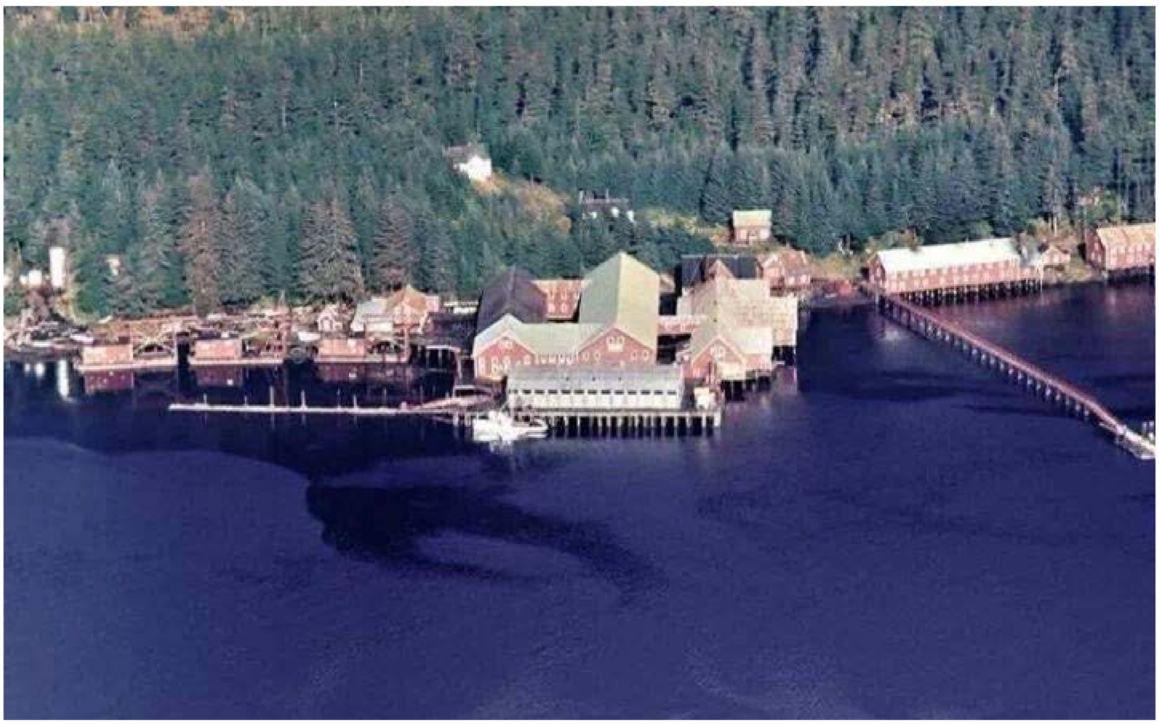
HAWK INLET MONITORING PROGRAM 2019 ANNUAL REPORT



Hecla Greens Creek Mining Company

1 March 2020

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HAWK INLET MONITORING PROGRAM
2019 ANNUAL REPORT

1. INTRODUCTION

1.1 Site Description

The Greens Creek Mine, located on Admiralty Island is 18 miles southwest of the city of Juneau, Alaska. Dense forests cover the mountain slopes up to an elevation of 2,500 feet, above which the vegetation is alpine. The climate is maritime, with precipitation averaging 60 to 70 inches per year at the mine site, and 45 to 55 inches per year near the port facilities. The mine and mill facilities (920 area) are located over 6 miles from Hawk Inlet tidewater.

Zinc, lead, silver, and gold are the target recovery metals. The production of ore concentrate began in February 1989 and operated approximately four years before production was suspended in April 1993. The mine and mill were recommissioned, and operations restarted in mid-1996. A milling facility and support facilities are in place in the 920 area. Filter pressed tailings from the milling process are backfilled in the mine and also deposited at a surface dry-stack tailings pile. Ore concentrate (concentrate) is transported from the mill to the Hawk Inlet port facilities area (Port), where it is stored until it is shipped offsite. Support facilities for the mining and milling operation at the Port include rock core storage, concentrate storage, shipping port, shift housing, and a domestic wastewater treatment plant.

One wastewater discharge outfall and ten stormwater discharge sites are authorized by the HGCMC Alaska Pollutant Discharge Elimination System (APDES) Permit Number AK-0043206. Sewage treatment effluent, previously discharged through Outfall 001, is combined with area surface runoff and pumped to Pond 7. At Pond 7, the water is combined with effluent streams from the 920 and the Tailings Facility, treated and discharged through the submarine APDES Outfall 002 to the ocean at the mouth of Hawk Inlet. Authority over the federal permitting, compliance, and enforcement of the NPDES program transferred to the State in November of 2010 for the mining industry. This report fulfills the requirements of APDES Permit Number AK-0043206, effective October 1st, 2015.

Hawk Inlet is a marine inlet formed during the late Holocene glaciation and is underlain by a series of late-Paleozoic to Mesozoic phyllitic-schist and greenstone formations. Hawk Inlet extends seven miles north from Chatham Strait to a tidal mudflat estuary about 0.6 miles in diameter. The narrow channel connecting the Inlet to Chatham Strait, located between the top of the Greens Creek delta and the western shore of Hawk Inlet, has a minimum low tide depth of 35 feet. The mid-channel depth ranges from 35 feet to 250 feet. The Inlet has regular, twice-daily tides, with a maximum tidal variation of 25 feet. On the flood tide, the surface 35-foot layer contains the bulk of the water transport entering the inlet and is then flushed out on the ebb tide. Flushing describes the rate and extent to which a body of water is replenished by tidal or other currents. Flushing rates are also indicative of the length of time that mining effluent may remain in a water body and become incorporated into the physical and biological ecosystem through ingestion, adsorption, or other means. In 1983, dispersion dye testing in Hawk Inlet determined that over each tidal cycle, an average of 13 billion gallons of water is flushed from the inlet (SEA 1983). At that rate, it is estimated that the inlet completely flushes once every five tidal cycles. Based on the average daily output in 2019, the effluent from the mining operations over a day represents approximately 0.007% of the total volume flushed daily.

Greens Creek geology exploration began in 1973, which led to the predevelopment of mining operations in 1986. Before this, the Hawk Inlet cannery was constructed in 1910 and operated until it burned in 1976. It is estimated that the summer population at Hawk Inlet during cannery operation was 500. Additionally, up until 1946, gold was being mined near Hawk Inlet, beginning in 1919 at the Alaska Empire Mine (Forest Service 2013). “In September 2014, the Forest Service conducted a Preliminary Assessment/Site Inspection of the Alaska Empire Mine site. Elevated concentrations of metals were found in the soil, sediment, surface water, and groundwater at the Upper Camp as well as soil stained by petroleum hydrocarbons. Tailings piles with elevated concentrations remain adjacent to the creek and continue to erode tailings into the creek.” (Palmieri 2016).

1.2 Hawk Inlet Monitoring Program

In anticipation of the Greens Creek Mine development, government agencies, scientists, and biological consultants carried out surveys of marine life and baseline studies of heavy metals in the environment beginning in the early 1980s. Several researchers have studied marine life in Hawk Inlet, and the on-going quarterly and annual monitoring events have generated an extensive time-series data set of metal levels in the water, sediment, and marine tissue samples.

The primary objective of the Hawk Inlet monitoring program is to document the water quality, sediment chemistry, and biological conditions in receiving waters and marine environments that may be impacted by the mine’s operations. Seawater is sampled quarterly at three locations in Hawk Inlet. Sediment and invertebrate samples are collected annually at three and seven locations, respectively (Figure 1-1). Additional sediment samples are collected at two locations every five years. Table 1-1 summarizes the requirements of the permit for sample parameters, sample preservation and holding time, sampling frequency, analytical method, and required method detection limits

(MDL). Specific quality assurance/quality control (QA/QC) requirements (i.e., sampling procedures, documentation, chain of custody processes, calibration procedures and frequency, data validation, corrective actions, etc.) are outlined in the APDES Quality Assurance Project Plan: Project Monitoring Manual (HGCMC 2018).

In August 2019, Global Diving & Salvage, Inc., using an remote operated vehicle (ROV), surveyed the 002 Outfall pipeline for corrosion and damage. Video of the survey footage can be found as Appendix B. The following points summarize the major findings of the inspection:

Diffuser:

- All anodes that the ROV could get to on the type 4 anchors were inspected and found to be in good shape, all anodes were noted with 70 to 80% of the anode remaining. All the stainless-steel hardware appears to be in good condition and remains intact.

- On the type 2 anchors, the anode nuts that were replaced last year have approximately 90-95% remaining still. Other zinc nuts that were not replaced seem to all be above 80% remaining.

- On the diffuser pipe itself no damage was found and outside of light marine growth, the pipeline appears to be in very good condition.

- The “duckbill” valves were inspected and seem to be flowing freely. Light to moderate marine growth was found on the duckbills. As the ROV cannot “touch” the difference in volume of water coming out of the duckbills is hard to determine, however, as seen in the video, all the duckbills do seem to be flowing and working as intended.

- As seen the previous year, light scouring on the East side of the diffuser remains. On the West side, the natural bottom still comes half way up the pipeline. This is a sign that the inflow of sediment is slowly covering the pipe from the Chatham Strait side. The scouring that has occurred on the Hawk Inlet side is from the back eddies as the current is disrupted by the diffuser. All scouring and back filling is minimal at this time but could become an issue in the future.

Outfall pipeline:

- The pipeline was inspected throughout its length and found to be in very good overall condition. The anchor blocks were typical throughout the length and all the stainless hardware was intact. The capabilities of the ROV make it difficult to see each individual nut due to marine growth and/or the angle at which the ROV would have to be flown. However, it is highly unlikely that the corrosion from one location to the next would be significantly different. The Zinc nuts that were inspected all seemed to be in satisfactory condition. It is estimated that 85-90% of the zinc nuts remain on all 100% of the anchor blocks. There were 3 flanges noted and the corresponding videos show the condition and make up of these. The flanges were problematic for the ROV to see the entirety of it due to marine growth and the risk of entanglement. No damage was noted, and all the hardware seen was intact. The pipeline lays on nature bottom and all the anchors appear to be evenly spaced and secured as intended. For all practical purposes this pipeline remains true to its design.

This report presents information on each of the three media sampled in Hawk Inlet: water column, sediment, and in-situ bioassay. Results for the samples collected are presented along with the associated QA/QC data. Statistical evaluation of the data showing averages, variations, and changes over time are included. The next section describes any deviations from the monitoring program that occurred and the reasons why.

1.1 Deviation(s) from Monitoring Program and Incidents

There were no reportable deviations associated with the annual Hawk Inlet monitoring program.

Table 1- 1. Summary of Permit Sampling Requirements for Hawk Inlet

APDES Requirement	Parameter	Required Sampling Frequency	Sample Type	Sample Container	Sample Preservation	Laboratory	Holding Time	Analytical Method(s)	Minimum Required Method Detection Limit	Units	Comments
RECEIVING WATER COLUMN MONITORING											
1.6.1.1.3 Table 5	Dissolved Cadmium	Quarterly	Grab (1 sample for Cd, Cu, Pb, Zn)	1 ea. 500 ml Teflon bottle (1 bottle for Cd, Cu, Pb, Zn)	HNO_3 to pH <2 by lab	Battelle Marine Sciences	6 months	EPA 213.2/ 1638	0.10	µg/L	MDLs set by APDES permit Section 1.6.1.1.3, Table 5
1.6.1.1.3 Table 5	Dissolved Copper	Quarterly						EPA 220.2/ 1638	0.03	µg/L	
1.6.1.1.3 Table 5	Dissolved Lead	Quarterly						EPA 239.2/ 1638	0.05	µg/L	
1.6.1.1.3 Table 5	Dissolved Zinc	Quarterly					6 months	EPA 289.2/ 1638	0.200	µg/L	
1.6.1.1.3 Table 5	Total Mercury	Quarterly	Grab	1 ea. 250 ml Teflon bottle			28 days	EPA 245.1/ 1631	0.002	µg/L	
1.6.1.1.3 Table 5	Total Suspended Solids	Quarterly	Grab	1 ea. 1 liter plastic bottle	Cool to 4°C	ACZ Labs	7 days	EPA 160.2/ SM 2540D	--	mg/L	
1.6.1.1.3 Table 5	Turbidity	Quarterly	Grab	1 ea. 1 liter plastic bottle	Cool to 4°C	Field measurement	48 hours	EPA 180.1	--	NTU	
1.6.1.1.3 Table 5	WAD Cyanide	Quarterly	Grab	1 ea 1 liter plastic bottle	NaOH to pH >12, cool to 4°C	ACZ Labs	14 days	EPA 335.2/ SM 4500-CN-E	5.00	µg/L	Add 0.6g ascorbic acid, if chlorine is present.
1.6.1.1.3 Table 5	pH	Quarterly	Grab	NA	NA	Field measurement	15 min	EPA 150.1/ SM 4500-H, B	--	SU	
1.6.1.1.3 Table 5	Conductivity	Quarterly	Grab	NA	NA	Field measurement	20 days	EPA 120.1	--	µmhos/cm	
1.6.1.1.3 Table 5	Temperature	Quarterly	Grab	NA	NA	Field measurement	15 min	NA	--	°C	
BIOACCUMULATION WATER SEDIMENT MONITORING											
1.6.1.2.3 Table 6	Total Cadmium	Annual	Grab	6 ea. 8 oz. plastic or glass jar	Chill and ice sample (not frozen)	ALS Environmental		PSEP/GFAA	0.30	mg/Kg	MDLs set by APDES permit Section 1.6.1.2.3, Table 6
1.6.1.2.3 Table 6	Total Copper	Annual	Grab			ALS		PSEP/ICP	15.00	mg/Kg	
1.6.1.2.3 Table 6	Total Lead	Annual	Grab			ALS		PSEP/ICP	0.50	mg/Kg	NMFS request dupilicate sampling
1.6.1.2.3 Table 6	Total Mercury	Annual	Grab			ALS		PSEP/ EPA 7471A	0.02	mg/Kg	
1.6.1.2.3 Table 6	Total Zinc	Annual	Grab			ALS		PSEP/ICP	15.00	mg/Kg	
BIOACCUMULATION WATER IN-SITU BIOASSAY MONITORING											
1.6.1.3.2 Table 7	Total Cadmium	Annual	Grab	6 ea. 8 oz. plastic or glass jar	Chill and ice sample (not frozen)	ALS		EPA 200.8/ 6020	not specified	mg/Kg	NMFS request dupilicate sampling since Fall 2004
1.6.1.3.2 Table 7	Total Copper	Annual	Grab			ALS		EPA 200.8/ 6020	not specified	mg/Kg	
1.6.1.3.2 Table 7	Total Lead	Annual	Grab			ALS		EPA 200.8/ 6020	not specified	mg/Kg	
1.6.1.3.2 Table 7	Total Mercury	Annual	Grab			ALS		EPA 7471A	not specified	mg/Kg	
1.6.1.3.2 Table 7	Total Zinc	Annual	Grab			ALS		EPA 200.8/ 6020	not specified	mg/Kg	

2. WATER COLUMN MONITORING

The receiving water column monitoring requirements originate from Part 1.6.1.1 and Table 5 of the APDES permit. The objective of the receiving water column monitoring element of the sampling program is to provide scientifically valid data on specific physical and chemical parameters for Hawk Inlet water quality. These data are used to evaluate potential changes in the Hawk Inlet marine environment.

In fulfillment of the first EPA issued NPDES permit in 1987, Greens Creek Mining Company sampled quarterly at five locations (104, 105, 106, 107, and 108) for ten total recoverable metals (Ag, As, Ni, Zn, Cd, Cr, Cu, Hg, Pb, and Se) at depths of five feet and 20 feet. In 1998 the NPDES permit was reissued, with the number of sample locations reduced to three (106, 107, and 108) and a reduction in the metals analyzed to five metals (Cd, Cu, Pb, Hg, and Zn), collected at a depth of five feet every quarter. With the 2005 re-issuance of the NPDES permit, the water column monitoring program was changed to require the analyses of Cd, Cu, Pb, and Zn as dissolved concentrations rather than total recoverable. The requirement for effluent toxicity testing was discontinued in 2005.

The current Hawk Inlet water column monitoring program is essentially the same as was put in effect in 2005. Seawater samples are collected quarterly from the sites on an outgoing tide, with the Chatham Strait sample (Site 106) collected just after low, slack water. The two other sites are Station 107, located about mid-way east-west in Hawk Inlet and west of the ship loader facility, and Station 108, located proximal to the 002 diffuser at the edge of the mixing zone. Samples at all three locations are taken at a depth of five feet. The sample timing in each quarter is tide and weather dependent. As required by Permit Part 1.6.3.2, quarterly receiving water sample collection occurs on the same day as effluent sample collection.

Water samples are sent to Battelle Marine Science Lab in Sequim, Washington, for low-level mercury and dissolved trace metals analyses (Cd, Cu, Pb, and Zn) and ACZ Laboratories in Steamboat Springs, Colorado for WAD CN and total suspended solids analyses. Temperature, pH, turbidity, and conductivity are measured in the field by the Environmental staff.

2.1 Analytical Results

The tables in this section summarize the results for the quarterly water column monitoring conducted.

Table 2- 1. Hawk Inlet Field Parameters

Quarter	Sample date	Site Number	Sample Time	Water Temperature (°C)	pH (s.u.)	Conductivity (µmhos/cm @ 25°C)	Turbidity (NTU)
1	12-Mar-19	106	12:01	4.5	7.83	53,300	0.18
		107	11:30	4.2	7.75	53,600	0.28
		108	11:45	4.3	7.79	53,400	0.23
2	4-Jun-19	106	9:05	9.6	8.21	47,030	0.32
		107	8:30	9.6	8.19	46,480	1.10
		108	8:50	9.2	8.17	46,480	0.63
3	6-Aug-19	106	12:07	12.6	8.06	42,320	0.26
		107	11:36	13.2	8.08	43,890	0.47
		108	11:55	12.8	8.06	44,060	0.40
4	19-Nov-19	106	11:53	7.1	7.57	46,080	0.25
		107	11:24	6.7	7.53	44,190	0.72
		108	11:40	6.6	7.56	43,900	0.75

Table 2- 2. Hawk Inlet Water Column Monitoring: Nonmetal Parameters (ACZ Laboratories)

Site	Sample Quarter	TSS (mg/L)	WAD CN (µg/L)
	Lab MDL	*(5.0)*	*(3.0)*
	Req. MDL		*(5.0)*
106	1	46	-3
	2	27	-3
	3	-5	-3
	4	17	-3
107	1	46	-3
	2	41	-3
	3	20	-3
	4	21	-3
108	1	37	-3
	2	40	-3
	3	27	-3
	4	18	-3

Note: "-" denotes the sample was analyzed for but was not detected above the level of the method detection limit.

Table 2- 3. Hawk Inlet Water Column Monitoring: Metals (Battelle Marine Sciences Laboratory)

Site	Sample Quarter	Cd (µg/L) Dissolved	Cu (µg/L) Dissolved	Hg (µg/L) Total	Pb (µg/L) Dissolved	Zn (µg/L) Dissolved
	Lab MDL	*(0.002)*	*(0.023)*	*(0.0001)*	*(0.001)*	*(0.042)*
	Req. MDL	*(0.10)*	*(0.03)*	*(0.002)*	*(0.05)*	*(0.20)*
106	1	0.087	0.214	0.0002	0.002	0.366
	2	0.072	0.216	0.0001	0.004	0.123
	3	0.066	0.209	0.0001	0.003	0.099
	4	0.073	0.254	0.0002	-0.005	0.537
107	1	0.086	0.211	0.0003	0.003	0.441
	2	0.079	0.292	0.0003	0.014	0.331
	3	0.067	0.215	0.0002	0.004	0.340
	4	0.073	0.330	0.0005	0.009	0.777
108	1	0.087	0.212	0.0019	0.008	0.588
	2	0.074	0.254	0.0003	0.010	0.251
	3	0.068	0.206	0.0002	0.003	0.176
	4	0.072	0.323	0.0006	0.018	0.749

Note: "-" denotes the sample was analyzed for, but was not detected above the level of the method detection limit.

Table 2- 4. Site 35 APDES Outfall 002 and Water Column Site 108 Results

Site	Analyte	Units	Quarter 1	Quarter 2	Quarter 3	Quarter 4	*AWQS**
APDES Outfall 002 Site 35	Cd Total	µg/L	0.08	0.07	-0.05	0.47	100
	Cu Total	µg/L	-0.8	1.2	1	1.3	99
	Hg Total	µg/L	-0.2	-0.2	-0.2	-0.2	1.9
	Pb Total	µg/L	3	8.6	5	3.1	327
	Zn Total	µg/L	13.0	9.0	8.0	77.0	1000
	WAD CN	µg/L	-3.0	-3.0	-3.0	-3.0	19
	TSS	mg/L	-5.0	-5.0	-5.0	-5.0	30
	pH	s.u.	7.57	7.61	6.9	7.86	6.0-9.0
Water Column Site 108	Cd Dissolved	µg/L	0.087	0.074	0.068	0.072	8.8
	Cu Dissolved	µg/L	0.212	0.254	0.206	0.323	3.1
	Hg Total	µg/L	0.0019	0.0003	0.0002	0.0006	0.94
	Pb Dissolved	µg/L	0.008	0.010	0.003	0.018	8.1
	Zn Dissolved	µg/L	0.588	0.251	0.176	0.749	81
	WAD CN	µg/L	-3.0	-3.0	-3.0	-3.0	1.0
	TSS	mg/L	37.0	40.0	27.0	18.0	--
	pH	s.u.	7.79	8.17	8.06	7.56	6.0-9.0

Notes: "-" denotes the sample was analyzed for, but was not detected above the level of the method detection limit.
Samples for Site 108 were collected on the same day as Outfall 002.
* AWQS displayed are daily maximum

2.2 Data Evaluation

Figures 2-1a, b, c through 2-7a, b, c show the time series plots of field pH, conductivity, cadmium, copper, lead, mercury, and zinc for stations 106 (2-1a through 2-7a), 107 (2-1b through 2-7b) and 108 (2-1c through 2-7c). The Alaska Water Quality Standards (AWQS) for marine aquatic life – chronic levels, are shown or noted on the graphs where applicable. The graphs show that Hawk Inlet water quality has remained within AWQS standards in all historical and 2019 samples.

Table 2-4 summarizes the 2019 quarterly site 35 APDES outfall 002 and water column seawater station 108 results. The outfall 002 results remain significantly below the permitted effluent limits for total cadmium, total copper, total mercury, total lead, total zinc, WAD cyanide, and TSS. The pH remained within the permitted range. Similarly, station 108 data remain significantly below AWQS for marine life. The sampling requirements for outfall 002 and station 108 differ in multiple respects. Comparison requires looking at the permit effluent limits and AWQS while factoring in dissolved metals concentrations (lower MDLs) vs. total metals concentrations (higher MDLs).

Figures 2-8a through 2-8f show comparative time series plots of field pH, cadmium, copper, lead, mercury, and zinc from 2012 through 2019 for station 108 and Outfall 002. The graphs demonstrate that the mixing zone authorized by the APDES permit is protective of the AWQS for all measured parameters.

Table 2-5 is a comparison of metal values averaged from 2014 through 2018 (n=20), and 2019 (n=4) results at the three seawater monitoring locations. The 2019 results remained near or below the previous five-year average.

Table 2- 5. Hawk Inlet Water Column Average Dissolved Metal Concentrations

	Cd (µg/L)		Cu (µg/L)		Pb (µg/L)		Hg (Total - µg/L)		Zn (µg/L)	
Site	2014 through 2018	2019	2014 through 2018	2019	2014 through 2018	2019	2014 through 2018	2019	2014 through 2018	2019
106	0.071	0.074	0.236	0.223	0.005	0.001	0.0003	0.0002	0.358	0.281
107	0.072	0.076	0.275	0.262	0.009	0.008	0.0004	0.0003	0.409	0.472
108	0.074	0.075	0.298	0.249	0.015	0.010	0.0003	0.0007	0.484	0.441

2.3 QA/QC Results

Battelle Marine Sciences Laboratory and ACZ Laboratories analyzed the required parameters (refer to Table 1-1) in the seawater samples. Complete QA plans and reports are kept on file in each lab's office and are available upon request. The remainder of this section summarizes the relevant QA/QC results from each laboratory for the quarterly 2019 seawater samples. Elevated levels of zinc in the field blanks, often at levels higher than all the other seawater samples, have been noted consistently by Battelle for this sampling program.

Battelle Marine Science (low level dissolved trace metals analyses in salt water matrices):
1Q: The analytes of interest were found at detectable levels in all field samples. Concentrations in the method blank were less than the MDL for all metals. Concentrations in the field blank were less than the MDL for all metals except for Zn, Cu, and Pb which were detected at 51.9, 2.41 and 6.60 times the MDL, respectively. Trip blank results were below the MDL for all metals. No corrective action was taken considering field samples were 12.6, 9.66 and 4.36 times the MDL on average for Zn, Cu and Pb, respectively, and within the expected range. Target detection limits (TDLs) were met for all metals. Standard reference material (SRM), matrix spike and duplicate results were within our default criteria of ±25%.

2Q: The analytes of interest were found at detectable levels in all field samples. Concentrations in the method blank were less than the MDL for all metals. Concentrations in the field blank were less than the MDL for all metals except for Zn and Pb, which were detected at 52.8 and 2.40 times the MDL, respectively. Trip blank results were below the MDL for all metals except Pb which was 0.77 times the MDL. No corrective action was taken considering field samples were 39.3 and 9.8 times the MDL on average for Zn and Pb, respectively, and within the expected range. Target detection limits (TDLs) were met for all metals. Standard reference material (SRM), matrix spike, and duplicate results were within our default criteria of ±25%.

3Q: The analytes of interest were found at detectable levels in all field samples. Concentrations in the method blank were less than the MDL for all metals. Concentrations in the field blank were less than the MDL for all metals. Trip blank results were below the MDL for all metals except Zn, which was 4.3 times the MDL; the high Zn value could be a result of not being rinsed well. With the field blank results being less than the MDL, the level of zinc in the trip blank should not be a concern for the field samples. Target detection limits (TDLs) were met for all metals. Standard reference material (SRM), matrix spike, and duplicate results were within our default criteria of ±25%.

4Q: The analytes of interest were found at detectable levels in all field samples, with the exception of Pb in one field sample. Concentrations in the method blank were less than the MDL for all metals. Concentrations in the field blank were less than the MDL for all metals with the exception of Cu, Zn, and Pb, which were detected at 1.60, 513, and 30.8 times the MDL, respectively. Trip blank results were below the MDL for all metals. The average Cu values in field samples were 15.3 times higher than the MDL. Thus the elevated field blank is not a concern. However, the high Zn and Pb values in the field blank indicate a source of contamination during field blank sampling considering field samples on average had Zn and Pb levels 92.5 and 6.66 times the MDL, respectively. Average Zn and Pb concentrations in field samples were 6.19 and 2.89 times the average concentrations measured in November 2018, respectively, so it is possible that slight contamination occurred throughout the sampling. However, the field samples were not blank corrected, considering the field blank had higher concentrations than the field samples. Standard reference material (SRM), matrix spike and duplicate results were within our default criteria of ±25%. Note that the SRM used, NASS-7 has Pb levels below the reported MDL. However, recovery was still within range, so this is not a concern.

ACZ Laboratories (WAD cyanide analyses):

1Q: No certification qualifiers associated with this analysis.
2Q: No certification qualifiers associated with this analysis.
3Q: No certification qualifiers associated with this analysis.
4Q: No certification qualifiers associated with this analysis.

3. SEDIMENT MONITORING

The requirements for the sediment monitoring originate from Section 1.6.1.2, Sediment Monitoring, and Table 6 of the APDES permit. The objective of this element of the monitoring program is to provide scientifically valid data on five specific trace metal parameters analyzed at dry weight (dw) from sediments at four locations in Hawk Inlet (see Figure 1-1 for locations). These data are used to evaluate potential changes in the Hawk Inlet marine environment over time.

Sediment samples were collected semi-annually through 2015. With the re-issuance of the permit, the sampling frequency was changed to annual. Samples are collected at the Greens Creek delta (Site S-1), Pile Driver Cove near the mouth of the inlet (Site S-2), ~400 feet south of the concentrate loading facility (Site S-4), and under the loading facility (Sites S-5N and S-5S which bracket the area where concentrate was spilled in 1989). Samples are analyzed at ALS Environmental (formerly Columbia Analytical Services, Inc.) in Kelso, Washington, for total concentrations of cadmium, copper, lead, mercury, and zinc.

