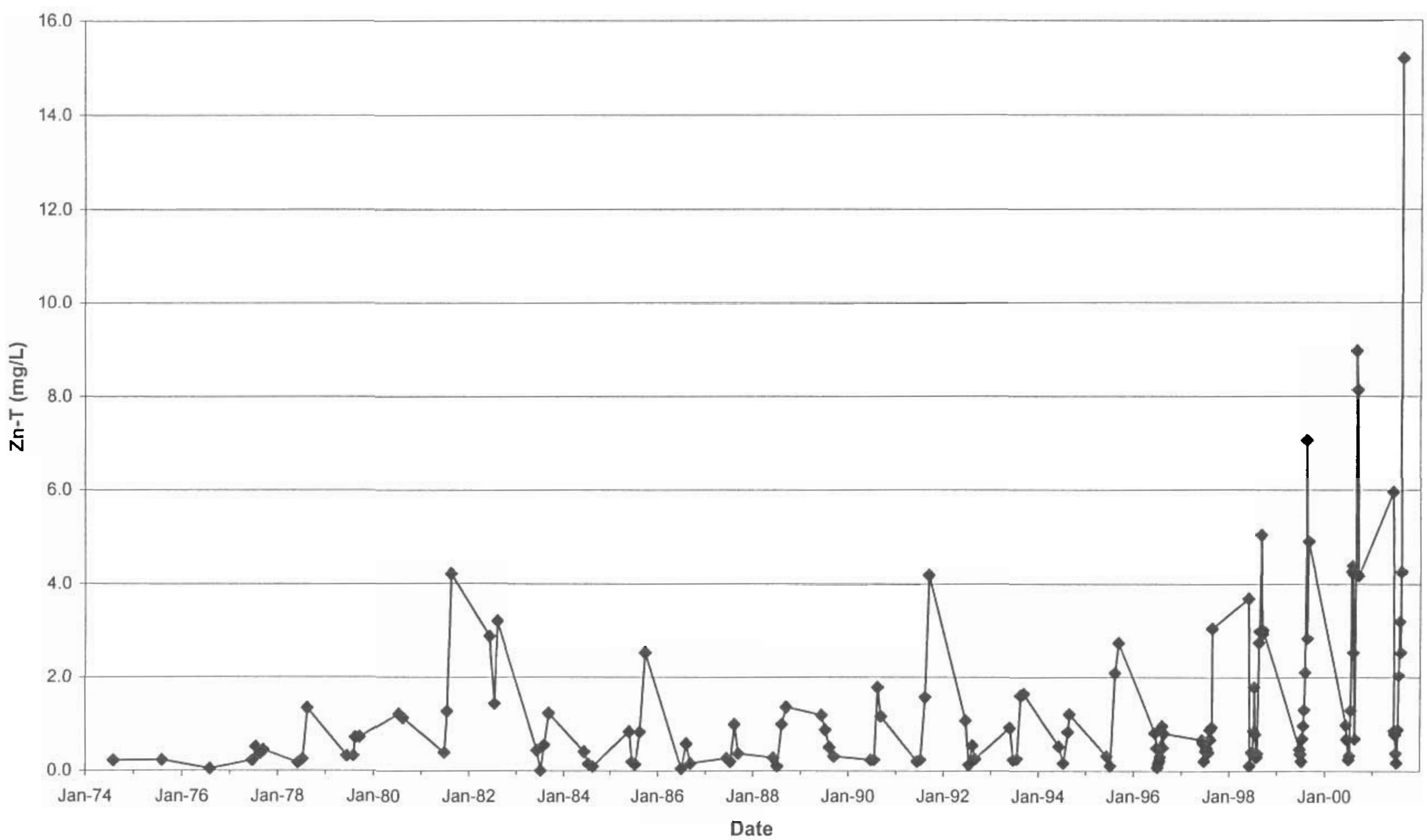
Nanisivik Mine Surface Water Quality
SNP 159-6 Total Zinc, 1974 to 2001



