Wild and Scenic Rivers

Arsenic Data Compilation Report
Delaware River Watershed – River Miles 210.8 to 141.8
Delaware Water Gap to Washington Crossing

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EXECUTIVE SUMMARY

This report presents a compilation of information/data related to arsenic in the environment of the Delaware River watershed between the Delaware Water Gap in the north (River Mile 210.8) and the bridge at Washington Crossing, Pennsylvania (River Mile 141.8) to the south. The goal of the data compilation project is to establish a baseline for arsenic concentrations in surface water and groundwater along this reach of the River. This report has been prepared to present available arsenic data for this region of the watershed only, and is considered a "white paper", in that the document is an unbiased, information-only report. As a result, the arsenic data have not been interpreted to draw conclusions related to anthropogenic activities, or used to support any position related to environmental quality.

Data compilation involved on-line searches and database reviews to identify relevant data sets. Additionally, regulatory agencies responsible for water-quality data collection and management were contacted to identify those parties involved in soil, surface-water and groundwater data collection and/or research activities on the Delaware River and in the surrounding watershed.

Arsenic data for environmental media within the watershed included soil, groundwater, surface water and sediment sampling results from various sources. A summary of arsenic data from within the watershed indicates:

- Arsenic occurs naturally in soils within the watershed with 90th-percentile concentrations of 9.96 mg/kg and 7.32 mg/kg for the Highlands Province and Ridge and Valley Province of New Jersey, respectively. In addition, soil arsenic concentrations at two known-contaminated sites within the watershed adjacent to the River showed average arsenic concentrations in surface soil samples of 7.7 mg/kg and 9.9 mg/kg, similar to the above naturally-occurring background concentrations.

- Concentrations of arsenic in groundwater within the surrounding watershed typically showed concentrations less than 5 ug/L for private potable wells, ambient monitoring wells, and water supply wells, but in some instances higher concentrations were detected in ambient groundwater monitoring wells.

- Examples of higher concentrations of arsenic in ambient groundwater monitoring wells include a maximum concentration of 60 ug/L detected in groundwater in central Bucks County, PA, and a maximum concentration of 25 ug/L detected in a monitoring well in western Hunterdon County, NJ. These higher concentrations of arsenic in groundwater may be related to the location of these wells in the Piedmont physiographic province, where arsenic is known to occur naturally in the rock formations.

- Results for arsenic in surface water were limited, but typically showed concentrations less than 1 ug/L in filtered samples. Surface-water samples collected by the DRBC showed an average concentration of 0.37 ug/L in ambient surface water, and surface-water samples collected in the River adjacent to a known-contaminated Site showed an average concentration of 0.34 ug/L.

- River sediment sampling data for arsenic are limited and appear to be associated with contaminated site investigations, when available. Those sediment data compiled usually showed low concentrations of arsenic relative to sediment quality screening levels for aquatic life as published by the NJDEP.

A review of the information/data gathered indicates that naturally-occurring levels of arsenic are found in soil, groundwater and surface water throughout the watershed area of interest, but that limited geographic areas have concentrations of arsenic elevated above background. These areas are primarily located within the Piedmont physiographic province in central and upper Bucks County, PA and western Hunterdon County, NJ, where arsenic occurs naturally at elevated concentrations in the rock formations.

Although this report is comprehensive in its scope, there is additional work that could be conducted to provide more in-depth information/data and to fill "data gaps" that were identified during report preparation. Examples of potential additional tasks include the generation of a comprehensive map with existing sampling locations in a coordinate system (to the extent possible), and collection and analysis of additional surface-water samples from focused locations on the River. These additional tasks would provide information/data useful in more fully understanding the nature and distribution of arsenic in the watershed area of interest.

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LIST OF ACRONYMS AND ABBREVIATIONS

As	Arsenic
ATSDR	Agency for Toxic Substances and Disease Registry
CCA	Chromated Copper Arsenate
CW	Central West
DRBC	Delaware River Basin Commission
DSRT	NJDEP Division of Science, Research, and Technology
EPA	U.S. Environmental Protection Agency
J-Value	An estimated concentration less than the detection limit
LLC	Limited Liability Company
LTM	Long-term Monitoring
Max	Maximum
MCL	Maximum Contaminant Level
mg/kg	Milligrams per Kilogram
mg/L	Milligrams per Liter
Min	Minimum
NJDEP	N.J. Dept. of Environmental Protection
NJDOH	N.J. Dept. of Health
NJGS	N.J. Geological Survey
NW	Northwest
PADEP	P.A. Department of Environmental Protection
PPB	Parts per Billion, expressed as ug/L
PPL	P.A. Power and Light
PPM	Parts per Million, expressed as mg/L or mg/kg
QA/QC	Quality Assurance/Quality Control
RFP	Request for Proposal
RI	Remedial Investigation
SW	Southwest
USGS	U.S. Geological Survey
USDHHS	U.S. Dept. of Health and Human Service
μg/L	Micrograms per Liter
WHO	World Health Organization

1 INTRODUCTION

This report presents a compilation of information/data related to arsenic in the environment of the Delaware River watershed between the Delaware Water Gap in the north (River Mile 210.8) and the bridge at Washington Crossing, Pennsylvania (River Mile 141.8) to the south (referred to hereafter as "the watershed area of interest"). The River extends for approximately 69.0 river miles between these points, and the watershed geographic area along this reach includes portions of Bucks and Northampton Counties in Pennsylvania, and portions of Mercer, Hunterdon and Warren Counties in New Jersey. A map of the watershed area of interest and surrounding area is provided in Attachment 1.

This report has been prepared on behalf of the Lower Delaware Wild and Scenic River Management Council in response to their 29 November 2017 "Arsenic Testing" Request for Proposal (RFP). The data compilation project described in the RFP involved the gathering of existing, publically-available analytical results for arsenic in surface water of the Delaware River between the Delaware Water Gap, PA and Washington Crossing, PA/NJ. Data from studies involving the evaluation of arsenic in soil within this region are also of interest. The goal of the data compilation project is to establish a baseline for arsenic concentrations in groundwater and surface water along this reach of the River, and to identify potential sources of arsenic in soil. This baseline could then be used for future data comparison purposes to evaluate water-quality changes potentially caused by human (anthropogenic) activities.

Subsequent to the RFP, an increased interest in arsenic data related to groundwater resources was expressed, so this task was added to the data collection scope of work. A comprehensive data compilation approach involving on-line searches and database reviews was used initially to identify relevant data sets. Additionally, contacting agencies responsible for data collection and management, including the United States Geological Survey (USGS), the New Jersey Department of Environmental Protection (NJDEP), the Delaware River Basin Commission (DRBC), the New Jersey Geological Survey (NJGS), the Pennsylvania Department of Environmental Protection (PADEP) and other organizations, was conducted to identify those parties involved in soil, surface-water and groundwater data collection and/or research activities on the Delaware River and in the surrounding watershed.

This report summarizes the findings of the arsenic data compilation project within the watershed area described above. To this end, the report includes the following sections:

- Section 2 provides background information on arsenic in the environment and describes both natural and anthropogenic (man-made) sources
- Section 3 presents arsenic data for environmental media within the watershed, including soil, groundwater, surface water and sediment data collected from various sources
- Section 4 provides a summary of the arsenic data gathered, discusses conclusions related to the data compilation, and presents recommendations for additional data gathering/evaluation
- Section 5 provides references

Tables with summary statistics of the data are provided for various data sets. In addition, Attachments to the report include supporting information, such as excerpted data tables, maps or figures from various sources showing sampling locations, and tables for the gathered data sets. Where available, tables with comprehensive data sets are also provided.

2 BACKGROUND

2.1 ARSENIC IN THE ENVIRONMENT

Arsenic is a naturally occurring element widely distributed in the earth's crust. In the environment, arsenic is combined with oxygen, chlorine, and sulfur to form inorganic arsenic compounds. Arsenic in animals and plants combines with carbon and hydrogen to form organic arsenic compounds.

Inorganic arsenic compounds are mainly used to preserve wood. Breathing high levels of inorganic arsenic can cause a sore throat or irritated lungs. Ingesting high levels of inorganic arsenic can cause death. The World Health Organization (WHO), the United States Department of Health and Human Services (USDHHS), and the United States Environmental Protection Agency (USEPA) have determined that inorganic arsenic is a human carcinogen (ATSDR 2007).

Organic arsenic compounds are used as pesticides, primarily on cotton plants and other crops. Organic arsenic compounds are less toxic than inorganic arsenic; however, exposure to high levels of some organic arsenic compounds may cause similar effects as those caused by inorganic arsenic. Organic arsenic is not characterized as a human carcinogen (ATSDR 2007).

2.1.1 Naturally-Occurring Arsenic

Arsenic occurs naturally in soil and may be present in the atmosphere as airborne dust. It also naturally occurs in coal and oil and may be released to the atmosphere by means of combustion of these materials. For instance, coal- and oil-fired power plants release arsenic to the atmosphere in their emissions (ATSDR 2007). Arsenic also occurs naturally in sea water and vegetation and is released into the atmosphere in sea salt spray and forest fires.

Arsenic may be released to water from the natural weathering of soil and rocks, and in areas of vulcanism. Arsenic may also leach from soil and minerals into groundwater (ATSDR 2007). In groundwater, arsenic primarily occurs in two forms, As^{+3} (arsenite) and As^{+5} (arsenate). Organic arsenic compounds are not known to occur at significant levels in groundwater (Murphy 2002).

Inorganic arsenic exists naturally at various levels in geologic formations throughout New Jersey and Pennsylvania. In some of these formations, arsenic is present at high concentrations, but is relatively immobile. In other formations, arsenic may become mobile as a result of the chemical and physical properties of the geologic material. This is the situation in the Piedmont Physiographic Province of New Jersey and Pennsylvania, where conditions in rocks formed from organic-rich, and ancient lake beds lead to increased mobility of arsenic. The location of the Piedmont Physiographic Province is provided as part of Attachment 2.

Results from research conducted by the NJGS and the NJDEP's Division of Science, Research and Technology (DSRT) indicate that elevated levels of arsenic can exist in some aquifers of the Piedmont Province, particularly in the western portion. In that study, arsenic was detected in groundwater collected from private wells within the western Piedmont at concentrations greater than 10 µg/L in 14 out of 91 homes sampled (15%), with one well showing arsenic at 57 µg/L (Murphy 2002). The NJGS and NJDEP sampling results are discussed in greater detail in Section 3.2. A similar situation exists for the Piedmont Province in Pennsylvania, where elevated levels of arsenic were detected in aquifers located in northern Bucks County and southern Lehigh County (Burkert 2006).

Additionally, the NJGS conducted whole rock geochemical analyses, which showed that arsenic concentrations increased from red to gray to black shale. Maximum concentrations of arsenic were 13, 50 and 130 parts per million (ppm), or milligrams per kilogram (mg/kg), in the red, gray and black shale, respectively. The mineral pyrite (FeS2) was identified as the major source of arsenic in the black shale. Pyrite was found at concentrations of 40,000 ppm and 3,000 ppm in different black shale members of the Passaic Formation. A spatial relationship between arsenic concentrations of 40 parts per billion (ppb), or micrograms per liter (ug/L, in groundwater and the local occurrence of black shale was found by the NJGS in the Lockatong and Passaic formations (NJGS 2006). A copy of the NJGS publication is provided in Attachment 2.

2.1.2 Anthropogenic Arsenic

Anthropogenic sources of arsenic include nonferrous metal smelting, coal, oil and wood combustion, and municipal waste incineration. Arsenic's use in agriculture and industrial processes also contributes to its emissions. Anthropogenic sources of arsenic releases to water include mining, nonferrous metals smelting (especially copper smelting), waste water discharges, dumping of sewage sludge, coal-burning power plants, manufacturing processes, urban runoff, atmospheric deposition and poultry farms (ATSDR 2007).

In 2005, the United States was the world's largest consumer of arsenic, with annual usage of approximately 21,600 metric tons. Production of wood preservatives, primarily chromated copper arsenate (CCA) (CrO3•CuO•As2O5), accounted for greater than 65% of domestic consumption of arsenic trioxide. The remainder was used for the production of agricultural chemicals, including herbicides and insecticides. CCA is the most widely used wood preservative in the world. Wood treated with CCA is known as 'pressure-treated' wood (ATSDR 2007).

In the past, the predominant use of arsenic was in agriculture. From the mid-nineteenth century to the introduction of organic pesticides in the 1940s, inorganic arsenic compounds were the dominant pesticides available to farmers and fruit growers. For example, lead arsenate was used as a growth regulator on citrus, calcium arsenate as an herbicide on turf, and sodium arsenite as a fungicide on grapes. Additionally, lead arsenate was used on apple and other fruit orchards as well as on potato fields. Sodium arsenite was used to control weeds on railroad right-of-ways, potato fields, and in industrial areas.

Arsenic was used in New Jersey as a pesticide on cropland, turf, and golf courses. From 1900 to 1980, about 49 million pounds of lead arsenate and 18 million pounds of calcium arsenate were applied to soils (Murphy and Aucott, 1998). Estimates of total arsenical pesticide applications for each county indicate that the largest amounts of arsenic were applied in counties in the Coastal Plain, in the southern part of the State (Vowinkel et al. [no date]). Attachment 2 provides additional information on historical arsenic use in New Jersey.

2.1.3 New Jersey Soil Background Concentrations

The NJDEP has published background concentrations for arsenic in surface soil within different physiographic provinces of New Jersey (Sanders 2003). Table 1 provides a summary of ambient arsenic concentrations in soil of urban and rural areas within the Piedmont, Highlands, and Ridge and Valley physiographic provinces. For data comparison purposes in their regulatory programs, the NJDEP uses the 90th-percentile concentration of a given soil background data-set, which is slightly less than the maximum value and thought to be representative of the highest concentration likely to be encountered under natural conditions in the environment.

The New Jersey geologic provinces within the Delaware River watershed area of interest being addressed in this report include the following:

- The southern portion of Mercer County is located within the Coastal Plain physiographic province and the northern half is within the Piedmont province (NJGS 1977)
- The southern two-thirds of Hunterdon County is found within the Piedmont physiographic province and the northern one-third is found within the Highlands province (NJGS 1979)
- The southern portion of Warren County lies within the Highlands physiographic province and the northern portion is within the Ridge and Valley province (NJGS 1971)

Sanders (2003) reports the following 90th-percentile background, or ambient, concentrations of arsenic in surface soil of urban areas:

- Urban Piedmont Soil: 24.2 mg/kg
- Urban Coastal Plain: 13.6 mg/kg

Rural areas of New Jersey showed the following 90th-percentile background or ambient concentrations of arsenic in surface soil:

- Coastal Plain Province: 6.15 mg/kg
- Highlands Province: 9.96 mg/kg
- Ridge and Valley Province: 7.32 mg/kg

As indicated, the Ridge and Valley and Highlands Provinces border the Delaware River along the northern portion of the reach from the Delaware Water Gap to Washington Crossing, mostly in Warren County. The Piedmont Province borders the River in Hunterdon and Mercer Counties. A copy of the Sanders 2003 document, including a map showing the physiographic provinces, is provided in Attachment 3. Although the Piedmont physiographic province is also present in Pennsylvania, background concentrations for arsenic in soil are unavailable for this region of Pennsylvania.

2.1.4 Health-Based Standards for Arsenic in Drinking Water

Environmental standards have been established by regulatory agencies for levels of arsenic in drinking water, including groundwater and surface-water sources. The drinking water standards are also known as Maximum Contaminant Levels or MCLs.

In January 2001, a revised drinking water standard of 0.01 mg/L (10 parts per billion, or ppb) for arsenic was promulgated by the United States Environmental Protection Agency (USEPA), to take effect in January 2006. The old drinking water standard of 0.05 mg/L (equal to 50 ppb) for arsenic had been set by USEPA in 1975.

In January 2006, the USEPA adopted 10 ug/L as its new primary drinking water standard, or MCL, for arsenic in drinking water. At the same time, the Pennsylvania Department of Environmental Protection (PADEP) also adopted 10 ug/L as the drinking water standard in Pennsylvania. However, the New Jersey Department of Environmental Protection (NJDEP) concurrently adopted a more stringent standard of 5 ug/L for arsenic drinking water. These standards remain in effect as of 2018.

The current human health-based environmental standards for arsenic in drinking water, include the following:

Summary of Drinking Water Standards for Arsenic

Regulatory Agency	**Historical Arsenic MCL in ug/L (Pre-2006)**	**Current Arsenic MCL in ug/L (Post-2006)**
USEPA (Federal)	50	10
PADEP (State)	50	10
NJDEP (State)	50	5

All units are micrograms per liter (ug/L)

MCL = Maximum contaminant level (or primary drinking water standard)

The current MCLs of 10 ug/L in Pennsylvania and 5 ug/L in New Jersey are appropriate for data comparisons in this instance and are referenced in this report as part of the arsenic data presentation.

3 *ARSENIC WITHIN THE DELAWARE RIVER WATERSHED*

This report presents a compilation of information/data related to arsenic in the environment of the Delaware River watershed between the Delaware Water Gap (River Mile 210.8) and the bridge at Washington Crossing, Pennsylvania (River Mile 141.8) (i.e., the "watershed area of interest").

The data compilation project involved gathering and summarizing existing, publically-available analytical results (or data) for arsenic in soil, groundwater (private and public drinking water), and surface water within the Delaware River watershed area of interest.

The goal of the data compilation project is to establish a baseline for arsenic concentrations in various environmental media, including groundwater and surface water along this reach of the River, and to identify potential sources of arsenic in soil. This baseline can be used for future data comparison purposes to evaluate water-quality changes.

The following sections summarize the findings of the arsenic data compilation.

3.1 *ARSENIC IN SOIL*

As part of a project conducted cooperatively by the USGS and NJDEP, stream-sediment and soil samples were collected and analyzed for arsenic. Vowinkel et al. reported that concentrations of arsenic in streambed sediments differed significantly among physiographic provinces, and that results of regression analyses demonstrated that the presence of arsenic in streambed sediments is related to agricultural land use. Results of chemical fingerprinting to determine the possible sources of arsenic in soils in an area in the east-central Coastal Plain indicated that arsenic concentrations greater than 20 mg/kg occurred naturally in clays, but that concentrations of this magnitude in sandy soils were a result of agricultural pesticide use or waste disposal from a nearby industrial site (Vowinkel et al.). Sediment sampling was not conducted in the Piedmont physiographic province as part of this study.

Background data for metals in soil are presented in Section 2.1.3 and summarized below:

Table 1. Ambient Concentrations of Arsenic in New Jersey Soil

	Urban Piedmont					Rural Areas of New Jersey							
						Ridge and Valley Province					Highlands Province		
TAL Metal	MDL (mg/kg)	No. of Detects	Median Conc. (mg/kg)	90th-percentile Conc. (mg/kg)		MDL (mg/kg)	No. of Detects	Median Conc. (mg/kg)	90th-percentile Conc. (mg/kg)		MDL (mg/kg)	No. of Detects	Median Conc. (mg/kg)	90th-percentile Conc. (mg/kg)
Arsenic	0.13	67/67	5.2	24.2		0.28	23/23	4.9	7.32		0.28	23/23	4.8	9.96

TAL = Target analyte list
67/67 = Detections out of total number of samples
mg/kg = milligrams per kilogram
Conc. = Concentration

As indicated, the literature values for 90th-percentile concentrations of arsenic in ambient surface soil are:

- Highlands Province: 9.96 mg/kg
- Ridge and Valley Province: 7.32 mg/kg

The Urban Piedmont ambient concentration of 24.2 mg/kg relates to soil samples collected in the central and northeastern areas of the State (Sanders 2003), so is not directly applicable to the Piedmont area within the Delaware River watershed. It is likely that a 90th-percentile concentration for arsenic in surface soil of the Piedmont within the watershed would range between 7.32 mg/kg and 24.2 mg/kg, the values for the Ridge and Valley Province and the Urban Piedmont, respectively.

The other source of data for arsenic in soil are known-contaminated sites within the watershed. As discussed in greater detail in Section 3.2.3, concentrations in surface soil samples collected at two sites adjacent to the River showed arsenic concentrations of 7.7 mg/kg and 9.9 mg/kg, similar to the background concentrations presented above.

3.2 *ARSENIC IN GROUNDWATER*

Concentrations of dissolved arsenic in groundwater samples collected by the USGS from more than 2,000 wells in New Jersey showed differences among four major aquifer types—unconfined Coastal Plain, confined Coastal Plain, bedrock, and glacial (Vowinkel et al.). Concentrations of arsenic in ground water typically are less than 2 µg/L, but arsenic may occur naturally at concentrations greater than 50 µg/L. Arsenic concentrations routinely exceeded 5 µg/L (the current NJDEP MCL for arsenic in drinking water) and in some cases exceeded 10 µg/L in groundwater from wells installed in fractured bedrock aquifers in the Piedmont Physiographic Province. In this Province, arsenic is present naturally in the black shale (Szabo and others, 1997; Surfes and others, 2000). Concentrations of arsenic greater than 50 µg/L in groundwater are usually associated with known contaminated sites (Vowinkel et al.).

The evaluation of groundwater data within the watershed area of interest primarily involved the review of water quality databases, including those sponsored by governmental agencies. Historical groundwater sampling results obtained by the USGS, the NJGS, the NJDEP, and the PADEP are stored in various databases, which were accessed to obtain the most recent data available. The primary databases accessed to obtain sampling information/data included:

- PADEP Drinking Water Reporting System
  http://www.drinkingwater.state.pa.us/dwrs/HTM/Welcome.html
- National Water Quality Monitoring Council (NWQMC)
  https://www.waterqualitydata.us/portal/
- NJ Private Well Testing Act Data
  http://njdep.maps.arcgis.com/apps/MapSeries/index.html?appid=826ec9fae77543caa582a787d5f088e7
- New Jersey Drinking Water Watch
  https://www9.state.nj.us/DEP_WaterWatch_public/

In addition, published reports and other on-line information readily available on various web sites were used to obtain published documents that are in the public domain in some instances.

3.2.1 Private Well Testing Results

New Jersey Private-Well Testing Results

In New Jersey, private domestic water wells are prevalent throughout the watershed area of interest in Mercer, Hunterdon and Warren Counties. Attachment 4 shows private well sampling locations in these Counties. These private homeowner wells are typically found in areas not served by a municipal water supply. It is worthy of note that the arsenic analyses associated with these groundwater samples were conducted by New Jersey-certified laboratories with quality assurance programs.

Historical arsenic data obtained for these wells from the NJDEP is summarized as follows:

Table 2. NJDEP Private Well Testing Act - Arsenic Results by County from September 2002 to April 2007

County	Municipality	# Wells Sampled	# Wells with 10 ug/l MCL Exceedances	Percentage of Exceedances	# Wells Sampled	# Wells with 5 ug/l MCL Exceedances	Percentage of Exceedances
Hunterdon		4858	272	5.6%	3791	673	17.8%
	Alexandria Township	218	64	29.4%			
	Delaware Township	234	53	22.6%			
	Esast Amwell	226	93	41.2%			
	Frenchtown Boro	14	8	57.1%			
	Holland Township	167	16	9.6%			
	Kingwood Township	194	79	40.7%			
	Lambertville	36	4	11.1%			
	Milford	NR	NR	-			
	Readington Township	500	101	20.2%			
	Stockton	2	0	0.0%			
Mercer		1489	108	7.3%	1381	272	19.7%
	Hopewell Township	838	240	28.6%			
Warren		2377	NR	NR	2377	NR	NR

MCL = maximum contaminant limit
NR = Sampling for arsenic not required

These results indicate the following:

- In Mercer County, during the same period, a total of 1,381 well samplings occurred and of these samples 272 (or 19.7%) had arsenic concentrations greater than the 5 ug/L MCL for drinking water
- In Hunterdon County, from 2002 to 2007, a total of 3,791 well samplings occurred and of these samples 673 (or 17.8%) had arsenic concentrations greater than the 5 ug/L MCL for drinking water
- In Warren County, during the same period, a total of 2,377 well samplings occurred, but arsenic analysis was not required, so results are unavailable for these private wells

Additional information/data related to these private-well samplings, including a breakdown by municipality within a given County, is provided in Attachment 4.

More recent data from private well testing in New Jersey Counties and municipalities bordering the River is summarized in the following table:

Table 3. Private Well Testing Data for New Jersey Counties and Municipalities Bordering the Delaware River.

County	Municipality	N	% Below RL*	% > 5 (ug/L)	# > 5 (ug/L)	90P (ug/L)	95P (ug/L)
Warren	Hardwick Township	103	93.2	1	1	2.0	2.0
	Harmony Township	113	95.6	0.9	1	2.0	2.0
	White Township	151	82.8	7.3	11	4.2	6.5
	Knowlton Township	119	87.4	0.8	1	2.0	2.0
	Lopatcong Township	37	100.0	0	0	2.0	2.0
	Pohatcong Township	56	94.6	0	0	2.0	2.0
	Belvidere Town	<10	85.7	-	-	-	-
	Phillipsburg Town	<10	100.0	-	-	-	-
Hunterdon	Delaware Township	449	45.9	20.5	92	10.0	15.5
	Frenchtown Boro	30	10.0	70	21	21.2	25.7
	Holland Township	482	73.9	8.3	40	4.3	7.0
	Kingwood Township	425	22.8	42.6	181	12.1	17.1
	Lambertville City	73	52.1	9.6	7	5.0	16.0
	West Amwell Township	272	39.0	18.4	50	7.5	10.9
	East Amwell Twp	398	22.4	42.2	168	13.0	18.8
	Alexandria Township	529	50.7	24.2	128	12.1	19.0
	Milford Boro	<10	100.0	-	-	-	-
	Stockton Boro	<10	33.3	-	-	-	-
Mercer	Hopewell Township	1443	22.6	26.5	382	9.2	12.7

< 10 = Fewer than 10 wells Sampled
*RL = Reporting Limit represents summary statistics calculated using replacement of 1/2 the laboratory reporting limit
" - " indicates data are unavailable
Source Information: Division of Science, Research, and Environmental Health, NJDEP.
Source Site: NJDEP

The following results were available for Mercer County:

- A total of 1,443 well samplings occurred and of these samples 382 (or 26.5%) had arsenic concentrations greater than the 5 ug/L MCL for drinking water

- The 90th-percentile concentration of arsenic in private-well drinking water in Hopewell Township was 9.2 ug/L, and the 95th-percentile concentration was 12.7 ug/L. Hopewell Township is the only municipality in Mercer County within the watershed area of interest that borders the Delaware River

The following results were available for Hunterdon County:

- A total of 2,678 well samplings occurred and of these samples 687 (or 25.6%) had arsenic concentrations greater than the 5 ug/L MCL for drinking water

- The 90th-percentile concentrations of arsenic in private-well drinking water ranged from 4.3 ug/L to 21.2 ug/L, and 95th-percentile concentrations ranged from 7.0 to 25.7 ug/L

- Within Hunterdon County, Frenchtown Boro had the highest percentage of exceedances of the 5 ug/L MCL at 70%, and the highest 90th- and 95th-percentile arsenic concentrations at 21.2 ug/L and 25.7 ug/L, respectively

- Kingwood Township, East Amwell Township and Alexandria Township also showed concentrations of arsenic elevated above the 5 ug/L MCL, but at levels less than Frenchtown Boro

The following results were available for Warren County:

- A total of 579 well samplings occurred and of these samples 14 (or approximately 2%) had arsenic concentrations greater than the 5 ug/L MCL for drinking water

- The 90th-percentile concentrations of arsenic in private-well drinking water in various municipalities ranged from 2.0 ug/L to 4.2 ug/L, and 95th-percentile concentrations ranged from 2.0 to 6.5 ug/L

- Within Warren County, White Township had the highest percentage of exceedances of the 5 ug/L MCL at 7.3%, and the highest 90th- and 95th-percentile arsenic concentrations at 4.2 ug/L and 6.5 ug/L

Attachment 4 provides additional details related to the private-well testing results for New Jersey. Based on these private-well testing results, Warren County had the fewest exceedances of the MCL for arsenic and the lowest concentrations of arsenic in drinking water (i.e., groundwater). Hopewell Township in Mercer County showed moderate arsenic exceedances and concentrations, and Hunterdon County showed the greatest number of exceedances and highest concentrations of arsenic in groundwater used for drinking water. Quality assurance/quality control (QA/QC) information/data were unavailable for the private-well testing results. In addition, private well locations are typically not provided by regulatory agencies, nor are they part of the public record.

Pennsylvania Private-Well Testing Results

Private well testing results were unavailable for Bucks and Northampton Counties because Pennsylvania does not have a program that collects private well data. Private well testing results are solely for the homeowner's use, and are not compiled into a database or made public by other means.

However, an arsenic research project conducted by Lori Burkert in 2005, as part of a Master's Thesis program at Lehigh University (Burkert 2006), involved sampling of private wells in upper Bucks County and lower Lehigh County, Pennsylvania. This area is part of the Piedmont physiographic province in Pennsylvania. Results of the research showed the following results for arsenic in groundwater:

Table 4A: Burkert Study - 2005 Drinking Water Well Arsenic Data Northern Bucks County and Southern Lehigh County, Pennsylvania

Formation	**# of As samples**	**# of As samples > 10** µg/L	**Mean As** (µg/L)	**Median As** (µg/L)	**Max As** (µg/L)	**Min As** (µg/L)
Entire study	53	12	7.76	2.87	64.86	0.01
Passaic	27	9	10.12	6.4	46.14	0.02
Lockatong	6	2	20.04	6.26	64.86	0.58
Diabase	7	1	2.1	0.19	11.83	0.06
Precambrian / Cambrian	12	0	0.2	0.07	1.27	0.01
Other	1	0	0.7	0.7	0.7	0.7

As = Arsenic

"Other" indicates Trenton gravel geologic formation

Overall, results indicated that arsenic was detected in all 53 groundwater samples, and 23% of all samples contained elevated concentrations of arsenic (> 10 µg/L (ppb)).

The research also involved a review of existing PADEP databases (namely, the Pennsylvania Drinking Water and Sampling Information System [PADWIS]) for arsenic in drinking water wells installed in different geologic formations. Results of this database review from 2004 indicated the following:

Table 4B: Burkert Study – 2004 PADEP Drinking Water Well Database Arsenic Data

Formation	**# of As samples**	**# of As samples > 10** µg/L	**Mean As** (µg/L)	**Median As** (µg/L)	**Max As** (µg/L)	**Min As** (µg/L)
*All PA DEP**	2310	630	9	2	83	ND
Passaic	1538	577	13	5	83	ND
Lockatong	283	42	4	ND	64	ND
Diabase	142	7	2	ND	42	ND
Precambria/ Cambrian	347***	4	<1	ND	24	ND

As = Arsenic

*Represents data from PA DEP Drinking Water and Sampling Information System database (PA DEP, 2004) from the same formations as this study. PA DEP data may represent parts of some formations that are outside the extent of this study.

Additional findings of the research included:

- The highest concentrations of arsenic are found within the Passaic and Lockatong formations in both datasets

- The percentage of samples with arsenic concentrations greater than 10 µg/L are similar between the Burkert study and the PA DEP data when comparing the entire datasets, data from the Passaic Formation, and other formations

- Mobility of both arsenate and arsenite is correlated with pH in this study. Arsenate is the dominant inorganic species due to oxidizing conditions

- Natural variations in redox potential and pH affect the arsenic concentrations and arsenic speciation in the groundwater

Additional details of the research can be found in the 2006 Masters Thesis (Burkert 2006), a copy of which is provided in Attachment 5.

3.2.2 Ambient Groundwater Monitoring Results

New Jersey Ambient Groundwater Monitoring Results

The NJGS has established a monitoring well network across the State, which is periodically sampled to evaluate groundwater quality. Attachment 6 provides a map with the groundwater monitoring well locations. A search of the ambient well results database for those wells in Mercer, Hunterdon and Warren Counties was conducted. A summary of the ambient groundwater monitoring results for the above counties is provided below in Table 5 and additional supporting information is provided in Attachment 6.

Table 5. Ambient Groundwater Sampling Results for Arsenic in Hunterdon and Mercer Counties

										Arsenic
#									**Date**	µg/l
STAID	**UID**	**Network Id**	**Mon Well #**	**WMA**	**Hydro Aqui**	**Land Use**	**County**	**Municipality**	**Sampled**	**P01000**
403921074515901	190451	mw-101	101	8	400PCMG	AG	Hunterdon	Clinton	20030624	<0.3
403921074515901	190451	MW101	101	8	400PCMG	AG	Hunterdon	Clinton	20080415	0.1
403100074464101	190455	mw-107	107	8	227PSSC	AG	Hunterdon	Readington	20030626	1.4
403100074464101	190455	MW107	107	8	227PSSC	AG	Hunterdon	Readington	20080708	2.5
402501074505001	190452	mw-106	106	8	227PSSC	AG	Hunterdon	East Amwell	20030701	2.1
402501074505001	190452	MW106	106	8	227PSSC	AG	Hunterdon	East Amwell	20080811	2.2
402633074541301	190456	mw-91	91	8	227PSSC	AG	Hunterdon	Delaware	20030910	2.9
402633074541301	190456	MW91	91	8	227PSSC	AG	Hunterdon	Delaware	20080709	1.4
402051074400001	210630	mw-122	122	10	231SCKN	URB	Mercer	Princeton	20040616	0.2
402051074400001	210630	mw-122	122	10	231SCKN	URB	Mercer	Princeton	20070820	0.12
401829074513301	21033	mw-80	80	11	227PSSC	UND	Mercer	Hopewell	20040617	1.1
401829074513301	21033	mw-80	80	11	227PSSC	UND	Mercer	Hopewell	20090629	1.5
404900075043601	410568	mw-95	95	1	112SFDF	AG	Warren	White	20040623	0.4
404900075043601	410568	MW95	95	1	112SFDF	AG	Warren	White	20080813	0.24

Arsenic results are for filtered groundwater samples

"<"- Less Than

Results of the ambient monitoring by NJGS showed:

- Ambient well data from 2003 through 2008 from wells in Mercer County had concentrations ranging from 0.12 ug/L to 1.5 ug/L in filtered groundwater samples

- Ambient well data from 2003 through 2008 from wells in Hunterdon County had concentrations ranging from non-detect (<0.3 ug/L) to 2.9 ug/L in filtered groundwater samples

- The two ambient well data points for Warren County were 0.24 ug/L and 0.4 ug/L

Additional ambient groundwater monitoring results include:

Table 6. Ambient water data associated with shallow wells for two sampling cycles.

# STAID	**UID**	**Network Id**	**Mon Well #**	**WMA**	**Hydro Aqui**	**Land Use**	**County**	**Municipality**	**Date Sampled**	**As (ug/L)**
402501074505001	190452	mw-106	106	8	227PSSC	AG	Hunterdon	East Amwell	20030701	2.1
402501074505001	190452	MW106	106	8	227PSSC	AG	Hunterdon	East Amwell	20080811	2.2
402633074541301	190456	mw-91	91	8	227PSSC	AG	Hunterdon	Delaware	20030910	2.9
402633074541301	190456	MW91	91	8	227PSSC	AG	Hunterdon	Delaware	20080709	1.4
401829074513301	21033	mw-80	80	11	227PSSC	UND	Mercer	Hopewell	20040617	1.1
401829074513301	21033	mw-80	80	11	227PSSC	UND	Mercer	Hopewell	20090629	1.5
404900075043601	410568	mw-95	95	1	112SFDF	AG	Warren	White	20040623	0.4
404900075043601	410568	MW95	95	1	112SFDF	AG	Warren	White	20080813	0.24

Source Data: NJGS

These results show arsenic concentrations in groundwater samples from the same monitoring well, but four to five years apart as follows:

- Groundwater sampled from well mw-80, located in Hopewell, Mercer County, showed 1.1 ug/L in 2004 and 1.5 ug/L in 2009

- Groundwater sampled from well mw-106, located in East Amwell, Hunterdon County, showed 2.1 ug/L in 2003 and 2.2 ug/l in 2008; and groundwater from well mw-91 in Delaware Township showed 2.9 ug/L and 1.4 ug/L of arsenic in 2003 and 2008, respectively

- Groundwater sampled from well mw-95, located in White Township, Warren County, showed 0.4 ug/L in 2004 and 0.24 ug/l in 2008

These results indicate relatively stable concentrations of arsenic in groundwater in these areas between 2003 and 2009.

In addition, USGS and NJDEP conducted groundwater monitoring for arsenic in different areas of western Hunterdon County. These results are summarized below:

Table 7. USGS and NJDEP Well Data for As (ug/L) within 3 miles of the Delaware River.

Location	Latitude	Longitude	N	Min	Max	Mean	Median	90thP	95thP
SW Hunterdon	40.362382	-74.89838	51.0	0.0	24.7	4.9	3.0	13.0	15.2
CW Hunterdon	40.470057	-75.02	26.0	0.0	25.0	5.3	3.6	10.9	11.6
NW Hunterdon	40.598112	-75.01881	22.0	0.0	9.0	2.3	1.2	6.0	7.9

All units are micrograms per liter (ug/L)
Values with "0" were added in instances where As was "not detected" in raw data files
*Based on well data that lie within a 5 mile radius of the coordinates.
Source Site: NWQMC

These results indicate the following:

- For southwest (SW) Hunterdon County, arsenic groundwater results ranged from non-detect to 24.7 ug/L, the mean arsenic concentration was 4.9 ug/L, and the 90th-percentile concentration was 13.0 ug/L

- For central western (CW) Hunterdon County, arsenic groundwater results ranged from non-detect to 25.0 ug/L, the mean arsenic concentration was 5.3 ug/L, and the 90th-percentile concentration was 10.9 ug/L

- For northwest (NW) Hunterdon County, arsenic groundwater results ranged from non-detect to 9.0 ug/L, the mean arsenic concentration was 2.3 ug/L, and the 90th-percentile concentration was 6.0 ug/L

These groundwater results and summary statistics show similar concentrations of arsenic in the data-sets collected from SW and CW Hunterdon County, both of which appear to have greater arsenic concentrations relative to the NW Hunterdon data-set. Additional supporting information for these ambient groundwater monitoring results is provided in Attachment 6. These data are consistent with the geological information provided in Section 2.1.3, which indicates the presence of the Piedmont physiographic province in the southern two-thirds of Hunterdon County and the Highlands province in the northern one-third of the County. The Piedmont province in this area is known to have naturally-occurring arsenic-rich rock formations, which can contribute to concentrations of arsenic in groundwater (Szabo and others, 1997; Surfes and others, 2000).

Table 8 provides similar results for Warren County:

Table 8. NWQMC Well Data for As (ug/L) in Warren County within 3 miles of the Delaware River.

Location	Latitude	Longitude	N	Min	Max	Mean	Median	90thP	95thP
NW Warren Co.	40.81365	-75.048423	18	0.0	2.0	0.4	0.2	1.3	2.0
WC Warren Co.	40.742117	-75.147405	12	0.0	0.4	0.1	0.0	0.1	0.3
SW Warren Co.	40.678221	-75.139582	10	0.0	0.7	0.1	0.0	0.2	0.4

Values with "0" were added in instances where As was "not detected" in raw data files
*Based on well data that lie within a 5 mile radius of the coordinates.
Source Site: NWQMC

These results indicated:

- For southwest (SW) Warren County, arsenic groundwater results ranged from non-detect to 0.7 ug/L, the mean arsenic concentration was 0.1 ug/L, and the 90th-percentile concentration was 0.2 ug/L

- For central western (CW) Warren County, arsenic groundwater results ranged from non-detect to 0.4 ug/L, the mean arsenic concentration was 0.1 ug/L, and the 90th-percentile concentration was 0.1 ug/L

- For northwest (NW) Warren County, arsenic groundwater results ranged from non-detect to 2.0 ug/L, the mean arsenic concentration was 0.4 ug/L, and the 90th-percentile concentration was 1.3 ug/L

These groundwater results and summary statistics show similar concentrations of arsenic in the data-sets collected from SW and CW Warren County, both of which appear to have lower arsenic concentrations relative to the NW Warren County data-set. Additionally, the Warren County groundwater results for arsenic are substantially less than the Hunetrdon County arsenic results for groundwater collected from well locations within approximately three miles of the River. Supporting information for the Warren County ambient groundwater monitoring events is also provided in Attachment 6. QA/QC information/data were also unavailable for the ambient groundwater monitoring results. In addition, while ambient well designations (I.D.s) were available from the databases in some instances, the precise locations of the monitoring wells were not provided. Follow-up calls to the relevant regulatory agencies were unsuccessful in procuring this information.

Pennsylvania Ambient Groundwater Monitoring Results

Ambient groundwater monitoring results are unavailable for Pennsylvania, and it appears that PADEP does not sponsor an ambient groundwater monitoring program in Bucks and Northampton Counties. However, the municipal water supply information/data discussed in next section provides some insight into ambient conditions in Bucks and Northampton Counties.

3.2.3 Municipal Water Supply Results

New Jersey Municipal Water Supply Results

The table below provides a summary of arsenic results for municipal water supplies in the New Jersey Counties.

Table 9. New Jersey Municipal Water Supply Arsenic Data

COUNTY	Municipality*	Sample Date/Time	CGW	CGU	CSW
WARREN	Knowlton Township	10/28/2015 / 11:00	1.72 UG/L		
	Belvidere Town	02/14/2018 / 09:34	<0.001 MG/L		
	Harmony Township	08/30/2017 / 10:43	1.3 UG/L		
	Knowlton Township	10/28/2015 / 11:00	1.72 UG/L		
	Phillipsburg Town	01/18/2018 / 13:59		<1 UG/L	
	Pohatcong Township	08/30/2017 / 09:52	<0.001 MG/L		
	White Township	12/28/2015 / 06:10	<0.247 UG/L		
	Hardwick Township	NA	NA		
	Lopatcong Township	NA	NA		
HUNTERDON	Alexandria Township	08/31/2017 / 08:45	0.0034 MG/L*		
	Delaware Township	01/31/2018 / 14:00	0.0026 MG/L		
	Frenchtown Boro	2/13/2018	<0.28 UG/L		
	Holland Township	05/08/2017 / 11:40	<1 UG/L		
	Kingwood Township	NA	NA		
	Lambertville City	04/18/2017 / 10:02			<0.0004 MG/L
	Milford Boro	08/31/2017 / 08:45	0.0034 MG/L		
	Stockton Boro	09/25/2015 / 09:15	0.0031 MG/L		
	West Amwell Township	04/18/2017 / 10:02			<0.0004 MG/L*
MERCER	Hopewell Township	03/19/2018 / 09:06	<3.5 UG/L		

"<" less than
*Served by another municipality
NOTE: Data documented here reflects the most recent raw data reported for each municipality in data base. There may be more than one supplier.
To convert to ug/L (ppb): 1 mg/L = 1000 ug/L
Source Site: JDEPWaterWatch

Additional supporting information/data associated with these well results are provided in Attachment 7. Results indicated the following arsenic concentrations in municipal water supplies:

- For Hopewell Township, the single water supply well in Mercer County for which data were reported, a non-detectable concentration (< 3.5 ug/L) was found in 2018

- For six municipal supply wells in Hunterdon County, arsenic concentrations range from non-detect (< 0.28 ug/L) in Frenchtown in 2018 to 3.4 ug/L in both Alexandria Township and Milford in 2017. The two surface-water municipal supplies, one in Lambertville and the other in West Amwell Township, both showed non-detectable (< 0.4 ug/L) concentrations of arsenic.

- For six municipal supply wells in Warren County, arsenic concentrations range from non-detect (< 1.0 ug/L) in Belvidere in 2018 to 1.72 ug/L in Knowlton Township in 2015.

These results are similar and are all less than the NJDEP's 5 ug/L MCL. Additional information is provided in Attachment 7.

Pennsylvania Municipal Water Supply Results

A summary of arsenic results for municipal water supplies in Bucks and Northampton Counties, Pennsylvania is provided below in Table 10, and supporting information is provided in Attachment 8.

Table 10. Summary of PADEP Municipal Water Supply Arsenic Data

County	Municipality	N	Min	Max	Median	Mean
Bucks	New Hope	4	4	5.6	4.8	4.8
	Solebury	5	0	7	1	3.2
	Tinicum	2	0	2.6	na	1.3
	Upper Makefield	3	0	2.8	2.6	1.87
	Riegelsville	2	0	0.26	na	0.13
Northampton	Easton City	6	-	-	-	-
	Upper Mt. Bethel	6	-	-	-	-

Note: Pennsylvania reports MCL for As < .01 mg/L. Data reported here were converted to ug/L.
All units are micrograms per liter (ug/L)
" - " indicates not available
Source Site: PADEPDrinkingWaterReport

Results reported in the PADEP Drinking Water Report database include:

- For Bucks County, arsenic concentrations in municipal water supplies ranged from non-detect to 7 ug/L, with mean concentrations ranging from 0.13 to 4.8 ug/L in the five water supplies. Solebury Township and New Hope had the highest concentrations with mean concentrations of 3.2 ug/L and 4.8 ug/L, respectively

- Results were unavailable for Easton and Upper Mt. Bethel, the two municipalities in Northampton County

Table 11 below provides additional water supply well arsenic results for north and central Bucks County. Results were unavailable for municipal water supplies in Northampton County.

Table 11. Summary of NWQMC Well Data for As (ug/L) in select areas of Bucks and Northampton Counties.

Well Cluster Location	Latitude	Longitude	# Wells	N	Min*	Max	Mean	Median	90thP	95thP
NorthBucks	40.419519	-75.067461	24	28	0	13	2.35	1.5	3.8	9.95
CentralBucks	40.419519	-75.067461	41	27	0	60	9.29	3	28	46.2
Northampton	40.683343	-75.213923	4	NA	NA					

*Zero was substituted when As was "not detected" (i.e., below the limit of detection available in laboratory tests).
NA = Not available.
All units are micrograms per liter (ug/L)
Source Site: NWQMC

These results indicated:

- For North Bucks County, arsenic groundwater results ranged from non-detect to 13 ug/L, the mean arsenic concentration was 2.4 ug/L, and the 90th-percentile concentration was 3.8 ug/L

- For Central Bucks County, arsenic groundwater results ranged from non-detect to 60 ug/L, the mean arsenic concentration was 9.3 ug/L, and the 90th-percentile concentration was 28 ug/L

Additional information/data related to these well results are provided in Attachment 8.

These results show higher arsenic concentrations in the groundwater of central Bucks County compared to north Bucks County. These data also appear to be consistent with arsenic concentrations on the New Jersey side of the River in this area, where arsenic concentrations are greater in southwest and central west Hunterdon County relative to areas further north.

3.2.4 Data from Known-Contaminated Sites

Several known-contaminated sites along the Delaware River were identified and research was conducted to obtain arsenic data for soil, groundwater and/or sediment associated with these sites. The sites identified include:

- Crown Vantage Landfill – Alexandria Township, NJ
- Curtis Specialty Papers Superfund Site – Milford, NJ
- Martins Creek Power Station – Martins Creek, PA

Potential arsenic contamination associated with each of these sites in discussed in greater detail below.

Crown Vantage Landfill Superfund Site – Alexandria Township, NJ

The Crown Vantage Landfill Site is located on the River in Alexandria Township between Frenchtown and Milford. The Site consists predominately of a fly ash landfill, with lesser amounts of paper wastes (e.g., foil-backed paper, off-specification paper and labels, etc.) and construction debris (e.g., bricks, concrete, etc.). Drums, drum remnants and drum carcasses were removed during previous site remediation activities (TRC 2010).

During the 2010 Remedial Investigation (RI), surface soil, sediment, surface water and pore water were sampled for various constituents, including arsenic. Table 12 summarizes the soil, surface-water and pore-water results, which indicated the following:

Table 12A: Surface Soil Results Summary – Crown Vantage Site

		Frequency of	Soil Concentration		
	n	Detection	Min.	Max.	Mean
Parameter			(mg/kg)		
Metals (mg/kg)					
Arsenic	35	35/35	2.8	14.7	7.7

n = number of samples analyzed

Arsenic was detected in all 35 surface soil samples at concentrations ranging from 2.8 mg/kg to 14.7 mg/kg. The average arsenic concentration in these samples was 7.7 mg/kg.

Table 12B: Surface-water Results Summary – Crown Vantage Site

		Frequency of	Surface-water Concentration		
	n	Detection	Min.	Max.	Mean
Parameter			(ug/L)		
Metals (ug/l)					
Arsenic	5	5/5	0.286	0.388	0.344

n = number of samples analyzed

Arsenic was detected in the five surface-water samples collected from the Delaware River at concentrations ranging from 0.29 ug/L to 0.39 ug/L. The average arsenic concentration in surface water was 0.34 ug/L. Upstream surface-water samples showed arsenic concentrations of 1 ug/L and 1.7 ug/L.

Table 12C: Pore-water Results Summary – Crown Vantage Site

		Frequency of	Pore-water Concentration		
	n	Detection	Min.	Max.	Mean
Parameter			(ug/L)		
Metals (ug/l)					
Arsenic	5	5/5	<0.25	14.1	3.0

n = number of samples analyzed

Pore-water results for arsenic in five samples ranged from non-detect (less than 0.25 ug/L) to 14.1 ug/L, with a mean concentration of 3.0 ug/L.

Additional information is provided in Attachment 9. RI data validation packages were provided in Appendix A of the RI Report. In summary, all results were found to be usable for project objectives. Data qualifiers for detections less than the reporting limit and detections in blank samples were applied to the data, as appropriate. The positive results for arsenic in all sediment samples were qualified as estimated (or J-value) results due to positive interferences seen in the sample analyses. Additional information is available in the data validation reports.

Curtis Specialty Papers Superfund Site – Milford, NJ

The site is a former food-grade paper mill, or manufacturing facility, located along the Delaware River at 404 Frenchtown Road (County Route 619) near the town of Milford, Hunterdon County, New Jersey. Paper production began in 1907 and ended in 2003. During its 96-year operational history, four operational areas were present on the 86-acre Site, including: a 28-acre Main Mill Area; a 5-acre Coatings Facility Area; a 13-acre Wastewater Treatment Plant Area; and a 40-acre Coal Pile and Aeration Basin Area.

Remedial investigation was conducted at the Site in the 2007 to 2008 timeframe, and the remedial investigation results were used by the New Jersey Department of Health (NJDOH) and ATSDR to generate a Public Health Assessment Report dated January 2011. Sampling results evaluated in the report included surface soil and sediment results for various constituents, including arsenic. The results the Curtis Specialty Papers Site sampling, summarized in Table 13 indicated the following:

Table 13A: Surface Soil Results Summary – Curtis Paper Company

		Frequency of	Soil Concentration		
	n	Detection	Min.	Max.	Mean
Parameter			(mg/kg)		
Metals (mg/kg)					
Arsenic	36	36/36	1.4	79	9.9

n = number of samples analyzed

Arsenic was detected in all 36 surface soil samples at concentrations ranging from 1.4 mg/kg to 79 mg/kg. The average arsenic concentration in these samples was 9.9 mg/kg.

Table 13B: Surface-water Results Summary – Curtis Paper Company

		Frequency of	Surface-water Concentration		
	n	Detection	Min.	Max.	Mean
Parameter			(mg/kg)		
Metals (ug/l)					
Arsenic	20	20/20	ND	4.4	2.6

n = number of samples analyzed

Arsenic was detected in all 20 sediment samples at concentrations ranging from non-detect to 4.4 mg/kg. The average arsenic concentration in these samples was 2.6 mg/kg

Attachment 9 provides additional information related to this Site.

Martins Creek Power Station – Martins Creek, PA

PPL Generation LLC's Martins Creek Power Station is an electricity generating station located in the town of Martins Creek. Historically, the power station used coal-fired burners as the energy source to generate electricity, and the fly ash waste from coal combustion was stored in onsite holding ponds.

In 2005, a release of fly-ash from an onsite holding pond, or impoundment, flowed into an adjacent stream and the Delaware River. According to Site-related documents, on August 23, 2005, one of the wooden stop logs failed in the discharge structure of the impoundment. As the result of this failure, approximately 100 million gallons of water and fly ash flowed out through the discharge piping and from various associated manholes. It flowed over about 10 acres of surrounding fields and into the Oughoughton Creek and Delaware River. The release was completely stopped on August 27, 2005, and PPL began an immediate cleanup effort including removal of the fly ash from the fields, Oughoughton Creek, and the Delaware River. The emergency response actions were completed in March 2006, and the follow-up river assessment work continued through September 2006. In June 2007, PPL submitted the Phase IV Completion Report to PADEP summarizing the emergency response actions and follow-up river assessment work.

In conjunction with PADEP, the DRBC conducted post-release surface-water monitoring work for this project. Results from their monitoring on the Delaware River on August 26, 2005 indicated:

- Non-detectable concentrations of arsenic in surface water upstream of the discharge area

- Concentrations of arsenic ranging from approximately 30 ug/l to 60 ug/l in surface water at the facility

- Concentrations of arsenic ranging from approximately 10 ug/l to 50 ug/l in surface water from 5 to 10 miles downstream of the facility

- Concentrations of arsenic ranging from approximately 10 ug/l to 20 ug/l in surface water from 20 to 30 miles downstream of the facility

- Concentrations of arsenic less than 10 ug/l in surface water greater than 30 miles downstream of the facility

- Concentrations of arsenic less than 1 ug/l in surface water greater than 50 miles downstream of the facility

DRBC concluded the following from the monitoring event:

- There were apparent exceedances of PA arsenic criteria immediately after the release in the vicinity of the release. These exceedances are not observed in upstream surface-water samples.

- The apparent signature of release observable downstream, but at concentrations less than PA arsenic criteria.

- Quantifiable concentrations of arsenic exceed NJ criteria (both upstream and downstream)

Additional information and data related to the surface-water monitoring work associated with the Martins Creek Site is provided in Attachment 9.

In general, the surface soil, surface water, sediment and pore water results for arsenic from the above known-contaminated sites were at concentrations comparable to background concentrations and/or present at concentrations thought be within acceptable ranges. The possible exception are the surface-water monitoring results associated with the Martins Creek fly-ash release. This monitoring was conducted soon after the release occurred, and remedial action was conducted subsequent to the surface-water monitoring event. As a result of the clean-up activities, it is anticipated that the elevated levels of arsenic in surface water associated with the Martins Creek release have decreased to normal background concentrations.

3.3 ARSENIC IN SURFACE WATER

Arsenic in surface-water samples may be associated with suspended particulates resulting from natural weathering of soils and sediments such as glauconitic sands and clays. Arsenic in surface water may also result from human activities, such as application of arsenical pesticides in agricultural areas and subsequent stormwater runoff. Concentrations of arsenic in unfiltered surface-water samples collected by the USGS from streams varied among five major drainage basins in New Jersey. Arsenic concentrations in surface water were typically less than 2 µg/L. The greatest concentrations of arsenic were detected in surface-water samples collected in the southern Coastal Plain downstream of an arsenic processing facility (Vowinkel et al.).

With the exception of the known-contaminated Sites data, the availability of arsenic data for surface water within the Delaware River watershed area of interest is limited because arsenic is not a parameter typically analysed to evaluate “water quality” along this reach of the River. Water sampling or monitoring parameters for surface water in this reach of the River are typically related to eutrophication from nutrient inputs or direct effects from wastewater treatment facility discharges. These parameters may include nutrients, such as nitrogen and phosphorous compounds, dissolved and suspended solids, ammonia, alkalinity and hardness.

However, the DRBC has historically investigated the presence metals in surface water within the watershed area of interest. In 2013, the DRBC generated a data set for metals, including arsenic, within the watershed area of interest consisting of surface-water samples from 6 locations. The surface-water samples were filtered and analysed using EPA Method 200.9 to generate results for dissolved arsenic as follows:

Table 14: Surface-water Results Summary – DRBC 2013 Monitoring

Parameter	n	Frequency of Detection	Surface-water Concentration Min. (ug/L)	Max.	Mean
Metals (ug/l)					
Arsenic *	6	6/6	0.27	0.57	0.37

n = number of samples analyzed

For the 2013 surface-water monitoring event, dissolved arsenic results ranged from 0.27 to 0.57 ug/L in the samples, and the arithmetic mean for dissolved arsenic concentrations in the samples was 0.37 ug/L.

Table 14 summarizes the 2013 DRBC surface-water data set, and Attachment 10 provides the complete data table and additional information.

The freshwater aquatic-life criteria published by NJDEP for arsenic are 150 ug/l for chronic effects and 340 ug/L for acute effects. As a result, the arsenic results from the 2013 DRBC surface-water sampling event show very low potential for effects to aquatic life in the River from arsenic.

Although data quality assurance information was not readily available for this data set, experienced DRBC field sampling personnel collected the samples and a New Jersey-certified laboratory, NJ Environmental and Clinical Laboratory Services, was used for arsenic analyses. As a result, the usability of these data is expected to be high. A Data Quality Manual is available on the laboratory web site at http://www.nj.gov/health/phel/env-testing/.

3.4 ARSENIC IN SEDIMENT

With the exception of the known-contaminated Sites data, the availability of arsenic data for sediment within the watershed area of interest is limited because arsenic is not a parameter typically analysed to evaluate "water quality" along this reach of the River. As a result, sediment is not typically sampled for arsenic analyses as well. See Section 3.2.3 for a discussion of sediment data available for several larger known-contaminated sites along the River.

4 *ARSENIC DATA COMPILATION SUMMARY*

This report presents a compilation of information/data related to arsenic in the environment of the Delaware River watershed between the Delaware Water Gap (River Mile 210.8) and the bridge at Washington Crossing, Pennsylvania (River Mile 141.8). More specifically, a comprehensive data compilation approach involving on-line searches and database reviews was used to identify relevant data sets. Arsenic data from samples collected within the watershed area of interest are summarized by matrix (i.e., soil, groundwater, surface water, sediment, etc.) in this report. Attachment 11 provides a table containing a comprehensive summary of the arsenic baseline data compiled as a result of this project.

The goal of the data compilation project is to establish a baseline for arsenic concentrations in surface water and groundwater along this reach of the River. This report has been prepared to present available arsenic data for this region of the watershed, and is considered an unbiased, information-only report. As a result, the arsenic data have not been interpreted to draw conclusions related to anthropogenic activities, or used to support any position related to environmental quality.

The majority of arsenic data available for the "watershed area of interest" relates to groundwater sampling and analysis conducted for private wells by homeowners; for ambient groundwater monitoring wells by governmental agencies (NJDEP, USGS, NJGS, etc.); and for municipal water supplies by water purveyors and/or governmental agencies. There has been a limited amount of surface-water sampling for arsenic analysis along this reach of the Delaware River based on interactions with the DRBC and the NJDEP and information/data provided by these agencies.

The arsenic data compiled in this report indicate the following:

- Surface soil data for arsenic were generally consistent with ambient or background concentrations published by the NJDEP
- Groundwater data typically showed arsenic concentrations less than 5 ug/L for private potable wells, ambient monitoring wells, and water supply wells, but in some instances higher concentrations were detected in ambient groundwater monitoring wells

- For example, a maximum concentration of arsenic of 60 ug/L was detected in an ambient groundwater monitoring well in central Bucks County, PA, and a maximum concentration of 25 ug/L was detected in a monitoring well in western Hunterdon County, NJ. However, average arsenic concentrations in groundwater from all of wells monitored in these areas were less than 10 ug/L and less than 5 ug/L, respectively. The higher concentrations of arsenic in groundwater may be related to these geographical areas, where arsenic is known to occur naturally in the rock formations. As indicated previously, the Piedmont physiographic province in Hunterdon County is known to have naturally-occurring arsenic-rich rock formations, which can contribute to concentrations of arsenic in groundwater (Szabo and others, 1997; Surfes and others, 2000). A similar situation exists on the Pennsylvania side of the River in northern Bucks County.

- Results for arsenic in surface water were only found to be available from two sources: the DRBC's non-tidal river monitoring program, and contaminated site investigations at facilities adjacent to the River. Results from both sources typically showed concentrations less than 1 ug/L in filtered samples. The DRBC surface-water samples showed an average or mean concentration of 0.37 ug/L in ambient surface water, and surface-water samples collected in the River adjacent to the Crown Vantage Landfill Superfund Site showed an average concentration of 0.34 ug/L

- River sediment sampling data for arsenic are infrequently encountered and appear to be primarily associated with contaminated site investigations. Those sediment data compiled usually showed low concentrations of arsenic relative to sediment quality screening levels for aquatic life as published by the NJDEP

The Comprehensive Arsenic Baseline Data Summary Table provided in Attachment 11 summarizes the arsenic data compiled in this report.

While the general locations of sampled groundwater wells are known and that information is provided herein, the specific coordinates of the wells were unavailable for inclusion in this report in many instances. In some instances, the specific locations of private wells are made unavailable to the public at the request of the well owners. In other instances, this information may be available for some wells through the regulatory programs (agencies) associated with the sampling events, but will take additional research to obtain. This research may involve freedom of information act (FOIA) or

Open Public Records Act (OPRA) information requests to the specific regulatory programs.

Although this report is comprehensive in its scope, there is additional work that could be conducted to provide more in-depth information/data and to fill “data gaps” that were noted during report preparation. Some of these areas include:

- Further evaluation of potential changes in arsenic concentrations in groundwater and surface water over time. This relates primarily to the private-well data and the ambient monitoring well data
- Research additional surface-water data related to the Martins Creek fly-ash release
- Research additional surface-water monitoring data associated with the known-contaminated sites to see if long-term monitoring (LTM) programs are in place
- Obtain greater detail regarding well locations and specifications (e.g., depth, screened interval, open hole, etc.)
- Generate a comprehensive map, or set of maps, with combined sampling locations and plotted data, to the extent available
- Based on the results of the above search for LTM surface-water monitoring data, consider the collection of additional surface-water samples for arsenic analysis at key locations within the river reach of interest.

Implementation of some, or all, of the above tasks would provide additional information/data useful in more fully understanding the nature and extent of arsenic in the watershed area of interest.

Notwithstanding the above additional information/data, the use of this baseline arsenic results report is encouraged to further understand environmental conditions within the watershed area of interest, and to help sustain and improve the water quality of the River.

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Acknowledgements: Special thanks to Dr. Allison Brown for conducting data-base searches and compiling groundwater results for arsenic.

TABLES

Table 1
Ambient Concentrations of Arsenic in New Jersey Soil

	Urban Piedmont				Rural Areas of New Jersey							
					Ridge and Valley Province				Highlands Province			
TAL Metal	MDL (mg/kg)	No. of Detects	Median Conc. (mg/kg)	90th-percentile Conc. (mg/kg)	MDL (mg/kg)	No. of Detects	Median Conc. (mg/kg)	90th-percentile Conc. (mg/kg)	MDL (mg/kg)	No. of Detects	Median Conc. (mg/kg)	90th-percentile Conc. (mg/kg)
Arsenic	0.13	67/67	5.2	24.2	0.28	23/23	4.9	7.32	0.28	23/23	4.8	9.96

TAL = Target analyte list
67/67 = Detections out of total number of samples
mg/kg = milligrams per kilogram
Conc. = Concentration

From: Sanders, P.F. 2003. Ambient Concentrations of Metals in New Jersey Soils. Research Project Summary, New Jersey Department of Environmental Protection, Environmental Assessment and Risk Analysis Element. May 2003.

Table 2. NJDEP Private Well Testing Act - Arsenic Results by County from September 2002 to April 2007

County	Municipality	# Wells Sampled	# Wells with 10 ug/l MCL Exceedances	Percentage of Exceedances	# Wells Sampled	# Wells with 5 ug/l MCL Exceedances	Percentage of Exceedances
Hunterdon		4858	272	5.6%	3791	673	17.8%
	Alexandria Township	218	64	29.4%			
	Delaware Township	234	53	22.6%			
	Esast Amwell	226	93	41.2%			
	Frenchtown Boro	14	8	57.1%			
	Holland Township	167	16	9.6%			
	Kingwood Township	194	79	40.7%			
	Lambertville	36	4	11.1%			
	Milford	NR	NR	-			
	Readington Township	500	101	20.2%			
	Stockton	2	0	0.0%			
Mercer		1489	108	7.3%	1381	272	19.7%
	Hopewell Township	838	240	28.6%			
Warren		2377	NR	NR	2377	NR	NR

MCL = maximum contaminant limit

NR = Sampling for arsenic not required

Table 3. Private Well Testing Data for New Jersey Counties and Municipalities Bordering the Delaware River.

County	Municipality	N	% Below RL*	% > 5 (ug/L)	# > 5 (ug/L)	90P (ug/L)	95P (ug/L)
Warren	Hardwick Township	103	93.2	1	1	2.0	2.0
	Harmony Township	113	95.6	0.9	1	2.0	2.0
	White Township	151	82.8	7.3	11	4.2	6.5
	Knowlton Township	119	87.4	0.8	1	2.0	2.0
	Lopatcong Township	37	100.0	0	0	2.0	2.0
	Pohatcong Township	56	94.6	0	0	2.0	2.0
	Belvidere Town	<10	85.7	-	-	-	-
	Phillipsburg Town	<10	100.0	-	-	-	-
Hunterdon	Delaware Township	449	45.9	20.5	92	10.0	15.5
	Frenchtown Boro	30	10.0	70	21	21.2	25.7
	Holland Township	482	73.9	8.3	40	4.3	7.0
	Kingwood Township	425	22.8	42.6	181	12.1	17.1
	Lambertville City	73	52.1	9.6	7	5.0	16.0
	West Amwell Township	272	39.0	18.4	50	7.5	10.9
	East Amwell Twp	398	22.4	42.2	168	13.0	18.8
	Alexandria Township	529	50.7	24.2	128	12.1	19.0
	Milford Boro	<10	100.0	-	-	-	-
	Stockton Boro	<10	33.3	-	-	-	-
Mercer	Hopewell Township	1443	22.6	26.5	382	9.2	12.7

< 10 = Fewer than 10 wells Sampled

*RL = Reporting Limit represents summary statistics calculated using replacement of 1/2 the laboratory reporting limit

" - " indicates data are unavailable

Source Information: Division of Science, Research, and Environmental Health, NJDEP.

Source Site: NJDEP

Table 4A: Burkert Study - 2005 Drinking Water Well Arsenic Data
Northern Bucks County and Southern Lehigh County, Pennsylvania

Formation	**# of As samples**	**# of As samples > 10** µg/L	**Mean As (µg/L)**	**Median As (µg/L)**	**Max As (µg/L)**	**Min As (µg/L)**
Entire study	53	12	7.76	2.87	64.86	0.01
Passaic	27	9	10.12	6.4	46.14	0.02
Lockatong	6	2	20.04	6.26	64.86	0.58
Diabase	7	1	2.1	0.19	11.83	0.06
Precambrian / Cambrian	12	0	0.2	0.07	1.27	0.01
Other	1	0	0.7	0.7	0.7	0.7

As = Arsenic

"Other" indicates Trenton gravel geologic formation

ug/L = micrograms per Liter

Source: Lori Burkert Masters Thesis entitled "Geochemical Controls on Arsenic Distribution and Mobilization in Groundwater of Southeastern Pennsylvania", Lehigh University, 2006.

Table 4B: 2004 PADEP Drinking Water Well Database Arsenic Data

Formation	**# of As samples**	**# of As samples > 10** µg/L	**Mean As (µg/L)**	**Median As (µg/L)**	**Max As (µg/L)**	**Min As (µg/L)**
*All PA DEP**	2310	630	9	2	83	ND
Passaic	1538	577	13	5	83	ND
Lockatong	283	42	4	ND	64	ND
Diabase	142	7	2	ND	42	ND
Precambria/ Cambrian	347***	4	<1	ND	24	ND

As = Arsenic

*Represents data from PA DEP Drinking Water and Sampling Information System database (PA DEP, 2004) from the same formations as the Burkert study. PA DEP data may represent parts of some formations that are outside of this study's extent.

ug/L = micrograms per Liter

Table 5. Ambient Groundwater Sampling Results for Arsenic in Hunterdon and Mercer Counties

# STAID	UID	Network Id	Mon Well #	WMA	Hydro Aqui	Land Use	County	Municipality	Date Sampled	Arsenic µg/l P01000
403921074515901	190451	mw-101	101	8	400PCMG	AG	Hunterdon	Clinton	20030624	<0.3
403921074515901	190451	MW101	101	8	400PCMG	AG	Hunterdon	Clinton	20080415	0.1
403100074464101	190455	mw-107	107	8	227PSSC	AG	Hunterdon	Readington	20030626	1.4
403100074464101	190455	MW107	107	8	227PSSC	AG	Hunterdon	Readington	20080708	2.5
402501074505001	190452	mw-106	106	8	227PSSC	AG	Hunterdon	East Amwell	20030701	2.1
402501074505001	190452	MW106	106	8	227PSSC	AG	Hunterdon	East Amwell	20080811	2.2
402633074541301	190456	mw-91	91	8	227PSSC	AG	Hunterdon	Delaware	20030910	2.9
402633074541301	190456	MW91	91	8	227PSSC	AG	Hunterdon	Delaware	20080709	1.4
402051074400001	210630	mw-122	122	10	231SCKN	URB	Mercer	Princeton	20040616	0.2
402051074400001	210630	mw-122	122	10	231SCKN	URB	Mercer	Princeton	20070820	0.12
401829074513301	21033	mw-80	80	11	227PSSC	UND	Mercer	Hopewell	20040617	1.1
401829074513301	21033	mw-80	80	11	227PSSC	UND	Mercer	Hopewell	20090629	1.5
404900075043601	410568	mw-95	95	1	112SFDF	AG	Warren	White	20040623	0.4
404900075043601	410568	MW95	95	1	112SFDF	AG	Warren	White	20080813	0.24

Arsenic results are for filtered groundwater samples
"<"- Less Than

Table 6. Ambient water data associated with shallow wells for two sampling cycles.

# STAID	UID	Network Id	Mon Well #	WMA	Hydro Aqui	Land Use	County	Municipality	Date Sampled	As (ug/L)
402501074505001	190452	mw-106	106	8	227PSSC	AG	Hunterdon	East Amwell	20030701	2.1
402501074505001	190452	MW106	106	8	227PSSC	AG	Hunterdon	East Amwell	20080811	2.2
402633074541301	190456	mw-91	91	8	227PSSC	AG	Hunterdon	Delaware	20030910	2.9
402633074541301	190456	MW91	91	8	227PSSC	AG	Hunterdon	Delaware	20080709	1.4
401829074513301	21033	mw-80	80	11	227PSSC	UND	Mercer	Hopewell	20040617	1.1
401829074513301	21033	mw-80	80	11	227PSSC	UND	Mercer	Hopewell	20090629	1.5
404900075043601	410568	mw-95	95	1	112SFDF	AG	Warren	White	20040623	0.4
404900075043601	410568	MW95	95	1	112SFDF	AG	Warren	White	20080813	0.24

Source Data: NJGS

Table 7. USGS and NJDEP Well Data for As (ug/L) within 3 miles of the Delaware River.

Location	Latitude	Longitude	N	Min	Max	Mean	Median	90thP	95thP
SW Hunterdon	40.362382	-74.89838	51.0	0.0	24.7	4.9	3.0	13.0	15.2
CW Hunterdon	40.470057	-75.02	26.0	0.0	25.0	5.3	3.6	10.9	11.6
NW Hunterdon	40.598112	-75.01881	22.0	0.0	9.0	2.3	1.2	6.0	7.9

All units are micrograms per liter (ug/L)

Values with "0" were added in instances where As was "not detected" in raw data files

*Based on well data that lie within a 5 mile radius of the coordinates.

Source Site: NWQMC

Table 8. NWQMC Well Data for As (ug/L) in Warren County within 3 miles of the Delaware River.

Location	Latitude	Longitude	N	Min	Max	Mean	Median	90thP	95thP
NW Warren Co.	40.81365	-75.048423	18	0.0	2.0	0.4	0.2	1.3	2.0
WC Warren Co.	40.742117	-75.147405	12	0.0	0.4	0.1	0.0	0.1	0.3
SW Warren Co.	40.678221	-75.139582	10	0.0	0.7	0.1	0.0	0.2	0.4

Values with "0" were added in instances where As was "not detected" in raw data files

*Based on well data that lie within a 5 mile radius of the coordinates.

Source Site: NWQMC

Table 9. New Jersey Municipal Water Supply Arsenic Data

COUNTY	Municipality*	Sample Date/Time	CGW	CGU	CSW
WARREN	Knowlton Township	10/28/2015 / 11:00	1.72 UG/L		
	Belvidere Town	02/14/2018 / 09:34	<0.001 MG/L		
	Harmony Township	08/30/2017 / 10:43	1.3 UG/L		
	Knowlton Township	10/28/2015 / 11:00	1.72 UG/L		
	Phillipsburg Town	01/18/2018 / 13:59		<1 UG/L	
	Pohatcong Township	08/30/2017 / 09:52	<0.001 MG/L		
	White Township	12/28/2015 / 06:10	<0.247 UG/L		
	Hardwick Township	NA	NA		
	Lopatcong Township	NA	NA		
HUNTERDON	Alexandria Township	08/31/2017 / 08:45	0.0034 MG/L*		
	Delaware Township	01/31/2018 / 14:00	0.0026 MG/L		
	Frenchtown Boro	2/13/2018	<0.28 UG/L		
	Holland Township	05/08/2017 / 11:40	<1 UG/L		
	Kingwood Township	NA	NA		
	Lambertville City	04/18/2017 / 10:02			<0.0004 MG/L
	Milford Boro	08/31/2017 / 08:45	0.0034 MG/L		
	Stockton Boro	09/25/2015 / 09:15	0.0031 MG/L		
	West Amwell Township	04/18/2017 / 10:02			<0.0004 MG/L*
MERCER	Hopewell Township	03/19/2018 / 09:06	<3.5 UG/L		

"<" less than

*Served by another municipality

NOTE: Data documented here reflects the most recent raw data reported for each municiaplaity in data base.
There may be more than one supplier.

To convert to ug/L (ppb): 1 mg/L = 1000 ug/L

Source Site: JDEPWaterWatch

Table 10. Summary of PADEP Municipal Water Supply Arsenic Data

County	Municipality	N	Min	Max	Median	Mean
Bucks	New Hope	4	4	5.6	4.8	4.8
	Solebury	5	0	7	1	3.2
	Tinicum	2	0	2.6	na	1.3
	Upper Makefield	3	0	2.8	2.6	1.87
	Riegelsville	2	0	0.26	na	0.13
Northampton	Easton City	6	-	-	-	-
	Upper Mt. Bethel	6	-	-	-	-

Note: Pennsylvania reports MCL for As < .01 mg/L. Data reported here was converted to ug/L.

