MAXIM
TECHNOLOGIES INC®

A TETRA TECH COMPANY

2436 Dixon (59801)
P.O. Box 2730
Missoula, MT 59806

(406) 543-3045
Fax (406) 543-3088

FINAL

TECHNICAL MEMORANDUM

To: Mary Beth Marks – On Scene Coordinator
Frank Ehernberger – Project Engineer

From: Cam Stringer

Date: June 20, 2003

Re: Estimate of Drainage from Waste into Repository Sump
New World Mining District Response and Restoration Project

This memorandum presents several estimates for the total volume of water that may be expected to drain from the waste placed in the Selective Source repository into the sump. The purpose of this analysis was to determine what volume of water might reasonably drain from the waste placed in the repository.

Sump water volume calculations were made using data obtained from Frank Ehernberger with respect to sump construction and repository closure conditions. The basic assumption for the estimates presented in this memorandum is that the sump was sealed to moisture as of September 2002, and no water inputs into the sump were received following this date. The following are estimates calculated for drainage into the sump based on three different methods.

METHOD	RANGE
Moisture content and storage	503 cubic meters (m^3) to 2,104 m^3 (133,000 gallons to 556,000 gals)
Moisture content	503 m^3 to 2,764 m^3 (133,000 gallons to 730,000 gallons)
Moisture content plus infiltration:	620 m^3 to 2,881 m^3 (164,000 gallons to 761,000 gallons)

Based on our professional analysis, the estimate based on moisture content and storage (133,000 gallons to 556,000 gallons) provides the most reasonable range for potential drainage volume from the repository. The following text presents the basis for the three estimates presented above. Tables 1 through 4 (attached) are spreadsheets that were used to develop the estimates.

Material Volume Estimates

The first step in calculating the volume available for drainage into the sump is to estimate the volume of material in the repository. Volume estimates for the four types of waste material (slimes and lean clays, silty lean clay, sandy silt, and coarse rock with silty sand) are based on construction notes. These volumes are shown on Table 1.

The next step was to estimate the volume of sand between the waste and the drainage gravel. The low end estimate of drainage sand (Table 1) was developed using the as-built repository topography drawing showing the approximate extent of drainage sand and gravel, along with information on Sheets 29, 30, and 32 of the final construction drawings. The length and average width of the area containing drainage sand were measured directly off the as-built repository topography drawing. The volume of sand was calculated by multiplying the length and average width by the thickness of 0.3 meters as indicated on the drawings. The high end sand estimate was based on the total quantity of sand available (Sheet 23) multiplied by a factor of 0.6, since only a portion of the sand delivered to the site was placed below the waste.

The next step was to estimate the volume of drainable gravel at the bottom of the repository. A low range estimate was calculated by summing the volume of gravel in the toe drain, the sump, and the area surrounding the sump using the dimensions shown on the drawings (Table 1). The volume of gravel in the sump was calculated using the length times the width times the height of gravel in the sump. The toe drain volume was calculated by measuring the length and estimating the average width of the as-built repository. The average area of the triangular section shown on Sheet 30 was calculated by multiplying ½ the base times the height of the triangle of gravel. Then the average thickness was calculated by dividing this area by the average width of the gravel in the toe drain shown on Sheet 30. A similar approach was used to estimate the volume of gravel surrounding the sump by using the cross-section shown on Sheet 32, subtracting the 1.0 meter-wide rectangle of the sump, and treating the remainder as a triangle as described for the toe drain. The high end total gravel volume estimate was based on the estimates in construction documents for the total weight of gravel delivered minus the total volume used for other portions of the repository shown at the bottom of Table 1.

Drainage Volume Based on Moisture Content

This method uses the estimated moisture content of materials placed in the repository to estimate the volume available to drain from the waste into the repository sump. To calculate this volume, we assumed that the amount of moisture in each material type as placed in the repository was the total quantity of water available to drain after the repository was sealed in September 2002. The following assumptions were used for this calculation:

1) The density of materials in the repository is not below the range of what would be expected under natural conditions.

