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Remedial Investigation Addendum

Nelson Tunnel/Commodore Waste Rock Superfund Site

Near Creede, Mineral County, Colorado

April 2019

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List of Acronyms

ABA	Acid Based Accounting
ABS	Activity-Based Sampling
AP	Acid Potential
ATV	All-Terrain Vehicle
bgs	Below Ground Surface
°C	Degrees Celsius
$CaCO_3$	Calcium Carbonate
CDPHE	Colorado Department of Public Health and Environment
cfs	Cubic Feet per Second
COC	Contaminants of Concern
CV	Coefficient of Variation
CWR	Commodore Waste Rock
DRMS	Colorado Division of Reclamation, Mining and Safety
EPA	United States Environmental Protection Agency
ESAT	EPA Region 8 Environmental Services Assistance Team
ft	feet
gpm	Gallons per Minute
EC_{50}	Half Maximal Effective Concentration
HHRA	Human Health Risk Assessment
HI	Hazard Index
kg	Kilograms
lbs	Pounds
MMI	Multi-Metric Index
NNP	Net Neutralizing Potential
NP	Neutralization Potential
NPR	Neutralizing Potential Ratio
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
Site	Nelson Tunnel/ Commodore Waste Rock National Priority List Site
STD DEV	Standard Deviation
TSP	Total Suspended Particulates
TVS	Table Value Standard
µg/dL	Micrograms per Deciliter
µg/L	Micrograms per Liter
µg/m3	Micrograms per Cubic Meter
USGS	United States Geological Survey
WCRC	Willow Creek Reclamation Committee
WQCC	CDPHE Water Quality Control Commission
WQS	Water Quality Standard

1 Introduction

1.1 Purpose

The purpose of this Remedial Investigation (RI) Addendum is to supplement the RI Report for the Nelson Tunnel/ Commodore Waste Rock National Priority List Site (Site), which was finalized in November 2011. Since the completion of the RI Report, a significant amount of water quality data has been collected from Nelson Tunnel and the water quality monitoring stations established for West Willow Creek, Willow Creek, and the Rio Grande. In addition, multiple studies and other data collection events relevant to Nelson Tunnel RI have occurred. This RI Addendum incorporates new information into the RI and updates RI conclusions.

Information included in the RI is generally not repeated in this RI Addendum with the exception of site location information and RI conclusions. Site location information is repeated to orient the reader of this document. RI conclusions are restated to clarify how information collected since the completion of the RI enhances understanding of the nature and extent of contaminants and Site risks.

This RI Addendum is not a stand-alone RI Report. Refer to the Nelson Tunnel RI Report to understand site context, previous data, studies, and evaluations.

1.2 Organization

This addendum is organized to match the RI Report:

Section 1.0 – Introduction – This section describes the purpose of the RI addendum and summarizes prior work and Site history and setting.

Section 2.0 – Site Characteristics – Since completion of the RI, several studies have been completed that enhanced the understanding of the Nelson Tunnel hydrology. Summaries of these studies are provided in this section.

Section 3.0 – Nature and Extent of Contamination – Additional data and studies completed are summarized in this section, updating the understanding of the nature and extent of contamination.

Section 4.0 – Baseline Risk Assessment – New air data presented in Section 3 was used to update the human health risks from All-Terrain Vehicle (ATV) riding on County Road 503.

Section 5.0 – Conclusions – General conclusions from the RI Report are restated and modifying statements are added where appropriate.

Section 6.0 – References – This section provides references for citations in the report.

Section 5 of the RI Report is *Contaminant Fate and Transport*. There were no changes to this section; therefore this section is not included in this report.

Figures are located following the report text.

1.3 Site Location

The Site is located in the San Juan Mountains in south-central Colorado and lies one mile north of the town of Creede in Mineral County, Colorado (Figure 1-1). It includes the abandoned Nelson Tunnel, which drains directly into West Willow Creek, and Commodore Waste Rock pile outside of the Nelson Tunnel portal (Figure 1-2).

A topographic map illustrating Nelson Tunnel alignment and location of major mines in the area is provided as Figure 1-3.

Approximately 360 gallons per minute (gpm) of water contaminated with heavy metals flows from the collapsed Nelson Tunnel portal into West Willow Creek. West Willow Creek drains into Willow Creek, which flows into the Rio Grande approximately four miles from the Site (Figure 1-1). Although the Site itself is limited to the Nelson Tunnel and Commodore Waste Rock pile, the study area addressed in this RI Report Addendum includes the following:

- West Willow Creek from above the Nelson Tunnel to the confluence with East Willow Creek
- The confluence of East and West Willow Creeks
- Willow Creek to its confluence with the Rio Grande
- Segment 4 of the Rio Grande
- Portions of County Road 503 both north and south of the Nelson Tunnel

2 Site Characteristics

2.1 Mine Working Hydrology

Operable unit 2 of the Site, generally includes the Nelson Tunnel which discharges acid mine drainage and the Commodore[1] 5 Level adit. The Commodore 5 Portal is located approximately 50 feet above and offset to the east of the Nelson Tunnel collapsed portal. Historic collapses in the Nelson Tunnel have resulted in the formation of three known Mine pools (Figure 2-1) including:

- The Nelson Tunnel Portal Pool extends from the portal to almost the Bachelor Shaft.
- The Lower Mine Pool extends from the Bachelor Blockage just upstream of the Bachelor Shaft to just past No Name Winze.
- The Upper Mine Pool appears to extend from the No Name Blockage to just beyond the Decline.

Since the completion of the RI, additional studies and investigations focused on the hydrology of the mine workings have been completed. The following provides a summary of each, presented chronologically.

2.1.1 Geological Model of the Nelson Tunnel Mine Drainage by Craig Byington

Studies by Craig Byington of Millennium Geosciences were conducted in 2011 and 2012 to construct a geological model of the Nelson Tunnel mine drainage. Mr. Byington is a geologist with extensive experience with the Creede Mining District. His studies included examining historical evidence of water flow in the mine district, review of recent water quality data, review of isotopic and tracer studies completed by Dr. Mark Williams at the University of Colorado Institute of Arctic and Alpine Research, as well as observations and the collection of geologic and geochemical data. Report conclusions regarding the source of waters from Nelson Tunnel are listed below, verbatim (Byington, 2012):

1. *Historically the vast majority of the water encountered in the Nelson tunnel and along all other workings following the Amethyst fault system came from the hanging wall within a short distance of the Amethyst fault. There is no record of any water coming from the OH or P veins nor was any evidence found during this study suggesting that significant amounts of water could penetrate the OH or P vein fractures.*

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[1] The Commodore 5 Level adit has been called several names in documents by EPA and others including: Commodore, Commodore 5, Commodore Level 5, and Commy. In reference to the Commodore 5, the terms “adit” and “tunnel” are used interchangeably in this and other Site documents.

2. *During advance of the various headings, they often encountered an initial high flow rate of water (reportedly as much as 5,000 to over 8,000 gpm). After this extreme flow rate "bled off", the water typically oozed up from below into the lowest level of workings (i.e. the Nelson tunnel). Very little water is currently entering into the Commodore 5 level from the overlying workings, and the Nelson tunnel was filled with water and ferrihydrite in all exposures so that the inflow of sub-level water could not be determined.*
3. *Although there certainly must be a very significant component of meteoric recharge in the Nelson tunnel waters, less than a few gallons per minute are currently accounted for elsewhere in the mine workings. This "missing" meteoric input could represent a significant amount of the Nelson tunnel total flow. If these waters could be captured and re-directed before they become contaminated then the size of the acid mine drainage outflow problem could be significantly reduced.*
4. *The model presented herein and supported by various lines of evidence envisions downward percolating meteoric recharge water through the Happy Thought workings, in particular the open and vertically continuous stopes, and into the hanging wall fracture system of the Amethyst fault.*
5. *In addition, deep upwelling Nelson tunnel recharge waters may be entering the Amethyst fault system via a 700-foot-long (230 meter) transtensional segment where the strike of the fault has inflected toward a more-likely-to-be "open" orientation. The fluids following this strike-related conduit may or may not make it to the Nelson tunnel level at that point and they may or may not have an ancient isotopic signature (most likely not, in the author's opinion).*
6. *Abundant anecdotal and circumstantial evidence presented herein documenting that a very significant inflow, well beyond what is coming from the Nelson portal currently, was encountered during some 1917-1920 exploration/development work. The input points for this flow occur in the north faces of the headings driven from the Commodore shaft, and more likely, from the north faces of the headings driven under the Happy Thought stopes from the Berkshire shaft. In the author's opinion water flowing from the north face of the heading driven at 200 (?) feet below the Nelson tunnel and advanced from the Berkshire shaft to well under the Happy Thought stopes will account for most of the water coming into the upper "mine pool".*
7. *No evidence was found to support the hypothesis that warm waters were encountered during the historical work anywhere in any of the mine workings nor is there evidence that warm springs existed historically along the surface trace of the Amethyst fault system prior to or during mining. This does not preclude the possibility of warm water up-flows, but it recognizes that there is no historical analog for the warm (19-21 °C) spring waters currently hypothesized to be entering the Nelson tunnel.*

The highest temperature measured is about 5° C above what, according to the author's calculations would be expected in a standard geothermal gradient. If geochemical or bio-geochemical exothermic reactions or an above-standard geothermal gradient (i.e. a still cooling volcanic field) are contributing to the temperature difference then there may not be any unexpectedly elevated temperatures.

8. *No analogue for juvenile magmatic waters which would be low in pH (i.e. 4.4 as per CDMG/WCRC, 2003) and exhibit a strong oxidizing character is known anywhere else in the San Juan Volcanic Field. Haba, et al (1985) calculated that the mineralizing waters at Creede were near a pH of 5.4 which "is nearly neutral pH at 250 °C". They calculate that the magmatic waters were very saline with a range of 4-12 percent by weight and had a total sulfur concentration of 0.018-0.30 molal. No evidence was found to support an upwelling "spring" with waters that geochemically resemble the initial waters envisioned by Haba, et al. The proposition that carbon and hydrogen isotopic analysis documents extremely old waters is questionable when the inorganic carbon input from the abundant carbonates in the district has not been factored into the equation.*
9. *There is hard evidence and anecdotal testimony that the water flow rate from the Nelson tunnel is seasonal or at least appears to approximately vacillate on an annual basis. After development mining on the Nelson tunnel and Commodore 5 level ceased early in the last century, the flow equilibrated somewhat to reportedly around the current Nelson tunnel output.*
10. *Evidence is presented herein that the internal reservoirs, both large and small, tend to normalize the flow rate downstream to the Nelson tunnel portal. Given connected reservoirs with water-flow constrictions (roof-fall dams) and ferrihydrite terraces throughout the Nelson tunnel, the greatest fluctuations in water level should occur where the water inflow is the greatest. Evidence was presented documenting that the greatest fluctuations in water level occurred near the Del Monte shaft, which is directly below the Last Chance workings, and the Berkshire shaft.*
11. *Evidence is presented that a very unusual water inflow was encountered by the Humphreys Tunnel Company in an area north of the Berkshire shaft during advance in the Nelson tunnel. Specifically an extraordinary flow was reportedly encountered where the Nelson tunnel conspicuously jogs into the footwall.*

2.1.2 Source Water Investigation Report of the Nelson Tunnel Mine Drainage by the University of Colorado

Hydrogeologic investigation of the sources and pathways of water contributing to acid mine drainage discharge were conducted by Colorado University's Institute of Arctic and

Alpine Research from 2009 through 2013. The investigation included review of historic information, collection of geochemical and physical data from samples of mine waters at various locations, as well as samples from surface waters, springs, domestic wells and precipitation collectors in the West Willow Creek watershed. Isotopic analyses for tritium, deuterium, stable water isotopes, and dissolved inorganic carbon were used to provide information on the source of mine pool water. Tritium isotopes indicated that the Berkshire, Nelson, and Bulldog mine water has an apparent age >50 years compared samples from watershed areas (streams, seeps, springs, domestic wells) that contained measurable tritium, suggesting that these waters are primarily modern in origin. Radiocarbon 14C isotopes from dissolved inorganic carbon indicate that Nelson Tunnel and Bulldog mine water has an apparent age > 5,000 years. Results from the isotopic analysis provided the basis for a conceptual model for the Creede Mining District (Williams, 2014):

1. *Water was recharged to the groundwater system at high-elevations.*
2. *That water could not pass through the low-permeability northern caldera wall at the Equity fault.*
3. *This barrier forced water down to a depth of about 1-2 kilometers, where it reached a subsurface barrier below the Bulldog and Amethyst faults.*
4. *Water then flowed towards the Rio Grande until it reached a similar barrier at the southern caldera wall. Some groundwater flows through the caldera wall in what is probabl[y] a highly preferential flow path and some groundwater moves upward into a network of variable permeability fractures associated with the intragraben area between the Amethyst and Bulldog graben faults, with long residence times and circulation depths sufficient to generate consistently warm (~20 °C) discharge.*
5. *Prior to mining the potentiometric surface within the intragraben area was higher than the Nelson Tunnel portal elevation due to the high recharge area elevation. The sub-Nelson mine workings were excavated into a water-bearing zone within the intragraben area and below the pre-mining potentiometric surface.*
6. *Water within this intragraben area is interconnected, and perturbations of the water level at any point in the area will affect water levels throughout the intragraben area.*
7. *These results indicate a large regional extent of mineralization associated with the graben fault system, and suggest that degraded groundwater quality may exist beyond the extent of the mine environment.*

2.1.3 Nelson Tunnel Hydraulics

In 2015, an estimate of the peak discharge flow rate from Nelson Tunnel was calculated, in the unlikely event that the No-Name Collapse was dislodged, allowing the upper mine pool to drain rapidly. The estimate included a range of discharge rates, depending on the roughness factors. The worst-case scenario results in about 850 cubic feet per second (cfs) flowing through Nelson Tunnel (HDR, 2015).

Hydraulic analysis by the Natural Resources Conservation Service, indicates that the flume which conveys Willow Creek through Creede has a capacity of 1,550 cfs, without freeboard (Yochum, S.E. Hyde, B., 2002). Based on discharge frequency analysis completed for the hydraulic analysis, the worst case discharge from Nelson Tunnel would have to occur concurrently with a flood event with a return period of greater than 10 years to exceed the flume capacity. As of the writing of this addendum, the town is rehabilitating the flume structure through Creede.

2.1.4 Commodore-Nelson Tunnel Mine Pool Observations

The Colorado Division of Reclamation, Mining and Safety (DRMS) has been monitoring mine pool elevations and developed a technical memorandum in 2015 on Nelson Tunnel Mine Pool characteristics based on measurements and visual observations. Appendix A contains the technical memorandum. The following is a summary of the mine pool characteristics (Graves, 2015). The technical memorandum includes a map entitled "Mine Pool Locations" that shows the locations referenced in this summary.

- Nelson Tunnel Portal Pool
  - The pool is formed by a collapse of the portal entry structure and surrounding ground.
  - The blockage appears to consist of mine timbers and a well graded matrix of collapsed debris.
  - Water is discharging approximately three vertical feet above the toe of the collapse.
  - The possibility exists for multiple collapses within the Nelson Tunnel Portal Pool since that section of tunnel cannot be accessed or observed from the workings except at the Bachelor Shaft.
  - Measurements of the Nelson Tunnel Portal Pool at the Bachelor shaft indicate a relatively constant pool elevation of 9197'.
  - The maximum attainable head is 43 feet against Nelson Tunnel Portal Blockage, controlled by the collar of the Bachelor shaft. Once the pool reached the collar elevation of 9240', discharge would occur through the 5 Level.
  - It is conservatively estimated that the Nelson Tunnel Portal Pool has a volume of 1.2 million gallons.
  - If Nelson Tunnel Portal Pool achieved maximum head, the volume would increase significantly due not only to increased vertical storage, but increased flooding of upstream workings.
- Lower Mine Pool
  - This blockage consists of some mine timbers (stuffs) and poorly graded stope material. The material is composed mostly of six to 12 inch diameter blasted rock within a matrix of fine grained material.
  - It is difficult to determine the thickness of the debris forming this blockage, but the majority of material is standing at angle of repose on the downstream side.

- Currently the water discharges over the top of the collapsed debris which is approximately 10 feet high.
- Mine pool elevations of the Lower Mine Pool can be measured at the Javelin Winze, Daylight Winze, Commodore Shaft, and YO2 Winze and have indicated a relatively steady pool elevation at 9214' over the last 12 years.
- There are likely small collapses that exist between the Bachelor Blockage and the upper end of the mine pool, but they do not appear to significantly alter the observed pool elevation along its length.
- Unless a significant amount of debris is added to the blockage raising the spill height, additional impoundment is unlikely. The next control on the Lower Mine Pool elevation would be the collar elevation of Daylight Winze, since this would allow discharge into the 5 Level. The mine pool would have to exceed an elevation of 9238' to enter the 5 Level.
- It is conservatively estimated that the Lower Mine Pool has a volume of 1.4 million gallons.
- Significant additional storage within the Lower Mine Pool is unlikely since the majority of Nelson working are already flooded through this section.

- Upper Mine Pool
  - Upper Mine Pool blockage appears to consist mostly of material less than six inches in diameter. Additionally, there is a significant amount of ferri-hydroxide precipitate and clay that comprises the debris matrix. The blockage appears to be significant in thickness due to a gradual outslope gradient of approximately 10%.
  - There are probably additional collapses between the blockage and the Nelson beyond the Decline, but those collapses, if they exist, do not alter the consistency of pool elevation observations across those locations. Observations of the Upper Mine Pool can be made at the Del Monte Raise, Berkshire Shaft and the Decline indicating a consistent pool elevation throughout.
  - Observations of pool elevation have ranged from a minimum of 9235' and a maximum of 9246'. The maximum head is controlled by maximum floor elevation on the 5 Level between Del Monte Raise and YO2 Winze.
  - Volume of the Upper Mine Pool using data from a dewatering test in 2007 was calculated to be 19.4 million gallons. An estimate of 19.5 million gallons was made using assumed flooded length and drift widths. This estimate is more uncertain because it is not possible to know the horizontal extent of flooding, and the amount of stoping within the Upper Mine Pool is difficult to determine since this portion of the mine encountered the most significant mineralization.

- The long term stability of the blockages forming the three mine pools is unknown, and could change significantly if conditions within the mine workings alter the existing flow regime.

2.1.5 Commodore-Nelson Tunnel Upper Mine Pool Data

In late 2013, DRMS installed pressure transducers in two locations to collect mine pool elevation and temperature data. One transducer is located at the Del Monte Raise, which is the furthest downstream location where the Upper Mine Pool elevation can be directly measured. The second location is approximately 2,000 feet upstream at the Berkshire Shaft. A technical memorandum which provides interpretation of the data collected since the transducers were installed and comparison of historic isotopic data to the mine pool elevation and temperature data was completed by DRMS in 2018 (Graves, 2018). Appendix B contains the technical memorandum. The following is a summary of the interpretations.

- The data reveals a consistent pattern of seasonal mine pool and temperature fluctuations. Pool elevations increase, on average, about five feet every April, which likely corresponds to initial snowmelt. The increase in mine pool elevation is also followed very shortly by an overall decrease in mine pool temperature, with the magnitude of the reduction averaging about 2º F. Both of these patterns reverse between summer and winter each year.
- The magnitude of temperature fluctuation at Del Monte is greater than the Berkshire shaft suggesting that Del Monte is closer to the source of cold water input; however, the start of temperature change are nearly simultaneous.
- To roughly estimate the magnitude of the inflows, DRMS constructed a simple temperature mixing model to estimate the volume of the inflow over a range of inflow temperatures. Assuming the temperature of the inflow water is between 35º F and 40º F, which is typical of water derived from snowmelt, the inflow was estimated to be about 5% to 10% of the Upper Mine Pool volume.
- Isotopic data was collected in 2001, 2008, 2009, and 2010 from Commodore Mine Complex water samples. The isotopic data, particularly tritium, a man made isotope of hydrogen (^3H) formed as a result of atmospheric testing of nuclear weapons, was interpreted to date water exiting Nelson Tunnel as decades old, or older. This interpretation contradicts the April rise in the Upper Pool elevation and drop in temperature, which clearly point to an influx of cold young water.
- One possible reason for the contradiction is that the water sampling conducted for the isotopic age dating occurred after snowmelt and therefore “missed” the majority of the inflow. It was noted that dye testing to calculate travel time from the Berkshire Shaft to the Nelson Tunnel Portal indicated that the dye concentration exiting the portal peaked at 8.5 days. Thus, much of the cold, young water entering the Upper Mine Pool may be flushed out in a matter of a few weeks, prior to when the sample collection for the age dating occurred.
- Another possible reason for the contradiction is that the volume of the cold, young water entering the Upper Mine Pool is small enough that its influence on the isotopic concentration was within the measurement error of the analyses.

3 Nature and Extent of Contamination

Each year from 2012 through 2017, United States Environmental Protection Agency (EPA) has collected surface water data and conducted various investigations and studies at the Site to advance the understanding of the nature and extent of surface water contamination, temporal trends in contaminant concentrations, and metal loading. In addition, studies have been conducted on environmental media including waste rock, groundwater, sediment, pore water, and air to further the understanding of the impact on the environment from mining activities.

3.1 Surface Water Quality

Since publishing the RI in 2011, the EPA has collected surface water samples from West Willow Creek, East Willow Creek, Willow Creek, and the Rio Grande to assess the impact of discharge from Nelson Tunnel. Typically, sampling has occurred four times a year. Samples have been analyzed by the EPA Region 8 Laboratory in Golden Colorado. Surface water sampling locations are shown on Figure 3-1.

The Human Health Risk Assessment (HHRA) completed for the RI identified no chemicals posing risks above a level of concern from incidental ingestion or dermal contact with surface water. The Baseline Ecological Risk Assessment identified several metals in water that may pose risks above a level of concern for eco receptors. Chief among these are cadmium, zinc, lead, and copper. Therefore, these metals will be used to describe the nature and extent of contamination in surface water.

3.1.1 Surface Water Quality Standards

The State of Colorado Department of Public Health and Environment Water Quality Control Commission (WQCC) regulates water quality and publishes water quality standards (WQS) specific to streams and stream segments in the state. The stream segments that correspond to the Site surface water sampling locations shown on Figure 3-1 include:

- Rio Grande Segment 2, which is the river segment immediately upstream of the confluence with Willow Creek.
- Rio Grande Segment 4a, which is the river segment immediately downstream of the confluence with Willow Creek.
- Rio Grande Segment 7, which includes West Willow Creek and Willow Creek.

Water quality standards are applied based on the use classification. The applicable classifications for the three segments are listed in Table 3-1.

Table 3-1: Stream Segment Classifications

Stream Segment	Classifications
Willow Creek, West Willow Creek (Rio Grande Segment 7)	Aquatic Life Cold Stream Tier 2 Recreation Existing Primary Agriculture
Rio Grande Segment 2 (Upstream of Willow Creek)	Aquatic Life Cold Stream Tier 1 Recreation Existing Primary Water Supply Agriculture
Rio Grande Segment 4a (Downstream of Willow Creek)	Aquatic Life Cold Stream Tier 1 Recreation Existing Primary Water Supply Agriculture

Over the past several years, the WQCC has issued site specific standards and future standards (Tier 1and Tier 2 Standards) for Rio Grande Segments 4a and 7. The site specific standards have been in place since 2007 in recognition of high concentrations of several metals and plans for water quality improvements. Future standards were adopted in 2013 with the understanding that the Bulldog Mine, located southwest of Nelson Tunnel would eventually return to operation. The Bulldog Mine was last operational from 1965-1985 and required substantial dewatering. A result of the dewatering the Bull Dog Mine was significantly lower flow from Nelson Tunnel, reported to be approximately 20 gpm (WQCC, 2013). Lower flows from the Nelson Tunnel would reduce metal loading from this source and is likely to improve water quality in Willow Creek and the Rio Grande.

The site specific standards for Segment 4a are effective through 12/31/2021 and include:

- Cadmium (chronic)
  - Low flow: 0.50 micrograms per liter (µg/L)
  - High flow: 0.42 µg/L
- Zinc(chronic)
  - Low flow: 164 µg/L
  - High flow: 88 µg/L
- Manganese (chronic)
  - Low flow: Water Supply
  - High flow: Water Supply

For manganese, the "Water Supply" designation means:

> For all surface waters with an actual water supply use, the less restrictive of the following two options shall apply as numerical standards, as specified in the Basic Standards and Methodologies at 31.11(6);
>
> - existing quality as of January 1, 2000; or
> - 50 µg/l (dissolved)

The site specific standards for Segment 7 are based on ambient conditions that were statistically calculated from available datasets. Numeric values were calculated for three different portions of segment 7, which have very different water quality: West Willow Creek, Windy Gulch, and mainstem Willow Creek. Chronic standards for West Willow Creek and Willow Creek are presented in Table 3-2:

Table 3-2: Site-Specific Chronic Standards for Rio Grande Segment 7 Micrograms per Liter

Metal	West Willow		Willow Creek	
	Low flow	High flow	Low flow	High flow
Cadmium	27.4	15.5	16.9	8.5
Copper	TVS	28	TVS	8.2
Lead	102	23.5	24.4	14.2
Manganese	2,425	TVS	TVS	TVS
Zinc	9,360	3,765	5,427	1,873

TVS = Table Value Standards

The WQCC adopted two tiers of future site-specific standards for Rio Grande Segments 4a and 7 based on the feasibility of reversing historic man-induced sources of metals, including dewatering and discharge of treated water from the Bull Dog Mine. Future standards include Tier 1, effective January 1, 2022 through December 31, 2023 and Tier 2, effective starting on January 1, 2024.

The Bulldog Mine has yet to open and future plans are uncertain. Due to the uncertainty of the future WQS for these segments, for purposes of the RI, surface water data will be compared to the underlying standards. The underlying standards are published Table Value Standards (TVS), which are a function of water hardness for each of the four metals. Table 3-3 lists the TVS for cadmium, copper, lead, manganese, and zinc. Chronic standards, which are more stringent than acute standards, are shown. Standards are measured against dissolved metals.

Table 3-3: Table Value Standards in Micrograms per Liter

Stream Segment	Table Value Standard
Cadmium	$((1.101672-[\ln(hardness)\ x(0.041838)]\ x\ e^{0.7998[\ln(hardness)]-4.4451}$
Copper	$e^{(0.8545[\ln(hardness)]-1.7428)}$
Lead	$(1.46203-[(\ln(hardness)*\ (0.145712)])*e^{(1.273[\ln(hardness)]-4.705)}$
Manganese	$e^{(0.3331[\ln(hardness)]+5.8743)}$
Zinc	$0.986*e^{(0.9094[\ln(hardness)]+0.6235)}$

3.1.2 Willow and West Willow Creek Surface Water Concentrations, Metal Loads, and Comparison to Standards

For cadmium, copper, lead, and zinc, figures showing the high and low flow concentration and load are presented and discussed. As defined in the WQCC standards, high flow in the applicable Rio Grande segments occurs April through July. Statistics are provided on how often the concentrations exceed TVS in West Willow Creek, both upstream of Nelson Tunnel and downstream, and Willow Creek. Concentrations are shown on log charts, due to the large range in measurements.

Each metal load from Willow Creek above Nelson Tunnel, and from Nelson Tunnel are compared to the sum of the loads calculated at the monitoring stations at the end of Willow Creek (W-I, W-J, and WSN). In evaluating Nelson Tunnel load data, note that, in addition to typical challenges of accurately measuring flow in a rocky creek, the poor condition of the flume used to measure flows from Nelson Tunnel add uncertainty to load measurements. The flume structure is dented and may read a higher value than actual. It is also likely that a portion of the flow from Nelson Tunnel discharges below the surface channel and is not captured by the flume.

Also, Nelson Tunnel flows are much more acidic than flows in West Willow Creek. Figures 3-2 and 3-3 display pH measurements during high and low flow. As can be seen in the charts, pH in West Willow and Willow Creeks is generally between 6-8, and the pH of Nelson Tunnel discharge is between 3.2 and 4.5, with few exceptions. As the waters mix and pH increases toward neutral, precipitation and settling of certain pH sensitive metals as solids will reduce the load from Nelson Tunnel in West Willow and Willow Creeks, and the Rio Grande River.

Cadmium

Figures 3-4 and 3-5 display the low flow and high flow cadmium concentrations from 2012 through 2017. Low flow and high flow loads during this period are provided on Figures 3-6 and 3-7. The following are general observations from these figures:

- In both the low and high flow concentrations charts, cadmium in West Willow rises because of Nelson Tunnel flows then stays relatively constant. A drop in concentration is notable from West Willow to Willow Creek.
- During low flow, cadmium load appears generally constant in West Willow Creek, through station WW-A. Overall, a higher load is apparent in West Willow Creek than Willow Creek. A similar pattern occurs during high flow.
- During both high and low flow conditions, the majority of the cadmium load in West Willow Creek and Willow Creek can be attributed to the discharge from Nelson Tunnel.

Table 3-4 summarizes the number of dissolved cadmium concentrations recorded from 2012 through 2017 in Willow and West Willow Creeks and compares the results to the calculated TVS. The range of concentrations and the range of calculated TVS are also included in Table 3-4.

Table 3-4: Comparison of Concentrations versus the TVS for Cadmium in Willow and West Willow Creeks

Stream Condition	Number of Measurements*	% Exceeding the TVS	Range of Concentrations (µg/L)	Range of TVS (µg/L)
High Flow	88	100%	3.48-26.50	0.12-0.34
Low Flow	119	100%	5.15-541	0.12-1.07

* Does not include concentrations from Nelson Tunnel flow

As displayed in Table 3-4, all measurements for cadmium concentration exceeded the TVS. This includes all measurements from monitoring station WW-G, which is located upstream of Nelson Tunnel. Generally, the calculated standards are significantly lower, between one and three orders of magnitude, than concentrations in West Willow and Willow Creeks.

Table 3-5 compares the cadmium load contribution in Willow Creek from West Willow Creek upstream of Nelson Tunnel, represented by monitoring station WW-G, and from Nelson Tunnel for high and low flows and for all flows.

Table 3-5: Average Cadmium Load Contribution to Willow Creek

Stream Condition	WW-G n	WW-G Average Load (lbs/Day)	WW-G %	WW-NT n	WW-NT Average Load (lbs/Day)	WW-NT %	Willow Creek* n	Willow Creek* Average Load (lbs/Day)*
High Flow	8	0.31	15%	8	1.36	65%	8	2.10
Low Flow	11	0.09	10%	12	0.44	50%	12	0.89
Combined	19	0.18	13%	20	0.81	59%	20	1.37

* Represented by the sum of loads at monitoring stations WW-I, WW-J, and WSN
% = Percent of Willow Creek Load
n = number of measurements

Based on this analysis, on average, 59% of the cadmium load exiting Willow Creek can be attributed to Nelson Tunnel.

Copper

Figures 3-8 and 3-9 display the low flow and high flow copper concentrations from 2012 through 2017. Low flow and high flow loads are provided on Figures 3-10 and 3-11. The following are general observations from these figures:

- In both the low and high flow concentrations charts, copper in West Willow rises because of Nelson Tunnel flows then stays relatively constant. A drop in concentration is notable from West Willow Creek to Willow Creek.
- Loading charts for both high and low flow are variable and difficult to discern consistent patterns. In nearly every measurement, discharge from Nelson Tunnel contributes significant load, and often a load contribution from Willow Creek is apparent.

Table 3-6 summarizes the dissolved copper concentrations recorded from 2012 through 2017 in the upstream monitoring station (WW-G), Willow and West Willow Creeks and the comparison to the TVS.

Table 3-6: Comparison of Concentrations versus the TVS for Copper in Willow and West Willow Creeks

Stream Condition	n WW-G	WW-G > TVS	%	n West Willow	West Willow >TVS	%	n Willow	Willow >TVS	%
High Flow	8	3	38%	30	12	40%	42	17	40%
Low Flow	11	0	0%	40	9	23%	57	10	18%
Combined	19	3	16%	70	21	30%	99	27	27%

n = number of measurements
WW-G = West Willow Creek monitoring station upstream of Nelson Tunnel Portal
n West Willow = Number of measurements in West Willow Creek downstream of the Nelson Tunnel Portal
n Willow = Number of measurements in Willow Creek

Relatively few of the upstream measurements exceeded the TVS. Willow Creek had a similar occurrence of exceedances as West Willow Creek.

Table 3-7 compares the copper load contribution in Willow Creek from West Willow Creek upstream of Nelson Tunnel, represented by monitoring station WW-G, and from Nelson Tunnel for high and low flows and for all flows.

Table 3-7: Average Copper Load Contribution to Willow Creek

Stream Condition	WW-G			WW-NT			Willow Creek*	
	n	Average Load (lbs/Day)	%	n	Average Load (lbs/Day)	%	n	Average Load (lbs/Day)*
High Flow	8	0.35	19%	8	2.21	119%	8	1.85
Low Flow	12	0.09	23%	12	0.23	66%	11	0.35
Combined	20	0.19	19%	20	1.02	104%	19	0.98

* Represented by the sum of loads at monitoring stations WW-I, WW-J, and WSN
% = Percent of Willow Creek Load
n = number of measurements

On average, the copper load exiting Nelson Tunnel is greater than the load discharging from Willow Creek. Copper is relatively pH sensitive and it is likely that some of the load from Nelson Tunnel is removed from the creek water by solids precipitation as the pH rises downstream of Nelson Tunnel.

Lead

Figures 3-12 and 3-13 display the low flow and high flow lead concentrations from 2012 through 2017. Low flow and high flow loads are provided on Figures 3-14 and 3-15. The following are general observations from these figures:

- In both the low and high flow concentrations charts, lead in West Willow rises because of Nelson Tunnel flows then decreases slightly across both West Willow and Willow Creeks. A drop in concentration is notable from West Willow to Willow Creek.
- Loading charts for both high and low flow are variable and difficult to discern consistent patterns. In nearly every measurement, discharge from Nelson Tunnel contributes significant load. An increase in the load at the first Willow Creek station (WA-Opp) occurs inconsistently.

Table 3-8 summarizes the number of dissolved lead concentrations recorded from 2012 through 2017 in Willow and West Willow Creeks and comparison the results to the calculated TVS. The range of concentrations and the range of calculated TVS are also included in Table 3-8.

Table 3-8: Comparison of Concentrations versus the TVS for Lead in Willow and West Willow Creeks

Stream Condition	Number of Measurements	% Exceeding the TVS	Range of Concentrations* (µg/L)	Range of TVS (µg/L)
High Flow	88	100%	2.0-29.6	0.57-1.65
Low Flow	119	100%	1.74-804	0.7-9.37

*Does not include concentrations from Nelson Tunnel flow

As displayed in Table 3-8, all measurements for lead concentration exceeded the TVS. This includes all measurements upstream of Nelson Tunnel Portal (WW-G). Generally, the calculated standards are 10 to 30 times lower than concentrations in West Willow and Willow Creeks.

Table 3-9 compares the lead load contribution in Willow Creek from West Willow Creek upstream of Nelson Tunnel, represented by monitoring station WW-G, and from Nelson Tunnel for high and low flows and for all flows.

Table 3-9: Average Lead Load Contribution to Willow Creek

Stream Condition	WW-G			WW-NT			Willow Creek*	
	n	Average Load (lbs/Day)	%	n	Average Load (lbs/Day)	%	n	Average Load (lbs/Day)*
High Flow	8	0.54	20%	7	3.91	147%	8	2.65
Low Flow	11	0.13	11%	12	4.86	416%	12	1.17
Combined	19	0.29	18%	19	4.18	253%	20	1.65

* Represented by the sum of loads at monitoring stations WW-I, WW-J, and WSN
% = Percent of Willow Creek Load
n = number of measurements

On average, the lead load exiting Nelson Tunnel is much greater than the load discharging from Willow Creek into the Rio Grande. Lead is relatively pH sensitive and it is apparent that significant load from Nelson Tunnel precipitates as the pH rises downstream of Nelson Tunnel.

Manganese

Figures 3-16 and 3-17 display the low flow and high flow manganese concentrations from 2012 through 2017. Low flow and high flow loads during this period are provided on Figures 3-18 and 3-19. The following are general observations from these figures:

- In both the low and high flow concentrations charts, manganese in West Willow rises because of Nelson Tunnel flows then stays relatively constant. A drop in concentration is notable from West Willow to Willow Creek.
- During both high and low flow conditions, the majority of the manganese load in West Willow Creek and Willow Creek can be attributed to the discharge from Nelson Tunnel.

Table 3-10 summarizes the number of dissolved manganese concentration measurements recorded from 2012 through 2017 in Willow and West Willow Creeks and compares the results to the calculated TVS. The range of concentrations and the range of calculated TVS are also included in Table 3-10.

Table 3-10: Comparison of Concentrations versus the TVS for Manganese in Willow and West Willow Creeks

Stream Condition	Number of Measurements*	% Exceeding the TVS	Range of Concentrations (µg/L)	Range of TVS (µg/L)
High Flow	72	0%	3 -1,340	1,053-1,505
Low Flow	99	22%	1-54,700	1,129—2,489

* Does not include concentrations from Nelson Tunnel flow

During high flow measurements for manganese concentration are below the TVS on all occasions. The TVS is exceeded 22% of the time during low flow, all within West Willow Creek or at WSN.

Table 3-11 compares the manganese load contribution in Willow Creek from West Willow Creek upstream of Nelson Tunnel, represented by monitoring station WW-G, and from Nelson Tunnel for high and low flows and for all flows.

Table 3-11: Average Manganese Load Contribution to Willow Creek

Stream Condition	WW-G			WW-NT			Willow Creek*	
	n	Average Load (lbs/Day)	%	n	Average Load (lbs/Day)	%	n	Average Load (lbs/Day) *
High Flow	8	1.1	15%	8	65	125%	8	52
Low Flow	11	0.2	10%	12	57	198%	12	29
Combined	19	0.6	13%	20	60	158%	20	38

* Represented by the sum of loads at monitoring stations WW-I, WW-J, and WSN
% = Percent of Willow Creek Load
n = number of measurements

Based on the table, the Nelson Tunnel contributes a significant amount of manganese load, some of which precipitates prior to reaching the Rio Grande.

Zinc

Figures 3-20 and 3-21 display the low flow and high flow zinc concentrations from 2012 through 2017. Low flow and high flow loads are provided on Figures 3-22 and 3-23. The following are general observations from these figures:

- In both the low and high flow concentrations charts, zinc in West Willow rises because of the Nelson Tunnel contribution and a drop in concentration is notable from West Willow to Willow Creek. In both Willow and West Willow Creeks, zinc concentration rises slightly during high and low flows, with the rise more pronounced during high flows.
- Loading charts for both high and low flow are variable but an overall increase in load from upstream to downstream is apparent. In every measurement, discharge from Nelson Tunnel contributes significant load.
- The decrease in West Willow Creek load compared to the load discharging from Nelson Tunnel is less pronounced than in other metals, such as lead.

Table 3-12 summarizes the dissolved zinc concentrations recorded from 2012 through 2017 in monitoring station WW-G, Willow and West Willow Creeks and the comparison to the TVS.

Table 3-12: Comparison of Concentrations versus the TVS for Zinc in Willow and West Willow Creeks

Stream Condition	Number of Measurements	% Exceeding the TVS	Range of Concentrations* (µg/L)	Range of TVS (µg/L)
High Flow	88	100%	111-4,120	36-85
Low Flow	119	100%	120-161,000	43-373

*Does not include concentrations from Nelson Tunnel flow

All measurements for zinc concentration exceeded the TVS. This includes all measurements upstream of Nelson Tunnel Portal (WW-G). The calculated standards are, on average, about 50 times lower than concentrations in West Willow and Willow Creeks.

Table 3-13 compares the zinc load contribution in Willow Creek from West Willow Creek upstream of Nelson Tunnel, represented by monitoring station WW-G, and from Nelson Tunnel for high and low flows and for all flows.

Table 3-13: Average Zinc Load Contribution to Willow Creek

Stream Condition	WW-G			WW-NT			Willow Creek*	
	n	Average Load (lbs/Day)	%	n	Average Load (lbs/Day)	%	n	Average Load (lbs/Day)*
High Flow	8	25.42	6%	8	231.57	56%	8	412.63
Low Flow	11	10.43	4	12	189.88	78%	11	242.68
Combined	19	14.24	5%	20	202.28	68%	19	297.40

* Represented by the sum of loads at monitoring stations WW-I, WW-J, and WSN
% = Percent of Willow Creek Load
n = number of measurements

On average, the zinc load exiting Nelson Tunnel composes over half the load discharging from Willow Creek. However, it appears that other sources of zinc are significant in Willow Creek particularly in high flow conditions.

3.1.3 Rio Grande Surface Water Concentrations, Metal Loads, and Comparison to Standards

Similar to the analysis for West Willow and Willow Creeks, figures showing the high and low flow concentration and load for cadmium, copper, lead, and zinc are presented and discussed. Because flow measurements during high flow are not available for the Rio Grande, high flow loads could not be calculated. Load charts include load from RG-2, which is upstream of Willow Creek's confluence with the Rio Grande, cumulative load at the three Willow Creek's monitoring station located just above the confluence (W-I, W-J, and WSN), and the three Rio Grande monitoring stations (RG-4, RG-8, and RG-9). Statistics are provided on how often the concentrations exceed TVS.

Cadmium

Figures 3-24 and 3-25 display the high flow and low flow cadmium concentrations in the Rio Grande monitoring stations from 2012 through 2017. Low flow loads during this period are provided on Figure 3-26. The following are general observations from these figures:

- In both the low and high flow concentrations charts, cadmium in the Rio Grande rises considerably downstream of the Willow Creek confluence.
- During low flow, cadmium load from Willow Creek is considerably higher than the load in the Rio Grande.

- In five of the six events displayed on Figure 3-26, the load is higher in Willow Creek than in the first Rio Grande monitoring station downstream of the Willow Creek confluence, which is RG-4. A trend over the next two monitoring stations is not discernable.

Table 3-14 summarizes the number of dissolved cadmium concentrations recorded from 2012 through 2017 in the Rio Grande and how many of those results exceed the calculated TVS.

Table 3-14: Comparison of Cadmium Concentrations versus the TVS Rio Grande Monitoring Stations

Stream Condition	n RG-2	RG-2> TVS	%	n Rio Grande (RG-4, RG-8, RG-9)	Rio Grande >TVS	%
High Flow	6	0	0%	18	16	89%
Low Flow	9	0	0%	26	24	92%
Combined	15	0	0%	44	40	91%

n RG-2 = Number of measurements in Rio Grande upstream of the Willow Creek
n Rio Grande = Number of measurements in Rio Grande downstream of the Willow Creek

As displayed in Table 3-14, none of the cadmium concentrations measured at RG-2 exceeded the TVS and 91% of the measurements downstream of the confluence of Willow Creek exceeded the TVS.

Copper

Figures 3-27 and 3-28 display the high flow and low flow copper concentrations in the Rio Grande monitoring stations from 2012 through 2017. Low flow loads during this period are provided on Figure 3-29. The following are general observations from these figures:

- In both the low and high flow charts, copper concentrations in the Rio Grande rises downstream of the Willow Creek confluence, with a few exceptions during low flow.
- During low flow, copper load is higher at RG-4 than at RG-2, indicating a load from Willow Creek.

Table 3-15 summarizes the number of dissolved copper concentrations recorded from 2012 through 2017 in the Rio Grande and how many of those results exceed the calculated TVS.

Table 3-15: Comparison of Copper Concentrations versus the TVS Rio Grande Monitoring Stations

Stream Condition	n RG-2	RG-2> TVS	%	n Rio Grande (RG-4, RG-8, RG-9)	Rio Grande >TVS	%
High Flow	6	0	0%	18	0	0%
Low Flow	9	0	0%	26	0	0%
Combined	15	0	0%	44	0	0%

n RG-2 = Number of measurements in Rio Grande upstream of the Willow Creek confluence
n Rio Grande = Number of measurements in Rio Grande downstream of the Willow Creek confluence

As displayed in Table 3-15, none of the copper concentrations exceeded the TVS.

Lead

Figures 3-30 and 3-31 display the high flow and low flow lead concentrations in the Rio Grande monitoring stations from 2012 through 2017. Low flow loads during this period are provided on Figure 3-32. The following are general observations from these figures:

- In both the low and high flow charts, lead concentrations are not detected in the Rio Grande upstream of the Willow Creek confluence, with few exceptions. Concentrations rise to between 0.2 and 1.1 µg/L at station RG-4. In most instances, lead concentration drops between stations RG-4 and RG-8, then is generally flat between stations RG-8 and RG-9.
- Low flow lead load from Willow Creek is generally higher than the load calculated at RG-4. Loads from Station RG-4 through RG-9 are generally flat.

Table 3-16 summarizes the number of dissolved lead concentrations recorded from 2012 through 2017 in the Rio Grande and how many of those results exceed the calculated TVS.

Table 3-16: Comparison of Lead Concentrations versus the TVS Rio Grande Monitoring Stations

Stream Condition	n RG-2	RG-2> TVS	%	n Rio Grande (RG-4, RG-8, RG-9)	Rio Grande >TVS	%
High Flow	6	0	0%	18	0	0%
Low Flow	9	0	0%	26	5	19%
Combined	15	0	0%	44	5	11%

n RG-2 = Number of measurements in Rio Grande upstream of the Willow Creek confluence
n Rio Grande = Number of measurements in Rio Grande downstream of the Willow Creek confluence

As displayed in Table 3-16, none of the lead concentrations at RG-2, which were mostly non-detect, exceeded the TVS. During high flow, none of the lead concentrations exceeded the standard. The standard was exceeded five times in the downstream monitoring stations. Four of the exceedances were at RG-4 and concentrations of all five instances were about 10%-30% higher than the standard.

Manganese

Figures 3-33 and 3-34 display the high flow and low flow manganese concentrations in the Rio Grande monitoring stations from 2012 through 2017. Low flow loads during this period are provided on Figure 3-35. The following are general observations from these figures:

- Concentrations rises between RG-2 and RG-4 range from 40%-550%. Manganese concentrations drops between stations RG-4 and RG-8, then is generally flat between stations RG-8 and RG-9.
- Low flow manganese load from Willow Creek is 73% to more than 6 times the load in the Rio Grande measured at RG-2.

Table 3-17 summarizes the number of dissolved manganese concentrations recorded from 2012 through 2017 in the Rio Grande and how many of those results exceed the calculated TVS.

Table 3-17: Comparison of Manganese Concentrations versus the TVS Rio Grande Monitoring Stations

Stream Condition	n RG-2	RG-2> TVS	%	n Rio Grande (RG-4, RG-8, RG-9)	Rio Grande >TVS	%
High Flow	6	0	0%	18	0	0%
Low Flow	9	0	0%	26	1	4%
Combined	15	0	0%	44	1	2%

n RG-2 = Number of measurements in Rio Grande upstream of the Willow Creek confluence
n Rio Grande = Number of measurements in Rio Grande downstream of the Willow Creek confluence

As displayed in Table 3-17, none of the manganese concentrations at RG-2 exceeded the TVS. During high flow, none of the manganese concentrations exceeded the standard in RG-4, RG-8, or RG-9. The standard was exceeded once at RG-9 during low flow. The manganese concentration in both high and low flow exceeded the secondary drinking water standard of 50 µg/L once, during the August 2017 sampling event at RG-9. The recorded concentration of 2,960 µg/L is likely an error or is an extreme outlier.

Zinc

Figures 3-36 and 3-37 display the high flow and low flow zinc concentrations in the Rio Grande monitoring stations from 2012 through 2017. Low flow loads during this period are provided on Figure 3-38. The following are general observations from these figures:

- In both the low and high flow charts, zinc concentrations rise sharply downstream of the Willow Creek confluence.
- Zinc concentrations are generally flat across station RG-4, RG-8, and RG-9 during high flow.
- During low flow, zinc concentrations are more variable than during high flow. Between stations RG-4 and RG-8, there is not a consistent pattern; however, between RG-8 and RG-9 the zinc concentration rose during most sampling events.
- Low flow zinc load from Willow Creek is generally higher than the load calculated at RG-4. Loads from Station RG-4 to RG-8 are generally flat, with few exceptions. From RG-8 to RG-9, the zinc load increased during most sampling events.

Table 3-18 summarizes the number of dissolved zinc concentrations recorded from 2012 through 2017 in the Rio Grande and how many of those results exceed the calculated TVS.

Table 3-18: Comparison of Zinc Concentrations versus the TVS Rio Grande Monitoring Stations

Stream Condition	n RG-2	RG-2> TVS	%	n Rio Grande (RG-4, RG-8, RG-9)	Rio Grande >TVS	%
High Flow	6	0	0%	18	14	78%
Low Flow	9	0	0%	26	24	92%
Combined	15	0	0%	44	38	86%

n RG-2 = Number of measurements in Rio Grande upstream of the Willow Creek confluence
n Rio Grande = Number of measurements in Rio Grande downstream of the Willow Creek confluence

As displayed in Table 3-18, none of the zinc concentrations at RG-2, which were almost always non-detect, exceeded the TVS. The standard was exceeded in 86% in the downstream monitoring stations measurements.

3.2 Metal Concentrations Compared to Precipitation at Monitoring Station WW-A

From August 9 through September 1, 2016, EPA Region 8 Environmental Services Assistance Team (ESAT) collected samples from an auto sampler located at Monitoring Station WW-A at 12 hour intervals (6:00 AM and 6:00 PM each day). The samples were subsequently analyzed for total recoverable metals by ESAT. During the same period, precipitation was recorded every 15 minutes. The purpose of this investigative activity was to evaluate whether precipitation events result in an increase in metal concentrations in West Willow Creek. Monitoring Station WW-A is situated in West Willow Creek above its confluence with Willow Creek and below the Commodore Waste Rock Pile.

During the auto sampler monitoring period, rainfall occurred on 11 days; however, only once did the precipitation exceed 0.1 inches. On August 10th, 0.26 inches of rain was recorded between 10:15-10:30 PM. The auto sampler was programmed to collect an opportunistic sample after 0.25 inches of rain. At 10:31 PM on August 10th, an opportunistic sample was collected.

Charts that compare arsenic, cadmium, copper, iron, lead, manganese, nickel, selenium, and zinc concentrations to precipitation during the auto sampler monitoring period are included in Appendix C.

All of the metals, with the exception of nickel and selenium, exhibited an increase in concentration in the opportunistic sample. Arsenic, copper, iron, and lead all increased substantially, whereas cadmium, manganese, and zinc increased to a lesser degree. Nickel and selenium concentrations remained below detection level throughout the study period. Total recoverable concentrations of arsenic, copper, iron, and lead continued to exhibit elevated concentrations in the sample collected about seven and one half hours after the rainfall, at 6:00 AM on August 11th. Arsenic, iron and lead also appear to be elevated in the sample collected 12 hours later. Conversely, total recoverable concentrations of cadmium, manganese, and zinc do not appear to have been significantly elevated following the opportunistic sample collected immediately after rainfall.

Three of the samples collected during the August 9 through September 1 study period were also filtered and analyzed for dissolved metals. Concentrations of dissolved metals are also shown on the charts contained in Appendix C. Comparing dissolved and total recoverable data reveals that metals which increased in concentration after the rainfall (copper, iron, and lead) reside in the stream at WW-A, in part, in precipitated form. It is suspected that arsenic does also, since arsenic is typically found adsorbed to iron hydroxide precipitates, but detection levels prevent confirmation of this.

Based on the data collected, it is likely that significant rain events cause precipitated metals to become suspended, increasing the load within the stream. The Commodore Waste Rock pile is likely a major source.

3.3 Diel Sampling

The purpose of diel surface water sampling at the Site was to evaluate daily fluctuations of total and dissolved metals concentrations in Willow Creek and the Rio Grande. Studies have shown that surface water can exhibit substantial diel variations in the concentration of a number of constituents. Diel variations in concentrations of various constituents in streams occur in response to changes in temperature, pH, the intensity of incident sunlight, and microbiological and algae activity in the water and sediments. Diel variations in the intensity photosynthesis and respiration occurring in the creek result in diel variations in geochemical conditions in the water column and underlying sediments that affect the equilibrium solubility of many constituents, including trace elements (USGS, 2009).

Diel sampling was performed in August 2016 at surface water monitoring station W-I and in August 2017 at surface water monitoring stations W-I and RG-4. W-I was selected because significant algae growth occurs at this location. RG-4 was added in 2017 to determine if the next sampling location downstream from W-I also exhibited diel fluctuations. During each event, samples were collected every two hours starting one hour before sunrise and ending one hour after sunset for dissolved metals and total recoverable metals. Samples were analyzed at the Region 8 Laboratory in Golden Colorado, by TechLaw, Inc., the ESAT contractor.

Charts that display cadmium, copper, iron, lead, manganese, and zinc concentrations from the diel sampling are included in Appendix D.

Cadmium, manganese and zinc each exhibited distinct diel variation, with the minimum concentrations occurring mid-day and the maximum concentrations occurring before sunrise and after sunset. The magnitudes of variation ranged from 1.4 to 5.1. Zinc exhibited the greatest variation; on average the dissolved zinc concentration was nearly four times greater before sunrise than late in the afternoon. Magnitudes of variation are summarized in Table 3-19. Diel variation was not apparent in the concentrations of copper, iron, and lead.

