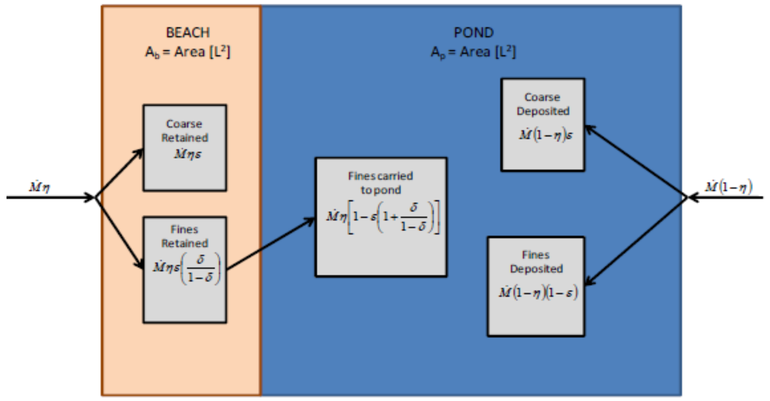
Model Portion	Elements	Note	Equation
Model	•\	To use the model to check inputs: 1) Right click ***Inputs_Checking*** , select Properties, and Enable Time History Results 2) Set ***Write_Inputs*** equal to true (in the ***Globals*** container) 3) Go into the menu “Model” and select Options a) Go the Results tab and make sure “Export results after simulation” is selected in the dropdown menu To use the model to output results: 1) Right click ***Results*** , select Properties, and Enable Time History Results 2) Set ***Write_Results*** equal to true (in the ***Globals*** container) 3) Go into the menu “Model” and select Options a. Go to the Results tab and select Edit next to the Display settings for probability histories b. Make sure the statistics to plot are the Mean 10%/90% and Median ONLY! c. Go to the Results tab and make sure “Export results after simulation” is selected in the dropdown menu	
Inputs	•\Inputs\Background\	**Randomly-generated mean groundwater concentrations** • Lognormal distributions fit to the entire sample dataset X • Mean "μ" = E(X) • Standard deviation "σ" = Std(X) • Mean and standard deviation of log-transformed data • Log mean "α" = E(ln X) • Log standard deviation "β" = Std(ln X) • Uncertainty in the true mean "μ" simulated by random number generator • Log mean "α" assumed to be normally distributed, generated once per realization • Standard deviation of "α" is the standard error of "a" (b/ sqrt(N) where N is number of samples) • Log standard deviation β assumed to be known from sample dataset • μ for each realization calculated by exp(a+0.5*(b^2))	
	•\Inputs\Buttress_Geochem\Cat1\Cat1_Inputs_LAM\AMAX_pH_Lookups_LAM	**Concentration caps from AMAX data** • Lookup tables for observed concentration percentiles as a function of pH • Based on dta from AMAX 0.64% sulfur piles • Used with randomly-generated pH and percentile to define concentration cap • Generated once per realization	
	•\Inputs\Buttress_Geochem\Cat1\Cat1_Release_Random	**Constituent release rate methods** **Humidity cell rates** • Release rates developed directly from humidy cell data **Aqua regia ratios** • Metal-to-metal or metal-to-sulfur ratios from aqua regia analysis of drill core data **Other methods** • Release rates from humidity cell metal-to-metal release ratios • Metal-to-metal or metal-to-sulfur ratios from microprobe analysis of specific minerals • Metal-to-metal ratios from mineral formulae	
	• \Inputs\Concentration_Caps\Atmospheric_Caps • \Inputs\Concentration_Caps\CO2_Enriched_Caps	**pH-Dependent Concentration Caps** • For each pH-Dependent constituent, there is a range of concentration caps at any given pH (see container pH_Function_Lookups). • The concentration cap at any given time is interpolated between pH values and between the range of caps at a given pH value.	