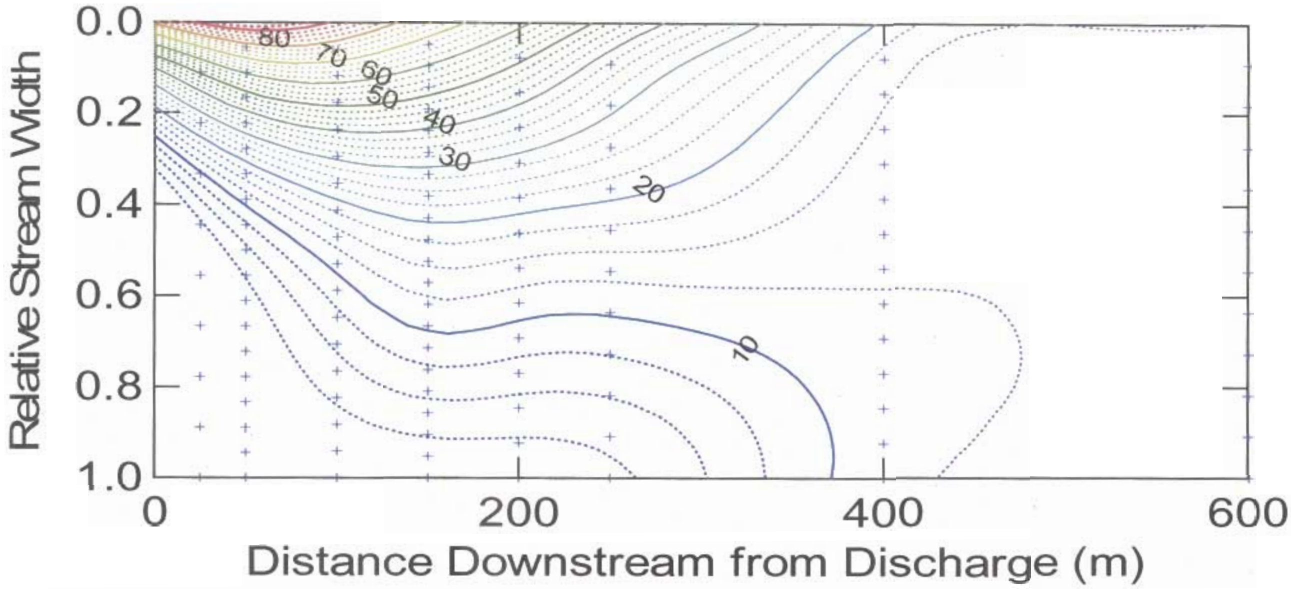


Figure 2.2 Effluent Dilution Measured by Conductivity

Based on the temperature measurements, at a distance of 100 m downstream (JWEL, 2003b and Figure 2.3), the effluent concentration ranged from 88% at a distance of 1 m from the left bank, to 0% effluent at a distance of 1 m from the right bank. At 255 m downstream, the effluent concentration ranged from 22.7% effluent near the left bank, to 1% effluent near the right bank. By 400 m downstream, the effluent concentration ranged from 13.3% near the left bank, to 10% near the right bank. Finally, after plunging over a 10 m waterfall approximately 600 m downstream of the effluent discharge point, the effluent concentration stabilized at 12% effluent across the full width of the creek.

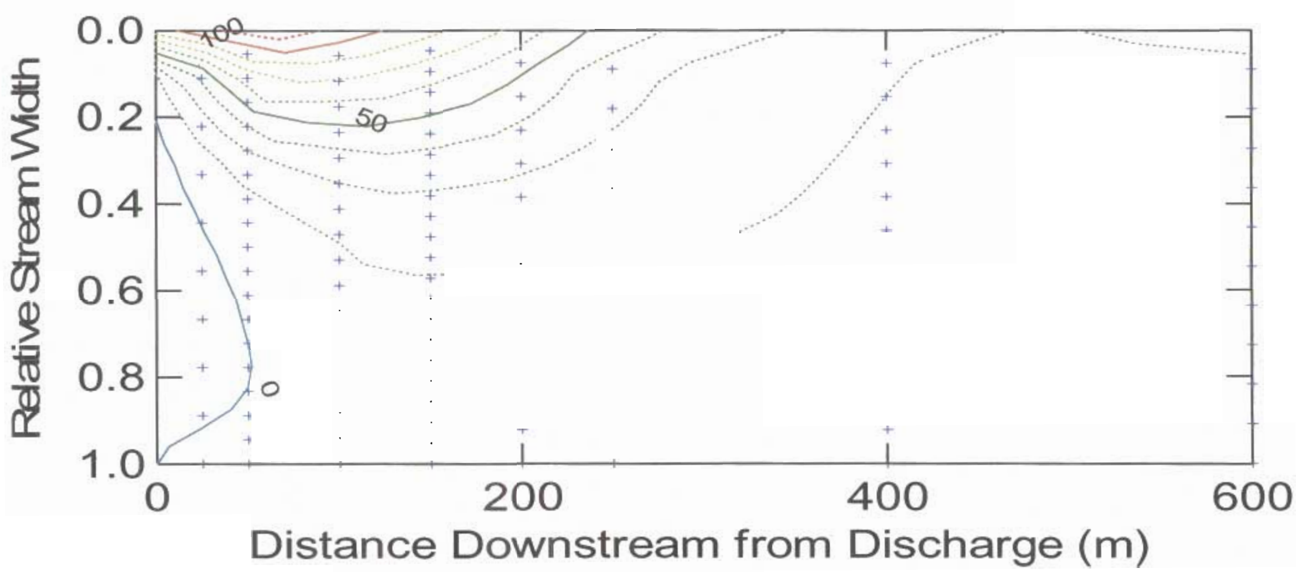


Figure 2.3 Effluent Dilution Measured by Temperature

The plume delineation dilution estimates were also directly corroborated (JWEL, 2003b) by flow measurements that were made in-stream, and at the effluent discharge weir, at the time of the study. Based upon the stream flow measurements, the effluent discharge stream was between 12.0 % and 13.2 % of the total stream flow.

