GREENS CREEK

31 March 2016

ADEC
Division of Water
Compliance and Enforcement Program
555 Cordova Street
Anchorage, AK 99501

RE: Hawk Inlet Monitoring Program 2015 Annual Report (NPDES Permit AK-004320-6)

Attached please find the Hecla Greens Creek Mining Company (HGCMC) Hawk Inlet Monitoring Program 2015 Annual Report.

The Hawk Inlet Monitoring Program components include monitoring and reporting of the following:

- Inlet receiving water quality (permit Section I.D.1)
- Inlet sediment monitoring (permit Section I.D.2)
- In-situ bioassays (permit I.D.3)
- Quality assurance/quality control information (permit I.D.4)
- Consolidated reporting of the results (permit I.D.5)

Per the requirement in permit Section I.D.5, both an electronic and hard copy will be submitted. The electronic version will be sent via email to personnel listed below. The hard copy also includes a CD of the 2015 outfall pipeline inspection video.

Should you or other staff have any questions or concerns regarding this report, please feel free to contact me at cwallace@hecla-mining.com or 907-790-8473.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Sincerely,

Christopher Wallace
Environmental Affairs Manager

Attachment and CD
cc: W. Collingwood – ADEC, E. DeMaria –USEPA, M. Reece – USFS

# HAWK INLET MONITORING PROGRAM
# 2015 ANNUAL REPORT

**Hecla Greens Creek Mining Company**

**March 2016**

# TABLE OF CONTENTS



**TABLES**

**TABLES (continued)**



**FIGURES (located at end of text)**



**FIGURES (continued)**

## APPENDICES

# 1.0 INTRODUCTION

## 1.1 Site Description

The Greens Creek Mine on Admiralty Island is located 18 miles southwest of the city of Juneau, Alaska. Dense forests cover the mountain slopes up to an elevation of 2500 feet, above which the vegetation is alpine. The climate is maritime, with precipitation similar to that in Juneau, 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 Greens Creek Mine operations began in August 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 2,200 ton/day milling facility and appurtenant support facilities are in place at the 920 area. Filter pressed tailings from the milling process are backfilled in the mine and also deposited in a surface dry-stack tailings pile. Concentrate is transported from the mill to the Hawk Inlet area, where it is stored until it is shipped off-site.

Support facilities to the mining and milling operation at port facility include core storage, concentrate storage, shipping port, and shift housing. A domestic waste water treatment plant is located at the port site.

Two waste water discharge outfalls and 10 storm water discharge sites are authorized by the HGCMC Alaska Pollutant Discharge Elimination System (APDES) Permit Number AK-004320-6. Sewage effluent previously discharged through Outfall 001 is combined with area surface runoff, and pumped to Pond 7. There it is combined with effluent streams from the 920 and the Tailings Basin areas, 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 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-004320-6, which expired September, 30$^{th}$, 2015. Permit AK-004320-6 was reissued in 2015 with an effective date of October 1$^{st}$, 2015. Because the majority of the marine monitoring was completed, except for the 4$^{th}$ quarter, prior to the effective date of the new permit, this report was prepared in accordance with the previous permit.

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 1981, 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 Associates, 1981). At that rate, it is estimated that the Inlet will completely flush at least once every five tidal cycles. Based on the average daily output in 2015, the input of effluent from the mining operations over a day represents approximately 0.007 percent of the total flushed daily.

## 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 semi-annual monitoring events have generated an extensive time-series data set of coincident metal levels in water, sediment, and marine tissue samples.

The primary objective of the Hawk Inlet monitoring program is to document the water quality, sediment and biological conditions in receiving waters and marine environments that may be impacted by the mine’s operations. Sea water is sampled quarterly at three locations in Hawk Inlet, and sediment and invertebrate samples are taken each year in the spring and in the fall at four and seven locations, respectively (Figure 1-1 Site Map). 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 limit (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 NPDES Quality Assurance Plan: Project Monitoring Manual (HGCMC, 2015).

# TABLE 1-1 Summary of Permit Sampling Requirements for Hawk Inlet

| NPDES 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 all metals) | 1 ea. 500 ml Teflon bottle (1 bottle for all metals) | $HNO_3$ 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 | Total Mercury | Quarterly | | | | | 28 days | EPA 245.1/ 1631 | 0.002 | µg/L | |
| 1.6.1.1.3 Table 5 | Dissolved Zinc | Quarterly | | | | | 6 months | EPA 289.2/ 1638 | 0.2 | 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 | 1.00 | 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** | | | | | | | | | | | |
| I.D.2 Table 5 | Total Cadmium | Semi-annual | Grab | 3 ea. 8 oz. plastic or glass jar | Freeze sample | ALS Environmental | | PSEP/GFAA | 0.30 | mg/Kg | MDLs set by NPDES permit Section I.D.2, Table 5 |
| I.D.2 Table 5 | Total Copper | Semi-annual | Grab | | | ALS | | PSEP/ICP | 15.00 | mg/Kg | |
| I.D.2 Table 5 | Total Lead | Semi-annual | Grab | | | ALS | | PSEP/ICP | 0.50 | mg/Kg | NMFS request dupilicate sampling |
| I.D.2 Table 5 | Total Mercury | Semi-annual | Grab | | | ALS | | PSEP/ EPA 7471A | 0.02 | mg/Kg | |
| I.D.2 Table 5 | Total Zinc | Semi-annual | Grab | | | ALS | | PSEP/ICP | 15.00 | mg/Kg | |
| **BIOACCUMULATION WATER IN-SITU BIOASSAY MONITORING** | | | | | | | | | | | |
| I.D.3 Table 6 | Total Cadmium | Semi-annual | Grab | 3 ea. 8 oz. plastic or glass jar | Freeze sample | ALS | | EPA 200.8/ 6020 | not specified | mg/Kg | NMFS request dupilicate sampling since Fall 2004 |
| I.D.3 Table 6 | Total Copper | Semi-annual | Grab | | | ALS | | EPA 200.8/ 6020 | not specified | mg/Kg | |
| I.D.3 Table 6 | Total Lead | Semi-annual | Grab | | | ALS | | EPA 200.8/ 6020 | not specified | mg/Kg | |
| I.D.3 Table 6 | Total Mercury | Semi-annual | Grab | | | ALS | | EPA 7471A | not specified | mg/Kg | |
| I.D.3 Table 6 | Total Zinc | Semi-annual | Grab | | | ALS | | EPA 200.8/ 6020 | not specified | mg/Kg | |

In May 2015, Marine Taxonomic Services surveyed the 002 Outfall pipeline for corrosion and damage. A CD of the survey footage can be found in Appendix B. The following points summarize the major findings of the inspection (Marine Taxonomic Services, 2015):

- The outfall pipe is in good overall condition. No cracks or leaks were found, and all diffusers have full flow.
- All diffuser ports were found to have moderate to considerable biofouling that was completely removed with the use of scrapers and brushes.
- The zinc anode end caps installed to protect the stainless hardware show considerable corrosion in some cases. Those caps are being maintained through replacement of approximately 1/3rd of the caps per annual inspection event.
- The minimal sediment accretion inside the diffuser is not a threat to discharge flow rates and requires no maintenance removal at the present time.
- The pipeline hardware is in good overall condition.

This report presents information on each of the three media sampled in Hawk Inlet: water column, sediment, and in-situ bioassay. All results for the samples collected in 2015 are presented, along with the associated QA/QC data. Statistical evaluation of the data showing averages, variations, and changes over time are also included. The next section describes any deviations from the monitoring program that occurred in 2015, and the reasons for the deviations.

## 1.3 Deviation(s) from Monitoring Program and Incidents in 2015

There was a deviation in the monitoring program during the August 4th, 2015 seawater sampling event. An error by the sampling team resulted in seawater samples for Total Suspended Solids (TSS), at locations 106, 107, and 108, not being collected for analysis. Turbidity field analysis was not collected during the third quarter sampling event. Field analysis of pH and conductivity was still collected during the third quarter sampling event.

The weak acid dissociable (WAD) cyanide lab MDL of 3.0 µg/L is higher than the 1.0 µg/L MDL specified in the APDES Permit No AK-004320-6, Table 4 for the Hawk Inlet water column monitoring parameters. With the reissuance of the permit in 2015 the MDL for WAD cyanide was increased to 5 µg/L.

## 2.0 WATER COLUMN MONITORING

The receiving water column monitoring requirements originate from Section I.D.1 and Table 4 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.

Three ocean sites in Hawk Inlet are sampled to monitor potential water quality effects from the mine. 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 in the mixing zone. Samples at all three locations are taken at a depth of five feet. Sample timing in each quarter is tide and weather dependent, as safety of the personnel conducting the sampling is a primary concern.

Water samples are sent to Battelle Marine Science Lab in Sequim, Washington, for low level dissolved trace metals analyses, 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 2015 Analytical Results

The tables in this section summarize the results for the quarterly water column monitoring conducted in 2015.

**TABLE 2-1 Hawk Inlet Field Parameters 2015 (sample depth 5')**

| | Sample Date | Sample Time | Weather Conditions | Conductivity (µmhos/cm) | pH (SU) | Temp. (°C ) | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|
| ***Site 106*** | | | | | | | |
| | 3/10/15 | 10:47 | cloudy | 48,670 | 8.10 | 5.2 | 1.0 |
| | 6/8/15 | 12:08 | rainy | 47,860 | 8.38 | 10.0 | 0.44 |
| | 8/4/15 | 10:44 | cloudy | 41,270 | 8.17 | 13.1 | -- |
| | 10/19/15 | 12:10 | cloudy | 43,770 | 7.87 | 8.9 | 0.72 |
| ***Site 107*** | | | | | | | |
| | 3/10/15 | 10:02 | cloudy | 48,130 | 8.10 | 4.8 | 1.0 |
| | 6/8/15 | 11:17 | rainy | 47,360 | 8.36 | 9.9 | 0.62 |
| | 8/4/15 | 10:10 | cloudy | 41,760 | 8.11 | 12.8 | -- |
| | 10/19/15 | 11:30 | cloudy | 43,020 | 7.81 | 9.1 | 0.6 |
| ***Site 108*** | | | | | | | |
| | 3/10/15 | 10:29 | cloudy | 48,440 | 8.10 | 5.0 | 1.0 |
| | 6/8/15 | 11:39 | rainy | 47,330 | 8.39 | 9.8 | 0.63 |
| | 8/4/15 | 10:32 | cloudy | 43,330 | 8.08 | 12.5 | -- |
| | 10/19/15 | 11:55 | cloudy | 42,930 | 7.86 | 8.9 | 2.4 |

**TABLE 2-2 Hawk Inlet Water Column Monitoring 2015: Nonmetal Parameters**
(ACZ Laboratories) (sample depth 5')

| | Sample Date | TSS (mg/L) | WAD CN (µg/L) |
|---|---|---|---|
| ***Site 106*** | | | |
| | 3/10/15 | 25 | <3.0 |
| | 6/8/15 | 22 | <3.0 |
| | 8/4/15 | -- | <3.0 |
| | 10/19/15 | 32 | <3.0 |
| ***Site 107*** | | | |
| | 3/10/15 | 23 | <3.0 |
| | 6/8/15 | 27 | <3.0 |
| | 8/4/15 | -- | <3.0 |
| | 10/19/15 | 19 | <3.0 |
| ***Site 108*** | | | |
| | 3/10/15 | 26 | <3.0 |
| | 6/8/15 | 26 | <3.0 |
| | 8/4/15 | -- | <3.0 |
| | 10/19/15 | 31 | <3.0 |

**TABLE 2-3 Hawk Inlet Water Column Monitoring Results 2015: Metals**
(Battelle Marine Sciences Laboratory) (sample depth 5')

| | Sample Date | Cd (µg/L) Dissolved | Cu (µg/L) Dissolved | Pb (µg/L) Dissolved | Hg (µg/L) Total | Zn (µg/L) Dissolved |
|---|---|---|---|---|---|---|
| *Lab MDL* | | *(0.002)* | *(0.023)* | *(0.001)* | *(0.0001)* | *(0.042)* |
| *Req. MDL* | | *(0.10)* | *(0.03)* | *(0.05)* | *(0.002 )* | *(0.20)* |
| **Site 106** | | | | | | |
| | 3/10/15 | 0.0841 | 0.242 | 0.00234 | 0.000193 | 0.3430 |
| | 6/8/15 | 0.0654 | 0.214 | 0.00237 | 0.000184 | 0.1220 |
| | 8/4/15 | 0.0610 | 0.327 | 0.00362 | 0.000136 | 0.0863 |
| | 10/19/15 | 0.0701 | 0.269 | 0.00387 | 0.000311 | 0.6880 |
| **Site 107** | | | | | | |
| | 3/10/15 | 0.0850 | 0.213 | 0.00757 | 0.000317 | 0.554 |
| | 6/8/15 | 0.0653 | 0.282 | 0.00846 | 0.000275 | 0.205 |
| | 8/4/15 | 0.0673 | 0.350 | 0.00460 | 0.000350 | 0.170 |
| | 10/19/15 | 0.0699 | 0.313 | 0.01020 | 0.000457 | 0.833 |
| **Site 108** | | | | | | |
| | 3/10/15 | 0.0835 | 0.234 | 0.00720 | 0.000247 | 0.529 |
| | 6/8/15 | 0.0653 | 0.266 | 0.00714 | 0.000206 | 0.183 |
| | 8/4/15 | 0.0739 | 0.291 | 0.00968 | 0.000220 | 0.205 |
| | 10/19/15 | 0.0712 | 0.327 | 0.00741 | 0.000524 | 0.900 |

## 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. Two pH reading were not in alignment with the AWQS high of 8.5 standard units at site 106 in May of 2013 (8.55) and at site 107 in June of 2007 (8.52), respectively. Otherwise, the graphs show that Hawk Inlet water quality has remained within or below these standards in all historical and 2015 samples.

Table 2-2 includes WAD cyanide results which were non-detect during 2015. Although results were non-detect the lab did not meet the required MDL of 1.0 µg/L. This MDL has been revised in the APDES Permit Number AK0043206 from 1.0 µg/L to 5 µg/L effective October 1st, 2015.

Table 2-4 summarizes the past five year's average metals values for the sea water samples, compared to the current year's results.

**TABLE 2-4 Hawk Inlet Water Column Average Dissolved Metal Concentrations**

| | Cd (µg/L) | | Cu (µg/L) | | Pb (µg/L) | | Hg (TOTAL - µg/L) | | Zn (µg/L) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2010 through 2014 | 2015 | 2010 through 2014 | 2015 | 2010 through 2014 | 2015 | 2010 through 2014 | 2015 | 2010 through 2014 | 2015 |
| **Site 106** | 0.0713 | 0.0702 | 0.291 | 0.263 | 0.0463 | 0.003 | 0.0004 | 0.0002 | 1.11 | 0.31 |
| **Site 107** | 0.0755 | 0.0719 | 0.481 | 0.290 | 0.0567 | 0.008 | 0.0006 | 0.0003 | 1.31 | 0.44 |
| **Site 108** | 0.0709 | 0.0735 | 0.343 | 0.280 | 0.0399 | 0.008 | 0.0004 | 0.0003 | 1.32 | 0.45 |

## 2.3 QA/QC Results

Battelle Marine Sciences Laboratory, ACZ Laboratories, and Admiralty Environmental analyzed the required parameters (see Table 1-1) in the sea water 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 2015 sea water samples. Elevated levels of zinc in the field blanks, often at levels higher than all the other sea water samples, have been noted consistently by Battelle for this sampling program. The 1Q15 field blank results contained zinc levels higher than those contained at sample locations 106 and 108 respectively.

Battelle Marine Science (low level dissolved trace metals analyses in salt water matrices):
1Q15: Target detection limits were met for all metals at all sample site locations. Results for the method blank were less than the MDL for all metals. The field blank detected copper, zinc, and lead. Zinc was detected well above the MDL and at high enough concentrations to impact field sample concentrations. Lead was detected above the MDL although not to the extent of the zinc concentrations. Copper was detected just over the

detection limit. Cadmium and mercury were reported as non-detects. Standard reference material (SRM) results were within the default criteria of ±25%.

2Q15: Target detection limits were met for all metals. Method blank results were less than the MDL for all metals. The field blank was non-detect for all metals except zinc which was detected higher than the MDL. Zinc was detected above the MDL and at a concentration high enough to impact field sample concentrations. Standard reference material (SRM) results were within the default criteria of ±25%.

3Q15: Target detection limits were met for all metals. Method blank results were less than the MDL for all metals. The field blank was non-detect for all metals. Standard reference material (SRM), matrix spike and duplicate results were within the default criteria of ±25%.

4Q15: Target detection limits were met for all metals. Detected levels were less than the MDL for all metals in the method blank. The field blank was non-detect for all metals except zinc which was detected higher than the MDL. Zinc was detected above the MDL and at a concentration high enough to impact field sample concentrations. Standard reference material (SRM), matrix spike and duplicate results were within the default criteria of ±25%.

ACZ Laboratories (WAD cyanide analyses):
1Q15: No certification qualifiers associated with this analysis.
2Q15: No certification qualifiers associated with this analysis.
3Q15: No certification qualifiers associated with this analysis.
4Q15: The samples were received outside of the recommended temperature range of 0 to 6 degrees C.

The MDL of 3.0 µg/L is higher than the required 1.0 µg/L MDL. This MDL has been revised in the APDES Permit Number AK0043206 from 1.0 µg/L to 5 µg/L effective October 1$^{st}$, 2015.

ACZ Laboratories (total suspended solids (TSS) analyses):
1Q15, 2Q15, 4Q15: The method specifications and required MDL were met.

## 3.0 SEDIMENT MONITORING

The requirements for the sediment monitoring originate from Section I.D.2, Sediment Monitoring, and Table 5 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 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.

The sediment samples are collected semi-annually at the Greens Creek delta (Site S-1), Pile Driver Cove near the mouth of the inlet (Site S-2), south of the concentrate loading facility (Site S-4), and under the loading facility (Site S-5N and S-5S which bracket the area where concentrate was spilled in 1989). The samples are analyzed at ALS Environmental (formerly Columbia Analytical Services, Inc.) in Kelso, Washington for total concentrations of five trace metals (Cd, Cu, Pb, Hg, and Zn).

### 3.1 2015 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. Tables 3-2 and 3-3 in this section summarize the total metals results for the semi-annual sediment monitoring events. Sample labels I, II, and III denote duplicate samples taken at each sample site.

**TABLE 3-1 Hawk Inlet Sediment Monitoring Field Parameters 2015**

| Locations | Date Sampled | Time Sampled | Weather Conditions | Tide (ft) |
|---|---|---|---|---|
| S-1 | 5/18/15 | 07:58 | Sunny | -3.8 |
| | 9/24/15 | 05:00 | Partly Cloudy | +3.7 |
| S-2 | 5/17/15 | 07:15 | Sunny | -3.3 |
| | 9/27/15 | 06:45 | Cloudy, Light Rain | -1.0 |
| S-4 | 5/15/15 | 05:40 | Partly Cloudy | -0.9 |
| | 9/24/15 | 04:25 | Dark | +1.2 |
| S-5S | 5/15/15 | 15:48 | Sunny | +1.5 |
| | 9/24/15 | 07:30 | Partly Cloudy | +8.0 |
| S-5N | 5/15/15 | 15:48 | Sunny | +1.5 |
| | 9/24/15 | 07:38 | Partly Cloudy | +8.0 |

**TABLE 3-2 Hawk Inlet Sediment Results for Spring 2015**
(ALS Environmental)

| Sample No. | Sample date | Cd (mg/kg dw) | Cu (mg/kg dw) | Pb (mg/kg dw) | Hg (mg/kg dw) | Zn (mg/kg dw) |
|---|---|---|---|---|---|---|
| *Lab MRL** | | *(0.01, 0.02)* | *(0.05, 0.06, 0.07, 0.08, 0.09, 0.10)* | *(0.03, 0.04, 0.05 0.26,)* | *(0.01, 0.02)* | *(0.3, 0.4, 0.5,)* |
| *Required MDL* | | *(0.3)* | *(15.0)* | *(0.05)* | *(0.02)* | *(15.0)* |
| S-1 Sediments-Metals I | 5/18/15 | 0.09 | 15.4 | 5.56 | 0.028 | 85.8 |
| S-1 Sediments-Metals II | 5/18/15 | 0.1 | 14.3 | 5.17 | 0.026 | 92.8 |
| S-1 Sediments-Metals III | 5/18/15 | 0.09 | 13.8 | 5.31 | 0.023 | 85.9 |
| S-2 Sediments-Metals I | 5/17/15 | 0.1 | 11.9 | 2 | <0.02 | 47.0 |
| S-2 Sediments-Metals II | 5/17/15 | 0.07 | 11.5 | 1.74 | <0.02 | 47.8 |
| S-2 Sediments-Metals III | 5/17/15 | 0.08 | 9.05 | 1.62 | <0.02 | 43.9 |
| S-4 Sediments-Metals I | 5/15/15 | 0.06 | 12.2 | 10.7 | <0.02 | 81.2 |
| S-4 Sediments-Metals II | 5/15/15 | 0.11 | 15.1 | 14.8 | <0.02 | 61.2 |
| S-4 Sediments-Metals III | 5/15/15 | 0.27 | 19.2 | 27.8 | 0.033 | 66.5 |
| S-5N Sediments-Metals I | 5/15/15 | 5.05 | 78.6 | 159 | 0.47 | 368 |
| S-5N Sediments-Metals II | 5/15/15 | 1.54 | 76.1 | 185 | 0.12 | 335 |
| S-5N Sediments-Metals III | 5/15/15 | 1.26 | 65.9 | 136 | 0.098 | 264 |
| S-5S Sediments-Metals I | 5/15/15 | 1.23 | 219 | 2180 | 0.057 | 304 |
| S-5S Sediments-Metals II | 5/15/15 | 3.84 | 506 | 378 | 0.28 | 851 |
| S-5S Sediments-Metals III | 5/15/15 | 2.69 | 157 | 406 | 0.21 | 707 |

*Method Reporting Limit (MRL) – Define by ALS Environmental as being times the MDL (or greater).

**TABLE 3-3 Hawk Inlet Sediment Results for Fall 2015**
(ALS Environmental)

| Sample No. | Sample date | Cd (mg/kg dw) | Cu (mg/kg dw) | Pb (mg/kg dw) | Hg (mg/kg dw) | Zn (mg/kg dw) |
|---|---|---|---|---|---|---|
| *Lab MRL** | | *(0.01, 0.02)* | *(0.05,0.06, 0.07, 0.09, 0.10)* | *(0.02, 0.03, 0.04, 0.05, )* | *(0.02)* | *(0.2, 0.3, 0.4, 0.5, 2.9,)* |
| *Required MDL* | | *(0.3)* | *(15.0)* | *(0.05)* | *(0.02)* | *(15.0)* |
| S-1 Sediments-Metals I | 9/24/15 | 0.16 | 14 | 5.52 | 0.04 | 113 |
| S-1 Sediments-Metals II | 9/24/15 | 0.1 | 12.6 | 5.03 | 0.02 | 70.2 |
| S-1 Sediments-Metals III | 9/24/15 | 0.1 | 12 | 4.41 | 0.02 | 73.2 |
| S-2 Sediments-Metals I | 9/27/15 | 0.16 | 11.2 | 1.85 | <0.02 | 42.4 |
| S-2 Sediments-Metals II | 9/27/15 | 0.15 | 9.53 | 1.77 | <0.02 | 41 |
| S-2 Sediments-Metals III | 9/27/15 | 0.13 | 8.26 | 1.67 | <0.02 | 37.9 |
| S-4 Sediments-Metals I | 9/24/15 | 0.38 | 29.7 | 23.9 | 0.02 | 81.2 |
| S-4 Sediments-Metals II | 9/24/15 | 0.27 | 17.5 | 49.7 | 0.03 | 61.2 |
| S-4 Sediments-Metals III | 9/24/15 | 0.29 | 18.1 | 18.4 | 0.03 | 66.5 |
| S-5N Sediments-Metals I | 9/24/15 | 2.33 | 290 | 248 | 0.22 | 462 |
| S-5N Sediments-Metals II | 9/24/15 | 1.38 | 99.8 | 140 | 0.06 | 729 |
| S-5N Sediments-Metals III | 9/24/15 | 5.46 | 116 | 223 | 0.53 | 997 |
| S-5S Sediments-Metals I | 9/24/15 | 2.18 | 233 | 303 | 0.22 | 1130 |
| S-5S Sediments-Metals II | 9/24/15 | 2.1 | 133 | 330 | 0.06 | 362 |
| S-5S Sediments-Metals III | 9/24/15 | 1.51 | 88.8 | 246 | 0.53 | 383 |

*Method Reporting Limit (MRL) – Define by ALS Environmental as being times the MDL (or greater).

## 3.2 Data Evaluation

Prior to opening the Greens Creek mine for full production in 1989, sediment and biota tissues were sampled for heavy metal concentrations. Sampling sites S-1 and S-2 were chosen to represent natural conditions; therefore, results from these sites from June of 1984 until May 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 (Table 3-4), 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 cannery operation and mine exploration work and are not suitable for background calculations.

**TABLE 3-4 Hawk Inlet Sediment Data: Pre-Production Baseline, Production Period and Current Year Comparison**

| Metal | Pre-Production (6/1984-5/1989) | | | Production (6/1989-9/2014) | | | Current Year 2015 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max |
| Cd | 0.22 | 0.03 | 0.42 | 0.19 | 0.06 | 0.9 | 0.111 | 0.07 | 0.16 |
| Cu | 18.14 | 11.9 | 28.5 | 13.73 | 6 | 39.5 | 11.96 | 8.26 | 15.4 |
| Pb | 6.53 | 2.2 | 11.2 | 5.14 | 1.32 | 23.7 | 3.47 | 1.62 | 5.56 |
| Hg | 0.032 | 0.002 | 0.063 | 0.025 | 0.003 | 0.14 | 0.018 | 0.01 | 0.04 |
| Zn | 94.51 | 52.8 | 140 | 71.55 | 26.1 | 188 | 65.08 | 37.9 | 113 |

**Note:** Data are compilation of results from Stations S-1 and S-2; underlined average values higher than baseline. Non-detects are averaged using half of the MRL value.

The comparison of pre-production and production sediment metal values in Table 3-4 shows that across Stations S-1 and S-2, the average metal levels are lower during the production/mining period than they were during pre-production. The current year's results show the average metals levels to be equal or below the production period's average values for all metals. Based on these data, it appears that heavy metals in sediment continue to vary from year to year, and have not increased above the range of area-wide baseline levels during mining years.

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 by the mean and include the standard deviation and standard error visually through error bars.

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 ore concentrate resulted in a spill of approximately 1,000 pounds of concentrate into Hawk Inlet. During the recommissioning of the mine (mid-nineties) State and Federal agencies provided oversite as Greens Creek Mine cleaned up the spilled concentrate. A suction dredge company was brought on-site in 1995 to dredge the concentrate from the ocean floor. This effort was confounded by the residual debris from the 1974 cannery facility fire. Although clean-up efforts were extensive, annual sediment monitoring indicates that there is still concentrate present.

After the 1995 clean-up, the sampling methodology at S-5 was expanded. The site was sub-divided into two separate locations: adding site S-5S located on the south side of the spill area, to complement S-5N located on the north side. Following the spill, metal concentrations in the sediment in this area have been elevated and variable. The lead concentration at site S-5S for one of the spring 2015 samples showed a concentration of 2,180 mg/kg. The duplicate samples at S-5S showed lead concentrations of 406 mg/kg and 378 mg/kg, respectively, which are within the historical range. The fall 2015, zinc concentrations at S-5S showed a concentration of 1130 mg/kg. 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 and include the standard error bars, unless otherwise noted.

Table 3-5 shows the average metal concentrations and the associated standard deviations for each sediment sampling site during pre-production, production, and the current year. Pre-production sediment metals average values show some consistency across stations, but the standard deviations for these data indicate high variability, representative of typical natural distributions. Beginning in the fall of 2004 replicate sampling of these sites was initiated.

**TABLE 3-5 Average and Standard Deviation Values for Pre-Production, Production, and Current Year Sediment Data**

| Metal (mg/kg dw) | S-1 | | | | | S-2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | pre-production (9/1984-5/1989) | | production (6/1989 - 9/2014) | | Current Year 2015 | pre-production (9/1984-5/1989) | | production (6/1989 - 9/2014) | | Current Year 2015 |
| | avg | stdev | avg | stdev | avg | avg | stdev | avg | stdev | avg |
| | | | | | | | | | | |
| **Cd** | 0.20 | 0.11 | 0.21 | 0.17 | 0.11 | 0.24 | 0.12 | 0.16 | 0.10 | 0.12 |
| **Cu** | 21.55 | 4.20 | 16.61 | 6.45 | 13.68 | 14.74 | 2.64 | 10.73 | 4.22 | 10.24 |
| **Pb** | 7.74 | 2.25 | 7.75 | 3.52 | 5.17 | 5.33 | 2.25 | 2.38 | 1.33 | 1.78 |
| **Hg** | 0.04 | 0.01 | 0.04 | 0.02 | 0.03 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 |
| **Zn** | 126.8 | 8.61 | 98.75 | 29.00 | 86.82 | 62.20 | 6.48 | 43.19 | 12.92 | 43.33 |

| Metal (mg/kg dw) | S-4 | | | | | S-5N | | | S-5S | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | pre-production (9/1986-5/1989) | | production (6/1989 - 9/2014) | | Current Year 2015 | post cleanup (6/1995 -9/2014) | | Current Year 2015 | post cleanup (6/1995 - 9/2014) | | Current Year 2015 |
| | avg | stdev | avg | stdev | avg | avg | stdev | avg | avg | stdev | avg |
| | | | | | | | | | | | |
| **Cd** | 0.41 | 0.28 | 0.58 | 0.74 | 0.23 | 2.55 | 2.49 | 2.84 | 3.87 | 3.63 | 2.26 |
| **Cu** | 49.8 | 20.44 | 35.15 | 41.53 | 18.63 | 145.17 | 130.9 | 121.07 | 96.35 | 68.07 | 222.80 |
| **Pb** | 99.2 | 143.4 | 63.31 | 101.4 | 24.22 | 453.42 | 609.1 | 181.83 | 320.20 | 320.76 | 640.50 |
| **Hg** | 0.09 | 0.06 | 0.11 | 0.40 | 0.02 | 0.63 | 2.86 | 0.25 | 0.34 | 0.27 | 0.23 |
| **Zn** | 140.5 | 50.80 | 117.8 | 140.7 | 69.63 | 587.28 | 519.8 | 525.83 | 840.66 | 752.59 | 622.83 |

**Note:** Non-detects are averaged using half of the MRL value; underlined average values higher than baseline.

## 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 spring and fall sampling events in 2015.

Spring 2015: The Relative Percent Difference (RPD) for the replicate analysis of Lead in sample S-1 Sediment-Metals Rep I was outside the normal ALS control limits. The variability in the results was attributed to the heterogeneous character of the sample. Standard mixing techniques were used, but were not sufficient for complete homogenization of this sample.

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

Fall 2015: The control criteria for matrix spike recovery of Copper, Lead, and Zinc for sample S-5s Sediment-Metals Rep I were not applicable. The analyte concentration in the sample was significantly higher than the added spike concentration, preventing accurate evaluation of the spike recovery.

The Relative Percent Difference (RPD) for the replicate analysis of Cadmium, Copper, Lead, and Zinc in sample S-5s Sediment-Metals Rep I was outside the normal ALS control limits. The variability in the results was attributed to the heterogeneous character of the sample. Standard mixing techniques were used, but were not sufficient for complete homogenization of this sample.

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 (the standard deviation relative to the mean, expressed as a percent) is shown for the duplicate samples from 2015 in Table 3-6.

## TABLE 3-6 RSDs for Duplicate Sediment Samples

| Sample ID | Sample Date | Cadmium | Copper | Lead | Mercury | Zinc |
|---|---|---|---|---|---|---|
| | | (mg/kg dw) | (mg/kg dw) | (mg/kg dw) | (mg/kg dw) | (mg/kg dw) |
| S-1 Sediments I | 5/18/2015 | 0.09 | 15.4 | 5.56 | 0.028 | 85.8 |
| S-1 Sediments II | 5/18/2015 | 0.1 | 14.3 | 5.17 | 0.026 | 92.8 |
| S-1 Sediments III | 5/18/2015 | 0.09 | 13.8 | 5.31 | 0.023 | 85.9 |
| **RSD** | | **6.19** | **5.65** | **3.70** | -- | **4.55** |
| S-2 Sediments I | 5/17/2015 | 0.1 | 11.9 | 2 | <0.02 | 47 |
| S-2 Sediments II | 5/17/2015 | 0.07 | 11.5 | 1.74 | <0.02 | 47.8 |
| S-2 Sediments III | 5/17/2015 | 0.08 | 9.05 | 1.62 | <0.02 | 43.9 |
| **RSD** | | -- | **14.26** | **10.87** | -- | **4.46** |
| S-4 Sediments I | 5/15/2015 | 0.06 | 12.2 | 10.7 | <0.02 | 81.2 |
| S-4 Sediments II | 5/15/2015 | 0.11 | 15.1 | 14.8 | <0.02 | 61.2 |
| S-4 Sediments III | 5/15/2015 | 0.27 | 19.2 | 27.8 | 0.033 | 66.5 |
| **RSD** | | -- | **22.69** | **50.25** | -- | **14.88** |
| S-5N Sediments I | 5/15/2015 | 5.05 | 78.6 | 159 | 0.47 | 368 |
| S-5N Sediments II | 5/15/2015 | 1.54 | 76.1 | 185 | 0.12 | 335 |
| S-5N Sediments III | 5/15/2015 | 1.26 | 65.9 | 136 | 0.098 | 264 |
| **RSD** | | **80.71** | **9.15** | **15.32** | **91.01** | **16.49** |
| S-5S Sediments I | 5/15/2015 | 1.23 | 219 | 2180 | 0.057 | 304 |
| S-5S Sediments II | 5/15/2015 | 3.84 | 506 | 378 | 0.28 | 851 |
| S-5S Sediments III | 5/15/2015 | 2.69 | 157 | 406 | 0.21 | 707 |
| **RSD** | | **50.57** | **63.33** | **104.49** | -- | **45.68** |

| Site | Sample Date | Cadmium | Copper | Lead | Mercury | Zinc |
|---|---|---|---|---|---|---|
| | | (mg/kg dw) | (mg/kg dw) | (mg/kg dw) | (mg/kg dw) | (mg/kg dw) |
| S-1 Sediments I | 9/24/2015 | 0.16 | 14 | 5.52 | 0.04 | 113 |
| S-1 Sediments II | 9/24/2015 | 0.1 | 12.6 | 5.03 | 0.02 | 70.2 |
| S-1 Sediments III | 9/24/2015 | 0.1 | 12 | 4.41 | 0.02 | 73.2 |
| **RSD** | | **28.87** | **7.98** | **11.16** | -- | **27.95** |
| S-2 Sediments I | 9/27/2015 | 0.16 | 11.2 | 1.85 | <0.02 | 42.4 |
| S-2 Sediments II | 9/27/2015 | 0.15 | 9.53 | 1.77 | <0.02 | 41 |
| S-2 Sediments III | 9/27/2015 | 0.13 | 8.26 | 1.67 | <0.02 | 37.9 |
| **RSD** | | **10.41** | **15.26** | **5.11** | -- | **5.70** |
| S-4 Sediments I | 9/24/2015 | 0.38 | 29.7 | 23.9 | 0.02 | 81.2 |
| S-4 Sediments II | 9/24/2015 | 0.27 | 17.5 | 49.7 | 0.03 | 61.2 |
| S-4 Sediments III | 9/24/2015 | 0.29 | 18.1 | 18.4 | 0.03 | 66.5 |
| **RSD** | | **18.70** | **31.59** | **54.49** | -- | **14.88** |
| S-5N Sediments I | 9/24/2015 | 2.33 | 290 | 248 | 0.22 | 462 |
| S-5N Sediments II | 9/24/2015 | 1.38 | 99.8 | 140 | 0.06 | 729 |
| S-5N Sediments III | 9/24/2015 | 5.46 | 116 | 223 | 0.53 | 997 |
| **RSD** | | **69.84** | **62.54** | **27.76** | -- | **36.68** |
| S-5S Sediments I | 9/24/2015 | 2.18 | 233 | 303 | 0.22 | 1130 |
| S-5S Sediments II | 9/24/2015 | 2.1 | 133 | 330 | 0.06 | 362 |
| S-5S Sediments III | 9/24/2015 | 1.51 | 88.8 | 246 | 0.53 | 383 |
| **RSD** | | **18.96** | **48.73** | **14.64** | -- | **70.00** |

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

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. Fourteen out of the 39 (~36%) RSDs calculated for the 2015 dataset were not within this data quality objective. All of the samples that were above this RSD were from sample sites S-4, S-5S, and S-5N, which are in the vicinity of the 1989 concentrate spill. Due to concentrate remaining following the dredging in 1995, sampling at these sites continues to have the greatest variability, with associated higher RSDs typical of mixed population samples.

## 4.0 IN-SITU BIOASSAYS

The requirements for the bioassay monitoring originate from Section I.D.3, In-situ Bioassays, and Table 5 of the APDES permit. The objective of this monitoring element is to provide scientifically valid data on five specific trace metal parameters from the tissues of polychaete worms (*Nephtys*) and mussels 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 semi-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 (*Mytilus edulis*). 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 when available sediment dwelling bivalves (*Cockles* and *Littleneck Clams*), are collected at three additional sites (S-1, S-2, and S-4).

An additional location, Site S-3, has also been sampled for biota since the 1980s. Site S-3 is located near the head of Hawk Inlet. Field observations of a mass wasting event in the watershed above S-3 appears to have released metals from abandoned historic mine workings (Alaska Rand Group) into the environment (Ridgeway, 2003). For this reason, when the reissued permit became effective (July 1, 2005) S-3 was dropped from the list of active bioassay sampling sites and data from S-3 are not presented in this report.

### 4.1 2015 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. Tables 4-2 and 4-3 in this section summarize the total metals results for the semi-annual bioassays. Sample labels I, II, and III denote duplicate samples taken at each site. Duplicate samples are not taken for all species due to the negative impact such removal would have on the relatively sparse populations present on the Hawk Inlet bioassay monitoring sample sites.

**TABLE 4-1 Hawk Inlet Tissue Sampling Field Data 2015**

| Locations | Sample Type | Date Sampled | Time Sampled | Weather Conditions | Tide (ft) |
|---|---|---|---|---|---|
| S-1 | Nephtys | 5/18/15 | 07:58 | Sunny | -3.8 |
| | Cockle | 5/18/15 | 07:58 | Sunny | -3.8 |
| | Nephtys | 9/24/15 | 04:22 | Partly Cloudy | +3.4 |
| | Cockle | 9/26/15 | 06:10 | Partly Cloudy, Light Rain | +1.0 |
| S-2 | Nephtys | 5/17/15 | 07:15 | Sunny | -3.3 |
| | Cockle | 5/17/15 | 07:15 | Sunny | -3.3 |
| | Littleneck | 5/17/15 | 07:15 | Sunny | -3.3 |
| | Nephtys | 9/27/15 | 07:00 | Cloudy, Light Rain | -1.5 |
| | Cockle | 9/27/15 | 06:45 | Cloudy, Light Rain | -1.0 |
| | Littleneck | 9/27/15 | 07:15 | Cloudy, Light Rain | -1.0 |
| S-4 | Nephtys | 5/15/15 | 05:40 | Sunny | -0.9 |
| | Cockle | 5/15/15 | 05:40 | Partly Cloudy | -0.9 |
| | Nephtys | 9/24/15 | 04:30 | Dark | +1.2 |
| | Cockle | 9/24/15 | 04:35 | Dark | +1.1 |
| STN-1 | Mussels | 5/22/15 | 10:00 | Sunny | -0.5 |
| | Mussels | 9/21/15 | 14:30 | Cloudy, Rain | +5.9 |
| STN-2 | Mussels | 5/22/15 | 10:15 | Sunny | -0.7 |
| | Mussels | 9/25/15 | 16:00 | Partly Cloudy | +4.0 |
| STN-3 | Mussels | 5/22/15 | 10:30 | Sunny | -0.9 |
| | Mussels | 9/21/15 | 14:40 | Cloudy, Rain | +5.7 |
| ESL | Mussels | 5/22/15 | 9:45 | Sunny | -0.3 |
| | Mussels | 9/25/15 | 17:10 | Partly Cloudy | +3.7 |

**TABLE 4-2 Hawk Inlet Tissue Results for Spring 2015**
(ALS Environmental)

| Sample No. | Sample date | Cd (mg/kg dw) | Cu (mg/kg dw) | Pb (mg/kg dw) | Hg (mg/kg dw) | Zn (mg/kg dw) |
|---|---|---|---|---|---|---|
| **BIOASSAYS** | | | | | | |
| *Lab MRL* | | (0.02) | (0.1) | (0.02) | (0.02, 0.03) | (0.5) |
| S-1 Nephtys I | 5/18/15 | 3.82 | 7.1 | 0.56 | 0.058 | 250 |
| S-1 Nephtys II | 5/18/15 | 3.75 | 5.8 | 0.61 | 0.043 | 229 |
| S-1 Nephtys III | 5/18/15 | 3.73 | 11 | 0.75 | 0.055 | 233 |
| S-1 Cockles | 5/22/15 | 1.09 | 5.7 | 1.02 | 0.04 | 78.5 |
| S-2 Nephtys I | 5/17/15 | 1.11 | 7.6 | 0.53 | 0.032 | 169 |
| S-2 Nephtys II | 5/17/15 | 1.05 | 6.4 | 0.6 | <0.02 | 165 |
| S-2 Nephtys III | 5/17/15 | 1.07 | 6.7 | 0.65 | 0.022 | 156 |
| S-2 Cockles | 5/22/15 | 1.2 | 5.4 | 0.48 | 0.043 | 85.2 |
| S-2 Littlenecks | 5/17/15 | 3.6 | 9.2 | 0.32 | 0.038 | 92.6 |
| S-4 Nephtys I | 5/15/15 | 1.19 | 29.0 | 4.33 | 0.044 | 213 |
| S-4 Nephtys II | 5/15/15 | 1.22 | 24.2 | 3.99 | 0.042 | 234 |
| S-4 Nephtys III | 5/15/15 | 1.59 | 33.4 | 4.42 | 0.044 | 239 |
| S-4 Cockles | 5/15/15 | 0.84 | 5.4 | 2.63 | 0.048 | 77.6 |
| STN-1 Mussels | 5/22/15 | 15.9 | 7.2 | 1.12 | 0.049 | 125 |
| STN-2 Mussels | 5/22/15 | 15.2 | 7.3 | 0.66 | 0.049 | 103 |
| STN-3 Mussels | 5/22/15 | 11.7 | 7.8 | 1.02 | 0.042 | 108 |
| ESL Mussels | 5/22/15 | 8.55 | 9.9 | 1.46 | 0.035 | 106 |

**TABLE 4-3 Hawk Inlet Tissue Results for Fall 2015**
(ALS Environmental)

| Sample No. | Sample date | Cd (mg/kg dw) | Cu (mg/kg dw) | Pb (mg/kg dw) | Hg (mg/kg dw) | Zn (mg/kg dw) |
|---|---|---|---|---|---|---|
| **BIOASSAYS** | | | | | | |
| *Lab MRL* | | (0.02) | (0.1) | (0.02) | (0.02) | (0.5) |
| S-1 Nephtys I | 9/24/15 | 4.52 | 9.4 | 0.49 | 0.06 | 189 |
| S-1 Nephtys II | 9/24/15 | 5.0 | 8.2 | 0.5 | 0.06 | 234 |
| S-1 Nephtys III | 9/24/15 | 5.58 | 5.4 | 0.44 | 0.06 | 237 |
| S-1 Cockles | 9/25/15 | 0.52 | 4.2 | 1.03 | 0.03 | 67 |
| S-2 Nephtys I | 9/27/15 | 0.86 | 15 | 0.7 | <0.02 | 136 |
| S-2 Nephtys II | 9/27/15 | 1.08 | 8.8 | 0.6 | 0.03 | 169 |
| S-2 Nephtys III | 9/27/15 | 1.2 | 10.6 | 0.51 | 0.02 | 155 |
| S-2 Cockles | 9/25/15 | 0.49 | 3.5 | 0.40 | 0.02 | 65.6 |
| S-2 Littlenecks | 9/27/15 | 2.28 | 7.8 | 0.3 | 0.02 | 71.1 |
| S-4 Nephtys I | 9/24/15 | 0.81 | 17.5 | 4.11 | 0.04 | 204 |
| S-4 Nephtys II | 9/24/15 | 0.58 | 16.2 | 4 | 0.03 | 180 |
| S-4 Nephtys III | 9/24/15 | 1.46 | 66.2 | 5.36 | 0.07 | 217 |
| S-4 Cockles | 9/24/15 | 0.32 | 7.3 | 1.99 | 0.02 | 67 |
| STN-1 Mussels | 9/21/15 | 11.7 | 10.8 | 1.6 | 0.06 | 109 |
| STN-2 Mussels | 9/25/15 | 9.59 | 10.1 | 2.27 | 0.06 | 84.7 |
| STN-3 Mussels | 9/21/15 | 8.58 | 9.4 | 2.64 | 0.05 | 110 |
| ESL Mussels | 9/25/15 | 4.79 | 7.2 | 1.37 | 0.03 | 76.1 |

## 4.2 Data Evaluation

Prior to 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 and S-2 from June of 1984 until August 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 (Table 4-4 and 4-5).

As noted by 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 result in no acute effects."

**TABLE 4-4 Hawk Inlet Mussels Tissue Data: Pre-Production Baseline, Production Period and Current Year Comparison***

| Metal (mg/kg dw) | Pre-Production (6/1984-8/1989) | | | Production (9/1989-9/2014) | | | Current Year 2015 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max |
| Cd | 7.67 | 3.25 | 15.76 | 8.05 | 0.125 | 14.5 | 10.75 | 4.79 | 15.9 |
| Cu | 8.51 | 5.5 | 21.1 | 8.09 | 0.25 | 110 | 8.71 | 7.2 | 10.8 |
| Pb | 0.57 | 0.15 | 1.73 | 2.45 | 0.05 | 126 | 1.52 | 0.66 | 2.64 |
| Hg | 0.06 | 0.014 | 0.56 | 0.04 | 0.01 | 0.1 | 0.05 | 0.03 | 0.06 |
| Zn | 88.39 | 65 | 142 | 84.89 | 1.25 | 126 | 102.73 | 76.1 | 125 |

*Data are compilation of results from Stations ESL, STN-1, STN-2 and STN-3; underlined average values higher than baseline. Non-detects are averaged using half of the MDL value.

Average lead concentrations in mussel tissues are currently approximately five times higher during the production period than the pre-production period. Average lead values in 2015 were less than 1 mg/kg higher than the pre-production and lower than the production average values (2.56 mg/kg dw). Average zinc values in 2015 (102.73 mg/kg dw) were greater in concentration to pre-production values (88.39 mg/kg dw), and higher than production values (84.89 mg/kg dw). Average cadmium values in 2015 (10.75 mg/kg dw) were similar although higher to pre-production values (7.67 mg/kg dw) and production values (8.05 mg/kg). Figures 4-1 through 4-20 show the time series plots for cadmium, copper, lead, mercury and zinc in mussel samples for sample sites STN-1, STN-2, STN-3, and ESL.

When compared to the Mussel Watch averages for Alaska, cadmium and zinc exceeded these averages (2.87 mg/kg and 87.95 mg/kg, respectively) during pre-production. Cadmium and lead exceeded these averages (2.87 mg/kg and 1.17 mg/kg, respectively) during production. These levels were similarly noted in the 2003 Review of the Status of Essential Fish Habitat in Hawk Inlet Subsequent to Mining Operations (p 57):

> "…the average mining production period metal levels are generally below Mussel Watch averages for Alaska. The exception to this is Cd, which was above Mussel Watch Alaska averages prior to and subsequent to mining operations. Because the USFWS Hawk Inlet-wide levels of Pb increased similarly to the outfall monitoring site levels of Pb, these increases over time may be due to natural increases in Pb in the environment."

**TABLE 4-5 Hawk Inlet *Nephtys* Tissue Data: Pre-Production Baseline, Production Period and Current Year Comparison***

| Metal (mg/kg dw) | Pre-Production (6/1984-8/1989) | | | Production (9/1989-9/2014) | | | Current Year 2015 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max |
| Cd | 2.65 | 0.24 | 6.91 | 2.03 | 0.28 | 8.33 | 2.73 | 0.86 | 5.58 |
| Cu | 10.24 | 6.24 | 17.4 | 9.34 | 4.3 | 42.1 | 8.50 | 5.4 | 15 |
| Pb | 0.48 | 0.13 | 1.07 | 0.87 | 0.1 | 4.76 | 0.58 | 0.44 | 0.75 |
| Hg | 0.033 | 0.009 | 0.074 | 0.41 | 0.01 | 72.4 | 0.038 | 0.01 | 0.06 |
| Zn | 205.95 | 121 | 303 | 194.45 | 62.6 | 357 | 193.50 | 136 | 250 |

Data are compilation of results from Stations S-1 and S-2; underlined average values higher than baseline.
Non-detects are averaged using half of the MDL value.

