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**2000 GEOCHEMICAL STUDIES
SA DENA HES MINE**

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1.0 INTRODUCTION

1.1 Background

Cominco Ltd manages the Sa Dena Hes Mine located in south central Yukon Territory, approximately 70 km north of Watson Lake for the Sa Dena Hes Joint Venture. The mine was operated from July 1991 to December 1992 and is currently under care-and-maintenance. In 1999, Cominco submitted a closure plan for the mine (Cominco 1999). Indian and Northern Affairs Canada (Water Resources Division) (INAC 2000) and Environment Canada (EC 2000) reviewed the plan. Specific questions were raised on three areas of the mine:

- The fate of drainage from the Burnick Portal;
- The trend of zinc concentrations in North Dam seepage (MH-2); and
- The impact of Main Zone Pit drainage on Camp Creek.

SRK Consulting prepared a work plan (Appendix A, SRK 2000) to collect additional data during the 2000 field season to address these questions. This report describes the results of these studies.

The objectives of the specific studies in each area of the site are described in the following sections. The methods and results are described in Sections 2.0 to 4.0.

1.2 Objectives of Specific Studies

1.2.1 Fate of Burnick Portal Discharge

The Burnick Zone is located 3 km from the Sa Dena Hes mill (Figure 1). The mineralization is accessed by two portals (1200 and 1300). The lower portal drains continuously. The drainage flows through a buried culvert and cascades over the crest of rock fill deposited at the portal and disappears to subsurface. The general flow direction would be expected to be directly downslope to the ENE (Figure 1).

Cominco (1999) concluded that drainage from the Burnick Portal is not having a detectable impact on False Canyon Creek (via "Tributary E") (Figure 1). Environment Canada (2000) commented that attenuation of zinc from the drainage may be occurring, and at some time in the distant future, the zinc load from this source may have an impact on zinc concentrations in False Canyon Creek as the capacity for attenuation is depleted. A field program was therefore designed to evaluate the degree to which attenuation might be occurring.

1.2.2 North Dam Seepage Chemistry

Seepage from the North Dam of the tailings pond is sampled at location MH-2 (Figure 1).

The water quality database for MH-2 indicates that total sulphate, zinc and cadmium concentrations increased between 1993 and 1998 (Cominco 1999). In 1999, zinc and cadmium concentrations appeared to stabilize, but sulphate concentrations continued to increase. Cominco (1999) attributed the increases to oxidation of sphalerite in the tailings and the slow emergence of pore waters containing elevated zinc concentrations originating from exposed tailings. A second explanation is that increases were due to emergence of process water. For either explanation, the stabilization of zinc and cadmium concentrations is believed to be due to the formation of secondary minerals with limited solubility. Sulphate minerals tend to be more soluble and sulphate concentrations have not yet reached stable conditions.

The objective of the study was to determine if pore water zinc concentrations in the tailings indicate that zinc and cadmium concentrations in seepage would increase substantially in the future.

1.2.3 Main Zone Drainage to Camp Creek

The Main Zone Pit is a box cut located in the headwaters of Camp Creek (Figure 1). A portal is located at the south end of the cut. In June 1999, drainage from the portal was noted. The drainage disappears into the coarse rock fill at the mouth of the box cut.

Cominco (1999) reported that the drainage from the Main Zone pit portal contained elevated zinc concentrations (40 mg/L). The flow was estimated at 1 L/s indicating a dissolved zinc load of about 40 mg/s. This load was substantially more than that estimated for Camp Creek at MH-4 (Figure 1) (0.3 mg/s, based on a peak flow and total zinc concentration of 1000 L/min and 0.02 mg/L, respectively). It was suspected that the flow from the Main Zone Pit was ephemeral and that the load was not apparent in Camp Creek either due to the monthly sampling frequency or because the discharge from Main Zone Pit was added slowly via groundwater throughout the spring and summer. The study was designed to evaluate this conclusion by increasing the monitoring frequency for both the Main Zone pit drainage and MH-4.

2.0 FATE OF BURNICK PORTAL DRAINAGE

2.1 Methods

The proposed study consisted of two components (Appendix A):

1. A field reconnaissance of the area downslope of the Burnick Portal to identify locations where the drainage re-emerges.
2. A tracer study to evaluate possible attenuation of zinc between the disappearance and re-emergence of the drainage.

2.2 Results

The detailed reconnaissance of the toe of the Burnick Dump in late June 2000 failed to identify any evidence of emerging seepage. It was apparent that overland flow occurs briefly during high runoff periods. This water collects in the North Hill Settlement Basin (Figure 1), and then infiltrates into the forest soils a short distance downgradient. For several hundred metres downgradient of the basin, the slopes were traversed but were found to lack any evidence of surface drainage. Near surface soils in the vicinity were silty and contained some ice.

A second traverse across the slopes below the portal was completed by following a single-track road north from the garbage dump on the slopes above Tributary E – West Fork (Figure 1). Approximately 1600 m northwest of the garbage dump surface runoff was encountered. This runoff was found to originate from a small natural pond with no obvious inflow (Figure 1). The pond is approximately 1000 m downslope and towards the northeast from the Burnick Portal (ie not immediately downslope of the portal). Samples of Burnick Drainage (MH-22) and the outflow from the small pond are summarized in Table 1. The pond water resembles background water chemistry for the area. If the water did originate from the Burnick Portal it shows that Zn concentrations have been attenuated by greater than 90% after accounting for the dilution suggested by the lower sulphate concentrations.

TABLE 1
Summary of Results of Sampling of Burnick Portal and
Downslope Pond Outflow

Location	pH	Conductivity	SO ₄ (mg/L)	Total Zn (mg/L)
Burnick Portal	8.3	221	44.9	0.218
Pond Outflow	8.3	267	9.5	0.003

Due to the lack of surface drainage clearly linked to the Burnick Discharge and the distance of the pond from the portal, the tracer study was not conducted.

2.3 Conclusions

The fieldwork indicated that the Burnick Drainage flow does not normally re-emerge as a seep immediately down slope of the rock dump. The only surface flow on the slopes below the Burnick Portal emerges approximately 1000 m below the portal but not directly downslope. The surface flow contains concentrations of indicator parameters similar to other background waters in the area and is not obviously related to the Burnick Portal. The water may originate as shallow groundwater from North Hill rather than specifically from the Burnick Portal.

It appears that the Burnick Discharge does not emerge at any specific location but eventually recharges Tributary E – West Fork, 1600 m downslope from the portal after passing through extensive silty surficial deposits. This represents an extremely long flow path for attenuation by contact with silty soils, and given the relatively low zinc

concentrations in the Burnick Zone drainage, the likelihood of this capacity being exhausted is negligible.

3.0 NORTH DAM SEEPAGE CHEMISTRY

3.1 Methods

The main component of the study was the installation of shallow, stainless steel drive point piezometers in the tailings beach upstream of the North Dam. Tailings samples were also collected from the vicinity of each drive point piezometer for geochemical and mineralogical analysis. Samples were collected from surface and at about 50 cm below surface.

Eight drive point piezometers were driven into the tailings beach manually (Figure 1, inset). The piezometers were installed in three, approximately equally-spaced, lines perpendicular to the dam.

Water levels in the piezometers were monitored eight times from June to October. Water samples were collected on July 22 and September 13, 2000. Low water volumes were recovered on July 22; therefore alkalinity could not be determined. Insufficient water for analysis was recovered from DP01, and DP08 was dry. On September 13, recovery improved and the sufficient water was available for alkalinity determinations. However, sample collection occurred over several hours as the piezometers were pumped dry and allowed to recharge.

Insufficient water for analysis was recovered from DP08.

3.2 Results

3.2.1 Tailings Composition

The composition of the tailings did not vary significantly from location to location, or with shallow depth (Table 2). The results were also consistent with three previous samples collected in 1999 (Cominco 1999). Acid-base accounting in 1999 indicated that the sulphur content was primarily contained in residual lead and zinc minerals (galena and sphalerite, respectively) in the tailings.