An additional station S-3 located near the head of Hawk Inlet, established as a background site, has also been sampled for sediment and biota since the 1980s. Though dropped from the official sampling program in the early 2000s, HGCMC continued to monitor the site yearly and has included the data in this report.

3.1 Sediment Analytical Results

All sediment samples were collected by Marine Taxonomic Services, LTD. The sample locations, dates, times, weather conditions, and tides are shown in Table 3-1. Table 3-2 summarize the total metals results for the sediment monitoring events. Sample replicates (reps) 1 through 6 were averaged at each sample site.

Table 3- 1. Hawk Inlet Sediment Monitoring Field Parameters

Locations	Date Sampled	Time Sampled (24 hour)	Air Temperature (°F)	Weather Conditions	Tide (ft MLLW)
S-1	4/19/2019	7:30	39	Cloudy, slight wind	-2.00
S-2	4/21/2019	8:30	39	Cloudy, slight wind	-0.95
S-3	4/18/2019	6:30	43	Light rain, slight wind	-0.01
S-4	4/20/2019	7:45	43	Cloudy, slight wind	-3.47

3.2 Data Evaluation

Before opening the Greens Creek Mine for full production in 1989, sediment and biota tissues were sampled for heavy metal concentrations. Sampling sites S-1, S-2, and S-3 were chosen to represent natural conditions; therefore, results from these sites from September of 1984 until January of 1989 were used to calculate baseline, pre-production values. These data are useful as baseline values against which to compare metal values after mining began, and the results for the current year's sampling. Sampling sites S-4 and S-5 are thought to have been influenced by the old industrial cannery operation and are not used for background comparisons.

Figures 3-1 through 3-5, show the time series plots for cadmium, copper, lead, mercury and zinc including replicate samples for sample site S-1. Figures 3-6 through 3-10, show the time series plots for cadmium, copper, lead, mercury, and zinc including replicate samples for sample site S-2. Replicate samples are plotted with a single point, representing the mean value of the data, and error bars represent the overall distribution of the data.

Sampling sites S-4 and S-5N and S-5S are located near the ore concentrate loading facility. In May 1989, the first attempt to load a barge with bulk ore concentrate resulted in a spill of approximately 1,000 pounds of bulk ore concentrate into Hawk Inlet. During the re-commissioning of the mine (mid-nineties) State and Federal agencies provided oversight as Greens Creek Mine cleaned up the spilled concentrate. A suction dredge contractor removed approximately 550 cubic yards of concentrate and sediment from the spill site in 1994. This effort was confounded by the residual debris from the 1976 cannery facility fire. Metal scrap was removed from the area along with inert debris. Although clean-up efforts were extensive, annual sediment monitoring indicates that there may still be some concentrate present at the spill site.

Following the 1994 clean-up effort at the concentrate spill site, the sampling methodology at S-5 was expanded. The site was subdivided into two separate locations. Sampling site S-5S was added on the south side of the spill area. This station complements S-5N located on the north side of the spill area (site S-5N is a continuation of the original site 5). Average concentrations of heavy metals at S-4 and S-5N remain below or equal to average concentrations reported since production began. However, following the spill, metal concentrations in the sediment at S-5S have been elevated and variable. Sites S-5N and S-5S are sampled every five years and will be sampled again in 2021. See the 2016 Hawk Inlet Monitoring report for a discussion of heavy metals at sites S-5N and S-5S. Figures 3-11 through 3-15 show the metal time-series graphs for site S-4. Figures 3-16 through 3-20 show the metal time-series graphs for site S-5N. Figures 3-21 through 3-25 show the metal time-series graphs for site S-5S. Since 2004 replicate samples have been taken at each site, and all replicates were included, plotted by the mean with standard error bars unless otherwise noted.

Table 3-2 shows the average metal concentrations and the associated standard deviations for each sediment sampling site during pre-production, production, and the current year. At site S-1, located at the Greens Creek delta and closest to Outfall 002, the 2019 average concentrations for cadmium, copper, lead, and mercury were all less than or equal to both the production and pre-production period averages. The average zinc concentration was higher than the production period but lower than the pre-production period. At site S-2, the background site in Pile Driver Cove, the 2019 average concentrations for cadmium, copper, mercury, and lead were lower than both the production and pre-production period averages. The average zinc concentration was higher than the production period but lower than the pre-production period. At site S-4, near the historic cannery facilities, the 2019 average concentrations of cadmium, copper, lead, mercury, and zinc were lower than both the production and pre-production periods.

Site S-3 is located near the head of Hawk Inlet and approximately four miles north of the Greens Creek Mine port facilities. The 2019 average concentrations for all metals were greater than pre-production averages at this location. Concentrations of copper, lead, mercury, and zinc were also greater than production averages. Further, the 2019 average concentrations of cadmium, copper, mercury, and zinc were significantly higher than those at the other sediment monitoring locations. Given these data and the spatial distance between the monitoring locations, it is evident that there are inputs of metals to Hawk Inlet that are not associated with the Greens Creek Mine.

Table 3- 2. Sediment Data Comparison of Pre-Production, Production, and Current Year Values for Sites S-1, S-2, S-3, S-4, S-5N, and S-5S

Station	Period	Cd (mg/kg)		Cu (mg/kg)		Pb (mg/kg)		Hg (mg/kg)		Zn (mg/kg)	
		Avg	*Stdev*	*Avg*	*Stdev*	*Avg*	*Stdev*	*Avg*	*Stdev*	*Avg*	*Stdev*
S-1	Pre-Production (9/1984 - 1/1989) (n=9)	0.22	0.11	21.8	3.8	7.8	2.1	0.04	0.01	125.0	7.7
	Production (1989 - 2018) (n=124)	0.19	0.15	16.4	5.8	7.4	3.2	0.03	0.02	100.2	26.9
	Reporting Year 2019 (n=6)	0.11	0.01	13.3	1.0	5.8	0.4	0.03	0.00	104.1	7.8
S-2	Pre-Production (9/1984 - 1/1989) (n=9)	0.27	0.11	14.9	2.6	5.3	2.4	0.03	0.01	60.5	5.4
	Production (1989 - 2018) (n=120)	0.15	0.10	10.6	3.8	2.3	1.3	0.01	0.01	43.5	12.0
	Reporting Year 2019 (n=6)	0.08	0.01	9.6	1.2	1.9	0.1	0.01	0.00	44.2	4.5
S-3	Pre-Production (9/1984 - 1/1989) (n=9)	0.62	0.28	37.0	9.1	10.0	3.3	0.07	0.02	127.0	49.8
	Production (1989 - 2018) (n=123)	0.76	0.36	37.1	13.3	14.4	5.0	0.07	0.03	135.3	42.9
	Reporting Year 2019 (n=6)	0.67	0.04	49.7	8.6	19.7	2.6	0.10	0.00	167.2	19.9
S-4	Pre-Production (9/1984 - 1/1989) (n=6)	0.34	0.17	46.2	12.1	53.8	20.2	0.11	0.06	136.5	41.6
	Production (1989 - 2018) (n=124)	0.53	0.66	33.1	38.3	59.2	98.1	0.09	0.35	110.4	128.4
	Reporting Year 2019 (n=6)	0.25	0.03	26.2	23.4	16.8	5.9	0.03	0.01	56.4	9.9
S-5N	Production (2/1989 - 5/2016)	7.04	25.93	178.5	263.8	751.4	1659.9	1.00	3.59	1,194	3,551
S-5S	Production (2/1989 - 5/2016)	3.72	3.43	106.5	78.9	341.9	360.1	0.32	0.26	812	712

Notes: Underlined concentrations are higher than pre-production averages. Non-detects are averaged using half of the MRL/MDL value.

3.3 QA/QC Results

ALS Environmental analyzed the required parameters (see Table 1-1) in the sediment samples. Complete QA plans and reports are kept on file at the ALS Environmental office and are available upon request. The remainder of this section summarizes any relevant QA/QC results that were exceptions for the 2019 sampling event.

Beginning in the fall of 2004, duplicate samples have been collected from each site, where possible, to address a National Marine Fisheries Service request. Precision can be calculated from the results of duplicate samples. In this case, the Relative Standard Deviation (RSD) is calculated as follows:

$$RSD = \frac{\text{standard deviation} * 100}{\text{sample mean}}$$

The RSD is shown for the duplicate samples from 2019 in Table 3-3.

The data quality objective for the RSD is that it is less than or equal to 30 percent when the values are at least four times the detection limit. All RSDs calculated for the 2019 duplicate samples were within this data quality objective, except copper and lead at Site S-4.

Table 3- 3. Relative Standard Deviation for Replicate Sediment Samples

Site	Rep	Sample Date	Cd (mg/kg dw)	Cu (mg/kg dw)	Pb (mg/kg dw)	Hg (mg/kg dw)	Zn (mg/kg dw)
S-1 Sediments	1	4/19/2019	0.13	14.80	5.83	0.028	114.0
	2		0.11	13.30	5.67	0.026	98.7
	3		0.12	13.60	6.47	0.032	110.0
	4		0.10	11.30	5.14	0.034	93.3
	5		0.11	13.10	5.74	0.027	97.7
	6		0.12	13.50	5.94	0.024	111.0
		RSD (%)	***8.1***	***8.5***	***7.4***	***13.3***	***8.2***
S-2 Sediments	1	4/21/2019	0.07	9.24	1.73	<0.022	41.0
	2		0.09	8.25	1.68	<0.023	41.4
	3		0.08	11.30	2.09	<0.021	52.3
	4		0.09	10.90	1.99	<0.023	48.4
	5		0.10	9.63	1.86	<0.021	41.1
	6		0.07	8.25	1.80	<0.023	41.2
		RSD (%)	***11.8***	***13.5***	***8.4***	***--***	***11.1***
S-3 Sediments	1	4/18/2019	0.74	46.00	18.80	0.097	164.0
	2		0.62	54.70	22.50	0.098	175.0
	3		0.65	44.60	17.60	0.098	152.0
	4		0.66	48.60	20.40	0.101	170.0
	5		0.64	65.80	23.10	0.087	203.0
	6		0.72	38.70	15.90	0.092	139.0
		RSD (%)	***7.3***	***19.0***	***14.3***	***5.3***	***13.1***
S-4 Sediments	1	4/20/2019	0.28	16.40	12.10	0.035	57.2
	2		0.22	15.20	13.40	0.028	49.5
	3		0.27	14.70	27.30	0.040	56.0
	4		0.22	14.70	12.40	0.029	48.0
	5		0.26	17.70	22.30	0.033	77.1
	6		0.28	78.40	13.30	0.023	50.4
		RSD (%)	***10.9***	***97.8***	***38.2***	***19.0***	***19.2***

"--" indicates RSD was not calculated because three or more of the values were less than 4 times the MRL.

"<" denotes the sample was analyzed for, but was not detected above the MRL/MDL.

4. IN-SITU BIOASSAYS

The requirements for the bioassay monitoring originate from Section 1.6.1.3, In-situ Bioassays, and Table 7 of the APDES permit. The objective of this monitoring element is to provide scientifically valid data on five specific trace metal parameters analyzed at dry weight from the tissues of polychaete worms (*Nephtys*) and bay mussels (*Mytilus edulis*) at seven locations in Hawk Inlet. These data are used to evaluate potential changes in the Hawk Inlet marine environment.

Bioaccumulation in-situ bioassay sampling in Hawk Inlet consists of annual testing of trace metal tissue burdens of selected species of invertebrate organisms with different feeding guilds. In the Hawk Inlet sill area, where no fine-grained sediments occur, four sites (Stations STN-1, STN-2, STN-3, and East Shoal Light (ESL)) are used for in-situ bioassay monitoring of trace metals in bay mussels. Data gathered from this area measures the response in organisms in the immediate vicinity of the 002 Outfall discharge. In most other areas of Hawk Inlet, the bottom is covered with sediment. Consequently, samples of sediment-dwelling polychaete worms (*Nephtys procera and Nereis sp.*) are collected at three additional sites (S-1, S-2, and S-4). *Nereis sp*. were not encountered in sufficient numbers for analysis in 2019, so only *Nephtys* were collected.

4.1 Analytical Results

All tissue samples were collected by Marine Taxonomic Services, LTD. The sample locations, types, dates, times, weather conditions, and tides are shown in Table 4-1.

Table 4- 1. Hawk Inlet Tissue Sampling Field Data

Locations	Sample Type	Date Sampled	Time Sampled (24 hour)	Air Temperature (°F)	Weather Conditions	Tide (ft MLLW)
S-1	*Nephtys*	4/19/2019	9:00	39	Cloudy, slight wind	-0.99
S-2	*Nephtys*	4/21/2019	9:15	45	Cloudy, slight wind	-2.62
S-3	*Nephtys*	4/18/2019	8:15	43	Light rain, slight wind	0.02
S-4	*Nephtys*	4/20/2019	8:30	43	Light rain, slight wind	-2.82
STN-1	Mussels	4/20/2019	12:01	43	Cloudy, slight wind	8.19
STN-2	Mussels	4/21/2019	11:30	45	Light rain, slight wind	2.62
STN-3	Mussels	4/20/2019	14:01	45	Cloudy, slight wind	15.31
ESL	Mussels	4/21/2019	14:01	45	Light rain, slight wind	12.93

4.2 Data Evaluation

Before opening the Greens Creek Mine for full production in 1989, sediment and biota tissues were sampled for heavy metal concentrations. Results for mussels from sites STN-1, STN-2, STN-3, and ESL, and for *Nephtys* from sites S-1, S-2, and S-3 from September of 1984 until January of 1989 were used to calculate baseline, pre-production values. These data are useful as baseline values against which to compare metal values after mining began and the results for the current year's sampling.

As noted by the Oceanographic Institute of Oregon in the 1998 Kennecott Greens Creek Mine Risk Assessment (p 4-3),

> "Sampling stations were selected to demonstrate a range of potential exposures including "worst case" exposure to Outfall discharges. Some of the test organisms placed in cages directly on the Outfall diffuser ports lived for six months. These results indicate that even maximum exposure to the Outfall discharge results in no acute effects."

The average and standard deviation results for pre-production, production, and current year periods for the individual sites for mussels are provided in Table 4-2. In 2019, cadmium and zinc concentrations at all sites were higher than the pre-production period. Copper and mercury concentrations were less than the pre-production period for all sites. The lead concentration at STN-2 was slightly greater than the pre-production period.

Table 4- 2. Average and Standard Deviation Values for Pre-Production, Production, and Current Year Mussel Data – Sites STN-1, STN-2, STN-3, and ESL.

Station	Period	Cd (mg/kg)		Cu (mg/kg)		Pb (mg/kg)		Hg (mg/kg)		Zn (mg/kg)	
		Avg	*Stdev*	*Avg*	*Stdev*	*Avg*	*Stdev*	*Avg*	*Stdev*	*Avg*	*Stdev*
ESL	**Pre-Production (9/1984 - 1/1989) (n=9)**	6.67	1.60	8.16	0.68	0.42	0.11	0.03	0.01	91.40	8.38
	Production (2/1989 - 4/2018) (n=74)	6.63	1.70	10.45	12.59	1.15	0.76	0.03	0.02	84.98	18.08
	Reporting Year 2019 (n=6)	8.25	0.21	6.94	0.16	0.40	0.02	0.01	0.00	97.25	2.06
STN-1	**Pre-Production (9/1984 - 1/1989) (n=9)**	7.41	1.80	7.96	1.20	0.62	0.41	0.07	0.09	94.92	11.21
	Production (2/1989 - 4/2018) (n=74)	9.15	2.45	8.04	2.23	1.30	0.86	0.05	0.05	95.03	24.60
	Reporting Year 2019 (n=6)	9.11	0.13	6.34	0.12	0.36	0.02	0.01	0.01	97.65	1.60
STN-2	**Pre-Production (9/1984 - 1/1989) (n=9)**	8.60	3.10	7.71	1.05	0.37	0.19	0.04	0.01	82.36	11.20
	Production (2/1989 - 4/2018) (n=74)	9.40	2.44	8.46	3.64	3.04	14.46	0.04	0.02	92.98	25.02
	Reporting Year 2019 (n=6)	9.64	0.10	6.64	0.18	0.38	0.01	0.01	0.01	96.97	1.79
STN-3	**Pre-Production (9/1984 - 1/1989) (n=9)**	9.27	3.05	8.50	1.69	0.59	0.21	0.04	0.01	95.73	17.80
	Production (2/1989 - 4/2018) (n=74)	9.39	2.24	7.85	2.16	2.48	10.61	0.05	0.06	92.76	17.32
	Reporting Year 2019 (n=6)	10.58	0.23	7.22	0.21	0.37	0.02	0.02	0.01	97.58	1.51

Notes: Underlined concentrations are higher than pre-production averages. Non-detects are averaged using half of the

The historical and year 2019 metals concentration in *Nephtys* is shown in Table 4-3. Concentrations of cadmium and mercury in *Nephtys* show a general decline over time. Cadmium and average mercury concentrations were similar to or lower at all four sample stations relative to both pre-production and production levels. Zinc concentrations in 2019 were similar to or slightly higher than the pre-production and production levels. Copper concentrations were less than pre-production, with the exception being site S-1. Lead concentrations at S-1 and S-2 have been higher on average since production began relative to pre-production; however, 2019 concentrations were lower than the average for the other production years. Lead concentrations at S-3 and S-4 were lower in 2019 than the production and pre-production average concentrations. Figures 4-21 through 4-35 show the time series plots for cadmium, copper, lead, mercury, and zinc including replicate samples in *Nephtys* for sample sites S-1, S-2, and S-4. Replicate samples are plotted by the mean and include standard error bars.

Table 4- 3. Average and Standard Deviation Values for Pre-Production, Production, and Current Year *Nephtys* Data – Sites S-1, S-2, S-3, and S-4

Station	Period	Cd (mg/kg)		Cu (mg/kg)		Pb (mg/kg)		Hg (mg/kg)		Zn (mg/kg)	
		Avg	*Stdev*	*Avg*	*Stdev*	*Avg*	*Stdev*	*Avg*	*Stdev*	*Avg*	*Stdev*
S-1	**Pre-Production (9/1984 - 1/1989) (n=9)**	4.00	1.61	9.04	1.12	0.49	0.15	0.05	0.01	243.6	40.1
	Production (2/1989 - 4/2018) (n=122)	2.97	0.97	9.96	5.19	0.96	0.78	0.04	0.02	214.5	34.0
	Reporting Year 2019 (n=6)	3.12	0.09	11.26	2.64	0.62	0.06	0.02	0.02	206.0	5.7
S-2	**Pre-Production (9/1984 - 1/1989) (n=9)**	1.70	0.70	12.37	3.12	0.59	0.22	0.02	0.01	181.1	27.7
	Production (2/1989 - 4/2018) (n=122)	1.08	0.46	8.58	4.52	0.71	0.35	0.02	0.01	172.7	33.3
	Reporting Year 2019 (n=6)	0.98	0.02	9.02	0.47	0.65	0.02	0.01	0.00	165.0	3.7
S-3	**Pre-Production (9/1984 - 1/1989) (n=8)**	4.08	2.45	16.45	4.92	0.82	0.45	0.14	0.22	241.4	70.7
	Production (2/1989 - 4/2018) (n=120)	2.04	1.12	14.14	14.78	0.91	0.73	0.04	0.02	238.0	42.6
	Reporting Year 2019 (n=6)	2.16	0.11	12.92	1.71	0.63	0.26	0.01	0.00	249.5	12.4
S-4	**Pre-Production (9/1984 - 1/1989) (n=2)**	1.21	0.70	16.80	6.70	4.16	1.27	0.11	0.06	193.5	10.5
	Production (2/1989 - 4/2018) (n=122)	0.81	0.53	19.11	15.74	7.04	8.74	0.02	0.02	194.8	41.9
	Reporting Year 2019 (n=6)	0.60	0.03	8.57	0.50	2.95	0.14	0.01	0.01	185.8	3.8

Notes: Underlined concentrations are higher than pre-production averages. Non-detects are averaged using half of the MRL/MDL

4.3 QA/QC Results

ALS Environmental analyzed the required parameters (see Table 1-1) for the bioassay samples. Complete QA plans and reports are kept on file at the ALS Environmental office and are available upon request. The remainder of this section summarizes the relevant QA/QC results for 2019 sampling.

No anomalies associated with the analysis of these samples were observed.

Beginning in the fall of 2004, replicate samples have been collected from each site, where possible, to address a National Marine Fisheries Service request. Precision can be calculated from the results of duplicate samples. In this case, RSD is shown for the duplicate samples in Table 4-4. The data quality objective for the RSD is that it is less than or equal to 30% when the values are at least four times the detection limit. All RSDs calculated for the 2019 duplicate samples were within this data quality objective.

Table 4- 4. Relative Standard Deviation for Replicate Tissue Samples

Sample ID	Rep	Date	Cd (mg/kg dw)	Cu (mg/kg dw)	Pb (mg/kg dw)	Hg (mg/kg dw)	Zn (mg/kg dw)
S-1 Nephtys	1	4/19/2019	3.26	7.34	0.63	0.034	203.0
	2		3.09	12.4	0.65	0.050	202.0
	3		3.20	15.4	0.68	<0.02	207.0
	4		3.10	9.7	0.67	<0.019	215.0
	5		2.98	9.7	0.55	<0.02	198.0
	6		3.06	13	0.53	<0.019	211.0
		RSD (%)	***3.2***	***25.7***	***10.4***	***26.94***	***3.0***
S-2 Nephtys	1	4/21/2019	0.96	9.63	0.68	<0.019	163.0
	2		0.99	8.46	0.63	<0.019	166.0
	3		1.01	8.85	0.67	<0.02	171.0
	4		0.98	8.71	0.63	<0.02	161.0
	5		1.01	8.8	0.64	<0.02	168.0
	6		0.94	9.69	0.62	<0.02	161.0
		RSD (%)	***2.8***	***5.7***	***4.0***	***--***	***2.5***
S-4 Nephtys	1	4/20/2019	0.59	8.49	2.89	<0.02	180.0
	2		0.60	8.34	2.98	<0.02	186.0
	3		0.62	9.03	2.85	0.026	188.0
	4		0.64	8.33	3.02	<0.02	188.0
	5		0.60	9.36	3.20	<0.019	191.0
	6		0.55	7.84	2.74	<0.019	182.0
		RSD (%)	***5.31***	***6.4***	***5.39***	***--***	***2.2***
STN-1 Mussels	1	4/20/2019	8.99	6.4	0.39	<0.02	99.8
	2		9.30	6.46	0.35	<0.02	98.0
	3		8.95	6.15	0.33	<0.02	94.7
	4		9.24	6.47	0.38	0.025	98.8
	5		9.05	6.24	0.35	<0.02	96.9
	6		9.13	6.31	0.38	<0.02	97.7
		RSD (%)	***1.5***	***2.0***	***6.0***	***--***	***1.8***
STN-2 Mussels	1	4/21/2019	9.61	6.69	0.37	<0.02	97.3
	2		9.67	6.71	0.39	<0.019	98.4
	3		9.47	6.34	0.37	<0.02	93.4
	4		9.77	6.69	0.39	<0.02	97.8
	5		9.58	6.51	0.39	<0.02	96.2
	6		9.74	6.92	0.38	0.030	98.7
		RSD (%)	***1.1***	***3.0***	***1.5***	***--***	***2.0***
STN-3 Mussels	1	4/20/2019	10.50	7.26	0.38	<0.02	98.4
	2		10.30	6.89	0.34	0.027	95.0
	3		10.30	7.03	0.35	0.020	96.6
	4		10.70	7.25	0.37	0.032	98.8
	5		10.80	7.41	0.38	<0.02	97.2
	6		10.90	7.49	0.39	<0.02	99.5
		RSD (%)	***2.42***	***3.1***	***5.09***	***22.89***	***1.7***
ESL Mussels	1	4/21/2019	8.45	7.08	0.42	<0.02	99.4
	2		8.27	6.99	0.42	<0.019	96.4
	3		8.47	7.1	0.41	<0.02	99.2
	4		8.30	7.03	0.40	<0.02	98.1
	5		8.19	6.8	0.38	<0.02	97.1
	6		7.83	6.66	0.38	<0.02	93.3
		RSD (%)	***2.82***	***2.5***	***4.56***	***--***	***2.3***

5. CONCLUSIONS

Water quality, sediments, and invertebrate tissue monitoring began in Hawk Inlet before production to establish a baseline against which future monitoring (during production) could be evaluated within the context of potential natural changes over time. Greens Creek Mine has built a 30+ year monitoring database for many of the sites used to determine the original baseline. This monitoring program has been modified as needed (e.g., splitting of S-5 into S-5N and S-5S and dropping of S-3) to account for changes at the site and to facilitate compliances with the APDES permit.

Long-term water column monitoring for cadmium, copper, lead, mercury, and zinc indicates no impairment (exceedance of marine water quality standards) of the Hawk Inlet water column.

Sediment monitoring has been occurring annually for 30+ years. The 2019 average concentrations for cadmium, copper, lead, mercury, and zinc at sites S-1, S-2, and S-4 were similar or less than the averages established during the pre-production and production periods at each location. Time-series graphs for each site show an overall decrease in concentrations for most metals over time, with less variability in recent years compared to the earlier years of the monitoring program. Conversely, sediment samples collected in 2019 at site S-3, a former background location at the head of Hawk Inlet, showed higher cadmium, copper, mercury, and zinc concentrations than those measured at S-1, S-2, and S-4, and higher average concentrations for all metals compared to the pre-production and production period averages at that location. With the variation in metal concentrations between S-3 and the other locations, it is evident that there are sources of metals at the head of Hawk Inlet that are not associated with the Greens Creek Mine. The Alaska Department of Fish and Game (ADFG) conducted a freshwater investigation around Hawk Inlet including streams near S-3. In the report (ADFG 2019), they stated, "At the head of Hawk Inlet, most median cadmium, copper, lead, mercury, and zinc concentrations in freshwater sediments were similar or greater than medians observed at Hawk Inlet Site S-3."

Site S-1 is located at the Greens Creek delta near the vicinity of Outfall 002. Site S-2 is a background site located over 1.5 miles to the south of S-1, and S-3 is located approximately 6 miles to the north. Comparing the average concentrations of metals for the three sites during the pre-production period, production period, and 2019, S-3 had the highest concentrations of all metals during each period, whereas S-2 had the lowest. Given that S-1 is geographically located between the two sites, it is evident that metals concentrations at S-1 are within the range of natural conditions.

Metals results from tissue monitoring of *Nephtys* show that concentrations are variable from year to year. While annual average concentrations at site S-1 are consistently higher than those observed at S-2, there are typically similar variations among the sites. If the temporal variation in the *Nephtys* tissue concentrations at S-1 was a result of discharge from the 002 Outfall, the similar variation observed at S-2 would not be expected. Based on this, HGCMC believes that the variation in concentration monitored in organisms near the 002 Outfall is natural and that the monitoring program is sufficient for detecting changes.

The effectiveness of the sediment monitoring system for detecting change can be evaluated by examining metal concentrations at sites near the ship loader (S-4, S-5N, and S). These sites are influenced by the original activities of the cannery, the burning down of the cannery in 1976, and concentrate spillage associated with the ship loader spill in 1989. For example, before the spill, pre-production lead levels at S-4 were approximately 50 mg/kg dw. Post concentrate spillage, between 1989-1994, resulted in a drastic increase of lead concentration (around 200 mg/kg dw) at S-4. During re-commissioning (mid 1990s), sediments were dredged in the vicinity of the ship loader. Following dredging, the average lead level returned to pre-productions levels. Since the early 2000s, lead levels at S-4 have routinely been less than 30 mg/kg, attributed to natural process (e.g., sedimentation) and repeated debris cleanup efforts of dive crews that have removed contaminated materials associated with pre-mine site users (e.g., batteries).

As discussed in the report, there have been some elevated metal concentrations in the invertebrate and sediment samples. However, the recent *Nephtys* tissue and sediment samples exhibit similar variations despite their spatial distances. These results indicate that there is natural variability, the relatively low trophic level organisms studied are not greatly impacted and that the APDES monitoring program is valid for measuring potential impacts associated with the Greens Creek Mine.

