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 the 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.

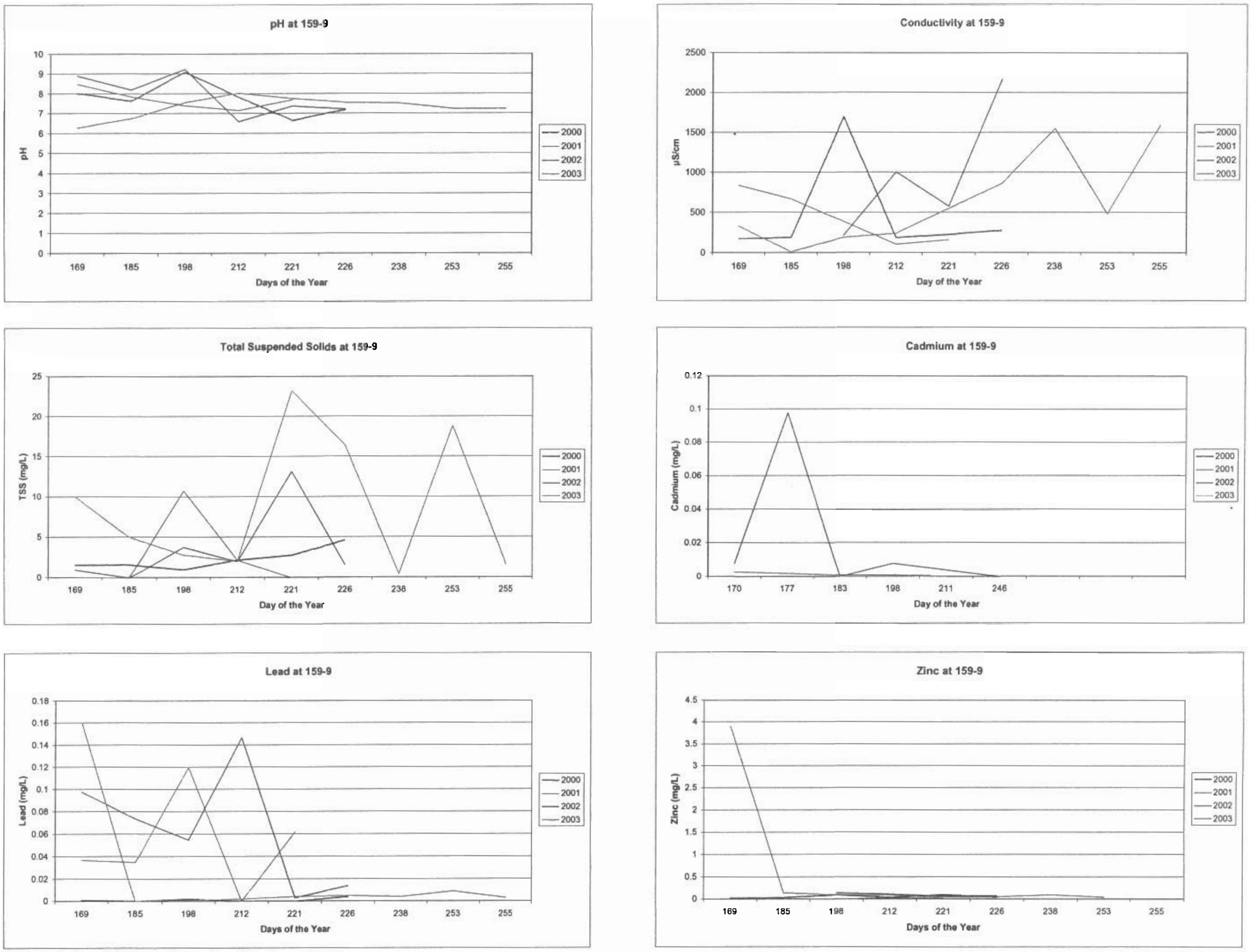

Figure 2.4 Effluent Quality Station 159-9

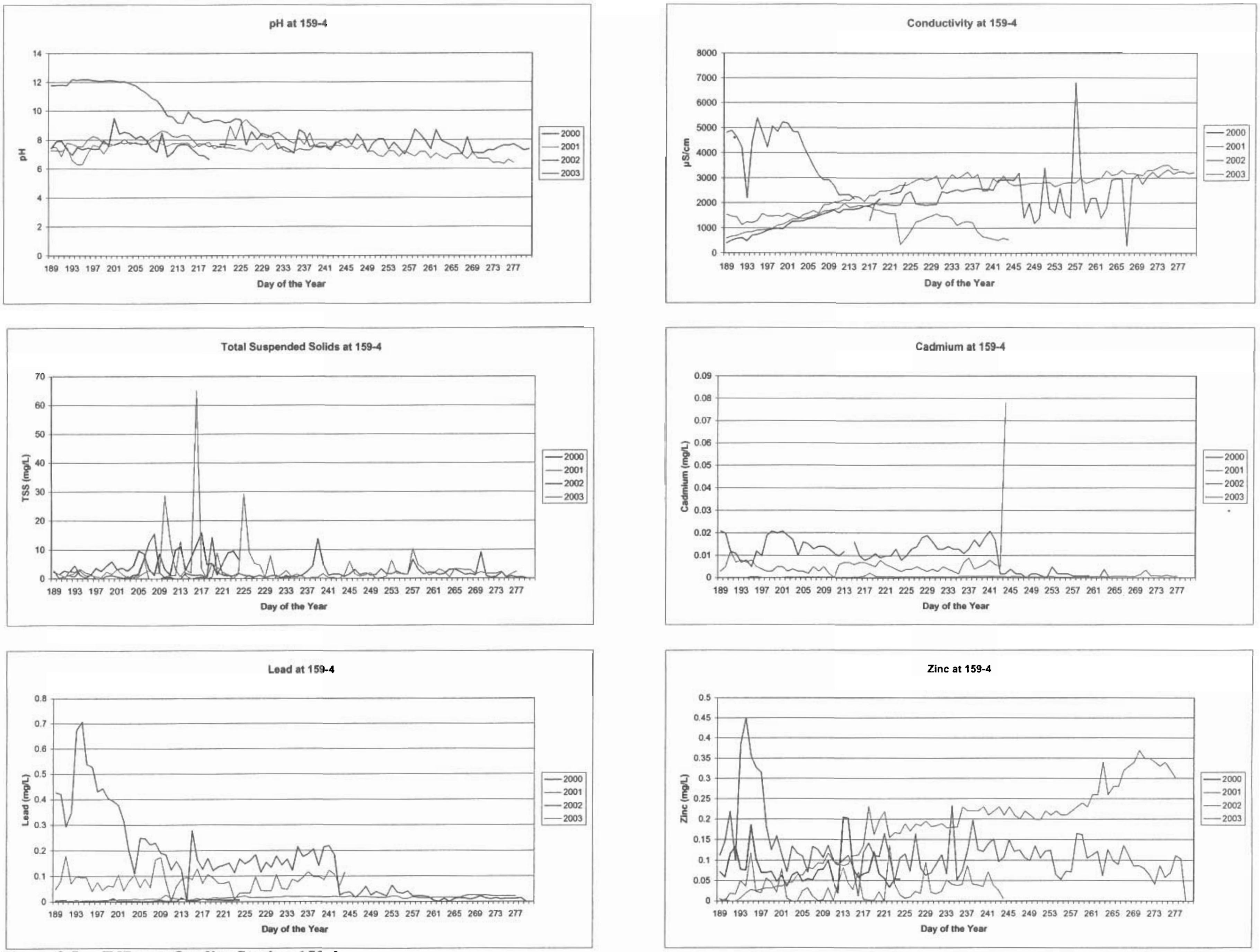

Figure 2.5 Effluent Quality Station 159-9

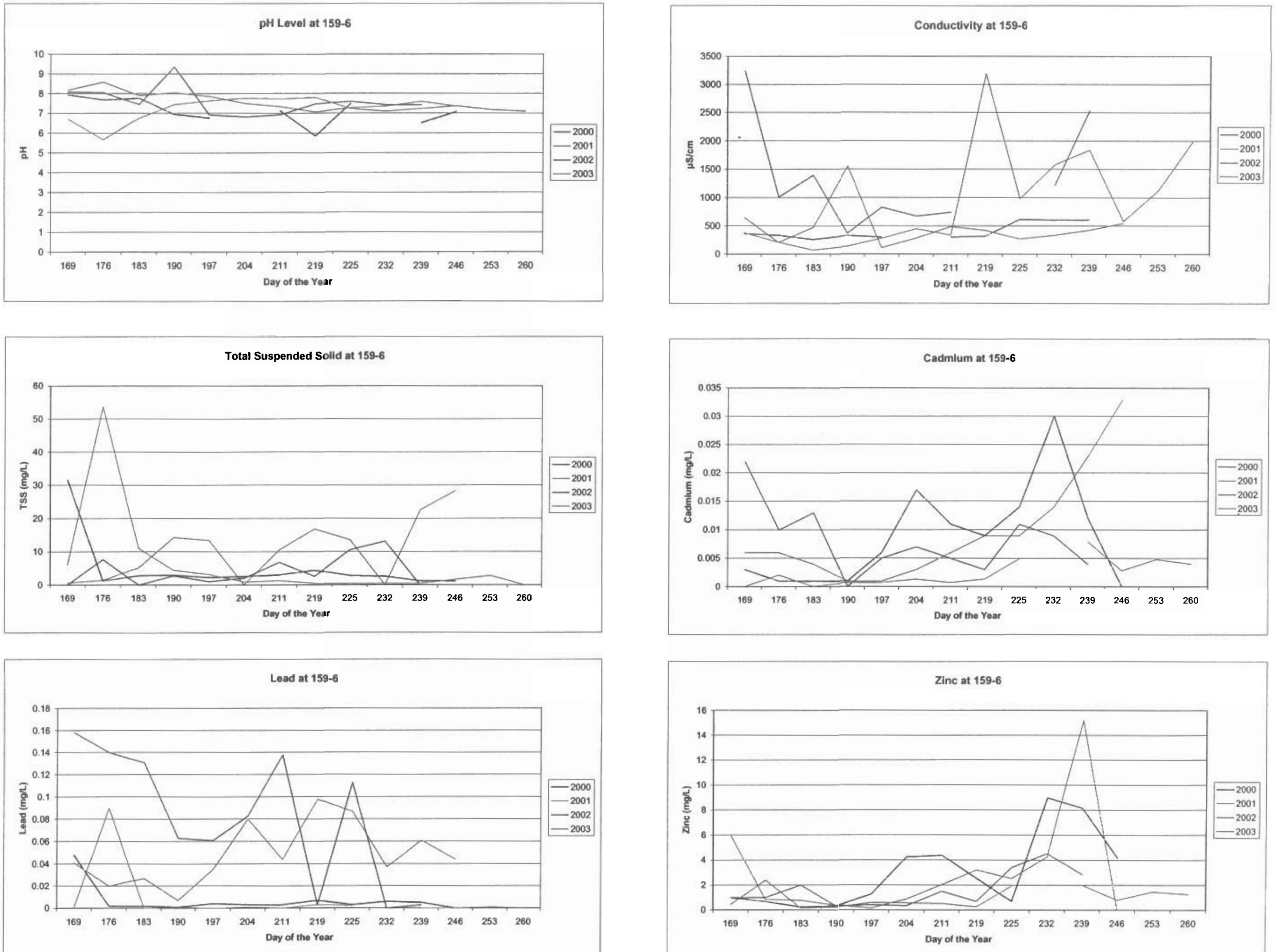

Figure 2.6 Effluent Quality Station 159-6

APPENDIX A
Terrestrial Sampling at Nanisivik Mine, July, 2003

	Station 159-9 (Twin Lakes Creek Below WTDA)				Station 159-6 (Twin Lakes Creek at Mouth)			
	Year 2000 Data				Year 2000 Data			
Outliers	Mean	Minimum	Usual Maximum	Outliers	Mean	Minimum	Usual Maximum	Outliers
none	7.75	6.65	9.1	none	7.12	5.86	7.94	none
none	459	1694	173	none	404	257	616	none
none	2.3	1	4.6	none	4.88	1.2	4.4	31.6
none	<0.001	<0.001	<0.001	none	0.01	0.001	0.017	none
none	0.002	<0.001	0.004	none	0.008	<0.001	0.007	0.048
none	0.055	0.019	0.103	none	3.065	0.256	8.968	none
	Year 2001 Data				Year 2001 Data			