Table 3-19: Magnitude of Diel Variations in Cadmium, Manganese, and Zinc

Element	Location and Year	Maximum Concentration		Minimum Concentration		Magnitudes of Variation
		µg/L	Time	µg/L	Time	
Cadmium	WW-I, 2016	10.1	5:30 AM	3.38	3:30PM	3.0
Cadmium	WW-I, 2017	6.68	9:30PM	2.98	5:30PM	2.2
Cadmium	RG-4, 2017	0.319	5:30 AM	0.154	5:30PM	2.1
Manganese	WW-I, 2016	245	9:30PM	122	3:30PM	2.0
Manganese	WW-I, 2017	171	9:30PM	102	1:30PM	1.7
Manganese	RG-4, 2017	15.6	9:30PM	10.9	11:30 AM	1.4
Zinc	WW-I, 2016	2,560	5:30 AM	505	3:30PM	5.1
Zinc	WW-I, 2017	1,510	5:30 AM	443	5:30PM	3.4
Zinc	RG-4, 2017	83	5:30 AM	26.3	5:30PM	3.2

3.4 2002 Rio Grande Zinc Concentrations from USGS Sampling

In May 2002, the United States Geological Survey (USGS) sampled four locations along the Rio Grande for the Willow Creek Restoration Committee and reported the findings (USGS, 2002). The purpose of the sampling was to evaluate river mixing of the relatively high zinc concentrations from Willow Creek. At each of the four locations, grab samples were collected from up to ten discrete samples across the river and analyzed for dissolved zinc. Water quality parameters including temperature, pH, dissolved oxygen, and specific conductance were recorded at each discrete location. In addition, a depth and width integrated composite sample was collected from each location. The four sampling locations included:

- Rio Grande above Deep Creek, which is a right-bank tributary of the Rio Grande with its confluence with the Rio Grande about one half mile upstream of Willow Creek's confluence. This location is similar to surface water monitoring station RG-2.
- Rio Grande at about a mile downstream from the Willow Creek-Rio Grande confluence, near a private ranch. This location is similar to surface water monitoring station RG-4, slightly more than a mile below the Willow Creek-Rio Grande confluence.
- Rio Grande above Spring Creek is upstream of Wagon Wheel Gap and in a similar location to surface water monitoring station RG-8, about 6.5 miles below the Willow Creek-Rio Grande confluence.
- Rio Grande at Wagon Wheel Gap is nearly the same location as surface water monitoring station RG-9, about 7.8 miles from the Willow Creek-Rio Grande confluence.

Table 3-20 summarizes the analytical results.

Table 3-20: Zinc Concentrations from Rio Grande Sampling by USGS in 2002

Rio Grande Location	Location from Left Bank (ft)	Dissolved Zinc Concentration (µg/L)	Location	Location from Left Bank	Dissolved Zinc Concentration (µg/L)
Upstream of Willow Creek (RG-2)	6	-	Upstream of Spring Creek (RG-8)	10	110
	18	<1		19	107
	30	-		27	110
	42	<1		36	107
	54	-		45	103
	66	-		54	107
	78	<1		84	105
	90	-		93	104
	102	<1		102	104
	114	<1		111	105
	Composite	**<1**		**Composite**	**107**
Near Private Ranch (RG-4)	4	155	Near Wagon Wheel Gap (RG-9)	10	151
	13	154		10	152
	22	167		20	155
	31	129		30	151
	40	105		40	149
	49	100		50	148
	58	97		60	151
	67	96		70	149
	76	97		80	149
	85	96		90	146
	Composite	**124**		100	143
				Composite	**147**

The results suggest incomplete mixing of inflows from Willow Creek one mile downstream, near a private ranch, which is analogous to surface water monitoring station RG-4. In addition, the results suggest a substantial zinc load from Spring Creek, or other inflow between the furthest two downstream sampling points, during this sampling event.

Table 3-21 compares the composite zinc concentrations from the 2002 USGS data collection to the average high flow zinc concentrations in samples collected by the EPA at analogous stations. Results from upstream of Willow Creek and RG-2 are omitted because all are below laboratory detection limits.

Table 3-21: Comparison of USGS and EPA Rio Grande Zinc Concentrations

USGS Location/Analogous EPA Location	Dissolved Zinc Concentration (µg/L)				
	USGS Composite from 2002	EPA High Flow Samples 2014-2017			
		Average	n	STD DEV	CV
Downstream of Willow and Rio Grande confluence /RG-4	124	45	5	11.4	0.25
Upstream of Spring Creek/RG-8	107	41	5	12.0	0.29
Near Wagon Wheel Gap/RG-9	147	42	5	13.1	0.32

STD DEV = Standard Deviation
CV = Coefficient of Variation

As can be seen in Table 3-21, Rio Grande zinc concentrations in 2002 are significantly higher, by a factor of about three times. Statistics for the EPA data are presented to illustrate that the concentrations have been relatively consistent.

Based on this information, an increased zinc concentration at RG-9 that was recorded during the 2002 is not evident in the high flow data collection from 2014-2017. However, calculated low flow loads from RG-8 to RG-9 displayed on Figure 3-38 indicate that zinc load increased during most sampling events between these two stations.

3.5 Well Installation and Groundwater Sampling and Analysis

During October 2013, four groundwater monitoring wells were drilled and installed for the Site. Three wells were installed into the Commodore Waste Rock (CWR) and one was the alluvium of Willow Creek, located approximately one mile north of Creede, Colorado. Figure 3-39 shows the location of the wells that were installed. All four wells were drilled into bedrock.

The objective of drilling wells in the CWR was to determine whether a groundwater system existed in the CWR, and to evaluate the groundwater as a source of metals contamination to Willow Creek. The objective of drilling a well in the alluvium of Willow Creek was to evaluate if the amethyst vein, or other vein structure produced upwelling of contaminated water in this area of the creek.

Table 3-22 summarizes the well construction details for the installed wells.

Table 3-22: Monitoring Well Construction Summary

Well ID	Date Installed	Screen Interval (ft. bgs)	Formation in Screen Interval	Well Diameter	Completion
CWR-1	10/2/2013	29-49	Waste Rock	2-inch	2.5 foot stick-up
CWR-2	10/3/2013	26.5-56.5	Waste Rock to 32 ft. bgs, then purple-gray welded tuff		2.5 foot stick-up
CWR-3	10/7/2013	37-57	Waste Rock		2.5 foot stick-up
EWWC-1	10/5/2013	7-33	Alluvium		At-grade

Since installation, water levels and samples have been collected four times per year. Well CWR-2 has consistently been dry, thus no samples have been collected from this well. Table 3-23 summarizes the groundwater elevations measured in wells in 2014-2017.

Table 3-23: Monitoring Well Groundwater Elevations

	CWR-1	CWR-3	EWWC-1
Ground Surface Elevation, ft.*	9269	9157	9010
Stickup	2.5	2.5	0
March 18, 2014 GW Elevation, ft.	9232.1	9107.2	NR
May 9, 2014 GW Elevation, ft.	9232.1	9107.4	9003.5
August 19, 2014 GW Elevation, ft.	9232.1	9107.0	9003.1
November 5, 2014 GW Elevation, ft.	9232.0	9107.0	9002.9
March 24, 2015 GW Elevation, ft.	9232.1	9107.1	9003.0
May 6, 2015 GW Elevation, ft.	9232.0	9107.3	9003.2
August 19, 2015 GW Elevation, ft.	9232.0	9107.1	9003.0
November 11, 2015 GW Elevation, ft.	9232.0	NR	9002.8
April 14, 2016 GW Elevation, ft.	9232.1	9107.1	9003.2
May 11, 2016 GW Elevation, ft.	9232.0	9107.2	9003.0
August 10, 2016 GW Elevation, ft.	9232.0	9105.7	NR
November 11, 2016 GW Elevation, ft.	NR	NR	NR
April 10, 2017 GW Elevation, ft.	9232.2	9107.1	9002.9
May 8, 2017 GW Elevation, ft.	9232.2	9107.2	9003.2
August 8, 2017 GW Elevation, ft.	9232.1	9107.1	9002.8
November 9, 2017 GW Elevation, ft.	9232.0	9106.2	9002.2

* 1983 North American Datum
NR = Not recorded

As can be seen from Table 3-23, very little variation in the groundwater elevation is evident.

Sampling and analysis for metals has been completed up to four times a year from each well. Figures 3-40 through 3-43 summarize the results for cadmium, copper, lead, and zinc. For comparison, the charts include primary or secondary drinking water standards. In addition, surface water quality data from West Willow Creek is used to compare the concentrations in groundwater versus surface water. Surface water monitoring station WW-D was selected for the comparison. This location was selected because it is the first monitoring station downstream of the CWR that is regularly being monitored.

Monitoring well CRW-1 in waste rock at the northern edge of the CWR and upstream of the location where Nelson Tunnel discharges into West Willow Creek, while CRW-3 is located in the south center of the CWR. Cadmium and zinc concentrations are two to three orders of magnitude higher in CRW-3 than CRW-1. This may be due to both the effect of Nelson Tunnel discharge and/or waste rock on groundwater. Conversely, lead and copper concentrations, which are more pH sensitive, exhibit similar concentrations in wells CRW-1 and CRW-3.

Monitoring well EWWC-1, which is screened in alluvium just downstream of where West Willow and East Willow creeks join to form Willow Creek. Concentrations of metals in samples collected from EWWC-1 are similar to the concentrations from surface water monitoring station WW-D.

3.6 Sediment and Pore Water

Sediment samples have been collected from each of the four surface water monitoring stations in the Rio Grande from 2012 through 2017. From 2014-2017, pore water samples have also been collected at these locations. Samples were collected once per year, in August or early September.

Figures 3-44 through 3-47 display sediment concentrations of cadmium, copper, lead, and zinc over time at the four Rio Grande monitoring stations (RG-2, RG-4, RG-8, and RG-9). Sediment screening values published by EPA Region 4 (EPA, 2018a) are included on the charts for comparison. These screening values are typically used in the screening level step (Step 2) of an ecological risk assessment. Comparisons for the four metals include:

- Cadmium: Concentrations of cadmium in sediment samples collected from monitoring station RG-2, upstream of the Willow Creek confluence, are all below the screening value. Conversely, all of the sediment samples collected below Willow Creek had cadmium concentrations above the screening value, except one.
- Copper: All sediment samples collected exhibit copper concentrations well below the screening value. Samples from each monitoring station exhibit similar concentrations.
- Lead: Concentrations of lead in sediment samples collected from monitoring station RG-2 are all below the screening value. Fifteen of the eighteen sediment samples (83%) collected below Willow Creek had lead concentrations above the screening value.
- Zinc: All sediment samples collected exhibit zinc concentrations well below the screening value. Samples from RG-2 range in concentration from about 25 to 75 µg/L while samples from RG-4, RG-8, and RG-9 range in concentration from about 102 to 940 µg/L.

Figures 3-48 through 3-51 compare pore water concentrations of cadmium, copper, lead, and zinc over time. Pore water concentrations were compared to TVS, computed using pore water hardness. Table 3-24 summarizes the number of time pore water exceeded TVS for cadmium, copper, lead, and zinc.

Table 3-24: Pore Water Comparison to Colorado TVS Standards

Station	Cadmium		Copper		Lead		Zinc	
	n	>TVS	n	> TVS	n	> TVS	n	> TVS
RG-2	4	1	4	0	4	0	4	0
RG-4	4	3	4	0	4	0	4	3
RG-8	4	0	4	0	4	0	4	0
RG-9	4	1	4	0	4	1	4	1
Total	**16**	**5**	**16**	**0**	**16**	**1**	**16**	**4**

3.7 Waste Rock

In 2015, waste rock from the CWR pile was evaluated for acid generating potential, to provide information on whether the pile is a source of metal loading in West Willow Creek. Thirteen waste rock samples were collected during July. Refer to Figure 3-52 for sample locations. An additional four samples were collected about one mile north of the Site, in a location that was considered appropriate to represent background. Samples collected were 5-point composites, collected from the surface, and biased toward collecting smaller particle sizes. Each of the samples was split, with an aliquot sent to the EPA Region 8 ESAT laboratory and an aliquot sent to ACZ Laboratory in Steamboat Springs, Colorado. The EPA Region 8 ESAT laboratory analyzed the samples for total recoverable metals (EPA Methods 200.7 and 200.8) and mercury (EPA Method 7473 A).

Acid based accounting (ABA) and paste pH were analyzed at ACZ Laboratory in Steamboat Springs, Colorado. Results of the testing are shown in Table 3-25. The laboratory used the modified calculation method, which means it used sulfide sulfur (also referred to as pyritic sulfur) rather than total sulfur in the calculation of the acid potential.

Table 3-25: ABA Results and Paste pH

Sample ID	Neutralization Potential (NP) tons $CaCO_3$ /1000 ton	Acid Potential (AP) tons $CaCO_3$ /1000 ton	Net Neutralizing Potential (NNP = NP-AP)	Neutralizing Potential Ratio (NPR = NP/AP)	Paste pH
CRW-01	13.0	5.6	7.4	2.3	7.4
CRW-03	11.0	19.4	-8.4	0.6	6.1
CRW-05	10.0	5.6	4.4	1.8	6.4
CRW-07	14.0	2.2	11.8	6.4	7.4
CRW-09	4.0	18.1	-14.1	0.2	5.9
CRW-10	7.0	5.0	2.0	1.4	6
CRW-14	11.0	8.8	2.3	1.3	6.3
CRW-16	9.0	9.7	-0.7	0.9	6.4
CRW-18	7.0	11.9	-4.9	0.6	6.5
CRW-21	5.0	6.9	-1.9	0.7	5.6
CRW-23	9.0	6.9	2.1	1.3	6.3
CRW-25	8.0	6.6	1.4	1.2	6.3
CRW-27	5.0	5.0	0.0	1.0	6.1
BG-01	10.0	0.6	9.4	16.7	6.8
BG-02	10.0	0.9	9.1	11.1	6.9
BG-03	8.0	0.0	8.0	NM	7.2
BG-04	9.0	0.0	9.0	NM	7.2

NM = Not Meaningful
$CaCO_3$ = calcium carbonate

Net Neutralizing Potential (NNP) is evaluated as follows:

- If the NNP is greater than 20 kg/ton $CaCO_3$, it is generally accepted that the material is non-acid producing.
- If the NNP is less than –20 kg/ton $CaCO_3$, it is generally accepted that the material is acid producing.
- If NNP is > 0 the sample is potentially acid neutralizing
- if NNP is < 0 the sample is potentially acid generating

Neutralizing Potential Ratio (NPR) is evaluated as follows:

- If the NPR value is < 1, the material is considered acid producing.

- If the NPR value is > 3, the material is considered non-acid producing

Applying these evaluating principles to the data, five out of the 13 samples are likely acid producing. When considering spatial distribution of the data, a pattern is not discernable. Generally, the paste pH data appears to be correlated to NNP, which would be expected.

3.8 Air Sampling and Analysis

During August 2017, activity-based sampling (ABS) for air was conducted near the Site using two All-Terrain Vehicles (ATV). The purpose of the sampling was to reevaluate ABS sampling completed in 2010 for the RI. ABS simulated an ATV ride along the Bachelor Loop, one ATV lead and the other ATV followed. Two portable air samplers with attached SKC GS-3 respirable dust cyclones were mounted to each ATV. One sampler was set at a high flow pumping rate and the other was set to a low pumping rate and the air intake was mounted near the breathing zone of each rider. Inline filter cartridges were changed after 2 mg of sample had accumulated on the disc. Both total suspended particulates (TSP) and PM10 particles were collected. The PM10 data represent a subset of smaller, respirable particles of the total suspended particulate fraction. The air filters were analyzed by ICP-MS (mass spectrometer) which provided a significantly lower reporting limit (approximately 2 orders of magnitude lower). The results of those analysis are detailed in the October 16, 2017 ALS Global laboratory report (ALS, 2017).

Refer to Section 4 for a discussion of how the results of the ABS were used to re-evaluate human health risks associated with County Road 503.

3.9 Multi-Metric Index Bioassessment

Since 2012, macroinvertebrate samples were collected each year from Rio Grande surface water monitoring stations (RG-2, RG-4, RG-8, and RG-9). The samples were submitted to Timberline Aquatics for bioassessment. Beginning in 2014, the bioassessment included calculation of Multi-Metric Index (MMI) scores.

The State of Colorado developed the MMI Bioassessment Tool to provide a basis for a direct assessment of the health of aquatic communities. Multi-metric indices were calibrated for three biotypes in the State (mountains, transition, and plains/xeric) and numeric thresholds for attainment and impairment established. The Site biotype is “transition” and the thresholds for attainment and impairment are 45 and 34, respectively (CDPHE, 2017).

Table 3-26 summarizes the MMI scores from 2014 through 2017 at each of the four monitoring stations.

Table 3-26: MMI for Rio Grande Monitoring Stations

Station	2014	2015	2016	2017
RG-2	62.8	64.4	57.3	60.9
RG-4	63.7	66.1	68.1	74.2
RG-8	61.5	63.6	52.1	72.9
RG-9	66.1	58.4	65.9	73.6

Reference: EPA, 2015; EPA, 2016; EPA, 2017; EPA, 2018

All of the MMI scores are above the attainment threshold. Monitoring station RG-2 is located just upstream of the confluence of Willow Creek with the Rio Grande. In each year, the MMI score at RG-4, which is downstream of the Willow Creek and Rio Grande confluence, is higher than the score at RG-2. Based solely on the reported MMIs, it could be concluded that flow from Willow Creek is not degrading the macroinvertebrate community in the Rio Grande.

3.10 Surface Water Toxicity Testing

In April 2012, surface water samples were collected for toxicity testing. The purpose of the toxicity testing was to improve understanding of the chemistry and potential aquatic toxicity of metal contamination in Willow Creek and the Rio Grande associated with historical mining activities and to provide data to support ecological risk-based decisions for the Nelson Tunnel Mining Site.

Toxicity testing was also completed in 2010 for the Baseline Ecological Risk Assessment summarized in the RI report. The test results for the Rio Grande surface water samples were contradictory: RG-4 was non-toxic but RG-8 was toxic, even though RG-8 was located several miles downstream from RG-4. This toxicity testing event was conducted to reduce uncertainty regarding fish toxicity resulting from Willow Creek discharge into the Rio Grande.

A single surface water sample was collected from Willow Creek surface water monitoring stations W-I and W-J and samples were collected from surface water sampling stations RG-2, RG-4, and RG-8 on the Rio Grande. These samples represent the winter low flow conditions (i.e., before the May-June snowmelt period).

Ninety-six hour static toxicity tests were performed in April of 2012 at the EPA Region 8 Laboratory using juvenile rainbow trout (*Oncorhynchus mykiss*) to evaluate the acute toxicity of surface water samples collected from Willow Creek and from the Rio Grande. The following tests were performed:

- Samples from each of the three Rio Grande monitoring stations (RG-2, RG-4, and RG-8) were tested undiluted.
- A control test was completed at the same time using laboratory control water to verify the health of juvenile rainbow trout.
- The Willow Creek surface water aliquots (W-I/W-J) were serially diluted with either RG-2 (reference) water or the laboratory control water to determine the percentage of site water that causes acute toxicity to juvenile rainbow trout. The serial dilutions resulted in Willow Creek surface water samples of 50%, 25%, 12.5%, 6.25% and 3.125% strength.
- Control tests consisting of full-strength RG-2 and laboratory control water were also tested at the same time to evaluate whether dilution waters affected survival in the exposed fish.
- Reference toxicity tests were performed using laboratory control water spiked with zinc sulfate. The zinc concentrations were verified in the analytical laboratory using EPA Method 200.7/200.8. The following values present the average dissolved zinc concentrations:
    - 100% concentration (919 µg/L Zn)
    - 50% concentration (467 µg/L Zn)
    - 25% concentration (237 µg/L Zn)

- 12.5% concentration (118 µg/L Zn)
- 6.25% concentration (64 µg/L Zn)

Table 3-27 summarizes the results of the toxicity testing.

Table 3-27: Summary of 2012 Toxicity Testing

Location	Description	Survival
Rio Grande Toxicity Testing		
RG-2	Rio Grande upstream of Willow Creek confluence, undiluted	100%
RG-4	Rio Grande 1.5 miles downstream of Willow Creek confluence, undiluted	92.5%
RG-8	Rio Grande 5.5 miles downstream of Willow Creek confluence, undiluted	100%
Control	Laboratory Control Water	100%
Willow Creek Toxicity Testing – Water from RG-2 as Diluent		
W-I/W-J	3.125% West Willow Sample	90%
W-I/W-J	6.25% West Willow Sample	82.5%
W-I/W-J	12.5% West Willow Sample	82.5%
W-I/W-J	25% West Willow Sample	75%
W-I/W-J	50% West Willow Sample	20%
Control	Water collected from RG-2	95%
Willow Creek Toxicity Testing – Laboratory Control Water as Diluent		
W-I/W-J	3.125% West Willow Sample	97.5%
W-I/W-J	6.25% West Willow Sample	92.5%
W-I/W-J	12.5% West Willow Sample	90%
W-I/W-J	25% West Willow Sample	97.5%
W-I/W-J	50% West Willow Sample	62.5%
Control	Laboratory Control Water	87.5%
Reference Toxicity Tests		
6.25%	64 µg/L zinc	90%
12.5%	118 µg/L zinc	85%
25%	237 µg/L zinc	82.5%
50%	467 µg/L zinc	60%
100%	919 µg/L zinc	25%

Reference: EPA, 2013a

Rio Grande surface water toxicity test showed that no significant acute toxicity occurred to juvenile rainbow trout exposed to water samples collected downstream of the confluence with Willow Creek.

The results of the Willow Creek serial dilution toxicity tests showed that surface water from this creek was acutely toxic to juvenile rainbow trout under the conditions that prevailed in April 2012. Using the results from the tests that used RG-2 as the diluent, a half maximal effective concentration (EC_{50}) of 35.5% was computed. This value indicates that 50% of juvenile rainbow trout can be expected to die after 96 hours of exposure to a surface water mixture that contains 35.5% of Willow Creek water. This result is consistent with toxicity testing used for the Baseline Ecological Risk Assessment.

The toxicity of Willow Creek samples decreased when diluted with laboratory control water. However, the results of the control test using 100% laboratory control water did not meet the minimum acceptability criterion of 90% survival after 96 hours of exposure, so the results of the lab water serial dilution are considered an estimation.

The reference toxicity test data was used to compute a 96-hour EC_{50} for juvenile rainbow trout equal to 552.6 µg/L zinc.

4 Baseline Risk Assessment

In the RI Report for the Site, the HHRA concluded that the health risks to ATV riders exceeded EPA's risk criteria. Specifically,

- Inhalation of manganese indicated non-carcinogenic risks above EPA's Hazard Index (HI) of 1
- Inhalation of arsenic indicated non-carcinogenic risks above EPA's HI of 1
- Inhalation of lead resulted in blood lead levels exceeding EPA's goal of no more than a 5% chance of exceeding a blood lead level of 10 micrograms per deciliter (µg/dl)

These conclusions were based on ABS air data collected during ATV riding. Significantly, the air samples collected were analyzed by inductively coupled plasma atomic emission spectrometry. This method of analysis had higher than required reporting limits. Many of the results were reported as non-detects, however, the use of one half of the reporting limit as the value used in the risk calculations resulted in unacceptable risks. Due to the previous method of evaluation, it appeared likely that the risks were overestimated.

As described in Section 3-8, activity based air sampling while ATV riding was conducted again in the fall of 2017. Samples collected in 2017 were analyzed by inductively coupled plasma atomic mass spectrometry. Using the equations and exposure assumptions from the HHRA, EPA re-calculated the non-carcinogenic risks to both the reasonable maximum exposed (RME) adult and RME child ATV riders. A comparison of the results of the 2011 and 2017 human health risk calculations are shown in Table 4-1 below.

Table 4-1: Comparison of 2011 and 2017 Human Health Risk Calculations

Risks to Adult and Child ATV Riders					
Metal	**TSP Air ($\mu g/m^3$) 2011**	**TSP Air ($\mu g/m^3$) 2017**	**PM10 Air Concentrations* (µg/m3) 2017**	**Non-cancer risks (2011 RI Report)**	**Non-cancer risks (2017 data)**
Arsenic	4.8	0.1.8	0.61	HI = 1.8	HI= 0.23
Manganese	139	19	6.3	HI= 15.9	HI= 0.72
Lead	188	24	6.1	P10 = 11.5%	P5 < 0.1%

$\mu g/m^3$ = micrograms per cubic meter

Using the 2017 PM10 data analyzed by ICP-MS, the non-cancer risks are below the HI of 1.0 and are acceptable to EPA. The decrease in apparent risk is due to the lower detection and reporting limits available by ICP-MS, and the use of the respirable portion of the particulate concentrations as measured by the PM10 in the 2017 data.

Based on the RI Report, a geometric mean blood lead level of 5.5 µg/dL was calculated for the ATV rider with an 11.5% probability of exceeding a blood lead level of 10 µg/dl. At the time of the report, EPA's risk criteria was no more than a 5% probability of exceeding a 10 µg/dL blood lead level. In December 2016, EPA issued guidance which recommended an acceptable blood lead range of 2 – 8 µg/dL. Using the 2017 air sampling data, a geometric mean blood lead level of 1.0 μg/dL was calculated with no more than a 0.1% probability of exceeding a blood lead of 5 μg/dL.

Based on the ABS air data collected in 2017, risks to both adult and child ATV riders meet EPA’s risk criteria and are acceptable to EPA. Refer to Appendix E for the “Update on Risks from ATV Riding at the Nelson Tunnel Superfund Site”, dated February 5, 2019.

5 Conclusions

The RI listed 13 conclusions based on data and information available through 2011. Over the last six years, 2012-2017, additional data have been generated which modify the conclusions of the RI. This RI Addendum has summarized and evaluated this data.

Each of the RI conclusions are numbered and listed below in italics. Where appropriate, statements based on the 2012-2017 data which modify or amplify the conclusions are listed below. New conclusions from data collection activities are also included, and are numbered sequentially.

1. *Most water enters the Nelson Tunnel as ground water through faults and fractures in undifferentiated ash flow tuff bedrock. Radiocarbon dating of Nelson Tunnel water suggests a medial age on the scale of hundreds to thousands of years.*

There is uncertainty as to the source of the majority of the water entering into the Nelson-Wooster-Humphrey Tunnel.

- Craig Byington studied available data in 2012 and developed a conceptual water model where the recharge water, derived in large part from annual precipitation, moves along complex fracturing in the hanging wall of the Amethyst fault system and through old mine workings before entering the Nelson Tunnel.
- The University of Colorado Institute of Arctic and Alpine Research developed a conceptual water model in 2014 that hypothesizes that the primary source of Nelson Tunnel discharge is deep groundwater upwelling into sub-Nelson workings.

2. *A minor amount of surface water is known to enter the Nelson Tunnel at various locations via Mine workings that extend to the surface.*
3. *Since 2002, Nelson Tunnel portal discharge ranged between 200 and 380 gallons per minute. Most of this water is thought to enter the tunnel in its upper reaches.*
4. *The contaminants of concern (COCs) associated with human health include arsenic, chromium (VI), lead and manganese in CR-503 roadbase. The COCs associated with ecological risks include cadmium, copper, lead and zinc.*

Based on risk assessment using ABS air data collected in 2017, risks to both adult and child ATV riders on CR-503 meet EPA's risk criteria and are acceptable to EPA.

5. *Oxidation of sulfide minerals release cadmium and zinc to Mine pool water. Metals in the water column are transported by advection to West Willow and Willow Creeks and the Rio Grande.*
6. *West Willow and Willow Creeks and the Rio Grande are currently in compliance with TVS. However, Segment 4 of the Rio Grande exceeds the TVS for cadmium and zinc underlying the current temporary modification and is on the 303(d) List of impaired waters.*

Segment 4a of the Rio Grande is on Colorado's 303(d) list of impaired waters for lead and Segment 7 is on the 303(d) list for copper, cadmium, lead, and zinc (CDPHE, 2018).

The following summarizes the comparison of cadmium, copper, lead, manganese, and zinc concentrations to TVS:

- Cadmium: Concentrations exceed TVS in all samples collected in West Willow and Willow Creeks, including samples collected upstream of Nelson Tunnel. In the Rio Grande, 91% of samples collected downstream of the confluence with Willow Creek exceeded TVS, while none of the samples collected upstream of that confluence exceeded TVS.
- Copper: During high flow, concentrations exceed TVS about 40% of the time upstream and downstream of the Nelson Tunnel inflow in West Willow Creek and in Willow Creek. During low flow, none of the samples collected upstream of Nelson Tunnel exceeded TVS, while slightly more exceeded TVS in West Willow Creek than Willow Creek (23% and 18%). In the Rio Grande, none of the samples exceeded TVS.
- Lead: Concentrations exceeded TVS in all samples collected in West Willow and Willow Creeks, including samples collected upstream of Nelson Tunnel. In the Rio Grande, during high flow, none of the lead concentrations downstream of the confluence with Willow Creek exceeded TVS, while 19% during low flow exceeded TVS. None of the samples collected upstream of that confluence exceeded TVS.
- Manganese: Manganese concentration were below the TVS in all Willow, West Willow, and Rio Grande measurements during high flow. The TVS is exceeded in 55% of the low flow samples collected in West Willow Creek and 12% of the low flow samples collected in Willow Creek. All of the exceedances in Willow Creek occurred at WSN. In the Rio Grande, one samples out of 26 exceeded the TVS downstream of the Willow Creek confluence and, based on the concentration, is likely due to an error.
- Zinc: Concentrations exceed TVS in all samples collected in West Willow and Willow Creeks, including samples collected upstream of Nelson Tunnel. In the Rio Grande, TVS during high and low flow was exceeded in 78% and 92% of the samples collected, respectively. None of the samples collected upstream of Willow Creek exceeded TVS.

7. *The Nelson Tunnel portal discharge is the largest known point source of cadmium and zinc load to West Willow Creek, Willow Creek, and Segment 4 of the Rio Grande.*
8. *In periods of the year when low flows are observed (August to mid-May), the Nelson Tunnel contributes approximately 11-48% and 22-78% of the highest load of cadmium and zinc, respectively, measured in Willow Creek. During high-runoff periods (mid-May to July), the Nelson Tunnel contributes between 19-39% and 30-55% of cadmium and zinc loads, respectively. Therefore, the Nelson Tunnel is not always the primary source of zinc and cadmium load in Willow Creek or the Rio Grande.*
9. *Additional cadmium and zinc load are introduced to Willow Creek, primarily along the floodplain below Creede. However, additional metal load has also been observed entering West Willow Creek between stations WW-E through WW-A. Under most flow conditions, the sum of these contributions exceeds the metals load introduced by the Nelson Tunnel portal discharge.*

The following summarizes the information on the cadmium, copper, lead, and zinc load contributions to Willow Creek and the Rio Grande, modifying the characterization of surface water impacts from Nelson Tunnel discharge described in Paragraphs 8 and 9:

- Cadmium: On average, 59% of the cadmium load exiting Willow Creek can be attributed to Nelson Tunnel. In the Rio Grande, the average load above Willow Creek is about 10% of the load below Willow Creek.
- Copper: The average copper load from Nelson Tunnel is 119% and 66% of the average load exiting Willow Creek during high and low flow, respectively. Copper is relatively pH sensitive and it is likely that some of the load from Nelson Tunnel precipitates as the pH rises downstream of Nelson Tunnel. In the Rio Grande, loads measured at RG-2 average 66% of the copper load below Willow Creek. Note that copper does not exceed the TVS in the Rio Grande.
- Lead: The average lead load from Nelson Tunnel is 147% and 416% of the average load exiting Willow Creek during high and low flow, respectively. Lead is pH sensitive and it is apparent that some of the load from Nelson Tunnel precipitates as the pH rises downstream of Nelson Tunnel. In the Rio Grande, loads measured at RG-2 average less than 10% of the lead load below Willow Creek.
- Manganese: The average manganese load from Nelson Tunnel is 125% and 198% of the average load exiting Willow Creek during high and low flow, respectively. In the Rio Grande, loads measured at RG-2 average 66% of the manganese load at RG-4, below the confluence with Willow Creek.
- Zinc: The average zinc load from Nelson Tunnel is 56% and 78% of the average load exiting Willow Creek during high and low flow, respectively. In the Rio Grande, loads measured at RG-2 average less than 5% of the zinc load below the confluence with Willow Creek.

10. *For the adult and child rock hunter, cancer risks and non-cancer effects (including from lead) are below a level of concern.*
11. *For the adult and child ATV rider, non-cancer effects (including from lead) are above a level of concern. Cancer risks are below a level of concern.*

Based on the ABS data collected in 2017, risks to both adult and child ATV riders meet EPA's risk criteria and are acceptable.

12. *The weight of evidence indicates ecological risks above a level of concern for aquatic and some terrestrial receptors from exposure to sediment, water and aquatic plants in Willow Creek at and downstream of the Site. Risks to most terrestrial receptors are hypothetical given their food sources (e.g. fish) are not present in Willow Creek.*
13. *A benthic survey of the Rio Grande below the confluence with Willow Creek indicates relatively mild mine-related impacts to invertebrates. Impacts to other aquatic receptors in the Rio Grande were based on methods other than population surveys (e.g. site-specific toxicity study for fish). The weight of evidence indicates the potential for ecological risks above a level of concern for water column invertebrates, trout, and aquatic insectivorous birds.*

In 2012, toxicity testing was conducted using waters collected from Willow Creek and the Rio Grande downstream of the confluence with Willow Creek to evaluate aquatic toxicity of metals contamination in Willow Creek and the Rio Grande associated with historical mining activities. The following conclusions were reached:

- In Willow Creek, serial dilution toxicity tests showed that surface water from this creek was acutely toxic to juvenile rainbow trout under the conditions that prevailed in April 2012.
- Rio Grande surface water toxicity test showed that no significant acute toxicity occurred to juvenile rainbow trout exposed to water samples collected downstream of the confluence with Willow Creek.

14. Based on evaluation of the autosampler data collected downstream of the CWR, it is likely that significant rain events cause precipitated metals to become suspended, increasing the load within the stream. The CWR is likely a major source.
15. Diel sampling performed 2016 and August 2017 indicate that cadmium, manganese and zinc exhibit distinct diel variation, with the minimum concentrations occurring mid-day and the maximum concentrations occurring before sunrise and after sunset. Zinc exhibited the greatest variation: on average the dissolved zinc concentration was nearly four times greater before sunrise than late in the afternoon. Diel variation was not apparent in the concentrations of copper, iron, and lead.
16. Four monitoring wells were installed in 2013. Since installation, water levels and samples have been collected four times per year in three wells; one well (CRW-2) has been consistently dry. Monitoring well CRW-1 is screened in waste rock at the northern edge of the CWR and upstream of the location where Nelson Tunnel discharges into West Willow Creek, while CRW-3 is located in the south center of the CWR. Cadmium and zinc concentrations are two to three orders of magnitude higher in CRW-3 than CRW-1. This may be due to both the effect of Nelson Tunnel discharge and/or waste rock on groundwater. Conversely, lead and copper concentrations, which are more pH sensitive, exhibit similar concentrations in wells CRW-1 and CRW-3. Monitoring well EWWC-1, which is screened in alluvium just downstream of where West Willow and East Willow creeks join to form Willow Creek. Concentrations of metals in samples collected from EWWC-1 are similar to concentrations from nearby surface water monitoring station WW-D, suggesting that it is influenced by surface water.
17. Evaluation of sediment data collected from the Rio Grande monitoring stations suggest that discharge from Willow Creek has increased cadmium and lead concentrations to a level above EPA screening values. Zinc concentrations in sediment also indicate an increase downstream of Willow Creek, but to a level that does not exceed the screening values. Concentrations of copper in sediment were similar upstream and downstream of Willow Creek.
18. Pore water samples were collected from the Rio Grande monitoring stations and concentrations of metals in pore water were compared to TVS. None of the lead or copper pore water samples exhibited concentrations above TVS. Cadmium concentrations exceeded TVS is 25% of samples collected at RG-2 and 25% of

samples downstream of Willow Creek. Zinc concentrations exceeded TVS in 25% of samples.

19. In 2015, waste rock from the CWR pile was evaluated for acid generating potential. Five out of the 13 samples were found to be likely acid producing. When considering spatial distribution of the data collected across the CWR, a pattern is not discernable.
20. Bioassessment of macroinvertebrate samples collected at the Rio Grande surface water monitoring stations using MMI scoring was completed from 2014-2017.   All of the MMI scores are above the threshold for attainment, indicating the aquatic communities at the Rio Grande monitoring stations are not impaired.

6 References

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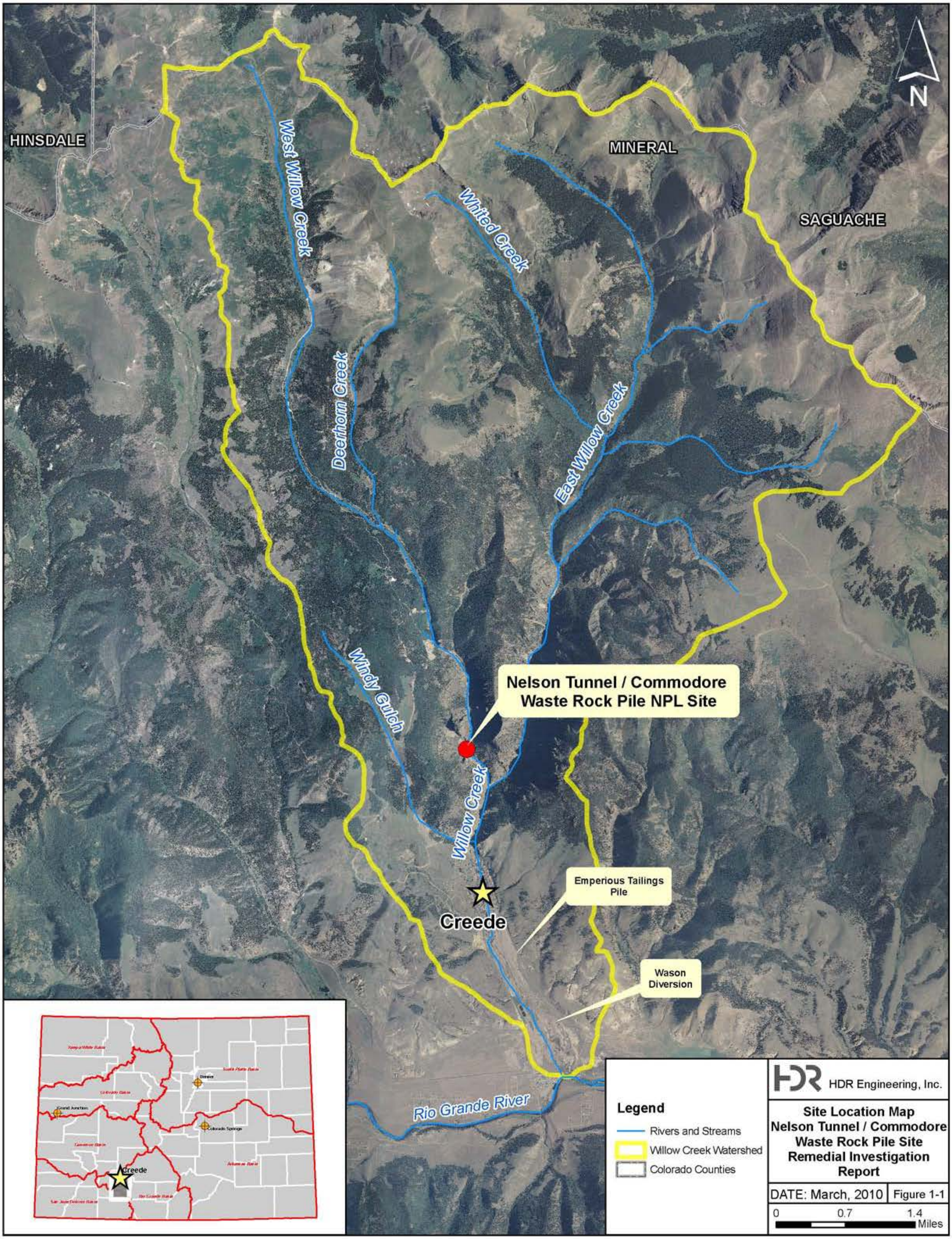
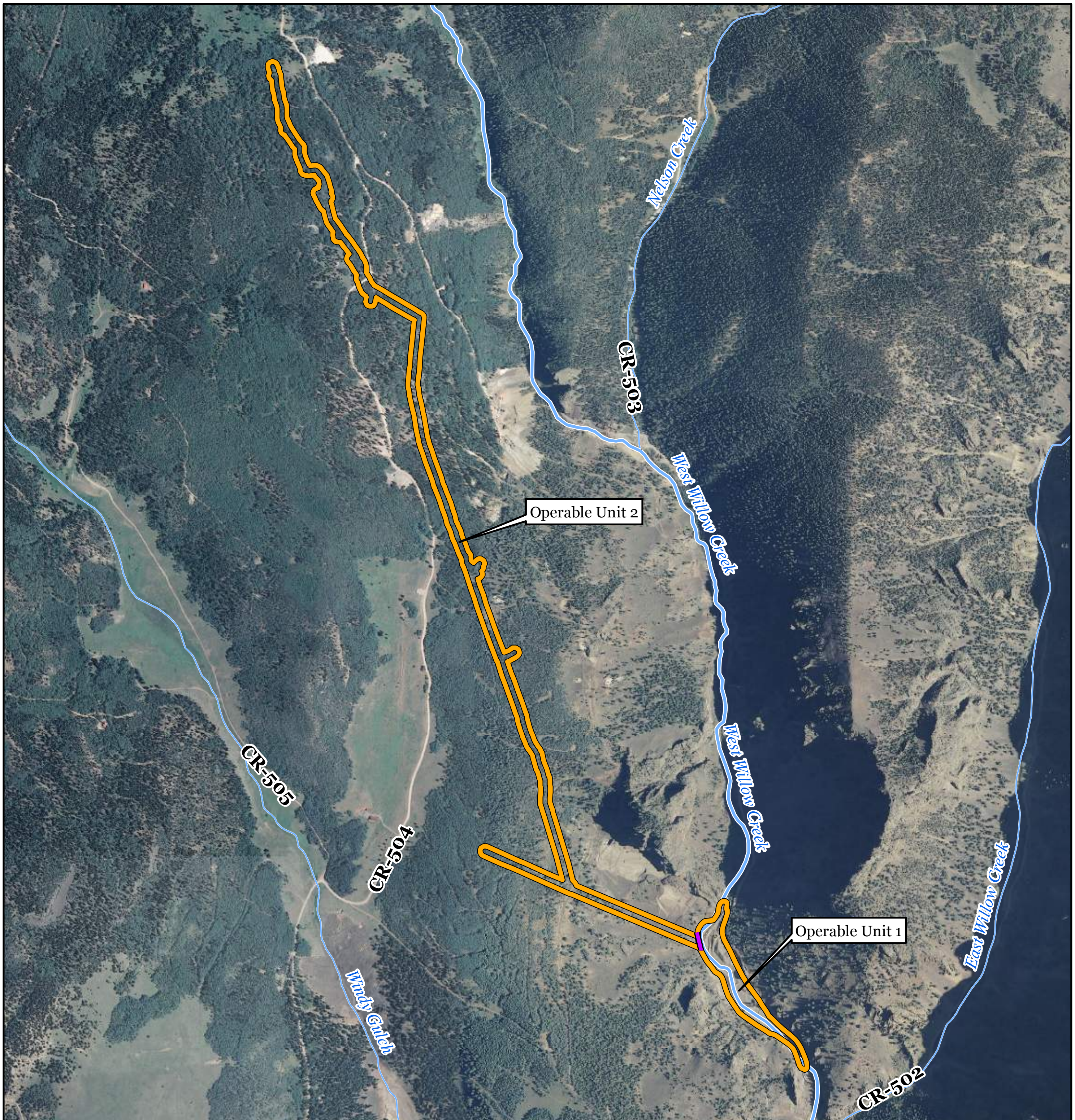
Figures


HINSDALE
MINERAL
SAGUACHE
N
West Willow Creek
Whited Creek
Deerhorn Creek
East Willow Creek
Windy Gulch
Willow Creek
Nelson Tunnel / Commodore Waste Rock Pile NPL Site
Emperious Tailings Pile
Creede
Wason Diversion
Rio Grande River
Denver
Grand Junction
Colorado Springs
Creede
Legend
Rivers and Streams
Willow Creek Watershed
Colorado Counties
HDR Engineering, Inc.
Site Location Map
Nelson Tunnel / Commodore Waste Rock Pile Site
Remedial Investigation Report
DATE: March, 2010
Figure 1-1
0 0.7 1.4 Miles



Nelson Tunnel/Commodore Waste Rock NPL Site
Operable Units
Mineral County, Colorado

FIGURE 1-2

NPL & Operable Unit Boundaries

OU Boundary

River

*ICs do not exist for this site

0 1,000 2,000 Feet

0 250 500 Meters

N

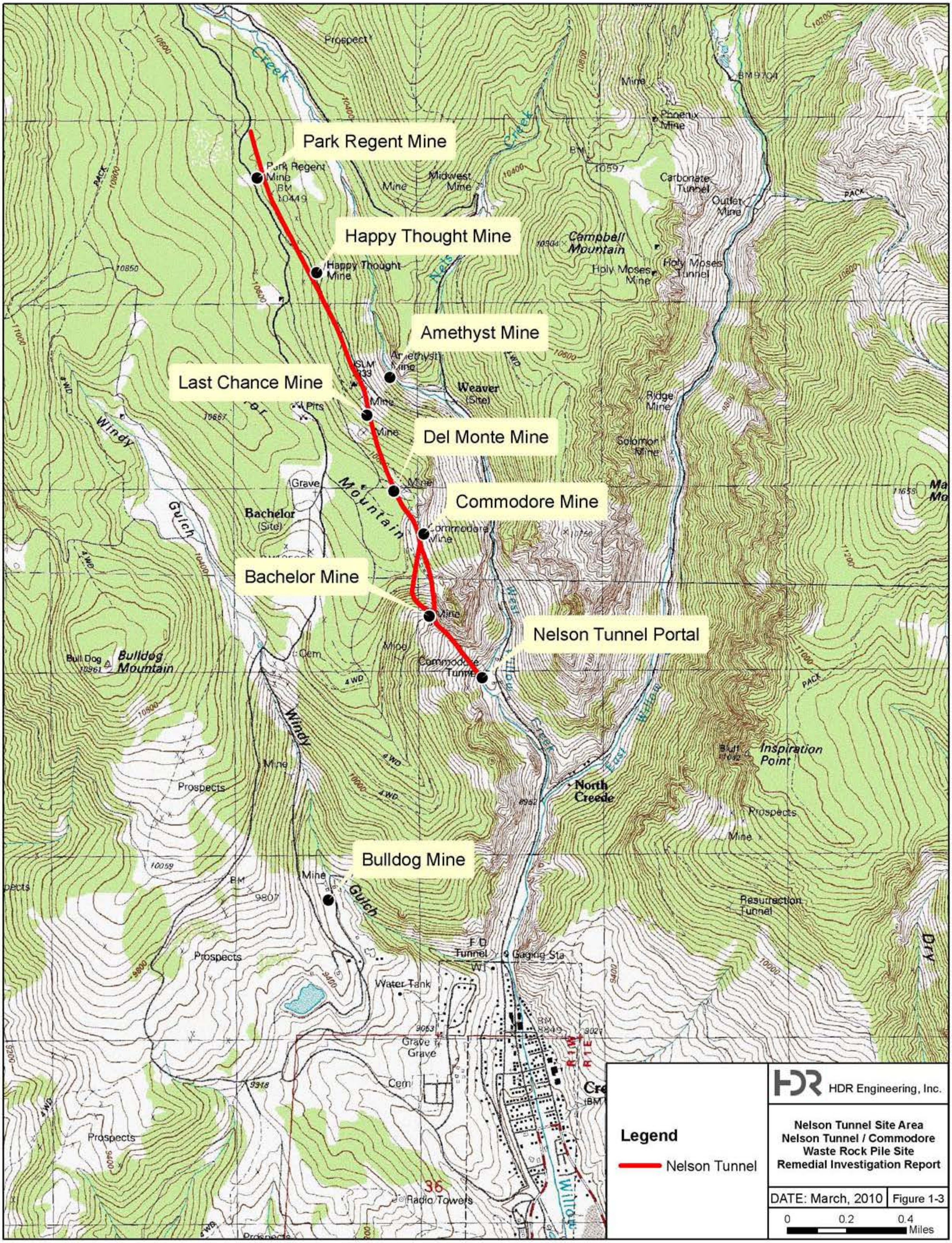
Map Date: April 16, 2012

Map Projection: UTM, Meters, 13 North, NAD83
Data Sources: *Boundaries* - U.S. EPA Region 8 (2012);
Imagery - USDA NAIP 1-meter aerial photo (2009).

Colorado

Area Enlarged

*Boundaries are based on the nature and extent of contamination and are subject to change.

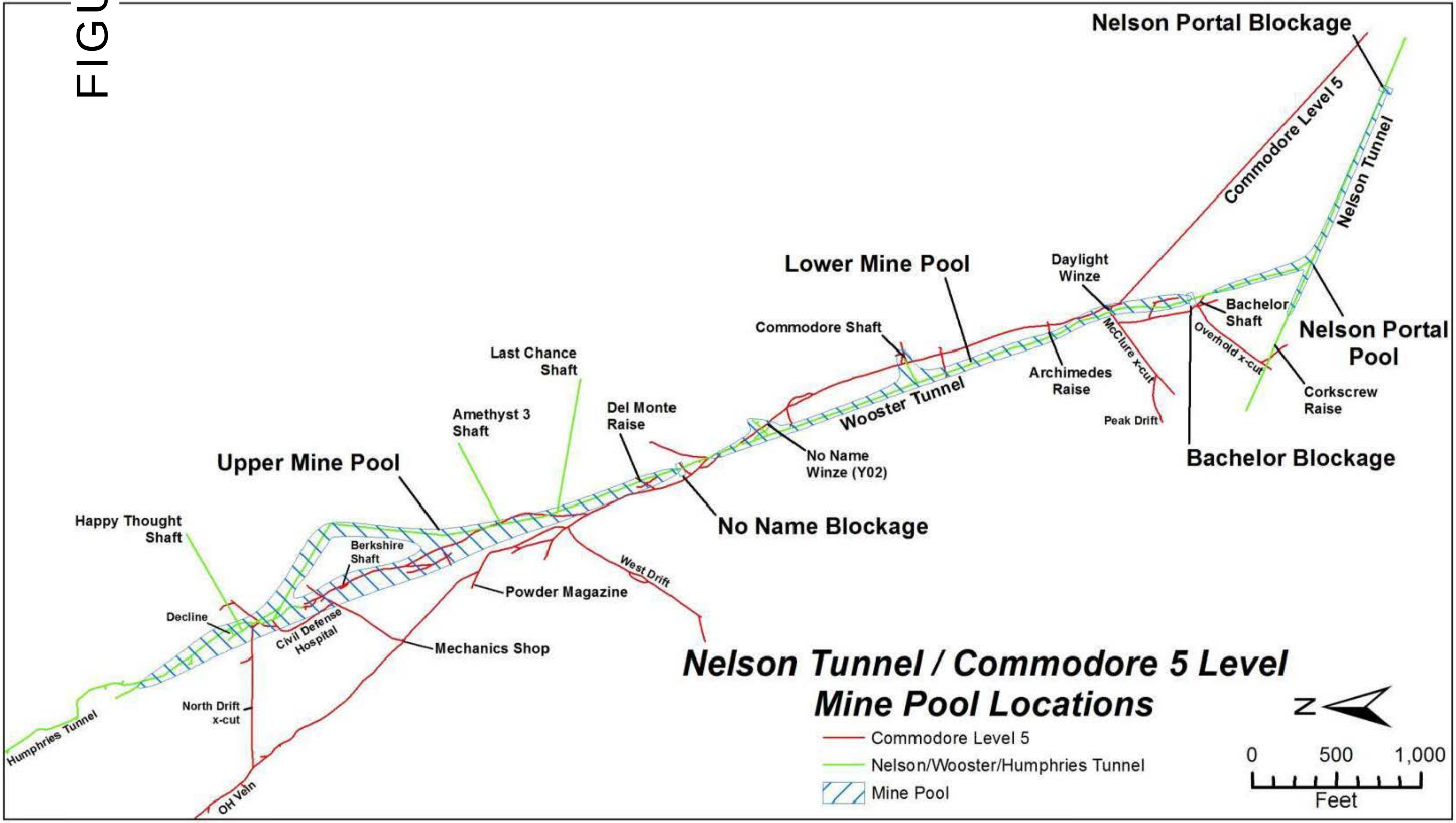


HDR Engineering, Inc.