Three oxidized tailings samples (01-Surface, 02-Surface, 07-Sub-surface) were examined using a scanning electron microscope. The mineralogical report is provided in Appendix B. The main findings were:

- The oxidized tailings are composed primarily of calcite, quartz and gypsum.
- Sphalerite and galena were present
- The principle iron sulphide is marcasite;
- Pyrite occurs in trace quantities;
- Zinc secondary carbonate minerals were observed (smithsonite, hemimorphite).
- Small amounts of lime were noted in the tailings.

No discrete cadmium secondary minerals were observed but cadmium was found in solid solution with sphalerite and smithsonite. Smithsonite was found to occur in two forms (Cd-bearing and Cd-absent). Smithsonite was observed to be associated with lime. This occurrence suggested that it formed either during processing or after deposition but was not present in the ore, and would therefore not be expected in the unoxidized tailings.

3.2.2 Water Levels

Water levels were measured from late June to early October on eight occasions. As absolute elevations have not been determined for the piezometers, the levels given a semi-quantitative indication of the elevation of the water table in the tailings.

DP08 was dry until October 3 (Table 3). All piezometers showed increasing water levels through the summer. Water was generally deeper near the dam (DP2, 8 and 5) and shallowest near the pond (DP1, 3 and 6). The level in DP4 was consistent with this general trend, but the water level in DP7 was deeper than the other piezometers until October when the level increased sharply. As this is a single measurement it cannot be validated.

3.2.3 Water Chemistry

Water chemistry is summarized in Table 4. Detailed results are provided in Appendix C.

Four of the seven tested piezometers (DP3, 4, 5, 6) yielded similar waters in both sampling rounds. The pH was 7.2 to 7.9 (laboratory measurements), alkalinity was 33

to 40 mgCaCO₃/L, sulphate concentrations were between 668 and 786 mg/L and zinc concentrations were typically between 0.085 mg/L and 0.42 mg/L. DP-1 had similar chemistry though sulphate concentrations (550 mg/L) were lower and zinc concentrations were higher (0.73 mg/L) and iron concentrations were higher than other piezometers in the September sampling round. DP2 sulphate and zinc concentrations were higher (906 and 1120 mg/L; 0.59 and 0.47 mg/L, respectively). In general, the chemistry of water in these two piezometers (DP1 and DP2) appears to be similar to DP3, 4, 5 and 6.

Water extracted from DP7 was significantly different from the other seven piezometers. Zinc concentrations were elevated (27 and 14 mg/L). Sulphate, alkalinity, calcium, cadmium, magnesium and manganese concentrations were also greater than the other piezometers. For most parameters, these concentrations indicate similar though more concentrated water for all piezometers. For example, element ratios are similar for all waters. The exception for DP7 is that potassium concentrations exceeded sodium concentrations. Sodium concentrations were much lower and potassium concentrations slightly higher in DP7.

All piezometers monitored in both July and September showed decreasing concentrations of zinc, lead and cadmium. Iron was detectable in June but undetectable in September. Sulphate concentrations increased for DP2, 3, 5, and 7, but decreased for DP4 and 6. Concentrations of calcium and magnesium tended to increase or decrease following sulphate, with some exceptions.

3.3 Interpretation

Three aspects of the field observations have been evaluated:

1. The explanation for spatial variations in pore water chemistry (particularly the elevated zinc concentrations at DP7).
2. The explanation for seasonal variations in pore water chemistry.
3. The long term trend in zinc concentrations in seepage at MH2.

Figure 2 illustrates some of the geochemical concepts presented below.

3.3.1 Spatial Variation of Pore Water Chemistry

The tailings appear to be chemically uniform, therefore, other factors were evaluated.

As a first step, typical waters were modeled using MINTEQA2 (Allison et al, 1991). Three drivepoint waters collected on September 13, 2000 were selected (DP1, DP5 and DP7). A sample collected from MH2 on June 4, 2000 was also modeled. Data used in the modeling is shown in Table 4 and logarithms of saturation indices (log SI) are provided in Table 5.

The two waters with lower dissolved solids concentrations (DP1, DP5) indicated that the water is not chemically saturated (indicated by $\log SI=0$) with respect to any of the major components in the tailings. Malachite was oversaturated at DP1 due to copper concentrations of 0.043 mg/L and barite was oversaturated in both waters. Carbonates of calcium (calcite), manganese (rhodochrosite) and lead (cerrusite) had negative log SIs between -1 and 0, indicating that the solutions were near chemical saturation with respect to these minerals. No zinc minerals (including zinc carbonate-smithsonite) were near chemical saturation.

The lack of saturation with respect to calcite was unexpected because it is a major component of the tailings and it is typically readily soluble when fine grained in tailings. It is possible that the analyzed alkalinity was not reliable because the sample volumes were low and there was a large headspace in the sample bottles. Also the sampling method allowed the sample to equilibrate with the atmosphere. Both factors would be expected to result in loss of alkalinity. To evaluate this effect, the log saturation indices were re-calculated using the same alkalinity observed at MH2. Calcite saturation was found to occur at alkalinity below that measured routinely at MH2. However, smithsonite would not be saturated. It was concluded that the alkalinity measurements were unreliable.

In contrast, DP7 water was near saturation with respect to several minerals including calcite, otavite (cadmium), rhodochrosite, cerrusite and smithsonite. Several lead minerals are oversaturated, though this is an artifact of the non-detectable lead concentrations (<0.03 mg/L). A lead concentration of 0.015 mg/L was used in the modeling.

MH2 had much greater alkalinity than the tailings pore waters and therefore was predicted to be near saturation with respect to calcite, dolomite (calcium and

magnesium carbonate), rhodochrosite and cerrusite despite lower concentrations of elements such as manganese and lead than the porewaters.

The anomalous water at DP7 is consistent with the findings of the mineralogical study, which indicated the presence of secondary minerals particularly of zinc and cadmium. The water at DP7 appears to represent water that is in contact with these minerals and has reach solubility limits with respect to the minerals. Alkalinity and metal concentrations in the other waters are lower than would be expected in contact with these minerals.

DP7 represents a different sampling environment compared to the other wells and this possibly explains the difference in results. The other piezometers sampled below the water table and draw water from the saturated zone of the tailings. The screen in DP7 crosses the water table thereby collecting water from just below the water table.

These observations indicate that water infiltrating through the near surface oxidized tailings has elevated dissolved solids load reflecting either dissolution of sphalerite oxidation products or dissolution of process chemical residues (Figure 2). As this water moves downward it appears to mix with water that has lower concentrations of most parameters possibly originating as dilute recharge from the pond contained snowmelt at the south end of the tailings pond and trapped process water (Figure 2).

The seepage emerging at MH2 appears to represent a dilute equivalent of the pore waters producing by mixing with dilute groundwater from the valley sides and runoff from the North Dam face. Ratios of calcium to sulphate, magnesium to sulphate and cadmium to zinc were similar for MH2 and the tailings porewaters. The difference for alkalinity is probably due to the difficulty in obtained a reliable alkalinity measurement for the tailings pore waters.

3.3.2 Seasonal Variation in Pore Water Chemistry

For the six piezometers sampled in both July and September, concentrations of iron, zinc and cadmium concentrations were lower in September. This effect was not apparent for sulphate, calcium, magnesium, potassium and sodium. The decrease in iron concentrations was substantial and indicates a significant change in groundwater conditions at near neutral pH. The higher iron concentrations in July can only be sustained under reducing conditions, whereas the low iron concentrations in September are indicative of oxidizing conditions. These observations suggest that in

June the tailings pore waters have not been recharged by oxidized surface waters, or that snow cover during the winter excluded oxygen. During the summer, oxygen penetrates into the tailings either by diffusion or by surface water. The latter seems likely because the water level increased through the summer.

3.3.3 Long Term Trend in Zinc Concentrations at MH2

Monitoring of MH2 has established that zinc concentrations initially increased through 1998 but then stabilized in 1999. Sulphate concentrations increased throughout this period. In 2000, these trends have continued.

