NorthMet Mine Site Water Modeling Work Plan

February 14, 2012 – Version 6

This document is the work plan for water modeling at the NorthMet Project Mine Site as specified in the following Water Resources IAP Position Documents:

- Geochemistry (June 20, 2011)
- Groundwater (June 30, 2011)
- Surface Water (June 30, 2011)
- Impact Criteria (October 19, 2011)

Modeling of the estimated impacts to surface and groundwater quality at the selected evaluation locations will be performed as a probabilistic Monte Carlo simulation in the GoldSim simulation software (see Reference (1) Section 3.1 *Monte Carlo Simulation Background* and 3.2 *Probabilistic Model Overview*). The model output will be continuous from the start of mining (year 0) to approximately steady state post-closure conditions (estimated duration of 200-500 years), with calculations performed on a monthly time step and results summarized as monthly or annual values as appropriate. Steady state post-closure conditions are defined as:

- The West Pit is flooded and overflowing with constant or decreasing concentrations
- The Category 1 Waste Rock Stockpile cover system is at the long-term modeled effectiveness (fully established vegetation)
- The groundwater concentrations at the furthest evaluation locations (i.e., Partridge River) have peaked and are declining towards an approximate steady state

The model inputs that are known or have very small variability and can be modeled as deterministic (as either time-series or constant through time) are termed *deterministic inputs*. Typical deterministic inputs are engineering design parameters (stockpile area, pit dimensions, pump capacity, etc.), operational parameters (mining schedule, tons in stockpiles, etc.) and physical characteristics (flowpath dimensions, stream segment length, etc.).

The model inputs that have uncertainty in their true values or temporal or spatial variability at any point in the life of the project are termed *uncertain inputs*. These uncertain inputs may be constant through time or vary through mine operations and closure. Typical uncertain inputs represent natural variability (annual precipitation and evaporation, stream flow, etc.), environmental parameters (average aquifer conductivity, average recharge water quality, etc.), geochemical parameters (constituent generation rates, scale factors, concentration caps, etc.) and performance of engineered systems (cover effectiveness, liner effectiveness, etc.) Each uncertain input has a defined probability distribution, frequency of sampling and correlation coefficients (if appropriate).

Table 1-1 contains a complete list of all deterministic and uncertain inputs to the Mine Site water quality model, including parameters to define all probability distributions. Tables 1-2 through 1-34 and Figures 1-1 through 1-7 provide additional detailed input information for selected model inputs. All numerical inputs to the probabilistic water quality model are represented in these tables and figures.

The probabilistic water quality model will be executed for a number of simulation realizations (runs) consistent with the desired result percentiles. For each realization, the uncertain inputs will be randomly sampled based on the defined probability distributions. Within each realization the deterministic inputs may vary as a function of time and the uncertain inputs may be sampled according to a defined frequency (e.g., precipitation sampled every year).

The model outputs are selected constituent concentrations at selected surface and groundwater evaluation locations through time. See Table 2-1 for a list of constituents and Table 2-2 for a list of evaluation locations. The model results will provide sufficient data to demonstrate compliance with specified impact criteria (ex. water quality standards). Impact criteria will be compared to each model realization to determine compliance or non-compliance for that model realization. According to the Impact Criteria Final Summary Memo, a "compliant" model realization at an evaluation point is defined as having no exceedances of applicable water quality standards (surface or groundwater). If greater than 10% of model realizations are non-compliant (< 90% probability of compliance) at an evaluation point, the impact from the project will be considered to be significant without further mitigation. In interpreting these results the Lead Agencies will consider the results of the No Action Alternative model and the surface water flow scenarios used for permitting, as well as the potential mitigation measures available to achieve a 90% probability of compliance.

In addition to demonstrating the overall probability of a project resulting in non-significant impacts, model results will be presented to quantify the overall impact of the project. The results may be presented in multiple formats, including:

1. A series of charts showing the time-series of each model output from start to stable closure as trend lines at specified probabilities (e.g., 10 and 90 percent), including the applicable water quality standard (see Figure 2-1 for a typical output)
2. A series of charts showing the histogram or cumulative distribution function for selected time-independent outputs, such as the peak concentration from each realization at a groundwater evaluation location, including the applicable water quality standard (see Figure 2-2 for a typical output)
3. A series of charts showing the change in water quality exceedances (if applicable) relative to the no action condition as a histogram or cumulative probability function (e.g., there is an XX percent chance that Y more exceedances will occur at location Z, see Figure 2-3 for a typical output)
4. A series of tables summarizing the results shown on the above figures

It should be noted that mercury is not included in the list of constituents for inclusion in the probabilistic model, which is consistent with the IAP Position Documents. A separate evaluation of expected mercury concentrations in the West Pit outfall is presented in Section 5.8 of Reference (1).

The modeling described in this document is for initial modeling of potential project impacts. This modeling may be refined and/or models for additional engineering controls may be added as part of mitigations that may be developed during the modeling process. If this occurs, changes will be documented in a Change Definition Form that will identify the change as a model refinement, mitigation to be incorporated into the project or mitigation to be included as part of adaptive management. The Change Definition Form will describe the change and provide supporting information, list the Project Description, Data Package and Management Plan sections that will be updated as a result of the change and identify potential impacts of the change to other impact areas being evaluated in the SDEIS. There will be a Change Definition Form for each change.

The Change Definition Form will be submitted to the Lead Agencies for review and approval. Once modeling is complete, the information contained in all Change Definition Forms will be transferred to the Project Description, Data Packages and Management Plans and those documents will be submitted to the Lead Agencies for audit to ensure that all Change Definition Form information has been properly transferred to project documents.

There are alternate modeling assumptions that have been discussed in the Impacts Assessment Planning Process that are not included in the initial modeling of potential project impacts. These alternate modeling assumptions may be used as directed by Lead Agencies.

Conceptual Models:

The project that will be modeled is the project described in the Lead Agency Draft Alternative Summary of 03/04/2011. As modeling proceeds, model inputs that represent engineering controls may be adjusted to achieve acceptable outcomes in the most cost effective manner. If that is done, there will be multiple sets of model outputs provided – one with engineering controls as originally specified and others with modified engineering controls.

Figures A, B and C show simple block diagrams of the conceptual model for the Mine Site in operations and closure. The conceptual model includes water available, constituent sources, flow paths (attenuation of select constituents, dilution), engineered features (liners, covers), existing conditions, etc.

A companion model for the No Action Alternative at the Mine Site will be constructed using the same input assumptions as described in this document, but with the removal of all project-related components. This model will allow for the comparison of project impacts to modeled No Action conditions, which are identical to the existing conditions for the Mine Site. It may be desirable to run the No Action model in parallel to project models (i.e., using the sample uncertainty inputs at each time step) to determine whether specific model results are due to project conditions or existing conditions.

The following paragraphs describe individual conceptual model components.

Stockpile Conceptual Model

The waste rock stockpiles and the Ore Surge Pile are modeled by determining the water available at the top of the stockpile (function of precipitation, evaporation, runoff and stockpile area) and calculating how much water will reach the bottom of the stockpile (function of cover design and effectiveness) for each model time step (see Reference (1) Section 6.1.1 *Stockpile Hydrology Modeling*). For that same time step, the mass of constituent available is calculated by multiplying constituent generation rates from lab tests on specific types of rock and whole rock metals concentrations (see Reference (2) Section 8.1 *Laboratory Release Rates*) by the amount of that rock in the stockpile and applying scale factors that account for lab/field differences in temperature, rock size and water contact (see Reference (2) Section 8.2 *Lab to Field Scale-Up*). The available constituent is mixed with the volume of water that reaches the bottom of the stockpile to calculate the estimated concentration in the water at the bottom of the stockpile. The estimated concentration is compared to expected limiting concentration under field conditions (the "concentration cap"), and the lower of the two concentrations is selected (see Reference (2) Section 8.3 *Concentration caps*). Any constituent mass that cannot be leached due to concentration caps is retained in the stockpile as precipitated mass, available for leaching in the future. The amount of water leaking from the stockpile is determined by the amount of water reaching the bottom of the stockpile and the liner/containment system design and effectiveness (see Reference (1) Section 6.1.3 *Process Water*). The amount of water collected by the liner/containment system that does not leak and must be treated is the water reaching the bottom of the stockpile minus the water leaking. The small amount of additional loss of this water in the leakage from the double-lined stockpile sumps is negligible and will not be considered in the model (see Reference (1) Section 6.1.3.4.3 *Stockpile Sumps*).

Saturated overburden material is placed in the temporary Category 2/3 and Category 4 Waste Rock Stockpiles. This material is not modeled separately but is assumed to behave as additional mass of the waste rock in each stockpile, including the contribution of chemical load to the East Pit backfill (see Reference (2) Section 7.0 *Geochemical Parameters – Overburden*).

The water collected from the stockpile sumps is combined with the water collected from other stockpile sumps, mine pit sumps, haul road ponds and the Rail Transfer Hopper pond at the Waste Water Treatment Facility (WWTF) (see WWTF Conceptual Model).

The water infiltrating the Category 1 Stockpile is either collected in the groundwater containment system or is purposely not collected and flows directly to the West Pit. The groundwater containment system is designed with a clay barrier to prevent outflow of stockpile drainage and to minimize inflow from adjacent areas (see Reference (1) Section 6.1.3.1.1 *Infiltration Water Balance*). The loss of Category 1 Stockpile drainage through this system and the inflow of surficial groundwater from outside of the Mine Site are assumed to be zero.

The water leaking from the lined stockpiles (Category 2/3, Category 4, OSP) percolates to the unconsolidated aquifer and flows to a groundwater evaluation point (see Groundwater Transport Conceptual Model).

Pit Conceptual Model

The mine pits are modeled by determining the water at the bottom of the pit (function of precipitation, evaporation, runoff, pit area and groundwater inflow) for a given month of mine life (see Reference (1) Section 6.1.3.3 *Mine Pits*). Annual precipitation and open-water evaporation for all features on the Mine Site are selected from uncertainty input distributions and distributed among months using deterministic factors (i.e. percent of annual) (see Reference (1) Section 5.2 *Climate Model Inputs*). Runoff factors (i.e. percent of precipitation) for the pit walls and contributing areas outside of the pits are selected from uncertainty input distributions for both winter and open-water periods (see Reference (1) Section 6.1.3.3.2 *Runoff*). The constituent loading from each source of water to the pit is calculated by multiplying the flow by the constituent concentration. For that same time step, the constituent load released by the wall rock is calculated by multiplying constituent generation rates from lab tests on specific types of rock whole rock metals concentrations (see Reference (2) Section 9.1 *Laboratory Release Rates*) by the amount of that rock in the pit wall (see Reference (2) Section 9.2 *Mass of Reactive Wall Rock*) and applying scale factors that account for lab/field differences in temperature, rock size and water contact (see Reference (2) Section 9.3 *Lab to Field Scale Up*). The available constituent mass is mixed with the volume of water that is runoff on the pit walls to calculate the estimated concentration in the water in the pit wall runoff. The estimated concentration is compared to expected limiting concentration under field conditions (the "concentration cap"), and the lower of the two concentrations is selected (see Reference (2) Section 9.5 *Concentration caps*). Any constituent mass that cannot be leached due to concentration caps is retained in the pit walls as precipitated mass, available for leaching in the future during pit flooding. The total dissolved constituent is mixed with the water at the bottom of the pit to calculate the estimated concentration in the water at the bottom of the pit. The constituent loading from the in-pit inventory of blasted ore is calculated in the same manner as for the Ore Surge Pile (see Stockpile Conceptual Model) and is combined with the load from the pit walls during operations.

During operations, the water at the bottom of each pit is pumped to the WWTF and combined with the water collected from stockpile sumps, haul road ponds and the Rail Transfer Hopper pond (See WWTF Conceptual Model). The surface water and groundwater inflows increase during the mine life; the amount of rock in the pit wall is assumed to be equal to that in the final pit shell from the beginning of mining.

Once the East Pit ore is exhausted (year 11), the temporary Category 2/3 and 4 Stockpiles will be relocated to the East Pit and all Category 2, 3 and 4 rock mined after that point will go directly to the East Pit. The relocated rock will add constituent resulting from oxidation in the rock while in the temporary stockpiles (function of the constituent generation rates from lab tests on specific type of rock, the amount of rock in the stockpile, the time the rock was in the stockpile, scale factors for lab/field differences in temperature, rock size and water contact) to the pit water (see Reference (2) Section 8.0 *Geochemical Parameters – Waste Rock*). The East Pit will be flooded with water as this backfill rock is added, with all but the upper few feet of backfill rock submerged at any time provided enough water is available from the WWTF. During the later years of pit flooding, the water level will be maintained at a somewhat greater depth below the top of the backfilled rock in order to allow for safe mining in the Central Pit. The groundwater inflow and amount of exposed rock in the pit wall decrease as the pit floods with water. The East Pit overflows to the West Pit shortly after year 20 (see Reference (1) Section 6.1.3.3 *Mine Pits*). During the backfilling period the WWTF can treat the water in the East Pit to remove the constituents added with the relocated rock, and limestone can be added to the backfill to control the pH of the pore water as adaptive management strategies. After the East Pit is full the WWTF can continue to pump and treat the backfill water as long as necessary to meet water quality goals, while returning the treated water to the backfill so as to maintain subaqueous conditions.

Once the West Pit ore is exhausted (year 20), the pit will not be pumped and will flood with water. The groundwater inflow and amount of exposed rock in the pit wall decrease as the pit floods. The East Pit overflows to the West Pit shortly after year 20 (see Reference (1) Section 6.1.3.3 *Mine Pits*). Eventually, the West Pit overflows to the Partridge River and the cumulative effects of water inflow and constituent generation from mine walls is used to calculate the overflow water quality. During the flooding period the WWTF can treat the water in the West Pit to remove constituent mass (and return treated water to the pit), or other in-pit treatment strategies can be used. Once the West Pit reaches its overflow elevation, the pit can discharge either continuously or in a limited seasonal discharge as necessary to achieve water quality goals (see Reference (1) Section 5.5.2 *West Pit Overflow*). The West Pit will be assumed to be a well-mixed system in initial model runs, which will test the appropriateness of this assumption (see Reference (1) Section 6.1.3.3.6 *Pit Mixing*).

Ore Handling Areas Conceptual Model

The water collected from surface runoff of the haul roads and the Rail Transfer Hopper is routed to the WWTF along with the water collected from the waste rock stockpile sumps and the mine pit sumps. Water quality of runoff from the haul roads will be calculated from the Category 1 waste rock properties (see Reference (2) Section 8.0 *Geochemical Parameters – Waste Rock*) with an assumed one foot depth of crushed rock top dressing. Water quality of runoff from the Rail Transfer Hopper will be calculated from an estimated one foot depth of spilled fine ore using methods proposed to evaluate impacts of spilled ore along the transport corridor (see Reference (2) Section 8.4.3 *Ore Spillage from Rail Cars*). The liner leakage quantity from the double-lined Rail Transfer Hopper sump and the lined haul road process water ponds (which only hold water during storm events) is negligible and is not included in the model.

Ponds Conceptual Model

The quantity and quality of water leaking through the pond liners from the WWTF ponds is determined by the liner design and effectiveness and the amount of water assumed to be ponded on the liner (see Reference (1) Section 6.1.3.4 *Other Facilities*). The water quality of the liner leakage from these areas is based on the estimated water quality entering the ponds. The liner leakage quantity from all double-lined ponds and sumps is negligible and is not included in the model.

WWTF Conceptual Model

The water quantity and quality delivered to the WWTF are estimated as described in the Stockpile, Mine Pit and Ore Handling Area Conceptual Models. The WWTF is designed to treat the influent water as required to manage the Flotation Tailings Basin pond water quality. Target effluent concentrations from the WWTF are based on the required level of treatment and are model constants.

The WWTF is also used to remove constituents from the East Pit during backfilling of the East Pit and the West Pit during flooding of the West Pit, to ultimately manage the water quality of the West Pit overflow. Water will be pumped from the East Pit backfill and/or the West Pit to the WWTF and treated water will be returned to the pits proportionally.

Overburden Storage and Laydown Area Conceptual Model

The Overburden Storage and Laydown Area (OSLA) will not be lined; the properties of the in-situ soils and expected properties of the stockpiled overburden material are used to determine the rate of flow into groundwater (see Reference (1) Section 6.1.3.4 *Other Facilities*). This flow is treated in the models in a manner similar to the liner leakage from the waste rock stockpiles. The results of the Meteoric Water Mobility Procedures test leachate for peat and unsaturated overburden material are used to estimate water quality for the groundwater flow from the OSLA (see Reference (2) Section 7.0 *Geochemical Parameters – Overburden*).

The surface runoff collected from the OSLA is sent to the Central Pumping Station (CPS), combined with the effluent from the WWTF, and pumped to the Flotation Tailings Basin (see NorthMet Plant Site Water Modeling Approach).

Groundwater Transport Conceptual Model

Liner leakage from temporary stockpiles and groundwater seepage from flooded pits in closure will be carried via groundwater transport from the Mine Site to the Partridge River. In general, groundwater flows to the south and southeast from the Mine Site toward the Partridge River (see Reference (1) Section 5.4 *Groundwater Modeling*). Liner leakage from the OSP, WWTF ponds and OSLA, and temporary Category 2/3 Waste Rock Stockpile is assumed to reach the Partridge River between monitoring locations SW-003 and SW-004. Groundwater outflow from the flooded East Pit (surfical and bedrock flow paths) and East Pit mitigation wetland is also assumed to reach the Partridge River between monitoring locations SW-003 and SW-004. Groundwater outflow from the flooded West Pit is assumed to reach the Partridge River between monitoring locations SW-003 and SW-004 (portion of bedrock flow path) and between SW-004 and SW-004a (surficial and bedrock flow paths). Stockpile drainage from the Category 1 permanent waste rock stockpile will be collected by the groundwater seepage containment system and flow by gravity to the mine pits (if necessary this water could be routed to the WWTF). Liner leakage from the temporary Category 4 Waste Rock Stockpile is assumed to be drawn into the nearby East Pit until the stockpile is removed and the ground beneath it excavated to form the Central Pit portion of the East Pit.

The flow of water along each groundwater flow path is dependent on the amount of recharge applied to the aquifer from non-stockpile areas, the time-varying liner leakage from stockpile areas, and the groundwater flow discharging from the East or West pits (after the pits have flooded). The liner leakage rate from the stockpile areas will be estimated as described in the Stockpile Conceptual Model. The recharge rate from non-stockpile areas will be calculated at the initial time step of each realization based on the hydraulic conductivity along the flow path and the average hydraulic gradient along the flow path, both of which are uncertainty inputs to the model. Hydraulic conductivity and the recharge rate applied to non-stockpile areas will then be held constant for each realization. The gradient will be allowed to vary during the simulation to account for changes in the discharge from the flow path to the river due to temporal changes in liner leakage rates and pit inflow rates with the assumption that the head in the river is constant. Flow from the Mine Site pits will be calculated in the GoldSim model based on the calculated recharge to non-stockpile areas, the selected hydraulic conductivity, and an estimated hydraulic gradient which takes into account the pit water elevation.

Each source of water to the aquifer has dissolved constituents (at either elevated or background concentrations), which are added to the aquifer and transported via advection and dispersion. Attenuation due to sorption to the aquifer matrix will be simulated in the surficial aquifer for selected constituents (As, Cu, Ni, Sb). Sorption coefficients will be either a deterministic input (As, Cu, Ni) or a probabilistic input (Sb) to the model and with values determined using published information. The flow and transport models provide estimates of the water flow and dissolved concentrations at the groundwater evaluation points (see Reference (1) Section 5.4.1 *Groundwater Flowpath Modeling*).

<u>Surface Water Conceptual Model</u>

The probabilistic model will combine loads from the above sources transported via groundwater and other non-project sources (e.g. surface runoff, groundwater, Peter Mitchell Pit discharge) to calculate resulting water quality in the Partridge River at specific locations (see Table 2).

During each model time step, total flow in the Partridge River at each evaluation point is sampled from a flow distribution developed using a combination of observed data and XP-SWMM models (see Reference (1) Section 5.6.5 *Developing Probabilistic Inputs*). The total flow at each evaluation location is a combination of groundwater and surface water components. Constituent concentrations in natural (i.e. non-project) groundwater inflow are based on probabilistic distributions of observed data (see Reference (1) Section 5.3 *Input Chemistry*). For stockpile liner and stockpile sump leakage that flows via groundwater to the Partridge River, the estimated groundwater flow and constituent load is added to the river flow and constituent load and the resulting concentration in the river is calculated. Checks will be in place to ensure that discharge from the groundwater flow paths is proportional to the discharge from non-impacted portions of the watershed during low flow conditions (see Reference (1) Section 5.5.1 *Adjustment for Low Flow*).

Constituent concentrations in surface runoff are determined from calibration of an existing conditions model to observed concentrations in the Partridge River. The component of surface runoff in the Partridge River flow is the residual of the total flow minus the expected groundwater inflow (see Reference (1) Section 5.3.2 *Background Surface Runoff*).

Changes Relative to DEIS Deterministic Modeling:

There are changes in the modeling approach presented in this document compared to the approach used in the DEIS.

<u>Modeling Approach and Tools</u>

The DEIS used deterministic modeling that calculated a base, high and low case value for each modeled output. The deterministic models consisted of various proprietary spreadsheet and recognized specialized models with outputs of one being inputs of another. The models were run three times with a base (all *flow* inputs at best conservative engineering estimate), high (all *flow* inputs at worst case) and low (all *flow* inputs at best case). This approach accounted for uncertainty about the input *flow* values by calculating an absolute high and absolute low outputs but did not calculate the probability of those absolute highs and lows occurring, nor did it account for uncertainty in other (non-flow) input values.

The approach presented will use a probabilistic modeling platform (GoldSim) that combines all models into a single integrated package (see Reference (1) Section 3.1 *Monte Carlo Simulation Background* and 3.3 *GoldSim Model Platform Overview*). The tool includes Monte Carlo simulation, which will run the model hundreds or thousands of times. The number of realizations will be determined to achieve sufficient accuracy in the desired results. All uncertain inputs will be adjusted for each realization (and time-step, if appropriate) based on their individual probability distribution. The result will be a probability distribution of outputs.

<u>Modeling Concept Changes</u>

Stockpile Conceptual Model:

Constituent generation rates for most metals are now based on waste rock metal to sulfur ratios indicated in the NorthMet drill core database (see Reference (2) Section 8.1 *Laboratory Release Rates*). This is because the laboratory data indicated that concentration caps in the test cells may be influencing the apparent laboratory release rates.

The modeled mass of waste rock in the temporary stockpiles will be increased to account for the presence of the saturated overburden material that will be treated as waste rock.

The amount of water from the bottom of the stockpile that goes to the WWTF is now correctly calculated as the total water reaching the bottom minus the amount that leaks through the liner. The amount of water reaching the bottom of the stockpile (infiltration) is linked to annual precipitation, evaporation or evapotranspiration, and runoff (see Reference (1) Section 6.1.1 *Stockpile Hydrology Modeling*).

As directed by the Lead Agencies, the lab to field scale-up factor for the Category 1 Waste Rock stockpile is based on factors developed by MDNR from the Dunka Mine data rather than the first-principles method used previously.

Pit Conceptual Model:

Constituent generation rates are based on metal to sulfur ratios as described above for the waste rock stockpiles.

Long-term decay in sulfate release rates is based on both MDNR long-term test data and NorthMet humidity cell data.

Ore Handling Areas Conceptual Model:

Leakage from double-lined ponds and sumps and lined ponds with infrequent water storage is not included in the model.

Ponds Conceptual Model:

Leakage from double-lined ponds and sumps and lined ponds with infrequent water storage is not included in the model.

WWTF Conceptual Model:

No changes from DEIS modeling approach.

Overburden Storage and Laydown Area Conceptual Model:

No changes from DEIS modeling approach.

Groundwater Transport:

Groundwater transport was previously simulated using MODFLOW/MT3D models that represented the groundwater flow paths between mining features and the Partridge River. For the current modeling, the groundwater flow paths will be incorporated into the GoldSim modeling environment using the GoldSim Contaminant Transport (CT) module (see Reference (1) Section 5.4.4 *Groundwater Transport in GoldSim*). The NorthMet model will use a set of the GoldSim CT "cell pathways" linked in series for this process. The setup is essentially a finite-difference or finite-volume analysis which is similar to MODFLOW/MT3D and many other contaminant transport models.

The groundwater flow paths transport mass using a mix of analytical and numerical solution methods. In short, the flow equation is solved analytically and is an exact solution to the idealized representation of the aquifer; the transport equation is solved numerically using a series of well-mixed cells of known volume and flow characteristics. The solution to the network of cells is not explicit in a sense that one cell is solved, then the next, then the next, etc. The entire coupled system of cells is solved at once using a set of matrices.

The number of cells used to represent each aquifer is not a random choice of discretization but is instead optimized to best represent dispersion. Using a numerical method to transport mass always results in some amount of dispersion. In the case of GoldSim, the dispersion length is equivalent to one-half of the cell length. The same dispersion relationship that was used in the modeling for the DEIS is proposed here, so the dispersion length is based on the aquifer length. Knowing the length of the aquifer, the dispersion length, and the relationship between dispersion length and cell length, the number of cells to properly represent each flow path is a direct calculation in the model.

Results from GoldSim groundwater flow paths will be compared with previous modeling results to ensure that the models match as closely as possible. In the cases where the GoldSim model estimates potential groundwater exceedances, more detailed MODFLOW modeling may be completed to refine the results from GoldSim.

Partridge River Water Quality:

The concentrations resulting from loading to the Partridge River will be calculated based on a cumulative probability density function (CDF) of daily flow in the Partridge River (see Reference (1) Section 4.4.1 *Hydrology* and Section 5.6.5 *Developing Probabilistic Model Inputs*). The Partridge River CDF will be re-sampled at each model time-step of each realization. This allows water quality impacts to be computed over a wide range of estimated flows in the Partridge River. The results of this approach are analogous to the probability of exceeding a given concentration on a randomly selected sampling date.

In GoldSim, the groundwater loads from the Mine Site will be added to Partridge River via the GoldSim CT pathways (and not as virtual piped discharges as was modeled in RS74A) (see Reference (1) Section 5.4.4 *Groundwater Transport in GoldSim*). Groundwater inputs are assumed to be independent of instantaneous flow in the Partridge River, with the exception that during extreme low flows, modeled groundwater inflows may be reduced to maintain continuity with total river flow (see Reference (1) Section 5.5.1 *Adjustment for Low Flow*).

The West Pit overflow to the Partridge River, if continuous, will be scaled in order to maintain continuity with modeled flow in the river (i.e. higher than the average annual rate during high flow conditions in the river, lower overflow rate during low river flow conditions) (see Reference (1) Section 5.5.2 *West Pit Overflow*). No such scaling is necessary if the West Pit discharge is controlled and limited to a defined seasonal period.

References

1. **PolyMet Mining Inc.** *NorthMet Project Water Modeling Data Package Volume 1 - Mine Site (v9).* December 2011.

2. —. *NorthMet Project Waste Characterization Data Package (v8).* February 2012.

