Anvil Range Mining Complex Supplemental Treatment of Grum Pit Water

2007/08 Task 18e - FINAL

Prepared for:

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On behalf of
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Prepared by:

SRK Consulting
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Project Reference Number:
SRK 1CD003.099

May 2008

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On behalf of

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Executive Summary

The scope of this investigation comprised:

- Reassessment of the maximum allowable water elevation in Grum Pit based on the benefits of reduced metal loadings determined against the criteria used for establishing the trigger elevation.
- Bench scale treatability tests undertaken on water from the Grum Pit during the 2007 summer program to assess the potential effects of this water on the Vangorda/Grum water treatment system, and to determine lime demand, sludge generation rates, sludge densities and treated effluent water quality (including analysis of ammonia, nitrate and phosphorus concentrations).

A preliminary evaluation of the Grum Pit lake monitoring data indicated that, under current conditions, up to 76 % of the net inflow to the pit lake may be groundwater inflow (wall seeps), with the balance from natural runoff. Using the observed changes in groundwater inflows with increased elevation, it is apparent that the annual inflow rate will decrease by about 48% to 60% as the lake level reaches elevation 1210.8 m asl. and 1220.8m asl., respectively.

Based on these estimated inflow rates, the storage capacity remaining in the pit above the threshold elevation of 1210.8 m asl. would be sufficient to store average inflows for up to 40 years. At an elevation 10 m above this (i.e. 1220.8 m asl.) the decrease in flow rate would result in storage for in excess of 20 years. Even at current inflow rates, storage for about 8 years would remain.

Increasing the threshold elevation from that proposed in the AMP by 10 m could have significant benefits to the pit lake water quality. In particular, at the higher elevation a significant proportion of the reactive sulphidic wall rock will be inundated and thus long terms loadings will be reduced. Short term loadings however could increase as a result. Another benefit is that it will be possible to extend the biological treatment program to further improve the water quality within the pit lake.

In the event that it becomes necessary to treat and discharge water from the Grum Pit lake, the bench scale tests indicated that it is likely that the presence of algae will not interfere with the treatment efficiency. Even if there is interference not detected by the bench scale tests, the experience gained at the Faro Mill treatment system has indicated that a lead time of about 1 year between termination of biological treatment and commencement of lime treatment should reduce interference to the point it is not longer of concern.

It is therefore recommended that:

- the threshold elevation of 1210.8 m asl., as proposed in the AMP, be raised by 10 m to 1220.8 m asl.; and
- biological treatment be ceased a minimum of one year in advance of active treatment, should active treatment and discharge from the Grum Pit lake become necessary.

* * *

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1 Introduction

1.1 Terms of Reference

In conjunction with the development of the adaptive management plan for the Anvil Range Mining Complex, an elevation of 1210.8 m asl. has been proposed by others as a trigger water level for the Grum Pit lake. That elevation has been set as a ‘safe’ level whereby seepage losses to groundwater from the pit are not expected to be significant. The elevation is about 20 m below the overflow elevation. If controlled at this elevation, a significant proportion of the mineralized wall rock will remain exposed which could contribute zinc metal loadings to the pit lake. Considering the low actual inflow rates, a much higher elevation may be equally feasible. Therefore, the proposed elevation was reassessed and the benefits of reduced metal loadings be assessed against the criteria used for establishing the trigger elevation.

That trigger elevation is predicted to be reached by 2011 or 2012, by which time it may become necessary to treat the Grum Pit lake water by conventional methods if the current in-pit biological treatment system does not achieve a water quality acceptable for release. Fertilisation of the Faro Pit lake in 2005 was found to interfere with the efficacy of the Faro Mill treatment system. As a result, concern has been expressed that, should biological treatment on the Grum Pit lake be continued, it may interfere with the conventional Grum/Vangorda lime treatment system and potentially put the site at risk of one or more violations of the Water Licence.

Therefore, the scope of this investigation, which has been completed as 2007/08 Task 18e, comprised the following:

- Reassessment of the maximum allowable water elevation in Grum Pit based on the benefits of reduced metal loadings determined against the criteria used for establishing the trigger elevation.
- Bench scale treatability tests undertaken on water from the Grum Pit during the 2007 summer program to assess the potential effects of this water on the Vangorda/Grum water treatment system, and to determine the corresponding lime demand, sludge generation rates, sludge densities and treated effluent water quality (including analysis of ammonia, nitrate and phosphorus concentrations).

1.2 Background

The 2005 biotreatment of the Faro Pit water hampered the ability to treat Faro Pit water, primarily as a consequence of froth formation leading to an inability to adequately settle and densify the treatment sludges. Although no biotreatment of the Faro pit water occurred in 2006, residual algae remaining in the Faro Pit water during the 2006 operating year caused minor disruptions to the Faro Mill water treatment system. These disruptions were overcome.

The Faro Mill treatment system however is not a conventional water treatment system. The facility utilizes mineral flotation devices which utilize high energy mixers designed to induce air as fine bubbles into the slurry of high density sulphide mineral particles while maintaining the solids in suspension. These ‘high shear’ design features are not representative of conventional treatment systems and likely exacerbated the effects of the algae present in water.

Nonetheless, as a result of the difficulties experienced at the Faro Mill treatment plant, concern has been expressed with respect to the possibility that the Grum Pit bioremediation program may impact the ability to treat the Grum Pit water when its water level reaches the proposed action level elevation in 2011 or 2012 (Gartner Lee Limited, 2006).

Therefore, bench scale treatability tests on water from the Grum Pit lake obtained during the summer 2007 biotreatment program were proposed to assess the potential effects of algae on more conventional water treatment technology, such as that utilized in the Vangorda/Grum water treatment system.

The intent of the bench scale tests were to establish requirements for early termination of biological treatment should the tests indicate that conventional treatment will be impacted by the presence of algae. In that event, as indicated by the experience at Faro treatment system, a one year lag time before treatment commences should be adequate to prevent significant impacts on the treatment system, should treatment of Grum Pit lake water be required.

Specifically, the testing program was designed to measure lime demand, sludge generation rates, sludge densities and treated effluent water quality, including analysis of nutrients (i.e. ammonia, nitrate, nitrate and phosphorus concentrations) in the treated effluent.

A water elevation of 1210.8 m asl. has been proposed in the Anvil Range Mine Adaptive Management Plan Implementation Protocol (AMP), prepared by Gartner Lee Limited (GLL), as a threshold elevation for the Grum Pit lake (GLL, 2004). An extract of the chapter from the AMP dealing with the Grum Pit lake is provided in Appendix A. The elevation is 2.6 m below the “maximum desired water elevation” and 21.5 m below the pit overflow elevation.

