%	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%
Southwest Pit Wall Dump (SWPWD)	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%

TABLE 5A
Faro Neutral Conditions
Faro Mine Remediation Project

	Faro Type 1	Faro Type 2 Ore	Faro Type 2 Waste	Faro Type 3 Ore	Faro Type 3 Waste	FD04	FD05/06	FD14	FD19	FD37	FD40
WRD	**F1**	**F2W**	**F2O**	**F3W**	**F3O**	**FD04**	**FD05_06**	**FD14**	**FD19**	**FD37**	**FD40**
Stock Piles Base1 (SPB)	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
Upper Northeast Dump (NEU)	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
Upper Northwest Dump (NWU)	70%	0%	20%	0%	10%	0%	0%	0%	0%	0%	0%
Upper Parking Lot Dump (UPL)	95%	0%	5%	0%	0%	0%	0%	0%	0%	0%	0%
Zone II East (Z2E)	50%	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%
Zone II West (Z2W)	40%	0%	60%	0%	0%	0%	0%	0%	0%	0%	0%

TABLE 5B
Vangorda Neutral Conditions
Faro Mine Remediation Project

	Grum Type 1a	Grum Type 1b	Grum Type WGD	Grum Type 2	Grum Type 3 (Faro 3w)	Vangorda Type 2	Vangorda Type 3
	G1a	G1b	WGD	G2	G3	V2	V3
Main Dump Sulphide Cell (G1-S)	0%	90%	0%	0%	0%	10%	0%
Main Dump (G1-B)	0%	100%	0%	0%	0%	0%	0%
Southwest Dump (G2)	0%	0%	100%	0%	0%	0%	0%
Overburden Dump (G3-O)	100%	0%	0%	0%	0%	0%	0%
Main Dump Sulphide Cell (V1-S)	0%	0%	0%	0%	0%	0%	100%
Main Dump (V1-B)	0%	0%	0%	0%	0%	80%	20%
Barite Dump (V2)	0%	0%	0%	0%	0%	0%	100%
Overburden Dump (V3-O)	0%	90%	0%	0%	0%	10%	0%
Ore Transfer Pad (OTP)	0%	90%	0%	0%	0%	10%	0%
Dump Southwest of Ramp (VPL1)	0%	0%	0%	0%	0%	50%	50%
Dump Inside Hairpin (VPL2)	0%	0%	0%	0%	0%	80%	20%
Oxide Fines Dump (VPL3)	0%	0%	0%	0%	0%	0%	100%

TABLE 6A
Faro Acidic Conditions
Faro Mine Remediation Project

WRD	Type										
	Faro Type 1	Faro Type 2 Ore	Faro Type 2 Waste	Faro Type 3 Ore	Faro Type 3 Waste	FD04	FD05/06	FD14	FD19	FD37	FD40
Crusher Stockpile (CHSP)	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
Faro Valley North (FVN)	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
Faro Valley South (FVS)	0%	0%	80%	0%	20%	0%	0%	0%	0%	0%	0%
Fuel Tank Dump E (FTE)	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Tank Dump W (FTW)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
Intermediate Dump (ID)	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
Intermediate Dump Sulphide Cell (IDSC)	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
Low Grade Stockpile A (LGSPA)	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
Low Grade Stockpile C (LGSPC)	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
Lower Northeast Dump (NEL)	0%	0%	50%	0%	50%	0%	0%	0%	0%	0%	0%
Lower Northeast sulphide cell (NELS)	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
Lower Northwest Dump (NWL)	0%	0%	50%	0%	50%	0%	0%	0%	0%	0%	0%
Lower Parking Lot Dump (LPL)	0%	0%	80%	0%	20%	0%	0%	0%	0%	0%	0%
Main Dump East MDE (MDE)	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
Main Dump West (MDW)	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
Main East Sulphide Cell (MESC)	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
Medium Grade Stockpile (MGSP)	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
Middle Northwest Dump (NWM)	0%	0%	50%	0%	50%	0%	0%	0%	0%	0%	0%
Mt. Mungly East (MME)	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
Mt. Mungly West (MMW)	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
Outer Haul Road East (OHRE)	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
Outer Haul Road West (OHRW)	0%	0%	50%	0%	50%	0%	0%	0%	0%	0%	0%
Outer Northeast Dump (NEO)	50%	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%
Oxide Fines Stockpile (OXSP)	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
Ramp Zone Dump (RZD)	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Ranch Dump RD (RD)	0%	0%	50%	0%	50%	0%	0%	0%	0%	0%	0%
Southwest Pit Wall Dump (SWPWD)	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%

TABLE 6A
Faro Acidic Conditions
Faro Mine Remediation Project

	Type										
WRD	**Faro Type 1**	**Faro Type 2 Ore**	**Faro Type 2 Waste**	**Faro Type 3 Ore**	**Faro Type 3 Waste**	**FD04**	**FD05/06**	**FD14**	**FD19**	**FD37**	**FD40**
Stock Piles Base1 (SPB)	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
Upper Northeast Dump (NEU)	0%	0%	50%	0%	50%	0%	0%	0%	0%	0%	0%
Upper Northwest Dump (NWU)	0%	0%	50%	0%	50%	0%	0%	0%	0%	0%	0%
Upper Parking Lot Dump (UPL)	95%	0%	5%	0%	0%	0%	0%	0%	0%	0%	0%
Zone II East (Z2E)	50%	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%
Zone II West (Z2W)	0%	0%	20%	0%	80%	0%	0%	0%	0%	0%	0%

TABLE 6B
Vangorda Acidic Conditions
Faro Mine Remediation Project

	Grum Type 1a	Grum Type 1b	Grum Type WGD	Grum Type 2	Grum Type 3 (Faro 3w)	Vangorda Type 2	Vangorda Type 3
	G1a	**G1b**	**WGD**	**G2**	**G3**	**V2**	**V3**
Main Dump Sulphide Cell (G1-S)	0%	0%	0%	0%	0%	10%	100%
Main Dump (G1-B)	0%	50%	0%	45%	5%	0%	0%
Southwest Dump (G2)	0%	50%	50%	0%	0%	0%	0%
Overburden Dump (G3-O)	100%	0%	0%	0%	0%	0%	0%
Main Dump Sulphide Cell (V1-S)	0%	0%	0%	0%	0%	0%	100%
Main Dump (V1-B)	0%	0%	0%	0%	0%	0%	100%
Barite Dump (V2)	0%	0%	0%	0%	0%	0%	100%
Overburden Dump (V3-O)	0%	90%	0%	0%	0%	10%	0%
Ore Transfer Pad (OTP)	0%	0%	0%	0%	0%	0%	100%
Dump Southwest of Ramp (VPL1)	0%	0%	0%	0%	0%	0%	100%
Dump Inside Hairpin (VPL2)	0%	0%	0%	0%	0%	70%	30%
Oxide Fines Dump (VPL3)	0%	0%	0%	0%	0%	0%	100%

TABLE 7
Percent of Total Average along Type
Faro Mine Remediation Project

	Type																	
Water Quality Parameter	**Faro Type 1**	**Faro Type 2 Ore**	**Faro Type 2 Waste**	**Faro Type 3 Ore**	**Faro Type 3 Waste**	**FD04**	**FD05/06**	**FD14**	**FD19**	**FD37**	**FD40**	**Grum Type 1a**	**Grum Type 1b**	**Grum Type 2**	**Grum Type 3 (Faro 3w)**	**Grum Type WGD**	**Vangorda Type 2**	**Vangorda Type 3**
pH	130%	115%	120%	54%	71%	41%	130%	131%	126%	42%	72%	133%	131%	123%	71%	132%	111%	69%
Acidity	0%	8%	1%	327%	26%	599%	0%	0%	2%	575%	6%	0%	0%	2%	26%	0%	12%	213%
Alkalinity	115%	128%	84%	3%	6%	1%	125%	71%	236%	1%	6%	201%	321%	190%	6%	210%	82%	14%
Ag	0%	6%	1%	511%	12%	0%	0%	0%	2%		4%	1%	23%	1%	12%	1%	10%	215%
Al	0%	0%	1%	332%	41%	746%	0%	0%	0%	460%	19%	0%	0%	0%	41%	0%	0%	160%
As	0%	0%	0%	7%	4%	1%	0%	0%	0%		0%	0%	0%	0%	4%	0%	0%	1%
B	43%	13%	21%	644%	47%	0%	39%	45%	13%	644%	13%	30%	39%	13%	47%	30%	54%	64%
Be	1%	27%	4%	225%	280%	0%	0%	2%	7%	390%	98%	1%	8%	1%	280%	1%	88%	387%
Ca	53%	174%	104%	117%	63%	139%	44%	65%	209%	106%	24%	57%	123%	113%	63%	67%	121%	158%
Cd	0%	3%	1%	353%	40%	286%	0%	0%	1%	822%	109%	0%	0%	1%	40%	0%	4%	137%
Cl	5%	40%	5%	338%	13%		6%	3%	8%	8%	4%	5%	7%	6%	13%	4%	4%	7%
Co	0%	17%	4%	240%	24%	446%	0%	0%	4%	412%	10%	0%	0%	6%	24%	0%	74%	539%
Cr	0%	8%	0%	376%	62%	558%	0%	0%	0%	568%	16%	0%	0%	0%	62%	0%	7%	140%
Cu	0%	0%	0%	361%	8%	584%	0%	0%	0%	808%	3%	0%	0%	1%	8%	0%	0%	27%
Fe	0%	4%	0%	305%	26%	786%	0%	0%	0%	454%	5%	0%	0%	1%	26%	0%	11%	183%
K	103%	193%	119%	83%	103%	0%	58%	236%	156%	0%	21%	47%	111%	116%	103%	48%	148%	157%
Mg	25%	99%	64%	119%	50%	331%	19%	46%	120%	123%	15%	16%	49%	52%	50%	20%	96%	506%
Mn	0%	20%	4%	167%	11%	505%	0%	0%	11%	192%	2%	0%	0%	1%	11%	0%	73%	800%
Mo	5%	38%	6%	78%	9%	0%	1%	16%	18%	154%	2%	10%	9%	17%	9%	10%	64%	
Na	155%	253%	63%	216%	53%	59%	35%	532%	120%	16%	18%	19%	62%	40%	53%	23%	45%	38%
Ni	2%	26%	12%	228%	41%	344%	2%	3%	18%	411%	8%	4%	18%	30%	41%	4%	122%	486%
Pb	1%	2%	5%	178%	160%	25%	0%	2%	4%		89%	0%	1%	2%	160%	0%	1%	85%
Sb	0%	0%	0%	695%	2%	0%	0%	1%	1%		0%	1%	2%	2%	2%	1%	0%	53%
Se	4%	17%	6%	85%	4%	56%	18%	15%	75%		6%	6%	11%	54%	4%	15%	4%	10%
Sn	0%	105%	0%	5%	0%	0%	0%	0%	0%	10%	0%	20%	17%	0%	0%	20%	63%	
SO4	9%	46%	26%	261%	32%	449%	6%	20%	48%	453%	10%	5%	17%	22%	32%	7%	45%	313%
Sr	82%	244%	114%	60%	52%	40%	43%	197%	273%	36%	22%	56%	112%	90%	52%	71%	112%	144%
Tl	3%	39%	43%	214%	133%	37%	7%	18%	9%		24%	2%	11%	78%	133%	6%	29%	94%
U	18%	4%	3%	390%	71%	0%	5%	48%	8%	772%	15%	10%	17%	7%	71%	10%	9%	340%
V	17%	102%	20%	103%	41%	0%	0%	36%	52%	194%	1%	1%	23%	1%	41%	1%	37%	
Zn	0%	11%	2%	366%	14%	347%	0%	0%	3%	789%	3%	0%	0%	2%	14%	0%	16%	233%

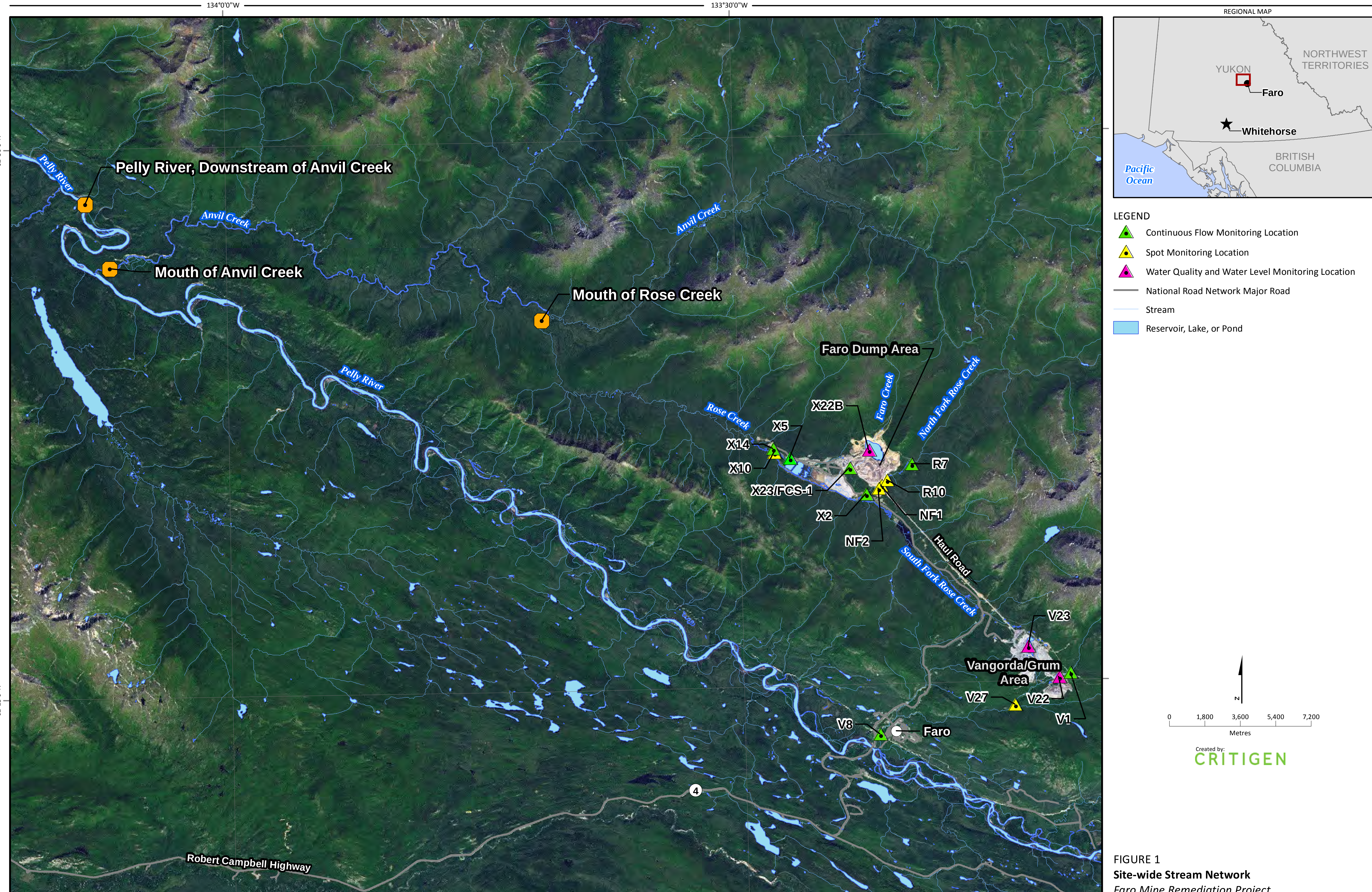

FIGURE 1
Site-wide Stream Network
Faro Mine Remediation Project

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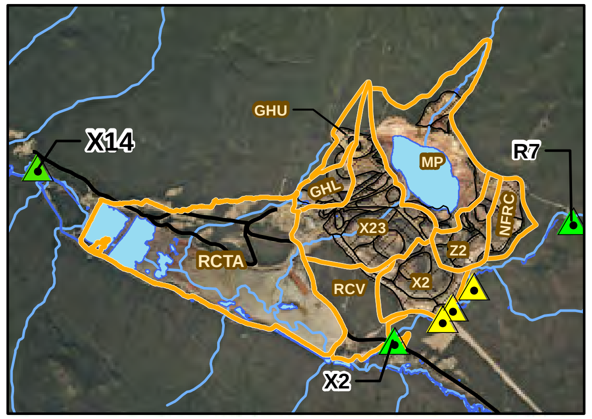
VICINITY MAP



LEGEND

- Continuous Flow Monitoring Location
- Spot Monitoring Location
- Road
- Stream
- Roads Unpaved
- Reservoir, Lake, or Pond
- Catchment Area
- Waste Rock Dump Area

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. Rose Creek Tailings Area (RCTA) is also referred as Down Valley Tailings (DVT) Area, and is where the Rose Creek Alluvial Aquifer (RCAA) is located.

N

0 130 260 390 520

Metres

Created by:
CRITIGEN

FIGURE 2a
Faro Mine Area – Waste Rock Dump and Catchment Boundaries
Faro Mine Remediation Project

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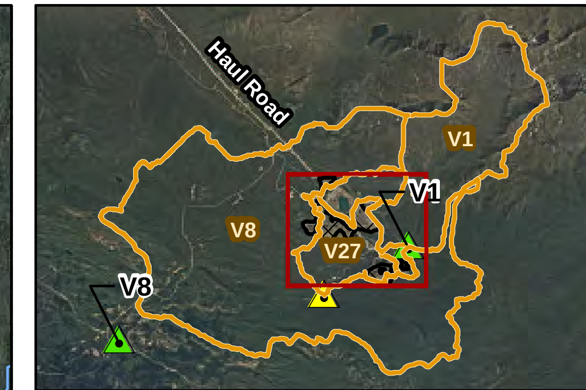
VICINITY MAP



LEGEND

- Continuous Flow Monitoring Location
- Spot Monitoring Location
- Faro Site Watercourse
- Roads Unpaved
- Faro Site Waterbody
- Waste Rock Dump Area
- Catchment Area

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. Locations of VPL1, VPL2, and VPL3 are approximate.

N

0 150 300 450 600
Metres

Created by:
CRITIGEN

FIGURE 2b
Vangorda/Grum Mine Area – Waste Rock Dump and Catchment Boundaries
Faro Mine Remediation Project

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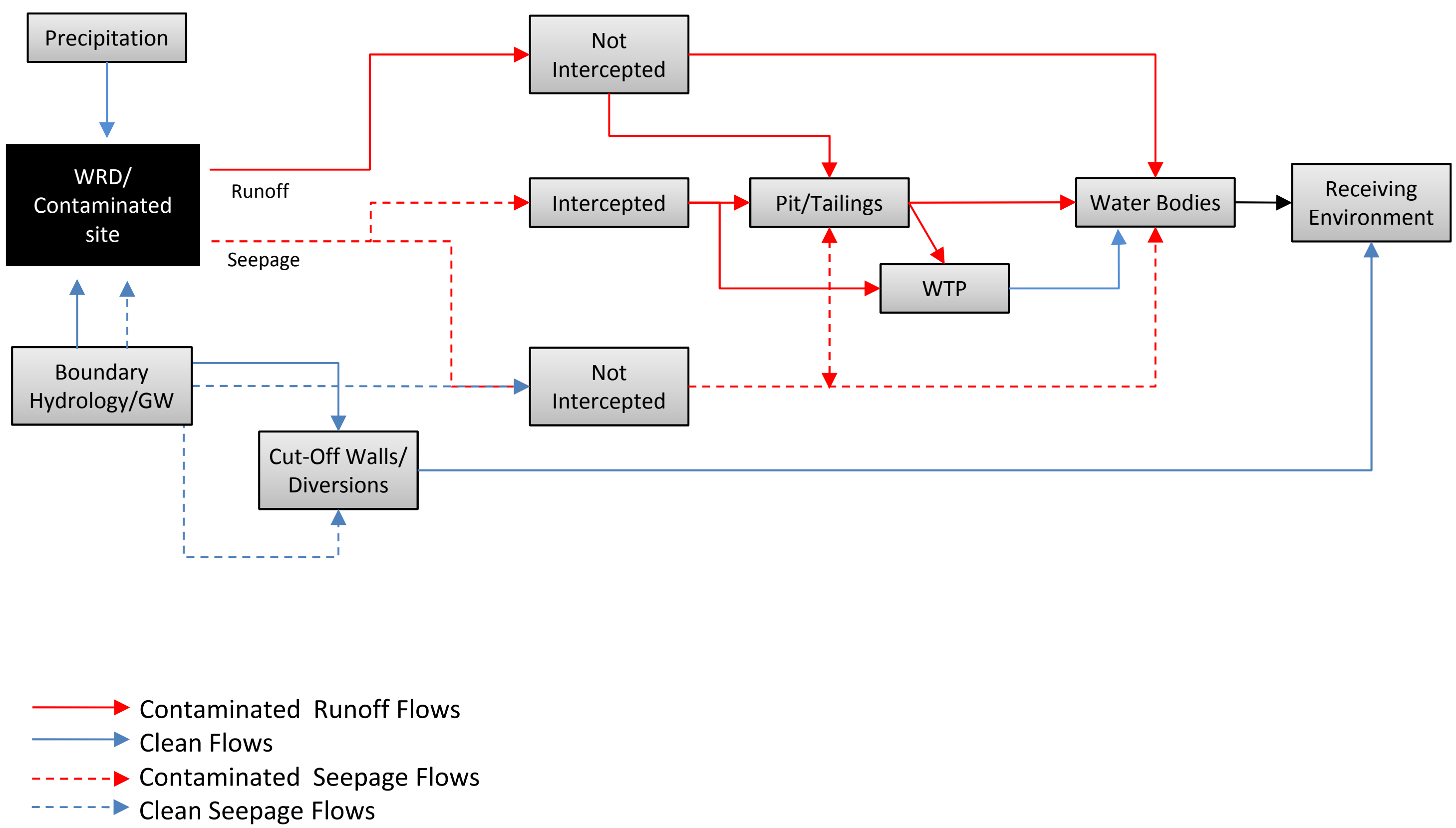
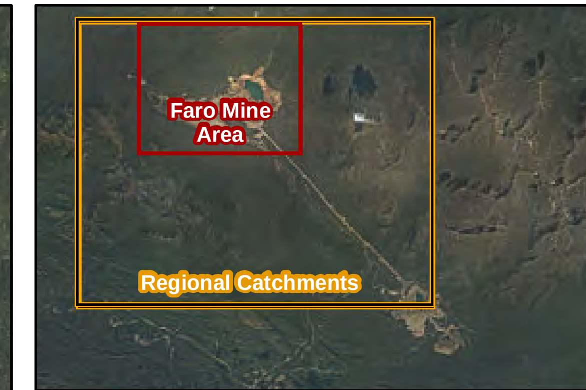


Notes:
Connections represent current and possible future connections.

FIGURE 3
General WRD Flow Routing in the FMC
Faro Mine Remediation Project

VICINITY MAP



LEGEND

- GoldSim Model Node with Flow and Concentration Output
- Stream
- Lake, Pond, or Pool

Water Line Type

- Pump
- Proposed Groundwater Collection
- Runoff
- Seepage
- WTP Flows

Seepage Collection System

- Installed Groundwater Collection System
- Proposed Groundwater Collection System
- Pump/Discharge Collection System
- Water Treatment Plant (WTP)
- Local Catchments
- Regional Catchment
- Groundwater Seepage and Underflow

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. ETA = Emergency Tailing Area
4. Downstream model output nodes "Mouth RC," "Confluence with Upper Anvil Creek," and "Mouth of Anvil Creek" not shown, out of view.
5. SIS = Subsurface Interception System
6. Regional catchment areas are approximate and do not exactly match the GoldSim model input areas. Regional catchments correspond to input parameters listed on Figure 4a.
7. Local catchment areas do match the water quality model. Local catchments correspond to catchments identified on Figure 4a.
8. SFRC inputs (posted on Figure 4a) include the following regional catchments shown in the inset: South Fork Rose Creek, Rose Creek Diversion, and Upper Guardhouse Creek/North Wall Interceptor.

N

0 250 500 750 1,000

Metres

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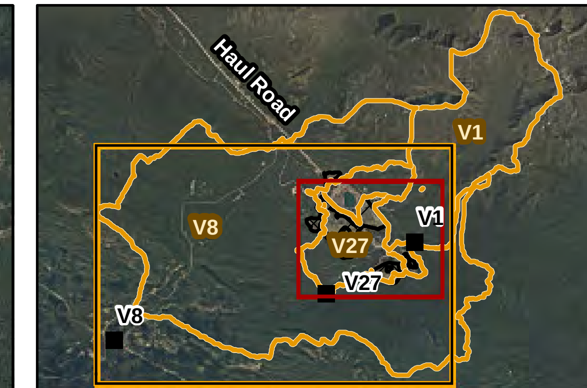
FIGURE 4a

Faro Mine Area – Major System Elements and Connections

Faro Mine Remediation Project

CH2MHILL

REGIONAL CATCHMENTS MAP



LEGEND

- GoldSim Model Node with Flow and Concentration Output
- Stream
- Lake, Pond, or Pool

Water Line Type

- Pump
- Proposed Groundwater Collection
- Runoff
- Seepage
- WTP Flows

Seepage Collection System

- Installed Groundwater Collection System
- Proposed Groundwater Collection System
- Water Treatment Plant (WTP)
- Local Catchments
- Regional Catchment
- Waste Rock Dump Areas, Vangorda/Grum
- Groundwater Seepage and Underflow

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. SIS = Subsurface Interception System
4. Regional catchment areas are approximate and do not exactly match the GoldSim model input areas. Regional catchments correspond to input parameters shown on Figure 4b.
5. Grum and Vangorda Waste Rock Dump areas represent approximate areas of the GR and VG catchments identified on Figure 4b.
6. Water from Grum and Vangorda Pit may alternatively be routed to Faro WTP.
7. Locations of VPL1, VPL2, and VPL3 are approximate.

N

0 150 300 450 600
Metres

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FIGURE 4b
Vangorda/Grum Mine Area – Major System Elements and Connections
Faro Mine Remediation Project

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Catchment

X23	MP	X2	RCV	GHU	Z2	NFRC	GHL
CHSP	FVN	IDSC	MDE_RCV	NWM_GHU	NEO	NEL_NFRC	LPL
FTE	FVS	OHRE	OHRW_RCV	NWU_GHU	ZIIW	NELS_NFRC	UPL
FTW	LGSPA_MP	ID_X2			ID_Z2	NEU_NFRC	NWL_GHL
MDW	LGSPC_MP	MDE_X2			NEL_Z2	ZIIE_NFRC	NWM_GHL
MESC	NEL_MP	OHRW_X2			NELS_Z2		NWU_GHL
MGSP	NEU_MP	RZD_X2			NEU_Z2		
MME	RD_MP				RZD_Z2		
MMW	RZD_MP				ZIIE_Z2		
OXSP	SWPWD_MP						
SBP							
LGSPA_X23							
LGSPC_X23							
MDE_X23							
NWL_X23							
NWM_X23							
NWU_X23							
OHRW_X23							
RD_X23							
SWPWD_X23							

Seepage Collected at
S-Wells
ETA
Z2
Faro Pit
Other
Not Collected

Runoff

WTP Flows IN/OUT

Seepage

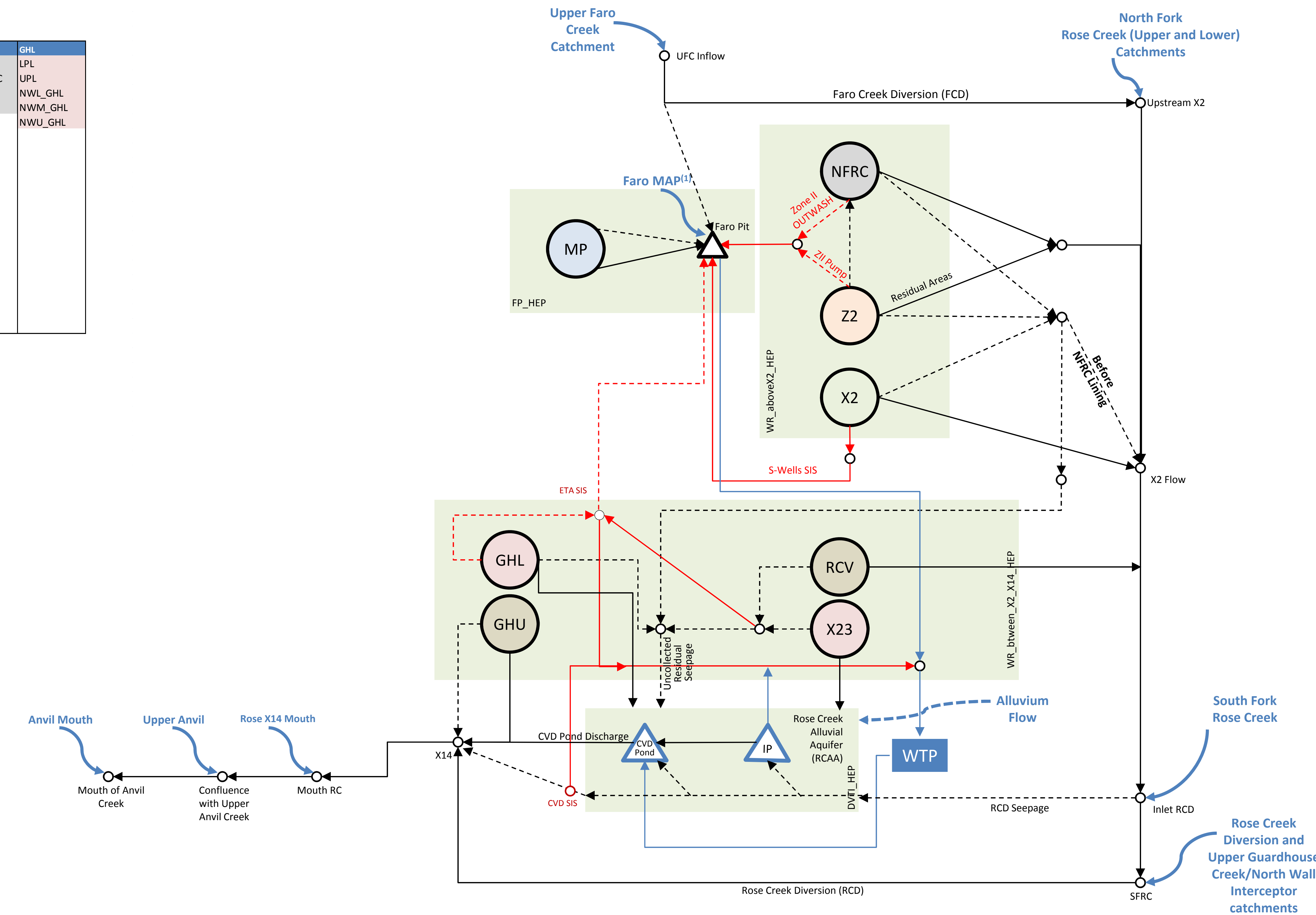
GW Collection System

Proposed GW Collection System

Boundary Hydrology as HEP[2]

Catchment

Storage



Notes:
(1)MAP refers to Mean Annual Precipitation.

(2)HEP refers to Annual Hydrologic Effective Precipitation.

FIGURE 5a
Faro Mine Area – Model Schematic
Faro Mine Remediation Project

CH2MHILL.

Waste Rock Dumps in each catchment

WRD

Catchment

V27	V8	Vpit
G1_S	G2_V8	VPL1
G1_B	OTP	VPL2
G2_V27	V1_B_V8	VPL3
G3_O	V1_S_V8	
V1_S_V27	V2_V8	
V1_B_V27	V3_O_V8	
V2_V27		
V3_O_V27		

Seepage Collected at

- Vangorda Pit
- V27
- V8

WRD with "_xxx" code indicates that the WRD is positioned across the boundaries of one or more catchments

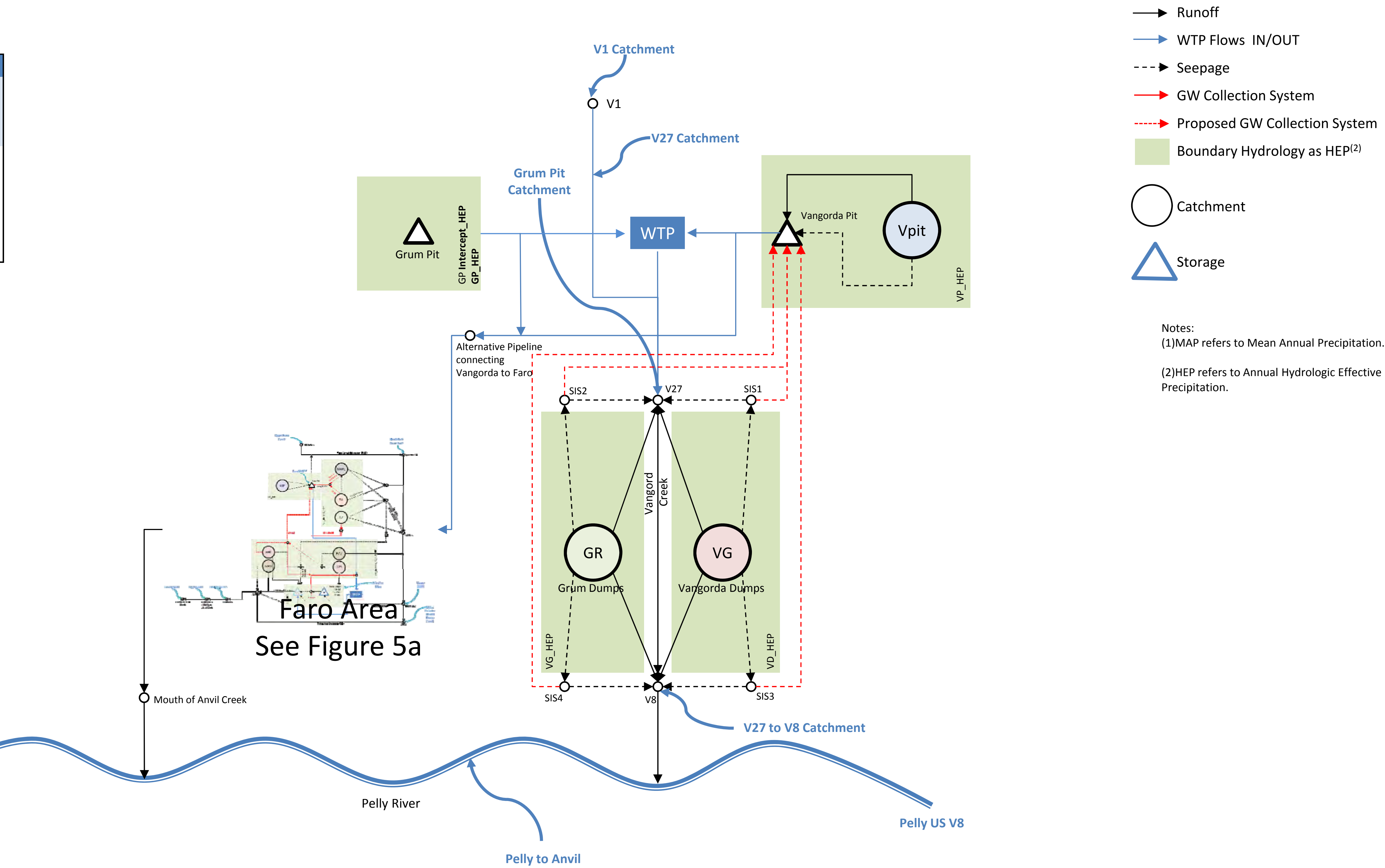


FIGURE 5b
Vangorda /Grum Mine Area– Model Schematic
Faro Mine Remediation Project

CH2MHILL.

WRD Codes

Faro Mine Area

CHSP	Crusher Stockpile
FTE	Fuel Tank Dump East
FTW	Fuel Tank Dump West
FVN	Faro Valley North
FVS	Faro Valley South
ID_WD	Intermediate Dump
IDSC	Intermediate Dump Sulphide Cell
LGSPA	Low Grade Stockpile A
LGSPC	Low Grade Stockpile C
LPL	Lower Parking Lot Dump
MDE	Main Dump East MDE
MDW	Main Dump West
MESC	Main East Sulphide Cell
MGSP	Medium Grade Stockpile
MME	Mt. Mungly East
MMW	Mt. Mungly West
NEL	Lower Northeast Dump
NELS	Lower Northeast sulphide cell
NEO	Outer Northeast Dump
NEU	Upper Northeast Dump
NWL	Lower Northwest Dump
NWM	Middle Northwest Dump
NWU	Upper Northwest Dump
OHRE	Outer Haul Road East
OHRW	Outer Haul Road West
OXSP	Oxide Fines Stockpile
RD	Ranch Dump RD
RZD	Ramp Zone Dump
SBP	Stock Piles Base1
SWPWD	Southwest Pit Wall Dump
UPL	Upper Parking Lot Dump
Z2E	Zone 2 East
Z2W	Zone 2 West

Flow Monitoring

Waste Rock Dumps

Catchments

Main Drainage Network

WRD Drainage

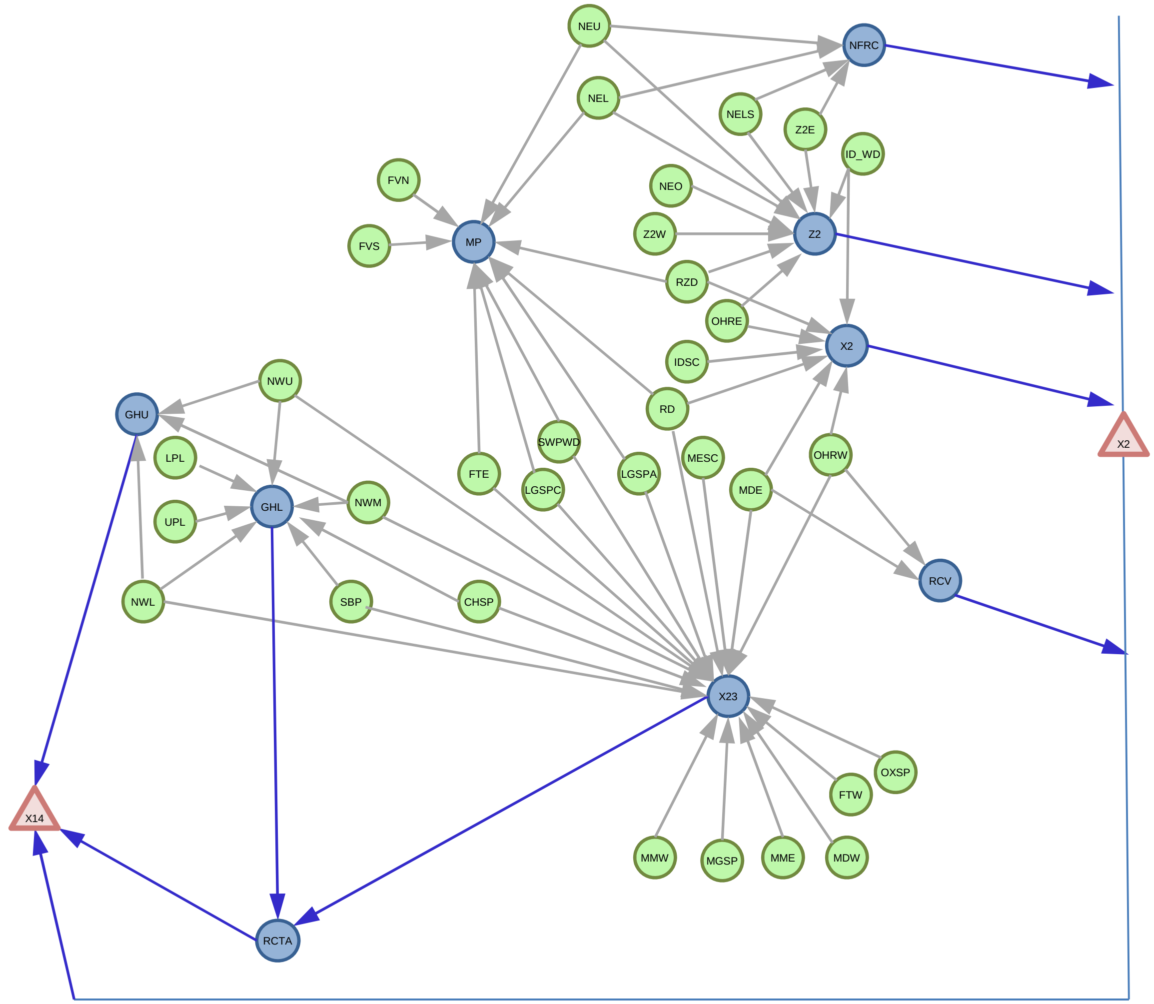


FIGURE 6a

Faro Mine Area – Surface Water Model Schematic

Faro Mine Remediation Project

CH2MHILL.

WRD Codes

Vangorda/Grum Mine Area

G1-S	Grum Main dump Sulphide Cell
G1-B	Grum Main Dump
G2	Grum Southwest Dump
G3-O	Grum Overburden Dump
VPL1	Vangorda In-Pit Dump - Southwest of Ramp
VPL2	Vangorda In-Pit Dump - Inside Hairpin
VPL3	Vangorda In-Pit Dump - Oxide Fines
V1-S	Vangorda Main Dump Sulphide Cell
V1-B	Vangorda Main Dump
V2	Vangorda Barite Dump
V3-O	Overburden Dump
OTP	Ore Transfer Pad

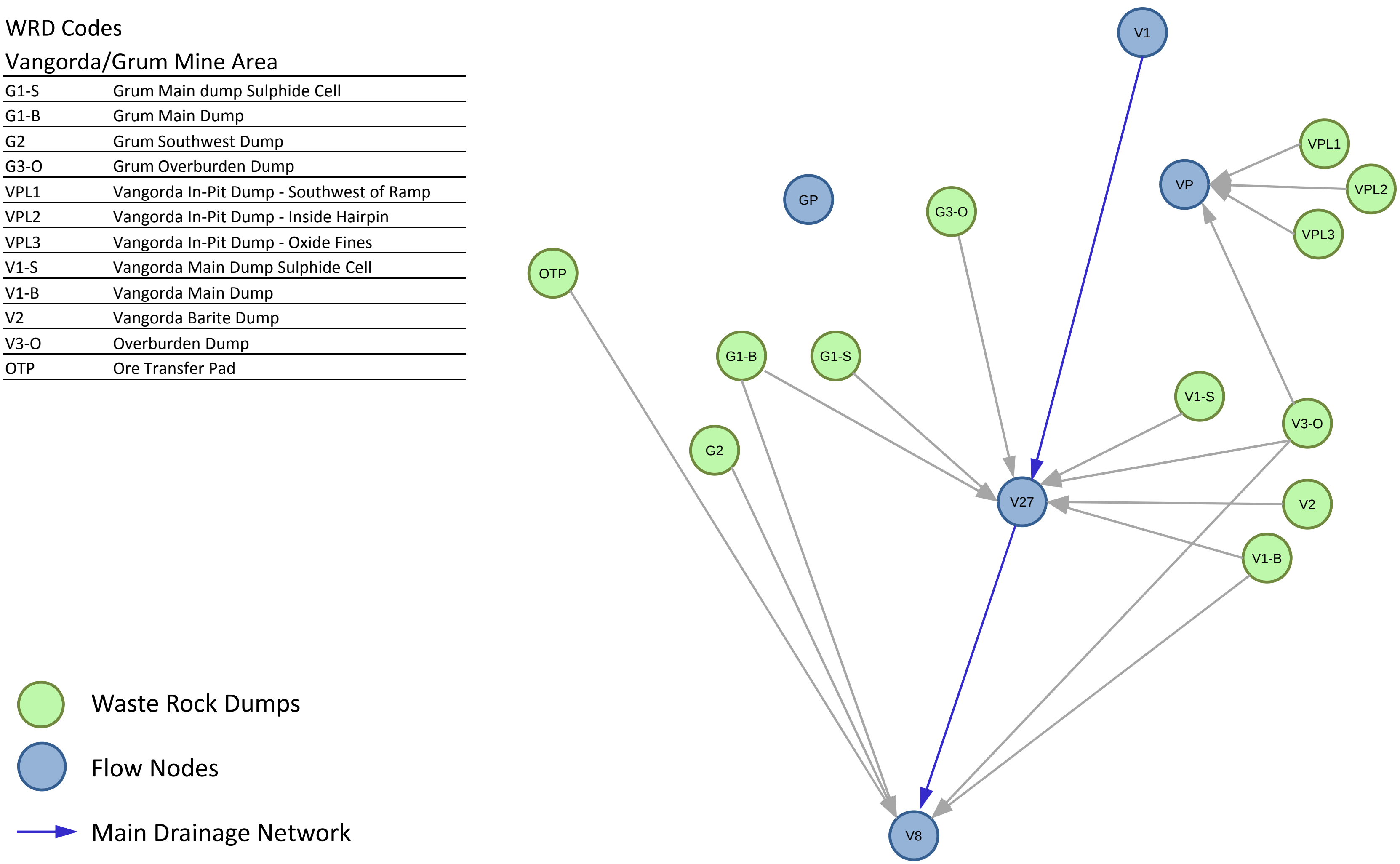


FIGURE 6b

Vangorda/Grum Mine Area – Surface Water Model Schematic

Faro Mine Remediation Project

WRD Codes

Faro Mine Area

CHSP	Crusher Stockpile
FTE	Fuel Tank Dump East
FTW	Fuel Tank Dump West
FVN	Faro Valley North
FVS	Faro Valley South
ID_WD	Intermediate Dump
IDSC	Intermediate Dump Sulphide Cell
LGSPA	Low Grade Stockpile A
LGSPC	Low Grade Stockpile C
LPL	Lower Parking Lot Dump
MDE	Main Dump East MDE
MDW	Main Dump West
MESC	Main East Sulphide Cell
MGSP	Medium Grade Stockpile
MME	Mt. Mungly East
MMW	Mt. Mungly West
NEL	Lower Northeast Dump
NELS	Lower Northeast sulphide cell
NEO	Outer Northeast Dump
NEU	Upper Northeast Dump
NWL	Lower Northwest Dump
NWM	Middle Northwest Dump
NWU	Upper Northwest Dump
OHRE	Outer Haul Road East
OHRW	Outer Haul Road West
OXSP	Oxide Fines Stockpile
RD	Ranch Dump RD
RZD	Ramp Zone Dump
SBP	Stock Piles Base1
SWPWD	Southwest Pit Wall Dump
UPL	Upper Parking Lot Dump
Z2E	Zone 2 East
Z2W	Zone 2 West

Waste Rock Dumps

Run-off Collection

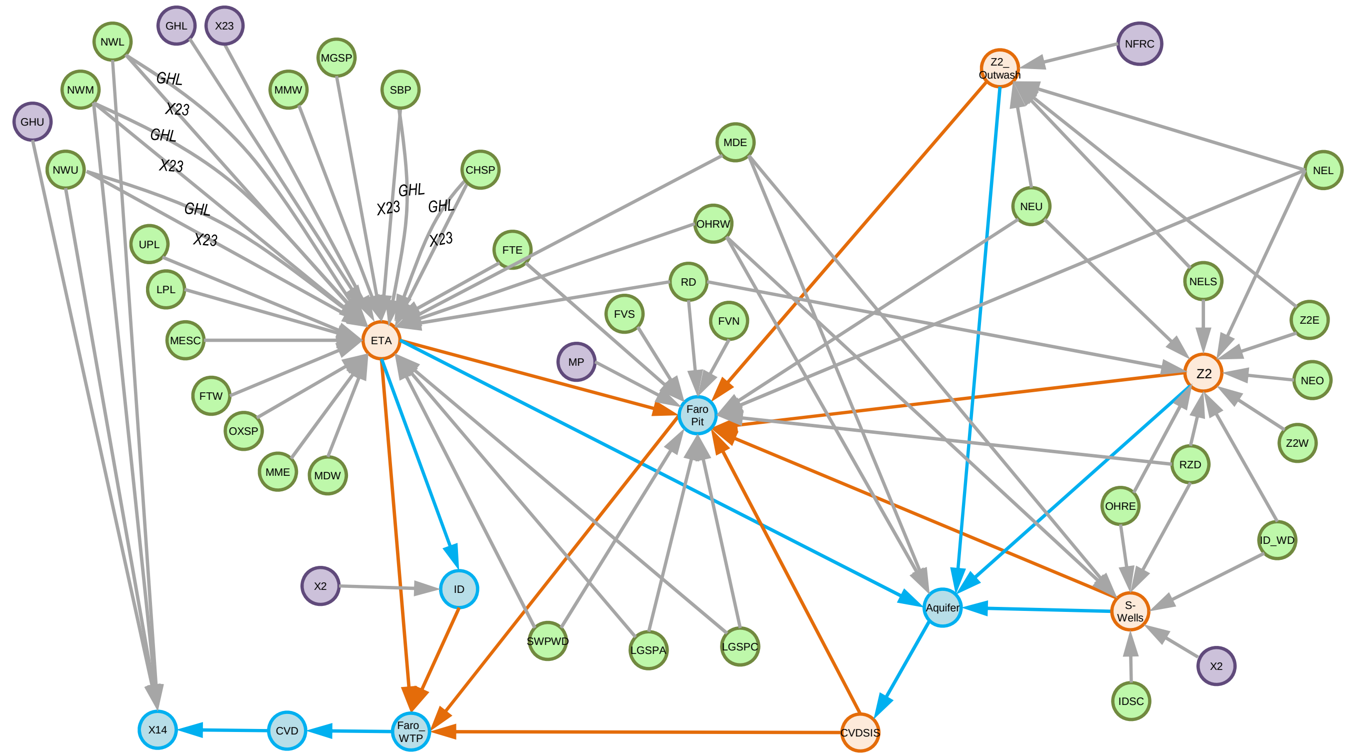
Seepage Interception Systems (SIS)

Residual Catchment Area

Main SIS Connections

WRD Connections to SISs

Other



Notes:
Connections represent current and possible future connections.

