WATER TREATMENT SLUDGE CHARACTERIZATION

AND

DISPOSAL PLAN

prepared for

003158

Curragh Inc.

Project No. L.R. 4400

NOTE:

This report refers to the samples as received.

LAKEFIELD RESEARCH
A DIVISION OF FALCONBRIDGE LIMITED
January 22nd, 1993

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ABSTRACT

Curragh Inc. operates a water treatment plant to remove soluble metals from acid drainage associated with mining operations on the Vangorda Plateau near Faro, Yukon. Under Part E.1 (a) of water license IN89-002, Curragh is required to develop a disposal plan for the treatment plant sludge.

At Curragh's request, Lakefield Research sampled the sludge on Dec. 1, 1992 and performed characterization tests. The sludge is 83 percent calcium carbonate. The principal metal contaminant, zinc, is present in the amount of 2 percent. Leachability tests show that in the neutral pH range of 8.0 to 7.0, leachate zinc will fall in the range of 0.5 to 25 mg/L.

The sludge volume is small and therefore manageable. Repositories such as the Vangorda Pit should be avoided because the potential volume of water, Vangorda Creek, which may become sludge contaminated, is high. Deposition of the sludge adjacent to or within the Vangorda Waste Cells could limit sludge effluent contamination to the relatively small and similarly contaminated exfiltration flows from the Waste Cells.

This point in time is early in the development of the treatment plant sludge bed. The characterization presented in this report is the first carried out. Ongoing sludge bed profiling and characterization should be planned to ensure that the predictions of this report are valid and to detect possibly important changes in sludge character.

INTRODUCTION

Curragh Inc. (Curragh) operates a water treatment plant as part of mining operations on the Vangorda Plateau near Faro, in the central Yukon Territory. The treatment plant employs lime to neutralize acidity and remove heavy metals from acid rock drainages associated with the Grum and Vangorda open pits. Precipitates of calcium carbonate ($CaCO_3$) and heavy metal hydroxides are captured and retained in a sedimentation pond. At certain intervals, which will depend on the amount of water treated and the quantity of precipitate generated, the sedimentation pond will fill and sludge will have to be removed to an alternate site or otherwise disposed. Under Part E.1 (a) of Curragh's water license IN89-002, Curragh is required to develop a sludge disposal plant. In November 1992, Lakefield Research was requested to sample the sedimentation sludge, characterize the sludge and develop a sludge disposal plan. This documents presents the results of the testwork and the recommendations resulting from it.

LAKEFIELD RESEARCH

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SUMMARY

1. Background

In 1992, Cominco Engineering Services Ltd. (CESL) under contract to Curragh, developed a Sludge Stability Study Plan. This plan identified certain knowledge required for the design of secondary and long term sludge storage:

- sludge density as settled
- sludge density after freeze/thaw
- permeability as settled
- permeability after freeze/thaw
- detailed chemical composition
- leachability of the sludge components as settled
- leachability of the sludge components after freeze/thaw

The CESL plan also included certain recommendations with respect to sampling and laboratory procedure.

2. Sampling

Sludge samples were taken on December 1, 1992. The sedimentation pond was frozen over with an ice cap of about 20 inches. Initially three holes were drilled with an ice auger and 'sounded' using a length of 3/4" plastic pipe. The approximate location of the holes is shown in Figure 1. At location 1, the pond floor was probed. No sludge could be 'felt' and no sludge was retrieved by the pipe probe. At location 2, the bottom of the pond could not be reached because of what felt like a sub-layer of ice. This could well have been a remnant of ice which remained in place when the pond level was raised about two weeks before the sampling was done. At location 3, an obvious sludge bed was encountered having a depth of 1 to 1 1/2 metres. Visual assessment before freeze-up by Curragh personnel had indicated that sludge deposition was confined to a relatively small delta emanating from the pond inflow. The limited assessment possible under the conditions prevailing at the time of sampling, tended to confirm that view. Accordingly, the entire sample was taken at location 3.

Samples were taken using a WILDCO model 196T sediment dredge. The 196T is box-like with dimensions of 6" x 6" x 9" long. The claws, spring loaded, are released by a messenger which travels the security/retrieval rope. At location 3, ice and water over sludge was about 16 feet By allowing the dredge about 10 feet of free fall, the dredge would penetrate the sludge bed and fill with sludge. Roughly 15 gallons of sludge was taken and split into two fractions. One fraction was couriered to Lakefield Research for characterization. The remaining half was retained at the Faro site against possible loss or spoilage of the Lakefield shipment.

3. Sludge Characterization

Sludge characterization generally followed the CESL recommendations with slight departures in the leachability evaluations. All of the leach tests were done with a modified SWEP procedure using 1:1 H_2SO_4/HNO_3 instead of acetic acid. In addition, the acid addition limit specified in the SWEP procedure was exceeded to generate more information as to potential leachate content.

3.1 Solids

The sludge as received at Lakefield Research was 19.6% solids. After settling/compacting for two days, the % solids increased to 23.7. It is interesting to note that sludge after a freeze/thaw cycle compacted to only 22.2% solids. In percolation tests, the sludge compacted to about 26.5% solids after only 5 hours. Since the sedimentation pond is also in a percolating mode, we suspect that the insitu sludge density approaches 30% solids.