Figure A - Mine Site Water Modeling - operations

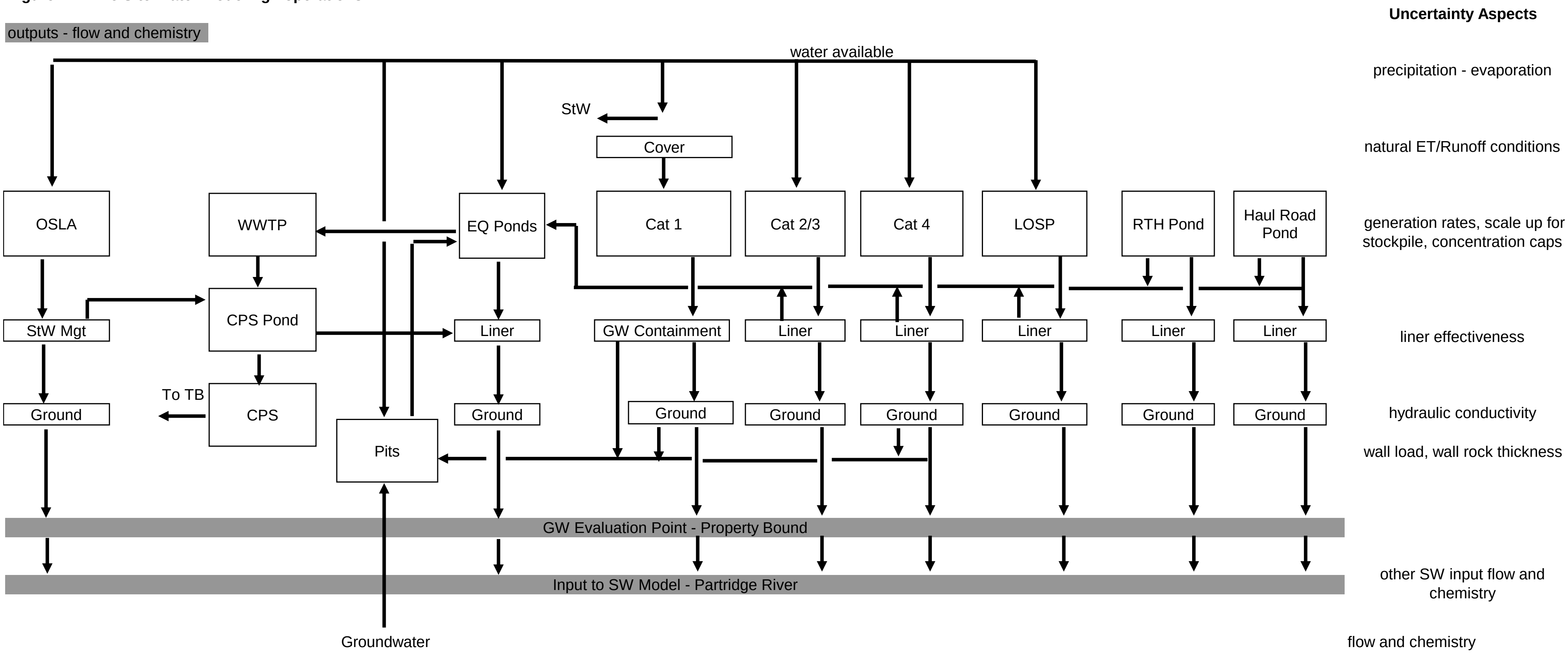


Figure B - Mine Site Water Modeling - operations - East Pit Backfilling

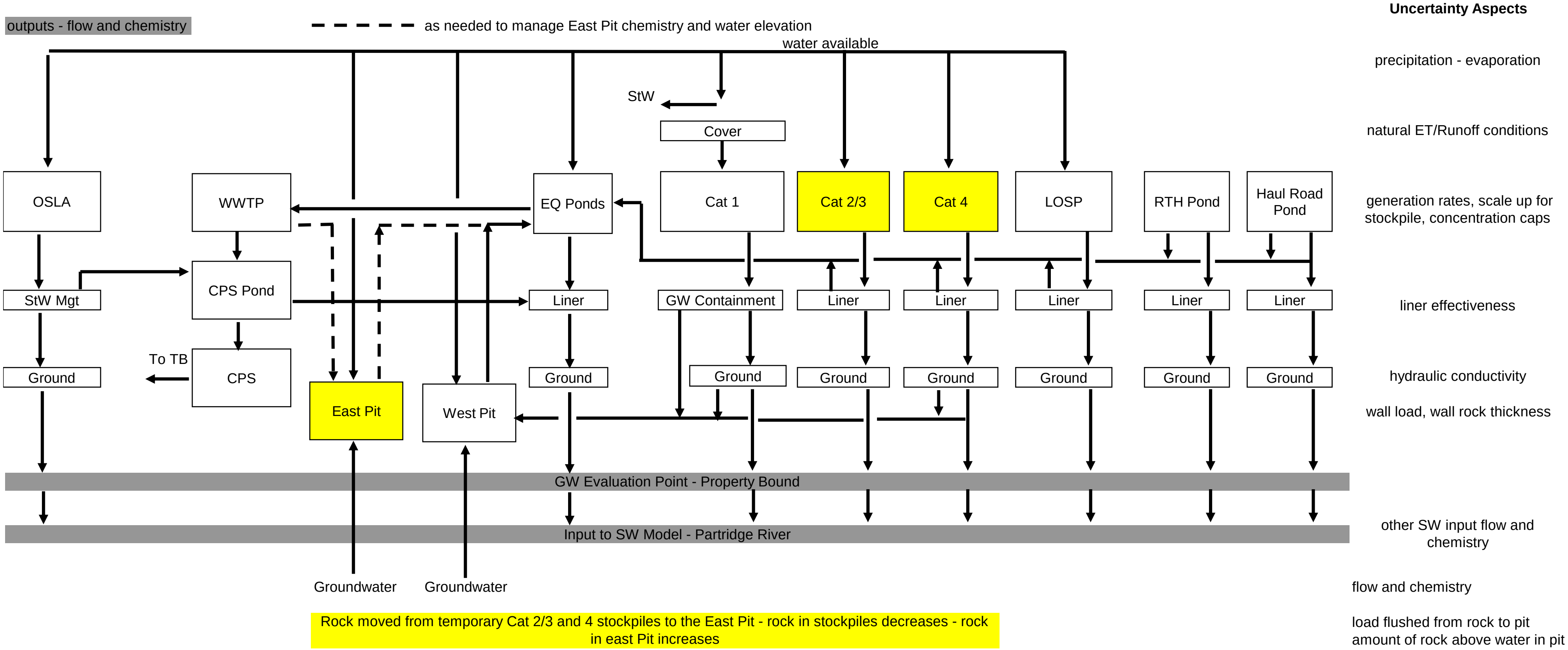


Figure C - Mine Site Water Modeling - closure - model until closure activities complete and the West Pit overflows

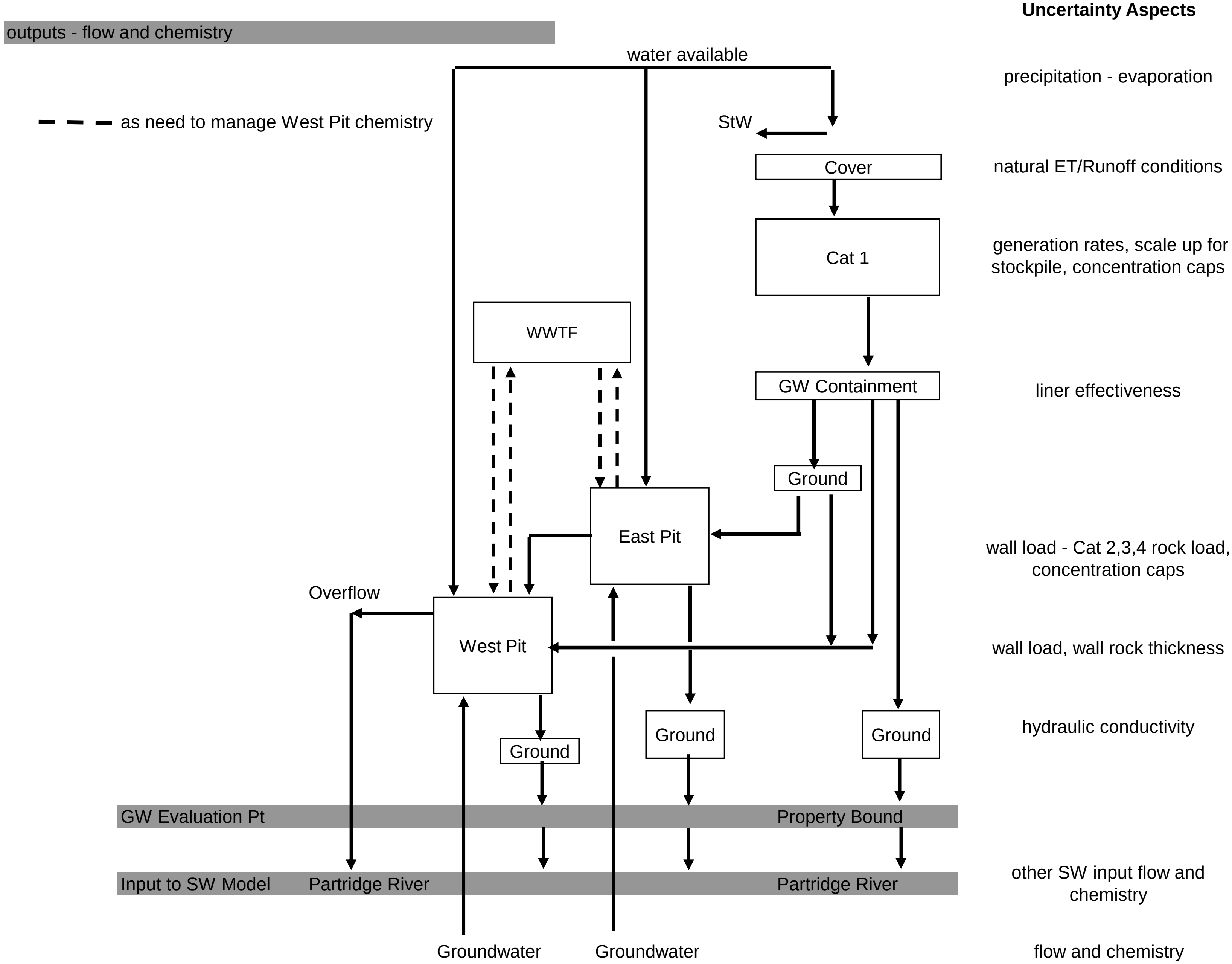


Table 1-1 **Input Variables for the Mine Site Model**

Variable Name	*Units*	*Deterministic/ Uncertain*	*Sampling/ Calculation Frequency*	*Distribution*	*Mean or Mode*	*Standard Deviation*	*Minimum*	*Maximum*	*Description*	*Source of Input Data*	*Modeling Package Section*
Grey cells indicate changes from the previously published version											
Water Quality Standards											
Ground_Standards	[mg/L]	Deterministic	N/A	Constant	Vector by Constituent. Reference Table 1-2				Primary and secondary groundwater quality standards applicable to the project	MN Rules 7050 and 4717	Water Section 2.1 *MN GW Standards*
Surface_Standards	[mg/L]	Deterministic	N/A	Constant	Vector by Constituent. Reference Table 1-3				Constant surface water quality standards applicable to the project	MN Rules 7050 and 7052	Water Section 2.2 *MN SW Standards*
Hardness_Coefficients	[--]	Deterministic	N/A	Constant	Vector by Constituent. Reference Table 1-4				Hardness-dependent surface water quality standards applicable to the project	MN Rules 7050 and 7052	Water Section 2.2 *MN SW Standards*
Wild_Rice_Sulfate	[mg/L]	Deterministic	N/A	Constant	10	N/A	N/A	N/A	Seasonal sulfate standard in wild rice waters	MN Rules 7050	Water Section 2.3 *Wild Rice Standard*
Wild_Rice_Start	[--]	Deterministic	N/A	Constant	4	N/A	N/A	N/A	First month of wild rice standard application	MPCA staff recommendation	Water Section 2.3 *Wild Rice Standard*
Wild_Rice_End	[--]	Deterministic	N/A	Constant	8	N/A	N/A	N/A	Last month of wild rice standard application	MPCA staff recommendation	Water Section 2.3 *Wild Rice Standard*
Wild_Rice_Locs	[--]	Deterministic	N/A	Constant	Vector by location. Reference Table 1-17				Locations where the wild rice standard applies	MPCA staff guidance	Water Section 2.3 *Wild Rice Standard*
General Engineering Variables											
Closure_Year	[yr]	Deterministic	N/A	Constant	20	N/A	N/A	N/A	Year after mining when operations cease and closure begins	Project Description	Water Section 5.1 *Conceptual Model*
Ore_Processing_Rate	[tonm/day]	Deterministic	N/A	Constant	30,860	N/A	N/A	N/A	Mine rate of ore production and transfer to Plant Site	Project Description	Water Section 5.1 *Conceptual Model*
Ore_Storage_Time	[mon]	Uncertain	Realization	Uniform	N/A	N/A	1	6	Length of time that any unit of ore is stored in in-pit stockpiles	Assumed	Waste Section 10.6.3.1 *Ore Leaching Load*
Category 1 Waste Rock Stockpile Characteristics											
Cat1SP_Mass	[ton]	Deterministic	Timestep	Time Series	Imported from worksheet. Reference Table 1-5				Mass of waste rock in stockpile from Mine Plan	Rock/OB Management Plan	Water Section 5.1 *Conceptual Model*
Cat1SP_Bare	[acre]	Deterministic	Timestep	Time Series	Imported from worksheet. Reference Table 1-5				Bare area of stockpile from Mine Plan	Rock/OB Management Plan	Water Section 5.1 *Conceptual Model*
Cat1SP_Reclaim	[acre]	Deterministic	Timestep	Time Series	Imported from worksheet. Reference Table 1-5				Reclaimed area of stockpile from Mine Plan	Rock/OB Management Plan	Water Section 5.1 *Conceptual Model*
Cat1SP_RO_EP	[acre]	Deterministic	N/A	Constant	26	N/A	N/A	N/A	Area with runoff directed to the East Pit during pit flooding	XPSWMM Model GIS analysis	Water Section 5.1 *Conceptual Model*
Cat1SP_RO_WP	[acre]	Deterministic	N/A	Constant	268	N/A	N/A	N/A	Area with runoff directed to the West Pit during pit flooding	XPSWMM Model GIS analysis	Water Section 5.1 *Conceptual Model*
Cat1SP_Contain_EastPit	[acre]	Deterministic	N/A	Time Series	Imported from worksheet. Reference Table 1-5				Area with contained seepage that is directed to the East Pit	Rock/OB Management Plan	Water Section 6.1.3.1 *Active Waste Rock and Ore Stockpiles*
Cat1SP_Contain_WestPit	[acre]	Deterministic	N/A	Time Series	Imported from worksheet. Reference Table 1-5				Area with contained seepage that is directed to the West Pit	Rock/OB Management Plan	Water Section 6.1.3.1 *Active Waste Rock and Ore Stockpiles*
Cat1SP_Sulfur	[%S]	Deterministic	N/A	Constant	0.063	N/A	N/A	N/A	Mass-weighted average sulfur content of stockpile	Block Model	Waste Section 4.3.2 *Sulfur Content*
Category 2/3 Waste Rock Stockpile Characteristics											
Cat23SP_Mass	[ton]	Deterministic	Timestep	Time Series	Imported from worksheet. Reference Table 1-6				Mass of waste rock in stockpile from Mine Plan	Rock/OB Management Plan	Water Section 5.1 *Conceptual Model*
Cat23SP_SatOB	[yd^3]	Deterministic	Timestep	Time Series	Imported from worksheet. Reference Table 1-6				Volume of saturated overburden in stockpile from Mine Plan	Rock/OB Management Plan	Water Section 5.1 *Conceptual Model*
Cat23SP_Bare	[acre]	Deterministic	Timestep	Time Series	Imported from worksheet. Reference Table 1-6				Bare area of stockpile from Mine Plan	Rock/OB Management Plan	Water Section 5.1 *Conceptual Model*
Cat23SP_Sulfur	[%S]	Deterministic	N/A	Constant	0.21	N/A	N/A	N/A	Mass-weighted average sulfur content of stockpile	Block Model	Waste Section 4.3.2 *Sulfur Content*

Table 1-1 **Input Variables for the Mine Site Model**

Variable Name	*Units*	*Deterministic/ Uncertain*	*Sampling/ Calculation Frequency*	*Distribution*	*Mean or Mode*	*Standard Deviation*	*Minimum*	*Maximum*	*Description*	*Source of Input Data*	*Modeling Package Section*
Grey cells indicate changes from the previously published version											
Category 4 Waste Rock Stockpile Characteristics											
Cat4SP_MassDC	[ton]	Deterministic	Timestep	Time Series	Imported from worksheet. Reference Table 1-7				Mass of Duluth Complex waste rock in stockpile from Mine Plan	Rock/OB Management Plan	Water Section 5.1 *Conceptual Model*
Cat4SP_MassVF	[ton]	Deterministic	Timestep	Time Series	Imported from worksheet. Reference Table 1-7				Mass of Virginia Formation waste rock in stockpile from Mine Plan	Rock/OB Management Plan	Water Section 5.1 *Conceptual Model*
Cat4SP_SatOB	[yd^3]	Deterministic	Timestep	Time Series	Imported from worksheet. Reference Table 1-7				Volume of saturated overburden in stockpile from Mine Plan	Rock/OB Management Plan	Water Section 5.1 *Conceptual Model*
Cat4SP_Bare	[acre]	Deterministic	Timestep	Time Series	Imported from worksheet. Reference Table 1-7				Bare area of stockpile from Mine Plan	Rock/OB Management Plan	Water Section 5.1 *Conceptual Model*
Ore Surge Pile											
OSP_Mass	[ton]	Deterministic	Timestep	Time Series	Imported from worksheet. Reference Table 1-8				Mass in the OSP from Mine Plan	Rock/OB Management Plan	Water Section 5.1 *Conceptual Model*
OSP_Bare	[acre]	Deterministic	Timestep	Time Series	Imported from worksheet. Reference Table 1-8				Bare area of the OSP from Mine Plan	Rock/OB Management Plan	Water Section 5.1 *Conceptual Model*
OSP_Sulfur	[%S]	Deterministic	N/A	Constant	0.608	N/A	N/A	N/A	Mass-weighted average sulfur content of stockpile	Block Model	Waste Section 4.3.2 *Sulfur Content*
Overburden Storage and Laydown Area Characteristics											
UnsatOB_Bare	[acre]	Deterministic	Timestep	Constant	22.4	N/A	N/A	N/A	Area of unsaturated overburden in the OSLA, assumed to be half of the total area	Rock/OB Management Plan	Water Section 5.1 *Conceptual Model*
Peat_Bare	[acre]	Deterministic	Timestep	Constant	22.4	N/A	N/A	N/A	Area of peat in the OSLA, assumed to be half of the total area	Rock/OB Management Plan	Water Section 5.1 *Conceptual Model*
East Pit Characteristics											
EP_Elev_to_Volume	[ft^3]	Deterministic	N/A	Lookup	Imported from worksheet. Reference Figure 1-1				Volume of final pit shell as a function of elevation	Mine Plan	Water Section 5.1 *Conceptual Model*
EP_Volume_to_Elev	[ft]	Deterministic	N/A	Lookup	Imported from worksheet. Reference Figure 1-1				Water surface elevation as a function of volume of final pit shell (inverse of Elev_to_Volume)	Mine Plan	Water Section 5.1 *Conceptual Model*
EP_Elev_to_PlanArea	[ft^2]	Deterministic	N/A	Lookup	Imported from worksheet. Reference Figure 1-2				Plan view area of final pit shell as a function of elevation	Mine Plan	Water Section 5.1 *Conceptual Model*
EP_Footprint_Area	[acre]	Deterministic	N/A	Constant	154.7	N/A	N/A	N/A	Area contributing runoff during operations	Mine Plan	Water Section 5.1 *Conceptual Model*
EP_Min_Elev	[ft]	Deterministic	N/A	Constant	920	N/A	N/A	N/A	Minimum elevation in the East Pit	Mine Plan	Water Section 5.1 *Conceptual Model*
EP_Water_Limit_Elev	[ft]	Deterministic	N/A	Constant	1260	N/A	N/A	N/A	Limiting elevation for backfill flooding in the EP during CP mining	Mine Plan	Water Section 5.1 *Conceptual Model*
EP_BlastOre_Mass	[ton]	Deterministic	Timestep	Time Series	Imported from worksheet. Reference Table 1-9				Blasted inventory of ore in pit awaiting removal	Mine Plan	Water Section 5.1 *Conceptual Model*

Table 1-1 **Input Variables for the Mine Site Model**

Variable Name	*Units*	*Deterministic/ Uncertain*	*Sampling/ Calculation Frequency*	*Distribution*	*Mean or Mode*	*Standard Deviation*	*Minimum*	*Maximum*	*Description*	*Source of Input Data*	*Modeling Package Section*
Grey cells indicate changes from the previously published version											
Central Pit Characteristics											
CP_Elev_to_Volume	[ft^3]	Deterministic	N/A	Lookup	Imported from worksheet. Reference Figure 1-1				Volume of final pit shell as a function of elevation	Mine Plan	Water Section 5.1 *Conceptual Model*
CP_Volume_to_Elev	[ft]	Deterministic	N/A	Lookup	Imported from worksheet. Reference Figure 1-1				Water surface elevation as a function of volume of final pit shell (inverse of Elev_to_Volume)	Mine Plan	Water Section 5.1 *Conceptual Model*
CP_Elev_to_PlanArea	[ft^2]	Deterministic	N/A	Lookup	Imported from worksheet. Reference Figure 1-2				Plan view area of final pit shell as a function of elevation	Mine Plan	Water Section 5.1 *Conceptual Model*
CP_Footprint_Area	[acre]	Deterministic	N/A	Constant	51.9	N/A	N/A	N/A	Area contributing runoff during operations, only applies after CP_Mine_Start	Mine Plan	Water Section 5.1 *Conceptual Model*
CP_Min_Elev	[ft]	Deterministic	N/A	Constant	1260	N/A	N/A	N/A	Minimum elevation in the Central Pit	Mine Plan	Water Section 5.1 *Conceptual Model*
CP_Max_Elev	[ft]	Deterministic	N/A	Constant	1420	N/A	N/A	N/A	Maximum elevation of the pit, point where EP/CP combine	Mine Plan	Water Section 5.1 *Conceptual Model*
CP_Mine_Start	[yr]	Deterministic	N/A	Constant	11.5	N/A	N/A	N/A	Mine year that mining in the Central Pit begins	Mine Plan	Water Section 5.1 *Conceptual Model*
CP_Mine_End	[yr]	Deterministic	N/A	Constant	15.25	N/A	N/A	N/A	Mine year that mining in the Central Pit is complete	Mine Plan	Water Section 5.1 *Conceptual Model*
Combined East/Central Pit Characteristics											
EPCP_Elev_to_Volume	[ft^3]	Deterministic	N/A	Lookup	Imported from worksheet. Reference Figure 1-1				Volume of final pit shell as a function of elevation	Mine Plan	Water Section 5.1 *Conceptual Model*
EPCP_Volume_to_Elev	[ft]	Deterministic	N/A	Lookup	Imported from worksheet. Reference Figure 1-1				Water surface elevation as a function of volume of final pit shell (inverse of Elev_to_Volume)	Mine Plan	Water Section 5.1 *Conceptual Model*
EPCP_Elev_to_PlanArea	[ft^2]	Deterministic	N/A	Lookup	Imported from worksheet. Reference Figure 1-2				Plan view area of final pit shell as a function of elevation	Mine Plan	Water Section 5.1 *Conceptual Model*
EPCP_Sump_Area	[ft^2]	Deterministic	N/A	Constant	1,000	N/A	N/A	N/A	Water surface area in the sump	Assumed value	Water Section 6.1.3.3 *Water Balance, Mine Pits*
EPCP_Sump_Volume	[ft^3]	Deterministic	N/A	Constant	10,000	N/A	N/A	N/A	Volume of the sump, assumed to be always full	Assumed value	Water Section 6.1.3.3 *Water Balance, Mine Pits*
EPCP_Elev_to_WallArea	[ft^2]	Deterministic	N/A	Lookup	Vector by category, imported from worksheet. Reference Figures 1-3 and 1-4				Plan view area of wall rock in final pit shell as a function of elevation	Mine Plan	Water Section 5.1 *Conceptual Model,* Waste Section 4.3.2 *Sulfur Content*
EPCP_Elev_to_Sulfur	[%]	Deterministic	N/A	Lookup	Vector by category, imported from worksheet. Reference Figures 1-5, 1-6 and 1-7				Area-weighted average wall rock sulfur content in final pit shell as a function of elevation	Mine Plan	Waste Section 4.3.2 *Sulfur Content*
EPCP_Direct_Mass	[ton]	Deterministic	Timestep	Time Series	Vector by category, imported from worksheet. Reference Table 1-10				Mass of waste rock direct from West Pit to East Pit in Mine Plan	Rock/OB Management Plan	Water Section 5.1 *Conceptual Model*
EPCP_Max_Mass	[ton]	Deterministic	N/A	Constant	140,191,500	N/A	N/A	N/A	Maximum tonnage of backfill rock in the East Pit	Rock/OB Management Plan	Water Section 5.1 *Conceptual Model*
EPCP_Total_Mass	[ton]	Deterministic	N/A	Time Series	Imported from worksheet. Reference Table 1-10b				Mass of total backfill to East Pit in Mine Plan (all rock types together, no overburden)	Rock/OB Management Plan	Water Section 5.1 *Conceptual Model*
EPCP_Max_OBVol	[yd^3]	Deterministic	N/A	Constant	4,498,100	N/A	N/A	N/A	Maximum volume of backfill saturated OB in the East Pit	Rock/OB Management Plan	Water Section 5.1 *Conceptual Model*
EPCP_Total_OBVol	[yd^3]	Deterministic	N/A	Time Series	Imported from worksheet. Reference Table 1-10b				Volume of total saturated OB backfill to East Pit in Mine Plan	Rock/OB Management Plan	Water Section 5.1 *Conceptual Model*
EPCP_Backfill_Margin	[ft]	Deterministic	N/A	Constant	5	N/A	N/A	N/A	Required minimum distance between the top of the waste rock and the water	Mine Plan	Waste Section 9.6.2 *Backfill Modeling Parameters*
EPCP_RO_Flooding	[acre]	Deterministic	N/A	Constant	77	N/A	N/A	N/A	Area contributing to runoff to the East Pit during West Pit flooding	XPSWMM Model GIS analysis	Water Section 6.1.3.3 *Water Balance, Mine Pits*
EPCP_RO_PostClos	[acre]	Deterministic	N/A	Constant	21	N/A	N/A	N/A	Area contributing to runoff to the East Pit in post-closure	XPSWMM Model GIS analysis	Water Section 6.1.3.3 *Water Balance, Mine Pits*
EPCP_Outlet_Elev	[ft]	Deterministic	N/A	Constant	1592	N/A	N/A	N/A	Elevation at the constructed outlet structure	Mine Plan	Water Section 5.1 *Conceptual Model*
EPCP_Outlet_Length	[ft]	Deterministic	N/A	Constant	20	N/A	N/A	N/A	Length of the constructed outlet structure weir	Mine Plan	Water Section 5.1 *Conceptual Model*
EPCP_Spill_Elev	[ft]	Deterministic	N/A	Constant	1594	N/A	N/A	N/A	Elevation at the pit rim low point	Mine Plan	Water Section 5.1 *Conceptual Model*

Table 1-1 **Input Variables for the Mine Site Model**

Variable Name	*Units*	*Deterministic/ Uncertain*	*Sampling/ Calculation Frequency*	*Distribution*	*Mean or Mode*	*Standard Deviation*	*Minimum*	*Maximum*	*Description*	*Source of Input Data*	*Modeling Package Section*
Grey cells indicate changes from the previously published version											
West Pit Characteristics											
WP_Elev_to_Volume	[ft^3]	Deterministic	N/A	Lookup	Imported from worksheet. Reference Figure 1-1				Volume of final pit shell as a function of elevation	Mine Plan	Water Section 5.1 *Conceptual Model*
WP_Volume_to_Elev	[ft]	Deterministic	N/A	Lookup	Imported from worksheet. Reference Figure 1-1				Water surface elevation as a function of volume of final pit shell (inverse of Elev_to_Volume)	Mine Plan	Water Section 5.1 *Conceptual Model*
WP_Elev_to_PlanArea	[ft^2]	Deterministic	N/A	Lookup	Imported from worksheet. Reference Figure 1-2				Plan view area of final pit shell as a function of elevation	Mine Plan	Water Section 5.1 *Conceptual Model*
WP_Footprint_Area	[acre]	Deterministic	N/A	Time Series	Imported from worksheet. Reference Table 1-9b				Area contributing runoff during operations	Mine Plan	Water Section 5.1 *Conceptual Model*
WP_Min_Elev	[ft]	Deterministic	N/A	Constant	940	N/A	N/A	N/A	Minimum elevation in the West Pit	Mine Plan	Water Section 5.1 *Conceptual Model*
WP_Outlet_Elev	[ft]	Deterministic	N/A	Constant	1573	N/A	N/A	N/A	Elevation at the constructed outlet structure	Design variable	Water Section 5.5.2 *West Pit Overfow*
WP_Spill_Elev	[ft]	Deterministic	N/A	Constant	1579	N/A	N/A	N/A	Elevation at the pit rim low point	Mine Plan	Water Section 5.1 *Conceptual Model*
WP_Sump_Area	[ft^2]	Deterministic	N/A	Constant	1,000	N/A	N/A	N/A	Water surface area in the sump	Assumed value	Water Section 6.1.3.3 *Water Balance, Mine Pits*
WP_Sump_Volume	[ft^3]	Deterministic	N/A	Constant	10,000	N/A	N/A	N/A	Volume of the sump, assumed to be always full	Assumed value	Water Section 6.1.3.3 *Water Balance, Mine Pits*
WP_Elev_to_WallArea	[ft^2]	Deterministic	N/A	Lookup	Vector by category, imported from worksheet. Reference Figures 1-3 and 1-4				Plan view area of wall rock in final pit shell as a function of elevation	Mine Plan	Water Section 5.1 *Conceptual Model,* Waste Section 4.3.2 *Sulfur Content*
WP_Elev_to_Sulfur	[%]	Deterministic	N/A	Lookup	Vector by category, imported from worksheet. Reference Figures 1-5, 1-6 and 1-7				Area-weighted average wall rock sulfur content in final pit shell as a function of elevation	Mine Plan	Waste Section 4.3.2 *Sulfur Content*
WP_BlastOre_Mass	[ton]	Deterministic	Timestep	Time Series	Imported from worksheet. Reference Table 1-9				Blasted inventory of ore in pit awaiting removal	Mine Plan	Water Section 5.1 *Conceptual Model*
WP_RO_Flooding	[acre]	Deterministic	N/A	Constant	291	N/A	N/A	N/A	Area contributing to runoff to the West Pit during pit flooding	XPSWMM Model GIS analysis	Water Section 6.1.3.3 *Water Balance, Mine Pits*
WP_RO_PostClos	[acre]	Deterministic	N/A	Constant	47	N/A	N/A	N/A	Area contributing to runoff to the West Pit in post-closure	XPSWMM Model GIS analysis	Water Section 6.1.3.3 *Water Balance, Mine Pits*
WP_Discharge_Limit	[cfs]	Deterministic	N/A	Constant	12	N/A	N/A	N/A	Limiting flow on seasonal West Pit discharge, based on geomorphology of receiving stream (pending)	Design variable	Water Section 5.5.2.2 *Correction for Seasonal Discharge*
Waste Water Treatment Facility Characteristics											
WestPond_Area	[acre]	Deterministic	N/A	Constant	4.9	N/A	N/A	N/A	Liner area of the equalization pond receiving water from the Cat 1 stockpile, pit dewatering, and haul roads	Water Management Plan	Water Section 6.1.3.4 *Water Balance, Other Facilities*
EastPond_Area	[acre]	Deterministic	N/A	Constant	2.4	N/A	N/A	N/A	Liner area of the equalization pond receiving water from the other process water features	Water Management Plan	Water Section 6.1.3.4 *Water Balance, Other Facilities*
CPS_Pond_Area	[acre]	Deterministic	N/A	Constant	1.3	N/A	N/A	N/A	Liner area of the CPS pond	Water Management Plan	Water Section 6.1.3.4 *Water Balance, Other Facilities*
Pond_Leakage	[gal/ac/day]	Deterministic	N/A	Constant	5	N/A	N/A	N/A	Leakage from lined WWTF and CPS ponds when full (summer months)	Water Management Plan	Water Section 6.1.3.4 *Water Balance, Other Facilities*
Pump_Limit_EP	[gpm]	Deterministic	N/A	Constant	5,000	N/A	N/A	N/A	Highest pumping rate between the WWTF and East Pit allowed	Design variable, model results will determine appropriate design value (lower than shown)	Water Section 6.1.3.3 *Water Balance, Mine Pits*
Pump_Limit_CP	[gpm]	Deterministic	N/A	Constant	5,000	N/A	N/A	N/A	Highest pumping rate between the WWTF and Central Pit allowed	Design variable, model results will determine appropriate design value (lower than shown)	Water Section 6.1.3.3 *Water Balance, Mine Pits*
Pump_Limit_WP	[gpm]	Deterministic	N/A	Constant	5,000	N/A	N/A	N/A	Highest pumping rate between the WWTF and West Pit allowed	Design variable, model results will determine appropriate design value (lower than shown)	Water Section 6.1.3.3 *Water Balance, Mine Pits*
Closure_Pump	[gpm]	Deterministic	N/A	Constant	1,200	N/A	N/A	N/A	Rate of pumping and return to the East Pit porewater or West Pit water (if necessary)	Design variable, may change due to model results	Water Section 6.1.3.3 *Water Balance, Mine Pits*
WWTF_Effluent_Targets	[mg/L]	Deterministic	N/A	Constant	Vector by Constituent. Reference Table 1-34				Treatment effluent target concentrations	Water Management Plan	Water Section 6.1.3.4 *Water Balance, Other Facilities*
RTH_Trib_Area	[acre]	Deterministic	N/A	Constant	1.65	N/A	N/A	N/A	Contributing area to the RTH pond for runoff calculation	Water Management Plan	Water Section 6.1.3.4 *Water Balance, Other Facilities*
RTH_Ore_Depth	[ft]	Deterministic	N/A	Constant	1.0	N/A	N/A	N/A	Depth of spilled fine ore material on RTH	Water Management Plan	Water Section 6.1.3.4 *Water Balance, Other Facilities*
HR_Trib_Area	[acre]	Deterministic	N/A	Constant	72.4	N/A	N/A	N/A	Contributing area to the Haul Road ponds for runoff calculation	Water Management Plan	Water Section 6.1.3.4 *Water Balance, Other Facilities*