FIGURE 7a

Faro Mine Area – WRD and SIS Connectivity Model Schematic

Faro Mine Remediation Project

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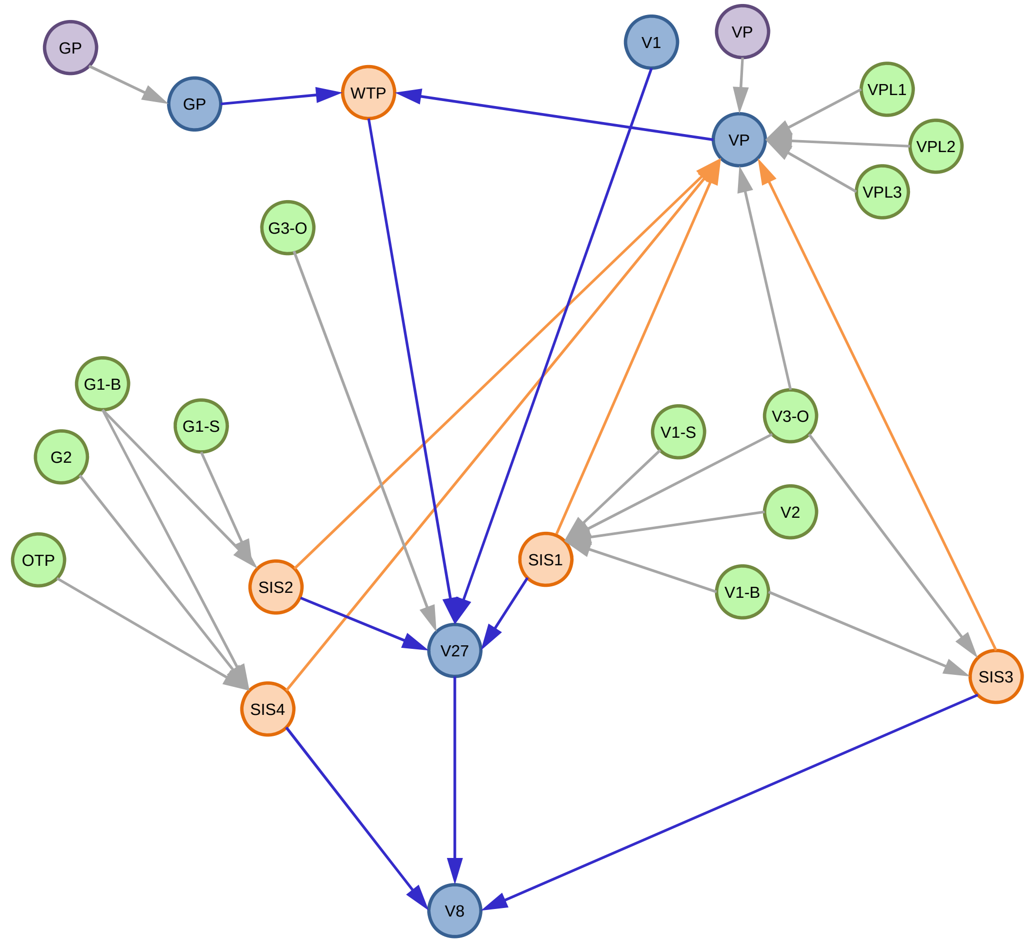
WRD Codes

Vangorda/Grum Mine Area

G1-S	Grum Main dump Sulphide Cell
G1-B	Grum Main Dump
G2	Grum Southwest Dump
G3-O	Grum Overburden Dump
VPL1	Vangorda In-Pit Dump - Southwest of Ramp
VPL2	Vangorda In-Pit Dump - Inside Hairpin
VPL3	Vangorda In-Pit Dump - Oxide Fines
V1-S	Vangorda Main Dump Sulphide Cell
V1-B	Vangorda Main Dump
V2	Vangorda Barite Dump
V3-O	Overburden Dump
OTP	Ore Transfer Pad



Waste Rock Dumps

Flow/Catchment Nodes

Seepage Interception Systems (SIS)

Residual Catchment Area

Main SIS Connections

WRD Connections

Main Drainage Network

Notes:
Connections represent current and possible future connections.

FIGURE 7b
Vangorda/Grum Mine Area - WRD and SIS Connectivity Model Schematic
Faro Mine Remediation Project

SECTION 4
GoldSim Model Update

The model refinements focused on the following key issues:

1. Development of model schematics
2. Development of mass-balance checks
3. Verification of catchment and WRD areas to ensure that all catchment areas are accounted for and to provide flexibility for future adjustments
4. Update of model input parameters and model logic
5. Refinement of modelling logic for the RCTA
6. Development of dashboards to facilitate using GoldSim model v2

The following sections provide descriptions of each of these items.

4.1 Model Schematic

The system schematic is an important element in the development of dynamic systems models. An effective system schematic defines the elements being modelled, the connectivity of the elements that represent specific locations and processes of the physical system, and the general assumptions that govern the interaction among the elements.

Illustrating all of the model element connections in a single schematic is challenging because there are multiple layers of model elements (for example, WRDs, pit lakes, SISs, SW components, and GW components). To illustrate the model elements more comprehensively, a more-detailed set of model schematics was developed for both the Faro and Vangorda/Grum portions of the FMC as part of the current modelling.

Figures 4a and 4b depict the general geographic connectivity of the elements included in the GoldSim models for the Faro and Vangorda/Grum mine areas, respectively, whereas Figures 5a and 5b show a more-detailed model schematic including all of the connections among catchments, storage elements, and SISs in the GoldSim models. Figures 5a and 5b are referred to as “model schematics” because they comprise comprehensive schematics of all GoldSim model connections.

Figures 6a and 6b show the drainages of the Faro and Vangorda/Grum mine areas, respectively. Modelled runoff is routed from each WRD through the drainage area to the downgradient discharge points at X2 and X14 (for the Faro Mine Area) and at V27 and V8 (for the Vangorda/Grum Mine Area). Figures 7a and 7b depict how the seepage flows downgradient from each WRD through the subsurface until being either collected by an SIS (existing or proposed) or bypassing it and discharging into a SW receiving node (for example, X14 for the Faro Mine Area and V8 for the Vangorda/Grum Mine Area). Additional SW nodes may be added to the model as necessary to inform particular future analyses. These system schematics, while complicated, help provide an understanding of the overall structure of the GoldSim model and how each WRD drains though the system.

4.2 Model Mass Balance Calculations

Several options are available to route flows and loads from their introduction into the model to their ultimate discharge location. The introduction of mass balance equations helps ensure that flows and loads are accounted for during each time step. Incorporation of mass balance equations was one of the first model improvements to be implemented during the refinement process. This process not only verified that GoldSim model v1 was not creating or losing mass, but also helped in implementing new model elements.

Two levels of mass balance equations were used with GoldSim model v2: flow balance equations and load mass balance equations. The general equation for the flow balance is presented as Equation 6 and the general equation for the load mass balance is presented as Equation 7.

$$\text{Inflows} = \text{Outflows} + \text{Change in Storage} \tag{6}$$

$$\text{Input Loads} = \text{Output Loads} + \text{Change in Storage Loads} + \text{Removed Loads} \tag{7}$$

Within the GoldSim model architecture, the mass balance equations are stored under the “Mass Balance” model container and are available for the following locations:

- X14
- Faro Pit
- RCTA
- V8
- Vangorda Pit

The mass balance equations provide an internal check on model accuracy because the model simulations automatically terminate if the mass balance cumulative difference of greater than 1 m^3 is computed for flows in a given time step or a cumulative mass balance difference greater than 1 kg is computed for loads (sum of all constituents).

4.3 Model Catchment Areas

The greatest source of mass inflow to the model is from the WRDs. Therefore, a comprehensive check was required to verify that the areas used in the model (WRD plus residual areas) matched the catchment areas computed based on geographic information system mapping.

For both the Faro and Vangorda/Grum mine areas, it was initially assumed that GoldSim model v1 accounted for the total area generating runoff or seepage, and that this area was equal to the aggregate area of the drainage catchments (WRD areas plus undisturbed areas in the drainage catchment). To confirm this assumption, a catchment and WRD area analysis was performed using Figures 5.1 and 5.2 from the GEEC (2010) report to evaluate whether all catchment areas were accounted for in the model. The results from this analysis indicated that the WRD areas presented on the GEEC (2010) figures were close to the areas reported in the ICAP report (Robertson GeoConsultants, Inc [RGC], 1996), but not to the areas used in GoldSim model v1. This analysis also indicated that the total WRD areas plus incremental areas (areas without WRDs, but generating seepage and runoff) used in the model were close to the values computed using the boundaries from Figures 5.1 and 5.2 from the GEEC report, except for the X23 catchment, which had a much smaller area in the model than was shown on the figures. This revealed that GoldSim model v1 is missing a significant portion of the X23 catchment area that did not contain WRDs but was still contributing to runoff and seepage.

The GEEC report indicates that the WRD areas contained in GoldSim model v1 were updated from those presented in the ICAP report (RGC, 1996), taking into account updated mapping. However, no figure was provided in the GEEC report showing the updated WRD delineations. Further, the figure provided in the GEEC report has catchment boundaries without identifying labels and WRD boundaries that reflect areas that are inconsistent with the areas used in the model.

The overall findings resulting from this evaluation are as follows:

- WRD boundaries and areas reported on Figures 5.1 and 5.2 of the GEEC report are consistent with those reported in the ICAP report.
- GoldSim model v1 contains updated areas for the WRDs; however, no figure was provided to illustrate the new WRD boundaries.
- The X23 catchment area computed using the AECOM (2009a) and GEEC (2010) boundaries is 53 percent higher than what is used in GoldSim model v1. This difference in the X23 catchment area indicates that either WRDs or undisturbed areas within the footprint of the X23 catchment are missing from the model.

- The catchments used in GoldSim model v1 for the Vangorda/Grum Mine Area were apparently based on the AECOM 2009a delineation; however, figure comparisons could not verify that assumption. A total area check (Total Vangorda/Grum Mine Area in the model v1 versus total Vangorda/Grum Mine Area calculated with most recent catchment delineation from LIDAR data) found that the values used in the GoldSim model v1 are satisfactorily close to the latest catchment delineation. The new catchment delineation was used to update the fractions of each WRD in the Vangorda/Grum Mine Area catchments.

It was assumed that the drainage catchments were delineated based on pre-mining topography. Although this may be a reasonable assumption for routing GW flows, SW drainage routing will be defined by the current site topography. As a result, some revisions to the runoff characteristics of the WRDs were necessary to achieve a reasonable agreement between modelled and historical flows. Based on these findings, GoldSim model v2 retains the modified WRD areas contained in GoldSim model v1, and assumes that the proportion of the WRD areas that contribute to each catchment remain the same. In other words, although the WRD areas in the models (v1 and v2) do not match the WRD areas shown on Figures 5.1 and 5.2 of the GEEC report, the proportions of these areas that are tributary to each catchment are kept the same. The adjustments to the area fractions contributing to each catchment are listed in Table 8a for the Faro Mine Area and Table 8b for the Vangorda/Grum Mine Area.

Within the structure of the GoldSim models, WRD seepage is aggregated and mixed into underlying catchments, and the flows from these catchments then report to downgradient SISs; some GW bypasses each SIS and is simulated to discharge to a downgradient receiving water (for example, X14). The connections between each SIS and its contributing catchments are presented schematically on Figures 5a and 5b. If desired, a model user can adjust where WRD seepage is routed by adjusting the WRD fraction that drains to a given catchment. This option is available within the SIS dashboard of GoldSim model v2. The fraction of a WRD contributing to a given catchment can vary as long as the connectivity presented on Figures 6a and 6b is maintained. The user should use the table presented on Figures 5a and 5b as a guide in selecting destination catchments for seepage originating from a particular WRD. For example, the low-grade stockpile A (LGSP A) WRD drains to both X23 and the MP, and the user can adjust the fractions going to X23 and the MP; however, the user cannot add a percentage going to catchment X2, because LGSP A WRD does not have any connections to that catchment.

GoldSim model v2 has an improved logic structure, which specifies that if the percentage of seepage contribution from a WRD into a particular catchment is reduced without an accompanying increase into another catchment, the area no longer accounted for in the model will be assumed to generate clean runoff and infiltration. The advantage of this logic is that the user can now, via the dashboard, adjust catchment and WRD areas to analyze different remedial scenarios. This capability will also facilitate modifying catchment and WRD delineations.

As part of the overall calibration process, an analysis was performed to ensure that all the catchment areas were being included in the runoff and seepage generation of flows. The results of this analysis showed that the “residual areas” between known WRDs was not being included in the runoff calculations, resulting in an underestimation of the quantity of “clean” runoff and seepage entering the RCTA. Although this is a conservative assumption with respect to estimating water quality, it resulted in significant errors when attempting to calibrate simulated SW flows with historical SW flows. After the additional “Residual Area” flows were included in GoldSim model v2, the resulting comparison of simulated flows against historical flows improved significantly. It is noteworthy to mention that model v1 was not created to consider existing conditions, and therefore it only considered the post-remediation condition in which water falling on the residual areas was routed out of the RCTA to X14 and was assumed to be clean water.

The WRD and catchment delineation is a work in progress and will probably change over time. The current methodology presented above is more robust for computing the flows and seepage from catchment areas by including in the calculations not only the WRD areas but also the catchment areas where those WRDs are located.

4.4 Model Input Parameters and Conceptual Changes

The model inputs are organized into five main groups, which are also represented in the model dashboard. The main model input parameter groups are as follows:

- Hydrology
- Water Quality
- Surface Water Management
- Groundwater and Interception Systems
- Operations
- Monthly Patterns

The model input parameters are summarized on Table C-1 (Appendix C), which is a comprehensive table describing all the model inputs in the GoldSim model v2. This section describes the model inputs relevant to the main modelling analysis as well as model input variables that were further evaluated to address the concerns raised by the Independent Peer Review Panel (IPRP) in the panel's review of the GoldSim model v1 (IPRP, 2010).

4.4.1 Hydrology

Under the Hydrology input group, the user can set options for precipitation inputs and boundary condition inflow parameters. A useful feature that was added to GoldSim model v2 is the ability to modify precipitation values. Modification of precipitation data was not included in v1, probably because of uncertainties regarding the accuracy of historical precipitation data. Despite that, historical precipitation can be used to include climate variability into stochastic runs with the model. Furthermore, the ability to use precipitation time series as a model input allows the user to evaluate different climate scenarios (for example, changes in precipitation associated with climate change effects or evaluation of the system during synthetic wet or dry periods defined by the user).

The current use of historical precipitation data from 2006 to 2011 is linked to initial conditions for pit elevation and pit water quality. The GoldSim model v2 allows for seven different initial conditions based on calendar years 2006 through 2011, plus a user-defined initial condition not necessarily associated with a historical year. The advantage of having a variety of initial conditions available is that this model can be used to simulate historical conditions. Such simulations allow the user to perform calibration checks of modelled flows and water quality parameters against field observations of interest.

Another useful feature that was incorporated into GoldSim model v2 was an index sequential methodology to loop historical monthly precipitation data used in stochastic runs rather than using fixed annual precipitation rates. This methodology incorporates historical precipitation variability to the model results and makes use of the entire 1978 to 2011 available precipitation sequence.

The current input options for hydrology in the GoldSim model v2 are as follows:

- **User-defined Fixed Precipitation.** This option allows the user to input the annual precipitation for the Faro and Vangorda/Grum mine areas. The HEP values for each mine area are scaled based on the average mean annual precipitation values that were used in GoldSim model v1. There is no difference in precipitation inputs when the user runs the deterministic versus the stochastic model options.
- **Historical Precipitation.** The user has the option to select the starting year for precipitation data from 2006 to 2011. The selection matches the precipitation data with pit water quality and volume to be used as initial conditions. The HEP values are scaled based on the historical annual precipitation rather than the mean annual precipitation values that were originally used in GoldSim model v2. The monthly precipitation patterns specified by the user remain constant throughout the simulation. This precipitation model is the best choice when comparing model results with observed data. If the user runs the model in the stochastic mode, this option will run from the selected initial condition to 2012, and then an index sequential methodology loops the precipitation back to 1978, which is the first year of available precipitation data. The index sequential methodology for the stochastic runs keeps the hydrological sequence unchanged. If the simulation period is longer than 35 years, the GoldSim model v2 repeats the historical hydrological sequence.

- **Ramping Adjustment.** The user has an option to create a constant annual increase in the input historical precipitation. This ramping parameter could be used for a simplified evaluation of future scenarios aimed at examining potential effects associated with climate change.
- **Historical Time Series.** The GoldSim model v2 includes monthly precipitation data from the Faro Airport Station. Data from this station are available from 1978 to 2012 and are presented in Table 9. Missing data were filled with the monthly average values. The Faro Airport Station is approximately 14 kilometres from the Faro Mine Area at an elevation of 717 m, approximately 457 m below the FMC. AECOM (2009a) indicated that precipitation at the FMC was between 7 and 10 percent higher than at the Faro Airport Station. An FMC precipitation factor that is used to increase the precipitation rates recorded at the Faro Airport Station is defined by the user in the dashboard. The default FMC precipitation factor is set at a 20 percent increase based on more-recent estimates (CH2M HILL, 2013).

4.4.2 Water Quality

Water quality input changes in the GoldSim model v2 were limited to a few updates on seepage water quality types and the replacement of the water quality of FCD seepage into the Faro Pit from background concentrations to a more-realistic set of values based on more-recent data (CH2M HILL, 2013).

The seepage water quality type corrections are described in detail in *Interim Water Modelling Analysis in Support of the Faro Water Treatment Plant Design, Faro Mine Remediation Project* (CH2M HILL, 2012a), and the updated concentrations for arsenic, lead, selenium, and thallium are noted on Tables 4a through 4c.

More-recent data revealed that the water quality from the Faro Creek Diversion seepage into the Faro Pit could be replaced from background water quality (used in GoldSim model v1) to a more-realistic set of values. Table 10 presents a comparison between the background concentrations and the current concentrations used for the Faro Creek Diversion seepage into the Faro Pit.

Although it would be ideal to have the NP and AP initial values adjusted for the initial year of the simulation (for historical runs from 2006 to 2011), no data to support an update of those values are available at this point, and the values used in GoldSim model v2are the same as those used in GoldSim model v1.

4.4.3 Surface Water Management

Under the Surface Water Management group, the user can set the stochastic parameters for the cover types, time of cover installation, seepage percentages, and time of the FCD upgrade that is designed to reduce seepage into the Faro Pit.

The cover type parameters define the effective infiltration rates that will govern infiltration behaviour when the covers are constructed. Currently, there are four options available to describe the WRD covers: (1) no cover, (2) rudimentary cover, (3) low infiltration cover, and (4) very low infiltration cover. The effective infiltration rate is determined by the effectiveness of the cover and the mean annual precipitation. The runoff is calculated as the difference between the HEP and the seepage for each WRD, as described in Section 3.3. The type and effectiveness of each WRD cover in GoldSim model v2 remains the same as those in GoldSim model v1. No additional data were available to inform a change in the cover effectiveness parameters, which the IPRP considered to be reasonable and appropriate (IPRP, 2010). The assumed timing of the implementation of covers was modified from that assumed in GoldSim model v1. The cover implementation timing used in GoldSim model v2 is more consistent with the current project schedule and is summarized in the matrix of assumptions (see Table 1).

The FCD seepage is a major flow contributor to the Faro Pit in both GoldSim models. The magnitude of Faro Creek leakage into the Faro Pit is also input in the Surface Water Management group and is specified as a percentage of the FCD flows. The user can also specify the year in which that leakage into the pit will be reduced or terminated. The current predictive model run assumes that the leakage to the pit persists into the future. The water quality attributed to the Faro Creek leakage in GoldSim model v1 is assumed to be background water quality, whereas the water quality attributed to the Faro Creek leakage in GoldSim model v2 is based on more current time-series data, as described in Section 4.4.2.

4.4.4 Subsurface Interception Systems

GoldSim model v2 isolates the inflows and outflows for each modelled SIS. The advantage of having isolated SISs is that unique effectiveness factors can now be assumed for each SIS, and each SIS can be turned on and off at specific times. This model improvement is consistent with IPRP comments regarding the use of various SIS effectivenesses for different systems and also the desire to conduct an analysis of an alternative where only the CVD SIS is active.

The parameters assumed for the SISs in both the Faro and Vangorda/Grum mine areas are presented in the matrix of assumptions in Table 1. The stochastic parameters, SIS switches, and assumed dates for SIS implementation are located on the model dashboard. GoldSim model v2 also re-samples the SIS efficiency at the beginning of each stochastic realization.

The model includes four SISs for the Faro Mine Area and four SISs for the Vangorda/Grum Mine Area. The user can specify the stochastic parameters associated with each SIS, the assumed effectiveness of each SIS, when each SIS is implemented, and set an overall switch that turns each SIS on and off. The SIS effectiveness is computed as the percent reduction in total contaminant flux from a given catchment to receiving waters downgradient from the SIS. The four modelled SISs for the Faro Mine Area include the Zone 2 Outwash, S-Wells, ETA, and CVD, whereas the four SISs for the Vangorda/Grum Mine Area include SIS1 through SIS4 (see Figure 4b).

Most of the modelled SISs do not currently exist and may eventually be implemented as part of the FMRP. The modelled connections between the WRD seepage and each downgradient SIS are presented on Figures 7a and 7b for the Faro and Vangorda/Grum mine areas, respectively.

The range of stochastic effectiveness of each SIS in the Faro Mine and CVD areas was updated based on recent modelling results (CH2M HILL, 2013), while the assumed values for the Vangorda/Grum areas are unchanged from v1 of the model as follows:

- Zone 2 Outwash SIS: 70 to 90 percent
- S-Wells SIS: 70 to 90 percent
- ETA SIS: 70 to 95 percent
- CVD SIS: 90 to 95 percent
- SIS1: 95 to 99.9 percent
- SIS2: 95 to 99.9 percent
- SIS3: 95 to 99.9 percent
- SIS4: 95 to 99.9 percent

GoldSim model v2 assumes that flows from the S-Wells SIS, Z 2 Pit extraction well, and the Z2 Outwash SIS (when implemented) will always be conveyed to the Faro Pit, and then to the Faro WTP after mixing with pit lake water. Flows from ETA can be directed to the Intermediate Dam Pond (ID Pond) for a user-specified duration, and then to the Faro Pit thereafter. Flows from the CVD SIS (when implemented) are conveyed to the Faro Pit during the non-treatment season, and to the Faro WTP during treatment season. The implementation of the CVD SIS assumes that once it is operational, pumping directly from the ID Pond to the WTP during the treatment season will cease.

4.4.5 Operations

The addition of operation controls was necessary to evaluate different project alternatives. The current inputs for WTPs control WTP flow capacity though time, the use of one versus two WTPs (one WTP at the Faro Mine Area or two WTPs, one at the Faro Mine Area and the other at the Vangorda/Grum Mine Area) and the treatment of the Grum pit flows.

The lining of the NFRC can also be controlled within the model by specifying the year that the lining would be implemented. The assumption is that before the creek is lined, all seepage from the Z2 and NFRC WRDs is routed to NFRC and then to the X2 monitoring location. Once lined, any uncollected seepage from the NFRC and Z2 catchment dumps is routed to the RCAA.

The storage releases from Faro Pit, ID Pond, and Polishing Pond are currently controlled in the GoldSim models by monthly rule curves. The user specifies the monthly target elevation for each storage impoundment and the model releases flows to retain the storage at that level. The rule curves are intended to mimic the reservoir operations and can be adjusted if operational conditions change in the future. The user also has the option to breach the CVD and change the rule curve for the Intermediate Pond by converting it into a terminal storage impoundment at the lower end of the FMC on GoldSim model v2.

4.4.6 Storage

Storage elements were added to pit and pond locations to improve tracking of the volumes, concentrations, and operations of these storage elements. The added storage elements also allow concentrations at these locations to be computed and could include future logic that incorporates the effects of nonconservative geochemical reactions.

The Faro Pit has two types of inflows: continuous and seasonal. The seasonal flows represent flows from SIS locations that pump to the Faro Pit outside of the treatment season. The continuous inflows represent the inflows that will always be conveyed to the pit before conveyance to the WTP. Seasonal inflows include flows from the ETA SIS and CVD SIS. Continuous inflows include (1) pumping from the S-wells SIS, (2) Z2 Pit extraction well, (3) future Z2 Outwash SIS pumping, (4) flows from WRDs within the Faro Pit catchment, and (5) local precipitation. Faro Pit releases are calculated according to a user-defined rule curve, where target elevations are defined for each month.

4.4.7 Water Treatment Plants

GoldSim model v1 did not consider WTP capacity; it was assumed that all the flows accumulated at the Faro Pit during the non-treatment period (October through April) were treated during the treatment months (May through September). This assumption precluded the use of the model to inform WTP sizing considerations.

GoldSim model v2 includes a WTP capacity input value that can be varied though time. The assumption that the WTP has a maximum capacity implies that flows exceeding WTP capacity will have to be stored. GoldSim model v2 assumes that the collected flows from each SIS, the pumping from the Intermediate Pond, and the flows from the Vangorda/Grum Mine Area (if the single WTP option is selected) will be treated first, followed by flows from the Faro Pit. If the inflows to the WTP exceed the WTP capacity, the excess volume will be diverted for storage within the Faro Pit. This feature allows the WTP capacity needed to address future flow conditions to be evaluated.

Future model updates will change the WTP effluent water quality based on the results of the pilot test program from 2012 (CH2M HILL, 2012b).

4.4.8 Monthly Patterns

During the development of GoldSim model v2, no further hydrological analyses were conducted to justify the modification of the monthly patterns assumed in GoldSim model v1. Therefore, most of the monthly patterns contained in GoldSim model v2 are identical to those in GoldSim model v1, except for the addition of the monthly pattern for lake evaporation. The monthly pattern for lake evaporation in GoldSim model v2 is based on AECOM (2009a) values, and the same evaporation pattern is assumed to apply to all storage impoundments.

All monthly patterns are grouped under one dashboard and can be reviewed and changed by the user. One possible model refinement would be to adjust monthly runoff and seepage patterns based on historical monthly precipitation patterns or future expected shifts caused by climate change effects. However, this would require additional hydrological analyses associated with rainfall/snowfall seasonal patterns.

4.5 Rose Creek Tailings Area Conceptual Refinements

GoldSim model v2 has significant conceptualization improvements associated with water movement through the RCTA. GoldSim model v1 assumes that the Polishing Pond and ID Pond would be removed from the system as part of the FMRP. Although elimination of the Polishing Pond upon implementation of the remedy may still be a valid assumption, this configuration of the model eliminates the ability to provide historical simulation results for comparison with historical observed data. This conceptualization also precludes using the model to evaluate the benefits of retaining a large storage impoundment at the lowest area of the FMC, as described by the IPRP (IPRP, 2010). The GoldSim model v2 includes the operation of both the ID Pond and Polishing Pond in the RCTA. Figure 8 illustrates how the RCTA is represented in GoldSim model v2, and the following discussion provides a description of the model assumptions regarding seepage flows, runoff, and loads through the area.

4.5.1 Inflows

Seepage enters the RCTA and RCAA from different locations. The main inflow originates as subsurface inflow from upgradient areas of the RCAA and includes leakage from the NFRC and SFRC that enters the RCAA. Flows through the RCAA have been estimated to be approximately 75 litres per second (L/sec), based on recent groundwater modelling of the area (CH2M HILL, 2013). The ICAP report (RGC, 1996) states that approximately 7.2 percent of the RCD) flow leaks into the RCAA as it flows through the RCTA. The AECOM report (2009a) estimates the seepage to be approximately 13 percent. The difference between the two reports indicates the level uncertainty related to the leak flows; however, independent of the uncertainty, it is a substantial flow (average of about 132 L/sec) that was not included in GoldSim model v1 due to its post-closure model assumptions. Some portion of the RCD leakage could become contaminated when entering the RCTA and would be captured at the CVD SIS. Also, the model assumes that 20 percent of the RCAA underflow enters the ID Pond and is pumped to the WTP. There remains significant uncertainty in the value of these flow components. Therefore, the GoldSim model v2 includes adjustable seepage coefficients for both leakage from the RCD and the quantity of RCAA underflow that discharges to the ID Pond.

The RCTA also receives flows from the GHL catchment (seepage and runoff) and flows from the X23 catchment, which has been modelled to be a combination of subsurface inflow and infiltrated SW through tailings. Flow from the X23 seep is augmented with runoff from the Mill Area at FCS-3 as it flows through the ETA area. The SW runoff entering the RCTA includes runoff from the GHL catchment and runoff generated within the RCTA. GHL runoff flows to the RCTA and into the ID Pond, whereas ETA flows are captured in the ID Pond if the ETA SIS is not implemented or operational. The RCTA also receives WTP effluent that is conveyed directly to the Polishing Pond.

4.5.2 Geochemical Loads

Geochemical loads entering the RCTA are calculated based on the corresponding source concentrations assigned to their areas of origin. The exceptions are the loads associated with RCTA seepage and subsurface inflow to the RCAA. The loads assigned to the RCTA seepage and RCAA subsurface inflows are assigned based on output from an external water quality tailings spreadsheet model developed by SRK, as described in GEEC (2010). The SRK spreadsheet model was not made available to the FWMT, so the information within this spreadsheet could not be included dynamically in the GoldSim model v2. As a result, the time-series data that were output from the SRK spreadsheet model were entered directly into the GoldSim model v2.

4.5.3 Intermediate Dam Pond and Cross Valley Dam

The Polishing Pond and ID Pond are the two storage elements in the RCTA; the flows to and from these storage elements are summarized here. Inflows to the RCTA storage elements are as follows:

- Uncollected seepage from all WRDs
- Subsurface inflow to the RCAA
- NFRC, RCD, and SFRC leakage
- Local runoff from the RCTA
- GHL to the ID Pond
- WTP effluent to the Polishing Pond

Outflows from the RCTA storage elements are as follows:

- CVD SIS flows to the Faro WTP
- CVD releases from the Polishing Pond to X14 on Rose Creek
- Seepage to X14 on Rose Creek
- Pump from ID Pond to the WTP

The ID Pond receives ETA discharge before the ETA SIS implementation, local runoff from the RCTA, runoff flows from the GHL creek catchment, and leakage from the RCD. It is assumed that after the implementation of the CVD SIS and the RCTA cover, flows from local sources will no longer be captured by the ID Pond. Instead, runoff flows will be diverted to the Polishing Pond and seepage will be intercepted by the CVD SIS. Pumping from the ID Pond to the WTP is simulated to occur during the treatment season until implementation of the CVD SIS, with the quantity of this pumping defined by the rule curve assumed for the ID Pond.

The Polishing Pond can receive flows from the ID Pond, runoff from the RCTA after the implementation of the RCTA cover, leakage from RCD, and WTP effluent discharge. The Polishing Pond releases flows to X14 on Rose Creek in the GoldSim models, according to a monthly rule curve to maintain storage at elevation targets. GoldSim model v2 offers the option to breach the CVD at a selected year, if desired. Once this option becomes active, the ID Pond continues to be an active storage element receiving runoff and seepage. Under this scenario, WTP effluent flows are discharged directly to X14 on Rose Creek.

4.5.4 Model Dashboards

GoldSim model v2 makes use of GoldSim's ability to create dashboards for model control. To create a model dashboard, the model inputs are divided into dashboard variables and Microsoft Excel variables. The dashboard variables can be changed directly from the dashboards. The Microsoft Excel variables can be accessed from the dashboards, but are be changed through spreadsheet calculations in Microsoft Excel. Selected model inputs are typically chosen to be managed as spreadsheet-based variables because it is easier for the user to modify values and provides more flexibility when conducting model updates. Table C-1 in Appendix C summarizes the variables in GoldSim model v2 that can be controlled by the dashboard versus Microsoft Excel.

The model dashboard organization follows the input categories presented in Table C-1, where input parameters are grouped by the following:

- Constants
- Operations
- Hydrology
- Surface Water Management
- Water Quality
- Subsurface Interception System
- Monthly Patterns
- Input Variables

Dashboards are also used to organize and present model results. Under the Model Results dashboard, the user can retrieve flow and water quality data at key nodes within the modelled domain.

TABLE 8A

Adjustment of the Fraction of Each WRD in each Catchment on the Faro Mine Area (Version 2.0 minus Version 1.0)

Faro Mine Remediation Project

	Catchments							
WRD	**X23**	**MP**	**X2**	**RCV**	**GHU**	**Z2**	**NFRC**	**GHL**
Crusher Stockpile (CHSP)	-30%	0%	0%	0%	0%	0%	0%	30%
Fuel Tank Dump E (FTE)	-3%	3%	0%	0%	0%	0%	0%	0%
Fuel Tank Dump W (FTW)	0%	0%	0%	0%	0%	0%	0%	0%
Faro Valley North (FVN)	0%	0%	0%	0%	0%	0%	0%	0%
Faro Valley South (FVS)	0%	0%	0%	0%	0%	0%	0%	0%
Intermediate Dump (ID)	0%	0%	-7%	0%	0%	7%	0%	0%
Intermediate Dump Sulphide Cell (IDSC)	0%	0%	0%	0%	0%	0%	0%	0%
Low Grade Stockpile A (LGSPA)	30%	-30%	0%	0%	0%	0%	0%	0%
Low Grade Stockpile C (LGSPC)	25%	-25%	0%	0%	0%	0%	0%	0%
Lower Parking Lot Dump (LPL)	0%	0%	0%	0%	0%	0%	0%	0%
Main Dump East MDE (MDE)	1%	0%	2%	-3%	0%	0%	0%	0%
Main Dump West (MDW)	0%	0%	0%	0%	0%	0%	0%	0%
Main East Sulphide Cell (MESC)	0%	0%	0%	0%	0%	0%	0%	0%
Medium Grade Stockpile (MGSP)	0%	0%	0%	0%	0%	0%	0%	0%
Mt. Mungly East (MME)	0%	0%	0%	0%	0%	0%	0%	0%
Mt. Mungly West (MMW)	0%	0%	0%	0%	0%	0%	0%	0%
Lower Northeast Dump (NEL)	0%	-7%	0%	0%	0%	-8%	15%	0%
Lower Northeast Sulphide Cell (NELS)	0%	0%	0%	0%	0%	3%	-3%	0%
Outer Northeast Dump (NEO)	0%	0%	0%	0%	0%	0%	0%	0%
Upper Northeast Dump (NEU)	0%	-8%	0%	0%	0%	3%	5%	0%
Lower Northwest Dump (NWL)	-17%	0%	0%	0%	2%	0%	0%	15%
Middle Northwest Dump (NWM)	-6%	0%	0%	0%	1%	0%	0%	5%
Upper Northwest Dump (NWU)	-5%	0%	0%	0%	5%	0%	0%	-3%
Outer Haul Road East (OHRE)	0%	0%	-9%	0%	0%	9%	0%	0%
Outer Haul Road West (OHRW)	6%	0%	33%	-40%	0%	0%	0%	0%
Oxide Fines Stockpile (OXSP)	0%	0%	0%	0%	0%	0%	0%	0%
Ranch Dump RD (RD)	0%	-2%	1%	0%	0%	1%	0%	0%
Ramp Zone Dump (RZD)	0%	6%	-2%	0%	0%	-4%	0%	0%
Stock Piles Base1 (SPB)	-10%	0%	0%	0%	0%	0%	0%	10%
Southwest Pit Wall Dump (SWPWD)	-11%	11%	0%	0%	0%	0%	0%	0%
Upper Parking Lot Dump (UPL)	0%	0%	0%	0%	0%	0%	0%	0%
Zone II East (Z2E)	0%	0%	0%	0%	0%	5%	-5%	0%
Zone II West (Z2W)	0%	0%	0%	0%	0%	0%	0%	0%

Notes:

The NWM and NWU WRD each have an adjustment on year 3; the model assumes the same values on version 1.0 after year 3.

No adjustments were made for the Vangorda Mine Area.

Blue indicates positive adjustment; **red,** negative.

TABLE 8B

Adjustment of the Fraction of each WRD in each Catchment of the Vangorda/Grum Mine Area (Version 2.0 minus Version 1.0)

Faro Mine Remediation Project

	Catchments		
WRD	**V27**	**V8**	**Vpit**
G1_S	0%	0%	0%
G1_B	**-8%**	**8%**	0%
G2	**-50%**	**50%**	0%
G3_O	0%	0%	0%
V1_S	**2%**	**-2%**	0%
V1_B	**-16%**	**16%**	0%
V2	**2%**	**-2%**	0%
V3_O	**-26%**	**3%**	**24%**
OTP	0%	0%	0%
VPL1	0%	0%	0%
VPL2	0%	0%	0%
VPL3	**0%**	0%	**0%**

Note: **Blue** indicates positive adjustment; **red,** negative.

TABLE 9
Precipitation at Faro Airport (mm)
Faro Mine Remediation Project

Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1978	0.4	11.9	12.4	4.1	11.6	27	38.1	41.6	7.8	32.4	20.2	19	226.5
1979	8.9	18.3	20.2	6.7	10.5	68.2	55.4	13.8	13.4	11.6	12.4	34.4	273.8
1980	19.7	2.4	11.7	12.5	10.5	11.1	95.4	33.2	46.7	24.7	21.3	13.3	302.5
1981	6.5	23.1	4	4.5	7.8	42.8	41.3	22.5	41.9	21.5	17	5.4	238.3
1982	10.2	18	9.5	4.1	18.2	14.3	58.3	47.3	47.2	42.3	11.8	13.6	294.8
1983	35.7	6.6	9.8	2.2	20.6	55.6	49.1	65.8	21.2	16.3	11.4	3.9	298.2
1984	27.6	24.1	5.9	2.4	38.8	49	16.6	64.9	5.5	10.8	10.7	22.5	278.8
1985	22.5	24.8	2.2	13.8	17.2	28.1	62.6	80.8	46.3	20	22.2	26.1	366.6
1986	8.4	4.7	34.6	12.9	35.1	12.8	81.8	77.4	44.4	22.7	15.9	5.6	356.3
1987	3.1	14	2.8	10	40.1	50.8	92.4	63.5	30.2	26.6	17.8	6.2	357.5
1988	7	10.4	17.2	8.2	38	37.3	97.2	25.5	43.8	29	17.9	16.5	348
1989	19.8	3.6	19.8	2	17.9	41	51.7	16.9	30.8	46.3	39.8	13.8	303.4
1990	14.4	25.8	5	7	23.4	45.4	30	64.4	66.2	22.7	25.4	24.8	354.5
1991	17.2	22.6	16.6	2.8	22.4	30.2	115.4	33	48.2	49.6	43.4	40	441.4
1992	22.8	24.6	7.6	15.8	14.4	11.4	66.1	34.4	47.8	13.8	18.8	13	290.5
1993	22.2	15	1.6	6	76.7	48.6	50.2	56	50.8	35.7	18.9	16.7	398.4
1994	20.2	8.4	11.4	5	39.8	24.2	19.6	25.2	45.6	41.6	24.4	8	273.4
1995	8.4	7.8	18.4	5.2	10.9	33.9	73.4	63.4	28.8	12.2	22.3	15.4	300.1
1996	10.2	9.1	27.1	7.2	13.4	20	64.4	70.8	52.7	34.8	3.5	5.9	319.1
1997	6.6	8.7	1.4	14	16.5	39.3	86.4	33.2	38.5	25.2	6.4	12.4	288.6
1998	7	2.8	4.8	4.2	14.4	29.6	19.2	24.2	23.4	24	4.6	8.2	166.4
1999	24.4	10	15.4	1.8	44.4	64.8	42	33.8	27	22.4	12.8	21.6	320.4
2000	12.2	2	12.4	6	9.6	39.6	48.1	116.2	102.2	8.6	19.4	5.8	382.1
2001	7.4	3	4	14.6	30.8	35	58.4	14.2	44.6	28.6	12.2	15.4	268.2
2002	9.2	5.8	9	7	19.6	19.4	34.9	64.1	38.4	18.2	9.6	9.4	244.6
2003	22.4	8	16	0.4	7.6	45.2	63.2	30.4	30.8	12.8	32.8	19.9	289.5
2004	31.1	11.4	45	4	15.6	34	13.5	38	48.5	33.6	9.8	45	329.5
2005	26.7	12.4	2.6	19.5	58.6	41	83.8	38.6	36.6	13	30	10.8	373.6

TABLE 9

Precipitation at Faro Airport (mm)

Faro Mine Remediation Project

Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2006	11	7	18.5	21.6	16.2	38	33.4	33.3	35.6	21	33.1	8.3	277
2007	16.4	16.4	14.4	3.6	11.4	52	43.5	33.5	50.7	39.6	13.4	28	322.9
2008	15.3	11.9	12.4	7.8	22.8	68.6	74.8	99	27.2	24.7	18.9	16.7	400.1
2009	15.3	15.4	20.3	20.4	19.9	26.1	16.8	62.4	28.2	24.7	18.9	16.7	285.1
2010	20.3	5.6	9	3.4	15	45.6	37.4	29	30.8	16.4	29.2	12.8	254.5
2011	9.5	9.8	0	4.4	6.8	74.2	51.1	55.8	28.8	12.4	15.8	31.4	300

Note:

Original data from Environmental Services (DES) 2012. Shaded cells represent missing values that were replaced by the monthly average

TABLE 10
Comparison between Background Water Quality Concentrations and the Updated Values for the FCD into Faro Pit Seepage
Faro Mine Remediation Project

	Background Water Quality	Updated Water Quality
pH	7.0800	2.9723
Alkalinity	14.8000	14.7820
Cl (mg/L)	0.5000	4.1030
SO4 (mg/L)	20.2000	489.9336
As (mg/L)	0.0005	0.0042
Ca (mg/L)	44.9000	50.6546
Mg (mg/L)	10.7400	56.0668
K (mg/L)	1.4000	1.2301
Na (mg/L)	3.4100	3.4324
Al (mg/L)	0.1560	7.0404
Cd (mg/L)	0.00004	0.0675
Co (mg/L)	0.0005	0.1277
Cu (mg/L)	0.0020	0.8164
Fe (mg/L)	0.2460	4.9581
Pb (mg/L)	0.0005	0.1940
Mn (mg/L)	0.0264	3.1516
Ni (mg/L)	0.0005	0.1257
Zn (mg/L)	0.0164	43.9171

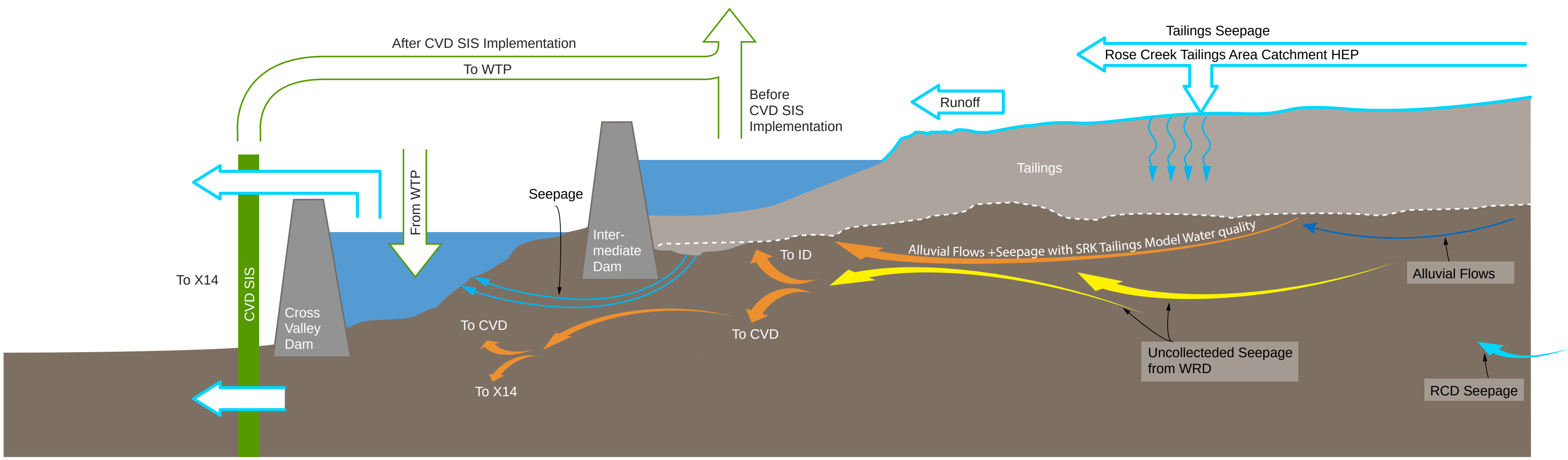


FIGURE 8
Schematic of Water Quality Model
Representation of the RCAA
Faro Mine Remediation Project

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SECTION 5

Model Application

Two sets of model runs are described in this section, including a historical calibration run where modelled results were compared against historical site data, and a predictive model run where the model was run for 200 years using current conditions as initial conditions.

A few key nodes in the modelled domain were selected in the GoldSim model v2 dashboard to output results. The selection of output nodes could easily be changed in future versions of the model as project needs change. The key nodes selected for output results are presented on Figures 5a and 5b. The selection of individual locations for the storage of model results is necessary to maintain manageable file sizes for long stochastic simulations. Stochastic simulations computed using monthly time steps for a simulation period of 200 years or more can quickly generate extremely large files that are difficult to use and manage.

The historical model calibration analysis was run using data from the period 2006 through 2011 and was performed to assess the ability of the model to adequately simulate conditions over the selected historical period and to identify possible aspects of the model that need further refinement or a more complete understanding to improve the model's predictive capability. The water quality predictive analysis was performed to forecast water quality at locations of interest within and downstream from the FMC under several project configurations. The assumptions used for the calibration analysis were different from those for the predictive simulations. The matrix of assumptions presented in Table 1 summarizes the differences in assumptions between the predictive GoldSim model v1, historical GoldSim model v2, and predictive GoldSim model v2.

5.1 Setup for Historical and Predictive Simulations

The adjustments needed to run both historical and predictive model simulations can both be achieved using the model dashboard. Because of the differences in assumptions between the historical and predictive model simulations, two separate model files were created, a historical model file and a predictive model file.

5.1.1 Historical Simulation

One advantage to incorporating historical time-series precipitation data was that model results could be compared against historical flow, pit elevation, and water quality data to assess the ability of the model to replicate observed site conditions. The period chosen for this comparison was January 2006 through December 2011, a period when data were collected more consistently and site conditions were similar to current mine conditions. The assumptions for the historical run were selected to be consistent with past operations and facilities that were in place during the calibration period. The historical model assumptions are summarized in Table 1.

The parameters that were adjusted during the calibration process were (1) FCD leakage into Faro Pit, (2) FMC precipitation percentage as a function of Faro Airport Station precipitation, (3) leakage coefficients for the RCD, (4) seepage rates into ID Pond, and (5) operation of the storage elements through adjustment of the rule curve. The historical data available for comparison included annual pumping data, flow data, storage elevations, and water quality. Note that these pumping data contain significant uncertainty because they are based on recorded days of pumping at the rated capacity of pumps, or in the example of the CVD siphons, whether the siphon was positioned as half open or fully open.

For the historical pumping data, annual values for pumping from Z2 Pit, Faro Pit, ID, S-Wells SIS, ETA SIS, and WTP inflows were available from various annual environmental monitoring reports (GLL, 2006 and 2007; AECOM, 2009b; DES, 2010, 2011 and 2012). Historical daily SW flow data are available for monitoring stations X14, X2, X10, X5, WTP discharge, V27, and V8. All the flow station locations are presented on Figure 1 or Figures 2a and 2b for the Faro and Vangorda/Grum mine areas, respectively. The observed daily flows were converted to monthly average values so they could be consistently compared with model results. Storage elevation data are available for the Faro Pit, Vangorda Pit, Grum Pit, ID Pond, and Polishing Pond. Water quality data are available for monitoring stations X2, X23, Polishing Pond (X5p), ID Pond (X4), Faro Pit (X22b), Vangorda Pit (V22), and V27(v23). Comparisons of modelled and historical data are presented in Appendix A and discussed in Section 5.2.

5.1.2 Predictive Simulations

The predictive simulations forecast water quality at locations of interest within and downstream from the FMC under different FMRP assumptions. Several simulations were performed with GoldSim model v2 using many of the recent updates. The predictive model results are consistent with the assumptions presented on Table 1 and are discussed in Section 5.2. The predictive simulation diverges from the historical simulation for the most part in the simulation duration (200 years) and by the inclusion of stochastic parameters. GoldSim model v2 retains the same simulation duration assumed in the stochastic simulations performed using GoldSim model v1, but increases the number of stochastic realizations from 25 to 100.

The predictive model results presented in this document are limited to the same predictive model results presented in the previous model report (GEEC,(2010), which includes zinc and cadmium concentrations for the X14 and V8 locations. These results are presented in Appendix B and discussed in Section 5.2.

5.2 Model Application Results

The results of the historical calibration simulation suggest that the GoldSim model v2 reasonably replicates the historical flows and water surface elevations in the various storage elements across the site for the 2006 through 2011 calibration period. The model results for this simulation are presented in Appendix A. Figures A-1 through A-4 present the comparison between modelled and historical flows for SW monitoring stations X2, X10, X14 and X5, respectively. These results suggest that the model matches the observed flows to a fairly high degree of accuracy, but discrepancies remain in some of the peak flows over this period. This is likely because of the monthly time step of the model, which limits its ability to replicate short-duration, high- intensity events.

Figures A-4 and A-5 present comparisons between modelled and historical flow from the Polishing Pond to Rose Creek (CVD to X14) and the effluent flows from the WTP, respectively. The model again appears to underestimate some of the peak releases from the Polishing Pond, which may again be a function of the monthly averaging in the model predictions. Although not many monthly flow data were available for WTP effluent flows (Figure A-5), the model appears to match the annual water treatment plant effluent flow reasonably well (Figure A-6a).

Figure A-6a presents the comparison between the simulated and observed pumping rates from the Faro Pit, ID Pond, and WTP influent. These results indicate the model provides accurate estimates for these rates. Figure A-6b confirms the assumed pumping rates in the historical model match the observed data for the S-wells, ETA, and Z2 pumping.

Figures A-7 through A-11 present comparisons between the modelled and historical water levels in the Faro Pit, ID Pond, Polishing Pond, Vangorda Pit, and Grum Pit, respectively. The model provides a reasonable match to the observed Faro Pit and ID Pond water levels, but tends to underestimate the variability in Polishing Pond water levels throughout the period of record (Figure A-9). The comparison of modelled and historical water levels in the Vangorda and Grum pits (Figures A-10 and A-11) systematically underestimate the historical water levels. This may result from unaccounted drainage areas in the Vangorda/Grum Mine Area of the model that result in an under-prediction of natural runoff quantities into these pits.

