This form has been developed to document changes to the NorthMet Project and/or Project SDEIS Water Modeling resulting from the water modeling process. The forms will be used during the water modeling process. At the end of the process, the Project Description, Data Packages and Management Plans will all be updated to reflect the content of all forms submitted during the process.

Change Type:

Model Refinement

Rationale for Change:

As part of the QA/QC review of the Plant Site Model, the co-lead agencies consultant (ERM) recommended a more appropriate method to calculate groundwater flow along the surficial aquifer flow paths at the Plant Site. This CDF presents an alternative approach for calculating groundwater flow, specifically the amount of seepage from the Tailings Basin that contributes to groundwater at the upstream ends of the flow paths, which incorporates ERM's recommendation.

Description:

This proposed change acknowledges that the ground to the north and west of the toe of the Tailings Basin is likely saturated, evidenced by the vast wetland coverage near the Tailings Basin. Because the water table is very near or at the ground surface, it is likely that the hydraulic gradient in this area is very similar to the ground surface gradient. Using the current approach to groundwater flow (see Section 5.4 of Reference 1), the gradient in the middle (length-wise) of the flow path is equal to the overall average ground surface gradient (averaged across the entire flow path length). Including recharge as an inflow to the flow path necessitates a varying hydraulic gradient along the flow path's length to maintain continuity (i.e., the gradient is increasing as distance from the Tailings Basin increases to facilitate increased flow due to the addition of recharge). Therefore, the current approach requires that the hydraulic gradient at the upstream end of the aquifer is less than the average hydraulic gradient, which is based on the average ground surface gradient.

The proposed approach is to assume that recharge is negligible along the upstream portion of the flow paths (due to already saturated conditions, as discussed above) and to use Darcy's Law to calculate the flow at the upgradient ends of the groundwater flow paths given a hydraulic gradient, hydraulic conductivity, and flow area as shown in Equation 1.

$$Q_u = -Kidw = -KiA \qquad \text{Equation 1}$$

where *K* is hydraulic conductivity [L/T], *i* is hydraulic gradient [L/L], *w* is aquifer length (perpendicular to flow) [L], and *d* is aquifer thickness [L].

The current method for calculating groundwater flow also requires *K*, *i*, *d*, and *w* as model inputs, but uses an equation that accounts for recharge to calculate Q_u. For the proposed approach, these same model inputs will be used, but with Equation 1. Model inputs *i*, *d*, and *w* are deterministic, while *K* is probabilistic. Table 1 shows the model input assumptions that are proposed (which are the same inputs that were previously agreed to) and the range in groundwater flow rates determined using the method proposed in this CDF.

Table 1 Model input assumptions with range of resulting groundwater flow values

		North Flow Path	**North-West Flow Path**	**West Flow Path**
i [m/m]		-0.00444	-0.00514	-0.00736
d [m]		7	7	7
w [m]		1920	2090	2920
Percentile	K [m/day]	Q_u Flow (gpm)	Q_u Flow (gpm)	Q_u Flow (gpm)
1%	1.52	16.6	20.9	41.8
5%	1.97	21.6	27.2	54.4
10%	2.27	24.8	31.3	62.6
25%	2.86	31.4	39.5	79.0
50%	3.71	40.7	51.2	102.5
75%	4.82	52.7	66.4	132.9
90%	6.08	66.6	83.9	167.9
95%	7.00	76.6	96.6	193.2
99%	9.10	99.6	125.5	251.2
Average	4.00	43.8	55.2	110.4

Groundwater flow in GoldSim is modeled using a series of cells. A "cell" in GoldSim represents a discrete, well-mixed fluid through which constituent mass and flow pass. Using the method proposed in this CDF, flow into the first cell of a groundwater flow path will be calculated using Equation 1. Flow along the length of the aquifer will be determined using a continuity calculation; the flow leaving a cell is equal to the flow entering a cell from upgradient plus the flow that enters the cell from recharge (see Figure 1). In other words, Darcy's Law is used to calculate flow entering the upstream end of the aquifer, and the flow along the aquifer is calculated by flow continuity (Equation 2).

$$Q_l = Q_u + Rwl \qquad \text{Equation 2}$$

where Q_l is flow at a distance "*l*" from the upstream end of the aquifer [L^3/T], Q_u is the flow into the aquifer [L^3/T], *R* is the aquifer recharge rate [L/T], and *w* is the width of the aquifer [L], and *l* is the distance from the upstream end of the aquifer at which Q_l is calculated [L].