$Ca\left(\frac{mmol}{L}\right)=\frac{2SO_{4,Cap}\left(\frac{mmol}{L}\right)+Alk_{Cap}\left(\frac{mmol}{L}\right)-K_{Cap}\left(\frac{mmol}{L}\right)}{2+\frac{[2Mg+Na]\left(\frac{mmol}{kg*week}\right)}{Ca\left(\frac{mmol}{kg*week}\right)}}$ $\log\left[Al\left(\frac{mg}{L}\right)\right]=0.909*pH-9.44$ $Cd\left(\frac{mg}{L}\right)=Zn_{cap}\left(\frac{mg}{L}\right)*\left[\frac{Cd}{Zn}\right]\left(\frac{mg}{kg*week}\right)$ $Mg\left(\frac{mg}{L}\right)=Ca_{Cap}\left(\frac{mg}{L}\right)*\left[\frac{Mg}{Ca}\right]\left(\frac{mg}{kg*week}\right)$
	• \Inputs\Concentration_Caps\Sulfate_Cap		$SO_4\left(\frac{mg}{L}\right)=1294\,x\,\frac{[Mg+.5Na+.5K]\left(\frac{mmol}{kg*week}\right)}{Ca\left(\frac{mmol}{kg*week}\right)}+1760$
	• \Inputs\Sat_Diff_Inputs		$D=\tau D_a[1-S]^C+\tau S\frac{D_w}{K_H}$ Diffusion from the Elberling Equation $C(z)=\frac{r}{2D}Z^2-\left(\frac{2C_0r}{D}\right)^{0.5}(z)+C_o$ Oxygen Concentration as a Function of Depth
	• \Inputs\Scaling\		$4FeS_{(s)}+9O_2+10H_2O\xrightarrow{yields}4Fe(OH)_{3(s)}+4H_2SO_4$ Conversion from Oxygen Consumption to Sulfide Generation

	• \Inputs\Scaling\Arrhenius_Eq		$k = Ae^{-E_a/RT}$ $k_T = \frac{K_{Field}}{K_{Lab}} = \frac{e^{-E_a/RT_{Field}}}{e^{-E_a/RT_{Lab}}} = e^{\frac{E_a}{R}\left[\frac{1}{T_{Lab}}-\frac{1}{T_{Field}}\right]}$
Material	• \Material\BNT_Amended_Hydr_Props • \Material\LTVSMC_Hydr_Props		$S_e = \frac{\sigma - \Theta_r}{\theta_s - \theta_r}$ $K = K_{sat}(S_e^{0.5})\left[1-\left(1-S_e^{1/\gamma}\right)^{\gamma}\right]^2$ $\sigma = \Theta_r + \frac{\Theta_s - \Theta_r}{(1+\alpha\lvert\phi\rvert^{\beta})^{\gamma}}$
	• \Material\NM_Hydr_Props		$S_e = \frac{\sigma - \Theta_r}{\theta_s - \theta_r}$ $K = K_{sat}(S_e^{0.5})\left[1-\left(1-S_e^{1/\gamma}\right)^{\gamma}\right]^2$ $\sigma = \Theta_r + \frac{\Theta_s - \Theta_r}{(1+\alpha\lvert\phi\rvert^{\beta})^{\gamma}}$ $\log(K_{sat}) = m_m(F)(\Theta) + b_m(\Theta) + m_b(F) + b_b$ $\alpha, \beta, \Theta_r = m_m(F)(\Theta) + b_m(\Theta) + m_b(F) + b_b$
	•\Project\Embarrass_River		$Hardness = 2.5 * [Ca] + 4.1 * [Mg]$
	•\Project\Embarrass_River\Load_Calcs		$M_0 = C_0V$ $\dot{M} = CQ$
	•\Project\Flowpaths\Flow_Path_Details	The hydraulic conductivity, ***K_Surficial*** , is randomly generated. ***Recharge*** is also randomly generated but is limited in function ***R_Calc.*** ***R_Calc*** takes the minimum of the randomly generated value, ***Recharge*** , and a calculated maximum acceptable recharge which would cause ***Qu_Max*** to equal zero. The control is to force ***Qu_Max*** to be greater than or equal to zero always	$Q(x) = Q_u + Rwx = -Ki(x)wd$ $\frac{d^2h}{dx^2} = -\frac{R}{Kd}$ $Q_{u,\max} = -\left[\frac{RL_AW}{2} + Kdw\bar{\imath}_{\max}\right]$
	•\Project\Flowpaths\NORTH_FP •\Project\Flowpaths\NORTHWEST_FP •\Project\Flowpaths\WEST_FP		$D = 0.83 * [\log(L_A)]^{2.414}$