The water quality results obtained from the historical calibration run are summarized on Figures A-12 and A-13. Figure A-12 presents a comparison between the modelled and all available historical concentrations of zinc, sulphate, magnesium, manganese, and iron for SW monitoring stations X2, X14, X23, and V27. As can be seen in this figure, the model results fall within the same order of magnitude as the observed values for many constituents evaluated; however, significant differences remain. This outcome is not unexpected; recent analysis of the accuracy of the geochemical representation of the WRD source areas in GoldSim concluded that significant deficiencies exist (CH2M HILL, 2013). In that study, it was recognized that the simple mixing of the contaminant mass fluxes emanating from the Faro WRD sources that drain to seep X23 in the GoldSim models are not able to match the water quality observed in seep discharge samples. It was suspected that one of the reasons that simple mixing of the waters originating from each WRD could not match X23 quality was that geochemical reactions occurring during mixing and transport may result in the precipitation of mineral species or interaction with aquifer solids, fundamentally altering the water chemistry.

In an attempt to account for these reactive mixing effects, the PHREEQC model was employed in the analysis (see CH2M HILL, 2013 for details). The result was that even after accounting for the effects of reactive geochemical mixing, the mixing of the WRD source waters currently in the GoldSim models was still not capable of replicating the water quality observed at the X23 seep. These results strongly suggest that the methodology currently employed to predict the geochemical quality of the seepage from each WRD source, and the appropriate transport time between the source and the discharge point, is insufficient to accurately predict downstream water quality conditions. Because there are potential inaccuracies in the WRD source terms, it is reasonable to expect that the predicted downstream SW quality (Figure A-12) will not closely match historical data. Examination of the modelled versus historical concentrations in the pit lakes and reservoirs at the site (Figure A-13) reveal discrepancies similar to those in the water quality predictions at the SW flow monitoring stations. Again, this result suggests that additional efforts, such as the update of WRD chemical compositions, the consideration of reactive geochemical mixing, and the incorporation of contaminant transport behavior along flow paths though the system, may be required in the GoldSim model before accurate forecasts of downstream water quality can be expected.

The predictive model results presented in Appendix B, Figures B-1 through B-12, are consistent with the results presented in the GEEC (2010) report. The evident differences are likely because of the inclusion of the RCTA water balance components that were not present in GoldSim model v1, and the effects of these components on the predicted water quality. Model results show significantly higher concentrations of zinc and cadmium at X14 at the beginning of the simulation, before implementation of the CVD SIS. After the CVD SIS is put into operation, the concentrations decrease to a range similar to those presented by GEEC (2010), but with greater variability. The greater variability could be attributed to the use of historical precipitation data and monthly variation of the SIS effectivenesses. However, given the discussion above, the results obtained from the predictive simulation may imply useful temporal trends in future site water quality, but likely are not accurate forecasts of the magnitude of future constituent concentrations.

Figures B-13 and B-14 show for Rose Creek (X14) and Vangorda Creek (V8) respectively, the predictive annual range (minimum and maximum) results of a stochastic run with 100 realizations in comparison with the Faro background water quality. The figures show a significant drop in concentrations during the first 30 years of the closure plan, when all the covers and SISs and projects are supposed to be in place. Despite the noticeable drop in concentrations, the model results are still above the background water quality.

5.3 Model Uses and Limitations

Results from the model will be used primarily to forecast water quality changes over time within and downstream from locations of interest in the FMC. The model is also intended to be a tool that will educate stakeholders about the flow and water quality conditions within the FMC and will help evaluate the impacts that various engineered actions could have on changing future water quality conditions. In other words, the model will help test the potential benefits of various remediation strategies and evaluate the cost-benefits for each.

Water quality changes forecast by the model are a function of several input assumptions, including the changing nature of the WRD source contributions over time, the timing of the WRD cover installations, the effectiveness of the cover types, the timing of when various SISs will be put into operation, and the effectiveness of the SISs to capture contaminated seepage. Other factors that can be evaluated by the model include the benefits for operating one versus two WTPs, the implications of the use of the Faro Pit to store pumped SIS flows, and the construction and use of a large storage element within the lower portion of the CVD. Model results will provide estimates of the benefits that these engineered actions could have on water quality downstream from the FMC.

Perhaps the greatest limitation of the GoldSim models is the apparent inaccuracies in the magnitude and timing of the mass flux terms being generated from the WRD sources at the site. As discussed previously, recent geochemical evaluations of the current WRD sources strongly suggest that modifications are necessary to develop a tool that can accurately replicate the water quality observed in major seepage sources adjacent to the toe of the

WRDs. Until these near-field sources can be accurately simulated in the model, forecasts of SW quality downstream from the FMC will not be adequate to achieve the modelling objectives.

Another model limitation is the use of historical precipitation records from the Faro Airport Station, modified for use at the site according to an empirical correlation between the Faro Airport Station and the FMC data records. Although the flow estimates using historical data from Faro Airport are reasonable, the 38 years of monthly precipitation data available might be limiting the model's capability to evaluate long-term climate variability. The Faro Airport Station precipitation data should be replaced with FMC precipitation data when more reliable FMC climate data become available. Also, the use of climate models should be considered when evaluating the FMC water balance over long periods (for example, 200 years). With better climate data available, additional hydrological analysis should be conducted to update the monthly patterns for runoff, seepage, transpiration, and evaporation.

A better climatic dataset would also benefit the hydrological model of the FMC and may result in more-accurate estimates for the HEP. With more-robust climatic data sets, the current assumption that there is a linear correlation between the average HEP and the mean annual precipitation used to adjust HEP values could be replaced with better estimates.

The model currently runs on a monthly time step. Monthly time discretization does not capture peak flow events that occur within the FMC. This limitation precludes the use of the model to investigate shorter-term variations in flow and water quality that may occur in extreme conditions, such as those experienced during freshet events.

The water types assigned in the GoldSim models represent average concentrations of many seep samples from a variety of locations. As a result, there is uncertainty associated with the averaging process and the variability of source materials, even within the same chemical type. In addition, the GoldSim models simulate the mixing of WRD inputs at the catchment level using a simple mass-balance approach. The simulations do not account for reactive mixing that may result in the removal of a fraction of the dissolved constituents from solution, contributions to solution from the aquifer matrix, or resulting adjustments in pH and acidity. Consequently, the geochemical loading at the catchment level is unrealistic in some cases. Significant differences between modelled and historical concentrations have been noted at several model nodes. Attempts to use an external reactive mixing model in conjunction with the GoldSim model inputs from WRDs has thus far produced mixed results (CH2M HILL, 2013). Observed water chemistry associated with the shallow portions of the Faro Pit Lake may be matched more accurately by adding a reactive mixing model to the GoldSim model. However, the mixing of WRD inputs in GW to produce observed catchment discharge chemistry (such as that of the X23 catchment) have not been successful; therefore, adjustment in the choice and method of water types in the GoldSim models need to be examined.

NP decay rates were assigned to the WRDs on the basis of the mineralogy and measured acid-base and oxidation properties of each WRD. These values, assigned to each WRD, are the key to forecasting the timing and nature of future water quality changes. Although the accuracy of the assigned NP decay rates have not been rigorously tested yet, uncertainty in the NP could lead to large differences in the forecast timing of acidification of many of the WRD waters, affecting design and site management planning decisions. Given the large uncertainties associated with choice of current water types described previously, the NP decay rates and assumed future (acidic) water types are assumed to be highly generalized and could be improved by more-rigorous analysis. This is anticipated to include using the abundant data and analysis results to produce a chemical modelling approach that more directly simulates the future process of changing water chemistry (CH2M HILL, 2013).

The original SRK spreadsheet model and GoldSim models incorporate only a subset of the known contributions to the RCAA, and essentially none of the data collected in this area. This makes it difficult, if not impossible, to assess the GoldSim model's ability to forecast water quality for locations downstream of the RCAA. Major shortcomings of the GoldSim models include the lack of inputs from several locations, including infiltration of SW that flows onto the tailings and is thus altered in chemistry, GW underflow from Guardhouse Creek drainage, and underflow from WRD areas to the east of ETA. As with the Faro Pit Lake and WRD areas, the GoldSim models do not account for reactions occurring while these inputs are mixing or interacting with the aquifer solids, which could greatly overestimate the future concentrations and rate of transport of trace metals in the RCAA.

5.4 Addressing the Independent Peer Review Panel Comments

Comments issued by the IPRP on August 15, 2010, on Draft 4A of the project description for the Faro Mine Complex Closure and Remediation Plan were reviewed to evaluate whether modifications to the GoldSim model could be pursued to address the comments. Table 11 contains a brief explanation of how GoldSim model features could be modified to address the IPRP concerns.

TABLE 11
Summary of Current Model Approaches that Address IPRP Comments
Faro Remediation Project

IPRP Comment	How it is being modelled
Use of Grum Pit for biological treatment	The user has to option to turn Grum treatment on and off. If biological treatment is turned off, the water quality of the Grum Pit is assumed to be defined by observed data and only SO4, Zn, and Fe values were changed from New values based on Grum_Pit_V23.xls spreadsheet.
Downstream cut-off wall on SFRC	The implementation of the cut-off wall will reduce the percentage of SFRC flows going into the RCTA. The effects of a cut-off wall can be modelled with adjustment to the RCD infiltration parameter.
Location of the CVD interception system	The model has the option to place the SIS upstream of the ID, downstream of the ID, and downstream of the CVD.
Evaluate CVD breach	The model can trigger a CVD breach at a certain point in time; when that happens, all the inflows to CVD will be diverted to X14.
Evaluate use of large storage at the lowest part of the system in lieu of the CVD Polishing Pond	The large storage element at tail end of the RCTA system would be modelled by assuming a CVD breach and an associated change in the IP Elevation-Area Capacity tables. The new ID Pond would represent the large storage at the low area of the system. The CVD SIS would be placed downstream of ID Pond in this case.
Single focused groundwater collection point at the CVD	The various SISs currently in the model are dispersed across the FMC. Within the model, the user can control if a particular SIS is on or off and prescribe its efficiency. This option could be modelled by turning off all SISs except the CVD SIS.
Report zinc, cadmium, and copper on model results	The model currently reports zinc, cadmium, and copper concentrations in surface water at several locations.
Evaluate climate variability	Climate variability can be evaluated by the use of a ramping parameter available in the dashboard or by changing the historical precipitation data available in the input spreadsheet.
Evaluate sensitivity of using 10% of seepage water quality for runoff water quality	The 10% parameter is a user input now. It can be changed or specified as a stochastic variable.
Evaluate increasing WTP capacity over time	The user can specify how the WTP capacity increases though time using a table available from within the dashboard. The mode can also evaluate the use of one versus two WTPs.
Report how individual elements are incorporated in the model structure	Section 4.3 of the report provides a detailed explanation of the model input variables and their role in model computations. The model input table offers a complete list of variables with an associated brief explanation and location of the variable in the model.
Evaluate triangular distribution for SIS efficiency	The use of triangular distributions instead of uniform distributions is a relatively simple adjustment to the model and should be evaluated in a sensitivity analysis.
Use different SIS efficiencies	The user can set different SIS efficiencies for each SIS directly on the model dashboard.
Increase stochastic realizations, sensitivity on the number of realizations	The only constraint keeping the model from running a large number of stochastic realizations is the resulting output file size. The model now isolates the main results in a model container so that results from all other model variables can be turned off, resulting in a smaller final stochastic model output file containing only the essential results.

SECTION 6

Recommendations for Future Modelling

The highest priority for future use of the GoldSim model to support remedial actions at the site and to support the development of a Project Proposal for submittal to the Yukon Environmental and Socio-economic Assessment Act (YESAA), is the undertaking of a geochemical study to improve the accuracy of the characterization of the WRD contaminant mass flux terms over time. Although the current model assumptions regarding contaminant transport and chemical reactions is believed to be conservative, until more-accurate source terms for the WRD sources are available, any water quality forecast made using the GoldSim model will be suspect. In most cases, the model currently appears to reasonably replicate observed pit lake and reservoir storage levels at the site, as well as the pumping rates observed from Faro Pit, the ID Pond, and the WTP influent and effluent. So, although minor model adjustments to improve these predictions may be warranted in the future, the highest priority by far is the refinement of the WRD source terms. The added capability to run the model in a historical mode and compare results against historical values can be used to prioritize areas in the model that need refinement. This historical mode capability will be especially useful in refining the geochemistry calculations in the model.

There is some remaining uncertainty regarding the inflows into the RCTA and RCAA areas. A better understanding of the contributing flows to that area would likely improve the model forecasts. Future model revision should focus on refining the assumptions regarding the RCD leakage into the RCAA, flows from NFRC and SFRC entering the RCTA, and GW recharge from the ID Pond and Polishing Pond. A more- accurate representation of those values would result in better estimates of the water quality at X14.

There is significant uncertainty regarding the background water quality concentration that is assigned to WRD areas once the covers are in place. Field sampling from covered areas will provide better estimates of the effectiveness of the covers at minimizing the contamination of runoff and would likely result in more-accurate model results.

Better estimates of FCD leakage to the Faro Pit (quantity and quality) would likely improve the forecasts of WTP flows because these modelled flows are significant (around 40 L/sec).

The water quality weighted average used to mix different water types and the assumption that no delay occurs during seepage flow from the source areas to downstream destination points was intended to be conservative. Geochemistry assumptions would have to be refined if final model results show violations of downstream water quality standards. The geochemistry approaches that could be modified to improve water quality forecasts include the following:

- Simulating geochemical reactions as dependent variables
- Estimating WRD and seep chemistry more accurately by refining the estimation methodology of source chemistry, and incorporating the processes of reactive mixing and contaminant transport along flow paths
- Refining the algorithm that calculates WRD chemistry change though time
- Estimating initial amounts of acid-generating and acid-neutralizing minerals within each WRD
- Simulating geochemical reactions in the pit lakes
- Accounting for contaminant transport time lags

Refinement of the model to reflect monthly patterns of runoff and seepage based on historical monthly precipitation data may result in more-accurate simulations of seasonal fluctuations at the site. There is currently a discrepancy between the WRD boundaries depicted on figures and the areas used in the model. GEEC (2010) does not provide an updated map of those catchment areas that are consistent with the areas used in GoldSim model v1. A new WRD boundary map should be produced so that there will be consistency between figures and areas used in the model.

Other model improvements could be added to better integrate the results of the SW flow, GW flow, and geochemistry modelling currently being undertaken on the project. The integration of the results of the modelling could significantly improve the predictive capability of the GoldSim models.

SECTION 7
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Appendix A
Historical Run Model Results

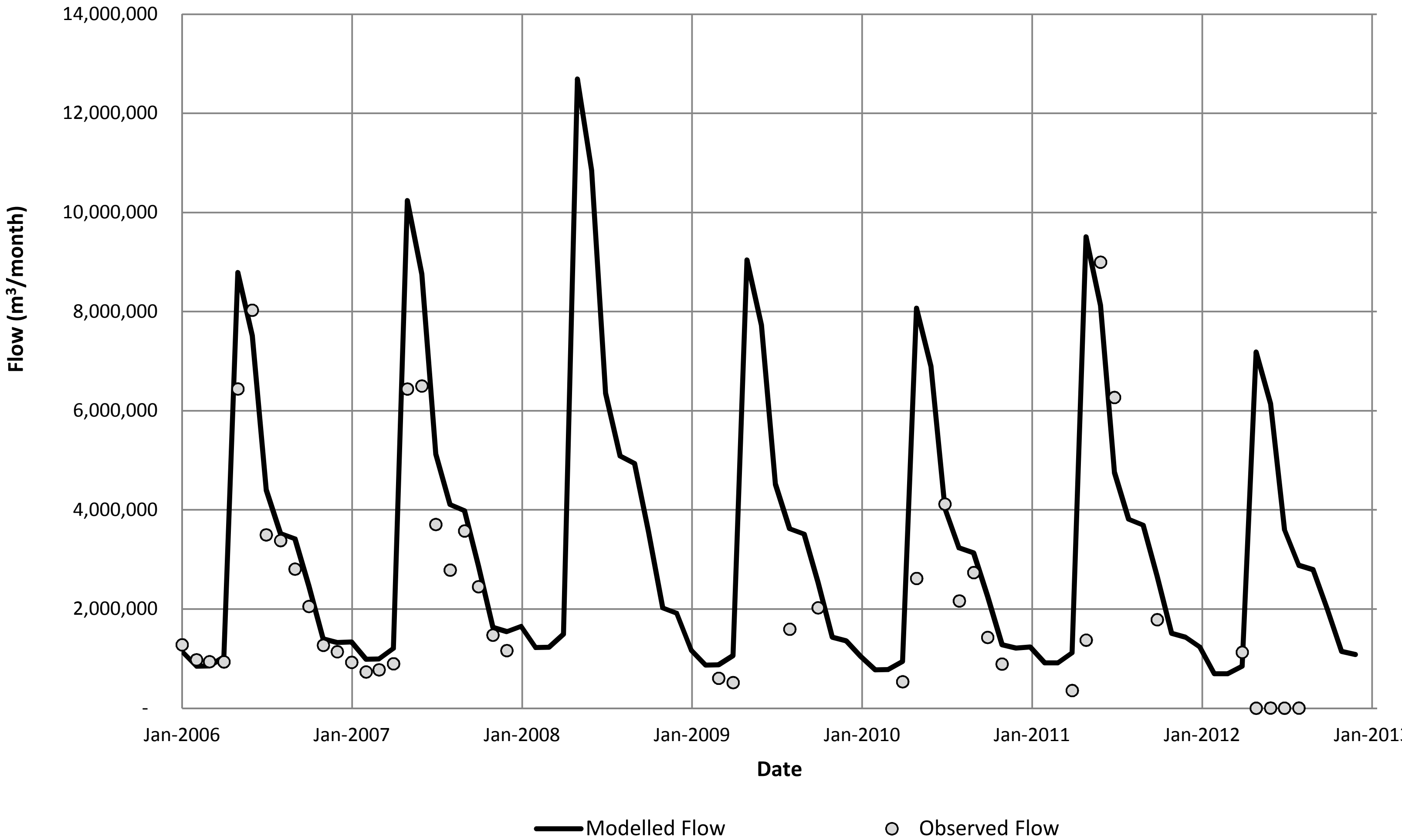

FIGURE A-1
X2 Monthly Flows
Faro Mine Remediation Project

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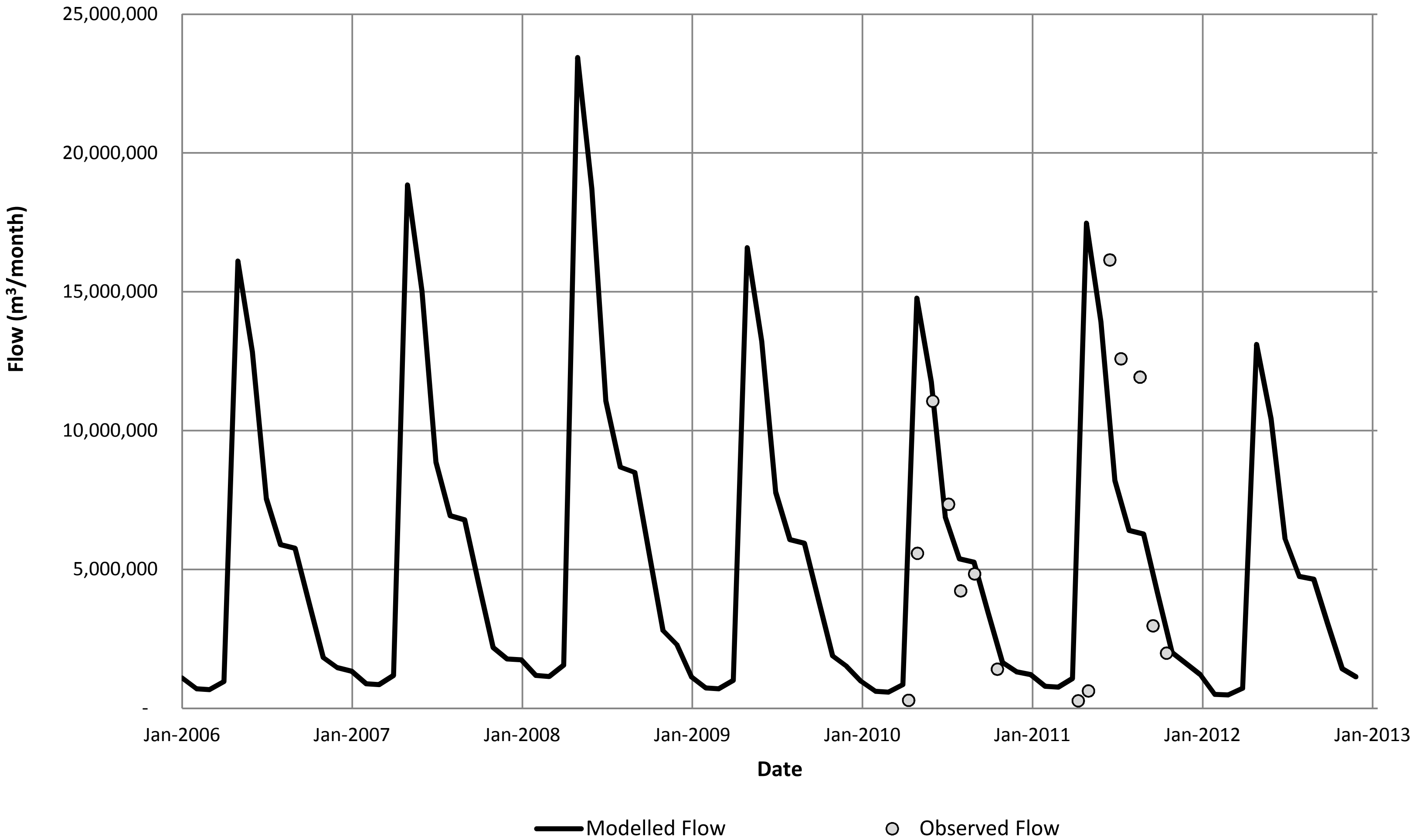


Note:
Observed flows at X10 compared to modeled flows upstream of RCTA after SFRC inflow.

FIGURE A-2
X10 Monthly Flows (RC upstream X14)
Faro Mine Remediation Project

CH2MHILL.

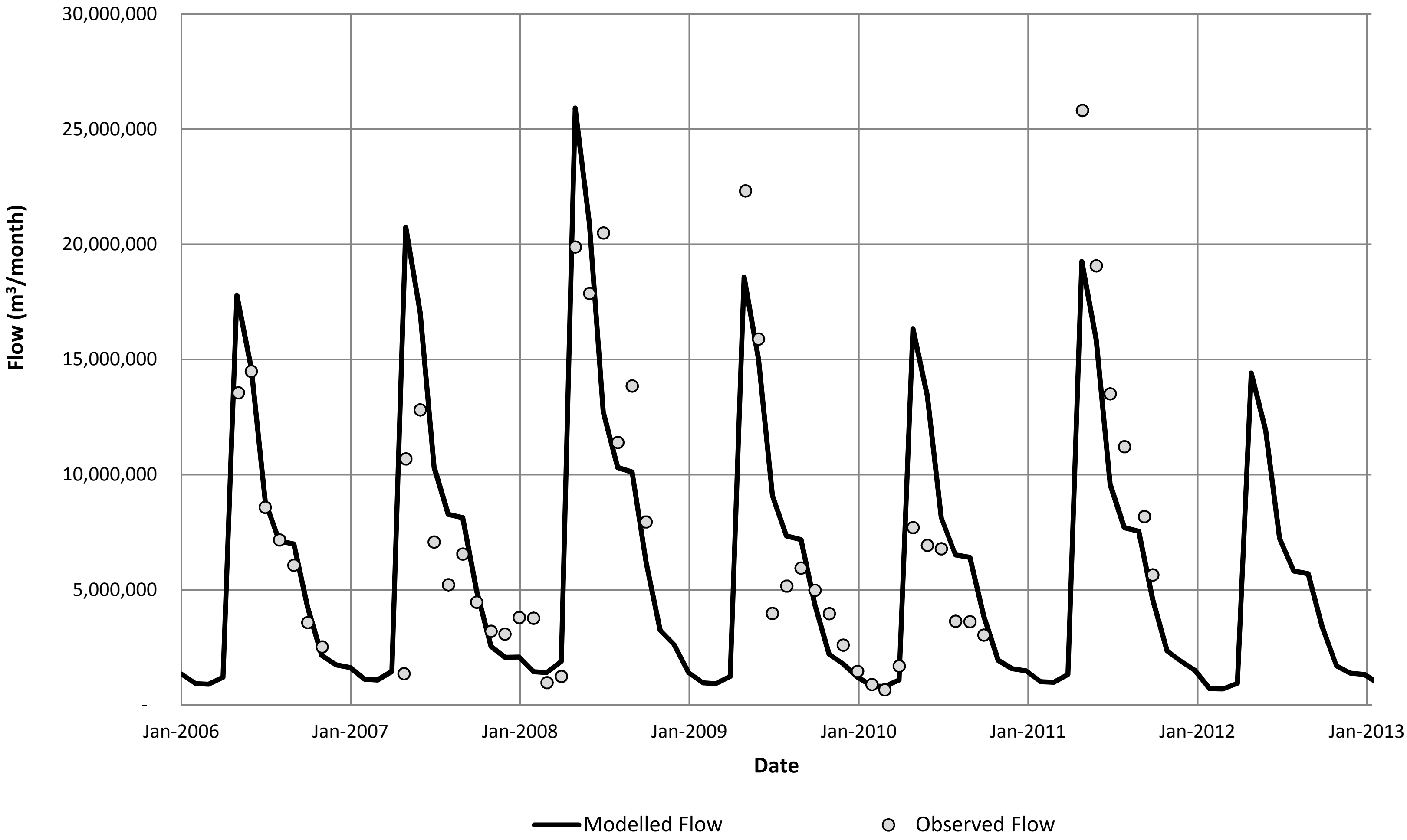


FIGURE A-3
X14 Monthly Flows
Faro Mine Remediation Project

CH2MHILL.

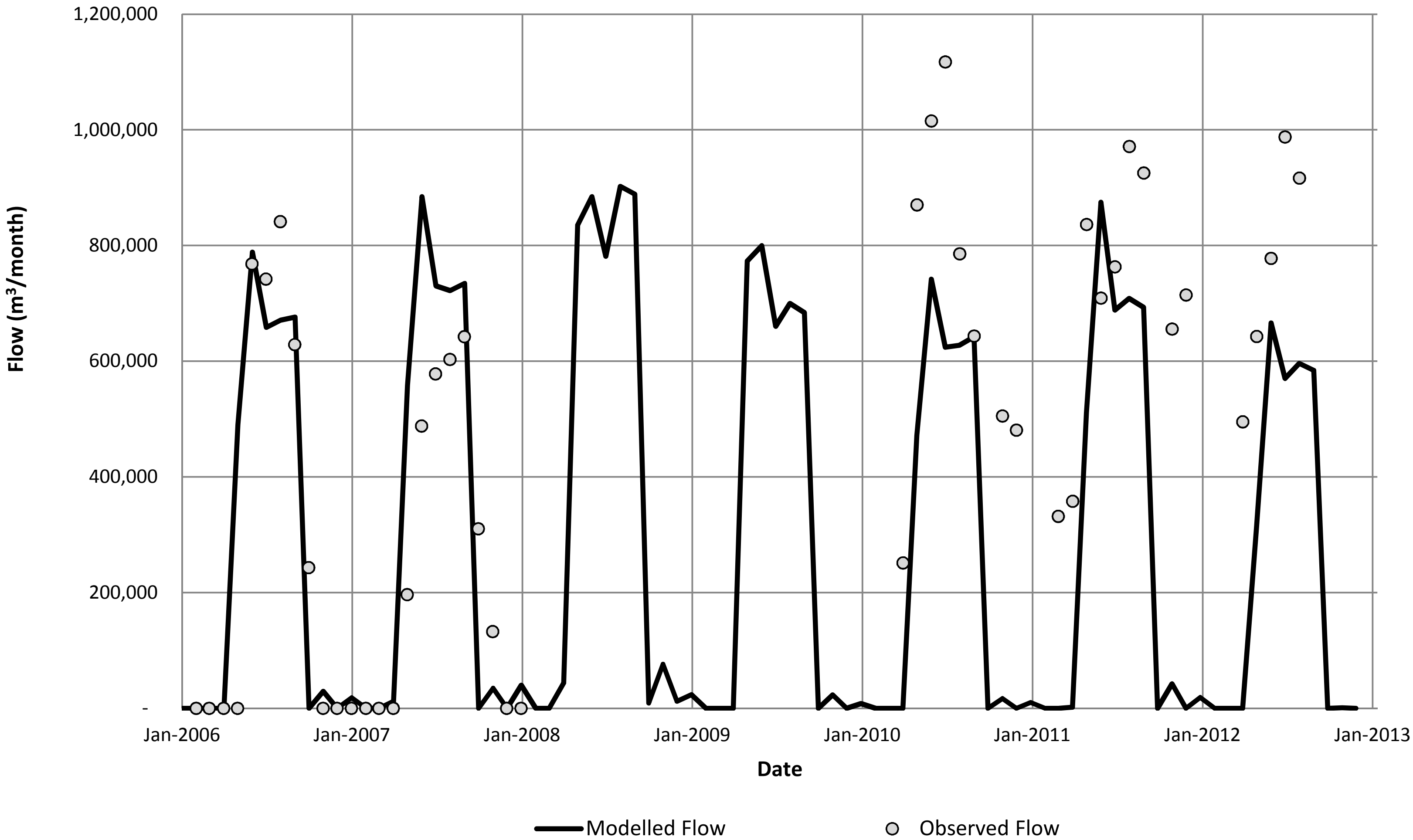
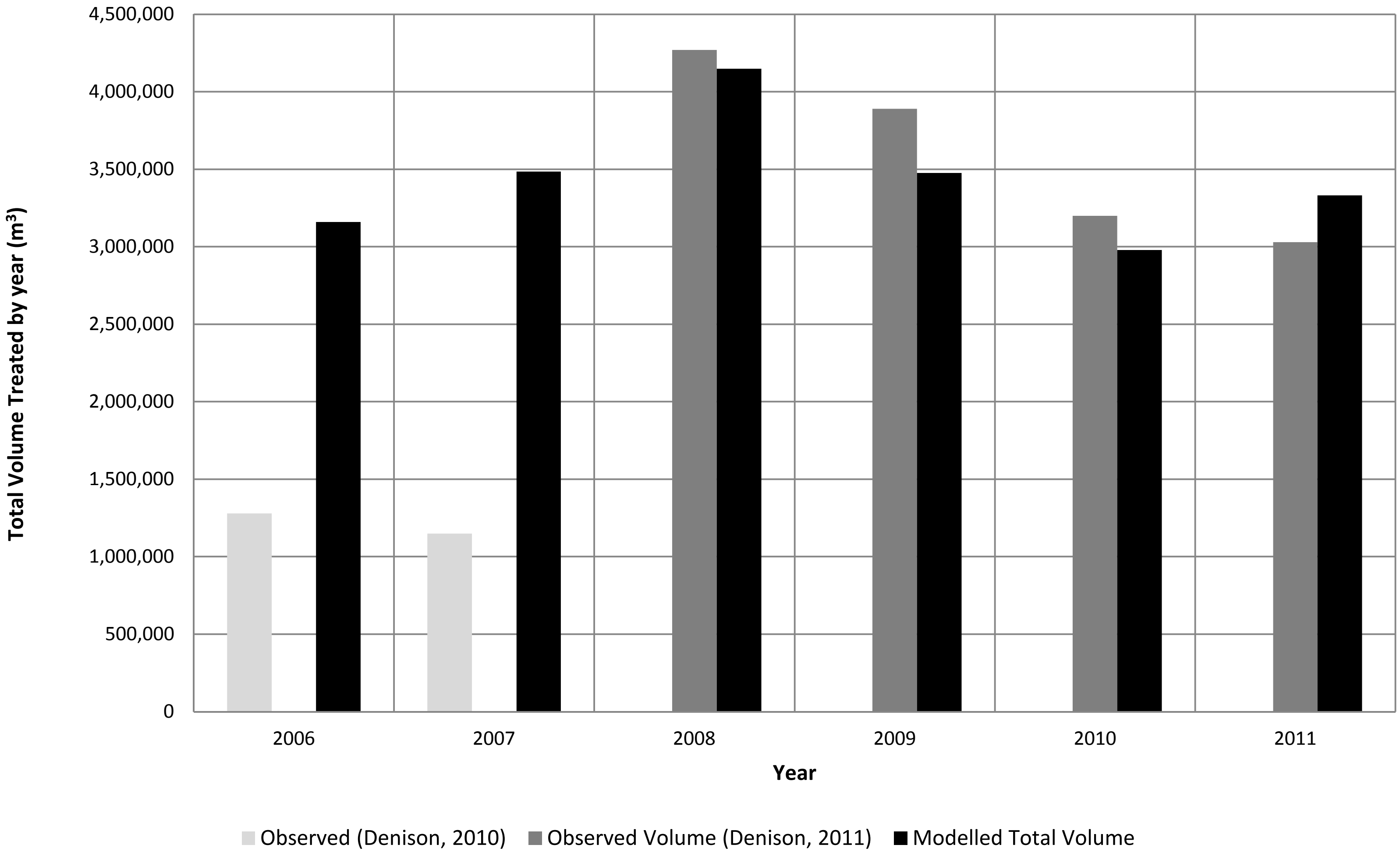


FIGURE A-4
Monthly Flows (CVD flows to X14)
Faro Mine Remediation Project

CH2MHILL.



Note:
Observed treatment volumes prior to 2008 are for Faro Pit only
(i.e., do not include water from IP and ETA).

FIGURE A-5
Annual Water Treatment Plant Treated Volume
Faro Mine Remediation Project

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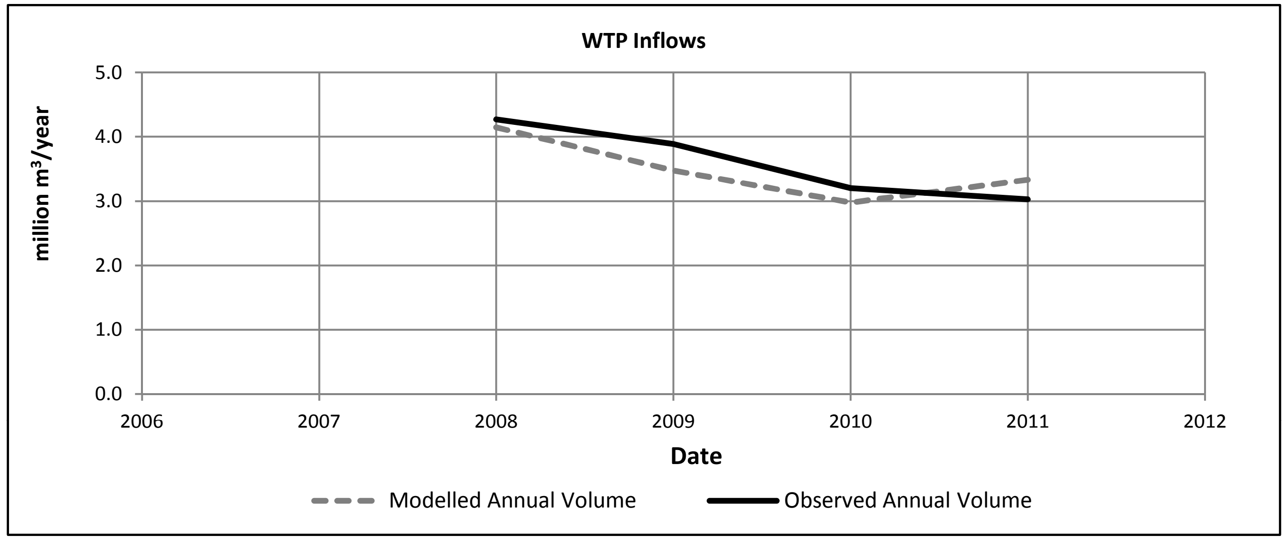
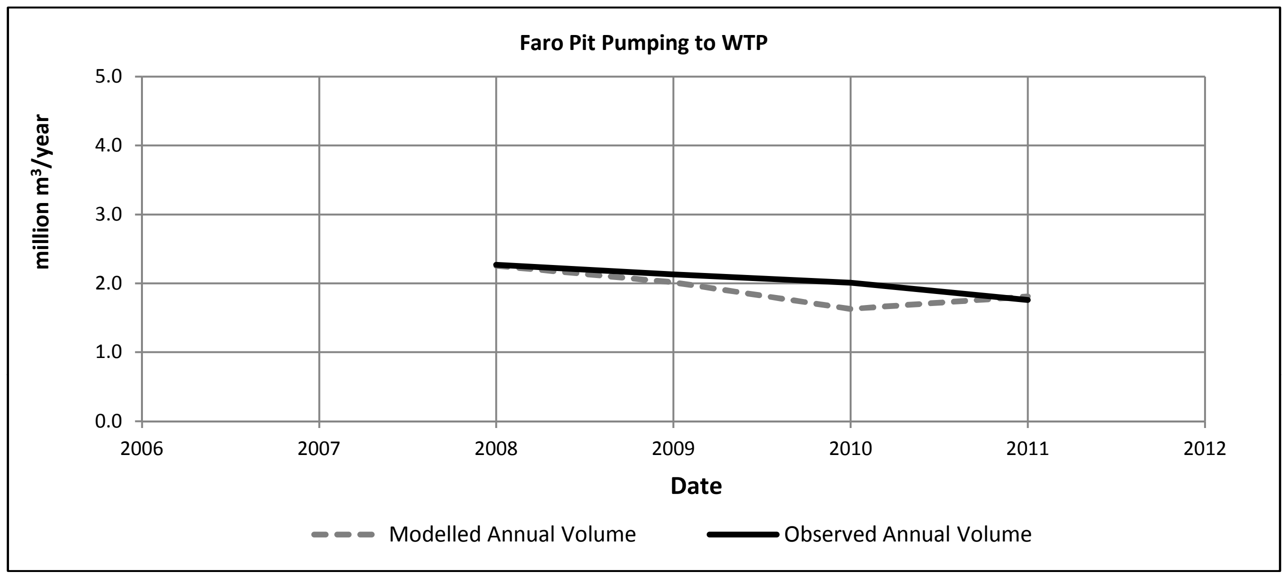
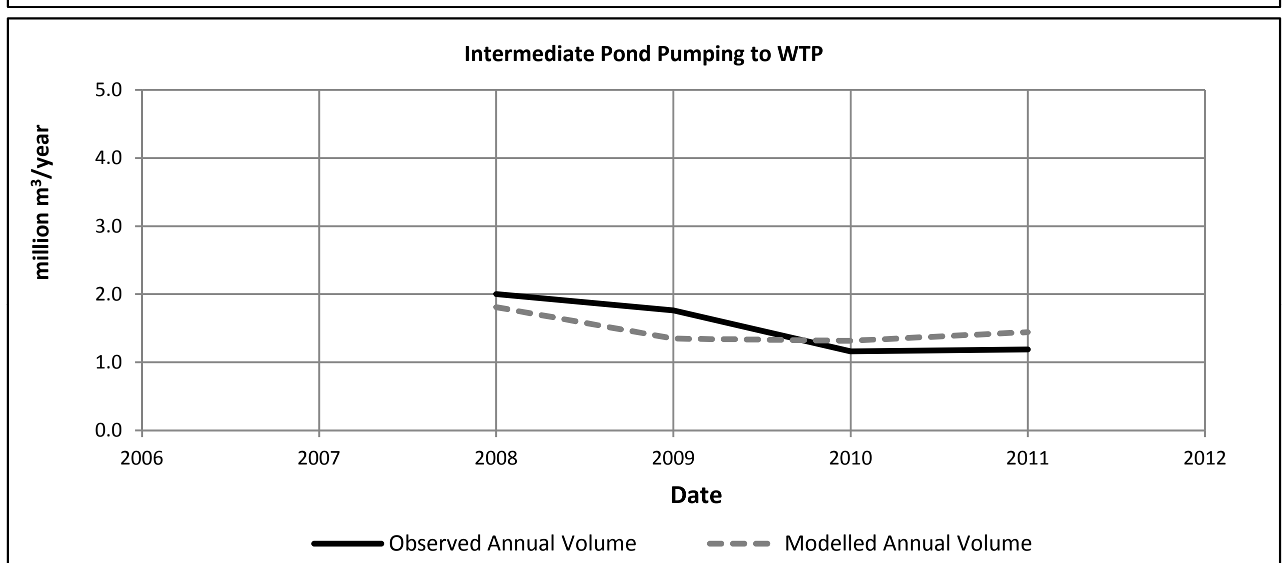


Year	Modelled Annual Volume	Observed Annual Volume	Difference (Modelled minus Observed	Difference (%)
2008	4.15	4.27	-0.1	-3
2009	3.31	3.89	-0.6	-15
2010	3.20	3.20	0.0	0
2011	3.12	3.03	0.1	3



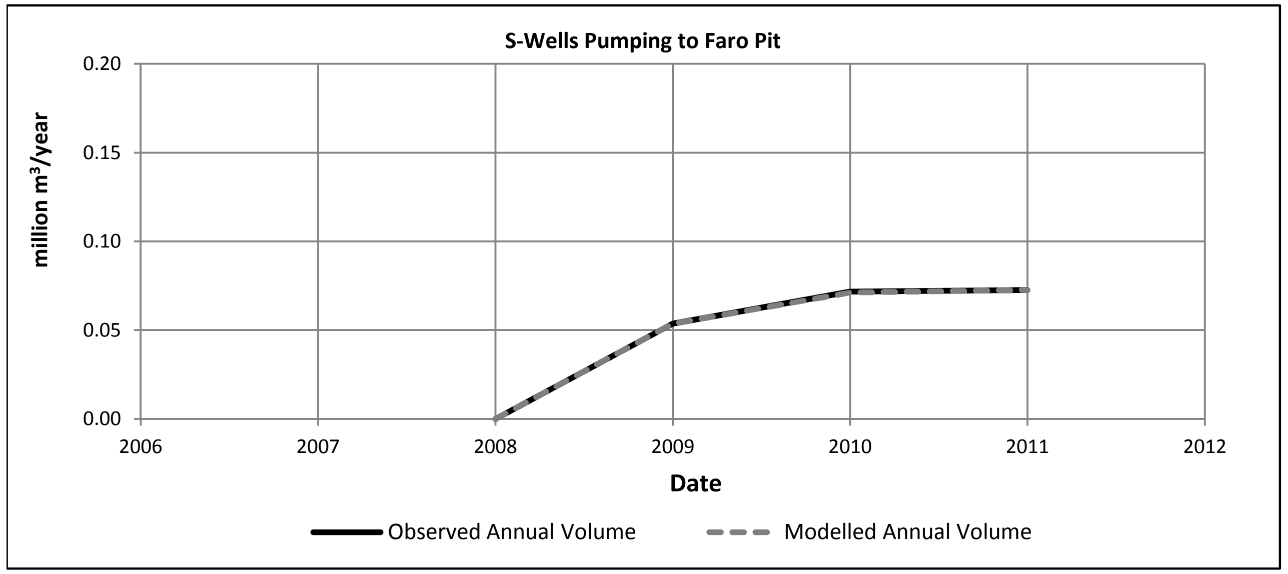
Year	Modelled Annual Volume	Observed Annual Volume	Difference (Modelled minus Observed	Difference (%)
2008	2.46	2.27	0.2	8
2009	2.03	2.13	-0.1	-5
2010	1.89	2.01	-0.1	-6
2011	1.88	1.76	0.1	7



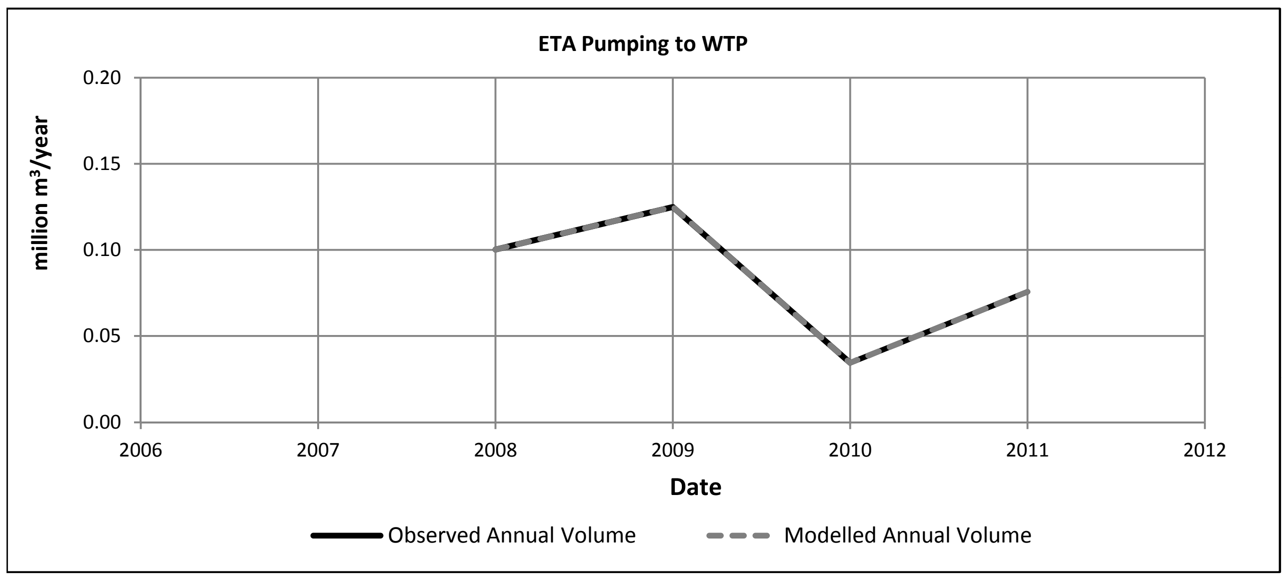
Year	Modelled Annual Volume	Observed Annual Volume	Difference (Modelled minus Observed	Difference (%)
2008	1.69	2.00	-0.3	-16
2009	1.28	1.76	-0.5	-27
2010	1.23	1.16	0.1	6
2011	1.17	1.19	0.0	-2

FIGURE A-6a

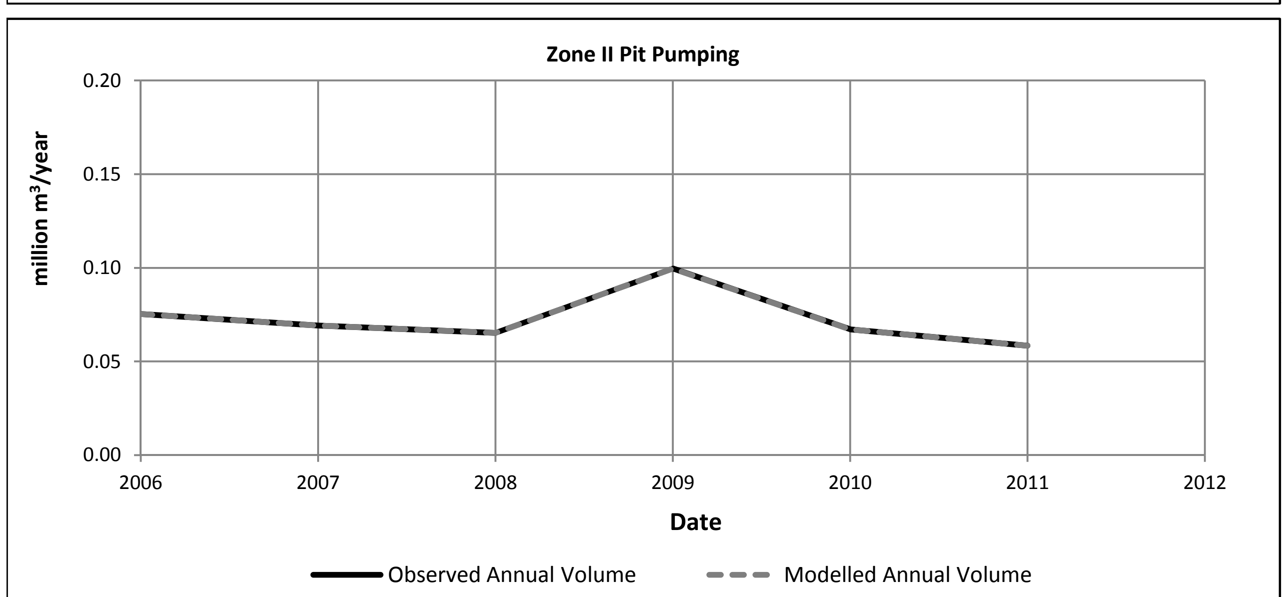
Comparison of Model Results vs.Values from 2011 Annual Environmental Monitoring and Activities Report



Year	Modelled Annual Volume	Observed Annual Volume	Difference (Modelled minus Observed	Difference (%)
2006		-		
2007		-		
2008	0.00	-	0.0	
2009	0.05	0.05	0.0	0
2010	0.07	0.07	0.0	0
2011	0.07	0.07	0.0	0



Year	Modelled Annual Volume	Observed Annual Volume	Difference (Modelled minus Observed	Difference (%)
2006		-		
2007		0.05		
2008	0.10	0.10		
2009	0.13	0.13		
2010	0.03	0.03	0.0	0
2011	0.08	0.08	0.0	0



Year	Modelled Annual Volume	Observed Annual Volume	Difference (Modelled minus Observed	Difference (%)
2005		0.05	-0.1	-100
2006	0.08	0.08	0.0	0
2007	0.07	0.07	0.0	0
2008	0.07	0.07	0.0	0
2009	0.10	0.10	0.0	0
2010	0.07	0.07	0.0	0
2011	0.058418	0.06	0.0	0

FIGURE A-6b
Comparison of Model Results vs. Values from 2011 Annual Environmental Monitoring and Activities Report

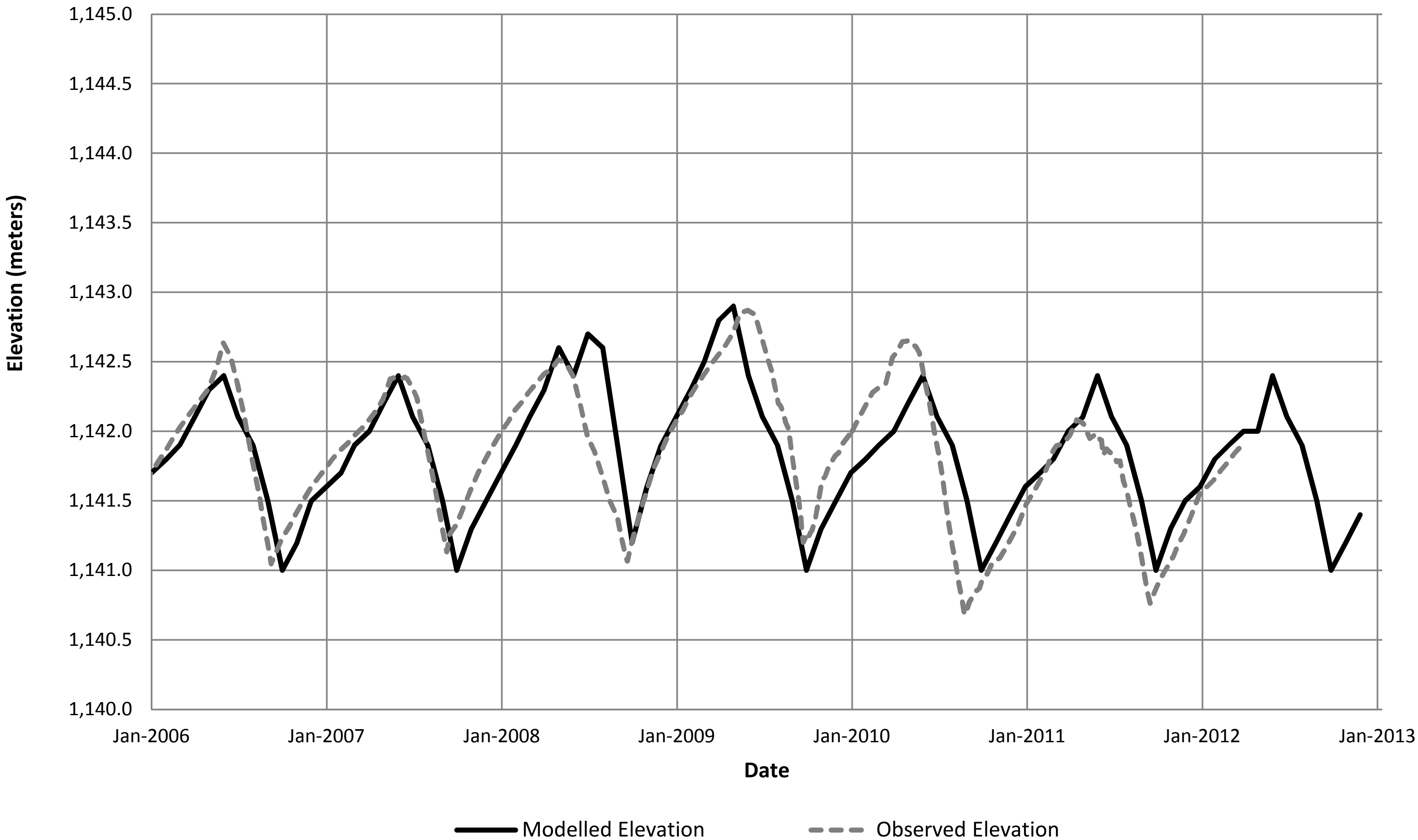


FIGURE A-7
Faro Pit Water-Level Elevation
Faro Mine Remediation Project

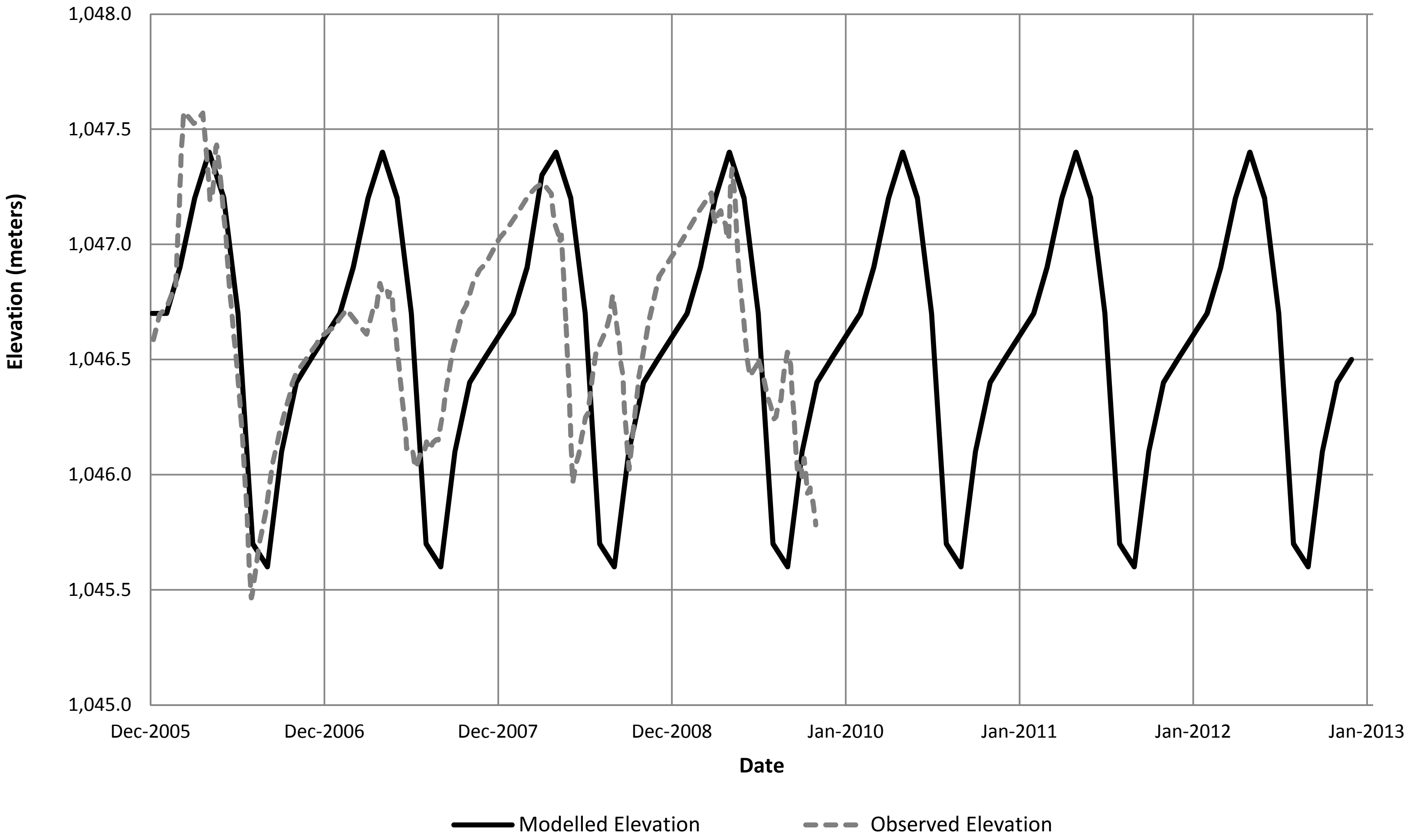


FIGURE A-8
Intermediate Dam Water-Level Elevation
Faro Mine Remediation Project

CH2MHILL.