All units are micrograms per liter (ug/L)

" - " indicates not available

Source Site: PADEPDrinkingWaterReport

Table 11. Summary of NWQMC Well Data for As (ug/L) in select areas of Bucks and Northampton Counties.

Well Cluster Location	Latitude	Longitude	# Wells	N	Min*	Max	Mean	Median	90thP	95thP
NorthBucks	40.419519	-75.067461	24	28	0	13	2.35	1.5	3.8	9.95
CentralBucks	40.419519	-75.067461	41	27	0	60	9.29	3	28	46.2
Northampton	40.683343	-75.213923	4	NA	NA					

*Zero was substituted for As when it was "not detected" in original queries. Technically, "not detected" means values were below the limit of detection available in laboratory tests. See raw NWQMC report: detection limits vary from lab to lab.

NA: Not avaialable. For Northampton data, As was not included among the characters tested in original query.
All units are micrograms per liter (ug/L)
Source Site: NWQMC

Table 12
Sampling Results Summary for Arsenic
Crown Vantage Landfill Site
Alexandria Township, New Jersey

Surface Soil Results Summary

Parameter	n	Frequency of Detection	Soil Concentration Min.	Soil Concentration Max.	Soil Concentration Mean
			(mg/kg)		
Metals (mg/kg)					
Arsenic	35	35/35	2.8	14.7	7.7

Surface-Water Results Summary (Delaware River)

Parameter	n	Frequency of Detection	Surface-water Concentration Min.	Surface-water Concentration Max.	Surface-water Concentration Mean
			(ug/L)		
Metals (ug/l)					
Arsenic	5	5/5	0.286	0.388	0.344

Pore-Water Results Summary (Delaware River)

Parameter	n	Frequency of Detection	Pore-water Concentration Min.	Pore-water Concentration Max.	Pore-water Concentration Mean
			(ug/L)		
Metals (ug/l)					
Arsenic	5	5/5	<0.25	14.1	3.0

NOTE:
n = number of samples analyzed
Data from: June 2010 (revised July 2010) Remedial Investigation Report for the Crown Vantage landfill Site - Alexandria Township, NJ; prepared by International Paper and Georgia-Pacific.

Table 13
Sampling Results Summary for Arsenic
Curtis Specialty Papers Site
Milford, New Jersey

Surface Soil Results Summary
(collected from 0-1 Ft. depth interval below ground surface during in 2007 and 2008)

		Frequency of	**Soil Concentration**		
	n	**Detection**	**Min.**	**Max.**	**Mean**
Parameter			**(mg/kg)**		
Metals (mg/kg)					
Arsenic	36	36/36	1.4	79	9.9

Sediment Results Summary

		Frequency of	**Surface-water Concentration**		
	n	**Detection**	**Min.**	**Max.**	**Mean**
Parameter			**(mg/kg)**		
Metals (ug/l)					
Arsenic	20	20/20	ND	4.4	2.6

NOTE:
n = number of samples analyzed
Data from: 2011 Public Health Assessment Report for the Curtis Specialty Papers Site - Alexandria Township and Milford, New Jersey; prepared by NJDOH and ATSDR, 27 January 2011.

Table 14
DRBC Surface-Water Monitoring Results For Arsenic
Main Stem Delaware River - 2013

Surface-Water Results Summary (Delaware River)

Parameter	n	Frequency of Detection	Surface-water Concentration Min.	Max.	Mean
			(ug/L)		
Metals (ug/l)					
Arsenic *	6	6/6	0.27	0.57	0.37

All- units in micrograms per liter (ug/L)

* indicates that samples were filtered and results reported are for dissolved arsenic

NOTE:

n = number of samples analyzed

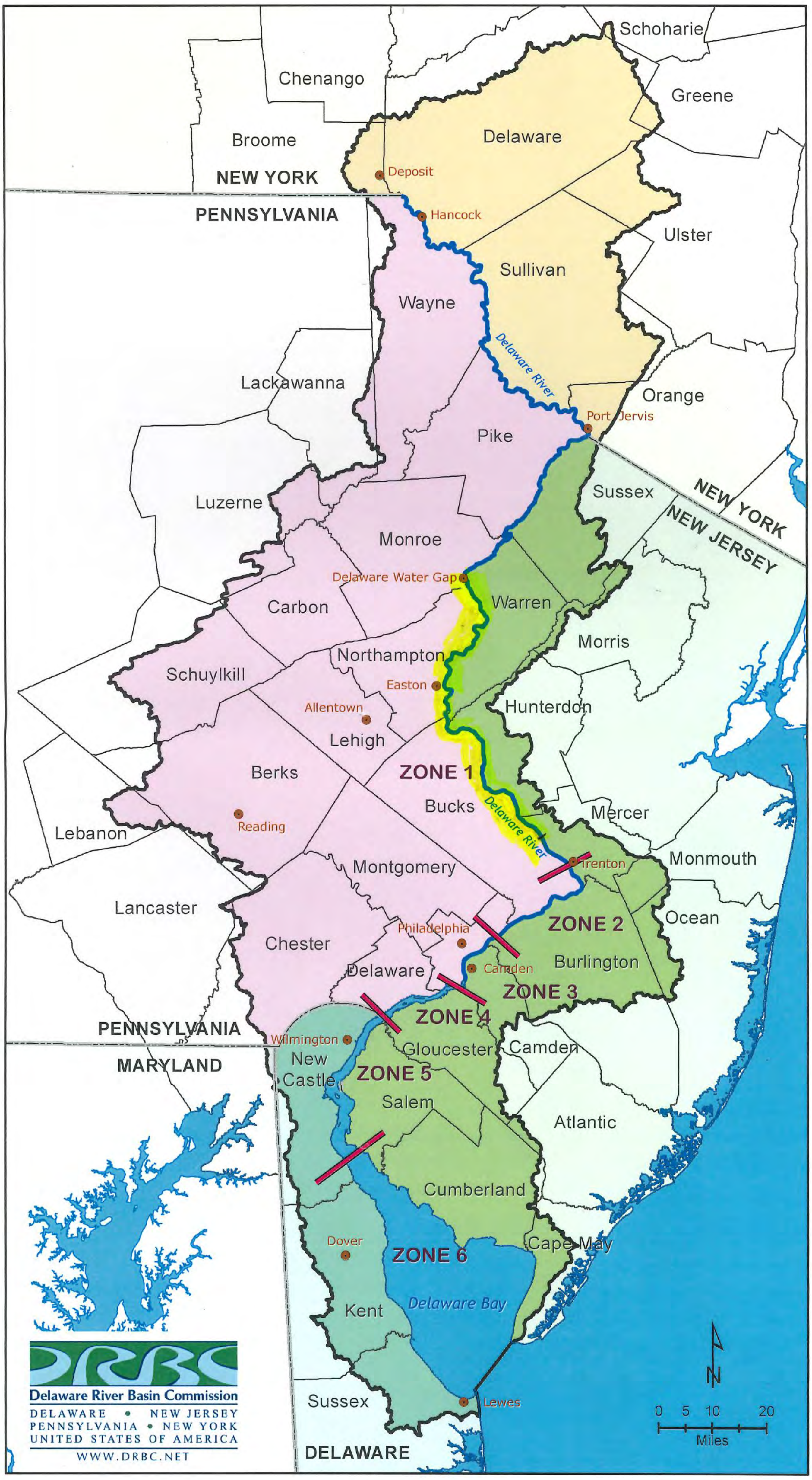
Data from: June 2013 Surface-water monitoring event by DRBC

ATTACHMENTS

ATTACHMENT 1

Map of the Delaware River Watershed

ATTACHMENT 1
DELAWARE RIVER WATERSHED



LEGEND

🟨 River Reach of Interest

ATTACHMENT 2

New Jersey Geological Survey (NJGS) 2006 'Arsenic in New Jersey' Publication

New Jersey Geological Survey Information Circular

Arsenic in New Jersey Ground Water

***A**rsenic (As) is a toxic element that is known to pose a risk of adverse health effects in people who consume water containing it. These impacts include, but are not limited to, cancer of the skin, bladder, lung, kidney, nasal passages, liver and prostate (USEPA, 2001). Because of these health concerns, the United States Environmental Protection Agency (USEPA) has lowered the drinking water standard for arsenic in public water supplies from 50 mircrograms per liter (ug/l) to 10 ug/l effective January 23, 2006. The New Jersey Department of Environmental Protection (NJDEP) has adopteded a lower standard of 5 ug/l to protect the public health. The statewide standard will apply to both public and non-public water systems and also become effective January 23, 2006.*

Introduction

Ground-water-quality data from the New Jersey Ambient Ground-Water Quality Network, Public Water Supplies and other studies in New Jersey reveal that arsenic concentrations in ground water are highest in the Piedmont Physiographic Province (fig. 1). In New Jersey, the Piedmont mostly includes a 195- to 225-million-year-old sediment-filled tectonic depression called the Newark Basin. This basin consists mainly of 3 water-bearing sedimentary bedrock formations that are gently folded and generally dip 5 to 15 degrees to the northwest. These rocks are locally faulted and interlayered with younger basaltic igneous rocks. From oldest to youngest the three major sedimentary formations are: (1) the Stockton, mainly comprised of arkosic sandstone, (2) the Lockatong, mostly black (organic rich) with some red, argillitic mudstone, siltstone and shale containing lenses of pyrite, and (3) the Passaic, mainly red hematitic mudstone, siltstone and sandstone interlayered with beds of black shale containing pyrite (fig. 2). Note: the term shale is used here for fine-grained sedimentary rock of the Passaic and Lockatong Formations. Detailed stratigraphic relationships, including the identification of specific members of the three principle formations in the Newark Basin, have been determined as part of the Newark Basin Coring Project (Olsen and others, 1996).

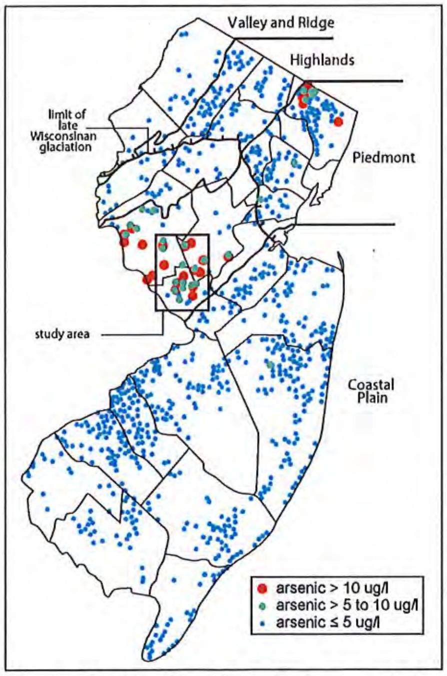


***Figure 1.** Location of study area and distribution of public community supply wells (shown by colored circles) in New Jersey.*

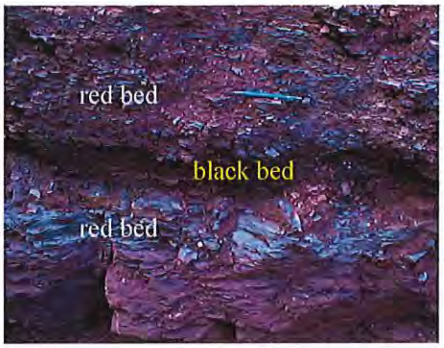


***Figure 2.** Outcrop showing metal-rich black shale between red beds in the Passaic Formation near Flemington, NJ. Blue pencil shown for scale.*

Domestic wells were randomly sampled in 2000 and 2001 in a 200-square-mile study area in the central part of the Newark Basin in western New Jersey. As shown on figures 1 and 3, arsenic concentrations in groundwater ranged from < 1 to 57 ug/l. For the purposes of water quality analysis, micrograms per leter (ug/l) is the same as parts per billion (ppb). Of the 94 wells sampled, 15 percent had arsenic concentrations exceeding 10 ug/l and 30 percent were greater than 5 ug/l (fig. 3 and 4). Water from the Passaic and Lockatong Formations had the highest arsenic concentrations and frequency of occurrence. Ground water with arsenic concentrations exceeding 10 ug/l generally had low dissolved oxygen (DO) concentrations (DO < 3 mg/L) and pH values range from 7.5 to 8.0 (fig. 5). Arsenic

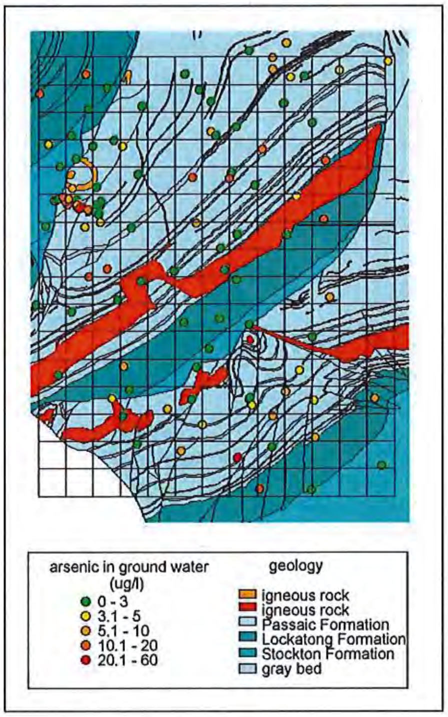


***Figure 3.** Geologic map of study area showing arsenic concentration ranges in water from domestic wells sampled on a 1-square-mile grid.*

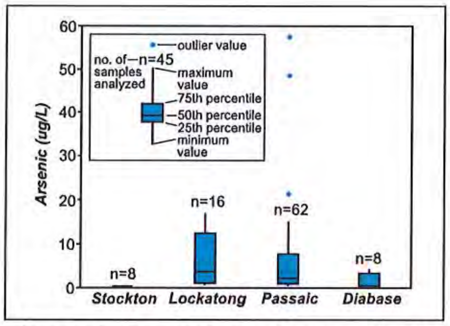


Figure 4. *Box and pin diagram showing arsenic concentration of geologic formations in study area.*

concentrations in water greater than 40 ug/l are associated with suboxic (DO < 1.0 mg/L) or nearly suboxic ground water. Subsequent analyses have identified 3 localized areas of ground water with as much as 90, 120 and 215 ug/l arsenic in each.

Potential Arsenic Source(s)

Potential sources for the regional occurrence of arsenic in ground water in the Newark Basin are arsenical pesticides and natural minerals in bedrock. Arsenical pesticides were widely used in this country, including New Jersey, from the late 1800's until the middle to late 1900's (Murphy and Aucott, 1998). The greatest use in New Jersey was in fruit orchards (NJDEP, 1999). Arsenical pesticides are not very water soluble and bind tightly to soil particles. Studies in North Dakota, South Dakota, Wisconsin and Minnesota all conclude that ground water is largely unaffected by past arsenical pesticide use (Welch and others, 2000). Therefore, arsenic from arsenical pesticides is generally not very mobile in soils and not a major source in ground water.

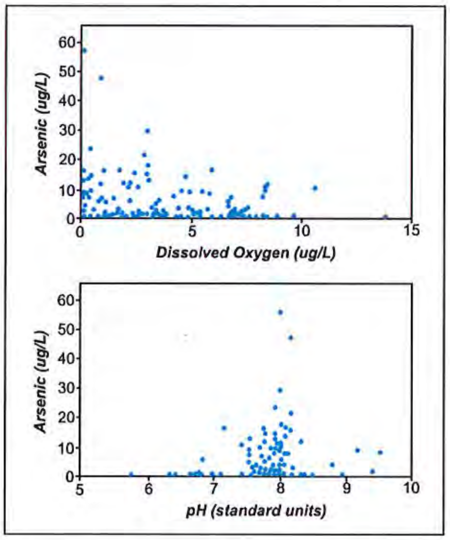


Figure 5. *Arsenic concentration versus dissolved oxygen and pH in ground water from study area. Based on data from all the formations sampled.*

Whole rock geochemical analyses conducted by the New Jersey Geological Survey (NJGS) showed that arsenic concentrations decreased from black to gray to red shale. Maximum concentrations found were 130, 50 and 13 parts per million (ppm) in the black, gray and red shale, respectively. Electron microprobe analysis of the black shale identified the mineral pyrite (FeS_2) as the major source of arsenic. Pyrite in two different black shale members of the Passaic Formation was shown to have maximum arsenic concentrations of 40,000 and 3000 ppm (fig. 6). A spatial relationship between arsenic concentrations greater than 40 ug/l in well water and the local occurrence of black shale has been observed in the Lockatong and Passaic Formations.

Therefore, the regional occurrence of arsenic in ground water is natural. Pyrite is the most significant mineral source of arsenic; however, hematite (Fe_2O_3) and clay minerals in red shale may also be sources. Three mechanisms for arsenic mobilization are likely (1) oxidation of pyrite, (2) release of arsenic from hematite and clays by desorption, and (3) dissolution of hematite. Pyrite oxidation is expected to be most significant in the shallow subsurface system in the unsaturated zone and at the water table where DO is generally readily available. Here, mobilized arsenic would follow the local ground water flow path, potentially recharging the deeper ground-water system via water-bearing zones. Arsenic may be mobilized from hematite and clay minerals under chemically alkaline and reducing conditions and during competitive adsorption with other ions. An alkaline pH and low DO (more reducing) aqueous environment is associated with high arsenic concentrations in water in the Newark Basin (fig. 5). NJGS continues to investigate this problem to determine vulnerable areas.

Figure 6. *Electron micrograph at 750 times magnification showing pyrite (light) and calcite (dark). Green and yellow circles show pyrite grains with 11,500 ppm 15,860 ppm arsenic respectively. Rock has 130 ppm As. (Core sample courtesy Zoltan Szabo, USGS).*

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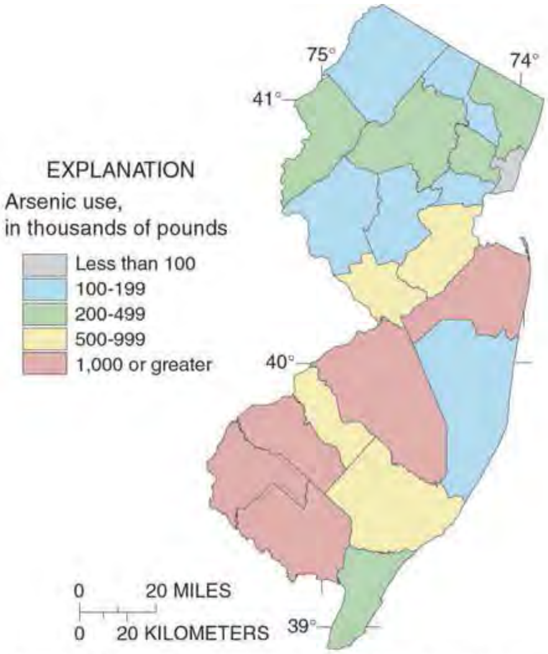

Figure 1. Estimated arsenic use in New Jersey, 1900-80. (Data from Murphy and Aucott, 1998)

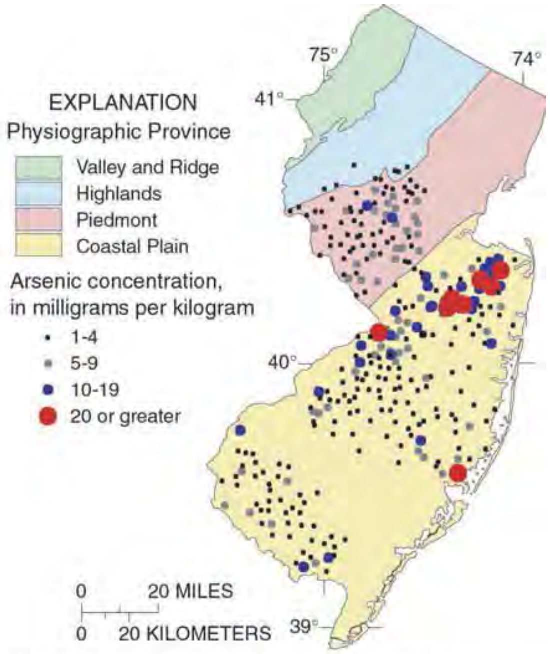

Figure 2. Distribution of arsenic in soils and streambed sediments in New Jersey, by physiographic province. (Data from National Uranium Resource Evaluation Program database (Grosz and others, 2000))

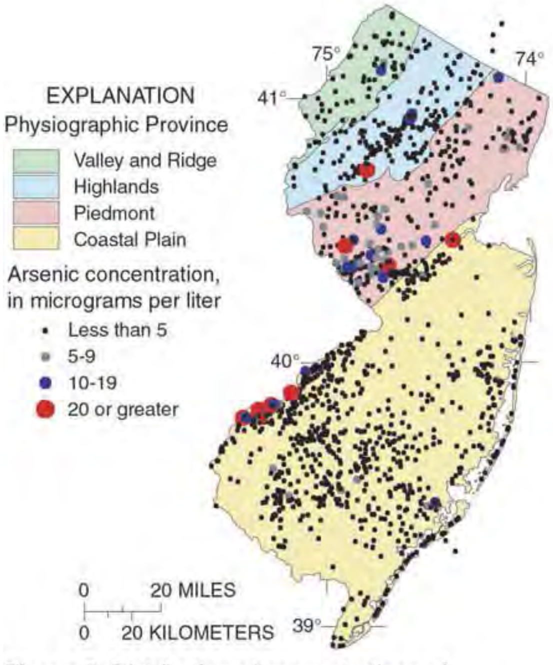

Figure 3. Distribution of concentrations of dissolved arsenic in ground water in New Jersey, by phsiographic province. (Data from U.S. Geological Survey National Water Information System database)

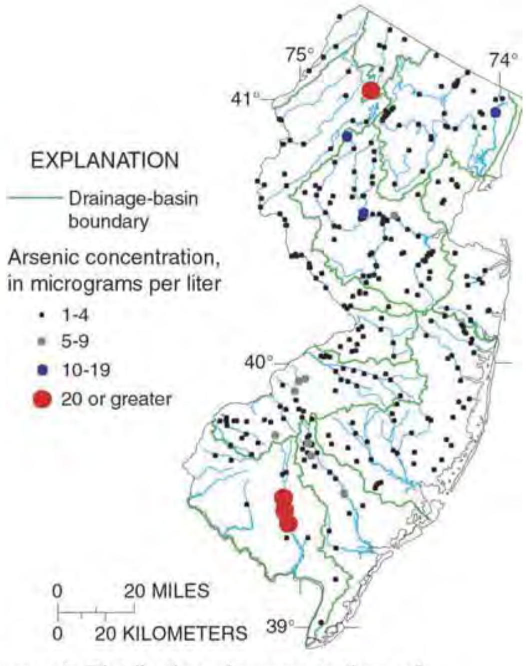

Figure 4. Distribution of concentrations of total arsenic in streams in New Jersey, by major drainage basin. (Data from U.S. Geological Survey National Water Information System database)

ATTACHMENT 3

Ambient Concentrations of Arsenic in New Jersey Soil

Environmental Assessment and Risk Analysis Element

Research Project Summary

NJDEP

Division of Science Research & Technology
Linking Science to New Jersey's Environmental Decision Making

May, 2003

Ambient Levels of Metals in New Jersey Soils

Paul F. Sanders, Ph.D.

Abstract

Between 1996 and 2001, three studies were conducted to determine the ambient levels of extractable metals in New Jersey soils. These studies were conducted to gather information to support the development of soil cleanup criteria, which cannot be set below ambient levels. A total of 248 soil samples were taken from the urban Piedmont region, the urban Coastal Plain region, and rural regions of the Valley and Ridge, Highlands, and Coastal Plain provinces. Local or point sources of contamination were avoided by the use of Geographic Information System databases and by following sample location guidelines in the field. Surface soil samples (0-6") were analyzed for acid-extractable Target Analyte List (TAL) metals using USEPA SW-846 methods that are normally used to conduct initial investigations at hazardous waste sites. With one exception, median and 90th percentile concentrations of all metals were below current soil cleanup criteria. The exception was the 90th percentile arsenic concentration from the urban Piedmont study, which slightly exceeded the arsenic criterion. Otherwise, only certain individual samples contained metal concentrations above current criteria. A single rural soil sample yielded a beryllium concentration slightly above the corresponding criterion. For the urban Coastal Plain study, three of the 91 samples contained levels of arsenic above the current criterion. The urban Piedmont study yielded eight samples out of 67 where levels of arsenic or lead exceeded the criteria.

Introduction

Current New Jersey law requires that the NJDEP determine background levels of contaminants in soils and that "Remediation [of contaminated areas] shall not be required below regional natural background levels for any particular contaminant" [N.J.S.A. 58:10B-12(g)(4)]. "Natural background level" is further defined as "...the concentration of a contaminant consistently present in the environment of the region of the site and which has not been influenced by localized human activities...." Therefore, naturally occurring constituents in soil and those resulting from regional deposition are included, but not those from point contamination sources. The concentrations of contaminants included in this definition are referred to as "ambient concentrations." To support the above directive, three studies were conducted to determine ambient levels of metals in several regions of New Jersey (BEM Systems, Inc., 1997, 1998, 2002). The first two studies investigated metal concentrations in the urban Piedmont and urban Coastal Plain regions of New Jersey. These two areas contain a majority of the hazardous waste sites in the state. Furthermore, the high population density and significant industrial activity in these regions yields an upper estimate of ambient metal concentrations, due to a larger impact of regional atmospheric deposition. The third study focused on rural areas of the Ridge and Valley, Highlands and Coastal Plain provinces, and provided an indication of metals concentrations in areas less impacted by atmospheric deposition.

Methods

A total of 248 soil samples were taken in the three studies: 67 from the urban Piedmont region, 91 from the urban Coastal Plain region, and 90 from the three rural provinces (Figure. 1). The rural soil samples were distributed among the predominant soil types in each of the regions on a rural acreage basis. The sample locations for the urban studies were generally distributed among municipalities classified as "urban" by population density criteria. For the urban Piedmont studies, the criterion usually applied was a population density of 7,500 or more people per square mile, as per the State Development and Redevelopment Plan. For the urban Coastal Plain study, the population density criteria was reduced to 4,000 or more people per square mile because a higher population density would have resulted in only eight municipalities being sampled. In addition, municipalities were added to both urban studies that did not meet the density criteria because they contained high population density regions or substantial industrial activity. For the urban studies, samples were located in public parks because of ease of access, a likelihood that these soils have been undisturbed for some time, and because they usually met a specified 50% open space (lawn) requirement. This latter requirement was specified because forest cover or other obstructions could reduce the impact of atmospheric deposition. Sports fields or other manicured areas were not acceptable locations because of turf maintenance issues often associated with them, including chemical applications. For the rural study, sampling in forested areas was usually unavoidable since this is the natural vegetation cover of much of New Jersey, and it was desired to avoid areas impacted by human activity. For all studies, sample locations were also required to be specified minimum distances from known hazardous waste sites, roadways, and railroads.

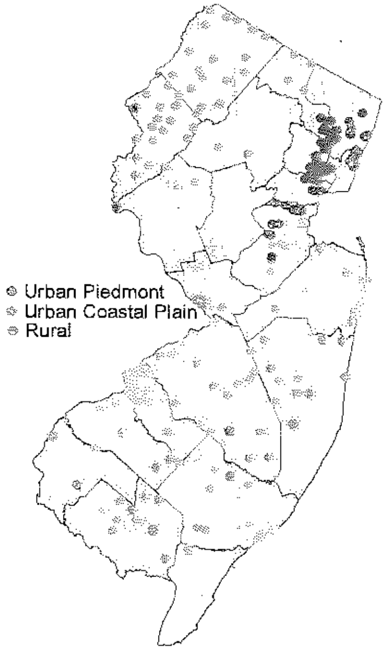

Figure 1. Sample locations

Soil samples were taken from a depth of 0-6 inches after removing surface litter. Samples were analyzed for acid-extractable Target Analyte List (TAL) metals using New Jersey certified laboratories. The methods used were those used to conduct site investigations at hazardous waste sites, specifically the U.S. Environmental Protection Agency Office of Solid Waste SW-846 methods. The extraction method used was Method 3050. Many metals were analyzed using inductively coupled plasma – atomic emission spectrometry (Method 6010). For certain metals, lower detection limits were desired because of low ambient concentrations or low soil ingestion criteria based on toxicity concerns. Atomic absorption furnace methods were used for arsenic, lead, selenium and thallium (Methods 7060, 7421, 7740 and 7841, respectively). Mercury was analyzed via cold vapor atomic adsorption (Method 7471).

Results

Acid-extractable median and 90th percentile concentrations, and the corresponding method detection limits for the twenty-three target analyte metals in 248 surface soil samples from the three studies were calculated (Table 1). The rural study results are separately presented for each of the three physiographic provinces.

Aluminum, iron, calcium, sodium, potassium, magnesium and manganese are abundant in soils and were frequently measured at several hundred to several thousand mg/kg. (Sodium concentrations are lower because it is largely leached from soils in humid climates.) Barium, chromium, vanadium and zinc are also relatively common in soils and were frequently measured at concentrations between 10 and 100 mg/kg. Zinc showed some indication of anthropogenic contribution in urban areas in that a few samples yielded concentrations in the 150-350 mg/kg range. (Naturally occurring total zinc concentrations in soil do not commonly exceed 100 mg/kg [Kabata-Pendias and Pendias, 1984].)

Nickel, copper, cobalt and lead are somewhat less common. The first three of these metals were generally measured at levels less than 50 mg/kg. Some samples in urban areas had copper concentrations in the 50-150 mg/kg range, while rural samples never exceeded 30 mg/kg. This suggests urban contribution above natural levels. Lead is well known to be elevated in surface soils due to industrial activities and the historical use of leaded gasoline (Kabata-Pendias and Pendias, 1984). Lead concentrations were highest in the urban Piedmont region (several samples in the 300 mg/kg range), somewhat lower in the urban Coastal plain (usually less than 200 mg/kg), and lowest in the rural study (only two samples greater than 125 mg/kg).

Mean total arsenic concentrations in United States soils have been reported to be 5-8 mg/kg (Kabata-Pendias and Pendias, 1984). In this study, median

Table 1. Ambient Concentration of Extractable Metals Measured in 248 New Jersey soil samples.

	Urban Piedmont				***Urban Coastal Plain***			
	Method Detection Limit (mg/kg)	*No. of detects n=67*	*Median Concentration (mg/kg)*	*90th Percentile Concentration (mg/kg)*	*Method Detection Limit (mg/kg)*	*No. of detects n=91*	*Median Concentration (mg/kg)*	*90th Percentile Concentration (mg/kg)*
Aluminum	1.5	67	10500	14400	20	91	6800	10800
Antimony	1.7	17	<DL	3.48	6	0	<DL	<DL
Arsenic	0.13	67	5.2	24.2	1	82	5.2	13.6
Barium	0.22	67	80.6	168	20	60	28.3	65.8
Beryllium	0.14	65	0.51	0.82	0.5	15	<DL	0.68
Cadmium	0.4	21	<DL	0.67	0.5	5	<DL	<DL
Calcium	11.2	67	1425	3010	500	59	995	2000
Chromium	0.9	67	18.5	29.9	1	91	11.8	34.7
Cobalt	0.5	67	6.3	10.4	5	7	<DL	<DL
Copper	0.52	67	29.5	75.5	2.5	82	9.3	33.3
Iron	2.2	67	14600	20000	10	91	8830	21100
Lead	0.063	67	111	297	10	82	37.6	144
Magnesium	5	67	2190	4614	500	54	673	1870
Manganese	0.21	67	311	859	1.5	91	62.4	206
Mercury	0.1	50	0.18	0.63	0.1	39	<DL	0.21
Nickel	0.9	67	12.4	24.6	4	43	<DL	12.3
Potassium	32	67	693	1524	500	45	<DL	1750
Selenium	0.5	61	0.41	0.71	1	0	<DL	<DL
Silver	0.22	28	<DL	0.86	1	3	<DL	<DL
Sodium	16.4	60	90.1	141	500	0	<DL	<DL
Thallium	0.2	28	<DL	0.25	1	2	<DL	<DL
Vanadium	0.95	67	29.6	41.7	5	86	16	35.5
Zinc	2	67	75.3	162	2	88	39.9	106

Rural Areas of New Jersey

	Rural studies	*Ridge and Valley Province*			*Highlands Province*			*Coastal Plain Province*		
	Method Detection Limit (mg/kg)	*No. of detects n=23*	*Median Concentration (mg/kg)*	*90th Percentile Concentration (mg/kg)*	*No. of detects n=23*	*Median Concentration (mg/kg)*	*90th Percentile Concentration (mg/kg)*	*No. of detects n=44*	*Median Concentration (mg/kg)*	*90th Percentile Concentration (mg/kg)*
Aluminum	3.23	23	15300	21080	23	16800	28980	44	1375	6760
Antimony	0.42	0	<DL	<DL	0	<DL	<DL	11	<DL	0.56
Arsenic	0.28	23	4.9	7.32	23	4.8	9.96	36	1.15	6.15
Barium	0.09	19	60.2	101.16	22	69.6	96.64	34	7.25	55.31
Beryllium	0.01	8	<DL	0.91	19	0.73	1.08	9	<DL	0.14
Cadmium	0.03	0	<DL	<DL	11	<DL	0.32	9	<DL	0.13
Calcium	41.7	10	<DL	2272	20	1160	4518	33	76.4	341.7
Chromium	0.17	23	14.3	21.2	23	17.7	26.64	44	2.9	11.76
Cobalt	0.18	12	7.3	11.4	18	6.8	12.44	32	0.37	1.18
Copper	0.33	23	17.2	26.04	23	16	28.96	44	4.2	11.43
Iron	4	23	14800	28540	23	18700	27860	44	1795	10587
Lead	0.22	23	31.6	54	23	26.6	59.02	44	17.5	54.05
Magnesium	14.4	19	2600	7182	23	2340	4024	34	79.65	513.2
Manganese	0.27	23	470	1192	23	407	836.8	44	11.65	35.39
Mercury	0.016	22	0.1	0.15	23	0.09	0.18	28	0.04	0.14
Nickel	0.21	20	15.7	22.5	23	11.6	19.04	30	0.84	3.87
Potassium	6.63	17	961	1660	21	955	1456	30	76	328
Selenium	0.49	0	<DL	<DL	10	<DL	0.99	7	<DL	0.68
Silvar	0.1	0	<DL	<DL	5	<DL	0.21	0	<DL	<DL
Sodium	6.78	0	<DL	<DL	8	<DL	85.1	28	54.65	91.9
Thallium	0.41	0	<DL	<DL	0	<DL	<DL	1	<DL	<DL
Vanadium	0.07	23	20.7	29.68	23	32.3	52.98	40	7.8	20.68
Zinc	0.18	23	75.8	112.3	23	69.7	111.6	44	6.7	27.64

extractable arsenic concentrations were typically about 5 mg/kg, and concentrations never exceeded 15 mg/kg in the rural study. In the urban studies, the maximum concentration was 83 mg/kg, and 95th percentile values were below 30 mg/kg. These higher concentrations are within the normal ranges for soils, particularly glauconitic soils naturally high in arsenic (Dooley, 2001). Some soil samples in the urban Coastal Plain study were taken from glauconitic soils, and they yielded some of the higher concentrations measured (including the maximum value measured, 83 mg/kg). However, other samples from this study with elevated arsenic were not from glauconitic regions. Furthermore, the urban Piedmont study did not include glauconitic soils, where a significant percentage of the samples also exhibited elevated levels of arsenic relative to the rural study. This suggests some anthropogenic contribution of arsenic to urban surface soils.

Mean total beryllium concentrations in United States soils are about 1-2 ppm (Kabata-Pendias and Pendias, 1984). Extractable concentrations of beryllium in this study ranged from non-detectable to

3 mg/kg. Total antimony concentrations in United States soils are generally less than 1 ppm (Kabata-Pendias and Pendias, 1984). This study yielded extractable antimony concentrations that ranged from non-detectable levels to 13 mg/kg, with the higher concentrations being associated with the urban Piedmont samples. Thallium, mercury, cadmium, silver and selenium are naturally present at only trace levels in soils (usually less than 1 ppm) in soils (Kabata-Pendias and Pendias, 1984). In this study, thallium and silver were seldom detected, and selenium, cadmium and mercury were either not detected or measured at concentrations that were usually less than 1 mg/kg. A few samples, mostly from urban areas, contained cadmium at concentrations above 0.5 mg/kg or mercury above 1.0 mg/kg, which suggests contribution from industrial activity or regional atmospheric deposition.

Statistically, several metals were found at lower concentrations in the coastal plain regions of the state relative to the remainder of the state. Coastal Plain soils have high sand contents, lower organic carbon contents and lower pH values than soils in the remainder of the state, which decrease their affinity for metals.

Discussion

The metals concentration data collected in these series of studies are useful for determining typical ambient levels of the various metals in the geographical regions studied. Levels significantly above these concentrations may indicate a spill or discharge has occurred. The metals of greatest environmental concern are those in which ambient levels in surface soils equal or exceed concentrations that are considered hazardous to human health. In such cases, regulatory levels applicable for remedial activities at contaminated sites may be limited by prevailing ambient concentrations. The most important example of this situation occurs with arsenic. The health-based soil ingestion criterion for arsenic (0.4 mg/kg) is significantly below observed ambient levels, even in soils unaffected by human activity. All studies except the rural Coastal Plain study yielded median extractable arsenic concentrations of about 5 mg/kg, more than ten times the health-based number. The rural Coastal Plain median concentration (1 mg/kg) was also above the health-based ingestion criteria.

The current soil cleanup criterion for arsenic in soil is 20 mg/kg, based on an earlier assessment of ambient levels. The 90th percentile concentration of arsenic from the urban Piedmont study (26 mg/kg) is somewhat higher than this value. In the urban Coastal Plain study, three of the ninety-one samples yielded arsenic levels above 20 mg/kg. The rural areas of the state yielded 95th percentile concentrations ranging from 5-10 mg/kg, and no samples exceeded 20 mg/kg.

Total arsenic levels in glauconite-bearing soils in New Jersey have been reported to range from 13-131 mg/kg, with a median of 30 mg/kg (Dooley, 2001). When only extractable arsenic from 0-6" soil samples are considered from the glauconite study, the median, 90th percentile and maximum concentrations are 8.2, 27.5, and 63.3 mg/kg, respectively. These concentrations are only moderately higher than those observed for the urban studies.

The health-based non-residential soil criterion for hexavalent chromium based on soil inhalation is 20 mg/kg, which is below the 90th percentile ambient concentrations reported in this study. However, chromium in soil has been reported to be dominated by the much less toxic trivalent form, so ambient concentrations are not likely to be of concern for this metal. A hexavalent chromium-specific method would be recommended for analysis of soil when this metal is known to be of concern.

With regards to the remaining metals, only one sample yielded a result where current criteria were exceeded. This sample was taken from the urban Piedmont region and yielded a lead concentration of 464 mg/kg, which is slightly greater than the current lead criterion of 400 mg/kg.

Other than arsenic, the only other metal with the current soil criterion set by ambient levels is beryllium (criterion = 2 mg/kg, based on earlier New Jersey data and other literature). In this study, 90th percentile concentrations frequently approached 1 mg/kg (Table 1), 95th percentile concentrations in the rural highlands exceeded 1 mg/kg (1.4 mg/kg), and overall, ten samples out of 248 yielded concentrations between 1 and 2 mg/kg. Only one sample exceeded 2 mg/kg (2.8 mg/kg from the rural Highlands province).

The thallium criterion is currently set by the Practical Quantitation Level (2 mg/kg), since the health-based criteria is lower (zero). Reporting Levels and/or Practical Quantitation Levels for this metal from the two New Jersey certified laboratories used in this study were somewhat lower (1 mg/kg or less), which suggests that analytical capabilities may have improved since the thallium criterion was set.

Metal concentrations reported in this summary were acid-extractable metals, not necessarily total metal concentrations. The extraction method (USEPA

Method 3050) is a vigorous extraction method designed to remove all metals that could become "environmentally available". In practice, the extraction method likely overestimates metals that could become available, since the sample is refluxed with both concentrated nitric acid and hydrogen peroxide. However, by design, the method will not extract chemicals incorporated in silica minerals, as they are usually not mobile in the environment. Thus, concentrations reported in these studies may be lower than those indicated from analyses using methods designed to measure total metal concentrations, such as x-ray fluorescence methods.

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RESEARCH PROJECT SUMMARY

ATTACHMENT 4

New Jersey Private Well Testing Results

Private Well Testing Data for New Jersey Counties and Municipalities Bordering the Delaware River.

County	Municipality	N	% Below RL*	% > 5 (ug/L)	# > 5 (ug/L)	90P (ug/L)	95P (ug/L)
Warren	Hardwick Township	103	93.2	1	1	2.0	2.0
	Harmony Township	113	95.6	0.9	1	2.0	2.0
	White Township	151	82.8	7.3	11	4.2	6.5
	Knowlton Township	119	87.4	0.8	1	2.0	2.0
	Lopatcong Township	37	100.0	0	0	2.0	2.0
	Pohatcong Township	56	94.6	0	0	2.0	2.0
	Belvidere Town	<10	85.7				
	Phillipsburg Town	<10	100.0				
Hunterdon	Delaware Township	449	45.9	20.5	92	10.0	15.5
	Frenchtown Boro	30	10.0	70	21	21.2	25.7
	Holland Township	482	73.9	8.3	40	4.3	7.0
	Kingwood Township	425	22.8	42.6	181	12.1	17.1
	Lambertville City	73	52.1	9.6	7	5.0	16.0
	West Amwell Township	272	39.0	18.4	50	7.5	10.9
	East Amwell Twp	398	22.4	42.2	168	13.0	18.8
	Alexandria Township	529	50.7	24.2	128	12.1	19.0
	Milford Boro	<10	100.0				
	Stockton Boro	<10	33.3				
Mercer	Hopewell Township	1443	22.6	26.5	382	9.2	12.7

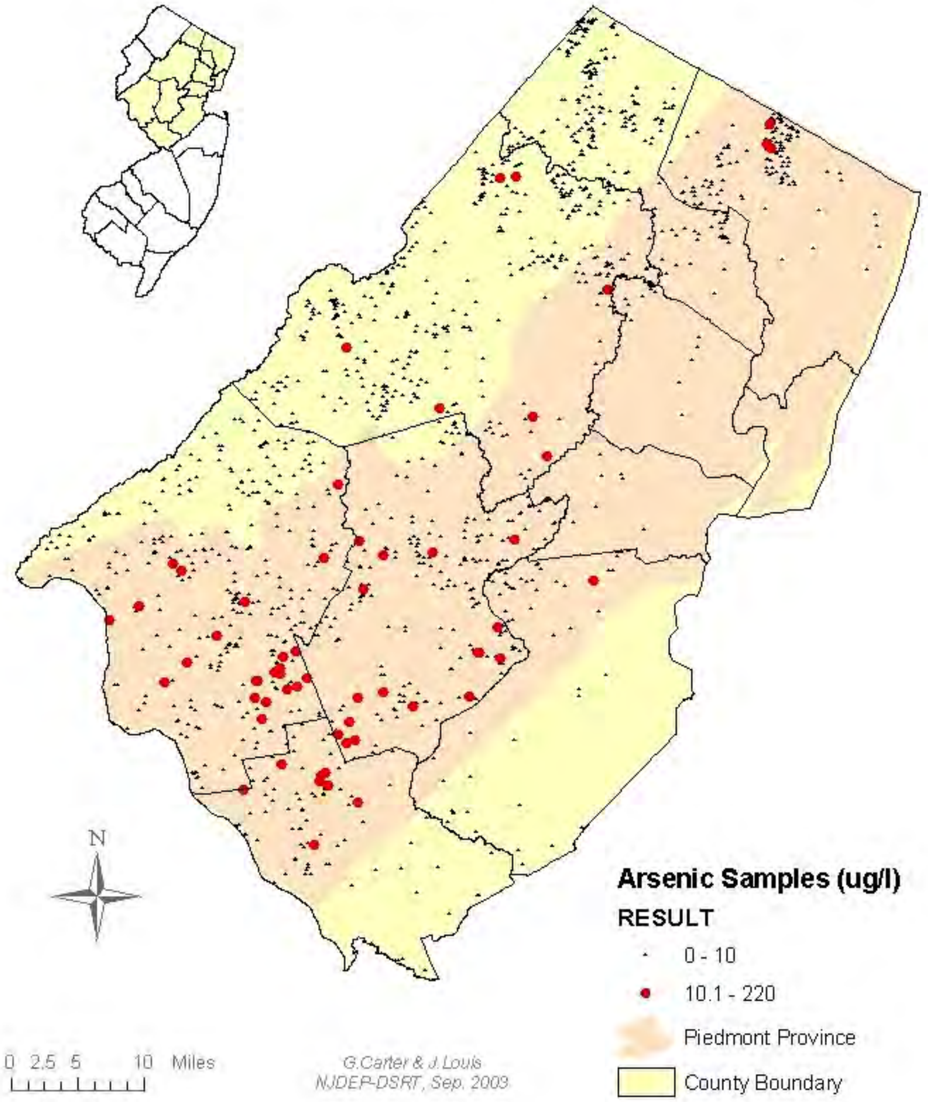
< 10 = Fewer than 10 wells Sampled

*RL = Reporting Limit represents summary statistics calculated using replacement of 1/2 the laboratory reporting limit

Source Information: Division of Science, Research, and Environmental Health, NJDEP.

Source Site: NJDEP

Figure 4
Arsenic Results from Private Well Testing Act September 2002 through March 2003



ATTACHMENT 5

Pennsylvania Private Well Testing Results from Burkert Study

Geochemical Controls on Arsenic Distribution and Mobilization in Groundwater of Southeastern Pennsylvania

by

Lori A. Burkert

A Thesis
Presented to the Graduate and Research Committee
of Lehigh University
in Candidacy for the Degree of
Master of Science

In

the Department of Earth and Environmental Sciences

Lehigh University

August 10, 2006

This thesis is accepted and approved in partial fulfillment of the requirements for the Master of Science.

Date

Stephen Peters - Thesis Adviser

Peter Zeitler - Chairperson of Department

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ABSTRACT

The goals of this study were to characterize the geographic distribution, concentration and inorganic speciation of arsenic (*As)* in the groundwater, and identify the geochemical factors correlated with *As* concentration and mobility in groundwater. The recent reduction of the United States federal drinking water standard for *As* from 50 μg/L (ppb) to 10 μg/L highlights the need to characterize the behavior of *As* in groundwater environments previously considered to be a low risk to human health. Initial data analysis of more than 18,000 existing groundwater samples queried from the Pennsylvania Department of Environmental Protection (PA DEP) Drinking Water and Sampling Information System database (1994-2004) suggested elevated average *As* concentrations throughout the Gettysburg-Newark Lowland Section of the Piedmont Province. Chemical analyses were completed on 53 samples collected in 2005 from the Newark Basin for total *As* concentration, *As* speciation, major anions and cations, and field parameters. Arsenic was detected in all groundwater samples. Twenty-three percent of all samples contained elevated concentrations of *As* (> 10 μg/L (ppb)). Elevated concentrations of *As* in the groundwater were most common in the Mesozoic sedimentary strata associated with the Newark Basin. The strata are composed of sandstone and red mudstone with interbedded grey shale, and grey to black siltstone and shale. Arsenic was typically not elevated in groundwater of diabase intrusions of the Newark Basin or in crystalline and calcareous aquifers to the north of the Newark Basin. pH and redox conditions are known to control the mobility of *As* and are the most important factors in this region. Conditions were predominantly oxidizing.

Approximately 85% of samples contained arsenate as the dominant (i.e. > 70% arsenate) *As* species. Variations in pH demonstrated the strongest correlations with *As* concentration and likely affected *As* mobility by influencing the surface affinity of the rock substrate for binding with *As*. In red mudstone aquifers, *As* is likely mobilized by oxidative desorption from Fe-oxyhydroxide minerals. Oxidative dissolution of pyretic minerals may occur where oxidizing and weakly reducing conditions are present in black and grey shale lithologies. Competitive inhibition from PO_4 is unlikely.

INTRODUCTION

Arsenic is a ubiquitous trace element found throughout the environment. Arsenic concentrations in groundwater vary greatly due to the variable distribution of source materials and geochemical controls on *As* mobility in aquifers (Cullen and Reimer, 1989). In approaching this problem, the mineral sources of *As*, physical processes affecting *As* concentration and aqueous geochemistry of the groundwater can be studied. In this investigation, we identify the probable factors affecting *As* mobility in the groundwater by considering the aqueous geochemistry of a region. Addressing the mobility of natural sources of *As* contamination in groundwater will help to understand the triggers of elevated concentrations of *As* in natural waters.

The causes of elevated *As* concentrations in groundwater, including the complex interactions between water, geologic substrate and biological processes, are not yet completely understood. Recent work in West Bengal (Nickson et al., 2000), Bangladesh (Ahmed et al., 2004), Vietnam (Berg et al., 2001), and Spain (García-Sánchez et al., 2005) underscore how little was known about *As* concentrations in groundwater around the world until recently. Areas with elevated *As* concentrations have also been described in Argentina, Mexico, Chile, China, Ghana, Hungary, Taiwan, Thailand, and the United States (Smedley and Kinniburgh, 2002).

The harmful health effects related to the consumption of elevated *As* in drinking water have been well documented in high-*As* (> 50 μg/L) groundwater provinces (Chowdhury et al., 2000; Morales et al., 2000; Smith et al., 2000). Areas in the United States with *As* concentrations previously thought to be low risk are receiving new attention as the United States federal drinking water standard for *As* has recently been reduced from 50 μg/L (ppb) to 10 μg/L (EPA, 2001).

A comprehensive analysis of the extent, levels, and causes of naturally occurring *As* contamination has not been conducted in Pennsylvania. The objectives of this research were to conduct a field study in a geographically-focused region of Pennsylvania concentrating on *As* concentration, *As* speciation, and potential mobilization mechanisms leading to elevated concentrations of *As* in the groundwater. In this paper, work is presented that examines these phenomena in an area in which a retrospective GIS analysis of existing groundwater quality data from state and federal databases (PA DEP, 2004; USGS, 2001) suggest *As* concentrations that are elevated compared to recently enacted federal drinking water standards (EPA, 2001). The relationship between the existing PA DEP database and this study's data is examined. The mechanisms responsible for *As* behavior may be applicable in similar environments.

BACKGROUND

Arsenic Geochemistry

Natural dissolution and desorption of *As*-containing minerals, geothermal water, and mining activity are key contributors to high-*As* groundwater provinces within the United States. Elevated *As* in groundwater has been identified in states in the Southwest (Welch and Lico, 1998; Savage et al., 2000), upper Midwest (Schreiber et al., 2000), and New England (Peters and Blum, 2003; Lipfert et al., 2006).

Arsenic is present in the environment in both inorganic and methylated forms (Cullen and Reimer, 1989). Inorganic forms have been found in *As*-containing minerals (O'Day et al., 2004; Thornburg and Sahai, 2004), sorbed on amorphous ferric oxyhydroxides (Wilkie and Hering, 1996; Raven et al., 1998), sorbed on crystalline Fe oxide phases (Manning et al., 1998), and as surface precipitates on sulfides or pyrite (Bostick and Fendorf, 2003). Nanoparticulate phases have been identified (Utsunomiya et al., 2003).

Major primary sources of *As* in groundwater are Fe oxide and sulfide minerals. They can act as sinks or sources of *As* depending on the environmental conditions. Strongly reducing or oxidizing conditions provide different mechanisms for the release of *As* into surrounding waters. Widespread mechanisms of elevated *As* concentrations include oxidation of sulfide ores, particularly pyrite and arsenopyrite oxidation, and desorption or dissolution of *As* from oxide minerals, especially Fe oxides (Welch et al., 2000). In the case of Fe oxide minerals, redox conditions, pH, solid-to-solution ratios, specific surface area of minerals, and competing ions such as PO_4 may affect *As* mobility and thus *As* concentrations in surrounding waters (Dixit and Hering, 2003). Desorption from Fe oxides occurs predominantly in oxidizing conditions. Dissolution of Fe oxides and subsequent desorption of *As* occur predominantly in reducing conditions.

Typical geochemical indicators for oxidizing release mechanisms include the presence of aqueous Fe, elevated Eh (> 100 mV), dissolved O_2 (3-7 mg/L and greater), pH (> 8), and alkalinity (300-500 mg/L and greater), and possibly high F (up to 7.4 mg/L), U (> 100 mg/L), B (up to 73,000 μg/L), Se (up to 1000 μg/L), Mo (up to 15,000 μg/L), and salinity (0.13-1.8 μg/L) (Smedley and Kinniburgh, 2002). Typical geochemical indicators for reducing release mechanisms include no dissolved O_2, low Eh (< 50 mV) and SO_4 (< 5 mg/L), elevated Fe (> 0.2 mg/L), Mn (> 0.5 mg/L), NH_4, and alkalinity (300-500 mg/L and greater), and possibly high dissolved organic carbon (> 10 mg/L) (Smedley and Kinniburgh, 2002).

Regional and Local Setting

The field study area is located in upper Bucks County and lower Lehigh County in southeastern Pennsylvania (Figure 1; Figure 2). The field area located in upper Bucks County is part of the Newark basin of the Gettysburg-Newark Lowland Section of the Piedmont physiographic province. The province is characterized by Upper Triassic and Lower Jurassic rocks of the Mesozoic Era. The Newark Basin is a half graben resulting from extension during Mesozoic continental rifting. The rocks primarily consist of red sandstone, shale, siltstone, and conglomerate with igneous diabase intrusions (Berg et al., 1986). Local lithostratigraphic units include the Lockatong Formation, Passaic Formation, and a sequence of diabase intrusions. The playa-lacustrine Passaic deposits laterally transition into the lacustrine-dominated Lockatong deposits. Although not mapped in the study area, fluvial deposits of the Stockton Formation interfinger with and are overlaid by Lockatong deposits to the south of the study area.

The Passaic Formation is mainly composed of quartzose sandstone grading into red mudstone, with some interbedded grey shale and argillite whereas Lockatong deposits are mainly composed of dark siltstone and shale and argillite (Low et al., 2000). Intrusive diabase sheets are quartz normative continental tholeiites of the York Haven type (Smith et al., 1975). The diabase is primarily composed of plagioclase and augite (Lyttle and Epstein, 1987). Grey mudstone, argillite, red siltstone, and red mudstone have been metamorphosed to various forms of hornfels where contact was made with diabase intrusions (Froelich and Gottfried, 1999). Cambrian limestone conglomerate, quartzite conglomerate and Precambrian gneiss exist to the north of the rift basin within the lower Lehigh County portion of the study area.

The sedimentary rocks of the Gettysburg-Newark Lowland Section are described as thin aquifers separated by thicker aquitards. Bedrock aquifers tend to be complex, anisotropic, and heterogeneous (Low et al., 2000). Groundwater flow in the limestone aquifers occurs through solution-enlarged fractures, joints, and bedding planes. Water-bearing zones in the crystalline rocks tend to be located in the weathered zones near the ground surface and through fractures and joints at depth (Sloto and Schreffler, 1994).

Previous studies of the water geochemistry indicate that waters are neutral to slightly basic in the Lockatong Formation whereas water is neutral to slightly acidic in the Passaic Formation and diabase, and elevated concentrations of iron, manganese, and sulfate occur but are not common throughout the aquifers (Low et al., 2000).

A focused study in Southeastern Pennsylvania has specific applicability locally, regionally, and potentially within similar Mesozoic rift basins along the Atlantic coast of North America. This research also increases the understanding of the geochemistry of *As* in a way that is broadly applicable to understanding fundamental processes in other similarly affected regions.

MATERIALS AND METHODS

Retrospective GIS analysis

A GIS was prepared to analyze the relationship between *As* occurrence, geography, and bedrock geology in Pennsylvania to determine an appropriate field study location. The main criteria used to determine an appropriate location was evidence of both low (< 10 µg/L (ppb)) and elevated (> 10 µg/L (ppb)) *As* concentrations in the groundwater within a single region. The preliminary GIS considered the entire state of Pennsylvania. Arsenic results from drinking water samples were obtained from the Pennsylvania Department of Environmental Protection (PA DEP) Drinking Water and Sampling Information System (PA DEP, 2004) and the USGS National Water Information System (USGS, 2001). Some data entry errors exist in the PA DEP database which required correction before analyzing the geochemical data. The results from the PA DEP dataset were summarized in the GIS analysis according to geology and are presented in Figure 1. To prepare the summary, all the PA DEP drinking water sample results for *As* located within a geologic formation were averaged. The average *As* concentration was assigned to the formation wherever the formation occurs. The newly calculated averages suggested the occurrence of elevated concentrations of *As* in sandstone aquifers in the northeast corner and east-central parts of Pennsylvania, and in mudstone and shale aquifers in the southeast corner. Southern Lehigh County and northern Bucks County in southeastern Pennsylvania were chosen as the study area because they met the criteria for the presence of elevated concentrations of *As* and were also conveniently located close to the Lehigh University geochemical laboratory where time-sensitive chemical analyses were conducted.

Field Methods and Materials

Fifty-three groundwater samples were collected (July – October, 2005) in northern Bucks County and southern Lehigh County, PA from forty-nine private homes, two schools, and one municipal government building using wells as their source of drinking water, and one hillside spring used by local residents who fill their own containers. Samples were collected from aquifers in the following lithostratigraphic units: Passaic Formation, Lockatong Formation, diabase, Leithsville Formation, felsic to mafic gneiss, and hornblende gneiss. Well and spring locations were collected with a Garmin GPSMAP 76S handheld GPS unit. Temperature, pH (Corning 3-in-1 Combination IP67) and Eh (Hanna HI 98201) were collected in the field using a continuous flow cell. The probes were calibrated daily with commercial 4.0, 7.0 and 10.0 pH standards for the pH probe and commercial +468 and +220 mV standards for the Eh probe. Groundwater samples were collected from wells using outside taps after thoroughly flushing the tap for at least 15 minutes or until temperature measurements indicated that all onsite storage was purged and water originated from the well bore or aquifer (~11-14 ° C). Samples were collected separately for total *As*, *As* speciation, major anion, and cation analysis. All sampling containers were rinsed three times with the sample water before collecting the final sample. All samples were syringe-filtered to < 0.45 μm in the field. Samples for total *As*, major anion and cation analysis were collected in LDPE bottles. Samples for major cation analysis were fixed to pH 2 with ultrapure HNO_3 distilled in the laboratory from commercial grade 16 M HNO_3. Samples for *As* speciation analysis were collected in clear 60 mL glass vials (with Teflon-lined caps) with no headspace. All samples were kept on ice in the field. Arsenic speciation and major anion samples were refrigerated until chemical analysis.

Analytical Methods

Within 24 hours, groundwater samples were analyzed for *As* speciation using continuous-flow inline-coupling of Ion Chromatography (IC, Dionex IONPAC AG4A Guard and AS4A Analytical Columns), Hydride Generation (HG, in-house design) with ultraviolet oxidation and Inductively Coupled Plasma-Mass Spectrometry (ICP-MS, Thermo X-Series CCT) following the method of Klaue and Blum (1999). A 1.8 mM Na_2CO_3 and 1.9 mM $NaHCO_3$ eluent was prepared for the IC. 1% $NaBH_4$ in 0.1 M NaOH and 1 M HNO_3 eluents were prepared for the hydride generation. Solutions were prepared with deionized water (Milli-Q 18 MΩ–cm). The concentrations were chosen to create a 10:1 ratio between acid and $NaBH_4$ to promote optimal generation of hydrides and arsine gas for delivery to the ICP-MS. Hydride generation is used to abate an ArCl interference in the ICP-MS while also increasing sensitivity. Percent composition of arsenate and arsenite species, and estimated total *As* were determined. Samples were separately analyzed for total *As* using HG with UV oxidation coupled to ICP-MS. The analytical detection limit was approximately 0.01 µg/L total *As* concentration, which is below all sample concentrations. Major cations and a number of trace elements were determined using ICP-MS. Major anions were determined using IC with suppressed conductivity detection. Concentrations are reported as µmol/L except where relevant for regulatory comparison, where concentration is given as µg/L (ppb). Arsenic sample locations and analytical results are shown in Figure 2. All analytical results are reported in Table 1. Homeowner names and specific well location information are not included in Table 1 at the request of the homeowners; however, locations of homeowner wells are available upon request. Data collected during the field study was compared to the federal and state databases initially used to identify the study area.

RESULTS AND DISCUSSION

Total Arsenic Concentration in Groundwater

Arsenic was detected in all 53 samples. Approximately 23% (12 samples) of all groundwater samples contained elevated concentrations of total *As*. Furthermore, 33% of groundwater samples from the two sedimentary formations of the Newark Basin (11 of 33 samples) contained elevated concentrations of total *As*. The average and maximum *As* concentration within the Lockatong Formation is greater than surrounding formations, followed by the Passaic Formation (Table 2). There is no evidence of elevated *As* in aquifers in Precambrian and Cambrian rocks in the northern part of the study area. Arsenic was also not elevated in the diabase aquifers except for one sample in the diabase located in the northeastern part of the study area near a contact with the Passaic Formation (sample no. 142).

Table 3 presents summary statistics for total *As* concentrations in drinking water from the Pennsylvania Drinking Water Information System database (PA DEP, 2004) for the same geologic formations analyzed in this study. The summary statistics from the drinking water dataset are similar to this study's summary findings in Table 2. The highest concentrations of *As* are found within the Passaic and Lockatong formations in both datasets. The percentage of samples with *As* concentrations > 10 µg/L are similar between this study and the PA DEP data when comparing the entire datasets, and data from the Passaic Formation, diabase, and various Cambrian and Precambrian lithologies. Data for the Lockatong Formation differs between the datasets mostly due to a large number of nondetect results in the PA DEP dataset. The retrospective GIS analysis that was originally prepared with the PA DEP data was successful at identifying a geographic area in Pennsylvania with an increased likelihood of elevated concentrations of *As* in the groundwater.

In this study, the presence of total *As* in solution is correlated with circumneutral to high pH. Data presented in Figure 3 are consistent with literature regarding the relationship between *As* and pH (Smedley et al., 2005). All samples less than approximately pH 5.75 contained less than 1 ppb total *As*. The data suggest a transitional zone around pH 6 in which other geochemical factors in addition to pH begin to affect As mobility. These data suggest that *As* mobility is enhanced at circumneutral to high pH and suppressed at low pH. There were no samples greater than pH 7.5.

The role of Eh is unclear (Figure 4). Both elevated and low *As* concentrations are found throughout the range of Eh values; however, the Eh range may be indicative of the general method of *As* mobilization. The presence of predominantly weakly to strongly oxidizing conditions and strong pH control suggest the most widespread mobilization mechanism is likely oxidative desorption. In some areas where a few results indicate weakly oxidizing to strongly reducing conditions, reductive desorption or primary dissolution cannot be ruled out as minor, localized mechanisms.

Total *As* is inversely correlated with both NO_3 and Cl. Assuming that NO_3 and Cl are mainly from anthropogenic sources (i.e. agricultural fertilizer and road salt), higher concentrations of these constituents may represent younger waters. The inverse relationship suggests that waters with elevated *As* concentrations are older and younger waters may be diluting *As*.

There does not appear to be a correlation between total *As* concentration and F, SO_4, Mg, Ca, Na, or K (R^2 range of 0.001 to 0.1431; see Appendix for plots of total *As* vs. ion concentrations). Nitrite (NO_2) was not detected in enough samples to determine a relationship. Phosphate (PO_4) was not detected in any samples (detection limit of 1 ppm = 10.41 μmol/L) and therefore we suggest little or no competition from PO_4 in this study.

Manganese (Mn) was only detected in eight samples; however, four of the eight samples also contained the four highest elevated concentrations of *As*.

Arsenic Speciation

The major *As* species analyzed were arsenate (As V) and arsenite (As III). Arsenate is oxidized relative to arsenite. Arsenate was the dominant *As* species. Approximately 85% of the samples had greater than 70% arsenate while only approximately 8% of the samples had greater than 70% arsenite. The remaining samples had an intermediate mix of both species present. Of the twelve samples with elevated concentrations of total *As*, ten samples are dominated by arsenate (i.e. greater than 70% of total As) while the remaining 2 samples were dominated by arsenite. This suggests that both oxidizing and reducing conditions may contribute to elevated concentrations of *As* in the sedimentary formations and diabase of the Newark Basin and gives further evidence for the presence of a dominant mechanism contributing to *As* mobilization and at least one other minor mechanism.

Arsenate-dominated samples occur throughout the pH range of the samples (Figure 3). The arsenite-dominated samples occur within a smaller pH range (pH 5.8-7.2). Arsenite-dominated samples were most likely not found often due to a lack of sampling locations finished in similar geochemical conditions. This may be caused by a scattering of localized reducing conditions related to lithostratigraphic changes within and between geologic formations.

The proportion of arsenate is generally related to Eh ($R^2 = 0.3825$). Arsenite-dominated samples do not occur at high Eh and arsenate-dominated samples do not occur at low Eh.

An Eh-pH diagram was constructed of the Fe-As-SO_4-H_2O system using the software Geochemist's Workbench to model stability fields of the system (Figure 5). This study's data were plotted in the context of the model according to measured Eh and pH. The dominant *As* species as modeled can be compared to the *As* species as measured in a sample. All samples fall within four stability fields. Samples with proportionately more arsenate (>80% arsenate) plot within the arsenate stability fields suggesting that the arsenic species in these samples are at or close to equilibrium (Figure 6). Samples with intermediate proportions of each species (20% - 80%) plot within both arsenate and arsenite stability fields, but occur close to the boundary line between these equilibrium species (Figure 6). A few samples plot in stability fields opposite to their measured *As* speciation. The samples with intermediate proportions of each species, and those that plot in opposing stability fields suggest that the waters may be subject to movement or mixing with waters of different redox status (Peters and Blum, 2003). The sample plotting within the orpiment stability field is likely out of equilibrium with its surrounding redox conditions.

Iron Geochemical Behavior and Arsenic-Binding

Iron behavior in solution may help elucidate *As* behavior because of the close association between Fe and *As* in mineral form, and the ability of Fe-oxides to adsorb *As* (Smedley and Kinniburgh, 2002). Iron is typically not elevated in the samples (Table 1). pH and Eh appear to exhibit control on dissolved Fe concentration (Figure 7; Figure 8). Iron samples with Eh less than 100 mV exhibit the highest Fe concentrations suggesting greater Fe mobility at Eh less than 100 mV. In generally oxidizing conditions and at low pH, Fe minerals are stable in solid form and release little to no aqueous Fe species. At circumneutral pH (~ pH 6 – pH 7.5) Fe is present in solution at varying concentrations. With respect to pH, iron equilibrium in solution is typically kinetically-constrained (Langmuir, 1997) rather than thermodynamically-constrained. Precipitation of Fe-oxyhydroxides in an oxidizing environment has been shown to be kinetically controlled by pH (Peters and Blum, 2003). The downward trend in Fe concentration with increasing pH in this pH range may be a result of slow Fe-oxyhydroxide precipitation from aqueous Fe already present in solution.

Groundwaters of this study area are likely evolving separately under static geochemical conditions subject to kinetic controls on Fe-oxyhydroxide precipitation. Alternatively, waters evolving separately or following a flow path may also be subject to changing pH or redox conditions in place. Changing geochemical conditions may initiate the dissolution or precipitation of Fe present in solid or aqueous forms, respectively (Haque and Johannesson, 2006).

The precipitation of Fe-oxyhydroxides may effect *As* in solution by providing additional substrate for *As* adsorption if *As* is present (Pichler et al., 1999). In experimental trials individual site affinity for arsenate does not differ between more crystalline forms of Fe-oxyhydroxide minerals such as goethite and magnetite to less crystalline forms such as hydrous ferric oxides (HFO); however, more crystalline forms demonstrated an overall decrease in specific surface area and therefore site density (Dixit and Herring, 2003). Therefore, a conversion from less crystalline forms to more crystalline forms could result in decreased *As* adsorption and increased *As* mobility. In the case of precipitation of aqueous Fe anions to amorphous forms of Fe-oxyhydroxides, the newly formed Fe minerals may adsorb more *As* from solution relative to the surrounding crystalline Fe minerals.

A tradeoff exists between an increase in precipitated substrate and the properties of that substrate allowing the adsorption of *As*. At low pH Fe-oxyhydroxides are stable in a solid state and have a positively-charged surface that readily attracts *As* anions. As the pH increases through the circumneutral range, the surface charge of the mineral substrate becomes less positive thereby decreasing the total affinity of the Fe-oxyhydroxide surface for *As* anions. Although any aqueous Fe in solution will precipitate at a faster rate as the pH continues to increase, the surface affinity also continues to further decrease. The presence of *As* in solution at circumneutral and high pH may be related to Fe equilibrium in solution and/or the adsorption properties of Fe minerals for *As* at different pH values.

This study's results were plotted in the context of thermodynamic modeling of Fe solubility under different redox conditions using Geochemist's Workbench (Figure 9). Iron concentrations are mostly in agreement with pH and redox conditions as constrained by the model; however, samples plotting on or near solubility boundaries may be waters seeking equilibrium that are kinetically inhibited from precipitating due to pH conditions.

There does not appear to be a positive correlation between total *As* concentration and aqueous Fe concentration (Figure 7; Figure 10). Arsenic concentrations do not systematically decrease as Fe precipitation is favored at circumneutral to slightly alkaline pH. Elevated *As* concentrations also occur when Fe-oxyhydroxide precipitation is kinetically favorable at higher pH values. Oxidizing conditions favor Fe^{3+} and its associated mineral forms over high concentrations of aqueous Fe^{2+} in solution.

The low concentrations of aqueous Fe species under a variety of pH and redox conditions further suggest that Fe-oxyhydroxide minerals are fairly stable in solid form making the release of *As* due to substrate dissolution unlikely.

Source and Mobilization of Arsenic

At low concentrations of aqueous Fe^{2+} in solution, the adsorption and desorption of *As* anions from Fe-oxyhydroxide minerals is likely more strongly controlled by pH-controlled changes in surface affinity of available mineral substrate rather than pH-related kinetic limitations on Fe-oxyhydroxide precipitation. Similar mechanisms have been demonstrated in oxidizing environments (Smedley et al., 2005).

Work conducted by Serfes (2005) in the same geologic formations in New Jersey is consistent with desorption processes leading to the presence of aqueous *As* in waters of the Passaic Formation; clay minerals coated with early hematite were indicated to be the source of the *As* via desorption (Serfes, 2005).

Dissolution mechanisms were predicted by Serfes (2005) in the black shales of the Lockatong Formation. Although oxidizing to mildly reducing conditions present in all the Lockatong samples (Table 1; Eh range 17 to 112 mV) may support oxidative dissolution of pyrite, other geochemical factors measured in this study are less supportive. For example, SO_4 is abundant in solution relative to Fe. Sulfate and Fe would be expected close to 2:1 to 1:1 molar ratios in solution due to pyrite or arsenopyrite oxidation and subsequent dissolution in the mildly reducing conditions, especially at neutral to high pH. Actual ratios range from a minimum SO_4: Fe of 6:1 to a maximum of more than 3600:1 and median of 120:1. It is inconclusive from this study that pyrite dissolution is occurring under oxidizing or mildly reducing conditions.

The Passaic Formation also contains interbedded grey shales similar to the shales of the Lockatong Formation. It is also inconclusive whether Passaic samples with mildly reducing to mildly oxidizing conditions are attributed to oxidative dissolution of pyretic shales, or oxidative desorption from Fe-oxyhydroxides of the redbeds.

Although not common, reducing conditions were also found with elevated concentrations of *As* in this study. Samples with *As* concentrations dominated by arsenite were found in both the Passaic and Lockatong formations. The low concentrations of aqueous Fe provide greater support for reductive desorption from Fe-oxyhydroxide minerals rather than reductive dissolution of the same.

Sulfate and Ca in solution do not correlate and therefore gypsum dissolution is also an unlikely mechanism leading to elevated SO_4. The SO_4 probably remains behind in solution from the primary dissolution of pyrite at a previous up-gradient location of evolving waters or waters following a flow path over time. The SO_4 preferentially stays in solution whereas the Fe is precipitated as amorphous and crystalline forms of Fe-oxyhydroxides in oxidizing conditions.

CONCLUSION

Natural variations in redox potential and pH affect the Fe and *As* concentrations and *As* speciation of a groundwater. The Newark Basin of the Gettysburg-Newark Lowland

Section of the Piedmont province in Pennsylvania is dominated by oxidizing conditions. pH conditions are generally acidic to neutral with a pH range of 4.86-7.45.

The groundwaters of the Lockatong and Passaic formations may contain elevated concentrations of *As* depending on local pH and redox conditions. Arsenic is not typically elevated in the crystalline and limestone rocks in the northern part of the study area outside of the Mesozoic rift basins, and in the diabase intrusions throughout the sedimentary strata of the Mesozoic rift basins.

Mobility of both arsenate and arsenite is correlated with pH in this study. Arsenate is the dominant inorganic species due to the oxidizing conditions.

The low solubility of Fe in oxidizing conditions and kinetic controls on Fe equilibrium by pH result in low concentrations of aqueous Fe at low pH and variable concentrations of aqueous Fe at circumneutral pH. Where low concentrations of Fe are present, the direct effects of pH and Eh appear to exhibit direct control over *As* concentration and speciation, respectively.

At circumneutral pH, kinetic controls on the precipitation of Fe (Peters and Blum, 2003), forms of Fe present (Raven et al., 1998), surface structure attributes of Fe (Sherman and Randall, 2003; Goldberg and Johnson, 2001), and speciated forms of *As* (Dixit and Hering, 2003) simultaneously affect *As* mobility in the groundwater. In this study the surface structure affinity of Fe for As likely plays a large role in As mobility whereas kinetic controls on the precipitation of Fe likely play a secondary role.

Oxidative desorption from Fe-oxyhydroxides is the most common and most likely mechanism of release of *As* under oxidizing conditions, and is enhanced as pH increases.

Some geochemical conditions also give weak evidence for oxidative dissolution of pyrite and reductive desorption from iron oxyhydroxides. Reductive dissolution of Fe-oxyhydroxides is unlikely. Future research should be focused on mildly to very reducing conditions within these same geologic formations. This can be done by comparing spatial and temporal relations between waters derived from different units within the Passaic Formation, and at contacts between the Passaic and Lockatong formations.

