APPENDIX M-2: Facility Embankment Percolation (HELP) Model

Hydrometrics, Inc.
consulting scientists and engineers

M E M O R A N D U M

DATE: September 1, 2016

TO: Bob Jacko, Tintina Montana
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FROM: Greg Bryce
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SUBJECT: Black Butte Copper Facility Embankment Percolation Model

Hydrometrics was requested to perform a hydraulic analysis of the embankment areas at the Black Butte Copper (BBC) facility. The areas evaluated include the cement tailing facility, the process water pond, the mill pad, the temporary waste rock storage area, the portal pad, and the contact water pond. This memo discusses the modeling approach, input parameters, and analysis results.

MODELING APPROACH

Hydraulic behavior at the facilities 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 HELP model runs in one-year increments, but can provide daily or monthly results summaries. To calculate percolation through the embankments, the HELP model was run for fifteen years, the predicted life of the facility. The predicted average monthly percolation, in inches, was multiplied by the estimated embankment footprint to determine an average monthly percolation volume and summed to determine the average yearly percolation volume.

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, 2015). Tintina weather data were used to modify the HELP defaults for Helena and synthetically generate climate datasets for the BBC site. A summary of the climate input data is included in Attachment 1.

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. 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. The HELP precipitation inputs resulted in an average expected precipitation of 18.30 inches (46.5 cm) annually. Fifteen years of daily data were synthetically generated in HELP.

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). Fifteen years of daily data were synthetically generated in HELP.

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. A soil evaporative zone depth of 12 inches (30.5 cm), the depth of the topsoil layer, was used. A maximum leaf area index of 2.0 was used to represent a fair stand of grass.

PHYSICAL INPUT PARAMETERS

The rock to be placed in the facility embankments will consist of shales and granodiorite compacted to 95% Modified Proctor laboratory density and overlain by approximately one foot of top soil. The top soil material was represented by the HELP soil properties for a sandy loam. Physical properties include an effective saturated hydraulic conductivity of 0.00072 cm/s and porosity of 0.453. The compacted shales and gronodiorite material was

represented by the HELP soil properties for gravel and then modified for compaction. Physical properties include an effective saturated hydraulic conductivity of 0.013 cm/s and porosity of 0.370. All embankments were assumed to have a top slope of 40% and an average bank height to be half the total bank height estimated based on plan and profile drawings of the areas of concern (Tintina Montana, Inc., 2015). Average slope length was calculated based on total bank height and the top slope. A runoff curve number was calculated in HELP based on the top soil texture, the average slope and slope length, and a fair stand of grass for vegetation condition. Calculated curve numbers for all areas ranged from 73.4 to 77.0. Both layers were modeled as vertical percolation layers. The HELP model calculated approximate steady state conditions for initial moisture content of each layer. A summary of the soil and design input data are included as Attachment 1.

RESULTS

The average annual percolation results for the fifteen-year simulation period are shown in Table 1. Estimated annual runoff was 2.30 inches or 13% of the precipitation. Evapotranspiration accounted for another 73% of the precipitation (13.43 inches). Estimated annual percolation through the waste rock ranged from 1.68 to 2.47 inches or between 9% and 13% of the precipitation. The average flowrate percolating out from beneath the compacted gravel layer ranged from 2.0E-06 to 2.9E-06 gallons per minute per square foot. Monthly flows tend to peak in May, June and July with minimal flows in December through March. Average monthly data for all sites are included as Attachment 2.

TABLE 1. AVERAGE ANNUAL WATER PERCOLATION VALUES

Average Annual	Precip	Runoff		Evapotranspiration		Percolation			
Area	(in)	(in)	%	(in)	%	(in)	%	(gal)	(gal/sf)
Cement Tailings Facility	18.30	2.30	13%	13.44	73%	1.68	9%	56,906	1.99E-06
Process Water Pond	18.30	2.30	13%	13.43	73%	2.21	12%	37,751	2.62E-06
Mill Pad	18.30	2.30	13%	13.44	73%	2.46	13%	56,586	2.92E-06
Temporary Waste Rock Storage	18.30	2.30	13%	13.43	73%	2.47	13%	10,601	2.92E-06
Portal Pad	18.30	2.30	13%	13.44	73%	2.43	13%	19,722	2.88E-06
Contact Water Pond	18.30	2.30	13%	13.43	73%	2.45	13%	4,618	2.91E-06

REFERENCES

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

Tintina Montana, Inc., 2015. Mine Operating Permit Application, Black Butte Copper Project, Meagher County, MT. December 15, 2015.