At the time of the plume delineation study in July, 2003, Twin Lakes Creek was at a moderate flow stage (around 1.0 m^3/second). Higher flow rates are expected during spring runoff. Much lower flow rates are also expected later in the season (August), and at this time, the effluent stream will comprise a larger fraction of the overall stream flow. During low flow conditions, it is expected that the plume will disperse more gradually across the stream channel. However, it is still expected that the plume will be fully mixed with the stream flow as it passes over the waterfall located 600 m downstream from the effluent discharge weir.

It has thus been determined that a waterfall approximately 600 m downstream from the point of effluent discharge results in complete mixing during low stream flow scenarios, and it is likely that complete mixing will occur before the waterfall in high stream flow scenarios. In either scenario, samples taken after the waterfall can be regarded as representing a completely mixed condition, and the stream reach between the effluent discharge weir and the waterfall can be regarded as the mixing zone.

2.8.4 Biological Characteristics of Twin Lakes Creek

Twin Lakes Creek is a naturally fishless system from its headwaters at East Twin Lake until it reaches the marine waters of Strathcona Sound. The fishless condition is attributable to multiple factors, including naturally-occurring mineralized zones that cause elevated zinc concentrations in the creek water; the presence of waterfalls that are impassable to fish; and the general climatic conditions which cause the creek to completely freeze during the winter.

Despite the harsh environmental conditions, there is a sparse benthic invertebrate community present in the creek. As documented by BC Research (1975a), and as verified by JWEL (2003b) in a reconnaissance survey carried out in July, 2003, the community is dominated by Chironomidae (Orthocladiinae?), although a few Tipulidae and one other unidentified dipteran larva (Tabanidae?) were collected. Some Cladocerans (Daphnia?) were also collected, but these were presumably drifting down from the zooplankton population present in East Twin Lake, and do not represent true benthic fauna. These data can be found in Appendix B.

Three stations were sampled by JWEL during 2003, with five individual U-net samples (0.25 mm mesh size) being collected at each station. The first two stations were designated ETL (in the outflowing stream from East Twin Lake, upstream of the point where mine effluent enters the creek) and TLC (in Twin Lakes Creek downstream from the effluent discharge point, and exposed to the partially diluted mine effluent). The assemblages present at the ETL site were qualitatively and quantitatively similar to the assemblages present at the TLC site. However, no benthic invertebrates were recovered from a third site (WTL), located immediately below the effluent discharge weir, and exposed to undiluted mine effluent.

2.8.5 Special Features of Twin Lakes Creek

Twin Lakes Creek is a lake outflow system that drains East Twin Lake (which is undisturbed and serves as a potable water supply for the Nanisivik townsite) and West Twin Lake (the tailings area and polishing basin). The water quality of East Twin Lake is excellent. Chemical data collected from the outflow to East Twin Lake in July 2003 can be found in JWEL (2003b), included as Appendix B to this document. The two lakes are separate basins, and the channel of Twin Lakes Creek has been diverted over short area near the effluent discharge weir in order to further separate and regulate the flow from the tailings area.

Both East Twin Lake and West Twin Lake, as well as Twin Lakes Creek are naturally fishless. Chris Creek, another stream draining a portion of the mine lease area is also naturally fishless. The nearest freshwater fish habitat (supporting a landlocked population of Arctic char) is located in Kuhulu Lake, several kilometres east of the mine site, and unaffected by mining activities.

Scientific studies of mine effluent effects on fish and fish habitat in Twin Lakes Creek will be confounded by the following features:

- the creek is not fish habitat, being naturally fishless;
- the creek receives metal loadings (particularly zinc, but also lead and copper) from waste rock piles and a natural mineral outcrop located in the reach between the mill and the townsite, which substantially exceed the loadings from the West Twin Lake tailings area (mine effluent discharge);
- the creek receives an input of nutrients near the mill location, in the form of sewage from the townsite;
- the mine effluent is discharged only during the months of June, July, and August; and
- during the winter months, Twin Lakes Creek freezes completely.

2.8.6 Exposure and Reference Areas in Twin Lakes Creek

Exposure and reference areas in Twin Lakes Creek apply only to the benthic invertebrate survey, and water quality monitoring. Exposure and reference areas for the fish study will be discussed below, in the sections describing Strathcona Sound.

The general proposed reference area from which reference samples for the benthic invertebrate survey and water quality monitoring will be collected is located in the portion of Twin Lakes Creek upstream from the effluent discharge point to East Twin Lake where creek flow is originated. The general proposed exposure area begins at the effluent discharge weir from WTDA and extends downstream to the naturally occurring weathering mineralized zone, rich in zinc and lead sulphides.

2.8.7 Chris Creek

Chris Creek is a smaller creek that drains surface water into Strathcona Sound from the watershed on the east side of the mine area. Specifically, surface run off from the East Adit area, waste rock piles, and K-Baseline area enters Strathcona Sound via Chris Creek. Water quality in Chris Creek is also monitored under the Water License from the Nunavut Water Board.

2.9 Marine Environmental Conditions in Strathcona Sound

Baseline information on the marine environment of Strathcona Sound was documented by BC Research (1975b), and most of the following discussion is derived from that document. Additional observations were made by JWEL (2003c), and this source is identified where it is relevant.

2.9.1 Oceanography of Strathcona Sound

Strathcona Sound is a marine inlet approximately 55 km long that reaches east to southeast from Admiralty Inlet, in northern Baffin Island. The sound is cradled between steeply sloping hills with narrow beach zones. The steeply sloping ground contours along most of the Sound continue below sea level, gradually levelling out at bottom depths that vary from approximately 50 m to over 300 m. In the vicinity of the mine property and the mouth of Twin Lakes Creek, the sea floor drops rapidly and reaches a maximum depth of approximately 250 m. There is a deep sill located approximately 8 km into the sound from its mouth at Admiralty Inlet, and this sill confines a deep hole in the inner Sound.

The intertidal zone of Strathcona Sound, as is typical of intertidal zones elsewhere in the high Arctic, is virtually barren. Tidal ice scouring, possibly in combination with extremely low levels of nutrients and harsh winter conditions at low tide effectively prohibit the growth of the rockweed community that is common in more temperate areas. Below the intertidal zone, BC Research (1975b) observed sea urchins and shorthorn sculpins (*Myxocephalus scorpius*). The latter fish were readily caught by jigging with a baited hook. JWEL (2003c) were also able to catch shorthorn sculpin at the present wharf with similar gear.