Nelson Tunnel Site Area
Nelson Tunnel / Commodore Waste Rock Pile Site
Remedial Investigation Report

DATE: March, 2010 | Figure 1-3

FIGURE 2-



Nelson Tunnel / Commodore 5 Level
Mine Pool Locations
Nelson Portal Blockage
Commodore Level 5
Nelson Tunnel
Lower Mine Pool
Daylight Winze
Bachelor Shaft
Nelson Portal Pool
Commodore Shaft
Last Chance Shaft
Archimedes Raise
McClure x-cut
Overhold x-cut
Corkscrew Raise
Wooster Tunnel
Peak Drift
Amethyst 3 Shaft
Del Monte Raise
No Name Winze (Y02)
Bachelor Blockage
Upper Mine Pool
No Name Blockage
Happy Thought Shaft
Berkshire Shaft
West Drift
Powder Magazine
Decline
Civil Defense Hospital
Mechanics Shop
North Drift x-cut
Humphries Tunnel
OH Vein
Commodore Level 5
Nelson/Wooster/Humphries Tunnel
Mine Pool
N
0
500
1,000
Feet

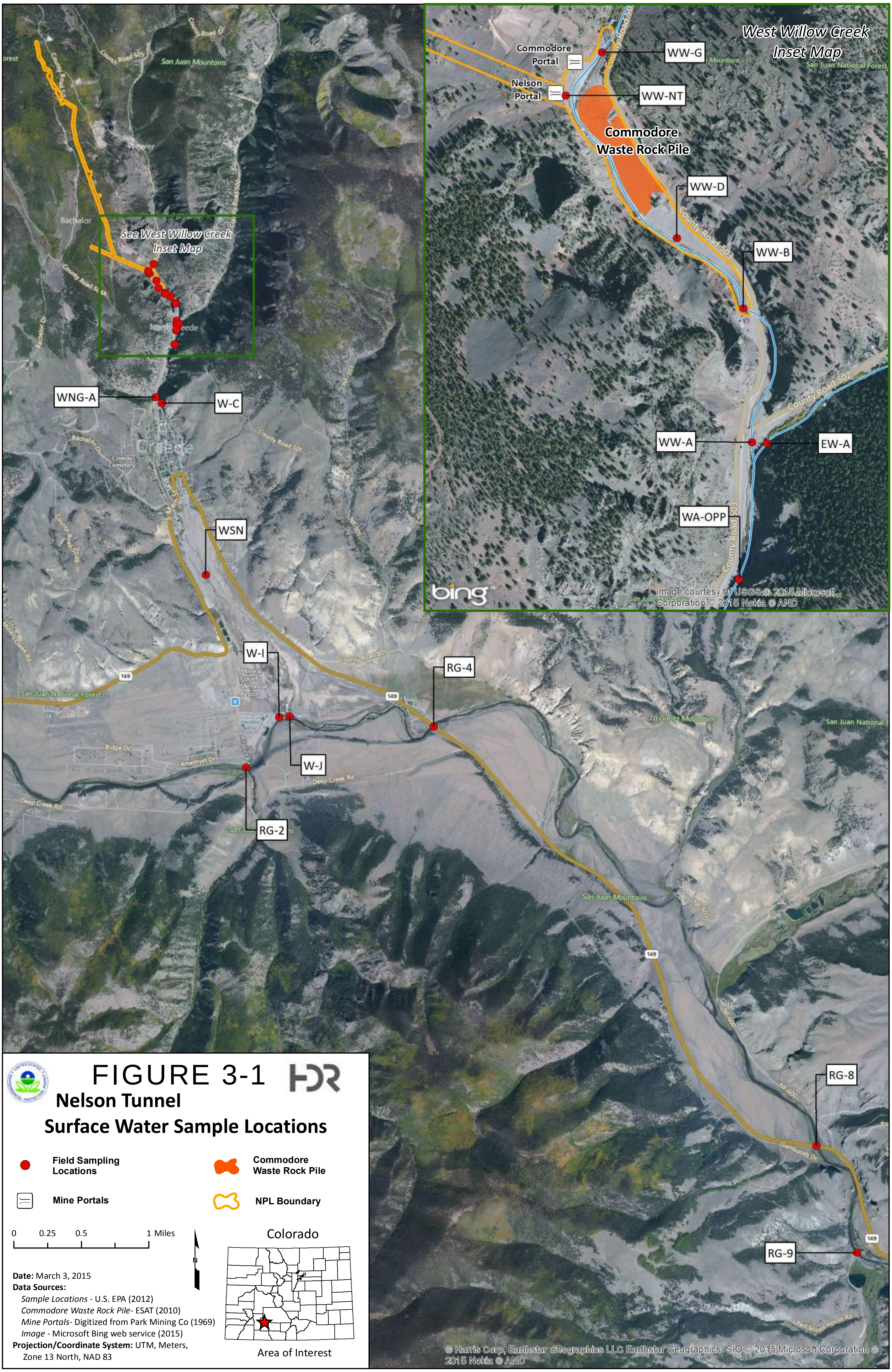


FIGURE 3-1
Nelson Tunnel
Surface Water Sample Locations

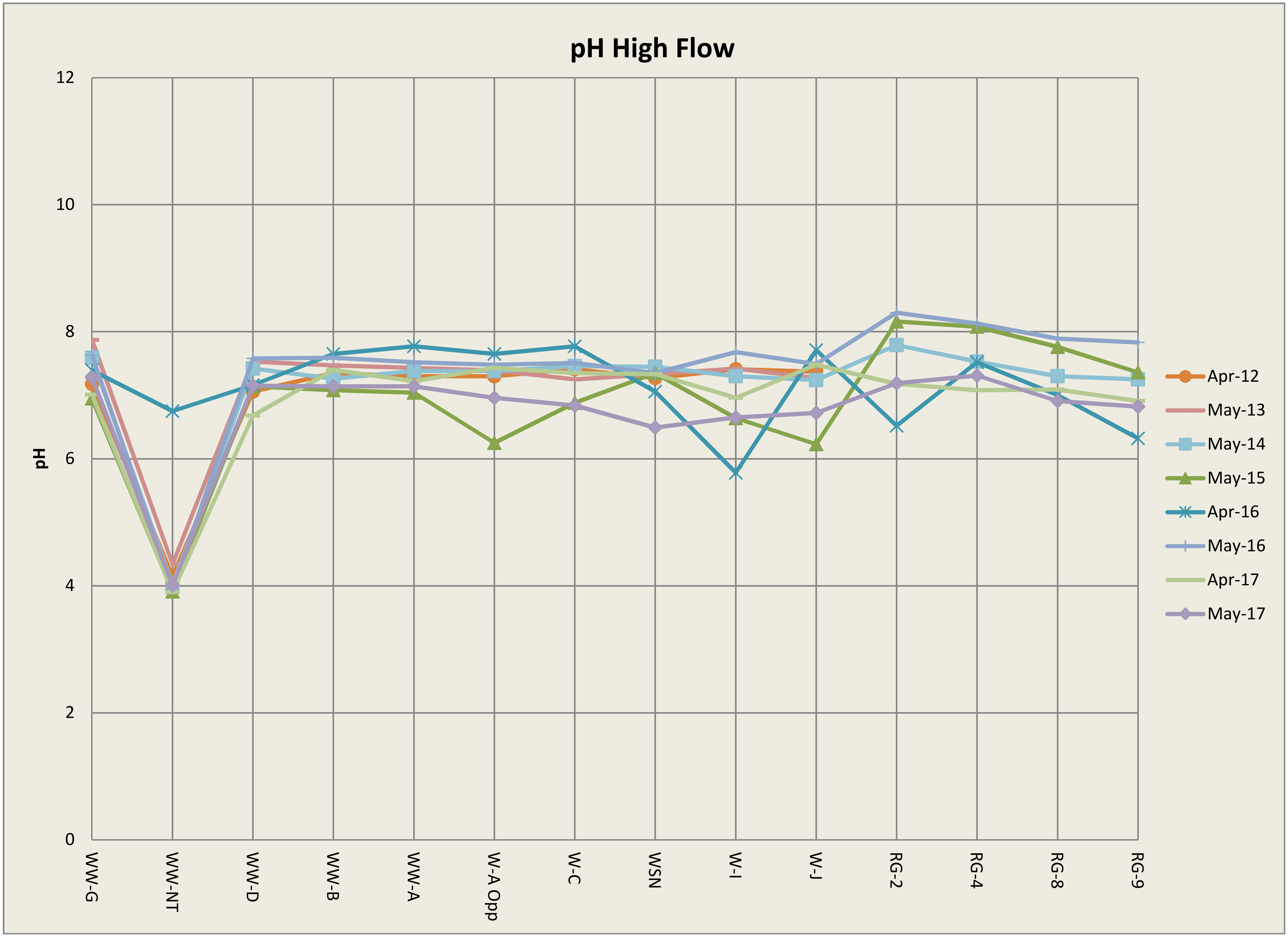

pH High Flow
pH
0
2
4
6
8
10
12
WW-G
WW-NT
WW-D
WW-B
WW-A
W-A Opp
W-C
WSN
W-I
W-J
RG-2
RG-4
RG-8
RG-9
Apr-12
May-13
May-14
May-15
Apr-16
May-16
Apr-17
May-17

Figure 3-2

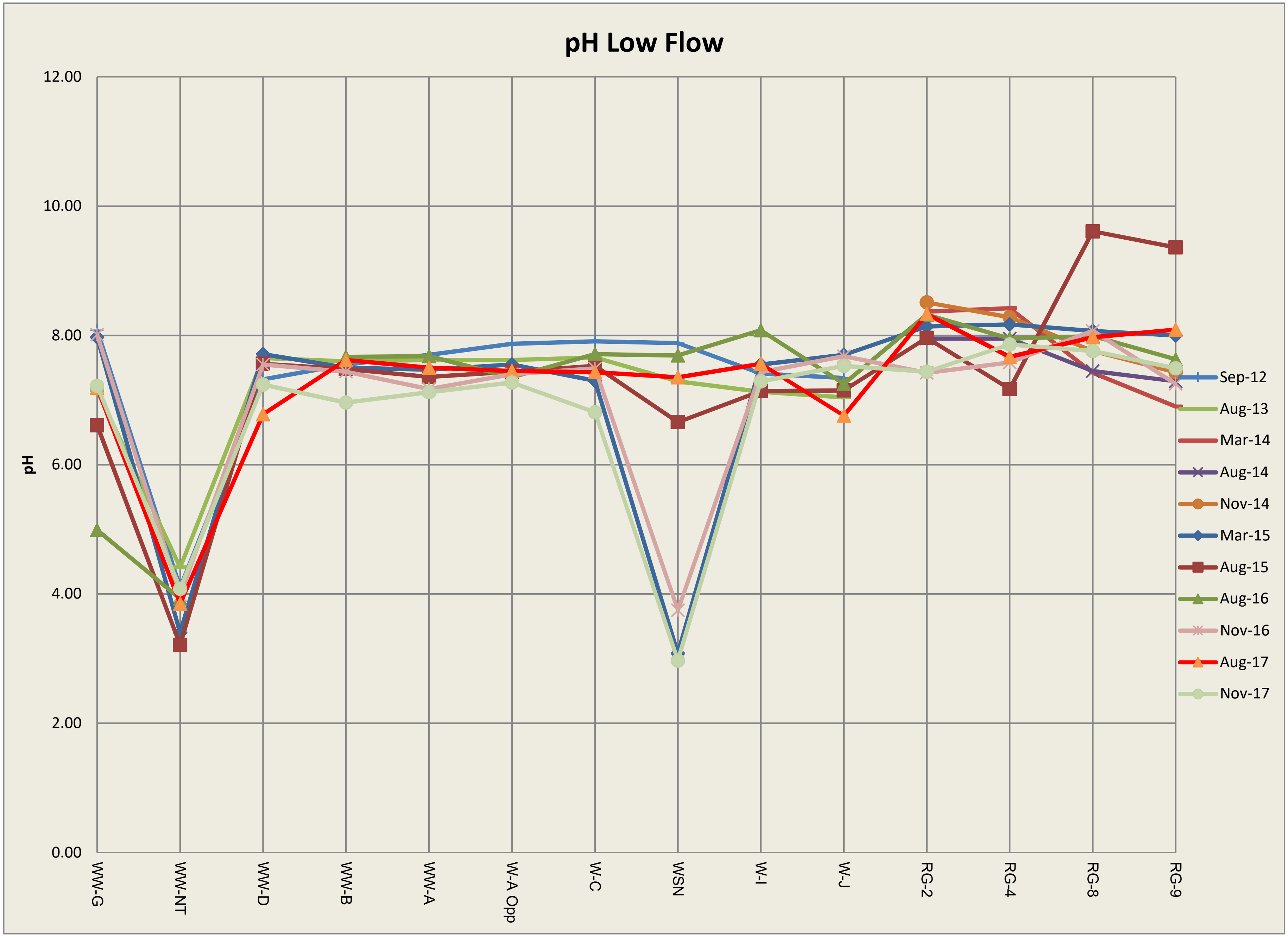

pH Low Flow
12.00
10.00
8.00
6.00
4.00
2.00
0.00
pH
WW-G
WW-NT
WW-D
WW-B
WW-A
W-A Opp
W-C
WSN
W-I
W-J
RG-2
RG-4
RG-8
RG-9
Sep-12
Aug-13
Mar-14
Aug-14
Nov-14
Mar-15
Aug-15
Aug-16
Nov-16
Aug-17
Nov-17