It is unlikely that an authigenic source of *As* is present as iron-sulfide minerals such as arsenian pyrite or arsenopyrite in the redbeds of the Passaic Formation, but an iron-sulfide source of As is plausible in the shales of the Lockatong Formation and interbedded shales of the Passaic Formation but inconclusive from this study's findings.

Geographic analysis of drinking water results from the PA DEP Drinking Water and Sampling Information System database (PA DEP, 2004) has proven to be a useful tool as a predictive GIS coverage of elevated concentrations of *As* in the groundwater. The PA DEP dataset is useful for suggesting geographic areas warranting further study. Further research with this tool could use field-based studies to validate regions with both elevated and low concentrations of *As* in the groundwater, study mineral sources of *As* and geochemical controls on *As* mobility, and spatially define and correlate areas prone to natural *As* contaminations around the state. A temporal analysis may be possible due to the long-term nature of data collection at the same locations. While developing a research program utilizing this tool, future researchers should be aware of the sensitive nature of drinking water source locations when requesting this information from government agencies, and the presence of erroneous results due to data entry errors.

Similar large-scale analyses have been performed by the United States Geological Survey using data from the USGS National Water Information System (Welch et al., 2000). Future researchers can merge the PA DEP, USGS, and any other identified datasets to create a large database of *As* sample results in Pennsylvania. Such a program has enormous possibility to be extended to larger regions due to the large amount of analytical drinking water results maintained by different states. Surface water results can also be integrated into the dataset. Data verification and manipulation may pose challenges while merging data from a variety of sources.

This study's results emphasize the need to better characterize *As* sources, distribution, solubility and mobility in oxidizing groundwater environments everywhere. Much emphasis has been placed on reducing conditions in Quaternary river delta environments throughout the world because of the gravity of human health conditions; however, aquifers located in older geological environments have been shown to also pose risks to human health. With the implementation of more stringent *As* standards in drinking water in the United States, there is also a need to determine and characterize the factors affecting *As* mobility in groundwater environments previously considered to be low risk.

Temporal and geological connections to other Mesozoic rift basins along the Atlantic Coast of North America also warrant further consideration of *As* in these environments.

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TABLES

Sample	Date	Temp (°C)	pH	Eh (mV)	Fl (µmol/L)	Cl (µmol/L)	NO_3 (µmol/L)	SO_4 (µmol/L)
001-003	72005	12.6	5.87	456.8	6.7304	78	55	262
004-006	72005	12.1	7.45	298.4	6.3030	304	35	44
007-009	72505	12.3	5.12	321	4.9936	702	190	219
010-012	72505	13.0	4.86	292	5.4825	580	111	116
013-015	72505	13.1	5.26	261	ND	2388	159	310
016-018	72805	13.0	4.92	257	5.5517	113	44	150
019-021	72805	14.7	5.26	234	6.9311	460	777	132
022-024	72805	14.3	6.86	109	5.7974	1772	203	279
025-027	72805	13.0	7.19	122	8.1177	213	195	50
028-030	80205	13.9	5.50	333	7.7697	178	170	349
031-033	80205	15.4	5.58	176	0.0000	647	210	342
034-036	80205	13.7	6.03	22	18.7332	340	9	608
037-039	80205	14.1	6.82	133	6.7137	248	344	281
040-042	80205	14.1	5.60	148	ND	1953	173	270
043-045	80205	13.1	5.26	172	ND	1294	408	331
046-048	92605	15.8	6.92	103	ND	239	9	5421
049-051	92605	13.5	7.01	124	6.7750	526	226	272
052-054	92605	13.1	7.17	132	6.5121	277	145	235
055-057	92605	14.1	7.11	141	6.7401	525	316	278
058-060	92605	16.6	7.16	136	7.0277	2942	111	163
061-063	92905				5.3252	367	298	161
064-066	92905				8.2931	108	58	296
067-069	92905				6.3733	142	87	163
070-072	92905				11.3217	333	76	257
073-075	92905				5.7879	322	101	357
076-078	92905				5.3780	266	48	577
079-081	100305	14.2	6.85	360	6.1457	121	9	658
082-084	100305	13.5	6.74	169	6.8983	1432	190	259
085-087	100305	14.6	6.98		7.5777	1346	131	360
088-090	100305	14.0	7.02		ND	1799	200	72
091-093	104005	14.3	7.20	-232	14.2673	79	9	358
094-096	100405	14.3	7.20	105	9.4115	347	55	540
097-099	100405	13.9	7.29	155	7.4640	331	169	307
100-102	100405	14.0	7.22	105	5.3687	1342	246	122
103-105	100405	16.0	7.23	119	7.2108	343	151	417
106-108	100405	14.1	7.04	111	5.9018	600	262	201
109-111	101305	13.4	5.76	23	17.1575	8864	38	692
112-114	101305	14.2	6.56	83	7.4029	1261	235	248
115-117	101305	14.2	6.63	98	6.2168	200	97	1514
118-120	101305	14.0	6.71	100	10.1710	200	101	279
121-123	101305	13.9	6.42	87	6.1279	1176	508	348
124-126	101305	18.6	5.23	157	5.6235	273	74	245
127-129	101805	13.5	6.74	17	10.4236	132	9	410
130-132	101805	16.1	6.50	83	15.1908	824	9	263
133-135	101805	13.9	6.48	80	4.4702	10749	113	553
136-138	101805	13.1	7.40	76	104.2565	162	15	148
139-141	101805	17.0	5.55	182	4.9065	1459	203	250
142-144	101805	15.0	6.42	141	7.2805	203	13	496
145-147	101805	12.9	5.35	157	5.5692	1234	315	200
148-150	101805	13.4	6.72	50	7.4349	339	58	165
151-153	101805	12.7	6.71	107	8.8755	238	120	255
154-156	101805	12.7	6.78	112	7.7486	331	111	197
157-159	101805	12.6	5.09	173	11.4534	223	414	221

ND=nondetect SD=Standard Deviation

**Br and PO_4 were nondetect for all samples*

Table 1.

Sample	Bedrock Geology	As (µg/L)	As SD (ug/L)	As (µmol/L)	As SD (µmol/L)	As(III) %	As(V) %
001-003	Hornblende gneiss	1.27	0.02	0.0169	0.0003	3.8	96.2
004-006	Felsic to mafic gneiss	0.54	0.01	0.0072	0.0001	0.4	99.6
007-009	Felsic to mafic gneiss	0.01	0.00	0.0002	0.0001	16.5	83.5
010-012	Felsic to mafic gneiss	0.01	0.01	0.0002	0.0001	0.0	100.0
013-015	Felsic to mafic gneiss	0.01	0.01	0.0002	0.0001	14.0	86.0
016-018	Hornblende gneiss	0.11	0.00	0.0014	0.0001	0.0	100.0
019-021	Hornblende gneiss	0.07	0.00	0.0009	0.0000	0.0	100.0
022-024	Leithsville Formation	0.03	0.01	0.0004	0.0001	3.3	96.7
025-027	Leithsville Formation	0.09	0.01	0.0012	0.0001	4.8	95.2
028-030	Diabase	0.19	0.01	0.0025	0.0001	5.9	94.1
031-033	Diabase	0.07	0.00	0.0009	0.0001	35.2	64.8
034-036	Passaic Formation	2.07	0.01	0.0277	0.0002	70.8	29.2
037-039	Passaic Formation	10.12	0.10	0.1351	0.0013	0.5	99.5
040-042	Diabase	0.13	0.01	0.0018	0.0001	15.1	84.9
043-045	Passaic Formation	0.02	0.00	0.0003	0.0001	17.2	82.8
046-048	Passaic Formation	39.32	0.37	0.5248	0.0050	28.0	72.0
049-051	Passaic Formation	8.33	0.13	0.1111	0.0018	2.9	97.1
052-054	Passaic Formation	4.75	0.05	0.0634	0.0007	2.2	97.8
055-057	Passaic Formation	1.57	0.03	0.0209	0.0003	5.4	94.6
058-060	Passaic Formation	5.37	0.03	0.0717	0.0005	12.6	87.4
061-063	Passaic Formation	2.87	0.05	0.0383	0.0006	11.5	88.5
064-066	Passaic Formation	18.50	0.32	0.2469	0.0042	15.2	84.8
067-069	Passaic Formation	12.38	0.15	0.1652	0.0021	8.9	91.1
070-072	Passaic Formation	8.57	0.05	0.1144	0.0006	12.2	87.8
073-075	Passaic Formation	4.61	0.04	0.0615	0.0005	12.2	87.8
076-078	Passaic Formation	4.80	0.16	0.0641	0.0022	16.3	83.7
079-081	Passaic Formation	22.92	0.32	0.3059	0.0042	21.1	78.9
082-084	Passaic Formation	1.07	0.01	0.0142	0.0001	16.8	83.2
085-087	Passaic Formation	5.09	0.08	0.0680	0.0011	27.2	72.8
088-090	Passaic Formation	5.10	0.04	0.0681	0.0005	15.7	84.3
091-093	Passaic Formation	46.14	0.48	0.6158	0.0064	91.2	8.8
094-096	Passaic Formation	19.89	0.19	0.2655	0.0026	17.4	82.6
097-099	Passaic Formation	11.35	0.09	0.1515	0.0013	18.8	81.2
100-102	Passaic Formation	7.28	0.08	0.0972	0.0011	19.9	80.1
103-105	Passaic Formation	7.89	0.10	0.1054	0.0014	16.9	83.1
106-108	Passaic Formation	2.29	0.02	0.0306	0.0003	8.3	91.7
109-111	Passaic Formation	0.50	0.01	0.0066	0.0001	70.8	29.2
112-114	Passaic Formation	2.96	0.06	0.0395	0.0008	17.1	82.9
115-117	Passaic Formation	13.81	0.10	0.1843	0.0014	10.9	89.1
118-120	Passaic Formation	6.40	0.12	0.0854	0.0016	12.8	87.2
121-123	Leithsville Formation	0.17	0.01	0.0023	0.0001	54.8	45.2
124-126	Hornblende gneiss	0.05	0.00	0.0007	0.0000	50.4	49.6
127-129	Lockatong Formation	39.42	0.38	0.5262	0.0051	83.5	16.5
130-132	Lockatong Formation	64.86	1.01	0.8657	0.0135	8.4	91.6
133-135	Lockatong Formation	0.58	0.01	0.0077	0.0001	49.8	50.2
136-138	Diabase	2.18	0.02	0.0292	0.0003	21.7	78.3
139-141	Diabase	0.27	0.00	0.0036	0.0000	16.0	84.0
142-144	Diabase	11.83	0.11	0.1579	0.0015	21.0	79.0
145-147	Diabase	0.06	0.01	0.0007	0.0001	26.4	73.6
148-150	Trenton Gravel	0.70	0.01	0.0093	0.0001	29.8	70.2
151-153	Lockatong Formation	7.19	0.05	0.0960	0.0007	16.9	83.1
154-156	Lockatong Formation	5.33	0.07	0.0711	0.0010	16.2	83.8
157-159	Hornblende gneiss	0.06	0.01	0.0008	0.0001	23.7	76.3

Table 1. (continued)

Sample	B (µmol/L)	B SD (µmol/L)	Na (µmol/L)	Na SD (µmol/L)	Mg (µmol/L)	Mg SD (µmol/L)	Si (µmol/L)	Si SD (µmol/L)
001-003	0.425	0.020	1751	28	ND	0	451	5
004-006	3.119	0.085	119	3	723	16	778	6
007-009	0.222	0.009	383	5	265	2	405	2
010-012	15.595	0.615	399	12	148	2	390	5
013-015	1.272	0.025	1483	31	590	12	520	6
016-018	0.334	0.013	167	1	133	2	364	4
019-021	3.645	0.091	620	13	304	9	468	6
022-024	0.787	0.024	1497	38	1342	15	340	3
025-027	0.243	0.011	233	1	734	10	306	4
028-030	2.260	0.055	432	4	444	10	837	8
031-033	5.625	0.144	281	6	517	3	794	13
034-036	2.432	0.059	549	11	519	7	933	9
037-039	0.917	0.034	503	6	841	12	422	6
040-042	4.163	0.115	759	10	715	10	727	8
043-045	1.780	0.042	490	9	739	4	597	6
046-048	89.705	1.481	1233	11	997	8	451	4
049-051	10.841	0.166	532	7	867	9	391	3
052-054	5.608	0.118	430	6	674	8	328	4
055-057	2.219	0.038	492	6	895	11	324	2
058-060	10.684	0.332	956	15	1726	30	406	3
061-063	3.460	0.059	461	5	956	14	395	4
064-066	11.784	0.399	510	8	733	6	344	5
067-069	2.028	0.017	354	7	729	12	391	7
070-072	38.886	1.619	431	6	595	13	438	3
073-075	3.036	0.099	377	7	732	11	313	2
076-078	4.609	0.141	355	6	799	10	328	2
079-081	9.223	0.140	4091	5	ND	0	370	6
082-084	2.477	0.054	734	12	1296	13	350	5
085-087	2.241	0.028	602	3	1137	7	278	2
088-090	2.905	0.037	541	7	1268	20	457	7
091-093	69.291	2.075	1246	18	387	5	463	3
094-096	29.701	0.416	619	7	851	10	432	4
097-099	3.055	0.065	425	5	757	8	375	2
100-102	4.607	0.105	499	10	1160	25	413	5
103-105	16.085	0.205	533	8	843	9	362	2
106-108	3.158	0.059	367	4	801	9	335	4
109-111	1.962	0.057	3951	25	2648	57	671	8
112-114	4.205	0.077	857	9	1059	17	317	4
115-117	23.578	0.276	599	5	994	14	388	6
118-120	19.332	0.681	682	11	841	11	399	2
121-123	1.995	0.047	807	8	1543	25	147	2
124-126	0.748	0.025	157	1	157	2	261	3
127-129	22.024	0.318	986	10	480	5	495	5
130-132	2.192	0.057	512	7	360	4	360	3
133-135	50.153	0.840	1266	23	2260	37	521	5
136-138	260.105	2.867	786	6	94	1	594	5
139-141	4.729	0.470	482	9	738	10	623	9
142-144	25.613	0.559	340	3	1030	17	663	6
145-147	4.240	0.058	262	2	704	7	622	5
148-150	3.392	0.086	328	6	682	11	152	1
151-153	10.240	0.242	483	5	805	8	329	3
154-156	5.032	0.163	376	10	615	9	291	4
157-159	0.864	0.025	241	3	265	2	411	5

***Cation exchange softeners were in use at the sites of samples 001-003 and 079-081*

Table 1. (continued)

Sample	K (µmol/L)	K SD (µmol/L)	Ca (µmol/L)	Ca SD (µmol/L)	Mn (µmol/L)	Mn SD (µmol/L)	Fe (µmol/L)	Fe SD (µmol/L)
001-003	0.97	0.03	ND	0.04	ND	0.000	ND	0.045
004-006	28.95	0.24	658	9.02	ND	0.000	0.453	0.038
007-009	52.53	0.56	316	2.13	ND	0.001	0.059	0.024
010-012	37.52	0.57	186	2.86	ND	0.001	0.027	0.034
013-015	84.38	1.80	703	7.67	0.383	0.006	0.096	0.044
016-018	28.39	0.38	183	1.61	ND	0.001	0.064	0.024
019-021	45.76	0.91	337	6.77	ND	0.000	ND	0.034
022-024	39.57	0.56	1424	16.23	ND	0.000	0.503	0.117
025-027	64.38	1.23	702	7.29	ND	0.000	0.588	0.028
028-030	18.33	0.26	568	3.59	ND	0.000	ND	0.022
031-033	19.48	0.29	800	9.82	ND	0.001	0.103	0.034
034-036	68.62	1.01	608	8.02	16.613	0.103	5.407	0.099
037-039	26.11	0.39	1151	20.83	ND	0.001	0.028	0.024
040-042	43.63	0.59	930	13.08	ND	0.001	0.443	0.031
043-045	15.56	0.26	732	9.06	ND	0.000	ND	0.020
046-048	28.75	0.82	5070	94.29	2.121	0.015	1.478	0.104
049-051	21.51	0.39	1066	17.48	ND	0.000	0.158	0.035
052-054	18.21	0.24	897	11.60	ND	0.000	0.195	0.030
055-057	25.09	0.22	1110	11.35	ND	0.000	0.215	0.024
058-060	64.45	0.91	2070	27.72	ND	0.000	0.331	0.092
061-063	23.17	0.41	1133	15.20	ND	0.000	0.229	0.027
064-066	19.44	0.26	973	16.12	ND	0.000	0.154	0.012
067-069	20.63	0.23	838	10.73	ND	0.000	0.156	0.024
070-072	28.16	0.33	1011	13.10	ND	0.000	0.094	0.016
073-075	16.93	0.10	909	13.16	ND	0.000	0.094	0.031
076-078	15.78	0.22	908	11.61	ND	0.000	0.035	0.048
079-081	3.47	0.11	ND	0.10	ND	0.000	ND	0.031
082-084	30.44	0.56	1708	29.02	ND	0.000	0.254	0.035
085-087	26.06	0.29	1413	23.26	ND	0.000	0.359	0.024
088-090	28.52	0.54	1362	23.23	ND	0.000	0.248	0.015
091-093	23.74	0.21	1023	10.43	0.646	0.008	1.649	0.089
094-096	21.65	0.17	987	10.11	ND	0.000	0.045	0.020
097-099	20.86	0.22	920	3.97	ND	0.001	0.087	0.050
100-102	29.44	0.51	1134	22.51	ND	0.000	0.113	0.039
103-105	20.76	0.19	1005	6.02	ND	0.000	ND	0.013
106-108	19.45	0.47	934	12.41	ND	0.000	0.098	0.039
109-111	100.08	2.90	1351	29.44	0.819	0.008	10.487	0.119
112-114	23.62	0.33	1504	15.45	ND	0.000	0.236	0.017
115-117	22.99	0.53	1343	20.75	ND	0.000	0.040	0.047
118-120	38.72	0.79	1113	15.92	ND	0.000	0.161	0.019
121-123	79.29	1.70	1572	34.51	ND	0.000	0.282	0.029
124-126	54.81	0.78	832	12.84	0.097	0.002	0.125	0.021
127-129	9.02	0.12	1293	25.20	0.531	0.009	4.167	0.082
130-132	50.28	0.99	1421	24.57	1.580	0.017	0.131	0.030
133-135	88.93	0.87	3892	51.37	ND	0.000	3.726	0.108
136-138	3.12	0.04	470	6.26	ND	0.000	ND	0.019
139-141	37.78	0.57	659	5.69	ND	0.001	ND	0.023
142-144	46.83	0.70	947	8.39	ND	0.000	ND	0.035
145-147	9.28	0.24	506	6.88	ND	0.000	ND	0.023
148-150	31.08	0.45	956	11.47	ND	0.000	0.403	0.040
151-153	33.38	0.25	987	6.14	ND	0.000	ND	0.022
154-156	29.82	0.63	856	12.14	ND	0.000	ND	0.028
157-159	33.53	0.40	362	1.90	ND	0.000	ND	0.036

***Cation exchange softeners were in use at the sites of samples 001-003 and 079-081*

Table 1. (continued)

Sample	Cu (µmol/L)	Cu SD (µmol/L)	Zn (µmol/L)	Zn SD (µmol/L)	Sr (µmol/L)	Sr SD (µmol/L)	Ba (µmol/L)	Ba SD (µmol/L)
001-003	0.082	0.002	ND	0.001	ND	0.000	ND	0.000
004-006	0.079	0.001	1.426	0.018	0.659	0.011	0.346	0.005
007-009	0.790	0.010	0.448	0.008	1.032	0.009	0.348	0.004
010-012	1.668	0.016	0.469	0.005	0.764	0.011	0.446	0.003
013-015	1.736	0.015	0.313	0.004	1.449	0.017	0.235	0.004
016-018	1.896	0.022	0.335	0.008	0.281	0.005	0.028	0.001
019-021	2.014	0.016	0.294	0.005	1.375	0.017	0.111	0.003
022-024	0.021	0.002	0.040	0.001	1.174	0.016	0.537	0.007
025-027	0.071	0.001	0.034	0.001	0.184	0.003	0.218	0.004
028-030	1.377	0.010	0.265	0.004	0.801	0.007	0.004	0.000
031-033	0.284	0.006	0.121	0.004	1.201	0.007	ND	0.000
034-036	0.020	0.001	ND	0.001	1.214	0.018	0.253	0.003
037-039	0.265	0.004	0.022	0.002	4.356	0.091	0.429	0.007
040-042	0.542	0.008	0.756	0.010	1.307	0.020	ND	0.000
043-045	0.295	0.004	0.382	0.005	1.021	0.011	ND	0.000
046-048	ND	0.000	ND	0.001	84.901	1.549	0.184	0.005
049-051	0.059	0.002	0.003	0.002	10.361	0.120	1.290	0.020
052-054	0.063	0.002	0.026	0.002	5.098	0.049	1.199	0.014
055-057	0.095	0.001	0.058	0.002	4.480	0.059	0.698	0.012
058-060	0.107	0.002	3.134	0.040	21.867	0.322	4.336	0.068
061-063	0.090	0.001	ND	0.002	15.875	0.163	5.178	0.080
064-066	0.093	0.001	0.005	0.001	46.405	0.654	0.214	0.003
067-069	0.183	0.004	0.073	0.004	6.616	0.072	3.260	0.036
070-072	0.020	0.001	ND	0.002	10.194	0.082	0.599	0.007
073-075	0.134	0.002	0.013	0.001	3.450	0.028	0.641	0.006
076-078	0.070	0.002	ND	0.001	4.047	0.045	0.828	0.010
079-081	ND	0.001	ND	0.001	ND	0.000	ND	0.000
082-084	0.051	0.002	0.017	0.002	6.145	0.084	0.715	0.012
085-087	0.076	0.002	0.425	0.006	9.912	0.161	0.359	0.007
088-090	0.025	0.002	0.082	0.002	5.632	0.069	8.884	0.134
091-093	ND	0.000	0.000	0.001	93.540	1.284	0.392	0.005
094-096	0.148	0.004	0.574	0.006	32.504	0.308	0.970	0.010
097-099	1.277	0.010	0.053	0.002	4.812	0.049	0.793	0.011
100-102	0.020	0.001	0.020	0.003	9.313	0.127	5.762	0.060
103-105	0.181	0.002	ND	0.002	12.257	0.149	1.379	0.024
106-108	0.306	0.004	0.162	0.002	1.666	0.013	3.320	0.054
109-111	0.065	0.000	1.646	0.020	6.431	0.101	0.033	0.001
112-114	0.237	0.004	0.104	0.003	5.567	0.064	1.911	0.029
115-117	0.331	0.005	0.086	0.002	19.916	0.279	0.232	0.006
118-120	0.291	0.004	0.046	0.002	25.542	0.283	0.713	0.010
121-123	0.016	0.001	0.094	0.002	0.412	0.005	0.089	0.002
124-126	3.586	0.037	3.959	0.050	1.392	0.010	0.558	0.007
127-129	0.012	0.001	0.835	0.007	41.908	0.656	0.884	0.014
130-132	0.018	0.001	0.050	0.003	3.668	0.048	0.142	0.002
133-135	0.006	0.001	1.858	0.023	5.221	0.064	ND	0.001
136-138	0.068	0.001	0.000	0.001	0.473	0.006	ND	0.000
139-141	1.714	0.018	1.382	0.023	0.652	0.008	ND	0.001
142-144	0.305	0.005	0.113	0.003	1.195	0.012	ND	0.000
145-147	0.465	0.008	0.000	0.002	0.503	0.006	ND	0.000
148-150	0.463	0.006	0.387	0.009	1.161	0.020	1.001	0.018
151-153	ND	0.001	ND	0.001	13.091	0.131	1.789	0.028
154-156	0.108	0.002	ND	0.001	7.921	0.119	1.779	0.028
157-159	1.588	0.011	0.075	0.002	0.749	0.008	0.013	0.000

***Cation exchange softeners were in use at the sites of samples 001-003 and 079-081*

Table 1. (continued)

Formation	**# of As samples**	**# of As samples > 10** µg/L	**Mean As (**µg/L**)**	**Median As (**µg/L**)**	**Max As (**µg/L**)**	**Min As (**µg/L**)**
Entire study	53	12	7.76	2.87	64.86	0.01
Passaic	27	9	10.12	6.40	46.14	0.02
Lockatong	6	2	20.04	6.26	64.86	0.58
Diabase	7	1	2.10	0.19	11.83	0.06
Precambrian / Cambrian*	12	0	0.20	0.07	1.27	0.01
Other**	1	0	0.70	0.70	0.70	0.70

Results greater than 10 µg/L are considered elevated according to federal and Pennsylvania state drinking water standards.

* = Precambrian and Cambrian lithologic units: combined results of felsic to mafic gneiss, Hornblende gneiss, and Leithsville Formation
** Other = Trenton Gravel

Table 2.

Formation	**# of As samples**	**# of As samples > 10** μg/L	**Mean As (**μg/L**)**	**Median As (**μg/L**)**	**Max As (**μg/L**)**	**Min As (**μg/L**)**
*All PA DEP**	2310	630	9	2	83	ND
Passaic	1538	577	13	5	83	ND
Lockatong	283	42	4	ND	64	ND
Diabase	142	7	2	ND	42	ND
Precambrian / Cambrian**	347***	4	<1	ND	24	ND

Results greater than 10 μg/L are considered elevated according to federal and Pennsylvania state drinking water standards.

*Represents data from PA DEP Drinking Water and Sampling Information System database (PA DEP, 2004) from the same formations as this study. PA DEP data may represent parts of some formations that are outside of this study's extent
** = Precambrian and Cambrian lithologic units: combined results of felsic to mafic gneiss, Hornblende gneiss, and Leithsville Formation
***one sample result not included due to a data entry decimal point placement error
ND = Nondetect

Table 3.

FIGURES

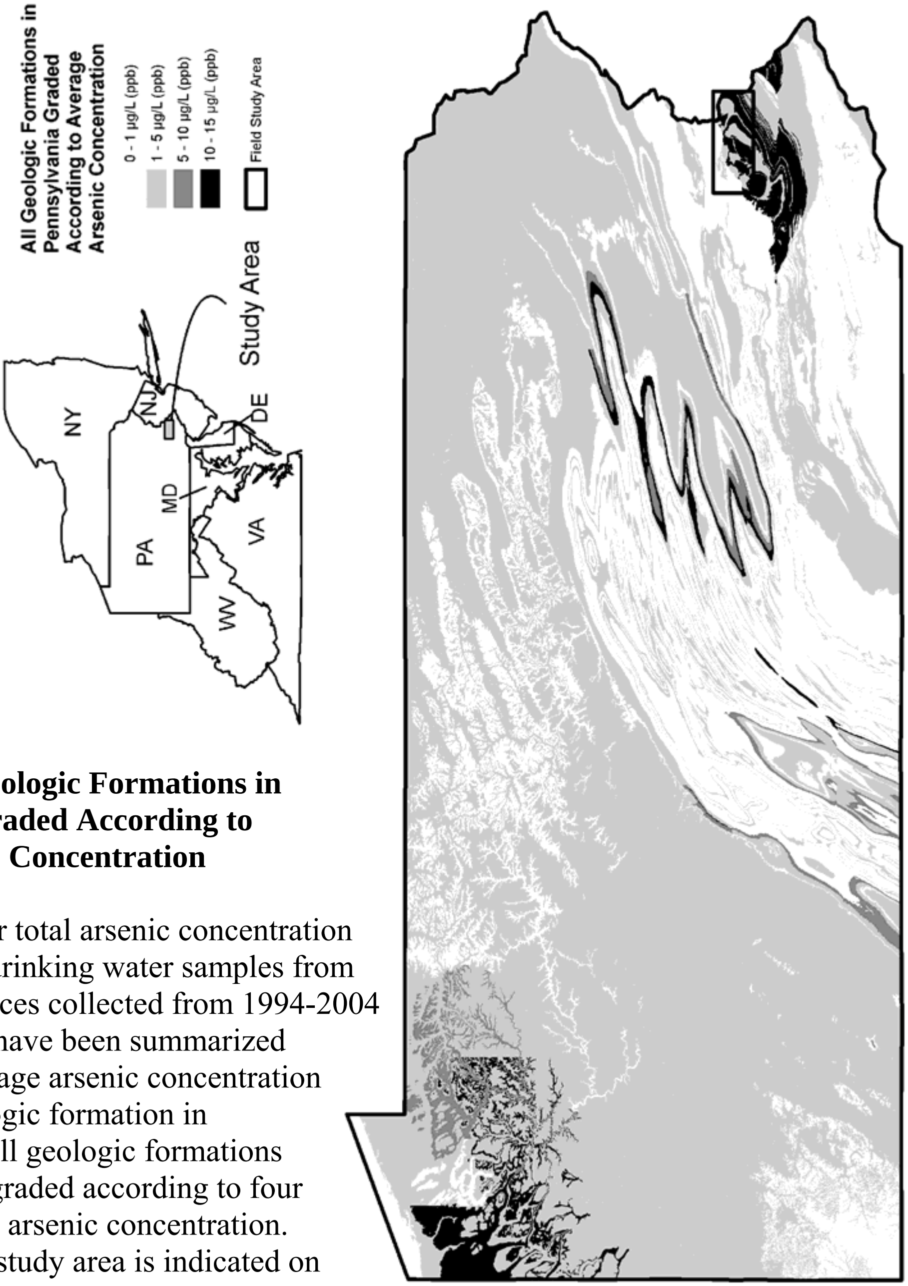


Figure 1. All Geologic Formations in Pennsylvania Graded According to Average Arsenic Concentration (PA DEP, 2004).
18, 277 results for total arsenic concentration in Pennsylvania drinking water samples from groundwater sources collected from 1994-2004 (PA DEP, 2004) have been summarized according to average arsenic concentration within each geologic formation in Pennsylvania. All geologic formations have been color-graded according to four ranges of average arsenic concentration. The chosen field study area is indicated on the map and is also shown in Figure 2. Bedrock geology used in the summary is from Miles and Whitfield (2001).

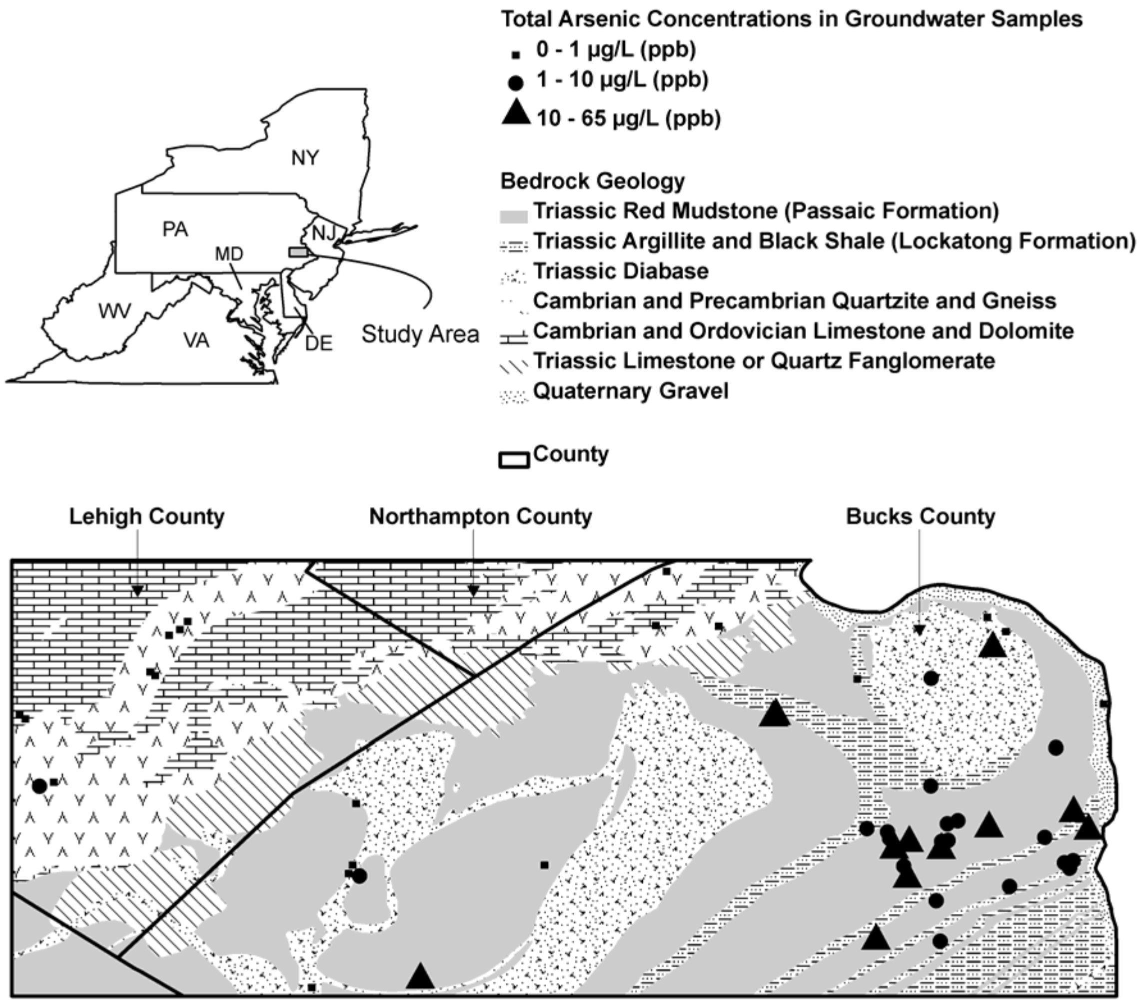


Figure 2. Field Study Site Location Map.
Groundwater sample locations are plotted on the bedrock geology from Miles and Whitfield (2001). All groundwater samples were filtered to 0.45 micron.

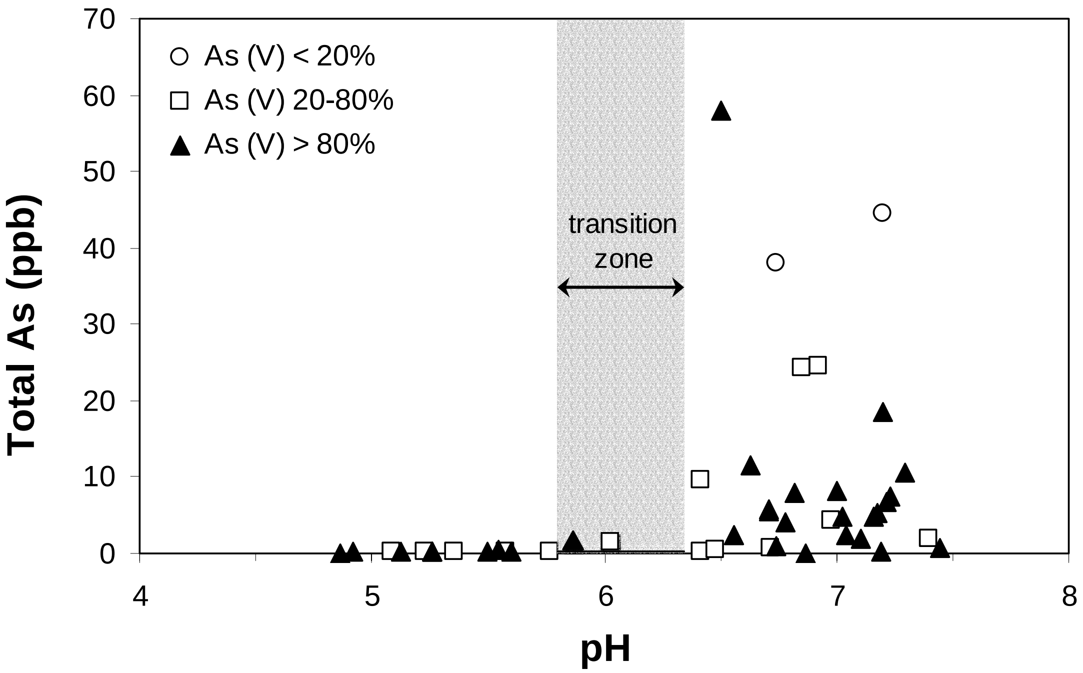


Figure 3. Plot of total As concentration vs. pH in groundwater samples. Open circles contain less than 20% arsenate (As (V)). Open squares contain between 20 and 80% As (V). Solid triangles contain more than 80% As (V).

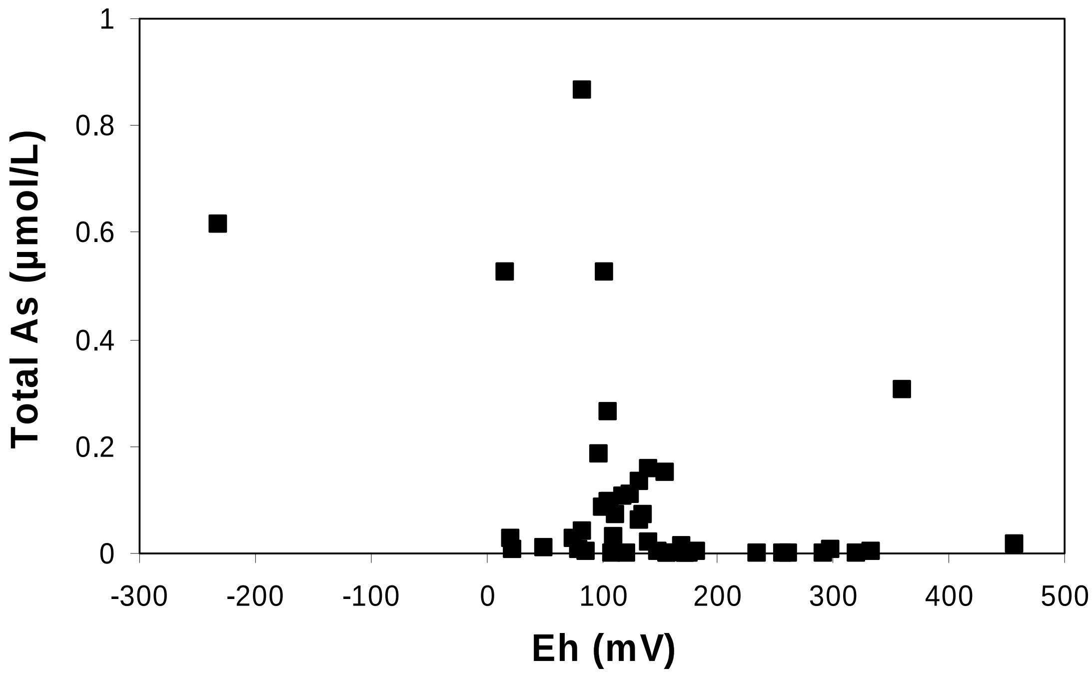


Figure 4. Plot of total As concentration vs. Eh in groundwater samples.

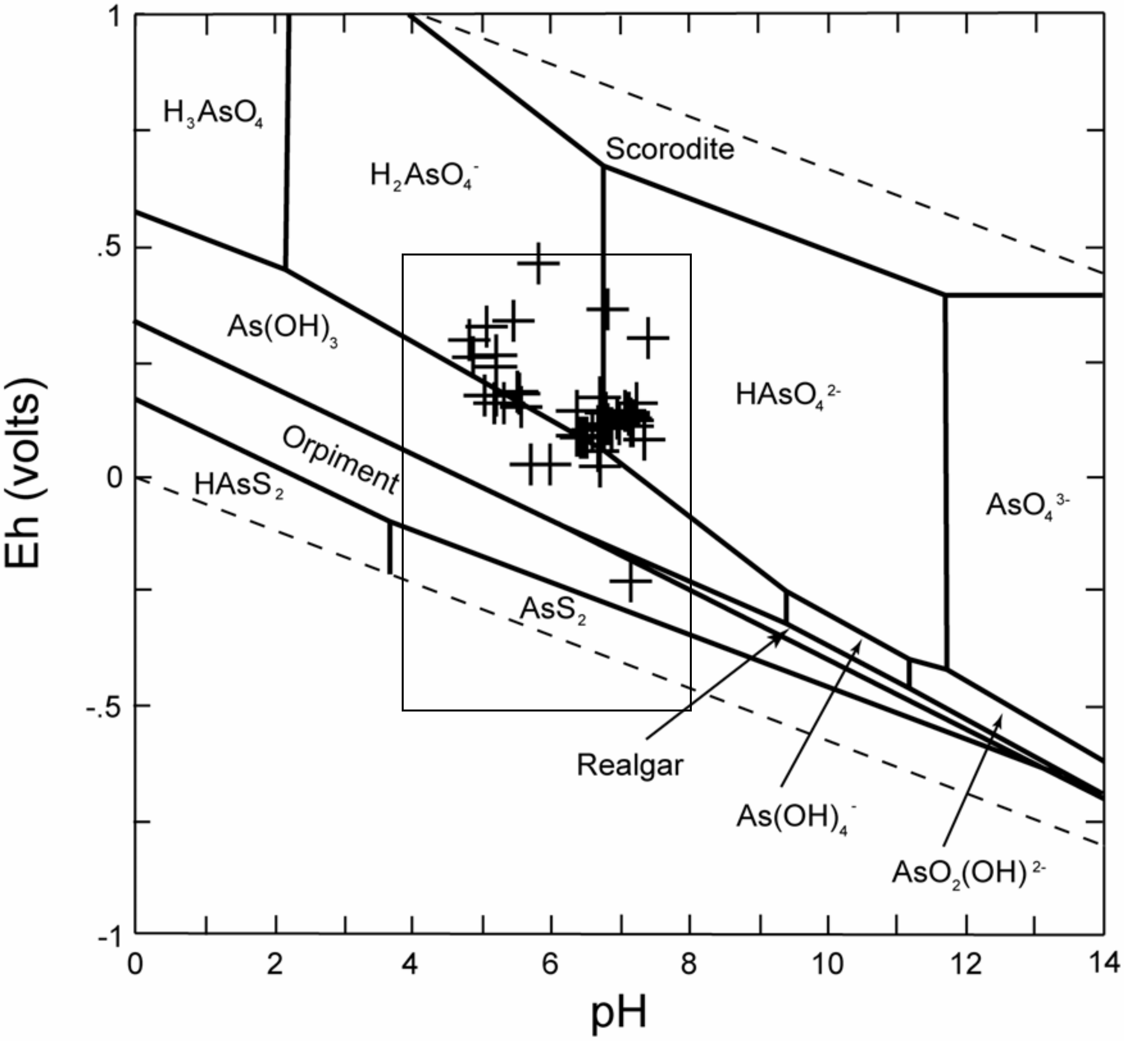


Figure 5. Eh-pH diagram of the Fe-As-SO$_4$-H$_2$O system.
Stability fields modeled using Geochemist's Workbench (Bethke, 2000). *As* concentration fixed at 10 ppb = 0.13 µmol/L for modeling purposes. Fe concentration fixed at 10 ppb = 0.18µmol/L. SO$_4$ concentration fixed at 30 ppm = 312 µmol/L. Temperature fixed at 13°C. This study's data are plotted by measured Eh and pH. The box around the data represents the data range shown in Figure 6.

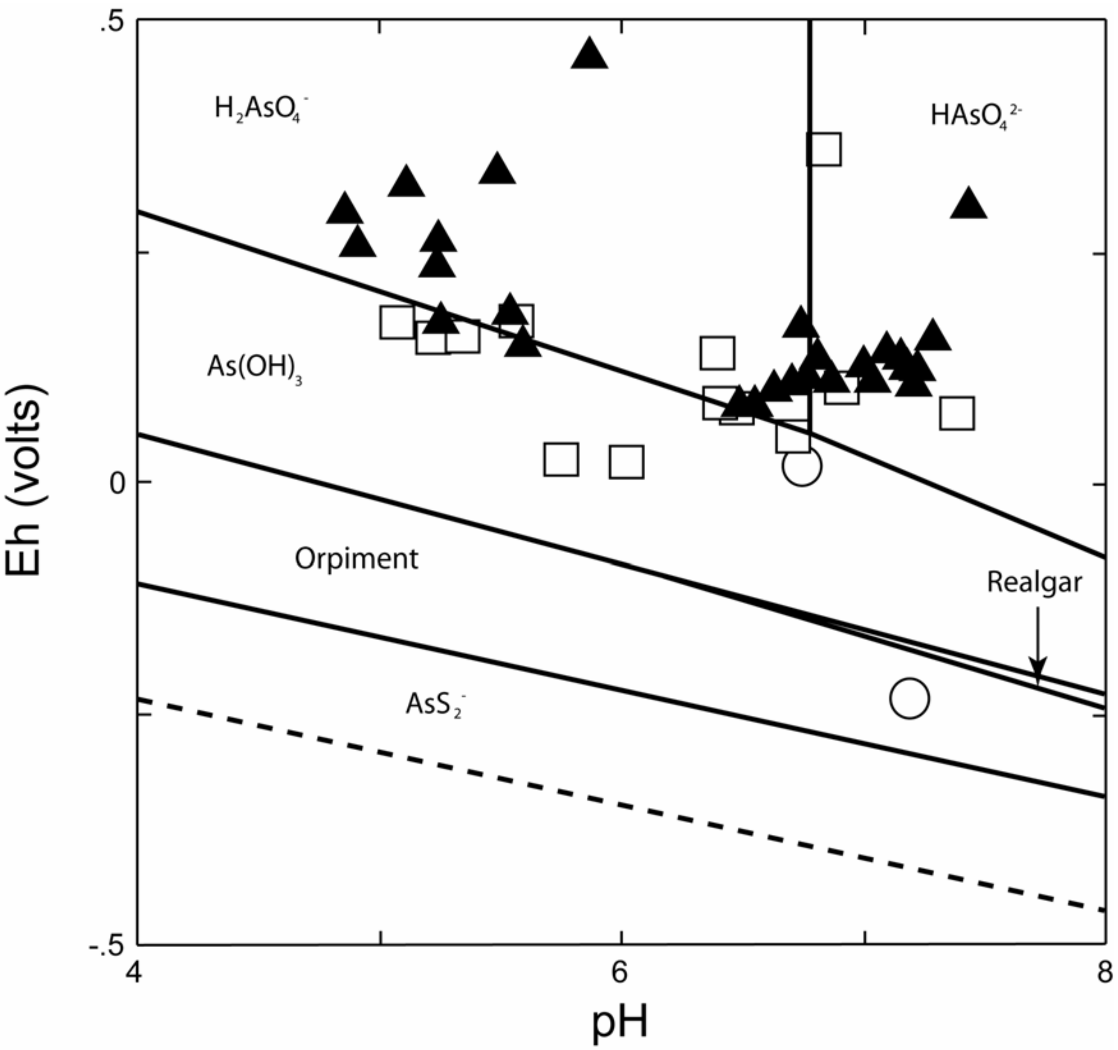


Figure 6. Eh-pH diagram of the Fe-As-SO_4-H_2O system plotted for dominant As species, Eh range -0.5 to 0.5 and pH range 4 to 8.
Stability fields modeled using Geochemist's Workbench (Bethke, 2000). *As* concentration fixed at 10 ppb = 0.13 µmol/L for modeling purposes. Fe concentration fixed at 10 ppb = 0.18µmol/L. SO_4 concentration fixed at 30 ppm = 312 µmol/L. Temperature fixed at 13°C. This study's data are plotted by measured Eh and pH according to different percentages of arsenate (As(V)) present. Open circles contain less than 20% As (V). Open squares contain between 20 and 80% As (V). Solid triangles contain more than 80% As (V). n=45

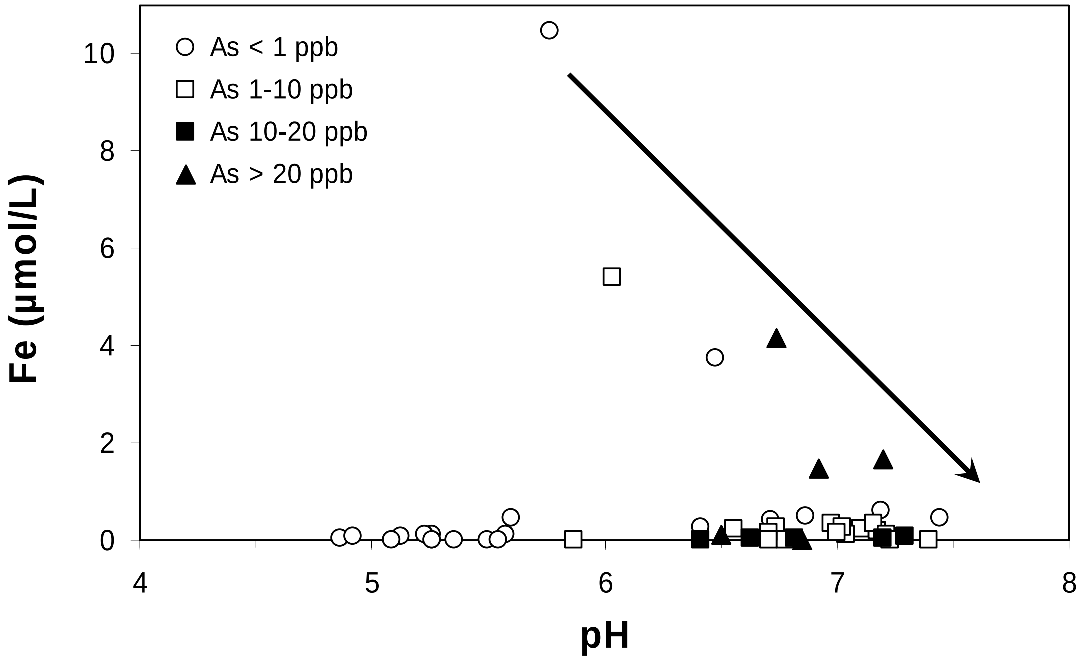


Figure 7. Plot of aqueous Fe concentration vs. pH in groundwater samples. Precipitation of Fe is kinetically controlled by pH. Open circles contain total As < 1 ppb (µg/L). Open squares contain total As 1-10 ppb (µg/L). Solid Squares contain total As 10-20 ppb (µg/L). Solid triangles contain total As > 20 ppb (µg/L).

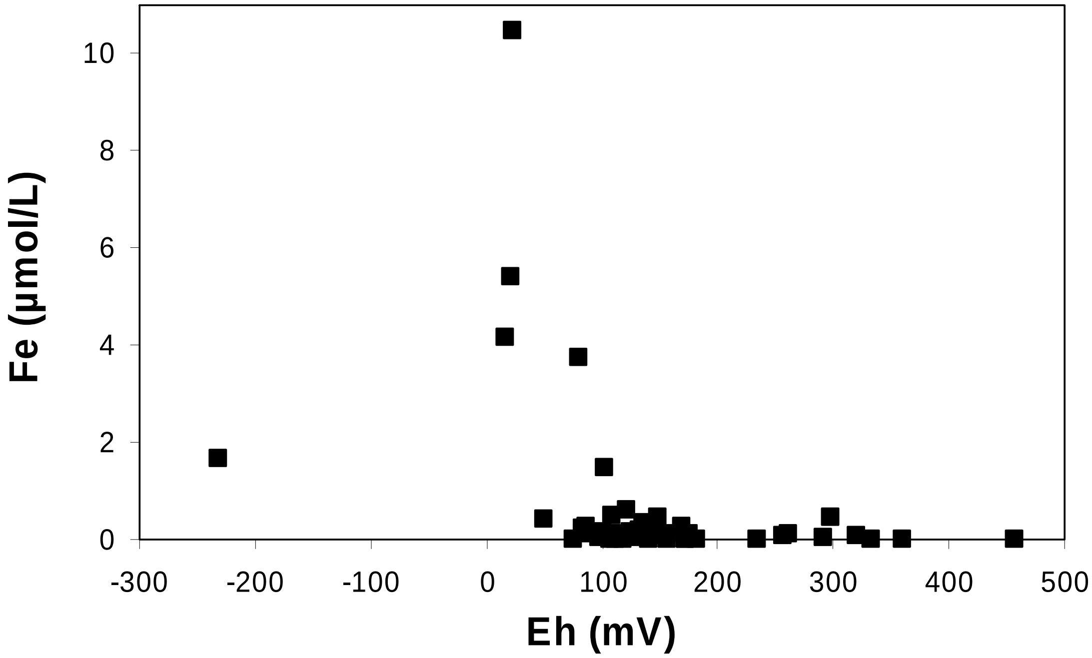


Figure 8. Plot of aqueous Fe concentration vs. Eh in groundwater samples.

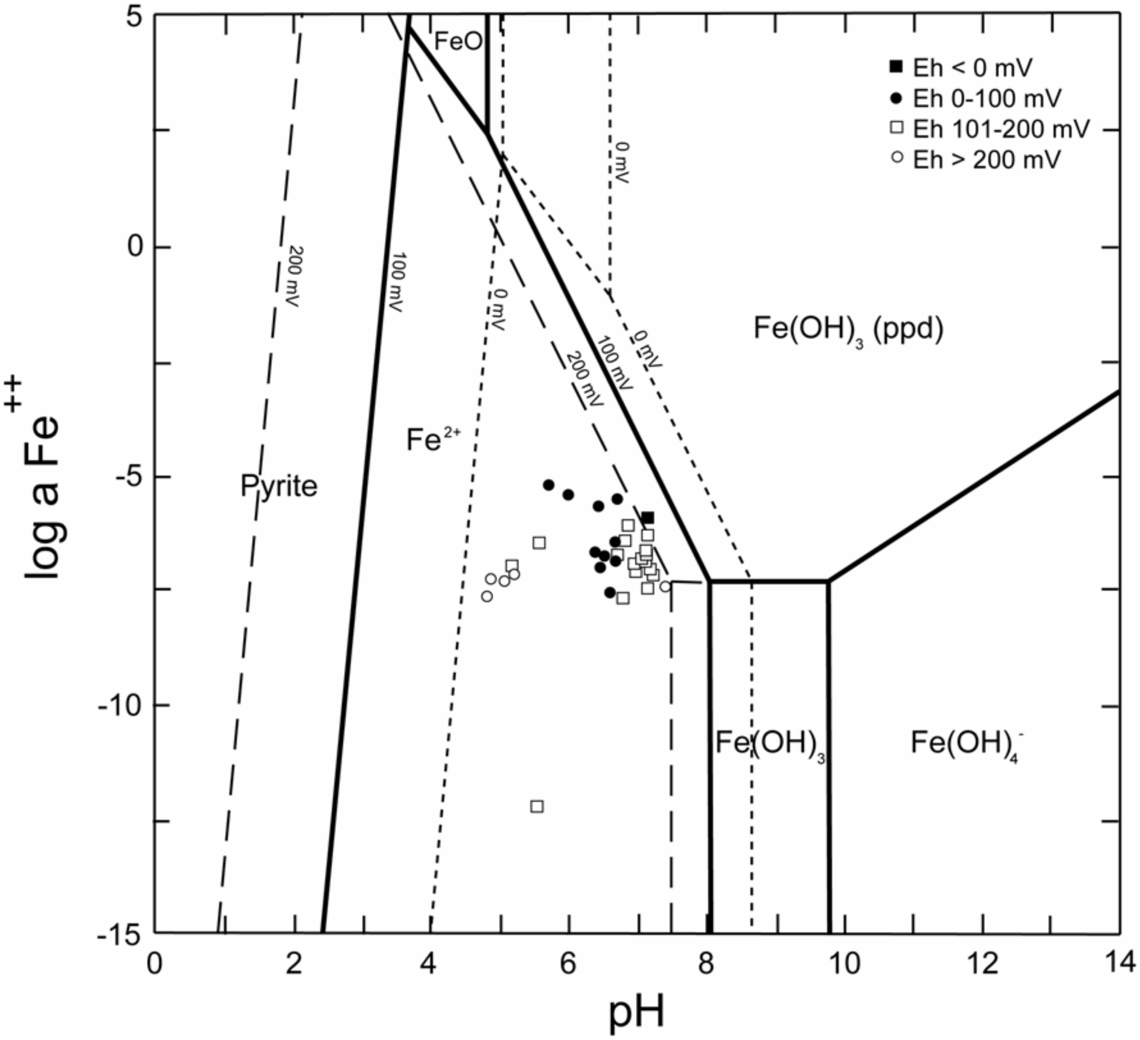


Figure 9. Activity diagram of Fe activity under variable pH conditions.
Stability fields are based on thermodynamic calculations of Fe solubility from Bethke (2000). Stability fields were calculated for Eh = 0 mV, Eh = 100 mV and Eh = 200 mV. SO_4 concentration fixed at 30 ppm = 312 µmol/L. Temperature fixed at 13°C. This study's data are plotted by measured Fe activity and pH according to different measured Eh ranges. Eh ranges are represented by different markers. Closed squares represent Eh < 0 mV. Closed circles represent Eh 0-100 mV. Open squares represent Eh 100 – 200 mV. Open circles represent Eh > 200 mV. Goethite, hematite, magnetite, and malanterite were suppressed during modeling. n = 32

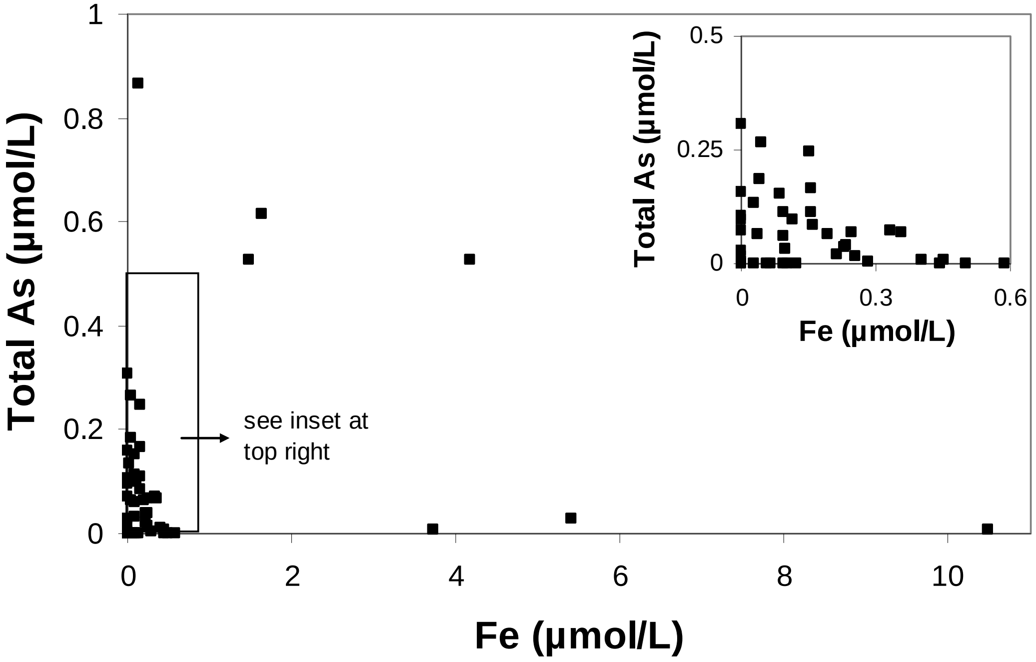
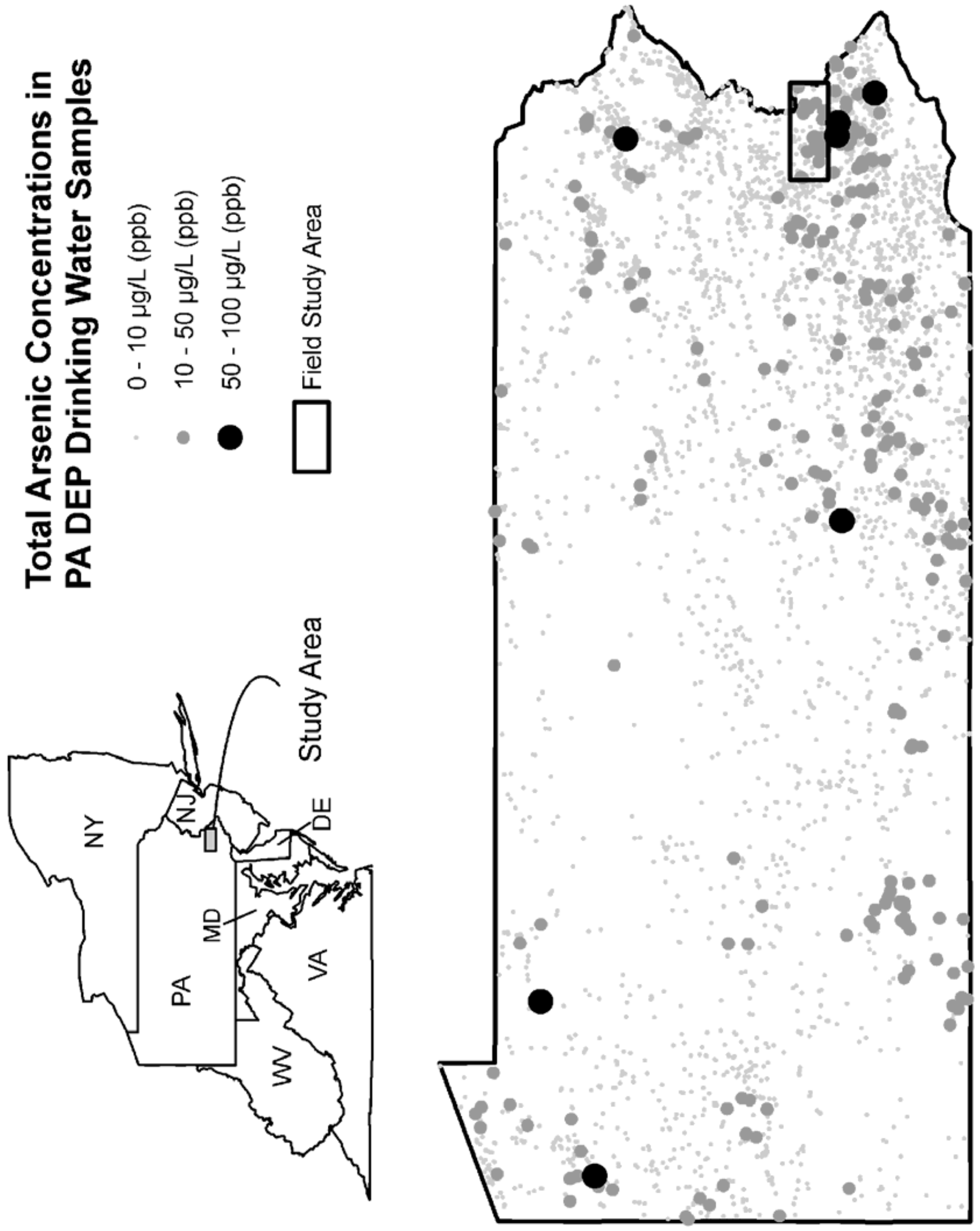
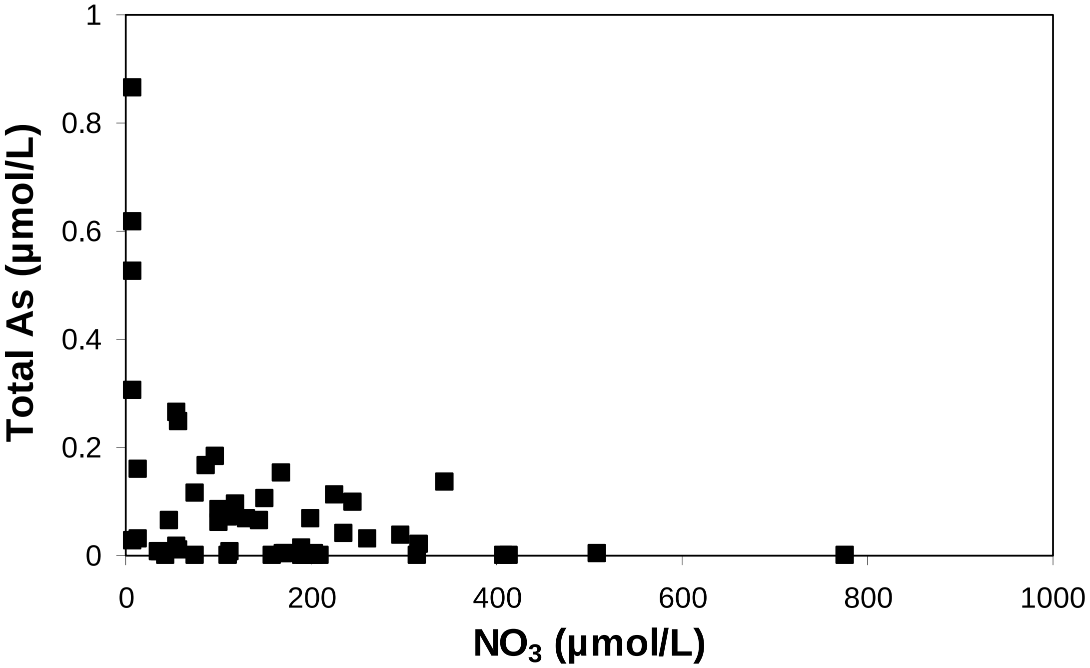


Figure 10. Plot of total As concentration vs. Fe in groundwater samples. See inset in top right corner for enlargement of total As (µmol/L) vs. Fe (µmol/L) at low concentrations of each.

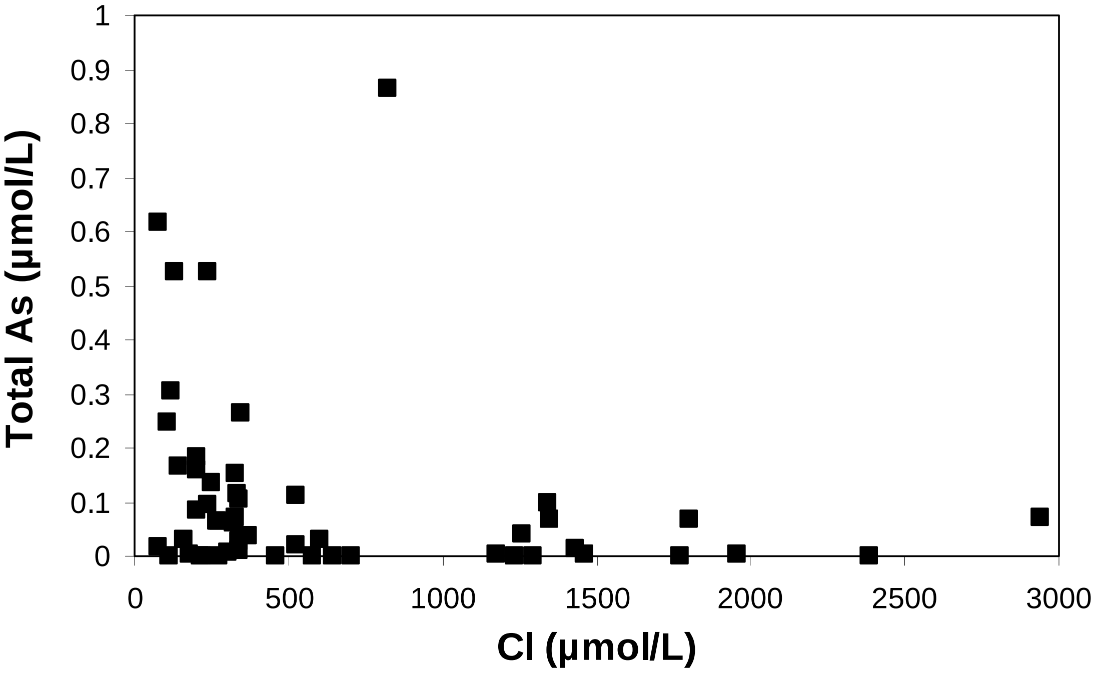
APPENDIX



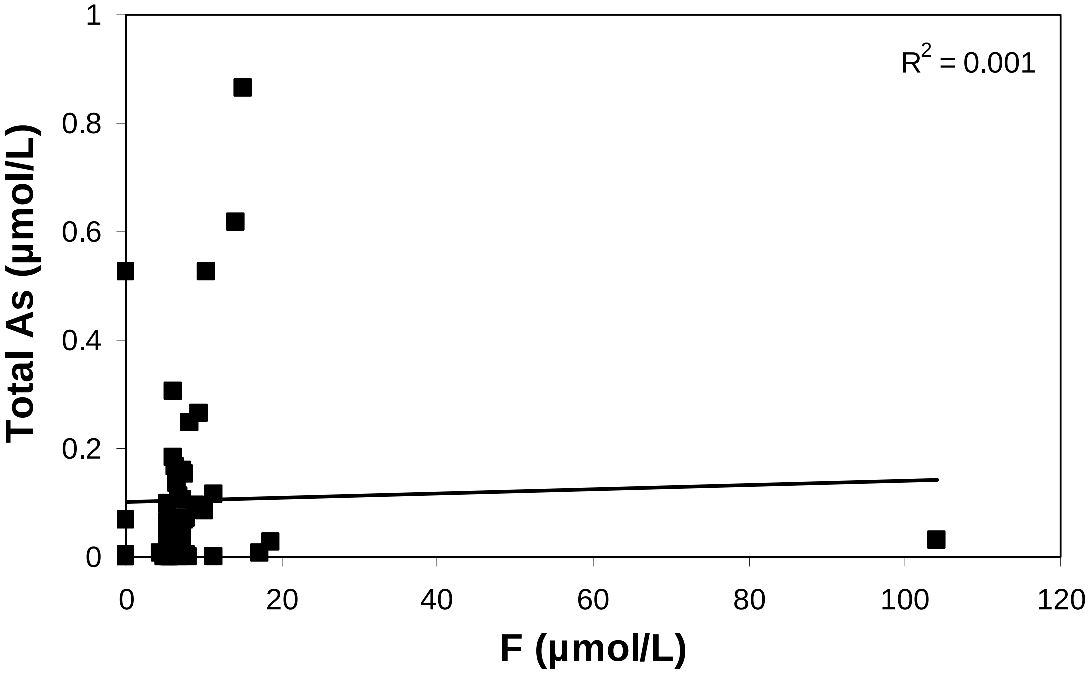
Appendix Figure 1: Distribution of total arsenic concentrations in drinking water samples from the PA DEP Drinking Water and Sampling Information System database (PA DEP, 2004). Samples represent all drinking water samples for As collected for regulatory purposes by regulated public water systems from 1994-2004. Multiple samples collected at individual sites plot on top of each other. n=18,277



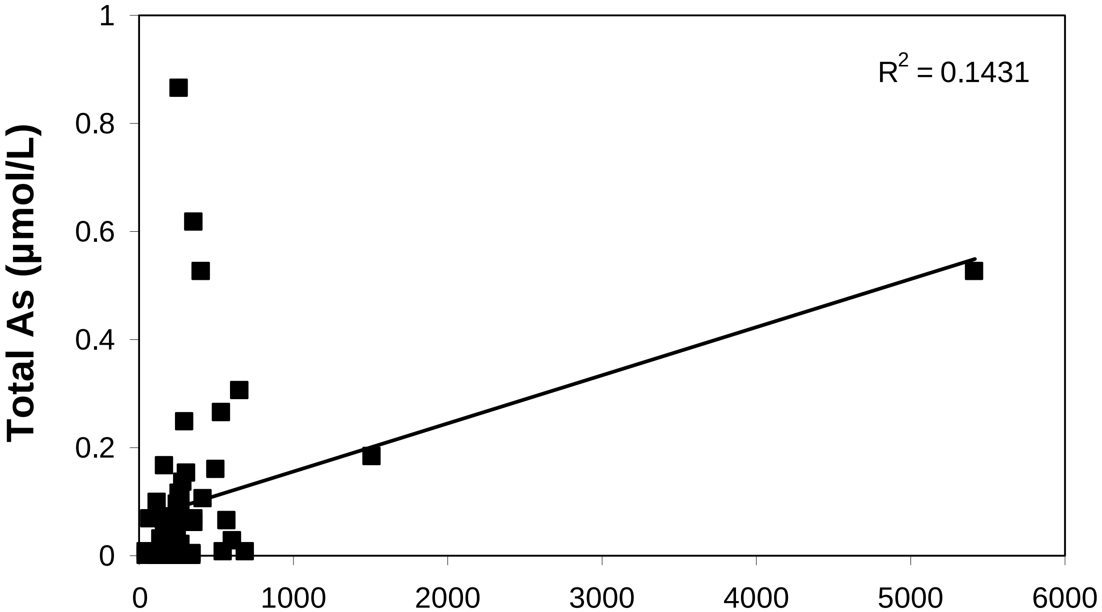
Appendix Figure 2: Plot of Total As vs. NO$_3$. Inverse relationship.



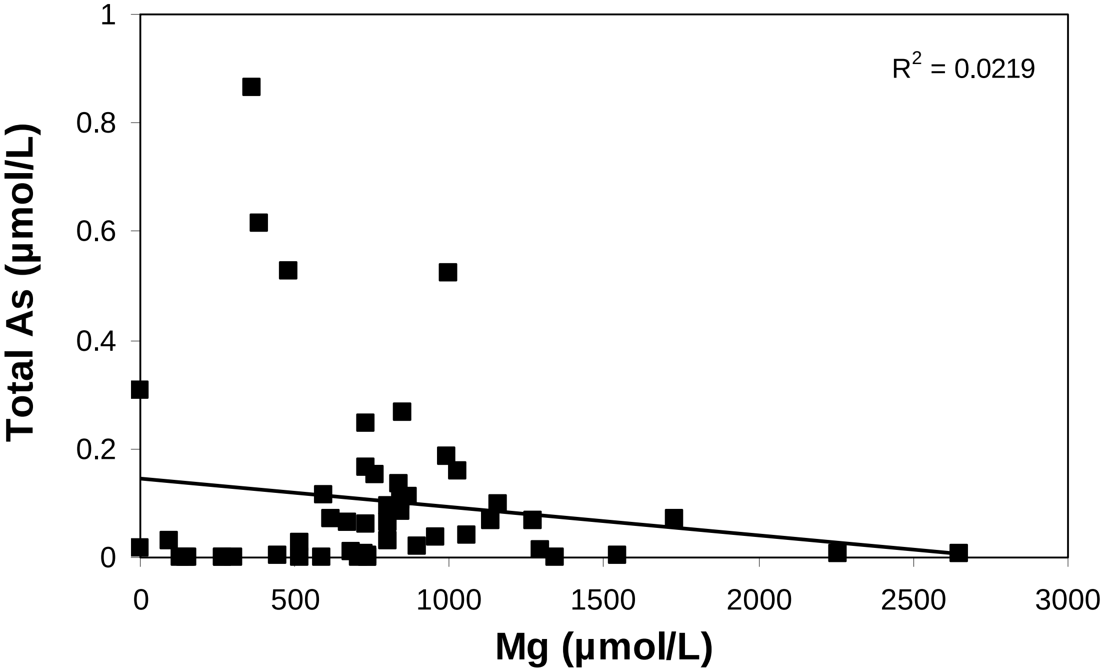
Appendix Figure 3: Plot of Total As vs. Cl. Inverse relationship.



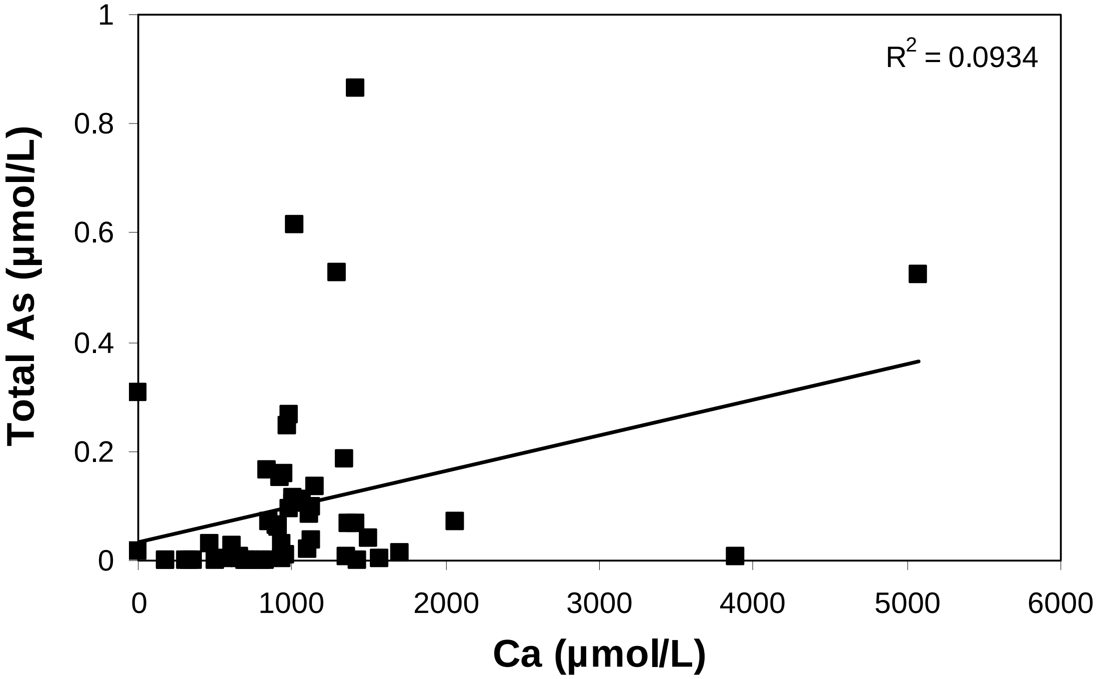
Appendix Figure 4: Plot of Total As vs. F. Relationship unlikely.



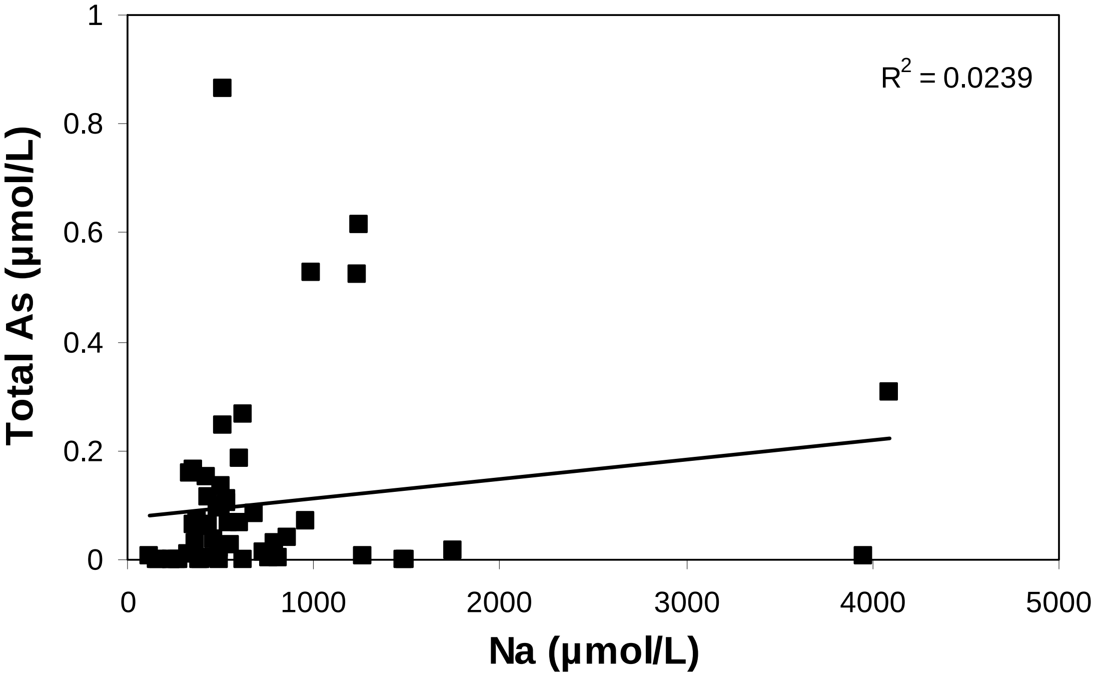
Appendix Figure 5: Plot of Total As vs. SO$_4$. Relationship unlikely.



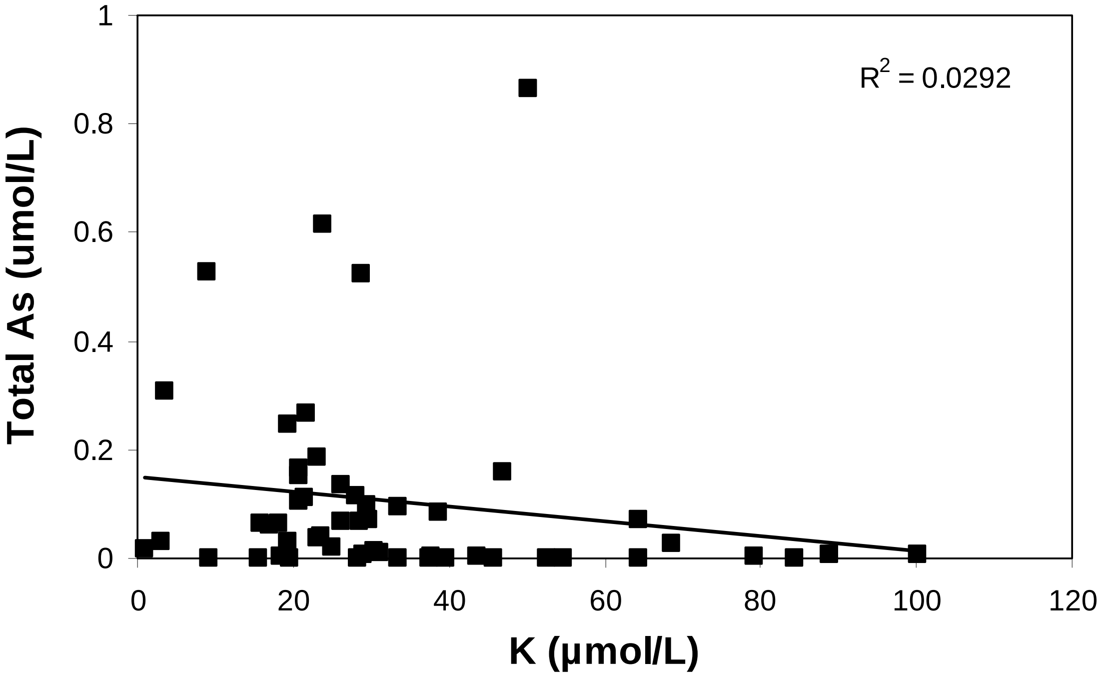
Appendix Figure 6: Plot of Total As vs. Mg. Relationship unlikely.



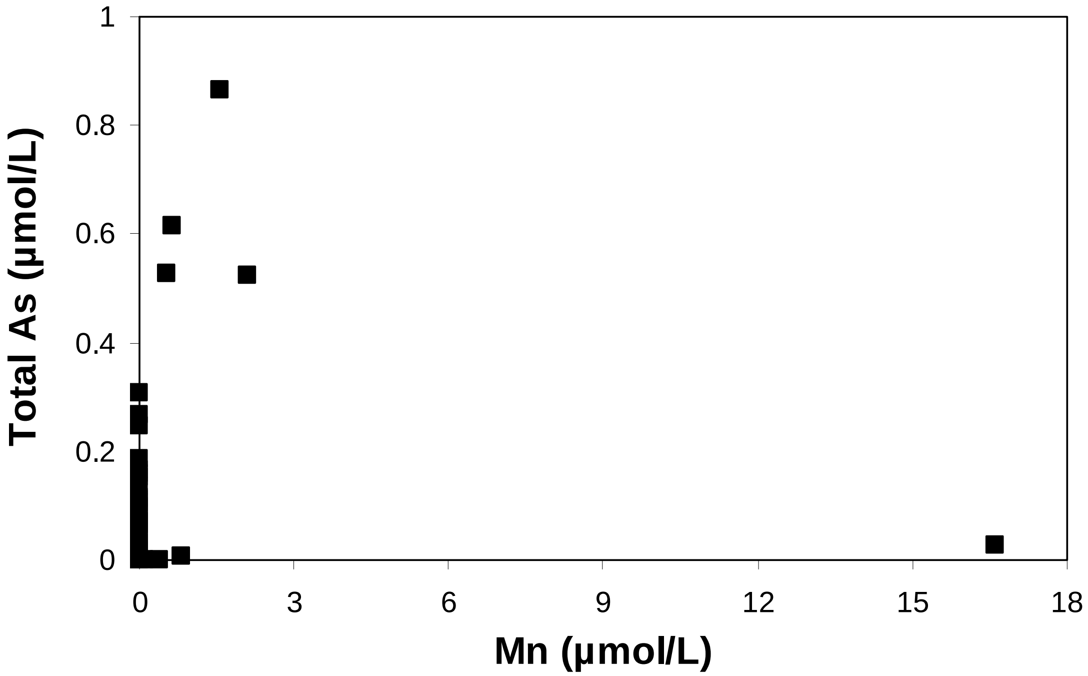
Appendix Figure 7: Plot of Total As vs. Ca. Relationship unlikely.



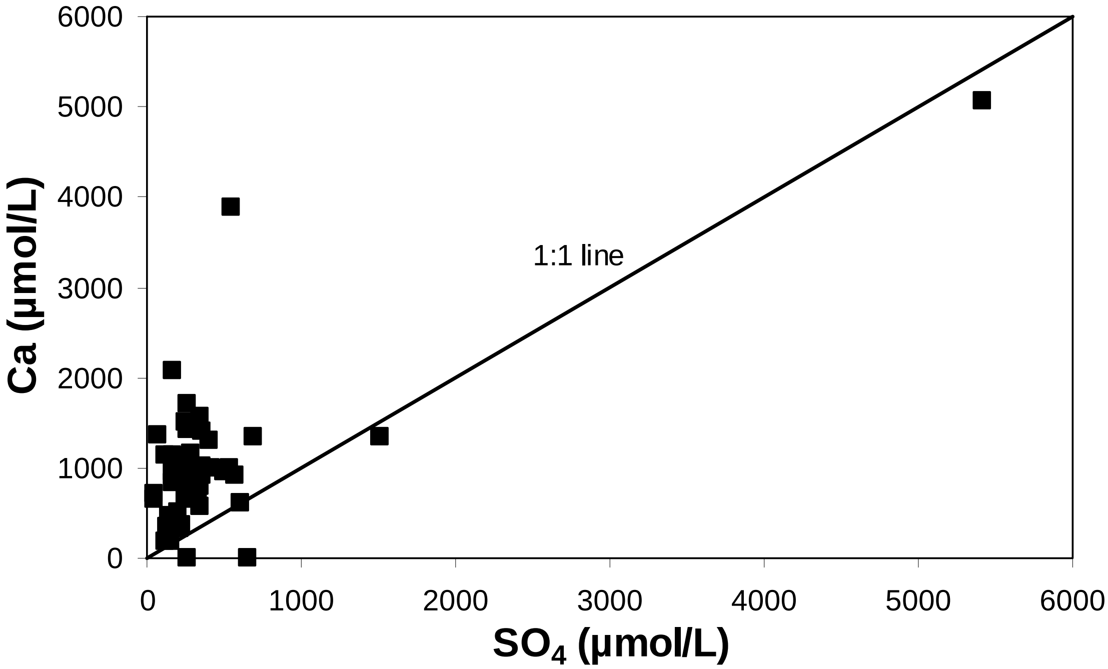
Appendix Figure 8: Plot of Total As vs. Na. Relationship unlikely.



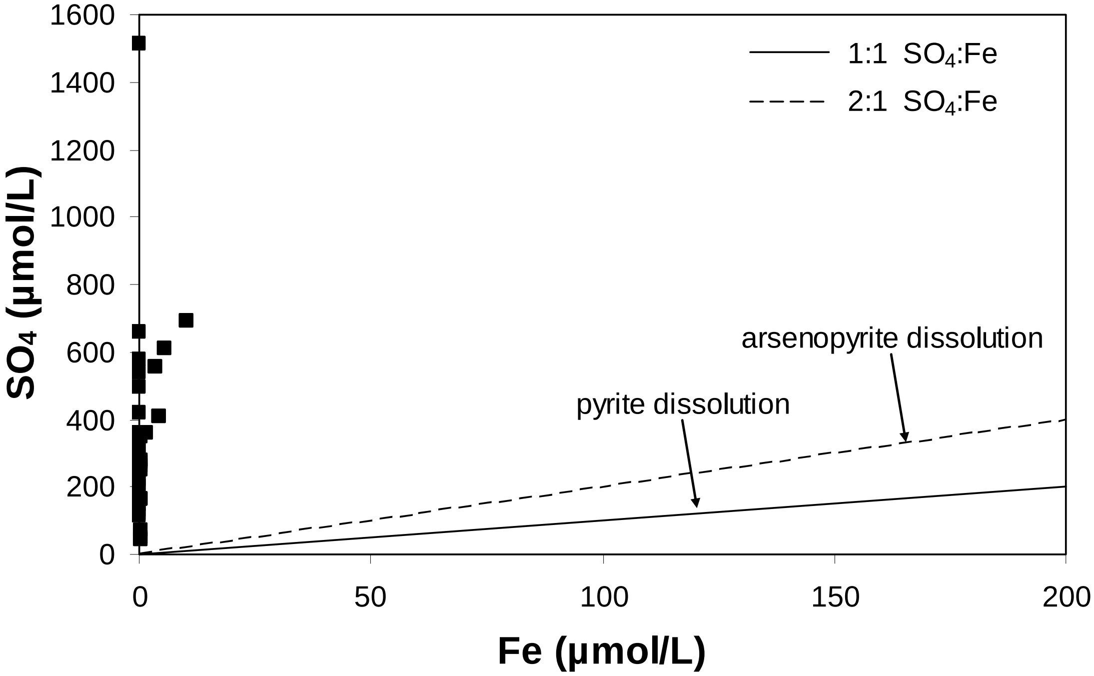
Appendix Figure 9: Plot of Total As vs. K. Relationship unlikely.



Appendix Figure 10: Plot of Total As vs. Mn. Relationship unlikely.



Appendix Figure 11: Plot of Ca vs. SO_4. Lack of 1:1 molar agreement between Ca and SO_4 suggest gypsum ($CaSO_4$) dissolution is unlikely.



Appendix Figure 12: Plot of SO_4 vs. Fe. Molar quantities of SO_4 and Fe do not suggest pyrite or arsenopyrite oxidation as major release mechanisms.

CURRICULUM VITAE

Mrs. Lori A. (Skibiel) Burkert

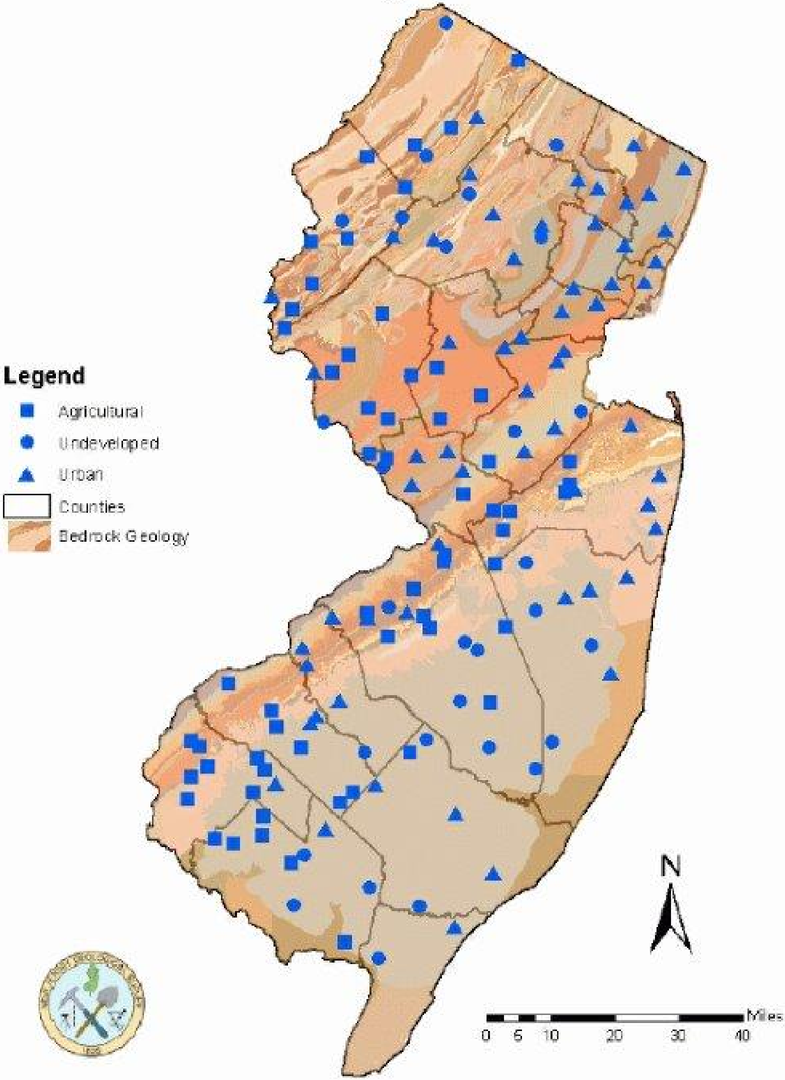
Date of Birth	September 15, 1979
Place of Birth	Pottsville, Pennsylvania
Mother	Patricia A. (Spolski) Skibiel
Father	Joseph R. Skibiel
Education	Lehigh University, Department of Earth and Environmental Sciences, Bethlehem, PA • M.S. graduate coursework, Hydrogeology and Geochemistry, Fall 2004 to Fall 2006 Elizabethtown College, Department of Biology, Elizabethtown, PA • Bachelor of Science in Environmental Science, August 2001 La Universidad San Francisco de Quito, Quito, Ecuador • Study abroad, Spring 2001
Honors & Titles	• Environmental Protection Agency Science to Achieve Results (STAR) Graduate Fellow (FP-916622) – 2005-2006 • Lehigh University Palmer Grant – Summer 2005 • Lehigh University Provost Fellowship – Fall 2004 • Elizabethtown College – Graduated Summa Cum Laude • Elizabethtown College Scholar Distinction – 1999, 2000 • Elizabethtown College Presidential Scholar – 1997-2001
Publications	Geological Society of America Annual Meeting, Fall 2006: Peters, S and Burkert, L. Arsenic Along the Appalachian Mountain Belt, Patterns and Processes. Electronic Abstract. Online. Northeast Regional Geological Society of America Meeting, Spring 2006: Burkert, L. Geologic Controls on Arsenic Distribution and Mobilization in Pennsylvania Groundwater. Electronic Abstract. EPA grant number FP-916633. Online.
Professional	**Environmental Specialist (May 29, 2006 – Present, *as of 8/11/06*)** **Spotts, Stevens & McCoy, Inc.** **Reading, PA; Geoenvironmental Services: Water Resources** Conduct groundwater studies for new sources of drinking water supply, watershed protection, and contaminant delineation modeling.

Water Supply Specialist (November 19, 2001 – August 2004)
Pennsylvania Department of Environmental Protection
Reading, PA; Water Supply Management, Reading District
Enforced PA Safe Drinking Water Act and inspected public drinking water systems. Advised grant recipients receiving Pennsylvania Department of Environmental Protection Growing Greener grants.

ATTACHMENT 6

New Jersey Ambient Groundwater Monitoring Results

New Jersey's Ambient Groundwater Quality Monitoring Network



Ambient water data associated with shallow wells for two sampling cycles.

# STAID	**UID**	**Network Id**	**Mon Well #**	**WMA**	**Hydro Aqui**	**Land Use**	**County**	**Municipality**	**Date Sampled**	**As (ug/L)**
402501074505001	190452	mw-106	106	8	227PSSC	AG	Hunterdon	East Amwell	20030701	2.1
402501074505001	190452	MW106	106	8	227PSSC	AG	Hunterdon	East Amwell	20080811	2.2
402633074541301	190456	mw-91	91	8	227PSSC	AG	Hunterdon	Delaware	20030910	2.9
402633074541301	190456	MW91	91	8	227PSSC	AG	Hunterdon	Delaware	20080709	1.4
401829074513301	21033	mw-80	80	11	227PSSC	UND	Mercer	Hopewell	20040617	1.1
401829074513301	21033	mw-80	80	11	227PSSC	UND	Mercer	Hopewell	20090629	1.5
404900075043601	410568	mw-95	95	1	112SFDF	AG	Warren	White	20040623	0.4
404900075043601	410568	MW95	95	1	112SFDF	AG	Warren	White	20080813	0.24

Source Data: NJGS

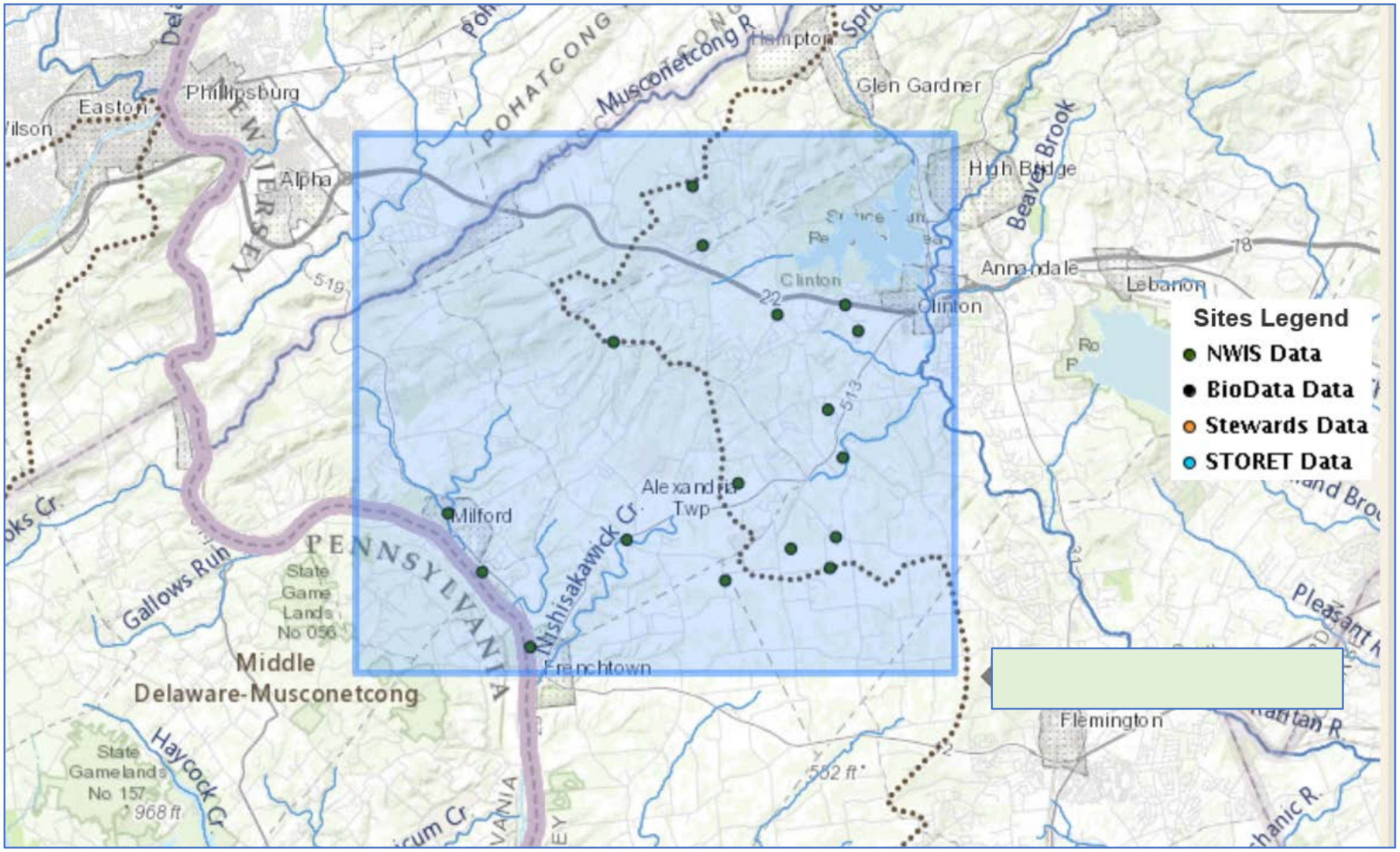
USGS and NJDEP Well Data for As (ug/L) within 3 miles of the Delaware River.

Location	Latitude	Longitude	N	Min	Max	Mean	Median	90thP	95thP
SW Hunterdon	40.362382	-74.89838	51.0	0.0	24.7	4.9	3.0	13.0	15.2
CW Hunterdon	40.470057	-75.02	26.0	0.0	25.0	5.3	3.6	10.9	11.6
NW Hunterdon	40.598112	-75.01881	22.0	0.0	9.0	2.3	1.2	6.0	7.9

Values with "0" were added in instances where As was "not detected" in raw data files

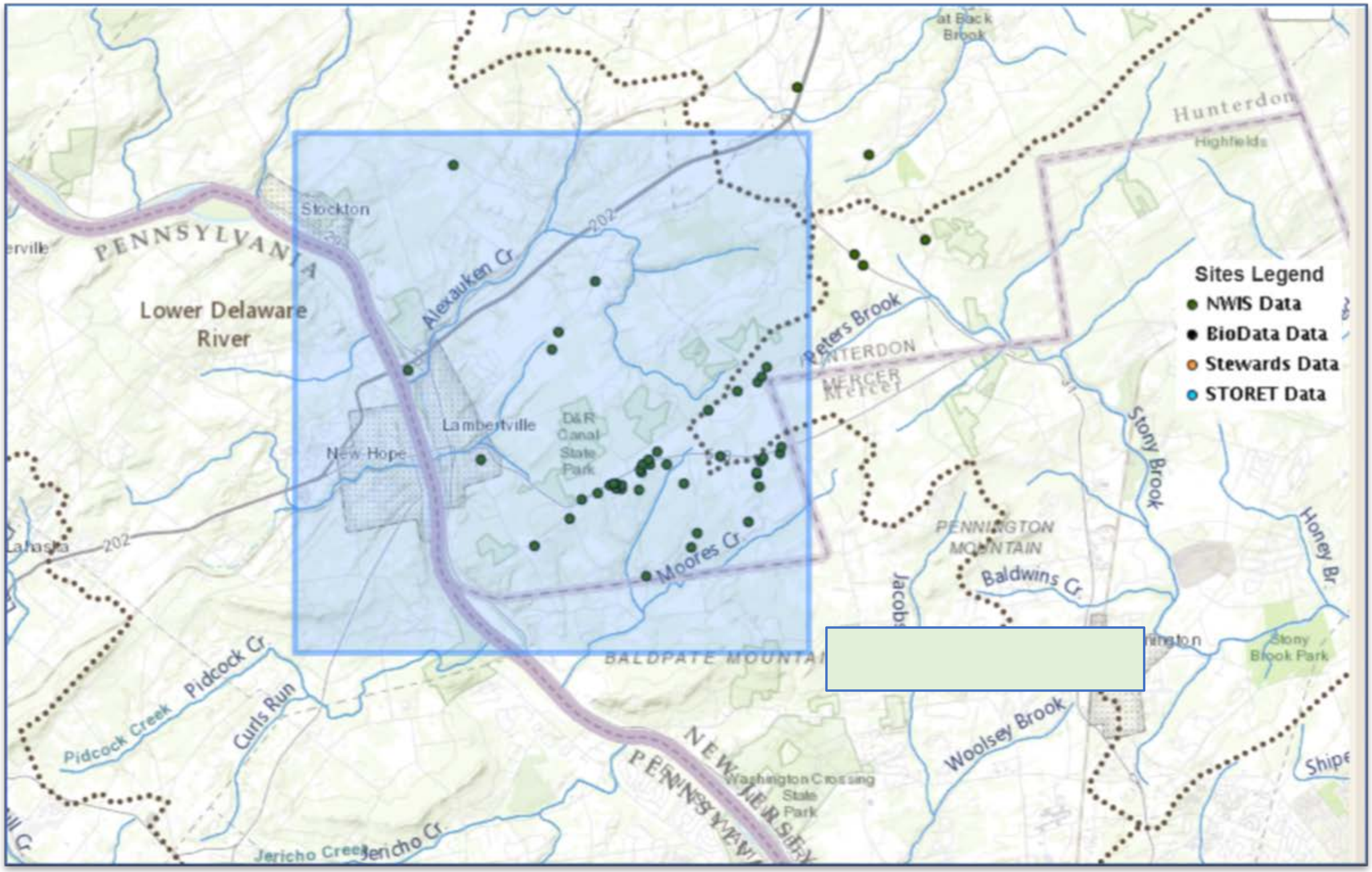
*Based on well data that lie within a 5 mile radius of the coordinates.

Source Site: NWQMC



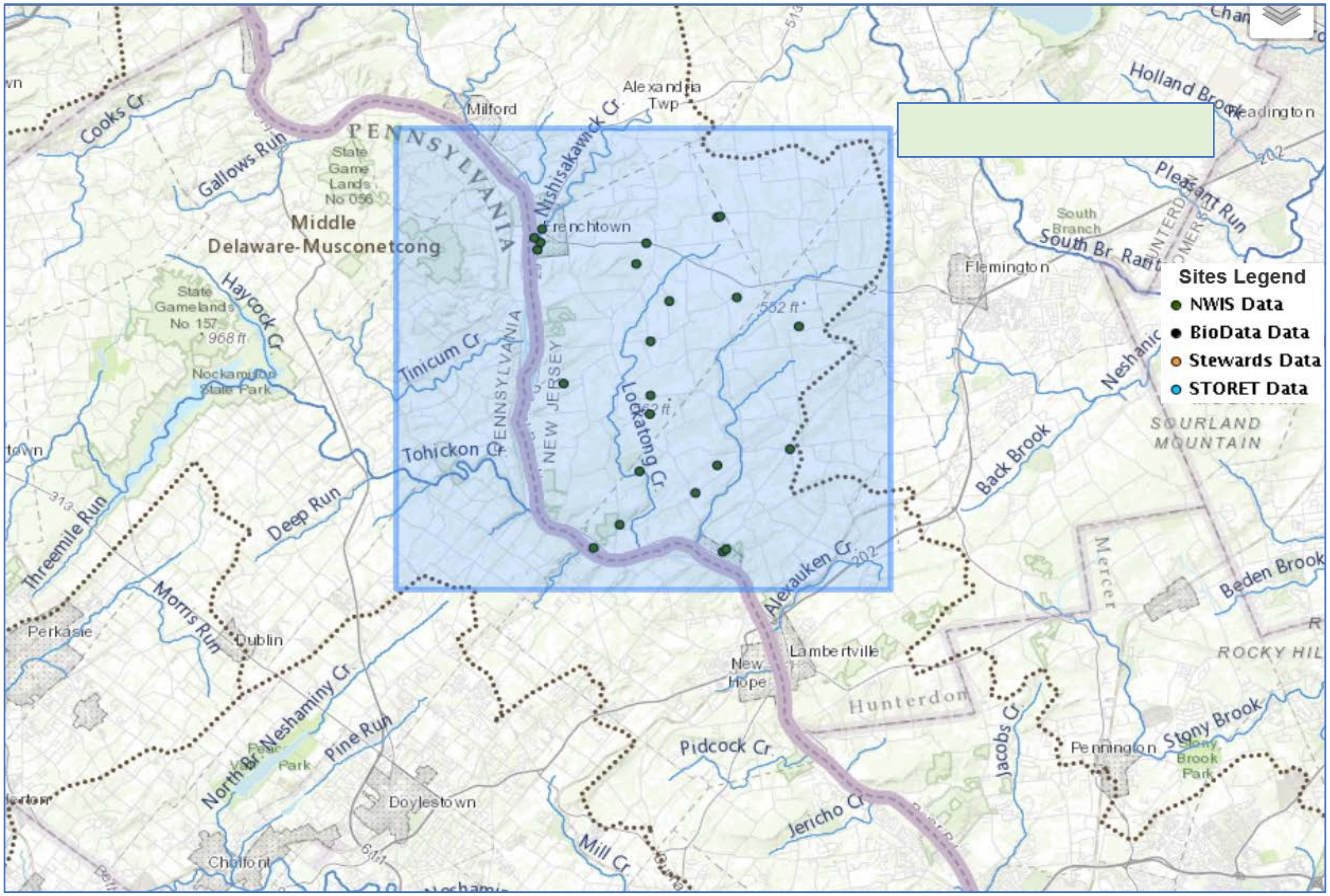
Screen shot of mapped well clusters in Northwest Hunterdon that were used for NWQMC As data aquisition

Source Site: NWQMC



Screen shot of mapped well clusters in Southwest Hunterdon that were used for NWQMC As data aquisition

Source Site: NWQMC



Screen shot of mapped well clusters in West Central Hunterdon that were used for NWQMC As data aquisition

Source Site: NWQMC

NJGWS Digital Geodata Series DGS05-2 New Jersey's Ambient Groundwater Quality Network Data

Abstract

This workbook includes the data from the original ambient groundwater quality network (pre-1999) and both complete sampling cycles of the redesigned ambient groundwater quality monitoring network (1999-2008). The pre-1999 data is separated from the redesigned network data. The redesigned network data is further separated into sampling sets, which are designated by the year the well was initially sampled. The first sampling set of sampling cycle one began in 1999 and fifth sampling set occurred in 2003-2004. The second sampling cycle began in 2004 and concluded in 2008. Sampling cycle data for each sampling set are combined with the second sampling cycle whose values are highlighted in blue for simplified distinction. The data sets includes concentrations for field parameters, major ions, metals, nutrients, pesticides, VOC, and radionuclides.

Pre-1999 Data

Major Ions & Field Parameters

Metals

"-99999" - Estimated Value
"<"- Less Than
Blank cells indicate no sampling performed

Note: None of these wells are used in the current AGWQMN

GWSI Number	Municipality	County	Top Open	Bottom Open	Dates	Temperature Water Degrees Celsius **P00010**	Barometric Pressure mm of Mercury **P00025**	Specfic Conductance Wat. Unfilt. microsimens per cm @25 degrees Celsius **P00095**	Dissolved Oxygen Wat. Unfilt. mg/l **P00300**	pH Wat. Unfilt. Field Standard Units **P00400**	pH Wat. Unfilt. Laboratory Standard Units **P00403**	Arsenic Wat. Filt. µg/l **P01000**
190010	Lebanon Twp	Hunterdon	51.67000	545.00000	10/30/1989	11.800		259.000	0.500	6.900	7.000	<1
190015	Delaware Twp	Hunterdon	26.00000	250.00000	7/23/1987	12.000	760.000	140.000	7.200	6.700	7.000	<1
190017	Kingwood Twp	Hunterdon	50.00000	450.00000	3/8/1988	12.000	760.000	689.000	0.200	9.400	9.100	<1
190019	Readington Twp	Hunterdon	67.00000	150.00000	6/7/1988	12.000	745.000	199.000	6.000	6.400	6.400	<1
190028	Clinton Town	Hunterdon	76.00000	475.00000	5/13/1988	12.500	765.000	342.000	2.700	8.000	7.900	9.000
190032	Raritan Twp	Hunterdon	44.00000	502.00000	7/29/1987	14.000	760.000	830.000	1.900	7.500	7.500	2.000
190037	Delaware Twp	Hunterdon	53.00000	280.00000	7/21/1987	12.000	755.000	340.000	6.600	7.800	7.900	1.000
190039	Alexandria Twp	Hunterdon	42.00000	192.00000	7/21/1987	12.000	755.000	160.000	7.800	6.100	6.400	<1
190043	Raritan Twp	Hunterdon	40.00000	300.00000	7/22/1987	13.000	760.000	1100.000	0.100	7.700	8.000	16.000
190050	East Amwell Twp	Hunterdon	50.00000	350.00000	8/17/1988	14.500	760.000	362.000	3.900	7.600	8.100	3.000
190055	West Amwell Twp	Hunterdon	52.00000	430.00000	6/9/1988	13.000	750.000	395.000	0.100	8.000	7.800	2.000
190063	Tewksbury Twp	Hunterdon	107.00000	230.00000	5/27/1987	12.000		460.000	1.200	7.400	7.600	<1
190069	Union Twp	Hunterdon	61.50000	148.00000	3/3/1988	12.500	755.000	342.000	5.200	7.000	7.200	3.000
190074	West Amwell Twp	Hunterdon	30.33000	107.00000	3/9/1988	13.500	750.000	610.000	4.100	6.500	7.700	9.000
190077	Stockton Boro	Hunterdon	41.40000	278.00000	4/22/1987	12.000		210.000	9.800	6.700	7.100	2.000
190236	Lebanon Twp	Hunterdon	68.00000	200.00000	9/29/1989	10.500	755.000	94.000	5.500	6.300	6.500	<1
190239	East Amwell Twp	Hunterdon	25.00000	42.00000	8/30/1994	11.000	754.000	231.000	6.000	6.200	6.000	<1
190245	Califon Boro	Hunterdon	50.00000	300.00000	10/30/1989	10.600		199.000	9.800	6.600	6.700	<1
190248	Lebanon Twp	Hunterdon	72.00000	330.00000	9/19/1989	11.000	760.000	212.000	6.900	7.100	7.300	<1
190249	West Amwell Twp	Hunterdon	11.50000	63.50000	8/11/1994	13.500	756.000	772.000	5.200	6.800	6.600	<1
190270	Readington Twp	Hunterdon	52.00000	101.00000	8/12/1994	12.500	762.000	97.000	7.200	6.200	6.200	<1
190272	Bethlehem Twp	Hunterdon	51.00000	275.00000	8/27/1990	12.000	740.000	174.000	8.300	6.200	6.400	<1
190273	Glen Gardner Boro	Hunterdon	50.00000	300.00000	9/6/1990	10.500	745.000	154.000	6.500	6.200	6.300	<1
190274	Lebanon Twp	Hunterdon	100.00000	200.00000	9/25/1990	10.500	740.000	202.000	6.400	6.100	6.500	<1
190275	Lebanon Twp	Hunterdon	60.00000	275.00000	9/14/1990	12.000	740.000	185.000	8.400	5.100	5.500	<1
190327	Clinton Twp	Hunterdon	2.00000	20.00000	9/27/1994	15.000	752.000	261.000	1.900	6.500		<1
190328	Tewksbury Twp	Hunterdon	20.00000	50.00000	8/16/1994	11.000	764.000	460.000	2.400	7.500	7.500	<1
190329	East Amwell Twp	Hunterdon	20.00000	40.00000	9/22/1994	12.000	753.000	187.000		6.400	6.200	<1
190330	Franklin Twp	Hunterdon	10.00000	20.00000	9/29/1994	18.000	754.000	408.000	7.700	6.000	6.600	<1
190331	Readington Twp	Hunterdon	60.00000	85.00000	8/31/1994	14.000	756.000	369.000	6.800	7.400	7.400	1.000
190332	Delaware Twp	Hunterdon	13.00000	23.00000	9/29/1994	11.900	767.000	411.000		6.700	6.600	5.000
190333	Union Twp	Hunterdon	52.00000	500.00000	9/12/1995	13.500	762.000	354.000	0.400	8.100	7.600	8.000
190360	Alexandria Twp	Hunterdon	22.00000	150.00000	8/17/1998	13.500	756.000	356.000	0.060	8.000	8.000	9.000
190361	Delaware Twp	Hunterdon	50.00000	200.00000	7/13/1998	13.500	758.000	369.000	0.200	7.700	7.600	2.000

Pre-1999 Data

Major Ions & Field Parameters

Metals

"-99999" - Estimated Value
"<"- Less Than
Blank cells indicate no sampling performed

Note: None of these wells are used in the current AGWQMN

						Temperature Water Degrees Celsius	Barometric Pressure mm of Mercury	Specfic Conductance Wat. Unfilt. microsimens per cm @25 degrees Celsius	Dissolved Oxygen Wat. Unfilt. mg/l	pH Wat. Unfilt. Field Standard Units	pH Wat. Unfilt. Laboratory Standard Units	Arsenic Wat. Filt. µg/l
GWSI Number	**Municipality**	**County**	**Top Open**	**Bottom Open**	**Dates**	**P00010**	**P00025**	**P00095**	**P00300**	**P00400**	**P00403**	**P01000**
190362	Delaware Twp	Hunterdon	51.00000	175.00000	8/21/1998	14.000	758.000	426.000	0.020	7.800	8.000	57.000
190363	Raritan Twp	Hunterdon	50.00000	175.00000	7/17/1998	12.000	752.000	469.000	4.000	7.800	7.900	3.000
190364	Readington Twp	Hunterdon	50.00000	240.00000	7/28/1998	19.500	759.000	427.000	5.900	7.700	7.900	4.000
190365	Readington Twp	Hunterdon	50.00000	175.00000	7/16/1998	12.500	758.000	252.000	7.300	8.000	7.800	5.000
190366	Readington Twp	Hunterdon	50.00000	200.00000	7/9/1998	12.500	757.000	282.000	9.400	7.900	7.800	4.000
190367	Readington Twp	Hunterdon	49.00000	175.00000	7/29/1998	12.500	753.000	339.000	5.700	7.800	7.900	3.000
190368	Union Twp	Hunterdon	102.00000	200.00000	7/15/1998	12.500	754.000	224.000	8.000	6.200	6.200	<1
190369	Union Twp	Hunterdon	110.00000	200.00000	8/14/1998	13.000	749.000	514.000	7.800	6.800	7.100	<1
210146	Lawrence Twp	Mercer	50.00000	500.00000	4/22/1987	12.000		260.000	5.600	6.600	6.800	<1
210198	Princeton Boro	Mercer			9/9/1987	11.800	755.000	394.000	3.510	6.490	8.000	<1
210244	Hopewell Twp	Mercer	105.00000	235.00000	8/15/1988	13.000	760.000	449.000	2.900	7.600	7.800	4.000
210277	Hopewell Boro	Mercer	50.00000	380.00000	3/1/1988	13.000	760.000	462.000	4.100	7.600	7.700	1.000
210557	Hopewell Twp	Mercer	30.00000	230.00000	7/10/1998	13.000	756.000	485.000	5.700	7.500	7.500	3.000
210558	Hopewell Twp	Mercer	50.00000	200.00000	7/30/1998	16.500	758.000	402.000	4.000	7.700	7.800	4.000
210559	Hopewell Twp	Mercer	50.00000	200.00000	7/8/1998	12.500	756.000	318.000	6.200	7.900	7.900	5.000
410001	Blairstown Twp	Warren	210.00000	300.00000	4/11/1991	11.500	760.000	519.000	0.200	7.200	8.000	<1
410015	Liberty Twp	Warren	90.00000	110.00000	9/22/1992	10.500	750.000	612.000	7.800	7.300	8.100	<1
410017	Liberty Twp	Warren	150.00000	215.00000	9/22/1992	10.000	750.000	607.000	6.700	7.500	7.700	<1
410021	Washington Twp	Warren	152.00000	407.00000	9/30/1991	11.500		410.000	7.400	7.600	7.800	<1
410233	Frelinghuysen Twp	Warren	20.00000	153.00000	9/9/1991	13.000	745.000	1150.000	2.700	7.300	7.200	<1
410252	Independence Twp	Warren	34.25000	136.00000	9/11/1990	10.000	750.000	192.000	9.100	6.700	7.200	<1
410253	Independence Twp	Warren	80.00000	123.00000	9/28/1990	12.000	745.000	599.000	9.000	7.600	7.600	<1
410254	Hardwick Twp (Pahaquarry)	Warren	61.00000	100.00000	3/15/1991	10.000	750.000	178.000	7.300	8.600	8.200	<1
410263	Independence Twp	Warren			8/27/1992	12.000	760.000	251.000	5.800	8.100	8.200	<1
410264	Independence Twp	Warren	212.00000	214.00000	9/21/1992	11.000	755.000	487.000	6.000	7.800	7.800	<1
410265	Liberty Twp	Warren	69.00000	135.00000	9/29/1992	10.500	740.000	408.000	9.600	7.600	7.500	<1
410266	Hardwick Twp (Pahaquarry)	Warren	100.00000	172.00000	9/17/1992	11.000	745.000	229.000	2.200	8.100	8.200	<1
410267	Oxford Twp	Warren	52.00000	150.00000	8/27/1992	11.500	760.000	106.000	8.700	6.800	7.300	2.000
410268	White Twp	Warren	50.00000	252.00000	9/9/1992	12.500	760.000	584.000	2.700	7.400	7.500	<1
410269	White Twp	Warren	53.00000	448.00000	9/10/1992	15.000	760.000	268.000	5.900	8.000	8.000	<1
410270	White Twp	Warren	50.00000	270.00000	9/16/1992	12.000	765.000	388.000		7.800	8.300	2.000
410272	Mansfield Twp	Warren	60.00000	198.00000	8/12/1993	12.500	745.000	95.000	7.000	6.600	6.900	<1
410273	Blairstown Twp	Warren	18.83000	125.00000	8/12/1993	13.500	745.000	418.000	0.200	7.800	7.600	<1
410274	Mansfield Twp	Warren	144.00000	400.00000	9/17/1993	11.000	755.000	585.000	7.900	8.000	7.900	<1

Pre-1999 Data

Major Ions & Field Parameters

Metals

"-99999" - Estimated Value
"<"- Less Than
Blank cells indicate no sampling performed

Note: None of these wells are used in the current AGWQMN

GWSI Number	Municipality	County	Top Open	Bottom Open	Dates	Temperature Water Degrees Celsius **P00010**	Barometric Pressure mm of Mercury **P00025**	Specfic Conductance Wat. Unfilt. microsimens per cm @25 degrees Celsius **P00095**	Dissolved Oxygen Wat. Unfilt. mg/l **P00300**	pH Wat. Unfilt. Field Standard Units **P00400**	pH Wat. Unfilt. Laboratory Standard Units **P00403**	Arsenic Wat. Filt. µg/l **P01000**
410275	Mansfield Twp	Warren	103.00000	333.00000	9/16/1993	13.500	755.000	157.000	0.100	8.200		<1
410276	Frelinghuysen Twp	Warren	50.00000	400.00000	8/25/1993	11.000	740.000	256.000	0.100	7.400	7.500	<1
410277	Frelinghuysen Twp	Warren	60.00000	245.00000	9/17/1993	13.500	755.000	304.000	8.300	8.200	8.000	<1
410293	Franklin Twp	Warren	17.00000	37.00000	9/27/1994	12.000	749.000	202.000		6.000	6.900	<1
410304	Allamuchy Twp	Warren	14.00000	24.00000	8/28/1995	12.500	750.000	776.000	8.800	7.200	7.200	<1
410305	Hackettstown Town	Warren	7.00000	27.00000	9/7/1995	16.000	750.000	572.000	0.700	7.400	7.400	<1
410312	Blairstown Twp	Warren	60.00000	400.00000	9/14/1995	12.500	741.000	554.000	2.100	7.800	7.500	<1
410313	Knowlton Twp	Warren	115.00000	350.00000	9/14/1995	13.500	752.000	581.000	0.400	7.700	7.500	<1

Sampling Set 4 Data (2002, 2007)

Sampling Cycle 1
Sampling Cycle 2

"<"- Less Than
Blank cells indicate no sampling performed

										Major ions & Field Parameters							**Traceelements**
# STAID	**UID**	**Network Id**	**Mon Well #**	**WMA**	**Hydro Aqui**	**Land Use**	**County**	**Municipality**	**Date Sampled**	Temperature Water Degrees Celsius **P00010**	Barometric Pressure mm of Mercury **P00025**	Specfic Conductance Wat. Unfilt. microsimens per cm @25 degrees Celsius **P00095**	Dissolved Oxygen Wat. Unfilt. mg/l **P00300**	pH Wat. Unfilt. Field Standard Units **P00400**	pH Wat. Unfilt. Laboratory Standard Units **P00403**		Arsenic Wat. Filt. µg/l **P01000**
401942074510101	210608	mw-76	76	11	231LCKG	AG	Mercer	Hopewell	20020523	14	764	466	0.4	7.9	8.1		4
401942074510101	210608	mw-76	76	11	231LCKG	AG	Mercer	Hopewell	20070625	15.2	760	514	0.6	7.6	7.7		4.2
404324075041801	410389	mw-94	94	1	371ALNN	AG	Warren	Franklin Twp	20021204	12	764	520	9	8.1	7.7		<0.3
404324075041801	410389	mw-94R	94R	1	371ALNN	AG	Warren	Franklin Twp	20070709	12.4	748	1080	10.7	7.4	7.5		0.06
403951075075301	410390	mw-93	93	1	364JKBG	AG	Warren	Pohatcong	20021216	11	748	1710	8.8	7	7.5		<0.3
403951075075301	410390	mw-93	93	1	364JKBG	AG	Warren	Pohatcong	20070724	13.3	758	2360	8.1	6.5	7.2		0.07
402310074453801	210609	mw-120	120	10	227PSSC	URB	Mercer	Hopewell	20030116	12.5	765	500	3.8	7.6	7.6		3.4
402310074453801	210609	mw-120	120	10	227PSSC	URB	Mercer	Hopewell	20070411	10.8	762	412	0.6	7.4	7.5		0.51
410033074544701	410459	mw-96	96	1	371ALNN	AG	Warren	Hardwick	20030624	14.5	760	590	4.3	6.9	7.2		<0.3
410033074544701	410459	mw-96	96	1	371ALNN	AG	Warren	Hardwick	20070724	11.2	758	611	5	7.2	7.5		<0.12
404937074580501	410460	mw-105	105	1	112SFDF	AG	Warren	Oxford	20030625	10.3	751	408	11		7.9		<0.3
404937074580501	410460	mw-105	105	1	112SFDF	AG	Warren	Oxford	20070717	9.9	755	373	9.6	7.3	7.6		0.09
403121075003901	190450	mw-89	89	11	227PSSC	AG	Hunterdon	Kingwood	20030625	15.6	758	406	0.2	8	8.1		7.4
403121075003901	190450	mw-89	89	11	227PSSC	AG	Hunterdon	Kingwood	20070716	15	752	404	0.2	7.8	8.1		7.7
404146075112101	410461	mw-119	119	1	360KTTN	URB	Warren	Phillipsburg	20030626	15.4	752	408	6.8	8.4	8.2		0.4
404146075112101	410461	mw-119	119	1	360KTTN	URB	Warren	Phillipsburg	20070711	15.4	751	494	6.7	7.5	7.8		0.12
403347074575101	190453	mw-98	98	8	231LCKG	AG	Hunterdon	Franklin	20030709	11.4	753	275	2	7.2	7.8		4.1
403347074575101	190453	mw-98	98	8	231LCKG	AG	Hunterdon	Franklin	20070709	12.3	745	287	1.8	6.9	7.5		2.3
403129075034701	190454	mw-118	118	11	227PSSC	URB	Hunterdon	Frenchtown	20030625	12.5	761	478	6.8	6.5	7		1.4
403129075034701	190454	mw-118	118	11	227PSSC	URB	Hunterdon	Frenchtown	20070716	13.9	759	627	5.3	6.5	7.1		1.9

Sampling Set 3 Data (2001, 2006)

Sampling Cycle 1
Sampling Cycle 2

"<"- Less Than
Blank cells indicate no sampling performed

										Major ions & Field Parameters						**Traceelements**
# STAID	**UID**	**Network Id**	**Mon Well #**	**WMA**	**Hydro Aqui**	**Land Use**	**County**	**Municipality**	**Date Sampled**	Temperature Water Degrees Celsius **P00010**	Barometric Pressure mm of Mercury **P00025**	Specfic Conductance Wat. Unfilt. microsimens per cm @25 degrees Celsius **P00095**	Dissolved Oxygen Wat. Unfilt. mg/l **P00300**	pH Wat. Unfilt. Field Standard Units **P00400**	pH Wat. Unfilt. Laboratory Standard Units **P00403**	Arsenic Wat. Filt. µg/l **P01000**
405154074585701	410385	mw-88	88	1	112SFDF	UND	Warren	Liberty	20010924	12	752	207	4.8	7.4	7.64	0.155
405154074585701	410385	MW 88	88	1	112SFDF	UND	Warren	Liberty	20060614	11.8	750	146	6	7.1	7.1	<0.12
410049075045801	410386	mw-92	92	1	112SFDF	UND	Warren	Hardwick	20010919	13	760	244	3.9	7	7.188	0.205
410049075045801	410386	MW 92	92	1	112SFDF	UND	Warren	Hardwick	20060626	12.6	754	39	6.7	6.1	7.5	0.08
403719075091801	410387	mw-82	82	1	112SFDF	AG	Warren	Pohatcong	20010924	23	755	342	4.5	6.9	7.327	<0.2
403719075091801	410387	MW 82	82	1	112SFDF	AG	Warren	Pohatcong	20060628	14.8	759	353	4.7	6.2	6.6	<0.12
405035074502201	410388	mw-85	85	1	112SFDF	URB	Warren	Hackettstown	20010927	9.5	745	538	6.9	7.2	7.305	<0.2
405003074495001	272061	mw-85R	85R	1	112SFDF	URB	Warren	Hackettstown	20070717	12.6	755	601	0.5	7.2	7.5	0.17
402431075020801	190439	mw-78	78	11	111ALVM	UND	Hunterdon	Delaware	20010919	12	763	202	5.3	6.2	6.501	0.116
402431075020801	190439	MW 78	78	11	111ALVM	UND	Hunterdon	Delaware	20060614	11.6	761	281	5.2	5.4	6.3	0.07
402018074540301	210605	mw-77	77	11	227PSSC	AG	Mercer	Hopewell	20010906	17	763	315	3.8	6.8	7.305	0.361
402018074540301	210605	MW 77	77	11	227PSSC	AG	Mercer	Hopewell	20060620	14.9	757	262	1.9	6.1	6.8	0.27

Sampling Set 5 Data (2003-2004, 2008)

Sampling Cycle 1
Sampling Cycle 2

"<"- Less Than
Blank cells indicate no sampling performed

										Major ions & Field Parameters						Traceelements
# STAID	**UID**	**Network Id**	**Mon Well #**	**WMA**	**Hydro Aqui**	**Land Use**	**County**	**Municipality**	**Date Sampled**	Temperature Water Degrees Celsius **P00010**	Barometric Pressure mm of Mercury **P00025**	Specfic Conductance Wat. Unfilt. microsimens per cm @25 degrees Celsius **P00095**	Dissolved Oxygen Wat. Unfilt. mg/l **P00300**	pH Wat. Unfilt. Field Standard Units **P00400**	pH Wat. Unfilt. Laboratory Standard Units **P00403**	Arsenic Wat. Filt. µg/l **P01000**
403921074515901	190451	mw-101	101	8	400PCMG	AG	Hunterdon	Clinton	20030624	12.5	753	407	4	6.5	6.2	<0.3
403921074515901	190451	MW101	101	8	400PCMG	AG	Hunterdon	Clinton	20080415	12.4	758	364	2.9	6.5	6.9	0.1
403100074464101	190455	mw-107	107	8	227PSSC	AG	Hunterdon	Readington	20030626	14.3	755	261	2	7.5	7.5	1.4
403100074464101	190455	MW107	107	8	227PSSC	AG	Hunterdon	Readington	20080708	15.9	755	403	3.9	7.5	7.8	2.5
402501074505001	190452	mw-106	106	8	227PSSC	AG	Hunterdon	East Amwell	20030701	16.4	756	429	6.9	7.8	7.8	2.1
402501074505001	190452	MW106	106	8	227PSSC	AG	Hunterdon	East Amwell	20080811	13.6	750	456	9.8	7.7	7.8	2.2
402633074541301	190456	mw-91	91	8	227PSSC	AG	Hunterdon	Delaware	20030910	12.3	766	290	2.4	7.1	6.8	2.9
402633074541301	190456	MW91	91	8	227PSSC	AG	Hunterdon	Delaware	20080709	13	751	169	0.6	6.7	7.2	1.4
402051074400001	210630	mw-122	122	10	231SCKN	URB	Mercer	Princeton	20040616	14.1	758	492	2.5	6.2	6.4	0.2
402051074400001	210630	mw-122	122	10	231SCKN	URB	Mercer	Princeton	20070820	13.8	757	453	4.8	6	6.4	0.12
401829074513301	21033	mw-80	80	11	227PSSC	UND	Mercer	Hopewell	20040617	13.9	760	177	0.9	6.3	6.3	1.1
401829074513301	21033	mw-80	80	11	227PSSC	UND	Mercer	Hopewell	20090629	12.4	745	200	4.2	6.1	6.9	1.5
404900075043601	410568	mw-95	95	1	112SFDF	AG	Warren	White	20040623	13.3	753	1400	10.4	7.3	7.5	0.4
404900075043601	410568	MW95	95	1	112SFDF	AG	Warren	White	20080813	15.3	752	859	9.8	7.2	7.2	0.24

ATTACHMENT 7

New Jersey Municipal Water Supply Results

NJDEP DRINKING WATER WATCH Data

COUNTY	Municipality*	Sample Date/Time	CGW	CGU	CSW
WARREN	Knowlton Township	10/28/2015 / 11:00	1.72 UG/L		
	Belvidere Town	02/14/2018 / 09:34	<0.001 MG/L		
	Harmony Township	08/30/2017 / 10:43	1.3 UG/L		
	Knowlton Township	10/28/2015 / 11:00	1.72 UG/L		
	Phillipsburg Town	01/18/2018 / 13:59		<1 UG/L	
	Pohatcong Township	08/30/2017 / 09:52	<0.001 MG/L		
	White Township	12/28/2015 / 06:10	<0.247 UG/L		
	Hardwick Township	NA	NA		
	Lopatcong Township	NA	NA		
HUNTERDON	Alexandria Township	08/31/2017 / 08:45	0.0034 MG/L*		
	Delaware Township	01/31/2018 / 14:00	0.0026 MG/L		
	Frenchtown Boro	2/13/2018	<0.28 UG/L		
	Holland Township	05/08/2017 / 11:40	<1 UG/L		
	Kingwood Township	NA	NA		
	Lambertville City	04/18/2017 / 10:02			<0.0004 MG/L
	Milford Boro	08/31/2017 / 08:45	0.0034 MG/L		
	Stockton Boro	09/25/2015 / 09:15	0.0031 MG/L		
	West Amwell Township	04/18/2017 / 10:02			<0.0004 MG/L*
MERCER	Hopewell Township	03/19/2018 / 09:06	<3.5 UG/L		

"<" less than

*Served by another municipality

NOTE: Data documented here reflects the most recent raw data reported for each municiaplaity in data base. There may be more than one supplier.

To convert to ug/L (ppb): 1 mg/L = 1000 ug/L

Source Site: JDEPWaterWatch

ATTACHMENT 8

Pennsylvania Municipal Water Supply Results

Summary of As (ug/L) based on PADEP Municipal Water Data* for Bucks County

County	Municipality	N	Min	Max	Median	Mean
Bucks	New Hope	4	4	5.6	4.8	4.8
	Solebury	5	0	7	1	3.2
	Tinicum	2	0	2.6	na	1.3
	Upper Makefield	3	0	2.8	2.6	1.87
	Riegelsville	2	0	0.26	na	0.13
Northampton	Easton City	6	0	0	0	0
	Upper Mt. Bethel	6	0	0	0	0

Note: Pennsylvania reports MCL for As < .01 mg/L. Data reported here was converted to ug/L.

Detailed Summary Data Tables Available (see appendix p. __).
Source Site: PADEPDrinkingWaterReport

Summary of NWQMC Well Data for As (ug/L) in select areas of Bucks and Northampton Counties.

Well Cluster Location	Latitude	Longitude	# Wells	N	Min*	Max	Mean	Median	90thP	95thP
NorthBucks	40.419519	-75.067461	24	28	0	13	2.35	1.5	3.8	9.95
CentralBucks	40.419519	-75.067461	41	27	0	60	9.29	3	28	46.2
Northampton	40.683343	-75.213923	4	NA	NA					

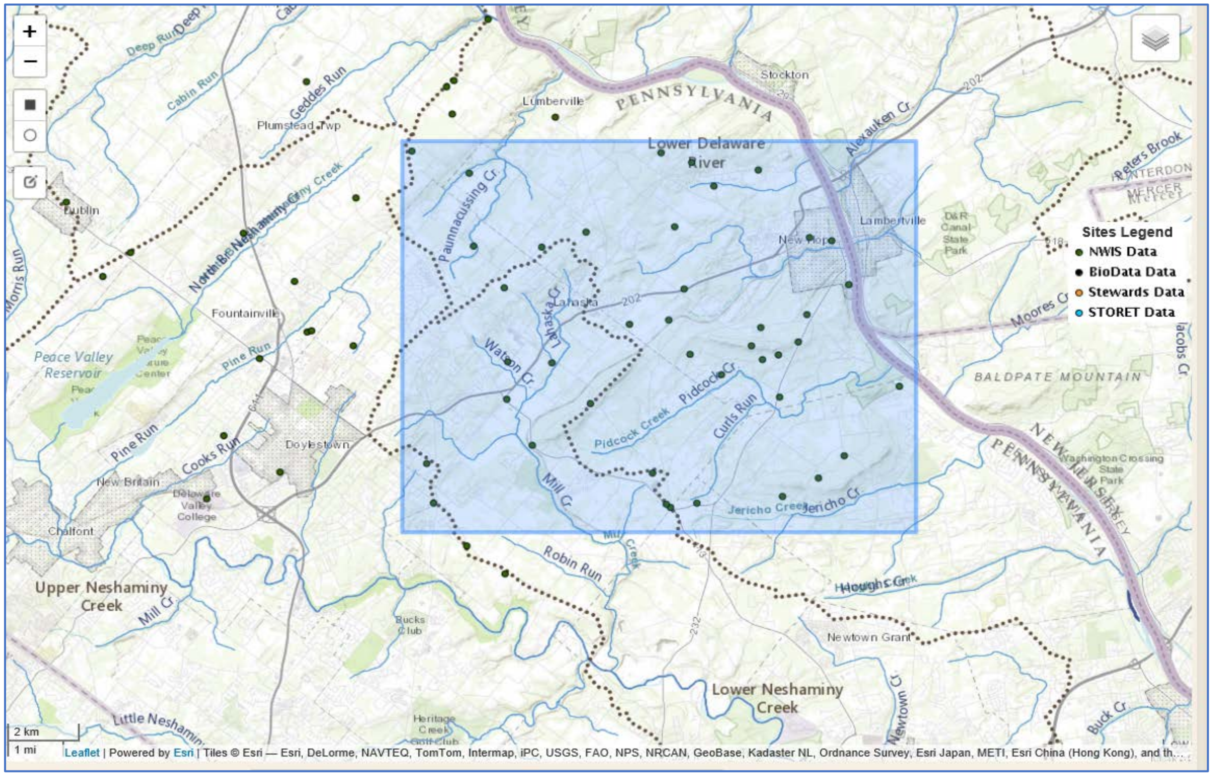
*Zero was substituted for As when it was "not detected" in original queries. Technically, "not detected" means values were below the limit of detection available in laboratory tests. See raw NWQMC report: detection limits vary from lab to lab.

NA: Not avaialable. For Northampton data, As was not included among the characters tested in original query.

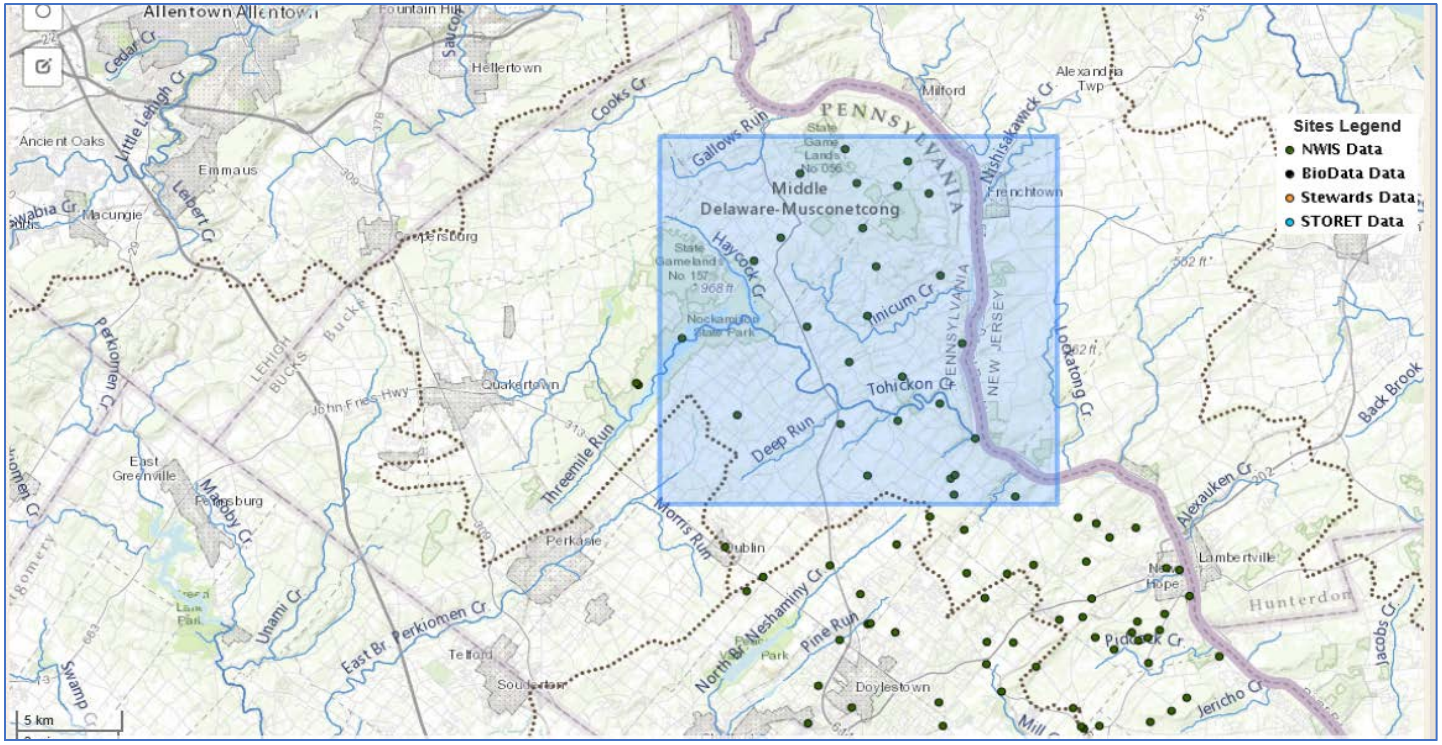
Detailed Raw Data Reports Available (see appendix p. __).

Source Site: NWQMC

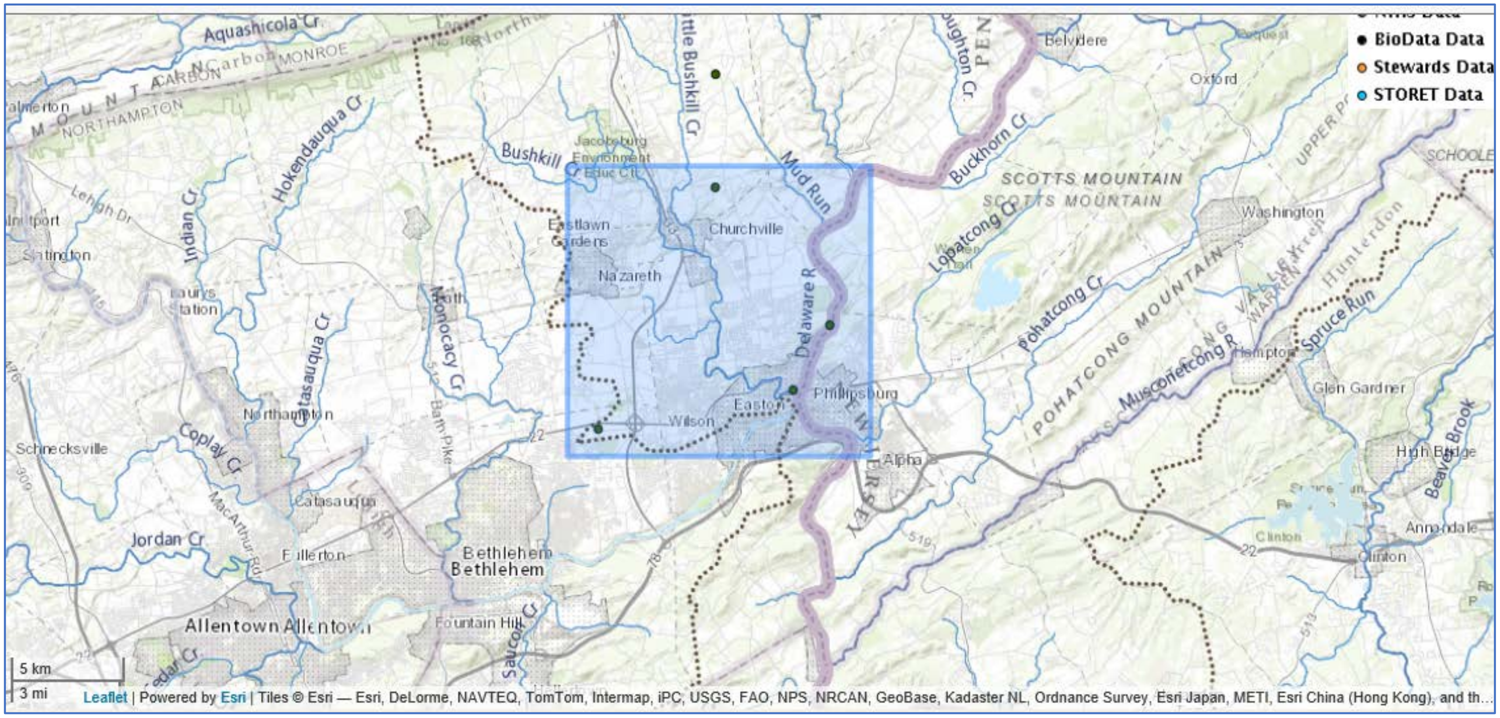
Screen Print of Wells used for As data associated with Central Bucks County, PA



Screen Print of Wells used for As data associated with Northern Bucks County, PA.



Screen Print of Wells used for As data associated with Northampton County, PA



Organizati	Organizati	ActivityIde	ActivityTyp	ActivityMe	ActivityMe	ActivityStartDate	ActivitySta	ActivitySta	ActivityEn	ActivityEn	ActivityEn	ActivityDe	ActivityDe	ActivityDe	ActivityTo	ActivityTo	ActivityBo	ActivityBo	ProjectIde
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	1992-06-16	13:35:00	EDT											
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	1992-06-11	14:45:00	EDT											
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	2005-02-16	11:00:00	EST											
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	2005-02-16	11:00:00	EST											
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	1992-06-03	09:30:00	EDT											
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	1992-06-08	12:25:00	EDT											
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	1992-06-09	12:35:00	EDT											
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	1999-06-15	11:00:00	EDT											National W
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	2003-07-29	11:00:00	EDT											National W
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	2005-06-28	11:10:00	EDT											National W
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	2007-06-19	15:00:00	EDT											National W
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	2009-06-29	16:05:00	EDT											National W
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	2011-07-12	07:52:00	EDT	2011-07-1	11:22:59	EDT								National W
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	2012-08-27	11:00:00	EDT											National W
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	1992-06-11	12:10:00	EDT											
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	1992-06-10	14:30:00	EDT											
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	1992-06-10	15:30:00	EDT											
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	1992-06-11	15:00:00	EDT											
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	1999-07-01	09:00:00	EDT											National W
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	2012-06-28	11:00:00	EDT											National W
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	1992-06-09	15:00:00	EDT											
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	1992-06-09	12:00:00	EDT											
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	1992-06-08	12:20:00	EDT											
USGS-PA	USGS Pen	nwispa.01.	Sample-R	Water	Groundwa	1992-06-04	12:54:00	EDT											

ActivityCor	Monitoring	ActivityCor	SampleAqu	Hydrologic	Hydrologic	SampleCol	SampleCol	SampleCol	SampleCol	ResultDete	Characteri	ResultSam	ResultMea	ResultMea	MeasureQ	ResultStatı	StatisticalE	ResultValu	ResultWei	ResultTime	ResultTem
U.S. Geolo	USGS-402347075023901			Stable, nor	Routine sa	USGS	USGS	USGS	Unknown	Not Detect	Arsenic	Dissolved				Historical		Actual			
U.S. Geolo	USGS-402350075044001			Stable, nor	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	11	ug/l		Historical		Actual			
U.S. Geolo	USGS-4024	A-0480114	Diabase Di	Not applic	Not applic	USGS	USGS	USGS	Unknown	Not Detect	Arsenic	Dissolved				Preliminary		Actual			
U.S. Geolo	USGS-4024	A-0480114	Diabase Di	Not applic	Not applic	USGS	USGS	USGS	Unknown	Not Detect	Arsenic	Total				Preliminary		Actual			
U.S. Geolo	USGS-402420075073101			Stable, nor	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	4	ug/l		Historical		Actual			
U.S. Geolo	USGS-402421075043801			Stable, nor	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	3	ug/l		Historical		Actual			
U.S. Geolo	USGS-4025	BTLS OK SPCOND RR		Stable, nor	Routine sa	USGS	USGS	USGS	Unknown	Not Detect	Arsenic	Dissolved				Historical		Actual			
U.S. Geolo	USGS-4025	A-1670069	3 drops hc	Not deterr	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	2	ug/l		Historical		Actual			
U.S. Geolo	USGS-4025	A-2110025	actual tim	Not deterr	Routine sa	4040	USGS para	Submersib	Submersible positive-		Arsenic	Dissolved	1.5	ug/l		Preliminary		Actual			
U.S. Geolo	USGS-4025	A-1800216	3 drops HC	Not deterr	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	1.4	ug/l		Preliminary		Actual			
U.S. Geolo	USGS-4025	A-1710100	4 drops HC	Not applic	Not applic	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	1.7	ug/l		Preliminary		Actual			
U.S. Geolo	USGS-4025	A-1810140	4 drops HC	Not applic	Not applic	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	1.5	ug/l		Preliminary		Actual			
U.S. Geolo	USGS-4025	L-1940130	Time on all	Not applic	Not applic	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	1.4	ug/l		Preliminary		Actual			
U.S. Geolo	USGS-4025	A-2420019	DELR NAW	Not applic	Routine sa	4040	USGS para	Submersib	Submersible gear pun		Arsenic	Dissolved	1.5	ug/l		Preliminary		Actual			
U.S. Geolo	USGS-402830075073101			Stable, nor	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	3	ug/l		Historical		Actual			
U.S. Geolo	USGS-402956075111501			Stable, nor	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	2	ug/l		Historical		Actual			
U.S. Geolo	USGS-403032075102201			Stable, nor	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	3	ug/l		Historical		Actual			
U.S. Geolo	USGS-403047075074001			Stable, nor	Routine sa	USGS	USGS	USGS	Unknown	Not Detect	Arsenic	Dissolved				Historical		Actual			
U.S. Geolo	USGS-4031	A-1830095	5 drops hc	Not deterr	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	3	ug/l		Historical		Actual			
U.S. Geolo	USGS-4031	A-1840027	DELR NAW	Not applic	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	3.3	ug/l		Preliminary		Actual			
U.S. Geolo	USGS-403157075075201			Stable, nor	Routine sa	USGS	USGS	USGS	Unknown	Not Detect	Arsenic	Dissolved				Historical		Actual			
U.S. Geolo	USGS-403212075094401			Stable, nor	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	13	ug/l		Historical		Actual			
U.S. Geolo	USGS-4032310750611		Brunswick	Stable, nor	Routine sa	USGS	USGS	USGS	Unknown	Not Detect	Arsenic	Dissolved				Historical		Actual			
U.S. Geolo	USGS-4032500750815		Diabase Di	Stable, nor	Routine sa	USGS	USGS	USGS	Unknown	Not Detect	Arsenic	Dissolved				Historical		Actual			

ResultPart	PrecisionV	ResultCom	USGSPCod	ResultDep	ResultDep	ResultDep	SubjectTax	SampleTiss	ResultAnal	ResultAnal	ResultAnal	MethodDe	Laboratory	AnalysisSta	ResultLabo	DetectionC	DetectionC	DetectionC	Preparatio	ProviderName
			01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77				Historical l	1	ug/l		NWIS
			01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77								NWIS
			01000						PLM40	USGS	Metals, wa	USGS OF 92-634		2005-03-04		Laboratory	0.2	ug/l		NWIS
			01002						GF096	USGS	Arsenic, w	USGS OF 98-639		2005-03-03		Laboratory	1.9	ug/l		NWIS
			01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77								NWIS
			01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77								NWIS
			01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77				Historical l	1	ug/l		NWIS
			01000						GF085	USGS	Arsenic, w	USGS OF 98-639								NWIS
			01000						PLM40	USGS	Metals, wa	USGS OF 92-634		2003-08-19		Laboratory	0.26	ug/l		NWIS
			01000						PLM40	USGS	Metals, wa	USGS OF 92-634		2005-08-06		Laboratory	0.2	ug/l		NWIS
			01000						PLM10	USGS	Elements,	USGS TMR	USGS-Nati	2007-06-27		Estimated	0.12	ug/l		NWIS
			01000						PLM10	USGS	Elements,	USGS TMR	USGS-Nati	2009-07-08		Laboratory	0.06	ug/l		NWIS
			01000						PLM10	USGS	Elements,	USGS TMR	USGS-Nati	2011-07-14		Long Term	0.022	ug/l		NWIS
			01000						PLM10	USGS	Elements,	USGS TMR	USGS-Nati	2012-08-30		Long Term	0.03	ug/l		NWIS
			01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77								NWIS
			01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77								NWIS
			01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77								NWIS
			01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77				Historical l	1	ug/l		NWIS
			01000						GF085	USGS	Arsenic, w	USGS OF 98-639								NWIS
			01000						PLM10	USGS	Elements,	USGS TMR	USGS-Nati	2012-07-04		Long Term	0.03	ug/l		NWIS
			01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77				Historical l	1	ug/l		NWIS
			01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77								NWIS
			01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77				Historical l	1	ug/l		NWIS
			01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77				Historical l	1	ug/l		NWIS

Organizati	Organizati	ActivityIde	ActivityTyp	ActivityMe	ActivityMe	ActivitySta	ActivitySta	ActivitySta	ActivityEn	ActivityEn	ActivityEn	ActivityDe	ActivityDe	ActivityDe	ActivityTo	ActivityTo	ActivityBo	ActivityBo	ProjectIde	ActivityCo	Monitoring	ActivityCo	SampleAq	Hydrologic	Hydrologic	SampleCol	SampleCol	SampleCol	SampleCol	ResultDete	Characteri	ResultSam	ResultMea	ResultMea	MeasureQ
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	1992-07-0	09:30:00	EDT												U.S. Geolo	USGS-401	BTLS OK		Stable, no	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	2	ug/l	
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	2004-10-0	13:10:00	EDT												U.S. Geolo	USGS-401754074581101			Stable, no	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	1.6	ug/l	
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	2004-10-0	13:10:00	EDT												U.S. Geolo	USGS-401754074581101			Stable, no	Routine sa	USGS	USGS	USGS	Unknown	Not Detec	Arsenic	Total			
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	2004-12-0	10:10:00	EST												U.S. Geolo	USGS-401	L-3370066	Brunswick	Stable, no	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	2.1	ug/l	
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	2004-12-0	10:10:00	EST												U.S. Geolo	USGS-401	L-3370066	Brunswick	Stable, no	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Total	2	ug/l	
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	2004-11-1	11:40:00	EST												U.S. Geolo	USGS-40183207456		Brunswick	Stable, no	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	7.3	ug/l	
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	2004-11-1	11:40:00	EST												U.S. Geolo	USGS-40183207456		Brunswick	Stable, no	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Total	7	ug/l	
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	2005-04-0	12:40:00	EDT												U.S. Geolo	USGS-401	A-0970082	Brunswick	Not applic	Not applic	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	5.5	ug/l	
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	2005-04-0	12:40:00	EDT												U.S. Geolo	USGS-401	A-0970082	Brunswick	Not applic	Not applic	USGS	USGS	USGS	Unknown		Arsenic	Total	6	ug/l	
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	1992-06-2	13:00:00	EDT												U.S. Geolo	USGS-401947074592401			Stable, no	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	28	ug/l	
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	1992-06-2	13:05:00	EDT												U.S. Geolo	USGS-401	BTLS OK		Stable, no	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	28	ug/l	
USGS-PA	USGS Penr	nwispa.01	Quality Co	Water	Groundwa	2005-02-0	12:01:00	EST												U.S. Geolo	USGS-402	A-0390031	MAY CON	Not applic	Not applic	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	3.4	ug/l	
USGS-PA	USGS Penr	nwispa.01	Quality Co	Water	Groundwa	2005-02-0	12:01:00	EST												U.S. Geolo	USGS-402	A-0390031	MAY CON	Not applic	Not applic	USGS	USGS	USGS	Unknown		Arsenic	Total	3	ug/l	
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	2005-02-0	12:00:00	EST												U.S. Geolo	USGS-402	A-0390032	MAY CON	Not applic	Not applic	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	3.3	ug/l	
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	2005-02-0	12:00:00	EST												U.S. Geolo	USGS-402	A-0390032	MAY CON	Not applic	Not applic	USGS	USGS	USGS	Unknown		Arsenic	Total	2	ug/l	
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	2004-12-0	12:10:00	EST												U.S. Geolo	USGS-402	A-342007	Brunswick	Stable, no	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	0.4	ug/l	
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	2004-12-0	12:10:00	EST												U.S. Geolo	USGS-402	A-342007	Brunswick	Stable, no	Routine sa	USGS	USGS	USGS	Unknown	Not Detec	Arsenic	Total			
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	1992-06-2	09:50:00	EDT												U.S. Geolo	USGS-402014074584901			Stable, no	Routine sa	USGS	USGS	USGS	Unknown	Not Detec	Arsenic	Dissolved			
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	2004-12-0	10:10:00	EST												U.S. Geolo	USGS-402	A-343017	Diabase Di	Stable, no	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	60.0	ug/l	
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	2004-12-0	10:10:00	EST												U.S. Geolo	USGS-402	A-343017	Diabase Di	Stable, no	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Total	54	ug/l	
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	1992-06-1	13:00:00	EDT												U.S. Geolo	USGS-402	PO4-D P-D RR	VALUE	Stable, no	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	7	ug/l	
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	1992-06-1	13:30:00	EDT												U.S. Geolo	USGS-402	BALANCES W/NUTRIE		Stable, no	Routine sa	USGS	USGS	USGS	Unknown	Not Detec	Arsenic	Dissolved			
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	1992-06-1	10:40:00	EDT												U.S. Geolo	USGS-402155074574101			Stable, no	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	24	ug/l	
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	1992-06-1	13:00:00	EDT												U.S. Geolo	USGS-402255075042001			Stable, no	Routine sa	USGS	USGS	USGS	Unknown	Not Detec	Arsenic	Dissolved			
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	1992-06-1	10:10:00	EDT												U.S. Geolo	USGS-402314075003501			Stable, no	Routine sa	USGS	USGS	USGS	Unknown	Not Detec	Arsenic	Dissolved			
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	1999-10-1	12:00:00	EDT											National W	U.S. Geolo	USGS-402	A-2870014	4 drops h	Not deter	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	4	ug/l	
USGS-PA	USGS Penr	nwispa.01	Sample-Rc	Water	Groundwa	2012-08-2	11:30:00	EDT											National W	U.S. Geolo	USGS-402	A-2350046	DELR NAV	Not applic	Routine sa	USGS	USGS	USGS	Unknown		Arsenic	Dissolved	0.10	ug/l	

ResultStat	Statistical	ResultValu	ResultWei	ResultTim	ResultTem	ResultPart	PrecisionV	ResultCom	USGSPCod	ResultDep	ResultDep	ResultDep	SubjectTa	SampleTis	ResultAna	ResultAna	ResultAna	MethodDe	Laborator	AnalysisSt	ResultLab	Detection	Detection	Detection	Preparatio	ProviderName
Historical		Actual							01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77								NWIS
Preliminary		Actual							01000						PLM40	USGS	Metals, wa	USGS OF 92-634		2004-10-29		Laborator	0.2	ug/l		NWIS
Preliminary		Actual							01002						GF096	USGS	Arsenic, w	USGS OF 98-639		2004-10-21		Laborator	1.9	ug/l		NWIS
Preliminary		Actual							01000						PLM40	USGS	Metals, wa	USGS OF 92-634		2005-01-27		Laborator	0.2	ug/l		NWIS
Preliminary		Estimated							01002						GF096	USGS	Arsenic, w	USGS OF 98-639		2005-01-0	below the	Laborator	1.9	ug/l		NWIS
Preliminary		Actual							01000						PLM40	USGS	Metals, wa	USGS OF 92-634		2004-12-03		Laborator	0.2	ug/l		NWIS
Preliminary		Actual							01002						GF096	USGS	Arsenic, w	USGS OF 98-639		2004-12-07		Laborator	1.9	ug/l		NWIS
Preliminary		Actual							01000						PLM40	USGS	Metals, wa	USGS OF 92-634		2005-04-16		Laborator	0.2	ug/l		NWIS
Preliminary		Actual							01002						GF096	USGS	Arsenic, w	USGS OF 98-639		2005-04-19		Laborator	1.9	ug/l		NWIS
Historical		Actual							01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77								NWIS
Historical		Actual							01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77								NWIS
Preliminary		Actual							01000						PLM40	USGS	Metals, wa	USGS OF 92-634		2005-02-18		Laborator	0.2	ug/l		NWIS
Preliminary		Actual							01002						GF096	USGS	Arsenic, w	USGS OF 98-639		2005-02-22		Laborator	1.9	ug/l		NWIS
Preliminary		Actual							01000						PLM40	USGS	Metals, wa	USGS OF 92-634		2005-02-18		Laborator	0.2	ug/l		NWIS
Preliminary		Actual							01002						GF096	USGS	Arsenic, w	USGS OF 98-639		2005-02-22		Laborator	1.9	ug/l		NWIS
Preliminary		Actual							01000						PLM40	USGS	Metals, wa	USGS OF 92-634		2005-01-25		Laborator	0.2	ug/l		NWIS
Preliminary		Actual							01002						GF096	USGS	Arsenic, w	USGS OF 98-639		2005-01-03		Laborator	1.9	ug/l		NWIS
Historical		Actual							01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77				Historical I	1	ug/l		NWIS
Preliminary		Actual							01000						PLM40	USGS	Metals, wa	USGS OF 92-634		2005-01-26		Laborator	0.2	ug/l		NWIS
Preliminary		Actual							01002						GF096	USGS	Arsenic, w	USGS OF 98-639		2005-01-0	sample wa	Laborator	3.8	ug/l		NWIS
Historical		Actual							01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77								NWIS
Historical		Actual							01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77				Historical I	1	ug/l		NWIS
Historical		Actual							01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77								NWIS
Historical		Actual							01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77				Historical I	1	ug/l		NWIS
Historical		Actual							01000						HY010	USGS	Arsenic, w	USGS TWRI 5-A1/1989, p 77				Historical I	1	ug/l		NWIS
Historical		Actual							01000						GF085	USGS	Arsenic, w	USGS OF 98-639								NWIS
Preliminary		Actual							01000						PLM10	USGS	Elements,	USGS TMR	USGS-Nati	2012-08-27		Long Term	0.03	ug/l		NWIS

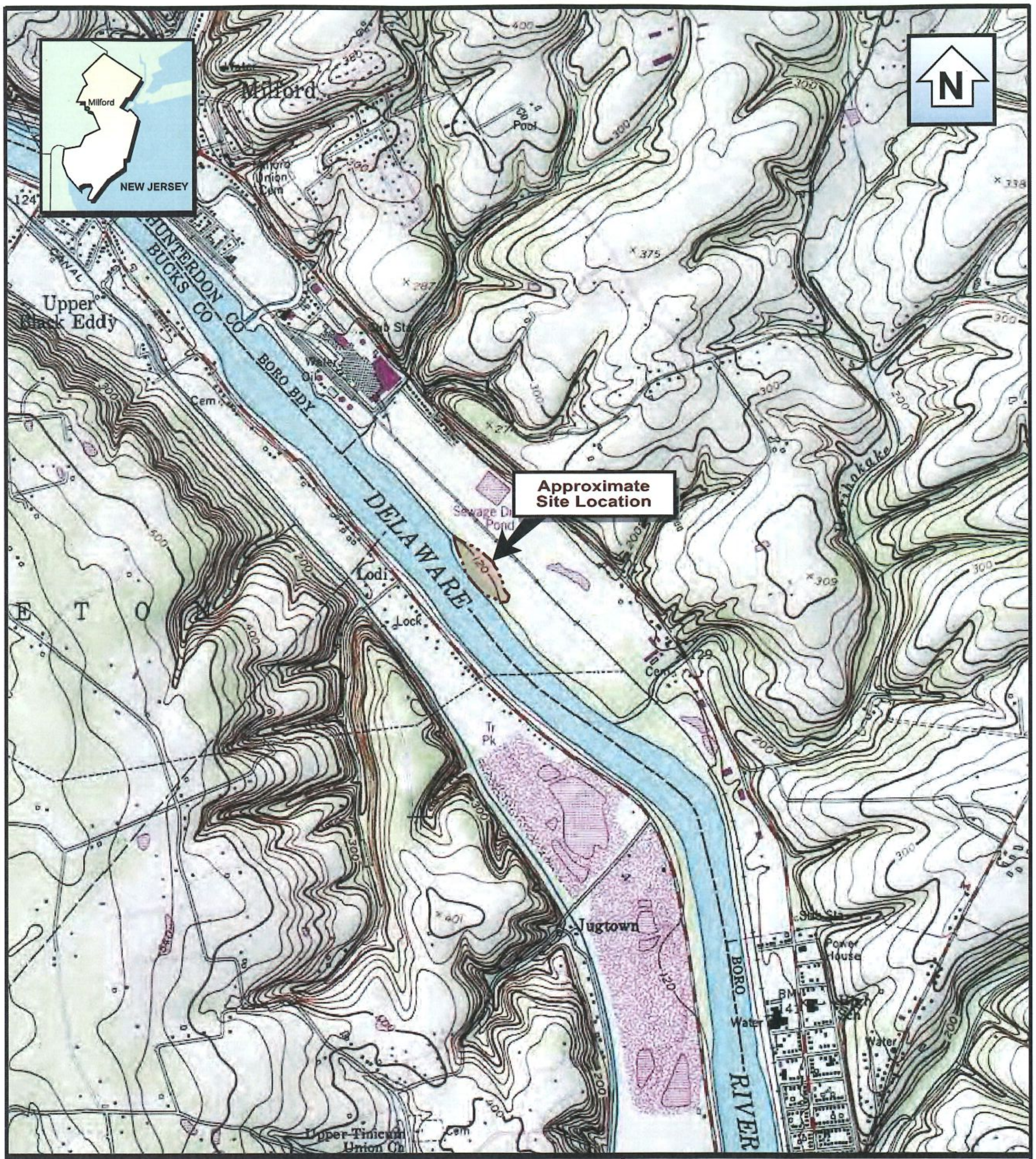
County	Municipality	PWSID	SYSTEM NAME	SAMPLE LOCATION	CONTAMINANT ID	ANALYSIS RESULT (mg/L)	MCL IN EFFECT (mg/L)	Analysis Result (ug/L)	SAMPLE DATE	SAMPLE TYPE	LABORATORY ID	ANALYSIS METHOI	ANALYSIS DATE	SAMPLE RECEIVED DATE
BUCKS	New Hope	1090160	BCWSA FOX RUN PRESERVE (GW)	101	ARSENIC (IOC)	0.005	0.01	5.0	12/14/2017	ENTRY POINT	SUBURBAN WATER TESTING LABS	ICP, MASS SPEC.	12/21/2017	12/27/2017
		1090130	BCWSA NEW HOPE (SW)	101	ARSENIC (IOC)	0.004	0.01	4.0	12/6/2017	ENTRY POINT	SUBURBAN WATER TESTING LABS	ICP, MASS SPEC.	12/12/2017	12/19/2017
		1090040	VILLAGE 2 COMMUNITY ASSOC	101	ARSENIC (IOC)	0.0046	0.01	4.6	4/11/2017	ENTRY POINT	LANCASTER LABORATORIES, INC.	ICP, MASS SPEC.	4/20/2017	5/7/2017
		1090133	VILLAGE OF BUCKINGHAM SPRINGS	101	ARSENIC (IOC)	0.0056	0.01	5.6	4/2/2015	ENTRY POINT	ANALYTICAL LABORATORY SERVICES	ICP, MASS SPEC.	4/7/2015	4/10/2015
	Solebury	1090102	HERMITAGE CONDOMINIUM ASSN	101	ARSENIC (IOC)	0.001	0.01	1.0	3/2/2015	ENTRY POINT	SUBURBAN WATER TESTING LABS	ICP, MASS SPEC.	3/6/2015	3/13/2015
		1090103	INGHAM MEWS CONDOMINUM ASSOC	101	ARSENIC (IOC)	0.007	0.01	7.0	3/2/2015	ENTRY POINT	SUBURBAN WATER TESTING LABS	ICP, MASS SPEC.	3/6/2015	3/13/2015
		1090129	BCWSA SOLEBURY	102	ARSENIC (IOC)	0.001	0.01	1.0	12/14/2017	ENTRY POINT	SUBURBAN WATER TESTING LABS	ICP, MASS SPEC.	12/21/2017	12/27/2017
		1090030	SOLEBURY SCHOOL	102	ARSENIC (IOC)	0	0.01	0.0	5/13/2015	ENTRY POINT	QC, INC	ICP, MASS SPEC.	5/14/2015	5/29/2015
		1090101	YORKSHIRE MEADOWS CONDO ASSOC	101	ARSENIC (IOC)	0.007	0.01	7.0	10/17/2017	ENTRY POINT	SUBURBAN WATER TESTING LABS	ICP, MASS SPEC.	10/28/2017	10/31/2017
	Tinicum	1090049	PEDIATRIC SPECIALTY CARE	101	ARSENIC (IOC)	0.0026	0.01	2.6	4/22/2015	ENTRY POINT	QC, INC	ICP, MASS SPEC.	4/23/2015	4/30/2015
		1090048	RED CLIFF MHP	101	ARSENIC (IOC)	0	0.01	0.0	11/1/2017	ENTRY POINT	SUBURBAN WATER TESTING LABS	ICP, MASS SPEC.	11/9/2017	11/10/2017
	Upper Makefield	1090122	TWP OF UPPER MAKEFIELD	101	ARSENIC (IOC)	0.0028	0.01	2.8	4/7/2015	ENTRY POINT	QC, INC	ICP, MASS SPEC.	4/10/2015	4/23/2015
		1090122	TWP OF UPPER MAKEFIELD	101	ARSENIC (IOC)	0.0028	0.01	2.8	4/7/2015	ENTRY POINT	QC, INC	ICP, MASS SPEC.	4/10/2015	4/23/2015
		1090121	UPPER MAKEFIELD ENCLAVE	100	ARSENIC (IOC)	0	0.01	0.0	11/16/2015	ENTRY POINT	QC, INC	ICP, MASS SPEC.	11/17/2015	11/30/2015
	Riegelsville	1090058	RIEGELSVILLE WATER AUTHORITY	101	ARSENIC (IOC)	0	0.01	0.0	4/10/2012	ENTRY POINT		ICP, MASS SPEC.	4/11/2012	4/30/2012
		1090058	RIEGELSVILLE WATER AUTHORITY	102	ARSENIC (IOC)	0.00026	0.01	0.3	4/10/2012	ENTRY POINT		ICP, MASS SPEC.	4/11/2012	4/30/2012
NORTHAMPTON*	Easton City	3480050	EASTON AREA WATER SYSTEM	101	ARSENIC (IOC)	0	0.01		1/4/2017	ENTRY POINT	SUBURBAN WATER TESTING LABS	ICP, MASS SPEC.	1/9/2017	1/23/2017
		3480055	PAW BLUE MOUNTAIN DIVISION	102	ARSENIC (IOC)	0	0.01		4/12/2017	ENTRY POINT	AMERICAN WATER CENTRAL LAB	ICP, MASS SPEC.	4/18/2017	5/4/2017
		3480038	PAW BANGOR DISTRICT	100	ARSENIC (IOC)	0	0.01		8/10/2017	ENTRY POINT	AMERICAN WATER CENTRAL LAB	ICP, MASS SPEC.	8/14/2017	9/6/2017
		3480055	PAW BLUE MOUNTAIN DIVISION	101	ARSENIC (IOC)	0	0.01		8/10/2017	ENTRY POINT	AMERICAN WATER CENTRAL LAB	ICP, MASS SPEC.	8/14/2017	9/6/2017
		3480057	NORTHAMPTON BORO MUNI AUTH	101	ARSENIC (IOC)	0	0.01		10/12/2017	ENTRY POINT	SUBURBAN WATER TESTING LABS	ICP, MASS SPEC.	10/18/2017	10/31/2017
		3480046	CITY OF BETHLEHEM	101	ARSENIC (IOC)	0	0.01		12/6/2017	ENTRY POINT	M J REIDER ASSOC INC	ICP, MASS SPEC.	12/11/2017	12/28/2017
	Upper Mt. Bethel	3480050	EASTON AREA WATER SYSTEM	101	ARSENIC (IOC)	0	0.01		1/4/2017	ENTRY POINT	SUBURBAN WATER TESTING LABS	ICP, MASS SPEC.	1/9/2017	1/23/2017
		3480055	PAW BLUE MOUNTAIN DIVISION	102	ARSENIC (IOC)	0	0.01		4/12/2017	ENTRY POINT	AMERICAN WATER CENTRAL LAB	ICP, MASS SPEC.	4/18/2017	5/4/2017
		3480038	PAW BANGOR DISTRICT	100	ARSENIC (IOC)	0	0.01		8/10/2017	ENTRY POINT	AMERICAN WATER CENTRAL LAB	ICP, MASS SPEC.	8/14/2017	9/6/2017
		3480055	PAW BLUE MOUNTAIN DIVISION	101	ARSENIC (IOC)	0	0.01		8/10/2017	ENTRY POINT	AMERICAN WATER CENTRAL LAB	ICP, MASS SPEC.	8/14/2017	9/6/2017
		3480057	NORTHAMPTON BORO MUNI AUTH	101	ARSENIC (IOC)	0	0.01		10/12/2017	ENTRY POINT	SUBURBAN WATER TESTING LABS	ICP, MASS SPEC.	10/18/2017	10/31/2017
		3480046	CITY OF BETHLEHEM	101	ARSENIC (IOC)	0	0.01		12/6/2017	ENTRY POINT	M J REIDER ASSOC INC	ICP, MASS SPEC.	12/11/2017	12/28/2017

*Other municipalites did not yield muni water data. Private wells are main source of drinking water there. The value"0" is the reported value for As in Mg/L

ATTACHMENT 9

Results for 'Known-Contaminated Sites' Adjacent to River

Crown Vantage Landfill Site



0 2000
SCALE FEET

0 1
SCALE 1:24000 MILE

BASE CREATED WITH TOPO™ © 1996 WILDFLOWERS PRODUCTIONS, www.topo.com
7.5' USGS TOPOGRAPHIC MAP

TRC
21 Griffin Road North
Windsor, CT 06095
(860) 298-9692

CROWN VANTAGE LANDFILL
ALEXANDRIA TOWNSHIP, NEW JERSEY

FIGURE 1-1
SITE LOCATION MAP

Date: 06/10 | **Project No.** 1164117.000040.0000007

HAZ54860 GEORGIA PACIFIC NJ/164117 topo.fh10

Table 2-4C
Summary of Metals Results for Surface Soil Samples That Exceed Comparison Criteria - January and March 2009
Remedial Investigation
Crown Vantage Landfill
Alexandria Township, New Jersey

Analysis	Analyte		Sample ID:	2009-SS-01		2009-SS-02	2009-SS-03	2009-SS-04	2009-SS-05	2009-SS-06	2009-SS-07	2009-SS-08	2009-SS-10	2009-SS-11	2009-SS-12	2009-SS-13	2009-SS-14
			Sample Date:	3/12/2009	3/12/2009 Field Dup	1/14/2009	1/14/2009	1/14/2009	1/15/2009	1/15/2009	3/12/2009	3/12/2009	3/12/2009	1/14/2009	1/14/2009	1/14/2009	1/14/2009
		Screening Levels/Standards															
		EPA RSL*	NJDEP**														
			Unit:	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Metals, total																	
	Arsenic	1.6	19^	**7.8 J**	**14.7 J**	**6.9**	**10.1**	**7.9**	**9.1**	**5.6**	**3.8 J**	**2.8 J**	**11.9 J**	**8.4**	**6.7**	**6.9**	**9.4**
	Vanadium	720	1,100	68.9 J	121 J	47.7 J	46.5 J	241 J	252 J	213 J	44.5	16.0	85.7	54.4 J	110 J	48.6 J	46.5 J

Analysis	Analyte		Sample ID:	2009-SS-15	2009-SS-16	2009-SS-18	2009-SS-19	2009-SS-20	2009-SS-21		2009-SS-22	2009-SS-23	2009-SS-24	2009-SS-25	2009-SS-26	2009-SS-27	2009-SS-28
			Sample Date:	1/15/2009	3/12/2009	3/12/2009	3/12/2009	3/13/2009	1/15/2009	1/15/2009 Field Dup	1/15/2009	1/15/2009	1/15/2009	3/13/2009	1/16/2009	1/15/2009	1/15/2009
		Screening Levels/Standards															
		EPA RSL*	NJDEP**														
			Unit:	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Metals, total																	
	Arsenic	1.6	19^	**6.2**	**8.5 J**	**3.8 J**	**8.6 J**	**9.4 J**	**7.6**	**8.8**	**6.5**	**9.5**	**8.9**	**7.0 J**	**7.1**	**11.3**	**7.0**
	Vanadium	720	1,100	119 J	**1,460**	110	385	42.3	**1,420 J**	**734 J**	89.5 J	74.9 J	113 J	257	79.8 J	436 J	134 J

Analysis	Analyte		Sample ID:	2009-SS-29	2009-SS-30	2009-SS-31	2009-SS-32	2009-SS-33	2009-SS-34	2009-SS-35	2009-SS-36	2009-SS-37	**Mean Conc.**	FB011409	FB011509	FB011609	FB031209
			Sample Date:	1/15/2009	1/15/2009	1/16/2009	3/13/2009	1/16/2009	1/15/2009	1/15/2009	1/16/2009	1/16/2009		1/14/2009 Equip. Blank	1/15/2009 Equip. Blank	1/16/2009 Equip. Blank	3/12/2009 Equip. Blank
		Screening Levels/Standards															
		EPA RSL*	NJDEP**														
			Unit:	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	ug/L	ug/L	ug/L	ug/L
Metals, total																	
	Arsenic	1.6	19^	**7.3**	**6.8**	**9.1**	**5.0 J**	**7.0**	**6.5**	**6.9**	**10.1**	**4.9**	**7.73**	3.0 UJ	8.0 U	8.0 U	3.0 U
	Vanadium	720	1,100	113 J	66.3 J	170 J	**1,530**	50.5 J	79.3 J	510 J	624 J	**1,060 J**	293	50 U	50 U	50 U	50 U

Notes:

mg/kg - milligrams per kilogram (dry weight) or parts per million (ppm).

ug/L - micrograms per liter or parts per billion (ppb).

J - Estimated value.

U - Compound was not detected at specified quantitation limit.

UJ - Estimated non-detect.

Values shown in Bold and shaded type exceed both the EPA RSL and NJDEP standards.

Values shown in Bold and double outlined exceed the EPA RSL but are below the NJDEP standard.

* - EPA Regional Screening Levels for Chemical Contaminants at Superfund Sites, Industrial Soil, April 2009.

** - NJDEP, Non-Residential Direct Contact Soil Remediation Standards, 6/2/08.

^ The direct contact standard for arsenic is based on natural background.

TABLE 2-6
Summary of Metals Results for Surface Water Samples That Exceed Comparison Criteria - March 2009
Remedial Investigation
Crown Vantage Landfill
Alexandria Township, New Jersey

Analysis	Analyte	Sample ID:			2009-SW-001	2009-SW-002	2009-SW-003	2009-SW-004	2009-SW-005	**Mean**	EB030309
		Sample Date:			3/3/2009	3/3/2009	3/3/2009	3/3/2009	3/3/2009	**Conc.**	3/3/2009
		Fresh Water (FW2) Criteria*									Equipment Blank
		Aquatic		Human							
		Acute	Chronic	Health	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
	Arsenic	N/A	N/A	0.017(hc)	**0.286 J**	**0.322 J**	**0.355 J**	**0.388 J**	**0.367 J**	**0.344**	0.250 U

Notes:
ug/L - micrograms per liter or parts per billion (ppb).
J - Estimated value.
N/A - Not applicable/available.
U - Compound was not detected at specified quantitation limit.
Values shown in Bold and shaded cells exceed Human Health criteria.
* - Surface Water Quality Standards, NJDEP, Last Amended June 16, 2008.
(hc) - Human health carcinogen

TABLE 2-7

Summary of Metals Results for Pore Water Samples That Exceed Comparison Criteria - March 2009
Remedial Investigation
Crown Vantage Landfill
Alexandria Township, New Jersey

Analysis	Analyte						Sample ID: Sample Date:	2009-PW-001 3/4/2009	2009-PW-002 3/4/2009	2009-PW-003 3/4/2009	2009-PW-004 3/4/2009	2009-PW-005 3/4/2009	**Mean Conc.**
					Fresh Water (FW2) Criteria*								
		EPA MCL	NJ MCL	NJ GWQS	Aquatic		Human Health	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
					Acute	Chronic							
Metals, total													
	Aluminum	N/A	N/A	200	N/A	N/A	N/A	**344**	200 U	200 U	200 U	200 U	149
	Arsenic	10	5	3	N/A	N/A	0.017(hc)	**0.461 J**	0.250 U	0.250 U	**0.317 J**	**14.1 J**	**3.0**
	Iron	N/A	N/A	300	N/A	N/A	N/A	**1,290**	148	171	214	**33,200**	**7,005**
	Manganese	N/A	N/A	50	N/A	N/A	N/A	27.6	15 UJ	48.3	**877**	**6,980**	**1,588**
Metals, dissolved													
	Arsenic	10	5	3	340(d)	150(d)	N/A	0.355 J	0.250 U	0.250 U	0.250 U	**19.5 J**	**4.0**
	Iron	N/A	N/A	300	N/A	N/A	N/A	100 U	100 U	100 U	100 U	**33,000**	**6,640**
	Manganese	N/A	N/A	50	N/A	N/A	N/A	19.3	22.8 J	39.0	**856**	**6,960**	**1,579**
	Zinc	N/A	N/A	2,000	114(a)	114(a)	N/A	59.7	**188**	**121**	113	**163**	**129**

Notes:

ug/L - micrograms per liter or parts per billion (ppb).

J - Estimated value.

N/A - Not applicable/available.

U - Compound was not detected at specified quantitation limit.

Values in Bold (no outline) exceed both Fresh Water Aquatic criteria.

Values shown in Bold and single outlined exceed the listed Human Health criteria.

Values shown in Bold and partially shaded cells with double outlining exceed EPA MCL, NJ MCL, and NJ GWQS.

Values shown in Bold and fully shaded cells exceed all of the listed criteria.

Values shown in Bold and double outlined exceed NJ GWQS.

MCL – Maximum Contaminant Level

NJ GWQS – New Jersey Ground Water Quality Standards, July 7, 2008.

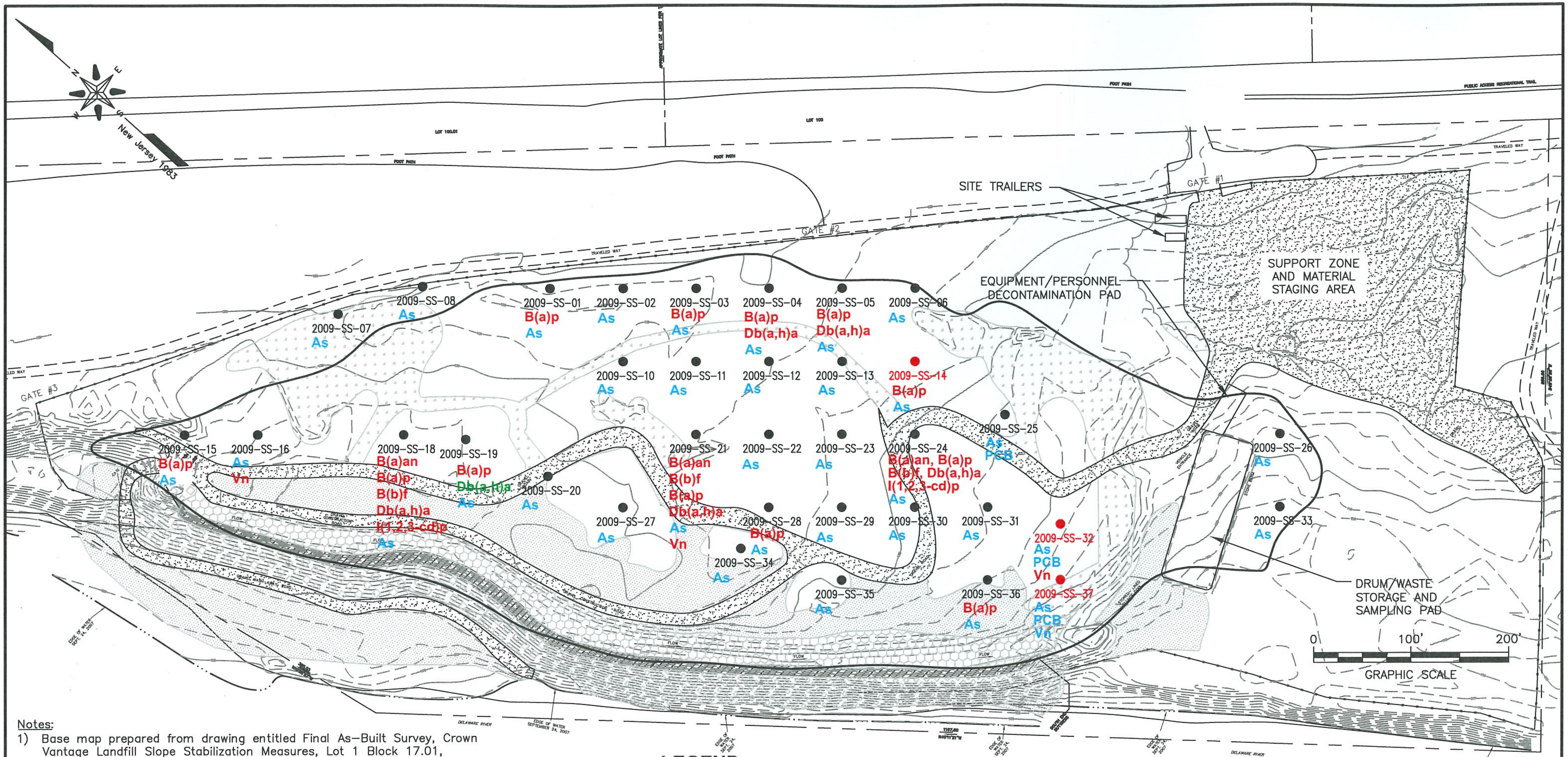
* - Surface Water Quality Standards, NJDEP, Last Amended June 16, 2008.

(a) - Dependent on water hardness. Value of 100 mg/L used in table.

(d) - Criterion is expressed as a function of the Water Effect Ratio (WER). For criterion in the table, WER equates to the default value of 1.0.

(hc) - Human health carcinogen

Mean - Computed by the sum of the detected values and half of the quantitation limits
for the non-detects divided by the number of samples analyzed for the analyte;
only the higher values of the pairs for the field duplicates are used.



Notes:

1) Base map prepared from drawing entitled Final As-Built Survey, Crown Vantage Landfill Slope Stabilization Measures, Lot 1 Block 17.01, Hunterdon County, Alexandria Township, New Jersey", Dated 10/25/07 (3 sheets), Scale: 1"=40' by ENSR Corporation.
2) Extent of landfill taken from drawing entitled "Monitoring Well Locations, James River Waste Disposal Area, Milford, New Jersey", prepared by Woodward-Clyde Consultants of Wayne New Jersey, dated February 3, 1995, original scale 1"=200'.
3) Elevation and horizontal datum from drawing referenced in Note #1 above:
   Elevation Reference/Vertical Datum: NAVD88 by means of high accuracy dual frequency GPS from the National Geodetic Survey C.O.R. Network. Held station WIL 1, ellipsoid height (GRS80): 18.877 feet, applied GEOID03 to establish on site orthometric heights.
   Horizontal Datum: New Jersey State Plan Coordinate System NAD83.

LEGEND

▬	EXTENT OF LANDFILL BASED ON 1991 VISUAL AND GEOPHYSICAL OBSERVATIONS
2009-SS-1 ●	RI SURFACE SOIL SAMPLE LOCATION
CYAN TEXT	EXCEEDS THE EPA REGIONAL SCREENING LEVELS (EPA RSLs) FOR CHEMICAL CONTAMINANTS AT SUPERFUND SITES, INDUSTRIAL CRITERIA
GREEN TEXT	EXCEEDS NJDEP NON-RESIDENTIAL DIRECT CONTACT SOIL REMEDIATION STANDARDS
RED TEXT	EXCEEDS BOTH THE EPA RSL AND THE NJDEP NON-RESIDENTIAL DIRECT CONTACT SOIL REMEDIATION STANDARDS

ABBREVIATIONS:

As	=ARSENIC
B(a)an	=BENZO(a)ANTHRACENE
B(b)f	=BENZO(b)FLUORANTHENE
B(a)p	=BENZO(a)PYRENE
Db(a,h)a	=DIBENZO(a,h)ANTHRACENE
I(1,2,3-cd)p	=INDENO(1,2,3-CD)PYRENE
PCB	=POLYCHLORINATED BIPHENYLS
Vn	=VANADIUM

J:\CAD\164117\000040\RI Report\
Plate-1.dwg Layout:FIGURE 2-3 June 09, 2010-1:16PM Khollenbeck

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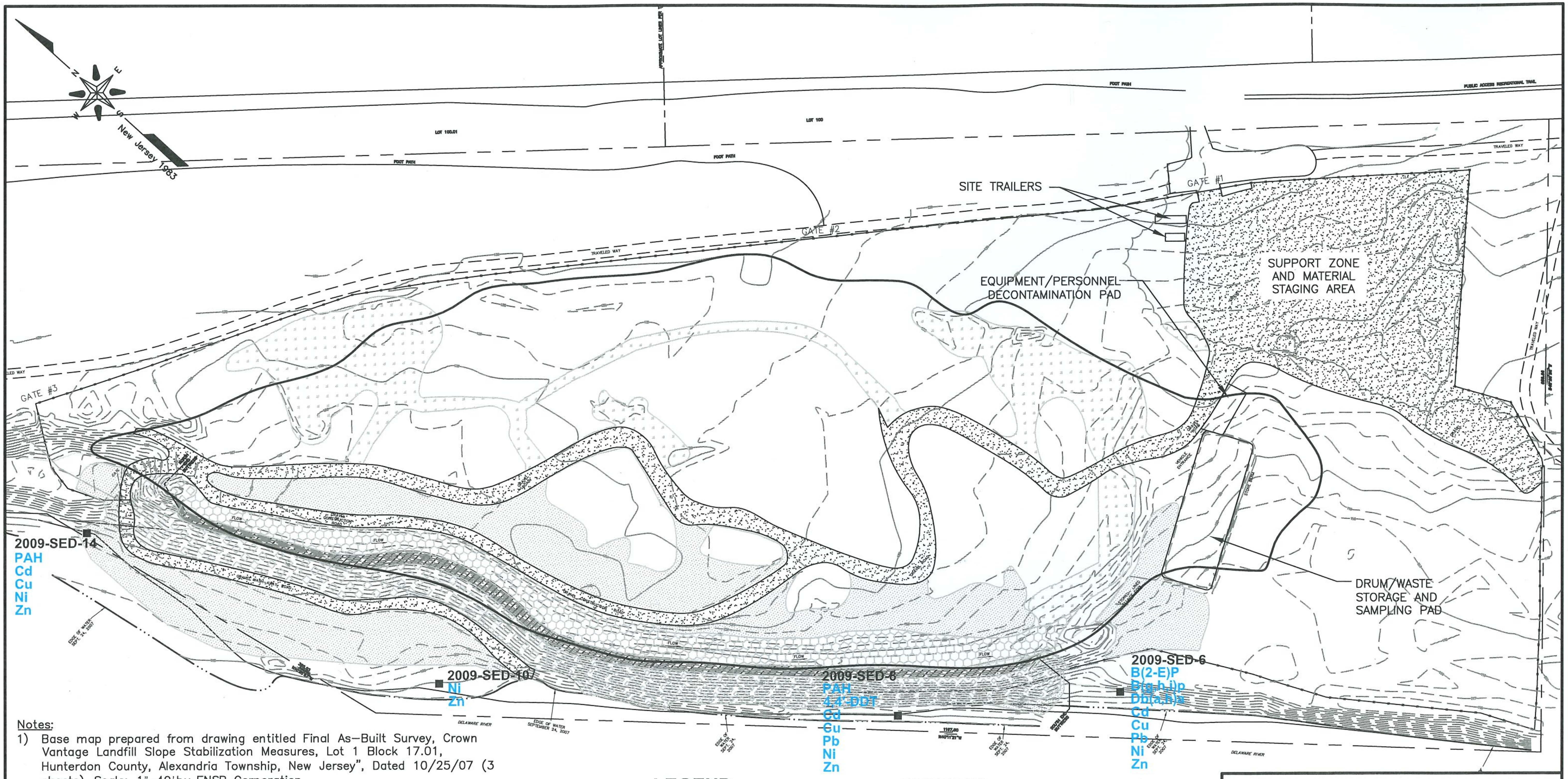
CROWN VANTAGE LANDFILL
ALEXANDRIA TOWNSHIP, NEW JERSEY

FIGURE 2-3
SURFACE SOIL SAMPLES EXCEEDING SCREENING CRITERIA

Date: 06/08/10 **Project No.** 164117.000040.000007



Notes:

1) Base map prepared from drawing entitled Final As–Built Survey, Crown Vantage Landfill Slope Stabilization Measures, Lot 1 Block 17.01, Hunterdon County, Alexandria Township, New Jersey", Dated 10/25/07 (3 sheets), Scale: 1"=40' by ENSR Corporation.
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   Elevation Reference/Vertical Datum: NAVD88 by means of high accuracy dual frequency GPS from the National Geodetic Survey C.O.R. Network. Held station WIL 1, ellipsoid height (GRS80): 18.877 feet, applied GEOID03 to establish on site orthometric heights.
   Horizontal Datum: New Jersey State Plan Coordinate System NAD83.

LEGEND

———	EXTENT OF LANDFILL BASED ON 1991 VISUAL AND GEOPHYSICAL OBSERVATIONS
2009-SED-6 ■	RI SEDIMENT SAMPLE LOCATION
CYAN TEXT	EXCEEDS NJDEP ECOLOGICAL SCREENING CRITERIA

0 100' 200'

GRAPHIC SCALE

ABBREVIATIONS:

PAH =MULTIPLE POLYCYCLIC AROMATIC HYDROCARBONS
4,4'–DDT =DICHLORODIPHENYLTRICHLOROETHANE
B(2–E)P =BIS (2–ETHYLHEXYL) PHTHALATE
B(g,h,i)P =BENZO (g,h,i) PERYLENE
Db(a,h)a =DIBENZO (a,h) ANTHRACENE
Cd =CADMIUM
Cu =COPPER
Ni =NICKEL
Pb =LEAD
Zn =ZINC

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CROWN VANTAGE LANDFILL
ALEXANDRIA TOWNSHIP, NEW JERSEY

FIGURE 2-4
ON-SITE SEDIMENT SAMPLES EXCEEDING SCREENING CRITERIA

Date: 06/08/10 **Project No.** 164117.000040.000007

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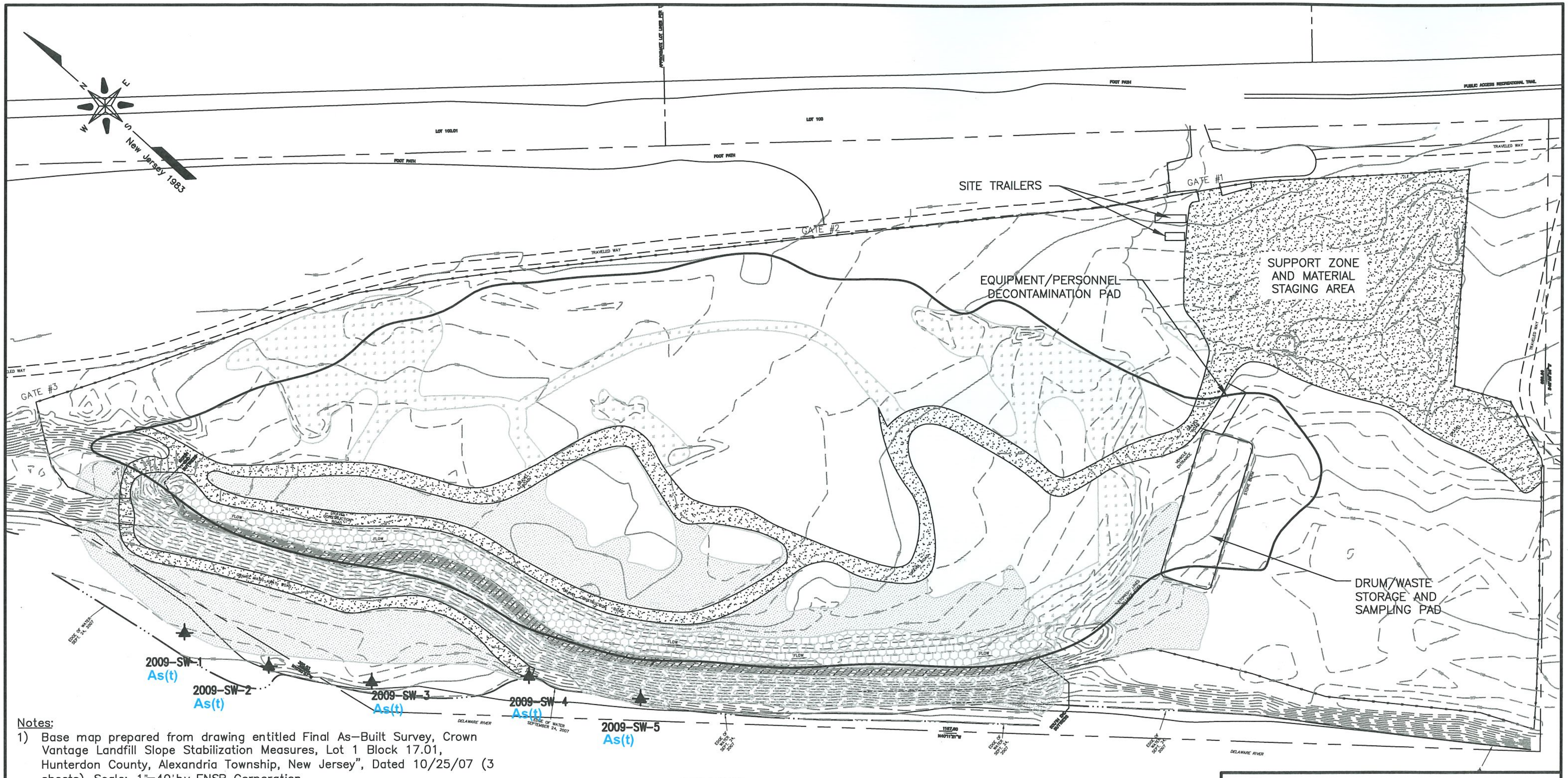
Plate–1.dwg Layout:FIGURE 2–4 June 09, 2010–8:28AM Khollenbeck



Notes:

1) Base map prepared from drawing entitled Final As-Built Survey, Crown Vantage Landfill Slope Stabilization Measures, Lot 1 Block 17.01, Hunterdon County, Alexandria Township, New Jersey", Dated 10/25/07 (3 sheets), Scale: 1"=40' by ENSR Corporation.
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3) Elevation and horizontal datum from drawing referenced in Note #1 above: <u>Elevation Reference/Vertical Datum</u>: NAVD88 by means of high accuracy dual frequency GPS from the National Geodetic Survey C.O.R. Network. Held station WIL 1, ellipsoid height (GRS80): 18.877 feet, applied GEOID03 to establish on site orthometric heights. <u>Horizontal Datum</u>: New Jersey State Plan Coordinate System NAD83.

J:\CAD\164117\000040\RI Report\
Plate-1.dwg Layout:FIGURE 2-6 June 09, 2010-8:31AM Khollenbeck

LEGEND

———	EXTENT OF LANDFILL BASED ON 1991 VISUAL AND GEOPHYSICAL OBSERVATIONS
2009-SW-1 ▲	RI SURFACE WATER SAMPLE LOCATION
CYAN TEXT	EXCEEDS NJDEP SURFACE WATER QUALITY STANDARDS FOR HUMAN HEALTH

<u>ABBREVIATIONS:</u>

As	=Arsenic
(t)	=Total Metals

0 100' 200'
GRAPHIC SCALE

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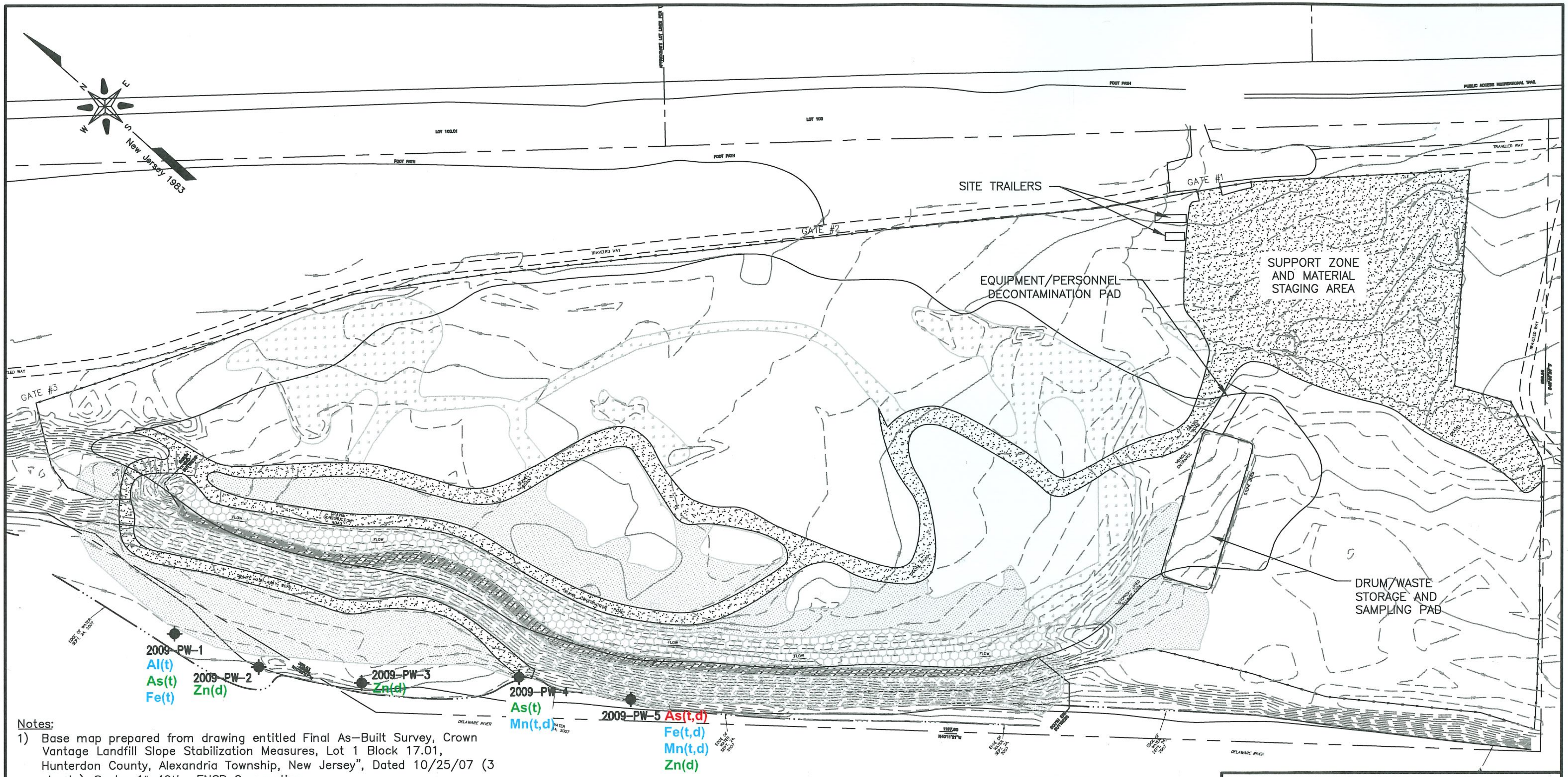
CROWN VANTAGE LANDFILL
ALEXANDRIA TOWNSHIP, NEW JERSEY

FIGURE 2-6
SURFACE WATER SAMPLES EXCEEDING SCREENING CRITERIA

Date: 06/08/10 **Project No.** 164117.000040.000007



Notes:

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   Horizontal Datum: New Jersey State Plan Coordinate System NAD83.

LEGEND

———	EXTENT OF LANDFILL BASED ON 1991 VISUAL AND GEOPHYSICAL OBSERVATIONS
2009-PW-1 ⯐	RI PORE WATER SAMPLE LOCATION
RED TEXT	EXCEEDS EPA MCL, NJDEP MCL, NJ GWQS AND NJ SWQS
CYAN TEXT	EXCEEDS NJ GWQS
GREEN TEXT	EXCEEDS NJ SWQS

ABBREVIATIONS:

Al =Aluminum
As =Arsenic
Fe =Iron
Mn =Manganese
Zn =Zinc
(t) =Total Metals
(d) =Dissolved Metals

0 100' 200'
GRAPHIC SCALE

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CROWN VANTAGE LANDFILL
ALEXANDRIA TOWNSHIP, NEW JERSEY

FIGURE 2-7
PORE WATER SAMPLES EXCEEDING SCREENING CRITERIA

Date: 06/08/10 **Project No.** 164117.000040.000007

J:\CAD\164117\000040\RI Report\Plate-1.dwg Layout:FIGURE 2-7 June 09, 2010-8:32AM Khollenbeck

Curtis Specialty Papers Site

Site Plan
Curtis Specialty Paper
Milford, New Jersey

NOTES:

1. BENZENE CONTOURS COVER A SMALLER AREAL EXTENT AND ARE ENTIRELY WITHIN THE TOLUENE CONTOURS. THEREFORE, BENZENE CONTOURS ARE NOT SHOWN.
2. CONCENTRATIONS IN MICROGRAMS PER LITER (μg/L).

Superfund Proposed Plan

U.S. Environmental Protection Agency

Curtis Specialty Papers Superfund Site

Hunterdon County, New Jersey

May 2015

EPA ANNOUNCES PROPOSED PLAN

This Proposed Plan describes the remedial alternatives considered for the Curtis Specialty Papers Superfund site and identifies the preferred remedial alternative along with the rationale for this preference.

This Proposed Plan was developed by the United States Environmental Protection Agency (EPA), the lead agency for the site, in consultation with the New Jersey Department of Environmental Protection (NJDEP), the support agency. EPA is issuing this document as part of its public participation responsibilities under Section 117(a) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended (CERCLA) and Section 300.430(f)(2) of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).

The nature and extent of the contamination at the site and the remedial alternatives summarized in this Proposed Plan are described in detail in the remedial investigation (RI) and feasibility study (FS) reports issued in September 2014 and April 2015, respectively. These and other documents are part of the publicly available administrative record file. EPA encourages the public to review these reports to gain a more comprehensive understanding of the site and the Superfund activities completed at the site.

EPA's preferred alternative builds upon cleanup actions conducted under CERCLA as the site investigation progressed. The major components of the preferred alternative are in-situ biological treatment (anaerobic biological oxidation, or ABOx) to remediate groundwater, institutional controls (ICs) to restrict groundwater use until cleanup standards are attained, monitoring, and review of site conditions every five years while cleanup standards are still exceeded to ensure that the remedy remains protective of human health and the environment.

The estimated total present worth cost of the preferred alternative is $1,239,000.

MARK YOUR CALENDAR

Public Comment Period - May 19 to June 18, 2015

EPA will accept written comments on the Proposed Plan during the public comment period. Written comments should be addressed to:

Alison Hess, Remedial Project Manager
U.S. Environmental Protection Agency
290 Broadway, 19th Floor
New York, NY 10007
Fax: (212) 637-4866
Email:hess.alison@epa.gov

Public Meeting - May 28, 2015 at 7:00 PM

EPA will hold a public meeting to explain the Proposed Plan and all of the alternatives presented in the Feasibility Study. Oral and written comments will also be accepted at the meeting. The meeting will be held at:

Milford Firehouse
21 Water Street
Milford, New Jersey

EPA's website for the Curtis Specialty Papers Site:

http://www.epa.gov/region2/superfund/npl/curtisspecialty

EPA's Proposed Plan:

http://www.epa.gov/region02/superfund/npl/curtisspecialty/ProposedPlan

Community Role in the Selection Process

This Proposed Plan is being issued to inform the public of EPA's preferred alternative and to solicit public comments pertaining to the remedial alternatives evaluated, including the preferred alternative. Changes to the preferred alternative, or a change from the preferred alternative to another alternative, may be made if public comments or additional data indicate that such a change would result in a more appropriate remedial action. The final decision regarding the selected remedy will be made after EPA has taken into consideration all public comments. EPA is soliciting public comments on the alternatives considered in the Proposed Plan, because EPA may select a remedy other than the preferred alternative. This Proposed Plan has been made available to the public for a public comment period that concludes on June 18, 2015.

A public meeting will be held during the public comment period to present the conclusions of the RI/FS, elaborate further on the reasons for recommending the preferred remedy, and receive public comments. The public meeting will include a presentation by EPA of the preferred alternative and other cleanup options. Information on the public meeting and submitting written comments can be found in the "Mark Your Calendar" text box on page 1.

Comments received at the public meeting, as well as written comments received during the comment period, will be documented in the Responsiveness Summary section of the Record of Decision (ROD). The ROD is the document that explains which alternative has been selected and the basis for the selection of the remedy.

SCOPE AND ROLE OF THE ACTION

This site is being addressed in its entirety as a single operable unit. The RI/FS was conducted for all contaminants, environmental media, and exposure pathways of concern. While the RI/FS was underway, several actions were taken to improve site safety and security and to address conditions that presented an immediate threat to human health and the environment. These actions are summarized on pages 4 to 6.

The response actions in this Proposed Plan were developed to address the present conditions at the site.

SITE BACKGROUND

The site is a former food-grade paper mill located along the Delaware River at 404 Frenchtown Road (County Route 619) in Hunterdon County, New Jersey. Security personnel and chain-link fencing currently restrict access to the site. The tax parcels that comprise the study area occupy approximately 109 acres in the Borough of Milford and Alexandria Township (Figure 1).

Paper production began in 1907 and ended in 2003. During these 96 years, four operational areas developed at the 86-acre site:

- Main Mill Area (MMA) – approximately 28 acres in Milford consisting of process and office facilities, a brick house, a cogeneration power plant, and loading/unloading areas.
- Coatings Facility Area (CFA) – approximately 5 acres in Milford consisting of the Coatings Facility, solvent recovery building, and supporting outbuildings (now mostly demolished).
- Wastewater Treatment Plant Area (WWTPA) – approximately 13 acres in Milford; two clarifier basins, a settling tank, and intake/outfall structures on the shoreline of the Delaware River.
- Coal Pile and Aeration Basin Area (CPABA) – approximately 40 acres in Alexandria Township currently undeveloped; historically a portion of the CPABA served as a staging area for coal that powered site operations.

Frenchtown Road borders the paper mill to the east, with residential and undeveloped properties along it. The Delaware River borders the paper mill to the west, with Pennsylvania on the other bank. Quequacommissacong Creek (Q Creek) borders the mill to the north. North of Q Creek is approximately 20 acres of property (called the "northern parcel") owned by each of the successive mill owner/operators but that was never developed and was not used for paper mill operations. Other properties north of Q Creek are residential and commercial/industrial. Farmland and the Crown Vantage Landfill border the site to the south.

A railroad right-of-way runs north to south through the site. Railroad sections to the north and south of the site have become part of a rails-to-trails program. According to current tax records of the Borough of Milford, the Belvidere and Delaware River Railroad owns the section of right-of-way that crosses the site.

Site owners and operators have changed through time among a number of entities, including Riegel Paper Corporation, Federal Paper Board Company, Inc., Riegel Products Corporation, James River Corporation, James River Paper Company, Inc., Crown Vantage and Curtis Papers, Inc. (including their predecessors, subsidiaries, and other related ventures). International Paper Company (IP) is the corporate successor to Federal Paper Board Company, Inc., and Georgia-Pacific Consumer Products LP (GP) is the successor to Fort James Operating Company and James River Paper Company, Inc.

Superfund History

In August 2008, EPA named IP and GP as potentially responsible parties associated with the site. In September 2008, the Curtis Specialty Papers site was proposed for inclusion on the National Priorities List (NPL) at the request of NJDEP. On September 23, 2009, EPA placed the Curtis Specialty Papers site on the NPL.

In June 2009, IP and GP entered into an Administrative Settlement and Order on Consent (AOC) with EPA to conduct a RI/FS at the site. In July 2009, IP and an indirect, wholly-owned subsidiary of Georgia-Pacific LLC (also the parent company of Georgia-Pacific Consumer Products LP) purchased the site. The AOC was amended in 2010 to add an early response action for pre-demolition activities. Under the terms of the AOC, IP and GP have completed numerous studies, investigations, removals, reports, and other actions.

A Community Advisory Group (CAG) has been meeting quarterly since September 2009. The local community is kept informed of the progress on the RI/FS and other Superfund actions through Community Notification flyers, presentations, and updates in accordance with the 2010 Community Involvement Plan for the site. The local community is interested in future use of the site.

Geology and Hydrology

The site is in the Piedmont Physiographic Province. The regional topography consists of flat, low-lying floodplains and steep valley walls. The relatively flat topography of the site steepens at slopes along Q Creek, the Delaware River, and the unnamed tributary. The site soil is classified as the Pope series, which consists of fine, sandy loam with medium organic content. The soil is deep, well-drained, and level with moderate soil water holding capacity, moderately rapid permeability, limited runoff potential, and slight erosion potential.

The bedrock underlying the site is the Jurassic and Triassic-age (225- to 190-million year old) Passaic Formation, which consists predominantly of grayish-red to reddish-brown shale, siltstone, very fine- to coarse-grained sandstone and a red-matrix conglomerate.

Two water-bearing units occur at the site: an overburden aquifer in the unconsolidated glacial drift and river alluvium and the Brunswick aquifer within the Passaic Formation. The depth to groundwater is approximately 14 to 29 feet. The groundwater elevations indicate groundwater flow is predominantly to the west toward the Delaware River. While the surface alluvium is permeable, the deposits are small in extent and scattered, and the overburden aquifer is not a major source of domestic water supply.

Groundwater from the Brunswick bedrock aquifer is a source of drinking water in the area. The Milford Water Department serves the Borough of Milford with two public water supply wells in the bedrock aquifer. Well 1 is approximately 3,600 feet north, 60 feet deep, and hydrogeologically upgradient of the site. Well 2 is approximately 880 feet north, 255 feet deep, and hydrogeologically upgradient of the site. The Milford Water Department has drilled two additional wells that are in the NJDEP permit review process. Well 3 is approximately 265 feet east, 420 feet deep, and hydrogeologically upgradient of the site. Well 4 is approximately 750 feet east, 220 feet deep, and hydrogeologically upgradient of the site. Residences and commercial businesses along Frenchtown Road near the site are connected to the public water supply.

The Delaware River near the site is a large non-tidal river with a dynamic seasonal flow pattern during the year (high flows after rain or snow melt events). The Lower Delaware is a federally-designated recreational river under the National Wild and Scenic Rivers Act, and the river reach adjacent to the site is designated as Special Protection Waters by the Delaware River Basin Commission. The Delaware River has a 50-foot riparian buffer zone. The most recent flood hazard area and floodway boundaries were drawn by the Federal Emergency Management Agency (FEMA) in September 2009, and most of the site is in the 100-year flood hazard area.

Q Creek originates upstream and flows east to west at the northern boundary of the paper mill before discharging into the Delaware River. Near the site, Q Creek typically has a shallow channel (except during high flow events) and steep banks. Near the confluence with the Delaware River, there is an alluvial fan of coarse sand and gravel. Q Creek is classified by NJDEP as a Trout Production (FW2-TP) – Category One waterway with a 300-foot riparian buffer zone on either side. The Borough of Milford wastewater treatment plant and its permitted outfall are on the north side of Q Creek near the confluence with the Delaware River.

The unnamed tributary is an intermittent drainage feature that originates off-site and collects rainwater and stormwater from Frenchtown Road, residential properties, and farmland. It runs east to west across the site and discharges the runoff into the Delaware River. NJDEP classifies the unnamed tributary as FW2-NT, indicating that it does not support trout populations, with a 50-foot riparian buffer zone on either side. A portion of the unnamed tributary channel onsite is a culvert pipe.

PRELIMINARY INVESTIGATIONS AND EARLY RESPONSE ACTIONS

Site characterization began as part of remedial activities related to releases such as spills during site operations (i.e., pre-2003). Responses to some spills resulted in a determination of No Further Action from NJDEP, while other spills required follow-up activities. The historical investigations and releases at the site as well as any associated response actions are summarized in the 2011 Site Characterization Summary Report.

EPA Removal Site Evaluation and Removal Action (2007 to 2008)

From 2007 to 2008, EPA collected 19 surface samples from locations where electrical transformers were either presently or historically located, and from areas where oil-stained soils were visible. In 2007, a EPA contractor sampled surface and subsurface soil, surface water, sediment, and soil gas. Additional Delaware River sediment samples were collected in 2008.

Also from 2007 to 2008, EPA conducted a removal action to dispose of approximately 30 pallets of containerized waste (i.e., drums, pails, small containers), vats, low-level radiation devices, and six 55-gallon galvanized steel drums left on-site when operations ceased in 2003.

These activities are summarized in the 2008 Removal Site Evaluation and the 2011 Site Characterization Summary Report.

Pre-RI/FS Activities and Oil-Containing Electrical Equipment Removal (2009)

Under the terms of the AOC, in 2009 IP and GP completed pre-RI/FS activities in and around the buildings at the site, such as identifying storage vessels, staging and storage areas, and discharge features. Also in 2009, IP and GP removed oil-containing electrical equipment identified during pre-RI/FS activities.

These activities are summarized in three reports issued in 2009: the Pre-Remedial Investigation/ Feasibility Study Building Survey Report, the Pre-Remedial Investigation/Feasibility Study Report, and the Early Response Action Report – Oil-Containing Electrical Equipment Removal.

Aeration Basin Closure (2010 to 2011)

In 2010 and 2011, IP and GP demolished the aeration basin in the southeast corner of the site. The basin had been excavated in the early 1990s and excess soil was used to construct a berm around the excavation. Infrastructure included an 80-millimeter (3-inch) high density polyethylene liner, mechanical aerators and mixers, an electrical shed, concrete pumping pit/lift station, valve pit, piping, and a perimeter fence. The demolition project involved characterizing water and sludge/sediment, dewatering the basin, clearing and preparing the area, removing the liner, demolishing ancillary structures, stabilizing sludge/sediment, transporting and disposing of off-site waste at permitted facilities, backfilling and final grading, and restoring the site. Six inches of topsoil and a native seed mix were placed throughout the disturbed area. The aeration basin area has returned to a vegetated, open habitat area.

These activities are summarized in the 2012 Aeration Basin Demolition Project Completion Report.

Miscellaneous Site Maintenance Projects (2010 to 2013)

In 2010, IP and GP demolished two small garages identified as Buildings 100 and 101 in the CFA to improve site security. Floor slabs were removed and the areas were regraded to match the surrounding grade, seeded, and mulched.

From 2011 to 2012, IP and GP closed the six production wells that had provided water for site operations. The wells were decommissioned, pumps and casings were removed, boreholes were filled and sealed with grout, and NJDEP Well Decommissioning Reports were filed for these wells.

In 2013, IP and GP demolished the above grade portion of four CPABA buildings and associated structures to improve site security and reduce the health and safety risks associated with abandoned structures. Buildings 114, 115, 116, and 117 were demolished to grade and underground storage tank (UST)-37, located adjacent to Building 114, was removed and the surrounding soil excavated. All asbestos-containing material (ACM), construction and demolition debris, liquid waste, petroleum-impacted soil, concrete and masonry materials, and scrap metal were properly disposed of.

These activities are summarized in the 2014 Miscellaneous Site Maintenance Project Completion Report.

Pre-Demolition Environmental Removal Activities (2011 to 2013)

In 2011 to 2013, IP and GP removed hazardous and regulated materials from the four operational areas of the site, including equipment oil, aboveground storage tank (AST) residuals, fly ash, lead-based paint, Galbestos, universal waste (batteries, mercury-containing devices, lamps, light ballasts, fire extinguishers, sprinkler heads, electronic waste, exit signs, containerized chemicals, and refrigerant-containing equipment); ACM, and process piping. All hazardous and regulated materials were properly disposed of off-site at licensed facilities.

These activities are summarized in the 2013 Pre-Demolition Environmental Removals Project Completion Report.

SAM and CFA Demolition (2012 to 2013)

In late 2011, the Delaware River basin and its tributaries, including Q Creek, experienced heavy rains and flooding, leading to the failure of a dam on Q Creek upstream of the site near Bridge Street in Milford. The rains and dam failure resulted in significant erosion of the banks of Q Creek, exposing USTs and piping and further deteriorating the structural integrity of certain buildings in the CFA. IP and GP proposed a Slope Area Mitigation project (SAM), including a drainage area velocity evaluation, to address the exposed discharge pipes and USTs and provide long-term stability for the eroded bank area of Q Creek at the site.

Planning began immediately for SAM activities, which were conducted from 2012 to 2013, including hydrologic and engineering analyses to understand erosive forces and flood stage conditions in Q Creek near the site; removal of CFA infrastructure (e.g., USTs, sumps, discharge pipes); soil excavation to establish stable slope conditions; and restoration. Some 10,679 cubic yards of soil in the CFA/Q Creek bank area were removed from the site, including soils impacted by toluene and polychlorinated biphenyls (PCBs). Post-excavation samples were collected and excavated areas were backfilled with three feet or more of clean cover, compacted, covered with at least 12 inches of topsoil, and seeded. To conduct the SAM activities, 11 buildings in the CFA were demolished to improve access to the bank of Q Creek. Building floor slabs were left in place unless they needed to be removed to accomplish SAM activities. The bank of Q Creek is now stable and restored with native vegetation.

These activities are summarized in the 2013 Slope Area Mitigation Project Completion Report and the 2014 Coatings Facility Area Demolition Project Completion Report.

Eastern Loadout and Vehicle Access Setup Activities (2014)

In 2014, IP and GP implemented eastern loadout and vehicle access setup (ELVAS) activities in a former electrical transformer area at the eastern perimeter of the MMA near Frenchtown Road. IP and GP dismantled infrastructure, including Building 109, which required removal of PCB-impacted soil, and regraded the area in preparation for future vehicle access and construction use.

These activities are summarized in the 2014 Eastern Loadout and Vehicle Access Setup Project Completion Report.

REMEDIAL INVESTIGATION

Site characterization activities outlined in the 2010 RI/FS Work Plan focused on three main objectives: 1) evaluating potential source materials, 2) characterizing the nature and extent of constituents of potential concern in groundwater and soil at the four operational areas of the site (i.e., MMA, WWTPA, CPABA, and CFA), and in floodplain/bank soil, sediment, and surface water in the Delaware River, Q Creek, and the unnamed tributary, and 3) performing work to support the human health and ecological risk assessments such as characterizing habitat and wildlife receptors, delineating wetlands and flood hazard areas, and identifying potential receptors and exposure pathways. Because the northern parcel was not used for mill operations, no investigatory or other work was performed at that parcel and it is not considered part of the site.

Cultural Resources

Activities conducted under CERCLA are required to comply with the National Historic Preservation Act of 1966. In addition, in 2003, the New Jersey State Historic Preservation Office determined that the site buildings are eligible for listing on the National Register of Historic Properties and together constitute the Curtis Paper Mill Historical District. As an early step in site characterization, IP and GP conducted architectural and pre-contact period cultural resource investigations, which are summarized in the 2010 Phase IA Cultural Resources Investigation Report, three 2010 Phase IB Cultural Resources Investigation Reports, and the 2011 Phase IB Cultural Resources Investigation Report.

Two special efforts on cultural resources are the 2013 Historic Industrial and Architectural Documentation of Former Curtis Specialty Papers Site, Milford, New Jersey (i.e., recordation report) and a set of three related documents (brochure, illustrated booklet, and teacher's guide) entitled, "The Milford Paper Mill: A Legacy of Achievement." This set of documents was released in draft for public input and is being finalized for use by the local community.

Reuse Assessment

To develop an understanding of the reasonably anticipated future use of the site, EPA requested that IP and GP perform a reuse assessment. The reuse assessment integrated several elements related to land use and planning, such as property ownership, physical constraints, zoning and local ordinance, regulatory constraints, and community input.

For the portion of the site within the Borough of Milford, the reasonably anticipated future use is industrial (i.e., the permitted and conditional industrial uses that are specified in the Code of the Borough of Milford for its Industrial Zones) or as specified in the redevelopment overlay in the Borough of Milford 2004 Redevelopment Plan. The redevelopment overlay uses are non-residential (approximately 21 acres), residential (13 acres), public (vacant brick house), mixed professional office and residential (2.8 acres), and conservation uses (balance of the property). Future development would be subject to the flood mapping (e.g., by FEMA in 2009) and associated floodplain regulations.

For the portion of the site within Alexandria Township, the reasonably anticipated future use is open space. The nearly 40 acres occurs within the 100-year flood hazard area. As specified in the Land Use Code of Alexandria Township, the CPABA occurs in a Floodplain District overlay, limiting permitted uses to agriculture, recreation, accessory residential, and accessory commercial. In addition, there is no public sewerage for this portion of the site property, and the use of septic systems would be severely limited under State law as a result of the proximity of the Delaware River.

The results of the reuse assessment were released in draft for public input. The Reuse Assessment Report was finalized in 2011.

RI Fieldwork

RI fieldwork was conducted in 2010 and was supplemented through 2014 with samples collected during early response actions and to support development of the 2015 FS Report. Table 1 summarizes the number of samples in the RI dataset that characterize the present site conditions.

Table 1:
Site Characterization Dataset*

Environmental Media	MMA	WWTPA	Delaware River	CPABA	Unnamed Tributary	CFA	Q Creek	Background
Upland surface soil	87	28	---	57	---	35	---	11
Upland subsurface soil	8	1	---	2	---	125	---	2
Floodplain/bank soil	---	---	---	---	38	---	22	---
Sediment	---	---	28	---	17	---	30	---
Surface water	---	---	10	---	5[+]	---	21	---
Sub-slab soil gas	---	---	---	---	---	3	---	---
Site-wide groundwater	16 monitoring wells ^							

Notes:

*Table 1 does not include samples collected of demolition debris (to evaluate for reuse on the site), topsoil, and imported fill analyzed as part of SAM and/or ELVAS activities.

[+] Portions of the unnamed tributary were dry during sampling activities in August 2007 and August 2010. Surface-water data are only available for upstream samples.

^Subsequent to the RI sampling, an additional five rounds of groundwater sampling were conducted in a subset of monitoring wells.

Groundwater

Analytical results from groundwater sampling identified two volatile organic compounds (VOCs) in the CFA at levels of concern: toluene and benzene. The high concentrations of toluene and benzene in groundwater correlated to locations of USTs, establishing that the toluene and benzene detected in UST contents and surrounding soil removed during the SAM activities were source materials for the groundwater contamination.

A comparison of groundwater sampling data collected before and after the SAM activities shows a substantial decline in the concentration of toluene at locations near the center of the plume due to the SAM activities (e.g., 284,000 micrograms per liter [ug/L] reduced to 82,500 mg/L, and 153,000 ug/L to 82,100 ug/L), although the concentration remains above the Safe Drinking Water Act maximum contaminant level (MCL) of 600 ug/L. The concentrations of benzene in groundwater started lower (e.g., 241 ug/L) and showed a similar substantial decline after the removal of the source materials, although levels remain above the MCL for benzene of 1 ug/L.

The VOC tetrachloroethylene (perc or PCE) was detected at low levels and at isolated locations in the MMA and WWTPA. In the MMA, PCE was detected at concentrations slightly above the MCL (from 6.4 ug/L to 10.6 ug/L, compared to the MCL of 5 ug/L). In the WWTPA, PCE was detected in one well at a concentration of 2.8 ug/L, which is below the MCL of 5 ug/L and above the State standard of 1 ug/L.

Soil

Soil samples collected in the MMA, WWTPA, and CPABA were generally consistent with background upland soil samples. Background is defined as naturally occurring or anthropogenic constituents or locations that are not influenced by releases from the site.

In the CFA, post-excavation soil sampling performed as part of the SAM activities showed non-detect or very low detections of the PCB mixture Aroclor 1260 for the majority of samples. There are two detections of note: one at 7.03 milligrams per kilogram (mg/kg) in upland soil, and one detection in floodplain/bank soil at 15.5 mg/kg. Both of these sample locations are covered by more than six feet of clean fill material, topsoil and native vegetation, and both are within the Q Creek riparian buffer zone.

Delaware River

Surface water and sediment samples collected by EPA in 2007 in the Delaware River were generally low or non-detect along and upriver of the site. PCBs were detected in one sediment sample adjacent to the site, at a lower concentration (0.053 mg/kg) than the upriver sediment samples. In Delaware River surface water, PCBs were not detected along or upriver of the site, except for one very low detection of Aroclor 1260 from a sample that was collected adjacent to the site in 2007 (estimated at 0.26 ug/L).

Q Creek

Aroclor 1260 was detected in Q Creek sediment samples collected by EPA in 2007 (from 0.12 to 3.3 mg/kg) and in one RI sediment sample collected in 2010 adjacent to the CFA (0.101 mg/kg). SAM activities in 2012 through 2013 permanently addressed potential sources of PCBs and related migration pathways to Q Creek sediment.

Unnamed Tributary

Analytical results of sediment samples and floodplain/bank soil samples from the unnamed tributary were generally very low or non-detect and consistent with concentrations observed upstream of the site. The portion of the unnamed tributary on the site was dry when RI field work was conducted, so surface water data are only available for upstream sample locations.

SUMMARY OF SITE RISKS

As part of the RI/FS, baseline risk assessments are conducted to estimate current and future risks to human and ecological receptors posed by hazardous substances at a site in the absence of any actions to control or mitigate exposures to the hazardous substances. The text boxes on page 10 present information on the process EPA uses for human health and ecological risk assessments conducted under CERCLA. Consistent with the NCP, the results of the baseline risk assessment are used to determine whether remediation is necessary and which pathways need to be remediated.

Human Health Risk Assessment

Potential current human receptors include off-site residents, recreators, and anglers. Potential future human receptors include commercial/industrial workers, groundskeepers, construction workers, and on-site residents. The media of interest evaluated include upland soil, ambient air, indoor air (evaluated through sub-slab soil gas samples), groundwater, and floodplain/bank soil, in addition to the sediment and surface water associated with Q Creek, the unnamed tributary, and the Delaware River. Fish consumption was evaluated for Q Creek and the Delaware River. Potential human health risks were evaluated for each exposure area associated with the four operational areas of the site and the three surface water receptor areas.

For almost all the exposure scenarios, the potential cancer risk and noncancer health hazards based on present site conditions are less than or within EPA acceptable levels (i.e., a cancer risk range of 10^{-4} to 10^{-6} and a hazard index [HI] of 1 or less).

The only exposure scenarios with potential risks/hazards due to site-related hazardous substances above EPA levels are exposure (through ingestion, dermal contact and inhalation while showering) to benzene and toluene in groundwater as a potable water supply for potential future on-site residents (adults and children).

The risks and hazards associated with the low-level, isolated detections of PCE in groundwater are within EPA's acceptable levels. The risks and hazards for future on-site residents exposed to soil in each of the four operation areas of the site are also within EPA's acceptable levels.

Detailed information regarding the site-specific human health risk assessment can be found in the 2013 Baseline Human Health Risk Assessment and Appendix L of the 2014 RI Report.

Ecological Risk Assessment

In the baseline ecological risk assessment, the locations of ecologically sensitive areas, chemicals of potential ecological concern, potentially complete exposure pathways, and the results of exposure modeling conducted during the screening level risk assessment, were used to evaluate four assessment endpoints (and associated measurement endpoints) that assess the potential risk to sustainability of the following: 1) mammals and birds that eat insects or worms, such as the short-tailed shrew and American robin; 2) mammals and birds that eat other animals, such as the red fox and red-tailed hawk; 3) mammals that eat fish, such as the mink; and 4) birds that eat aquatic insects, such as the tree swallow.

The risk characterization concluded that potential ecological risk is unlikely for each receptor, chemicals of potential ecological concern, and exposure area evaluated. Thus, the ecological risk assessment indicates that the present site conditions pose no unacceptable risks to ecological receptors.

Detailed information regarding the site-specific ecological risk assessment can be found in the 2012 Screening Level Ecological Risk Assessment and the 2013 Baseline Ecological Risk Assessment Report.

WHAT IS *HUMAN HEALTH* RISK AND HOW IS IT CALCULATED?

A Superfund baseline human health risk assessment is an analysis of the potential adverse health effects caused by hazardous substance releases from a site in the absence of any actions to control or mitigate these under current and future land uses. A four-step process is utilized to assess site-related human health risks for reasonable maximum exposure (RME) scenarios.

Hazard Identification: In this step, the chemicals of potential concern at a site in various media (*e.g.,* soil, surface water, and sediment) are identified based on such factors as toxicity, frequency of occurrence, fate and transport of the contaminants in the environment, concentrations of the contaminants in specific media, mobility, persistence, and bioaccumulation.

Exposure Assessment: In this step, the different exposure pathways through which people might be exposed to the contaminants identified in the previous step are evaluated. Examples of exposure pathways include incidental ingestion of contaminated soil. Factors relating to the exposure assessment include, but are not limited to, the concentrations that people might be exposed to and the potential frequency and duration of exposure. Using these factors, a reasonable maximum exposure scenario, which portrays the highest level of human exposure that could reasonably be expected to occur, is calculated.

Toxicity Assessment*:* In this step, the types of adverse health effects associated with chemical exposures and the relationship between magnitude of exposure and severity of adverse effects are determined. Potential health effects are chemical-specific and may include the risk of developing cancer over a lifetime or other non-cancer health effects, such as changes in the normal functions of organs within the body (*e.g.*, changes in the effectiveness of the immune system). Some chemicals are capable of causing both cancer and non-cancer health effects.

Risk Characterization: This step summarizes and combines outputs of the exposure and toxicity assessments to provide a quantitative assessment of site risks. Exposures are evaluated based on the potential risk of developing cancer and the potential for non-cancer health hazards. The likelihood of an individual developing cancer is expressed as a probability. For example, a 10^{-4} cancer risk means a one-in-ten-thousand excess cancer risk; or one additional cancer may be seen in a population of 10,000 people as a result of exposure to site contaminants under the conditions explained in the Exposure Assessment. Current guidelines for acceptable exposures are an individual lifetime excess cancer risk in the range of 10^{-4} to 10^{-6} (corresponding to a one-in-ten-thousand to a one-in-a-million excess cancer risk) with 10^{-6} being the point of departure. For noncancer health effects, a hazard index (HI) is calculated. An HI represents the sum of the individual exposure levels compared to their corresponding reference doses. The key concept for a noncancer HI is that a threshold level (measured as an HI of 1) exists below which noncancer health effects are not expected to occur.

WHAT IS *ECOLOGICAL* RISK AND HOW IS IT CALCULATED?

A Superfund baseline ecological risk assessment is an analysis of the potential adverse health effects caused by hazardous substance releases from a site in the absence of any actions to control or mitigate these under current and future land uses. The process used for assessing site-related ecological risks includes:

Problem Formulation: In this step, the contaminants of potential ecological concern at a site are identified. Assessment endpoints are defined to determine what ecological entities are important to protect. Then, the specific attributes of the entities that are potentially at risk and important to protect are determined. This provides a basis for measurement in the risk assessment. Once assessment endpoints are chosen, a conceptual model is developed to provide a visual representation of hypothesized relationships between ecological entities (receptors) and the stressors to which they may be exposed.

Exposure Assessment: In this step, a quantitative evaluation is made of what plants and animals are exposed to and to what degree they are exposed. This estimation of exposure point concentrations includes various parameters to determine the levels of exposure to a chemical contaminant by a selected plant or animal (receptor), such as area use (how much of the site an animal typically uses during normal activities); food ingestion rate (how much food is consumed by an animal over a period of time); bioaccumulation rates (the process by which chemicals are taken up by a plant or animal either directly from exposure to contaminated soil, sediment or water, or by eating contaminated food); bioavailability (how easily a plant or animal can take up a contaminant from the environment); and life stage (e.g., juvenile, adult).

***Ecological Effects Assessment**:* In this step, literature reviews, field studies or toxicity tests are conducted to describe the relationship between chemical contaminant concentrations and their effects on ecological receptors, on a media-, receptor- and chemical-specific basis. In order to provide upper and lower bound estimates of risk, toxicological benchmarks are identified to describe the level of contamination below which adverse effects are unlikely to occur and the level of contamination at which adverse effects are more likely to occur.

Risk Characterization: In this step, the results of the previous steps are used to estimate the risk posed to ecological receptor. Individual risk estimates for a given receptor for each chemical are calculated and a hazard quotient (HQ), which is the ratio of contaminant concentration to a given toxicological benchmark. In general, an HQ above 1 indicates the potential for unacceptable risk. The risk is described, including the overall degree of confidence in the risk estimates, summarizing uncertainties, citing evidence supporting the risk estimates and interpreting the adversity of ecological effects.

FEASIBILITY STUDY

The FS is the mechanism for the evaluation of alternative remedial actions. During the FS phase, remedial action objectives (RAOs) are developed, preliminary remediation goals (PRGs) are identified, technologies are screened based on overall implementability, effectiveness and cost, and remedial alternatives are assembled and analyzed in detail with respect to the nine criteria for remedy selection under CERCLA.

Detailed information is available in the 2011 Technical Memorandum of Candidate Technologies, the 2013 Technical Memorandum on the Development and Screening of Alternatives, and the 2015 FS Report.

The RAOs below only address groundwater. The HHRA did not identify unacceptable human exposures to soils, even under a future unrestricted use scenario; however, the RI did sporadically detect several constituents in excess of New Jersey's unrestricted use soil standards (i.e., the Residential Direct Contact Soil Remediation Standards). While these detections do not warrant a response action under CERCLA, EPA understands that NJDEP will require the imposition of an IC, in the form of a deed notice, on portions of the site property where levels of constituents are in excess of the Residential Direct Contact Soil Remediation Standards. Because additional actions are anticipated by the property owner, including demolition of additional structures and further post-demolition sampling, it is not possible to determine at this time if, and to what extent, an IC might be required. These determinations would be addressed between NJDEP and the property owner prior to the reuse of the site.

Remedial Action Objectives

RAOs describe what the proposed site cleanup is expected to accomplish. These objectives are based on available information and standards, such as applicable or relevant and appropriate requirements (ARARs), to-be-considered standards and guidance, and site-specific risk-based levels. The following RAOs have been developed to address the groundwater impacts at the site:

- Prevent ingestion of groundwater having constituent concentrations greater than their respective MCLs

- Reduce the cancer risk and noncancer health hazards due to exposure to toluene and benzene in groundwater to within or below EPA's acceptable levels of 10^{-6} to 10^{-4} for cancer and HI of 1 or less for noncancer

- Restore groundwater to unrestricted use by reducing concentrations of VOCs in groundwater, including benzene, toluene, and PCE.

Preliminary Remediation Goals

PRGs become final remediation goals when EPA makes a final decision to select a remedy for the site, after taking into consideration public comments. The PRGs for groundwater were developed to meet the site-specific RAOs.

Constituent in Groundwater	PRG (µg/L)
Benzene	1
Toluene	600
PCE	1

Remedial Alternatives

CERCLA § 121(b)(1), 42 U.S.C. § 9621 (b)(1), mandates that remedial actions be protective of human health and the environment, be cost effective, and use permanent solutions, alternative treatment technologies, and resource recovery alternatives to the maximum extent practicable. Section 121(b)(1) also establishes a preference for remedial actions which use, as a principal element, treatment to permanently and significantly reduce the volume, toxicity, or mobility of the hazardous substances, pollutants, and contaminants at a site. CERCLA § 121(d), 42 U.S.C. § 9621(d), further specifies that a remedial action must require a level or standard of control of the hazardous substances, pollutants, and contaminants, which at least attains ARARs under federal and state laws, unless a waiver can be justified pursuant to CERCLA § 121(d)(4), 42 U.S.C. § 9621(d)(4).

Remedial alternatives for the site are summarized below. Capital costs are those expenditures that are required to construct a remedial alternative. Operation and maintenance costs are those post-construction costs necessary to ensure or verify the continued effectiveness of a remedial alternative and are estimated on an annual basis. Present worth is the amount of money which, if invested in the current year, would be sufficient to cover all the costs over time associated with a project, calculated using a discount rate of seven percent and a 30-year time interval. Construction time is the time required to construct and implement the alternative and does not include the time required to design the remedy, negotiate performance of the remedy with the responsible parties, or procure contracts for design and construction.

Remedial Alternatives	
Alternative	**Description**
1	No Action
2	Institutional Controls
3	Physical/Chemical Treatment (Air Sparging/Soil Vapor Extraction) and Institutional Controls
4	In-situ Biological Treatment (Anaerobic Biological Oxidation) and Institutional Controls

Alternative 1: No Action

Capital Cost:	$0
Annual Operation & Maintenance (O&M) Cost:	$0
Present Worth Cost:	$0
Construction Time	0 months

The No Action alternative is required by the NCP and EPA guidance as a baseline with which to compare other remedial action alternatives. Alternative 1 is not protective of human health and the environment because it does not include any measures to prevent ingestion of contaminated groundwater, reduce cancer risks and noncancer health hazards, or restore the groundwater.

Because Alternative 1 would result in contaminants remaining above levels that allow for unrestricted use and unlimited exposure, a review of site conditions would be conducted at least once every five years, as required by CERCLA.

Alternative 2: Institutional Controls

Capital Cost:	$79,000
Annual O&M Cost:	$37,000
Present Worth Cost:	$532,000
Construction Time	1 year

In this alternative, institutional controls (ICs) would be used to control potential exposure routes to impacted groundwater. ICs would consist of a Classification Exception Area/Well Restriction Area (CEA/WRA) to restrict groundwater use and prevent future use of site groundwater for potable purposes. The CEA/WRA would be established pursuant to the substantive requirements of New Jersey Administrative Code (N.J.A.C.) 7:26C-7.3, and would remain in effect until RAOs and PRGs are achieved.

Because Alternative 2 would result in contaminants remaining above levels that allow for unrestricted use and unlimited exposure, a review of site conditions would be conducted at least once every five years, as required by CERCLA.

Alternative 3: Physical/Chemical Treatment (Air Sparging/Soil Vapor Extraction) and Institutional Controls

Capital Cost:	$761,000
Annual O&M Cost:	$75,000
Present Worth Cost:	$1,442,000
Construction Time:	15 years

This alternative involves physical/chemical treatment comprised of air sparging (AS) technology to remove VOCs from groundwater, and soil vapor extraction (SVE) technology to capture and remove vapors from the subsurface.

ICs in the form of a CEA/WRA would be established, as described under Alternative 2.

AS technology involves the injection of air into the subsurface through a network of sparge wells or trenches. Air bubbles released from sparge points rise up through the subsurface, contacting groundwater. This action results in a transfer of VOC mass from the dissolved (aqueous) phase to the vapor phase. The SVE technology involves inducing air flow in the subsurface with an applied vacuum. This vacuum creates a capture zone for the vapor-phase constituents.

Treatment and discharge of vapors would be aboveground by physical or chemical methods (e.g., activated carbon or catalytic oxidation) and would comply with effluent emissions requirements.

During remedial design, pilot testing would be conducted to maximize the air contact with impacted groundwater and identify the appropriate flow rates and the number and locations of sparge wells and vapor extraction wells, as well as the operating parameters for the aboveground vapor treatment system. For purposes of the FS Report, AS/SVE was assumed to be implemented in the area of highest concentration with eight sparge wells and four vapor extraction wells. A monitoring plan would be implemented to assess the effectiveness of the AS/SVE system in reducing VOC concentrations in groundwater and to optimize its performance.

This alternative would comply with EPA guidance for completion of groundwater remedies (e.g., May 2014 Groundwater Remedy Completion Strategy, OSWER Directive 9200.2-144).

Because Alternative 3 would result in contaminants remaining above levels that allow for unrestricted use and unlimited exposure, a review of site conditions would be conducted at least once every five years until the RAOs and PRGs are met.

Alternative 4: In-situ Biological Treatment (Anaerobic Biological Oxidation) and Institutional Controls

Capital Cost:	$444,000
Annual O&M Cost:	$87,000
Present Worth Cost:	$1,239,000
Construction Time:	10-15 years

In this alternative, in-situ biological treatment (anaerobic biological oxidation or ABOx) would be used to remove VOCs from the groundwater. A network of injection wells would be installed to deliver a sulfate solution to the subsurface.

ICs in the form of a CEA/WRA would be established, as described for Alternative 2.

The construction (clean-up) time is estimated to be 10 years for toluene and benzene in the CFA and 15 years for the low-level, isolated detections of PCE.

During remedial design, pilot testing would be conducted to assess injection hydraulics, sulfate concentrations, and the number and locations of the full-scale injection wells. For purposes of the FS Report, ABOx was assumed to be implemented in the area of highest concentration with quarterly injections over five years (20 total injection events). A monitoring plan would be implemented to assess the effectiveness of the biological treatment in reducing VOCs in groundwater and to optimize its performance.

This alternative would comply with EPA guidance for completion of groundwater remedies (e.g., May 2014 Groundwater Remedy Completion Strategy, OSWER Directive 9200.2-144).

Because Alternative 4 would result in contaminants remaining above levels that allow for unrestricted use and unlimited exposure, a review of site conditions would be conducted at least once every five years until RAOs and PRGs are met.

COMPARATIVE ANALYSIS OF ALTERNATIVES

In the FS, each alternative is assessed against the evaluation criteria for Superfund remedial alternatives and is compared to the other alternatives under consideration with respect to the Superfund evaluation criteria. A description of each criterion is provided in the text box on page 15. A summary of the comparative analysis of alternatives is provided in Table 5-1 of the 2015 FS Report.

Overall Protection of Human Health and the Environment

Alternative 1 would provide no additional protection to human health and the environment.

Alternative 2 would employ ICs to restrict the use of groundwater and thereby provide protection to human health and the environment for the first two RAOs. However, it would not achieve the third RAO of restoring groundwater to unrestricted use.

Alternatives 3 and 4 would provide the greatest protection to human health and the environment through active treatment and ICs, and would address all three RAOs.

Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)

Appendix C of the 2015 FS Report includes a summary of the action-specific, location-specific and chemical-specific ARARs for the remedial alternatives evaluated.

Alternative 1 does not trigger any action-specific ARARs. Alternative 2 would comply with the action-specific ARARs for establishing the CEA/WRA. Alternatives 1 and 2 do not involve any location-specific ARARs. Alternatives 1 and 2 would not comply with chemical-specific ARARs.

Alternatives 3 and 4 would comply with action-specific, location-specific and chemical-specific ARARs. Alternative 4 is preferred to Alternative 3 because the chemical-specific ARARs are expected to be met in a shorter period of time.

Long-Term Effectiveness and Permanence

Alternative 1 would not provide long-term effectiveness or permanence because groundwater impacts would not be addressed.

Alternative 2 calls for ICs, which would provide long-term effectiveness and permanence with respect to the first two RAOs. Alternative 2 would not provide long-term effectiveness and permanence with respect to the third RAO.

Alternatives 3 and 4 would provide long-term effectiveness and permanence for all three RAOs by removing VOCs from the groundwater.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternatives 1 and 2 would not use treatment to reduce toxicity, mobility, or the volume of the impacted groundwater and would be considered the least effective alternatives for meeting this criterion.

Alternatives 3 and 4 would use treatment to reduce toxicity, mobility and volume of VOCs though treatment. Alternative 3 would utilize air sparging, extraction, and aboveground treatment of VOC vapors, transferring the contaminants to another medium that requires further treatment and disposal. Alternative 4 would use in-situ biological treatment in the subsurface . Therefore, Alternative 4 is considered marginally more effective than Alternative 3 in meeting this criterion.

Short-Term Effectiveness

Alternatives 1 and 2 would not pose potential additional risk or hazard to the community, the workers, or the environment. However, this alternative does not mitigate existing potential exposure pathways.

Alternatives 3 and 4 are effective in the short-term. Alternatives 3 and 4 would have minimal potential risks or hazards associated with well installation activities, which would be minimized using administrative and engineering controls, health and safety measures, and proper personal protective equipment. The effectiveness monitoring for Alternative 4 would ensure that biological degradation does not cause transient surface water quality issues. Alternative 3 would have additional potential risks or hazards associated with the installation of the aboveground collection and treatment facilities for the extracted vapors. In addition, Alternative 3 is estimated to take longer (15 years) than Alternative 4 (10 years) to meet the RAOs and achieve the PRGs for toluene and benzene. Therefore, Alternative 4 is preferred to Alternative 3 with respect to this criterion.

Implementability

Alternative 1 would require no resources or effort to implement.

Alternative 2 is considered the most implementable alternative as it is administratively and technically feasible and requires minimal resources and limited effort to implement.

Alternatives 3 and 4 are administratively and technically feasible; however, implementation of either alternative would take a greater level of effort than Alternative 2. Alternative 4 is considered more administratively and technically feasible to implement than Alternative 3 because it does not require the design, construction, and implementation of an aboveground treatment and discharge system.

EVALUATION CRITERIA FOR SUPERFUND REMEDIAL ALTERNATIVES

1. Overall Protection of Human Health and the Environment evaluates whether an alternative eliminates, reduces, or controls threats to public health and the environment through institutional controls, engineering controls, or treatment.

2. Compliance with Applicable or Relevant and Appropriate Requirements (ARARs) evaluates whether the alternative meets federal and state environmental statutes, regulations, and other requirements that pertain to the site, or whether a waiver is justified.

3. Long-term Effectiveness and Permanence considers the ability of an alternative to maintain protection of human health and the environment over time.

4. Reduction of Toxicity, Mobility, or Volume of Contaminants through Treatment evaluates an alternative's use of treatment to reduce the harmful effects of principal contaminants, their ability to move in the environment, and the amount of contaminant present.

5. Short-term Effectiveness considers the length of time needed to implement an alternative and the risks the alternative poses to workers, the community, and the environment during implementation.

6. *Implementability* considers the technical and administrative feasibility of implementing the alternative, including factors such as the relative availability of goods and services.

7. *Cost* includes estimated capital and annual operation and maintenance costs, as well as present-worth cost. Present-worth cost is the total cost of an alternative over time in terms of today's dollar value. Cost estimates are expected to be accurate within a range of +50 to -30 percent.

8. *State Acceptance* considers whether the State agrees with EPA's analyses and recommendations, as described in the RI/FS and Proposed Plan.

9. *Community Acceptance* considers whether the local community agrees with EPA's analyses and preferred alternative. Comments received on the Proposed Plan are an important indicator of community acceptance.

Cost

A table of the estimated capital, annual O&M, and present worth costs for each alternative is provided below.

Alter-native	Capital Costs	Annual O&M Costs	Present Worth
1	$0	$0	$0
2	$79,000	$37,000	$532,000
3	$761,000	$75,000	$1,442,000
4	$444,000	$87,000	$1,239,000

State Acceptance

NJDEP is reviewing the proposed remedy.

Community Acceptance

Community acceptance of the preferred alternative will be assessed in the ROD following review of the public comments received on the Proposed Plan.

PREFERRED ALTERNATIVE AND BASIS FOR SELECTION

EPA's preferred alternative is Alternative 4: In-situ Biological Treatment (Anaerobic Biological Oxidation) and Institutional Controls.

The major components of the preferred alternative are as follows:

- Establishing and maintaining ICs in the form of a CEA/WRA to restrict groundwater use and ensure that groundwater is not used for potable purposes until the RAOs and PRGs have been met;
- Installing additional monitoring wells (approximately three wells are assumed) to supplement the existing monitoring well network;
- Implementing an ABOx injection program;

- Monitoring groundwater to evaluate biological treatment effectiveness until the RAOs and PRGs are met; and

- Reviewing site conditions at least once every five years, as required by CERCLA, until the RAOs are met.

The preferred alternative satisfies the two threshold criteria and achieves the best combination of the five balancing criteria of the comparative analysis. This alternative is preferred because it will achieve the RAOs and PRGs in the shortest amount of time. It provides underground treatment of VOCs in groundwater that constitute potential risk and hazard drivers at the site. Effectiveness monitoring will provide data to optimize the treatment during remedy implementation and will ensure that the RAOs and PRGs are achieved.

Based on information currently available, EPA believes the preferred alternative meets the threshold criteria and provides the best balance of tradeoffs among the other alternatives with respect to the balancing criteria. EPA expects the preferred alternative to satisfy the following statutory requirements of CERCLA § 121(b): 1) be protective of human health and the environment; 2) comply with ARARs; 3) be cost effective; 4) utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable; and 5) satisfy the preference for treatment as a principal element. EPA will assess the two modifying criteria of State acceptance and community acceptance in the Record of Decision to be issued following the close of the public comment period.

FOR FURTHER INFORMATION

The administrative record file, which contains copies of the Proposed Plan and supporting documentation, is available at the following locations:

Milford Public Library
40 Frenchtown Road
Milford, New Jersey 08848
(908) 995-4072
Hours: Mon, 12:00 PM-7:00 PM; Tues, 11:00 AM-5:00 PM; Wed, 12:00 PM-8:00 PM; Thurs, 11:00 AM-8:00 PM; Fri, 10:00 AM-1:00 and 5:00 PM-8:00 PM; Sat, 10:00 AM-1:00 PM.

EPA Region 2, Superfund Records Center
290 Broadway, 18th Floor
New York, New York 10007-1866
(212) 637-4308
Hours: Mon – Fri, 9:00 AM-5:00 PM

In addition, select documents from the administrative record are available on-line at:

http://www.epa.gov/region2/superfund/npl/curtisspecialtypapers/

CURTIS SPECIALTY PAPERS SITE
PROPOSED PLAN

SITE PLAN | **1**

Table 9: Calculated LECR associated with the contaminants detected in Sediment near Quequacommissacong Creek at the Curtis Specialty Paper Site

Contaminants of Concern	Exposure Point Concentration (mg/kg)		DHSS Cancer Class[a]	Potency Factor[b]	BaP Equiv.	Total BaP Equiv.	Maximum Exposure Dose[c] (mg/kg-day)	CSF[d] (mg/kg-day)$^{-1}$	LECR[e]
	Max.	Mean							
Benzo[a]pyrene	0.12	0.0678	1	1	0.12	0.12	5.5 x10^{-8} (3.1 x10^{-8})	7.3	4 x10^{-7} (2.3 x10^{-7})[g]
Benzo[g,h,i]perylene	0.085	0.0577	3[f]						
Phenanthrene	0.11	0.0788	3						
Aroclor-1260	3.3	1.12	2	NA	NA	NA	1.52 x10^{-6} (5.14 x10^{-7})	2	3.0 x10^{-6} (1.0 x10^{-6})
Arsenic	4.3	2.58	1	NA	NA	NA	1.97 x10^{-6} (1.18x 10^{-6})	1.5	3.0 x10^{-6} (1.8 x10^{-6})

[a] Department of Health and Human Services Cancer Class: 1 = known human carcinogen; 2 = reasonably anticipated to be a carcinogen; 3 = not classified; [b] Cancer potency factor relative to benzo[a]pyrene (BaP); [c] Exposure scenario: 7 days/week, 9 months/year, 100 mg/day ingestion rate, 70 kg body weight; [d] Cancer Slope Factor; [e] Lifetime Excess Cancer Risk; [f] not carcinogenic therefore no cancer risk calculation was derived; [g] cancer estimate based on mean contaminant concentration

Martins Creek Power Station Site

Assessment of Water Column data collected in response to a fly ash release on the Delaware River

Delaware River Basin Commission
DELAWARE · NEW JERSEY
PENNSYLVANIA · NEW YORK
UNITED STATES OF AMERICA

Delaware River Basin Commission

John R. Yagecic, P.E.
June 19, 2006

Executive Summary

- Ash basin leak at PPL's Martin's Creek power plant August 23rd-27th, 2005 released ~100 million gallons of ash and water into the Delaware River;
- The States of PA & NJ requested that DRBC compile and assess water column data from agencies and PPL;
- The results of this effort are as follows:

Arsenic

- Some apparent exceedance of PA human health arsenic criteria immediately after the release in the vicinity of the release. These exceedances are not observed upstream of the release.
- Apparent signature of release observable downstream but below PA arsenic criteria.

Executive Summary (continued)

Lead

- Apparent exceedances of PA and NJ lead criteria immediately after release in the vicinity of the release.

Aluminum

- Some short term local exceedance of PA aluminum criteria from release, but background and high flows account for most of the observed concentration.

Manganese

- Manganese concentrations appear to be background concentrations.

Executive Summary (continued)

Copper

- Short term copper exceedances of PA criteria at release and downstream.

Selenium

- Selenium concentrations appear to be background concentrations.

Mercury

- Mercury data almost completely below reporting limits.

Brief Background

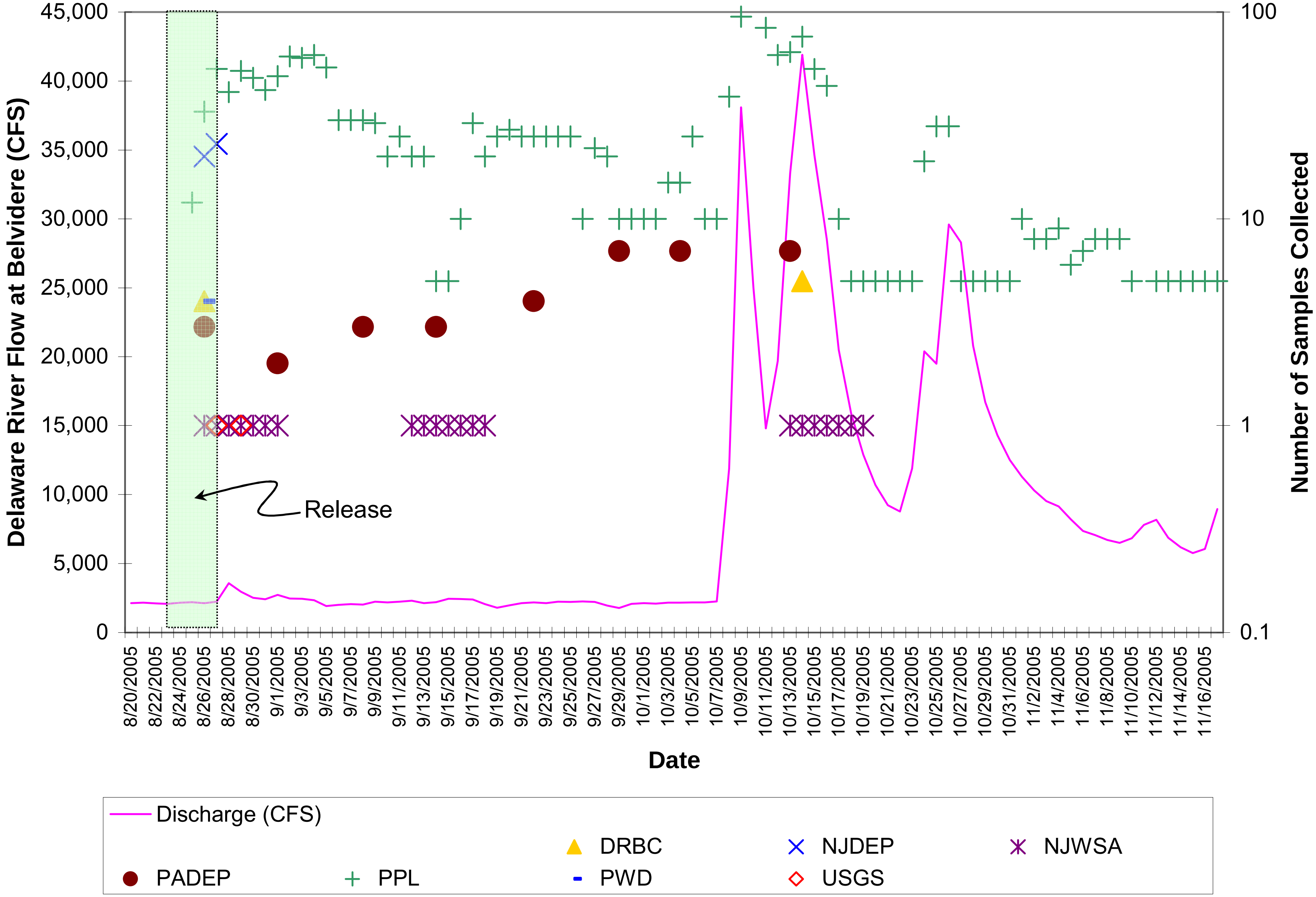
- Ash basin leak at PPL’s Martin’s Creek power plant August 23rd-27th, 2005 released ~100 million gallons of ash and water into the Delaware River;
- Agencies and PPL met at DRBC on November 3, 2005 to review data collected up to that point;
- DRBC agreed to compile and assess data from agencies and PPL;
- Agencies and PPL agreed that DRBC and PPL should perform separate but parallel assessments;
- Agencies and PPL previewed DRBC draft assessment on March 2, 2006. Recommended expansion of the data set and minor changes.
- This Document:
  - Results of DRBC’s assessment;
  - Narrowly focused on data – not an assessment of regulatory issues.

Post-Release Water Column Sampling Effort

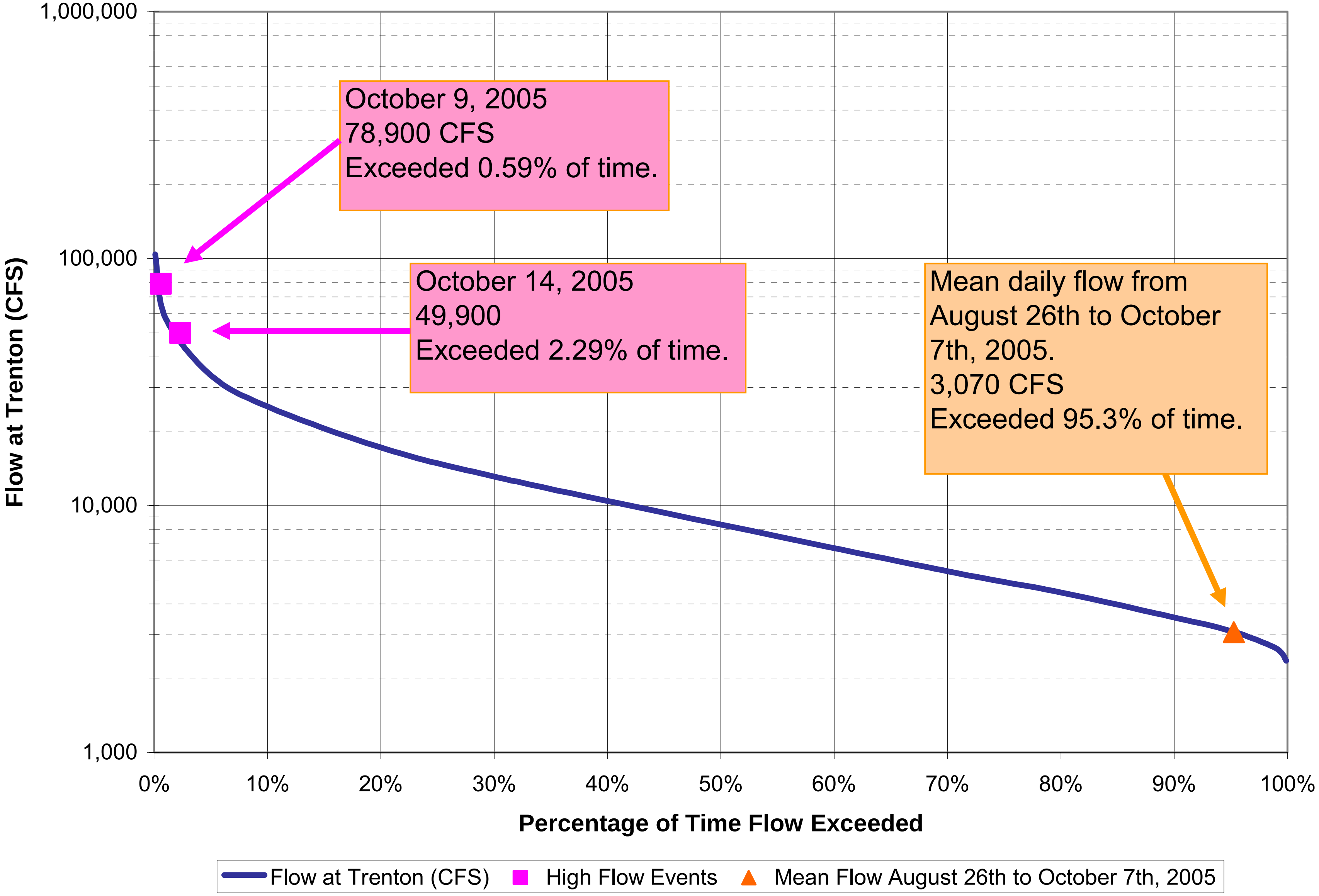
Data received by DRBC as of 12/2005

Organization	Samples Collected	Sampling Days	Locations	Analytical Parameters
PPL	>1,700	84	16	60
NJDEP	47	2	9	28
PADEP	36	8	16	up to 117
NJWSA	21	21	1	24
DRBC	9	2	4-5	30
PWD	4	1	4	5
USGS	2	2	1	10
Total	>1,819			

Post-Release Sampling Effort



Wide Range of Flows During Sampling



October 9, 2005
78,900 CFS
Exceeded 0.59% of time.

October 14, 2005
49,900
Exceeded 2.29% of time.

Mean daily flow from August 26th to October 7th, 2005.
3,070 CFS
Exceeded 95.3% of time.

Criteria at the time of release

(some criteria have subsequently changed)

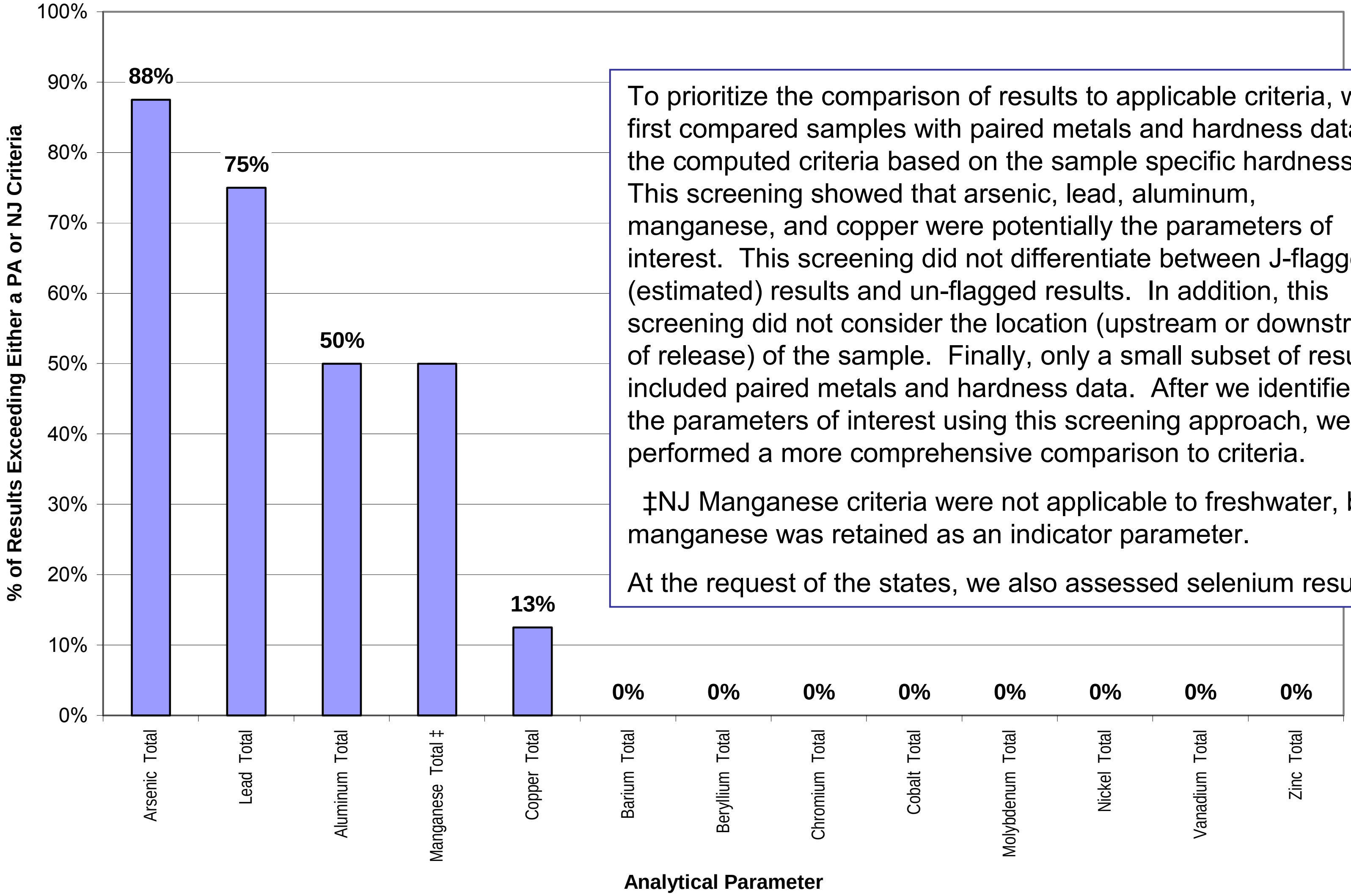
Pennsylvania

- Chapter 16. Water Quality Toxics Management Strategy – Statement of Policy;
- CCCs, CMCs, and Human Health Criteria.
- Governing (most stringent) PA criteria;
  - Human Health for arsenic;
  - CCC for all others.

New Jersey

- Surface Water Quality Standards N.J.A.C. 7:9B (June 2005);
- For the Delaware River, NJ defers to DRBC criteria where DRBC have criteria;
- Where DRBC doesn’t, use FW2-NT criteria for non-saline waters.

Prioritization of Analytical Parameters*



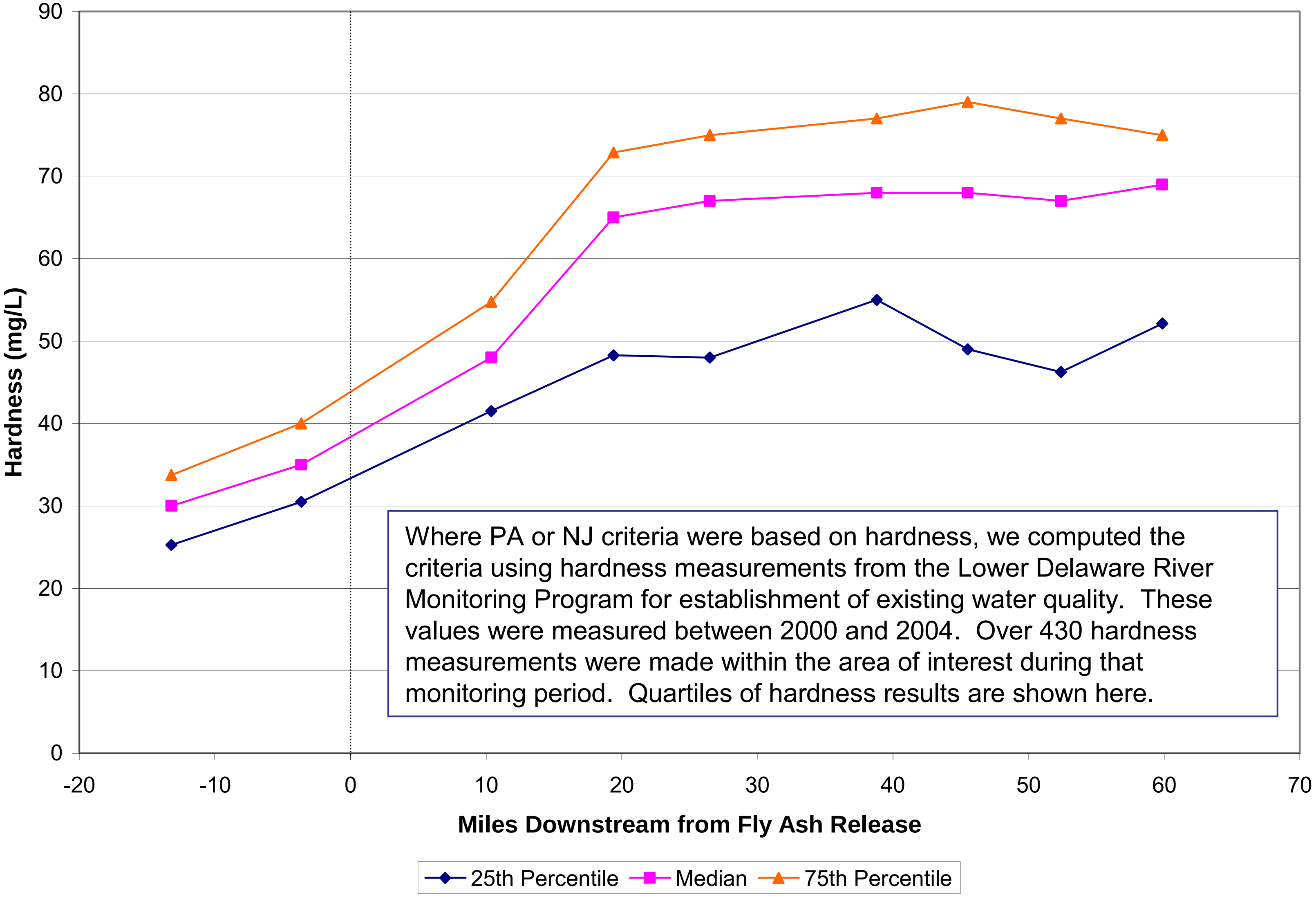
To prioritize the comparison of results to applicable criteria, we first compared samples with paired metals and hardness data to the computed criteria based on the sample specific hardness. This screening showed that arsenic, lead, aluminum, manganese, and copper were potentially the parameters of interest. This screening did not differentiate between J-flagged (estimated) results and un-flagged results. In addition, this screening did not consider the location (upstream or downstream of release) of the sample. Finally, only a small subset of results included paired metals and hardness data. After we identified the parameters of interest using this screening approach, we performed a more comprehensive comparison to criteria.

‡NJ Manganese criteria were not applicable to freshwater, but manganese was retained as an indicator parameter.

At the request of the states, we also assessed selenium results.

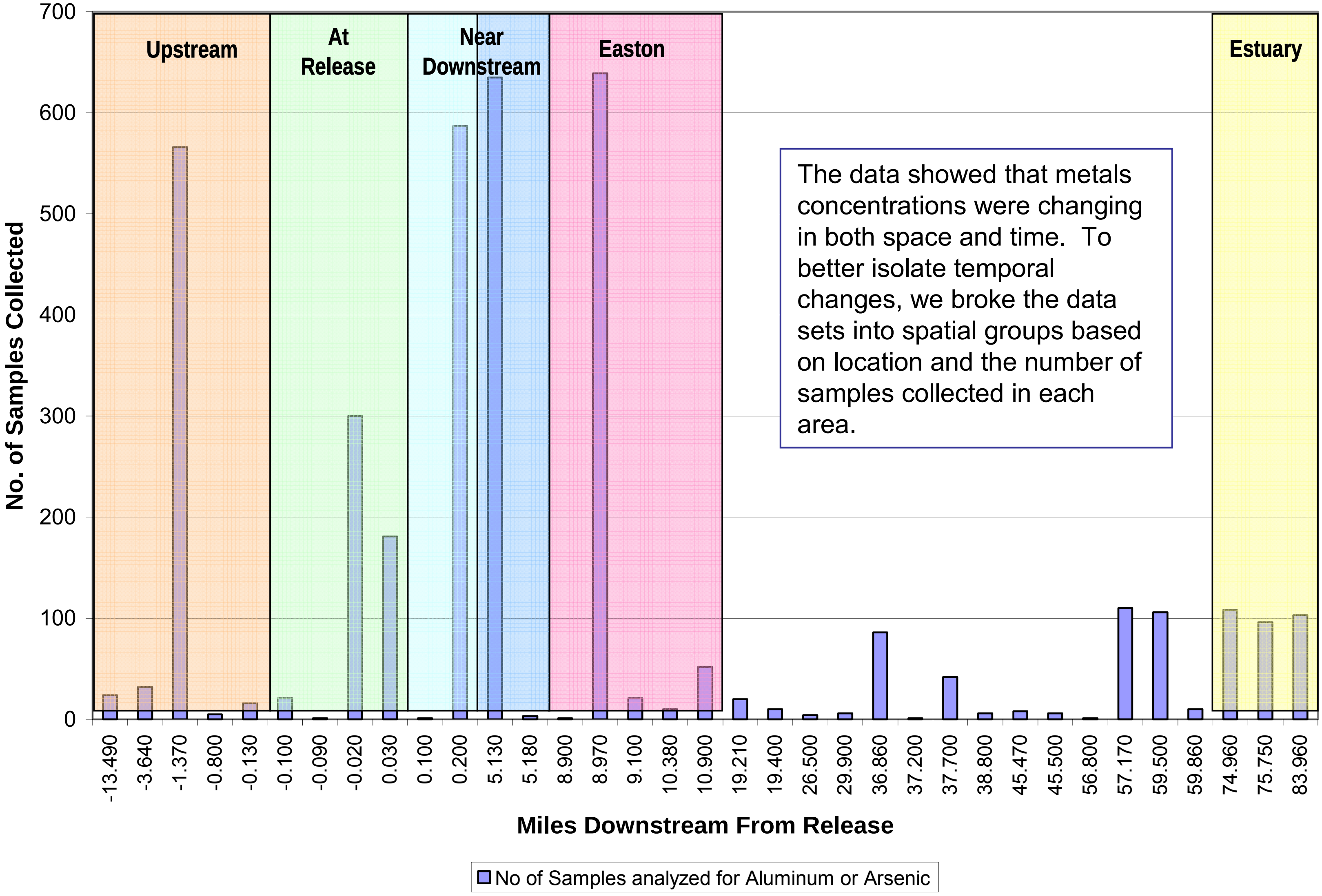
*For prioritization only – not for regulatory purposes

Hardness Ranges from Lower Delaware Existing Water Quality Study



Where PA or NJ criteria were based on hardness, we computed the criteria using hardness measurements from the Lower Delaware River Monitoring Program for establishment of existing water quality. These values were measured between 2000 and 2004. Over 430 hardness measurements were made within the area of interest during that monitoring period. Quartiles of hardness results are shown here.

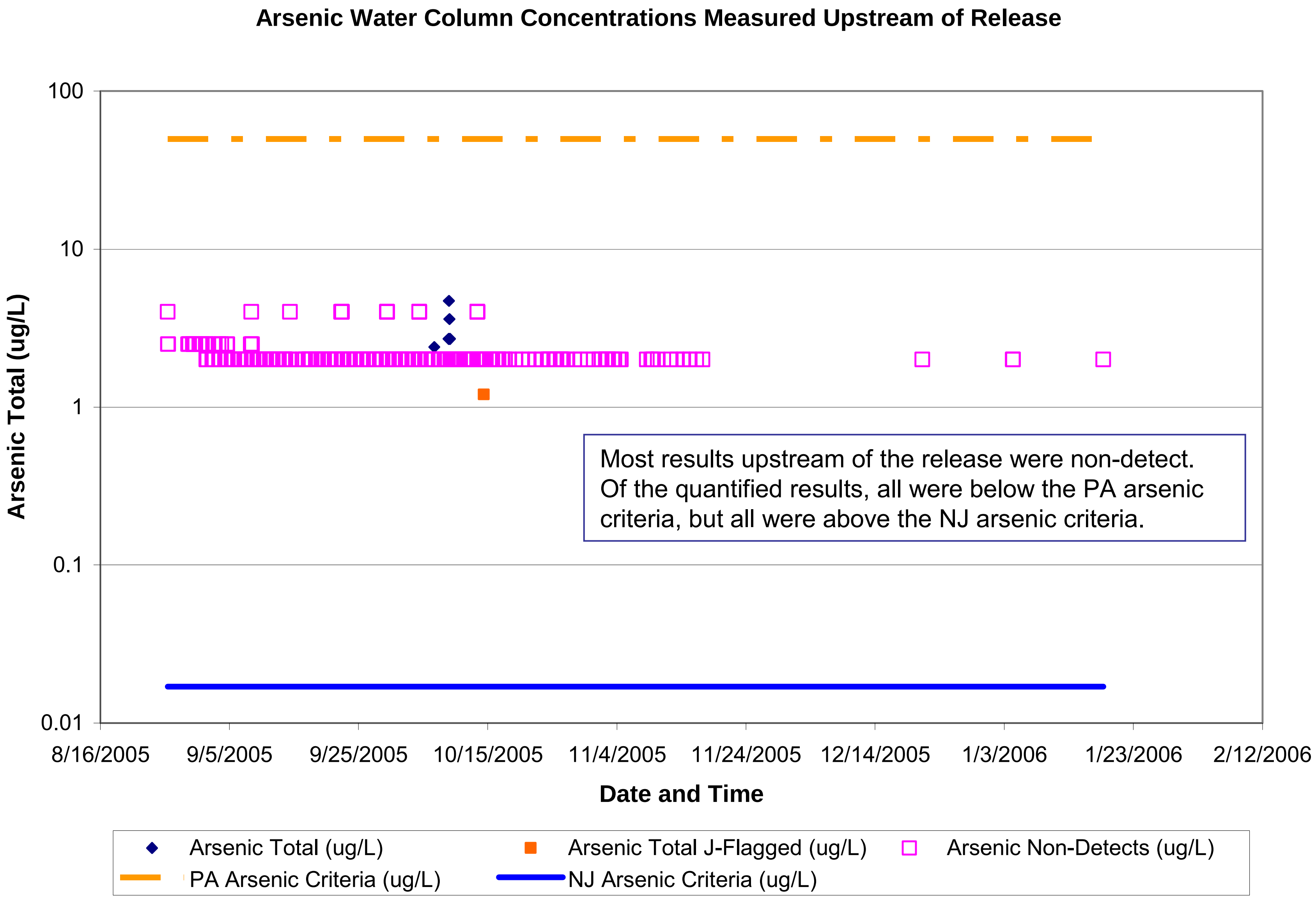
Spatial Grouping of Results
based on Arsenic and Aluminum Samples



The data showed that metals concentrations were changing in both space and time. To better isolate temporal changes, we broke the data sets into spatial groups based on location and the number of samples collected in each area.

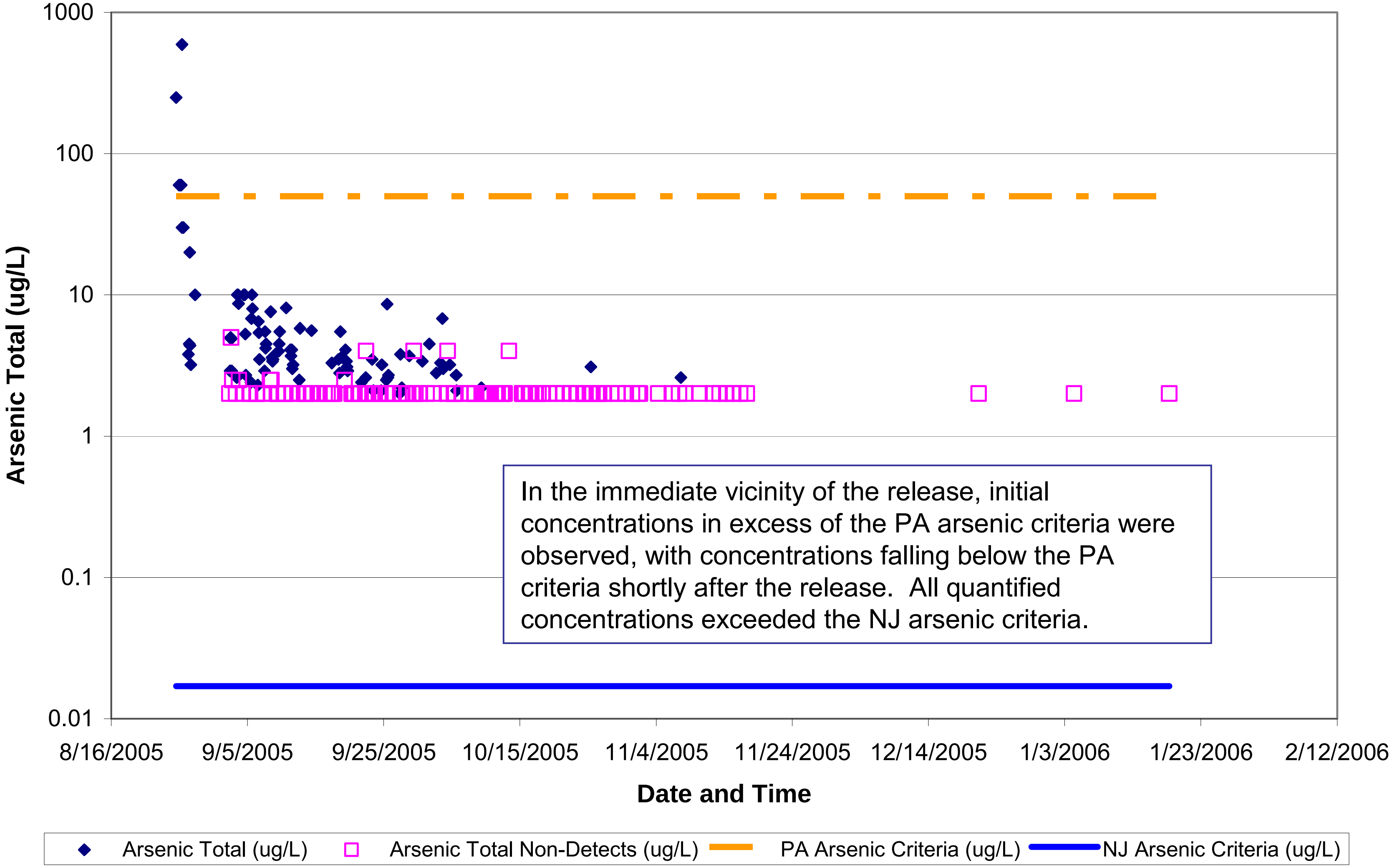
Arsenic Results

Arsenic Concentrations Upstream of Release



Most results upstream of the release were non-detect. Of the quantified results, all were below the PA arsenic criteria, but all were above the NJ arsenic criteria.

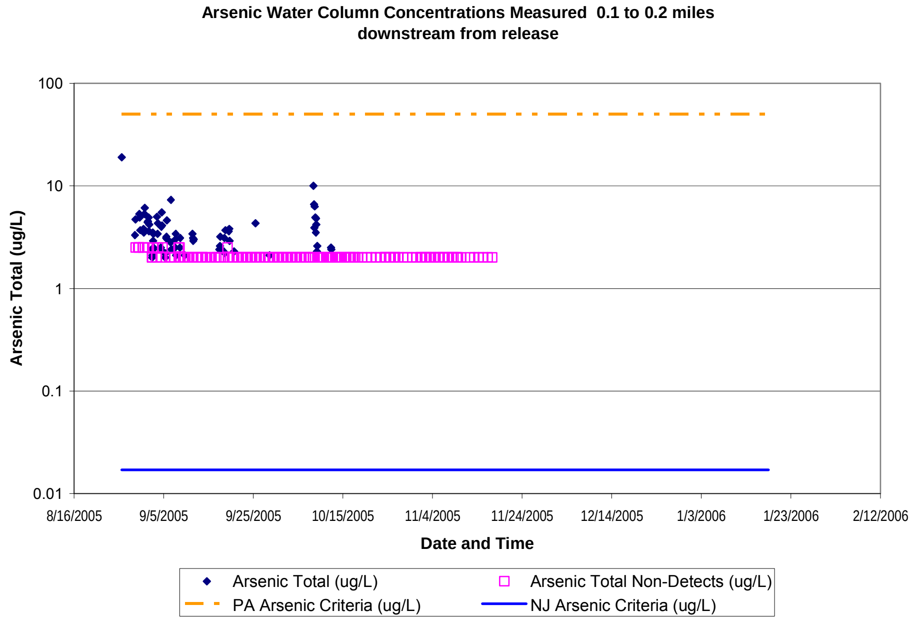
Arsenic Concentrations at Release

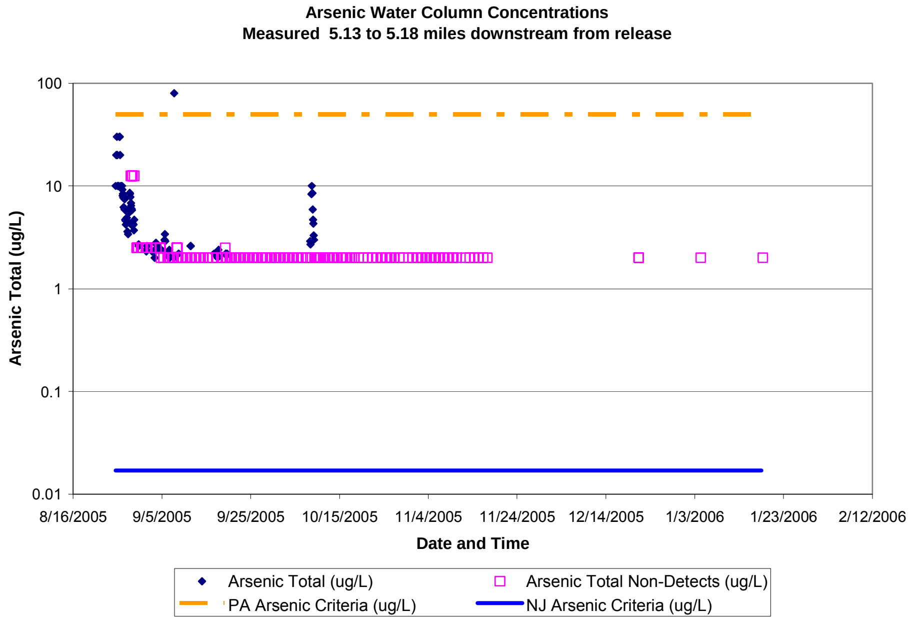


Arsenic Water Column Concentrations Measured in the immediate vicinity of the Release

In the immediate vicinity of the release, initial concentrations in excess of the PA arsenic criteria were observed, with concentrations falling below the PA criteria shortly after the release. All quantified concentrations exceeded the NJ arsenic criteria.

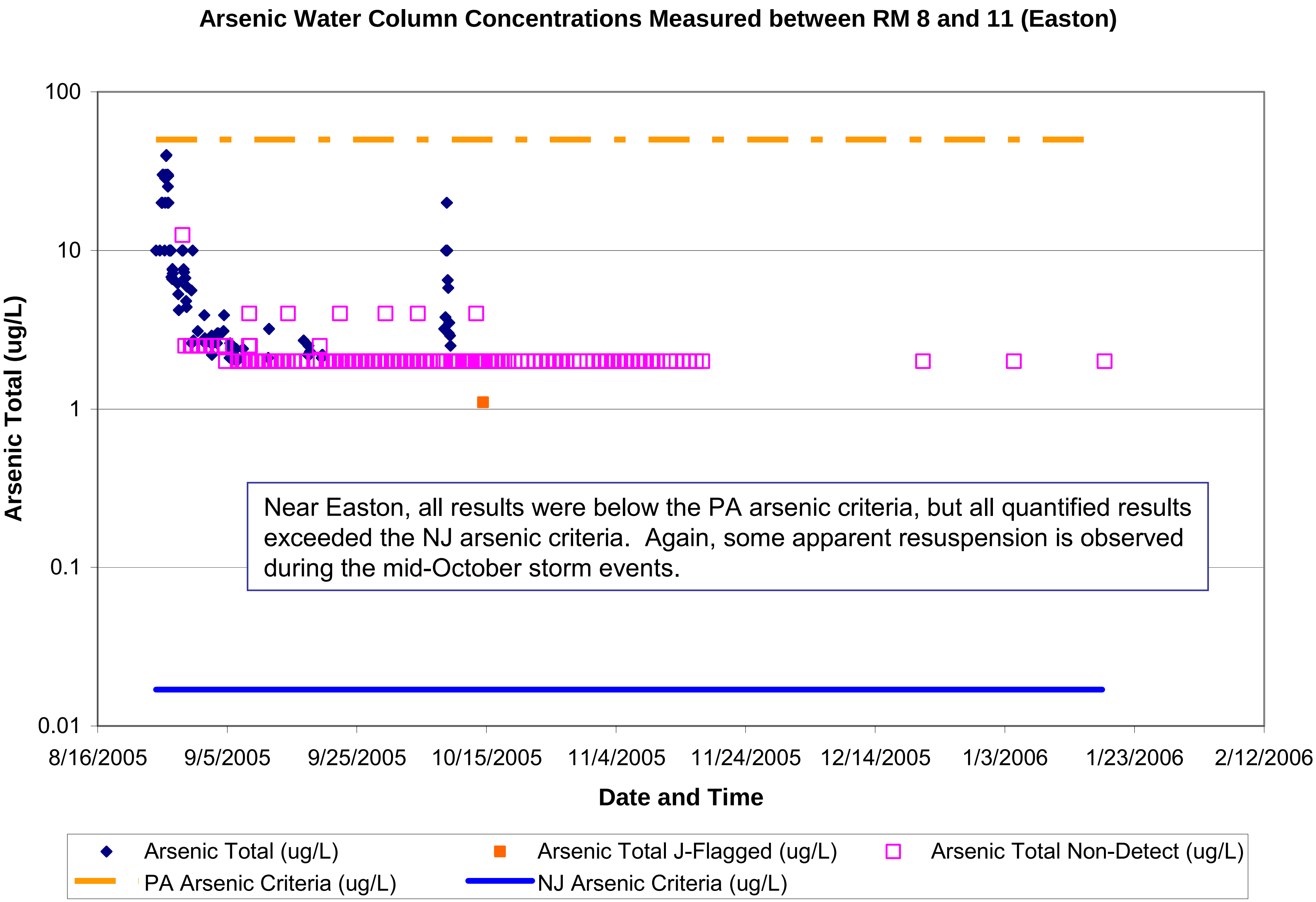
Arsenic Concentrations near Downstream





A comparison of time series arsenic measurements at two downstream ranges shows that most results were below the PA arsenic criteria, but all quantified results exceeded the NJ arsenic criteria. Both plots suggest resuspension of settled arsenic during the mid-October storm events.

Arsenic Concentrations near Easton

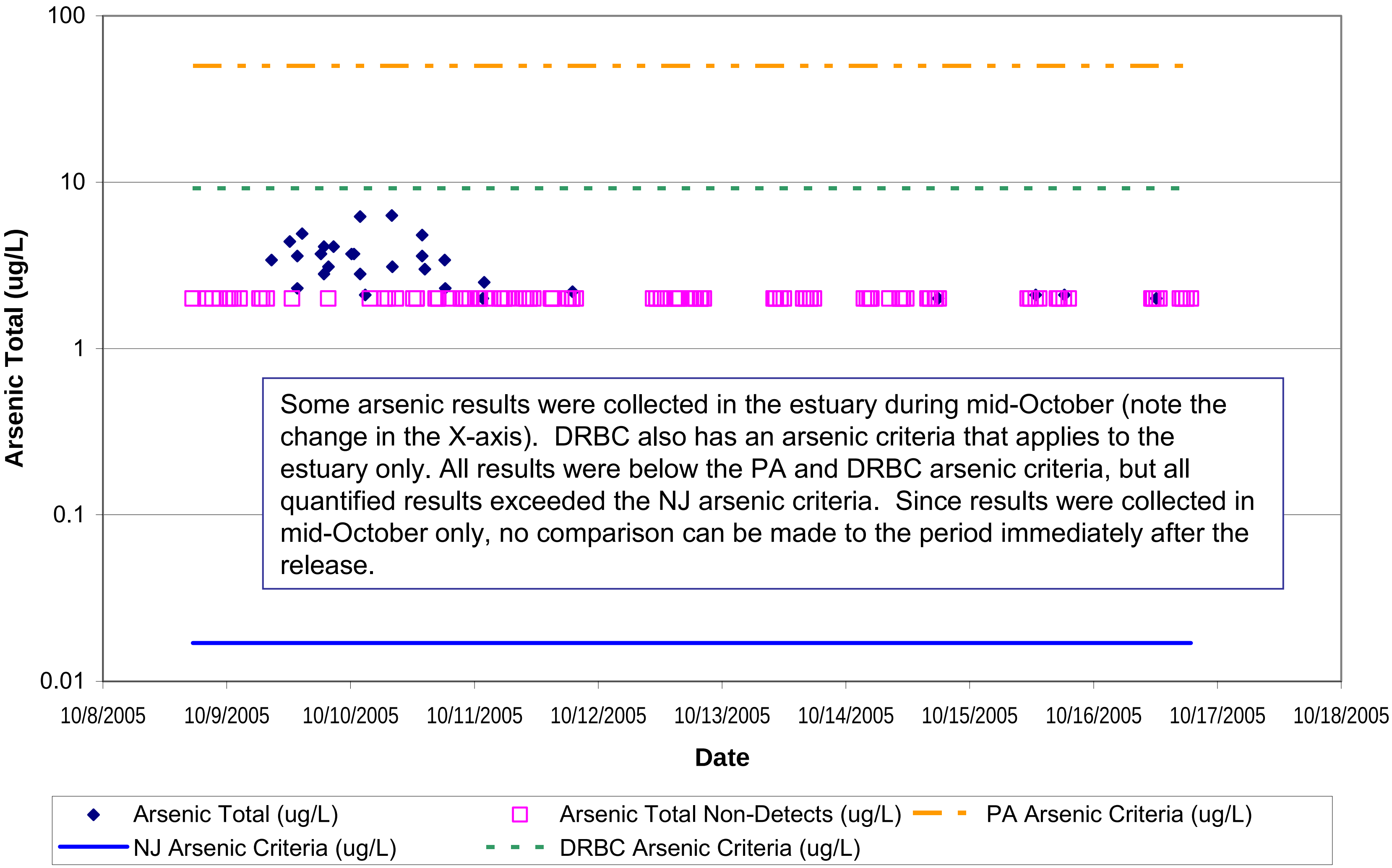


Arsenic Water Column Concentrations Measured between RM 8 and 11 (Easton)

Near Easton, all results were below the PA arsenic criteria, but all quantified results exceeded the NJ arsenic criteria. Again, some apparent resuspension is observed during the mid-October storm events.

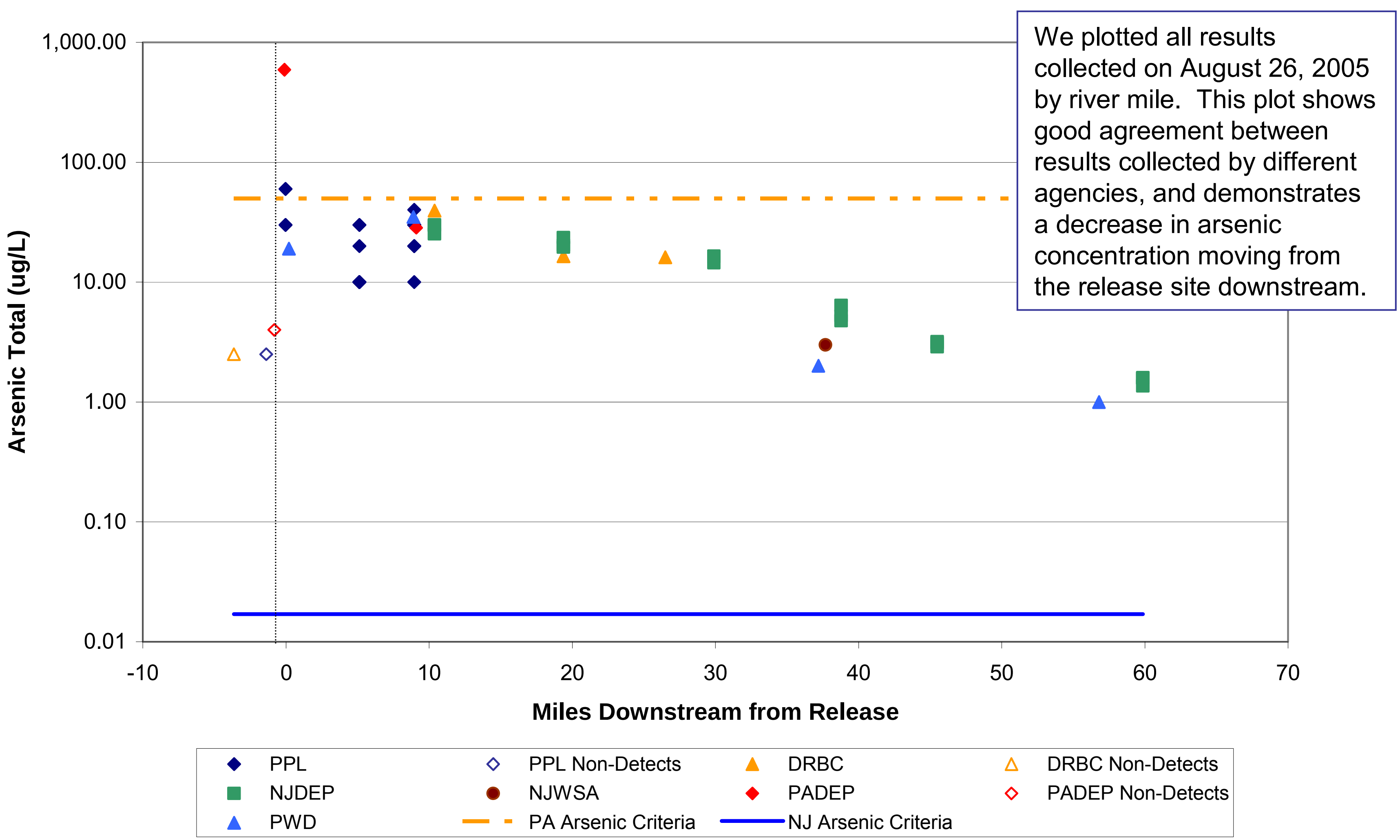
Arsenic Concentrations in Estuary

Arsenic Water Column Concentrations Measured in the Estuary



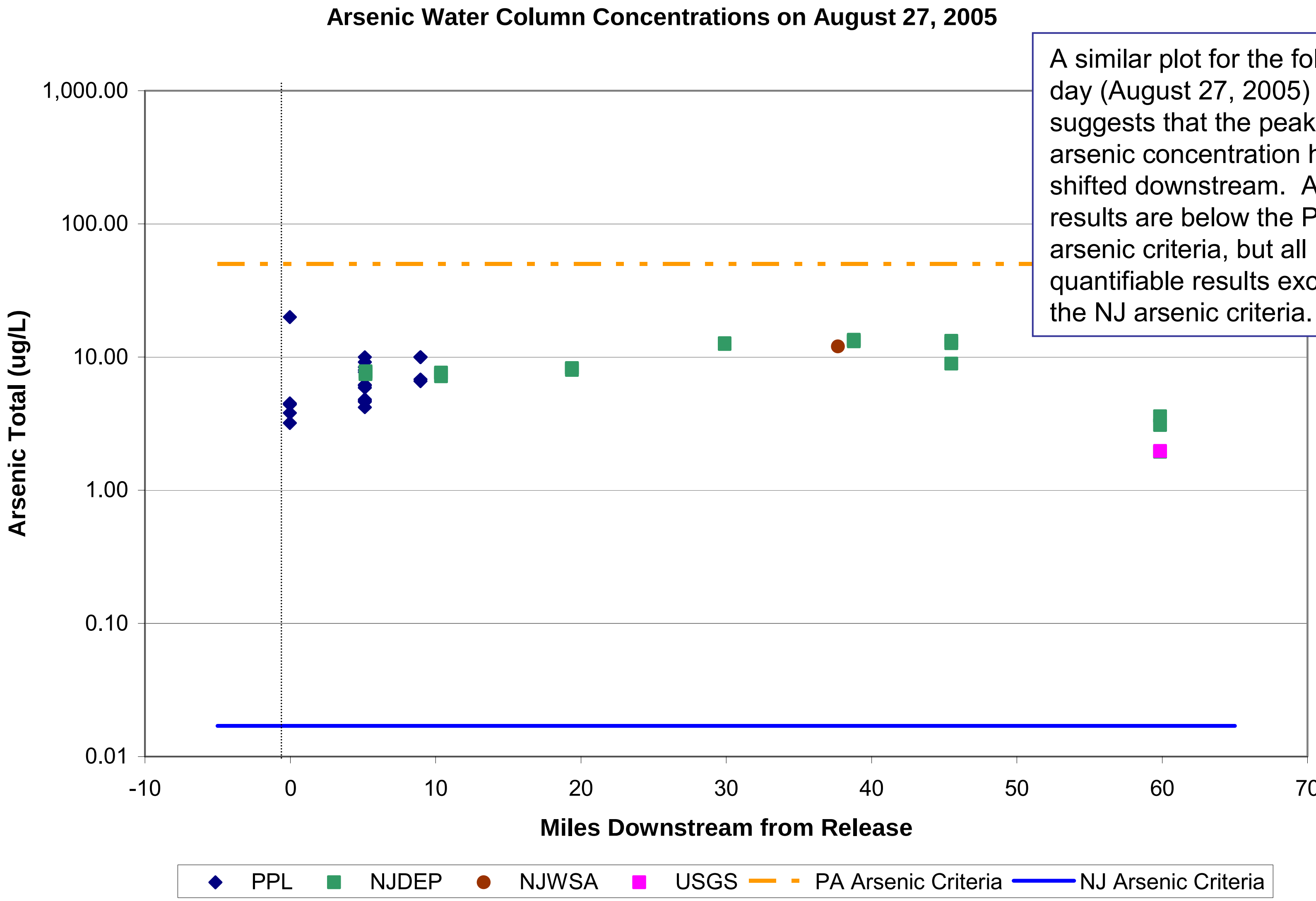
Some arsenic results were collected in the estuary during mid-October (note the change in the X-axis). DRBC also has an arsenic criteria that applies to the estuary only. All results were below the PA and DRBC arsenic criteria, but all quantified results exceeded the NJ arsenic criteria. Since results were collected in mid-October only, no comparison can be made to the period immediately after the release.

Arsenic Concentrations by Distance from Release, August 26, 2005


Arsenic Water Column Concentrations on August 26, 2005

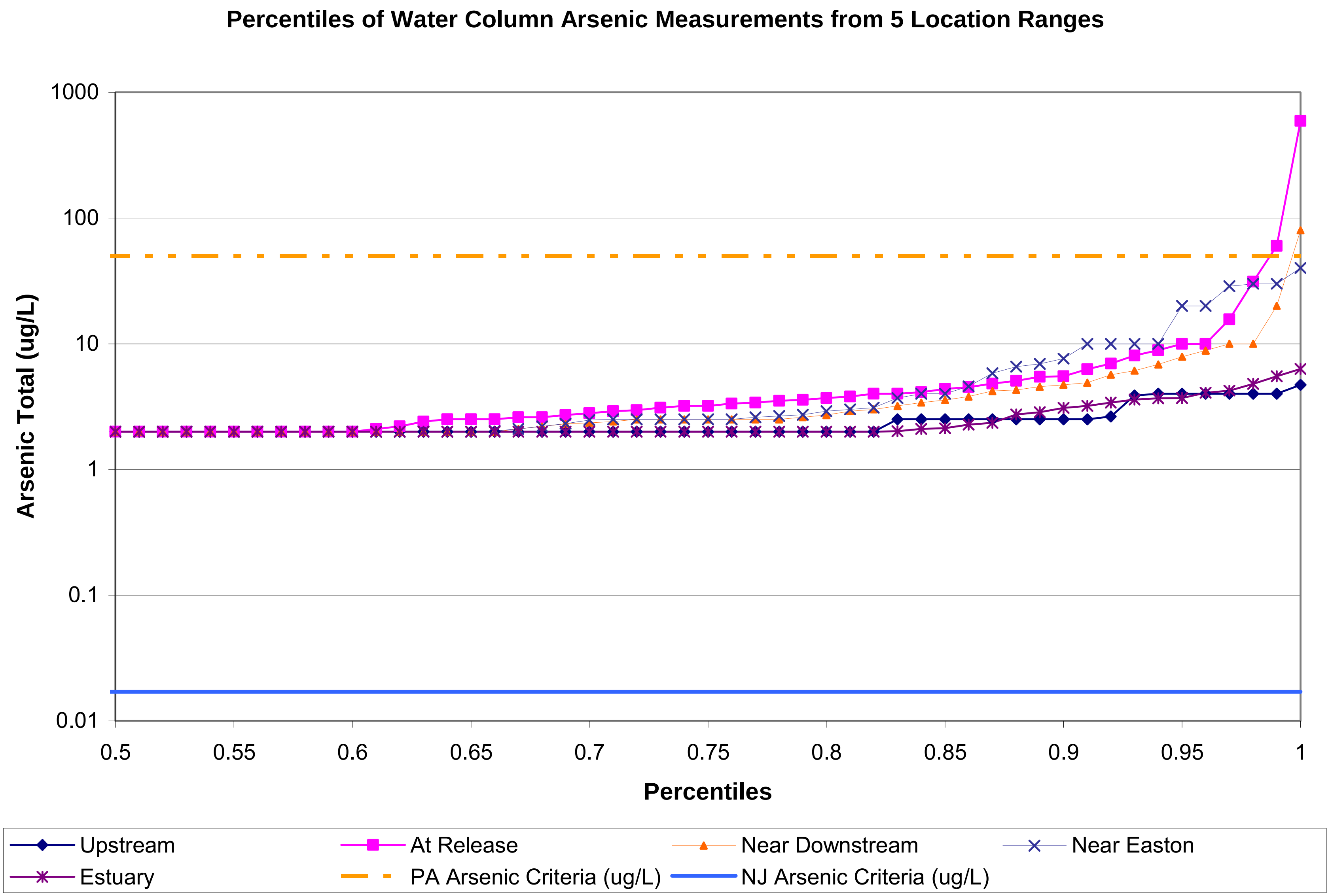
We plotted all results collected on August 26, 2005 by river mile. This plot shows good agreement between results collected by different agencies, and demonstrates a decrease in arsenic concentration moving from the release site downstream.

Arsenic Concentrations by Distance from Release, August 27, 2005

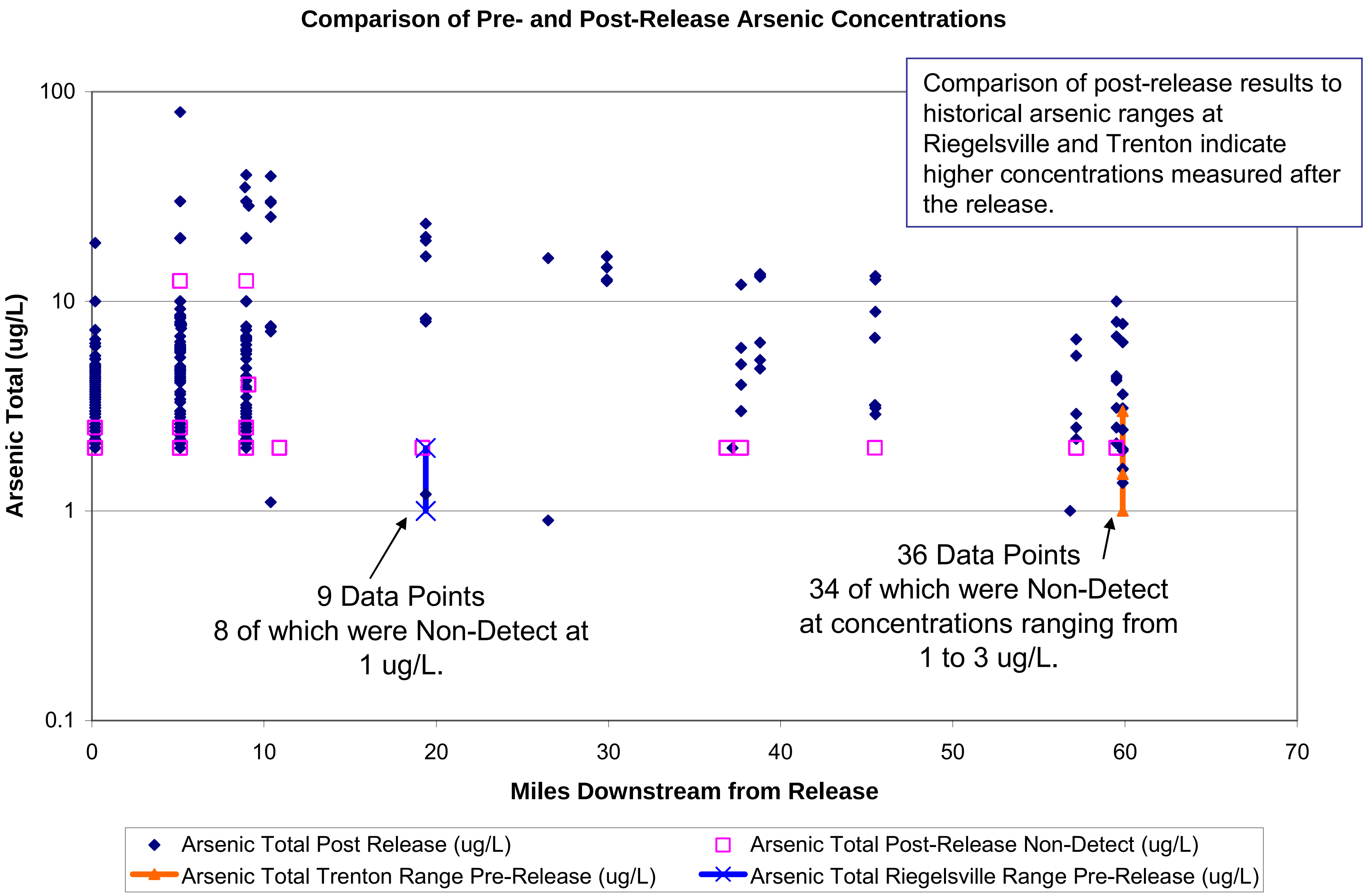

Arsenic Water Column Concentrations on August 27, 2005

A similar plot for the following day (August 27, 2005) suggests that the peak arsenic concentration has shifted downstream. All results are below the PA arsenic criteria, but all quantifiable results exceed the NJ arsenic criteria.

Percentiles of Arsenic Measurements



Comparison to Pre-Release Arsenic Data (1992-Present) found in NWIS and STORET



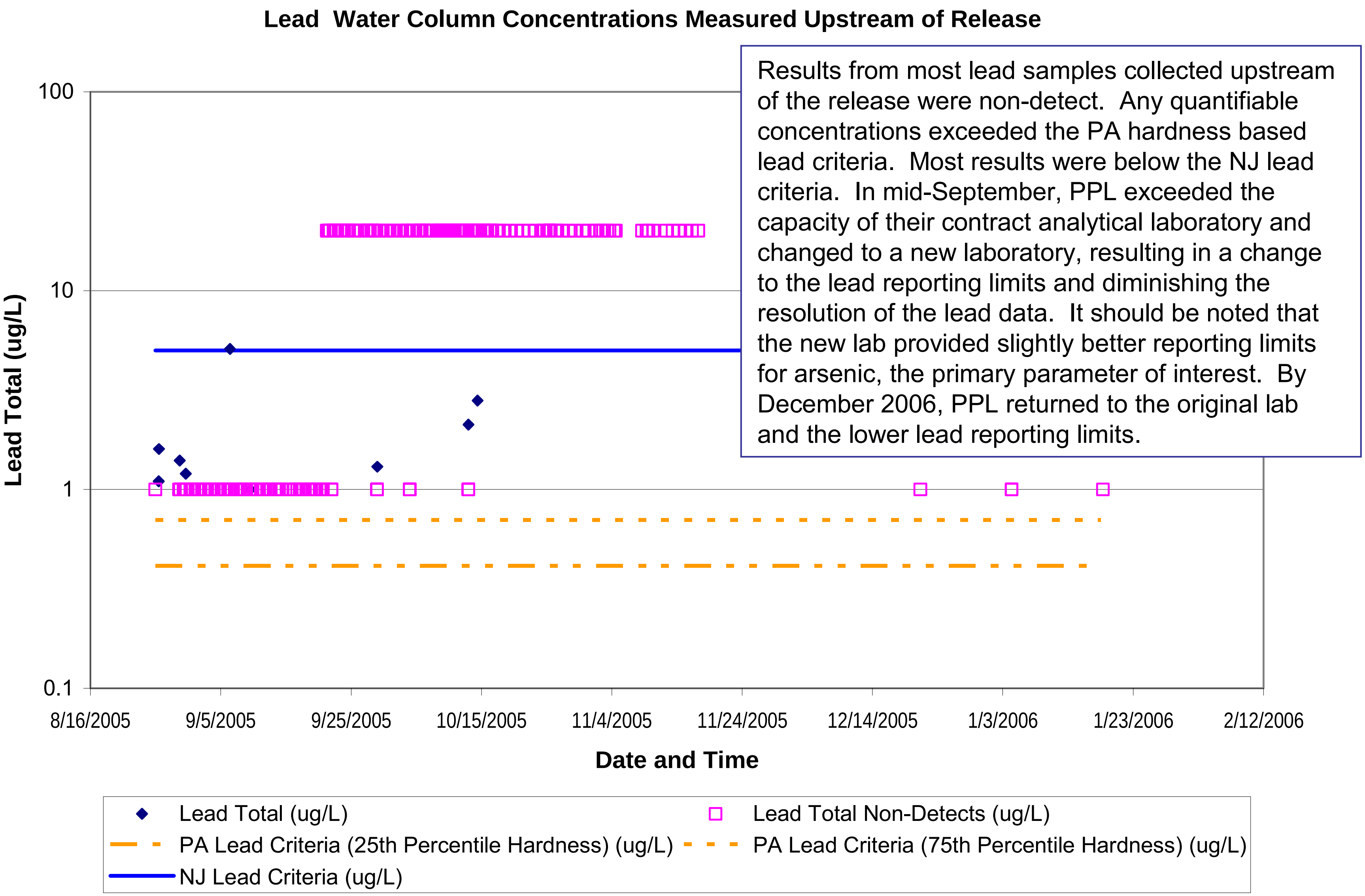
Comparison of post-release results to historical arsenic ranges at Riegelsville and Trenton indicate higher concentrations measured after the release.

9 Data Points
8 of which were Non-Detect at
1 ug/L.

36 Data Points
34 of which were Non-Detect
at concentrations ranging from
1 to 3 ug/L.

Lead Results

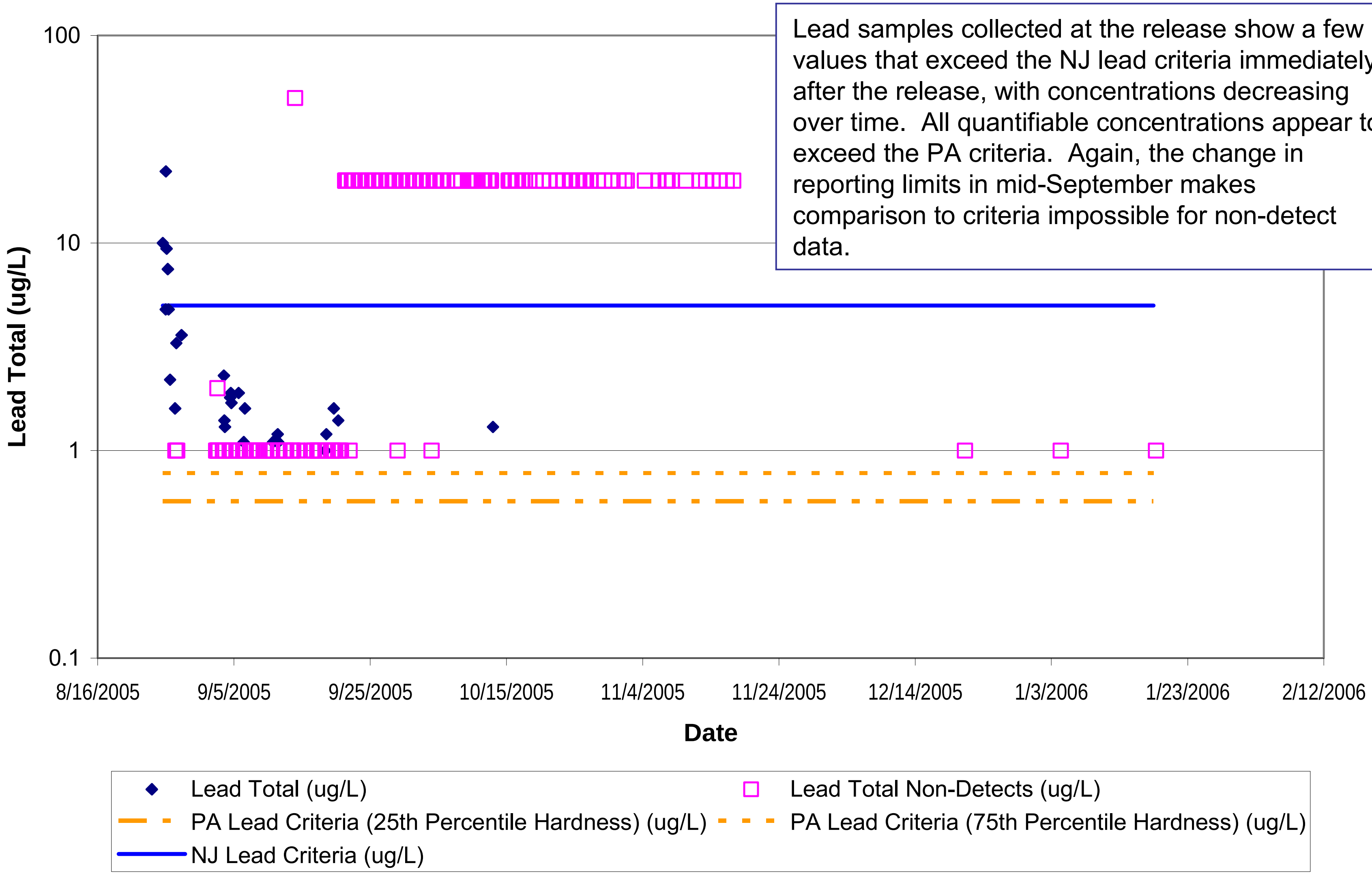
Lead Concentrations Upstream of Release



Results from most lead samples collected upstream of the release were non-detect. Any quantifiable concentrations exceeded the PA hardness based lead criteria. Most results were below the NJ lead criteria. In mid-September, PPL exceeded the capacity of their contract analytical laboratory and changed to a new laboratory, resulting in a change to the lead reporting limits and diminishing the resolution of the lead data. It should be noted that the new lab provided slightly better reporting limits for arsenic, the primary parameter of interest. By December 2006, PPL returned to the original lab and the lower lead reporting limits.

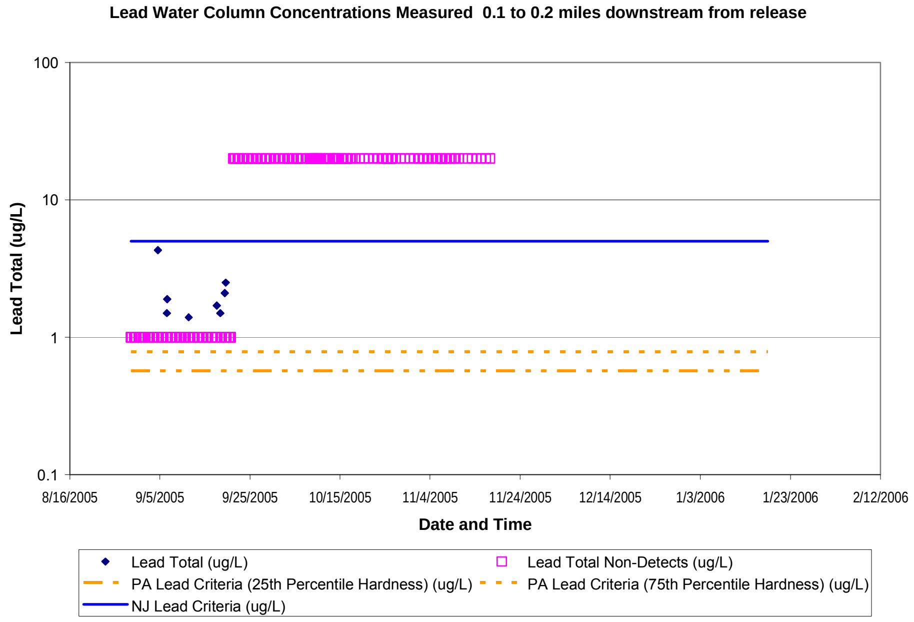
Lead Concentrations at Release

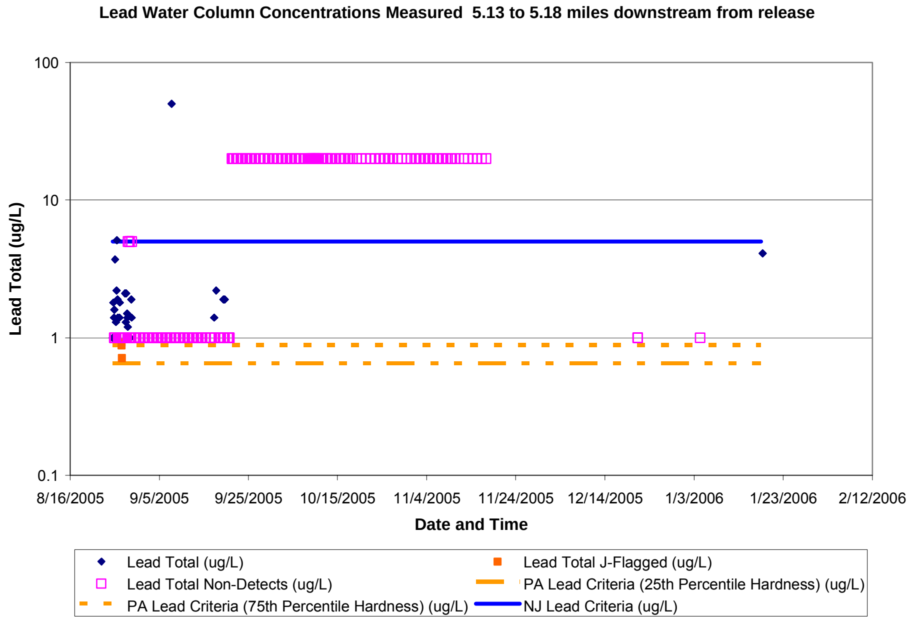
Lead Water Column Concentrations Measured in the immediate vicinity of the Release



Lead samples collected at the release show a few values that exceed the NJ lead criteria immediately after the release, with concentrations decreasing over time. All quantifiable concentrations appear to exceed the PA criteria. Again, the change in reporting limits in mid-September makes comparison to criteria impossible for non-detect data.

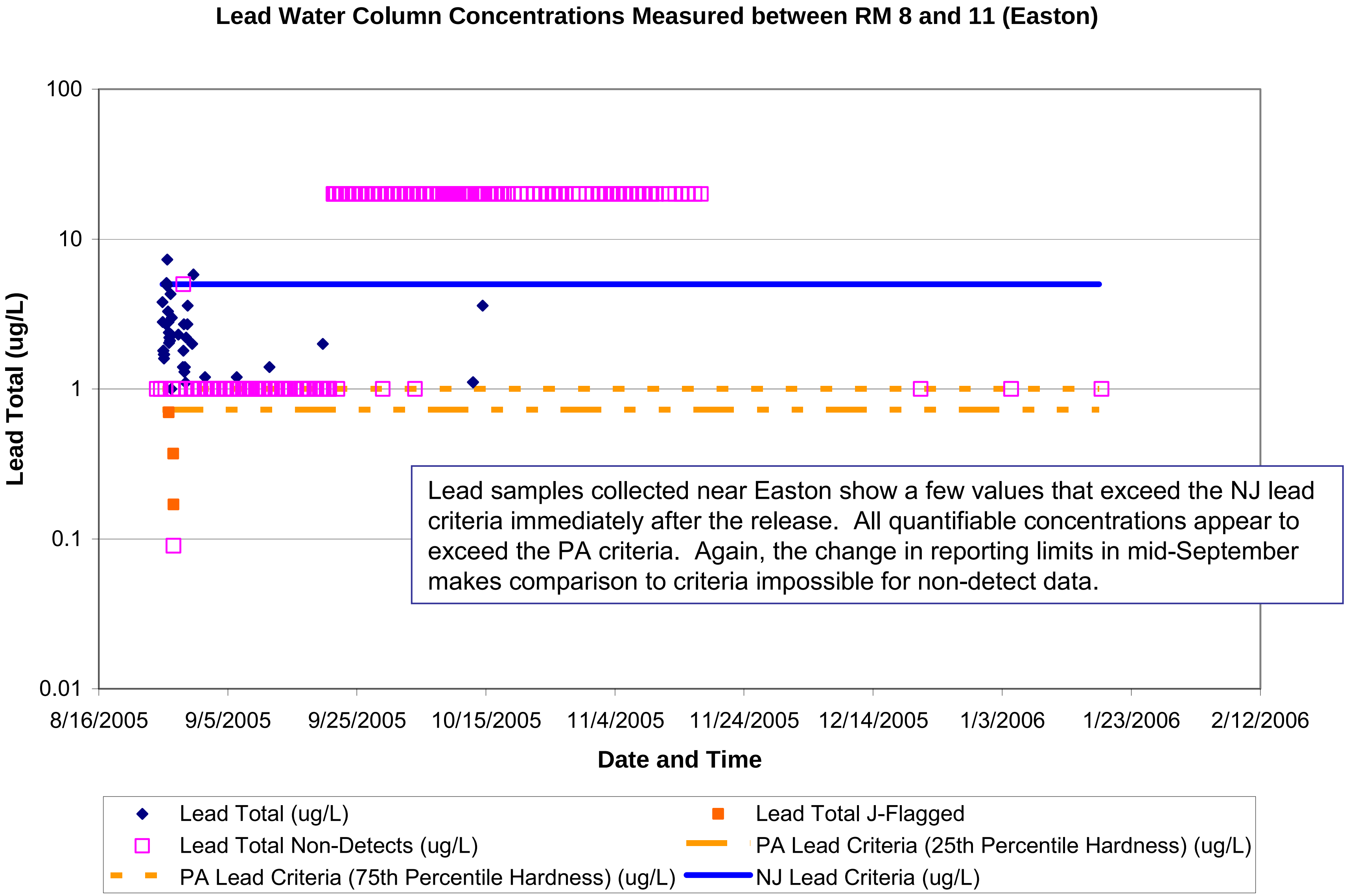
Lead Concentrations near Downstream


Lead Water Column Concentrations Measured 0.1 to 0.2 miles downstream from release


Lead Water Column Concentrations Measured 5.13 to 5.18 miles downstream from release

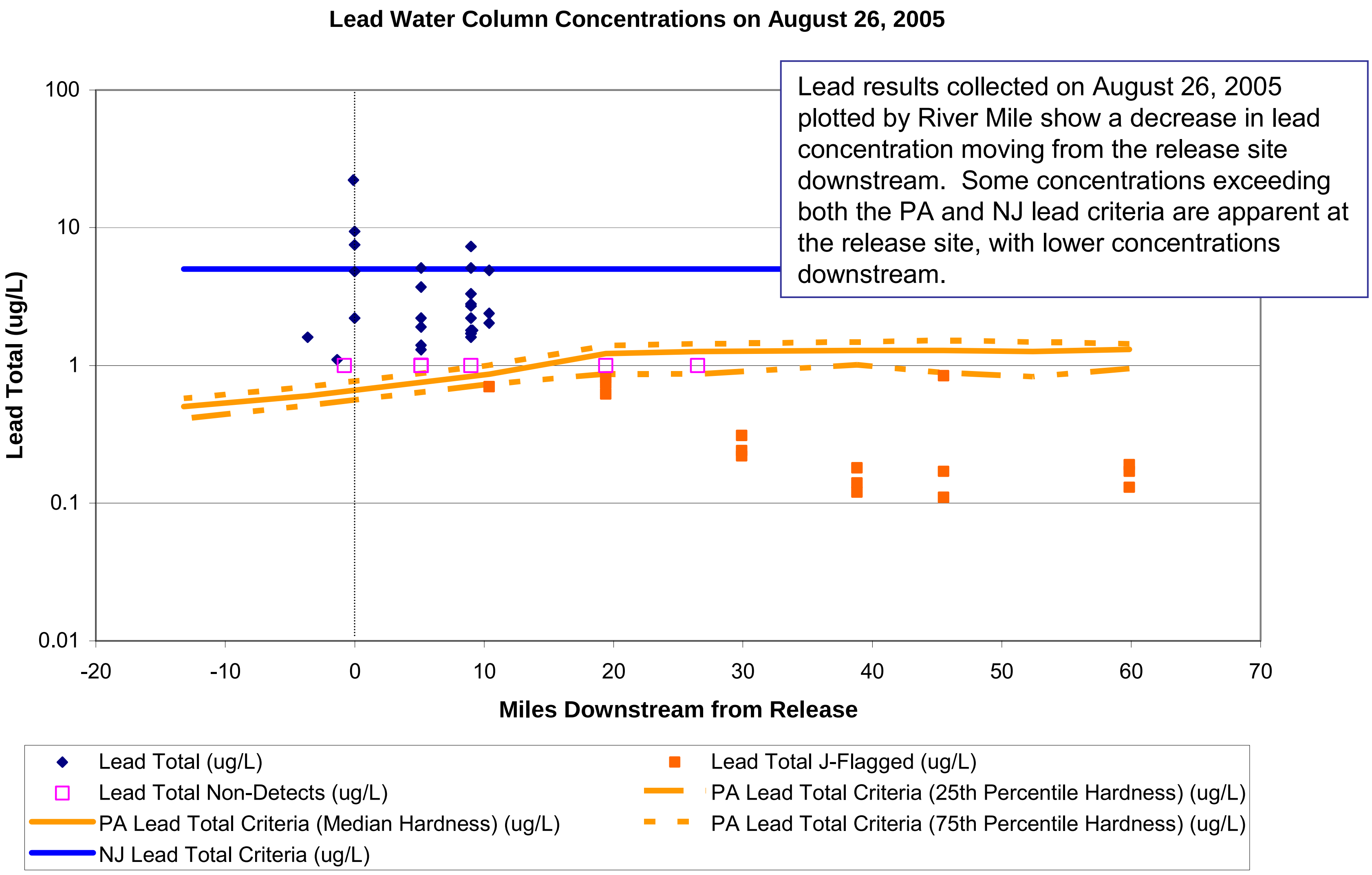
Lead samples collected downstream of the release are mostly below the NJ lead criteria. All quantifiable concentrations appear to exceed the PA criteria. Again, the change in reporting limits in mid-September makes comparison to criteria impossible for non-detect data.

Lead Concentrations near Easton



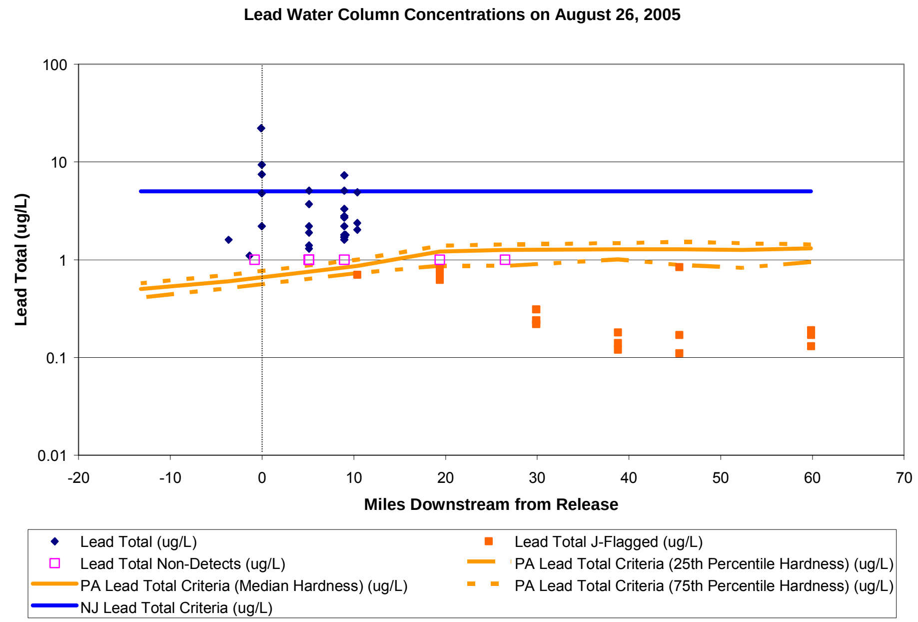
Lead samples collected near Easton show a few values that exceed the NJ lead criteria immediately after the release. All quantifiable concentrations appear to exceed the PA criteria. Again, the change in reporting limits in mid-September makes comparison to criteria impossible for non-detect data.

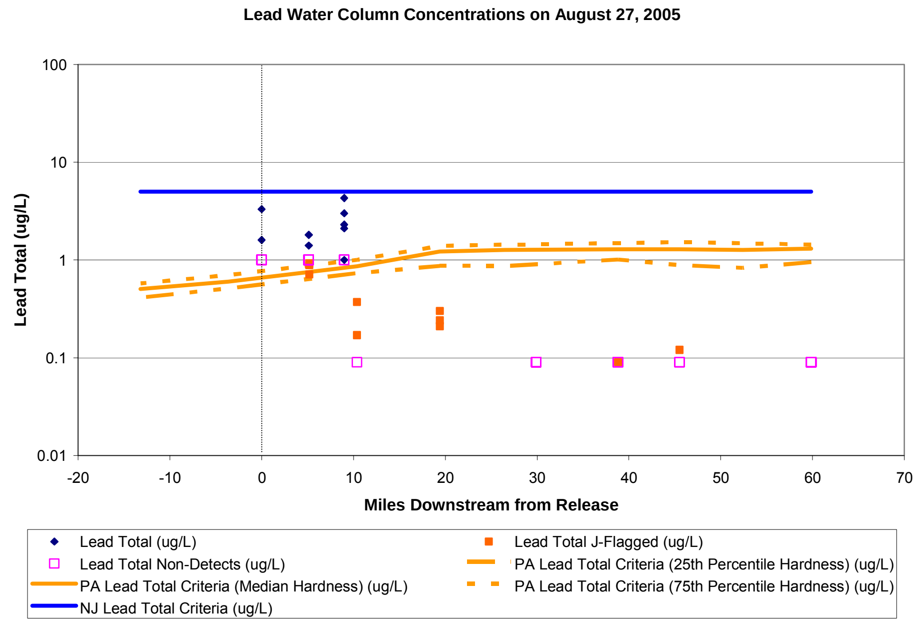
Lead Concentrations by Distance from Release, August 26, 2005



Lead results collected on August 26, 2005 plotted by River Mile show a decrease in lead concentration moving from the release site downstream. Some concentrations exceeding both the PA and NJ lead criteria are apparent at the release site, with lower concentrations downstream.

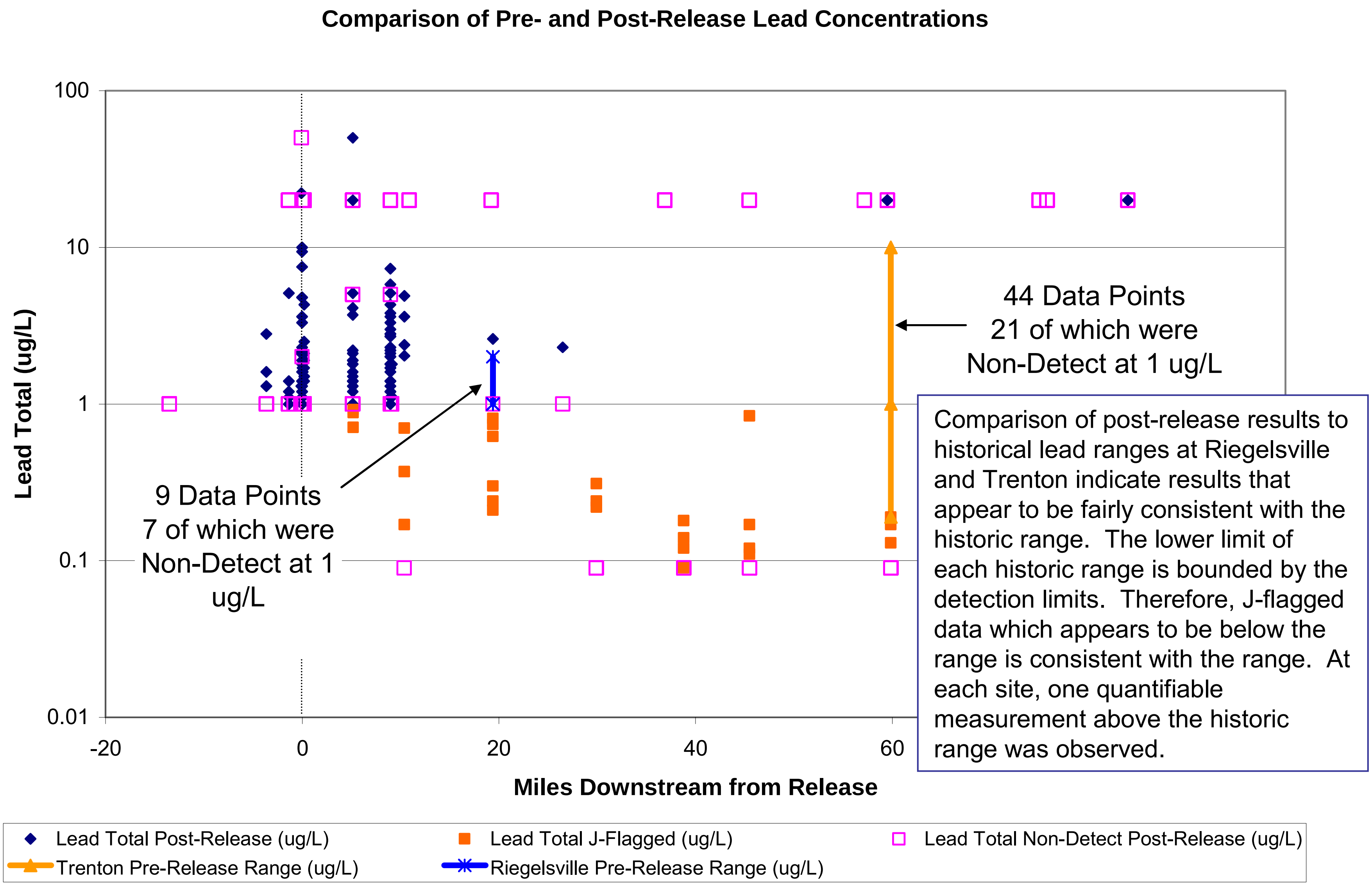
Lead Concentrations by Distance from Release, August 26 and 27, 2005





A side-by-side comparison of lead samples collected on August 26 and 27, 2005 plotted by River Mile indicates a decrease in concentration at the release site. Unlike arsenic, there is no apparent downstream movement of a concentration peak.

Comparison to Pre-Release Lead Data (1992-Present) found in NWIS and STORET



Comparison of Pre- and Post-Release Lead Concentrations

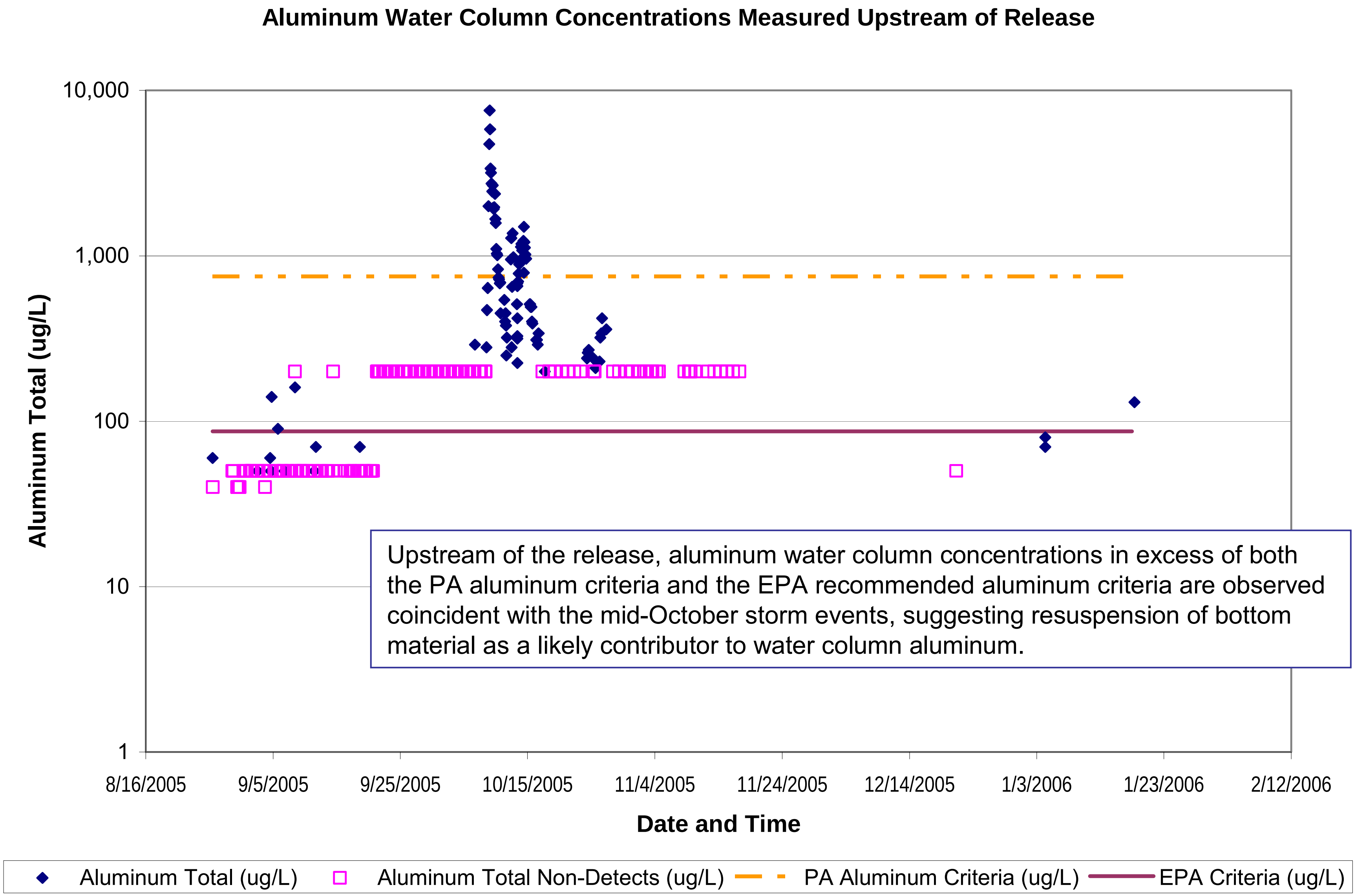
9 Data Points
7 of which were
Non-Detect at 1
ug/L

44 Data Points
21 of which were
Non-Detect at 1 ug/L

Comparison of post-release results to historical lead ranges at Riegelsville and Trenton indicate results that appear to be fairly consistent with the historic range. The lower limit of each historic range is bounded by the detection limits. Therefore, J-flagged data which appears to be below the range is consistent with the range. At each site, one quantifiable measurement above the historic range was observed.

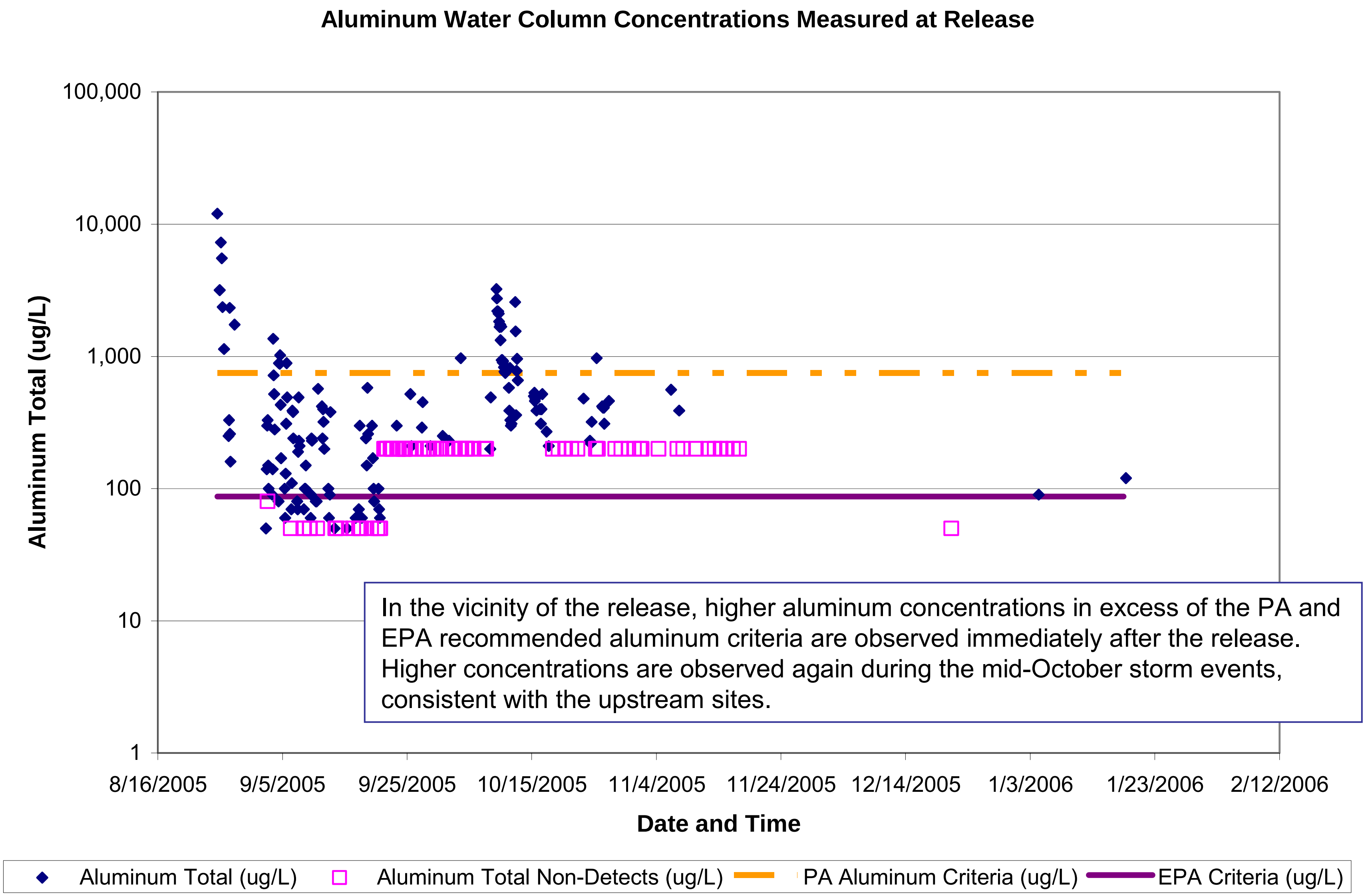
Aluminum Results

Aluminum Concentrations Upstream of Release



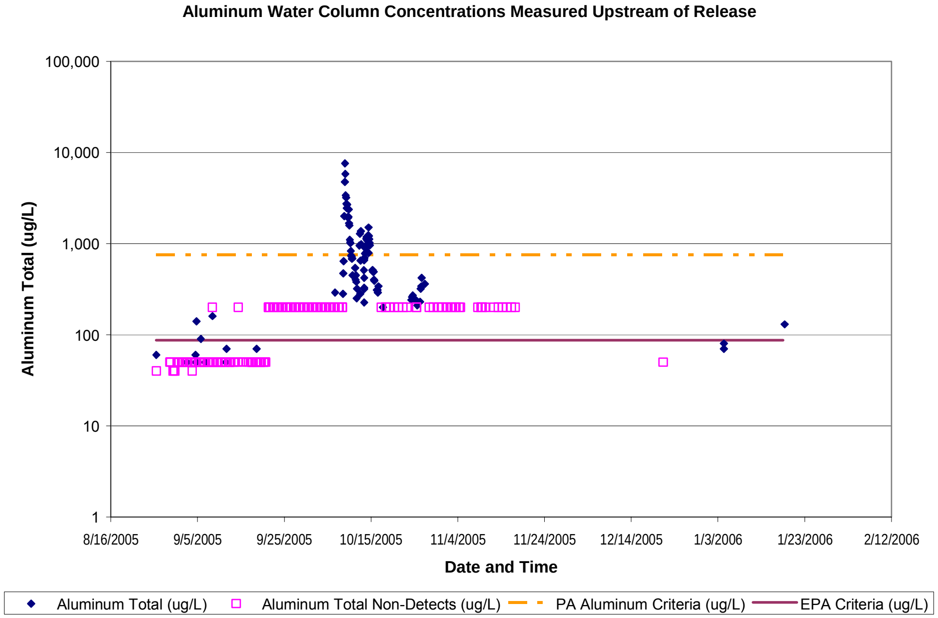
Upstream of the release, aluminum water column concentrations in excess of both the PA aluminum criteria and the EPA recommended aluminum criteria are observed coincident with the mid-October storm events, suggesting resuspension of bottom material as a likely contributor to water column aluminum.

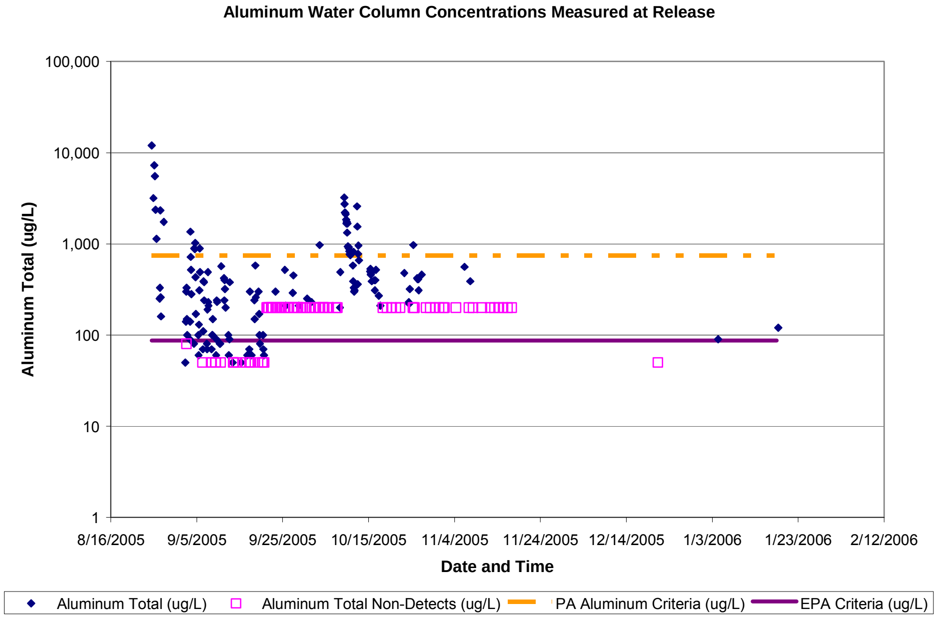
Aluminum Concentrations at Release



In the vicinity of the release, higher aluminum concentrations in excess of the PA and EPA recommended aluminum criteria are observed immediately after the release. Higher concentrations are observed again during the mid-October storm events, consistent with the upstream sites.

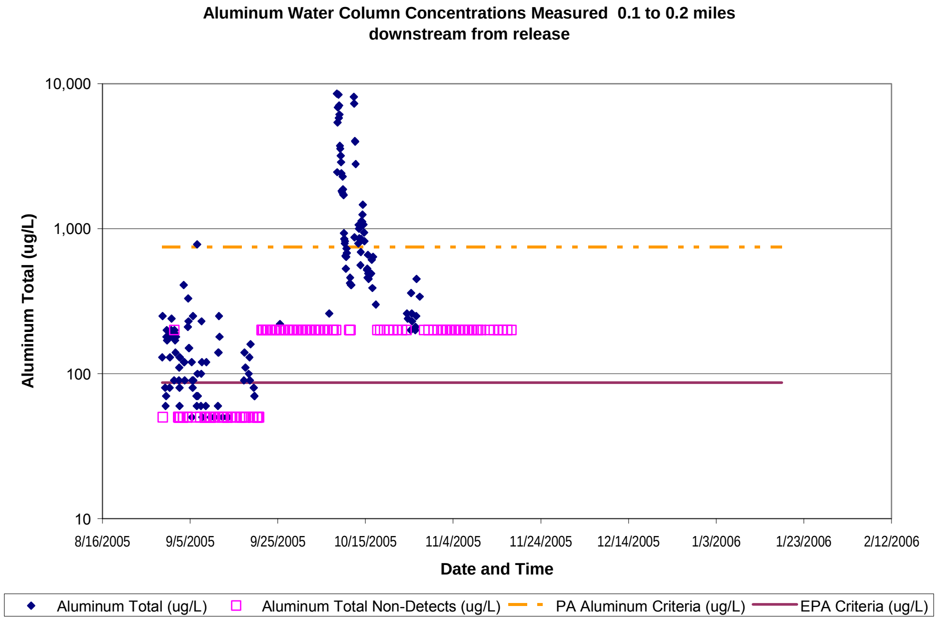
Aluminum Concentrations upstream and at release

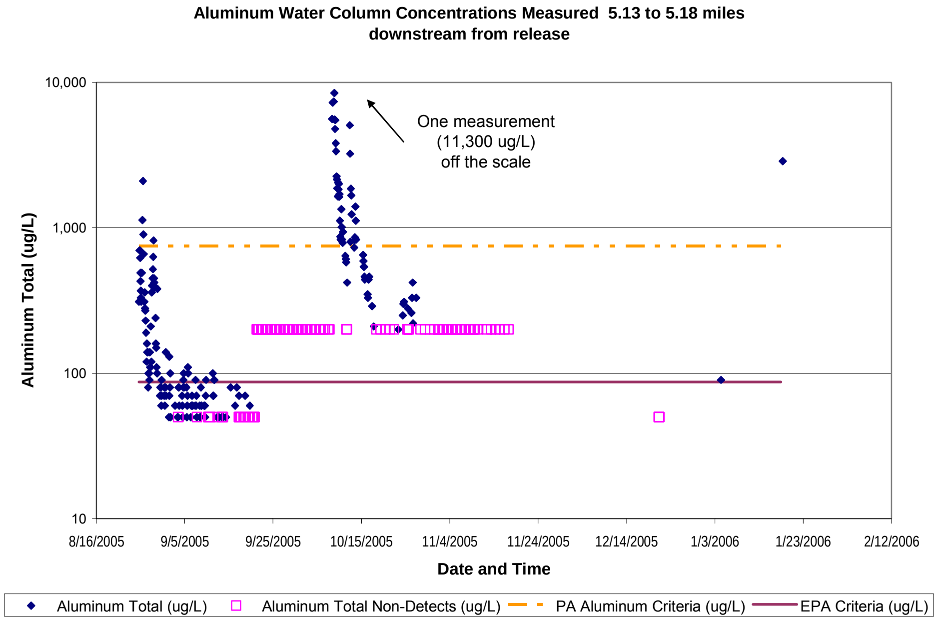




A side-by-side comparison of the upstream and release site plots suggests an initial increase in water column aluminum at the release site, followed by a storm related increase that is consistent with the upstream sites.

Aluminum Concentrations at near downstream locations

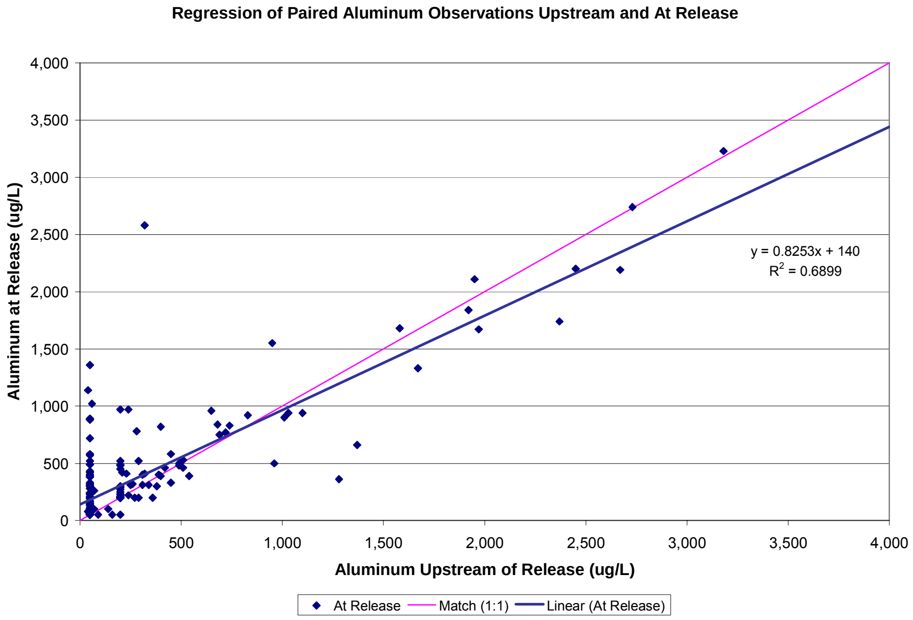

Aluminum Water Column Concentrations Measured 0.1 to 0.2 miles downstream from release

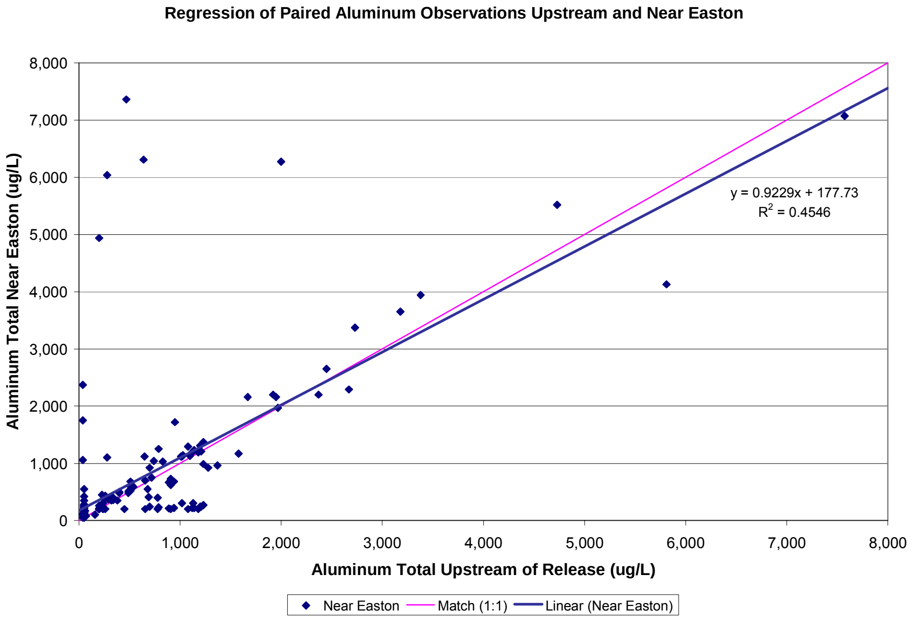

Aluminum Water Column Concentrations Measured 5.13 to 5.18 miles downstream from release

One measurement (11,300 ug/L) off the scale

A side-by-side comparison of plots for the 2 near downstream ranges shows an initial increase in water column aluminum concentration after the release, followed by storm related increases in mid October. The structure of the initial concentration increase is more apparent at the second downstream range, even though that range is further from the initial release site. We observed this difference in structure for other analytical parameters as well. One possible explanation is that the second downstream range is shallower and has a higher velocity, keeping more material in suspension. By contrast, the first downstream range is more of a pool and may tend to dampen the signal of the release. As with lead, a change to a higher aluminum reporting limit interferes with direct comparison to the EPA recommended criteria for non-detect data.

Regression of Paired Aluminum Concentrations



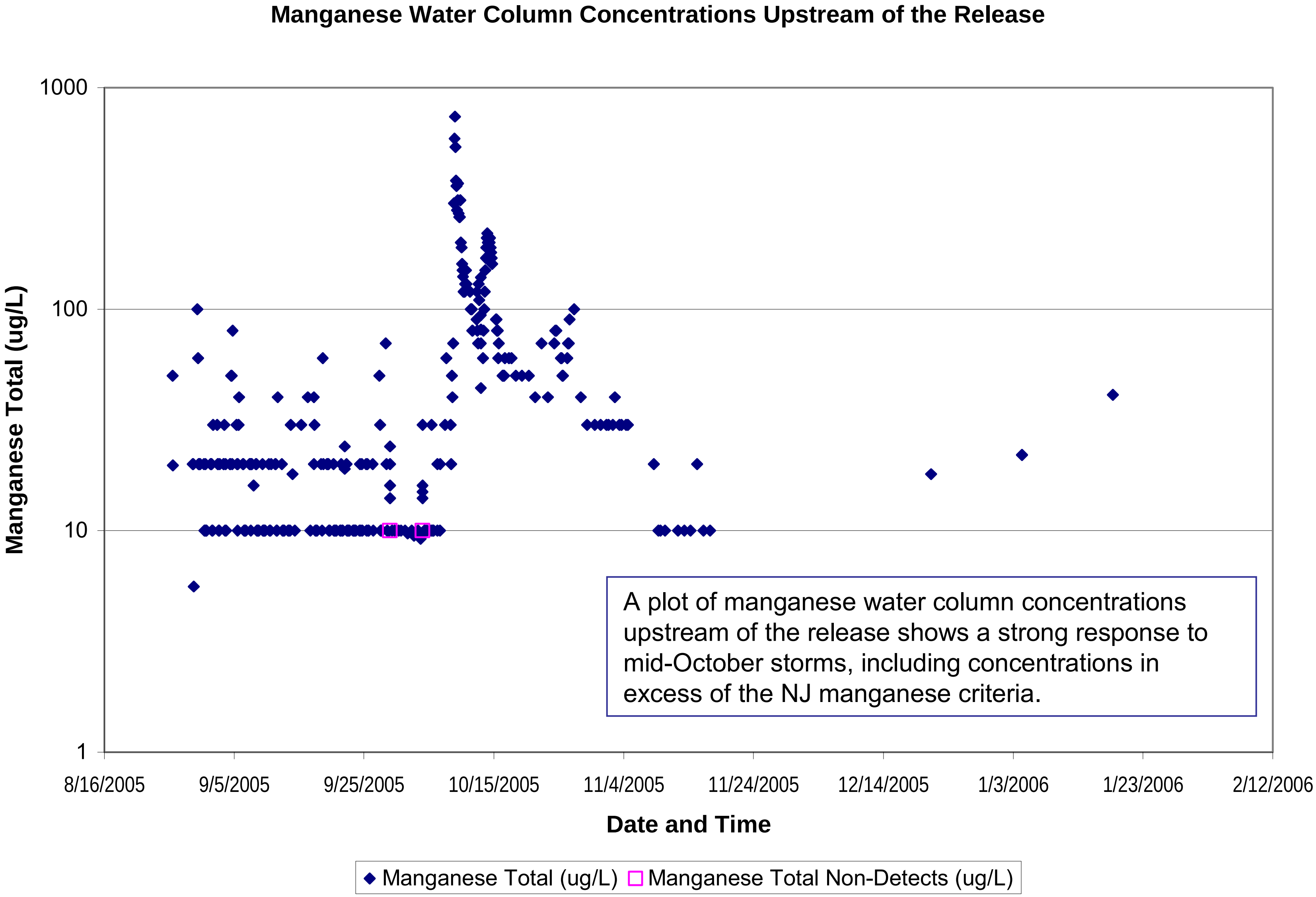


Bivariate plots of aluminum concentrations at the release site and at Easton versus the upstream concentrations, suggests that portion of the variability in the downstream concentrations is explained by the upstream concentration. At each location, however, a subset of values not following this relationship is apparent.

Our interpretation is that the initial peaks are associated with the release, but subsequent peaks strongly follow the upstream storm related pattern.

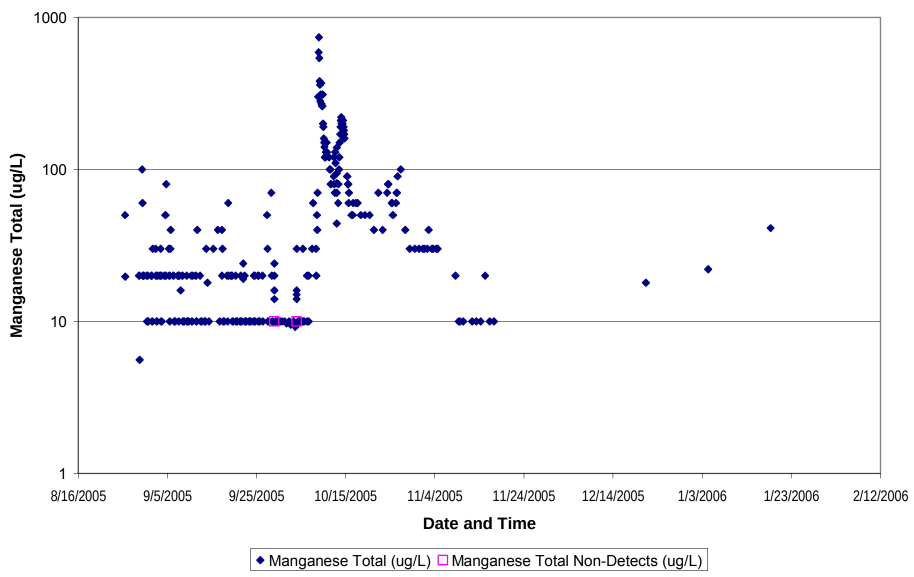
Manganese

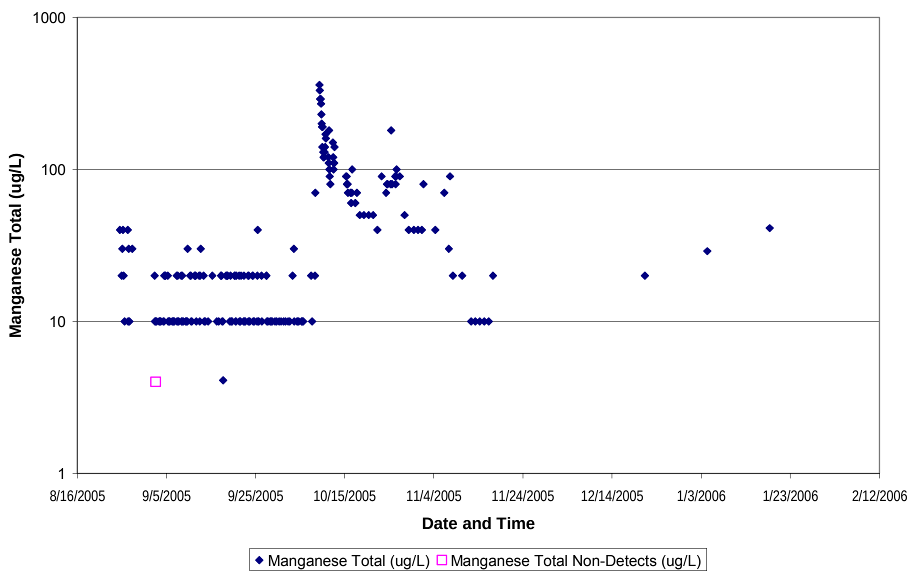
Manganese Concentrations Upstream of Release



A plot of manganese water column concentrations upstream of the release shows a strong response to mid-October storms, including concentrations in excess of the NJ manganese criteria.

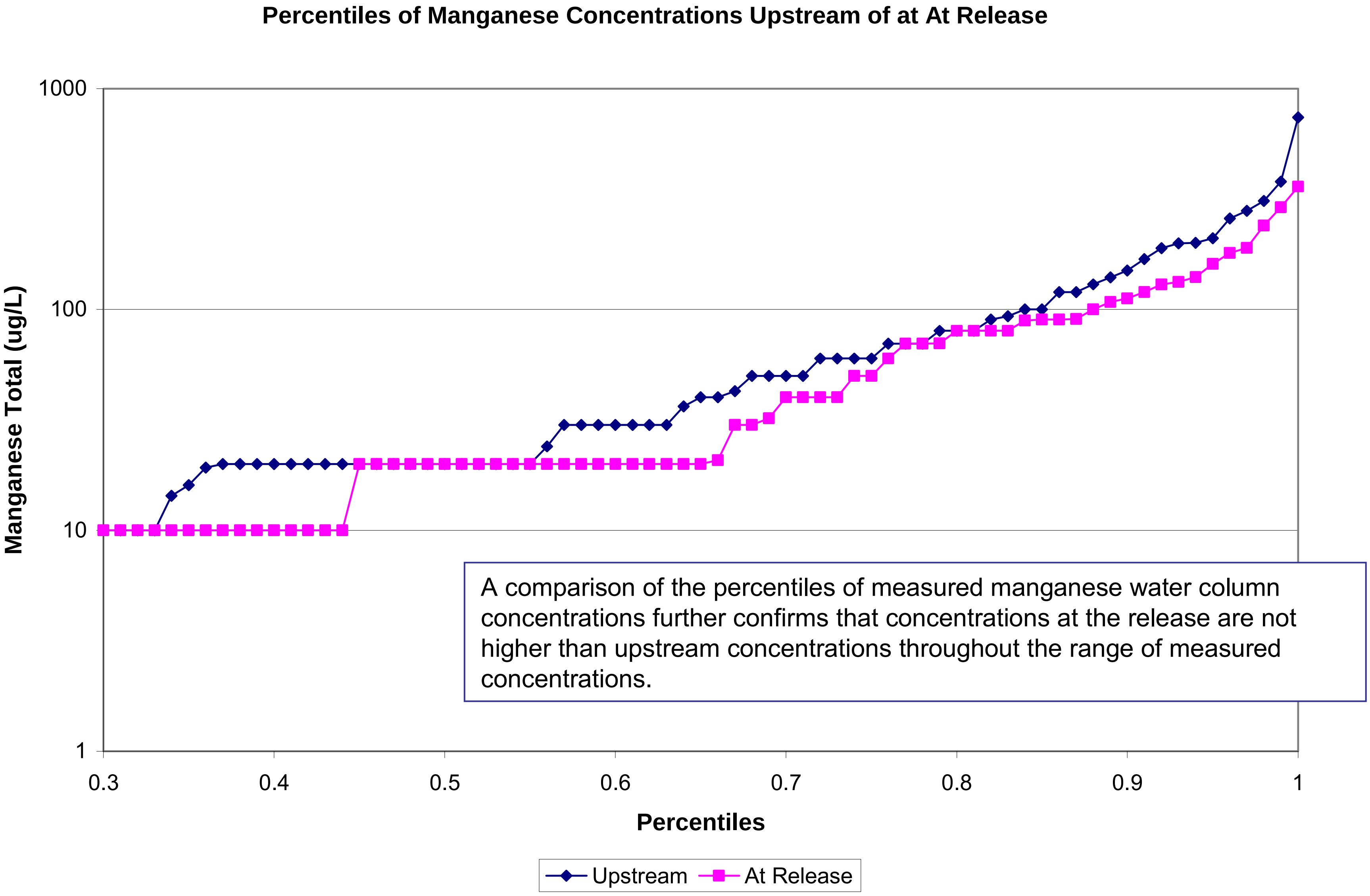
Manganese Concentrations Upstream of and at Release


Manganese Water Column Concentrations Upstream of the Release


Manganese Concentrations at Release

A side-by-side comparison of plots of manganese water column concentrations upstream and at the release indicates that both sites show a strong response to mid-October storm events, including concentrations in excess of the NJ manganese criteria. There are no apparent elevated concentrations of manganese at the release site relative to the upstream sites. In fact the range of concentrations for the upstream sites is slightly higher than for the release site.

Percentiles of Manganese Concentrations Upstream of and At Release

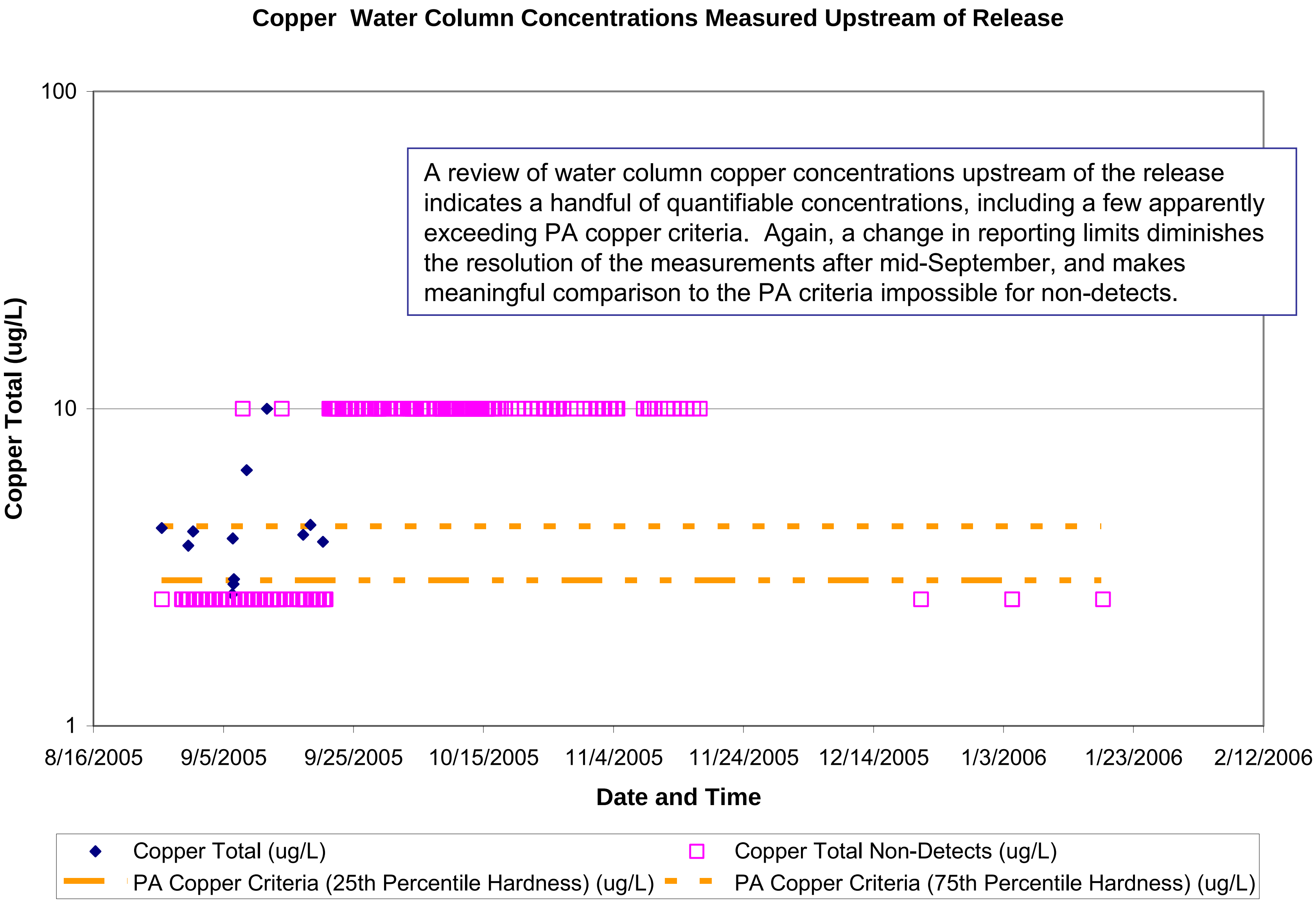


Percentiles of Manganese Concentrations Upstream of at At Release

A comparison of the percentiles of measured manganese water column concentrations further confirms that concentrations at the release are not higher than upstream concentrations throughout the range of measured concentrations.

Copper Results

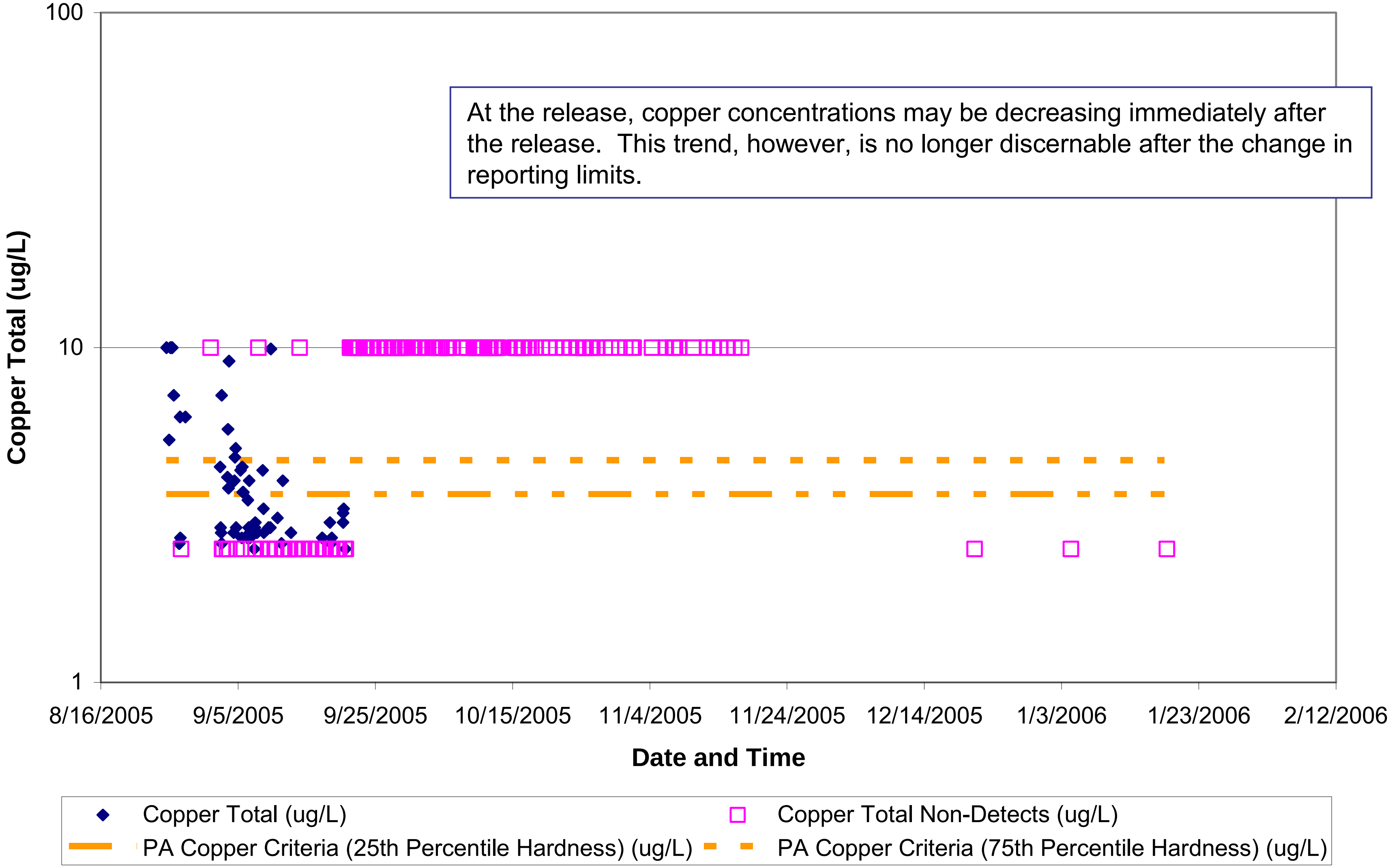
Copper Concentrations Upstream



A review of water column copper concentrations upstream of the release indicates a handful of quantifiable concentrations, including a few apparently exceeding PA copper criteria. Again, a change in reporting limits diminishes the resolution of the measurements after mid-September, and makes meaningful comparison to the PA criteria impossible for non-detects.

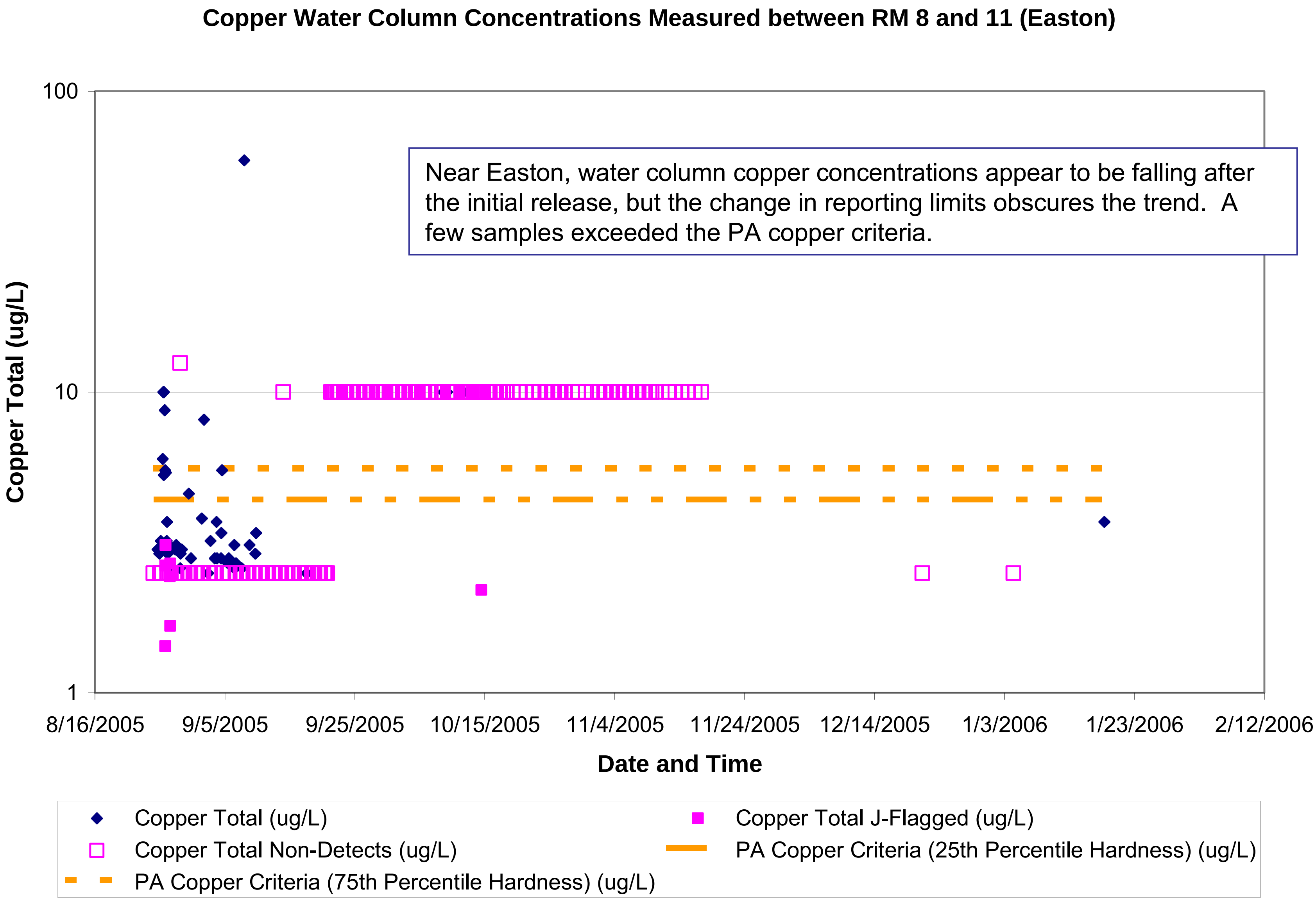
Copper at Release

Copper Water Column Concentrations Measured at the Release



At the release, copper concentrations may be decreasing immediately after the release. This trend, however, is no longer discernable after the change in reporting limits.

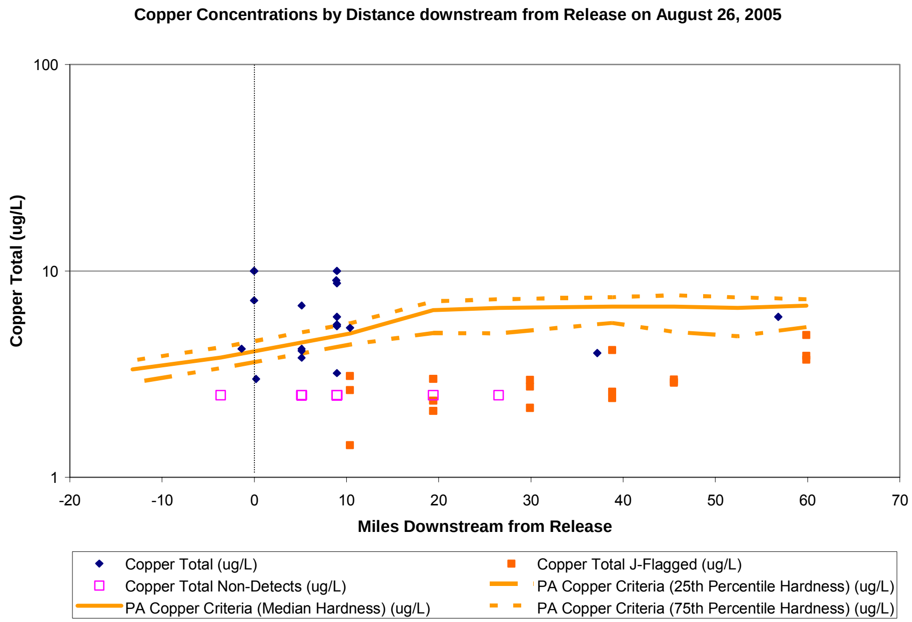
Copper Near Easton

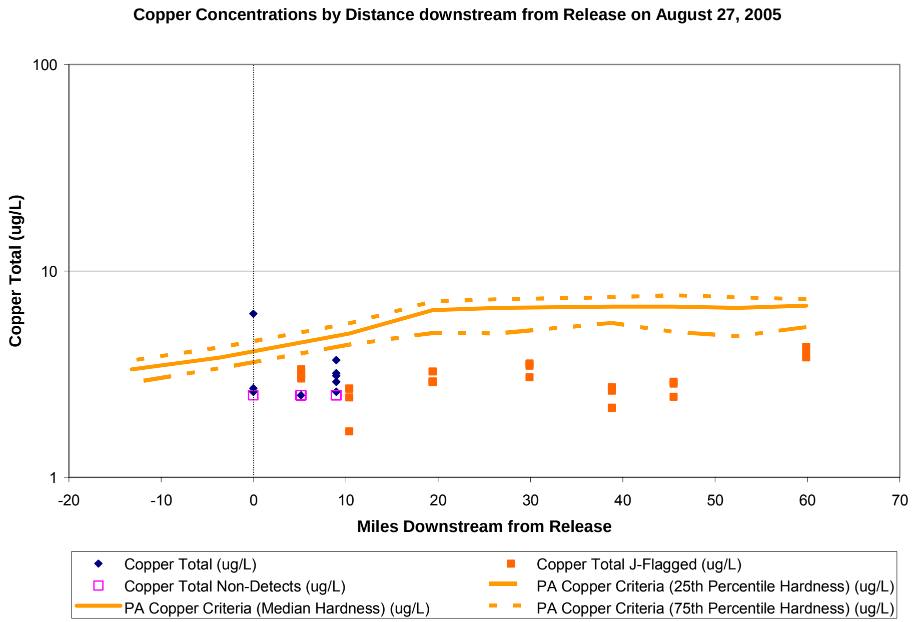


Copper Water Column Concentrations Measured between RM 8 and 11 (Easton)

Near Easton, water column copper concentrations appear to be falling after the initial release, but the change in reporting limits obscures the trend. A few samples exceeded the PA copper criteria.

Copper by Miles from Release on August 26th and 27th, 2005

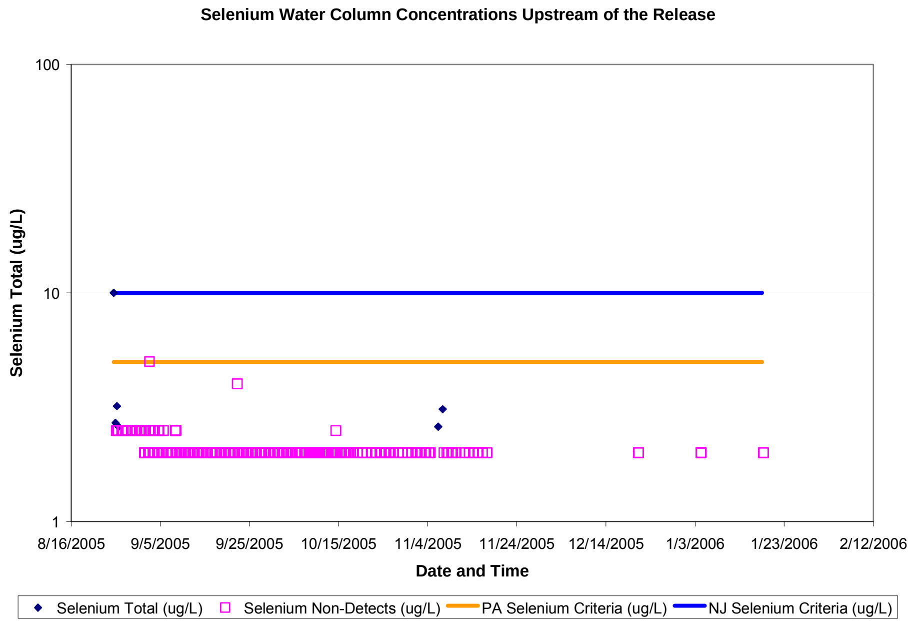

Copper Concentrations by Distance downstream from Release on August 26, 2005

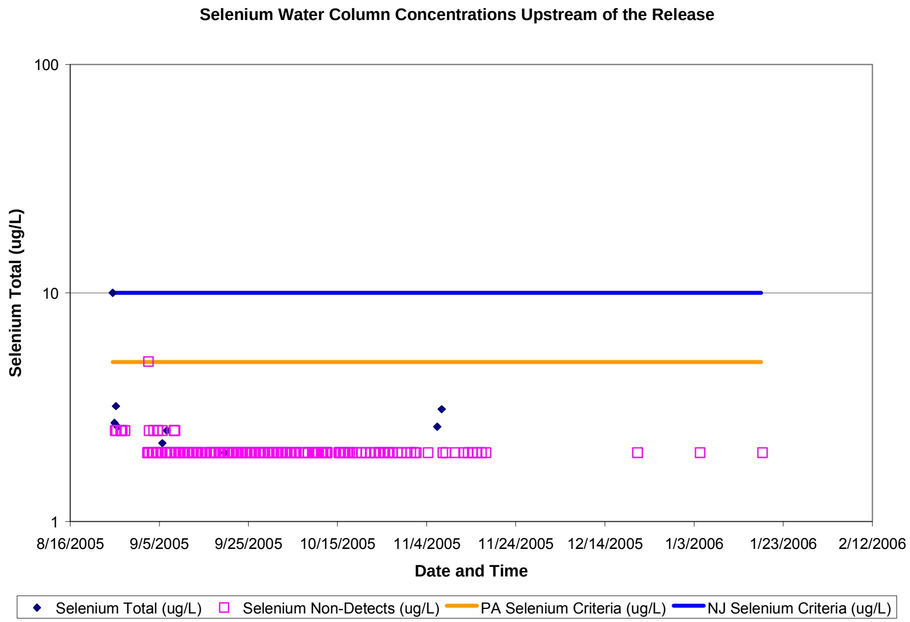

Copper Concentrations by Distance downstream from Release on August 27, 2005

A side-by-side comparison of copper concentration measured on August 26 and 27, 2005 plotted by River Mile suggests that higher concentrations observed near the release on August 26th have decreased by August 27th. Unlike arsenic, there is no apparent downstream movement of a concentration peak.

Selenium Results

Selenium Concentrations Upstream of and at the Release


Selenium Water Column Concentrations Upstream of the Release


Selenium Water Column Concentrations Upstream of the Release

A side-by-side comparison of water column selenium concentrations measured upstream of and at the release are nearly identical, suggesting that the release did not contribute to water column selenium concentrations.

Mercury

- All mercury measurements (1,805) were non-detect except for one sample collected 0.2 miles downstream of the release on 10/13/05;
- About 65% of the samples had a reporting limit of 0.2 ug/L and about 35% of the samples had a reporting limit of 0.5 ug/L.

Conclusions

Arsenic

- Some apparent exceedance of PA arsenic criteria immediately after the release in the vicinity of the release. These exceedances are not observed upstream.
- Apparent signature of release observable downstream but below PA arsenic criteria.
- Any quantifiable concentration of arsenic exceeds NJ criteria (both upstream and downstream).

Conclusions (continued)

Lead

- Apparent exceedances of PA and NJ lead criteria immediately after release in the vicinity of the release.
- Most quantifiable lead concentrations exceed PA criteria (including upstream).

Aluminum

- Some short term local exceedance of PA aluminum criteria from release, but background and high flows account for most of the observed concentration.

Conclusions (continued)

Manganese

- Manganese concentrations appear to be background concentrations.

Copper

- Short term copper exceedances of PA criteria at release and downstream.

Conclusions (continued)

Selenium

- Selenium concentrations appear to be background concentrations.

Mercury

- Mercury data almost completely below reporting limits.

Assessment of Water Column data collected in response to a fly ash release on the Delaware River

Delaware River Basin Commission
DELAWARE · NEW JERSEY
PENNSYLVANIA · NEW YORK
UNITED STATES OF AMERICA

Delaware River Basin Commission

John R. Yagecic, P.E.
June 19, 2006

ATTACHMENT 10

Delaware River Basin Commission (DRBC) Surface-Water Monitoring Results

Lab Sample ID	Customer	ProjectNa	LabName	CustomerS	CustomerSampleLocation	Matrix	CollectionD	CollectionT	AnalysisDate	AnalysisTi	Parameter	Method	Result	Reporting	Qualifier	MDL	MDLUnits	RL	RLUnits	Fraction
3061201-02	Delaware	Non Tidal	NJECLS	203222	Delaware-Lordville	Surface Wa	6/10/2013	2:30 PM	7/2/2013	4:57 PM	Arsenic	200.9	0.48	ug/L	JR	0.17	ug/L	1	ug/L	Dissolved
3061201-04	Delaware	Non Tidal	NJECLS	203223	Route 13 Bridge Blank	Surface Wa	6/10/2013	5:00 PM	7/2/2013	5:24 PM	Arsenic	200.9	0.23	ug/L	JR	0.17	ug/L	1	ug/L	Dissolved
3061201-06	Delaware	Non Tidal	NJECLS	203224	Delaware-Narrowsburg	Surface Wa	6/10/2013	5:05 PM	7/2/2013	5:50 PM	Arsenic	200.9	0.54	ug/L	JR	0.17	ug/L	1	ug/L	Dissolved
3061201-08	Delaware	Non Tidal	NJECLS	203221	Lackawaxen-Lackawaxen	Surface Wa	6/10/2013	6:30 PM	7/2/2013	6:34 PM	Arsenic	200.9	0.53	ug/L	JR	0.17	ug/L	1	ug/L	Dissolved
3061201-10	Delaware	Non Tidal	NJECLS	203219	Neversink-Port Jervis	Surface Wa	6/10/2013	7:30 PM	7/2/2013	10:36 AM	Arsenic	200.9	0.43	ug/L	JR	0.17	ug/L	1	ug/L	Dissolved
3061201-12	Delaware	Non Tidal	NJECLS	203220	Delaware-Port Jervis	Surface Wa	6/11/2013	7:30 AM	7/10/2013	11:58 AM	Arsenic	200.9	0.2	ug/L	JR	0.2	ug/L	1	ug/L	Dissolved
3061201-14	Delaware	Non Tidal	NJECLS	203235	Brodhead-Minisink	Surface Wa	6/11/2013	10:15 AM	7/10/2013	12:41 PM	Arsenic	200.9		ug/L	K	0.2	ug/L	1	ug/L	Dissolved
3061201-16	Delaware	Non Tidal	NJECLS	203229	Railroad Bridge Blank	Surface Wa	6/11/2013	11:00 AM	7/10/2013	1:06 PM	Arsenic	200.9		ug/L	K	0.2	ug/L	1	ug/L	Dissolved
3061201-18	Delaware	Non Tidal	NJECLS	203233	Delaware-Portland	Surface Wa	6/11/2013	11:15 AM	7/10/2013	10:48 AM	Arsenic	200.9		ug/L	K	0.2	ug/L	1	ug/L	Dissolved
3061201-20	Delaware	Non Tidal	NJECLS	203227	Delaware-Easton	Surface Wa	6/11/2013	1:00 PM	7/10/2013	1:34 PM	Arsenic	200.9	0.32	ug/L	JR	0.2	ug/L	1	ug/L	Dissolved
3061201-22	Delaware	Non Tidal	NJECLS	203236	Lehigh-Easton	Surface Wa	6/11/2013	1:30 PM	7/10/2013	2:19 PM	Arsenic	200.9	0.27	ug/L	JR	0.2	ug/L	1	ug/L	Dissolved
3061201-24	Delaware	Non Tidal	NJECLS	203231	Delaware-Riegelsville	Surface Wa	6/11/2013	2:30 PM	7/10/2013	2:47 PM	Arsenic	200.9	0.34	ug/L	JR	0.2	ug/L	1	ug/L	Dissolved
3061201-26	Delaware	Non Tidal	NJECLS	203228	Elm St Bridge Blank	Surface Wa	6/11/2013	3:00 PM	7/10/2013	3:15 PM	Arsenic	200.9		ug/L	K	0.2	ug/L	1	ug/L	Dissolved
3061201-28	Delaware	Non Tidal	NJECLS	203232	Musconetcong-Rt627	Surface Wa	6/11/2013	3:25 PM	7/10/2013	3:59 PM	Arsenic	200.9	0.57	ug/L	JR	0.2	ug/L	1	ug/L	Dissolved
3061201-30	Delaware	Non Tidal	NJECLS	203230	Delaware-Bullsisland	Surface Wa	6/11/2013	4:45 PM	7/10/2013	4:26 PM	Arsenic	200.9	0.37	ug/L	JR	0.2	ug/L	1	ug/L	Dissolved
3061201-32	Delaware	Non Tidal	NJECLS	203234	Fishing Pier Blank	Surface Wa	6/11/2013	4:50 PM	7/10/2013	6:16 PM	Arsenic	200.9	0.33	ug/L	JR	0.2	ug/L	1	ug/L	Dissolved
3061201-34	Delaware	Non Tidal	NJECLS	203226	Culvert Outlet Blank	Surface Wa	6/11/2013	6:20 PM	7/10/2013	7:02 PM	Arsenic	200.9		ug/L	K	0.2	ug/L	1	ug/L	Dissolved
3061201-36	Delaware	Non Tidal	NJECLS	203225	Delaware-Trenton	Surface Wa	6/11/2013	6:35 PM	7/10/2013	7:29 PM	Arsenic	200.9	0.44	ug/L	JR	0.2	ug/L	1	ug/L	Dissolved
A324023-BLK	Delaware	Non Tidal	NJECLS						7/2/2013	11:24 AM	Arsenic	200.9		ug/L	K	0.17	ug/L	1	ug/L	Dissolved
A326018-BLK	Delaware	Non Tidal	NJECLS						7/10/2013	11:40 AM	Arsenic	200.9		ug/L	K	0.2	ug/L	1	ug/L	Dissolved
A327006-BLK	Delaware	Non Tidal	NJECLS						7/10/2013	5:58 PM	Arsenic	200.9		ug/L	K	0.2	ug/L	1	ug/L	Dissolved

Lab Sample ID	Customer	ProjectNa	LabName	CustomerSampleID	Matrix	CollectionDate	Collection	AnalysisDate	AnalysisTi	Parameter	Method	Result	Reporting	Qualifier	MDL	MDLUnits	RL	RLUnits	Fraction
3011601-02	Delaware	Non Tidal	NJECLS	Brodhead-Minisink-011513	Surface Wa	1/15/2013	10:00 AM	1/25/2013	9:52 AM	Arsenic	200.9		ug/L	K	0.13	ug/L	1	ug/L	Dissolved
3011601-04	Delaware	Non Tidal	NJECLS	Lehigh-Easton-011513	Surface Wa	1/15/2013	1:00 PM	1/25/2013	12:03 PM	Arsenic	200.9		ug/L	K	0.13	ug/L	1	ug/L	Dissolved
3011601-06	Delaware	Non Tidal	NJECLS	Musconetcong-Rt627-011513	Surface Wa	1/15/2013	3:00 PM	1/25/2013	12:28 PM	Arsenic	200.9		ug/L	K	0.13	ug/L	1	ug/L	Dissolved
3011601-08	Delaware	Non Tidal	NJECLS	Delaware-Narrowsburg 011413	Surface Wa	1/14/2013	3:00 PM	1/25/2013	1:09 PM	Arsenic	200.9		ug/L	K	0.13	ug/L	1	ug/L	Dissolved
3011601-10	Delaware	Non Tidal	NJECLS	Neversink-Port Jervis-011513	Surface Wa	1/15/2013	7:30 AM	1/25/2013	1:34 PM	Arsenic	200.9		ug/L	K	0.13	ug/L	1	ug/L	Dissolved
3011601-12	Delaware	Non Tidal	NJECLS	Delaware-PortJervis-011513	Surface Wa	1/15/2013	8:30 AM	1/25/2013	1:59 PM	Arsenic	200.9		ug/L	K	0.13	ug/L	1	ug/L	Dissolved
3011601-14	Delaware	Non Tidal	NJECLS	Delaware-Portland-011513	Surface Wa	1/15/2013	10:30 AM	1/25/2013	2:39 PM	Arsenic	200.9		ug/L	K	0.13	ug/L	1	ug/L	Dissolved
3011601-16	Delaware	Non Tidal	NJECLS	Delaware-Reigelsville-011513	Surface Wa	1/15/2013	2:30 PM	1/25/2013	3:04 PM	Arsenic	200.9		ug/L	K	0.13	ug/L	1	ug/L	Dissolved
3011601-18	Delaware	Non Tidal	NJECLS	Delaware-Trenton-011613	Surface Wa	1/16/2013	9:45 AM	1/25/2013	3:30 PM	Arsenic	200.9		ug/L	K	0.13	ug/L	1	ug/L	Dissolved
3011601-20	Delaware	Non Tidal	NJECLS	Delaware-Bullsisland-011513	Surface Wa	1/15/2013	4:00 PM	1/31/2013	12:48 PM	Arsenic	200.9		ug/L	K	0.19	ug/L	1	ug/L	Dissolved
3011601-22	Delaware	Non Tidal	NJECLS	Delaware-Easton-011513	Surface Wa	1/15/2013	2:00 PM	1/31/2013	1:14 PM	Arsenic	200.9		ug/L	K	0.19	ug/L	1	ug/L	Dissolved
3011601-24	Delaware	Non Tidal	NJECLS	Lackawaxen-Lackawaxen-011413	Surface Wa	1/14/2013	4:00 PM	1/31/2013	1:40 PM	Arsenic	200.9	0.25	ug/L	JR	0.19	ug/L	1	ug/L	Dissolved
3011601-26	Delaware	Non Tidal	NJECLS	ForestRun-Midville-011513 Blank	Surface Wa	1/15/2013	10:45 AM	1/31/2013	2:24 PM	Arsenic	200.9		ug/L	K	0.19	ug/L	1	ug/L	Dissolved
3011601-28	Delaware	Non Tidal	NJECLS	Delaware-Lordville-011413	Surface Wa	1/14/2013	1:15 PM	1/31/2013	2:53 PM	Arsenic	200.9		ug/L	K	0.19	ug/L	1	ug/L	Dissolved
A304016-BLK	Delaware	Non Tidal	NJECLS					1/25/2013	10:41 AM	Arsenic	200.9		ug/L	K	0.13	ug/L	1	ug/L	Dissolved
A304034-BLK	Delaware	Non Tidal	NJECLS					1/31/2013	11:35 AM	Arsenic	200.9		ug/L	K	0.19	ug/L	1	ug/L	Dissolved

DRBC

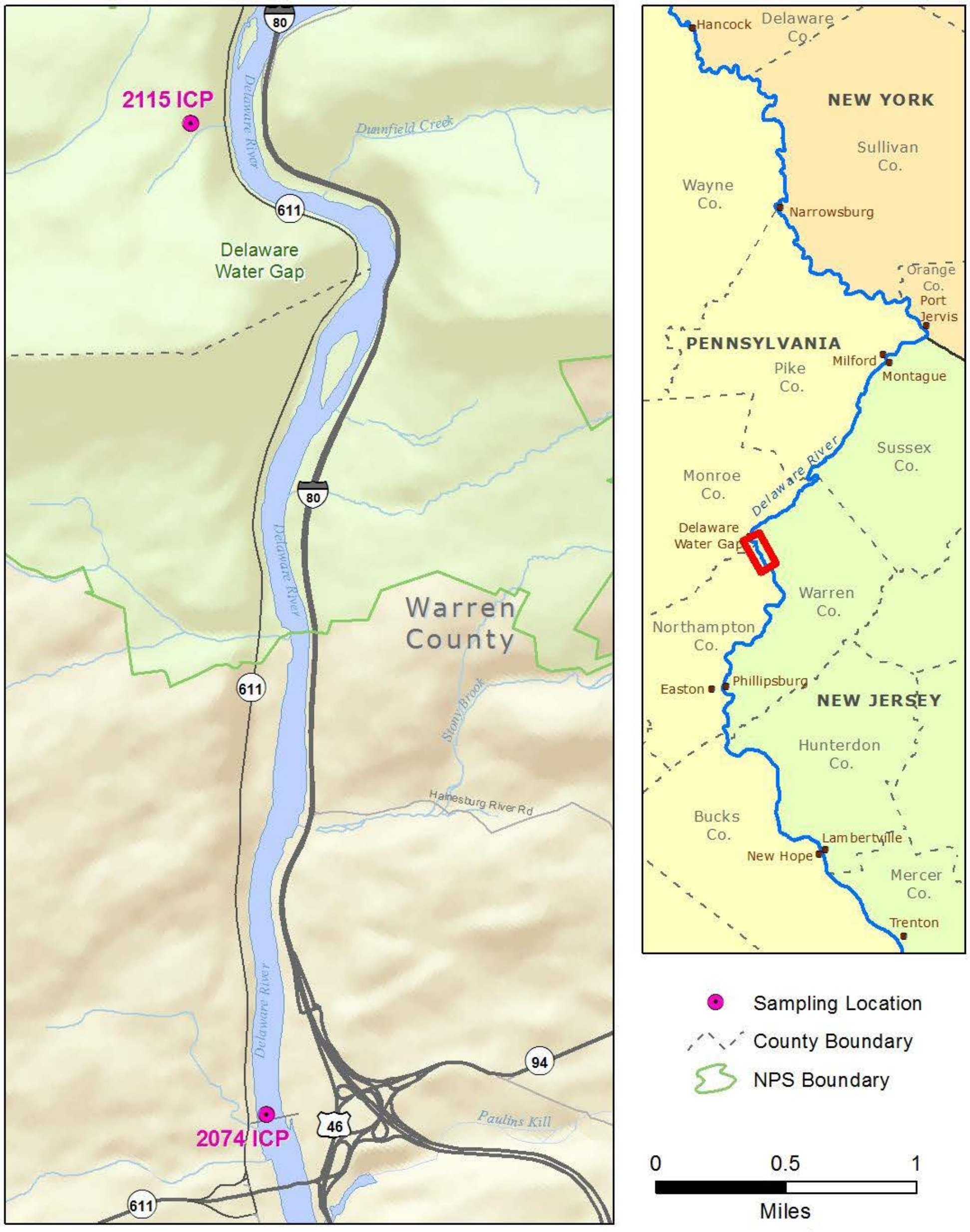
Sampling Locations - Non-tidal Surface-water Data Sets

RM	River	Location	Lat	Long	Notes
321	Delaware	Lordville	41.867872	-75.21376	
290	Delaware	Norrowsburg	41.609613	-75.061728	
277.7	Lackawaxen	Lackawaxen	41.486666	-74.991647	Hamlin Highway
254.8	Delaware	Port Jervis	41.371708	-74.697156	
253.6	Neversink	Neversink at Port Jervis	41.361128	-74.685213	Route 6
213	Brodhead Creek	Brodhead Creek Minisink Hills	40.99341	-75.137766	State Highway 2028
207.6	Delaware	Portland	40.924122	-75.095479	
183.8	Delaware	Easton (Northampton St.)	40.691476	-75.203874	
183.6	Lehigh	Lehigh River at Easton	40.686903	-75.208445	3rd St.
175	Delaware	Riegelsville	40.59423	-75.190793	
174.6	Musconetcong River	Musconetcong River Rt627	40.592388	-75.186241	
155.7	Delaware	Bulls Island	40.41075	-75.034121	
134.3	Delaware	Calhoun St. Bridge	40.219749	-74.778284	

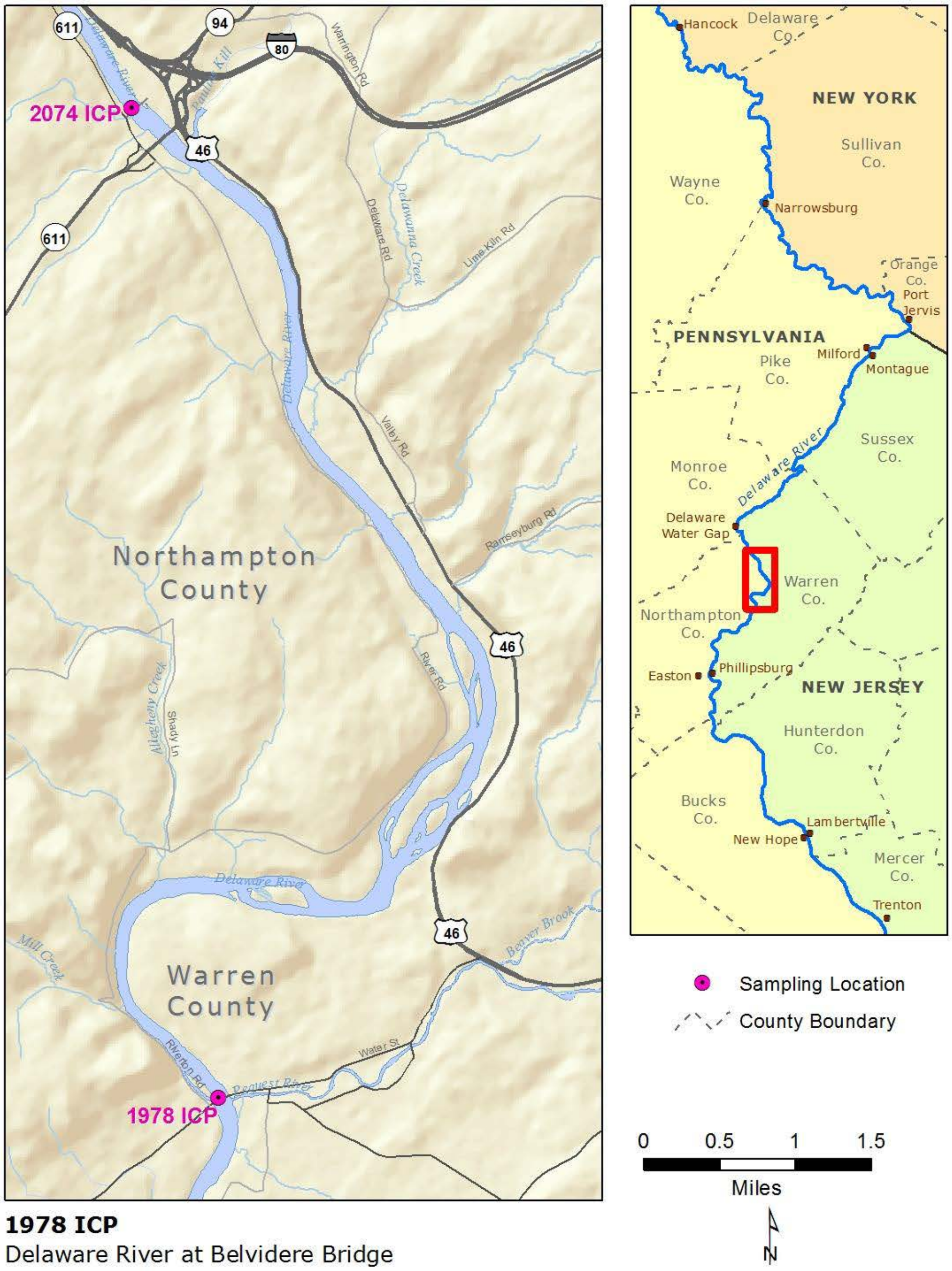
Delaware Water Gap - RM 210.80

Trenton, NJ - RM 134

DRBC Surface-Water Monitoring Locations
Main Stem Delaware River from Delaware Water Gap to Washington Crossing Bridge

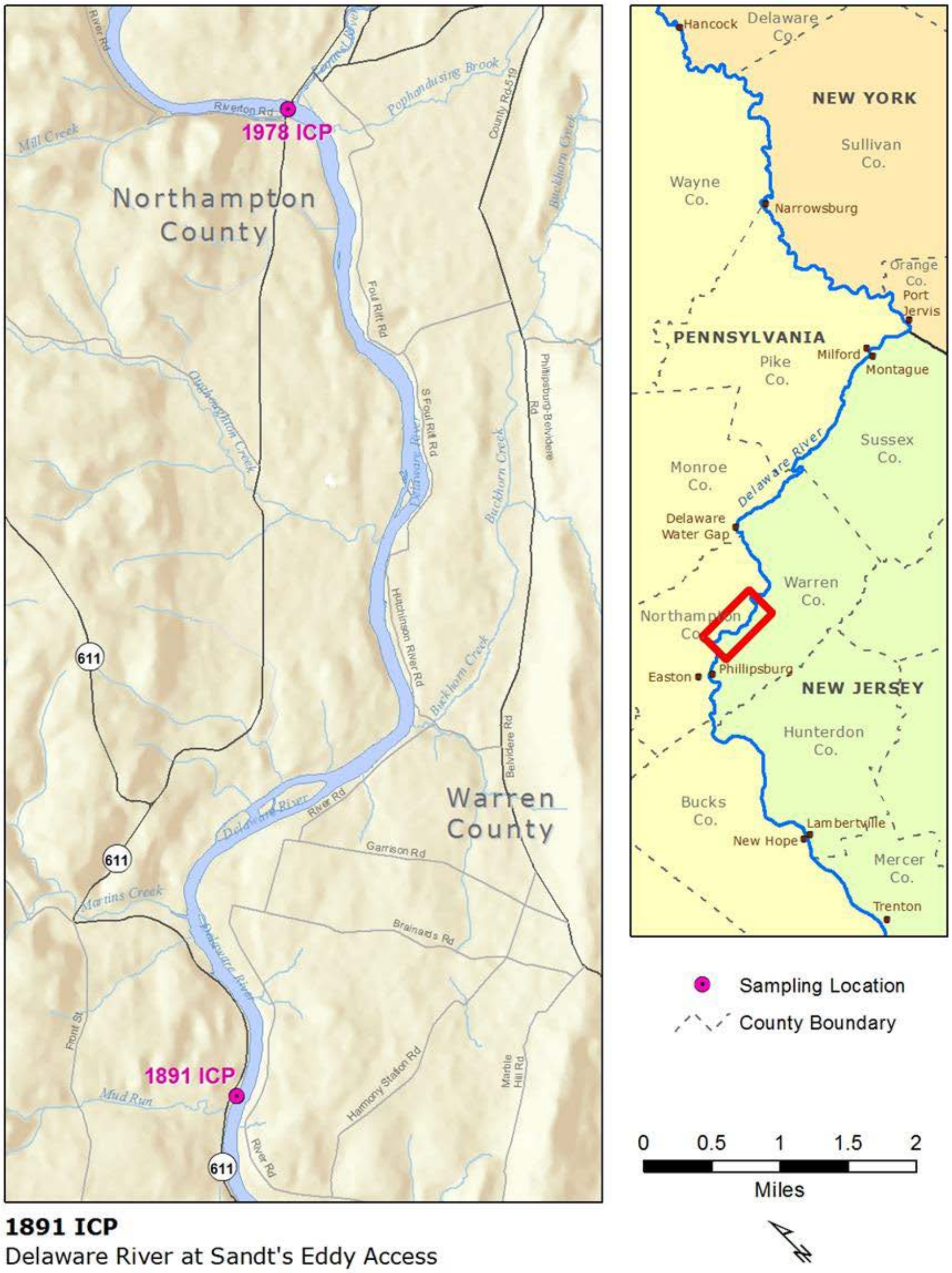


2074 ICP
Delaware River at Portland Foot Bridge

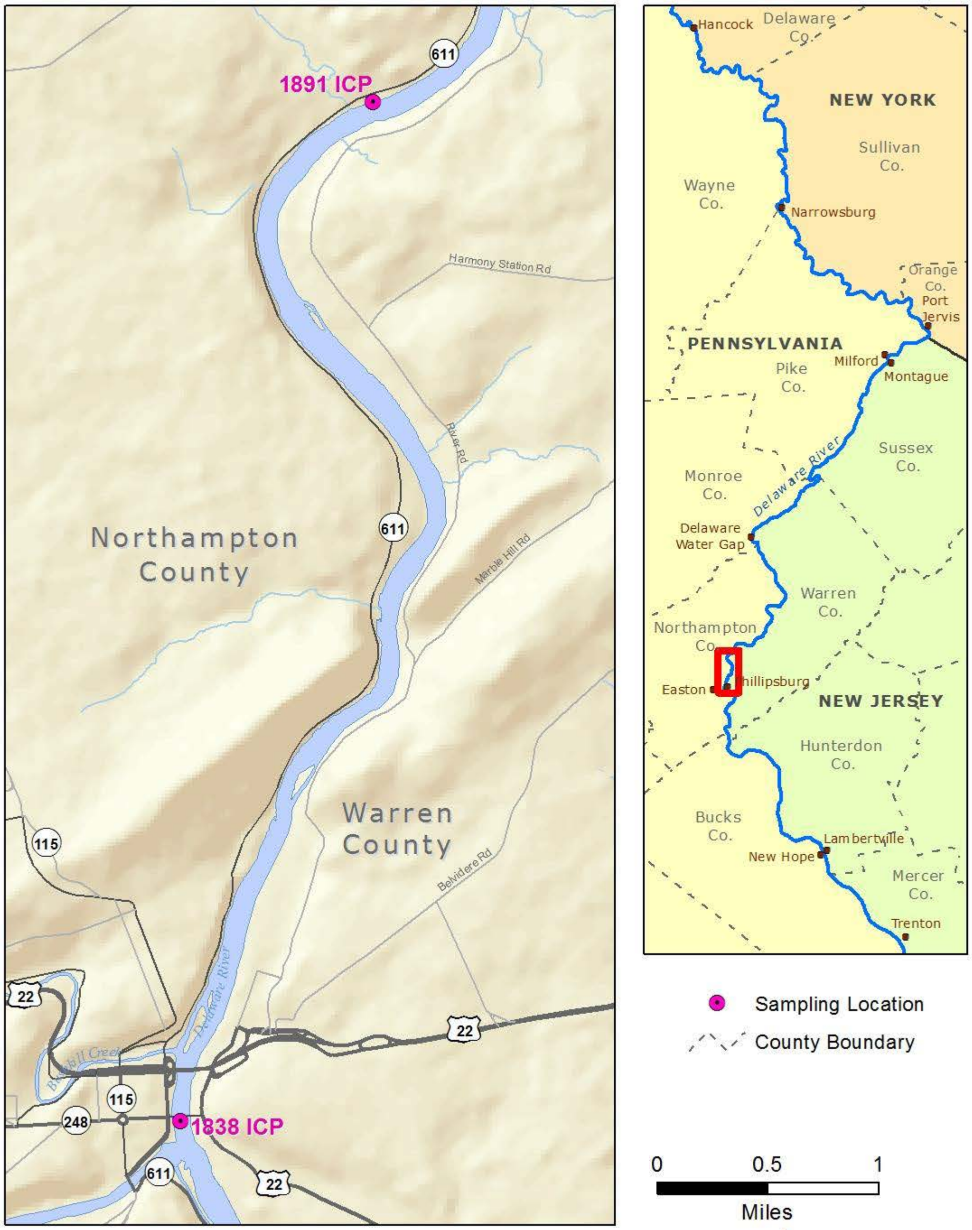


1978 ICP

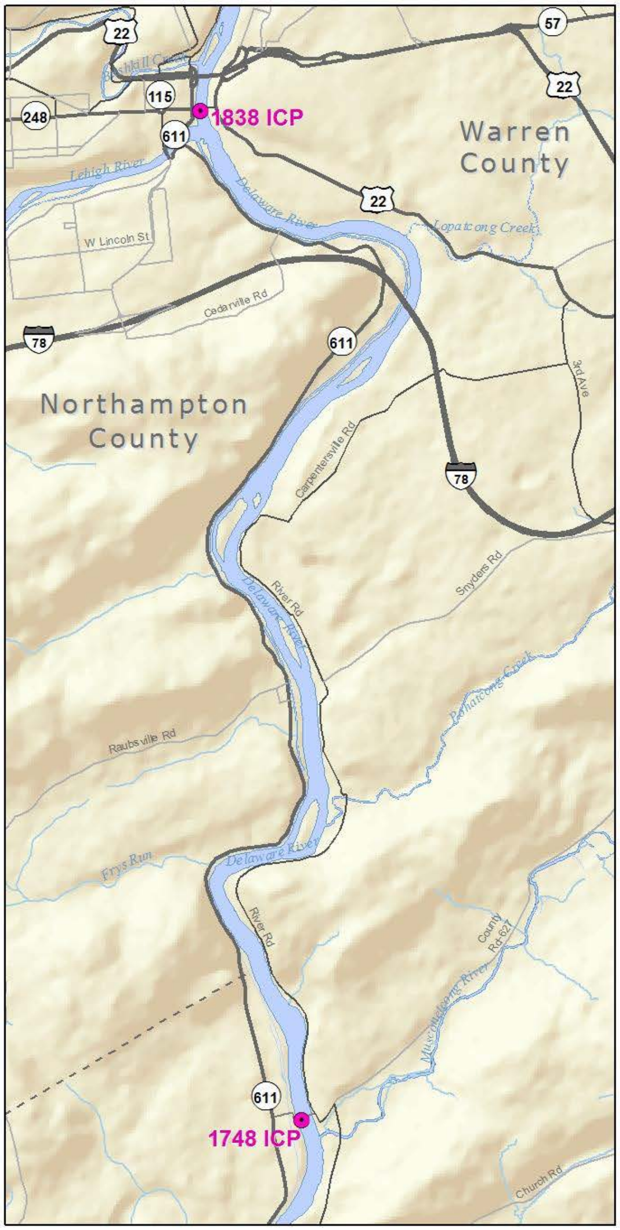
Delaware River at Belvidere Bridge



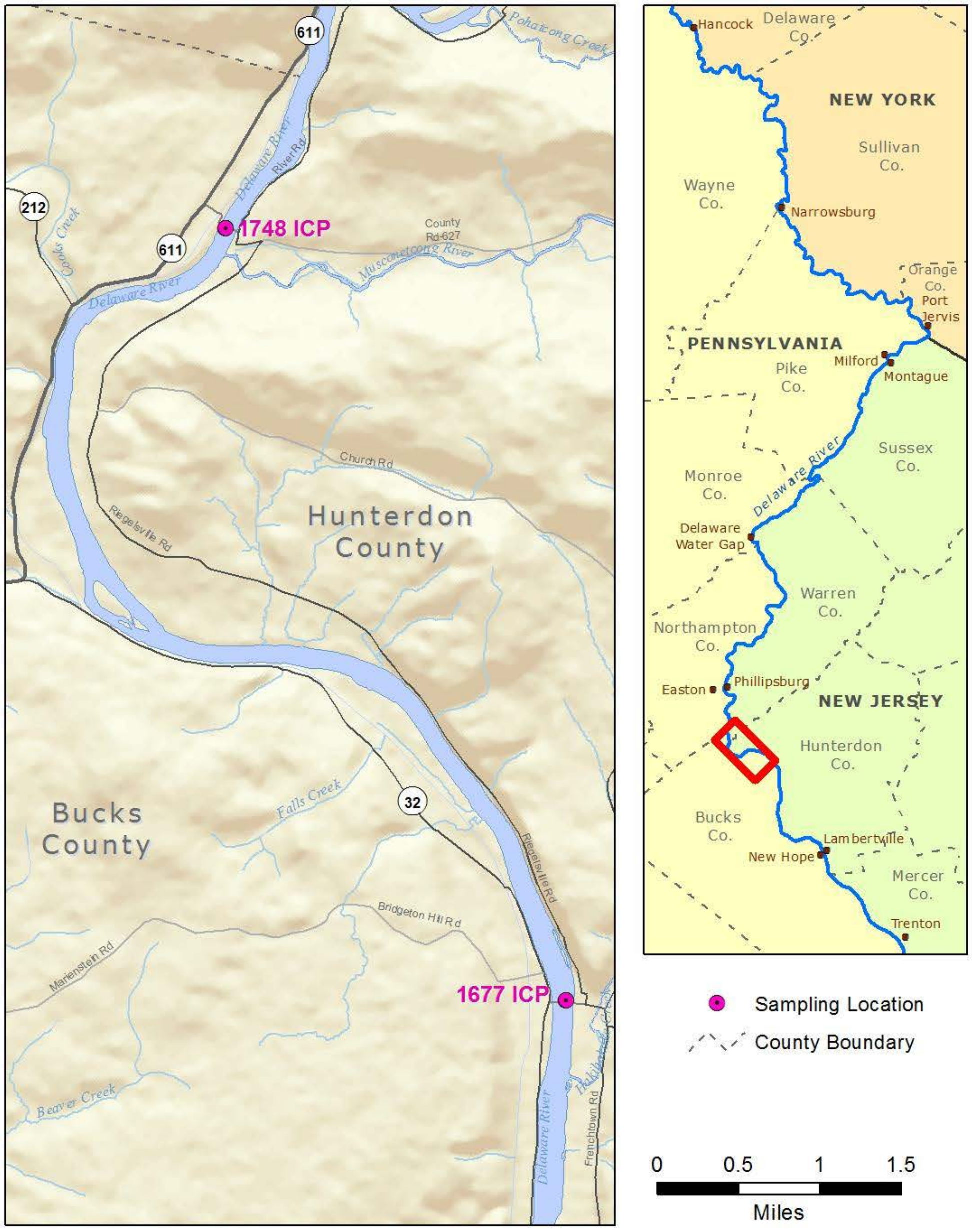
1891 ICP
Delaware River at Sandt's Eddy Access



1838 ICP
Delaware River at Northampton Street Bridge

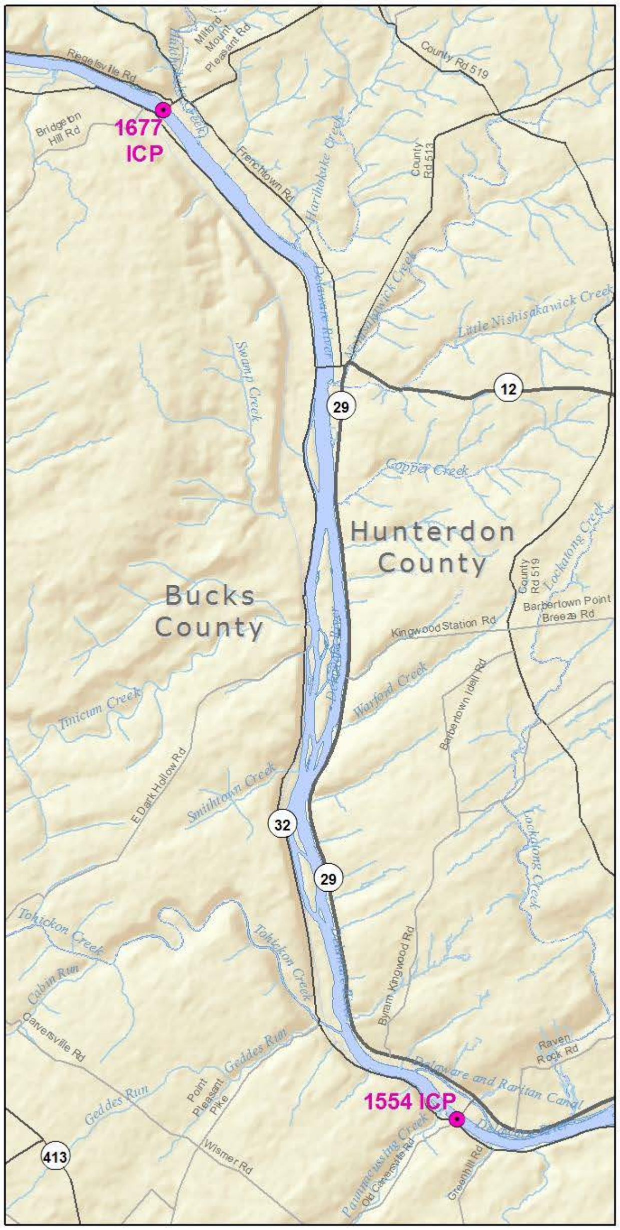


1748 ICP
Delaware River at Riegelsville Bridge

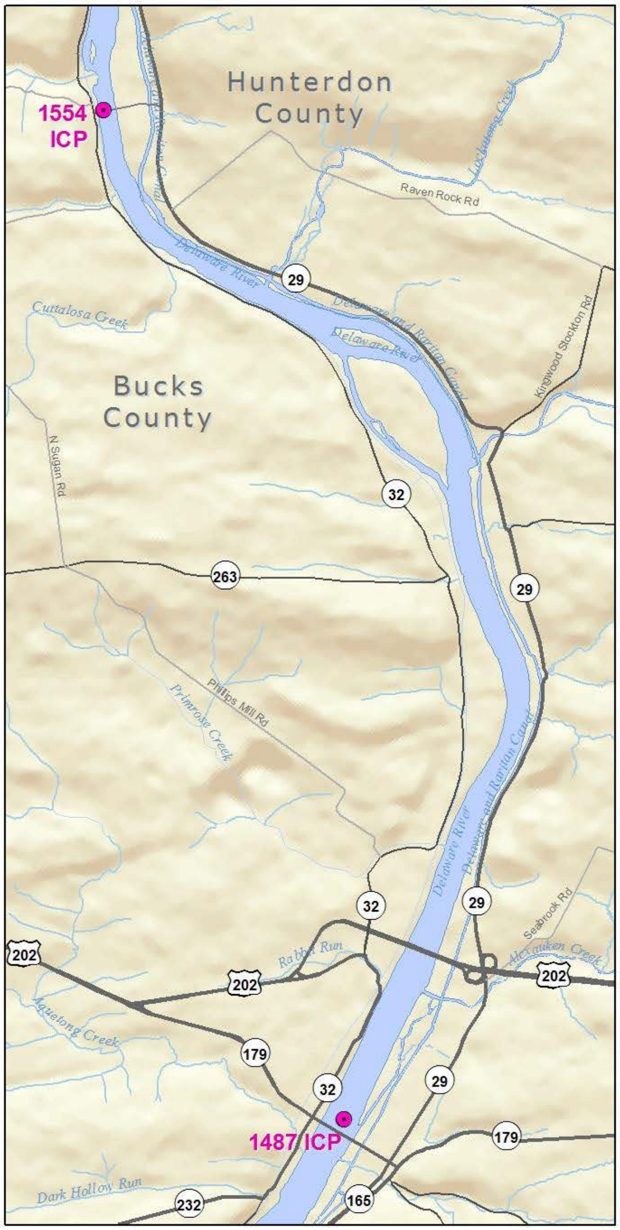


1677 ICP

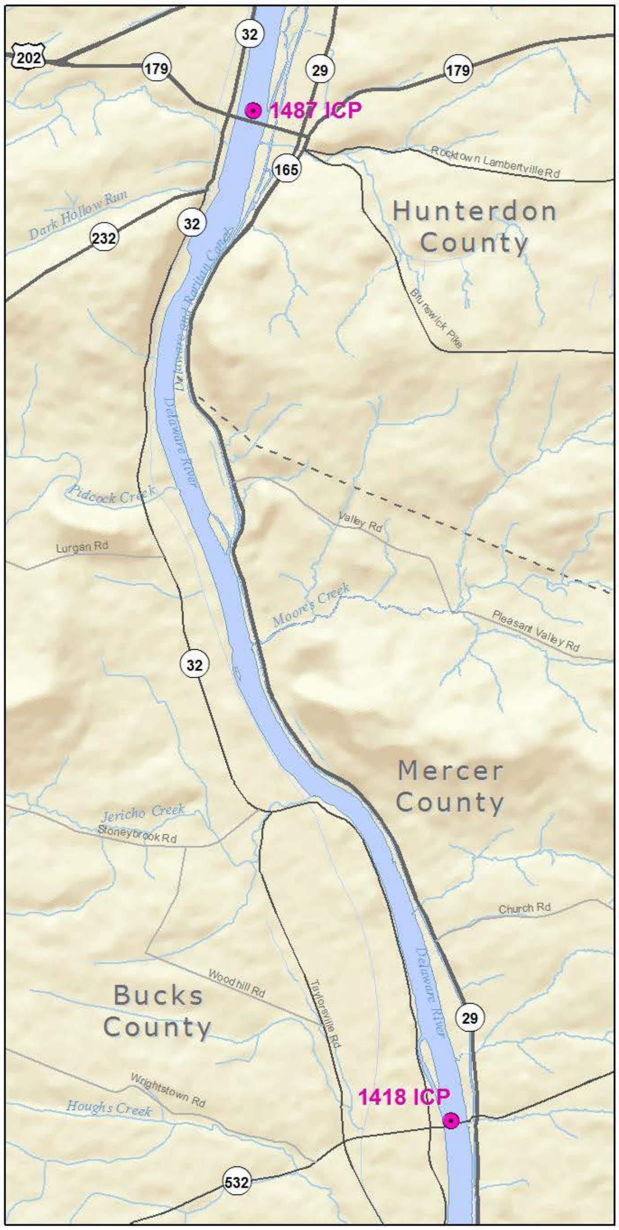
Delaware River at Upper Black Eddy Bridge



1554 ICP
Delaware River at Bull's Island Foot Bridge



1487 ICP
Delaware River at Lambertville Bridge



1418 ICP

Delaware River at Washington Crossing Bridge

ATTACHMENT 11

Comprehensive Arsenic Baseline Data Summary Table

Comprehensive Arsenic Baseline Data Summary Table - Delaware River Watershed between River Miles 210.8 and 141.8

Sample Matrix	**Soil**			**Groundwater**			**Surface Water**			**Sediment**		
Arsenic Concentration	**Range** (mg/kg)	**Mean** (mg/kg)	**90th-P** (mg/kg)	**Range** (ug/L)	**Mean** (ug/L)	**90th-P** (ug/L)	**Range** (ug/L)	**Mean** (ug/L)	**90th-P** (mg/kg)	**Range** (ug/L)	**Mean** (ug/L)	**90th-P** (ug/L)
Ambient Soil in New Jersey												
Urban Piedmont	**1.7 - 49.7**	**10.03**	**24.2**	NA	NA	NA	NA	NA	NA	NA	NA	NA
Highlands *	**-**	**4.8**	**9.96**	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ridge and Valley *	**-**	**4.9**	**7.32**	NA	NA	NA	NA	NA	NA	NA	NA	NA
Known Contaminated Sites												
Crown Vantage	**2.8 - 14.7**	**7.7**	**-**	**-**	**-**	**-**	**0.29 - 0.39**	**0.34**	**-**	**-**	**-**	**-**
Curtis Paper	**1.4 - 79**	**9.9**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**ND - 4.4**	**2.6**	**-**
Martins Creek	**-**	**-**	**-**	**-**	**-**	**-**	**30 - 60**	**-**	**-**	**-**	**-**	**-**
Private Well Data												
New Jersey												
Mercer County [1]	NA	NA	NA	**-**	**-**	**9.2**	NA	NA	NA	NA	NA	NA
Hunterdon County [1]	NA	NA	NA	**4.3 - 21.2**	**-**	**21.2**	NA	NA	NA	NA	NA	NA
Warren County [1]	NA	NA	NA	**2.0 - 4.2**	**-**	**4.2**	NA	NA	NA	NA	NA	NA
Pennsylvania												
Bucks and Lehigh Counties	NA	NA	NA	**0.01 - 64.86**	**7.76**	-	NA	NA	NA	NA	NA	NA
Ambient Groundwater Data												
New Jersey												
Mercer County	NA	NA	NA	**0.12 - 1.5**	**-**	**-**	NA	NA	NA	NA	NA	NA
Hunterdon County	NA	NA	NA	**<0.3 - 2.9**	**-**	**-**	NA	NA	NA	NA	NA	NA
SW [2]	NA	NA	NA	**ND - 24.7**	**4.9**	**13**	NA	NA	NA	NA	NA	NA
CW [2]	NA	NA	NA	**ND - 25.0**	**5.3**	**10.9**	NA	NA	NA	NA	NA	NA
NW [2]	NA	NA	NA	**ND - 9.0**	**2.3**	**6**	NA	NA	NA	NA	NA	NA
Warren County	NA	NA	NA	-	-	-	NA	NA	NA	NA	NA	NA

Comprehensive Arsenic Baseline Data Summary Table - Delaware River Watershed between River Miles 210.8 and 141.8

Sample Matrix	**Soil**			**Groundwater**			**Surface Water**			**Sediment**		
Arsenic Concentration	**Range** (mg/kg)	**Mean** (mg/kg)	**90th-P** (mg/kg)	**Range** (ug/L)	**Mean** (ug/L)	**90th-P** (ug/L)	**Range** (ug/L)	**Mean** (ug/L)	**90th-P** (mg/kg)	**Range** (ug/L)	**Mean** (ug/L)	**90th-P** (ug/L)
Pennsylvania												
Bucks County												
Northern	NA	NA	NA	**ND - 13**	**2.4**	**3.8**	NA	NA	NA	NA	NA	NA
Central	NA	NA	NA	**ND - 60**	**9.3**	**28**	NA	NA	NA	NA	NA	NA
Northampton County	NA	NA	NA	-	-	-	NA	NA	NA	NA	NA	NA
Bucks and Lehigh Counties	NA	NA	NA	**ND - 83.0**	**9**	-	NA	NA	NA	NA	NA	NA
Surface-Water Monitoring												
DRBC 2013 Data Set	NA	NA	NA	NA	NA	NA	**0.27 - 0.57**	**0.38**	**-**	NA	NA	NA

NA = Not applicable

" - " indicates no information/data currently available

* indicates the median concentration is reported instead of the mean

1 - indicates that ranges are for 90th-percentile results from various municipalities within the County, and the highest 90th-percentile value is reported in the 90th-percentile column

2 - indicates USGS and NJDEP data from within 3 miles of the Delaware River

Sources of Groundwater Data include:

PADEP Drinking Water Reporting System http:www.drinkingwater.state.pa.us/dwrs/HTM/Welcome.html
National Water Quality Monitoring Council (NWQMC) https://www.waterqualitydata.us/portal/
NJ Private Well Testing Act Data http://njdep.maps.arcgis.com/apps/MapSeries/index.html?appid=826ec9fae77543caa582a787d5f088e7
PA Private Well and Ambient Testing Data - Bucks and Lehigh Counties: Lori Burkert Masters Thesis, Lehigh University, 2006.
New Jersey Drinking Water Watch https://www9.state.nj.us/DEP_WaterWatch_public/

Sources of Soil, Surface-water and Sediment Data include: the New Jersey Department of Environmental Protection (Ambient Soil Data) (http://www.nj.gov/dep/srp/)

Crown Vantage Landfill Site (for Soil, Surface-water, and/or Sediment Data) (https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0204492)
Curtis Specialty Paper Site (for Soil, Surface-water, and/or Sediment Data) (https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0203733)
Delaware River Basin Commission (DRBC) (Surface-water Data) (http://www.state.nj.us/drbc/quality/datum/index.html)