6. REFERENCES

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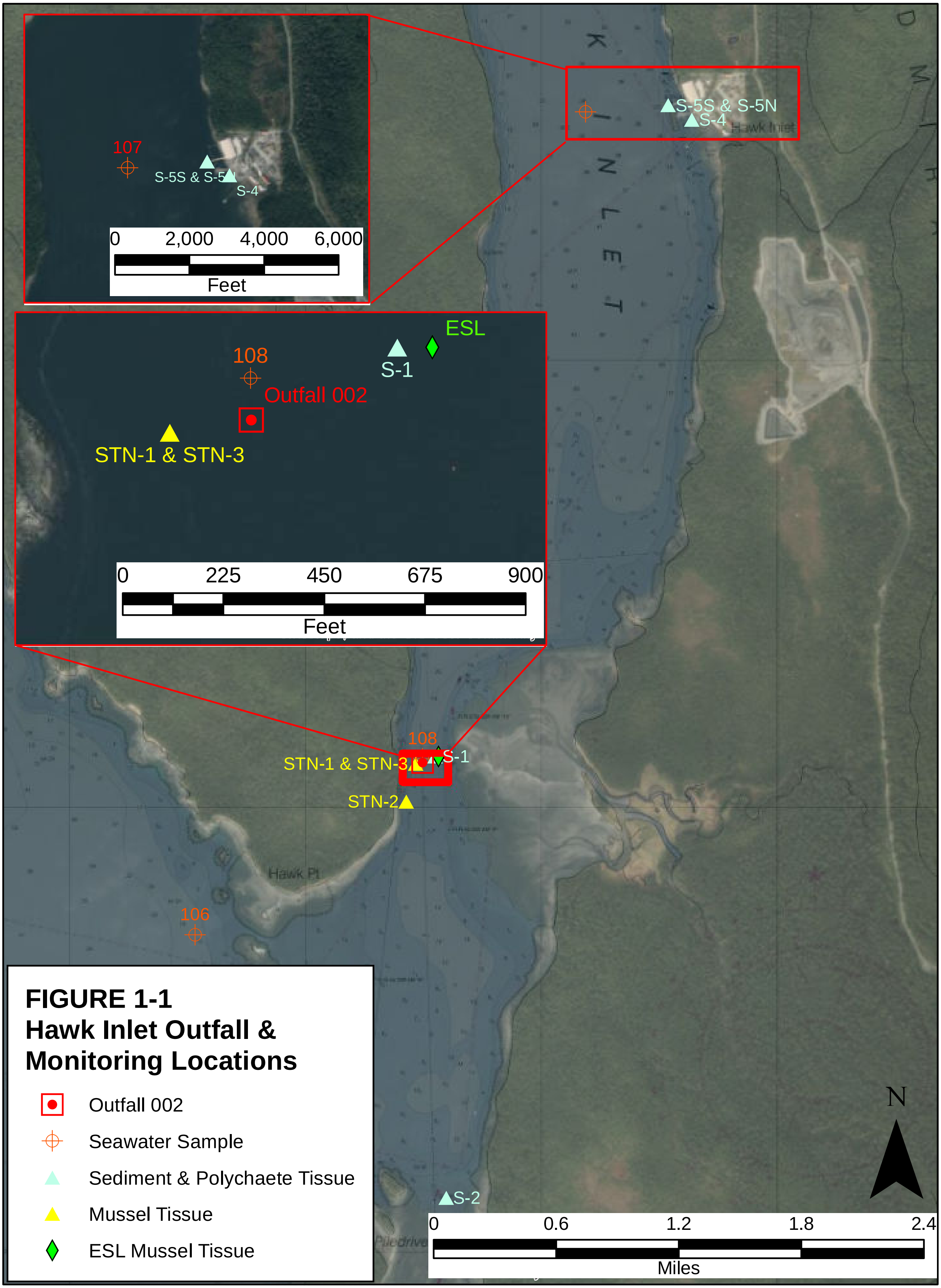
FIGURES


107
S-5S & S-5N
S-4
0
2,000
4,000
6,000
Feet
108
ESL
S-1
Outfall 002
STN-1 & STN-3
0
225
450
675
900
Feet
S-5S & S-5N
S-4
Hawk Inlet
108
STN-1 & STN-3
S-1
STN-2
Hawk Pt
106
S-2
N
0
0.6
1.2
1.8
2.4
Miles
FIGURE 1-1
Hawk Inlet Outfall &
Monitoring Locations
Outfall 002
Seawater Sample
Sediment & Polychaete Tissue
Mussel Tissue
ESL Mussel Tissue

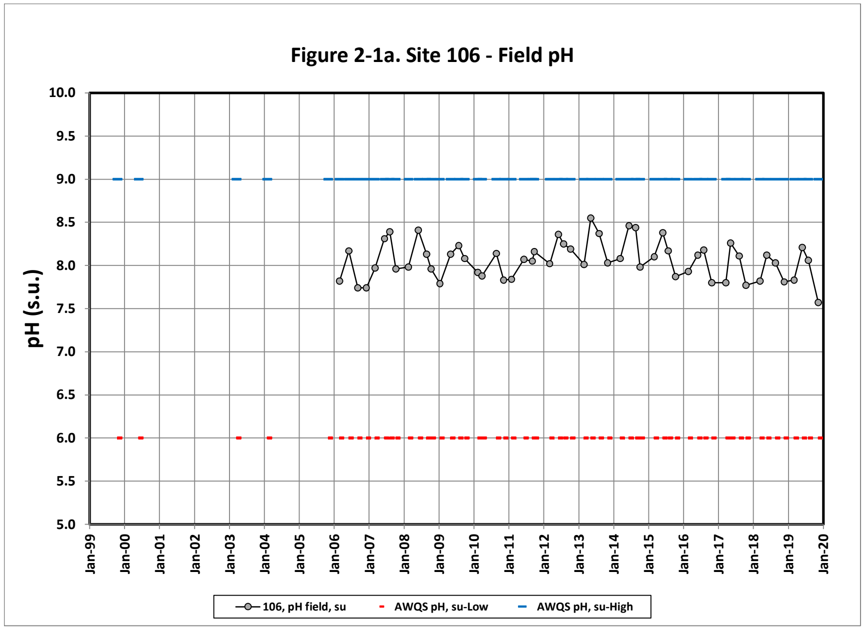


Figure 2-1a. Site 106 - Field pH
pH (s.u.)
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
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Jan-17
Jan-18
Jan-19
Jan-20
106, pH field, su
AWQS pH, su-Low
AWQS pH, su-High

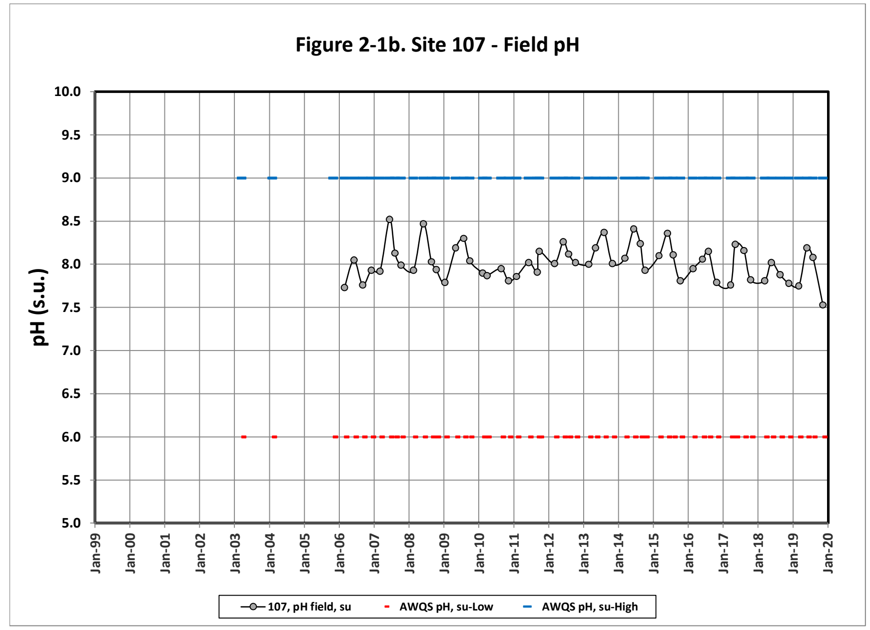


Figure 2-1b. Site 107 - Field pH
pH (s.u.)
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
Jan-20
107, pH field, su
AWQS pH, su-Low
AWQS pH, su-High

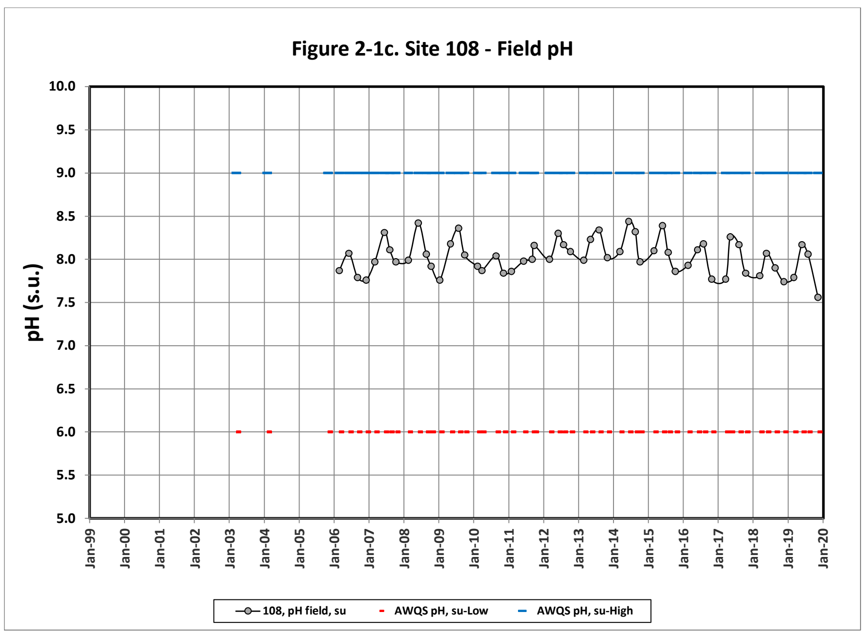


Figure 2-1c. Site 108 - Field pH
pH (s.u.)
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
Jan-20
108, pH field, su
AWQS pH, su-Low
AWQS pH, su-High

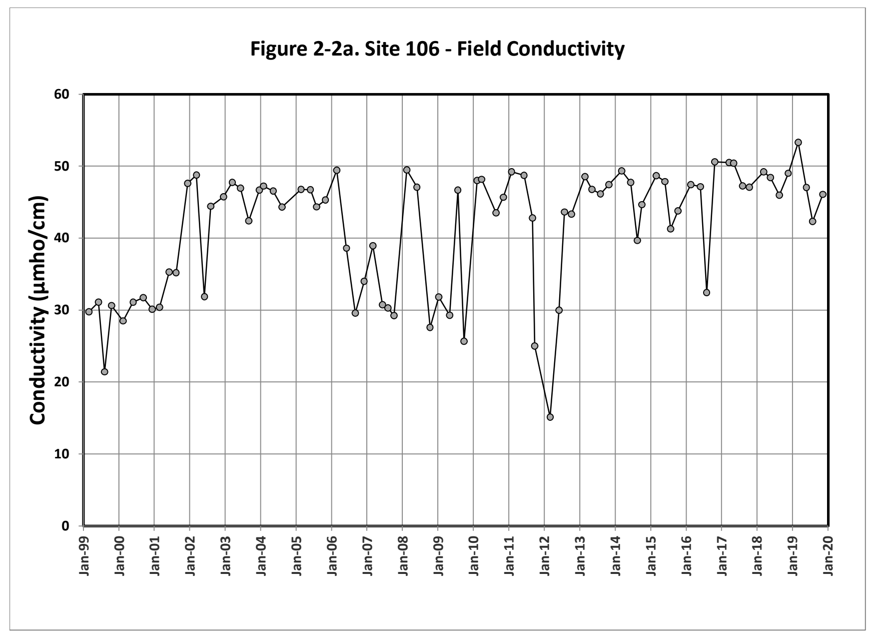


Figure 2-2a. Site 106 - Field Conductivity
Conductivity (µmho/cm)
60
50
40
30
20
10
0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
Jan-20

Figure 2-2b. Site 107 - Field Conductivity

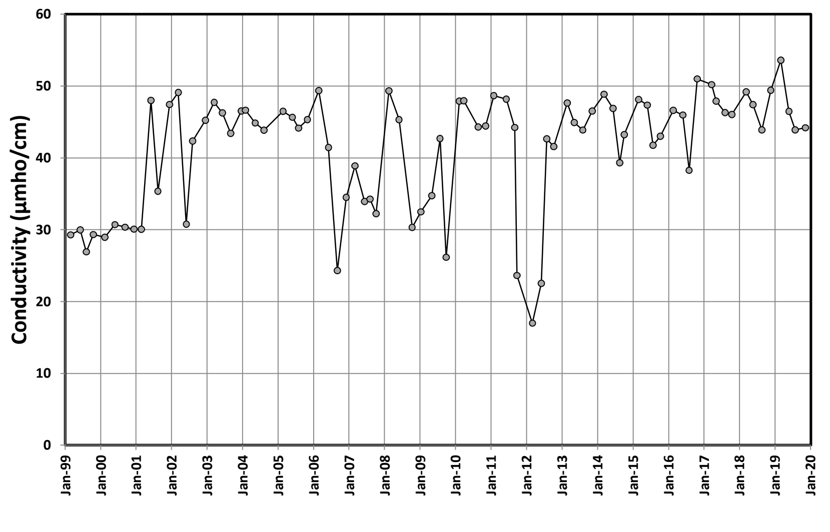


Figure 2-2c. Site 108 - Field Conductivity

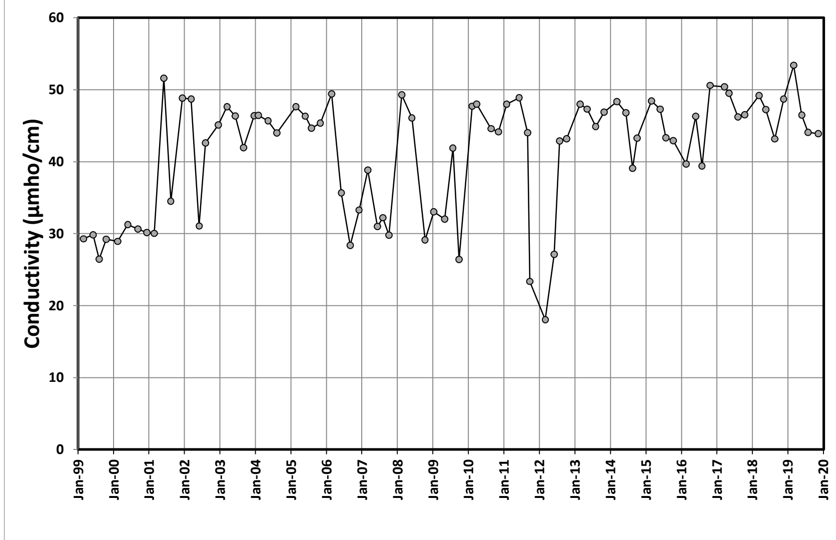


Figure 2-3a. Site 106 - Cadmium

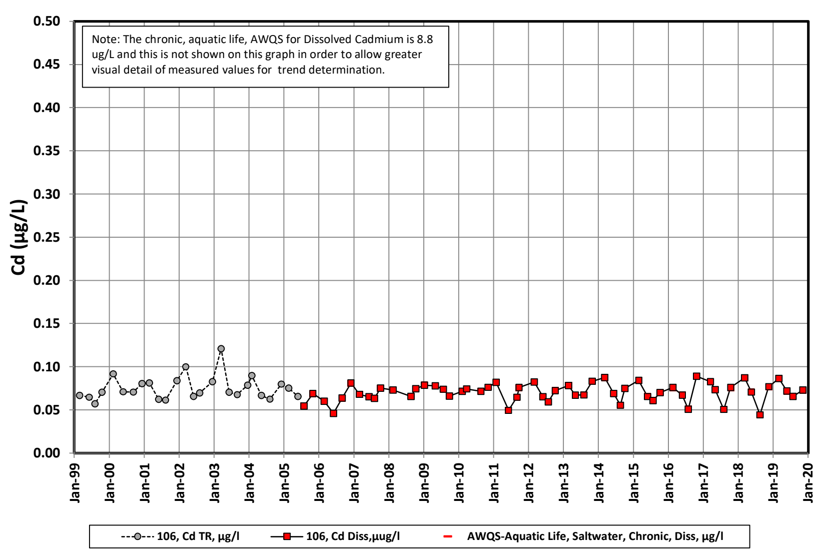
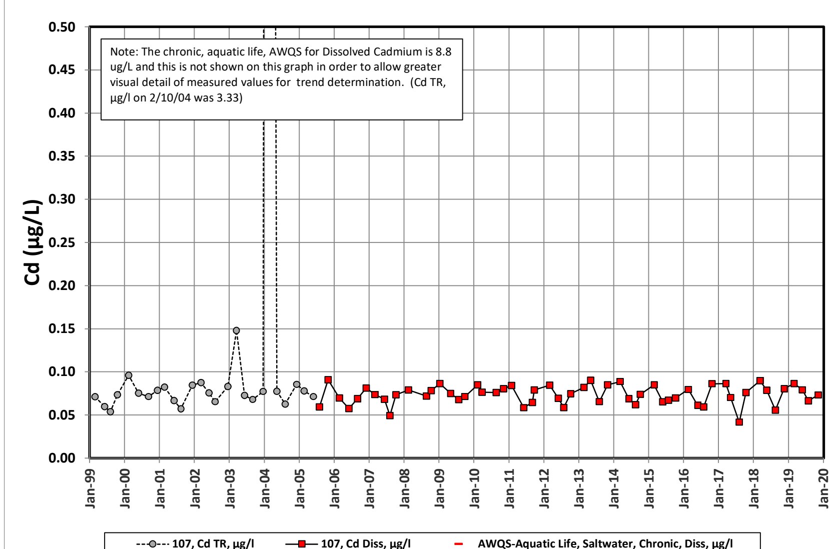


Figure 2-3b. Site 107 - Cadmium



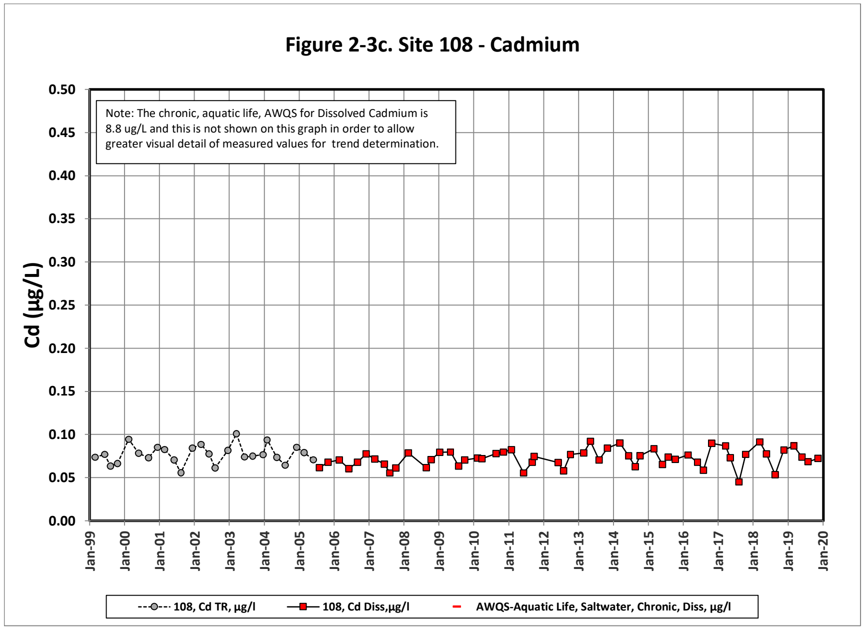


Figure 2-3c. Site 108 - Cadmium
Note: The chronic, aquatic life, AWQS for Dissolved Cadmium is 8.8 ug/L and this is not shown on this graph in order to allow greater visual detail of measured values for trend determination.
Cd (µg/L)
108, Cd TR, µg/l
108, Cd Diss,µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

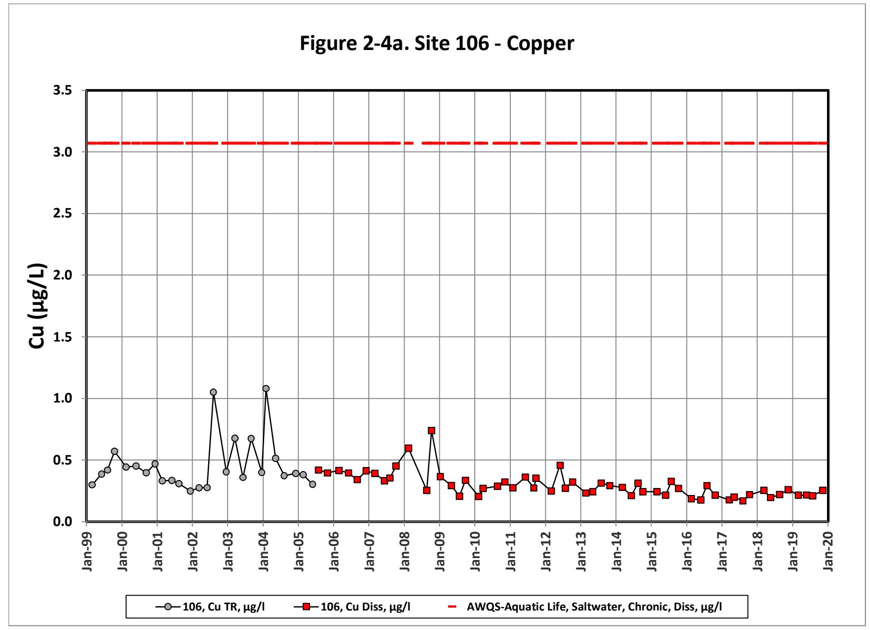


Figure 2-4a. Site 106 - Copper
Cu (µg/L)
106, Cu TR, µg/l
106, Cu Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

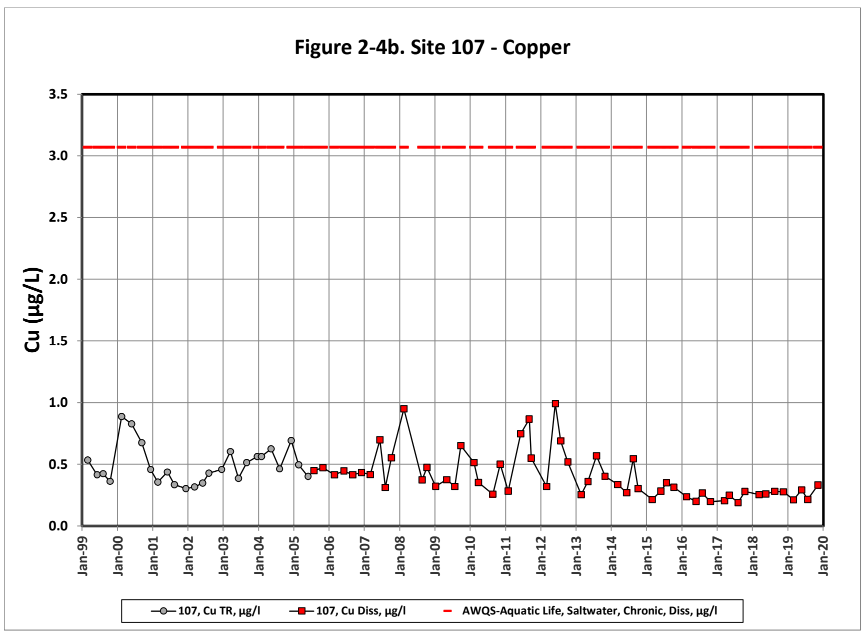


Figure 2-4b. Site 107 - Copper
Cu (µg/L)
107, Cu TR, µg/l
107, Cu Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

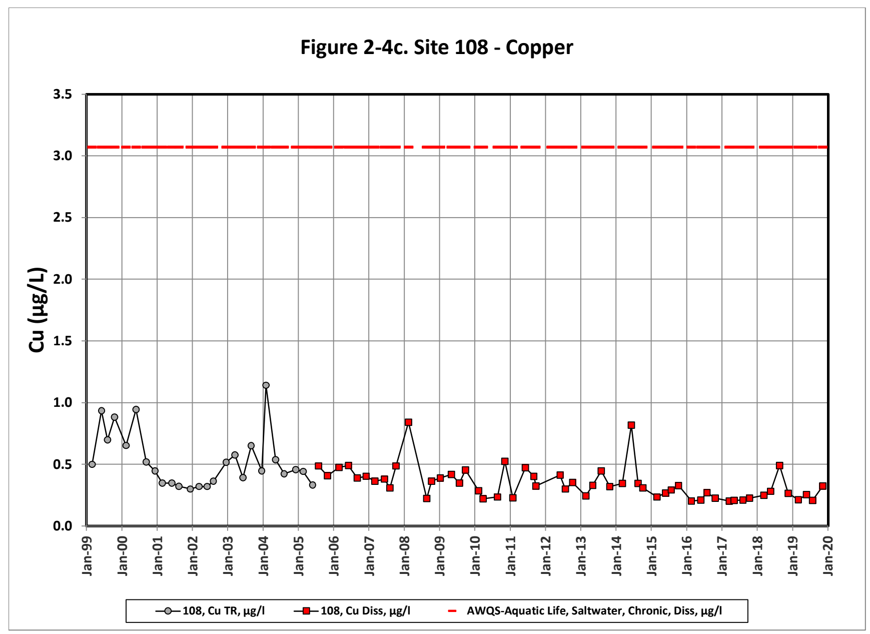


Figure 2-4c. Site 108 - Copper
Cu (µg/L)
108, Cu TR, µg/l
108, Cu Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-5a. Site 106 - Mercury