Outliers	Mean	Minimum	Usual Maximum	Outliers	Mean	Minimum	Usual Maximum	Outliers
none	7.73	7.17	8.5	none	7.68	7.08	8.59	none
none	437	110	845	none	483	117	1556	none
none	6.5	2.2	10.8	none	12.7	0.6	28.4	none
none	0.001	0	0.003	none	0.01	0.001	0.033	none
none	0.051	0	0.12	none	0.048	0.007	0.098	none
none	0.013	0	0.029	none	3.306	0.184	15.2	none
	Year 2002 Data				Year 2002 Data			
Outliers	Mean	Minimum	Usual Maximum	Outliers	Mean	Minimum	Usual Maximum	Outliers
none	7.94	6.61	9.25	none	7.6	6.83	9.36	none
none	1015	219	2170	none	1337	369	3240	none
none	3.6	0.001	3.8	none	4.25	0	13.2	none
none	0.02	0	0.098	none	0.008	0	0.022	none
none	0.065	0.003	0.147	none	0.081	0	0.158	none
none	0.1	0.071	0.144	none	1.658	0.342	4.54	none
	Year 2003 Data				Year 2003 Data			
Outliers	Mean	Minimum	Usual Maximum	Outliers	Mean	Minimum	Usual Maximum	Outliers
none	7.33	6.29	8.04	none	7.19	5.67	7.81	none
none	644	10	1590	none	940	70	3190	none
65.2	8.91	0.4	23.2	none	6.17	0	6	53.73
none	0.0002	<0.0001	<0.001	none	0.003	0.0007	0.0079	none
