TETRA TECH WARDROP

SEABRIDGE GOLD

Appendix E9

Open Pit – Till Excavation and Storage

MMMemo

From: Sue Bird

Date: 24 Apr 2010

Re: Till Excavation and Storage Issues

1.0 Problem Definition

Problem Statement – In the KSM mine plan the design, operation, and reclamation design for the waste rock storage facilities needs a multi-discipline solution.

The following issues are to be considered:

1. All material suitable for reclamation re-surfacing of the final dump surfaces must be salvaged or some other mitigation must be shown to meet all end land use requirements. If material can't be salvaged, reasons for non-salvage must be justified and alternatives given to meet end land use objectives
2. There is an opportunity to cover the dumps on closure to minimize surface water infiltration and provide material for re-vegetation. Problems associated with this include:
    i. Storage space of till material – lack of storage area, and stability issues related to disturbed till material
    ii. Safety of storage site to other operations over LOM
    iii. Excavation before active dumping starts or alternatively a means of safely excavating below an active dump,
    iv. Diggability of recovering stored till material
    v. Effectiveness of placing till for reducing infiltration. What techniques are required to seal the dump and then protect from erosion
    vi. What is targeted end land use vegetation and what construction techniques are required for planting and nurturing this re-vegetation.
    vii. Method of placing till on flat and sloped dump surfaces, how to accomplish, how much is required, and cost.
3. Cost of Reclamation to determine the mining component of the required Reclamation Bond.

2.0 Summary and Conclusion

1. Stockpiling of all the till in the waste dump foundation areas is not required, as it not all needed for closure and would cause more disturbance than leaving some if it in situ.
2. There are several options for stockpiling of the tills which may be required for closure. Each option has stability and timing issues which must be resolved.
3. Obtaining till from beneath the final dumps and placing directly on final dump faces requires a re-design of the dumping, and the mining schedule to mine Sulphurets and Kerr concurrently.
4. Obtaining the required till from a borrow source, such as the Ted Morris Valley is the current best option to avoid stockpiling.
5. Geotechnical properties of the till material are required to define stability on final re-sloped dumps surfaces at an overall angle of 26 degrees, and at the original dump slopes of 37 degrees. This is required to determine the required dump volumes and strategies.
6. End land use Objective need to be define so the amount of till cover on the dumops can be determined.
7. The effective use of the till for re-growth and seepage issues must be defined. Additional use of tailings and/or NAG waste rock with the till must be quantified for re-growth, seepage and water quality issues.

3.0 Required Till Material

The final dump configuration, gives the following surfaces areas which could possibly be covered with till. The volume required is calculated assuming a 2 ft. (0.6m) cover is required and swell factor is 15%. The tonnage assumes an SG of 2.1 kg/m^3.

Table 1: Surface Area of LOM Dumps

Case	Description	Area (Mm2)	Vol. Required (Mm3)	Required tonnage (Mt)
LOM Not re-sloped	**Total**	**11.4**	**7.0**	**14.6**
	Slope-Mitchell	2.7	1.7	3.5
	Slope-McTagg	1.8	1.1	2.3
	Slope-Total	**4.5**	**2.7**	5.7
	Flat-Mitchell	1.7	**1.0**	2.1
	Flat-McTagg	5.3	**3.2**	6.7
	Flat-Total	**6.9**	**4.2**	**8.9**
Re-sloped to	**Total**	**11.1**	**6.8**	**14.2**

26 deg	Slope-Mitch	3.0	1.8	3.9
	Slope-McTagg	1.8	1.1	2.3
	Slope-Total	**4.8**	**2.9**	**6.1**
	Flat-Mitchell	1.0	0.6	1.3
	Flat-McTagg	5.3	3.2	6.7
	Flat-Total	**6.3**	**3.8**	**8.1**

As indicated in the table above, the overall amount of till required is slightly less for the re-sloped case. However, the flat area has decreased and the sloped portion increased when re-sloped to 26 degrees. On the other hand, the stability of the till on 37 degree slopes (original dump faces) will be more of an issue than on the re-sloped faces. The McTagg Valley and lower Mitchell (slope to the water treatment pond) did not require re-sloping, as dumping was placed at 26 degrees. Flat and sloped portions are illustrated for both cases in the two figures below (flats are outlined in black).