If controlled at this elevation, a significant proportion of the mineralized wall rock will remain exposed which could contribute zinc metal loadings to the pit lake. Considering the low actual inflow rates, a much higher elevation may be equally feasible. Therefore, the proposed elevation was reassessed by evaluating the potential benefits of reduced metal loadings against the criteria used for establishing the trigger elevation.

2 Grum Pit Lake Threshold Elevation

2.1 Basis of Threshold Elevation

The water quality at the time of preparing the AMP (GLL, 2004) was non compliant with the discharge criteria in Water Licence QZ03-059 for the Faro and Vangorda Plateau mine sites (YWB, 2004). The water still remains non-compliant and cannot, therefore, be directly released to the receiving environment. In developing the threshold elevation, GLL showed that "a series of extreme natural events" could cause the in-pit water level to rise to a "maximum desired" operating range by 2008. The basis for the determining the maximum desired elevation was as follows:

- A recommended maximum desired operating water level to maintain adequate storage for unforeseen flood events (i.e., an "action level");
  The recommendation is 1213.4 m asl., which is 18.9 m below the overflow elevation.

The basis for the threshold elevation was as follows:

- The pit water elevation reaches 1210.8 m asl.
  This threshold elevation, 2.6 m below the maximum desired water elevation and 21.5 m below the pit overflow elevation, will be used to initiate an early management response such that any necessary protocols or equipment can be put into place before the in-pit water elevation reaches the maximum desired elevation. This threshold should provide preparatory timeframes of approximately 1½ years and 1 year for the normal and conservative filling projections, respectively, which is considered to be sufficient for implementation of the action plan.
- The projected timeframe for reaching the maximum desired water elevation is projected to be one year or less under the conservative projection.
  This threshold will be used to initiate an early management response such that any necessary protocols or equipment can be put into place before the in-pit water elevation reaches the maximum desired elevation. A one-year timeframe is considered to be sufficient for implementation of the action plan.

In summary, the purpose of the "maximum desired elevation" is to provide sufficient storage capacity for extreme climate conditions, and the "threshold elevation" is to provide sufficient lead time to implement an action plan (i.e. active treatment).

2.2 Rate of Rise Remaining Capacity

2.2.1 Rate of Rise

Recharge Conditions

The Grum Pit lake monitoring data since 2003 are summarised in Table 2.1. The table also shows the estimated rate of water accumulation in the pit lake for the time periods shown. While the winter 2007/08, the table shows the inferred water balance assuming that the 2007/08 winter inflow is equivalent to the winter 2006/07 inflows.

Table 2.1: Summary of Grum Elevation Monitoring and Estimated Inflows

Year	Period	Elevation (m)	Avg. Rise Rate (mm/day)	Est. Inflow (m^3/day)	Time (days)	Volume Per Period (m^3)	Annual Inflow (m^3)
2003	May-Jun	1184.058	13.0	1285	60	77,122	
	Jul-Aug	1184.373	11.9	1173	62	72,742	
	Sept-Oct	1185.243	11.5	1141	61	69,607	
	Nov-Apr	1185.733	8.2	809	182	147,306	366,778
2004	May-Jun	1188.008	18.8	1901	60	114,089	
	Jul-Aug	1188.408	7.8	791	62	49,026	
	Sept-Oct	1189.015	11.0	1129	61	68,862	
	Nov-Apr	1189.718	7.1	731	182	132,955	364,931
2005	May-Jun	1191.223	12.2	1302	60	78,096	
	Jul-Aug	1192.235	9.3	1010	62	62,651	
	Sept-Oct	1192.748	9.2	1001	61	61,041	
	Nov-Apr	1193.435	5.9	648	182	117,878	319,666
2006	May-Jun	1194.355	11.0	1242	60	74,532	
	Jul-Aug	1195.119	7.3	839	62	51,989	
	Sept-Oct	1195.609	8.4	969	61	59,090	
	Nov-Apr	1196.111	5.3	623	182	113,379	298,989
2007	May-Jun	1197.027	8.7	1043	60	62,590	
	Jul-Aug	1197.584	6.2	748	62	46,407	
	Sept-Oct	1198.011	8.3	1014	61	61,877	
	Nov-Apr			*623*	*182*	*113,379*	*284,253*

Note: Values in Italic-bold are inferred for 2007/08 assuming winter inflow is equivalent to 2006/07.

Since winter precipitation does not contribute significant runoff that flows into the pit lake, it can be assumed that the inflow for the period November to April represents baseline groundwater recharge to the pit lake. As shown in the table, the net winter recharge or inflow has steadily been decreasing from about 147,000 m^3 in 2003/04 to about 113,000 m^3 in 2006/07. The results are also shown in Figure 2.1. The decrease is consistent with expectation that, as the water elevation approaches the natural groundwater table, the hydraulic head will decrease and groundwater inflow will decrease. Annually it appears that the groundwater influx has slowed by about 8 %, on average, for the period 2003 to 2007.

Furthermore, the annual net inflows are showing a similar trend, indicating that groundwater inflows are dominating the annual inflows. In fact, if it is assumed that the base groundwater recharge for the entire year remains constant at the rate observed for the winter period, then the net annual inflow on average for the period 2003 to 2007 to the pit comprised about 76 % groundwater inflow (about 260,000 m^3/year) and only about 24 % surface runoff and direct precipitation (about 81,000 m^3/year).