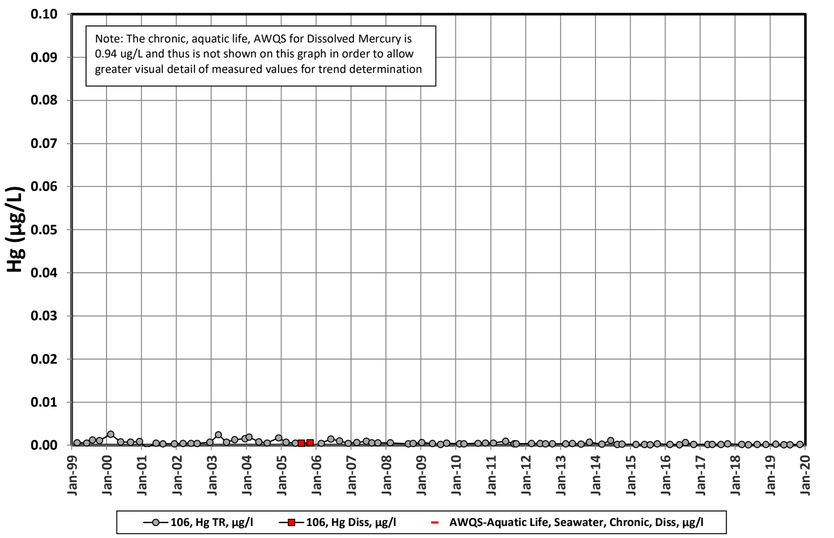


Figure 2-5b. Site 107 - Mercury

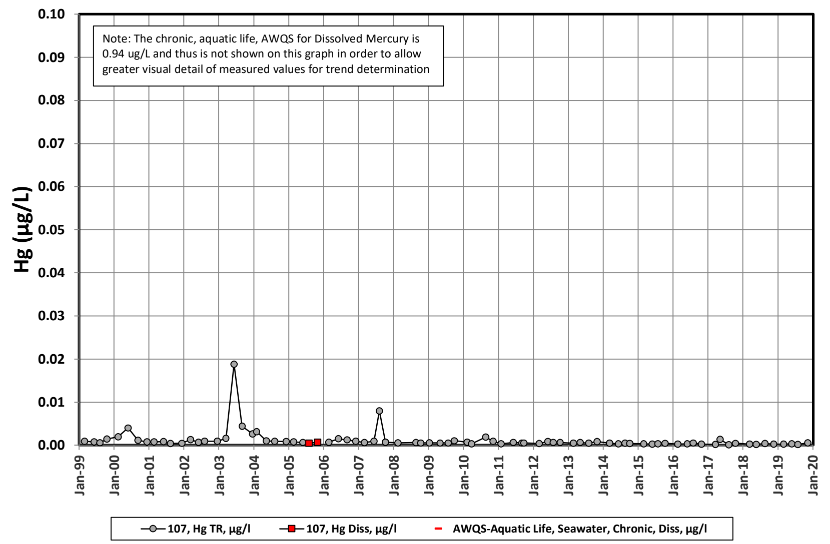


Figure 2-5c. Site 108 - Mercury

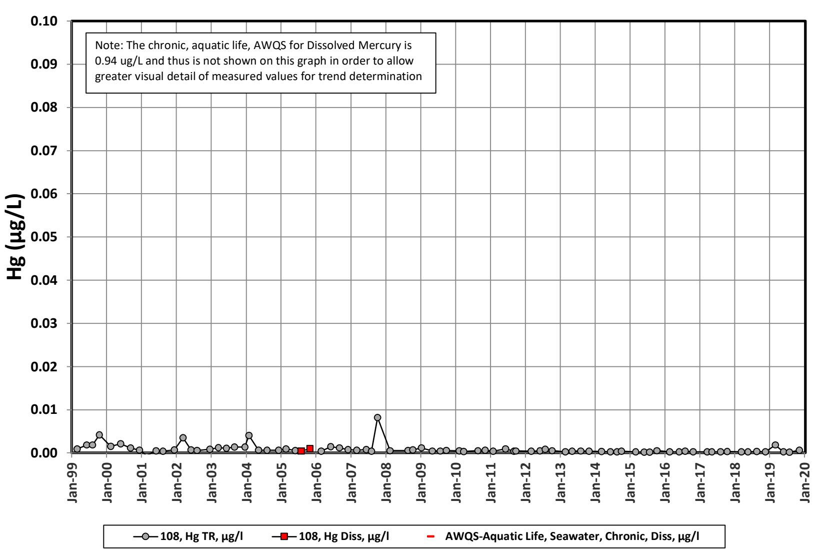
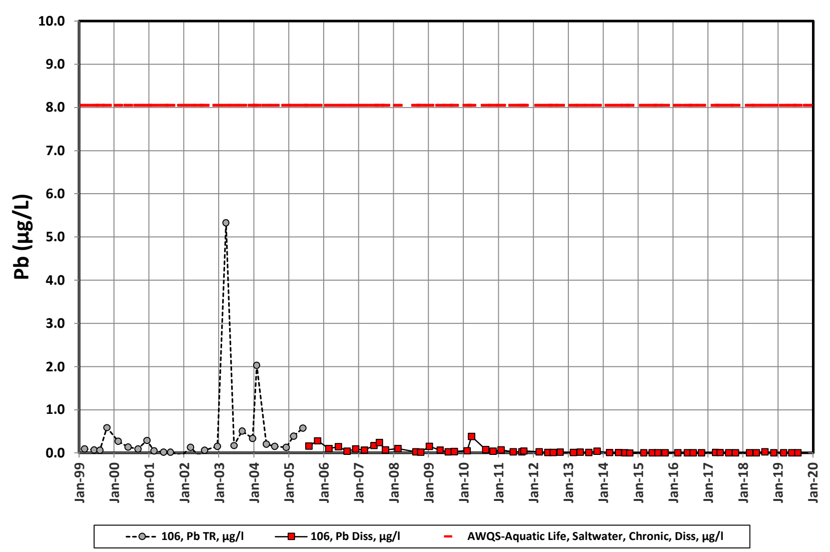


Figure 2-6a. Site 106 - Lead



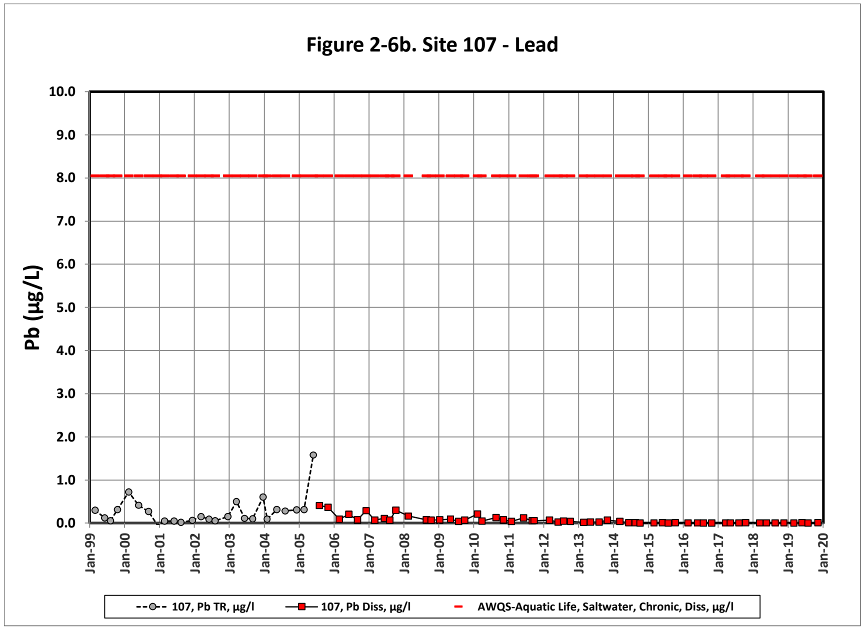


Figure 2-6b. Site 107 - Lead
Pb (µg/L)
107, Pb TR, µg/l
107, Pb Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

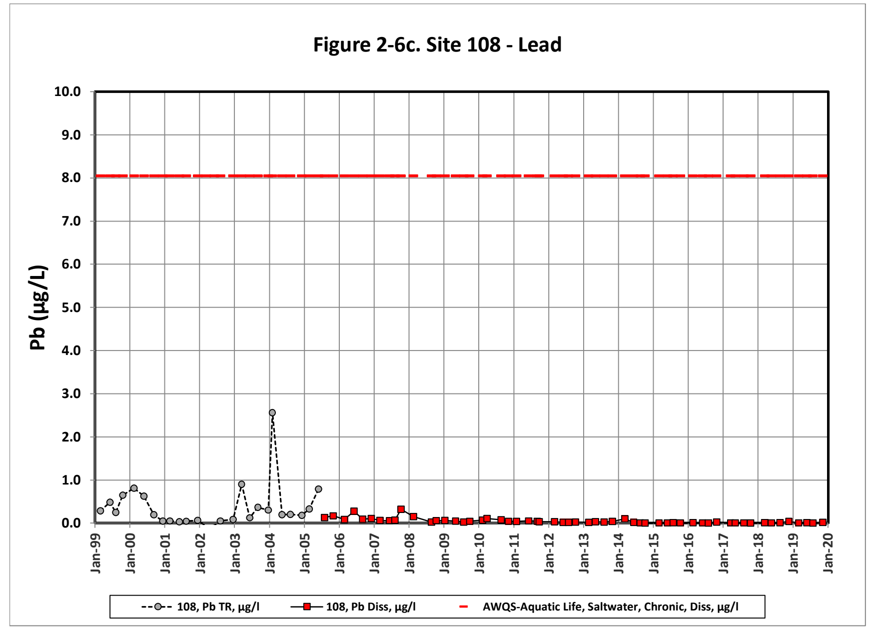


Figure 2-6c. Site 108 - Lead
Pb (µg/L)
108, Pb TR, µg/l
108, Pb Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

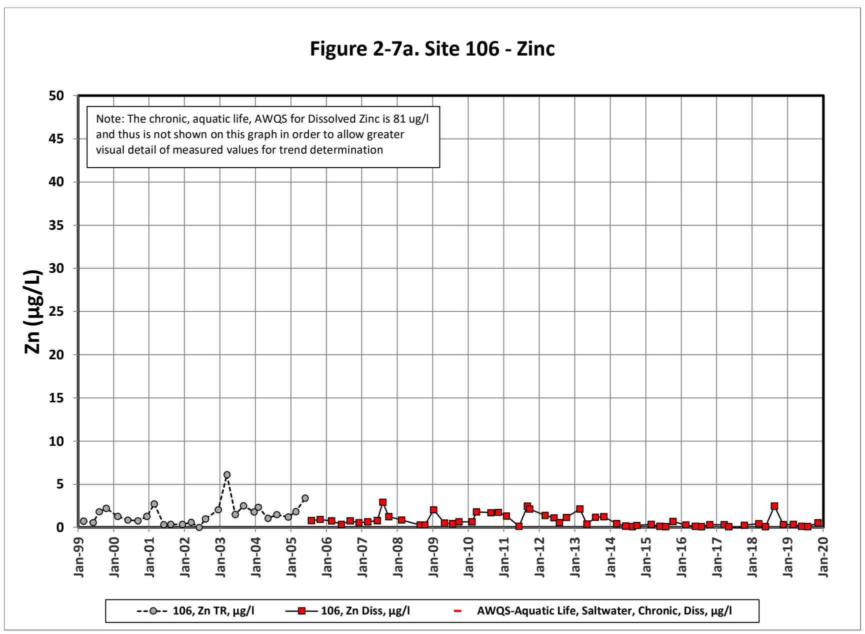


Figure 2-7a. Site 106 - Zinc
Note: The chronic, aquatic life, AWQS for Dissolved Zinc is 81 ug/l and thus is not shown on this graph in order to allow greater visual detail of measured values for trend determination
Zn (µg/L)
106, Zn TR, µg/l
106, Zn Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

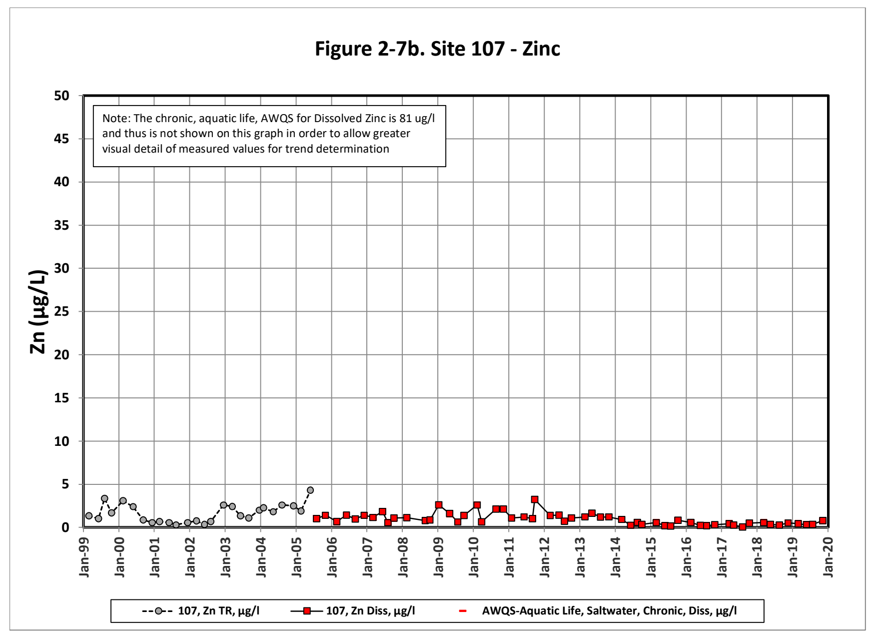


Figure 2-7b. Site 107 - Zinc
Note: The chronic, aquatic life, AWQS for Dissolved Zinc is 81 ug/l and thus is not shown on this graph in order to allow greater visual detail of measured values for trend determination
Zn (µg/L)
107, Zn TR, µg/l
107, Zn Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

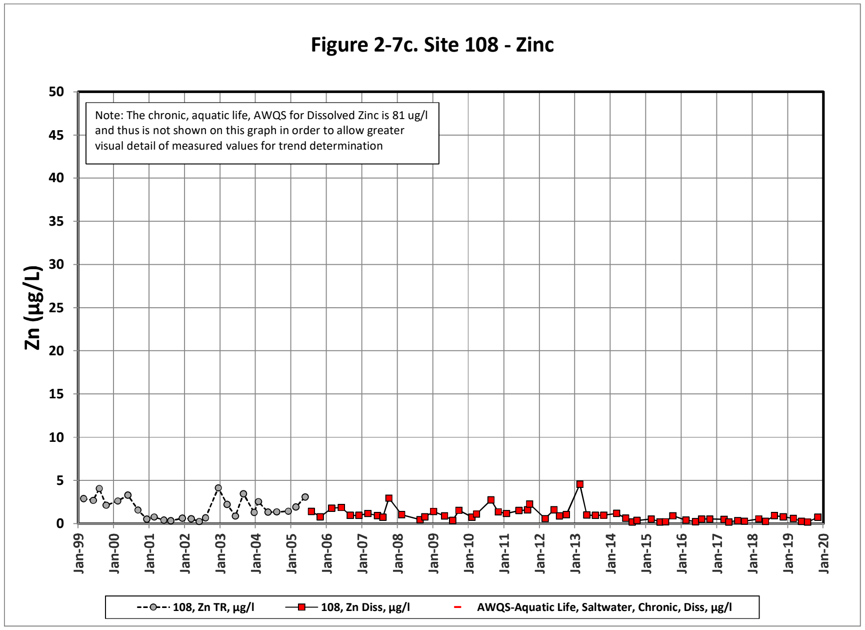


Figure 2-7c. Site 108 - Zinc
Note: The chronic, aquatic life, AWQS for Dissolved Zinc is 81 ug/l and thus is not shown on this graph in order to allow greater visual detail of measured values for trend determination
Zn (µg/L)
50
45
40
35
30
25
20
15
10
5
0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
Jan-20
108, Zn TR, µg/l
108, Zn Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

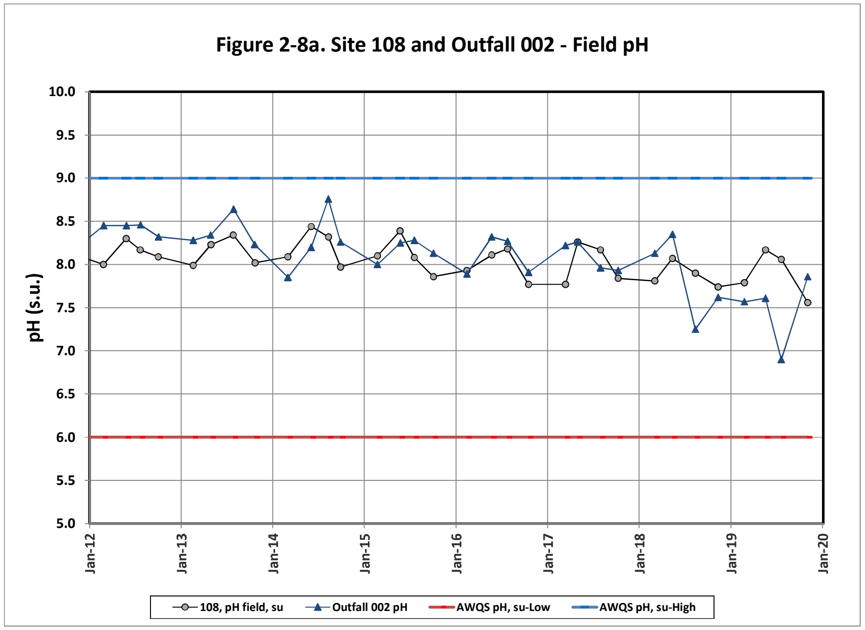


Figure 2-8a. Site 108 and Outfall 002 - Field pH
pH (s.u.)
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
Jan-20
108, pH field, su
Outfall 002 pH
AWQS pH, su-Low
AWQS pH, su-High

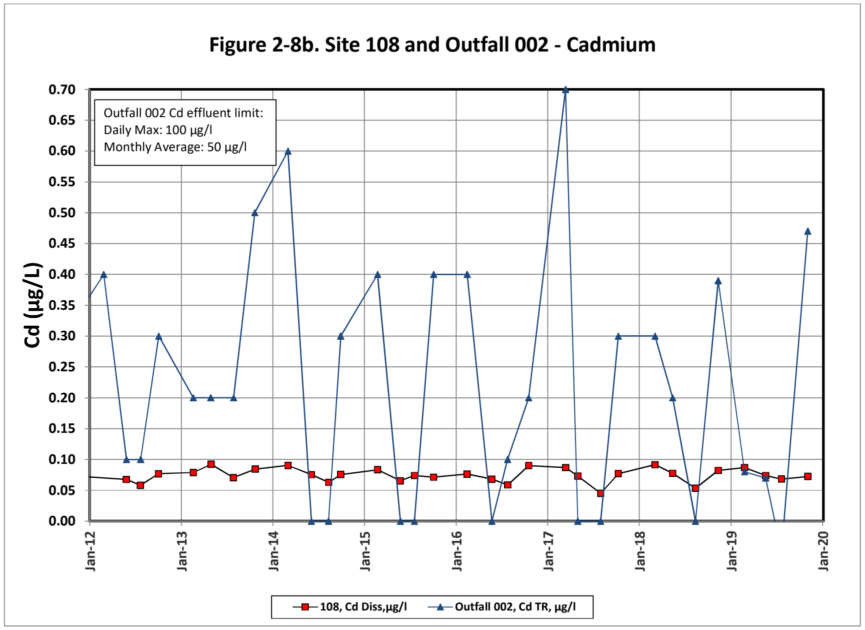


Figure 2-8b. Site 108 and Outfall 002 - Cadmium
Outfall 002 Cd effluent limit:
Daily Max: 100 µg/l
Monthly Average: 50 µg/l
Cd (µg/L)
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
Jan-20
108, Cd Diss,µg/l
Outfall 002, Cd TR, µg/l

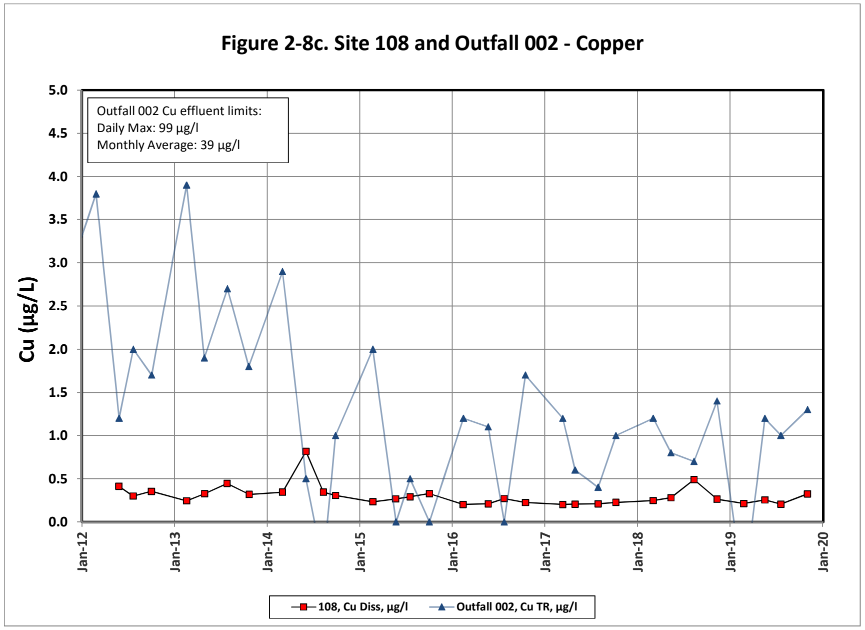


Figure 2-8c. Site 108 and Outfall 002 - Copper
Outfall 002 Cu effluent limits:
Daily Max: 99 µg/l
Monthly Average: 39 µg/l
Cu (µg/L)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
Jan-20
108, Cu Diss, µg/l
Outfall 002, Cu TR, µg/l