ATTACHMENT 1

HELP MODEL INPUT DATA

CLIMATE DATA

Monthly Temperature and Precipitation Data

	Precip, in	Precip, mm	Mean Temp, F	Mean Temp, C
	Tintina	**Tintina**	**Tintina**	**Tintina**
	2012-2014	**2012-2014**	**2012-2014**	**2012-2014**
Jan	1.14	29	17.8	-7.9
Feb	0.75	19	13.6	-10.2
Mar	3.11	79	25.0	-3.9
Apr	1.38	35	32.4	0.2
May	2.01	51	44.1	6.7
Jun	4.57	116	50.5	10.3
Jul	1.50	38	61.7	16.5
Aug	1.85	47	57.9	14.4
Sep	0.79	20	49.8	9.9
Oct	0.98	25	35.8	2.1
Nov	0.79	20	25.2	-3.8
Dec	0.83	21	17.2	-8.2
Total	*19.7*	*500*	*35.9*	*2.2*

File Name: **BBC-P.d4** **BBC-T.d7**

Millegan: http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?mt5712

Evapotranspiration Data

	Helena (default)	**Tintina**	
Latitude	46.59	46.77	
Max Leaf Area Index (1)		2.0	
Start Growing Season	138	138	
End Growing Season	266	266	
Evap Zone Depth	14	14	in
Wind	7.8	7.8	mph
Q1 rel. hum.	63	63	
Q2 rel. hum.	54	54	
Q3 rel. hum.	49	49	
Q4 rel. hum.	63	63	

File Name: **BBC-ET.d11**

(1) 0- Bare Ground, 1 - Poor Stand of Grass, 2 - Fair Stand of Grass, 3 - Good Stand of Grass, 4 - Excellent Stand of Grass

Solar Radiation Data

Generated using coefficients for Helena, Montana and a latitude of 46.77.

File Name: **BBC-S.d13**

SOIL AND DESIGN DATA

Site	Surface Area (ft2)	Surface Area (ac)	Total Bank Height (ft)	Average Bank Height (ft)	Layer 1 - Topsoil (in)	Layer 2 - Gravel (in)	Average Top Slope	Average Slope Length (ft)	Vegetation (1)	HELP Model CN
Cement Tailings Facility	53570.4	1.23	44	22	12	252	40%	118	3	73.4
Process Water Pond	27354.5	0.63	22	11	12	120	40%	59	3	74.5
Mill Pad	36842.2	0.85	4	2.0	12	12	40%	11	3	77.0
Temporary Waste Rock Storage	6897.9	0.16	9	4.5	12	42	40%	24	3	75.9
Portal Pad	13017.4	0.30	12	6.0	12	60	40%	32	3	75.5
Contact Water Pond	3020.6	0.07	11	5.5	12	54	40%	30	3	75.6

(1) 1- Bare Ground, 2 - Poor Stand of Grass, 3 - Fair Stand of Grass, 4 - Good Stand of Grass, 5 - Excellent Stand of Grass

Soil Characteristics:	Default #	Soil Type	Porosity	Field Capacity	Wilting Point	Sat. Hyd. Cond. (cm/sec)
Layer 1: Topsoil	6	Sandy Loam	0.453	0.190	0.085	7.2E-04
Layer 2: Compacted Gravel	21	Compacted Gravel	0.370	0.038	0.018	1.3E-02