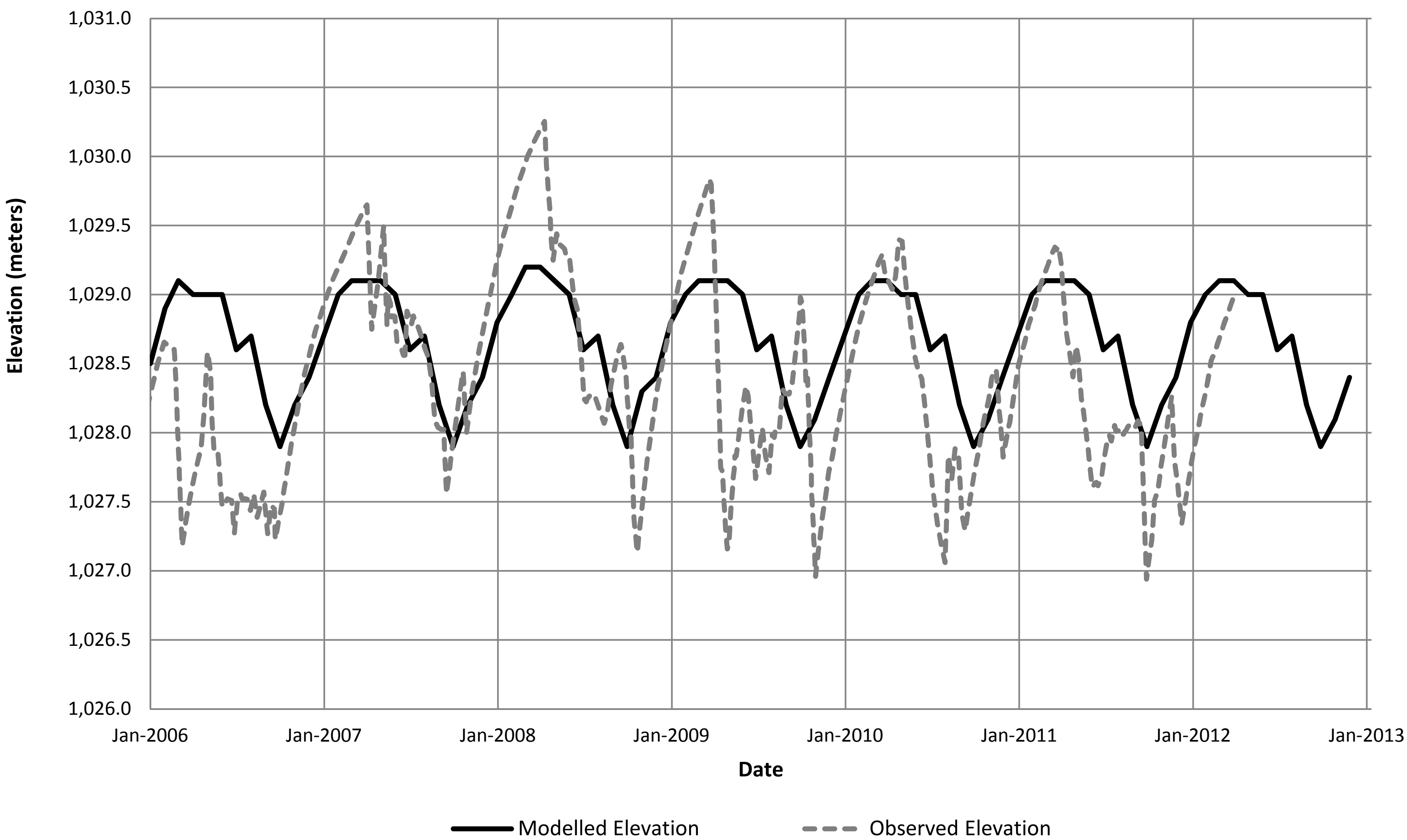


FIGURE A-9
Cross Valley Dam Water-Level Elevation
Faro Mine Remediation Project

CH2MHILL.

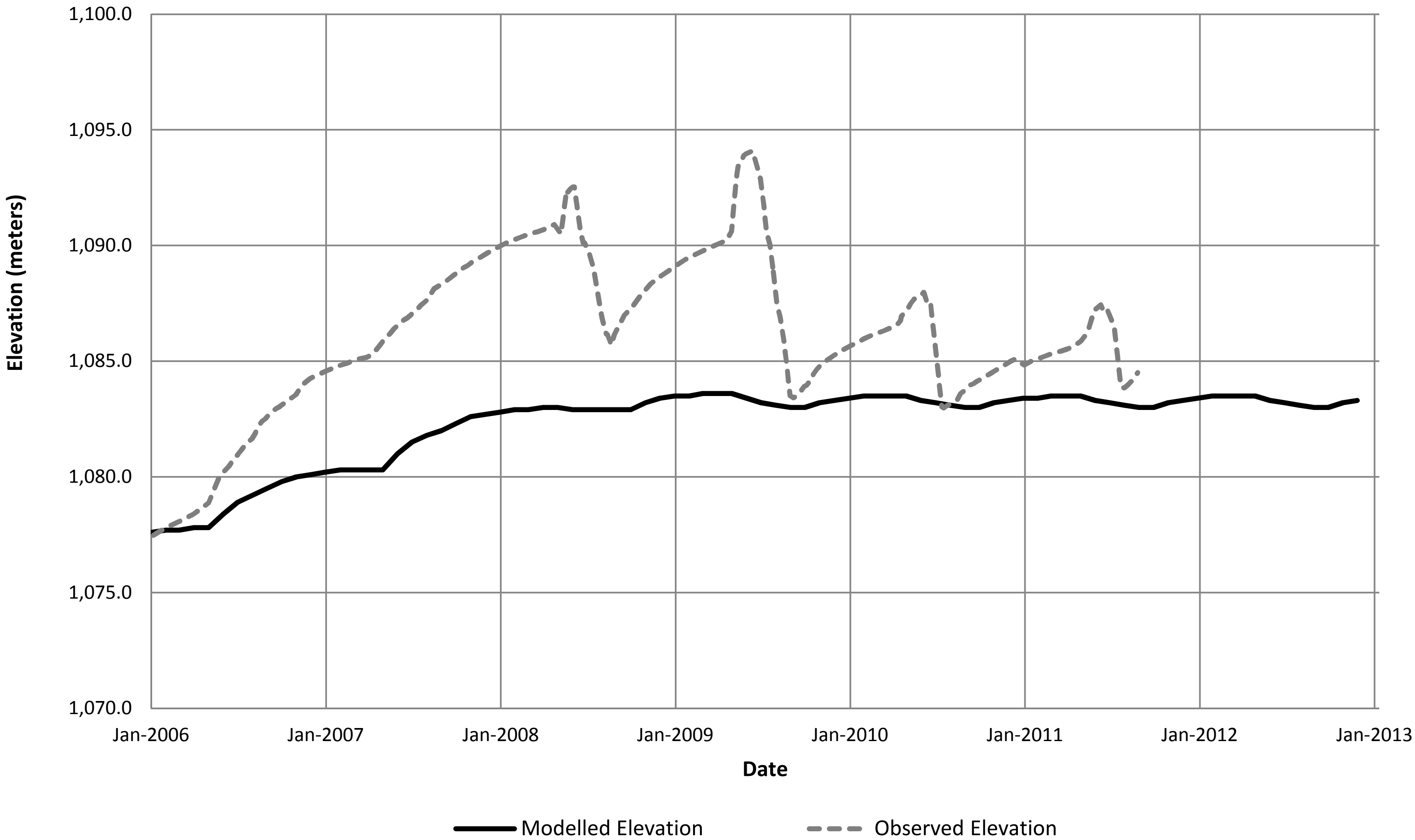


FIGURE A-10

Vangorda Pit Water-Level Elevation

Faro Mine Remediation Project

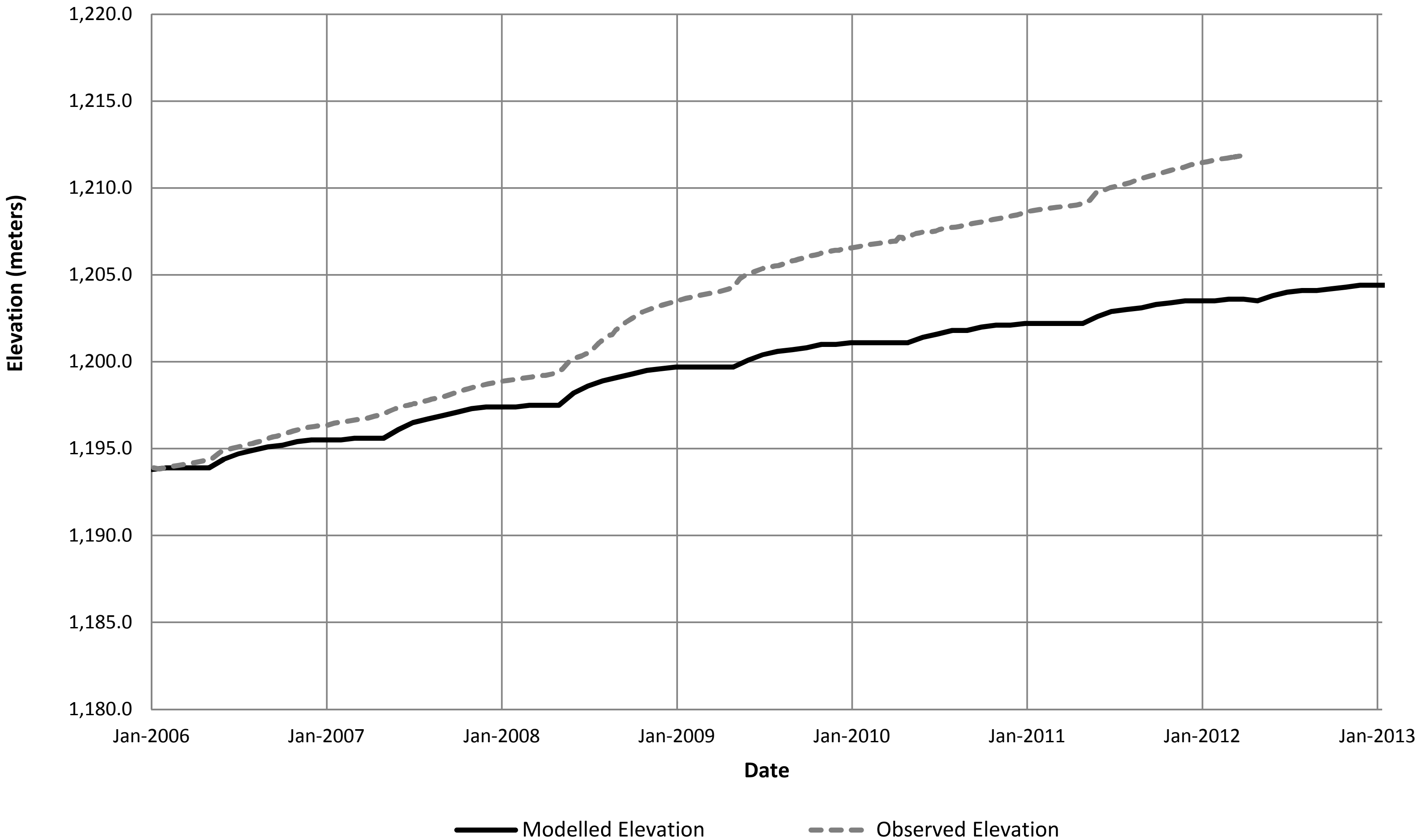


FIGURE A-11
Grum Pit Water-Level Elevation
Faro Mine Remediation Project

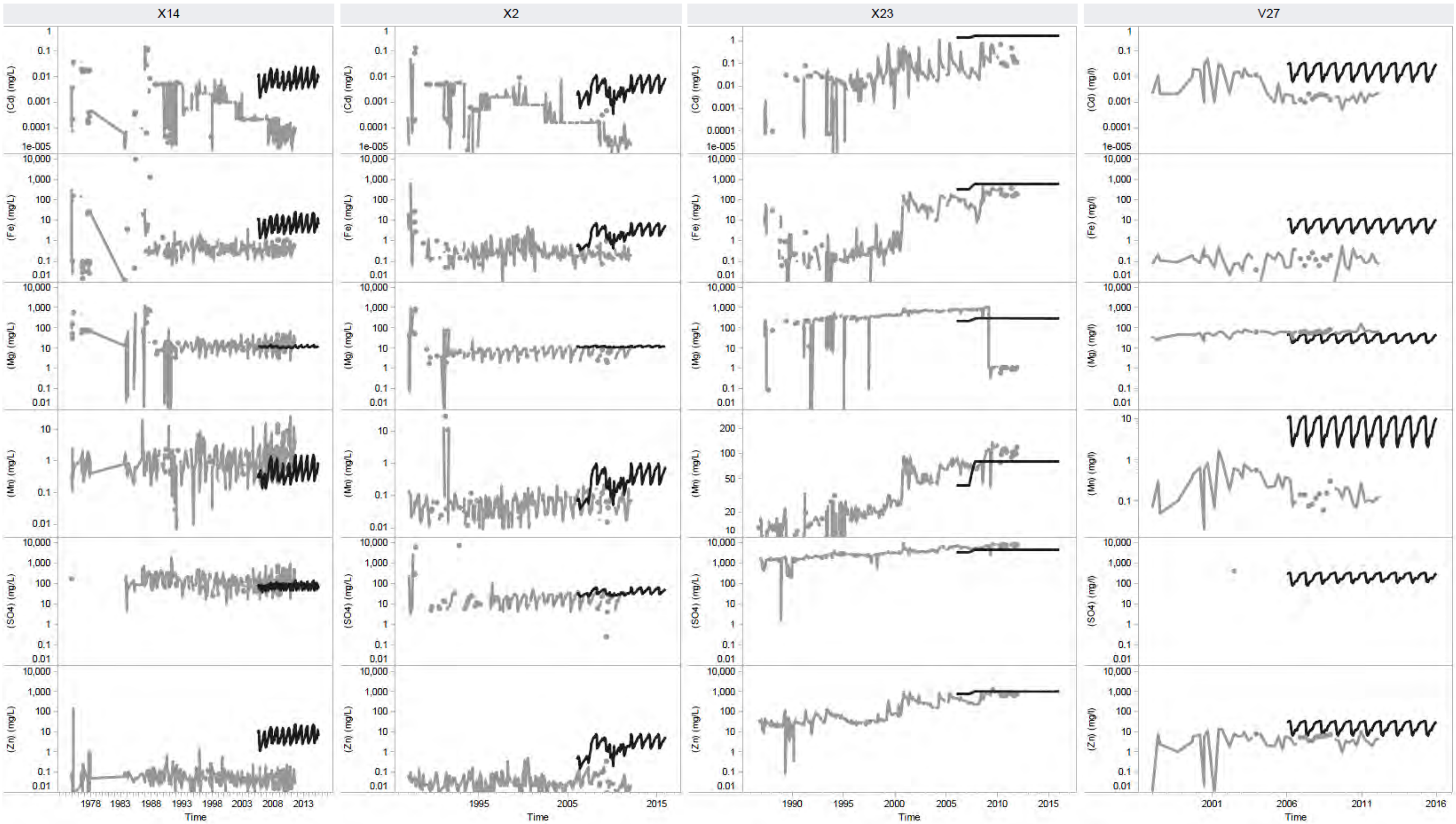


FIGURE A-12

Water Quality comparison Observed versus Model Results - Flow Locations

Faro Mine Remediation Project

CH2MHILL.

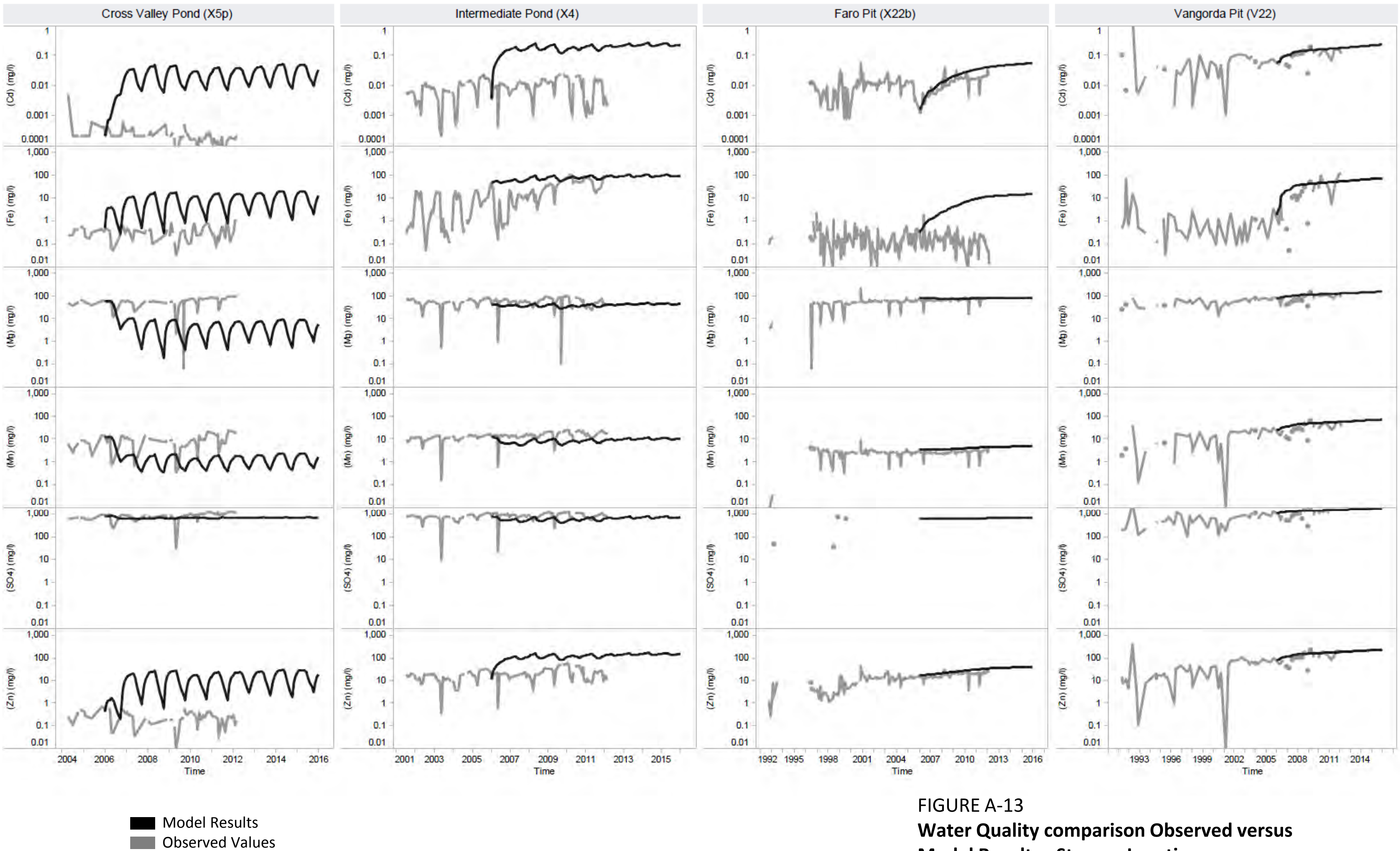


FIGURE A-13
Water Quality comparison Observed versus Model Results - Storage Locations
Faro Mine Remediation Project

Appendix B
Predictive Run Model Results

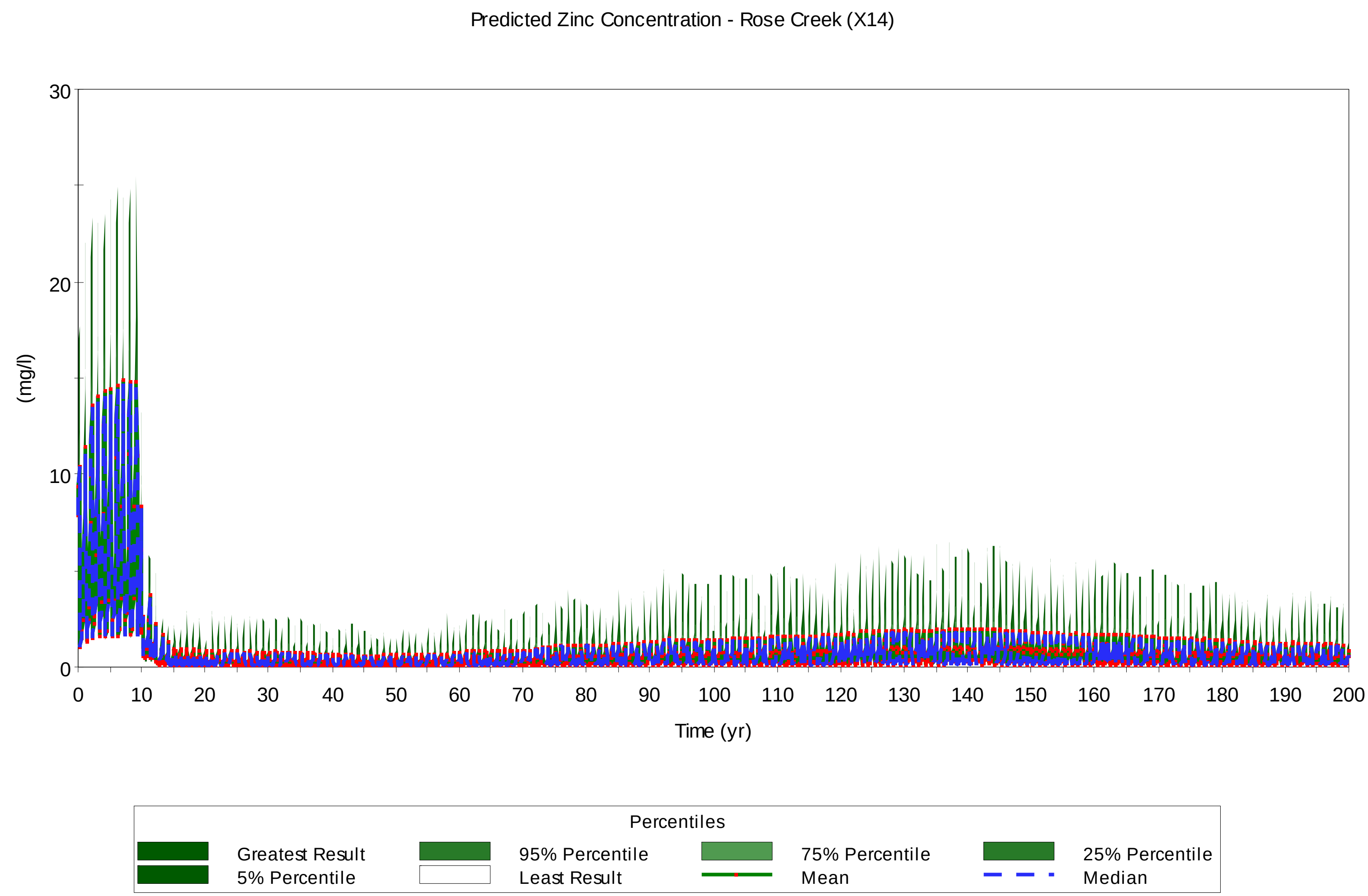


FIGURE B-1
Predicted Zinc Concentration – Rose Creek (X14) – Model V2
Faro Mine Remediation Project

CH2MHILL.

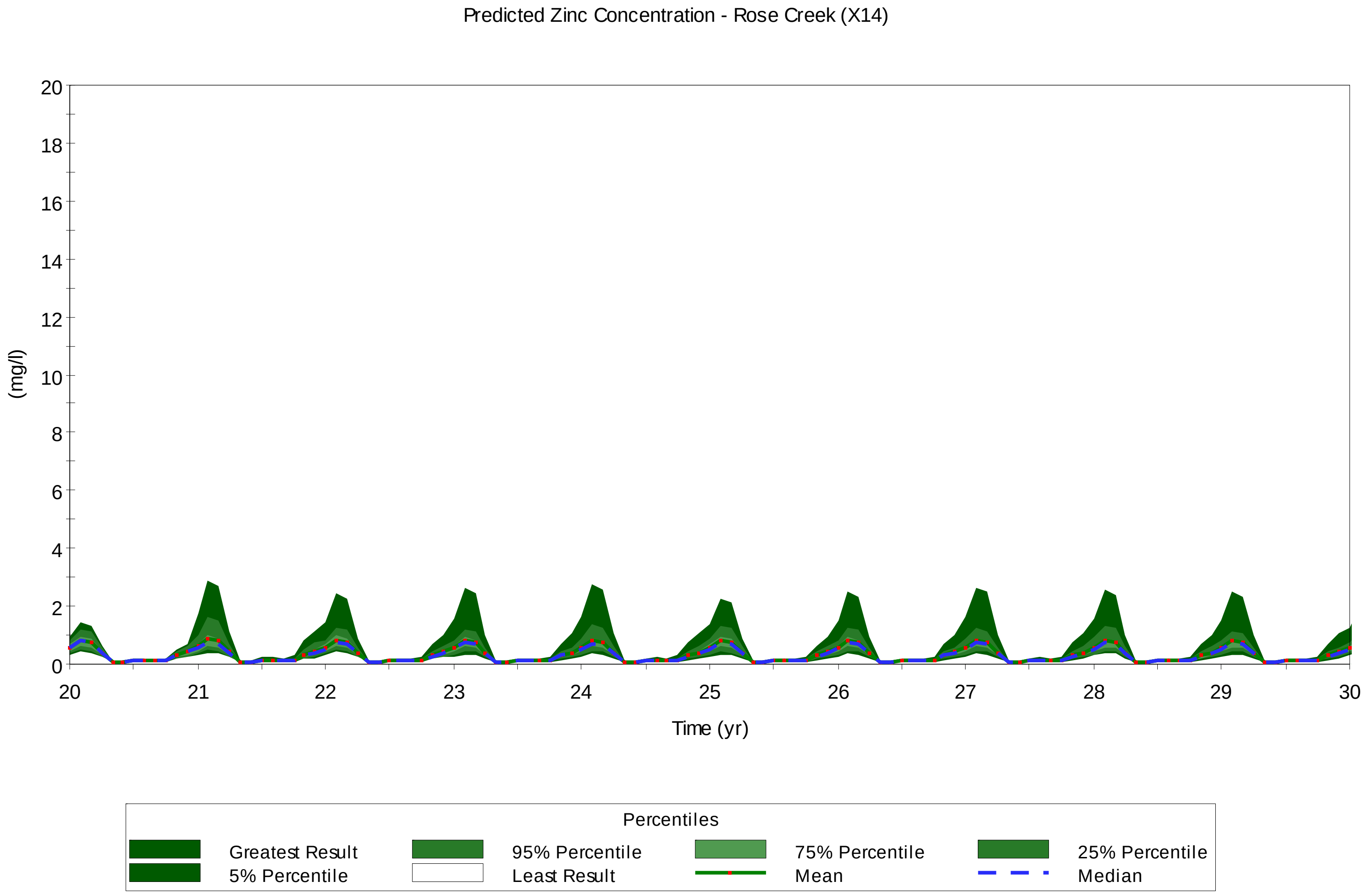


FIGURE B-2
Predicted Zinc Concentration –
Rose Creek (X14) – Year 20 to 30 – Model V2
Faro Mine Remediation Project

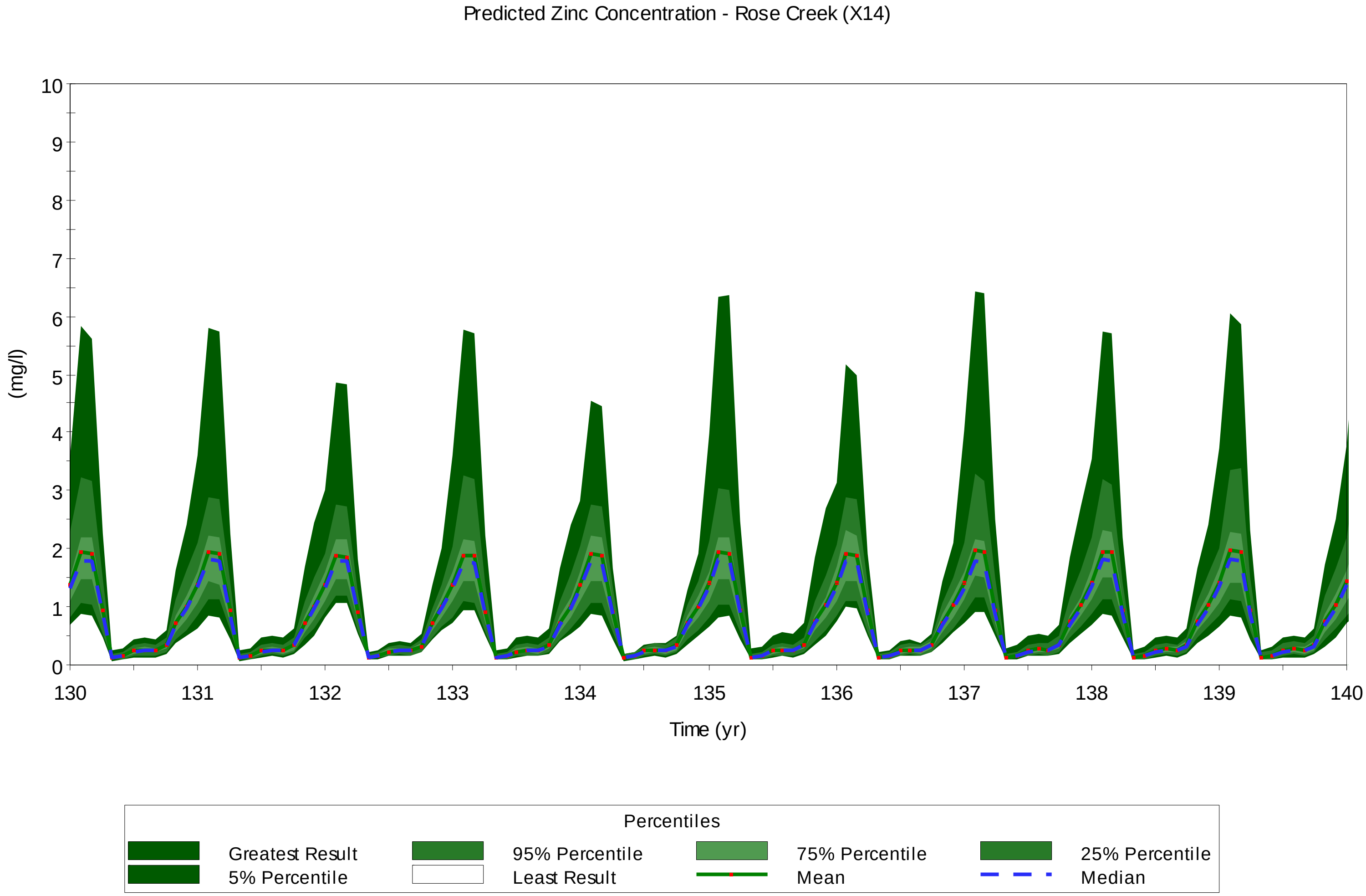


FIGURE B-3

Predicted Zinc Concentration –
Rose Creek (X14) – Year 130 to 140 – Model V2

Faro Mine Remediation Project

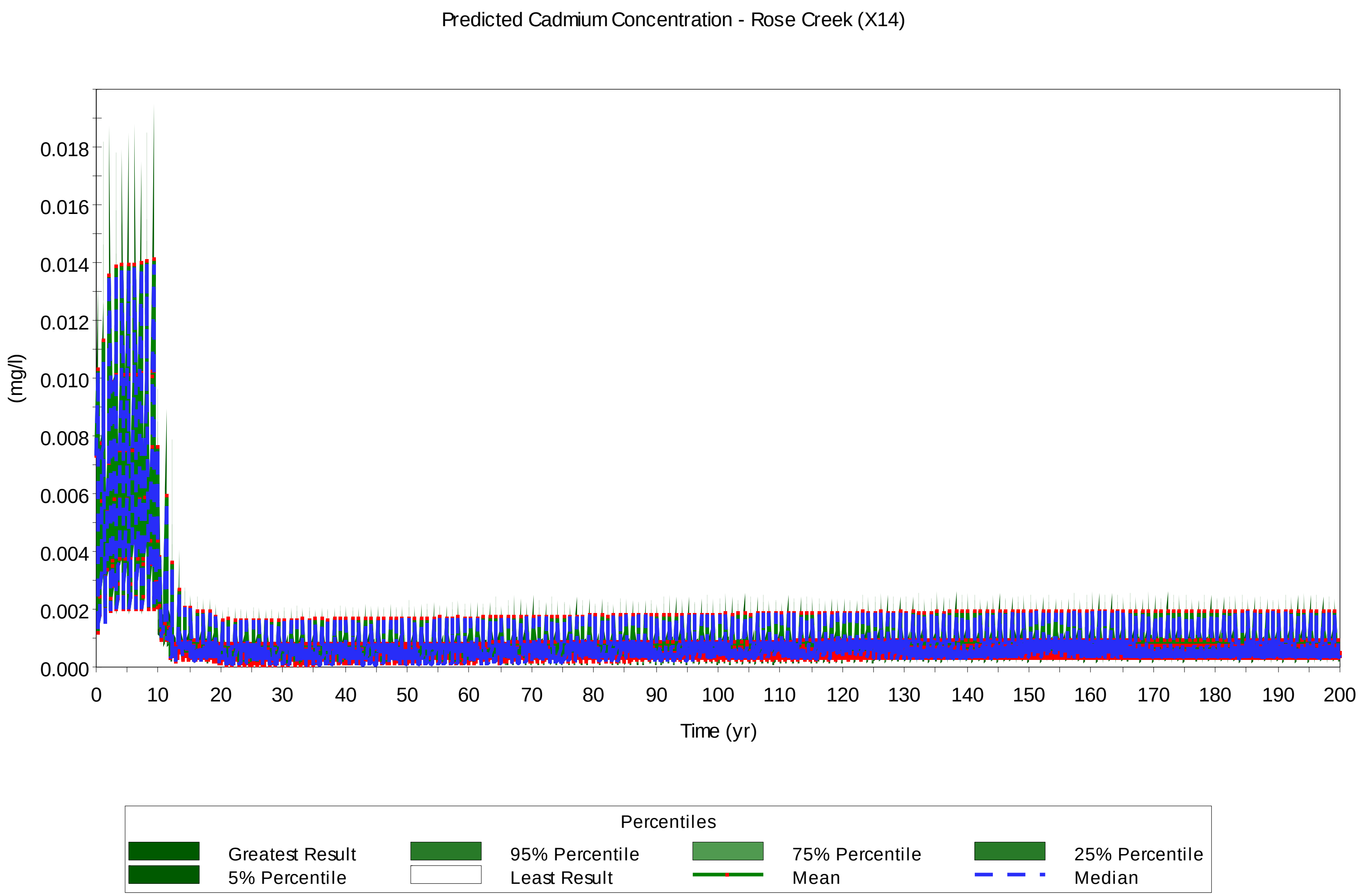


FIGURE B-4

Predicted Cadmium Concentration – Rose Creek (X14) – Model V2

Faro Mine Remediation Project

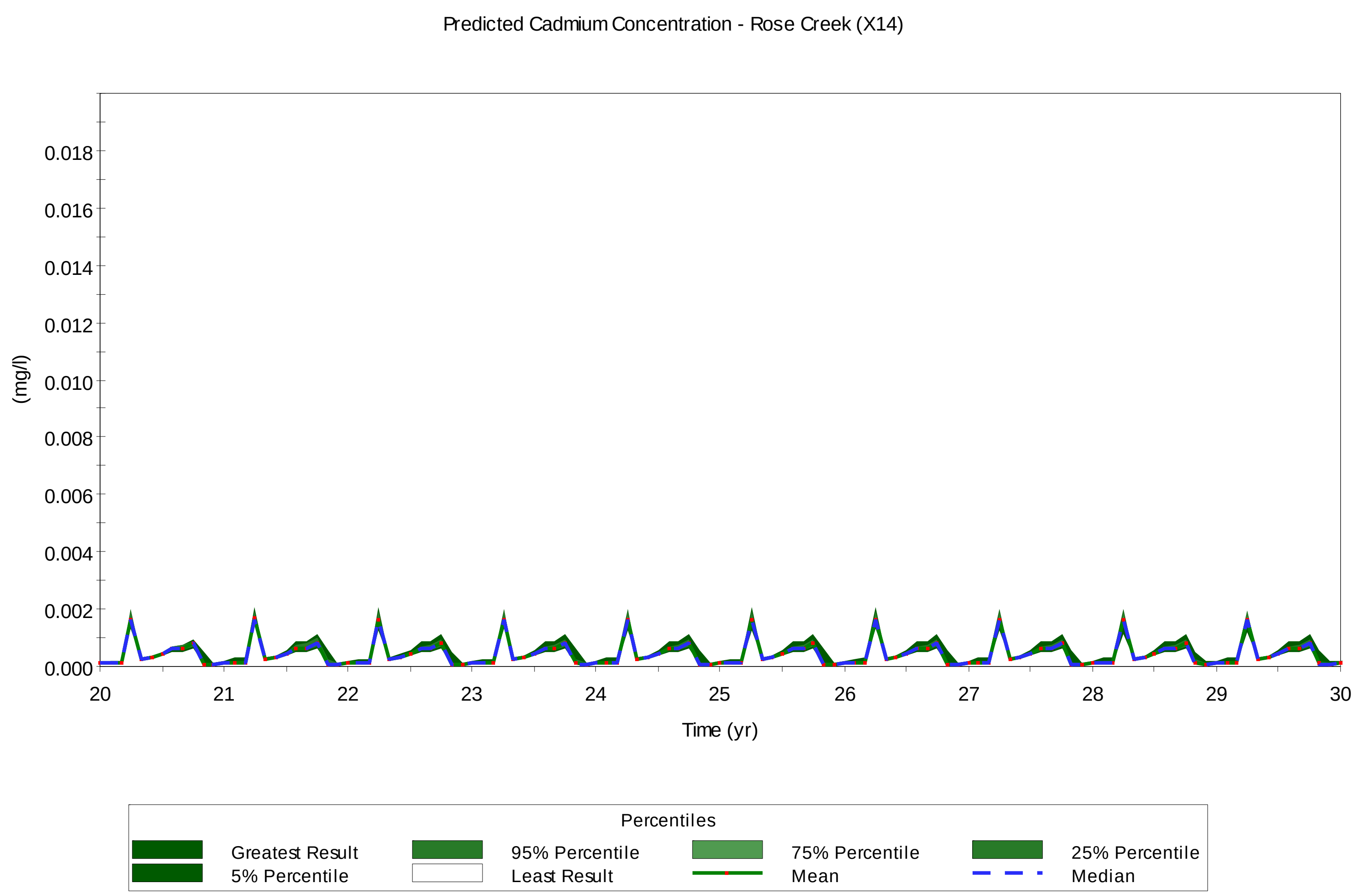


FIGURE B-5
Predicted Cadmium Concentration –
Rose Creek (X14) – Year 20 to 30 – Model V2
Faro Mine Remediation Project

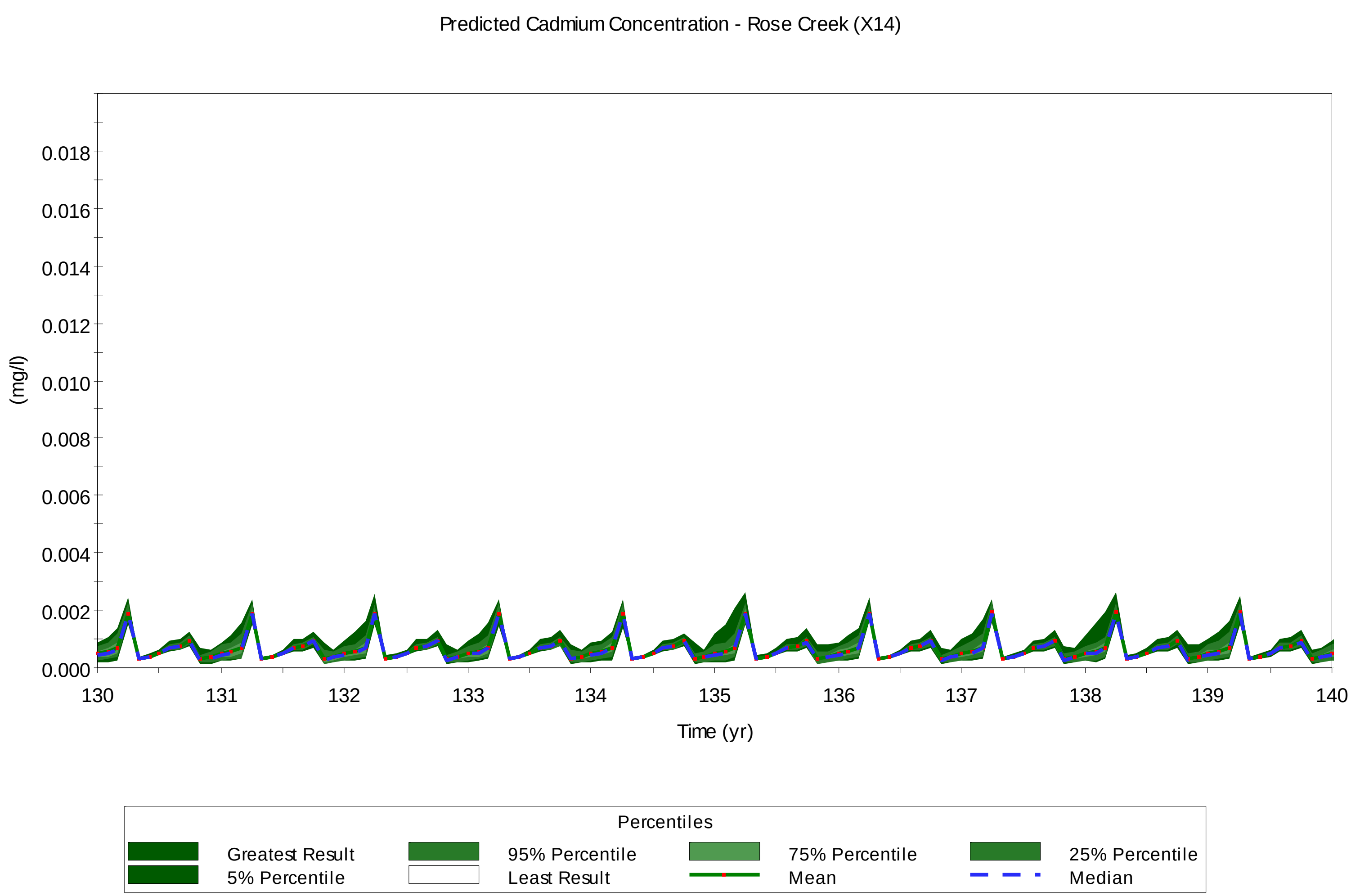


FIGURE B-6

Predicted Cadmium Concentration –
Rose Creek (X14) – Year 130 to 140 – Model V2

Faro Mine Remediation Project

CH2MHILL.