Figure 3-3

West Willow and Willow Creeks

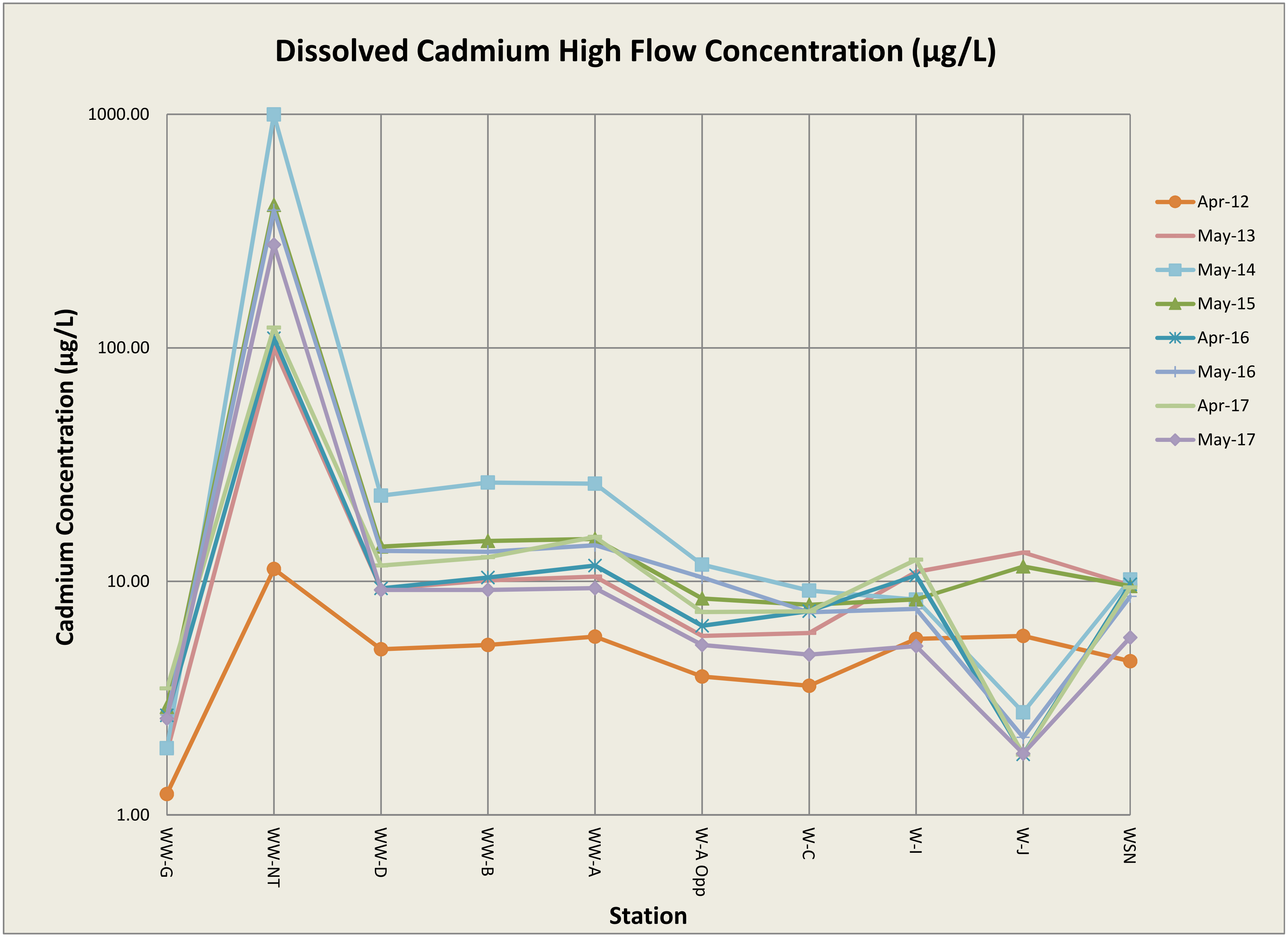


Figure 3-4

West Willow and Willow Creeks

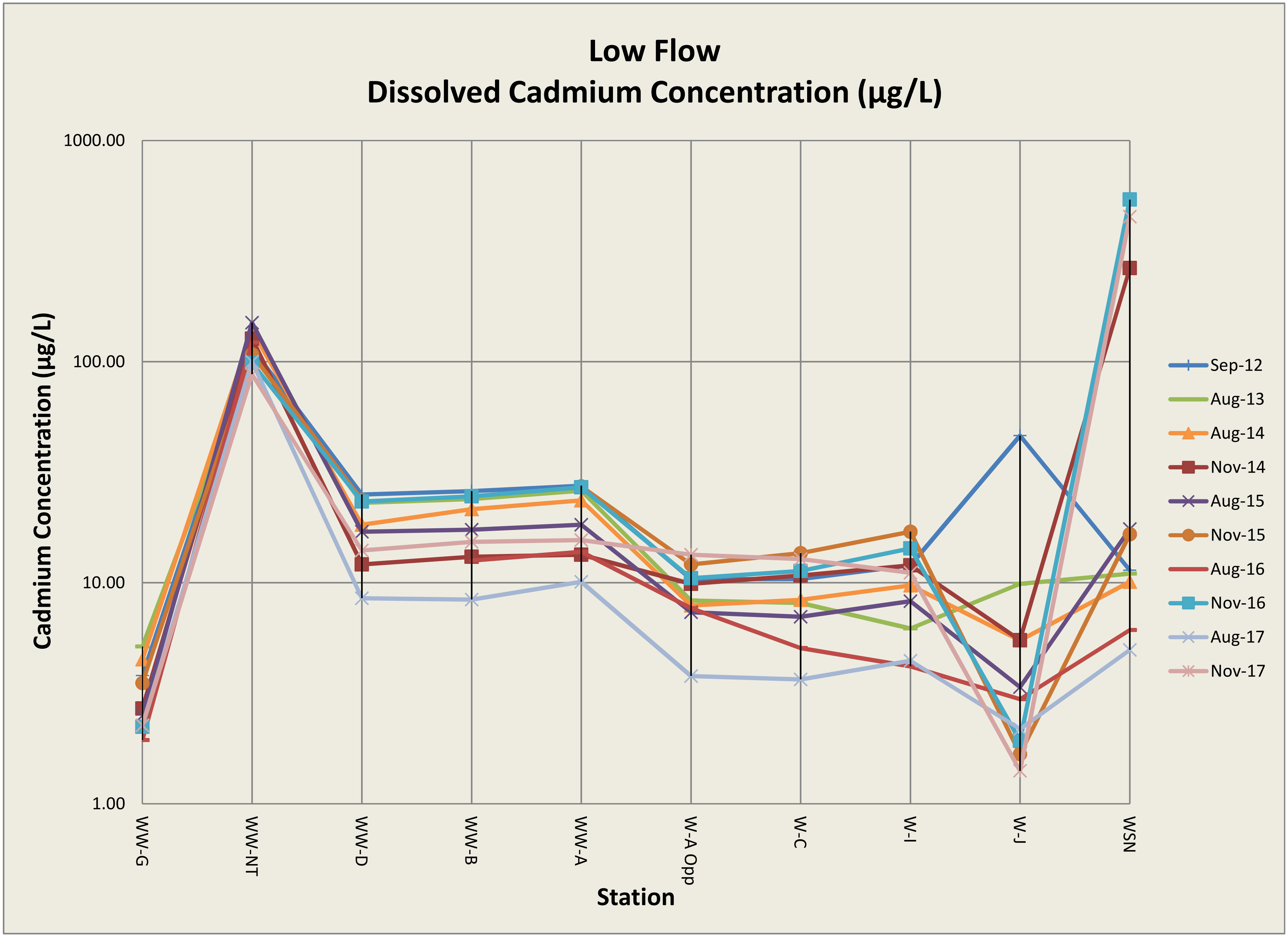


Figure 3-5

West Willow and Willow Creeks

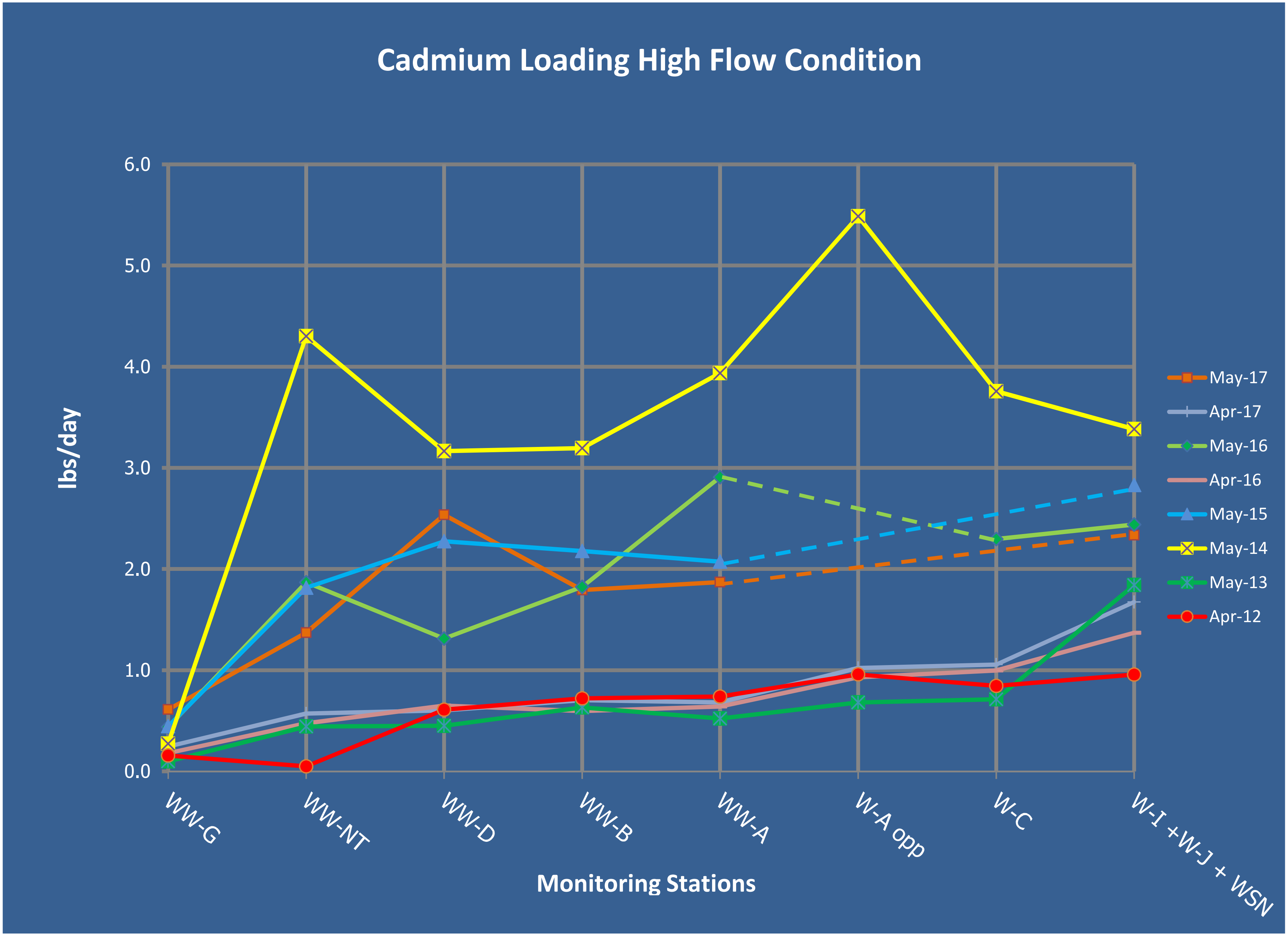


Figure 3-6

West Willow and Willow Creeks

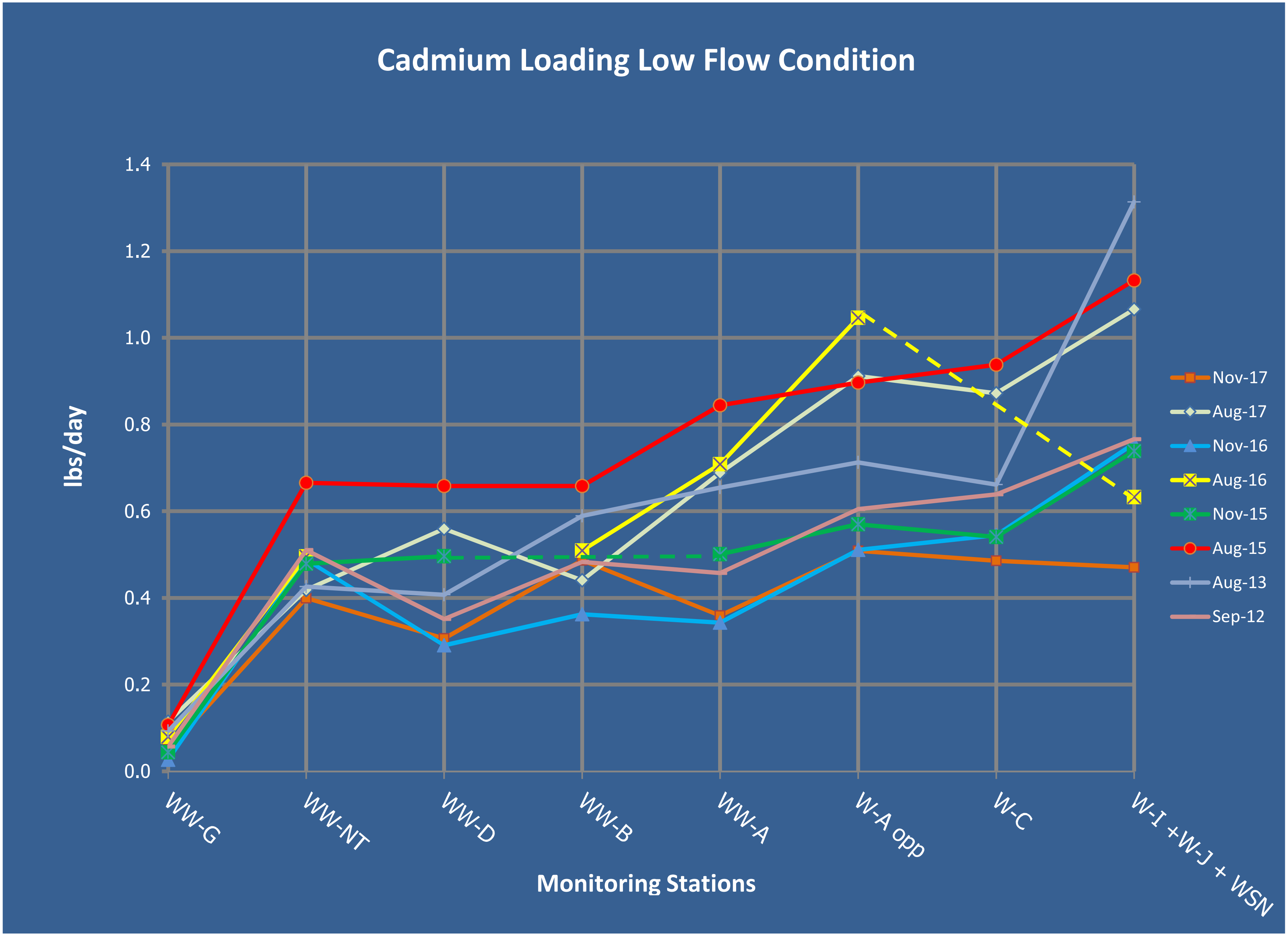


Figure 3-7

West Willow and Willow Creeks

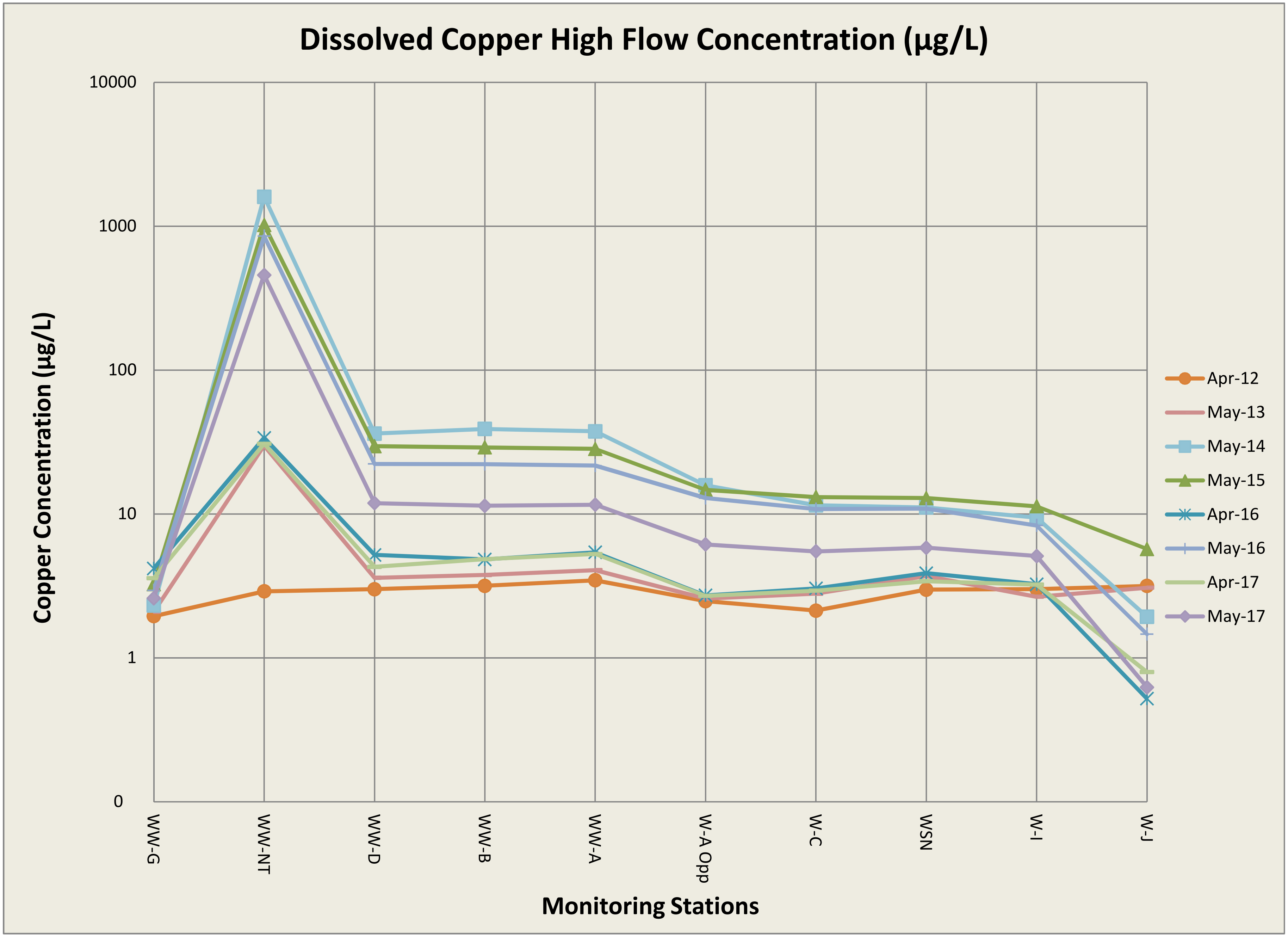


Figure 3-8

West Willow and Willow Creeks

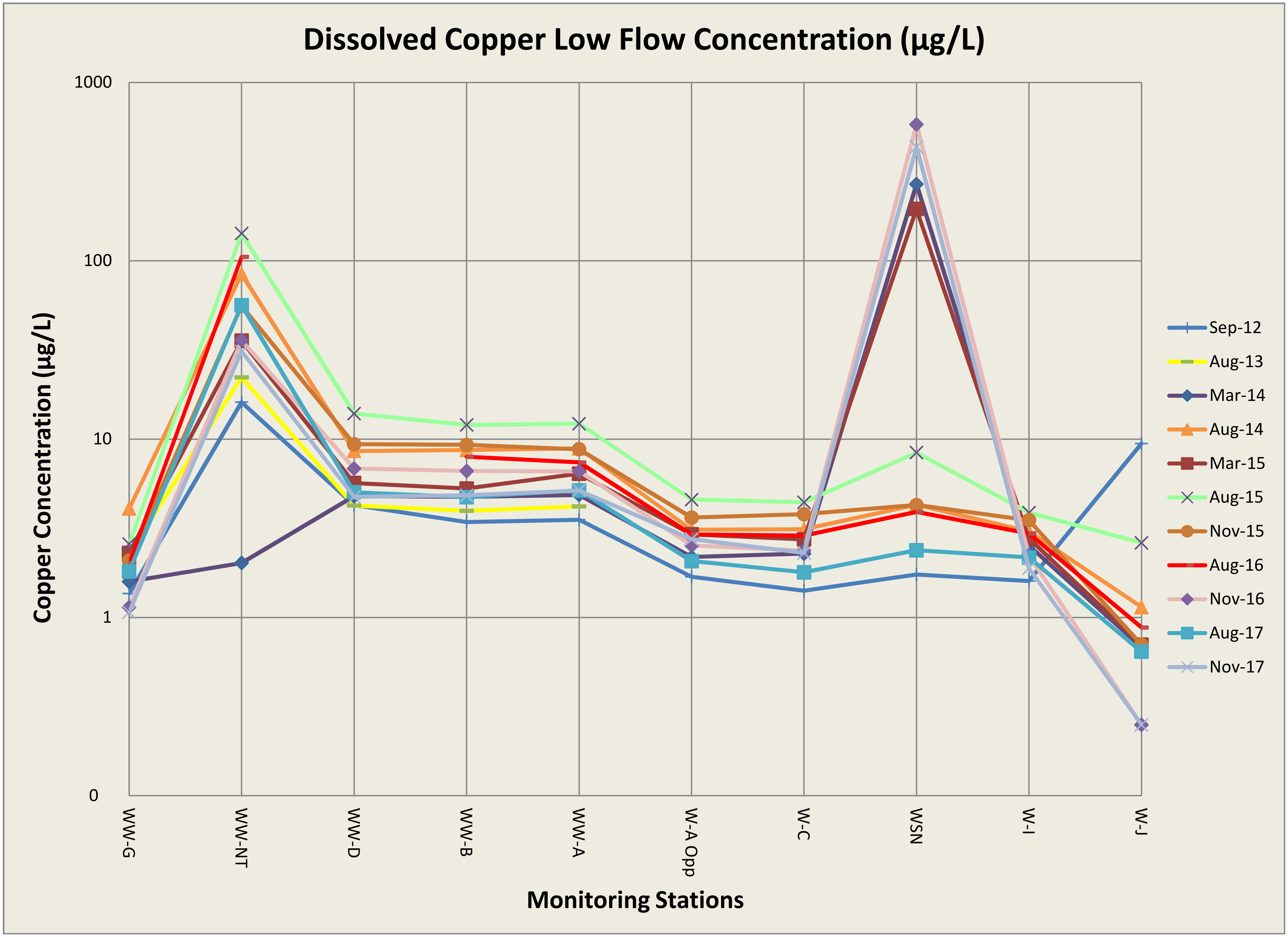


Figure 3-9

West Willow and Willow Creeks

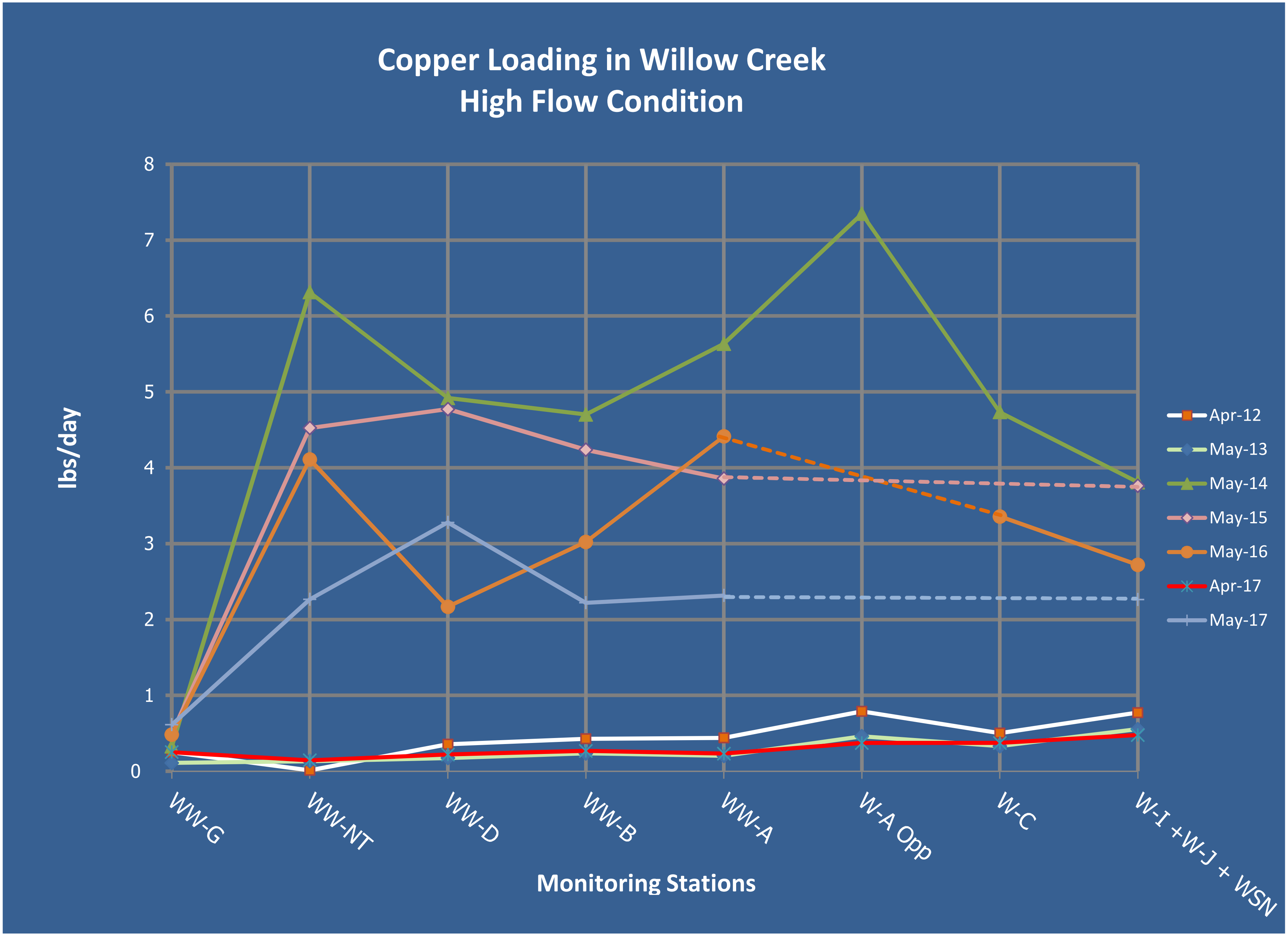


Figure 3-10

West Willow and Willow Creeks

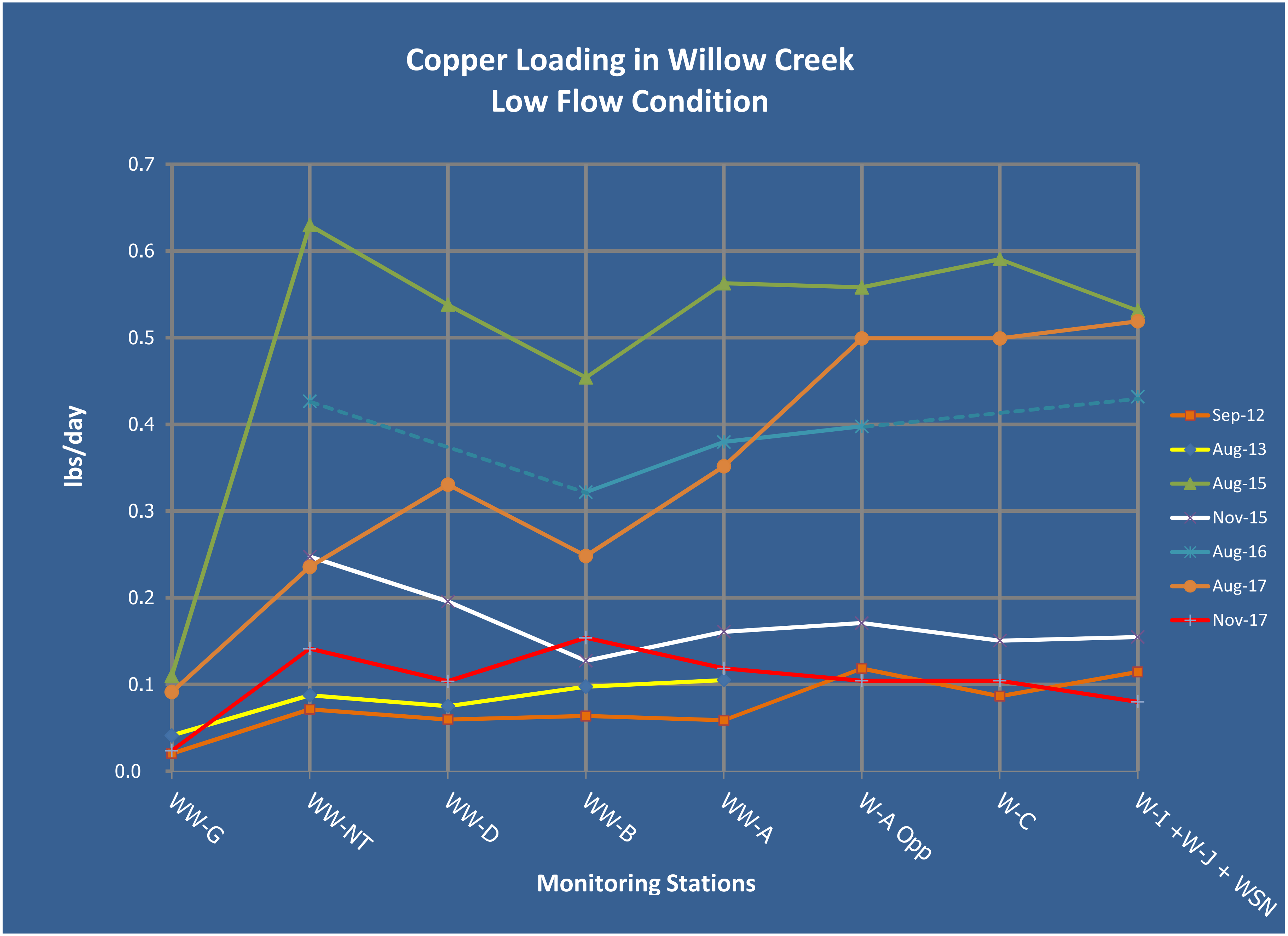


Figure 3-11

West Willow and Willow Creeks

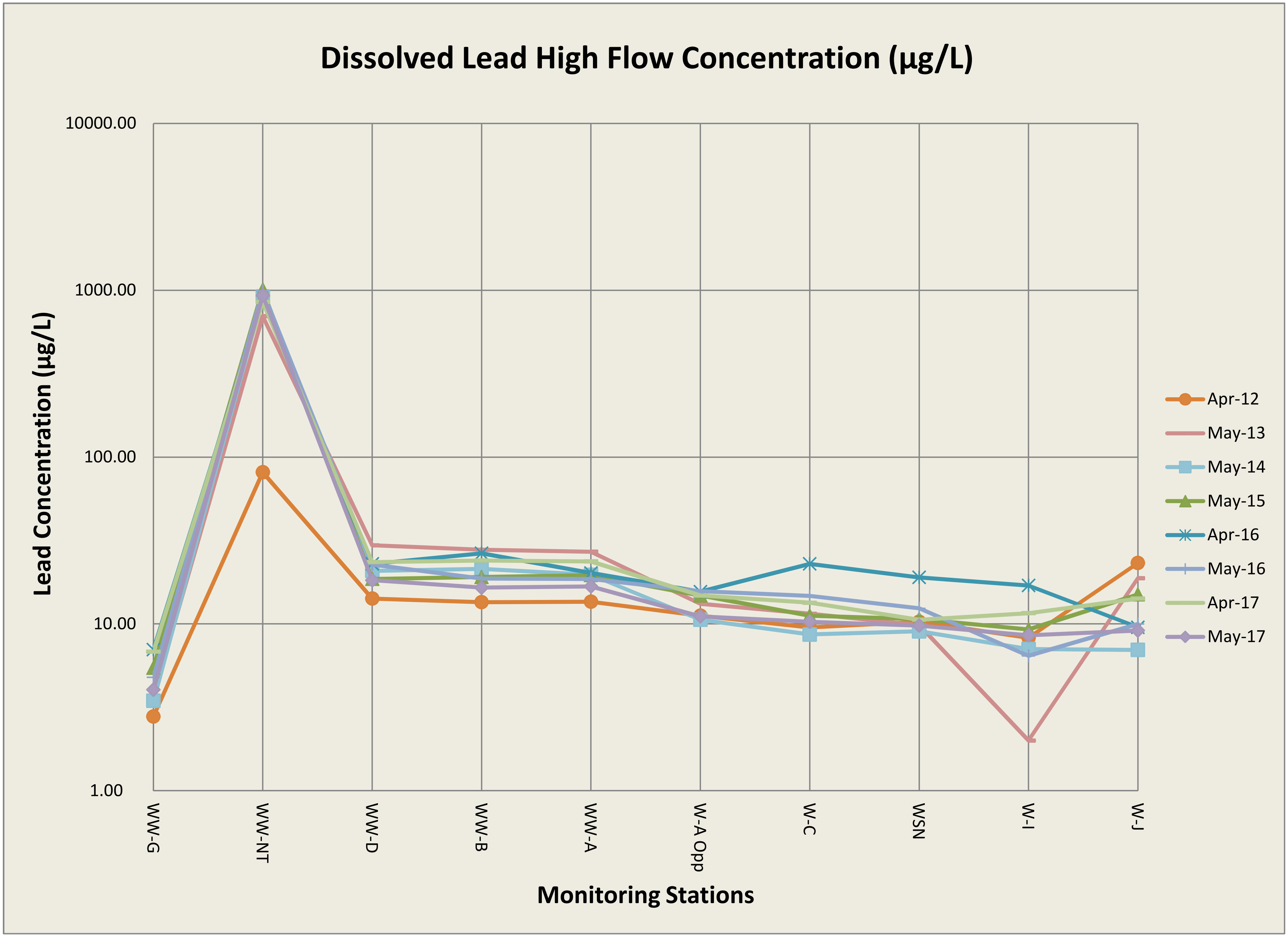


Figure 3-12

West Willow and Willow Creeks

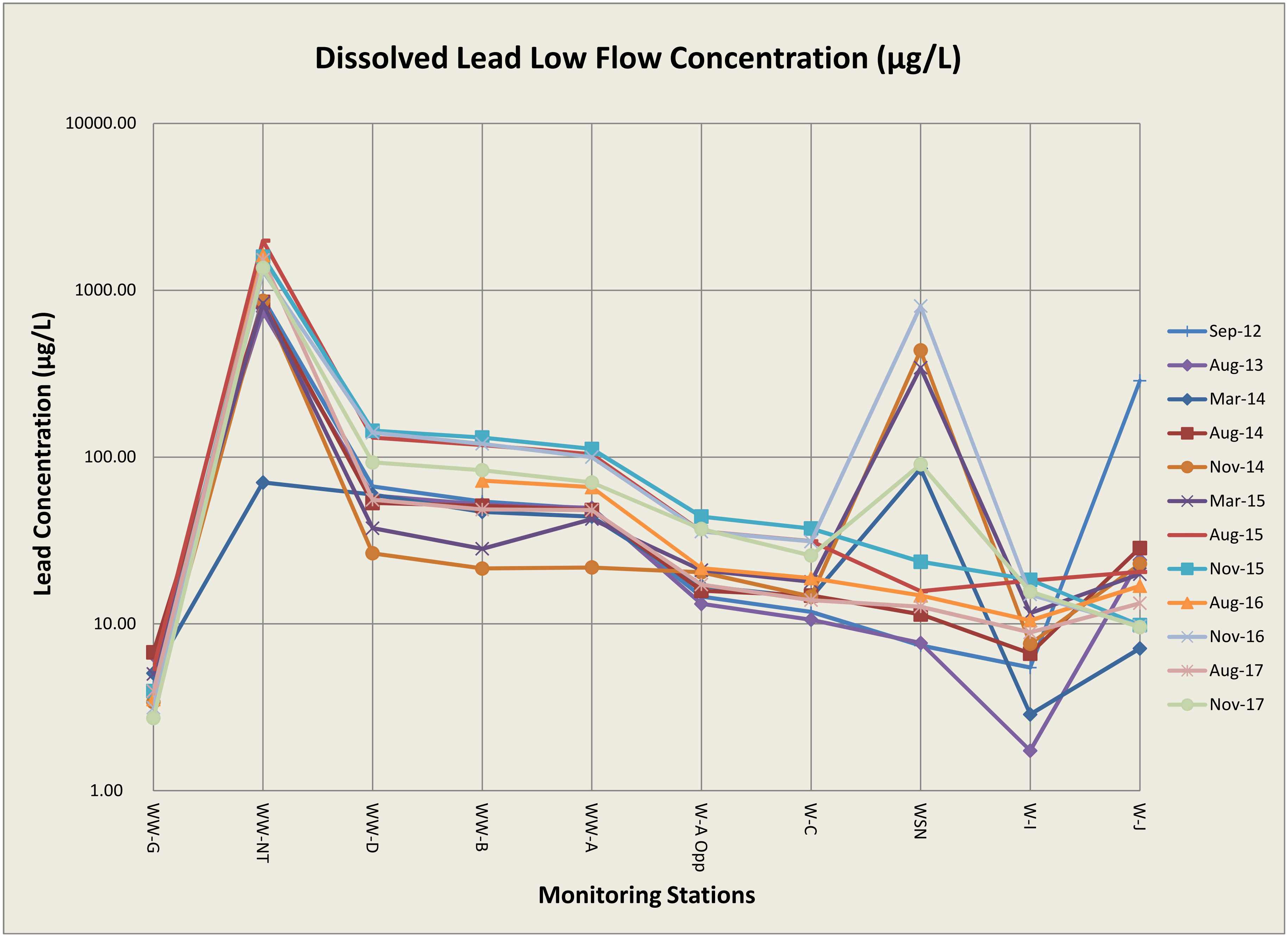


Figure 3-13

West Willow and Willow Creeks

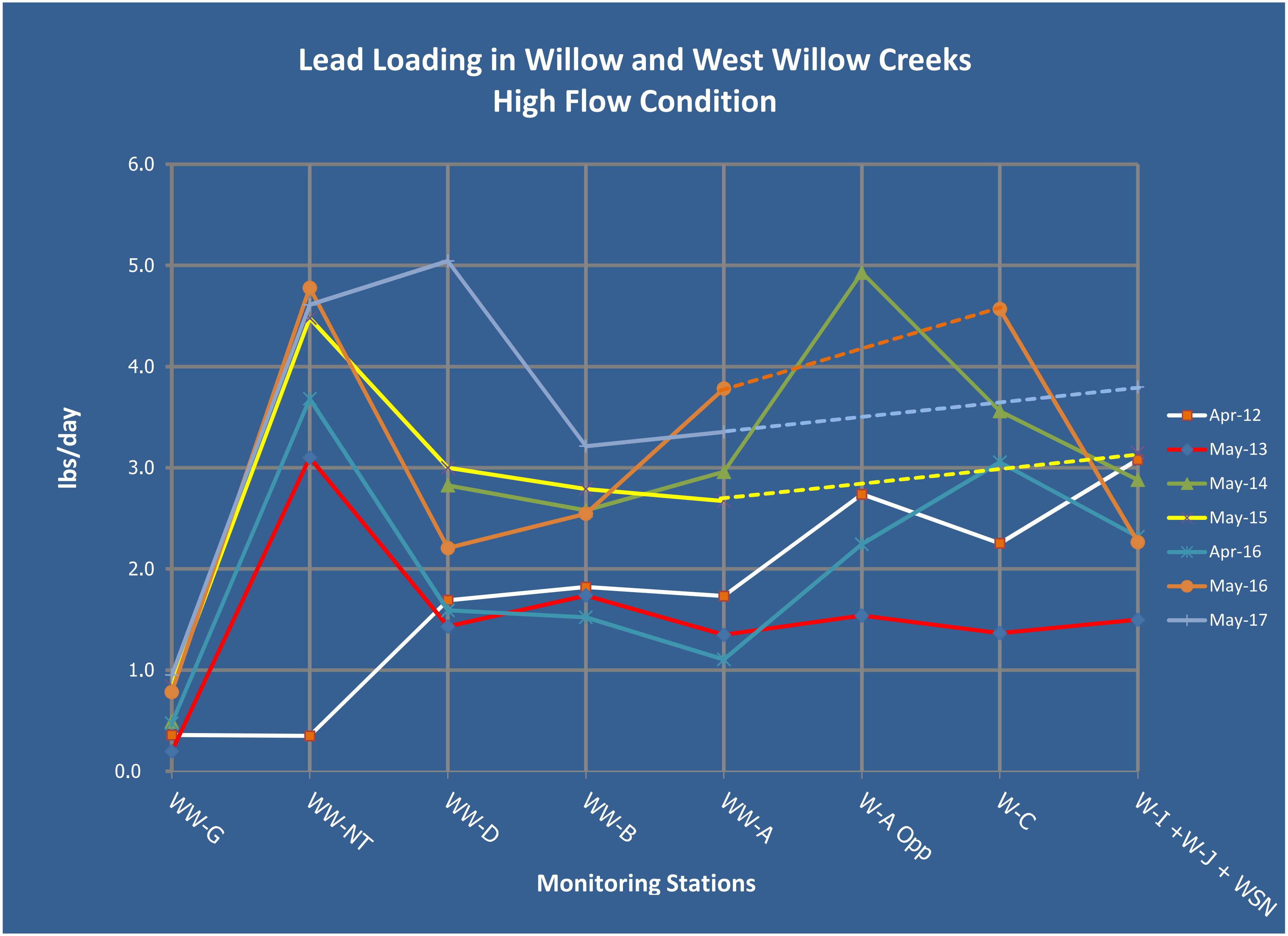


Figure 3-14

West Willow and Willow Creeks

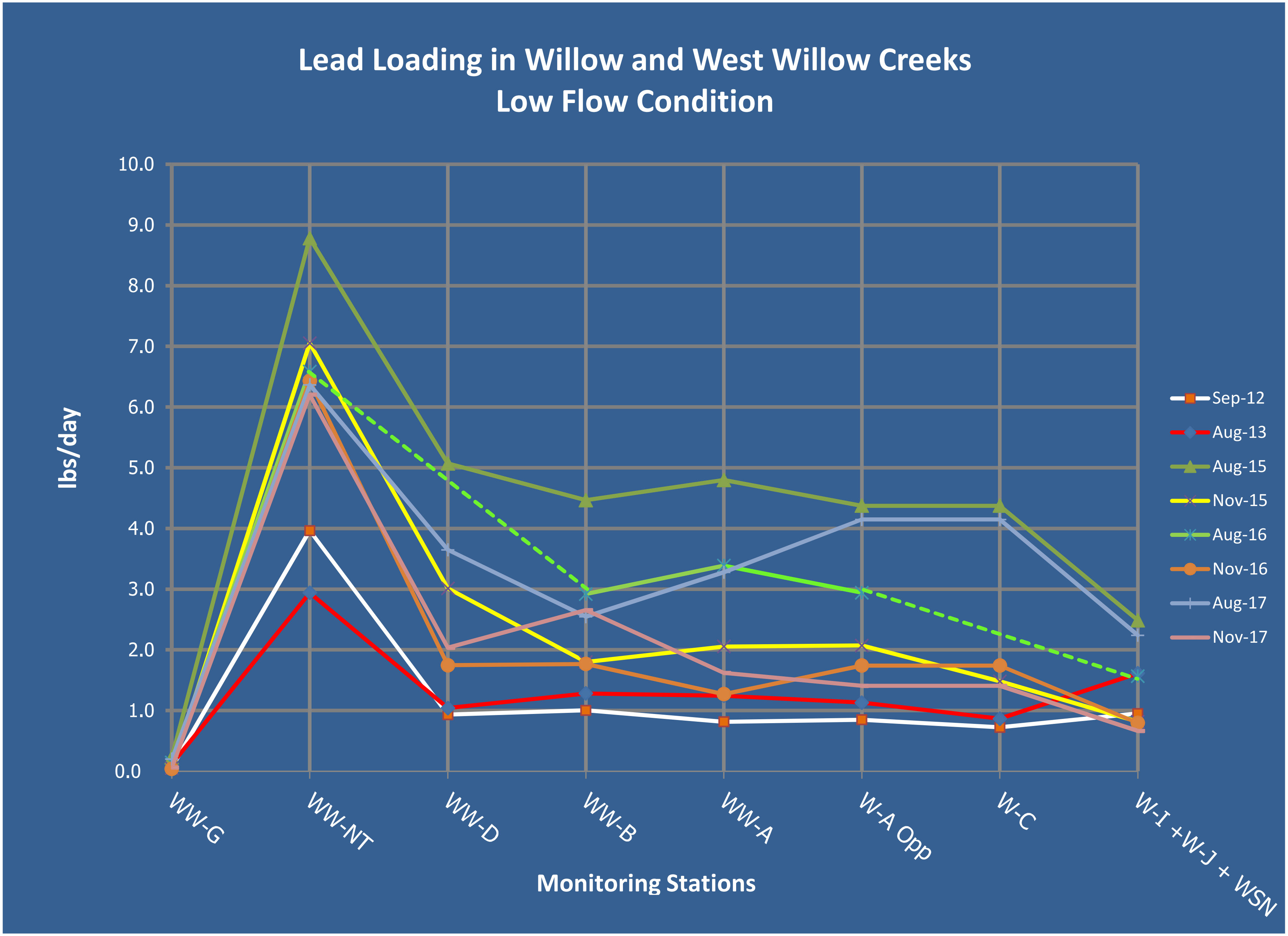


Figure 3-15

West Willow and Willow Creeks

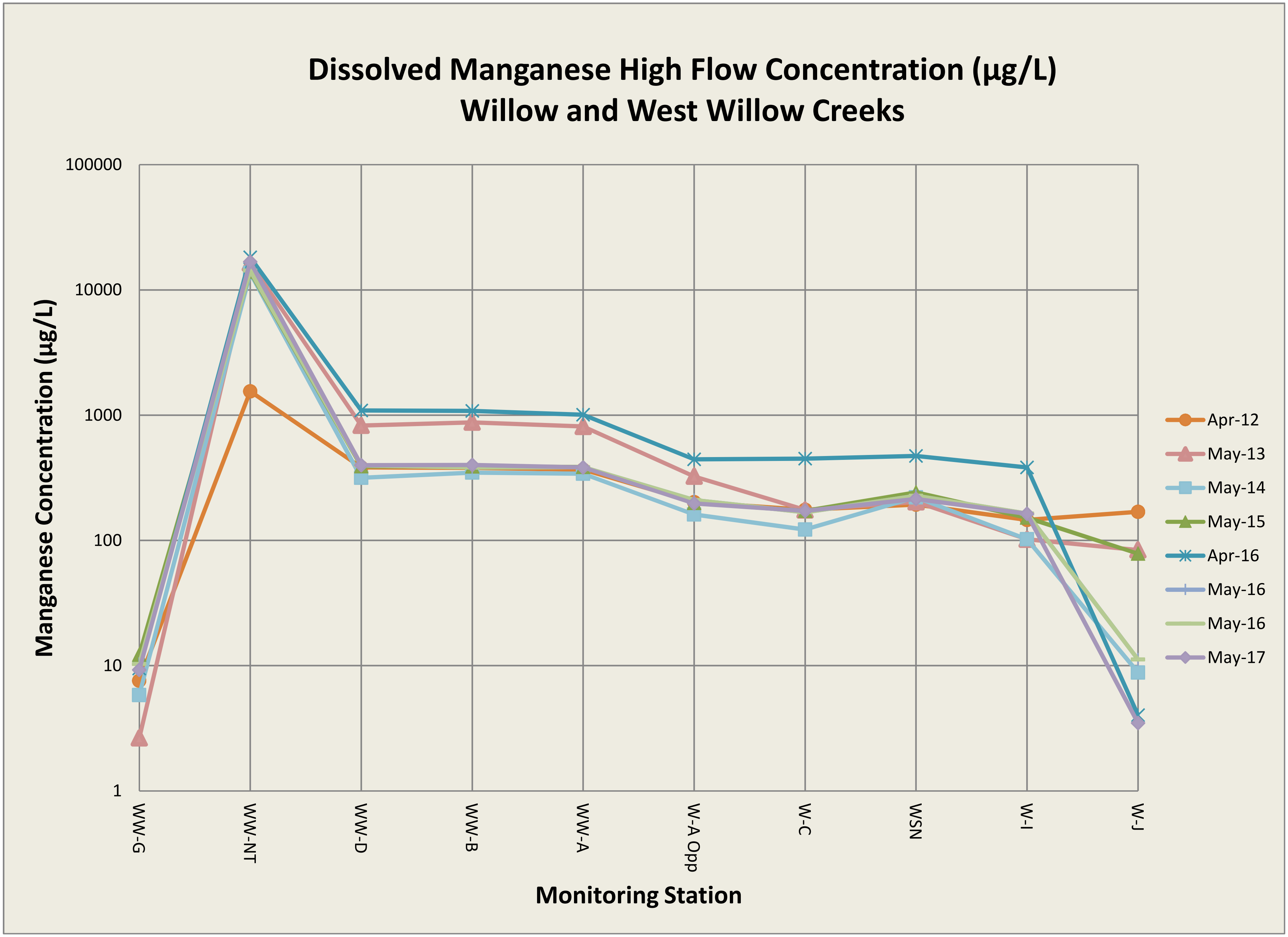


Figure 3-16

West Willow and Willow Creeks

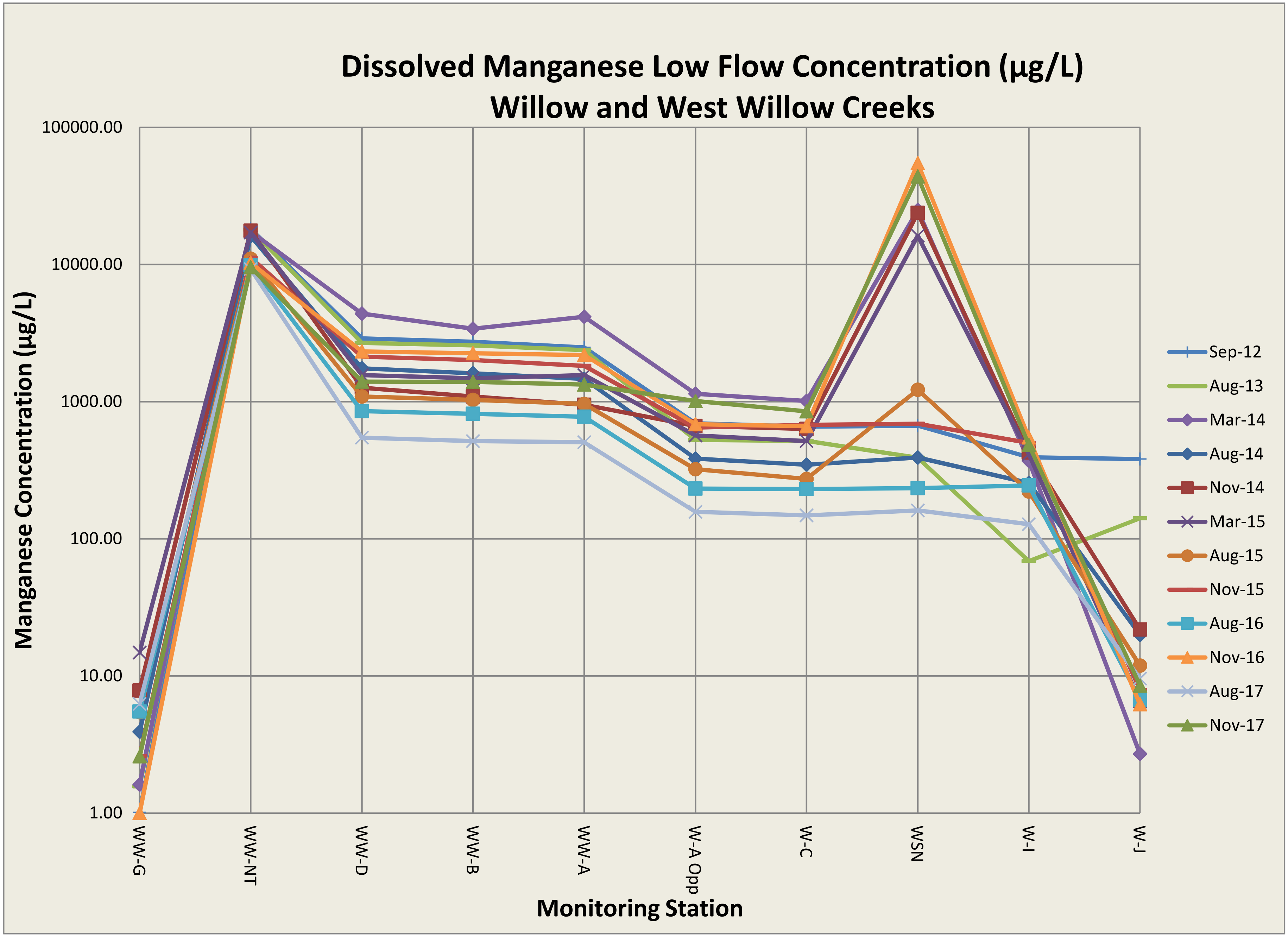


Figure 3-17

West Willow and Willow Creeks

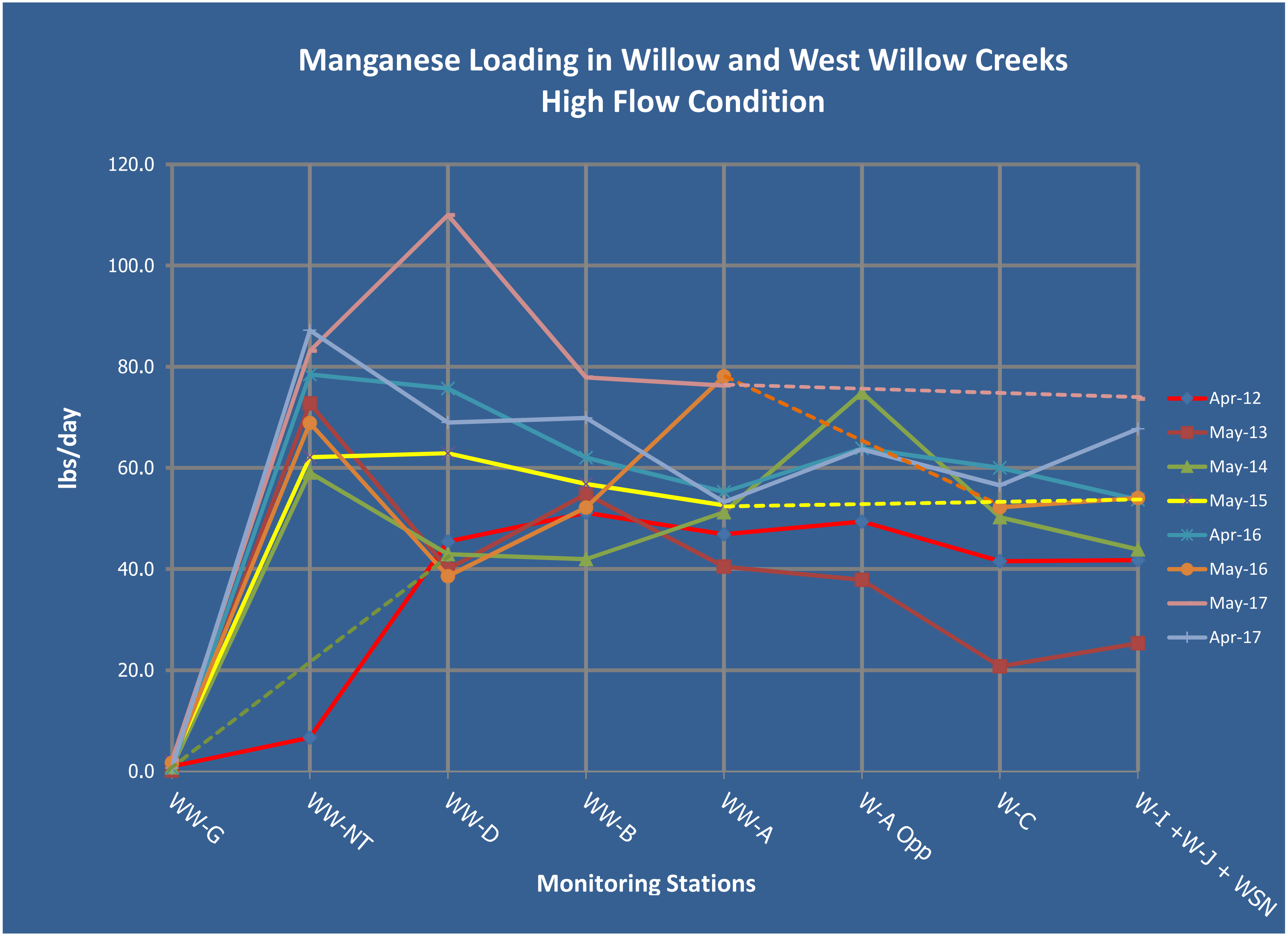


Figure 3-18

West Willow and Willow Creeks

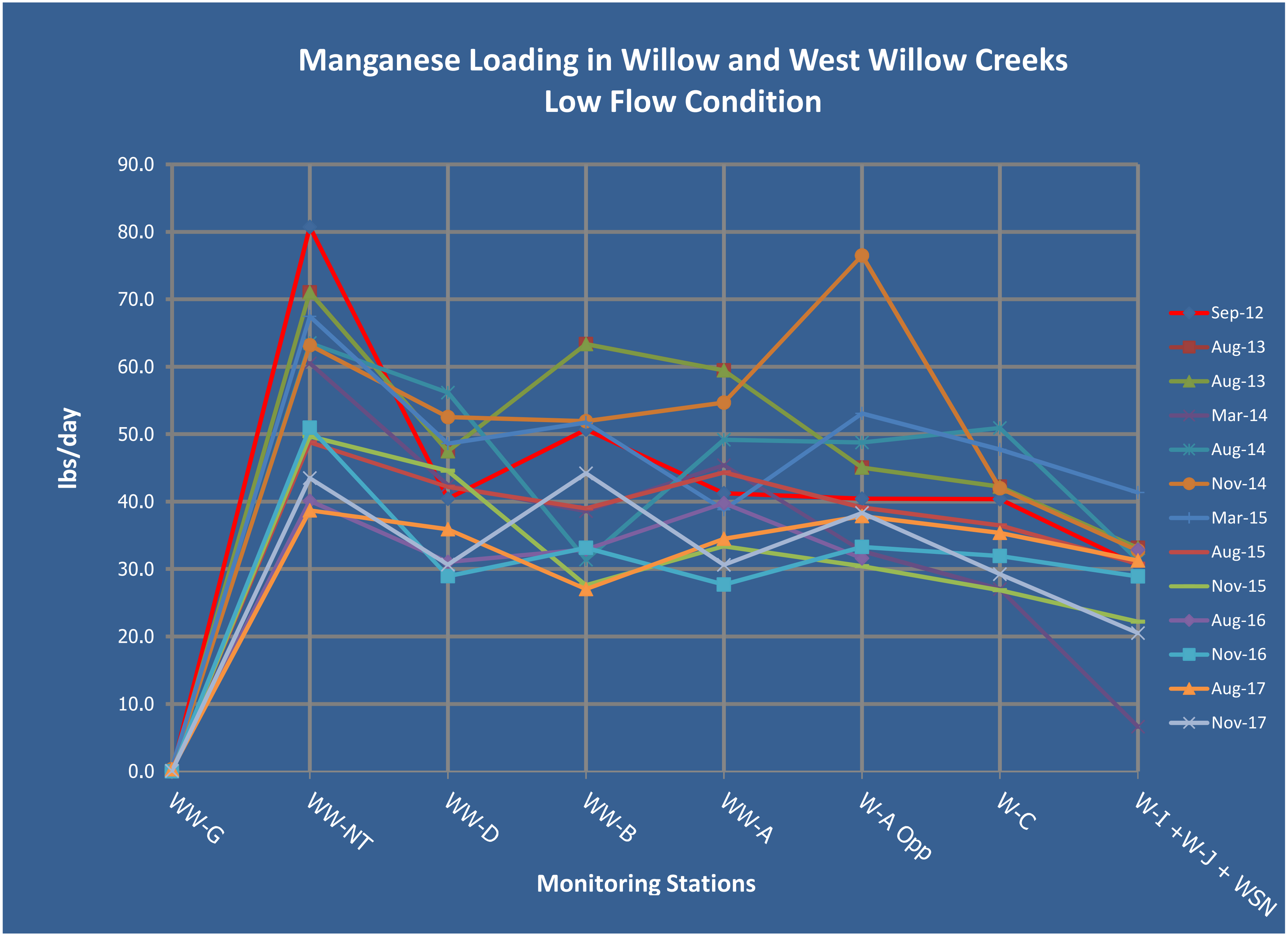


Figure 3-19

West Willow and Willow Creeks

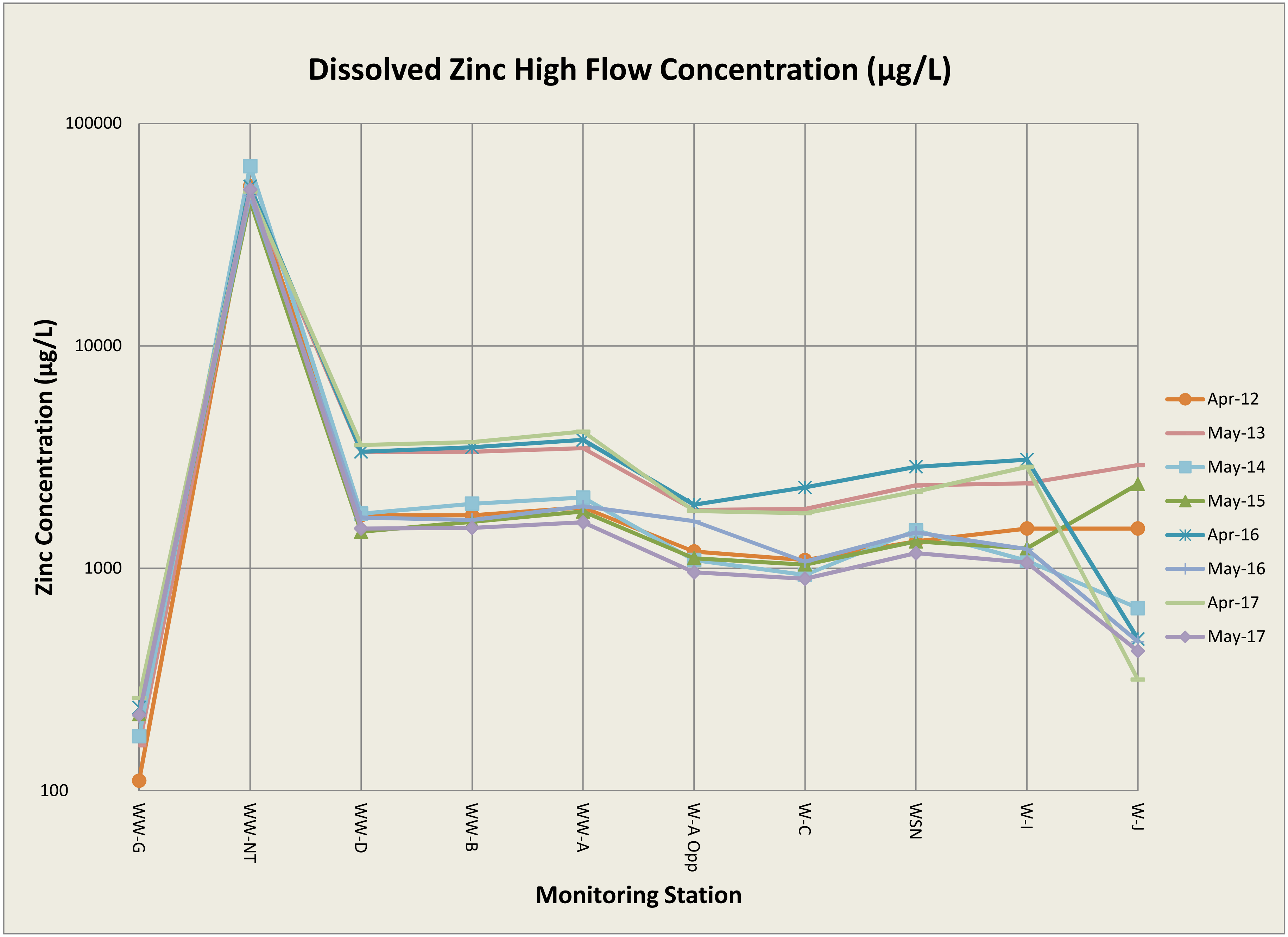


Figure 3-20

West Willow and Willow Creeks

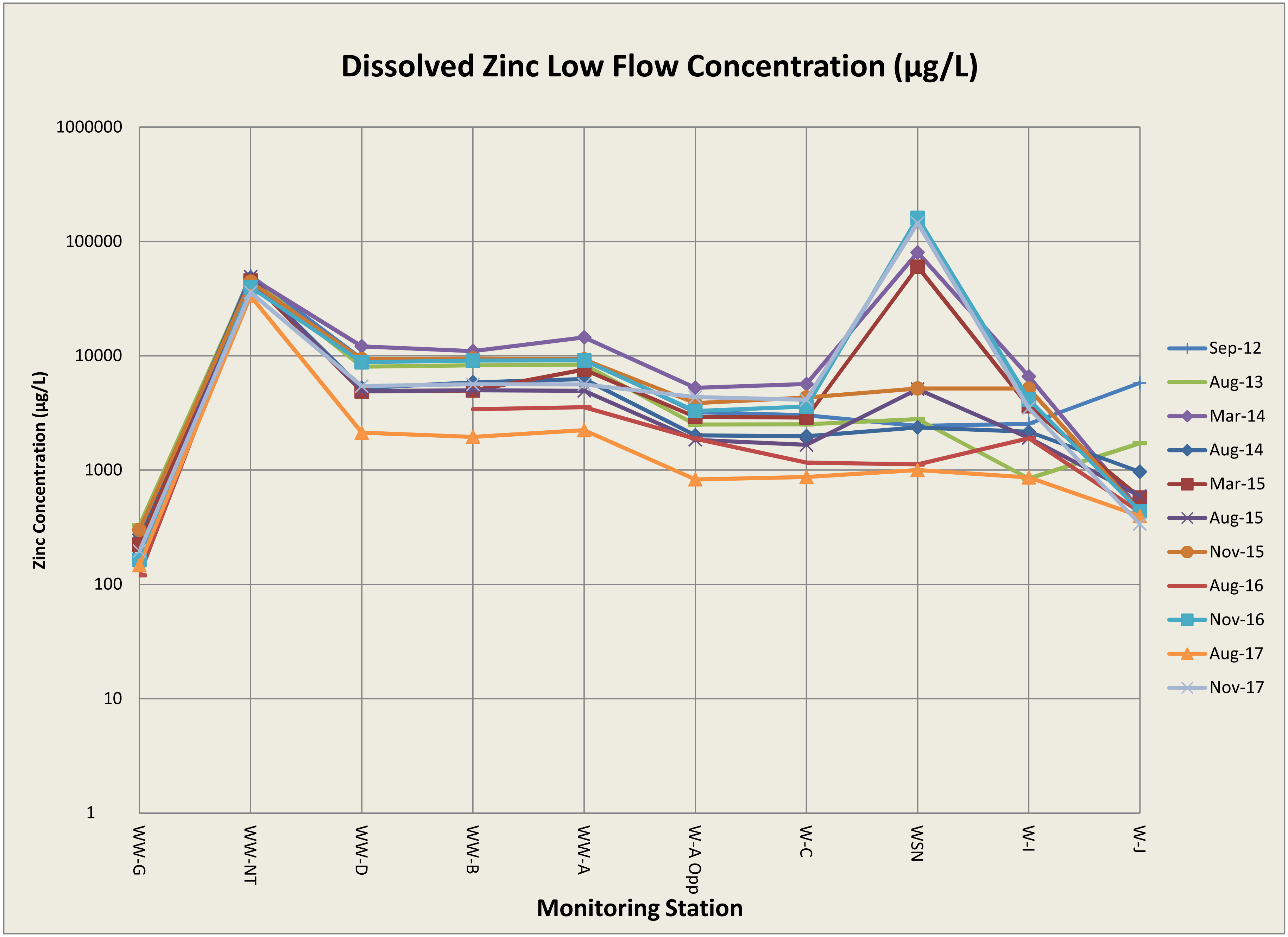


Figure 3-21

West Willow and Willow Creeks