ATTACHMENT 2

SUMMARY OF HELP MODEL OUTPUT DATA

HELP MODEL RESULTS

Modeled 15 years

CEMENT TAILINGS FACILITY

Area = 53,570.4 ft^2

Average Monthly	January	February	March	April	May	June	July	August	September	October	November	December	TOTAL
Precipitation (in)	1.07	0.65	2.49	1.43	1.97	4.09	1.52	1.59	0.96	1.10	0.76	0.67	**18.30**
Runoff (in)	0.071	0.022	0.886	0.995	0.303	0.000	0.000	0.000	0.000	0.003	0.009	0.007	**2.30**
Evapotranspiration (in)	0.500	0.470	0.594	0.681	2.119	3.512	1.784	1.362	0.926	0.714	0.414	0.364	**13.44**
Percolation (in)	0.1370	0.1169	0.1207	0.1123	0.0935	0.0672	0.0799	0.1904	0.2060	0.2020	0.1814	0.1726	**1.68**
Percolation (cf)	611.6	521.9	538.8	501.3	417.4	300.0	356.7	850.0	919.6	901.8	809.8	770.5	**7,499**
Percolation (gal)	4,575	3,904	4,030	3,750	3,122	2,244	2,668	6,358	6,879	6,745	6,057	5,763	**56,096**
Percolation (gpm)	0.102	0.096	0.090	0.087	0.070	0.052	0.060	0.142	0.159	0.151	0.140	0.129	**0.107**
Percolation (gpm/sf)	1.91E-06	1.79E-06	1.69E-06	1.62E-06	1.31E-06	9.70E-07	1.12E-06	2.66E-06	2.97E-06	2.82E-06	2.62E-06	2.41E-06	**1.99E-06**

PROCESS WATER POND

Area = 27,354.5 ft^2

Average Monthly	January	February	March	April	May	June	July	August	September	October	November	December	TOTAL
Precipitation (in)	1.07	0.65	2.49	1.43	1.97	4.09	1.52	1.59	0.96	1.10	0.76	0.67	**18.30**
Runoff (in)	0.071	0.022	0.887	0.995	0.303	0.001	0.000	0.000	0.000	0.003	0.009	0.007	**2.30**
Evapotranspiration (in)	0.500	0.470	0.594	0.681	2.140	3.483	1.784	1.361	0.921	0.715	0.414	0.364	**13.43**
Percolation (in)	0.1313	0.1061	0.1045	0.0935	0.0721	0.1449	0.3322	0.3447	0.2874	0.2386	0.1913	0.1674	**2.21**
Percolation (cf)	299.3	241.9	238.2	213.1	164.4	330.3	757.3	785.8	655.1	543.9	436.1	381.6	**5,047**
Percolation (gal)	2,239	1,809	1,782	1,594	1,229	2,471	5,664	5,877	4,900	4,068	3,262	2,854	**37,751**
Percolation (gpm)	0.050	0.044	0.040	0.037	0.028	0.057	0.127	0.132	0.113	0.091	0.076	0.064	**0.072**
Percolation (gpm/sf)	1.83E-06	1.63E-06	1.46E-06	1.35E-06	1.01E-06	2.09E-06	4.64E-06	4.81E-06	4.15E-06	3.33E-06	2.76E-06	2.34E-06	**2.62E-06**

MILL PAD

Area = 36,842.2 ft^2

Average Monthly	January	February	March	April	May	June	July	August	September	October	November	December	TOTAL
Precipitation (in)	1.07	0.65	2.49	1.43	1.97	4.09	1.52	1.59	0.96	1.10	0.76	0.67	**18.30**
Runoff (in)	0.071	0.022	0.886	0.995	0.303	0.004	0.000	0.000	0.000	0.003	0.009	0.007	**2.30**
Evapotranspiration (in)	0.500	0.470	0.594	0.680	2.119	3.515	1.782	1.360	0.925	0.714	0.414	0.364	**13.44**
Percolation (in)	0.0136	0.0107	0.0103	0.2273	1.2850	0.4866	0.2705	0.0627	0.0353	0.0259	0.0194	0.0167	**2.46**
Percolation (cf)	41.8	32.9	31.6	697.9	3945.2	1494.0	830.5	192.5	108.4	79.5	59.6	51.3	**7,565**
Percolation (gal)	312	246	237	5,220	29,510	11,175	6,212	1,440	811	595	446	384	**56,586**
Percolation (gpm)	0.007	0.006	0.005	0.121	0.661	0.259	0.139	0.032	0.019	0.013	0.010	0.009	**0.108**
Percolation (gpm/sf)	1.90E-07	1.64E-07	1.44E-07	3.28E-06	1.79E-05	7.02E-06	3.78E-06	8.76E-07	5.09E-07	3.62E-07	2.80E-07	2.33E-07	**2.92E-06**