Table 1-1 **Input Variables for the Mine Site Model**

Variable Name	*Units*	*Deterministic/ Uncertain*	*Sampling/ Calculation Frequency*	*Distribution*	*Mean or Mode*	*Standard Deviation*	*Minimum*	*Maximum*	*Description*	*Source of Input Data*	*Modeling Package Section*
Grey cells indicate changes from the previously published version											
Climatic Variables											
Annual_Precip_Cuberoot	[$in^{1/3}$]	Uncertain	Annual	Trunc. Normal	3.05	0.16	0	N/A	Cube root of the annual precipitation	HiDen Climate network for Mine Site (1980-2010 climate normal)	Water Section 5.2.1 *Climate Inputs*
Monthly_Precip_Factors	[%]	Deterministic	N/A	Constant	Vector by month. Reference Table 1-11				Factors for partitioning annual precipitation to monthly	HiDen Climate network for Mine Site (1980-2010 climate normal)	Water Section 5.2.1 *Climate Inputs*
Annual_Evap	[in/yr]	Uncertain	Annual	Normal	20.8	1.33	N/A	N/A	Annual evaporation from open water	HiDen Climate network for Mine Site (1980-2010 climate normal); Baker (1979)	Water Section 5.2.1 *Climate Inputs*
Monthly_Evap_Factors	[%]	Deterministic	N/A	Constant	Vector by month. Reference Table 1-11				Factors for partitioning annual open water evaporation to monthly	Baker (1979) for partitioning ratios	Water Section 5.2.1 *Climate Inputs*
Snowmelt	[--]	Deterministic	N/A	Constant	4	N/A	N/A	N/A	Month when snowmelt occurs	USGS Gage Data	Water Section 6.1.3.3 *Water Balance, Mine Pits*
Freezeup	[--]	Deterministic	N/A	Constant	11	N/A	N/A	N/A	Month when freezeup occurs, consistent with WWTF design team definition	USGS Gage Data	Water Section 6.1.3.3 *Water Balance, Mine Pits*
Background Chemistry											
GW_Conc_Surf	[mg/L]	Uncertain	Realization	Lognormal	Vector by Constituent. Reference Table 1-12				Surficial groundwater concentrations in the Partridge River watershed	Analysis of PolyMet background water quality data	Water Section 5.3.1 *Background Groundwater*
GW_Conc_Bed	[mg/L]	Uncertain	Realization	Lognormal	Vector by Constituent. Reference Table 1-12				Bedrock groundwater concentrations in the Partridge River watershed	Analysis of PolyMet background water quality data	Water Section 5.3.1 *Background Groundwater*
SW_Conc_RO	[mg/L]	Uncertain	Realization	Lognormal	Vector by Constituent. Reference Table 1-13				Calibrated surface runoff concentrations in the Partridge River watershed	Initial calibration of model to baseline conditions	Water Section 5.3.1 *Background Surface Runoff*
SW_Conc_PMP	[mg/L]	Deterministic	N/A	Constant	Vector by Constituent. Reference Table 1-13				Concentration leaving the Peter Mitchell Pits	2004-2007 WQ modeling at SW-001	Water Section 5.5.3.1 *Other (Non-Project) Loads*
Flow_PMP	[cfs]	Deterministic	N/A	Constant	1	N/A	N/A	N/A	Flow from Peter Mitchell Pit dewatering to SW-001	Initial calibration of model to baseline conditions	Water Section 5.5.3.1 *Other (Non-Project) Loads*
SW_Conc_Partridge	[mg/L]	Deterministic	N/A	Constant	Matrix by Constituent and location. Reference Table 1-14				Baseline existing chemistry in Partridge River used to evaluate model	2004-2010 Monitoring Data of Partridge River	Water Section 4.4.4.1 *Water Quality ,Partridge River*
Groundwater Flowpath Characteristics											
I_ops	[--]	Uncertain	Realization	Uniform	Vector by flowpath. Reference Table 1-15				Average hydraulic gradient along aquifer	Mine Site MODFLOW model	Water Section 5.4.1 *Groundwater Flowpath Modeling*
I_close	[--]	Uncertain	Realization	Uniform	Vector by flowpath. Reference Table 1-15				Average hydraulic gradient along aquifer in closure	Mine Site MODFLOW model	Water Section 5.4.1 *Groundwater Flowpath Modeling*
Thick	[m]	Deterministic	N/A	Constant	Vector by flowpath. Reference Table 1-15				Aquifer thickness	Assumed value	Water Section 5.4.1 *Groundwater Flowpath Modeling*
EL_Pit	[ft]	Deterministic	N/A	Constant	Vector by flowpath. Reference Table 1-15				Pit surficial outflow elevation	GIS data/calculations	Water Section 5.4.1 *Groundwater Flowpath Modeling*
Width	[m]	Deterministic	N/A	Constant	Vector by flowpath. Reference Table 1-15				Flowpath width	GIS data/calculations	Water Section 5.4.1 *Groundwater Flowpath Modeling*
L_Upstream	[m]	Deterministic	N/A	Constant	Vector by flowpath. Reference Table 1-15				Length upstream of stockpile	GIS data/calculations	Water Section 5.4.1 *Groundwater Flowpath Modeling*
L_Stock	[m]	Deterministic	N/A	Constant	Vector by flowpath. Reference Table 1-15				Source (stockpile) length	GIS data/calculations	Water Section 5.4.1 *Groundwater Flowpath Modeling*
L_Eval_1	[m]	Deterministic	N/A	Constant	Vector by flowpath. Reference Table 1-15				Length to Evaluation Point #1	GIS data/calculations	Water Section 5.4.1 *Groundwater Flowpath Modeling*
L_Eval_2	[m]	Deterministic	N/A	Constant	Vector by flowpath. Reference Table 1-15				Length to Evaluation Point #2	GIS data/calculations	Water Section 5.4.1 *Groundwater Flowpath Modeling*
L_Eval_3	[m]	Deterministic	N/A	Constant	Vector by flowpath. Reference Table 1-15				Length to Evaluation Point #3	GIS data/calculations	Water Section 5.4.1 *Groundwater Flowpath Modeling*
L_Total	[m]	Deterministic	N/A	Constant	Vector by flowpath. Reference Table 1-15				Total flowpath length	GIS data/calculations	Water Section 5.4.1 *Groundwater Flowpath Modeling*

Table 1-1 **Input Variables for the Mine Site Model**

Variable Name	*Units*	*Deterministic/ Uncertain*	*Sampling/ Calculation Frequency*	*Distribution*	*Mean or Mode*	*Standard Deviation*	*Minimum*	*Maximum*	*Description*	*Source of Input Data*	*Modeling Package Section*
Grey cells indicate changes from the previously published version											
Groundwater Flow Variables											
Bedrock_Porosity	[--]	Deterministic	N/A	Constant	0.05	N/A	N/A	N/A	Porosity of the bedrock flowpaths	Mine Site MODFLOW model (Bedrock units)	Water Section 5.4.1 *Groundwater Flowpath Modeling*
Surficial_Porosity	[--]	Deterministic	N/A	Constant	0.3	N/A	N/A	N/A	Porosity of the surficial flowpaths	Assumed value, e.g. Fetter, 2001	Water Section 5.4.1 *Groundwater Flowpath Modeling*
K_Flowpath	[m/d]	Uncertain	Realization	Triangular	Vector by flowpath. Reference Table 1-15				Hydraulic conductivity of the surficial and bedrock material	Mine Site MODFLOW model (Duluth Complex), constraints discussed in Water Section 5.4.1	Water Section 5.4.4 *Groundwater Transport in GoldSim*
Recharge_min	[in/yr]	Deterministic	N/A	Constant	0.3	N/A	N/A	N/A	Minimum allowed recharge in surficial aquifer (for checking calculated value)	Mine Site MODFLOW model	Water Section 5.4.1 *Groundwater Flowpath Modeling*
Recharge_max	[in/yr]	Deterministic	N/A	Constant	1.5	N/A	N/A	N/A	Maximum allowed recharge in surficial aquifer (for checking calculated value)	Mine Site MODFLOW model	Water Section 5.4.1 *Groundwater Flowpath Modeling*
Surficial_Density	[kg/m3]	Deterministic	N/A	Constant	1,500	N/A	N/A	N/A	Dry (bulk) Density of the surficial deposits	USDA St. Louis County Soil Survey Database	Water Section 5.4.1 *Groundwater Flowpath Modeling*
Kd_Surficial	[L/kg]	Deterministic	N/A	Constant	Vector by Constituent. Reference Table 1-16				Sorption coefficients for the surficial aquifer (As, Sb, Cu, Ni)	EPA screening-level values	Water Section 5.4.3 *Sorption*
Stream Reach Characteristics											
Segment_Area	[m^2]	Deterministic	N/A	Constant	Vector by location. Reference Table 1-17				Cross sectional area of each segment upstream of each node	RS26 geomorphic surveys	Water Section 5.5 *Surface Water Modeling*
Segment_Length	[m]	Deterministic	N/A	Constant	Vector by location. Reference Table 1-17				Length of river upstream of each node	GIS data	Water Section 5.5 *Surface Water Modeling*
Colby_Volume	[acre-ft]	Deterministic	N/A	Constant	5,300	N/A	N/A	N/A	Colby Lake storage volume from RS73B	DNR bathymetric maps (summarized in RS73B)	Water Section 6.1.5 *Water Balance, Colby Lake*
Contributing_Area	[acre]	Deterministic	N/A	Time Series	Matrix by location and year. Reference Table 1-18				Contributing watershed area to each river node (incremental), used to calculate recharge	XPSWMM Model GIS analysis	Water Section 5.6.4 *Modeling Future Conditions*
Stream Flow Variables											
Streamflow_SW006_(Month)	[cfs]	Uncertain	Timestep	User-defined	Imported from worksheet. Reference Table 1-19				Randomly sampled daily streamflow at SW-006 for each month	USGS gage data (corrected for PMP dewatering)	Water Section 5.6.5 *Developing Probabilistic Model Inputs*
Inc_Flow_Factor_(Month)	[--]	Deterministic	N/A	Time Series	Imported from worksheet. Reference Table 1-20a through 1-20l				Factor to multiply Q at SW006 to get the incremental inflow between nodes for each month	XP-SWMM model results (relative differences)	Water Section 5.6.5 *Developing Probabilistic Model Inputs*
GW_Inc_Baseflow	[cfs]	Deterministic	N/A	Time Series	Imported from worksheet. Reference Table 1-21				Baseflow adding to evaluation points via natural groundwater	XP-SWMM model results scaled to observed baseflow at SW-006	Water Section 5.6.5 *Developing Probabilistic Model Inputs*
Stockpile Hydrology											
Bare_ET	[--]	Uncertain	Realization	Normal	0.524	0.020	N/A	N/A	ET from bare waste rock as a fraction of precipitation	Analysis of Amax test pile data (Eger and Lapakko, 1985)	Water Section 6.1.1 *Stockpile Hydrology Modeling*
Bare_RO	[--]	Deterministic	N/A	Constant	0	N/A	N/A	N/A	Runoff from bare portion of the stockpile as a fraction of precipitation	Assumed value	Water Section 6.1.1 *Stockpile Hydrology Modeling*
Reclaim_ET	[--]	Uncertain	Realization	Normal	0.704	0.023	N/A	N/A	ET from reclaimed waste rock as a fraction of precipitation	Analysis of Amax test pile data (Eger and Lapakko, 1985)	Water Section 6.1.1 *Stockpile Hydrology Modeling*
Reclaim_RO	[--]	Uncertain	Realization	Trunc. Normal	0.082	0.0027	0	N/A	Runoff from reclaimed waste rock as a fraction of precipitation	Analysis of Amax test pile data (Eger and Lapakko, 1985)	Water Section 6.1.1 *Stockpile Hydrology Modeling*
Cat1_Contain_Leak	[--]	Deterministic	N/A	Constant	0	N/A	N/A	N/A	Fraction of water in the Cat 1 Stockpile containment system that leaks	Assumed value	Water Section 6.1.3.1 *Active Waste Rock and Ore Stockpiles*
Mean_Bare_Infilt	[in/yr]	Deterministic	N/A	Constant	13.5	N/A	N/A	N/A	Infiltration for mean stockpile conditions (precip., ET, RO) for use as flowpath initial condition	Calculated from mean of other model parameters	Water Section 6.1.1 *Stockpile Hydrology Modeling*
Mean_Reclaim_Infilt	[in/yr]	Deterministic	N/A	Constant	6.1	N/A	N/A	N/A	Infiltration for mean stockpile conditions (precip., ET, RO) for use as flowpath initial condition	Calculated from mean of other model parameters	Water Section 6.1.1 *Stockpile Hydrology Modeling*
Liner_Leak_23	[--]	Uncertain	Realization	Lognormal	0.000302	0.000274	N/A	N/A	Fraction of water from the top of the liner that leaks (Cat 2/3 stockpile)	FOSM Analysis on HELP model results	Water Section 6.1.3 *Water Balance, Active Stockpiles*
Liner_Leak_4_OSP	[--]	Uncertain	Realization	Lognormal	0.000081	0.000073	N/A	N/A	Fraction of water from the top of the liner that leaks (Cat 4 and OSP)	FOSM Analysis on HELP model results	Water Section 6.1.3 *Water Balance, Active Stockpiles*

Table 1-1 **Input Variables for the Mine Site Model**

Variable Name	*Units*	*Deterministic/ Uncertain*	*Sampling/ Calculation Frequency*	*Distribution*	*Mean or Mode*	*Standard Deviation*	*Minimum*	*Maximum*	*Description*	*Source of Input Data*	*Modeling Package Section*
Grey cells indicate changes from the previously published version											
Pit Hydrology											
Wall_RO	[--]	Uncertain	Realization	Uniform	N/A	N/A	0.4	0.6	Runoff from bare pit walls as a fraction of precipitation	Best professional judgment (watershed avg ~40%)	Water Section 6.1.3.3 *Water Balance, Mine Pits*
Natural_RO_Winter	[--]	Uncertain	Annual	Trunc. Normal	0.63	0.275	0	N/A	Runoff (frozen period) from non-stockpile areas as a fraction of precipitation	Calculated from annual fraction and open-water seasonal fraction	Water Section 6.1.3.3 *Water Balance, Mine Pits*
Natural_RO_Summer	[--]	Uncertain	Annual	Trunc. Normal	0.30	0.092	0	N/A	Runoff (open water period) from non-stockpile areas as a fraction of precipitation	Average watershed yield from Partridge River (USGS gage)	Water Section 6.1.3.3 *Water Balance, Mine Pits*
Pit_GW_Uncertainty_unshift	[--]	Uncertain	Realization	Log-Normal	0.3	0.31	N/A	N/A	Uncertainty multiplier for the groundwater flow into the pits (un-shifted)	Best professional judgment	Water Section 6.1.3.3 *Water Balance, Mine Pits*
Pit_GW_Uncertainty_shift	[--]	Deterministic	N/A	Constant	0.7	N/A	N/A	N/A	Upward shift for uncertainty multiplier for the groundwater flow into the pits (shifted mean = 1.0)	Best professional judgment	Water Section 6.1.3.3 *Water Balance, Mine Pits*
WP_GW_Inflow	[gpm]	Deterministic	Timestep	Time Series/ Constant	Imported from worksheet. Reference Table 1-22a and 1-22b				Groundwater inflow to the pit as a function of time or elevation	MODFLOW modeling	Water Section 5.4.5 *Groundwater Modeling, MODFLOW*
EP_GW_Inflow	[gpm]	Deterministic	Timestep	Time Series/ Constant	Imported from worksheet. Reference Table 1-22a and 1-22b				Groundwater inflow to the pit as a function of time or elevation	MODFLOW modeling	Water Section 5.4.5 *Groundwater Modeling, MODFLOW*
CP_GW_Inflow	[gpm]	Deterministic	Timestep	Time Series/ Constant	Imported from worksheet. Reference Table 1-22a and 1-22b				Groundwater inflow to the pit as a function of time or elevation	MODFLOW modeling	Water Section 5.4.5 *Groundwater Modeling, MODFLOW*
CP_to_WP	[gpm]	Deterministic	N/A	Constant	16.5	N/A	N/A	N/A	Flow through bedrock from East Pit porewater to West Pit during pit filling (0 after West Pit is full)	MODFLOW modeling	Water Section 5.4.5 *Groundwater Modeling, MODFLOW*
Geochemical Parameters for Pollutant Release											
OB_Concs_Unsat	[mg/L]	Uncertain	Realization	Uniform	Vector by Constituent. Reference Table 1-23				Seepage concentrations from unsaturated OB storage areas	Analysis of overburden leach test data	Waste Section 7.1 *Leachate Water Quality, Unsaturated Overburden*
OB_Concs_Peat	[mg/L]	Uncertain	Realization	Uniform	Vector by Constituent. Reference Table 1-23				Seepage concentrations from peat storage areas	Analysis of overburden leach test data	Waste Section 7.1 *Leachate Water Quality, Peat*
Cat1_Release	[varies]	Uncertain	Realization	Varies	Vector by Constituent. Reference Table 1-24				Release rates and ratios for Category 1 waste rock	Analysis of HCT, Aqua Regia, and Microprobe data	Waste Section 8.1 *Laboratory Release Rates*
Cat23_Release	[varies]	Uncertain	Realization	Varies	Vector by Constituent. Reference Table 1-25				Release rates and ratios for Category 2/3 waste rock	Analysis of HCT, Aqua Regia, and Microprobe data	Waste Section 8.1 *Laboratory Release Rates*
Cat4DC_Release	[varies]	Uncertain	Realization	Varies	Vector by Constituent. Reference Table 1-26				Release rates and ratios for Duluth Complex Category 4 waste rock	Analysis of HCT, Aqua Regia, and Microprobe data	Waste Section 8.1 *Laboratory Release Rates*
Ore_Release	[varies]	Uncertain	Realization	Varies	Vector by Constituent. Reference Table 1-27				Release rates and ratios for ore in the OSP	Analysis of HCT, Aqua Regia, and Microprobe data	Waste Section 8.1 *Laboratory Release Rates*
Cat4VF_Release	[varies]	Uncertain	Realization	Varies	Vector by Constituent. Reference Table 1-28				Release rates and ratios for Virginia Formation Category 4 waste rock	Analysis of HCT, Aqua Regia, and Microprobe data	Waste Section 8.1 *Laboratory Release Rates*
Rock_Content_All	[mg/kg]	Deterministic	N/A	Constant	Matrix by Constituent and Rock Type. Reference Table 1-29				Content of constituents of concern in waste rock	Analysis of Aqua Regia data	Waste Section 8.4.1 *Depletion*
Cat1_ConcCaps	[mg/L]	Uncertain	Realization	Varies	Vector by Constituent. Reference Table 1-30				Concentration caps for Category 1 waste rock	Analysis of laboratory and analog site data	Waste Section 8.3 *Concentration caps*
Cat1_pH	[s.u.]	Uncertain	Realization	Uniform	N/A	N/A	7.0	7.5	Assumed distribution of porewater pH in the Category 1 stockpile	Geochemical modeling of Category 1 waste rock	Waste Section 8.3 *Concentration caps*
Cat234_pH	[s.u.]	Uncertain	Realization	Uniform	N/A	N/A	6.0	7.5	Assumed distribution of porewater pH in the nonacidic Category 2/3 and Category 4 rock	Assumed pH prior to onset of acidic conditions	Waste Section 8.3 *Concentration caps*
Cat234_nonacid_ConcCaps	[mg/L]	Uncertain	Realization	Varies	Vector by Constituent. Reference Table 1-31				Concentration caps for nonacidic Duluth Complex Category 2/3/4 waste rock and ore	Analysis of laboratory and analog site data	Waste Section 8.3 *Concentration caps*
Cat234_acid_ConcCaps	[mg/L]	Uncertain	Realization	Varies	Vector by Constituent. Reference Table 1-32				Concentration caps for acidic Duluth Complex Category 2/3/4 waste rock and ore	Analysis of laboratory and analog site data	Waste Section 8.3 *Concentration caps*
Cat4VF_ConcCaps	[mg/L]	Uncertain	Realization	Varies	Vector by Constituent. Reference Table 1-33				Concentration caps for acidic Virginia Formation Category 4 waste rock	Analysis of laboratory and analog site data	Waste Section 8.3 *Concentration caps*

Table 1-1 **Input Variables for the Mine Site Model**

Variable Name	*Units*	*Deterministic/ Uncertain*	*Sampling/ Calculation Frequency*	*Distribution*	*Mean or Mode*	*Standard Deviation*	*Minimum*	*Maximum*	*Description*	*Source of Input Data*	*Modeling Package Section*
Grey cells indicate changes from the previously published version											
Geochemical Parameters for Scaling											
Scale_Factor_MDNR	[--]	Uncertain	Realization	User-defined	Imported from worksheet. Reference Table 1-30b				Scaling factor for Category 1 stockpile	MDNR analysis of Dunka Mine data.	Waste Section 8.2.8 *Lab to Field Scale Up, Category 1 Waste Rock Stockpile*
Contact_Factor	[--]	Uncertain	Realization	Triangular	0.5	N/A	0.1	0.9	Fraction of waste rock contacted by water	Professional judgement	Waste Section 8.2 *Lab to Field Scale Up*
Size_Factor	[--]	Uncertain	Realization	Triangular	0.14	N/A	0.08	0.35	Scaling factor to adjust to field scale waste rock	Analysis of NorthMet and AMAX data	Waste Section 8.2 *Lab to Field Scale Up*
Field_Temp	[C]	Uncertain	Year	Normal	2.004	1.388	N/A	N/A	Stockpile or wall internal temperature, same as air temperature	HiDen Climate data for1981-2010	Waste Section 8.2 *Lab to Field Scale Up*
Field_Temp_Mean	[C]	Uncertain	Realization	Normal	2.004	0.2534	N/A	N/A	Average annual temperature, used for acid onset timing	HiDen Climate data for1981-2010	Waste Section 8.2 *Lab to Field Scale Up*
Lab_Temp	[C]	Deterministic	N/A	Constant	20	N/A	N/A	N/A	Laboratory temperature (known)	RS 53/42	Waste Section 8.2 *Lab to Field Scale Up*
Activation_Energy	[kJ/mol]	Uncertain	Realization	Uniform	N/A	N/A	47	63	Activation energy of pyrrhotite for the Arrhenius equation	Literature-reported range	Waste Section 8.2 *Lab to Field Scale Up*
Wall_Temp_Solar	[C]	Deterministic	N/A	Constant	1.5	N/A	N/A	N/A	Average temp. increase for portion of pit wall that has solar heating	Energy balance for pit wall face	Waste Section 9.3 *Lab to Field Scale Up*
Size_factor_walls	[--]	Uncertain	Realization	Uniform	N/A	N/A	0.05	0.15	Scaling factor to adjust to field scale wall rock	Professional judgement	Waste Section 9.3 *Lab to Field Scale Up*
Geochemical Parameters for Acidic Conditions and Decay											
Acid_Onset_Time_23	[yr]	Uncertain	Realization	Triangular	6.81	N/A	5.33	7.79	Time for Category 2/3 rock to go acidic in the laboratory	Analysis of DNR long-term reactor data	Waste Section 8.2 *Lab to Field Scale Up*
Acid_Onset_Time_4DC	[yr]	Uncertain	Realization	Triangular	5.41	N/A	4.97	6.81	Time for Duluth Complex Category 4 rock to go acidic in the laboratory	Analysis of DNR long-term reactor data	Waste Section 8.2 *Lab to Field Scale Up*
Acid_Factor_DC	[--]	Uncertain	Realization	Beta	8.20	7.48	1.01	32.36	Increase in sulfate release when Duluth Complex rock goes acidic **(correlation to a1 = -0.831)**	Analysis of DNR long-term reactor data and NorthMet humidity cells	Waste Section 8.2 *Lab to Field Scale Up*
Decay_a1	[--]	Uncertain	Realization	Uniform	N/A	N/A	-1.088	-0.087	Parameter to define shape of decay of sulfate release in wall rock **(correlated to acid factor and a0)**	Analysis of DNR long-term reactor data and NorthMet humidity cells	Waste Section 9.4 *Acidificatoin and Long-Term Decay*
Decay_a0	[--]	Uncertain	Realization	Uniform	N/A	N/A	1.60	3.48	Parameter to define shape of decay of sulfate release in wall rock **(correlation to a1 = -0.989)**	Analysis of DNR long-term reactor data and NorthMet humidity cells	Waste Section 9.4 *Acidificatoin and Long-Term Decay*
Geochemical Parameters for Pit Wall and Backfill											
Begin_Oxidizing_EP	[yr]	Deterministic	Realization	Constant	0	N/A	N/A	N/A	Average point in the mine life when rock walls begin oxidizing	Assumed	Waste Section 9.6.1 *Age of Pit Walls*
Begin_Oxidizing_WP	[yr]	Deterministic	Realization	Constant	0	N/A	N/A	N/A	Average point in the mine life when rock walls begin oxidizing	Assumed	Waste Section 9.6.1 *Age of Pit Walls*
Wall_Depth_DC	[m]	Uncertain	Realization	Triangular	2	N/A	1	3	Average depth of oxidizing Duluth Complex wall rock	Professional judgement	Waste Section 9.2 *Mass of Reactive Wall Rock*
Wall_Depth_VF	[m]	Uncertain	Realization	Triangular	4	N/A	2	6	Average depth of oxidizing Virginia Formation wall rock	Professional judgement	Waste Section 9.2 *Mass of Reactive Wall Rock*
South_Face_EP	[--]	Deterministic	N/A	Constant	0.5	N/A	N/A	N/A	Portion of pit wall that is south-facing and subject to solar heating	Assumed	Waste Section 9.3 *Lab to Field Scale Up*
South_Face_WP	[--]	Deterministic	N/A	Constant	0.5	N/A	N/A	N/A	Portion of pit wall that is south-facing and subject to solar heating	Assumed	Waste Section 9.3 *Lab to Field Scale Up*
WR_Swell	[--]	Deterministic	N/A	Constant	0.3	N/A	N/A	N/A	Swelling of the rock due to void spaces	Rock/OB Management Plan	Waste Section 9.6.2 *Backfill Modeling Parameters*
WR_Sp_Gravity	[--]	Deterministic	N/A	Constant	2.93	N/A	N/A	N/A	Specific gravity of the waste rock	Rock/OB Management Plan	Waste Section 9.6.2 *Backfill Modeling Parameters*
SatOB_Porosity	[--]	Deterministic	N/A	Constant	0.2	N/A	N/A	N/A	Porosity of the saturated overburden backfill	Rock/OB Management Plan	Waste Section 9.6.2 *Backfill Modeling Parameters*
SatOB_BulkDens	[ton/cy]	Deterministic	N/A	Constant	1.472	N/A	N/A	N/A	Compacted bulk density of the saturated overburden	Rock/OB Management Plan	Waste Section 9.6.2 *Backfill Modeling Parameters*
Parameters for Model Stability											
Water_Depth	[in]	Deterministic	N/A	Constant	0.1	N/A	N/A	N/A	Average depth of water at the bottom of stockpile (for volume calculation)	Assumed, small value leads to less "memory" of previous timestep	
Tiny_Area	[acre]	Deterministic	N/A	Constant	0.001	N/A	N/A	N/A	Tiny area to prevent dividing by zero	Assumed	
Tiny_Mass	[kg]	Deterministic	N/A	Constant	0.001	N/A	N/A	N/A	Tiny mass to prevent dividing by zero	Assumed	
Tiny_Volume	$[m^3]$	Deterministic	N/A	Constant	0.001	N/A	N/A	N/A	Tiny volume to prevent dividing by zero	Assumed	