Nanisivik Mine Surace Water Quality, SNP 159-15, 1996 to 2001

Location	Station	Date	Temp	pH	Cond	TSS	Total Cd	Total Pb	Total Zn	Dis Cd	Dis Pb	Dis Zn
Chris Ck u.s.	159-15	10-Jul-96	2.8	7.70	444		<0.001	<0.001	0.002			
Chris Ck u.s.	159-15	22-Jul-96	0.7	7.86	863		<0.001	<0.001	0.058			
Chris Ck u.s.	159-15	21-Aug-96	0.4	7.63	546	0.4	<0.001	0.003	0.097			
Chris Ck u.s.	159-15	24-Jun-97	4.9	7.21	290	0.0	<0.001	0.002	0.016			
Chris Ck u.s.	159-15	07-Jul-97	5.5	6.70	450	2.4	<0.001	<0.001	0.046			
Chris Ck u.s.	159-15	22-Jul-97	10.5	6.52	330	1.8	<0.001	<0.001	0.136			
Chris Ck u.s.	159-15	07-Aug-97	0.8	6.63	360	1.0	<0.001	<0.001	0.044			
Chris Ck u.s.	159-15	08-Jun-98	3.2	8.13	290	7.4	<0.001	<0.001	0.020			
Chris Ck u.s.	159-15	22-Jun-98	1.5	6.65	280	0.2	<0.001	0.001	0.139			
Chris Ck u.s.	159-15	30-Jun-98	2.6	6.50	300	0.0	<0.001	<0.001				
Chris Ck u.s.	159-15	07-Jul-98	4.0	7.30	500	0.6	<0.001	<0.001	0.034			
Chris Ck u.s.	159-15	21-Jul-98	8.2	6.96	420	0.0	0.001	0.008	0.058			
Chris Ck u.s.	159-15	05-Aug-98	2.6	6.90	690	0.0	<0.001	0.002	0.055			
Chris Ck u.s.	159-15	28-Jul-99	1.8	8.00	430	1.4	<0.001		0.361			
Chris Ck u.s.	159-15	21-Aug-99	6.0	6.41	1050	0.0	0.000	0.001	0.183			
Chris Ck u.s.	159-15	20-Jun-00	2.1	7.96	330	0.2	<0.001	<0.001	0.003			
Chris Ck u.s.	159-15	04-Jul-00	10.2	7.86	1870	1.2	<0.001	0.005	0.092			
Chris Ck u.s.	159-15	01-Aug-00	6.3	7.66	1189	1.2	<0.001	<0.001	0.020			
Chris Ck u.s.	159-15	13-Jul-01	2.6	8.33	396	10.3	0.000	0.008	0.000			
Chris Ck u.s.	159-15	11-Aug-01	4.1	7.59	728		0.004	0.023	0.049			
		average	4.0	7.33	588	1.7	0.001	0.006	0.074	-	-	-
		max	10.5	8.33	1870	10.3	0.004	0.023	0.361	-	-	-
		min	0.4	6.41	280	0.0	0.000	0.001	0.000	-	-	-

Nanisivik Mine Surace Water Quality, SNP 159-17, 1996 to 2001

Location	Station	Date	Temp	pH	Cond	TSS	Total Cd	Total Pb	Total Zn	Dis Cd	Dis Pb	Dis Zn
Chris Ck mouth	159-17	27-Jun-96	3.2	7.43	261		0.001	0.002	0.116			
Chris Ck mouth	159-17	10-Jul-96	5.9	7.91	199		0.001	0.001	0.088			
Chris Ck mouth	159-17	22-Jul-96	6.0	8.02	284		0.001	0.001	0.073			
Chris Ck mouth	159-17	08-Aug-96	3.1		586	0.4	0.001	0.001	0.303			
Chris Ck mouth	159-17	21-Aug-96	2.4	7.73	549			0.001	0.044			
Chris Ck mouth	159-17	20-Jun-00	8.5	7.97	267	7.2	0.001	0.003	0.102			
Chris Ck mouth	159-17	06-Jul-00	12.9	8.05	284	0.6	0.001	0.003	0.118			
Chris Ck mouth	159-17	19-Jul-00	11.6	7.85	353	1.6	0.001	0.002	0.130			
Chris Ck mouth	159-17	15-Jun-01	1.8	8.57	316	0.2	0.004	0.042	0.347			
Chris Ck mouth	159-17	30-Jun-01	9.4	7.91	204		0.000	0.013	0.094			
Chris Ck mouth	159-17	27-Jul-01	11.5	7.76	496		0.003	0.027	0.074			
		average	6.9	7.92	345	2.0	0.001	0.009	0.135	-	-	-
		max	12.9	8.57	586	7.2	0.004	0.042	0.347	-	-	-
		min	1.8	7.43	199	0.2	0.000	0.001	0.044	-	-	-

Nanisivik Mine Surace Water Quality, NML-12&13, 1996 to 2001

Location	Station	Date	Temp	pH	Cond	TSS	Total Cd	Total Pb	Total Zn	Dis Cd	Dis Pb	Dis Zn
seep to Kuhulu	NML 12	17-Jul-96	5.9	8.07	162		<0.001	<0.001	0.017			
seep to Kuhulu	NML 13	17-Jul-96	3.4	7.98	113		<0.001	<0.001	0.067			
seep to Kuhulu	NML 12	08-Aug-96	2.0	8.20	381	0.0	<0.001	<0.001	0.068			
seep to Kuhulu	NML 12	08-Jul-98		7.06	220	0.0	<0.001	0.004	0.048			
seep to Kuhulu	NML 13	08-Jul-98		7.14	140		<0.001	0.013	0.050			
seep to Kuhulu	NML 12	25-Aug-98	3.4	5.78	53				0.116			
seep to Kuhulu	NML 13	25-Aug-98										
seep to Kuhulu	NML 12	24-Jun-99	0.5	6.95	250	1.6	0.001	0.172	0.057			
seep to Kuhulu	NML 12	30-Jun-00	7.8	7.97	146	1.0	<0.001	<0.001	0.073			
seep to Kuhulu	NML 13	30-Jun-00	5.2	7.95	66	0.4	<0.001	<0.001	0.048			
seep to Kuhulu	NML 12	21-Jul-00	6.8	8.05	335	0.6	<0.001	<0.001	0.226			
seep to Kuhulu	NML 12	02-Aug-01	8.6	7.74	384		0.00049	0.030	0.154			
seep to Kuhulu	NML 13	02-Aug-01	7.5	7.71	313		0.001	0.065	0.020			
seep to Kuhulu	NML 12	05-Jul-01	6.9	7.99	145.9		0.001	0.021	0.092			
seep to Kuhulu	NML 13	05-Jul-01	4.6	7.89	92.7		0	0.029	0.054			
		average	5.2	7.61	200	0.6	0.001	0.048	0.078	-	-	-
		max	8.6	8.20	384	1.6	0.001	0.172	0.226	-	-	-
		min	0.5	5.78	53	0.0	0.000	0.004	0.017	-	-	-