Based on the pore water sampling and mineralogical work, it is apparent that different minerals control the chemistry of zinc and sulphate. Sulphate is controlled by the dissolution of gypsum and zinc is controlled by the dissolution of zinc carbonate. Both minerals occur in the oxidized zone of the tailings near surface and could be generated by the oxidation of sulphide minerals (sphalerite, galena, marcasite and pyrite) and dissolution of calcite, eg:

- Oxidation of Sphalerite:
$$\text{ZnS} + 2\text{O}_2 \rightarrow \text{Zn}^{2+} + \text{SO}_4^{2-}$$
- Oxidation of Marcasite and Pyrite:
$$\text{FeS}_2 + 15/4\text{O}_2 + 7/2\text{H}_2\text{O} \rightarrow \text{Fe}(\text{OH})_3 + 2\text{SO}_4^{2-} + 4\text{H}^+$$
- Dissolution of Calcite:
$$\text{CaCO}_3 + \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{Ca}^{2+} + 2\text{HCO}_3^-$$
- Formation of Zinc Carbonate
$$\text{Zn}^{2+} + \text{HCO}_3^- \rightarrow \text{ZnCO}_3 + \text{H}^+$$
- Formation of Gypsum:
$$\text{Ca}^{2+} + \text{SO}_4^{2-} + \text{H}_2\text{O} \rightarrow \text{CaSO}_4 \cdot 2\text{H}_2\text{O}$$

Alternately, these minerals may be present as process residues resulting from the use of mill reagents such as:

- Zinc sulphate (ZnSO_4)

- Lime ($\text{Ca}(\text{OH})_2$)
- Copper sulphate (CaSO_4)

Copper sulphate reacts with sphalerite to displace zinc to solution.

The difference in sulphate and zinc trends observed at MH2 may be due to differences in the timing of the onset of the mineralogical control. If smithsonite began to form sooner than gypsum, zinc concentrations would be expected to stabilize sooner than sulphate. This is a reasonable interpretation because the sulphide content of the tailings is low and sulphate content would be expected to take longer to reach concentrations at which gypsum would form. In contrast, carbonate is abundant in the tailings and represents optimal conditions for formation of smithsonite at relatively low concentrations. This appears to have occurred in the tailings but the effect has not yet been observed at MH2.

3.4 Conclusions

Mineralogical and pore water analysis indicates that pore water chemistry in the tailings is controlled by the formation of secondary minerals. Zinc concentrations in the tailings appear to be stable and reflect formation of zinc carbonate in the tailings. Zinc carbonate was found in all three near surface samples of tailings implying that zinc concentrations cannot increase above the concentrations currently observed.

Monitoring of MH-2 indicates that zinc concentrations have stabilized. Sulphate concentrations were increasing in 2000. Sulphate concentrations are controlled by the formation of gypsum but the effect of this process is not yet apparent at MH-2.

4.0 MAIN ZONE DRAINAGE TO CAMP CREEK

4.1 Field Methods

A detailed program of sampling both the Main Zone Pit drainage and Camp Creek was started in the May 2000. Camp Creek (MH-4) was monitored from May 15 to August 2, 2000. The Main Zone Pit was inspected every other day and was first sampled on June 4. Both locations were sampled every two days and samples analyzed for total and dissolved zinc, sulphate, pH and electrical conductivity.

The methodology allowed for continued monitoring on this schedule until the Main Zone Pit stopped discharging, after which Camp Creek was to be monitored for another two weeks.

The slopes above the Main Zone Pit were also examined for evidence of a discrete inflow feeding the pit. No flow was identified.

4.2 Results

Monitoring results are summarized in Figure 3.

Main Zone Pit was continuing to discharge in early August and a total of 30 samples had been collected. Flow varied from 120 L/min in late June to 15 L/min in mid-July. Flow increased again in late July to 100 L/min. Dissolved zinc concentrations began near 50 mg/L, decreased to 35 mg/L in early July then increased again to 56 mg/L in mid-July during low flow, then decreased again to 40 mg/L as flows increased in late July. Zinc load was greatest in June (60 to 90 mg/s) and the last two samples in July (70 mg/s), and lowest throughout the most of July (10 to 20 mg/s). Sulphate followed a similar pattern with loads varying from 100 to 400 mg/s.

Camp Creek flow was greatest in mid-June (12,000 L/min) decreasing to less than 2000 L/min in late July. Flow increased slightly in August (3000 L/min). Dissolved zinc concentrations were much lower than the Main Zone discharge (typically 0.005 mg/L). Typical loads were much less than the Main Zone discharge (less than 1 mg/s) except for a brief period in June when loads were near 3 mg/s). Sulphate loads in Camp Creek were initially comparable to Main Zone (350 mg/s) but were much greater by mid-June (4000 mg/s). By late July, sulphate loads in Camp Creek (500 to 1000 mg/s) were only slightly greater than Main Zone Pit Discharge (500 mg/s).

4.3 Interpretation

Monitoring through the summer of 2000 indicated that the Main Zone Pit discharge was continuous but varied in response to snowmelt (June) and rainfall (late July). The summer was apparently very wet, which may account for the continuous flow.

The monitoring confirmed that dissolved zinc loads in the Main Zone Pit drainage are much greater than Camp Creek, and that this condition can occur throughout the summer. The initial explanation that the Main Zone Pit drainage is ephemeral does not account for the lack of elevated zinc loads in Camp Creek. Possible explanations are either that:

1. Main Zone Pit drainage does not enter Camp Creek above MH-4; or
2. Zinc is being removed from solution, thereby reducing the zinc load observed at MH-4.

The former explanation is not supported by field observations. Drainage from the Main Zone Pit can be seen and heard in the waste rock dumps above the upper reaches of Camp Creek and the distance from the pit to Camp Creek is less than 200 m (Figure 1).

Zinc removal probably occurs by contact of Main Zone Pit drainage, which has low alkalinity (23 mg CaCO₃/L, June 1999) with calcareous waste rock, and mixing with Camp Creek water, which has alkalinity of between 100 and 160 mg CaCO₃/L. These alkalinity measurements are consistently obtained at MH-4 but were also confirmed on one occasion at MH-3 in the headwaters of Camp Creek. This mixing effect was modeled using MINTEQA2. The modeling was performed as follows:

- MINTEQA2 was used to determine log saturation indices for Camp Creek water and Main Zone Pit water.
- Camp Creek water and Main Zone Pit water were arithmetically mixed in ratios of 200, 10, 1 and 0.1 to 1. MINTEQA2 was used to calculate log saturation indices for each of these solutions.
- The mix ratio at which the log saturation index (log SI) was greatest was determined for possible controlling phases (smithsonite, ZnCO₃.H₂O, otavite).

- The chemistry of mixed water at the mix ratio with highest log SI was predicted using MINTEQ by assuming that these minerals are present.

The chemistry of Camp Creek water and Main Zone Pit water used as input is shown in Table 6. The saturation index results for three minerals are shown in Figure 4.

Figure 4 shows that log SI for all three minerals exceeds 0 at low mixing ratios, implying qualitatively that these minerals would precipitate from solution when Main Zone Pit water mixes with Camp Creek water. A limitation of MINTEQA2 is that it does not consider the kinetics of mineral formation; however, the North Dam tailings study showed that zinc carbonates can form in surficial environments at Sa Dena Hes. This suggests that it could also form in Camp Creek.

Low mix ratios can be expected in the upper reaches of Camp Creek where flows are low, and Main Zone Pit drainage mixes gradually, possibly in groundwater. The maximum log SIs occur at a mix ratio of 1.4 parts Camp Creek to 1 part Main Zone Pit water. $\text{ZnCO}_3 \cdot \text{H}_2\text{O}$ has the highest log SI (0.957). The chemistry resulting from mixing the waters at this ratio, and the predicted chemistry by MINTEQ assuming that smithsonite, $\text{ZnCO}_3 \cdot \text{H}_2\text{O}$ and otavite are precipitated are shown in Table 7. Calcite was also assumed to be present because it is abundant in the talus above Camp Creek. Lead concentrations also indicated saturation with respect to hydrocerrusite so this was also included.