2) Water will drain from material in the repository due to the force of gravity.

3) The amount that could drain from each type of material was the initial moisture content minus the specific retention for that material.

The total pore space available to hold water in each material type is equal to the porosity of the material. Porosity (n) is defined as the portion of soil or rock void of material (air space) and is equal to the ratio of volume of void space in a unit volume of earth material to the unit volume of earth material, including both voids and solids (Fetter 1988). The volume of water that can drain from an earth material naturally under the influence of gravity is referred to as specific yield. Specific yield (S_y) is equal to the ratio of the volume of water that drains from saturated soil or rock due to gravity to the total volume of the soil or rock. The specific retention (S_r) of a soil or rock is the ratio of the volume of water the material can retain against the force of gravity to the total volume of the material. The relationship between these materials can be expressed by the equation:

$$n = S_y + S_r$$

For this calculation, the first step was to estimate the amount of moisture present in each type of material when it was placed in the repository. These estimates are shown in Table 2 and are based on the estimated moisture content available from construction records.

The next step was to estimate the S_r for each material type in the repository. The ranges of estimates of S_r listed in Table 2 were generated based on material properties listed in Fetter (1988) and Stephens (1996), and on professional judgment.

Finally, a range of drainage volume for each type of material was calculated by multiplying the portion of water available for gravity drainage from each material by the total volume of that material. Estimates for the entire repository were calculated by summing the totals for each material. These calculations are shown in Table 3.

Results in Table 3 show that the all materials have the potential to drain under gravity using the high estimate of drainable fraction, but slimes/lean clay, silty lean clay and sand will not drain under the low estimate of drainable fraction. The estimated range of total drainage from the repository generated using this method is about 503 m^3 to 2,764 m^3 (133,000 gallons to 730,000 gallons).

Drainage Volume Based on Moisture Content and Storage Capacity

Because some of the assumptions used to generate the estimate of drainage volume presented in Table 3 could result in over estimation, another method to estimate drainage volume was calculated using moisture content and storage capacity. To generate the estimate of drainage volume using moisture content alone, the calculation presented in Table 2 includes the assumption that water would drain from each material type as if these materials were placed separately in the repository, and water would be free to gravity drain according to the properties of each material. In reality, the different types of waste materials were not placed in the repository in any type of order, as the materials were likely mixed in some areas and layered in others. As Table 2 shows, the low estimate of initial moisture content for slimes and lean clays, silty lean clays and sand (columns B and D) are less than their respective S_r estimates suggesting that these materials have the capacity to store more water and hold that water by capillarity against the force of gravity, thereby preventing drainage.

Results in Table 4 presents a low end range for drainage from waste material. The upper portion of Table 4 calculates estimates of the additional water that materials could store against gravity drainage by multiplying the difference between S_r and initial moisture content estimates by the material volume for each material type. The box on the lower right portion of Table 4 shows the results of removing this moisture. The range resulting from these calculations is approximately 503 m^3 to 2,104 m^3 (133,000 gallons to 556,000 gallons).

Drainage Volume Based on Moisture Content Plus Infiltration

Material in the repository was reportedly exposed to precipitation during a wet period in the summer of 2002 before the repository cover was sealed in September. Infiltrating precipitation probably added some additional drainable moisture to materials in the repository. This method attempts to calculate drainage volume added to the repository by precipitation. Because on-site precipitation data are not available for that period, the following assumptions were used for this estimate of drainage volume.

1) A moderate storm event dropped 0.0508 meters (m) (2.0 inches [in]) of precipitation on the surface of the repository.

2) Fifty percent of this precipitation ran off the surface of the repository and 50 percent infiltrated into the sediments over the entire surface of the repository.

3) Fifty percent of the surface of the repository was exposed to the elements

The approximate surface area of the capped repository is 9,180 m^2 and 50 percent of this would be 4,590 m^2. If this area is multiplied by the 0.0254 m (1.0 in) of assumed infiltration, it yields a total infiltration volume of approximately 117 m^3 (30,800 gal) of additional water. If this volume is added to the range of estimates based on moisture content presented above (Table 3), it yields estimates of 620 m^3 to 2,881 m^3 (164,000 gallons to 761,000 gallons).