Figure 1: Final Dump Configuration with Flat Areas Outlined

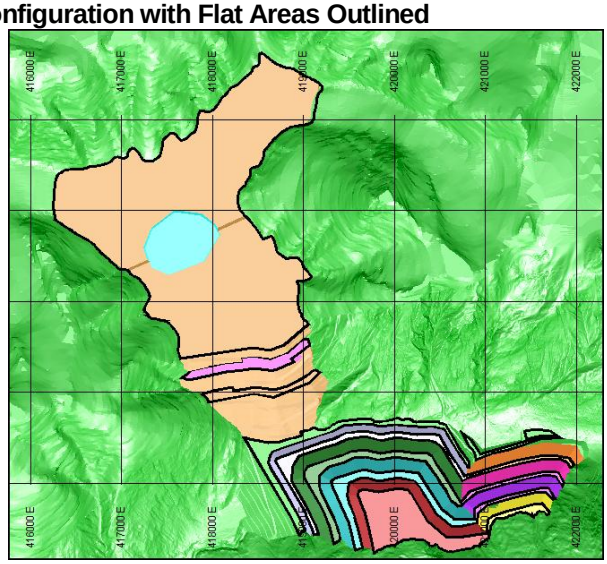
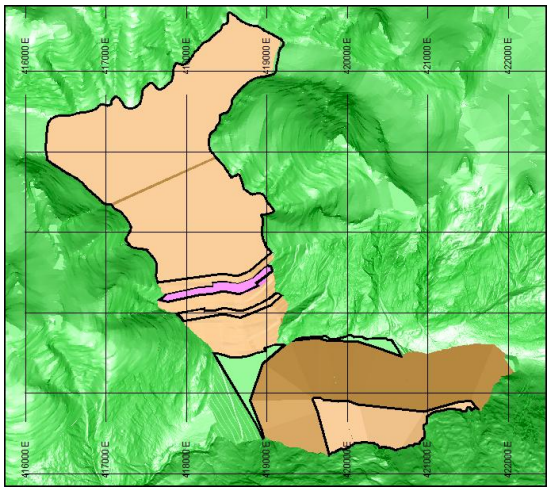


Figure 2: Re-Sloped Dumps Surface with Flat Areas Outlined



3.1 Assumption for Till Coverage Areas

1. The required thickness of till is assumed to be 0.6m. There does exist an opportunity to use the tailings as an additional cover upon closure, which would reduce the amount of till required for growth and reduction of water infiltration.
2. There is also the opportunity to use NAG rock over the till to improve water quality. This option is not considered in the costing or in the design of the waste water treatment pond and facilities.
3. Because of the thickness of the overall dumps, settling will be an issue for many years after closure. It is assumed that the till and tailings placed on the waste rock will be self-healing and that erosion will not be a factor. Further investigation of the till material may be required to validate this assumption.
4. It is assumed that the till will be stable at both the re-sloped angle of 26 degrees and the original dump angle of repose case of 37 degrees. However, the clay content of the available tills raises issues with this assumption. Further geotechnical work is necessary to validate.

3.2 Cost of Re-Sloping

The Mitchell Valley waste dump slopes are currently designed at the angle of repose, terraced to give an overall slope between 26 and 30 degrees. To re-slope to a constant overall angle of 26 degrees would cost in the order of 6 M$, as indicated in Table 2.

These costs were calculated using Caterpillar's DOZSIM program assuming use of a D11. The average push distance was calculated based on lift height as the distance from the centroid of the cut to the centroid of the fill. The volume moved was based on an estimate of the downhill push required, which gave:

Volume/m length=1.26*Cross-sectional Area.

Additional assumptions are given in Table 3.

Table 2: Re-Sloping Costs

Lift Elev. (m)	Lift Height (m)	Face Length (m)	Cost/m length	Cost (000s)
900	60	3,624	$133	$482
1005	105	3,380	$694	$2,346
1110	105	2,936	$694	$2,038
1200	90	2,576	$438	$1,128
Total				**$5,994**

Table 3: Dozer and Material Property Assumptions for Re-Sloping Cost Calculations

Dozer Parameter	Assumed Value
Cost / hr	$135
Weight	94,476 kg
Shoe Width	812.8
% Availability	85 %
Job Efficiency	83 %
Skill Level	0.85
Material Properties	**Assumed Value**
Dozability	0.92
Specific Gravity	2100 kg/m^3

3.3 Cost Comparison

A simplified cost comparison of placing the till on re-sloped vs. original waste dumps is given in the table below. It is assumed that excavation and placement of the till would cost $4 /tonne.