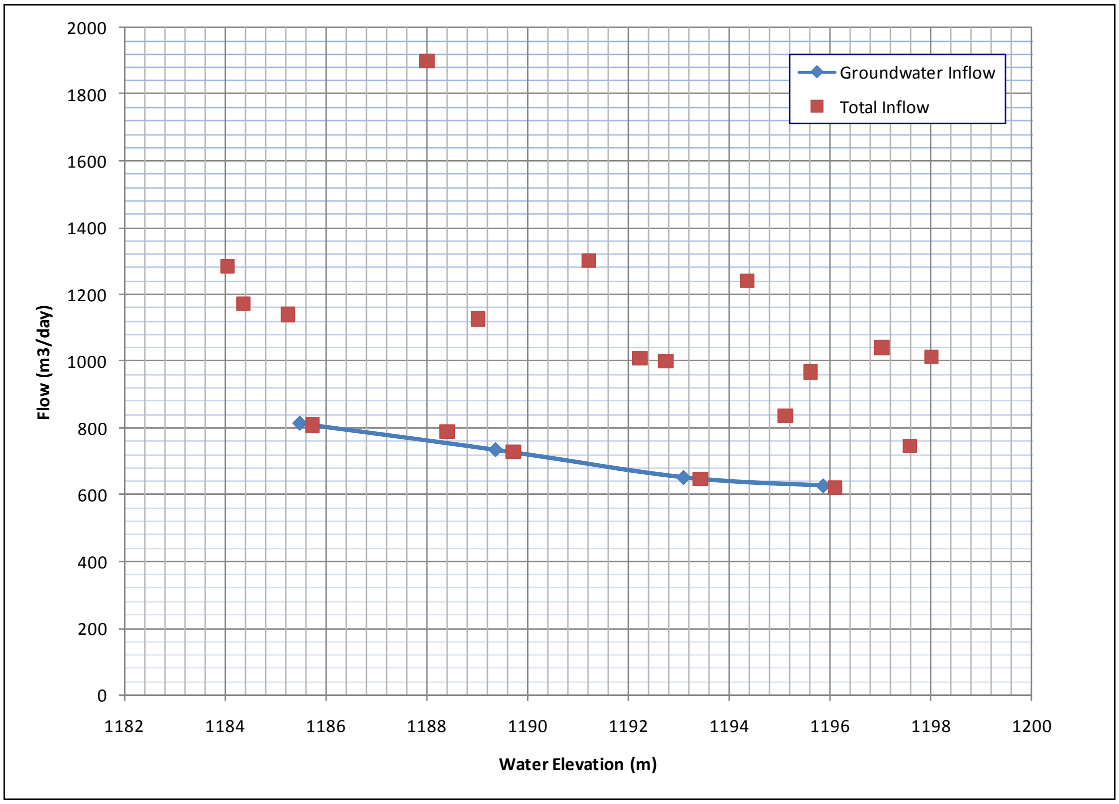

Figure 2.1: Inflows to the Grum Pit as a Function of Water Elevation

By curve fitting the rate of change to a simple exponential equation, it can be shown that the rate of groundwater inflow could decrease by about 40 % (from current rates, to about 154,000 m^3/year) when the threshold elevation of 1210.8 m asl. is reached. The average annual net inflow at that time is estimated to be on the order of about 230,000 m^3 per year, or about 63 % of inflows in 2003. If it is further considered that the storage volume per unit rise in the water level increases significantly as the water level rises, the rate of rise when the threshold elevation is reached would slow from the current average rate of rise of about 1.8 to 2 m per year to about 1 to 1.2 m per year. This represents a decrease in the rate of rise of about 40 to 50 %.

At an elevation 10 m above the proposed threshold elevation, i.e. at an elevation of about 1220.8 m asl., the estimated average annual groundwater recharge would decrease by approximately 53 % from current inflows (to about 120,000 m^3/year) and the annual inflow would be less than 200,000 m^3/year. The corresponding rate of rise at that time would be less than 1 m per year.

Maximum Inflow Conditions

The total catchment of the Grum Pit (excluding the lake) is about 1.3 km^2. Using a probable maximum precipitation event of 200 mm (Northwest Hydraulic Consultants, 2004), and assuming that all of the water in the catchment report to the pit lake, then the total volume of water that would enter the lake is about 260,000 m^3. At the AMP proposed threshold elevation of 1210.8, the total inflow would represent an increase in the water elevation in the pit of only about 1.5 to 1.7 m (inclusive of direct precipitation on the lake). At an elevation 10 m above the threshold elevation proposed in the AMP (i.e. at 1220.8 m asl.), the PMP would raise the pit lake level by about 1.3 to 1.5 m.

A more recent evaluation of the PMP (Taylor and in Hale, 2006) concluded the precipitation would be 184 mm over a 24-hour period. Regardless of which PMP value is used, and even though the PMP represents an extreme and very rare weather event, the net increase in the lake elevation would be equivalent to only about 1 year's worth of accumulated pit inflow.

2.2.2 Storage Capacity

The estimate total storage capacity of the Grum Pit lake at overflow (1232.3 m asl.) is estimated to be about 9.3 million m^3. At the threshold elevation of 1210.8 m, as proposed in the AMP, the estimated pit lake volume would be about 4.8 million m^3 and the remaining storage volume would be 4.5 million m^3. Based on the estimated annual inflow rates at the time the threshold elevation is reached, in excess of 20 years of storage capacity would remain (assuming no further decrease in the inflow rates occurs). If further reductions in groundwater inflows are considered, then the remaining storage time may be as much as 40 years. For the worst case (i.e. assuming no change from current average inflows) the remaining storage capacity would be in excess of 13 years. The occurrence of a PMP event at that time would reduce the available storage time by about 1 year. Therefore, the proposed threshold elevation has clearly been set very conservatively.

At an elevation about 10 m above the proposed threshold (i.e. 1220.8 m asl), the pit lake volume would equate to about 6.5 million m^3, and the remaining capacity to the overflow elevation would be about 2.7 million m^3. At that time, the estimated net inflow would be about 120,000 m^3/year, so that the remaining storage time would be about 22 years assuming no further reductions in flows. At worst, assuming net inflows equal the current average inflows, then the remaining storage capacity would be in the order of about 8 years before the pit lake would overtop. The effect of a PMP at that time would be to reduce the storage time by about 1 year, i.e. the remaining storage time would be about 7 years. Considering that, based on the criteria used in the AMP, a lead time of about 1 to 1.5 years is adequate to implement an action plan (e.g. pump and treat), then increasing the threshold from 1210.8 m asl. to 1220.8 m asl., which still leaves a freeboard of 10 m before overtopping could occur, is not unreasonable. At that elevation under normal inflow conditions, the rate of rise would be less than about 1 m per year. Therefore, assuming a leeway of 2 years of uncontrolled inflow, the increase in the pit lake elevation would be less than 2 m and the upper operational elevation could safely be set at 1222.8 m asl., leaving an operational freeboard of 8 m, which would easily accommodate extreme weather events.

2.3 Other Considerations

The recent assessment of the water quality changes in the Grum Pit lake (SRK, 2008) indicates that actual zinc loadings to the lake are much higher than previously estimated. The assessment also suggests that the loading may be occurring from a combination of sources, including:

a) Seepage or groundwater flows into and out of the pit lake;

b) Release of stored acidity during the inundation of the talus on the benches; and

c) Runoff from pit walls.

As discussed previously, an increase in the pit lake elevation will lower the hydraulic head relative to the surrounding natural water table and, therefore, groundwater inflows will be less at a higher pit lake elevation. This means that the loading associated with (a) above would be lower if a higher threshold elevation is adopted. An increase in the water elevation will also lead to a reduction of the surrounding reactive bedrock that is oxygenated. Exclusion of oxygen as a result would further contribute to reducing contaminant loadings.

A cross section of the pit through the centre of the slot cut extending to Vangorda Creek is shown in Figure 2.2. The section illustrates the elevations of the pit lake (2003, 2007) and the proposed change in the maximum operating elevation of the pit lake relative to that proposed in the AMP. The net increase in the water elevation could result in an increase of the hydraulic gradient of about 10 m/ ~750 m = ~1.3 % (along the length of the slot cut) above that which would have existed for the elevation previously proposed in the AMP. This may increase seepage from the pit fractionally.

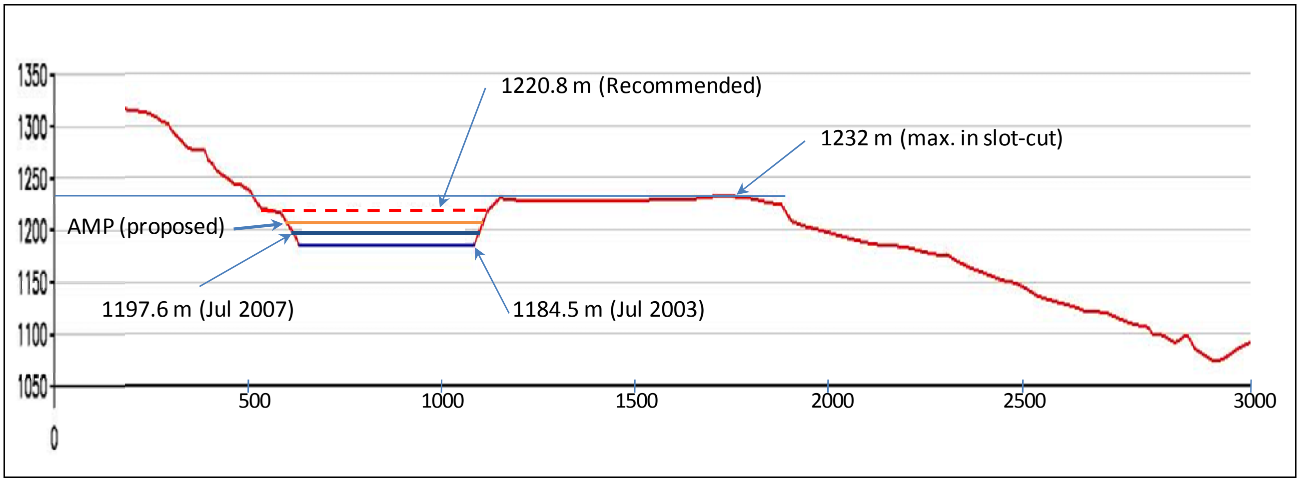

Figure 2.2: Cross Section through Grum Pit along the Centre of the Slot Cut

The stored acidity that is present in the talus would generally be associated with reactive waste rock. Ultimately, any acidity generated within the exposed wall rock and the talus would tend to be transported to the pit lake over time by mechanism (c) above, and would be ongoing. However, as the lake elevation rises and the reactive wall rock (and talus) is inundated, it will be cut off from oxygen and therefore no additional acidity will be generated. So, while a higher pit lake elevation may not necessarily affect the short-term release of stored acidity, it will eliminate future loadings by mechanism (c).

Based on previous wall rock mapping, it is anticipated that a sulphidic wall rock will remain above the threshold elevation of 1210.8 m asl. proposed in the AMP. By increasing the threshold elevation by 10 m, to 1220.8 m asl., it is estimated that as much as 50 % of the reactive sulphidic wall rocks could be inundated (SRK, 2005). This means that the long-term loadings could be reduced correspondingly.

3 Water Treatment Assessment

3.1 Objectives

Treatment of the Grum Pit water was initiated on the basis that fertilization and algae growth in the Faro Pit lake interfered with the Faro Mill water treatment system, primarily causing excessive frothing and preventing treatment solids to settle from the water column. The objective of the testing was therefore to assess the potential effects of algae on more conventional water treatment technology such as that utilized in the Vangorda/Grum water treatment system, specifically on the ability to adequately settle and densify the treatment sludges. The intent of the bench scale tests were to establish requirements for early termination of biological treatment should the bench-scale planned for 2007 indicate that conventional treatment will be impacted by the presence of algae.

3.2 Approach

A summary of the water quality in Grum Pit lake water column at the end of 2006 is shown in Table 3.1. As shown, the nutrient levels in the water column decreased to very low concentrations, with ammonia-N well below the CCME Guideline for protection of freshwater aquatic life of 0.44 mg/L (function of pH and temperature). Similarly, the nitrate/nitrite-N concentration is low (CCME guideline for nitrate-N is 13 mg/L). The results also indicated that metal concentrations in the Grum Pit lake are comparatively low, and that the zinc concentration on average is about 6 mg/L, with a maximum concentration of 9.55 mg/L (total).

Table 3.1: Summary of Grum Pit Lake Water Quality at End of 2006

Parameter	2006 Conc. (mg/L)	
	Average	Maximum
Ammonia - N	0.078	0.091
Nitrite/Nitrate -N	1.01	1.3
Dissolved ortho-Phosphate-P	0.001	0.001
Total Phosphate-P	0.010	0.021
Metals		
Copper D-Cu	0.001	0.002
Copper T-Cu	0.002	0.002
Iron D-Fe	0.121	0.121
Iron T-Fe	0.144	0.176
Nickel D-Ni	0.166	0.201
Nickel T-Ni	0.172	0.209
Zinc D-Zn	5.9	9.33
Zinc T-Zn	6.4	9.55

Based on these water quality properties, it was expected that very low rates of solids generation would occur during the treatment of the Grum Pit lake water. At full scale, this would not pose a concern. However, at laboratory scale where only small volumes of water is treated, the low rates of generation would pose a significant constraint on generating a sufficient quantity of solids to enable settling tests to be conducted. For this reason it was decided to blend the Grum Pit water with Vangorda Pit water which has much higher metals concentrations and would generate sufficient quantities of treatment solids to enable completion of the testing program. In the event that that the tests should show that a high Vangorda to Grum water ration would be required to effectively treat the Grum water, then this was considered to be reasonable from a practical perspective since it is not impossible to transfer water from the Grum Pit to the Vangorda Pit and considering that the annual inflow to the Grum Pit is not a particularly large flow.

Therefore water samples were obtained from the Grum Pit lake at a depth of 5 m (normal intake depth for the treatment system and also the depth at which water was withdrawn from the Faro Pit lake when treatment difficulties were encountered) and at the same depth from the Vangorda Pit lake. The Grum water sample was obtained in mid to late summer when the algal growth would be expected to be at a maximum, i.e. potential inference would be at a maximum. (Note: the chlorophyll ‘a’ concentration at 5m in the Grum Pit water was 7.81 ug/L compared to about 5.62 ug/L in the Faro Pit lake at the time the treatment difficulties occurred.)

In the event that the presence of algae would result in treatment difficulties, a range of conditions were selected for evaluation as follows:

- Test 1 (20%Vangorda, 80%Grum) treat to pH 9.5;
- Test 2 (60%Vangorda, 40%Grum) treat to pH 9.5; and
- Test 3 (80%Vangorda, 20%Grum) treat to pH 9.5.

The first test represents almost entirely Grum water with only a minor amount of Vangorda water to ensure sufficient treatment solids are generated; the second and third tests represent increasing proportions of Vangorda water to determine at what point treatment would become feasible in the event the first test did not yield acceptable results.

The tests were carried out as follows. Treatment reactors were filled to 2L with the relevant water mixtures. Lime (a 5% lime solution) was added to reach the target pH of 9.5 while the beaker is agitated for 60 minutes and continuously aerated. A small amount of Magnafloc 10 was added and the slurry was settled for 30 minutes. Clear water was decanted (~ 1900 or 1950mL). Lime slurry was then added to the treatment sludge and 2.0 litre of fresh sample solution were added to the mixture. Neutralization to the same pH with lime was carried out as above, and the procedure is repeated for a total of 20 cycles. A settling test was conducted on the total sludge generated in the final cycle. Decanted solution from the final cycle was analysed by ICP-MS for metals. The final solids were filtered, dried and weighed.

3.3 Results and Discussion

3.3.1 Water Analyses

A summary of the analytical results for the water samples obtained from the Grum Pit lake and Vangorda Pit lake is provided in Table 3.2. As shown, the Grum Pit water contained low metals concentrations, with zinc similar to the maximum concentration detected in 2006. These results confirm that the solids generation from the water would be low. The metal concentrations in the Vangorda sample were significantly higher and would support higher precipitate formation rates. As shown, the blended sample feed analyses indicate metals concentrations that would generate sufficient treatment solids for completing the tests.

Table 3.2: Summary of Grum Pit Lake Water Quality and Blended Feed Solutions

Dissolved Metals	Units	RDL	Vangorda	Grum	T1-Feed	T2-Feed	T3-Feed
Aluminium (Al)	mg/L	0.001	1.53	0.009	0.006	0.015	0.187
Copper (Cu)	mg/L	0.0002	0.908	0.0107	0.0429	0.236	0.544
Iron (Fe)	mg/L	0.005	5.2	0.009	<0.005	0.006	0.074
Manganese (Mn)	mg/L	0.001	30.2	0.248	5.96	17.8	24.6
Nickel (Ni)	mg/L	0.008	0.414	0.185	0.214	0.312	0.375
Zinc (Zn)	mg/L	0.005	118	9.4	26.9	68.6	90.7

3.3.2 Treatment Results

A summary of the water quality achieved in the final cycle of each of the tests is provided in Table 3.3. When compared to the feed concentrations summarised in Table 3.2, it is apparent that the treatment effectively removes metals from solution to low concentrations.

Table 3.3: Summary of Metal Concentrations in Treated Solutions

Parameter	Units	RDL	T1-C20	T2-C20	T3-C20
Aluminium (Al)	mg/L	0.001	0.007	0.007	0.006
Copper (Cu)	mg/L	0.0002	0.0052	0.0036	0.0038
Iron (Fe)	mg/L	0.005	<0.005	<0.005	<0.005
Manganese (Mn)	mg/L	0.001	0.05	0.005	0.004
Nickel (Ni)	mg/L	0.008	<0.008	<0.008	<0.008
Zinc (Zn)	mg/L	0.005	0.067	0.05	0.069

3.3.3 Settling Rates

Additional settling tests were carried to determine the total zinc concentration in the overflow to assess the settling rate. A 1.0 liter slurry sample from the final cycle was tested in a 1.0 liter graduated cylinder. For these tests, samples were drawn 1.3 cm (0.5 inches) below the surface every 15 minutes. As indicated in Table 3-4 settling was very rapid with total zinc concentration at 0.07 mg/L after 15 minutes.

Table 3.4: Summary of Settling Test Results

Time	Zinc (mg/L)		
	T1-C20	T2-C20	T3-C20
15 mins	0.071	0.07	0.083
30 mins	0.067	0.06	0.074
45 mins	0.067	0.05	0.069
60 mins	0.067	0.05	0.069

Settling curves for the three tests are shown in Figures 3.1 to 3.3. These figures represent the visual tracking of the interface between the clear supernatant and the treatment solids. As shown, the settling rates were very similar and settled rapidly within the first five to ten minutes, irrespective of the blend. For Test 1, during the first 3 cycles and last 4 cycles, the decanted water was slightly murky. Otherwise no significant frothing was observed. The results suggest that the algae present in the Grum water did not interfere with the treatment solids settling rate.

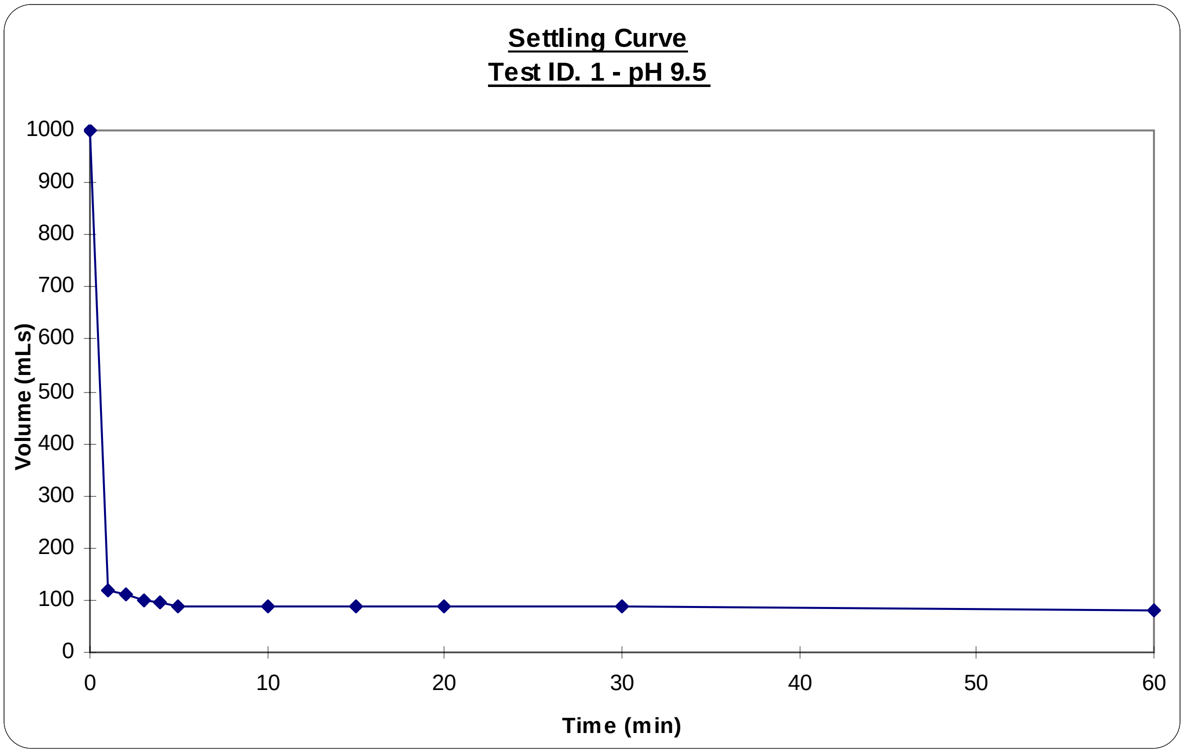

Figure 3.1: Test 1 – 80 % Grum Water Settling Rates

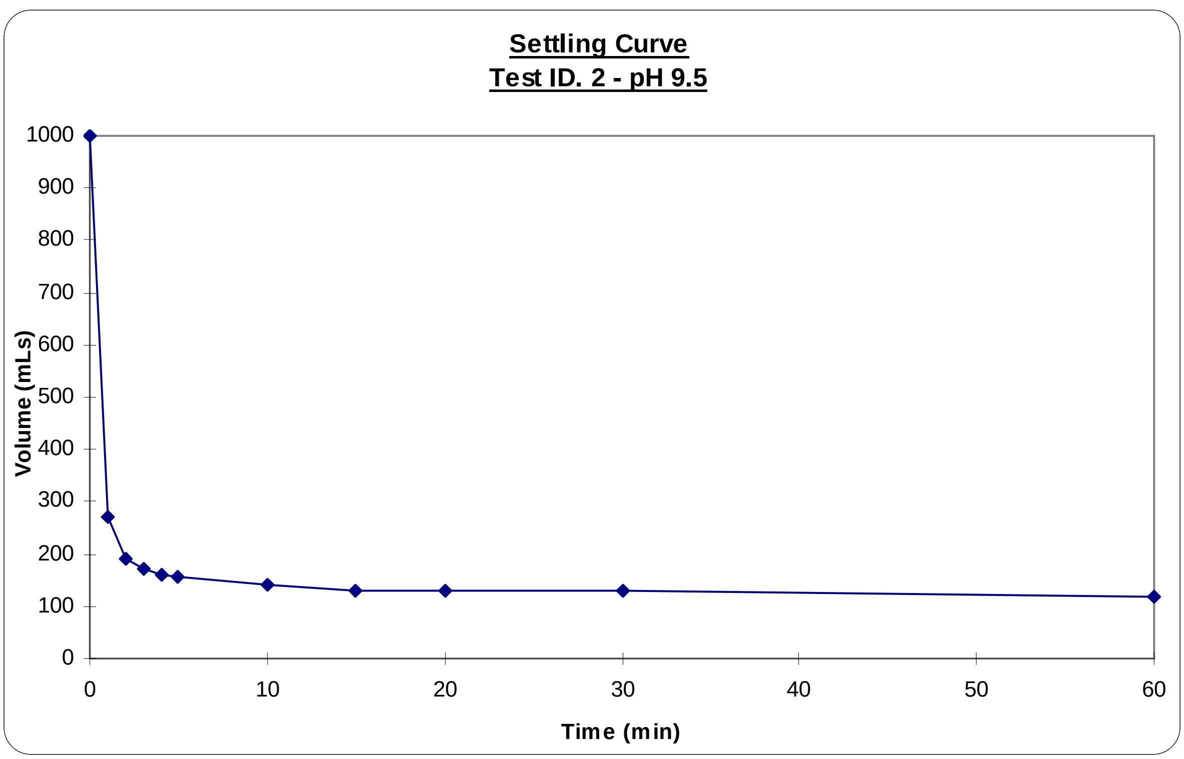

Figure 3.2: Test 2 – 40 % Grum Water Settling Rates

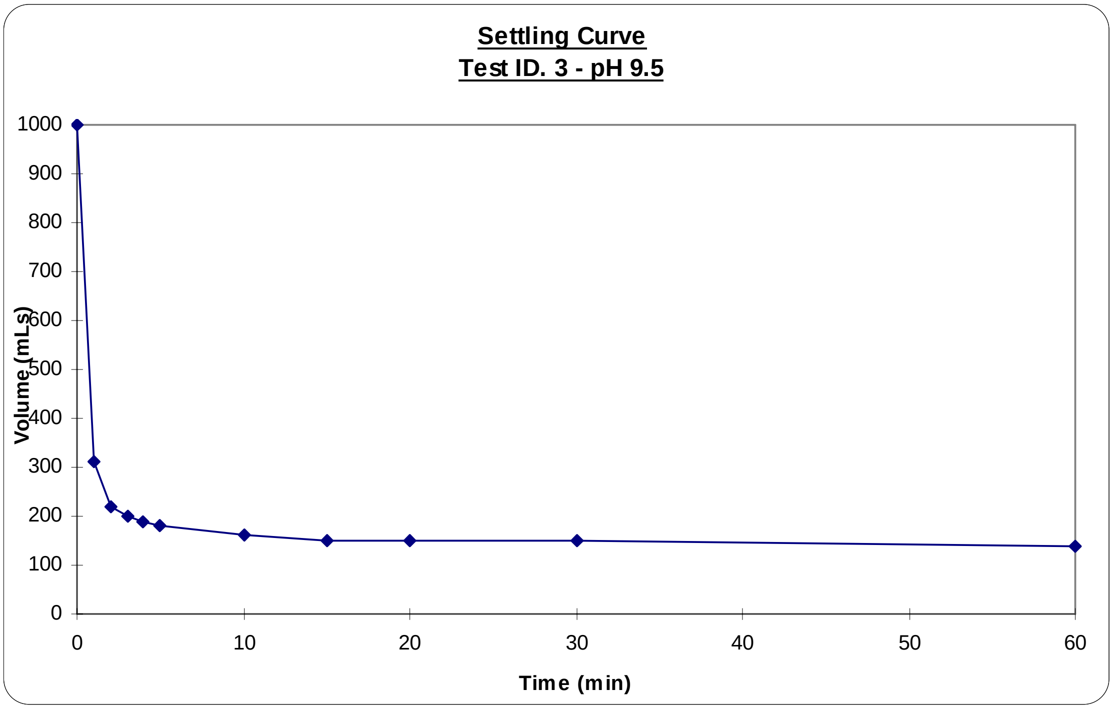

Figure 3.3: Test 3 – 20 % Grum Water Settling Rates

3.3.4 Summary

The results from the testing can be summarised as follows:

- The blended solutions were effectively treated achieving low concentrations of metals in the final solutions; and
- Settling tests indicated that the treatment solids settled rapidly.

The presence of algae in the Grum water did not affect treatment efficiencies, and did not appear to affect settling rates or cause excessive frothing, even at an 80 % Grum water blend. It is important to note that the water sample from the Grum Pit lake was obtained at midsummer, when algal productivity is at its highest and most likely to cause adverse effects, and yet none were observed. Also, as noted previously, nutrient concentrations in the pit lake are generally low when the fertilization program is restricted to the early summer period and should not require active treatment to lower concentrations prior to discharge.

In practice, it is likely that fertilization would be terminated one to two years before active treatment of the Grum water would be implemented. Therefore, nutrient levels are likely to be lower than in the water tested, as would algal populations. Thus, if the 80 % Grum water blend did not indicate interference with treatment, the water that has been allowed to stabilise for one to two years is unlikely to pose treatment difficulties. It is concluded that treatment of 100 % Grum water, or any blend of Grum and Vangorda water, will not affect treatment efficiencies or sludge settling rates.

4 Conclusions and Recommendations

An evaluation of the Grum Pit lake monitoring data suggests that annual winter inflows, when surface inflows are expected to minimal and contributions from direct precipitation are small, are likely attributable to baseline groundwater inflows. Furthermore, these winter inflows have decrease steadily over time as the pit lake elevation has increased, which is consistent with decreasing groundwater inflows as hydraulic heads decrease relative to the surrounding natural water table.

Using these winter baseflows and extrapolating over the remainder of the year, it can be shown that under current conditions up to 76 % of the net inflow to the pit lake may be groundwater inflow (wall seeps), with the balance from natural runoff.

Using the observed changes in groundwater inflows with increased elevation, it is projected that the annual ground water influx would decrease by up to 40 % by the time the threshold elevation of 1210.8 m asl., as proposed in the AMP, is reached. At an elevation of about 1220.8 m asl, i.e. 10 m above the threshold elevation proposed in the AMP, the groundwater inflows would decrease further, by up to 53 % of current flows. Correspondingly, annual inflows would decrease by about 48 % and 60 % respectively.