	•\Project\Flowpaths\NORTH_FP\N_FP_Calcs •\Project\Flowpaths\NORTHWEST_FP\NW_FP_Calcs •\Project\Flowpaths\WEST_FP\W_FP_Calcs	The initial concentration in each cell is the flow-weighted average of the seepage concentration and the recharge concentration. If the recharge concentration is lower than the seepage concentration at time zero, then initial concentrations in the mixing cells will decrease with respect to distance from the Tailings Basin, and vice-versa Volume of water is width * depth * individual cell length * porosity (assuming fully saturated) Mass of surficial material is width * depth * individual cell length * (1 – porosity) * material density Initial mass of each constituent takes into account the initial concentration, the volume of water, and the mass of the surficial material, and assumes a linear isotherm for sorption	$M_0 = C_0(V_{water} + K_dM_{surficial})$
	•\Project\Process_Plants\Beneficiation_Plant\Chemistry\Ore_Loading_To_Plant		$L = \dot{M} * t_w * k_T * k_s * (1 - k_c)$
	•\Project\Process_Plants\Beneficiation_Plant\Flow\Plant_Delivery_Calcs		 Figure 6-7 Schematic of the mass balance of Flotation Tailings delivered to the FTB $\eta = \left\{\varepsilon\left(1+\frac{\delta}{1-\delta}\right)\left[1+\frac{A_p(1-\Theta_p)}{A_b(1-\Theta_b)}\right]\right\}^{-1}$

Project	•\Project\Tailings_Basin\CELL_2W\Unsat_Coarse\Saturation_Calcs •\Project\Tailings_Basin\CELL_2W\Unsat_Embankment\Saturation_Calcs •\Project\Tailings_Basin\CELL_2W\Unsat_Fine\Saturation_Calcs •\Project\Tailings_Basin\NorthMet_Basin\CELL_1E\Unsat_Coarse\Saturation_Calcs •\Project\Tailings_Basin\NorthMet_Basin\CELL_1E\Unsat_Fine\Saturation_Calcs •\Project\Tailings_Basin\NorthMet_Basin\CELL_2E\Unsat_Coarse\Saturation_Calcs •\Project\Tailings_Basin\NorthMet_Basin\CELL_2E\Unsat_Embankment\Saturation_Calcs •\Project\Tailings_Basin\NorthMet_Basin\CELL_2E\Unsat_Fine\Saturation_Calcs •\Project\Tailings_Basin\NorthMet_Basin\Closure_Beaches\C_NM_Beach\TLNGS_Sat_Calcs •\Project\Tailings_Basin\NorthMet_Basin\East_Dam\E_NM_Beach\TLNGS_Sat_Calcs •\Project\Tailings_Basin\NorthMet_Basin\East_Dam\E_NM_Dam\TLNGS_Sat_Calcs •\Project\Tailings_Basin\NorthMet_Basin\North_Dam\N_NM_Beach\TLNGS_Sat_Calcs •\Project\Tailings_Basin\NorthMet_Basin\North_Dam\N_NM_Dam\TLNGS_Sat_Calcs •\Project\Tailings_Basin\NorthMet_Basin\South_Dam\S_NM_Beach\TLNGS_Sat_Calcs •\Project\Tailings_Basin\NorthMet_Basin\South_Dam\S_NM_Dam\TLNGS_Sat_Calcs	***Iteration Method to Solve for Saturation*** The standard Newton-Raphson Iteration method is used here. The looping process is to initially guess a saturation ***(Sat_e_Guess)*** , to calculate the relative conductivity ***(Calc_Kr)*** at that saturation, and determine the error in relative conductivity ***(Kr_Exact – Calc_Kr)*** and the slope of Kr as a function of saturation (dKr_ds) at the initially guessed saturation. Using ***Sat_e_Guess*** , ***dKr_ds*** , and the error in relative conductivity ***(Kr_Exact – Calc_Kr)*** , the Newton-Raphson method solves for a new guess of saturation ***(New_Sat_eff)*** which is closer to the solution. This process is looped until the convergence criteria is met, defined by ***New_Sat_eff – Sat_e_Guess*** < 0.0001. Finally, based on the effective saturation and other hydraulic properties, the water content and the saturation are calculated and used to eventually determine constituent loading.	