This analysis indicates that an overall increase in cost of 8% would be incurred for re-sloping. However, if it is only effective and necessary to place till on the flat areas, it will be less expensive and there will be more area covered, if no re-sloping is done. These costs will be realized at the end of mine life, and will therefore be insignificant from an NPV point of view on the project economics. The question then becomes to design the waste dump remediation from an environmentally effective perspective.

Table 4: Comparison of Simplified Costs for Till Placement Options

Case	Description	Required till tonnage	Cost of Till ($M)	Re-Sloping	Total Cost	% Increase for Re-

		(Mt)		Cost ($M)	($M)	sloping
LOM (Not Resloped)	**Total**	**14.6**	58.4	0.0	58.4	-
	Slope-Total	5.7	22.9	0.0	22.9	-
	Flat-Total	8.9	35.4	0.0	35.4	-
Re-sloped to 26 deg	**Total**	**14.2**	56.8	6.0	62.8	8%
	Slope-Total	6.1	24.5	6.0	30.5	33%
	Flat-Total	8.1	32.3	6.0	38.3	8%

It is evident from this analysis that an in depth cost-benefit analysis is required. Factors which must be determined prior to this analysis include:

1. The end land use of the waste dumps. Since the current slopes contain very little vegetation, it may be unnecessary to place till on the slopes for re-vegetation .
2. The slope at which till placement is effective. It must be determined from geotechnical properties if placement of till on 26 deg or 37 degree slopes will be at all effective.
3. The use and effectiveness of tailings on these slopes must also be determined.
4. It must be determined if the use of NAG rock on the sloped areas is a sufficient remediation device for water quality, assuming re-vegetation on slopes is not required.

4.0 Available Till Material

Isopachs of the till material were obtained from Klohn Crippen Berger ltd. (KCB). The isopachs for the entire project area are shown in Figure 3 below. A solid of the till for the Mitchell and McTagg valley is illustrated in Figure 4. As indicated, the till is a fairly homogenous layer, with deep portions in areas of previous landslides. There are, however, areas of till along the steep slopes, greater than approximately 30 degrees. The volume within the steep slopes was not included as available till.

Figure 3: Till Isopachs in the Mitchell, McTagg, and Sulphurets Valleys

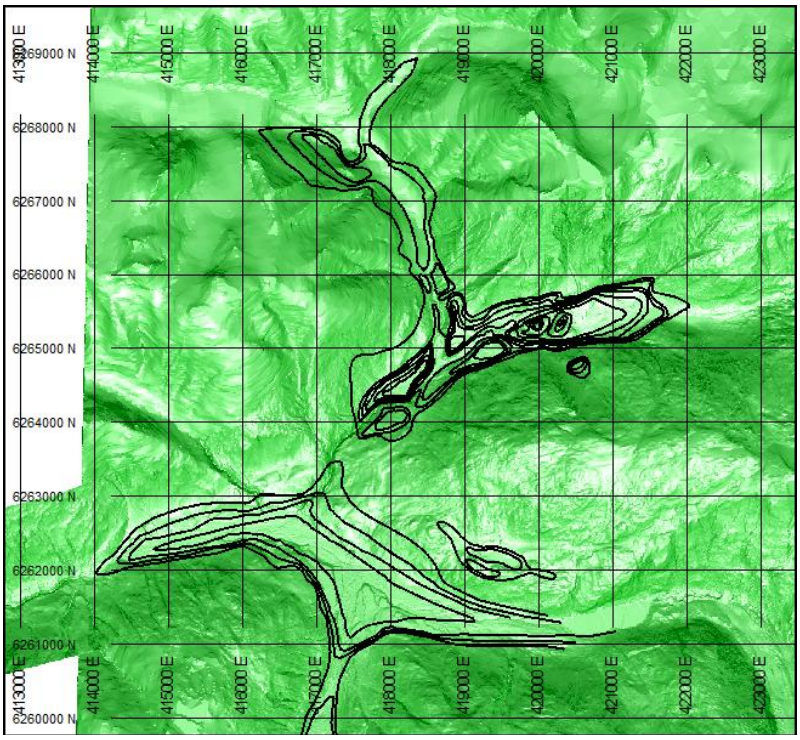

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Figure 4: Till Solid in the Mitchell and McTagg Valleys

The volumes within the Mitchell and McTagg Valleys, which will be covered by potential dumping are given in the table below. The swell factor is assumed to be 15% for disturbed volumes. The tonnages were calculated assuming a specific gravity of 2.1 kg/m3. It is assumed that till on slopes greater than approximately 30 degrees cannot be extracted, and therefore are not included in "Available Till" for reclamation. This amount is 14% of the total till in the valleys. The following image indicates the till areas corresponding to the table.