Currents in the Sound were reported by BC Research (1975b) to be most pronounced in the surface 10 to 20 m, with minimal currents below that depth. The Sound is tidal, and currents of up to 30 cm/second were observed, with tidal action. The Sound is also highly exposed to westerly winds, and wave action could potentially be significant. The maximum tidal range recorded by BC Research (1975b) was 2.74 m.

Salinity in the Sound was reported to range from 15 ppt (parts per thousand) to 24 ppt in the surface layers during August, 1974. During July 2003, JWEL observed surface salinities as low as 2 ppt in association with melting sea ice and moderate stream flows from Twin Lakes Creek. In both cases, salinity increased below 2 m, to the 25 ppt range. BC Research reported a halocline around 10 m depth (presumably reflecting the depth of surface water warming and mixing during August), with salinity increasing to 31 to 33 ppt below 10 m depth.

Surface water temperatures ranged from 7°C to 10°C during August 1974. Colder waters were present below 10 m depth. Dissolved oxygen concentrations were typically highest at 10 m depth, and decreased significantly at greater depth, in most cases to less than 5 mg/L. These observations may suggest a semi-stagnant bottom water zone in Strathcona Sound (as confined by the sill near the mouth of the Sound), with full mixing occurring only at irregular intervals when severe wind stress on the surface of the Sound causes turnover.

Twin Lakes Creek has a high flow rate in the early summer, and at the same time, the sea ice on Strathcona Sound is melting. The ice left the Sound in mid July during 2003, but some variability in this date can be expected. The combined freshwater inputs from Twin Lakes Creek and the melting sea ice 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, fresh water discharged from Twin Lakes Creek does not mix rapidly with the marine waters of Strathcona Sound. Instead, a fresh water lens may extend 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.

The behaviour of fresh water entering Strathcona Sound from Twin Lakes Creek is relevant because the most common local fish species (shorthorn sculpin) is a bottom dweller. Therefore, the degree of exposure of these fish to the freshwater plume from Twin Lakes Creek, and any associated metals regardless of origin, is uncertain.

2.9.2 Metal Concentrations in Fish from Strathcona Sound

Relatively high concentrations of the metals zinc and lead were documented in marine biota both by BC Research (1975b), prior to the mine development, and by JWEL (2003c), after the mine had ceased operating.

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 arsenic concentration reported by JWEL (2003c) 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). The mean mercury concentration in shorthorn sculpin tissues was 0.15 mg/kg (range 0.07 to 0.26 mg/kg). This is an important observation since the *MMER* considers the usability of fish tissues be impaired at a mercury concentration greater than 0.45 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. 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 and in some cases exceeded 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. Much less variability was observed for zinc, for example. However, zinc concentrations in fish tissue are subject to biological regulation, whereas lead may not be. The conclusion 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 (1975b). 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, their 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 (JWEL, 2003c).

2.9.3 Exposure and Reference Areas in Strathcona Sound

Following discussions with the Technical Advisory Panel for the Nanisivik Mine EEM study, it has been determined that the most appropriate area for a fish study is in Strathcona Sound, near the mouth of Twin Lakes Creek. Accordingly, this area will be designated the exposure area for the fish study, and a reference area will be located on the opposite side of Strathcona Sound, near the mouth of the Strathcona River.

2.10 Mine Production Process and Environmental Protection Practices

The following information was obtained from the Phase 2 ESA Report (GLL, 2002).

2.10.1 Mine Production Process

The Nanisivik Mine began construction in 1974 and in 1976 operation and processing activities commenced. The mill and mine are located approximately 3 km from Strathcona Sound and the tailings disposal facility is located approximately 7 km from the Sound. A concentrate storage shed, ship loading facility, a fuel tank farm, reagent storage area and a dock used by the Canadian Coast Guard as a storage facility for marine emergency response equipment and fueling station, are all located at the Sound.
The mine was primarily an underground operation, in addition to three satellite areas, with smaller contributions of ore from four open pits. Prior to thc last months of operation in 2002, the underground mining method had been predominantly room and pillar, however shut-down operations shifted focus from primary workings to pillar recovery.

The alignment of the mine's primary underground workings approximately extend east-west and daylight on either side of the topographic ridge which measures about 3 km long × 100 m wide × 10 m thick. Several adits enabled passage of both heavy and light vehicles and equipment into the underground mine. Permafrost conditions, which extend to at least 600 meters below the surface, create very dry conditions underground, necessitated specialized dust collection apparatus on drilling equipment.

The concentrator plant was a conventional grind/flotation plant that produced two mineral concentrates from sulphide ore. The DMS plant, constructed in 2000/2001, enabled a pre-concentration process that removed gangue material from the ore before it entered the mill circuit. Other major mill equipment included flotation cells, pumps, piping, cyclones, grinding mills, thickeners, dewatering filters, air compressors, blowers, vacuum pumps, controllers and instrumentation.

The mill had a proven capability of processing 780,000 tonnes per year using conventional crushing, rod and ball mill grinding, differential lead and zinc flotation, and concentrate drying. Waste heat from the diesel power generators heated the buildings and dried the concentrates. Run-of-mine ore was crushed in an underground jaw and cone crusher circuit. The crushed ore was stored underground to prevent thawing. From the underground bin the ore was conveyed to the mill where it was pre-concentrated in the DMS circuit to remove waste rock from the ore. The upgraded ore passed through a rod and ball mill circuit to liberate the contained minerals, prior to reagent addition and selective flotation for lead and zinc. Lead and zinc flotation concentrates were thickened, filtered and dried in rotary dryers to about 5% moisture, using waste heat from the power plant. The concentrates were trucked approximately 3 km to the 125,000 tonne capacity storage shed at the dock site.

Flotation tailings were pumped through a 4 km pipeline to the WTDA. Process water for the mill was recycled from the Reservoir portion of the tailings disposal area.

2.10.2 Environmental Protection Practices

Process tailings were pumped from the mill to the WTDA. Tailings were deposited under a water cover in West Twin Lake until 1990, at which time a frozen core dyke was constructed of tailings and shale that divided the lake into two approximately equal sections. The dyke was built in annual upstream lifts of approximately 2 metres each to ensure permafrost aggradation. The dyke is currently 18 metres high and 800 metres in length. Tailings deposition at the toe of the dyke provides increased physical stability for the structure. Tailings have been confirmed to possess the potential to produce acidic drainage under certain environmental conditions, and are managed to prevent this from occurring.