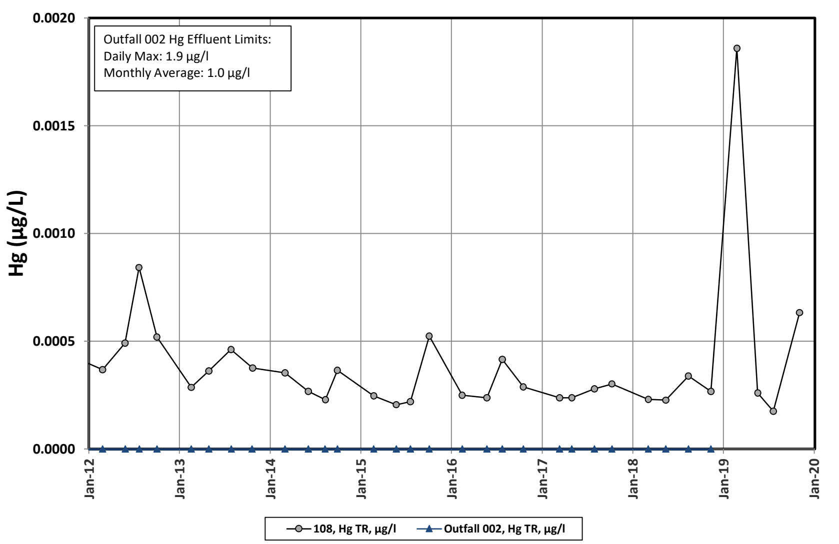


Figure 2-8d. Site 108 and Outfall 002 - Mercury

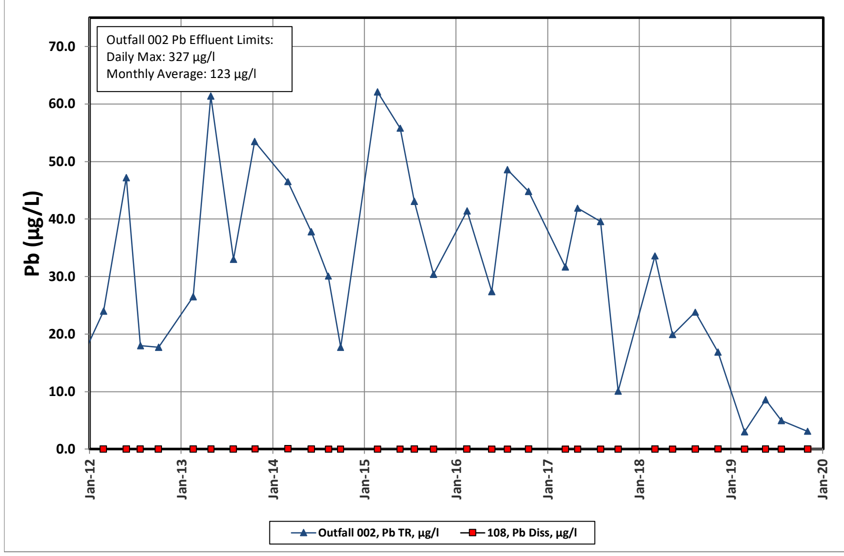


Figure 2-8e. Site 108 and Outfall 002 - Lead

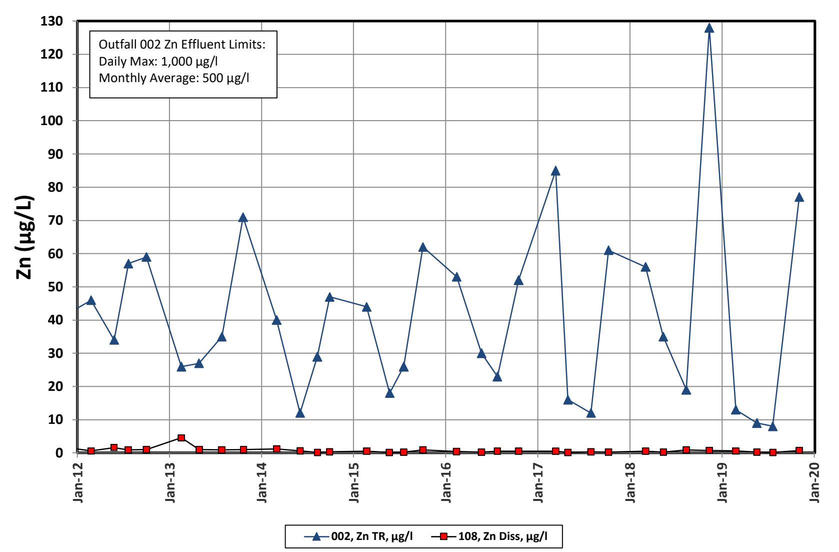


Figure 2-8f. Site 108 and Outfall 002 - Zinc

Figure 3-1. Cadmium in Sediment at Site S-1

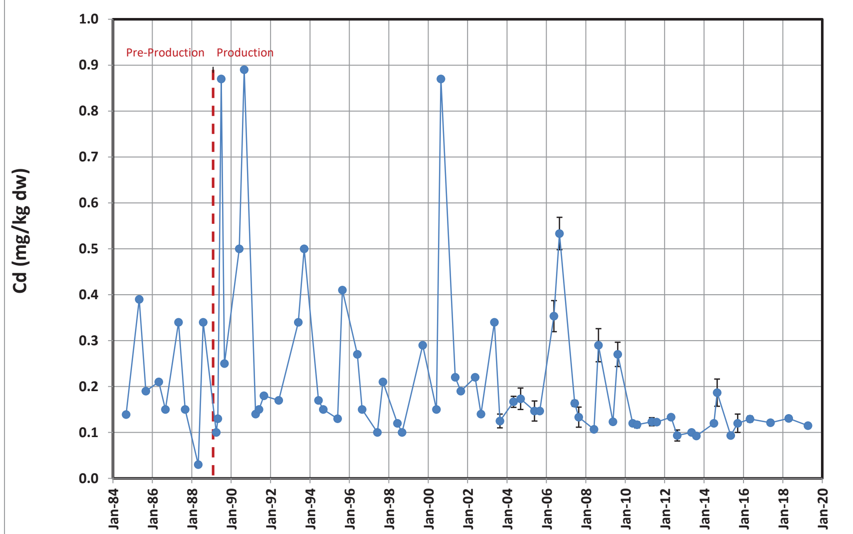


Figure 3-2. Copper in Sediment at Site S-1

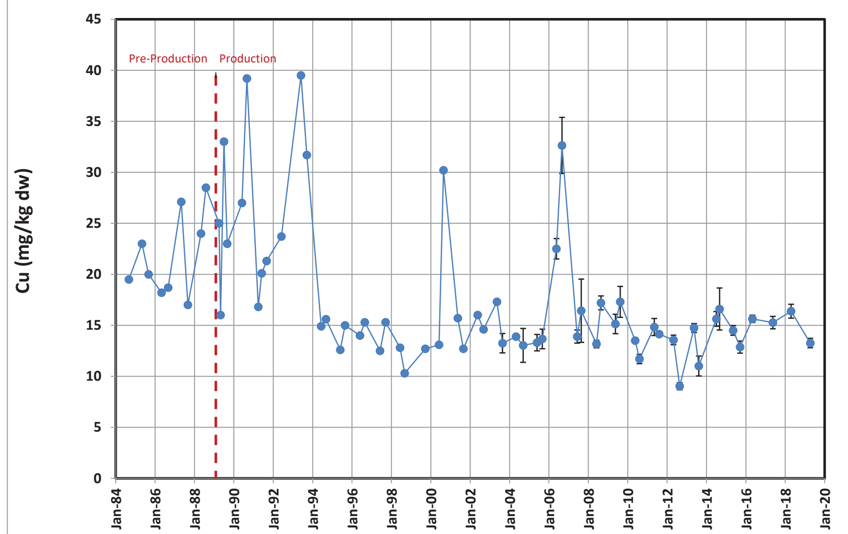


Figure 3-3. Lead in Sediment at Site S-1

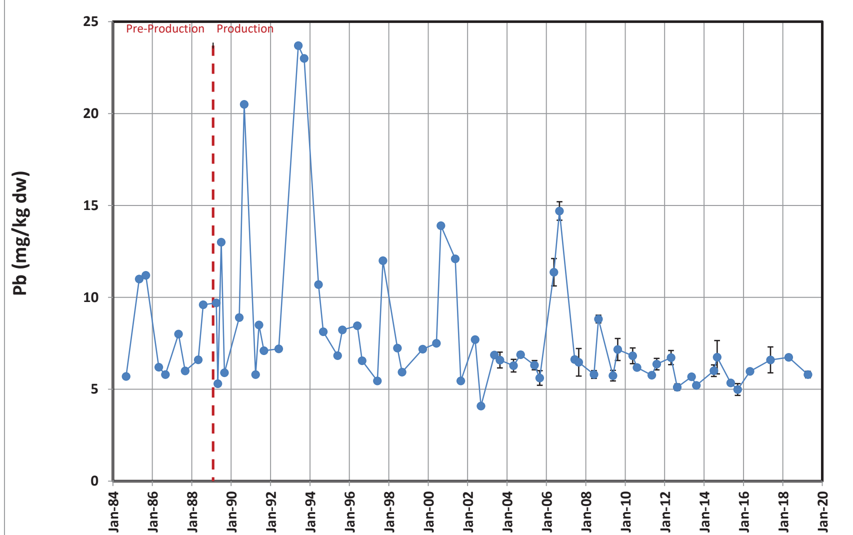


Figure 3-4. Mercury in Sediment at Site S-1

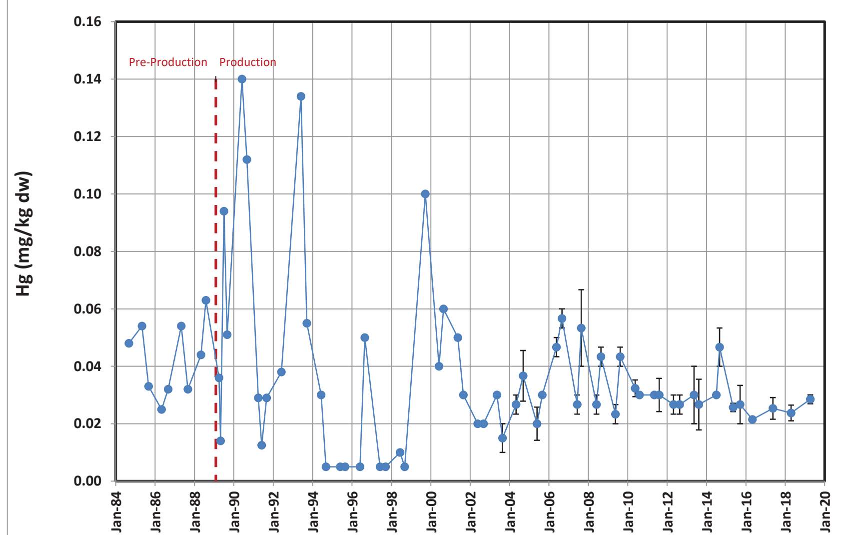


Figure 3-5. Zinc in Sediment at Site S-1

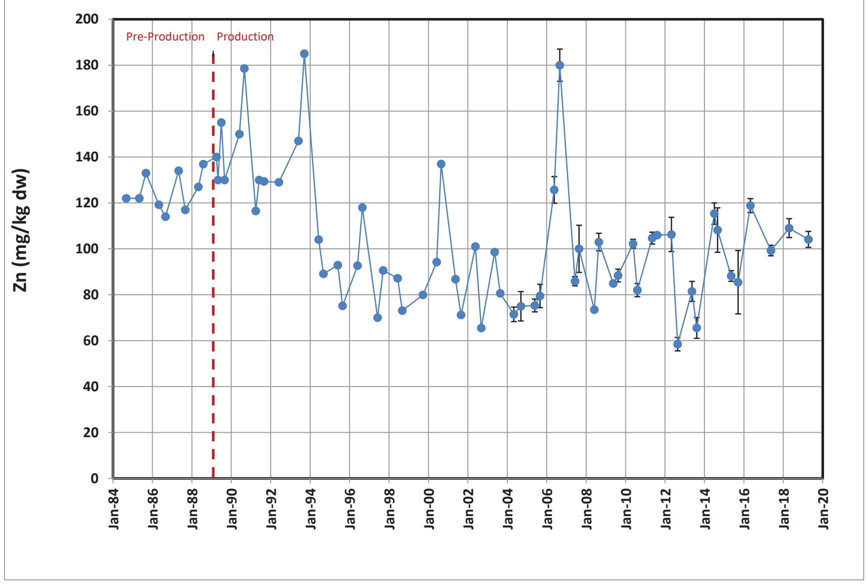


Figure 3-6. Cadmium in Sediment at Site S-2

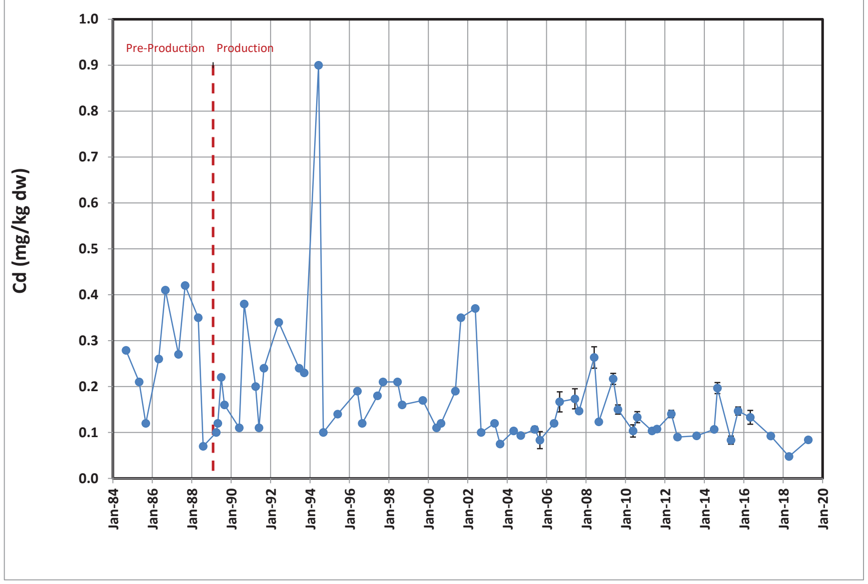


Figure 3-7. Copper in Sediment at Site S-2

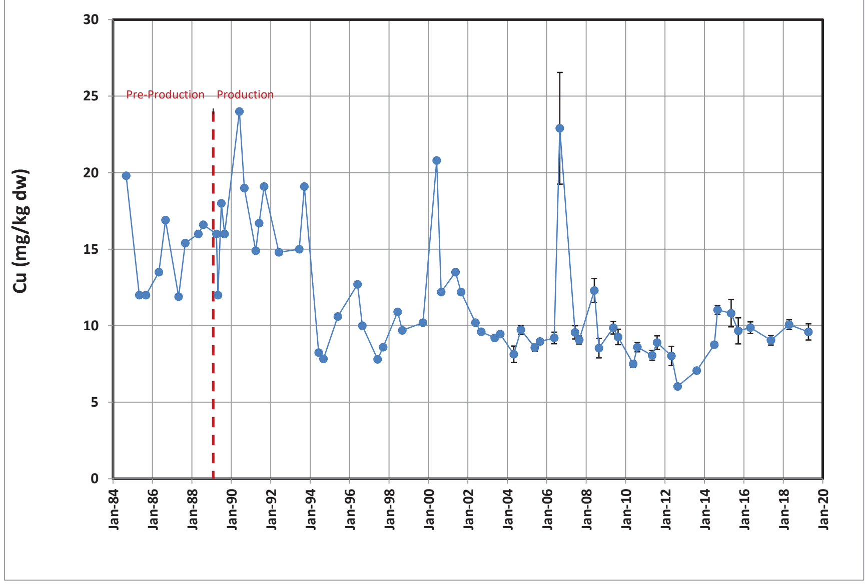
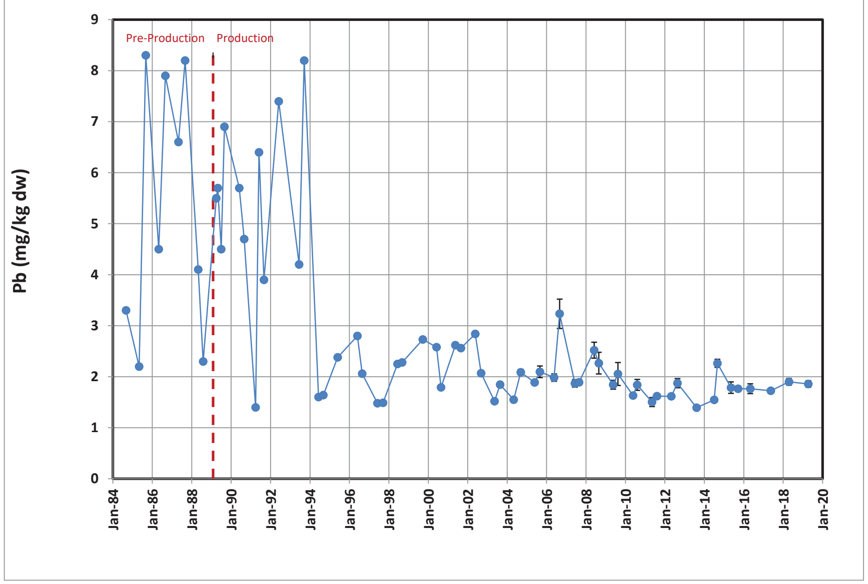


Figure 3-8. Lead in Sediment at Site S-2



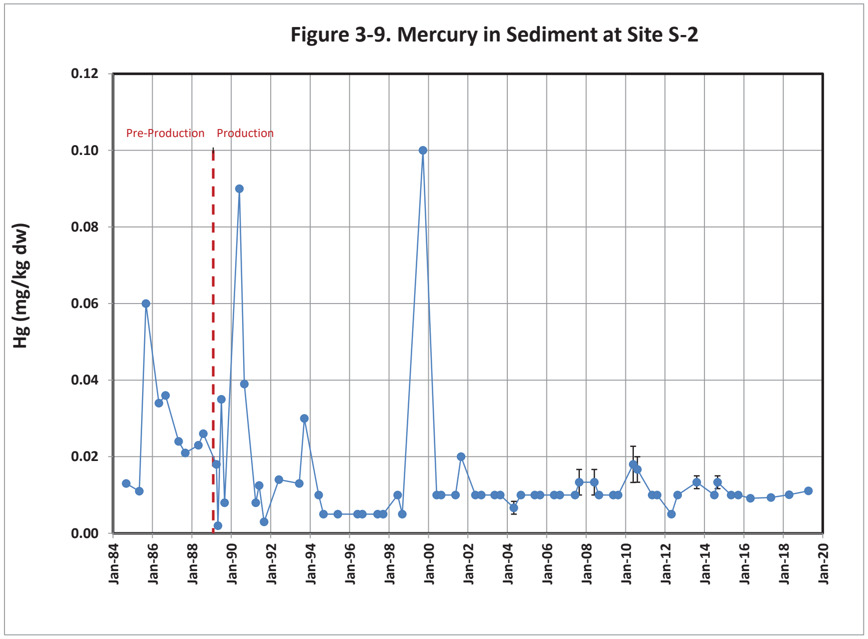


Figure 3-9. Mercury in Sediment at Site S-2
Hg (mg/kg dw)
Pre-Production
Production
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

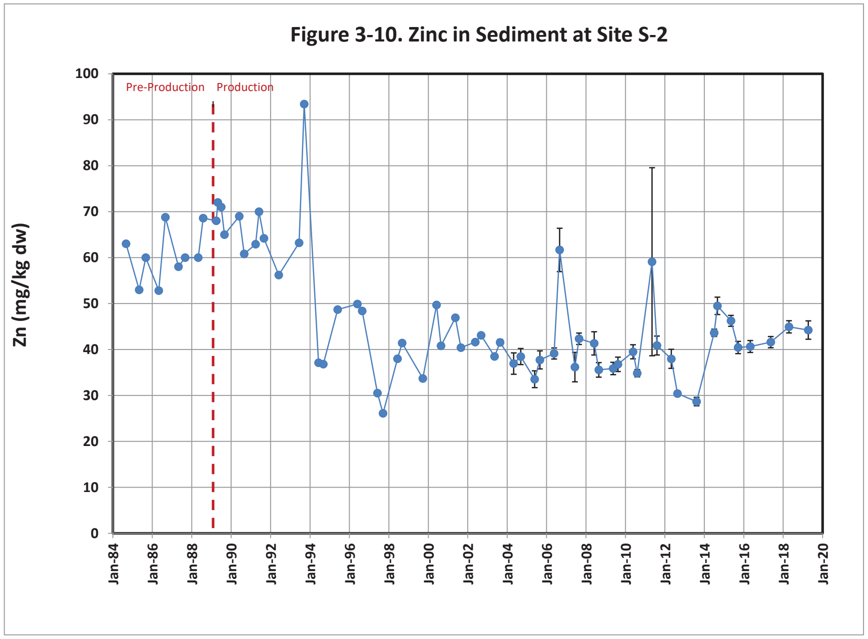


Figure 3-10. Zinc in Sediment at Site S-2
Zn (mg/kg dw)
Pre-Production
Production
100
90
80
70
60
50
40
30
20
10
0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

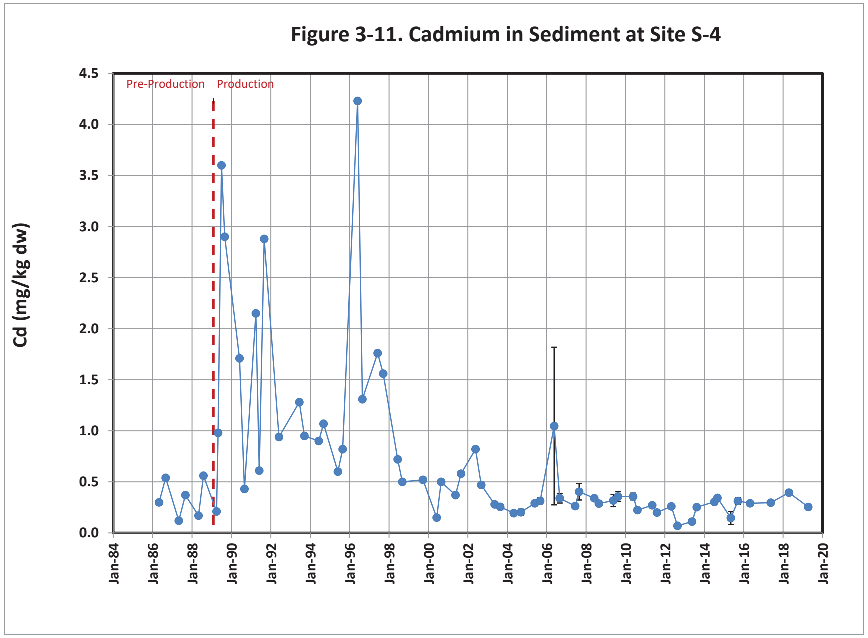


Figure 3-11. Cadmium in Sediment at Site S-4
Cd (mg/kg dw)
Pre-Production
Production
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

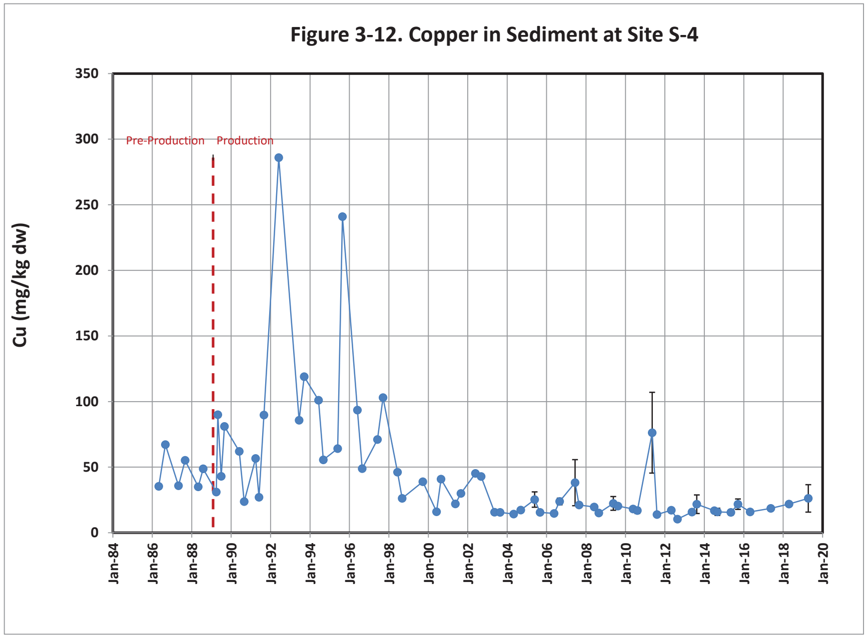


Figure 3-12. Copper in Sediment at Site S-4
Cu (mg/kg dw)
Pre-Production
Production
350
300
250
200
150
100
50
0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

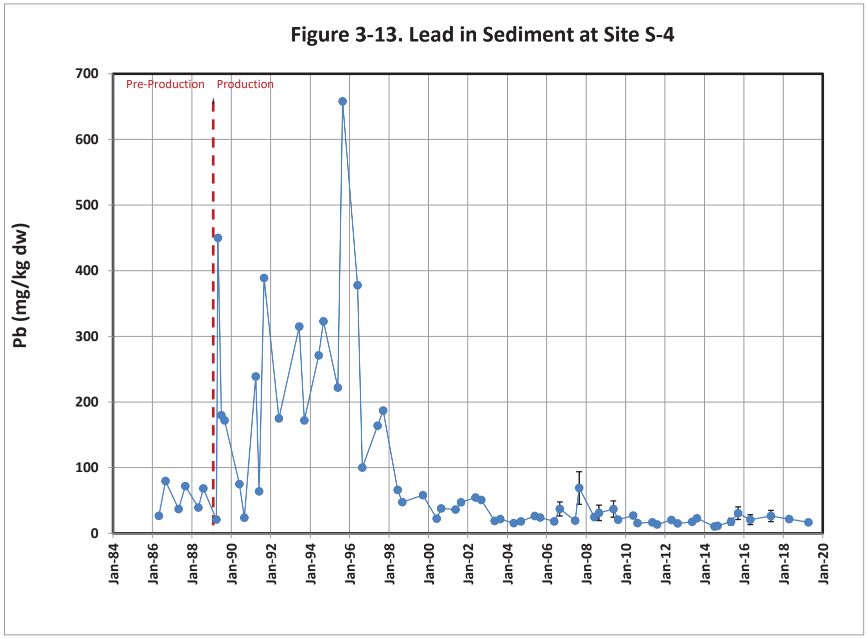


Figure 3-13. Lead in Sediment at Site S-4
Pb (mg/kg dw)
Pre-Production
Production
0
100
200
300
400
500
600
700
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

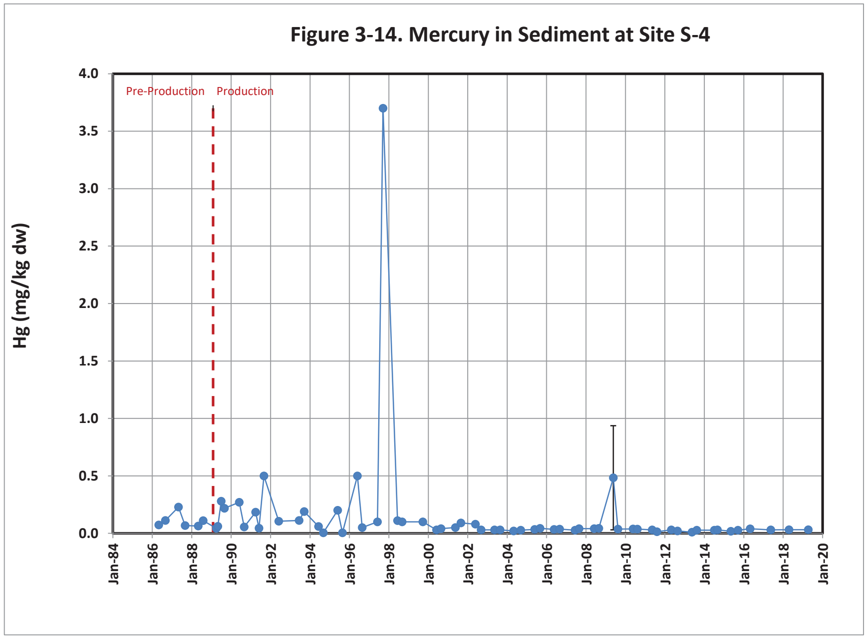


Figure 3-14. Mercury in Sediment at Site S-4
Hg (mg/kg dw)
Pre-Production
Production
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

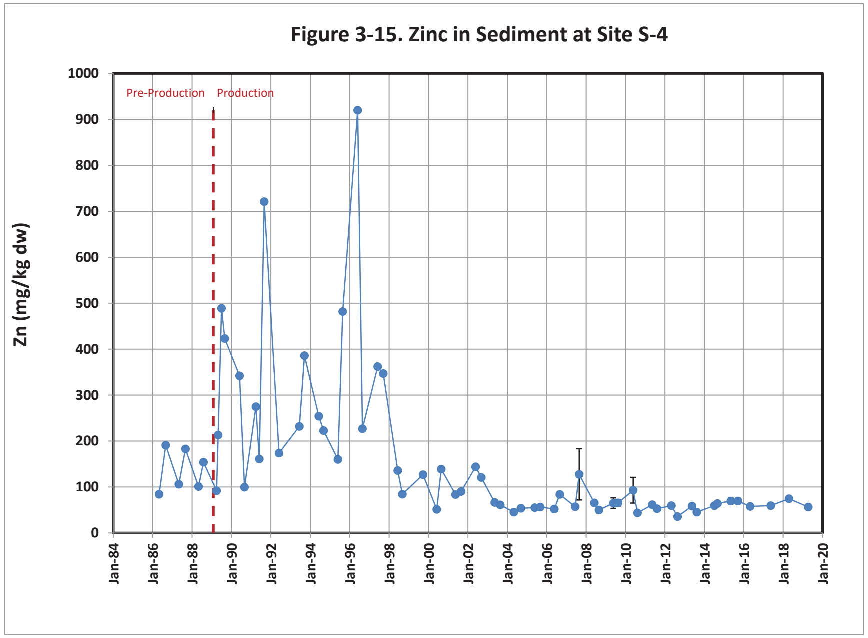


Figure 3-15. Zinc in Sediment at Site S-4
Zn (mg/kg dw)
Pre-Production
Production
0
100
200
300
400
500
600
700
800
900
1000
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

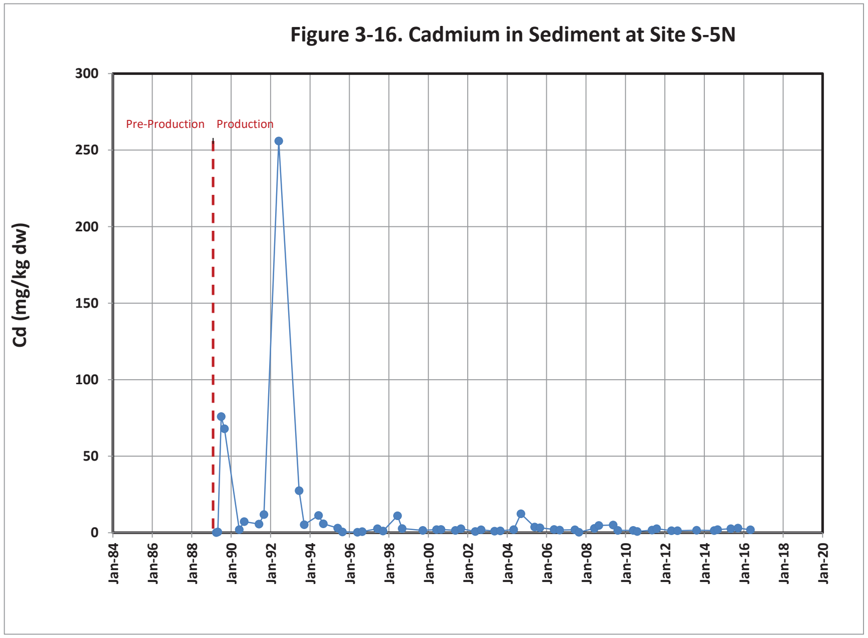


Figure 3-16. Cadmium in Sediment at Site S-5N
Cd (mg/kg dw)
Pre-Production
Production
0
50
100
150
200
250
300
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
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Jan-14
Jan-16
Jan-18
Jan-20

