APPENDIX M-1: Temporary WRS Facility Percolation (HELP) Model

Hydrometrics, Inc.
consulting scientists and engineers

M E M O R A N D U M

DATE: February 18, 2016

TO: Allan Kirk, Geomin Resources, Inc.
Lisa Kirk, Enviromin, Inc.

FROM: Greg Bryce
George Metzger

SUBJECT: Black Butte Copper Temporary Waste Rock Storage Facility Percolation Model

Hydrometrics was requested to perform a hydraulic analysis for the Black Butte Copper (BBC) temporary waste rock storage (WRS) facility. This memo discusses the modeling approach, input parameters, and analysis results.

MODELING APPROACH

Hydraulic behavior at the proposed temporary WRS facility was modeled using the Hydrologic Evaluation of Landfill Performance (HELP) model, version 3.07, developed by the Army Corps of Engineers. The model uses climate data to predict one-dimensional moisture flow through a user-specified soil profile.

The proposed WRS facility has a construction disturbance footprint of 11.1 acres (4.5 ha) and a waste rock footprint of approximately 7.5 acres (3.0 ha). Waste rock will be placed in three 16.4-foot (5 m) lifts. The footprint of each successive lift decreases due to side slopes and benches along the lift perimeter. The final surface area of the second and third lifts are estimated to be 5 acres (2.0 ha) and 3.1 acres (1.3 ha), respectively. The first lift will use approximately 50 percent of the available storage volume based on the cross-section in Figure 3.16 (Knight Piesold, 2015a). Assuming constant production over two years, the first lift will therefore be completed around the end of year one. The second lift will be completed about seven months later and the third lift will be completed at the end of year two. Three separate HELP models were ran to simulate the three lifts. The first lift was ran for two years, with the second and third lifts being ran for one year each; output for August through December were only used from the third lift simulation as this lift is scheduled to be exposed for five months.

The HELP model runs in one-year increments, but can provide daily or monthly results summaries. To calculate percolation through the waste rock, the HELP model was run with a 16.4 foot lift in year one. The predicted monthly percolation, in inches, was multiplied by

the estimated waste rock footprint at the end of each month to determine a monthly percolation volume.

In year two, the WRS facility was represented by three separate models and results were combined to estimate total percolation. The first model simulated one lift of waste rock, the second simulated two lifts, and the third simulated the final surface with three lifts. The exposed area of each lift at the end of each month is shown in Table 1. The percolation result from each model was multiplied by the appropriate surface area to determine the percolation volume.

TABLE 1. WRS LIFT EXPOSED AREA

		Lift 1 Area		**Lift 2 Area**		**Lift 3 Area**	
Year	Month	(ac)	(ha)	(ac)	(ha)	(ac)	(ha)
1	1	0.6	0.3	-	-	-	-
1	2	1.3	0.5	-	-	-	-
1	3	1.9	0.8	-	-	-	-
1	4	2.5	1.0	-	-	-	-
1	5	3.1	1.3	-	-	-	-
1	6	3.8	1.5	-	-	-	-
1	7	4.4	1.8	-	-	-	-
1	8	5.0	2.0	-	-	-	-
1	9	5.6	2.3	-	-	-	-
1	10	6.3	2.5	-	-	-	-
1	11	6.9	2.8	-	-	-	-
1	12	7.5	3.0	-	-	-	-
2	1	6.8	17.2	0.7	1.8	-	-
2	2	6.1	15.4	1.4	3.6	-	-
2	3	5.4	13.6	2.1	5.4	-	-
2	4	4.6	11.8	2.9	7.3	-	-
2	5	3.9	10.0	3.6	9.1	-	-
2	6	3.2	8.2	4.3	10.9	-	-
2	7	2.5	6.4	5.0	12.7	-	-
2	8	2.5	6.4	4.4	11.1	0.6	1.6
2	9	2.5	6.4	3.8	9.6	1.2	3.1
2	10	2.5	6.4	3.1	8.0	1.9	4.7
2	11	2.5	6.4	2.5	6.4	2.5	6.3
2	12	2.5	6.4	1.9	4.8	3.1	7.9

CLIMATE INPUT PARAMETERS

The HELP model requires several user-specified climate parameters to complete moisture flow simulations. The four inputs are precipitation, mean daily temperature, solar radiation, and evapotranspiration. HELP includes default datasets for seven locations in Montana and also allows the user to enter location-specific data. The input data can be used to synthetically generate daily data for use in the model.

The nearest stations with default data in HELP are Helena and Great Falls, which are both located approximately 50 miles (80 km) from the BBC site. The latitude and elevation at BBC are nearer to Helena than Great Falls, so default Helena values were used as the baseline for climate data. Helena also has lower average wind speed and higher relative humidity than Great Falls, which would tend to increase percolation estimates.

Tintina operates a weather station near the BBC site and has precipitation and temperature records from May 2012 through November 2014 (Knight Piesold, 2015b). Tintina weather data were used to modify the HELP defaults for Helena and synthetically generate climate datasets for the BBC site.

Precipitation

To synthetically generate daily precipitation, the default Helena dataset was loaded and then the monthly precipitation averages were edited to reflect those from the Tintina weather station. Two modifications were made to the Tintina monthly averages. First, the March 2013 value was excluded from the set. That month included a 4-inch (10.2-cm) precipitation event that exceeded the estimated 100-year, 24-hour storm for the site. Second, precipitation averages from November to March were reduced by 75 percent to account for snow removal on the waste rock pile. As the waste rock is placed with a bulldozer, most snow will be pushed from the surface and the moisture will not percolate through the waste rock.