none	0.024	<0.001	0.009	none	0.016	<0.001	<0.01	0.09
none	0.556	0.04	0.014	none	0.979	0.183	2.39	none
none	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
none	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
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.

Some of the limitations of the marine fish study are outlined below.

- The only fish species that is known to be present in the area of the mouth of Twin Lakes Creek in numbers sufficient for the study, and is expected to be relatively sedentary, is shorthorn sculpin (*Myoxocepalus scorpius*);
- Due to the timing of reproduction for shorthorn sculpin (eggs appear to be deposited during the winter months), it is likely that fish that are caught during the summer sampling period will not be sexually mature.
- Due to the behaviour of fresh water entering the marine environment, it is predicted that the freshwater plume will form a thin layer on the surface, subject to winds and tidal (east-west) movement, and will be highly dispersed at the surface before mixing downwards. Therefore, the exposure of the fish to the plume may be limited to very high dilutions.
- The creek water is modified by a number of potentially confounding factors, in addition to receiving the mine effluent. These confounding factors include heavy metals from areas of waste rock and natural mineral exposures, and sewage inputs from the townsite.

However, the advantages of the marine fish study, listed below, are felt to outweigh these disadvantages.

- The marine environment is the nearest location where fish and fish habitat are exposed to the mine effluent, even if there are confounding factors present.
- The primary question asked by the first *MMER* EEM program is whether there is a statistically significant difference between areas exposed to the effluent, and a reference area. While the exact cause of the difference may not be identified by the first biological survey, a statistically significant difference may be observed.