Appendix G

Letter from Jacques Whitford Environment Limited per Malcolm Stephenson to Mr. Robert Carreau, Breakwater Resources Limited, October 10, 2003 re. Sampling in Kuhulu Lake, July, 2003 (JWEL 15058)

October 10, 2003

Mr. Robert Carreau
Corporate Manager, Environmental Affairs
Breakwater Resources Limited
Suite 2000, 95 Wellington Street East
Toronto, Ontario
M5J 2N7

JWEL 15058

Dear Mr. Carreau,

Re: Sampling in Kuhulu Lake, July, 2003

This letter is to provide you with the results of sampling that was carried out in Kuhulu Lake, during July, 2003. Specifically, sampling included collection of water, sediment and fish tissue samples for chemical analysis. The purpose of this sampling was to evaluate whether there is any evidence to suggest that Kuhulu Lake may have been affected by mining activities over the last 25 years, or whether consumption of fish from Kuhulu Lake may pose any risk to human health. The remainder of this letter provides a brief description of the methods used to collect the samples, the results of the chemical analyses, and the conclusions reached as a result of the new data. Details of the sampling that was carried out, including sample identification codes and location information can be found in Table 1, attached to this letter.

Due to the timing of the sampling, Kuhulu Lake remained largely ice-covered at the time of sampling, although a moat of ice-free water had formed around much of the lake. The ice was heavily "candled" near the margin, making access to the middle of the lake unsafe. Despite this limitation, it was possible to collect most of the intended samples. Information on the specific samples collected, and sampling locations, can be found in Attachment 1 to this letter.

Methods

Water samples were collected on July 12, 2003, at two locations, the west end of Kuhulu Lake where the road first reaches the lake; and at the east end of Kuhulu Lake, at the outflow stream. Water samples were collected as surface grab samples, using either 250 mL HDPE bottles (general chemistry samples) or 50 mL polypropylene centrifuge tubes (trace element samples), as supplied by the analytical laboratory (Research and Productivity Council (RPC) in Fredericton, New Brunswick). RPC is a CAEAL-accredited laboratory that specializes in environmental analytical chemistry. Sample bottles and caps were partially filled and rinsed three times with lake water prior to collecting the water samples. After collection, the bottles were held refrigerated, in the dark, until they could be returned to the laboratory for analysis.

Sediment samples (two cores) were collected on July 12, 2003, at the western end of Kuhulu Lake, at the ice margin. The core sampler used was a Wildco KB gravity core sampler, with stainless steel barrel and nose cone, and polycarbonate core tube liners. Although the ice conditions precluded collection of sediment samples from the deepest portion of the lake, the area sampled was classified as a depositional site, and provided acceptable undisturbed cores of fine-grained silt. The core samples were approximately 30 cm long. Sediment samples were collected from the surface 1-cm layer (samples 1-1 and 2-1, to represent recently deposited sediments) and from a depth of 10 cm (sample 1-5) or 30 cm (sample 2-6) in the core, to represent deeper and older sediments. The sediments were initially frozen, and were subsequently air-dried prior to being ground and analyzed for trace elements by RPC.

Fish were collected using a standard scientific gill net, with an overnight set from 14:30 on July 12, 2003 to 11:00 on July 13, 2003. The gill net gang consisted of 6 randomly-ordered panels, each approximately 3 m high by 10 m long, and having stretched mesh sizes ranging from 2.5 cm to 8.9 cm (1 inch to 3.5 inch). After recovery, fish were frozen, and were subsequently dissected at a laboratory facility in Fredericton, New Brunswick, to eliminate any possibility of contamination in the Nanisivik mine and townsite environments. Samples of muscle tissue (fillet including skin) were dissected from the fish, and were submitted to the RPC laboratory for trace element analysis (including total mercury).

Results

The data reports prepared by RPC to provide the results of all chemical analyses (water, sediments and fish) are presented in Appendix A.

Water samples collected from the western and eastern ends of the lake differed in their chemistry, although both sets of results are considered to be indicative of excellent water quality. The sample collected from the western end of the lake (near an inflowing stream) had higher water hardness (calcium and magnesium), alkalinity (bicarbonate), sulphate, and electrical conductivity, than water collected at the lake outflow. Both stations had low total organic carbon (TOC) concentrations, low turbidity, and neutral to slightly alkaline pH. The above differences in the major ion concentrations at the two stations indicate that the lake was not fully mixed at the time of sampling (due to residual ice cover), and are presumably due to local geological variation within the watershed of Kuhulu Lake. Trace metal concentrations at both sites were generally very low to non-detectable. Concentrations of arsenic, cadmium, copper, lead, nickel and zinc in particular were below the analytical detection limit of the laboratory for both stations.

Sediment samples collected from Kuhulu Lake had moisture contents (see Table 2) ranging from 44% to 65% by weight, consistent with a description of these sediments as sandy silt to silt. In both cores, a moisture content minimum was observed at a depth of 3 cm, suggesting that at some point in the recent past, there was a disturbance in the watershed leading to deposition of more sand. This could correlate with the construction of the road leading to Kuhulu Lake from Nanisivik. If this hypothesis is correct, then the deeper sediments collected in both cores would pre-date the mine.