Table 2: Available Till in Mitchell and McTagg Valleys

Till Area	Description	In Situ Volume (Mm^3)	Disturbed Volume (Mm^3)	Tonnage (Mt)
Total Available	Recoverable Till - slopes < 30 deg	96.8	111.3	233.8
Total	Total – including unrecoverable	112.3	129.1	271.2

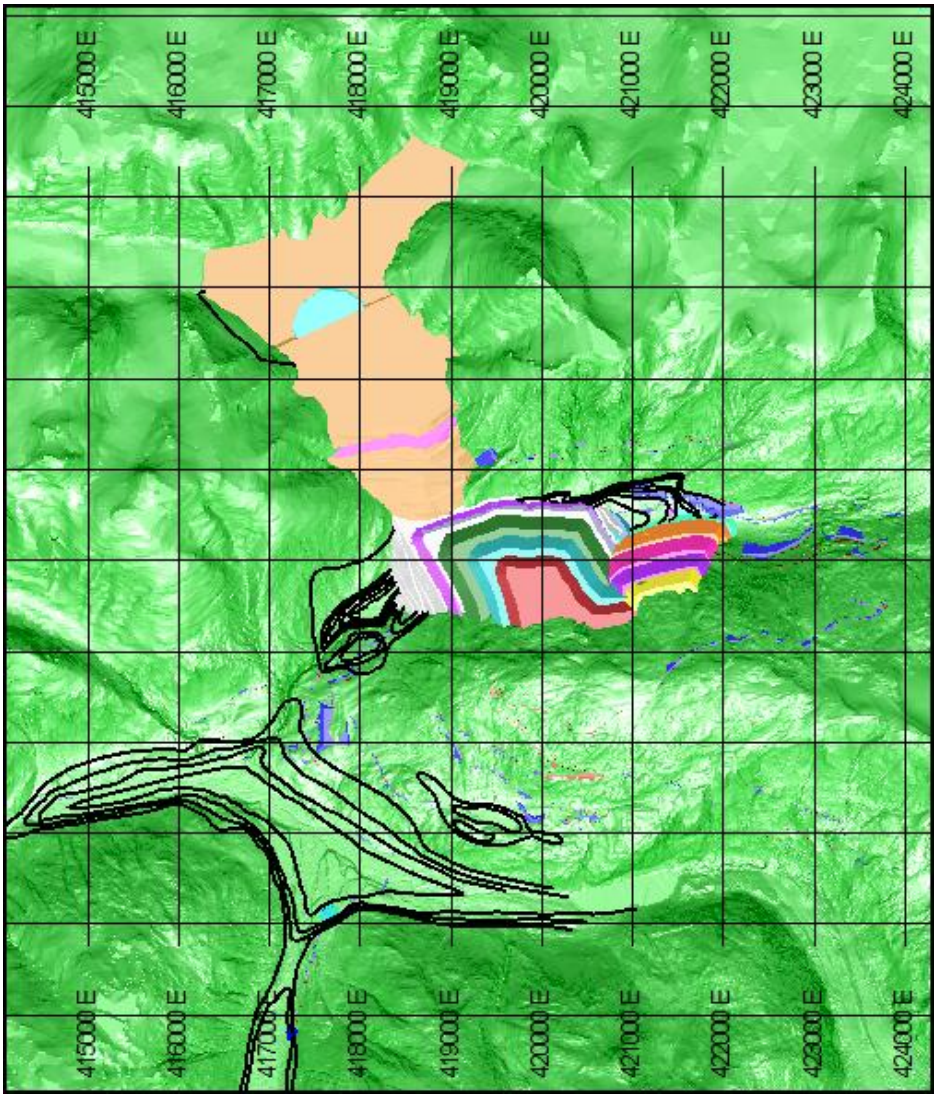
The total amount of extractable till which will be covered by waste dumps is approximately 234 Mt. This is well in excess of the amount required to cover the RSF's with a 0.6m layer of till (about 15 Mt) should this be required from future planning.

5.0 Stockpiling of Till

Storage of most of this material for future re-surfacing within the project area is not feasible due to lack of storage space. The figure below indicates the final dump configuration, with the till

isopachs on the original topography. This illustrates that all the till within the Mitchell and McTagg Valleys is covered by either dumping or the waste water pond. Once the till is stockpiled it cannot be moved to another Stockpile due to diggability issues for the second reclaim. Stockpiling must therefore occur outside of these areas. Even if stockpiled only once, the pile can only be a single lift, since a higher pile cannot be excavated without serious trafficability issues for the loading units and trucks.