The resulting chemistry indicates a removal rate of 84% of zinc, 74% for lead and 46% for cadmium. This compares with the observed zinc attenuation of greater than 95% at MH4. The above process does not account for all the attenuation observed at MH4, however other factors that could account for the additional load loss are:

- Part of the flow in Camp Creek may be occurring as groundwater, therefore the load calculation at MH-4 does not account for all load passing MH4.
- Zinc may be removed by other processes such as adsorption in sediments and biological uptake (passive treatment).

The majority of attenuation is a result of the high alkalinity in Camp Creek water. As Camp Creek drains limestone, this source of alkalinity will continue indefinitely,

providing natural attenuation of the zinc, lead and cadmium load originating from the Main Zone Pit.

4.4 Conclusions

Monitoring during the wet summer of 2000 showed that the Main Zone pit discharged continuously and that the zinc loads observed at MH4 on Camp Creek were much less than the zinc load discharged from the Main Zone Pit.

Modelling of the process of mixing of Main Zone Pit discharge with Camp Creek showed that attenuation of the zinc, lead and cadmium load occurs by formation of zinc, lead and cadmium carbonates, probably as precipitates in Camp Creek.

5.0 OVERALL CONCLUSIONS

It can be concluded:

- Drainage from the Burnick Portal does not appear to emerge after it infiltrates a short distance downstream of the Portal. The flow path to the nearest surface water is probably more than 1600 m long through silty soils. This is sufficient to allow long term attenuation.
- Pore water in tailings upstream of the North Dam contains zinc concentrations greater than zinc concentrations in seepage from the Dam but generally less than the discharge criterion of 0.5 mg/L. Zinc concentrations are not expected to increase due to the formation of zinc carbonate in the tailings.
- Water drained from the Main Zone Pit throughout the summer of 2000. The zinc loads observed in Camp Creek are much less than the drainage implying that contact with limestone and mixing with alkaline surface water remove zinc from solution.

This report, 1CC005.06, 2000 Geochemical Studies - Sa Dena Hes, has been prepared by:

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TABLES

TABLE 2
Tailings Chemistry - Drive Point Piezometer Locations

Location	Depth	Mo	Cu	Pb	Zn	Ag	Ni	Co	Mn	Fe	As	U	Au	Th	Sr	Cd
		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm
01	Surface	18	260	9796	10531	8.6	48	13	4492	4.06	69	-8	-2	2	133	48.9
01	Sub-surface	11	58	6224	7117	4.5	44	7	2207	2.01	61	-8	-2	2	121	32.8
02	Surface	16	59	6730	5884	5.1	28	7	2308	2.22	46	-8	-2	2	103	27.4
02	Sub-surface	8	55	4707	5978	3.9	26	6	2400	2.09	39	-8	-2	2	123	24.4
03	Surface	18	67	5943	6332	4.9	59	8	2321	2.31	71	-8	-2	2	125	31.5
03	Sub-surface	13	54	5013	6076	3.9	53	7	1968	1.85	64	-8	-2	-2	126	27.7
04	Surface	12	46	3929	5125	3.7	46	6	1747	1.81	61	-8	-2	2	127	22.0
04	Sub-surface	14	54	7156	6853	5.5	45	8	2030	2.01	68	8	-2	2	107	32.1
05	Surface	14	51	5997	5487	4.8	34	7	2032	2.06	51	-8	-2	2	101	25.9
05	Sub-surface	11	50	4777	6920	3.6	35	6	2105	2	58	-8	-2	-2	126	31.7
06	Surface	15	63	6303	6595	4.3	43	7	2133	2.19	53	-8	-2	2	112	32.0
06	Sub-surface	13	46	3340	5083	3.0	56	7	1822	1.8	61	-8	-2	3	122	21.6
07	Surface	12	53	4264	4693	3.4	52	7	2070	2.06	64	-8	-2	2	126	19.3
07	Sub-surface	12	51	5471	7801	4.2	47	8	1863	1.87	67	-8	-2	2	117	39.3
08	Surface	12	49	4481	6543	7.2	44	7	1834	1.87	60	-8	-2	3	124	31.1
08	Sub-surface	11	45	5472	6977	6.3	37	6	2092	1.92	58	8	-2	2	96	33.2

Surface - 0 to 10 cm

Sub-surface - 50 to 60 cm

TABLE 3
Depth of Water in Drivepoint Piezometers

Date (2000)	29-Jun	30-Jun	2-Jul	14-Jul	17-Jul	1-Aug	3-Sep	4-Oct
DP01	2.56	2.34	2.24	2.32	2.36	2.04	1.81	1.84
DP02	3.22	3.20	3.20	3.17	3.16	3.12	2.87	2.55
DP03	2.80	2.81	2.80	2.80	2.78	2.67	2.47	2.38
DP04	3.00	2.99	2.85	2.96	2.96	2.91	2.72	2.49
DP05	3.01	3.02	2.95	2.97	2.96	2.95	2.84	2.52
DP06	2.74	2.70	2.70	2.78	2.77	2.71	2.60	2.29
DP07	3.75	3.75	3.74	3.76	3.76	3.78	3.67	2.25
DP08	dry	dry	dry	dry	dry	dry	dry	3.73

All depths in metres

TABLE 4
North Tailings Groundwater Analytical Results

Location	Sampling Date	DP Depth m	Water Depth m	Water Column m	pH	EC uS/cm	Alkalinity mg/L	SO4 mg/L	Al mg/L	Cd mg/L	Ca mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Mg mg/L	Mn mg/L	K mg/L	Na mg/L	Sr mg/L	Zn mg/L
DP01	00/07/22	3.3	NS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DP01	00/09/13		1.81	1.49	7.3	1070	37	550	0.02	0.005	157	0.043	0.366	0.05	16.9	2.71	9	47.4	0.676	0.733
DP02	00/07/22	3.88	3.16	0.72	7.3	1640	#N/A	906	0.03	0.013	292	0.041	0.129	0.2	27.1	2.5	10	52.7	0.77	0.594
DP02	00/09/13		2.87	1.01	7.2	1640	39	1120	<0.02	0.009	325	0.028	<0.005	0.04	29.2	4.1	12	59.5	0.901	0.473
DP03	00/07/22	3.95	2.78	1.17	7.9	1260	#N/A	668	0.03	0.022	220	<0.005	0.033	0.13	16.1	1.9	8	36.1	0.512	0.358
DP03	00/09/13		2.47	1.48	7.6	1250	33	709	<0.02	0.019	242	0.007	<0.005	0.11	18.3	2.29	10	38.9	0.572	0.237
DP04	00/07/22	3.94	2.955	0.985	7.7	1430	#N/A	761	0.04	0.015	236	0.009	0.137	0.23	23.5	3.77	10	59	0.836	0.418
DP04	00/09/13		2.72	1.22	7.6	1270	39	708	<0.02	0.003	206	0.011	<0.005	0.08	20.3	3.31	8	48.6	0.704	0.085
DP05	00/07/22	3.55	2.955	0.595	7.6	1350	#N/A	699	<0.02	0.008	211	<0.005	0.073	0.07	21.3	10.9	12	49.6	0.57	0.391
DP05	00/09/13		2.84	0.71	7.4	1280	40	726	<0.02	0.004	224	<0.005	<0.005	0.05	21.7	7.11	10	39.7	0.682	0.132
DP06	00/07/22	3.94	2.765	1.175	7.8	1380	#N/A	786	<0.02	0.01	253	<0.005	0.082	0.3	31.5	5.2	7	13.2	1.2	0.391
DP06	00/09/13		2.6	1.34	7.5	1310	38	768	<0.02	0.009	240	<0.005	<0.005	0.13	30.4	5.53	8	12.8	1.13	0.232
DP07	00/07/22	3.91	3.76	0.15	7.7	2330	#N/A	1570	<0.02	0.126	501	<0.005	0.013	0.1	51	59.8	13	3.63	1.02	27.1
DP07	00/09/13		3.67	0.24	7.7	2270	95	1720	<0.02	0.121	476	<0.005	<0.005	<0.03	51.9	55.1	12	2.96	0.978	14.9
DP08	00/07/22	3.74	Dry	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DP08	00/09/13		Dry	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MH2	00/06/04	-	-	-	8	979	264	274	0.03	0.0011	119	<0.005	0.375	0.007	10.6	1.32	1	23.2	0.645	0.161
Detection Limit					0.1	1		1	0.02	0.002	0.05	0.005	0.005	0.03	0.05	0.001	1	0.05	0.001	0.005

Notes

DP Depth - Depth to bottom of drivepoint piezometer

Water Depth - Depth from surface to water level

Water Column - Length from water level to bottom of drivepoint

NS - For slow recovery of water in piezometer. No sample collected.