Discussion

The ranges of sump water volumes presented in this memorandum suggest that there may be a considerable volume of water within waste material in the repository that could still drain under the influence of gravity. However, there is a considerable amount of uncertainty associated with the variables that were used to generate the estimates of drainage. Much of the data used for the analysis was estimated and not based on actual site data. The drainage estimates themselves are sensitive to each of these inputs as well as being sensitive to some of the assumptions used in the analysis. The end result is a fairly large range from the lowest estimate to the highest estimate.

Because of the high degree of uncertainty associated with the data used in these analyses, it would be difficult to generate a robust, best engineering estimate of the potential volume of drainage from waste placed in the repository. Based on our professional analysis, the estimate based on moisture content and storage (503 m^3 to 2,104 m^3) provides the most reasonable range for potential drainage volume from the repository.

References

Fetter, C.W. 1988. *Applied Hydrogeology.* Merrill Publishing Company, Columbus

Stephens, D.B 1996. *Vadose Zone Hydrology.* Lewis Publishers, New York.

ATTACHMENT

TABLES

Table 1: Material Volume Estimates

Repository Waste Material [1]		Low Volume Estimate (m^3)	High Volume Estimate (m^3)
Slimes/Lean Clay		5,000	6,000
Silty Lean Clay		2,000	2,500
Sandy Silt		5,000	5,200
Coarse Waste Rock (plus silty sand)		11,000	12,000
	Total	23,000	25,700

Toe Drain and Sump Low End Volume Estimates [2]	Avg. Thickness (m)	Length (m)	Average Width (m)	Volume (m^3)
Sand	0.3	120	30	1080
Gravel				
Toe Excluding Sump	0.45	105	8	378
Sump gravel volume	1.7	22	1	37.4
Toe surrounding sump	0.85	22	12	224.4
Total Gravel				639.8

High End Gravel Volume Estimates [3]		
Mass of gravel delivered	2,800	M tons
	6,172,943	pounds
Gravel density	2,900	lbs/yd^3
Volume of gravel delivered	2,129	yd^3
	1,627	m^3
Estimated gravel used in other portions of the repository	380	m^3
Estimated gravel used in Sump	1,247	m^3

[1] Volume estimates from construction records

[2] Averge thickness, length, and width esitmated from design and as-built drawings

[3] Mass and dentisty values from construction records

Table 2: Drainage Based on Moisture Content

	Moisture Content (1)		Specific Retention (2)		Drainable Fraction of Pore Space (3)					
Material	Low Estimate	High Estimate	Low Estimate	High Estimate	A	B	C	D	Min	Max
Slimes/Lean Clay	0.22	0.23	0.18	0.3	0.04	<0.0	0.05	<0.0	<0.0	0.05
Silty Lean Clay	0.22	0.23	0.11	0.28	0.11	<0.0	0.12	<0.0	<0.0	0.12
Sandy Silt	0.19	0.23	0.10	0.17	0.09	0.02	0.13	0.06	0.02	0.13
Coarse Waste Rock (with silty sand)	0.12	0.16	0.05	0.08	0.07	0.04	0.11	0.08	0.04	0.11
Sump & Toe Sand	0.04	0.05	0.01	0.06	0.03	<0.0	0.04	<0.0	<0.0	0.04
Sump & Toe Gravel	0.05	0.06	0.005	0.03	0.045	0.02	0.055	0.03	0.02	0.055

Drainage volume = estimated Moisture Content - Specific Retention [Sr]

(1) Moisture content estimates based on constructions records

(2) Sr estimates generated using literature values and professional judgment.

(3) Represents portion of pore space containing water that will gravity drain; calculated by subtracting the specific retention from the moisture content.