Using these inflow rates, the remaining storage capacity in the pit after the threshold elevation of 1210.8 m asl. is reached would be sufficient to store inflows for up to 40 years. At an elevation 10 m above this (i.e. 1220.8 m asl.) the decrease in flow rate would still result in storage for in excess of 20 years. Even at current inflow rates, storage for about 8 years would remain.

Under extreme climate conditions, such as a PMP event and assuming all of the precipitation that falls in the catchment reports to the pit, would have the effect of reducing the storage capacity by the equivalent of about 1 year storage time. Consequently the threshold elevation proposed in the AMP has been set very conservatively.

Increasing the threshold elevation by 10 m from that proposed in the AMP could have significant benefits to the pit lake water quality. In particular, at the higher elevation a significant proportion of the reactive sulphidic wall rock will be inundated and thus long-term loadings will be reduced. Short-term loadings, however, could increase as a result.

Another benefit is that it would be possible to extend the biological treatment program to further improve the water quality within the pit lake.

In the event that it becomes necessary to treat and discharge water from the Grum Pit lake, the bench scale tests indicated that it is likely that the presence of algae will not interfere with the treatment efficiency. Even if there is interference not detected by the bench scale tests, the experience gained at the Faro Mill treatment system has indicated that a lead time of about 1 year between termination of biological treatment and commencement of lime treatment should reduce interference to the point it is not longer of concern.

It is therefore recommended that:

- the threshold elevation of 1210.8 m asl., as proposed in the AMP, be raised by 10 m to 1220.8 m asl.; and
- biological treatment be ceased at least one year in advance of active treatment, should active treatment and discharge from the Grum Pit lake become necessary.

This report, **"1CD003.099 – Anvil Range Mining Complex- Supplemental Treatment of Grum Pit Water: 2007/08 Task 18e – FINAL",** was prepared by SRK Consulting (Canada) Inc.

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Appendix A

Extract of Anvil Range AMP, Chapter 8 (GLL, 2004)

8. AMP Event 6, Water level in Grum Pit Reaches Maximum Desired Elevation

8.1 Description

Water quality in the Grum Pit is currently non compliant with the discharge criteria in Water Licence QZ03-059 for the Faro and Vangorda Plateau mine sites (YWB 2004) and can not, therefore, be directly released to the receiving environment. The water elevation in the Grum Pit has been rising since mine shut down in 1998 but remained safely below an overflow level at the end of 2003. Further, a report has been completed (GLL 2003a) that indicates that it is unlikely that the pit will fill to a level requiring active management during the term of the Water Licence (to the end of 2008). Nonetheless, it remains possible that a series of extreme natural events could cause the in-pit water level to rise to a maximum desired operating range by 2008 and, therefore, an AMP is required to ensure that appropriate responses are implemented if necessary.

The environmental consequences of the water elevation in the Grum Pit reaching the maximum desired elevation could result in the absence of adequate emergency storage capacity for containment of a flood event and, ultimately, a release of non compliant water to the receiving environment, Vangorda Creek. This could result in the exposure of aquatic resources, terrestrial resources and human resource users to increased levels of contaminants in Vangorda Creek and the Pelly River.

Zinc is currently the primary contaminant of concern and zinc and sulphate are currently the primary indicators of acid rock drainage. However, the consideration of degraded water quality should include other metals and contaminants that could source from the pit.

8.2 Specific Information or Issues

An investigation of the Grum Pit was completed in 2003 (GLL 2003a) that developed information important to the AMP:

- A recommended maximum desired operating water level to maintain adequate storage for unforeseen flood events (i.e., an "action level");
  The recommendation is 1213.4 m asl, which is 18.9 m below the overflow elevation
- The projected filling timeframe with respect to the maximum desired water elevation; and
  The water level is projected to reach the maximum recommended elevation in 2014 ("normal" conditions) or 2012 ("conservative" conditions)
- A recommended management plan for the care and maintenance period.
  The recommended plan includes monthly monitoring of the in-pit water level, quarterly monitoring of the pit lake water chemistry and implementation of a seasonal (summer) pumping and treatment program via the existing water treatment plant as the contingency against faster than projected filling.

Pertinent information from this study will be filed with the YWB by June 30, 2004 as required by Part , Item of the Water Licence and this information, as possibly modified before 2008, forms the basis of the AMP.

8.3 Narrative Trigger

The trigger for the implementation of contingency measures is "the water elevation in the Grum Pit
reaches the maximum desired operating level."

8.4 Specific Indicators

The specific indicators that should be monitored to provide the information necessary to assess whether the trigger has been activated are:

- Pit water elevation; and
- Projected timeframe to maximum desired water elevation.

Supplementary monitoring information regarding pit lake water chemistry would be beneficial in the event that an action plan is required in the future that includes the treatment of pit water. However, this information is not essential to the AMP.

8.5 Specific Thresholds

The specific thresholds that will initiate the action plan will be as follows:

- The pit water elevation reaches 1210.8 m asl; and
  This threshold elevation, 2.6 m below the maximum desired water elevation and 21.5 m below the pit overflow elevation (1231.5m asl), will be used to initiate an early management response such that any necessary protocols or equipment can be put into place before the in-pit water elevation reaches the maximum desired elevation. This threshold should provide preparatory timeframes of approximately 1½-years and 1-year for the normal and conservative filling projections, respectively, which is considered to be sufficient for implementation of the action plan.
- The projected timeframe for reaching the maximum desired water elevation is projected to be one year or less under the conservative projection.
  This threshold will be used to initiate an early management response such that any necessary protocols or equipment can be put into place before the in-pit water elevation reaches the maximum desired elevation. A one-year timeframe is considered to be sufficient for implementation of the action plan.

8.6 Monitoring Requirements

The monitoring information that is required is:

- The pit water elevation; and

For direct comparison to the specific thresholds and to enable an updated projection of the filling timeframe

- Local precipitation.
  To enable an updated projection of the filling timeframe

The collection of this information is provided through the monitoring requirements of the Water Licence. Schedule A of the Water Licence requires the monitoring of water elevations in the Grum pit (station V23) on a monthly basis. The monitoring should be by direct survey, as per the current protocol carried out by the site environmental technicians, or by staff gauge calibrated by direct survey. The monthly monitoring frequency serves the purpose of the AMP.

Schedule C of the Water Licence requires the collection and review of precipitation data on an annual basis. In recent years, the best data available has been collected by Environment Canada at the Town of Faro airport and this data has been obtained from Environment Canada for the mine's reporting and review purposes. Beginning in 2004, climate measurement stations will be operated by the mine on both the Faro and Vangorda Plateau mine sites such that the precipitation data will be more representative of the conditions at the mine sites. Regardless of whether the airport data or the on-site data is employed, for the AMP, an annual review of monthly precipitation summaries will be undertaken to enable an update to the filling projection timeframes. An annual review of the data is sufficient for the purpose of the AMP.

8.7 Evaluation of Monitoring Results

A management review of the pit water elevations will be made on a monthly basis when the water level reading is obtained. This will provide an immediate assessment against the specific threshold value for the pit water elevation.

The updated pit filling projection will be prepared and evaluated as part of the annual AMP review. This is to be completed by February 28 of each year for inclusion into the Annual Environmental Report that is required to be filed with the YWB. In this way, the filling projection for the Grum Pit will be updated by February 28 such that appropriate actions can be initiated, if required, prior to the summer work season.

8.8 Approaches to Responses

As per the general approach to the adaptive management plan, a staged response to an increasing water elevation in the Grum Pit will be implemented if the response trigger is activated.

The initial response to crossing either of the specific thresholds will be verification of the monitoring information. This will involve either re-survey of the pit elevation or recalculation and cross checking of the pit filling projection. This should be done within 2 weeks of the initial indication from the monitoring data.

Upon verification of the monitoring data that a threshold has been crossed, the YG Water Inspector and the YWB will be notified in writing of the circumstances. At this time, the most recent pit lake water chemistry will be reviewed in the context of determining compliance with the Water Licence discharge criteria. This should be done within a one-week timeframe. Based on this compliance check, one of two plans will be implemented.

1. Design of an operating system, which may or may not incorporate in-pit treatment, for direct release of water from the Grum pit to Vangorda Creek in a safe manner. The system should be designed to the same minimum operational safety standards as other similar operating facilities and structures on the Vangorda Plateau mine site; or
2. Design of a pumping system for integration of Grum Pit water into the summer season pumping program that is currently in operation for the Vangorda Pit.

In either event, notifications and designs will be provided to the YWB according to the procedures provided in the Water Licence for minor modifications of existing structures (YWB 2004, Part D, Items 32 to 37). Specifically, this will include:

- Filing of design documents at least 90 days prior to construction (Item 32);
- All dams and diversions designed to withstand the 1:475 year return period earthquake (Item 33);
- All designs shall be sealed by a Professional Engineer registered to practice in the Yukon Territory (Item 34);
- Filing of a detailed construction schedule and other information at least 10 days prior to construction (Item 35);
- Notification of field amendments to the filed designs prior to their implementation (Item 36); and,
- Filing of as-built report within 90 days of completion (Item 37).

Construction of any required facilities and implementation of any required workplans will then proceed according to the filed information and any directives returned by the YWB. Any works and/or activities not covered by the requirements of the Water Licence may be subject to a licence amendment and the need for an amendment would be evaluated at that time.