Table 1-2 Groundwater Quality Standards

Constituent	*Primary Standard (mg/L)*	*Secondary Standard (mg/L)*
Ag*	0.03	0.1
Al†	--	0.2
Alk	--	--
As	0.01	--
B*	1	--
Ba	2	--
Be*	0.00008	--
Ca	--	--
Cd*	4	--
Cl	--	250
Co	--	--
Cr	0.1	--
Cu	--	--
F	4	2
Fe†	--	0.30
K	--	--
Mg	--	--
Mn*†	0.1	0.05
Na	--	--
Ni*	0.1	--
Pb	--	--
Sb	0.006	--
Se*	0.03	--
SO_4	--	250
Tl*	0.0006	--
V*	0.05	--
Zn*	2	5
Hardness	--	--

Notes
* Primary standard from MN Rules 4717 (HRLs); all other primary standards from MN Rules 7050 (EPA MCLs)

-- indicates no applicable standard

† Secondary standards presented for reference but not used for impact assessment

Table 1-3 Constant Surface Water Quality Standards

Constituent	*All Surface Waters except Colby Lake (mg/L)*	*Colby Lake (mg/L)*
Ag	0.001	0.001
Al	0.125	0.125
Alk	--	--
As*	0.053	0.002
B	0.50	0.50
Ba	--	2
Be	--	0.004
Ca	--	--
Cd†	--	0.005
Cl	230	230
Co	0.005	0.0028
Cr*	0.011	0.011
Cu†	--	--
F	--	4
Fe	--	0.30
K	--	--
Mg	--	--
Mn	--	0.05
Na	--	--
Ni†	--	--
Pb†	--	--
Sb	0.031	0.0055
Se*	0.005	0.005
SO_4 (non-wild rice areas)	--	250
Tl	0.00056	0.00028
V	--	--
Zn†	--	--
Hardness	500	500

Notes

* From MN Rules 7052; all others from MN Rules 7050

† See Table 1-4 for hardness-based standards

-- indicates no applicable constant standard or hardness standard is limiting

Table 1-4 Coefficients for Hardness-Dependent Surface Water Quality Standards

Constituent	***A***	***B***	**Value at 100 mg/L Hardness (mg/L)**
Cd*	0.7852	-2.715	0.0025
Cu*	0.8545	-1.702	0.0093
Ni*	0.846	0.0584	0.0522
Pb	1.273	-4.705	0.0032
Zn*	0.8473	0.884	0.1198

Notes

* From MN Rules 7052; all others from MN Rules 7050

$$Std\left({}^{mg}\!/\!_{L}\right) = \frac{e^{A\cdot\ln\left(Hardness\left({}^{mg}\!/\!_{L}\right)\right)+B}}{1000}$$

Table 1-5 Mine Plan Summary for the Category 1 Waste Rock Stockpile

Time (years)	*Stockpile Mass (short tons)*	*Bare Area (acres)*	*Reclaimed Area (acres)*	*Containment Area to East Pit (acres)**	*Containment Area to West Pit (acres)**
0	0	212.7	0.0	132.3	0.0
1	18,707,500	212.7	0.0	132.3	0.0
2	33,724,200	172.1	40.6	132.3	0.0
3	49,863,200	213.7	81.2	150.7	0.0
4	62,659,900	255.3	121.8	155.8	0.0
5	74,401,200	296.9	162.4	168.9	64.0
6	91,243,400	338.5	203.1	185.6	120.6
7	101,648,400	318.2	223.4	185.6	120.6
8	118,588,200	297.9	243.7	185.6	120.6
9	131,144,400	277.6	264.0	185.6	120.6
10	144,118,600	257.3	284.3	185.6	120.6
11	154,299,000	237.0	304.6	185.6	120.6
12	165,072,100	118.5	423.1	0.0	306.2
13	167,922,100	0.0	541.6	0.0	306.2
20	167,922,100	0.0	541.6	0.0	306.2
21	167,922,100	0.0	541.6	0.0	306.2
2000	167,922,100	0.0	541.6	0.0	306.2

Notes

Based on PolyMet block model and GIS shapefile data

* Area with seepage reporting to the pits via the seepage containment system; remaining area has seepage reporting directly to the West Pit

Table 1-6 **Mine Plan Summary for the Category 2/3 Waste Rock Stockpile**

Time (years)	*Duluth Complex Stockpile Mass (short tons)*	*Saturated Overburden Stockpile Volume (cubic yards)*	*Bare Area (acres)*
0	0	203,000	62.1
1	5,238,800	346,300	62.1
2	9,671,600	489,600	62.1
3	13,968,700	632,900	117.8
4	17,624,300	776,200	117.8
5	20,039,300	919,500	117.8
6	24,388,300	1,151,600	171.1
7	26,954,300	1,383,700	171.1
8	31,286,500	1,615,800	171.1
9	35,946,700	1,847,900	171.1
10	40,017,200	2,080,000	171.1
11	44,021,100	2,312,100	171.1
12	38,281,600	2,023,100	171.1
13	32,542,100	1,734,100	171.1
14	26,802,500	1,445,100	171.1
15	21,063,000	1,156,000	142.6
16	15,323,500	867,000	114.1
17	9,584,000	578,000	85.6
18	3,844,400	289,000	57.1
19	0	0	28.6
20	0	0	0.0
2000	0	0	0.0

Notes

Based on PolyMet block model, overburden management, and GIS shapefile data

Overburden quantity based on 2010 LIDAR data for pit and stockpile stripping, 2009 data for other sources

Table 1-7 **Mine Plan Summary for the Category 4 Waste Rock Stockpile**

Time (years)	*Duluth Complex Stockpile Mass (short tons)*	*Virginia Formation Stockpile Mass (short tons)*	*Saturated Overburden Stockpile Volume (cubic yards)*	*Bare Area (acres)*
0	0	0	140,500	28.9
1	34,900	1,454,300	273,100	28.9
2	38,400	2,213,300	405,700	28.9
3	152,200	3,227,200	538,300	52.9
4	218,500	3,988,400	670,900	52.9
5	218,500	4,430,300	803,500	52.9
6	268,700	5,045,700	1,033,900	52.9
7	352,900	5,510,500	1,264,300	52.9
8	451,500	5,522,500	1,494,800	52.9
9	572,800	5,534,800	1,725,200	52.9
10	631,600	5,552,800	1,955,600	52.9
11	649,000	5,557,800	2,186,000	52.9
11.5	0	0	0	52.9
12	0	0	0	0.0
2000	0	0	0	0.0

Notes

Based on PolyMet block model, overburden management, and GIS shapefile data

Overburden quantity based on 2010 LIDAR data for pit and stockpile stripping, 2009 data for other sources

Table 1-8 Mine Plan Summary for the Ore Surge Pile

Time (years)	*Stockpile Mass (short tons)*	*Bare Area (acres)*
0	0	28.3
1	970,000	28.3
2	1,940,000	28.3
3	2,910,000	28.3
4	3,880,000	28.3
5	4,850,000	28.3
10	4,850,000	28.3
11	4,100,000	28.3
12	3,350,000	28.3
13	2,600,000	28.3
14	1,850,000	28.3
18	1,850,000	28.3
19	925,000	28.3
20	0	28.3
21	0	0.0
2000	0	0

Notes
Based on PolyMet operational plan and GIS shapefile data

Table 1-9 Blasted Ore Inventory in the Mine Pits

Time (years)	*East Pit Blasted Ore Mass (short tons)*	*West Pit Blasted Ore Mass (short tons)*
0	0	0
1	1,455,000	1,455,000
10	1,455,000	1,455,000
11	0	2,910,000
19	0	2,910,000
20	0	0
2000	0	0

Notes

Based on PolyMet operational plan, equivalent to 3 months capacity

Table 1-9b Mine Pit Footprint Area

Time (years)	*West Pit Footprint Area (acres)*
0	0
1	0
2	89.8
5	130.0
11	320.5
11.5	320.5
2000	320.5

East and Central Pit footprint areas removed per Phase I QA/QC, see Table 1-1

Table 1-10 Cumulative Waste Rock Moved Directly to the East Pit from the West Pit

Time (years)	*Category 1 Waste Rock Total Mass (short tons)*	*Category 2/3 Waste Rock Total Mass (short tons)*	*Duluth Complex Category 4 Waste Rock Total Mass (short tons)*	*Virginia Formation Category 4 Waste Rock Total Mass (short tons)*	*Ore Total Mass (short tons)*
0	0	0	0	0	0
11	0	0	0	0	0
12	0	4,784,600	50,100	0	0
13	5,283,600	10,497,500	86,400	0	0
14	13,757,800	14,134,000	153,300	0	0
15	19,923,800	18,823,800	247,400	0	0
16	24,367,900	22,612,600	1,113,700	0	0
17	28,390,300	25,017,600	1,642,000	0	0
18	33,982,800	27,966,500	1,942,100	0	0
19	40,927,300	32,745,900	2,162,400	0	0
20	48,772,600	38,761,200	2,429,800	0	0
2000	48,772,600	38,761,200	2,429,800	0	0

Notes

Based on PolyMet block model data, does not include mass from temporary stockpiles

Table 1-10b Cumulative Total Waste Rock Moved to the East Pit

Time (years)	*Category 1 Waste Rock Total Mass (short tons)*	*Category 2/3 Waste Rock Total Mass (short tons)*	*Duluth Complex Category 4 Waste Rock Total Mass (short tons)*	*Virginia Formation Category 4 Waste Rock Total Mass (short tons)*	*Ore Total Mass (short tons)*	*Total Backfill Waste Rock Mass (short tons)*	*Saturated Overburden Total Volume (cubic yards)*
0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
11.5	0	5,262,050	674,050	5,557,800	0	11,493,900	2,330,500
12	0	10,524,100	699,100	5,557,800	0	16,781,000	2,475,000
13	5,283,600	21,976,500	735,400	5,557,800	0	33,553,300	2,764,000
14	13,757,800	31,352,600	802,300	5,557,800	0	51,470,500	3,053,000
15	19,923,800	41,781,900	896,400	5,557,800	0	68,159,900	3,342,100
16	24,367,900	51,310,200	1,762,700	5,557,800	0	82,998,600	3,631,100
17	28,390,300	59,454,700	2,291,000	5,557,800	0	95,693,800	3,920,100
18	33,982,800	68,143,200	2,591,100	5,557,800	0	110,274,900	4,209,100
19	40,927,300	76,767,000	2,811,400	5,557,800	0	126,063,500	4,498,100
20	48,772,600	82,782,300	3,078,800	5,557,800	0	140,191,500	4,498,100
2000	48,772,600	82,782,300	3,078,800	5,557,800	0	140,191,500	4,498,100

Notes

Based on PolyMet block model data, **includes** mass of rock (not saturated overburden) from temporary stockpiles

Table 1-11 Seasonal Distribution of Annual Open Water Evaporation and Annual Precipitation

Month	*Open Water Evaporation*	*Precipitation*
January	0.0%	2.8%
February	0.0%	2.4%
March	0.0%	3.1%
April	4.7%	6.5%
May	18.5%	11.6%
June	21.0%	14.0%
July	23.6%	14.0%
August	18.8%	13.9%
September	10.9%	13.5%
October	2.4%	9.6%
November	0.0%	5.2%
December	0.0%	3.3%
Annual Total	100.0%	100.0%

Notes

Source: Open water evaporation based on Baker (1979)

Source: Precipitation from UMN Climatology Working Group - NWS data near Mine Site

Table 1-12 Average Background Groundwater Quality Distributions

Constituent	Distribution	Surficial Aquifer: Log Mean α ln(ug/L)	Surficial Aquifer: Log Mean α Std. Error ln(ug/L)	Surficial Aquifer: Log Std. Dev. B ln(ug/L)	Bedrock: Log Mean α ln(ug/L)	Bedrock: Log Mean α Std. Error ln(ug/L)	Bedrock: Log Std. Dev. B ln(ug/L)
Ag	Lognormal	-2.12E+00	6.95E-02	5.11E-01	-1.67E+00	1.39E-01	7.99E-01
Al	Lognormal	3.69E+00	2.12E-01	1.56E+00	2.79E+00	1.14E-01	6.64E-01
Alk	Lognormal	1.08E+01	7.76E-02	5.70E-01	1.07E+01	1.51E-01	8.68E-01
As	Lognormal	-8.54E-01	1.14E-01	7.39E-01	4.25E-01	1.60E-01	9.31E-01
B	Lognormal	3.26E+00	2.87E-02	2.11E-01	3.68E+00	1.45E-01	8.43E-01
Ba	Lognormal	3.46E+00	1.43E-01	1.05E+00	1.62E+00	1.30E-01	7.57E-01
Be	Lognormal	-1.95E+00	8.67E-02	6.37E-01	-2.25E+00	3.07E-02	1.79E-01
Ca	Lognormal	9.52E+00	7.13E-02	5.24E-01	9.51E+00	8.48E-02	4.95E-01
Cd	Lognormal	-2.30E+00	4.63E-02	3.41E-01	-2.26E+00	3.33E-02	1.91E-01
Cl	Lognormal	6.41E+00	1.07E-01	7.84E-01	6.87E+00	2.30E-01	1.32E+00
Co	Lognormal	-8.66E-01	2.19E-01	1.14E+00	6.03E-02	1.89E-01	1.10E+00
Cr	Lognormal	-1.76E-01	1.04E-01	7.62E-01	-6.53E-01	2.84E-02	1.63E-01
Cu	Lognormal	8.89E-01	1.56E-01	1.15E+00	1.89E-01	1.07E-01	6.26E-01
F	Lognormal	4.21E+00	7.00E-02	5.14E-01	4.81E+00	1.64E-01	9.39E-01
Fe	Lognormal	4.52E+00	2.43E-01	1.57E+00	7.50E+00	3.30E-01	1.93E+00
K	Lognormal	7.57E+00	6.16E-02	4.53E-01	7.36E+00	5.22E-02	3.04E-01
Mg	Lognormal	8.74E+00	6.08E-02	4.47E-01	8.84E+00	1.35E-01	7.84E-01
Mn	Lognormal	4.14E+00	2.58E-01	1.73E+00	3.87E+00	2.38E-01	1.39E+00
Na	Lognormal	8.58E+00	5.72E-02	4.20E-01	8.61E+00	1.96E-01	1.14E+00
Ni	Lognormal	3.40E-01	1.15E-01	8.48E-01	2.00E+00	3.10E-01	1.81E+00
Pb	Lognormal	-1.16E-01	1.78E-01	1.31E+00	-8.00E-01	1.13E-01	6.61E-01
Sb	Lognormal	-9.61E-01	1.46E-01	7.57E-01	-5.56E-01	1.47E-01	8.55E-01
Se	Lognormal	-6.36E-01	6.73E-02	4.94E-01	-4.20E-01	5.99E-02	3.44E-01
SO_4	Lognormal	9.28E+00	4.80E-02	3.53E-01	9.69E+00	1.77E-01	1.02E+00
Tl	Lognormal	-2.24E+00	3.10E-02	2.15E-01	-1.24E+00	1.85E-01	1.08E+00
V	Lognormal	1.66E+00	4.60E-02	2.39E-01	1.66E+00	4.60E-02	2.39E-01
Zn	Lognormal	1.68E+00	8.90E-02	6.54E-01	2.29E+00	1.84E-01	1.06E+00

Notes

Values highlighted grey are changed since the most recent submittal and are as shown in "Calibration of the Existing Natural Watershed at the Mine Site", Version 3 (January 2012) for the surficial aquifer. The same analysis method (see Water Modeling Data Package Section 5.3.1.2) was used to develop distributions for the bedrock water quality, which are uncalibrated and reflect PolyMet monitoring data only.

Table 1-13 Existing Surface Water Concentrations

Constituent	RO Concentration Mean (mg/L)	RO Concentration St. Dev. (mg/L)	Northshore Discharge (mg/L)
Ag	1.00E-04	7.00E-06	1.00E-04
Al	8.10E-02	8.20E-02	1.80E-02
Alk	6.30E+01	5.90E+01	9.46E+01
As	1.60E-04	5.10E-05	6.53E-03
B	8.10E-02	1.50E-01	9.60E-02
Ba	1.10E-03	7.20E-04	5.00E-03
Be	9.00E-05	9.00E-07	1.00E-04
Ca	1.63E+01	1.31E+01	2.46E+01
Cd	5.70E-05	5.20E-05	1.00E-04
Cl	1.27E+01	9.10E+00	1.64E+00
Co	3.20E-04	1.10E-04	4.50E-04
Cr	9.50E-04	8.60E-04	2.50E-04
Cu	5.10E-04	6.10E-04	1.57E-03
F	9.90E-02	8.80E-02	1.41E-01
Fe	2.00E+00	4.10E-01	2.57E-02
K	1.60E+00	1.90E+00	2.65E+00
Mg	8.10E+00	4.50E+00	1.04E+01
Mn	1.15E-01	1.42E-01	7.93E-03
Na	7.30E+00	1.57E+01	4.78E+00
Ni	1.50E-03	1.60E-03	1.39E-03
Pb	2.50E-06	2.50E-08	2.95E-04
Sb	1.60E-03	1.60E-05	1.50E-03
Se	2.00E-04	2.10E-04	5.00E-04
SO_4	5.90E+00	1.17E+01	2.18E+01
Tl	1.00E-05	6.00E-06	2.86E-04
V	5.40E-03	5.40E-05	4.30E-03
Zn	1.32E-02	1.40E-02	8.85E-03

Notes

Values highlighted grey are changed since the most recent submittal and are as shown in "Calibration of the Existing Natural Watershed at the Mine Site", Version 3 (January 2012).

Runoff values pending analysis of background groundwater quality data

Source for NorthShore Discharge: Surface water monitoring at SW-001, mean values

Surface water data not available for V, mean groundwater value assumed

Table 1-14 Initial Concentrations in the Partridge River (mg/L)

Constituent	Partridge River Evaluation Point								
	SW-001	***SW-002***	***SW-003***	***SW-004***	***SW-004a***	***SW-004b***	***SW-005***	***SW-006***	***Colby Lake***
Ag	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Al	0.0180	0.0459	0.0171	0.0334	0.0719	0.0955	0.0949	0.0949	0.0752
Alk	94.6	75.6	78.2	118	74.3	53.8	52.6	52.6	28.4
As	0.0065	0.0010	0.0010	0.0011	0.0011	0.0012	0.0011	0.0011	0.0007
B	0.0960	0.0585	0.0661	0.0783	0.126	0.0814	0.0454	0.0454	0.0416
Ba	0.0050	0.0096	0.0100	0.0076	0.0117	0.0098	0.0092	0.0092	0.0069
Be	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Ca	24.6	20.7	19.8	19.8	21.2	15.6	13.4	13.4	19.9
Cd	0.0001	0.0001	0.0001	0.0001	0.0001	0.00003	0.0001	0.0001	0.0001
Cl	1.64	1.83	6.97	8.29	15.0	9.07	4.97	4.97	2.17
Co	0.0005	0.0005	0.0004	0.0005	0.0002	0.0003	0.0006	0.0006	0.0002
Cr	0.0003	0.0008	0.0007	0.0009	0.0005	0.0005	0.0008	0.0008	0.0005
Cu	0.0016	0.0011	0.0011	0.0013	0.0013	0.0014	0.0016	0.0016	0.0027
F	0.141	0.114	0.108	0.111	0.106	0.0960	0.093	0.093	0.0880
Fe	0.026	1.04	1.40	1.21	1.53	1.94	1.67	1.67	0.857
K	2.65	2.00	1.96	1.98	2.68	1.70	1.17	1.17	0.940
Mg	10.4	7.51	8.36	8.80	10.3	8.12	6.84	6.84	8.49
Mn	0.0079	0.142	0.136	0.112	0.110	0.153	0.145	0.145	0.0649
Na	4.78	3.16	3.82	5.59	12.9	8.29	3.93	3.93	3.25
Ni	0.0014	0.0015	0.0015	0.0015	0.0017	0.0019	0.0018	0.0018	0.0021
Pb	0.0003	0.0004	0.0003	0.0003	0.0001	0.0002	0.0013	0.0013	0.0003
Sb	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0003
Se	0.0005	0.0005	0.0005	0.0004	0.0002	0.0003	0.0011	0.0011	0.0005
SO_4	21.8	6.29	9.69	11.8	15.9	9.9	7.49	7.49	34.1
Tl	0.0006	0.0002	0.0002	0.00001	0.00001	0.00001	0.0003	0.0003	0.0001
V*	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0005
Zn	0.0089	0.0101	0.0122	0.0095	0.0040	0.0030	0.0147	0.0147	0.0030

Notes

Source: Surface water monitoring, mean values

Surface water data not available for V, mean groundwater value assumed

Surface water data not available for SW-006, values for SW-005 assumed

Table 1-15 Groundwater Flowpath Characteristics

Variable Name	Units	Description	*Groundwater Flowpath*							
			East Pit (Bedrock)	*East Pit & Cat 2/3 Stockpile (Surficial Aquifer)*	*Ore Surge Pile*	*Waste Water Treatment Facility*	*Overburden Storage Area*	*West Pit (Surficial Aquifer)*	*West Pit (Bedrock to SW-004)*	*West Pit (Bedrock to SW-004a)*
I_ops	[--]	Minimum flowpath gradient (uniform distribution)	N/A	3.87E-03	9.68E-03	8.32E-03	9.63E-03	4.04E-03	N/A	N/A
		Maximum flowpath gradient (uniform distribution)	N/A	4.34E-03	1.04E-02	8.90E-03	1.03E-02	4.71E-03	N/A	N/A
I_close	[--]	Minimum flowpath gradient (uniform distribution)	8.43E-03	6.32E-03	N/A	N/A	N/A	8.70E-03	8.44E-03	8.80E-03
		Maximum flowpath gradient (uniform distribution)	8.96E-03	6.79E-03	N/A	N/A	N/A	9.37E-03	9.10E-03	9.47E-03
Thick	[m]	Aquifer thickness	100	5	5	5	5	5	100	100
EL_Pit	[ft]	Pit surficial outflow elevation	N/A	1577	N/A	N/A	N/A	1550	N/A	N/A
Width	[m]	Flowpath width	1735	1440	430	240	550	665	535	810
L_Upstream	[m]	Length upstream of stockpile	N/A	775	N/A	N/A	N/A	N/A	N/A	N/A
L_Stock	[m]	Source (stockpile) length	N/A	395	230	420	375	N/A	N/A	N/A
L_Eval_1	[m]	Length to Evaluation Point #1 (Dunka Rd.)	N/A	30	40	60	5	175	N/A	N/A
L_Eval_2	[m]	Length to Evaluation Point #2 (Prop. or river)	1435	140	1085	910	235	680	505	340
L_Eval_3	[m]	Length to Evaluation Point #3 (Average river)	440	780	60	340	985	650	1115	1160
L_Total	[m]	Total flowpath length	1875	2120	1415	1730	1600	1505	1620	1500
K_Flowpaths	[m/d]	Minimum hydraulic conductivity	0.00023	1.02	0.28	0.41	0.32	0.34	0.00023	0.00023
		Most likely hydraulic conductivity (mode)	0.00073	2.15	0.59	0.84	0.67	0.70	0.00073	0.00073
		Maximum hydraulic conductivity	0.00231	5.71	1.52	2.17	1.73	1.80	0.00231	0.00231

Grey indicates a change in value since the previous publication

Table 1-16 Coefficients for Surficial Aquifer Sorption

Constituent	***Units***	***Distribution***	***Min K_d***	***Mean/Mode K_d***	***Max K_d***
As*	L/kg	Constant	N/A	25	N/A
Cu*	L/kg	Constant	N/A	22	N/A
Ni*	L/kg	Constant	N/A	16	N/A
Sb†	L/kg	Triangular	1.3	1.6	6.1

Notes

* Constant values shown are recommended screening values from EPA guidance document:

U.S. EPA, 1996. Soil Screening Guidance: User's Guide.
U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response,
Washington, D.C., EPA/540/R-96/018.

† Minimum value shown is lowest reported value from EPA summary document:
U.S. EPA, 2005. Partition Coefficients for Metals in Surface Water, Soil, and Waste.
U.S. Environmental Protection Agency, Office of Solid Research and Development,
Washington, D.C., EPA/600/R-05/074.
Mode and maximum values shown are the lowest values from PolyMet site-specific testing (Mine and Plant sites).

Table 1-17 Partridge River Reach Characteristics

Partridge River Evaluation Point	***Upstream Reach Length (m)***	***Cross Sectional Area (m^2)***	***Wild Rice Location?***
SW-001	400	0.3	No
SW-002	4,800	2.0	No
SW-003	4,200	2.5	No
SW-004	6,600	4.8	No
SW-004a	1,300	13.8	No
SW-004b	5,200	20.6	Yes
SW-005	15,300	26.7	Yes
SW-006	5,200	28.0	Yes
Colby Lake	1,200	28.0	Yes*

Notes

Dimensions shown are for the reach upstream of each evaluation point, wild rice location applies to point itself

Based on GIS public waters shapefile data and PolyMet stream surveys

Wild rice locations based on pending MPCA staff guidance

* Wild rice is present downstream of Colby Lake on the Partridge River, not in the lake itself. The model assumes that if Colby Lake meets the standard the downstream location does also.