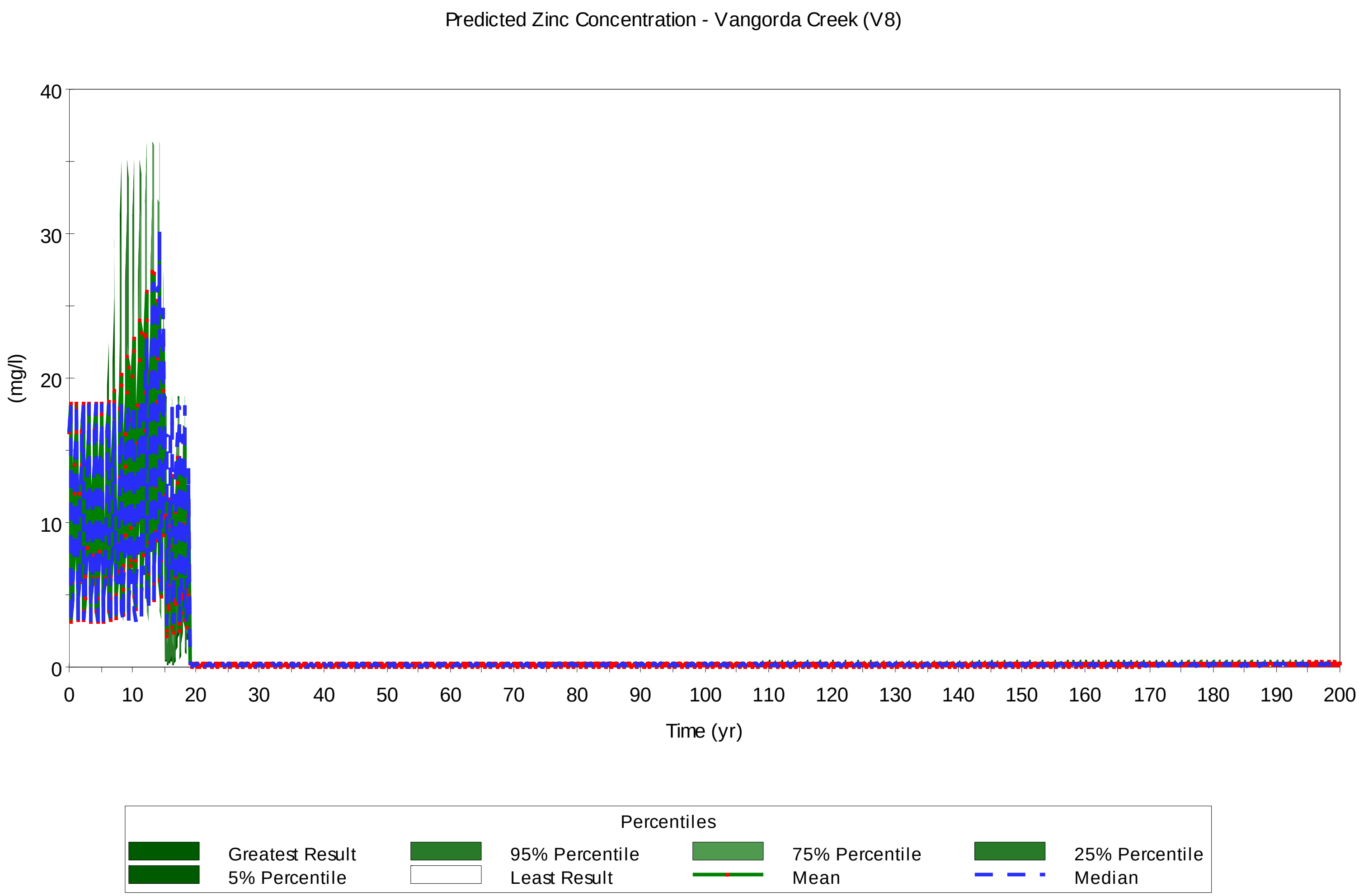


FIGURE B-7
Predicted Zinc Concentration – Vangorda Creek (V8) – Model V2
Faro Mine Remediation Project

CH2MHILL.

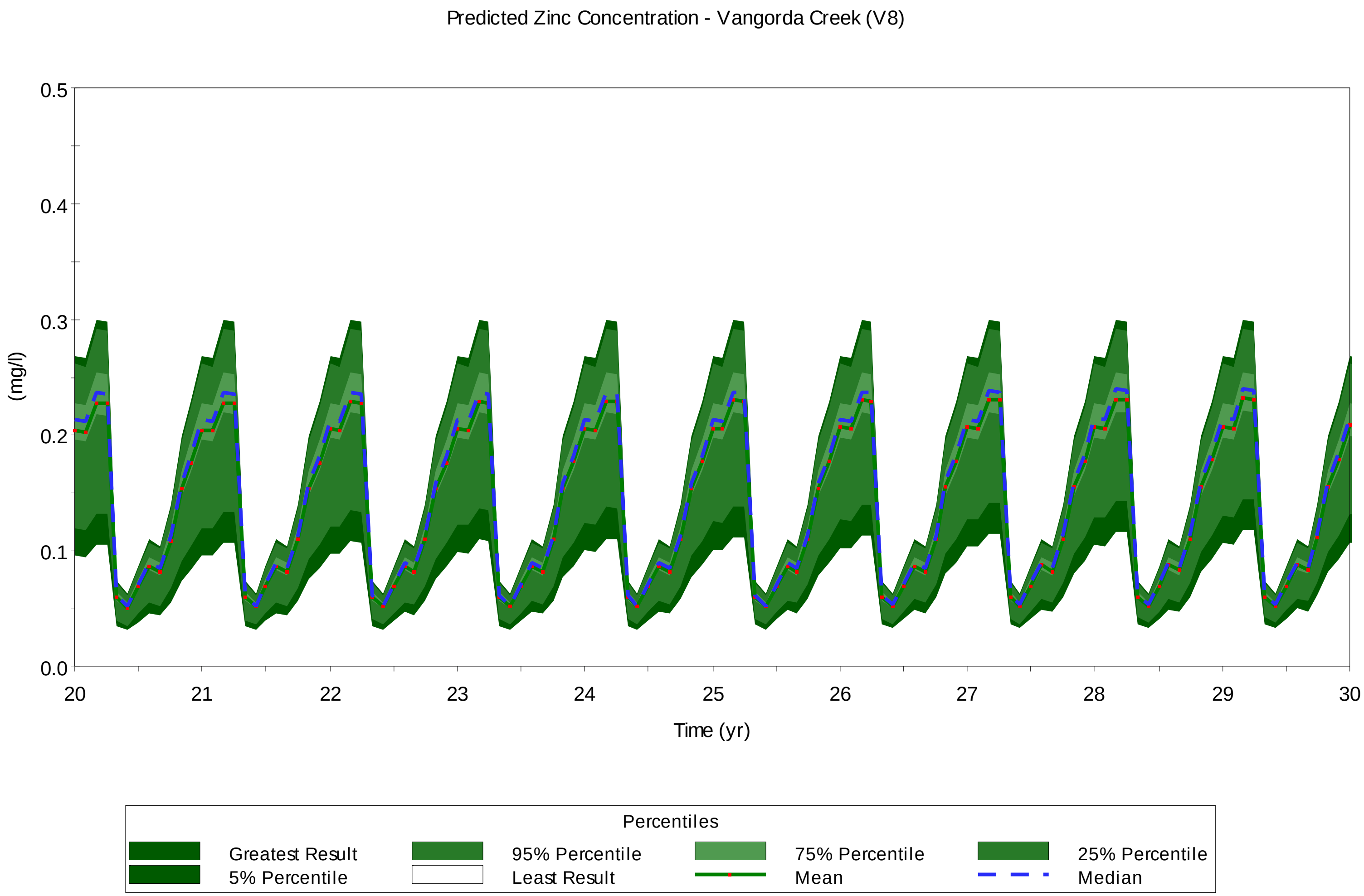


FIGURE B-8

Predicted Zinc Concentration –
Vangorda Creek (V8) – Year 20 to 30 – Model V2

Faro Mine Remediation Project

Predicted Zinc Concentration - Vangorda Creek (V8)

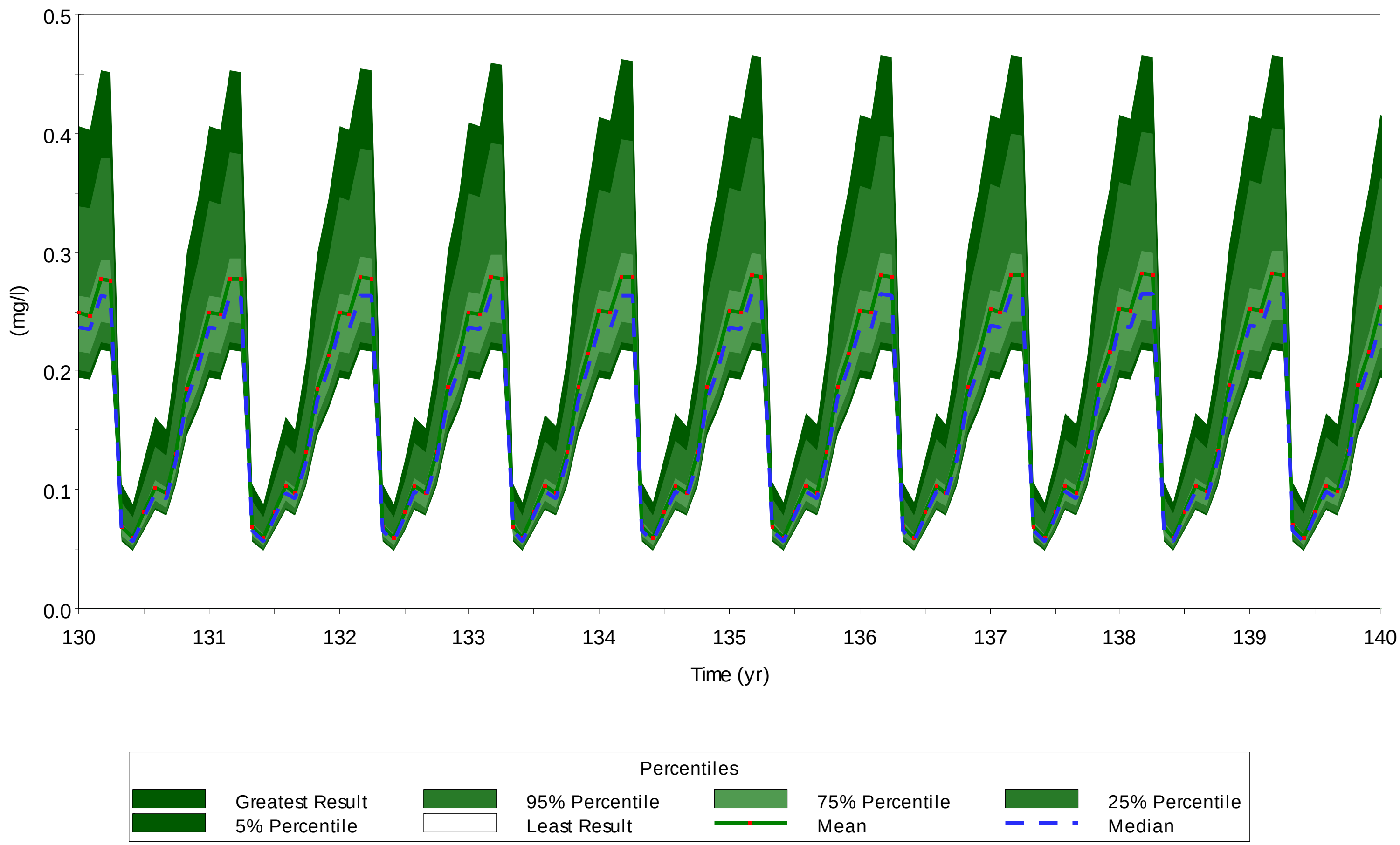


FIGURE B-9
Predicted Zinc Concentration –
Vangorda Creek (V8) – Year 130 to 140 – Model V2
Faro Mine Remediation Project

CH2MHILL.

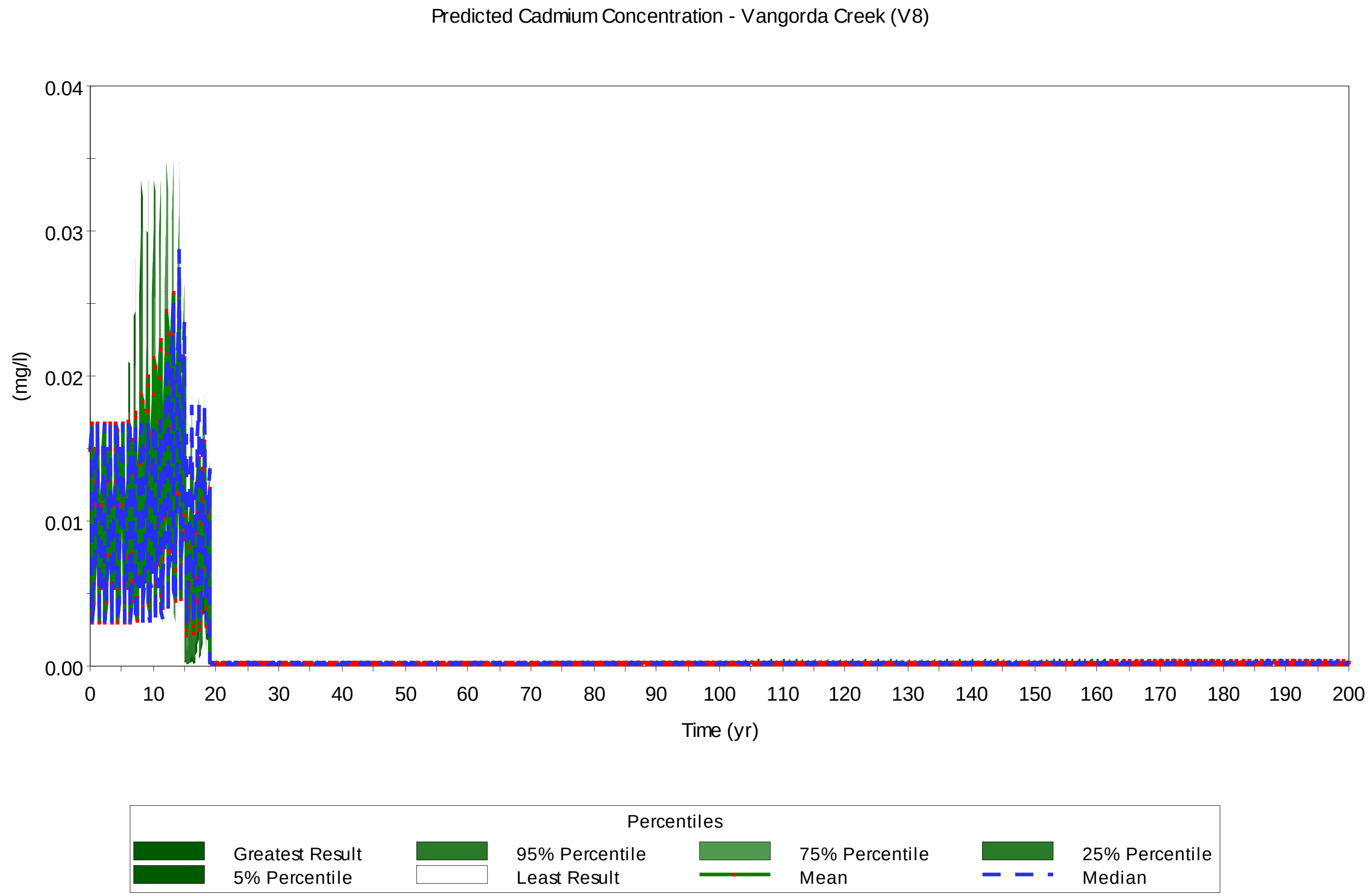


FIGURE B-10
Predicted Cadmium Concentration – Vangorda Creek (V8) – Model V2
Faro Mine Remediation Project

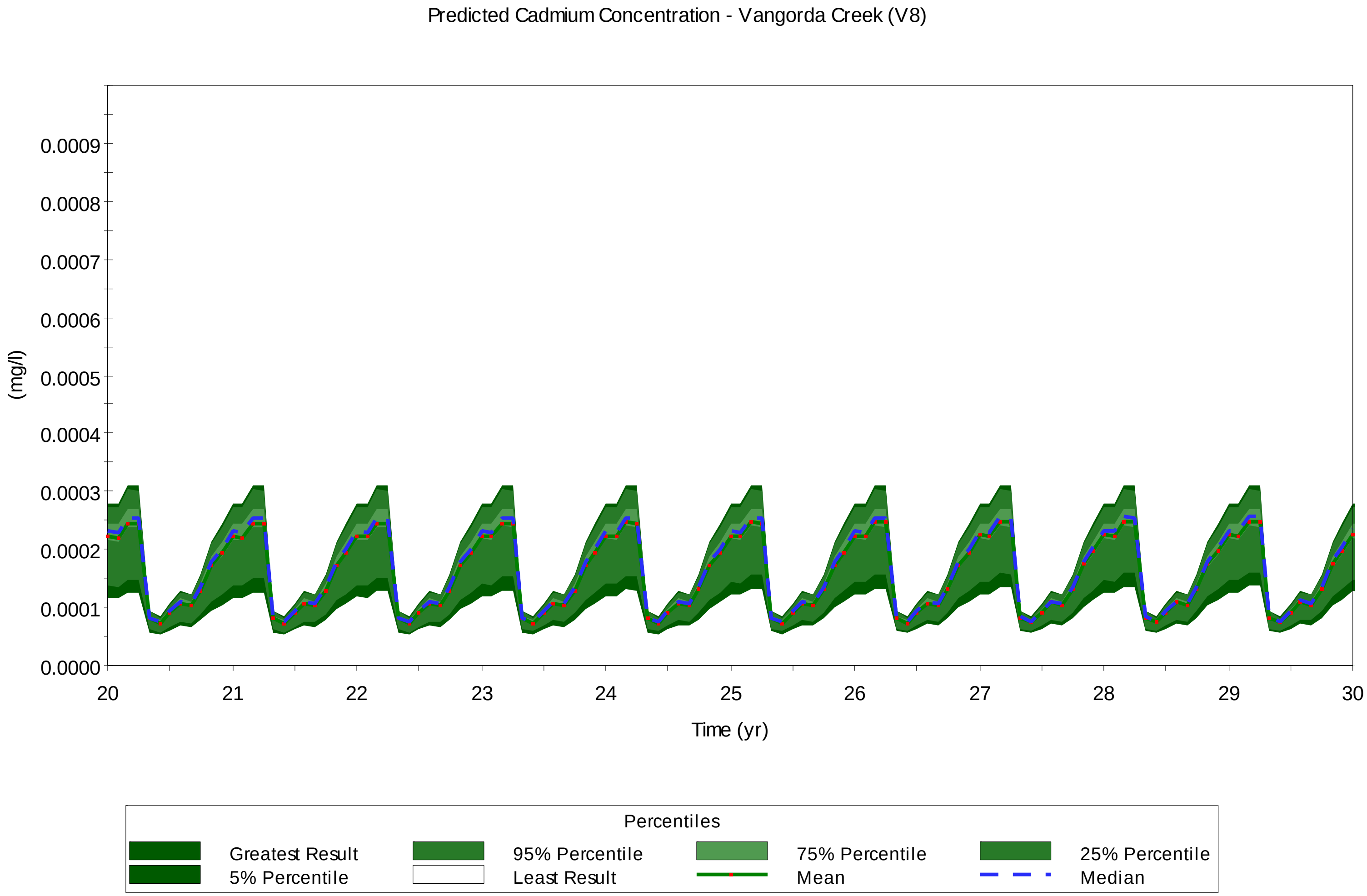


FIGURE B-11

Predicted Cadmium Concentration – Vangorda Creek (V8) - Year 20 to 30 – Model V2

Faro Mine Remediation Project

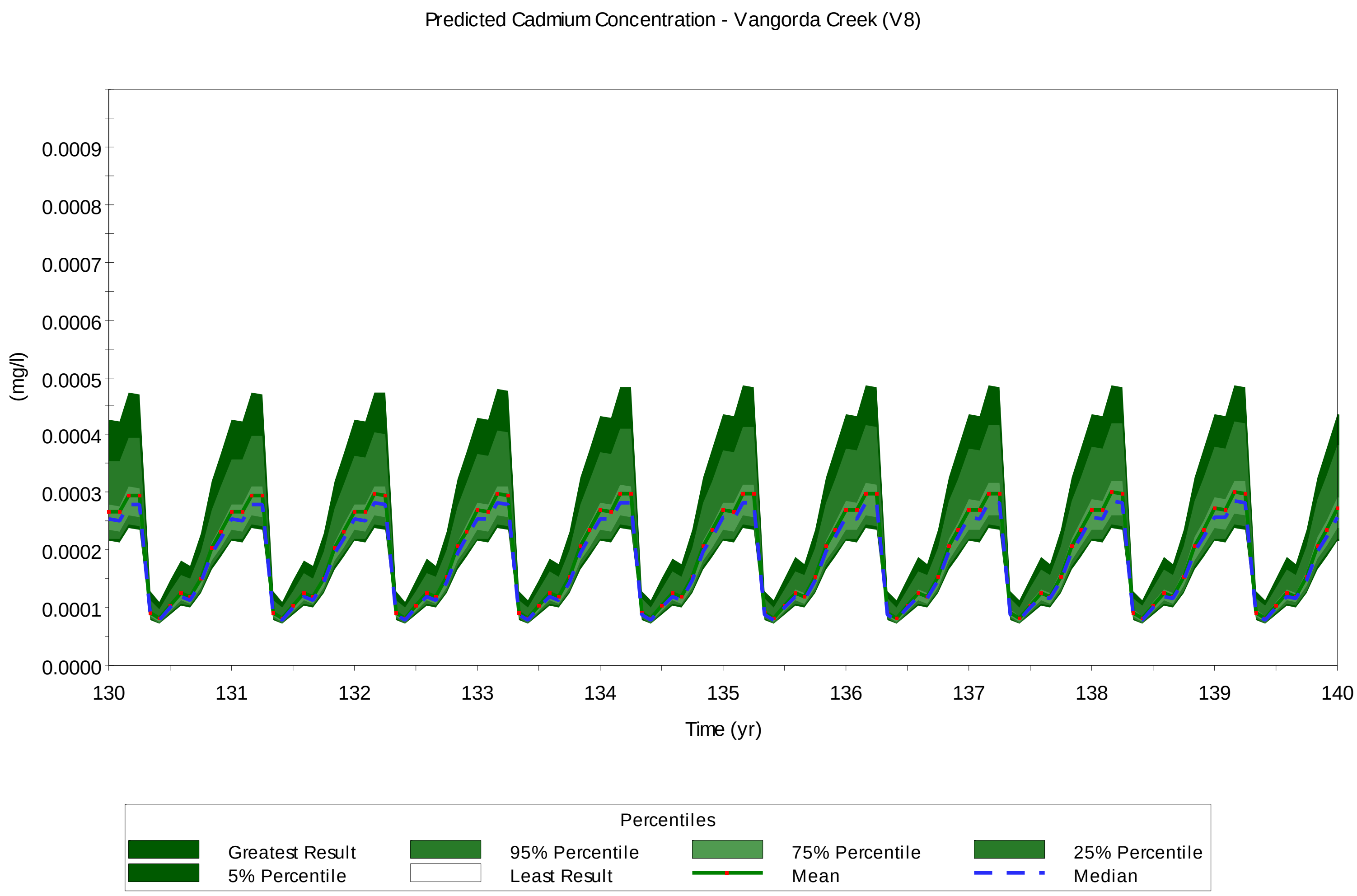


FIGURE B-12
Predicted Cadmium Concentration –
Vangorda Creek (V8) - Year 130 to 140 – Model V2
Faro Mine Remediation Project

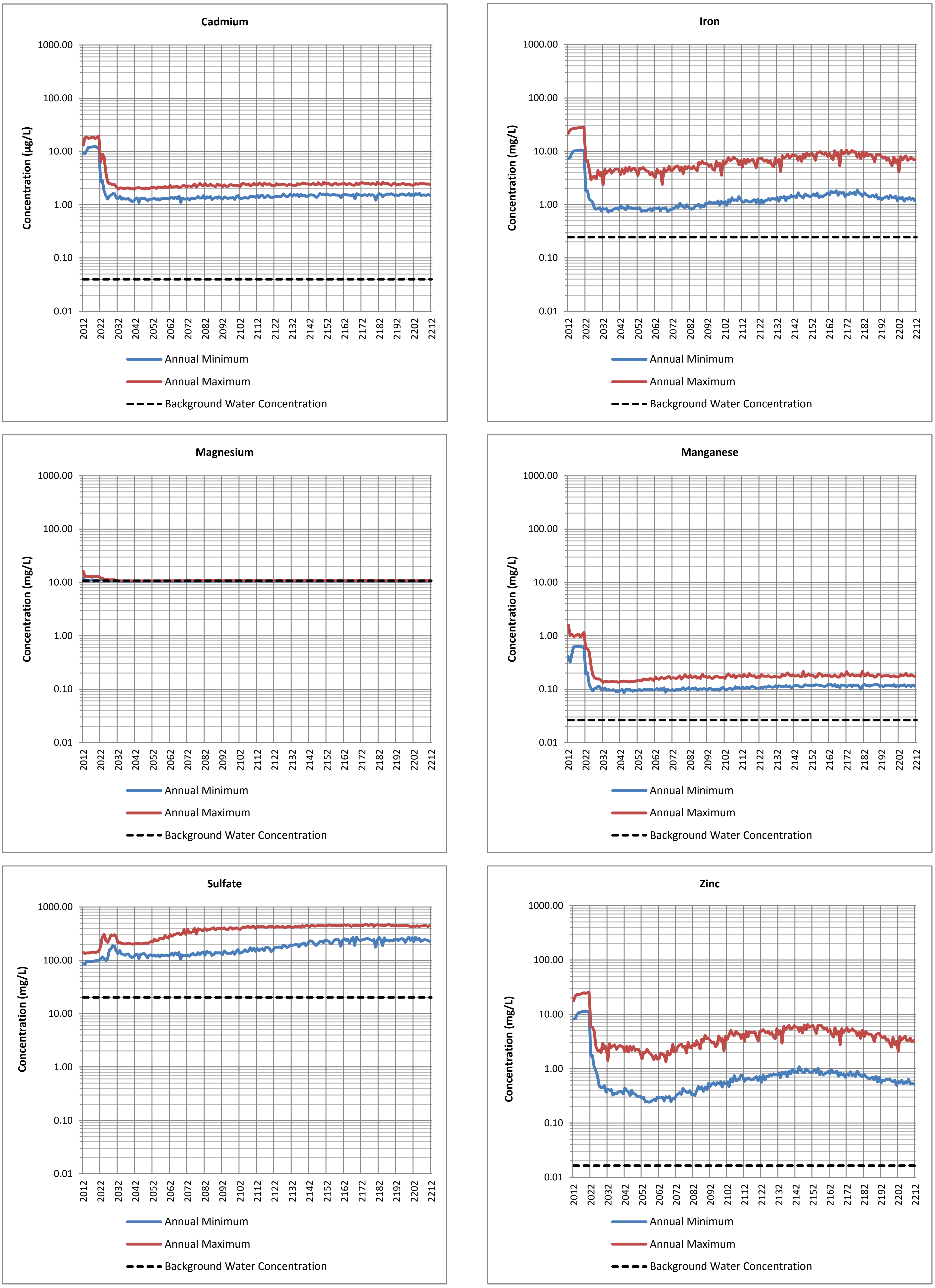
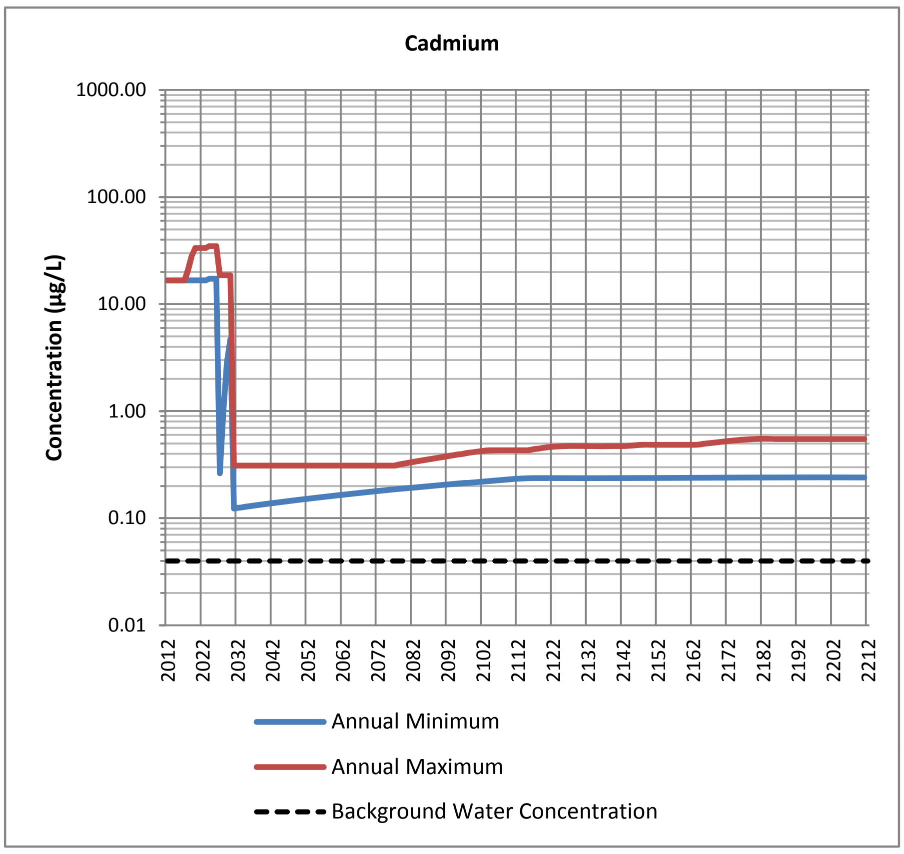
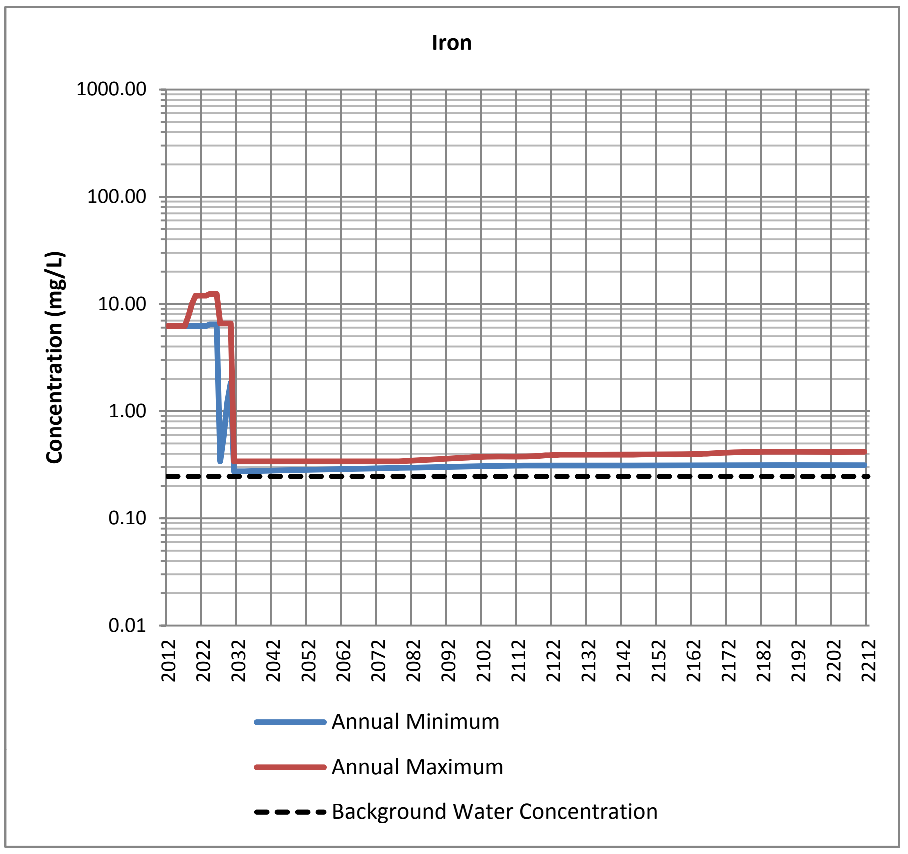
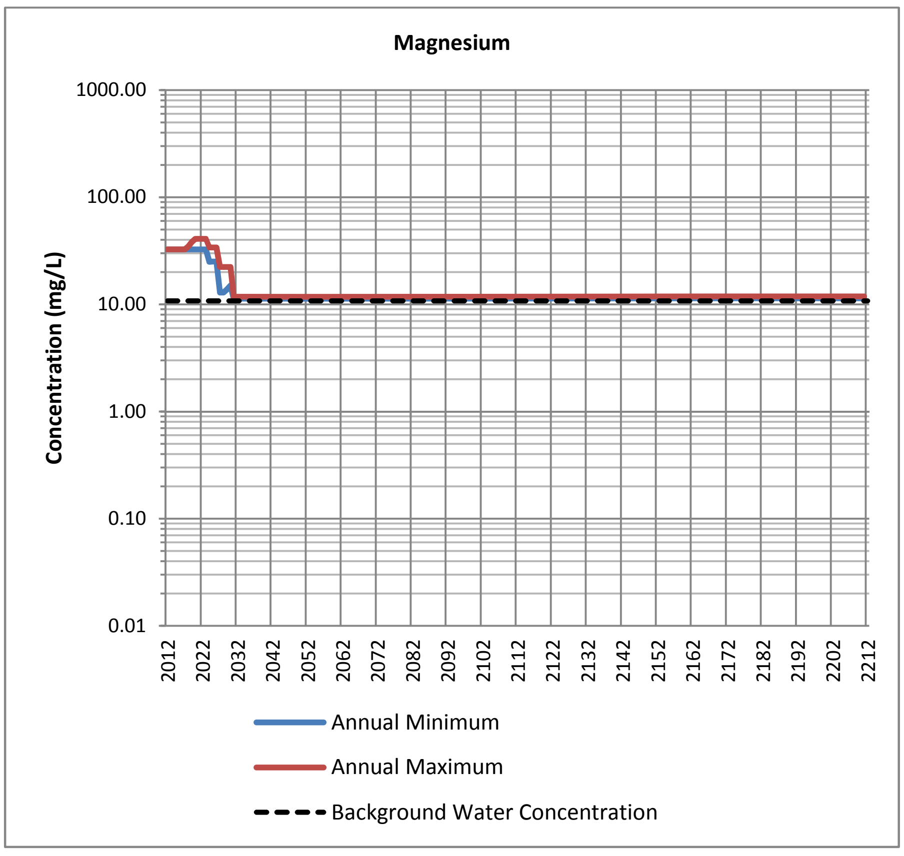


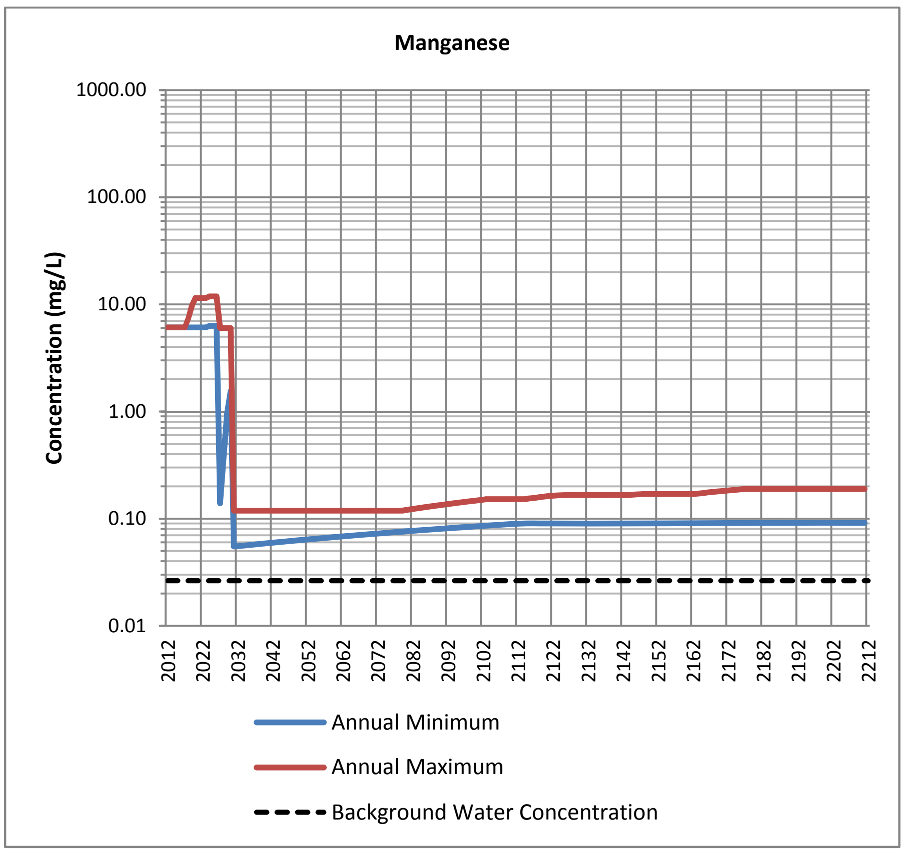
FIGURE B-13
Rose Creek (X14) Maximum and Minimum Annual Predicted Concentrations for Cadmium, Iron, Magnesium, Manganese, Sulfate, and Zinc
Faro Mine Remediation Project

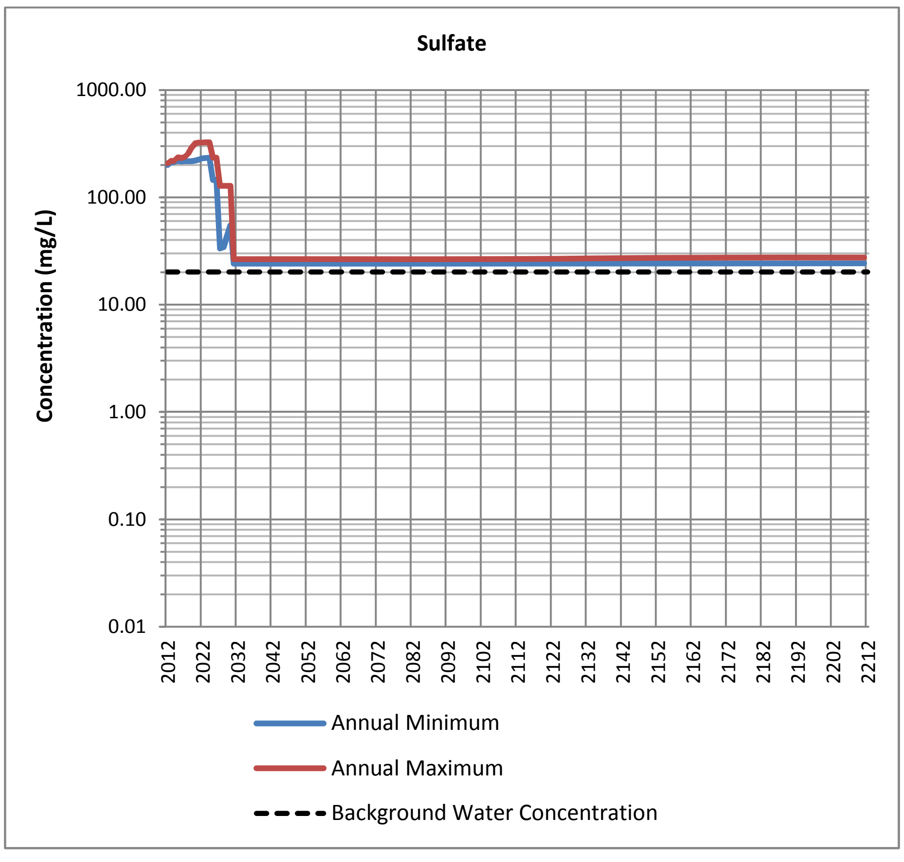
CH2MHILL.











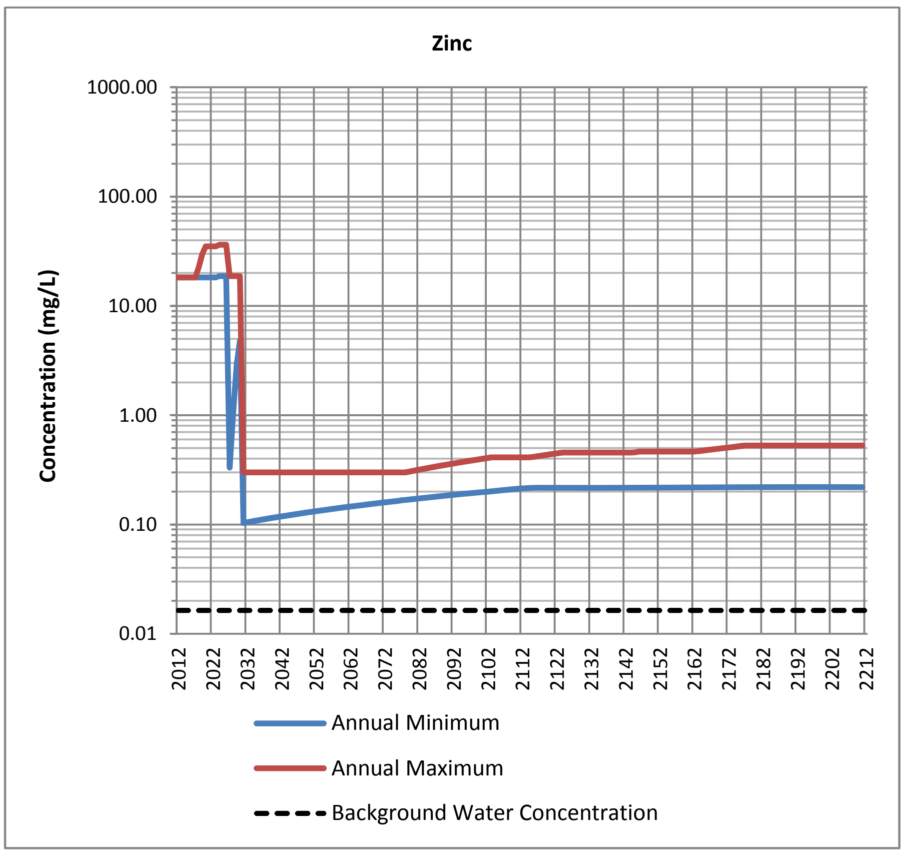


FIGURE B-14
Vangorda Creek (V8) Maximum and Minimum Annual Predicted Concentrations for Cadmium, Iron, Magnesium, Manganese, Sulfate, and Zinc
Faro Mine Remediation Project

Appendix C
Model Table of Inputs

TABLE C-1
Model Inputs
Faro Mine Remediation Project

Input Type	Input	Units	Dashboard	GS Element Controlling	Data Type	Description
C	AP depletion rate	1/yr	Exclude	AP_Dep_Slope	Deterministic value	Slope of AP depletion rate
C	Percent of NP Availability at transition to Acidic conditions	%	Exclude	Acid_Transition_Target	Deterministic value	% NP remaining for transition to acidic conditions
OP	Year CVD is breached	yr	Dashboard	CVDBreachyr	Deterministic value	Implements year that Cross Valley Dam is breached
OP	Link Grum Pit to VG/WTP	boolean	Dashboard	Grum_to_WTP	Deterministic value	Turns on the linkage between Grum Pit and a WTP (Vangorda or Faro depending on VGtoFaroWTP control setting)
OP	Grum Pit Pumping	yr	Dashboard	StartofGPPumping	Deterministic value	Time when Grum Pumping will start. Without this Grum_to_WTP can't function
OP	Capacity of Faro WTP	gpm	Dashboard	FaroWTPCapacityRamping	Deterministic, look-up table	Allows increase in capacity of Faro WTP based on input year. Currently 5000 gpm for any year selected
OP	Target Elevation-Faro Pit	m	Exclude	TGTElev_Faro	Deterministic value	Target Elevation at the end of treatment season for the Faro Pit Lake
OP	Target Elevation-ID Pond	m	Exclude	TGTElev_ID	Deterministic value	Target Elevation at the end of treatment season for the ID
OP	Target Elevation-CVD Pond	m	Exclude	TGTElev_CVD	Deterministic value	Target Elevation at the end of treatment season for the CVD
OP	Target Elevation-Vangorda Pit	m	Exclude	TGTElev_VG	Deterministic value	Target Elevation at the end of treatment season for the Vangorda Pit Lake
OP	Target Elevation-Grum Pit	m	Exclude	TGTElev_GR	Deterministic value	Target Elevation at the end of treatment season for the Grum Pit Lake
OP	VG pit to Faro WTP	boolean	Dashboard	VGtoFaroWTP	Deterministic value	Controls if flows from VG pit are to be sent to Faro WTP (default 0 = to Vangorda/Grum WTP)
OP	Intercept runoff to Grum Pit	yr	Dashboard	Grum_Intercept_Timing	Deterministic value	Controls switch to divert Grum Interceptor ditch to Grum Pit
OP	Lining of NFRC	yr	Dashboard	Lined_NFRC	Deterministic value	Timing for implementation for lining of NFRC
OP	Timing to Reslope NE Dump	yr	Dashboard	ReslopeNWDtiming	Deterministic value	Timing to reslope the toe of the NW Dump away from Upper Guardhouse Creek
OP	Start of WTP Operation Faro	month	Dashboard	OpenWaterStart_FR	Deterministic value	WTP is operational 5 months in a year: May (5), June, July, August, September (9).
OP	End WTP Operation Faro	month	Dashboard	OpenWaterEnd_FR	Deterministic value	WTP is operational 5 months in a year: May (5), June, July, August, September (9).
OP	Start of WTP Operation VG	month	Dashboard	OpenWaterStart_VG	Deterministic value	WTP is operational 5 months in a year: May (5), June, July, August, September (9).
OP	End of WTP Operation VG	month	Dashboard	OpenWaterEnd_VG	Deterministic value	WTP is operational 5 months in a year: May (5), June, July, August, September (9).
OP	Implementation of VG WTP	yr	Dashboard	VG_WTP	Deterministic value	Timing for implementation of Vangorda/Grum WTP
OP	Rule Curve CVD Pond	m	Dashboard	RuleCV_CVD	Deterministic, look-up table	Historical monthly average elevation of CVD pond
OP	Rule Curve ID Pond	m	Dashboard	RuleCV_IP	Deterministic, look-up table	Historical monthly average elevation of ID pond
OP	Rule Curve Faro Pit	m	Dashboard	RuleCV_FP	Deterministic, look-up table	Historical monthly average elevation of Faro Pit
HY	Start of the Simulation Year	year	Dashboard	StartSimYear	Deterministic value	The start of the simulation year sets the initial condition for flow and load at the pit lakes and sets the initial hydrology. It is possible to set between 2006 and 2012.
HY	Historical Monthly Precipitation	mm	Excel	MonthlyHistPrecip	Deterministic, look-up table	The Monthly precipitation is converted to Annual to adjust HEP values. The monthly precipitation data scales the initial fixed pattern when running the model with historical data.
HY	Historical and Predicted Annual Precipitation	mm	Excel	AnnualPrecipitation	Deterministic, look-up table	Annual precipitation from Faro Airport station between 1978 and 2011; annual precipitation between 2012 and 2045 repeats pattern between 1978 and 2011.
HY	Precipitation adjustment	-	Dashboard	PrecipCoefInput	Deterministic value	Coefficient to adjust Faro Airport precipitation (input) to FMC precipitation
HY	Faro Mean Annual Precipitation	mm	Dashboard	Faro_MAPinput	Deterministic value	Mean annual precipitation from Faro side of FMC
HY	Vangorda Average Annual Precipitation	mm	Dashboard	VG_MAPinput	Deterministic value	Mean annual precipitation from Vangorda side of FMC. Vangorda side precipitation is automatically adjusted based on the ratio between VG_MAPinput:Faro_MAPinput.
HY	Precipitation Ramping	%	Dashboard	PrecipRamp	Deterministic value	Ramps precipitation through time
SWM	WRD infiltration, no cover (minimum value)	%	Dashboard	No_Cover_Inf_min	Deterministic value	Minimum value for percent of MAP that infiltrates into WRD when no cover present
SWM	WRD infiltration, no cover (maximum value)	%	Dashboard	No_Cover_Inf_max	Deterministic value	Maximum value for percent of MAP that infiltrates into WRD when no cover present
SWM	WRD infiltration, rudimentary cover (minimum value)	%	Dashboard	Rud_Cover_Inf_min	Deterministic value	Minimum value for percent of MAP that infiltrates into WRD when rudimentary cover present
SWM	WRD infiltration, rudimentary cover (maximum value)	%	Dashboard	Rud_Cover_Inf_max	Deterministic value	Maximum value for percent of MAP that infiltrates into WRD when rudimentary cover present
SWM	WRD infiltration, low cover (minimum value)	%	Dashboard	Low_Cover_Inf_min	Deterministic value	Minimum value for percent of MAP that infiltrates into WRD when low cover present
SWM	WRD infiltration, low cover (maximum value)	%	Dashboard	Low_Cover_Inf_max	Deterministic value	Maximum value for percent of MAP that infiltrates into WRD when low cover present
SWM	WRD infiltration, very low cover (minimum value)	%	Dashboard	VLow_Cover_Inf_min	Deterministic value	Minimum value for percent of MAP that infiltrates into WRD when very low cover present
SWM	WRD infiltration, very low cover (maximum value)	%	Dashboard	VLow_Cover_Inf_max	Deterministic value	Maximum value for percent of MAP that infiltrates into WRD when very low cover present
SWM	Year that Faro Creek Diversion leakage stops	yr	Dashboard	FCLeakageStopYr	Deterministic value	Year that is assumed that the Faro Creek Diversion leakage will stop
SWM	Faro Creek Leakage	%	Dashboard	FCLeakage	Deterministic value	Faro Creek Diversion leakage as a percentage of Faro Creek Diversion flow
SWM	Rose Creek Diversion Leakage	%	Dashboard	RCDCLeakage	Deterministic value	Controls the amount of leakage from Rose Creek Diversion as a percentage of flows upstream tailings area
WQ	Water Quality Scenario	boolean	Dashboard	SeepageWQStats	Deterministic value	Switch to select Average or Maximum Seepage water quality to be applied to WRD concentrations.
WQ	Minimum Neutralization Potential available	%	Dashboard	MinNP	Deterministic value	Minimum total NP available
WQ	Maximum Neutralization Potential available	%	Dashboard	MaxNP	Deterministic value	Maximum total NP available
WQ	Background Water Quality	mg/L	Excel	Background_WQ	Deterministic, values table	Background water quality as defined by Minnow