TEMPORARY WASTE ROCK STORAGE

Area = 6,897.9 ft^2

Average Monthly	January	February	March	April	May	June	July	August	September	October	November	December	TOTAL
Precipitation (in)	1.07	0.65	2.49	1.43	1.97	4.09	1.52	1.59	0.96	1.10	0.76	0.67	**18.30**
Runoff (in)	0.071	0.022	0.886	0.995	0.303	0.002	0.000	0.000	0.000	0.003	0.009	0.007	**2.30**
Evapotranspiration (in)	0.500	0.470	0.594	0.681	2.140	3.483	1.784	1.361	0.924	0.715	0.415	0.364	**13.43**
Percolation (in)	0.0538	0.0424	0.0411	0.0367	0.5882	0.5986	0.4761	0.2398	0.1409	0.1043	0.0783	0.0654	**2.47**
Percolation (cf)	30.9	24.4	23.6	21.1	338.1	344.1	273.7	137.8	81.0	60.0	45.0	37.6	**1,417**
Percolation (gal)	231	182	177	158	2,529	2,574	2,047	1,031	606	448	337	281	**10,601**
Percolation (gpm)	0.005	0.004	0.004	0.004	0.057	0.060	0.046	0.023	0.014	0.010	0.008	0.006	**0.020**
Percolation (gpm/sf)	7.51E-07	6.50E-07	5.74E-07	5.30E-07	8.21E-06	8.64E-06	6.65E-06	3.35E-06	2.03E-06	1.46E-06	1.13E-06	9.13E-07	**2.92E-06**

PORTAL PAD

Area = 13,017.4 ft^2

Average Monthly	January	February	March	April	May	June	July	August	September	October	November	December	TOTAL
Precipitation (in)	1.07	0.65	2.49	1.43	1.97	4.09	1.52	1.59	0.96	1.10	0.76	0.67	**18.30**
Runoff (in)	0.071	0.022	0.887	0.996	0.303	0.002	0.000	0.000	0.000	0.003	0.009	0.007	**2.30**
Evapotranspiration (in)	0.500	0.470	0.594	0.681	2.117	3.515	1.782	1.362	0.920	0.715	0.415	0.364	**13.44**
Percolation (in)	0.0751	0.0593	0.0575	0.0503	0.1920	0.5541	0.5445	0.3313	0.2025	0.1521	0.1151	0.0968	**2.43**
Percolation (cf)	81.5	64.3	62.4	54.6	208.3	601.1	590.7	359.4	219.7	165.0	124.9	105.0	**2,637**
Percolation (gal)	609	481	467	408	1,558	4,496	4,418	2,688	1,643	1,234	934	785	**19,722**
Percolation (gpm)	0.014	0.012	0.010	0.009	0.035	0.104	0.099	0.060	0.038	0.028	0.022	0.018	**0.037**
Percolation (gpm/sf)	1.05E-06	9.09E-07	8.03E-07	7.26E-07	2.68E-06	8.00E-06	7.60E-06	4.63E-06	2.92E-06	2.12E-06	1.66E-06	1.35E-06	**2.88E-06**

CONTACT WATER POND

Area = 3,020.6 ft^2

Average Monthly	January	February	March	April	May	June	July	August	September	October	November	December	TOTAL
Precipitation (in)	1.07	0.65	2.49	1.43	1.97	4.09	1.52	1.59	0.96	1.10	0.76	0.67	**18.30**
Runoff (in)	0.071	0.022	0.886	0.995	0.303	0.002	0.000	0.000	0.000	0.003	0.009	0.007	**2.30**
Evapotranspiration (in)	0.500	0.470	0.594	0.682	2.137	3.486	1.784	1.359	0.929	0.713	0.415	0.364	**13.43**
Percolation (in)	0.0670	0.0538	0.0530	0.0463	0.2893	0.6047	0.5261	0.3034	0.1829	0.1366	0.1030	0.0864	**2.45**
Percolation (cf)	16.9	13.5	13.3	11.7	72.8	152.2	132.4	76.4	46.0	34.4	25.9	21.7	**617**
Percolation (gal)	126	101	100	87	545	1,139	991	571	344	257	194	163	**4,618**
Percolation (gpm)	0.003	0.002	0.002	0.002	0.012	0.026	0.022	0.013	0.008	0.006	0.004	0.004	**0.009**
Percolation (gpm/sf)	9.36E-07	8.24E-07	7.40E-07	6.68E-07	4.04E-06	8.73E-06	7.35E-06	4.24E-06	2.64E-06	1.91E-06	1.49E-06	1.21E-06	**2.91E-06**