Tailings were deposited subaerially (exposed) in the upper containment area (the "surface cell") according to a strategic plan that ensures the maximum utilization of the available storage capacity. Water was decanted from the upper surface cell to the lower "reservoir" via syphon pipes and pumping. The water was largely clear due to rapid settlement of solids.

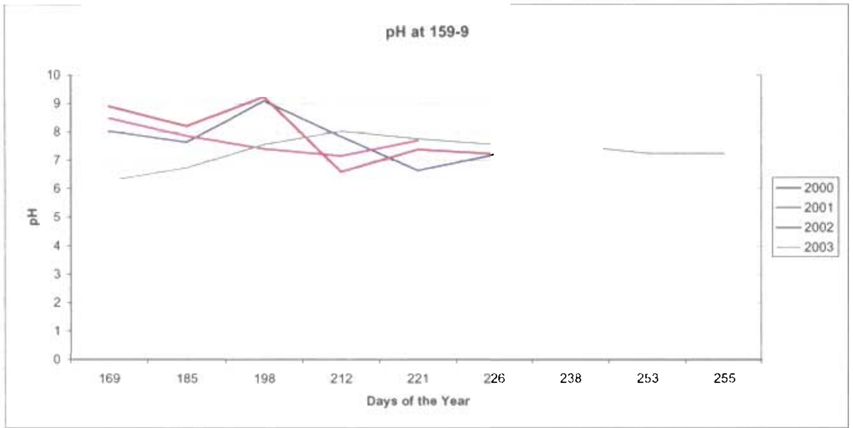
The lower containment area (the "reservoir") contains subaqueous tailings that are covered with water and a relatively small amount of tailings that are exposed in a reclamation test cell area and around the littoral area of the reservoir. Water was pumped from the reservoir to the mill for reuse in the concentrator process. The water elevation in the reservoir is manually controlled at a valved discharge structure where water is released to Twin Lakes Creek. The water elevation is managed in such a way to maintain adequate water supply for the reclaim pumping system and to maintain a water cover over the subaqueous tailings. The water level is also managed to remain below the water elevation in East Twin Lake as a means of reducing the possibility for subsurface flow from the WTDA to East Twin Lake. Metal concentrations in the effluent released from the WTDA are in compliance with the *MMER*.

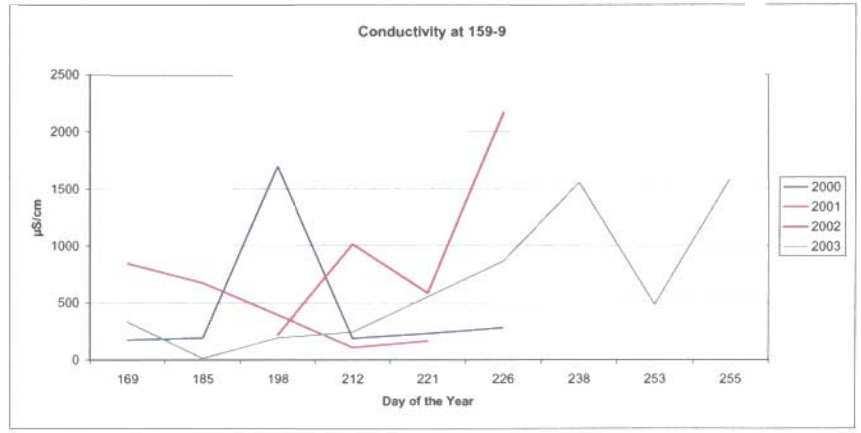
The reclamation test area (the "test cell") is located within the lower containment area separated from the wet reservoir by a small (approximately 4 metres high) dyke constructed of tailings and shale. The test cell area has been used to evaluate the efficiency of various materials and methods of placement as the reclamation soil for closure cover of sub aerial tailings.

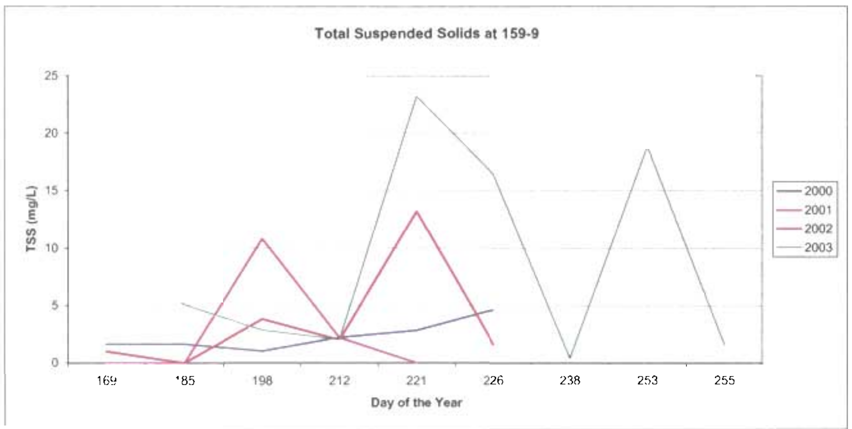
Wind dispersion of tailings was an issue of environmental concern for a period starting in 1991. Wind dispersion was typically been observed during the winter when the surface of the upper containment area might be windswept clear of snow cover exposing dry tailings particles. The wind direction is predominantly from the south-southeast and dispersion of particles was observed to the lee side of the surface cell. Dust control methods were implemented to mitigate wind dispersion including: induced ice cover (through flooding and water cannons), natural and induced snow cover (through fencing), shale cover, and water saturation during periods of thaw.