TABLE C-1

Model Inputs

Faro Mine Remediation Project

Input Type	Input	Units	Dashboard	GS Element Controlling	Data Type	Description
WQ	Neutralization Potential Rate for different Cover Types	%	Excel	NP_Rate	Deterministic, look-up table	NP depletion rate modifier - rate of oxidation is a function of the cover type through reduced oxygen transfer and reduced infiltration, this input sets the NP (%) for each cover Type
WQ	Runoff Water Quality	%	Dashboard	SurfaceWQcoef	Deterministic value	Percentage of the seepage water chemistry to represent the surface water runoff chemistry prior to covers being placed
WQ	Faro Neutralization Potential	kg/tonne	Excel	\FaroWQModel\Faro\Faro_Input_WQ\NP_Depletion_Calcs\Faro_NP	Deterministic value	Initial condition for neutralization potential for each WRD at the Faro site
WQ	Faro Acid Potential	kg/tonne	Excel	\FaroWQModel\Faro\Faro_Input_WQ\NP_Depletion_Calcs\Faro_AP	Deterministic value	Initial condition for acid potential for each WRD at the Faro site
SIS	WRD drainage split percentages	%	Excel	Faro_Drainage_spilt	Deterministic, look-up table	Defines proportion of water flows from each Faro WRD into the 8 catchments(X23, MP, X2, RCV, GHU, Z2, NFRC, GHL)
SIS	Vangorda/Grum WRD drainage split percentages	%	Excel	VG_Drainage_spilt	Deterministic, look-up table	Defines proportion of water flows from each Vangorda/Grum WRD into the 3 catchments(V27, V8, Vpit)
SIS	Minimum efficiency of ETA SIS	%	Dashboard	ETA_GW_Efficiency_min	Deterministic value	Minimum value for efficiency of ETA groundwater collection system
SIS	Maximum efficiency of ETA SIS	%	Dashboard	ETA_GW_Efficiency_max	Deterministic value	Maximum value for efficiency of ETA groundwater collection system
SIS	Switch for ETA	boolean	Dashboard	ETA_Switch	Deterministic value	This switch turns the connection to Faro Pit ON and stops sending ETA to IP.
SIS	Initial Efficiency of ETA SIS	%	Dashboard	initETAEfficiency	Deterministic value	Initial efficiency of ETA SIS
SIS	ETA collection of F1 (RCV) drainage	yr	Dashboard	ETA_F1_GW_Timing	Deterministic value	Timing for implementation of drainage collection from F1 (RCV) at ETA
SIS	ETA collection of F2 (X23) drainage	yr	Dashboard	ETA_F2_GW_Timing	Deterministic value	Timing for implementation of drainage collection from F2 (X23) at ETA
SIS	ETA collection of F3 (GHL) drainage	yr	Dashboard	ETA_F3_GW_Timing	Deterministic value	Timing for implementation of drainage collection from F3 (GHL) at ETA
SIS	ETA collection of F4 (GHU) drainage	yr	Dashboard	ETA_F4_GW_Timing	Deterministic value	Timing for implementation of drainage collection from F4 (GHU) at ETA
SIS	Minimum efficiency of CVD SIS	%	Dashboard	DVT_GW_Efficiency_min	Deterministic value	Minimum value for efficiency of CVD groundwater collection system
SIS	Maximum efficiency of CVD SIS	%	Dashboard	DVT_GW_Efficiency_max	Deterministic value	Maximum value for efficiency of CVD groundwater collection system
SIS	CVD SIS switch	boolean	Dashboard	DVT_Switch	Deterministic value	This switch allows the CVD SIS to be turned on or off to assess remediation scenarios.
SIS		yr		DVT_GW_Timing_1	Deterministic value	
SIS	Implementation of CVD SIS	yr	Dashboard	DVT_GW_Timing	Deterministic value	Timing for implementation of groundwater collection at CVD SIS
SIS	Location of CVD SIS, downstream of CVD	boolean	Dashboard	SIS_2_switch	Deterministic value	Determines location of CVD SIS, locates CVD SIS downstream of CVD
SIS	Location of CVD SIS, downstream of ID	boolean	Dashboard	SIS_1_switch	Deterministic value	Determines location of CVD SIS, locates CVD SIS downstream of ID
SIS	Location of CVD SIS, upstream of ID	boolean	Dashboard	SIS_0_switch	Deterministic value	Determines location of CVD SIS, locates CVD SIS upstream of ID
SIS	Minimum efficiency of Swells SIS	%	Dashboard	Swells_GW_Efficiency_min	Deterministic value	Minimum value for efficiency of Swells groundwater collection system
SIS	Maximum efficiency of Swells SIS	%	Dashboard	Swells_GW_Efficiency_max	Deterministic value	Maximum value for efficiency of Swells groundwater collection system
SIS	Swells switch		Dashboard	Swells_Switch	Deterministic value	This switch allows the S-wells to be turned on or off to assess remediation scenarios.
SIS	Implementation of Swells SIS	yr	Dashboard	Swells_X2_GW_Timing	Deterministic value	Timing for implementation of groundwater collection at Swells SIS
SIS	Minimum efficiency of Z2 SIS	%	Dashboard	Z2_OW_GW_Efficiency_min	Deterministic value	Minimum value for efficiency of Z2 groundwater collection system (Z2 OW)
SIS	Maximum efficiency of Z2 SIS	%	Dashboard	Z2_OW_GW_Efficiency_max	Deterministic value	Maximum value for efficiency of Z2 groundwater collection system
SIS	Z2 OW switch	boolean	Dashboard	Z2_OW_Switch	Deterministic value	This switch allows the Z2 OW to be turned on or off to assess remediation scenarios
SIS	Implementation of Z2 SIS	yr	Dashboard	Z2Outwash_GW_Timing	Deterministic value	Timing for implementation of groundwater collection at Z2 SIS
SIS	Implementation of Z2 Pumping well	yr	Dashboard	Z2_Pump_GW_Timing	Deterministic value	Timing for implementation of groundwater collection from Z2 Pit
SIS	Minimum efficiency of SIS1	%	Dashboard	GRVG1_GW_Efficiency_min	Deterministic value	Minimum value for efficiency of SIS1 groundwater collection system (Vangorda WRD within V27)
SIS	Maximum efficiency of SIS1	%	Dashboard	GRVG1_GW_Efficiency_max	Deterministic value	Maximum value for efficiency of SIS1 groundwater collection system (Vangorda WRD within V27)
SIS	SIS1 switch	boolean	Dashboard	GRVG1_Switch	Deterministic value	This switch allows the SIS1 to be turned on or off to assess remediation scenarios
SIS	Implementation of SIS1	yr	Dashboard	SIS1_Timing	Deterministic value	Timing for implementation of groundwater collection at SIS1 (Vangorda WRD within V27)
SIS	Minimum efficiency of SIS2	%	Dashboard	GRVG2_GW_Efficiency_min	Deterministic value	Minimum value for efficiency of SIS2 groundwater collection system (Grum WRD within V27)
SIS	Maximum efficiency of SIS2	%	Dashboard	GRVG2_GW_Efficiency_max	Deterministic value	Maximum value for efficiency of SIS2 groundwater collection system (Grum WRD within V27)
SIS	SIS2 switch	boolean	Dashboard	GRVG2_Switch	Deterministic value	This switch allows the SIS2 to be turned on or off to assess remediation scenarios
SIS	Implementation of SIS2	yr	Dashboard	SIS2_Timing	Deterministic value	Timing for implementation of groundwater collection at SIS2 (Grum WRD within V27)
SIS	Minimum efficiency of SIS3	%	Dashboard	GRVG3_GW_Efficiency_min	Deterministic value	Minimum value for efficiency of SIS3 groundwater collection system (Vangorda WRD within V8)
SIS	Maximum efficiency of SIS3	%	Dashboard	GRVG3_GW_Efficiency_max	Deterministic value	Maximum value for efficiency of SIS3 groundwater collection system (Vangorda WRD within V8)
SIS	SIS3 switch	boolean	Dashboard	GRVG3_Switch	Deterministic value	This switch allows the SIS3 to be turned on or off to assess remediation scenarios
SIS	Implementation of SIS3	yr	Dashboard	SIS3_Timing	Deterministic value	Timing for implementation of groundwater collection at SIS3 (Vangorda WRD within V8)
SIS	Minimum efficiency of SIS4	%	Dashboard	GRVG4_GW_Efficiency_min	Deterministic value	Minimum value for efficiency of SIS4 groundwater collection system (Grum WRD within V8)
SIS	Maximum efficiency of SIS4	%	Dashboard	GRVG4_GW_Efficiency_max	Deterministic value	Maximum value for efficiency of SIS4 groundwater collection system (Grum WRD within V8)
SIS	SIS3 switch	boolean	Dashboard	GRVG4_Switch	Deterministic value	This switch allows the SIS4 to be turned on or off to assess remediation scenarios
SIS	Implementation of SIS4	yr	Dashboard	SIS4_Timing	Deterministic value	Timing for implementation of groundwater collection at SIS4 (Grum WRD within V8)

TABLE C-1

Model Inputs

Faro Mine Remediation Project

Input Type	Input	Units	Dashboard	GS Element Controlling	Data Type	Description
MP	Surface water monthly distribution for Faro	1/mon	Excel	Faro_Surface_Dist	Deterministic, look-up table	Monthly distribution applied to computed annual runoff from each boundary condition catchment and from each WRD for Faro area
MP	WRD seepage monthly distribution for Faro	1/mon	Excel	Faro_WR_Seep_dist	Deterministic, look-up table	Monthly distribution applied to computed annual seepage from each WRD for Faro area
MP	Tailings seepage monthly distribution	1/mon	Excel	Faro_DVT_Seep	Deterministic, look-up table	Monthly distribution applied to computed annual seepage from tailings
MP	Rose Creek monthly flow distribution	1/mon	Excel	Rose_Creek_Dist	Deterministic, look-up table	Monthly distribution applied to computed annual flows in North Fork Rose Creek
MP	Surface water monthly distribution for Vangorda/Grum	1/mon	Excel	VG_Surface_Dist	Deterministic, look-up table	Monthly distribution applied to computed annual runoff from each boundary condition catchment and from each WRD for Vangorda /Grum area
MP	WRD seepage monthly distribution for Vangorda/Grum	1/mon	Excel	VG_WR_Seep_dist	Deterministic, look-up table	Monthly distribution applied to computed annual seepage from each WRD for Vangorda/Grum area
MP	Vangorda Creek monthly flow distribution	1/mon	Excel	VG_Creek_Dist	Deterministic, look-up table	Monthly distribution applied to computed annual flows in Vangorda Creek
MP	Vangorda/Grum monthly precipitation distribution	1/mon	Excel	VG_Precip_Dist	Deterministic, look-up table	Not used
MP	Faro monthly precipitation distribution	1/mon	Excel	Faro_Precip_Dist	Deterministic, look-up table	For fixed precipitation scenario, applies monthly precipitation distribution
MP	Vangorda/Grum monthly evaporation distribution	1/mon	Excel	VG_MAE_Dist	Deterministic, look-up table	Monthly evaporation distribution for Vangorda/Grum area
MP	Faro monthly evaporation distribution	1/mon	Excel	Faro_MAE_Dist	Deterministic, look-up table	Monthly evaporation distribution for Faro area
VAR	WRD timing (Faro)	yr	Excel	InputVar/FaroWRDyr	External Excel	Controls the year when WRDs in the Faro area will be covered
VAR	WRD cover type (Faro)		Excel	InputVar/FaroWRDTypes	External Excel	Controls what type of cover will be assigned to each WRD in the Faro area
VAR	WRD timing (Vangorda)	yr	Excel	InputVar/VGWRDyr	External Excel	Controls the year when a WRD in the Vangorda area will be covered
VAR	WRD cover type (Vangorda)		Excel	InputVar/VGWRDTypes	External Excel	Controls what type of cover will be assigned to each WRD in the Vangorda area
VAR	Initial Volume for Faro Pit	m^3	Excel	Input_VAR/InitVolFaro	External Excel	Initial volumes in the pits and ponds are located in the input spreadsheet. User can set the initial Volume Condition for the 35 constituents for the 5 storages in the model, Faro Pit, Intermediate Pond, Cross Valley Pond, Vangorda Pit, and Grum Pit.
VAR	Initial Volume for Intermediate Pond	m^3	Excel	Input_VAR/InitVolIntDam	External Excel	
VAR	Initial Volume for CVD Pond	m^3	Excel	Input_VAR/InitVolCVD	External Excel	
VAR	Initial Volume for Vangorda Pit	m^3	Excel	Input_VAR/InitVolVang	External Excel	
VAR	Initial Volume for Grum Pit	m^3	Excel	Input_VAR/InitVolGrum	External Excel	
VAR	Initial Load for Faro Pit	kg	Excel	Input_Var/InitLoadFaro	External Excel	Initial loads in the pits and ponds located in the input spreadsheet. User can specify initial concentration and the load is estimated from the storage volume for the 35 constituents for the 5 storages in the model, Faro Pit, Intermediate Pond, Cross Valley Pond, Vangorda Pit, and Grum Pit.
VAR	Initial Load for ID Pond	kg	Excel	Input_Var/InitLoadIntDam	External Excel	
VAR	Initial Load for CVD Pond	kg	Excel	Input_Var/InitLoadCVD	External Excel	
VAR	Initial Load for Vangorda Pit	kg	Excel	Input_Var/InitLoadVang	External Excel	
VAR	Initial Load for Grum Pit	kg	Excel	Input_Var/InitLoadGrum	External Excel	

Notes:

% =	percent
AP =	acidic potential
CVD =	Cross Valley Dam
ETA =	Emergency Tailings Area
gpm =	gallons per minute
ID =	Intermediate Dam
kg =	kilogram
m =	metre(s)
m3 =	cubic metres
NFRC =	North Fork Rose Creek
NP =	neutralization potential
OW =	outwash
SIS =	Seepage Interception System
VG =	Vangorda
WRD =	waste rock dump
WTP =	Water Treatment Plan
yr =	year

C	Constants
OP	Operations
HY	Hydrology
SWM	Surface Water Management
WQ	Water Quality
SIS	Seepage Interception System
MP	Monthly Patterns
VAR	Input Variables

Dashboard

Dashboard - allow user control directly on dashboard

Excel - allow user control via adjusting inputs in excel table

Exclude - exclude access for user control for now

Appendix D
Faro Mine Complex Closure and Reclamation–Site Wide Water Quality Model (GEEC, 2010)

Faro Mine Complex
Closure and Reclamation

Site Wide Water Quality Model

Draft 1

Prepared for

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April 2010

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Disclaimer

This initial draft has not been reviewed in its entirety by the members of the Technical Advisory Team for consistency in technical content and is not intended for general circulation at this time.

1 Introduction

Water quality predictions have been prepared previous for the waste rock, tailings, pit lakes, and downstream receiving environments at the Faro Mine Complex. Previous work was carried out by SRK (2009b) to consolidate the earlier separate versions of the tailings and waste rock models into a single EXCEL model. In addition, as part of that project, the coding and overall presentation of the model was modified to allow for the calculation of loading and concentrations in the receiving environment at specific points in time, after implementation of the proposed closure plan,

Based on the consolidated EXCEL model, a site wide water quality and water balance model has been developed in Goldsim to provide estimates of future trends in contaminant concentrations in the receiving environment over time following implementation of the proposed closure plan. As part of this conversion, several components of the model were updated to reflect more recent advancement in the closure plan for the site as well as updates to various components of the model. The overall objective of the model is for use as a tool to predict water quality in the receiving environment for use in the environmental assessment and Human Health and Ecological Assessment (HHERA) of the proposed closure and reclamation plan.

One of the benefits of using the Goldsim platform is that the model can be run with a range of inputs selected to represent the uncertainties associated with specific components of the project: stochastically. Specific input parameters that are being modeled stochastically include cover infiltration for rudimentary and low infiltration covers, NP availability and groundwater collection efficiency. The results from the Goldsim model are time-base predictions of a range of contaminant concentrations with "error bars" denoting the uncertainty.

1.1 Approach to Model

The three main contributors of contaminant load to the receiving environment are the waste rock dumps, the tailings impoundment and discharge of compliant water from the water treatment facilities.

The approach taken for the development of time based estimates for loadings from the waste rock dumps was to develop a stochastic model that would attempt to predict the possible range of concentrations at any one time based on the known properties and conditions within the waste rock dumps, including the potential effects of the closure measures including changes in infiltration due to cover placement. Consideration was given to the rate of neutralization potential (NP) and acid potential (AP) depletion based on current measures of oxidation rate in the dumps. Then, assuming covers are placed, the oxidation rates were adjusted to reflect the changed conditions. The existing seep water quality data set (average (best estimate) and maximum (upper bound) concentrations) was used as a measure of potential water quality conditions that may develop within each of the dumps over time.

For the Faro tailings, estimates of porewater displacement have been combined with porewater quality estimates to provide time-based estimates of contaminant loadings from the base of the tailings deposit. Attenuation below the tailings and within the aquifer has recently been demonstrated to be important in limiting the ultimate release of these contaminants. Attenuation has not been accounted for in the predictions presented to date.

The model assumes that all groundwater seepage, from either the tailings area or the waste rock dumps, that is collected is then routed to Faro Pit on the Faro side and Vangorda Pit on the Vangorda Plateau side. The model also assumes that the pit water is treated using a high density sludge treatment system and discharged seasonally (May to September) to the receiving environment. The discharge location on the Faro side is assumed to be immediately downstream of the confluence of the North and South Forks of Rose Creek. On the Vangorda side the discharge locations is assumed to be in the area where Vangorda Creek crosses the site access road, below the existing drop structure. In addition the model assumes that the water in Grum Pit will continue to be treated biologically. During the open water season treated surface water in Grum Pit will be discharged to Vangorda Creek.

Conceptual schematics of the Faro Water Quality and Water Balance Model are presented in Figures 1.1 and 1.2. Receiving environment water quality model points are presented in Figure 1.3. In the Rose Creek/Anvil Creek drainage the model points include:

- X2 – North Fork of Rose Creek;
- Confluence of the North and South Forks of Rose Creek;
- X14 – Rose Creek downstream of the water treatment plant discharge;
- Mouth of Rose Creek;
- Anvil Creek, downstream of confluence with Rose Creek; and
- Mouth of Anvil Creek.

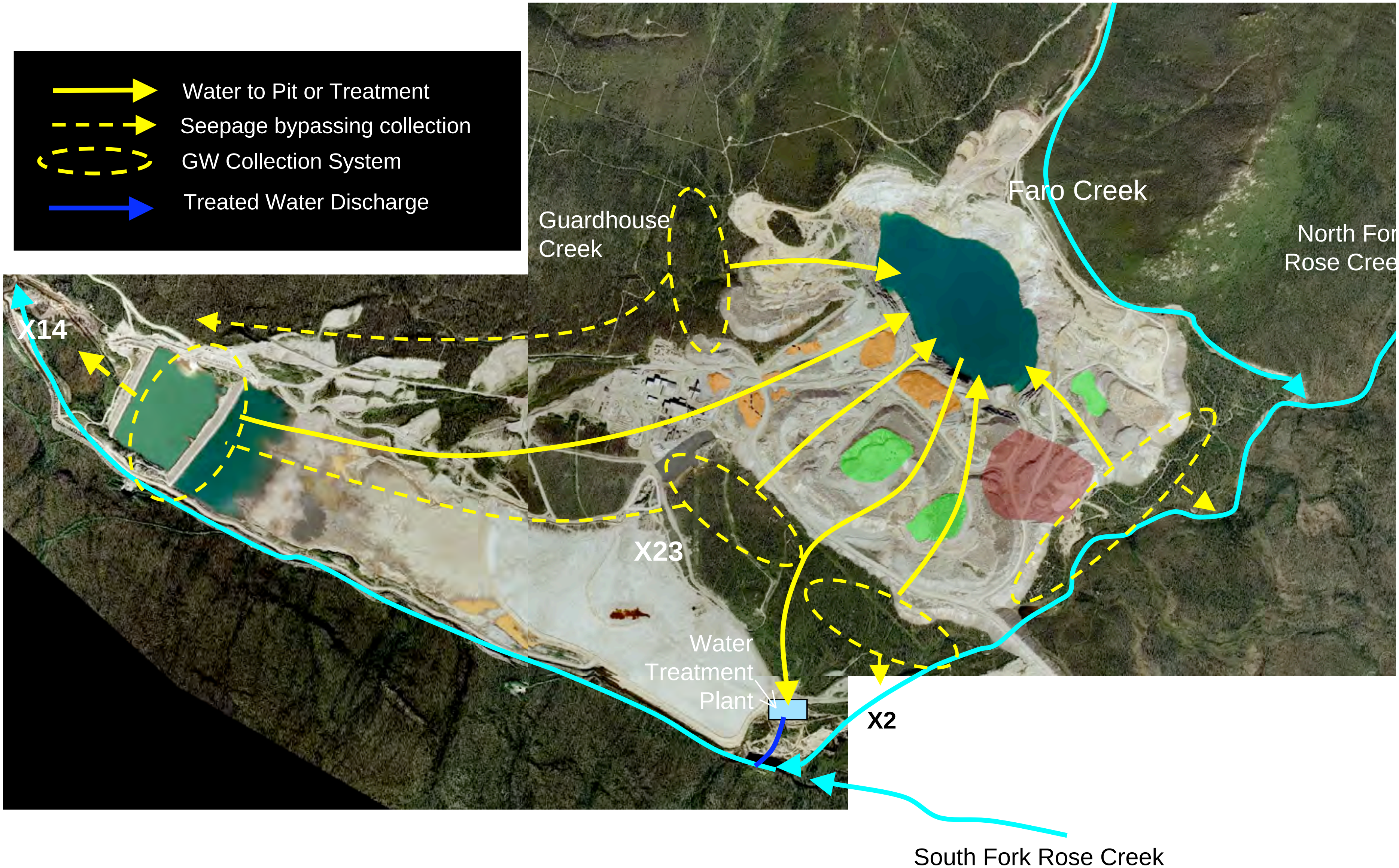
In the Vangorda Creek drainage, the model points include the main stem of Vangorda Creek at V27, downstream of the discharge location, and in Vangorda Creek at V8 near the Town of Faro at location V8.

In the Pelly River drainage, water quality model points include:

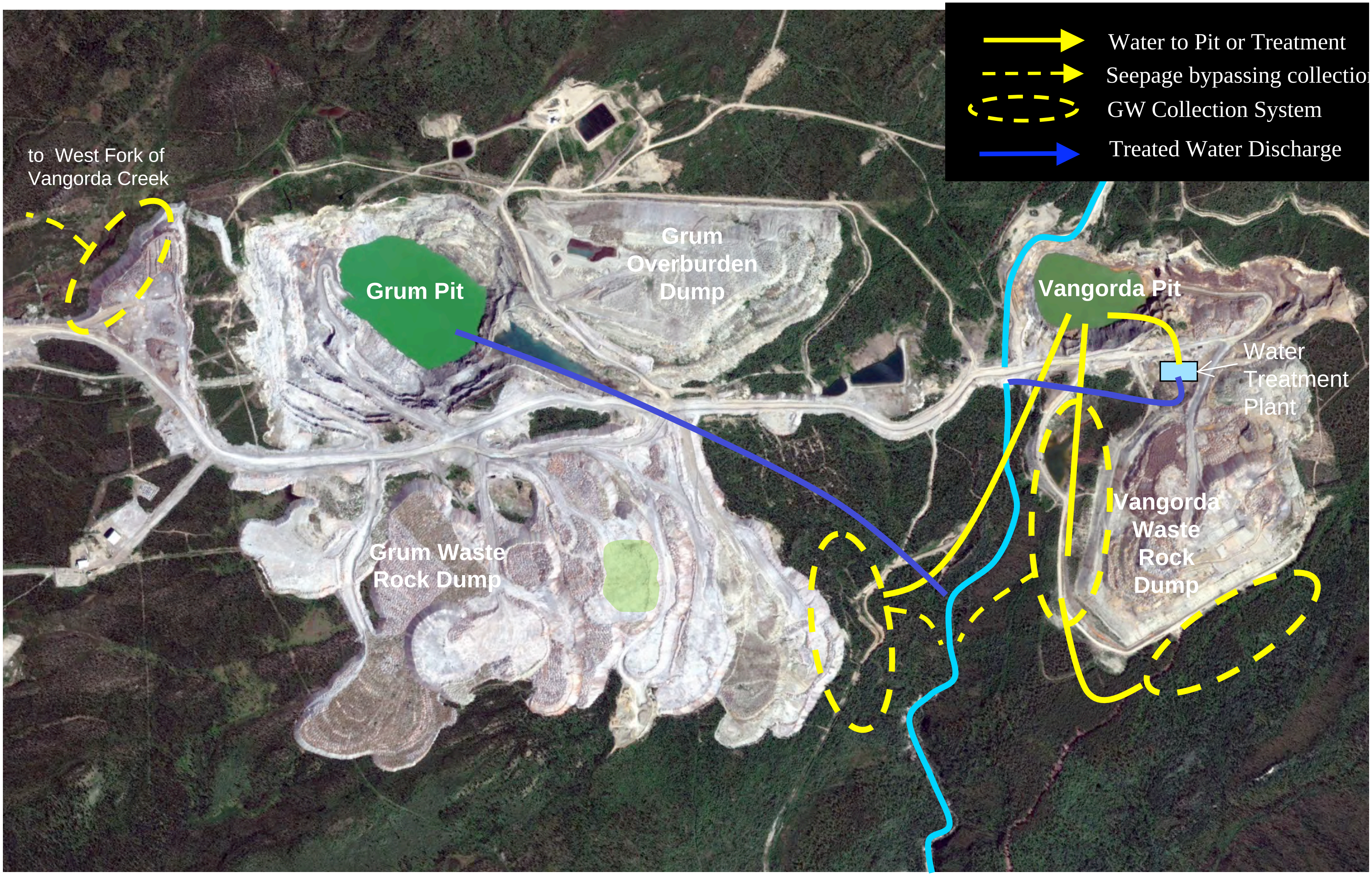
- Pelly River downstream of the inflow of Vangorda Creek;
- Pelly River upstream of the inflow of Anvil Creek; and
- Pelly River downstream of the inflow of Anvil Creek.

Two scenarios have been run using the model: Best Estimate and Upper Bound and Year-round treatment. The Best Estimate scenario assumes the average statistic of the compiled seepage data for both current (neutral) and future (acidic) conditions. The Upper Bound Scenario assumes the maximum statistic of the seepage data set for both current and future conditions. For both scenarios it is assumed that current chemistry applies until 70% of the available NP has been depleted. Then there is a linear increase in chemistry from current to future chemistry between 70% and 100 % NP depletion.

The model is run on monthly time steps for 200 years from the start of closure implementation (2211) for 25 realizations. Results of the predicted water quality at the various model points in the receiving environment post-closure implementation (2026 to 2211) were provided to AECOM, Minnow Environmental and SENES for incorporation into the environmental assessment and HHERA of the closure plan. This report provides details of the model framework, assumptions and inputs as well as a summary of the results from the various model runs. Detailed assessment of the results, particularly in relation to potential aquatic effects, is being carried out as part of the environmental assessment (Minnow and AECOM) and HHERA (SENES) and is not provided as part of this report.



Faro Mine Closure Fermeture de la mine Faro	Faro Mine Complex Closure and Remediation	**Conceptual Schematic** **Water Balance Mode** **Faro - Tailings**
Job No:		



Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex
Closure and Remediation

Conceptual Schematic Water Balance Mode Vangorda

Job No

Faro Mine Closure Fermeture de la mine Faro	Faro Mine Complex Closure and Remediation	Project Proposal **Water Quality Model Poi** **Receiving Environmer**
Job No:		

2 Key Assumptions from the Project Description

The model has been developed based on the proposed Faro Mine Complex Final Closure and Remediation Plan as outlined in Project Description Draft 4A (SRK 2010). The following provides a summary of the key components of the Project Description that are incorporated into the Goldsim Model, including timing and implementation assumptions. Further details, specifically related to assumptions regarding waste rock cover, groundwater collection and water treatment are provided in Sections 5 and 6.

2.1 Implementation and Timing

The following has been assumed with respect to the implementation and timing of completion of key components of the proposed closure plan and is based on the information provided in Chapter 11, Project Execution Strategy, of the Project Description (SRK 2010).

Faro Mine Area

- S-Well Collection System – upgraded and in full operation prior to implementation of the closure plan (< year 1 or 2012).
- Zone II pumping system is upgraded to year-round operations prior to closure implementation.
- Implementation of HDS Treatment – Year 1.
- Consolidation and cover of oxide fines and low grade stock piles – Year 1 (2012).
- Cover of sulphide cells – Year 2.
- Cover of Mt. Mungly and South West Pit Wall Dumps – Year 3.
- Partial relocation of North West Dumps – Year 3.
- Implementation of Lower Guardhouse Creek water management system – Year 3.
- Cover of remaining Faro Waste Rock Dumps Year 9.

- Upgrade of Faro Creek Diversion – Year 7. Prior to this the existing diversion is assumed to leak at a rate of 20%.

- Upgrade of ETA Collection System – Year 8. Prior to that the existing system is assumed to operate year-round at a collection efficiency of 70%.

- Cover of tailings – Year 6.

- Installation of other waste rock collection systems – Year 9. This includes collection from waste rock adjacent to the North Fork of Rose Creek above the Haul Road. It is assumed that there is no collection system installed adjacent to dumps draining to Upper Guardhouse Creek.

- Installation of tailings groundwater collection system – Year 13.

- Lining of the North Fork of Rose Creek – Year 13.

Vangorda/Grum Mine Area

- Grum Sulphide Cell cover in place prior to closure implementation (< Year 1).

- Vangorda Creek Diversion Upgrade in place prior to closure implementation (< Year 1).

- Cover of the Ore Transfer Pad – Year 2.

- Cover of the Vangorda Dumps and Vangorda In-Pit Dumps – Year 10.

- Cover of the remaining Grum Dumps – Year 12.

- Installation of groundwater collection systems for both Vangorda Dumps and the portion of Grum Dump draining to the Main Stem of Vangorda Creek – Year 12. It is assumed that there is no collection system installed adjacent to the Ore Transfer Pad or the portion of the Grump Dump that drains to the West Fork of Vangorda Creek.

In addition to the assumptions outlined throughout this document there are a number of assumptions inherent to the model:

- There are no groundwater losses from Faro, Grum or Vangorda Pits. However, the model assumes that there is groundwater seepage from the Zone II Pit to the North Fork of Rose Creek at a rate of 10%.

- All diversion ditches are assumed to be 100% efficient with the exception of the Faro Creek Diversion prior to upgrade which is assumed to leak at a rate of 20% into Faro Pit.

- Attenuation is not accounted for in the model for seepage from waste rock or tailings.

- The model is run for average flow and precipitation conditions only.

- Once discharge into the receiving environment, instantaneous mixing of all seepages and point source discharges is assumed.

- Water storage in the waste rock dumps is not considered. Any precipitation that falls on a dump in a given year will report as potential seepage that same year.

3 Mean Annual Precipitation and Mean Annual Runoff

A key driver in the model is Mean Annual Precipitation (MAP). MAP is used to determine the amount of water that infiltrates into the various waste rock dumps and any subsequent loading of contaminants from the waste rock dumps. MAP values used in model were taken from AECOM 2009 (Baseline Conditions) and are summarized in Table 3-1.

Table 3-1 Mean Annual Precipitation for the Faro Mine Complex

Area	Mean Annual Precipitation (mm)
Faro	357
Vangorda/Grum	369

Mean annual runoff (MAR) or mean annual yield is defined as the total amount of available water from specific catchment area that reports to a given location and includes both surface water and seepage components. For example the MAR at X2 in the North Fork of Rose Creek would be the total amount of water in mm that would report to X2 in a year and include both contributions from surface water and those from seepage and groundwater inflows to the North Fork of Rose Creek at that point. The difference between MAR and MAP would be losses of water due to processes such as evaporation and evapotranspiration. MAR values used in the model were taken from AECOM 2009 and are summarized in Table 3-2.

From a hydrology perspective, the model assumes the MAR values presented in Table 3.1.10 of the AECOM 2009 for each of the various catchment areas. Infiltration into the dumps is a function of MAP. The amount of infiltration is then subtracted from the MAR at each location to provide the amount of overland runoff.

Table 3-2 Mean Annual Runoff and Catchment Areas for the Faro Mine Complex

Area	Catchment Area (km^2)	Mean Annual Runoff (mm)
Anvil Creek Watershed		
Faro Creek	15.3	352
North Fork Rose Creek above X2 (excluding mine development area and Faro Creek drainage)	103.9	325
Incremental Catchment of Faro Pit	2.15	247
Footprint of waste rock dumps draining to North Fork above X2	1.18	202
Footprint of waste rock dumps draining to Rose Creek between X2 and X14	2.51	214
Rose Creek at X14 which includes South Fork Rose Creek and incremental area controlled by Rose Creek Diversion Channel and North Wall Interceptor Ditch	102.1	292
Rose Creek at confluence with North Fork Rose Creek including incremental drainage area between X2 and confluence	74.25	342
Incremental catchment controlled by tailings facility (excluding footprint of waste rock dumps)	4.1	161
Incremental catchment of Rose Creek between X14 and mouth	105	255
Anvil Creek Catchment excluding drainage area of Rose Creek	643	267
Vangorda Creek Watershed		
Drainage Controlled by Vangorda Creek Diversion	20.2	374
Incremental Catchment of Vangorda Pit	0.8	206
Catchment of Vangorda Dump including Little Creek Dam	0.72	193
Incremental catchment of Grum Pit	1	263
Drainage area controlled by Grum Interceptor Ditch including Grum Overburden Dump	3.2	263
Footprint of Grum Dump including contributing areas upstream of the dump	2.0	243
Incremental catchment of Vangorda Creek above V27 and below Vangorda Creek Diversion (excluding mine related areas and drainage area controlled by Grum Interceptor Ditch)	3.0	193
Incremental catchment of Vangorda Creek between V27 and V8 including Shrimp Creek and the West Fork	59.6	193

4 Modeled Parameters

The previous EXCEL version of the model predicted loadings, and subsequent concentrations, for the following parameters: sulphate, chloride, aluminum, arsenic, calcium, cadmium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, sodium and zinc. As part of a more detailed assessment of potential contaminants of concern that was carried out as part of the Human Health and Ecological Risk Assessment (SENES 2010), a broader suite of metals were identified. In the Goldsim version of the model, these additional potential contaminants of concern were added to the suite of parameters being modeled. In addition, due to potential concerns related to nutrients associated with in-situ biological treatment, ammonia, nitrate, nitrite and phosphorus were also added to the suite of modeled parameters. The full suite of parameters model is presented in Table 4.1. For modeling purposes, it is assumed that all constituents behave conservatively. In addition hardness is calculated based on modeled calcium and magnesium concentrations.

Table 4-1 Water Quality Modeled Parameters

Parameter	
Acidity	Manganese
Alkalinity	Molybdenum
Sulphate	Nickel
Chloride	Potassium
Aluminum	Selenium
Antimony	Silver
Arsenic	Sodium
Beryllium	Strontium
Boron	Thallium
Cadmium	Tin
Calcium	Uranium
Chromium	Vanadium
Cobalt	Zinc
Copper	Ammonia-N
Iron	Nitrate-N
Lead	Nitrite-N
Magnesium	Phosphorus

5 Source Loading Terms

The three main contributors of contaminant load to the receiving environment are the waste rock dumps, the tailings impoundment and discharge of compliant water from the water treatment facilities. The following sections describe the derivation of the source terms for contributions from both the waste rock and tailings. Section 6 outlines the assumptions related to water treatment and target effluent concentrations.

5.1 Waste Rock Seepage

The location of the waste rock dumps and low grade ore stockpiles is presented in Figure 5.1 for the Faro Mine Area and Figure 5.2 for the Vangorda/Grum Area. Estimates in the model of contaminant concentrations and loading in drainage from the waste rock and ore dumps at the Faro Mine Complex are based on previous work carried out by SRK in 2004 (SRK 2004 and SRK 2004b) and updated in 2006 (SRK 2006) and again in 2009. The prediction of contaminant loading from the waste rock dumps is based on an empirical model that uses actual seepage data from the site and estimates of infiltration rates for various cover types to calculate the potential loads from each dump. Generally, each rock dump is assigned two seepage chemistries: current and future. Current conditions assume neutral conditions, prior to any significant deterioration due to changes in pH. Future seepage chemistry reflects a more mature (lower pH) seepage chemistry. Rates of depletion of neutralization potential and acid potential are used to estimate the timing for the transition from current (neutral) to future (acidic) conditions.

Specific water quality types are assigned to each of the waste rock and low grade ore stockpiles. Contaminant concentrations for each of these water quality types are defined on the basis of results from seepage surveys, utilizing results from specific seepage locations that are considered representative of specific rock types. As a result, seepage predictions for specific stockpiles are not necessarily based on seepage monitoring results from that specific stockpile. The assignment of seepage chemistry is based on the estimated proportions of rock type in each dump and the static geochemical characteristics of each of the rock types. The rational for the initial grouping into the seeps into a limited number of representative types is outlined in Geochemical Studies of Waste Rock at the Anvil Range Complex (SRK 2004a).

As part of the 2009 update of seepage chemistry for each of the different water types used in the model the following updates were made to reflect the current seepage data and understanding of the site conditions:

- All of the data as of July 2009 were used in the statistical calculations.
- Ore and waste rock seeps were separated in the statistics.

- Seeps that reflect the influence of both ore and waste rock were assigned to a new category of mixed ore and waste.

- Seeps that are considered to be highly diluted by an upstream flow were removed from the statistics as they do not adequately reflect source concentrations.

- Seeps that are used to represent specific components of the site are also used to represent the general water type that they belong with.

- Three new water types were defined for seepage from the Grum Dump.

- Some seepage assignments for water types were updated on the basis of recent data and analysis.

- The assignments for the Vangorda and Grum dumps were revised.

- Grum Ore Transfer Pad, not modelled previously, has been added to the model and assumed to have the same properties at the Grum Sulphide Cell.

- In-pit dumps at Vangorda have been added to the model. These were previously in the pit lake model. Updated seepage terms and assignments were developed based on recent field investigations and delineation of dump areas.

The updated statistics for each of the water types and specific seeps use are provided in Table 5-1. Seepage assignments for the dumps are provided in Table 5-2 for current conditions (neutral) and in Table 5-3 for future conditions (acidic). These results form the basis for the inputs into the model.

As outlined in detail in Water Quality Estimates for Anvil Range Rock (SRK 2004b), the following steps were taken to estimate the water quality associated with water draining from each waste rock or ore dump.

- Water quality is defined for each of the seepage types based on site seepage survey water quality data (Table 5-1).

- Seepage types are assigned to each source area using the methods outlined in SRK 2004a and updated as outlined above in 2009. Table 5-2 shows the proportion of each dump that is assumed to produce each water type for current (neutral) conditions. Table 5-3 shows the proportion for future (acidic) conditions when the dumps have depleted all available neutralizing potential.

Table 5-1 Updated Seepage Survey Statistics

Area	Type	Statistic	Acidity (to pH 8.3) CaCO3 mg/L	Alkalinity - Total CaCO3 mg/L	Chloride Cl mg/L	Sulphate SO4 mg/L	Al mg/L	Sb mg/L	As mg/L	Be mg/L	B mg/L	Cd mg/L	Ca mg/L	Cr mg/L	Co mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Mg mg/L	Mn mg/L	Mo mg/L	Ni mg/L	K mg/L	Se mg/L	Ag mg/L	Na mg/L	Sr mg/L	Tl mg/L	Sn mg/L	U	V mg/L	Zn mg/L
Faro	1	Average	12	180	1.4	730	0.041	0.00025	0.00032	0.000077	0.033	0.0052	140	0.00017	0.0068	0.0095	0.12	0.011	120	0.16	0.00055	0.054	6.4	0.0017	0.000013	26	0.97	0.00033	1.6E-05	0.031	0.0077	3
		Median	12	190	1.3	510	0.0036	0.0002	0.00026	0.00005	0.035	0.0035	130	0.0001	0.0028	0.0037	0.026	0.00029	97	0.081	0.00013	0.055	4.4	0.0017	0.000009	8	0.66	0.0002	0.00001	0.011	0.0002	2.3
		Min	3	40	0.5	210	0.0016	0.00005	0.00014	0.00001	0.01	0.00046	54	0.0001	0.000056	0.0011	0.002	0.000061	27	0.00015	0.00005	0.014	2.2	0.0005	0.000005	2.2	0.21	0.000079	0.00001	0.0056	0.0002	0.045
		Max	34	320	2.7	2700	0.35	0.0007	0.0007	0.00019	0.05	0.02	280	0.0005	0.029	0.06	0.89	0.15	400	0.69	0.0022	0.14	24	0.0043	0.00003	150	3.8	0.0013	0.00005	0.15	0.049	14
		N	49	49	46	49	13	13	13	7	12	15	49	9	17	16	11	14	49	49	13	25	49	10	11	49	49	13	7	7	11	49
Faro	2w	Average	72	130	1.4	2100	0.6	0.00024	0.0013	0.00034	0.017	0.041	280	0.00018	0.085	0.1	2.7	0.05	320	7.7	0.00064	0.26	7.5	1.8	0.00008	11	1.4	0.00037	0.00001	0.006	0.0095	38
		Median	62	57	1.3	1300	0.22	0.0002	0.0007	0.0003	0.01	0.035	220	0.0002	0.06	0.042	1.1	0.046	160	3.7	0.0004	0.18	7.6	0.004	0.0001	5.6	0.84	0.00029	0.00001	0.0015	0.0002	30
		Min	14	2	0.5	330	0.002	0.00006	0.00016	0.00009	0.01	0.0025	49	0.0001	0.01	0.0034	0.02	0.0013	35	0.037	0.00005	0.014	0.2	0.00034	0.00001	2	0.18	0.00009	0.00001	0.00018	0.0002	3.9
		Max	280	450	3.2	11000	3.6	0.0004	0.0059	0.0006	0.05	0.1	680	0.0002	0.56	0.7	20	0.16	2000	36	0.0021	1.8	25	9	0.00012	65	3.8	0.0012	0.00001	0.015	0.048	170
		N	57	57	47	57	19	10	11	5	6	45	57	6	53	42	39	21	57	57	6	56	53	15	5	57	57	10	1	5	9	57
Faro	2ow	Average	420	200	10.0	3700	0.19	0.00027	0.0013	0.0021	0.01	0.11	470	0.011	0.4	0.2	37	0.046	500	38	0.0044	0.57	12	0.0032	0.00031	43	2.9	0.029	0.14	0.0075	0.047	230
		Median	420	220	13.0	4200	0.24	0.00025	0.0014	0.00069	0.01	0.047	490	0.00035	0.44	0.038	23	0.014	630	49	0.0046	0.63	13	0.0039	0.0002	45	3.1	0.0015	0.03	0.0073	0.034	220
		Min	22	13	0.7	950	0.002	0.0002	0.0003	0.0002	0.01	0.01	220	0.0002	0.015	0.01	0.05	0.0002	38	0.84	0.0003	0.05	5.7	0.0006	0.00006	7	0.72	0.0005	0.00005	0.0045	0.0002	14
		Max	2200	370	25.0	6300	0.38	0.0004	0.0021	0.007	0.01	0.65	620	0.033	1.1	2.4	140	0.23	870	85	0.0083	1.4	29	0.0049	0.00063	79	4.4	0.2	0.31	0.011	0.12	660
		N	40	40	30	40	12	6	7	4	3	39	40	6	40	32	39	12	40	40	4	38	40	6	6	40	40	7	5	3	8	40
Faro	3w	Average	1300	10	3.3	2500	27	0.0013	0.32	0.022	0.037	1.4	170	0.082	0.56	3.4	220	0.43	250	21	0.0011	0.93	6.5	1.6	0.00066	8.9	0.62	0.038	0.00061	0.13	0.019	270
		Median	220	2	0.7	1300	9.2	0.0002	0.0014	0.0088	0.05	0.12	130	0.02	0.24	1	27	0.29	140	6.3	0.00035	0.31	5.9	0.006	0.00012	4	0.49	0.0011	0.0001	0.023	0.001	59
		Min	27	1	0.5	69	0.23	0.0001	0.00037	0.0019	0.01	0.018	6.5	0.0002	0.03	0.03	0.042	0.069	3.8	0.16	0.00013	0.05	0.01	0.0004	0.000028	1.6	0.044	0.00015	0.00001	0.0062	0.0002	2.2
		Max	20000	92	48.0	28000	410	0.009	3.5	0.21	0.05	47	470	0.52	6.3	61	4300	1.6	2100	320	0.003	12	20	9	0.0043	110	2.1	0.4	0.0025	0.59	0.081	4500
		N	49	49	40	49	46	8	13	23	3	47	49	19	48	49	48	36	49	49	6	48	38	15	9	49	49	11	5	8	7	49
Faro	3o	Average	17000	4.1	87	21000	220	0.48	85	0.018	0.5	12	320	0.5	5.7	150	2600	1.9	590	310	0.0092	5.1	5.2	0.24	0.028	37	0.72	0.16	0.0068	0.69	0.048	7300
		Median	8700	1.0	2.5	12000	94	0.41	29	0.0086	0.5	6.3	330	0.35	3.1	8.3	1200	1.7	380	150	0.0092	3.2	4	0.014	0.0058	17	0.49	0.0097	0.0068	0.55	0.048	5500
		Min	210	0.50	0.5	700	2.4	0.003	0.04	0.001	0.5	0.082	80	0.012	0.08	0.12	1.3	0.36	39	5.7	0.0003	0.08	0.94	0.001	0.0007	2	0.22	0.0029	0.0001	0.0036	0.006	99
		Max	53000	31	1100	67000	990	1.5	450	0.05	0.5	57	510	1.2	20	560	15000	4.9	3200	2400	0.018	16	11	0.7	0.1	220	2.4	0.6	0.013	1.7	0.09	35000
		N	24	24	16	24	22	6	14	6	1	24	24	10	24	23	24	16	24	24	2	23	5	3	4	13	24	4	2	4	2	24
	Others																															
Faro	SRK-FD04	Average	31000	1	340.0	36000	500		38			9.6	380	0.74	11	250	6700		1700	940		7.7				10	0.48					6900
	(Other 1)	Median	34000	1	160.0	38000	500		17			11	420	0.9	11	130	5300		1600	630		7.5				10	0.4					7800
		Min	5800	1	0.5	7500	27		9			1.7	160	0.22	1.4	55	1300		190	130		0.8				10	0.22					1200
		Max	50000	1	1100.0	59000	990		87			16	500	1.1	20	560	15000		3200	2400		15				10	0.9					11000
		N	4	4	4	4	4		3			4	4	3	4	3	4		4	4		4				1	4					4
Faro	SRK-FD05/6	Average	11	200	1.5	450	0.003	0.00017	0.00027	0.00001	0.03	0.0021	120	0.00014	0.00081	0.0019	0.008	0.00021	93	0.085	0.00017	0.044	3.7	0.0014	0.000011	5.9	0.51	0.00014	0.00001	0.0088	0.0002	2.9
	(Other 2)	Median	9	210	1.3	400	0.0021	0.0002	0.0002	0.00001	0.02	0.0016	120	0.0001	0.0002	0.0017	0.006	0.00024	86	0.005	0.00013	0.031	3.6	0.0017	0.000007	5.8	0.46	0.00011	0.00001	0.01	0.0002	2
		Min	3	85	0.6	210	0.0016	0.00011	0.00016	0.00001	0.01	0.00046	54	0.0001	0.000056	0.0013	0.002	0.000061	45	0.00015	0.0001	0.014	2.2	0.0005	0.000005	2.2	0.21	0.000079	0.00001	0.0056	0.0002	0.53
		Max	31	320	2.5	1200	0.006	0.0002	0.0005	0.00001	0.05	0.0057	200	0.0002	0.0028	0.0033	0.02	0.00031	210	0.49	0.0003	0.12	5.2	0.0025	0.00002	9	0.84	0.00021	0.00001	0.011	0.0002	14
		N	20	20	20	20	7	7	7	3	7	7	20	5	7	7	5	7	20	20	7	10	20	5	5	20	20	7	3	3	5	20
Faro	SRK-FD14	Average	9	110	0.9	1600	0.0076	0.00056	0.00045	0.00015	0.035	0.01	180	0.0003	0.009	0.018	0.38	0.0026	230	0.18	0.0019	0.069	15	0.0027	0.000018	90	2.3	0.00096	0.00003	0.086	0.017	3.8
	(Other 3)	Median	8	120	0.5	1400	0.0036	0.00065	0.0005	0.00015	0.035	0.0076	180	0.0003	0.012	0.0046	0.21	0.0038	220	0.079	0.0021	0.063	15	0.0021	0.00002	120	2.2	0.0011	0.00003	0.086	0.001	2.9
		Min	3	40	0.5	510	0.003	0.00034	0.00014	0.00011	0.02	0.0049	72	0.0001	0.0002	0.0011	0.05	0.00019	88	0.005	0.0014	0.04	7	0.0018	0.000005	13	0.93	0.00051	0.00001	0.022	0.0002	1
		Max	24	160	2.5	2700	0.016	0.0007	0.0007	0.00019	0.05	0.02	280	0.0005	0.02	0.06	0.89	0.0039	400	0.5	0.0022	0.14	24	0.0043	0.00003	150	3.8	0.0013	0.00005	0.15	0.049	11
		N	10	10	8	10	3	3	3	2	2	4	10	2	5	4	3	3	10	10	3	10	10	3	3	10	10	3	2	2	3	10
Faro	SRK-FD19	Average	120	380	2.1	3800	0.16	0.00037	0.003	0.0006	0.01	0.028	570	0.0002	0.086	0.052	0.4	0.0072	600	21	0.0021	0.41	9.8	0.005	0.00009	20	3.2	0.00031		0.014	0.024	66
	(Other 4)	Median	110	400	2.1	3800	0.007	0.0004	0.0018	0.0006	0.01	0.014	590	0.0002	0.062	0.018	0.07	0.007	580	18	0.0021	0.38	10	0.0053	0.00009	21	3.3	0.00032		0.014	0.024	53
		Min	67	260	1.1	3100	0.002	0.0003	0.0013	0.0006	0.01	0.0073	450	0.0002	0.035	0.011	0.02	0.0014	400	12	0.0021	0.27	6.9	0.004	0.00006	15	2.3	0.00026		0.013	0.0002	36
		Max	280	450	2.8	5100	0.48	0.0004	0.0059	0.0006	0.01	0.082	680	0.0002	0.29	0.18	2.9	0.014	770	36	0.0021	0.68	12	0.0057	0.00012	26	3.8	0.00036		0.015	0.048	170
		N	14	14	9	14	3	3	3	1	1	7	14	1	14	8	9	4	14	14	1	14	14	3	2	14	14	3		2	2	14
Faro	SRK-FD37	Average	30000	1	2.0	36000	310	0.72	130	0.031	0.5	28	290	0.75	9.8	340	3900	2.9	610	360	0.018	9.2		0.36	0.055	2.7	0.42	0.3	0.013	1.4	0.09	16000
	(Other 5)	Median	31000	2	0.5	35000	280	0.53	90	0.035	0.5	26	280	0.82	9.7	320	3200	2.4	600	360	0.018	9		0.36	0.055	2.7	0.42	0.3	0.013	1.4	0.09	14000
		Min	11000	1	0.5	13000	71	0.3	9.7	0.009	0.5	10	220	0.26	3.2	120	1000	0.6	240	130	0.018	3.2		0.014	0.01	2	0.28	0.0029	0.013	1.1	0.09	6100
		Max	53000	2	5.0	67000	580	1.5	450	0.05	0.5	57	350	1.2	17	560	9400	4.9	1100	660	0.018	16		0.7	0.1	3.4	0.6	0.6	0.013	1.7	0.09	35000
		N	8	8	3	8	8	4	8	3	1	8	8	3	8	8	8	5	8	8	1	8		2	2	2	8	2	1	2	1	8
Faro	SRK-FD40	Average	300	9	0.9	750	13	0.00023	0.0016	0.0079	0.01	3.7	65	0.021	0.23	1.3	44	0.25	74	4.1	0.00025	0.18	1.3	0.00087	0.0002	3.1	0.26	0.00047	0.00005	0.027	0.0006	69
	(Other 6)	Median	150	2	0.5	610	8.3	0.0002	0.0013	0.0074	0.01	0.07	68	0.023	0.17	0.65	29	0.15	61	3.2	0.00025	0.12	1.2	0.0008	0.00012	3	0.24	0.00029	0.00005	0.027	0.0006	44
		Min	43	1	0.5	330	0.48	0.0001	0.0004	0.0019	0.01	0.02	23	0.0041	0.019	0.01	1.1	0.08	29	0.037	0.0002	0.06	1.1	0.0008	0.0001	1.6	0.12	0.00027	0.00005	0.0099	0.0002	21
		Max	1200	29	2.5	2000	39	0.0004	0.0036	0.017	0.01	47	120	0.042	0.65	5.1	160	0.75	180	13	0.0003	0.48	1.7	0.001	0.00038	4.6	0.4	0.00085	0.00005	0.045	0.001	200
		N	13	13	11	13	10	3	4	6	1	13	13	5	10	13	9	10	13	13	2	13	3	3	3	13	13	3	1	2	2	13