Combined S-1 and S-2 average lead, cadmium, and mercury concentrations in *Nephtys*, are marginally higher than pre-production values.

Tables 4-6 and 4-7 show the average and standard deviation results for pre-production and production periods for the individual sites for mussels and *Nephtys*, respectively. Table 4-6 shows larger standard deviations in production levels of lead and copper concentrations in mussels at all sites. Table 4-7 shows larger standard deviations in production levels of lead concentrations in *Nephtys* at S-1, S-2 and S-4. Beginning in the fall of 2004 replicate sampling of *Nephtys* was initiated. The replicate samples are reflected in Table 4-7. 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 4-6 Average and Standard Deviation Values for Pre-Production, Production, and Current Year Mussel Data – Sites STN-1, STN-2, STN-3, and ESL.**

| Metal (mg/kg dw) | ESL | | | | | STN-1 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | pre-production (9/1984-8/1989) | | production (9/1989 - 9/2014) | | Current Year 2015 | pre-production (9/1984-8/1989) | | production (9/1989 - 9/2014) | | Current Year 2015 |
| | avg | stdev | avg | stdev | avg | avg | stdev | avg | stdev | avg |
| Cd | 6.17 | 1.78 | 6.62 | 1.87 | 6.67 | 7.48 | 1.72 | 8.13 | 1.90 | 13.8 |
| Cu | 9.61 | 3.77 | 10.03 | 15.09 | 8.55 | 8.05 | 1.19 | 7.23 | 1.75 | 9.0 |
| Pb | 0.53 | 0.26 | 1.36 | 0.81 | 1.415 | 0.66 | 0.44 | 1.32 | 0.81 | 1.36 |
| Hg | 0.034 | 0.012 | 0.034 | 0.017 | 0.033 | 0.101 | 0.142 | 0.040 | 0.016 | 0.055 |
| Zn | 90.22 | 8.07 | 81.96 | 18.34 | 91.05 | 88.53 | 15.44 | 85.34 | 13.87 | 117 |

| Metal (mg/kg dw) | STN-2 | | | | | STN-3 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | pre-production (9/1984-8/1989) | | production (9/1989 - 9/2014) | | Current Year 2015 | pre-production (9/1984-8/1989) | | production (9/1989 - 9/2014) | | Current Year 2015 |
| | avg | stdev | avg | stdev | avg | avg | stdev | avg | stdev | avg |
| Cd | 8.01 | 3.01 | 8.94 | 2.43 | 12.40 | 9.00 | 2.81 | 8.51 | 1.95 | 10.14 |
| Cu | 7.82 | 1.02 | 7.77 | 3.79 | 8.70 | 8.54 | 1.58 | 7.32 | 2.11 | 8.60 |
| Pb | 0.45 | 0.27 | 3.99 | 17.50 | 1.47 | 0.65 | 0.24 | 3.13 | 12.92 | 1.83 |
| Hg | 0.038 | 0.012 | 0.038 | 0.017 | 0.055 | 0.084 | 0.150 | 0.040 | 0.017 | 0.046 |
| Zn | 83.02 | 14.53 | 85.23 | 17.26 | 93.85 | 91.80 | 17.92 | 87.09 | 15.69 | 109 |

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

**TABLE 4-7 Average and Standard Deviation Values for Pre-Production, Production, and Current Year *Nephtys* Data – Sites S-1, S-2, and S-3**

| Metal (mg/kg dw) | S-1 *Nephtys* | | | | | S-2 *Nephtys* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | pre-production (9/1984-8/1989) | | production (9/1989 - 9/2014) | | Current Year 2015 | pre-production (9/1984-8/1989) | | production (9/1989 - 9/2014) | | Current Year 2015 |
| | avg | stdev | avg | stdev | avg | avg | stdev | avg | stdev | avg |
| Cd | 3.91 | 1.72 | 2.94 | 0.92 | 4.40 | 1.40 | 0.85 | 1.12 | 0.51 | 1.06 |
| Cu | 9.27 | 1.41 | 9.89 | 5.75 | 7.82 | 11.21 | 3.56 | 8.79 | 5.04 | 9.18 |
| Pb | 0.45 | 0.16 | 1.01 | 0.83 | 0.56 | 0.50 | 0.26 | 0.73 | 0.36 | 0.60 |
| Hg | 0.047 | 0.010 | 0.045 | 0.020 | 0.056 | 0.019 | 0.008 | 0.017 | 0.012 | 0.021 |
| Zn | 243.33 | 42.96 | 212.11 | 34.77 | 228.67 | 168.56 | 34.45 | 176.80 | 35.14 | 158.33 |

| Metal (mg/kg dw) | S-4 *Nephtys* | | | | |
|---|---|---|---|---|---|
| | pre-production (9/1984-8/1989) | | production (9/1989 - 9/2014) | | Current Year 2015 |
| | avg | stdev | avg | stdev | avg |
| Cd | 0.93 | 0.72 | 0.81 | 0.58 | 1.14 |
| Cu | 21.02 | 9.25 | 19.27 | 16.65 | 31.08 |
| Pb | 3.65 | 1.08 | 8.05 | 9.71 | 4.37 |
| Hg | 0.060 | 0.062 | 0.025 | 0.017 | 0.045 |
| Zn | 210.20 | 17.91 | 198.24 | 44.46 | 214.50 |

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

Additional tissue samples of *Cockles and Littlenecks* were collected in 2015. Table 4-8 summarizes the average metal values for the available data for these additional tissue samples. Only *Cockles* at site S-4 has pre-production period data available for comparison (Table 4-8).

**TABLE 4-8 Summary of Results for Additional Tissue Samples**

| Metal-average | S-2 *Cockles* | S-2 *Littlenecks* | S-4 *Cockles* | |
|---|---|---|---|---|
| (mg/kg dw) | (1999-2014) | (1999-2015) | (5/88-7/89) | (9/89-2015) |
| Cd | 0.81 | 2.41 | 0.71 | 0.69 |
| Cu | 4.66 | 8.84 | 9.27 | 7.15 |
| Pb | 0.53 | 0.40 | 9.92 | 6.26 |
| Hg | 0.03 | 0.02 | 0.04 | 0.04 |
| Zn | 69.43 | 78.72 | 100.14 | 77.31 |

Effluent toxicity testing, conducted since the mining operations began, was discontinued in 2005 with re-issuance of the NPDES Permit (AK-004320-6). Over 17 years of testing, initially acute toxicity testing (February 1989 – October 1998), and then chronic toxicity testing (November 1998 – June 2005), showed no sub-lethal deleterious effects to tested marine aquatic organisms from prolonged exposure to the treated effluent;

> “The data show that the effluent from Outfall 002 has no reasonable potential to contribute to an exceedance of the (Alaska) WQS for toxicity.” (USEPA Fact Sheet dated October 28, 2004; page 14, Section VI.B Whole Effluent Toxicity Testing).

## 4.3 QA/QC Results

ALS Environmental analyzed the required parameters (see Table 1-1) in 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 the spring and fall sampling events in 2015.

Sping 2015: The control criteria for matrix spike recovery of Zinc for sample S-1 Nephtys Rep I were not applicable. The analyte concentration in the sample was significantly higher than the added spike concentration, preventing accurate evaluation of the spike recovery.

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

Fall 2015: The matrix spike recovery of Copper for sample S-4 Nephtys Rep II was outside control criteria. Recovery in the Laboratory Control Sample (LCS) was acceptable, which indicated the analytical batch was in control. No further corrective action was appropriate.

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

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 (the standard deviation relative to the mean, expressed as a percent) is shown for the duplicate samples in Table 4-9. 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. Three out of 24 (~13%) of the RSDs calculated for the 2015 duplicate samples were not within this data quality objective.

## TABLE 4-9 Relative Standard Deviation (RSD) for Duplicate Tissue Samples

| Sample ID | Sample Date | Cadmium | Copper | Lead | Mercury | Zinc |
|---|---|---|---|---|---|---|
| | | (mg/kg dw) | (mg/kg dw) | (mg/kg dw) | (mg/kg dw) | (mg/kg dw) |
| Lab MRL | | **0.02** | **0.1** | **0.02** | **0.02** | **0.4, 0.5** |
| S-1 Nephtys I | 5/18/2015 | 3.82 | 7.1 | 0.56 | 0.058 | 250 |
| S-1 Nephtys II | 5/18/2015 | 3.75 | 5.8 | 0.61 | 0.043 | 229 |
| S-1 Nephtys III | 5/18/2015 | 3.73 | 11 | 0.75 | 0.055 | 233 |
| **RSD** | | **1.25** | **33.97** | **15.39** | **--** | **4.70** |
| S-2 Nephtys I | 5/17/2015 | 1.11 | 7.6 | 0.53 | 0.032 | 169 |
| S-2 Nephtys II | 5/17/2015 | 1.05 | 6.4 | 0.6 | <0.02 | 165 |
| S-2 Nephtys III | 5/17/2015 | 1.07 | 6.7 | 0.65 | 0.022 | 156 |
| **RSD** | | **2.84** | **9.05** | **10.16** | **--** | **4.08** |
| S-4 Nephtys I | 5/15/2015 | 1.19 | 29 | 4.33 | 0.044 | 213 |
| S-4 Nephtys II | 5/15/2015 | 1.22 | 24.2 | 3.99 | 0.042 | 234 |
| S-4 Nephtys III | 5/15/2015 | 1.59 | 33.4 | 4.42 | 0.044 | 239 |
| **RSD** | | **16.71** | **15.94** | **5.34** | **--** | **6.03** |
| S-1 Nephtys I | 9/24/2015 | 4.52 | 9.4 | 0.49 | 0.06 | 189 |
| S-1 Nephtys II | 9/24/2015 | 5 | 8.2 | 0.5 | 0.06 | 234 |
| S-1 Nephtys III | 9/24/2015 | 5.58 | 5.4 | 0.44 | 0.06 | 237 |
| **RSD** | | **10.55** | **26.77** | **6.74** | **--** | **12.22** |
| S-2 Nephtys I | 9/27/2015 | 0.86 | 15 | 0.7 | <0.02 | 136 |
| S-2 Nephtys II | 9/27/2015 | 1.08 | 8.8 | 0.6 | 0.03 | 169 |
| S-2 Nephtys III | 9/27/2015 | 1.2 | 10.6 | 0.51 | 0.02 | 155 |
| **RSD** | | **16.47** | **27.82** | **15.75** | **--** | **10.80** |
| S-4 Nephtys I | 9/24/2015 | 0.81 | 17.5 | 4.11 | 0.04 | 204 |
| S-4 Nephtys II | 9/24/2015 | 0.58 | 16.2 | 4 | 0.03 | 180 |
| S-4 Nephtys III | 9/24/2015 | 1.46 | 66.2 | 5.36 | 0.07 | 217 |
| **RSD** | | **48.04** | **85.58** | **16.83** | **--** | **9.37** |

**-- Indicates the RSD was not calculated because one or more of the results was less than four times the MRL**

## 5.0 CONCLUSIONS

Water quality, sediments, and invertebrate tissue monitoring began in Hawk Inlet prior to production to establish a baseline against which future monitoring (during production) can be evaluated, and to monitor for natural changes. Greens Creek Mine has established a 30+ year monitoring database for many of the sites used to establish the original baseline. This monitoring program as needed has been modified (e.g. splitting of S-5 into S-5N and S-5S) to accommodate changes at the site.

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 at S-1 and S-2 has been occurring annually for 30+ years. When comparing S-1 which is located in the vicinity of the 002 outfall to S-2, a background site located over 1.5 miles to the south, it is evident that metal concentrations at the two sites exhibit similar concentration ranges. Furthermore, the yearly variability is similar between the two sites. Given the spatial distance but similar concentrations and the temporal similarity between the sites, the sediment metals concentrations at S-1 appear within the range of natural conditions.

Observations by fishermen and researchers suggest that the physical features and biotic communities of Hawk Inlet remain intact following over a decade of operation of the mine and they remain similar to adjacent inlets (Ridgeway, 2003). Halibut and crab numbers are reported to have declined significantly with the closing of the fish processing facilities which previously operated at the Hawk Inlet Cannery, which is now the HGCMC port facility.

Marine species which consume sedentary seafloor organisms (lowest trophic level) such as worms and bivalves would be most susceptible to trophic transfer of some metals. Therefore, the Hawk Inlet Monitoring Program was designed to monitor the potential impact of the mines discharge on the lowest trophic levels. Based on the suite of species listed as having Essential Fish Habitat in Hawk Inlet, the species most likely to encounter these elevated metal levels through their diet and habitat uses would include the flatfishes (*e.g.* yellowfin sole, arrowtooth flounder, flathead sole, and rock sole), pacific cod, sculpin and crab species. These species are extremely mobile predators, by comparison the mussels and polychaetes are monitored in the mine-associated areas (i.e. diffuser and port facility) are constantly exposed to the water of interest.

Lead levels from the tissue monitoring of *Nephtys* at site S-4 have a similar pattern as described for the sediment monitoring. Visually, it appears that there is a strong correlation between the two monitoring programs. This ‘correlation’ also exists when comparing lead in sediments to lead in *Nephtys* at site S-1. If the temporal variation in the sediment load at S-1 was a result of discharge from the 002 Outfall, the similar variation observed at S-2 would not be expected. This similarity in temporal variation and with spatial distances occurs with the other metals as well. 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 (S-4 and S-5 (N and S)) near the ship loader. These sites are influenced from the original activities of the cannery, the burning down of the cannery in the 1970’s, and concentrate spillage associated with the ship loader spill in 1989. For example, pre-production lead levels at S-4 averaged around 50 mg/kg about 8 times higher than at S-1. After the concentrate spill the lead levels average around 250 mg/kg dw at S-4. During re-commissioning (mid 1990s) sediments were dredged in the vicinity of the ship loader, after this the average lead level returned to pre-productions levels. Since the early 2000’s lead levels at S-4 have routinely been less than 30 mg/kg, attributed to natural process (e.g. sedimentation).

As discussed in the report there have been some elevated metals concentrations in the invertebrate and sediment samples. However, the recent tissue samples are similar to pre-mining levels and the sediments exhibit similar variation despite their spatial distances. These results indicate that there is natural variability, the lowest trophic levels are unaffected, and that the APDES monitoring program is effective for measuring potential impacts associated with the Greens Creek Mine.

## 6.0 REFERENCES

Greens Creek Tailings Disposal: Final Environmental Impact Statement; USDA Forest Service, November 2003.

Kennecott Greens Creek Mine Risk Assessment NPDES Permit No. AK-004320-6, Admiralty Island, Alaska, Oregon Institute of Oceanography, and Remediation Technologies, Inc. June 22, 1998.

Marine Taxonomic Services Ltd, Hawk Inlet Facilities Year 2015 Annual Inspection Report, September 2015.

Alaska Pollutant Discharge Elimination System (APDES) permit AK-0043206, ADEC, effective date October 1, 2015.

APDES Quality Assurance Project Plan (QAPP), HGCMC, November 2015.

Technical Review of the Status of Essential Fish Habitat in Hawk Inlet Subsequent to Mining Operations, M. Ridgeway, Oceanus Alaska, October 2003.

# FIGURES

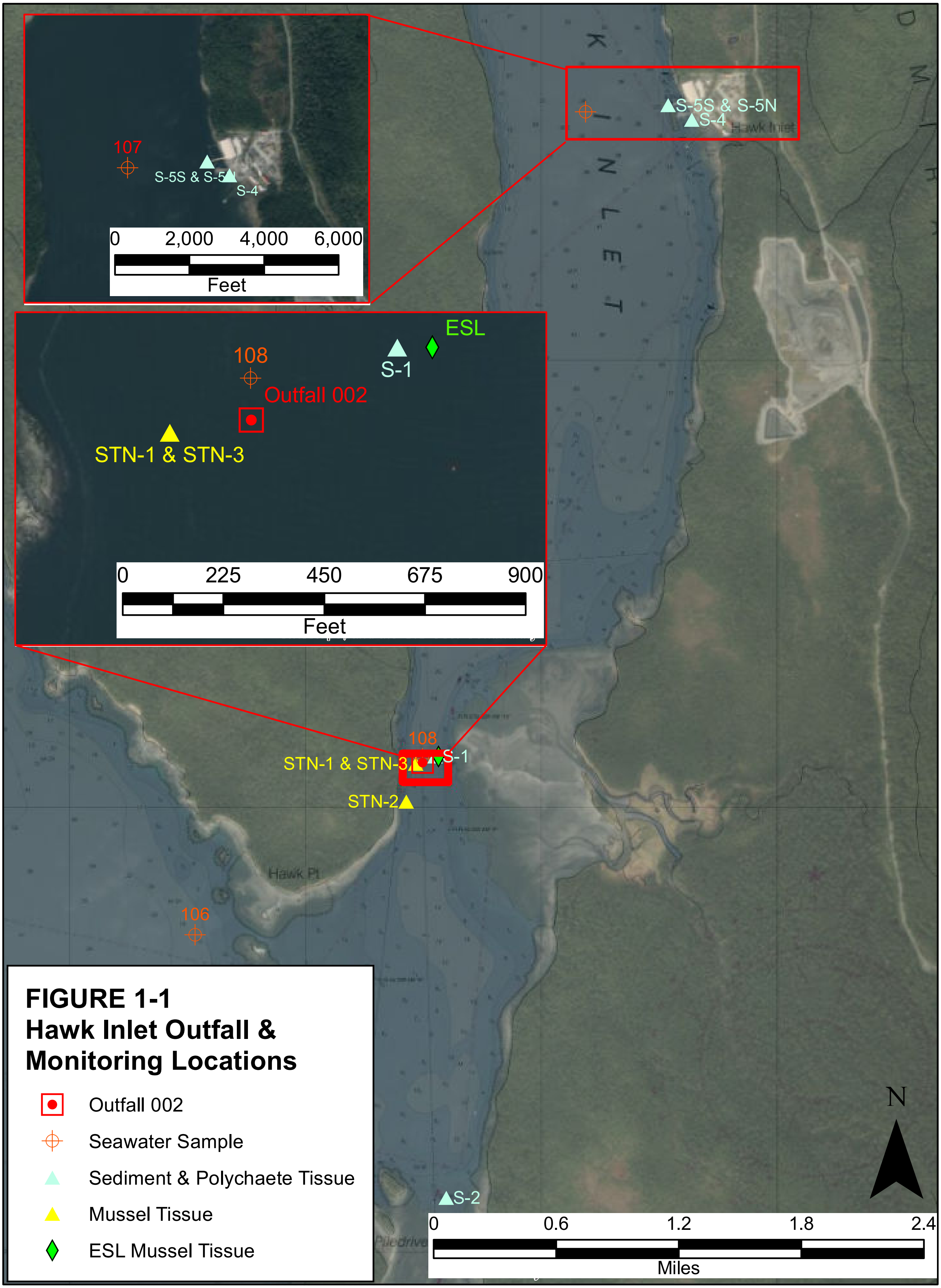
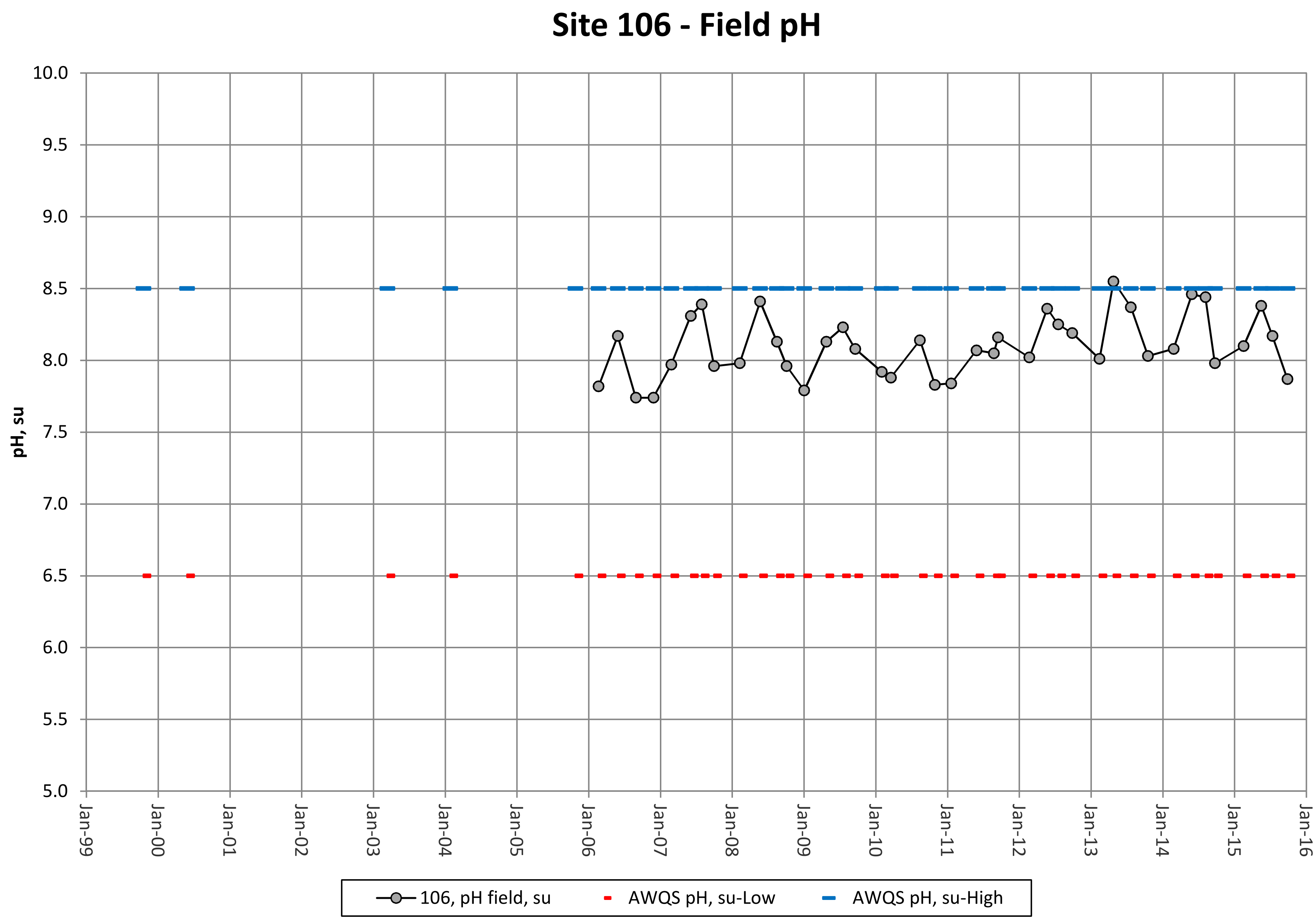
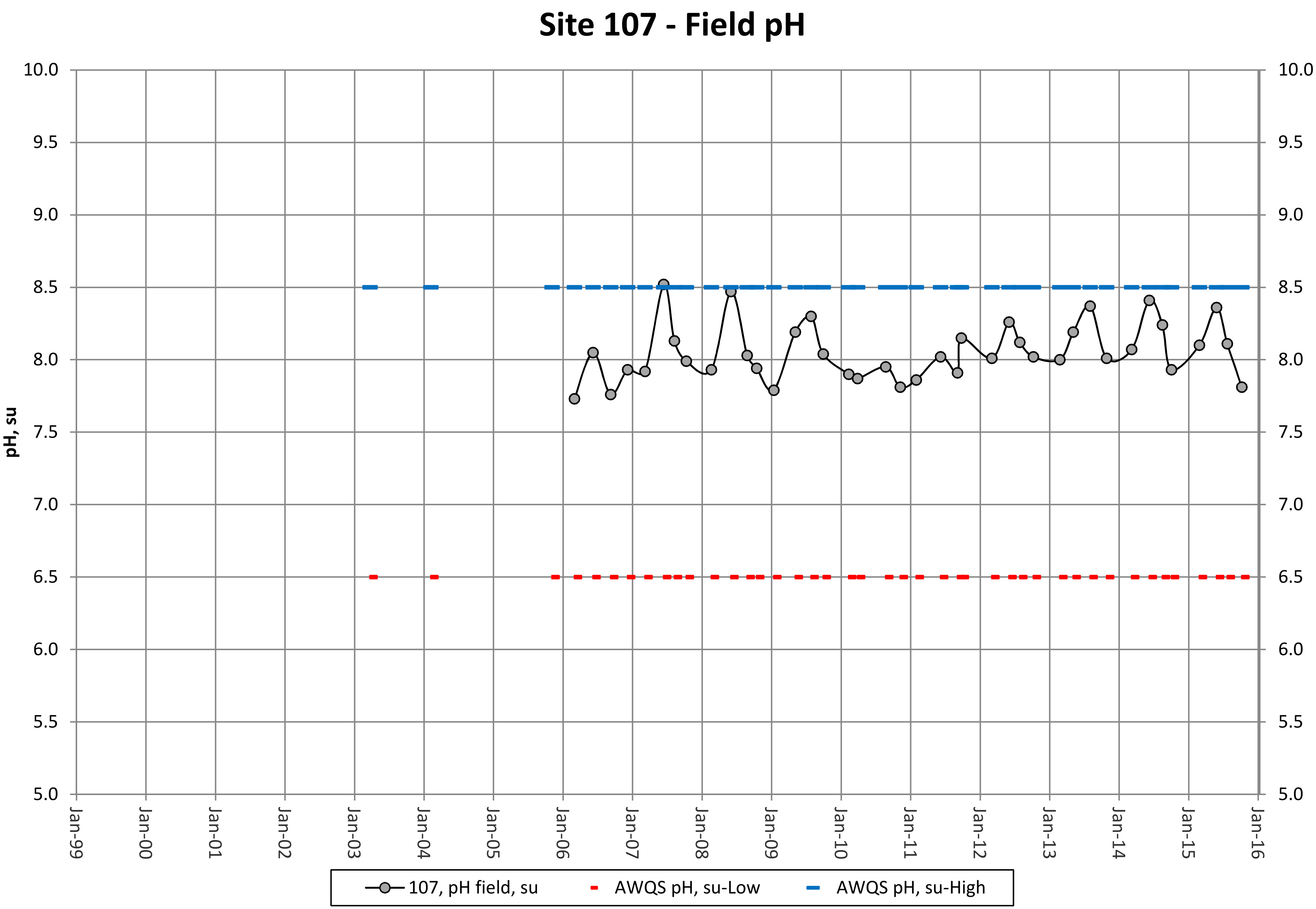

107
S-5S & S-5N
S-4
0
2,000
4,000
6,000
Feet
108
ESL
S-1
Outfall 002
STN-1 & STN-3
0
225
450
675
900
Feet
S-5S & S-5N
S-4
Hawk Inlet
108
STN-1 & STN-3
S-1
STN-2
Hawk Pt
106
S-2
0
0.6
1.2
1.8
2.4
Miles
N
FIGURE 1-1
Hawk Inlet Outfall & Monitoring Locations
Outfall 002
Seawater Sample
Sediment & Polychaete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

Figure 2-1a



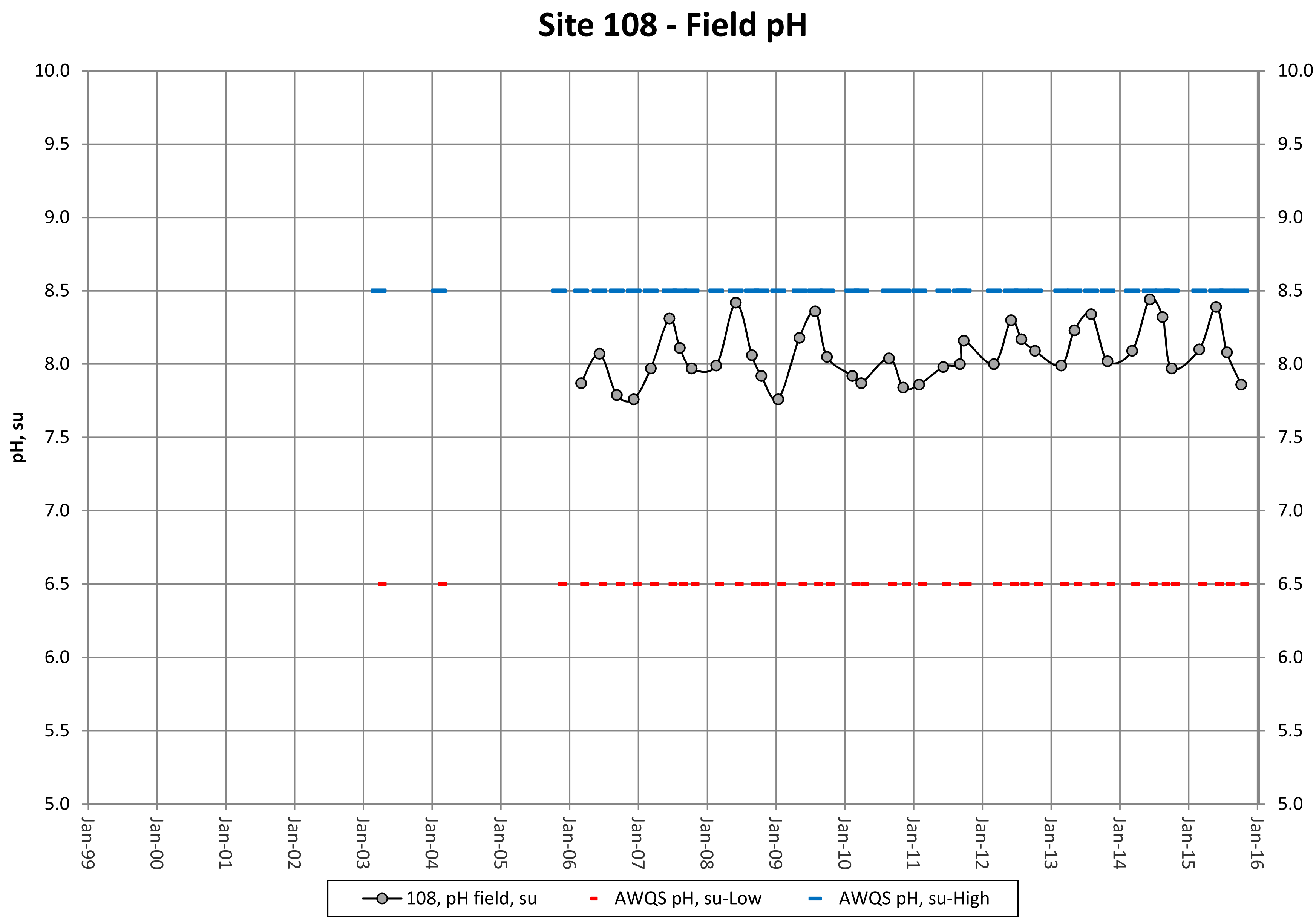
Site 106 - Field pH
pH, su
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
106, pH field, su
AWQS pH, su-Low
AWQS pH, su-High

Figure 2-1b



Site 107 - Field pH
pH, su
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
107, pH field, su
AWQS pH, su-Low
AWQS pH, su-High

Figure 2-1c



Site 108 - Field pH
pH, su
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
108, pH field, su
AWQS pH, su-Low
AWQS pH, su-High

Figure 2-2a

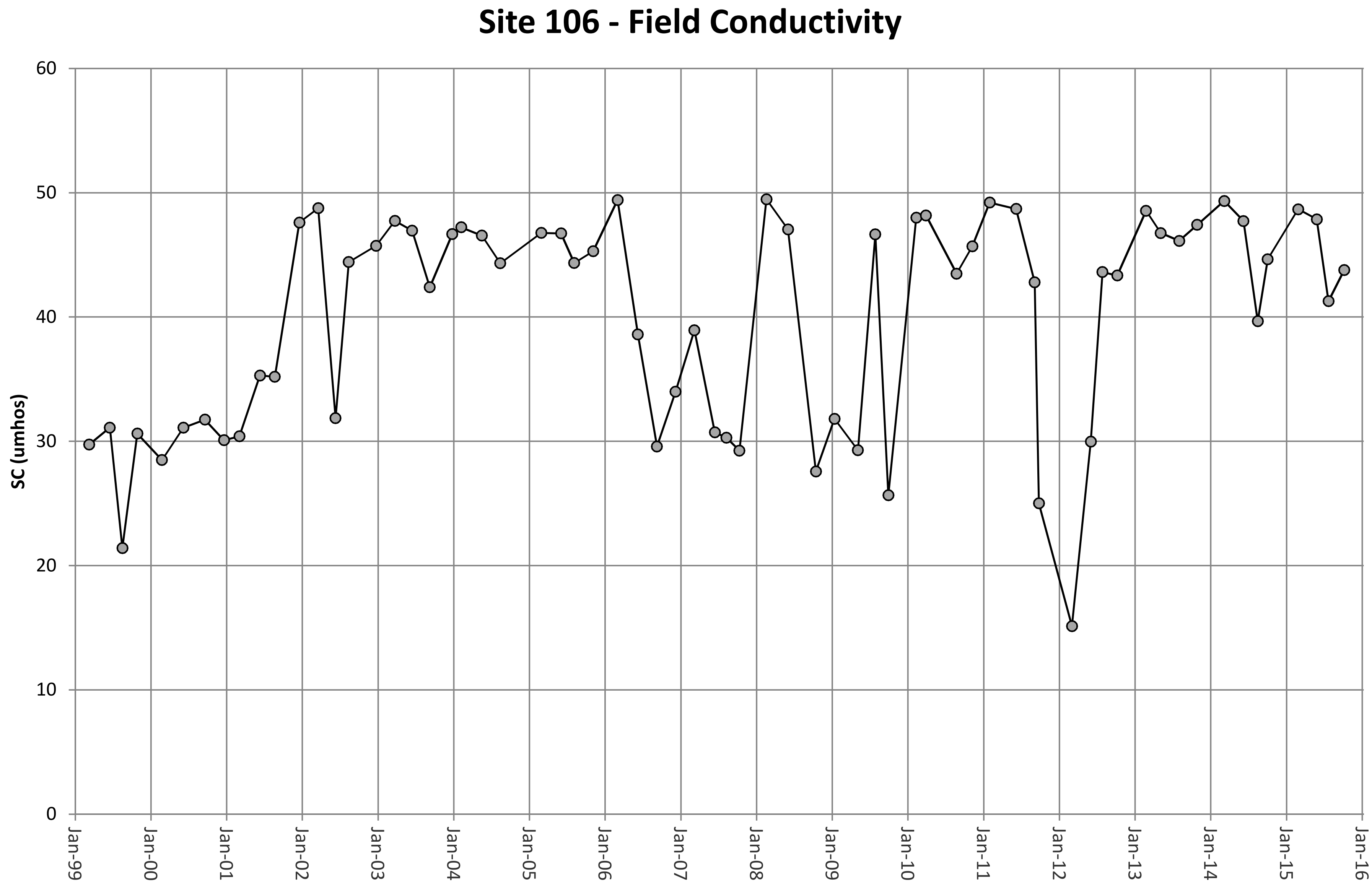
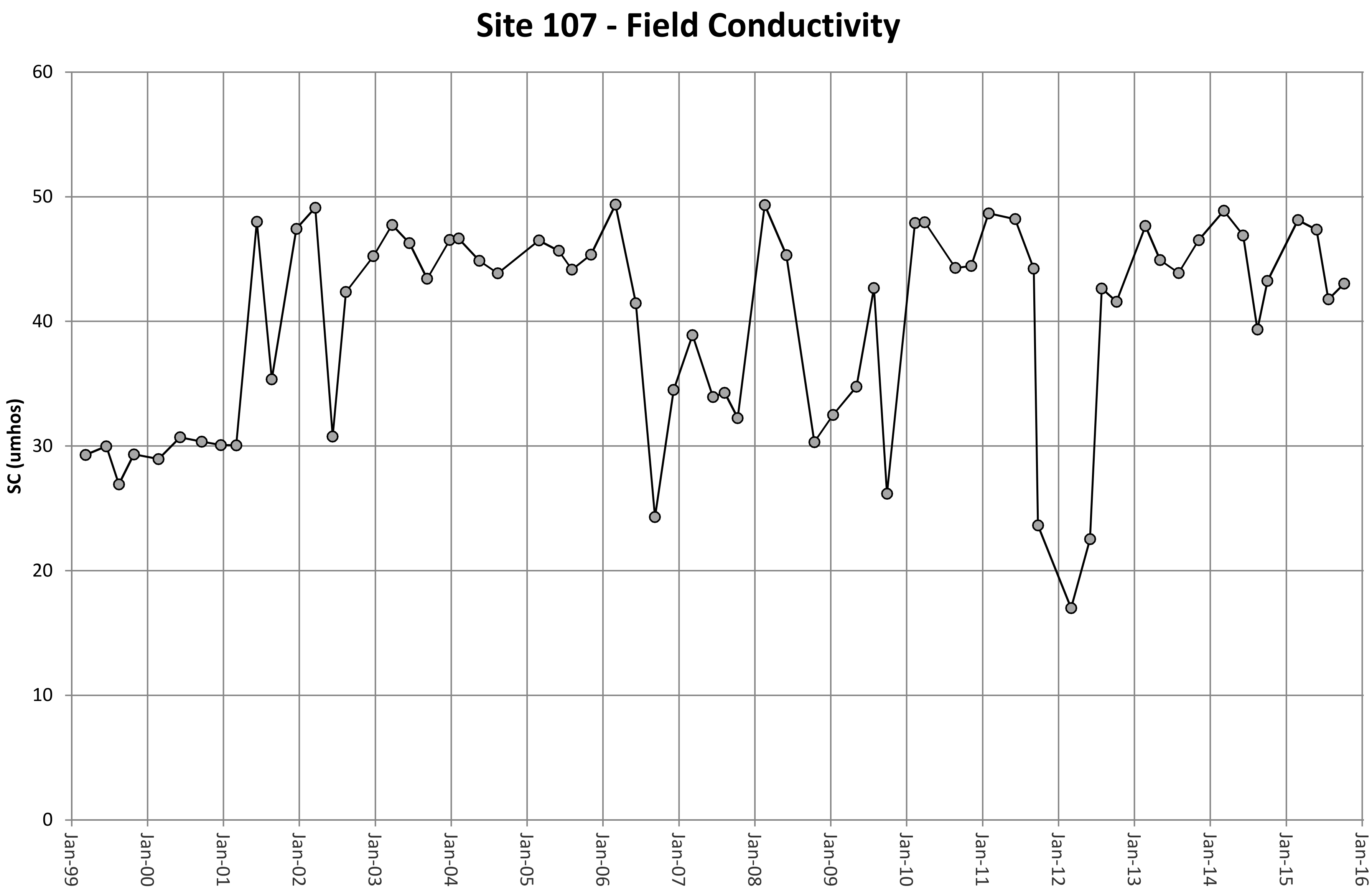
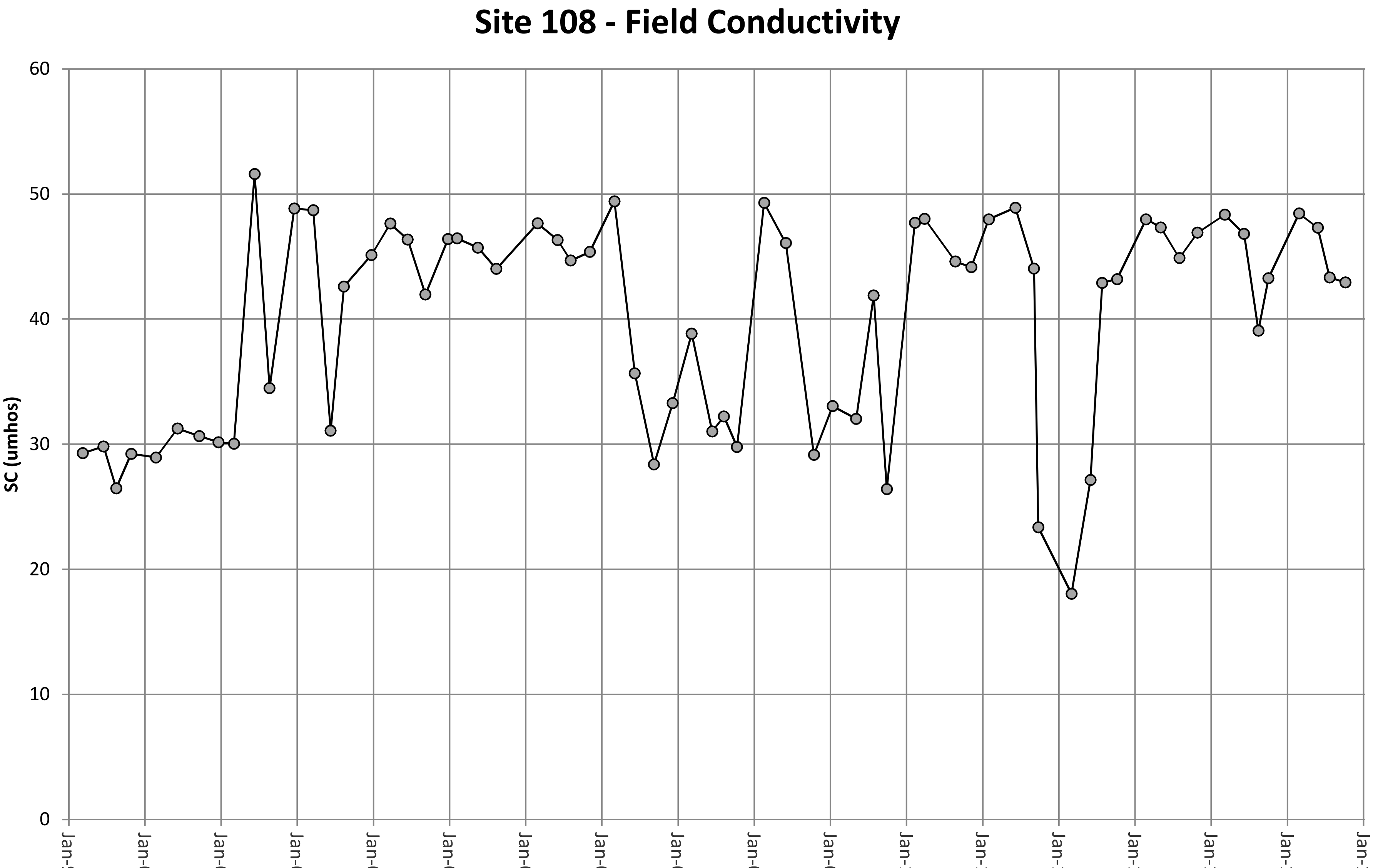

Site 106 - Field Conductivity
SC (umhos)
0
10
20
30
40
50
60
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16

Figure 2-2b



Site 107 - Field Conductivity
SC (umhos)
0
10
20
30
40
50
60
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

Figure 2-2c



Site 108 - Field Conductivity
SC (umhos)
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

Figure 2-3a

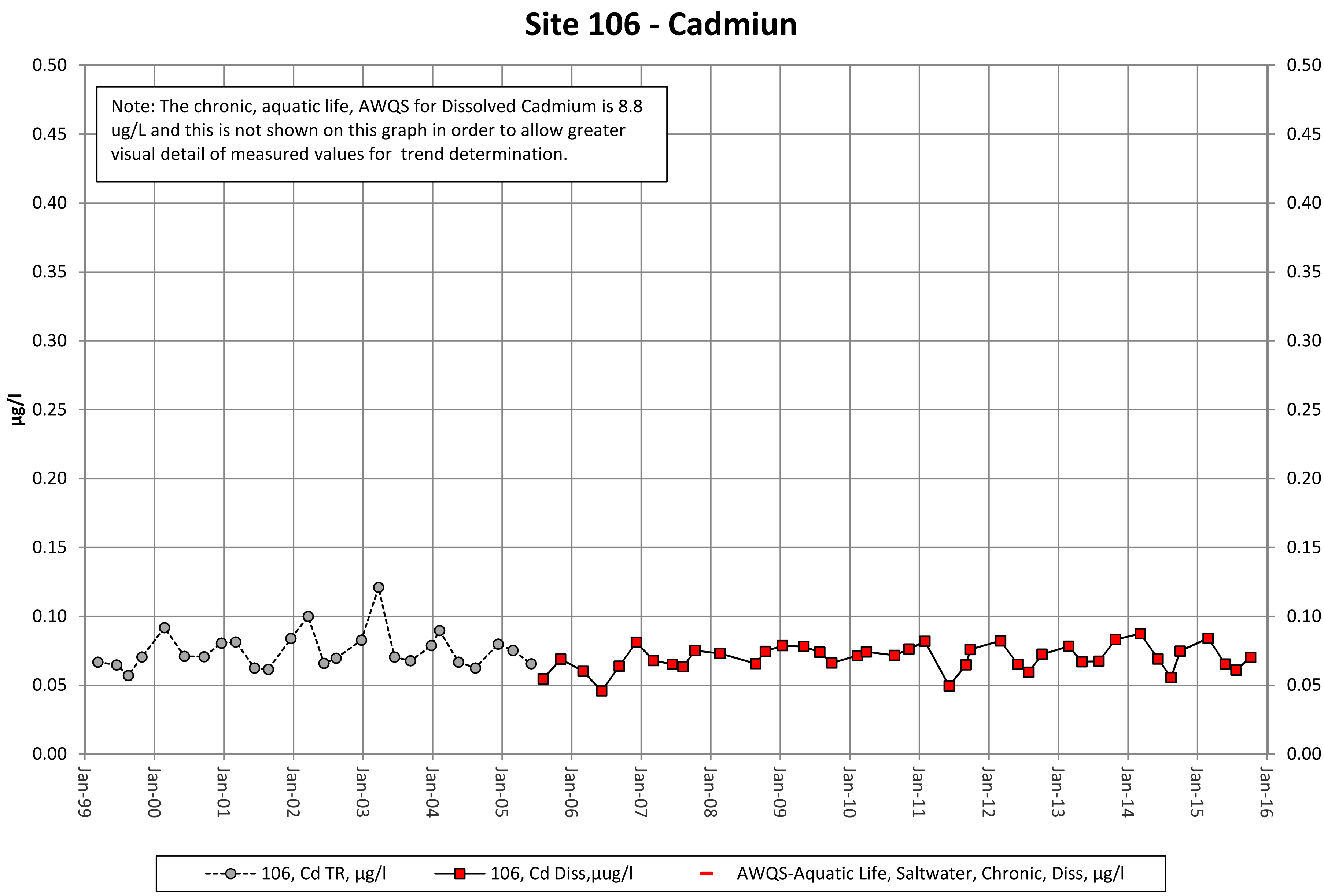
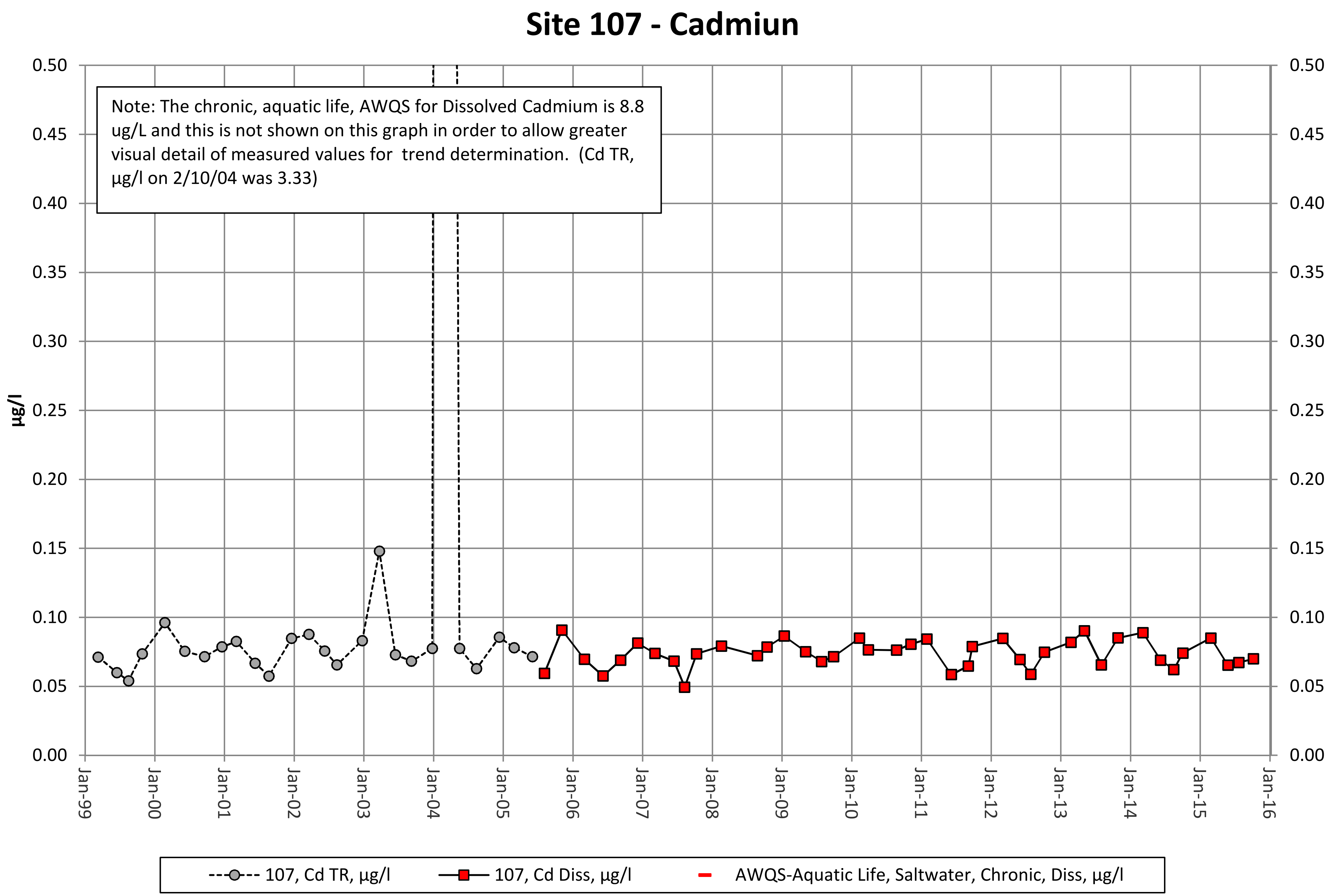
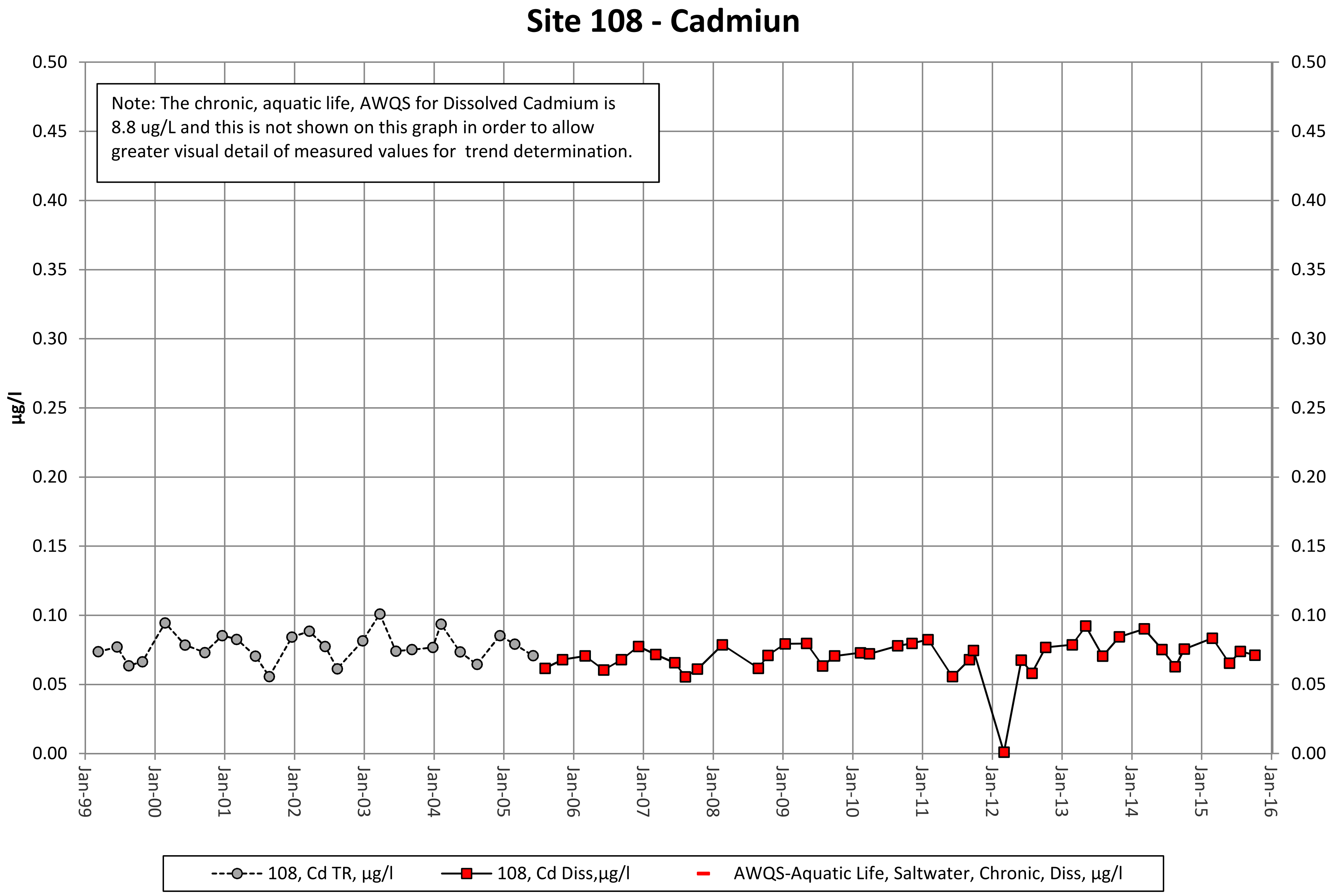