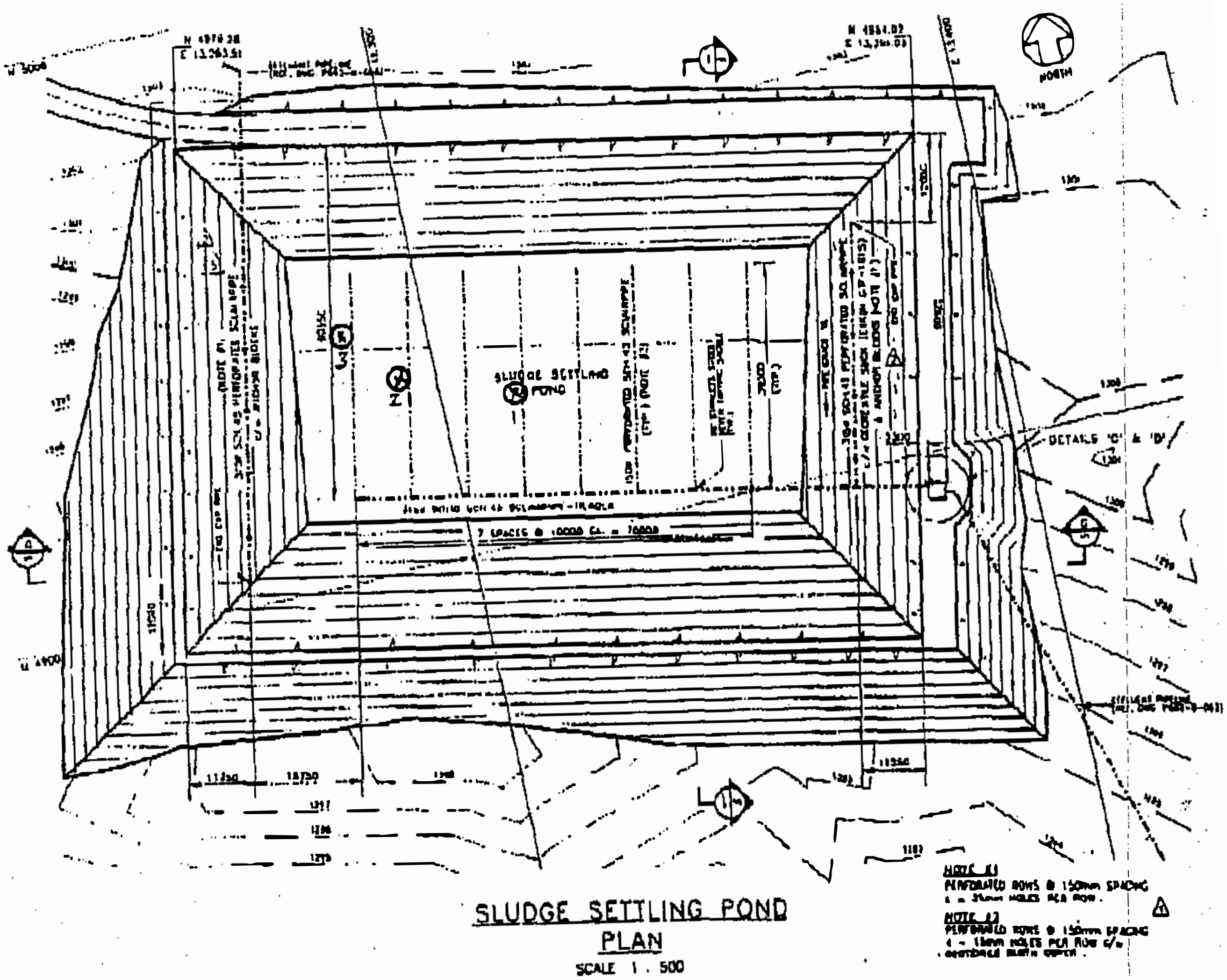
3.2 Percolation Rates

Sludge as received had a measured percolation rate of about 0.47 cm/hr. After freeze/thaw, the rate dropped to about 0.22 cm/hr. If the entire pond bed were covered with a 0.47 cm/hr sludge, the exfiltration rate would be roughly 100 gpm. This is substantially less than the design rate and about half the current estimate of exfiltration rate. No impact is expected on the accumulated sludge volume or character. For maximum exfiltration, sludge in the sedimentation pond should not be allowed to freeze/thaw.

FIGURE 1

Sampling

⊗ Approximate Location of Sampling Sites, Dec. 1, 1992



SLUDGE SETTLING POND
PLAN
SCALE 1 : 500

3.3 Chemical Analyses

Element		Cu	Pb	Zn	Fe	Cd	As	Mg	Al
Concentration	%	0.016	0.009	2.07	0.29	0.008	0.002	1.84	0.43
Duplicate	%	0.017	0.008	2.05	0.27	0.008	0.003	1.83	0.43

Element		SO_4	CO_3	Ca
Concentration	%	0.40	50.0	32.7
Duplicate	%	0.54	50.5	32.5

The sludge is roughly 83% $CaCO_3$ and as such has a very high buffering capacity in the neutral pH region. The high carbonate content may also explain the deleterious effect of freeze/thaw on the sludge density and percolation rate. Metal hydroxides become less gelatinous after freeze/thaw which results in higher settled densities and percolation rates. In this case, the carbonate precipitate particles which are already compact, may actually be breaking down after freeze/thaw.

3.4 Leachability

In order to generate data revealing actual leach potential on exposure to acid rock drainage and acid rain, modified SWEP procedure was used substituting 1:1 H_2SO_4/HNO_3 for acetic acid. Also, the rate of acid addition, limited by the SWEP procedure, was exceeded. For all tests, 50 grams (dry) sludge was leached.

Leachate	Leach pH		mLs 5N	Analyses - mg/L					
	Initial	Final	H_2SO_4/HNO_3	Cu	Pb	Zn	Fe	Cd	As
As Received	9.5	9.5	-	0.02	0.05	0.02	0.02	0.01	0.05
Fr/Thaw	9.5	9.5	-	0.02	0.05	0.02	0.02	0.01	0.05
As Received	7.0	7.1	6.6	0.02	0.05	33.5	0.02	0.01	0.05
As Received	7.0	7.1	7.4	0.02	0.05	40.5	0.02	0.01	0.05
Fr/Thaw	7.0	7.1	6.8	0.02	0.05	36.0	0.02	0.01	0.05
Fr/Thaw	7.0	7.1	6.6	0.02	0.05	27.6	0.02	0.01	0.05
As Received	5.5	5.7	43.0	0.27	0.05	740	0.02	0.37	0.05
As Received	5.5	5.7	45.8	0.24	0.05	681	0.02	0.37	0.05
Fr/Thaw	5.5	5.8	41.4	0.24	0.05	688	0.02	0.28	0.05
Fr/Thaw	5.5	5.7	39.8	0.25	0.05	720	0.02	0.30	0.05
As Received	4.5	5.3	89.8	1.01	0.05	953	0.02	1.90	0.05
Fr/Thaw	4.5	5.3	84.9	0.86	0.05	900	0.02	1.72	0.05
SWEP Limit	5.0 ± 0.2		20.0	100	5.0	500	N/A	0.50	5.0

Freeze/thaw seems to have resulted in marginally lower extractions of the hydroxides but not enough to attach real significance. In Figures 2 and 3, leachate zinc and acid consumption are plotted against pH. At acid consumption roughly equivalent to SWEP procedure, leachate zinc would have been in the range of 350 to 400 mg/L. In spite of the high buffering capacity of the carbonates, the mobility of Cu, Cd and Zn is fairly high and in the particular case of zinc, roughly theoretical. Evidently, the carbonates and hydroxides have not co-precipitated in a manner which protects the hydroxides. It is apparent that iron is present as Fe^{+3} or is otherwise immobile. Our interpretation of these results is that even at neutral pH levels, the zinc is sufficiently mobile to warrant careful management of the sludge.

4. Sludge Volume

Using the estimated volume of water treated during 1992, the zinc content, sludge analyses and sludge density, the weight and volume of sludge generated in 1992 is estimated:

Total volume of water treated	90×10^6 US gal
Estimated Zn precipitated	3.5 tonnes
Weight of sludge at 2.06% Zn	170 tonnes
Volume of sludge (dry basis)	61 m^3
% solids	30 %
Volume of water with sludge	399 m^3
Sludge volume at 30% solids	460 m^3

While this sampling campaign did not allow sludge bed profiling, the estimated sludge volume corresponds roughly to the delta shaped sludge bed observed before freeze-up by Curragh personnel. Pond capacity, filled to a depth of 2 metres would exceed 10,000 m^3. At the present rate of sludge production, even allowing for Grum coming on-stream, it could be nominally ten years before de-sludging of the pond is required.

However, because the sludge settles so quickly, distribution problems and thus a necessity to de-sludge, may well develop before that time.

FIGURE 2

MODIFIED SWEP TEST RESULTS

VANGORDA WATER TREATMENT

SLUDGE

DEC. /92

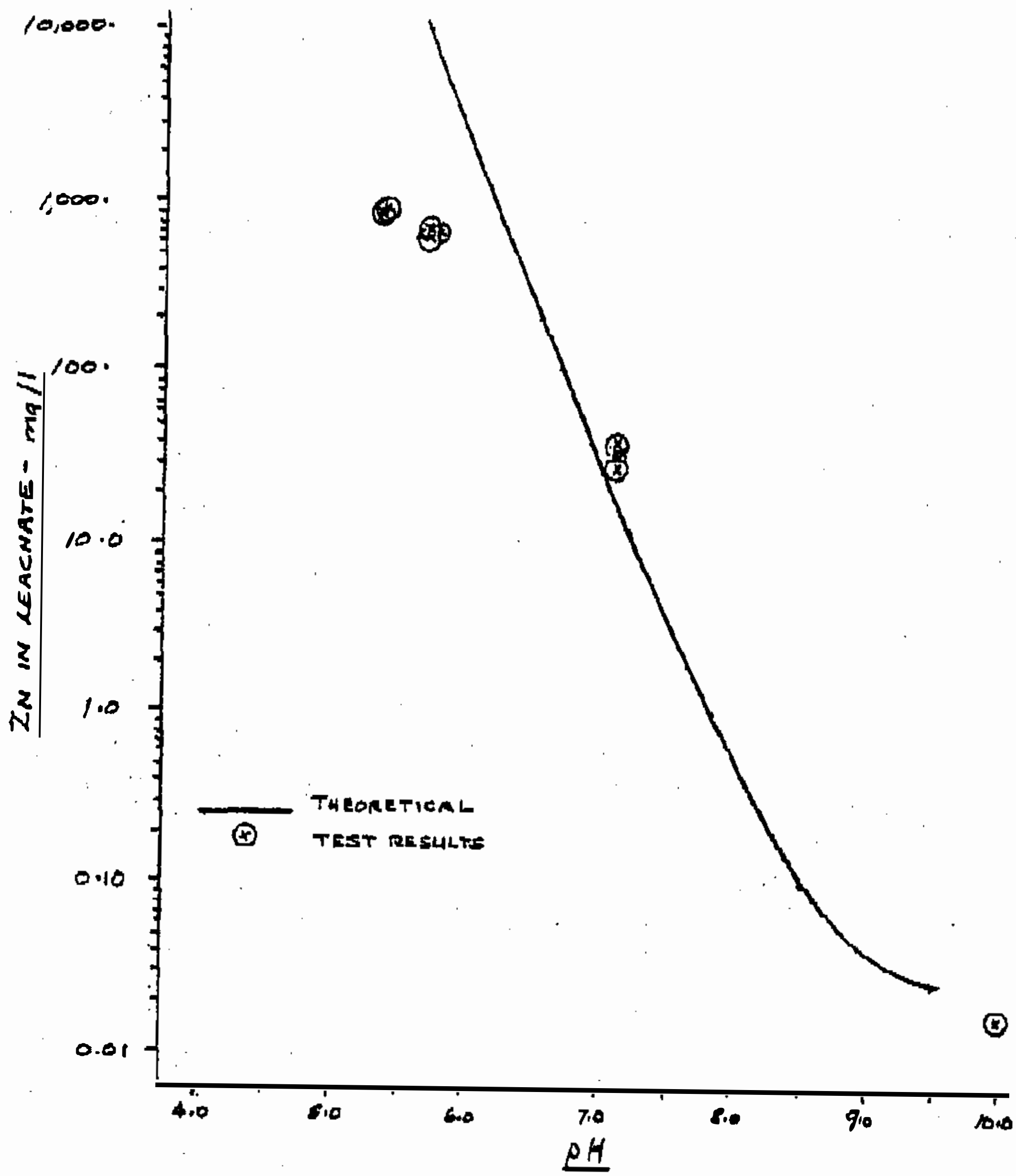
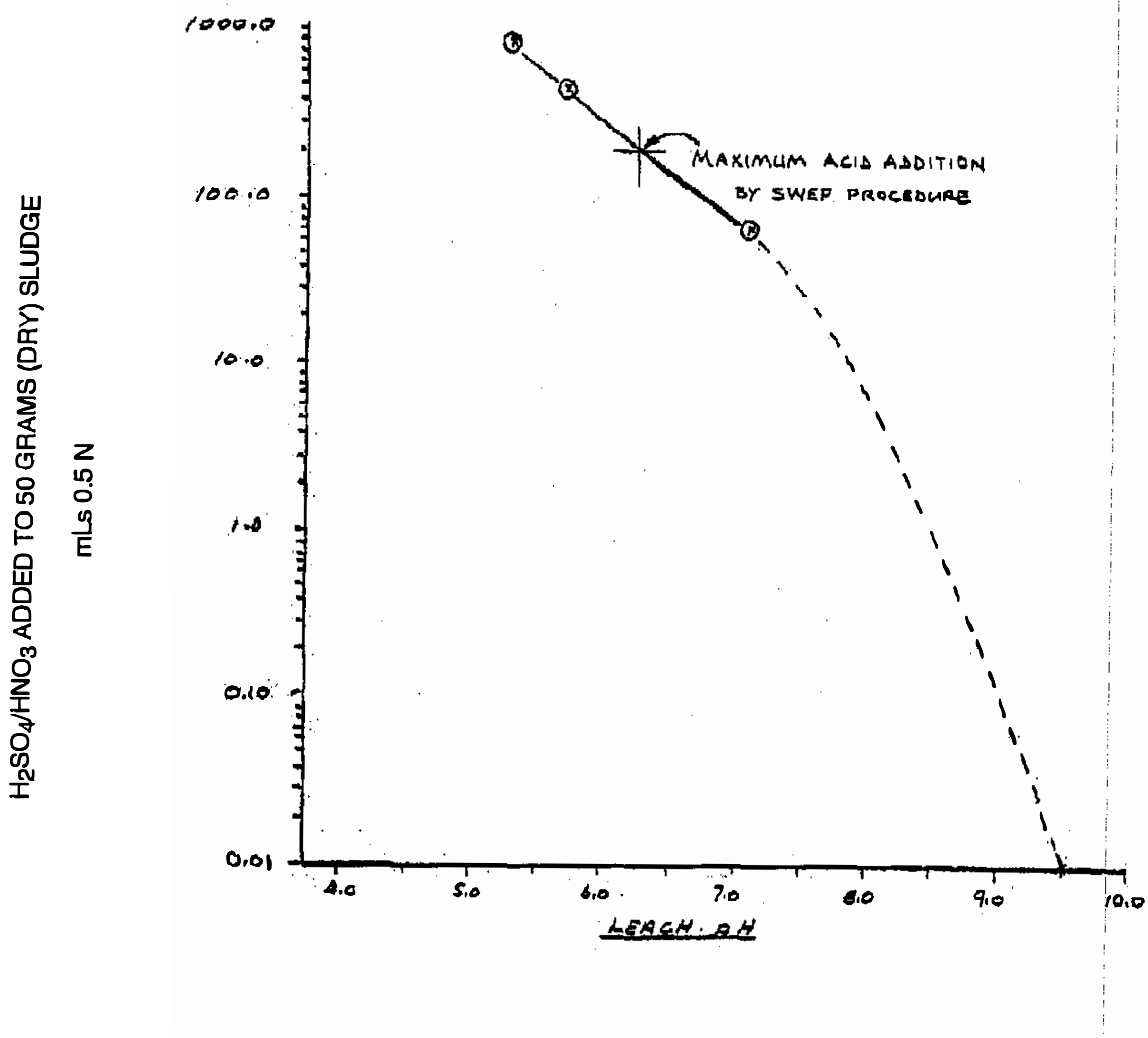


FIGURE 3

MODIFIED SWAP TESTS

ACID CONSUMPTION



5. Sludge Disposal Options

Sludge disposal options commonly considered but not necessary applicable to the Curragh situation are:

1) Burial insitu, with additional protective alkalinity added and contoured with natural and/or synthetic air/water barriers.

2) Retreatment to produce useful products.

3) Solidification using cement or proprietary mixes such as ChemFix.

4) Shipment off-property with concentrate where the sludge analysis is compatible.

5) Storage on-site in sub-aqueous or sub-aerial locations such as spoil piles, abandoned pits or the like.

Burial insitu is inappropriate since the sedimentation pond will most likely have to be de-sludged before abandonment is possible. That is, a disposal site other than the pond is inevitable. Retreatment does not offer much opportunity. There is not enough metal to warrant recovery. At 83% $CaCO_3$, the sludge could be burned to produce lime. However, the low tonnage offers no economy of scale and although the sludge compacts to 30% solids, filtration rates are very low. Solidification could be attractive in view of the low tonnage involved. However, the long term stability of solidification methods is not well defined and somewhat suspect. Shipment with concentrate is not an option in this case because the Zn grade is so low. Dilution of concentrate grade and the cost of transport would make this a high cost approach. In any event, shipment would not be available for on-going sludge production after milling operations cease.

Alternative storage on-site is the most practicable option. The apparent mobility of Cu, Zn and Cd in neutral leaching conditions suggests that a sub-aerial site would be preferred to a sub-aqueous one.

6. Sludge Disposal Plan

The water treatment plant is located on the Vangorda Plateau in the vicinity of the Vangorda Pit and Vangorda Waste Dump. The sludge is expected to be a generator of soluble zinc with levels in the order of 0.5 to 25 mg/L and should be placed within areas that re predicted to be like generators. Within the property boundaries there are several sites that are expected to generate zinc contaminated effluent. Examples are: the mill tailings area; the Faro Pit; the Grum Pit and Waste Piles, the Vangorda Pit and Waste Piles. An important limiting factor is transportation. The sludge, even at 30% solids, is sloppy and trucking sludges is liable to result in spillage along the truck route. For this reason, a disposal site should be chosen close to the present sedimentation pond so that pumping is a practical alternative to trucking. These criteria make the most logical choices the Vangorda Pit or the Vangorda Waste Piles.

Vangorda Plateau Development by Steffen, Robertson and Kirsten (B.C.) Ltd., 1990, presents a number of abandonment plans for the Vangorda Plateau. Predicted water quality and flows are:

Site	Mean Monthly Discharge L/sec	Mean Monthly Zinc Level mg/L
Vangorda Pit	20 - 30	1 - 5
Vangorda Sulphide Cell		
- Infiltration	0.33	29
- Run-off	1.08	0.03
Vangorda Phyllitic Cell		
- Infiltration	0.46	16
- Run-off	1.50	0.03

The plan further predicts water quality downstream of the mine and speculates on the possibility of passive wetlands water treatment. The probability is that active or passive, some form of treatment will be required, possibly in perpetuity. In planning the disposition of contaminated effluent generators, it is important to be able to isolate the most contaminated sources. Passive treatment is most likely to succeed with the lowest possible concentration of contaminants in the inflow. Thus it is possible to envisage that by active treatment of a relatively small concentrated flow, passive treatment may successfully handle the major volumetric flows or might not be required at all. For this reason we believe that the Vangorda Pit is an inappropriate sludge repository. We recommend that the sludge be placed in such a manner that run-off and exfiltration from the sludge can be combined with exfiltration from the waste cells.

The volume of sludge is relatively low and may reasonably be expected to be in the order of 10,000 m^3 or less over the next ten years. Placed 1 m deep, roughly 1 hectare would be required. The combined catchment areas for the Vangorda waste cells is estimated at about 40 hectares. By either creating separate sludge cells or mixing sludge with waste, effluent from the sludge could be limited to waste cell exfiltration. The extent to which the waste cells may eventually tum acid is not known. If the waste cell exfiltration is substantially lower than pH 7, rapid mobilization of the sludge heavy metals could occur. For this reason, creation of a separate cell for sludge is probably the preferred option. The area adjacent to the upstream, east, side of the waste cell is suggested as shown in Figure 4. Detailed design of the sludge cell is beyond the scope of this study and much depends on when and how remediation of the waste cells is undertaken.