MH2 metal analysis are on unfiltered samples except for Ca, Mg and Zn (TSS was <4 mg/L)

TABLE 5
North Dam Groundwater - MINTEQ Results

MINTEQ					
ID	Name	DP1	DP5	DP7	MH2
	Date	9/13/00	9/13/00	9/13/00	6/4/00
Log Saturation Indices					
2016000	Cd(OH)2 (am)	-8.0	-7.9	-6.0	-7.2
2016001	Cd(OH)2	-8.0	-7.9	-6.0	-7.2
2016002	MONTEPONITE	-9.6	-9.5	-7.6	-8.8
2023100	Cu(OH)2	-1.6	-2.8	-2.6	-2.7
2023101	TENORITE		-1.8	-1.7	-1.8
2028000	WUSTITE	-3.7	-5.6	-5.1	-2.2
2060000	MASSICOT	-6.5	-6.4	-3.1	-6.9
2060001	LITHARGE	-6.3	-6.2	-2.9	-6.7
2060002	PbO:0.3H2O	-5.7	-5.6	-2.3	-6.1
2060004	Pb(OH)2	-1.6	-1.5	1.8	-2.1
2060005	Pb2O(OH)2	-11.6	-11.4	-4.8	-12.5
2095000	Zn(OH)2 (am)	-4.2	-4.8	-2.3	-3.6
2095001	Zn(OH)2	-2.9	-3.5		-2.2
2095002	Zn(OH)2 (beta)	-3.6	-4.1	-1.6	-2.9
2095003	Zn(OH)2 (gamma)	-2.4	-3.0		-1.8
2095004	Zn(OH)2 (epsilon)	-3.3	-3.9	-1.4	-2.7
2095005	ZnO (active)	-3.1	-3.7	-1.1	-2.4
2095006	ZINCITE	-3.2	-3.8	-1.3	-2.6
5015000	ARAGONITE	-1.0		0.0	0.5
5015001	CALCITE			0.2	0.7
5015002	DOLOMITE (ordered)	-2.6	-2.1		0.3
5015003	HUNTITE	-10.5	-9.7	-7.7	-4.8
5015004	DOLOMITE (disordered)	-3.2	-2.8	-1.6	
5016000	OTAVITE	-2.2	-2.2		-1.3
5023100	CuCO3	-1.8	-3.0	-2.8	-2.7
5023101	MALACHITE	0.3	-1.5	-1.2	-1.2
5023102	AZURITE	-3.1	-6.7	-6.1	-6.1
5046002	MAGNESITE	-2.2	-2.0	-1.6	
5046003	NESQUEHONITE	-5.6	-5.4	-5.0	-4.2
5047000	RHODOCHROSITE			1.1	0.3
5060000	CERRUSITE			3.0	
5060001	Pb2OCO3	-6.5	-6.3	0.3	-7.2
5060002	Pb3O2CO3	-11.7	-11.4	-1.5	-12.8
5060003	HYDROCERRUSITE	-1.5	-1.3	8.6	-2.5
5060004	Pb10(OH)6O(CO3)6	-44.8	-43.9	-11.1	-48.1
5095000	SMITHSONITE	-2.0	-2.6		-1.2
5095001	ZnCO3:1H2O	-1.5	-2.2	0.3	
6010000	BARITE	0.6	0.6	0.7	1.2
6015000	ANHYDRITE	-1.0			-1.4
6015001	GYPNUM				-1.0
6016000	Cd3(OH)4SO4	-19.0	-18.9	-13.5	-18.4
6016001	Cd3OH2(SO4)2	-20.3	-20.4	-15.3	-21.4
6016002	Cd4(OH)6SO4	-17.9	-17.8	-10.4	-16.6
6016003	CdSO4	-10.8	-10.8	-9.3	-11.7
6016004	CdSO4:1H2O	-8.9	-9.0	-7.4	-9.9
6016005	CdSO4:2.67H2O	-8.6	-8.7	-7.1	-9.5
6023100	ANTLERITE	-2.6	-6.1	-5.9	-7.5
6023101	BROCHANTITE	-4.0	-8.6	-8.2	-10.0
6023102	LANGITE	-5.7	-10.3	-10.0	-11.8
6023103	CuOCuSO4	-13.7	-16.1	-16.1	-17.6
6023104	CuSO4	-13.3	-14.5	-14.7	-16.0
6023105	CHALCANTHITE	-6.7	-7.9	-8.1	-9.4
6046000	EPSOMITE	-3.8	-3.6	-3.6	-4.2
6047000	MnSO4	-10.6	-10.2	-9.1	-11.2
6060000	LARNAKITE	-2.4	-2.3	3.9	-5.0
6060001	Pb3O2SO4	-7.0	-6.8	2.7	-10.0
6060002	Pb4O3SO4	-11.7	-11.3	1.5	-15.1
6060003	ANGLESITE	-1.9	-1.9	1.0	-4.0
6060004	Pb4(OH)6SO4	-9.1	-8.7	4.0	-12.5
6095000	Zn2(OH)2SO4	-6.1	-7.3	-2.7	-6.4
6095001	Zn4(OH)6SO4	-8.4	-10.8	-1.1	-7.4
6095002	Zn3O(SO4)2	-28.8	-30.7	-23.9	-30.1
6095003	ZINCOSITE	-12.9	-13.6	-11.4	-13.9
6095004	ZnSO4:1H2O	-7.8	-8.5	-6.4	-8.8
6095005	BIANCHITE	-6.1	-6.8	-4.7	-7.1
6095006	GOSLARITE	-5.7	-6.4	-4.2	-6.7

Input chemistry shown in Table 4

TABLE 6
Input Data for Main Zone Pit Discharge and Camp Creek Mizing Model

Parameter	Main Zone Portal June 1999	MH4
pH	6.9	8.15
Alkalinity	23	141
Sulphate	183	15.6
Al	<0.005	<0.05
Sb	0.0004	<0.02
As	<0.0001	<0.04
Ba	0.012	<0.01
Be	<0.001	<0.001
Cd	0.363	0.0007
Ca	49	61.7
Cr	<0.001	#N/A
Co	0.011	#N/A
Cu	0.002	0.0064
Pb	0.345	0.0127
Li	<0.01	#N/A
Mg	1.55	1.39
Mn	0.351	0.0041
Mo	<0.001	0.0049
Ni	<0.001	0.0041
K	0.75	#N/A
Se	0.003	<0.02
Ag	<0.0001	<0.01
Sr	0.059	#N/A
Tl	<0.001	#N/A
Sn	<0.001	#N/A
U	0.00004	#N/A
V	<0.005	#N/A
Zn	40.6	0.0194

Concentrations in mg/L

MH4 data are from unfiltered samples determined as average of low non-detectable TSS results.