Surface sediments from both cores contained substantially higher (i.e., a factor of 10 or more) concentrations of calcium than deeper sediments. Specifically, the recent sediments contained calcium at 36,000 and 37,700 mg/kg, whereas the deeper sediments contained 2,960 and 2,880 mg/kg. Concentrations of lead, magnesium, manganese, sodium, strontium and zinc were also about 2 times higher in surface sediments than in deeper sediments. Notably, there was no significant enrichment of iron in surface sediments. Therefore, these differences do not appear to be related to the deposition of mine tailings, which are rich in pyritic minerals. The dramatic increase in calcium concentrations is more likely attributable to accelerated weathering of shale that has been mined locally and used as a road building material in the watershed adjacent to the inflowing stream. This is also consistent with the observed differences in water chemistry at this station, when compared with the lake outflow. However, if this interpretation is correct, then it is unlikely that the observed differences in water or sediment quality extend beyond the small bay where the road approaches the western end of the lake.

Trace element concentrations in surface sediments (including arsenic, cadmium, copper, lead and zinc) slightly exceed the CCME (2001) Interim Sediment Quality Guideline (ISQG) values, but in no case was the Probable Effects Level (PEL) guideline exceeded. The ISQG is a highly protective generic guideline that is exceeded by natural background levels in many parts of Canada.

Arctic char (*Salvelinus alpinus*) collected from Kuhulu Lake were rather small, ranging in total length from 32.4 cm to 41.0 cm, and in weight from 0.23 to 0.6 kg (see Table 3). This is a typical range for landlocked Arctic char, which are restricted to feeding on benthic invertebrates, zooplankton, and cannibalizing smaller fish. All of the Arctic char examined contained large numbers of white nodules around the stomach and intestines, believed to be caused by infection with the larvae of the tapeworm *Diphyllobothrium dendriticum*. This is common in Arctic char, particularly on Baffin Island, where cannibalism among landlocked fish provides a pathway to massive infections (Stewart and Bernier, 1999). This tapeworm can infect humans and dogs if fish are not properly cooked, although the infection is not life-threatening.

Analysis of Arctic char (fish) fillets from Kuhulu Lake (samples AC1 to AC9) found concentrations of arsenic and cadmium that were generally non-detectable (<0.05 and <0.005 mg/kg, respectively). The Canadian guideline for arsenic in fish and fish products is 0.5 mg/kg. Lead concentrations ranged from 0.012 to 0.034 mg/kg. These concentrations are extremely low, and well below the Canadian guideline for lead in fish and fish products (0.5 mg/kg). Mercury concentrations ranged from 0.05 to 0.36 mg/kg, and again these values are below the Canadian guideline for mercury in fish and fish products (0.5 mg/kg). Concentrations of copper and zinc, which are physiologically essential elements regulated by vertebrates, ranged from 0.38 to 1.57 mg/kg (copper) and from 5.4 to 8.4 mg/kg (zinc). These concentrations are considered to be in the normal range for fish muscle tissues. There is no Canadian guideline for these metals in fish or fish products. None of the above results indicates that there should be any concern regarding consumption of properly cooked Arctic char from Kuhulu Lake.

Conclusions

Water and fish collected from the western end of Kuhulu Lake during the summer, 2003, contained low concentrations of trace elements, including lead. Water quality was excellent overall, both at the western inflow, and at the outflow of the lake. Arctic char tissue metals (arsenic, lead and mercury) concentrations were within Canadian guidelines for fish and fish products.

There is some evidence to suggest that recent sediments in the western bay of Kuhulu Lake are chemically distinct from older sediments. The presence of a sediment layer having lower water content (typically associated with coarser sediments) at a depth of 3 cm in both cores suggests that there was a recent disturbance in the watershed, leading to increased erosion of coarse silt to fine sand sized particles. This would be consistent with shale quarrying and road construction in the area starting approximately 30 years ago. Minor changes in trace element composition of the recent (surface) sediments, accompanied by a dramatic increase in the calcium concentration suggests that weathering of a new source of calcium-rich minerals began in the recent past. It is hypothesized that shale quarrying and use as road construction materials may have caused these changes.

Closing

We trust that this letter provides the information you require. Please do not hesitate to contact the undersigned at (506) 457-3200 should you require any further information.

Sincerely

JACQUES WHITFORD ENVIRONMENT LIMITED

Malcolm Stephenson, Ph.D.
Senior Aquatic Scientist

References:

Canadian Council of Ministers of the Environment (CCME). 2001. Canadian Sediment Quality Guidelines for the Protection of Freshwater Aquatic Life.

Stewart, D.B. and L.M.J. Bernier. 1999. Common Parasites, Diseases and Injuries of Freshwater Fishes in the Northwest Territories and Nunavut. Fisheries and Oceans Canada.

Table 1. Water, Sediment and Fish Sampling Details, Kuhulu Lake, July, 2003		
Sample Description	**Sample Code**	**Sample Location**
Water samples for general chemistry and trace element analysis, west end of Kuhulu Lake	K1	73 02 09.772N 84 22 19.761W 265 m ASL
Water samples for general chemistry and trace element analysis, east end of Kuhulu Lake	K2	73 02 01.372N 84 18 05.593W 261 m ASL
Sediment samples, near west end of Kuhulu Lake. Samples 1-1 and 1-5 were submitted for chemical analysis. Remaining samples are archived.	1-1 0-1 cm interval 1-2 1-2 cm interval 1-3 2-3 cm interval 1-4 3-5 cm interval 1-5 9-10 cm interval	73 02 09.470N 84 22 13.569W 259 m ASL
Sediment samples, near west end of Kuhulu Lake. Samples 2-1 and 2-6 were submitted for chemical analysis. Remaining samples are archived.	2-1 0-1 cm interval 2-2 1-2 cm interval 2-3 2-3 cm interval 2-4 3-4 cm interval 2-5 9-10 cm interval 2-6 30-31 cm interval	73 02 09.470N 84 22 13.569W 259 m ASL
Gill net set at west end of Kuhulu Lake, at ice edge (similar location to sediment coring location). Gill net set from 14:30 on July 12, 2003 until 11:00 on July 13, 2003. The net was inspected approximately 2 hours after first being set, but contained no fish at that time. When recovered, the net contained 9 arctic char, identified as AC1 to AC9.	AC1 AC2 AC3 AC4 AC5 AC6 AC7 AC8 AC9	73 02 09.470N 84 22 13.569W 259 m ASL