RECOMMENDATIONS

- The treatment plant sludge storage effluent is expected to contain 0.5 to 25 mg/L Zn. The volume of sludge is relatively low and isolation of the sludge effluent should be easily accomplished.

- Placement of the sludge should be such as to allow effluent collection with similar effluents.

- Exfiltration effluent from the Vangorda waste cells is predicted to be similar to the sludge storage effluent.

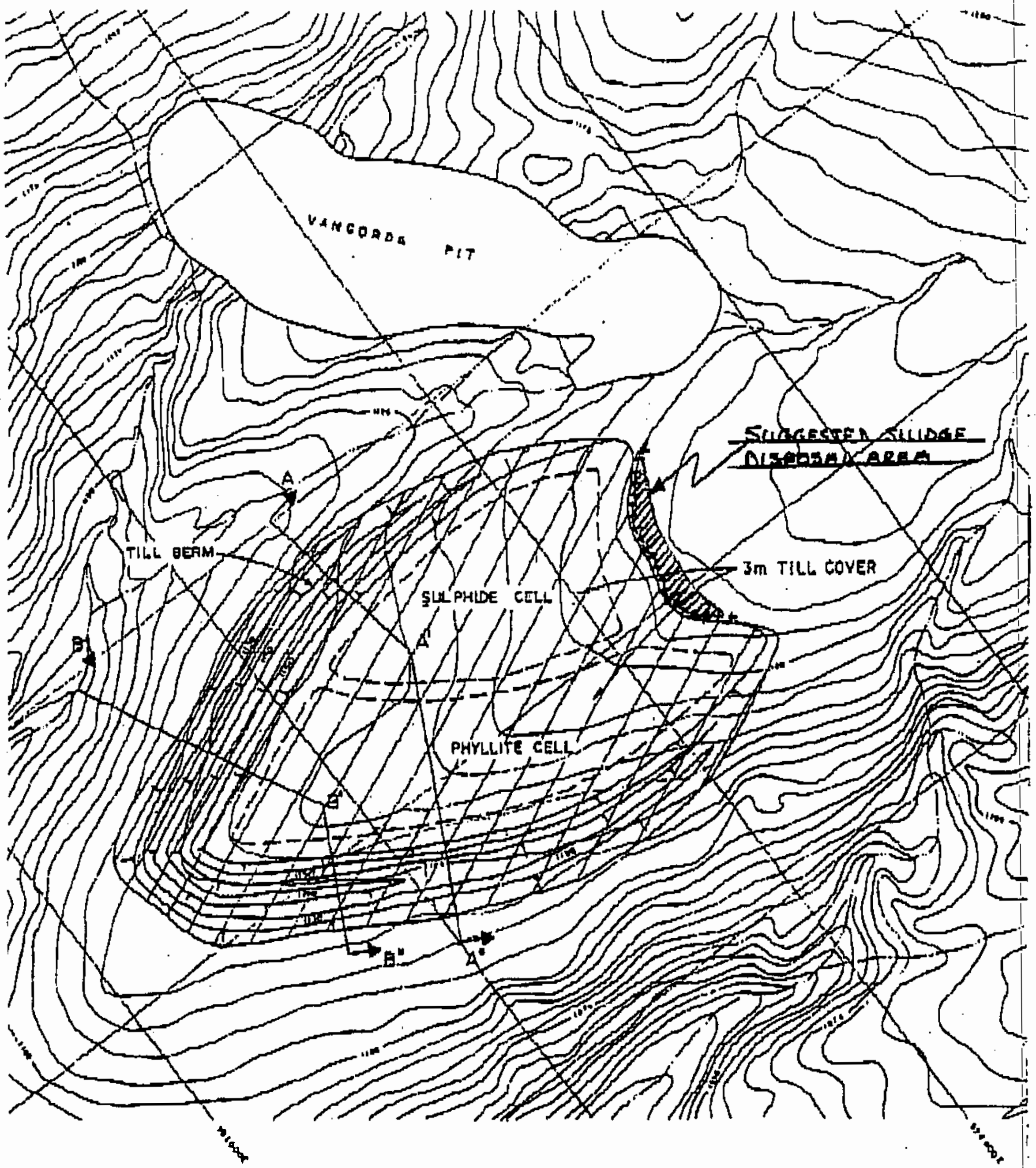
- Sludge storage in separate cells adjacent and upstream of the waste cells is appropriate.

- Further evaluation of the waste cell remediation plan and scheduling is required so that those plans can be integrated with sludge disposal design.

- Since sedimentation pond de-sludging is not expected to be required for some years, on-going sludge bed profiling and characterization should be undertaken to ensure that the predictions of this study are realized. It must be appreciated that this is the first sludge characterization undertaken and that changes may occur.

FIGURE 4

SUGGESTED SLUDGE DISPOSAL



APPENDIX I: Test Results

December 29, 1992

Project 4400

Curragh - Faro (Paul Shibley)

The percolation rate decreased after a single freeze thaw cycle.

Prior to freezing the percolation rate was 0.46 cm/hour. After freezing and thawing, the percolation rate had decreased to 0.20 cm/hour.

Project 4400 Date: Dec. 13, 1992 Operator: GC

Purpose: To determine percolation characteristics of a tailing product.

Procedure: Duplicate perc tests were conducted in tubes 45.7 cm long by 3.18 cm in diameter. Pulp was added unlformily at approximately 80% solids, and allowed to settle for 30 minutes. The Erlenmeyer flask, filled with room temperature water and closed with a stopper containing a glass tube was placed inverted over the tube, to supply water at a constant level.

Feed: Test A Tailing
Test B Tailing

Test Data and Results

Test	Time min	Mudline mL	H2O Ht mL	Void	Porosity	Hydraulic Gradient	Cum H2O mL	Ind H2O mL	H2O/h mL	Perc Rt cm/hour	SG	Dry Wt grams	Insitu SG
A	15	37.0	46.1	8.566	0.895	2.246	1.5	1.5	6.00	0.756	2.81	86.3	0.294
	30	36.8	46.1	8.514	0.895	2.253	3.7	2.2	8.80	1.108	2.81	86.3	0.295
	60	36.7	46.1	8.488	0.895	2.256	6.4	2.7	5.40	0.680	2.81	86.3	0.296
	90	36.2	46.1	8.359	0.893	2.273	8.9	2.5	5.00	0.630	2.81	86.3	0.300
	120	35.7	46.1	8.230	0.892	2.291	10.9	2.0	4.00	0.504	2.81	86.3	0.304
	150	35.1	46.1	8.075	0.890	2.313	13.0	2.1	4.20	0.529	2.81	86.3	0.310
	180	34.9	46.1	8.023	0.889	2.321	15.1	2.1	4.20	0.529	2.81	86.3	0.311
	210	34.6	46.1	7.945	0.888	2.332	17.2	2.1	4.20	0.529	2.81	86.3	0.314
	270	34.0	46.1	7.790	0.886	2.356	20.6	3.4	3.40	0.428	2.81	86.3	0.320
	300	33.9	46.1	7.764	0.886	2.360	22.4	1.8	3.60	0.453	2.81	86.3	0.321

Test	Time min	Mudline mL	H2O Ht mL	Void	Porosity	Hydraulic Gradient	Cum H2O mL	Ind H2O mL	H2O/h mL	Perc Rt cm/hour	SG	Dry Wt grams	Insitu SG
B	15	38.2	46.6	8.641	0.896	2.220	2.0	2.0	8.00	1.008	2.81	88.4	0.291
	30	37.6	48.6	8.490	0.895	2.239	4.2	2.2	8.80	1.108	2.81	88.4	0.296
	60	37.2	46.6	8.389	0.893	2.253	7.2	3.0	6.00	0.756	2.81	88.4	0.299
	90	37.0	46.6	8.338	0.893	2.259	9.8	2.6	5.20	0.655	2.81	88.4	0.301
	120	36.8	46.6	8.288	0.892	2.266	12.0	2.2	4.40	0.554	2.81	88.4	0.303
	150	36.1	46.6	8.111	0.890	2.291	14.4	2.4	4.80	0.605	2.81	88.4	0.308
	180	35.8	46.6	8.036	0.889	2.302	16.5	2.1	4.20	0.529	2.81	88.4	0.311
	210	35.2	46.6	7.884	0.887	2.324	18.4	1.9	3.80	0.479	2.81	88.4	0.318
	270	34.9	46.6	7.808	0.886	2.335	21.6	3.2	3.20	0.403	2.81	88.4	0.319
	300	34.8	46.6	7.733	0.885	2.347	23.5	1.9	3.80	0.479	2.81	88.4	0.322

Project 4400 Date: Dec. 22, 1992 Operator: GC

Purpose: To determine percolation characteristics of a tailing product after a freeze - thaw cycle.

Procedure: Duplicate perc tests were conducted in tubes 45.7 cm long by 3.18 cm In diameter. Pulp was thickened, added uniformily and allowed to settle for 30 minutes. The Erlenmeyer flask, filled with room temperature water and closed with a stopper containing a glass tube was placed inverted over the tube, to supply water at a constant level.

Feed: Test C Tailing, frozen then thawed
Test D Tailing, frozen then thawed

Test Data and Results

Test	Time min	Mudline mL	H2O Ht mL	Void	Porosity	Hydraulic Gradient	Cum H2O mL	Ind H2O mL	H2O/h mL	Perc Rt cm/hour	SG	Dry Wt grams	Insitu SG
A	15	35.0	46.1	7.997	0.889	2.317	0.5	0.5	2.00	0.252	2.81	86.8	0.312
	30	35.0	46.1	7.997	0.889	2.317	1.4	0.9	3.60	0.453	2.81	86.8	0.312
	60	34.8	46.1	7.945	0.888	2.325	2.1	0.7	1.40	0.176	2.81	86.8	0.314
	90	34.2	46.1	7.791	0.886	2.348	3.6	1.5	3.00	0.378	2.81	86.8	0.320
	120	34.0	46.1	7.739	0.886	2.356	4.3	0.7	1.40	0.176	2.81	86.8	0.322
	150	34.0	46.1	7.739	0.886	2.356	5.3	1.0	2.00	0.252	2.81	86.8	0.322
	180	34.0	46.1	7.739	0.886	2.356	6.3	1.0	2.00	0.252	2.81	86.8	0.322
	210	.33.8	46.1	7.688	0.885	2.364	7.0	0.7	1.40	0.176	2.81	86.8	0.323
	270	31.0	46.1	6.968	0.875	2.487	8.2	1.2	1.20	0.151	2.81	86.8	0.353

Test	Time min	Mudline mL	H2O Ht mL	Void	Porosity	Hydraulic Gradient	Cum H2O mL	Ind H2O mL	H2O/h mL	Perc Rt cm/hour	SG	Dry Wt grams	Insitu SG
B	15	37.0	46.6	6.630	0.869	2.259	0.4	0.4	1.60	0.202	2.81	108.2	0.368
	30	37.0	46.6	6.630	0.869	2.259	1.0	0.6	2.40	0.302	2.81	108.2	0.368
	60	36.9	46.6	6.609	0.869	2.263	1.4	0.4	0.80	0.101	2.81	108.2	0.369
	90	36.5	46.6	6.526	0.867	2.277	2.3	0.9	1.80	0.227	2.81	108.2	0.373
	120	36.3	46.6	6.485	0.866	2.284	2.7	0.4	0.80	0.101	2.81	108.2	0.375
	150	36.1	46.6	6.444	0.866	2.291	2.8	0.1	0.20	0.025	2.81	108.2	0.377
	180	36.1	46.6	6.444	0.866	2.291	3.9	1.1	2.20	0.277	2.81	108.2	0.377
	210	35.2	46.6	6.258	0.862	2.324	4.1	0.2	0.40	0.050	2.81	108.2	0.387
	270	34.0	46.6	6.011	0.857	2.371	6.4	2.3	2.30	0.290	2.81	108.2	0.401

Curragh - Faro

Sludge Density

Initial Volume, ml	2000.0
Pulp Weight, g	2282.3
Dry Weight	447.0
Initial Density, gpl	19.6
Final Volume (2 days), ml	1600.0
Final Density, gpl	23.7
Specific Gravity Solids	2.81

Sludge Density after Freeze-Thaw

Initial Volume, ml	2000.0
Pulp Weight, g	2279.4
Dry Weight	440.2
Initial Density, gpl	19.3
Final Volume (2 days), ml	1700.0
Final Density, gpl	22.2
Specific Gravity Solids	2.81

LAKEFIELD RESEARCH
A division of Falconbridge Limited
Postal Bag 4300, 185 Concession Street,
Lakefield, ON K0L 2H0 Phone-705-652-3341 / Fax 705-652-6365

Certificate of Analysis

Client:	Mr. Paul Shibley	Date:	Dec. 22, 1992
	1789 Southmere Crescent	Sample Received:	Dec. 9, 1992
	South Surrey, BC V4A 6P7	No. of Samples:	1
		Our Reference No.:	9241330
RE:	**Curragh Resources**	Project:	4400

Sample Description: Curragh Tailings Slurry Filter Cake

Frozen/thawed - adjusted pH 4.5

The above sample was subjected to the modified SWEPS leachate procedure. The solution produced gave the following analytical results:

Moisture %	64.5
50 Dry equivalent gm	140.8
5N HNO_3 H_2SO_4 acid added mL	84.6
Initial pH	10.2
Final pH	5.3

Arsenic mg/L	<0.05
Iron mg/L	<0.02
Cadmium mg/L	1.72
Copper mg/L	0.86
Lead mg/L	<0.05
Zinc mg/L	900.

Additional: ______________________

Signed: J R Johnston
J. R. Johnston
Chief Chemist.

LAKEFIELD RESEARCH
A division of Falconbridge Limited
Postal Bag 4300, 185 Concession Street,
Lakefield, ON K0L 2H0 Phone-705-652-3341 / Fax 705-652-6365

Certificate of Analysis

Client:	Mr. Paul Shibley	Date:	Dec. 22, 1992
	1789 Southmere Crescent	Sample Received:	Dec. 9, 1992
	South Surrey, BC V4A 6P7	No. of Samples:	1
		Our Reference No.:	9241330
RE:	**Curragh Resources**	Project:	4400

Sample Description: Curragh Tailings Slurry Filter Cake

as received - adjusted pH 4.5

The above sample was subjected to the modified SWEPS leachate procedure. The solution produced gave the following analytical results:

Moisture %	62.7
50 Dry equivalent gm	134
5N HNO_3 H_2SO_4 acid added mL	89.8
Initial pH	10.2
Final pH	5.3

Arsenic mg/L	<0.05
Iron mg/L	<0.02
Cadmium mg/L	1.90
Copper mg/L	1.01
Lead mg/L	<0.05
Zinc mg/L	953.

Additional: ______________________________

Signed: J R Johnston

J. R. Johnston
Chief Chemist.

LAKEFIELD RESEARCH
A division of Falconbridge Limited
Postal Bag 4300, 185 Concession Street,
Lakefield, ON K0L 2H0 Phone-705-652-3341 / Fax 705-652-6365

Certificate of Analysis

Client:	Mr. Paul Shibley 1789 Southmere Crescent South Surrey, BC V4A 6P7	Date: Sample Received: No. of Samples: Our Reference No.:	Dec. 22, 1992 Dec. 9, 1992 1 9241330
RE:	**Curragh Resources**	Project:	4400

Sample Description: Curragh Tailings Slurry Filter Cake

Frozen/thawed - adjusted pH 5.5 - Duplicate

The above sample was subjected to the modified SWEPS leachate procedure. The solution produced gave the following analytical results:

Moisture %	64.5
50 Dry equivalent gm	140.8
5N HNO_3 H_2SO_4 acid added mL	39.8
Initial pH	10.0
Final pH	5.7

Arsenic mg/L	<0.05
Iron mg/L	<0.02
Cadmium mg/L	0.30
Copper mg/L	0.25
Lead mg/L	<0.05
Zinc mg/L	720.

Additional: ______________________

Signed: J R Johnston

J. R. Johnston
Chief Chemist.

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Certificate of Analysis

Client:	Mr. Paul Shibley 1789 Southmere Crescent South Surrey, BC V4A 6P7	Date:	Dec. 22, 1992
		Sample Received:	Dec. 9, 1992
		No. of Samples:	1
		Our Reference No.:	9241330
RE:	**Curragh Resources**	Project:	4400

Sample Description: Curragh Tailings Slurry Filter Cake

Frozen/thawed - adjusted pH 5.5

The above sample was subjected to the modified SWEPS leachate procedure. The solution produced gave the following analytical results:

Moisture %	64.5
50 Dry equivalent gm	140.8
5N HNO_3 H_2SO_4 acid added mL	41.4
Initial pH	9.8
Final pH	5.8

Arsenic mg/L	<0.05
Iron mg/L	<0.02
Cadmium mg/L	0.28
Copper mg/L	0.24
Lead mg/L	<0.05
Zinc mg/L	688.

Additional: ______________________

Signed: J R Johnston
J. R. Johnston
Chief Chemist.

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Certificate of Analysis

Client:	Mr. Paul Shibley 1789 Southmere Crescent South Surrey, BC V4A 6P7	Date: Sample Received: No. of Samples: Our Reference No.:	Dec. 22, 1992 Dec. 9, 1992 1 9241330
RE:	**Curragh Resources**	Project:	4400

Sample Description: Curragh Tailings Slurry Filter Cake
as received - adjusted pH 5.5 - Duplicate

The above sample was subjected to the modified SWEPS leachate procedure. The solution produced gave the following analytical results:

Moisture %	62.7
50 Dry equivalent gm	134
5N HNO_3 H_2SO_4 acid added mL	45.8
Initial pH	10.0
Final pH	5.7

Arsenic mg/L	<0.05
Iron mg/L	<0.02
Cadmium mg/L	0.37
Copper mg/L	0.24
Lead mg/L	<0.05
Zinc mg/L	681.

Additional: ______________________________

Signed: [signature]
J. R. Johnston
Chief Chemist.

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Certificate of Analysis

Client:	Mr. Paul Shibley	Date:	Dec. 22, 1992
	1789 Southmere Crescent	Sample Received:	Dec. 9, 1992
	South Surrey, BC V4A 6P7	No. of Samples:	1
		Our Reference No.:	9241330
RE:	**Curragh Resources**	Project:	4400

Sample Description: Curragh Tailings Slurry Filter Cake as received - adjusted pH 5.5

The above sample was subjected to the modified SWEPS leachate procedure. The solution produced gave the following analytical results:

Moisture %	62.7
50 Dry equivalent gm	134
5N HNO_3 H_2SO_4 acid added mL	43.0
Initial pH	10.0
Final pH	5.7

Arsenic mg/L	<0.05
Iron mg/L	<0.02
Cadmium mg/L	0.37
Copper mg/L	0.27
Lead mg/L	<0.05
Zinc mg/L	740.

Additional: ____________________

Signed: J R Johnston
J. R. Johnston
Chief Chemist.

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Certificate of Analysis

Client:	Mr. Paul Shibley 1789 Southmere Crescent South Surrey, BC V4A 6P7	Date:	Dec. 22, 1992
		Sample Received:	Dec. 9, 1992
		No. of Samples:	1
		Our Reference No.:	9241330
RE:	**Curragh Resources**	Project:	4400

Sample Description: Curragh Tailings Slurry Filter Cake

Frozen/Thawed - adjusted pH 7.0

The above sample was subjected to the modified SWEPS leachate procedure. The solution produced gave the following analytical results:

Moisture %	64.5
50 Dry equivalent gm	140.8
5N HNO_3 H_2SO_4 acid added mL	6.8
Initial pH	9.5
Final pH	7.1

Arsenic mg/L	<0.05
Iron mg/L	<0.02
Cadmium mg/L	<0.01
Copper mg/L	<0.02
Lead mg/L	<0.05
Zinc mg/L	36.0

Additional: ______________________

Signed: [signature]
J. R. Johnston
Chief Chemist.

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Certificate of Analysis

Client:	Mr. Paul Shibley 1789 Southmere Crescent South Surrey, BC V4A 6P7	Date: Sample Received: No. of Samples: Our Reference No.:	Dec. 22, 1992 Dec. 9, 1992 1 9241330
RE:	**Curragh Resources**	Project:	4400

Sample Description: Curragh Tailings Slurry Filter Cake

Frozen/Thawed - adjusted pH 7.0 - Duplicate

The above sample was subjected to the modified SWEPS leachate procedure. The solution produced gave the following analytical results:

Moisture %	64.5
50 Dry equivalent gm	140.8
5N HNO_3 H_2SO_4 acid added mL	6.6
Initial pH	9.5
Final pH	7.1

Arsenic mg/L	<0.05
Iron mg/L	<0.02
Cadmium mg/L	<0.01
Copper mg/L	<0.02
Lead mg/L	<0.05
Zinc mg/L	27.6

Additional: ______________________________

Signed: *J R Johnston*
J. R. Johnston
Chief Chemist.

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Certificate of Analysis

Client:	Mr. Paul Shibley	Date:	Dec. 22, 1992
	1789 Southmere Crescent	Sample Received:	Dec. 9, 1992
	South Surrey, BC V4A 6P7	No. of Samples:	1
		Our Reference No.:	9241330
RE:	**Curragh Resources**	Project:	4400

Sample Description: Curragh Tailings Slurry Filter Cake

as received - adjusted pH 7.0

The above sample was subjected to the modified SWEPS leachate procedure. The solution produced gave the following analytical results:

Moisture %	62.7
50 Dry equivalent gm	134
5N HNO_3 H_2SO_4 acid added mL	6.6
Initial pH	9.5
Final pH	7.1

Arsenic mg/L	<0.05
Iron mg/L	<0.02
Cadmium mg/L	<0.01
Copper mg/L	<0.02
Lead mg/L	<0.05
Zinc mg/L	33.5

Additional: ____________________

Signed: ____________
J. R. Johnston
Chief Chemist.

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Certificate of Analysis

Client:	Mr. Paul Shibley 1789 Southmere Crescent South Surrey, BC V4A 6P7	Date: Sample Received: No. of Samples: Our Reference No.:	Dec. 22, 1992 Dec. 9, 1992 1 9241330
RE:	**Curragh Resources**	Project:	4400

Sample Description: Curragh Tailings Slurry Filter Cake

as received - adjusted pH 7.0 - Duplicate

The above sample was subjected to the modified SWEPS leachate procedure. The solution produced gave the following analytical results:

Moisture %	62.7
50 Dry equivalent gm	134
5N HNO_3 H_2SO_4 acid added mL	7.4
Initial pH	9.5
Final pH	7.1

Arsenic mg/L	<0.05
Iron mg/L	<0.02
Cadmium mg/L	<0.01
Copper mg/L	<0.02
Lead mg/L	<0.05
Zinc mg/L	40.5

Additional: ______________________

Signed: [signature]
J. R. Johnston
Chief Chemist.

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Certificate of Analysis

Client:	Mr. Paul Shibley	Date:	Dec. 22, 1992
	1789 Southmere Crescent	Sample Received:	Dec. 9, 1992
	South Surrey, BC V4A 6P7	No. of Samples:	1
		Our Reference No.:	9241330
RE:	**Curragh Resources**	Project:	4400

Curragh Tailings Slurry

Element	Concentration
% Solids	15.5

Freeze-thaw filtrate - Dissolved metals

Element	Concentration mg/L
As	<0.05
Cd	<0.01
Cu	<0.02
Fe	<0.02
Pb	<0.05
Zn	0.02

Slurry Solid Initial

Element	Concentration %	Concentration %
Fe	0.29	0.27
Ca	32.7	32.5
Mg	1.84	1.83
Al	0.43	0.43
Zn	2.07	2.05
Cu	0.016	0.017
Cd	0.008	0.008
Pb	0.009	0.008
As	0.002	0.003
SO_4	0.40	0.54
CO_3	50.0	50.5

Signed: [signature]
J. R. Johnston
Chief Chemist.

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Mr. Paul Shibley
1789 Southmere Crescent
South Surrey, BC
V4A 6P7

Da e: Dec. 29, 1992
Sample Received: Dec. 9, 1992
No. of Samples: 1
Our Reference No.: 9241330
Project: 4400

RE: Curragh Resources

CERTIFICATE OF ANALYSIS

Curragh Tailings Slurry

As-Received Filtrate

Element	Concentration mg/L
As	<0.05
Cd	<0.01
Cu	<0.02
Fe	<0.02
Pb	<0.05
Zn	0.02

Signed [signature]
J. R. Johnston, Chief Chemist

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Certificate of Analysis

Client:	Mr. Paul Shibley	Date:	Jan. 12, 1993
	1789 Southmere Crescent	Sample Received:	Dec. 9, 1992
	South Surrey, BC V4A 6P7	No. of Samples:	1
		Our Reference No.:	9241330
RE:	**Curragh Resources**	Project:	4400

Freeze-thaw slurry

% Solids wt/vol	19.5

Note: Sample settles rapidly making suspended solids determination difficult.

Signed: J R Johnston
J. R. Johnston
Chief Chemist.

LAKEFIELD RESEARCH
A Division of Falconbridge Limited
Lakefield, Ontario
January 22nd, 1993/ jm