$S_{new} = S_{guess} + \frac{K_{r,calc} - K_{r,exact}}{\partial \mathrm{K_r} / \partial \mathrm{S_e}}$ $\frac{\partial \mathrm{K_r}}{\partial \mathrm{S_e}} = \frac{K_r}{2S_e} + 2\sqrt{K_r S_e^{0.5}}\left[1 - S_e^{1/\gamma}\right]^{\gamma-1} S_e^{\left(1/\gamma - 1\right)}$ $S_{new} = S_{guess} + \frac{K_{r,calc} - K_{r,exact}}{\partial \mathrm{K_r} / \partial \mathrm{S_e}}$
	•\Project\Tailings_Basin\NorthMet_Basin\Pond_Design		$A = m_1 z + b_1$ $V = \frac{m_1}{2} z^2 + b_1 z$ $A = m_2 z + b_2$ $V = \frac{m_2}{2} z^2 + b_2 z$
	•\Project\Tailings_Basin\Tailings_Basin_Toes\North_Buttress •\Project\Tailings_Basin\Tailings_Basin_Toes\South_Buttress	**Waste rock stockpile modeling** • ***Dimensions*** container includes waste rock movement and stockpile physical dimensions; also includes acidic fraction calculations if applicable • ***WaterBal*** container includes stockpile hydrology calculations and consistent water balance • ***Geochem*** container includes applicable release rates, scaling factors, and concentration caps • ***MassBal*** container includes contaminant transport calculations: mass release, contact/noncontact partitioning, concentration caps, and ultimate drainage chemistry	
	•\Project\Tailings_Basin\Tailings_Basin_Toes\North_Buttress\Cat1SP_MassBal\Cat1SP_Seepage_bare\Cat1_Solubility_calcs •\Project\Tailings_Basin\Tailings_Basin_Toes\South_Buttress\Cat1SP_MassBal\Cat1SP_Seepage_bare\Cat1_Solubility_calcs		$\log\left[Ba\left(\frac{mg}{L}\right)\right] = -0.32\ X \log\left[SO_4\left(\frac{mg}{L}\right)\right] - 0.87$ $Se\left(\frac{mg}{L}\right) = 6.35\ X\ 10^{-6}\ X\ SO_4\left(\frac{mg}{L}\right) + 0.0020$ $F\left(\frac{mol}{L}\right) = \sqrt{\frac{8.91x10^{-11}\left(\frac{mol^3}{kg^3}\right)}{Ca\left(\frac{mol}{L}\right)} X \left[\rho_{water}\left(\frac{kg}{L}\right)\right]^{1.5}}$
	•\Project\Tailings_Basin\NorthMet_Basin\CELL_2E\Pond\H2O_Balance\Bank_RO •\	If the ponds have combined, the runoff from the banks of Cell 2W is zero because runoff is handled in Cell 1E, Else, the runoff from the banks of Cell 2W is the total runoff times the contributing bank area.	
	•\Project\Tailings_Basin\NorthMet_Basin\CELL_2E\Pond\H2O_Balance\Tailings_RO •\	If the ponds have combined, the runoff volumetric flow rate is zero, Else, the runoff volumetric flow rate is the sum of only the North Flotation Tailings Beach, and the runoff from the coarse and fine LTVSMC tailings in Cell 2E	
	•\Project\Tailings_Basin\NorthMet_Basin\CELL_2E\Pond\H2O_Balance\Wtrshd_RO	If the ponds have combined, the runoff from the contributing natural watersheds is zero because the runoff is handled in Cell 1E, Else, the runoff from the contributing natural watersheds is the total watershed yield times the watershed area.	