Table 5-1 Updated Seepage Survey Statistics (cont'd)

Area	Type	Statistic	Acidity (to pH 8.3) CaCO3	Alkalinity-Total CaCO3	Chloride Cl	Sulphate SO4	Al	Sb	As	Be	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	K	Se	Ag	Na	Sr	Tl	Sn	U	V	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L
Grum	1a	Average	11	320	1.4	380	0.006	0.00047	0.0037	0.00005	0.023	5.3E-05	160	0.0003	0.004	0.0017	0.23	0.00021	78	0.11	0.0012	0.09	3	0.0027	0.00003	3.2	0.67	0.00017	0.026	0.018	0.0006	0.036
		Median	9	340	1.3	410	0.004	0.00049	0.0029	0.00005	0.01	0.00004	170	0.0002	0.002	0.001	0.23	0.00023	71	0.007	0.0014	0.087	3	0.0023	0.00003	3	0.67	0.000075	0.026	0.018	0.0004	0.011
		Min	1	110	0.5	7	0.002	0.0003	0.0016	0.00005	0.01	0.00002	42	0.0002	0.00029	0.0008	0.008	0.00008	23	0.0014	0.0005	0.05	2	0.0012	0.00003	2	0.19	0.00002	0.00005	0.018	0.0004	0.005
		Max	40	470	2.5	840	0.014	0.0006	0.0076	0.00005	0.05	0.0001	290	0.0005	0.012	0.0038	0.43	0.0003	180	1.9	0.0016	0.13	4.1	0.0045	0.00003	5.9	1.3	0.0005	0.051	0.018	0.001	0.39
		N	29	29	26	29	4	4	4	1	3	3	29	3	4	4	4	4	29	29	4	12	18	3	1	29	29	4	2	1	3	29
Grum	1b	Average	25	510	1.9	1400	0.0027	0.0015	0.0048	0.00066	0.03	0.0016	340	0.00037	0.01	0.0084	0.23	0.0061	250	0.13	0.001	0.4	7	0.0017	0.0012	11	1.3	0.00041	0.022	0.031	0.011	3.7
		Median	22	540	1.9	1300	0.002	0.0013	0.0036	0.00005	0.03	0.0015	350	0.0005	0.0044	0.0024	0.015	0.0013	240	0.056	0.0009	0.35	7	0.0014	0.00003	11	1.4	0.00035	0.00005	0.028	0.001	2.9
		Min	1	260	0.5	330	0.001	0.0005	0.0006	0.00001	0.01	0.00028	120	0.0001	0.0004	0.0014	0.006	0.00076	70	0.0016	0.0003	0.086	1.8	0.0002	0.000005	2	0.46	0.00022	0.00001	0.0092	0.0002	1.1
		Max	69	700	2.8	2500	0.005	0.0038	0.02	0.0056	0.05	0.005	480	0.0005	0.05	0.041	0.8	0.072	440	1	0.0033	1.4	12	0.0045	0.011	18	2.4	0.00071	0.099	0.052	0.059	17
		N	50	50	37	50	15	15	15	9	8	15	50	12	21	19	13	15	50	50	15	50	50	12	9	50	50	15	12	8	15	50
Grum	2	Average	93	300	1.6	1700	0.037	0.0011	0.0016	0.00005	0.01	0.044	310	0.0003	0.14	0.22	8.8	0.021	260	2.2	0.0019	0.66	7.3	0.0031	0.00003	6.8	1.1	0.0033	0.00005	0.013	0.0006	44
		Median	83	290	1.8	1700	0.002	0.0009	0.0009	0.00005	0.01	0.025	320	0.0002	0.063	0.0055	0.75	0.0045	250	1.5	0.0008	0.5	6.5	0.0029	0.00003	5.4	0.96	0.0044	0.00005	0.0037	0.0006	17
		Min	7	39	0.5	570	0.001	0.0005	0.0006	0.00005	0.01	0.0024	170	0.0002	0.0084	0.0015	0.015	0.0012	110	0.11	0.0003	0.1	2.7	0.0002	0.00003	2.3	0.51	0.00048	0.00005	0.0019	0.0002	7.7
		Max	240	660	2.8	4100	0.28	0.0029	0.0048	0.00005	0.01	0.18	460	0.0005	0.7	2.1	46	0.14	570	7.5	0.0044	2.7	20	0.0092	0.00003	15	1.8	0.006	0.00005	0.033	0.001	140
		N	15	15	14	15	8	7	7	2	4	12	15	6	15	11	9	8	15	15	7	15	15	7	2	15	15	7	2	3	6	15
Grum	SRK-GD13/18	Average	13	330	1.1	520	0.006	0.00047	0.0037	0.00005	0.023	5.3E-05	180	0.0003	0.004	0.0017	0.23	0.00021	100	0.064	0.0012	0.09	3	0.0027	0.00003	3.9	0.84	0.00017	0.026	0.018	0.0006	0.059
		Median	12	390	1.0	500	0.004	0.00049	0.0029	0.00005	0.01	0.00004	170	0.0002	0.002	0.001	0.23	0.00023	96	0.034	0.0014	0.087	3	0.0023	0.00003	3.9	0.86	0.000075	0.026	0.018	0.0004	0.021
		Min	2	110	0.5	300	0.002	0.0003	0.0016	0.00005	0.01	0.00002	80	0.0002	0.00029	0.0008	0.008	0.00008	44	0.0014	0.0005	0.05	2	0.0012	0.00003	2	0.36	0.00002	0.00005	0.018	0.0004	0.007
		Max	30	470	2.5	840	0.014	0.0006	0.0076	0.00005	0.05	0.0001	290	0.0005	0.012	0.0038	0.43	0.0003	180	0.61	0.0016	0.13	4.1	0.0045	0.00003	5.9	1.3	0.0005	0.051	0.018	0.001	0.39
		N	16	16	14	16	4	4	4	1	3	3	16	3	4	4	4	4	16	16	4	12	13	3	1	16	16	4	2	1	3	16
Vangorda	2	Average	640	130	1.1	3600	0.042	0.0003	0.023	0.007	0.042	0.13	330	0.0099	1.8	0.027	91	0.041	480	140	0.0075	2.7	9.3	0.0045	0.00057	7.6	1.3	0.068	0.082	0.016	0.017	310
		Median	310	150	0.8	2900	0.026	0.0004	0.002	0.007	0.05	0.08	390	0.0005	0.91	0.015	7.9	0.0064	400	45	0.0022	2.4	11	0.006	0.0005	8.8	1.6	0.0013	0.036	0.016	0.001	130
		Min	35	5	0.4	320	0.004	0.0001	0.0004	0.00005	0.01	0.028	69	0.0002	0.029	0.001	0.06	0.0008	27	2.4	0.0003	0.065	0.92	0.001	0.00027	0.3	0.25	0.0005	0.00005	0.011	0.0002	13
		Max	6200	350	4.0	19000	0.1	0.0004	0.13	0.014	0.05	1.1	530	0.029	10	0.072	1100	0.11	2800	1200	0.028	7.2	14	0.008	0.0012	16	2.3	0.4	0.26	0.021	0.11	2600
		N	33	33	25	33	7	3	7	2	5	33	33	3	33	12	31	10	33	33	6	33	26	7	5	31	33	9	4	2	7	33
Vangorda	3	Average	11000	22	1.8	25000	110	0.037	6.7	0.031	0.05	4.6	430	0.19	13	12	1600	0.96	2500	1500	0.16	11	9.8	0.056	0.012	6.5	1.7	2.4	2	0.6	0.52	4700
		Median	5900	2	0.5	18000	29	0.002	0.045	0.024	0.05	1.6	440	0.11	7.7	0.7	1000	1	2000	1100	0.021	6.6	10	0.026	0.004	5	1.5	0.0077	2.6	0.49	0.068	2800
		Min	210	1	0.5	1600	0.4	0.0004	0.005	0.0064	0.05	0.14	200	0.013	0.3	0.032	0.12	0.0007	110	18	0.018	0.75	3	0.0068	0.0005	1.3	0.45	0.0017	0.006	0.003	0.001	87
		Max	42000	130	11.0	89000	690	0.11	48	0.082	0.05	23	600	0.57	38	180	8400	2.5	8400	4800	0.43	38	28	0.14	0.026	15	5.5	16	3	1.7	2.6	17000
		N	45	45	21	45	34	3	10	8	3	43	45	9	45	25	45	25	45	45	3	45	21	9	9	24	45	12	4	6	7	45

Table 5-2 Current (Neutral) Seepage Types

a) Faro Mine Area Waste Rock Dumps

Source	Code	Current Seep Types (as fraction)										
		F1	F2 Waste	F2 Ore	F3 Waste	F3-ore	Other 1	Other 2	Other 3	Other 4	Other 5	Other 6
Faro Valley North	FVN				1							
Faro Valley South	FVS				1							
Medium Grade Stockpile	MGSP										1	
Crusher Stockpile	CHSP					1						
Oxide Fines Stockpile	OXSP						1					
Low Grade Stockpile A	LGSPA					1						
Upper Northwest Dump	NWU	0.7	0.2		0.1							
Middle Northwest Dump	NWM	0.7	0.2		0.1							
Lower Northwest Dump	NWL									1		
Mt. Mungly West	MMW				1							
Mt. Mungly East	MME				1							
Fuel Tank Dump W	FTW				1							
Fuel Tank Dump E	FTE		1									
Upper Parking Lot Dump	UPL	0.95	0.05									
Lower Parking Lot Dump	LPL	0.9	0.1									
Stock Piles Base	SPB		1									
Southwest Pit Wall Dump	SWPWD				1		0					
Low Grade Stockpile C	LGSPC					1						
Main East Sulphide Cell	MESC				1		0					
Intermediate Dump Sulphide Cell	IDSC				1		0					
Ranch Dump	RD	0.5	0.5									
Ramp Zone Dump	RZD								1			
Main Dump West	MDW		0.9		0.1							
Main Dump East	MDE	0.4	0.4		0.2							
Intermediate Dump	ID	0.5	0.3		0.2							
Outer Haul Road West	OHRW	0.5	0.5									
Outer Haul Road East	OHRE	0.4	0.6									
Lower Northeast sulphide cell	NELS				1							
Outer Northeast Dump	NEO	0.5	0.5									
Zone II West	ZIIW	0.4	0.6									
Zone II East	ZIIE	0.5	0.5									
Lower Northeast Dump	NEL							1				
Upper Northeast Dump	NEU							1				

b) Vangorda/Grum Area Mine Waste Rock Dumps

Source	Code	Current Seep Types (as fraction)						
		G1a	G1b	WGD	G2	G3	V2	V3
Grum Main Sulphide Cell	G1-S		0.9				0.1	
Grum Main Dump	G1-B		1					
Grum Southwest Dump	G2			1				
Overburden Dump	G3-O	1						
Vangorda Main Sulphide Cell	V1-S							1
Vangorda Main Dump	V1-B						0.8	0.2
Baritic Fines Dump	V2							1
Overburden Dump	V3-O		0.9				0.1	
Ore Transfer Pad	OTP		0.9				0.1	
Dump Southeast of Ramp	VPL1						0.5	0.5
Dump inside Hairpin	VPL2						0.8	0.2
Oxide Fines Dump	VPL3							1

Table 5-3 Future (Acidic) Seepage Types

a) Faro Mine Area Waste Rock Dumps

Source	Code	Future Seep Types (as fraction)										
		F1	F2 Waste	F2 Ore	F3 Waste	F3-ore	Other 1	Other 2	Other 3	Other 4	Other 5	Other 6
Faro Valley North	FVN						1					
Faro Valley South	FVS		0.8		0.2							
Medium Grade Stockpile	MGSP										1	
Crusher Stockpile	CHSP					1						
Oxide Fines Stockpile	OXSP						1					
Low Grade Stockpile A	LGSPA					1						
Upper Northwest Dump	NWU		0.5		0.5							
Middle Northwest Dump	NWM		0.5		0.5							
Lower Northwest Dump	NWL		0.5		0.5							
Mt. Mungly West	MMW				1							
Mt. Mungly East	MME				1							
Fuel Tank Dump W	FTW											1
Fuel Tank Dump E	FTE		1									
Upper Parking Lot Dump	UPL	0.95	0.05									
Lower Parking Lot Dump	LPL		0.8		0.2							
Stock Piles Base	SPB		1									
Southwest Pit Wall Dump	SWPWD						1					
Low Grade Stockpile C	LGSPC					1						
Main East Sulphide Cell	MESC						1					
Intermediate Dump Sulphide Cell	IDSC						1					
Ranch Dump	RD		0.5		0.5							
Ramp Zone Dump	RZD								1			
Main Dump West	MDW						1					
Main Dump East	MDE						1					
Intermediate Dump	ID						1					
Outer Haul Road West	OHRW		0.5		0.5							
Outer Haul Road East	OHRE						1					
Lower Northeast sulphide cell	NELS						1					
Outer Northeast Dump	NEO	0.5	0.5									
Zone II West	ZIIW		0.2		0.8							
Zone II East	ZIIE	0.5	0.5									
Lower Northeast Dump	NEL		0.5		0.5							
Upper Northeast Dump	NEU		0.5		0.5							

b) Vangorda/Grum Area Mine Waste Rock Dumps

Source	Code	Future Seep Types (as fraction)						
		G1a	G1b	WGD	G2	G3	V2	V3
Grum Main Sulphide Cell	G1-S							1
Grum Main Dump	G1-B		0.5		0.45	0.05		
Grum Southwest Dump	G2		0.5	0.5				
Overburden Dump	G3-O	1						
Vangorda Main Sulphide Cell	V1-S							1
Vangorda Main Dump	V1-B							1
Baritic Fines Dump	V2							1
Overburden Dump	V3-O		0.9				0.1	
Ore Transfer Pad	OTP							1
Dump Southeast of Ramp	VPL1							1
Dump inside Hairpin	VPL2						0.7	0.3
Oxide Fines Dump	VPL3							1

- The estimated contaminant concentration in drainage from each dump is then calculated as the weighted averages of the water quality for the various seepage types, weighted using the proportions outlined in Table 5-2 for current conditions and Table 5-3 for future conditions.

In the previous version of the model, three different set of estimates were developed to represent the progression of waste rock source terms over time:

- Case 1 – Current Average Estimates

  The calculated average seep statistic was used for this scenario and the assigning of water types for each dump reflected the current understanding of the dump's geochemical composition. This cased provided an indication of current seepage from the waste rock dumps

- Case 2 – Current Maximum Estimates

  In this case the maximum statistic was assumed for each seep type with the same assumptions for the assigning of water types as for Case 1. This case provided an indication of near future dump water quality.

- Case 3 – Worst Case Future Estimates

  For this case the seepage proportions for each dump were reassigned to reflected anticipated future conditions at the time when all the dumps have depleted their available neutralizing potential and go acidic at the same time. The maximum seepage statistic was used for each seep type.

The updated model is now dynamic and provides predictions of waste rock seepage water quality (and loading) with time. As such, given the unique characteristics of each dump, not all the dumps change from current conditions to future acidic conditions at the same time. The updated model now assumes the following for the evolution waste rock seepage chemistry for each waste rock dump.

- Current (Neutral) Conditions

  Current (Neutral) conditions for each dump are assumed from time zero until the time when 70% of the available neutralizing potential is depleted.

- Transition from Current to Future Conditions

  Once 70% of a specific dump's available neutralizing potential has been depleted, there is a transition from neutral to acidic conditions. For this transitional period a linear increase in chemistry from 100% neutral conditions to 100 % acidic conditions was assumed for each dump from the time of 70% NP depletion to 100% NP depletion. For example, at 73% depletion of the available NP the water quality of the dump seepage is a blend of 10% acidic quality and 90% neutral chemistry and at 76% the seepage would be a blend of 20% acidic and 80% neutral.

- Future (Acidic) Conditions

  Similar to previous version of the model for this case, the seepage proportions for each dump were reassigned to reflected anticipated future conditions at the time when each dump has depleted its available neutralizing potential and go acidic.

The seepage types for each dump for current (neutral) and future (acidic) conditions are presented in Table 5-2 and 5-3.

Two different scenarios were used to estimate the contaminant concentration from waste rock and ore dumps: Best Estimate and Upper Bound. In the Best Estimate scenario, the calculated average seep properties were assumed for current, transitional and future conditions. For the Upper Bound scenario, the maximum concentrations for each seep type were used.

5.1.1 NP and AP Depletion

As noted before, the waste rock dump seepage quality will be influenced by the closure measures and their impacts on NP availability and NP depletion. Closure measures (i.e. covers) will affect the rate of infiltration as well as the rate of oxygen entry and thus the rate of oxidation within the dumps. In the model the rate of oxidation has been adjusted for each cover type. Table 5-4 outlines the assumed oxidation rate used in the model for each cover type.

Table 5-4 Assumed Oxidation Rates for Covers

Cover Type	Oxidation Rate (%)
No Cover	100
Rudimentary Cover	90
Low Infiltration Cover	50
Very Low Infiltration Cover	5

NP and AP

The ABA data assigned to each waste rock dump is summarized in Table 5-5. This data is the same as that presented in SRK (2004b) with the exception of data for Vangorda

Main Dump. A recent review of the ABA data for this dump indicated that the values previously used were not consistent with the current understanding of the composition of this dump. A review of the raw data for the material in this dump confirmed that the majority of the material in this dump is PAG and the ABA values have been updated accordingly.

Using the linear relationship that exists between sulphide content and the oxidation rate (SRK 2004b) it is possible to estimate the oxidation rate into the future and estimate the time to NP depletion and the onset of acidic conditions. For a detailed discussion on the derivation of these calculations, the reader is referred to SRK (2004b). In general, for each time step the NP value is multiplied by the NP availability to provide an estimate of the available NP for each dump. From this base data, the residual NP is calculated for each time step. The residual available NP is then used to determine the transition from neutral to transitional to acidic conditions.

Table 5-5 Waste Rock Dump ABA Data

Source	Code	AP	NP	NNP	NP/AP	S (%)
Faro Mine Area						
Faro Valley North	FVN	116	28	-88	0.24	3.72
Faro Valley South	FVS	28	26	-2	0.91	0.91
Medium Grade Stockpile	MGSP	623	5	-618	0.01	19.94
Crusher Stockpile	CHSP	623	5	-618	0.01	19.94
Oxide Fines Stockpile	OXSP	623	5	-618	0.01	19.94
Low Grade Stockpile A	LGSPA	623	5	-618	0.01	19.94
Upper Northwest Dump	NWU	61	22	-39	0.36	1.95
Middle Northwest Dump	NWM	82	42	-39	0.52	2.61
Lower Northwest Dump	NWL	71	38	-33	0.54	2.27
Mt. Mungly West	MMW	320	24	-297	0.07	10.25
Mt. Mungly East	MME	206	30	-175	0.15	6.58
Fuel Tank Dump W	FTW	623	5	-618	0.01	19.94
Fuel Tank Dump E	FTE	39	45	6	1.15	1.26
Upper Parking Lot Dump	UPL	50	59	9	1.19	1.60
Lower Parking Lot Dump	LPL	76	64	-12	0.84	2.43
Stock Piles Base	SPB	29	33	4	1.14	0.92
Southwest Pit Wall Dump	SWPWD	299	19	-280	0.06	9.57
Low Grade Stockpile C	LGSPC	623	5	-618	0.01	19.94
Main East Sulphide Cell	MESC	623	5	-618	0.01	19.94
Intermediate Dump Sulphide Cell	IDSC	623	5	-618	0.01	19.94
Ranch Dump	RD	63	29	-35	0.45	2.02
Ramp Zone Dump	RZD	33	59	27	1.81	1.05
Main Dump West	MDW	91	32	-59	0.35	2.91
Main Dump East	MDE	114	41	-73	0.36	3.65
Intermediate Dump	ID	140	48	-92	0.34	4.48
Outer Haul Road West	OHRW	43	34	-10	0.77	1.38
Outer Haul Road East	OHRE	90	26	-64	0.29	2.88
Lower Northeast sulphide cell	NELS	623	5	-618	0.01	19.94
Outer Northeast Dump	NEO	23	45	23	2.00	0.72
Zone II West	ZIIW	86	34	-52	0.40	2.74
Zone II East	ZIIE	30	39	9	1.28	0.97
Lower Northeast Dump	NEL	51	38	-13	0.74	1.62
Upper Northeast Dump	NEU	49	37	-12	0.75	1.58
Vangorda/Grum Mine Area						
Main dump Sulphide Cell	G1-S	397	26	-371	0.07	12.7
Main Dump	G1-B	25	69	43	2.70	0.82
Southwest Dump	G2	25	69	43	2.70	0.82
Overburden Dump	G3-O	0	0	0		
Main Dump Sulphide Cell	V1-S	426	26	-400	0.06	13.64
Main Dump	V1-B	67	28	-39	0.42	2.18
Barite Dump	V2	625	0	-625	0.00	20.00
Overburden Dump	V3-O					

NP Availability

Recent studies by SRK (SRK 2009) showed that for most rock units, laboratory measurements of NP provided a reasonable indication of the buffering potential provided by reactive carbonate minerals. In some of the rock units, notably the intrusive volcanics (10E and 10F) and the calc-silicates (3D) at Faro, up to half of the NP may be contributed by silicate minerals, which may not be as effective at maintaining neutral pH conditions. The physical availability of NP and sulphides in the field is dependent on the distribution of these minerals in the rock, size of individual mineral grains, the relative reactivity, precipitation of secondary minerals and a number of other macro-scale features that cannot be accurately quantified. Therefore, sensitivity analyses have been recommended to assess a range of possible conditions.

NP Availability was assigned a range of 25 to 75% with a uniform distribution in the current version of the model as recommended by SRK. This accounts for a reduction of up to 50% of the total NP to account for reduced reactivity (SRK 2009), and an additional reduction of 50 to 75% to account for limited physical availability of reactive NP. Given the uncertainty in these inputs, SRK recommended to apply a simple uniform probability distribution between 25% and 75% to assess the sensitivity of the model over the expected range of NP availability.

5.1.2 Waste Rock Loading

The surface area of the dumps pre and post-closure is presented in Table 5-6. The increase in surface area due to resloping of the sloped portion of the dumps, particularly the external or perimeter dumps, and proposed partial or complete dump re-locations is taken into consideration in determining the post-closure surface area and are based on the closure assumptions for each dump outlined in Draft 4A of the Project Description. For modeling purposes, the surface area is important because it affects the amount of water predicted to flow through the dumps.

The proportion of dump seepage reporting to various drainage areas is outlined in Table 5-7 and 5-8. This is an update from values used in previous versions of the model based on updated mapping which included pre-mining catchment areas, existing mine area catchments, receiving environment catchment areas and waste rock dumps surface areas.

For each dump there are two components of loading: waste rock seepage and surface runoff. Waste rock seepage is the water that infiltrates through the dump while surface runoff is the residual water that runs off the surface of the dump. For long-term post-closure conditions, seepage is assumed to contaminated while runoff is assumed to be clean.

Table 5-6 Pre and Post-Closure Waste Rock Dump Surface Areas

Waste Rock Element	Pre-closure Area (m^2)	Post-Closure Area (m^2)
Faro Mine Area		
Faro Valley North	130,803	130,803
Faro Valley South	31,116	31,116
Medium Grade Ore Stockpile	26,600	Relocated
Crusher Stockpile	22,916.8	Relocated
Oxide Fines Stockpile	29,200	Relocated
Low Grade Stockpile A	36,139	36,139
Upper Northwest Dump	120,901	56,801 partial relocation
Middle Northwest Dump	150,497	145,797 partial relocation
Lower Northwest Dump	105,110	124,366
Mt. Mungly West	33,947	33,947
Mt. Mungly East	38,500	38,500
Fuel Tank Dump W	10,283	10,283
Fuel Tank Dump E	105,025	105,025
Upper Parking Lot Dump	50,355	55,119
Lower Parking Lot Dump	28,524	30,253
Stock Piles Base	86,387	86,387
Low Grade Stockpile C	40,000	91,000
South West Pit Wall Dump	72,400	72,400
Main Sulphide Cell	80,000	80,000
Intermediate Sulphide Cell	88,500	88,500
Ranch Dump	47,000	47,000
Ramp Zone Dump	64,311	64,311
Main Dump West	191,789	191,789
Main Dump East	324,089	324,089
Intermediate Dump	316,928	316,928
Outer Haul Road West	162,463	198,813
Outer Haul Road East	76,304	92,348
North East Sulphide Cell	18,000	18,000
Outer Northeast Dump	20,000	20,000
Zone II West	89,936	89,936
Zone II East	122,939.8	150,019
Lower Northeast Dump	214,811.8	284.752
Upper Northeast Dump	245,910	285.523

Waste Rock Element	Pre-closure Area (m^2)	Post-Closure Area (m^2)
Vangorda/Grum Mine Area		
Grum Dump Sulphide Cell	95,900	95,900
Grum Main Dump	1,162,251	1,226,002
Grum Southwest Dump	184,448	184,448
Ore Transfer Pad	132,800	143,820
Vangorda Main Sulphide Cell	52,623	52,623
Vangorda Main Dump	331,502	407,227
Barite Fines Dump	5,635	5,635
Vangorda In-Pit Dump – SW of Ramp	50,000	50,000
Vangorda In-Pit Dump - Hairpin	23,000	23,000
Vangorda In-Pit Dump – Oxide Fines	4000	4000

Table 5-7 Waste Rock Dump Drainage – Faro Mine Area

Waste Rock Element	**% Total Dump area Draining to Each Catchment**							
	X23	MP	X2	RCV	ZII	NFRC	GHU	GHL
Faro Valley North		100						
Faro Valley South		100						
Medium Grade Ore Stockpile	100							
Crusher Stockpile	100							
Oxide Fines Stockpile	100							
Low Grade Stockpile A	70	30						
Upper Northwest Dump	50 / 75						40 / 0	10 / 25
Middle Northwest Dump	70 / 72						10 / 7	20 / 21
Lower Northwest Dump	50							50
Mt. Mungly West	100							
Mt. Mungly East	100							
Fuel Tank Dump W	100							
Fuel Tank Dump E	100							
Upper Parking Lot Dump								100
Lower Parking Lot Dump								100
Stock Piles Base	100							
Low Grade Stockpile C	70	30						
South West Pit Wall Dump	30	70						
Main Sulphide Cell	100							
Intermediate Sulphide Cell			100					
Ranch Dump	90	10						
Ramp Zone Dump		20	5		75			
Main Dump West	100							
Main Dump East	70		20	10				
Intermediate Dump			90		10			

Waste Rock Element	**% Total Dump area Draining to Each Catchment**							
	X23	MP	X2	RCV	ZII	NFRC	GHU	GHL
Outer Haul Road West	20		30	50				
Outer Haul Road East			100					
North East Sulphide Cell					95	5		
Outer Northeast Dump		100						
Zone II West					100			
Zone II East					90	10		
Lower Northeast Dump		10			40	50		
Upper Northeast Dump		30			20	50		

Notes:

X23 – Drainage reporting to X23 at toe of Main Dump
MP – Drainage reporting to Faro Main Pit
X2 – Drainage reporting North Fork Rose Creek between Rock Drain and X2
RCV – Drainage reporting to Rose Creek between X2 and X14
ZII – Drainage reporting to Zone II Pit Catchment
NFRC – Drainage reporting to North Fork Rose Creek upstream of Rock Drain
GHU – Drainage reporting to Upper Guardhouse Creek (pre-and post-relocation)
GHL – Drainage reporting to Lower Guardhouse Creek

Table 5-8 Waste Rock Dump Drainage – Vangorda/Grum Mine Area

Waste Rock Element	% Total Dump area Draining to Each Catchment		
	V27	V8	VP
Grum Dump Sulphide Cell	100		
Grum Main Dump	100		
Grum Southwest Dump	50	50	
Ore Transfer Pad		100	
Vangorda Main Sulphide Cell*	98.5	1.5	
Vangorda Main Dump*	98.5	1.5	
Barite Fines Dump*	98.5	1.5	
Vangorda In-Pit Dump – SW of Ramp			100
Vangorda In-Pit Dump - Hairpin			100
Vangorda In-Pit Dump – Oxide Fines			100

Notes:

V27 – Drainage reporting to main stem Vangorda Creek upstream of V27.
MP – Drainage reporting to Vangorda Creek below V27 including Shrimp Creek and the West Fork of Vangorda Creek.
VP – Drainage reporting to Vangorda Pit
* For the Vangorda Dump area model assumes split above for seepage and for surface runoff that 65 % drains to Vangorda Creek at V27 and the remainder to Shrimp Creek.

Waste Rock Seepage

Water storage in the dumps is not considered. Therefore, precipitation that falls on a dump and infiltrates into the dump in a given year is assumed to report as seepage from the dump that same year. In reality there will be a transport delay, but the model assumes the most conservative condition.

The infiltration rates used for the various types of covers are presented in Table 3.2 Draft 4A Project Description and are summarized below in Table 5-9 and Table 5-10 for the Faro and Vangorda/Grum Mine Areas. Uncovered areas are assumed to have an infiltration rate of 45% of MAP.

Table 5.9 Faro Mine Area Waste Rock Cover Type and Infiltration Rates

Faro Mine Waste Rock Element	Closure Treatment	Infiltration Rate (% of MAP)
Faro Valley North	Rudimentary Cover	15 - 25
Faro Valley South	Rudimentary Cover	15 - 25
Medium Grade Ore Stockpile	Relocate to Low Grade Stockpile C and cover remaining area with Rudimentary Cover.	15 - 25
Crusher Stockpile	Relocate to Low Grade Stockpile C and cover remaining area with Rudimentary Cover.	15 - 25
Low Grade Ore	Relocate to Low Grade Stockpile C and cover remaining area with Low Infiltration Cover.	3 - 8
Oxide Fines Stockpile	Relocate to Low Grade Stockpile C and cover remaining area with Rudimentary Cover.	15 - 25
Low Grade Stockpile A	Very Low Infiltration Cover.	0.5
Upper Northwest Dump	Remove portion of rock from Guardhouse Creek for use in tailings trafficability layer. Cover remaining area with Rudimentary Cover.	15 - 25
Middle Northwest Dump	Rudimentary Cover	15 - 25
Lower Northwest Dump	Rudimentary Cover	15 - 25
Mt. Mungly West	Low Infiltration Cover	3 - 8
Mt. Mungly East	Low Infiltration Cover	3 - 8
Fuel Tank Dump W	Rudimentary Cover	15 - 25
Fuel Tank Dump E	Rudimentary Cover	15 - 25
Upper Parking Lot Dump	Rudimentary Cover.	15 - 25
Lower Parking Lot Dump	Rudimentary Cover.	15 - 25
Stock Piles Base	Rudimentary Cover	15 - 25
Low Grade Stockpile C	Very Low Infiltration Cover	0.5
South West Pit Wall Dump	Low Infiltration Cover	3 - 8
East Sulphide Cell	Very Low Infiltration Cover	0.5
Main + Intermediate Dump Sulphide Cell	Very Low Infiltration Cover	0.5
Ranch Dump	Rudimentary Cover	15 - 25

Faro Mine Waste Rock Element	Closure Treatment	Infiltration Rate (% of MAP)
Ramp Zone Dump	Rudimentary Cover	15 - 25
Main Dump West	Rudimentary Cover	15 - 25
Main Dump East	Rudimentary Cover	15 - 25
Intermediate Dump	Rudimentary Cover	15 - 25
Outer Haul Road West	Rudimentary Cover	15 - 25
Outer Haul Road East	Rudimentary Cover	15 - 25
Outer Northeast Dump	Rudimentary Cover	15 - 25
Zone II West	Rudimentary Cover	15 - 25
Zone II East	Rudimentary Cover	15 - 25
Lower Northeast Dump	Rudimentary Cover	15 - 25
Upper Northeast Dump	Rudimentary Cover	15 - 25

Table 5.10 Vangorda/Grum Mine Area Waste Rock Cover Type and Infiltration Rates

Vangorda/Grum Mine Waste Rock Element	Closure Treatment	Infiltration Rate (% of MAP)
Vangorda Main Dump Sulphide Cell	Very Low Infiltration Soil Cover	0.5
Baritic Fines	Very Low Infiltration Soil Cover	0.5
Vangorda Dump	Low Infiltration Cover	3 - 8
Vangorda Pit Waste Rock Piles	Low Infiltration Soil Cover	3 - 8
Grum Dump Sulphide Cell	Very Low Infiltration Soil Cover	0.5
Grum Dump (excl. Sulphide Cell)	Rudimentary Cover	15 - 25
Ore Transfer Pad	Very Low Infiltration Cover	0.5
Vangorda In-Pit Dumps	Low Infiltration Cover	3 - 8

In the Goldsim model, the infiltration rates for both the rudimentary and low infiltration covers are modeled stochastically assuming a uniform distribution of 15 to 25 % for the rudimentary cover and 3 to 8 % for the low infiltration cover.

The basis for calculating the loading to each catchment area from infiltration into a specific dump is the following:

In general the annual volume of water infiltrating into a dump is calculated as:

Total Infiltration (m^3) = Area (m^2) x Mean Annual Precipitation (mm) x % Infiltration

The area for each dump used in this calculation is either the original area of the dump or the resloped area of the dump, depending on timing.

The annual volume of infiltration water that could ultimately report to a specific catchment area is calculated as:

Infiltration (m^3) = Total Infiltration (m3) x proportion of dump area reporting to that specific catchment

The monthly seepage from a dump that could potentially report to a specific catchment is calculated as:

Monthly Seepage (m^3) = Infiltration (m^3) x % Monthly Distribution

For each dump, the total about of monthly seepage is divided into two pathways: seepage collected and routed for treatment and seepage bypassing the collections system.

The monthly volume of seepage that is collected and routed for treatment is calculated as:

Monthly Seepage Collected (m^3) =Monthly Seepage (m^3) x Collection Efficiency (%)

For each dump the amount of seepage that reports to any specific catchment or receiving environment, after groundwater (or seepage collection) is calculated as:

Monthly Seepage Bypass (m^3) =Monthly Seepage (m^3) x (1-Monthly Seepage Collected (m^3))

A monthly distribution is applied to the water that infiltrates into a dump in a given year and reports as seepage (Table 5-11). On the Faro side this distribution is based on the assessment of historical flows measured at X23, a well defined seep located at the toe of the Main Dump. For waste rock seepage from the Vangorda and Grum waste rock dumps the monthly distribution is based on flows measured at the toe of the Grum Dump.

Waste rock seepage water quality is determined as outlined in the previous section. Attenuation is not accounted for in this model. For each dump area contributing loading to a specific catchment area, the loading is calculated for using either current, transitional or future water quality, depending on the amount of residual NP remaining.

The annual loading from waste rock dump could ultimately report to a specific catchment area is calculated as:

Total Annual Load (kg) = Total Infiltration (m3) x proportion of dump area reporting to that specific catchment x Seepage Water Quality (mg/L)

The monthly loading from a dump that could potentially report to a specific catchment is then calculated as:

Monthly loading (kg) = Annual Load (kg) x % Monthly Distribution

The proportion of loading that is either, collected and routed for treatment or bypasses the collection system, is calculated using the same method outlined above for the volume of seepage collected for treatment.

Table 5-11 Monthly Waste Rock Dump Seepage Distribution (%)

Month	Faro Area	Vangorda Grum Area
January	6.8	4.4
February	4.7	3,2
March	6.5	3.3
April	6.2	4.6
May	12.9	17.7
June	12.5	11.4
July	8.6	11,8
August	9.6	10.4
September	10.8	10.3
October	8.7	10.5
November	6.2	6.8
December	6.6	5.7

Waste Rock Surface Water Runoff

In general surface water runoff (mm) from the dumps is defined as:

Surface Water Runoff (mm) = Mean Annual Runoff (mm) – Dump Infiltration (mm), or

Surface Water Runoff (mm) = MAR (mm) – MAP (mm) x % Infiltration

The annual volume of surface runoff water is calculated using:

Annual Runoff (m^3) = Area (m^2) x MAR (mm) – Area (m^2) x MAP (mm) x % Infiltration

The monthly runoff from a dump to a specific catchment is calculated using:

Monthly Runoff (m^3) = Annual Runoff (m^3) x % Monthly Distribution x proportion of area reporting to that specific catchment

The monthly distributions of surface runoff from the surface of the dumps are presented in Section 6 and were developed based on the available data from long-term flow monitoring locations. For the Faro Mine area, the waste rock surface runoff distribution is assumed to be the same as the surface water runoff distribution at R7 in the North Fork of Rose Creek (See Section 7). For the Vangorda/Grum waste rock dumps the surface runoff distribution is assumed to be the same as that in Vangorda Creek at V8.

The water quality of the runoff from the surface of the dumps is set to 10% of that of the seepage water quality prior to the dumps being covered and assumed to be the same as background water quality (see Section 7) once the dump is covered.

Table 5-12 Monthly Waste Rock Dump Surface Runoff Distribution (%)

Month	Faro Area	Vangorda Grum Area
January	3.1	1.5
February	2.3	1.1
March	2.3	1.0
April	2.8	1.4
May	24.0	26.8
June	20.5	21.2
July	12	14.4
August	9.6	9.6
September	9.3	10.2
October	6.7	7.3
November	3.8	3.2
December	3.6	2.3

5.2 Tailings

The tailings model developed in 2005 was developed as an independent EXCEL spreadsheet model. The derivation of the sulphate and metal concentration predictions for the tailings area are described in detail in SRK memorandum to Robertson GeoConsultant (RGC) in June 2005 (SRK 2005). The following provides a summary of the key components of the tailings model as outlined in SRK 2005.

The tailings prediction model predicts the soluble contaminant loading currently in the tailings facility from estimated resident pore water concentrations at different depths and zones within the tailings area and the total volume of porewater present in the tailings.

The rate of front propagation over time was estimated based on the rate of movement of the oxidation front in both fine and coarse tailings (5-13). This was inferred from the depth of oxidation products in the tailings, the time that has elapsed since deposition of the tailings, and the geometry of the tailings facility. Rates at which fronts are being propagated through the tailings were then estimated and then used to extract rates of infiltration.

Table 5-13 Summary of Rates of Advance and Infiltration (SRK 2005)

Area	Average Advance			Maximum Advance		
	Unsaturated (m/year)	Saturated (m/year)	Infiltration (mm/year)	Unsaturated (m/year)	Saturated (m/year)	Infiltration (mm/year)
Coarse	0.203	0.083	34	0.444	0.181	75
Fine	0.047	0.036	16	0.074	0.056	26

Loadings to the aquifer are spread out over time as a result of the different tailings thicknesses, rates of pore water displacement in the fine versus coarse tailings, and presence of buried oxidation products from surfaces exposed during periods when tailings deposition did not occur.

As part of a 2003 drilling program, tailings samples were collected from discrete depths for both coarse and fine-grained tailings. Metal and sulphate concentrations in the samples were determine via shake flask extraction tests, the results of which were extrapolated to provide porewater concentrations. Porewater concentrations (mg/L) were then calculated by dividing the moisture content of the tailings (L/kg) by the load (mg/kg) measured in the extraction tests. The extraction tests were carried out at a 20:1water to solids ratios and the moisture contents typically ranged around 15% (0.15 L/kg). This represented a scale-up factor of approximately 130 times relative to the original laboratory concentrations.

Future sulphate and zinc concentrations were predicted by estimating how far the sulphate and metal fronts would advance due to the precipitation infiltrating into the surface of the tailings impoundment. In this calculation, it was assumed that sulphate and zinc will not attenuate as they progress through the tailings bed. Furthermore, the concentrations in the porewater above the front will be close to zero since all sulphides would have been oxidized and the oxidation products would have been transported out in the main front.

The total load of sulphate and zinc leaving the tailings impoundment in a given year was then calculated as the load passing through the contact between the base of the tailings and the original ground surface. This was done by determining the area of the contact surface at 0.5m depth intervals and calculating the load passing though each discrete contact surface area. The load calculation was made using the property values specific to coarse or fine tailings, whichever is present above the discrete contact surface.

Sulphate and zinc loading from the tailings impoundment were calculated for each year from 2002 to 2010. From 2010 to 2100 the calculation is for every 2nd year. From 2100 to 2300 the calculation is every 5 years. From 2300 to 2750, the calculation is every 10 years.

In the current model, the tailings model is not integrated into the Goldsim Model and remains as a stand-alone model. The yearly loading data for sulphate and zinc generated by the tailings model for the model period up to 2211 is brought into the Goldsim Model as a time series which is enabled for interpolation of annual loadings for years where zinc and sulphate loading are not estimated in the tailings model.

Predicted load of other metals in seepage from tailings are then calculated in the model as a proportional relationship to the estimated sulphate loading using measured porewater data from a specific reference station located in the near surface tailings as a reference.

A monthly distribution is applied to the annual loading of the various contaminants from the tailings to the aquifer at the toe of the facility. This distribution is based on the assessment of historical flows measured at X13 (AECOM 2009), a well-defined seep located 100 m downstream of the toe of the Cross Valley Dam that is essentially discharge from the valley aquifer in the area between the Cross Valley Dam and X13 (Table 5-14).

Table 5-14 Monthly Aquifer Flow Distribution (%)

Month	Seepage Distribution at X13
January	8.9
February	8.3
March	7.3
April	7.4
May	10.2
June	9.6
July	9.8
August	8.3
September	7.2
October	7.1
November	7.4
December	8.5

For purposes of the modeling average propagation rates are used which corresponds to an infiltration rate into the tailings of 16 mm/year for fine tailings and 34 mm/year for coarse tailings. Assuming an annual average precipitation of 357 mm for the Faro side of the property, these values correspond to infiltration rates of approximately 5% and 10% respectively for fine and coarse tailings. Therefore this model assumes that the placement of the cover on the tailings area will essentially result in conditions similar to average propagation rates outlined above.

Aquifer Flow

The model assumes that the aquifer flow is approximately 60 L/s at the toe of the tailings area without and contribution from groundwater inflows from waste rock dump areas in areas upstream, such as the Emergency Tailings Area (ETS), and aquifer recharge from the Intermediate and Cross Valley Ponds. This estimate is based on the following assumptions:

- Under current conditions groundwater flow in the aquifer below the Cross Valley Dam is approximately 107 L/s (RGC 2006 and AECOM 2009).

- Current waste rock seepage from areas reporting the aquifer including that from the ETA area via Old Faro Creek Channel is estimated at an average of 6.7 L/s (AECOM 2009).

- The Intermediate and Cross Valley Ponds are known to add significant recharge to the aquifer upstream of the Cross Valley Dam: 30 L/s and 9 L/s respectively. The model assumes that these two ponds are removed as part of closure, further reducing the potential flow through the aquifer at the area of the Cross Valley Dam by approximately 40 L/s.

- Overall, the model assumes that the flow in the aquifer at the area of the toe of the Cross Valley Dam after closure implementation, without contributions from waste rock areas upstream, is:

$$107 \text{ L/s} - (6.7 \text{ L/s} + 40 \text{ L/s}) = 60 \text{ L/s}$$

5.3 Open Pits

5.3.1 Faro and Vangorda Pits

The model developed by SRK to predict contaminant loading from the open pits (SRK 2006) is a standalone empirical model that divides the pits into zones on the basis of geological/geochemical characteristics. Specific water quality is then assigned to each zone using seepage data specific to that rock type. Loadings are then calculated using an area-based flow estimate. The loads and flows entering the pit are used to estimate the pit lake water quality. The model was run for various closure scenarios including breaching of the diversions around the pit and allowing the pits to fill to a spill elevation with the exposed area of the pit walls changes as the pit lake is allowed to fill. Seepage concentrations were assumed to be constant over time.

The pit lake model outlined above to predict contaminant loading from the open pits has not been fully incorporated in to the current version of the Goldsim model. This will be done at a future date. Instead the annual pit wall loadings from the 2006 pit lake model developed for current conditions for Faro and Vangorda Pits (without flooding of the pits) was used as an estimate of the annual pit wall loading in the Goldsim model. The Goldsim model incorporates this annual pit wall loading from the 2006 pit lake model as a direct input to the model. For each pit, this annual loading is then multiplied by a monthly runoff distribution to estimate the monthly loading from wall rock.

At present, the model does not predict the predicted inventory of contaminants in the pit lakes as a result of the influx of contaminants from various sources: pit walls, waste rock in pit catchment, water from groundwater and surface water collection systems, and dissolution of secondary minerals. These components will be added when the complete pit lake models are incorporated. In the interim, similar to the previous version of the model in EXCEL (SRK 2009a), the model uses the combined monthly loading and flow rate for the various sources to provide an estimate of the overall incoming water quality and quantity of water that will need to be treated and ultimately discharge.

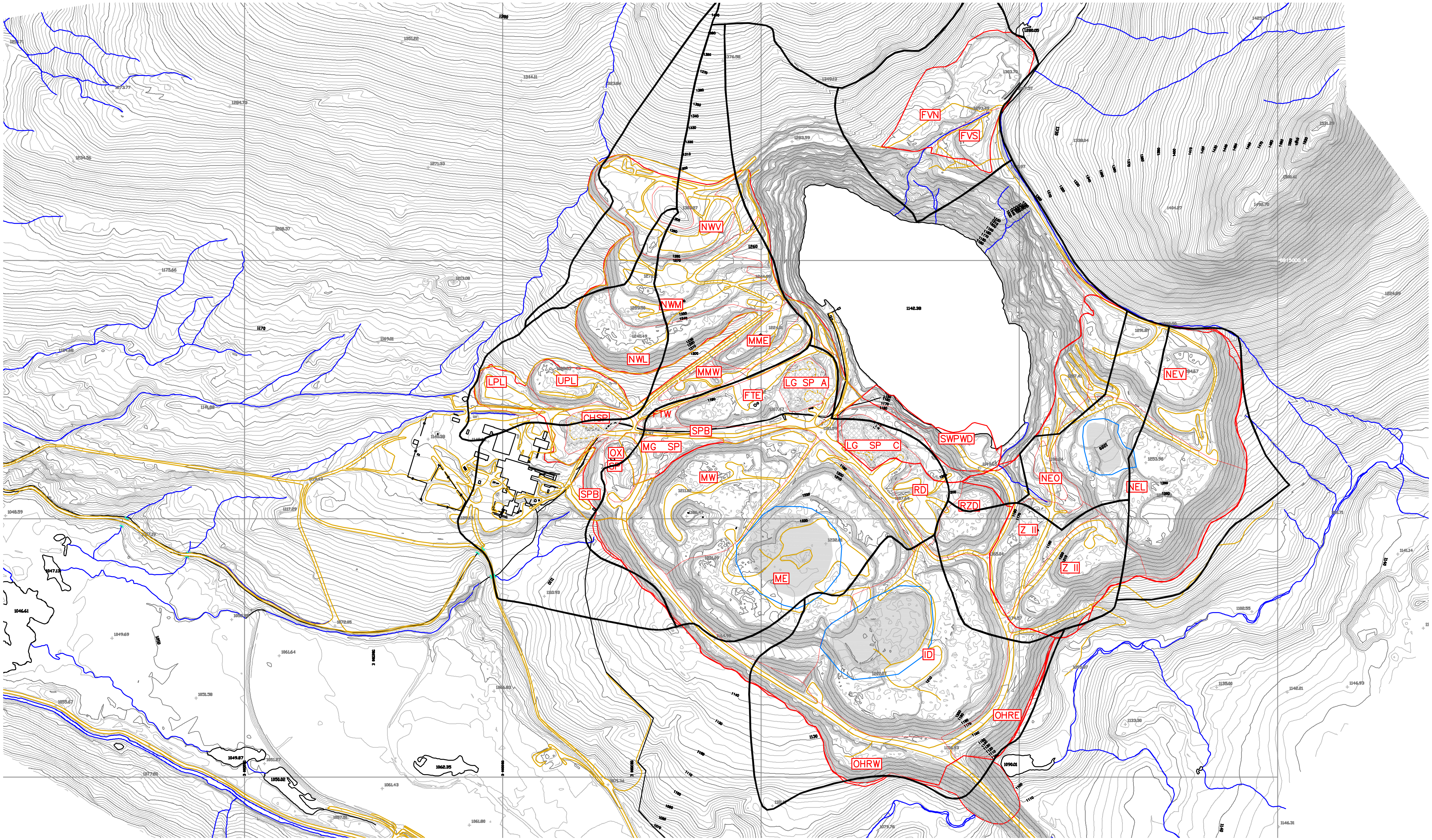
Because the pits are used as storage reservoirs for contaminated water prior to treatment, the loading form the pit wall will not make any significant contribution to receiving environment conditions, except through the discharge of treated water. This is already accounted for in the modeling and the water quality of the treatment plant discharges is essentially independent of the loading to the pits.