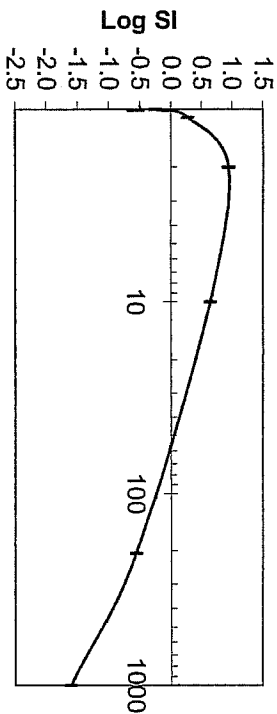
TABLE 7
Calculated Chemistry for Mixed Main Zone Pit Water and Camp Creek

Parameter	Mixed mg/L	Equilibrated mg/L	Removal %
pH		7.9	
SO ₄	86	86	0
Mn	0.149	0.149	0
Ca	56	113	101
Cu	0.005	0.005	-1
Mg	1.5	1.4	-1
Pb	0.15	0.04	-74
Zn	17	2.8	-84
Cd	0.2	0.08	-46
Alkalinity	92	120	30

Equilibrated chemistry assumes that calcite, hydrocerrusite, smithsonite, ZnCO₃.H₂O and otavite are present.

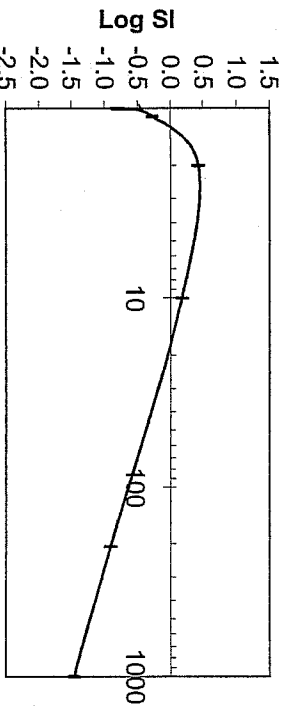
FIGURES

Log SI vs Mix Ratio for $ZnCO_3 \cdot H_2O$



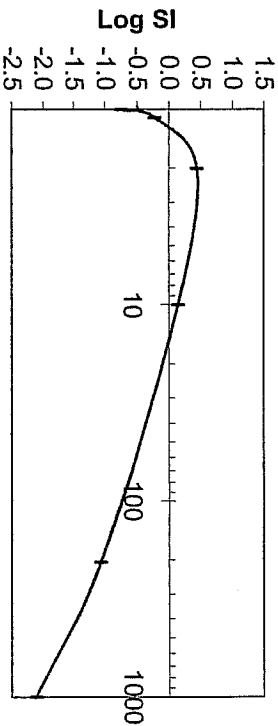
Mix Ratio

Log SI vs Mix Ratio for Otavite

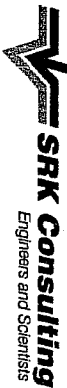


Mix Ratio

Log SI vs Mix Ratio for Smithsonite



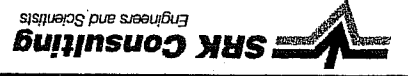
Mix Ratio



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2000 GEOCHEMICAL STUDIES			
SA DENA HES MINE			
SATURATION INDICES FOR MIXED			
CAMP CREEK AND MAIN ZONE WATER			
Project	Date	Approved	Figure
1CC005.08	Oct 2000		4

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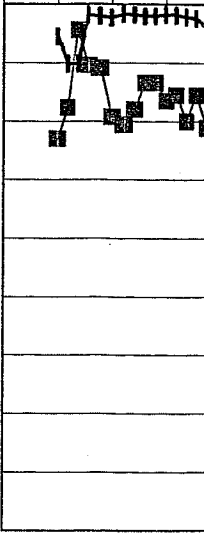
2000 GEOCHEMICAL STUDIES SA DENA HES MINE

Results of Summer 2000

Monitoring - Main Zone Pit

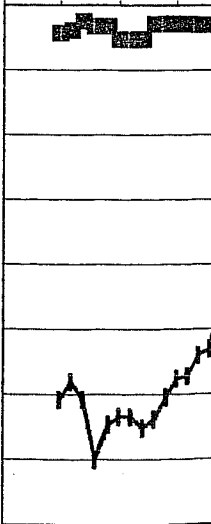
Project	Date	Approved	Figure
IC005.04	Oct 2000		3