	•\Project\Tailings_Basin\NorthMet_Basin\CELL_2E\Pond\H2O_Balance\Cell2E_Precip	If the ponds have combined, the precipitation amount is zero, Else, the precipitation amount in L/T is applied to the calculated pond area.	
	•\Project\Tailings_Basin\NorthMet_Basin\CELL_2E\Pond\H2O_Balance\Pump_2E_to_1E	If the ponds have combined, this value is zero gpm because no individual pond in Cell 2E exists, Else, what is pumped from the pond in Cell 2E to the pond in Cell 1E is the amount of water that is not required by the pond design.	
	•\Project\Tailings_Basin\NorthMet_Basin\CELL_2E\Pond\H2O_Balance\Cell2E_Evap	If the ponds have combined, the open water evaporation rate is zero, Else, the earlier open water evaporation rate in L/T is applied to the calculated pond area.	
	•\Project\Tailings_Basin\NorthMet_Basin\CELL_2E\Pond\H2O_Balance\Entrainment	If the ponds have combined, the entrainment rate is zero, Else, the entrainment rate is the porosity of the volumetric rate of tailings added to the pond.	
	•\Project\Tailings_Basin\NorthMet_Basin\CELL_2E\Pond\H2O_Balance\Cell2E_Seepage	If in closure, the seepage rate from the pond in Cell 2E is the pre-determined seepage rate (from MODFLOW) applied to the calculated pond area, Else, the seepage rate from the pond is zero.	
	•\Project\Tailings_Basin\NorthMet_Basin\CELL_1E\Pond\H2O_Balance\Tailings_RO	If the ponds have combined, the runoff volumetric flow rate is the sum of runoff from all 4 Project beaches and from the coarse AND fine LTVSMC tailings in both Cell 1E AND 2E, Else, the runoff volumetric flow rate is the sum of only the runoff from the coarse and fine LTVSMC tailings in Cell 1E.	
	•\Project\Tailings_Basin\NorthMet_Basin\CELL_1E\Pond\H2O_Balance\Treatment_Cycle_in_Closure	If Treat_Pond is true (mitigation measure in closure), then some flow is cycled from the pond, through the FTB WWTP and back into the pond, Else, this value is zero and the FTB WWTP does not treat the pond at all.	

•\Project\Tailings_Basin\NorthMet_Basin\CELL_1E\Pond\H2O_Balance\Cell1E_Precip	If the ponds have combined, the precipitation amount in L/T is applied to the calculated pond area, Else, the precipitation amount in L/T is applied to the initial, existing pond area in Cell 1E.	
•\Project\Tailings_Basin\NorthMet_Basin\CELL_1E\Pond\H2O_Balance\Pump_1E_to_Plant	If in closure, no pumping is necessary so the flow is zero gpm, Else, what is pumped from the pond in Cell 1E to the Beneficiation Plant is the amount of water that is not required by the pond design, up to the demand of the Beneficiation Plant.	
•\Project\Tailings_Basin\NorthMet_Basin\CELL_1E\Pond\H2O_Balance\Cell1E_Evap	If the Plant Site is closed (Closure), then the closure open water evaporation rate in L/T is applied to the calculated pond area, Else, if the ponds have combined, the later operational open water evaporation rate in L/T is applied to the calculated pond area, Else, the earlier open water evaporation rate in L/T is applied to the initial, existing pond area in Cell 1E.	
•\Project\Tailings_Basin\NorthMet_Basin\CELL_1E\Pond\H2O_Balance\Entrainment	If the ponds have combined, the entrainment rate is the porosity of the volumetric rate of tailings added to the pond, Else, there is no loss due to entrainment in this pond so the value is zero.	
•\Project\Tailings_Basin\NorthMet_Basin\CELL_1E\Pond\H2O_Balance\Cell1E_Seepage	If the ponds have combined, the seepage from the pond is the pre-determined seepage rate (from MODFLOW) applied to the calculated pond area, Else, the seepage rate from the pond is the existing seepage rate applied to the initial, existing area of the pond in Cell 1E	
\Project\Tailings_Basin\Interception_System\Controlled_Pumping_Percent	If, for water quality purposes, additional pumping is necessary, a higher percentage of water can be collected, Else, the pumping amount will be controlled by the seepage flow limitation (500 gallons per acre per day).	