Site 106 - Cadmiun
Note: The chronic, aquatic life, AWQS for Dissolved Cadmium is 8.8 ug/L and this is not shown on this graph in order to allow greater visual detail of measured values for trend determination.
µg/l
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
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
106, Cd TR, µg/l
106, Cd Diss,µug/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-3b



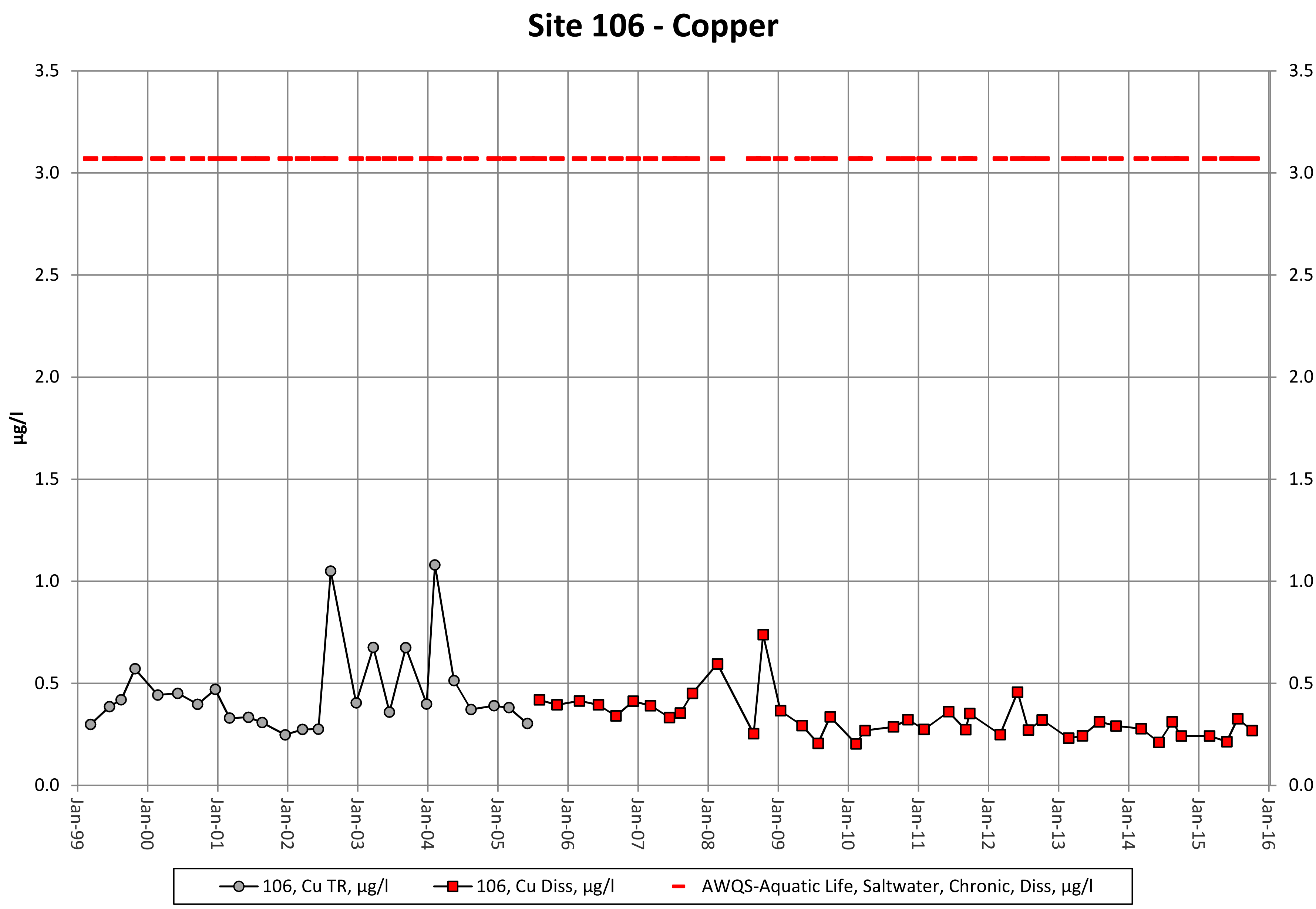
Site 107 - Cadmiun
Note: The chronic, aquatic life, AWQS for Dissolved Cadmium is 8.8 ug/L and this is not shown on this graph in order to allow greater visual detail of measured values for trend determination. (Cd TR, µg/l on 2/10/04 was 3.33)
µg/l
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
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
107, Cd TR, µg/l
107, Cd Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-3c



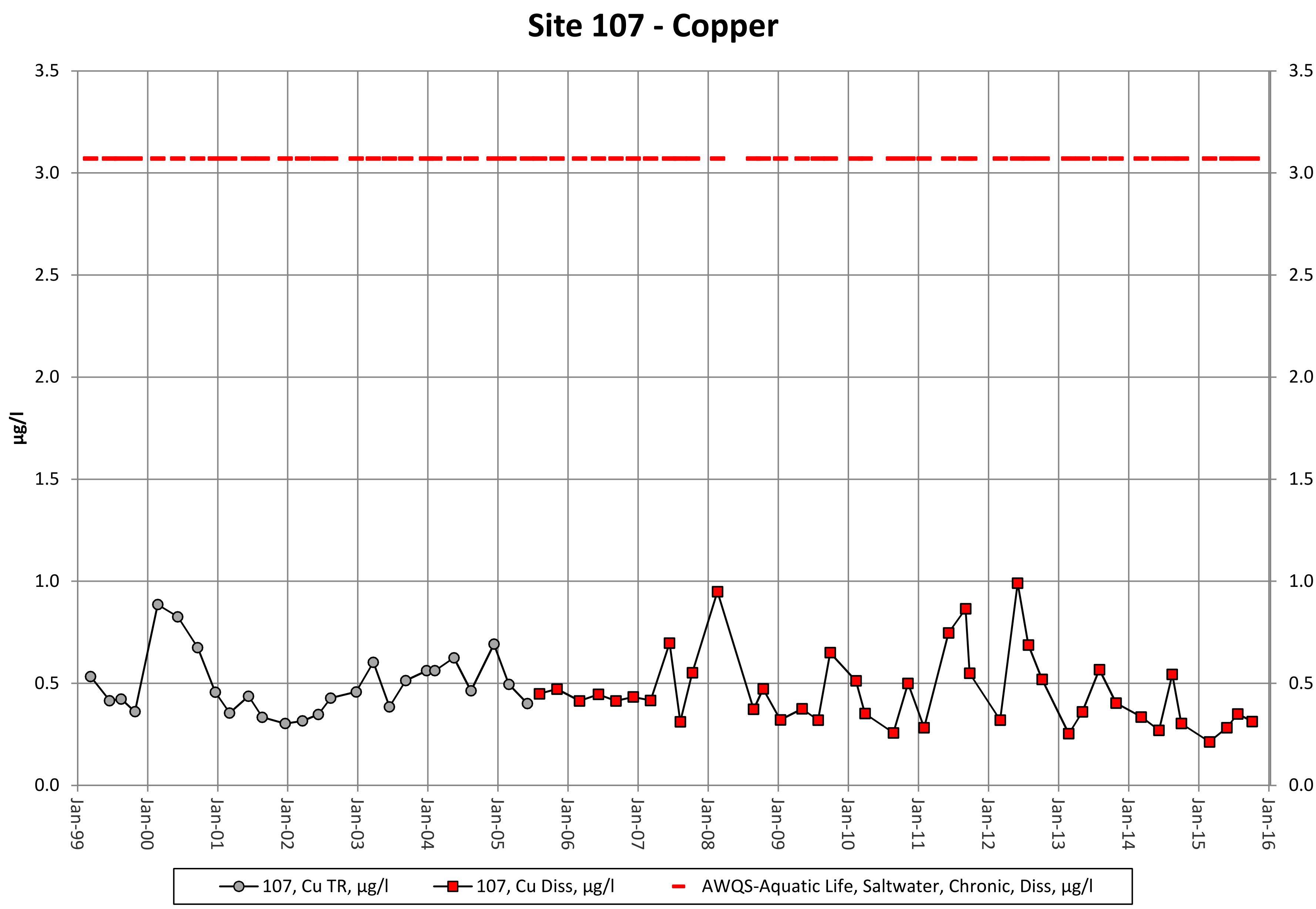
Site 108 - Cadmiun
Note: The chronic, aquatic life, AWQS for Dissolved Cadmium is 8.8 ug/L and this is not shown on this graph in order to allow greater visual detail of measured values for trend determination.
µg/l
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
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
108, Cd TR, µg/l
108, Cd Diss,µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-4a



Site 106 - Copper
µg/l
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
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
106, Cu TR, µg/l
106, Cu Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-4b



Site 107 - Copper
µg/l
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
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
107, Cu TR, µg/l
107, Cu Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-4c

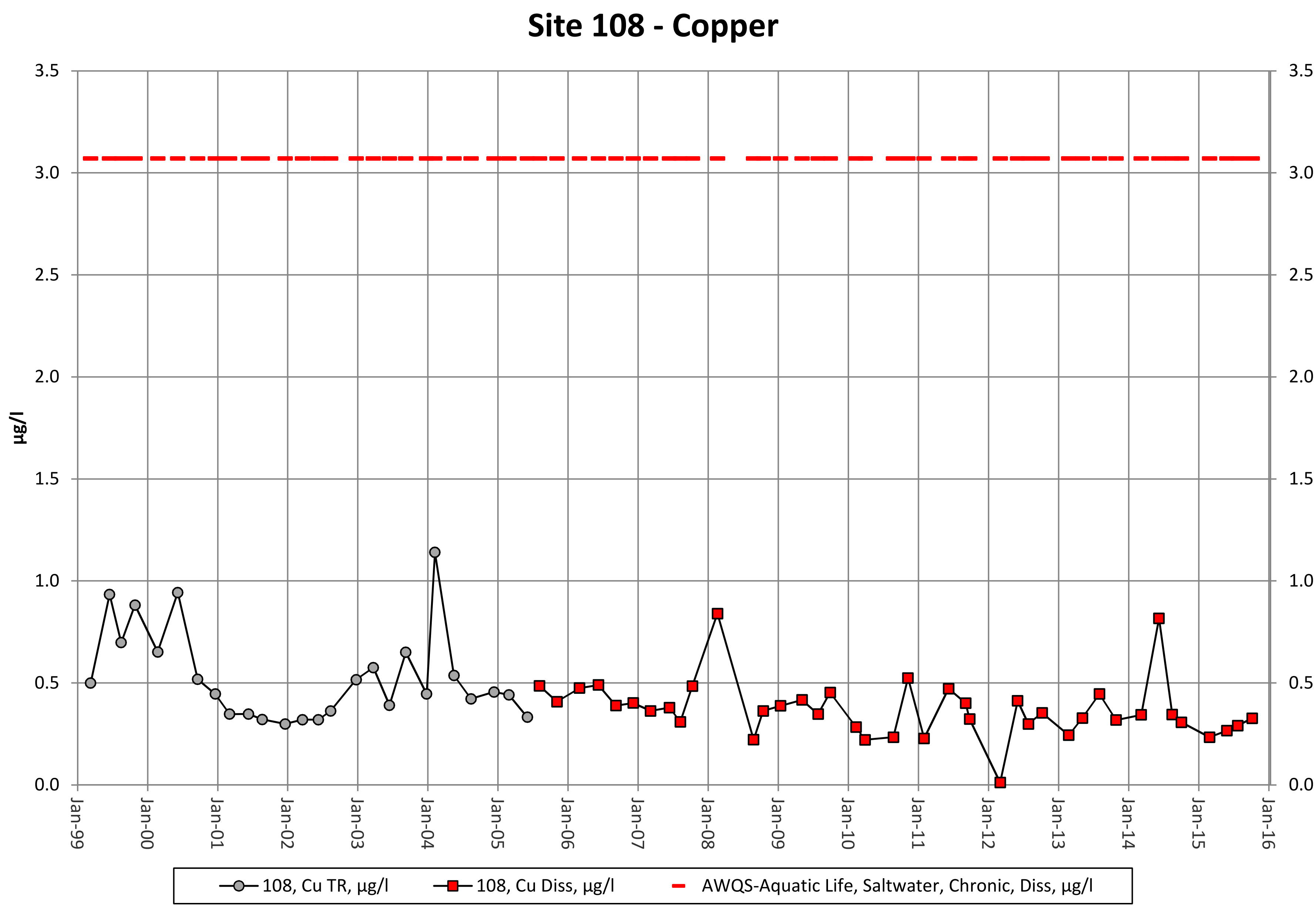
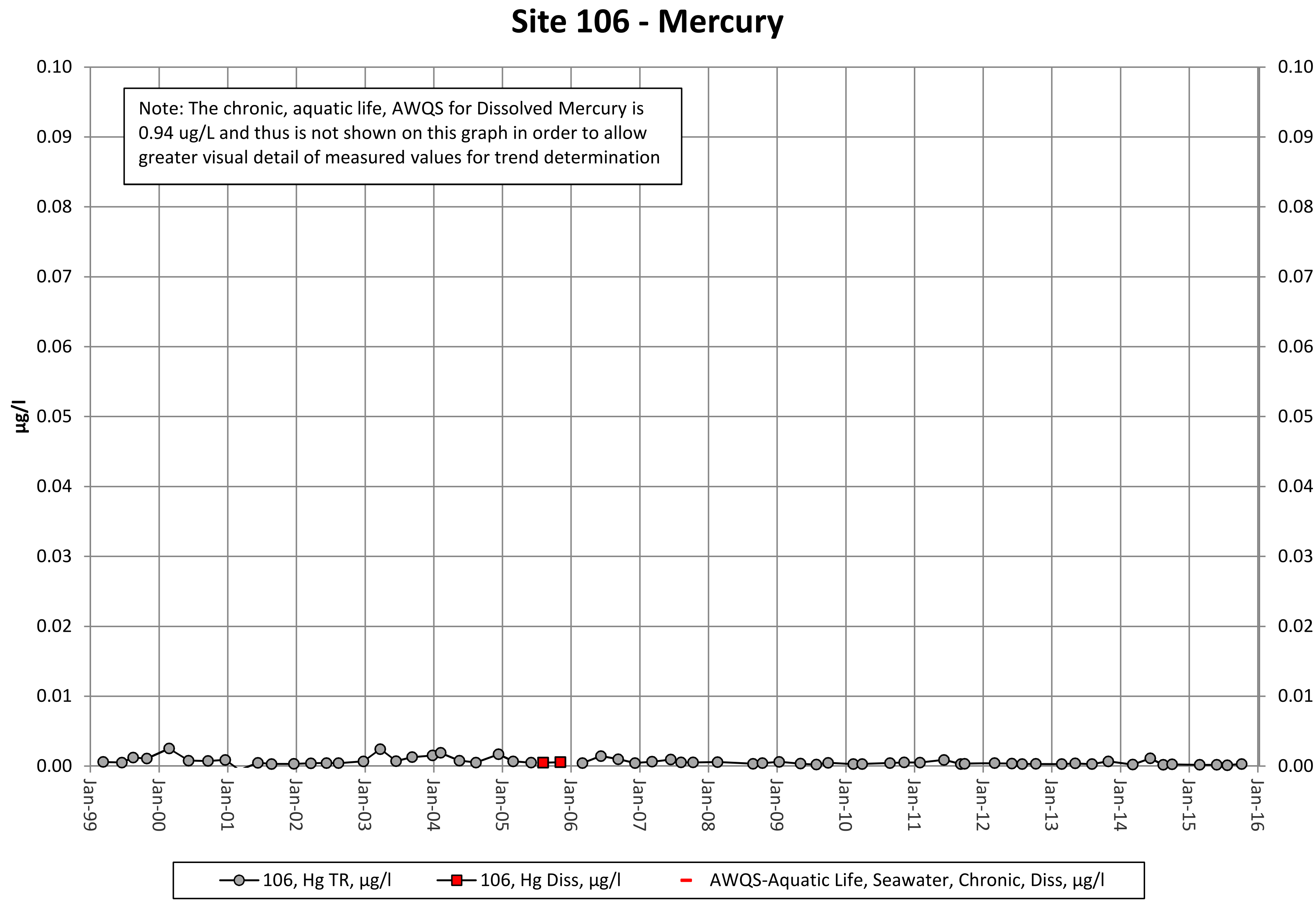

Site 108 - Copper
µg/l
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
108, Cu TR, µg/l
108, Cu Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-5a



Site 106 - Mercury
Note: The chronic, aquatic life, AWQS for Dissolved Mercury is 0.94 ug/L and thus is not shown on this graph in order to allow greater visual detail of measured values for trend determination
µg/l
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
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
106, Hg TR, µg/l
106, Hg Diss, µg/l
AWQS-Aquatic Life, Seawater, Chronic, Diss, µg/l

Figure 2-5b

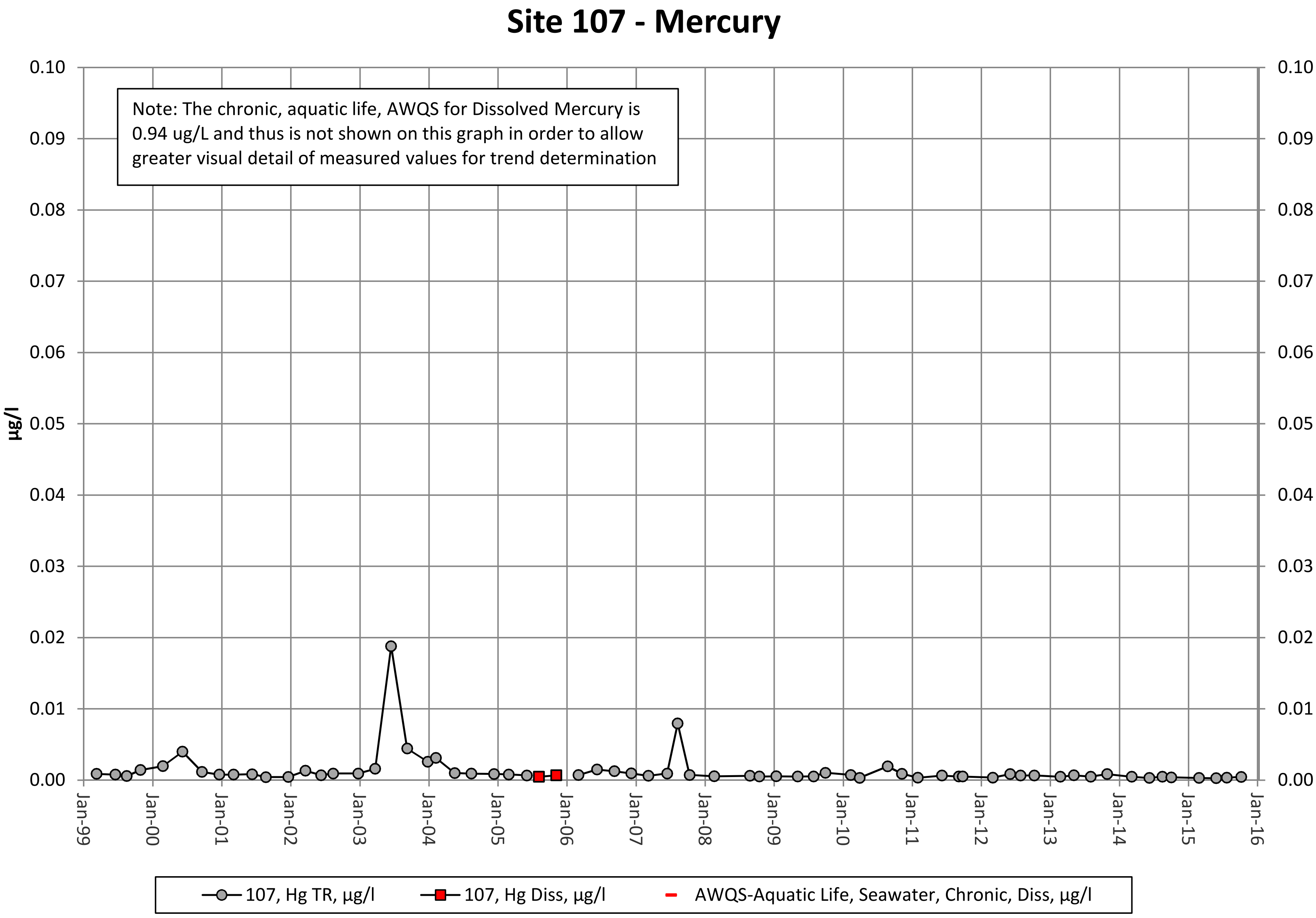
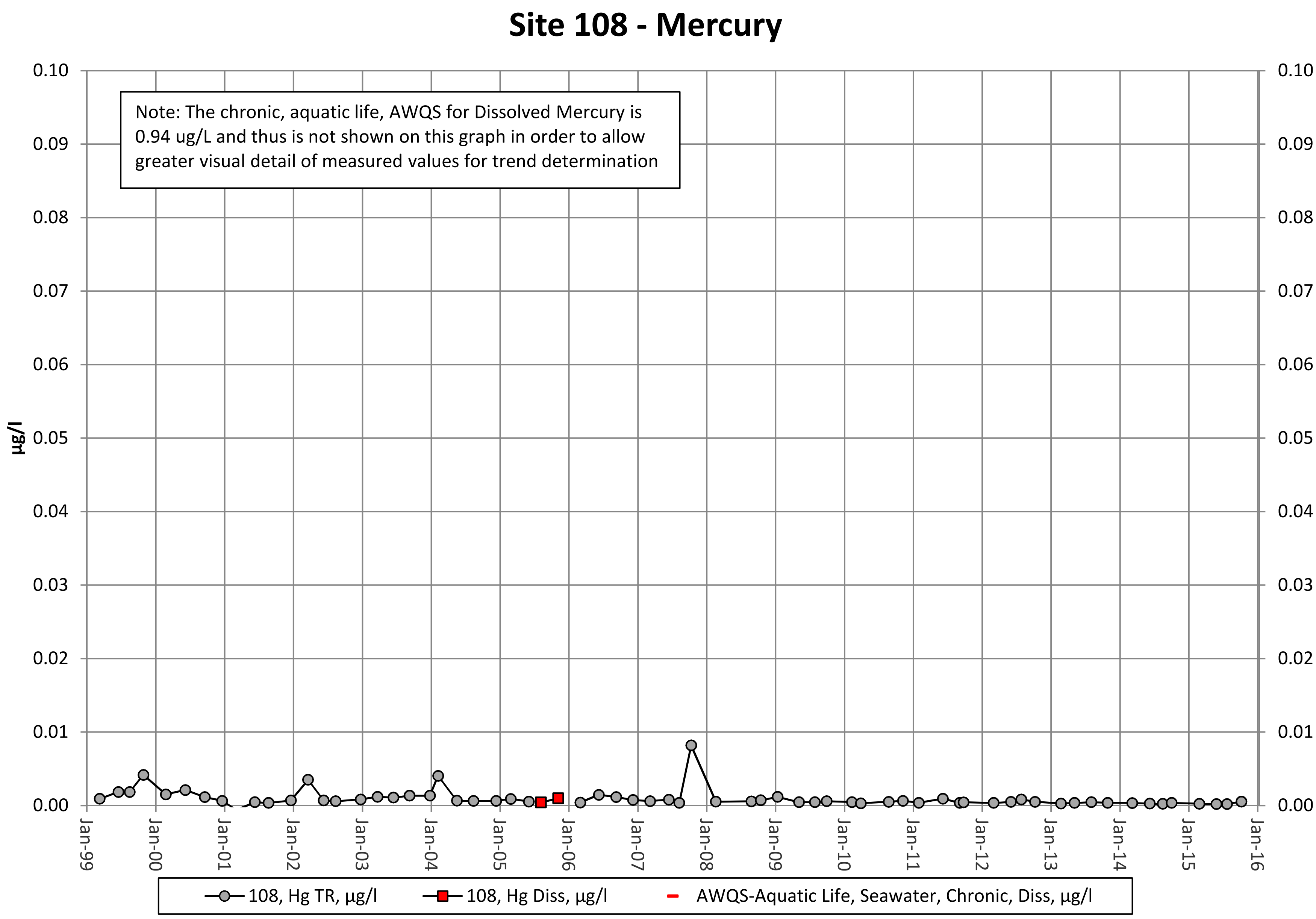
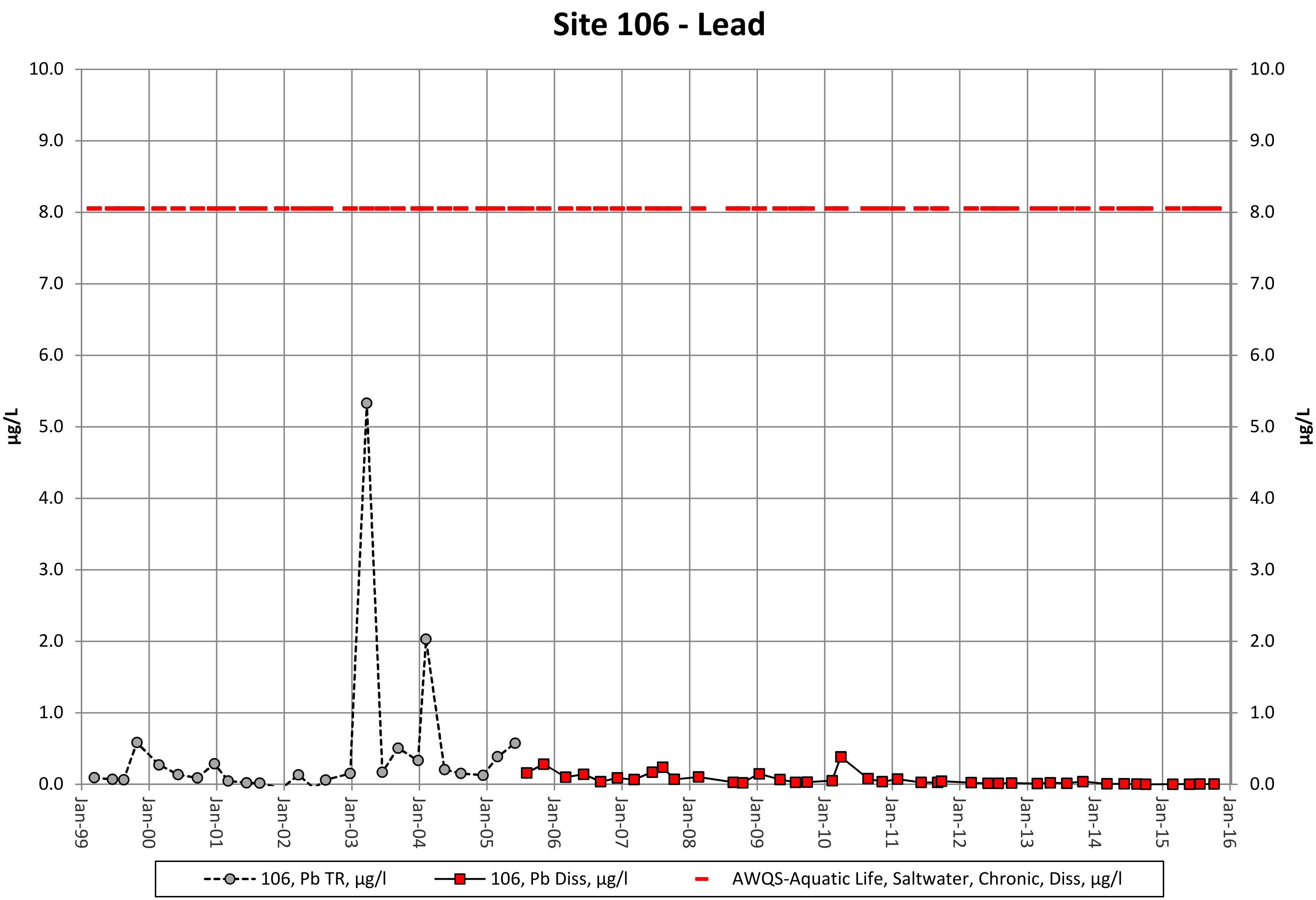

Site 107 - Mercury
Note: The chronic, aquatic life, AWQS for Dissolved Mercury is 0.94 ug/L and thus is not shown on this graph in order to allow greater visual detail of measured values for trend determination
µg/l
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
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
107, Hg TR, µg/l
107, Hg Diss, µg/l
AWQS-Aquatic Life, Seawater, Chronic, Diss, µg/l

Figure 2-5c



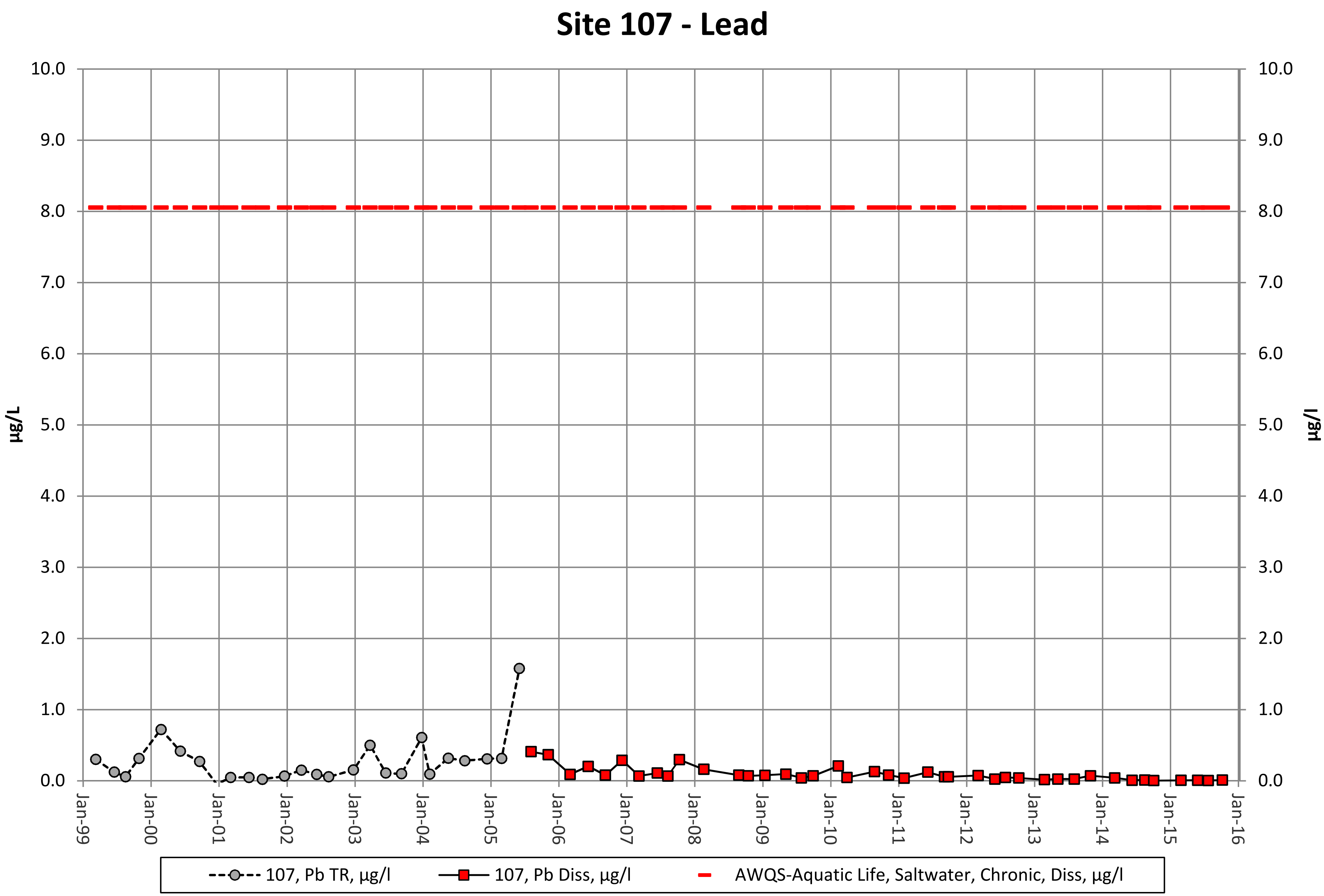
Site 108 - Mercury
Note: The chronic, aquatic life, AWQS for Dissolved Mercury is 0.94 ug/L and thus is not shown on this graph in order to allow greater visual detail of measured values for trend determination
µg/l
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
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
108, Hg TR, µg/l
108, Hg Diss, µg/l
AWQS-Aquatic Life, Seawater, Chronic, Diss, µg/l

Figure 2-6a



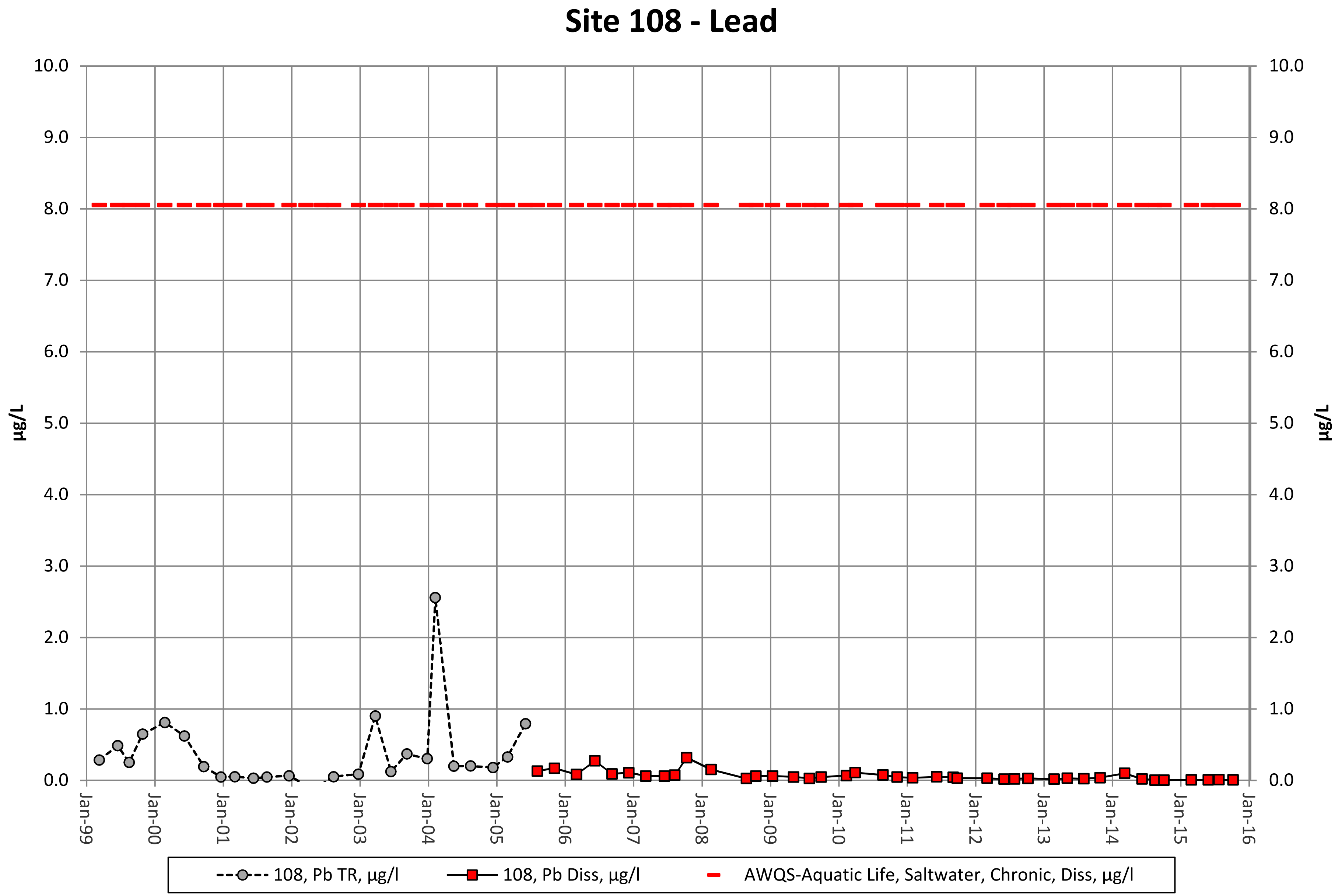
Site 106 - Lead
μg/L
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
106, Pb TR, µg/l
106, Pb Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-6b



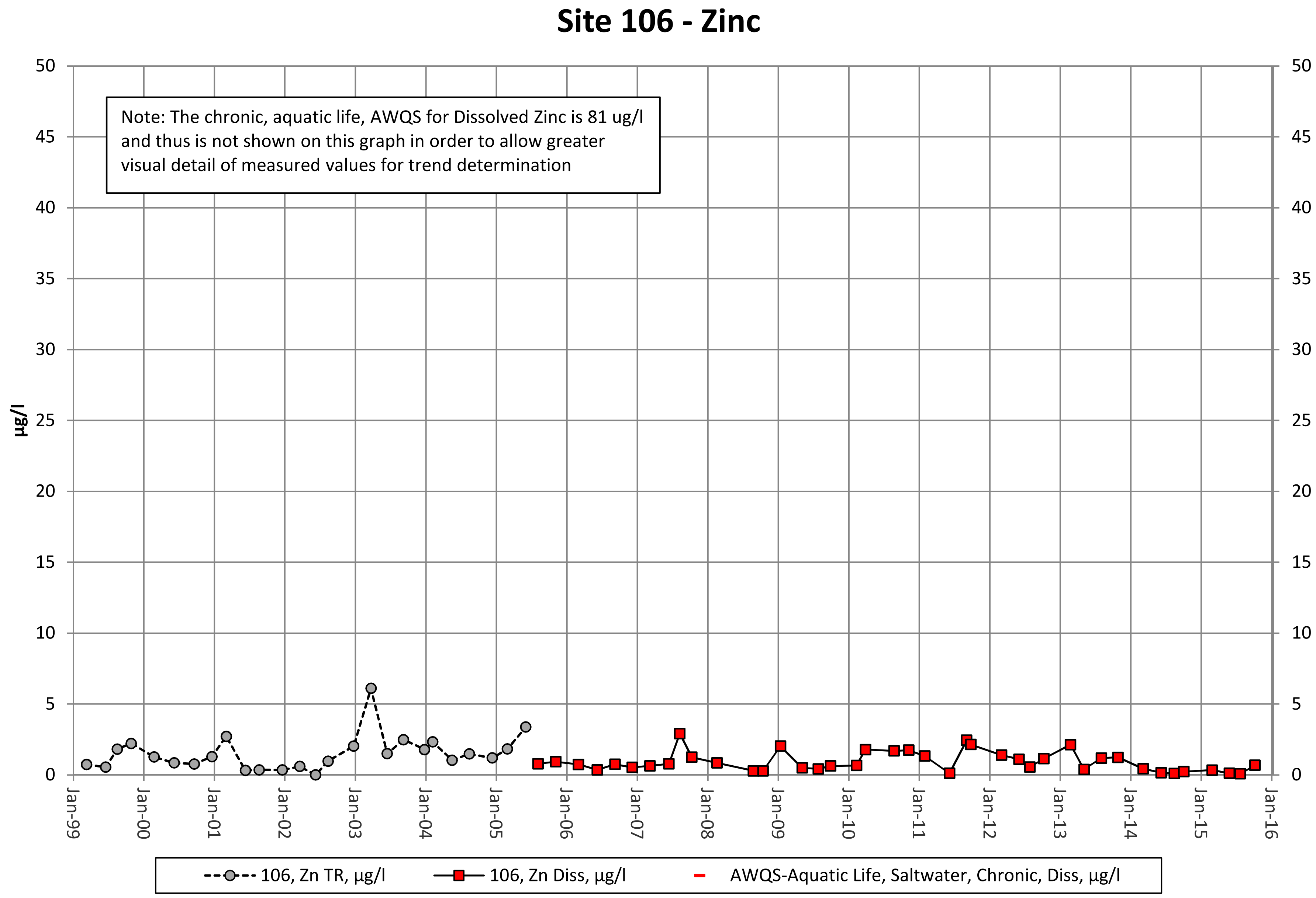
Site 107 - Lead
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
µg/L
µg/l
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
107, Pb TR, µg/l
107, Pb Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-6c



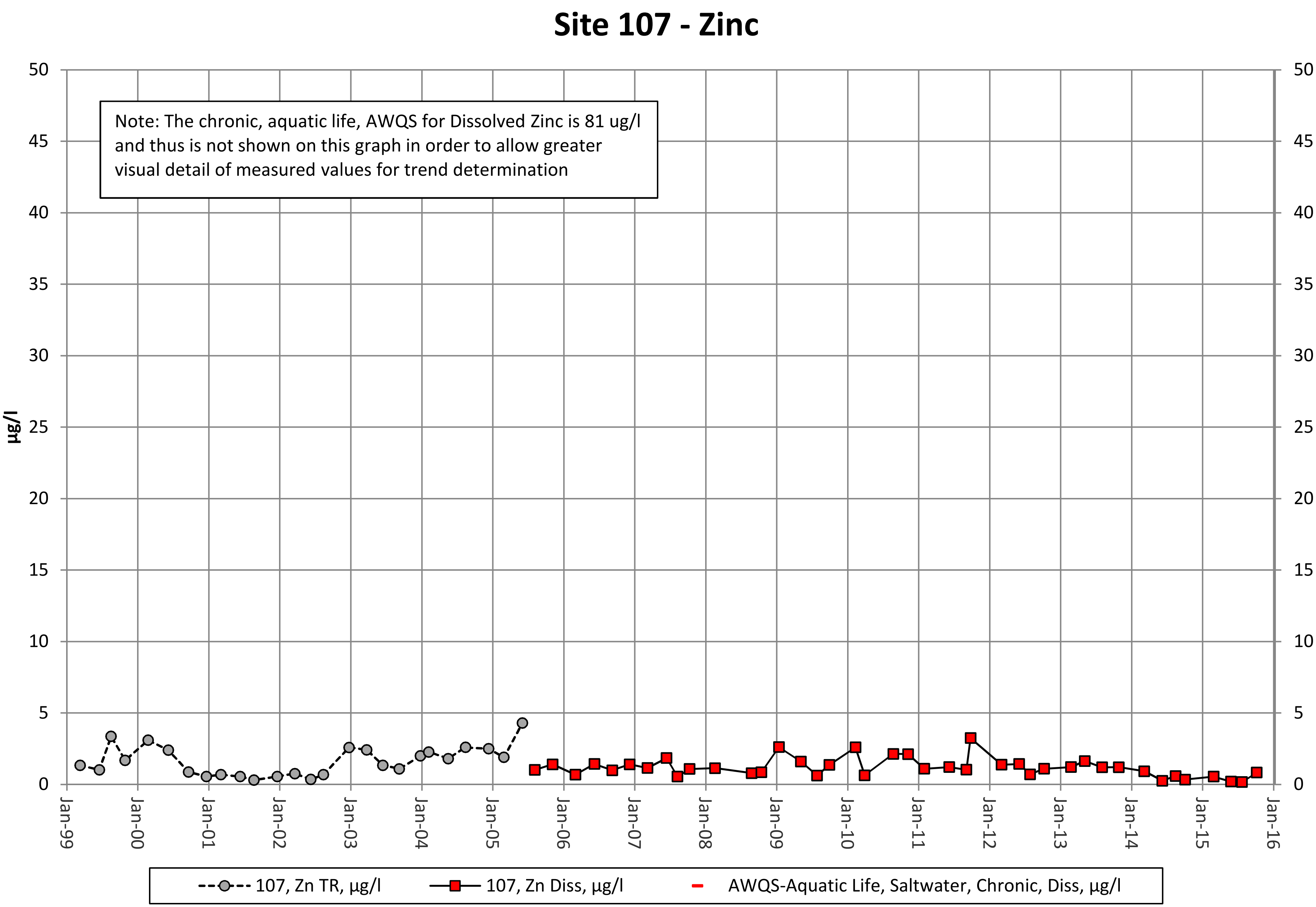
Site 108 - Lead
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
µg/L
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
108, Pb TR, µg/l
108, Pb Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-7a