Table 1-18 Partridge River Tributary Areas

Year	*Incremental Tributary Area (acres)*								
	SW-001	***SW-002***	***SW-003***	***SW-004***	***SW-004a***	***SW-004b***	***SW-005***	***SW-006***	***Colby Lake***
0	672	3,838	1,043	5,018	19,994	15,110	13,402	2,989	12,580
1	672	3,619	1,043	4,672	19,840	15,110	13,402	2,989	12,580
2	672	3,647	1,043	4,672	19,744	15,110	13,402	2,989	12,580
11	672	3,658	1,037	4,608	19,130	15,110	13,402	2,989	12,580
20	672	3,902	1,037	4,608	19,174	15,110	13,402	2,989	12,580
21	672	3,792	1,043	4,934	18,938	15,110	13,402	2,989	12,580
65	672	3,931	1,043	4,934	19,232	15,110	13,402	2,989	12,580
2000	672	3,931	1,043	4,934	19,232	15,110	13,402	2,989	12,580

Notes

Based on updated GIS shapefile data

* Area tributary to the West Pit during and after filling is not included (modeled seperately)

Table 1-19 Distributions of Daily Flow at SW-006 (Existing Conditions) by Month

Percentile	***January***	***February***	***March***	***April***	***May***	***June***	***July***	***August***	***September***	***October***	***November***	***December***
Minimum	1.70	1.00	0.61	4.00	17.00	6.00	0.54	0.68	5.30	17.00	13.00	5.30
5%	1.91	1.10	0.90	18.75	25.22	8.50	1.84	2.55	6.29	17.00	14.00	6.21
10%	2.00	1.16	1.11	41.70	43.58	10.00	4.08	11.00	6.97	17.10	14.00	6.73
25%	2.38	1.50	1.90	59.60	67.72	32.59	10.21	16.25	23.27	28.00	18.19	7.83
50%	8.00	2.00	6.55	168.18	171.80	74.90	46.26	37.00	61.90	62.15	37.38	14.00
75%	11.75	8.95	27.00	340.72	317.97	128.97	101.20	168.75	108.72	117.83	62.00	21.71
90%	15.20	14.18	91.90	497.65	589.80	199.97	554.60	268.70	167.21	262.45	129.98	31.54
95%	17.55	19.79	141.90	575.97	742.05	283.92	741.55	403.55	214.00	376.45	181.16	41.63
Maximum	22.00	23.89	209.00	1940.48	874.00	566.01	866.00	480.00	366.97	760.23	459.38	86.49

Notes

Based on USGS data adjusted for Peter Mitchell Pit dewatering (see modeling package)

Table 1-20a Incremental Percent of Predicted Flow at SW-006 Entering Each Evaluation Point - January*

Year	*SW001*	*SW-002*	*SW-003*	*SW-004*	*SW-004a*	*SW-004b*	*SW-005*	*SW-006*	*CL*
0	1.03%	5.87%	1.98%	7.75%	28.18%	27.23%	23.22%	4.74%	20.00%
1	1.03%	5.87%	1.98%	7.57%	28.18%	27.22%	23.21%	4.74%	20.00%
2	1.03%	5.61%	1.96%	7.21%	27.83%	27.15%	23.20%	4.75%	20.00%
11	1.03%	5.58%	2.18%	7.17%	26.91%	27.33%	23.32%	4.93%	20.00%
20	1.03%	5.77%	1.96%	7.10%	26.95%	27.09%	23.19%	4.75%	20.00%
21	1.03%	5.65%	1.96%	7.63%	26.49%	27.09%	23.19%	4.75%	20.00%
65	1.03%	5.82%	1.97%	7.62%	27.05%	27.14%	23.19%	4.75%	20.00%
2000	1.03%	5.82%	1.97%	7.62%	27.05%	27.14%	23.19%	4.75%	20.00%

Table 1-20b Incremental Percent of Predicted Flow at SW-006 Entering Each Evaluation Point - February*

Year	*SW001*	*SW-002*	*SW-003*	*SW-004*	*SW-004a*	*SW-004b*	*SW-005*	*SW-006*	*CL*
0	1.05%	5.95%	1.78%	7.85%	31.92%	25.11%	21.36%	4.98%	20.00%
1	1.05%	5.95%	1.78%	7.67%	31.91%	25.11%	21.36%	4.98%	20.00%
2	1.05%	5.68%	1.76%	7.31%	31.47%	25.10%	21.38%	4.99%	20.00%
11	1.05%	5.66%	1.98%	7.27%	30.49%	25.33%	21.50%	5.17%	20.00%
20	1.05%	5.84%	1.76%	7.20%	30.53%	25.09%	21.38%	4.99%	20.00%
21	1.05%	5.73%	1.76%	7.73%	30.07%	25.08%	21.39%	4.99%	20.00%
65	1.05%	5.90%	1.77%	7.72%	30.69%	25.09%	21.37%	4.99%	20.00%
2000	1.05%	5.90%	1.77%	7.72%	30.69%	25.09%	21.37%	4.99%	20.00%

Table 1-20c Incremental Percent of Predicted Flow at SW-006 Entering Each Evaluation Point - March*

Year	*SW001*	*SW-002*	*SW-003*	*SW-004*	*SW-004a*	*SW-004b*	*SW-005*	*SW-006*	*CL*
0	0.69%	6.09%	2.53%	8.05%	33.75%	27.11%	10.24%	11.54%	20.00%
1	0.69%	6.09%	2.53%	7.87%	33.73%	27.11%	10.27%	11.53%	20.00%
2	0.69%	5.83%	2.49%	7.49%	33.27%	27.09%	10.43%	11.46%	20.00%
11	0.69%	5.80%	2.71%	7.45%	32.23%	27.33%	10.62%	11.60%	20.00%
20	0.69%	5.98%	2.50%	7.38%	32.28%	27.07%	10.55%	11.40%	20.00%
21	0.69%	5.87%	2.49%	7.93%	31.79%	27.07%	10.56%	11.39%	20.00%
65	0.69%	6.04%	2.52%	7.93%	32.44%	27.08%	10.44%	11.45%	20.00%
2000	0.69%	6.04%	2.52%	7.93%	32.44%	27.08%	10.44%	11.45%	20.00%

Table 1-20d Incremental Percent of Predicted Flow at SW-006 Entering Each Evaluation Point - April*

Year	*SW001*	*SW-002*	*SW-003*	*SW-004*	*SW-004a*	*SW-004b*	*SW-005*	*SW-006*	*CL*
0	0.12%	2.51%	1.59%	7.30%	23.04%	27.27%	31.09%	7.07%	20.00%
1	0.12%	2.51%	1.59%	7.19%	23.02%	27.24%	31.07%	7.07%	20.00%
2	0.12%	2.41%	1.55%	6.87%	22.70%	27.10%	30.93%	7.05%	20.00%
11	0.12%	2.40%	1.65%	6.88%	22.00%	27.18%	30.97%	7.22%	20.00%
20	0.12%	2.47%	1.57%	6.83%	22.03%	26.97%	30.81%	7.03%	20.00%
21	0.12%	2.43%	1.56%	7.17%	21.71%	26.97%	30.81%	7.03%	20.00%
65	0.12%	2.49%	1.58%	7.21%	22.15%	27.08%	30.91%	7.04%	20.00%
2000	0.12%	2.49%	1.58%	7.21%	22.15%	27.08%	30.91%	7.04%	20.00%

Percentages are incremental flow relative to SW-006 (i.e. total flow into Colby Lake is 120% of flow into SW-006)

Predicted flow percentages reflect updated XP-SWMM modeling

Table 1-20e **Incremental Percent of Predicted Flow at SW-006 Entering Each Evaluation Point - May***

Year	*SW001*	*SW-002*	*SW-003*	*SW-004*	*SW-004a*	*SW-004b*	*SW-005*	*SW-006*	*CL*
0	0.52%	2.73%	1.46%	8.42%	27.37%	30.70%	22.08%	6.73%	20.00%
1	0.52%	2.73%	1.46%	8.28%	27.35%	30.68%	22.08%	6.72%	20.00%
2	0.52%	2.60%	1.44%	7.92%	26.95%	30.52%	22.07%	6.71%	20.00%
11	0.52%	2.59%	1.55%	7.94%	26.14%	30.64%	22.19%	6.88%	20.00%
20	0.52%	2.68%	1.45%	7.88%	26.17%	30.40%	22.07%	6.69%	20.00%
21	0.52%	2.62%	1.44%	8.26%	25.80%	30.38%	22.07%	6.69%	20.00%
65	0.52%	2.70%	1.46%	8.31%	26.32%	30.50%	22.07%	6.70%	20.00%
2000	0.52%	2.70%	1.46%	8.31%	26.32%	30.50%	22.07%	6.70%	20.00%

Table 1-20f **Incremental Percent of Predicted Flow at SW-006 Entering Each Evaluation Point - June***

Year	*SW001*	*SW-002*	*SW-003*	*SW-004*	*SW-004a*	*SW-004b*	*SW-005*	*SW-006*	*CL*
0	0.72%	3.99%	1.31%	10.17%	26.68%	26.45%	21.89%	8.78%	20.00%
1	0.72%	3.99%	1.31%	10.01%	26.69%	26.43%	21.89%	8.78%	20.00%
2	0.72%	3.81%	1.29%	9.57%	26.36%	26.36%	21.89%	8.73%	20.00%
11	0.72%	3.79%	1.44%	9.58%	25.48%	26.53%	22.00%	8.90%	20.00%
20	0.72%	3.92%	1.29%	9.51%	25.52%	26.30%	21.88%	8.70%	20.00%
21	0.72%	3.84%	1.29%	9.99%	25.07%	26.29%	21.88%	8.70%	20.00%
65	0.72%	3.95%	1.30%	10.04%	25.60%	26.35%	21.88%	8.73%	20.00%
2000	0.72%	3.95%	1.30%	10.04%	25.60%	26.35%	21.88%	8.73%	20.00%

Table 1-20g **Incremental Percent of Predicted Flow at SW-006 Entering Each Evaluation Point - July***

Year	*SW001*	*SW-002*	*SW-003*	*SW-004*	*SW-004a*	*SW-004b*	*SW-005*	*SW-006*	*CL*
0	0.78%	3.87%	1.36%	10.61%	21.31%	26.76%	26.93%	8.37%	20.00%
1	0.78%	3.87%	1.36%	10.44%	21.34%	26.74%	26.92%	8.36%	20.00%
2	0.78%	3.69%	1.35%	9.98%	21.14%	26.63%	26.84%	8.33%	20.00%
11	0.78%	3.68%	1.49%	10.00%	20.34%	26.75%	26.91%	8.49%	20.00%
20	0.78%	3.80%	1.35%	9.93%	20.39%	26.53%	26.76%	8.30%	20.00%
21	0.78%	3.72%	1.35%	10.42%	19.94%	26.53%	26.76%	8.30%	20.00%
65	0.78%	3.84%	1.36%	10.47%	20.38%	26.61%	26.82%	8.32%	20.00%
2000	0.78%	3.84%	1.36%	10.47%	20.38%	26.61%	26.82%	8.32%	20.00%

Table 1-20h **Incremental Percent of Predicted Flow at SW-006 Entering Each Evaluation Point - August***

Year	*SW001*	*SW-002*	*SW-003*	*SW-004*	*SW-004a*	*SW-004b*	*SW-005*	*SW-006*	*CL*
0	0.77%	4.54%	1.25%	11.35%	23.99%	24.59%	22.47%	11.05%	20.00%
1	0.77%	4.54%	1.25%	11.16%	24.02%	24.58%	22.47%	11.03%	20.00%
2	0.77%	4.33%	1.24%	10.67%	23.78%	24.53%	22.44%	10.97%	20.00%
11	0.77%	4.32%	1.40%	10.69%	22.90%	24.70%	22.54%	11.12%	20.00%
20	0.77%	4.46%	1.23%	10.61%	22.96%	24.48%	22.42%	10.91%	20.00%
21	0.77%	4.37%	1.24%	11.14%	22.47%	24.48%	22.42%	10.91%	20.00%
65	0.77%	4.50%	1.24%	11.20%	22.96%	24.52%	22.43%	10.96%	20.00%
2000	0.77%	4.50%	1.24%	11.20%	22.96%	24.52%	22.43%	10.96%	20.00%

Percentages are incremental flow relative to SW-006 (i.e. total flow into Colby Lake is 120% of flow into SW-006)

Predicted flow percentages reflect updated XP-SWMM modeling

Table 1-20i Incremental Percent of Predicted Flow at SW-006 Entering Each Evaluation Point - September*

Year	*SW001*	*SW-002*	*SW-003*	*SW-004*	*SW-004a*	*SW-004b*	*SW-005*	*SW-006*	*CL*
0	0.39%	3.80%	2.54%	8.26%	19.51%	21.83%	35.06%	8.62%	20.00%
1	0.39%	3.80%	2.54%	8.10%	19.53%	21.82%	35.02%	8.61%	20.00%
2	0.39%	3.64%	2.48%	7.73%	19.35%	21.75%	34.82%	8.57%	20.00%
11	0.39%	3.62%	2.65%	7.72%	18.62%	21.88%	34.82%	8.73%	20.00%
20	0.39%	3.73%	2.51%	7.66%	18.67%	21.70%	34.65%	8.54%	20.00%
21	0.39%	3.66%	2.49%	8.12%	18.26%	21.69%	34.64%	8.54%	20.00%
65	0.39%	3.77%	2.53%	8.14%	18.66%	21.74%	34.79%	8.57%	20.00%
2000	0.39%	3.77%	2.53%	8.14%	18.66%	21.74%	34.79%	8.57%	20.00%

Table 1-20j Incremental Percent of Predicted Flow at SW-006 Entering Each Evaluation Point - October*

Year	*SW001*	*SW-002*	*SW-003*	*SW-004*	*SW-004a*	*SW-004b*	*SW-005*	*SW-006*	*CL*
0	0.35%	3.34%	3.24%	5.94%	23.16%	28.05%	31.78%	4.14%	20.00%
1	0.35%	3.34%	3.24%	5.81%	23.16%	28.02%	31.76%	4.14%	20.00%
2	0.35%	3.19%	3.16%	5.53%	22.86%	27.87%	31.62%	4.15%	20.00%
11	0.35%	3.18%	3.32%	5.49%	22.12%	27.97%	31.67%	4.34%	20.00%
20	0.35%	3.28%	3.20%	5.44%	22.16%	27.75%	31.50%	4.16%	20.00%
21	0.35%	3.22%	3.17%	5.85%	21.80%	27.74%	31.50%	4.16%	20.00%
65	0.35%	3.31%	3.23%	5.85%	22.25%	27.85%	31.60%	4.16%	20.00%
2000	0.35%	3.31%	3.23%	5.85%	22.25%	27.85%	31.60%	4.16%	20.00%

Table 1-20k Incremental Percent of Predicted Flow at SW-006 Entering Each Evaluation Point - November*

Year	*SW001*	*SW-002*	*SW-003*	*SW-004*	*SW-004a*	*SW-004b*	*SW-005*	*SW-006*	*CL*
0	0.64%	4.16%	3.73%	6.77%	30.95%	32.72%	17.71%	3.32%	20.00%
1	0.64%	4.16%	3.73%	6.62%	30.94%	32.69%	17.72%	3.32%	20.00%
2	0.64%	3.97%	3.63%	6.29%	30.50%	32.55%	17.80%	3.35%	20.00%
11	0.64%	3.96%	3.84%	6.25%	29.57%	32.70%	17.96%	3.53%	20.00%
20	0.64%	4.08%	3.68%	6.19%	29.61%	32.43%	17.85%	3.36%	20.00%
21	0.64%	4.00%	3.65%	6.68%	29.17%	32.42%	17.86%	3.36%	20.00%
65	0.64%	4.12%	3.71%	6.67%	29.77%	32.53%	17.80%	3.35%	20.00%
2000	0.64%	4.12%	3.71%	6.67%	29.77%	32.53%	17.80%	3.35%	20.00%

Table 1-20l Incremental Percent of Predicted Flow at SW-006 Entering Each Evaluation Point - December*

Year	*SW001*	*SW-002*	*SW-003*	*SW-004*	*SW-004a*	*SW-004b*	*SW-005*	*SW-006*	*CL*
0	0.88%	5.13%	2.87%	7.19%	33.47%	25.25%	21.26%	3.94%	20.00%
1	0.88%	5.13%	2.87%	7.02%	33.45%	25.25%	21.26%	3.95%	20.00%
2	0.88%	4.90%	2.82%	6.68%	32.97%	25.24%	21.28%	3.96%	20.00%
11	0.88%	4.88%	3.03%	6.63%	31.98%	25.48%	21.41%	4.14%	20.00%
20	0.88%	5.04%	2.84%	6.57%	32.01%	25.23%	21.29%	3.97%	20.00%
21	0.88%	4.94%	2.83%	7.09%	31.56%	25.23%	21.30%	3.97%	20.00%
65	0.88%	5.09%	2.86%	7.08%	32.20%	25.24%	21.28%	3.96%	20.00%
2000	0.88%	5.09%	2.86%	7.08%	32.20%	25.24%	21.28%	3.96%	20.00%

Percentages are incremental flow relative to SW-006 (i.e. total flow into Colby Lake is 120% of flow into SW-006)

Predicted flow percentages reflect updated XP-SWMM modeling

Table 1-21 **Incremental Flows from Groundwater (Baseflow) into each Evaluation Point (cfs)**

Year	*SW-001*	*SW-002*	*SW-003*	*SW-004*	*SW-004a*	*SW-004b*	*SW-005*	*SW-006*	*Colby Lake*
0	0.054	0.281	0.086	0.336	1.287	1.127	0.909	0.302	0.876
1	0.054	0.281	0.086	0.331	1.288	1.131	0.905	0.302	0.876
2	0.054	0.265	0.086	0.312	1.269	1.131	0.909	0.301	0.876
11	0.054	0.263	0.082	0.310	1.220	1.129	0.916	0.297	0.876
20	0.054	0.269	0.087	0.312	1.234	1.129	0.918	0.292	0.876
21	0.054	0.263	0.087	0.334	1.205	1.129	0.917	0.297	0.876
65	0.054	0.271	0.088	0.334	1.239	1.128	0.917	0.293	0.876
2000	0.054	0.271	0.088	0.334	1.239	1.128	0.917	0.293	0.876

Notes

Source: 2011 XP-SWMM modeling (and area relationship for Colby Lake), scaled from USGS data, see modeling package

Incremental flows reflect updated XP-SWMM modeling.

Table 1-22a Groundwater Inflows to the Pits During Operations

	East Pit	Central Pit	West Pit
Year	***Flow Rate (gpm)***	***Flow Rate (gpm)***	***Flow Rate (gpm)***
0	0	0	0
1	320	0	0
2	270	0	60
3	340	0	50
4	420	0	50
5	760	0	50
6	730	0	70
7	740	0	70
8	770	0	70
9	1010	0	70
10	1050	0	70
11	1160	0	140
11.5	1145	0	130
12	1130	8	120
13	1030	9	120
14	1030	10	120
15	1030	10	120
16	*1030*	*10*	130
17	*1030*	*10*	140
18	*1030*	*10*	150
19	*1030*	*10*	170
20	*1030*	*10*	190
2000	*1030*	*10*	*190*

Note: Time series not used beyond year 15 for East/Central pit and year 20 for West Pit, values shown are necessary for input but not used in model. See Table 1-22b for inflow lookup in closure.

Table 1-22b Groundwater Inflows to Pits During Backfilling and Closure

West Pit	
WS Elevation (ft)	***Flow Rate (gpm)***
940	210
1000	210
1100	200
1200	190
1320	170
1450	120
1579	33
1585	24

East Pit	
WS Elevation (ft)	***Flow Rate (gpm)***
1260	1030
1360	800
1435	490
1485	330
1530	170
1565	120
1592	21
1595	21

Central Pit	
WS Elevation (ft)	***Flow Rate (gpm)***
1260	10
1360	16
1435	13
1485	10
1530	6
1565	2
1592	2
1595	1

Table 1-23 Peat and Unsaturated Overburden Leachate Concentrations

Constituent	Distribution	Peat Minimum (mg/L)	Peat Maximum (mg/L)	Unsaturated Overburden Minimum (mg/L)	Unsaturated Overburden Maximum (mg/L)
Ag	Uniform	0.000025	0.0014	0.000025	0.00005
Al	Uniform	0.042	0.13	0.068	0.32
Alk	Uniform	8.54	82.69	4.62	13.06
As	Uniform	0.0029	0.0044	0.0004	0.0032
B	Uniform	0.18	0.23	0.0005	0.03
Ba	Uniform	0.01	0.035	0.003	0.014
Be	Uniform	0.0001	0.0002	0.0001	0.0002
Ca	Uniform	15.8	22.9	1.77	5.92
Cd	Uniform	0.00002	0.00004	0.00005	0.00016
Cl	Uniform	2.73	9.16	0.74	3.62
Co	Uniform	0.00005	0.0007	0.00005	0.0016
Cr	Uniform	0.0001	0.001	0.0001	0.0011
Cu	Uniform	0.003	0.011	0.005	0.0083
F	Uniform	0.08	1.1	0.025	0.48
Fe	Uniform	0.02	0.12	0.02	0.06
K	Uniform	1.47	5.69	0.66	1.28
Mg	Uniform	7.76	10.9	0.66	2.07
Mn	Uniform	0.0592	0.192	0.0075	0.105
Na	Uniform	4.23	47.3	1.82	4.26
Ni	Uniform	0.0015	0.0066	0.0008	0.0033
Pb	Uniform	0.000025	0.00023	0.000025	0.00005
Sb	Uniform	0.0005	0.0007	0.00005	0.0011
Se	Uniform	0.0006	0.0009	0.0001	0.0006
SO_4	Uniform	68.3	93.4	1.74	16.5
Tl	Uniform	0.00001	0.00011	0.00001	0.00003
V	Uniform	0.0025	0.0043	0.0004	0.0006
Zn	Uniform	0.0005	0.004	0.002	0.006

Notes

Minimum values from MWMP tests; LOD/2 substituted for non-detects

Maximum value from MWMP tests; LOD substituted for non-detects

Table 1-24 Category 1 Release Distributions

Constituent	*Method*	*Source*	*Units*	*Distribution*	*Mean/Mode*	*St. Dev.*	*Minimum*	*Maximum*
Ag	S ratio	Aqua Regia	mg Ag / mg S	Normal	4.72E-04	1.53E-05	N/A	N/A
Al	Ca ratio	Anorthite Formula	mg Al / mg Ca	Constant	1.35E+00	N/A	N/A	N/A
Alkalinity	Rate	HCT (1+2)	mg Alk/kg/week	Beta	4.92E+00	2.21E+00	2.63E+00	1.15E+01
As	S ratio	Aqua Regia	mg As / mg S	Normal	8.29E-03	3.92E-04	N/A	N/A
B	Rate	HCT (1+2)	mg B/kg/week	Beta	3.87E-03	4.12E-03	5.62E-04	1.81E-02
Ba	K ratio	Aqua Regia	mg Ba / mg K	Normal	2.90E-02	1.98E-04	N/A	N/A
Be	K ratio	Aqua Regia	mg Be / mg K	Normal	2.02E-04	3.14E-06	N/A	N/A
Ca	Rate	HCT (1+2)	mg Ca/kg/week	Beta	1.15E+00	3.48E-01	5.78E-01	2.34E+00
Cd	Zn rate ratio	HCT (2)	mg Cd / mg Zn	Beta	2.03E-02	5.10E-03	1.44E-02	4.44E-02
Cl	Flush	HCT (all)	mg Cl/kg	Beta	9.78E+00	1.17E+01	1.38E+00	7.30E+01
Co	Ni rate ratio	HCT (2)	mg Co / mg Ni	Beta	1.55E-01	5.11E-02	7.28E-02	3.11E-01
Cr	Rate	HCT (1+2)	mg Cr/kg/week	Beta	1.01E-04	5.61E-06	9.36E-05	1.21E-04
Cu	S ratio	Aqua Regia	mg Cu / mg S	Normal	5.87E-01	2.51E-02	N/A	N/A
F	Rate	HCT (1+2)	mg F/kg/week	Beta	2.33E-02	1.08E-03	1.99E-02	2.52E-02
Fe	S ratio	Pyrrhotite microprobe	mg Fe / mg S	Beta	1.62E+00	8.72E-02	1.49E+00	1.92E+00
K	Rate	HCT (1+2)	mg K/kg/week	Beta	2.14E-01	9.17E-02	1.02E-01	4.98E-01
Mg	Rate	HCT (1+2)	mg Mg/kg/week	Beta	3.14E-01	2.04E-01	1.31E-01	1.10E+00
Mn	SO_4 rate ratio	HCT (2)	mg Mn / mg SO_4	Beta	1.96E-03	9.73E-04	1.15E-03	5.95E-03
Na	Rate	HCT (1+2)	mg Na/kg/week	Beta	4.13E-01	4.02E-01	1.28E-01	2.50E+00
Ni	S ratio	Cat 4 Aqua Regia	mg Ni / mg S	Normal	3.06E-02	1.86E-03	N/A	N/A
Pb	S ratio	Aqua Regia	mg Pb / mg S	Normal	9.78E-03	5.71E-04	N/A	N/A
Sb	S ratio	Aqua Regia	mg Sb / mg S	Normal	4.89E-03	1.48E-04	N/A	N/A
Se	SO_4 rate ratio	HCT (2)	mg Se / mg SO_4	Beta	1.71E-04	7.76E-05	5.96E-05	4.32E-04
SO_4	Rate Regression	HCT (1+2)	mg SO_4/kg/week/%S	Normal	13.92	0.581	N/A	N/A
Tl	Rate	HCT (1+2)	mg Tl/kg/week	Beta	9.19E-06	4.48E-07	7.80E-06	1.00E-05
V	K ratio	Aqua Regia	mg V / mg K	Normal	2.44E-02	5.10E-04	N/A	N/A
Zn	Mg ratio	Aqua Regia	mg Zn / mg Mg	Normal	1.81E-03	1.35E-05	N/A	N/A

Additional Distributions for Selected Constituents

Constituent	*Method*	*Source*	*Units*	*Distribution*	*Mean/Mode*	*St. Dev.*	*Minimum*	*Maximum*
Al	Na ratio	Albite Formula	mg Al / mg Na	Constant	1.17E+00	N/A	N/A	N/A
Fe	Mg ratio	Olivine microprobe	mg Fe / mg Mg	Beta	1.87E+00	6.75E-01	1.19E+00	4.51E+00
Ni	Mg ratio	Olivine microprobe	mg Ni / mg Mg	Beta	4.59E-03	1.95E-03	1.10E-04	7.43E-03

N/A = not used

Notes

- HCT (1+2) indicates average rates from humidity cells over Condition 1 and Condition 2.
- HCT (2) indicates average rates from humidity cells over Condition 2.
- Except for SO_4, all distributions from humidity cell data represent the full range of the observed values, with no weighting.
- Distributions from aqua regia data represent the uncertainty in the average ratios, weighted by geologic unit.
- Distributions from microprobe data represent the full range of the observed ratios for each mineral, with no weighting.
- For nickel, S ratio from Category 4 aqua regia data represents the effect of all sulfide minerals combined.
- For chloride, release is a one-time flush from newly-exposed waste rock with a distribution determined from all humidity cells combined.

Table 1-25 **Category 2/3 Release Distributions**

Constituent	*Method*	*Source*	*Units*	*Distribution*	*Mean/Mode*	*St. Dev.*	*Minimum*	*Maximum*
Ag	S ratio	Aqua Regia	mg Ag / mg S	Normal	1.32E-04	4.54E-06	N/A	N/A
Al	Ca ratio	Anorthite Formula	mg Al / mg Ca	Constant	1.35E+00	N/A	N/A	N/A
Alkalinity	Nonacidic rate	HCT (1+2)	mg Alk/kg/week	Beta	4.50E+00	2.59E+00	1.45E+00	1.10E+01
As	S ratio	Aqua Regia	mg As / mg S	Normal	1.67E-03	1.28E-04	N/A	N/A
B	Nonacidic rate	HCT (1+2)	mg B/kg/week	Beta	4.82E-03	2.42E-03	6.08E-04	8.99E-03
Ba	K ratio	Aqua Regia	mg Ba / mg K	Normal	2.93E-02	5.69E-04	N/A	N/A
Be	K ratio	Aqua Regia	mg Be / mg K	Normal	1.87E-04	3.77E-06	N/A	N/A
Ca	SO_4 rate ratio	HCT (1+2)	mg Ca / mg SO_4	Beta	6.81E-01	4.29E-01	2.61E-01	2.59E+00
Cd	Zn rate ratio	HCT (2)	mg Cd / mg Zn	Beta	1.65E-02	1.20E-02	1.01E-03	5.84E-02
Cl	Flush	HCT (all)	mg Cl/kg	Beta	9.78E+00	1.17E+01	1.38E+00	7.30E+01
Co	Ni rate ratio	HCT (2)	mg Co / mg Ni	Beta	8.29E-02	3.91E-02	2.24E-02	2.06E-01
Cr	Nonacidic rate	HCT (1+2)	mg Cr/kg/week	Beta	9.84E-05	4.46E-06	8.25E-05	1.04E-04
Cu	S ratio	Aqua Regia	mg Cu / mg S	Normal	3.59E-01	8.84E-03	N/A	N/A
F	Nonacidic rate	HCT (1+2)	mg F/kg/week	Beta	2.36E-02	1.45E-03	2.04E-02	2.74E-02
Fe	S ratio	Pyrrhotite microprobe	mg Fe / mg S	Beta	1.62E+00	8.72E-02	1.49E+00	1.92E+00
K	SO_4 rate ratio	HCT (1+2)	mg K / mg SO_4	Beta	1.29E-01	8.54E-02	5.39E-02	4.00E-01
Mg	SO_4 rate ratio	HCT (1+2)	mg Mg / mg SO_4	Beta	1.39E-01	1.06E-01	3.37E-02	4.96E-01
Mn	SO_4 rate ratio	HCT (2)	mg Mn / mg SO_4	Beta	2.81E-03	2.56E-03	4.36E-04	1.10E-02
Na	SO_4 rate ratio	HCT (1+2)	mg Na / mg SO_4	Beta	1.33E-01	9.29E-02	3.54E-02	4.51E-01
Ni	S ratio	Cat 4 Aqua Regia	mg Ni / mg S	Normal	3.06E-02	1.86E-03	N/A	N/A
Pb	S ratio	Aqua Regia	mg Pb / mg S	Normal	1.24E-03	5.95E-05	N/A	N/A
Sb	S ratio	Aqua Regia	mg Sb / mg S	Normal	6.53E-04	2.81E-05	N/A	N/A
Se	SO_4 rate ratio	HCT (2)	mg Se / mg SO_4	Beta	3.54E-05	1.67E-05	1.30E-05	9.16E-05
SO_4	Rate Regression	HCT (1+2)	mg SO_4/kg/week/%S	Normal	13.92	0.581	N/A	N/A
Tl	Nonacidic rate	HCT (1+2)	mg Tl/kg/week	Beta	9.08E-06	5.42E-07	8.11E-06	1.04E-05
V	K ratio	Aqua Regia	mg V / mg K	Normal	2.32E-02	7.29E-04	N/A	N/A
Zn	Ni rate ratio	HCT (2)	mg Zn / mg Ni	Beta	3.35E-01	3.71E-01	3.31E-02	1.60E+00

Additional Distributions for Selected Constituents

Constituent	*Method*	*Source*	*Units*	*Distribution*	*Mean/Mode*	*St. Dev.*	*Minimum*	*Maximum*
Al	Na ratio	Albite Formula	mg Al / mg Na	Constant	1.17E+00	N/A	N/A	N/A
Fe	Mg ratio	Olivine microprobe	mg Fe / mg Mg	Beta	1.87E+00	6.75E-01	1.19E+00	4.51E+00
Ni	Mg ratio	Olivine microprobe	mg Ni / mg Mg	Beta	4.59E-03	1.95E-03	1.10E-04	7.43E-03

Acidic-Conditions Distributions for Selected Constituents

Constituent	*Method*	*Source*	*Units*	*Distribution*	*Mean/Mode*	*St. Dev.*	*Minimum*	*Maximum*
Alkalinity	Acidic rate	No release	mg Alk/kg/week	Constant	0	N/A	N/A	N/A
B	Acidic rate	HCT (3)	mg B/kg/week	Triangular	4.58E-04	N/A	4.58E-04	1.61E-02
Cr	Acidic rate	HCT (3)	mg Cr/kg/week	Triangular	9.17E-05	N/A	9.17E-05	1.06E-04
F	Acidic rate	HCT (3)	mg F/kg/week	Triangular	2.29E-02	N/A	2.27E-03	2.29E-02
Tl	Acidic rate	HCT (3)	mg Tl/kg/week	Triangular	9.17E-06	N/A	9.17E-06	2.29E-05

N/A = not used

Notes

- HCT (1+2) indicates average rates from humidity cells over Condition 1 and Condition 2.
- HCT (2) indicates average rates from humidity cells over Condition 2.
- HCT (3) indicates average rates from humidity cells over Condition 3.
- Except for SO4, all distributions from humidity cell data represent the full range of the observed values, with no weighting.
- Acidic release rate for SO_4 to be determined from nonacidic rate times an acidic increase factor, as discussed in Section 8.2.
- Distributions from aqua regia data represent the uncertainty in the average ratios, weighted by geologic unit.
- Distributions from microprobe data represent the full range of the observed ratios for each mineral, with no weighting.
- For nickel, S ratio from Category 4 aqua regia data represents the effect of all sulfide minerals combined.
- For chloride, release is a one-time flush from newly-exposed waste rock with a distribution determined from all humidity cells combined.