The HELP precipitation inputs resulted in an average expected precipitation of 14.7 inches (37.4 cm) annually. Two years of daily data were synthetically generated in HELP, with resulting annual totals of 14.3 inches (36.3 cm) and 19.4 inches (49.3 cm), respectively.

Mean Daily Temperature

Mean daily temperature data were synthetically generated in the same way as precipitation data. The default dataset for Helena was loaded, and then monthly mean temperature values were edited to reflect those for the Tintina weather station. The average annual temperature was 35.9 °F (2.2 °C).

Solar Radiation

Daily solar radiation data were synthetically generated in HELP by loading the Helena dataset and modifying the latitude to 46.77, which is the latitude at the BBC site.

Evapotranspiration

Evapotranspiration values for the HELP model were based on the default Helena dataset. Wind speed, growing season, and relative humidity used the default Helena values, while site latitude was modified to 46.77. The recommended bare soil evaporative zone depth of 14 inches (35.6 cm) was used. A maximum leaf area index of zero was used to represent no vegetative growth.

PHYSICAL INPUT PARAMETERS

The waste rock to be placed in the WRS facility consists of cobble and gravel with very little sand or fine-grained material. The material was represented by the HELP soil properties for gravel. Physical properties include an effective saturated hydraulic conductivity of 0.30 cm per second and porosity of 0.397. A runoff curve number of 69.8 was determined in HELP based on the gravel soil texture, 2 percent cross-slope, 300-foot slope length, and bare vegetation condition. All waste rock lifts were modeled as vertical percolation layers.

For the first year, the HELP model was allowed to calculate the initial moisture content of the waste rock. The approximate steady-state moisture content calculated by HELP was 1.3 percent in the evaporative zone and 4.8 percent over the entire lift.

Initial water contents were specified for the second year simulations. Water content in the 14-inch evaporative zone was specified at 1.3 percent for each case. In the one lift simulation, an initial moisture content of 5.45 percent was specified based on the final water content at the end of the first year simulation. In the two lift simulation, the second lift used the HELP-derived value of 4.8 percent, while a water content of 5.45 percent was specified in the first lift. In the three lift simulation, initial moisture in the third lift was 4.8 percent. The first and second lift initial moisture contents were 6.58 percent and 5.84 percent, respectively, based on the final conditions from the two lift simulation.

RESULTS

Percolation results over the two-year simulation period are shown in Table 2. Estimated percolation through the waste rock over the entire period is 118,330 cubic feet (3,351 m^3). The average flow rate over the two-year period is less than one gallon per minute (gpm), with a maximum monthly average of 2.7 gpm in July of the second year. It is assumed all water percolating out the bottom of the waste rock will drain laterally through the bedding material on top of the liner to the outlet pipe on the south edge of the WRS pad.

TABLE 2. SIMULATED WRS FACILITY PERCOLATION TO UNDERDRAIN

		Percolation		WRS Footprint		Volume		Average Flow Rate	
Year	Month	(in)	(cm)	(ac)	(ha)	(ft^3)	(m^3)	(gpm)	(m^3/day)
1	1	0	0	0.63	0.25	-	-	-	-
1	2	0.028	0.072	1.25	0.51	129	4	0.0	0.1
1	3	0.081	0.206	1.88	0.76	551	16	0.1	0.5
1	4	0.084	0.214	2.50	1.01	765	22	0.1	0.7
1	5	0.056	0.142	3.13	1.26	634	18	0.1	0.6
1	6	0.151	0.383	3.75	1.52	2,050	58	0.4	1.9
1	7	0.102	0.259	4.38	1.77	1,617	46	0.3	1.5
1	8	0.373	0.946	5.00	2.02	6,761	192	1.1	6.2
1	9	0.388	0.985	5.63	2.28	7,916	224	1.4	7.5
1	10	0.215	0.546	6.25	2.53	4,876	138	0.8	4.5
1	11	0.242	0.613	6.88	2.78	6,027	171	1.0	5.7
1	12	0.244	0.620	7.50	3.04	6,643	188	1.1	6.1
2	1	0.084	0.212	7.50	3.04	2,274	64	0.4	2.1
2	2	0.114	0.289	7.50	3.04	3,093	88	0.6	3.1
2	3	0.142	0.361	7.50	3.04	3,872	110	0.6	3.5
2	4	0.136	0.345	7.50	3.04	3,699	105	0.6	3.5
2	5	0.106	0.268	7.50	3.04	2,876	81	0.5	2.6
2	6	0.122	0.310	7.50	3.04	3,327	94	0.6	3.1
2	7	0.588	1.494	7.50	3.04	16,017	454	2.7	14.6
2	8	0.417	1.059	7.50	3.04	11,351	322	1.9	10.4
2	9	0.313	0.795	7.50	3.04	8,523	241	1.5	8.0
2	10	0.284	0.720	7.50	3.04	7,722	219	1.3	7.1
2	11	0.379	0.963	7.50	3.04	10,319	292	1.8	9.7
2	12	0.268	0.680	7.50	3.04	7,288	206	1.2	6.7
Total						**118,330**	**3,351**	**0.9**	**4.8**

REFERENCES

Knight Piesold Consulting, 2015a. Figure 3.16, Cross-Section of Waste Rock Storage Facility, Black Butte Copper. October 28, 2015.

Knight Piesold Consulting, 2015b. Memorandum – Black Butte Copper Project Meteorology Data Analysis Update. From Brendan Worrall, To Bob Jacko. Cont. No. VA15-02445. May 27, 2015.