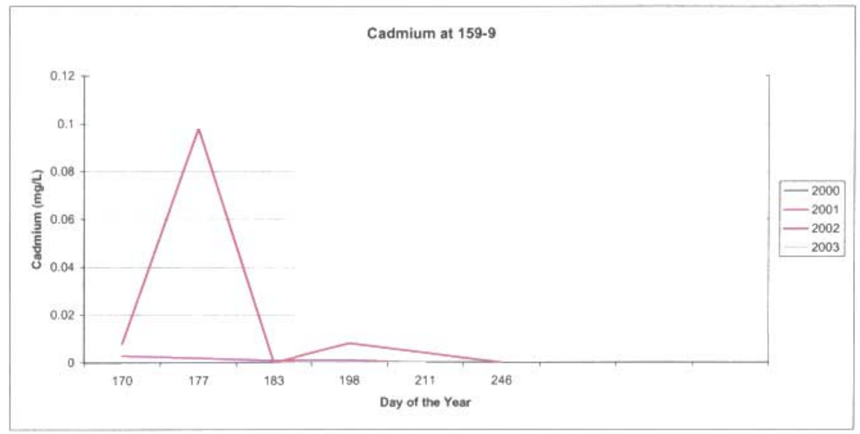
2.10.3 Mine Effluent Quality

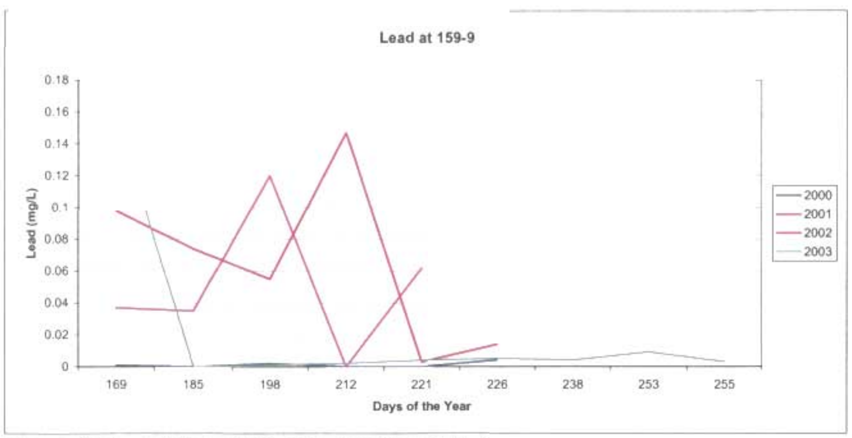
Graphs summarizing mine effluent quality between 2000 and 2003 (effluent discharged from the WTDA, Station 159-4), and water quality in Twin Lakes Creek (at Stations 159-9 and 159-6) are provided as Figures 2.4, 2.5 and 2.6, respectively. These graphs are summaries of data regularly reported to the Nunavut Water Board as part of regulatory compliance, and more recently to Environment Canada as part of the *MMER*. In some cases, outlier data points have been removed to ensure that the graph ranges are representative of normal operating conditions. The mean, minimum, usual maximum, and outlier values for each year are provided in Table 2.3.