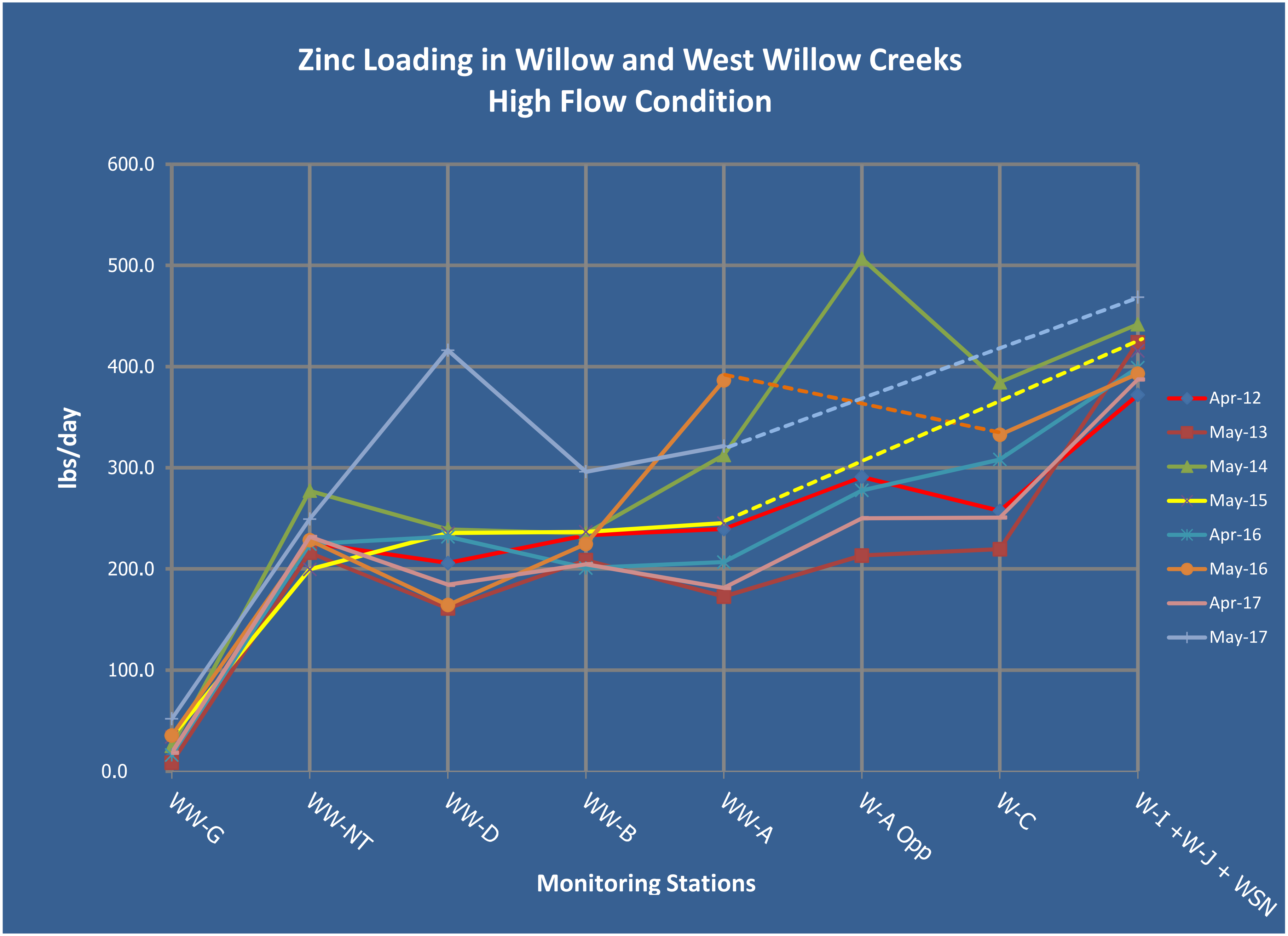


Figure 3-22

West Willow and Willow Creeks

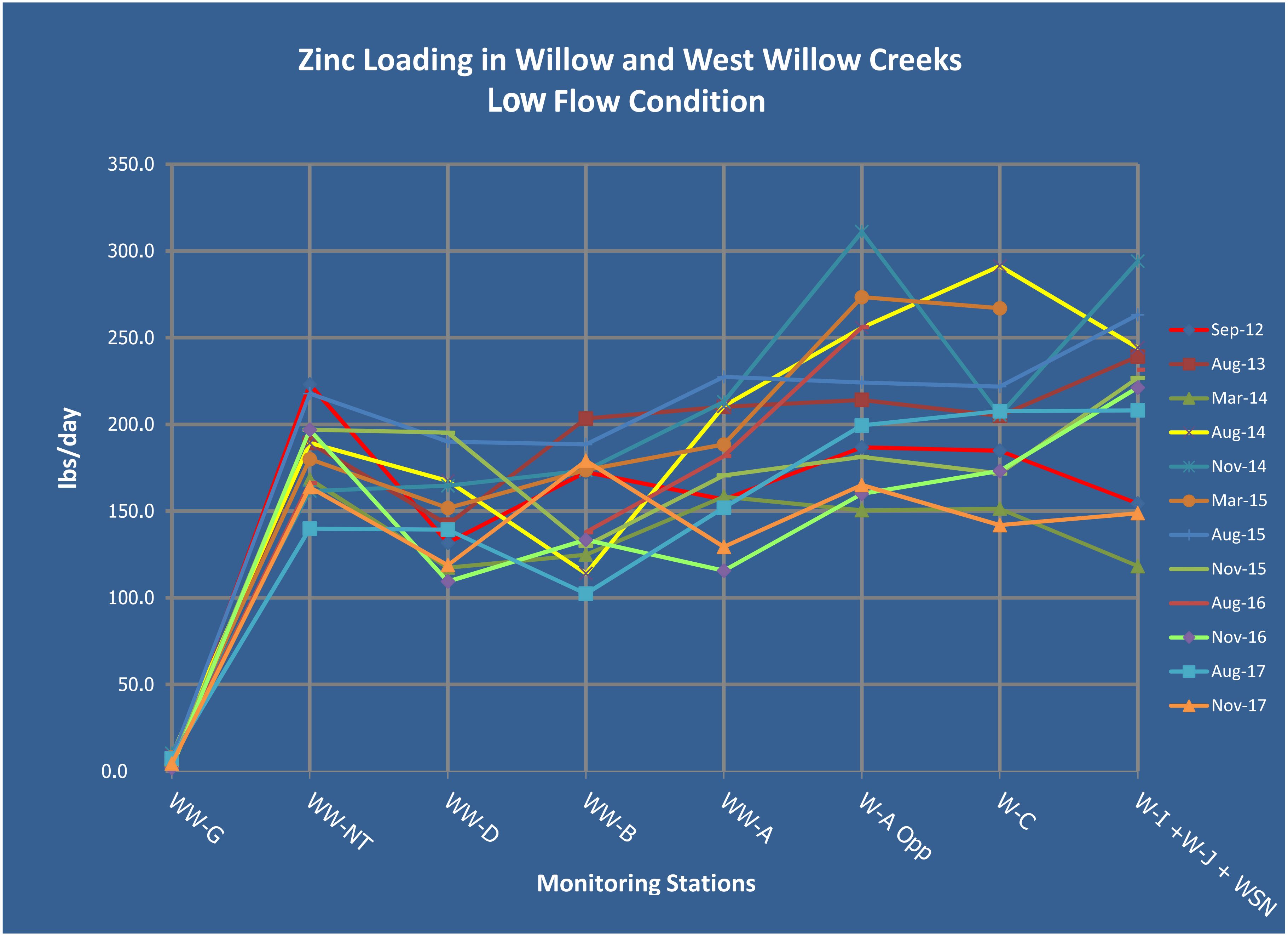


Figure 3-23

Rio Grande

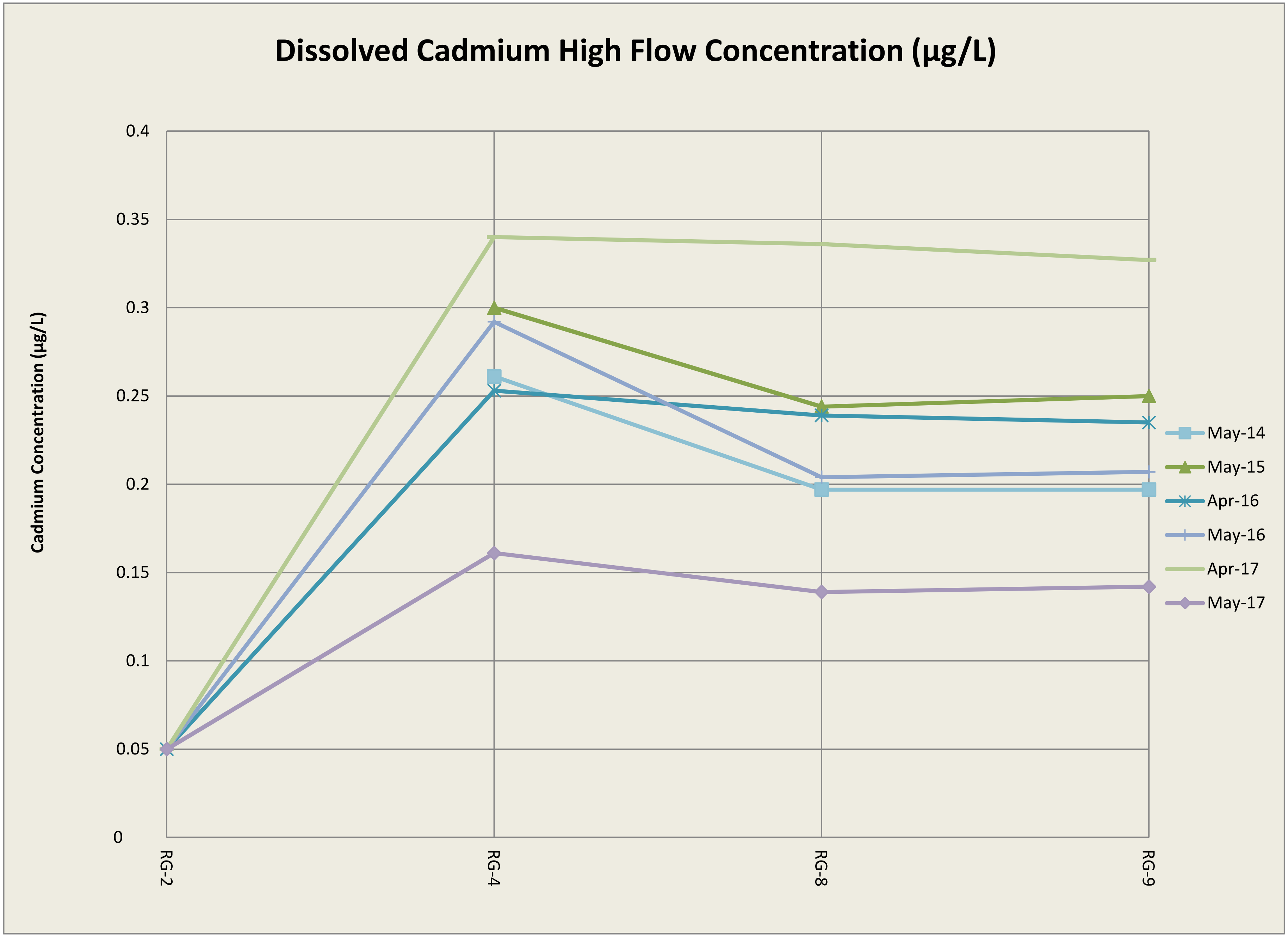


Figure 3-24

Rio Grande

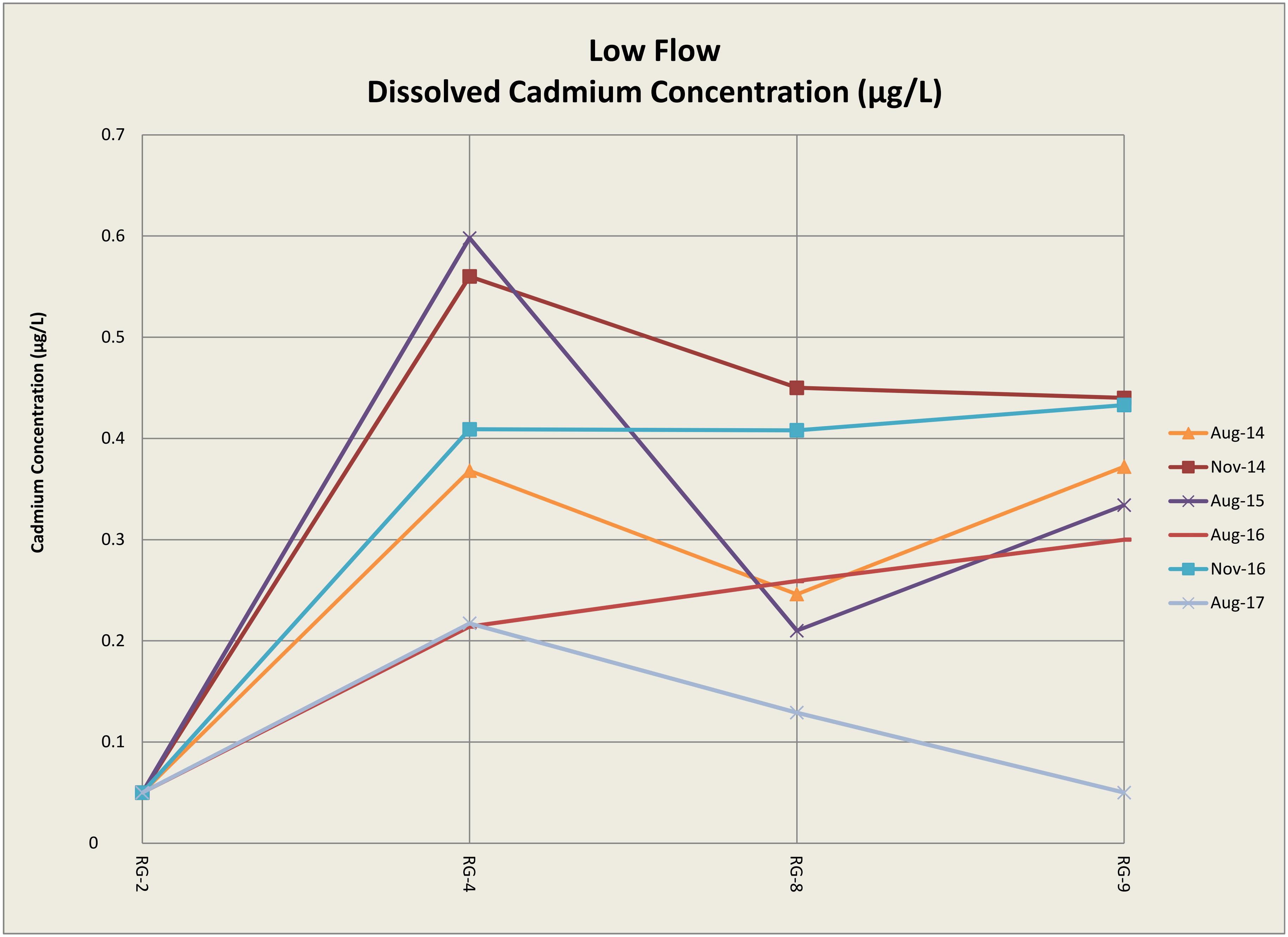


Figure 3-25

Rio Grande

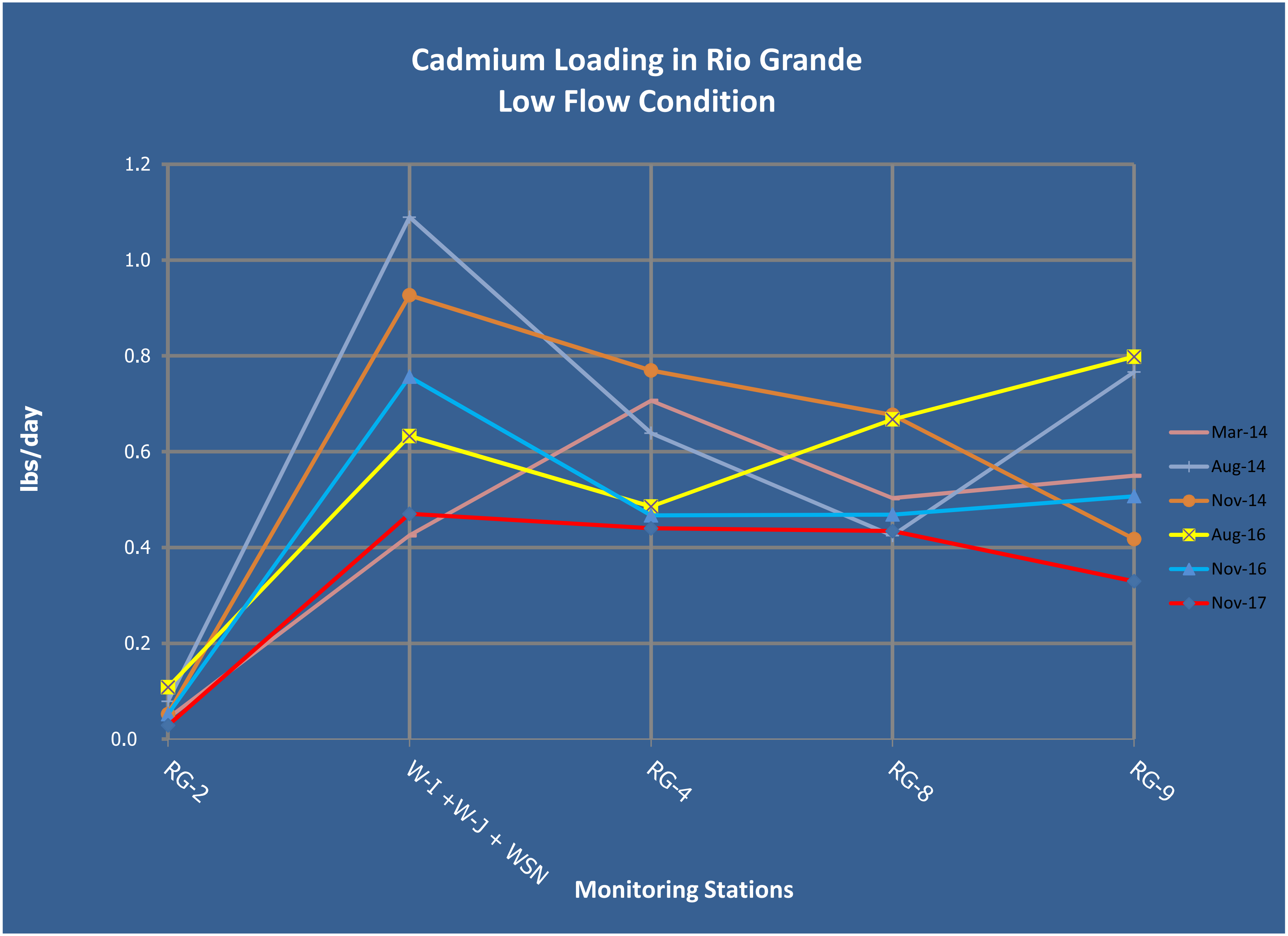


Figure 3-26

Rio Grande

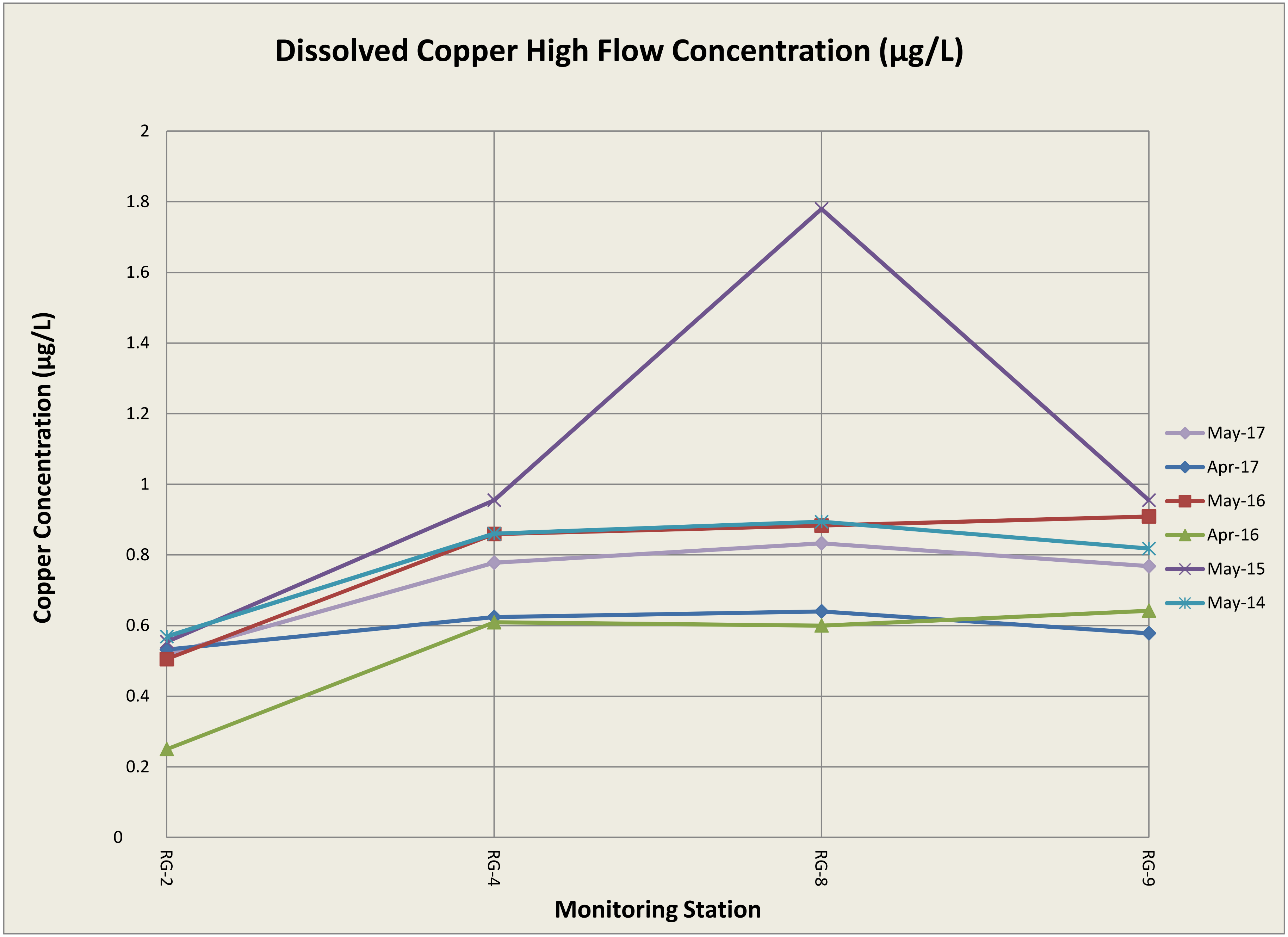


Figure 3-27

Rio Grande

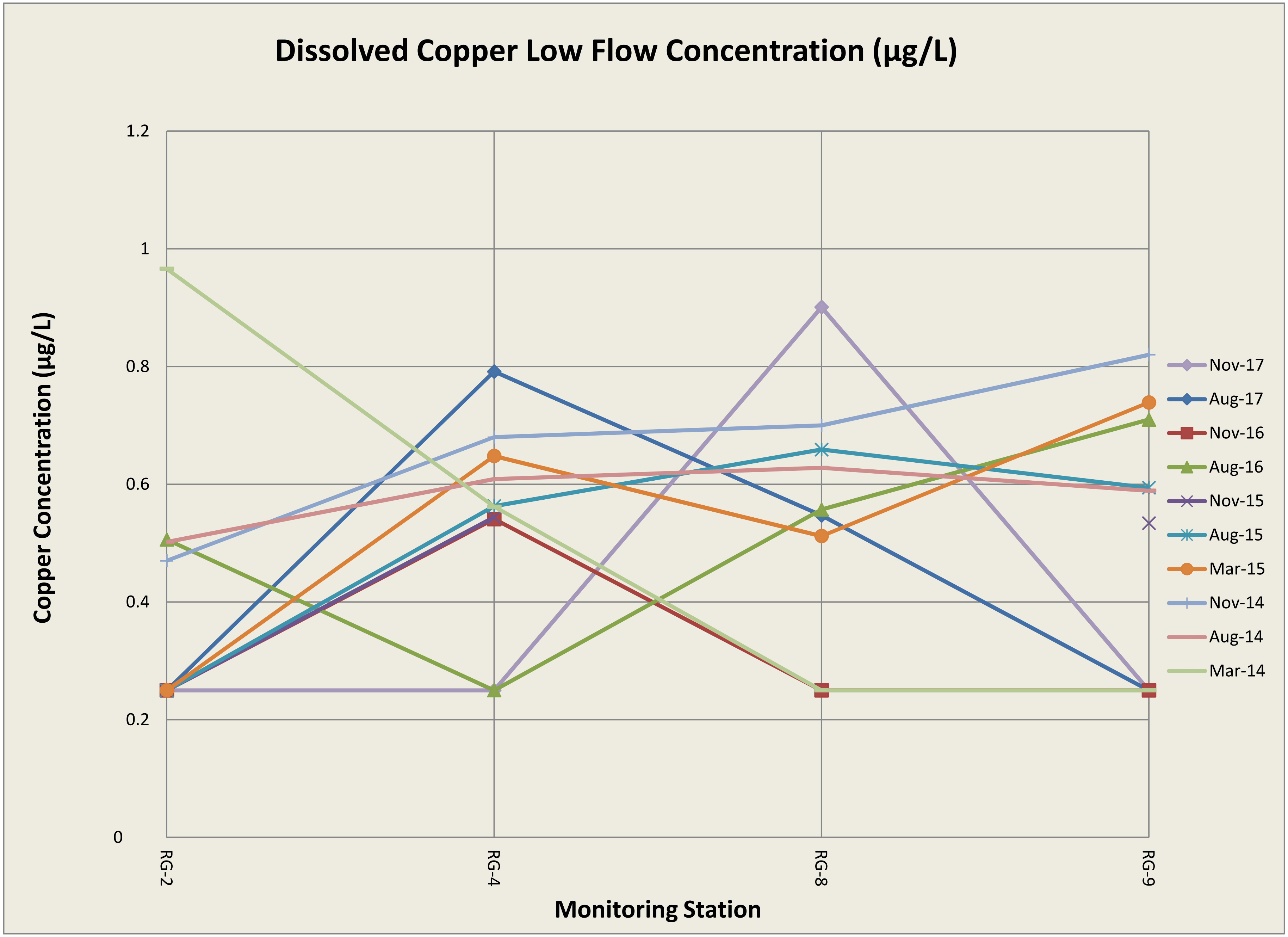


Figure 3-28

Rio Grande

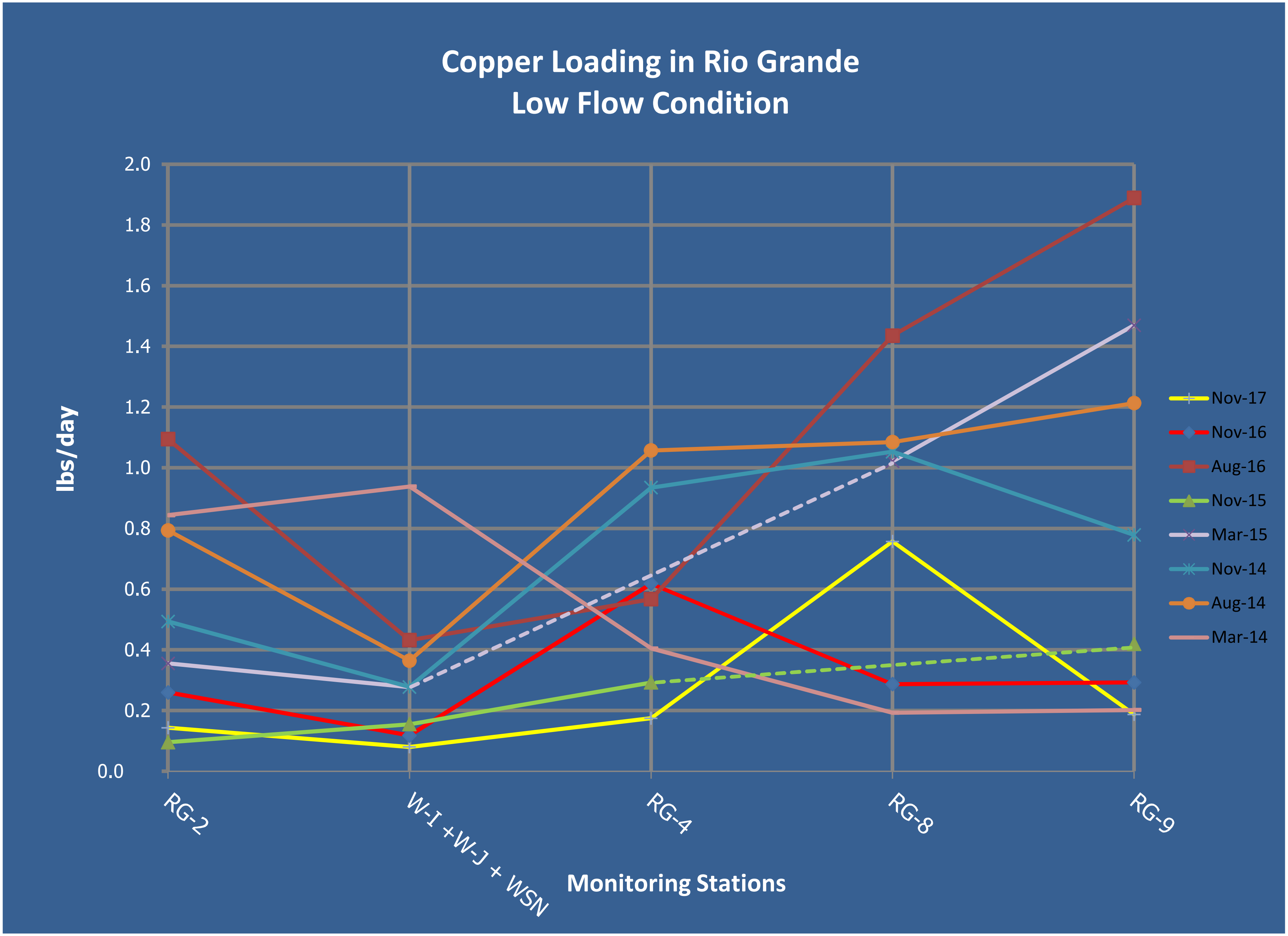


Figure 3-29

Rio Grande

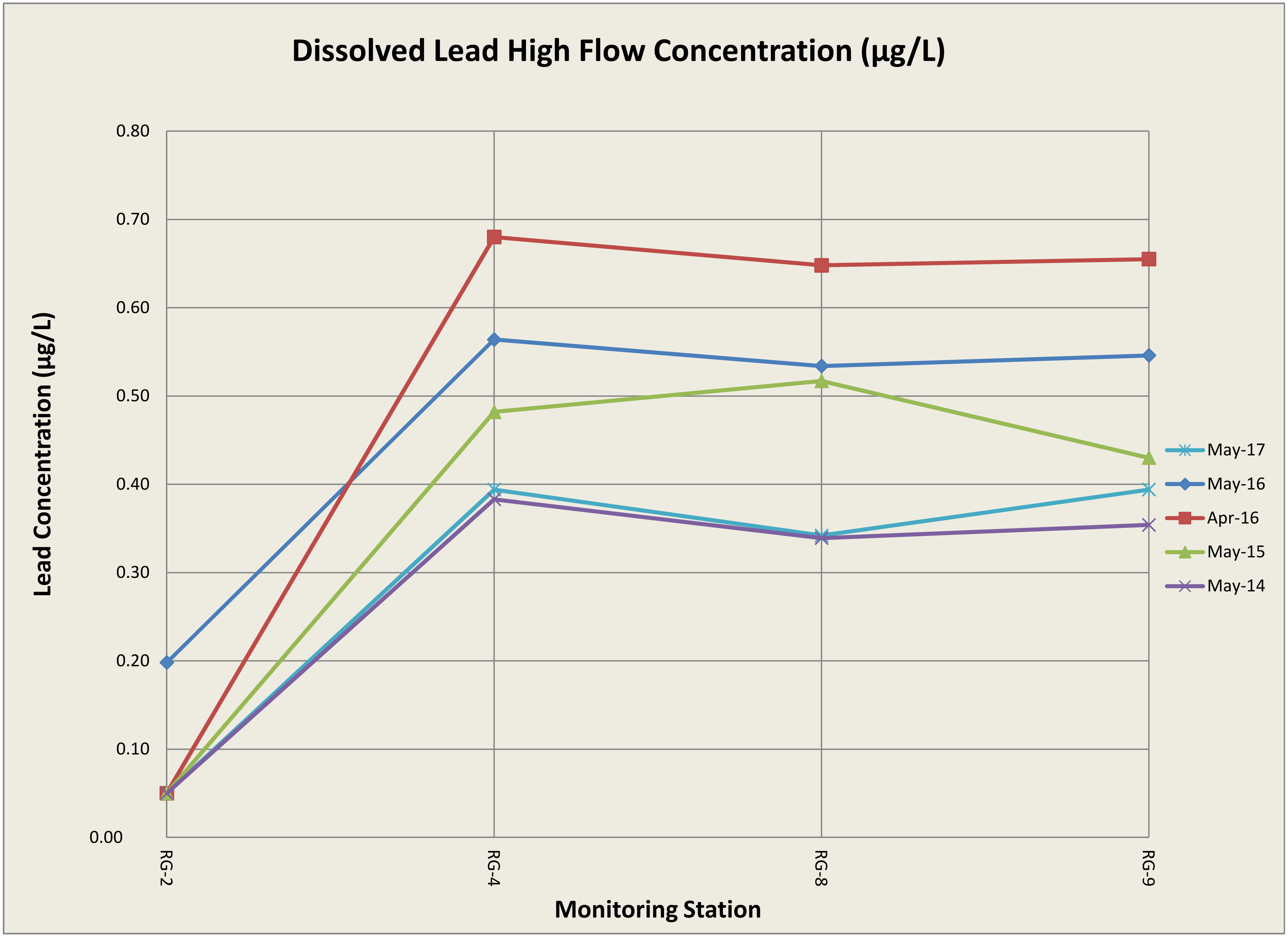


Figure 3-30

Rio Grande

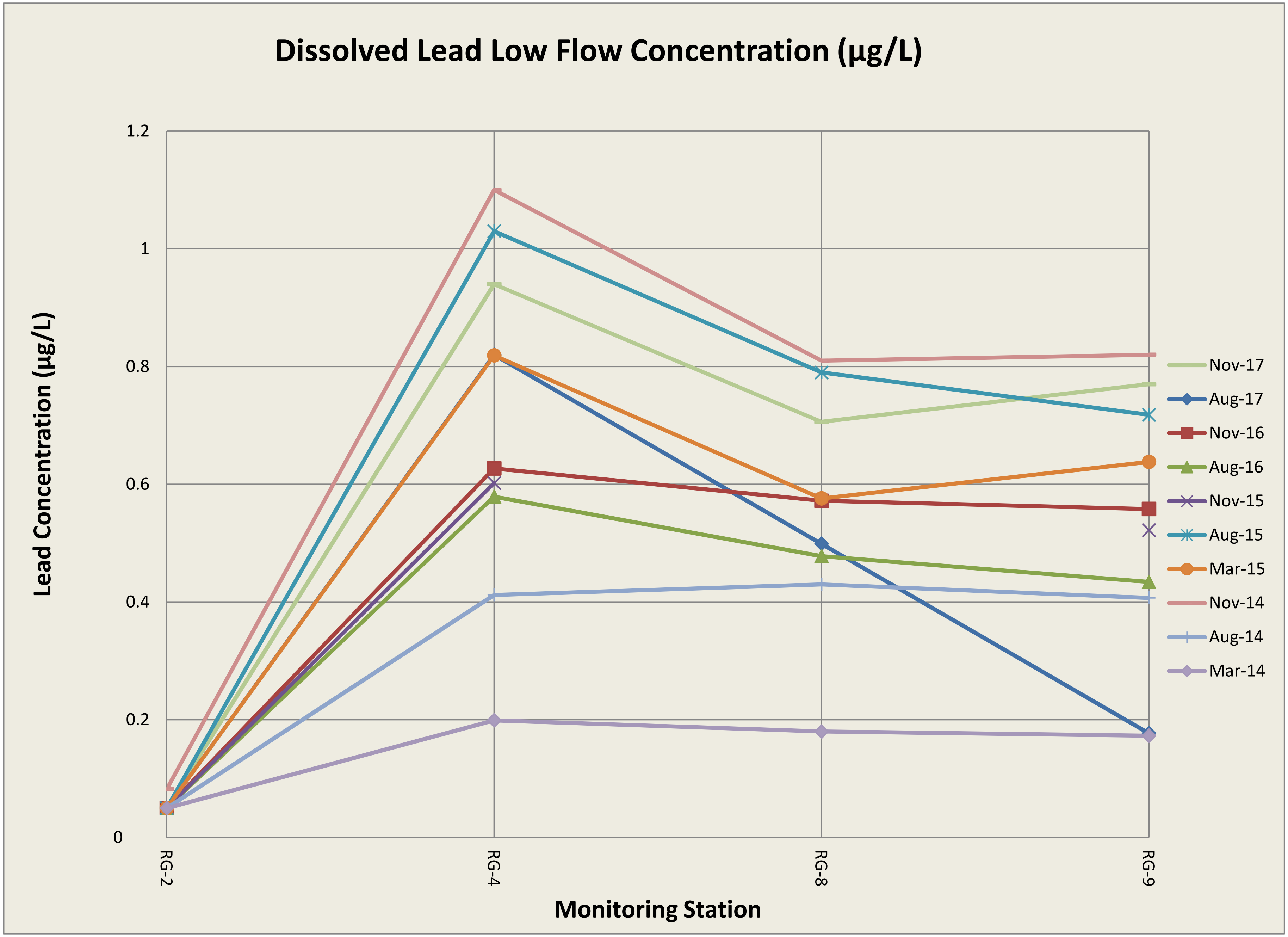


Figure 3-31

Rio Grande

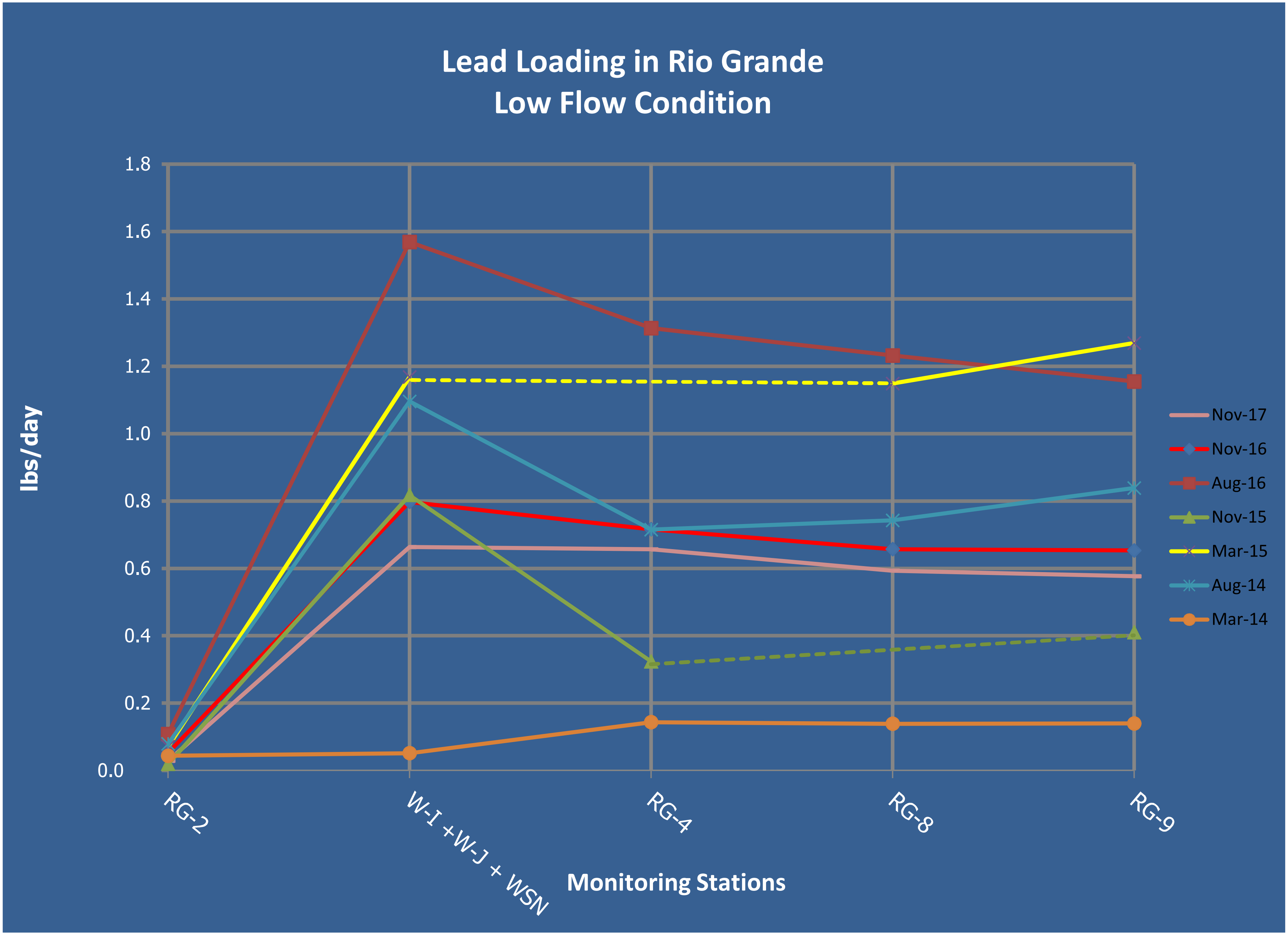


Figure 3-32

Rio Grande

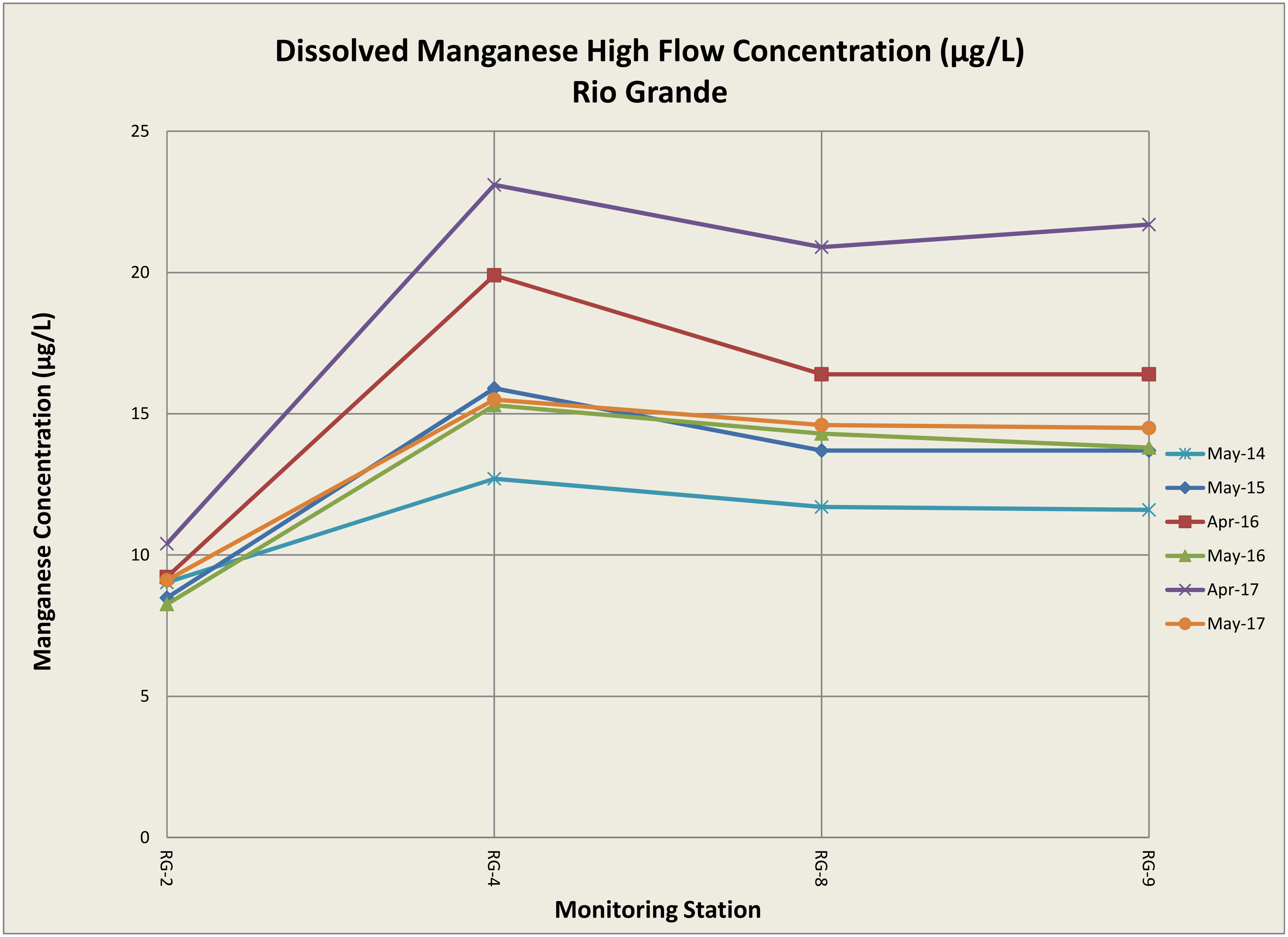


Figure 3-33

Rio Grande

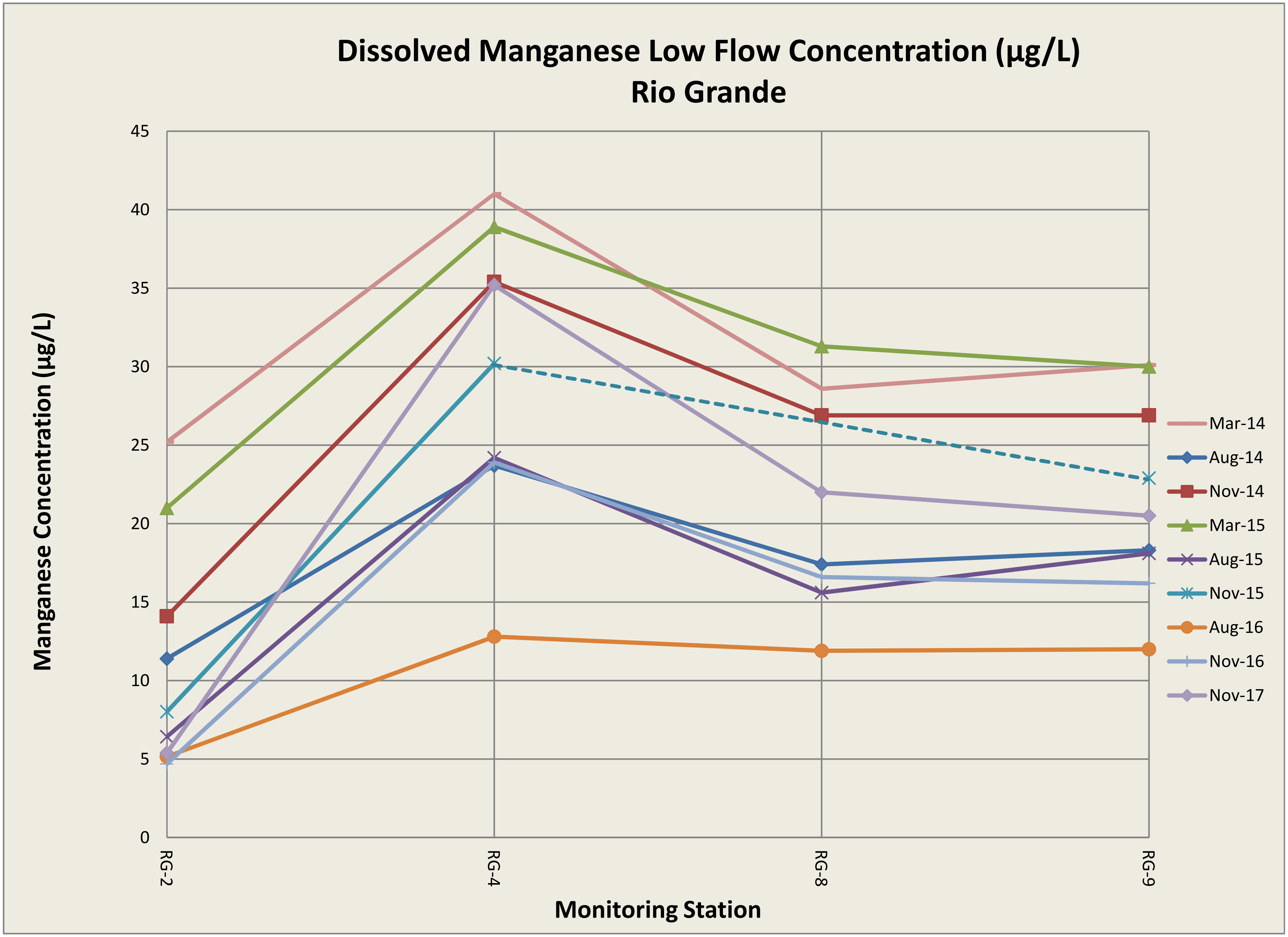


Figure 3-34

Rio Grande

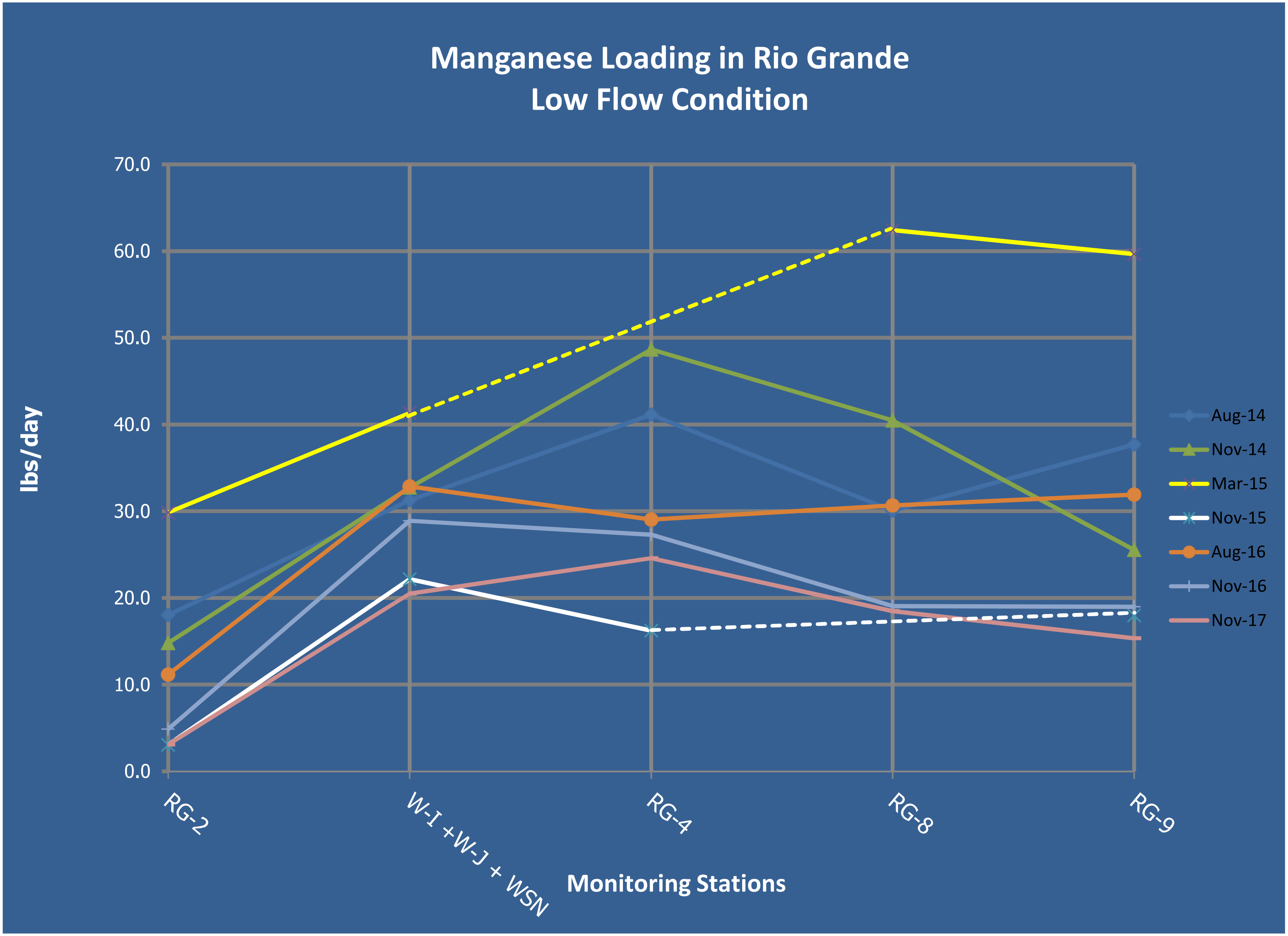


Figure 3-35

Rio Grande

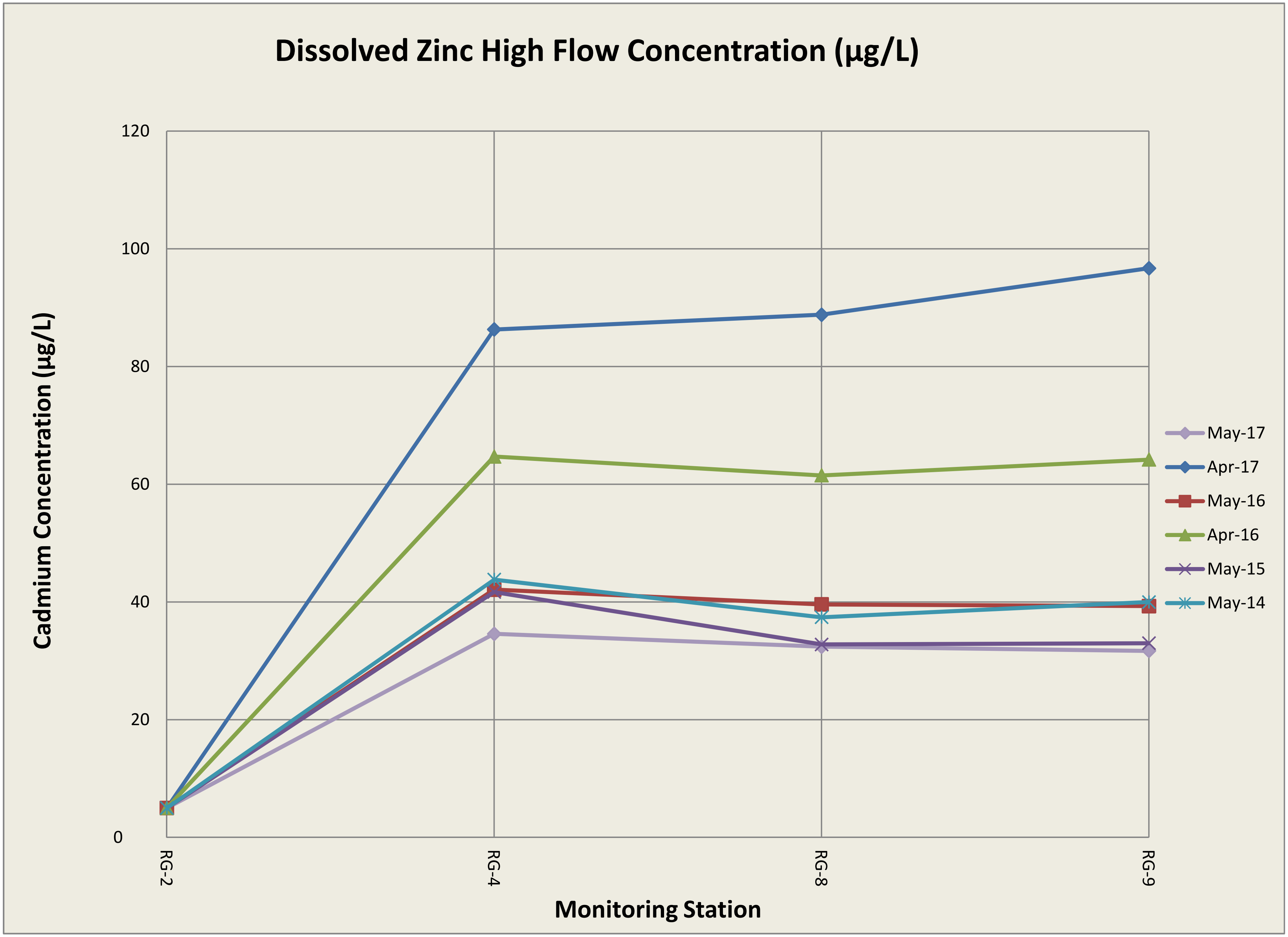


Figure 3-36

Rio Grande

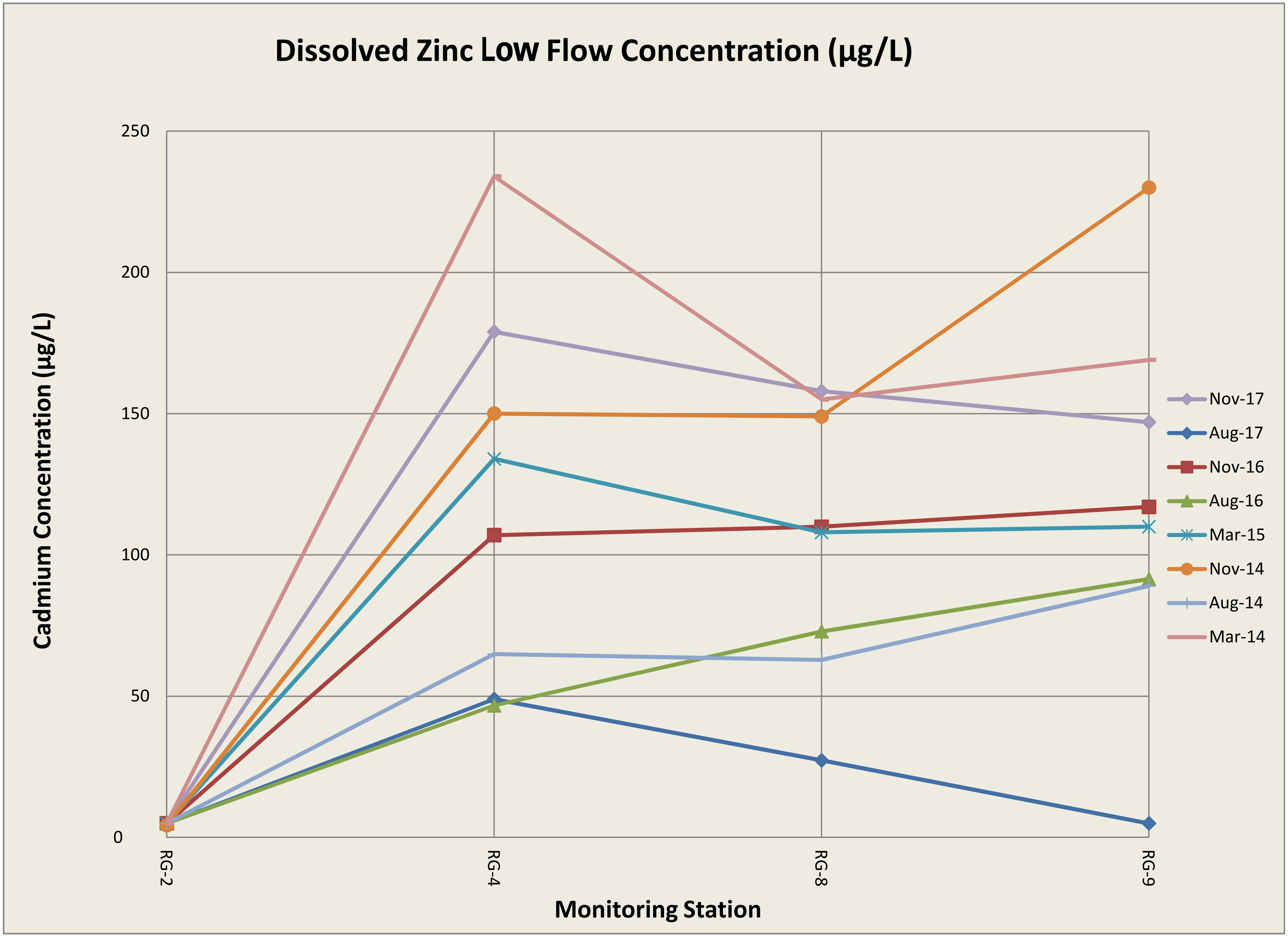


Figure 3-37

Rio Grande

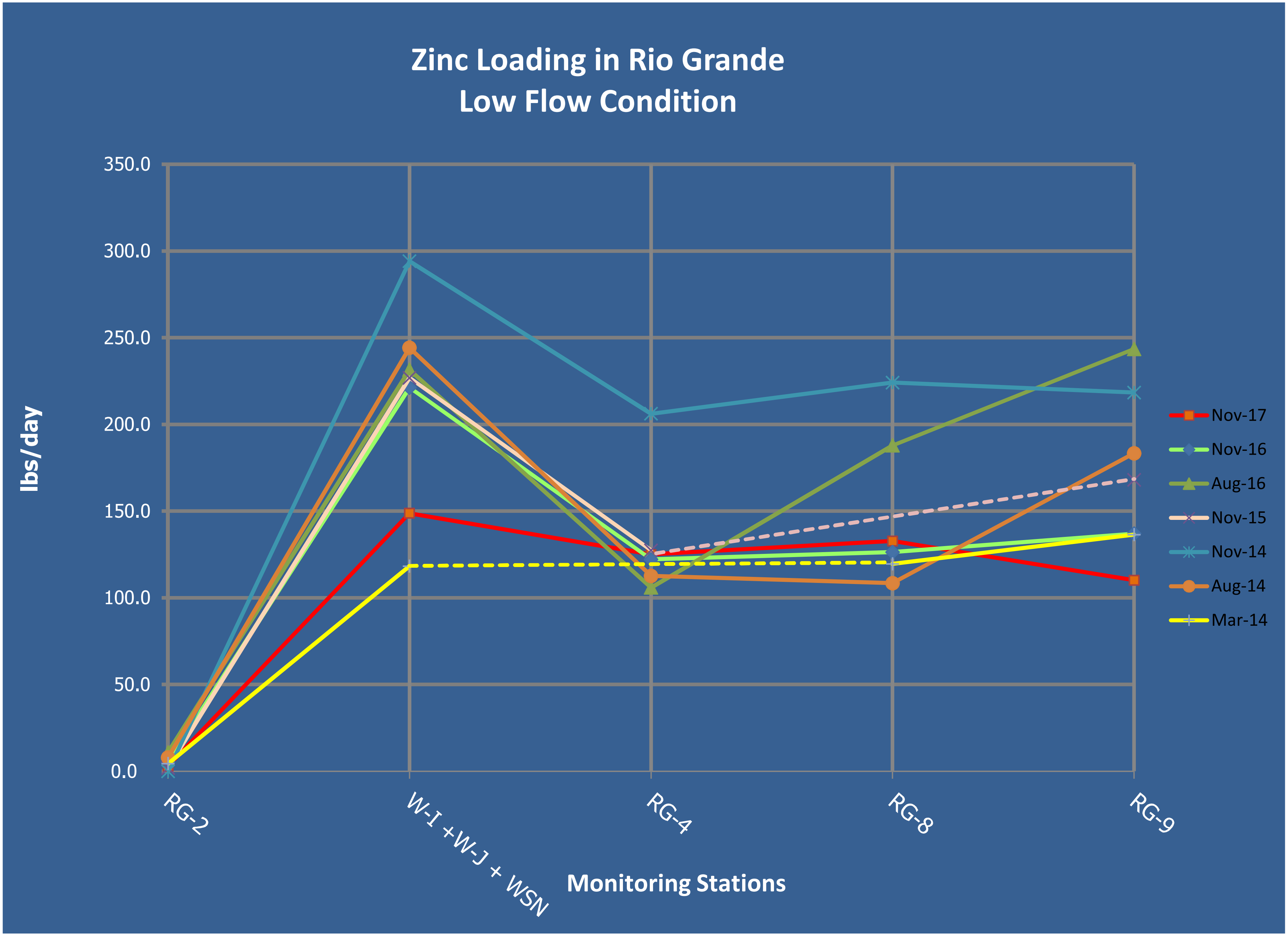


Figure 3-38

Monitoring Well Locations

Nelson Tunnel NPL Site

DATE: NOVEMBER, 2013	Figure 3-39

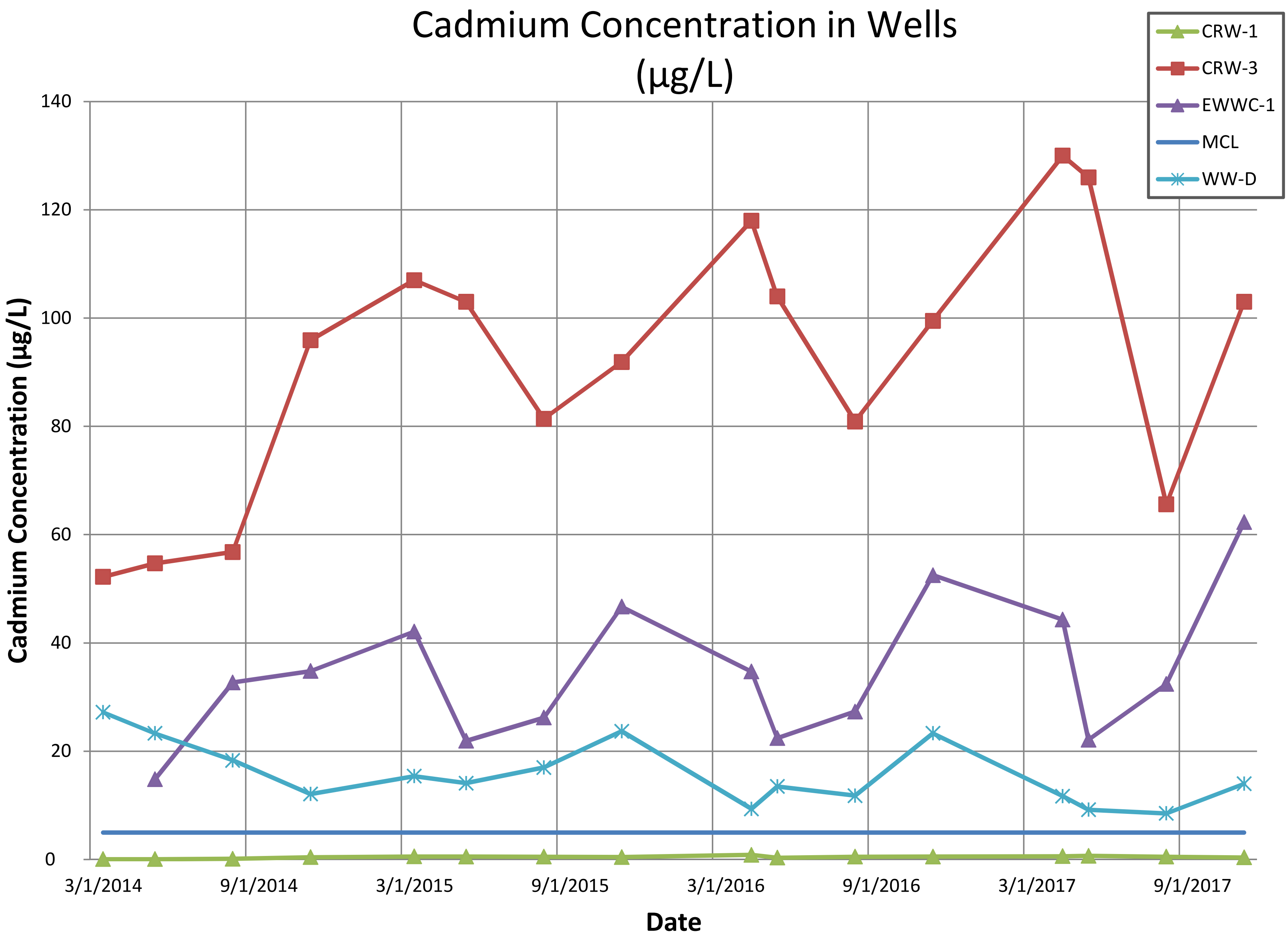

Cadmium Concentration in Wells
(µg/L)
CRW-1
CRW-3
EWWC-1
MCL
WW-D
140
120
100
80
60
40
20
0
Cadmium Concentration (µg/L)
3/1/2014
9/1/2014
3/1/2015
9/1/2015
3/1/2016
9/1/2016
3/1/2017
9/1/2017
Date

Figure 3-40

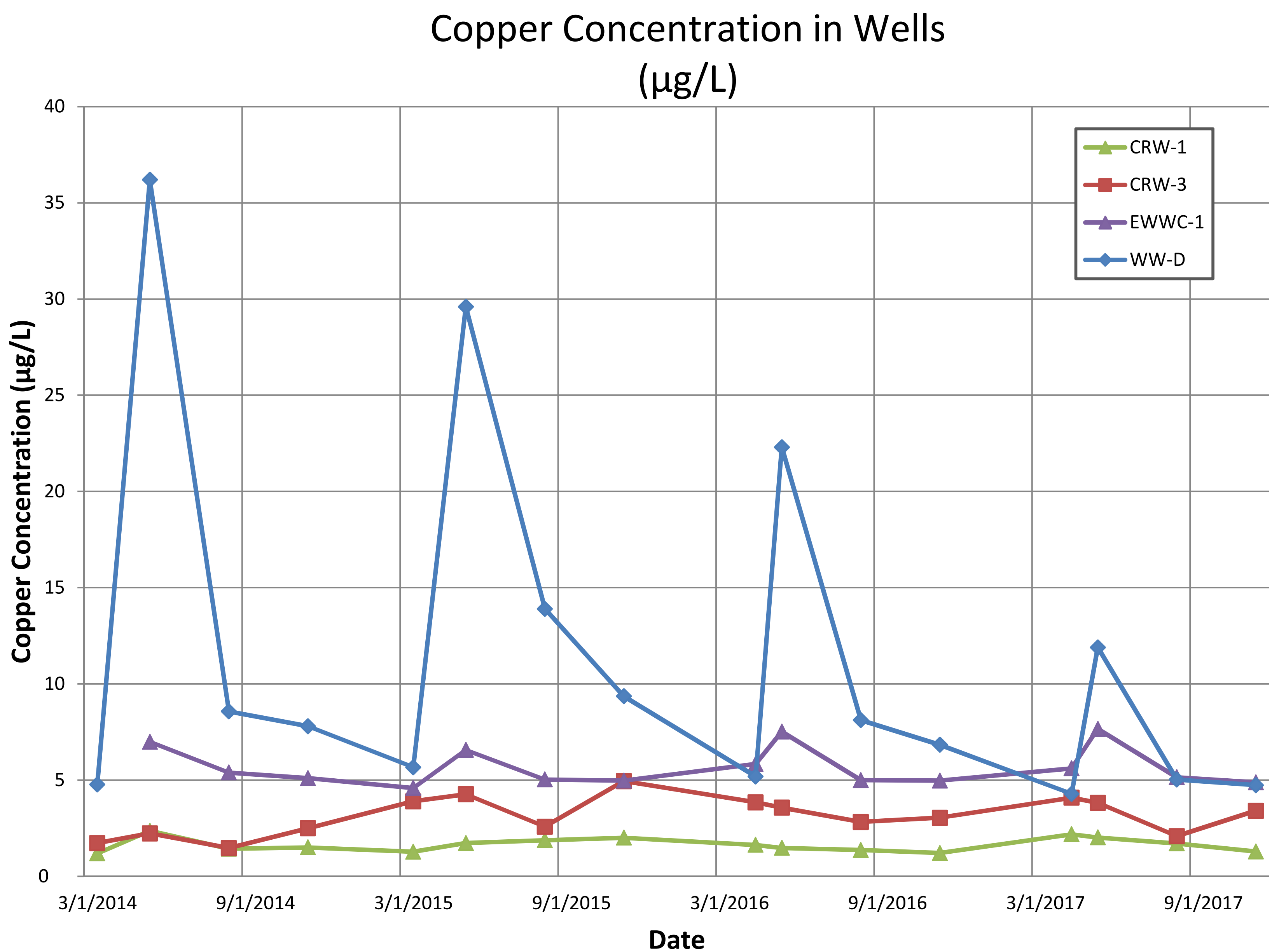
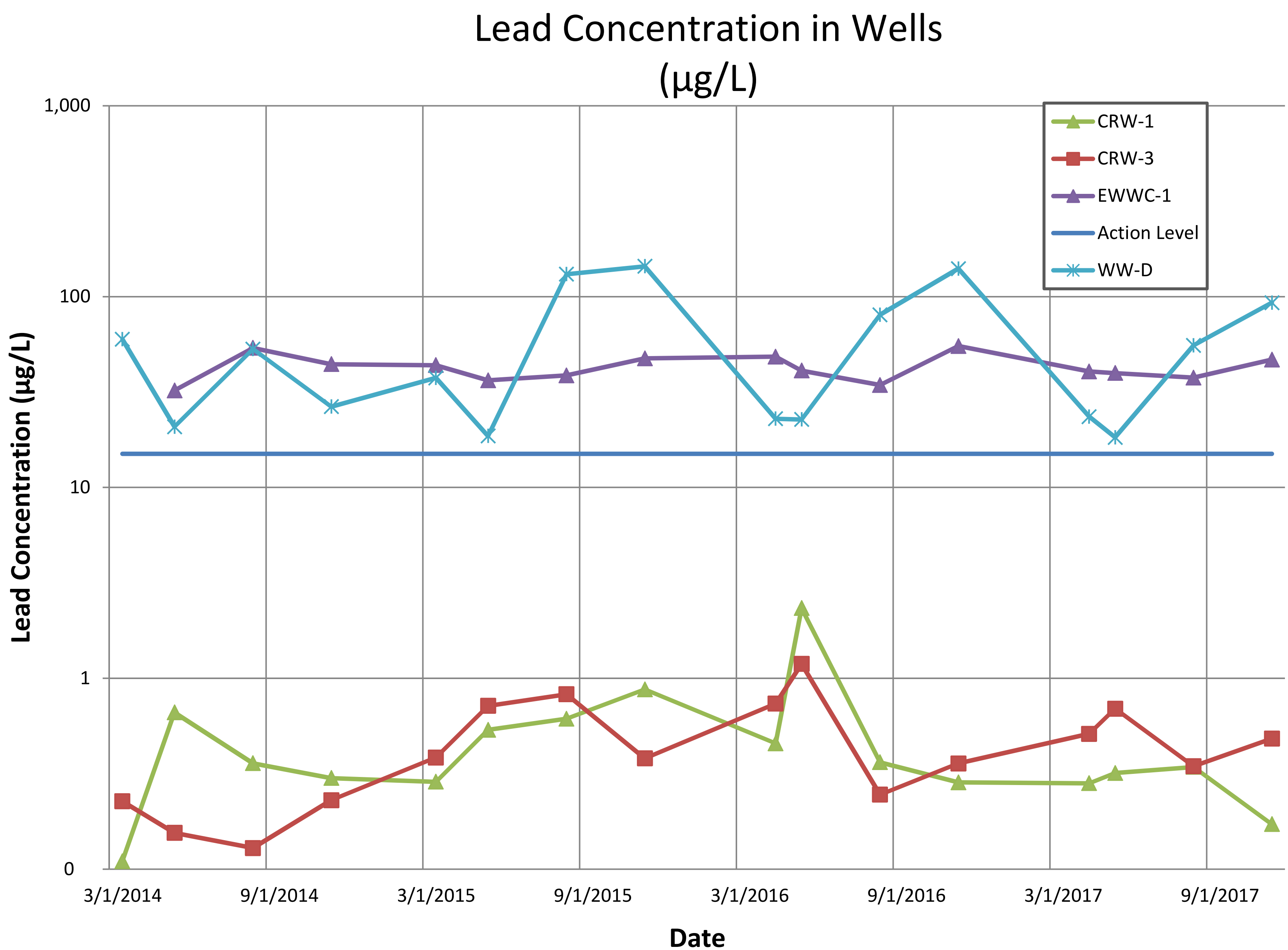

Copper Concentration in Wells
(µg/L)
Copper Concentration (µg/L)
40
35
30
25
20
15
10
5
0
3/1/2014
9/1/2014
3/1/2015
9/1/2015
3/1/2016
9/1/2016
3/1/2017
9/1/2017
Date
CRW-1
CRW-3
EWWC-1
WW-D

Figure 3-41



Lead Concentration in Wells
(µg/L)
1,000
100
10
1
0
Lead Concentration (µg/L)
3/1/2014
9/1/2014
3/1/2015
9/1/2015
3/1/2016
9/1/2016
3/1/2017
9/1/2017
Date
CRW-1
CRW-3
EWWC-1
Action Level
WW-D

Figure 3-42

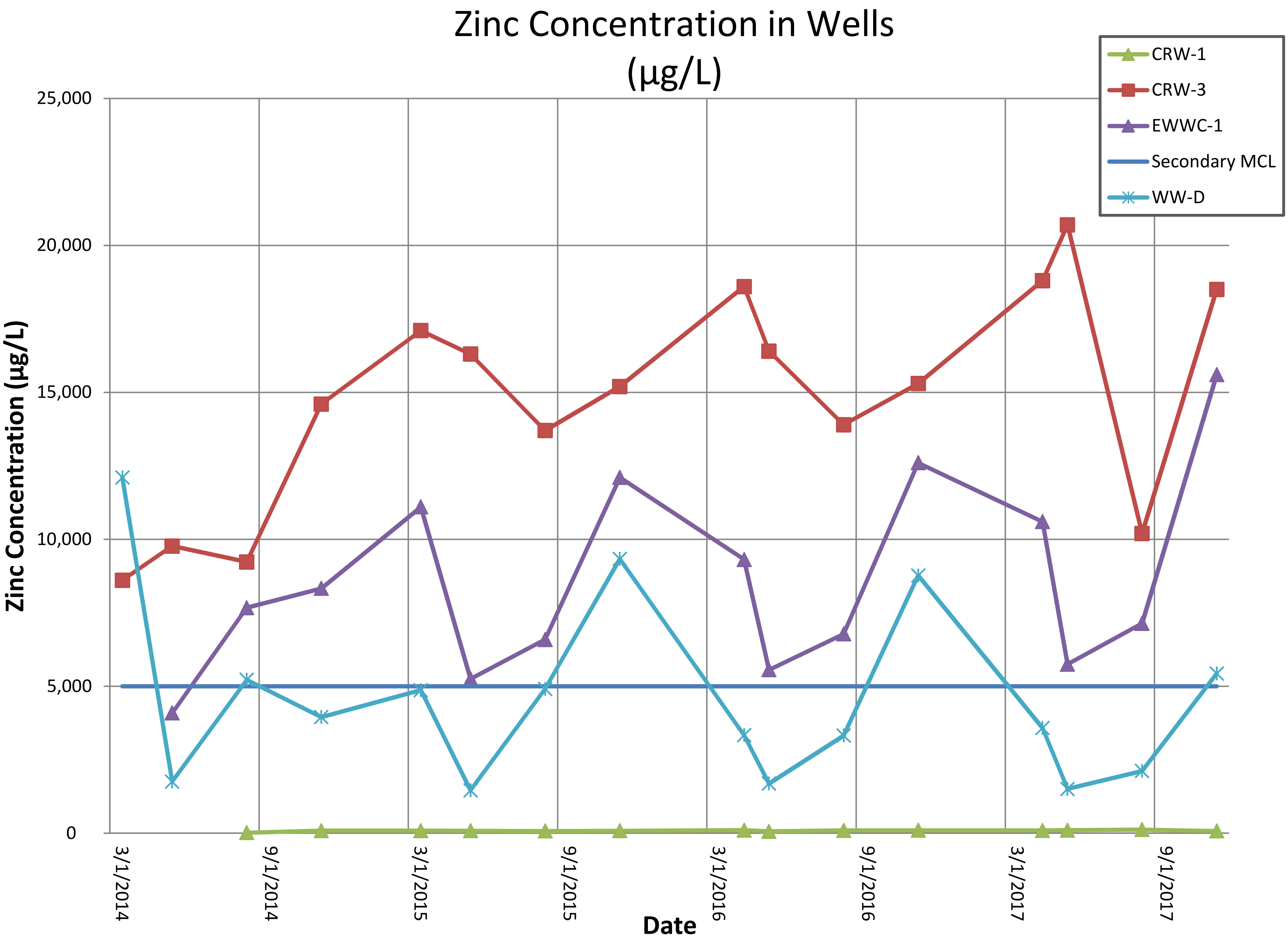

Zinc Concentration in Wells
(µg/L)
CRW-1
CRW-3
EWWC-1
Secondary MCL
WW-D
25,000
20,000
15,000
10,000
5,000
0
Zinc Concentration (µg/L)
3/1/2014
9/1/2014
3/1/2015
9/1/2015
3/1/2016
9/1/2016
3/1/2017
9/1/2017
Date

Figure 3-43

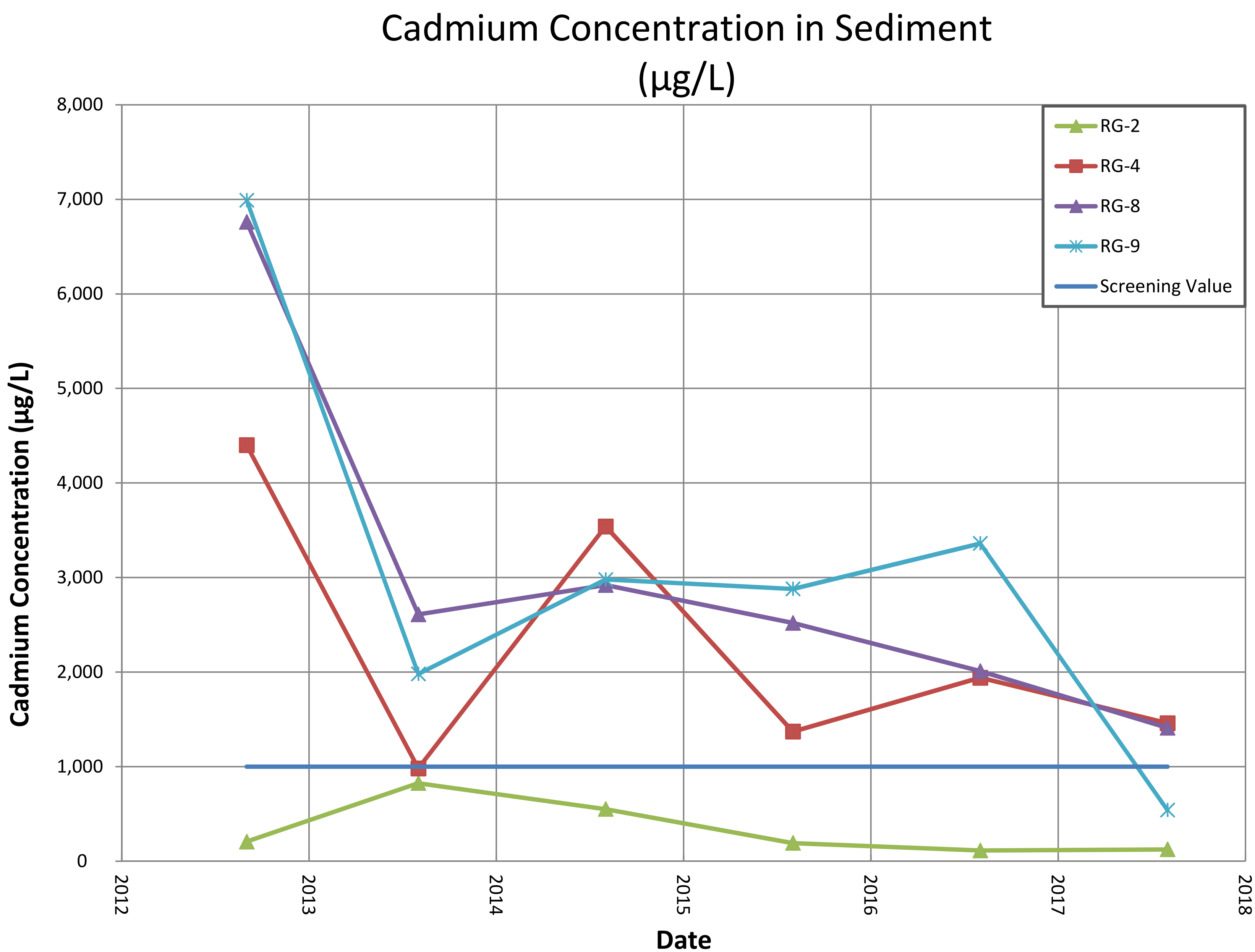

Cadmium Concentration in Sediment
(µg/L)
Cadmium Concentration (µg/L)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
2012
2013
2014
2015
2016
2017
2018
Date
RG-2
RG-4
RG-8
RG-9
Screening Value

Figure 3-44

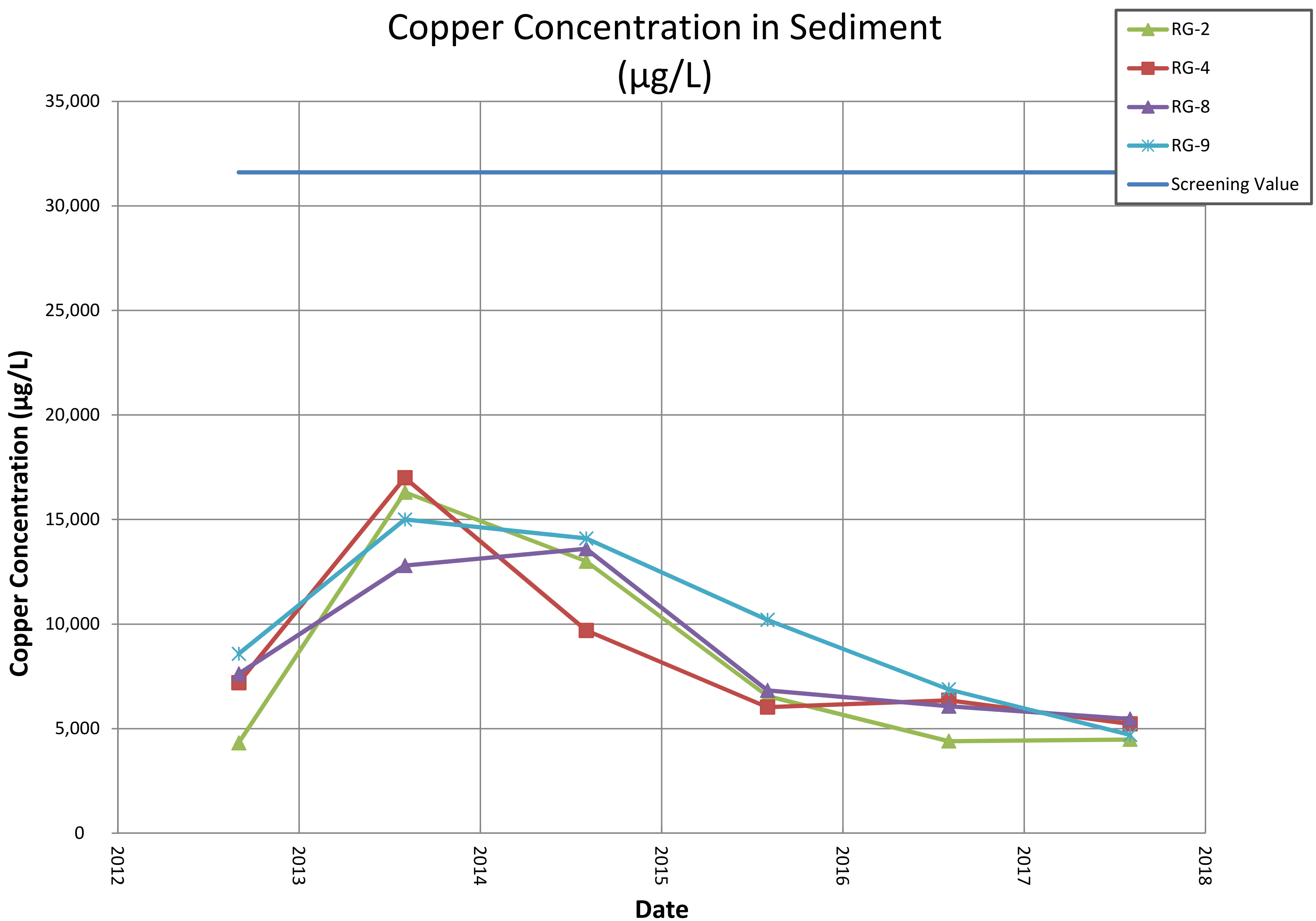

Copper Concentration in Sediment
(µg/L)
RG-2
RG-4
RG-8
RG-9
Screening Value
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Copper Concentration (µg/L)
2012
2013
2014
2015
2016
2017
2018
Date

Figure 3-45

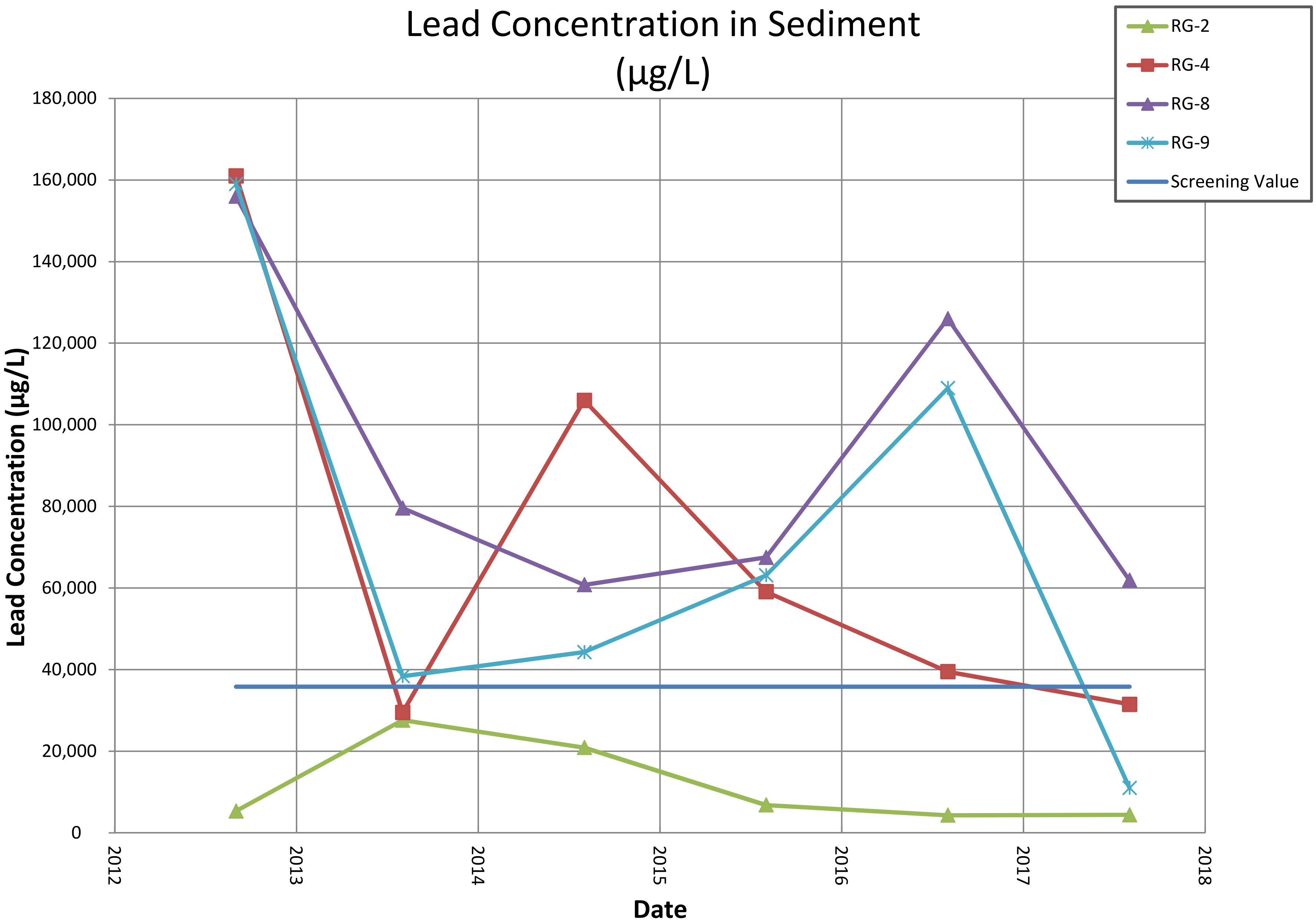

Lead Concentration in Sediment
(µg/L)
RG-2
RG-4
RG-8
RG-9
Screening Value
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Lead Concentration (µg/L)
2012
2013
2014
2015
2016
2017
2018
Date

Figure 3-46

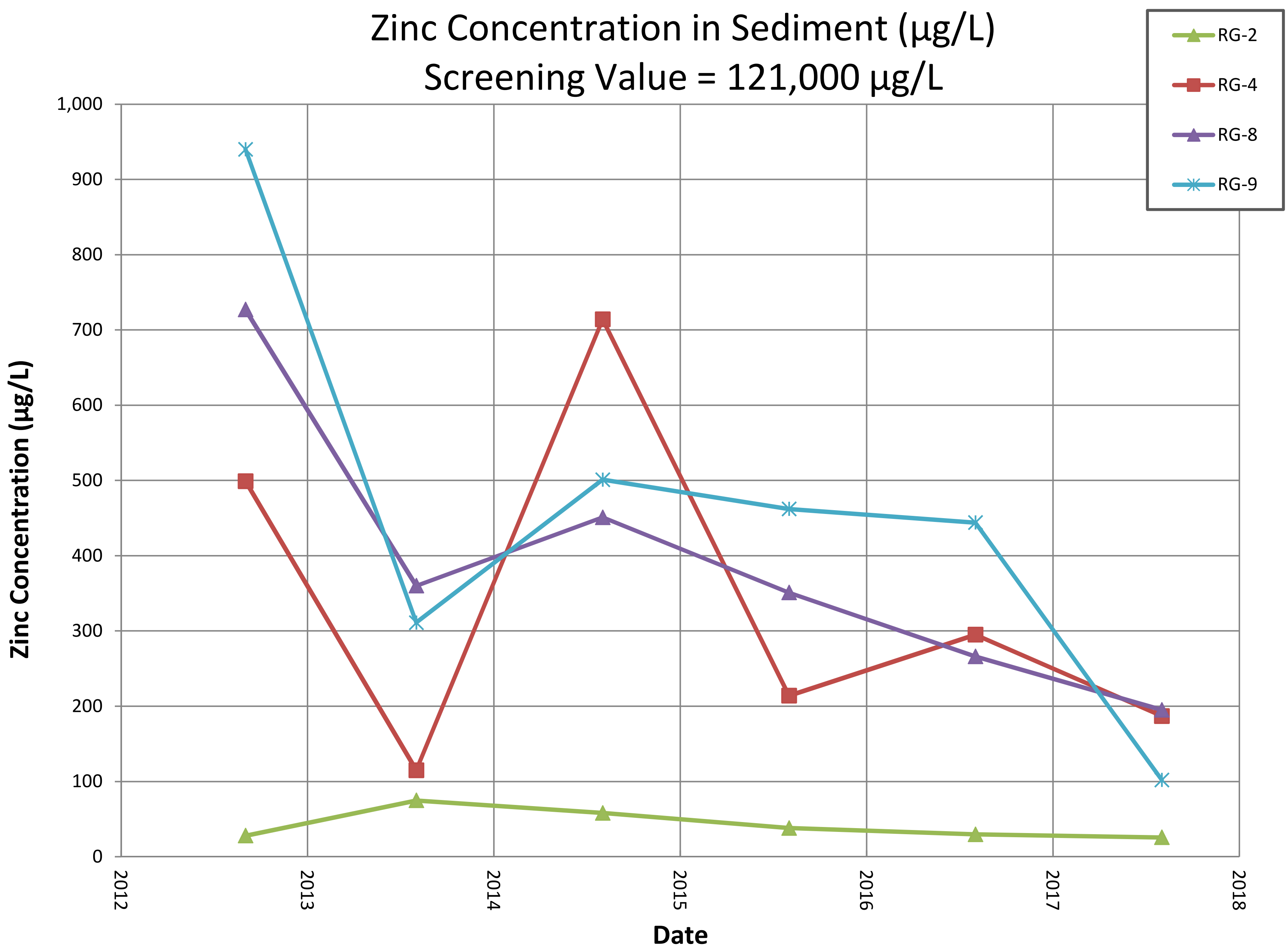

Zinc Concentration in Sediment (µg/L)
Screening Value = 121,000 µg/L
RG-2
RG-4
RG-8
RG-9
Zinc Concentration (µg/L)
1,000
900
800
700
600
500
400
300
200
100
0
2012
2013
2014
2015
2016
2017
2018
Date

Figure 3-47

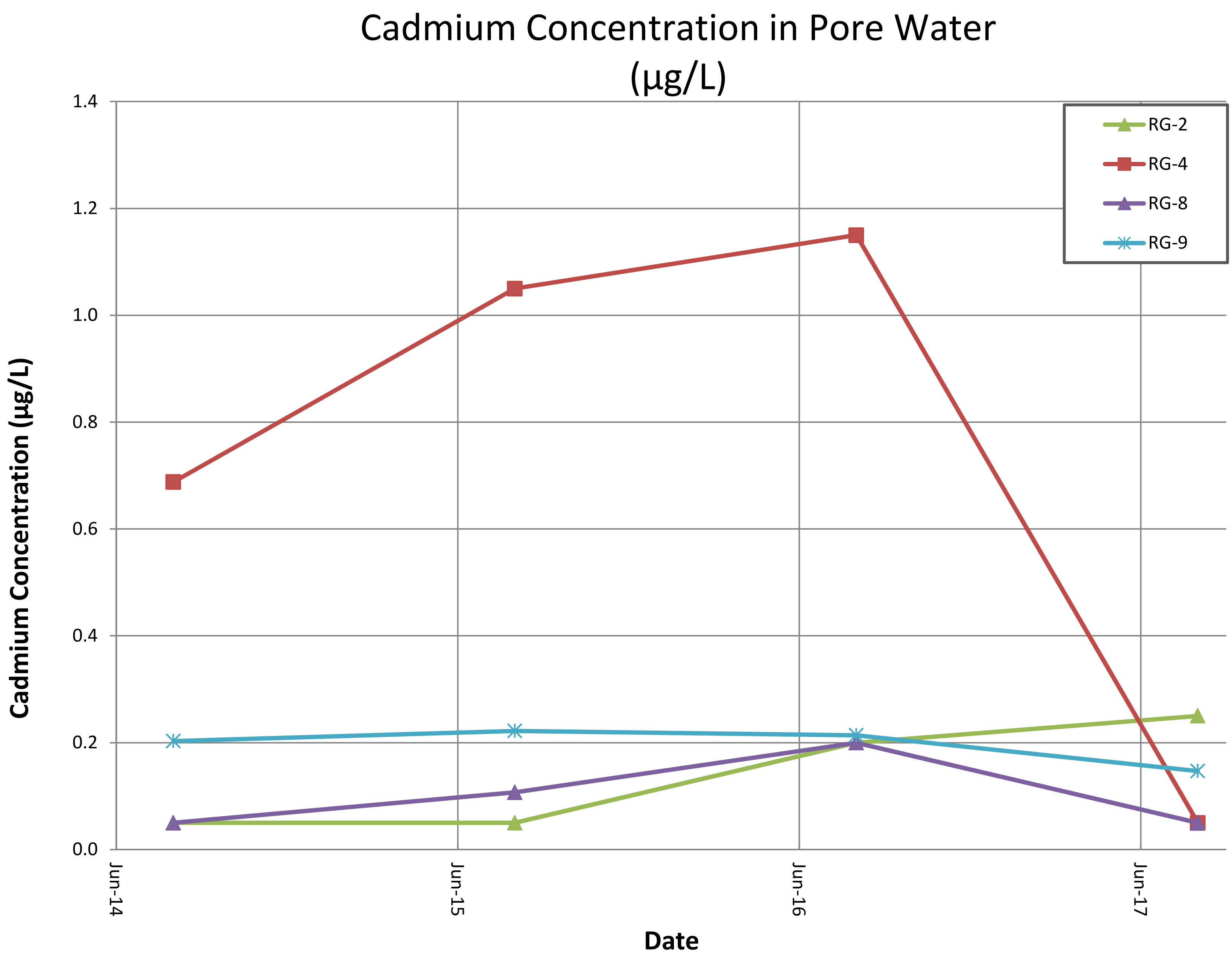
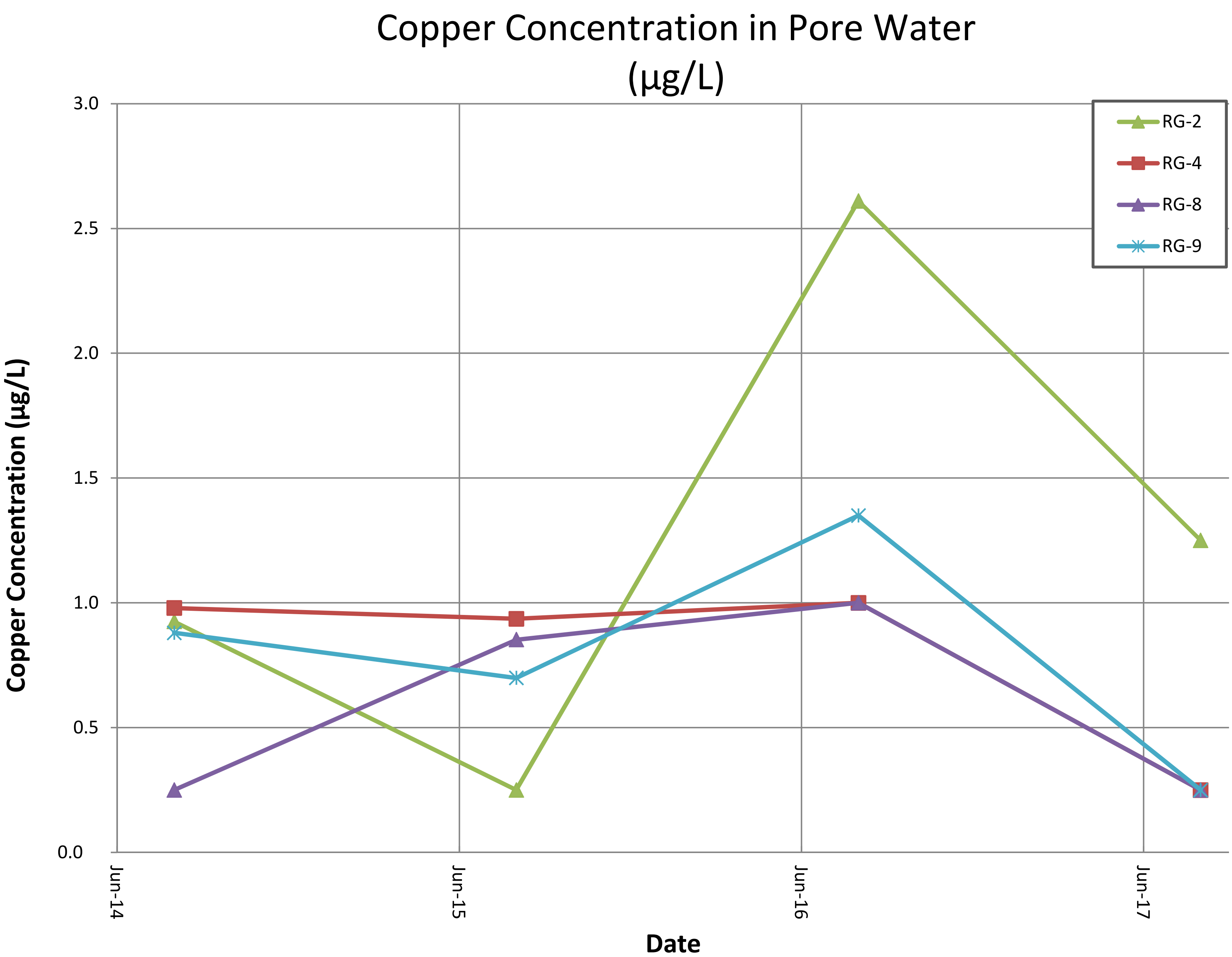

Cadmium Concentration in Pore Water
(µg/L)
Cadmium Concentration (µg/L)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Jun-14
Jun-15
Jun-16
Jun-17
Date
RG-2
RG-4
RG-8
RG-9

Figure 3-48



Copper Concentration in Pore Water
(µg/L)
Copper Concentration (µg/L)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jun-14
Jun-15
Jun-16
Jun-17
Date
RG-2
RG-4
RG-8
RG-9

Figure 3-49

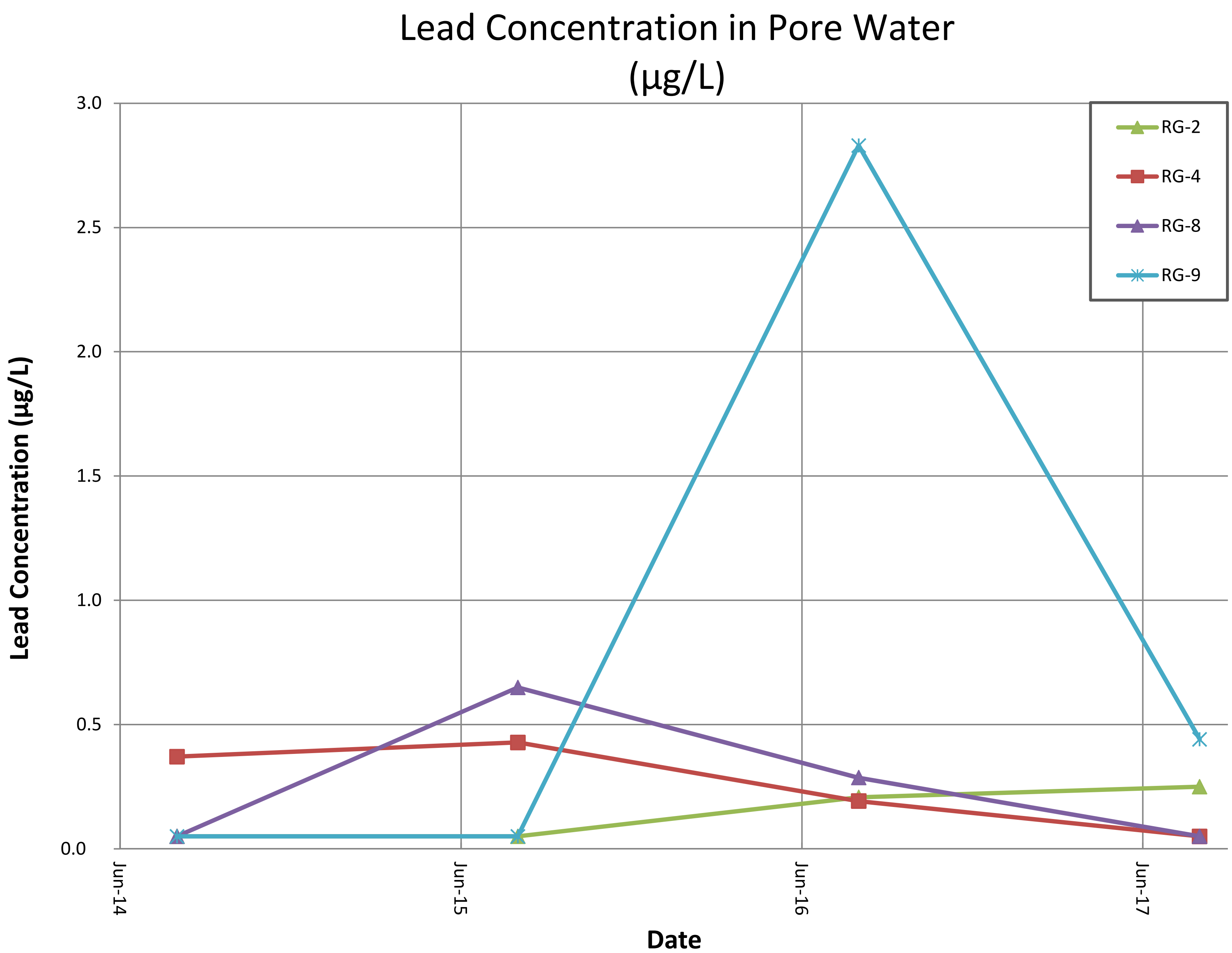

Lead Concentration in Pore Water
(µg/L)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Lead Concentration (µg/L)
Jun-14
Jun-15
Jun-16
Jun-17
Date
RG-2
RG-4
RG-8
RG-9

Figure 3-50

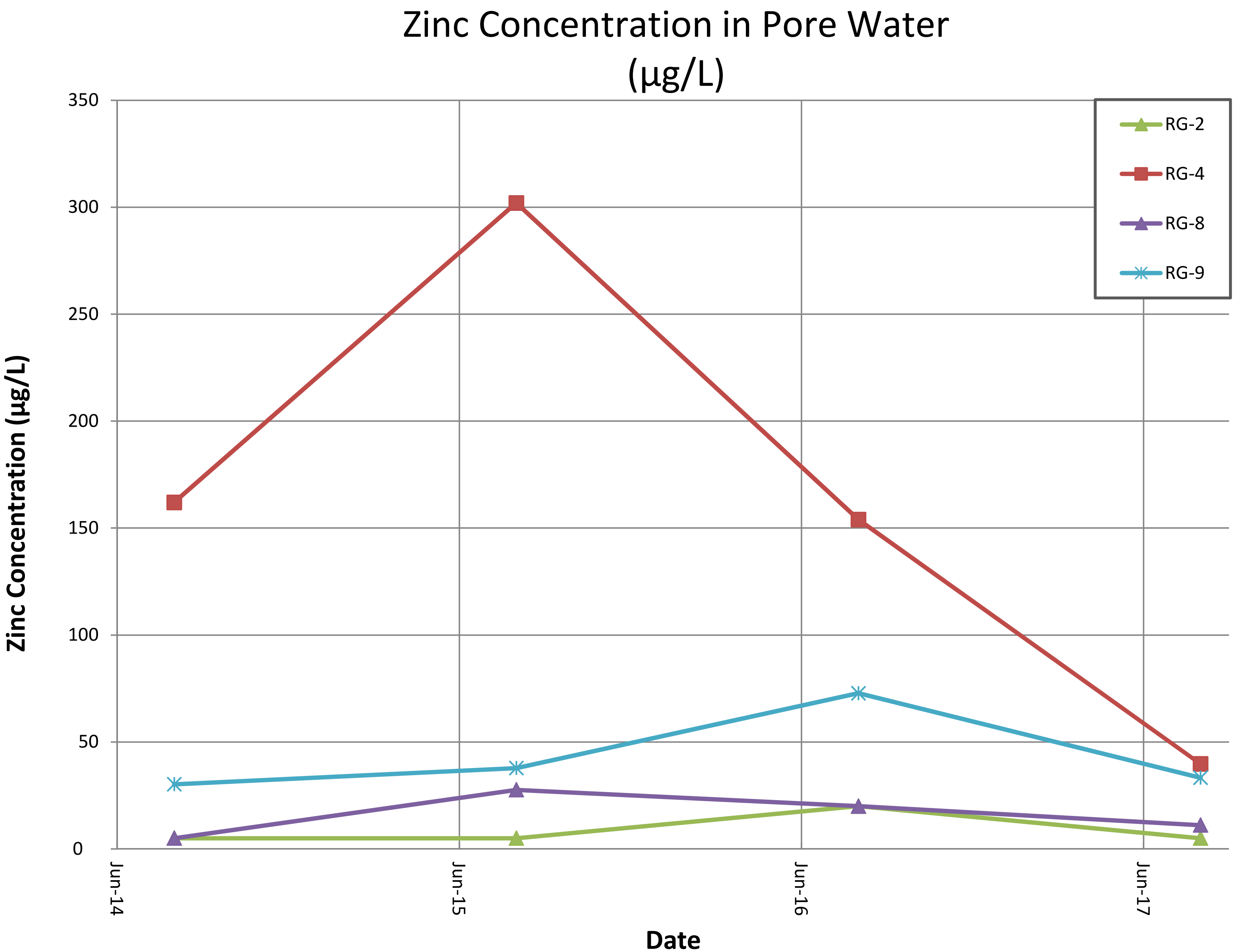

Zinc Concentration in Pore Water
(µg/L)
Zinc Concentration (µg/L)
0
50
100
150
200
250
300
350
Jun-14
Jun-15
Jun-16
Jun-17
Date
RG-2
RG-4
RG-8
RG-9

Figure 3-51

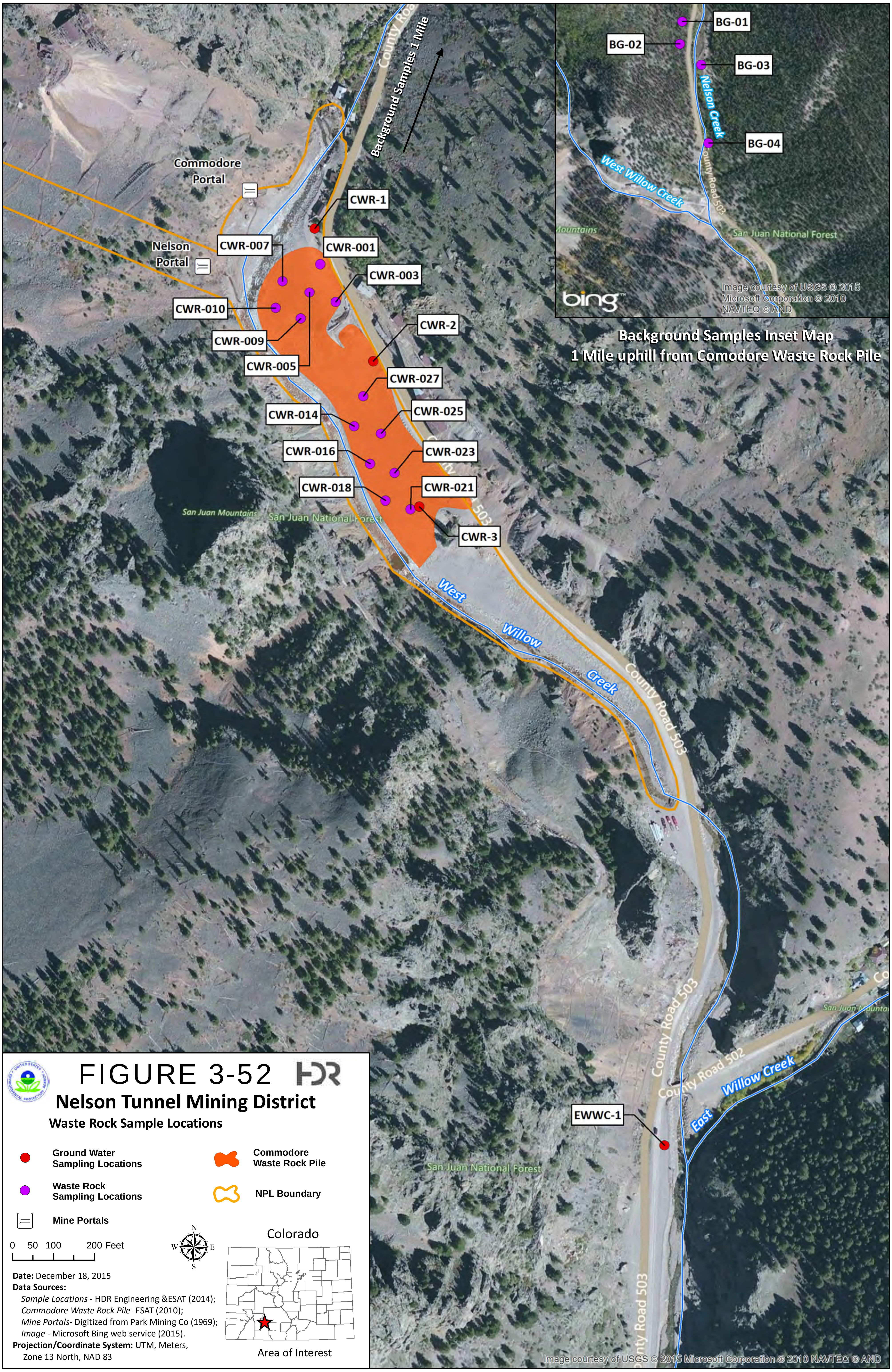


FIGURE 3-52
Nelson Tunnel Mining District
Waste Rock Sample Locations
Ground Water Sampling Locations
Waste Rock Sampling Locations
Mine Portals
Commodore Waste Rock Pile
NPL Boundary
0 50 100 200 Feet
Colorado
Area of Interest
Date: December 18, 2015
Data Sources:
Sample Locations - HDR Engineering &ESAT (2014);
Commodore Waste Rock Pile- ESAT (2010);
Mine Portals- Digitized from Park Mining Co (1969);
Image - Microsoft Bing web service (2015).
Projection/Coordinate System: UTM, Meters, Zone 13 North, NAD 83
Background Samples Inset Map
1 Mile uphill from Comodore Waste Rock Pile
BG-01
BG-02
BG-03
BG-04
Nelson Creek
West Willow Creek
County Road 503
San Juan National Forest
Image courtesy of USGS © 2015 Microsoft Corporation © 2010 NAVTEQ © AND
Background Samples 1 Mile
Commodore Portal
Nelson Portal
CWR-1
CWR-001
CWR-003
CWR-007
CWR-010
CWR-009
CWR-005
CWR-2
CWR-027
CWR-025
CWR-014
CWR-016
CWR-023
CWR-018
CWR-021
CWR-3
San Juan Mountains
San Juan National Forest
West Willow Creek
County Road 503
County Road 502
East Willow Creek
EWWC-1
Image courtesy of USGS © 2015 Microsoft Corporation © 2010 NAVTEQ © AND

APPENDIX A

Colorado Division of Reclamation, Mining and Safety Technical Memorandum:
Commodore-Nelson Tunnel Mine Pool Observations

COLORADO
Division of Reclamation, Mining and Safety
Department of Natural Resources

1313 Sherman Street, Room 215
Denver, CO 80203

Wendy Naugle
Engineer/Hydrogeologist
Colorado Dept. of Health and Environment
4300 Cherry Creek Drive South
Denver, CO 80246-1530

November 6, 2015

Technical Memorandum Re: Commodore-Nelson Tunnel Mine Pool Observations

Note: For purposes of this discussion, the attached map "Mine Pool Elevations" will be used to reference locations and mine pools, and the Nelson Tunnel when mentioned is defined as the Nelson-Wooster-Humphries unless otherwise noted.

The Nelson Tunnel (Nelson) is an approximate two (2) mile haulage and drainage tunnel that functions as the minimum outlet elevation for discharge of mine water from the Commodore Mine Complex. At its collapsed portal, it lies approximately fifty (50) feet below (elevation ~9175') the Commodore 5 Level (5 Level) portal (elevation 9230'), but joins the 5 Level near the Park Regent Shaft almost two (2) miles from the entrance. The Nelson was driven at varying gradients between a half (1/2) percent and one (1) percent over its entire length while the 5 Level was driven at a quarter (1/4) percent or less resulting in the eventual junction at the Park Regent.

Discharge from the Nelson has been measured as low as 180 gallons per minute (gpm), and as high as 315 gpm. Since no datalogger is installed at the Nelson flume, fluctuations in flow rate cannot be correlated to seasonal influences. Based on spot measurements taken by the Division of Reclamation, Mining and Safety (DRMS), eighteen (18) observations made over eight (8) years provides an average flow rate of 270 gpm. Discharge from the Nelson currently flows through a collapse at the portal and then is collected in a six (6) inch Parshall flume used by the City of Creede to measure discharge. The current flume is in disrepair, and likely does not capture the entire Nelson discharge due to its current installation. DRMS installed a four (4) inch cutthroat flume in the Nelson at the Bachelor Shaft to more accurately measure discharge from the Nelson. Discharge measurements performed in the Nelson at Bachelor neglect inputs from the Corkscrew Raise, but still represent flow measurements that are typically 5% higher than those at the portal flume.

The Nelson can only be accessed from the 5 Level at the following locations due to the portal collapse and various mine pools: Bachelor Shaft, Javelin Shaft/Winze, Daylight Winze, Commodore Shaft, No Name (YO2) Winze, Del Monte Raise, Berkshire Shaft, Decline, Park Regent Junction. Only the Bachelor Shaft, YO2 and Park Regent Junction allow access into the Nelson Tunnel, while all other locations only allow for mine pool observations of the Nelson.

The Nelson Tunnel currently has at least three (3) distinct mine pools formed by various falls of ground along the tunnel alignment. Those pools as noted on the attached map are the Nelson Portal Pool (B), the Lower Mine Pool (D), and the Upper Mine Pool (F), which are formed by blockages at the Nelson Portal (A), the Bachelor Shaft (C) and the near the No Name/YO2 Winze (E). The distinction of each pool is based on pool elevation observations performed at all access points to the Nelson.

<u>Nelson Portal Pool</u>

The Nelson Portal Pool (B) is formed by a collapse of the portal entry structure and surrounding ground. The blockage appears to consist of both mine timbers, and a well graded matrix of collapse debris. Some large diameter boulders (>2') were observed within the visible debris plug. Water is discharging through the debris material approximately three (3) vertical feet from the toe of the collapse. The collapse forming the portal blockage appears to express itself nearly forty (40) feet above the portal suggesting a significant blockage is present, but determining the actual thickness of the plug is impossible without additional subsurface information. Significant ferri-hydroxide deposits are likely present within the debris plug as evidenced by orange precipitate present along the discharge pathway immediately downstream of the plug.

The possibility exists for multiple collapses within Pool B since that section of tunnel cannot be accessed or observed from the workings except at the Bachelor Shaft. Measurements taken in the Nelson at the Bachelor shaft indicate a relatively constant pool elevation of 9197', with no significant elevation changes noted. The maximum attainable head for Pool B would be controlled by the collar elevation of the Bachelor Shaft access from 5 Level. Once the pool reached the collar elevation of 9240', discharge would occur through the 5 Level. The maximum attainable head of forty-three (43) feet at the Nelson portal blockage is the difference between portal elevation and Bachelor Shaft access collar elevation.

An estimated flooded length of 2500 feet includes the Nelson tunnel from portal to the Bachelor Shaft 2100') and an estimated 300 feet of flooded tunnel from the Nelson-Wooster junction toward Corkscrew Raise. At the current pool elevation the entire 2500 feet is not completely flooded, but to facilitate a conservative estimate of the current pool volume, complete flooding is assumed. An average drift width of eight (8) feet and drift height of eight (8) feet is also assumed based on observations made within the Nelson near Bachelor and a historic photo of the Nelson Portal. Based on those assumptions, a current volume for the Nelson Portal Pool (B) is 1.2 million gallons. If Pool B achieved maximum head, the volume would increase significantly due not only to increased vertical storage, but increased flooding of upstream workings.

<u>Lower Mine Pool</u>

The mine pool directly upstream of the Nelson Portal Pool (B) is the Lower Mine Pool (D), which is formed by a collapse of ground (stope run) just upstream of the Bachelor Shaft (C) within the Nelson. This blockage consists of some mine timbers (stulls) and poorly graded stope material. The material is composed mostly of six to twelve (6-12) inch diameter blasted rock within a matrix of fine grained material. It is difficult to determine the thickness of the debris forming this blockage, but the majority of material is standing at angle of repose on the downstream side. Currently the water discharges over the top of the collapsed debris which is approximately ten (10) feet high.

There are likely small collapses that exist between the blockage at Bachelor and the upper end of Pool D near YO2 Winze, but they do not appear to significantly alter the observed pool elevation along its length. Mine pool elevations of Pool D can be measured at the Javelin Winze, Daylight Winze, Commodore Shaft, and YO2 Winze and have indicated a relatively steady pool elevation at 9214' over the last twelve (12) years. The Nelson at YO2 is not completely flooded which allows for entry and observation of the Nelson at that location.

The maximum attainable head for Pool D is currently controlled by the height of the blockage at location C. Unless a significant amount of debris is added to the blockage raising the spill over height, additional impoundment is unlikely. The next control on Pool D elevation would be the collar elevation of Daylight Winze, since this would allow discharge into the 5 Level if Pool D where to attain sufficient elevation. The mine pool would have to exceed an elevation of 9238' to enter the 5 Level. Based on current observations of Pool D, there is approximately ten (10) vertical feet of impounded water on the blockage at C, which results in complete flooding of the Nelson beyond the Commodore Shaft, and partial flooding all the way to the No Name/YO2 Blockage (E).

The horizontal tunnel distance between blockage C and E is approximately 3000 feet, with an assumed average width and height of eight (8) feet. If the tunnel is assumed to be completely flooded for that distance, then 1.4 million gallons of water is stored in the Lower Mine Pool at current pool elevations. Significant additional storage within Pool D is unlikely since the majority of Nelson working are already flooded through this section.

<u>Upper Mine Pool</u>
The most upstream, observed, impoundment is the Upper Mine Pool (F) formed by a blockage or fall of ground near YO2 Winze (E). This blockage appears to consist of no timber or large diameter debris, but instead consists mostly of material less than six (6) inches in diameter. Additionally, there is a significant amount of ferri-hydroxide precipitate and clay that comprises the debris matrix. The blockage appears to be significant in thickness due to a gradual outslope gradient of approximately 10%. The debris eventually pinches to the back of the tunnel where water exits from Pool E. There is some visual evidence suggesting blowouts at this blockage in the past, which could explain the long and gradual outslope of debris. There is currently no way to determine the thickness of the blockage at E without additional subsurface information.

As with both other mine pools, there are probably additional collapses between the blockage at E and the Nelson beyond the Decline, but those collapses, if they exist, do not alter the consistency of pool elevation observations across those locations. Observations of Pool F can be made at the Del Monte Raise, Berkshire Shaft and the Decline indicating a consistent pool elevation throughout. There is currently no location where the Nelson can be entered and observations made of Pool F. The Nelson can be entered at the Park Regent, but the northern extent of Pool F cannot be reached due to numerous falls of ground.

Pool F is subject to the most variability in observed pool elevation. A minimum pool elevation of 9235' has been observed at the Del Monte Raise, while a maximum pool elevation of 9246' was recently observed. Over the last two (2) years the difference between maximum and minimum pool elevations was roughly five (5) feet. The maximum eleven (11) foot difference between pool elevations occurred over a thirteen (13) year period of time. There appears to be a strong spring melt signal that corresponds well with the rising Rio Grande River hydrograph, and results in a spiked mine pool increase. An increased Pool F elevation appears to have no significant influence on pool elevation at other downstream pools, or even on measured discharge at the portal.

The maximum attainable pool elevation in Pool F is approximately 9246', and is controlled by the maximum floor elevation on the 5 Level between Del Monte Raise and YO2 Winze. As Pool F elevation approaches 9246', water from the Nelson floods up the Del Monte Raise into the 5 Level, and begins flowing toward the portal. As water moves along 5 Level toward the portal, it encounters YO2 Winze where it pours back down into the Nelson, downgradient of the blockage at E. The 5 Level is the control on maximum head for Pool F since it is the bypass conduit. If additional collapses occurred along the bypass section of 5 Level, the maximum attainable head would increase on Pool F to the point at which water could flow over or through the collapse to reach YO2 Winze. The maximum current attainable pool elevation of 9246' would result in a theoretical maximum stored water head of thirty-four (34) feet, assuming a Nelson floor elevation of 9212'.

The current maximum head on Pool F was reached in July of this year, and has likely been reached in the past as evidenced by a high water line consistent with the 9246' elevation. The attainment of maximum head appears to have had little impact on stability of the blockage at E or on the stability of downstream pools and blockages.

The original estimate of mine pool volume in Pool F was made during a pilot dewatering test conducted during 2007. The calculated volume of 19.4 million gallons was derived based on observations of drawdown in Pool F corresponding to flow rates of withdrawal. The calculated volume appeared consistent with the known flooded conditions existing within Pool F. Since the northern extent of Pool F is not accessible it is not possible to know the horizontal extent of flooding, which makes estimation of storage volume based on length of flooded workings challenging. Additionally, the amount of stoping that occurred within Pool F is difficult to determine since this portion of the mine encountered the most significant mineralization. Given the significant number of unknowns within Pool F, relying on the volume calculated during the dewatering test appears to provide the most reasonable estimate, but making an estimate based on assumed flooded length and drift width is possible. Assuming a drift width of twelve (12) feet is reasonable since stoping through this area was more significant. A flooded drift length of 6400 feet is probably reasonable when considering that stoping was done between the 5 Level and the

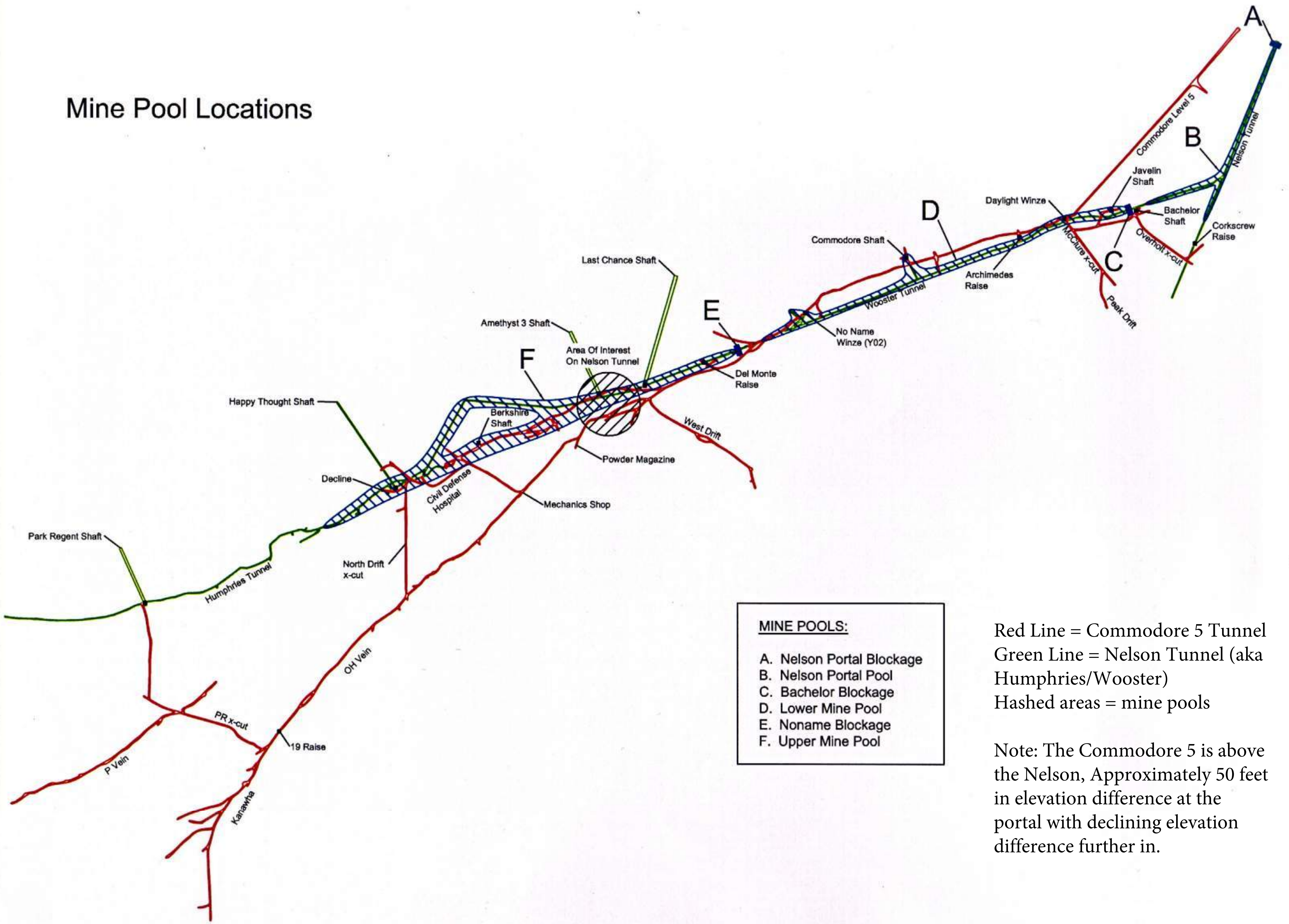
Nelson along the Amethyst Vein. A maximum storage volume of 19.5 million gallons at maximum head is calculated.

The long term stability of blockages A, C and E is unknown, and could change significantly if conditions within the mine workings alter the existing flow regime. Under current conditions the only pool that demonstrates significant fluctuation is Pool F, which appears to have little impact on stability of the existing system. Additional alteration of hydraulic conductivity of the blockages due to precipitation of ferri-hydroxides is unlikely since the flow regime within the tunnel has remained relatively constant since flow returned following cessation of pumping at the Bulldog. New runs of ground within the Nelson could certainly alter the flow regime, but would likely be mitigated and controlled by release through the 5 Level. Currently the 5 Level functions much like a pressure release valve, limiting the maximum head possible on collapses within the Nelson. The possibility of a seismic event must be considered when evaluating the long term stability of any blockages that impound water. This process of evaluation is severely complicated by the unknown nature and extent of the debris forming the blockage.

Respectfully Submitted,

Jeff Graves
Senior Project Manager/Geological Engineer
Inactive Mine Reclamation Program

Mine Pool Locations



Red Line = Commodore 5 Tunnel
Green Line = Nelson Tunnel (aka Humphries/Wooster)
Hashed areas = mine pools

Note: The Commodore 5 is above the Nelson, Approximately 50 feet in elevation difference at the portal with declining elevation difference further in.

APPENDIX B

Colorado Division of Reclamation, Mining and Safety Technical Memorandum: Upper Mine Pool Data and Interpretation

COLORADO
Division of Reclamation, Mining and Safety
Department of Natural Resources

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Denver, CO 80203

Ross Davis
Environmental Protection Specialist
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4300 Cherry Creek Drive South
Denver, CO 80246-1530

September 18th, 2018

Technical Memorandum Re: Upper Mine Pool Data and Interpretation

Note: For purposes of this discussion, the attached charts, “Upper Mine Pool Elevations and Temperature” along with “Inflow to Upper Mine Pool at Del Monte” will be referenced.

Temperature and Pool Elevations

During the winter of 2013, In-situ Level Troll 100 pressure transducers where placed in two different locations of the Upper Mine Pool to facilitate long term collection of mine pool elevation data and temperature data. The pressure transducers measure pressure and temperature every 6 hours, and are periodically downloaded. The two locations, Del Monte and Berkshire have established vertical control spads that mine pool elevation data can be correlated to. The Del Monte is the furthest downstream location of the Upper Mine Pool where water levels can be directly measured, while the Berkshire Shaft provides a location approximately 2000’ upstream within the mine pool.

From 2001 to 2013, periodic spot measurements were made of both the Upper and Lower Mine Pools, but no consistent monitoring plan or data loggers were in place to facilitate higher resolution time series information. The spot measurements indicated there was significant fluctuation in the Upper Pool of up to 9’, but insufficient resolution was available to determine if there was any real pattern to the data.

Following installation of the pressure transducers in 2013, a pattern of seasonal mine pool and temperature fluctuation became very apparent. There is a very dominant seasonal increase in mine pool elevation nearly every April which likely corresponds to initial snowmelt. The increase in mine pool elevation is also followed very shortly by an overall decrease in mine pool temperature, highlighting the colder nature of the inflow. Both of these patterns for pool elevation and temperature reverse between summer and winter, and are repeated each year. The magnitude of change varies slightly from year to year, but averages out to a 5’ fluctuation in mine pool elevation and a 2°F temperature change.

There are some additional anomalies in the Del Monte temperature patterns that likely have to do with Commodore 5 Level flooding and subsequent increase in mine pool surface area exposed to ambient air ventilation. The magnitude of temperature fluctuation at Del Monte is greater than the Berkshire shaft suggesting that Del Monte is closer to the source of cold water input, but the start of temperature change is similar at both locations. There remain a number of unexplained characteristics of the temperature patterns that could have implications for understanding groundwater hydrology and surface infiltration.

In an attempt to quantify the amount of colder water inflow that could result in the magnitude of change seen at both monitoring locations, a very basic static temperature mixing model was applied. The temperature mixing model and assumptions are shown below:

$T_F = (m_1*T_1 + m_2*T_2)/(m_1+m_2)$

<u>where:</u>
T_F = final temperature of mine pool (˚F)
T_1 = initial temperature of mine pool (˚F)
T_2 = temperature of inflow (˚F) *unknown
m_1 = mass of mine pool (unit less)
m_2 = mass of inflow (unit less) *unknown

<u>assumptions:</u>
1. Static mixing model with no inflow or outflow from mine pool other than calculated inflow. In other words, closed system that doesn't account for current known inflow and outflow.
2. No heat loss or gain from surrounding rock or airflow.
3. Complete volume of inflow is instantaneous.
4. Temperature at measurement point is representative of entire mine pool.
5. Inflow derived from snowmelt.
6. Mass/volume of mine pool equivalent to 1, therefore mass/volume of inflow equivalent to fraction or percent of total mine pool.

The attached graph titled, "Inflow to the Upper Mine Pool at Del Monte," depicts the calculated mass/volume of the inflow as a function of temperature. Since the inflow is assumed to be snowmelt derived, temperatures were varied from 33˚F to 55˚F. In most other cases that the author has observed where recharge to a groundwater system is snowmelt derived, snowmelt temperatures are between 35˚F and 40˚F. As can be seen in the graph, the inflow percentage or fraction of the mine pool required to lower the temperature doesn't exceed 10% for the most likely range of temperature for the inflow. Obviously as the temperature of the inflow is increased, the corresponding percentage of the mine pool that the inflow accounts for increases. Based on a previous estimate of the mine pool volume at 19 million gallons, 10% would amount to nearly 2 million gallons. As a side note, 2 million gallons represents approximately 4 days of discharge at a Nelson Tunnel discharge rate of 400 gallons per minute. Additionally, 2 million gallons amounts to approximately 1% of the total yearly discharge from the Nelson Tunnel.

Recognizing the above assumptions and likelihood of numerous other unknowns, the calculations of both inflow temperature and mass of the inflow represent only an estimate. It is difficult to determine if the calculated values represent a conservative estimate of inflow mass/volume, since few constraints exist regarding the inflow. One consideration is that with such a high turnover rate within the upper mine pool, the final temperature of the mine pool following cold inflow is significantly impacted. Assuming that the inflow temperature is similar to the stabilized winter temperature of the mine pool, then the calculated cold inflow probably accounts for a greater volume than the simple mixing model provides. With additional time, a more robust dynamic model that accounts for the current inflow and outflow could be developed to help refine the estimate for cold inflow volume.

Isotope Analysis

Isotope sampling of the discharge from the Nelson Tunnel has been conducted on a number of occasions to help characterize and understand the possible sources associated with discharge from the Tunnel. Comparing the isotopic analysis to mine pool elevation and temperature fluctuations provides additional insight into possible sources for the inflows.

Isotopic sampling at the Commodore Mine Complex, including the Nelson Tunnel, is well summarized in two reports, Source Water Investigation Report: Isotopic and Geochemical Approaches to Characterizing Water Movement Through Abandoned Mine Working, Nelson-Wooster-Humphrey Tunnel Creede, Colorado, by R. Cowie, M. Williams, and A. Krupicka, dated July 19th, 2014, and in a report titled Results of Ground-Water Tracing Experiments in the Nelson-Wooster-Humphrey Tunnel, by Cambrian Ground Water Co. Both reports indicate that a large percentage of groundwater discharging from the Nelson Tunnel can be dated prior to the 1960s, based on the lack of Tritium Units (TU). The Cowie report provides additional data suggesting a large percentage of the groundwater could be thousands of years old.

The spring transition in mine pool temperature would suggest that any age dating of the discharge should reflect a younger water source than all the previously conducted age dating has determined. One question is whether or not the water sampling for age dating has been conducted during the appropriate period of time to capture potential younger surface inflows. As seen in the attached graph, age date water samples have been overlaid with mine pool elevation fluctuation for 2014-2017. The actual water samples don't correspond with any of the years shown, but considering the consistency in mine pool fluctuations, it can be reasonably assumed to be similar. The graph indicates that water samples for age dating were collected during the period of increased mine pool elevation which corresponds to potential increased surface (younger) inflows suggesting that tritium samples should show some younger water if there was any. Those tritium samples don't show younger water, or any perceived patter across the sampling time period. When looking at the temperature trend data for the mine pools, the temperature generally stays depressed from the beginning of the mine pool elevation change through the entire summer which pretty well covers the sampling period. If pool temperature is remaining depressed, it would also confirm that surface (younger) inflow waters were still present. As mentioned before, no significant amount of apparently younger water is present.

The Cambrian Ground Water report details a dye trace test that was conducted during 2001 to calculate groundwater travel time from the Berkshire Shaft to the Nelson Portal. The report indicates first arrival of dye at 4.5 days with a peak at 8.5 days, and dye still visible beyond 41 days, but at a much lower concentration. Applying those travel times with the onset of mine pool fluctuation, it is possible that the water sample collected in mid-June could have missed the high concentration of potentially younger water. Even though this is possible, it does appear likely that the water samples would have indicated at least a slight increase in tritium considering the residence time of water within the Upper Mine Pool.

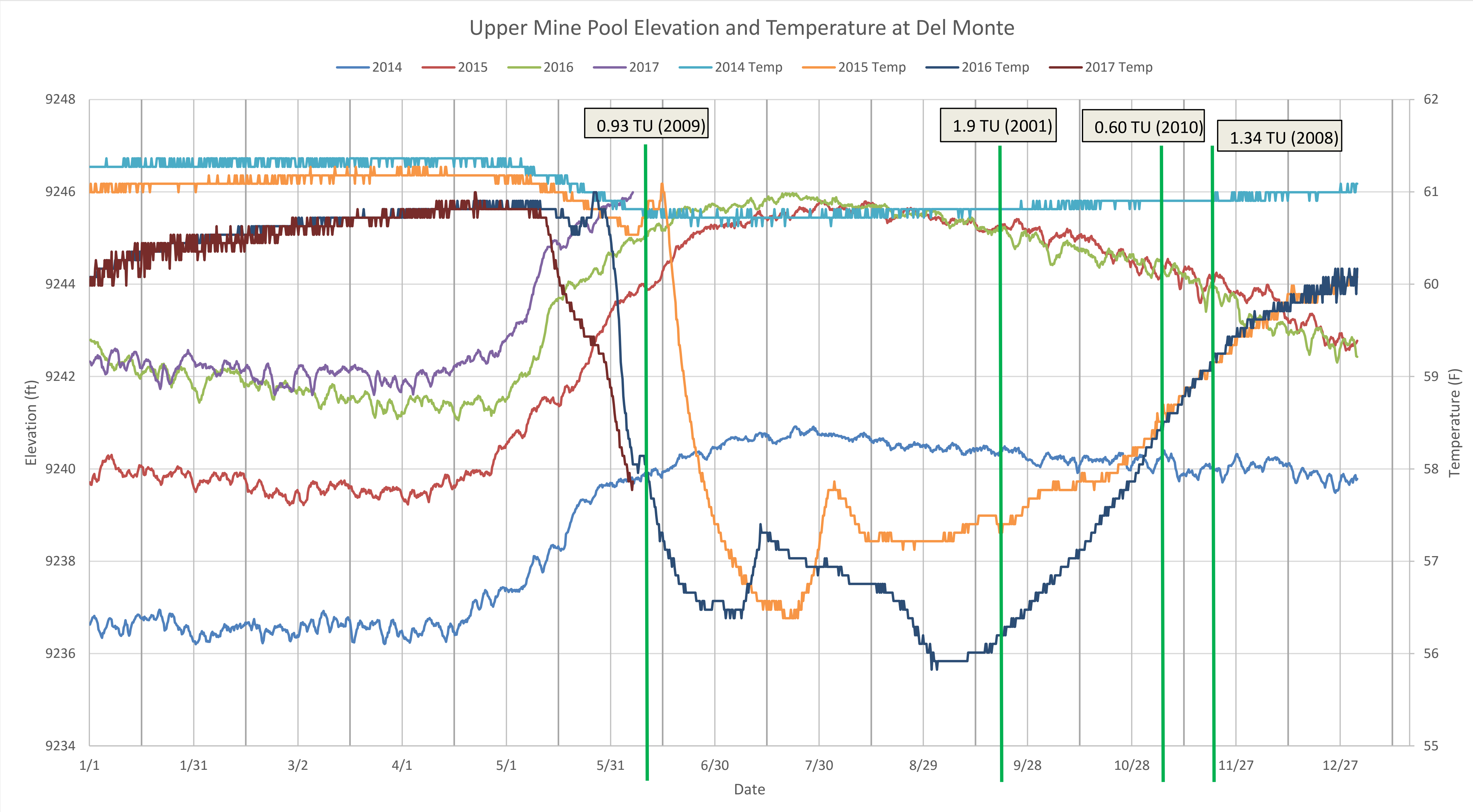
If a similar mixing model like that used for temperature is applied to the Tritium samples, there is a strong possibility that the amount of young water inflow is insignificant enough that it cannot be resolved against the larger volume of “old” water. As discussed in the temperature analysis, a surface inflow volume of 10% of the total mine pool is possible, and accordingly, the tritium variation might not exceed the error associated with the tritium measurement.

Summary and Conclusions

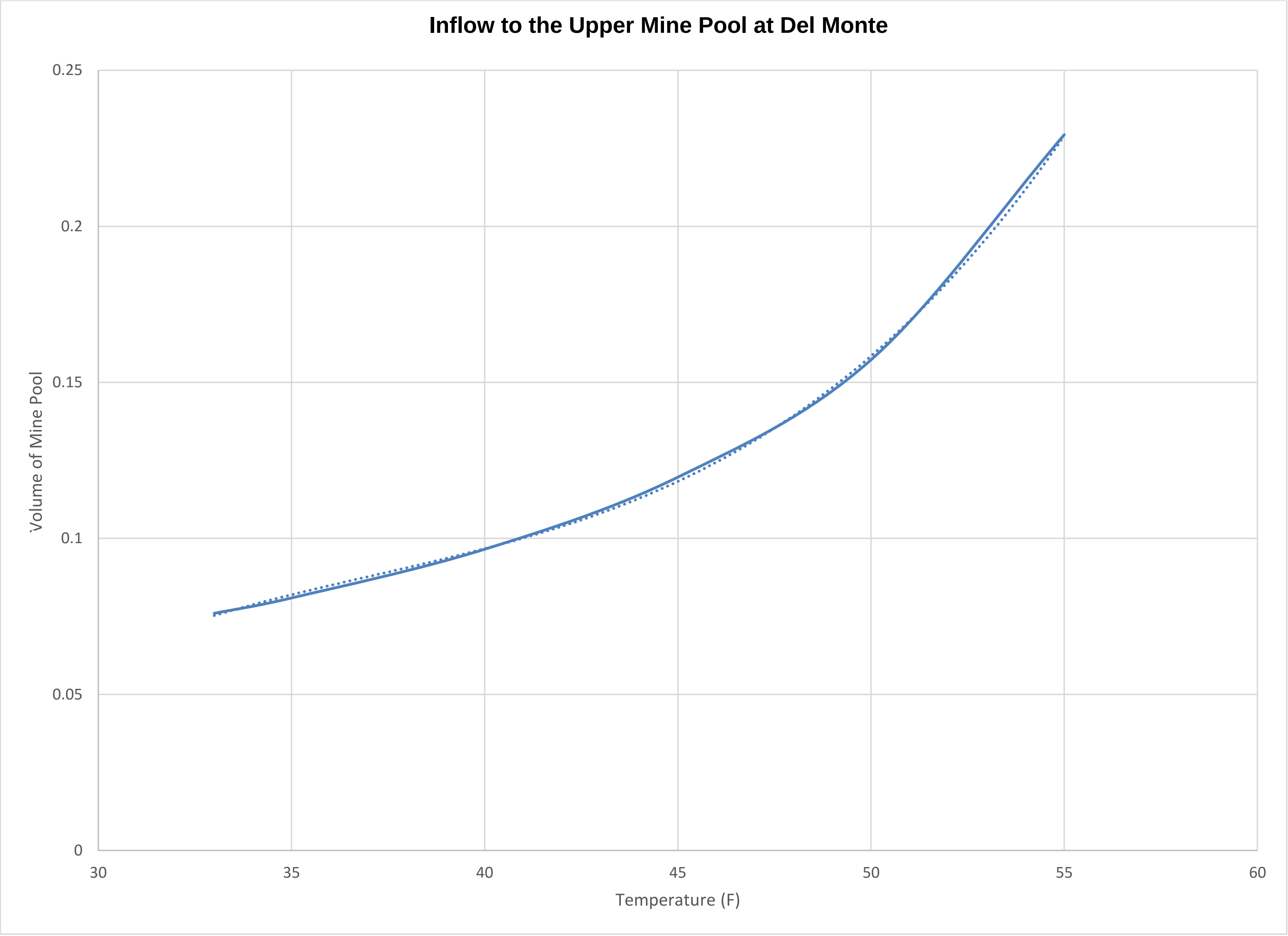
The seasonal fluctuation of Upper Mine Pool elevation along with a corresponding decrease in overall mine pool temperature suggests an influx of cold, young, surface water, which contradicts existing isotope samples dating the majority of groundwater at over 60 years. Based on the analysis, it is possible that the amount of young, surface water inflow is insignificant enough that it isn’t resolvable per the sampling and analysis method for tritium. It is also possible that the sampling dates do not sufficiently capture the peak concentration of young water due to the travel times associated with outflow from the Upper Mine Pool. Conducting additional tritium sampling in Nelson discharge water during early to mid-May could provide some resolution regarding possible younger surface inputs to the system. It is also worth considering that resolving the actual amount of surface inflow may be not warranted since it may amount to only 1% of the total annual discharge from the tunnel.

Respectfully Submitted,

Jeff Graves
Program Director/Geological Engineer
Inactive Mine Reclamation Program



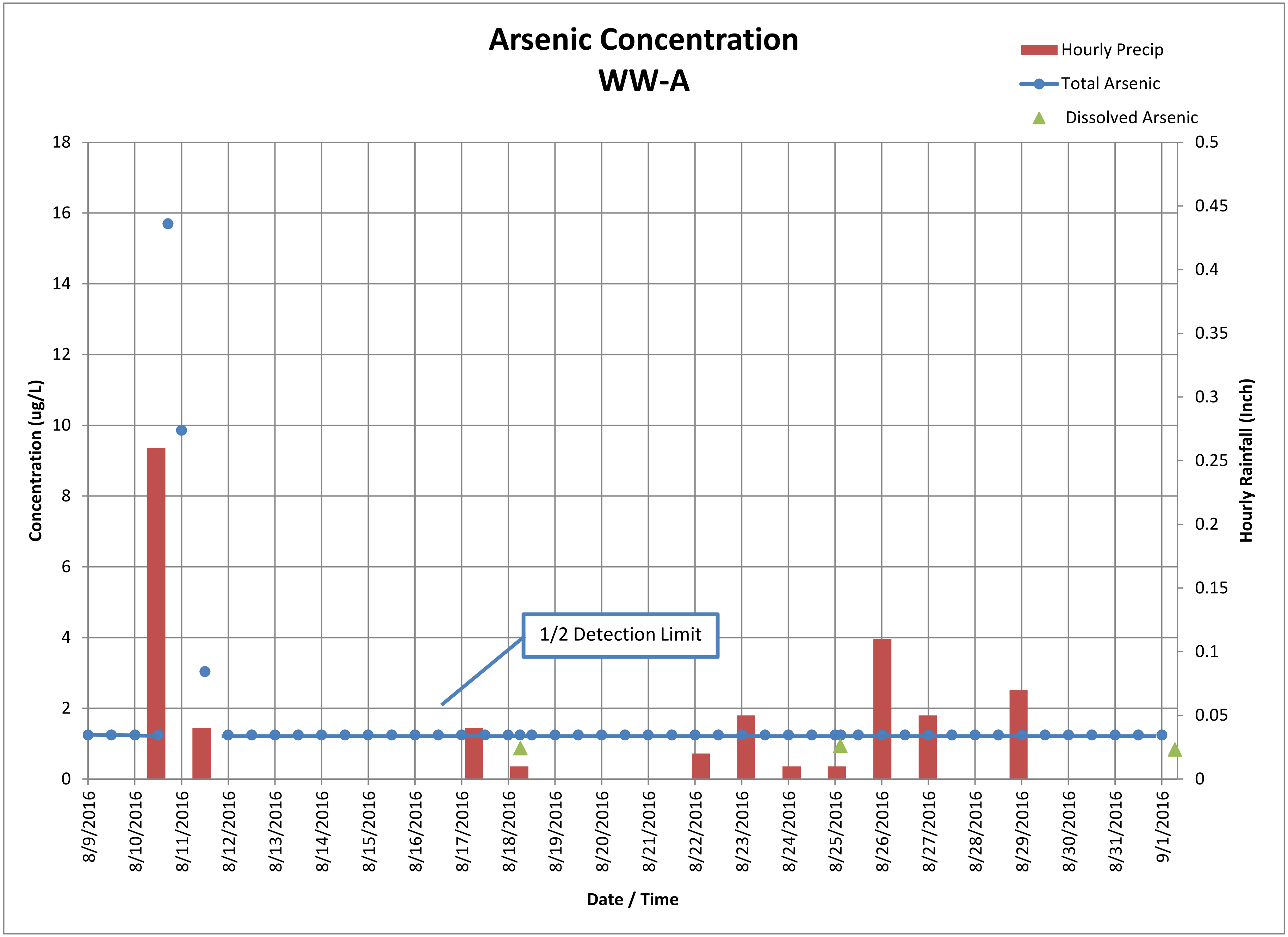
Upper Mine Pool Elevation and Temperature at Del Monte
2014
2015
2016
2017
2014 Temp
2015 Temp
2016 Temp
2017 Temp
0.93 TU (2009)
1.9 TU (2001)
0.60 TU (2010)
1.34 TU (2008)
Elevation (ft)
9248
9246
9244
9242
9240
9238
9236
9234
Temperature (F)
62
61
60
59
58
57
56
55
Date
1/1
1/31
3/2
4/1
5/1
5/31
6/30
7/30
8/29
9/28
10/28
11/27
12/27



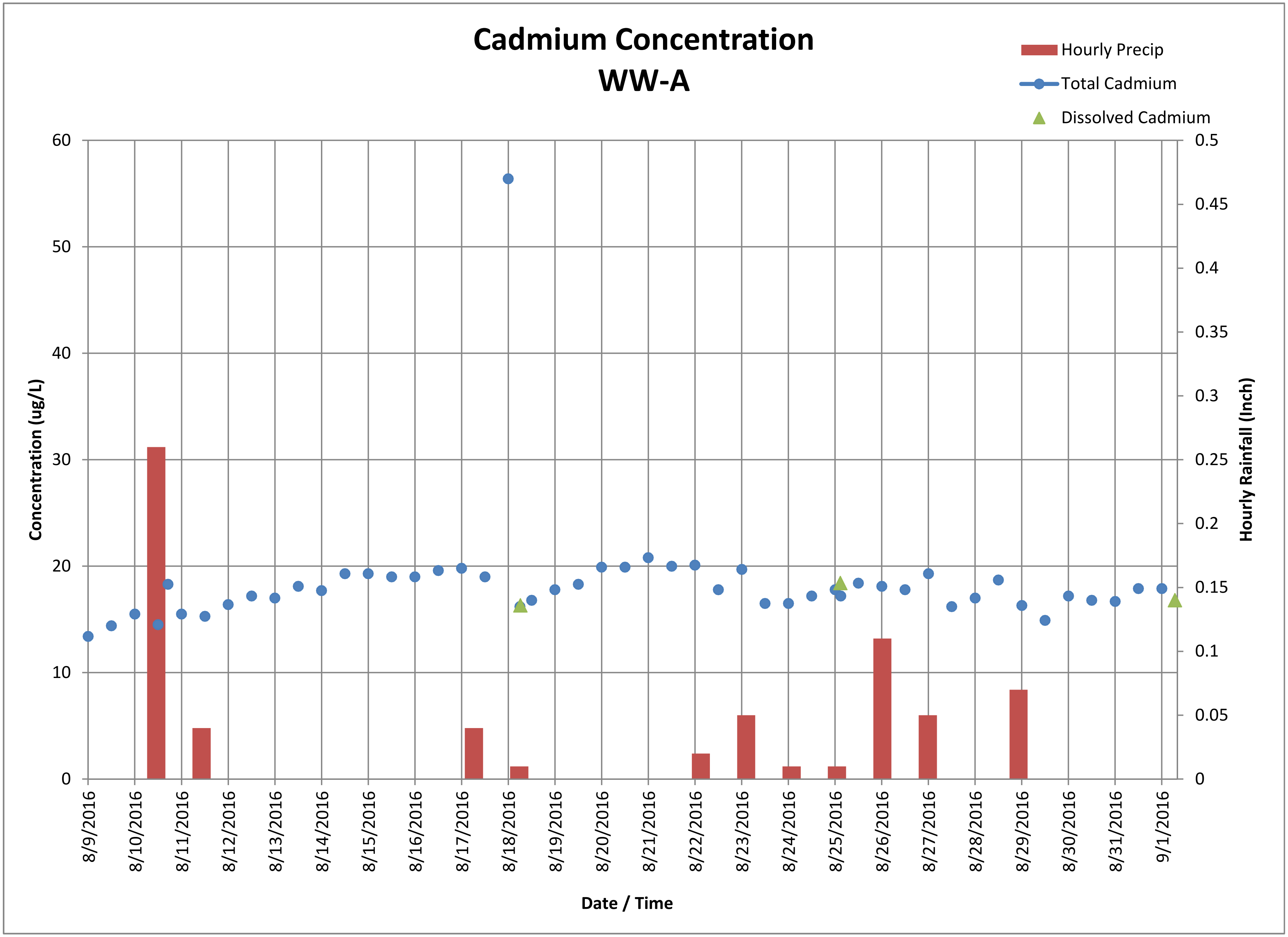
Inflow to the Upper Mine Pool at Del Monte
0.25
0.2
0.15
0.1
0.05
0
Volume of Mine Pool
30
35
40
45
50
55
60
Temperature (F)

APPENDIX C

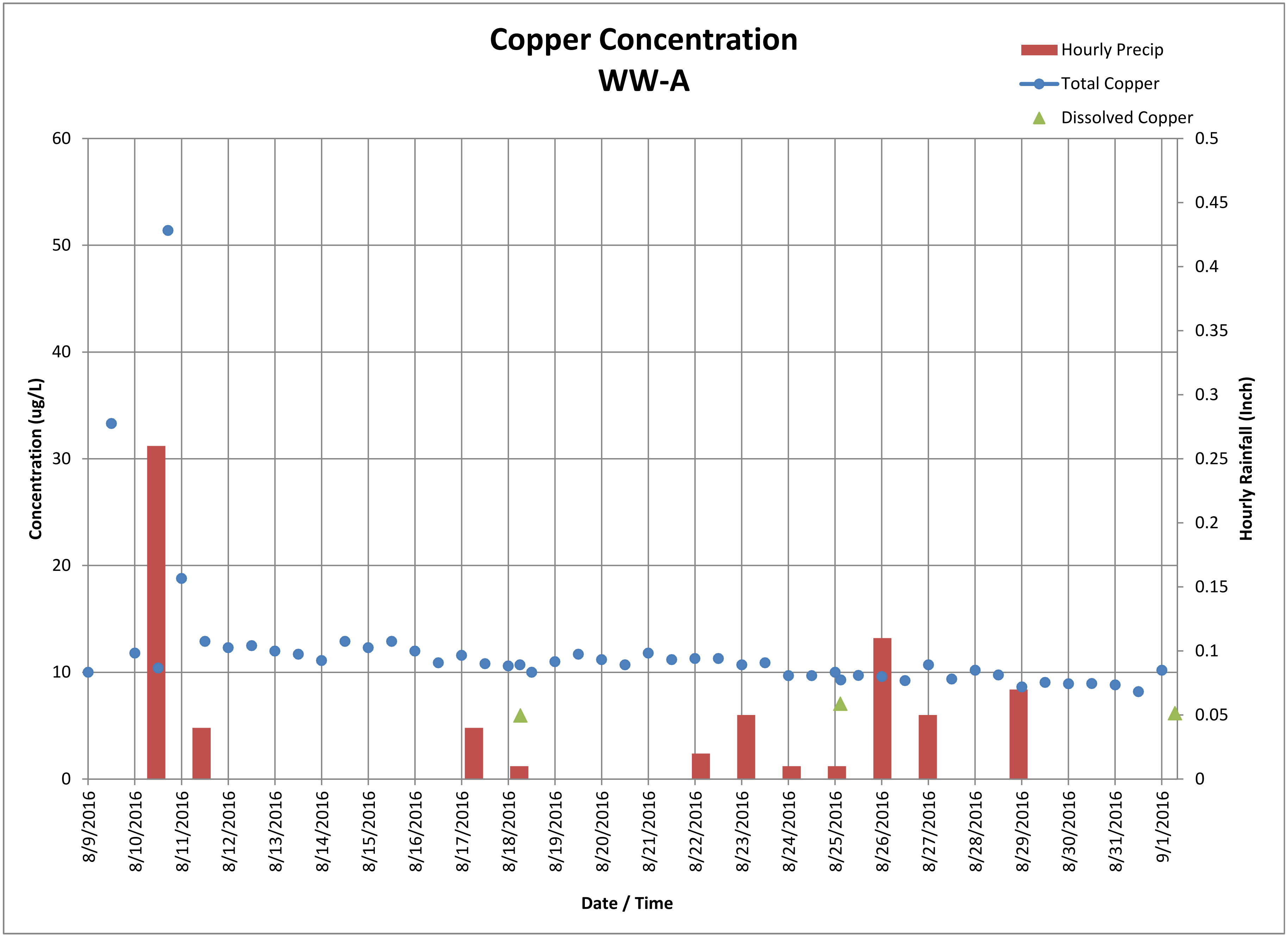
Metal Concentrations Compared to Precipitation at Monitoring Station WW-A



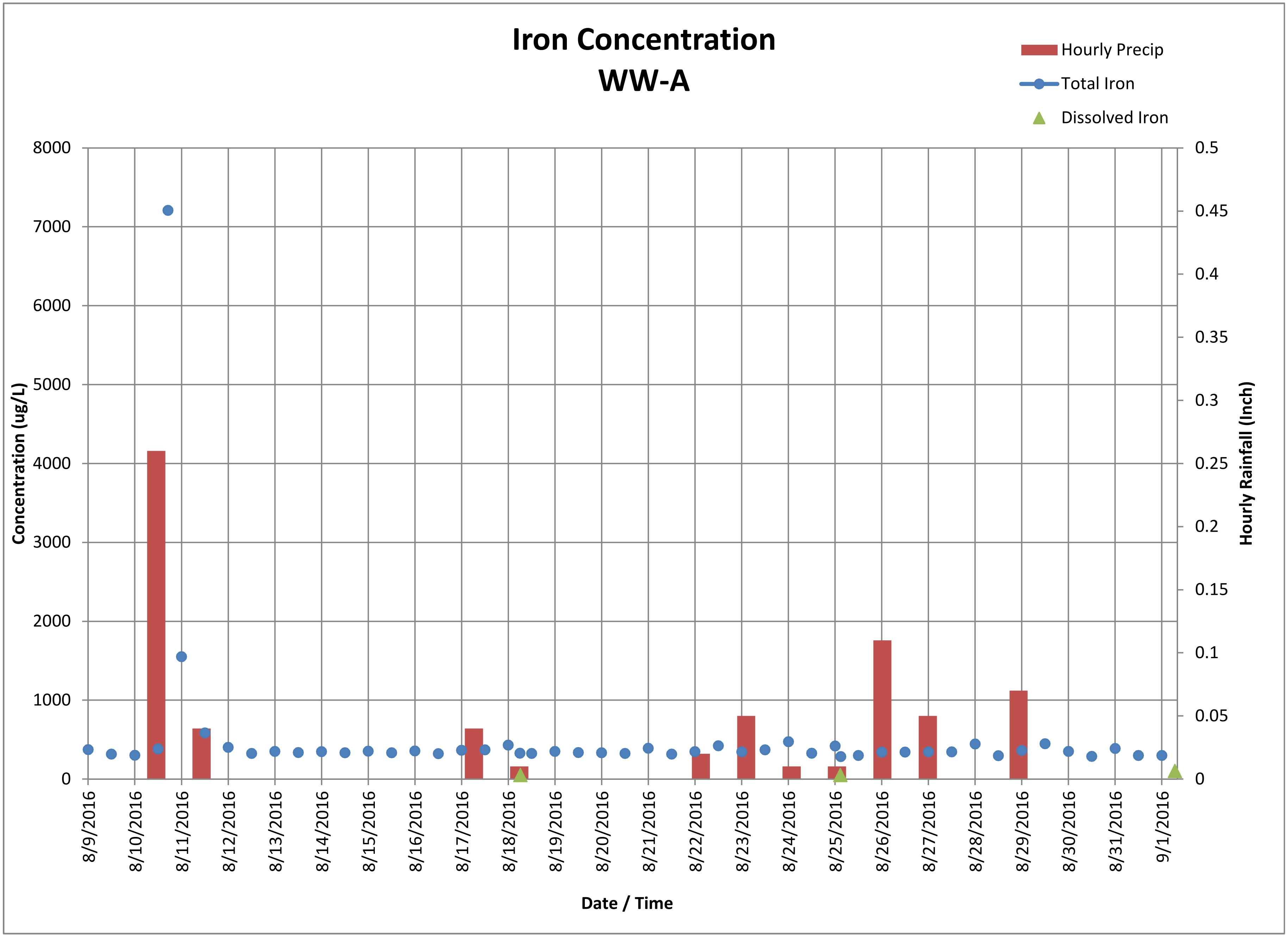
Arsenic Concentration
WW-A
Hourly Precip
Total Arsenic
Dissolved Arsenic
Concentration (ug/L)
Hourly Rainfall (Inch)
1/2 Detection Limit
Date / Time
18
16
14
12
10
8
6
4
2
0
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
8/9/2016
8/10/2016
8/11/2016
8/12/2016
8/13/2016
8/14/2016
8/15/2016
8/16/2016
8/17/2016
8/18/2016
8/19/2016
8/20/2016
8/21/2016
8/22/2016
8/23/2016
8/24/2016
8/25/2016
8/26/2016
8/27/2016
8/28/2016
8/29/2016
8/30/2016
8/31/2016
9/1/2016



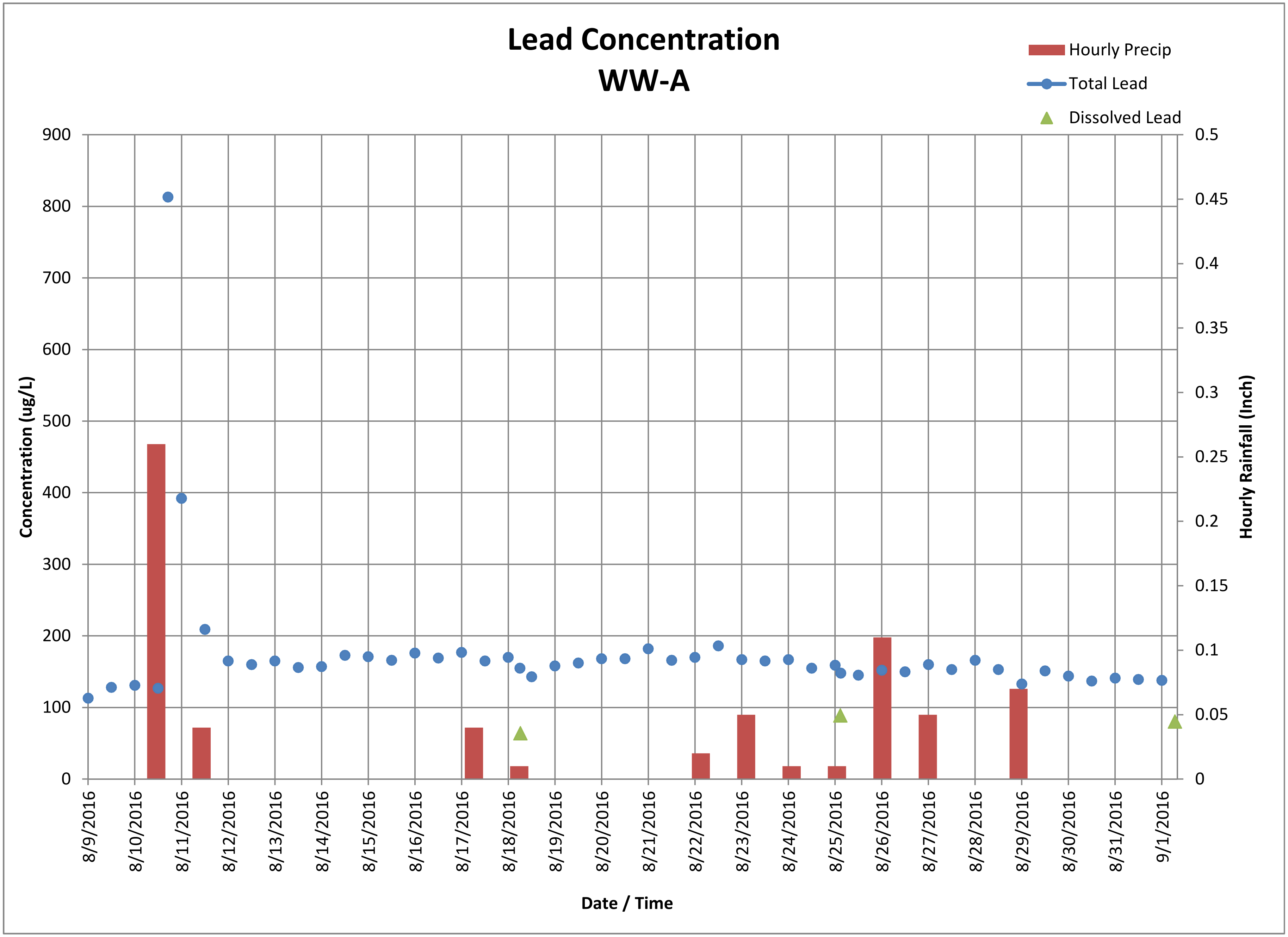
Cadmium Concentration
WW-A
Hourly Precip
Total Cadmium
Dissolved Cadmium
Concentration (ug/L)
Hourly Rainfall (Inch)
60
50
40
30
20
10
0
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
8/9/2016
8/10/2016
8/11/2016
8/12/2016
8/13/2016
8/14/2016
8/15/2016
8/16/2016
8/17/2016
8/18/2016
8/19/2016
8/20/2016
8/21/2016
8/22/2016
8/23/2016
8/24/2016
8/25/2016
8/26/2016
8/27/2016
8/28/2016
8/29/2016
8/30/2016
8/31/2016
9/1/2016
Date / Time



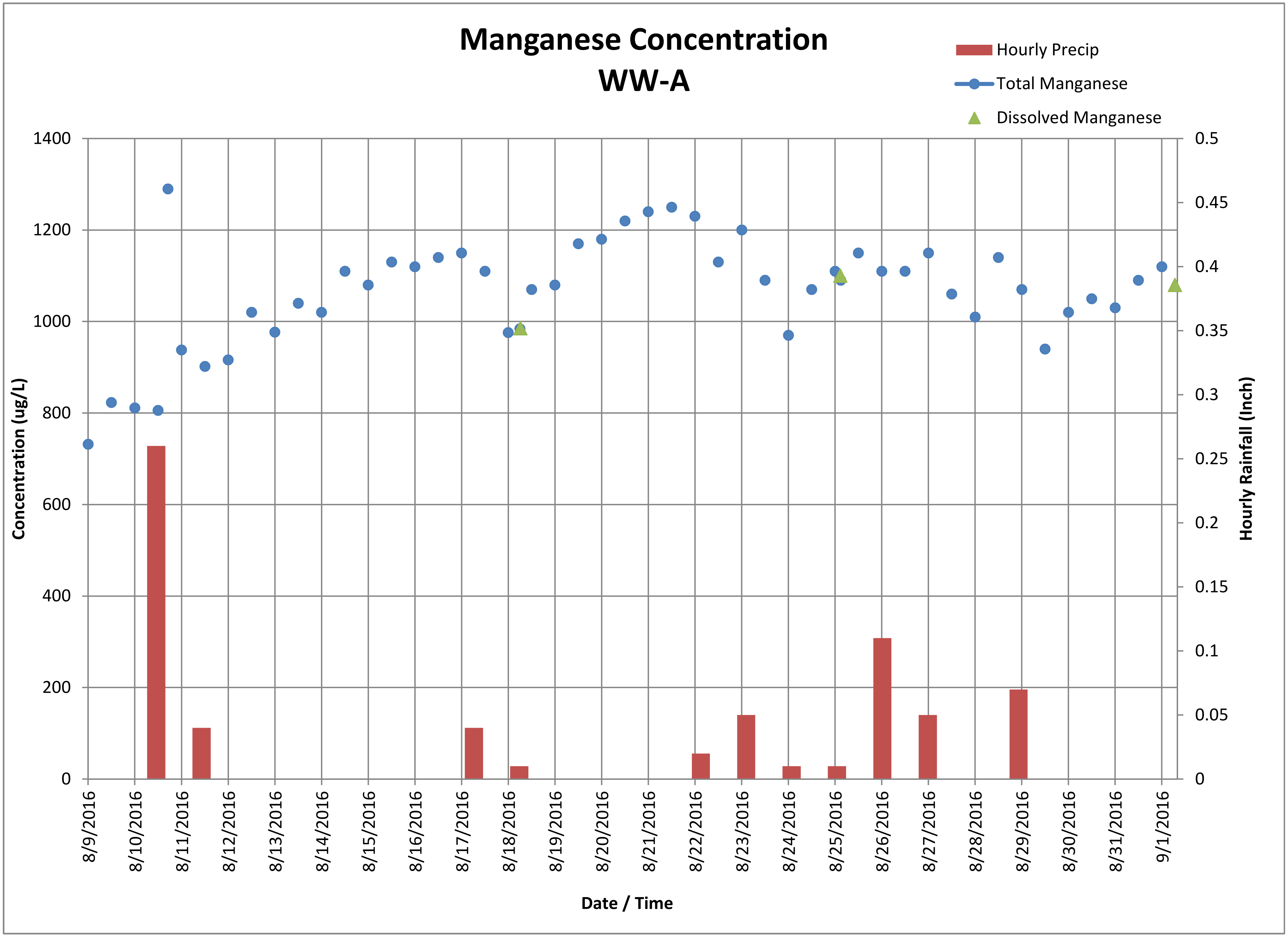
Copper Concentration
WW-A
Hourly Precip
Total Copper
Dissolved Copper
Concentration (ug/L)
Hourly Rainfall (Inch)
0
10
20
30
40
50
60
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
8/9/2016
8/10/2016
8/11/2016
8/12/2016
8/13/2016
8/14/2016
8/15/2016
8/16/2016
8/17/2016
8/18/2016
8/19/2016
8/20/2016
8/21/2016
8/22/2016
8/23/2016
8/24/2016
8/25/2016
8/26/2016
8/27/2016
8/28/2016
8/29/2016
8/30/2016
8/31/2016
9/1/2016
Date / Time



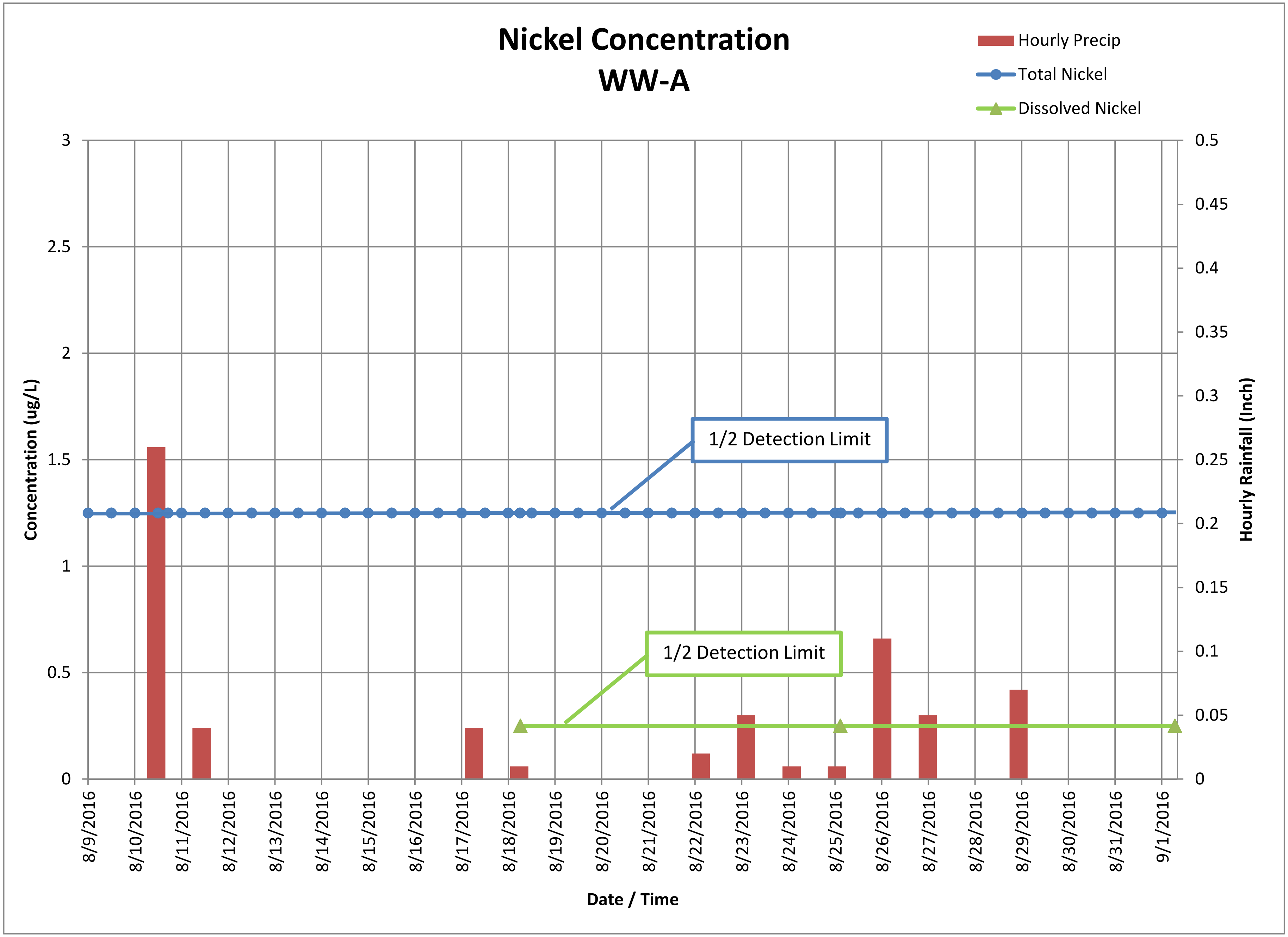
Iron Concentration
WW-A
Hourly Precip
Total Iron
Dissolved Iron
Concentration (ug/L)
8000
7000
6000
5000
4000
3000
2000
1000
0
Hourly Rainfall (Inch)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
8/9/2016
8/10/2016
8/11/2016
8/12/2016
8/13/2016
8/14/2016
8/15/2016
8/16/2016
8/17/2016
8/18/2016
8/19/2016
8/20/2016
8/21/2016
8/22/2016
8/23/2016
8/24/2016
8/25/2016
8/26/2016
8/27/2016
8/28/2016
8/29/2016
8/30/2016
8/31/2016
9/1/2016
Date / Time



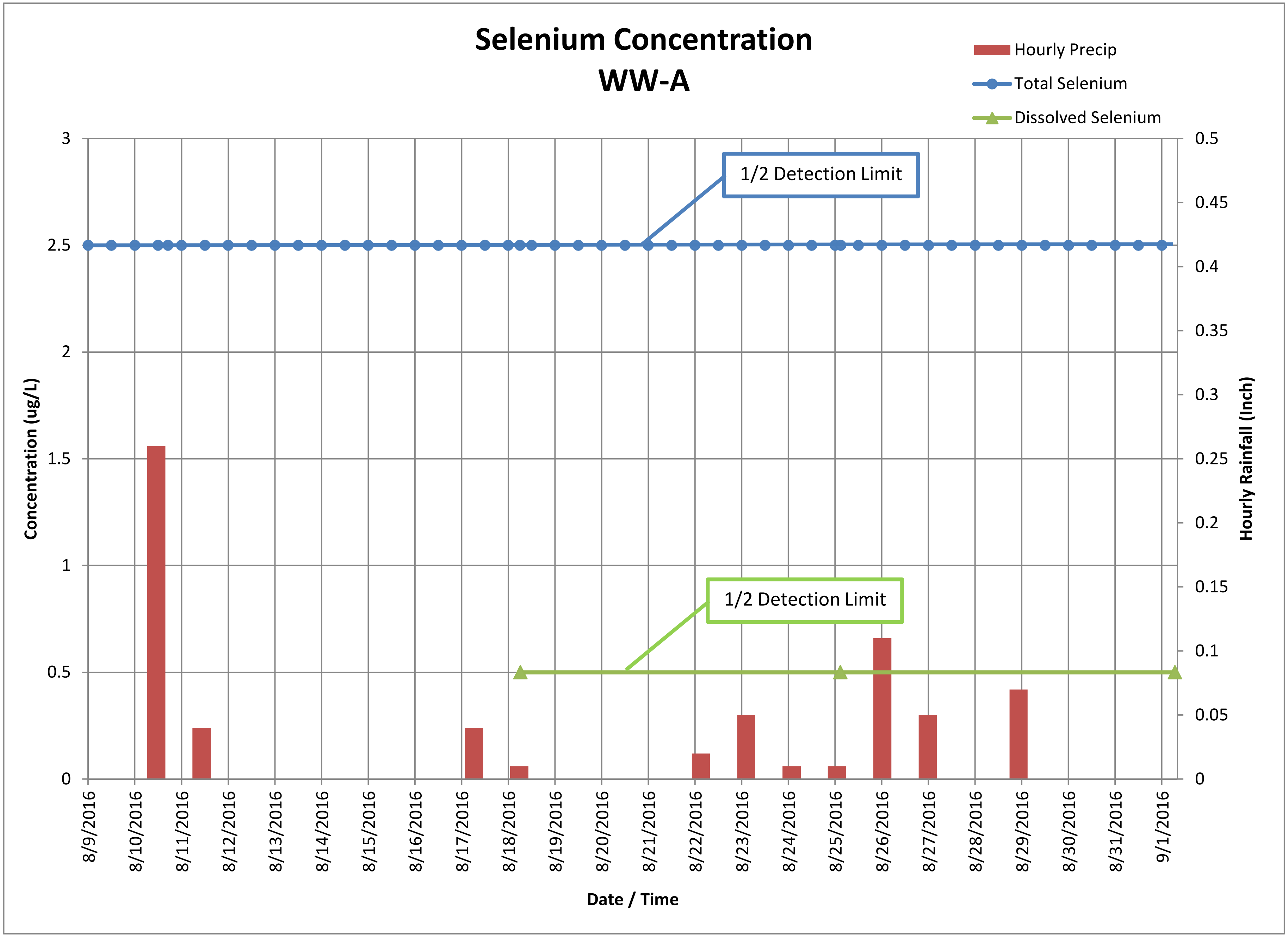
Lead Concentration
WW-A
Hourly Precip
Total Lead
Dissolved Lead
Concentration (ug/L)
Hourly Rainfall (Inch)
Date / Time
0
100
200
300
400
500
600
700
800
900
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
8/9/2016
8/10/2016
8/11/2016
8/12/2016
8/13/2016
8/14/2016
8/15/2016
8/16/2016
8/17/2016
8/18/2016
8/19/2016
8/20/2016
8/21/2016
8/22/2016
8/23/2016
8/24/2016
8/25/2016
8/26/2016
8/27/2016
8/28/2016
8/29/2016
8/30/2016
8/31/2016
9/1/2016



Manganese Concentration
WW-A
Hourly Precip
Total Manganese
Dissolved Manganese
Concentration (ug/L)
Hourly Rainfall (Inch)
1400
1200
1000
800
600
400
200
0
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
8/9/2016
8/10/2016
8/11/2016
8/12/2016
8/13/2016
8/14/2016
8/15/2016
8/16/2016
8/17/2016
8/18/2016
8/19/2016
8/20/2016
8/21/2016
8/22/2016
8/23/2016
8/24/2016
8/25/2016
8/26/2016
8/27/2016
8/28/2016
8/29/2016
8/30/2016
8/31/2016
9/1/2016
Date / Time



Nickel Concentration
WW-A
Hourly Precip
Total Nickel
Dissolved Nickel
1/2 Detection Limit
1/2 Detection Limit
Concentration (ug/L)
Hourly Rainfall (Inch)
Date / Time
0
0.5
1
1.5
2
2.5
3
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
8/9/2016
8/10/2016
8/11/2016
8/12/2016
8/13/2016
8/14/2016
8/15/2016
8/16/2016
8/17/2016
8/18/2016
8/19/2016
8/20/2016
8/21/2016
8/22/2016
8/23/2016
8/24/2016
8/25/2016
8/26/2016
8/27/2016
8/28/2016
8/29/2016
8/30/2016
8/31/2016
9/1/2016



Selenium Concentration
WW-A
Hourly Precip
Total Selenium
Dissolved Selenium
1/2 Detection Limit
1/2 Detection Limit
Concentration (ug/L)
Hourly Rainfall (Inch)
Date / Time
3
2.5
2
1.5
1
0.5
0
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
8/9/2016
8/10/2016
8/11/2016
8/12/2016
8/13/2016
8/14/2016
8/15/2016
8/16/2016
8/17/2016
8/18/2016
8/19/2016
8/20/2016
8/21/2016
8/22/2016
8/23/2016
8/24/2016
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8/27/2016
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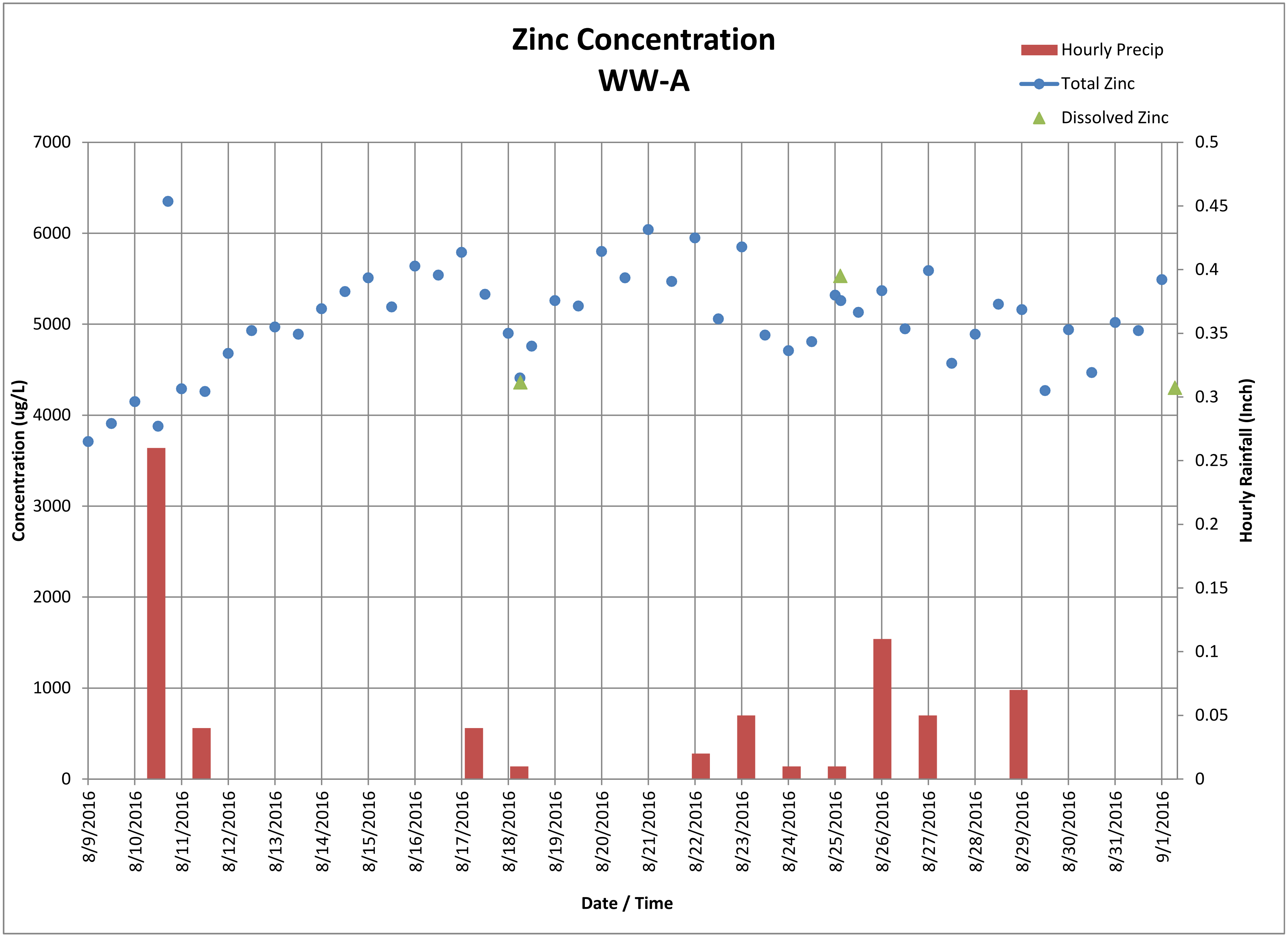
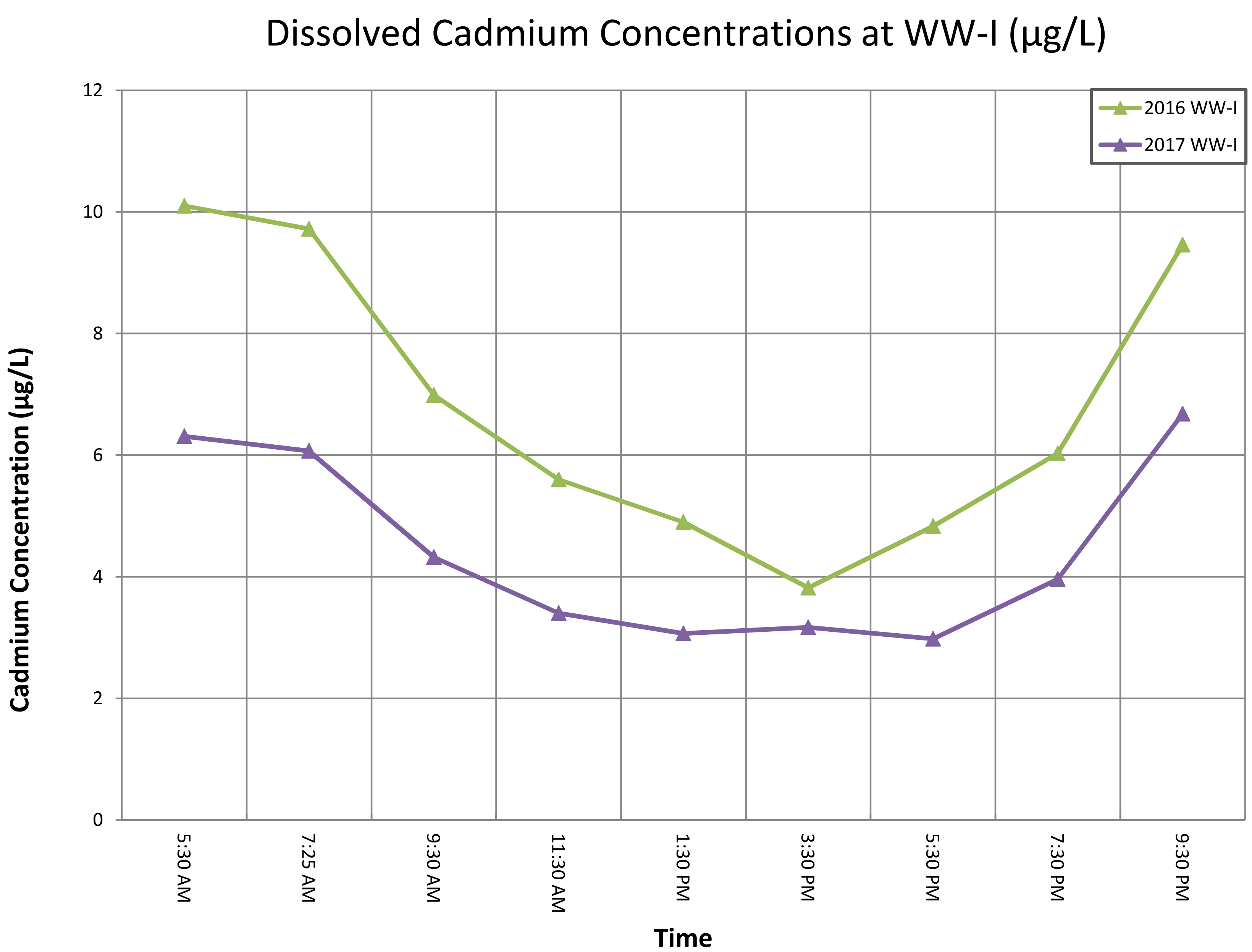
8/29/2016
8/30/2016
8/31/2016
9/1/2016


Zinc Concentration
WW-A
Hourly Precip
Total Zinc
Dissolved Zinc
Concentration (ug/L)
Hourly Rainfall (Inch)
Date / Time
0
1000
2000
3000
4000
5000
6000
7000
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
8/9/2016
8/10/2016
8/11/2016
8/12/2016
8/13/2016
8/14/2016
8/15/2016
8/16/2016
8/17/2016
8/18/2016
8/19/2016
8/20/2016
8/21/2016
8/22/2016
8/23/2016
8/24/2016
8/25/2016
8/26/2016
8/27/2016
8/28/2016
8/29/2016
8/30/2016
8/31/2016
9/1/2016

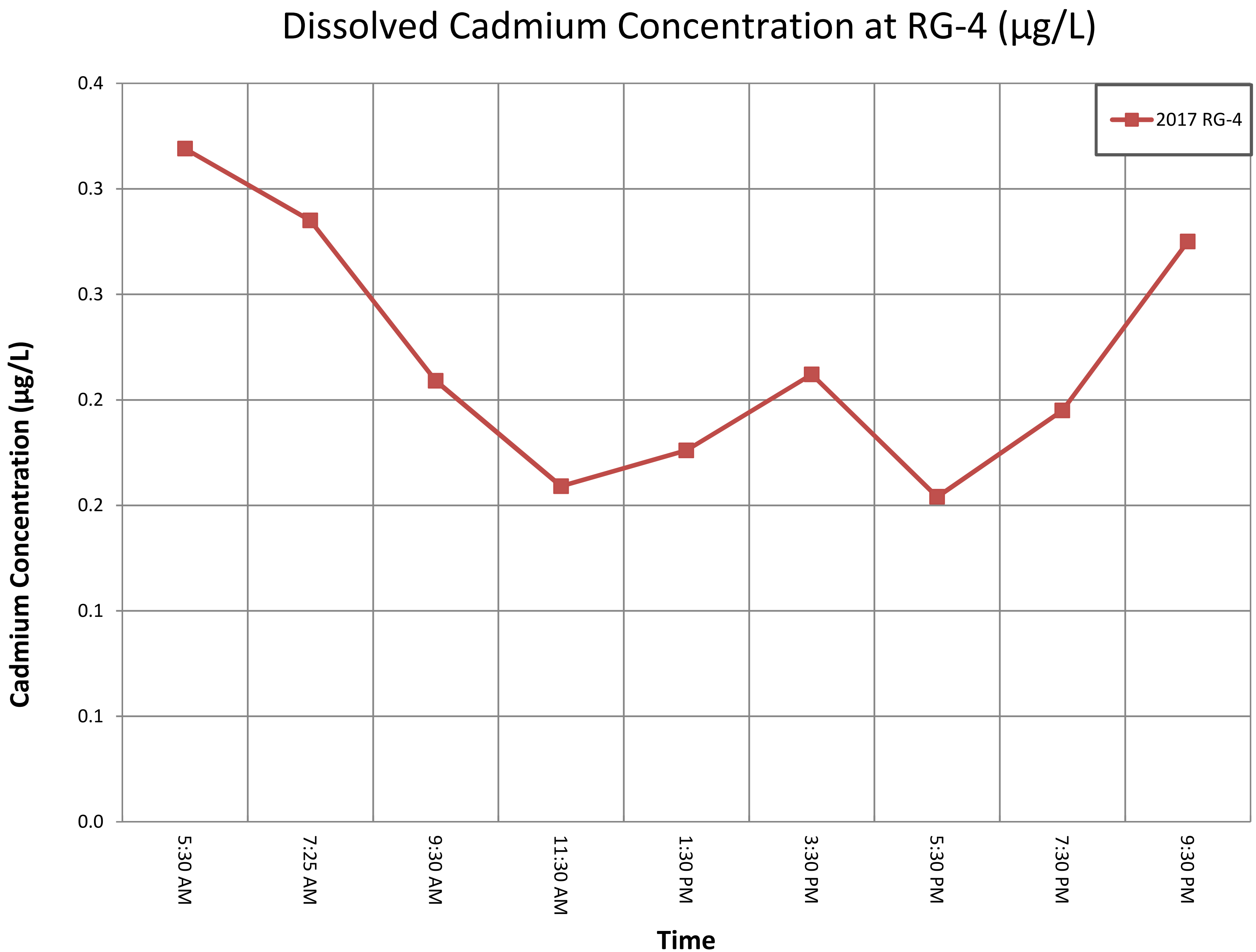
APPENDIX D

Diel Concentration Charts

Appendix D

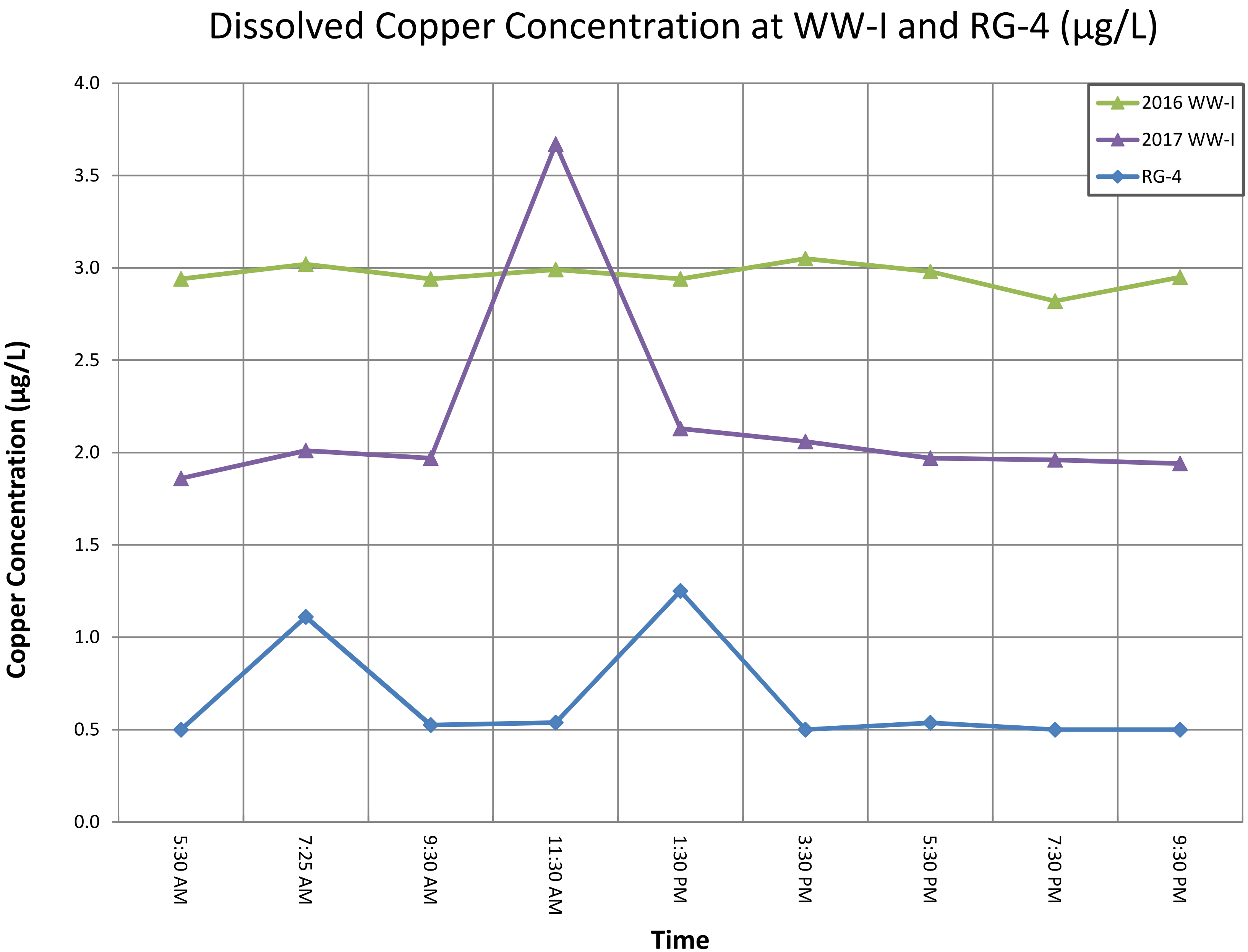

Dissolved Cadmium Concentrations at WW-I (µg/L)
12
10
8
6
4
2
0
Cadmium Concentration (µg/L)
2016 WW-I
2017 WW-I
5:30 AM
7:25 AM
9:30 AM
11:30 AM
1:30 PM
3:30 PM
5:30 PM
7:30 PM
9:30 PM
Time

Appendix D



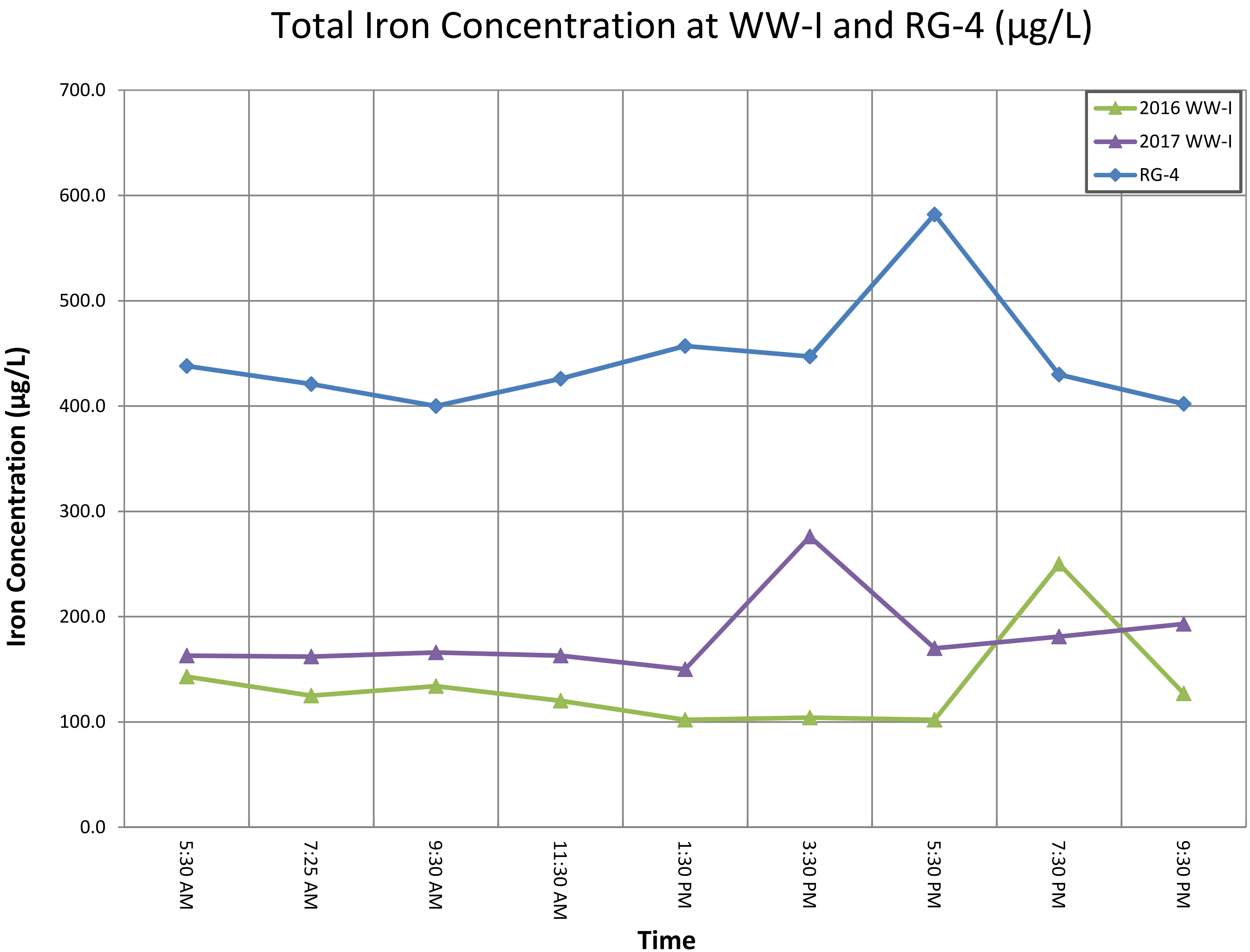
Dissolved Cadmium Concentration at RG-4 (µg/L)
2017 RG-4
Cadmium Concentration (µg/L)
0.4
0.3
0.3
0.2
0.2
0.1
0.1
0.0
5:30 AM
7:25 AM
9:30 AM
11:30 AM
1:30 PM
3:30 PM
5:30 PM
7:30 PM
9:30 PM
Time

Appendix D



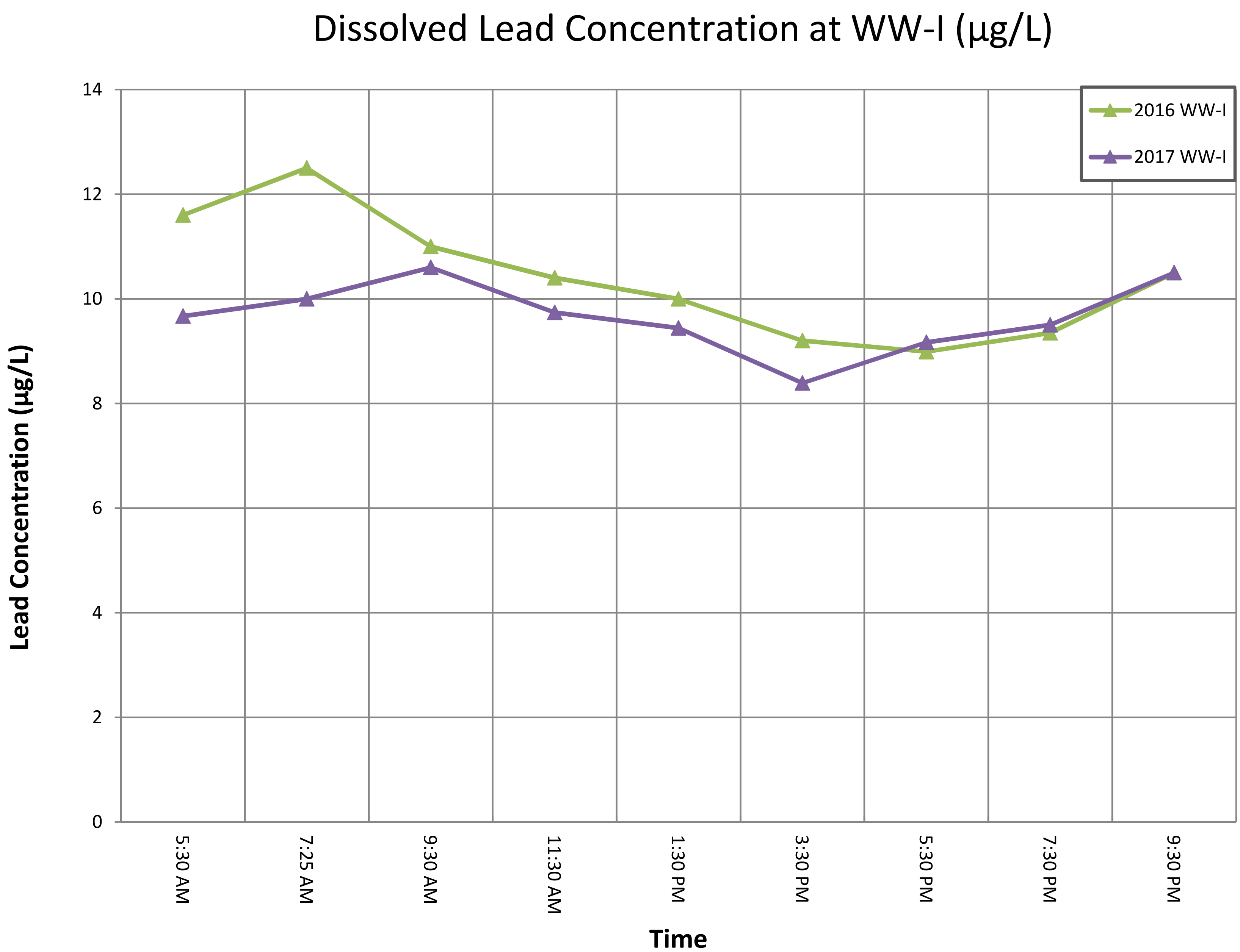
Dissolved Copper Concentration at WW-I and RG-4 (µg/L)
Copper Concentration (µg/L)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2016 WW-I
2017 WW-I
RG-4
5:30 AM
7:25 AM
9:30 AM
11:30 AM
1:30 PM
3:30 PM
5:30 PM
7:30 PM
9:30 PM
Time

Appendix D



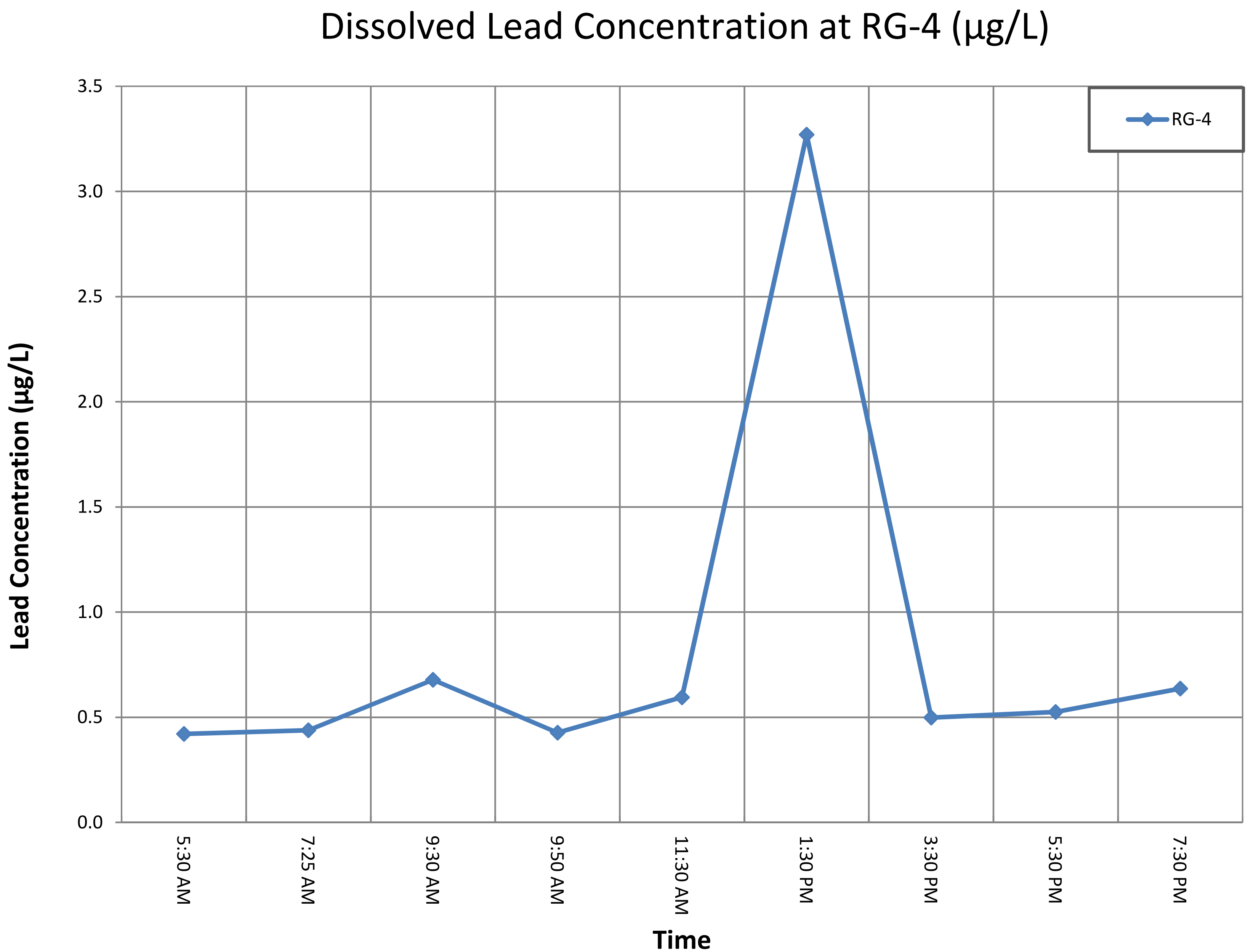
Total Iron Concentration at WW-I and RG-4 (µg/L)
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
Iron Concentration (µg/L)
2016 WW-I
2017 WW-I
RG-4
5:30 AM
7:25 AM
9:30 AM
11:30 AM
1:30 PM
3:30 PM
5:30 PM
7:30 PM
9:30 PM
Time

Appendix D



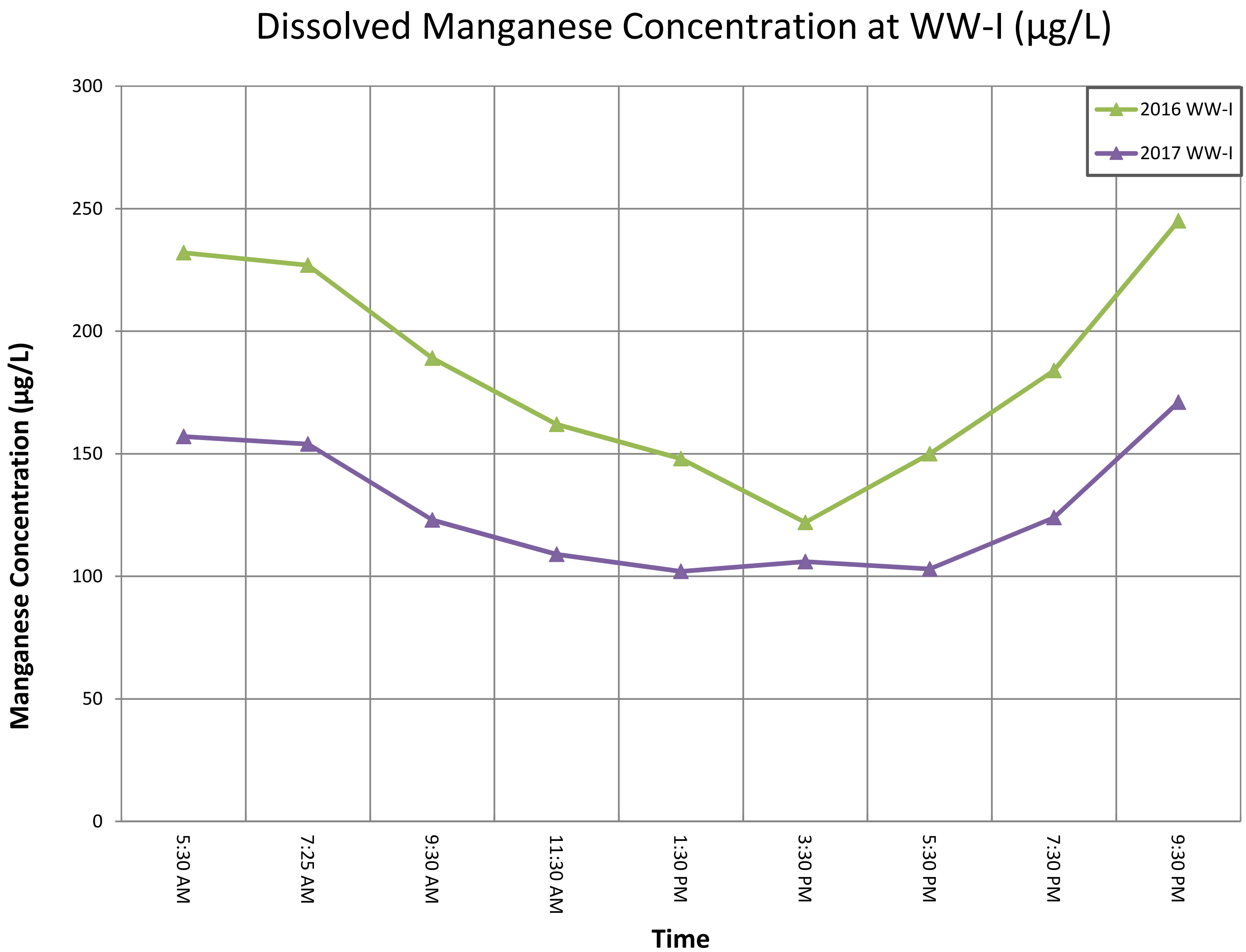
Dissolved Lead Concentration at WW-I (µg/L)
2016 WW-I
2017 WW-I
Lead Concentration (µg/L)
0
2
4
6
8
10
12
14
5:30 AM
7:25 AM
9:30 AM
11:30 AM
1:30 PM
3:30 PM
5:30 PM
7:30 PM
9:30 PM
Time

Appendix D



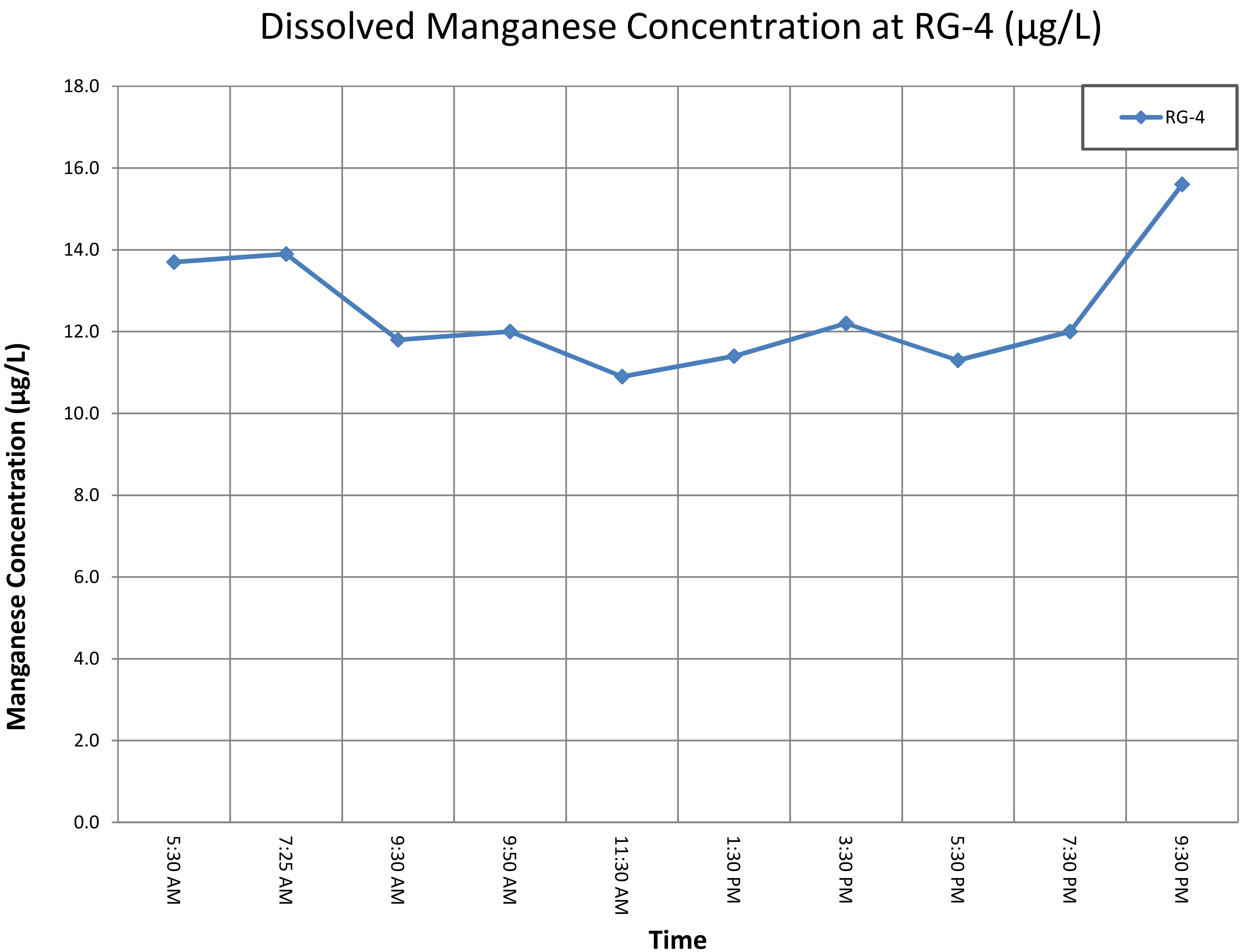
Dissolved Lead Concentration at RG-4 (µg/L)
RG-4
Lead Concentration (µg/L)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
5:30 AM
7:25 AM
9:30 AM
9:50 AM
11:30 AM
1:30 PM
3:30 PM
5:30 PM
7:30 PM
Time

Appendix D



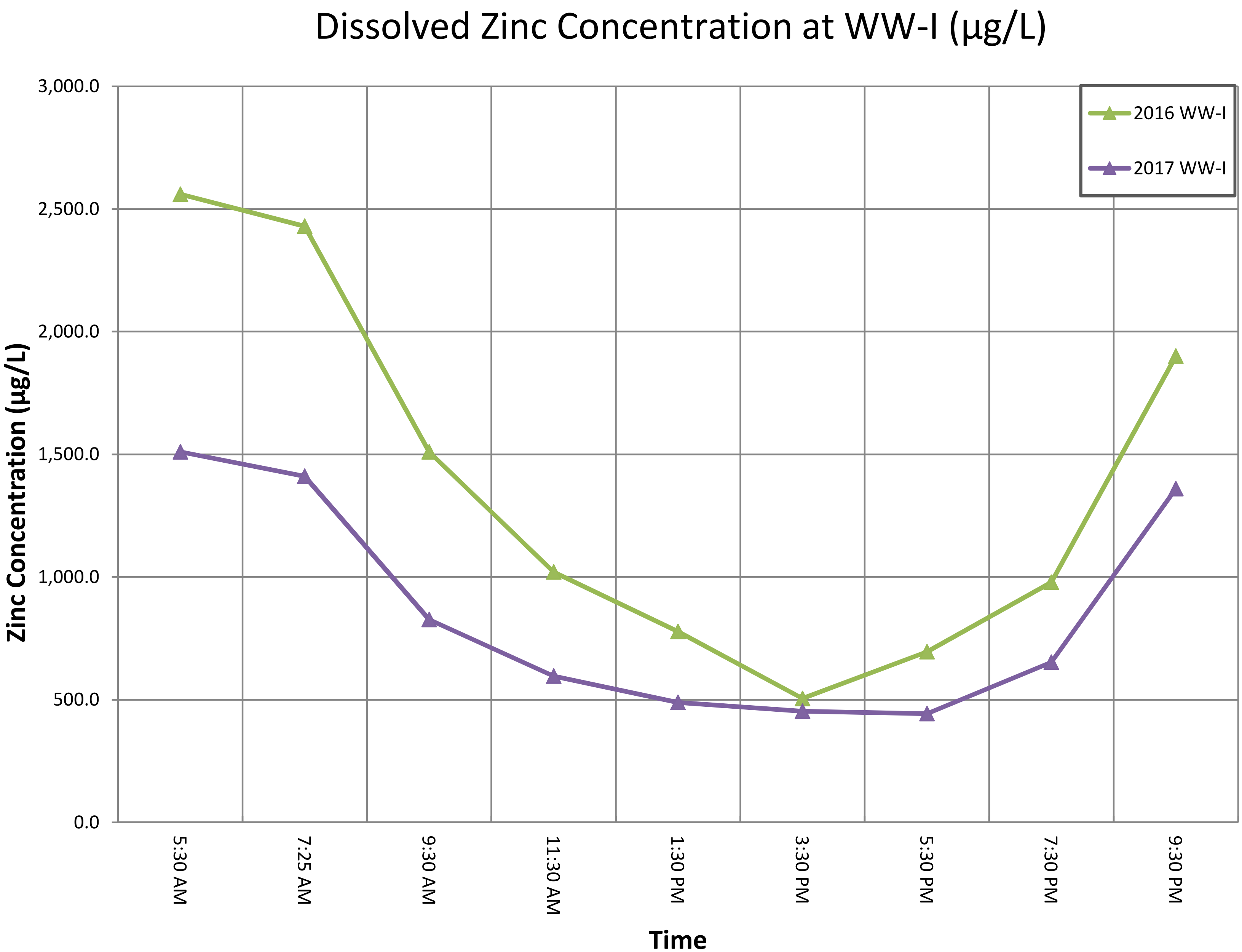
Dissolved Manganese Concentration at WW-I (µg/L)
300
250
200
150
100
50
0
Manganese Concentration (µg/L)
2016 WW-I
2017 WW-I
5:30 AM
7:25 AM
9:30 AM
11:30 AM
1:30 PM
3:30 PM
5:30 PM
7:30 PM
9:30 PM
Time

Appendix D



Dissolved Manganese Concentration at RG-4 (µg/L)
Manganese Concentration (µg/L)
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
RG-4
5:30 AM
7:25 AM
9:30 AM
9:50 AM
11:30 AM
1:30 PM
3:30 PM
5:30 PM
7:30 PM
9:30 PM
Time

Appendix D



Dissolved Zinc Concentration at WW-I (µg/L)
3,000.0
2,500.0
2,000.0
1,500.0
1,000.0
500.0
0.0
Zinc Concentration (µg/L)
2016 WW-I
2017 WW-I
5:30 AM
7:25 AM
9:30 AM
11:30 AM
1:30 PM
3:30 PM
5:30 PM
7:30 PM
9:30 PM
Time

APPENDIX E

Update on Risks from ATV Riding
Nelson Tunnel Superfund Site

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 8
1595 Wynkoop Street
DENVER, CO 80202-1129
Phone 800-227-8917
http://www.epa.gov/region08

February 5, 2019

MEMORANDUM

SUBJECT: Update on Risks from ATV Riding at the Nelson Tunnel Superfund Site

FROM: David L. Berry, PhD
Senior Toxicologist

TO: Joy Jenkins
Remedial Project Manager

In the 2011 Remedial Investigation report for the Nelson Tunnel Superfund Site, the human health risk assessment concluded that the health risks to ATV riders exceeded EPA's risk criteria. Specifically,

- Inhalation of manganese indicated non-carcinogenic risks above EPA's Hazard Quotient of 1
- Inhalation of arsenic indicated non-carcinogenic risks above EPA's Hazard Quotient of 1
- Inhalation of lead resulted in blood lead levels exceeding EPA's goal of no more than a 5% chance of exceeding a blood lead level of 10 μg/dl

These conclusions were based on activity-based air sampling while ATV riding. The air filters were analyzed by ICP-AES (inductively coupled plasma atomic emission spectroscopy). This method of analysis had very high reporting limits. Many of the results were reported as non-detects for the leading rider, however, the use of one half of the artificially high reporting limit as the value used in the risk calculations resulted in unacceptable risks.

The activity-based air sampling while ATV riding was conducted again in the fall of 2017. SKC portable air samplers were mounted on each ATV at operator breathing level. Both total suspended particulates [TSP] and PM10 particles were collected. The PM10 data represent a subset of smaller, respirable particles of the total suspended particulate fraction. The air filters were analyzed by ICP-MS (mass spectrometer) which provided a significantly lower reporting limit (approximately 2 orders of magnitude lower). The results of those analysis are detailed in the October 16, 2017 ALS Global laboratory report conducted for Tech Law.

Using the equations and exposure assumptions from the human health risk assessment for the Nelson Tunnel site, I re-calculated the non-carcinogenic risks to both the reasonable maximum exposed (RME) adult and child ATV riders. As a conservative estimation of the exposure, the maximum air value for the following rider was used to estimate risk. The 2017 air sampling data analyzed by ICP-MS was used in those calculations. The results are shown in the table below.

Risks to Adult and Child ATV Riders					
	TSP Air Concentrations* ($\mu g/m^3$) 2011	TSP Air Concentrations* ($\mu g/m^3$) 2017	PM_{10} Air Concentrations* ($\mu g/m^3$) 2017	Non-cancer risks (2011 RI)	Non-cancer risks using maximum air concentrations (2017 data)
Arsenic	4.8[a]	1.8	0.61	HI = 1.8	HI= 0.23
Manganese	139	19	6.3	HI= 15.9	HI= 0.72
Lead	188	24	6.1	P10 = 11.5%	P5 < 0.1%

Notes: [a] the concentration of arsenic in the air was calculated using a particulate emission factor; * maximum detected concentration

As shown above the inhalation risks from ATV riding based on the ICP-AES data in the 2011 RI report exceeded EPA's non-cancer risk/hazard criteria or hazard index (HI) of 1.0. Using the 2017 PM10 data analyzed by ICP-MS, the non-cancer risks are below the HI of 1.0 and are acceptable to EPA. The decrease in apparent risk is due to the lower detection and reporting limits available by ICP-MS, and the use of the respirable portion of the particulate concentrations as measured by the PM10 in the 2017 data.

Lead risks are evaluated differently than other contaminants because lead is not thought to have a threshold. So, blood lead levels are calculated and compared to EPA criteria which are protective of the unborn fetus. Based on the 2011 RI report, a geometric mean blood lead level of 5.5 µg/dL was calculated for the ATV rider with an 11.5% probability of exceeding a blood lead level of 10 µg/dl. At the time of the 2011 report, EPA's risk criteria was no more than a 5% probability of exceeding a 10 µg/dL blood lead level. In December 2016 EPA issued guidance which recommended an acceptable blood lead range of 2 – 8 µg/dL. Using the 2017 air sampling data, a geometric mean blood lead level of 1.0 µg/dL was calculated with no more than a < 0.1% probability of exceeding a blood lead of 5 µg/dL.

Pursuant to our review of the 2017 data, we concur that the conclusions presented in the November 29, 2017 Technical Memorandum are accurate based on the data employed in the risk evaluations. However; based on using more conservative exposure values in this revised evaluation, the calculated risks are slightly higher than those calculated in the November 29, 2017 memo. Based on the improved reporting limits and exposure concentrations from the 2017 activity-based sampling, risks to both adult and child ATV riders meet EPAs' risk criteria and are acceptable to EPA.

Please see the attachment for responses to CDPHE questions on the ATB sampling procedures.

Attachment

Response to CDPHE questions submitted to EPA by Tom Simmons

Tom Simmons of CDPHE had several questions regarding the August 2017 sampling event and specific questions concerning distance between ATV samplers, filter cassettes, flow rates, and other specifics. EPA contacted Steve Auer of ESAT (Environmental Services Assistance Team) concerning the questions posed by Mr. Simmons and Mr. Auer provided clarification of his issues. The following text provides clarification:

1. *What was the distance between the lead and following ATV?*
   Varied from approximately 15-30 meters depending on terrain and dust conditions. We attempted to drive the same as other tourists in the area.

2. *What type of cyclone was used?*
   SKC GS-3 Respirable dust cyclone, 10mm with 37mm MCE cassette adapter.

3. *Flow rates with and without cyclones?*
   Flow rates for the cassette/cyclone filters [BLL-01 through BLF-06D] ranged from 2725 to 2804 mL/min. Flow rates for the cassettes only [BLL-07 through BLL-10] ranged from 3999 to 4030 mL/min.

4. *Did particle concentrations differ between cyclone and non-cyclone filter cassettes?*
   They were visibly different--the non-cyclone filters had a lot of visible dust while the cyclone filters had minimal visible dust. The analytical lab did not provide mass measurements for the samples.

5. *Where were the air samplers located? On the rider or the vehicle?*
   The ATV sampling event occurred along the Bachelor Loop road adjacent to the tunnel. The air intake of the pump was mounted near the breathing zone on each of the riders.

6. *Sample numbers for lead and following samplers?*
   In the attached table the Sample I.D.'s prefix is BLL or BLF, with BLL being Bachelor Loop Lead and BLF is Bachelor Loop Follow (BLL n=7, BLF n=9).

7. *Why were there no blanks taken? Filter Blank, Trip blank?*
   It is unclear why a blank was not included, as it was planned. But a blank filter was not included in the COC (Chain of Custody). There were six duplicates taken; three for lead and three for follower. I have been unable to determine if blanks were taken as suggested in NIOSH 7300. This was an unfortunate oversight. This does not appear to adversely affect the data since the duplicate values are quite similar. Sample results are low so there does not appear to be any high bias introduced.

8. *Soil and weather conditions during sampling?*
   The weather was sunny and dry with dew during early morning. The road was dustier after the first lap and very dusty each consecutive run thereafter.

9. *Exposure point concentrations reported in the [DRAFT] February 2018 Sampling Activities Report do not align with the exposure point concentrations listed in the November 2017 Technical Memo.*

The exposure point values utilized in the November Technical Memo were derived from the filter cassettes fitted with the SKC GS-3 cyclones. The values questioned were derived from the filter cassettes without the dust cyclone [samples for total particulates] In this case the sample volume was approximately 129 liters. While the volume was approximately 88 liters for the filter cassettes with cyclones [<PM10].