Table 1-26 Duluth Complex Category 4 Release Distributions

Constituent	Method	Source	Units	Distribution	Mean/Mode	St. Dev.	Minimum	Maximum
Ag	S ratio	Aqua Regia	mg Ag / mg S	Normal	3.30E-05	3.21E-06	N/A	N/A
Al	Ca ratio	Anorthite Formula	mg Al / mg Ca	Constant	1.35E+00	N/A	N/A	N/A
Alkalinity	Nonacidic rate	HCT (1+2)	mg Alk/kg/week	Beta	4.43E+00	2.60E+00	1.47E+00	1.10E+01
As	S ratio	Aqua Regia	mg As / mg S	Normal	1.40E-03	1.13E-04	N/A	N/A
B	Nonacidic rate	HCT (1+2)	mg B/kg/week	Beta	3.77E-02	7.88E-02	8.81E-04	9.05E-01
Ba	K ratio	Aqua Regia	mg Ba / mg K	Normal	2.46E-02	1.17E-03	N/A	N/A
Be	K ratio	Aqua Regia	mg Be / mg K	Normal	3.30E-04	3.04E-05	N/A	N/A
Ca	SO_4 rate ratio	HCT (1+2)	mg Ca / mg SO_4	Beta	3.56E-01	1.26E-01	1.80E-01	7.91E-01
Cd	Zn rate ratio	HCT (2)	mg Cd / mg Zn	Beta	9.16E-03	5.39E-03	2.70E-03	3.15E-02
Cl	Flush	HCT (all)	mg Cl/kg	Beta	9.78E+00	1.17E+01	1.38E+00	7.30E+01
Co	Ni rate ratio	HCT (2)	mg Co / mg Ni	Beta	1.56E-01	7.51E-02	7.79E-02	4.64E-01
Cr	Nonacidic rate	HCT (1+2)	mg Cr/kg/week	Beta	9.73E-05	9.22E-06	8.52E-05	1.22E-04
Cu	S ratio	Aqua Regia	mg Cu / mg S	Normal	6.81E-02	4.76E-03	N/A	N/A
F	Nonacidic rate	HCT (1+2)	mg F/kg/week	Beta	4.68E-02	4.78E-02	2.16E-02	3.37E-01
Fe	S ratio	Pyrrhotite microprobe	mg Fe / mg S	Beta	1.62E+00	8.72E-02	1.49E+00	1.92E+00
K	SO_4 rate ratio	HCT (1+2)	mg K / mg SO_4	Beta	1.00E-01	5.61E-02	2.61E-04	2.45E-01
Mg	SO_4 rate ratio	HCT (1+2)	mg Mg / mg SO_4	Beta	6.61E-02	4.17E-02	2.92E-02	2.00E-01
Mn	SO_4 rate ratio	HCT (2)	mg Mn / mg SO_4	Beta	2.94E-03	2.15E-03	5.94E-04	9.00E-03
Na	SO_4 rate ratio	HCT (1+2)	mg Na / mg SO_4	Beta	1.06E-01	1.02E-01	1.43E-02	4.51E-01
Ni	S ratio	Cat 4 Aqua Regia	mg Ni / mg S	Normal	3.06E-02	1.86E-03	N/A	N/A
Pb	S ratio	Aqua Regia	mg Pb / mg S	Normal	3.97E-04	4.33E-05	N/A	N/A
Sb	S ratio	Aqua Regia	mg Sb / mg S	Normal	1.30E-04	9.01E-06	N/A	N/A
Se	SO_4 rate ratio	HCT (2)	mg Se / mg SO_4	Beta	1.87E-05	9.12E-06	9.15E-06	4.91E-05
SO_4	Nonacidic rate	HCT (1+2)	mg SO_4/kg/week	Beta	1.27E+01	8.37E+00	3.74E+00	5.50E+01
Tl	Nonacidic rate	HCT (1+2)	mg Tl/kg/week	Beta	1.01E-05	1.68E-06	8.68E-06	1.55E-05
V	K ratio	Aqua Regia	mg V / mg K	Normal	4.33E-02	3.24E-03	N/A	N/A
Zn	Ni rate ratio	HCT (2)	mg Zn / mg Ni	Beta	4.42E-01	6.69E-01	3.47E-02	3.50E+00

Additional Distributions for Selected Constituents

Constituent	Method	Source	Units	Distribution	Mean/Mode	St. Dev.	Minimum	Maximum
Al	Na ratio	Albite Formula	mg Al / mg Na	Constant	1.17E+00	N/A	N/A	N/A
Fe	Mg ratio	Olivine microprobe	mg Fe / mg Mg	Beta	1.87E+00	6.75E-01	1.19E+00	4.51E+00
Ni	Mg ratio	Olivine microprobe	mg Ni / mg Mg	Beta	4.59E-03	1.95E-03	1.10E-04	7.43E-03

Acidic-Conditions Distributions for Selected Constituents

Constituent	Method	Source	Units	Distribution	Mean/Mode	St. Dev.	Minimum	Maximum
Alkalinity	Acidic rate	No release	mg Alk/kg/week	Constant	0	N/A	N/A	N/A
B	Acidic rate	HCT (3)	mg B/kg/week	Beta	2.52E-03	2.33E-03	5.06E-04	1.00E-02
Cr	Acidic rate	HCT (3)	mg Cr/kg/week	Beta	1.07E-04	1.20E-05	9.34E-05	1.47E-04
F	Acidic rate	HCT (3)	mg F/kg/week	Beta	2.57E-02	4.30E-03	2.25E-02	4.19E-02
Tl	Acidic rate	HCT (3)	mg Tl/kg/week	Beta	1.54E-05	7.45E-06	9.73E-06	4.26E-05

N/A = not used

Notes

- HCT (1+2) indicates average rates from humidity cells over Condition 1 and Condition 2.
- HCT (2) indicates average rates from humidity cells over Condition 2.
- HCT (3) indicates average rates from humidity cells over Condition 3.
- All distributions from humidity cell data represent the full range of the observed values, with no weighting.
- Acidic release rate for SO4 to be determined from nonacidic rate times an acidic increase factor, as discussed in Section 8.2.
- Distributions from aqua regia data represent the uncertainty in the average ratios, weighted by geologic unit.
- Distributions from microprobe data represent the full range of the observed ratios for each mineral, with no weighting.
- For nickel, S ratio from Category 4 aqua regia data represents the effect of all sulfide minerals combined.
- For chloride, release is a one-time flush from newly-exposed waste rock with a distribution determined from all humidity cells combined.

Table 1-27 **Ore Release Distributions**

Constituent	*Method*	*Source*	*Units*	*Distribution*	*Mean/Mode*	*St. Dev.*	*Minimum*	*Maximum*
Ag	S ratio	Aqua Regia	mg Ag / mg S	Normal	1.87E-04	2.80E-06	N/A	N/A
Al	Ca ratio	Anorthite Formula	mg Al / mg Ca	Constant	1.35E+00	N/A	N/A	N/A
Alkalinity	Nonacidic rate	HCT (1+2)	mg Alk/kg/week	Triangular	1.52E+00	N/A	1.37E+00	1.52E+00
As	S ratio	Aqua Regia	mg As / mg S	Normal	9.20E-04	3.48E-05	N/A	N/A
B	Nonacidic rate	HCT (1+2)	mg B/kg/week	Triangular	5.85E-03	N/A	5.09E-03	1.49E-02
Ba	K ratio	Aqua Regia	mg Ba / mg K	Normal	2.77E-02	1.06E-04	N/A	N/A
Be	K ratio	Aqua Regia	mg Be / mg K	Normal	1.22E-04	1.97E-06	N/A	N/A
Ca	SO_4 rate ratio	HCT (1+2)	mg Ca / mg SO_4	Triangular	2.16E-01	N/A	2.16E-01	2.18E-01
Cd	Zn rate ratio	HCT (2)	mg Cd / mg Zn	Triangular	5.76E-03	N/A	5.76E-03	6.72E-03
Cl	Flush	HCT (all)	mg Cl/kg	Beta	9.78E+00	1.17E+01	1.38E+00	7.30E+01
Co	Ni rate ratio	HCT (2)	mg Co / mg Ni	Triangular	4.86E-02	N/A	4.86E-02	6.08E-02
Cr	Nonacidic rate	HCT (1+2)	mg Cr/kg/week	Triangular	1.10E-04	N/A	1.10E-04	1.18E-04
Cu	S ratio	Aqua Regia	mg Cu / mg S	Normal	5.04E-01	5.62E-03	N/A	N/A
F	Nonacidic rate	HCT (1+2)	mg F/kg/week	Triangular	2.39E-02	N/A	2.39E-02	2.96E-02
Fe	S ratio	Pyrrhotite microprobe	mg Fe / mg S	Beta	1.62E+00	8.72E-02	1.49E+00	1.92E+00
K	SO_4 rate ratio	HCT (1+2)	mg K / mg SO_4	Triangular	3.97E-02	N/A	3.22E-02	4.16E-02
Mg	SO_4 rate ratio	HCT (1+2)	mg Mg / mg SO_4	Triangular	7.29E-02	N/A	7.29E-02	8.22E-02
Mn	SO_4 rate ratio	HCT (2)	mg Mn / mg SO_4	Triangular	5.89E-03	N/A	5.45E-03	6.27E-03
Na	SO_4 rate ratio	HCT (1+2)	mg Na / mg SO_4	Triangular	1.21E-02	N/A	1.21E-02	2.96E-01
Ni	S ratio	Ore Aqua Regia	mg Ni / mg S	Normal	1.53E-01	3.26E-03	N/A	N/A
Pb	S ratio	Aqua Regia	mg Pb / mg S	Normal	1.05E-03	4.85E-05	N/A	N/A
Sb	S ratio	Aqua Regia	mg Sb / mg S	Normal	3.38E-04	1.17E-05	N/A	N/A
Se	SO_4 rate ratio	HCT (2)	mg Se / mg SO_4	Triangular	4.01E-05	N/A	4.01E-05	4.42E-05
SO_4	Rate Regression	HCT (1+2)	mg SO_4/kg/week/%S	Normal	13.92	0.581	N/A	N/A
Tl	Nonacidic rate	HCT (1+2)	mg Tl/kg/week	Triangular	2.22E-05	N/A	1.74E-05	2.22E-05
V	K ratio	Aqua Regia	mg V / mg K	Normal	2.19E-02	3.36E-04	N/A	N/A
Zn	Ni rate ratio	HCT (2)	mg Zn / mg Ni	Triangular	2.28E-02	N/A	2.26E-02	3.00E-02

Additional Distributions for Selected Constituents

Constituent	*Method*	*Source*	*Units*	*Distribution*	*Mean/Mode*	*St. Dev.*	*Minimum*	*Maximum*
Al	Na ratio	Albite Formula	mg Al / mg Na	Constant	1.17E+00	N/A	N/A	N/A
Fe	Mg ratio	Olivine microprobe	mg Fe / mg Mg	Beta	1.87E+00	6.75E-01	1.19E+00	4.51E+00
Ni	Mg ratio	Olivine microprobe	mg Ni / mg Mg	Beta	4.59E-03	1.95E-03	1.10E-04	7.43E-03

N/A = not used

Notes

- HCT (1+2) indicates average rates from humidity cells over Condition 1 and Condition 2.
- HCT (2) indicates average rates from humidity cells over Condition 2.
- Except for SO4, all distributions from humidity cell data represent the full range of the observed values in the humidity cells, with no weighting. Distributions from humidity cells shown here are only used for the blended OSP; Category 2/3 humidity cells are used to capture the full range of variability in the ore wall rock.
- Acidic release rate for SO4 to be determined from nonacidic rate times an acidic increase factor, as discussed in Section 8.2.
- Distributions from aqua regia data represent the uncertainty in the average ratios, weighted by geologic unit.
- Distributions from microprobe data represent the full range of the observed ratios for each mineral, with no weighting.
- For nickel, S ratio from ore aqua regia data represents the effect of all sulfide minerals combined.
- For B, Cr, F, and Tl no increase in release rates due to acidic conditions is indicated by laboratory data.
- For chloride, release is a one-time flush from newly-exposed waste rock with a distribution determined from all humidity cells combined.

Table 1-28 **Virginia Formation Category 4 Release Distributions**

Constituent	*Method*	*Source*	*Units*	*Distribution*	*Mean/Mode*	*St. Dev.*	*Minimum*	*Maximum*
Ag	S ratio	Aqua Regia	mg Ag / mg S	Normal	3.42E-05	2.23E-06	N/A	N/A
Al	Ca ratio	Anorthite Formula	mg Al / mg Ca	Constant	1.35E+00	N/A	N/A	N/A
Alkalinity	Acidic rate	No release	mg Alk/kg/week	Constant	0	N/A	N/A	N/A
As	S ratio	Aqua Regia	mg As / mg S	Normal	2.87E-03	1.28E-04	N/A	N/A
B	Acidic rate	HCT (3)	mg B/kg/week	Triangular	6.70E-03	N/A	6.70E-03	1.70E-02
Ba	K ratio	Aqua Regia	mg Ba / mg K	Normal	1.51E-02	5.79E-04	N/A	N/A
Be	S ratio	Aqua Regia	mg Be / mg S	Normal	1.02E-04	1.02E-05	N/A	N/A
Ca	SO_4 rate ratio	HCT (3)	mg Ca / mg SO_4	Triangular	2.32E-02	N/A	2.32E-02	2.50E-01
Cd	S ratio	Aqua Regia	mg Cd / mg S	Normal	1.88E-04	5.11E-05	N/A	N/A
Cl	Flush	HCT (all)	mg Cl/kg	Beta	9.78E+00	1.17E+01	1.38E+00	7.30E+01
Co	S ratio	Aqua Regia	mg Co / mg S	Normal	4.26E-03	6.15E-04	N/A	N/A
Cr	Acidic rate	HCT (3)	mg Cr/kg/week	Triangular	1.11E-04	N/A	9.14E-05	1.28E-04
Cu	S ratio	Aqua Regia	mg Cu / mg S	Normal	2.51E-02	2.59E-03	N/A	N/A
F	Acidic rate	HCT (3)	mg F/kg/week	Triangular	2.50E-02	N/A	2.50E-02	4.98E-02
Fe	SO_4 rate ratio	HCT (3)	mg Fe / mg SO_4	Triangular	5.80E-02	N/A	3.98E-02	3.16E-01
K	SO_4 rate ratio	HCT (3)	mg K / mg SO_4	Triangular	8.03E-03	N/A	8.03E-03	1.79E-02
Mg	SO_4 rate ratio	HCT (3)	mg Mg / mg SO_4	Triangular	5.32E-02	N/A	2.93E-02	7.83E-02
Mn	Acidic rate	HCT (3)	mg Mn/kg/week	Triangular	7.11E-02	N/A	3.49E-02	1.56E-01
Na	SO_4 rate ratio	HCT (3)	mg Na / mg SO_4	Triangular	5.64E-03	N/A	5.64E-03	1.79E-02
Ni	S ratio	Aqua Regia	mg Ni / mg S	Normal	1.76E-02	1.39E-03	N/A	N/A
Pb	S ratio	Aqua Regia	mg Pb / mg S	Normal	9.23E-04	3.07E-04	N/A	N/A
Sb	S ratio	Aqua Regia	mg Sb / mg S	Normal	2.70E-04	2.28E-05	N/A	N/A
Se	SO_4 rate ratio	HCT (3)	mg Se / mg SO_4	Triangular	8.52E-06	N/A	4.86E-06	9.20E-06
SO_4	Acidic rate	HCT (3)	mg SO_4/kg/week	Triangular	5.76E+01	N/A	4.44E+01	5.76E+01
Tl	Acidic rate	HCT (3)	mg Tl/kg/week	Triangular	1.11E-05	N/A	9.92E-06	1.21E-05
V	K ratio	Aqua Regia	mg V / mg K	Normal	2.18E-02	1.07E-03	N/A	N/A
Zn	S ratio	Aqua Regia	mg Zn / mg S	Normal	3.03E-02	2.88E-03	N/A	N/A

Additional Distributions for Selected Constituents

Constituent	*Method*	*Source*	*Units*	*Distribution*	*Mean/Mode*	*St. Dev.*	*Minimum*	*Maximum*
Al	Na ratio	Albite Formula	mg Al / mg Na	Constant	1.17E+00	N/A	N/A	N/A

N/A = not used

Notes

- HCT (3) indicates average rates from humidity cells over Condition 3.
- All distributions from humidity cell data represent the full range of the observed values, with no weighting.
- Distributions from aqua regia data represent the uncertainty in the average ratios, weighted by geologic unit.
- For chloride, release is a one-time flush from newly-exposed waste rock with a distribution determined from all humidity cells combined.

Table 1-29 **Average Whole Rock Content for Depletion (ppm)**

Constituent	*Units*	*Category 1*	*Category 2/3*	*Category 4 Duluth Complex*	*Category 4 Virginia Formation*	*Ore*
Ag	ppm	1.35E-01	2.80E-01	3.63E-01	3.61E-01	1.31E+00
Al	ppm	4.07E+04	3.86E+04	4.04E+04	3.23E+04	3.84E+04
Alkalinity*	ppm	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
As	ppm	2.47E+00	3.52E+00	1.99E+01	3.20E+01	6.92E+00
B	ppm	7.94E+00	7.32E+00	9.16E+00	8.82E+00	5.02E+00
Ba	ppm	4.07E+01	4.85E+01	5.57E+01	1.04E+02	4.72E+01
Be	ppm	2.43E-01	2.66E-01	6.15E-01	5.77E-01	1.81E-01
Ca	ppm	2.22E+04	2.18E+04	1.79E+04	5.93E+03	2.11E+04
Cd	ppm	4.19E-01	4.59E-01	7.34E-01	1.42E+00	9.72E-01
Cl*	ppm	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
Co	ppm	4.83E+01	4.99E+01	6.05E+01	2.56E+01	7.48E+01
Cr	ppm	1.01E+02	8.74E+01	1.23E+02	1.86E+02	8.26E+01
Cu	ppm	2.15E+02	7.47E+02	7.18E+02	2.17E+02	3.58E+03
F*	ppm	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
Fe	ppm	6.17E+04	5.97E+04	5.47E+04	5.28E+04	7.14E+04
K	ppm	1.40E+03	1.72E+03	2.66E+03	8.18E+03	1.75E+03
Mg	ppm	4.00E+04	3.30E+04	2.00E+04	1.37E+04	3.63E+04
Mn	ppm	7.01E+02	6.28E+02	3.69E+02	2.43E+02	6.65E+02
Na	ppm	5.80E+03	5.12E+03	3.40E+03	9.94E+02	4.87E+03
Ni	ppm	2.55E+02	3.29E+02	3.33E+02	1.35E+02	9.72E+02
Pb	ppm	2.45E+00	2.52E+00	5.10E+00	5.87E+00	6.22E+00
Sb	ppm	1.34E+00	1.31E+00	1.48E+00	1.74E+00	1.78E+00
Se*	ppm	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
SO_4†	ppm	1.90E+03	6.30E+03	2.85E+04	7.28E+04	2.70E+04
Tl	ppm	4.78E+00	4.74E+00	4.75E+00	4.30E+00	3.40E+00
V	ppm	3.32E+01	3.77E+01	9.11E+01	1.36E+02	3.69E+01
Zn	ppm	6.83E+01	7.18E+01	1.04E+02	2.51E+02	8.11E+01

Notes

* Whole rock content data not available. No depletion modeled.

† Sulfur data from Block Model (S converted to SO_4), all others from drill core dataset

Table 1-30 Category 1 Concentration Cap Distributions

Constituent	*Method*	*Source*	*Units*	*Distribution*	*Mean/Mode*	*St. Dev.*	*Minimum*	*Maximum*
Ag	Limit	Whistle Mine	mg/L	Constant	2.00E-02	N/A	N/A	N/A
Al	Function pH (Solubility equation)		mg/L		N/A	N/A	N/A	N/A
Alkalinity	Function pH (AMAX data)		mg/L		N/A	N/A	N/A	N/A
As	Limit	Whistle Mine	mg/L	Constant	1.00E-01	N/A	N/A	N/A
B	Limit	Whistle Mine	mg/L	Constant	1.00E-01	N/A	N/A	N/A
Ba	Solubility equation				N/A	N/A	N/A	N/A
Be	Limit	Whistle Mine	mg/L	Constant	5.00E-03	N/A	N/A	N/A
Ca	Solubility equation				N/A	N/A	N/A	N/A
Cd	Function Zn limit, Cd/Zn release ratio				N/A	N/A	N/A	N/A
Cl	No limit				N/A	N/A	N/A	N/A
Co	Function pH (AMAX data)				N/A	N/A	N/A	N/A
Cr	Limit	Whistle Mine	mg/L	Constant	1.00E-02	N/A	N/A	N/A
Cu	Function pH (AMAX data)				N/A	N/A	N/A	N/A
F	Solubility equation				N/A	N/A	N/A	N/A
Fe	Function pH (AMAX data)		mg/L		N/A	N/A	N/A	N/A
K	Function pH (AMAX data)		mg/L		N/A	N/A	N/A	N/A
Mg	Function Ca limit, Mg/Ca release ratio				N/A	N/A	N/A	N/A
Mn	Function pH (AMAX data)		mg/L		N/A	N/A	N/A	N/A
Na	Function pH (AMAX data)		mg/L		N/A	N/A	N/A	N/A
Ni	Function pH (AMAX data)		mg/L		N/A	N/A	N/A	N/A
Pb	Limit	Whistle Mine	mg/L	Constant	1.00E-01	N/A	N/A	N/A
Sb	Limit	Whistle Mine	mg/L	Constant	1.00E+00	N/A	N/A	N/A
Se	Function SO4 limit, Se/SO4 release ratio				N/A	N/A	N/A	N/A
SO4	Solubility equation				N/A	N/A	N/A	N/A
Tl	Limit	Vangorda Mine	mg/L	Constant	2.10E-02	N/A	N/A	N/A
V	Limit	Whistle Mine	mg/L	Constant	1.00E-02	N/A	N/A	N/A
Zn	Function pH (AMAX data)		mg/L		N/A	N/A	N/A	N/A

N/A = not used

pH-based Range from AMAX Data
(95th percentile values, all units mg/L)

pH	*Alkalinity*	*Co*	*Cu*	*Fe*	*K*	*Mn*	*Na*	*Ni*	*Zn*
7.5	4.82E+01	5.00E-02	1.00E-01	4.00E-02	4.60E+01	2.27E-01	2.18E+02	9.05E-01	9.64E-02
7.4	4.92E+01	7.00E-02	9.68E-02	4.20E-02	4.28E+01	1.72E-01	2.19E+02	1.28E+00	7.00E-02
7.3	3.59E+01	9.30E-02	2.00E-01	5.00E-02	5.04E+01	2.00E-01	2.31E+02	1.62E+00	1.33E-01
7.2	3.55E+01	1.36E-01	1.78E-01	1.01E-01	4.28E+01	1.75E-01	1.73E+02	2.08E+00	1.70E-01
7.1	3.45E+01	2.33E-01	2.85E-01	7.50E-02	4.61E+01	3.86E-01	1.38E+02	4.31E+00	2.93E-01
7.0	2.60E+01	2.80E-01	5.20E-01	4.00E-02	3.99E+01	3.08E-01	1.32E+02	5.91E+00	4.05E-01

pH-based Range from AMAX Data
(maximum values, all units mg/L)

pH	*Alkalinity*	*Co*	*Cu*	*Fe*	*K*	*Mn*	*Na*	*Ni*	*Zn*
7.5	5.27E+01	5.00E-02	1.30E-01	7.00E-02	6.00E+01	2.40E-01	3.13E+02	1.70E+00	1.00E-01
7.4	5.40E+01	8.00E-02	1.80E-01	6.00E-02	5.32E+01	1.90E-01	3.22E+02	1.35E+00	1.12E-01
7.3	3.60E+01	1.20E-01	2.60E-01	6.00E-02	5.90E+01	3.00E-01	2.60E+02	2.29E+00	2.30E-01
7.2	4.50E+01	1.50E-01	3.40E-01	7.00E-01	4.43E+01	2.40E-01	2.00E+02	3.42E+00	2.30E-01
7.1	4.10E+01	3.10E-01	7.50E-01	8.00E-02	4.80E+01	9.70E-01	5.91E+02	7.02E+00	3.70E-01
7.0	4.30E+01	6.20E-01	2.30E+00	4.00E-02	4.30E+01	3.80E-01	2.60E+02	1.30E+01	5.50E-01

Notes

- All distributions from Whistle Mine data represent the detection limit used for nonacidic conditions.
- All distributions from Vangorda Mine data represent the highest observed concentration under acidic conditions.
- All distributions from AMAX data represent a uniform distribution between the 95th percentile and maximum observed value at the referenced pH for AMAX piles with 0.64% S.
- Concentration caps for all constituents not shown are calculated from the equations shown below.

$$SO_4\left(\frac{mg}{L}\right) = 1294 \times \frac{[Mg + .5Na + .5K]\left(\frac{mmol}{kg \cdot week}\right)}{Ca\left(\frac{mmol}{kg \cdot week}\right)} + 1760$$

$$Ca\left(\frac{mmol}{L}\right) = \frac{2SO_{4,Cap}\left(\frac{mmol}{L}\right) + Alk_{Cap}\left(\frac{mmol}{L}\right) - K_{Cap}\left(\frac{mmol}{L}\right)}{2 + \frac{[2Mg + Na]\left(\frac{mmol}{kg \cdot week}\right)}{Ca\left(\frac{mmol}{kg \cdot week}\right)}}$$

$$Mg\left(\frac{mg}{L}\right) = Ca_{Cap}\left(\frac{mg}{L}\right) \cdot \left[\frac{Mg}{Ca}\right]\left(\frac{mg}{kg \cdot week}\right)$$

$$\log\left[Ba\left(\frac{mg}{L}\right)\right] = -0.32 \times \log\left[SO_4\left(\frac{mg}{L}\right)\right] - 0.87$$

$$F\left(\frac{mol}{L}\right) = \sqrt{\frac{8.91\text{x}10^{-11}\left(\frac{mol^3}{kg^3}\right)}{Ca\left(\frac{mol}{L}\right)}} \times \left[\rho_{water}\left(\frac{\text{kg}}{L}\right)\right]^{1.5}$$

$$\log\left[Al\left(\frac{mg}{L}\right)\right] = 0.909 \cdot \text{pH} - 9.44$$

Table 1-30b Category 1 Scale-up Factor Distribution

Value	*Percentile*
0.032	0
0.067	0.071
0.072	0.142
0.093	0.214
0.098	0.285
0.111	0.357
0.120	0.428
0.146	0.500
0.153	0.571
0.174	0.642
0.187	0.714
0.198	0.785
0.264	0.857
0.277	0.928
0.376	1

Table 1-31 Duluth Complex Category 2/3, 4, and Ore Concentration Cap Distributions (Nonacidic Conditions)