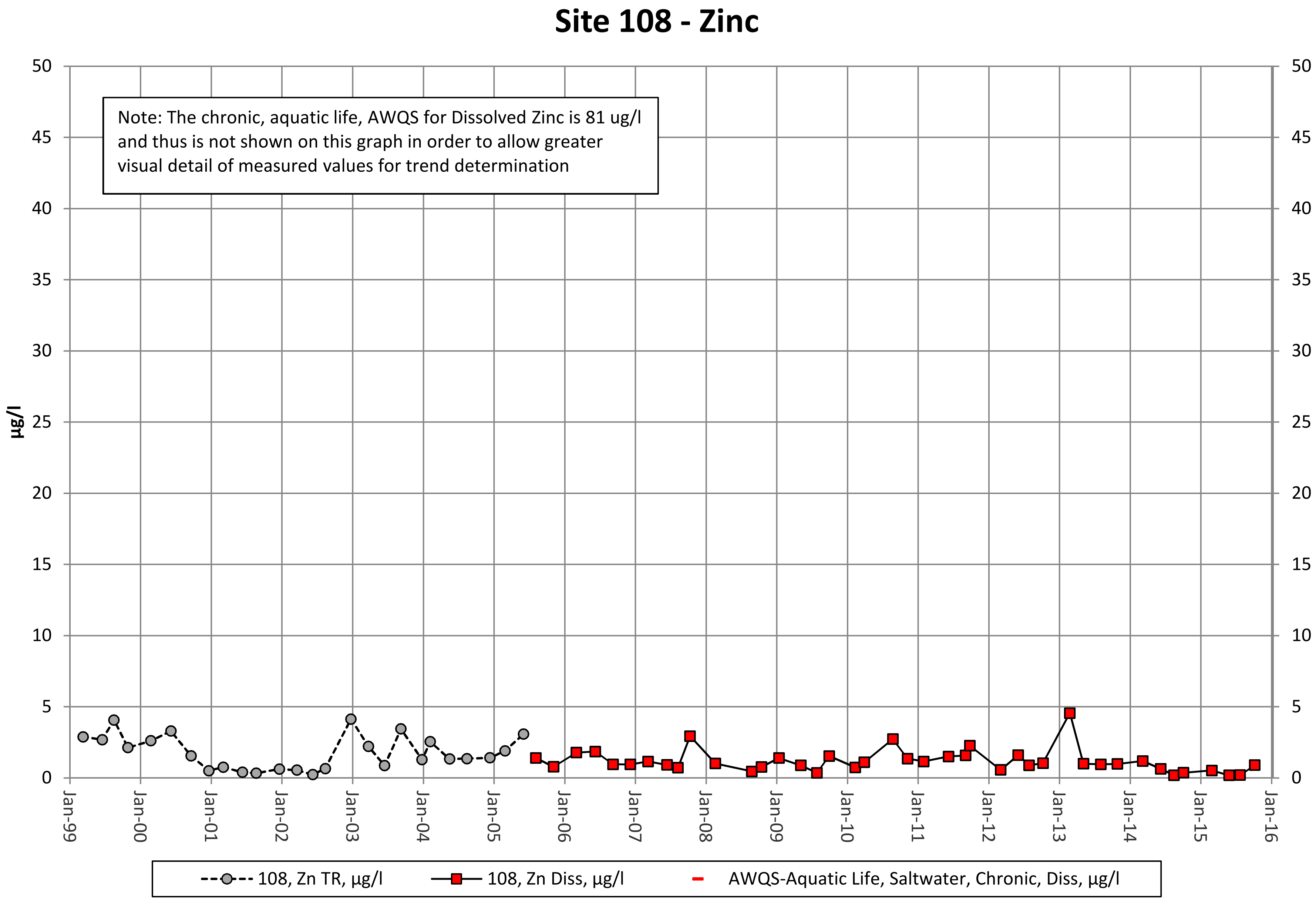
Site 106 - Zinc
Note: The chronic, aquatic life, AWQS for Dissolved Zinc is 81 ug/l and thus is not shown on this graph in order to allow greater visual detail of measured values for trend determination
µg/l
0
5
10
15
20
25
30
35
40
45
50
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
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
µg/l
0
5
10
15
20
25
30
35
40
45
50
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
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
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
108, Zn TR, µg/l
108, Zn Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

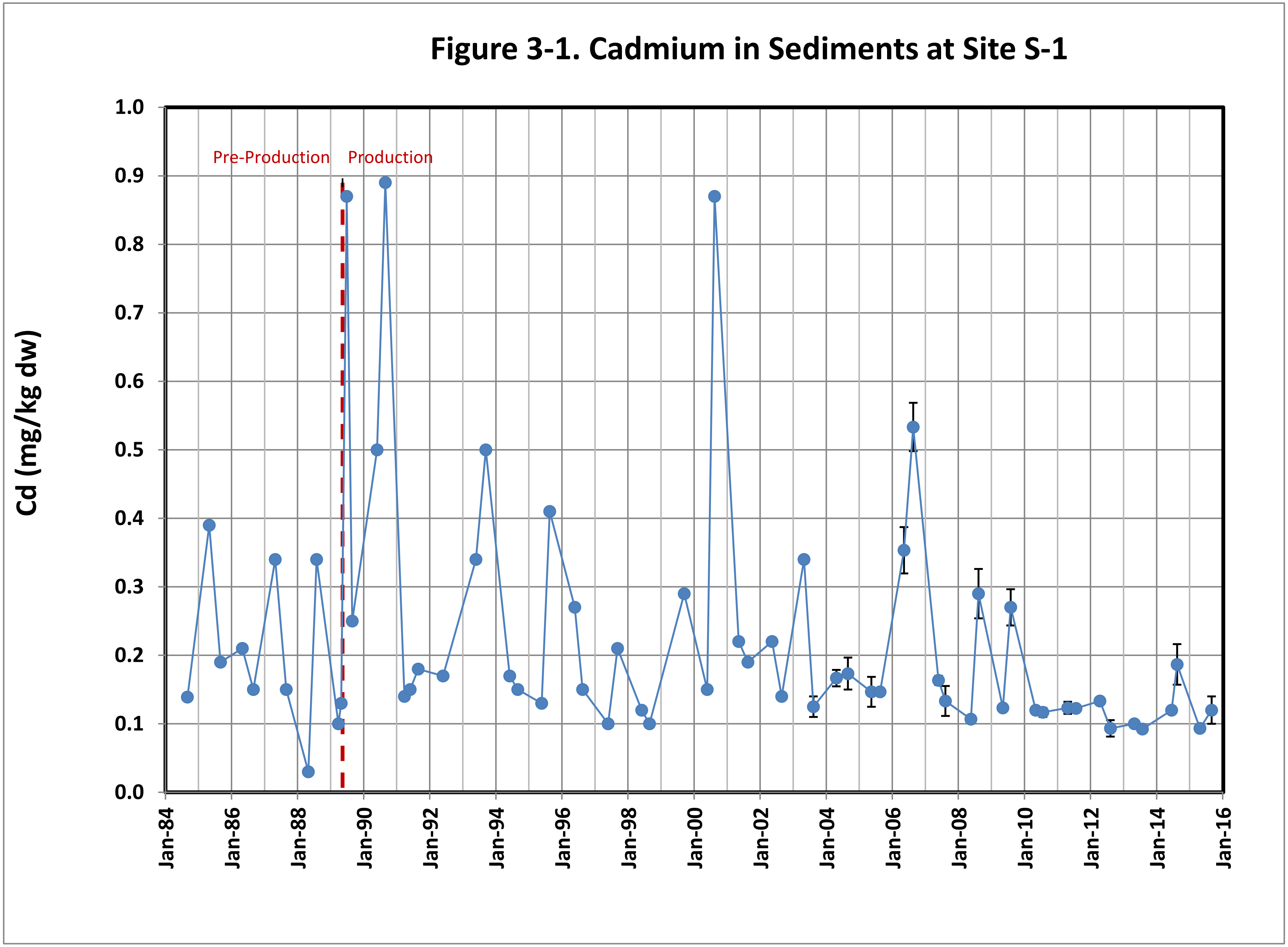


Figure 3-1. Cadmium in Sediments at Site S-1
Cd (mg/kg dw)
Pre-Production
Production
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

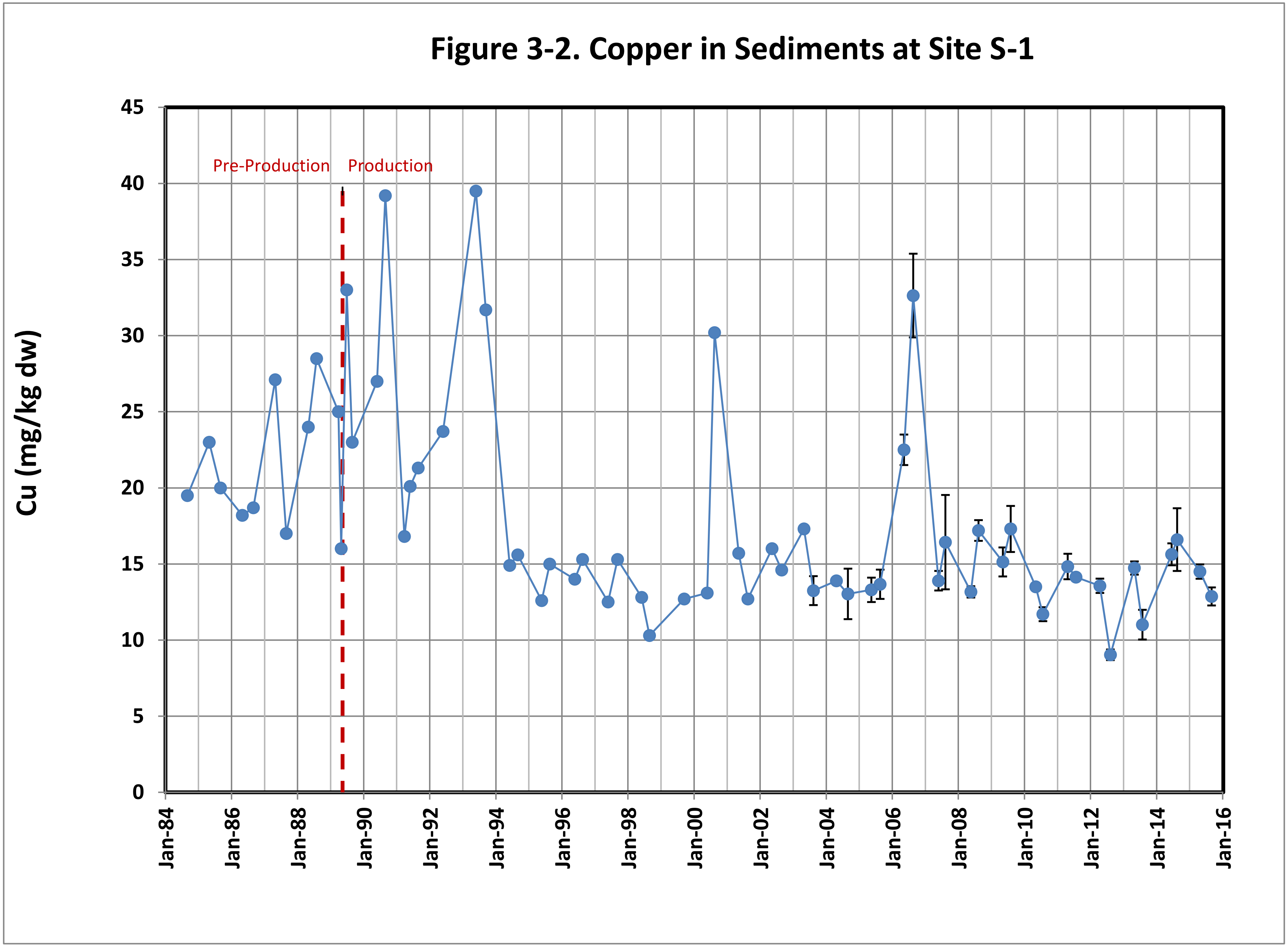


Figure 3-2. Copper in Sediments at Site S-1
Cu (mg/kg dw)
Pre-Production
Production
0
5
10
15
20
25
30
35
40
45
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

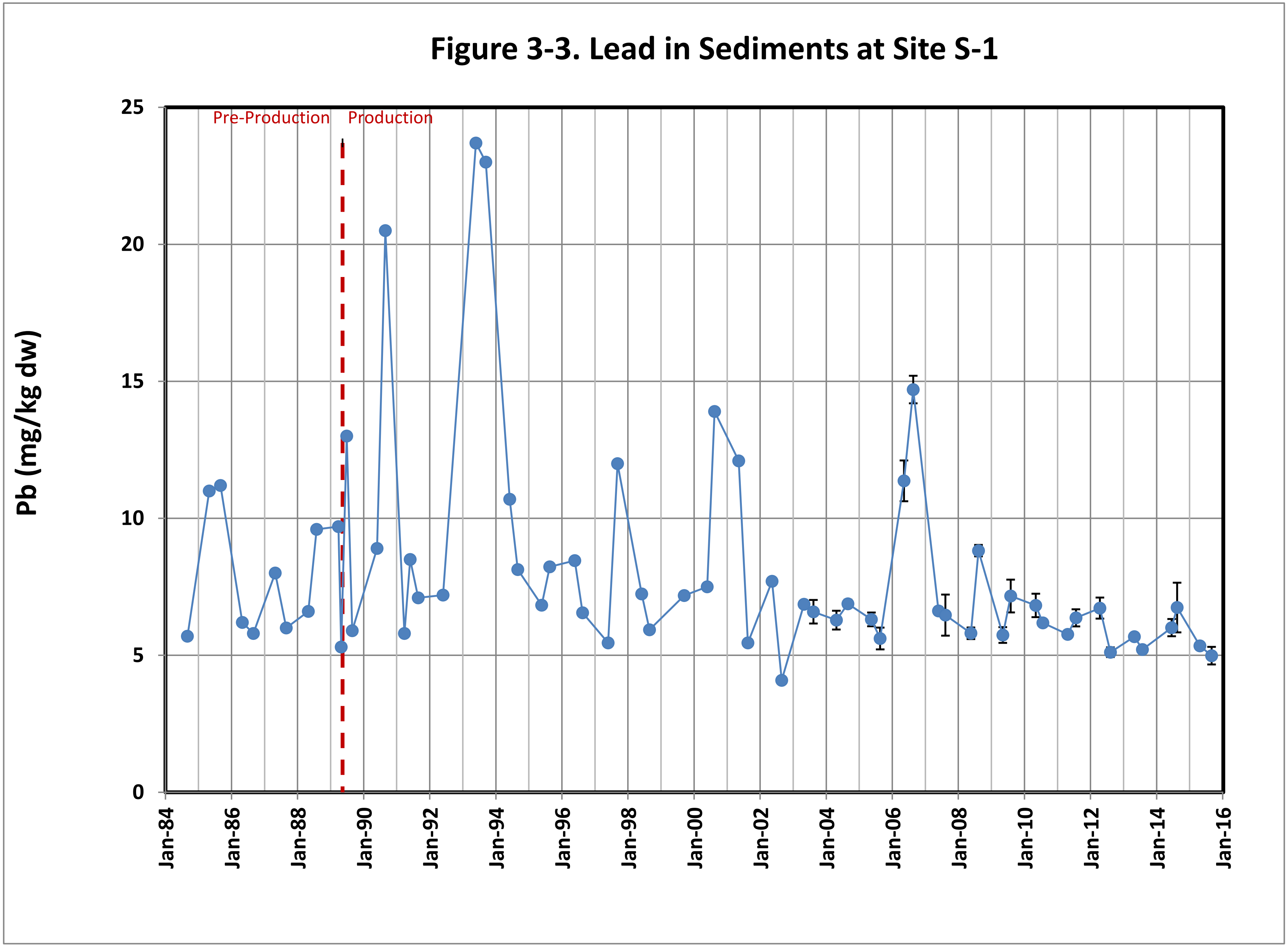


Figure 3-3. Lead in Sediments at Site S-1
Pre-Production
Production
Pb (mg/kg dw)
25
20
15
10
5
0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

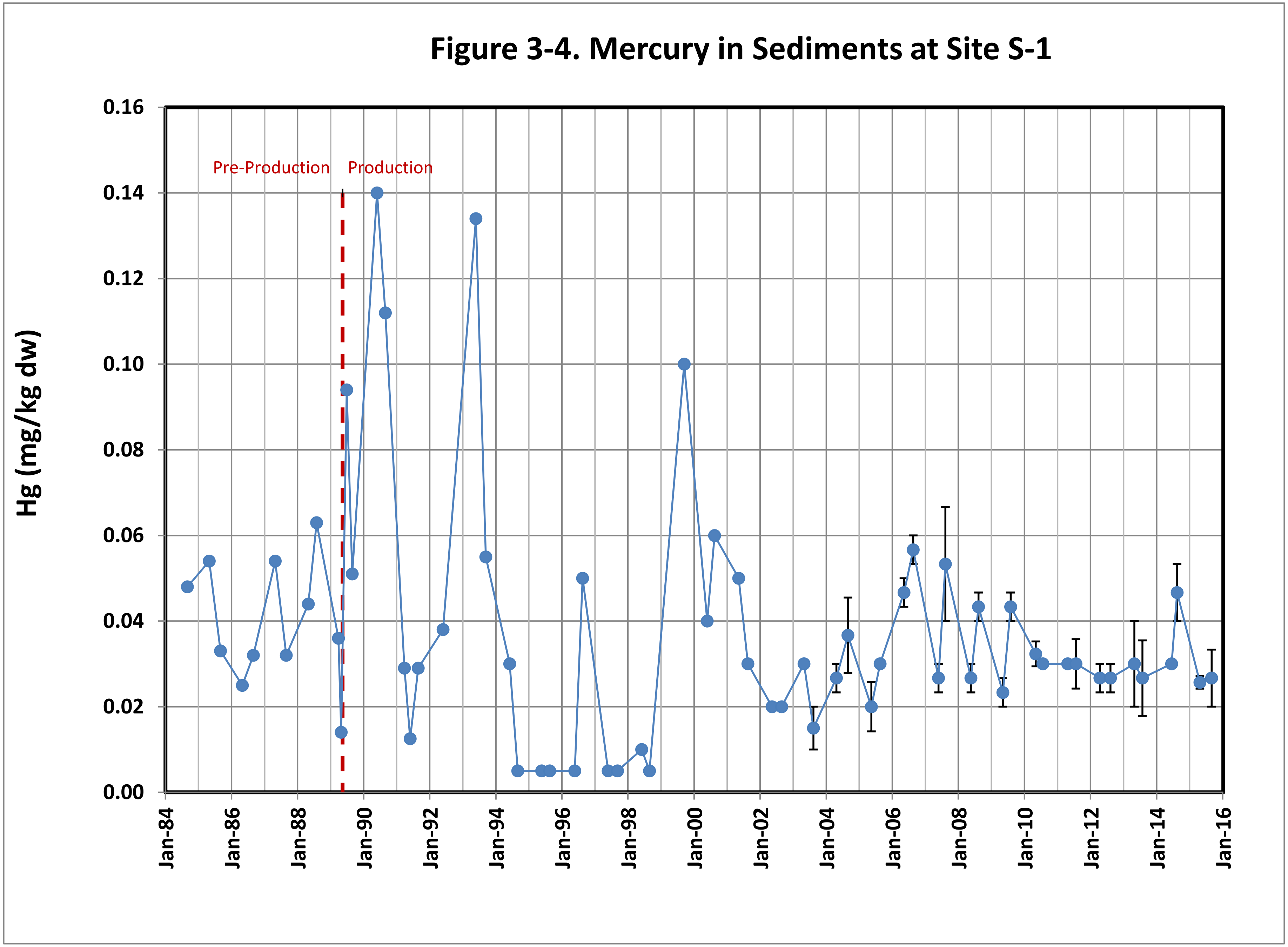


Figure 3-4. Mercury in Sediments at Site S-1
Hg (mg/kg dw)
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

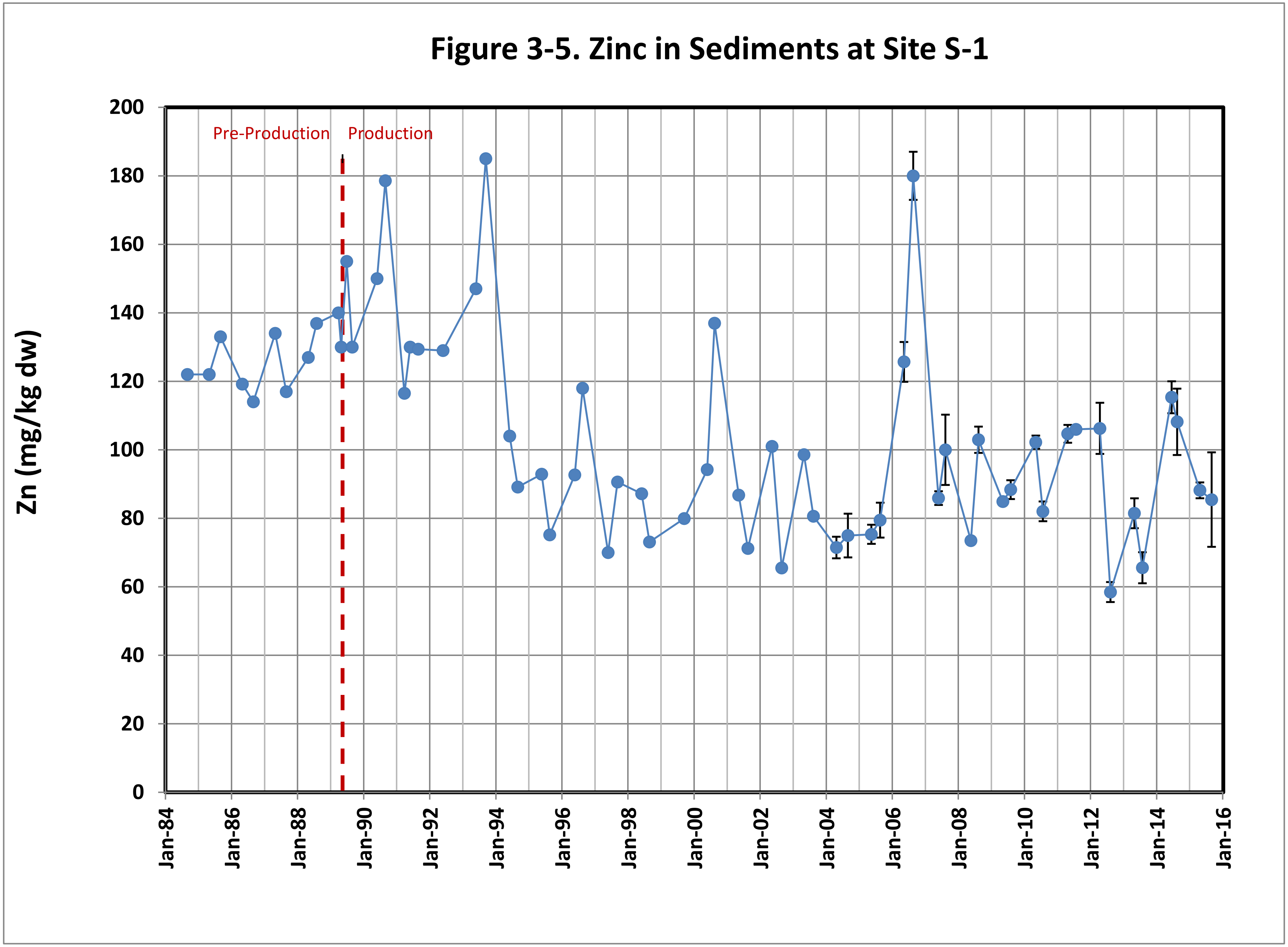


Figure 3-5. Zinc in Sediments at Site S-1
Pre-Production
Production
Zn (mg/kg dw)
0
20
40
60
80
100
120
140
160
180
200
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

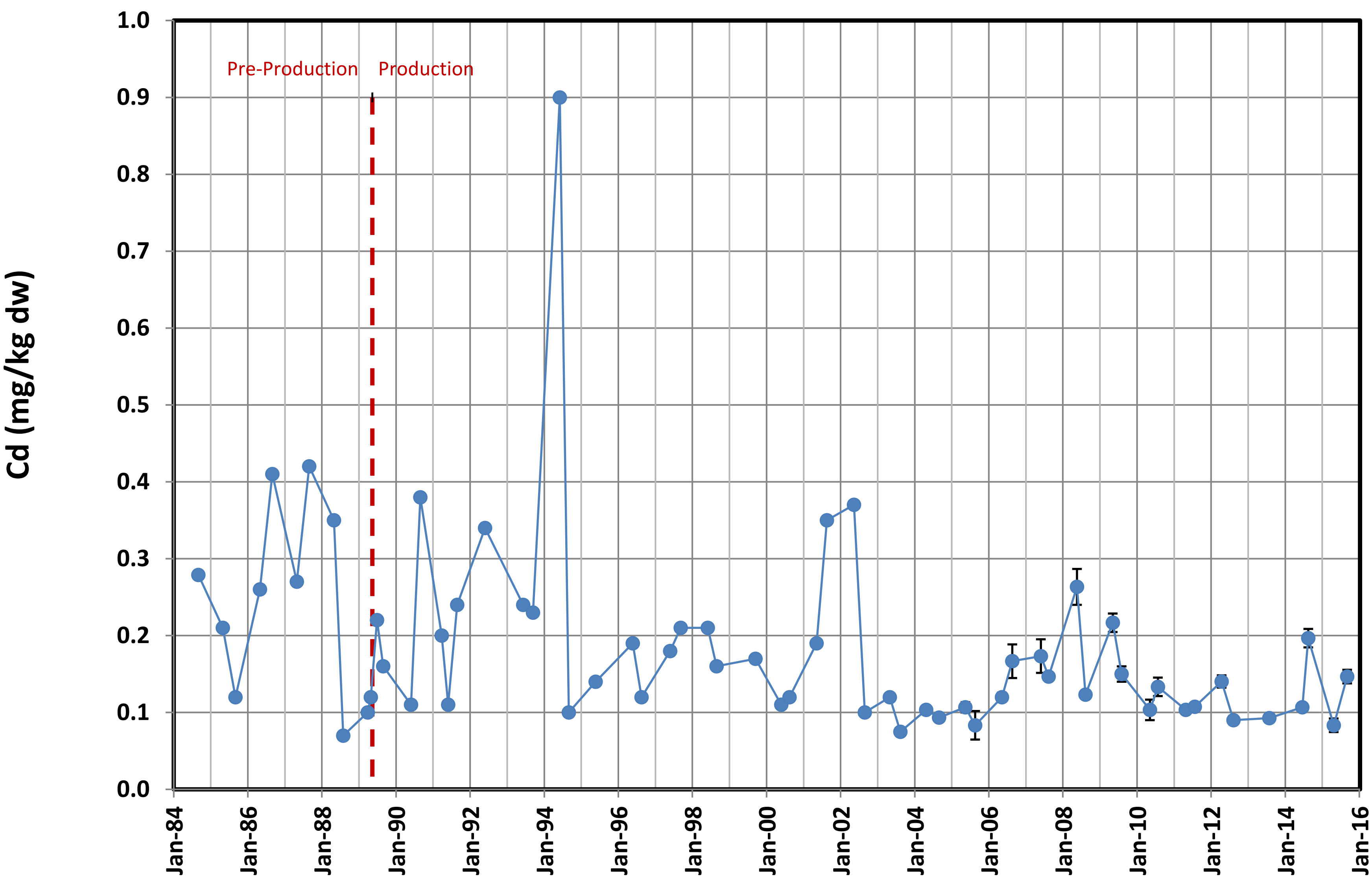



**Figure 3-6. Cadmium in Sediments at Site S-2**

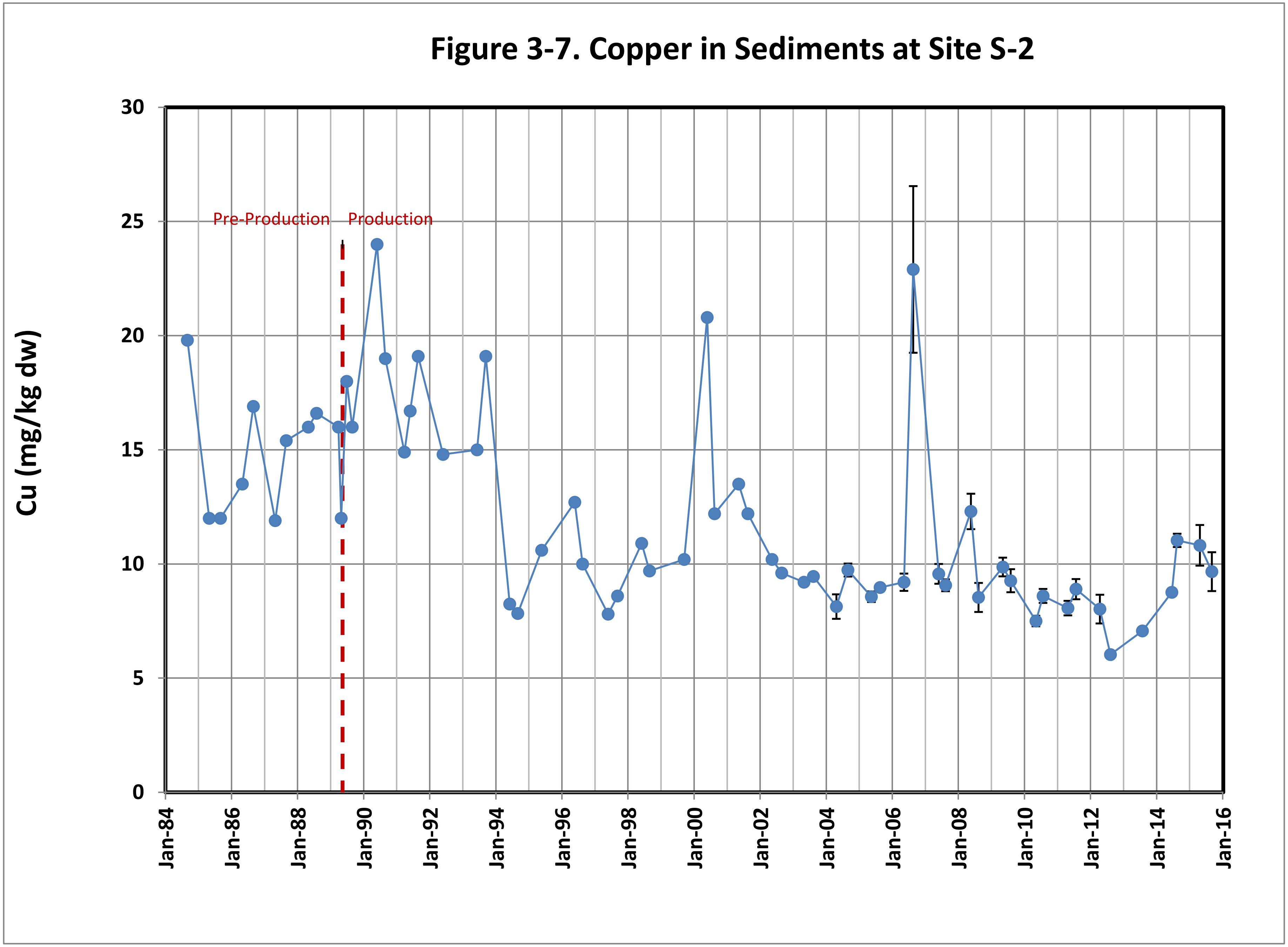


Figure 3-7. Copper in Sediments at Site S-2
Cu (mg/kg dw)
Pre-Production
Production
30
25
20
15
10
5
0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

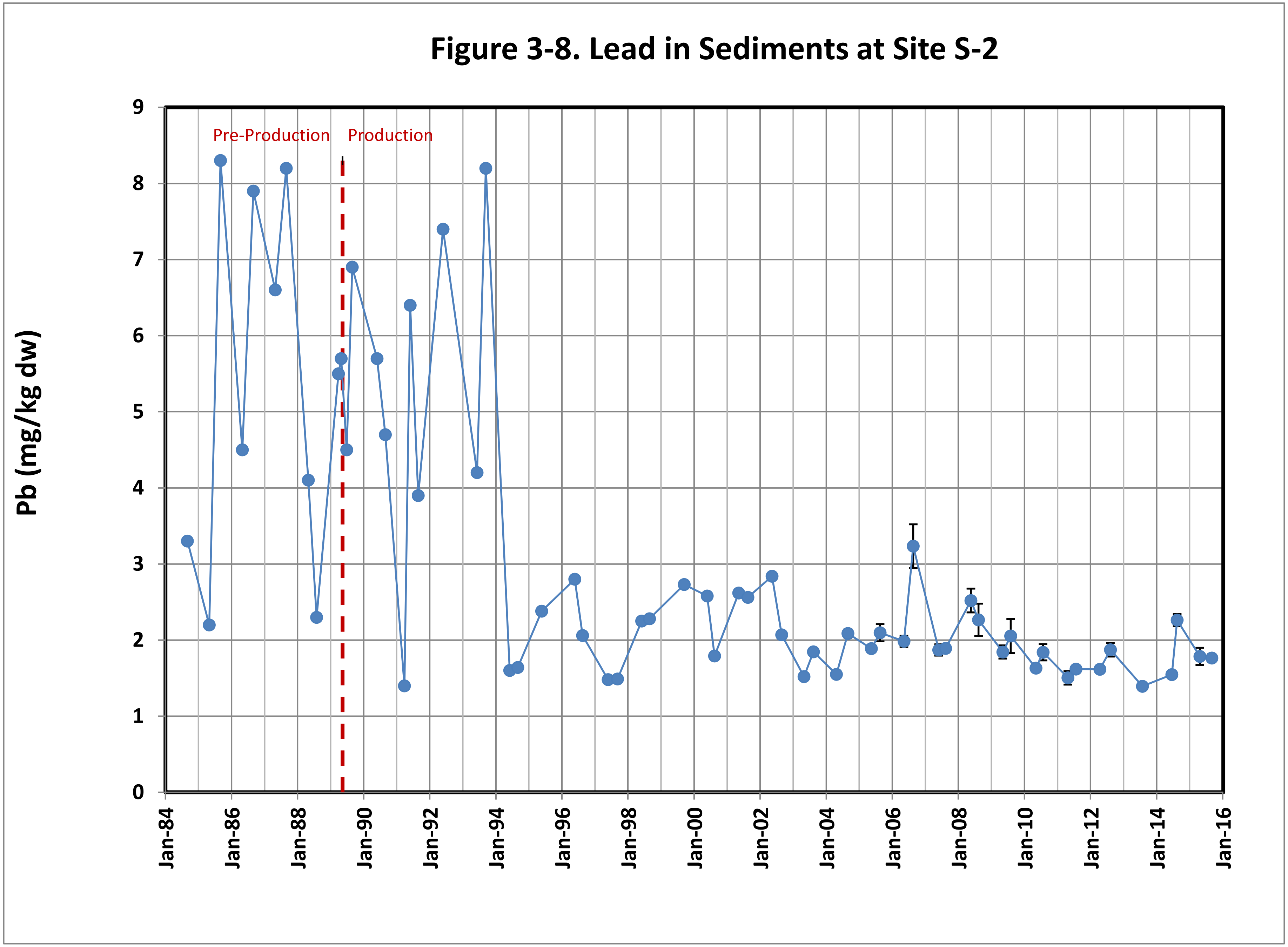


Figure 3-8. Lead in Sediments at Site S-2
Pb (mg/kg dw)
Pre-Production
Production
0
1
2
3
4
5
6
7
8
9
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

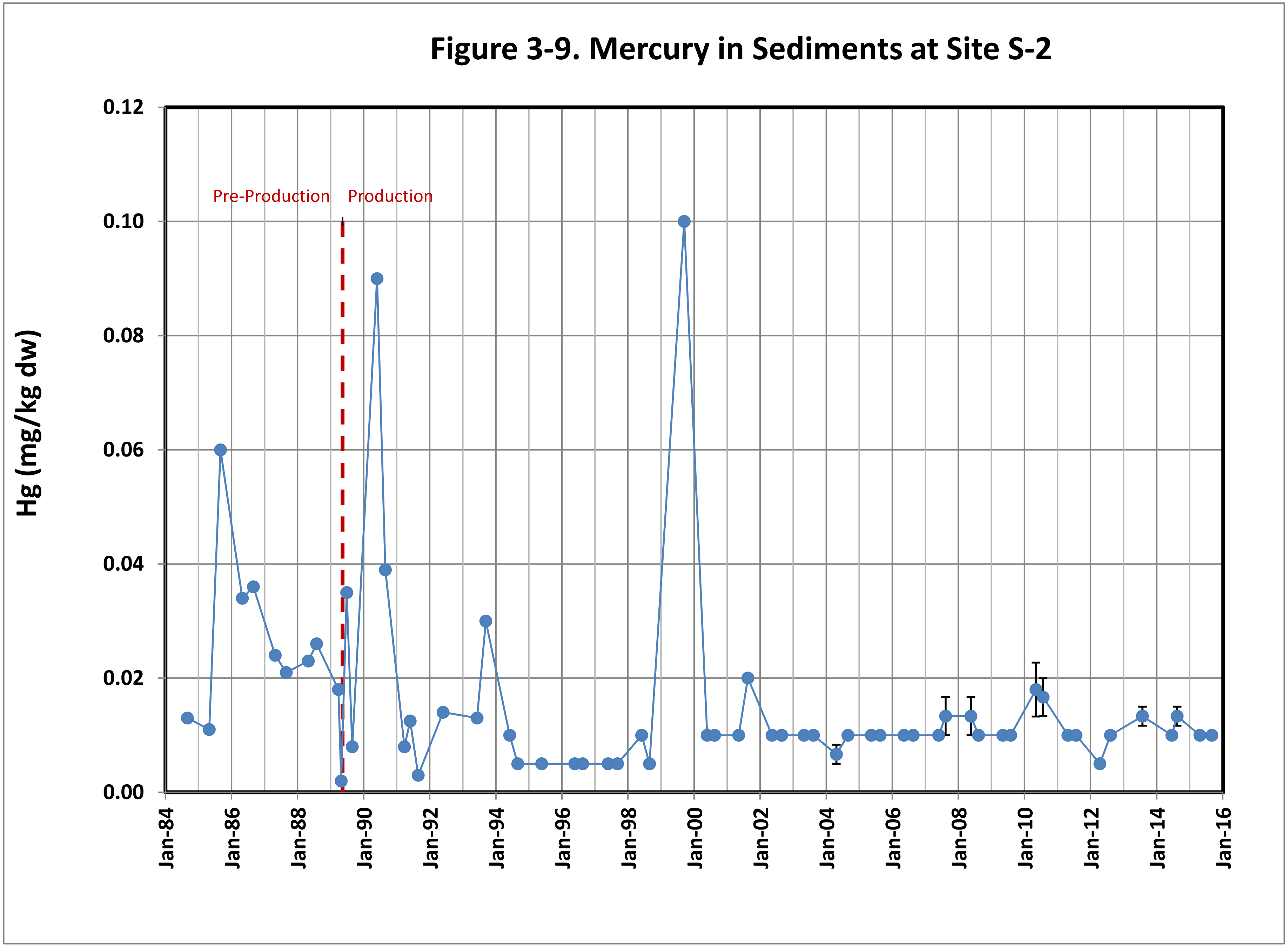


Figure 3-9. Mercury in Sediments at Site S-2
Hg (mg/kg dw)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

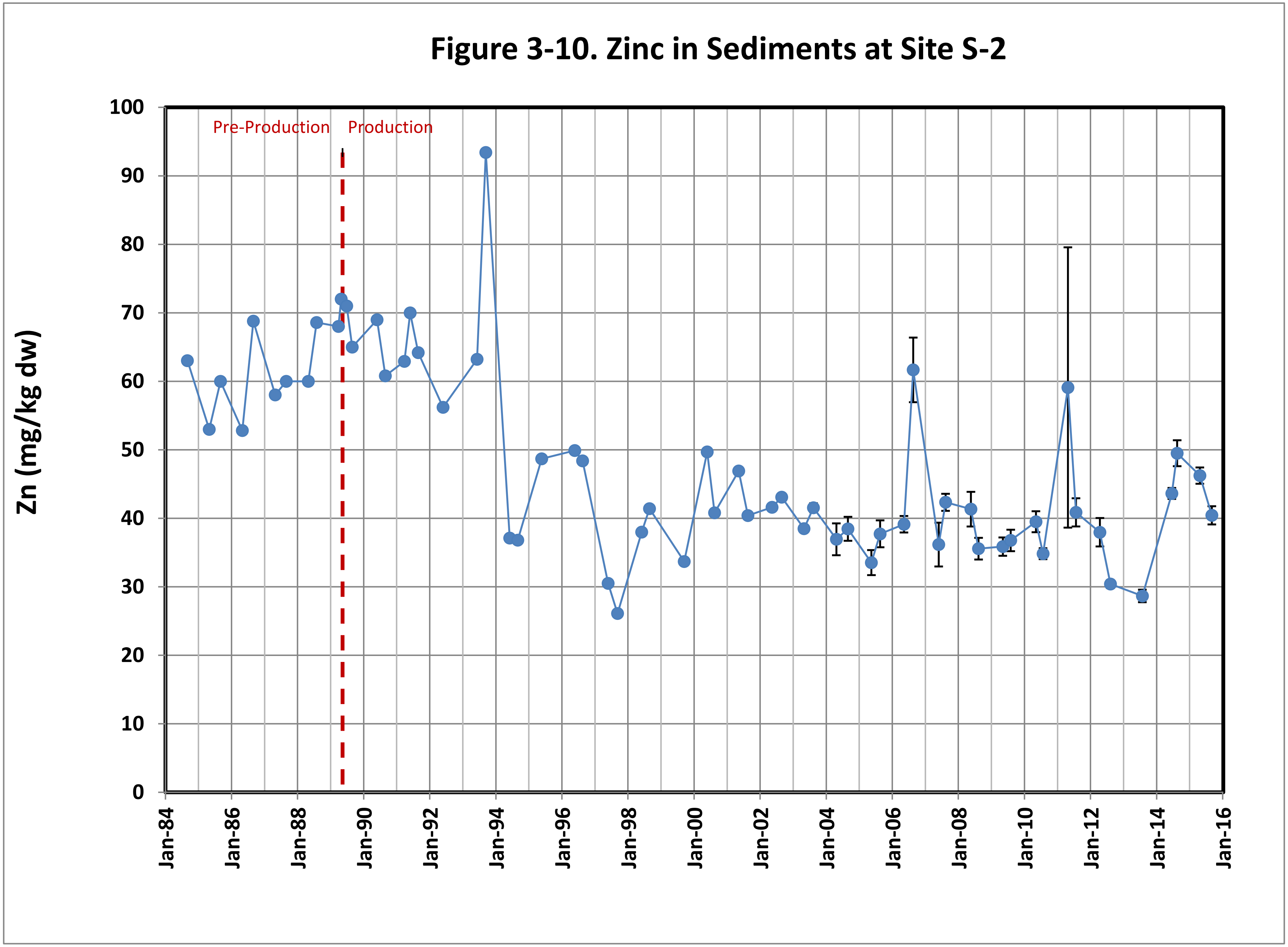
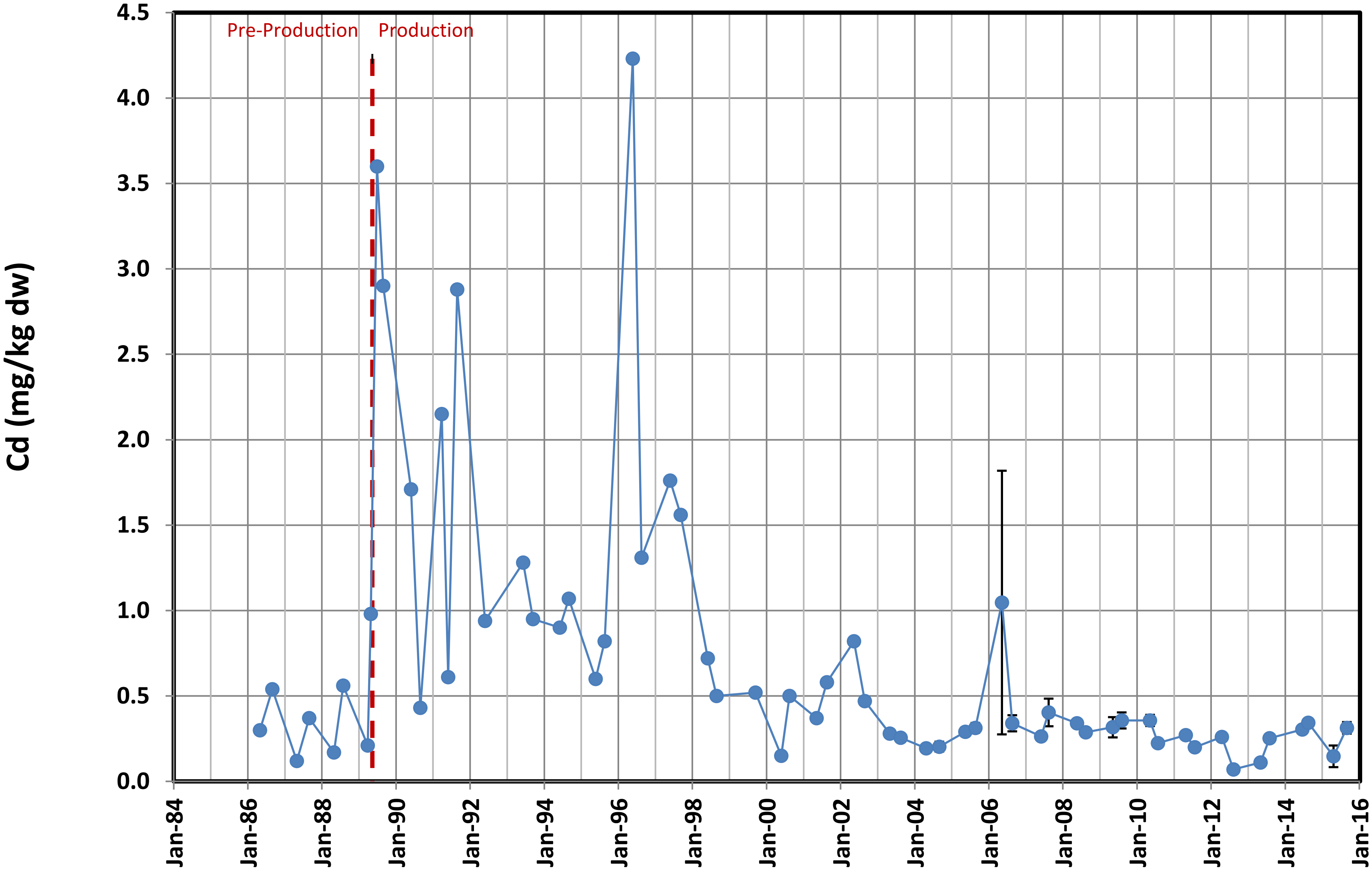
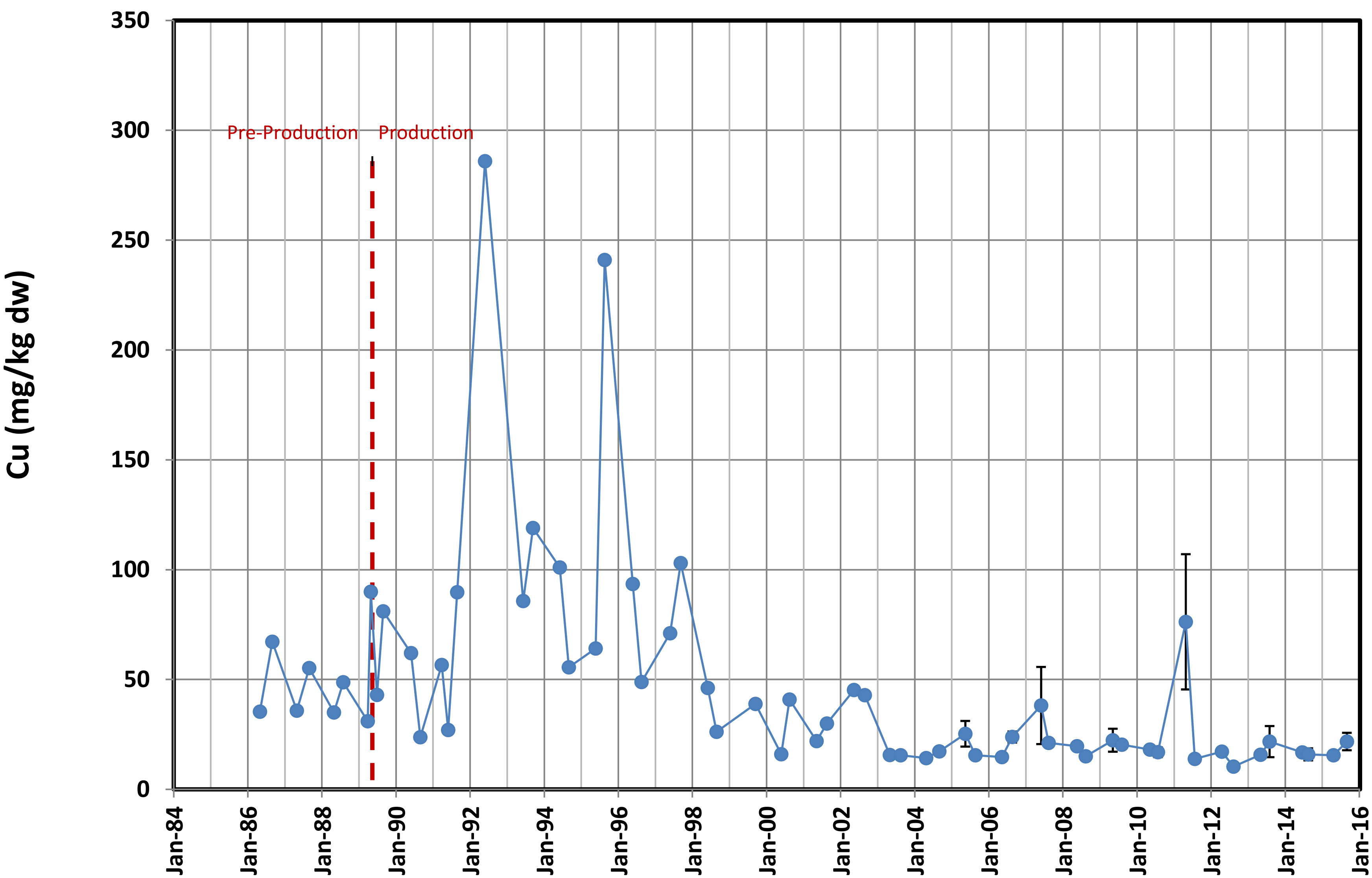