\Project\Tailings_Basin\Interception_System\Need_to_Pump_West_Toe	If Cell 2W is not included in the seepage limitation because it's not part of the project, then the West Toe does not need to be pumped, Else, if the seepage lost is greater than the allowable limit even if the North and NorthWest Toes are fully captured, then the West Toe does have to be pumped, Else, collecting seepage along only the North and NorthWest Toes is sufficient to meet the requirement and the West Toe does not need to be pumped.	
\Project\Tailings_Basin\Interception_System\Min_Intercept_Percentage	If the project is 30 years into closure (50 years in project life), pumping may cease because the Tailings Basin is at steady state, Else, if Cell 2W is not included in the seepage limitation, then the capture percentage is based on only the seepage from the North Toe, Else, if the West Toe has to be pumped (see Need_to_Pump_West_Toe), then the capture percentage is based on seepage from the North, NorthWest, and West Toes, Else, the capture percentage is based on the seepage from the North and NorthWest Toes.	
\Project\Tailings_Basin\Interception_System\Interception_Flow	If the project is 30 years into closure (50 years in project life), pumping may cease because the Tailings Basin is at steady state, Else, under all conditions, if the year is less than 5 years, which is the minimum travel time for loading from the Tailings Basin, the capture percentage is based on the flow constraint because the toe water quality has not yet been affected by the project, Else, if Cell 2W is not included in the seepage limitation, then the capture percentage is based on only the seepage from the North Toe and the greater of the flow-based (Min_Intercept_Percentage) or the quality-based (Controlled_Pumping_Percent) capture percentages, Else, if the West Toe has to be pumped (see Need_to_Pump_West_Toe), then the capture percentage is based on seepage from the North, NorthWest, and West Toes and the greater of the flow-based (Min_Intercept_Percentage) or the quality-based (Controlled_Pumping_Percent) capture percentages, Else, the capture percentage is based on the seepage from the North and NorthWest Toes and the greater of the flow-based (Min_Intercept_Percentage) or the quality-based (Controlled_Pumping_Percent) capture percentages.	

	\Project\Tailings_Basin\Interception_System\Excess_System_Water	If in closure, the excess system water is the inflows less the outflows to Cell 1E, plus the collected water (Trench_Sum or Total_Flow_Intercepted depending on Use_Trench), minus any desired volume change in the pond of Cell 1E over one time step duration in case the pond is not at the design volume, Else, if the ponds of Cell 1E and 2E have combined, the excess system water is the inflows less the outflows to Cell 1E, plus the collected water (Trench_Sum or Total_Flow_Intercepted depending on Use_Trench), minus any desired volume change in the pond of Cell 1E over one time step duration in case the pond is not at the design volume, minus the demand of NOT-clean water from the Beneficiation Plant, Else, if the ponds of Cell 1E and 2E have NOT combined, the excess system water is the inflows less the outflows to Cell 1E and to Cell 2E, plus the collected water (Trench_Sum or Total_Flow_Intercepted depending on Use_Trench), minus any desired volume change in the ponds of Cell 1E and of Cell 2E over one time step duration in case the pond is not at the design volume, minus the demand of NOT-clean water from the Beneficiation Plant. This determines how much water cannot be handled by the system and must be treated and discharged.	
	\Project\Tailings_Basin\Interception_System\Intercepted_Flow_Split	First, the total flow is either the total flow collected by the wells (Total_Flow_Intercepted) or by the trench (Trench_Sum), depending on Use_Trench. The collected water, less the excess system water, is sent to either Cell 1E or Cell 2E, depending on whether the ponds have combined or not respectively (Combined_Switch.Completion_Status becomes true). Collected water is sent to the Mine Site West Pit in closure until the West Pit has received all that it can handle (Stop_Sending_Water_to_Mine becomes true). Any unused water that cannot be sent to the Mine Site or to the FTB pond must be treated and is sent to the FTB WWTP.	