3.2 Past Monitoring Results and Conclusions

There are two recent reports that provide some information on environmental effects of Twin Lakes Creek water entering the marine environment. These are: *Toxicity Testing, Mouth of Twin Lakes Creek in Strathcona Sound* (Lorax, 2000); and *Marine Sampling in Strathcona Sound, July, 2003* (JWEL, 2003c).

3.2.1 Toxicity Testing at the Mouth of Twin Lakes Creek

In compliance with a condition of the Nanisivik Mine water license issued by the Nunavut Water Board, water samples were collected from the estuarine mixing zones of Twin Lakes Creek and Kuhulu Creek (reference site) in late August, 2000. The purpose of these samples was to examine water quality, and to carry out toxicity testing with sand dollar (*Dendraster excentricus*) and Microtox tests, in the mixing zone. At the time of collection, there was no evidence of stratification in the upper 5 m of the water column. However, the samples were collected at a time of low flow in the creek, and the nearest sampling station to the creek was 60 m offshore, at a sample depth of 0.1 m.

Surface waters at 60 m offshore from the mouth of Twin Lakes Creek and 0.1 m depth were characterized by higher concentrations of cadmium (0.16 μg/L), copper (0.9 μg/L), lead (1.11 μg/L) and zinc (217 μg/L) when compared with another station 75 m offshore at a depth of 5 m, or with the reference station near the mouth of Kuhulu Creek.

The metal concentrations at a depth of 0.1 m, 25 m off the mouth of Kuhulu Creek were cadmium (0.06 μg/L), copper (0.35 μg/L), lead (0.22 μg/L) and zinc (23 μg/L).

Toxicity testing with the sand dollar demonstrated that fertilization was inhibited 50% at the Twin Lakes Creek station, when compared with the reference stations. Microtox testing did not indicate differences at any station. It was concluded that the fertilization tests demonstrated that loadings from Twin Lakes Creek have the potential to exert fertilization inhibition on biota in the local receiving environment at Strathcona Sound, however, the spatial extent of potentially toxic waters was not established.

3.2.2 Marine Sampling in Strathcona Sound, 2003

JWEL collected samples of fish tissues and sediments from Strathcona Sound for analysis during 2003 (JWEL, 2003c). The full report is included with this document as Appendix C. The fish tissue sampling was for trace metal analysis, although a number of parameters typically required during the fish study were also measured (including length, weight, gonad and liver weight). Sediment samples were also collected and analysed for trace metals. In addition, incidental observations on the stratification of Strathcona Sound in mid July were also documented.

The fish were collected at the Nanisivik wharf using rod and line, with baited jigs. Shorthorn sculpin were readily caught at this location. During the period when 12 shorthorn sculpin were collected, a single Arctic cod was also taken, and released. The fish were frozen shortly after being collected, and were subsequently thawed and dissected at the JWEL office in Fredericton, New Brunswick. Dorsal muscle samples (fillet with skin on) were submitted for chemical analysis of trace metal concentrations.

The Technical Guidance Document for Metal Mining EEM cites an Ontario guideline of 0.45 mg/kg for mercury as being the level above which an impairment of the usability of the fish resource may have occurred. At the Nanisivik wharf, the mean mercury concentration for 12 fish analysed was 0.15 mg/kg, and the range of observed concentrations was 0.07 to 0.26 mg/kg. Therefore, there is no reason to believe that either natural processes or human activities have led to a situation where there is an impairment of the usability of the fish resource at Nanisivik. Moreover a comparison of fish tissue metal data collected in 2003 with data reported by BC Research (1975) showed that there did not appear to have been a significant change in tissue metal concentrations over that period.

The sediment cores that were collected were sectioned into surface and deep layers. The sediments were highly calcareous, reflecting the local geological environment. Trace metal concentrations observed in the sediments are summarized in Table 3.1 below:

Table 3.1 Observed Metal Concentration Ranges in Marine Sediments Near the Mouth of Twin Lakes Creek, July, 2003.