A = low moisture - low specific retention

B = low moisture - high specific retention

C = high moisture - low specific retention

D = high moisture - high specific retention

Min = minimum calculated drainable pore space value from column A through D

Max = maximum calculated drainable pore space value from column A through D

Table 3: Drainage Volume Based on Moisture Content

Material Volume			Drainable Fraction		Drainable Volume [8]			
Material	Low (m^3)	High (m^3)	Low	High	Low (m^3)	High (m^3)	Low (gals)	High (gals)
Slimes/ Lean Clay	5,000 [1]	6,000 [2]	<0.0 [6]	0.050 [7]	0.00	300	0.00	79,252
Silty Lean Clay	1,500 [1]	2,500 [2]	<0.0 [6]	0.12 [7]	0.00	300	0.00	79,252
Sandy silt	4,500 [1]	5,500 [2]	0.02 [6]	0.13 [7]	90	715	23,775	188,883
Coarse Waste Rock (plus silty sand)	10,000 [1]	12,000 [2]	0.04 [6]	0.11 [7]	400	1320	105,669	348,707
Sump & Toe Drain Sand	1,080 [3]	1,500 [4]	<0.0 [6]	0.040 [7]	0.00	60	0.00	15,850
Sump Gravel	~~640~~ [3]	~~1,250~~ [5]	0.02 [6]	0.055 [7]	~~13~~	~~69~~	~~3,381~~	~~18,162~~
Totals	**22,700**	**28,750**			**503**	**2,764**	**132,826**	**730,105**

[1] Repository waste low volume estimate from Table 1

[2] Repository waste high volume estimate from Table 1

[3] Toe drain and sump low volume estimate from Table 1

[4] 60% of total volume of sand available from Sheet 23

[5] High end gravel volume estimate from Table 1

[6] Minimum drainable fraction value from Table 2

[7] Maximum drainable fraction value from Table 2

[8] Drainable volume = material volume x drainable fraction

Table 4: Drainage Volume Based on Moisture Content and Storage Capacity

Material Volume			Storage fraction						Storage Volume			
Material	Low (m^3)	High (m^3)	A	B	C	D	Min	Max	Low (m^3)	High (m^3)	Low (m^3)	High (m^3)
Slimes/ Lean Clay	5,000 [1]	6,000 [2]	-0.04	-0.05	0.08	0.07	<0.00	0.08	<0.00	480	<0.00	126,803
Silty Lean Clay	1,500 [1]	2,500 [2]	-0.11	-0.12	0.06	0.05	<0.00	0.06	<0.00	150	<0.00	39,626
Sandy silt	4,500 [1]	5,500 [2]	-0.09	-0.13	-0.02	-0.06	<0.00	<0.00	<0.00	<0.00	<0.00	<0.00
Coarse Waste Rock (plus silty sand)	10,000 [1]	12,000 [2]	-0.07	-0.11	-0.04	-0.08	<0.00	<0.00	<0.00	<0.00	<0.00	<0.00
Toe Drain Sand	1,080 [3]	1,500 [4]	-0.03	-0.04	0.02	0.01	<0.00	0.02	<0.00	30	<0.00	7,925
Sump Gravel	640 [3]	1,250 [5]	-0.05	-0.06	-0.02	-0.03	<0.00	<0.00	<0.00	<0.00	<0.00	<0.00
Totals	22,700	28,750							<0.00	660	<0.00	174,354

(1) Repository waste low volume estimate from Table 1

(2) Repository waste high volume estimate from Table 1

(3) Toe drain and sump low volume estimate from Table 1

(4) 60% of total volume of sand available from Sheet 23

(5) High end gravel volume estimate from Table 1

A = low specific retention - low moisture

B = low specific retention - high moisture

C = high specific retention - low moisture

D = high specific retention - high moisture

Min = minimum calculated available storage for that material

Max = maximum calculated available storage for that material

Storage volume= material volume x storage fraction

	Low (m^3)	High (m^3)	Low (gals)	High (gals)
Drainage volume from Table 3	503	2,764	132,826	730,105
Storage volume from Table 4	<0.00	660	<0.00	174,354
Net drainage volume = drainage - storage	**503**	**2,104**	**132,826**	**555,751**