Constituent	*Method*	*Source*	*Units*	*Distribution*	*Mean/Mode*	*St. Dev.*	*Minimum*	*Maximum*
Ag	Limit	Whistle Mine	mg/L	Constant	2.00E-02	N/A	N/A	N/A
Al	Function pH (Solubility equation)		mg/L		N/A	N/A	N/A	N/A
Alkalinity	Function pH (AMAX data)		mg/L		N/A	N/A	N/A	N/A
As	Limit	Whistle Mine	mg/L	Constant	1.00E-01	N/A	N/A	N/A
B	Limit	Whistle Mine	mg/L	Constant	1.00E-01	N/A	N/A	N/A
Ba	Solubility equation				N/A	N/A	N/A	N/A
Be	Limit	Whistle Mine	mg/L	Constant	5.00E-03	N/A	N/A	N/A
Ca	Solubility equation				N/A	N/A	N/A	N/A
Cd	Function Zn limit, Cd/Zn release ratio				N/A	N/A	N/A	N/A
Cl	No limit				N/A	N/A	N/A	N/A
Co	Function pH (AMAX data)				N/A	N/A	N/A	N/A
Cr	Limit	Whistle Mine	mg/L	Constant	1.00E-02	N/A	N/A	N/A
Cu	Function pH (AMAX data)				N/A	N/A	N/A	N/A
F	Solubility equation				N/A	N/A	N/A	N/A
Fe	Function pH (AMAX data)		mg/L		N/A	N/A	N/A	N/A
K	Function pH (AMAX data)		mg/L		N/A	N/A	N/A	N/A
Mg	Function Ca limit, Mg/Ca release ratio				N/A	N/A	N/A	N/A
Mn	Function pH (AMAX data)		mg/L		N/A	N/A	N/A	N/A
Na	Function pH (AMAX data)		mg/L		N/A	N/A	N/A	N/A
Ni	Function pH (AMAX data)		mg/L		N/A	N/A	N/A	N/A
Pb	Limit	Whistle Mine	mg/L	Constant	1.00E-01	N/A	N/A	N/A
Sb	Limit	Whistle Mine	mg/L	Constant	1.00E+00	N/A	N/A	N/A
Se	Function SO4 limit, Se/SO4 release ratio				N/A	N/A	N/A	N/A
SO4	Solubility equation				N/A	N/A	N/A	N/A
Tl	Limit	Vangorda Mine	mg/L	Constant	2.10E-02	N/A	N/A	N/A
V	Limit	Whistle Mine	mg/L	Constant	1.00E-02	N/A	N/A	N/A
Zn	Function pH (AMAX data)		mg/L		N/A	N/A	N/A	N/A

N/A = not used

= change in previously published value

pH-based Range from AMAX Data
(95th percentile values, all units mg/L)

pH	*Alkalinity*	*Co*	*Cu*	*Fe*	*K*	*Mn*	*Na*	*Ni*	*Zn*
7.5	4.79E+01	2.48E-01	1.30E-01	7.45E-02	4.60E+01	1.40E+00	4.68E+02	1.50E+00	1.00E-01
7.4	4.90E+01	2.04E-01	1.47E-01	5.90E-02	4.21E+01	1.49E+00	3.94E+02	1.58E+00	9.73E-02
7.3	3.59E+01	9.30E-02	2.00E-01	5.00E-02	5.04E+01	2.00E-01	2.31E+02	1.62E+00	1.33E-01
7.2	3.53E+01	1.89E-01	2.33E-01	1.68E-01	4.25E+01	1.72E+00	3.47E+02	3.21E+00	1.82E-01
7.1	3.45E+01	2.31E-01	2.84E-01	8.00E-02	4.60E+01	6.46E-01	1.85E+02	4.31E+00	2.91E-01
7.0	2.60E+01	5.08E-01	5.59E-01	5.00E-02	3.96E+01	2.48E+00	2.41E+02	7.40E+00	4.09E-01
6.9	2.80E+01	1.02E+00	3.70E+00	1.78E-01	4.18E+01	1.90E+00	1.82E+02	1.98E+01	7.30E-01
6.8	2.16E+01	1.45E+00	5.02E+00	7.00E-02	5.06E+01	1.13E+00	1.50E+02	2.98E+01	1.24E+00
6.7	2.18E+01	1.24E+00	4.30E+00	1.02E-01	4.80E+01	3.61E+00	1.69E+02	2.06E+01	8.78E-01
6.6	1.44E+01	1.05E+00	5.44E+00	1.26E-01	5.07E+01	2.91E+00	2.05E+02	2.46E+01	8.66E-01
6.5	1.60E+01	1.52E+00	6.50E+00	6.00E-02	4.65E+01	1.39E+00	1.42E+02	3.15E+01	1.26E+00
6.4	1.53E+01	2.10E+00	7.09E+00	1.86E-01	4.88E+01	3.45E+00	1.78E+02	5.08E+01	1.51E+00
6.3	1.17E+01	2.11E+00	8.85E+00	8.40E-02	5.04E+01	3.03E+00	2.38E+02	4.75E+01	1.29E+00
6.2	6.90E+00	2.56E+00	1.02E+01	4.00E-02	5.37E+01	4.01E+00	4.39E+02	7.00E+01	1.87E+00
6.1	9.90E+00	3.13E+00	1.49E+01	5.85E-02	6.15E+01	3.26E+00	1.27E+02	8.35E+01	2.33E+00
6.0	9.40E+00	1.42E+00	8.56E+00	3.00E-02	4.97E+01	3.40E+00	1.64E+02	3.02E+01	1.60E+00

pH-based Range from AMAX Data
(maximum values, all units mg/L)

pH	*Alkalinity*	*Co*	*Cu*	*Fe*	*K*	*Mn*	*Na*	*Ni*	*Zn*
7.5	5.27E+01	2.80E-01	1.70E-01	1.50E-01	6.00E+01	1.68E+00	7.00E+02	1.70E+00	1.74E-01
7.4	5.40E+01	2.16E+00	1.80E-01	7.00E-02	5.32E+01	2.40E+00	4.91E+02	2.15E+01	3.96E-01
7.3	3.60E+01	1.20E-01	2.60E-01	6.00E-02	5.90E+01	3.00E-01	2.60E+02	2.29E+00	2.30E-01
7.2	4.50E+01	8.10E-01	3.40E-01	7.00E-01	4.43E+01	2.14E+00	8.62E+02	6.70E+00	2.30E-01
7.1	4.10E+01	3.10E-01	7.50E-01	1.20E-01	4.80E+01	1.64E+00	1.11E+03	7.02E+00	3.70E-01
7.0	4.30E+01	1.24E+00	2.30E+00	6.00E-02	4.30E+01	3.05E+00	2.69E+02	1.30E+01	5.50E-01
6.9	5.03E+01	1.71E+00	6.24E+00	3.00E-01	5.52E+01	2.28E+00	2.13E+02	4.50E+01	1.15E+00
6.8	3.30E+01	2.41E+00	7.25E+00	1.20E-01	5.80E+01	1.74E+00	3.13E+02	4.40E+01	1.65E+00
6.7	3.30E+01	1.41E+00	5.01E+00	1.30E-01	4.84E+01	5.57E+00	3.30E+02	4.10E+01	1.17E+00
6.6	3.90E+01	3.22E+00	1.10E+01	1.02E+00	8.40E+01	3.23E+00	2.40E+02	8.00E+01	2.25E+00
6.5	2.10E+01	1.87E+00	6.95E+00	6.00E-02	5.60E+01	1.89E+00	3.04E+02	4.30E+01	1.53E+00
6.4	2.20E+01	3.24E+00	7.57E+00	3.90E-01	5.10E+01	4.07E+00	2.70E+02	7.95E+01	1.69E+00
6.3	1.36E+01	2.30E+00	1.70E+01	1.00E-01	5.20E+01	3.32E+00	2.49E+02	6.70E+01	1.56E+00
6.2	6.90E+00	3.65E+00	1.20E+01	4.00E-02	5.40E+01	4.10E+00	6.09E+02	9.10E+01	2.01E+00
6.1	9.90E+00	3.34E+00	1.70E+01	6.00E-02	6.35E+01	3.36E+00	1.30E+02	9.10E+01	2.58E+00
6.0	1.11E+01	1.60E+00	1.10E+01	3.00E-02	5.20E+01	3.40E+00	2.01E+02	3.20E+01	1.61E+00

Notes

- All distributions from Whistle Mine data represent the detection limit used for nonacidic conditions.
- All distributions from Vangorda Mine data represent the highest observed concentration under acidic conditions.
- All distributions from AMAX data represent a uniform distribution between the 95th percentile and maximum observed value at the referenced pH for all AMAX piles (0.64% S to 1.4% S).
- Concentration caps for all constituents not shown are calculated from the equations shown below.

$$SO_4\left(\frac{mg}{L}\right) = 1294 \times \frac{[Mg + .5Na + .5K]\left(\frac{mmol}{kg\cdot week}\right)}{Ca\left(\frac{mmol}{kg\cdot week}\right)} + 1760$$

$$\log\left[Al\left(\frac{mg}{L}\right)\right] = 0.909 \cdot \text{pH} - 9.44$$

$$Ca\left(\frac{mmol}{L}\right) = \frac{2SO_{4,Cap}\left(\frac{mmol}{L}\right) + Alk_{Cap}\left(\frac{mmol}{L}\right) - K_{Cap}\left(\frac{mmol}{L}\right)}{2 + \frac{[2Mg + Na]\left(\frac{mmol}{kg\cdot week}\right)}{Ca\left(\frac{mmol}{kg\cdot week}\right)}}$$

$$Mg\left(\frac{mg}{L}\right) = Ca_{Cap}\left(\frac{mg}{L}\right) \cdot \left[\frac{Mg}{Ca}\right]\left(\frac{mg}{kg\cdot week}\right)$$

$$\log\left[Ba\left(\frac{mg}{L}\right)\right] = -0.32 \times \log\left[SO_4\left(\frac{mg}{L}\right)\right] - 0.87$$

$$F\left(\frac{mol}{L}\right) = \sqrt{\frac{8.91\text{x}10^{-11}\left(\frac{mol^3}{kg^3}\right)}{Ca\left(\frac{mol}{L}\right)}} \times \left[\rho_{water}\left(\frac{\text{kg}}{L}\right)\right]^{1.5}$$

Table 1-32 Duluth Complex Category 2/3, 4, and Ore Concentration Cap Distributions (Acidic Conditions)

Distribution Fit to AMAX, Whistle, and Vangorda Mine Data

Constituent	*Method*	*Source*	*Units*	*Distribution*	*Mean/Mode*	*St. Dev.*	*Minimum*	*Maximum*
Ag	Cap	Whistle Mine	mg/L	Beta	4.20E-02	4.62E-03	3.40E-02	5.00E-02
Al	Cap	Whistle Mine	mg/L	Beta	4.33E+02	2.56E+02	1.13E+02	1.00E+03
Alkalinity	No cap				N/A	N/A	N/A	N/A
As	Cap	Whistle Mine	mg/L	Constant	1.00E-01	N/A	N/A	N/A
B	Cap	Whistle Mine	mg/L	Beta	2.19E-01	9.45E-02	9.23E-02	5.00E-01
Ba	Solubility equation				N/A	N/A	N/A	N/A
Be	Cap	Whistle Mine	mg/L	Beta	1.62E-02	4.31E-03	5.26E-03	2.21E-02
Ca	Cap	Whistle Mine	mg/L	Beta	4.09E+02	4.15E+01	2.62E+02	5.54E+02
Cd	Cap	Whistle Mine	mg/L	Beta	1.47E-01	8.84E-02	5.35E-02	4.51E-01
Cl	No cap				N/A	N/A	N/A	N/A
Co	Cap	Whistle Mine	mg/L	Beta	3.04E+01	9.27E+00	8.68E+00	4.14E+01
Cr	Cap	Whistle Mine	mg/L	Beta	1.60E-02	5.77E-04	1.50E-02	1.70E-02
Cu	Cap	AMAX pH 3-4	mg/L	Beta	1.49E+02	1.30E+01	9.79E+01	1.79E+02
F	Solubility equation				N/A	N/A	N/A	N/A
Fe	Cap	Whistle Mine	mg/L	Beta	9.57E+01	5.56E+01	1.61E+00	4.32E+02
K	Cap	Whistle Mine	mg/L	Beta	2.92E+01	9.52E+00	9.39E+00	1.53E+02
Mg	Cap	Whistle Mine	mg/L	Beta	9.92E+02	3.92E+02	4.82E+02	2.11E+03
Mn	Cap	Whistle Mine	mg/L	Beta	5.48E+01	2.32E+01	1.75E+01	1.03E+02
Na	Cap	Whistle Mine	mg/L	Beta	8.75E+01	6.32E+01	2.48E+01	7.17E+02
Ni	Cap	Whistle Mine	mg/L	Beta	6.41E+02	1.90E+02	9.97E+01	8.41E+02
Pb	Cap	Whistle Mine	mg/L	Beta	3.64E-01	1.36E-01	1.28E-01	6.00E-01
Sb	Cap	Whistle Mine	mg/L	Beta	2.00E+00	5.77E-01	1.00E+00	3.00E+00
Se	Cap	Whistle Mine	mg/L	Constant	1.00E-01	N/A	N/A	N/A
SO4	Cap	Whistle Mine	mg/L	Beta	9.52E+03	3.39E+03	3.29E+03	1.81E+04
Tl	Cap	Vangorda Mine	mg/L	Beta	4.47E-02	1.22E-01	2.00E-03	2.18E+00
V	Cap	Whistle Mine	mg/L	Beta	5.50E-02	2.89E-03	5.00E-02	6.00E-02
Zn	Cap	Whistle Mine	mg/L	Beta	1.54E+01	1.21E+01	6.34E+00	6.00E+01

N/A = not used

Notes

- All distributions from Whistle and Vangorda Mine data represent the full range of the observed values.
- All distributions from AMAX data represent the full range of the highest 5% of observed values in each 0.1 pH increment over the indicated pH range.
- Concentration caps for all constituents not shown are calculated from the equations shown below.

$$\log\left[Ba\left(\frac{mg}{L}\right)\right] = -0.32 \times \log\left[SO_4\left(\frac{mg}{L}\right)\right] - 0.87$$

$$F\left(\frac{mol}{L}\right) = \sqrt{\frac{8.91\text{x}10^{-11}\left(\frac{mol^3}{kg^3}\right)}{Ca\left(\frac{mol}{L}\right)}} \times \left[\rho_{water}\ \left(\frac{\text{kg}}{L}\right)\right]^{1.5}$$

Table 1-33 **Virginia Formation Category 4 Concentration Cap Distributions (Acidic Conditions)**

Distribution Fit to AMAX, Whistle, and Vangorda Mine Data

Constituent	*Method*	*Source*	*Units*	*Distribution*	*Mean/Mode*	*St. Dev.*	*Minimum*	*Maximum*
Ag	Cap	Vangorda Mine	mg/L	Beta	5.86E-02	7.07E-02	6.24E-03	8.65E-01
Al	Cap	Whistle Mine	mg/L	Beta	4.33E+02	2.56E+02	1.13E+02	1.00E+03
Alkalinity	No cap				N/A	N/A	N/A	N/A
As	Cap	Vangorda Mine	mg/L	Beta	4.21E-01	5.54E-01	1.13E-02	2.50E+00
B	Cap	Vangorda Mine	mg/L	Beta	1.39E+00	9.65E-01	1.30E-02	3.27E+00
Ba	Cap	Vangorda Mine	mg/L	Beta	2.61E-01	3.60E-01	4.96E-03	1.92E+00
Be	Cap	Vangorda Mine	mg/L	Beta	4.59E-02	6.33E-02	5.24E-03	3.20E-01
Ca	Cap	Vangorda Mine	mg/L	Beta	4.09E+02	4.85E+01	3.28E+02	4.98E+02
Cd	Cap	Whistle Mine	mg/L	Beta	1.47E-01	8.84E-02	5.35E-02	4.51E-01
Cl	No cap				N/A	N/A	N/A	N/A
Co	Cap	Vangorda Mine	mg/L	Beta	1.53E+01	6.81E+00	6.98E+00	3.08E+01
Cr	Cap	Vangorda Mine	mg/L	Beta	9.19E-02	1.52E-01	9.60E-03	8.70E-01
Cu	Cap	Vangorda Mine	mg/L	Beta	1.37E-01	1.03E-01	3.06E-02	6.08E-01
F	Solubility equation				N/A	N/A	N/A	N/A
Fe	Cap	Vangorda Mine	mg/L	Beta	8.60E+02	1.14E+03	6.00E+00	5.08E+03
K	Cap	Vangorda Mine	mg/L	Beta	1.26E+01	8.42E+00	6.00E-01	3.00E+01
Mg	Cap	Vangorda Mine	mg/L	Beta	2.03E+03	1.48E+03	5.75E+02	6.20E+03
Mn	Cap	Vangorda Mine	mg/L	Beta	1.55E+03	1.10E+03	3.30E+02	4.32E+03
Na	Cap	Vangorda Mine	mg/L	Beta	1.67E+01	1.01E+01	7.39E+00	1.22E+02
Ni	Cap	Vangorda Mine	mg/L	Beta	1.08E+01	5.45E+00	4.17E+00	2.33E+01
Pb	Cap	Whistle Mine	mg/L	Beta	3.64E-01	1.36E-01	1.28E-01	6.00E-01
Sb	Cap	Vangorda Mine	mg/L	Beta	3.25E+00	2.78E+00	1.00E-03	1.60E+01
Se	Cap	Vangorda Mine	mg/L	Beta	4.34E-01	5.99E-01	7.33E-02	3.20E+00
SO4	Cap	Vangorda Mine	mg/L	Beta	2.23E+04	2.21E+04	3.54E+03	1.00E+05
Tl	Cap	Vangorda Mine	mg/L	Beta	4.47E-02	1.22E-01	2.00E-03	2.18E+00
V	Cap	Vangorda Mine	mg/L	Beta	6.00E-02	9.66E-02	3.00E-03	5.15E-01
Zn	Cap	Whistle Mine	mg/L	Beta	1.54E+01	1.21E+01	6.34E+00	6.00E+01

N/A = not used

Notes

- All distributions from Whistle and Vangorda Mine data represent the full range of the observed values.
- Concentration caps for all constituents not shown are calculated from the equations shown below.

$$F\left(\frac{mol}{L}\right) = \sqrt{\frac{8.91\text{x}10^{-11}\left(\frac{mol^3}{kg^3}\right)}{Ca\left(\frac{mol}{L}\right)}} \times \left[\rho_{water}\ \left(\frac{\text{kg}}{L}\right)\right]^{1.5}$$

Table 1-34 Waste Water Treatment Facility Effluent Targets

Constituent	*Target Concentration (mg/L)*
Ag	0.001
Al	0.125
Alk	N/A
As	0.01
B	0.5
Ba	2
Be	0.004
Ca*	N/A
Cd	0.004
Cl	230
Co	0.005
Cr	0.011
Cu	0.03
F	2
Fe	0.3
K	N/A
Mg*	N/A
Mn	0.05
Na	N/A
Ni	0.1
Pb	0.019
Sb	0.031
Se	0.005
SO_4	250
Tl	0.00056
V	0.050
Zn	0.388
Hardness	250

Notes
Source: WWTF design (ongoing)
* Calcium and magnesium concentrations are limited by the target hardness concentration
Constituents without defined limits are assumed to not be removed by the WWTF

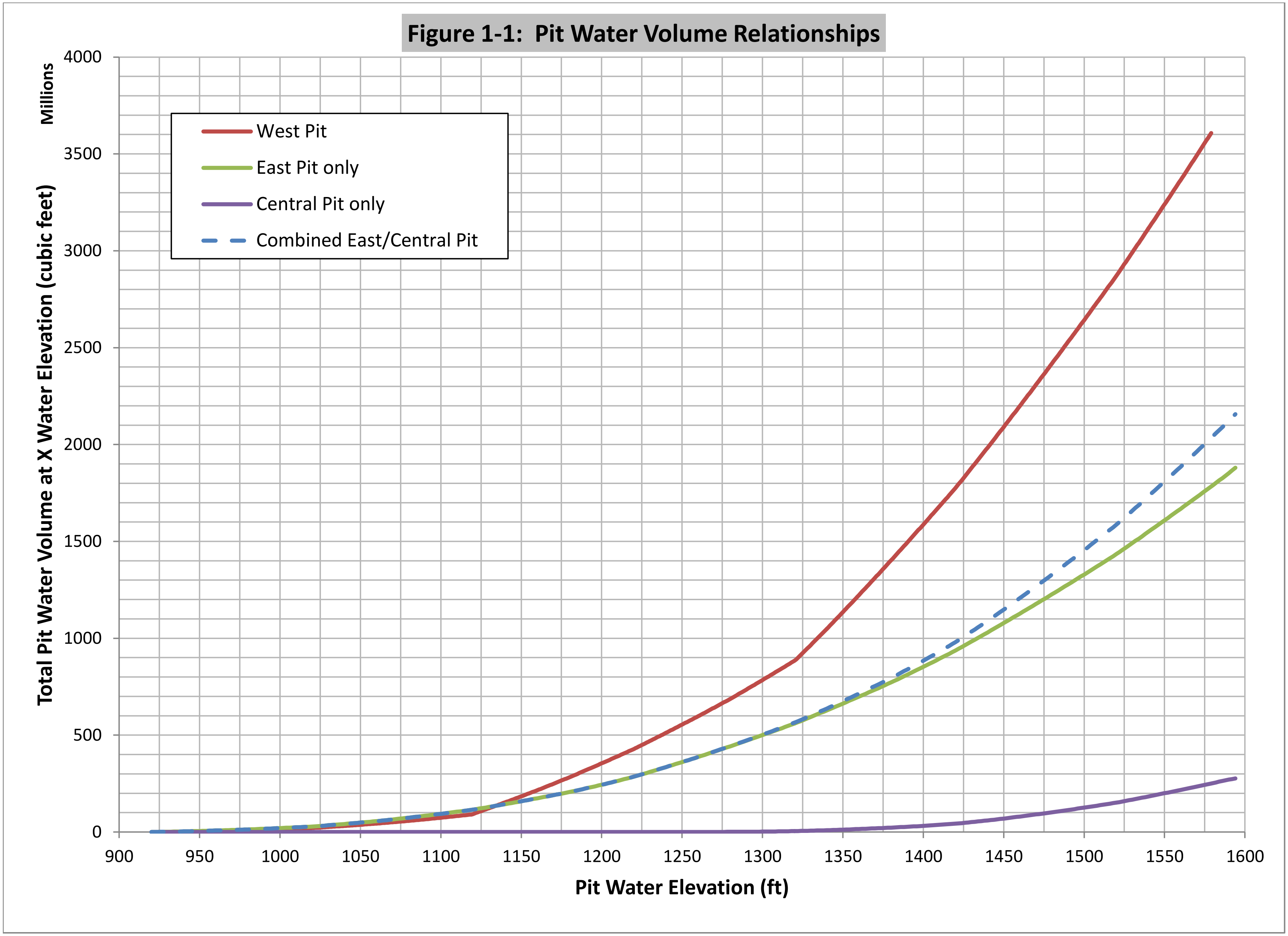
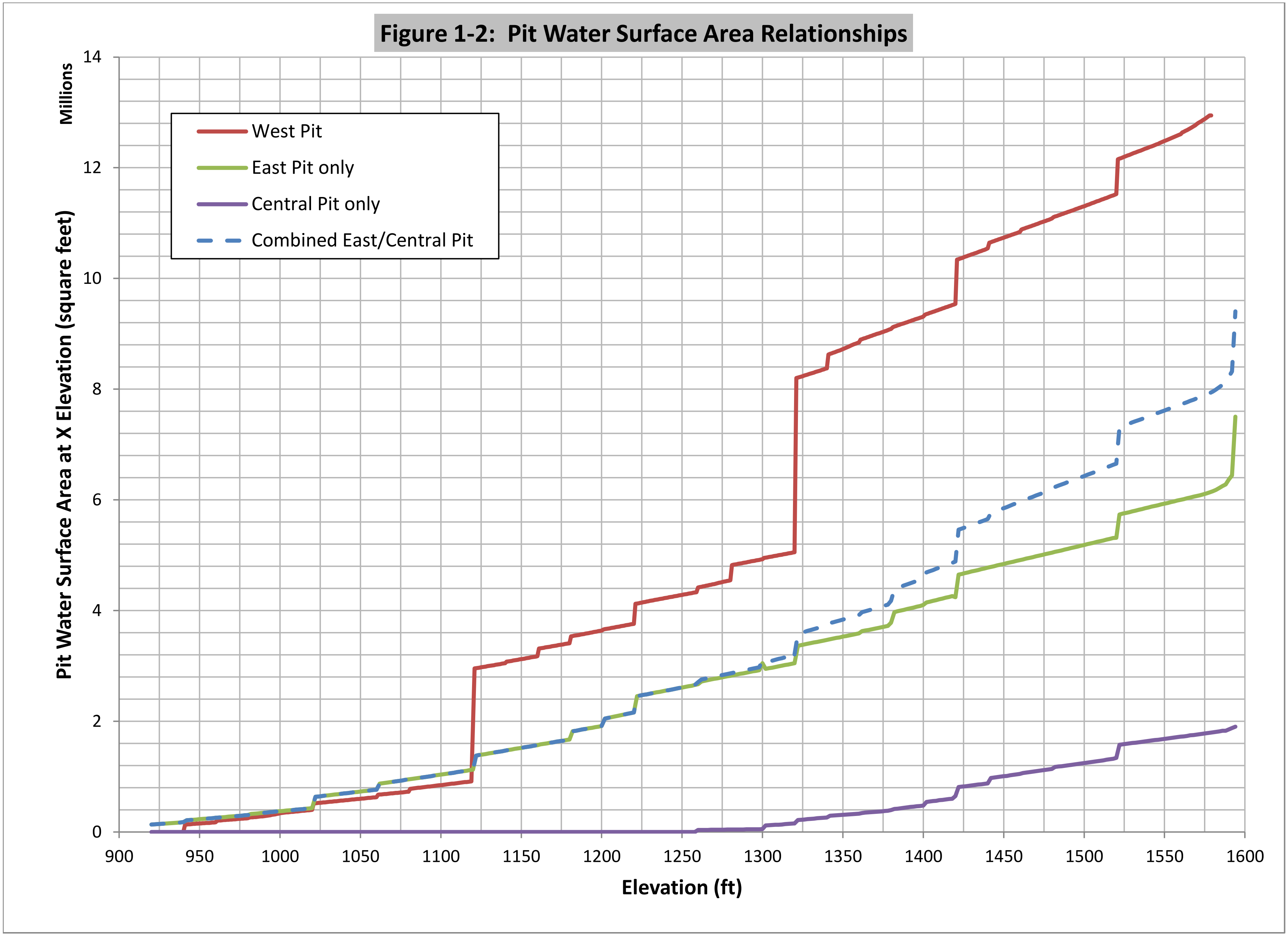


Figure 1-1: Pit Water Volume Relationships
Millions
Total Pit Water Volume at X Water Elevation (cubic feet)
4000
3500
3000
2500
2000
1500
1000
500
0
900
950
1000
1050
1100
1150
1200
1250
1300
1350
1400
1450
1500
1550
1600
Pit Water Elevation (ft)
West Pit
East Pit only
Central Pit only
Combined East/Central Pit



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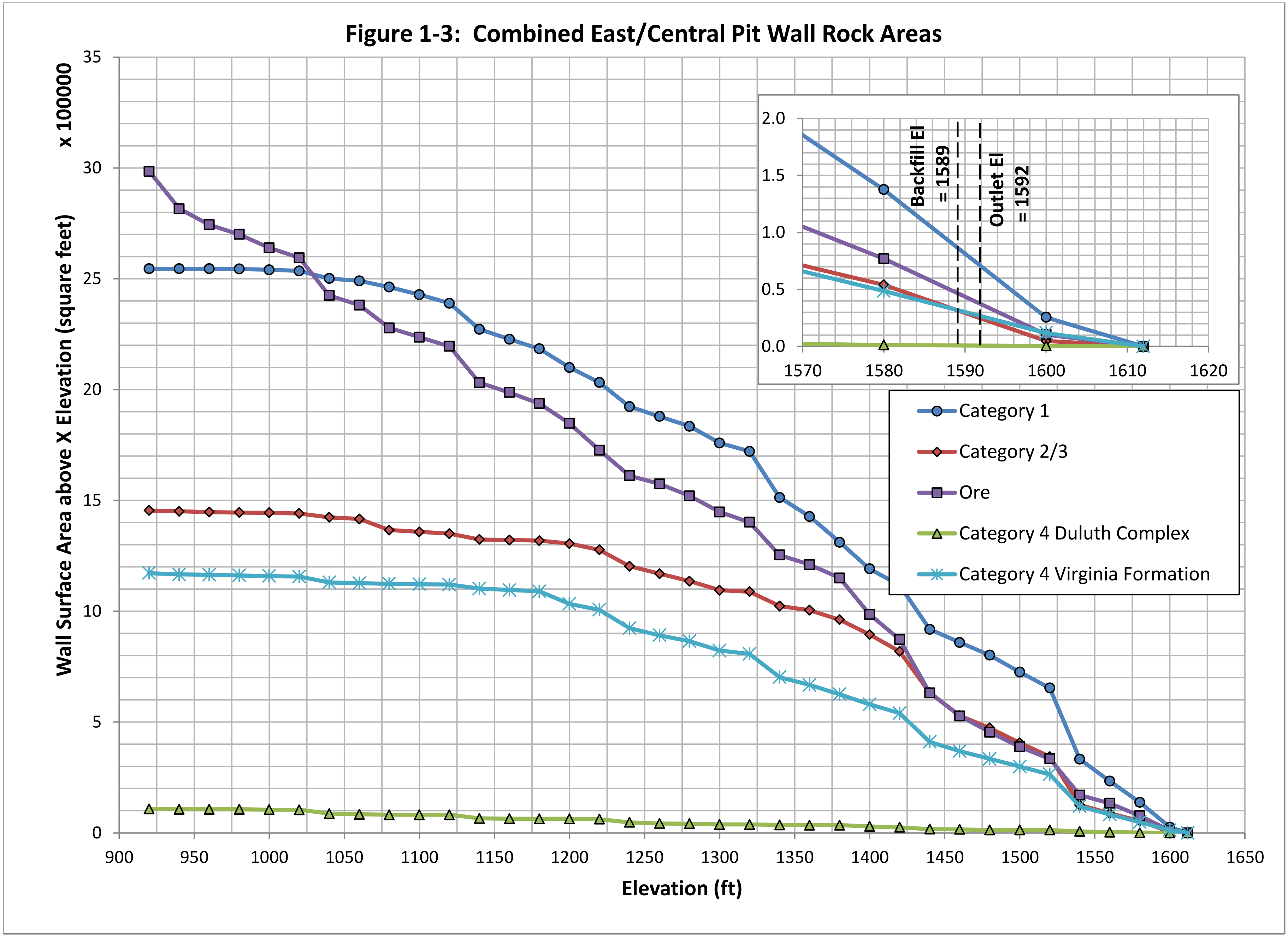