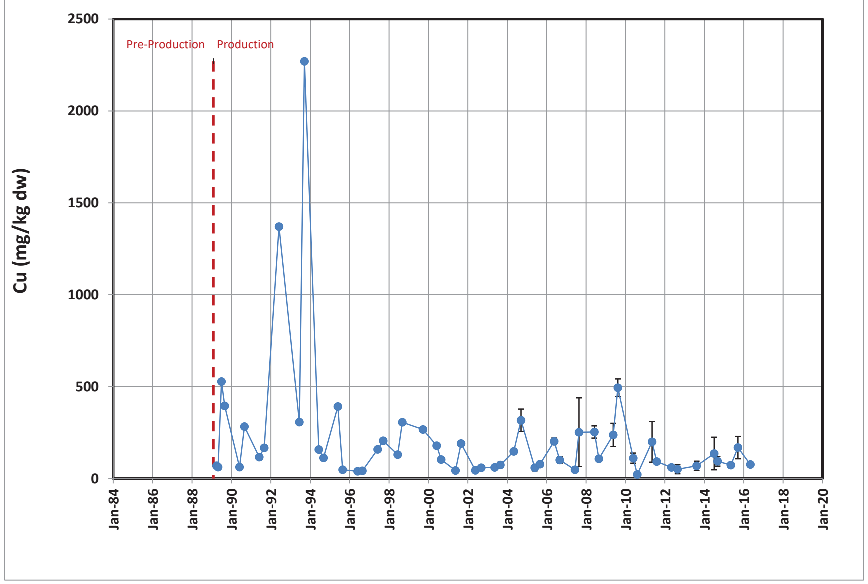

Figure 3-17. Copper in Sediment at Site S-5N

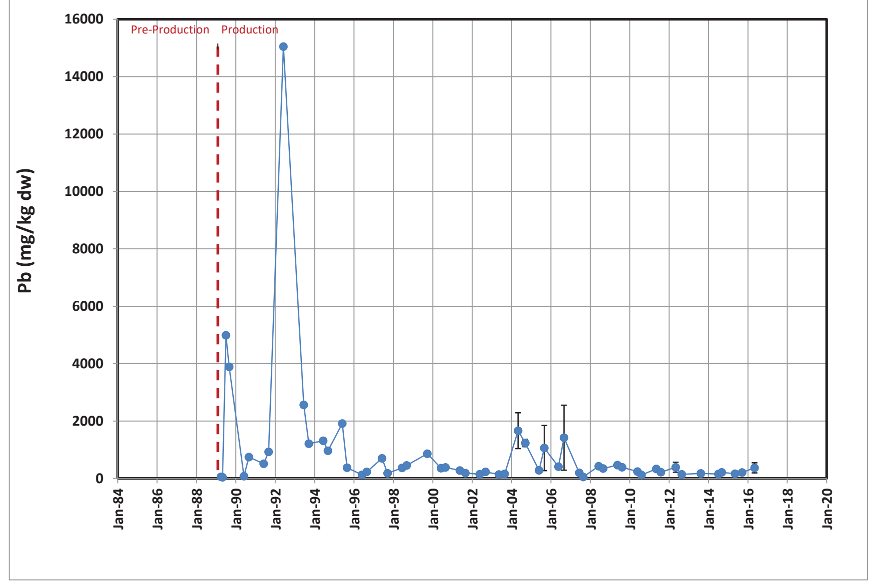

Figure 3-18. Lead in Sediment at Site S-5N

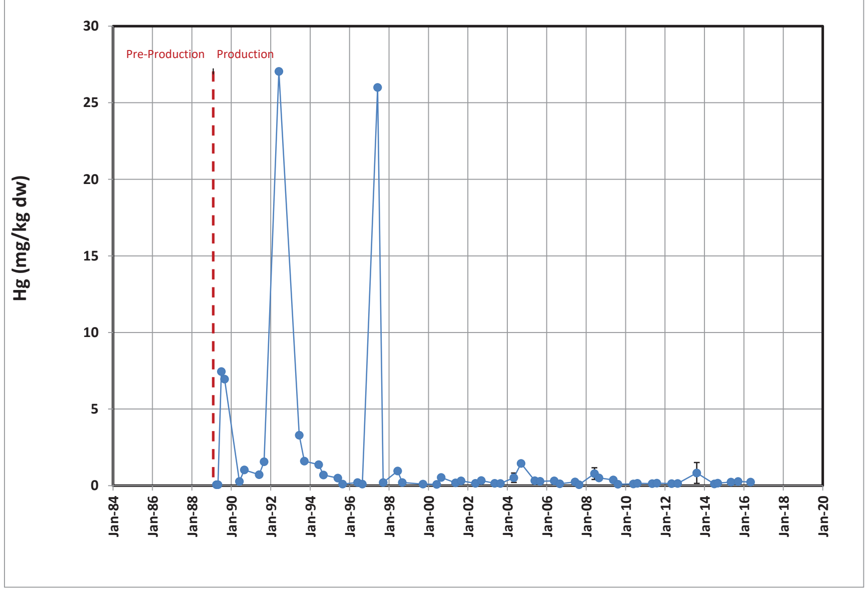

Figure 3-19. Mercury in Sediment at Site S-5N

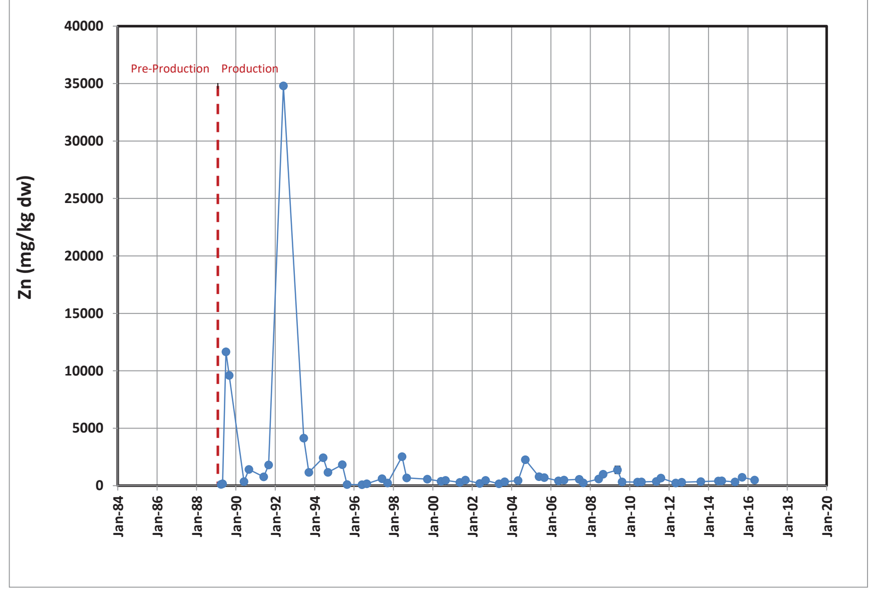

Figure 3-20. Zinc in Sediment at Site S-5N

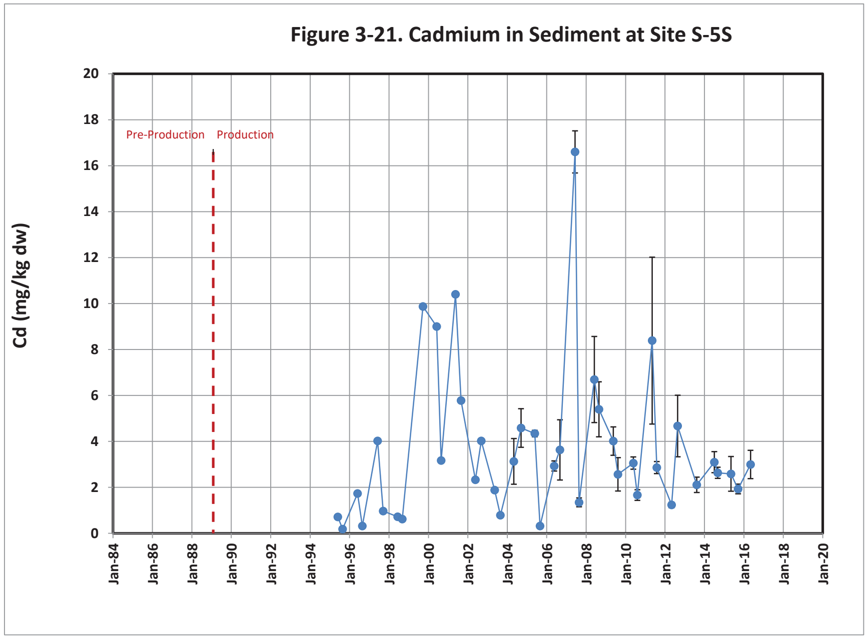
Figure 3-21. Cadmium in Sediment at Site S-5S
Cd (mg/kg dw)
Pre-Production
Production
0
2
4
6
8
10
12
14
16
18
20
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

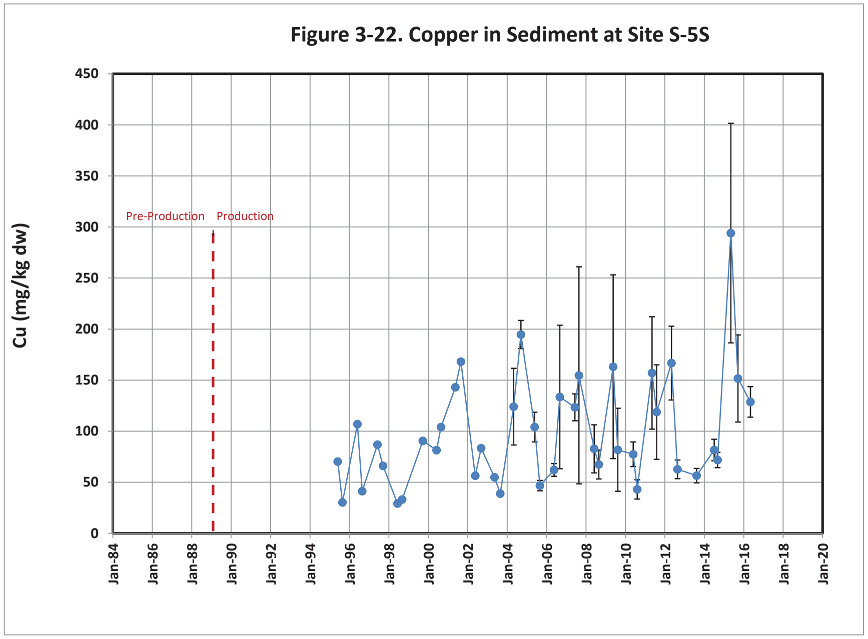
Figure 3-22. Copper in Sediment at Site S-5S
Cu (mg/kg dw)
Pre-Production
Production
0
50
100
150
200
250
300
350
400
450
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

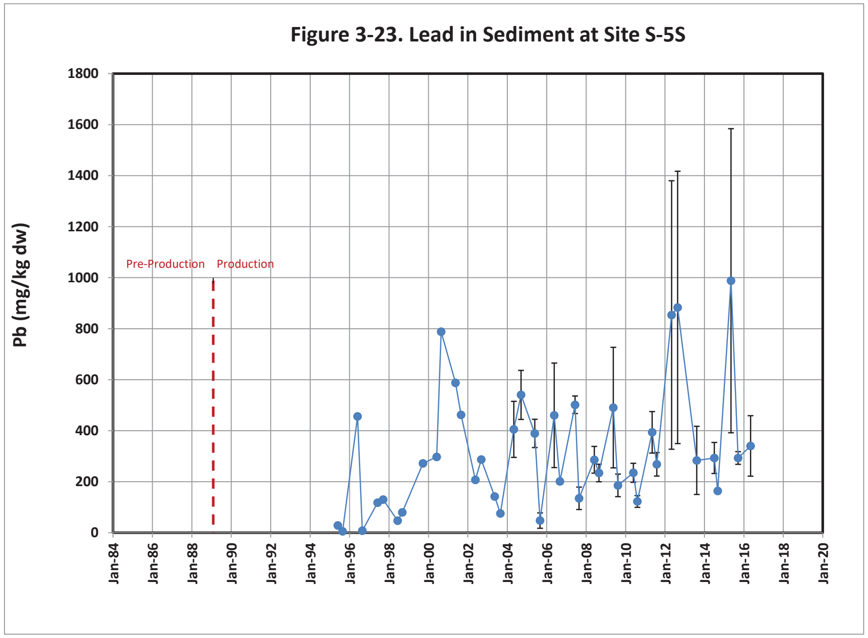
Figure 3-23. Lead in Sediment at Site S-5S
Pb (mg/kg dw)
Pre-Production
Production
0
200
400
600
800
1000
1200
1400
1600
1800
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

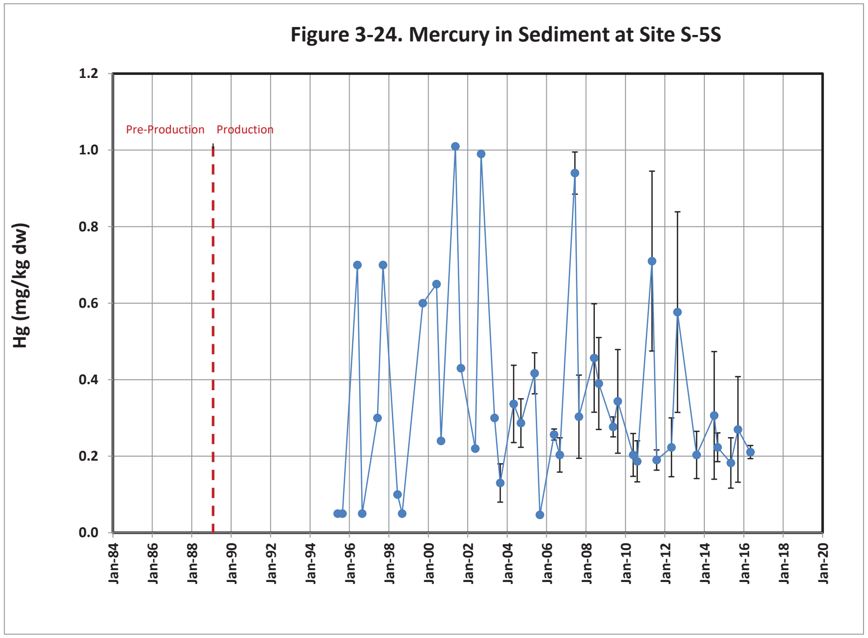
Figure 3-24. Mercury in Sediment at Site S-5S
Hg (mg/kg dw)
Pre-Production
Production
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

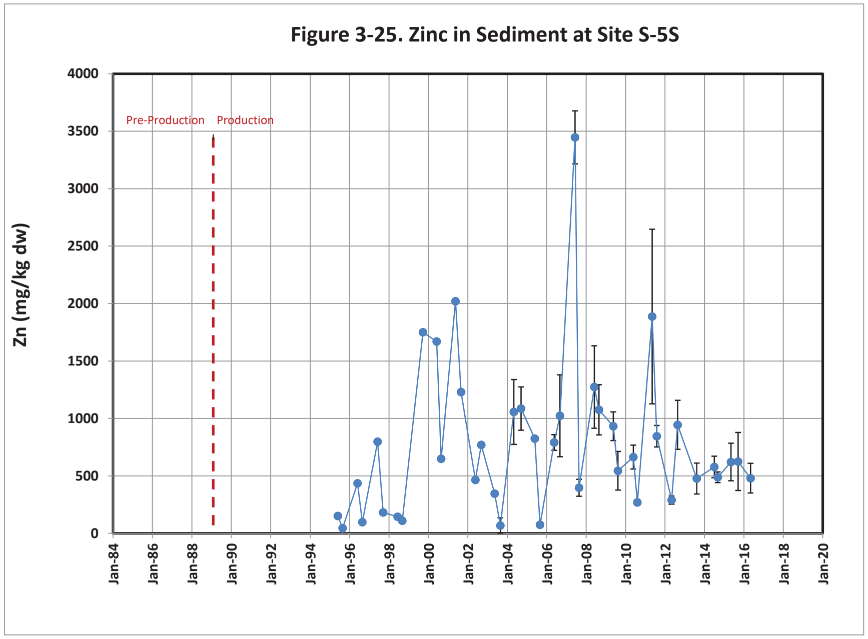
Figure 3-25. Zinc in Sediment at Site S-5S
Zn (mg/kg dw)
Pre-Production
Production
0
500
1000
1500
2000
2500
3000
3500
4000
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

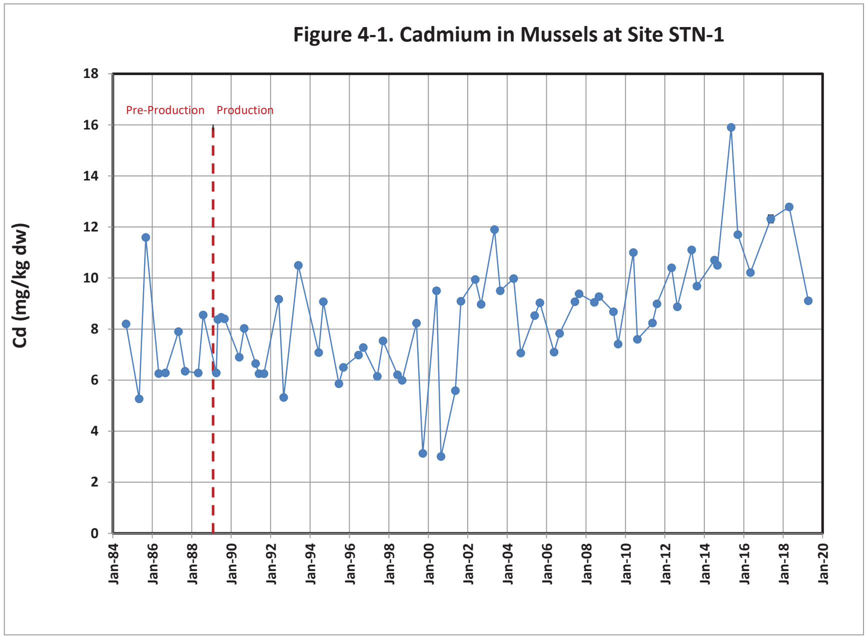
Figure 4-1. Cadmium in Mussels at Site STN-1
Cd (mg/kg dw)
Pre-Production
Production
0
2
4
6
8
10
12
14
16
18
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

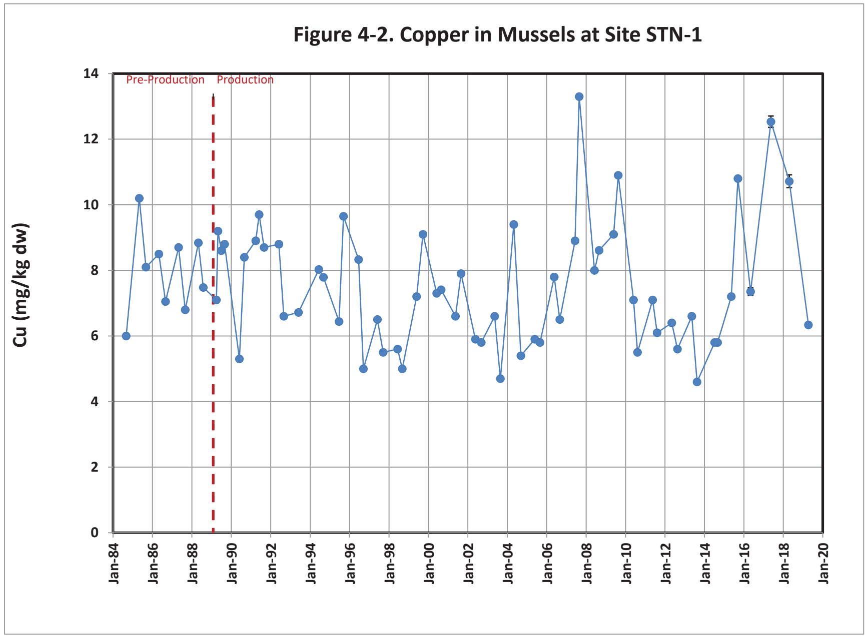
Figure 4-2. Copper in Mussels at Site STN-1
Cu (mg/kg dw)
Pre-Production
Production
0
2
4
6
8
10
12
14
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

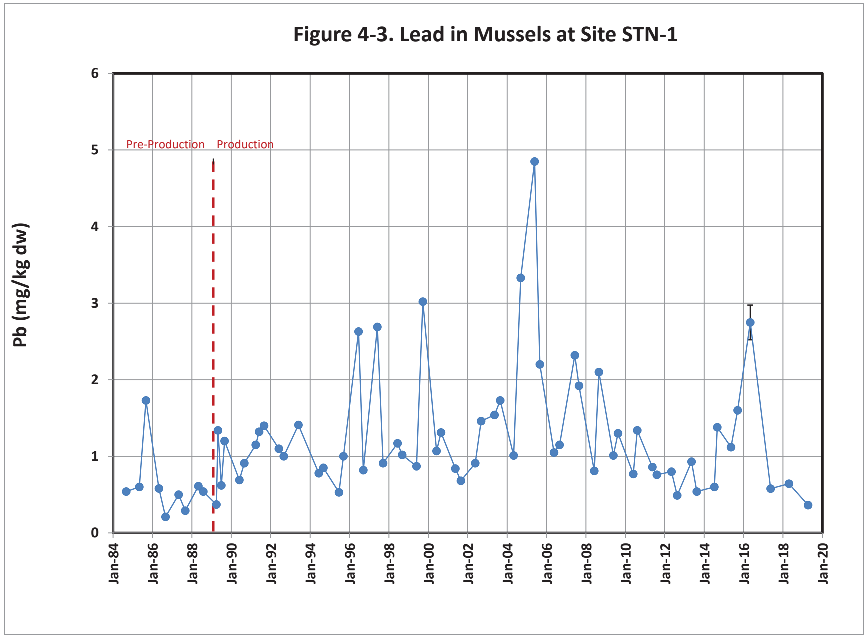
Figure 4-3. Lead in Mussels at Site STN-1
Pb (mg/kg dw)
Pre-Production
Production
0
1
2
3
4
5
6
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
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Jan-16
Jan-18
Jan-20

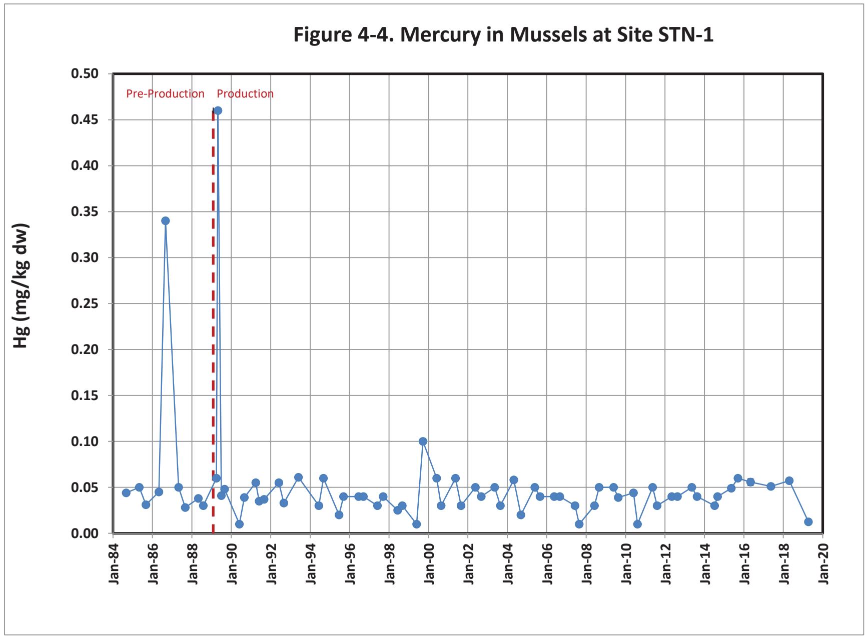
Figure 4-4. Mercury in Mussels at Site STN-1
Hg (mg/kg dw)
Pre-Production
Production
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

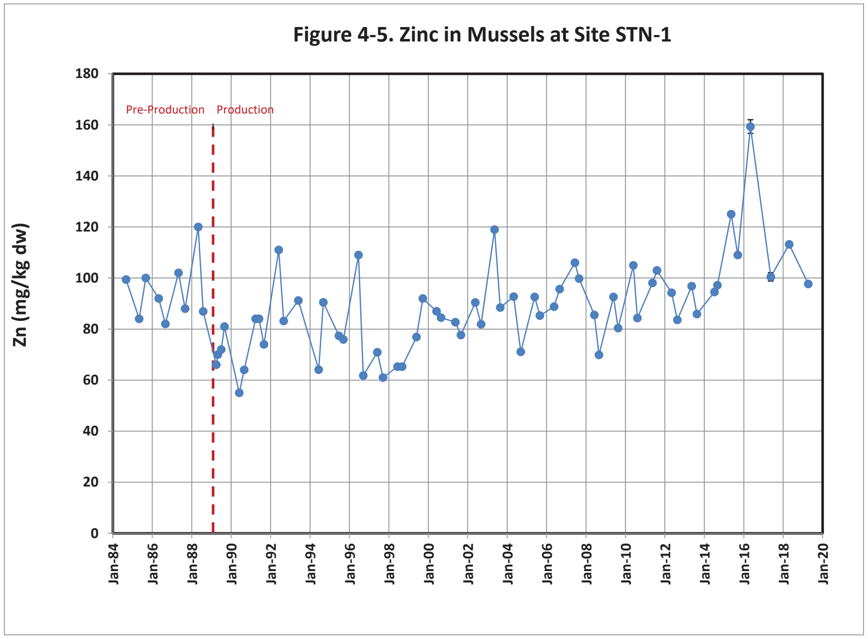
Figure 4-5. Zinc in Mussels at Site STN-1
Zn (mg/kg dw)
Pre-Production
Production
0
20
40
60
80
100
120
140
160
180
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

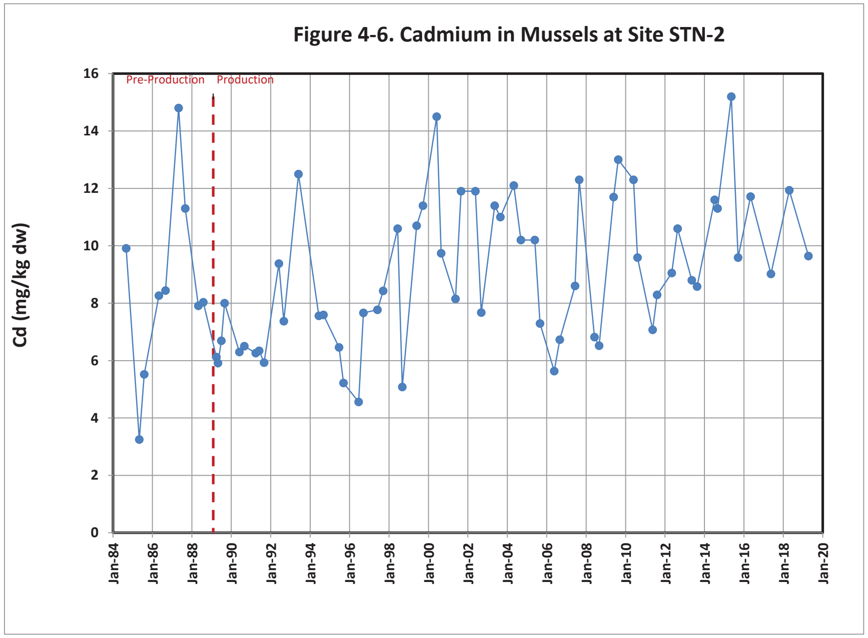
Figure 4-6. Cadmium in Mussels at Site STN-2
Cd (mg/kg dw)
Pre-Production
Production
0
2
4
6
8
10
12
14
16
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
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Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

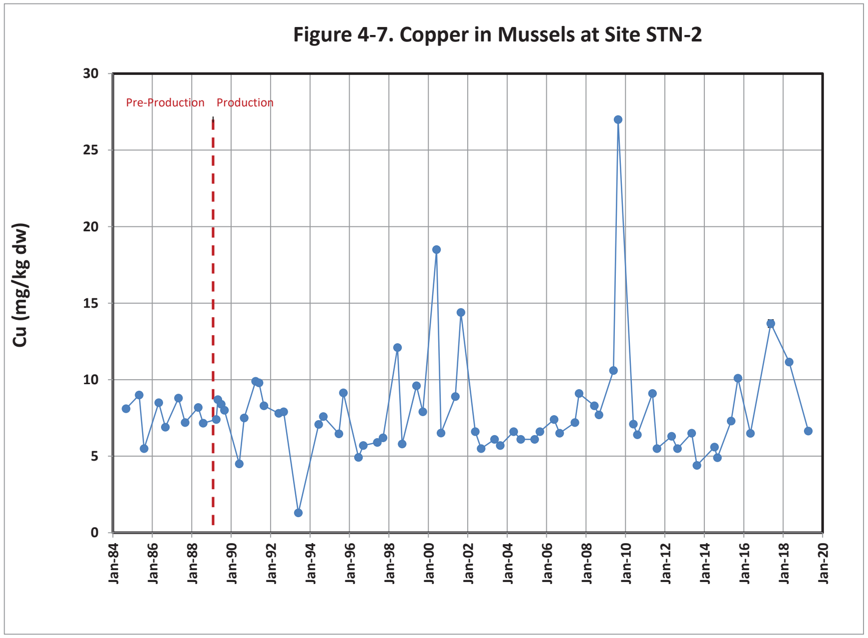


Figure 4-7. Copper in Mussels at Site STN-2
Cu (mg/kg dw)
Pre-Production
Production
0
5
10
15
20
25
30
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

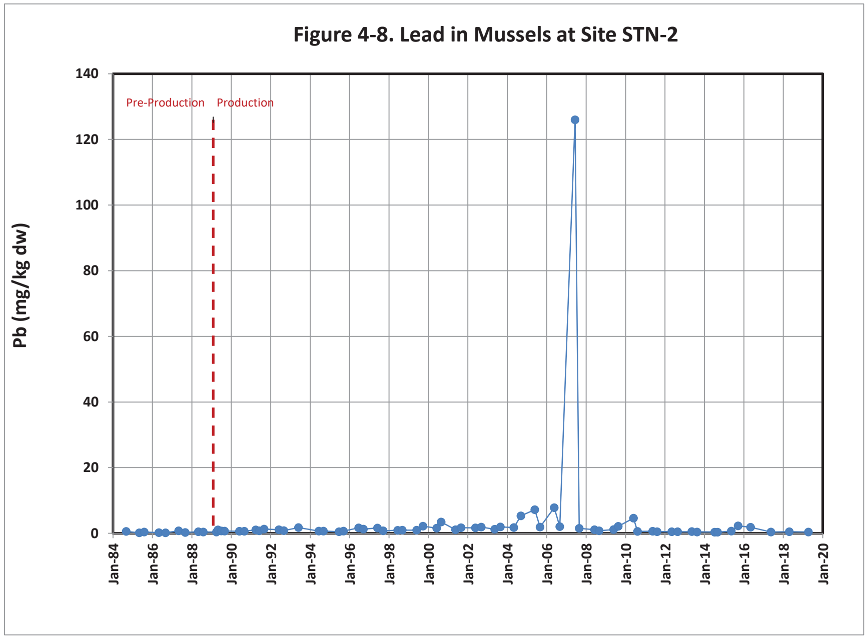


Figure 4-8. Lead in Mussels at Site STN-2
Pb (mg/kg dw)
Pre-Production
Production

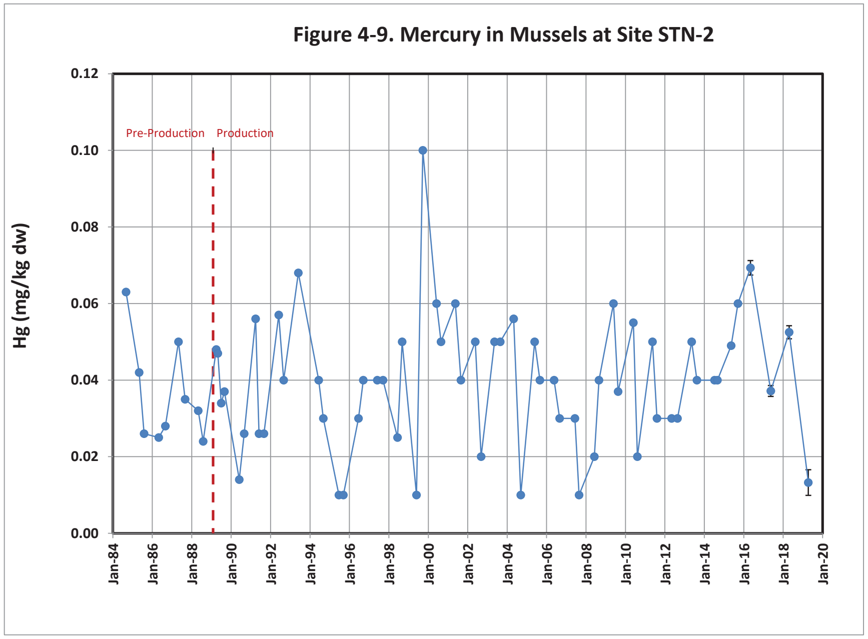


Figure 4-9. Mercury in Mussels at Site STN-2
Hg (mg/kg dw)
Pre-Production
Production