0 00 00 00 00
8/1/20 8/1/20 8/1/20 8/1/20 8/1/20



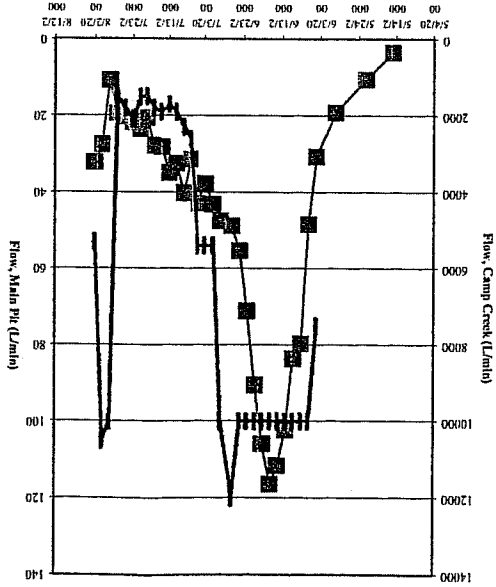
te Loads

0 0 0
7/13/00 7/13/200 8/2/2000 8/1/2/00



centrations

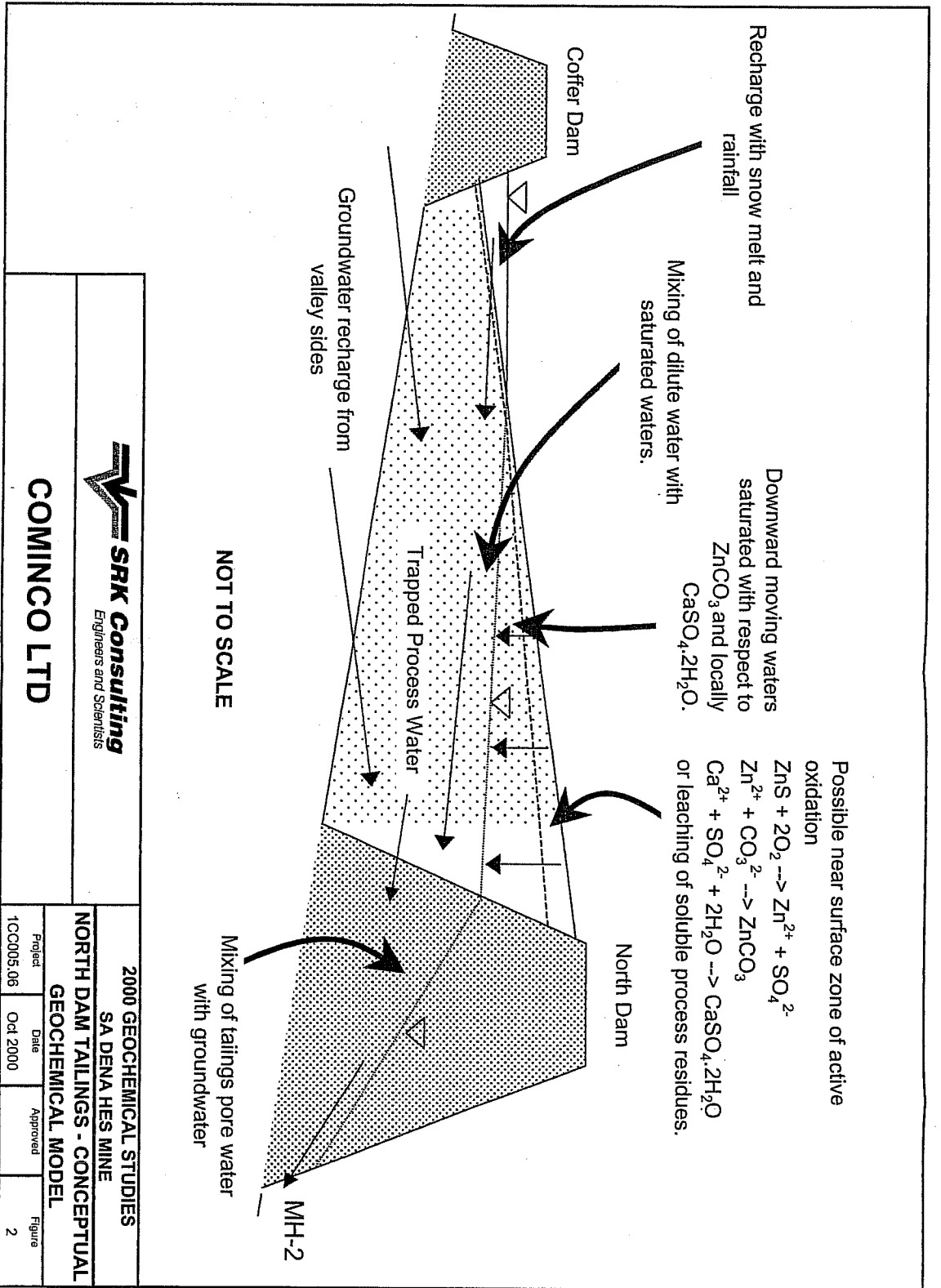
—■— Camp Creek
—+— Main Zone Pit



—+— Main Zone Pit
—■— Camp Creek

—■— Camp Creek
—+— Main Zone Pit

Flows



SRK Consulting
Engineers and Scientists

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2000 GEOCHEMICAL STUDIES			
SA DENA HES MINE			
NORTH DAM TAILINGS - CONCEPTUAL			
GEOCHEMICAL MODEL			
Project	Date	Approved	Figure
1CC005.06	Oct 2000		2

APPENDIX A
Work Plan

MEMORANDUM

DATE: April 15, 2000

TO: Bruce Donald, Cominco

FROM: Peter Healey
Stephen Day

PROJECT: 1CC005.05

RE: **SÄ DENA HES ACTIVITIES FOR SPRING/SUMMER 2000**

As requested, this memorandum provides SRK's recommendations for activities to address issues identified during preparation of the Closure Plan last year. We understand the items were:

1. Confirm that the discharge from the Main Pit (1380 Portal) is ephemeral and evaluate the impact on Camp Creek.
2. Evaluate the zinc in seepage from the North end of the tailings impoundment
3. Evaluate zinc attenuation in the Burnick Portal discharge

Proposed site activities to address these issues are described below.

1. MAIN PIT DISCHARGE

The Main Pit discharge was observed during our site visit, but the estimated Zn load in the discharge was not consistent with the load in Camp Creek. We suggested the discharge was a short duration event, which would not be recognized as an instantaneous load in Camp Creek. The objective of the proposed work is to evaluate this hypothesis. The following tasks could be completed by Randy Flanagan (except Task 1.5, which would be conducted by SRK during the North Dam seepage assessment).

- 1.1. Inspect the 1380 portal every other day as soon as melting is observed at lower elevations. A pit may need to be dug in the snow at the portal to detect flow under the snow.
- 1.2. When discharge is observed, collect water samples for total and dissolved metal analysis every other day until the discharge stops. Determine field pH and electrical conductivity during sampling.

- 1.3. Estimate the flow during sampling. The flow may be estimated in an ice channel in the mouth of the portal by estimating the velocity and flow cross-section.
- 1.4. Collect water samples and measure flow in Creek Camp at MH-04 every week (starting immediately) until 1380 portal discharge is observed and every other day when flow is observed at the pit, and continue sampling very other day for two weeks until after pit discharge stops.
- 1.5. Inspect the area above the pit to identify the possible source of the portal discharge. Conduct dye tests if candidate sources are identified.
- 1.6. Ship samples for analysis of sulphate and zinc as a priority.
- 1.7. Report field results to SRK weekly.
- 1.8. Interpretation and reporting

2. NORTH DAM SEEPAGE

Zinc concentrations in the North Dam seepage decreased in 1999 following several years of increase. Sulphate concentrations did not decrease. It is expected that seepage from the dam originates as tailings pore water.

The field program would attempt to characterize zinc concentrations in tailings pore water and mineral solubility controls on metal concentrations.

SRK/Randy, as indicated would complete the following tasks. This work would be done in late May/early June to coincide with monitoring the main pit discharge.

- 2.1. Install shallow piezometers (approximately 12) in the North Dam beach. To reduce costs, these will be installed by pushing slotted 25 mm diameter stainless tubing using a backhoe. It is assumed that the depth will be no more than 3 m (SRK/Randy).
- 2.2. Collect and analyze samples from tailings profiles for chemical analysis and determination of weathering products (SRK).

2.3. Sample the piezometers (SRK) following installation. Analyze waters for pH, EC and redox potential during sampling, and dissolved metals, pH, EC and conductivity.

2.4. Sample the piezometers monthly through the summer (Randy).

2.5. Reporting

3. ZINC ATTENUATION - BURNICK PORTAL DISCHARGE

DIAND review of the Closure Plan indicated some concern that attenuation of zinc is occurring and that higher zinc loads may be observed downstream at some time in the future. The purpose of this work would be to estimate whether zinc load is currently being attenuated.

The Burnick discharge goes underground in the waste rock dump and is therefore a diffuse flow. This precludes determining zinc load loss or conservation at locations downstream by simple flow and water chemistry monitoring. The suggested approach is to use a tracer to obtain a flow balance. For example, if the concentration of a conservative tracer added to the discharge at the top of the dump is maintained at locations downstream, it implies that the flow volume has not increased. If the tracer concentration decreases, the increase in flow volume can be estimated. This flow can be applied to measured zinc concentrations to estimate zinc load at locations downstream of the site.

Randy could conduct the tracer test with assistance from SRK during the site visit.

COST ESTIMATE

Estimated costs are shown in Table 1 (not attached). The cost estimate assumes:

- Majority of task 1 item conducted by site caretaker.
- SRK will conduct indicated items.
- One site visit is included (approximately 1.5 mob/demob days, 7 field days, 2 travel days)
- The cost for a backhoe capable of travelling on the tailings beach and pushing a tube into the tailings is not included.
- Equipment costs cover (to be filled in)
- Water analysis costs are not included.
- Solids tailings analysis will include soluble metals analysis and SEM examination to evaluate formation of secondary minerals.

APPENDIX B
Tailings Mineralogical Report



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FAX TRANSMITTAL FORM

TO:	Steve Day	AT:	SRK Vancouver
COPY TO:		FAX No:	Auto
FILE REF:	U1636 Sa Dena Hes\1636bowc01_days.doc	DATE:	23 August 2000
FROM:	Rob Bowell	Page 1 of	5 (including this page)
SUBJECT:	Sa Dena Hes tailings (DEACT)		

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MINERALOGY OF THREE TAILINGS SAMPLES, SA DENA HES

1. INTRODUCTION

Three tailings samples were submitted for mineralogical analysis to SRK Consulting in Cardiff. These samples are from the Sa Dena Hes deposit and are splits from tailings samples currently being evaluated for acid generation and metal leaching characteristics. This work is being supervised by Steve Day, SRK Consulting-Vancouver, who also selected the samples to be submitted for mineralogical analysis.

The aims of the mineralogical work were:

- Determine the presence of Zn and Cd secondary minerals and/or mineralogical controls on Zn and Cd solubility
- Determine the mineralogical control(s) on the low Pb solubility from the tailings
- Identify any further sulfides or metal-bearing secondary minerals in the tailings

2. SAMPLE MINERALOGY

A summary of the minerals observed in this study and recorded in each of the samples is given in Table 1.