Element	Observed Concentrations
Arsenic	9 to 14 mg/kg, above the CCME (1999) ISQG value of 7.24 mg/kg, but below the PEL value of 41.6 mg/kg in all cases.
Cadmium	1.6 to 10.2 mg/kg, spanning the range of the CCME (1999) PEL guideline of 4.2 mg/kg.
Chromium	23 to 27 mg/kg, below the CCME (1999) ISQG value (52.3 mg/kg) in all cases.
Copper	26 to 40 mg/kg, between the CCME (1999) ISQG value (18.7 mg/kg) and the PEL value (108 mg/kg) in all cases.
Lead	88.4 to 568 mg/kg, spanning the range of the CCME (1999) PEL guideline (112 mg/kg).
Mercury	0.03 to 0.1 mg/kg, below the CCME (1999) ISQG value (0.13 mg/kg) in all cases.
Zinc	481 to 2,740 mg/kg, above the CCME (1999) PEL guideline (271 mg/kg) in all cases.

Although concentrations of some of the metals are elevated in comparison with the CCME (1999) marine sediment quality guidelines, the values reported by BC Research (1975b) occupy similar ranges. Moreover, while one core had higher concentrations of cadmium, lead and zinc in the surface section, the other core had higher concentrations of these elements in the deeper section.

Therefore, there is not a clear pattern that would suggest that the mining activities have caused a substantive change in metal concentrations in the biota or sediments near the mouth of Twin Lakes Creek.

3.3 Fish Study Design for EEM

This section provides the proposed Fish Study design for the Nanisivik Mine EEM program.

3.3.1 Rationale

A fish study in the marine environment of Strathcona Sound is the most appropriate study to meet the requirements of the *MMER* because this is the nearest location to the point of effluent discharge where fish populations, or fish habitat, might be affected by the mine effluent released from the West Twin Lake tailings area.

3.3.2 Hypotheses

The null hypothesis to be evaluated is:

- Measurements of length-at-age, weight-at-age, condition, liversomatic index, and gonadsomatic index for fish collected near the mouth of Twin Lakes Creek (the exposure area) are not significantly different from those for fish collected at a reference area.

If this null hypothesis is rejected ($p<0.05$) for any of the biological measurements, it will be concluded that there is a statistically significant difference present.

The proposed study, and the null hypothesis to be tested, applies only to the comparison of Twin Lakes Creek with a reference location. Due to confounding factors present in Twin Lakes Creek (see below), the study design can not uniquely attribute an effect observed at the mouth of Twin Lakes Creek to the release of mine effluent, or other mine-related activities or effects. This statement of the null hypothesis, and the scientific limitations of a first study design, is consistent with and meets the requirements of the *MMER*.

3.3.3 Confounding Factors

As was described in Section 2 of this document, there are two main confounding factors present in Twin Lakes Creek that limit the ability for this investigation to identify a cause-effect relationship, if it is concluded that there is a significant difference between fish from the exposure and reference areas. The confounding factors include:

- sources of metal loading to Twin Lakes Creek other than the WTDA; and
- deposit of untreated sewage from a sewage station owned by the Government of Nunavut into Twin Lakes Creek.

Twin Lakes Creek cuts through a naturally occurring zone of metal sulfide mineralization about half way down its length, as well as passing by several waste rock areas and the former mill. Seasonal thaws, and episodes of rain periodically wash high loadings of zinc, lead and other metals from various sources into the creek. As a result of these high metal loadings, which are substantially larger than the metal loadings from the mine effluent, the concentration of zinc at the creek mouth is usually elevated. In addition, raw sewage from a sewage station owned by the Government of Nunavut, is deposited into the creek at a location close to the former Mill. These two factors (other metal loadings and nutrient addition due to raw sewage discharge) are considered to be confounding factors that will make it impractical to isolate the effects of mine effluent discharge on fish in the marine environment.

