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DE BEERS
A DIAMOND IS FOREVER

10 February 2003

Mackenzie Valley Environmental Impact Review Board (MVEIRB)
Box 938, 5102 – 50th Avenue
Yellowknife, NT X1A 2N7

Attention: Glenda Fratton, Environmental Assessment Coordinator

Dear: Glenda

SUBJECT: TDS Removal Technology for Mine Water Treatment at Snap Lake

Please accept the attached technical memo titled "Consideration of TDS Removal Technology for Mine Water Treatment at Snap Lake" for submission to the Public Registry. This memo was compiled in response to issues raised by Indian and Northern Affairs Canada and Environment Canada during the MVEIRB Technical Sessions.

The analysis provided in the attached memo concurs with a report issued by Indian and Northern Affairs Canada in April 2002 titled "Applicable Technologies for the Management of Mining Effluents in the Northwest Territories", which rejects the alternative treatment technologies on an environmental and practical basis due to high energy consumption and issues associated with transportation and disposal of solid by-products. Additionally, the cost of such treatment is prohibitively expensive.

Should you have any questions, please feel free to contact the undersigned.

Sincerely,
SNAP LAKE DIAMOND PROJECT

Robin Johnstone
Senior Environmental Manager

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SNAP LAKE DIAMOND PROJECT

MEMO

To:	Robin Johnstone, Senior Environmental Manager De Beers Canada Mining Inc	Date	8 February 2003
From:	Tom Higgs, Senior Process Engineer, Water Treatment	File No.	4.9.3/1019
Tel:	604-664-4542	Project No.	U638A
CC:			
Subject:	***TDS Removal Technology for Mine Water Treatment at Snap Lake***		

Introduction

In this memo available technologies for total dissolved solids (TDS) removal from the treated minewater at Snap Lake are reviewed. TDS removal is a common requirement in the field of boiler feed treatment and the same unit operations would apply to TDS removal at Snap Lake. The TDS in the Snap Lake case consists primarily of sodium chloride, calcuim chloride, magnesium chloride and calcium sulfate. Boiler feed water systems typically use a combination of coagulation, lime softening, conventional filtration, ultra-filtration, reverse osmosis (RO) and ion exchange (IX) to remove the above salts. Final selection of unit operations is typically based on the feed chemistry, product water specifications and waste disposal options. Consideration is given to environmental, practical and capital cost related issues in this review of RO and IX treatment technologies.

Ion Exchange

The use of IX systems would not be attractive at Snap Lake compared to RO, due to a number issues associated with regeneration of the IX resins. The use of ion exchange for removal of TDS requires both cation and anion exchange units, requiring two separate regeneration solutions - hydrochloric acid and sodium hydroxide. Significant quantities of these hazardous chemicals would be required for resin regeneration based on the flows and large amount of salt removed. These chemicals would have to hauled to site in bulk and stored, resulting in concurrent risks of spills. The use of these chemicals would add substantially to solids load on the downstream evaporator/crystallizer system required to produce a dry solid for ultimate disposal. In order to displace cations and anions from exchange resins during regeneration excess reagents, substantially greater than the stoichiometric amounts, are required. The use of ion exchange for demineralization (TDS removal) in this case could produce twice as much salt for off-site disposal as would be the case with RO. From an environmental impact and operating cost perspective, the increased handling of chemicals and salt waste with the IX alternative versus RO, would negate consideration of the IX alternative.

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Reverse Osmosis

In the case of Snap Lake, filtration followed by RO would be the preferred alternative to ion exchange. The RO system could recover approximately 85% of the water in the feed for direct discharge. The brine or retentate stream at 15% could be processed further to produce a clean distillate for direct discharge and a salt cake for disposal. The following sections provide a description of the process, design criteria, mass balance and order of magnitude capital and operating costs. Design data and costing have been taken from present Snap Lake data, and additional equipment cost data factored from a completed feasibility study conducted for a proposed "zero discharge" water treatment system for basal water on an oil sands project.

A process schematic for the overall system is provided below.

Process Description

Incorporation of reverse osmosis technology for water treatment of mine water at Snap Lake could proceed as follows.

- **Primary and Secondary Treatment**
  This would consist of the current proposed system involving a thickener, multi-media filters and ancillary pumping, chemical dosing and sludge handling equipment. This system would produce an effluent with a TSS of 5 mg/L or less. The product from the filters would have to be of high quality to protect the downstream membranes (RO).
- **Reverse Osmosis System**
  This would consist of a series of single or double pass units with inter-stage brine concentration selected to provide both high recovery of product water and a high degree of salt rejection. RO systems typically operate at high pressures (150 to 350 psi), which vary according to required recovery and salt rejections levels. These units would be protected by 5 micron U/S cartridge filters. The system would also include chemical dosing equipment for the addition of disinfectants and anti-scalants to reduce biological and chemical membrane fouling as well as a clean-in-place chemical injection systems for membrane cleaning. For assessment purposes it is assumed that an RO unit with an 85% recovery would be feasible, e.g. product water or permeate at 85% and brine flow or retentate at 15% of feed flow. Typically in studies involving RO, initial assumptions for percent recovery would be subject to detailed analyses of feed chemistry and ultimately pilot tests. Severe scaling problems can be encountered in situations where the feed contains elevated concentrations of Ba, Sr, Ca, Mg and SiO_2. Fouling problems can reduce percent recovery, leading to requirements for additional pre-treatment such as ultra-filtration or significantly shorter membrane life. The product water or permeate with a TDS around 100 mg/L would be of high quality and could be discharged to Snap Lake.
- **Evaporation and Crystallization**
  The RO retentate (or brine containing 0.6% TDS) would be fed to a mechanical vapour recompression evaporator and crystallization system to produce a dry cake for ultimate disposal. The crystallizer would include a centrifuge to produce a dry solid (5%