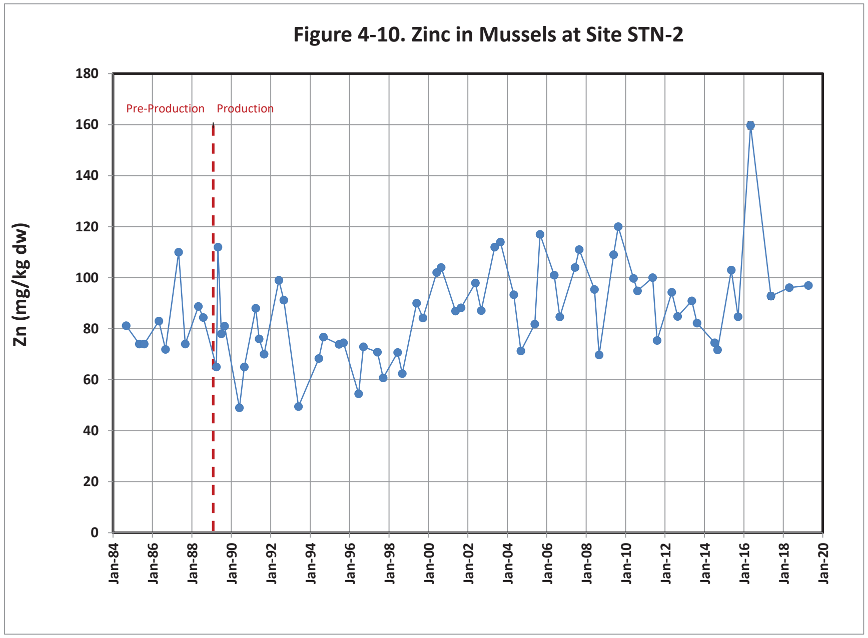


Figure 4-10. Zinc in Mussels at Site STN-2
Zn (mg/kg dw)
Pre-Production
Production

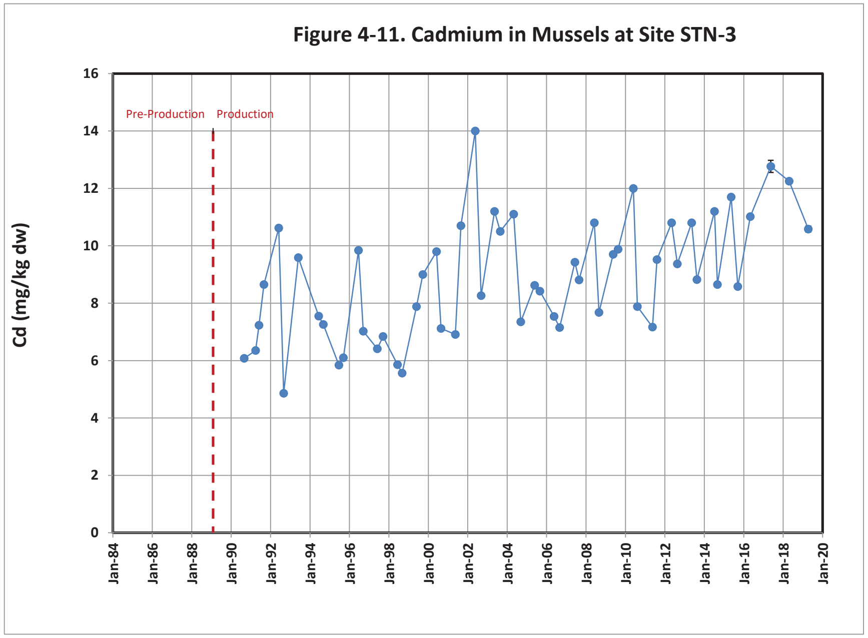


Figure 4-11. Cadmium in Mussels at Site STN-3
Cd (mg/kg dw)
Pre-Production
Production

Figure 4-12. Copper in Mussels at Site STN-3

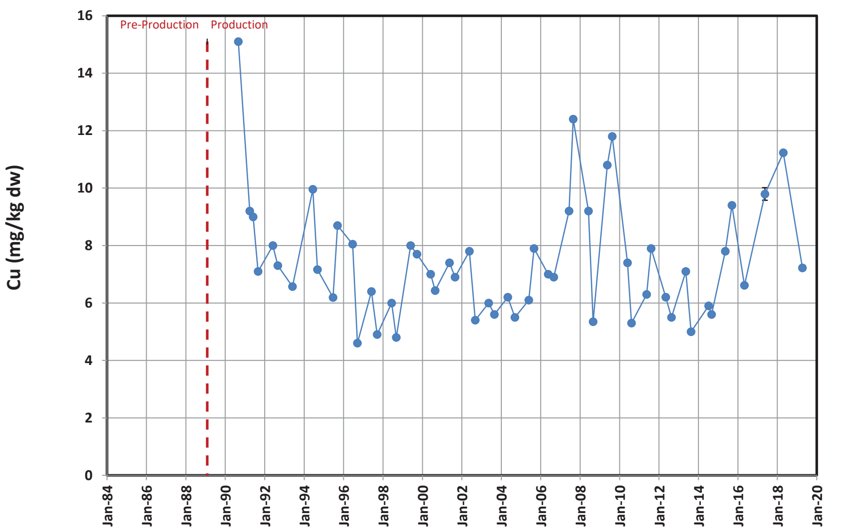


Figure 4-13. Lead in Mussels at Site STN-3

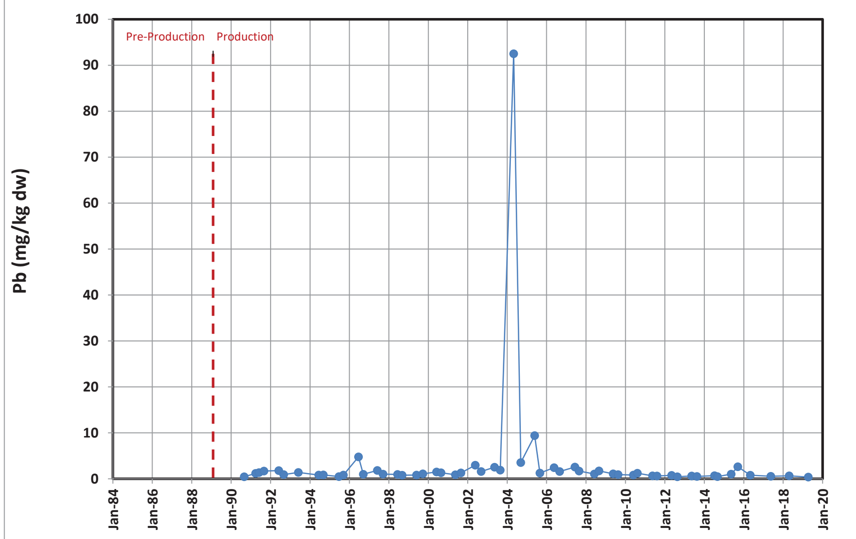


Figure 4-14. Mercury in Mussels at Site STN-3

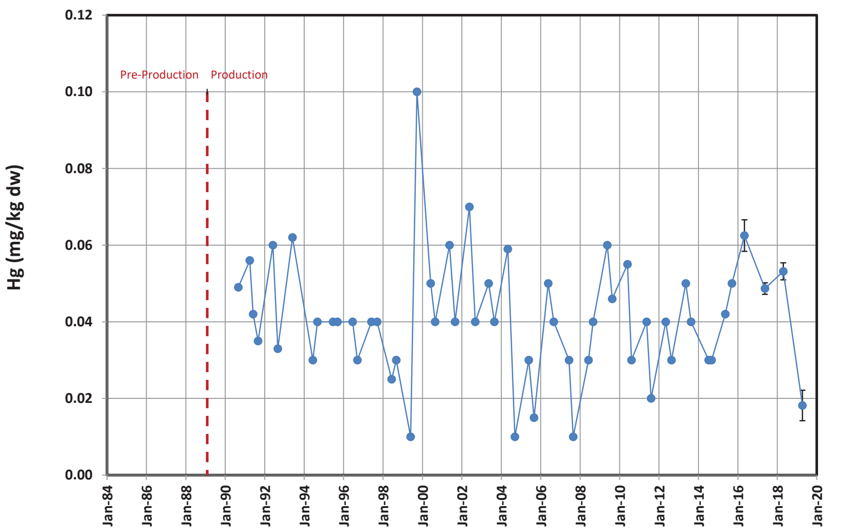
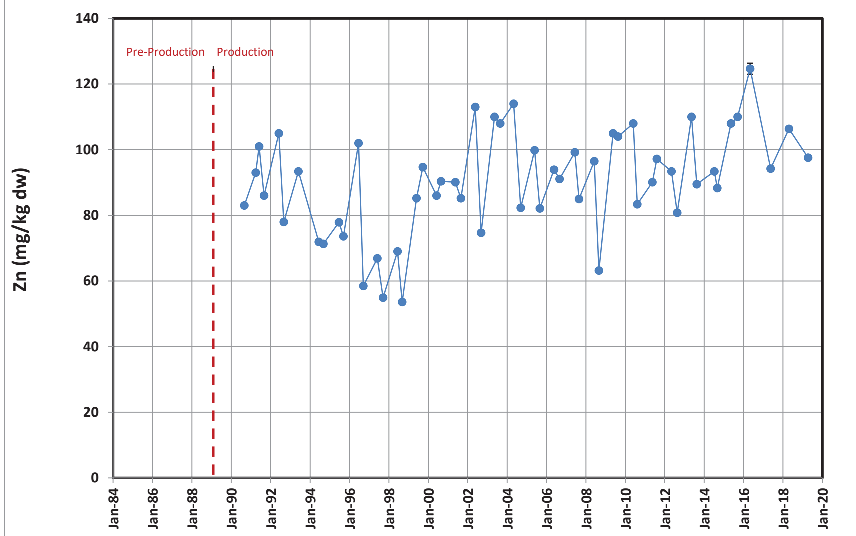


Figure 4-15. Zinc in Mussels at Site STN-3



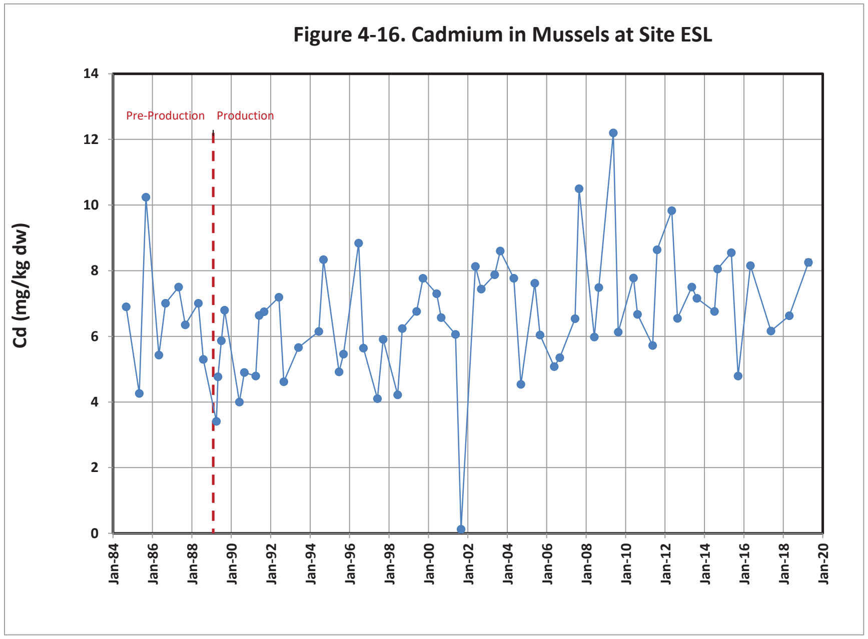


Figure 4-16. Cadmium in Mussels at Site ESL
Cd (mg/kg dw)
Pre-Production
Production
0
2
4
6
8
10
12
14
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
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Jan-14
Jan-16
Jan-18
Jan-20

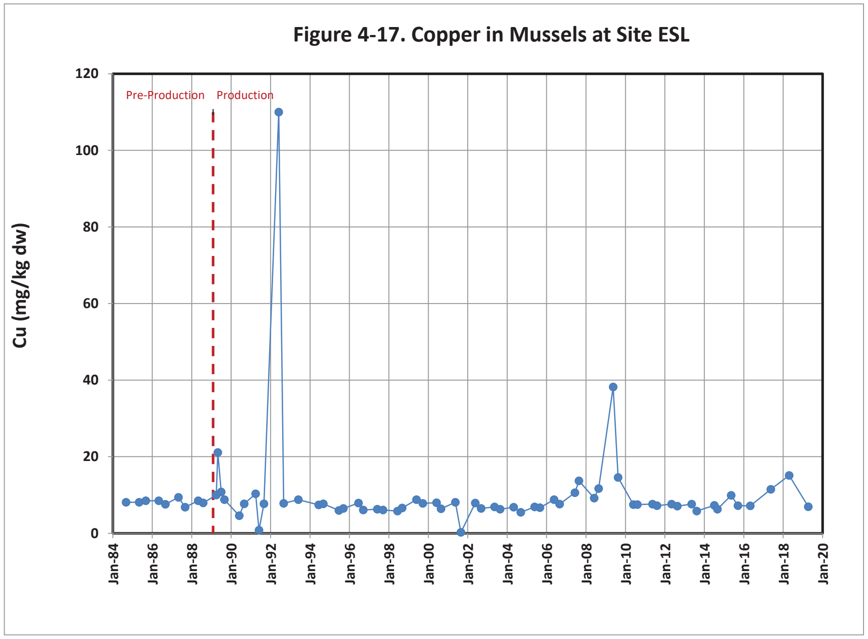
Figure 4-17. Copper in Mussels at Site ESL
Cu (mg/kg dw)
Pre-Production
Production
0
20
40
60
80
100
120
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
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Jan-16
Jan-18
Jan-20

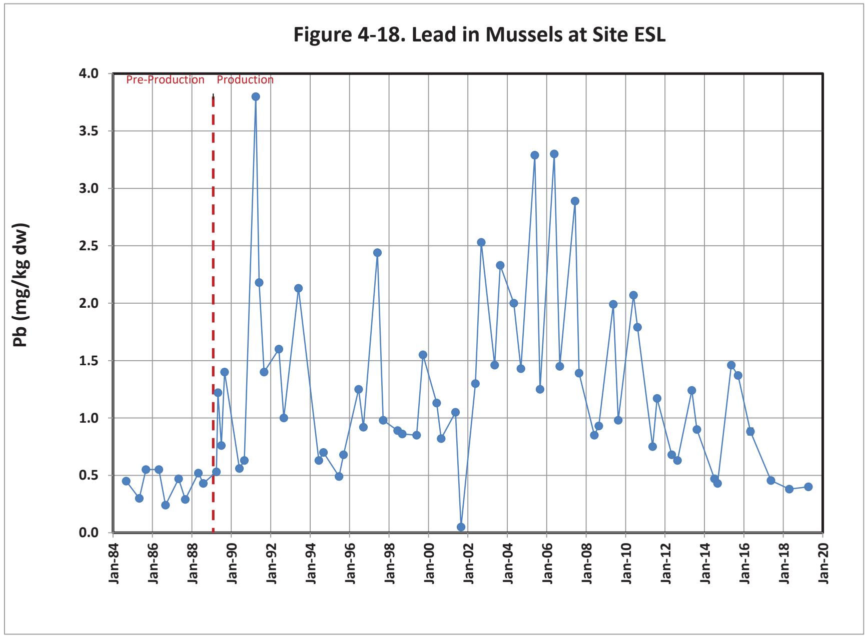
Figure 4-18. Lead in Mussels at Site ESL
Pb (mg/kg dw)
Pre-Production
Production
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

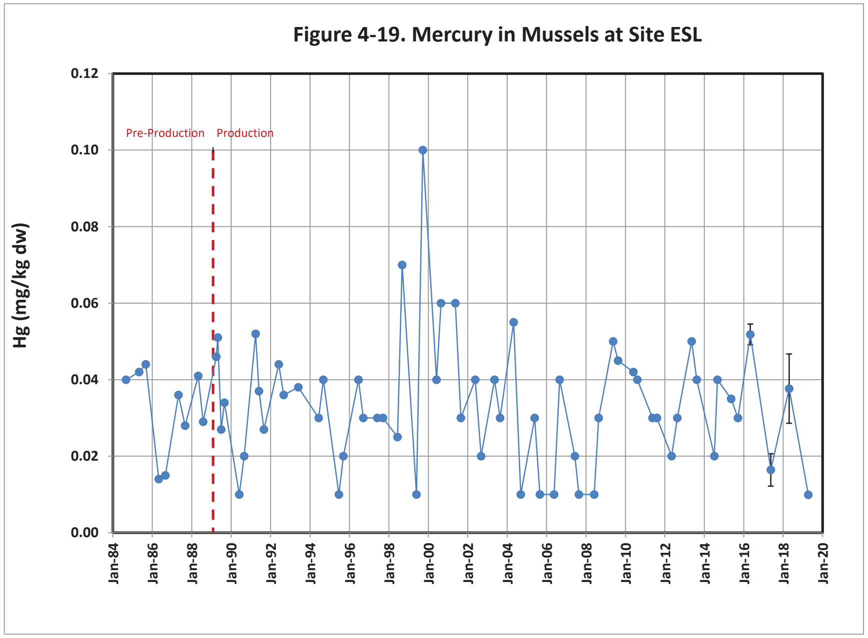
Figure 4-19. Mercury in Mussels at Site ESL
Hg (mg/kg dw)
Pre-Production
Production
0.00
0.02
0.04
0.06
0.08
0.10
0.12
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
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Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

Figure 4-20. Zinc in Mussels at Site ESL

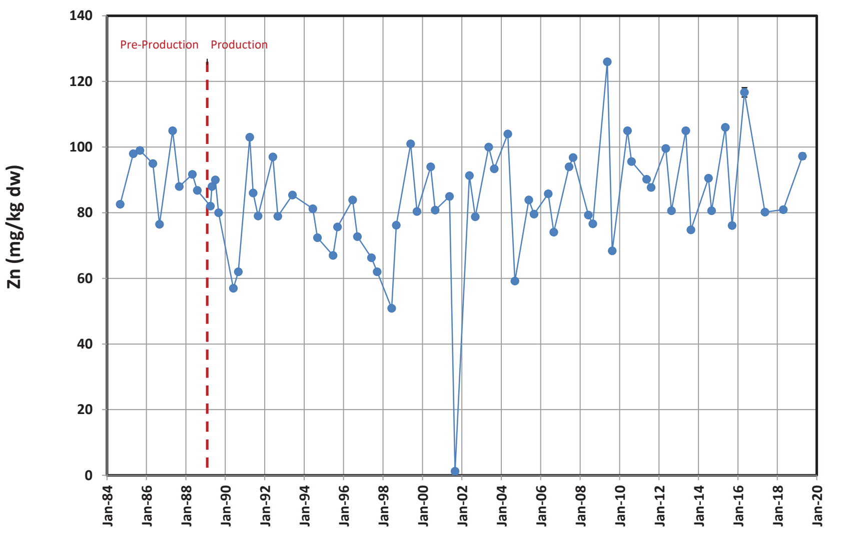


Figure 4-21. Cadmium in Nephtys at Site S-1

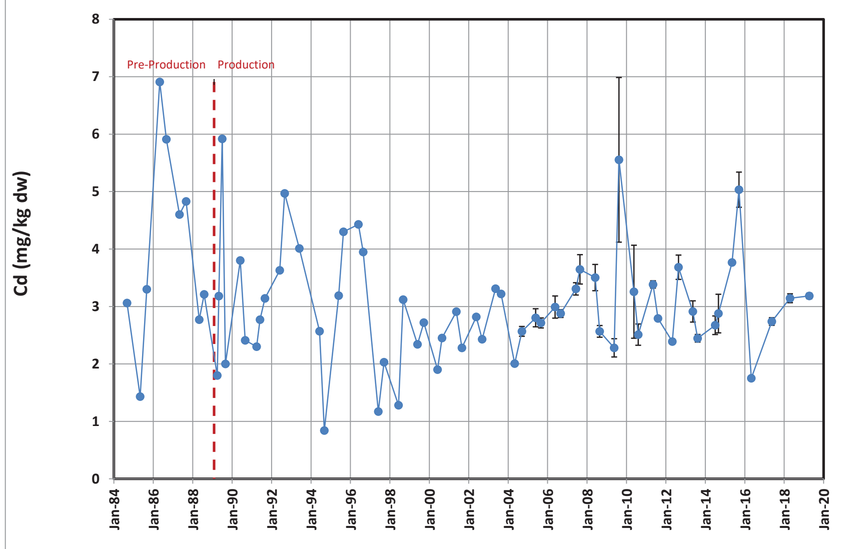


Figure 4-22. Copper in Nephtys at Site S-1

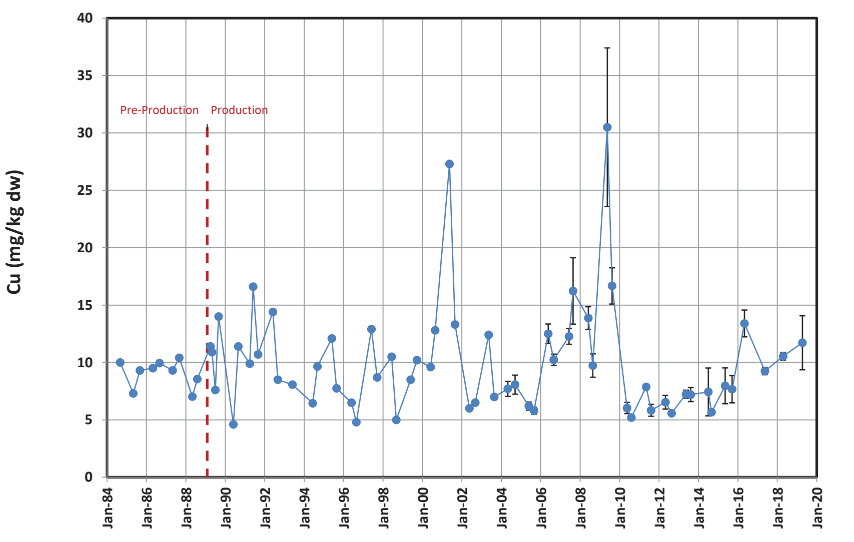
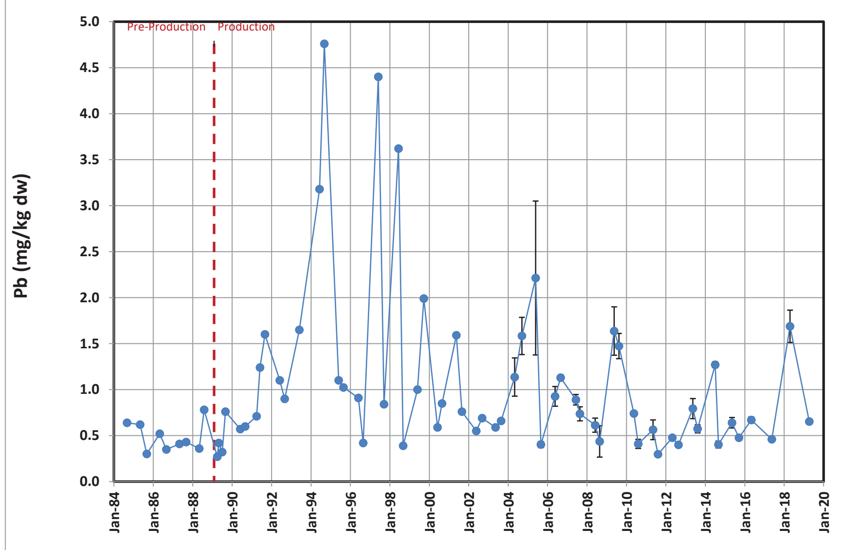


Figure 4-23. Lead in Nephtys at Site S-1



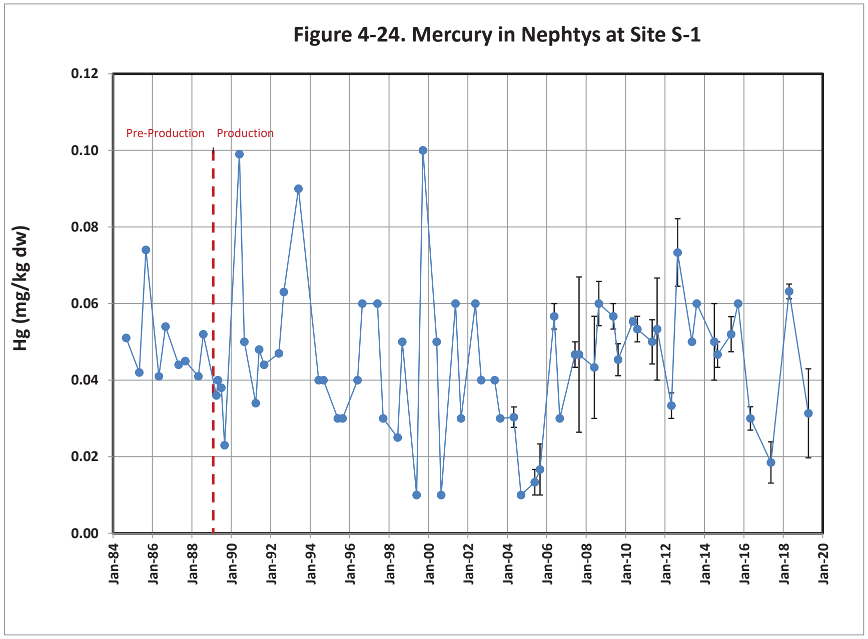


Figure 4-24. Mercury in Nephtys at Site S-1
Hg (mg/kg dw)
Pre-Production
Production