Adding to the confounding factors, the behaviour of the creek waters upon entering the marine environment also merits consideration. When visited in July 2003, the combination of melting sea ice and fresh water inflows resulted in the formation of a layer of fresh water on top of the marine water. Although the freshwater lens was probably at its thickest and greatest extent at this time (due to melting sea ice, as well as relatively high stream flows), the freshwater plume from the creek can be expected to "float" in a thin layer on top of the marine waters at all times, until wind and wave action physically mix the fresh water into the underlying sea water. In addition, the freshwater plume will be advected east-west with the rising and falling tide. This is typical behaviour of freshwater streams entering the marine environment.

The predominant species of fish in this area appears to be shorthorn sculpin (*Myxocephalus scorpius*), a bottom-dwelling species. The water column near the mouth of Twin Lakes Creek drops off rapidly from approximately 1 m at the creek mouth, to in excess of 200 m offshore. As a result, marine fish may not be exposed to creek water containing the effluent, except at very high dilution.

3.3.4 Statistical Design

The proposed fish study will focus on adult shorthorn sculpin, which may not be in reproductive condition (*i.e.*, the gonads of fish sampled may not be fully ripe) at the time of sampling due to the necessity of sampling in the summer months, while these fish spawn during the winter. The study will be an Initial Monitoring study, as defined in the *MMER*. In order to try to optimize the study, the field program will be scheduled later in the season while the mine is still releasing effluent (likely during late July or early August 2004).

The exposure area will be located near the mouth of Twin Lakes Creek. A reference area has been selected, in part based upon the advice of members of the TAP, at the mouth of the Strathcona River, on the opposite side of Strathcona Sound (the stations are approximately 7 km apart). Shorthorn sculpin are known to be abundant at both locations. The selection of the Strathcona River as the reference area should minimize the potential for fish to move between the two areas, due to the physical separation.

The recommended minimum sampling size for an Initial Monitoring study is 20 sexually mature males and 20 sexually mature females from both exposure and reference areas (80 fish in total per species sampled). This sample size is based upon the rationale that there is little change in the 95% confidence limits with increasing sample size beyond 20 fish.

The measures to be recorded on each fish will include:

- body total length (±1 mm);
- body weight (g, ±1%);

- external and internal appearance (normal, abnormal, lesions or parasites)
- sex (male or female) and state of maturity (mature or immature);
- liver weight (g, ±1%);
- gonad weight (g, ±1%);
- egg size (±1%, based upon measurements of eggs in preserved gonad samples)
- fecundity (number of eggs per female ±1%, based upon egg counts and diameters in preserved gonad samples);
- age (years, ±1) based on otoliths to be removed from the skull; and
- exposure, based on metals concentrations to be measured in liver samples removed from each fish.

Fish usability will not be investigated in this fish study, and mercury will not be requested as an analyte for fish liver samples, because a recent investigation (JWEL, 2003c) has shown that mercury concentrations in the edible portion of shorthorn sculpin collected near the mouth of Twin Lakes Creek are not greater than 0.45 mg/kg wet weight.

3.4 Fish Study Data Analysis and Interpretation

In the data assessment and interpretation step of the EEM study, the following questions are normally answered:

- is there an effect?
- is the effect mine related?
- is the magnitude and extent of the effect known?
- is the mine-related cause of the effect known?

However, since the Nanisivik mine has applied for recognized closed mine status, and the present investigation will be both an Initial Monitoring study, and the Final Biological Monitoring study prior to closing mine, there will be inherent limitations on the questions that it will be possible to answer. Specifically, it will be possible to determine whether there is an "effect" on the fish population as defined in the *MMER*, and what the magnitude of effects may be. However, due to confounding factors present, it will not be possible to determine whether the effect is mine related. Since this is the Final Biological Monitoring study, there will be no follow-up to evaluate any possible mine-related cause of effects. Finally, the study will not provide specific information on the spatial extent of possible effects, except to the extent that the exposure area represents the mouth of Twin Lakes Creek.

It is possible that the study will conclude that there is no significant effect on fish. The Metal Mining EEM Guidance Document states that there are at least three reasons that a mine in compliance with the *MMER* may not have receiving water effects: