Anvil Range Mine
2003 Studies of Care and Maintenance Management Alternatives for Grum Pit

prepared for:
Anvil Range Mining Corporation
(Interim Receivership)

prepared by:
Gartner Lee Limited

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Mine site, Faro Yukon
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October 21, 2003

Mr. Doug Sedgwick
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Mr. Dana Haggar
Anvil Range Mining Corp (Interim Receivership)
Mine site
P.O. Box 1000
Faro, YT
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Dear Messrs Sedgewick and Haggar:

Re: 2003 Studies of Care and Maintenance Management Alternatives for Grum Pit

Please find attached our report examining management alternatives for the Grum Pit. This report summarizes 2003 studies which included a detailed elevation survey, filling projection, pit water quality profiles, and water treatment analysis. Environmental management recommendations, as discussed with you during the review of the draft report, are provided in the report for consideration.

Don't hesitate to contact me if you have any questions regarding the contents of this report.

Yours very truly,
GARTNER LEE LIMITED

Eric Denholm, P.Eng.
Senior Mining Consultant

(23586 Grum Pit Final Rpt.doc)

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Executive Summary

The Grum Pit has been accumulating runoff water and groundwater inflows since the time of mine closure in January 1998. Water currently in the Grum Pit contains zinc concentrations above the discharge criteria in the current water license. In consideration of potential future issues related to discharge of the Grum Pit water, a number of studies have been undertaken in 2003. The specific objectives of these studies are to:

1. Develop an accurate projection of the pit filling rate;
2. Develop a (proposed) maximum recommended water elevation for the pit;
3. Provide a preliminary assessment of the potential treatment requirements for pit water; and
4. Provide a preliminary evaluation of possible environmental management plans and recommend those that should be developed and evaluated further for implementation before the pit water level is projected to reach the (proposed) maximum desired elevation.

A detailed survey of the Grum pit was completed in 2003, including the above and below water portions of the pit. The actual pit water volume, calculated using the recent survey, compares very closely with the volume predicted based on filling rates estimated in the 1996 Integrated Comprehensive Abandonment Plan. The July 2003 water elevation is approximately 48 metres below the point of overflow (1232.3 m ASL) from the Grum Pit, at the south end of the "slot cut". However, it is possible that seepage from the pit could occur at a lower elevation where till contacts the underlying bedrock. A maximum water elevation (1213.4 m ASL) has been proposed based on the till contact elevation and an allowance for emergency diversions into the pit during flood conditions. The July 2003 water elevation (1184.3 m ASL) is approximately 29 metres below the proposed maximum water elevation. It is estimated that the proposed maximum water elevation will be reached between the years 2012 and 2014, based on currently available data.

Field measurements of the pit water collected in August 2003 indicated the pond was slightly alkaline (pH: 7.5 - 8.1) and well oxygenated (D.O.: 8 – 9 mg/L) from surface to the bottom at 39 m depth. The pond was thermally stratified during August 2003. An upper warm layer (approximately 12 °C) existed between the surface and 3 m depth while a uniformly cold layer (5 °C) existed between 8 m and the pit bottom. A small dissolved oxygen peak was observed at the 5 m depth. Laboratory analysis of samples collected at various depths indicated that trace metal levels were lower in the surface layer of the pond (ie. zinc concentration of 4 mg/L) relative to samples at greater depths (ie. zinc concentration of 12 mg/L). Zinc was predominantly in the dissolved phase throughout the water column. Relatively clean pit inflows may be largely responsible for the better water quality observed in the surface water, relative to depth. Assuming the pit fills in future with relatively clean inflows, the zinc concentration when the pond reaches the proposed maximum water elevation could be 4 mg/L or lower (based on no treatment interventions prior to that time).

Bench-scale testing of pit pond samples was conducted to determine lime consumption rates, zinc removal at different pH levels, and precipitate settleability. Lime addition was effective at reducing dissolved zinc concentrations below 0.5 mg/L by raising the pH above 8.75. The precipitate produced during the pH adjustment tests did not settle rapidly. However, longer-term settling tests of 14-hour duration resulted in significantly improved precipitate settling and lower total zinc concentrations. The addition of an anionic polymer flocculent did not improve settling characteristics over the period of the longer test. An optimum pH range of 9.0 to 9.4 was determined through bench-scale testing. A relatively higher lime demand is required above this pH range, possibly as a result of manganese oxidation.

Using the results of the pit filling projection and the bench-scale treatment tests, the following six potential Grum Pit management alternatives have been assessed:

1. Future treatment in existing Grum/Vangorda Water Treatment Plant;
2. Immediate *in situ* lime treatment (entire pit pond);
3. Interception of groundwater inflows;
4. Future *in situ* lime treatment (epilimnion only);
5. Future *in situ* lime treatment (entire pit pond);
6. *In situ* treatment with nutrient addition.

Option #2 (immediate *in situ* lime treatment) is being put forward for consideration. Based on the bench-scale results, and previous treatments in similar applications, this option provides a good opportunity to create a long-term compliant pit pond. The treatment can be achieved at reasonable cost; an estimated 180 tonnes of lime would be applied to the pit pond over a 2-3 week period in late summer. Conducting this treatment program in 2004 would allow for several years of follow-up monitoring (elevation and water quality), prior to the pit pond reaching the proposed maximum water elevation. This option allows for the possibility of future, additional treatment interventions if the need is indicated through monitoring.

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1. Study Purpose

The Grum pit was empty of water at the time of mine closure in January 1998. Since that time, runoff water and groundwater inflows have been allowed to accumulate in the pit such that the in pit water level has increased. The water level in the Grum pit has increased at a rate that is slower than was observed for the Vangorda pit over the same timeframe due to the larger size of the Grum pit and the lower rate of inflow.

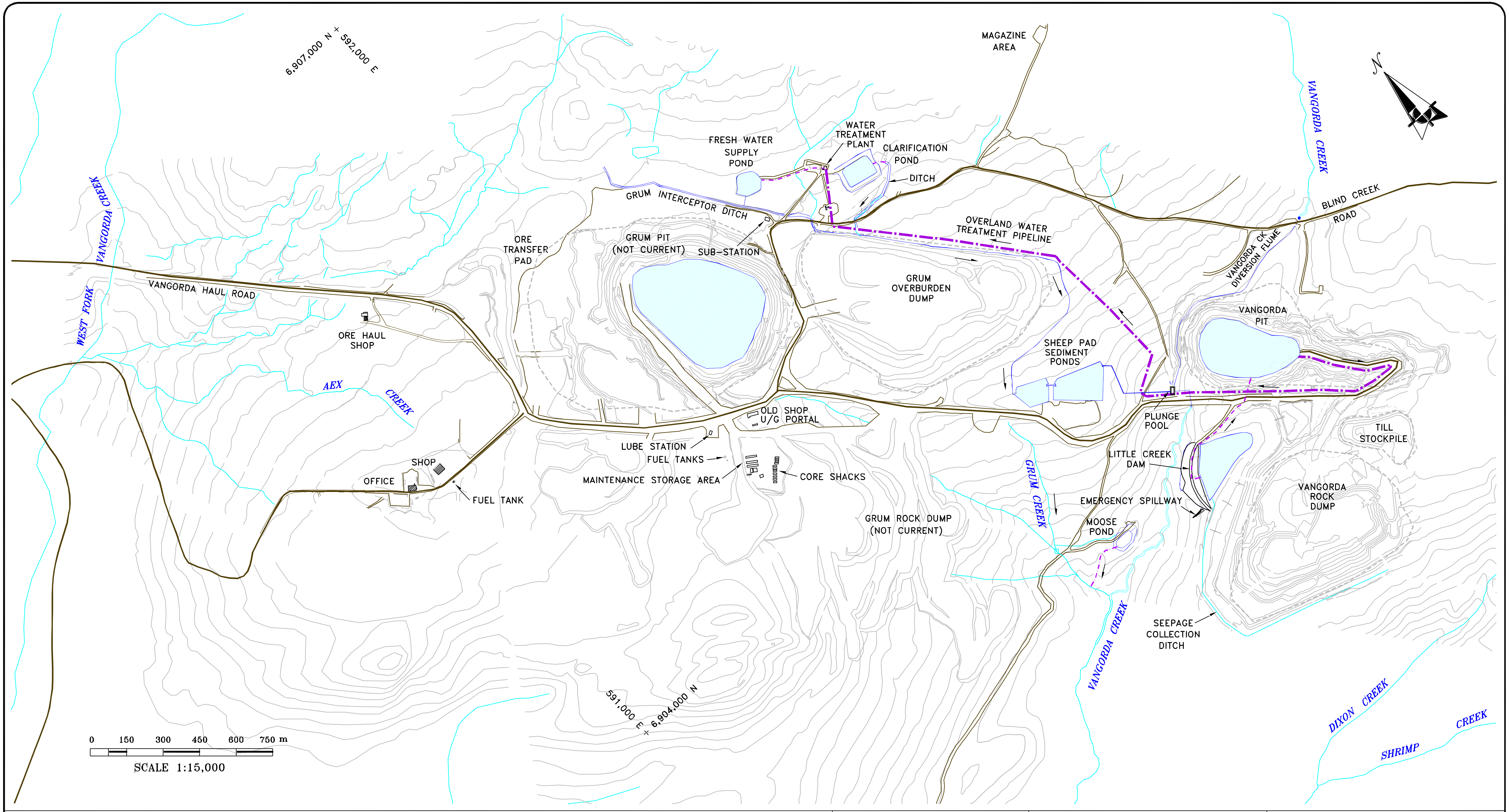
The water in the Grum pit is non-compliant with the discharge criteria in the current water licence with zinc being the contaminant of primary concern. Water quality in the Grum pit is substantially better than that in the Vangorda pit due to the much smaller presence and exposure of highly acid generating materials on the walls and benches of the Grum pit.

The progressive accumulation of non-compliant water in the Grum pit has been monitored and is now at the stage where additional information is required to ensure that an active management plan is in place for future implementation, if necessary.

The general layout of the of the Vangorda Plateau mine site, on which the Grum pit is identified, is illustrated in Figure 1. An aerial photograph of the Grum pit taken in spring 2002, looking in a generally southerly direction is provided in Figure 2.

The specific objectives of the 2003 studies are to:

1. Develop a more accurate projection of the future rate of filling of the pit.
2. Develop a (proposed) maximum recommended water elevation for the pit using a methodology similar to that employed for the Faro and Vangorda pits.
3. Provide a preliminary assessment of the potential treatment requirements for pit water, both in-situ and through the existing water treatment plant.
4. Provide a preliminary evaluation of possible environmental management plans and recommend those that that should be developed and evaluated further for implementation before the pit water level is projected to reach the (proposed) maximum desired elevation.



LEGEND:

- ROADS
- EXISTING SURFACE DRAINAGE
- PRE-MINE DRAINAGE
- E EFFLUENT PIPELINE
- PIPELINE
- WATER TREATMENT PIPELINE
- SURFACE WATER

SOURCES OF INFORMATION:

1. DIGITAL COPY OF 1:50,000 TOPOGRAPHIC MAP SUPPLIED BY SRK CONSULTING.
2. FARO MINE DETAILS ADAPTED FROM DRAWINGS BY ROBERTSON GEOCONSULTANTS INC.

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ANVIL RANGE MINE
2003 STUDIES OF CARE AND MAINTENANCE
MANAGEMENT ALTERNATIVES GRUM PIT

VANGORDA PLATEAU MINE SITE OVERVIEW

Gartner Lee
Deloitte & Touche

FIGURE NO.
1

Figure 2. Grum Pit

2. Filling Projection

2.1 Elevation – Capacity Relationship

A current and complete survey of the Grum pit, and especially the above water potion, was required for this project given that a complete survey of the as-built Grum pit was not located from the archived mine files and that such a survey would not have reflected the current pit conditions given the continued slumping of till in the southeast wall area.

The above water portion of the Grum pit was surveyed by Yukon Engineering Services (YES) in July 2003 using an electronic total station survey instrument and known survey control points in the Grum area for reference and setup. The below water portion of the pit was also surveyed, using a small boat, but in less detail than the above water portion of the pit. The surveying was completed in as much detail as safety concerns allowed given that some areas of the pit walls are not safely accessible. The level of detail and the precision provided in the survey is considered to be sufficient for management planning. The survey drawings, as provided by YES, are provided in Appendix A.

An elevation-capacity relationship for the pit was then established by YES, which is illustrated on Figure 3.

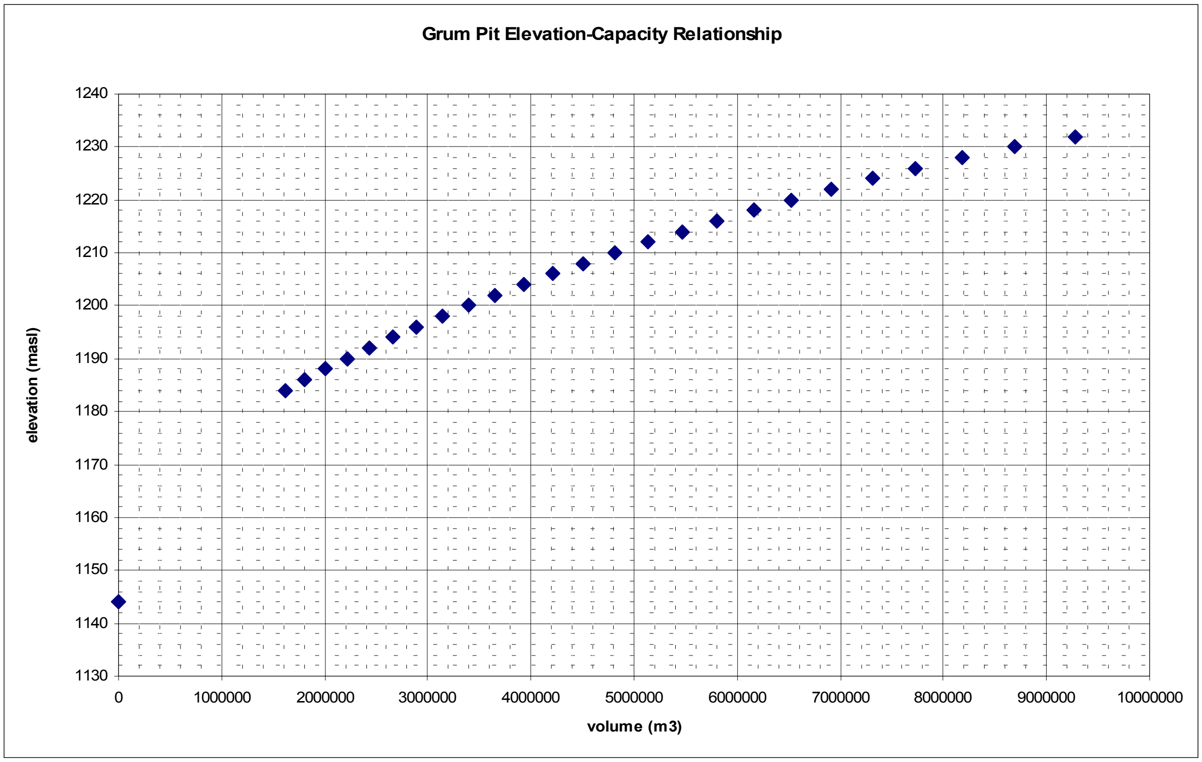
As a means of investigating whether the calculated elevation-capacity relationship is in general agreement with expectations, the in-pit volume of water at the time of the survey derived from the 2003 survey was compared to the anticipated volume derived from previous data.

The surveyed water elevation on July 1, 2003 was 1184.35 m above sea level (asl), which represents an in-pit water volume of 1.6 million m^3 (per Figure 3).

The average annual inflow into the pit that was presented in the 1996 Integrated Comprehensive Abandonment Plan (ICAP) based on an extensive hydrological analysis and observations of previous filling rates was estimated to be 10 L/s (page 8-9). This estimated average inflow, when modified according to the actual precipitation experienced from 1998 to 2002 (91% of the measured 20-year norm), suggests that the anticipated volume of water in the pit in July 2003 would be 1.6 million m^3.

Therefore, the comparison of the in-pit water volume derived from the calculated height-capacity relationship (Figure 3) with the anticipated volume derived from previous information indicates that the 2003 height-capacity relationship does not represent a substantial departure from expectations and the 2003 relationship has been used throughout this report.

Figure 3. Grum Pit Elevation-Capacity Relationship



The point of overflow from the Grum pit is at the south end of the “slot cut”, the road access for the south side of the pit at an elevation 1232.3 masl. However, the base of this access roadway is partially in the till that infills a bedrock valley that cuts through this area of the Grum pit. It is possible that seepage out of the Grum pit could occur at an elevation lower than the surface overflow elevation depending on the thickness of till and the orientation of the basal contact with underlying bedrock. For example, the basal contact between the till and the underlying rock above the pit is a known water flowpath into the pit.

The 1996 ICAP report also identified this as a possible seepage location and recommended that this be investigated further before implementation of the closure plan. Nonetheless, the ICAP referred to engineering analyses conducted by Piteau Associates which suggested that any seepage out of the Grum pit via this pathway would be expected to be relatively small (page 8-9).

Such an investigation would be extensive and not within the scope of this report. However, in recognition of this potential seepage pathway, an elevation of 1216 masl has been used in this report (i.e., approximately 16.3 m lower than the surface overflow point) as the assumed elevation at which seepage from the pit may occur based on visual observation of the contact of the till with the underlying rock on the pit wall below the slot cut.

2.2 Maximum Recommended Water Elevation

2.2.1 Methodology

A maximum recommended water elevation is required for the Grum pit to indicate when active management of the in-pit water elevation is required in the event that the pit water is non-compliant and requires treatment prior to release. If the pit water were compliant, then the pit may be allowed to fill to the overflow elevation and decant water in a natural cycle. However, in the event that the pit water is not compliant, then active management is required to maintain safety freeboard against unforeseen events and inflows that might cause an overflow and an uncontrolled release of non-compliant water to the environment. This latter situation is the case for the Faro Main pit, the Faro Zone 2 pit and the Vangorda pit, where active management plans are in place that maintain in-pit water elevation below a maximum desired water elevation.

The method that was used to calculate the maximum recommended water elevations for the Faro Main and Vangorda pits was to estimate a high flood inflow based on the estimated probable maximum flood (PMF) during an emergency event when the primary water diversion around the pit was completely breached into the pit. In the case of the Faro main pit, the recommended freeboard provides for containment of 100% inflow from the Faro Creek Diversion during an estimated 1-week PMF event. In the case of the Vangorda pit, the recommended freeboard provides for containment of 50% inflow from the Vangorda Creek Diversion during an estimated 1-week PMF event.

This same model has been applied to the Grum pit to determine a maximum recommended water elevation. In this case, the estimated PMF inflows are substantially smaller then for either the Faro or Vangorda pits because of the smaller catchment area that is captured into the Grum Interceptor Ditch above the Grum pit.

2.2.2 Maximum Recommended Water Elevation

The only surface water diversion around the Grum pit that could fail and provide increased inflow is the Grum Interceptor Ditch (GID). The upper section of the GID above the Grum pit is a relatively small flow as compared to the Faro Creek and Vangorda Creek diversions.

The PMF flow in the catchment area for the upper reach of the GID above the Grum Pit was estimated using the methodology described in the ICAP report, which is the methodology that was applied for the Faro Main pit and the Vangorda pit. If the PMF estimate is proven to be a sensitive parameter for the selected Grum pit management plan, then an updated PMF estimate can be obtained and utilized. However, the ICAP methodology is considered to be sufficient for the purposes of this planning report.

The ICAP report utilized previous information developed by SRK in which a statistical approach was used to estimate maximum rainfall depths for durations of 1 to 24 hours. The ICAP report then extrapolated this analysis to 7 days (a highly unusual and rare duration event) to obtain a maximum 7 day depth of rainfall of 370 mm (page 6-14). For the calculations of emergency storage volumes for the Faro Main pit and Vangorda pit, the ICAP applied a runoff co-efficient of 0.8 over the catchment area of the diversion that was being modeled.

Following this methodology and using a catchment area for the GID above the Grum pit of 0.5 km^2 (ICAP page 5-28), the estimated volume of a 7-day PMF event in this upper section of the GID is 148,000 m^3. However, in the event of a 7-day PMF, the catchment area of the pit itself would also be collecting substantial inflows and, in the case of the Grum pit, the catchment area of the pit itself is greater than that of the diversion being modeled and, therefore, for the Grum pit it is considered appropriate to include this catchment area into the estimated emergency storage volume. The estimated inflow volume from the 1.0 km^2 (ICAP page 5-28) pit catchment area using the same methodology is 296,000 m^3.

Therefore, the estimated total emergency storage volume required to contain 100% of the estimated PMF event during a complete breach of the GID into the Grum pit is 444,000 m^3. Given the estimated elevation at which seepage outflows from the pit could occur (1216 masl) and using the elevation-capacity relationship illustrated on Figure 3, this suggests a maximum recommended water elevation of 1213.4 masl. This is 18.9 m below the surface overflow elevation from the pit.

2.3 Estimated Filling Rate

2.3.1 Water Balance

The current water balance for the Grum pit includes inflows (direct precipitation, runoff from the local catchment area, shallow groundwater inflows at the base of the till in the southeast area and possible deeper groundwater inflows through rock entering the pit via the underground exploration workings that were intersected by development of the pit) and outflows (evaporation and groundwater losses through rock). There have been no external influences on the water balance (i.e., no pumped inflows or outflows and no new diversions) since mine shutdown in January 1998. Each of the above parameters may be described as follows:

1. Direct precipitation: snowfall and rain that falls directly onto the pit pond.
2. Local area runoff: runoff into the pit over pit walls that is captured in the local catchment area; the local catchment area is relatively small bounded by the Grum Interceptor Ditch to the north and gravity flow away from the pit in all other areas; the catchment area can be assumed, at this time, to include runoff over a portion of the Grum Ore Transfer pad.

3. Shallow Groundwater Inflows: water is known to flow along the base of the till that infills a bedrock valley cutting obliquely across the southeast are of the pit; during active mining pre-1998, a portion of this water was captured via pumping wells; this is considered to be the predominant inflow into the pit.
4. Deep Groundwater Inflows: development of the Grum pit intersected several drifts (approximately 2 m X 2 m) that were developed in the mid-1970's by a previous mine owner; these drifts all surface at the adit located to the south of the pit; these drifts released accumulated water into the pit when they were intersected and may act as groundwater inflow pathways for any groundwater seepage that enters the drifts above the current pit water elevation.
5. Evaporation: evaporation of water from the pit pond.
6. Groundwater Losses: the existence or volumes of groundwater losses from the pit are unknown at this time.

These descriptions are provided herein for context and information. A detailed pit water balance calculation that would provide detailed estimates for all of the parameters described has not been prepared for this study as it is not necessary at this stage of study and the available data may be too sparse to allow a useful calculation to be developed.

A net water balance estimate has been developed, however, to allow a projection of the future rate of filling of the pit. The net water balance is based on previous hydrology studies (i.e., the ICAP), observations of water levels since mine shutdown in January 1998, measured precipitation at the Faro airport and reasonable judgement, were necessary.

The net (i.e., inclusive of all inflows and outflows) volume of water that had accumulated in the pit over 5½ years from January 1998 to July 2003 is 1.6 million m^3. This represents an average annual inflow of 300,000 m^3 for this time period. This can be "normalized" in a simplified sense for planning purposes by adjusting this 5½ inflow record according to the actual precipitation measured during this period. The actual precipitation measured from January 1998 to December 2002 at the nearest climate station (Faro airport) was 91% of the 20-year normal annual precipitation. Precipitation measurements for 2003 have not yet been obtained and 2003 precipitation was taken at "normal" for this report. Therefore, the observed annual average inflow of 300,000 m^3 for the period from 1998 to mid-2003 suggests a normal average annual inflow volume of 330,000 m^3 (10.5 L/s), which has been used in this report for management planning purposes.

This estimated net average annual inflow compares favourably with the 1996 ICAP estimated inflow rate of 10 L/s.

2.3.2 Filling Projection

The estimated average annual net inflow into the Grum pit is 330,000 m^3 based on the 2003 elevation-capacity relationship and the observed inflows from 1998 to 2003 normalized to the 20-year actual precipitation levels, as described above.

In order to provide a more conservative (faster) estimate of pit filling for planning purposes, a projected annual net inflow of 130% of the estimated average (equal to 430,000 m^3) has also been considered herein.

The projected filling projection beginning with the surveyed elevation of July 01, 2003 is shown in Table 1. The inflow volumes used to represent July to December 2003 are 50% of the annual average, which is a recognized simplification of the seasonal characteristics of runoff and inflow temporal distribution.

Table 1. Projected Filling Timeframes

Date	Incremental Inflow		Cumulative Volume		Water Elevation	
	Normal	Conservative	Normal	Conservative	Normal	Conservative
Jul 01/03	n.a.	n.a.	1.66 M	1.66 M	1184.35	1184.35
Dec 31/03	165,000	215,000	1.82 M	1.87 M	1186.1	1186.6
Dec 31/04	330,000	430,000	2.15 M	2.30 M	1189.4	1190.8
Dec 31/05	330,000	430,000	2.48 M	2.73 M	1192.4	1194.6
Dec 31/06	330,000	430,000	2.81 M	3.16 M	1195.3	1198.2
Dec 31/07	330,000	430,000	3.14 M	3.59 M	1198.0	1201.5
Dec 31/08	330,000	430,000	3.47 M	4.02 M	1200.6	1204.6
Dec 31/09	330,000	430,000	3.80 M	4.45 M	1203.1	1207.6
Dec 31/10	330,000	430,000	4.13 M	4.88 M	1205.4	1210.4
Dec 31/11	330,000	430,000	4.46 M	5.31 M	1207.7	1213.1
Dec 31/12	330,000	430,000	4.79 M	5.74 M	1209.8	1215.6
Dec 31/13	330,000	430,000	5.12 M	6.17 M	1211.9	1218.1
Dec 31/14	330,000	430,000	5.45 M	6.60 M	1213.9	1220.4
Dec 31/15	330,000	430,000	5.78 M	7.03 M	1215.9	1222.6

Notes: all volumes are m^3; "M" = million; elevations are masl

Table 1 shows that the maximum recommended water elevation of 1213.4 masl is projected to be reached in a timeframe of 9 to 11 years (i.e., 2012 to 2014) based on the inflow rates and other data used. The recommendations provided in Section 6 include continued regular monitoring of the in-pit water elevation such that this filling projection can be updated as necessary.

2.4 Actual Filling Rate to 2003

The in-pit water elevation has been surveyed on a regular basis beginning in June 2003. This is completed by the on-site environmental technicians using standard level surveying equipment. Several accurate survey setup locations were initially established by Yukon Engineering Services.

Figure 4 illustrates the complete filling curve from an empty pit in January 1998 and Figure 5 illustrates the filling curve for 2003 only. The average rate of increase from June through August 2003 was 12 mm/day.

Figure 4. Grum Pit Complete Filling Curve

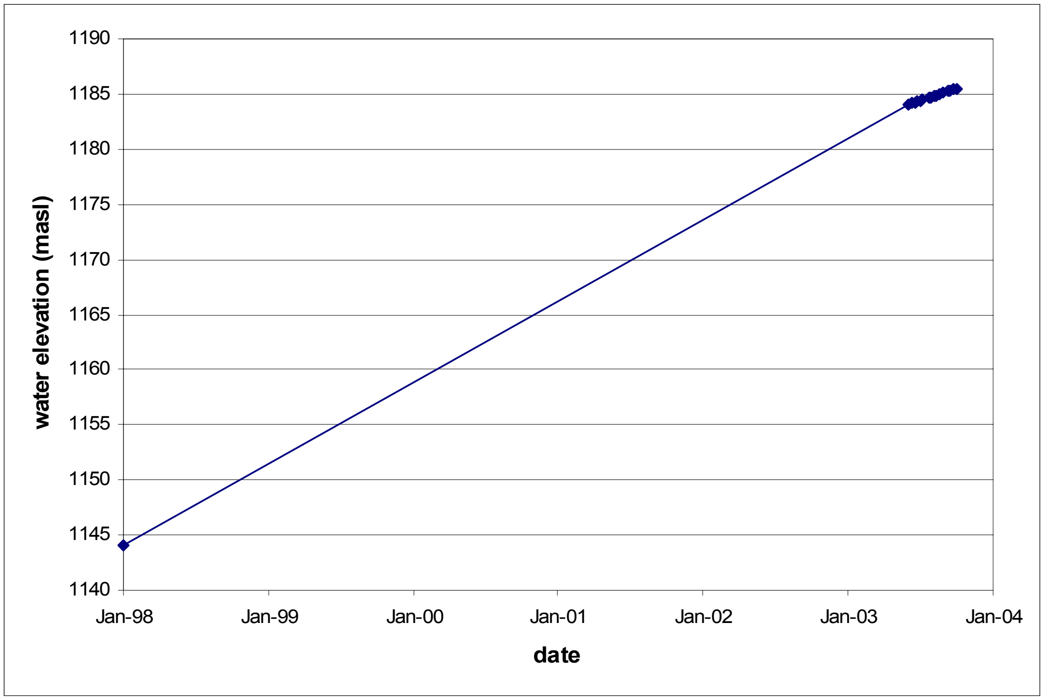
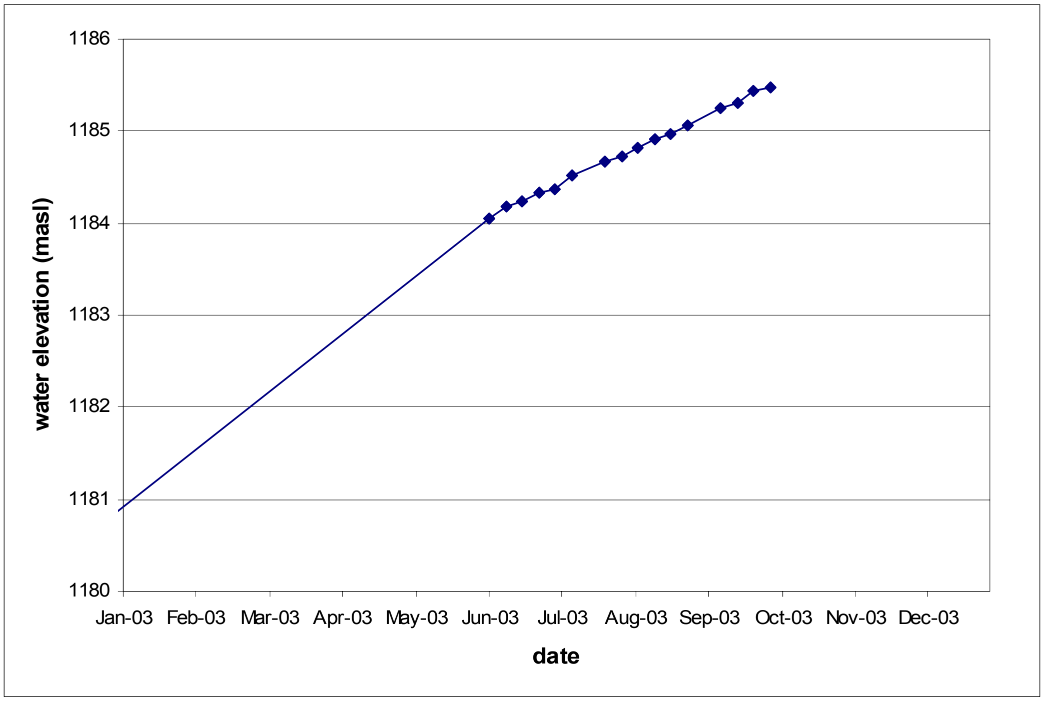


Figure 5. Grum Pit 2003 Filling Curve



3. Characterization of Pit Water

3.1 2003 Chemical Profiling

3.1.1 Description

Profiles of temperature, conductivity, pH, dissolved oxygen (D.O.) and pH were obtained on August 8 and 9, 2003 between the water surface and pit bottom (approximately 39 - 40 m depth) from two different surface locations within the pit. The data from this survey were obtained using a YSI 600 QS Sonde profiler, operated from a small boat. A subsequent more detailed temperature and D.O. profile (surface – 15 m depth) was obtained on August 21, 2003 to collect additional information in zones of interest that were identified in the initial survey. All profile data are included in Appendix B. Water samples were also collected at 10 m depth intervals using a 3-L Van Dorn sampler analyses. The following samples were collected at each depth:

- Unpreserved sample for *physical tests* and *dissolved ions* (pH, conductivity, hardness, alkalinity, acidity, sulphate);
- Preserved sample for *total metals*;
- Field-filtered (0.45 um) and preserved sample for *dissolved metals*.

All samples were shipped to ALS Laboratories (CAEAL-certified) in Vancouver, BC for analysis. All analytical results are included in Appendix B.

During the August 21, 2003 sampling event, one inflow to the pit was observed, emanating from a groundwater seep from the southeast pit wall in till. A sample of this water was obtained and analyzed for total Zinc content in the on-site laboratory (concentrated nitric acid digestion; flame AA spectrophotometer). Results from the inflow sample were as follows:

pH	7.5 (field)
Conductivity	267 uS/cm
Total Zinc	0.05 mg/L

3.1.2 Discussion of Results

Figure 6 illustrates the general water quality characteristics in the Grum Pit throughout depth. The pit was thermally stratified during August 2003. An upper, uniformly warm layer (approx. 12 ^{o}C) existed between the surface and 3 metres depth while a uniformly cold layer (5 ^{o}C) existed between 8 metres depth and the pit bottom. A thermocline (large vertical temperature gradient) was detected between 3 m and 8 m depth. Despite the thermal stratification, the waters were well oxygenated throughout depth (approximately 8-9 mg/L dissolved oxygen). A small peak in dissolved oxygen (D.O.) was observed at the 5 m depth during both the August 8 and 21, 2003 sampling events. This D.O. peak, in the thermocline zone, is likely related to biological (algae photosynthesis) activity. The pH of pit waters was slightly alkaline; the highest pH level was recorded in the surface water (pH of 8.1). Conductivity values were also relatively uniform, ranging from 1000 uS/cm at surface to 1100 uS/cm at pit bottom.

Variation in trace metal levels across depth was observed, as illustrated in Figure 7 for iron (Fe), manganese (Mn), and zinc (Zn). Zinc was predominantly in the dissolved form throughout depth. Lower Zn levels were observed in the surface water (4 mg/L) compared to samples at depth (12 mg/L). Manganese also existed predominantly in the dissolved form, with lower concentrations measured in the surface water. In contrast, no detectable dissolved iron was observed at any depth. Based on these results it is assumed that Mn exists predominantly in its reduced, soluble state (Mn^{+2}), while Fe exists predominantly in its oxidized, insoluble state (Fe^{+3}).

Lower concentrations of metals (including Zn and Mn) in the Grum Pit surface water, relative to depth, may be the result of the inflow of relatively clean water from shallow groundwater seeps, runoff over pit walls and direct precipitation during the period of thermal stratification.

3.2 Surface Water Quality 1998 to 2003

Surface water grab samples have been collected in the Grum Pit since September 1998 and analyzed for trace metals, physical, and general chemical parameters (i.e. pH, conductivity, alkalinity, etc.). As illustrated for zinc in Figure 8, there are no obvious water quality trends reflected in the data collected since the pit began filling. The highest total zinc concentration (at surface) was measured in June 2001, although a consistent declining trend since that time cannot be confirmed with the data available. The profile data collected in 2003 (discussed in report sections above) indicates that thermal stratification likely plays a significant role in determining surface water quality during the summer period. Variability in the historical surface water quality data is not unexpected since the data were collected at different times and seasons throughout the year.

Figure 6. Depth distribution of temperature, dissolved oxygen, pH and conductivity.

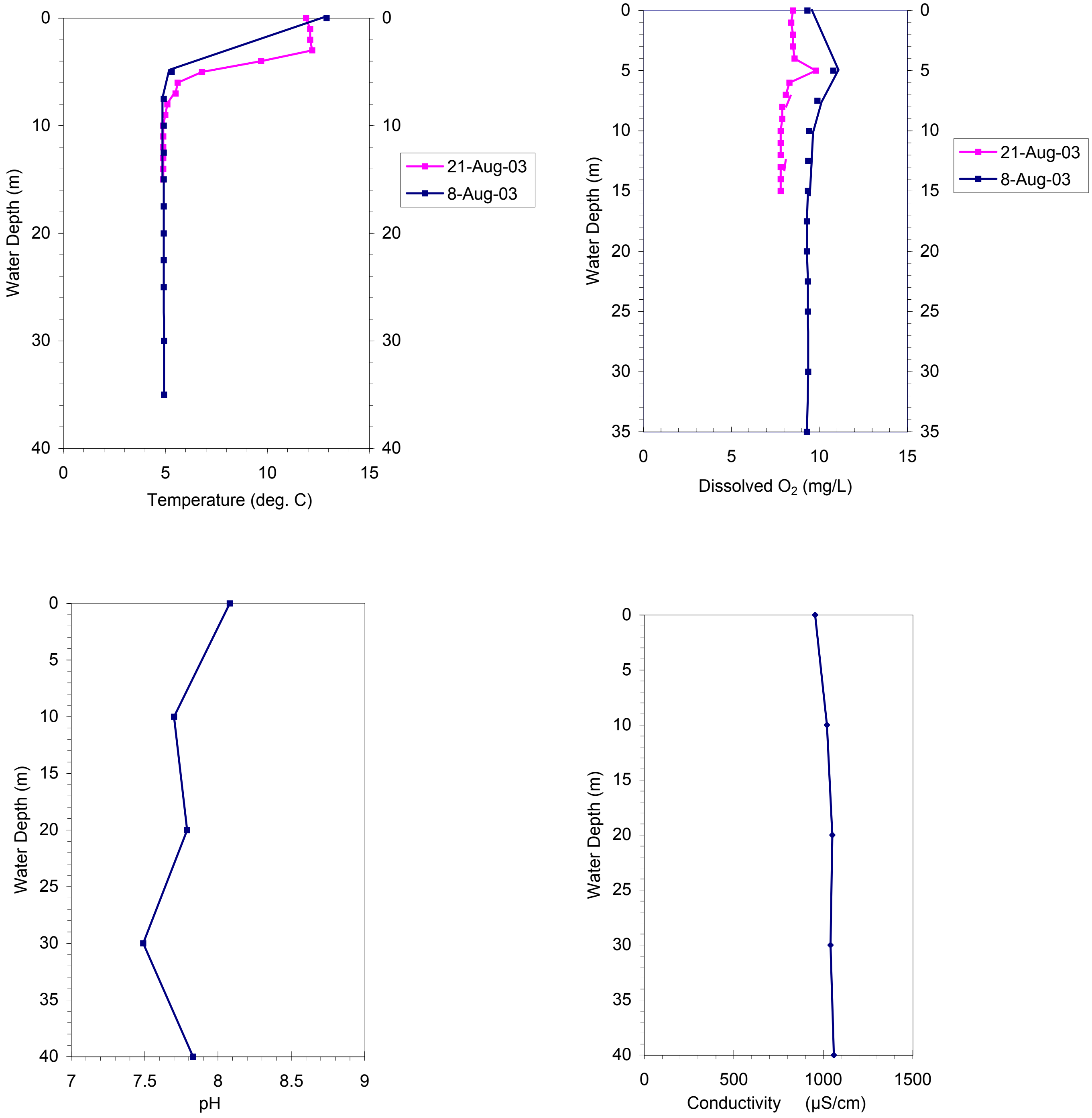


Figure 7. Water column distributions of total and dissolved Zn, Mn and Fe.

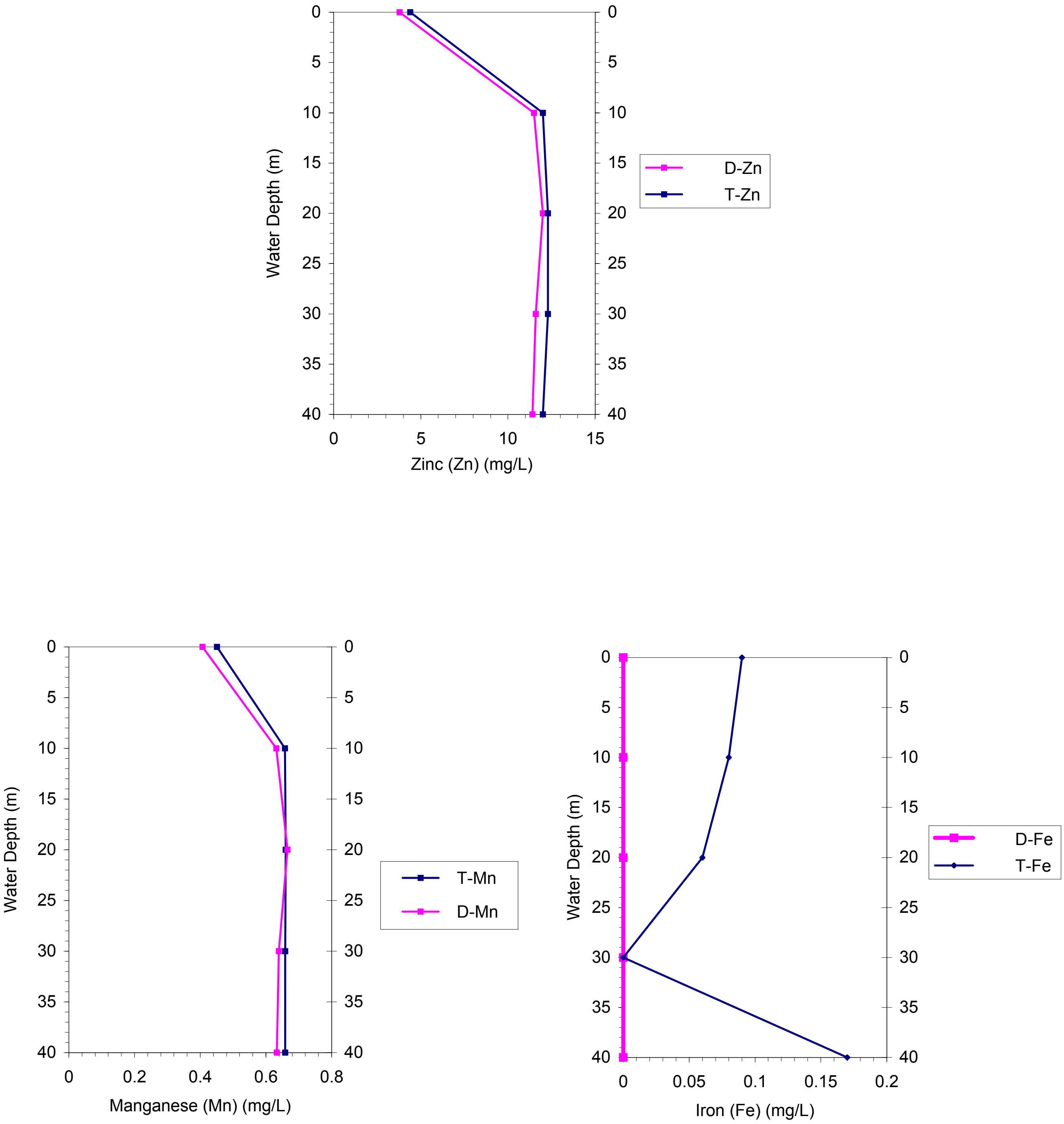
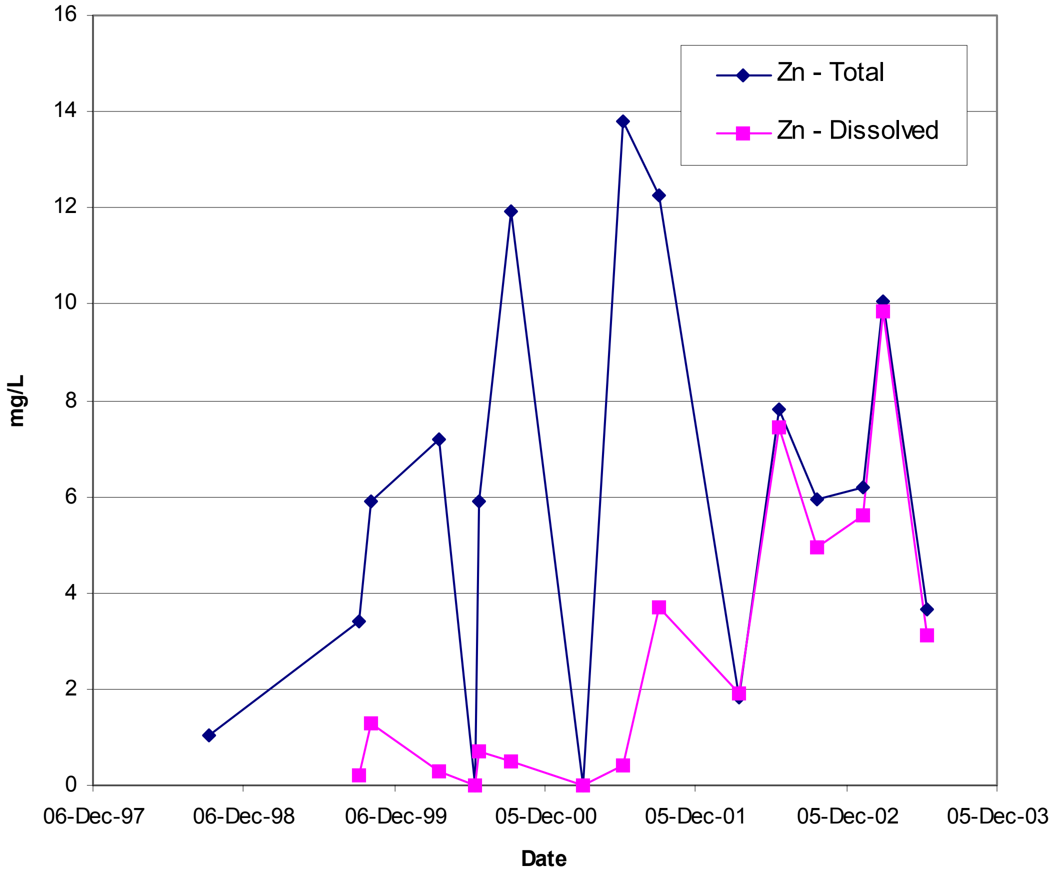


Figure 8. Historical Zinc levels in Grum Pit surface water



3.3 Projected Future Pit Pond Characteristics

The water quality in the Grum Pit is expected to change as the pit gradually fills with water. While the water quality at the maximum filling elevation cannot be predicted with certainty, current water quality observations can be used to provide an approximate estimate of future water quality conditions. The summer 2003 water quality measurements indicated that the zinc concentration in the epilimnion (surface layer) was significantly lower than the hypolimnion (bottom layer). It is assumed that this occurs largely because of dilution with clean water inflows. The following assumptions have been used to support this explanation:

- Uniform zinc concentration exists throughout depth immediately following the spring “turnover”, after the ice has cleared;
- Pit inflows are relatively “clean” (assume 0.05 mg/L or less, Zn);
- Inflows to the pit primarily enter the pond at surface or only slightly below surface;
- As the pit water thermally stratifies, the epilimnion (surface layer) becomes diluted with “clean” water inflows;
- The epilimnion (approximately 3 m deep in August 2003) does not mix with the hypolimnion (deeper layer) until the Fall turnover.

The assumptions described above have been tested using 2003 data as follows:

- Volume change in pit between June 8 and August 8, 2003, based on YES survey: 0.072×10^6 m^3
- Average inflow rate between June and August $= 0.072 \times 10^6\ m^3 / (60\ d \times 24\ hrs \times 60\ min \times 60s)$
  $= 0.014\ m^3/s$
  $= 14$ L/s
- Total volume in epilimnion on August 8, 2003 (assume 3 m depth and pit pond radius of 165 m):
  $= \pi * (165m)^2 * (3\ m)$
  $= 0.26 \times 10^6\ m^3$
- Hypolimnion Zn concentration on August 8, 2003: 12 mg/L (assume this concentration existed throughout depth at spring turnover);
- Estimated Concentration (“Y”) in surface layer on August 8, 2003 based on dilution assumption:
  $Y * 0.26 \times 10^6\ m^3 = (0.26 - 0.072) \times 10^6\ m^3 \times 12\ mg/L + 0.072 \times 10^6\ m^3 * 0.05\ mg/L$ Zn
  Predicted Zinc in epilimnion August 8, 2003 (Y) = 9 mg/L;
  Measured Zinc in epilimnion August 8, 2003 : 4 mg/L

This calculation indicates that clean inflows to the pit are only partially contributing to the lower zinc levels measured in the epilimnion in August 2003. The actual Zn concentration in the epilimnion (4 mg/L) was lower than predicted (9 mg/L), based only on dilution with clean inflow. Other potential zinc removal mechanisms in the epilimnion (i.e. precipitation, adsorption to algae and settling, etc.) were not evaluated during this study.

The future pit water quality can be projected assuming the pit fills with relatively clean water (as tested above). The estimated zinc concentration at the maximum filling elevation is calculated as follows:

- Grum Pit water volume in summer 2003: $1.6 \times 10^6\ m^3$
- Grum Pit water volume at maximum recommended water elevation: $5.0 \times 10^6\ m^3$
- "Bulk" Zinc concentration 2003: 12 mg/L
- Assumed Zn concentration of pit inflows 0.05 mg/L

Predicted Zn concentration at maximum recommended water elevation

$$= (1.6 \times 10^6\ m^3 * 12\ mg/L + 3.4 \times 10^6\ m^3 \times 0.05\ mg/L)/ 5.0 \times 10^6\ m^3$$

$$= \mathbf{4\ mg/L}$$

The calculations listed above assume relatively clean inflows. This assumption would need to be confirmed over time. However, the calculations may be somewhat conservative since they only consider dilution and do not take into account potential zinc removal mechanisms (i.e. precipitation, adsorption to algal matter)the potential for zinc precipitation if pit pH levels continue to rise.

4. Treatment Evaluation

Based on the results of the pit water characterization (Section 3), water samples were collected at both the surface and 10 metre depths during the week of August 18, 2003. Samples were analyzed in the on-site laboratory for the following parameters:

- pH response (in 500 mL samples) to the addition of 1 g/L lime solution (dry CaO obtained from on-site treatment plant, prior to hydration);
- Total and dissolved zinc concentrations at different pH endpoints (Zinc concentrations measured on-site using flame Atomic Absorption Spectrophotometry, preceded by digestion with concentrated nitric acid);
- Analysis of solids settling properties;

A small number of samples were also shipped to ALS Laboratories in Vancouver for trace metal analysis.

Additional Grum Pit surface water samples were collected on September 26, 2003 and analyzed in the on-site laboratory for the following parameters:

- pH response (in 500 mL samples) to the addition of:
  - 1 g/L lime solution (dry CaO obtained from on-site treatment plant, prior to hydration);
  - 1 g/L hydrated lime solution (dry $Ca(OH)_2$; reagent grade); and
  - 0.25 M sodium hydroxide (NaOH) solution.

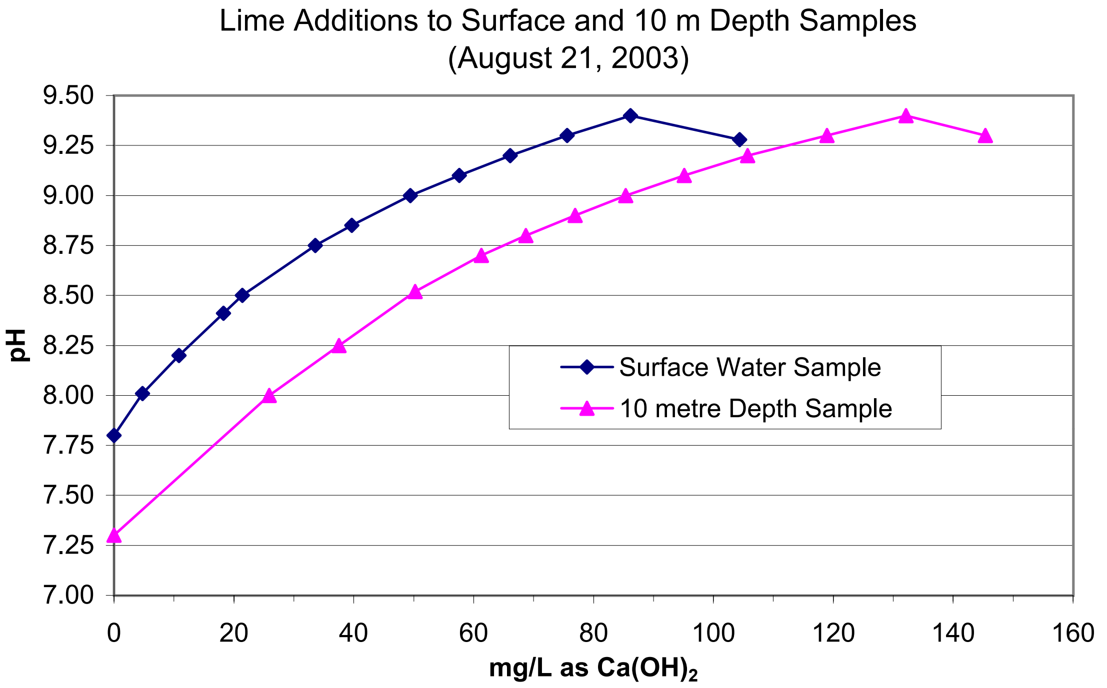
Detailed results are provided in Appendix C. All lime consumption results are presented on the basis of equivalent $Ca(OH)_2$.

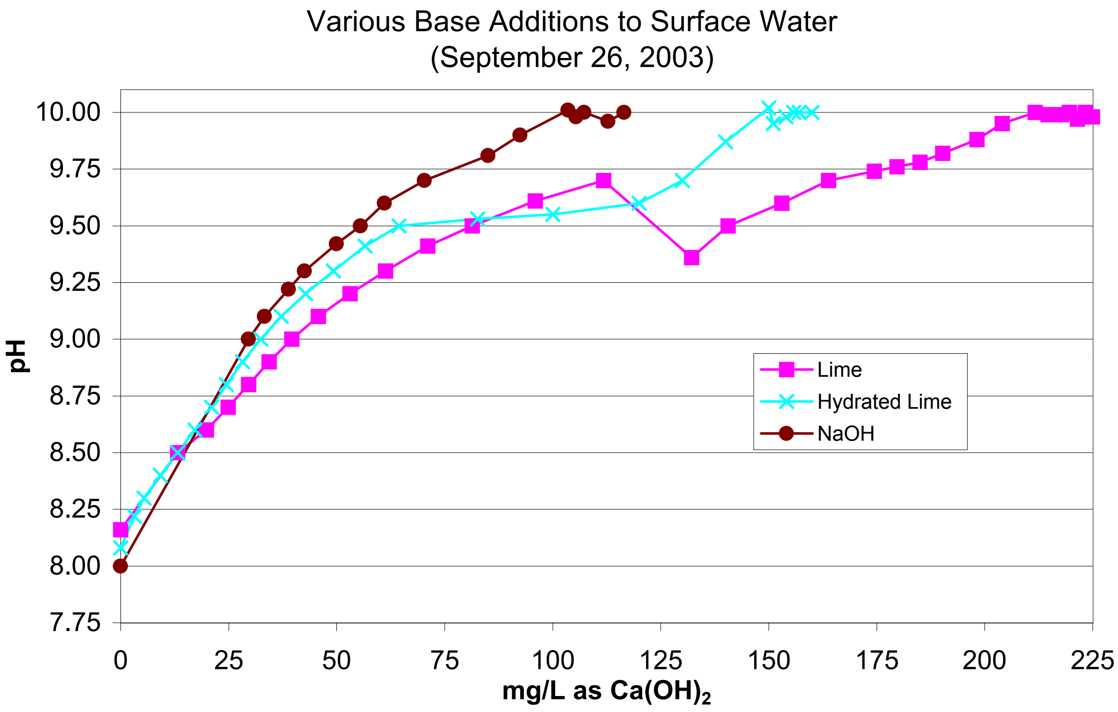
4.1 Lime consumption

The pH response to incremental additions of lime solution in both surface and 10 m depth samples is illustrated in the upper chart in Figure 9. The higher lime consumption requirements of the 10 m depth sample, relative to the surface water sample is the result of a lower initial pH. In both samples, pH levels began to decrease (with increasing lime additions) once the pH reached 9.4. The final pH measurements in both samples were continuing to decrease at the completion of the test.

Additional surface water samples were obtained on September 26, 2003 to determine the lime demand to reach pH levels above 9.5. Hydrated lime and sodium hydroxide were also utilized as base titrants for comparison purposes. The results of these titrations are illustrated in the lower chart in Figure 8. The pH levels shown were measured approximately 3 minutes following the addition of the titrant to the continuously mixed sample. As with the August sample results, pH levels decreased after initially reaching approximately 9.7 pH units (with lime addition). Of note, more lime was required to raise the pH

Figure 9. Lime Consumption in Grum Pit Water Samples


Lime Additions to Surface and 10 m Depth Samples
(August 21, 2003)


Various Base Additions to Surface Water
(September 26, 2003)

from 9.5 to 10 than was required to raise the pH from 8.0 (initial surface water pH) to 9.5. Similar results were obtained using hydrated lime.

4.2 Zinc Removal

4.2.1 Zinc Concentrations

Total and dissolved zinc analyses were conducted at various pH levels following lime addition. Flocculent (anionic polymer used in on-site treatment plants; Percol E10) was also added to a subset of the samples to assess its effects on precipitate settleability. Following lime treatment, samples were allowed to settle for 20 minutes and then a portion of the sample was carefully decanted for zinc analyses.

The results of the zinc analyses are illustrated in Figure 10. As expected, dissolved Zn levels rapidly decreased with increasing pH for both the surface water and 10 m depth samples. All the samples with pH values higher than 8.75 resulted in dissolved Zn concentrations lower than 0.5 mg/L. The addition of flocculent appeared to enhance the settleability of precipitates as shown in the lower chart of total Zn concentrations in Figure 10. However, only the sample taken to a pH of 9.5 (with flocculent addition) resulted in total Zn concentrations less than 0.5 mg/L (after 20 minutes of settling time).

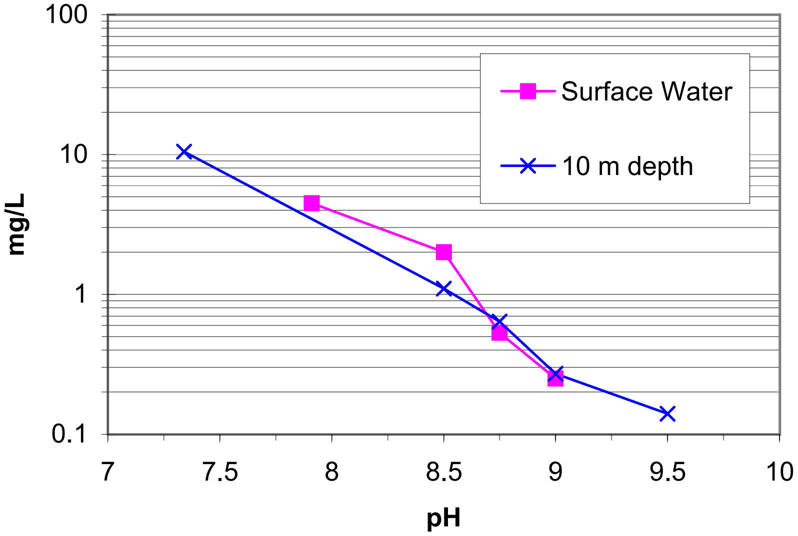
4.2.2 Longer-term Settleability Tests

A longer-term test was performed on a small number of samples obtained from the 10 m depth to assess whether a longer settling time would result in improved precipitate settling. Lime was used to increase the pH of samples to 9.0 and 9.5. Flocculent was added to a subset of the samples and the samples were allowed to settle for 14 hours at room temperature. At the end of the 14-hour period, floating white, amorphous solids were observed in each of the samples treated with flocculent. Samples were carefully decanted and analyzed for total and dissolved Zn.

The results of the Zn analyses from the longer term settling tests are illustrated in Figure 11. Significantly lower total Zn concentrations were observed following 14 hours of settling, compared to 20 minutes settling time, for those samples brought to an initial pH of 9.0. Lower total Zn concentrations were observed in the samples that were *not* treated with flocculent. This result can be explained by the apparent tendency for the flocculent to cause precipitate to become buoyant.

The results for the samples brought to an initial pH of 9.5 contrast with the results described above. Dissolved zinc concentrations actually increased over the 14-hour settling period. Likewise, total Zn concentrations increased over 14 hours (compared to the 20-minute settling results) in the samples treated with flocculent. The cause of these results can be at least partially explained by the change in pH levels

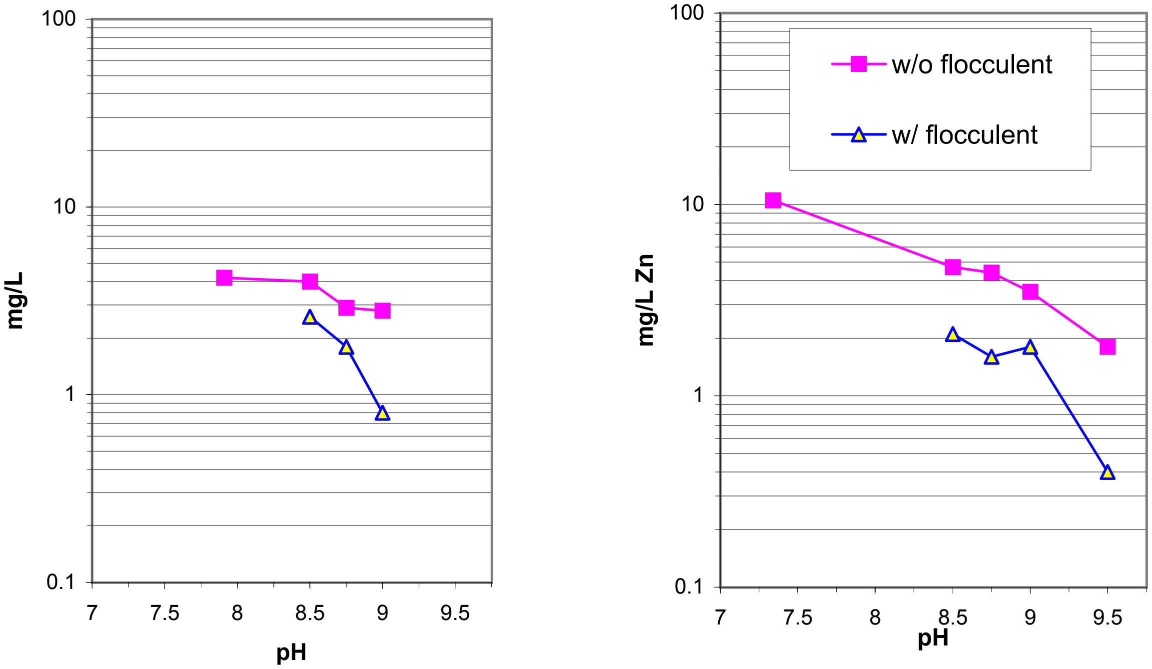
Figure 10. Zinc levels in Grum Pit water samples following treatment with Lime



DISSOLVED ZINC

TOTAL ZINC

(20 min. settling time)

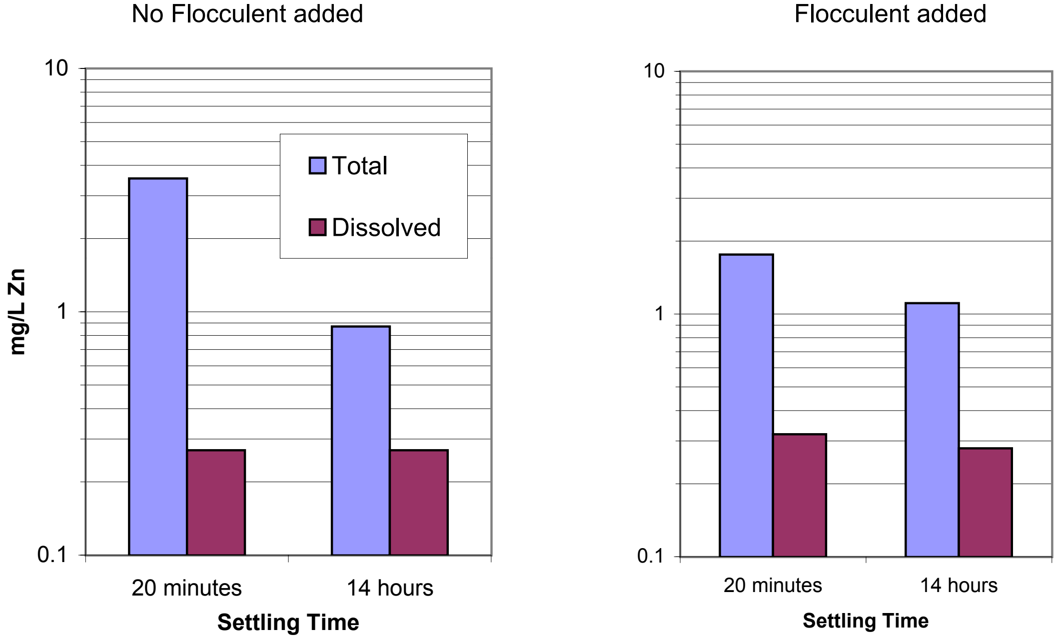


Surface Water

10 m Depth

Figure 11. Precipitate settleability following lime treatment
(10 m depth samples)

Initial pH - 9.0



Initial pH - 9.5

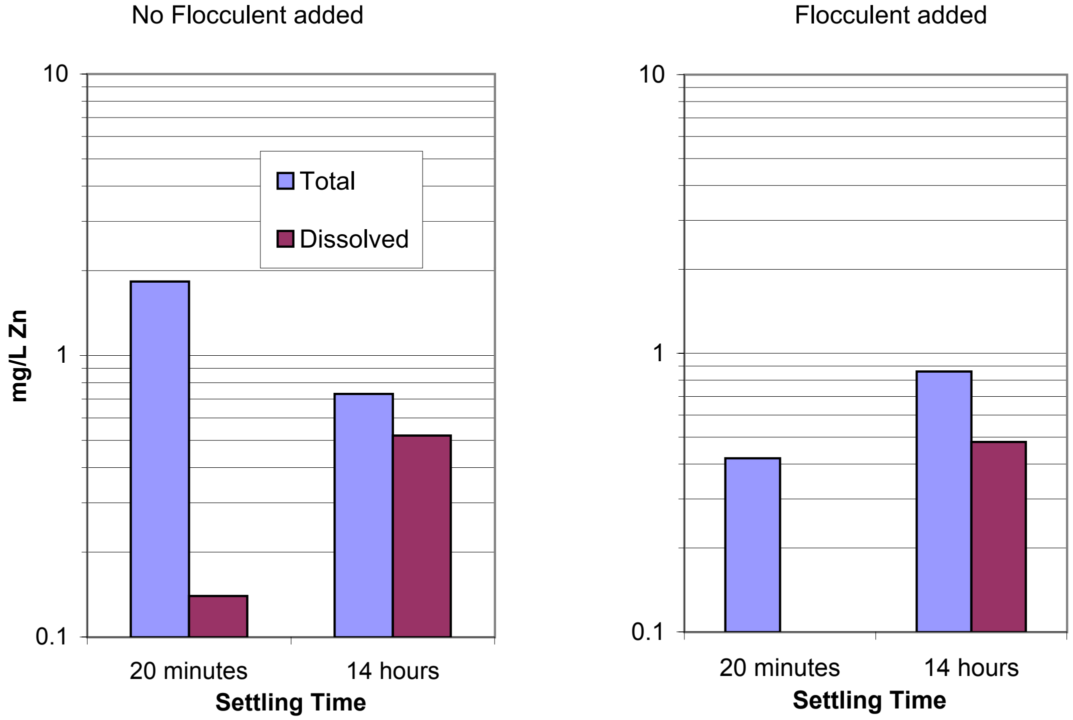


Table 2. Changes in pH and manganese concentrations over 14-hour settling period

	Final pH (after 14 hrs)	Dissolved Mn (mg/L)	
		Initial	Final (after 14 hrs
Initial pH: 9.0	8.3 - 8.5	0.38	0.37
Initial pH: 9.5	7.8 - 7.9	n/a	0.058

n/a – not available

that occurred over the 14-hour period. Table 2 illustrates that pH levels decreased in all samples over the 14-hour settling period. The largest decreases in pH occurred in those samples initially at a pH of 9.5.

A small number of samples were shipped to ALS Laboratories for trace metal analysis to determine the cause of the relatively large decrease in pH during the settling test. The manganese results from these analyses are presented in Table 2 and offer a potential explanation. Manganese, in it's reduced form (Mn^{+2}), is very soluble in natural water. When oxidized, however, Mn forms very insoluble precipitates and very little exists in the soluble, or dissolved form. The oxidation of Mn generates acid according to the reaction below:

$$2Mn^{2+}_{(aq)} + O_{2(g)} + 2H_2O_{(l)} \rightarrow 2MnO_{2\ (s)} + 4\ H+_{(aq)}$$

The results in Table 2 indicate that very little dissolved Mn remained in the sample initially brought to pH 9.5, compared to the sample brought to an initial pH of 9.0. Manganese oxidation reactions could have caused the sharp drop in pH over the 14-hour period of the settling test.

4.3 Discussion of Results

Based on the preliminary results obtained, lime is effective at reducing the dissolved concentration of zinc to acceptable levels in Grum Pit water. Dissolved Zn levels were reduced from approximately 12 mg/L to < 0.5 mg/L by raising the pH above 8.75. Discharging "compliant" water, however, requires *total* Zn concentrations (at this time) to be less than 0.5 mg/L. Results of this testing indicated that the precipitate does not settle rapidly. Flocculent addition aided settling in the short-term (20-minute settling); however, the pH had to be raised to 9.5 to obtain total zinc concentrations less than 0.5 mg/L, using a 20-minute settling period.

Longer-term settling tests (14-hours) resulted in significantly improved precipitate settling and lower total Zn concentrations following lime treatment to a pH of 9.0. Flocculent addition did not improve precipitate settling over the period of the longer test. The approximate lime consumption required to raise the Grum Pit water to a pH of 9.0 ranges from 50 – 85 mg/L (as $Ca(OH)_2$).

Raising the pH higher than approximately 9.4 could present potential challenges, as indicated by the preliminary results. A much higher lime demand is required above this level to obtain relative pH increases (see Figure 9). The rate of manganese oxidation becomes markedly higher above pH 9.4 and once initiated the reaction is "auto-catalyzed" by oxidized Mn particles (Benefield et al. 1982). This reaction creates hydrogen ions (acid), thus creating an additional lime demand.

5. Assessment of Management Alternatives

5.1 Summary of Management Alternatives

The management alternatives for the Grum pit that have been considered in this report are listed in Table 3 and are described in subsequent subsections of Section 5.

Table 3. Summary of Grum Pit Management Alternatives

Alternative	Implementation Timeframe	Primary Benefits	Primary Disadvantages	Recommendation
1. Future Treatment in WTP	Approaching MRWE and annually	High confidence; Existing WTP	Perpetual treatment	Future Consideration
2. Immediate In-Situ Lime Treatment	2004	Possible elimination of long term treatment; Observational approach	Uncertain post treatment water quality	Test in 2004; Monitor in 2005
3. Interception of Groundwater Inflows	2004 and continuous	Reduction of clean water contamination; Slower pit filling to delay treatment	Capital and operating costs; Reduced clean water inflows	Future Consideration (if annual treatment required)
4. Future Annual In-Situ Treatment with Lime	Approaching MRWE and annually	Rel. low pumping cost	Restricted schedule; Poor lime utilization	Not Recommended
5. Future Complete In-Situ Treatment with Lime	Approaching MRWE	Possible elimination of long term treatment	Increased Lime Requirement; Uncertain post treatment water quality	Not Recommended
6. In-Situ Treatment with Nutrients	Approaching MRWE	Possible elimination of long term treatment; Analagous case study (Equity Silver Mine)	Experimental in nature	Monitor Other Case Studies; Future Consideration

5.2 Alternative 1: Future Treatment in Water Treatment Plant

5.2.1 Description

The concept for this alternative is to institute an active pumping/treatment program similar to that used for the Faro Main and Vangorda pits whereby water from the Grum pit is pumped to the existing Grum/Vangorda Water Treatment Plant (WTP) in a seasonal summer basis such that the in-pit water elevation is maintained below the maximum desired elevation.

The Grum pit water could either be treated on a batch basis separately from the Vangorda pit water or be mixed with the Vangorda pit water to make a combined WQTP influent.

The treatment tests reported herein indicate that approximately 0.050 to 0.100 g/L of lime would be required to treat the Grum pit water and that a treatment pH of between 8.75 and 9.4 would be required. Flocculent may or may not be beneficial.

Treatment of the Grum pit water would not be recommended until the in-pit water elevation approached the maximum recommended water elevation which, as described in section 2, is not anticipated until 2012 to 2014. Pumping and treatment could be initiated sooner, but this would have the detrimental effect of increased costs for installation and operation of the pumping and pipeline system due to increased vertical head and longer distance. Additionally, allowing the in-pit water elevation to continue to increase towards the maximum recommended water elevation would take advantage of the anticipated reduction of in-pit metal concentrations over time as the pit fills with cleaner water, as described in Section 3.3.

5.2.2 Fundamental Requirements

The fundamental requirement to make this alternative successful is that the Grum pit water must be conducive to treatment in the WTP with, perhaps, minor adjustments to the treatment process, if necessary.

The treatment tests reported herein indicate that the Grum pit water is conducive to lime treatment although increased confidence may be beneficial regarding optimal settling timeframes and the effects of manganese oxidation at elevated pH, as described in Section 6, Recommendations. It is possible that the strategic mixing of WTP influent from the Vangorda and Grum pits may be a means of mitigating these effects of the Grum pit water.

An additional fundamental requirement would be the timely installation of a pumping and piping system from the Grum pit pond to the WTP. Such a system is envisioned to be designed and installed the year prior to implementation, as was done for the Vangorda pit pumping system.

5.2.3 Assessment

This alternative represents a "base-case" or "default" scenario that would be the action plan recommended in the event that the in-pit water elevation was approaching the maximum recommended water elevation and the pit water was non-compliant with the discharge criteria in place at that time.

Lime treatment for reduction of metals in mine waters is a proven technology that generally provides a high level of confidence in the ability to achieve the desired water quality objectives and we consider this to be true in this case for the Grum pit, notwithstanding the recommendation for increasing confidence in certain specific aspects of how lime treatment would be executed.

A Grum pit pumping and treatment program would represent an incremental increase to the existing on-site workload but would not represent the introduction of a new type of activity. Therefore, this alternative is considered to represent a relatively low operating cost once the capital outlay for installation of a pumping and pipeline system was incurred.

Implementation of this alternative would not be recommended until the in-pit water elevation approached the maximum recommended water elevation and, therefore, no specific actions are required at this time except monitoring of the pit filling rate and water quality and additional treatment confirmation testing.

5.2.4 Recommendation

This approach has two important benefits: a high level of confidence that water quality objectives will be consistently achieved and existing manpower/infrastructure.

It is likely that this approach will be recommended in the event that the in-pit water elevation had approached the maximum recommended water elevation and the pit pond water was non-compliant with the discharge criteria in place at that time.

If this approach were to be implemented, then confirmation treatment tests would be recommended to verify that the indications of the treatment tests reported herein remained valid, to identify optimal settling times and to further investigate the effects of manganese oxidation on treatment efficiency.

5.3 Alternative 2: Immediate In-Situ Treatment with Lime

5.3.1 Description

In-Situ pit treatment with lime would see the addition of lime (in either slurry or dry form) directly into the pit with the intent of increasing the general pH of the pit water to reduce metal concentrations in the pit water and to precipitate a high-pH sediment onto the pit bottom.

The details of the method for adding lime would be determined if this alternative were to be implemented. However, the methods that are envisioned at this time is the addition of lime slurry mixed in the Grum/Vangorda WTP via a gravity fed pipeline/hose from the WTP to the pit pond. The discharge end of the pipe/hose would be suspended just below surface and moved periodically around the pit to achieve a uniform application. In-pit mixing with a barge mounted pump/aerator at the lime addition points would be considered.

The addition of lime would be timed to take advantage of the natural pit turn-over periods (assumed spring and fall) to provide mixing throughout the pit profile. The quantity of lime added would be calculated to provide for the desired pH increase throughout the entire pit profile. If, in the future, a stable stratification forms in the pit such that natural mixing no longer occurs to the pit bottom, then only the epilimnion (upper layer) will be considered for treatment.

5.3.2 Fundamental Requirements

A fundamental requirement for this alternative to be successful is the absence of a continued release of substantial loadings of metals into the water column subsequent to the in-situ treatment. As described in Section 3, there are no known contaminated inflows into the pit and the in-pit pH is anticipated to remain neutral to slightly alkaline and, therefore, it may be reasonable to assume, at this time, that the pit pond water quality will remain at the post-liming levels. However, this represents an uncertainty to be recognized, as described in Section 5.3.3.

Another fundamental requirement of this alternative is that natural pond turn-over will provide adequate mixing of the near surface treated high-pH water with water from deeper in the pond to achieve a consistent increase in pH throughout the water column. It is considered likely that this will occur provided that the lime addition to the pond is timed to precede, as nearly as can be estimated, the natural turn over. These timeframes would be: 1) spring just before the pond surface water warms to 4^0 C; and 2) fall just before the pond surface water cools to 4^0 C.

The fall turn over would be the preferred targeted treatment time to take advantage of the longer timeframe before the next turnover (~9 months versus ~3 months). An early fall application of lime would also provide the benefit of the thermal stratification (~3 m in August 2003) to provide a contained layer for treatment awaiting the natural turn over. The settlement testing reported herein indicates that this timeframe should be adequate, notwithstanding the recommendation in Section 6 for additional testing to confirm the optimal settlement timeframes. The effects of colder water temperatures on treatment efficiency would also be considered during detailed design of the system.

An effective lime addition system would also be required for this alternative. It is assumed that such a system could be designed and installed largely by the on-site personnel during the summer preceding the early fall lime application.

5.3.3 Assessment

In-Situ lime treatment in the pit represents a means of creating a compliant pit pond and, provided that the pond water quality remains good following subsequent natural turnovers, a means of providing a possible clean-water pit for which no active treatment is required. For the purpose of treating the entire pit pond, in-situ lime treatment is considered more efficient, at this time, than circulating the entire pond volume through the WTP, with accompanying uncertainties and costs.

Nonetheless, although in-situ lime treatment of pit water has been successfully accomplished for other similar pit configurations, this alternative represents a lower confidence treatment method as compared to utilizing the WTP because of some uncertainties regarding, primarily, consistent mixing throughout the pit.

If the lime treated pit pond were to maintain compliance during subsequent natural turn overs, then substantial future cost savings would be realized for both the care and maintenance program and for the final closure program through elimination of the need for water treatment. The lack of any known contaminated inflows into the pit, the anticipated continued neutral to slightly alkaline pH and the absence of substantial mineralized, acid generating rock in the pit walls create confidence that this could be achieved. Nonetheless, this remains an uncertainty.

In response to this uncertainty, post-treatment changes in pit water quality could be physically modeled via a scaled model of the pit operated under controlled laboratory conditions as is common for limnological studies. Such physical models can effectively simulate thermal stratification, natural turn overs and bottom sediment interactions. This type of test program would reduce the uncertainty regarding post-treatment water quality. Alternately, this goal could be accomplished directly by conducting an in-situ trial of the method followed by observation of the pit pond behaviour.

Table 4 provides estimates, based on the testwork reported herein, of the quantities of lime that would be required to treat the entire pit pond (to pH 9.0) at current conditions and at the expected maximum filling elevation. For planning purposes, *in situ* pH adjustments with lime are assumed to be *70%* as efficient as bench-scale results.

Table 4. Lime Quantities Estimated to Treat the Pit Pond

Anticipated Treatment Date	Pond Volume Requiring Treatment (m^3)	Target Lime Dosage – Bench-scale (mg/L)[1]	Approximate Zinc levels immediately following treatment (mg/L)	Estimated Zinc levels at maximum filling projection[2]	Lime Requirements (Tonnes)[3]
2004	1.9×10^6	65	0.25	0.13	180
2011	5.0×10^6	65	0.25	0.25	460

Notes:

1. *Lime dosage required to reach a target pH of 9.0 based on bench-scale testing.*
2. *Assumes dilution with relatively clean pit inflows following treatment.*
3. *Assumes 70% efficiency factor for in situ lime treatment compared to bench-scale results.*

Table 4 illustrates that approximately 180 tonnes of lime would be required in 2004 to treat the pit pond to pH 9.0 where by the assumed concentration of total zinc would be less than 0.5 mg/L (i.e., compliant with the current water licence). The option of deferring *in situ* pond treatment would require significantly larger lime quantities (approximately 460 tonnes) because of the increased volume requiring treatment.

5.3.4 Recommendation

This approach offers the primary benefit of creating the possibility of creating a long term compliant pit pond, thereby eliminating the need for long term annual water treatment, utilizing the current, low pit water elevation to enable a multi-year, observational approach and utilizing an established treatment method (pH modification with lime). The treatment method uses the natural process of pond turnover and clean water inflow as part of the method, thereby requiring less mechanical intervention.

The risk that the pond water will revert to pre-treatment (or higher) metal concentrations over time following treatment is recognized but is considered to be outweighed by the potential benefits of eliminating the need for long term water treatment. If the method proves to be unsuccessful, then the "sunk costs" would be the costs for lime and manpower for the initial treatment; however, substantial technical understanding of the physical and chemical behaviour of the pit pond would have been gathered that could be of great importance to implementation of the ultimate treatment or remedial plan.

This approach is recommended for implementation in 2004. Lime slurry mixed in the WTP should be added into the epilimnion of the pit pond during later summer 2004 prior to the fall turnover. Water chemistry over the entire pit profile should subsequently be monitored on a regular basis throughout the remainder of 2004 and 2005 to evaluate the behaviour of the pit pond. The effectiveness of the method should be evaluated in detail following the fall 2005 pond turnover and a follow-up action plan developed at that time.

5.4 Alternative 3: Interception of Groundwater Inflows

5.4.1 Description

The concept for this alternative is to intercept, with pumping wells, groundwater inflows entering the pit via the known flow path at the base of the till in the southeast area of the pit with the intention of substantially slowing the rate of filling and, thereby, the timeframe to active intervention. This would be a re-initialization of the groundwater interception that was undertaken during the period of active mining pre-1998. Groundwater would be pumped directly into the GID.

This approach would provide the benefit of delaying expenditures related to active management of the pit such that available funding could be directed at other priority tasks.

In the case where the Grum pit pond was being actively managed under a seasonal pumping and treatment program, this approach would provide the additional benefit of minimizing the volume of clean water entering the pit that subsequently requires treatment. However, in the case where a clean-water pit was being pursued, this approach might not be complementary in that it effectively reduces clean water entering the pit.

Given that the pit pond elevation is not anticipated to approach the maximum recommended water elevation during the proposed care and maintenance timeframe of 2004 to 2008, this approach could be considered as being more directly related to the final closure program rather than the care and maintenance program. Nonetheless, this approach has implications for the care and maintenance program also and is included herein for this reason.

5.4.2 Fundamental Requirements

A groundwater dewatering system consisting, likely, of a network of pumping wells located along the top of the southeast pit wall in till is a fundamental requirement for this approach. Such a system was utilized during active mining pre-1998 but is assumed to be unusable at this time. Some of the old drillholes have slumped into the pit.

The design of such a system would require a hydrogeological analysis of existing data, including engineering reports and, likely, a drill investigation.

5.4.3 Assessment

The Grum pit water balance that was developed for the 1996 ICAP reviewed mine operating records and previous engineering reports and, ultimately, suggested that an estimated 4 L/s of water enters Grum pit along this subsurface flowpath (page 8-9). There is no known reason to suggest that the flow rate should have changed substantially since 1996. Nonetheless, a hydrogeological study specific to assessing the implementation of this alternative would be recommended should this alternative be pursued.

If groundwater capture were 4 L/s (126,000 m^3/ year), then this would represent a reduction of 38% of the normal and 29% of the conservative filling projections described in Section 3. If the 100%-effective groundwater interception system were to be installed and operational on December 31, 2004, this would extend the projected timeframes for reaching the maximum recommended water elevation to 2020 and 2014 for the normal and conservative approaches, respectively, that are described in Section 2.

Similarly, under the active pumping and treatment management scenario, groundwater interception would be anticipated to reduce the annual treatment volume by up to 126,000 m^3.

5.4.4 Recommendation

The primary benefit provided by this approach is the reduction of the inflow of clean water into a contaminated water pit pond, under the situation where the pit pond was noncompliant and required annual treatment. The approach of minimizing clean water inflows into the Faro Main pit and the Vangorda pit has proven effective in reducing treatment costs.

In the future situation where annual treatment of the pit pond was to be implemented, then an cost/benefit and an environmental evaluation should be conducted to determine whether the costs for installation and operation of a groundwater dewatering system would be offset by the benefits of reduced treatment cost and reduced environmental impacts related to the preservation of clean water.

5.5 Alternative 4: Future Annual In-Situ Treatment with Lime

5.5.1 Description

This approach could be considered in the event that the pit water elevation was approaching the maximum recommended water elevation and the pit pond water was non-compliant. As an alternative to treating Grum pit water in the WTP, the epilimnion (surface layer) of the pit pond could be treated in-situ with lime such that compliant water could be pumped or syphoned out of the pit for discharge to the environment.

In this approach, the capital costs associated with installation of a pumping and pipeline system to the WTP would be avoided and only a much smaller pumping system would be required to lift the water over the pit overflow elevation.

5.5.2 Fundamental Requirements

The fundamental requirements for this alternative are:

1. a confident understanding of the summer thermal stratification of the pit pond,
2. an effective system for addition of lime slurry uniformly through the epilimnion, and
3. a pumping and pipeline system to convey water from the pit pond to the Sheep Pad Pond.

An understanding of the future thermal stratification in the pit pond will come from ongoing monitoring of the pit pond. The mechanical and pumping systems would be designed at the time that they were to be required.

5.5.3 Assessment

In the event where the pit pond required active annual treatment, this alternative could be considered against pumping and treatment through the WTP. Given the filling timeframes described in Section 3, this is not anticipated to be a consideration for the 2004 to 2008 care and maintenance program and, therefore, this alternative may be more directly relevant to the final closure program. Nonetheless, it has implications for the care and maintenance program as, for example, a contingency program.

The application of lime slurry into the epilimnion is considered to be a realistic means of creating a compliant layer of water above the thermocline. This is currently a depth of approximately 3 m but the future behaviour of the thermocline as the pit fills to a higher elevation is unknown. The quantity of lime required and a comparison of costs and effectiveness with other alternatives would be considered at the time of implementation.

For this alternative, treatment of the epilimnion would be a transient effect that would be negated during the subsequent natural turnover. Therefore, this program would be timed for lime application in early summer immediately following the spring turn and water release would be scheduled for late summer after settlement of solids and prior to the fall turnover.

5.5.4 Recommendation

This approach can be directly compared to Alternative 1, Future Treatment in the WTP. In this comparison, alternative 4 is not recommended based, primarily, in reduced confidence in consistently achieving water quality objectives (i.e., short treatment/discharge window).

5.6 Alternative 5: Future Complete In-Situ Treatment with Lime

5.6.1 Description

This approach would intend to treat the entire pit with lime but would delay this treatment until the in-pit water elevation was approaching the maximum recommended water elevation. This would be based on the assumption that the pit pond would remain compliant post-treatment and would defer the costs of the treatment effort into the future such that the available funding cod be directed at other priorities.

This approach would take advantage of the anticipated dilution effect as the pit fills with clean water inflows to reduce the overall metal concentrations as compared to the current conditions.

5.6.2 Fundamental Requirements

The fundamental requirement for this alternative is a high degree of confidence that the quality of the pit pond will remain compliant following the initial treatment as described for Alternative 2.

5.6.3 Assessment

Section 3.3 suggests that the general in-pit zinc concentration when the pit pond reached the maximum recommended water elevation might be around 4 mg/L as compared to around 12 mg/L today. The pH of the pit pond is assumed to remain the same as current and, therefore, the lime consumption curves for modifying pH are assumed to be applicable.

Table 4 illustrates that the quantity of lime required to treat (to pH 9.0 for compliant water) based on the lime consumption tests reported herein is 460 tonnes; over 2.5 times the quantity estimated as required to treat the pond at its current volume.

Because the approach is to implement treatment at the maximum recommended water elevation, it does not provide for an observational period following the initial treatment to observe the chemical behaviour of the pit and does not allow a period for follow up treatment or activity, if necessary.

5.6.4 Recommendation

This approach has two important drawbacks: a greatly increased lime requirement as compared to treatment in 2004 and the absence of an observational/reaction period. The drawbacks are considered to negate the potential benefits of, primarily, deferred costs and this approach is not recommended.

5.7 Alternative 6: In-Situ Treatment with Nutrients

5.7.1 Description

The Grum pit water quality data collected in August 2003 provided some evidence that primary productivity processes (resulting from algae) were occurring in the pit water. Trace metals such as zinc are known to adsorb to algal particles if present in the water column. Recent experimental work on Equity Silver's Main Zone pit near Houston, BC has attempted to enhance the natural algal biomass to reduce metal levels in the pit. Metals are removed in this way by adsorbing to algal particles and eventually settling to the pit bottom.

Like the Grum Pit, the Main Zone pit at Equity Silver is well oxygenated to the bottom, thermally stratifies, and turns over twice per year. Without manipulation, surface concentrations of metals appeared to decrease throughout the summer, resulting from adsorption to algae and settling. The experimental work (McNee et al. 2003, Mining & the Environment Conference, Sudbury) indicated that nutrient additions (nitrate and phosphate) could reduce zinc levels from 0.25 mg/L to 0.002 mg/L in surface water within a 2-month fertilization period. A high-rate application (14 mmol P/m^2/wk; 140 mmol N/m^2/wk) resulted in the best metals removal. Based on this application ratio, the following nutrient addition rates would be projected for the Grum Pit (assume current pit pond radius of 165 m):

Phosphorus: 14 mmol/wk/m^2 * (π * 165^2) * 31 mg/mmol = 3.7 x 10^7 mg/week = 37 kg/week
Nitrogen: 140 mmol/wk/m^2 * (π * 165^2) * 14 mg/mmol = 1.7 x 10^8 mg/week = 170 kg/week

Further analysis and experimental work would be required to determine if this method would be feasible and produce a long-term solution for the Grum Pit (which has higher metal concentrations and a shorter growing season than the Equity Silver pit).

A small scale field trial of this methodology was conducted by Laberge Environmental Services at Little Creek Dam in 2002 under the Yukon's MERG (Mine Environmental Research Group). While the results of this study have been anecdotally reported as poor, a project report has not been reviewed and, therefore, the test conditions, methodologies and application rates are not known at this time.

It is understood that Steffen Robertson Kirsten (SRK) are currently conducting a closure planning project that involves an assessment of the potential for nutrient addition treatment at the Faro property and the result of this assessment should be taken into consideration as well.

5.7.2 Recommendation

This approach provides the possibility of achieving a clean water pit and, thereby, eliminating the need for long term annual water treatment and can be compared to Alternative 2 in this regard. However, the treatment methodology for alternative 6 is considered to be experimental in nature and offers reduced confidence (as regards application rates, costs and performance) as compared to the lime treatment provided in alternative 2.

Therefore, this approach is not recommended at this time, in favor of alternative 2. Nonetheless, it is recommended that case studies where this method is being applied to large open pits in a northern environment (i.e., Equity Silver mine) be monitored such that the growing body of information regarding the application of this methodology to the treatment of large open pits can be tracked and applied to the Grum pit in the future, if desired.

6. Conclusions and Recommendations

6.1 Conclusions

The following conclusions can be drawn from the information reported herein:

1. The proposed maximum recommended water elevation for the Grum pit pond to provide complete containment of a breach of the Grum Interceptor Ditch during an estimated 1-week PMF event (i.e., following from the calculation applied for the Faro Main pit) is 1213.4 masl, which is approximately 29 m above the water elevation in August 2003.

2. The in-pit water elevation is projected to reach the maximum recommended water elevation in 9 to 11 years (from 2003) or between 2012 and 2014.

3. The Grum pit pond was thermally stratified in August 2003 and is assumed to undergo complete natural mixing twice per year (spring and fall). Zinc concentrations were lower in the epilimnion (surface layer) and this is assumed to be due to the natural inflow of clean water, the absence of release of contaminants from pit walls and possible precipitation with algal matter.

4. The Grum pit water can be effectively treated with lime and pH control is important to control the effects of manganese oxidation.

5. If the pit pond were allowed to continue to fill with (assumed) natural clean water inflows to the maximum recommended water elevation, then the overall zinc concentration in the pit pond could be reduced from the current 12 mg/L to around 4 mg/L.

6. An estimated 180 tonnes of lime would be required to treat the current pit pond to compliance levels of zinc (<0.5 mg/L).

6.2 Recommendations

Although the Grum pit is not projected to fill to the maximum recommended water elevation during the proposed care and maintenance timeframe, an unusual sequence of very wet years (i.e., averaging greater than 130% of normal) or other unforeseen events may cause the pit pond to increase faster than anticipated such that the in-pit water elevation requires active management during the care and maintenance timeframe. This possibility is recognized in the Water Licence Renewal Application through the Adaptive Management Plan.

The possibility of rapid filling of the Grum pit and diligent environmental management suggest that monitoring of the rate of rise and water chemistry in the pit is required and that any activities that can reasonably be anticipated to reduce environmental risks associated with the pit as it fills throughout the care and maintenance timeframe should be considered.

To this end, and following from discussion of a draft version of this Project Report with Mssrs. Sedgwick and Haggar, the following recommendations are provided for consideration:

1. **Chemical Profiling of the Grum Pit.**
    - This should be carried out each year seasonally in late winter (~March), spring (~June), summer (~August) and fall (~October).
    - The profiling should include, at a minimum, temperature, dissolved oxygen, pH, total zinc and dissolved zinc at appropriate depth intervals.
    - The on-site environmental technicians should be trained and equipped to complete this work. The fundamental equipment needs are a Van Dorn or Kemmerer water sampler and a depth probe for insitu readings of (minimum) D.O., temperature and pH with a minimum 60 m depth capability. Training could be provided by Gartner Lee or another external firm.
    - Monitoring on the same schedule and for the same parameters is also recommended for the Faro Main pit and the Vangorda pit for both care and maintenance information and for closure planning information. The rationale for this recommendation can be expanded upon, if desired.
    - The data should be assessed by the Site Manager after each field program in conjunction with Gartner Lee or another external firm, as required

2. **Continuation of Water Elevation Monitoring.**
    - The water elevation in the Grum pit should continue to be monitored following the procedures implemented by on site personnel in 2003 or similar on a monthly schedule, with due consideration to safety and accuracy concerns during the winter season.
    - Monitoring on the same schedule and with the same level of precision is also recommended for both the Faro Main pit and the Vangorda pit for both care and maintenance information and for closure planning information. The rationale for this recommendation can be expanded upon, if desired.

- The pit filling curve should be regularly updated and compared to projections.

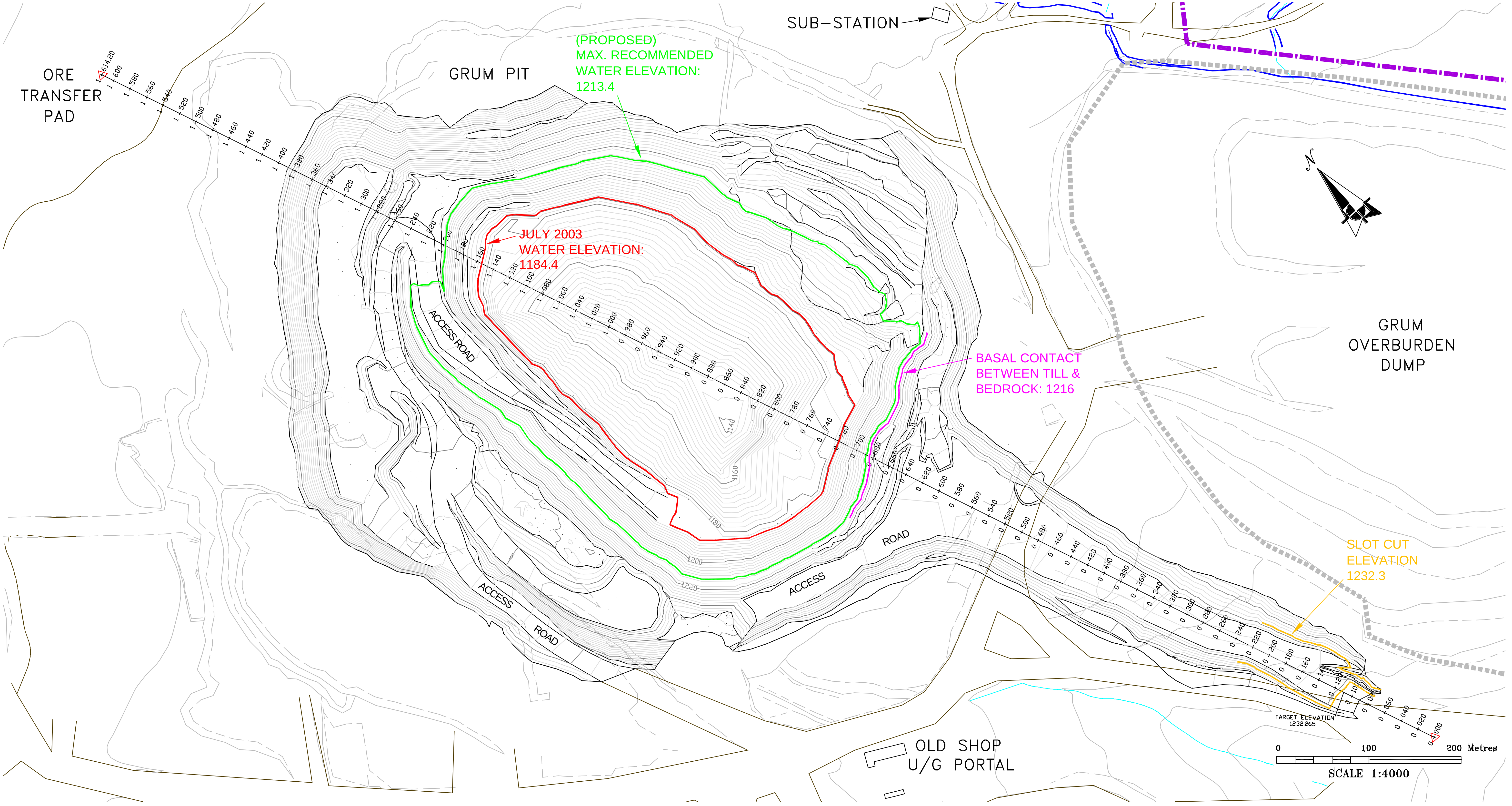
3. **Implement Management Alternative 2, Immediate In-Situ Treatment with Lime.**
    - Alternative 2, as described in Section 5, is recommended for implementation in 2004. This is recommended for 2004, rather than later years, to minimize the quantity of lime required and to provide an extended observation period to assess and react to observations.
    - We recommend that treatment be targeted at the application of 180 tonnes of lime applied over a 2-3 week period in late summer, timed to precede the fall turn over. The method of application should be designed by the Site Manager with input from Gartner Lee to distribute the lime around the pit (laterally) and throughout the epilimnion.
    - This program is anticipated to require in the order of $100,000 (2004 only) for implementation, inclusive of lime.
    - The 2004 work should be followed up with on-going monitoring and assessment of the pit chemical behaviour and water elevation according to Recommendation nos. 1 and 2 above; these assessments should feed into the annual planning and budgeting cycle.

4. **Additional Discussion**
    - This report should be presented to the Type II office and to others internal within Deloitte & Touche Inc. for their comment, input and approval.
    - This is recommended to take the form of distribution of this Project Report followed by a conference call to discuss questions and comments.

Appendices

Appendix A

Elevation Survey



LEGEND:

—	ROADS
—	EXISTING SURFACE DRAINAGE
-·-·-	WATER TREATMENT PIPELINE
—	MAJOR CONTOUR
—	MINOR CONTOUR

SOURCES OF INFORMATION:

SURVEY FILE PROVIDED BY YUKON ENGINEERING SERVICES

NOTE:
- COORDINATES ARE IN UTM NAD 83 ZONE 8
- CONTOURS ARE IN METRES ABOVE SEA LEVEL

DRAWING INFORMATION:

REVIEWED BY:	LH/ED
DRAWN BY:	CPW/NT
DATE ISSUED:	OCTOBER, 2003
PROJECT NUMBER:	23-586
FILE NAME:	23586-1D-02.DWG
REVISION:	0

ANVIL RANGE MINE
2003 STUDIES OF CARE AND MAINTENANCE
MANAGEMENT ALTERNATIVES
GRUM PIT

GRUM PIT ELEVATION SURVEY

Gartner Lee

Deloitte & Touche

APPENDIX

A

Appendix B

Water Quality Characterization

Table B-1 Grum Pit Water Quality Characterization - Laboratory Analysis

Sampling Date: August 8, 2003

	Location #1: UTM Zone 8: 592334E, 6905184N					Location #2: UTM Zone 8: 592311E, 6905143N				
Sample ID	GP1-5	GP1-10	GP1-20	GP1-30	GP1-40	GP2-5	GP2-10	GP2-20	GP2-30	GP2-40
Sample Depth (m)	0	10	20	30	40	0	10	20	30	40
Physical Tests										
Conductivity (uS/cm)	955	1020	1050	1040	1060	961	1050	1050	1060	1040
Hardness, mg/L CaCO3	522	563	510	505	460	520	558	566	567	569
pH	8.08	7.7	7.79	7.49	7.83	8.22	7.76	7.76	7.77	7.77
Dissolved Anions (mg/L)										
Acidity as CaCO3	2	28	27	26	23	<1	26	26	26	26
Alkalinity-Total as CaCO3	149	164	165	166	166	150	166	166	166	161
Sulphate	424	461	452	460	454	429	464	455	453	455
Nutrients (mg/L)										
Ammonia Nitrogen	0.03	0.02	<0.02	<0.02	0.08	0.05	<0.02	<0.02	<0.02	0.1
Total Metals (mg/L)										
Aluminum	0.07	0.05	0.04	0.06	0.1	0.08	0.04	0.05	0.06	0.06
Antimony	0.008	0.01	0.01	0.011	0.01	0.009	0.01	0.011	0.011	0.01
Arsenic	<0.001	<0.003	<0.003	<0.003	<0.003	<0.001	<0.003	<0.003	<0.003	<0.003
Barium	0.06	0.06	0.05	0.04	0.05	0.05	0.06	0.05	0.05	0.05
Beryllium	<0.002	<0.005	<0.005	<0.005	<0.005	<0.002	<0.005	<0.005	<0.005	<0.005
Boron	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium	0.0097	0.0159	0.0159	0.0159	0.0159	0.0099	0.0155	0.0165	0.0157	0.0161
Calcium	107	113	109	106	93.7	102	114	111	117	115
Chromium	<0.002	<0.005	<0.005	<0.005	<0.005	<0.002	<0.005	<0.005	<0.005	<0.005
Cobalt	0.0349	0.046	0.046	0.047	0.045	0.0362	0.045	0.047	0.046	0.046
Copper	<0.002	<0.005	<0.005	<0.005	<0.005	<0.002	<0.005	<0.005	<0.005	<0.005
Iron	0.09	0.08	0.06	<0.03	0.17	0.09	0.06	0.09	0.14	0.13
Lead	0.002	<0.003	<0.003	<0.003	<0.003	0.002	<0.003	<0.003	<0.003	<0.003
Lithium	0.03	<0.03	<0.03	<0.03	<0.03	0.03	<0.03	<0.03	<0.03	<0.03
Magnesium	64.6	67	65.2	62.9	55.6	61.5	67.6	66.3	69.3	68.9
Manganese	0.451	0.658	0.66	0.659	0.659	0.468	0.65	0.676	0.67	0.659
Mercury	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Molybdenum	0.004	<0.005	<0.005	<0.005	<0.005	0.004	<0.005	<0.005	<0.005	<0.005
Nickel	0.187	0.263	0.269	0.27	0.265	0.195	0.262	0.273	0.272	0.271
Potassium	4	3	4	3	3	3	4	4	4	4
Selenium	<0.002	<0.005	<0.005	<0.005	<0.005	<0.002	<0.005	<0.005	<0.005	<0.005
Silver	<0.00004	<0.0001	<0.0001	<0.0001	<0.0001	<0.00004	<0.0001	<0.0001	<0.0001	<0.0001
Sodium	11	11	11	11	9	10	11	11	12	12
Thallium	0.0012	0.001	0.001	0.001	0.001	0.0012	0.001	0.001	0.001	0.001
Tin	<0.001	<0.003	<0.003	<0.003	<0.003	<0.001	<0.003	<0.003	<0.003	<0.003
Titanium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium	0.0029	0.01	0.01	0.01	0.01	0.003	0.01	0.01	0.01	0.01
Vanadium	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Zinc	4.4	12	12.3	12.3	12	4.43	11.8	12.4	12	12

Table B-1 Grum Pit Water Quality Characterization - Laboratory Analysis

Sampling Date: August 8, 2003

	Location #1: UTM Zone 8: 592334E, 6905184N					Location #2: UTM Zone 8: 592311E, 6905143N				
Dissolved Metals										
Aluminum	<0.01	<0.03	<0.03	<0.03	<0.03	<0.01	<0.03	<0.03	<0.03	<0.03
Antimony	0.008	0.01	0.011	0.01	0.01	0.008	0.01	0.01	0.01	0.01
Arsenic	<0.001	<0.003	<0.003	<0.003	<0.003	<0.001	<0.003	<0.003	<0.003	<0.003
Barium	0.06	0.05	0.04	0.05	0.04	0.06	0.05	0.05	0.05	0.06
Beryllium	<0.002	<0.005	<0.005	<0.005	<0.005	<0.002	<0.005	<0.005	<0.005	<0.005
Boron	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium	0.0086	0.0151	0.0156	0.0151	0.0149	0.0088	0.0148	0.0147	0.0148	0.015
Calcium	105	113	103	103	92.6	105	113	114	115	115
Chromium	<0.002	<0.005	<0.005	<0.005	<0.005	<0.002	<0.005	<0.005	<0.005	<0.005
Cobalt	0.0329	0.044	0.046	0.044	0.043	0.034	0.045	0.043	0.044	0.043
Copper	<0.002	<0.005	<0.005	<0.005	<0.005	<0.002	<0.005	<0.005	<0.005	<0.005
Iron	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Lead	<0.001	<0.003	<0.003	<0.003	<0.003	<0.001	<0.003	<0.003	<0.003	<0.003
Lithium	0.02	<0.03	<0.03	<0.03	<0.03	0.02	<0.03	<0.03	<0.03	<0.03
Magnesium	63	68.2	61.2	60.4	55.5	62.9	67.1	68.1	67.9	68.5
Manganese	0.407	0.632	0.666	0.639	0.633	0.422	0.634	0.626	0.637	0.635
Mercury	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Molybdenum	0.004	<0.005	<0.005	<0.005	<0.005	0.004	<0.005	<0.005	<0.005	<0.005
Nickel	0.176	0.255	0.266	0.256	0.254	0.181	0.256	0.255	0.255	0.257
Potassium	3	3	4	3	2	3	4	3	3	3
Selenium	<0.002	<0.005	<0.005	<0.005	<0.005	<0.002	<0.005	<0.005	<0.005	<0.005
Silver	<0.00004	<0.0001	<0.0001	<0.0001	<0.0001	<0.00004	<0.0001	<0.0001	<0.0001	<0.0001
Sodium	11	12	11	11	10	11	12	12	12	12
Thallium	0.0011	0.001	0.001	0.001	0.001	0.0011	0.001	0.001	0.001	0.001
Tin	<0.001	<0.003	<0.003	<0.003	<0.003	<0.001	<0.003	<0.003	<0.003	<0.003
Titanium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium	0.0028	0.01	0.01	0.01	0.01	0.0028	0.009	0.01	0.01	0.01
Vanadium	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Zinc	3.79	11.5	12	11.6	11.4	3.85	11.4	11.3	11.4	11.4

Footnotes: Results are expressed as milligrams per litre except where noted.

< = Less than the detection limit indicated.

Table B-2 Grum Pit Water Quality Characterization - Laboratory Detection Limits

Sampling Date: August 8, 2003

	Location #1: UTM Zone 8: 592334E, 6905184N					**Location #2: UTM Zone 8: 592311E, 6905143N**				
Sample ID	GP1-5	GP1-10	GP1-20	GP1-30	GP1-40	GP2-5	GP2-10	GP2-20	GP2-30	GP2-40
Physical Tests										
Conductivity (uS/cm)	2	2	2	2	2	2	2	2	2	2
Hardness CaCO3	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
pH	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Dissolved Anions										
Acidity (to pH 8.3) CaC	1	1	1	1	1	1	1	1	1	1
Alkalinity-Total CaC	1	1	1	1	1	1	1	1	1	1
Sulphate SO4	1	1	1	1	1	1	1	1	1	1
Nutrients										
Ammonia Nitrogen	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Total Metals										
Aluminum T-Al	0.01	0.03	0.03	0.03	0.03	0.01	0.03	0.03	0.03	0.03
Antimony T-Sb	0.001	0.003	0.003	0.003	0.003	0.001	0.003	0.003	0.003	0.003
Arsenic T-As	0.001	0.003	0.003	0.003	0.003	0.001	0.003	0.003	0.003	0.003
Barium T-Ba	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Beryllium T-Be	0.002	0.005	0.005	0.005	0.005	0.002	0.005	0.005	0.005	0.005
Boron T-B	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Cadmium T-Cd	0.0001	0.0003	0.0003	0.0003	0.0003	0.0001	0.0003	0.0003	0.0003	0.0003
Calcium T-Ca	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Chromium T-Cr	0.002	0.005	0.005	0.005	0.005	0.002	0.005	0.005	0.005	0.005
Cobalt T-Co	0.0006	0.002	0.002	0.002	0.002	0.0006	0.002	0.002	0.002	0.002
Copper T-Cu	0.002	0.005	0.005	0.005	0.005	0.002	0.005	0.005	0.005	0.005
Iron T-Fe	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Lead T-Pb	0.001	0.003	0.003	0.003	0.003	0.001	0.003	0.003	0.003	0.003
Lithium T-Li	0.01	0.03	0.03	0.03	0.03	0.01	0.03	0.03	0.03	0.03
Magnesium T-Mg	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Manganese T-Mn	0.0006	0.002	0.002	0.002	0.002	0.0006	0.002	0.002	0.002	0.002
Mercury T-Hg	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
Molybdenum T-Mo	0.002	0.005	0.005	0.005	0.005	0.002	0.005	0.005	0.005	0.005
Nickel T-Ni	0.002	0.005	0.005	0.005	0.005	0.002	0.005	0.005	0.005	0.005
Potassium T-K	2	2	2	2	2	2	2	2	2	2
Selenium T-Se	0.002	0.005	0.005	0.005	0.005	0.002	0.005	0.005	0.005	0.005
Silver T-Ag	0.00004	0.0001	0.0001	0.0001	0.0001	0.00004	0.0001	0.0001	0.0001	0.0001
Sodium T-Na	2	2	2	2	2	2	2	2	2	2
Thallium T-Tl	0.0004	0.001	0.001	0.001	0.001	0.0004	0.001	0.001	0.001	0.001
Tin T-Sn	0.001	0.003	0.003	0.003	0.003	0.001	0.003	0.003	0.003	0.003
Titanium T-Ti	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Uranium T-U	0.0004	0.001	0.001	0.001	0.001	0.0004	0.001	0.001	0.001	0.001
Vanadium T-V	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Zinc T-Zn	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Table B-2 Grum Pit Water Quality Characterization - Laboratory Detection Limits

Sampling Date: August 8, 2003

	Location #1: UTM Zone 8: 592334E, 6905184N					**Location #2: UTM Zone 8: 592311E, 6905143N**				
Sample ID	GP1-5	GP1-10	GP1-20	GP1-30	GP1-40	GP2-5	GP2-10	GP2-20	GP2-30	GP2-40
Dissolved Metals										
Aluminum D-Al	0.01	0.03	0.03	0.03	0.03	0.01	0.03	0.03	0.03	0.03
Antimony D-Sb	0.001	0.003	0.003	0.003	0.003	0.001	0.003	0.003	0.003	0.003
Arsenic D-As	0.001	0.003	0.003	0.003	0.003	0.001	0.003	0.003	0.003	0.003
Barium D-Ba	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Beryllium D-Be	0.002	0.005	0.005	0.005	0.005	0.002	0.005	0.005	0.005	0.005
Boron D-B	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Cadmium D-Cd	0.0001	0.0003	0.0003	0.0003	0.0003	0.0001	0.0003	0.0003	0.0003	0.0003
Calcium D-Ca	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Chromium D-Cr	0.002	0.005	0.005	0.005	0.005	0.002	0.005	0.005	0.005	0.005
Cobalt D-Co	0.0006	0.002	0.002	0.002	0.002	0.0006	0.002	0.002	0.002	0.002
Copper D-Cu	0.002	0.005	0.005	0.005	0.005	0.002	0.005	0.005	0.005	0.005
Iron D-Fe	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Lead D-Pb	0.001	0.003	0.003	0.003	0.003	0.001	0.003	0.003	0.003	0.003
Lithium D-Li	0.01	0.03	0.03	0.03	0.03	0.01	0.03	0.03	0.03	0.03
Magnesium D-Mg	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Manganese D-Mn	0.0006	0.002	0.002	0.002	0.002	0.0006	0.002	0.002	0.002	0.002
Mercury D-Hg	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
Molybdenum D-Mo	0.002	0.005	0.005	0.005	0.005	0.002	0.005	0.005	0.005	0.005
Nickel D-Ni	0.002	0.005	0.005	0.005	0.005	0.002	0.005	0.005	0.005	0.005
Potassium D-K	2	2	2	2	2	2	2	2	2	2
Selenium D-Se	0.002	0.005	0.005	0.005	0.005	0.002	0.005	0.005	0.005	0.005
Silver D-Ag	0.00004	0.0001	0.0001	0.0001	0.0001	0.00004	0.0001	0.0001	0.0001	0.0001
Sodium D-Na	2	2	2	2	2	2	2	2	2	2
Thallium D-Tl	0.0004	0.001	0.001	0.001	0.001	0.0004	0.001	0.001	0.001	0.001
Tin D-Sn	0.001	0.003	0.003	0.003	0.003	0.001	0.003	0.003	0.003	0.003
Titanium D-Ti	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Uranium D-U	0.0004	0.001	0.001	0.001	0.001	0.0004	0.001	0.001	0.001	0.001
Vanadium D-V	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Zinc D-Zn	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Table B-3 Grum Pit Water Quality Characterization - Laboratory Duplicates

Sampling Date: August 8, 2003

Sample ID		GP1-40	GP1-40
Physical Tests			
Conductivity	(uS/cm)	1060	1080
Hardness	CaCO3	460	573
pH		7.83	7.84
Dissolved Anions			
Acidity (to pH 8.3)	CaCO3	23	23
Alkalinity-Total	CaCO3	166	166
Sulphate	SO4	454	460
Nutrients			
Ammonia Nitrogen	N	0.08	0.04
Total Metals			
Aluminum	T-Al	0.1	0.1
Antimony	T-Sb	0.01	0.01
Arsenic	T-As	<0.003	<0.003
Barium	T-Ba	0.05	0.05
Beryllium	T-Be	<0.005	<0.005
Boron	T-B	<0.1	<0.1
Cadmium	T-Cd	0.0159	0.0159
Calcium	T-Ca	93.7	114
Chromium	T-Cr	<0.005	<0.005
Cobalt	T-Co	0.045	0.046
Copper	T-Cu	<0.005	<0.005
Iron	T-Fe	0.17	0.19
Lead	T-Pb	<0.003	<0.003
Lithium	T-Li	<0.03	<0.03
Magnesium	T-Mg	55.6	67.4
Manganese	T-Mn	0.659	0.66
Mercury	T-Hg	<0.00005	<0.00005
Molybdenum	T-Mo	<0.005	<0.005
Nickel	T-Ni	0.265	0.265
Potassium	T-K	3	3
Selenium	T-Se	<0.005	<0.005
Silver	T-Ag	<0.0001	<0.0001
Sodium	T-Na	9	11
Thallium	T-Tl	0.001	0.001
Tin	T-Sn	<0.003	<0.003
Titanium	T-Ti	<0.01	<0.01
Uranium	T-U	0.01	0.01
Vanadium	T-V	<0.03	<0.03
Zinc	T-Zn	12	12

Table B-3 Grum Pit Water Quality Characterization - Laboratory Duplicates

Sampling Date: August 8, 2003

Sample ID	GP1-40	GP1-40
Dissolved Metals		
Aluminum D-Al	<0.03	<0.03
Antimony D-Sb	0.01	0.01
Arsenic D-As	<0.003	<0.003
Barium D-Ba	0.04	0.06
Beryllium D-Be	<0.005	<0.005
Boron D-B	<0.1	<0.1
Cadmium D-Cd	0.0149	0.0149
Calcium D-Ca	92.6	116
Chromium D-Cr	<0.005	<0.005
Cobalt D-Co	0.043	0.044
Copper D-Cu	<0.005	<0.005
Iron D-Fe	<0.03	<0.03
Lead D-Pb	<0.003	<0.003
Lithium D-Li	<0.03	<0.03
Magnesium D-Mg	55.5	68.8
Manganese D-Mn	0.633	0.634
Mercury D-Hg	<0.00005	<0.00005
Molybdenum D-Mo	<0.005	<0.005
Nickel D-Ni	0.254	0.25
Potassium D-K	2	4
Selenium D-Se	<0.005	<0.005
Silver D-Ag	<0.0001	<0.0001
Sodium D-Na	10	12
Thallium D-Tl	0.001	0.001
Tin D-Sn	<0.003	<0.003
Titanium D-Ti	<0.01	<0.01
Uranium D-U	0.01	0.01
Vanadium D-V	<0.03	<0.03
Zinc D-Zn	11.4	11.5

Table B-4 Grum Pit Water Quality Characterization - Field Profiles

Date: August 8, 2003

Location #1 UTM Zone 8: 592334E, 6905184N **Profile: GP1** **Total Depth - 39m**

Depth (m)	Conductivity (uS/cm)	Water Temp. (C)	pH	DO (mg/L)	ORP (mV)	TDS (mg/L)	Comments
0	1002	12.91	7.9	9.32	139.6	0.65	Sample GP1-S taken
5	1099	5.31	7.79	10.8	163.2	0.71	
7.5	1097	4.93	7.8	9.9	164.6	0.71	
10	1097	4.93	7.7	9.43	166.5	0.71	Sample GP1-10 taken
12.5	1096	4.92	7.7	9.37	168.1	0.71	
15	1096	4.93	7.7	9.36	167.7	0.71	
17.5	1096	4.93	7.6	9.3	168	0.71	
20	1096	4.93	7.6	9.3	168.3	0.71	Sample GP1-20 taken
22.5	1096	4.93	7.6	9.36	169	0.71	
25	1096	4.93	7.57	9.36	168.5	0.71	
30	1097	4.94	7.55	9.37	164	0.71	Sample GP1-30 taken
35	1097	4.94	7.5	9.3	161	0.71	
40	981	4.95	7.52	7.2	161	0.71	Sample GP1-40 taken

Date: August 8, 2003

Location #2 UTM Zone 8: 592311E, 6905143N **Profile: GP2** **Total Depth - 38m**

Depth (m)	Conductivity (uS/cm)	Water Temp. (C)	pH	DO (mg/L)	ORP (mV)	TDS (mg/L)	Comments
Surface	1002	13.05	8.26	10.36	219.9	0.65	Sample GP2-S taken
5	1098	4.96	8.1	11.23	233.6	0.71	
10	1097	4.94	8.03	9.72	239.2	0.71	Sample GP2-10 taken
15	1097	4.94	7.97	9.59	240.9	0.71	
20	1097	4.94	7.93	9.53	241.4	0.71	Sample GP2-20 taken
25	1096	4.94	7.89	9.52	241.3	0.71	
30	1096	4.94	7.85	9.52	240.8	0.71	Sample GP2-30 taken
35	1097	4.94	7.83	9.52	235	0.71	
40	1097	4.94	7.8	9.53	152	0.71	Sample GP2-40 taken

Table B-4 Grum Pit Water Quality Characterization - Field Profiles

Date: August 21, 2003

Depth (m)	Conductivity (uS/cm)	Water Temp. (C)	pH	DO (mg/L)	ORP (mV)	TDS (mg/L)	Comments
0	n/a	11.9	n/a	8.5	n/a	n/a	Profile was not continued to complete depth of pit
1	n/a	12.1	n/a	8.4	n/a	n/a	
2	n/a	12.1	n/a	8.5	n/a	n/a	
3	n/a	12.2	n/a	8.5	n/a	n/a	
4	n/a	9.7	n/a	8.6	n/a	n/a	
5	n/a	6.8	n/a	9.8	n/a	n/a	
6	n/a	5.6	n/a	8.3	n/a	n/a	
7	n/a	5.5	n/a	8.1	n/a	n/a	
8	n/a	5.1	n/a	7.9	n/a	n/a	
9	n/a	5	n/a	7.9	n/a	n/a	
10	n/a	4.9	n/a	7.8	n/a	n/a	
11	n/a	4.9	n/a	7.8	n/a	n/a	
12	n/a	4.9	n/a	7.8	n/a	n/a	
13	n/a	4.9	n/a	7.8	n/a	n/a	
14	n/a	4.9	n/a	7.8	n/a	n/a	
15	n/a	4.9	n/a	7.8	n/a	n/a	

Appendix C

Water Treatability Testing

- **C-1 Lime Consumption Tests**
- **C-2 Lime Treatment Testing**
- **C-3 Lime Treatment Testing with 14 hour settling period**

Table C-1 Grum Pit Lime Consumption Tests

Sample Collection and Testing Date: August 21, 2003

Surface Water Sample				10 metre Depth Sample			
Lime addition (1 g/L soln)				Lime addition (1 g/L soln)			
pH units	mL added	mg/L	mg/L as $Ca(OH)_2$	pH units	mL added	mg/L	mg/L as $Ca(OH)_2$
pH	Lime	Lime	Lime	pH	Lime	Lime	Lime
7.80	0.00	0	0.0	7.30	0.00	0	0.0
8.01	1.8	3.6	4.8	8	9.8	19.6	25.9
8.2	4.1	8.2	10.8	8.25	14.2	28.4	37.5
8.41	6.9	13.8	18.2	8.52	19	38	50.2
8.5	8.1	16.2	21.4	8.7	23.2	46.4	61.3
8.75	12.7	25.4	33.6	8.8	26	52	68.7
8.85	15	30	39.6	8.9	29.1	58.2	76.9
9	18.7	37.4	49.4	9	32.3	64.6	85.4
9.1	21.8	43.6	57.6	9.1	36	72	95.1
9.2	25	50	66.1	9.2	40	80	105.7
9.3	28.6	57.2	75.6	9.3	45	90	118.9
9.4	32.6	65.2	86.2	9.4	50	100	132.1
9.28	39.5	79	104.4	9.3	55	110	145.4

Table C-1 Grum Pit Lime Consumption Tests

Sample Collection and Testing Date: September 26, 2003

Lime addition (1 g/L soln)				Hydrated Lime addition (1 g/L soln			NaOH addition (0.25 M soln)		
pH units	mL added	mg/L	mg/L as $Ca(OH)_2$	pH units	mL added	mg/L as $Ca(OH)_2$	pH units	mL added	mg/L as $Ca(OH)_2$
pH	*Lime*	Lime	Lime	pH	Hydrated Lime	Hydrated Lime	pH	NaOH	NaOH
8.16	0.00	0	0.0	8.08	0.00	0	8.00	0.00	0
8.50	5.00	10	13.2	8.22	1.60	3.2	9.00	1.60	29.6
8.60	7.50	15	19.8	8.30	2.70	5.4	9.10	1.80	33.3
8.70	9.40	18.8	24.8	8.40	4.60	9.2	9.22	2.10	38.85
8.80	11.20	22.4	29.6	8.50	6.60	13.2	9.30	2.30	42.55
8.90	13.00	26	34.4	8.60	8.60	17.2	9.42	2.70	49.95
9.00	15.00	30	39.6	8.70	10.50	21	9.50	3.00	55.5
9.10	17.30	34.6	45.7	8.80	12.20	24.4	9.60	3.30	61.05
9.20	20.10	40.2	53.1	8.90	14.10	28.2	9.70	3.80	70.3
9.30	23.20	46.4	61.3	9.00	16.20	32.4	9.81	4.60	85.1
9.41	26.90	53.8	71.1	9.10	18.60	37.2	9.90	5.00	92.5
9.50	30.80	61.6	81.4	9.20	21.40	42.8	10.01	5.60	103.6
9.61	36.30	72.6	95.9	9.30	24.60	49.2	9.98	5.70	105.45
9.70	42.30	84.6	111.8	9.41	28.30	56.6	10.00	5.80	107.3
9.36	50.00	100	132.1	9.50	32.20	64.4	9.96	6.10	112.85
9.5	53.20	106.4	140.6	9.5	41.30	82.6	10.00	6.30	116.55
9.6	57.90	115.8	153.0	9.55	50.00	100			
9.7	62.00	124	163.9	9.6	60.00	120			
9.74	66.00	132	174.4	9.70	65.00	130			
9.76	68.00	136	179.7	9.87	70.00	140			
9.78	70.00	140	185.0	10.02	75.00	150			
9.82	72.00	144	190.3	9.95	75.50	151			
9.88	75.00	150	198.2	9.98	77.00	154			
9.95	77.20	154.4	204.0	10.00	77.90	155.8			
10.00	80.10	160.2	211.7	10.00	78.50	157			
9.99	81.20	162.4	214.6	10	80.00	160			
9.99	82.40	164.8	217.8						
10.00	83.10	166.2	219.6						
9.97	83.80	167.6	221.5						
10.00	84.50	169	223.3						
9.99	84.50	169	223.3						
9.98	85.10	170.2	224.9						
9.97	85.6	171.2	226.2						
9.98	86.7	173.4	229.1						

Notes:

1. All testing conducted on continuously mixed 500 mL samples
2. pH readings taken 2-3 minutes following addition of titrant
3. Dry lime obtained from on-site water treatment plant (assumed to be CaO for purpose of converting to equivalent Ca(OH)2
4. Reagent-grade hydrated lime used

Table C-2 Lime Treatment Testing

Surface Water (500 mL Samples)

Sample Date	Lime added (ml)	Lime Solution Conc. (mg/L)	Flocc-ulent Added ?	pH	Cond-uctivity (uS/cm)	Diss. Zinc (mg/L)	Total Zinc (mg/L)	Observations
Aug 20 /03	0	1.0	No	7.91	903	4.50	4.20	
Aug 20 /03	3.7	1.0	No	8.50	918	2.00	4.00	
Aug 20 /03	3.5	1.0	Yes	8.50	911	2.10	2.60	
Aug 20 /03	6.1	1.0	No	8.75	909	0.53	2.90	
Aug 20 /03	7.3	1.0	Yes	8.75	914	0.54	1.80	
Aug 20 /03	10.4	1.0	No	9.00	888	0.25	2.80	
Aug 20 /03	10.3	1.0	Yes	9.00	894	n/a	0.84	

10 m Depth (500 mL Samples)

Sample Date	Lime added (ml)	Lime Solution Conc. (mg/L)	Flocc-ulent Added ?	pH	Cond-uctivity (uS/cm)	Diss. Zinc (mg/L)	Total Zinc (mg/L)	Observations
Aug 19 /03	0	0.5	No	7.72	949	10.50	10.50	
Aug 19 /03	32.4	0.5	No	8.50	937	1.20	4.70	
Aug 19 /03	33.3	0.5	Yes	8.50	929	1.00	2.10	buoyant floc
Aug 19 /03	49.1	0.5	No	9.00	928	0.27	3.50	
Aug 19 /03	49.7	0.5	Yes	9.00	923	0.32	1.80	
Aug 20 /03	0	1.0	No	7.34	985	10.50	10.50	
Aug 20 /03	18.1	1.0	No	8.75	969	0.64	4.40	
Aug 20 /03	18.7	1.0	Yes	8.75	951	0.78	1.60	
Aug 20 /03	42	1.0	No	9.50	898	0.14	1.80	
Aug 20 /03	40.7	1.0	Yes	9.50	936	n/a	0.42	

Method Blank

Sample Date	Lime added (ml)	Lime Solution Conc. (mg/L)	Flocc-ulent Added ?	pH	Cond-uctivity (uS/cm)	Diss. Zinc (mg/L)	Total Zinc (mg/L)	Observations
Aug 20 /03	0	n/a	No	n/a	n/a	n/a	0.07	

Notes:

1. Samples allowed to settle for 20 minutes prior to decanting a portion of the sample for zinc analysis

Table C-3 Lime Treatment Testing with 14-hour Settling Period

10 m Depth (500 mL Samples)

			pH				
Sample Date	Sample ID	Flocc-ulent Added?	3 min. after lime addition	14 hrs after lime addition	Diss. Zinc (mg/L)	Total Zinc (mg/L)	Observations
Aug 20 /03	1	No	9.00	8.34	0.27	0.87	
Aug 20 /03	2	Yes	9.00	8.49	0.28	1.10	buoyant floc
Aug 20 /03	3	No	9.50	7.82	0.52	0.73	
Aug 20 /03	4	Yes	9.50	7.93	0.48	0.86	buoyant floc

Notes:

1. Samples allowed to settle for 45 minutes prior to decanting a portion of the sample for zinc analysis

Detailed Characterization of Sample ID's #2 and #4 (see table above)

Sample ID	#2	#4
Dissolved Metals		
Aluminum	<0.2	<0.2
Antimony	<0.2	<0.2
Arsenic	<0.2	<0.2
Barium	0.04	0.03
Beryllium	<0.005	<0.005
Bismuth	<0.2	<0.2
Boron	<0.1	<0.1
Cadmium	<0.01	<0.01
Calcium	108	90.6
Chromium	<0.01	<0.01
Cobalt	0.02	0.01
Copper	<0.01	<0.01
Iron	<0.03	<0.03
Lead	<0.05	<0.05
Lithium	0.02	0.03
Magnesium	53.7	56.6
Manganese	0.369	0.058
Molybdenum	<0.03	<0.03
Nickel	0.15	0.12
Phosphorus	<0.3	<0.3
Potassium	2	3
Selenium	<0.2	<0.2
Silicon	1.7	1.79
Silver	<0.01	<0.01
Sodium	9	9
Strontium	0.682	0.646
Thallium	<0.2	<0.2
Tin	<0.03	<0.03
Titanium	<0.01	<0.01
Vanadium	<0.03	<0.03
Zinc	0.229	0.425

Notes:

1. Samples submitted to ALS Laboratories for detailed characterization