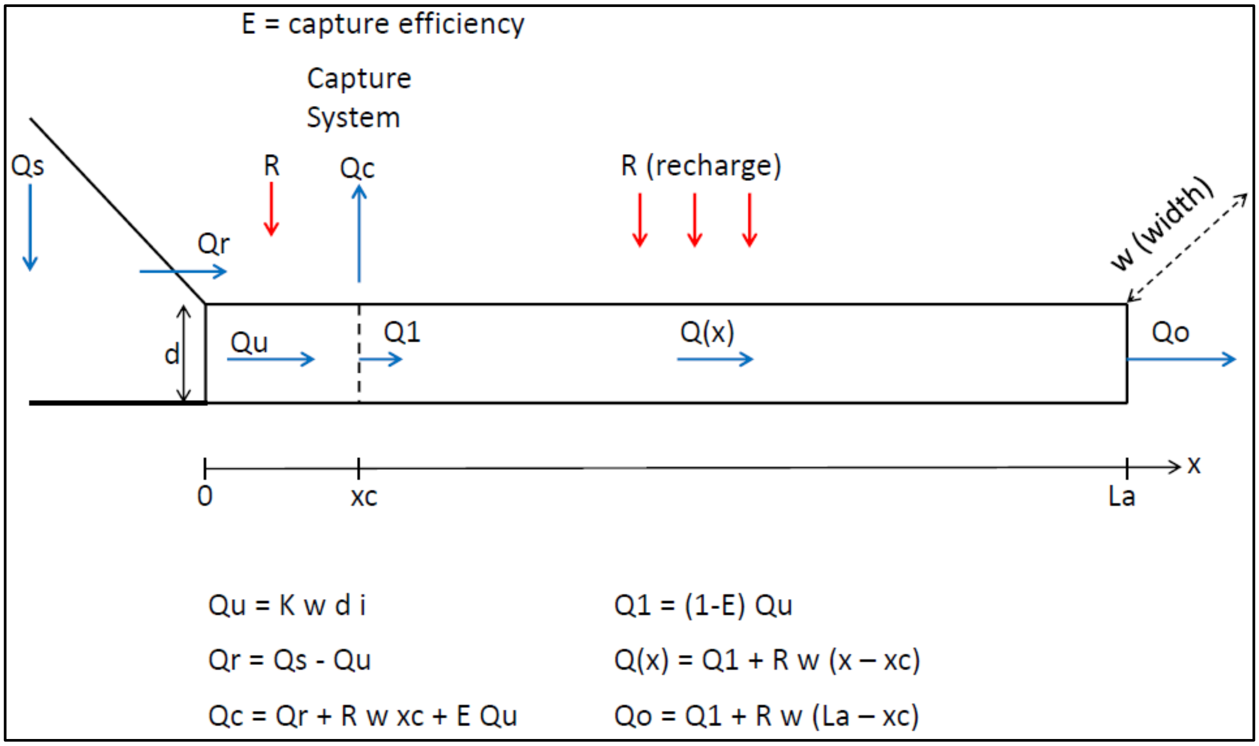

Figure 1 Conceptual drawing of the modeled groundwater flow paths at the Plant Site

In Figure 1, Q_s is the total seepage rate from the Tailings Basin to the toe (as calculated in the GoldSim model as a function of percolation rates through the tailings), Q_u is the flow that enters the aquifer, Q_r is the flow that is in excess of the aquifer capacity and upwells to surface flow, Q_1 is the flow that bypasses the containment system, Q_c is the flow that is captured by the containment system, and Q_o is the flow discharging from the flow path to surface water.

The proposed change in this CDF applies to both the existing conditions or No Action model and the Proposed Project model. In both models, the upstream flow (Q_u) will be calculated in the same manner and flow and mass load from recharge will be added to every cell of the flow path. However, in the Proposed Project model, a collection system will be installed a short distance (~250 feet) from the toe of the Tailings Basin. The collection system described in the Adaptive Water Management Plan (AWMP, see Section 7.4.3 of Reference 2) is designed to capture all surface and groundwater flow. However, for the modeling, it is assumed that the collection system will capture 100% of the surface flow (Q_s in excess of Q_u, or Q_r) and 90% of the flow at the upstream end of the aquifer (Q_u). Therefore, the groundwater flow that bypasses the collection system (Q_1) will be 10% of Q_u (see Equation 3). In the Proposed Project model, flow and mass load from recharge will continue to be added to flow path along the remaining length beyond the collection system until the discharge location.

$$Q_1 = (1 - 0.9) * Q_u \qquad \text{Equation 3}$$

The proposed groundwater flow method in this CDF will cause the flow into groundwater from the Tailings Basin to increase. In effect, the flow that bypasses the containment system will also increase, and the flow that is captured will decrease. Additionally, the difference in flow captured with this proposed CDF is on the order of single gallons per minute. Therefore, this CDF does not cause a significant change in the WWTP size and certainly does not cause the WWTP capacity to increase.

Advantages of this change:

1. The method for calculating flow into the aquifer at the toe of the Tailings Basin is likely more physically representative of hydraulic conditions near the toe of the Tailings Basin.
2. Independent reviewers of the model, with any amount of groundwater flow knowledge, would be more likely to perform the calculations in the manner proposed in this CDF rather than in the manner currently modeled.

Disadvantages of this change:

1. None

Other Potential Impacts:

No change in direct wetland impacts is expected.

No change in geotechnical impacts is expected.

No change in air emissions impacts is expected.

No change in project footprint is expected.

Attachments:

None

References:

(1) NorthMet Project, *Water Modeling Data Package, Volume 2 – Plant Site, Version 7* – July 3, 2012.

(2) NorthMet Project, *Adaptive Water Management Plan, Version 4* - October 31, 2012.

Project Description Changes:

None

Data Package Changes:

Section 4.3.2.2, Section 4.3.3, and Section 5.4 and its subsections of the Water Modeling Data Package, Volume 2 – Plant Site, Version 8:

Work Plan Changes:

None

Management Plan Changes:

None