Figure 3-10. Zinc in Sediments at Site S-2
Zn (mg/kg dw)
Pre-Production
Production
100
90
80
70
60
50
40
30
20
10
0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

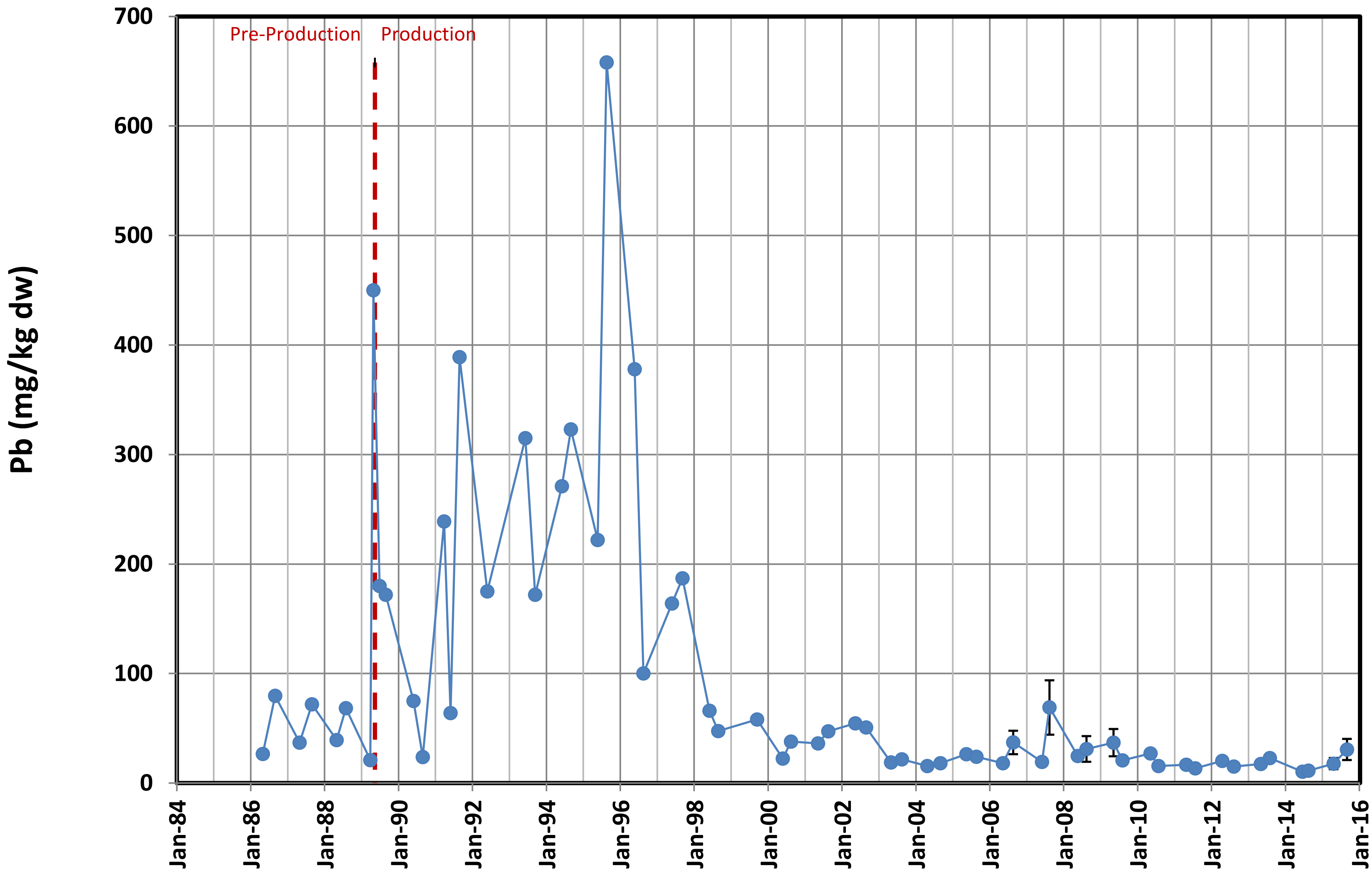
# Figure 3-11. Cadmium in Sediments at Site S-4



# Figure 3-12. Copper in Sediments at Site S-4



# Figure 3-13. Lead in Sediments at Site S-4



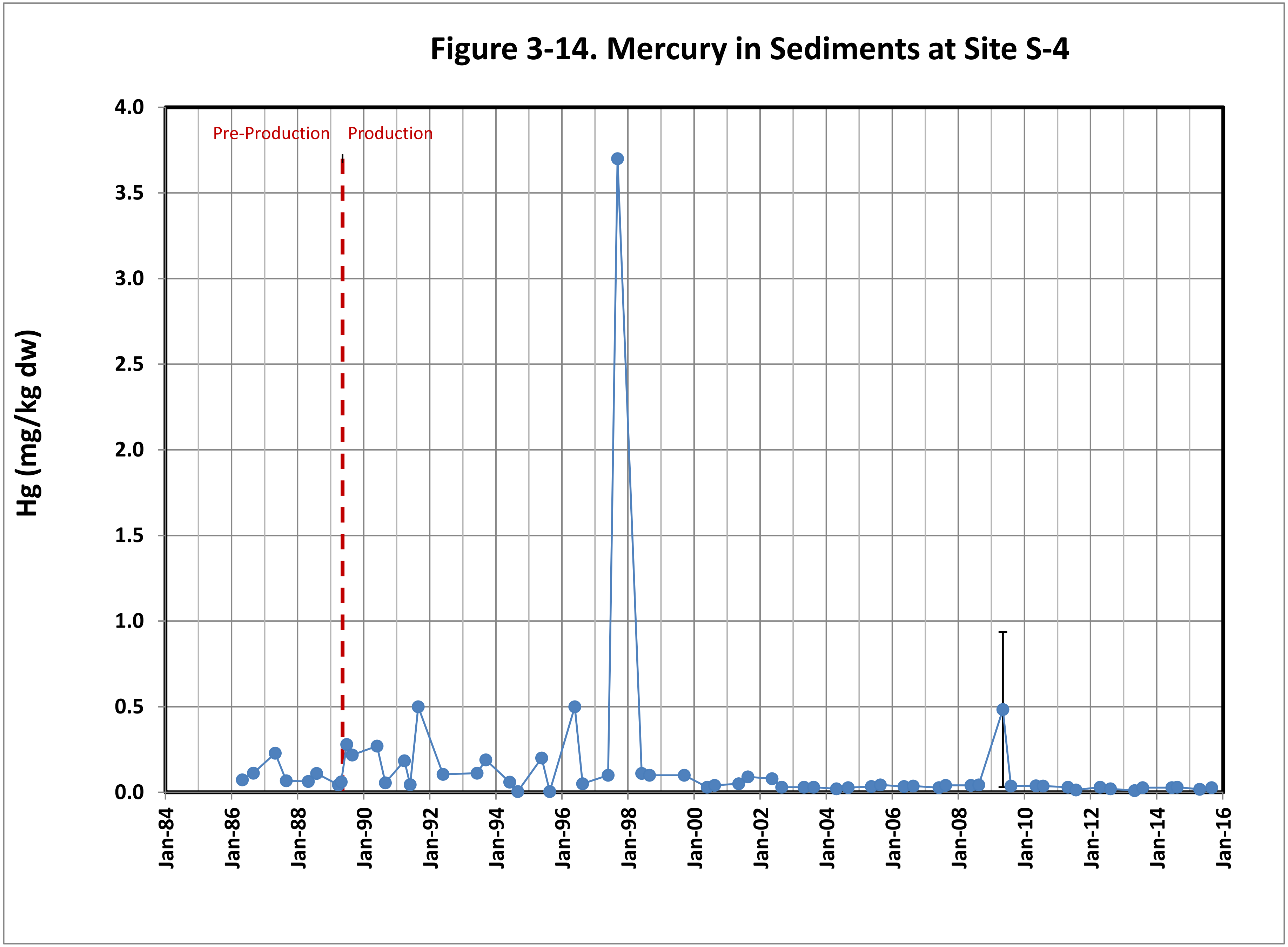
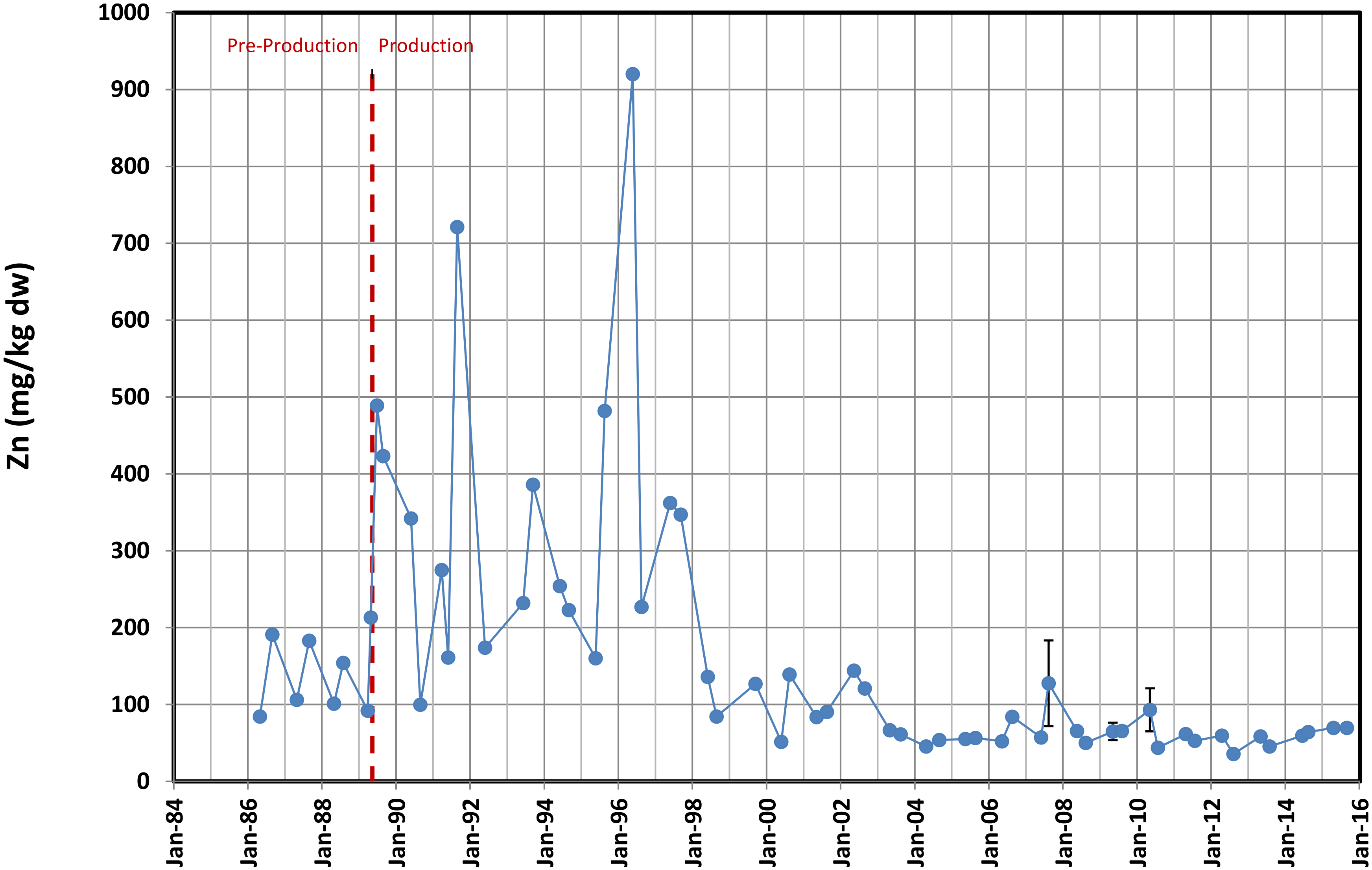


Figure 3-14. Mercury in Sediments at Site S-4
Hg (mg/kg dw)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

# Figure 3-15. Zinc in Sediments at Site S-4



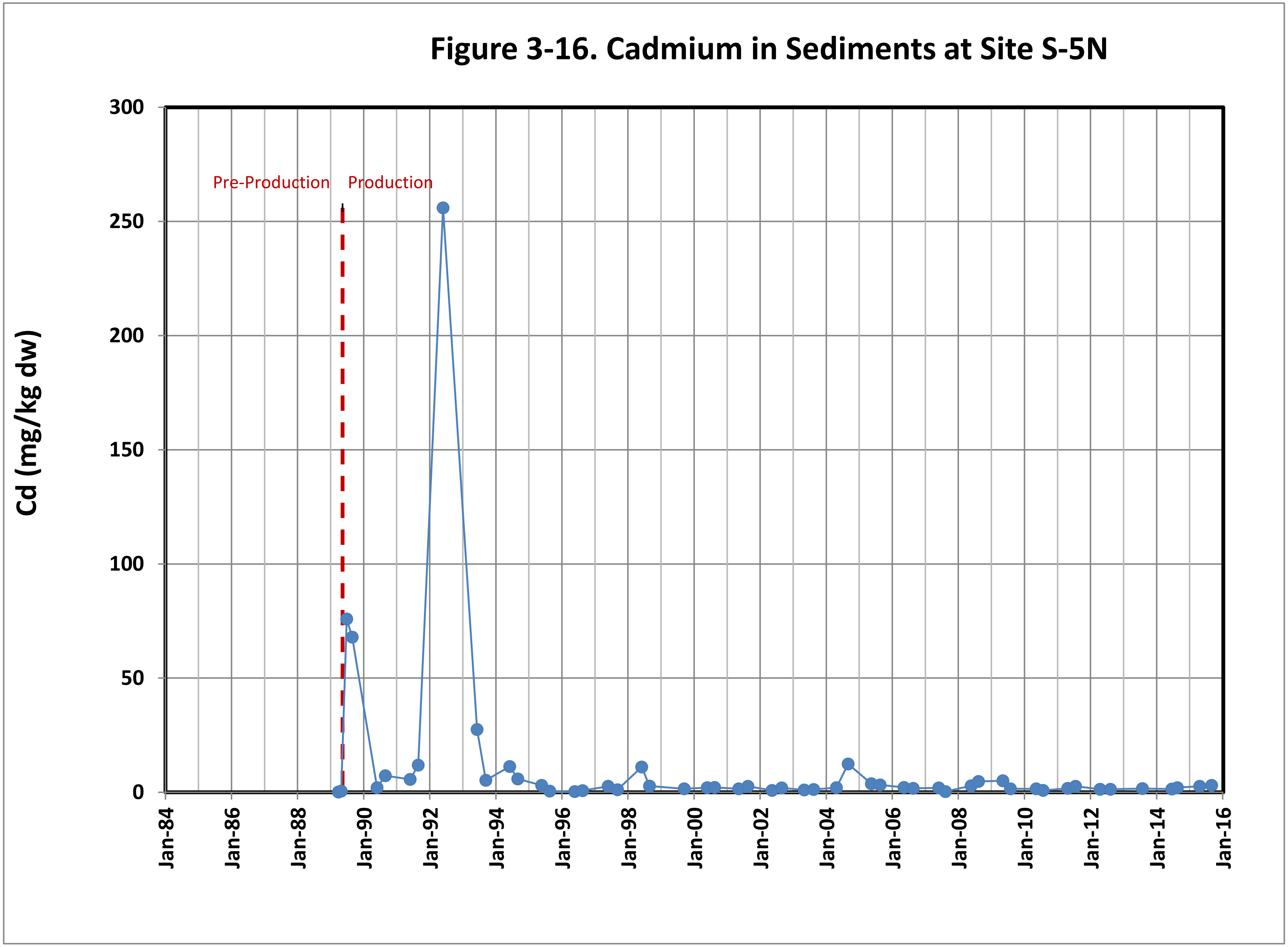


Figure 3-16. Cadmium in Sediments at Site S-5N
Cd (mg/kg dw)
300
250
200
150
100
50
0
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

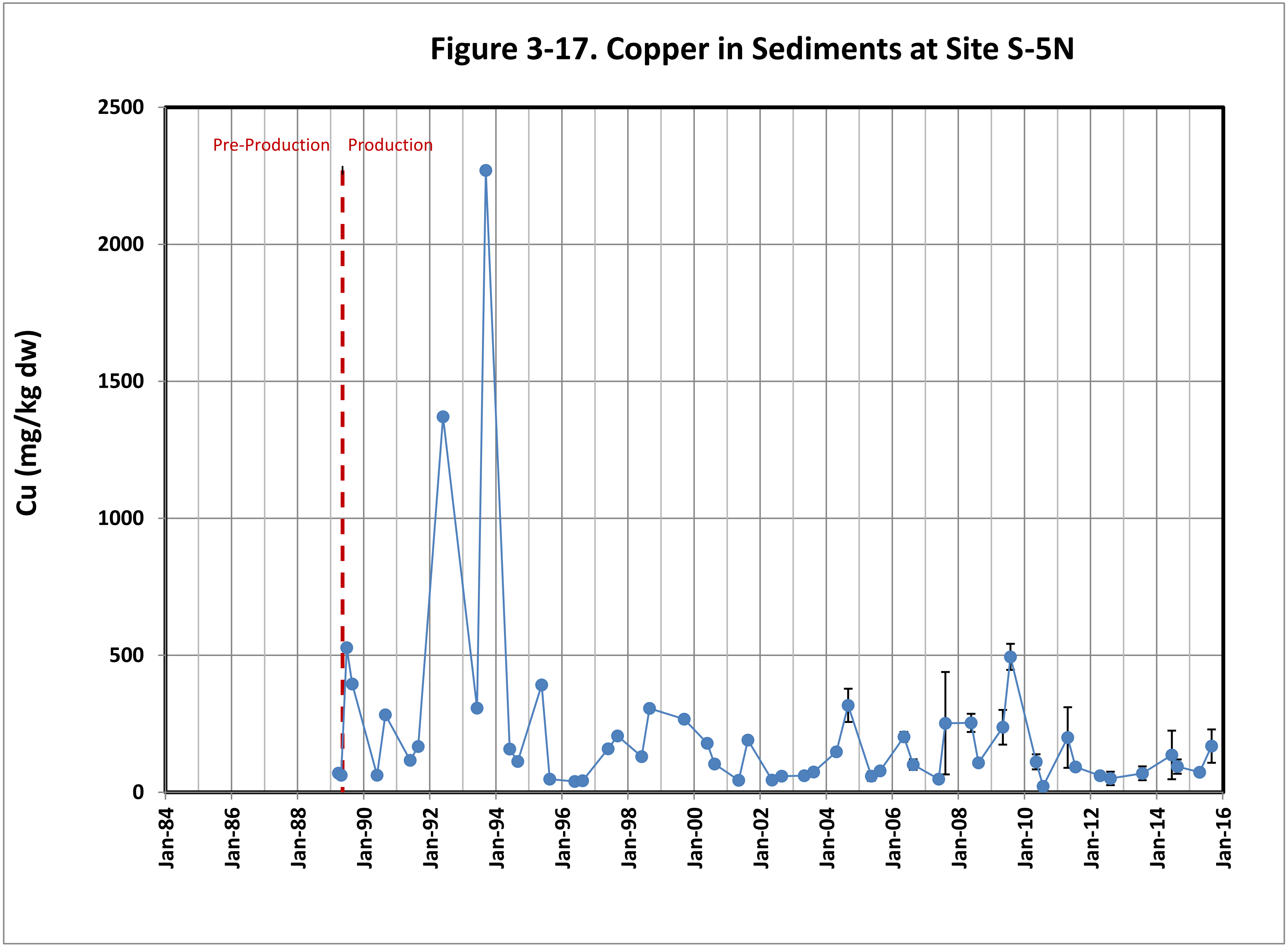
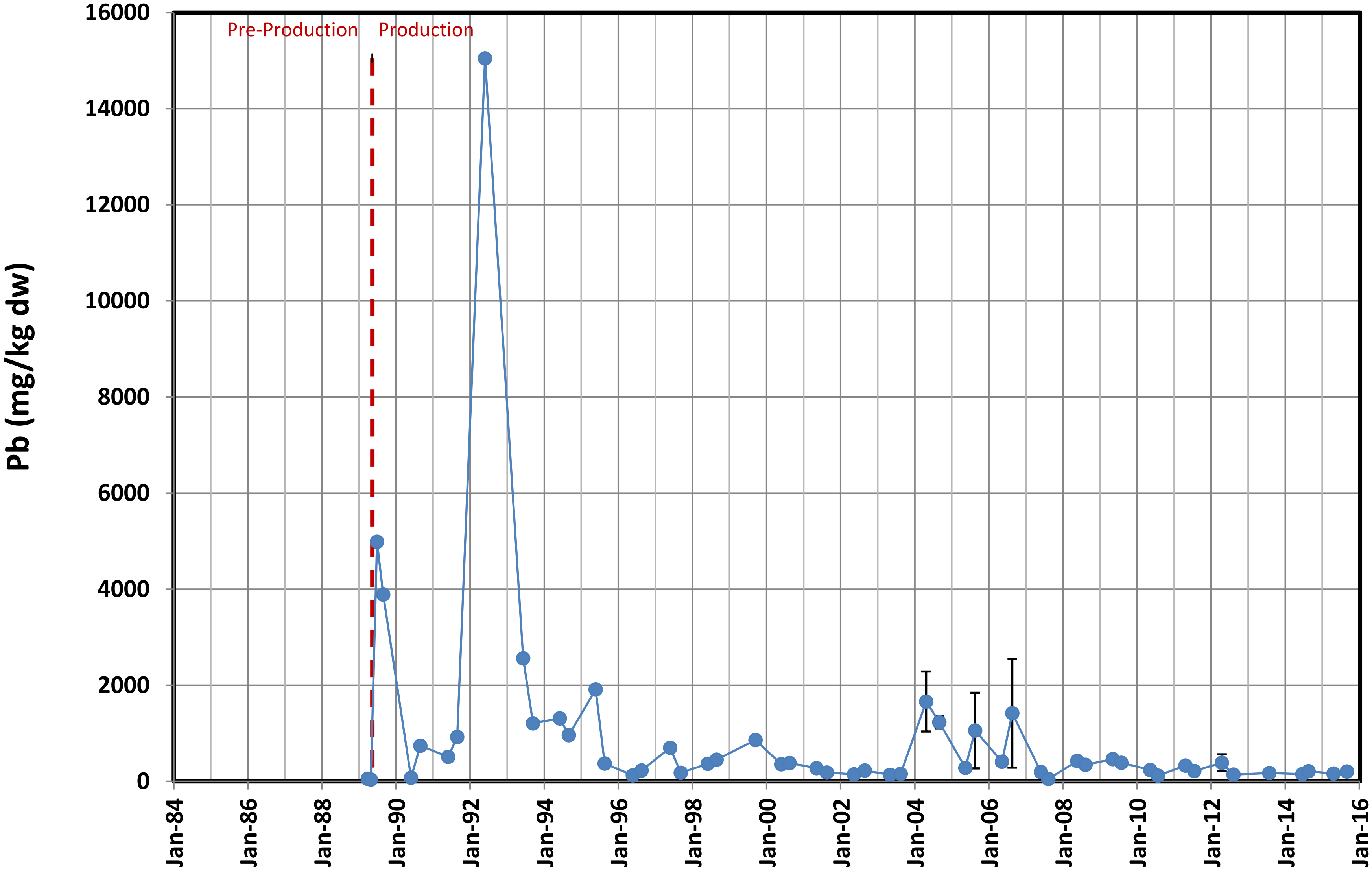
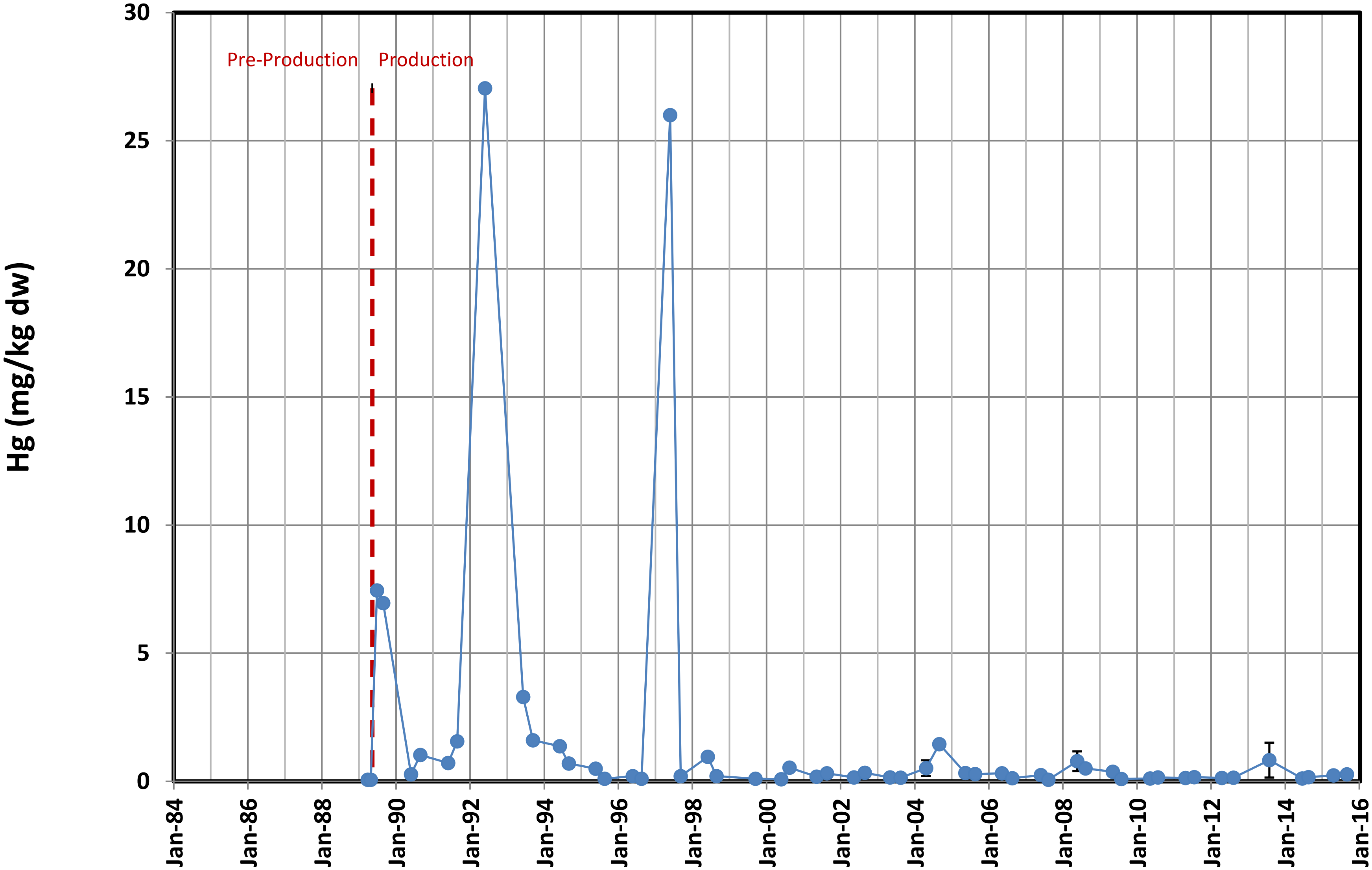


Figure 3-17. Copper in Sediments at Site S-5N
Pre-Production
Production
Cu (mg/kg dw)
2500
2000
1500
1000
500
0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

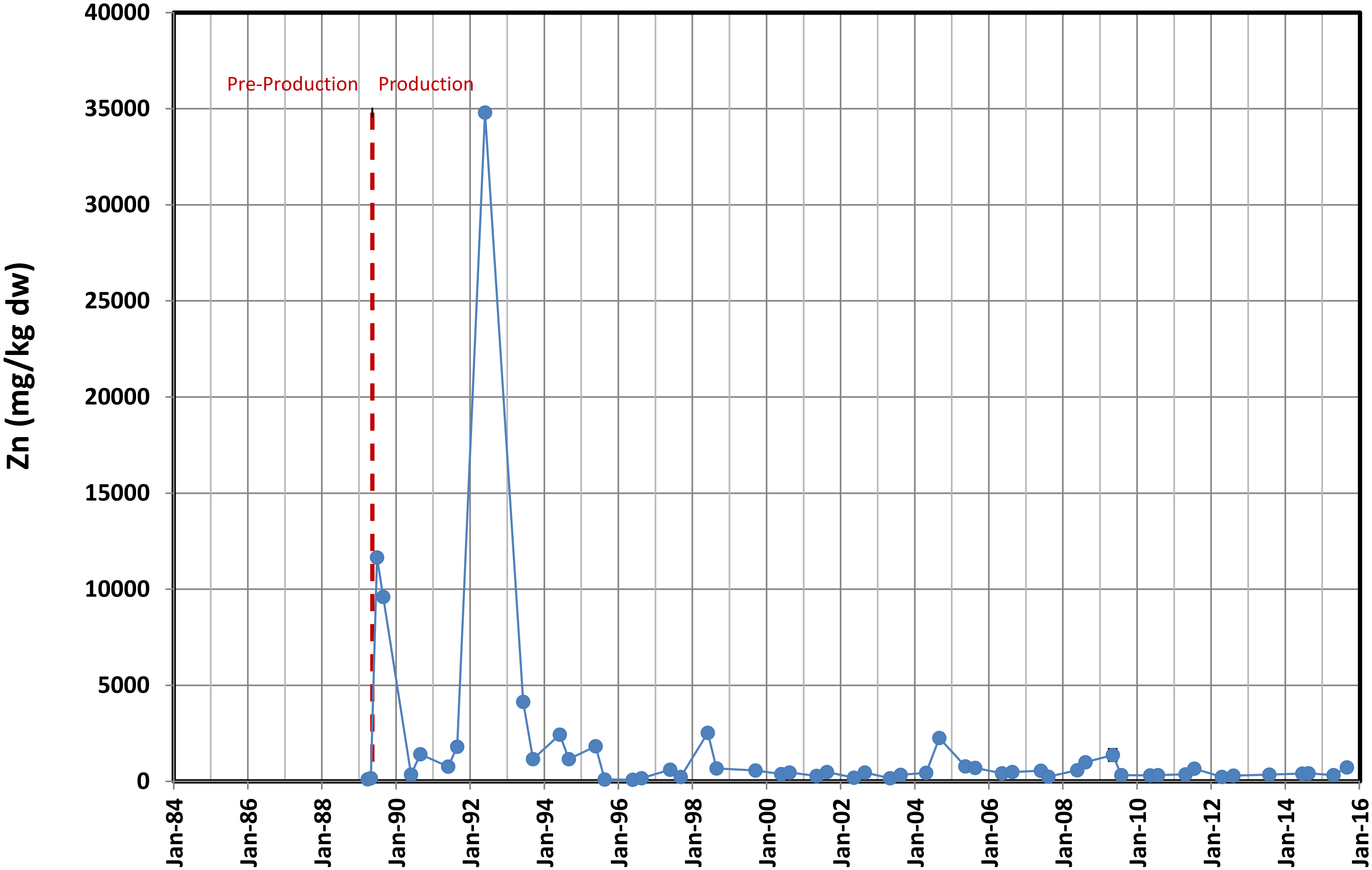
## Figure 3-18. Lead in Sediments at Site S-5N



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



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



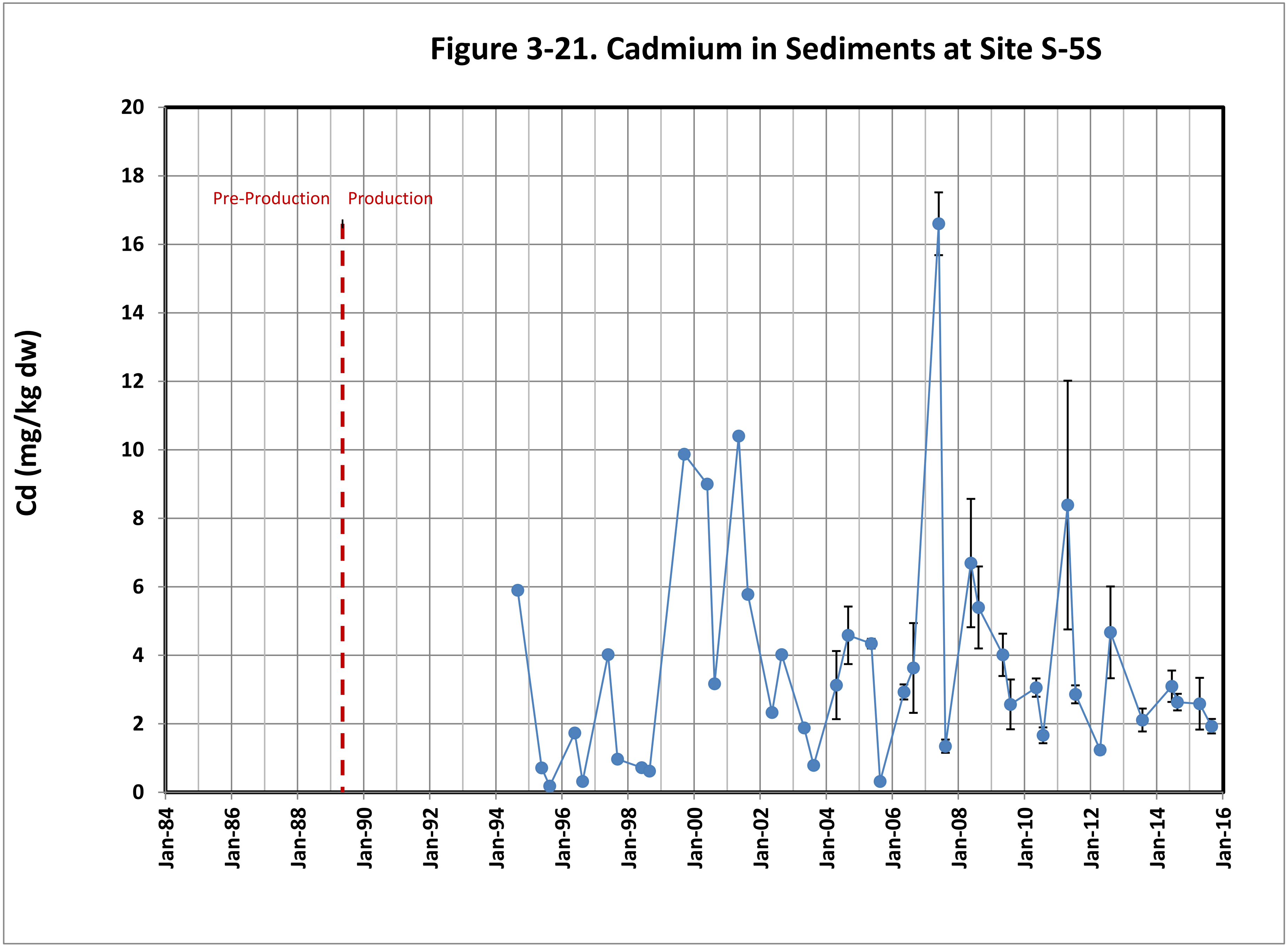


Figure 3-21. Cadmium in Sediments at Site S-5S
Cd (mg/kg dw)
Pre-Production
Production
0
2
4
6
8
10
12
14
16
18
20
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

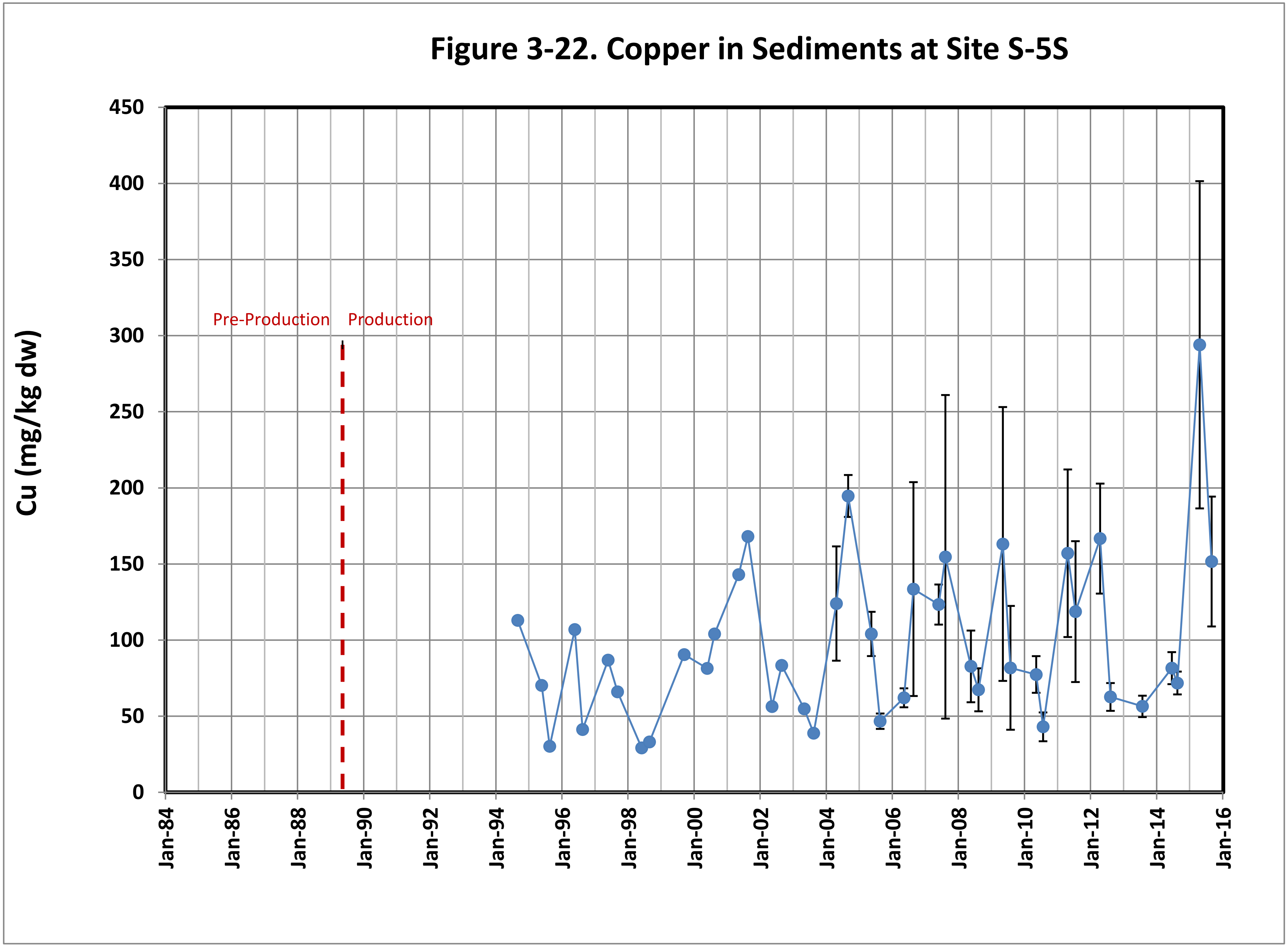
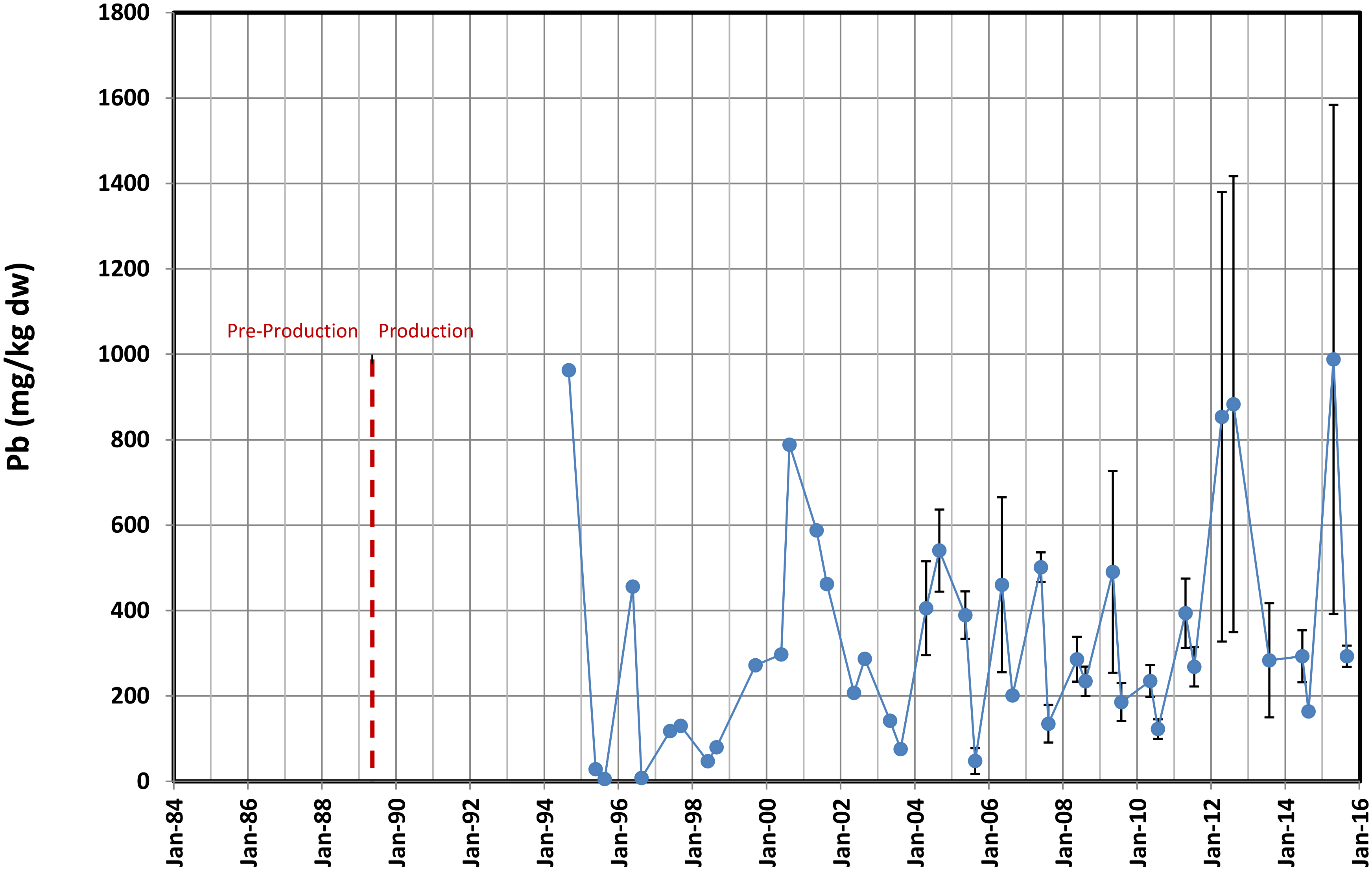


Figure 3-22. Copper in Sediments at Site S-5S
Cu (mg/kg dw)
Pre-Production
Production
0
50
100
150
200
250
300
350
400
450
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

## Figure 3-23. Lead in Sediments at Site S-5S



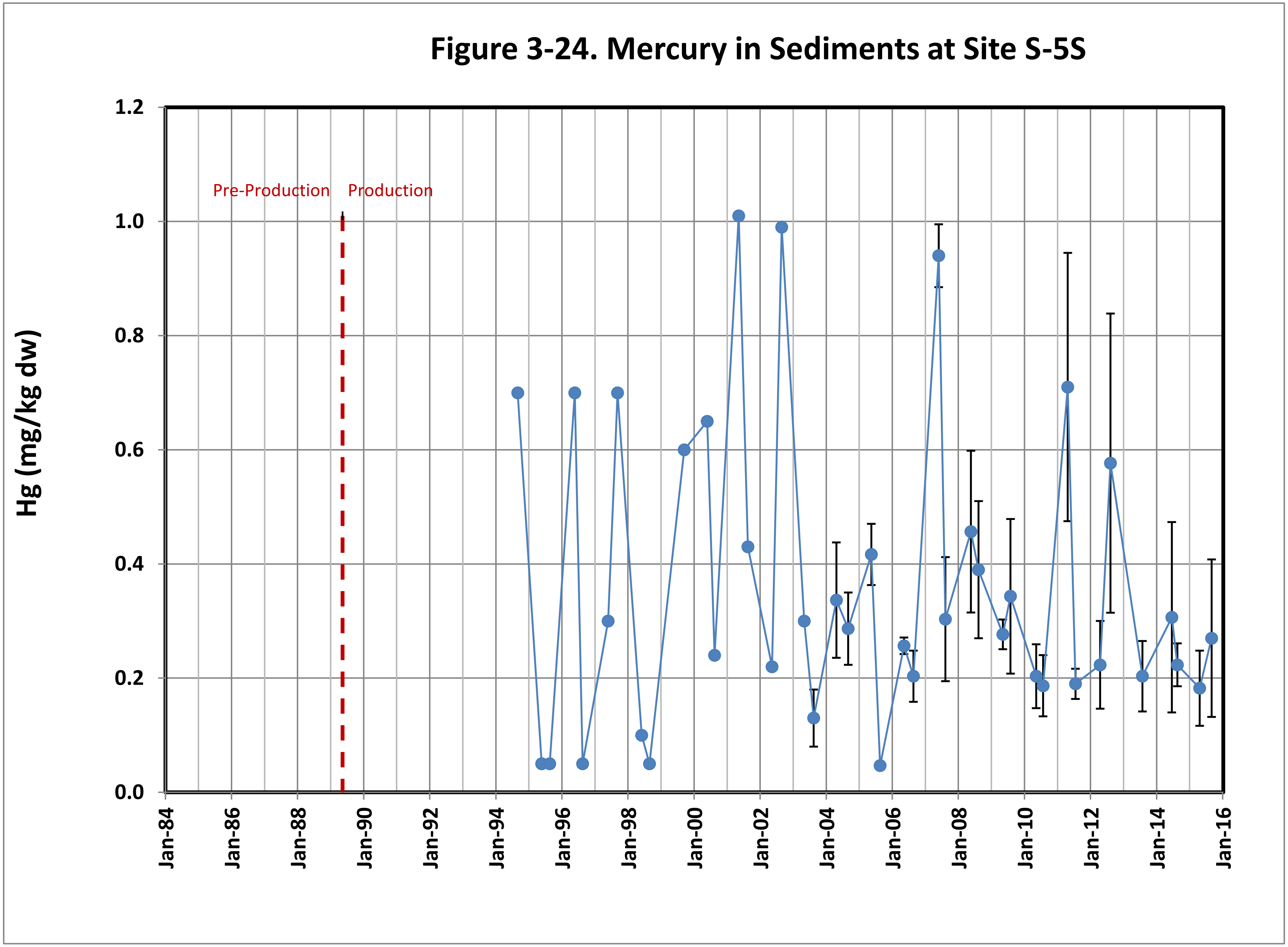


Figure 3-24. Mercury in Sediments at Site S-5S
Hg (mg/kg dw)
Pre-Production
Production
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

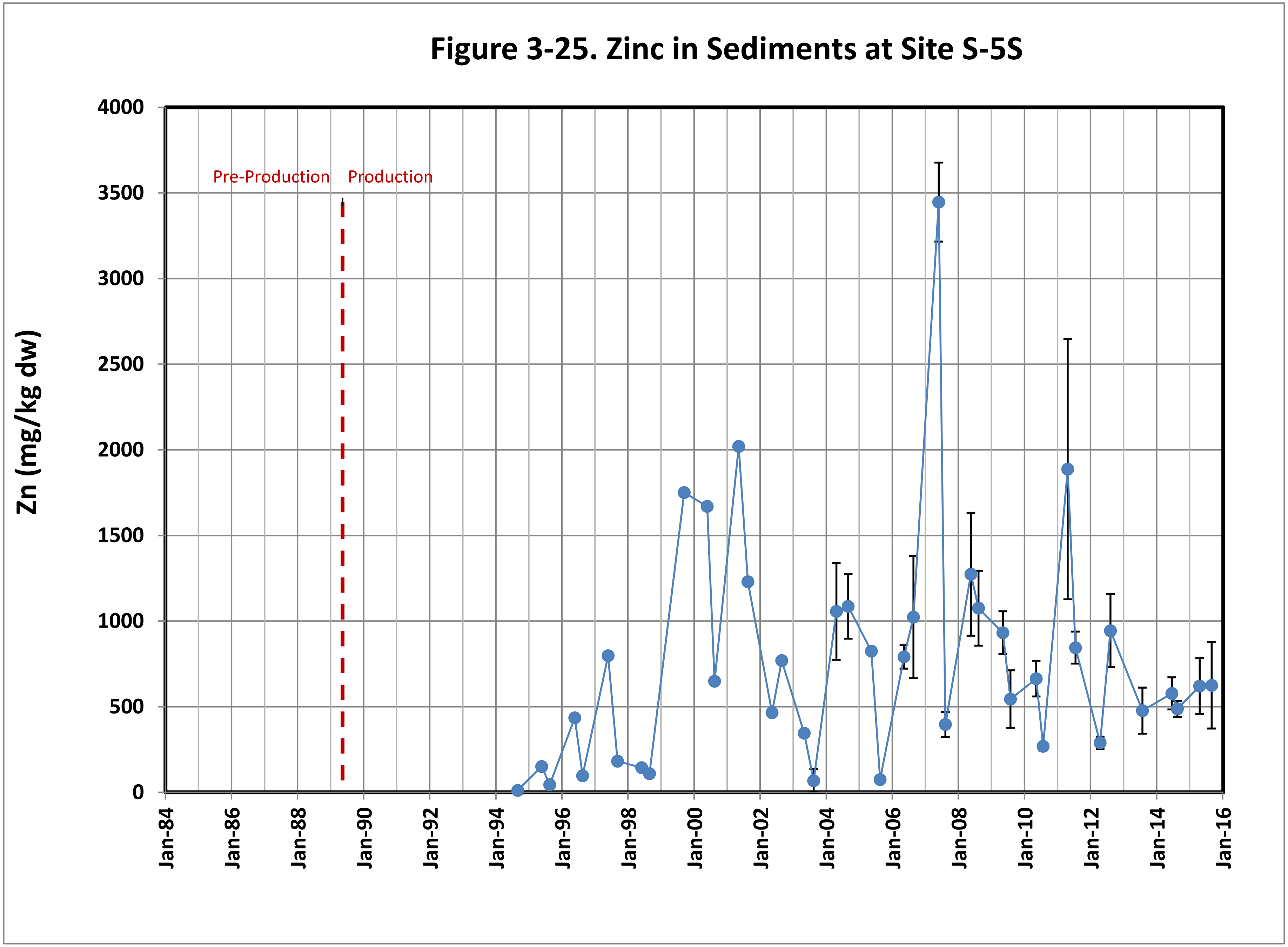


Figure 3-25. Zinc in Sediments at Site S-5S
Zn (mg/kg dw)
Pre-Production
Production
4000
3500
3000
2500
2000
1500
1000
500
0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

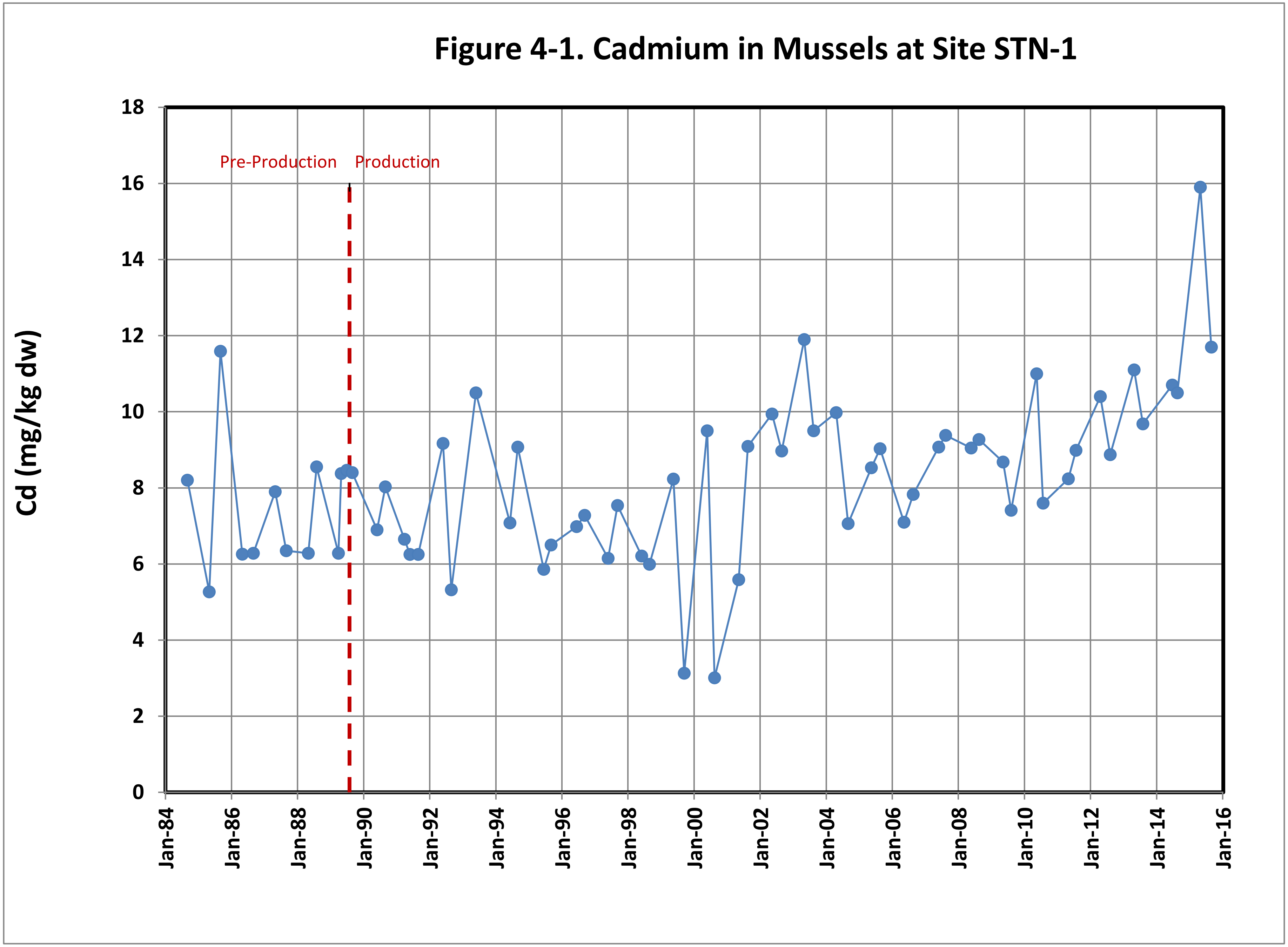


Figure 4-1. Cadmium in Mussels at Site STN-1
Cd (mg/kg dw)
0
2
4
6
8
10
12
14
16
18
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
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Jan-12
Jan-14
Jan-16

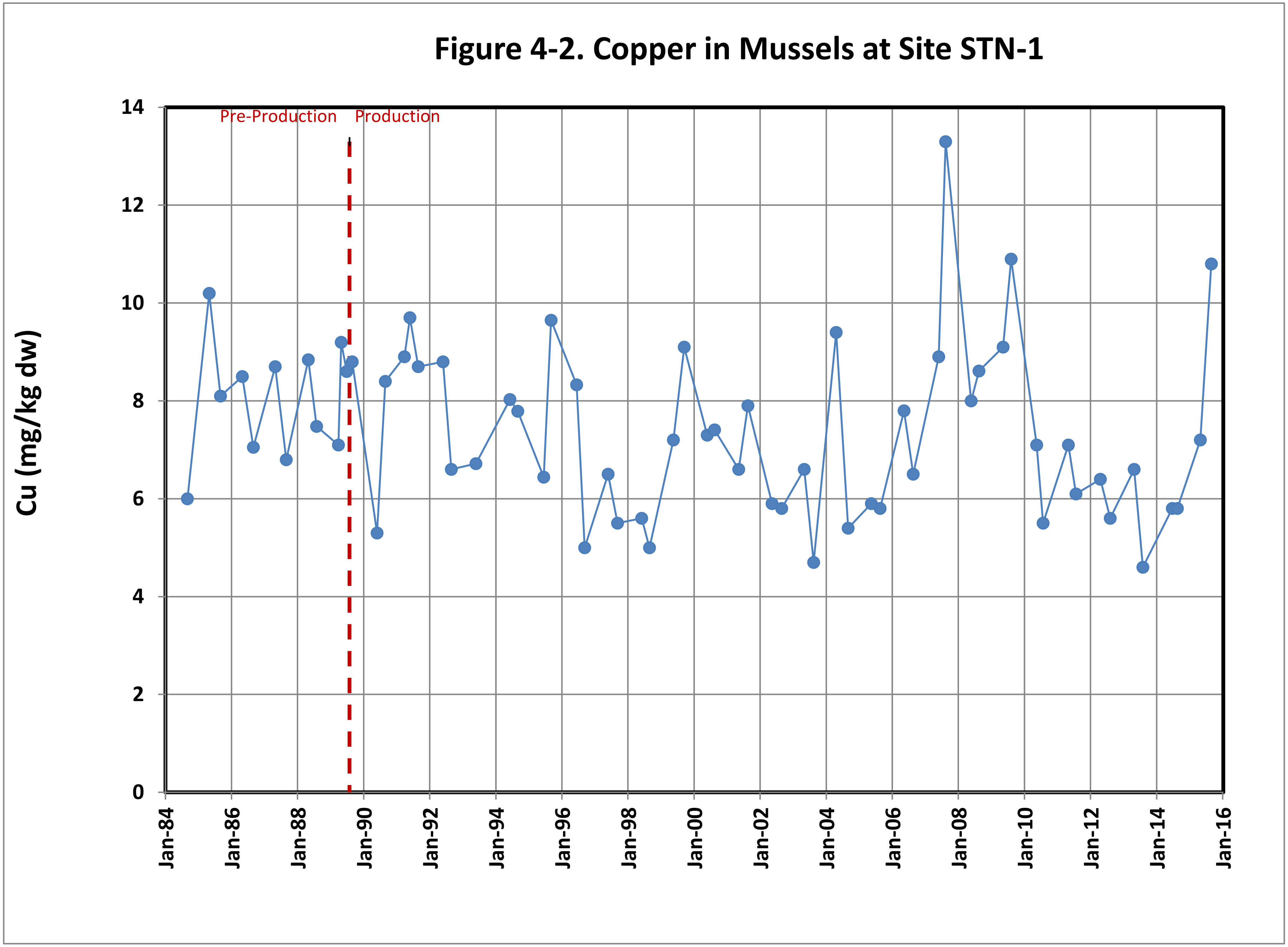


Figure 4-2. Copper in Mussels at Site STN-1
Cu (mg/kg dw)
Pre-Production
Production
0
2
4
6
8
10
12
14
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

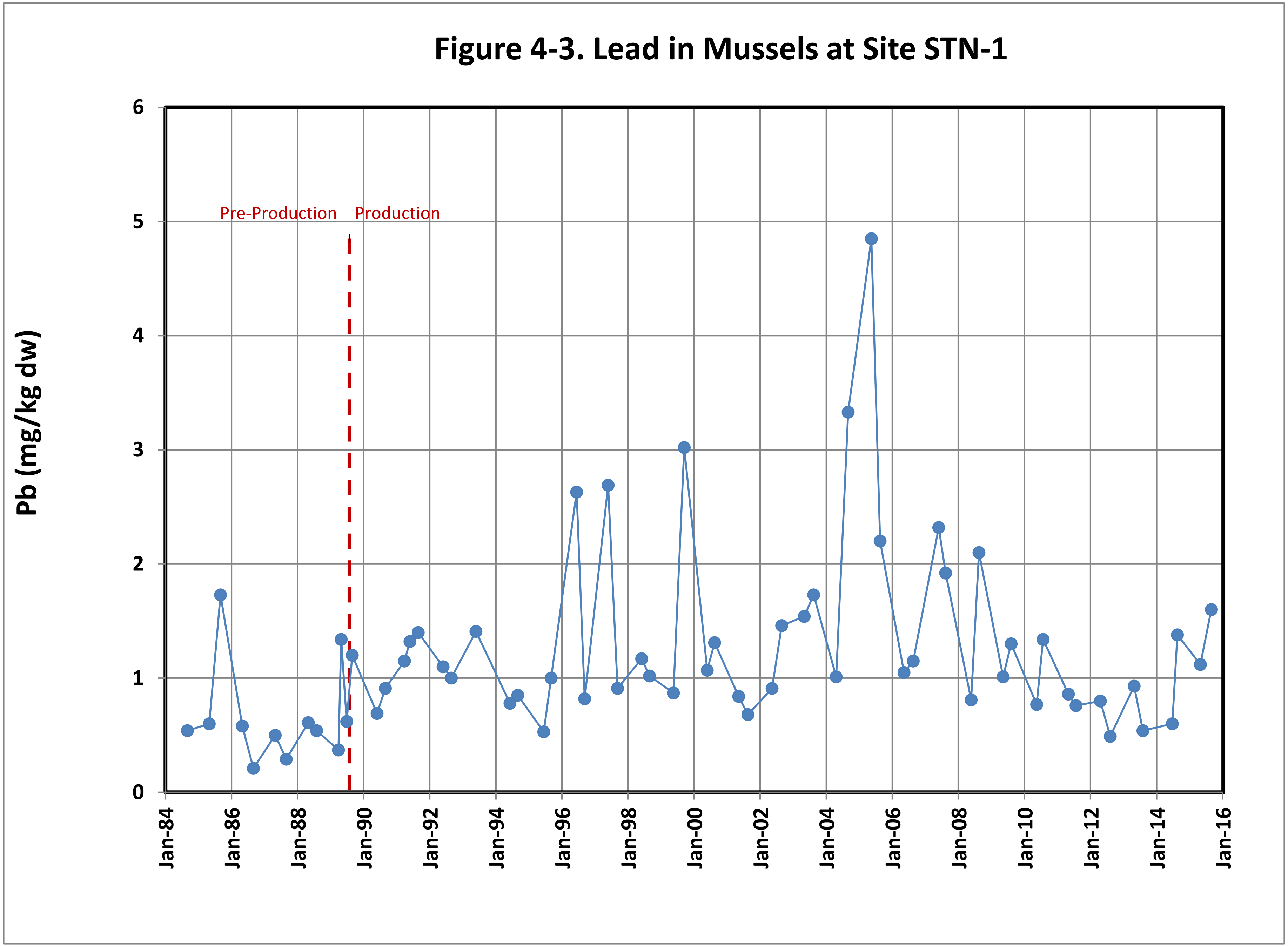
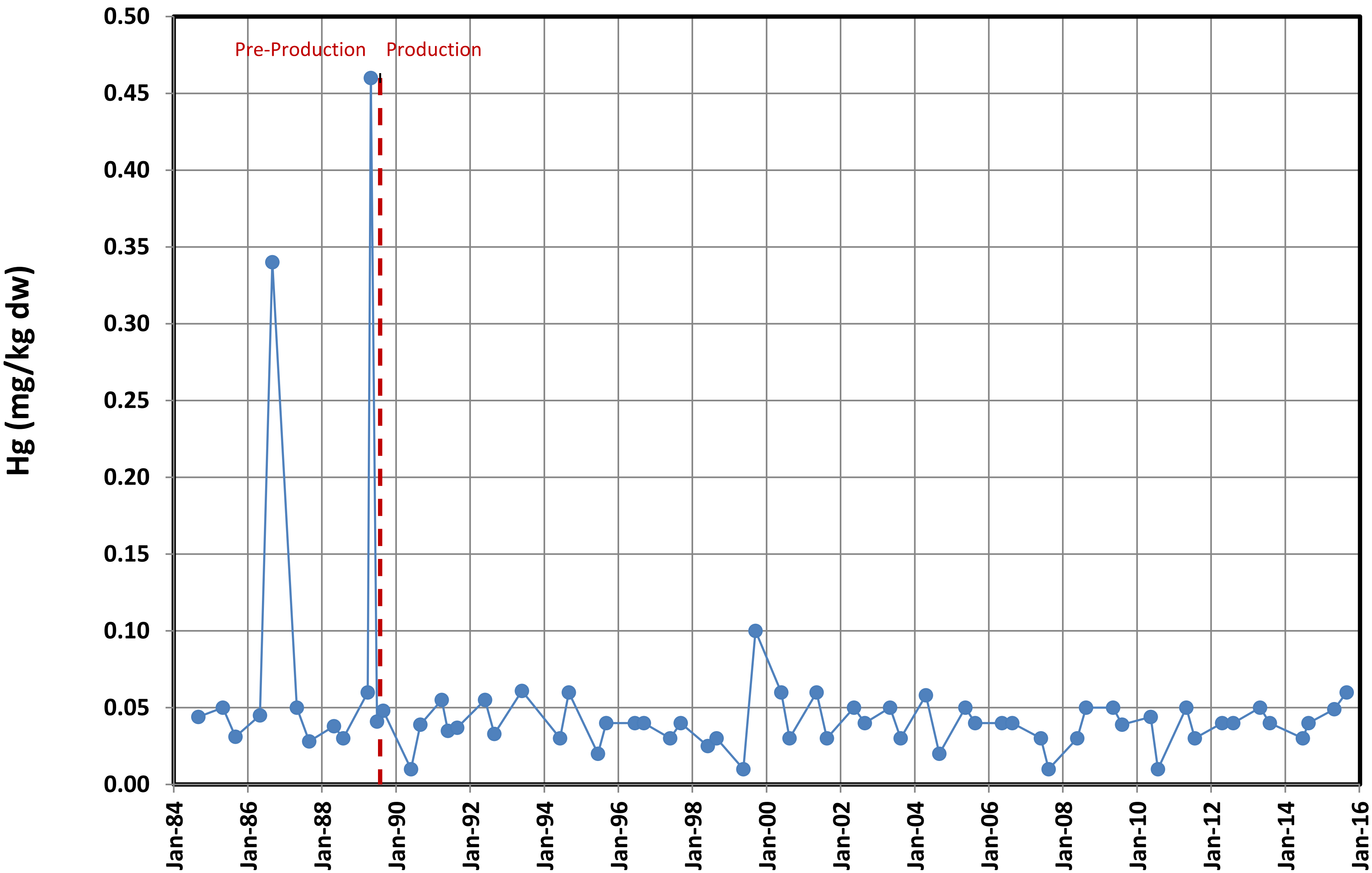


Figure 4-3. Lead in Mussels at Site STN-1
Pb (mg/kg dw)
0
1
2
3
4
5
6
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

## Figure 4-4. Mercury in Mussels at Site STN-1



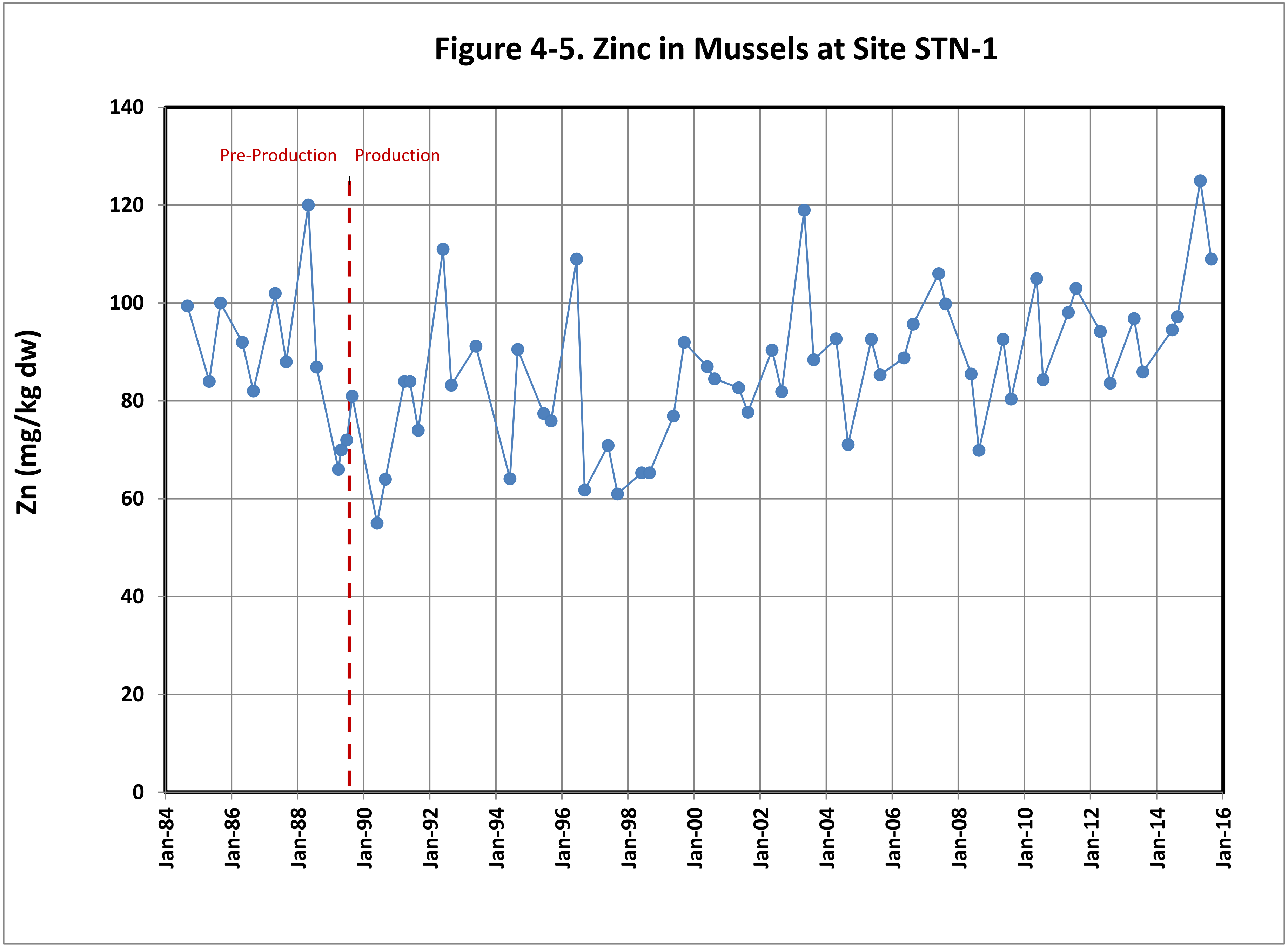


Figure 4-5. Zinc in Mussels at Site STN-1
Pre-Production
Production
Zn (mg/kg dw)
0
20
40
60
80
100
120
140
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
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Jan-12
Jan-14
Jan-16

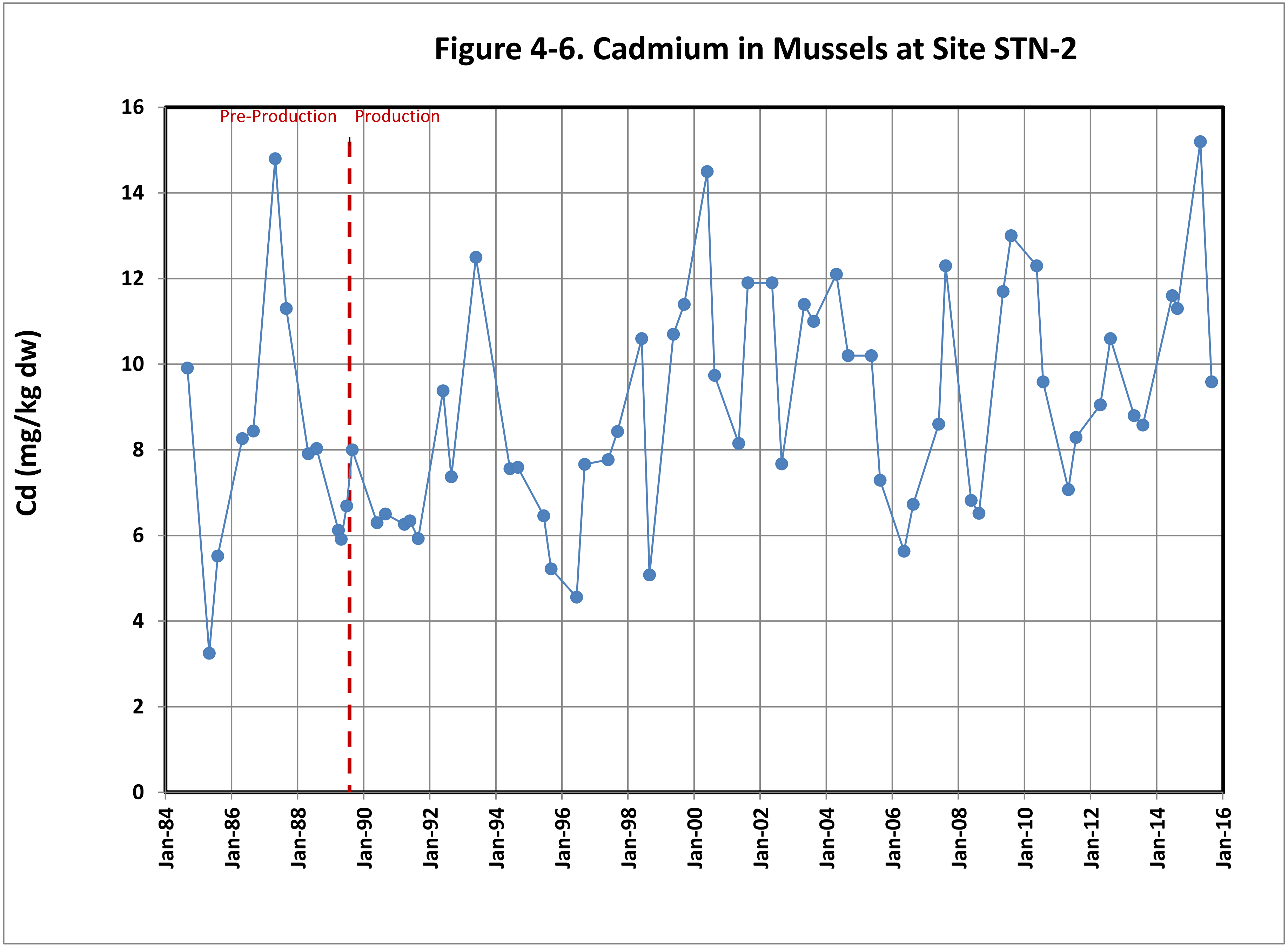
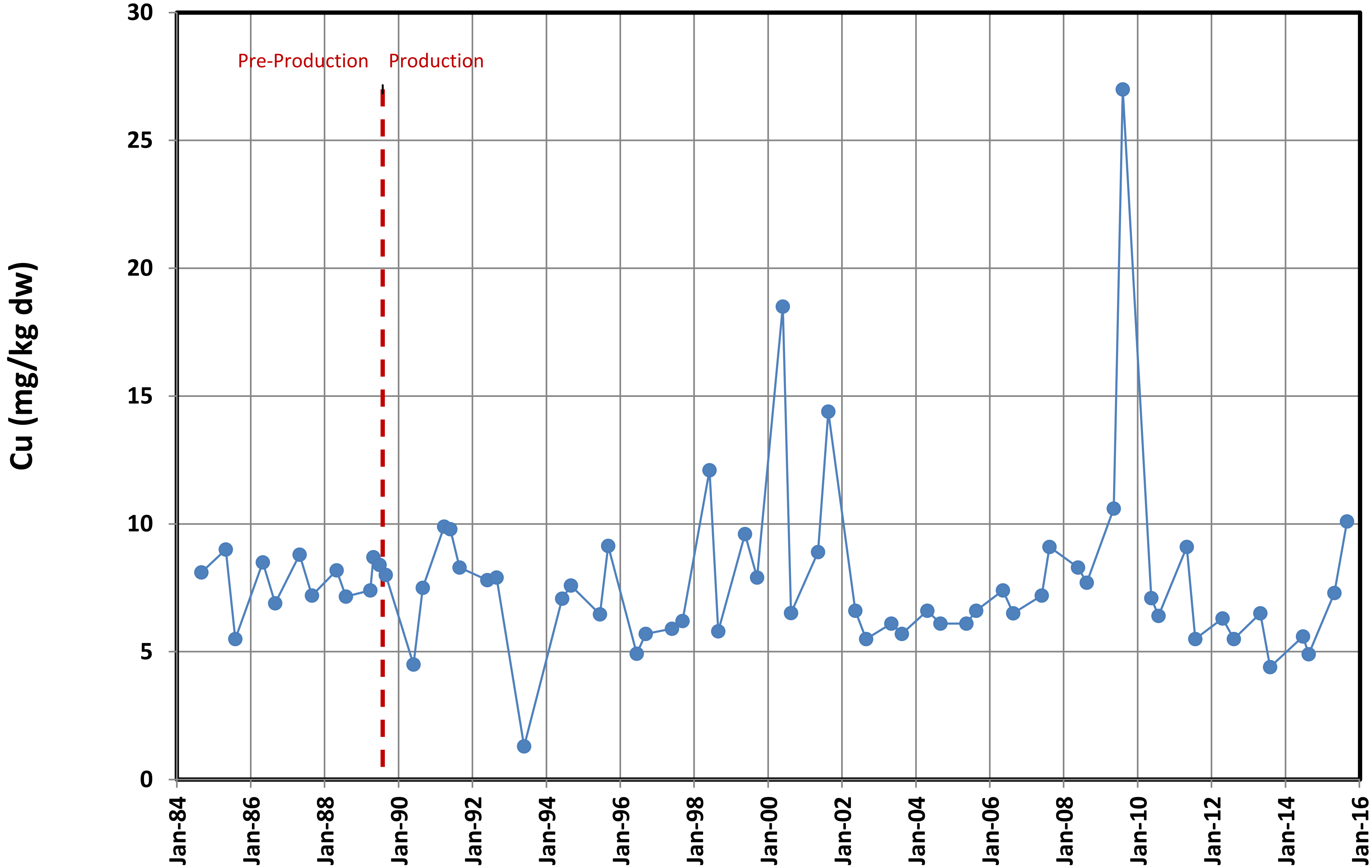


Figure 4-6. Cadmium in Mussels at Site STN-2
Pre-Production
Production
Cd (mg/kg dw)
0
2
4
6
8
10
12
14
16
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

# Figure 4-7. Copper in Mussels at Site STN-2



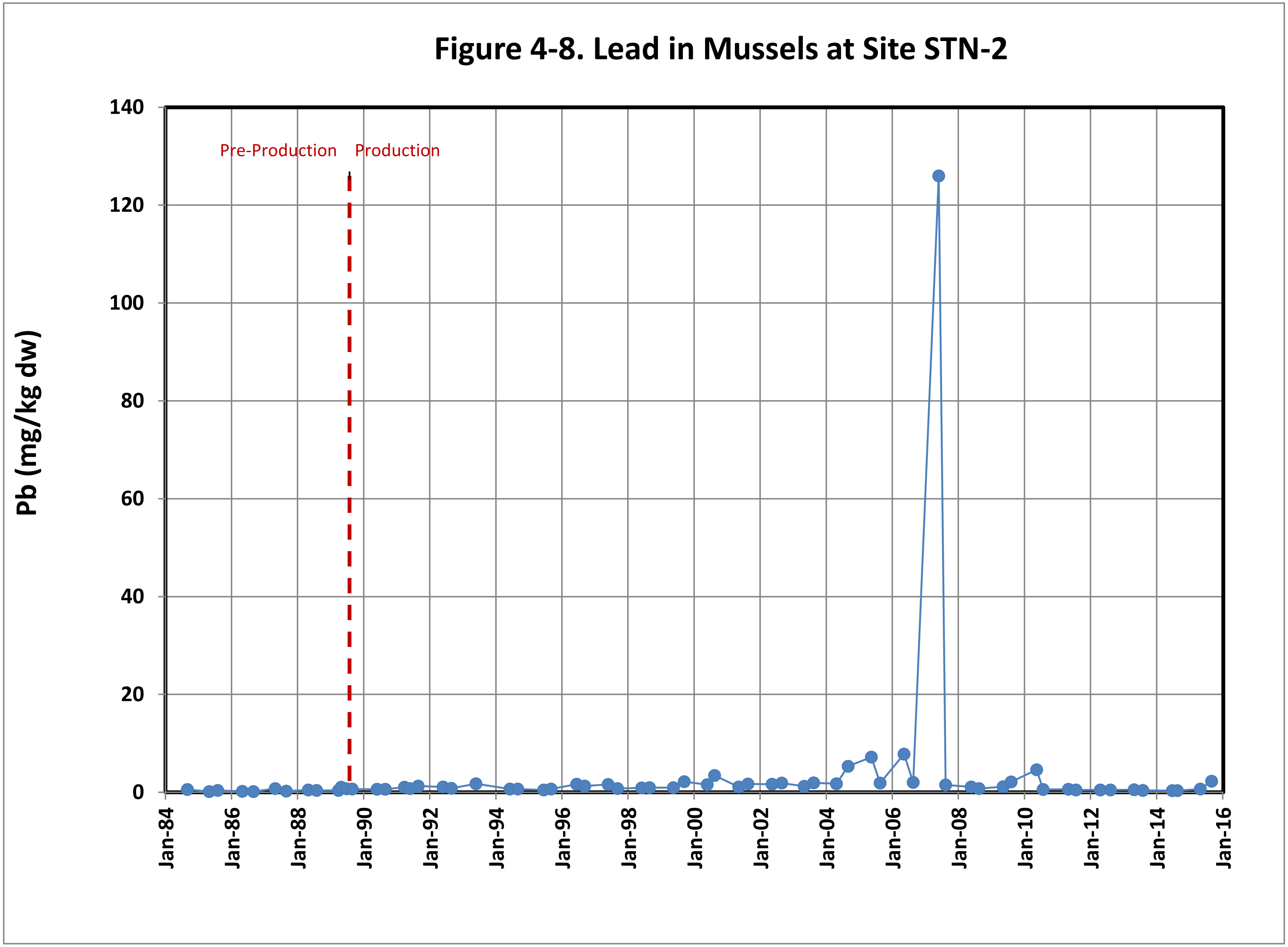


Figure 4-8. Lead in Mussels at Site STN-2
Pb (mg/kg dw)
0
20
40
60
80
100
120
140
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
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Jan-10
Jan-12
Jan-14
Jan-16

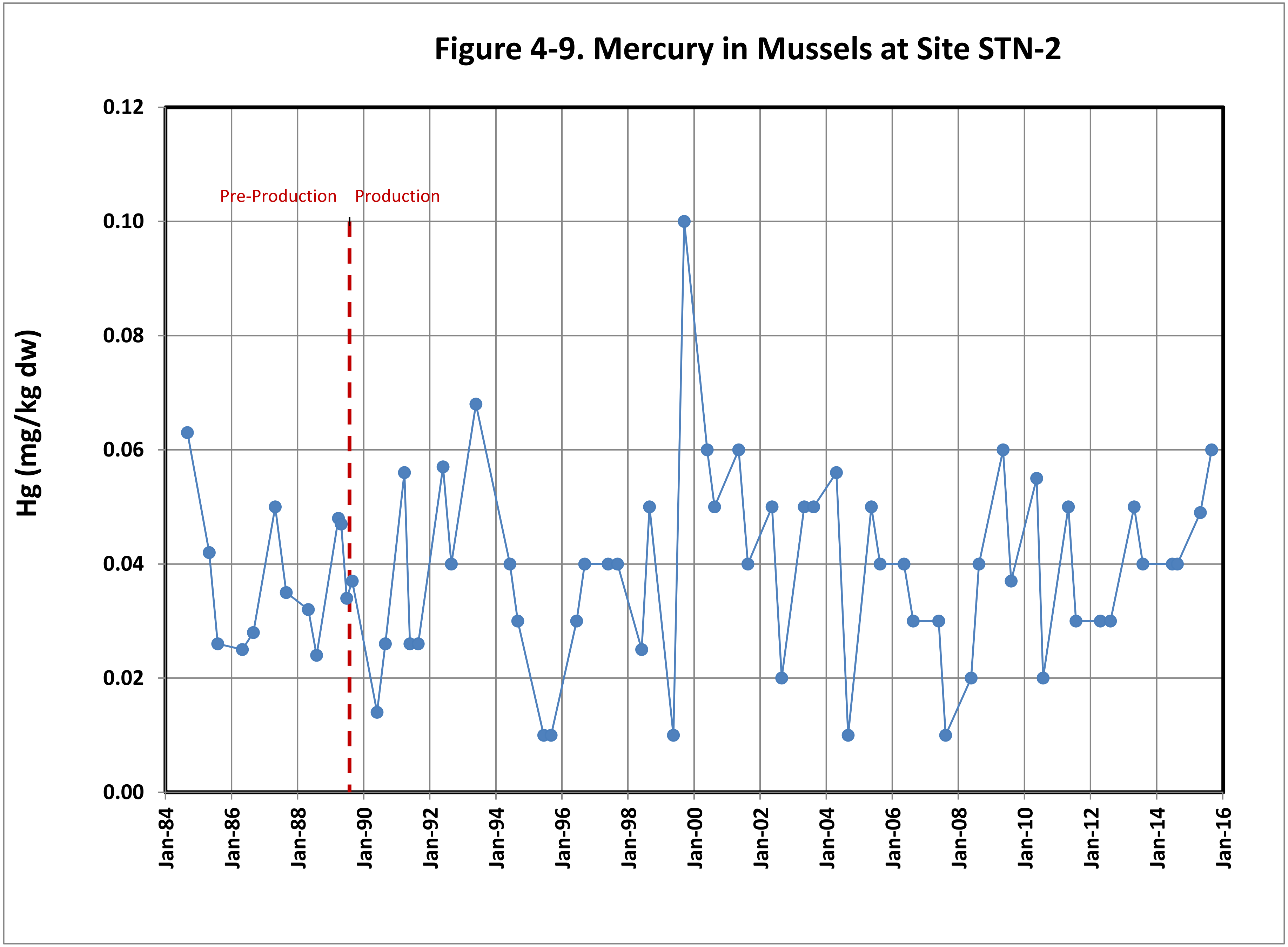


Figure 4-9. Mercury in Mussels at Site STN-2
Hg (mg/kg dw)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

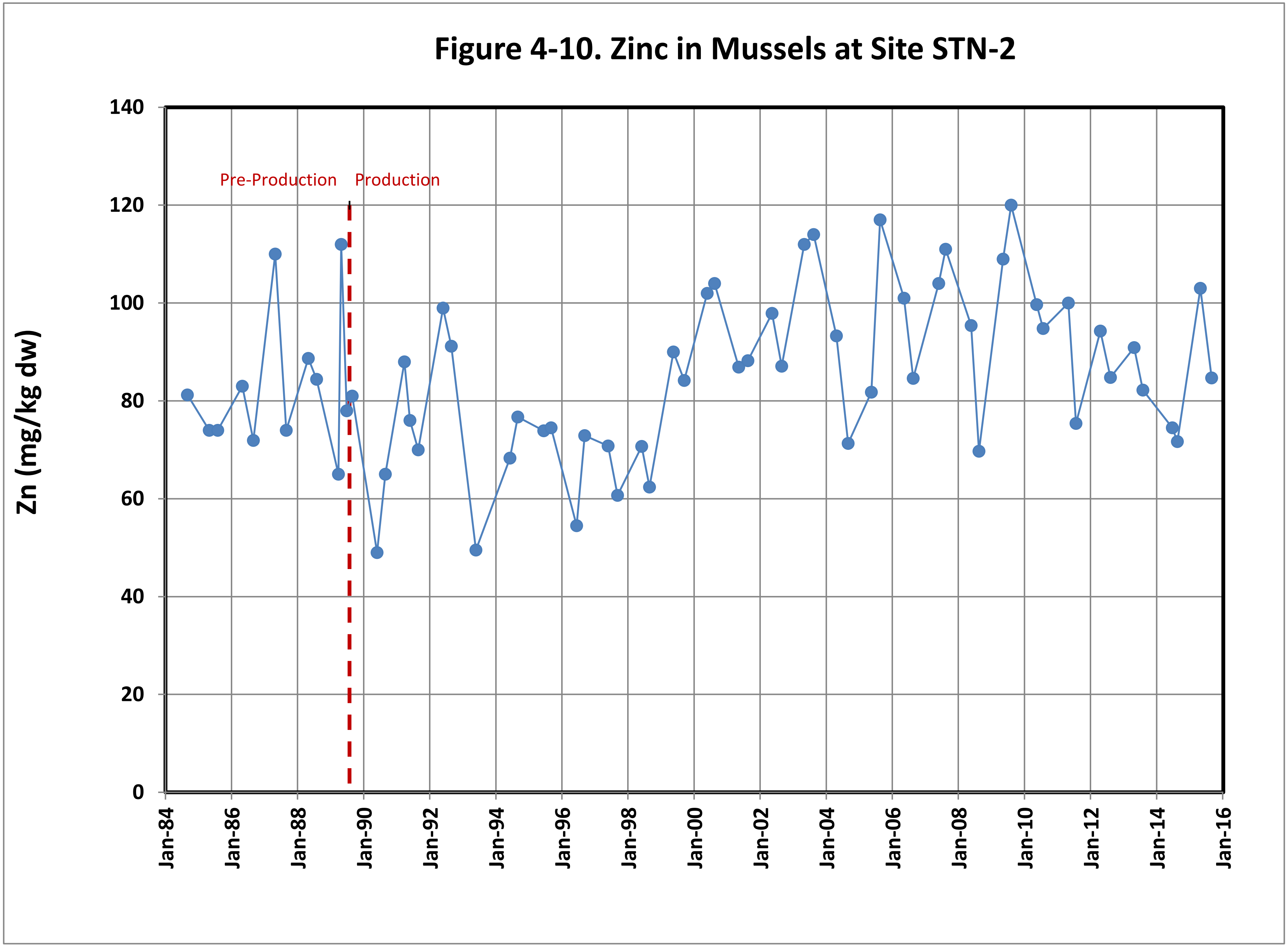
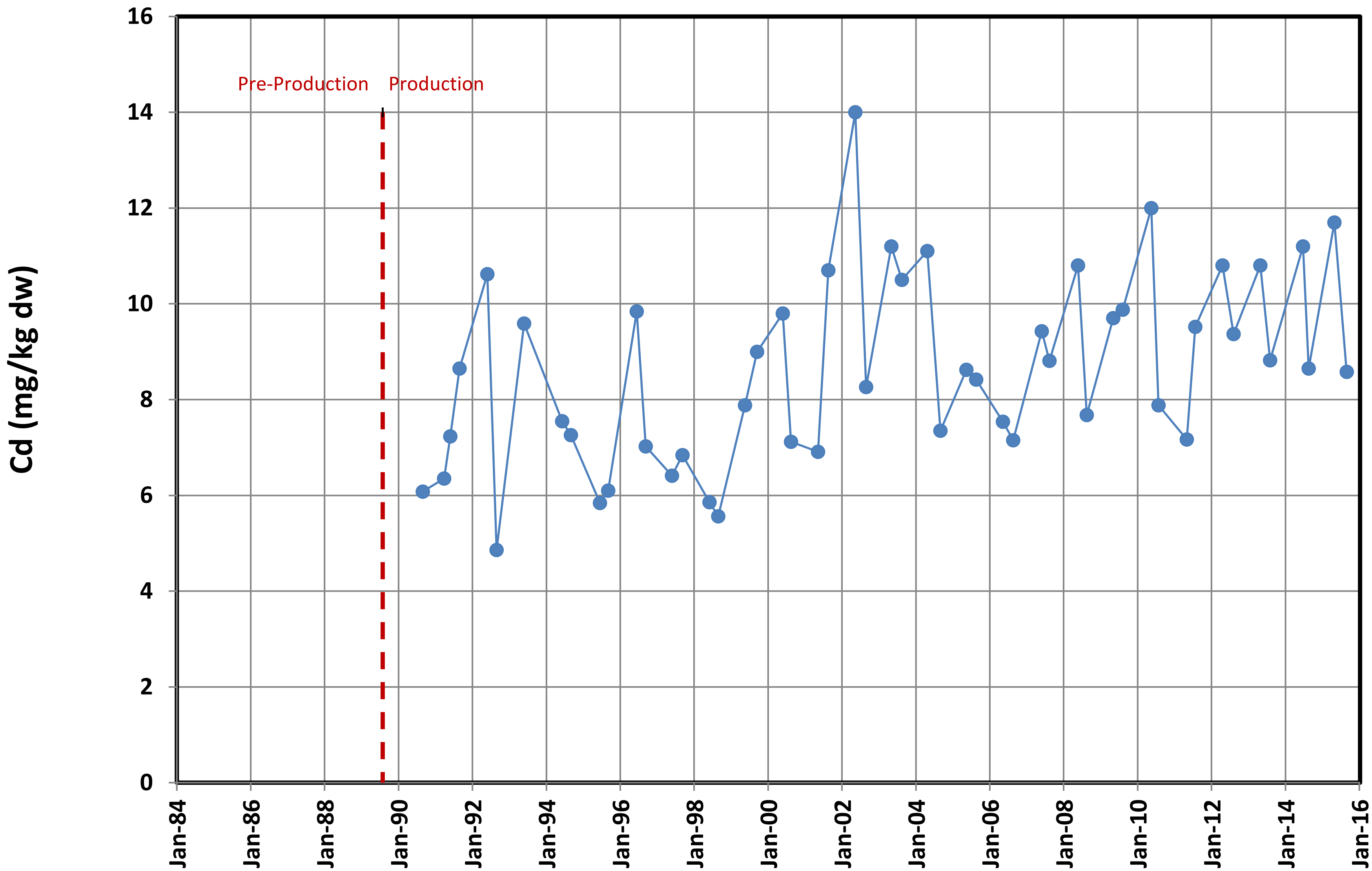


Figure 4-10. Zinc in Mussels at Site STN-2
Zn (mg/kg dw)
Pre-Production
Production
0
20
40
60
80
100
120
140
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

# Figure 4-11. Cadmium in Mussels at Site STN-3



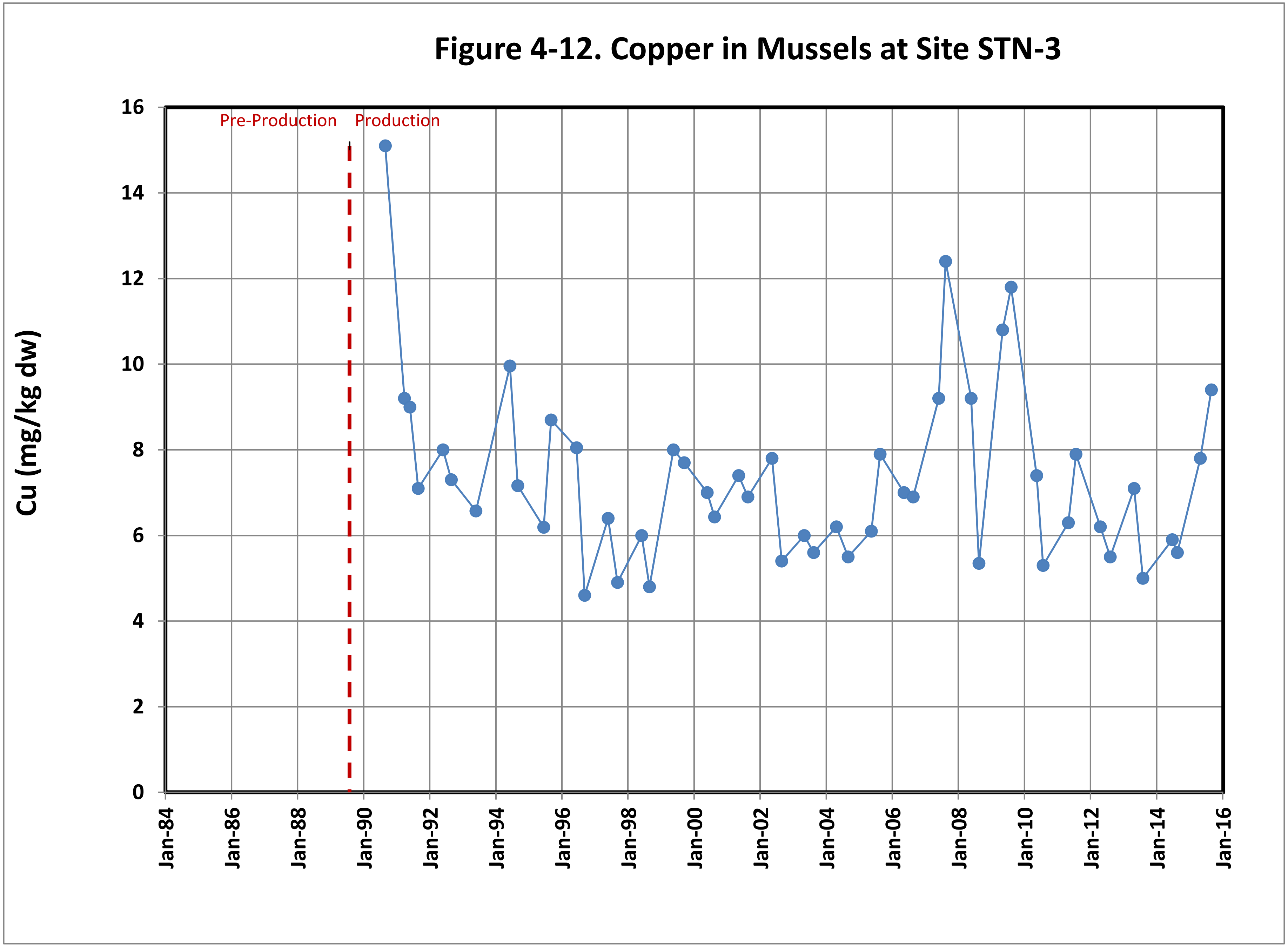


Figure 4-12. Copper in Mussels at Site STN-3
Cu (mg/kg dw)
Pre-Production
Production
0
2
4
6
8
10
12
14
16
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

