



30 January 2015

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

RE: Hawk Inlet Monitoring Program 2014 Annual Report (APDES Permit AK-004320-6)

Attached please find the Hecla Greens Creek Mining Company Hawk Inlet Monitoring Program 2013 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 the 2014 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,

A handwritten signature in black ink that reads "Christopher Wallace". The signature is written in a cursive style with a long, sweeping underline.

Christopher Wallace
Environmental Affairs Manager

Attachment and CD

cc: T. Pilon – ADEC, W. Collingwood – ADEC, E. DeMaria –USEPA, M. Reece – USFS

**HAWK INLET MONITORING PROGRAM
2014 ANNUAL REPORT**



Hecla Greens Creek Mining Company

January 2015

TABLE OF CONTENTS

1.0 INTRODUCTION

- 1.1 Site Description
- 1.2 Hawk Inlet Monitoring Program
- 1.3 Deviation(s) from Program and Incidents in 2014

2.0 WATER COLUMN MONITORING

- 2.1 2014 Analytical Results
- 2.2 Data Evaluation
- 2.3 QA/QC Results

3.0 SEDIMENT MONITORING

- 3.1 2014 Analytical Results
- 3.2 Data Evaluation
- 3.3 QA/QC Results

4.0 IN-SITU BIOASSAYS

- 4.1 2014 Analytical Results
- 4.2 Data Evaluation
- 4.3 QA/QC Results

5.0 CONCLUSIONS

6.0 REFERENCES

TABLES

- 1-1 Summary of Permit Sampling Requirements
- 2-1 Hawk Inlet Water Column Field Parameters 2014
- 2-2 Hawk Inlet Water Column Monitoring Results 2014: Nonmetal Parameters
- 2-3 Hawk Inlet Water Column Monitoring Results 2014: Metals
- 2-4 Hawk Inlet Water Column Average Dissolved Metal Concentrations
- 3-1 Hawk Inlet Sediment Monitoring Field Parameters 2014
- 3-2 Hawk Inlet Sediment Results for Summer 2014
- 3-3 Hawk Inlet Sediment Results for Fall 2014
- 3-4 Hawk Inlet Sediment Data: Pre-Production Baseline, Production Period and Current Year Comparison
- 3-5 Average and Standard Deviation Values for Pre-Production, Production, and Current Year Sediment Data
- 3-6 Relative Standard Deviations (RSD) for Duplicate Sediment Samples

TABLES (continued)

- 4-1 Hawk Inlet Bioassay Monitoring Field Parameters 2014
- 4-2 Hawk Inlet Tissue Results for Summer 2014
- 4-3 Hawk Inlet Tissue Results for Fall 2014
- 4-4 Hawk Inlet Mussel Data: Pre-Production Baseline, Production Period and Current Year Comparison
- 4-5 Hawk Inlet *Nephtys* Data: Pre-Production Baseline, Production Period and Current Year Comparison
- 4-6 Average and Standard Deviation Values for Pre-Production, Production, and Current Year Mussel Data
- 4-7 Average and Standard Deviation Values for Pre-Production, Production, and Current Year *Nephtys* Data
- 4-8 Summary of Results for Additional Tissue Samples
- 4-9 Relative Standard Deviations (RSD) for Duplicate Tissue Samples

FIGURES (located at end of text)

- 1-1 Aerial Photo of Lower Hawk Inlet, Admiralty Island with Water, Sediment and Tissue Sampling Site Locations**
- 2-1a Sea Water pH Data: Site 106**
- 2-1b Sea Water pH Data: Site 107**
- 2-1c Sea Water pH Data: Site 108**
- 2-2a Sea Water EC Data: Site 106**
- 2-2b Sea Water EC Data: Site 107**
- 2-2c Sea Water EC Data: Site 108**
- 2-3a Sea Water Cadmium Data: Site 106**
- 2-3b Sea Water Cadmium Data: Site 107**
- 2-3c Sea Water Cadmium Data: Site 108**
- 2-4a Sea Water Copper Data: Site 106**
- 2-4b Sea Water Copper Data: Site 107**
- 2-4c Sea Water Copper Data: Site 108**
- 2-5a Sea Water Mercury Data: Site 106**
- 2-5b Sea Water Mercury Data: Site 107**
- 2-5c Sea Water Mercury Data: Site 108**
- 2-6a Sea Water Lead Data: Site 106**
- 2-6b Sea Water Lead Data: Site 107**
- 2-6c Sea Water Lead Data: Site 108**
- 2-7a Sea Water Zinc Data: Site 106**
- 2-7b Sea Water Zinc Data: Site 107**
- 2-7c Sea Water Zinc Data: Site 108**
- 3-1 Cadmium in Sediments Site S-1**
- 3-2 Copper in Sediments Site S-1**
- 3-3 Mercury in Sediments Site S-1**
- 3-4 Lead in Sediments Site S-1**
- 3-5 Zinc in Sediments Site S-1**
- 3-6 Cadmium in Sediments Site S-2**

FIGURES (continued)

- 3-7 Copper in Sediments Site S-2**
- 3-8 Mercury in Sediments Site S-2**
- 3-9 Lead in Sediments Site S-2**
- 3-10 Zinc in Sediments Site S-2**
- 3-11 Cadmium in Sediments Site S-4**
- 3-12 Copper in Sediments Site S-4**
- 3-13 Mercury in Sediments Site S-4**
- 3-14 Lead in Sediments Site S-4**
- 3-15 Zinc in Sediments Site S-4**
- 3-16 Cadmium in Sediments Site S-5N**
- 3-17 Copper in Sediments Site S-5N**
- 3-18 Mercury in Sediments Site S-5N**
- 3-19 Lead in Sediments Site S-5N**
- 3-20 Zinc in Sediments Site S-5N**
- 3-21 Cadmium in Sediments Site S-5S**
- 3-22 Copper in Sediments Site S-5S**
- 3-23 Mercury in Sediments Site S-5S**
- 3-24 Lead in Sediments Site S-5S**
- 3-25 Zinc in Sediments Site S-5S**
- 4-1 Cadmium in Mussels STN-1, STN-2, STN-3 ESL**
- 4-2 Copper in Mussels STN-1, STN-2, STN-3 ESL**
- 4-3 Mercury in Mussels STN-1, STN-2, STN-3 ESL**
- 4-4 Lead in Mussels STN-1, STN-2, STN-3 ESL**
- 4-5 Zinc in Mussels STN-1, STN-2, STN-3 ESL**
- 4-6 Cadmium in *Nepthys* S-1**
- 4-7 Copper in *Nepthys* S-1**
- 4-8 Mercury in *Nepthys* S-1**
- 4-9 Lead in *Nepthys* S-1**
- 4-10 Zinc in *Nepthys* S-1**
- 4-11 Cadmium in *Nepthys* S-2**
- 4-12 Copper in *Nepthys* S-2**
- 4-13 Mercury in *Nepthys* S-2**
- 4-14 Lead in *Nepthys* S-2**
- 4-15 Zinc in *Nepthys* S-2**
- 4-16 Cadmium in *Nepthys* S-4**
- 4-17 Copper in *Nepthys* S-4**
- 4-18 Mercury in *Nepthys* S-4**
- 4-19 Lead in *Nepthys* S-4**
- 4-20 Zinc in *Nepthys* S-4**

APPENDIX

Appendix A Outfall Survey Footage

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 at the facilities near Hawk Inlet. The mine and mill facilities (920 area) are located over 6 miles up Greens Creek 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 2200 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 deposited in a surface dry-stack tailings pile near Hawk Inlet. 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 Hawk Inlet include core storage, concentrate storage, shipping port, and shift housing. A domestic waste water treatment plant is located at the Hawk Inlet port site.

Two waste water discharge outfalls and 10 storm water discharge sites are authorized by the HGCMA 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 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.

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 midchannel 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 mine output up through 1995, the input of effluent from the mining operations over this flushing period represents approximately 0.009 percent of the total flushing volume (Ridgeway, 2003).

For more in-depth information on the physical and biological characteristics of Hawk Inlet, see *Technical Review of the Status of Essential Fish Habitat in Hawk Inlet Subsequent to Mining Operations*, Ridgeway, October 2003.

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.

This *Hawk Inlet Monitoring Program 2014 Annual Report* has been prepared by Hecla Greens Creek Mining Company (HGCMC) in accordance with Section I.D.5 of the APDES Permit AK-004320-6. Reporting the Hawk Inlet monitoring program data in an annual report is a requirement of this permit.

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 shows a site map with the sampling locations. Table 1-1 summarizes the requirements of the permit for sample parameters, sample preservation and holding time, sampling frequency, analytical methods and method required detection limits (MDLs). 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, 2009).

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													
I.D.1 Table 4	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 NPDES permit Section I.D.1, Table 4		
I.D.1 Table 4	Dissolved Copper	Quarterly						EPA 220.2/ 1638	0.03	µg/L			
I.D.1 Table 4	Dissolved Lead	Quarterly						EPA 239.2/ 1638	0.05	µg/L			
I.D.1 Table 4	Total Mercury	Quarterly						28 days	EPA 245.1/ 1631	0.20		µg/L	
I.D.1 Table 4	Dissolved Zinc	Quarterly						6 months	EPA 289.2/ 1638	0.20		µg/L	
I.D.1 Table 4	Total Suspended Solids	Quarterly	Grab	1 ea. 1 liter plastic bottle	Cool to 4°C	Admiralty Environmental Labs	7 days	EPA 160.2/ SM 2540D	--	mg/L			
I.D.1 Table 4	Turbidity	Quarterly	Grab	1 ea. 1 liter plastic bottle	Cool to 4°C	Admiralty Environmental Labs	48 hours	EPA 180.1	--	NTU			
I.D.1 Table 4	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.		
I.D.1 Table 4	pH	Quarterly	Grab	NA	NA	Field measurement	15 min	EPA 150.1/ SM 4500-H, B	--	SU			
I.D.1 Table 4	Conductivity	Quarterly	Grab	NA	NA	Field measurement	20 days	EPA 120.1	--	µmhos/cm			
I.D.1 Table 4	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 duplicate 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 duplicate 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 September 2014, Marine Taxonomic Services surveyed the 002 Outfall pipeline for corrosion and damage. A CD of the survey footage can be found in Appendix A. The

following points summarize the major findings of the inspection (Marine Taxonomic Services, 2014):

- The pipeline was found to be in excellent overall condition.
- The pipeline showed no signs of degradation, cracking, leakage, and no restriction of the diffuser ports.
- The minimal sediment accretion inside the diffuser is not a threat to discharge flow rates and requires no maintenance removal at the present time.

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 2014 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 2014, and the reasons for the deviations.

1.3 Deviation(s) from Monitoring Program and Incidents in 2014

There was a deviation in the monitoring program during the August 2014 seawater sampling event. An error by the sampling team resulted in seawater samples for pH, conductivity, TSS, and turbidity at locations 106, 107, and 108 not being collected for laboratory analysis on August 27th, 2014. Field analysis of pH, conductivity, and turbidity was still collected during the third quarter sampling event.

The 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.

The Fall 2014 sediment sampling lab MDL for mercury was 0.03 mg/kg which is higher than the required MDL of 0.02 mg/kg as stated in the APDES Permit No AK-004320-6, Table 5.

The laboratory deviations will be discussed with the respective laboratory in order to prevent future deviation from the permit.

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 dependent, and is also 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, ACZ Laboratory in Steamboat Springs, Colorado for WAD CN, Admiralty Environmental in Juneau, Alaska for pH, conductivity, total suspended solids, and turbidity analyses. Temperature, pH, turbidity and conductivity are measured in the field by the Environmental staff.

2.1 2014 Analytical Results

The tables in this section summarize the results for the quarterly water column monitoring conducted in 2014.

TABLE 2-1 Hawk Inlet Field Parameters 2014 (sample depth 5')

	Sample Date	Sample Time	Weather Conditions	Conductivity (µmhos/cm)	pH	Temp. (°C)
Site 106						
	3/18/14	09:21	rainy	49,340	8.08	4.5
	6/19/14	12:52	cloudy	47,720	8.46	10.0
	8/27/14	08:50	sunny	39,660	8.44	12.9
	10/14/14	11:15	cloudy	44,650	7.98	9.2
Site 107						
	3/18/14	08:45	rainy	48,870	8.07	4.2
	6/19/14	12:19	cloudy	46,890	8.41	10.6
	8/27/14	08:07	sunny	39,340	8.24	12.5
	10/14/14	10:35	cloudy	43,240	7.93	9.2
Site 108						
	3/18/14	09:03	rainy	48,340	8.09	4.2
	6/19/14	12:38	cloudy	46,810	8.44	9.9
	8/27/14	08:34	sunny	39,080	8.32	12.5
	10/14/14	10:50	cloudy	43,270	7.97	9.3

TABLE 2-2 Hawk Inlet Water Column Monitoring 2014: Nonmetal Parameters
(ACZ Laboratories and Admiralty Environmental) (sample depth 5')

	Sample Date	TSS (mg/L)	Turbidity (NTU)	WAD CN (µg/L)	pH (su)	Conductivity (µmhos/cm)
Site 106						
	3/18/14	11	0.35	<3.0	7.61	50,100
	6/19/14	6.8	0.15	<3.0	8.04	48,200
	8/27/14	--	--	<3.0	--	--
	10/14/14	20	0.5	<3.0	7.9	47,700
Site 107						
	3/18/14	13	0.3	<3.0	7.63	50,000
	6/19/14	7.2	0.1	<3.0	7.99	47,600
	8/27/14	--	--	<3.0	--	--
	10/14/14	19	0.5	<3.0	7.9	46,000
Site 108						
	3/18/14	22	0.4	<3.0	7.62	49,500
	6/19/14	8.8	0.16	<3.0	8.08	47,800
	8/27/14	--	--	<3.0	--	--
	10/14/14	21	0.5	<3.0	7.8	46,100

Note: Missing data for the third quarter was due to an error by the field sampling team.

TABLE 2-3 Hawk Inlet Water Column Monitoring Results 2014: 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
	<i>Lab MDL</i>	(0.002)	(0.023)	(0.001)	(0.0001)	(0.042)
	<i>Req. MDL</i>	(0.10)	(0.03)	(0.05)	(0.0001)	(0.20)
Site 106						
	3/18/14	0.0875	0.278	0.0065	0.000228	0.44
	6/19/14	0.0692	0.211	0.0077	0.001120	0.16
	8/27/14	0.0556	0.311	0.0029	0.000210	1.11
	10/14/14	0.0755	0.307	0.0038	0.000365	0.37
Site 107						
	3/18/14	0.0889	0.335	0.0413	0.000473	0.93
	6/19/14	0.0690	0.270	0.0093	0.000313	0.26
	8/27/14	0.0621	0.544	0.0118	0.000498	0.60
	10/14/14	0.0741	0.303	0.0039	0.000397	0.35
Site 108						
	3/18/14	0.0902	0.344	0.0991	0.000353	1.19
	6/19/14	0.0753	0.817	0.0210	0.000268	0.63
	8/27/14	0.0628	0.345	0.0054	0.000229	0.20
	10/14/14	0.0755	0.307	0.0038	0.000365	0.37

2.2 Data Evaluation

Figures 2-1a, b, c through 2-7a, b, c show the time series plots of field pH, conductivity, cadmium, copper, lead, mercury and zinc for Stations 106 (2-1a through 2-7a), 107 (2-1b through 2-7b) and 108 (2-1c through 2-7c). The Alaska Water Quality Standards (AWQS) for marine aquatic life – chronic levels, are shown or noted on the graphs where applicable. The graphs show that the HGCMC results remain within or below these standards in all historical and 2014 samples.

Table 2-2 includes WAD cyanide results which were non-detect during 2014. Although results were non-detect the lab did not meet the required MDL of 1.0 µg/L.

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)	
	2009, 2010, 2011, 2012, and 2013	2014	2009, 2010, 2011, 2012, and 2013	2014	2009, 2010, 2011, 2012, and 2013	2014	2009, 2010, 2011, 2012, and 2013	2014	2009, 2010, 2011, 2012, and 2013	2014
Site 106	0.072	0.072	0.295	0.277	0.059	0.005	0.0004	0.0005	1.24	0.27
Site 107	0.076	0.074	0.492	0.363	0.068	0.017	0.0007	0.0004	1.51	0.53
Site 108	0.074	0.076	0.349	0.453	0.043	0.032	0.0005	0.0003	1.41	0.60

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 2014 sea water samples (taken quarterly – 1Q14, 2Q14, 3Q14, and 4Q14). 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. HGCMC has noticed an improvement in elevated zinc in the field blanks in 2013. In 2014 field blanks continued the trend of elevated levels of zinc. The 2Q14 and 3Q14 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):
 1Q14: 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 mercury, zinc, and lead. Zinc was detected well above the MDL and at high enough concentrations to impact field sample concentrations. Cadmium was reported as a non-

detect. Standard reference material (SRM) results were within the default criteria of $\pm 25\%$.

2Q14: 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 lead and zinc which were 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 $\pm 25\%$.

3Q14: 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 lead and zinc which were 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 $\pm 25\%$.

4Q14: 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 $\pm 25\%$.

ACZ Laboratories (WAD cyanide analyses):

1Q14: The samples were received outside of the recommended temperature range of 0 to 6 degrees C.

2Q14: The samples were received outside of the recommended temperature range of 0 to 6 degrees C.

3Q14: No certification qualifiers associated with this analysis.

4Q13: No certification qualifiers associated with this analysis.

The MDL of 3.0 $\mu\text{g/L}$ is higher than the required 1.0 $\mu\text{g/L}$ MDL and will be discussed with ACZ laboratories to prevent future discrepancies, also HGCMC quality assurance personnel will promptly review the laboratory results for specified MDLs. While preparing this report HGCMC contacted ADEC compliance personnel to discuss with and inform them of this non-compliance issue.

Admiralty Environmental (total suspended solids (TSS), pH, conductivity, and turbidity analyses):

1Q14, 2Q14, 4Q14: All method specifications and required MDLs 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), near the ore dock (Site S-4), and under the ship's berth near the old cannery (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).

An additional location, Site S-3, had also been sampled for sediments since the 1980s (located at the head of Hawk Inlet). Data collected from Site S-3 exhibited different trends from the other two background stations (S-1 and S-2). Most metals at S-3 were found at higher levels than at S-1 or S-2. 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 sediment sampling sites. Therefore, data from S-3 are not presented in this report.

3.1 2014 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. The fall 2014 sampling data in Table 3-3 indicates a lab MDL (0.03 mg/kg) that is higher than the required MDL (0.02 mg/kg) for Mercury as stated in the NPDES Permit No AK-004320-6, Table 5. This discrepancy will be discussed with ALS Environmental Laboratories in order to prevent future deviation from the permit.

TABLE 3-1 Hawk Inlet Sediment Monitoring Field Parameters 2014

Locations	Date Sampled	Time Sampled	Weather Conditions	Tide Ht.
S-1	7/9/14	6:00	Clear Skies, Light Air	0.6
	9/7/14	6:30	Partly Cloudy	-1.0
S-2	7/11/14	6:00	Partly Cloudy, Fresh Breeze	-2.0
	9/8/14	7:15	Cloudy	-2.5
S-4	7/12/14	6:30	Partly Cloudy, Light Air	-2.5
	9/8/14	8:30	Cloudy	-1.0
S-5S	7/10/14	12:00	Cloudy, Light Breeze	12.8
	9/11/14	10:30	Cloudy, Light Breeze	1.8
S-5N	7/10/14	10:00	Cloudy, Light Breeze	11.6
	9/11/14	10:30	Cloudy, Light Breeze	1.8

TABLE 3-2 Hawk Inlet Sediment Results for Summer 2014
(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)
<i>Lab MRL</i>		(0.01, 0.02)	(0.06, 0.07, 0.08, 0.09)	(0.04, 0.05, 0.29)	(0.01, 0.02)	(0.35, 0.36, 0.37, 0.38, 0.39, 0.40, 0.45, 0.46, 2.87)
<i>Required MDL</i>		(0.3)	(15.0)	(0.05)	(0.02)	(15.0)
S-1 Sediments-Metals I	7/9/14	0.12	16.2	6.56	0.03	120
S-1 Sediments-Metals II	7/9/14	0.12	14.2	6.00	0.03	120
S-1 Sediments-Metals III	7/9/14	0.12	16.5	5.47	0.03	106
S-2 Sediments-Metals I	7/11/14	0.11	9.01	1.54	<0.02	44.8
S-2 Sediments-Metals II	7/11/14	0.1	8.45	1.52	<0.02	42.1
S-2 Sediments-Metals III	7/11/14	0.11	8.83	1.58	<0.02	44
S-4 Sediments-Metals I	7/12/14	0.33	17.8	11.5	0.02	64.7
S-4 Sediments-Metals II	7/12/14	0.29	17.4	10.1	0.03	59.7
S-4 Sediments-Metals III	7/12/14	0.29	15.4	9.42	0.03	54.3
S-5N Sediments-Metals I	7/10/14	1.79	61.7	262	0.11	366
S-5N Sediments-Metals II	7/10/14	1.34	313	119	0.09	288
S-5N Sediments-Metals III	7/10/14	1.04	34.1	77.5	0.13	555
S-5S Sediments-Metals I	7/10/14	2.71	94.9	409	0.64	501
S-5S Sediments-Metals II	7/10/14	2.57	60.8	203	0.13	468
S-5S Sediments-Metals III	7/10/14	4.01	89	267	0.15	764

TABLE 3-3 Hawk Inlet Sediment Results for Fall 2014
(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)
<i>Lab MRL</i>		(0.01, 0.02)	(0.10)	(0.02, 0.03, 0.04, 0.54, 0.65, 0.66)	(0.02, 0.03)	(0.20, 0.30, 0.40, 5.40, 6.50, 6.60)
<i>Required MDL</i>		(0.3)	(15.0)	(0.05)	(0.02)	(15.0)
S-1 Sediments-Metals I	9/7/14	0.23	17.4	8.07	0.06	113
S-1 Sediments-Metals II	9/7/14	0.2	19.7	7.15	0.04	122
S-1 Sediments-Metals III	9/7/14	0.13	12.7	5.01	0.04	89.5
S-2 Sediments-Metals I	9/8/14	0.22	10.5	2.42	<0.03	46
S-2 Sediments-Metals II	9/8/14	0.18	11.5	2.17	<0.03	50
S-2 Sediments-Metals III	9/8/14	0.19	11.1	2.2	<0.02	52.5
S-4 Sediments-Metals I	9/8/14	0.36	21.4	11.4	0.04	72.3
S-4 Sediments-Metals II	9/8/14	0.37	13.7	13.6	0.03	64.5
S-4 Sediments-Metals III	9/8/14	0.3	12.7	9.29	0.02	56
S-5N Sediments-Metals I	9/11/14	1.58	135	260	0.12	416
S-5N Sediments-Metals II	9/11/14	1.3	45.4	119	0.27	258
S-5N Sediments-Metals III	9/11/14	3.17	101	253	0.10	570
S-5S Sediments-Metals I	9/11/14	2.32	80.7	175	0.22	521
S-5S Sediments-Metals II	9/11/14	2.47	77.8	147	0.16	396
S-5S Sediments-Metals III	9/11/14	3.11	56.9	170	0.29	546

3.2 Data Evaluation

Prior to opening the Greens Creek mine for full production in August 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 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 (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 (6/1984-8/1989)			Production (9/1989-9/2013)			Current Year 2014		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Cd	0.24	0.03	0.87	0.18	0.06	0.89	0.15	0.10	0.23
Cu	18.8	11.9	33.0	13.48	6.00	39.5	13.01	8.45	19.70
Pb	6.72	2.20	13.0	5.02	<0.02	23.7	4.14	1.52	8.07
Hg	0.035	0.002	0.094	0.02	<0.02	0.09	0.03	<0.02	0.06
Zn	96.1	52.8	155	69.8	26.1	188	79.2	42.1	122

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 MDL 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 except zinc and mercury which are approximately 10 mg/kg and 0.02 mg/kg respectively higher. 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.

Sampling sites S-4 and S-5N and S-5S are located near the ore concentrate loading facility. In 1989, the first attempt to load a barge with ore concentrate resulted in a spill of concentrate into Hawk Inlet. 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, liter-sized pockets of concentrate are still observed in the area.

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 2012 samples showed an elevated concentration of 1,950 mg/kg. The duplicate samples at S-5S showed lead concentrations of 391 mg/kg and 309 mg/kg, which are within the historical range. The 2013-2014, metals concentrations at S-5S were back at lower concentrations previously recorded for the site. 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. Replicate samples are taken at each site (started 2004) and all replicates were included in figures and calculation, 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 (9/1984-8/1989)		production (9/1989 - 9/2013)		Current Year 2014	pre-production (9/1984-8/1989)		production (9/1989 - 9/2013)		Current Year 2014
	avg	stdev	avg	stdev	avg	avg	stdev	avg	stdev	avg
Cd	0.25	0.22	0.20	0.15	0.15	0.24	0.12	0.15	0.07	0.15
Cu	22.50	5.19	16.33	6.32	16.12	15.01	2.68	10.62	4.22	9.90
Pb	8.18	2.63	7.72	3.58	6.38	5.26	2.16	2.33	1.34	1.91
Hg	0.04	0.02	0.03	0.02	0.04	0.03	0.01	0.01	0.02	0.01
Zn	129.2	11.6	97.0	29.2	111.8	62.9	6.7	42.6	13.0	46.6

Metal (mg/kg dw)	S-4					S-5N		S-5S			
	pre-production (9/1984-8/1989)		production (9/1989 - 9/2013)		Current Year 2014	post spill (9/1989 - 9/2013)		Current Year 2014	post spill (6/1995 - 9/2013)		Current Year 2014
	avg	stdev	avg	stdev	avg	avg	stdev	avg	avg	stdev	avg
Cd	0.76	1.10	0.56	0.70	0.32	7.03	28.48	1.70	3.95	3.78	2.87
Cu	49.04	19.25	36.83	43.76	16.40	192.63	294.16	115.03	98.43	70.72	76.68
Pb	108.19	136.84	66.07	104.86	10.89	742	1738	182	331	332	229
Hg	0.12	0.08	<u>0.12</u>	0.44	0.03	1.12	4.07	0.14	0.35	0.28	0.27
Zn	179.2	125.5	<u>119.5</u>	143.5	61.9	1208	3872	409	874	778	533

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

3.3 QA/QC Results

ALS Environmental analyzed the required parameters (see Table 1-1) in the sediment samples. Complete QA plans and reports are kept on file at the ALS Environmental office and are available upon request. The remainder of this section summarizes any relevant QA/QC results that were exceptions for the summer and fall sampling events in 2014.

Summer 2014: No anomalies associated with the analysis of these samples were observed.

Fall 2014: The Relative Percent Difference (RPD) for the replicate analysis of Cadmium and Copper in sample S-14 Sediment-Metals Rep II 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.

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 2014 in Table 3-6.

TABLE 3-6 RSDs for Duplicate Sediment Samples

SAMPLE ID	DATE	Cd	Cu	Pb	Hg	Zn
		(mg/kg dw)	(mg/kg dw)	(mg/kg dw)	(mg/kg dw)	(mg/kg dw)
	DL	0.05	0.1	0.05	0.02	0.5
S-1 Sediments-Metals I	7/9/14	0.12	16.2	6.56	0.03	120
S-1 Sediments-Metals II	7/9/14	0.12	14.2	6.00	0.03	120
S-1 Sediments-Metals III	7/9/14	0.12	16.5	5.47	0.03	106
RSD		--	8.0	9.07	--	7.0
S-2 Sediments-Metals I	7/11/14	0.11	9.01	1.54	<0.02	44.8
S-2 Sediments-Metals II	7/11/14	0.1	8.45	1.52	<0.02	42.1
S-2 Sediments-Metals III	7/11/14	0.11	8.83	1.58	<0.02	44
RSD			3.3	1.98	--	3.2
S-4 Sediments-Metals I	7/12/14	0.33	17.8	11.50	0.02	64.7
S-4 Sediments-Metals II	7/12/14	0.29	17.4	10.1	0.03	59.7
S-4 Sediments-Metals III	7/12/14	0.29	15.4	9.42	0.03	54.3
RSD		7.6	10.26	--	--	8.7
S-5N Sediments-Metals I	7/10/14	1.79	61.7	262	0.11	366
S-5N Sediments-Metals II	7/10/14	1.34	313	119	0.09	288
S-5N Sediments-Metals III	7/10/14	1.04	34.1	77.5	0.13	555
RSD		--	112.8	63.33	18.18	34.1
S-5S Sediments-Metals I	7/10/14	2.71	94.9	409	0.64	501
S-5S Sediments-Metals II	7/10/14	2.57	60.8	203	0.13	468
S-5S Sediments-Metals III	7/10/14	4.01	89	267	0.15	764
RSD		25.64	22.3	35.98	94.19	28.1

SAMPLE ID	DATE	Cd	Cu	Pb	Hg	Zn
		(mg/kg dw)	(mg/kg dw)	(mg/kg dw)	(mg/kg dw)	(mg/kg dw)
	DL	0.05	0.1	0.05	0.02	0.5
S-1 Sediments-Metals I	9/7/14	0.23	17.4	8.07	0.06	113
S-1 Sediments-Metals II	9/7/14	0.2	19.7	7.15	0.04	122
S-1 Sediments-Metals III	9/7/14	0.13	12.7	5.01	0.04	89.5
RSD		--	21.5	23.28	--	15.5
S-2 Sediments-Metals I	9/8/14	0.22	10.5	2.42	<0.03	46
S-2 Sediments-Metals II	9/8/14	0.18	11.5	2.17	<0.03	50
S-2 Sediments-Metals III	9/8/14	0.19	11.1	2.2	<0.02	52.5
RSD		--	4.6	6.03	--	6.6
S-4 Sediments-Metals I	9/8/14	0.36	21.4	11.4	0.04	72.3
S-4 Sediments-Metals II	9/8/14	0.37	13.7	13.6	0.03	64.5
S-4 Sediments-Metals III	9/8/14	0.3	12.7	9.29	0.02	56
RSD		--	29.9	18.86	--	12.7
S-5N Sediments-Metals I	9/11/14	1.58	135	260	0.12	416
S-5N Sediments-Metals II	9/11/14	1.3	45.4	119	0.27	258
S-5N Sediments-Metals III	9/11/14	3.17	101	253	0.1	570
RSD		--	48.2	37.72	56.89	37.6
S-5S Sediments-Metals I	9/11/14	2.32	80.7	175	0.22	521
S-5S Sediments-Metals II	9/11/14	2.47	77.8	147	0.16	396
S-5S Sediments-Metals III	9/11/14	3.11	56.9	170	0.29	546
RSD		15.93	18.1	9.11	29.13	16.5

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

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. Nine out of the 36 (~25%) RSDs calculated for the 2014 dataset were not within this data quality objective. All of the nine samples that were above this RSD were from sample sites S-5S and S-5N. These sites are near the ship loader where a concentrate spill occurred in 1989. Due to the isolated pockets of concentrate remaining from 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 2014 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 2014

Locations	Sample Type	Date Sampled	Time Sampled	Weather Conditions	Tide Ht.
S-1	Nephtys	7/9/14	7:00	Clear Skies, Light Air	0.8
	Cockle	7/9/14	7:30	Clear Skies, Light Air	0.9
	Nephtys	9/7/14	6:30	Partly Cloudy	-1.0
	Cockle	9/7/14	6:30	Partly Cloudy	-1.0
S-2	Nephtys	7/11/14	7:00	Partly Cloudy, Fresh Breeze	-2.0
	Cockle	7/11/14	7:30	Partly Cloudy, Fresh Breeze	-2.0
	Littleneck	7/11/14	8:00	Partly Cloudy, Fresh Breeze	-2.0
	Nephtys	9/8/14	7:15	Cloudy	-2.5
	Cockle	9/8/14	7:15	Cloudy	-2.5
	Littleneck	9/8/14	7:15	Cloudy	-2.5
S-4	Nephtys	7/12/14	7:30	Partly Cloudy, Light Air	-2.5
	Cockle	7/12/14	8:00	Partly Cloudy, Light Air	-2.5
	Nephtys	9/8/14	7:30	Cloudy	-1.0
	Cockle	9/8/14	8:30	Cloudy	-1.0
STN-1	Mussels	7/15/14	9:00	Clear Skies, Light Air	-3.0
	Mussels	9/9/14	19:00	Clear Skies	3.8
STN-2	Mussels	7/15/14	11:00	Clear Skies, Light Air	-3.0
	Mussels	9/9/14	19:00	Clear Skies	3.8
STN-3	Mussels	7/15/14	12:00	Clear Skies, Light Air	-3.0
	Mussels	9/9/14	19:00	Clear Skies	3.8
ESL	Mussels	7/14/14	9:00	Partly Cloudy, Fresh Breeze	-4.0
	Mussels	9/9/14	19:00	Clear Skies	3.8

TABLE 4-2 Hawk Inlet Tissue Results for Summer 2014
(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						
<i>Lab MRL</i>		(0.02)	(0.1)	(0.02)	(0.02, 0.03)	(0.5)
S-1 NephtysI	7/9/14	2.99	11.6	1.28	0.04	223
S-1 NephtysII	7/9/14	2.46	5.2	1.32	0.04	218
S-1 NephtysIII	7/9/14	2.57	5.5	1.21	0.07	253
S-1 Cockles	7/9/14	0.88	4.0	0.77	0.06	79.6
S-2 NephtysI	7/11/14	0.96	5.9	0.73	<0.02	150
S-2 NephtysII	7/11/14	0.77	6.0	0.79	<0.02	143
S-2 NephtysIII	7/11/14	0.82	6.1	0.82	<0.02	155
S-2 Cockles	7/11/14	0.87	3.5	0.26	<0.02	57.5
S-2 Littlenecks	7/11/14	2.61	6.1	0.2	0.03	70.6
S-4 NephtysI	7/12/14	0.51	7.2	3.68	0.02	181
S-4 NephtysII	7/12/14	0.56	7.3	3.9	<0.02	188
S-4 NephtysIII	7/12/14	0.73	8.6	3.87	<0.02	193
S-4 Cockles	7/12/14	0.82	5.0	4.41	0.04	96.1
STN-1 Mussels	7/15/14	10.7	5.8	0.6	0.03	94.5
STN-2 Mussels	7/15/14	11.6	5.6	0.32	0.04	74.5
STN-3 Mussels	7/15/14	11.2	5.9	0.69	0.03	93.4
ESL Mussels	7/14/14	6.76	7.3	0.47	0.02	90.5

TABLE 4-3 Hawk Inlet Tissue Results for Fall 2014
(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						
<i>Lab MRL</i>		(0.02)	(0.1)	(0.02)	(0.02)	(0.5)
S-1 NephtysI	9/7/14	2.98	5.4	0.4	0.04	176
S-1 NephtysII	9/7/14	3.4	5.5	0.34	0.05	192
S-1 NephtysIII	9/7/14	2.25	6.1	0.47	0.05	190
S-1 Cockles	9/7/14	0.42	2.6	0.56	0.03	84
S-2 NephtysI	9/8/14	0.84	6.1	0.5	<0.02	175
S-2 NephtysII	9/8/14	0.79	6.9	0.55	<0.02	162
S-2 NephtysIII	9/8/14	0.8	5.4	0.49	<0.02	133
S-2 Cockles	9/8/14	0.75	2.8	0.48	0.02	79.2
S-2 Littlenecks	9/8/14	2.5	6.8	0.14	0.02	72.7
S-4 NephtysI	9/8/14	0.64	30.7	5.62	0.02	187
S-4 NephtysII	9/8/14	0.58	35.4	11	0.03	193
S-4 NephtysIII	9/8/14	0.7	31.2	6.81	0.03	187
S-4 Cockles	9/8/14	0.44	2.7	2.21	0.04	66.2
STN-1 Mussels	9/9/14	10.5	5.8	1.38	0.04	97.2
STN-2 Mussels	9/9/14	11.3	4.9	0.34	0.04	71.7
STN-3 Mussels	9/9/14	8.65	5.6	0.47	0.03	88.3
ESL Mussels	9/9/14	8.05	6.3	0.43	0.04	80.6

4.2 Data Evaluation

Prior to opening the Greens Creek mine for full production in August 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	Pre-Production (6/1984-8/1989)			Production (9/1989-9/2013)			Current Year 2014		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Cd	7.67	3.25	15.8	<u>8.08</u>	3.01	14.5	<u>9.85</u>	6.76	11.6
Cu	8.51	5.50	21.1	8.36	1.30	110	5.90	4.90	7.30
Pb	0.57	0.15	1.73	<u>2.56</u>	<0.2	126	<u>0.59</u>	0.32	1.38
Hg	0.064	0.014	0.560	0.03	<0.2	0.52	0.03	0.020	0.04
Zn	88.4	65.0	142	86.1	49.5	126	<u>86.3</u>	74.8	97.2

Data are compilation of results from Stations ESL, STN-1, STN-2 and STN-3. 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 2014 were only 0.02 mg/kg higher than the pre-production, but considerably lower than the production average values (2.56 mg/kg). Average zinc values in 2014 (86.3 mg/kg) were similar to pre-production values (88.4 mg/kg), and higher than production values (85.8 mg/kg). Average cadmium values in 2014 (9.85 mg/kg) were similar although higher to pre-production values (7.67 mg/kg) and production values (8.08 mg/kg). Figures 4-1 through 4-5 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	Pre-Production (6/1984-8/1989)			Production (9/1989-9/2013)			Current Year 2014		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Cd	2.65	0.24	6.91	2.05	0.28	8.33	1.80	0.77	3.40
Cu	10.2	6.24	17.4	9.61	4.30	42.1	6.31	5.20	11.6
Pb	0.48	0.13	1.07	<u>0.87</u>	<0.02	4.76	<u>0.74</u>	0.34	1.32
Hg	0.03	0.01	0.07	<u>0.04</u>	<0.02	1.67	0.03	<0.02	0.07
Zn	206	121	303	195	62.6	357	180.8	133	253

Data are compilation of results from Stations S-1 and S-2. Non-detects are averaged using half of the MDL value.

Combined S-1 and S-2 average lead and mercury concentrations in the indicator polychaete worm, *Nephtys*, are currently higher in the production years than pre-production values. The 2014 average lead concentrations were 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. Also, copper shows a large increase in standard deviation for the ESL site during production sampling. This is thought to be due to a single extreme and potentially anomalous value of 110 mg/kg dw from 1992. 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 4-6 through 4-20 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.

TABLE 4-6 Average and Standard Deviation Values for Pre-Production, Production, and Current Year Mussel Data

Metal (mg/kg dw)	ESL					STN-1				
	pre-production (9/1984-8/1989)		production (9/1989 - 9/2013)		Current Year 2014	pre-production (9/1984-8/1989)		production (9/1989 - 9/2013)		Current Year 2014
	avg	stdev	avg	stdev	avg	avg	stdev	avg	stdev	avg
Cd	6.17	1.78	<u>6.87</u>	1.65	<u>7.41</u>	7.48	1.72	<u>8.04</u>	1.90	<u>10.60</u>
Cu	9.61	3.77	<u>10.83</u>	15.91	6.80	8.05	1.19	7.29	1.76	5.80
Pb	0.53	0.26	<u>1.35</u>	0.76	<u>0.45</u>	0.66	0.44	<u>1.32</u>	0.86	<u>0.99</u>
Hg	0.03	0.01	<u>0.03</u>	0.07	<u>0.03</u>	0.10	0.14	0.04	0.02	0.04
Zn	90.2	8.1	84.2	14.4	85.6	88.5	15.4	85.6	13.6	<u>95.9</u>

Metal (mg/kg dw)	STN-2					STN-3				
	pre-production (9/1984-8/1989)		production (9/1989 - 9/2013)		Current Year 2014	pre-production (9/1984-8/1989)		production (9/1989 - 9/2013)		Current Year 2014
	avg	stdev	avg	stdev	avg	avg	stdev	avg	stdev	avg
Cd	8.01	3.01	<u>8.91</u>	2.44	<u>11.45</u>	9.00	2.81	8.51	1.97	<u>9.93</u>
Cu	7.82	1.02	<u>7.93</u>	3.89	5.25	8.54	1.58	7.40	2.11	5.75
Pb	0.45	0.27	<u>4.26</u>	18.21	<u>0.33</u>	0.65	0.24	<u>3.31</u>	13.47	0.58
Hg	0.04	0.01	0.03	0.02	<u>0.04</u>	0.08	0.15	0.04	0.02	0.03
Zn	83.0	14.5	<u>86.6</u>	16.9	<u>73.1</u>	91.8	17.9	87.9	15.4	<u>90.9</u>

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

Metal (mg/kg dw)	S-1 <i>Nephtys</i>					S-2 <i>Nephtys</i>				
	pre-production (9/1984-8/1989)		production (9/1989 - 9/2013)		Current Year 2014	pre-production (9/1984-8/1989)		production (9/1989 - 9/2013)		Current Year 2014
	avg	stdev	avg	stdev	avg	avg	stdev	avg	stdev	avg
Cd	3.91	1.72	2.97	0.95	2.78	1.40	0.85	1.13	0.52	0.83
Cu	9.27	1.41	<u>10.17</u>	5.89	6.55	11.21	3.56	9.05	5.19	6.07
Pb	0.45	0.16	<u>1.01</u>	0.86	<u>0.84</u>	0.50	0.26	<u>0.73</u>	0.37	<u>0.65</u>
Hg	0.05	0.01	0.05	0.02	<u>0.05</u>	0.02	0.01	<u>0.04</u>	0.21	<0.02
Zn	243.3	43.0	212.2	35.7	208.7	168.6	34.5	<u>177.9</u>	35.8	153.0

Metal (mg/kg dw)	S-4 <i>Nephtys</i>				
	pre-production (9/1984-8/1989)		production (9/1989 - 9/2013)		Current Year 2014
	avg	stdev	avg	stdev	avg
Cd	0.93	0.72	0.83	0.60	0.62
Cu	21.02	9.25	19.33	17.03	20.07
Pb	3.65	1.08	<u>8.27</u>	10.10	<u>5.81</u>
Hg	0.060	0.062	0.026	0.019	0.03
Zn	210.2	17.9	199.3	46.3	188.2

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

Additional tissue samples of *Cockles* and *Little necks* were collected in 2014. 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 (mg/kg dw)	S-2 <i>Cockles</i>	S-2 <i>Little necks</i>	S-4 <i>Cockles</i>	
	(1999-2014)	(1999-2014)	(5/84-7/89)	(9/89-2014)
Cd	0.81	2.32	0.71	0.70
Cu	4.44	8.86	9.27	6.44
Pb	0.55	0.39	9.92	6.62
Hg	0.02	0.02	0.04	0.03
Zn	68.4	80.1	100	77.0

Effluent toxicity testing, conducted since the mining operations began, was discontinued in 2005 with re-issuance of the NPDES Permit (AK-004320-6). Over the 21 years of initially acute toxicity testing (February 1989 – October 1998), and then chronic toxicity testing (November 1998 – June 2005) no sublethal deleterious effects to tested marine aquatic organisms from prolonged exposure to the treated KGCMC effluent was determined to be likely:

“The data show that the effluent from Outfall 002 has no reasonable potential to contribute to an exceedence 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 summer and fall sampling events in 2014.

Summer 2014: The Method Blank (K1407401-MB1) contained low levels of lead above the Method Reporting Limit (MRL). In accordance with ALS QA/QC policy, all sample results less than ten times the level found in the Method Blank were flagged as estimated.

The control criteria for matrix spike recovery of zinc for sample S-1 Nephys 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 recovery of lead in the Standard Reference Material N.R.C.C. Dorm-4 (K1407401-SRM1) was below the normal ALS/Kelso control limit (i.e. 0.220 mg/kg versus a control limit of 0.290 mg/kg). However, the concentration of lead in the SRM is relatively low compared to the sensitivity of the analytical procedure. The associated QA/QC results (e.g. SRM N.R.C.C. Tort-3, LCS, matrix spike, method blank, calibration standards, etc.) indicate the analysis was in control. No further corrective action was appropriate.

Fall 2014: The Relative Percent Difference (RPD) for the replicate analysis of Lead in sample STN-21 mussels was outside the Method control limits. The variability in the results was attributed to the heterogeneous distribution of lead in the sample. Freeze drying, grinding in combination with standard mixing techniques were used, but were not sufficient for complete homogenization of this sample.

The recoveries of lead in the Standard Reference Material (SRM1) and (SRM3) N.R.C.C. Dorm-4 were below the normal ALS/Kelso control limits. However, the concentration of lead in the SRM is relatively low compared to the sensitivity of the analytical procedure. The associated QA/QC results (e.g. SRM N.R.C.C. Tort-3, LCS, matrix spike, method blank, calibration standards, etc.) indicate the analysis 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. Two out of the 24 (~8%) of the RSDs calculated for the 2014 duplicate samples was not within this data quality objective.

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

-- Indicates the RSD was not calculated because one or more of the results was not greater than four times the detection limit (DL)

SAMPLE ID	DATE	Cd (mg/kg dw)	Cu (mg/kg dw)	Pb (mg/kg dw)	Hg (mg/kg dw)	Zn (mg/kg dw)
Lab MRL		0.02	0.1	0.02	0.02	0.5
S-1 Nephthys I	7/9/14	2.99	11.6	1.28	0.04	223.0
S-1 Nephthys II	7/9/14	2.46	5.2	1.32	0.04	218.0
S-1 Nephthys III	7/9/14	2.57	5.5	1.21	0.07	253.0
RSD		10.46	48.6	4.38	--	8.2
S-2 Nephthys I	7/11/14	0.96	5.9	0.73	<0.02	150.0
S-2 Nephthys II	7/11/14	0.77	6.0	0.79	<0.02	143.0
S-2 Nephthys III	7/11/14	0.82	6.1	0.82	<0.02	155.0
RSD		11.59	1.7	5.88	--	4.0
S-4 Nephthys I	7/12/14	0.51	7.2	3.68	0.02	181.0
S-4 Nephthys II	7/12/14	0.56	7.3	3.9	<0.02	188.0
S-4 Nephthys III	7/12/14	0.73	8.6	3.87	<0.02	193.0
RSD		19.22	10.1	3.13	--	3.2
S-1 Nephthys I	9/7/14	2.98	5.4	0.4	0.04	176.0
S-1 Nephthys II	9/7/14	3.4	5.5	0.34	0.05	192.0
S-1 Nephthys III	9/7/14	2.25	6.1	0.47	0.05	190.0
RSD		20.23	6.7	16.13	--	4.7
S-2 Nephthys I	9/8/14	0.84	6.1	0.5	<0.02	175.0
S-2 Nephthys II	9/8/14	0.79	6.9	0.55	<0.02	162.0
S-2 Nephthys III	9/8/14	0.8	5.4	0.49	<0.02	133.0
RSD		3.27	12.2	6.26	--	13.7
S-4 Nephthys I	9/8/14	0.64	30.7	5.62	0.02	187.0
S-4 Nephthys II	9/8/14	0.58	35.4	11.0	0.03	193.0
S-4 Nephthys III	9/8/14	0.7	31.2	6.81	0.03	187.0
RSD		9.38	8.0	36.18	--	1.8

5.0 CONCLUSIONS

The current status of the health of marine and aquatic ecosystems can be viewed in a number of ways; 1) based on the number of types of species present in an area (species diversity, or “biodiversity”), 2) the number of individuals from each species in an area (species abundance), and 3) quality of the environment (habitat integrity relative to pristine 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 now Hawk Inlet Cannery which currently provides the HGCMC port facilities.

Marine species which consume sedentary seafloor organisms such as worms and bivalves would be most susceptible to trophic transfer of some metals. 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. Pacific halibut also have similar consumption patterns to these species. All of these species consume worms, bivalves, and crab.

Risk to higher trophic level organism (*ea.* humpback whale and sea lions) that potentially use Hawk Inlet could occur primarily through transfer of metals from prey items. These species are transient in Hawk Inlet and feed over a broad area. However, this spatial range of these organism reduces the likelihood of encountering the discharge directly or indirectly through prey consumption.

Hawk Inlet sediment monitoring at S-1 and S-2 has been in place now 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.

The sensitivity of the sediment monitoring system is evident when metal concentrations at sites (S-4 and S-5 (N and S)) near the ship loader are examined. 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 shiploader 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 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.

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 monitoring program is sufficient for detecting changes.

6.0 REFERENCES

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Marine Taxonomic Services Ltd, Hawk Inlet Facilities Year 2014 Annual Inspection Report, September 2014.

National Pollutant Discharge Elimination System (NPDES) permit AK-004320-6, USEPA, effective date July 1, 2005.

NPDES Quality Assurance Project (QAP), KGCMC, December 2009.

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

FIGURES

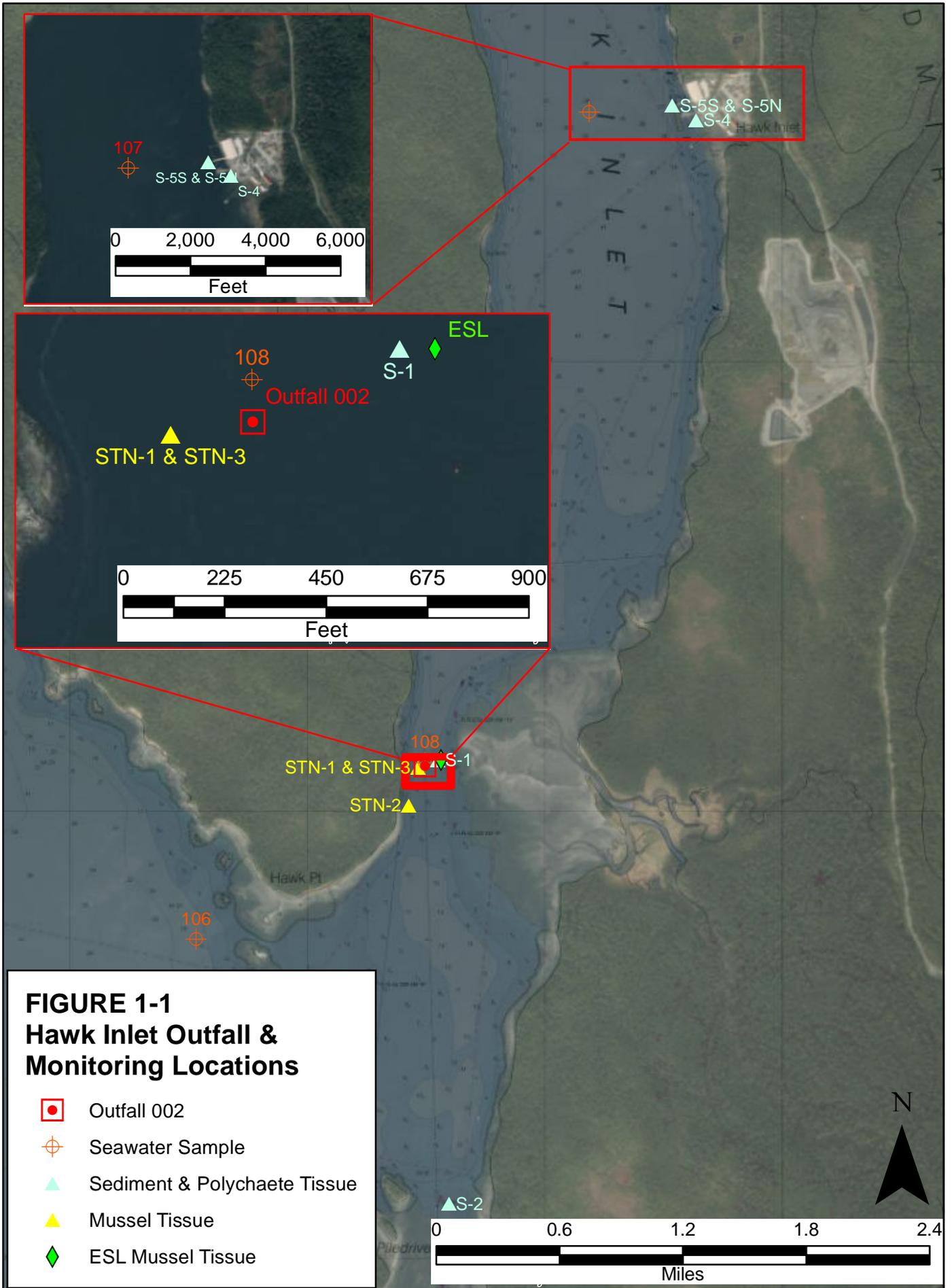


Figure 2-1a

Site 106 - Field pH

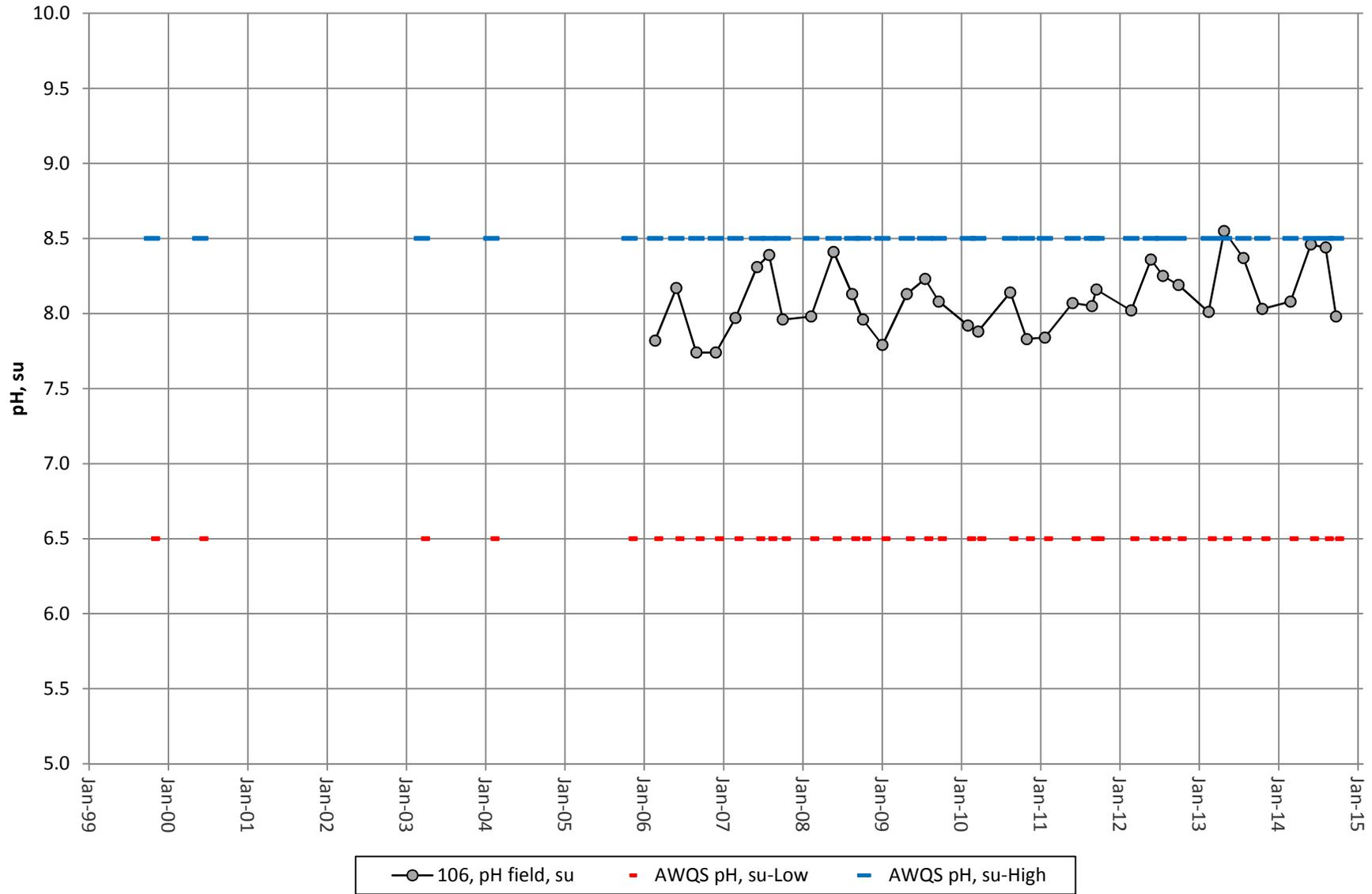


Figure 2-1b

Site 107 - Field pH

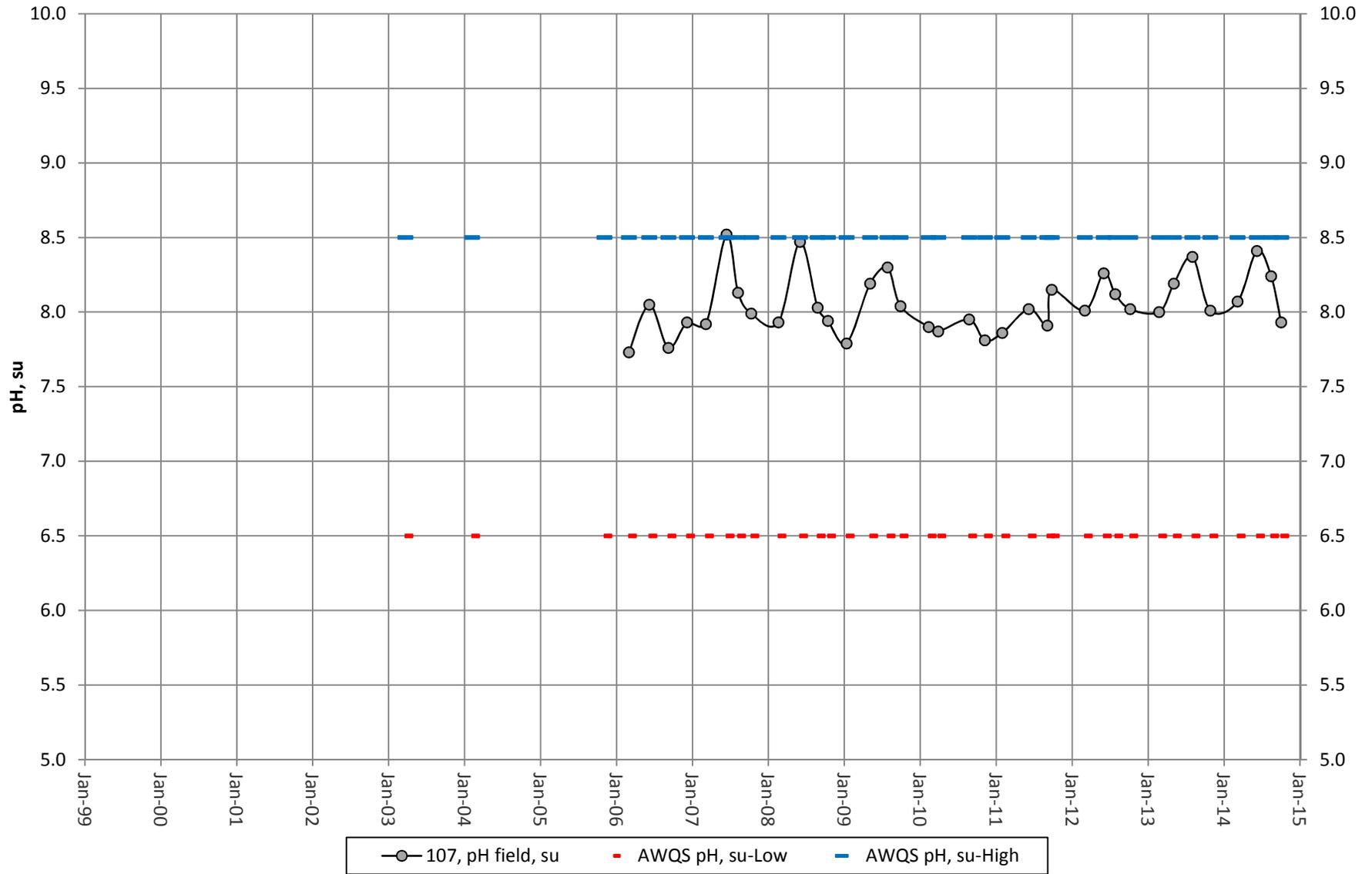


Figure 2-1c

Site 108 - Field pH

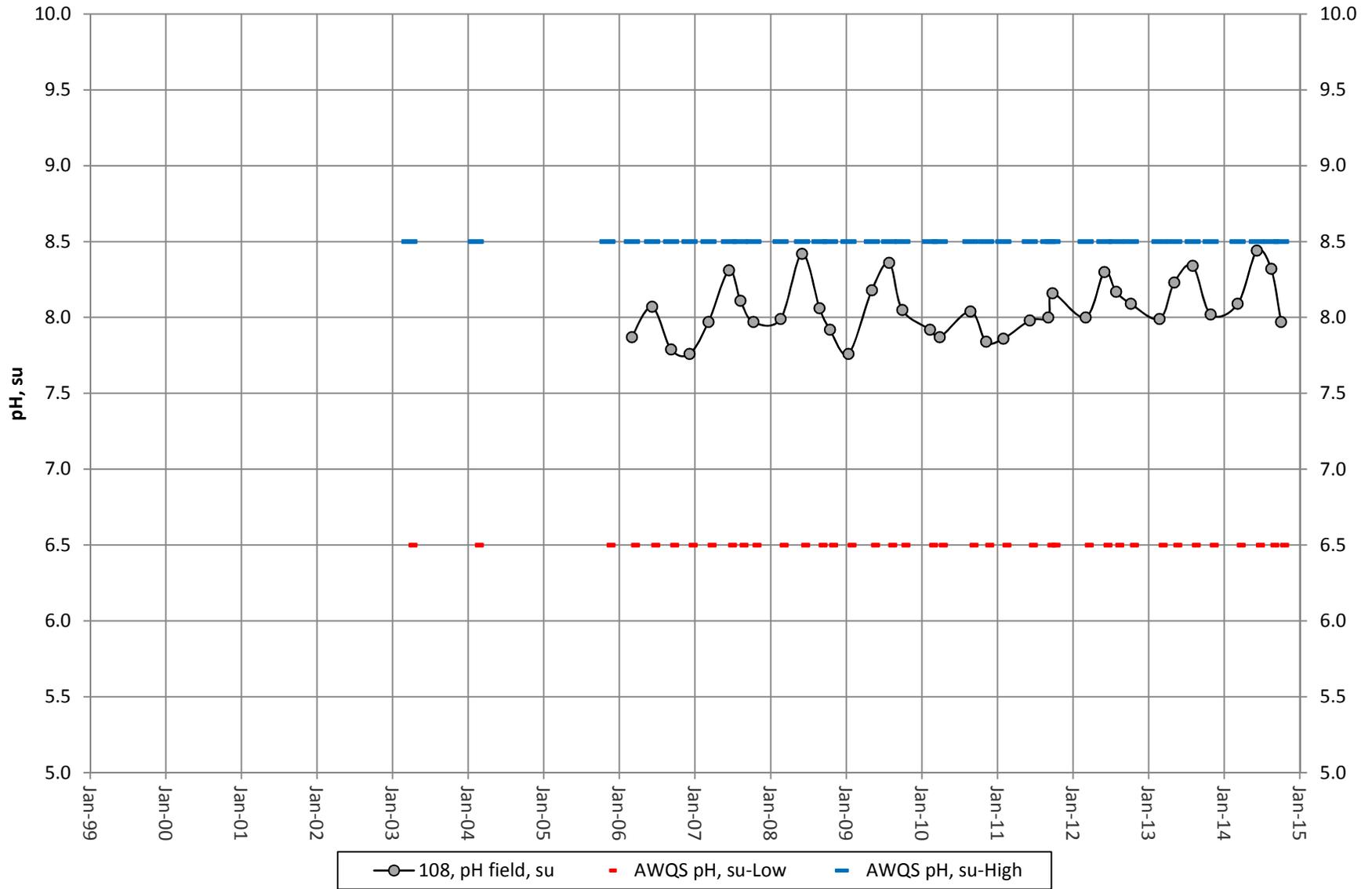


Figure 2-2a

Site 106 - Field Conductivity

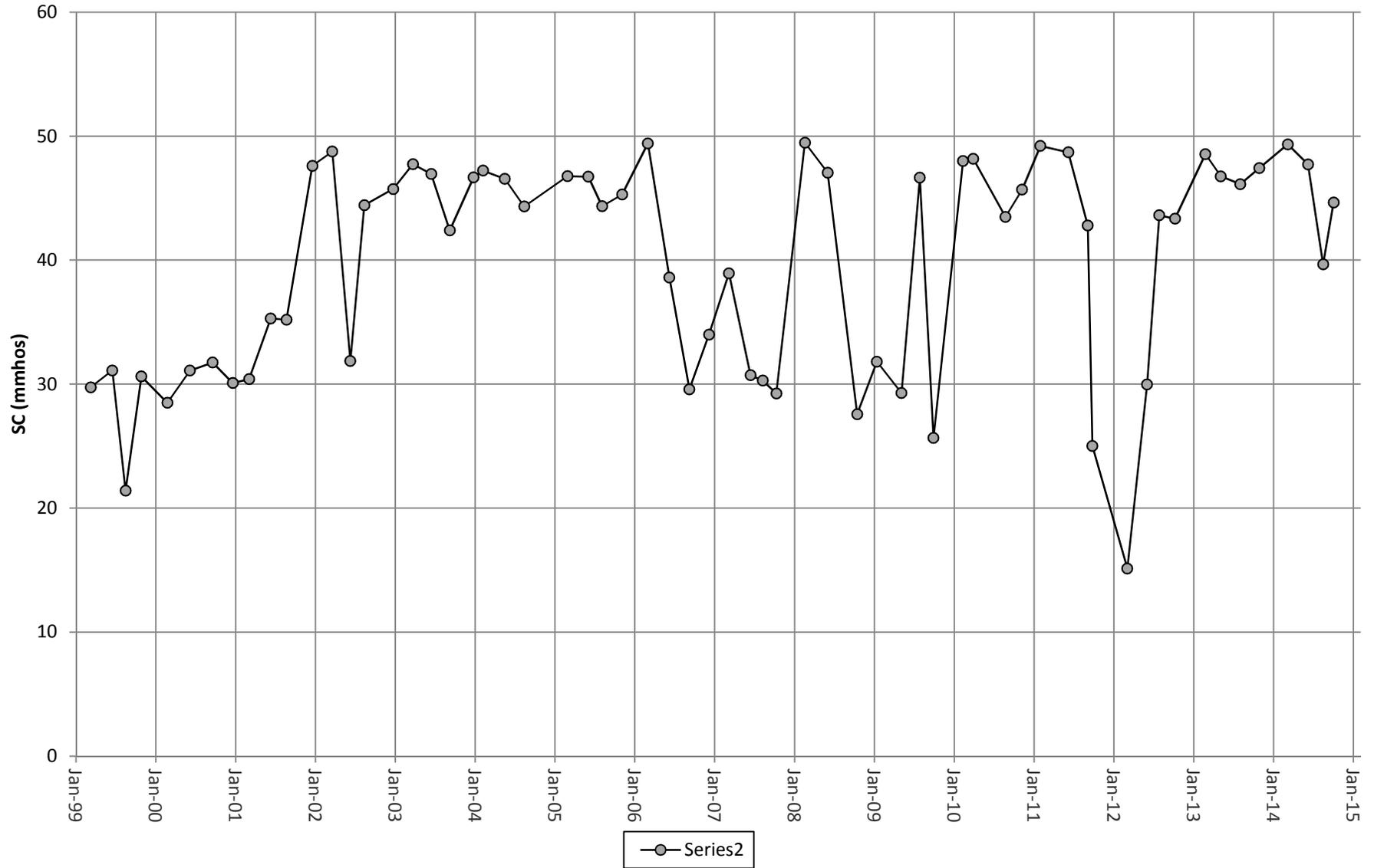


Figure 2-2b

Site 107 - Field Conductivity

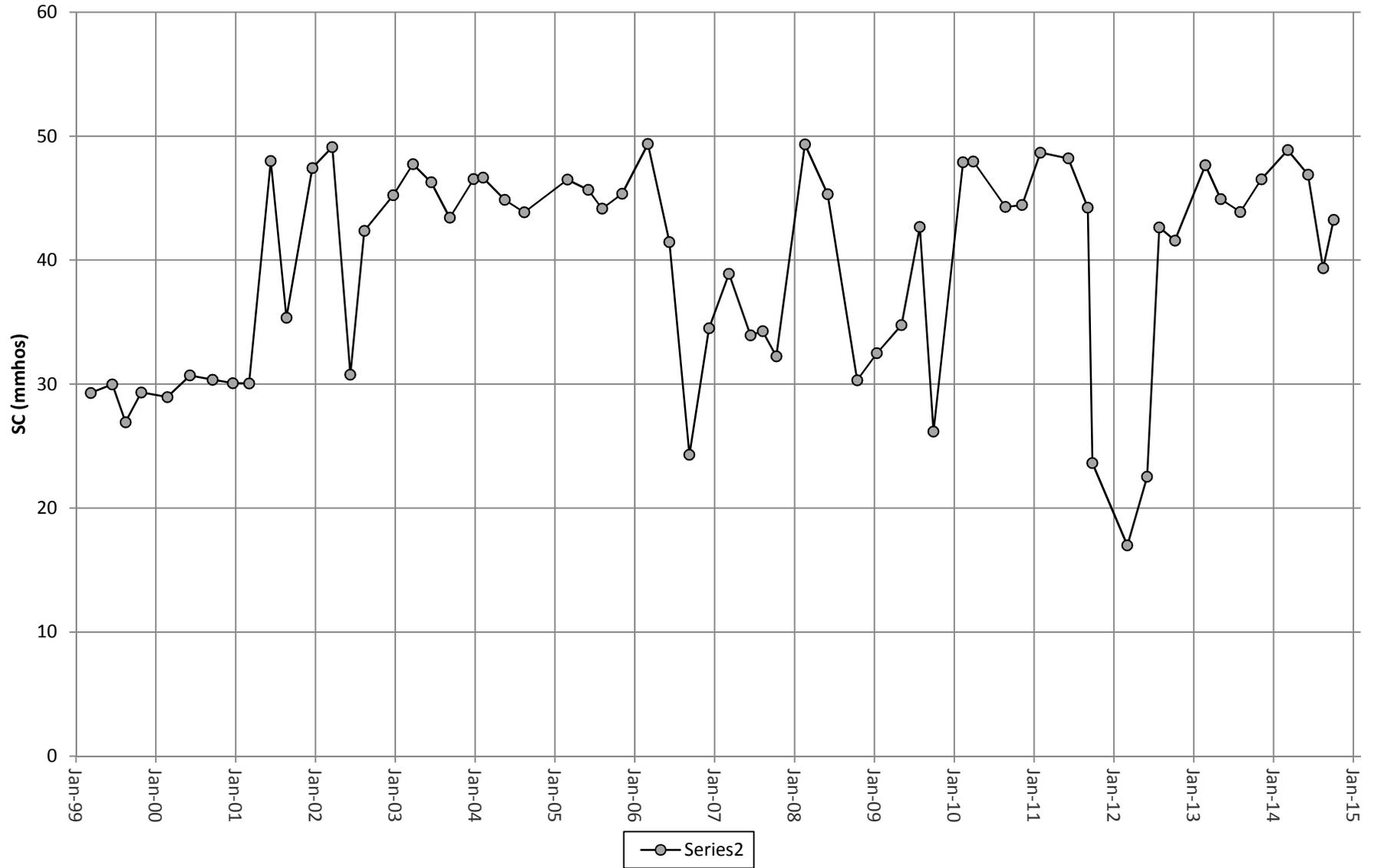


Figure 2-2c

Site 108 - Field Conductivity

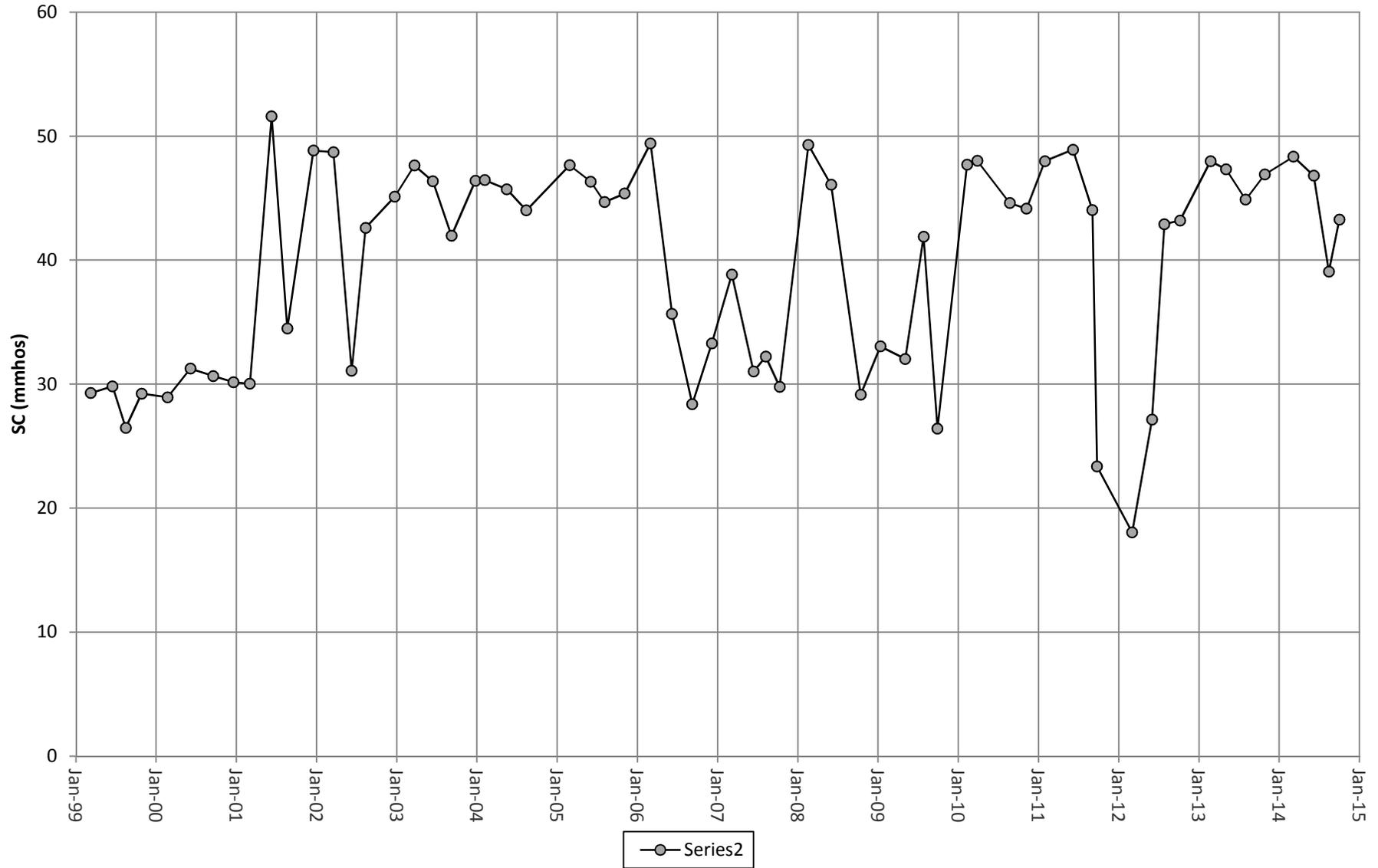


Figure 2-3a

Site 106 - Cadmium

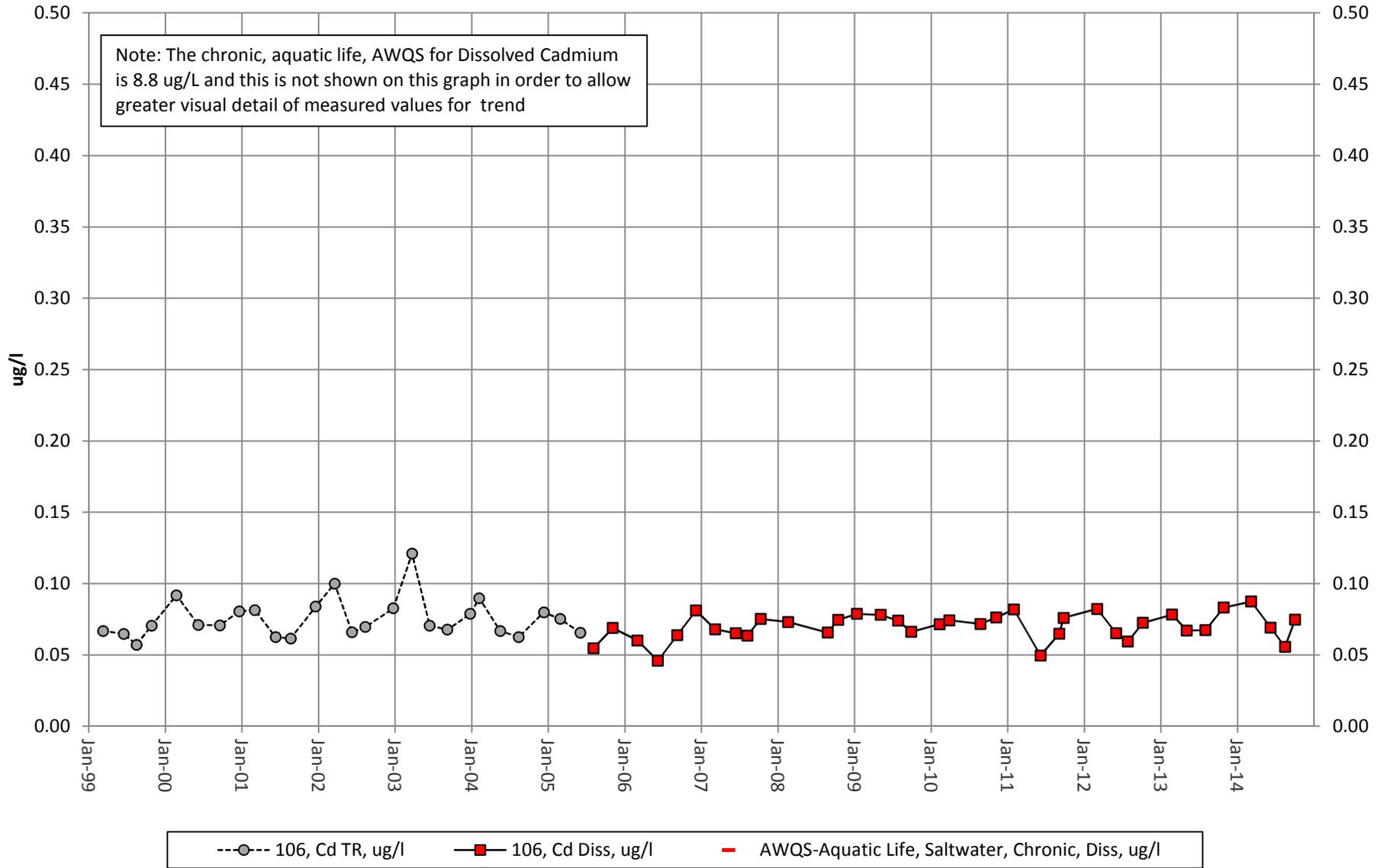


Figure 2-3b

Site 107 - Cadmium

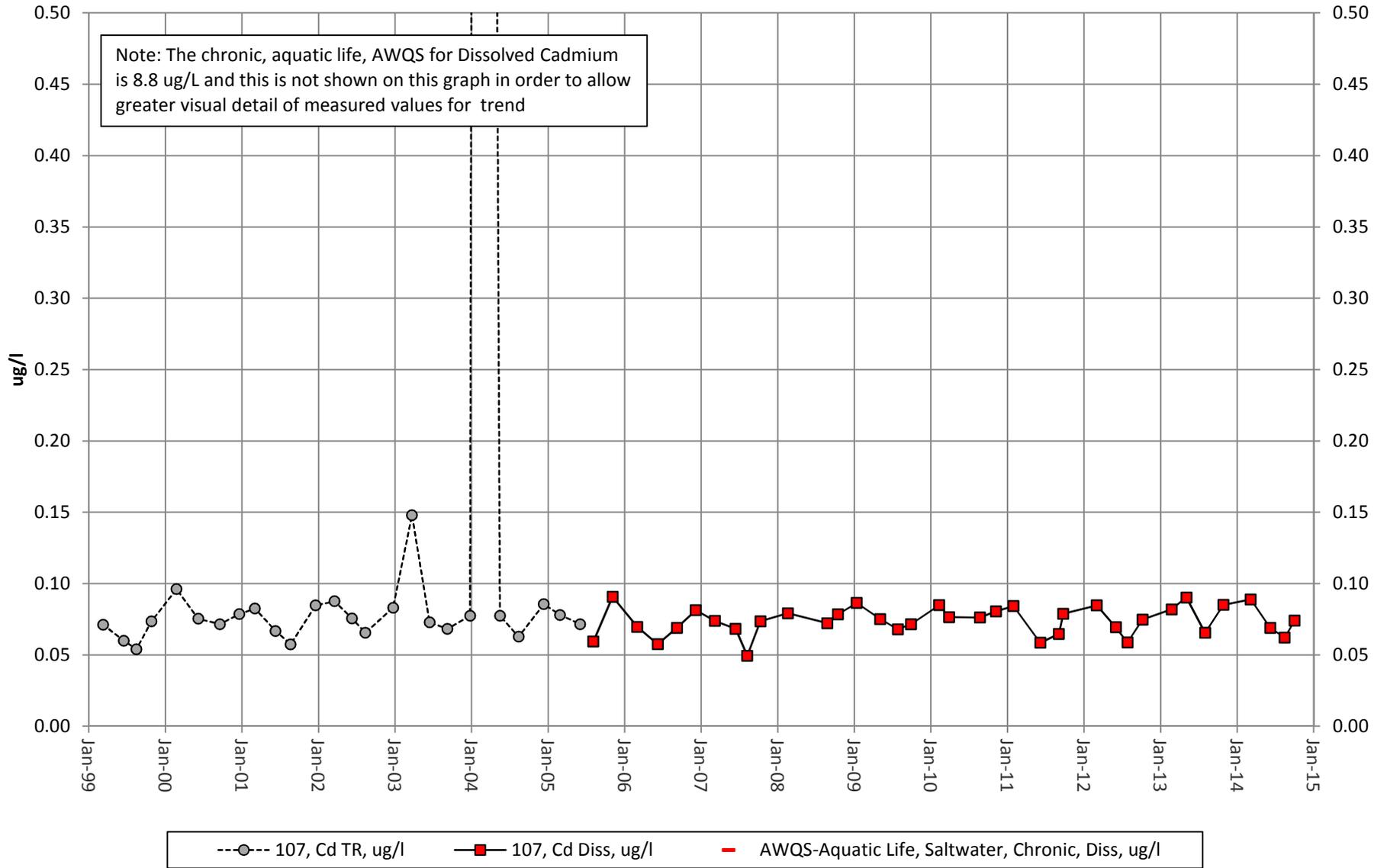


Figure 2-3c

Site 108 - Cadmium

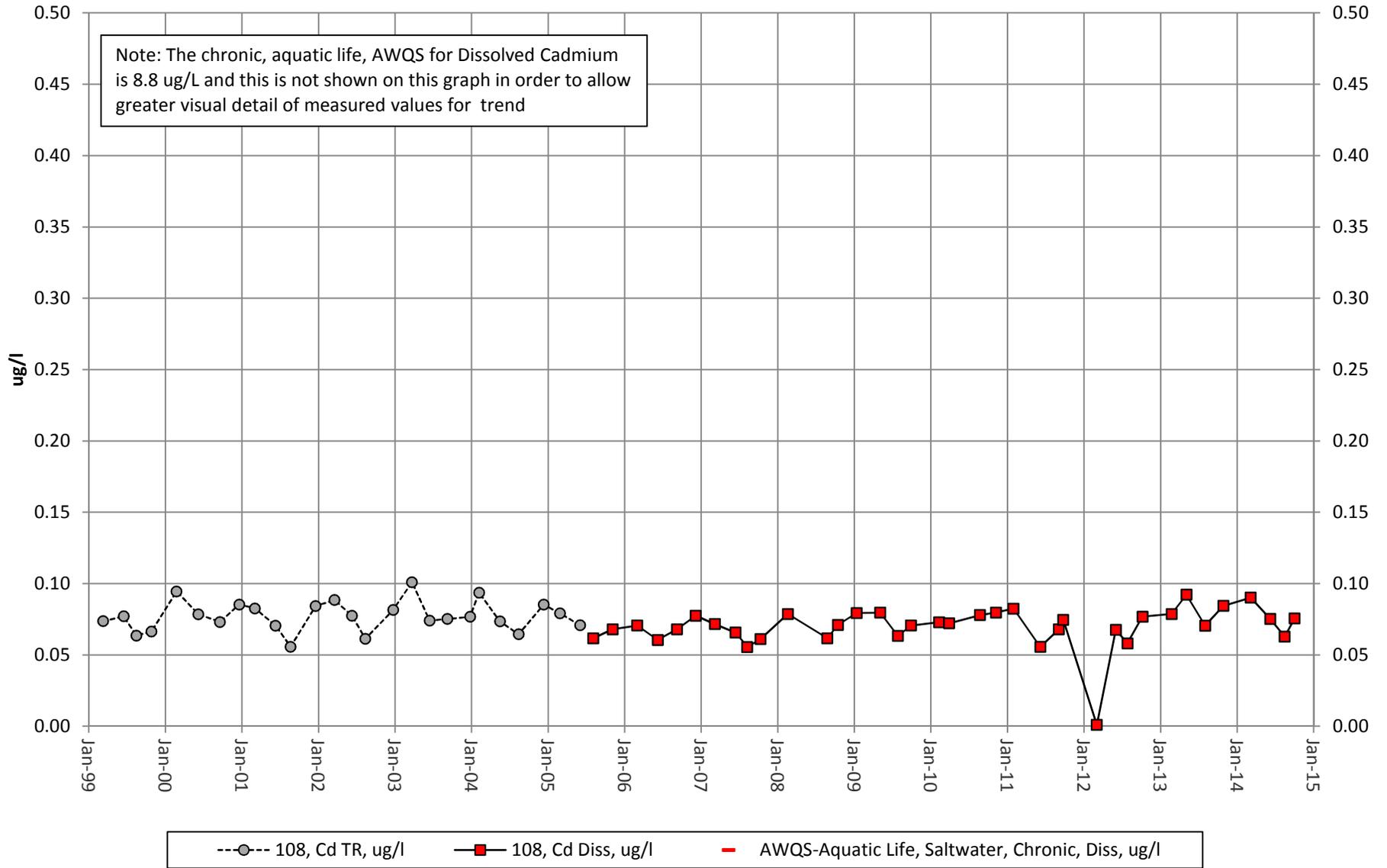


Figure 2-4a

Site 106 - Copper

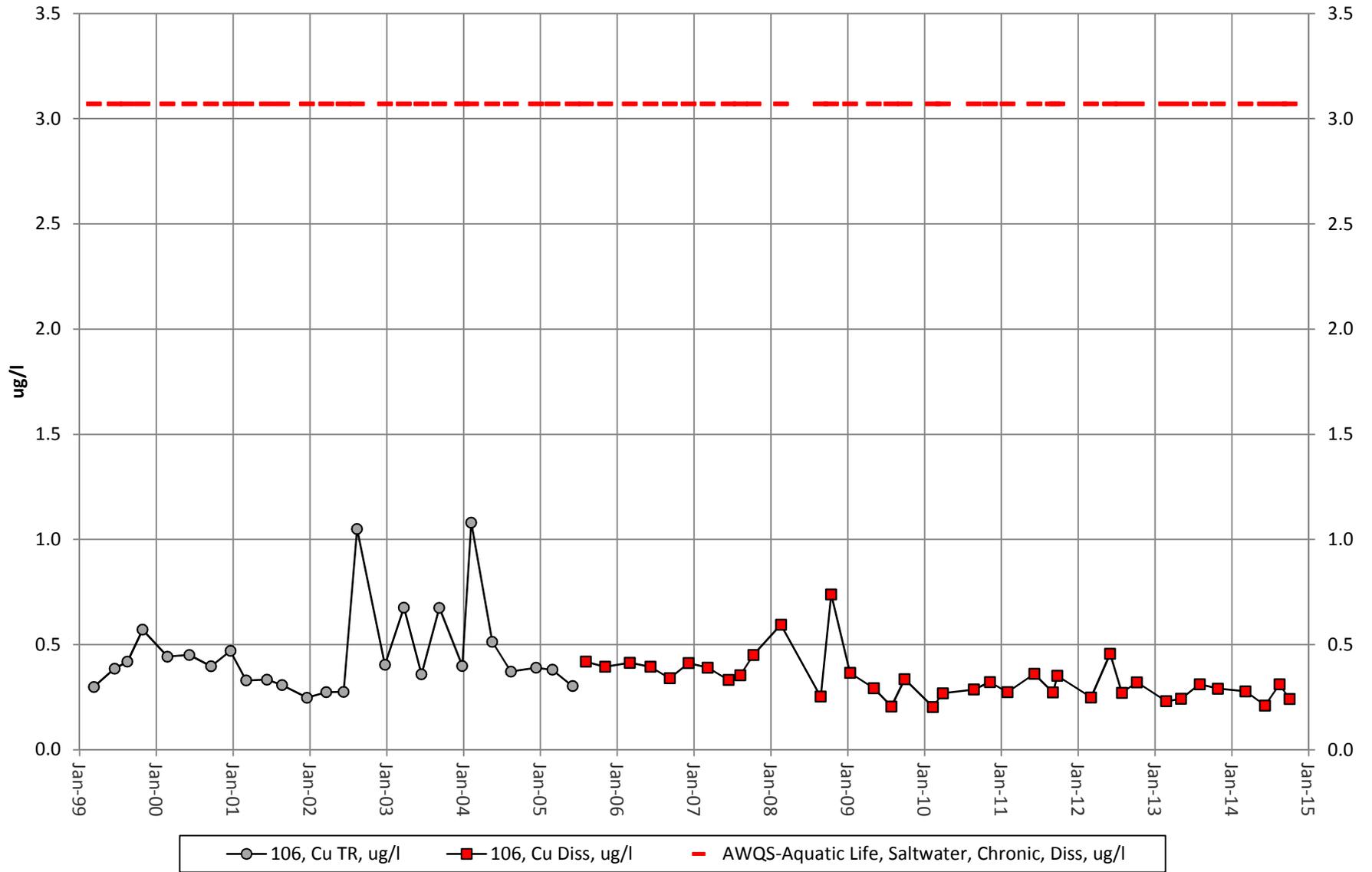


Figure 2-4b

Site 107 - Copper

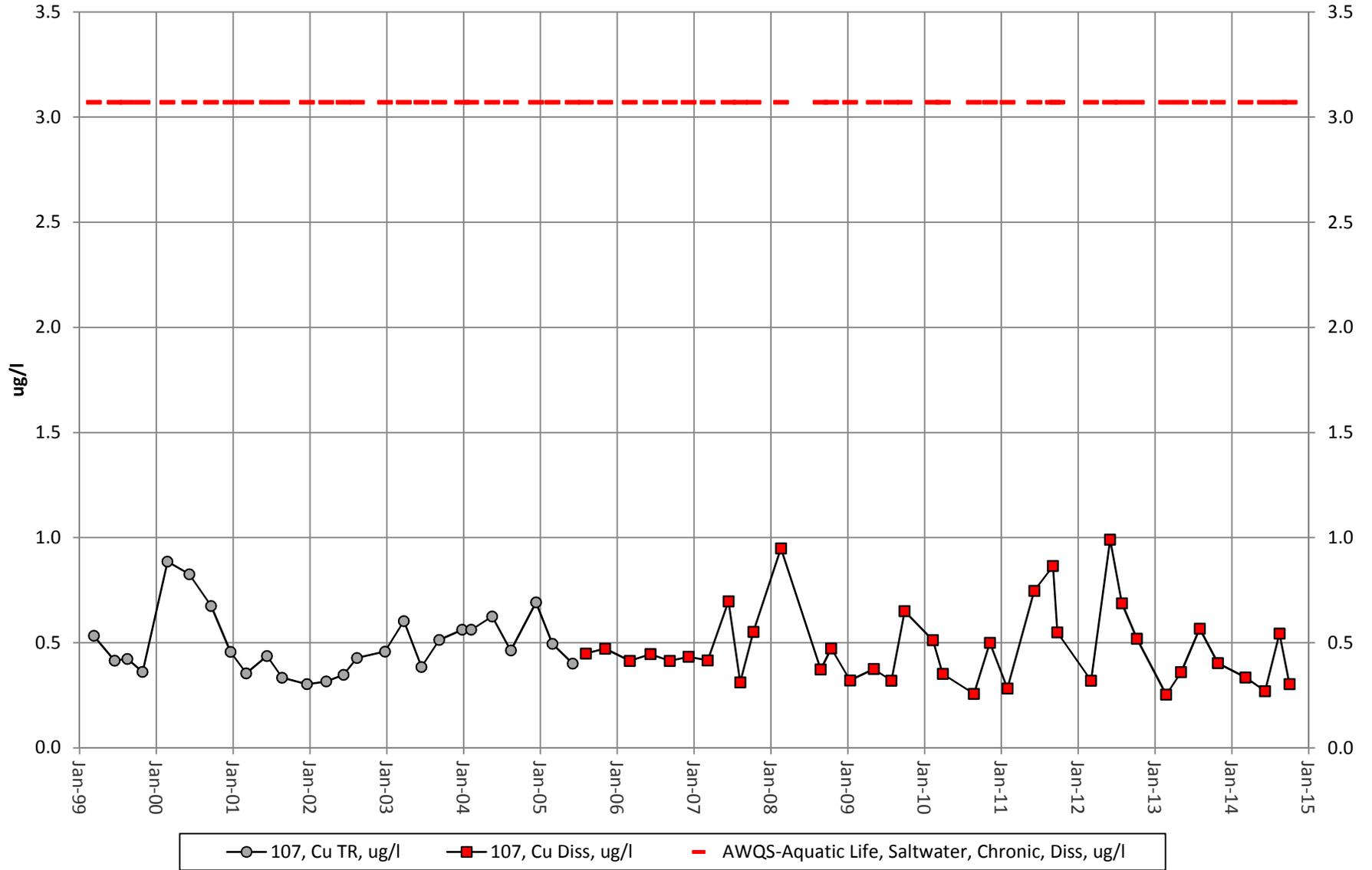


Figure 2-4c

Site 108 - Copper

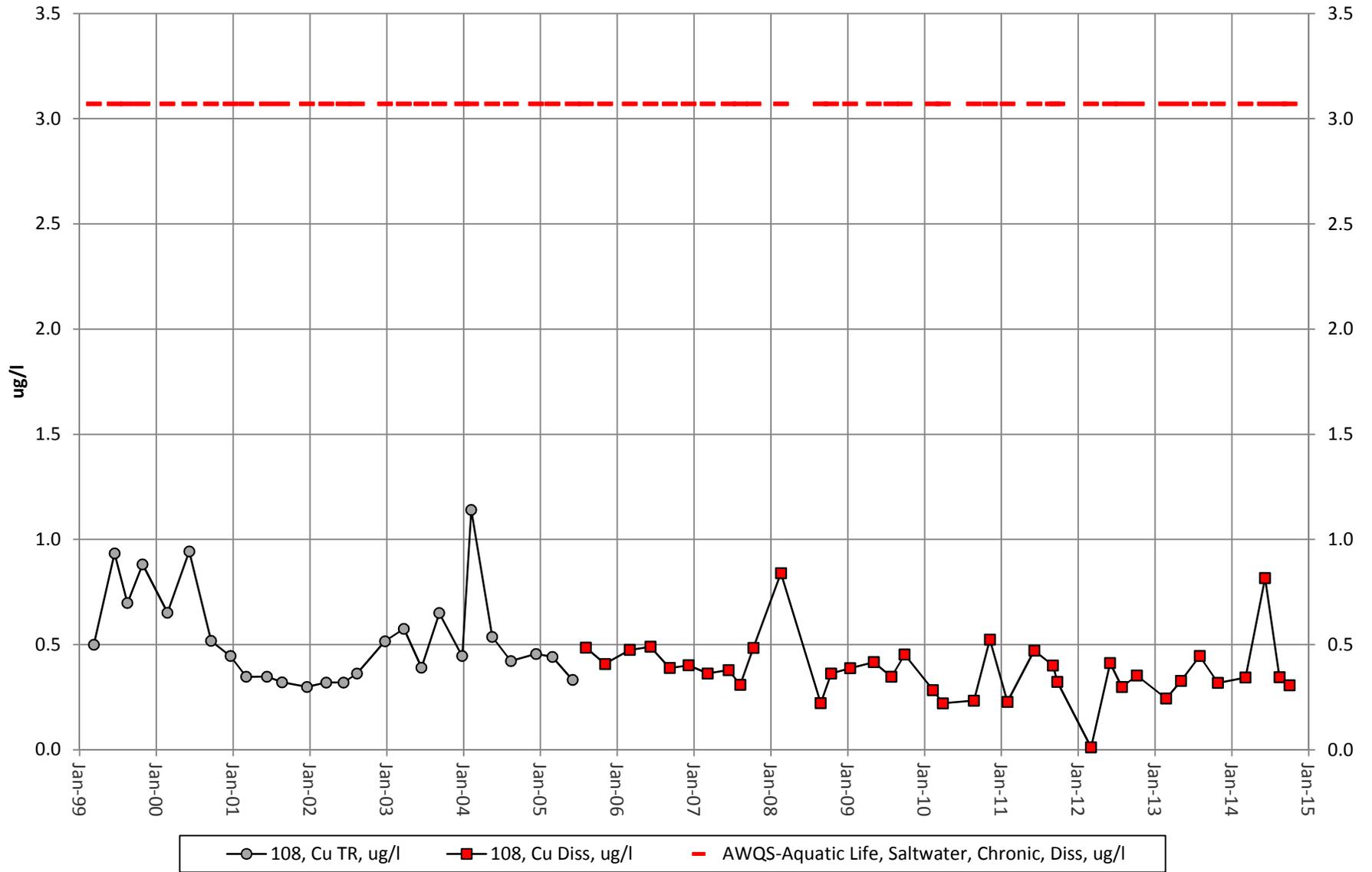


Figure 2-5a

Site 106 - Mercury

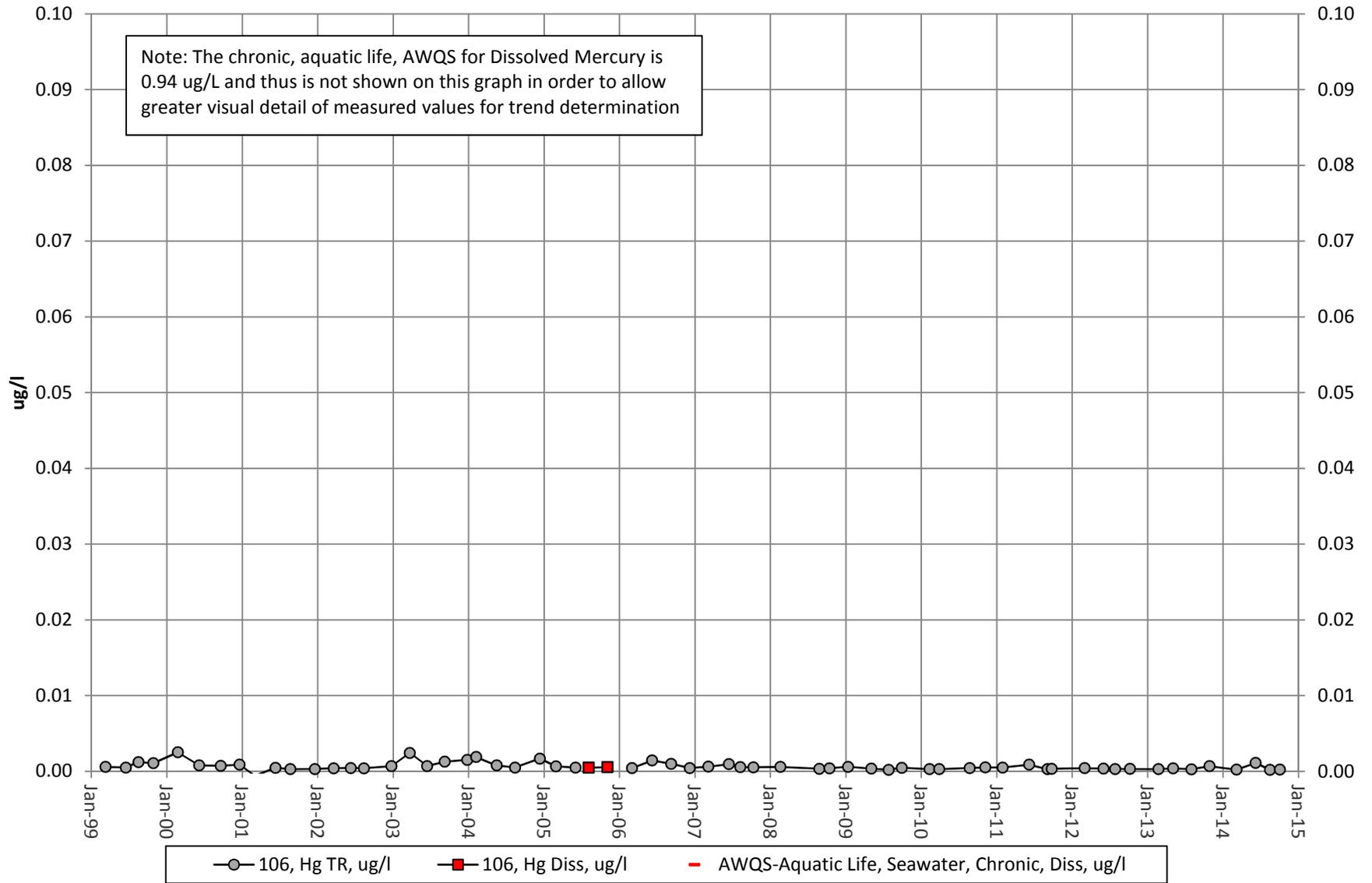


Figure 2-5b

Site 107 - Mercury

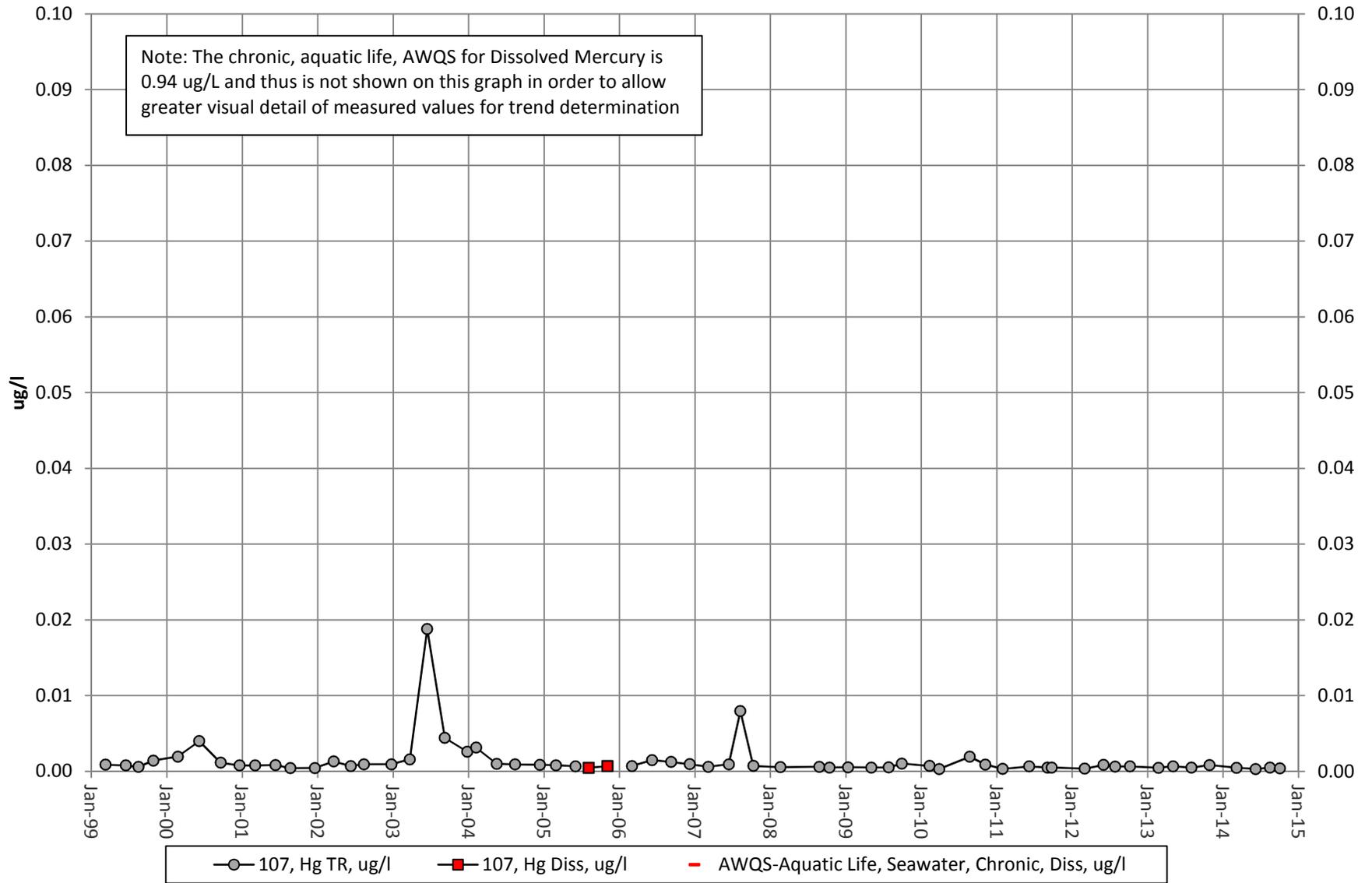


Figure 2-5c

Site 108 - Mercury

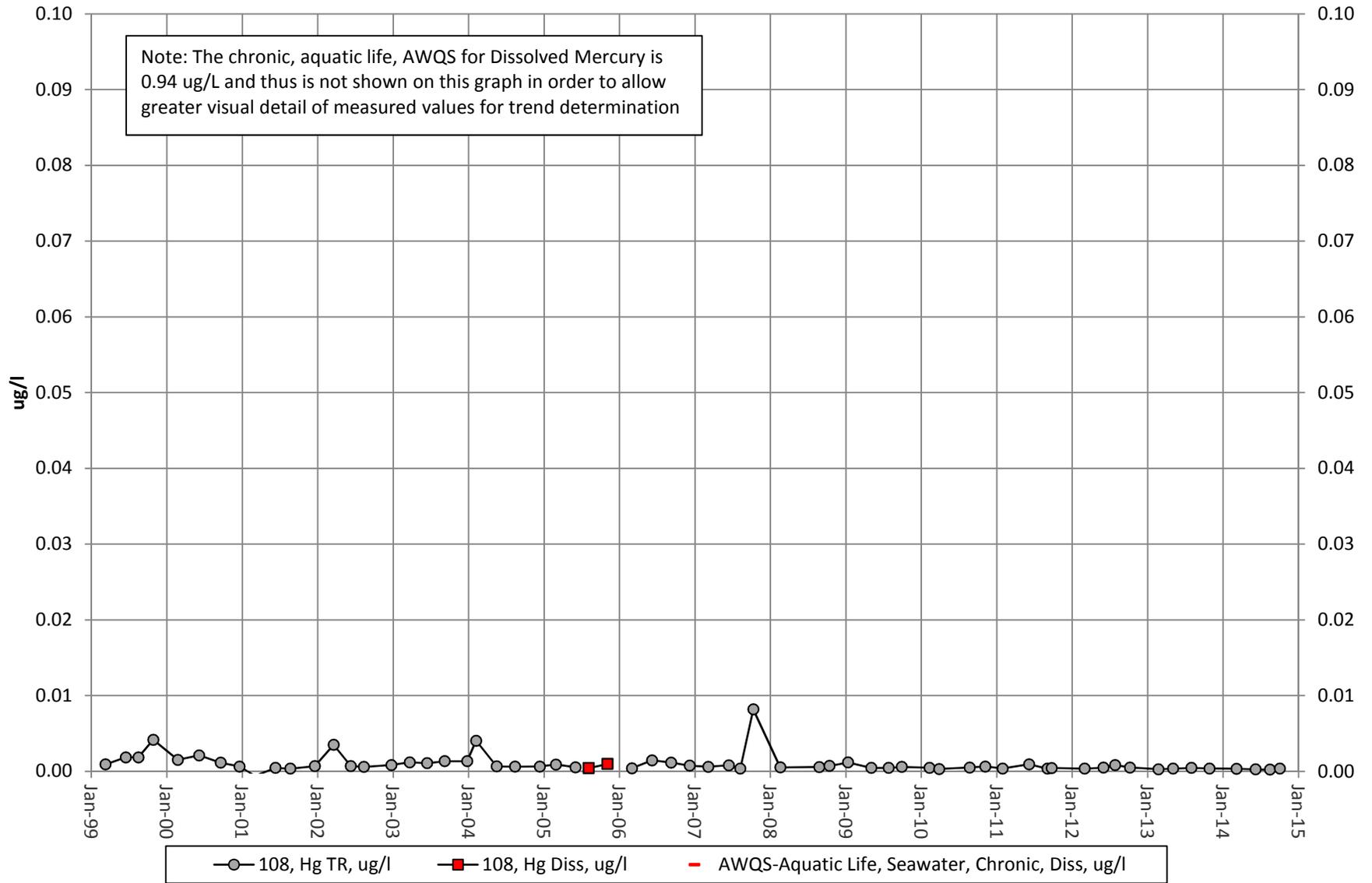


Figure 2-6a

Site 106 - Lead

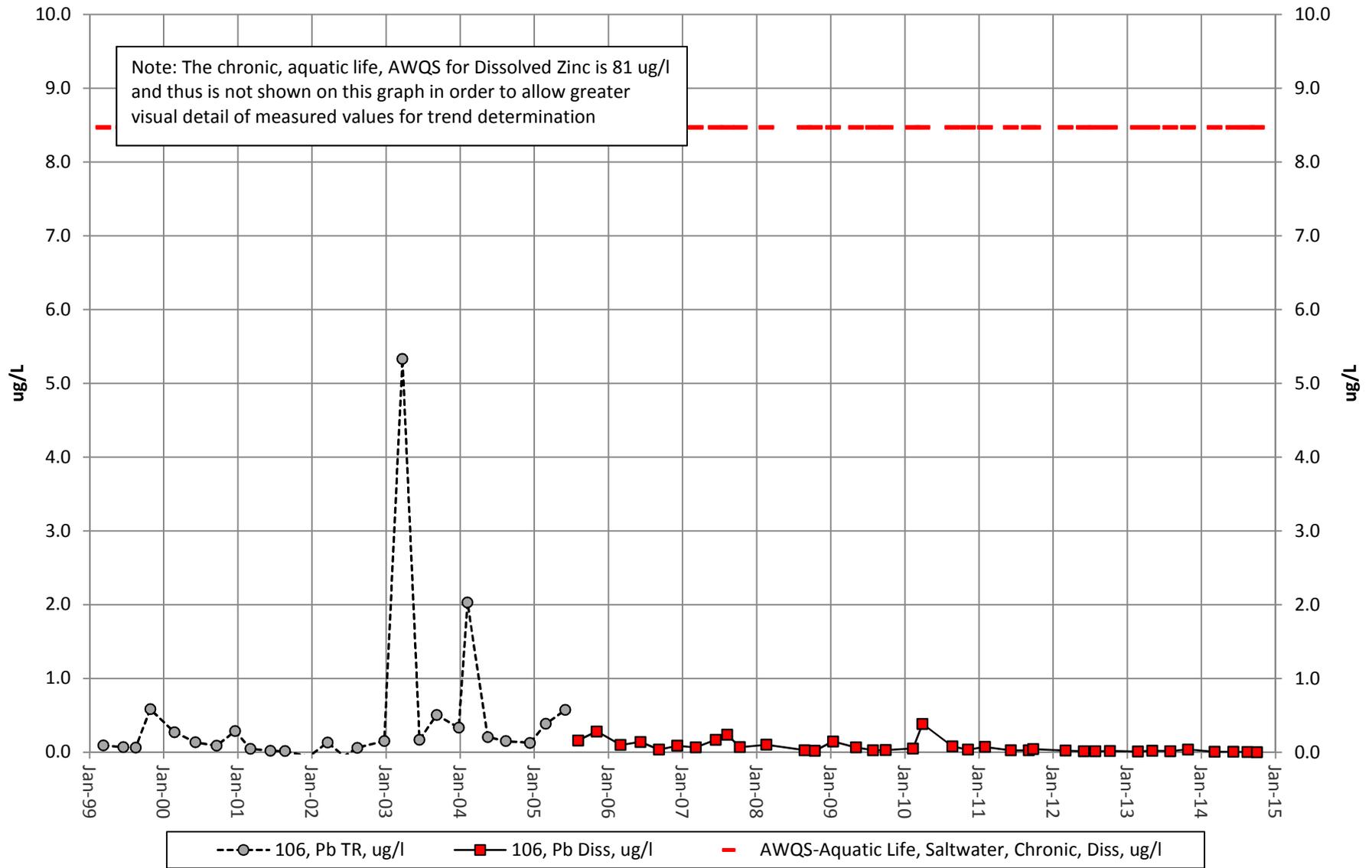


Figure 2-6b

Site 107 - Lead

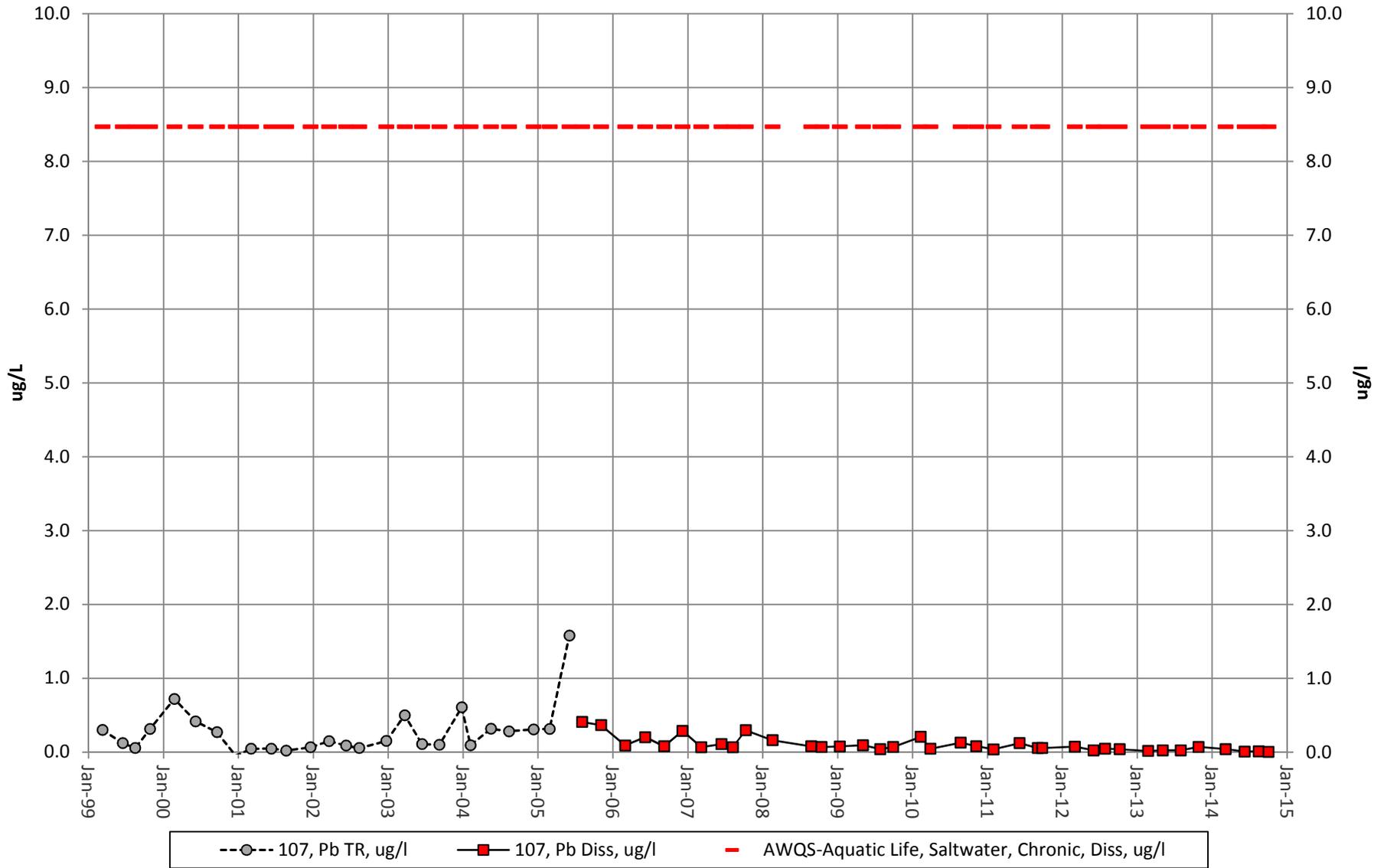


Figure 2-6c

Site 108 - Lead

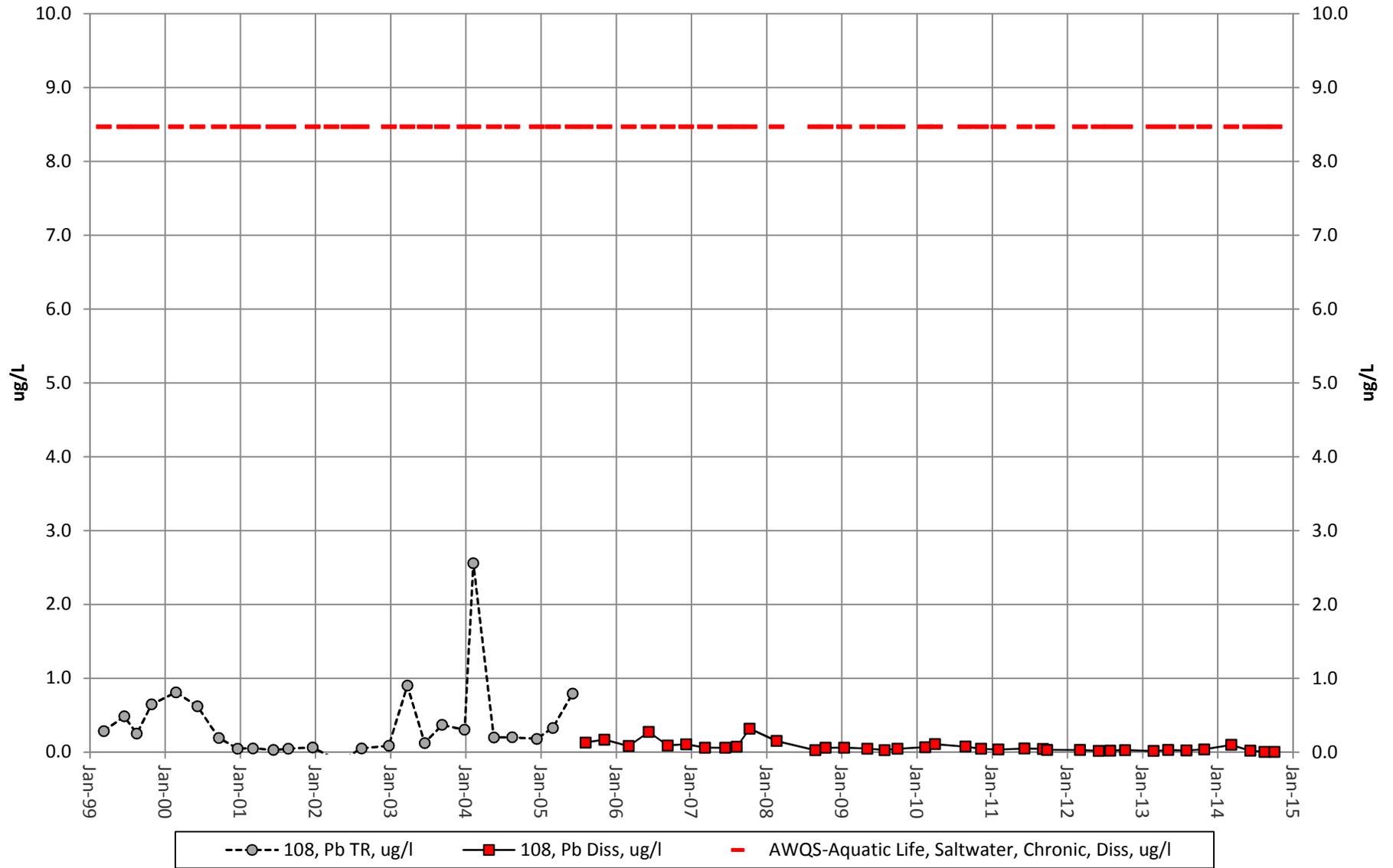


Figure 2-7a

Site 106 - Zinc

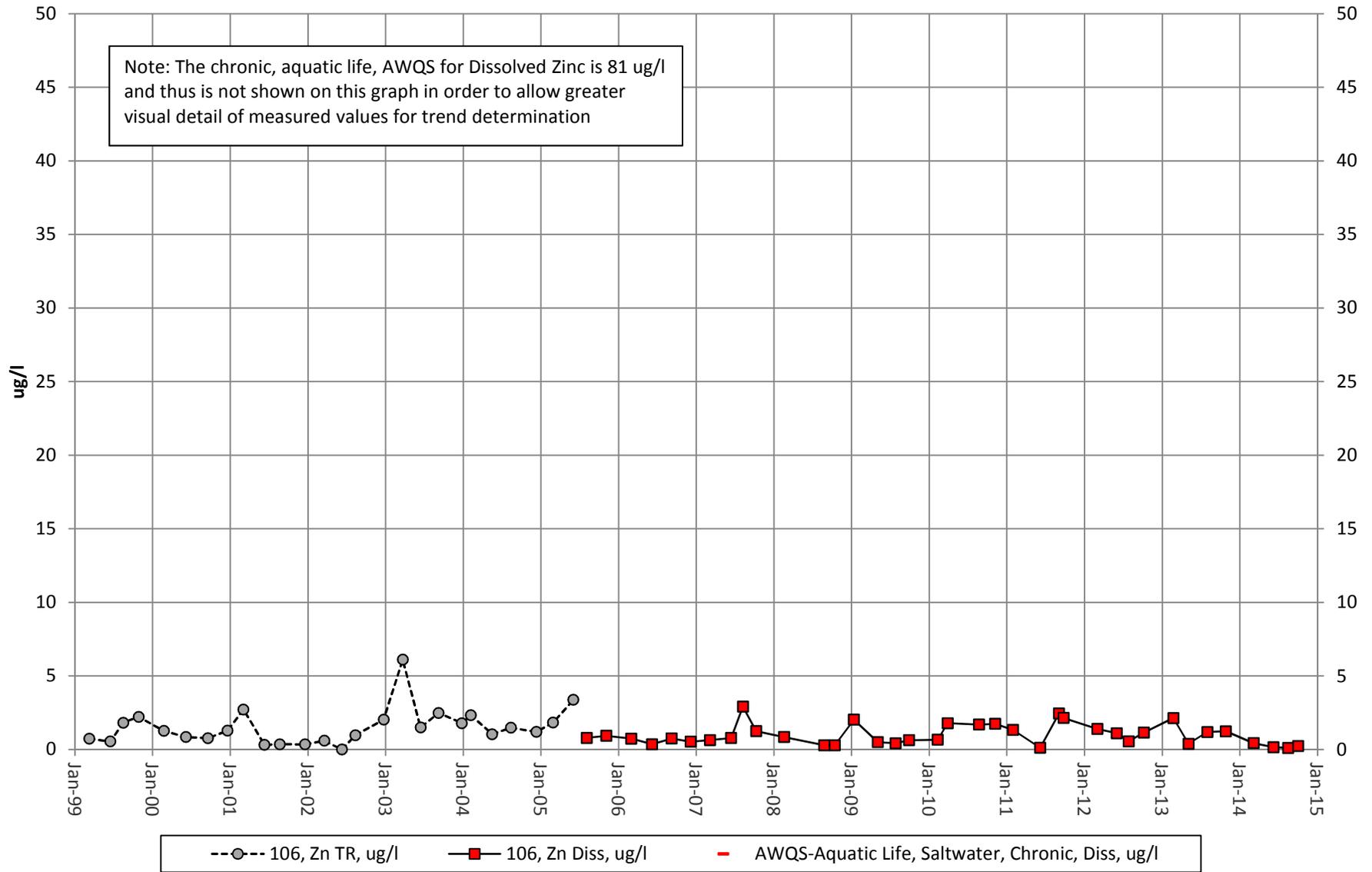


Figure 2-7b

Site 107 - Zinc

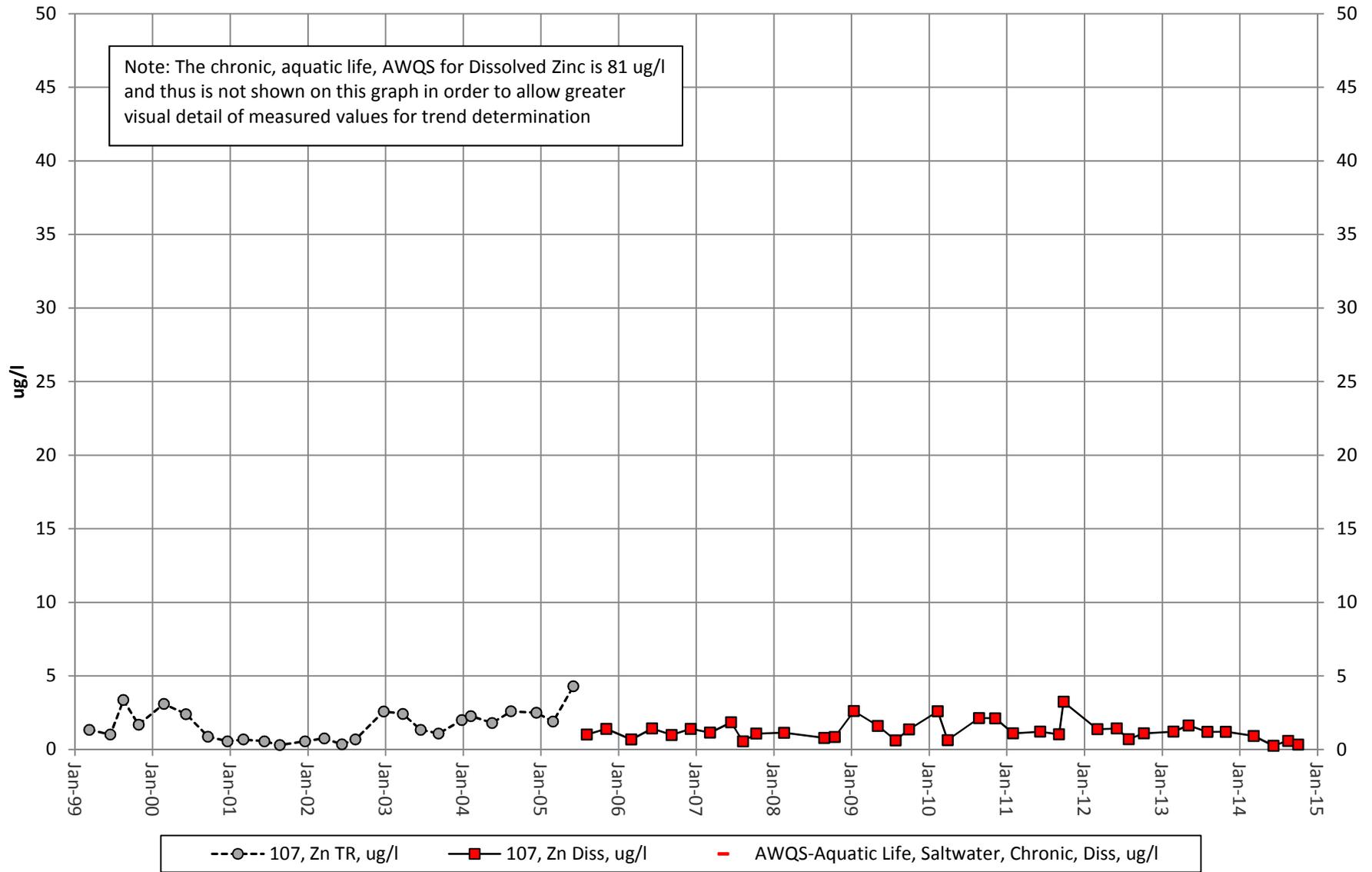


Figure 2-7c

Site 108 - Zinc

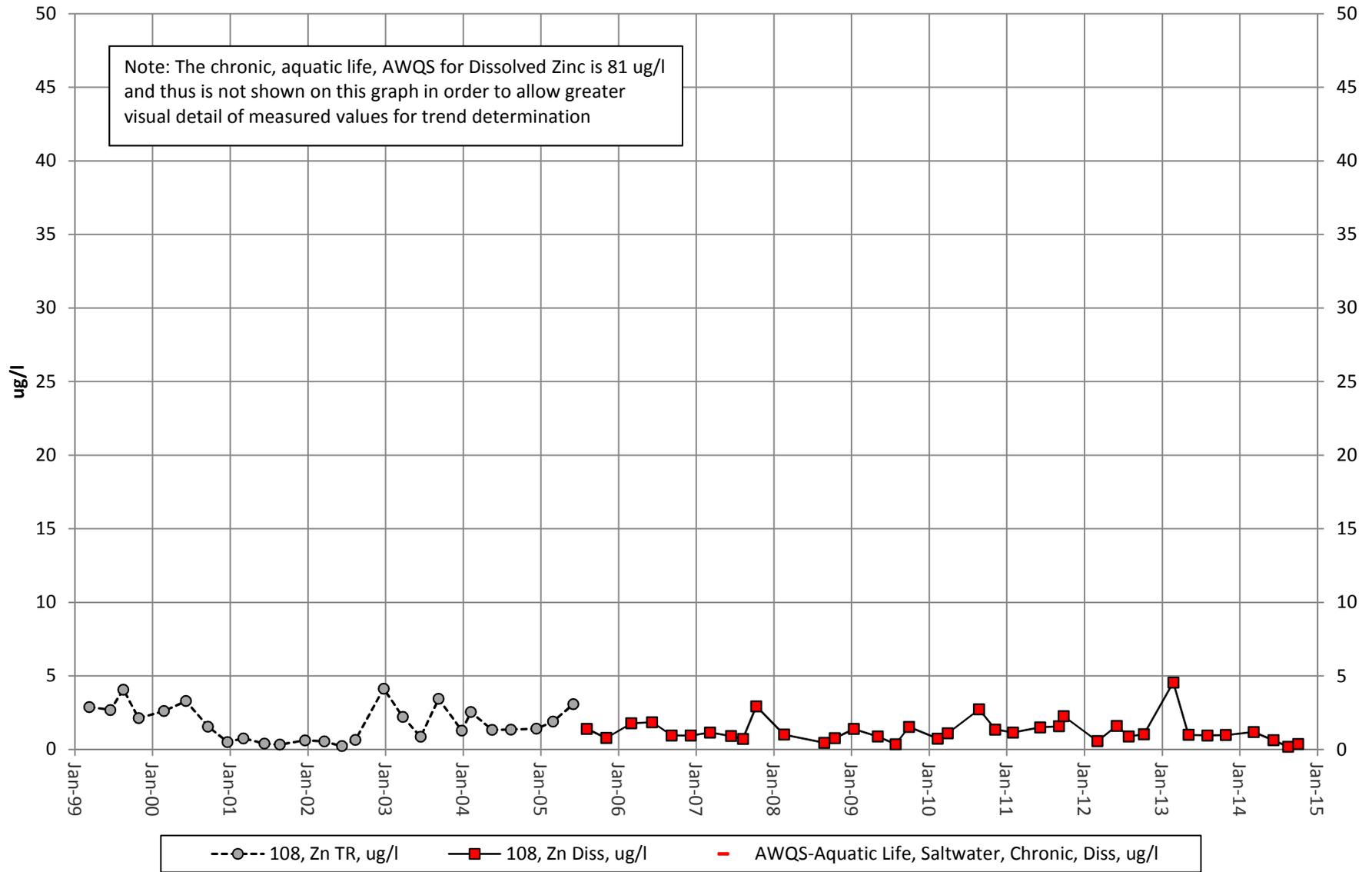


FIGURE 3-1

CADMIUM IN SEDIMENTS AT SITE S-1

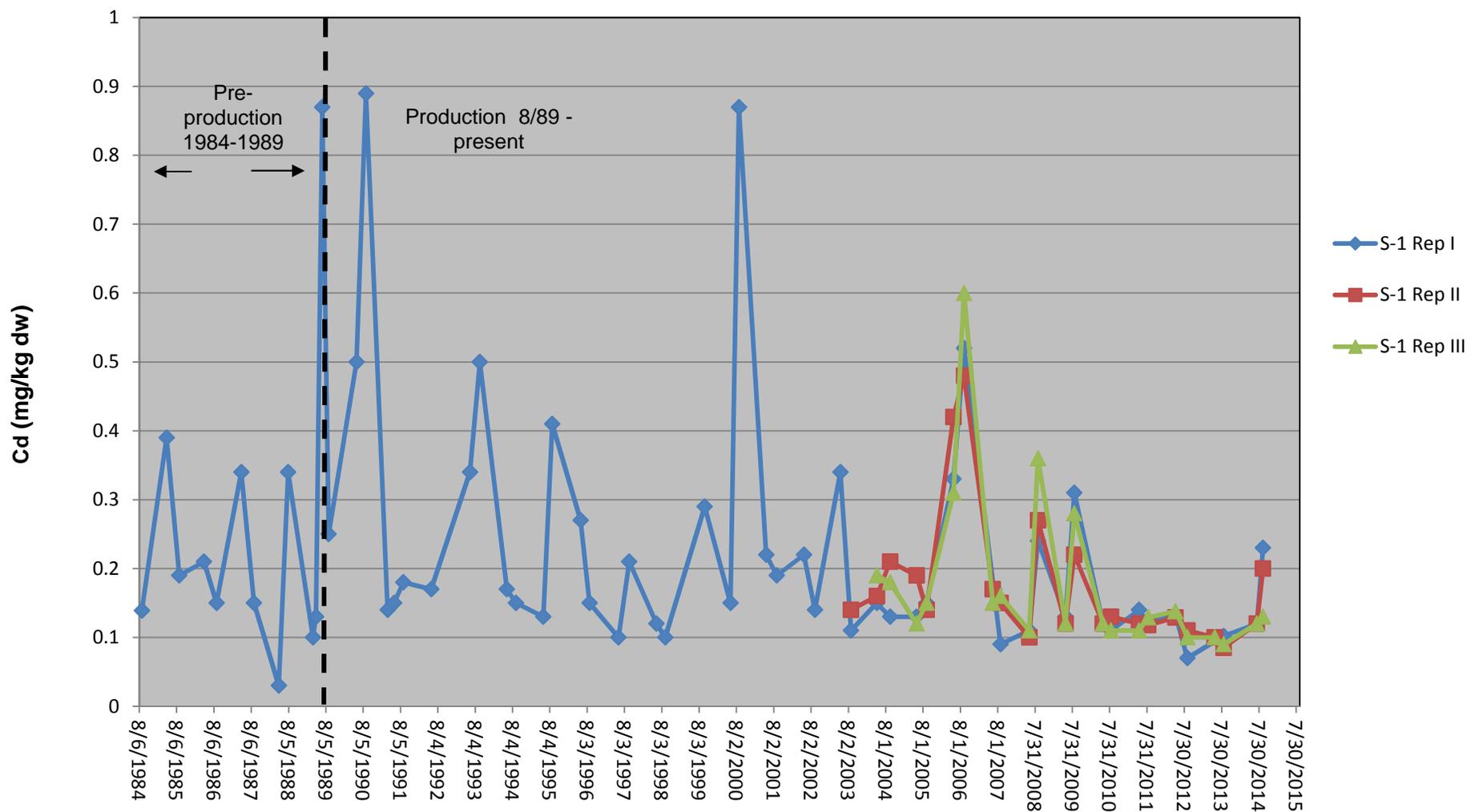


FIGURE 3-2

COPPER IN SEDIMENTS AT SITE S-1

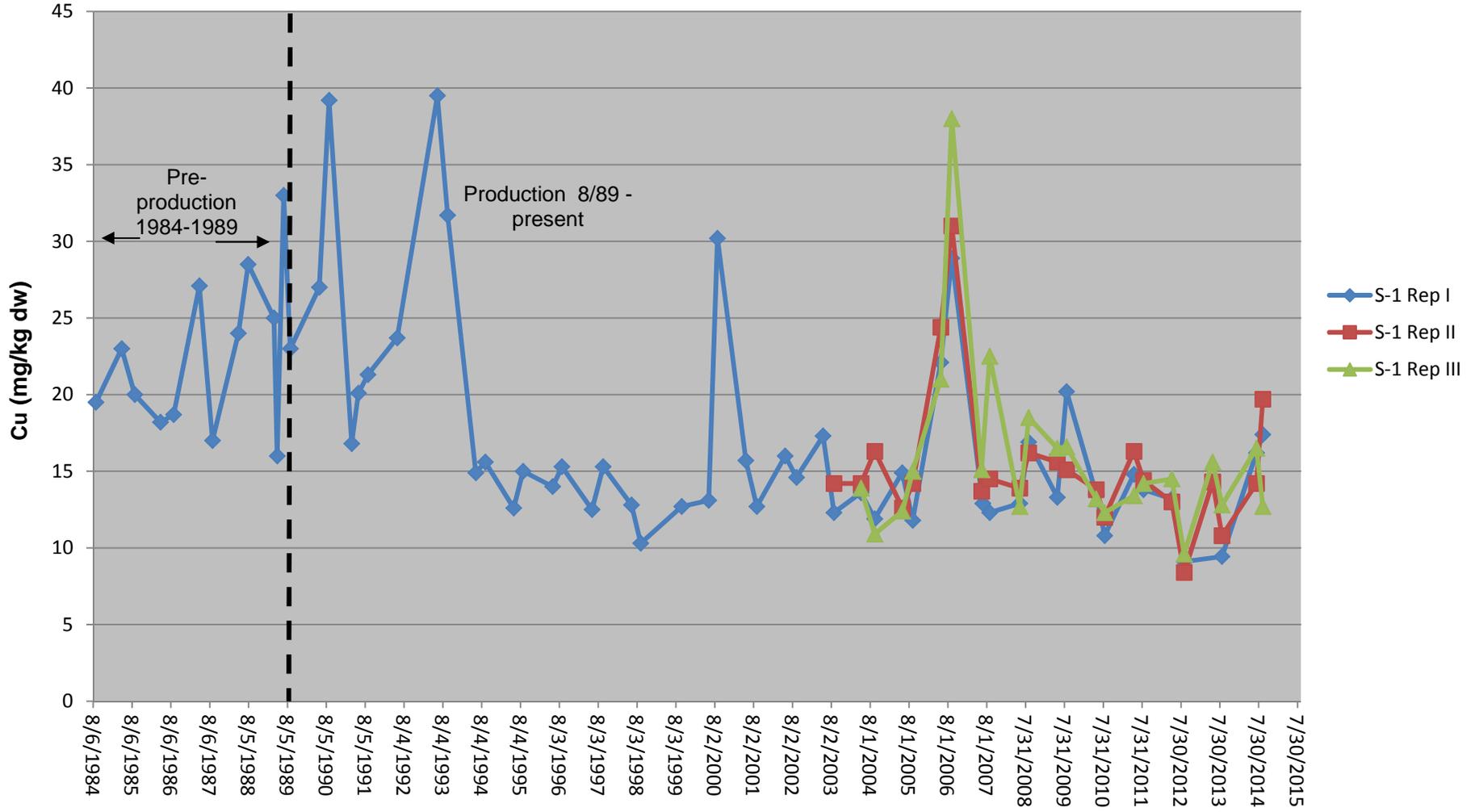


FIGURE 3-3

LEAD IN SEDIMENTS AT SITE S-1

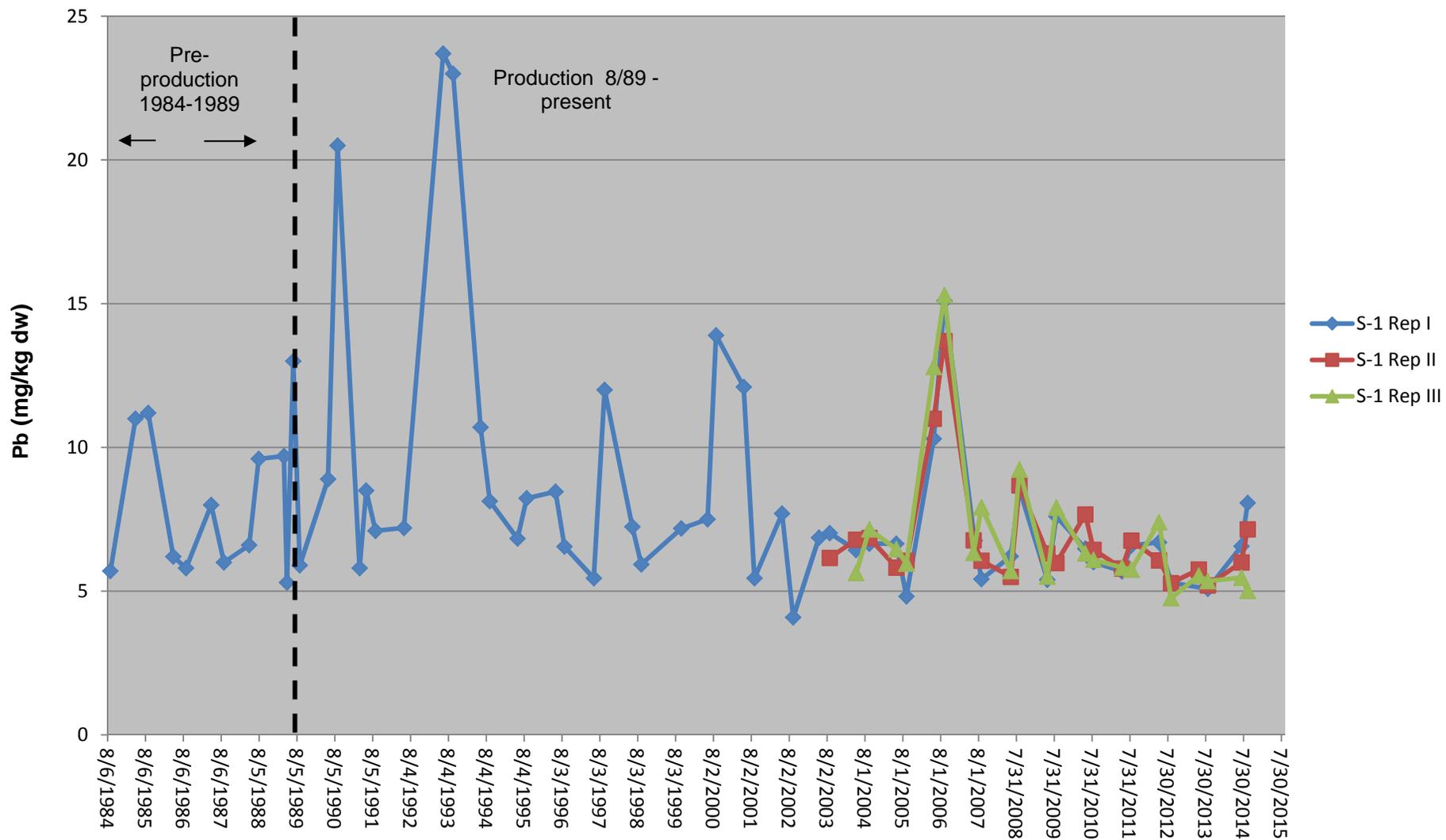


FIGURE 3-4

MERCURY IN SEDIMENTS AT SITE S-1

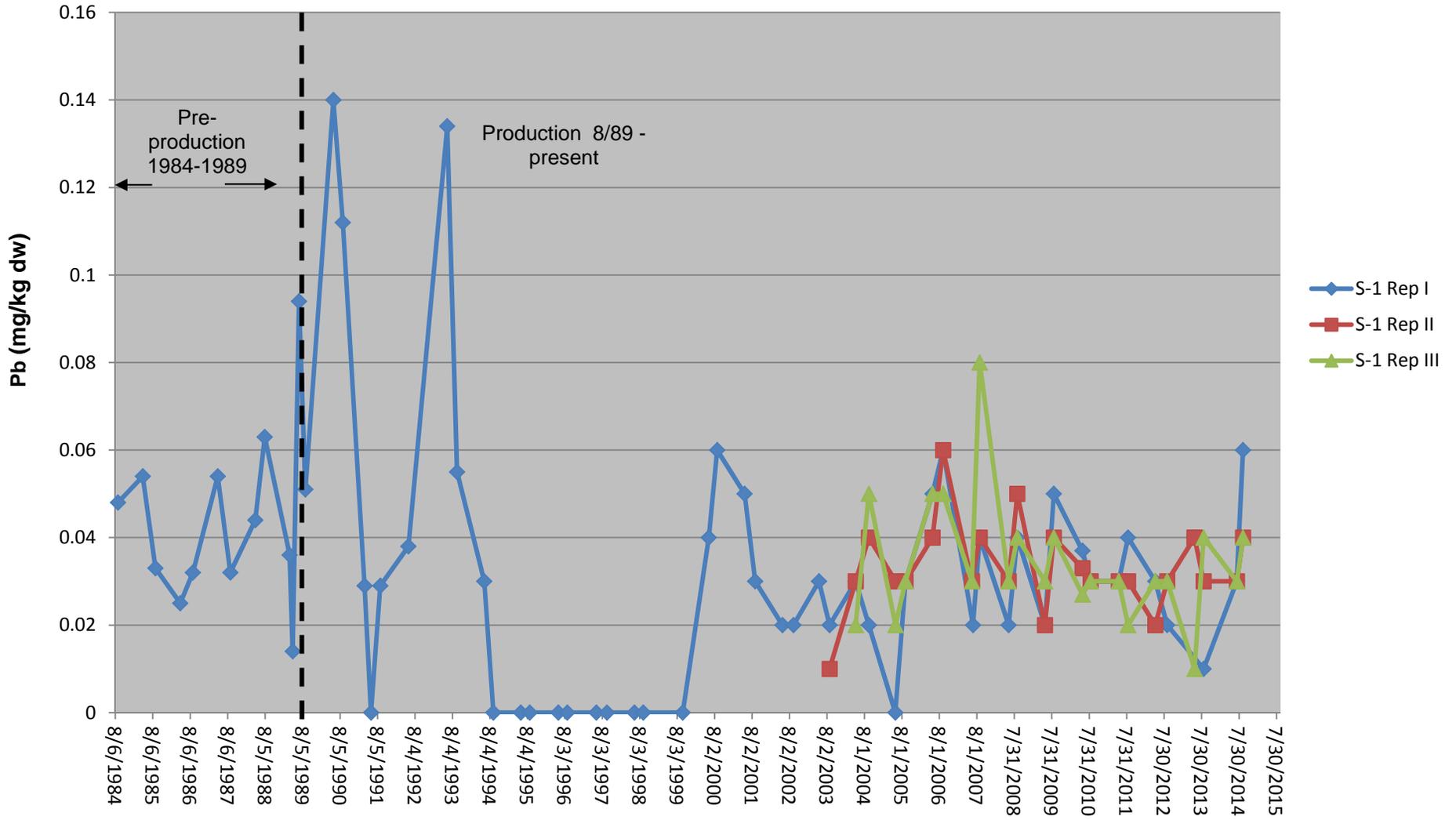


FIGURE 3-5

ZINC IN SEDIMENTS AT SITE S-1

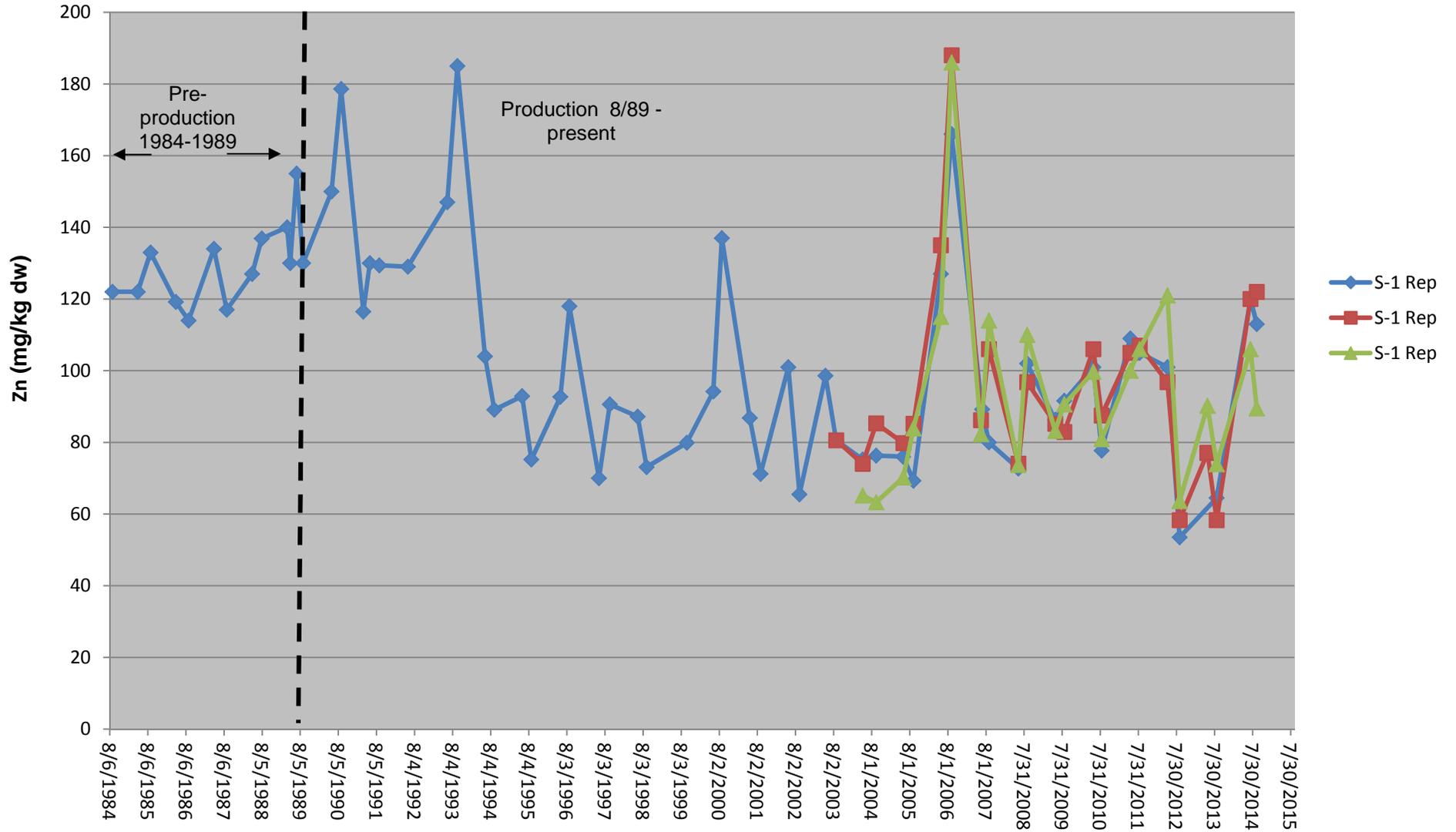


FIGURE 3-6

CADMIUM IN SEDIMENTS AT SITE S-2

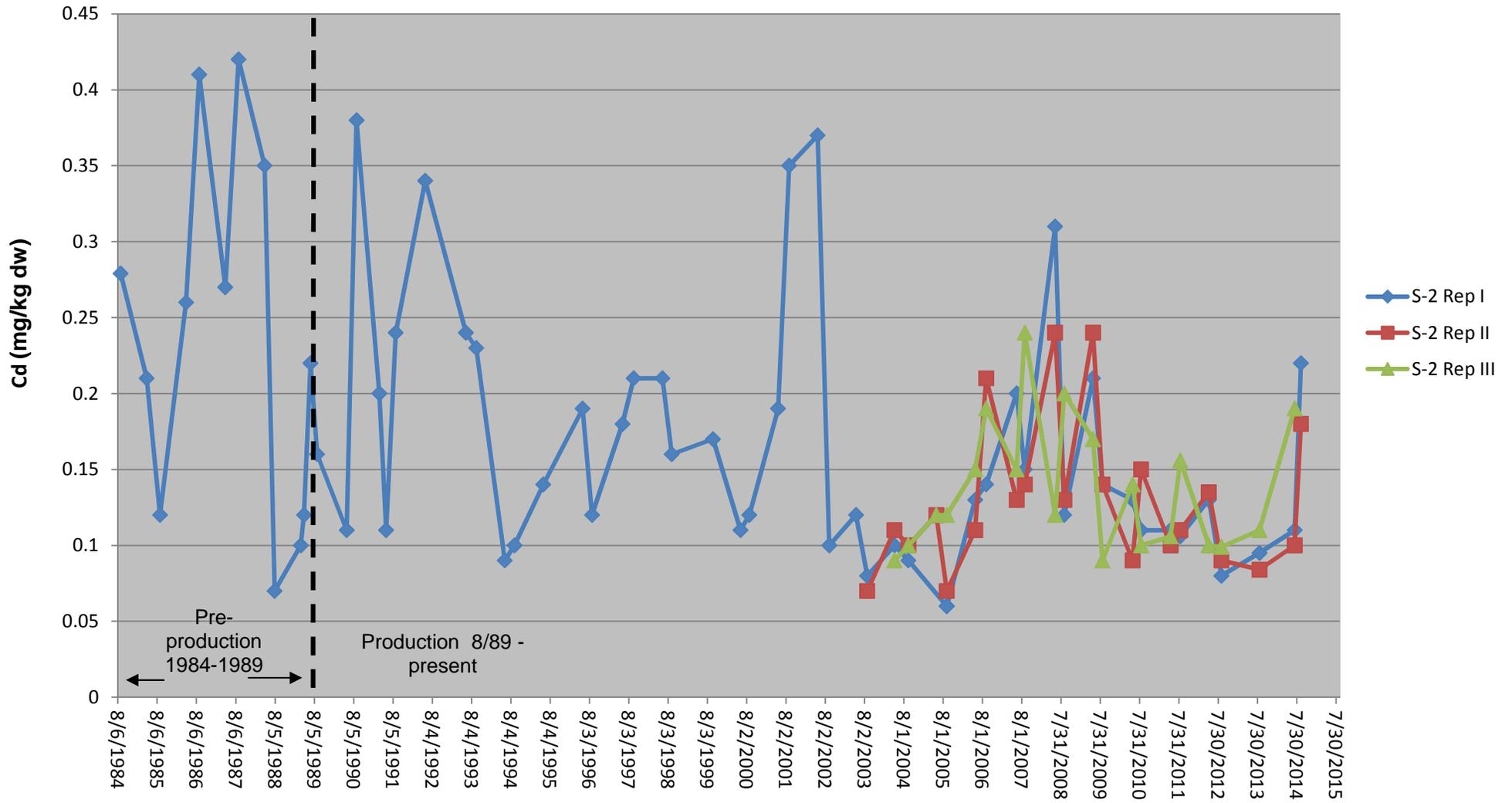


FIGURE 3-7

COPPER IN SEDIMENTS AT SITE S-2

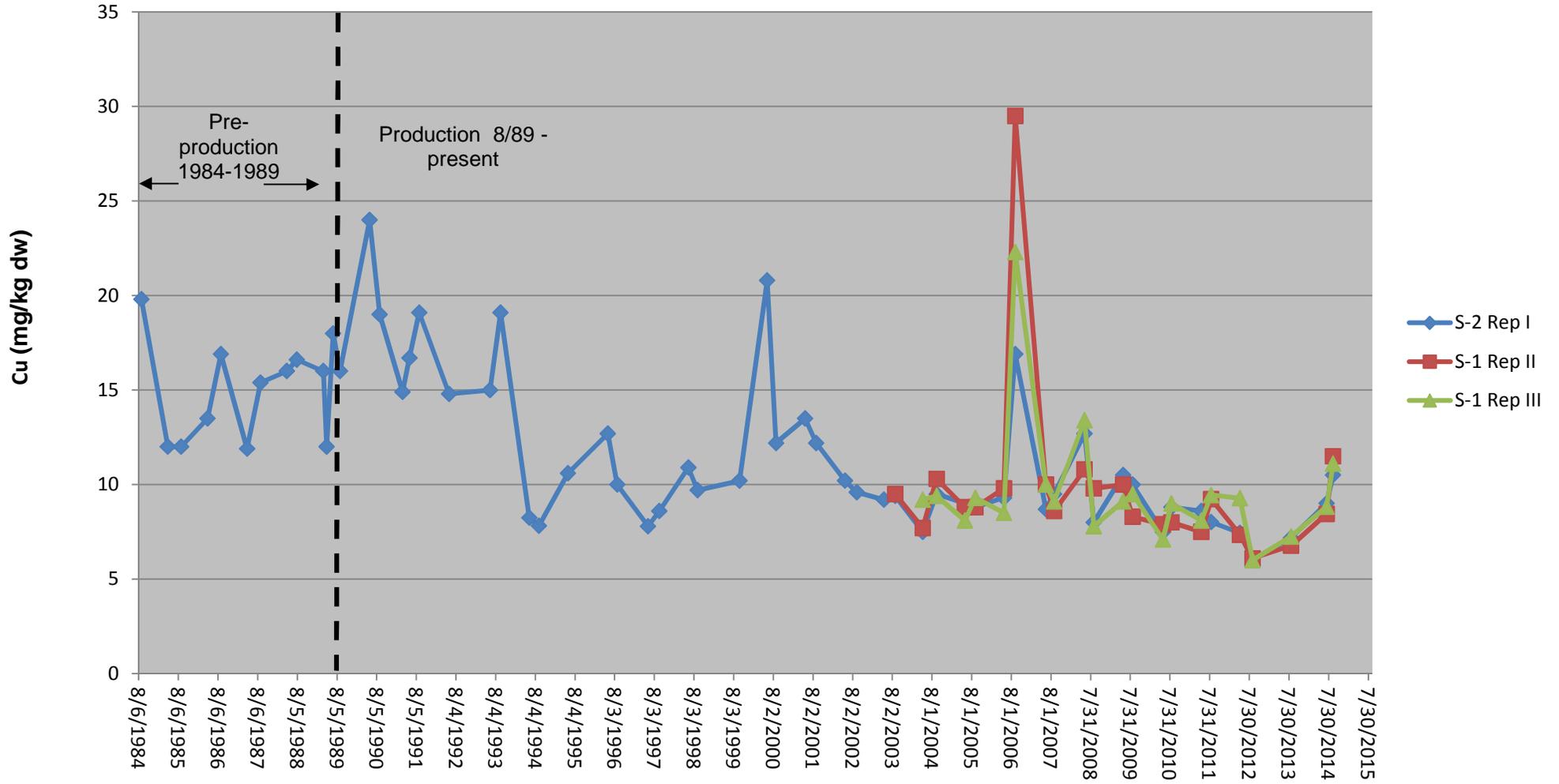


FIGURE 3-8

LEAD IN SEDIMENTS AT SITE S-2

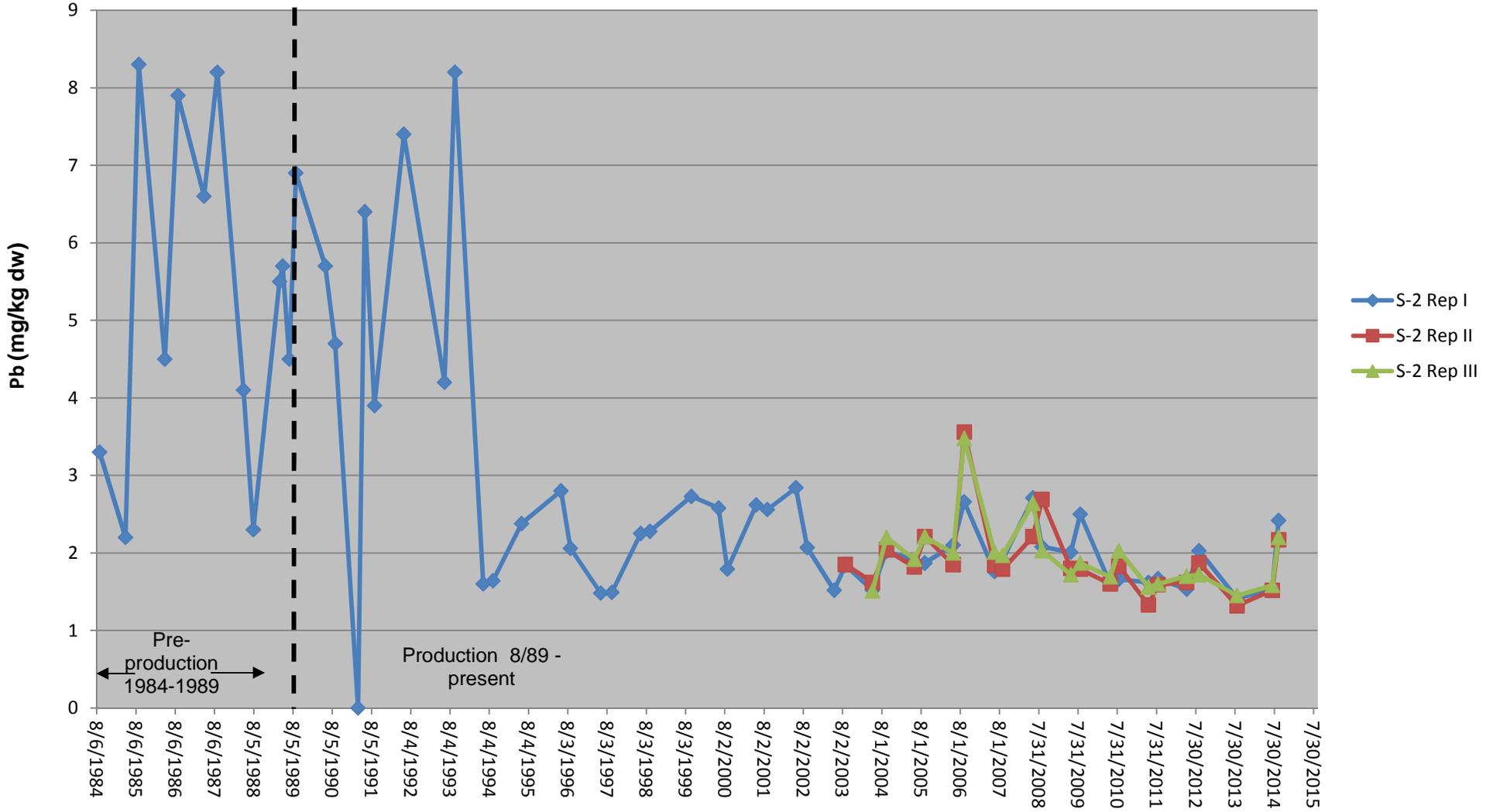


FIGURE 3-9

MERCURY IN SEDIMENTS AT SITE S-2

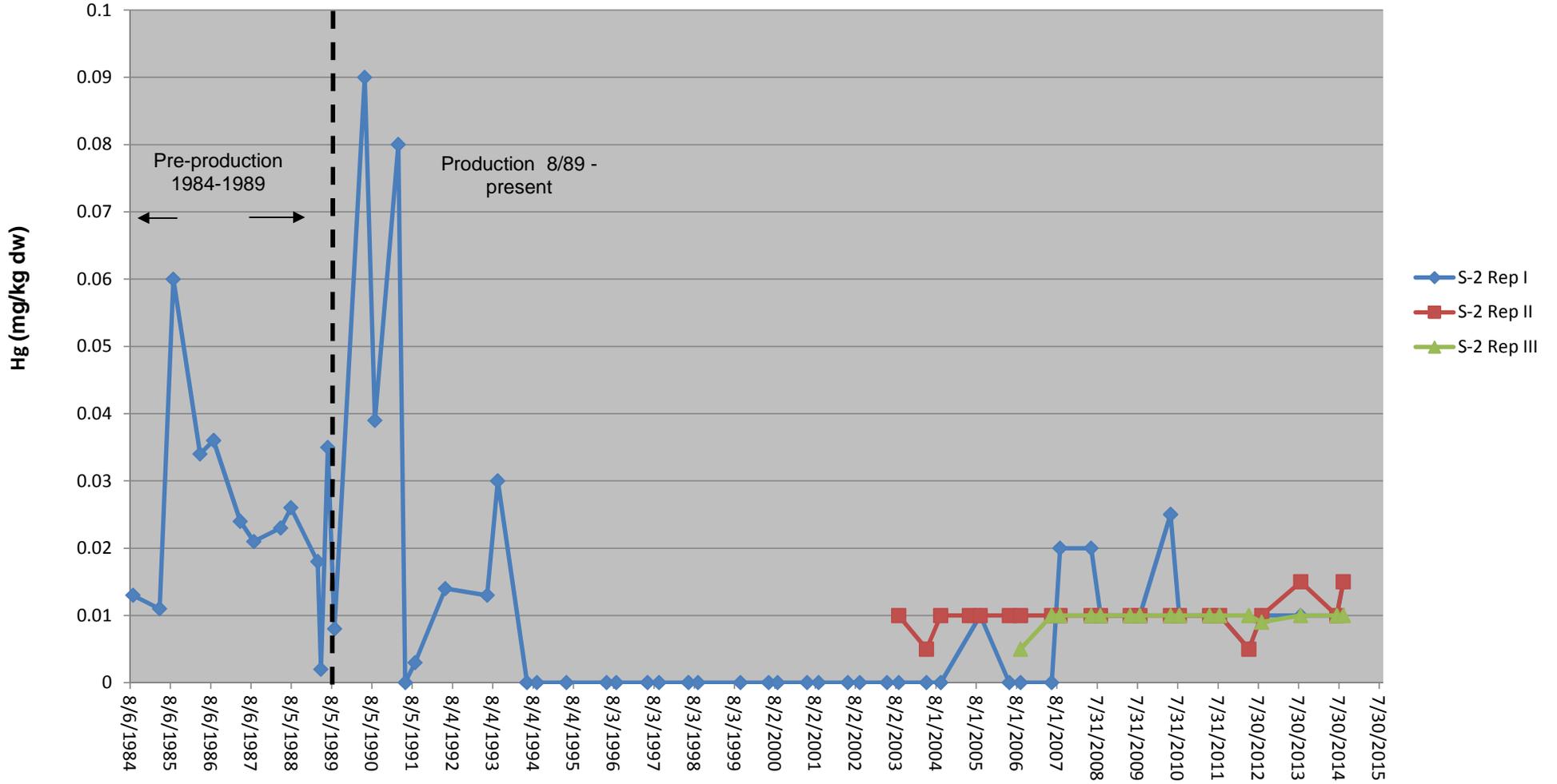


FIGURE 3-10

ZINC IN SEDIMENTS AT SITE S-2

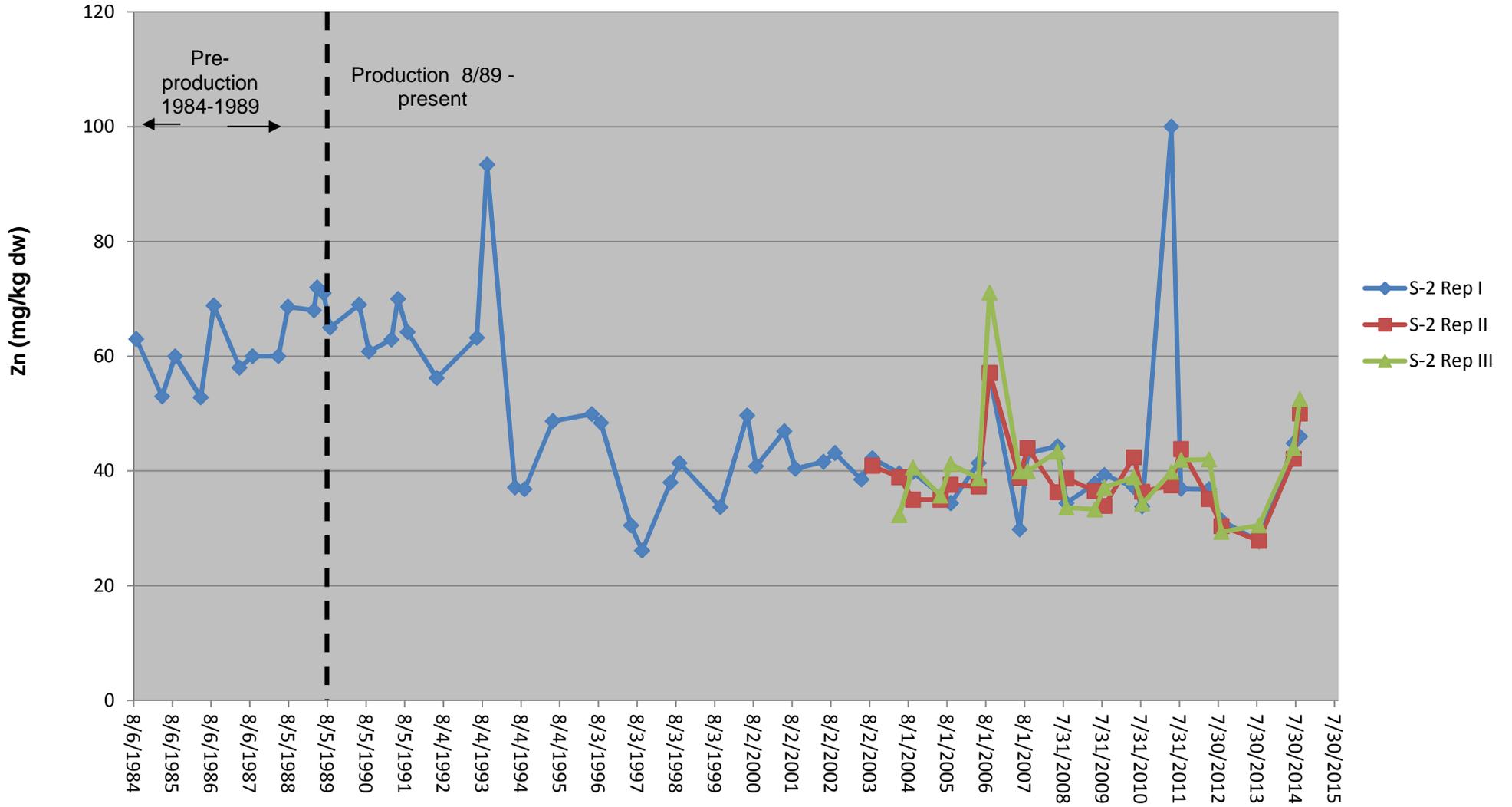


FIGURE 3-11

CADMIUM IN SEDIMENTS AT SITE S-4

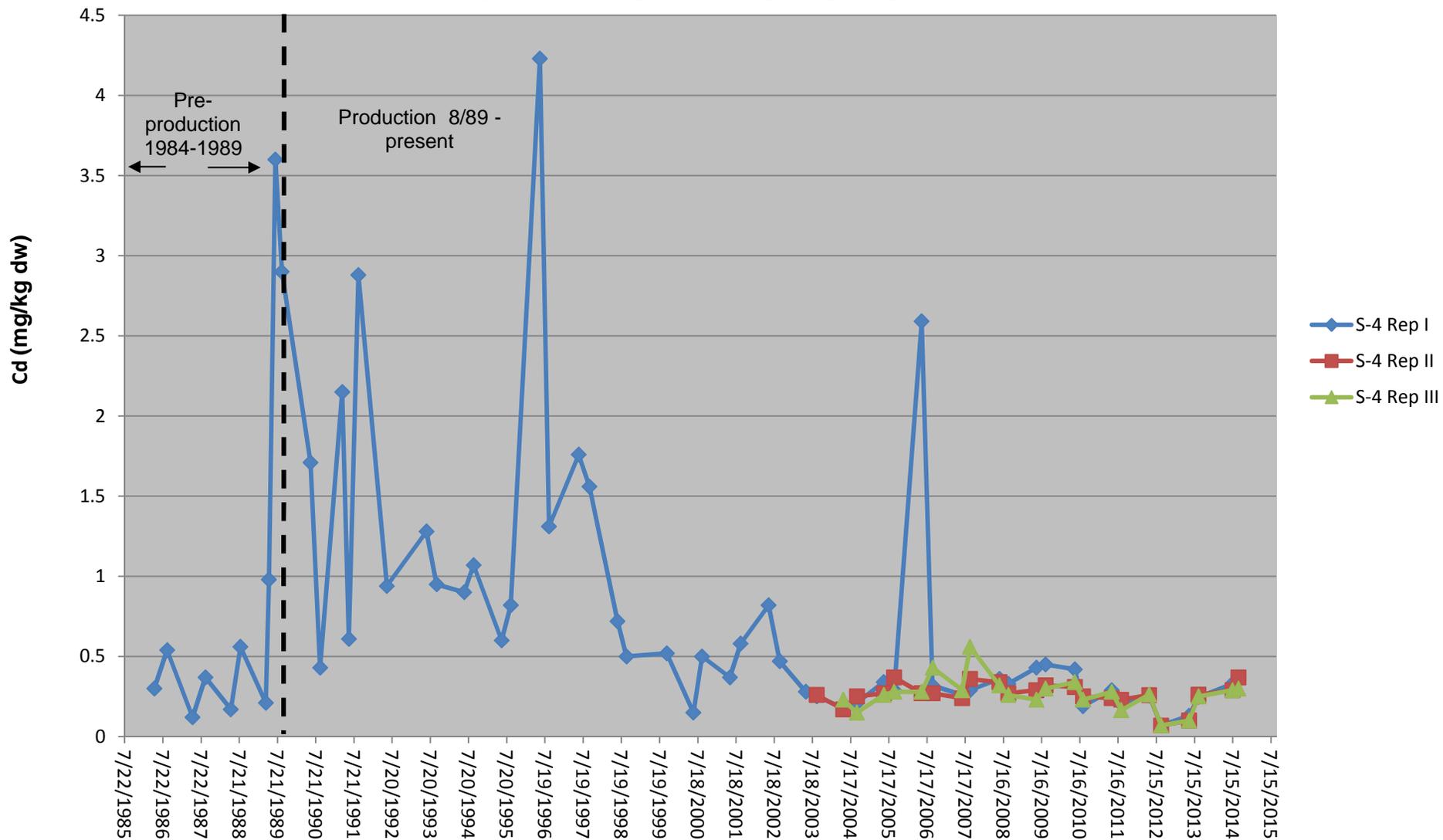


FIGURE 3-12

COPPER IN SEDIMENTS AT SITE S-4

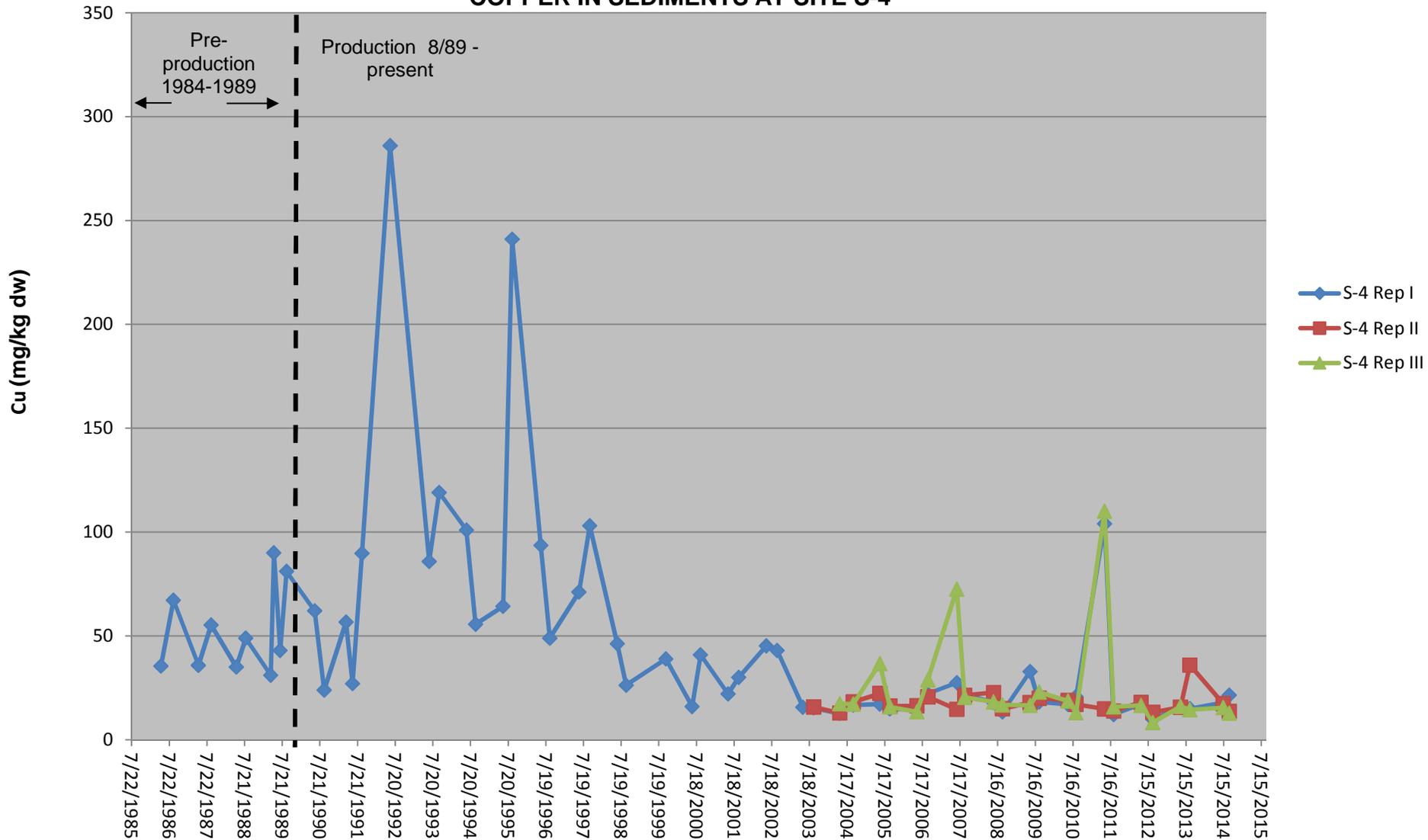


FIGURE 3-13

LEAD IN SEDIMENTS AT SITE S-4

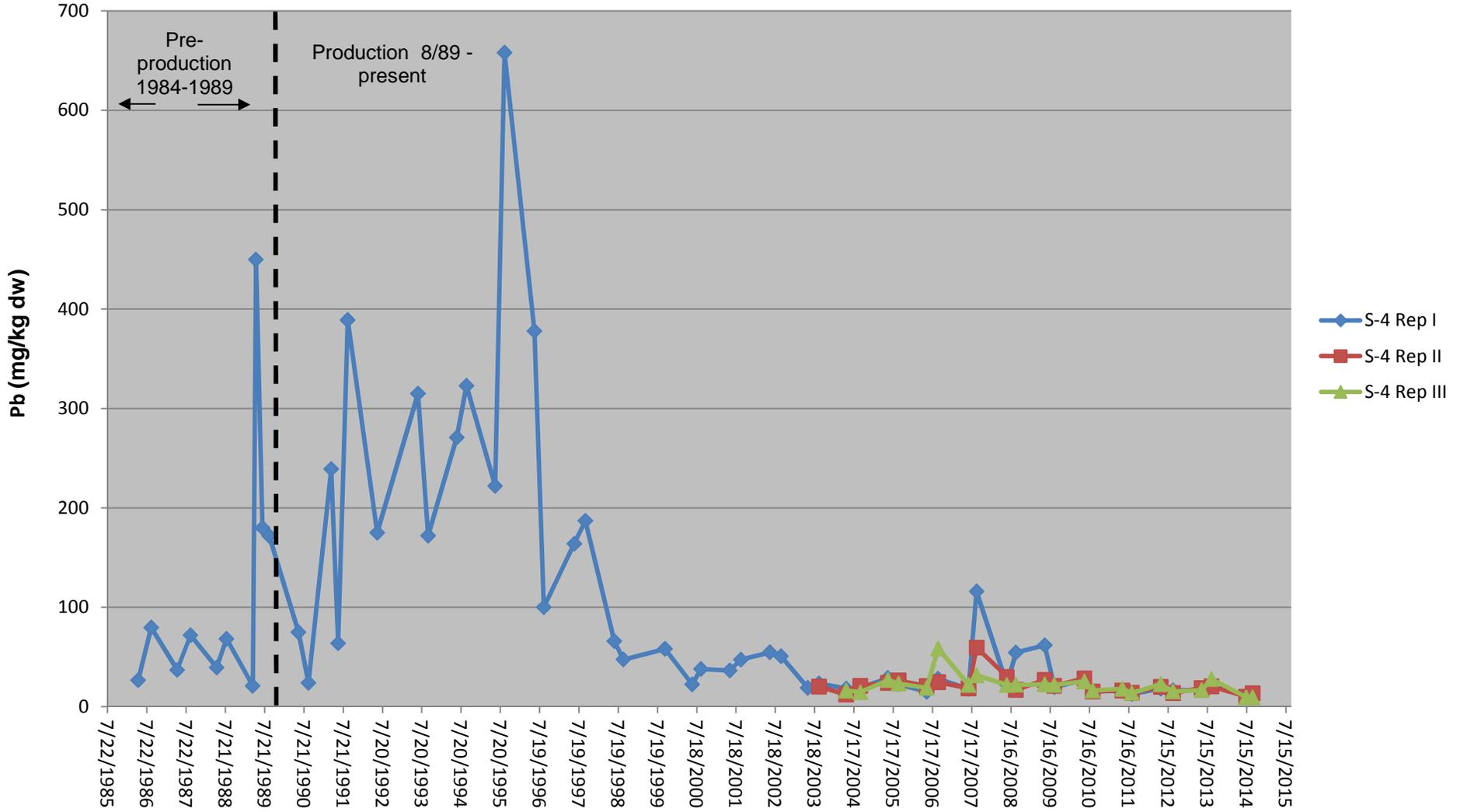


FIGURE 3-14

MERCURY IN SEDIMENTS AT SITE S-4

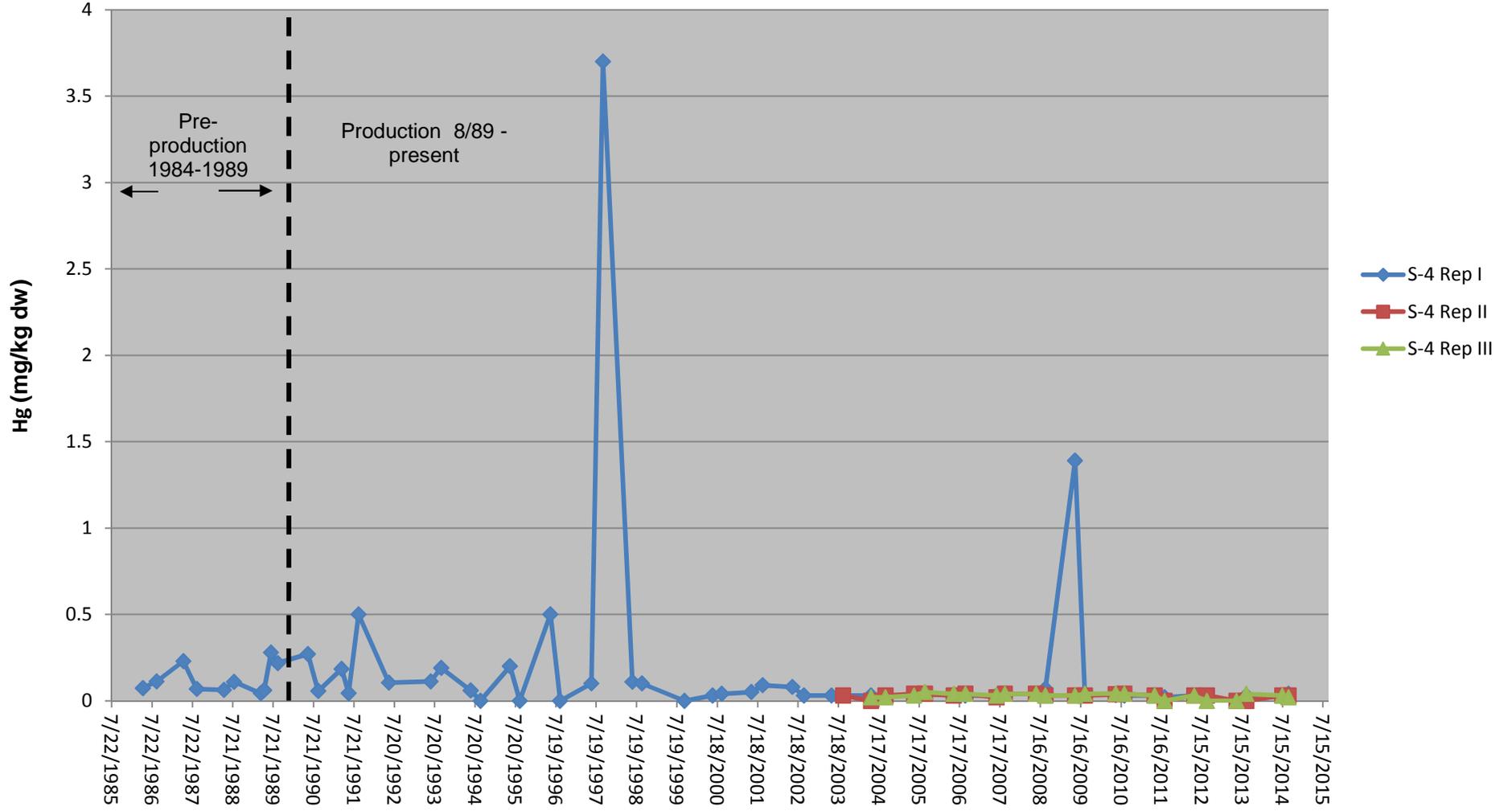


FIGURE 3-15

ZINC IN SEDIMENTS AT SITE S-4

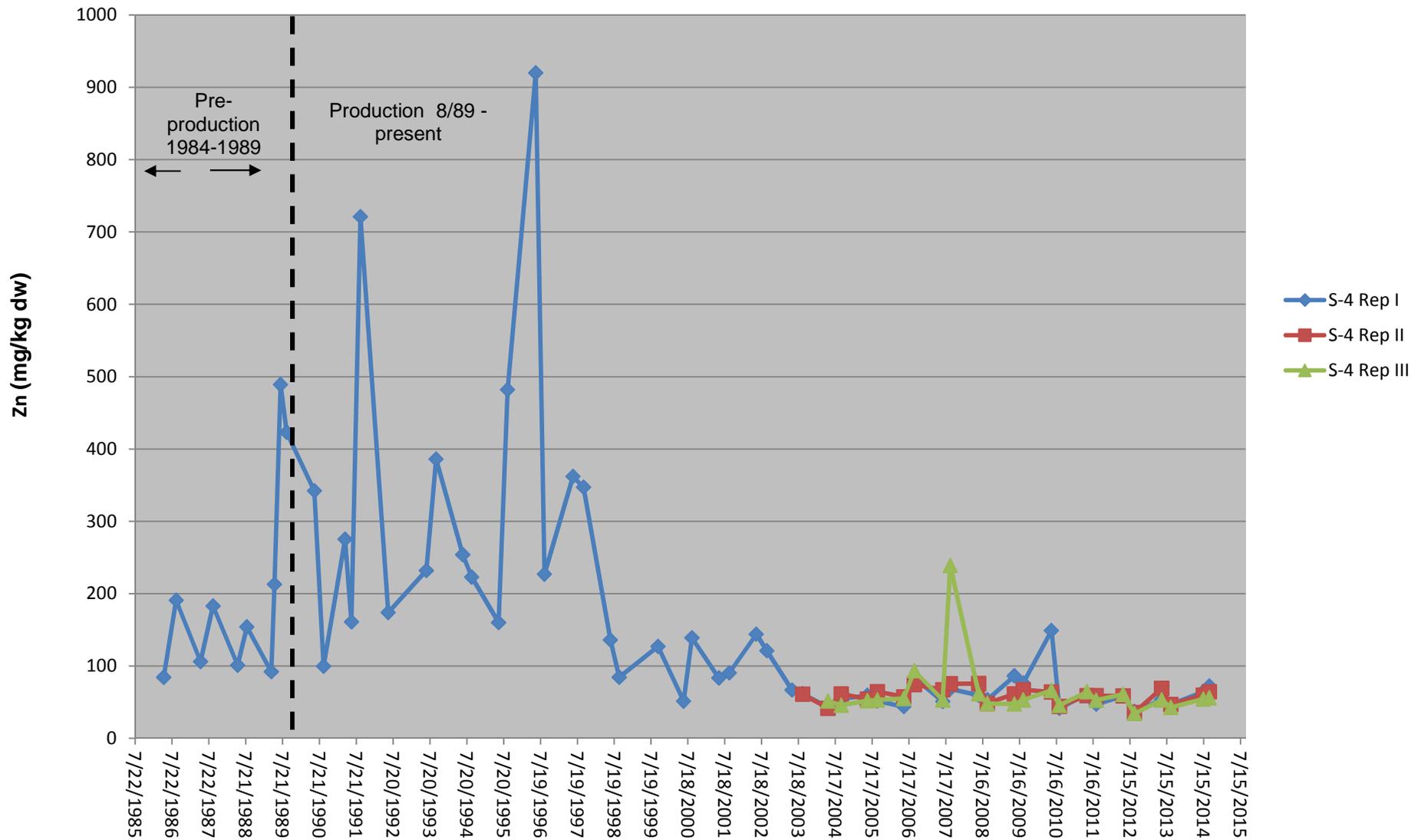


FIGURE 3-16

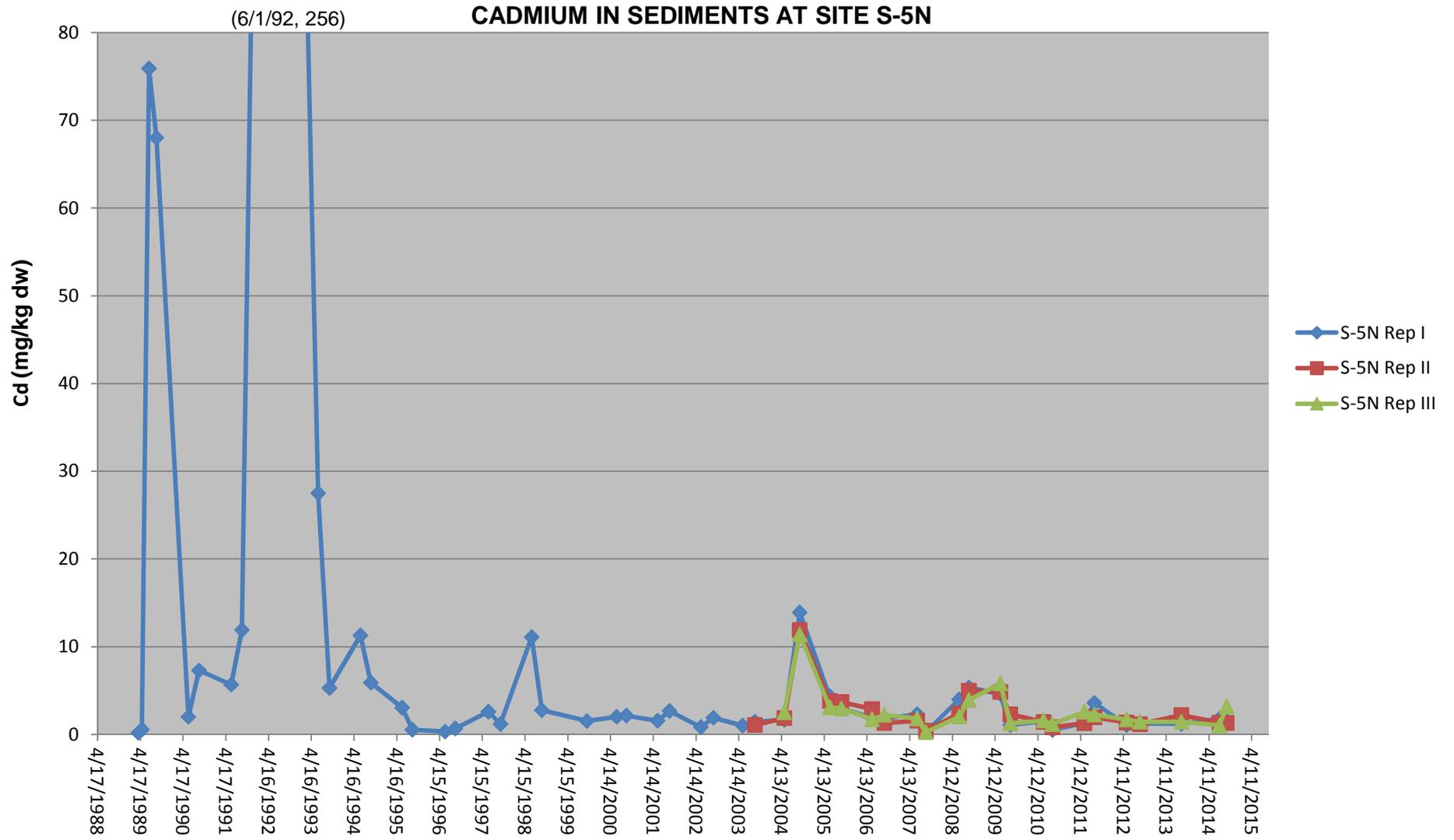


FIGURE 3-17

COPPER IN SEDIMENTS AT SITE S-5N

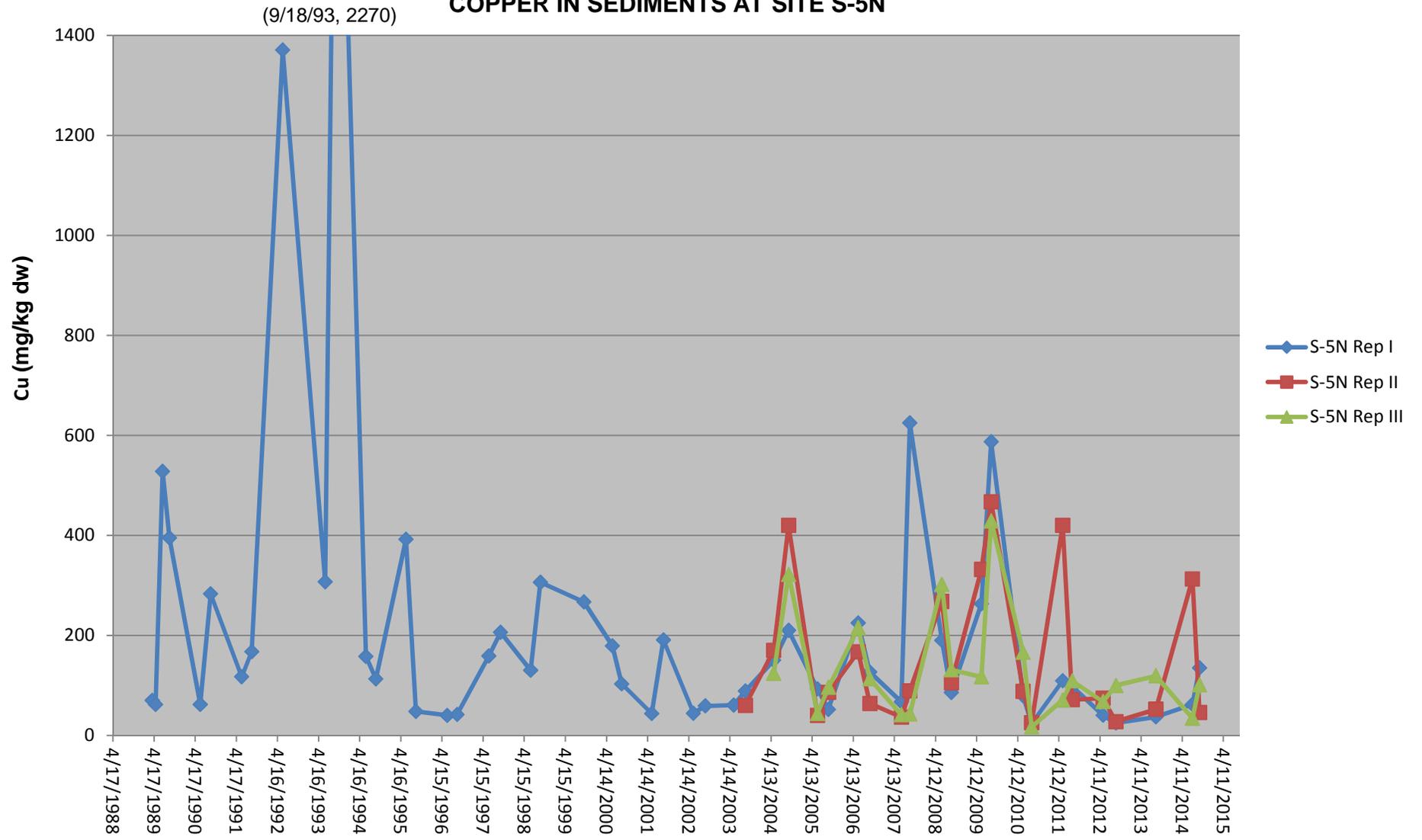


FIGURE 3-18

LEAD IN SEDIMENTS AT SITE S-5N

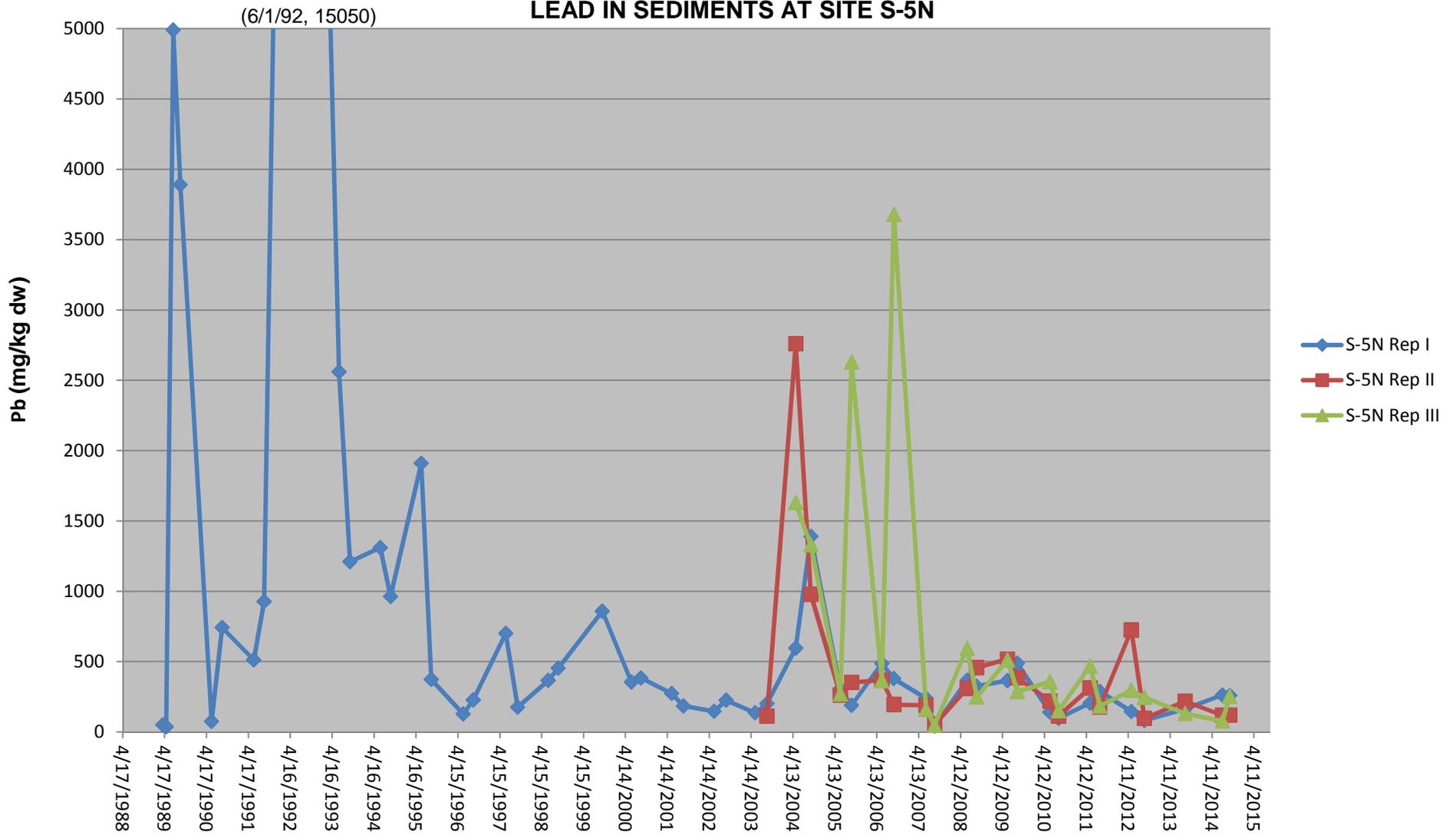


FIGURE 3-19

MERCURY IN SEDIMENTS AT SITE S-5N

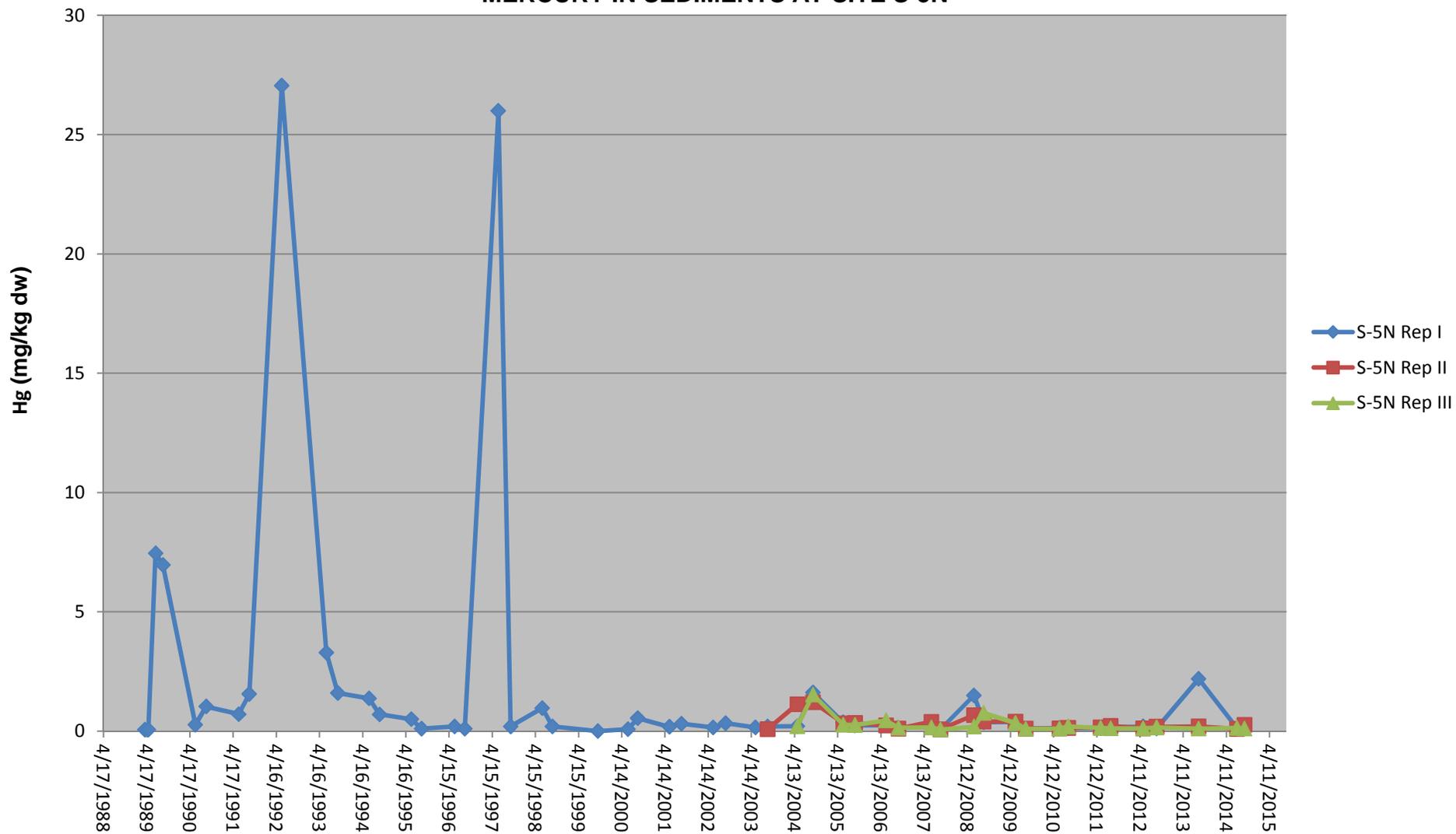


FIGURE 3-20

ZINC IN SEDIMENTS AT SITE S-5N

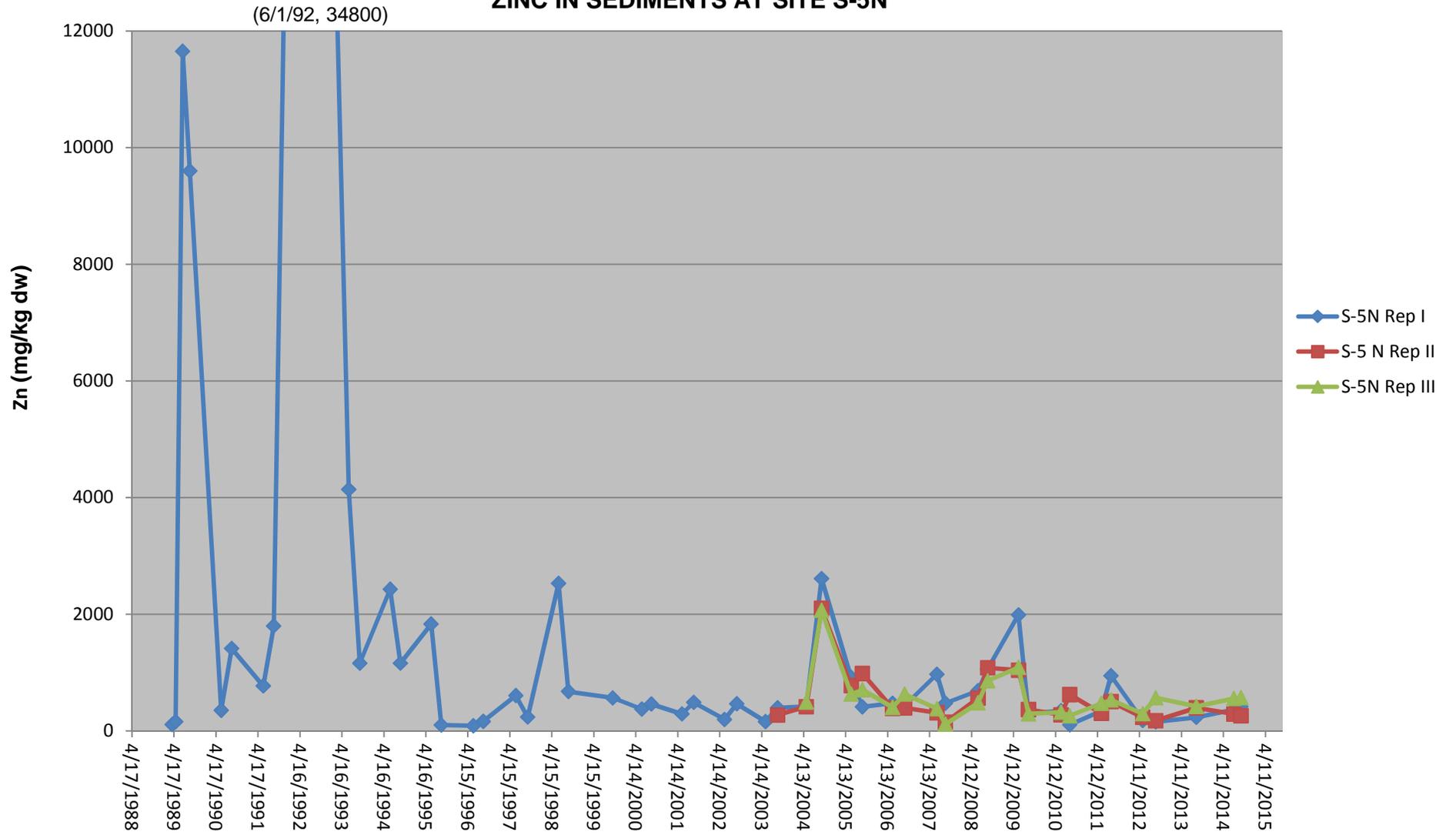


FIGURE 3-21

CADMIUM IN SEDIMENTS AT SITE S-5S

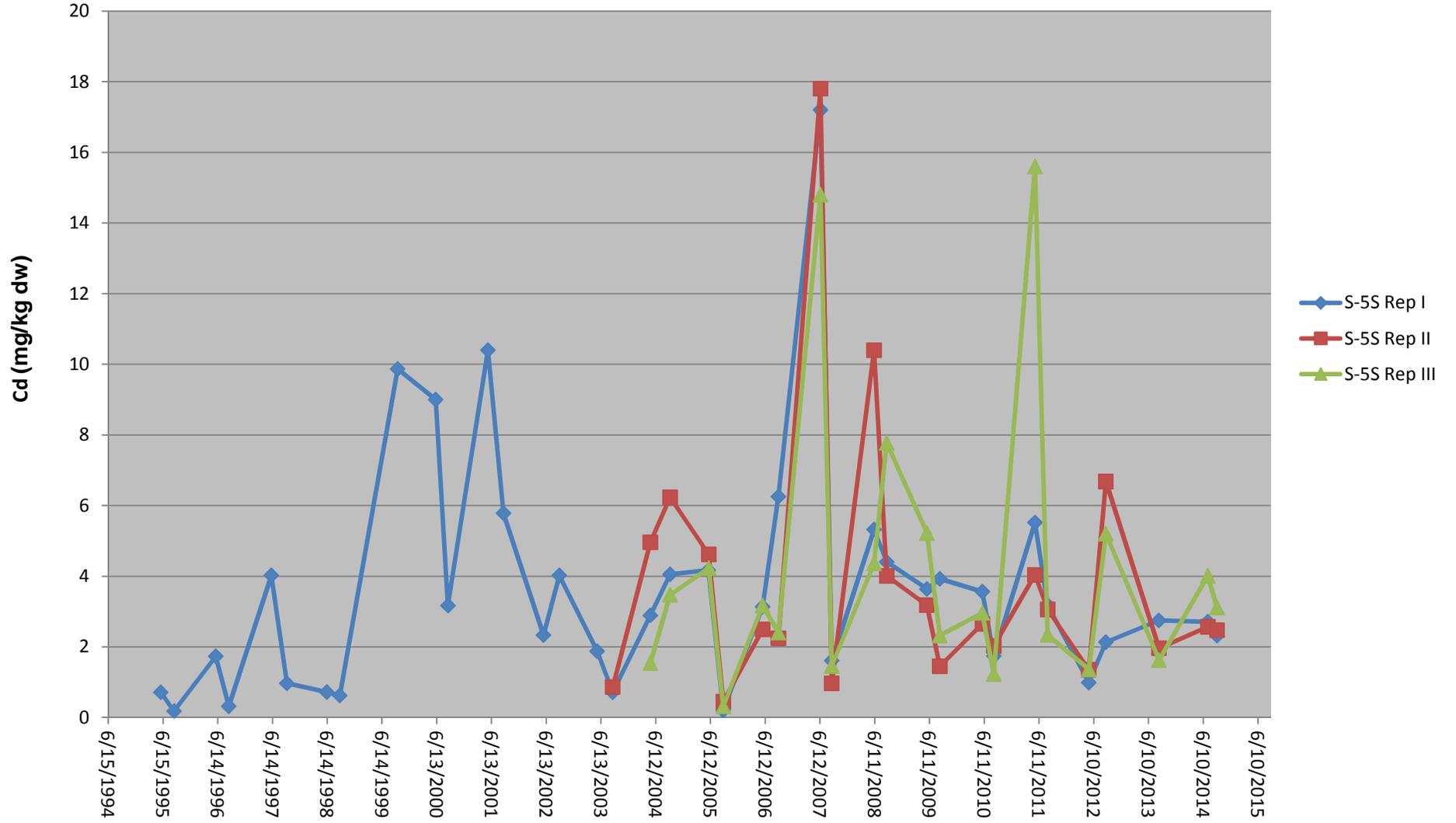


FIGURE 3-22

COPPER IN SEDIMENTS AT SITE S-5S

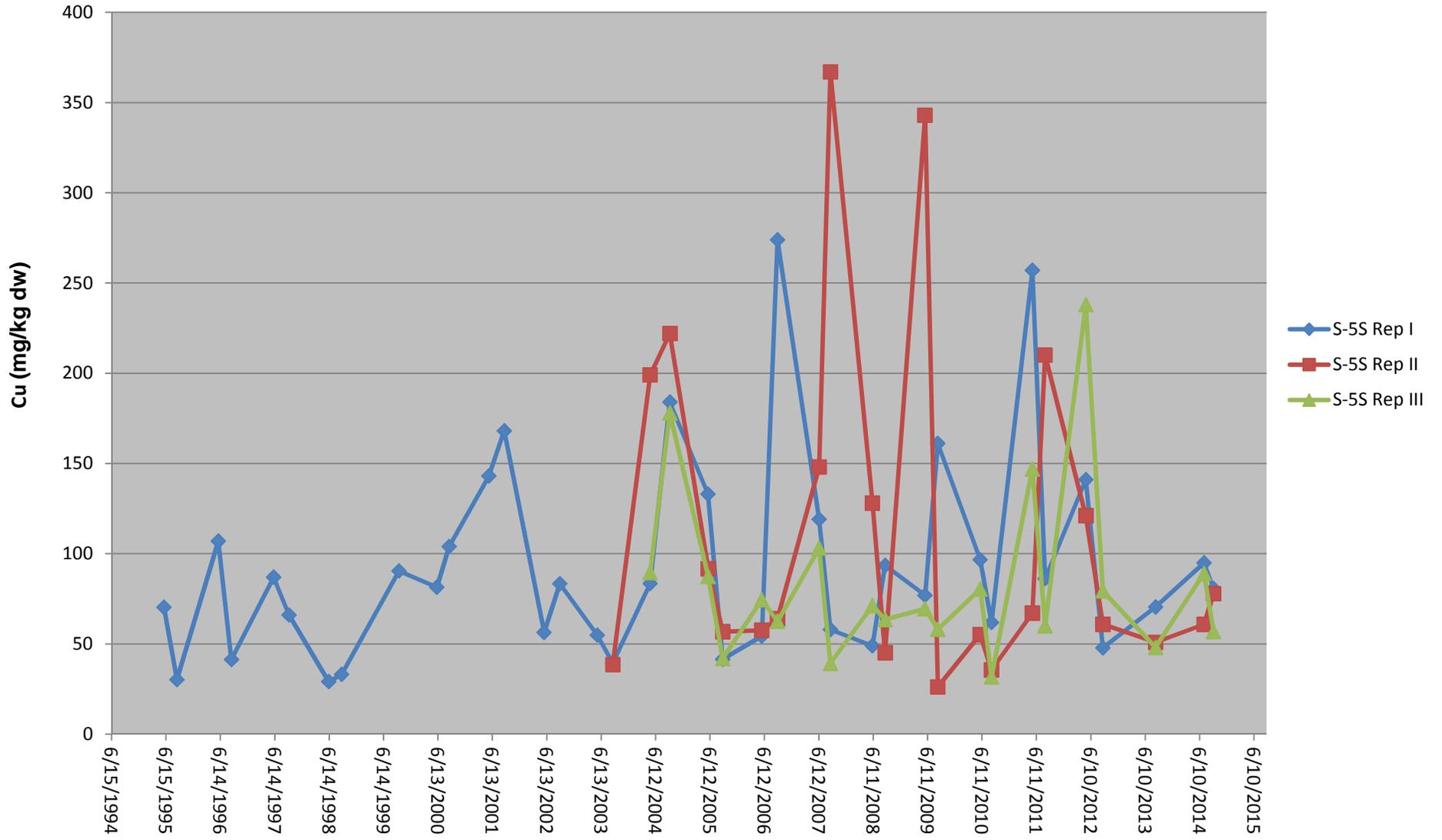


FIGURE 3-23

LEAD IN SEDIMENTS AT SITE S-5S

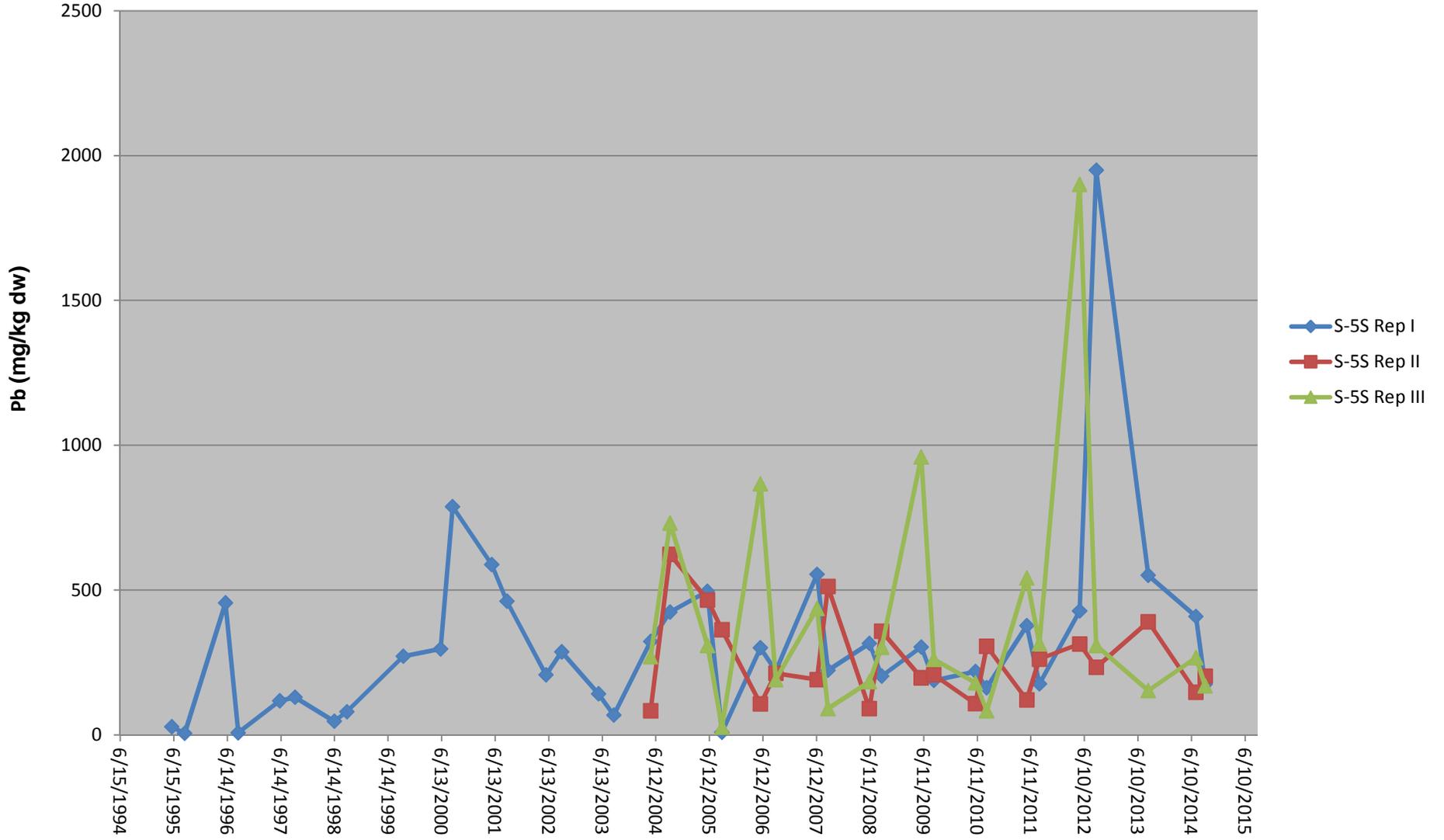


FIGURE 3-24

MERCURY IN SEDIMENTS AT SITE S-5S

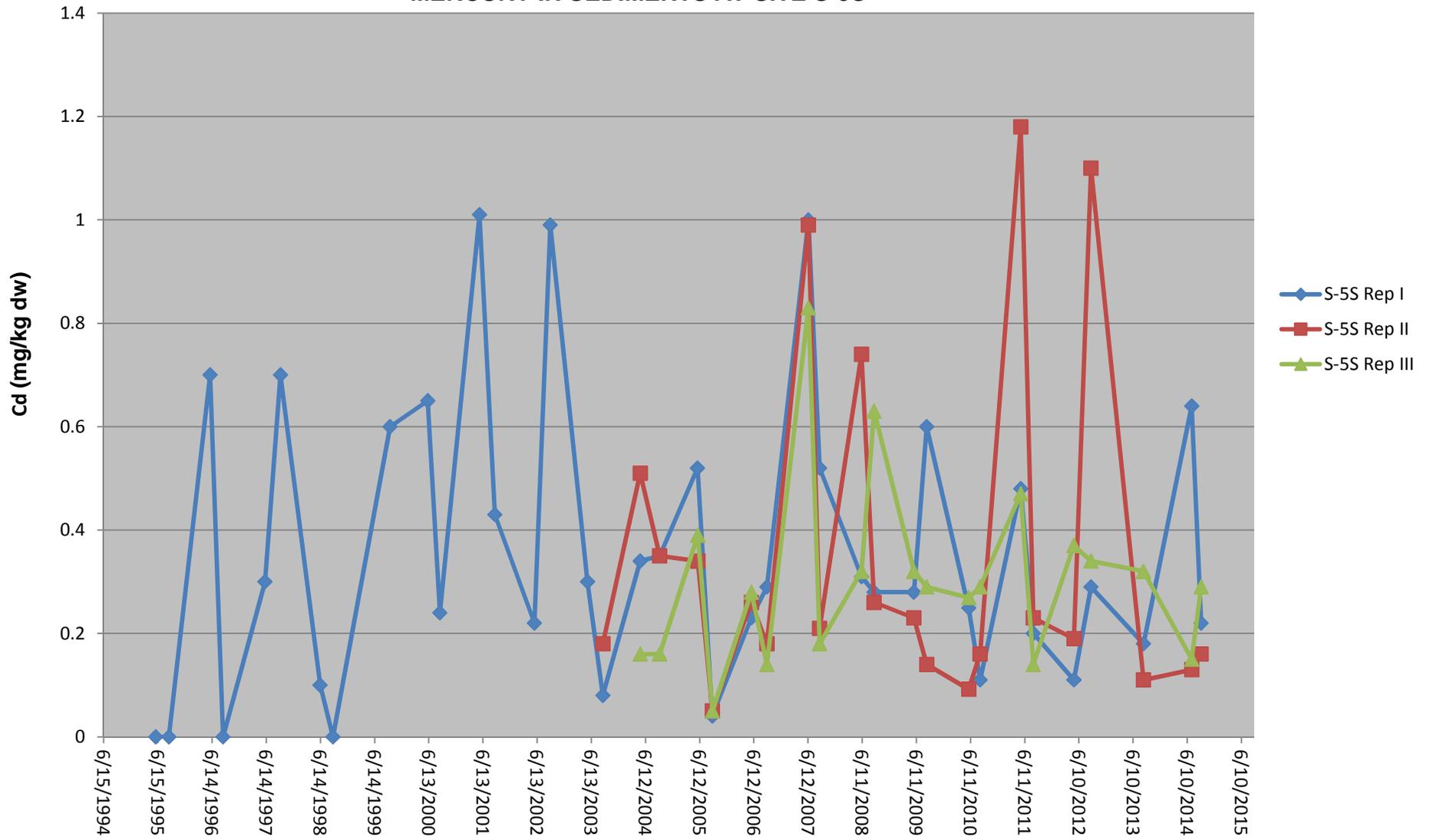


FIGURE 3-25

ZINC IN SEDIMENTS AT SITE S-5S

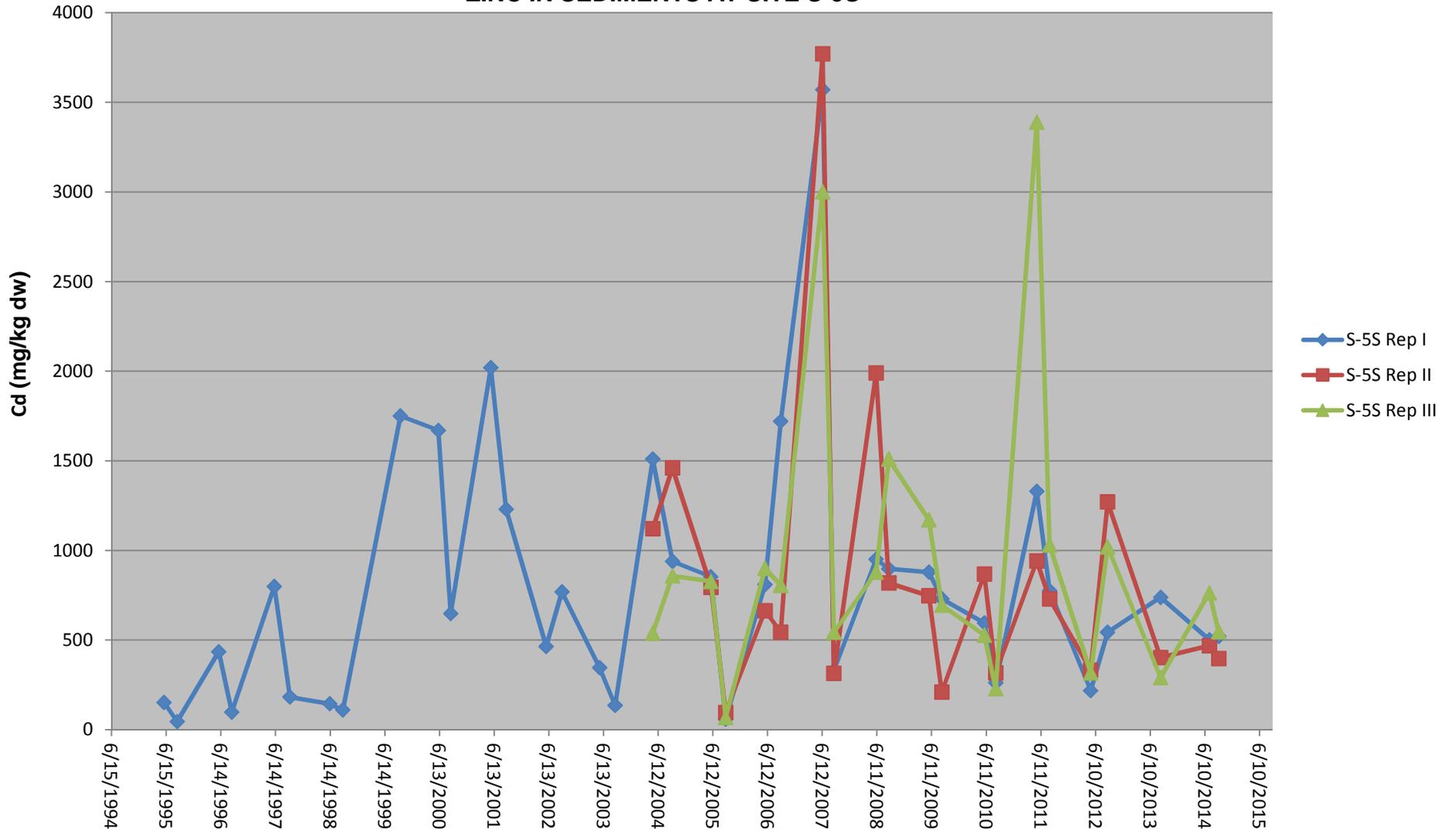


FIGURE 4-1

CADMIUM IN MUSSELS STN-1, STN-2, STN-3, ESL

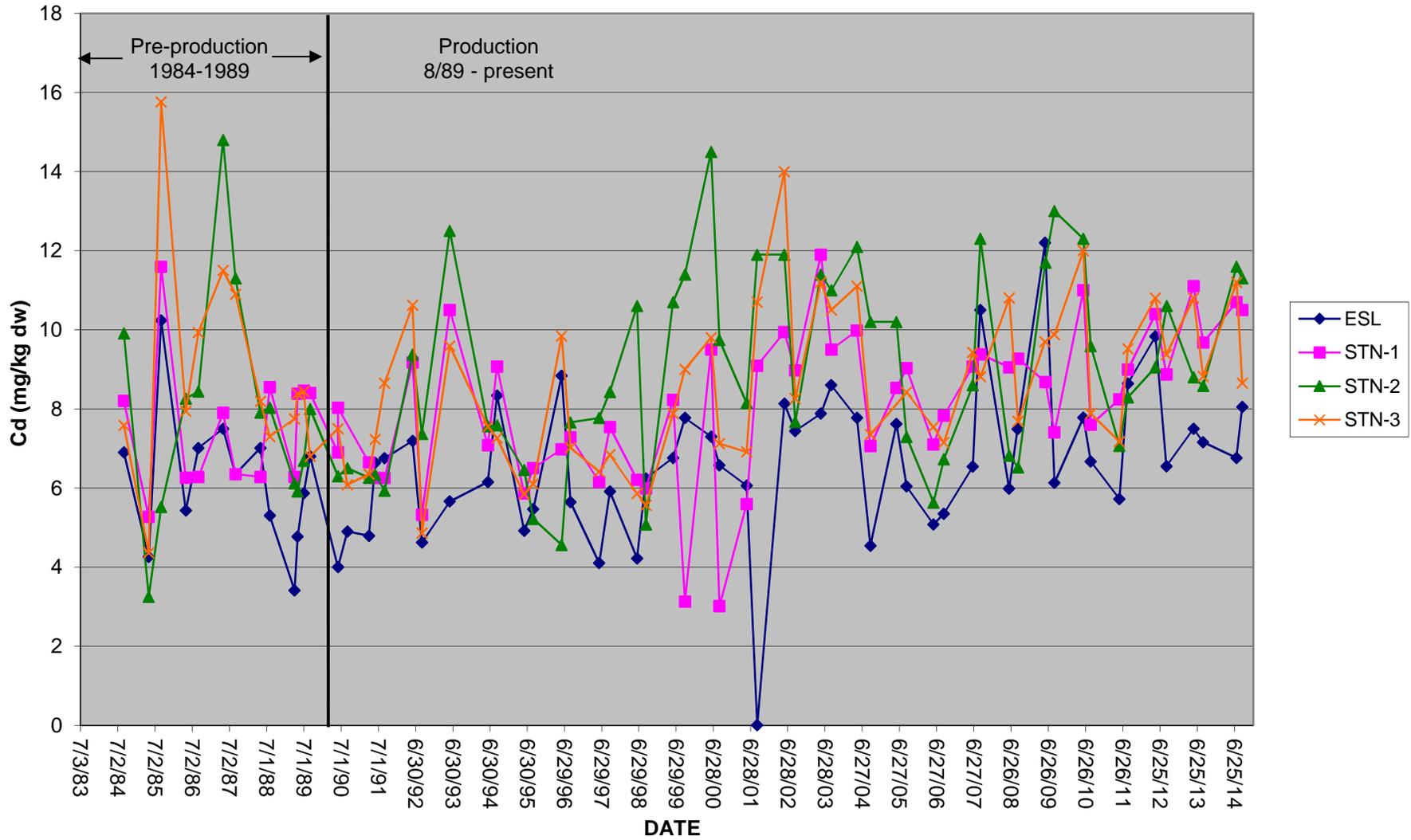


FIGURE 4-2

COPPER IN MUSSELS STN-1, STN-2, STN-3, ESL

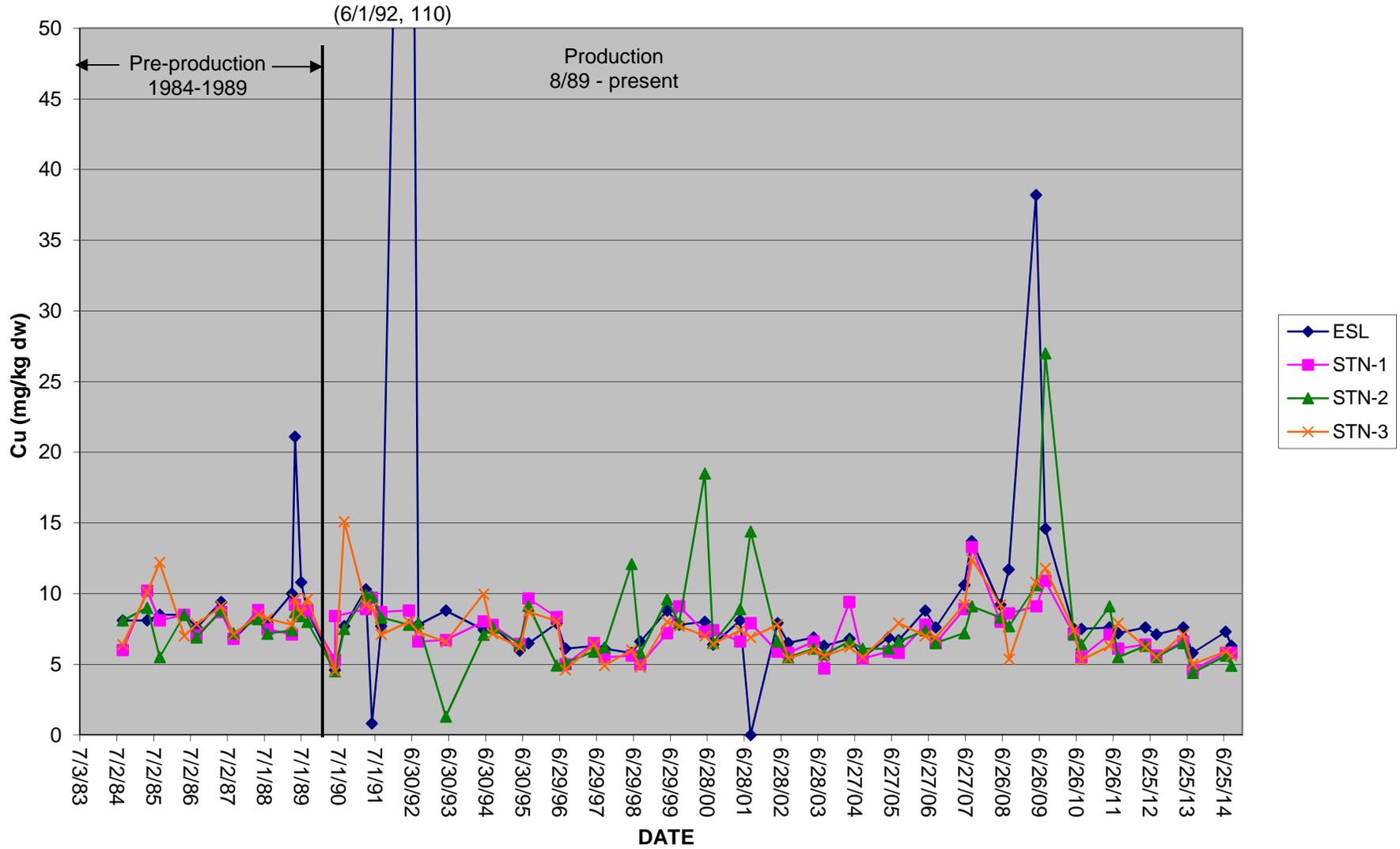


FIGURE 4-3

MERCURY IN MUSSELS STN-1, STN-2, STN-3, ESL

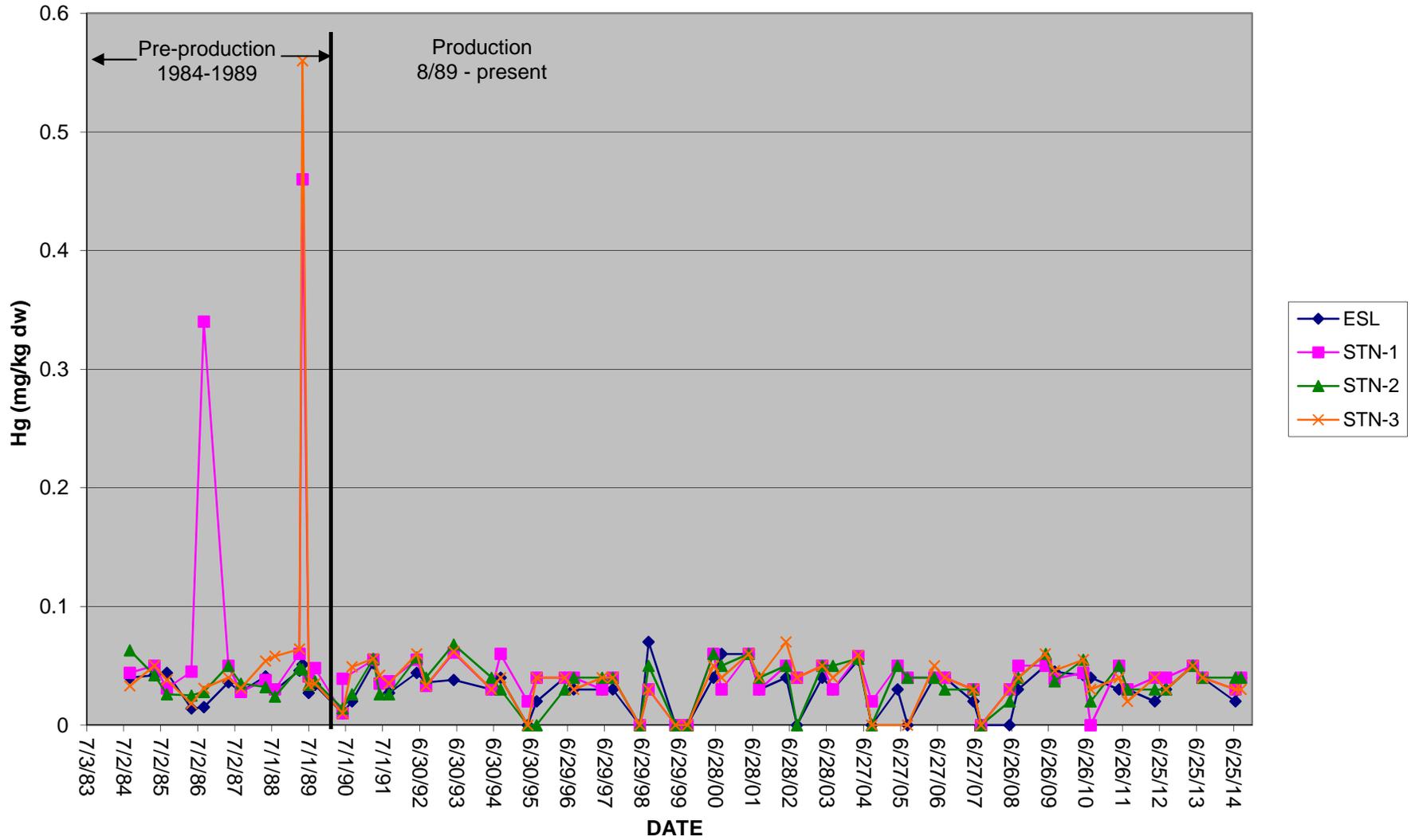


FIGURE 4-4

LEAD IN MUSSELS STN-1, STN-2, STN-3, ESL

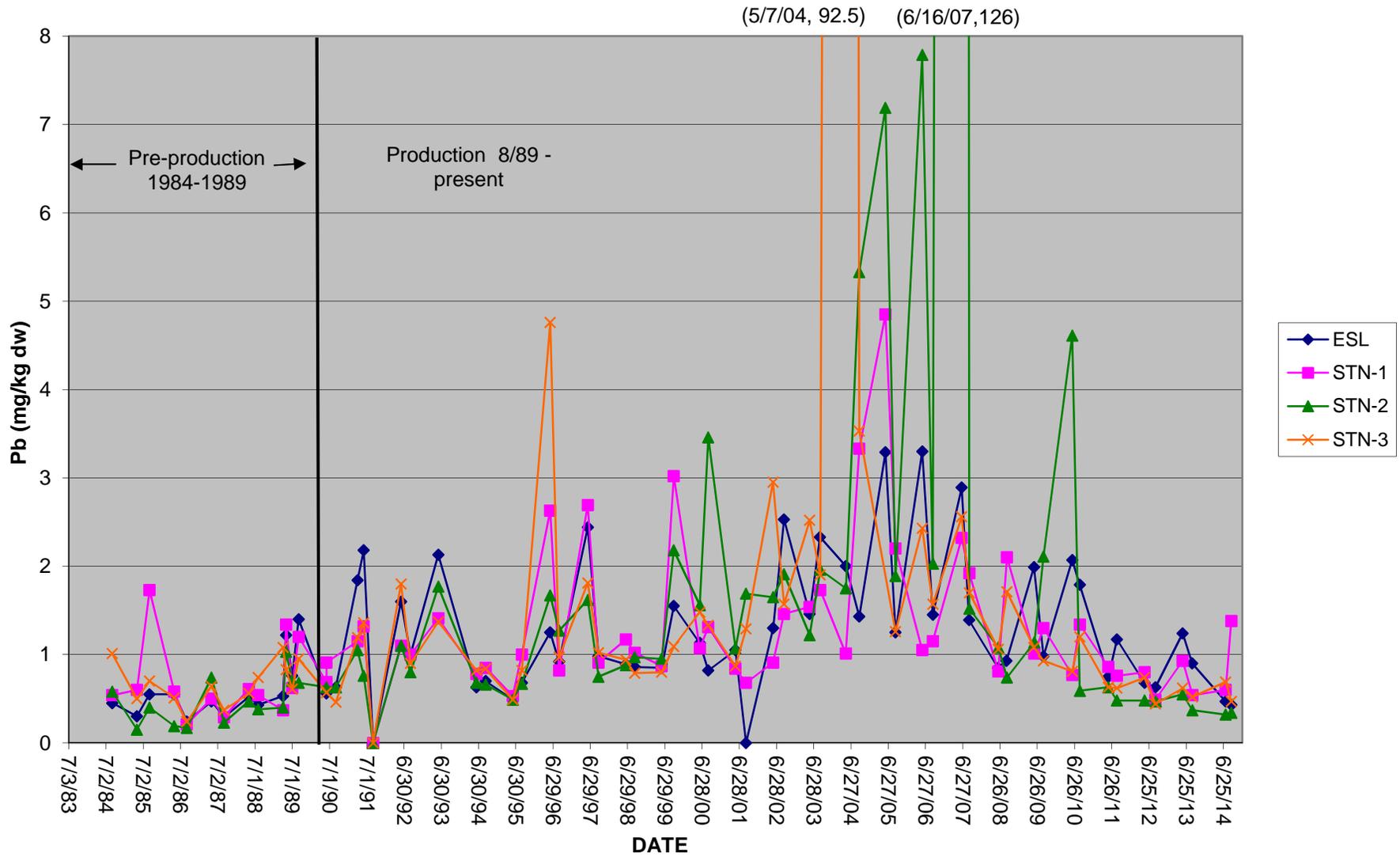


FIGURE 4-5

ZINC IN MUSSELS STN-1, STN-2, STN-3, ESL

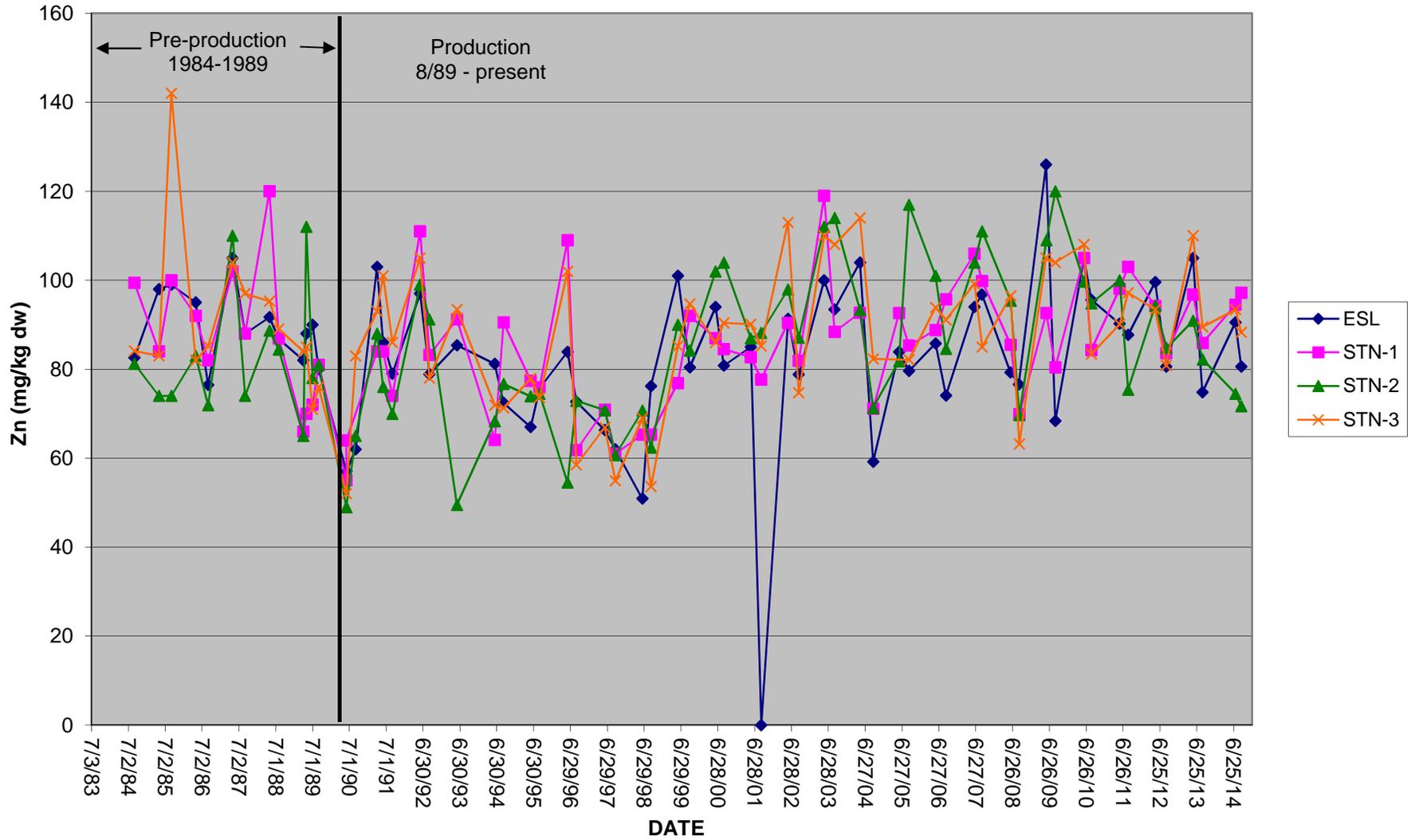


FIGURE 4-6

CADMIUM IN NEPHTYS AT SITE S-1

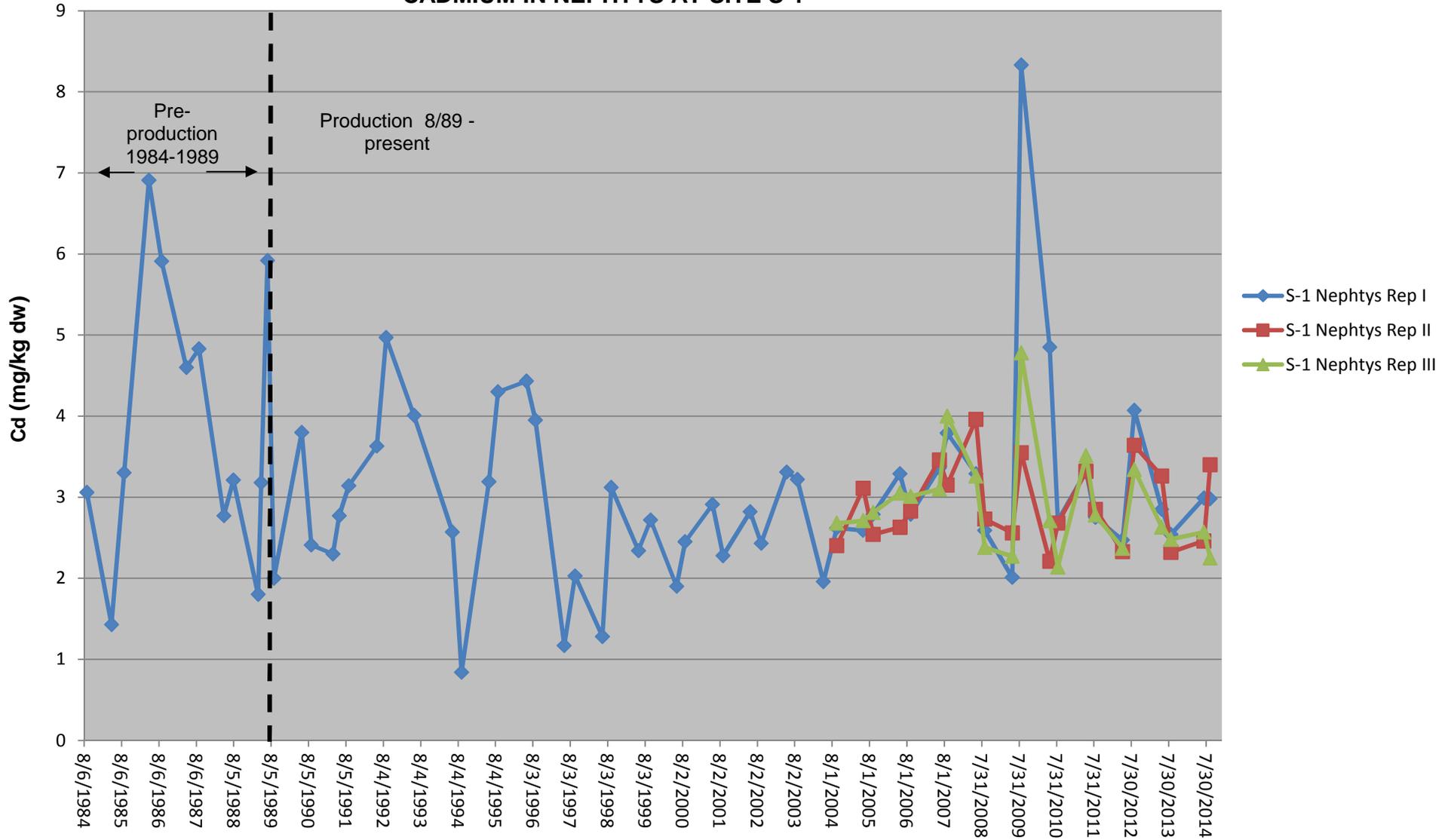


FIGURE 4-7

COPPER IN NEPHTYS AT SITE S-1

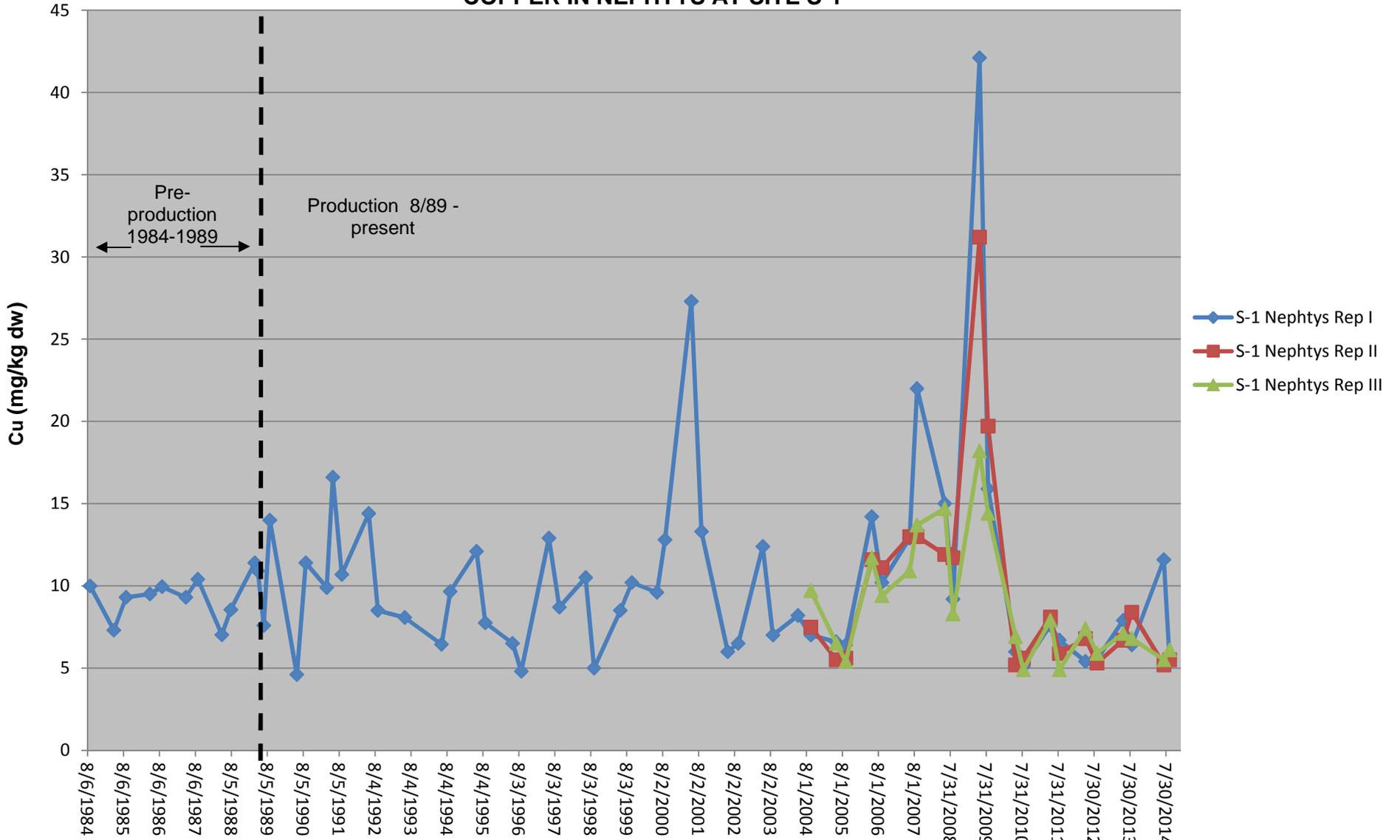


FIGURE 4-8

LEAD IN NEPHTYS AT SITE S-1

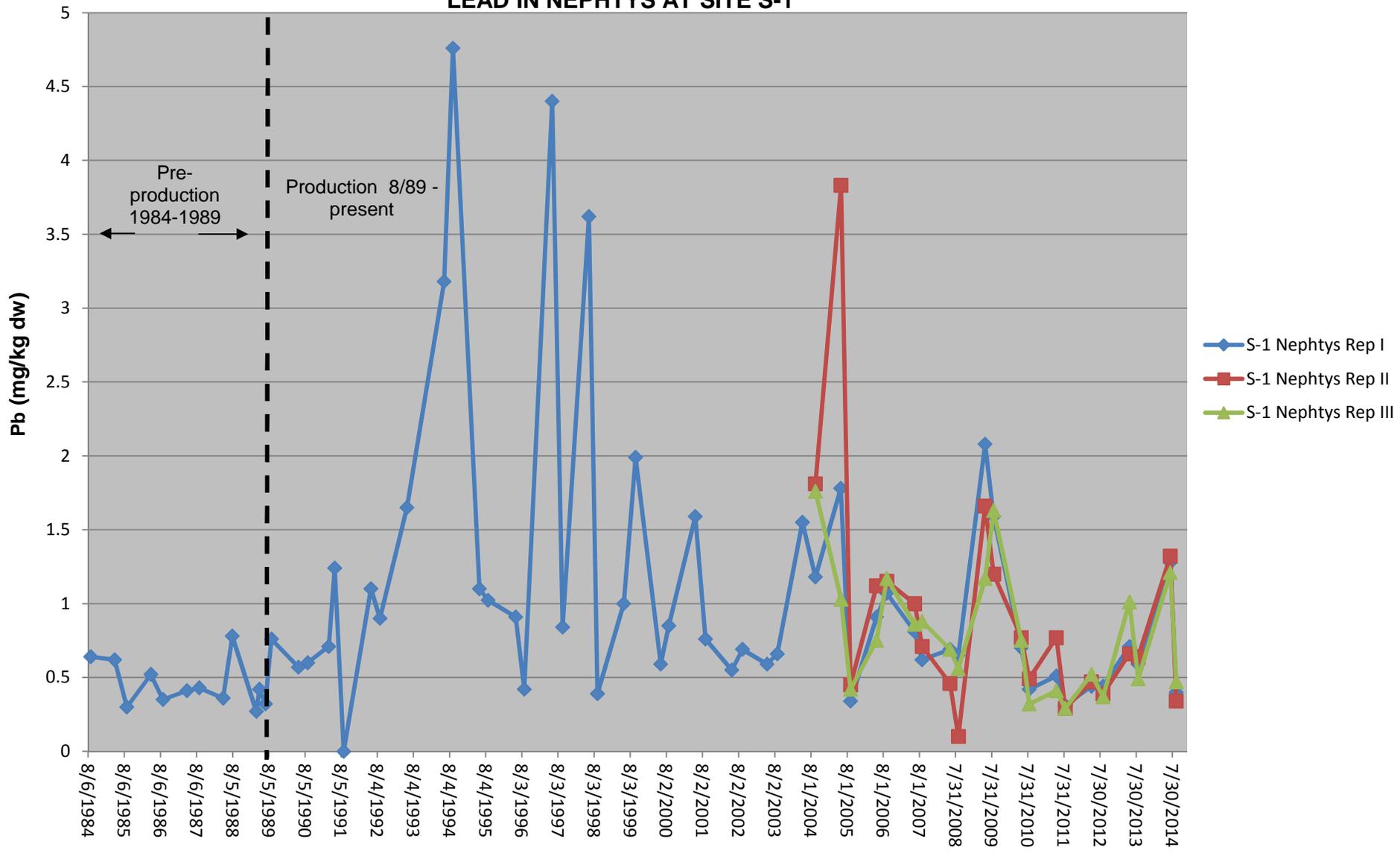


FIGURE 4-9

MERCURY IN NEPHTYS AT SITE S-1

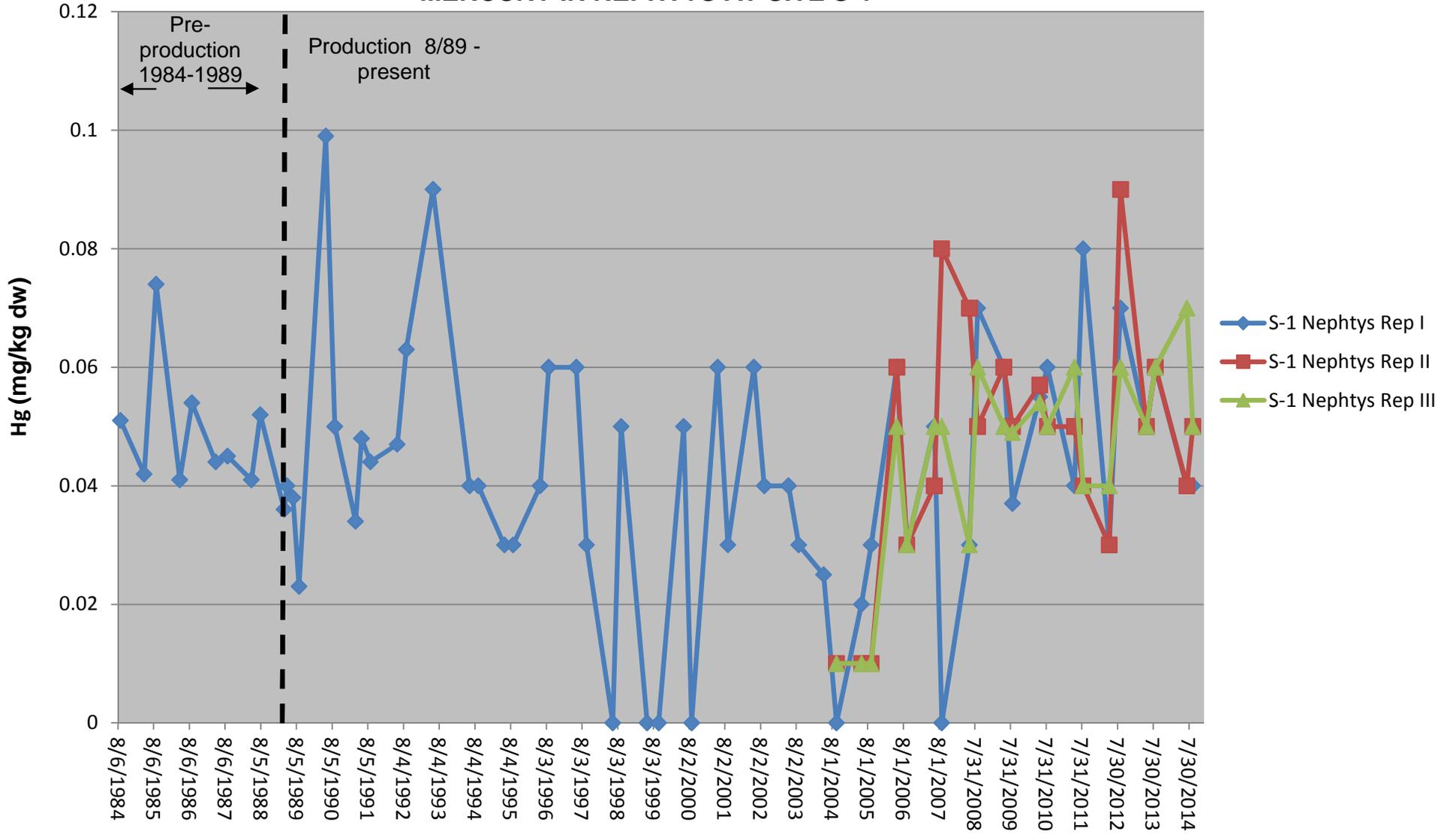


FIGURE 4-10

ZINC IN NEPHTYS AT SITE S-1

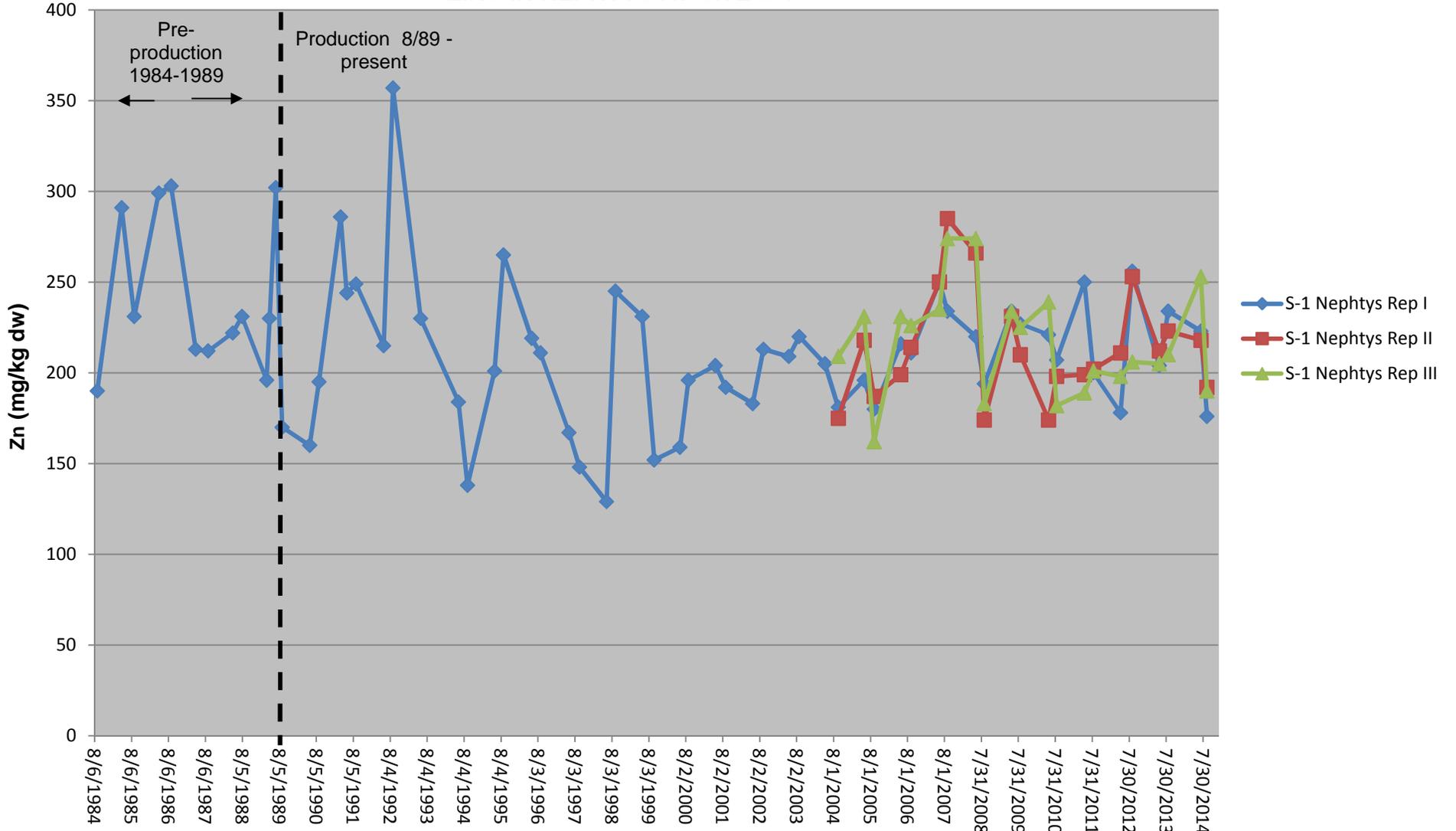


FIGURE 4-11

CADMIUM IN NEPHTYS AT SITE S-2

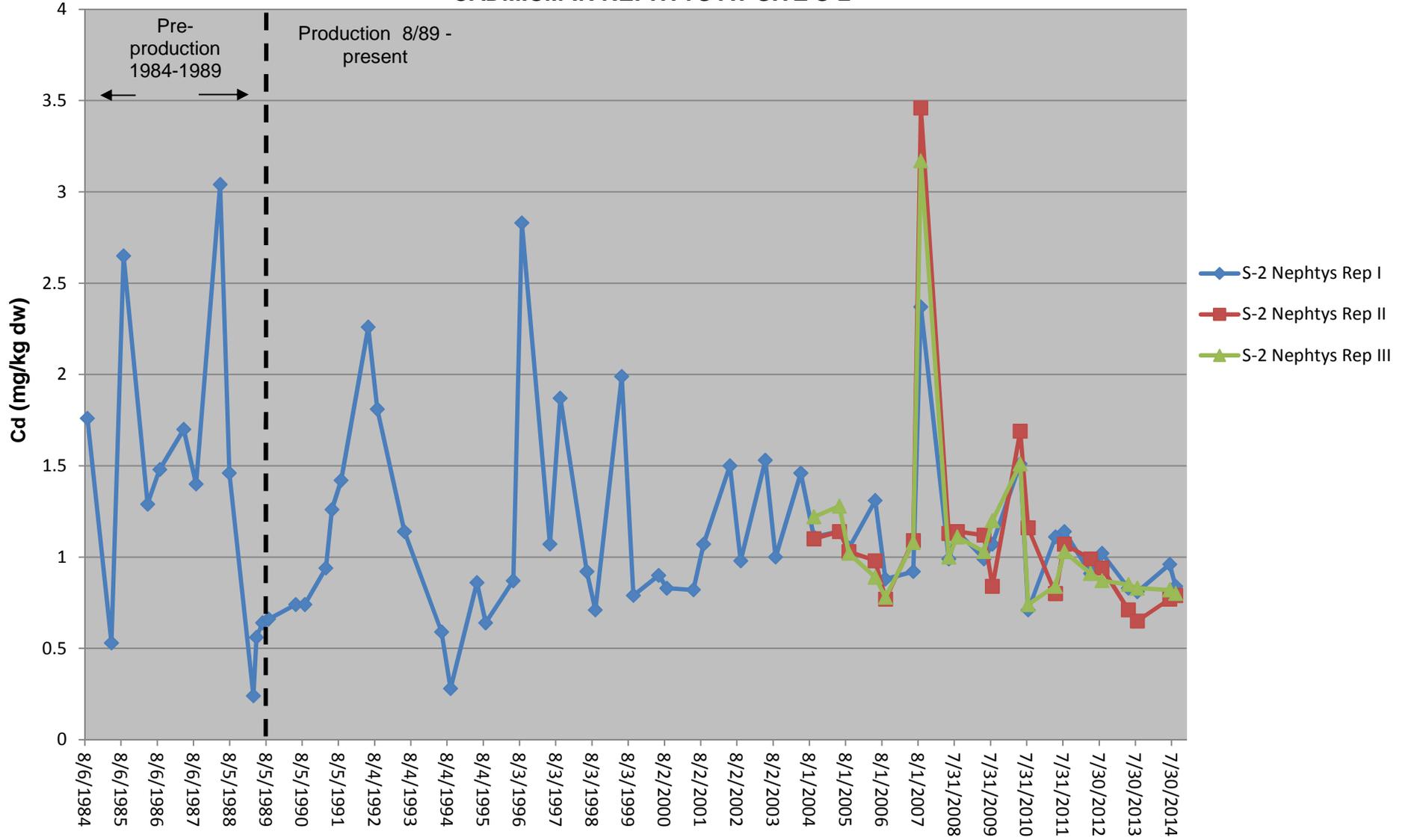


FIGURE 4-12

COPPER IN NEPHTYS AT SITE S-2

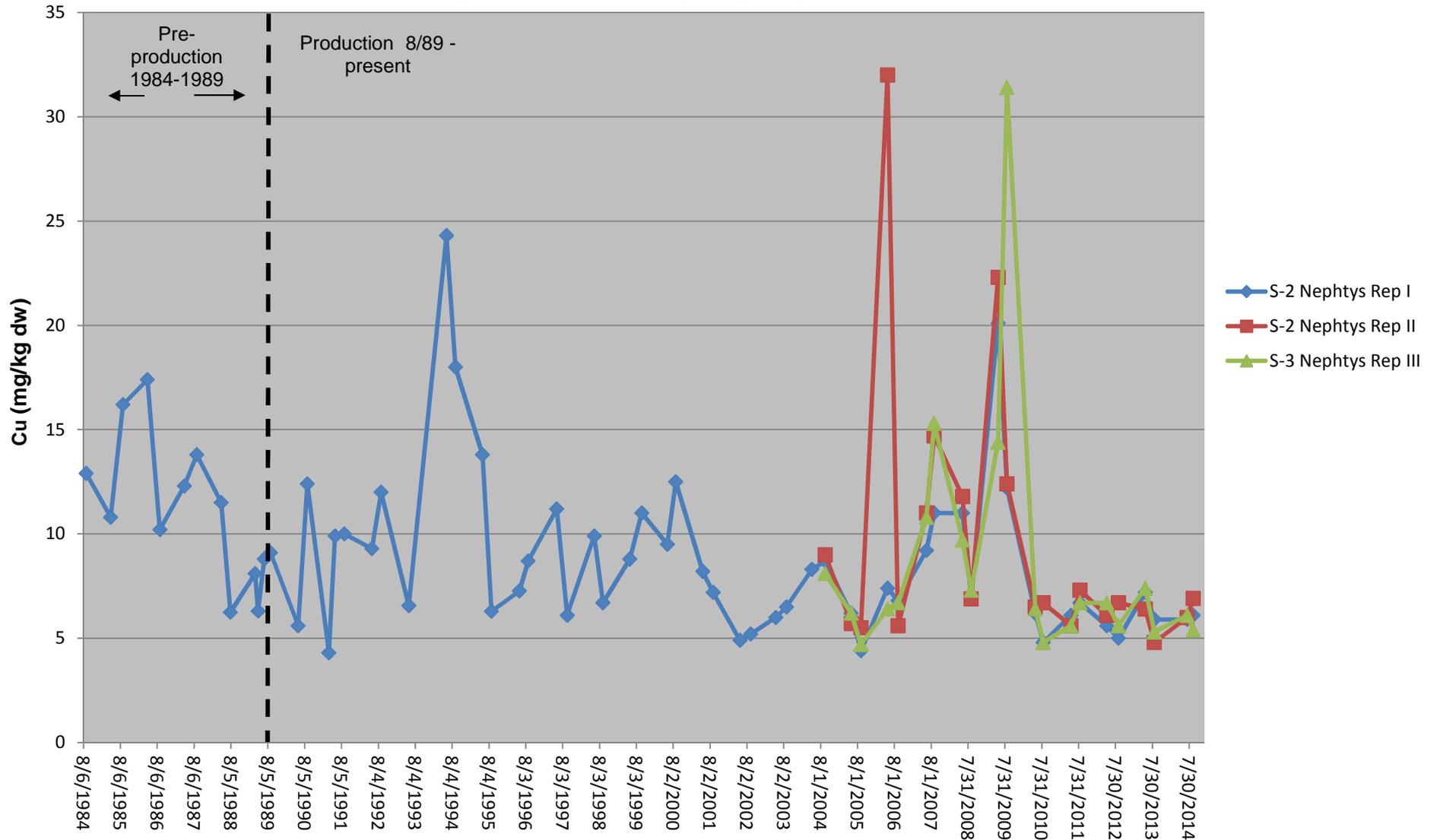


FIGURE 4-13

LEAD IN NEPHTYS AT SITE S-2

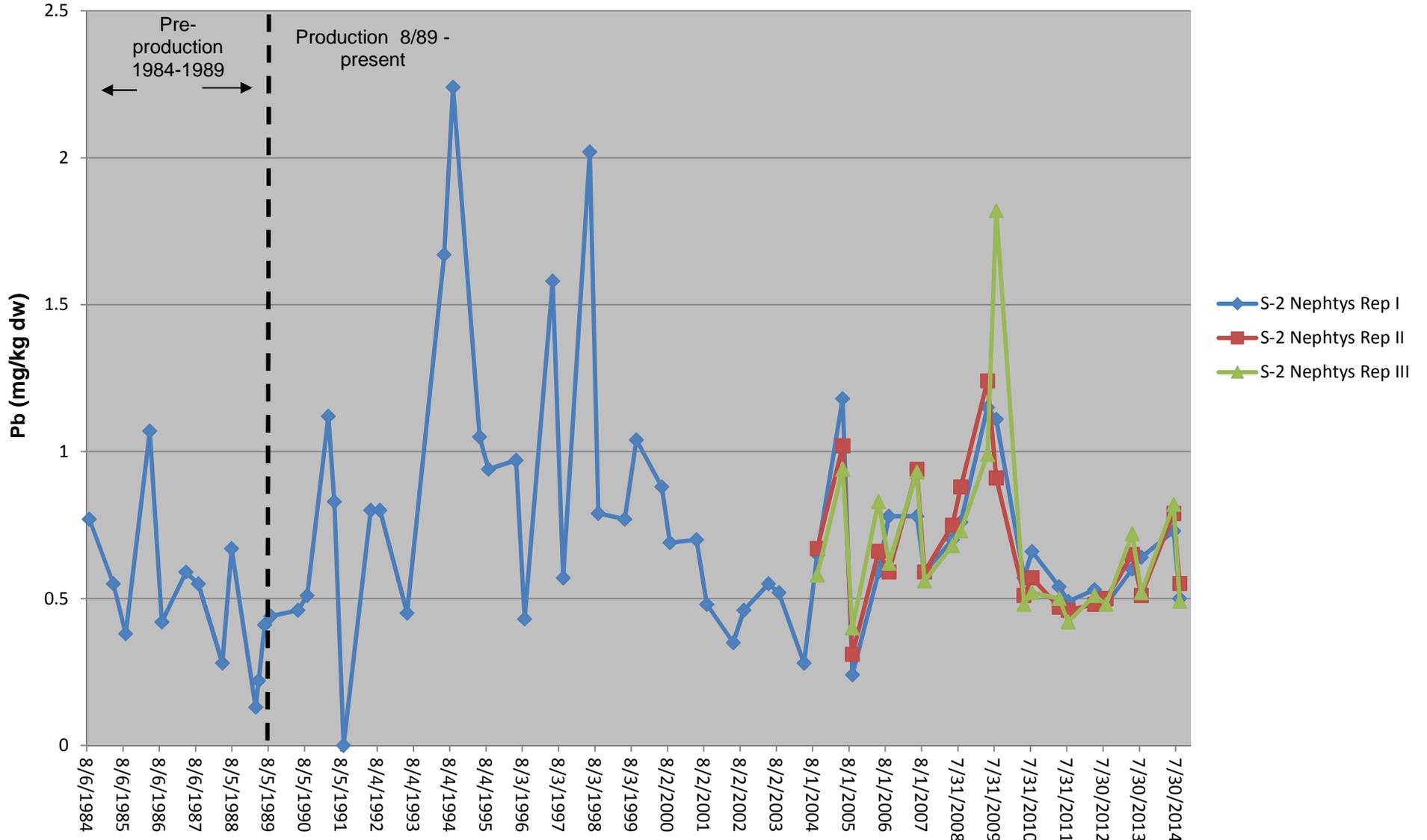


FIGURE 4-14

MERCURY IN NEPHTYS AT SITE S-2

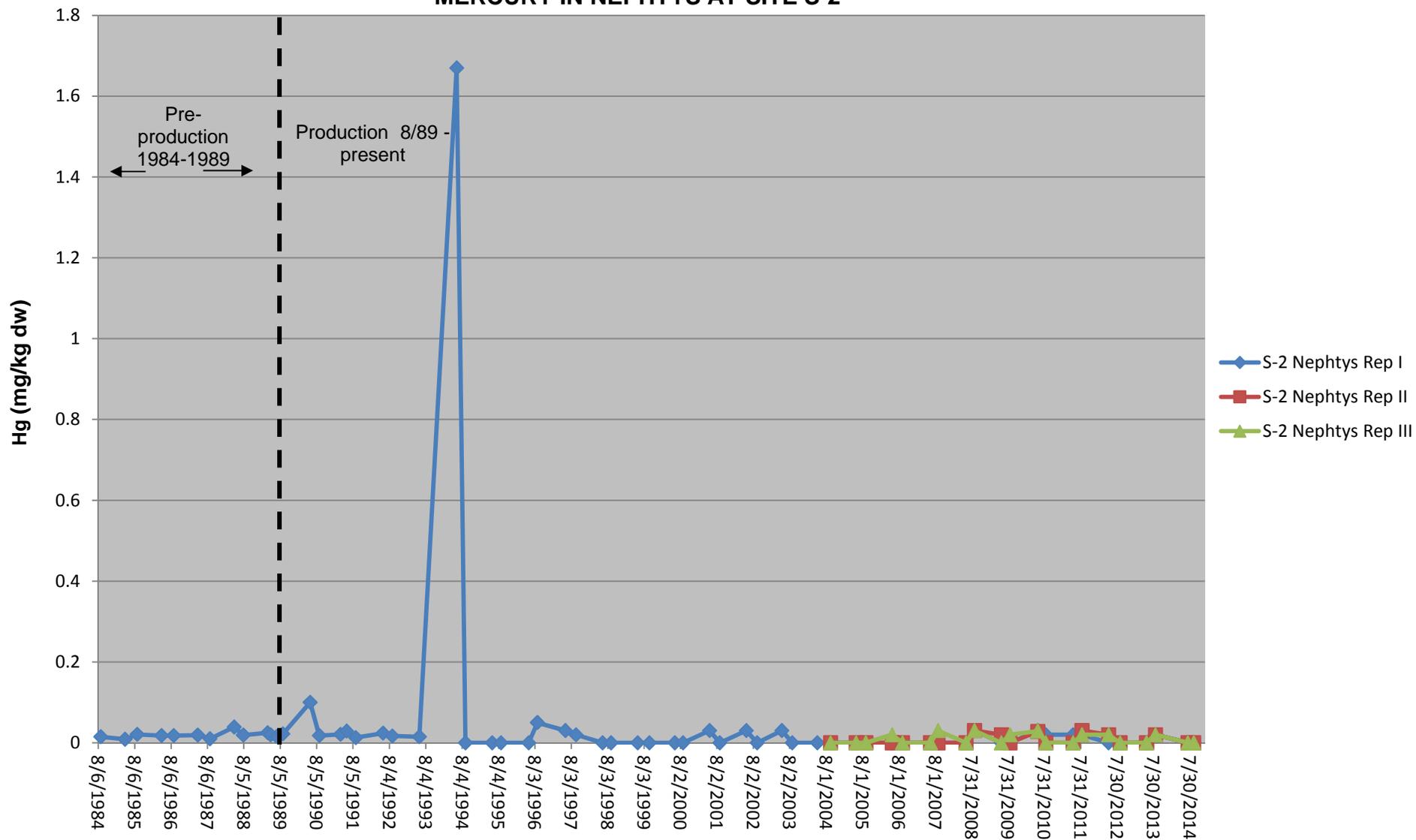


FIGURE 4-15

ZINC IN NEPHTYS AT SITE S-2

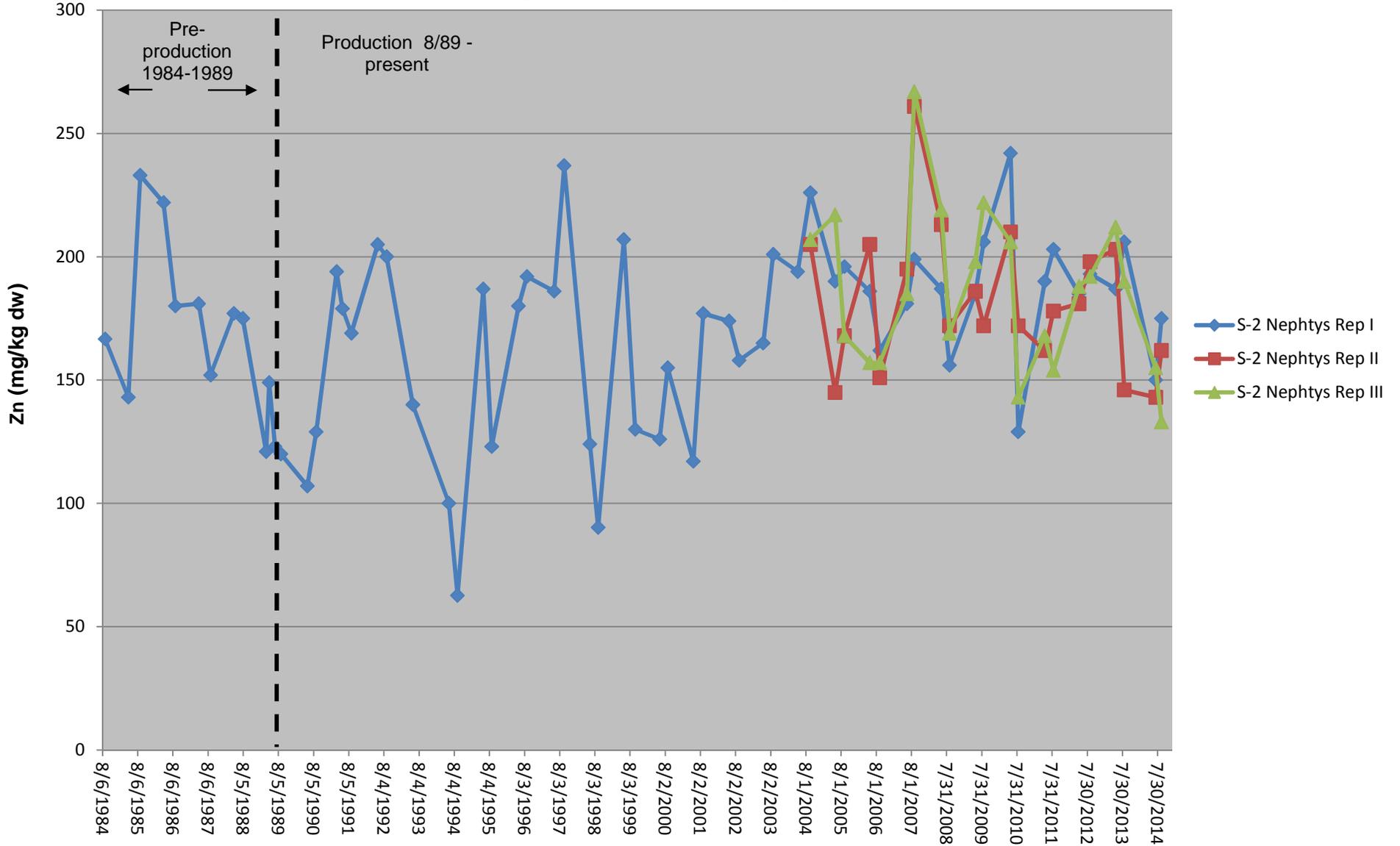


FIGURE 4-16

CADMIUM IN NEPHTYS AT SITE S-4

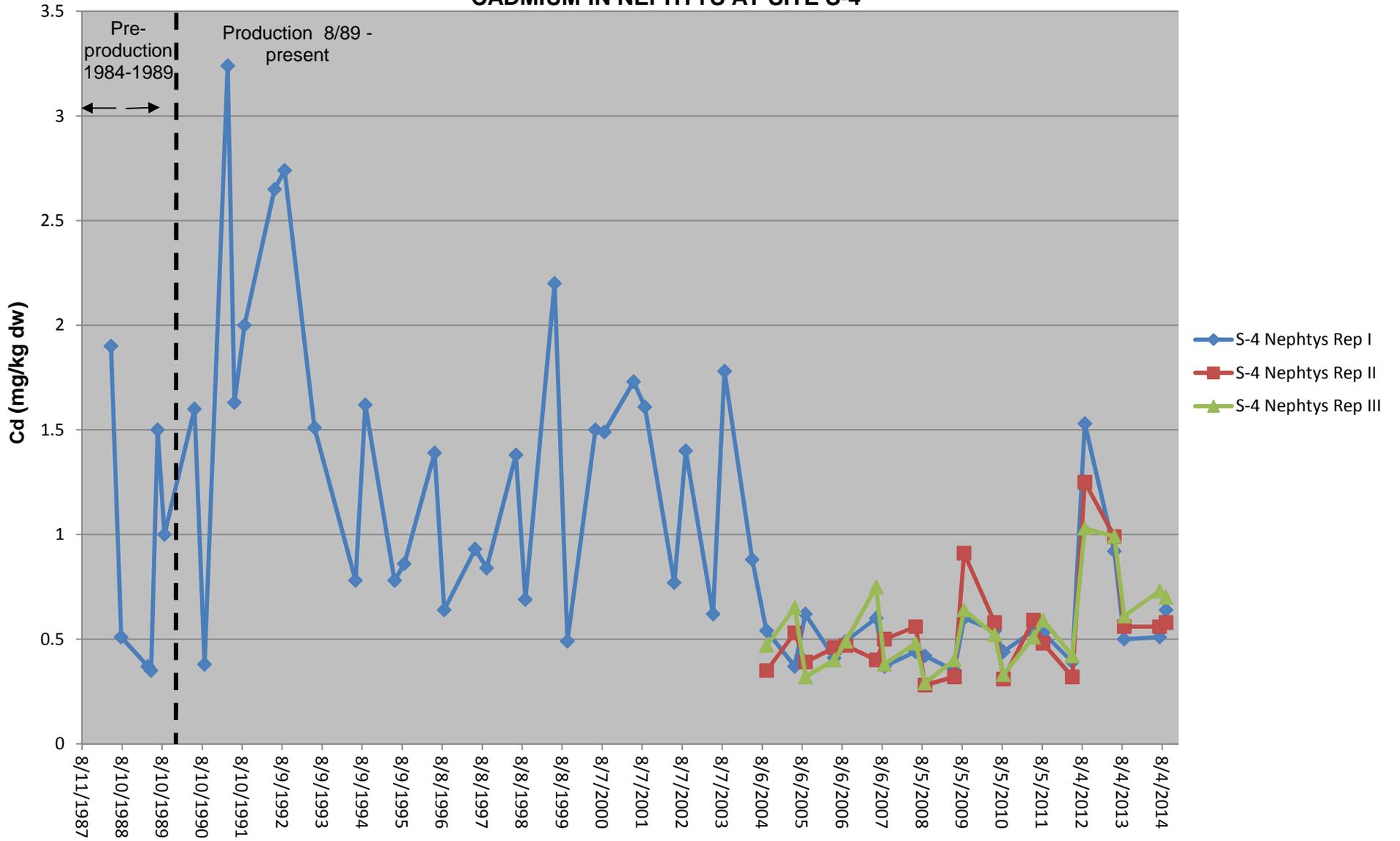


FIGURE 4-17

COPPER IN NEPHTYS AT SITE S-4

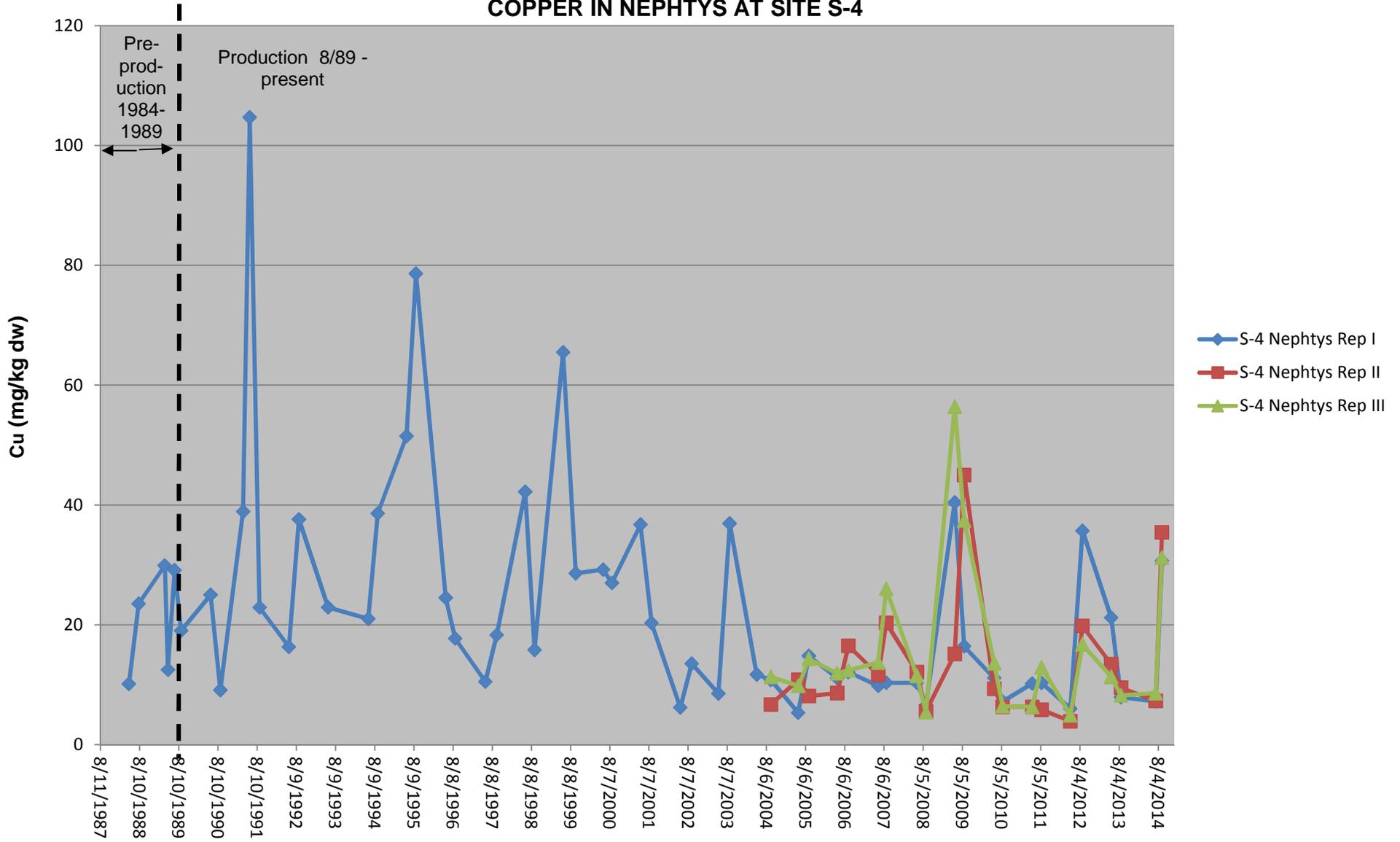


FIGURE 4-18

LEAD IN NEPHTYS AT SITE S-4

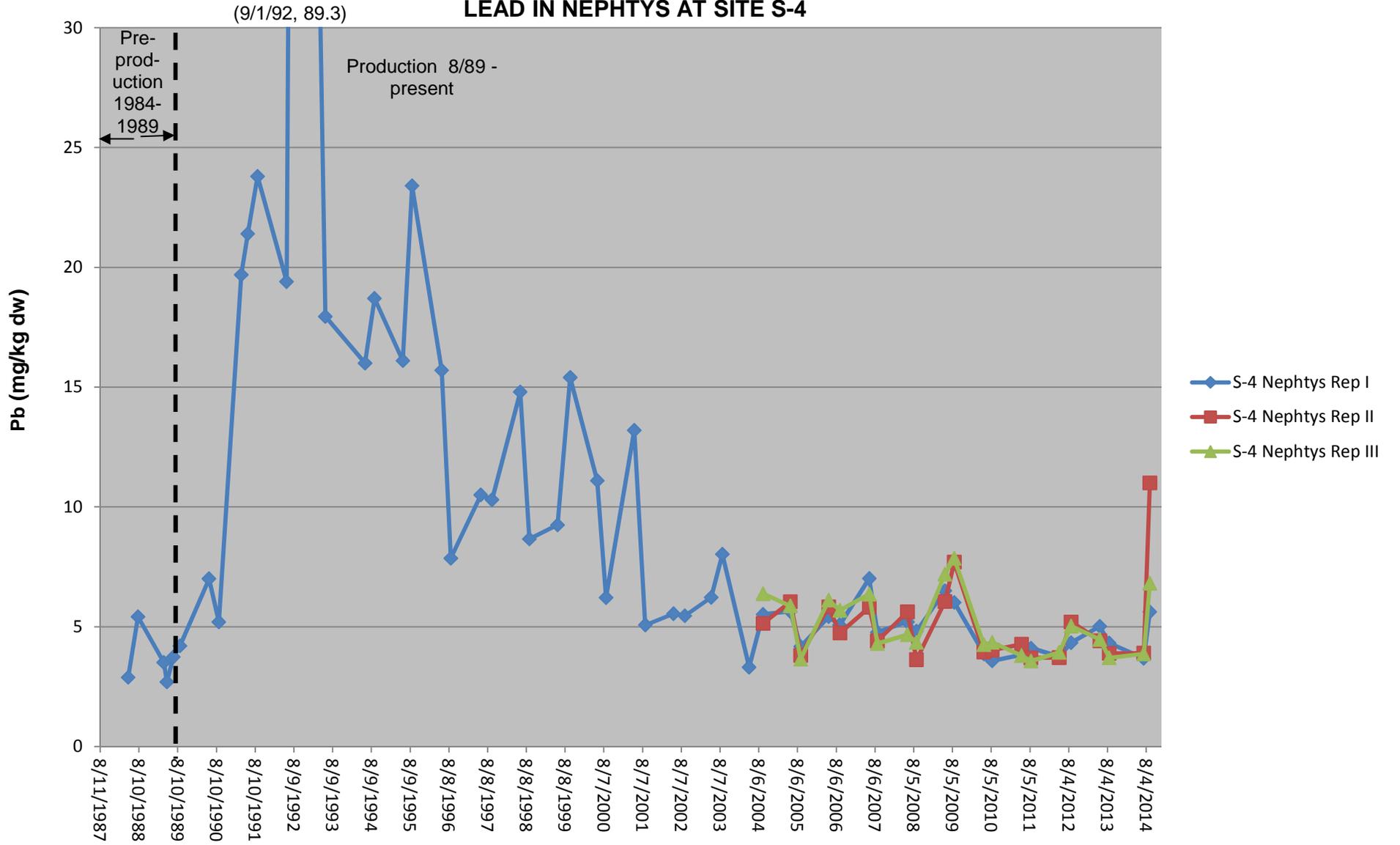


FIGURE 4-19

MERCURY IN NEPHTYS AT SITE S-4

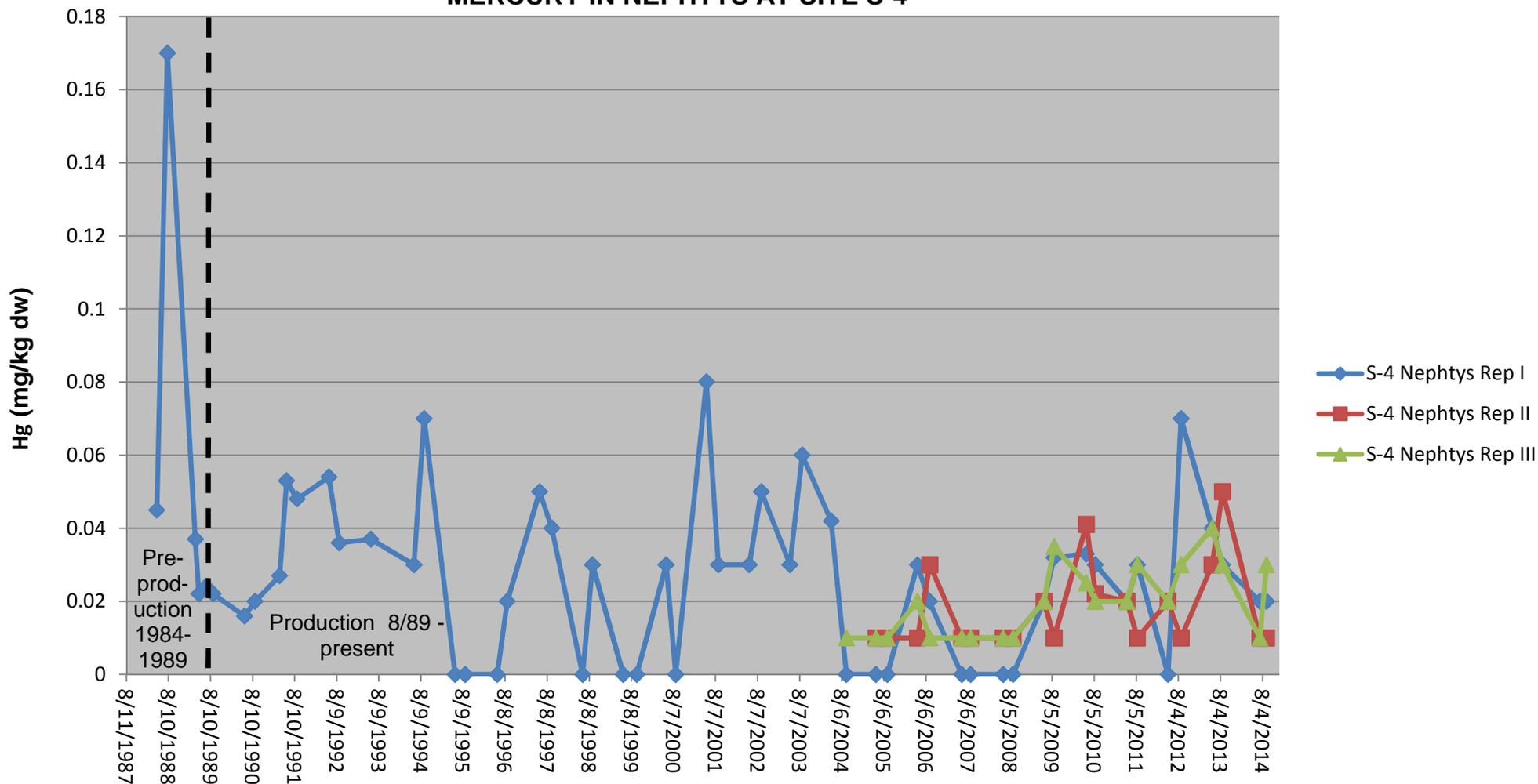


FIGURE 4-20

ZINC IN NEPHTYS AT SITE S-4