moisture). There are no obvious locations at the Snap Lake site where the disposal of brine from an RO system would be feasible. The evaporator would include condensers, heat exchangers and potential chilling units to recover heat and reduce the temperature of the distillate to a temperature acceptable for discharge to Snap Lake.

- **Salt Cake Disposal**
  Due to the water-soluble nature of the cake, it is unlikely that it would be acceptable for disposal on-site. The cake, approximately 34 tonnes/day at maximum flow, would have to be bagged and containerized on site to prevent moisture absorption during storage and ultimately shipped off-site for disposal, such as deep well injection at an un-specified location. Alternatively a cementation/solidification technique could be considered for on-site disposal, subject to pilot testing and permitting.

To:	Robin Johnstone	Date	3 February 2003
From:	Tom Higgs	File No.	U638A

Design Criteria and Mass Balances

Parameter	Units	Value
Flow[5]	m^3/d	35,000
Feed TDS	mg/L	1000
Feed TSS	mg/L	5
RO Recovery	%	85
RO Rejection	%	90
RO Permeate Flow	m^3/h	1275
RO Product Flow	m^3/h	225
RO Product TDS	mg/L	100
RO Brine Flow	m^3/h	1275
RO Brine TDS	mg/L	6000
Evap[3] Feed Rate[4]	m^3/h	300
Evap Recovery	%	75
Evap Distillate Flow	m^3/h	225
Evap Bottoms Flow	m^3/h	75
Evap Bottoms TDS	%	2.4
Crystallizer Salt Moisture	%	5
Salt Cake Production	kg/h	1421
	tonne/d	34

Notes

1 RO - Reverse Osmosis
2 Evap – Evaporator
3 Feed includes condensate return from cystallizer
4 Rounded up from Peak Ave. Ann. Conc. of 929 mg/L presented in Table IX.1-35
5 Maximum WTP Flow

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Operating Costs and Consumption

Parameter	Units	Value
Energy		
RO Power Demand	kW	1,050
Evaporator/Crystalliser Power Demand	kW	11,000
Annual Power Consumption[1 2]	million kWh	105
Annual Fuel Consumption for[3] Power Generation	million litres	29
Operating Costs		
Annual Power Cost @ $0.16/kWh	$ million	17
Annual proprietary chemicals for the Evaporator/Crystalliser	$ million	2.5
Annual anti-scalant and cleaning reagents for RO	$ million	0.5
Salt Cake Disposal Cost	$ million	2.5
Total Annual Operating Cost	**$ million**	**22.5**

Notes

1- For comparison estimated power and fuel consumption is equal to current expected level for the entire Snap Lake facility.

2- Requires three additional 4.4 MW diesel generators.

3- Requires an additional 30 million litres of fuel storage on site (double current planned storage capacity).

4- Excludes chemicals used in thickener and filtration portion of WTP

5- Reagent costs factored from oil sands project

6- Assumes transportation cost of $200/t to an un-specified off site location (most likely in Alberta) w/o a tipping fee.

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Capital Costs

Item	**Capital Cost[1] $ million**
Reverse Osmosis System	30
Evaporator/Crystallizer	72
Power Plant (Incremental)	20
Fuel Storage (Incremental)	6
Salt Cake Storage Facility	4
Total Capital Cost	**132**

1- RO and Evaporator/Crystalliser capital costs have been assumed to be 3 times the equipment costs which were factored according to relative capacity from an oil sands project.

Assumptions and Exclusions:

- The total capital cost and the operating costs exclude the proposed pre-treatment system thickener/filter system, which would be approximately $16,000,000 and $ 2,500,000/yr respectively.
- An RO recovery of 85% may not be feasible due to the fact that feed is currently saturated in terms of $BaSO_4$. The use of anit-scalants may not be sufficient to avoid scaling problems leading to a reduction in recovery.
- Operating labour requirements would be high and require highly skilled operators for this complex a plant. Labour costs have not been included in the operating costs.
- Distillate flow of 225 m^3/h would require cooling from approximately 30C to 6C prior to discharge. This may require a refrigeration system that has not been included in the capital or operating costs.
- The design assumes that multi-media filtration would be adequate for protection of the RO membranes. Subject to pilot plant testing, ultrafiltration may in fact be required. These costs have not been included.
- The design and costs assume 100% availability of all equipment. This may not be realistic.

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Summary

The TDS removal system would generate over 1200 tonne/y of solids waste, consisting of water-soluble salt cake that would require off-site disposal. This salt would have to be either land-filled in a hazardous landfill (potentially in Alberta) or re-solubilized into brine and deep-well injected into a salt cavern (also potentially in Alberta due to the lack of suitable locations in the NWT).

The power requirements for the RO/evaporation/cystallization system would be high. Approximately 30 million litres of additional fuel (700 trucks/year); equal to the current estimated consumption, would have to be transported to site and stored in a tank farm, which would be equivalent in size to the current proposed tank farm. Consumption of this additional fuel would result in a doubling of green-house-gas (GHG) emissions from the power plant. Off-site salt disposal and additional fuel consumption resulting from TDS removal would increase the number of truck loads on the highways/winter road (400 additional trucks/year) and subsequently further increase GHG emissions from the overall project above that resulting from just the additional power generation, required for the RO/evaporation/cystallization system.

The required treatment system for TDS removal at Snap Lake for a design flow of 35,000 m^3/d would require installation of a combined reverse osmosis, evaporation and crystalliser system at an order magnitude incremental cost of $132 million. Annual operating cost, including fuel and chemicals would exceed $22 million.

The above analyses concur with conclusions reached in an assessment of applicable technologies for the NWT completed under contract for the Department of Indian and Northern Affairs Canada ([i]INAC, 2002). The report rejected RO/Thermal Evaporation Plants in the NWT on a practical basis due to high energy consumption and issues associated with transportation and disposal of solid products.

[i] INAC, 2002. "Applicable Technologies for Management of Mining Effluent in the Northwest Territories", prepared for Department of Indian and Northern Affairs Canada by Lakefield Research and Senes Consultants, April, 2002.

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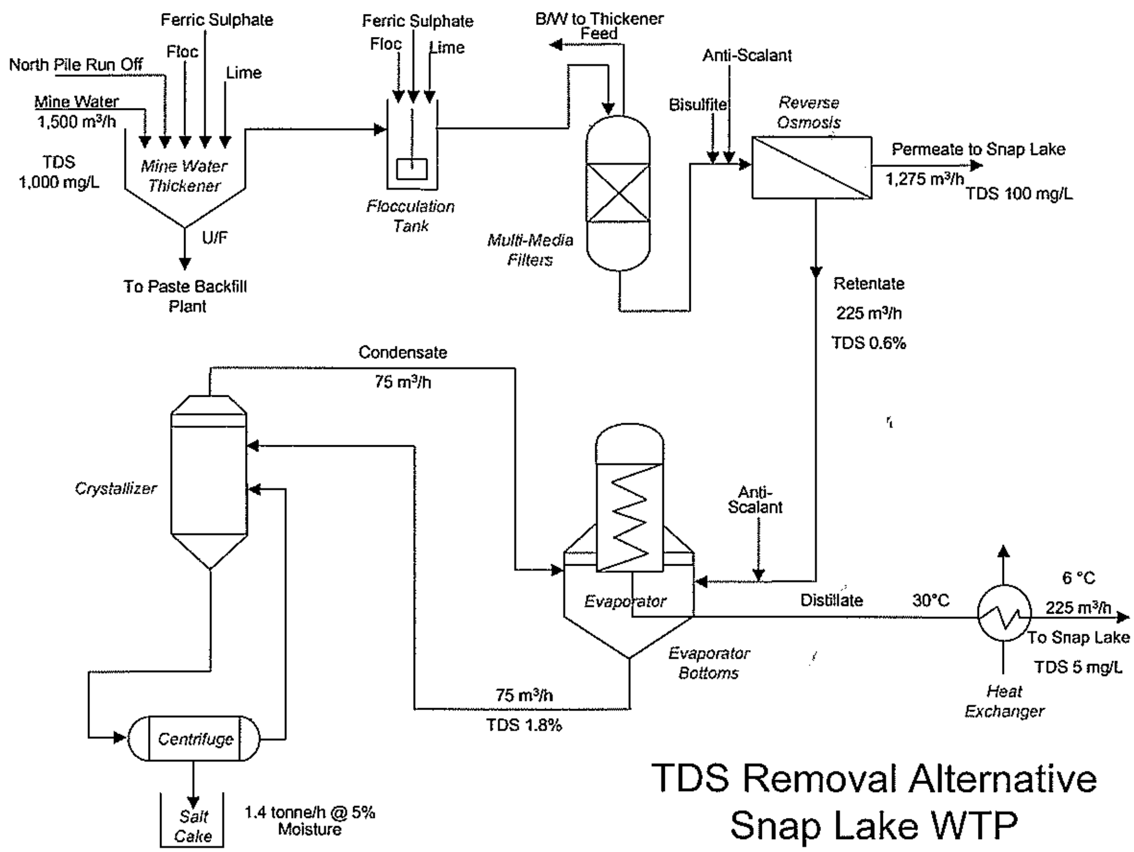

TDS Removal Alternative
Snap Lake WTP