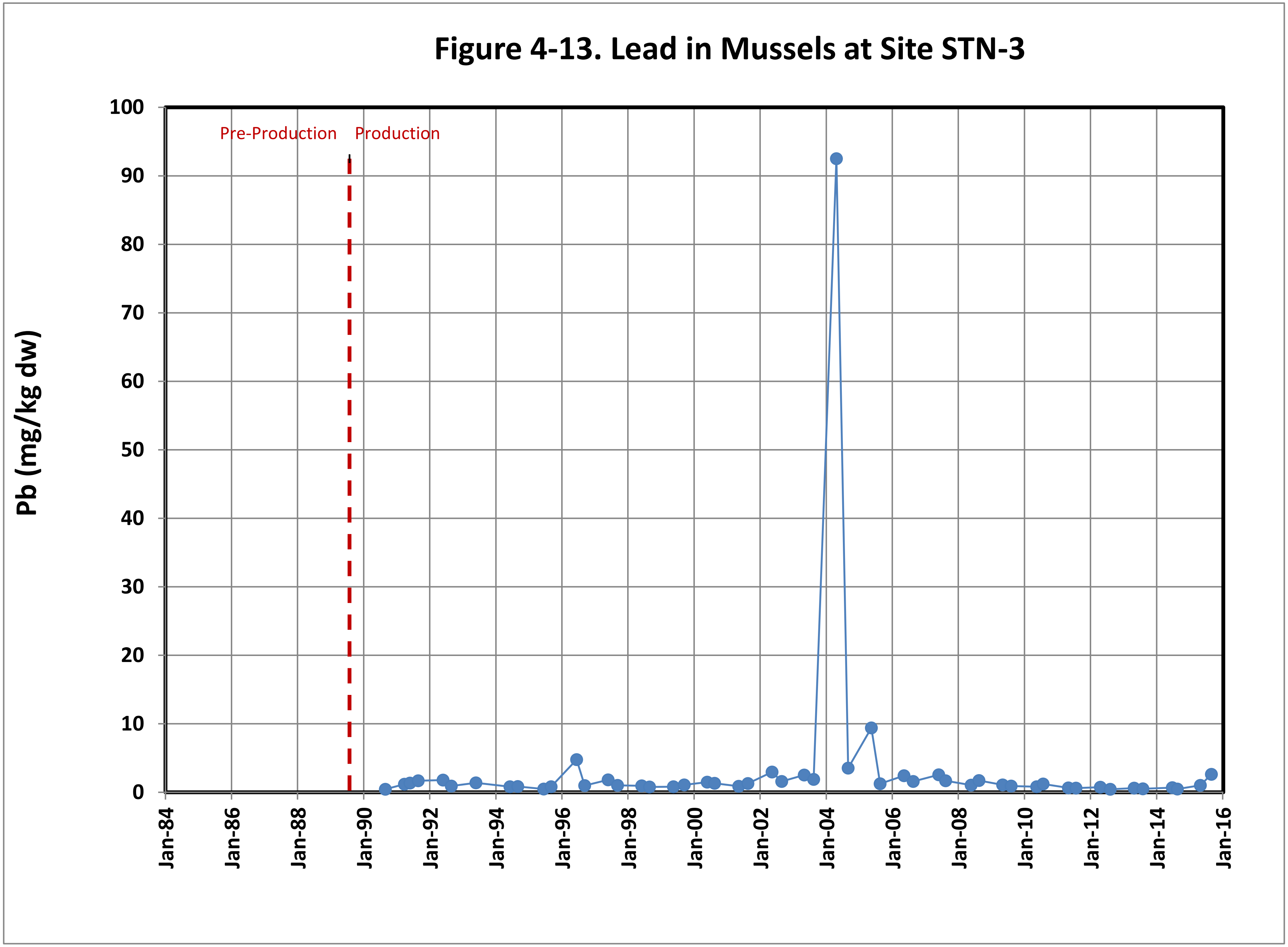


Figure 4-13. Lead in Mussels at Site STN-3
Pb (mg/kg dw)
Pre-Production
Production
0
10
20
30
40
50
60
70
80
90
100
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

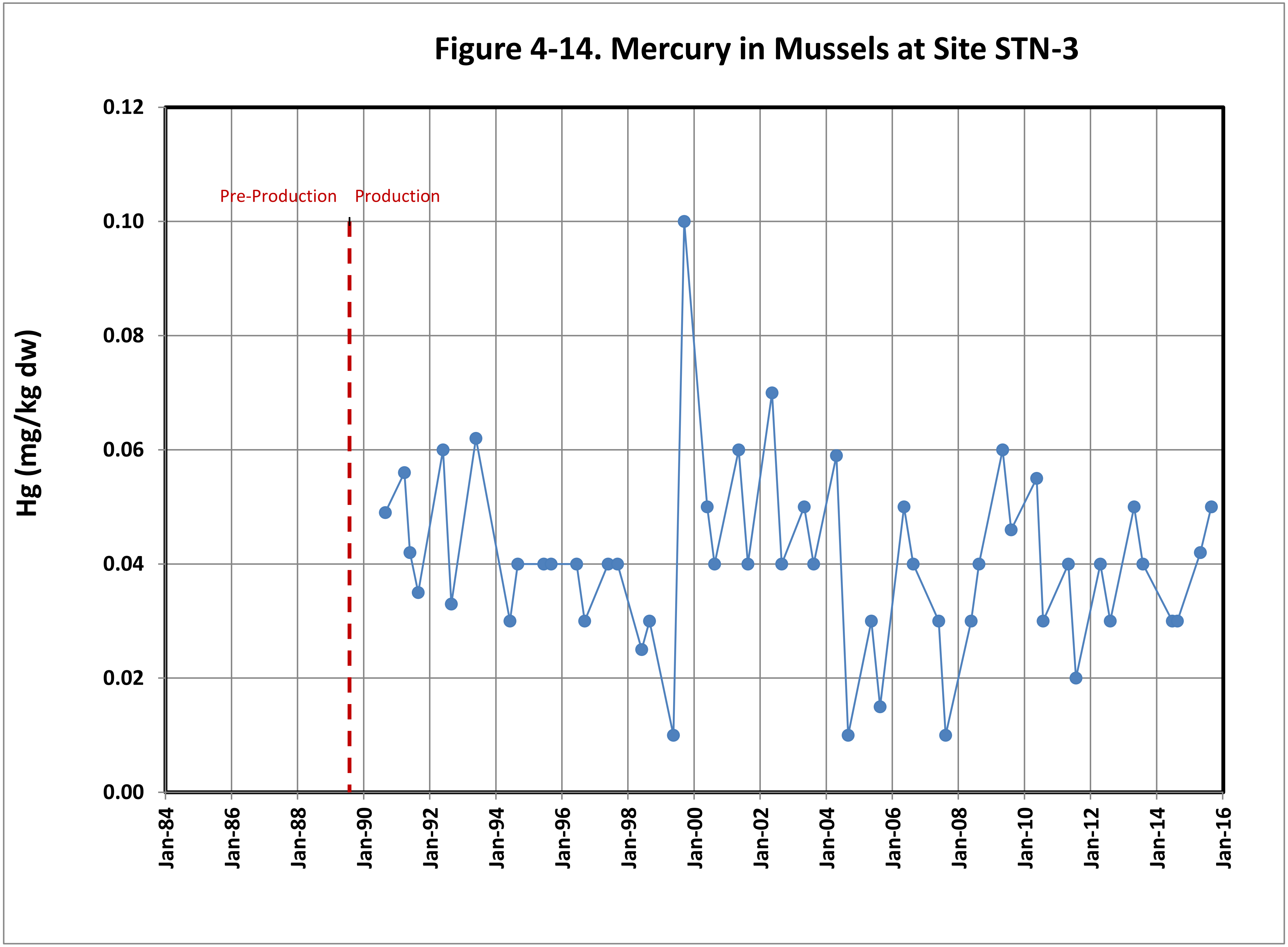
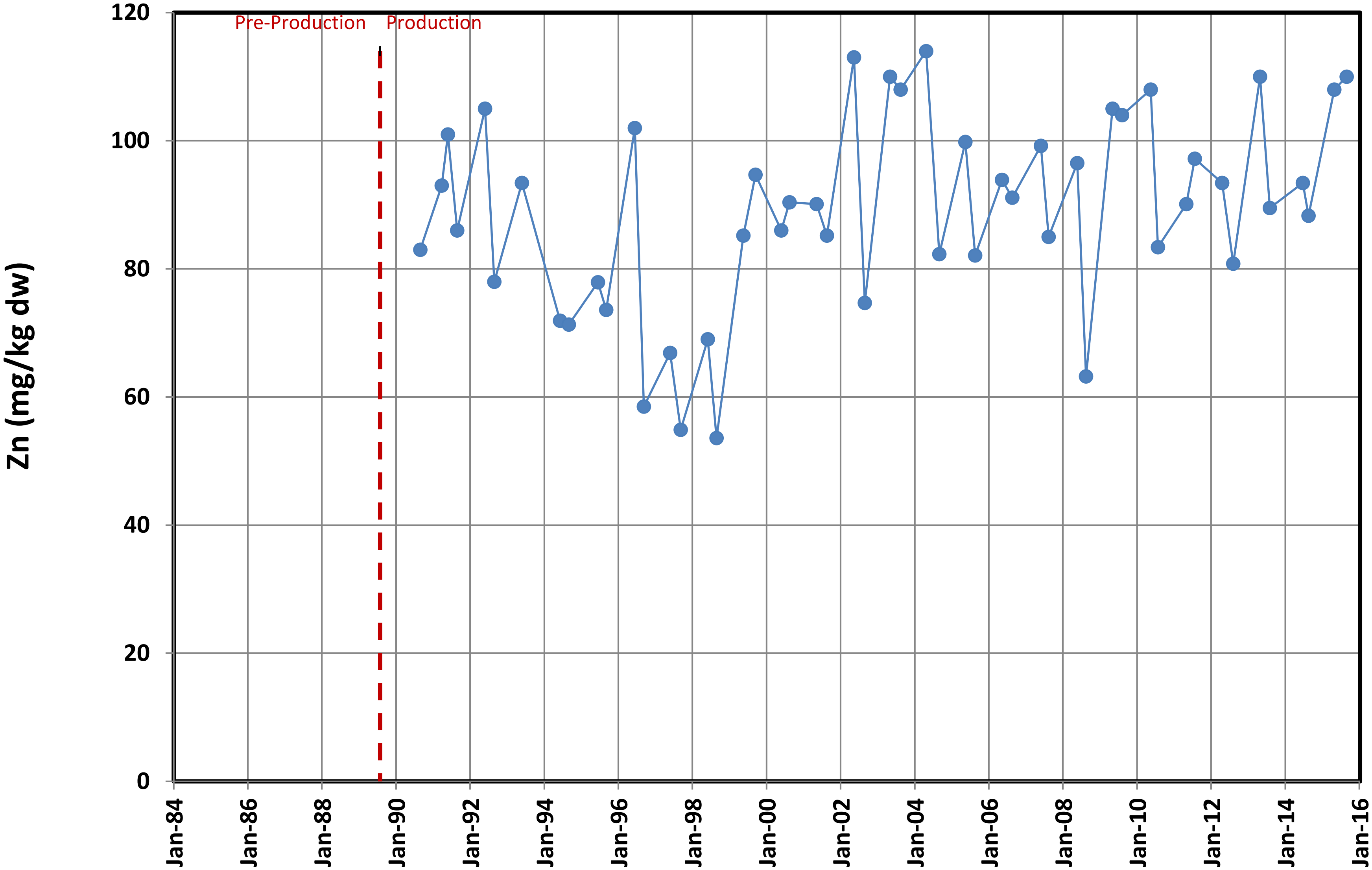


Figure 4-14. Mercury in Mussels at Site STN-3
Hg (mg/kg dw)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

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



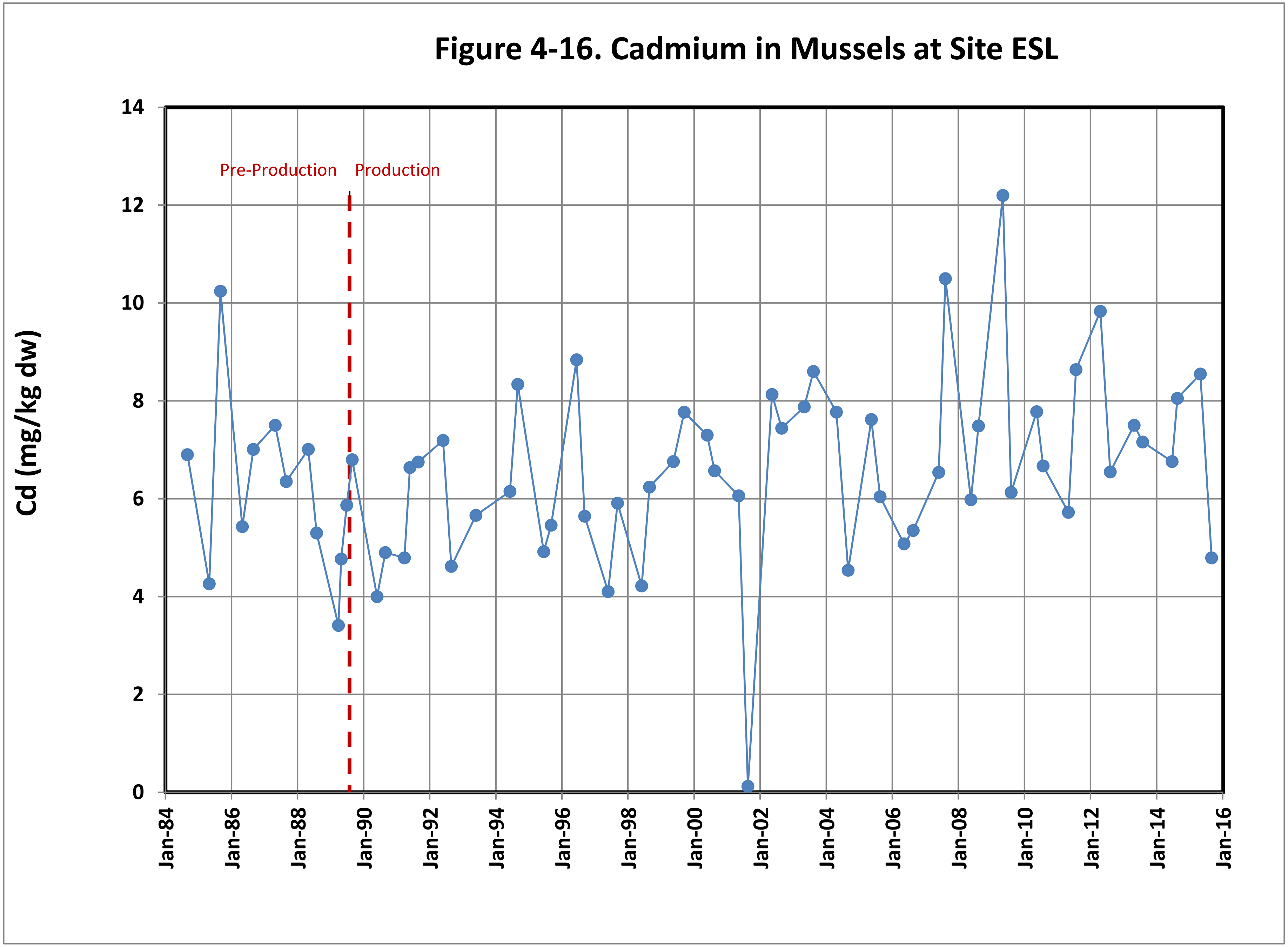


Figure 4-16. Cadmium in Mussels at Site ESL
Cd (mg/kg dw)
Pre-Production
Production
0
2
4
6
8
10
12
14
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

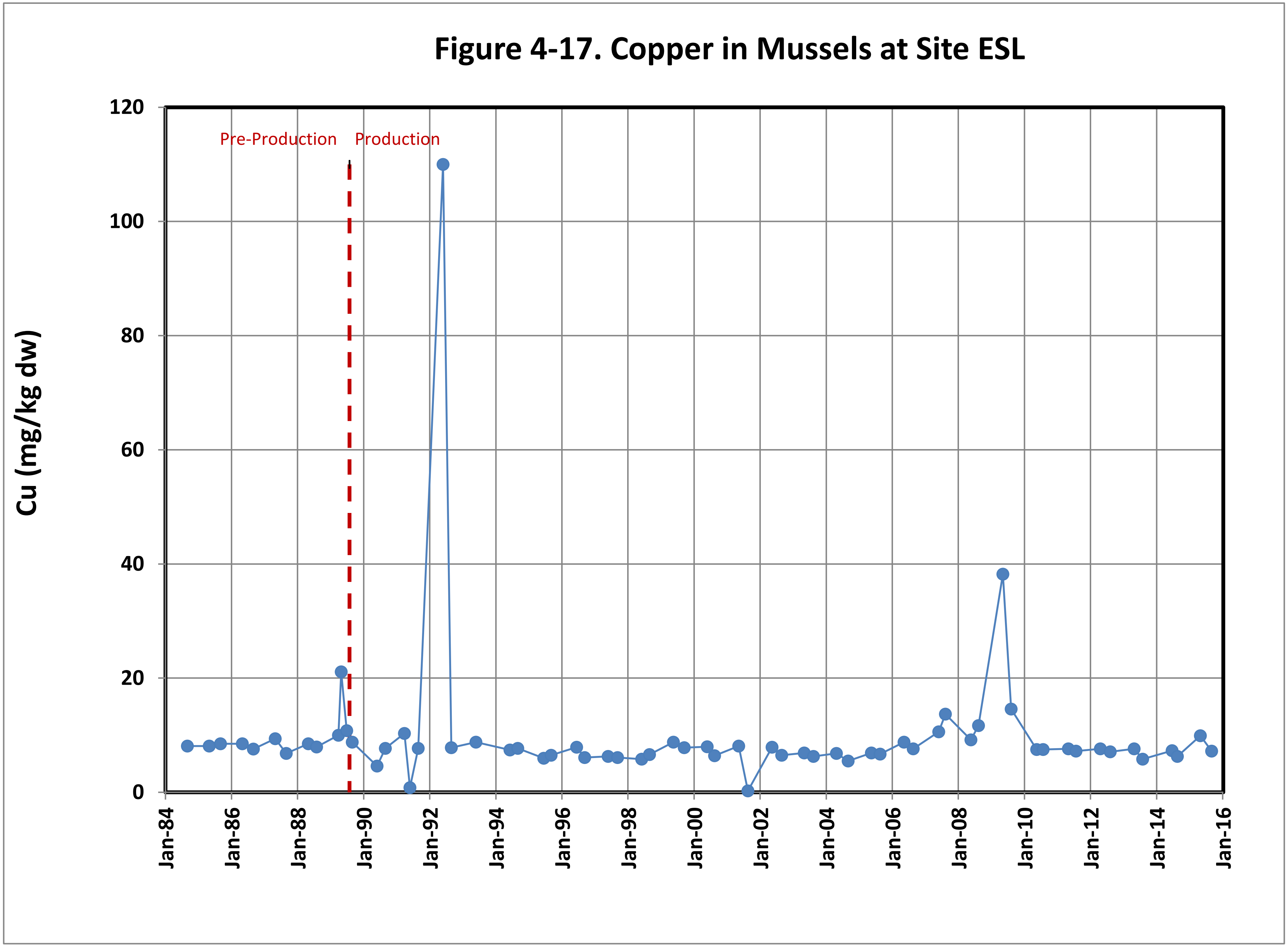


Figure 4-17. Copper in Mussels at Site ESL
Cu (mg/kg dw)
120
100
80
60
40
20
0
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

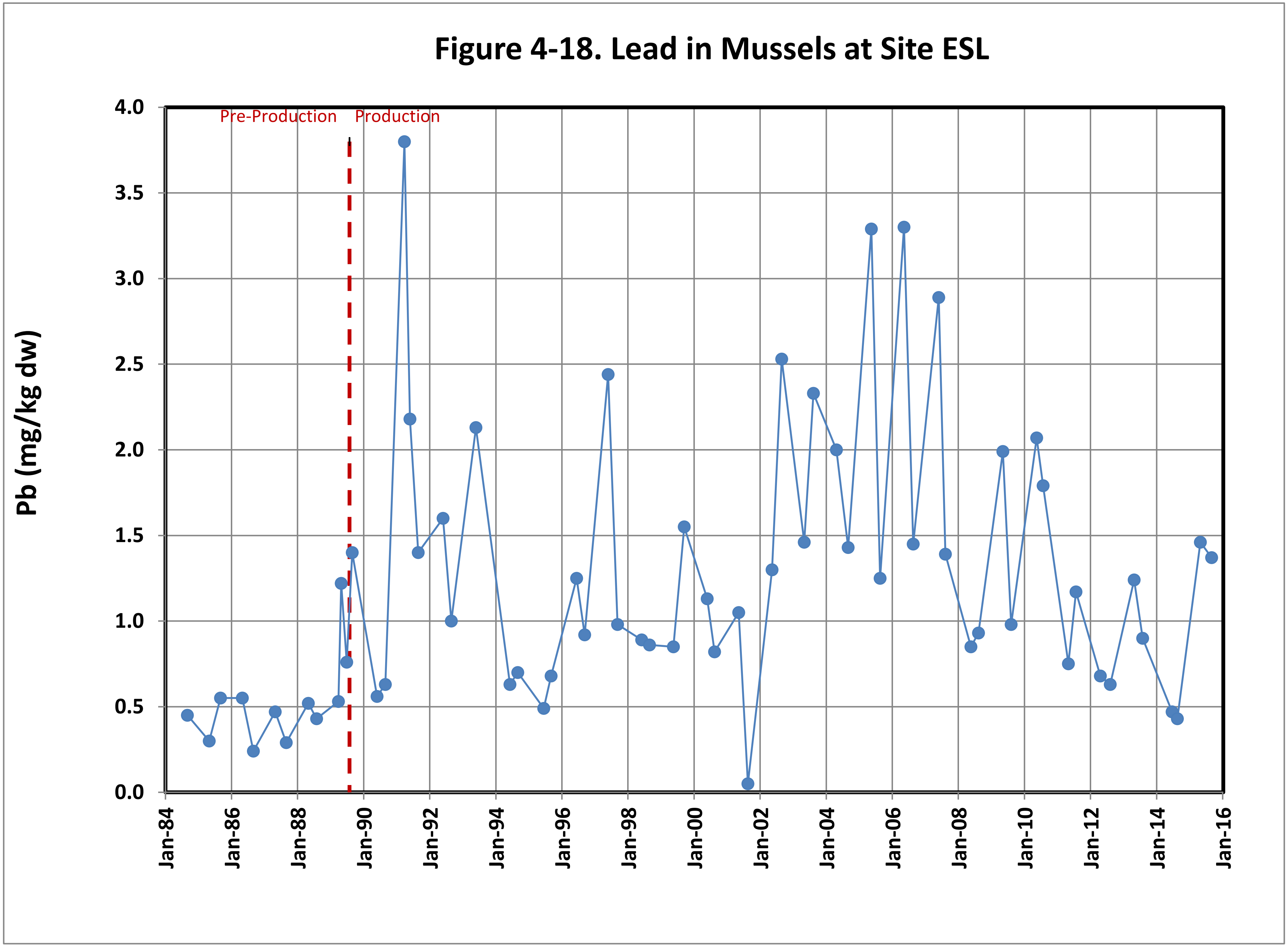


Figure 4-18. Lead in Mussels at Site ESL
Pb (mg/kg dw)
Pre-Production
Production
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

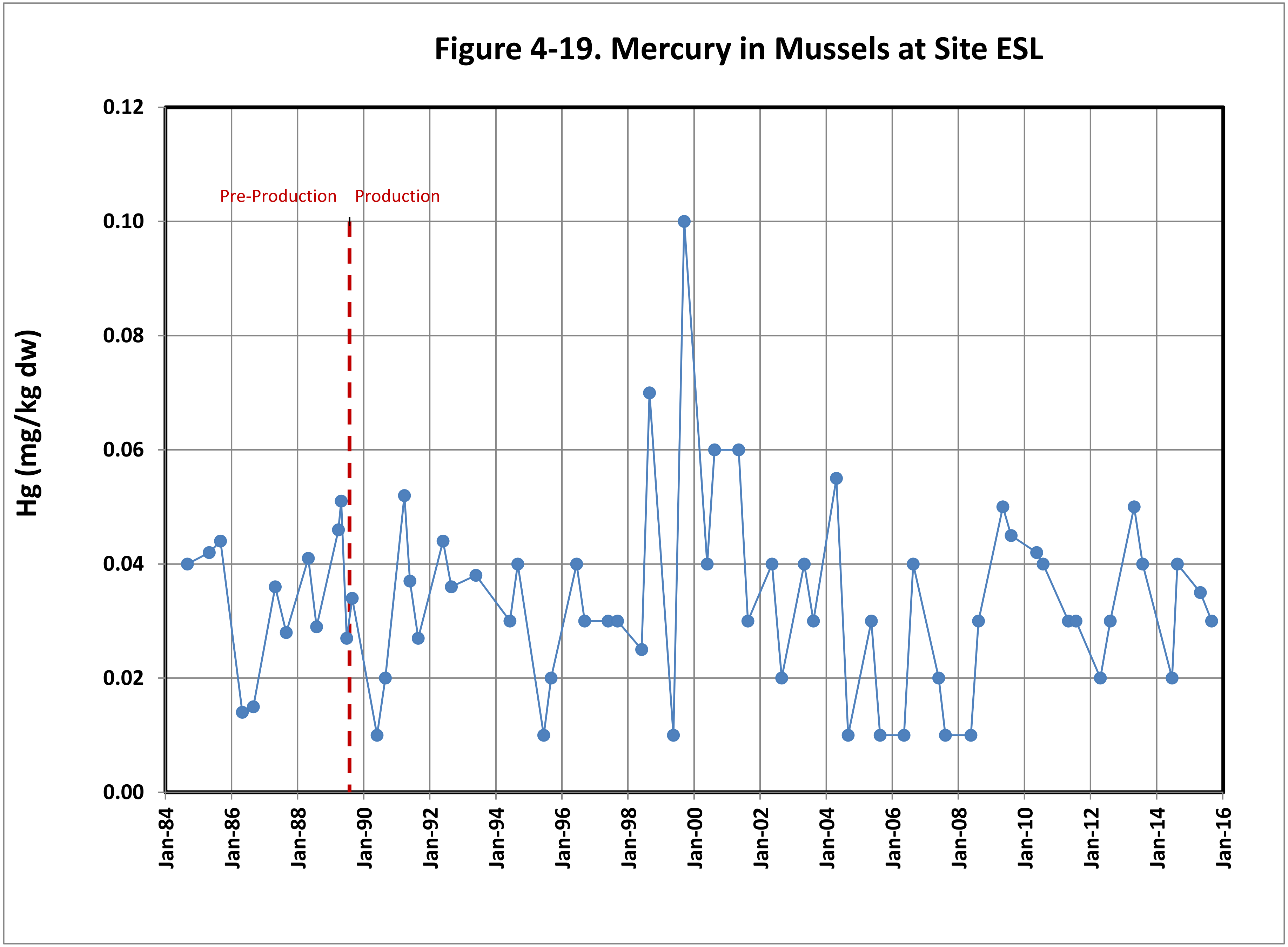


Figure 4-19. Mercury in Mussels at Site ESL
Hg (mg/kg dw)
Pre-Production
Production
0.00
0.02
0.04
0.06
0.08
0.10
0.12
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

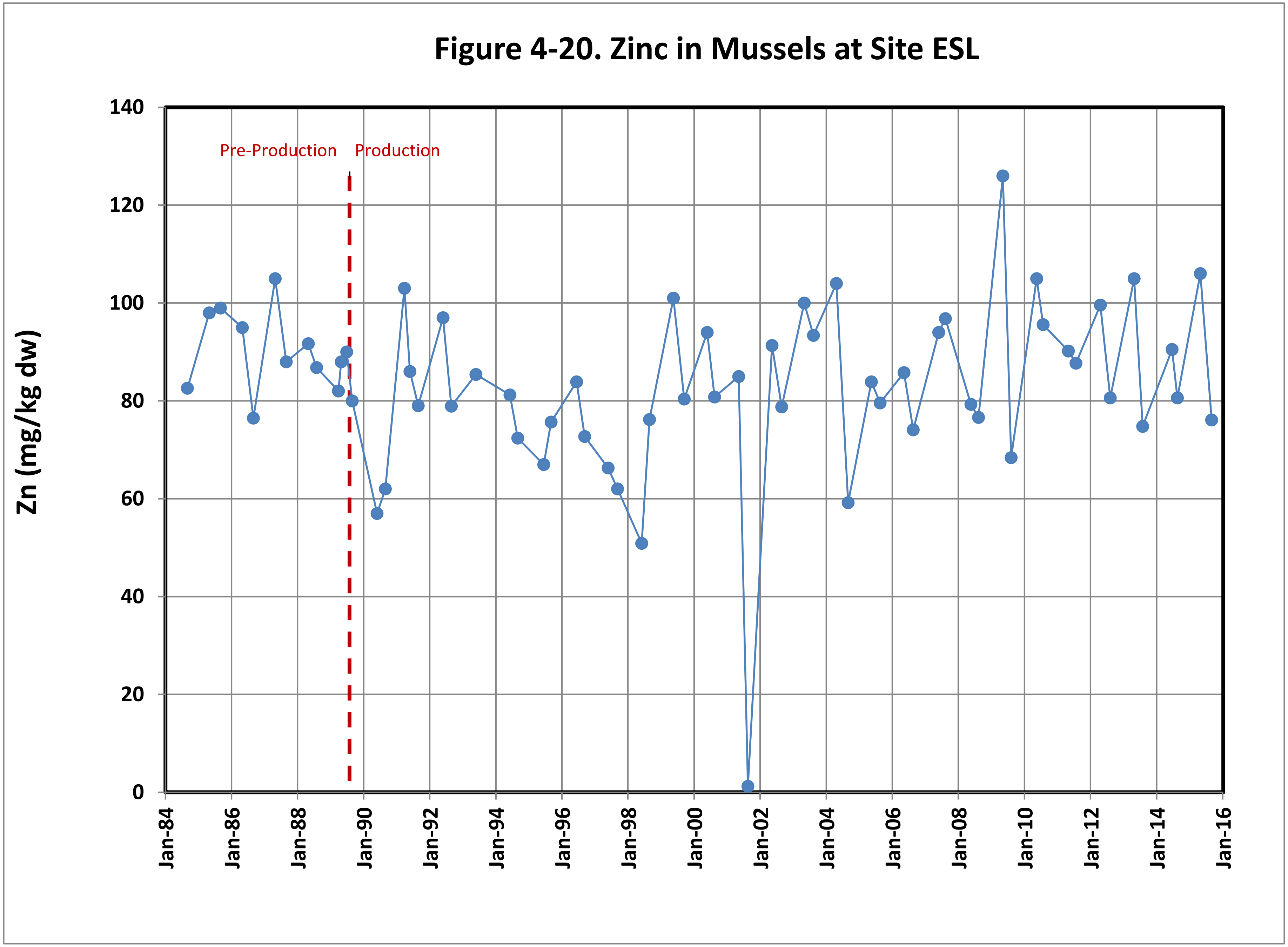


Figure 4-20. Zinc in Mussels at Site ESL
Zn (mg/kg dw)
Pre-Production
Production
0
20
40
60
80
100
120
140
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

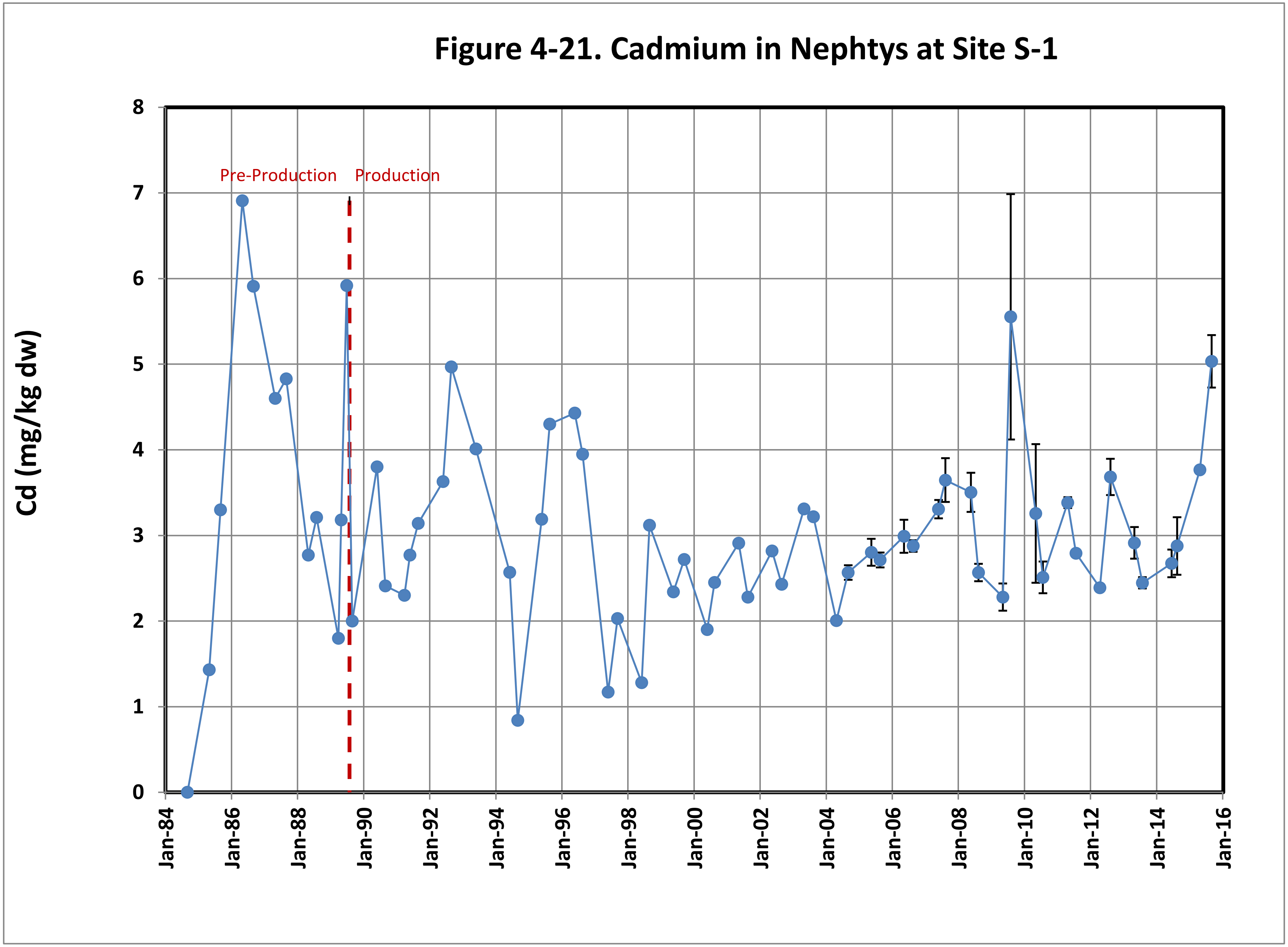


Figure 4-21. Cadmium in Nephtys at Site S-1
Cd (mg/kg dw)
0
1
2
3
4
5
6
7
8
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

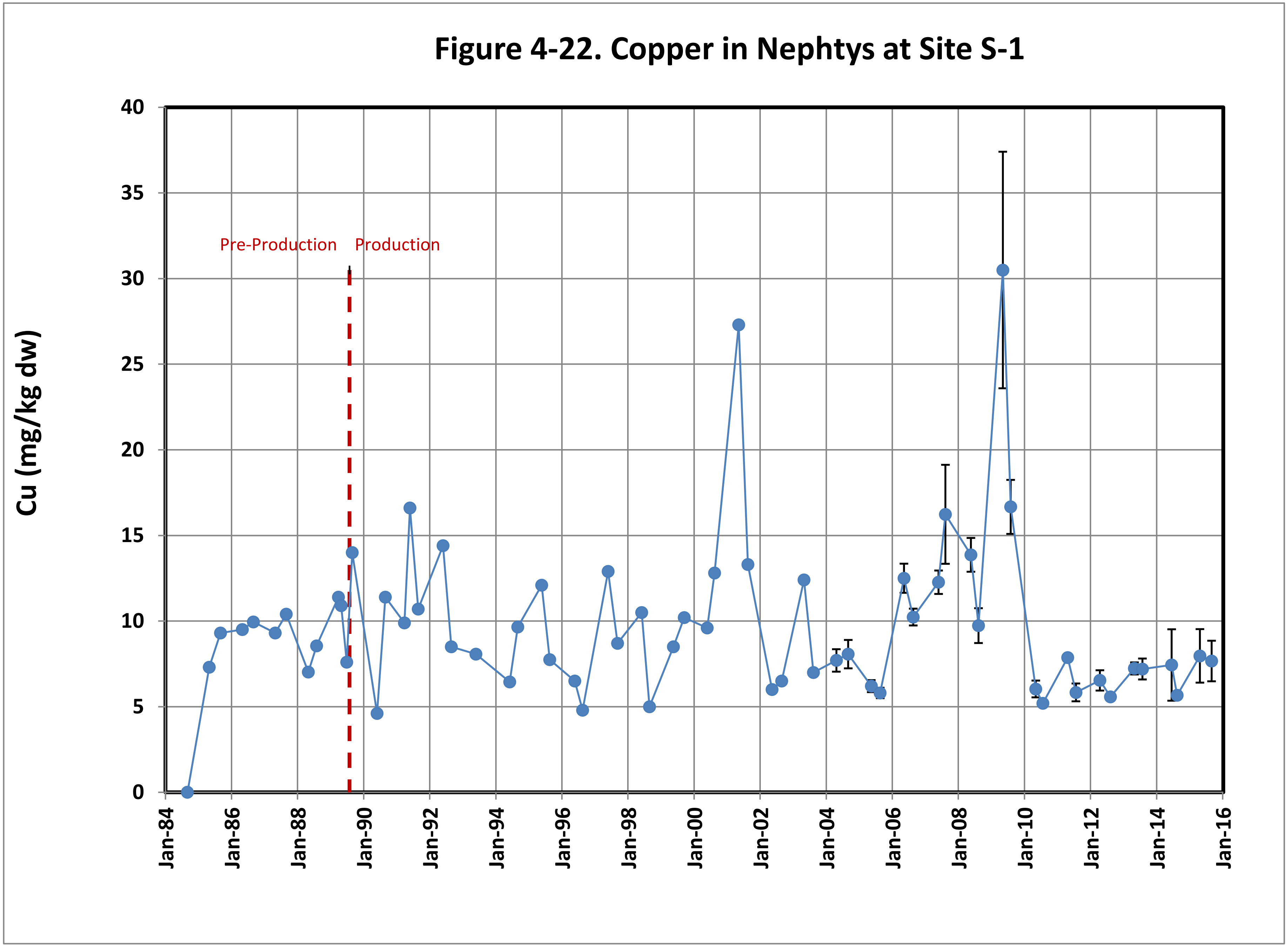


Figure 4-22. Copper in Nephtys at Site S-1
Cu (mg/kg dw)
Pre-Production
Production
0
5
10
15
20
25
30
35
40
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

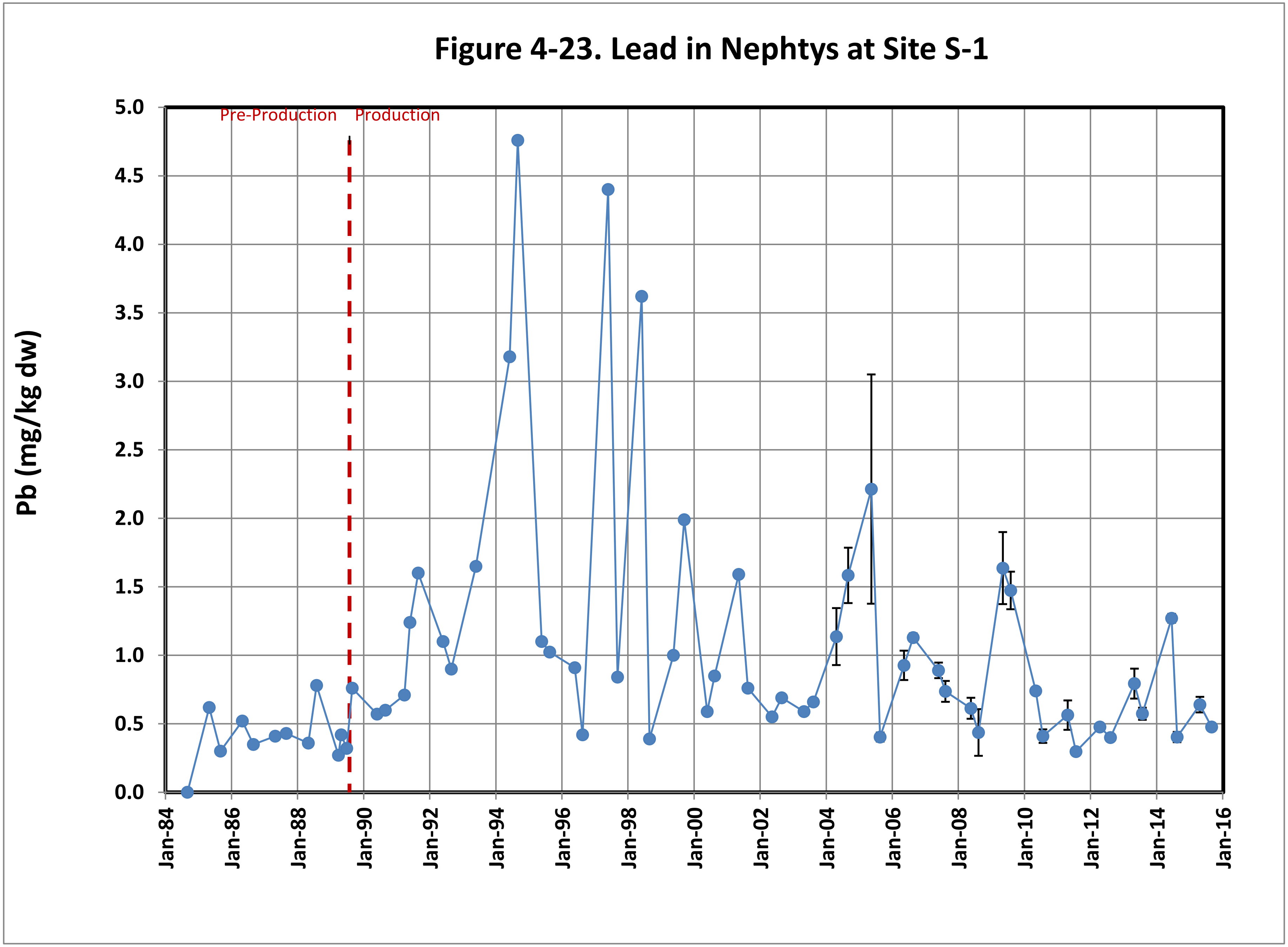


Figure 4-23. Lead in Nephtys at Site S-1
Pre-Production
Production
Pb (mg/kg dw)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

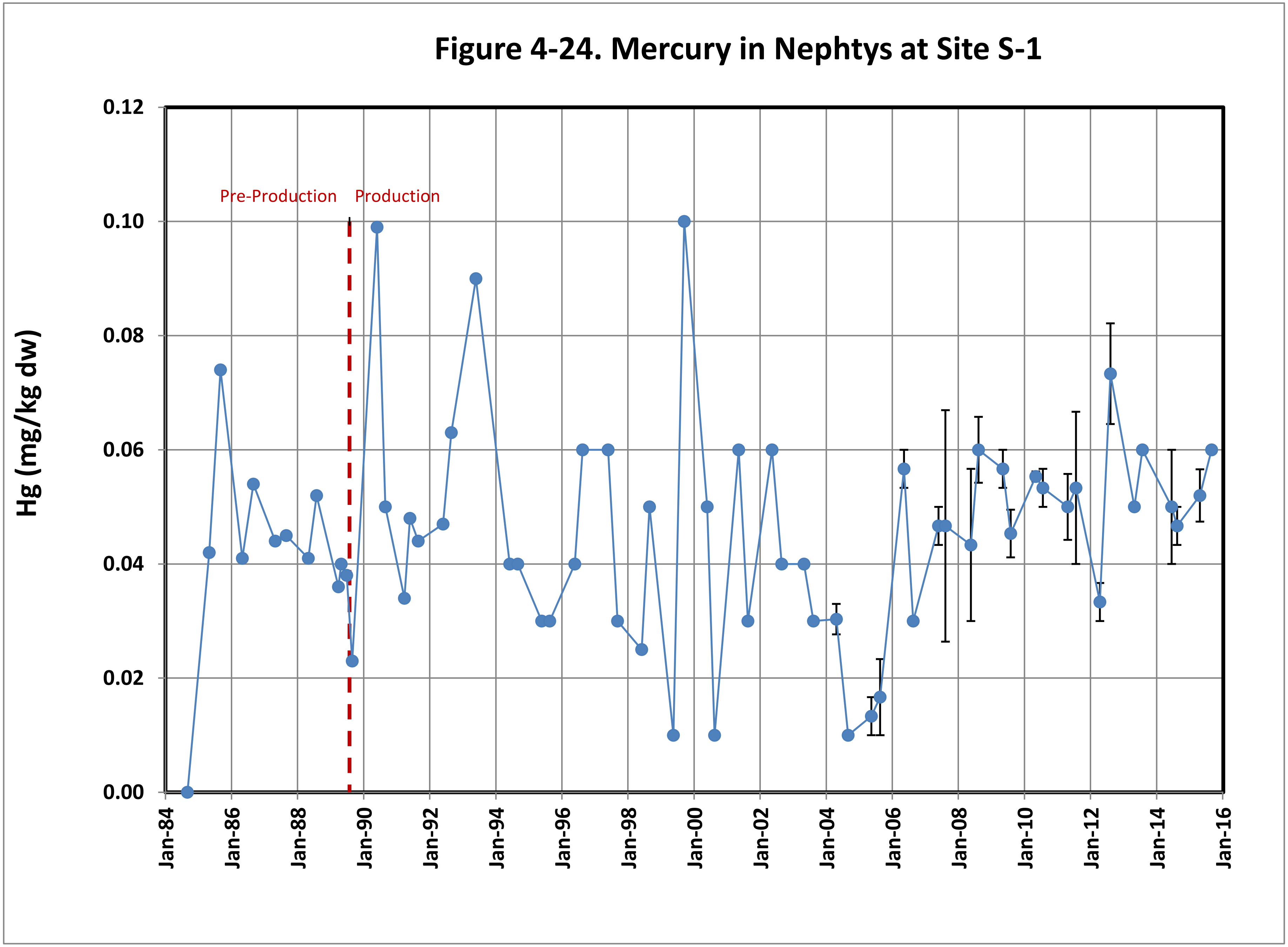


Figure 4-24. Mercury in Nephtys at Site S-1
Hg (mg/kg dw)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