5.3.2 Grum Pit

As outlined in the Project Description (SRK 2010), in-situ biological treatment is planned for Grum Pit. For modelling purposes it is assumed Grum Pit is essentially a “flow-in / flow-out” system. It assumes that the pit has reached the spill elevation and will discharge directly to the receiving environment at the water quality outlined in Table 5-15. The target effluent water quality for the in-situ biological treatment of Grum Pit is based on the average of the lowest values from the 2005 to 2008 monitoring period (J Chapman, SRK Consulting Inc, personal communication, November 2009).

Table 5-15 Grum Pit In-Biological Treatment Target Effluent Water Quality

Total Metals	Target Effluent Limit (mg/l)
Acidity	0.0
Alkalinity	5.2
Sulphate	341
Chloride	1.025
Aluminum	0.034
Arsenic	0.0007
Beryllium	0.0005
Boron	0.01
Cadmium	0.00063
Calcium	99.8
Chromium	0.0005
Cobalt	0.0054
Copper	0.00089
Iron	0.071
Lead	0.001
Magnesium	59.3
Manganese	0.129
Molybdenum	0.0025
Nickel	0.092
Potassium	2.55
Selenium	0.0014
Silver	0.000005
Sodium	8.82
Strontium	0.602
Thallium	0.00053
Tin	0.0001
Uranium	0.0088
Vanadium	0.0006
Zinc	0.493
Ammonia-N	0.183
Nitrate-N	0.66
Nitrite-N	0.004
Phosphorus	0.027



Legend

Catchment Outline

Dump Outline

Sulphide Cell

N

Notes

200 0 400 600 1200 feet

100 0 200 400 600 Metres

Faro Mine Closure
Fermeture de la mine Faro

JOB NO.: Gomm Environmental Engineering Consulting

FILE NAME: CoverOptimizationFaro2010.dwg

Faro Mine Complex
Closure and Remediation

Water Quality Model

Faro Mine Complex Site Wide Water Quality Model

DATE:	APPROVED:	FIGURE:
February 2010	Initials	5.1

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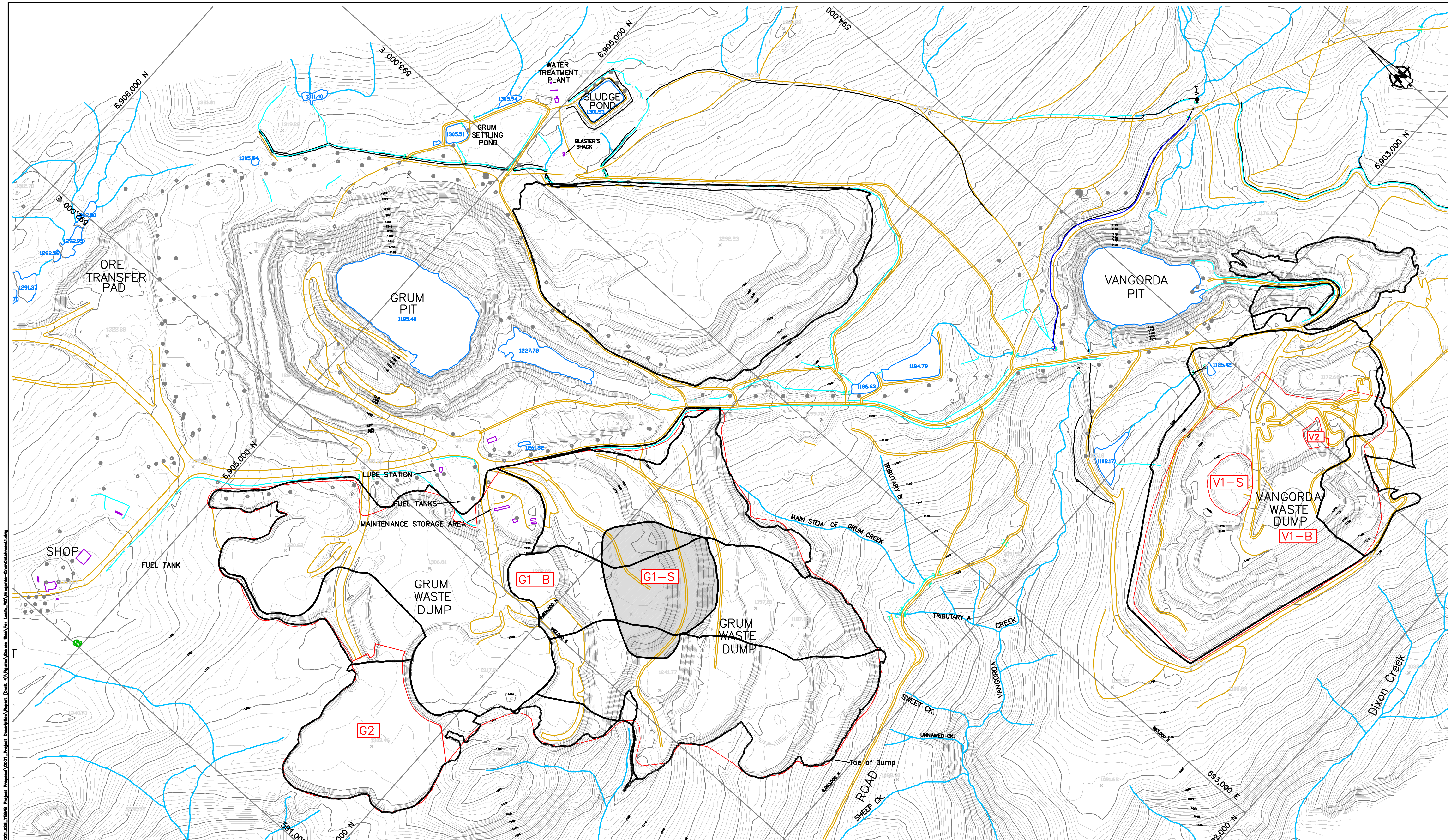


LEGEND

Catchment outline

Dump outline

Sulphide Cell

0 100 200 300 400 500 600 700 800 900 1000m

Faro Mine Closure
Fermeture de la mine Faro

JOB NO.:

File Name: Vangorda-GrumCatchment1.dwg

Faro Mine Complex
Closure and Remediation

Water Quality Model

Faro Mine Complex Site Wide Water Quality Model

DATE	APPROVED	FIGURE
Feb 2010		5.2

6 Collection and Treatment

At outlined in the Project Description (SRK 2010, groundwater interception will be required for many areas, although the timing and methods may differ. The model assumes that groundwater collection systems will be installed at the various locations around the site according to the plan schedule laid out in the Project Description (SRK 2010). This includes upgrading of areas with existing collections systems such as the ETA and S-Well area. Once implemented, the model assumes that the efficiency of the groundwater collections systems will range from 95 to 99.9 %. In the Goldsim model, groundwater collection efficiency is modeled stochastically assuming a uniform distribution ranging from 95 to 99.9%.

The model assumes that all groundwater seepage, from either the tailings area or the waste rock dumps, that is collected is then routed to Faro Pit on the Faro side and Vangorda Pit on the Vangorda Plateau side for storage prior seasonal treatment and discharge.

The model also assumes that the pit water is treated using a high density sludge treatment system and discharged seasonally (May to September) to the receiving environment. The assumed treated effluent concentration is presented in Table 6-1.

Table 6-1 Water Treatment Plant Target Effluent Water Quality

Total Metals	Target Effluent Limit (mg/l)
Aluminum	0.01
Arsenic	0.005
Beryllium	0.005
Boron	0.1
Cadmium	0.005
Cobalt	0.005
Copper	0.009
Iron	0.005
Lead	0.015
Magnesium	0.025
Manganese	0.3
Nickel	0.06
Zinc (without Sand Filter)	0.1
Zinc (With Sand Filter)	0.05

The discharge location on the Faro side is assumed to be immediately downstream of the confluence of the North and South Forks of Rose Creek. On the Vangorda side the discharge locations is assumed to be in the area where Vangorda Creek crosses the site access road, below the existing drop structure. In addition the model assumes that the water in Grum Pit will continue to be treated biologically. During the open water season treated surface water in Grum Pit will be discharged to Vangorda Creek.

7 Background and Downstream Receiving Environment

The monthly source loadings and source flows from the mine related sources outlined in the previous sections are added to the receiving environment flow at the model points listed in Section 1. At each location the combined monthly load and flow contributing is added to determine the total monthly load and flow.

Total Monthly Load (kg) = Upstream Load (kg) +
Contaminated Surface Runoff Load (kg) +
Clean Surface Runoff Load (kg) +
Contaminated Seepage Load (kg)

Total Monthly Flow (m^3) *= Upstream Flow* (m^3) *+*
Contaminated Surface Flow (m^3) *+*
Clean Surface Runoff Flow (m^3) *+*
Contaminated Seepage Flow (m^3)

At the mouth of the Rose Creek Diversion Channel model point on the Faro side the monthly load and flow contribution from the discharge of treated effluent is also added. On the Vangorda side at the V27 model point in Vangorda Creek, the discharge of treated effluent from Vangorda Pit is included as well as any discharge of pit water from Grum Pit.

The monthly concentration at each receiving environment model point is then calculated as:

$$\text{Monthly Concentration (mg/L)} = \text{load (kg)} / \text{flow } (m^3).$$

For unimpacted surface water in the Vangorda and Rose/Anvil Creek watersheds the water quality is set to the background water quality or benchmarks developed by Minnow Environmental Inc. (Minnow 2009). For the Pelly River, the upstream or background water quality is taken as the 95th percentile of the data set presented in AECOM (2009).

Monthly surface water runoff from the upstream watersheds and unimpacted areas is calculated using the same method outlined for surface runoff from the waste rock dump areas, with monthly distributions of runoff developed based on available data from long-term monitoring locations at the site. For the upper reaches of the Rose Creek watershed, specifically North Fork Rose Creek and Faro Creek the monthly distribution of runoff is based on the surface water runoff distribution at R7 in the North Fork of Rose Creek (Table 7-1). For the remainder of Rose Creek and Anvil Creek the monthly distribution of surface runoff is based on that at the flow monitoring station at X14 in Rose Creek (Table 7-1). On the Vangorda side, all surface water runoff distributions are based on the long-term monitoring record from station V8, located in Vangorda Creek near the Town of Faro (Table 7-1).

Table 7-1 Monthly Surface Runoff Distribution (%)

Month	R7 North Fork Rose Creek	X14 Rose Creek	V8 Vangorda Creek
January	3.1	1.4	1.5
February	2.3	1.0	1.1
March	2.3	0.9	1.0
April	2.8	1.3	1.4
May	24.0	28.6	26.8
June	20.5	21.4	21.2
July	12	13.2	14.4
August	9.6	10.3	9.6
September	9.3	10.2	10.2
October	6.7	6.5	7.3
November	3.8	3.1	3.2
December	3.6	2.1	2.3

8 Model Results

Results of the predicted water quality concentrations in the receiving environment for both scenarios were provided to Minnow Environmental Inc., AECOM and SENES to support the assessment of potential impacts of the predicted future water quality on the aquatic ecosystem and for incorporation into the HHERA. The environmental assessment and HHERA are still underway and the results are not yet available for distribution. The results of the work carried out by Minnow Environmental Inc., which focused on the potential impacts to the aquatic ecosystem as a result of elevated zinc, cadmium and sulphate concentrations, is available under separate cover.

Although, a detailed assessment of the impacts of predicted water quality is outside the scope of this project, a preliminary summary of the model results is presented in the following sections.

8.1 Load Contribution

The proportion of zinc loading from the various sources, prior to any groundwater interception/collection, is presented in Figures 8-1, 8-2 and 8-3 for Year 0 (prior to closure implementation), Year 20, and Year 150. These figures are based on the predicted median results for the Best Estimate Scenario. Illustrated in these figures is the progression over time (Year 0 to Year 150) of the dominant influences on zinc loading from the Faro Mine Complex.

Prior to the implementation of any closure related activities, including early reclamation, the oxide fines and low grade stockpiles in the Faro Mine Area are the largest contributor to zinc loading from the site, attributing up to 50 % of the total loading. The next largest contributors to zinc loading are the tailings (21%), Vangorda Main Dump (14%) and the Vangorda Sulphide Dump (9%).

In Year 20, five years after implementation of closure, the tailings become the largest potential contributor of zinc loading, attributing up to 80% of the total loading from the site, prior to any groundwater interception. The next largest contributors are the majority of the Faro Waste Rock Dumps (11%) and the Vangorda Main Dump (6%). At this time the majority of the dumps on the site are predicted to still be exhibiting neutral drainage conditions.

In Year 150, the Faro Waste Rock Dumps (excluding the sulphide cells) are predicted to become the largest potential contributor of zinc loading (72%). The dumps driving this loading are the Main Dumps (East and West), Ore Haul Road East Dump, and the Intermediate Dump. At this time the model predicts that these dumps have depleted available neutralizing potential and transitioned to acidic conditions. At Year 150, the Vangorda Main Dump has started the transition to acidic conditions but still has approximately 25% NP remaining. Once this dump depletes the residual NP and transitions fully to acidic conditions the breakdown of zinc load contribution will change, with increases in contribution from the Vangorda Dumps.

8.2 Predicted Concentrations – Receiving Environment

Plots of predicted zinc and cadmium concentrations in the receiving environment are presented in Figures 8-4 to 8-9 and for predicted zinc and cadmium concentrations in Rose Creek (X14) and in Figures 8-10 to 8-15 for Vangorda Creek (V8). As outlined previous, detailed assessment of the impact of the predicted water quality on the aquatic ecosystem is presently being carried out separately as part of the preparation of the Project Proposal submission for the Yukon Socio-Economic Assessment Board (YESAB).

These plots illustrate the predicted future trends in water quality in the downstream receiving environment after implementation of the proposed closure plan. Key conclusions that can be drawn from review of these plots are:

- Predicted future concentrations of both zinc and cadmium are predicted to increase well into the future to concentrations above those currently being measured downstream of the Faro Mine Complex.

- The increased in downstream concentrations are due to the increased loading, even with groundwater collection at efficiencies in the range of 98%, coming from seepage from waste rock and tailings that bypass the collection systems.

- Both zinc and cadmium concentrations are predicted to exhibit seasonal variations downstream of the site.

- Early post-closure (Year 20 to Year 30), zinc concentrations in the receiving environment at both the Faro and Vangorda/Grum Mine Areas peak during the winter low flow period due to the influence of seepage bypassing the groundwater collection systems.

- 100 years post-closure, zinc continues to exhibit the same seasonal variations, albeit, with significantly higher peak concentrations due to the ongoing degradation in the seepage water quality as the dumps transition from neutral to acidic conditions.

- Early after closure implementation (Year 20 to Year 30) cadmium concentrations are higher during the open water season. This is primarily due to the influence of the discharge of treated water from the site.

- Approximately 100 years post-closure, cadmium begins to exhibit a different seasonal trend as illustrated in Figures X and Y. At this time, the influence of the degrading seepage from the waste rock dumps bypassing the collections systems is starting to influence the downstream water quality, resulting in higher concentrations during the winter low flow period.

Figure 8-1 Zinc Load Contribution – Year 0

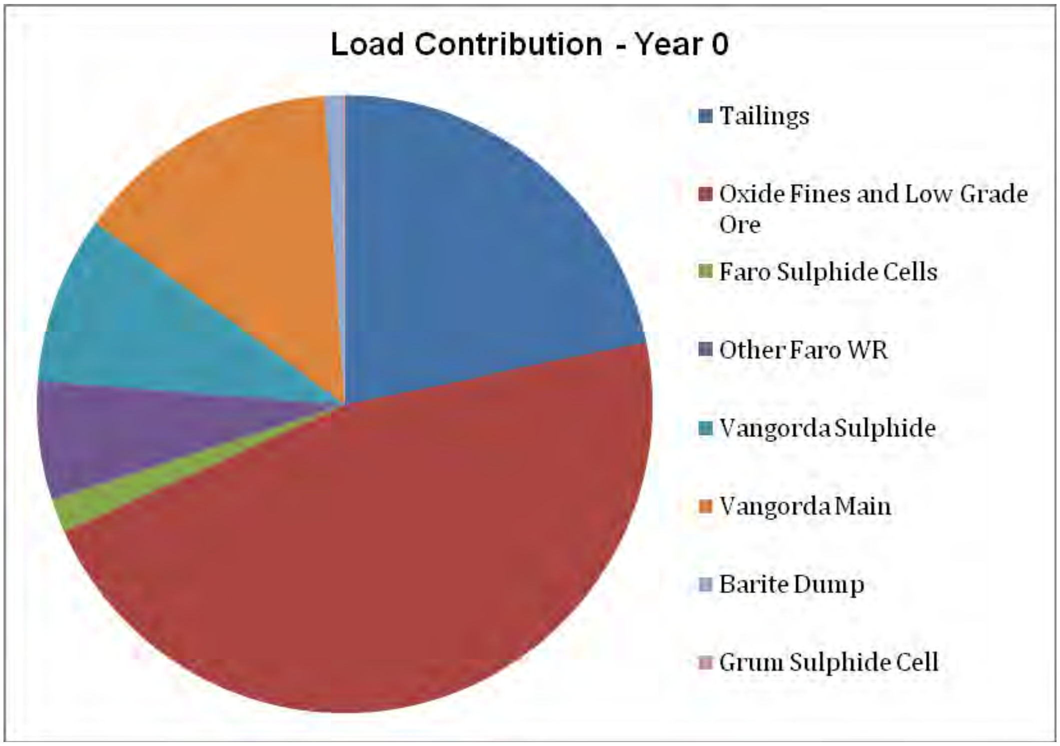


Figure 8-2 Zinc Load Contribution – Year 20

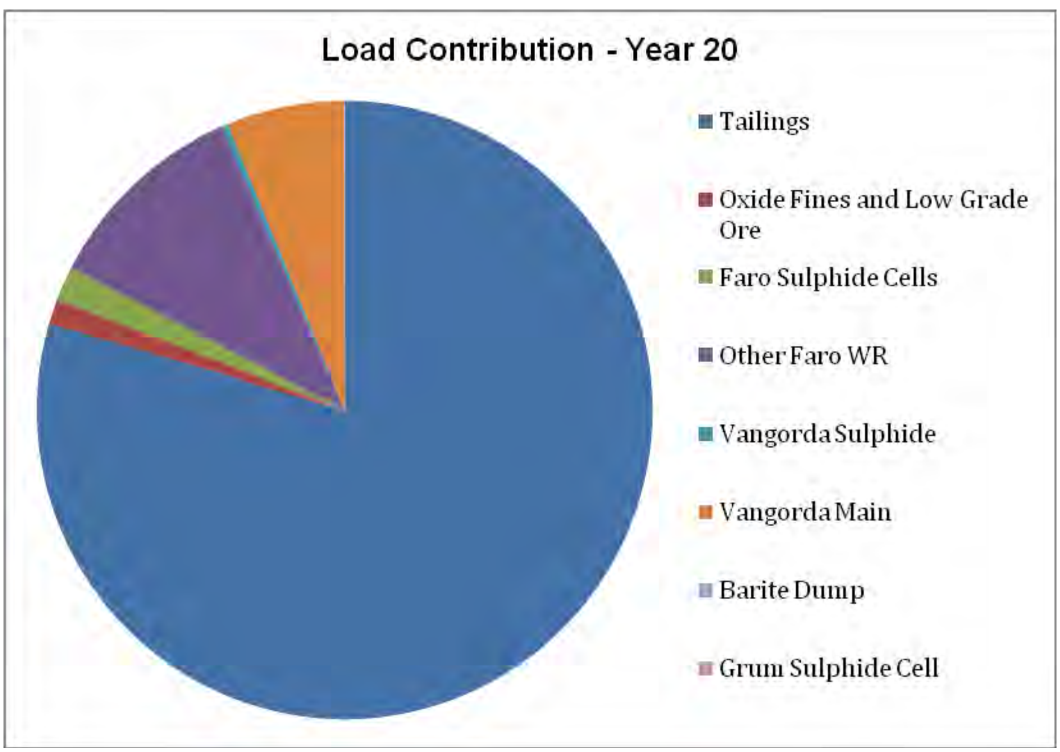


Figure 8-3 Zinc Load Contribution – Year 150

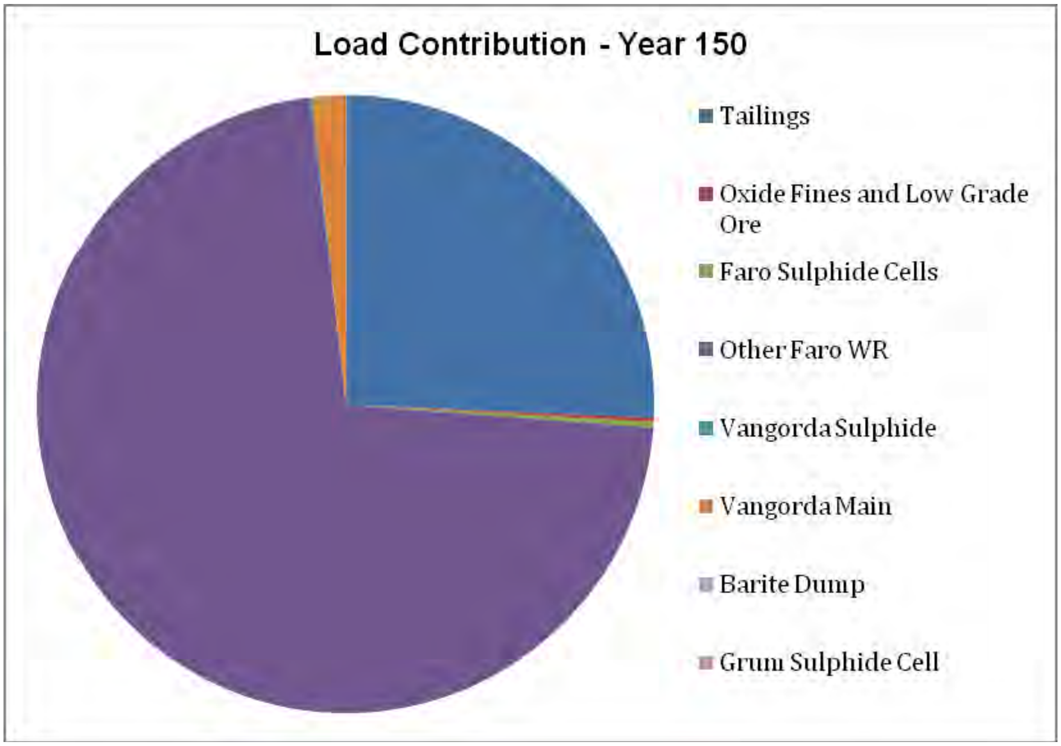


Figure 8-4 Predicted Zinc Concentration – Rose Creek (X14)

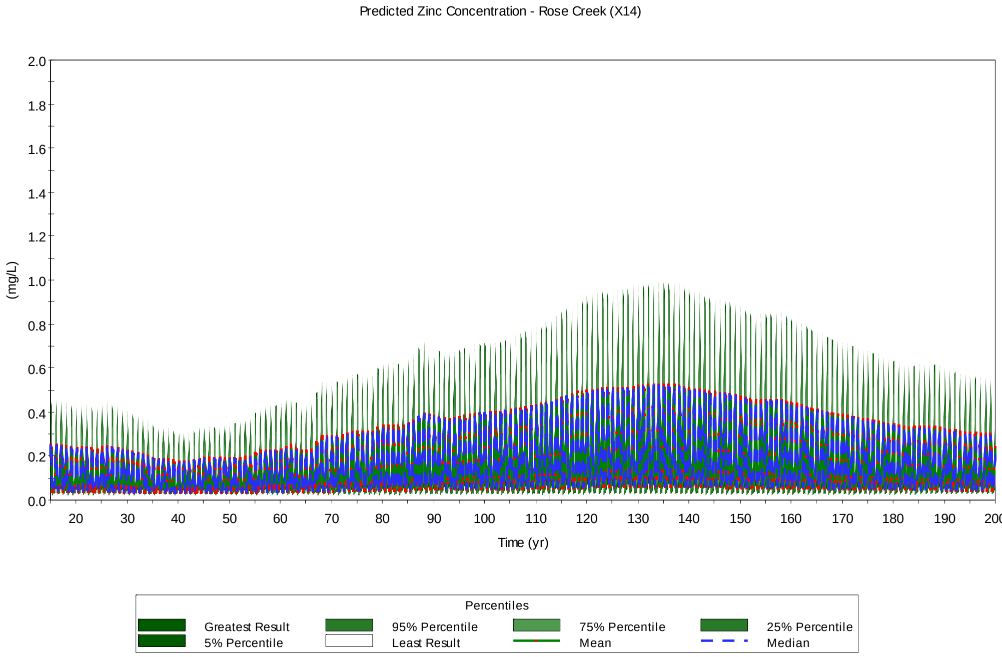


Figure 8-5 Predicted Zinc Concentration – Rose Creek (X14) – Year 20 to 30

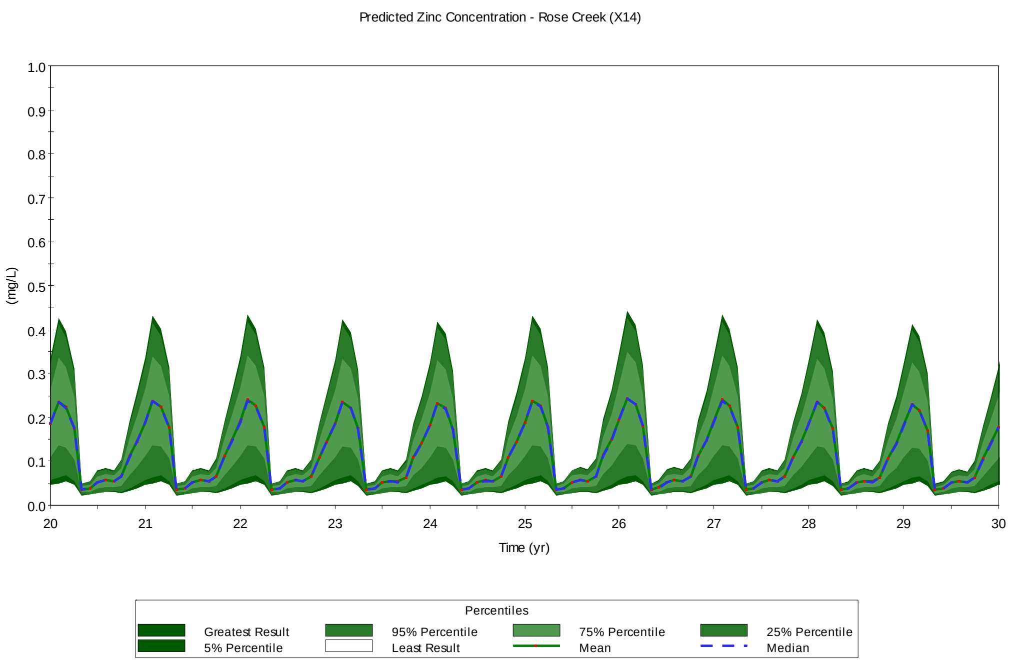


Figure 8-6 Predicted Zinc Concentration – Rose Creek (X14) – Year 130 to 140

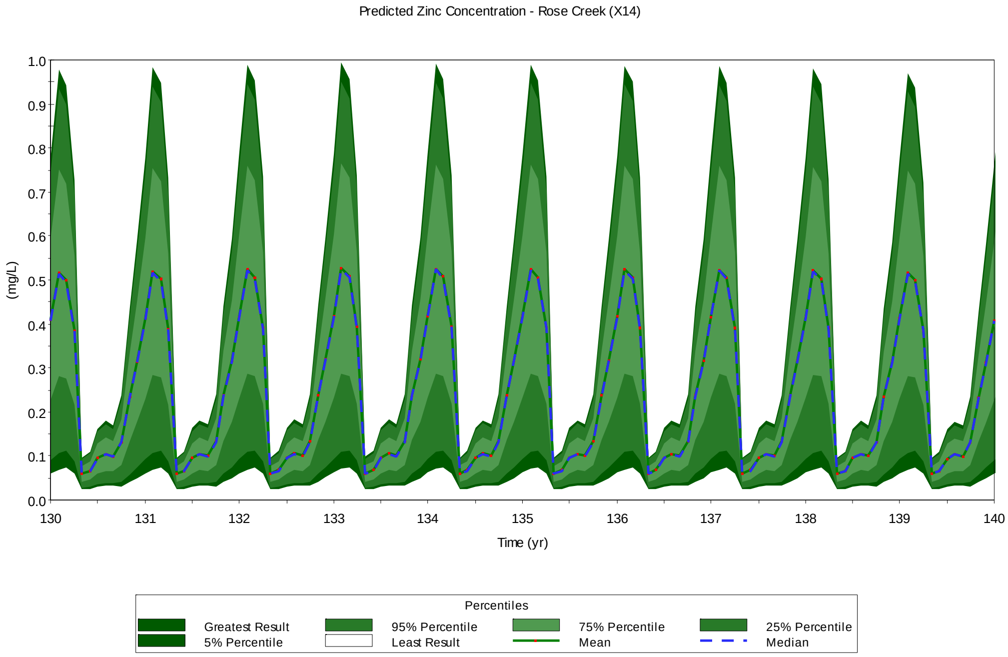


Figure 8-7 Predicted Cadmium Concentration – Rose Creek (X14)

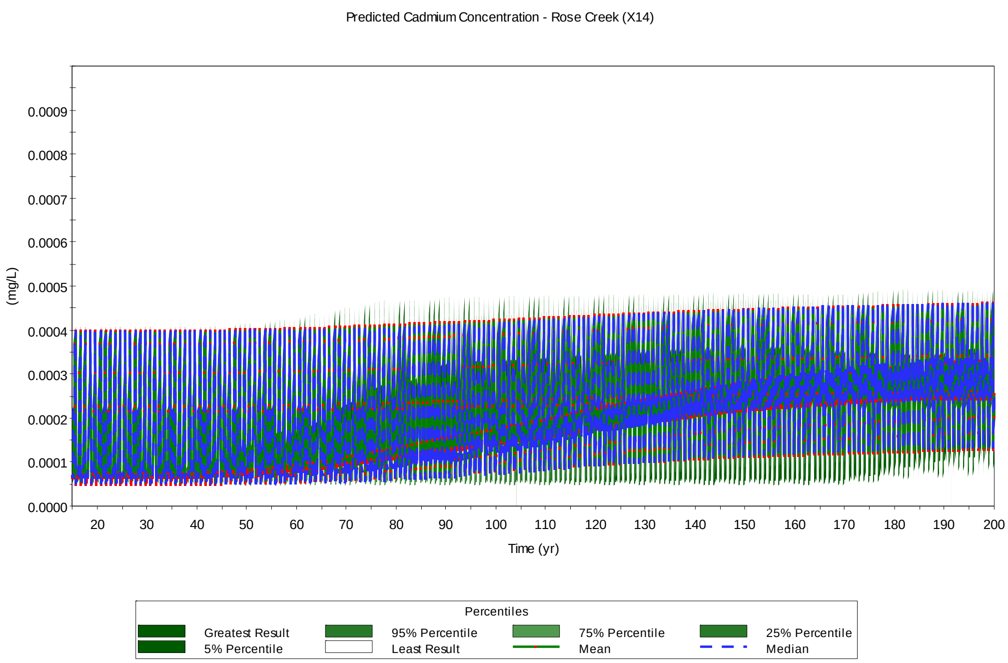


Figure 8-8 Predicted Cadmium Concentration – Rose Creek (X14) – Year 20 to 30

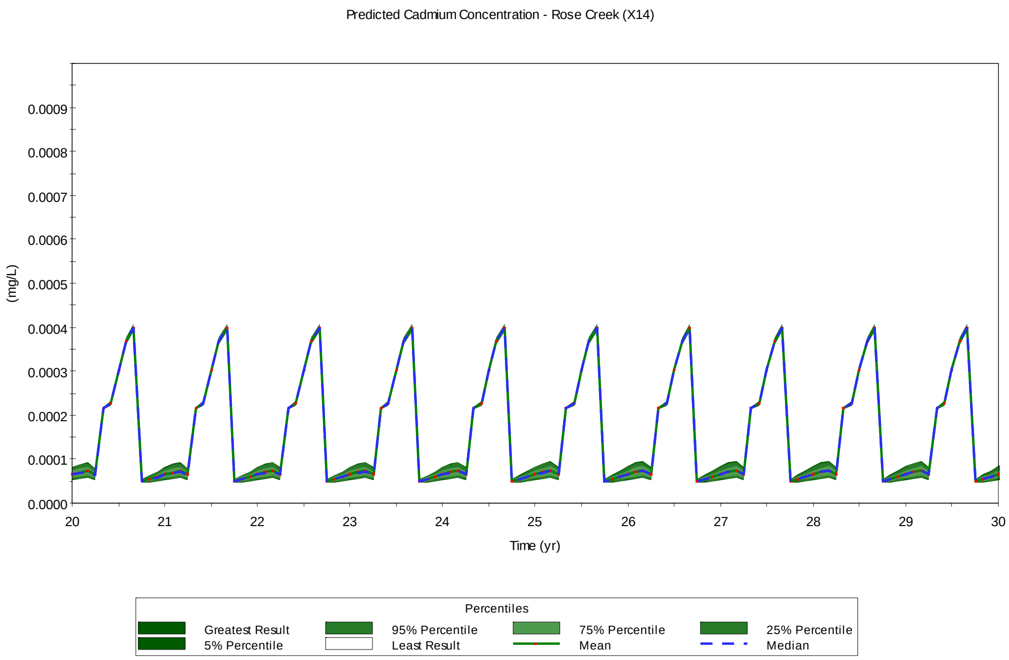


Figure 8-9 Predicted Cadmium Concentration – Rose Creek (X14) – Year 130 to 140

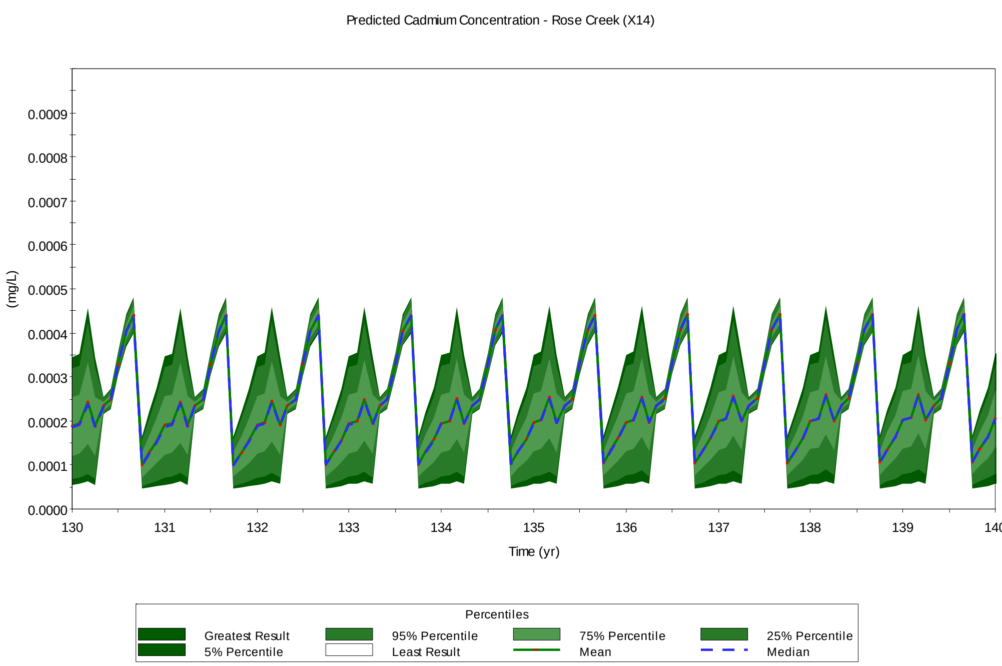


Figure 8-10 Predicted Zinc Concentration – Vangorda Creek (V8)

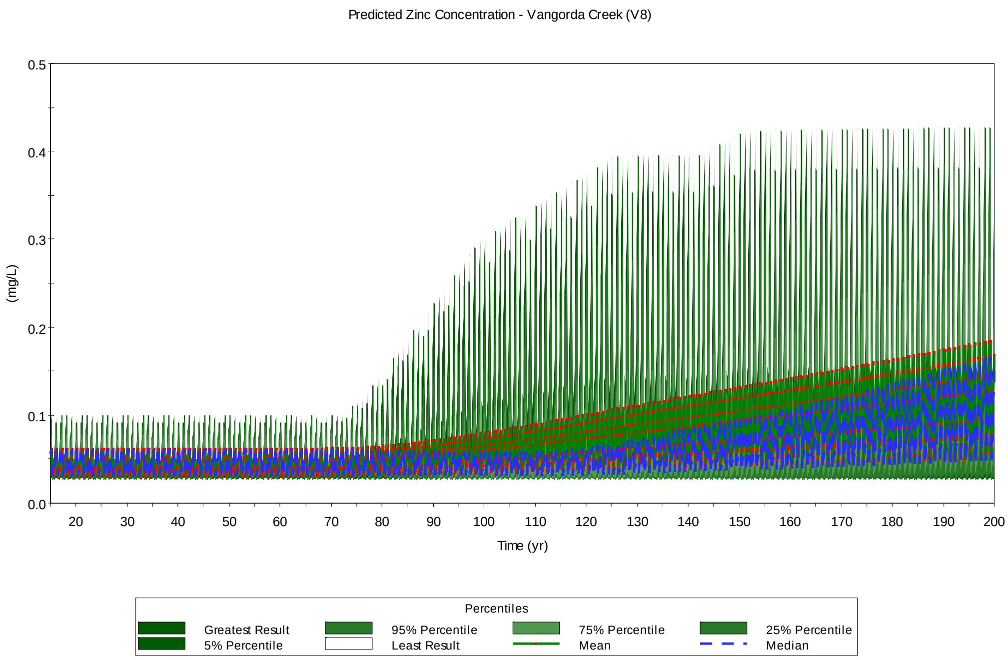


Figure 8-11 Predicted Zinc Concentration – Vangorda Creek (V8) – Year 20 to 30

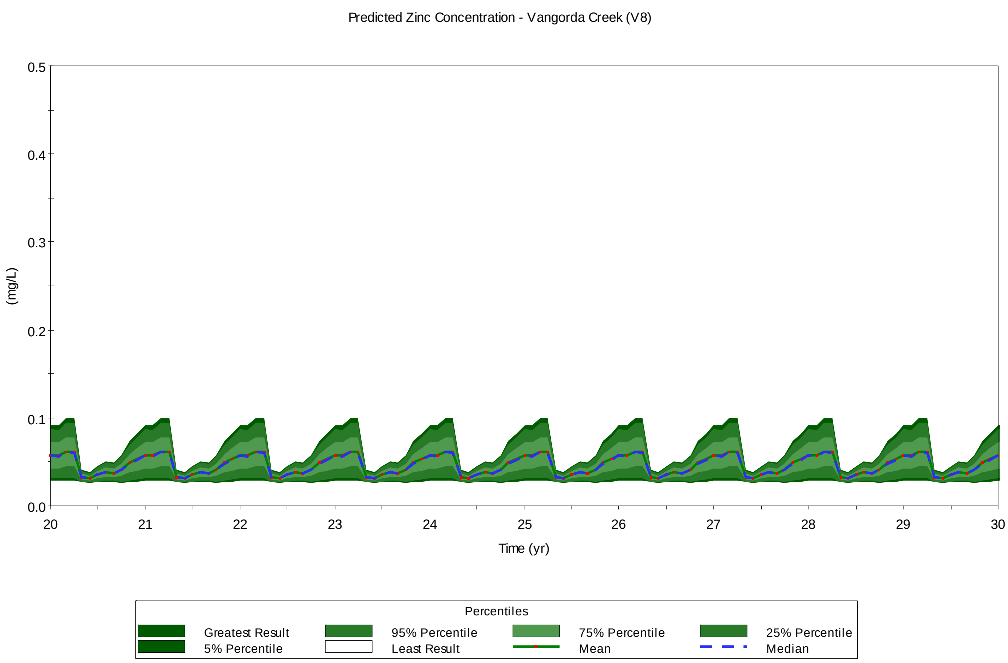


Figure 8-12 Predicted Zinc Concentration – Vangorda Creek (V8) – Year 130 to 140

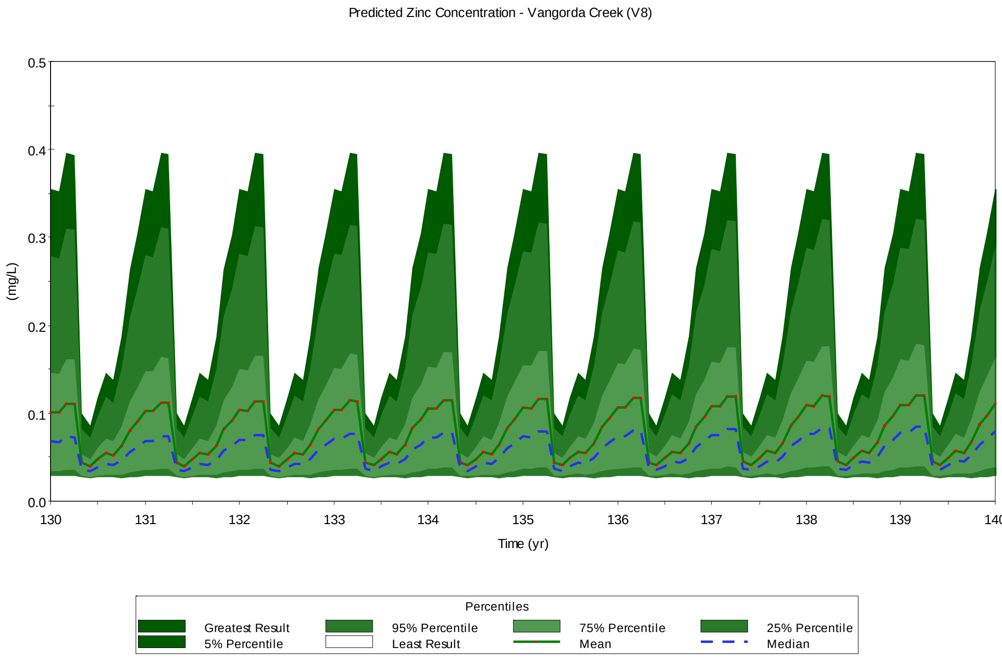


Figure 8-13 Predicted Cadmium Concentration – Vangorda Creek (V8)

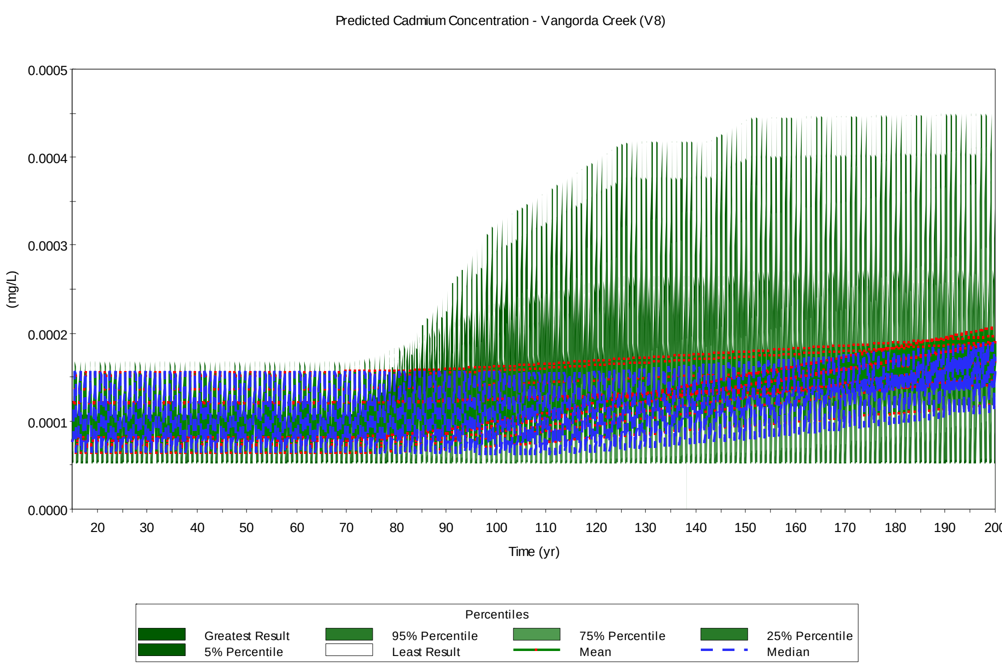


Figure 8-14 Predicted Cadmium Concentration – Vangorda Creek (V8) – Year 20 to 30

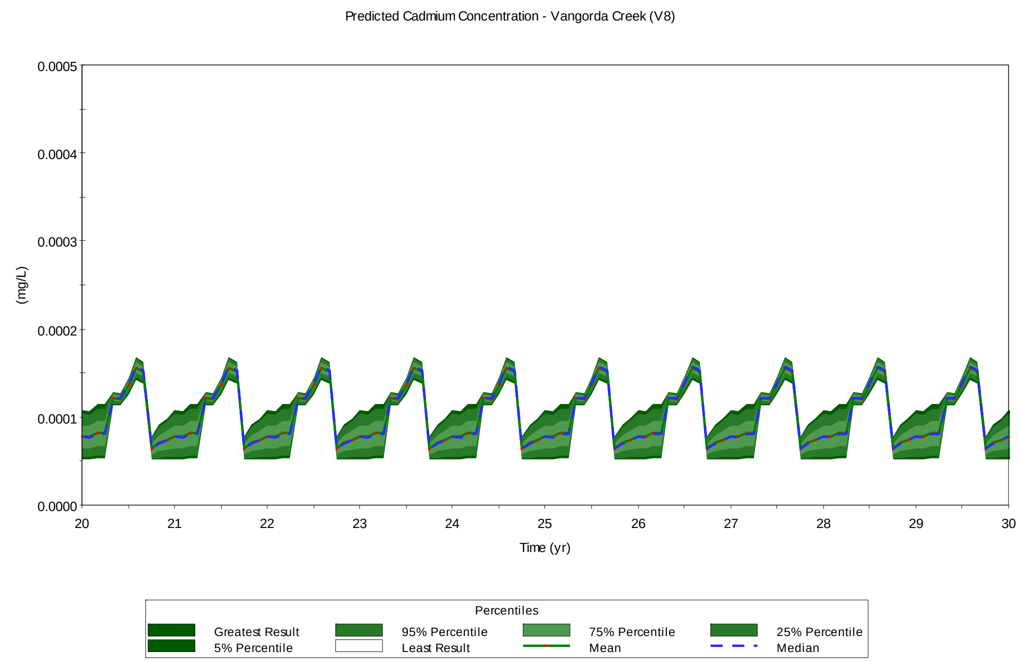
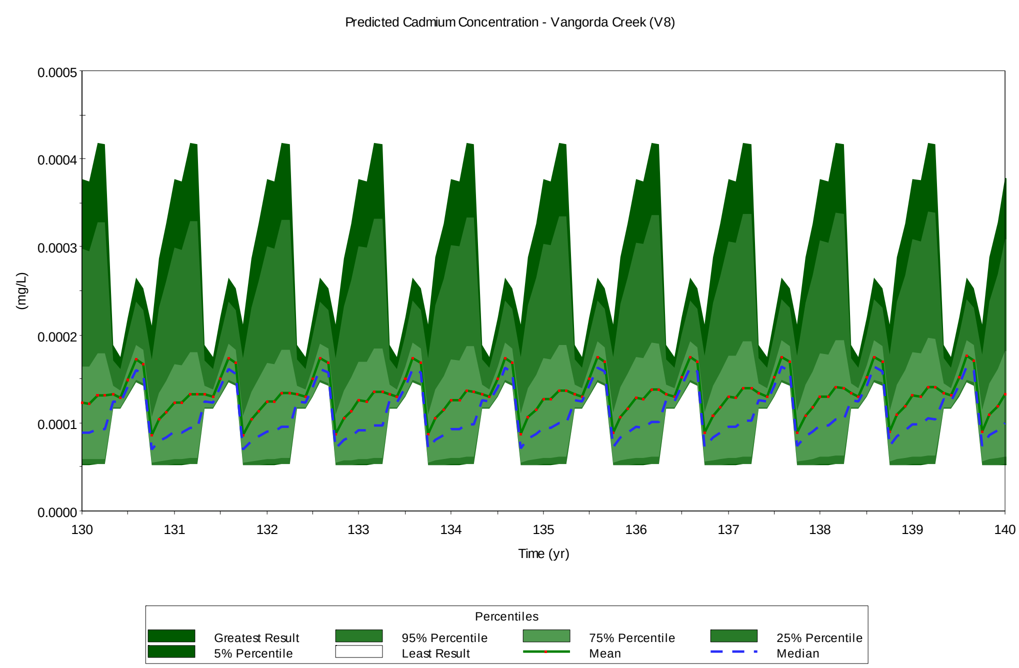


Figure 8-15 Predicted Cadmium Concentration – Vangorda Creek (V8) – Year 130 to 140



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