Table 2. Kuhulu Lake Sediment Sample Data, July, 2003			
Sample No.	**Wet Sediment Weight (g)**	**Dry Sediment Weight (g)**	**Moisture Content (%)**
1-1	16.18	5.61	65.33
1-2	23.44	9.96	57.51
1-3	30.49	16.32	46.47
1-4	44.65	19.32	56.73
1-5	24.01	8.44	64.85
2-1	18.46	7.14	61.32
2-2	26.74	11.75	56.06
2-3	27.36	15.12	44.74
2-4	26.79	11.52	57.00
2-5	24.95	9.07	63.65
2-6	28.80	13.05	54.69

Table 3. Biological Data for Arctic Char Caught at Kuhulu Lake, July, 2003.							
Fish No.	Total / Fork Length (cm)	Weight (g)	Sex*	Liver Wt. (g)	Gonad Wt. (g)	Muscle Tissue Sample (g)	Aging Structures Collected*
1	40.0 / 37.0	560	F (imm.)	5.49	1.96	58.60	S/F
2	32.4 / 30.5	230	M	2.79	11.82	68.74	S/F/O
3	41.0 / 38.3	600	F	9.10	6.35	52.25	S/F/O
4	38.2 / 35.4	450	M (imm.)	3.73	0.46	70.20	S/F/O
5	37.4 / 34.3	390	M	2.61	6.70	57.53	S/F/O
6	39.7 / 36.8	470	F (imm.)	5.14	0.96	58.07	S/F
7	37.3 / 35.7	480	F	5.59	2.78	58.26	S/F
8	39.4 / 36.7	470	M	4.07	0.42	55.33	S/F/O
9	37.2 / 34.2	380	M (imm.)	2.73	0.39	62.80	S/F/O

Comments: all fish had parasitic nodules around the stomach and intestines.
*Sex: imm. indicates gonads not sexually mature.
*Aging Structures: S = scale; F = fin; O = otolith. These structures are archived.

Appendix A
Chemical Certificates of Analysis

Appendix H

Letter from Jacques Whitford Environment Limited per Malcolm Stephenson to Mr. Robert Carreau, Breakwater Resources Limited, October 17, 2003 re. Marine Sampling in Strathcona Sound, July, 2003 (JWEL 15058)

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October 17, 2003

Mr. Robert Carreau
Corporate Manager, Environmental Affairs
Breakwater Resources Limited
Suite 2000, 95 Wellington Street East
Toronto, Ontario
M5J 2N7

JWEL 15058

Dear Mr. Carreau,

Re: Marine Sampling in Strathcona Sound, July, 2003

This letter is to provide you with the results of the biological and sediment sampling that was carried out in Strathcona Sound, during July, 2003. Specifically, sampling included collection of fish tissue and sediment core samples for chemical analysis. The purpose of the fish tissue sampling was to evaluate whether consumption of fish caught near the Nanisivik loading dock may pose any risk to human health. The purpose of the sediment sampling was to evaluate whether recently deposited (surface) sediments near the mouth of Twin Lakes Creek have higher metal concentrations than older (deeper) sediments. This comparison will help to evaluate whether activities associated with the development and operation of the Nanisivik Mine over the past three decades have substantially changed the rate of metal deposition in sediments. The remainder of this letter provides a brief description of the methods used to collect the samples, the results of the chemical analyses, and the conclusions reached as a result of the new data.

Information on the specific samples collected, and sampling locations, can be found in Tables A1 and A2, in Appendix A to this letter.

Methods

Samples of Shorthorn Sculpin were collected on July 12, 2003, by angling with baited jigs at the marine wharf. A total of 12 fish were collected. The fish were frozen shortly after collection, and were held in a frozen condition until they could be returned to Fredericton, New Brunswick, for dissection. The dissections were carried out in a laboratory in Fredericton in order to avoid any possibility heavy metal contamination in the Nanisivik mine and townsite environment. After dissection, muscle tissue samples (fillet with skin on) were submitted to the Research and Productivity Council (RPC) laboratory in Fredericton, New Brunswick, for heavy metal analysis. RPC is a CAEAL-accredited laboratory that specializes in environmental analytical chemistry.

Sediment samples (2 cores) were collected on July 13 and 14, 2003, in the vicinity of the outlet of Twin Lakes Creek. The core sampler used was a Wildco KB gravity core sampler, with stainless steel barrel and nose cone, and polycarbonate core tube liners.

Core sampling proved to be difficult in the targeted area around the mouth of Twin Lakes Creek, due to a combination of factors. Although the bottom sediments could not be directly inspected, the majority of attempted core samples did not penetrate the sediments. Rather, the sampler appeared to strike the sediments and then fall over, without significant penetration. Occasional short plugs of silty sediments were recovered, but these were only about 5 cm in length, and were disturbed.

Based upon a subjective evaluation of the core sampler performance and the professional experience of the operator, it is suggested that the bottom of Strathcona Sound near Twin Lakes Creek is predominantly composed of gravel and sand, with only a patchy veneer of fine sediments. The bottom is steeply sloping in this area, and the Sound is relatively exposed to winds, currents, and tidal water movement in an east-west direction. These factors will tend to minimize the accumulation of sediments in shallow waters and in the sloping near-shore area, favouring periodic slumping and/or resuspension, with subsequent re-deposition in deeper and flatter areas of the Sound.

Results

Results as provided by RPC, for chemical analysis of fish tissues and sediment samples (including QA/QC samples), are presented in Appendix B to this letter.

Fish Tissue Results

Canadian guidelines for chemical contaminants in fish and fish products exist for the heavy metals mercury (0.5 mg/kg in all fish products except swordfish), arsenic (3.5 mg/kg in fish protein concentrate) and lead (0.5 mg/kg in fish protein concentrate). The mean mercury concentration in Shorthorn Sculpin tissues was 0.15 mg/kg (range 0.07 to 0.26 mg/kg). The mean arsenic concentration was 5.3 mg/kg (range 2.02 to 9.98 mg/kg). The mean lead concentration was 0.48 mg/kg (range 0.027 to 2.22 mg/kg).

Of the three elements for which there are guidelines, only the mean arsenic concentration exceeds the guideline. However, arsenic concentrations in sediments near the mouth of Twin Lakes Creek are not excessive (see below). Arsenic concentrations in many marine biota, including shellfish, crustaceans and bottom-dwelling fish are commonly elevated, and of low significance to consumers. Many species of fish contain from 1 to 10 mg/kg total arsenic, and some bottom feeders and shellfish contain arsenic at or above 100 mg/kg (World Health Organization, 2001). Lobster tissues commonly contain from 10 mg/kg to 20 mg/kg total arsenic (U.S. Food and Drug Administration, 1993). Moreover, arsenic present in the tissues of marine organisms is predominantly present as a water-soluble organic form (arsenobetaine), which has low toxicity and does not biomagnify. There are no reported instances of toxicity in man or animals from the consumption of organic arsenic compounds in seafood. Therefore, the fact that Shorthorn Sculpin muscle tissues contain moderate concentrations of total arsenic (<10 mg/kg) should not be a source of concern.

Lead concentrations in fish tissues approached the Canadian guideline for fish protein concentrate, and were relatively variable both from fish to fish, and within fish tissues analyzed as replicate subsamples. The source of this variability is not clear, and such variability was not observed for most other elements. It may suggest that fish collected near the wharf are bioaccumulating lead, and that the degree of bioaccumulation may reflect factors such as the length of residency. Similar variability was not observed for zinc, however, zinc concentrations in fish tissue are subject to biological regulation, whereas lead may not be. The conclusion, however, remains that most fish collected at the wharf have low lead concentrations, and that the average exposure to lead from consuming these fish would be low.

In addition to the above metals, cadmium, copper and zinc are worthy of mention. Cadmium concentrations in Shorthorn Sculpin tissues were low (averaging 0.029 mg/kg, and ranging from 0.01 to 0.057 mg/kg). Copper concentrations were also low, and lay within a very narrow range (averaging 0.56 mg/kg, and ranging from 0.45 to 0.72 mg/kg), consistent with active biological regulation. Zinc concentrations were slightly elevated, but also lay within a narrow range consistent with active biological regulation (averaging 18.1 mg/kg, and ranging from 10.2 to 26.7 mg/kg). None of these metal concentrations merit concern about possible human consumption.

The data reported above can be compared with data collected by BC Research (1974). They reported arsenic concentrations in Shorthorn Sculpin fillet samples of 10.1 to 37.4 mg/kg dry weight. Assuming a water content of 80%, these results would translate into fresh tissue concentrations of 2.0 to 7.5 mg/kg, very similar to the results of the present survey. Lead concentrations were generally below the detection limit obtained by BC Research, however, reported results range from <7 to <46 mg/kg dry weight, with one reported detection of 4.6 mg/kg dry weight. The highest concentration reported during the 2003 survey was 2.2 mg/kg wet weight, which would translate into a dry weight concentration of about 11 mg/kg. Copper concentrations reported by BC Research ranged from 5.3 mg/kg to 26.3 mg/kg dry weight. This range would translate to a range of 1.1 to 5.3 mg/kg wet weight (results for 2003 were less than 1 mg/kg wet weight). Zinc concentrations reported by BC Research range from 57.6 to 144 mg/kg dry weight, which would translate to a range of 11.5 to 28.8 mg/kg wet weight. The zinc concentration reported for 2003 averaged 18.1 mg/kg wet weight. Taken overall, there appears to be a consistent weight of evidence to indicate that metal concentrations measured in the tissues of Shorthorn Sculpin in 2003 are very similar to those measured prior to the mine development, in 1974.

Sediment Core Results

Two short cores were successfully collected, and both "surface" and "deep" samples were segregated from each core. The cores were as follows:

- Core S (samples S1 and S2) collected at position 73° 04′ 15.069″ N, 84° 32′ 13.127″ W in 56 m water depth. This core was collected some distance east of the wharf.
- Core F (samples F1 and F2) collected at position 73° 04′ 19.370″ N, 84° 32′ 43.873″ W in 80 m water depth. This core was collected between the outlet of Twin Lakes Creek and the wharf.

Chemical analysis of the core samples reflects the local mineralogy. High concentrations of calcium (>60,000 mg/kg) and magnesium (>50,000 mg/kg) were recorded, in addition to relatively high concentrations of iron (>25,000 mg/kg). Aluminum, while still a major element, was present at relatively low concentrations (12,000 to 14,000 mg/kg). These results presumably reflect the locally dominant dolomitic and shale rock types.

Arsenic concentrations (9 to 14 mg/kg), while above the CCME (1999) interim marine sediment quality guideline (ISQG) of 7.24 mg/kg, were well below the probable effects level (PEL) of 41.6 mg/kg. Elevated arsenic is often found in association with high concentrations of iron, and high iron can reduce the bioavailability of arsenic. Arsenic was not notably enriched in the surface sediment layer at either location.

Cadmium concentrations (1.6 to 10.2 mg/kg) spanned the range of the PEL guideline (4.2 mg/kg). Cadmium has geochemistry similar to that of zinc, and is often found in association with zinc deposits. Cadmium concentrations were slightly elevated in the surface sediment layer of Core S when compared with the deeper layer (2.45 mg/kg compared to 1.6 mg/kg) but was present at a lower concentration in the surface of Core F than in the deeper layer (5.8 mg/kg compared with 10.2 mg/kg).

Chromium concentrations (23 to 27 mg/kg) were below the ISQG (52.3 mg/kg) in all cases.

Copper concentrations (26 to 40 mg/kg) were above the ISQG (18.7 mg/kg), but below the PEL (108 mg/kg) in all cases. Copper concentrations in the surface and deeper layers of both cores were comparable.

Lead concentrations (88.4 to 568 mg/kg) spanned the range of the PEL guideline (112 mg/kg). Lead concentrations were higher in the surface layer of Core S than in the deeper layer (143 mg/kg compared to 88.4 mg/kg). However, the lead concentration was lower in the surface layer of Core F than in the deeper layer (359 mg/kg compared with 568 mg/kg).

Mercury concentrations 0.03 to 0.1 mg/kg) were below the ISQG (0.13 mg/kg) in all cases.

Zinc concentrations (481 to 2,740 mg/kg) were above the PEL (271 mg/kg) in all cases. Zinc concentrations were higher in the surface layer of Core S than in the deeper layer (825 mg/kg compared to 481 mg/kg). However, the zinc concentration was lower in the surface layer of Core F than in the deeper layer (1,890 mg/kg compared to 2,740 mg/kg).

The results reported above can be compared with data collected by BC Research (1974). They reported metal concentrations in 14 core samples collected throughout Strathcona Sound. Most if not all of the BC Research sediment samples were collected using a Shipek dredge (taking roughly the surface 10-cm of sediments) from "deepwater" portions of the Sound, where sediments would be accumulating. In particular, the two stations located closest to the mouth of Twin Lakes Creek were at depths of 247 m (Station 9) and 304 m (Station 10), and appear to represent sediments from beyond the "toe" of the shoreline slope.

BC Research (1974) reported the following ranges of metal concentrations:

- Arsenic, 1.0 to 7.9 mg/kg;
- Cadmium, <0.4 mg/kg;
- Copper, 3.7 to 27.9 mg/kg;
- Iron, 2,820 to 34,000 mg/kg;
- Lead, 3.9 to 19.3 mg/kg;
- Nickel, 3.9 to 27.3 mg/kg; and
- Zinc, 3.9 to 171 mg/kg.

Notably, the comparison with BC Research data shows that while arsenic, copper, iron and nickel concentrations occupy similar ranges, the concentrations of cadmium, lead and zinc appear to be much higher in the near-shore sediments sampled during 2003. JWEL believes that the reason for this difference is that the near-shore sediments sampled during 2003 contain larger quantities of relatively coarse, dense mineral particles that would have been eroded from the exposed ore body, and been deposited in the alluvial fan at the mouth of Twin Lakes Creek. The samples collected by BC Research, coming from farther out in the Sound, would not contain these particles, and would therefore show less enrichment of the ore body metals, zinc, lead and cadmium.

Additional Observations

Twin Lakes Creek has a high flow rate in the springtime, and at the same time, the sea ice on Strathcona Sound is melting. The combined freshwater inputs from these two sources lead to the formation of a thin surface freshwater lens (1 to 2 parts per thousand total salinity) on top of more strongly marine influenced water (a halocline exists so that the salinity increases from about 4 ppt to 25 ppt at a depth of about 2 m. The halocline was strong enough to provide a reflecting surface for sonar, so that a hand-held sonar unit periodically gave depth readings of 2 m or less in waters that were substantially deeper.

As a result of the halocline, freshwater discharged from Twin Lakes Creek does not mix rapidly with the marine waters of Strathcona Sound. Instead, the freshwater lens extends some distance (perhaps several kilometres) away from the mouth of Twin Lakes Creek, and will be advected east-west by tidal action. Only the heaviest sediment particles will be deposited near the mouth of Twin Lakes Creek. These can be expected to include coarse particles including gravels and sands, and the denser fine-grained particles in the silt size range. Silt-sized particles with less dense mineralogy, and clay-sized particles will have low-enough settling rates to be advected a considerable distance away from the mouth of Twin Lakes Creek before settling. Likewise, dissolved trace metals can also be expected to be transported a considerable distance from the mouth of Twin Lakes Creek before mixing with the full water column. Therefore, it is not likely that substantial accumulations of fine-grained sediments will occur at the mouth of Twin Lakes Creek. However, most of the input of coarse material transported by the creek will deposit near the mouth.

In addition to the behaviour of suspended solids and dissolved trace metals discharged from Twin Lakes Creek, the sedimentary environment along the south shore of Strathcona Sound is worthy of discussion. There is a rapid drop off in depth from the mouth of Twin Lakes Creek, so that depths of 50 m or more are reached within approximately 200 m of the shoreline. The bottom is also exposed to erosional forces from tidal water movements in an east-west direction. As a result of these factors, it is expected that any fine-grained (silty) sediment that does accumulate near the shoreline will be susceptible to periodic slumping into deeper waters, or re-suspension by currents or wave action. As a result of the slumping process, it is likely that sediments at the toe of the slope in Strathcona Sound are highly disturbed.

The core sampling efforts that were conducted at water depths of 3 m to 80 m in front of Twin Lakes Creek during July, 2003, support this interpretation. At the 3 m water depth, the core sampler was observed to strike the sand and gravel bottom without significant penetration, and subsequently to fall over on its side. These coarse-grained materials resist penetration using a gravity core sampler, and are too loose to be retained in such a device. Although not directly observed, the core sampler could be felt as it hit the sediments in deeper water, without an audible "click" as would be heard if the sampler was striking bedrock or a substantial boulder. The core sampler could subsequently be felt as it fell over, indicating that there had been minimal penetration of sediments. Based upon these observations, it is believed that sand and gravel sediments predominate on the slope of Strathcona Sound at Twin Lakes Creek. There appear to be thin veneers of fine-grained (silty) sediments in some areas, and short plugs (approximately 10 cm in length) of these sediments were occasionally brought to the surface, although it was very difficult to recover them undisturbed from the core sampler. As noted above, thicker deposits of fine-grained sediments are not likely to be stable on the slope of the Sound.

Conclusions

Fish (Shorthorn Sculpin) muscle tissue concentrations of arsenic and lead are relatively high in comparison with Canadian guidelines for fish and fish products. However, they do not appear to be high enough to justify concern about occasional consumption, nor do they appear to have increased significantly in comparison with data collected by BC Research in 1974.

Concentrations of cadmium, lead and zinc regularly exceeded the CCME PEL guideline in sediments collected in the vicinity of the mouth of Twin Lakes Creek and the wharf. Concentrations of these elements exceeded concentrations measured in sediments by BC Research (1974). However, the historical samples were not collected in close proximity to the mouth of Twin Lakes Creek, and may not have properly reflected the natural background condition in this area. A comparison of surface (0-5 cm) to deeper (5-10 cm) sediments was ambiguous, in that higher concentrations of cadmium, lead and zinc were present in the deeper sediments of Core F than in the surface sediments.

Sediment deposition in the alluvial fan of Twin Lakes Creek is likely to be restricted to coarser grained sediments, or those fine-grained sediment particles that are composed of denser minerals. The physical aspects of the marine environment during spring runoff are such that fine-grained particles and dissolved metals are likely to be widely dispersed in Strathcona Sound before they are deposited to sediments.

Closing

We trust that this letter provides the information you require. Please do not hesitate to contact the undersigned at (506) 457-3200 should you require any further information.

Sincerely

JACQUES WHITFORD ENVIRONMENT LIMITED

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Senior Aquatic Scientist

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Appendix A
Information on Fish and Fish Tissue Samples (Table A1) and Location Information for Sediment Samples (Table A2).

Table A1. Biological Data for Shorthorn Sculpin Caught at Nanisivik Mine Wharf, July, 2003.

Fish No.	Length (cm)	Weight (g)	Sex	Liver Wt. (g)	Gonad Wt. (g)	Muscle Tissue Sample (g)	Otolith Collected
SC1	29.3	370	F	13.02	13.27	48.86	Y
SC2	36.6	610	F	26.65	22.33	78.30	Y
SC3	29.1	370	F	18.81	20.78	57.13	Y
SC4	25.0	210	M	7.86	4.45	41.10	Y
SC5	35.0	580	F	24.2	21.64	75.82	Y
SC6	20.4	90	M	2.69	2.23	21.94	Y
SC7	30.8	460	F	29.14	12.24	50.24	Y
SC8	30.4	400	F	19.96	11.2	38.43	Y
SC9	29.7	380	F	14.6	12.64	46.77	Y
SC10	24.5	170	M	5.84	2.52	39.21	Y
SC11	24.5	170	M	4.07	2.45	33.67	Y
SC12	24.2	160	M	2.41	2.55	33.23	Y

Comments – All Shorthorn Sculpin samples were collected by angling at the ship loading wharf, on Saturday, July 12, 2003.

Table A2. Sediment Core Sample Locations, Depth and Descriptions, Nanisivik Mine, July, 2003.

Core ID	Core Sections	Sampling Location	Water Depth	Comments
S	S1 (0 to 5 cm) S2 (6 to 10 cm)	73° 04′ 15.069 N 84° 32′ 13.127 W	56 m	This was the only successful core out of about 10 attempts in water depths between 3 m and 80 m. Core collected on Monday July 14, 2003.
F	F1 (0 to 5 cm) F2 (6 to 10 cm)	73° 04′ 19.370 N 84° 32′ 43.873 W	80 m	Core collected after about four unsuccessful tries between 45 and 60 m water depth. Core collected on Wednesday, July 16, 2003.

Appendix B

Analytical Data Reports by RPC, for Fish Tissue and Sediment Samples