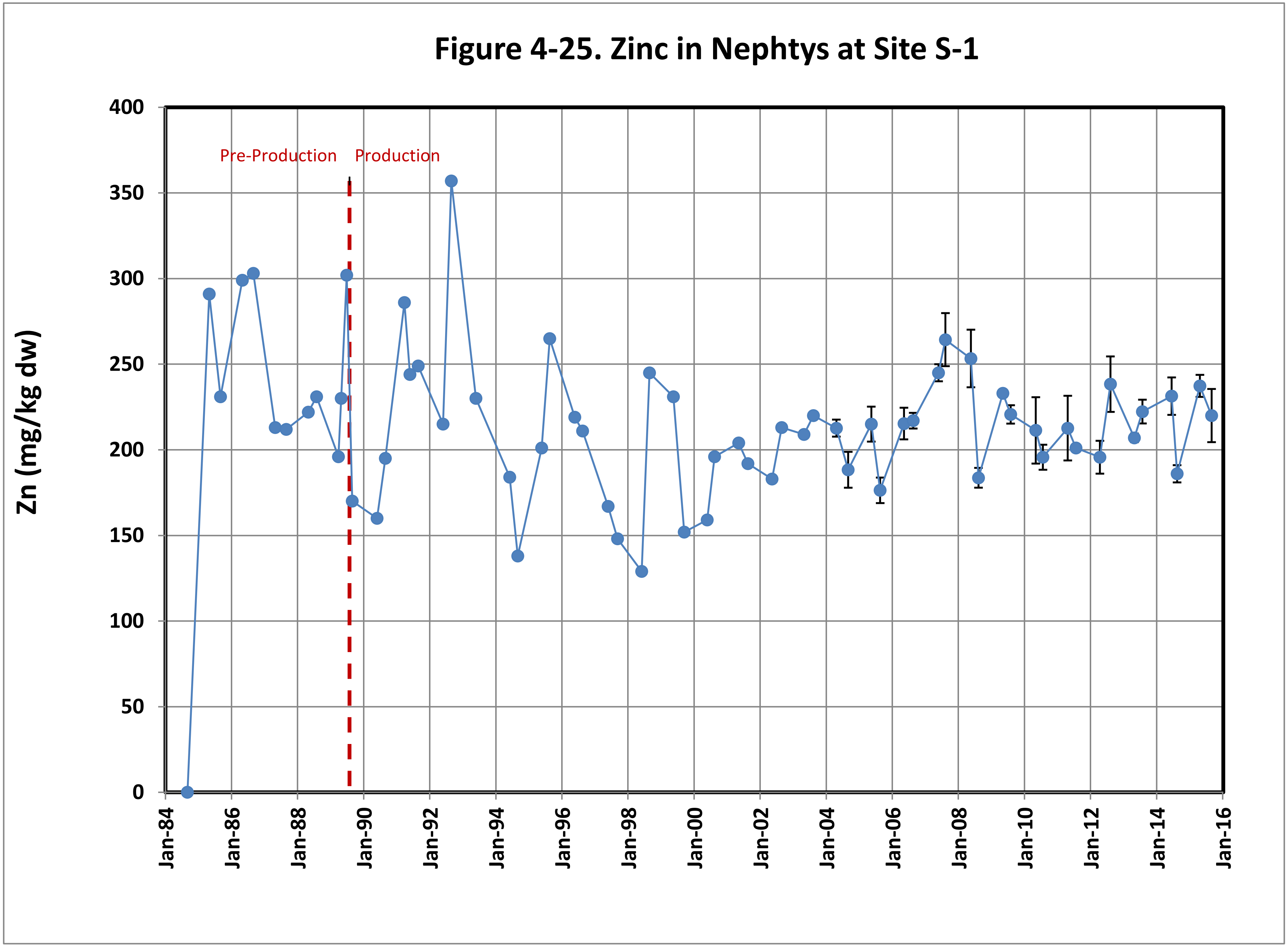


Figure 4-25. Zinc in Nephtys at Site S-1
Pre-Production
Production
Zn (mg/kg dw)
400
350
300
250
200
150
100
50
0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

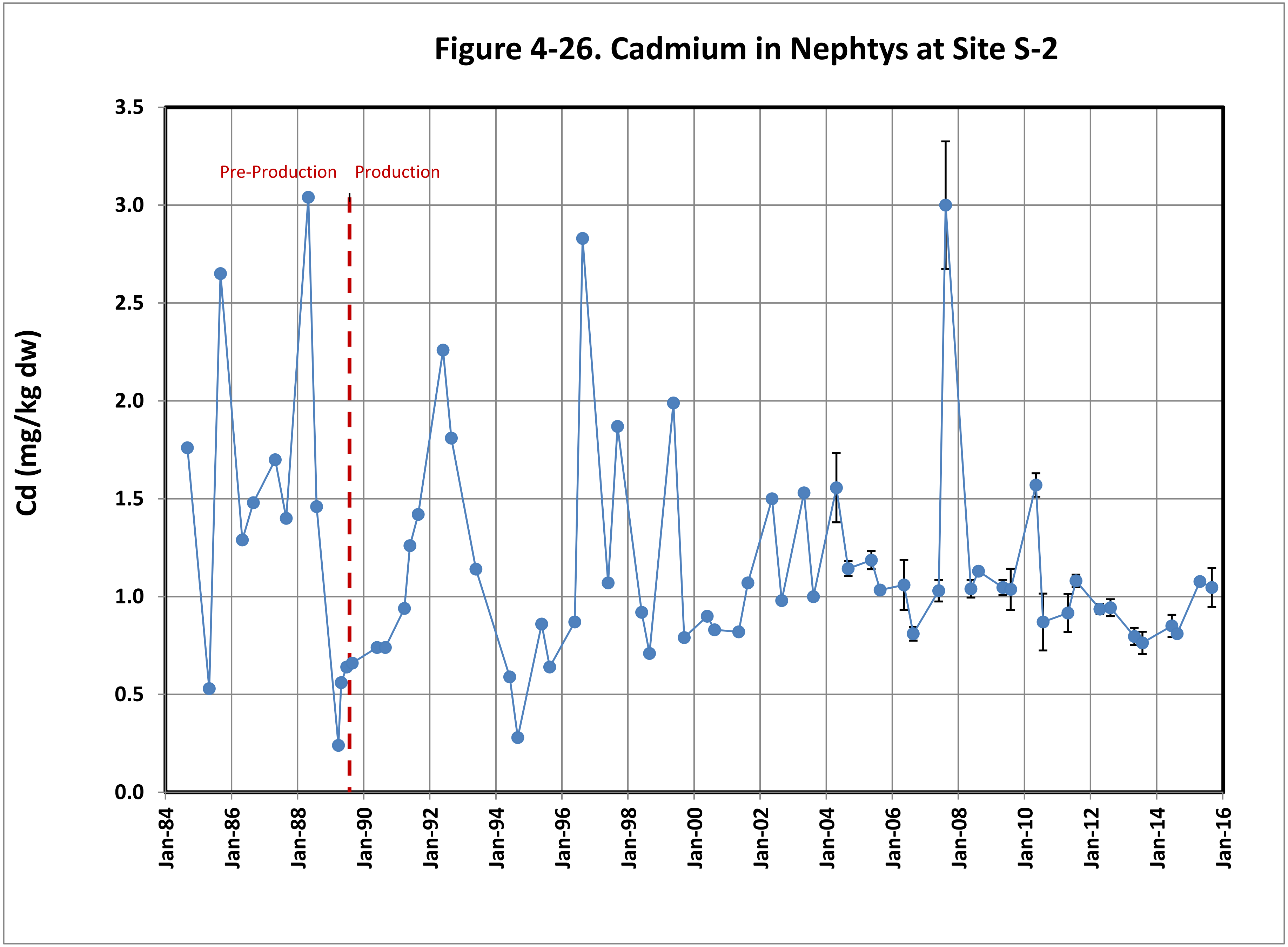


Figure 4-26. Cadmium in Nephtys at Site S-2
Cd (mg/kg dw)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
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Jan-12
Jan-14
Jan-16

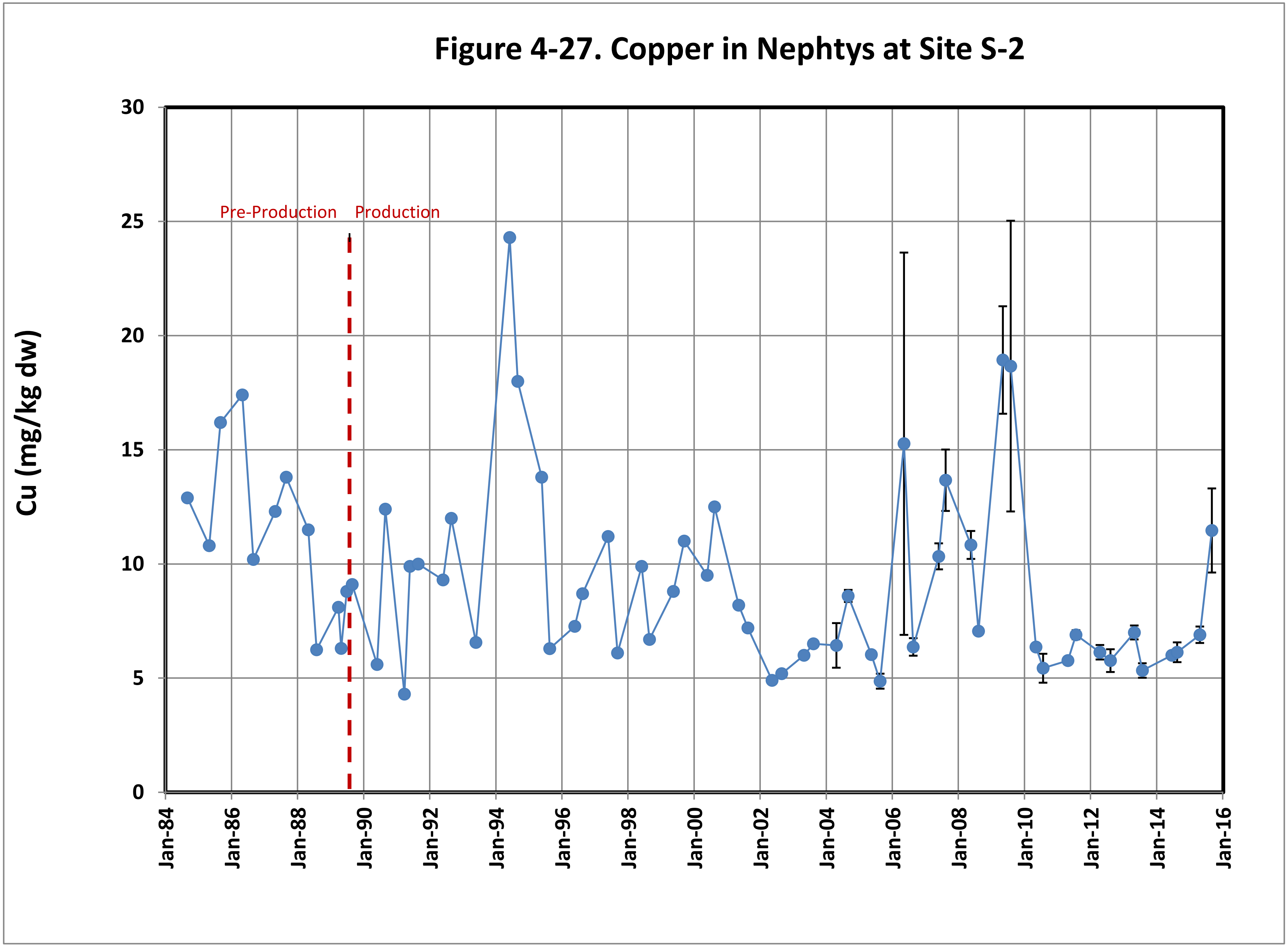
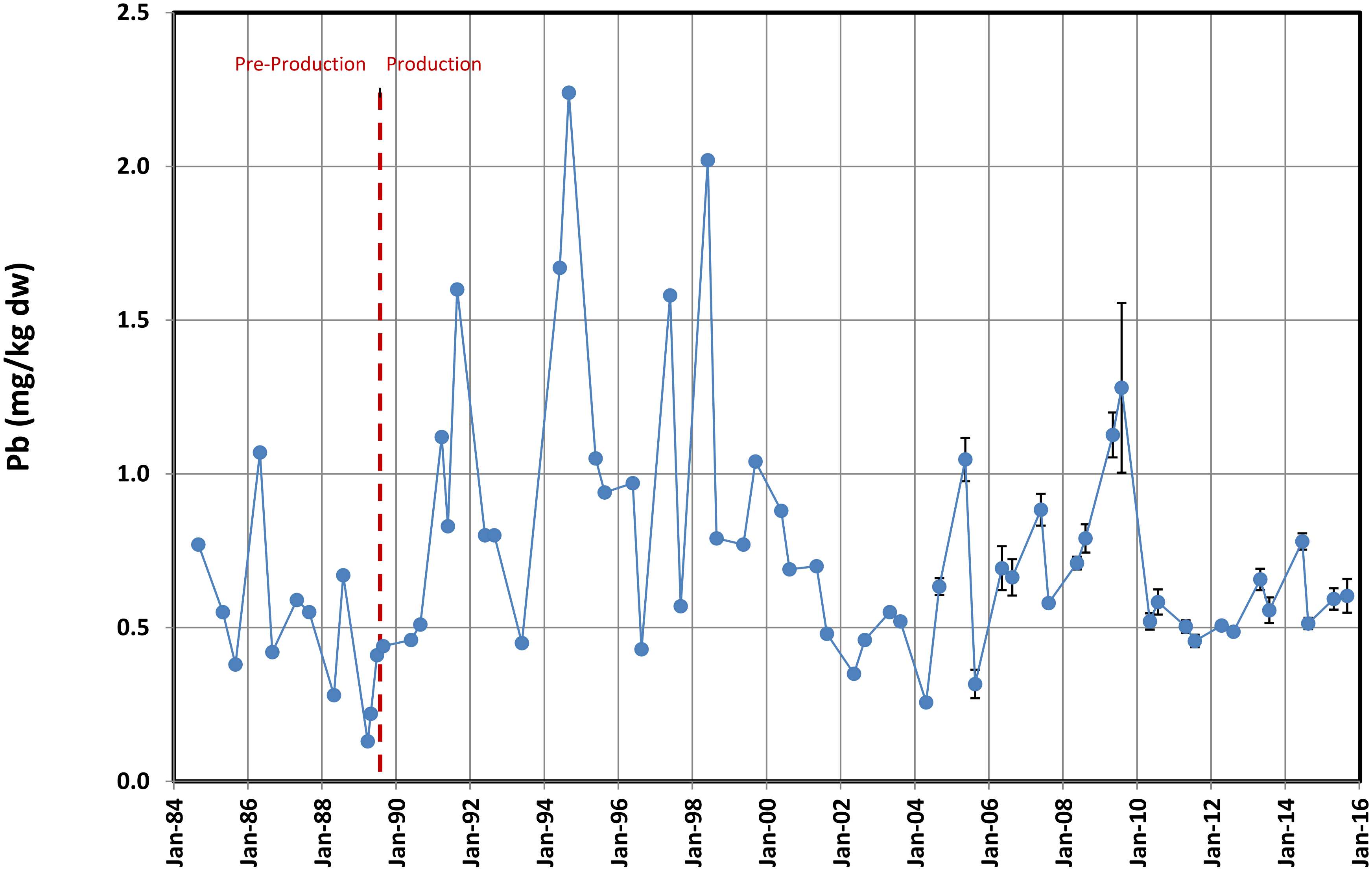


Figure 4-27. Copper in Nephtys at Site S-2
Cu (mg/kg dw)
Pre-Production
Production
30
25
20
15
10
5
0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

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



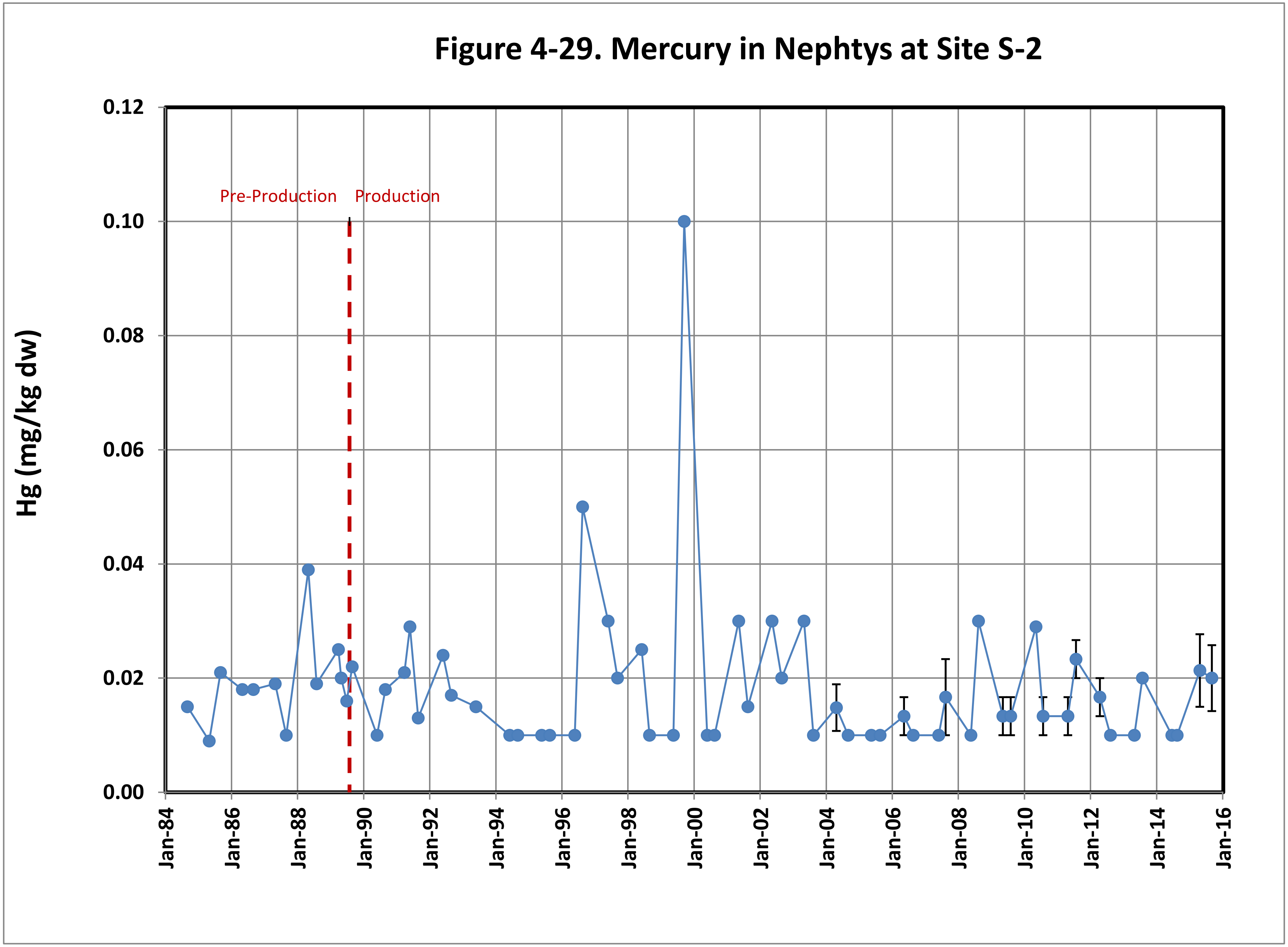


Figure 4-29. Mercury in Nephtys at Site S-2
Hg (mg/kg dw)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

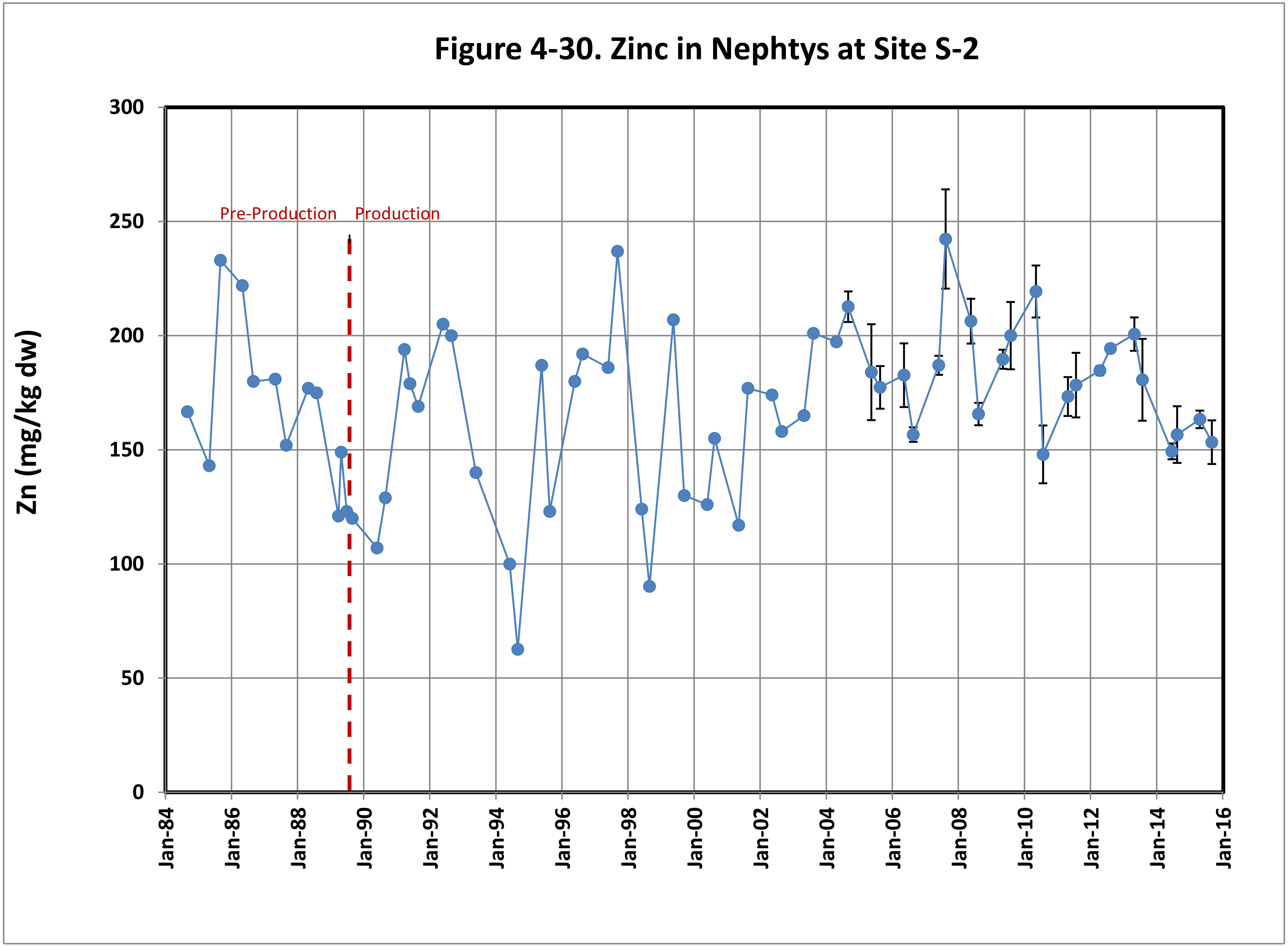
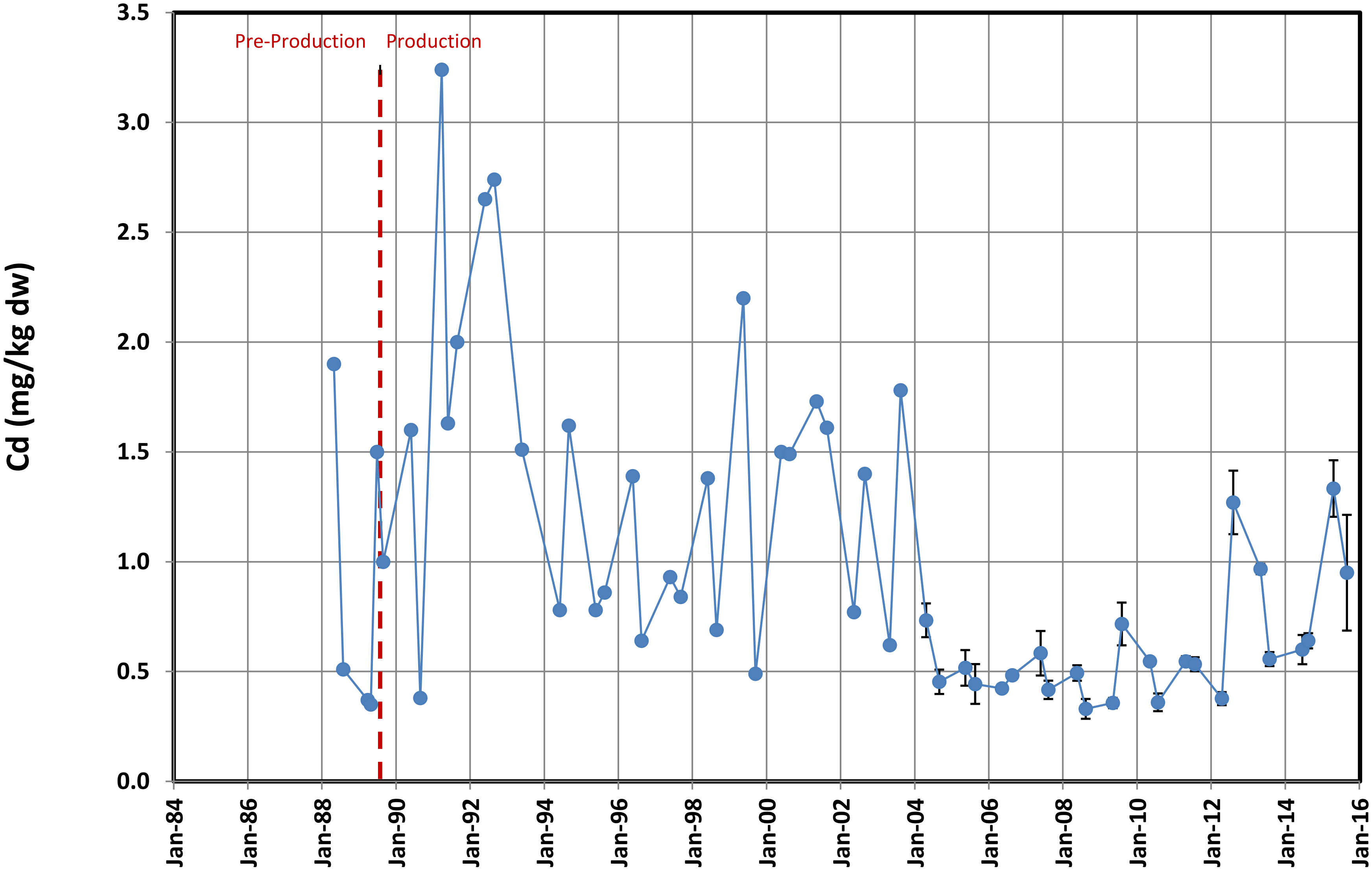
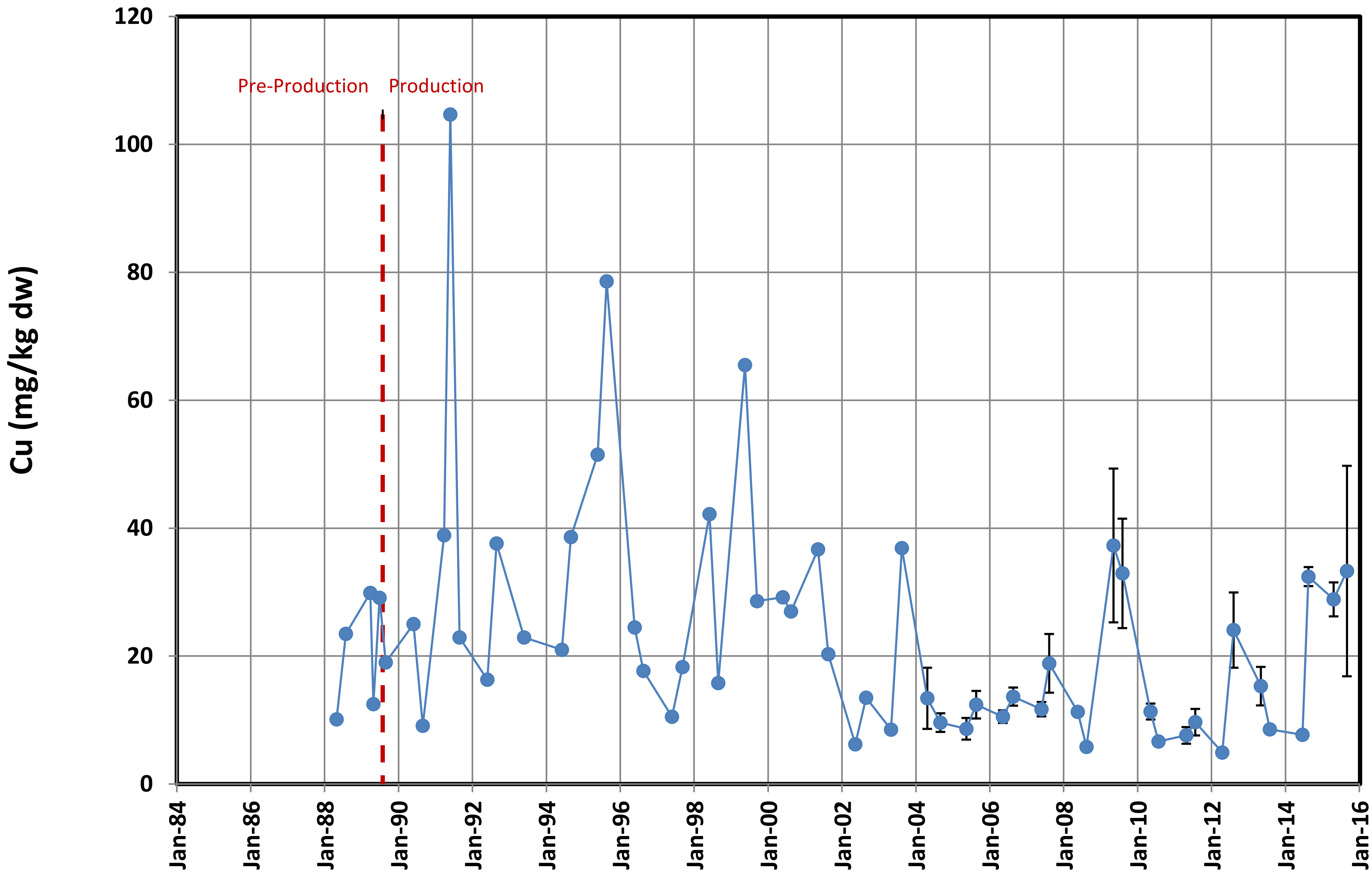


Figure 4-30. Zinc in Nephtys at Site S-2
Zn (mg/kg dw)
300
250
200
150
100
50
0
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

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



# Figure 4-32. Copper in Nephtys at Site S-4



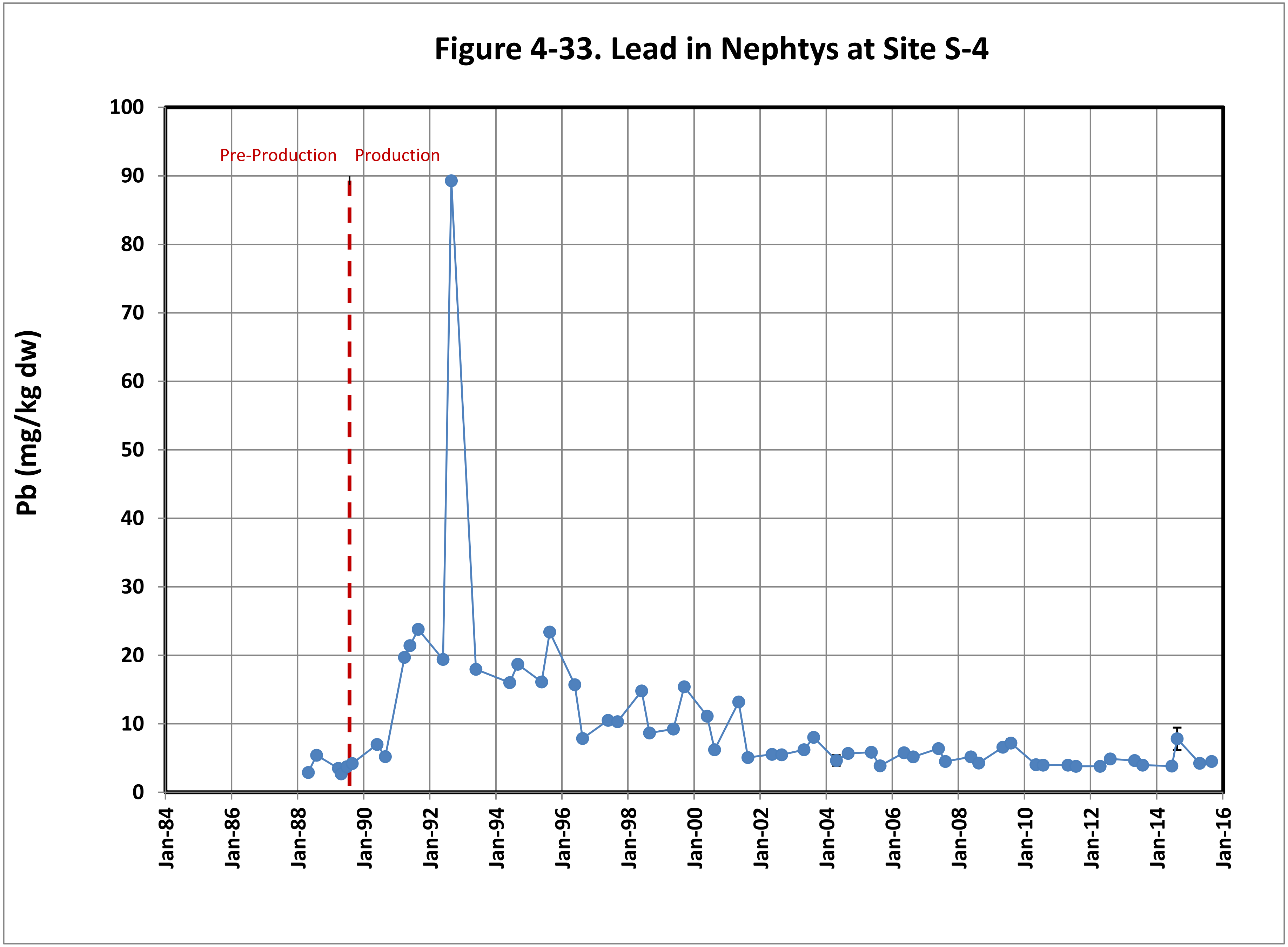
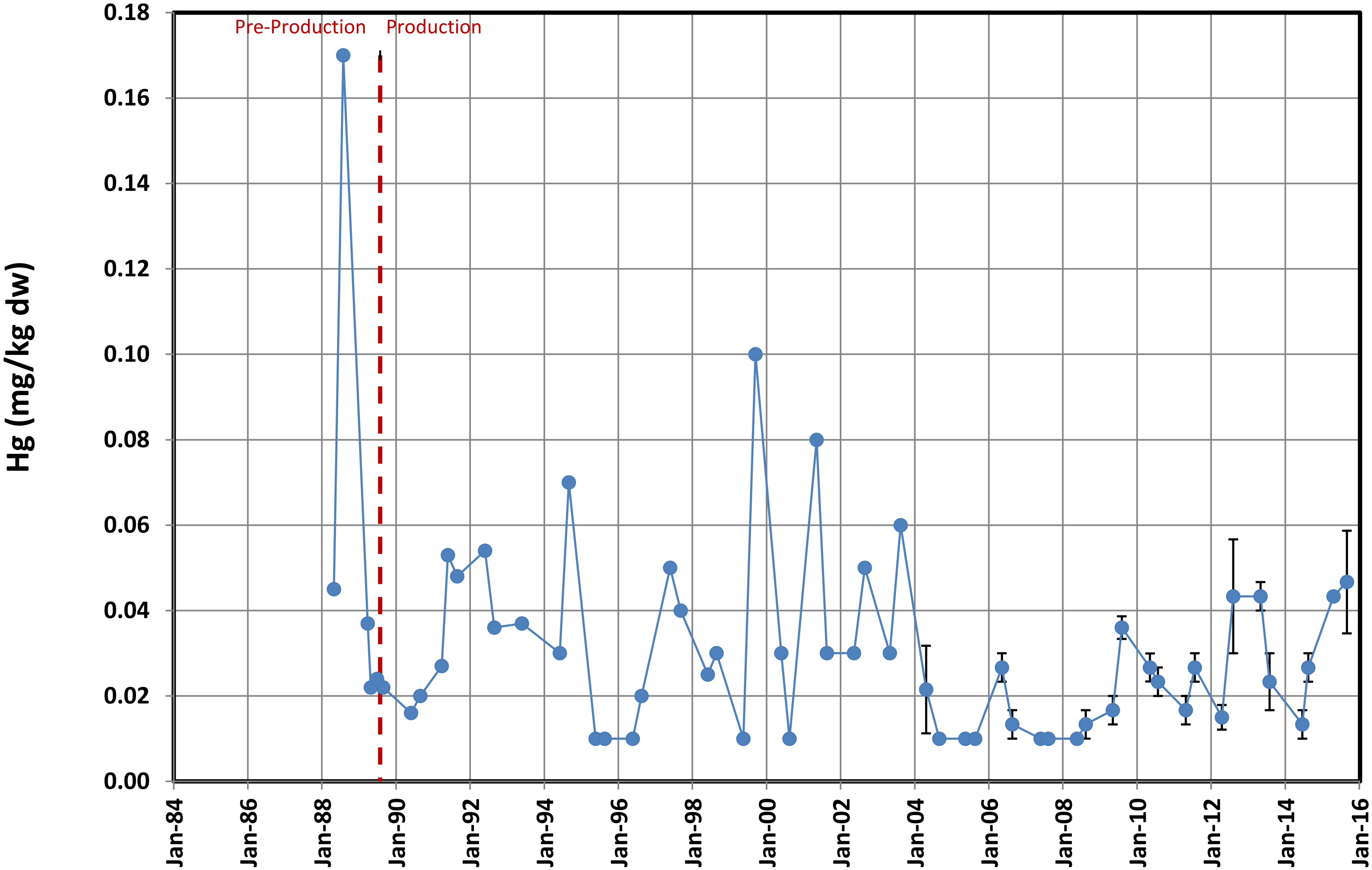
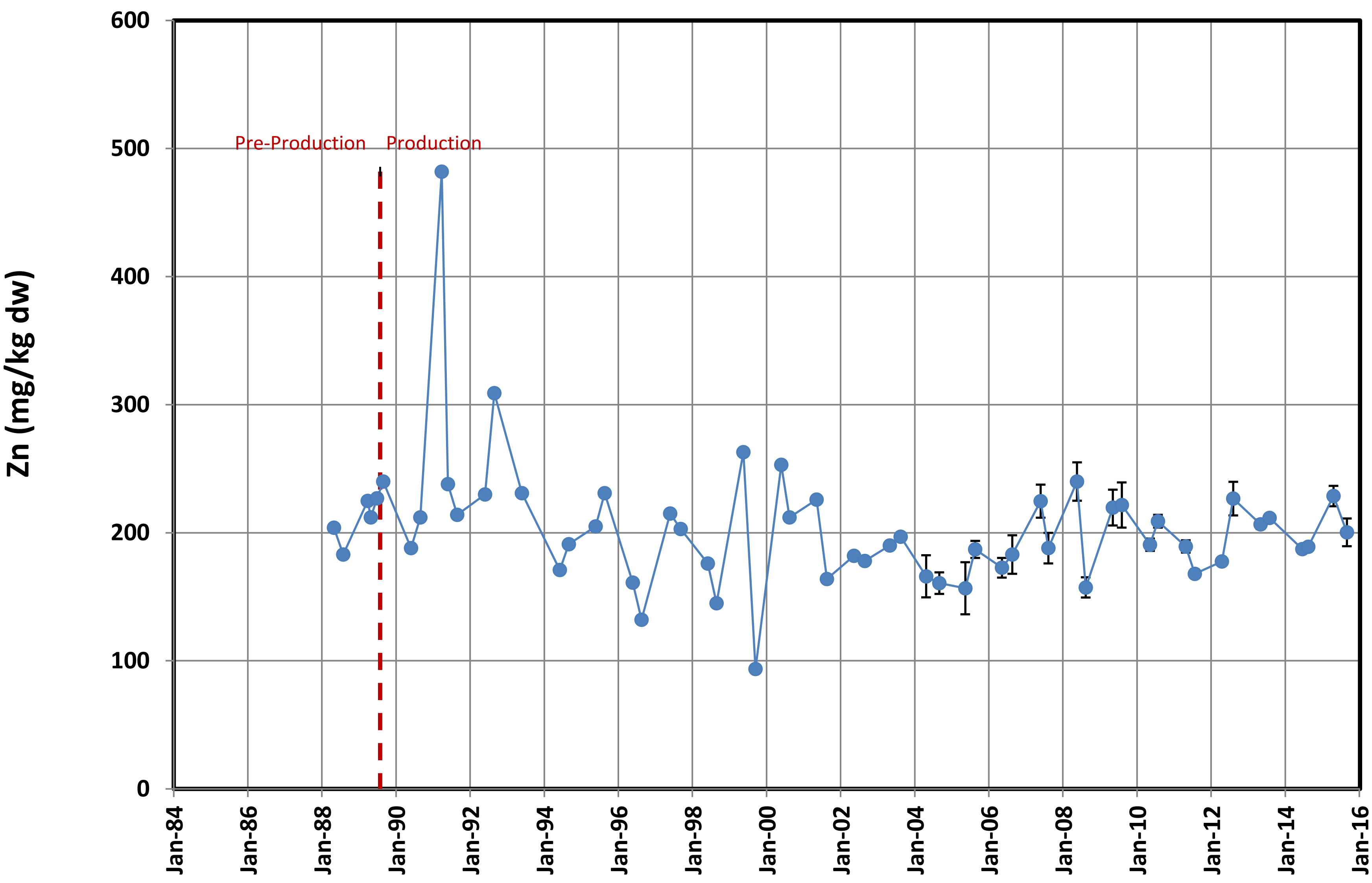


Figure 4-33. Lead in Nephtys at Site S-4
Pb (mg/kg dw)
100
90
80
70
60
50
40
30
20
10
0
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16

# Figure 4-34. Mercury in Nephtys at Site S-4



# Figure 4-35. Zinc in Nephtys at Site S-4



# APPENDIX A

# Sediment Laboratory Detection Limits

| 2015 Laboratory Method Reporting Limit* for Sediment Analysis | | | |
|---|---|---|---|
| **Sample ID** | **Metal** | **Spring** | **Fall** |
| | | mg/kg | mg/kg |
| S-1 Sediment-Metals Rep I | Cadmium | 0.02 | 0.02 |
| S-1 Sediment-Metals Rep I | Copper | 0.09 | 0.10 |
| S-1 Sediment-Metals Rep I | Lead | 0.05 | 0.05 |
| S-1 Sediment-Metals Rep I | Mercury | 0.02 | 0.02 |
| S-1 Sediment-Metals Rep I | Zinc | 0.5 | 0.5 |
| S-1 Sediment-Metals Rep II | Cadmium | 0.02 | 0.02 |
| S-1 Sediment-Metals Rep II | Copper | 0.09 | 0.09 |
| S-1 Sediment-Metals Rep II | Lead | 0.05 | 0.05 |
| S-1 Sediment-Metals Rep II | Mercury | 0.02 | 0.02 |
| S-1 Sediment-Metals Rep II | Zinc | 0.4 | 0.5 |
| S-1 Sediment-Metals Rep III | Cadmium | 0.02 | 0.02 |
| S-1 Sediment-Metals Rep III | Copper | 0.09 | 0.09 |
| S-1 Sediment-Metals Rep III | Lead | 0.05 | 0.04 |
| S-1 Sediment-Metals Rep III | Mercury | 0.02 | 0.02 |
| S-1 Sediment-Metals Rep III | Zinc | 0.5 | 0.4 |
| S2 Sediment-Metals Rep I | Cadmium | 0.02 | 0.01 |
| S2 Sediment-Metals Rep I | Copper | 0.10 | 0.05 |
| S2 Sediment-Metals Rep I | Lead | 0.05 | 0.02 |
| S2 Sediment-Metals Rep I | Mercury | 0.02 | 0.02 |
| S2 Sediment-Metals Rep I | Zinc | 0.5 | 0.2 |
| S-2 Sediment-Metals Rep II | Cadmium | 0.02 | 0.01 |
| S-2 Sediment-Metals Rep II | Copper | 0.08 | 0.05 |
| S-2 Sediment-Metals Rep II | Lead | 0.04 | 0.03 |
| S-2 Sediment-Metals Rep II | Mercury | 0.02 | 0.02 |
| S-2 Sediment-Metals Rep II | Zinc | 0.4 | 0.2 |
| S-2 Sediment-Metals Rep III | Cadmium | 0.02 | 0.01 |
| S-2 Sediment-Metals Rep III | Copper | 0.08 | 0.05 |
| S-2 Sediment-Metals Rep III | Lead | 0.04 | 0.03 |
| S-2 Sediment-Metals Rep III | Mercury | 0.02 | 0.02 |
| S-2 Sediment-Metals Rep III | Zinc | 0.4 | 0.3 |
| S-4 Sediment-Metals Rep I | Cadmium | 0.02 | 0.01 |
| S-4 Sediment-Metals Rep I | Copper | 0.09 | 0.05 |
| S-4 Sediment-Metals Rep I | Lead | 0.05 | 0.02 |
| S-4 Sediment-Metals Rep I | Mercury | 0.02 | 0.02 |
| S-4 Sediment-Metals Rep I | Zinc | 0.4 | 0.2 |
| S-4 Sediment-Metals Rep II | Cadmium | 0.02 | 0.01 |
| S-4 Sediment-Metals Rep II | Copper | 0.10 | 0.05 |
| S-4 Sediment-Metals Rep II | Lead | 0.05 | 0.02 |
| S-4 Sediment-Metals Rep II | Mercury | 0.02 | 0.02 |
| S-4 Sediment-Metals Rep II | Zinc | 0.5 | 0.2 |
| S-4 Sediment-Metals Rep III | Cadmium | 0.02 | 0.01 |
| S-4 Sediment-Metals Rep III | Copper | 0.08 | 0.06 |
| S-4 Sediment-Metals Rep III | Lead | 0.04 | 0.03 |

| Sample ID | Metal | Spring | Fall |
|---|---|---|---|
| | mg/Kg | mg/Kg | mg/Kg |
| S-4 Sediment-Metals Rep III | Mercury | 0.02 | 0.02 |
| S-4 Sediment-Metals Rep III | Zinc | 0.4 | 0.3 |
| S-5N Sediment-Metals Rep I | Cadmium | 0.01 | 0.01 |
| S-5N Sediment-Metals Rep I | Copper | 0.05 | 0.06 |
| S-5N Sediment-Metals Rep I | Lead | 0.03 | 0.03 |
| S-5N Sediment-Metals Rep I | Mercury | 0.02 | 0.02 |
| S-5N Sediment-Metals Rep I | Zinc | 0.3 | 0.3 |
| S-5N Sediment-Metals Rep II | Cadmium | 0.01 | 0.01 |
| S-5N Sediment-Metals Rep II | Copper | 0.05 | 0.06 |
| S-5N Sediment-Metals Rep II | Lead | 0.03 | 0.03 |
| S-5N Sediment-Metals Rep II | Mercury | 0.02 | 0.02 |
| S-5N Sediment-Metals Rep II | Zinc | 0.3 | 0.3 |
| S-5N Sediment-Metals Rep III | Cadmium | 0.01 | 0.02 |
| S-5N Sediment-Metals Rep III | Copper | 0.06 | 0.07 |
| S-5N Sediment-Metals Rep III | Lead | 0.03 | 0.04 |
| S-5N Sediment-Metals Rep III | Mercury | 0.02 | 0.02 |
| S-5N Sediment-Metals Rep III | Zinc | 0.3 | 0.4 |
| S-5s Sediment-Metals Rep I | Cadmium | 0.01 | 0.01 |
| S-5s Sediment-Metals Rep I | Copper | 0.05 | 0.06 |
| S-5s Sediment-Metals Rep I | Lead | 0.26 | 0.03 |
| S-5s Sediment-Metals Rep I | Mercury | 0.02 | 0.02 |
| S-5s Sediment-Metals Rep I | Zinc | 0.3 | 2.9 |
| S-5s Sediment-Metals Rep II | Cadmium | 0.01 | 0.01 |
| S-5s Sediment-Metals Rep II | Copper | 0.06 | 0.05 |
| S-5s Sediment-Metals Rep II | Lead | 0.03 | 0.03 |
| S-5s Sediment-Metals Rep II | Mercury | 0.02 | 0.02 |
| S-5s Sediment-Metals Rep II | Zinc | 0.3 | 2.5 |
| S-5s Sediment-Metals Rep III | Cadmium | 0.01 | 0.01 |
| S-5s Sediment-Metals Rep III | Copper | 0.06 | 0.06 |
| S-5s Sediment-Metals Rep III | Lead | 0.03 | 0.03 |
| S-5s Sediment-Metals Rep III | Mercury | 0.02 | 0.02 |
| S-5s Sediment-Metals Rep III | Zinc | 0.3 | 0.3 |

*Method Reporting Limit (MRL) – Define by ALS Environmental as being times the MDL (or greater).

# APPENDIX B

# Outfall Survey Footage