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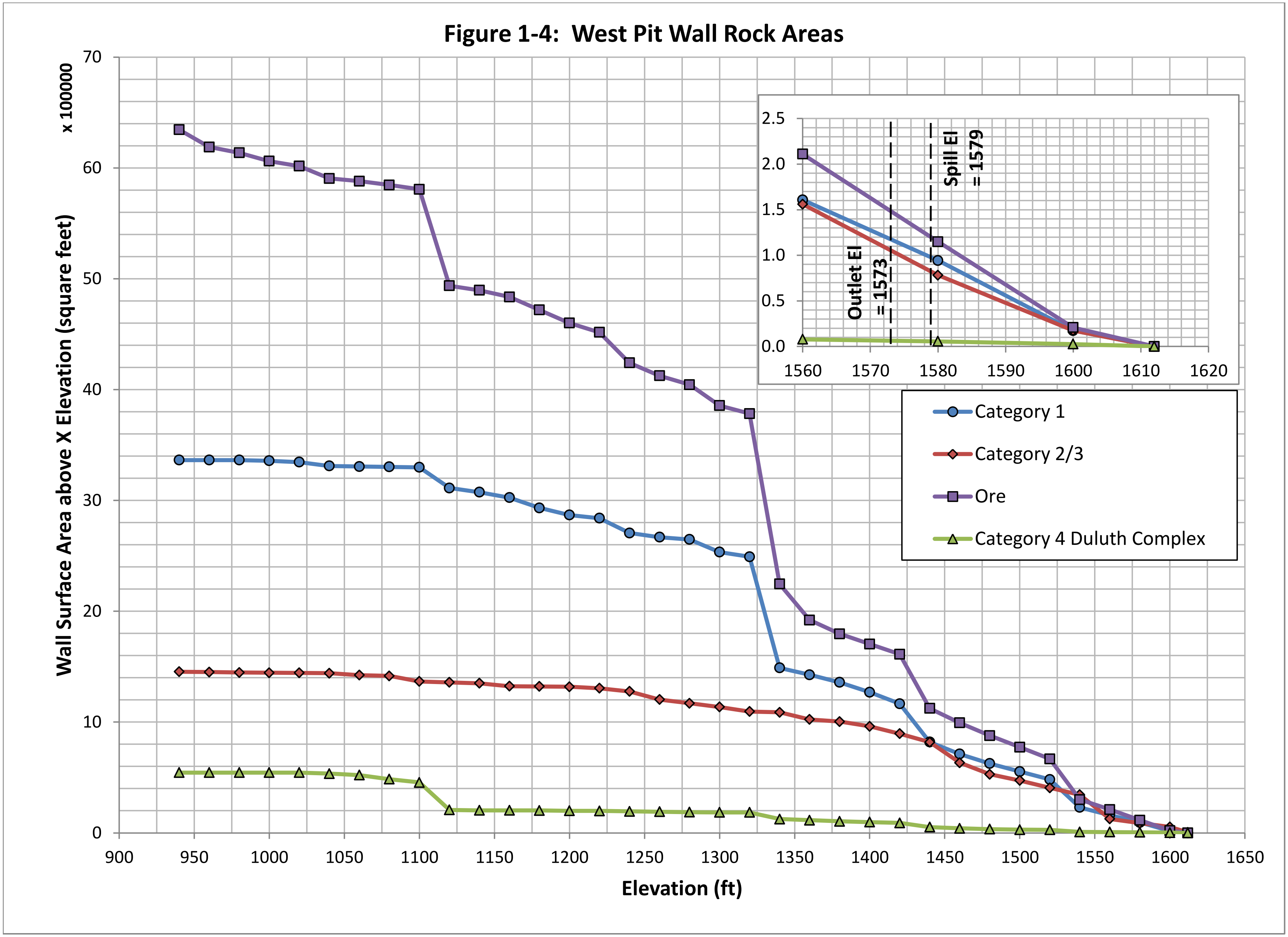
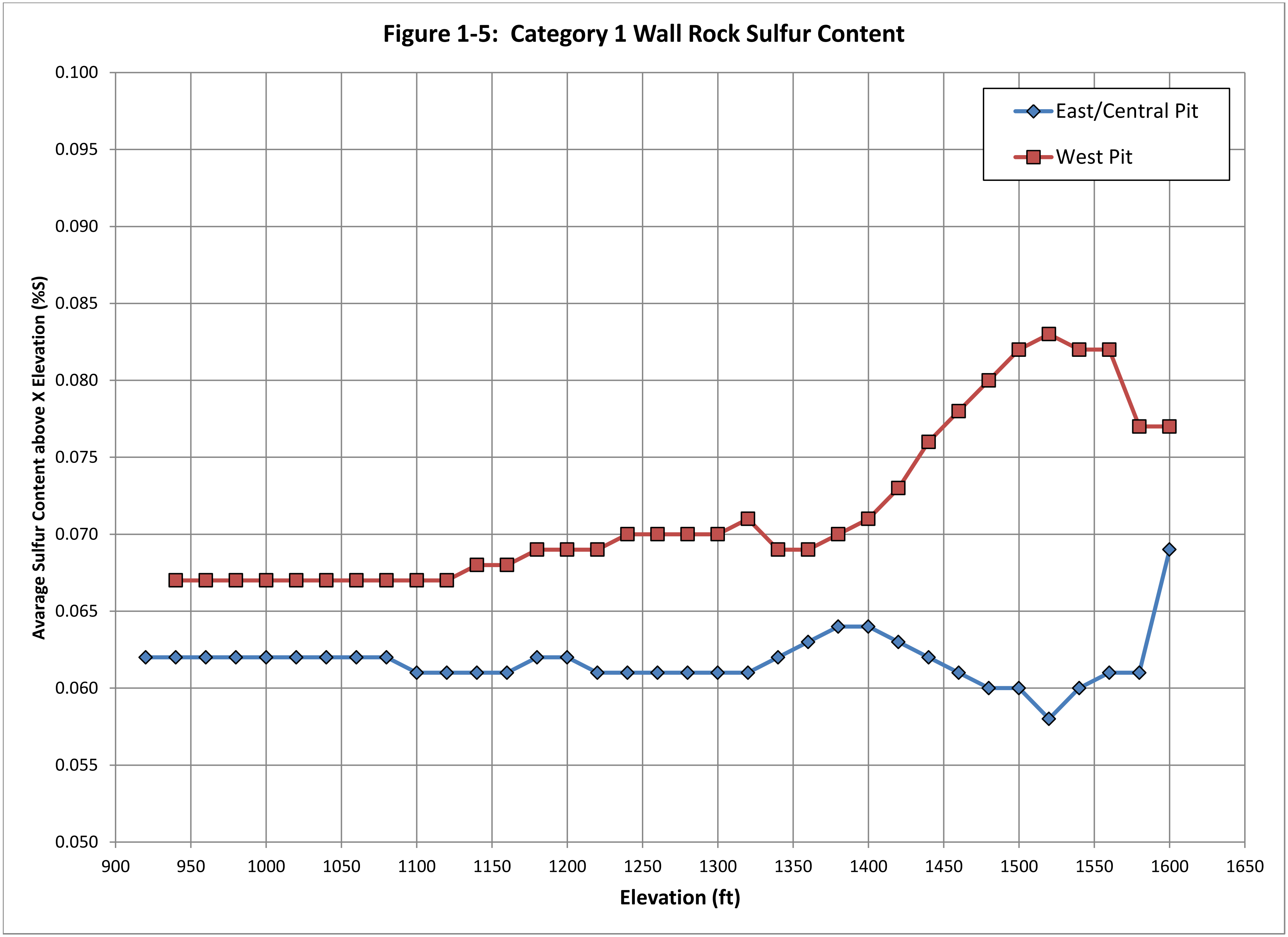


Figure 1-4: West Pit Wall Rock Areas
Wall Surface Area above X Elevation (square feet)
x 100000
Elevation (ft)
Category 1
Category 2/3
Ore
Category 4 Duluth Complex
Outlet El = 1573
Spill El = 1579



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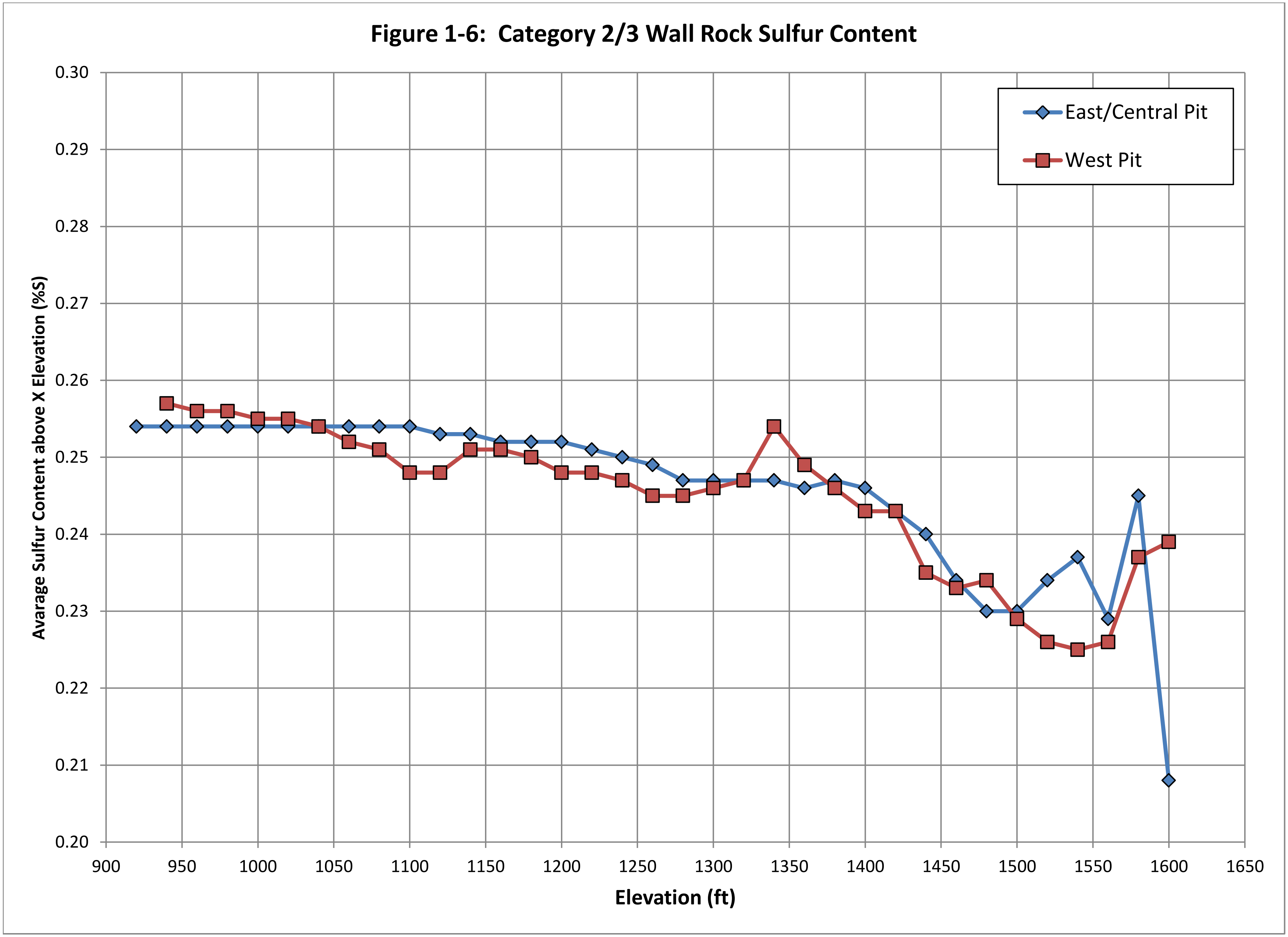

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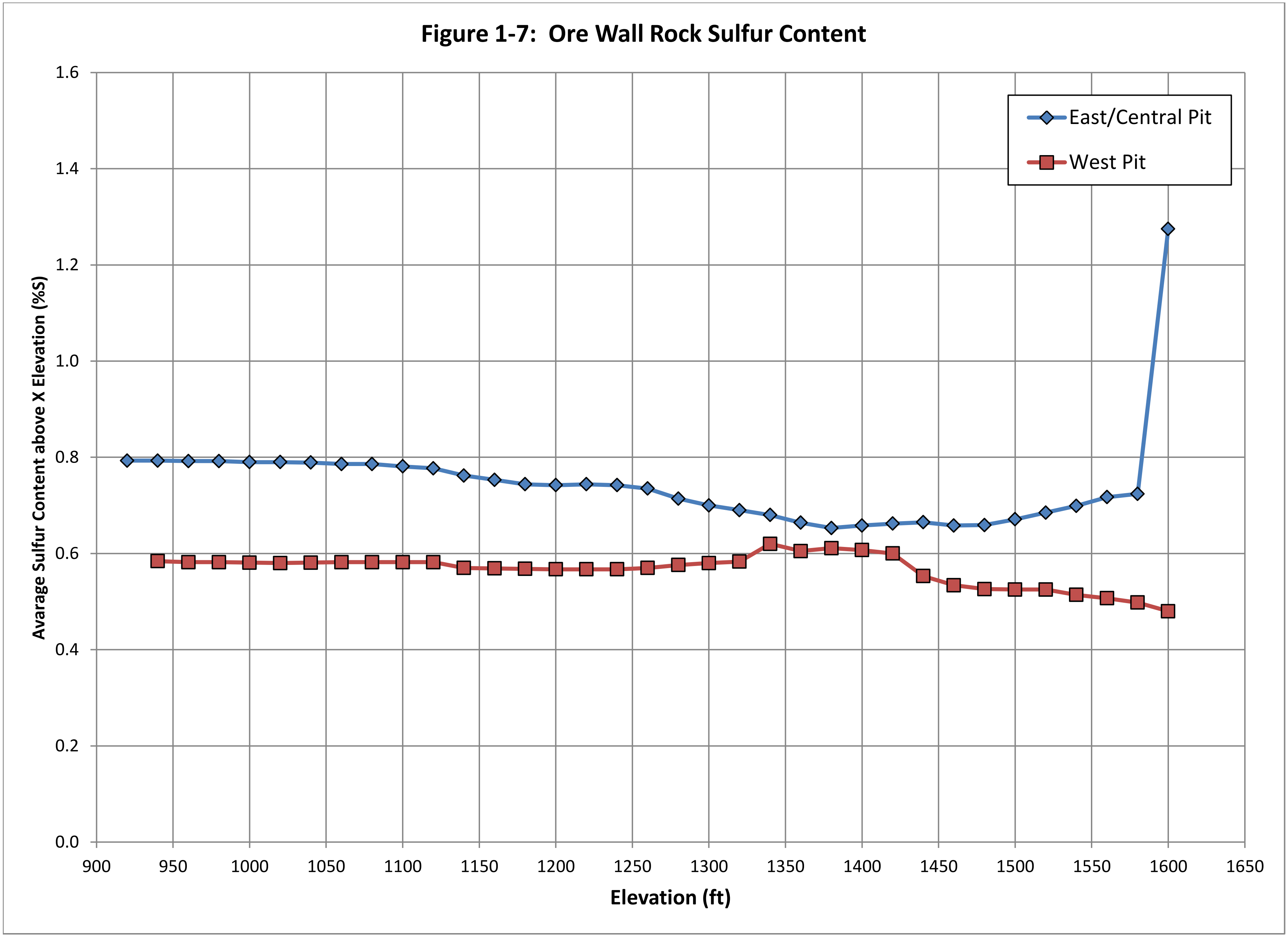

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Table 2-1 Output Constituents for the Mine Site Model

Constituent
Ag
Al
Alk
As
B
Ba
Be
Ca
Cd
Cl
Co
Cr
Cu
F
Fe
K
Mg
Mn
Na
Ni
Pb
Sb
Se
SO4
Tl
V
Zn
Hardness

Table 2-2 Output Locations for the Mine Site Model

Surface Water Evaluation Locations

Evaluation Location	*Applicable Standards*
SW-002	SW
SW-003	SW
SW-004	SW
SW-004a	SW
SW-004b	SW, WR
SW-005	SW, WR
SW-006	SW, WR
Colby Lake	SW, WR*
West Pit	SW

Groundwater Evaluation Locations

Flowpath	*Evaluation Locations*	*Applicable Standards*	*Receiving Partridge River Node*
East Pit & Cat 2/3 (surficial)	Dunka Rd., Prop. Bound.	GW	SW-004
East Pit (bedrock)	Prop. Bound.	GW	SW-004
OSP (surficial)	Dunka Rd., Partridge River	GW	SW-004
WWTF	Dunka Rd., Prop. Bound.	GW	SW-004
OSLA (surficial)	Dunka Rd., Prop. Bound.	GW	SW-004
West Pit (surficial)	Dunka Rd., Prop. Bound.	GW	SW-004a
West Pit (bedrock)	Prop. Bound.	GW	SW-004, SW-004a

Notes

* Wild rice is present downstream of Colby Lake on the Partridge River, not in the lake itself. The model assumes that if Colby Lake meets the standard the downstream location does also.

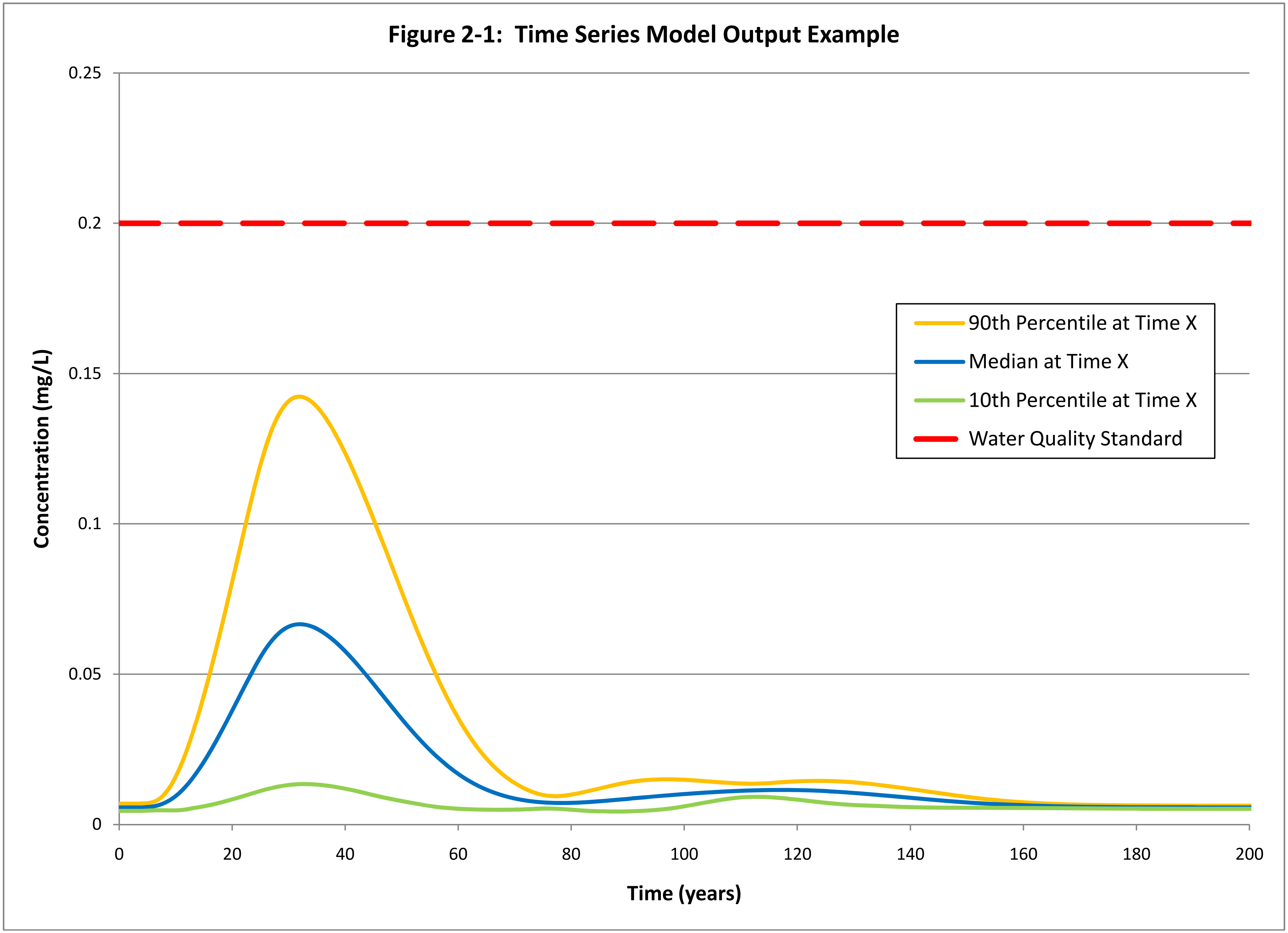
Figure 2-1: Time Series Model Output Example
0.25
0.2
0.15
0.1
0.05
0
Concentration (mg/L)
0
20
40
60
80
100
120
140
160
180
200
Time (years)
90th Percentile at Time X
Median at Time X
10th Percentile at Time X
Water Quality Standard

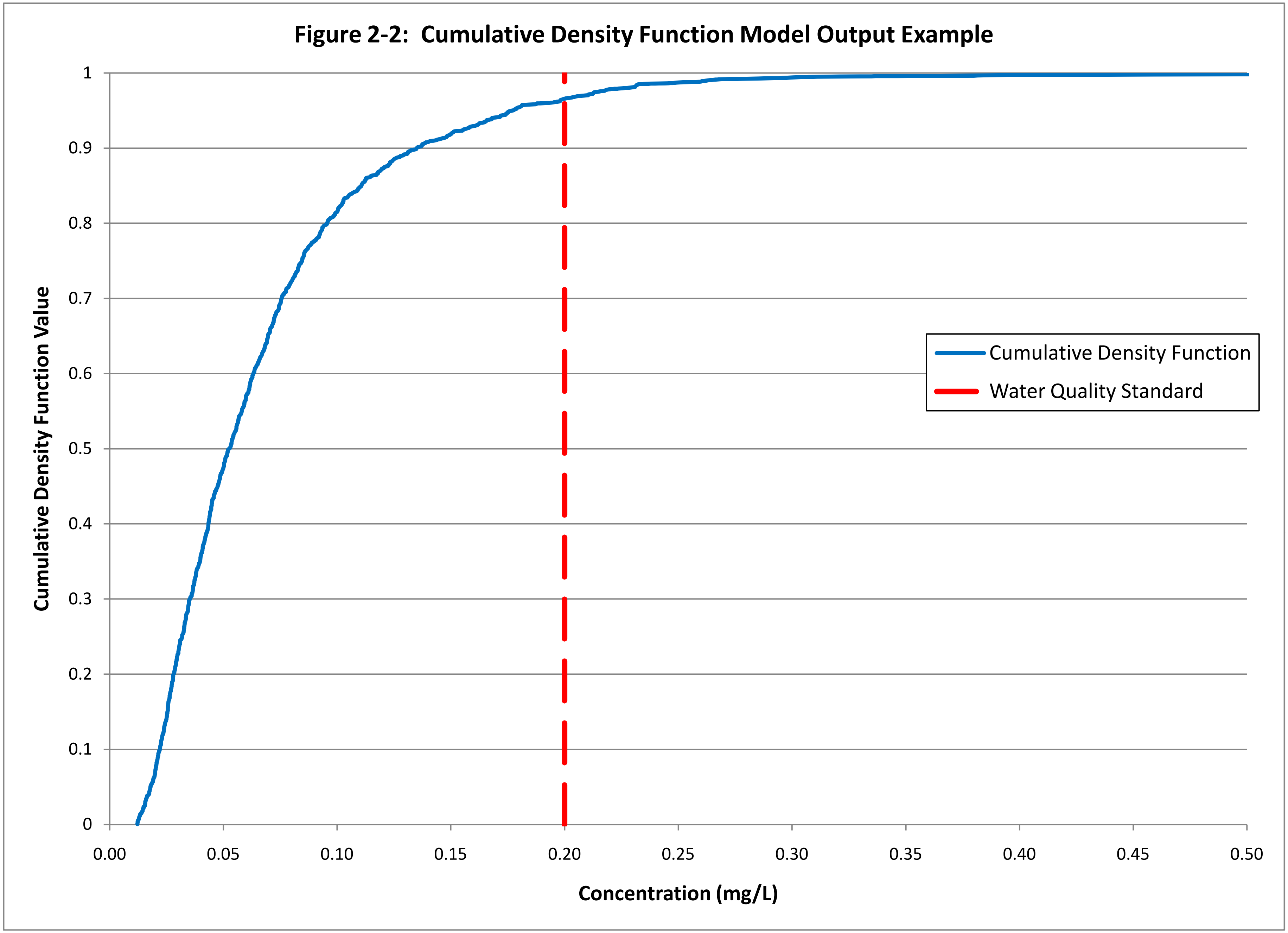

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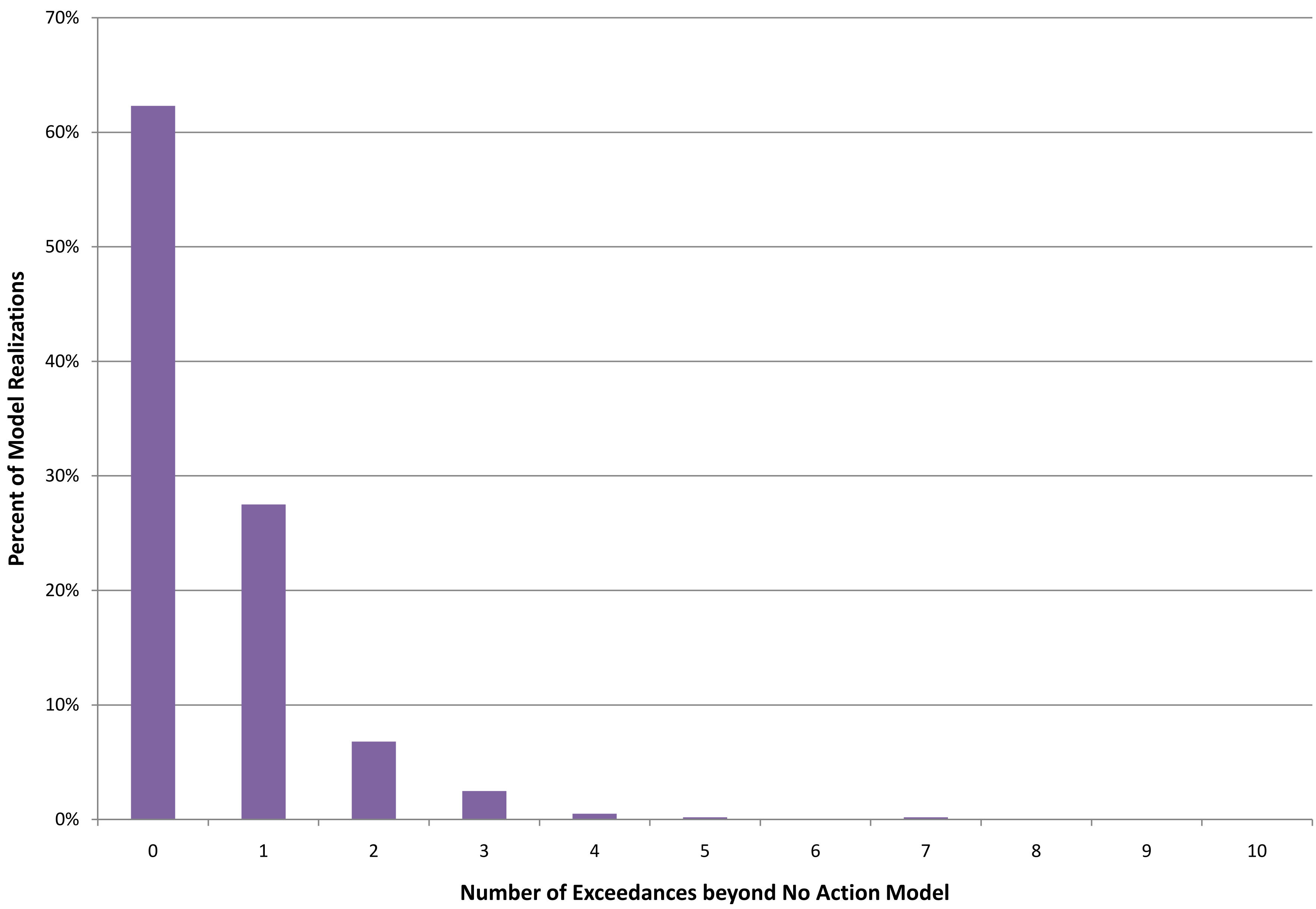
Figure 2-3: Increase in Exceedances Model Output Example



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