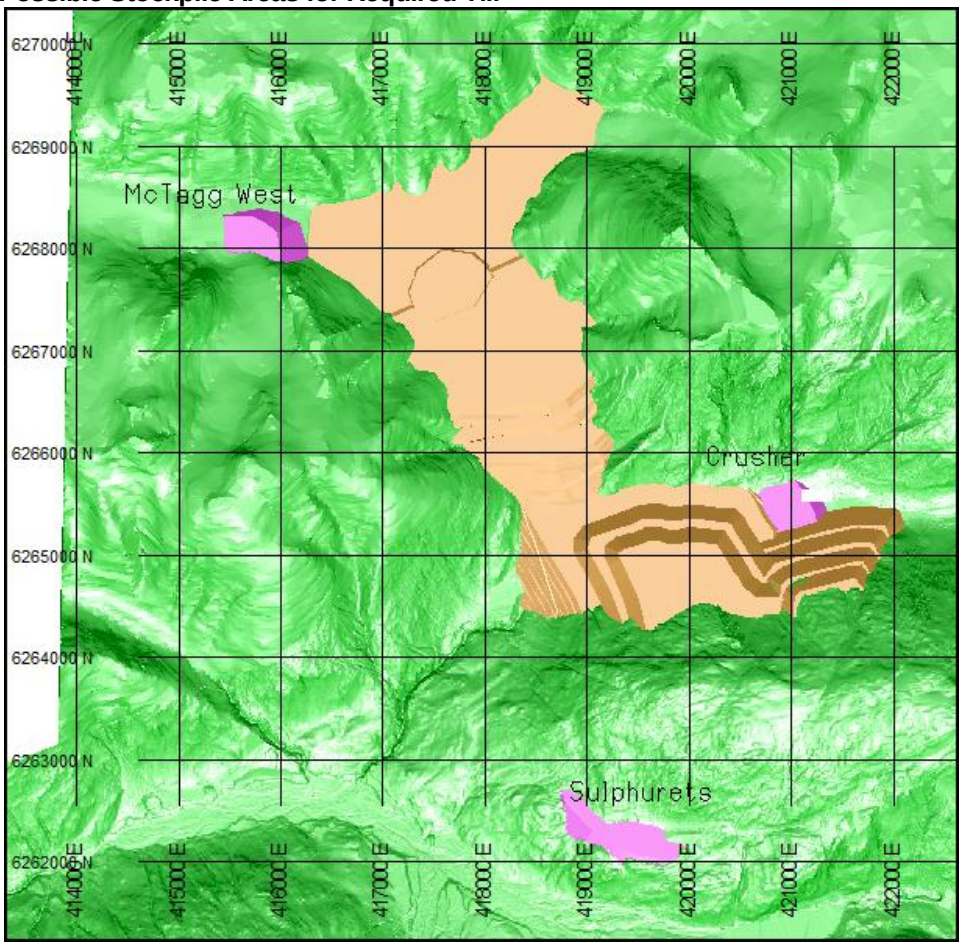
Figure 5: Final dump Configuration with till Isopachs (black outlines)



Stockpiling of the entire 111Mt of till is of course possible, but would require disturbance of the Sulphurets, Ted Morris and / or the lower Mitchell Valleys. This would therefore increase the area of disturbance, required additional permitting and be counter-productive.

In order to minimize area of disturbance, it is best to consider stockpiling of only the till required for dump coverage (15Mt). From a cost perspective, the three possible stockpile areas with the shortest hauls are shown in Figure 6, as the Crusher, Sulphurets and McTagg West Stockpiles.

Figure 6: Possible Stockpile Areas for Required Till



Till material for the Crusher and Sulphurets stockpiles could come from till in the Mitchell Valley with the shortest haul and easiest access for each case. There is sufficient till in the McTagg Valley from the areas shown below in Figure 7.