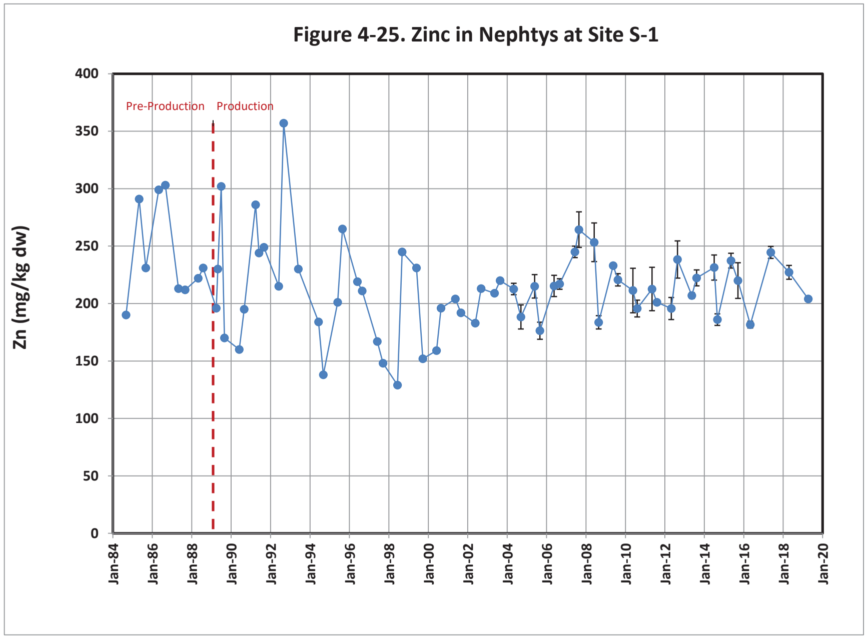


Figure 4-25. Zinc in Nephtys at Site S-1
Zn (mg/kg dw)
Pre-Production
Production

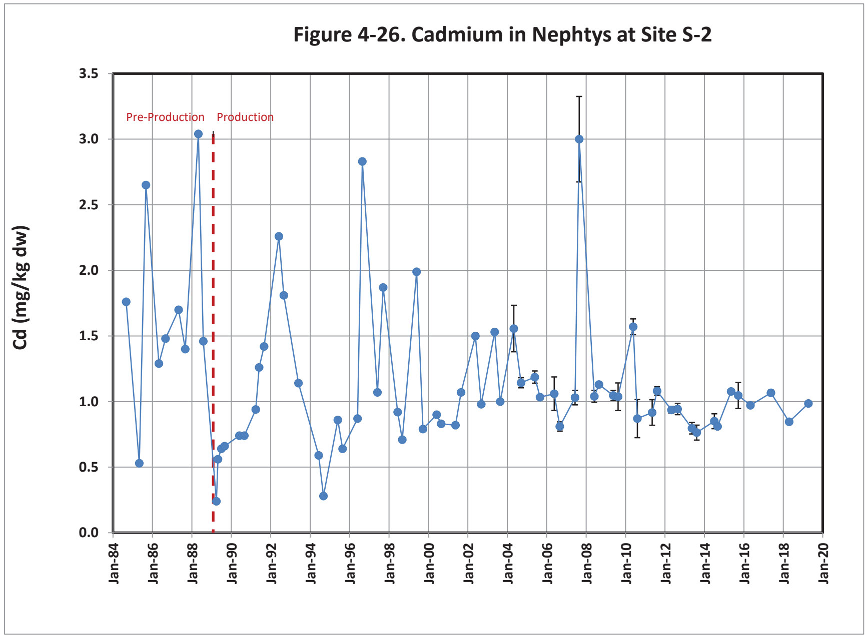


Figure 4-26. Cadmium in Nephtys at Site S-2
Cd (mg/kg dw)
Pre-Production
Production

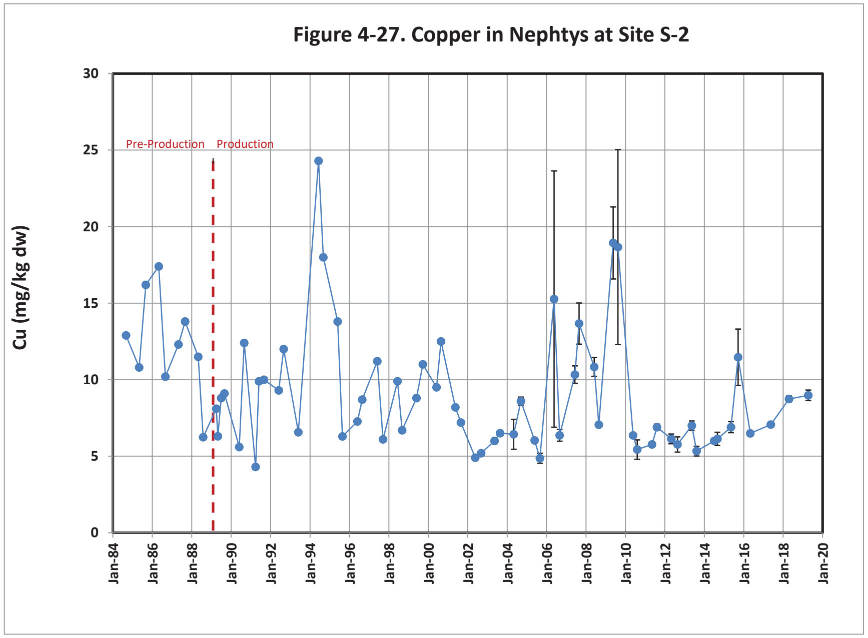


Figure 4-27. Copper in Nephtys at Site S-2
Cu (mg/kg dw)
Pre-Production
Production

Figure 4-28. Lead in Nephtys at Site S-2

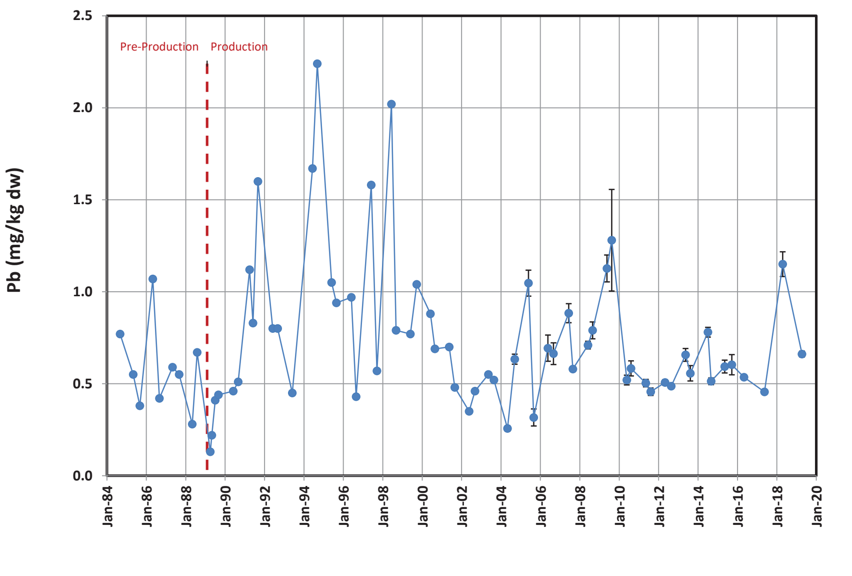


Figure 4-29. Mercury in Nephtys at Site S-2

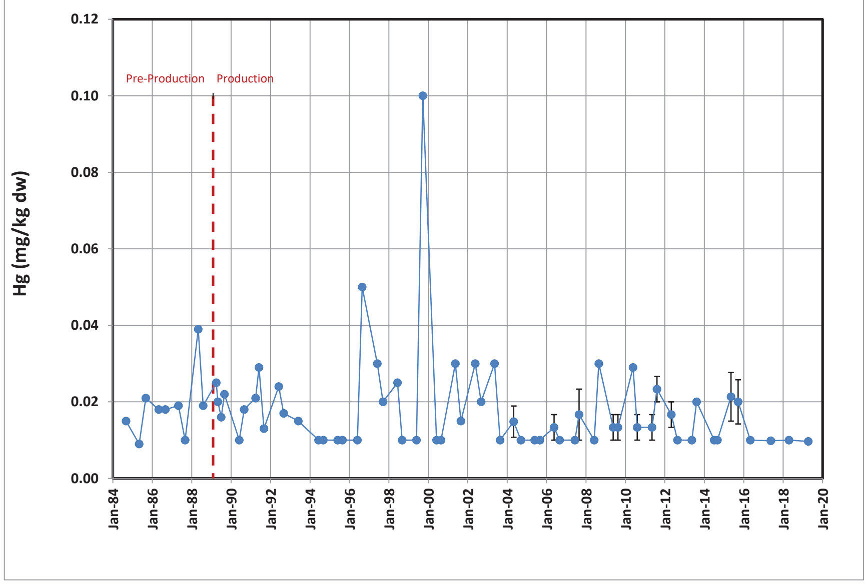


Figure 4-30. Zinc in Nephtys at Site S-2

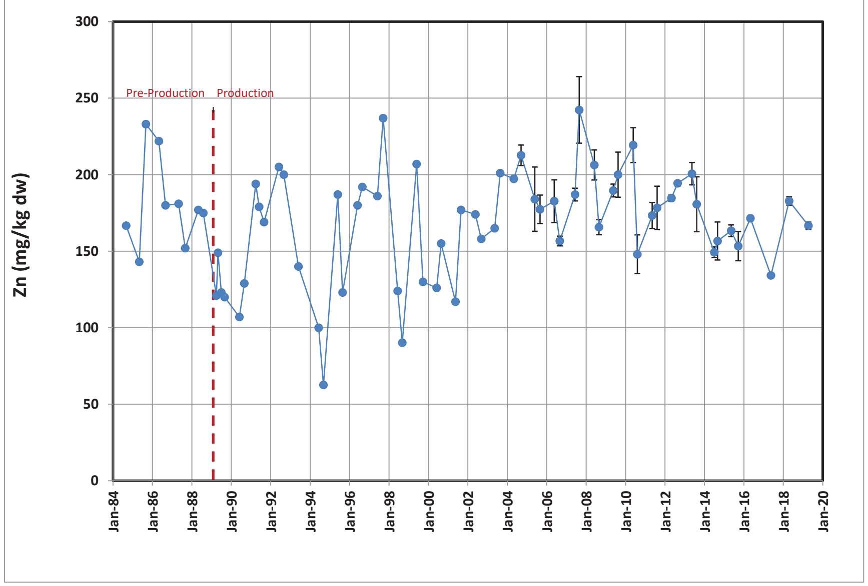
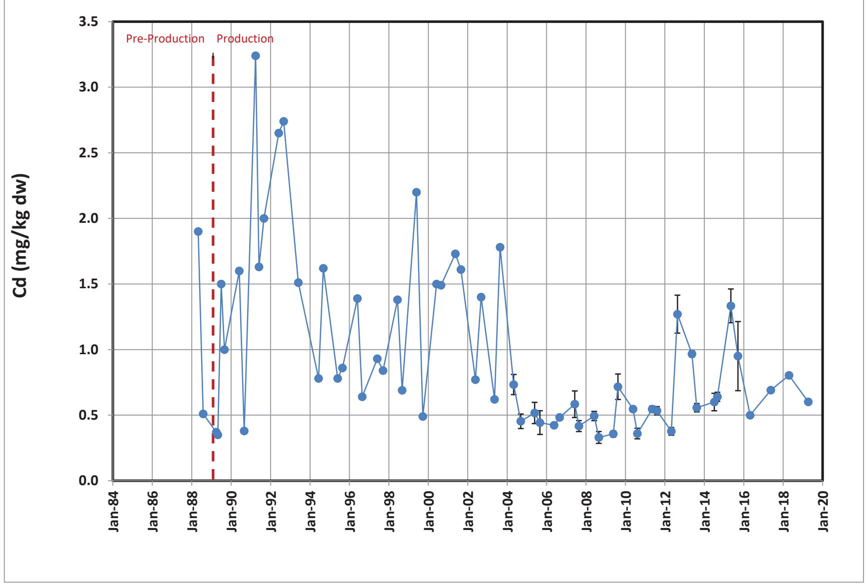


Figure 4-31. Cadmium in Nephtys at Site S-4



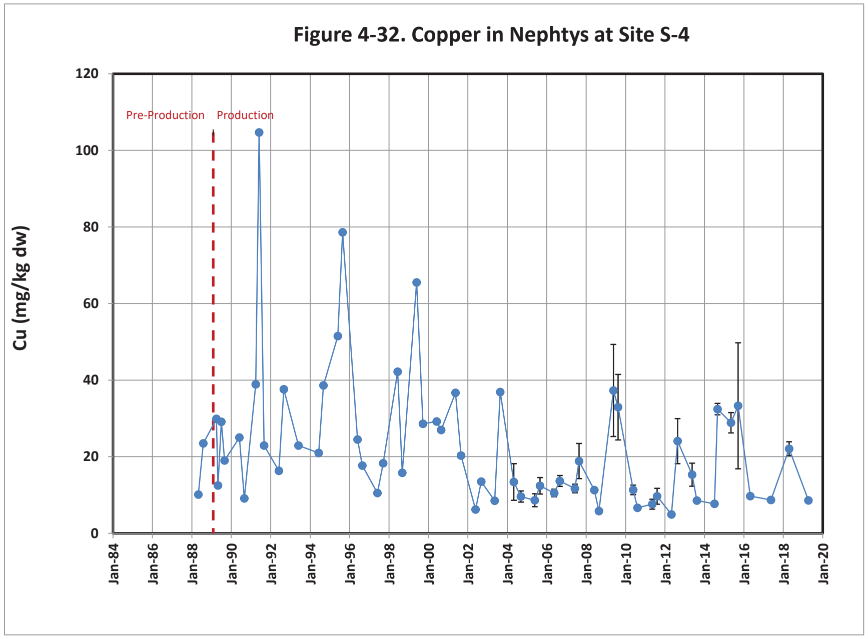


Figure 4-32. Copper in Nephtys at Site S-4
Cu (mg/kg dw)
Pre-Production
Production
120
100
80
60
40
20
0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

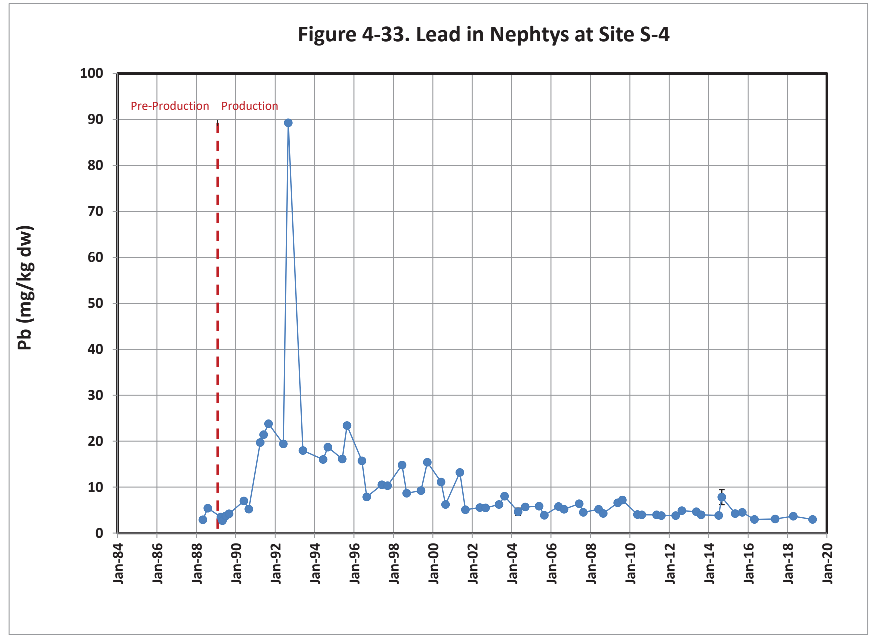


Figure 4-33. Lead in Nephtys at Site S-4
Pb (mg/kg dw)
Pre-Production
Production
100
90
80
70
60
50
40
30
20
10
0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

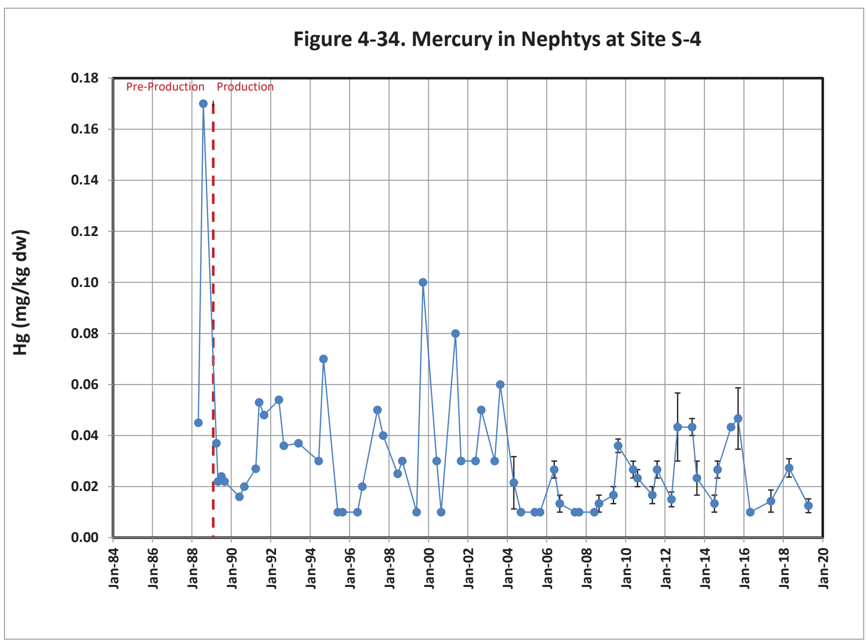


Figure 4-34. Mercury in Nephtys at Site S-4
Hg (mg/kg dw)
Pre-Production
Production
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

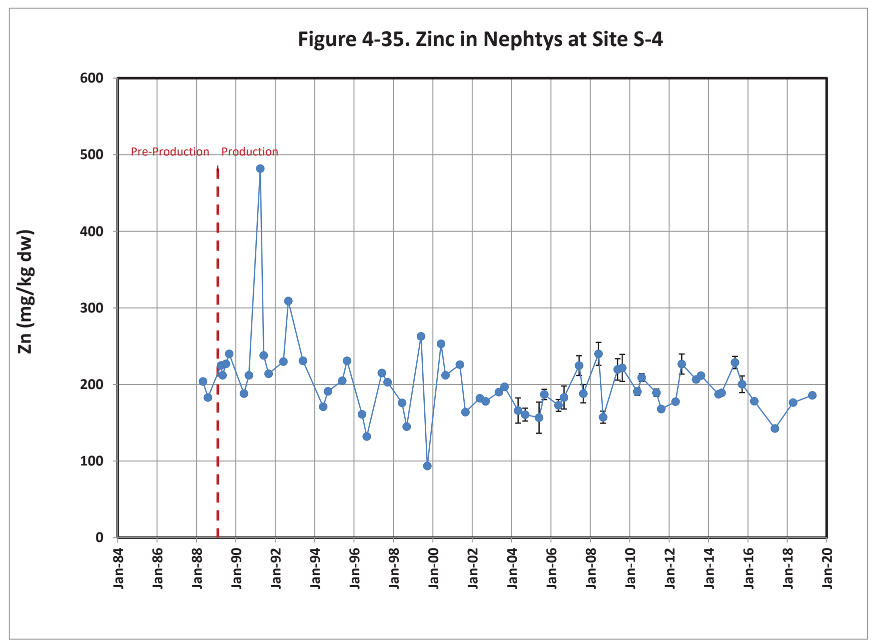


Figure 4-35. Zinc in Nephtys at Site S-4
Zn (mg/kg dw)
Pre-Production
Production
600
500
400
300
200
100
0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20

APPENDIX A

Sediment and Organism Method Reporting Limits

Laboratory Detection Limits for Mussels Analysis		
Sample ID	Metal (mg/Kg/dw)	2019 MRL
ESL Mussel Rep. I	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
ESL Mussel Rep. II	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.019
	Zinc, Total	0.5
ESL Mussel Rep. III	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
ESL Mussel Rep. IV	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
ESL Mussel Rep. V	Cadmium, Total	0.02
	Copper, Total	0.099
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
ESL Mussel Rep. VI	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
STN-1 Mussel Rep. I	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
STN-1 Mussel Rep. II	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5

Laboratory Detection Limits for Mussels Analysis		
Sample ID	Metal (mg/Kg/dw)	2019 MRL
STN-1 Mussel Rep. III	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
STN-1 Mussel Rep. IV	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
STN-1 Mussel Rep. V	Cadmium, Total	0.02
	Copper, Total	0.099
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
STN-1 Mussel Rep. VI	Cadmium, Total	0.02
	Copper, Total	0.099
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
STN-2 Mussel Rep. I	Cadmium, Total	0.02
	Copper, Total	0.099
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
STN-2 Mussel Rep. II	Cadmium, Total	0.02
	Copper, Total	0.099
	Lead, Total	0.02
	Mercury, Total	0.019
	Zinc, Total	0.5
STN-2 Mussel Rep. III	Cadmium, Total	0.02
	Copper, Total	0.099
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
STN-2 Mussel Rep. IV	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5

Method Reporting Limit (MRL) - Defined by ALS Environmental as being 3 times the MDL (or greater)

Laboratory Detection Limits for Mussels Analysis		
Sample ID	**Metal (mg/Kg/dw)**	**2019 MRL**
STN-2 Mussel Rep. V	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
STN-2 Mussel Rep. VI	Cadmium, Total	0.02
	Copper, Total	0.099
	Lead, Total	0.02
	Mercury, Total	0.019
	Zinc, Total	0.5
STN-3 Mussel Rep. I	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
STN-3 Mussel Rep. II	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.019
	Zinc, Total	0.5
STN-3 Mussel Rep. III	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.019
	Zinc, Total	0.5
STN-3 Mussel Rep. IV	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
STN-3 Mussel Rep. V	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
STN-3 Mussel Rep. VI	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5

Method Reporting Limit (MRL) - Defined by ALS Environmental as being 3 times the MDL (or greater)

Laboratory Detection Limits for Sediment Analysis		
Sample ID	**Metal (mg/Kg/dw)**	**2019 MRL**
S-1 Sediment Rep. I	Cadmium, Total	0.015
	Copper, Total	0.076
	Lead, Total	0.038
	Mercury, Total	0.021
	Zinc, Total	0.38
S-1 Sediment Rep. II	Cadmium, Total	0.014
	Copper, Total	0.07
	Lead, Total	0.035
	Mercury, Total	0.021
	Zinc, Total	0.35
S-1 Sediment Rep. III	Cadmium, Total	0.013
	Copper, Total	0.066
	Lead, Total	0.033
	Mercury, Total	0.02
	Zinc, Total	0.33
S-1 Sediment Rep. IV	Cadmium, Total	0.014
	Copper, Total	0.068
	Lead, Total	0.034
	Mercury, Total	0.021
	Zinc, Total	0.34
S-1 Sediment Rep. V	Cadmium, Total	0.014
	Copper, Total	0.068
	Lead, Total	0.034
	Mercury, Total	0.018
	Zinc, Total	0.34
S-1 Sediment Rep. VI	Cadmium, Total	0.016
	Copper, Total	0.079
	Lead, Total	0.039
	Mercury, Total	0.018
	Zinc, Total	0.39
S-2 Sediment Rep. I	Cadmium, Total	0.019
	Copper, Total	0.095
	Lead, Total	0.048
	Mercury, Total	0.022
	Zinc, Total	0.48
S-2 Sediment Rep. II	Cadmium, Total	0.022
	Copper, Total	0.11
	Lead, Total	0.056
	Mercury, Total	0.023
	Zinc, Total	0.56

Laboratory Detection Limits for Sediment Analysis		
Sample ID	**Metal (mg/Kg/dw)**	**2019 MRL**
S-2 Sediment Rep. III	Cadmium, Total	0.021
	Copper, Total	0.11
	Lead, Total	0.053
	Mercury, Total	0.021
	Zinc, Total	0.53
S-2 Sediment Rep. IV	Cadmium, Total	0.021
	Copper, Total	0.11
	Lead, Total	0.053
	Mercury, Total	0.023
	Zinc, Total	0.53
S-2 Sediment Rep. V	Cadmium, Total	0.015
	Copper, Total	0.076
	Lead, Total	0.038
	Mercury, Total	0.021
	Zinc, Total	0.38
S-2 Sediment Rep. VI	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.051
	Mercury, Total	0.023
	Zinc, Total	0.51
S-3 Sediment Rep. I	Cadmium, Total	0.025
	Copper, Total	0.13
	Lead, Total	0.064
	Mercury, Total	0.046
	Zinc, Total	0.64
S-3 Sediment Rep. II	Cadmium, Total	0.03
	Copper, Total	0.15
	Lead, Total	0.074
	Mercury, Total	0.039
	Zinc, Total	0.74
S-3 Sediment Rep. III	Cadmium, Total	0.029
	Copper, Total	0.15
	Lead, Total	0.073
	Mercury, Total	0.042
	Zinc, Total	0.73
S-3 Sediment Rep. IV	Cadmium, Total	0.031
	Copper, Total	0.15
	Lead, Total	0.077
	Mercury, Total	0.043
	Zinc, Total	0.77

Method Reporting Limit (MRL) - Defined by ALS Environmental as being 3 times the MDL (or greater)

Laboratory Detection Limits for Sediment Analysis		
Sample ID	**Metal (mg/Kg/dw)**	**2019 MRL**
S-3 Sediment Rep. V	Cadmium, Total	0.024
	Copper, Total	0.12
	Lead, Total	0.06
	Mercury, Total	0.043
	Zinc, Total	0.6
S-3 Sediment Rep. VI	Cadmium, Total	0.031
	Copper, Total	0.15
	Lead, Total	0.077
	Mercury, Total	0.041
	Zinc, Total	0.77
S-4 Sediment Rep. I	Cadmium, Total	0.018
	Copper, Total	0.089
	Lead, Total	0.044
	Mercury, Total	0.022
	Zinc, Total	0.44
S-4 Sediment Rep. II	Cadmium, Total	0.018
	Copper, Total	0.092
	Lead, Total	0.046
	Mercury, Total	0.021
	Zinc, Total	0.46
S-4 Sediment Rep. III	Cadmium, Total	0.019
	Copper, Total	0.093
	Lead, Total	0.047
	Mercury, Total	0.02
	Zinc, Total	0.47
S-4 Sediment Rep. IV	Cadmium, Total	0.014
	Copper, Total	0.07
	Lead, Total	0.035
	Mercury, Total	0.015
	Zinc, Total	0.35
S-4 Sediment Rep. V	Cadmium, Total	0.019
	Copper, Total	0.096
	Lead, Total	0.048
	Mercury, Total	0.017
	Zinc, Total	0.48
S-4 Sediment Rep. VI	Cadmium, Total	0.015
	Copper, Total	0.075
	Lead, Total	0.038
	Mercury, Total	0.019
	Zinc, Total	0.38

Method Reporting Limit (MRL) - Defined by ALS Environmental as being 3 times the MDL (or greater)

Laboratory Detection Limits for *Nephtys* Analysis		
Sample ID	**Metal (mg/Kg/dw)**	**2019 MRL**
S-1 Nephtys Rep. I	Cadmium, Total	0.02
	Copper, Total	0.099
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
S-1 Nephtys Rep. II	Cadmium, Total	0.02
	Copper, Total	0.099
	Lead, Total	0.02
	Mercury, Total	0.019
	Zinc, Total	0.5
S-1 Nephtys Rep. III	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
S-1 Nephtys Rep. IV	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.019
	Zinc, Total	0.5
S-1 Nephtys Rep. V	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
S-1 Nephtys Rep. VI	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.019
	Zinc, Total	0.5
S-2 Nephtys Rep. I	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.019
	Zinc, Total	0.5
S-2 Nephtys Rep. II	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.019
	Zinc, Total	0.5

Laboratory Detection Limits for *Nephtys* Analysis		
Sample ID	**Metal (mg/Kg/dw)**	**2019 MRL**
S-2 Nephtys Rep. III	Cadmium, Total	0.02
	Copper, Total	0.099
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
S-2 Nephtys Rep. IV	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
S-2 Nephtys Rep. V	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
S-2 Nephtys Rep. VI	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
S-3 Nephtys Rep. I	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
S-3 Nephtys Rep. II	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
S-3 Nephtys Rep. III	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
S-3 Nephtys Rep. IV	Cadmium, Total	0.02
	Copper, Total	0.099
	Lead, Total	0.02
	Mercury, Total	0.019
	Zinc, Total	0.5

Method Reporting Limit (MRL) - Defined by ALS Environmental as being 3 times the MDL (or greater)

Laboratory Detection Limits for *Nephtys* Analysis		
Sample ID	**Metal (mg/Kg/dw)**	**2019 MRL**
S-3 Nephtys Rep. V	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.019
	Zinc, Total	0.5
S-3 Nephtys Rep. VI	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
S-4 Nephtys Rep. I	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
S-4 Nephtys Rep. II	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
S-4 Nephtys Rep. III	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
S-4 Nephtys Rep. IV	Cadmium, Total	0.02
	Copper, Total	0.1
	Lead, Total	0.02
	Mercury, Total	0.02
	Zinc, Total	0.5
S-4 Nephtys Rep. V	Cadmium, Total	0.02
	Copper, Total	0.099
	Lead, Total	0.02
	Mercury, Total	0.019
	Zinc, Total	0.5
S-4 Nephtys Rep. VI	Cadmium, Total	0.02
	Copper, Total	0.099
	Lead, Total	0.02
	Mercury, Total	0.019
	Zinc, Total	0.5

Method Reporting Limit (MRL) - Defined by ALS Environmental as being 3 times the MDL (or greater)

APPENDIX B

Outfall Survey Footage

Video provided electronically to the Alaska Department of Environmental Conservation

APPENDIX C

Historical Hawk Inlet Data

Provided electronically to the Alaska Department of Environmental Conservation