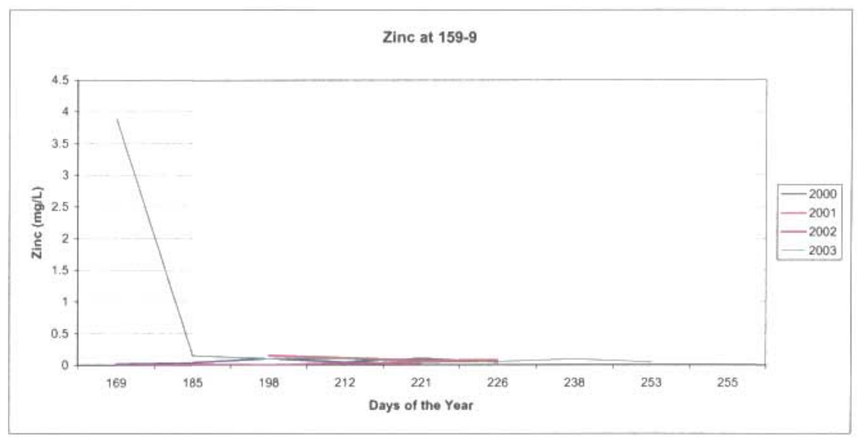


Figure 2.4 Effluent Quality Station 159-9

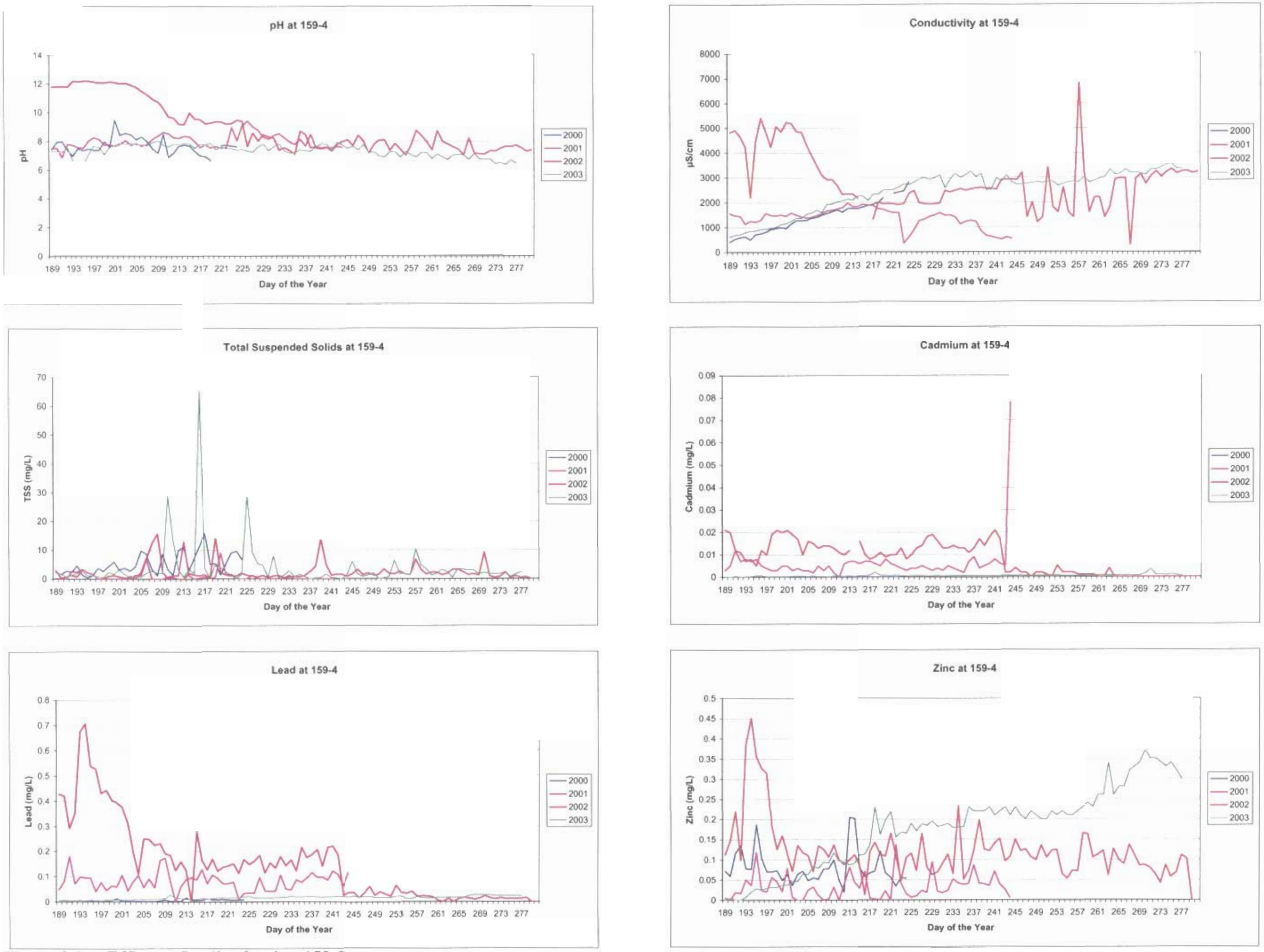


Figure 2.5 Effluent Quality Station 159-9

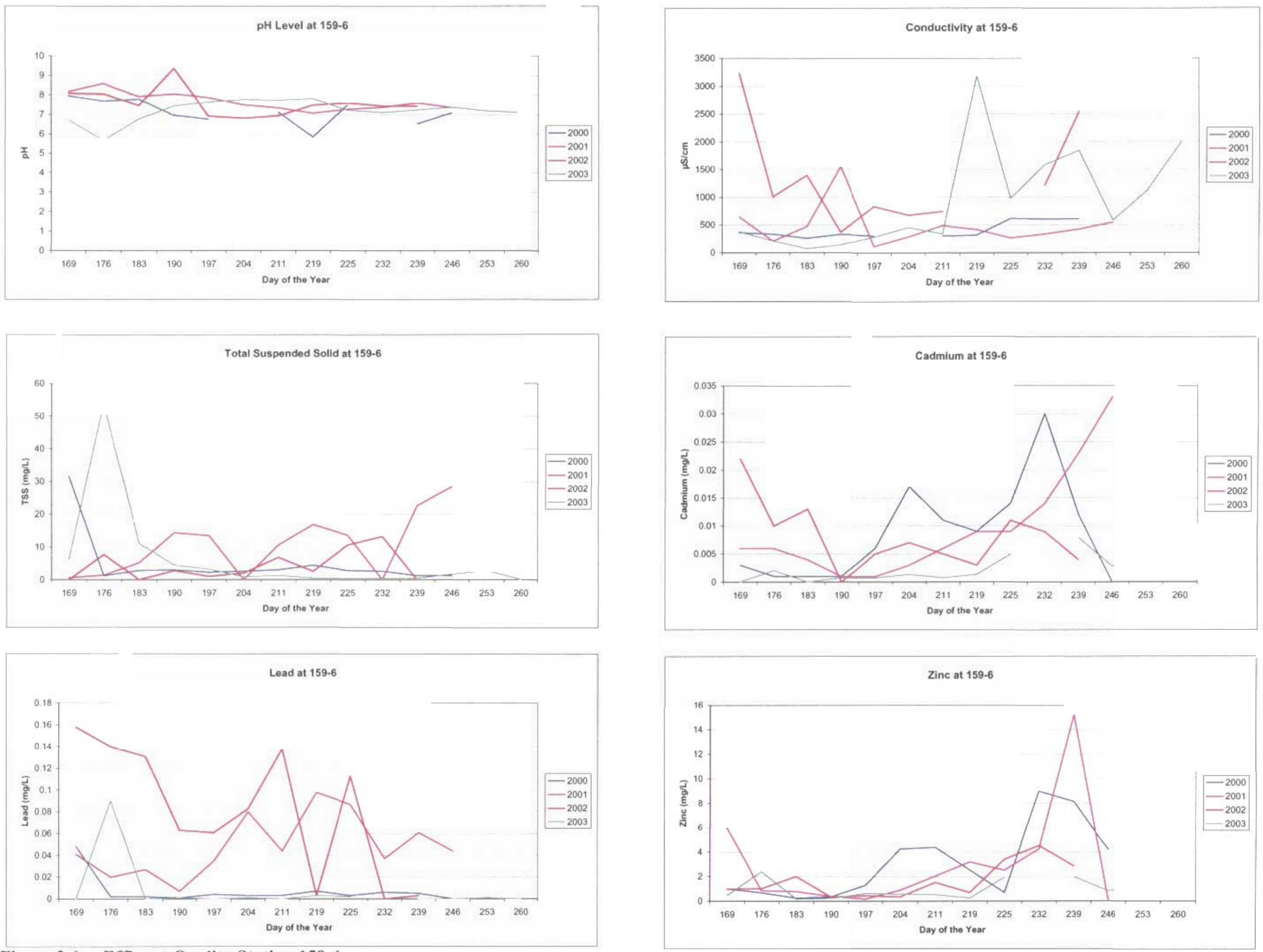


Figure 2.6 Effluent Quality Station 159-6

Table 2.3 Water Chemistry Outlier Data

	Station 159-4 (Mine Effluent)				Station 159-9 (Twin Lakes Creek Below WTDA)				Station 159-6 (Twin Lakes Creek at Mouth)			
	Year 2000 Data				Year 2000 Data				Year 2000 Data			
Parameter	Mean	Minimum	Usual Maximum	Outliers	Mean	Minimum	Usual Maximum	Outliers	Mean	Minimum	Usual Maximum	Outliers
pH	7.93	6.65	9.5	none	7.75	6.65	9.1	none	7.12	5.86	7.94	none
Conductivity (µS/cm)	1413	400	2820	none	459	1694	173	none	404	257	616	none
Total Suspended Solids (mg/L)	5.17	0.4	16	none	2.3	1	4.6	none	4.88	1.2	4.4	31.6
Cadmium (mg/L)	<0.001	<0.001	<0.001	none	<0.001	<0.001	<0.001	none	0.01	0.001	0.017	none
Lead (mg/L)	0.005	0.002	0.02	none	0.002	<0.001	0.004	none	0.008	<0.001	0.007	0.048
Zinc (mg/L)	0.08	0.02	0.205	none	0.055	0.019	0.103	none	3.065	0.256	8.968	none
	Year 2001 Data				Year 2001 Data				Year 2001 Data			
Parameter	Mean	Minimum	Usual Maximum	Outliers	Mean	Minimum	Usual Maximum	Outliers	Mean	Minimum	Usual Maximum	Outliers
pH	7.99	6.87	9.4	none	7.73	7.17	8.5	none	7.68	7.08	8.59	none
Conductivity (µS/cm)	1358	352	1990	none	437	110	845	none	483	117	1556	none
Total Suspended Solids (mg/L)	2.12	0	13	none	6.5	2.2	10.8	none	12.7	0.6	28.4	none
Cadmium (mg/L)	0.006	0.002	0.078	none	0.001	0	0.003	none	0.01	0.001	0.033	none
Lead (mg/L)	0.082	0.009	0.181	none	0.051	0	0.12	none	0.048	0.007	0.098	none
Zinc (mg/L)	0.034	0	0.137	none	0.013	0	0.029	none	3.306	0.184	15.2	none
	Year 2002 Data				Year 2002 Data				Year 2002 Data			
Parameter	Mean	Minimum	Usual Maximum	Outliers	Mean	Minimum	Usual Maximum	Outliers	Mean	Minimum	Usual Maximum	Outliers
pH	8.97	7.03	12.19	none	7.94	6.61	9.25	none	7.6	6.83	9.36	none
Conductivity (µS/cm)	2885	290	6800	none	1015	219	2170	none	1337	369	3240	none
Total Suspended Solids (mg/L)	2.17	0	15.7	none	3.6	0.001	3.8	none	4.25	0	13.2	none
Cadmium (mg/L)	0.008	0	0.021	none	0.02	0	0.098	none	0.008	0	0.022	none
Lead (mg/L)	0.15	0	0.708	none	0.065	0.003	0.147	none	0.081	0	0.158	none
Zinc (mg/L)	0.121	0	0.451	none	0.1	0.071	0.144	none	1.658	0.342	4.54	none
	Year 2003 Data				Year 2003 Data				Year 2003 Data			
Parameter	Mean	Minimum	Usual Maximum	Outliers	Mean	Minimum	Usual Maximum	Outliers	Mean	Minimum	Usual Maximum	Outliers
pH	7.3	6.29	8.04	none	7.33	6.29	8.04	none	7.19	5.67	7.81	none
Conductivity (µS/cm)	2446	600	3520	none	644	10	1590	none	940	70	3190	none
Total Suspended Solids (mg/L)	3.57	0	29	65.2	8.91	0.4	23.2	none	6.17	0	6	53.73
Cadmium (mg/L)	0.0006	<0.001	0.0036	none	0.0002	<0.0001	<0.001	none	0.003	0.0007	0.0079	none
Lead (mg/L)	0.02	0.003	0.03	none	0.024	<0.001	0.009	none	0.016	<0.001	<0.01	0.09
Zinc (mg/L)	0.184	<0.005	0.37	none	0.556	0.04	0.014	none	0.979	0.183	2.39	none
Arsenic (mg/L)	0.002	<0.001	0.003	none	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Copper (mg/L)	0.061	0.005	0.122	none	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Nickel (mg/L)	0.006	<0.005	0.016	none	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Radium (Bq/L)	0.072	<0.01	0.140	none	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ammonia (mg/L)	2.374	0.480	3.73	none	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

In addition to measuring pH, conductivity, total suspended solids (TSS), cadmium, lead and zinc, the Nanisivik Mine measured additional parameters required by the *MMER* during 2003. The additional parameters include arsenic, copper, nickel, radium-226 and ammonia. The range of values observed for these substances is also provided in Table 2.3.

The mine also monitors the acute toxicity of the mine effluent. The effluent is normally not lethal to rainbow trout as measured by the standard 96-hour LC50 test. However, the effluent is occasionally toxic to *Daphnia magna* in the standard 48-hour LC50 test.

Station 159-4 – Mine Effluent

Mine effluent is discharged from the WTDA mainly during the months of June, July and August, and this discharge is monitored at Station 159-4 (see Figure 2.4). The pH of the mine effluent is typically in the range of 6.5 to 8.5, and there has been little variation between years. Although the WTDA does not include a lime treatment step, the pH of the mine effluent is not acidic, and there has been no evidence of significant acid generation in the tailings. The specific conductance of the mine effluent is usually in the range of 500 to 3,000 µS/cm, and tends to increase steadily through the season. This is presumably due to an initial dilution from melting snow during the spring and early summer. Total suspended solids concentrations in the effluent are typically less than 10 mg/L.

Concentrations of zinc, cadmium and lead in the mine effluent are also shown in Figure 2.4. Zinc concentrations typically range from 0.02 to 0.2 mg/L, although a year end final concentration of 0.37 mg/L was observed during 2003. Lead concentrations are typically less than 0.2 mg/L, and cadmium concentrations are typically less than 0.01 mg/L.

In the spring of 2002, there was a period when high pH (12) was observed, and concurrently with this, high conductivity and higher than normal concentrations of zinc and lead were observed.

Station 159-9 – Twin Lakes Creek at Water Tank

Station 159-9 represents Twin Lakes Creek, downstream from the point of effluent discharge, but upstream from the major zone of mineralization and waste rock. This site best represents the effects of mine effluent discharge on the baseline water quality of Twin Lakes Creek.

The pH at this location is variable, but usually between 7 and 9. The specific conductance is typically less than 1,000 µS/cm, and the TSS concentration is typically less than 10 mg/L. Concentrations of zinc, lead, and cadmium, while reflecting loadings from the mine effluent, are generally very low. The zinc and lead concentrations are typically less than 0.1 mg/L, and the cadmium concentration is typically less than 0.01 mg/L.

Station 159-6 – Twin Lakes Creek at Strathcona Sound

Station 159-6 represents Twin Lakes Creek at its mouth, just before the water enters Strathcona Sound. This site is influenced by high metal loadings from the natural zone of mineralization, as well as waste rock, and the mine effluent. This site is also influenced by municipal sewage effluent from the townsite.

The pH at this location is typically between 6 and 9. The specific conductance is typically less than 1,000 μS/cm, although episodes of higher conductivity are observed in most years. The TSS concentration at the mouth of Twin Lakes Creek is typically less than 10 mg/l. The largest difference between Stations 159-9 and 159-6 is observed in the metals concentrations. Zinc concentrations at the mouth of Twin Lakes Creek range from less than 1 mg/L to more than 10 mg/L, and generally tend to increase towards the later part of the season (August). The high loadings in the latter part of the season have been attributed to the natural zone of mineralization in metal loading studies submitted to the Nunavut Water Board as part of the requirements of the Water License. Lead concentrations at Station 159-6 range from less than 0.01 mg/L to over 0.1 mg/L. Cadmium concentrations at Station 159-6 range from 0.001 mg/L to 0.03 mg/L.

3.0 FISH STUDY

According to *MMER*, the objective of the EEM program is to evaluate the effects of effluent on the aquatic environment, specifically fish, fish habitat and the use of fisheries resources. This information should reveal the effectiveness of pollution prevention and control technologies, practices, programs and regulations.

The Nanisivik Mine discharges effluent from the West Twin Lake tailings area, via a weir, to Twin Lakes Creek. A secondary effluent discharge point, at the East Adit Treatment Facility, did not discharge effluent in 2002 or 2003, and is not expected to discharge effluent in future, due to mine closure and reclamation. Therefore, the fish study study design will focus on the effluent discharged from the West Twin Lake tailings area.

A key assumption of Section 7 (1) of the *MMER* is that there is a fish population in the area, where effluent is deposited, that can be affected by the effluent. In addition, Section 7 (3) requires that the studies shall be performed and interpreted in accordance with good scientific practice. That means that the studies should be carried out in the expectation of being able to establish a cause and effect relationship. However, Twin Lakes Creek was described as a naturally fishless system by BC Research (1975a), prior to the development of Nanisivik Mine, and remains fishless today. The creek has a high gradient, with a number of natural waterfalls that act as a barrier to access by fish. Since there are no fish present in the primary effluent mixing zone downstream of the West Twin Lake tailings area, it is not possible to conduct a fish population or fish tissue study at this location.

In order to comply with the *MMER*, some kind of fish study is required. The following alternatives to a fish study in the primary receiving area for the mine effluent were considered:

- mesocosm studies;
- caged bivalve studies;
- expanded sublethal toxicity test studies; and
- a downstream fish study, in the marine environment, where the mine effluent eventually enters habitat where fish are present.

While a downstream fish study in the marine environment has been selected as the preferred option for the fish study, the advantages and disadvantages of the other potential alternatives are briefly summarized below.

Mesocosm Studies

Mesocosm studies would involve the installation of a set of tanks near the point of effluent discharge, where fish would be held for a period of weeks, while being exposed to differing effluent concentrations and a control treatment. At the end of the test, the fish would be sacrificed, and a suite of physical and biological measurements would be made, to evaluate the effects of the effluent on the fish. Mesocosms would allow the measurement of fish survival, and growth or condition factors, but would be unlikely to provide a reproductive endpoint. Mesocosm studies have the advantage of known effluent exposure in situations where exposure might otherwise be uncertain. However, the disadvantages of mesocosm studies at the Nanisivik Mine outweigh the potential benefits. The disadvantages at this site include:

- a remote location with no power available to run mesocosms;
- very high costs to bring materials to the site (remote high Arctic location);
- very high costs (travel, time, and accommodations) to bring and support a technician on-site for the mesocosm study;
- no known local source of fish to populate the mesocosm study;
- uncertainty about whether permits could be obtained to bring fish in from a southern source, and such fish would be subjected to considerable stress during shipping, if permitted; and
- high risk to the project caused by potential for flights in and out to be delayed, or for critical equipment to be "bumped" from cargo shipments by other, higher priority freight.

Caged Bivalve Studies

Caged bivalves are another alternative to the fish study. A caged bivalve study could be performed either in fresh water or in the marine environment, and would involve holding bivalves in cages to examine the biological performance of the bivalves when exposed to the effluent, in comparison with the performance of control groups that were not exposed to the effluent. The caged bivalve study generally does not provide a reproductive endpoint.

Disadvantages of the caged bivalve study at the Nanisivik Mine would include:

- no known source of freshwater bivalves, making a caged bivalve study in Twin Lakes Creek impractical.

Based on discussions with the TAP, there may be a source of bivalves located near the wharf at Nanisivik, however, the species is not known. Blue mussels (*Mytilus edulis*) have been the preferred species for caged bivalve studies elsewhere, however, it is not likely that they are present as far north as Nanisivik. Potential disadvantages of a marine caged bivalve study at Nanisivik include:

- it is not known whether the bivalve species that is locally present is suitable for a caged bivalve study;
- bivalve growth may be too slow to measure, given the short season, and the cold and unproductive Arctic waters of Strathcona Sound;
- there is a risk that cages would be damaged or destroyed by seals that occasionally visit the area; and
- a caged bivalve study would require at least two site visits, increasing cost due to the remote northern location.

Expanded Sublethal Toxicity Test Studies

The Technical Guidance Document for Metal Mining EEM notes that expanded sublethal toxicity testing might be an alternative to the fish study. In follow-up discussions with the TAP it was learned that this option did not imply carrying out additional sublethal tests (or the addition of marine sublethal tests to the planned freshwater series of tests). Rather, there would be an expectation of tests that run for longer periods of time than the standard fathead minnow or inland silverside tests, and that the expanded sublethal toxicity tests would include a reproductive endpoint. Upon consideration, it was felt that this option was not preferred because:

- longer tests would presumably require regular replacement of water (this could be costly and high-risk because of the potential for water shipments to be delayed due to flight delays); and
- these tests are not available "off the shelf", and therefore would be more of a research project, than a readily implemented monitoring test.

Having considered the possible alternatives, a downstream fish study in the marine environment has been selected. The advantages and disadvantages of this alternative, and the proposed study design, are described in detail below.

3.1 Goals and Objectives of the Marine Fish Study

The objective of the fish study is to evaluate the effects of effluent on the aquatic environment, by examining the condition and reproductive potential of fish populations that are exposed to the effluent.

For the Nanisivik Mine, the option that has been identified for the fish study is to perform a fish study in the marine environment of Strathcona Sound, where the effluent from the Nanisivik Mine is eventually dispersed, with the waters of Twin Lakes Creek.