Figure 7: Available Till Areas in the McTagg Valley

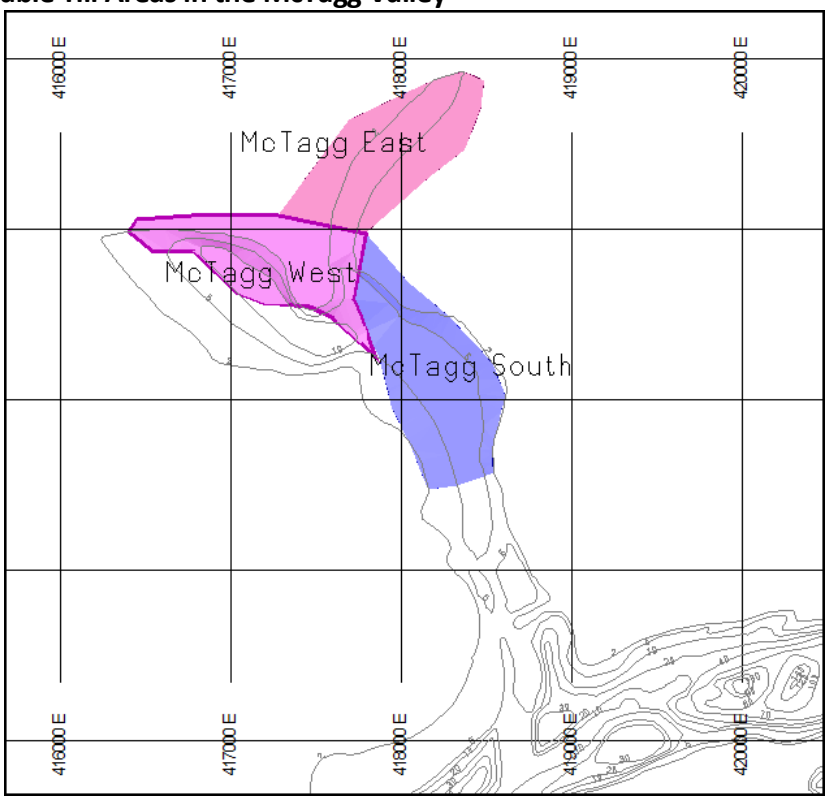


Table 5: Till Material Available from the McTagg Valley

Till Area	Description	In Situ Volume (Mm3)	Disturbed Volume (Mm3)	Tonnage (Mt)
1	McTagg West	2.3	2.6	5.6
2	McTagg East	1.1	1.3	2.7
3	McTagg South	2.9	3.3	7.0
Total - McTagg		6.3	7.2	15.2

Table 5 indicates that there is sufficient extractable till material in the two upper McTagg deposits (McTagg East and West) to cover the current flat areas of the LOM dumps (approximately 8Mt). McTagg South till as shown contains enough to cover the remainder required.

The issues associated with these stockpile areas include:

1. Stability of the Crusher stockpile over the life of the mine, due to its proximity to the crusher. Furthermore, the stockpile would have to be timed such that there is no dumping above the stockpiling.
2. The equipment pad adjacent to the crusher would have to be moved.
3. Timing of waste dumping in the Sulphurets dump would have to be moved to the end of mine life, after removal of the stockpiled till material.
4. Enough till material to cover the flat dumps could be attained from McTagg Valley and stockpiled to McTagg West with a short haul. However, the haul becomes longer for the remaining till, and the haul to cover the dumps at the end of mine life are long.

6.0 No StockpileTill Options

In order to avoid the diggability, stability and timing issues associated with stockpiling of the required till, sources which can be extracted and immediately placed on the dump are outlined below.

6.1 McTagg Till Directly to Dumps

The dumping could be re-scheduled to create final dump slopes in the Mitchell Valley prior to dumping within the McTagg Till area, as indicated in Figure 7. To do this, Sulphurets must be mined earlier. Because of grade issues in Mitchell, the Kerr pit must be mined early as well. This leads to the need for 2 crusher and conveying systems for the Sulphurets and Kerr pits. This may be desirable from an NPV point of view, and if so, dumping could be re-scheduled to allow the above McTagg till areas to be utilized for a new mine plan.

This plan would also entail re-designing the dumping in McTagg to create higher dumps further down the valley to final elevation. However, safety of working below active dumps becomes and issue. Any dumping in McTagg while extracting till from McTagg South would have to be bottom up dumping.

6.2 Till from a Borrow Source

Considering the mining and dumping schedule as it is for the PFS, the current best options for till material without stockpiling is to obtain the required till material from a borrow source outside of the permitted area. Sufficient till to cover the entire LOM dump with 2 ft of cover (15 Mt) can be obtained at the end of mine life, from the Ted Morris Valley as shown in the figure below. This is the area of the planned Explosive Magazine.

Figure 8: Till from the Ted Morris Valley