Swfen, Robertson and Kirslen (UK) Ltd
Registered in England and Wales
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Also At:
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Hes\1636bowa01_daya.doc

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Page 2

Table 1: Summary mineralogy of Sa Dena Hes tailings

Mineral/phase	<i>DPO Shallow</i>		
	Section 02441	Section 02446	Section 02455
Actinolite	**	*	*
Anglesite	*	**	*
Boulangerite	*		
Bourmonite	*		
Calcite	***	***	***
Chlorite	**	**	**
Dolomite	**	*	*
Galena	**	**	**
Goethite	**	**	**
Gypsum	***	***	***
Hemimorphite	*	*	*
Marcasite	**	*	*
Minium	*	*	*
Muscovite	**	**	*
Pyrite		*	*
Quartz	***	***	***
Sphalerite (Cd- Fe)	**		
Sphalerite	*	**	**
Smithsonite(Cd bearing)	**	*	
Smithsonite (no Cd)	*	*	**

- *** major mineral (>10% of observed phases)
- ** minor mineral (0.5-10% of observed phases)
- * trace mineral (<0.5% of observed phases)

3. SOLUBILITY CONTROLS ON ZINC

Several zinc minerals were observed in the samples with the dominant one being smithsonite (ZnCO₃). Smithsonite and sphalerite are considered to be the main controls on zinc solubility from the tailings.

4. SOLUBILITY CONTROLS ON CADMIUM

Discrete cadmium minerals were not observed in any of the sections. However cadmium was observed as being present in solid solution with zinc minerals, sphalerite and smithsonite and it is believed that these, particularly the latter that control cadmium solubility.

5. SOLUBILITY CONTROLS ON GALENA

The two dominant lead minerals have extremely low solubilities (gypsum and anglesite) especially when compared to lead carbonate, cerussite, or smithsonite.

Table 2: Summary of mineral phase solubility

Phase	Solubility product, K_{sp} (mol/m ³)
CaCO ₃	4.8×10^{-9}
ZnCO ₃	1.1×10^{-10}
PbCO ₃	1.6×10^{-11}
ZnS	1.8×10^{-24}
PbSO ₄	1.6×10^{-16}
PbS	1.3×10^{-28}

Due to these low solubilities both lead phases are still present in the waste and are unlikely to alter too much during the leaching program.

6. CONCLUSIONS

Mineralogical controls are exerted over the solubility of Zn, Cd and Pb in the Sa Dena Hes tailings.

For zinc and cadmium, the same control is in operation that being sphalerite and smithsonite and possibly in places hemimorphite.

For lead both galena and anglesite control element solubility and both of these minerals are present in sufficient concentration in all samples to dominate the behaviour of lead. Bourmonite and boulangerite although present would have a negligible control over lead solubility.

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Steve XRD results
largely confirm optical mineralogy
spinel not finished - will send images +
Fax trace tomorrow by
courier

To: ROB BOWELL From: TONY O'ROLOYD
Date: 23/08/00
Fax No: 20665413 No. of pages (including cover sheet): 2



Rob,
Here are the results for project 1636. For speed's sake, I've hand written them for you but I will type them up when I send you the full set of results.

SAMPLE 02441

- 47% CALCITE
- 22% QUARTZ
- 21% HEDENBERGITE (amphibole - clinoclase)
- 5% DOLOMITE
- 3% CLINOCTASE (chlorite)
- 2% ILLITE

POSSIBLE TRACE AMOUNTS OF SPINELITE

SAMPLE 02446

- 59.5% CALCITE
- 27% QUARTZ

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Cardiff University is the public name of the University of Wales, Cardiff, a constituent institution of the University of Wales.

(SAMPLE 02454 CONTINUED)
9% HYDROBURGITE
2% ILLITE
2% DOLOMITE
0.5% ILLITE

SAMPLE 02455

71% CALCITE
13% QUARTZ
12% HYDROBURGITE
4% DOLOMITE

Again I stress these are semi-quantitative results.

All the best.

Larry

APPENDIX C
Tailings Porewater Chemistry

Client : SA DENA HES
 Project : SDH
 Philip ID :
 Client ID :

10048400 10044623 10044624 10044625 10044626 10044627 10044628
 DP 02 DP 02 DP 03 DP 04 DP 05 DP 06 DP 07

Sparcode	Parameter	Unit	MDL							
PHYSICAL										
41220	pH	pH units	0.1		7.3	7.9	7.7	7.6	7.8	7.7
111160	Specific Conductance	uS/cm	1		1640	1260	1430	1350	1380	2330
1107CALC	Hardness Total -D	mg/L			841	616	686	615	761	1460
SULFATE										
11211405	Sulfate	mg/L	1		906	668	761	699	786	1570
METALS DISSOLVED										
Al-D0031	Aluminum Dissolved	mg/L	0.02		0.03	0.03	0.04	< 0.02	< 0.02	< 0.02
Sb-D0031	Antimony Dissolved	mg/L	0.05		< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
As-D0031	Arsenic Dissolved	mg/L	0.05		< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Ba-D0031	Barium Dissolved	mg/L	0.001		0.021	0.021	0.022	0.022	0.017	0.015
Be-D0031	Beryllium Dissolved	mg/L	0.0002		< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Bi-D0031	Bismuth Dissolved	mg/L	0.05		< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
B-D0031	Boron Dissolved	mg/L	0.008		0.047	0.029	0.047	0.067	0.041	0.055
Cd-D0031	Cadmium Dissolved	mg/L	0.002		0.013	0.022	0.015	0.008	0.01	0.126
Ca-D0031	Calcium Dissolved	mg/L	0.05		292	220	236	211	253	501
Cr-D0031	Chromium Dissolved	mg/L	0.005		0.005	< 0.005	0.005	< 0.005	< 0.005	< 0.005
Co-D0031	Cobalt Dissolved	mg/L	0.005		0.006	0.009	0.028	0.015	< 0.005	0.09
Cu-D0031	Copper Dissolved	mg/L	0.005		0.041	< 0.005	0.009	< 0.005	< 0.005	< 0.005
Fe-D0031	Iron Dissolved	mg/L	0.005		0.129	0.033	0.137	0.073	0.082	0.013
Pb-D0031	Lead Dissolved	mg/L	0.03		0.2	0.13	0.23	0.07	0.3	0.1
Mg-D0031	Magnesium Dissolved	mg/L	0.05		27.1	16.1	23.5	21.3	31.5	51
Mn-D0031	Manganese Dissolved	mg/L	0.001		2.5	1.9	3.77	10.9	5.2	59.8
Mo-D0031	Molybdenum Dissolved	mg/L	0.005		0.007	0.006	0.01	0.007	0.015	0.006
Ni-D0031	Nickel Dissolved	mg/L	0.008		0.014	0.012	0.021	0.017	< 0.008	0.329
P__D0031	Phosphorus Dissolved	mg/L	0.1		< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
K__D0031	Potassium Dissolved	mg/L	1		10	8	10	12	7	13
Se-D0031	Selenium Dissolved	mg/L	0.03		< 0.03	0.04	< 0.03	< 0.03	0.03	< 0.03
Ag-D0031	Silver Dissolved	mg/L	0.01		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Na_D0031	Sodium Dissolved	mg/L	0.05		52.7	36.1	59	49.6	13.2	3.63
Sr-D0031	Strontium Dissolved	mg/L	0.001		0.77	0.512	0.836	0.57	1.2	1.02
S__D0031	Sulfur Dissolved	mg/L	0.1		320	229	262	244	257	528
Te-D0031	Tellurium Dissolved	mg/L	0.05		< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Tl-D0031	Thallium Dissolved	mg/L	0.03		< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Sn-D0031	Tin Dissolved	mg/L	0.02		< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Ti-D0031	Titanium Dissolved	mg/L	0.003		< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
V--D0031	Vanadium Dissolved	mg/L	0.005		< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Zn-D0031	Zinc Dissolved	mg/L	0.005	0.275	0.594	0.358	0.418	0.391	0.391	27.1
Zr-D0031	Zirconium Dissolved	mg/L	0.005		< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005

Matrix : Water Water Water Water Water Water
 Sampled on: 00/07/22 00/07/22 00/07/22 00/07/22 00/07/22 00/07/22
 Sampled at:

