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New England District

Report on the Evaluation of Site-Specific Arsenic Background Concentrations in Groundwater

Shepley's Hill Landfill

Former Fort Devens Army Installation

Devens, Massachusetts

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CERTIFICATION

I hereby certify that the enclosed Work Plan, shown and marked in this submittal, is that proposed to be incorporated with Contract Number W912WJ-19-D-0014. This document was prepared in accordance with the U.S. Army Corps of Engineers Scope of Work and is hereby submitted for Government approval.

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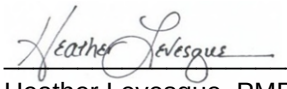

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Acronyms and Abbreviations

µg/L	microgram per liter
95-95UTL	95 percent upper tolerance limit with 95 percent coverage
bgs	below ground surface
CC	confidence coefficient
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CTV	central tendency value
DO	dissolved oxygen
FFS	Focused Feasibility Study
ft/day	foot per day
ft/ft	foot per foot
gpm	gallons per minute
IQR	interquartile range
LOQ	limit of quantitation
MCL	maximum contaminant level
mg/kg	milligram per kilogram
mg/L	milligram per liter
MK	Mann-Kendall
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NIA	North Impact Area
ORP	oxidation reduction potential
QAPP	Quality Assurance Project Plan
S-A JV	SERES-Arcadis 8(a) Joint Venture
SHL	Shepley's Hill Landfill
UCL	upper confidence limit
USACE	United States Army Corps of Engineering
USEPA	United States Environmental Protection Agency
UTL	upper tolerance limit
Work Plan	Work Plan to Evaluate Site-Specific Arsenic Background Concentrations in Groundwater

1 Introduction

The SERES-Arcadis 8(a) Joint Venture 2, LLC (S-A JV) has prepared this Report on the Evaluation of Site-Specific Arsenic Background Concentrations in Groundwater (Report) to document the evaluation of site-specific background concentrations of arsenic in groundwater for the Shepley's Hill Landfill (SHL or the site) located at the former Fort Devens Army Installation (Fort Devens) in Devens, Massachusetts (Figure 1). This evaluation was conducted in support of a Focused Feasibility Study (FFS) to evaluate the potential alternatives in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Section 121(c), applicable CERCLA guidance, and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The S-A JV prepared this Report on behalf of the United States Army Corps of Engineering (USACE) – New England District under Contract Number W912WJ-19-D-0014.

1.1 Objectives and Rationale

The primary objective of the background evaluation is to determine representative concentrations of arsenic in groundwater at SHL in the absence of anthropogenic site-related influences (including SHL). Arsenic concentrations greater than the United States Environmental Protection Agency (USEPA) maximum contaminant level (MCL; 10 micrograms per liter [µg/L]) have been detected in groundwater at SHL. Although groundwater downgradient of SHL contains arsenic that is in part either directly or indirectly related to the presence of the landfill, groundwater in areas of the site unaffected by the landfill also exhibit widely varying arsenic concentrations above and below the MCL due to natural conditions. Thus, this work was required to establish site-specific background arsenic concentrations that could be used when assessing the potential efficacy of remedial actions to reduce arsenic concentrations in groundwater in areas such as the North Impact Area (NIA) downgradient (to the north) of SHL.

This background evaluation summarizes the results of the statistical procedures outlined in the Army-approved Work Plan to Evaluate Site-Specific Arsenic Background Concentrations in Groundwater (Work Plan; S-A JV 2022).

1.2 Summary of Regional Groundwater

This section provides a summary of the regional hydrogeologic setting and regional background arsenic concentrations.

1.2.1 Regional Hydrogeologic Setting

Regionally, groundwater and surface water bodies across Fort Devens ultimately discharge to the Nashua River, whose tributaries include Nonacoicus Brook and Walker Brook on the former North Post. Cold Spring Brook (which is a tributary of Nonacoicus Brook via Grove Pond and Plow Shop Pond) and Willow Brook (another tributary to Nonacoicus Brook) flow through the former Main Post. Groundwater in the area of SHL discharges to Plow Shop Pond (which discharges to Nonacoicus Brook and then the Nashua River) and Nonacoicus Brook (Figure 1). Groundwater discharge maintains baseflow conditions for the ponds, wetlands, and tributaries across Fort Devens.

1.2.1.1 Overburden

Overburden (glacial meltwater deposits) constitutes the primary groundwater aquifer at Fort Devens. Zones of highest transmissivity within the overburden are generally found in areas of thick glacial meltwater deposits on the former North and Main Posts at Fort Devens (e.g., along Cold Spring Brook). Water supply wells, including the Shabokin, Patton, MacPherson, and Grove Pond water supply wells, are all completed within these meltwater deposits and can easily yield several hundred gallons per minute (gpm). Hydraulic conductivity values have been reported to vary between 30 and 300 feet per day (ft/day) in meltwater deposits, while lake bottom sediments are significantly less permeable with reported hydraulic conductivities ranging from 0.002 to 0.3 ft/day (HLA 2000). The regional depth to groundwater ranges from less than 1 foot below ground surface (bgs) to more than 60 feet bgs and averages approximately 15 feet bgs. Overburden groundwater is recharged in upland areas, and flow generally follows from topographic highs to topographic lows, where it discharges to wetlands, ponds, streams, and directly into the Nashua River.

1.2.1.2 Bedrock

The zones of lowest groundwater transmissivity at Fort Devens are typically associated with exposed till and fractured bedrock. Groundwater flow occurs in the underlying bedrock; however, it is more restrictive relative to the overburden because the bedrock lacks primary porosity and/or has been impacted by metamorphism. Groundwater in bedrock predominantly flows through secondary porosity features such as fractures, joints, and dissolution voids. While faulting and foliation of the bedrock align with major unit contacts, the fracture orientations are less systematic than the foliation patterns (Kopera et al. 2006; GZA 2011a, 2011b). Therefore, groundwater flow paths in the bedrock are constrained by the resulting (sparse) fracture network and biased by the underlying bedrock fabric, which results in preferential movement along strike (i.e., north-south/northeast-southwest direction; Kopera et al. 2006). Because of the sparse fracture network and corresponding low bulk transmissivity (effectively negligible to non-existent below approximately 500 feet bgs), bedrock supply wells across the area typically yield less than 2 gpm.

However, at SHL, the hydraulic connection between bedrock and overburden is more pronounced than in other areas of Fort Devens, with seasonal changes observed in the direction of vertical groundwater flow between the bedrock and overburden. During periods of high recharge and low evapotranspiration (generally winter/spring), the direction of groundwater flow is upward from the bedrock to the overburden beneath the landfill, primarily due to precipitation recharge on Shepley's Hill. During periods of low recharge and high evapotranspiration (generally summer/fall), the direction of groundwater flow is downward from the overburden sands to the underlying bedrock but with a lower gradient than that associated with the upward flows observed in the winter/spring (Gannett Fleming 2012).

1.2.1.3 Regional Groundwater Flow

Regional groundwater elevations at SHL are shown for spring and fall 2022 on Figures 2 and 3, respectively. These maps show groundwater flow in the shallow overburden wells only. Similar to previous monitoring events, the water levels measured in fall 2022 illustrate that groundwater flows generally from the southwest to the north toward Nonacoicus Brook, with a deflection of groundwater flow to the north by the barrier wall in the area west of the wall. The following groundwater hydraulic gradients were calculated in 2022:

- The gradient across the southern portion of the Landfill Area was calculated as 0.011 foot per foot (ft/ft) in fall 2022 using wells SHL-15 (Upgradient Area) and PZ-12-10 (Barrier Wall Area).

- The gradient across the northern portion of the Landfill Area was calculated as 0.010 ft/ft in fall 2022 using wells SHM-10-15 (Landfill Area) and SHL-23 (Nearfield Area).
- The gradient across the Nearfield Area ranged from 0.002 ft/ft (spring 2022) using wells EPA-PZ-2012-1A and SHP-2016-2A (Nearfield Area) to 0.004 ft/ft (fall 2022) using wells SHM-10-06A and SHM-10-16 (Nearfield Area).
- The gradient across the NIA ranged from 0.003 ft/ft (fall 2022) using wells SHM-05-40X and SHM-13-08 (NIA) to 0.004 ft/ft (spring 2022) using wells SHM-05-40X and SHM-13-03 (NIA), respectively.
- The gradient across the Barrier Wall Area was calculated as 0.097 ft/ft in spring 2022 and 0.032 ft/ft in fall 2022 using wells PZ-12-05 and PZ-12-06 (Barrier Wall Area).
- In general, the horizontal hydraulic gradient is steepest across the Landfill Area (typically two to three times greater in 2022) compared to other areas, and the gradient across the NIA is comparable to the gradient of the Nearfield Area.

The three sets of overburden and bedrock well pairs gauged during the fall 2022 monitoring event were assessed with respect to the presence of vertical gradients. The vertical gradient observations are summarized below:

- A positive vertical gradient (downward flow component) was observed in the Upgradient Area from overburden to bedrock. This is consistent with recent historical observations.
- A positive vertical gradient (downward flow component) was observed in the Barrier Wall Area near Red Cove. Gradients have fluctuated between positive and negative over the last five fall gauging events (-0.006 to 0.002), most likely due to the relative degree of groundwater discharge from the bedrock towards Plow Shop Pond, compared to the relative degree of influence from the water levels in Plow Shop Pond at the time of gauging.
- A negative vertical gradient (upward flow component) was observed in the Nearfield Area. The gradient in this area has generally been a positive/downward flow component in recent fall gauging events. However, some instances of upward flow have been observed in fall gauging events, similar to the fall 2018 event. These minor fluctuations are likely due to changes in precipitation from year to year and/or flowrates at the extraction wells at the time of gauging. At overburden triplet monitoring well SHM-05-41A/B/C, groundwater flow had both an upward and slight downward component from approximately 60 feet bgs toward the approximate 40 feet bgs and 95 feet bgs intervals.

1.2.2 Regional Background Arsenic Concentrations

Arsenic concentrations greater than the MCL (10 µg/L) are documented to occur in groundwater in the bedrock and overburden aquifers throughout eastern New England (e.g., Ayotte et al. 2003). Studies have shown that the source of the aqueous arsenic in New England is mostly natural and originates from minerals in the regional formations (Ayotte et al. 2003, Welch et al. 2000, Hon et al. 2001, Peters et al. 1999, Reeve et al. 2001). Regionally, arsenic has been found at concentrations of 3 to 40 milligram per kilogram (mg/kg) in whole rock samples taken from metasedimentary bedrock units. This naturally occurring arsenic represents a potential geologic source for dissolved arsenic (Ayotte et al. 2003).

Naturally occurring arsenic in groundwater may occur due to dissolution from host rock under certain geochemical conditions. A 2010 study performed at a site located in central Massachusetts demonstrated naturally occurring arsenic concentrations exceeding regulatory standards in groundwater collected from overburden and bedrock

wells attributable to geologic conditions (Nelson et al. 2010). Average arsenic concentrations in groundwater collected from bedrock wells ranged from 32 to 82 µg/L. The geochemical conditions in these bedrock wells included pH between 7 and 8, low dissolved oxygen (DO; < 1.2 milligrams per liter [mg/L]), and reducing conditions evidenced by relatively low oxidation reduction potential (ORP).

A 2011 regional-scale study performed on groundwater from 478 randomly selected private-use bedrock wells in east-central Massachusetts showed arsenic concentrations up to 1,540 µg/L, with 13 percent of the wells exhibiting concentrations greater than the arsenic MCL (Coleman 2011). This study also estimated that 5,741 wells in Massachusetts contain arsenic concentrations that exceed the MCL.

Table 1 below summarizes key studies and observed arsenic concentrations in New England.

Table 1 Summary of Regional Arsenic Concentrations in Groundwater

Study Area	Sample Depth Ranges (feet)	Stratigraphic Interval(s)	Concentration Range (µg/L)	Reference
Southeastern New Hampshire	14 - 350	--	1.3 - 41	Boudette et al. 1985
New Hampshire	--	Surficial and Bedrock	<0.0003 - 180	Peters et al. 1999
North Central Massachusetts	--	Bedrock	44 - 139	Hon et al. 2001
Northport, Maine	--	--	1 – 1,940	Reeve et al. 2001
Central Massachusetts	7 - 62	Sand/Gravel and Silt/Clay	< 4 - 82	Nelson et al. 2010
	140 - 180	Bedrock	32 - 82	
East-Central Massachusetts	--	Bedrock	< 0.2 - 1,540	Coleman 2011

Notes:
-- : not available
< : less than

2 Background Groundwater Dataset and Supplemental Sampling

The regional hydrogeology, geochemistry, and the SHL conceptual site model discussed in the Work Plan (S-A JV 2022) provide the context for understanding the influence of SHL on groundwater at SHL. Based on the groundwater flow dynamics, existing monitoring wells in place to monitor groundwater upgradient and cross-gradient of SHL were identified to the east, west, and south of SHL. Groundwater in the areas and at the depths monitored by these wells is not anticipated to be impacted by the presence of SHL. These wells were sampled historically for a limited subset of constituents.

This section provides a summary of the rationale for the selected background sampling locations and completed groundwater sampling to supplement the background arsenic concentration in the groundwater dataset. Except for proposed additional wells installed at SHL since 2016, the sampling performed for this background evaluation was consistent with the approach proposed by USEPA (USEPA 2016), with the caveat that background values estimated using wells from the east, west, and south of SHL may not completely represent pre-landfill groundwater conditions in the NIA north of SHL.

2.1 Background Sample Location Rationale

The USEPA proposed that groundwater arsenic concentration data from 31 monitoring wells screened in the overburden and 12 monitoring wells screened in the bedrock be used in calculating background values for arsenic (USEPA 2016). Data from 27 overburden monitoring wells (all included in the original USEPA list) and 16 bedrock monitoring wells (11 from the original USEPA list, plus five monitoring wells installed after the USEPA's proposed scope was documented in 2016) were used to calculate background values for arsenic (Table 2, Figure 4). Data from the following locations are included:

- Overburden monitoring wells:
    - Upgradient Area: 32M-01-14XOB, 32M-92-01X, 32Z-01-07XOB, N7-P2, SHL-12, SHL-15, SHL-17, and SHL-25;
    - Upgradient Area (adjacent to the Former Railroad Roundhouse/Rail Spur): SHL-7, SHL-18, SHL-24, SHM-93-24A, SHM-93-18B, and SHP-95-27X;
    - Adjacent to Plow Shop Pond: N1-P1, N1-P2, and N1-P3;
    - Nearfield Area: SHL-23; and
    - Shepley's Hill Area: MW-1, MW-4-1, MW-7, MW-11A, MW-14, MW-16, MW-22, SHL-1, and SHP-99-1B.
- Bedrock monitoring wells:
    - Upgradient Area: N7-P1;
    - Nearfield Area: SHP-2016-06A, SHP-2016-06B, and SHP-2016-06C; and
    - Shepley's Hill Area: 20-1, 27-1, 27-2, 3-2, CAP-2B, CH-1D, CH-1S, Q4-1, Q5-1, SHP-2016-07A, SHP-2016-07B, and SHP-99-1C.

Samples collected at five of these bedrock monitoring wells (SHP-2016-06A, SHP-2016-06B, SHP-2016-06C, SHP-2016-07A, and SHP-2016-07B), located in the vicinity of other bedrock monitoring wells USEPA proposed for inclusion in the evaluation in 2016, were included in the background dataset (S-A JV 2022). Locations selected are upgradient/cross-gradient from and outside the influence of SHL:

- Monitoring well cluster SHP-2016-06A/B/C is collocated with USEPA proposed overburden well SHL-23 (Figure 4). In this area, the groundwater hydraulic gradient is predominantly from bedrock to overburden. The elevated arsenic present in this well set is likely the result of geogenic arsenic released from the oxidative dissolution of arsenic-bearing sulfide minerals. The groundwater signature is distinctly different from that of landfill-influenced overburden groundwater to the east, which is characterized by much higher iron and manganese concentrations. In contrast, arsenic, iron, and manganese concentrations at the SHP-2016-06A/B/C well set are similar in relative proportions to the chemistry at CH-1D. Arsenic, iron, and manganese concentrations in these wells range from 210 to 2,800 µg/L, < 50 to 610 µg/L, and 83 to 1,300 µg/L, respectively.
- SHP-2016-07A/B are located between other bedrock well clusters on the previously recommended well list but are present at a depth and location relative to SHL boundary similar to those of other bedrock wells previously recommended for inclusion (i.e., 3-2, CH-1D, CH-1S, and Q4-1) in the evaluation by USEPA (Figure 4). Arsenic concentrations at these locations are lower than or similar to those in other bedrock monitoring wells proposed to be sampled (i.e., CH-1D and N7-P1).

2.2 Supplemental Groundwater Monitoring and Sampling

Groundwater monitoring and sampling were performed during three events: May 23 to June 2, 2022; August 23 to 30, 2022; and November 8 to 17, 2022. Sampling was completed in accordance with the Work Plan (S-A JV 2022). Several wells (MW-1, MW-4-1, MW-7, MW-9, MW-11A, MW-14, MW-16, MW-22, SHL-1, SHP-99-01B, SHP-99-01C, and SHP-2016-07A) could not be sampled in one or more events because they were dry. Groundwater sampling analytical results and field recorded water quality parameters are provided in Tables 3 and 4.

3 Methodology Used to Determine Background Concentration

As discussed in the Work Plan (S-A JV 2022), USEPA (1992, 2006, 2009) guidance recommends the following steps for establishing background values for groundwater:

1. Calculate descriptive statistics.
2. Create graphical representations.
3. Determine normality.
4. Evaluate data independence.
5. Identify outliers.
6. Calculate decision thresholds (i.e., upper tolerance limits [UTLs]).

These steps are summarized in the subsequent sections along with the methods used to prepare the data for the statistical evaluation.

3.1 Data Conditioning

Field duplicates were collected as part of the data validation and usability assessment; however, the field duplicates were not included in the background groundwater statistics datasets per USEPA guidance (2009).

The usability of the available analytical data was confirmed before statistical evaluation in accordance with the Quality Assurance Project Plan (QAPP; S-A JV 2020). The data used in the evaluation met USEPA quality assurance requirements.

Estimated concentrations (those denoted with the “J” qualifier) were treated as quantified detected concentrations for the purposes of the statistical analysis and were included in the dataset. Exceptions to this rule are discussed in the applicable sections. No data rejected through data validation were included in the datasets.

Censored (non-detect) data were handled in accordance with Section 15.6 of Unified Guidance (USEPA 2009). Based on this guidance, the “15% and 50% Non-Detect Rule” was followed. This rule states that arbitrary values, such as one half of the detection limit, can be substituted for the non-detects if a dataset has fewer than 15 percent non-detects. The rule also states that parametric methods should be used if the number of non-detects does not exceed 50 percent of the data. For parametric datasets with a non-detect rate greater than 15 percent, a method is needed to adjust the sample mean and standard deviation to account for the censorship. For this evaluation, the Kaplan-Meier estimator was used to adjust the mean and standard deviation if the datasets contained non-detects. If the proportion of non-detects was greater than 50 percent, then a non-parametric method was used.

Non-detected values with limits of quantitation (LOQs) greater than the maximum detected concentration in a well constituent dataset were not in included in the data evaluation.

3.2 Descriptive Statistics

Descriptive statistics quantitatively describe the main features of a dataset. Commonly presented descriptive statistics include sample size, number of detects, number of non-detects, frequency of detection, minimum, maximum, mean, median, and standard deviation. The mean and median are measures of central tendency and characterize the center of a dataset. The mean represents the arithmetic average, and the median represents the middle of the ordered dataset. The minimum, maximum, and standard deviation are measures of dispersion and characterize the distribution of the data. The minimum and maximum show the range of the data, and the standard deviation shows the spread of the data. A low standard deviation indicates that the observations are close to the mean, and a high standard deviation indicates that the observations are spread out over a wider range (USEPA 2006).

3.3 Graphical Representations

Graphical representations visually communicate the features of a dataset. Time-series plots, box-and-whisker plots, and probability plots were created for this analysis.

Time-series plots show constituent concentrations through time. They are useful for identifying inconsistent observations and were used to qualitatively evaluate the datasets for potential seasonality and for anomalous data points as part of the outlier evaluation. Time-series plots were created to depict arsenic concentrations in each well.

Box-and-whisker plots are useful because they present an overall picture of the distribution of a dataset by displaying several percentiles (10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th}). They provide insight into the location, shape, and spread of the data. Commonly, data are plotted together in side-by-side box-and-whisker plots so that an analyst can determine if concentrations are comparable across multiple datasets. Additionally, potential elevated or extreme values (i.e., outliers) are identified on the box-and-whisker plots as either 1.5 or 3 times the interquartile range (IQR; defined as the third quartile [75^{th} percentile] - first quartile [25^{th} percentile]; USEPA 2006). Box-and-whisker plots were created to depict arsenic concentrations by well and by interval (overburden and bedrock).

Probability plots serve multiple purposes when establishing background concentrations. They allow for visual inspection of the data distribution, which complements formal statistical tests for distribution testing. Inflection points or changes in slope can indicate that the data represent a mixture of multiple populations, which may reflect multiple background sources or a combination of background and site-related sources. Finally, probability plots can be used to identify extreme values in the upper tail of the distribution, which may indicate potential outliers. Probability plots evaluate fits to theoretical probability distributions such as normal, lognormal, and gamma distributions. For the purposes of this evaluation, probability plots were only generated for normal and lognormal distributions. A straight-line fit on a probability plot provides evidence that the data are from a single population with the specified distribution. Values that deviate substantially from this line may represent potential outliers or multiple populations and may require further statistical outlier testing. Probability plots were created for untransformed and transformed (where applicable) arsenic concentrations by well and by interval (overburden and bedrock).

3.4 Determination of Normality

Many of the tests described in this report are predicated on the normality of the dataset; therefore, when necessary, datasets were tested to demonstrate normality. The Shapiro-Wilk Test for Normality was used for datasets with sample sizes up to 50 (USEPA 2009, Shapiro and Wilk 1965). The test was run at the 5 percent critical level. For datasets with a sample size greater than 50, the Shapiro-Francia Test for Normality was used (USEPA 2009, Shapiro and Francia 1972).

If a dataset did not pass a test of normality, data were transformed following the ladder of powers. The ladder of powers is a sequence of transformations: square root, square, cube root, cube, logarithmic transformation, x^4, x^5, and x^6 (Helsel and Hirsch 2002, Box and Cox 1964). All points in the untransformed dataset were changed by one of these operations, and the new dataset was tested to determine if the transformed data meet the criterion of normality. If the test failed, the original data were transformed using the next transformation in the ladder. Transformations were attempted in the order of the ladder of powers until normality was achieved or until all of the options were exhausted. In the latter case, non-parametric tests were necessary.

3.5 Data Independence

USEPA (2009) guidance recommends evaluation of background groundwater datasets for temporal and spatial independence before determining the background value. The potential for temporal data dependence was mitigated using samples collected from evenly spaced time intervals.

Spatial data independence was evaluated by review of the raw data, descriptive statistics, box-and-whisker plots, and a background sample location map.

Groundwater samples were collected at varying intervals, and individual well datasets contain varying sample sizes. A central tendency value (CTV) was calculated to represent the arsenic concentration in each well as follows:

1. The arithmetic mean was used for normally distributed datasets or datasets with fewer than five data points.
2. The root mean square was used for square root normally distributed datasets.
3. The cube root mean cubed was used for cube root normally distributed datasets.
4. The geometric mean was used for lognormally distributed datasets.
5. The median was used for non-parametric datasets.
6. The median detection limit was used for datasets composed entirely of non-detects.

3.6 Outlier Evaluation

An outlier analysis can help identify potential outliers that may not represent the true background population.

Well constituent pairs with a rate of detection less than 50% and a detection count fewer than or equal to four were not analyzed for outliers. An outlier analysis was conducted according to the steps outlined in the Data Quality Assessment: Statistical Methods for Practitioners (USEPA 2006) as follows:

1. If the rate of detection for a well constituent pair was less than 50%, but the detection count was greater than four, then Tukey's IQR test (USEPA 2009, Tukey 1977) was used.
2. Normal quantile-quantile plots were inspected to identify potential outliers and isolated results that are separate from the majority of the data, as indicated by visible large gaps and deviation from concentration trends.
3. Distribution testing (Section 3.4) was performed on well constituent datasets with visually identified potential outliers removed. Statistical tests require that datasets be normally distributed or normalized by a transformation. If the dataset was not normally distributed or cannot be normalized, then Tukey's IQR test was used.

Datasets that pass step three (i.e., are normally distributed or can be normalized by a transformation) were then subjected to a statistical test. Dixon's test (USEPA 2009, Barnett and Lewis 1994) was used when the sample size was fewer than 25, and Rosner's test (USEPA 2009, Rosner 1975) was used when the sample size was equal to or greater than 25. Observations identified as statistical outliers at 5% significance were documented but were not removed from the background dataset solely on the basis of a statistical outlier test (USEPA 2009).

3.7 Upper Tolerance Limits

Following the outlier analysis and determination of the data distribution, statistical methods were used to calculate the upper bound limits of the background population. All historical data were included when calculating a CTV for each well, which were then used to calculate the background value.

Following USEPA Unified Guidance (2009), the 95% UTL with 95% coverage (95-95UTL) was used to represent background. The 95-95UTL represents the statistic, such that 95% of observations (current and future) from the target population will be less than or equal to the 95-95UTL with a confidence coefficient (CC) of 0.95. A 95-95UTL represents a 95% upper confidence limit (UCL) of the 95th percentile of the data distribution (population). A 95-95UTL is designed to simultaneously provide coverage for 95% of the potential observations (current and future) from the background population (or comparable to background) with a CC of 0.95.

A 95-95UTL may be calculated on the lumped dataset or for individual statistical populations based on population and normality determinations. As previously described, CTVs were calculated for each background monitoring well for use in calculating the 95-95UTLs.

4 Results

The background evaluation was performed in accordance with the Work Plan (S-A JV 2022) following USEPA guidance (USEPA 1992, 2006, 2009). The background groundwater analytical data used in this statistical evaluation are presented in Table 4. The outlier evaluation is presented in Table 5. Descriptive statistics and the Mann-Kendall (MK) trend evaluation are presented in Table 6. The CTV selection is shown in Table 7. Hypothesis test results comparing the overburden concentrations to the bedrock concentrations are provided in Table 8. The final arsenic background concentrations are presented in Table 9 and discussed below. Supporting time-series plots, combination probability and box-and-whisker plots, and ProUCL and ChemStat outputs are provided in Appendices A through D, respectively.

4.1 Overburden Wells

Twenty-five overburden wells were included in the evaluation. Elevated non-detect values and/or statistical outlier arsenic concentrations were identified for data from four monitoring wells (32M-92-01X, SHL-12, SHL-23, and SHP-95-27X; Table 4) and are summarized below:

- *SHL-12*. The result collected on 11/7/2019 (7.4 µg/L) failed Dixon's test (Section 2.6) but was retained in the dataset following a scientific review of the data.
- *SHL-23*. Six results were identified as elevated non-detects with LOQs greater than the maximum detected concentration, and excluded from the evaluation. The remaining LOQs for non-detects in this well ranged from 0.5 to 3 µg/L.
- *SHP-95-27X*. The result collected on 11/1/1999 (243 µg/L) was excluded due to Dixon's test and probable well installation effects.

The MK trend test could not be performed at 15 monitoring wells due to insufficient sample size (MW-1, MW 4-1, MW-7, MW-14, MW-22, SHL-1, and SHP-99-1B) or frequency of detection less than 25% (32M-92-01X, 32Z-01-07X, N1-P1, SHL-7, SHL-17, SHL-23, SHM-93-18B, and SHM-93-24A). For the seven wells with insufficient sample size, only one data point is available from a monitoring event in 2017; as noted above, these wells could

not be sampled in 2022 because they were dry. The MK trend test results indicate no statistically significant trends for 32M-01-14XOB, N7-P2, SHL-12, SHL-15, SHL-18, SHL-25, and SHP-95-27X. A statistically significant decreasing trend was identified for N1-P3 and SHL-24, and a statistically significant increasing trend was identified for N1-P2; however, the variability in these wells was small (indicated by coefficient of variations less than 1); therefore, the appropriate calculated CTV was used to represent the arsenic concentrations in each of these three wells. The most recent (and only) data point was used as the CTV to represent the seven monitoring wells with insufficient sample size to evaluate by the MK test. The MK trend results are summarized in Table 6.

The CTVs used to calculate the final 95-95UTL (Section 3.4) ranged from 1.5 µg/L (SHL-1) to 154 µg/L (N7-P2), are provided in Table 7 and summarized below.

- The most recent data point was assigned as the CTV in the seven wells with insufficient data size discussed above.
- Data were normally distributed, and the arithmetic mean was used to represent the CTV in six monitoring wells: 32M-01-14XOB, N1-P3, N7-P2, SHL-24, SHL-25, and SHP-95-27X.
- Data were lognormally distributed, and the geometric mean was used to represent the CTV in one monitoring well: SHL-15.
- Data did not follow a distribution (non-parametric), and the median was used to represent the CTV in eight monitoring wells: 32M-92-01X, N1-P2, SHL-7, SHL-12, SHL-17, SHL-23, SHM-93-18B, and SHM-93-24A.
- The datasets were entirely composed of non-detects and/or contained only detections lower than the LOQ), and the median LOQ was used to represent the CTV in three monitoring wells: 32Z-01-07X, N1-P1, and SHL-18.

4.2 Bedrock Wells

Sixteen bedrock wells were included in the evaluation. Elevated non-detect values (LOQs greater than the maximum detected concentration in a well) were identified for ten data points across six monitoring wells (20-1, 27-1, 27-2, CAP-2B, Q4-1, and Q5-1; Table 4); these data points were excluded from the evaluation. The remaining LOQs for non-detects in these wells ranged from 3.0 µg/L to 10 µg/L.

The MK trend test results indicate no statistically significant trends for 20-1, 27-1, 27-2, 3-2, CAP-2B, CH-1S, N7-P1, Q4-1, Q5-1, SHP-2016-07A, SHP-2016-07B, and SHP-99-1C. A statistically significant decreasing trend was identified for SHP-2016-06B, and a statistically significant increasing trend was identified for CH-1D, SHP-2016-06A, and SHP-2016-06C however, the variability in these wells was small (indicated by coefficient of variations less than 1), therefore, the appropriate calculated CTV was used to represent the arsenic concentration in each of these four wells. The MK trend results are summarized in Table 6.

The CTVs used to calculate the final 95-95UTL (Section 3.4) ranged from <2.45 µg/L (Q5-1) to 1,100 µg/L (SHP-2016-06A and SHP-2016-06B), are provided in Table 7 and summarized below.

- Data were normally distributed, and the arithmetic mean was used to represent the CTV in 14 monitoring wells: 20-1, 27-1, 27-2, 3-2, CAP-2B, CH-1D, CH-1S, N7-P1, Q4-1, SHP-2016-06A, SHP-2016-06C, SHP-2016-07A, SHP-2016-07B, and SHP-99-1C.
- Data did not follow a distribution (non-parametric), and the median was used to represent the CTV in on monitoring well: SHP-2016-06B.
- The dataset contained only detections lower than the LOQ, and the median LOQ was used to represent the CTV in monitoring well Q5-1.

4.3 Comparison of Overburden and Bedrock Concentrations

Hypothesis testing was used to determine whether the arsenic concentrations for the overburden and bedrock datasets could be pooled into one dataset for the 95-95UTL calculations. The overburden CTV values did not follow a discernible statistical distribution (i.e., the distribution was non-parametric), and the CTV values for the bedrock dataset were lognormally distributed. Additionally, there was a CTV represented by a non-detect value with an LOQ greater than the minimum CTV detection. Therefore, the Tarone-Ware hypothesis test was used. Results of the hypothesis test indicate a statistically significant difference between the overburden and bedrock concentrations; therefore, the datasets cannot be pooled into one dataset for the 95-95UTL calculation and must be evaluated separately. Results of the hypothesis test are summarized in Table 8.

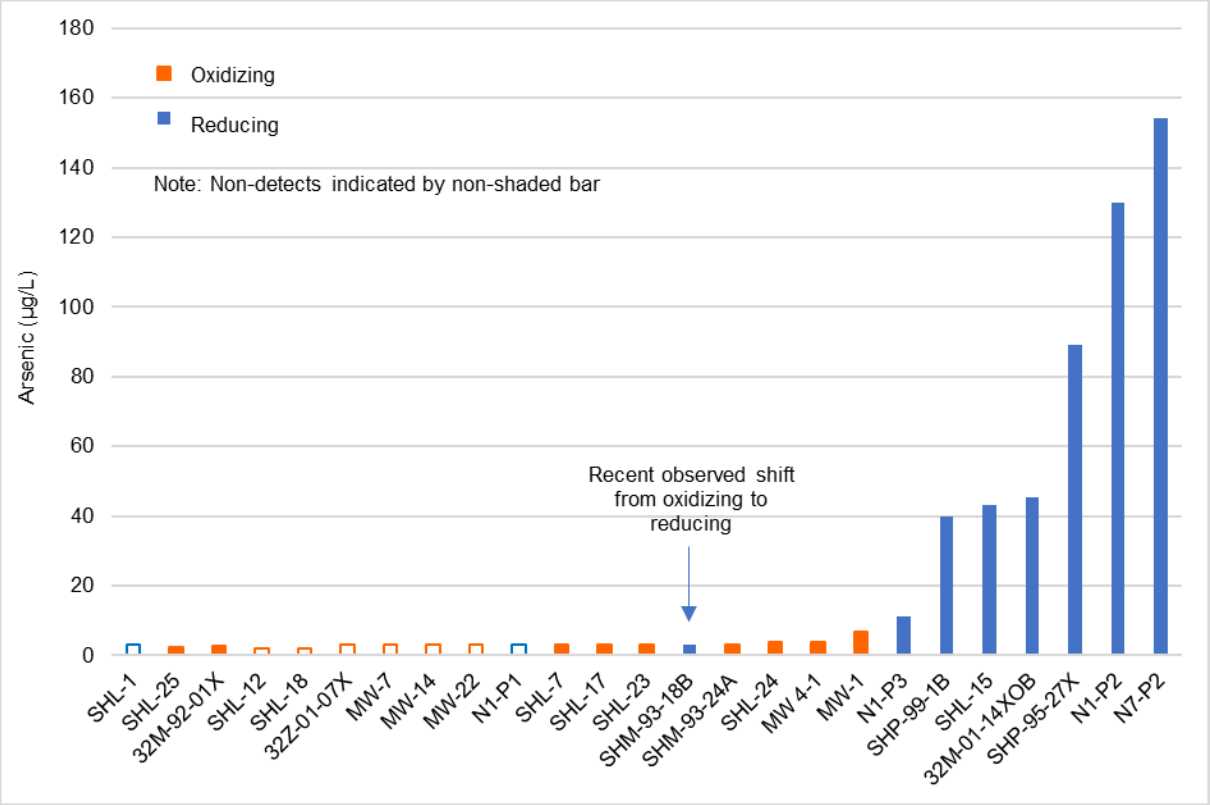
4.4 Calculated Upper Tolerance Limits

Arsenic concentrations in the overburden exhibit wide variability, with an apparent correlation to redox conditions. Specifically, as noted in the Work Plan (S-A JV 2022), the wells exhibiting higher arsenic concentrations also tend to exhibit reducing conditions based on a combination of redox parameters including DO, ORP, and concentrations of dissolved iron and manganese. The following conditions were used to determine whether a well exhibited primarily oxidizing or reducing conditions:

- Wells meeting at least one of the following criteria in the majority of sampling events were considered oxidizing:
    - DO concentrations greater than 1 mg/L.
    - Dissolved iron concentrations less than 1000 µg/L.
    - Dissolved manganese concentrations less than 1000 µg/L.
- Wells meeting at least one of the following criteria in the majority of sampling events were considered reducing:
    - DO concentrations less than 1 mg/L.
    - Dissolved iron concentrations greater than 1000 µg/L.
    - Dissolved manganese concentrations greater than 1000 µg/L.

The oxidation/reduction determination process is provided in Table 3. A bar chart showing the monitoring wells included in the reducing geochemical conditions dataset is provided in Figure 5, below:

Figure 5. Arsenic CTV Concentrations in Overburden Wells



Because of this apparent difference in arsenic concentrations with redox conditions, the determination of distribution and calculation of the 95-95UTL were completed separately using the full overburden monitoring well dataset and using the reducing monitoring well dataset. The full dataset does not fit a distribution (non-parametric), and the 95-95UTL for arsenic is equal to 154 µg/L, which is greater than the USEPA MCL of 10 µg/L. The dataset for reducing geochemical conditions fits a normal distribution (supporting the notion that the full dataset comprises multiple populations), and the 95-95UTL for arsenic is equal to 198 µg/L, which is greater than the USEPA MCL of 10 µg/L.

The bedrock dataset fits a lognormal distribution, and the 95-95UTL is equal to 7,839 µg/L.

The 95-95UTLs are presented in Table 9.

5 Summary

The results from the background evaluation indicate that naturally occurring (i.e., background) arsenic concentrations are greater than the USEPA MCL (10 µg/L) and a site-specific arsenic background value should be used when assessing the potential efficacy of remedial actions at SHL. A statistically significant difference between arsenic concentrations in overburden wells and bedrock wells was identified; therefore, it is recommended that different background values be assigned for overburden and bedrock. Accordingly, separate 95-95UTL values were calculated for overburden and bedrock wells for assigning representative background values. The evaluation also indicated that arsenic concentrations for wells with oxidizing versus reducing

geochemical conditions fell into separate populations, based on the observation that reducing wells follow a normal distribution, whereas the full dataset does not follow a distribution. The 95-95UTL values were calculated for both the full overburden dataset and the reducing monitoring well dataset (154 µg/L and 198 µg/L, respectively). Historical conditions in the downgradient area pre-SHL were variable and exhibited a range of redox conditions due to naturally occurring organic carbon deposits; however, the specific pre-SHL condition for any given well downgradient of the landfill cannot be determined. Therefore, the 95-95UTL arsenic concentration of 198 µg/L estimated from the reducing monitoring well dataset is recommended as the representative background value for the purposes of establishing any potential future site-specific cleanup goals within the overburden. The 95-95UTL calculated using CTVs from bedrock wells is equal to 7,839 µg/L.

6 References

Ayotte, J.D., D.L Montgomery, S.M. Flanagan, and K.W. Robinson. 2003. Arsenic in Groundwater in Eastern New England: Occurrence, Controls, and Human Health Implications. Environmental Science and Technology, 37, 2075 – 2083.

Barnett, V. and T. Lewis. 1994. Outliers in Statistical Data, 3rd edition. New York: John Wiley & Sons.

Boudette, E.L., Canney, F.C., Cotton, J.E., Davis, R.I., Ficklin, W.H., and J.M. Motooka. 1985. High levels of arsenic in the groundwaters of southeastern New Hampshire: a geochemical reconnaissance. United States Department of the Interior Geological Survey.

Box, G.E.P. and D.R. Cox. 1964. An analysis of transformations (with discussion). Journal of Royal Statistical Society Series B, 26, 211 – 252.

Coleman, J.A. 2011. Arsenic and uranium in water from private wells completed in bedrock of east-central Massachusetts – Concentrations, correlations with bedrock units, and estimated probability maps. U.S. Geological Survey Scientific Investigations Report. 2011 – 5013, 113 p.

Gannet Fleming. 2012. Final Shepley's Hill Bedrock Investigation. Prepared by Gannett Fleming, Inc. and USEPA Region 1, ROC Contract No. EP-W-05-020. July.

GZA GeoEnvironmental, Inc. 2011a. *Final Report Geothermal Pathfinder Well, Devens, MA USARC (Building 1410), Devens, Massachusetts*. Prepared for United States Army Corp of Engineers, Concord, Massachusetts. May.

GZA GeoEnvironmental, Inc. 2011b. *Final Report Geothermal Pathfinder Well, Ayer, MA AFRC Training Building, Ayer, Massachusetts*. Prepared for United States Army Corp of Engineers, Concord, Massachusetts. August.

Helsel, D.R. and R.M. Hirsch. 2002. Statistical methods in water resources: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 4, Chap. A3, 524 p. Available online at http://water.usgs.gov/pubs/twri/twri4a3/.

HLA. 2000. *Final Remedial Investigation Report Area of Contamination (AOC) 50, Devens, Massachusetts*.

Hon, R., McTigue, D., Stein, C., and W.C. Brandon. 2001. Arsenic in Bedrock and Bedrock Groundwater in North Central Massachusetts. Geological Society of America, Northeast Section, 36th Annual Meeting. Burlington, Vermont, 2000. Geological Society of America. March 12 – 14.

Kopera, J.P., Mabee, S.B., and D.C. Powers. 2006: Office of the Massachusetts State Geologist, Open-File Report OFR-06-03, scale 1:24,000.

Nelson, J.R., Batchelder G.L., Radville, M.E., and S.A. Albert. 2010. Using multiple lines of evidence to demonstrate that elevated arsenic groundwater concentrations are naturally occurring. Proceedings of the Annual International Conference on Soils, Sediments, Water and Energy. Vol. 12, Article 7. January. Available online at: https://scholarworks.umass.edu/soilsproceedings/vol12/iss1/7.

Peters, S.C., Blum, J.D., Klaue, B., and M.R. Karagas. 1999. Arsenic Occurrence in New Hampshire Drinking Water. Environmental Science and Technology. 33, 1328 – 1333.

Reeve, A.S., Horesh, M., Warner, B., and M. Yates. 2001. Geochemical evaluation of sources for arsenic in groundwater, Northport Maine. Geological Society of America, Northeast Section, 36th Annual Meeting. Burlington, VT. Geological Society of America. March 12 – 14.

Rosner, B. 1975. On the detection of many outliers. Technometrics, 17, 221-227.

SERES-Arcadis JV. 2020. Quality Assurance Project Plan Annual Long-Term Monitoring and Maintenance Program, Former Fort Devens Army Installation – BRAC Legacy Sites, Devens, Massachusetts. October.

SERES-Arcadis. 2022. Work Plan to Evaluate Site-Specific Arsenic Background Concentrations in Groundwater, Shepley's Hill Landfill, Former Fort Devens Army Installation, Devens Massachusetts. January 28.

Shapiro, S.S. and R.S. Francía. 1972. An approximate analysis of variance test for normality. Journal of American Statistical Association, 67(337), 215 – 216.

Shapiro, S.S. and M.B. Wilk. 1965. An analysis of variance test for normality (complete samples). Biometrika, 52, 591 – 611.

Tukey, J. 1977. Exploratory Data Analysis. Reading, MA: Addison-Wesley.

USEPA. 1992. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance. United States Environmental Protection Agency Office of Solid Waste, Permits and State Programs Division. July.

USEPA. 2006. Data Quality Assessment: Statistical Methods for Practitioners. United States Environmental Protection Agency Office of Information, Washington, D.C. EPA/240/B-06/003. February.

USEPA. 2009. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance. United States Environmental Protection Agency Office of Resource Conservation and Recovery, Washington, D.C. EPA 530/R-09-007. March.

USEPA. 2016. Letter to William J. O'Donnell, II RE: Former Fort Devens Installation – Dispute Resolution, 2015 Devens Five Year Review (FYR) Report. February 24.

Welch, A.H. Westjohn, D.B., Helsel D.R., and R.B. Wanty. 2000. Arsenic in ground water of the United States: occurrence and geochemistry. Groundwater, 38, 589 – 604.

Tables

Table 2
Summary of Background Locations
Former Fort Devens Army Installation
Devens, Massachusetts

Location	Screen Interval (feet bgs)	Area	Rationale and Well Status
Overburden Wells			
32M-01-14XOB	17.3 - 27.3	Upgradient Area	Outside of SHL cap; borders AOC 32
32M-92-01X	13.7 - 23.7		Outside of SHL cap; borders AOC 32
32Z-01-07X	12.7 - 22.7		Outside of SHL cap; borders AOC 32
N7-P2	29 - 35		Under southern edge of SHL cap; immediately downgradient of historical wetland area
SHL-12	15.0 - 30.0		Outside of SHL cap; historical and current wetland area
SHL-15	14.5 - 24.5		Outside of SHL cap; borders AOC 32
SHL-17	6 - 16		Outside of SHL cap; historical and current wetland area
SHL-25	23.5 - 33.5		Outside of SHL cap; borders AOC 32
SHL-7	11.0 - 21.0	Upgradient Area Adjacent to Former Railroad Roundhouse / Rail Spur	Outside of SHL cap; adjacent to rail spur [1]
SHL-18	16 - 26		Outside of SHL cap; adjacent to Railroad Roundhouse
SHL-24	110.0 - 120.0*		Outside of SHL cap; adjacent to rail spur
SHM-93-24A	13.2 - 23.2		Outside of SHL cap; adjacent to rail spur
SHM-93-18B	78.5 - 88.5		Outside of SHL cap; adjacent to Railroad Roundhouse
SHP-95-27X	Unknown		Outside of SHL cap at edge of historical landfill footprint [2]
N1-P1	65 - 75	Adjacent to Plow Shop Pond	Outside of SHL cap; adjacent to Plow Shop Pond
N1-P2	45 - 50		Outside of SHL cap; adjacent to Plow Shop Pond
N1-P3	12 - 17		Outside of SHL cap; adjacent to Plow Shop Pond
N4-P1	65 - 75		Outside of SHL cap; adjacent to Plow Shop Pond. Well abandoned, not included in well list.
N4-P2	45 - 50		Outside of SHL cap; adjacent to Plow Shop Pond. Well abandoned, not included in well list.
N4-P3	12 - 17		Outside of SHL cap; adjacent to Plow Shop Pond. Well abandoned, not included in well list.
SHL-23	23.0 - 33.0	Nearfield Area	Outside of SHL cap; Shepley's Hill soil
MW-1	6.58 - 8.58	Shepley's Hill Area	Outside of SHL cap; Shepley's Hill soil - water yield unknown
MW 4-1	3.72 - 5.72		Outside of SHL cap; Shepley's Hill soil - water yield unknown
MW-7	6.98 - 8.98		Outside of SHL cap; Shepley's Hill soil - water yield unknown
MW-9	7.65 - 9.65		Outside of SHL cap; Shepley's Hill soil. Insufficient recharge, not included in well list.
MW-11A	4.18 - 6.18		Outside of SHL cap; Shepley's Hill soil - water yield unknown
MW-14	5.14 - 7.14		Outside of SHL cap; Shepley's Hill soil - water yield unknown
MW-16	5.18 - 7.18		Outside of SHL cap; Shepley's Hill soil - water yield unknown
MW-22	4.70 - 6.70		Outside of SHL cap; Shepley's Hill soil - water yield unknown
SHL-1	2 - 7		Outside of SHL cap; Shepley's Hill soil
SHP-99-1B	4 - 8		Outside of SHL cap; Shepley's Hill soil

Table 2
Summary of Background Locations
Former Fort Devens Army Installation
Devens, Massachusetts

Location	Screen Interval (feet bgs)	Area	Rationale and Well Status
Bedrock Wells			
N7-P1	65 - 69	Upgradient Area	Under southern edge of SHL cap; immediately downgradient of historical wetland area
SHP-2016-06A	81 - 86	Nearfield Area	Outside of SHL cap; similar water chemistry to CH-1D
SHP-2016-06B	102 - 112		Outside of SHL cap; similar water chemistry to CH-1D
SHP-2016-06C	123 - 133		Outside of SHL cap; similar water chemistry to CH-1D
20-1	40 - 55	Shepley's Hill Area	Outside of SHL cap; Shepley's Hill bedrock
27-1	58.25 - 63.25		Outside of SHL cap; Shepley's Hill bedrock
27-2	58 - 68		Outside of SHL cap; Shepley's Hill bedrock
3-2	54 - 59		Outside of SHL cap; Shepley's Hill bedrock
CAP-2B	52 - 57		Outside of SHL cap; Shepley's Hill bedrock
CH-1D	85 - 95		Outside of SHL cap; Shepley's Hill bedrock
CH-1S	36 - 41		Outside of SHL cap; Shepley's Hill bedrock
Q4-1	30 - 40		Outside of SHL cap; Shepley's Hill bedrock
Q5-1	47 - 52		Outside of SHL cap; Shepley's Hill bedrock
SHP-2016-07A	22 - 32		Outside of SHL cap; Shepley's Hill bedrock
SHP-2016-07B	70 - 80		Outside of SHL cap; Shepley's Hill bedrock
SHP-99-1C	19.7 - 29.7		Outside of SHL cap; Shepley's Hill bedrock

Notes:

: well previously proposed by United States Environmental Protection Agency, but not included in well list.

: well proposed for addition to well list

[1] Well SHL-7 listed as abandoned; yields water with Waterra intertial pump; measured well bottom 23.3 feet below casing top.

[2] Well SHP-95-27X boring log and/or piezometer construction information needed; measured well bottom 42.8 feet below casing top.

Acronyms and Abbreviations:

AOC : Area of Concern
bgs : below ground surface
SHL : Shepley's Hill Landfill

Table 3
Geochemical Concentrations and Field Parameters in Groundwater - Background Events
Former Fort Devens Army Installation
Devens, Massachusetts

Analytical Method		Geochemical Parameters				Field Parameters						Oxidation/Reduction Determination		
Analyte		Dissolved Iron	Dissolved Manganese	Sulfate	DOC	Dissolved Oxygen	Oxidation Reduction Potential	pH	Sp. Cond.	Temp.	Turbidity	Oxidizing Conditions	Reducing Conditions	Final Decision
Unit		µg/L	µg/L	mg/L	mg/L	mg/L	mV	SU	µS/cm	°C	NTU			
Location	Date	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result			
Overburden Wells														
32M-01-14XOB	7/6/2016	**11000**	**3200**	**27**	**0.99 J**	0.29	25.4	5.84	432	19.01	25		x	
32M-01-14XOB	12/20/2016	**11000**	**3200**	**29 J**	**1.0**	0.49	36.0	5.80	470	9.7	3.9		x	Reducing
32M-01-14XOB	6/8/2017	**8100**	**2900**	**21**	**1.6**	0.78	15.7	5.94	382	13.12	9.64		x	
32M-92-01X	7/6/2016	50 U	3.0 U	**27**	**2.7**	4.96	152.9	5.82	540	15.41	7.61	x		
32M-92-01X	12/19/2016	50 U	**1.8 J**	**7.0 J**	**0.82 J**	9.30	94.0	7.00	120	7.8	3	x		Oxidizing
32M-92-01X	6/8/2017	50 U	3.0 U	**27**	**2.2**	6.74	171.6	6.40	395	9.77	7.09	x		
32Z-01-07X	7/6/2016	**4900**	**5800**	**16**	**2.4**	--	58.7	5.62	210	14.82	10.19		x	
32Z-01-07X	12/19/2016	50 U	3.0 U	**2.8 J**	**0.95 J**	--	--	--	--	--	--	x		Oxidizing
32Z-01-07X	6/9/2017	50 U	**1.6 J**	**29**	**2.6**	8.55	114.6	5.84	189	10.36	9.32	x		
MW-1	6/15/2017	50 U	**1.8 J**	**6.9**	**0.99 J**	6.36	110.2	5.62	71	13.31	9.73	x		Oxidizing
MW 4-1	6/12/2017	50 U	**4.7 J**	**7.5**	**0.84 J**	5.35	267.5	4.76	60	12.49	9.84	x		Oxidizing
MW-7	6/12/2017	**890**	**120**	**8.1**	**0.98 J**	9.51	391.2	4.46	56	14.27	22.39	x		Oxidizing
MW-14	6/14/2017	50 U	**34**	**7.6**	**0.69 J**	5.24	345.3	4.75	55	12.36	7.76	x		Oxidizing
MW-22	6/14/2017	**130**	**50**	**1.6**	**1.2**	2.08	306.1	4.63	48	11.44	9.41	x		Oxidizing
N1-P1	6/7/2017	**140**	**1600**	**7.9**	**1.3**	0.39	-2.5	6.83	531	12.14	13.17		x	
N1-P1	5/24/2022	**43 J**	**1300**	**7.9**	**1.2**	0.76	23.2	6.86	471	12.4	0.64		x	Reducing
N1-P1	8/25/2022	**91 J**	**1400**	**7.9**	**2**	0.68	45.4	6.46	468	14.3	12.8		x	
N1-P1	11/10/2022	**79 J**	**1300**	**6.9**	**1.1 J**	0.40	67.2	6.59	412	13.7	9.06		x	
N1-P2	7/11/2016	**6500**	**2200**	**12**	**2.2**	0.45	-59.7	6.06	407	13.8	2.24		x	
N1-P2	12/20/2016	**6100**	**1800**	**5.5 J**	**1.9**	0.57	-60.0	6.60	400	12	1.9		x	
N1-P2	6/7/2017	**7500**	**2100**	**5.8**	**1.9**	0.32	-73.9	6.89	498	13.49	9.73		x	Reducing
N1-P2	5/24/2022	**8400**	**1900**	**1.2**	**2.9**	0.29	-61.5	6.99	4.46	12.9	2.6		x	
N1-P2	8/25/2022	**6300**	**1500**	1 U	**2.4**	0.30	-28.5	6.67	366	14.4	1.09		x	
N1-P2	11/10/2022	**5800**	**1300**	**2.3**	**2.1**	0.27	-56.8	6.79	303	14	1.26		x	
N1-P3	7/11/2016	**1200**	**410**	**4.9**	**3.0**	0.56	25.2	5.99	467	17.3	1.19		x	
N1-P3	12/20/2016	**630**	**210**	**9.4 J**	**3.3**	7.20	15.0	6.70	330	5	14	x		
N1-P3	6/7/2017	**1100**	**300**	**9.1**	**2.5**	1.52	-304.8	8.30	425	6.59	15.9		x	Reducing
N1-P3	5/24/2022	**2700**	**190**	**5.8**	**2.5**	1.45	-5.2	7.08	366	9.16	1.01		x	
N1-P3	8/25/2022	**3800**	**180**	1 U	**3.7**	0.26	6.9	6.41	406	19.7	0.38		x	
N1-P3	11/10/2022	**3400**	**210**	**7.6**	**3.2**	0.32	-28.7	6.60	313	15.5	0.57		x	
N7-P2	7/13/2016	**39000**	**2100**	**57**	**2.1**	1.16	-50.2	6.12	413	24.89	10.49		x	
N7-P2	12/22/2016	**48000**	**2700**	**82 J**	**2.4**	2.40	25.0	5.80	540	8	78		x	
N7-P2	6/8/2017	**64000**	**2300**	**77**	**3.1**	0.30	-46.7	5.96	405	12.9	11.6		x	Reducing
N7-P2	6/2/2022	**28000**	**1600**	**42**	**1.1**	0.27	74.2	6.57	34.5	14	5.77		x	
N7-P2	8/24/2022	**22000**	**1600**	**48**	**1.4**	1.08	-71.6	6.39	326	17.5	5.25		x	
N7-P2	11/16/2022	**26000**	**1800**	**42**	**1.5**	0.73	-158.0	6.25	341	10.9	2.3		x	
SHL-1	6/5/2017	**1200**	**80**	**3.6**	**3.9**	0.69	74.2	4.69	41	10	4.73		x	Reducing

Table 3
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Former Fort Devens Army Installation
Devens, Massachusetts

Analytical Method		Geochemical Parameters								Field Parameters						Oxidation/Reduction Determination		
Analyte		Dissolved Iron		Dissolved Manganese		Sulfate		DOC		Dissolved Oxygen	Oxidation Reduction Potential	pH	Sp. Cond.	Temp.	Turbidity	Oxidizing Conditions	Reducing Conditions	Final Decision
Unit		µg/L		µg/L		mg/L		mg/L		mg/L	mV	SU	µS/cm	°C	NTU			
Location	Date	Result		Result		Result		Result		Result	Result	Result	Result	Result	Result			
SHL-12	7/7/2016	**18**	J	**3400**	J	**170**		**4.0**		0.50	107.3	6.43	686	13.57	5.57		x	Oxidizing
SHL-12	12/20/2016	**38**	J	**1800**		**110**	J	**2.8**		0.56	64.0	6.20	780	9.5	0.76		x	
SHL-12	6/8/2017	**44**	J	**2600**		**180**	D	**3.0**		0.72	101.9	6.68	752	8.63	2.06		x	
SHL-12	5/26/2022	**34**	J	**74**		**100**		**2.2**		2.18	140.0	6.51	534	12	10.2	x		
SHL-12	8/23/2022	50	U	**13**		**120**		**2.8**		3.12	141.0	5.92	635	12.6	0.99	x		
SHL-12	11/8/2022	50	U	5	U	**110**		**2**		2.22	151.0	6.02	476	12.2	1.96	x		
SHL-15	7/6/2016	**3700**		**250**		**14**		**2.9**		0.23	11.0	5.40	430	18	4.9		x	Reducing
SHL-15	12/19/2016	**2300**		**1200**		**9.3**	J	**3.8**		0.40	-21.0	5.70	220	9.8	2.2		x	
SHL-15	6/7/2017	**2400**		**350**		**25**		**7.3**		0.45	-190.2	6.79	431	9.12	13.8		x	
SHL-15	5/23/2022	**3100**		**140**		**14**		**3.1**		0.35	17.1	5.77	300	13.2	0.61		x	
SHL-15	8/23/2022	**2100**		**140**		**15**		**2.7**		0.45	-20.6	5.83	313	14.5	2.02		x	
SHL-15	11/8/2022	**2300**		**190**		**19**		**4.3**		0.65	20.4	5.95	288	11.6	1.27		x	
SHL-17	7/13/2016	**18**	J	**16**		**15**		**2.9**		1.70	62.3	5.96	1027	16.7	3.29	x		Oxidizing
SHL-17	12/20/2016	50	U	**19**		**3.3**	J	**0.89**	J	9.00	120.0	6.40	960	4.3	0.66	x		
SHL-17	5/26/2022	50	U	**74**		**37**		**1.7**		0.48	110.0	6.16	1,020	12.9	3.85		x	
SHL-17	8/24/2022	**32**	J	**19**		**65**		**2.9**		0.50	118.0	5.64	480	18.2	1.06		x	
SHL-17	11/8/2022	50	U	**6.4**	J	**85**		**1.6**		2.38	98.6	6.14	305	13.8	0.73	x		
SHL-18	7/11/2016	50	U	3.0	U	**7.9**		**0.84**	J	11.41	54.9	7.29	50	15.36	4.63	x		Oxidizing
SHL-18	12/19/2016	50	U	3.0	U	**5.3**		**0.39**	J	6.70	85.0	6.40	53	8	3.3	x		
SHL-18	6/1/2017	50	U	3.0	U	**6.0**		**0.75**	J	9.03	88.4	6.46	50	13.69	4.88	x		
SHL-18	5/31/2022	50	U	5.0	U	**9.3**		0.6	U	8.99	190.0	6.66	79	13.6	2.16	x		
SHL-18	8/25/2022	50	U	**12.0**		**15.0**		0.6	U	8.83	148.0	5.71	110	14	2.66	x		
SHL-18	11/9/2022	**30**	J	5.0	U	**4.7**	J	1	U	9.94	116.0	6.66	40	12	1.11	x		
SHL-23	7/8/2016	50	U	**9.9**	J	**4.0**		**0.60**	J	9.97	378.5	2.65	29	11.02	1.97	x		Oxidizing
SHL-23	12/22/2016	50	U	**20**		**16**		**1.5**		9.50	-150.0	5.90	56	7.7	2.4	x		
SHL-23	5/24/2017	17	U	**30**		**3.6**		**1.1**		11.03	54.1	5.17	73	9.03	6.31	x		
SHL-23	5/31/2022	50	U	**31**		**5.7**		0.6	U	9.77	155.0	5.44	36	10.4	6.14	x		
SHL-23	8/30/2022	50	U	**12**		**5.2**		**0.93**	J	9.57	90.0	5.35	39	12.3	6.19	x		
SHL-23	11/14/2022	**110**	J	**12**		**4.5**		**0.83**	J	10.80	-62.6	5.50	40	9.69	2.22	x		
SHL-24	7/12/2016	50	U	3.0	U	**20.0**		**0.47**	J	7.60	45.8	7.84	240	25.89	4.19	x		Oxidizing
SHL-24	12/23/2016	50	U	3.0	U	**20.0**	J	**0.53**	J	9.00	69.0	6.80	240	10	1.1	x		
SHL-24	6/15/2017	50	U	**1.4**	J	**20**		**0.49**	J	8.20	113.9	7.44	299	17.65	9.36	x		
SHL-24	6/2/2022	50	U	5	U	**25**		0.6	U	1.61	34.0	7.23	298	12.6	2.73	x		
SHL-24	8/30/2022	**180**		**1.3**	J	**24**		0.6	U	1.61	102.0	7.01	282	17.1	2.25	x		
SHL-24	11/10/2022	50	U	5	U	**25**		1	U	1.17	70.2	7.19	256	13.6	0.43	x		
SHL-25	7/7/2016	50	U	3.0	U	**76**		**0.97**	J	1.30	56.9	1.48	714	19.67	1.97	x		Oxidizing
SHL-25	12/22/2016	50	U	**660**		**71**	J	**1.7**		0.59	70.0	630.00	780	11	1.5		x	
SHL-25	6/9/2017	50	U	**24**		**84**		**2.3**		5.03	142.9	6.05	917	13.99	8.55	x		
SHL-25	5/26/2022	50	U	**5.3**	J	**57**		**1.7**		2.23	192.0	6.58	1,370	12.7	4.05	x		
SHL-25	8/24/2022	50	U	5	U	**54**		**1.7**		2.14	119.0	6.40	1,590	15.1	0.65	x		
SHL-25	11/8/2022	50	U	5	U	**57**		**1.3**	J	2.30	118.0	6.59	1,760	12.9	2.17	x		

Table 3
Geochemical Concentrations and Field Parameters in Groundwater - Background Events
Former Fort Devens Army Installation
Devens, Massachusetts

Analytical Method		Geochemical Parameters				Field Parameters						Oxidation/Reduction Determination		
Analyte		Dissolved Iron	Dissolved Manganese	Sulfate	DOC	Dissolved Oxygen	Oxidation Reduction Potential	pH	Sp. Cond.	Temp.	Turbidity	Oxidizing Conditions	Reducing Conditions	Final Decision
Unit		µg/L	µg/L	mg/L	mg/L	mg/L	mV	SU	µS/cm	°C	NTU			
Location	Date	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result			
SHL-7	7/12/2016	**43** J	**18**	**4.1**	**0.83** J	1.61	122.3	5.69	495	16.28	4.01	x		
SHL-7	12/23/2016	**150**	**32**	**6.7** J	**1.1**	1.30	100.0	6.30	140	10	14	x		
SHL-7	6/1/2017	17 U	**2.3** J	**9.6**	**0.59** J	6.87	194.7	5.46	276	10.5	5.03	x		
SHL-7	5/26/2022	**94** J	**3.4** J	**9.1**	0.6 U	3.56	134.0	5.99	170	12.9	19.8	x		Oxidizing
SHL-7	8/24/2022	**130**	**9.9** J	**2.4**	**0.75** J	0.47	115.0	5.89	765	13.1	2.97		x	
SHL-7	11/17/2022	**120**	**6** J	**9.4**	**0.91** J	0.71	81.6	6.43	140	11.6	2.46		x	
SHM-93-18B	7/12/2016	50 U	**110**	**31**	**0.57** J	1.62	45.2	6.55	358	19.19	2.71	x		
SHM-93-18B	12/19/2016	50 U	**39**	**31**	**0.74** J	1.10	89.0	6.30	350	8.5	0.71	x		
SHM-93-18B	6/1/2017	50 U	**2.5** J	**32**	**1.1**	4.31	125.4	6.64	261	12.97	4.18	x		
SHM-93-18B	5/26/2022	50 U	**860** J	**33**	0.6 U	0.24	69.8	6.36	794	12.3	2.55		x	Reducing
SHM-93-18B	8/25/2022	50 U	**570** J	**34**	**0.54** J	0.34	139.0	6.16	789	17.9	4.14		x	
SHM-93-18B	11/9/2022	50 U	**680**	**33**	1 U	0.39	152.0	6.25	751	11.9	1.36		x	
SHM-93-24A	7/12/2016	50 U	**3.4** J	**23**	**0.61** J	8.43	118.2	5.99	450	17.1	4.1	x		
SHM-93-24A	12/21/2016	50 U	**5.1** J	**24**	**0.49** J	9.40	200.0	5.90	480	11	0.19	x		
SHM-93-24A	6/15/2017	**36** J	**4.4** J	**24**	**0.84** J	9.74	100.7	5.72	538	12.46	9.81	x		
SHM-93-24A	6/2/2022	50 U	**6.4** J	**49**	0.6 U	7.24	76.1	6.09	774	12.6	5.22	x		Oxidizing
SHM-93-24A	8/30/2022	50 U	**6.4** J	**41**	**0.89** J	7.77	151.0	5.90	790	16	1.65	x		
SHM-93-24A	11/10/2022	50 U	**7.4** J	**40**	**0.75** J	3.43	177.0	6.00	632	14.2	0.59	x		
SHP-95-27X	7/11/2016	**11000**	**4000**	**4.8**	**0.79** J	1.50	-29.6	6.53	112	14.81	1.47		x	
SHP-95-27X	12/19/2016	**14000**	**5700**	**5.6** J	**0.79** J	0.62	-14.0	6.10	160	8.3	1.7		x	
SHP-95-27X	6/6/2017	**9500**	**3300**	**4.1**	**0.90** J	0.26	-27.1	6.19	66	9.17	5.28		x	
SHP-95-27X	6/2/2022	**7900**	**2500**	**2.9**	**2.10**	0.29	-65.9	6.56	78	13	8.48		x	Reducing
SHP-95-27X	8/25/2022	**10000**	**4200**	**3.1**	**0.91** J	1.46	-28.0	6.22	128	16	4.44		x	
SHP-95-27X	11/15/2022	**13000**	**5100**	**22**	**3.60**	0.90	-94.0	6.20	176	10.4	2.77		x	
SHP-99-1B	6/5/2017	**25000**	**450**	**1.1** J	**29**	0.46	47.9	5.07	79	10.42	19.6		x	Reducing
Bedrock Wells														
20-1	7/14/2016	**110**	**150**	**18**	**0.72** J	1.23	-62.9	7.50	313	13.44	8.27			
20-1	12/21/2016	**79**	**42**	**17** J	**0.91** J	2.30	72.0	7.00	320	7.2	0.79			
20-1	6/5/2017	50 U	**13**	**12**	**1.2**	5.31	128.1	7.30	265	7.2	1.66			
20-1	6/1/2022	50 U	**5.1** J	**8.7**	0.6 U	6.20	34.5	6.96	161	10.6	5.06			
20-1	8/25/2022	**20** J	**12**	**10**	**1.2**	2.94	-39.1	7.74	319	13.5	9.8			
20-1	11/9/2022	**64** J	**140**	**14** J	**2.6**	--	--	--	--	--	--			
27-1	7/14/2016	50 U	**2.2** J	**31**	**1.2**	6.39	224.3	5.40	49	16.71	3.28			
27-1	12/21/2016	50 U	3.0 U	**11** J	**0.88** J	8.40	120.0	5.90	70	6.8	0.87			
27-1	6/5/2017	50 U	3.0 U	**7.8**	**0.77** J	9.18	182.3	5.99	61	7.16	0.74			
27-1	5/31/2022	50 U	5.0 U	**6.1**	**0.55** J	5.57	147.0	5.98	52	12.2	3.72			
27-1	8/26/2022	50 U	**1.5** J	**6.6**	**0.51** J	4.39	58.2	5.71	55	17.5	2.8			
27-1	11/8/2022	50 U	**1.5** J	**8.9**	1 U	5.18	-70.8	5.64	65	10.5	2.23			
27-2	7/14/2016	50 U	**1.3** J	**7.7**	**1.3**	6.32	217.3	5.29	87	19.34	1.83			
27-2	12/21/2016	**1.3** J	**1.1** J	**8.7** J	**0.54** J	5.90	130.0	5.90	81	8.7	0.75			
27-2	6/5/2017	50 U	**2.2** J	**7.6**	**0.90** J	5.93	167.3	5.93	49	6.99	3.51			
27-2	5/31/2022	50 U	**11**	**6.5**	0.60 U	3.90	122.0	5.94	47	12.1	3.81			
27-2	8/29/2022	**130**	**130**	**7**	**1.60**	3.32	37.4	6.12	67	15.3	129			
27-2	11/8/2022	**54** J	**57**	**8.1**	**0.60** J	4.73	-75.8	5.57	62	10.3	23.5			

Differentiation by oxidation/reduction conditions not performed for the bedrock aquifer

Table 3
Geochemical Concentrations and Field Parameters in Groundwater - Background Events
Former Fort Devens Army Installation
Devens, Massachusetts

Analytical Method		Geochemical Parameters				Field Parameters						Oxidation/Reduction Determination		
Analyte		Dissolved Iron	Dissolved Manganese	Sulfate	DOC	Dissolved Oxygen	Oxidation Reduction Potential	pH	Sp. Cond.	Temp.	Turbidity	Oxidizing Conditions	Reducing Conditions	Final Decision
Unit		µg/L	µg/L	mg/L	mg/L	mg/L	mV	SU	µS/cm	°C	NTU			
Location	Date	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result			
3-2	7/13/2016	**47** J	**12**	**7.6**	**0.97** J	6.12	115.6	5.73	57	16.43	5.3			
3-2	12/21/2016	**700**	**93**	**9.3** J	**0.61** J	6.00	60.0	7.00	130	6.7	9.6			
3-2	6/13/2017	50 U	**1.3** J	**6.9** M	**0.71** J	6.37	277.1	6.59	159	14.97	9.89			
3-2	5/26/2022	**26** J	**8.9** J	**6.5**	0.6 U	5.32	55.5	6.67	95	11.1	9.9			
3-2	8/25/2022	50 U	**25**	**6.3**	**1.1**	4.93	24.6	6.62	112	14.4	29.3			
3-2	11/9/2022	50 U	**15**	**5.6**	**0.65** J	1.58	-836.0	5.81	82	10.9	6.14			
CAP-2B	7/11/2016	50 U	**7.7** J	**7.9**	**0.88** J	4.76	149.4	5.22	61	13.42	7.23			
CAP-2B	6/5/2017	**24** J	**13**	**7.8**	**0.84** J	5.59	37.7	5.90	78	11.12	11.17			
CAP-2B	6/1/2022	50 U	**15**	**6.5**	0.6 U	4.89	76.4	5.97	59	11.1	12			
CAP-2B	8/26/2022	50 U	**6.9** J	**6.2**	**1.1**	5.49	72.9	5.78	59	14.3	24.8			
CAP-2B	11/9/2022	50 U	**25**	**6.5**	**0.67** J	2.97	-63.7	5.79	77	11.1	337			
CH-1D	7/11/2016	**170**	**190**	**7.0**	**0.68** J	0.59	-50.4	7.36	275	15.24	7.54			
CH-1D	12/21/2016	**220**	**200**	**8.9** J	**0.65** J	1.70	-39.0	6.70	280	8.3	0.99			
CH-1D	6/5/2017	**340**	**270**	**8.0**	**0.71** J	1.44	-85.9	7.53	309	12.25	9.8			
CH-1D	5/31/2022	**470**	**230**	**5.3**	**2.4**	0.78	-64.8	7.44	279	16.8	15.7			
CH-1D	8/24/2022	**330**	**240**	**5.7**	**0.5** J	2.37	-99.0	7.60	272	13.6	9.9			
CH-1D	11/10/2022	**470**	**260**	**7.8**	1 U	0.59	-175.0	7.67	261	12.5	16.5			
CH-1S	7/11/2016	50 U	**11**	**7.0**	**0.70** J	6.91	118.4	6.11	85	14.69	53.2			
CH-1S	6/5/2017	**96**	**15**	**7.5**	**0.84** J	7.50	40.0	6.75	105	11.16	22.69			
CH-1S	5/26/2022	50 U	**2.2** J	**6.6**	**1**	5.42	75.3	5.45	82	12.3	3.04	Differentiation by oxidation/reduction conditions not performed for the bedrock aquifer		
CH-1S	8/24/2022	**100**	**11**	**6.2**	**0.54** J	5.48	12.1	6.10	84	15.2	16.6			
CH-1S	11/10/2022	**33** J	**22**	**5.5**	**0.83** J	1.51	-130.0	6.01	105	13.5	8.18			
N7-P1	7/13/2016	**21000**	**8100**	**110**	**5.0**	0.32	-60.9	6.49	504	19.78	4.96			
N7-P1	12/22/2016	**1100**	**4100**	**56** J	**3.5**	2.90	-32.0	6.10	370	5.3	2.9			
N7-P1	6/8/2017	**30000**	**15000**	**220** D	**4.8**	0.26	-49.3	6.13	563	13.4	9.64			
N7-P1	5/31/2022	**11000**	**5400**	**85**	**0.89** J	0.35	-12.9	6.49	634	15.9	2.46			
N7-P1	8/24/2022	**12000**	**5600**	**80**	**2.6**	--	--	--	--	--	--			
N7-P1	11/15/2022	**11000**	**5300**	**84**	**0.94** J	1.16	-175.0	6.51	573	9.23	0.82			
Q4-1	7/13/2016	50 U	3.0 U	**7.8**	**0.88** J	6.24	88.9	5.84	67	14.5	6.85			
Q4-1	12/21/2016	50 U	3.0 U	**7.7** J	**0.53** J	7.70	100.0	6.30	110	9	1.2			
Q4-1	6/14/2017	50 U	3 U	**7** M	**0.7** J	9.01	249.4	5.79	79	11.4	9.8			
Q4-1	5/31/2022	**20** J	**3.7** J	**6.5**	**2.5**	7.05	122.0	5.72	54	14.9	7.66			
Q4-1	8/25/2022	50 U	**1.7** J	**6.6**	**0.68** J	5.27	36.9	6.37	106	14.4	8.13			
Q4-1	11/9/2022	50 U	5 U	**7.6** J	1 U	4.29	-66.6	6.18	105	10.3	2.95			
Q5-1	7/13/2016	50 U	**1.0** J	**7.6**	**0.93** J	7.23	237.5	6.26	72	14.41	1.81			
Q5-1	12/21/2016	50 U	3.0 U	**8.4** J	**0.64** J	6.10	96.0	6.30	84	9.2	2			
Q5-1	6/13/2017	50 U	3 U	**7.8** M	**0.91** J	8.35	203.8	5.76	105	11.92	9.59			
Q5-1	5/31/2022	50 U	5 U	**7.3**	0.6 U	8.27	146.0	6.12	52	10.9	2.93			
Q5-1	8/26/2022	50 U	**28**	**7.4**	**0.87** J	3.12	31.4	6.11	85	13.5	24.9			
Q5-1	11/17/2022	50 U	**22**	**6.2**	1 U	5.34	-184.0	5.86	82	10.1	33.4			
SHP-99-1C	7/7/2016	**590**	**560**	**6.1**	**0.87** J	3.97	4.6	7.10	100	14.05	4.18			
SHP-99-1C	12/20/2016	**580**	**2600**	**6.8** J	**2.4**	0.55	61.0	5.40	150	9.3	1.7			
SHP-99-1C	6/5/2017	**35** J	**360**	**7.0**	**1.1**	5.49	73.9	5.61	53	9.04	4.73			
SHP-99-1C	6/1/2022	**26** J	**21**	**5.7**	0.6 U	4.00	75.7	6.51	88	9.41	4.06			

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Analytical Method		Geochemical Parameters								Field Parameters						Oxidation/Reduction Determination		
Analyte		Dissolved Iron		Dissolved Manganese		Sulfate		DOC		Dissolved Oxygen	Oxidation Reduction Potential	pH	Sp. Cond.	Temp.	Turbidity	Oxidizing Conditions	Reducing Conditions	Final Decision
Unit		µg/L		µg/L		mg/L		mg/L		mg/L	mV	SU	µS/cm	°C	NTU			
Location	Date	Result		Result		Result		Result		Result	Result	Result	Result	Result	Result			
SHP-2016-06A	6/15/2017	50	U	**430**		**26**		**3.4**		4.57	62.3	7.49	204	13.47	9.63			
SHP-2016-06A	5/25/2022	**440**		**1200**		**62**		**6.5**		0.46	-154.0	8.20	449	11.1	2.09			
SHP-2016-06A	8/23/2022	**610**		**1100**		**77**		**7**		4.70	-124.0	7.97	406	13.8	3.1			
SHP-2016-06A	11/14/2022	**530**		**1300**		**58**		**6.1**		0.58	-166.0	7.64	406	9.31	6.47			
SHP-2016-06B	6/15/2017	50	U	**180**		**28**		**1.8**		1.09	48.6	7.14	246	13.73	6.91			
SHP-2016-06B	5/26/2022	**140**		**200**		**16**		**0.91**	J	0.52	-129.0	8.29	281	10.3	3.63			
SHP-2016-06B	8/23/2022	**120**		**170**		**14**		**1.4**		4.12	-168.0	8.30	288	13.1	8.95	Differentiation by oxidation/reduction conditions not performed for the bedrock aquifer		
SHP-2016-06B	11/14/2022	**120**		**180**		**14**		**1.4**	J	0.80	-140.0	7.87	277	9.26	12.1			
SHP-2016-06C	6/14/2017	**19**	J	**83**		**20**		**2.9**		1.07	38.7	7.51	276	18.59	8.70			
SHP-2016-06C	5/25/2022	**120**		**180**		**9.3**		0.6	U	0.50	-129.0	8.16	255	10.7	2.68			
SHP-2016-06C	8/23/2022	**120**		**150**		**8.9**		**0.88**	J	4.18	-117.0	8.20	251	14.2	7.4			
SHP-2016-06C	11/14/2022	**150**		**190**		**9**		1	U	0.79	-126.0	7.83	239	9.14	4.16			
SHP-2016-07A	6/13/2017	**6000**		**5100**		**4.2**	M	**0.81**	J	0.43	103.6	4.49	62	13.37	8.59			
SHP-2016-07A	5/24/2022	**140**		**510**		**29**		**2.7**		0.77	-37.8	7.25	316	13.8	2.18			
SHP-2016-07B	6/13/2017	**330**		**970**		**59**	M	**3.3**		1.34	32.3	6.67	301	19.24	7.32			
SHP-2016-07B	5/23/2022	**72**	J	**140**		**24**		**1.6**		6.32	-3.1	7.32	264	11.7	2.64			
SHP-2016-07B	8/30/2022	**110**		**380**		**42**		**3.2**		1.02	-75.8	7.35	332	24.6	45.7			
SHP-2016-07B	11/16/2022	**500**		**520**		**22**		**3.6**		0.49	-222.0	7.15	285	10.4	36.5			

Notes:
Italics - data collected since the Work Plan submittal.
[1] Attempted sampling of MW-9 but insufficient recharge was observed

Acronyms and Abbreviations:

-- : no data available
°C : degrees Celsius
DOC : dissolved organic carbon
µg/L : microgram per liter
µS/cm : microsiemen per centimeter
mg/L : milligram per liter
mV : millivolt
ND : non-detect (reporting limit not available)
NTU : Nephelometric Turbidity Unit
ORP : oxidation-reduction potential
Sp. Cond. : specific conductivity
SU : standard unit
Temp. : temperature
x : selected oxidizing or reducing condition for this well sample date.

Qualifiers:

D The reported value is from a dilution
J The analyte was positively identified, the quantitation is an estimation.
M Manual integrated compound
U The analyte was analyzed for, but not detected. The associated numerical value is at or below the limit of detection.

Reference:
USACE. 1995. Record of Decision, Shepley's Hill Landfill Operable Unit, Fort Devens, Massachusetts. September.

Table 4
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Former Fort Devens Army Installation
Devens, Massachusetts

Analytical Method		Metals		
Analyte		Dissolved Arsenic	Total Arsenic	Arsenic Concentration Used in Evaluation
Unit		µg/L	µg/L	µg/L
Location	Date	Result	Result	Result
Overburden Wells				
32M-01-14XOB	4/1/2002	2.15 U	**9.8**	2.15 U
32M-01-14XOB	10/1/2002	2 U	**8.9**	2 U
32M-01-14XOB	6/1/2003	**19.1**	**19**	**19.1**
32M-01-14XOB	12/3/2003	4.1 U	**20.5**	4.1 U
32M-01-14XOB	5/26/2004	2.8 U	**5.9 B**	2.8 U
32M-01-14XOB	6/1/2006	**65**	**59**	**65**
32M-01-14XOB	10/1/2006	--	**49**	**49**
32M-01-14XOB	5/1/2007	--	**45**	**45**
32M-01-14XOB	10/1/2007	--	**69**	**69**
32M-01-14XOB	6/1/2008	--	**50**	**50**
32M-01-14XOB	10/1/2008	--	**70**	**70**
32M-01-14XOB	5/1/2009	--	**66**	**66**
32M-01-14XOB	5/1/2010	--	**43**	**43**
32M-01-14XOB	6/1/2011	--	**62**	**62**
32M-01-14XOB	5/1/2012	--	**80**	**80**
32M-01-14XOB	6/1/2013	--	**58**	**58**
32M-01-14XOB	6/17/2014	--	**62 J**	**62 J**
32M-01-14XOB	6/28/2015	**90.1**	**93.1**	**90.1**
32M-01-14XOB	6/10/2016	**13**	--	**13**
32M-01-14XOB	7/6/2016	**73**	**59**	**73**
32M-01-14XOB	12/20/2016	**75**	**74**	**75**
32M-01-14XOB	6/8/2017	**46**	**50**	**46**
32M-01-14XOB	6/28/2017	**30**	**33**	**30**
32M-01-14XOB	4/10/2018	--	**32**	**32**
32M-01-14XOB	4/9/2019	--	**29**	**29**
32M-01-14XOB	5/4/2020	--	**31**	**31**
32M-01-14XOB	5/25/2021	**56**	--	**56**
32M-92-01X	1/1/1999	--	1.85 U	1.85 U
32M-92-01X	4/1/1999	--	2.07 U	2.07 U
32M-92-01X	7/1/1999	--	**12**	**12**
32M-92-01X	10/1/1999	--	**39.3**	**39.3**
32M-92-01X	4/1/2002	2.15 U	2.15 U	2.15 U
32M-92-01X	10/1/2002	2 U	**7.3**	2 U
32M-92-01X	6/1/2003	1.8 U	1.8 U	1.8 U
32M-92-01X	12/3/2003	4.1 U	4.1 U	4.1 U
32M-92-01X	5/26/2004	2.6 U	2.6 U	2.6 U
32M-92-01X	6/1/2006	5.0 U	5.0 U	5.0 U
32M-92-01X	10/1/2006	--	0.5 U	0.5 U
32M-92-01X	7/6/2016	3.0 U	3.0 U	3.0 U
32M-92-01X	12/19/2016	3.0 U	3.0 U	3.0 U
32M-92-01X	6/8/2017	3.0 U	3.0 U	3.0 U
32Z-01-07X	7/6/2016	3.0 U	**3.0**	3.0 U
32Z-01-07X	12/19/2016	3.0 U	**4.40**	3.0 U
32Z-01-07X	6/9/2017	3.0 U	**3.0**	3.0 U
MW-1	6/15/2017	**6.6**	**6.1**	**6.6**
MW 4-1	6/12/2017	**3.8**	**3.3**	**3.8**
MW-7	6/12/2017	3.0 U	**4.5**	3.0 U
MW-9 [2]	6/13/2017	--	--	--

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Analyte		Dissolved Arsenic	Total Arsenic	Arsenic Concentration Used in Evaluation
Unit		µg/L	µg/L	µg/L
Location	Date	Result	Result	Result
MW-14	6/14/2017	3.0 U	3.0 U	3.0 U
MW-22	6/14/2017	3.0 U	3.0 U	3.0 U
N1-P1	11/1/1999	2.19 U	2.19 U	2.19 U
N1-P1	11/1/2001	--	ND U	ND U
N1-P1	10/27/2015	--	4.0 U	4.0 U
N1-P1	6/7/2017	3.0 U	3.0 U	3.0 U
N1-P1	*5/24/2022*	3.0 U	--	3 U
N1-P1	*8/25/2022*	3.0 U	--	3 U
N1-P1	*11/10/2022*	3.0 U	--	3 U
N1-P2	11/1/1999	**61**	**66.3**	**61**
N1-P2	11/1/2001	--	**92**	**92**
N1-P2	10/26/2015	--	**115**	**115**
N1-P2	7/11/2016	**120**	**130**	**120**
N1-P2	12/20/2016	**130**	**130**	**130**
N1-P2	6/7/2017	**120**	**130**	**120**
N1-P2	*5/24/2022*	**130**	--	**130**
N1-P2	*8/25/2022*	**120**	--	**120**
N1-P2	*11/10/2022*	**130**	--	**130**
N1-P3	11/1/1999	**29.5**	**30.7**	**29.5**
N1-P3	11/1/2001	--	**35**	**35**
N1-P3	10/27/2015	--	**17.6**	**17.6**
N1-P3	7/11/2016	**21**	**22**	**21**
N1-P3	12/20/2016	**21**	**28**	**21**
N1-P3	6/7/2017	**9.7**	**18**	**9.7**
N1-P3	*5/24/2022*	**5.9**	--	**5.9**
N1-P3	*8/25/2022*	**19**	--	**19**
N1-P3	*11/10/2022*	**11**	--	**11**
N7-P2	11/1/1999	**218**	**228**	**218**
N7-P2	10/22/2015	--	**157**	**157**
N7-P2	7/13/2016	**180**	**180**	**180**
N7-P2	12/22/2016	**150**	**140**	**150**
N7-P2	6/8/2017	**120**	**120**	**120**
N7-P2	*6/2/2022*	**140**	--	**140**
N7-P2	*8/24/2022*	**110**	--	**110**
N7-P2	*11/16/2022*	**160 J**	--	**160 J**
SHL-1	6/5/2017	**1.5 J**	**1.6 J**	**1.5 J**
SHL-12	11/1/1999	2.19 U	2.07 U	2.19 U
SHL-12	6/7/2011	**2.0 J**	--	**2.0 J**
SHL-12	11/20/2012	**1.6 J**	--	**1.6 J**
SHL-12	11/28/2013	**2.4 J**	--	**2.4 J**
SHL-12	11/25/2014	**1.9 J**	--	**1.9 J**
SHL-12	6/8/2015	**2.0 J**	--	**2.0 J**
SHL-12	7/7/2016	**1.6 J**	**1.6 J**	**1.6 J**
SHL-12	11/21/2016	**1.6 J**	--	**1.6 J**
SHL-12	12/20/2016	**1.6 J**	3.0 U	**1.6 J**
SHL-12	6/8/2017	**2.0 J**	3.0 U	**2.0 J**
SHL-12	11/29/2017	**2.4 J**	--	**2.4 J**
SHL-12	11/26/2018	**1.9 J**	--	**1.9 J**
SHL-12	11/7/2019	**7.4**	--	**7.4**

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Analyte		Dissolved Arsenic	Total Arsenic	Arsenic Concentration Used in Evaluation
Unit		µg/L	µg/L	µg/L
Location	Date	Result	Result	Result
SHL-12	11/2/2020	2.3 J	--	2.3 J
SHL-12	*11/9/2021*	2.8 J	--	2.8 J
SHL-12	*5/26/2022*	1.4 J	--	1.4 J
SHL-12	*8/23/2022*	3 U	--	*3* U
SHL-12	*10/18/2022*	3 U	--	*3* U
SHL-12	*11/8/2022*	3 U	--	*3* U
SHL-15	3/1/1993	--	91	91
SHL-15	6/1/1993	--	16.6	16.6
SHL-15	1/1/1999	--	16.2	16.2
SHL-15	4/1/1999	--	104	104
SHL-15	7/1/1999	--	63.9	63.9
SHL-15	11/1/1999	215	235	215
SHL-15	4/1/2002	111	116	111
SHL-15	10/1/2002	27.2	44.2	27.2
SHL-15	6/1/2003	29	35	29
SHL-15	12/3/2003	144	148	144
SHL-15	5/26/2004	20.6	21.8	20.6
SHL-15	4/13/2006	--	18	18
SHL-15	6/6/2006	--	16	16
SHL-15	9/25/2006	--	44	44
SHL-15	10/1/2006	--	11	11
SHL-15	12/12/2006	--	93	93
SHL-15	10/16/2007	--	42	42
SHL-15	10/3/2008	--	75	75
SHL-15	10/22/2009	35	26.7	35
SHL-15	10/14/2010	--	25	25
SHL-15	6/8/2011	32	--	32
SHL-15	10/6/2011	--	70.4	70.4
SHL-15	1/20/2012	19	--	19
SHL-15	10/16/2012	--	24.2	24.2
SHL-15	10/22/2013	34.9	--	34.9
SHL-15	11/14/2013	200	--	200
SHL-15	11/11/2014	44	--	44
SHL-15	6/9/2015	31.6	--	31.6
SHL-15	7/6/2016	55	59	55
SHL-15	11/21/2016	19	--	19
SHL-15	12/19/2016	95	150	95
SHL-15	6/7/2017	21	32	21
SHL-15	11/15/2017	200	--	200
SHL-15	11/12/2018	44	--	44
SHL-15	11/1/2019	110	--	110
SHL-15	11/2/2020	26	--	26
SHL-15	*11/2/2021*	22	--	22
SHL-15	*5/23/2022*	45	--	45
SHL-15	*8/23/2022*	28	--	28
SHL-15	*10/19/2022*	40	--	40
SHL-15	*11/8/2022*	58	--	58
SHL-17	11/1/1999	--	2.07 U	2.07 U
SHL-17	7/13/2016	3.0 U	10	3.0 U

Table 4
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Former Fort Devens Army Installation
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Analytical Method		Metals		
Analyte		Dissolved Arsenic	Total Arsenic	Arsenic Concentration Used in Evaluation
Unit		µg/L	µg/L	µg/L
Location	Date	Result	Result	Result
SHL-17	12/20/2016	3.0 U	**5.1**	3.0 U
SHL-17	*5/26/2022*	3 U	--	*3 U*
SHL-17	*8/24/2022*	**2.6 J**	--	**2.6 J**
SHL-17	*11/8/2022*	3 U	--	*3 U*
SHL-18	10/27/2015	--	**2.5 J**	**2.5 J**
SHL-18	7/11/2016	**2.0 J**	**2.1 J**	**2.0 J**
SHL-18	12/19/2016	3.0 U	**1.7 J**	3.0 U
SHL-18	6/1/2017	3.0 U	3.0 U	3.0 U
SHL-18	*5/31/2022*	**1.4 J**	--	**1.4 J**
SHL-18	*8/25/2022*	**1.7 J**	--	**1.7 J**
SHL-18	*11/9/2022*	**1.8 J**	--	**1.8 J**
SHL-23	11/1/2001	--	ND U	ND U
SHL-23	4/14/2006	--	5.0 U	5.0 U
SHL-23	6/12/2006	--	5.0 U	5.0 U
SHL-23	8/11/2006	**0.14 J**	--	**0.14 J**
SHL-23	9/25/2006	--	5.0 U	5.0 U
SHL-23	12/12/2006	--	5.0 U	5.0 U
SHL-23	4/10/2007	--	3.0 U	3.0 U
SHL-23	10/17/2007	--	**0.73 J**	**0.73 J**
SHL-23	4/18/2008	--	**0.19 J**	**0.19 J**
SHL-23	10/6/2008	--	1.0 UJ	1.0 UJ
SHL-23	4/24/2009	--	0.50 U	0.50 U
SHL-23	8/12/2010	**0.14 J**	--	**0.14 J**
SHL-23	10/13/2010	--	0.50 U	0.50 U
SHL-23	6/9/2011	2.0 U	--	2.0 U
SHL-23	10/25/2011	4.0 U	--	4.0 U
SHL-23	10/15/2012	--	0.50 U	0.50 U
SHL-23	11/21/2012	3.0 U	--	3.0 U
SHL-23	11/26/2013	3.0 U	--	3.0 U
SHL-23	11/7/2014	3.0 U	--	3.0 U
SHL-23	6/9/2015	2.0 U	--	2.0 U
SHL-23	10/26/2015	4.0 U	--	4.0 U
SHL-23	7/8/2016	3.0 U	3.0 U	3.0 U
SHL-23	11/22/2016	3.0 U	3.0 U	3.0 U
SHL-23	12/22/2016	3.0 U	3.0 U	3.0 U
SHL-23	5/24/2017	3.0 U	3.0 U	3.0 U
SHL-23	11/27/2017	3.0 U	--	3.0 U
SHL-23	11/8/2018	3.0 U	--	3.0 U
SHL-23	11/13/2019	3.0 U	--	3.0 U
SHL-23	11/12/2020	3.0 U	--	3.0 U
SHL-23	*11/9/2021*	*3 U*	--	*3 U*
SHL-23	*5/31/2022*	*3 U*	--	*3 U*
SHL-23	*8/30/2022*	3 U	--	*3 U*
SHL-23	*10/26/2022*	3 U	--	*3 U*
SHL-23	*11/14/2022*	**3.2 J**	--	**3.2 J**
SHL-24	6/8/2011	**4.9**	--	**4.9**
SHL-24	10/26/2011	**6.5**	--	**6.5**
SHL-24	11/20/2012	**5.5**	--	**5.5**

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Analyte		Dissolved Arsenic	Total Arsenic	Arsenic Concentration Used in Evaluation
Unit		µg/L	µg/L	µg/L
Location	Date	Result	Result	Result
SHL-24	11/28/2013	**4.8**	--	**4.8**
SHL-24	11/27/2014	**3.4**	--	**3.4**
SHL-24	6/9/2015	**4.9**	--	**4.9**
SHL-24	10/27/2015	**6.5**	--	**6.5**
SHL-24	7/12/2016	**5.9**	**5.5**	**5.9**
SHL-24	11/21/2016	**5.5**	--	**5.5**
SHL-24	12/23/2016	**4.8**	**5.4**	**4.8**
SHL-24	6/15/2017	**5.0**	**4.7**	**5.0**
SHL-24	11/29/2017	**4.8**	--	**4.8**
SHL-24	11/28/2018	**3.4**	--	**3.4**
SHL-24	11/7/2019	**4.2**	--	**4.2**
SHL-24	10/26/2020	**3.9**	--	**3.9**
SHL-24	*11/4/2021*	**3.8 J**	--	**3.8 J**
SHL-24	*6/2/2022*	**3.8 J**	--	**3.8 J**
SHL-24	*8/30/2022*	**4.1 J**	--	**4.1 J**
SHL-24	*10/14/2022*	**3.8 J**	--	**3.8 J**
SHL-24	*11/10/2022*	**3.7 J**	--	**3.7 J**
SHL-25	11/1/1999	--	2.07 U	2.07 U
SHL-25	7/7/2016	3.0 U	3.0 U	3.0 U
SHL-25	12/22/2016	**1.6 J**	2.5 U	**1.6 J**
SHL-25	6/9/2017	**3.6**	**4.9**	**3.6**
SHL-25	*5/26/2022*	**3.6 J**	--	**3.6 J**
SHL-25	*8/24/2022*	**2.6 J**	--	**2.6 J**
SHL-25	*11/8/2022*	**2.4 J**	--	**2.4 J**
SHL-7	11/14/2013	**3.0**	--	**3.0**
SHL-7	11/11/2014	3.0 U	--	3.0 U
SHL-7	7/12/2016	3.0 U	3.0 U	3.0 U
SHL-7	12/23/2016	3.0 U	**8.3**	3.0 U
SHL-7	6/1/2017	3.0 U	3.0 U	3.0 U
SHL-7	11/15/2017	**3.0**	--	**3.0**
SHL-7	11/12/2018	3.0 U	--	3.0 U
SHL-7	11/13/2019	3.0 U	--	3.0 U
SHL-7	11/3/2020	3.0 U	--	3.0 U
SHL-7	*11/4/2021*	3 U	--	*3* U
SHL-7	*5/26/2022*	3 U	--	*3* U
SHL-7	*8/24/2022*	3 U	--	*3* U
SHL-7	*10/19/2022*	3 U	--	*3* U
SHL-7	*11/17/2022*	3 U	--	*3* U
SHM-93-18B	7/12/2016	3.0 U	**1.6 J**	3.0 U
SHM-93-18B	12/19/2016	3.0 U	3.0 U	3.0 U
SHM-93-18B	6/1/2017	3.0 U	3.0 U	3.0 U
SHM-93-18B	11/15/2017	3.0 U	--	3.0 U
SHM-93-18B	11/12/2018	3.0 U	--	3.0 U
SHM-93-18B	11/13/2019	3.0 U	--	3.0 U
SHM-93-18B	11/12/2020	3.0 U	--	3.0 U
SHM-93-18B	*11/8/2021*	3 U	--	*3* U
SHM-93-18B	*5/26/2022*	3 U	--	*3* U
SHM-93-18B	*8/25/2022*	**0.93 J**	--	**0.93 J**
SHM-93-18B	*11/03/2022*	3 U	--	*3* U

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Analyte		Dissolved Arsenic	Total Arsenic	Arsenic Concentration Used in Evaluation
Unit		µg/L	µg/L	µg/L
Location	Date	Result	Result	Result
SHM-93-18B	*11/9/2022*	*3 U*	--	*3 U*
SHM-93-24A	7/12/2016	3.0 U	3.0 U	3.0 U
SHM-93-24A	12/21/2016	3.0 U	3.0 U	3.0 U
SHM-93-24A	6/15/2017	3.0 U	3.0 U	3.0 U
SHM-93-24A	11/29/2017	**2.2 J**	--	**2.2 J**
SHM-93-24A	11/26/2018	3.0 U	--	3.0 U
SHM-93-24A	11/8/2019	3.0 U	--	3.0 U
SHM-93-24A	10/26/2020	3.0 U	--	3.0 U
SHM-93-24A	*11/5/2021*	*3 U*	--	*3 U*
SHM-93-24A	*6/2/2022*	*3 U*	--	*3 U*
SHM-93-24A	*8/30/2022*	**1.2 J**	--	**1.2 J**
SHM-93-24A	*10/14/2022*	*3 U*	--	*3 U*
SHM-93-24A	*11/10/2022*	*3 U*	--	*3 U*
SHP-95-27X	11/1/1999	**243**	**226**	**243**
SHP-95-27X	10/28/2015	**100**	--	**100**
SHP-95-27X	7/11/2016	**95**	**91**	**95**
SHP-95-27X	12/19/2016	**100**	**100**	**100**
SHP-95-27X	6/6/2017	**100**	**99**	**100**
SHP-95-27X	*6/2/2022*	**74**	--	**74**
SHP-95-27X	*8/25/2022*	**69**	--	**69**
SHP-95-27X	*11/15/2022*	**86**	--	**86**
SHP-99-1B	6/5/2017	**40**	**52**	**40**
Bedrock Wells				
20-1	11/18/2009	--	10 U	10 U
20-1	3/16/2010	--	20 U	20 U
20-1	7/14/2016	**4.1**	**5.7**	**4.1**
20-1	12/21/2016	**3.0**	**3.8**	**3.0**
20-1	6/5/2017	**1.7 J**	3.0 U	**1.7 J**
20-1	*6/1/2022*	**1.1 J**	--	**1.1 J**
20-1	*8/25/2022*	**2.1 J**	--	**2.1 J**
20-1	*11/9/2022*	**6**	--	**6**
27-1	11/18/2009	--	10 U	10 U
27-1	3/17/2010	--	20 U	20 U
27-1	7/14/2016	**7.8**	**9.5**	**7.8**
27-1	12/21/2016	**8.0**	**7.5**	**8.0**
27-1	6/5/2017	**7.1**	**6.8**	**7.1**
27-1	*5/31/2022*	**6.6**	--	**6.6**
27-1	*8/26/2022*	**7.2**	--	**7.2**
27-1	*11/8/2022*	**7.8**	--	**7.8**
27-2	11/19/2009	--	10 U	10 U
27-2	3/16/2010	--	20 U	20 U
27-2	7/14/2016	**5.8**	**5.8**	**5.8**
27-2	12/21/2016	**10**	**10**	**10**
27-2	6/5/2017	**8.3**	**9.8**	**8.3**
27-2	*5/31/2022*	**5.3**	--	**5.3**
27-2	*8/29/2022*	**8.9**	--	**8.9**
27-2	*11/8/2022*	**8.4**	--	**8.4**
3-2	11/17/2009	--	**63**	**63**
3-2	3/16/2010	--	**91**	**91**

Table 4
Summary of Available Arsenic Concentrations in Groundwater
Former Fort Devens Army Installation
Devens, Massachusetts

Analytical Method		Metals		
Analyte		Dissolved Arsenic	Total Arsenic	Arsenic Concentration Used in Evaluation
Unit		µg/L	µg/L	µg/L
Location	Date	Result	Result	Result
3-2	6/24/2010	--	67	67
3-2	7/13/2016	6.9	11	6.9
3-2	12/21/2016	83	160	83
3-2	6/13/2017	79	76	79
3-2	*5/26/2022*	69	--	69
3-2	*8/25/2022*	71	--	71
3-2	*11/9/2022*	50	--	50
CAP-2B	11/2/2009	--	10 U	10 U
CAP-2B	3/16/2010	--	20 U	20 U
CAP-2B	7/11/2016	4.4	4.5	4.4
CAP-2B	6/5/2017	3.7	4.0	3.7
CAP-2B	*6/1/2022*	5.7	--	5.7
CAP-2B	*8/26/2022*	5.7	--	5.7
CAP-2B	*11/9/2022*	8.3	--	8.3
CH-1D	11/4/2009	--	370	370
CH-1D	3/16/2010	--	290	290
CH-1D	6/22/2010	--	400	400
CH-1D	7/11/2016	570	530	570
CH-1D	12/21/2016	570	520	570
CH-1D	6/5/2017	650	650	650
CH-1D	*5/31/2022*	650	--	650
CH-1D	*8/24/2022*	570	--	570
CH-1D	*11/10/2022*	590	--	590
CH-1S	11/2/2009	--	27	27
CH-1S	3/16/2010	--	20 U	20 U
CH-1S	7/11/2016	18	37	18
CH-1S	6/5/2017	22	47	22
CH-1S	*5/26/2022*	21	--	21
CH-1S	*8/24/2022*	31	--	31
CH-1S	*11/10/2022*	25	--	25
N7-P1	11/1/1999	119	113	119
N7-P1	10/23/2015	--	55.5	55.5
N7-P1	7/13/2016	140	130	140
N7-P1	12/22/2016	49	68	49
N7-P1	6/8/2017	170	160	170
N7-P1	*5/31/2022*	110	--	110
N7-P1	*8/24/2022*	120	--	120
N7-P1	*11/15/2022*	120	--	120
Q4-1	11/16/2009	--	10 U	10 U
Q4-1	3/16/2010	--	20 U	20 U
Q4-1	7/13/2016	8.6	9.0	8.6
Q4-1	12/21/2016	14	13	14
Q4-1	6/14/2017	9.7	8.4	9.7
Q4-1	*5/31/2022*	8.7	--	8.7
Q4-1	*8/25/2022*	12	--	12
Q4-1	*11/9/2022*	13	--	13
Q5-1	11/4/2009	--	10 U	10 U
Q5-1	3/16/2010	--	20 U	20 U
Q5-1	7/13/2016	3.0 U	3.0 U	3.0 U

Table 4
Summary of Available Arsenic Concentrations in Groundwater
Former Fort Devens Army Installation
Devens, Massachusetts

Analytical Method		Metals		
Analyte		Dissolved Arsenic	Total Arsenic	Arsenic Concentration Used in Evaluation
Unit		µg/L	µg/L	µg/L
Location	Date	Result	Result	Result
Q5-1	12/21/2016	3.0 U	3.0 U	3.0 U
Q5-1	6/13/2017	**2.1 J**	3.0 U	**2.1 J**
Q5-1	*5/31/2022*	**2.2 J**	--	**2.2 J**
Q5-1	*8/26/2022*	**2.7 J**	--	**2.7 J**
Q5-1	*11/17/2022*	**2.1 J**	--	**2.1 J**
SHP-99-1C	11/1/1999	--	**2.2 B**	**2.2 B**
SHP-99-1C	7/7/2016	**8.9**	**27 J**	**8.9**
SHP-99-1C	12/20/2016	**6.9**	**7.4**	**6.9**
SHP-99-1C	6/5/2017	**1.5 J**	**1.5 J**	**1.5 J**
SHP-99-1C	*6/1/2022*	**1.2 J**	--	**1.2 J**
SHP-2016-06A	6/15/2017	**520**	**670**	**520**
SHP-2016-06A	11/28/2017	**600**	--	**600**
SHP-2016-06A	4/18/2018	**280**	--	**280**
SHP-2016-06A	11/9/2018	**480**	--	**480**
SHP-2016-06A	4/17/2019	**2800**	--	**2800**
SHP-2016-06A	11/5/2019	**860**	--	**860**
SHP-2016-06A	5/21/2020	**760**	--	**760**
SHP-2016-06A	11/12/2020	**640**	--	**640**
SHP-2016-06A	5/25/2021	**960**	--	**960**
SHP-2016-06A	*11/9/2021*	**1000**	--	**1000**
SHP-2016-06A	*5/11/2022*	**1500**	--	**1500**
SHP-2016-06A	*5/25/2022*	**1100**	--	**1100**
SHP-2016-06A	*8/23/2022*	**1700**	--	**1700**
SHP-2016-06A	*10/26/2022*	**1900**	--	**1900**
SHP-2016-06A	*11/14/2022*	**1400**	--	**1400**
SHP-2016-06B	6/15/2017	**830 J**	**850**	**830 J**
SHP-2016-06B	11/28/2017	**1300**	--	**1300**
SHP-2016-06B	4/18/2018	**1300**	--	**1300**
SHP-2016-06B	11/7/2018	**1300**	--	**1300**
SHP-2016-06B	4/17/2019	**1300**	--	**1300**
SHP-2016-06B	11/5/2019	**1200**	--	**1200**
SHP-2016-06B	5/21/2020	**1100**	--	**1100**
SHP-2016-06B	11/12/2020	**1100**	--	**1100**
SHP-2016-06B	5/25/2021	**1200**	--	**1200**
SHP-2016-06B	*11/9/2021*	**510**	--	**510**
SHP-2016-06B	*5/11/2022*	**340**	--	**340**
SHP-2016-06B	*5/26/2022*	**540**	--	**540**
SHP-2016-06B	*8/23/2022*	**470**	--	**470**
SHP-2016-06B	*10/26/2022*	**290**	--	**290**
SHP-2016-06B	*11/14/2022*	**420**	--	**420**
SHP-2016-06C	6/14/2017	**320**	--	**320**
SHP-2016-06C	11/28/2017	**280**	--	**280**
SHP-2016-06C	4/18/2018	**210**	--	**210**
SHP-2016-06C	11/7/2018	**300**	--	**300**
SHP-2016-06C	4/17/2019	**250**	--	**250**
SHP-2016-06C	11/5/2019	**270**	--	**270**
SHP-2016-06C	5/21/2020	**310**	--	**310**
SHP-2016-06C	11/12/2020	**350**	--	**350**
SHP-2016-06C	5/25/2021	**310**	--	**310**

Table 4
Summary of Available Arsenic Concentrations in Groundwater
Former Fort Devens Army Installation
Devens, Massachusetts

Analytical Method		Metals		
Analyte		Dissolved Arsenic	Total Arsenic	Arsenic Concentration Used in Evaluation
Unit		µg/L	µg/L	µg/L
Location	Date	Result	Result	Result
SHP-2016-06C	*11/9/2021*	**290**	--	**290**
SHP-2016-06C	*5/11/2022*	**360**	--	**360**
SHP-2016-06C	*5/25/2022*	**370**	--	**370**
SHP-2016-06C	*8/23/2022*	**360**	--	**360**
SHP-2016-06C	*10/26/2022*	**380**	--	**380**
SHP-2016-06C	*11/14/2022*	**380**	--	**380**
SHP-2016-07A	6/13/2017	**81**	**77**	**81**
SHP-2016-07A	11/30/2017	**12**	--	**12**
SHP-2016-07A	4/19/2018	**84**	--	**84**
SHP-2016-07A	11/9/2018	**200**	--	**200**
SHP-2016-07A	4/22/2019	**19**	--	**19**
SHP-2016-07A	5/20/2020	**74**	--	**74**
SHP-2016-07A	*10/27/2021*	**130**	--	**130**
SHP-2016-07A	*5/11/2022*	**2.2 J**	--	**2.2 J**
SHP-2016-07A	*5/24/2022*	**93 J**	--	**93 J**
SHP-2016-07B	6/13/2017	**7.9**	**7.9**	**7.9**
SHP-2016-07B	11/30/2017	**11**	--	**11**
SHP-2016-07B	4/19/2018	**200**	--	**200**
SHP-2016-07B	11/8/2018	**150**	--	**150**
SHP-2016-07B	4/19/2019	**80**	--	**80**
SHP-2016-07B	11/6/2019	**35**	--	**35**
SHP-2016-07B	5/15/2020	**57**	--	**57**
SHP-2016-07B	11/13/2020	**65**	--	**65**
SHP-2016-07B	*10/27/2021*	**130**	--	**130**
SHP-2016-07B	*5/11/2022*	**100**	--	**100**
SHP-2016-07B	*5/23/2022*	**37**	--	**37**
SHP-2016-07B	*8/30/2022*	**67**	--	**67**
SHP-2016-07B	*10/18/2022*	**160**	--	**160**
SHP-2016-07B	*11/16/2022*	**120**	--	**120**

Notes:
Italics - data collected since the Work Plan submittal.
[1] The cleanup goal for arsenic at Shepley's Hill Landfill is 10 µg/L (USACE 1995)
[2] Attempted sampling of MW-9 but insufficient recharge was observed

Analytical Parameters:
#: Above Cleanup Goal

Acronyms and Abbreviations:
-- : no data available
µg/L : microgram per liter
ND : non-detect (reporting limit not available)

Qualifiers:
J The analyte was positively identified, the quantitation is an estimation.
U The analyte was analyzed for, but not detected. The associated numerical value is at or below the method detection limit.

Reference:
USACE. 1995. Record of Decision, Shepley's Hill Landfill Operable Unit, Fort Devens, Massachusetts. September.

Table 5
Outlier Evaluation
Former Fort Devens Army Installation
Devens, Massachusetts

Potential Outlier Identification				Outlier Analysis				
Well Identification	Sample Date	Analytical Result	Potential Outlier Rationale	Distribution After Outlier Removal	Statistical Outlier?[1]	Significance	Excluded from Dataset?	Rationale for Inclusion or Exclusion
Overburden Wells								
32M-92-01X	7/1/1999	12	Greater than 75th + 3xIQR	< 5 Detects	--	--	No	Included due to visual inspection
32M-92-01X	10/1/1999	39.3	Greater than first potential outlier				No	Included due to visual inspection
SHL-12	11/7/2019	7.4	Greater than 75th + 3xIQR	Normal	Yes	1%	No	Failed Dixon's test, retained following scientific review.
SHL-23	10/25/2011	4.0 U	Elevated non-detect	Nonparametric	--	--	Yes	Results are elevated non-detect values greater than the maximum detected value.
SHL-23	10/26/2015	4.0 U	Elevated non-detect					
SHL-23	4/14/2006	5.0 U	Elevated non-detect					
SHL-23	6/12/2006	5.0 U	Elevated non-detect					
SHL-23	9/25/2006	5.0 U	Elevated non-detect					
SHL-23	12/12/2006	5.0 U	Elevated non-detect					
SHP-95-27X	11/1/1999	243	Greater than 75th + 3xIQR	Normal	Yes	1%	Yes	Excluded due to probable well installation effects
Bedrock Wells								
20-1	11/18/2009	10 U	Elevated non-detect	Normal	--	--	Yes	Results are elevated non-detect values greater than the maximum detected value.
20-1	3/16/2010	20 U	Elevated non-detect					
27-1	11/18/2009	10 U	Elevated non-detect	Normal	--	--	Yes	Results are elevated non-detect values greater than the maximum detected value.
27-1	3/17/2010	20 U	Elevated non-detect					
27-2	3/16/2010	20 U	Elevated non-detect	Normal	--	--	Yes	Result is an elevated non-detect value greater than the maximum detected value.
CAP-2B	11/2/2009	10 U	Elevated non-detect	Normal	--	--	Yes	Results are elevated non-detect values greater than the maximum detected value.
CAP-2B	3/16/2010	20 U	Elevated non-detect					
Q4-1	3/16/2010	20 U	Elevated non-detect	Normal	--	--	Yes	Result is an elevated non-detect value greater than the maximum detected value.
Q5-1	11/4/2009	10 U	Elevated non-detect	Normal	--	--	Yes	Results are elevated non-detect values greater than the maximum detected value.
Q5-1	3/16/2010	20 U	Elevated non-detect					

Notes:

[1] Results are in units of microgram per liter (µg/L).

[2] Statistical outlier tests were performed using raw data for normal distributions and using log-transformed data for lognormal distributions. Statistical outlier tests were not performed for nonparametric or gamma distributions

Acronyms and Abbreviations:

ID : identification
IQR : interquartile range
-- : not available/not analyzed
% : percent
< : less than
> : greater than

Qualifiers:

U : The analyte was analyzed for, but the result was not detected above the method detection limit.

Table 6
Summary Statistics and Trend Results
Former Fort Devens Army Installation
Devens, Massachusetts

Well ID	Analyte	Date Range	FOD	Detected Results Summary [1]					Mann-Kendall Test [2]				Trend Designation Based on CV
				Range	Mean	Median	SD	CV	Result [4]	MK Result Note	P-Value	S Value	
Overburden Wells													
32M-01-14XOB	Arsenic	04/02 - 05/22	24 / 28	13 - 90.1	52.6	53	19.9	0.38	NST	--	0.099	66	STABLE
32M-92-01X	Arsenic	01/99 - 05/22	2 / 15	12 - 39.3	--	--	--	--	--	6	--	--	FOD <25%
32Z-01-07X	Arsenic	07/16 - 05/22	0 / 4	--	--	--	--	--	--	5, 6	--	--	All data ND
MW 4-1	Arsenic	06/17 - 06/17	1 / 1	3.8 - 3.8	--	--	--	--	--	5	--	--	Ins. Data
MW-1	Arsenic	06/17 - 06/17	1 / 1	6.6 - 6.6	--	--	--	--	--	5	--	--	Ins. Data
MW-14	Arsenic	06/17 - 06/17	0 / 1	--	--	--	--	--	--	5	--	--	All data ND
MW-22	Arsenic	06/17 - 06/17	0 / 1	--	--	--	--	--	--	5	--	--	All data ND
MW-7	Arsenic	06/17 - 06/17	0 / 1	--	--	--	--	--	--	5	--	--	All data ND
N1-P1	Arsenic	11/99 - 11/22	0 / 7	--	--	--	--	--	--	5, 6	--	--	All data ND
N1-P2	Arsenic	11/99 - 11/22	9 / 9	61 - 130	113	120	22.8	0.20	UP	--	0.006	24	Increasing
N1-P3	Arsenic	11/99 - 11/22	9 / 9	5.9 - 35	18.9	19	9.3	0.49	DWN	--	0.030	-19	Decreasing
N7-P2	Arsenic	11/99 - 11/22	8 / 8	110 - 218	154	153.5	34.1	0.22	NST	--	0.054	-14	STABLE
SHL-1	Arsenic	06/17 - 06/17	1 / 1	1.5 - 1.5	--	--	--	--	--	5	--	--	Ins. Data
SHL-12	Arsenic	11/99 - 11/22	15 / 19	1.4 - 7.4	2.3	2	1.5	0.65	NST	--	0.297	-16	STABLE
SHL-15	Arsenic	03/93 - 11/22	41 / 41	11 - 215	58.9	40	52.4	0.89	NST	--	0.420	19	STABLE
SHL-17	Arsenic	11/99 - 11/22	1 / 6	2.6 - 2.6	--	--	--	--	--	5 6	--	--	FOD <25%
SHL-18	Arsenic	10/15 - 11/22	5 / 7	1.4 - 2.5	1.9	1.8	0.41	0.22	NST	5	0.443	-2	STABLE
SHL-23	Arsenic	11/01 - 11/22	5 / 28	0.14 - 3.2	0.88	0.19	1.3	1.5	--	6	--	--	FOD <25%
SHL-24	Arsenic	06/11 - 11/22	20 / 20	3.4 - 6.5	4.7	4.8	0.96	0.20	DWN	--	<0.001	-96	Decreasing
SHL-25	Arsenic	11/99 - 11/22	5 / 7	1.6 - 3.6	2.8	2.6	0.85	0.30	NST	5	0.119	9	STABLE
SHL-7	Arsenic	11/13 - 11/22	2 / 14	3 - 3	--	--	--	--	--	6	--	--	FOD <25%
SHM-93-18B	Arsenic	07/16 - 11/22	1 / 12	0.93 - 0.93	--	--	--	--	--	6	--	--	FOD <25%
SHM-93-24A	Arsenic	07/16 - 11/22	2 / 12	1.2 - 2.2	--	--	--	--	--	6	--	--	FOD <25%
SHP-95-27X	Arsenic	10/15 - 11/22	7 / 7	69 - 100	89.1	95	13.1	0.15	NST	5	0.094	-10	STABLE
SHP-99-1B	Arsenic	06/17 - 06/17	1 / 1	40 - 40	--	--	--	--	--	5	--	--	Ins. Data
Bedrock Wells													
20-1	Arsenic	07/16 - 11/22	6 / 6	1.1 - 6	3	2.55	1.8	0.60	NST	5	0.500	-1	STABLE
27-1	Arsenic	07/16 - 11/22	6 / 6	6.6 - 8	7.4	7.5	0.54	0.073	NST	5	0.430	-2	STABLE
27-2	Arsenic	11/09 - 11/22	6 / 7	5.3 - 10	7.8	8.35	1.8	0.23	NST	5	0.191	7	STABLE
3-2	Arsenic	11/09 - 11/22	9 / 9	6.9 - 91	64.4	69	24.6	0.38	NST	--	0.381	-4	STABLE
CAP-2B	Arsenic	07/16 - 11/22	5 / 5	3.7 - 8.3	5.6	5.7	1.8	0.32	NST	5	0.080	7	STABLE
CH-1D	Arsenic	11/09 - 11/22	9 / 9	290 - 650	518	570	130	0.25	UP	--	0.012	22	Increasing
CH-1S	Arsenic	11/09 - 11/22	6 / 7	18 - 31	24	23.5	4.6	0.19	NST	5	0.191	7	STABLE
N7-P1	Arsenic	11/99 - 11/22	8 / 8	49 - 170	110	119.5	40.5	0.37	NST	--	0.317	5	STABLE
Q4-1	Arsenic	07/16 - 11/22	6 / 6	8.6 - 14	11	10.85	2.3	0.21	NST	5	0.235	5	STABLE
Q5-1	Arsenic	07/16 - 11/22	4 / 6	2.1 - 2.7	2.3	2.15	0.29	0.13	NST	5	0.068	9	STABLE
SHP-2016-06A	Arsenic	06/17 - 11/22	15 / 15	280 - 2800	1100	960	665	0.60	UP	--	0.002	59	Increasing
SHP-2016-06B	Arsenic	06/17 - 11/22	15 / 15	290 - 1300	880	1100	404	0.46	DWN	--	<0.001	-63	Decreasing

Table 6
Summary Statistics and Trend Results
Former Fort Devens Army Installation
Devens, Massachusetts

Well ID	Analyte	Date Range	FOD	Detected Results Summary [1]					Mann-Kendall Test [2]				Trend Designation Based on CV
				Range	Mean	Median	SD	CV	Result [4]	MK Result Note	P-Value	S Value	
SHP-2016-06C	Arsenic	06/17 - 11/22	15 / 15	210 - 380	316	310	50.8	0.16	UP	--	0.002	60	Increasing
SHP-2016-07A	Arsenic	06/17 - 05/22	10 / 10	2.2 - 200	85.6	82.5	64.8	0.76	NST	--	0.300	7	STABLE
SHP-2016-07B	Arsenic	06/17 - 11/22	15 / 15	7.9 - 200	88.1	80	56.3	0.64	NST	--	0.069	31	STABLE
SHP-99-1C	Arsenic	11/99 - 06/22	5 / 5	1.2 - 8.9	4.1	2.2	3.5	0.85	NST	[5]	0.117	-6	STABLE

Abbreviations:

-- : "insufficient data for calculating statistics (n < 4) or not available"
CV : coefficient of variation
DWN : downward trend
FOD : frequency of detection (# detects / # samples)
mean : arithmetic mean
ND : non-detect
NST : no significant trend
p-value : probability value
S-Value : Mann-Kendall S Statistic
SD : standard deviation
UP : upward trend
< : less than
MK : Mann-Kendall

Notes:

1. All analytical results are in micrograms per liter (µg/L).
2. Trend results are presented when the following criteria are met: at least four samples are available and the frequency of detection is greater than or equal to 20%.
3. Non-detects were assigned a common value less than the minimum detected value, equal to half the minimum limit of quantitation (LOQ) in the dataset (USEPA 2009).
   If half the minimum LOQ was greater than the minimum detected value, then half the minimum detect was assigned.
4. Statistically significant trend defined as having p-value ≤ 0.05, or 95% confidence.
5. MK Trend results for datasets with fewer than 8 samples may not be reliable and should be treated with caution.
6. MK Trend results for datasets with an FOD <20% may not be reliable and should be treated with caution.

Reference:

USEPA. 2009. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities. Unified Guidance. EPA/530/R-09/007, 2009.

Table 7
Central Tendency Value Selection
Former Fort Devens Army Installation
Devens, Massachusetts

Well ID	Sample Count	Detects	Trend Present?	Non-Detect Treatment	Distribution	Selected CTV Type	CTV[1]
Overburden Wells							
32M-01-14XOB	28	24	no	1/2 LOQ	Normal	Arithmetic Mean	45.3
32M-92-01X	15	2	n/a	n/a	Nonparametric	Median	3.0
32Z-01-07X	4	0	n/a	n/a	Unknown	Median LOQ	<3
MW 4-1	1	1	n/a	n/a	Unknown	Most Recent Result	3.8
MW-1	1	1	n/a	n/a	Unknown	Most Recent Result	6.6
MW-7	1	0	n/a	n/a	Unknown	Most Recent Result	<3
MW-14	1	0	n/a	n/a	Unknown	Most Recent Result	<3
MW-22	1	0	n/a	n/a	Unknown	Most Recent Result	<3
N1-P1	7	0	n/a	n/a	Unknown	Median LOQ	<3
N1-P2	9	9	YES	n/a	Nonparametric (Distribution)	Median	120
N1-P3	9	9	YES	n/a	Normal	Arithmetic Mean	18.9
N7-P2	8	8	no	n/a	Normal	Arithmetic Mean	154
SHL-1	1	1	n/a	n/a	Unknown	Most Recent Result	1.5
SHL-7	14	2	n/a	n/a	Nonparametric	Median	3
SHL-12	19	15	no	Kaplan-Meier	Nonparametric (Distribution)	Median	2
SHL-15	41	41	no	n/a	Lognormal	Geomean	43.2
SHL-17	6	1	n/a	n/a	Nonparametric	Median	3
SHL-18	7	5	no	Kaplan-Meier	Normal	Median LOQ	<2
SHL-23	28	5	n/a	n/a	Nonparametric	Median	3
SHL-24	20	20	YES	n/a	Normal	Arithmetic Mean	4.66
SHL-25	7	5	no	Kaplan-Meier	Normal	Arithmetic Mean	2.5
SHM-93-18B	12	1	n/a	n/a	Nonparametric	Median	3
SHM-93-24A	12	2	n/a	n/a	Nonparametric	Median	3
SHP-95-27X	7	7	no	n/a	Normal	Arithmetic Mean	89.1
SHP-99-1B	1	1	n/a	n/a	Unknown	Most Recent Result	40
Bedrock Wells							
20-1	6	6	no	n/a	Normal	Arithmetic Mean	3.0
27-1	6	6	no	n/a	Normal	Arithmetic Mean	7.4
27-2	7	6	no	1/2 LOQ	Normal	Arithmetic Mean	7.4
3-2	9	9	no	n/a	Normal	Arithmetic Mean	64.4
CAP-2B	5	5	no	n/a	Normal	Arithmetic Mean	5.6
CH-1D	9	9	YES	n/a	Normal	Arithmetic Mean	518
CH-1S	7	6	no	1/2 LOQ	Normal	Arithmetic Mean	22
N7-P1	8	8	no	n/a	Normal	Arithmetic Mean	110
Q4-1	6	6	no	n/a	Normal	Arithmetic Mean	10.9
Q5-1	6	4	no	Kaplan-Meier	Normal	Median LOQ	<2.45
SHP-2016-06A	15	15	YES	n/a	Normal	Arithmetic Mean	1100
SHP-2016-06B	15	15	YES	n/a	Nonparametric (Distribution)	Median	1100
SHP-2016-06C	15	15	YES	n/a	Normal	Arithmetic Mean	316
SHP-2016-07A	10	10	no	n/a	Normal	Arithmetic Mean	85.6
SHP-2016-07B	15	15	no	n/a	Normal	Arithmetic Mean	88.1
SHP-99-1C	5	5	no	n/a	Normal	Arithmetic Mean	4.1

Notes:

[1] Units are in micrograms per liter

Acronyms and Abbreviations:

CTV : central tendency value

LOQ : limit of quantitation

n/a : not applicable

< : less than

Table 8
Overburden and Bedrock Arsenic Groundwater Dataset Comparisons Using Two-Sided, Two-Sample Hypothesis Test
Former Fort Devens Installation
Devens, Massachusetts

Overburden Dataset						Bedrock Dataset						Central Tendency Test[4,5]		
													Two-Sided Test	
Sample Size	Detects	Mean[1]	Median[2]	FOD (%)	Distribution[3]	Sample Size	Detects	Mean[1]	Median[2]	FOD (%)	Distribution[3]	Test	P-Value	Site Different from Background?
25	18	22.37	3	72%	Nonparametric	16	15	215	43.2	94%	Lognormal	T-W	1.19E-03	**Overburden ≠ Bedrock**

Acronyms and Abbreviations:

FOD: frequency of detection
Ho: null hypothesis
mg/L: milligrams per liter
n: sample size
n/a: not analyzed
WMW: Wilcoxon-Mann-Whitney
T-W: Tarone-Ware
<: less than
≤: less than or equal to
=: equals
≠: does not equal

Notes:

[1] The mean concentration includes a Kaplan-Meier adjustment for nondetects if the dataset contains non-detects. Kaplan-Meier adjustments calculated using ProUCL version 5.2..

[2] The median concentration is the 50th percentile for the full dataset (i.e., includes detects and non-detects).

[3] Distribution assessed by goodness-of-fit tests using ChemStat software at a 95% confidence level (a = 0.05).
Distributions:
Normal (N): dataset follows a normal distribution according to the Shapiro-Wilk test (n ≤ 50) or Shapiro-Francia test (n > 50).
Lognormal (Ln): dataset follows a lognormal distribution according to the Shapiro-Wilk test (n ≤ 50) or Shapiro-Francia test (n > 50).
Nonparametric (NP): dataset does not follow any of the three distributions listed above.

[4] Hypothesis testing conducted on datasets with sample size ≥ 8 and detects ≥ 5 in ProUCL version 5.1.002. Appropriate hypothesis test selected based on degree of censoring, range of non-detects, and distribution of the dataset:
t-Test: FOD = 100% and both datasets are normally or lognormally distributed.
Wilcoxon-Mann-Whitney: 40% < FOD ≤ 100%, dataset includes non-detects with a single reporting limit or datasets were not normally distributed.
Gehan: FOD < 100%, dataset includes non-detects with multiple reporting limits.
Tarone-Ware: FOD < 100%, one or both datasets include detects at or below the minimum non-detect reporting limit.

[5] Two-sided Alternative Null hypothesis H_0: Overburden Mean/Median = Bedrock Mean/Median. Reject H_0 if p-value is less than 0.1. Conclusions are based on α = 0.1.
Gray shading indicates there is a statistically significant difference between overburden and bedrock concentrations.

References:

USEPA. 2015. ProUCL Version 5.1 Technical Guide. Office of Research and Development. EPA/600/R-07/041. October.

Table 9
Upper Tolerance Limits
Former Fort Devens Army Installation
Devens, Massachusetts

Dataset	Sample Count	Detects	Mean[1]	Standard Deviation[1]	K Value	Distribution	UTL95-95[2]	Achieved Confidence
Overburden Wells	25	18	n/a	n/a	n/a	Nonparametric	154	0.723
Bedrock Wells	16	15	3.65	2.11	2.524	Lognormal	7839	n/a
Overburden Reducing Wells	10	9	51.7	50.3	2.911	Normal	198	n/a

Notes:

[1] Data are transformed where required.

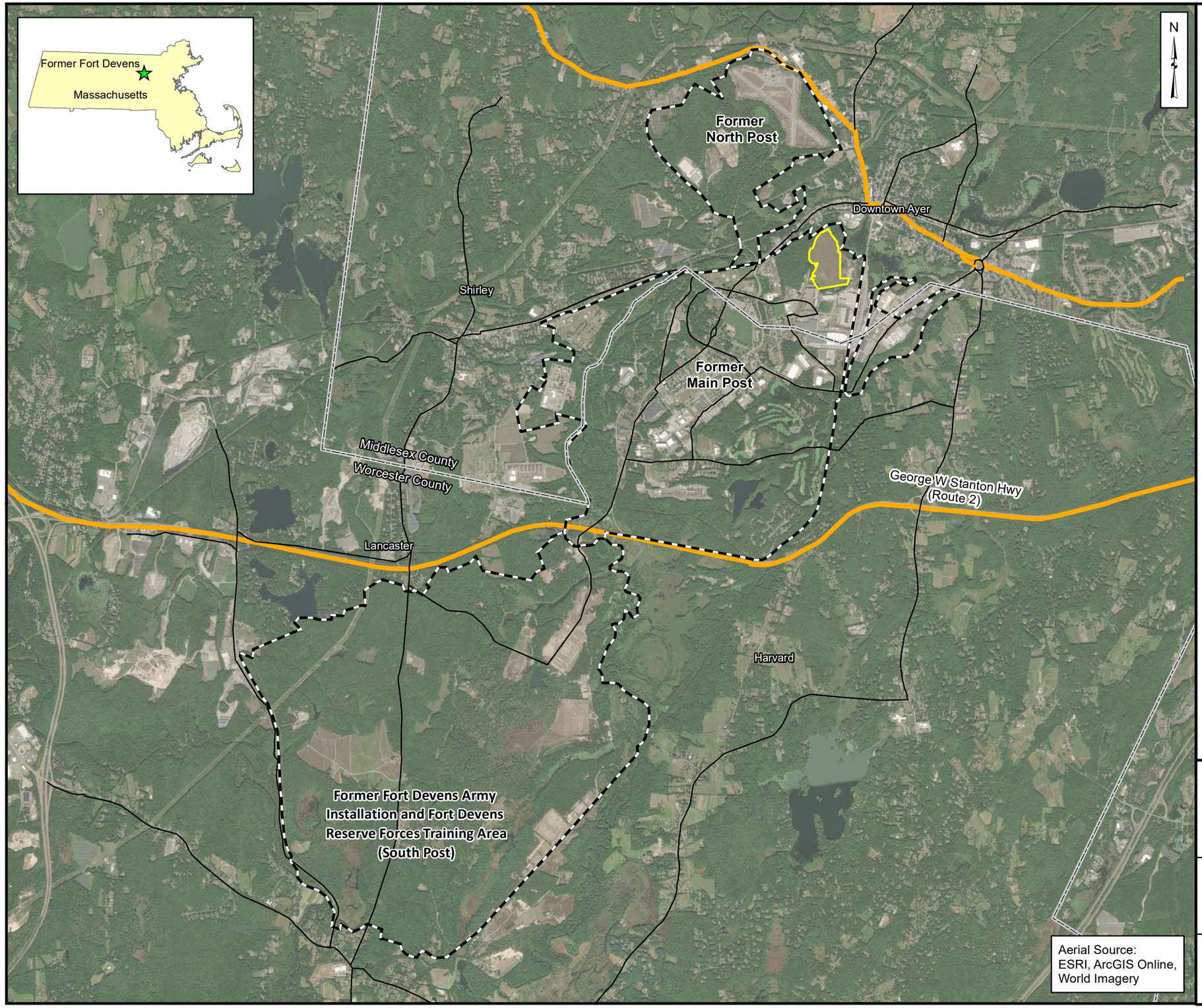
[2] Units are in micrograms per liter

Acronyms and Abbreviations:

n/a : not applicable

UTL95-95 : 95 percent upper tolerance limit with 95 percent coverage

Figures



Legend

- Former Fort Devens Boundary
- Shepley's Hill Landfill Boundary
- County Line
- Highway
- Major Road

0 1 2

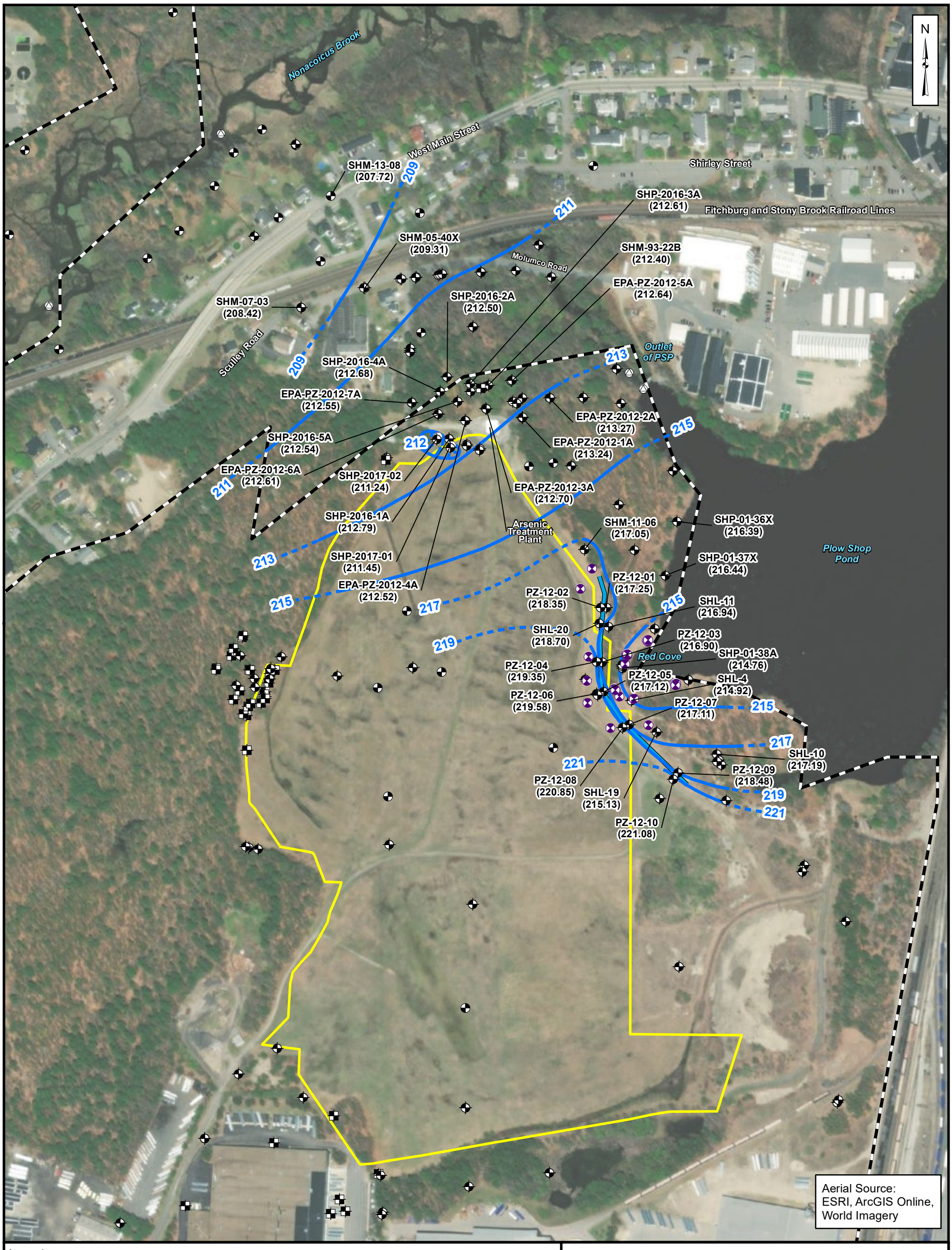
Miles

Report on the Evaluation of Site-Specific Arsenic Background Concentrations in Groundwater - Shepley's Hill Landfill
Former Fort Devens Army Installation
Devens, Massachusetts

Site Location

SERES Engineering & Services, LLC
ARCADIS
a joint venture

Figure
1



Aerial Source: ESRI, ArcGIS Online, World Imagery

Legend

- Former Fort Devens Boundary
- Shepley's Hill Landfill Boundary
- Overburden Monitoring Well/Piezometer
- Groundwater Profiling Location/Monitoring Well
- Monitoring Well
- Bedrock Monitoring Well
- Extraction Well
- Stream Gauge
- Barrier Wall
- Groundwater Contour (ft NAVD88) (Interval = 2 ft)
- Groundwater Contour (ft NAVD88) (Interval = 2 ft) (Inferred)
- Groundwater Extraction Zone

ft NAVD88 = North American Vertical Datum of 1988

0 200 400
Feet

Report on the Evaluation of Site-Specific
Arsenic Background Concentrations in Groundwater
Shepley's Hill Landfill
Former Fort Devens Army Installation

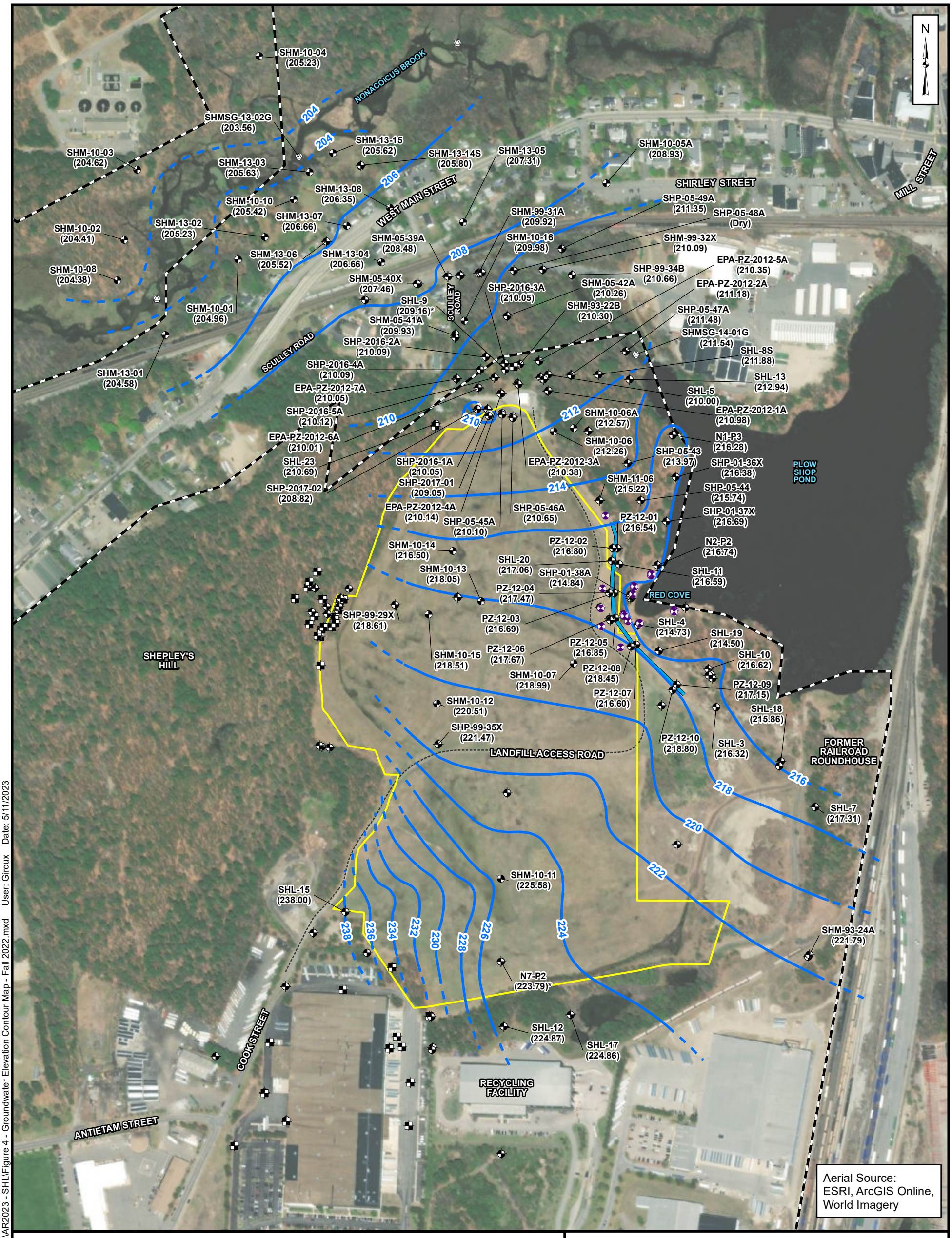
Groundwater Elevation Contour Map
Spring 2022

SERES Engineering & Services, LLC
ARCADIS a joint venture

Figure **2**

Document Path: T:_ENV\Devens_RFTA\Seed_Task_Order\MXDs\AR2023 - SHL\APR_2023\Figure 3 - SHL GWC - Spring 2022.mxd

File: Figure 3 - SHL GWC - Spring 2022.mxd



Legend

- Former Fort Devens Boundary
- Shepley's Hill Landfill Boundary
- Overburden Monitoring Well/Piezometer
- Groundwater Profiling Location/Monitoring Well
- Monitoring Well
- Bedrock Monitoring Well
- Extraction Well
- Stream Gauge
- Barrier Wall
- Landfill Access Road
- Groundwater Contour (ft NAVD88) (Interval = 2 ft) (dashed where inferred)
- Groundwater Extraction Zone

Note:
1. Wells N7-P2 and SHL-9 not used for contouring.
2. ft NAVD88 = North American Vertical Datum of 1988
3. 2-ft interval used for drafting contour lines, with the exception of near the EW-1 and EW-4 extraction well area (1-ft interval)

0 200 400
Feet

Report on the Evaluation of Site-Specific Arsenic Background Concentrations in Groundwater
Shepley's Hill Landfill
Former Fort Devens Army Installation

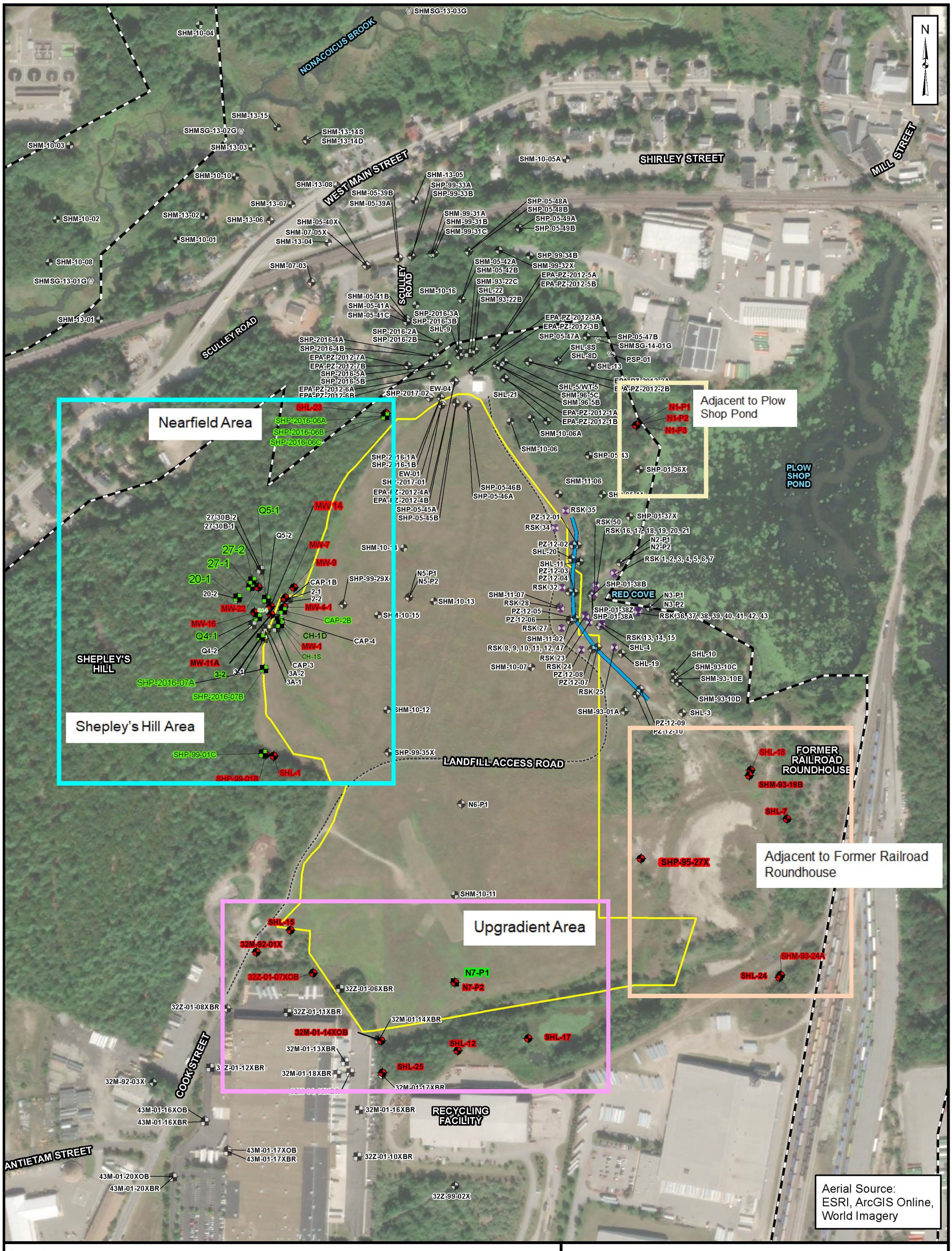
Groundwater Elevation Contour Map - Fall 2022

SERES Engineering & Services, LLC
ARCADIS a joint venture

Figure 3

Document Path: T:_ENV\Devens_RFTA\Seed_Task_Order\MXDs\AR2023 - SHL\Figure 4 - Groundwater Elevation Contour Map - Fall 2022.mxd User: Giroux Date: 5/11/2023

File: Figure 4 - Groundwater Elevation Contour Map - Fall 2022.mxd



Legend

- Bedrock Wells
- Overburden Wells
- Former Fort Devens Boundary
- Shepley's Hill Landfill Boundary
- Overburden Monitoring Well/Piezometer
- Groundwater Profiling Location/Monitoring Well
- Monitoring Well
- Bedrock Monitoring Well
- Extraction Well
- Stream Gauge
- Barrier Wall
- Landfill Access Road

0 200 400
Feet

Report on the Evaluation of Site-Specific Arsenic Background Concentrations in Groundwater - Shepley's Hill Landfill
Former Fort Devens Army Installation
Devens, Massachusetts

Site Plan

SERES Engineering & Services, LLC
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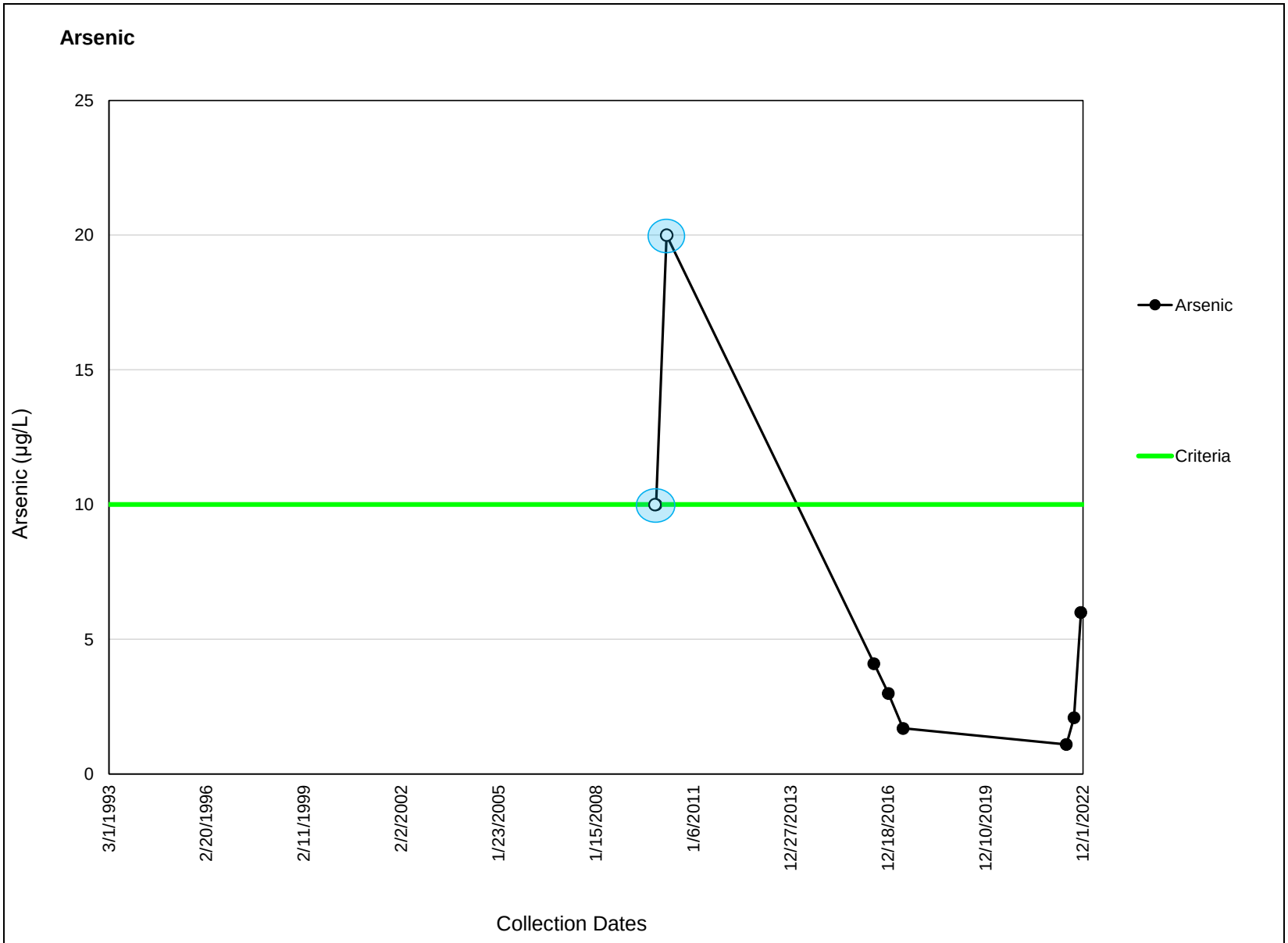
Figure
4

File: Figure 2 - SHL Site Layout REV.mxd

Appendix A

Time-Series Plots



Notes:

Detects indicated by full circle and nondetects indicated by open circle.

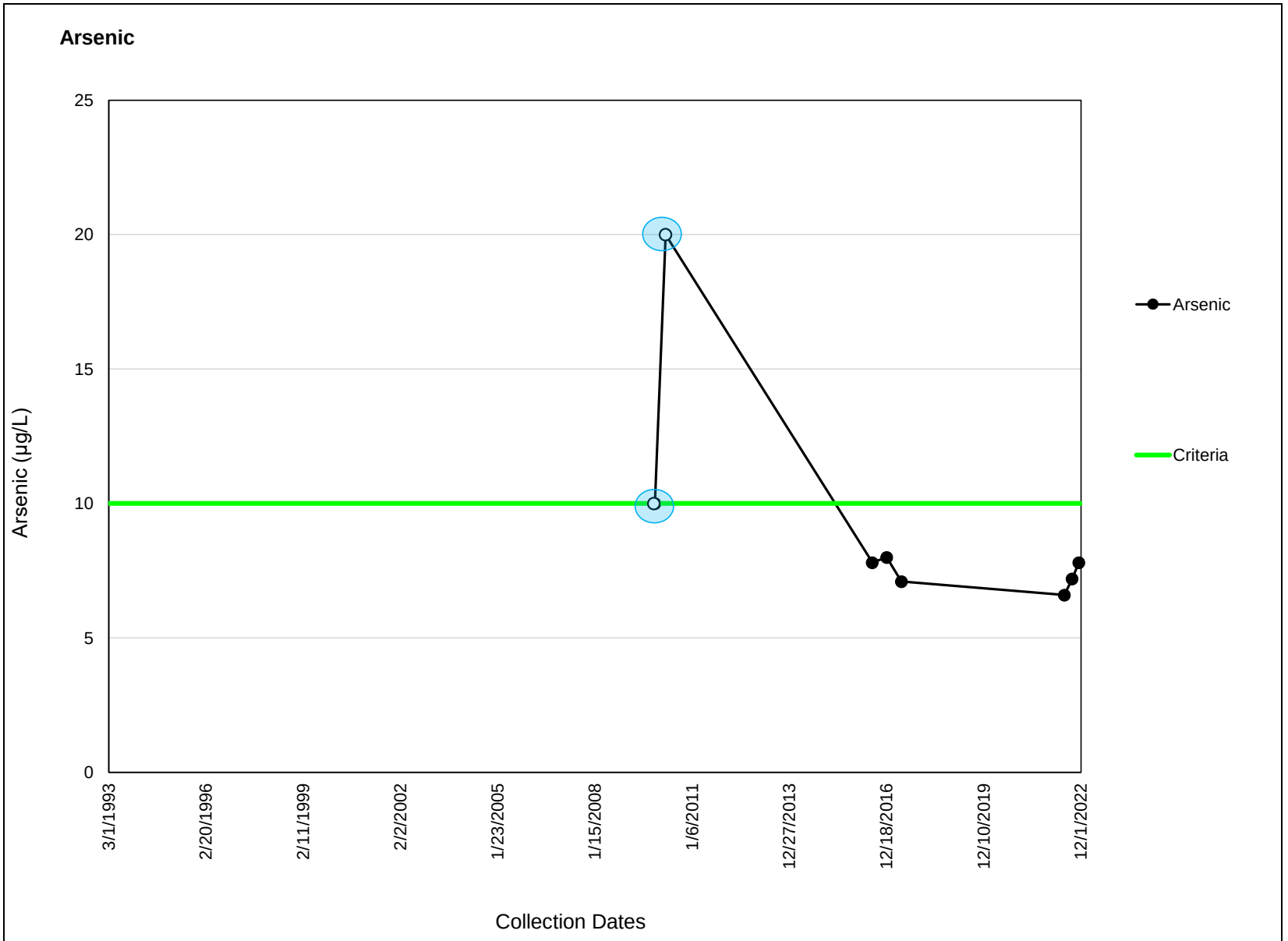
: Elevated non-detect excluded from evaluation.

Reporting limit is used for nondetects.

ARCADIS

Time-Series Trend Plot
Arsenic in Well 20-1
Shepley's Hill Landfill

FIGURE
A-1



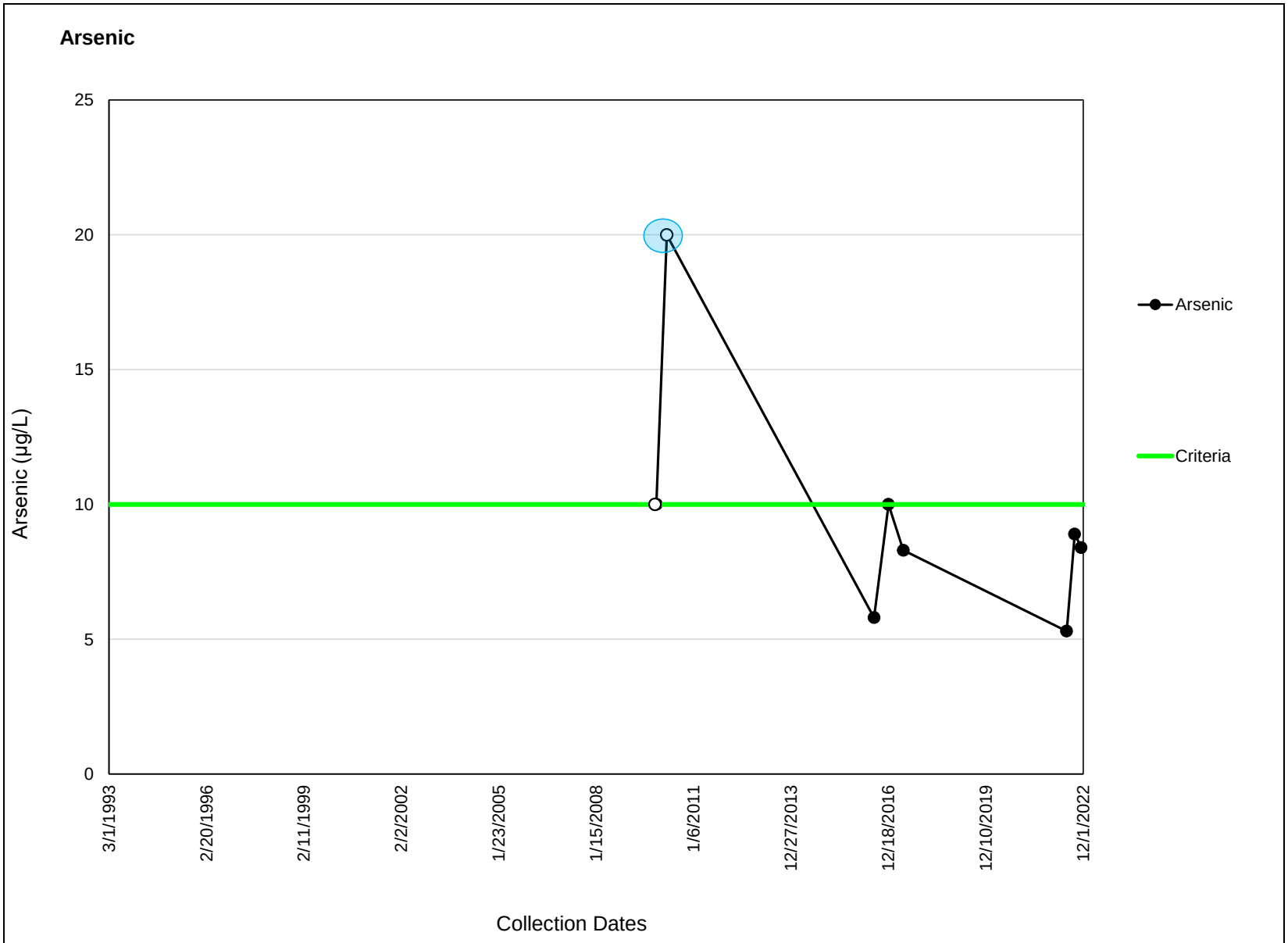
Notes:

Detects indicated by full circle and nondetects indicated by open circle.

: Elevated non-detect excluded from evaluation.

Reporting limit is used for nondetects.

ARCADIS	**Time-Series Trend Plot** **Arsenic in Well 27-1** Shepley's Hill Landfill	**FIGURE** **A-2**



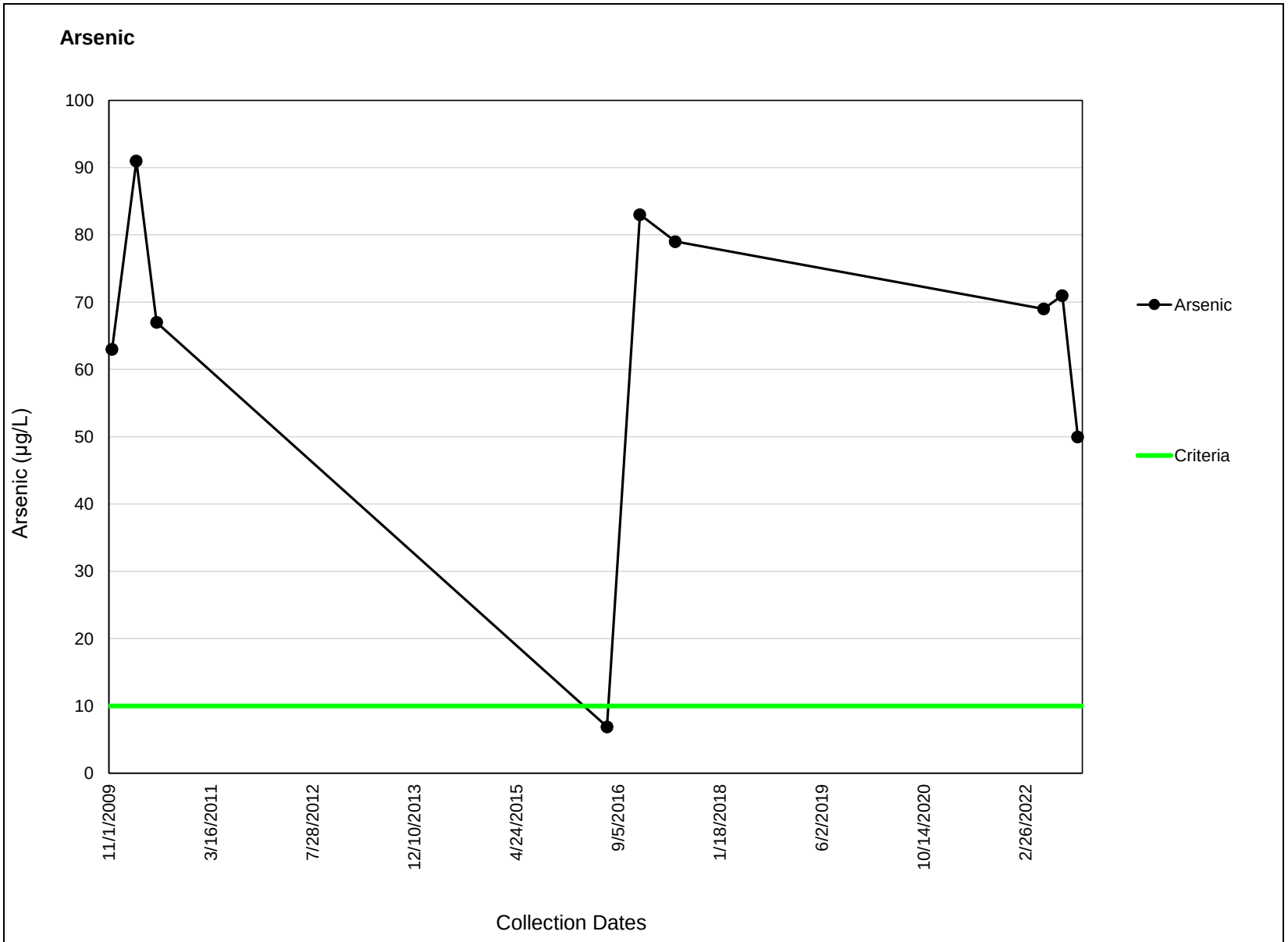
Notes:

Detects indicated by full circle and nondetects indicated by open circle.

: Elevated non-detect excluded from evaluation.

Reporting limit is used for nondetects.

ARCADIS	**Time-Series Trend Plot** **Arsenic in Well 27-2** Shepley's Hill Landfill	**FIGURE** **A-3**

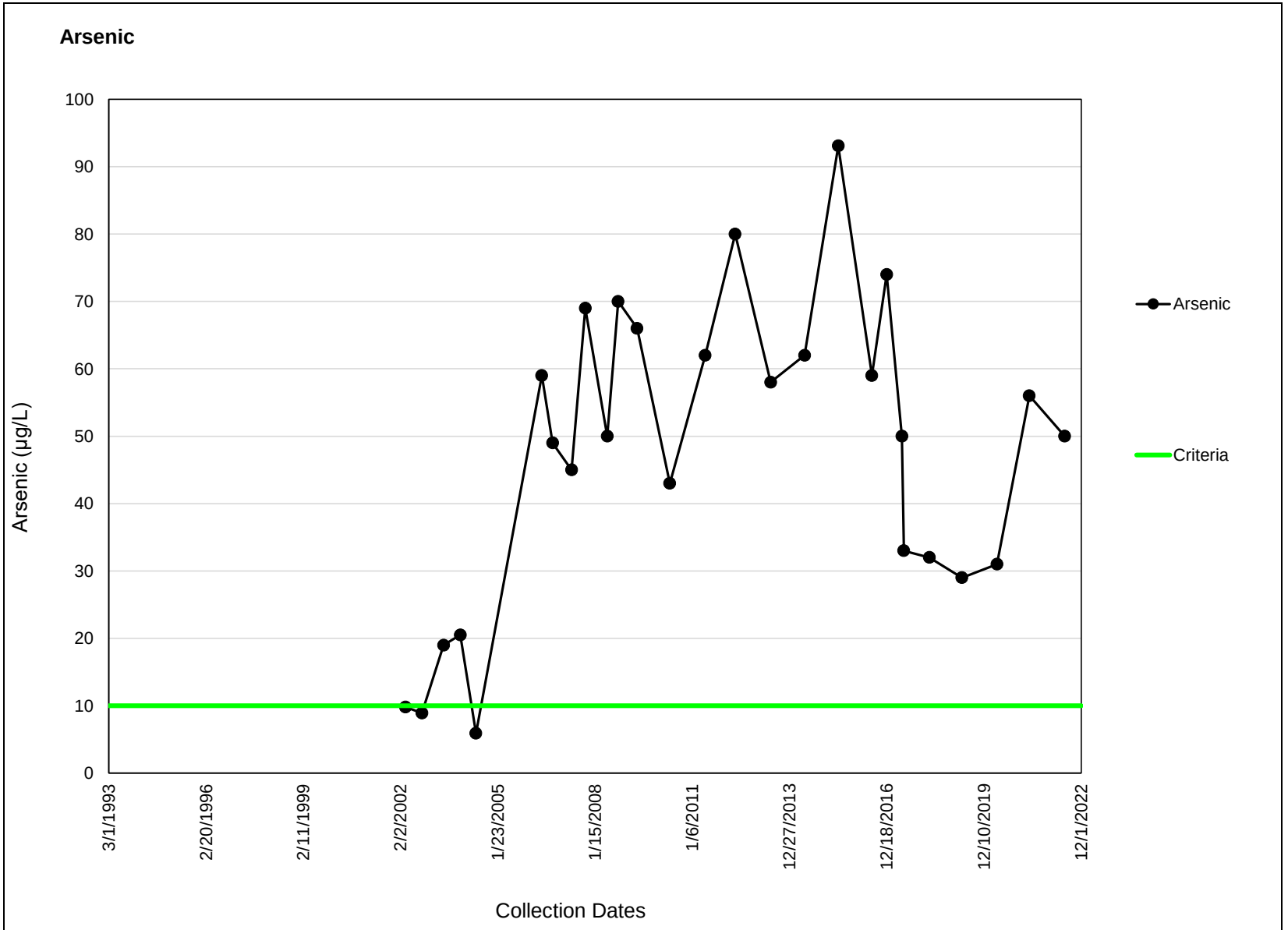


Notes:

Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS	**Time-Series Trend Plot** **Arsenic in Well 3-2** Shepley's Hill Landfill	**FIGURE** **A-4**



Notes:

Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS

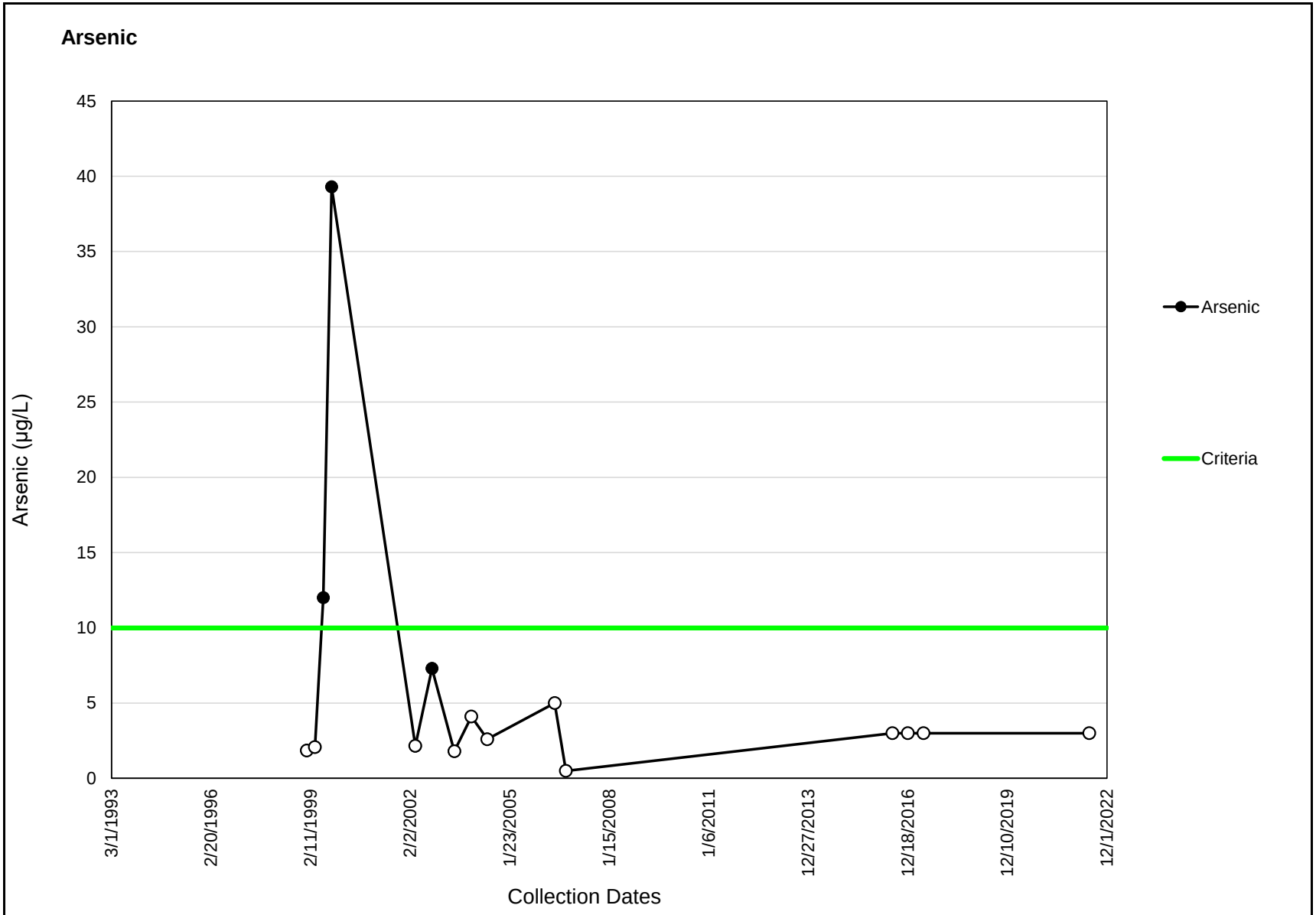
Time-Series Trend Plot

Arsenic in Well 32M-01-14XOB

Shepley's Hill Landfill

FIGURE

A-5



Notes:

Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS

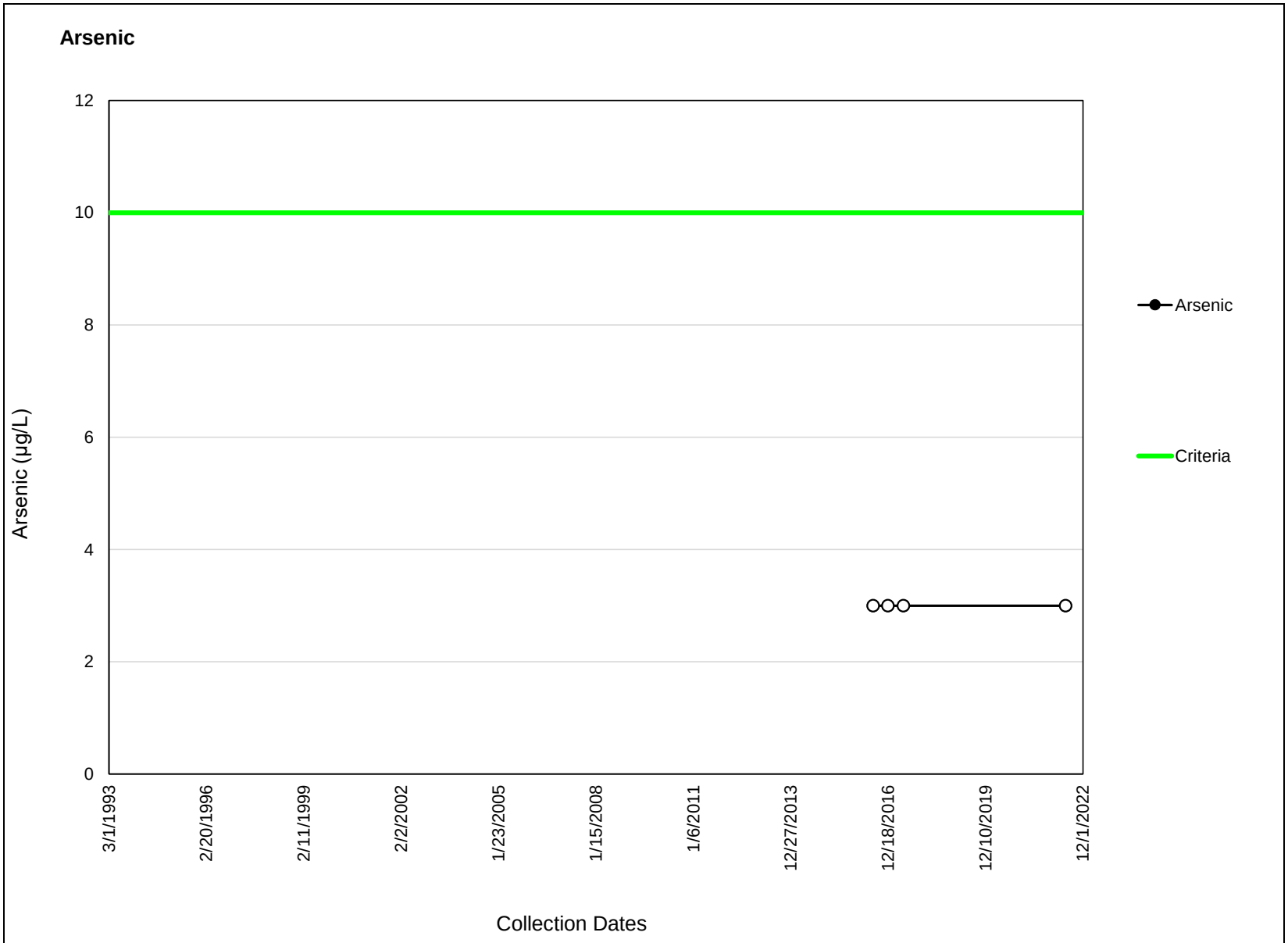
Time-Series Trend Plot

Arsenic in Well 32M-92-01X

Shepley's Hill Landfill

FIGURE

A-6



Notes:

Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS

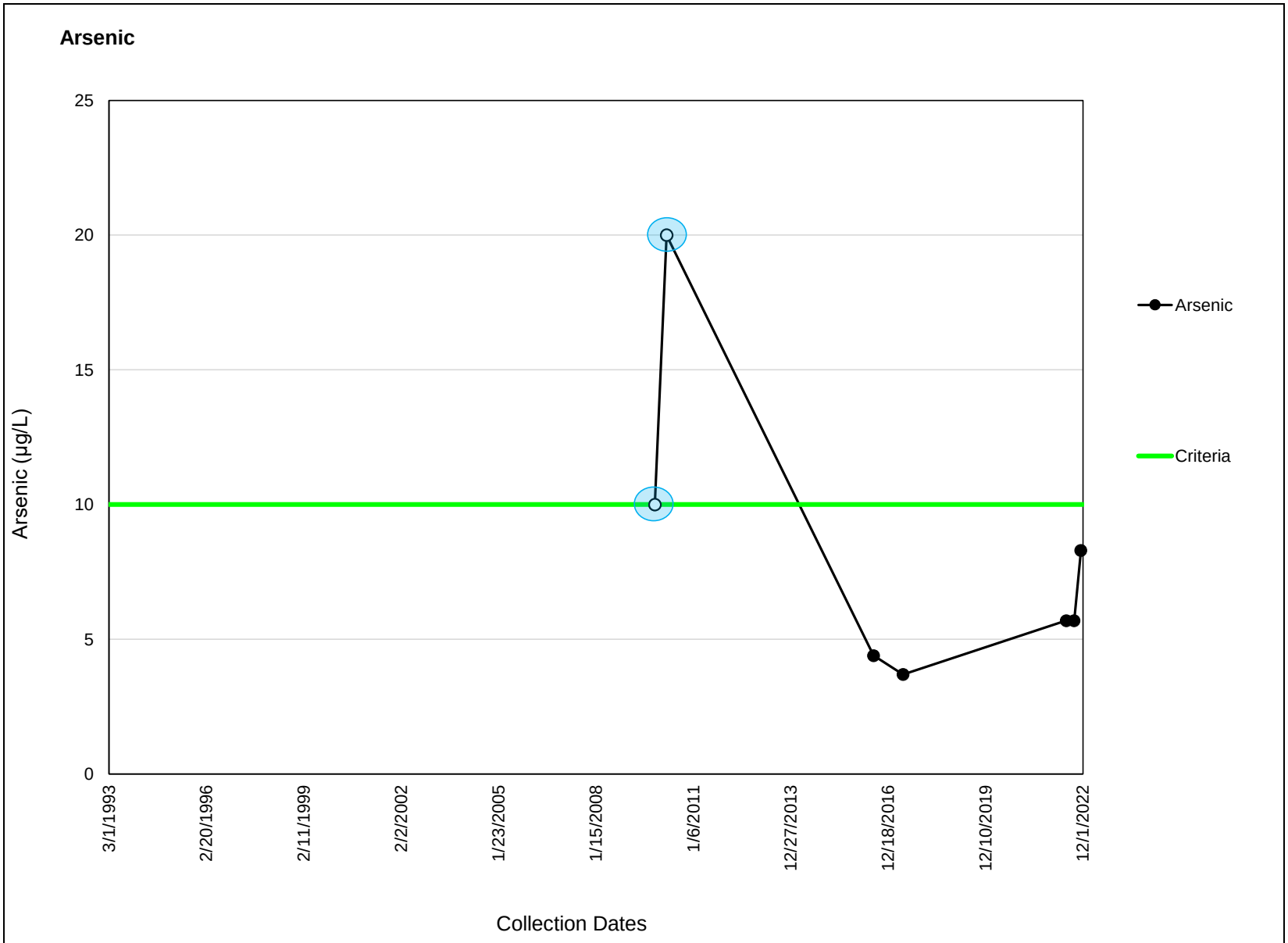
Time-Series Trend Plot

Arsenic in Well 32Z-01-07X

Shepley's Hill Landfill

FIGURE

A-7



Notes:

Detects indicated by full circle and nondetects indicated by open circle.

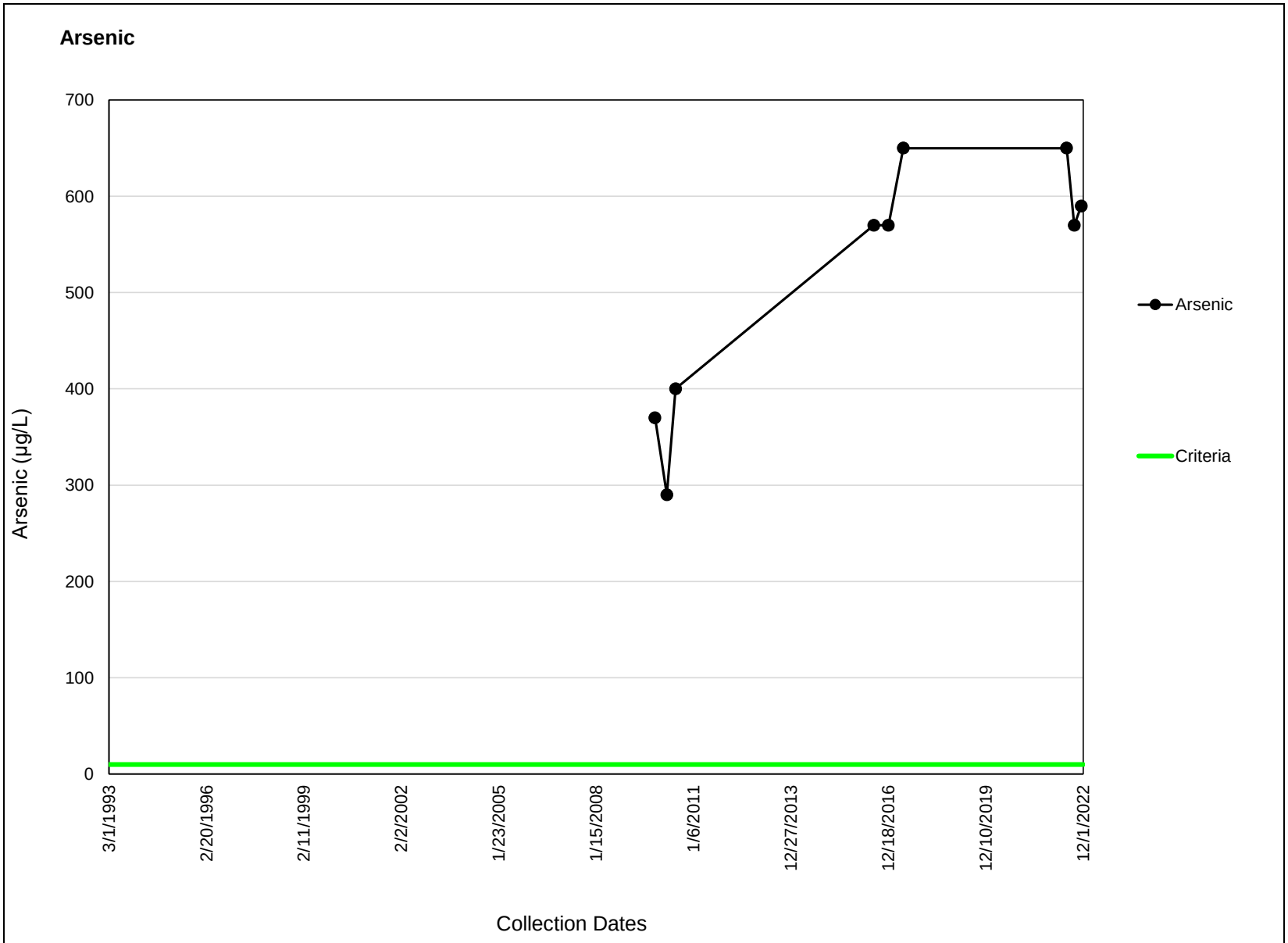
: Elevated non-detect excluded from evaluation.

Reporting limit is used for nondetects.

ARCADIS

Time-Series Trend Plot
Arsenic in Well CAP-2B
Shepley's Hill Landfill

FIGURE
A-8



Notes:

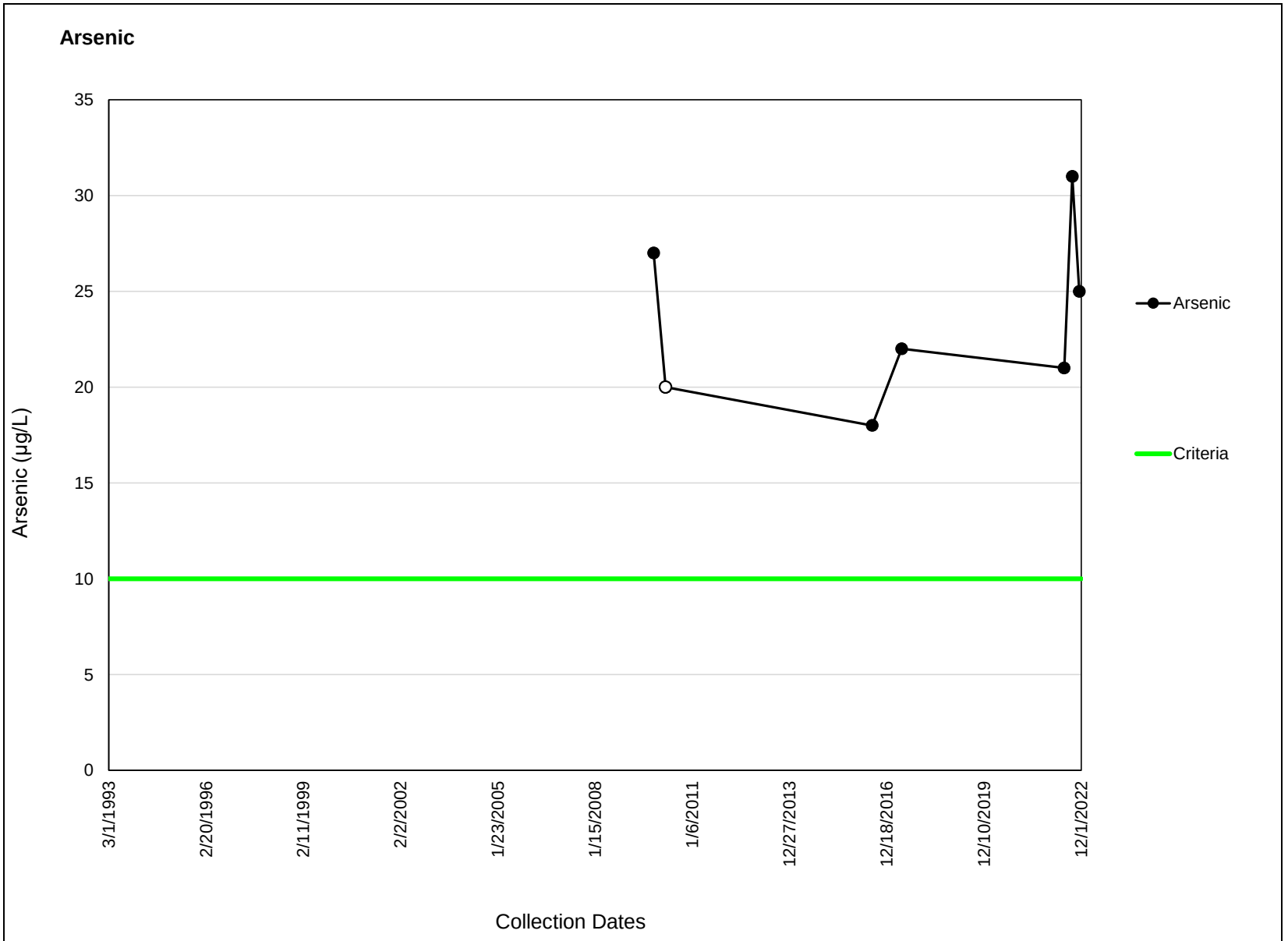
Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS

Time-Series Trend Plot
Arsenic in Well CH-1D
Shepley's Hill Landfill

FIGURE
A-9

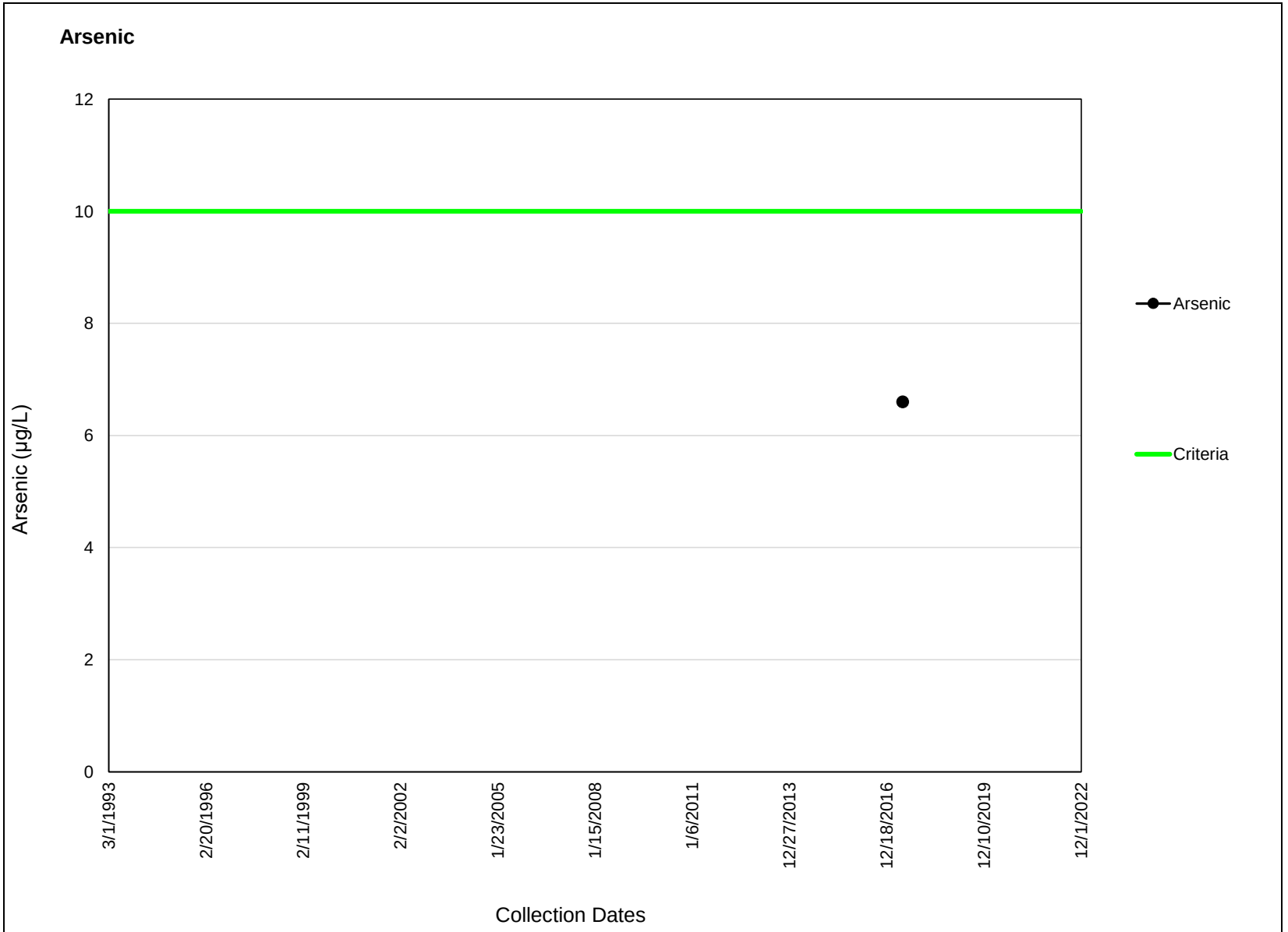


Notes:

Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS	**Time-Series Trend Plot** **Arsenic in Well CH-1S** Shepley's Hill Landfill	**FIGURE** **A-10**

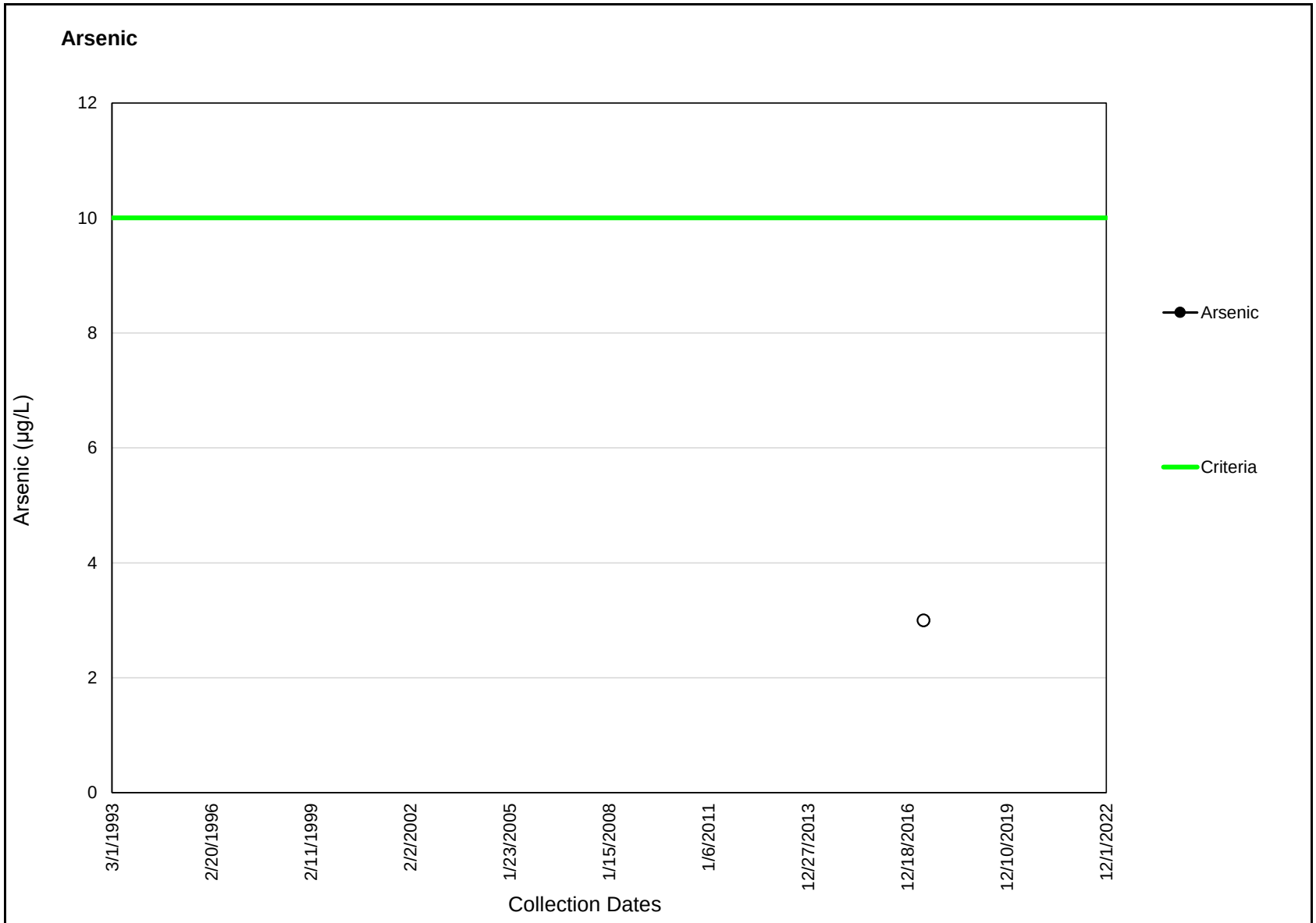


Notes:

Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS	**Time-Series Trend Plot** **Arsenic in Well MW-1** Shepley's Hill Landfill	**FIGURE** **A-11**

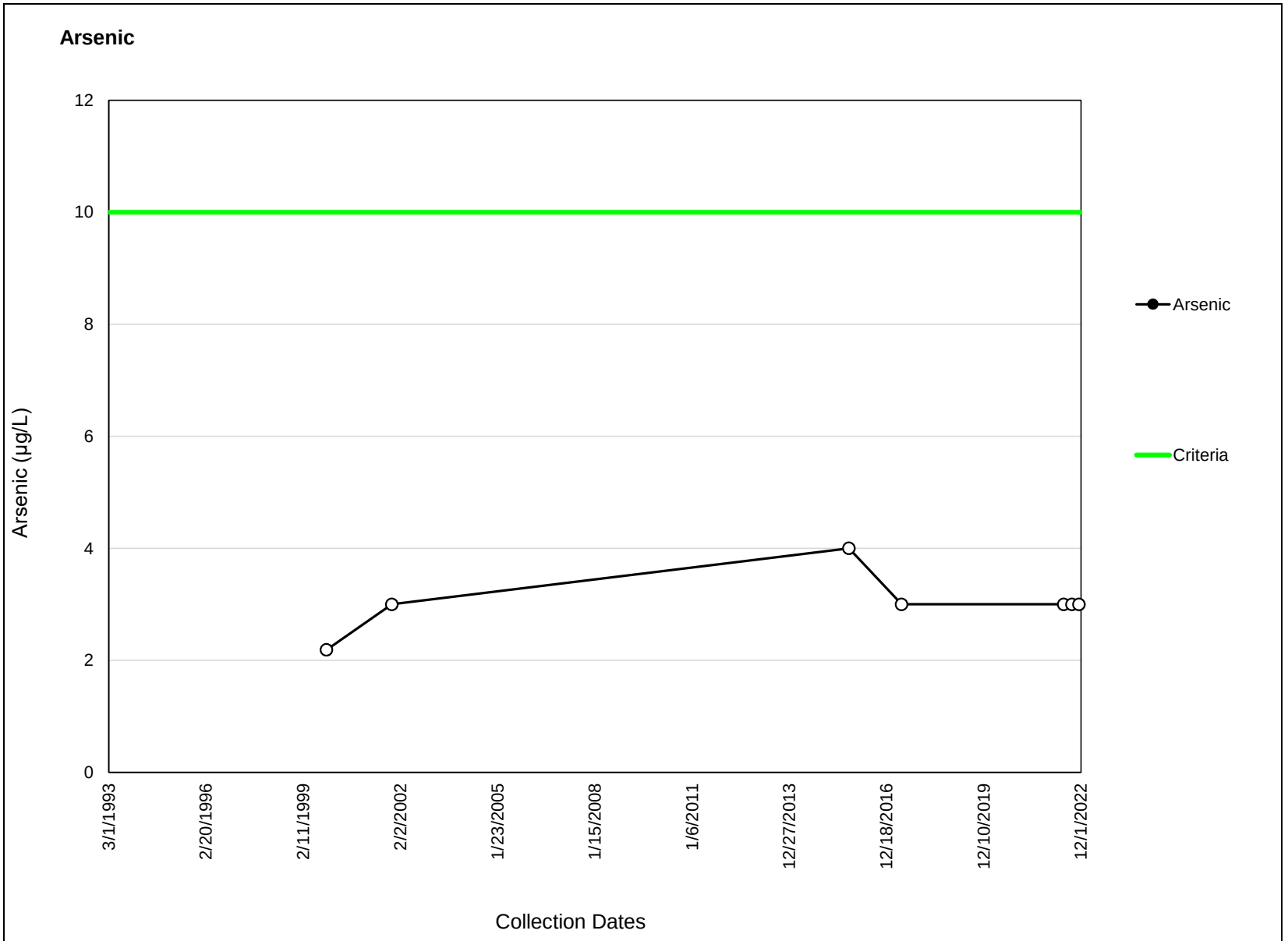


Notes:

Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS	**Time-Series Trend Plot** **Arsenic in Well MW-7** Shepley's Hill Landfill	**FIGURE** **A-12**



Notes:

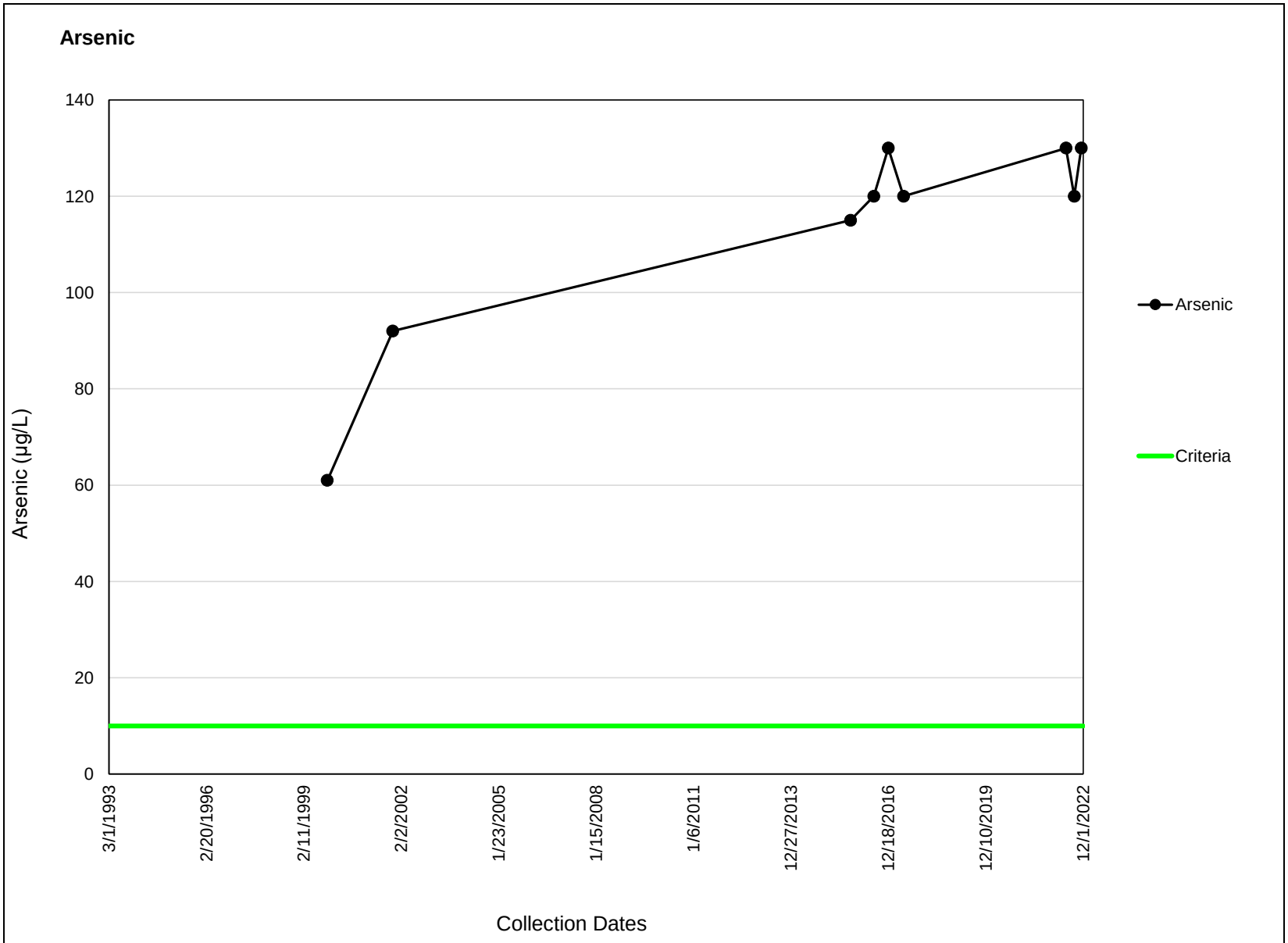
Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS

Time-Series Trend Plot
Arsenic in Well N1-P1
Shepley's Hill Landfill

FIGURE
A-13



Notes:

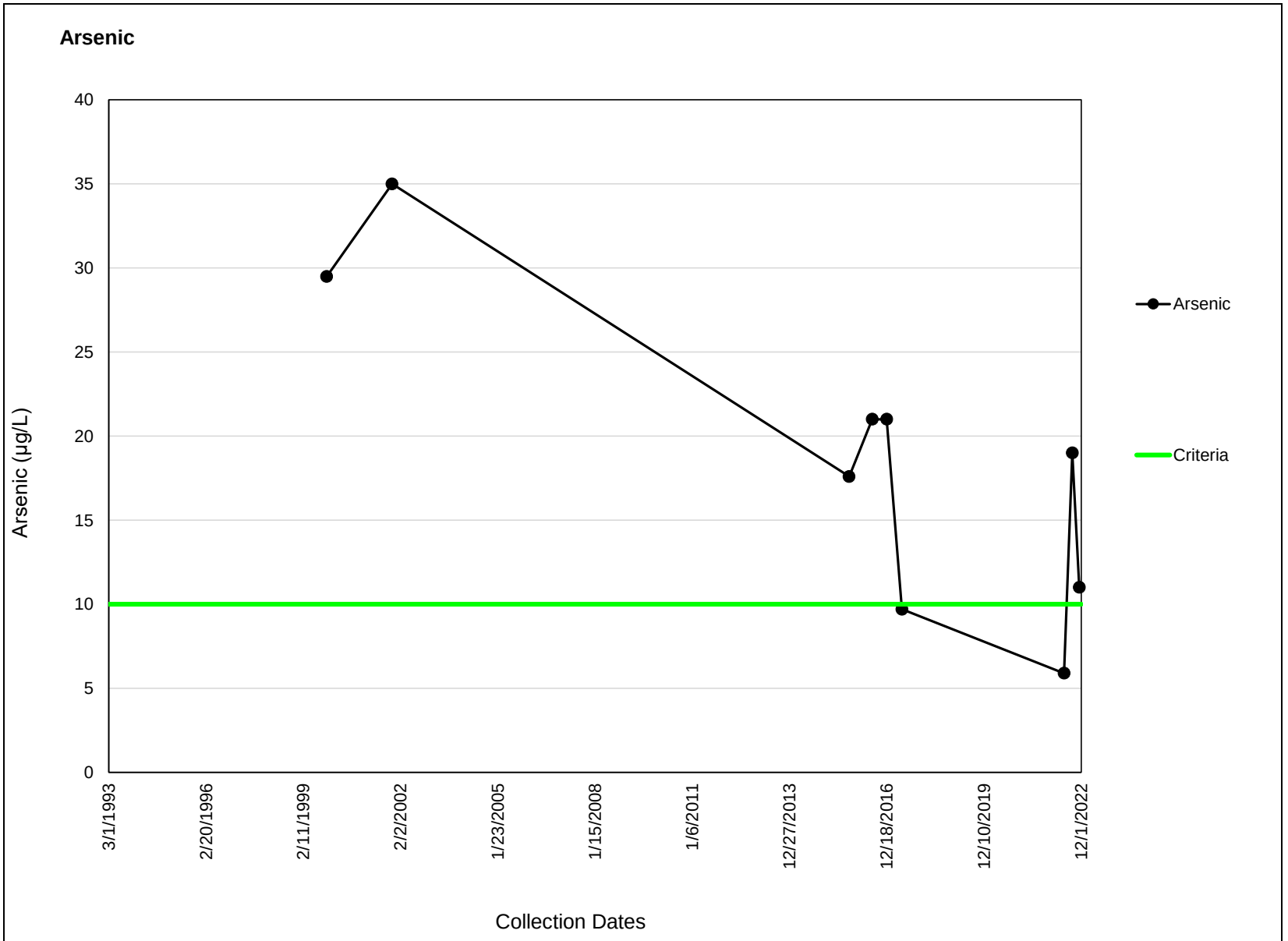
Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS

Time-Series Trend Plot
Arsenic in Well N1-P2
Shepley's Hill Landfill

FIGURE
A-14



Notes:

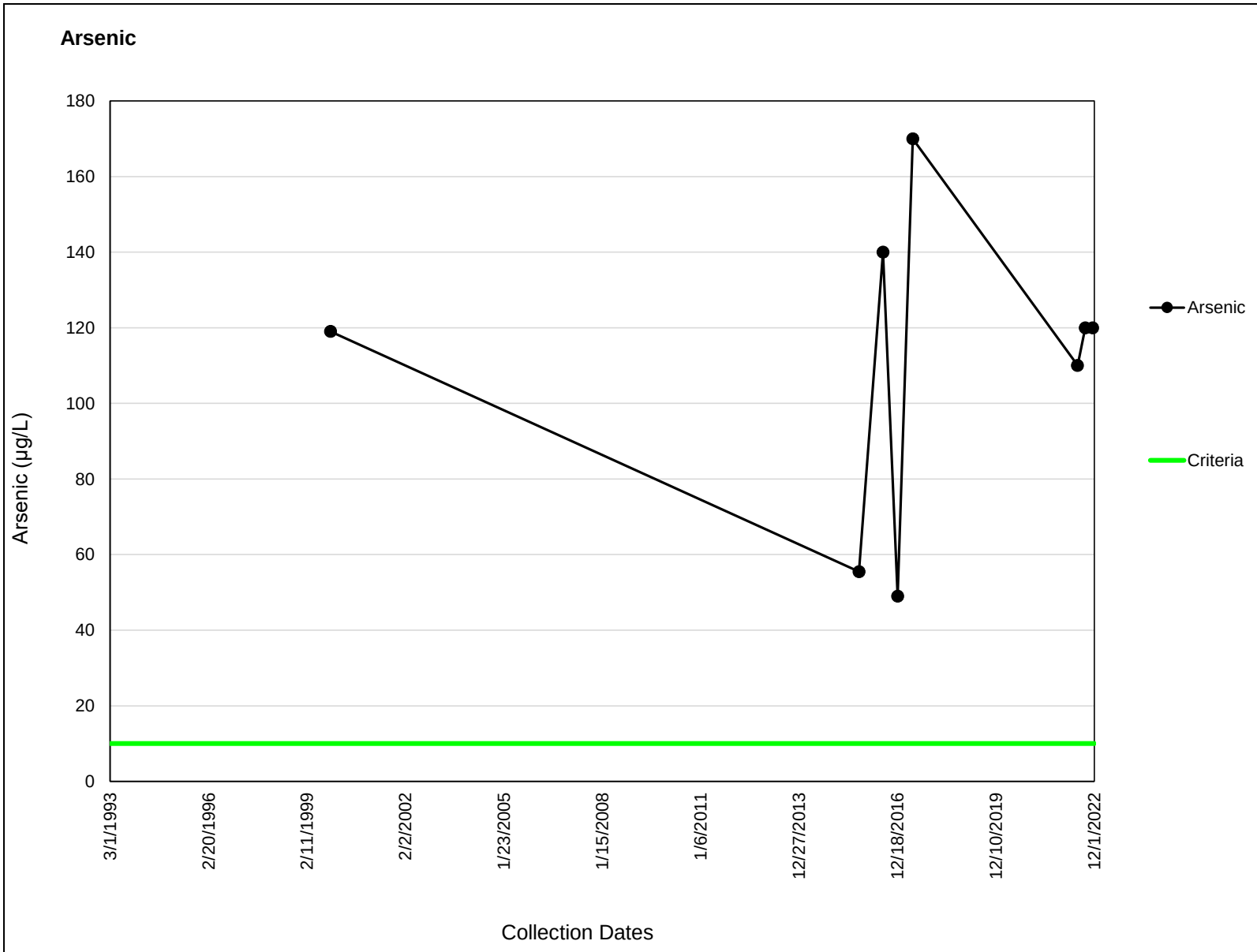
Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS

Time-Series Trend Plot
Arsenic in Well N1-P3
Shepley's Hill Landfill

FIGURE
A-15



Notes:

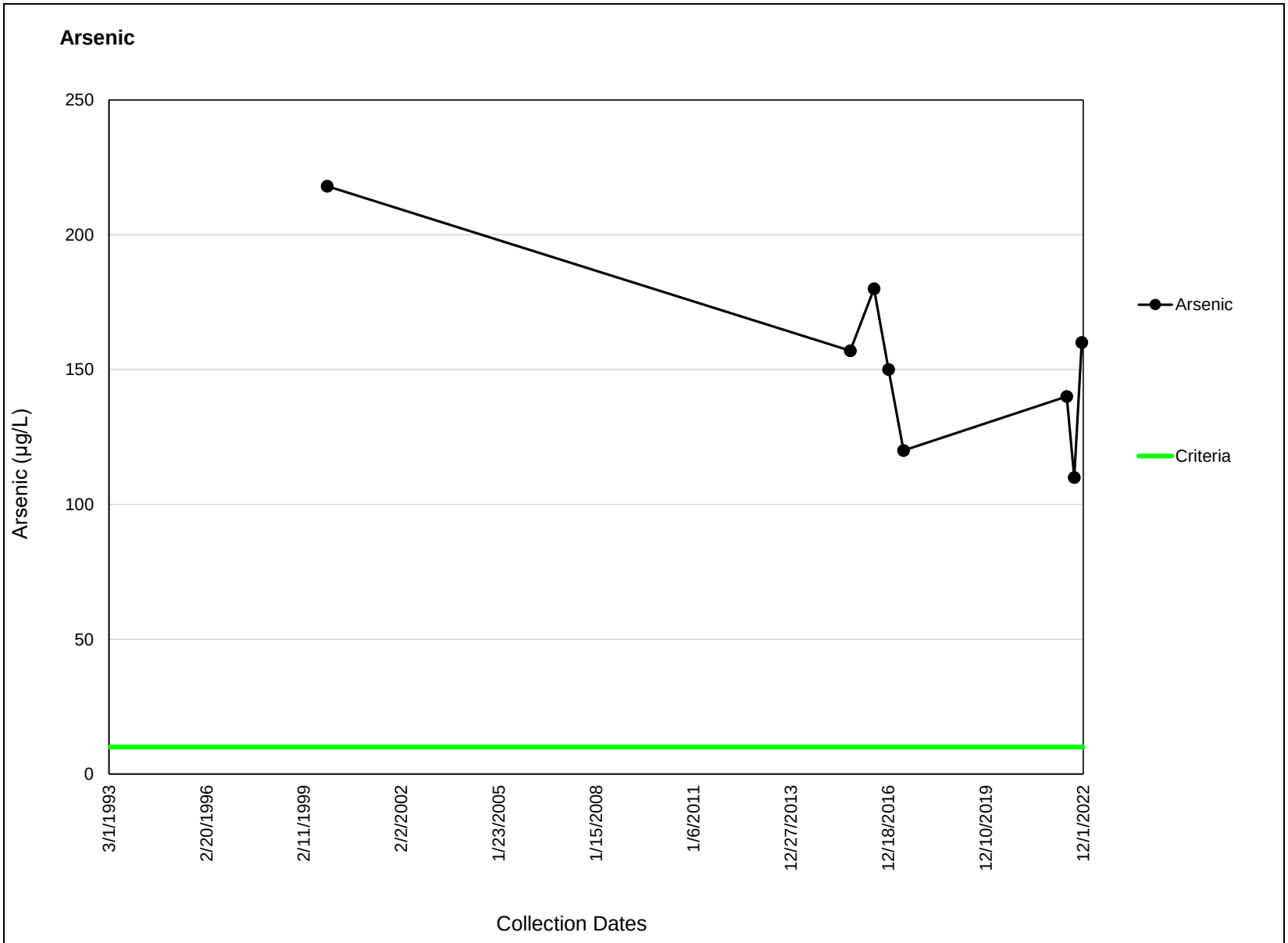
Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS

Time-Series Trend Plot
Arsenic in Well N7-P1
Shepley's Hill Landfill

FIGURE
A-16



Notes:

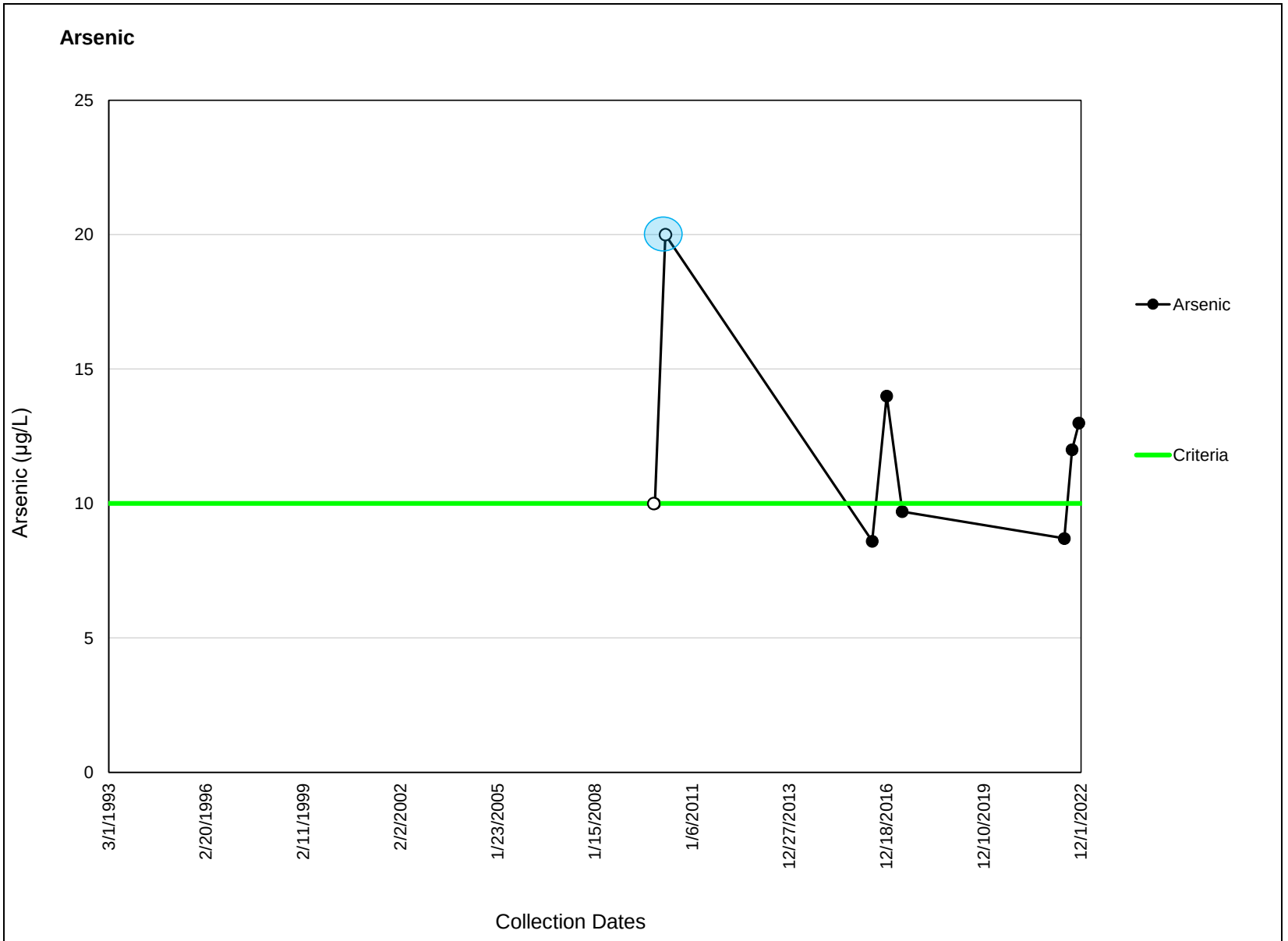
Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS

Time-Series Trend Plot
Arsenic in Well N7-P2
Shepley's Hill Landfill

FIGURE
A-17



Notes:

Detects indicated by full circle and nondetects indicated by open circle.

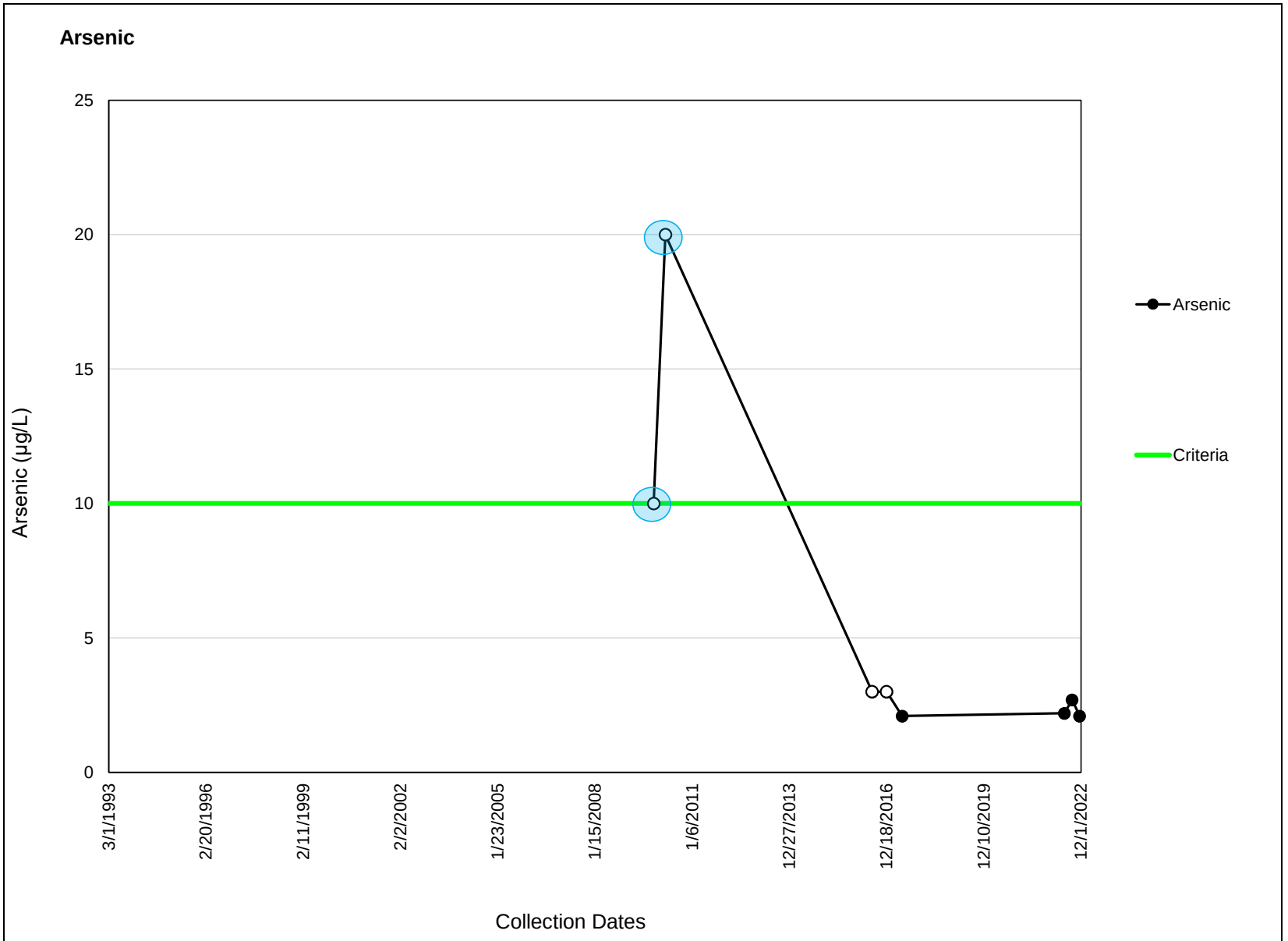
: Elevated non-detect excluded from evaluation.

Reporting limit is used for nondetects.

ARCADIS

Time-Series Trend Plot
Arsenic in Well Q4-1
Shepley's Hill Landfill

FIGURE
A-18



Notes:

Detects indicated by full circle and nondetects indicated by open circle.

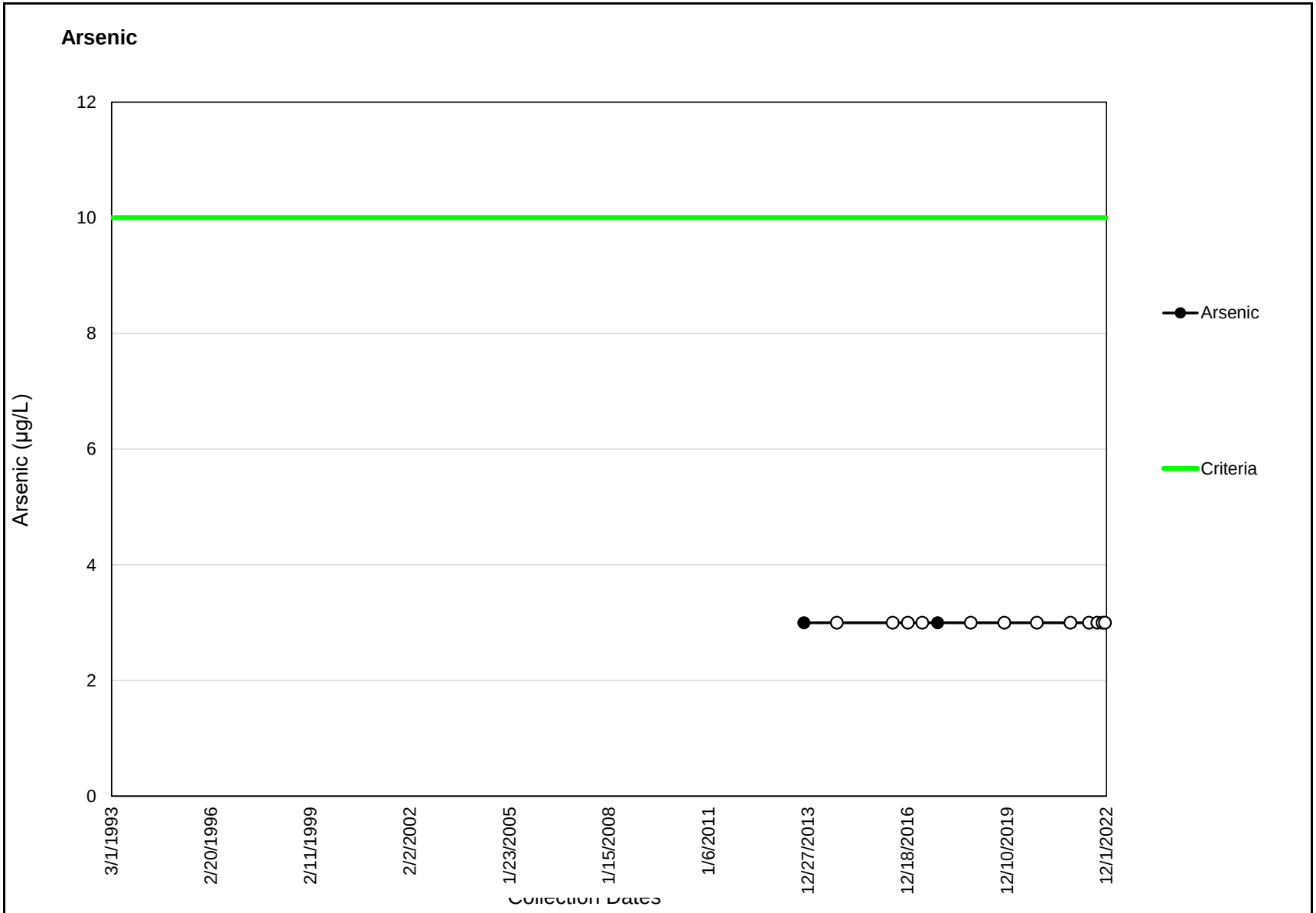
: Elevated non-detect excluded from evaluation.

Reporting limit is used for nondetects.

ARCADIS

Time-Series Trend Plot
Arsenic in Well Q5-1
Shepley's Hill Landfill

FIGURE
A-19

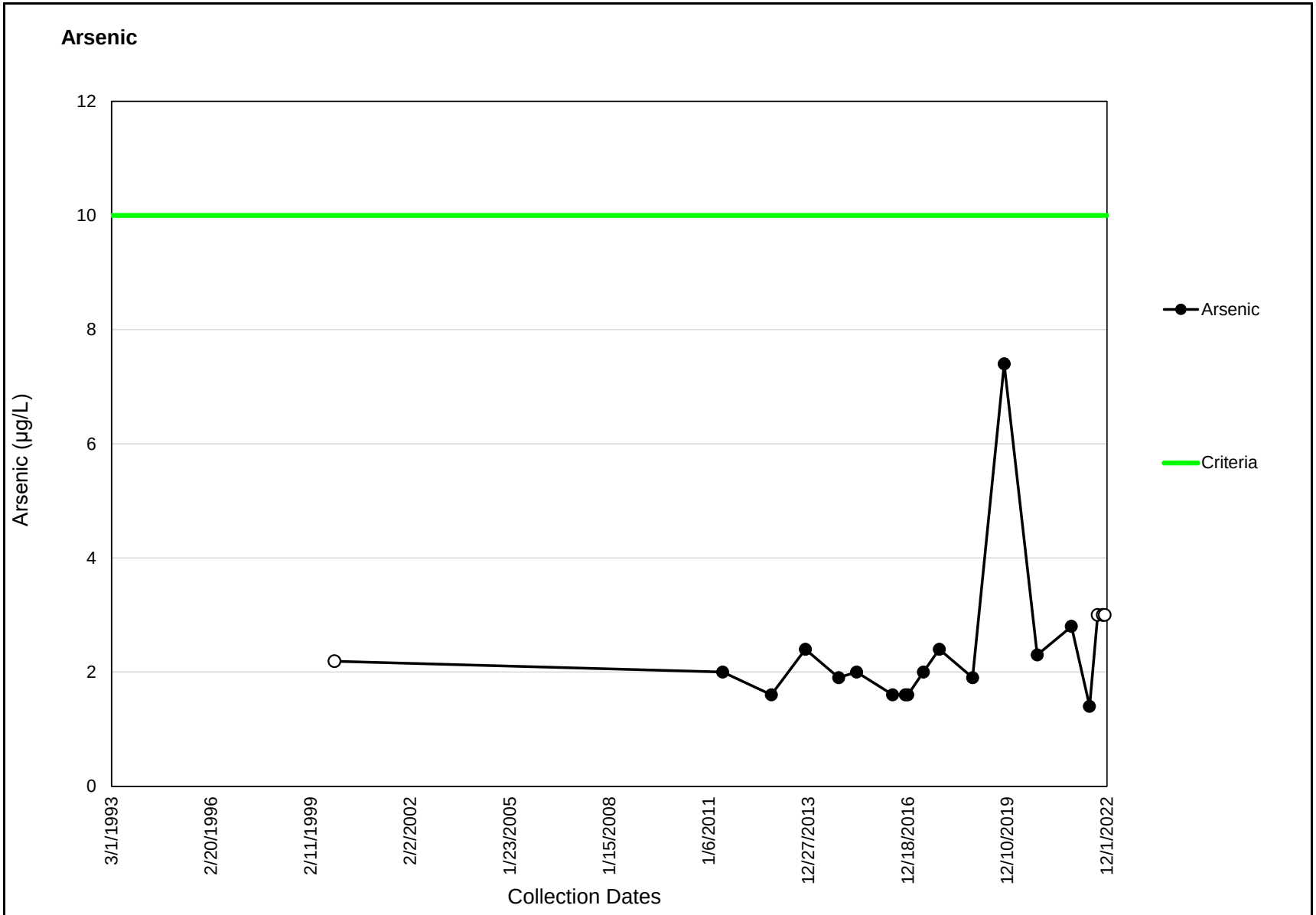


Notes:

Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS	**Time-Series Trend Plot** **Arsenic in Well SHL-7** Shepley's Hill Landfill	**FIGURE** **A-20**



Notes:

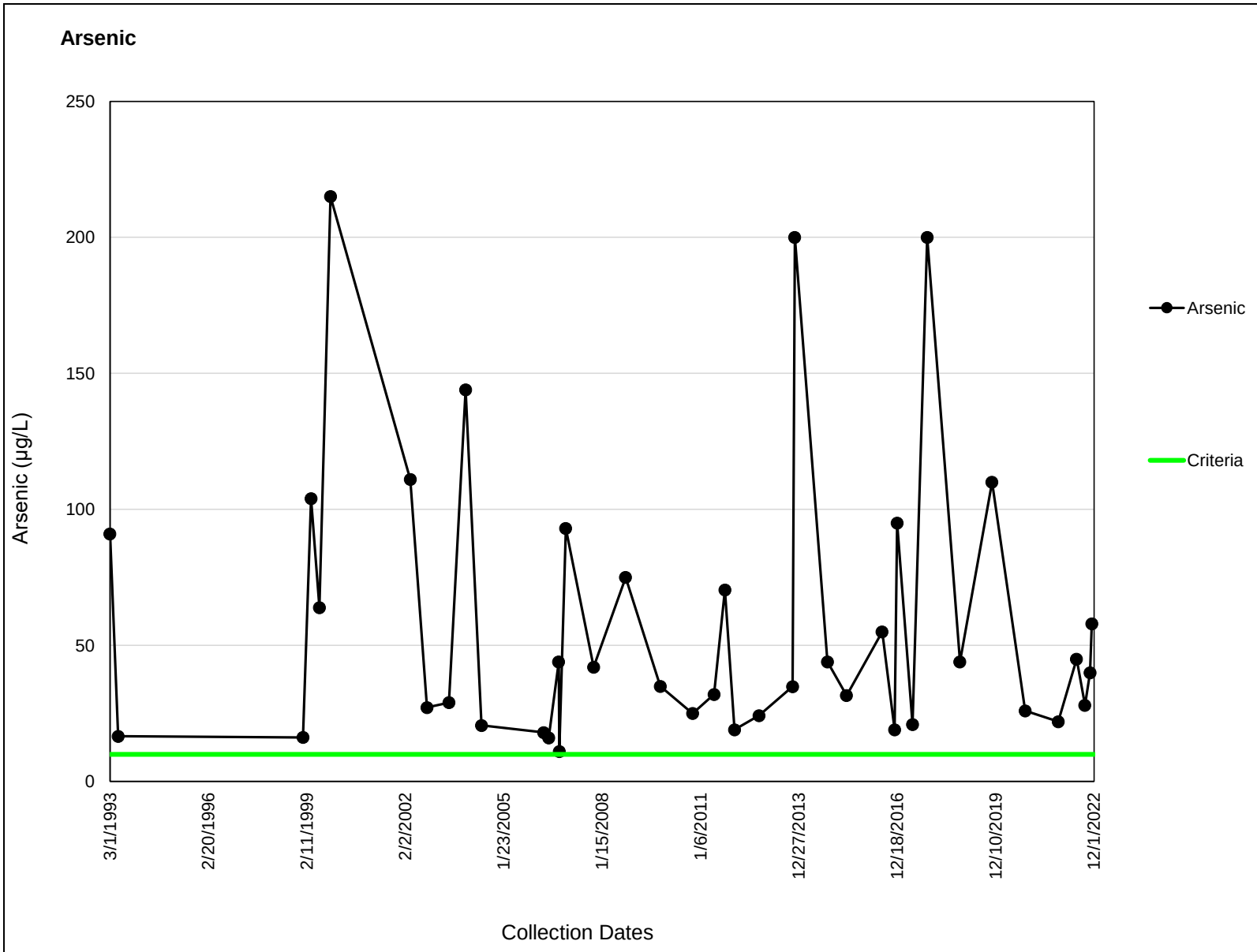
Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS

Time-Series Trend Plot
Arsenic in Well SHL-12
Shepley's Hill Landfill

FIGURE
A-21

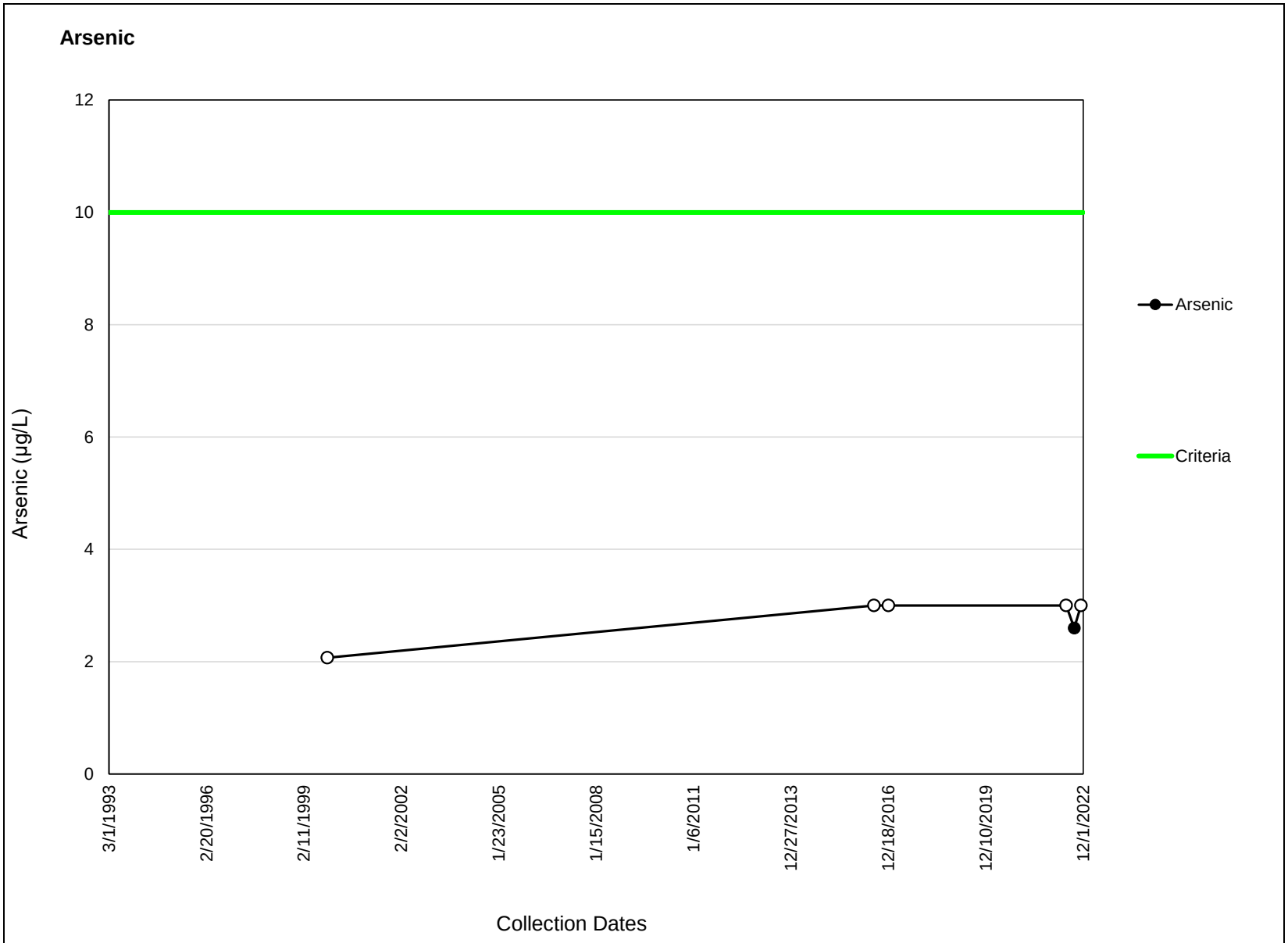


Notes:

Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS	**Time-Series Trend Plot** **Arsenic in Well SHL-15** Shepley's Hill Landfill	**FIGURE** **A-22**



Notes:

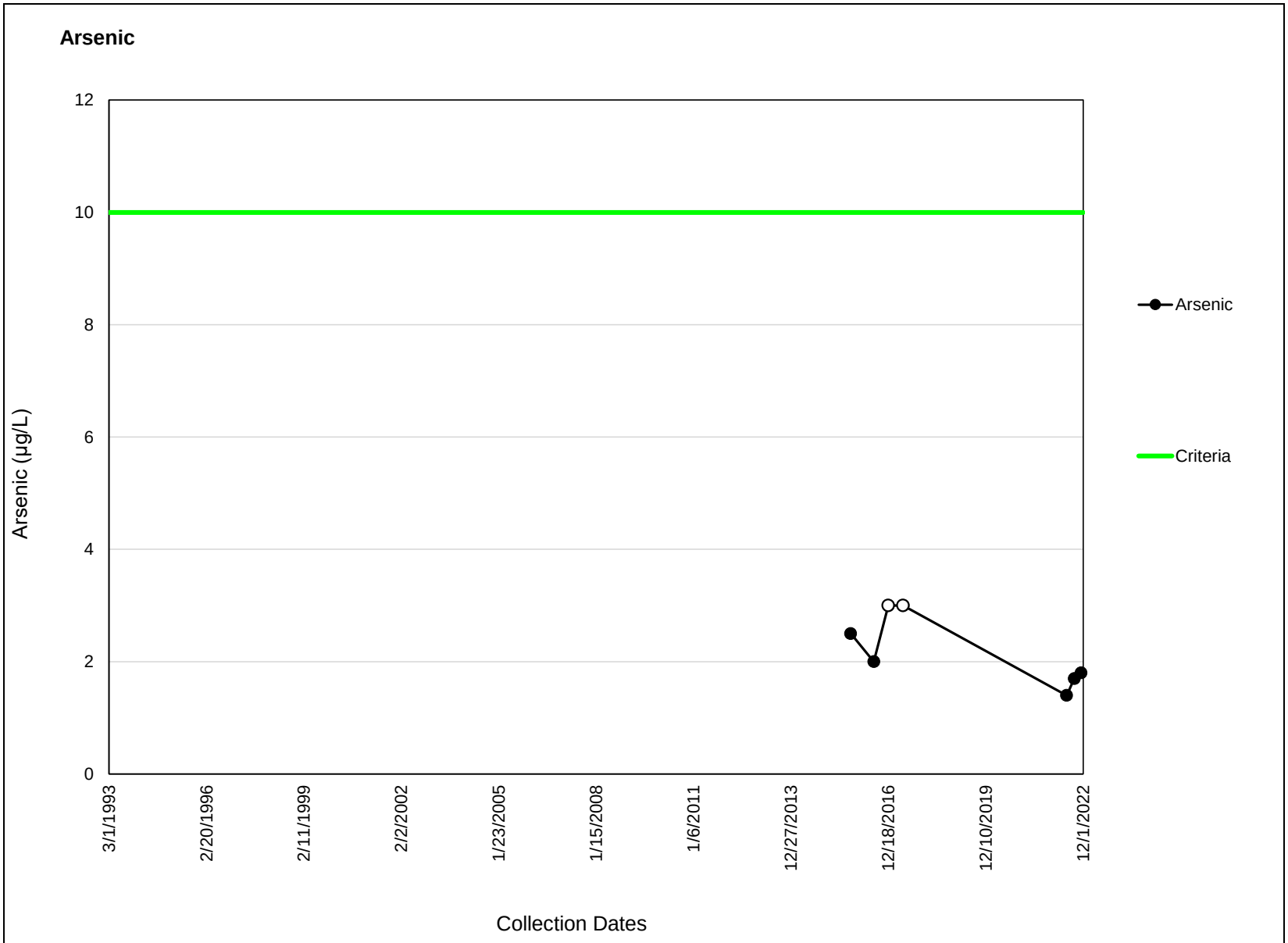
Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS

Time-Series Trend Plot
Arsenic in Well SHL-17
Shepley's Hill Landfill

FIGURE
A-23



Notes:

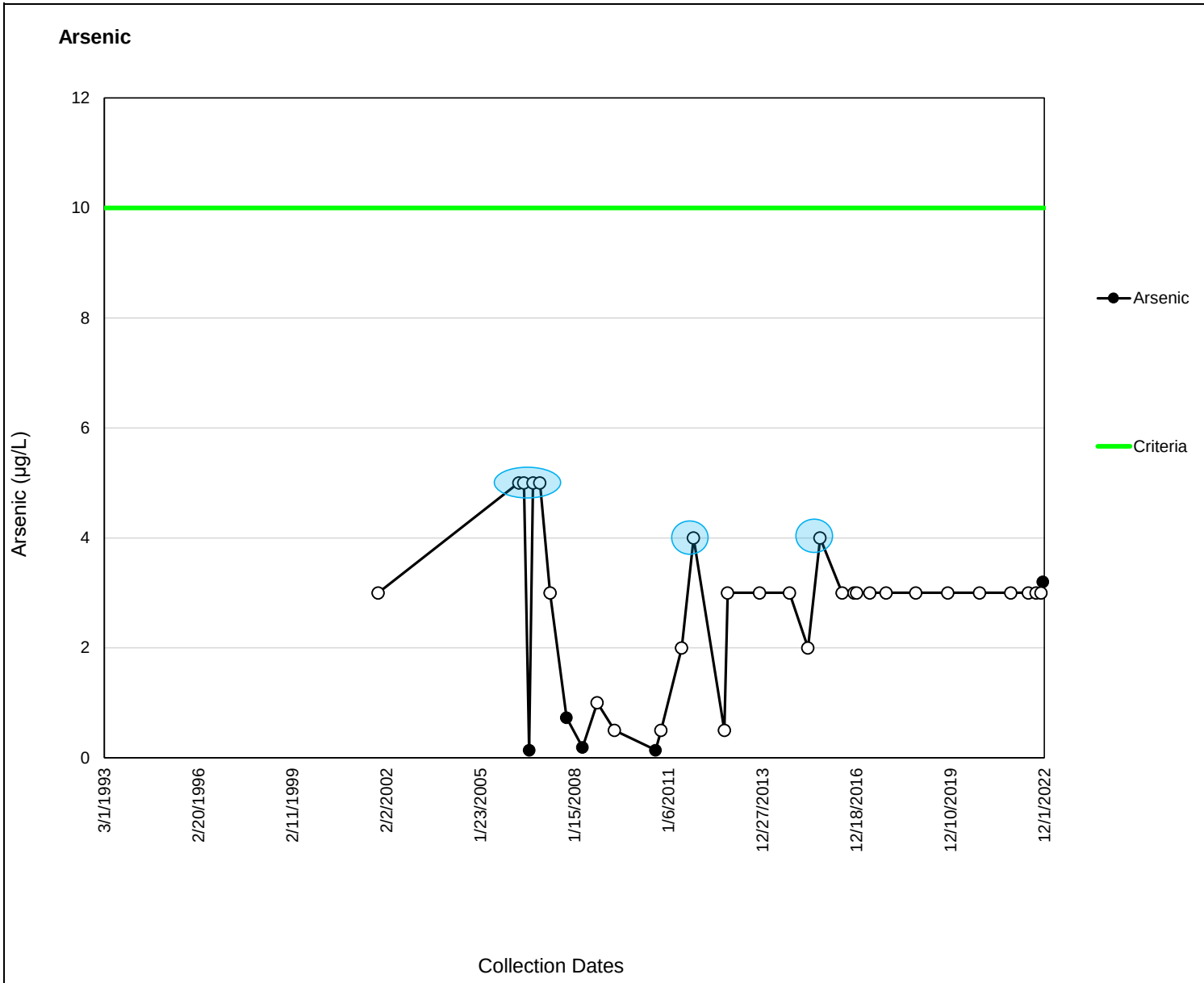
Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS

Time-Series Trend Plot
Arsenic in Well SHL-18
Shepley's Hill Landfill

FIGURE
A-24



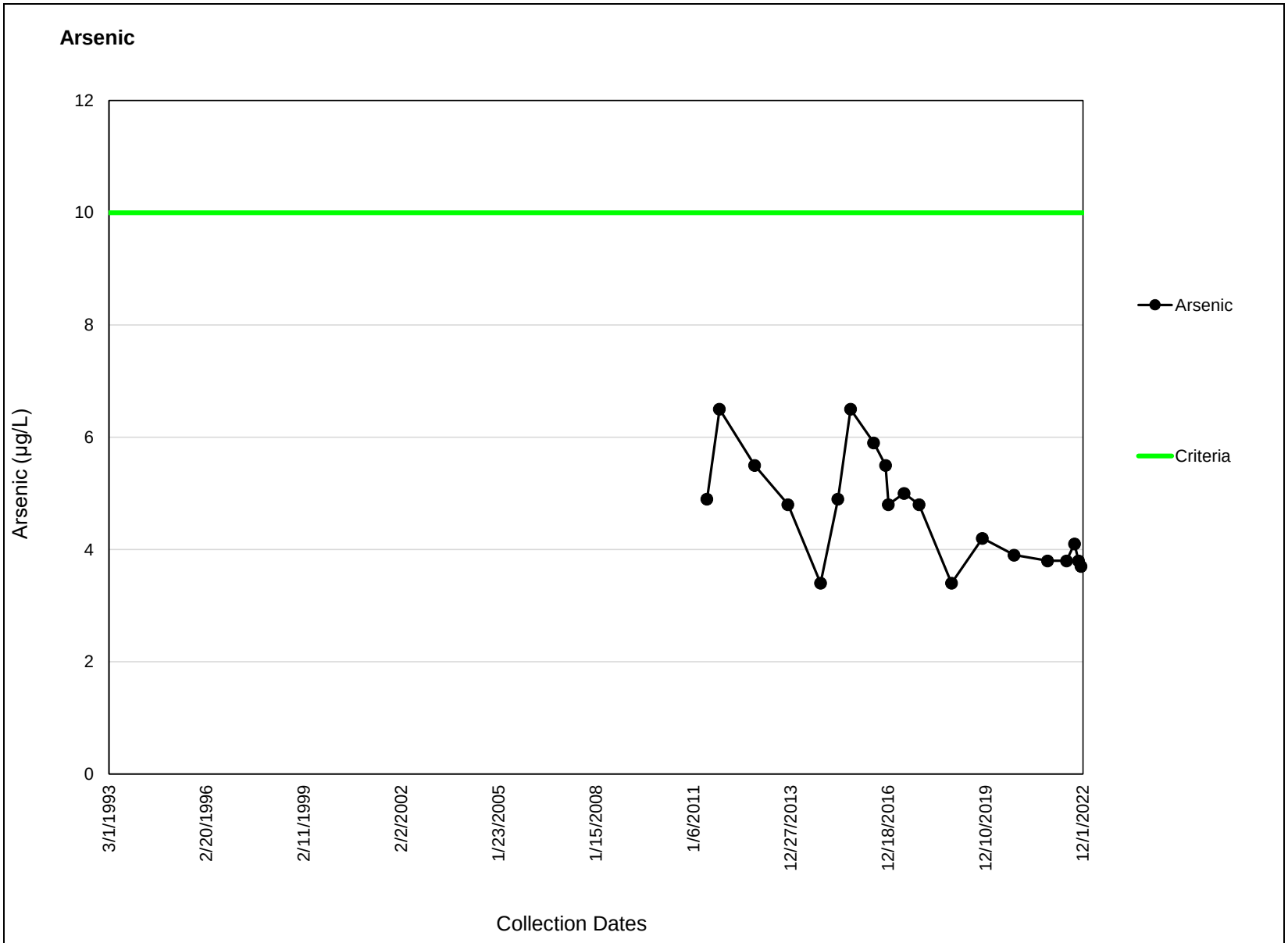
Notes:

Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

: Elevated non-detect excluded from evaluation.

ARCADIS	**Time-Series Trend Plot** **Arsenic in Well SHL-23** Shepley's Hill Landfill	**FIGURE** **A-25**



Notes:

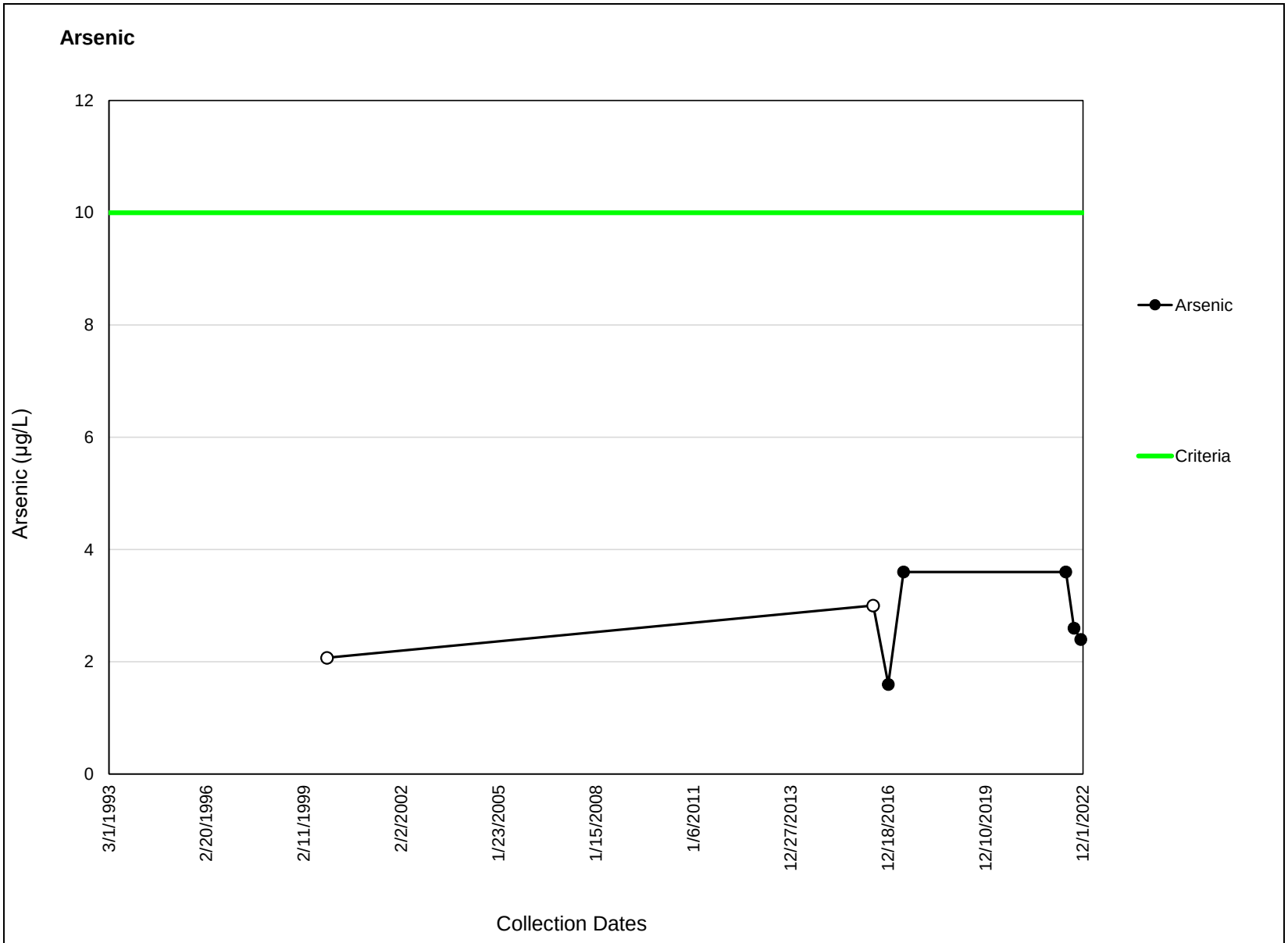
Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS

Time-Series Trend Plot
Arsenic in Well SHL-24
Shepley's Hill Landfill

FIGURE
A-26



Notes:

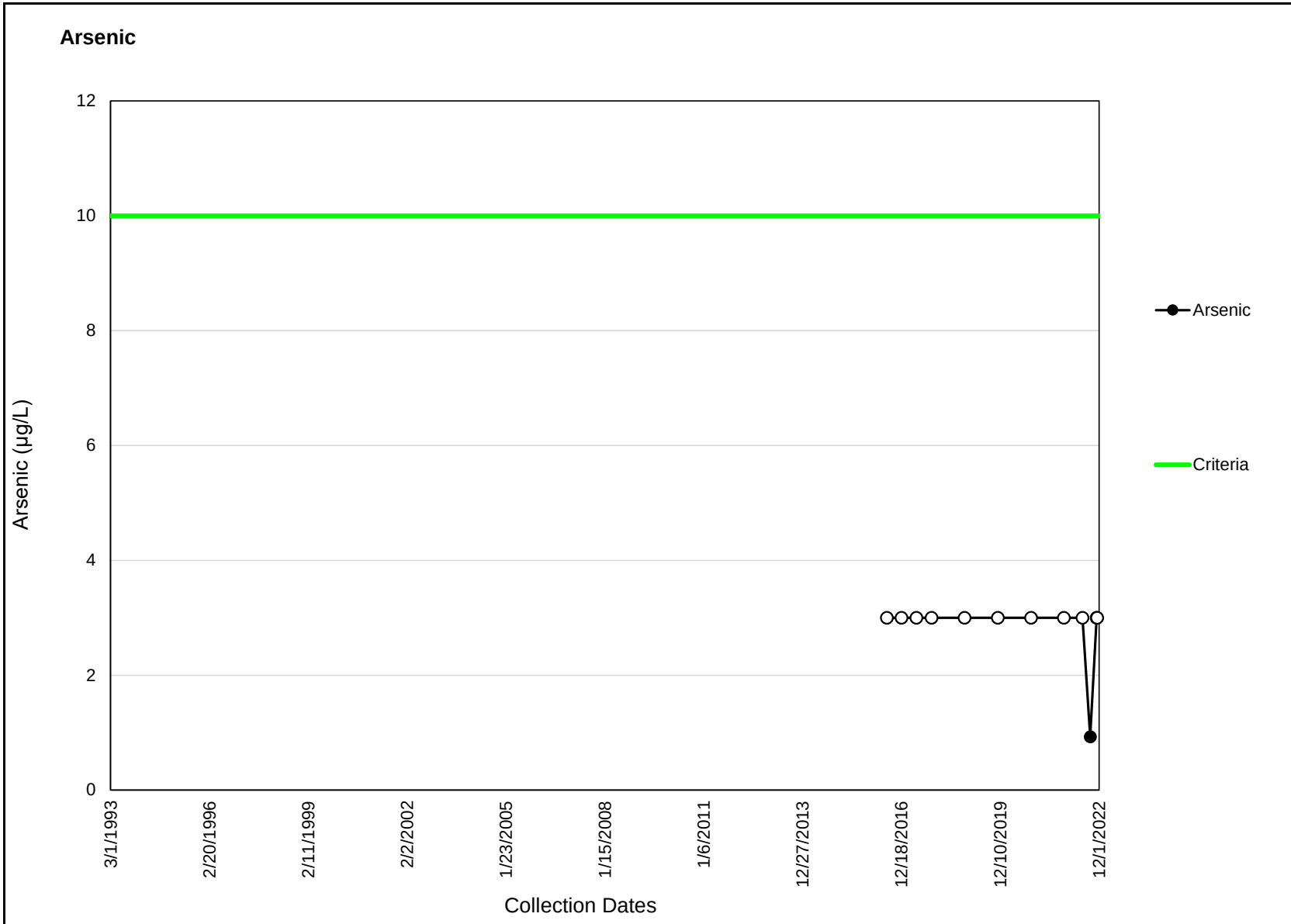
Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS

Time-Series Trend Plot
Arsenic in Well SHL-25
Shepley's Hill Landfill

FIGURE
A-27

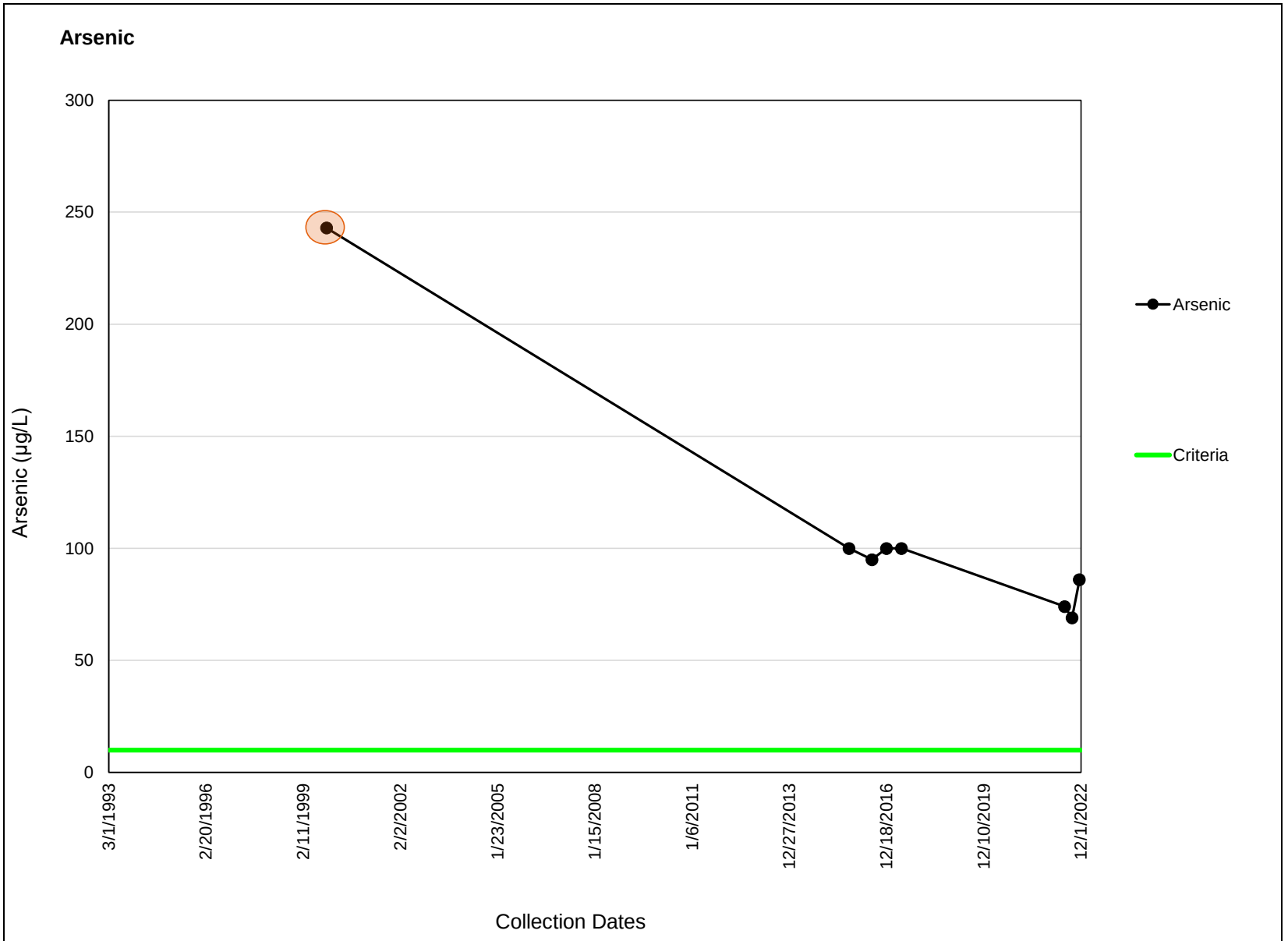


Notes:

Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS	**Time-Series Trend Plot** **Arsenic in Well SHM-93-18B** Shepley's Hill Landfill	**FIGURE** **A-28**



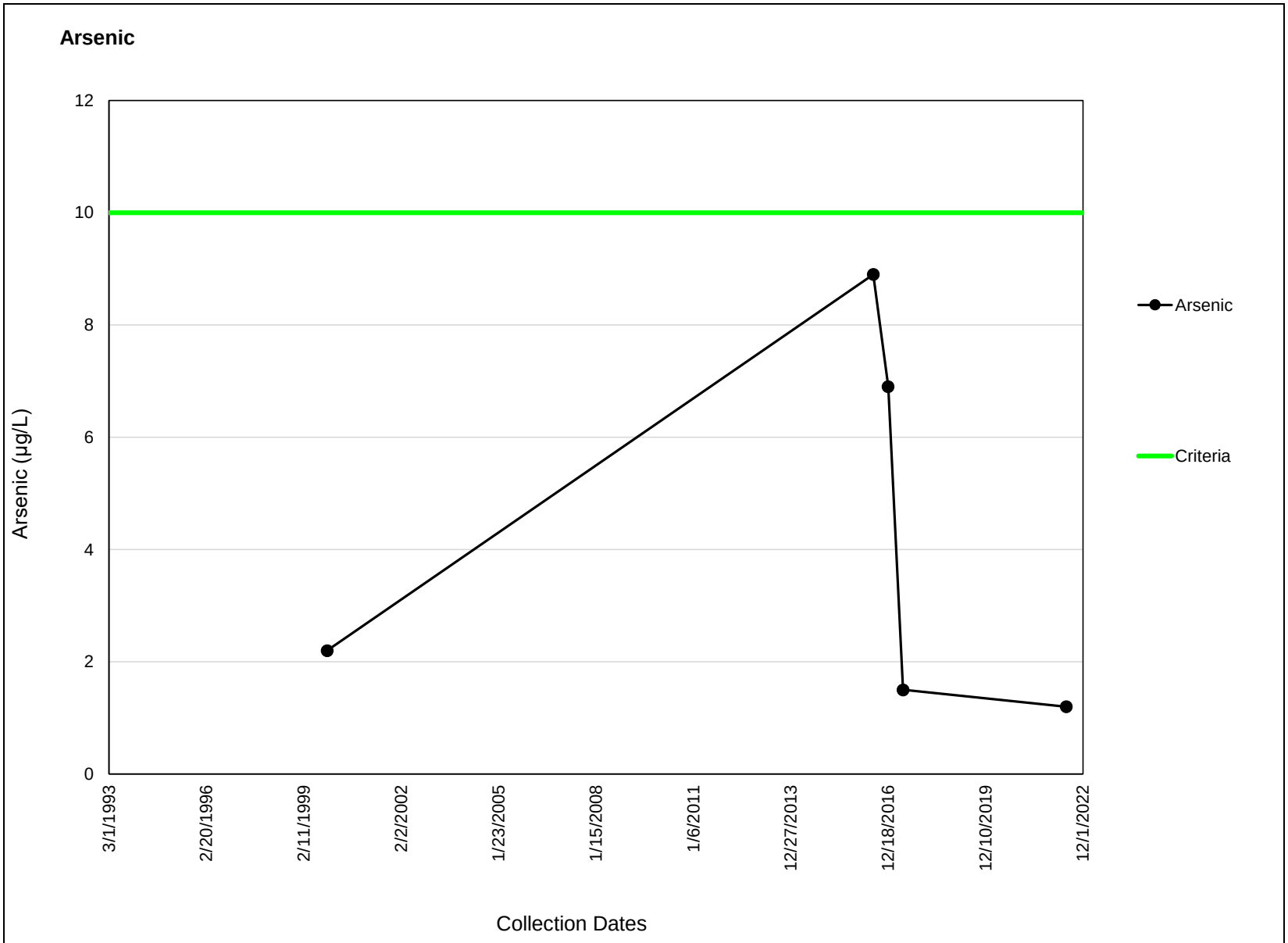
Notes:

Detects indicated by full circle and nondetects indicated by open circle.

: Excluded due to Dixon's test.

Reporting limit is used for nondetects.

ARCADIS	**Time-Series Trend Plot** **Arsenic in Well SHP-95-27X** Shepley's Hill Landfill	**FIGURE** **A-29**

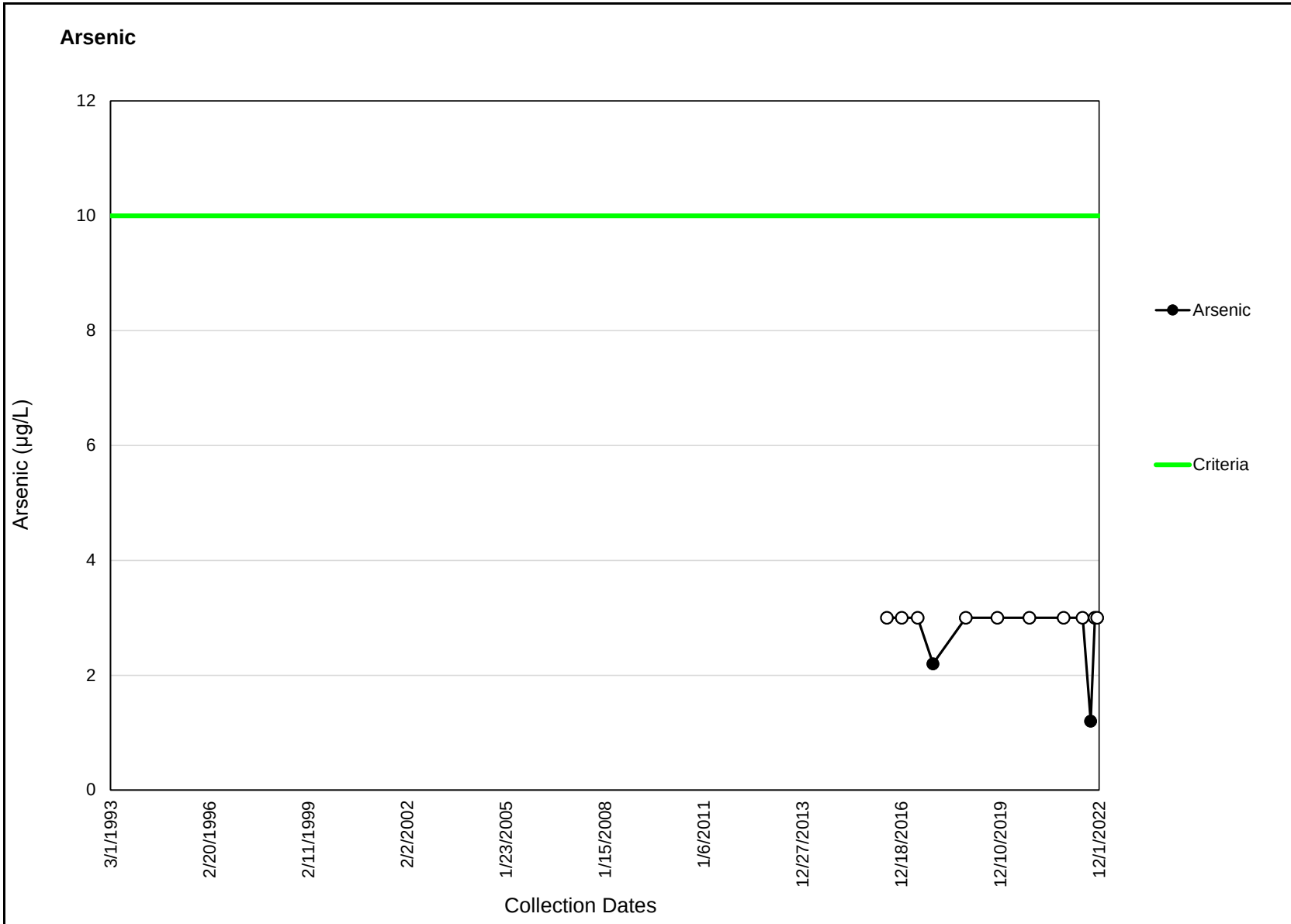


Notes:

Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS	**Time-Series Trend Plot** **Arsenic in Well SHP-99-1C** Shepley's Hill Landfill	**FIGURE** **A-30**

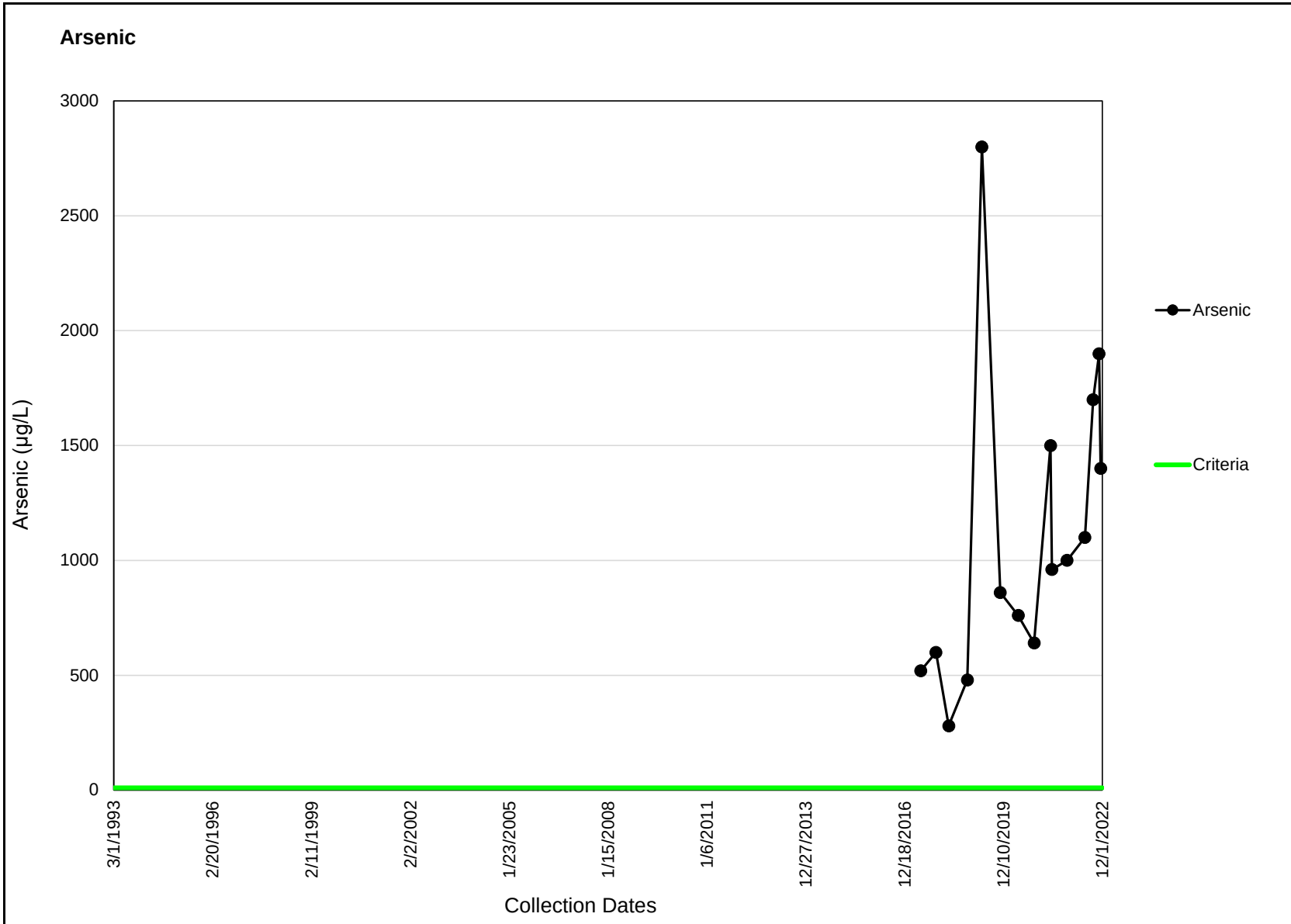


Notes:

Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS	**Time-Series Trend Plot** **Arsenic in Well SHM-93-24A** Shepley's Hill Landfill	**FIGURE** **A-31**

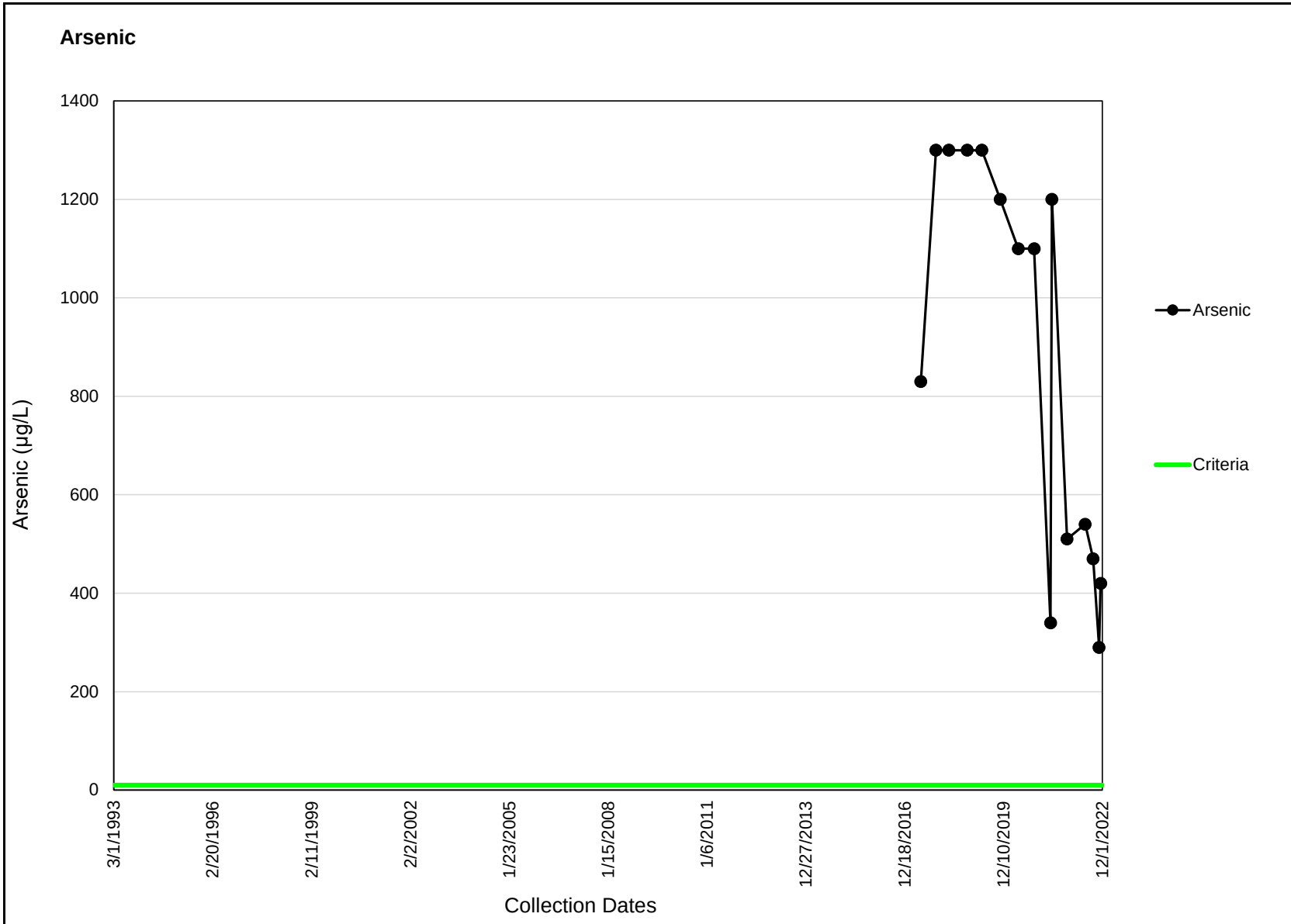


Notes:

Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS	**Time-Series Trend Plot** **Arsenic in Well SHP-2016-06A** Shepley's Hill Landfill	**FIGURE** **A-32**

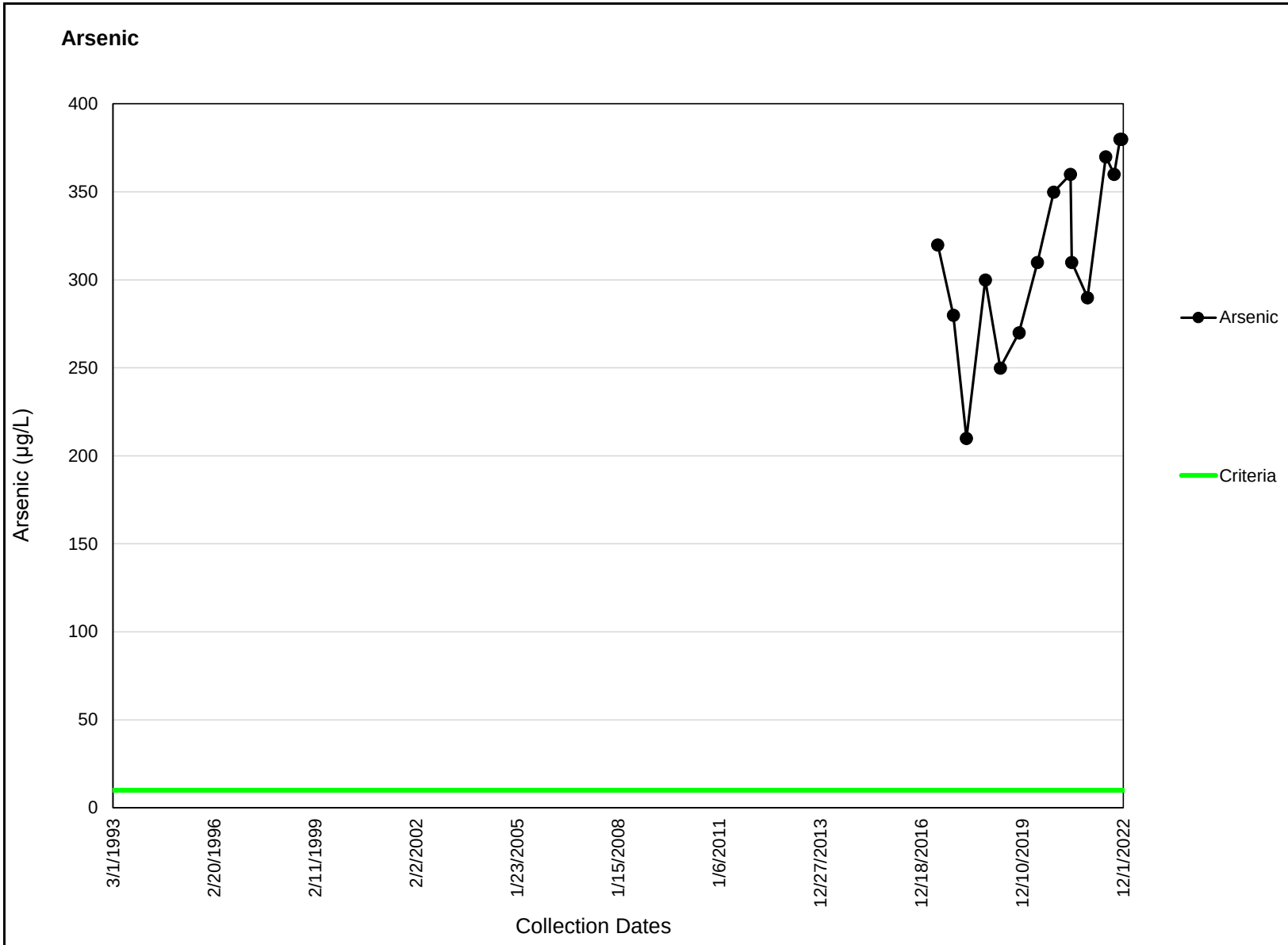


Notes:

Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS	**Time-Series Trend Plot** **Arsenic in Well SHP-2016-06B** Shepley's Hill Landfill	**FIGURE** **A-33**

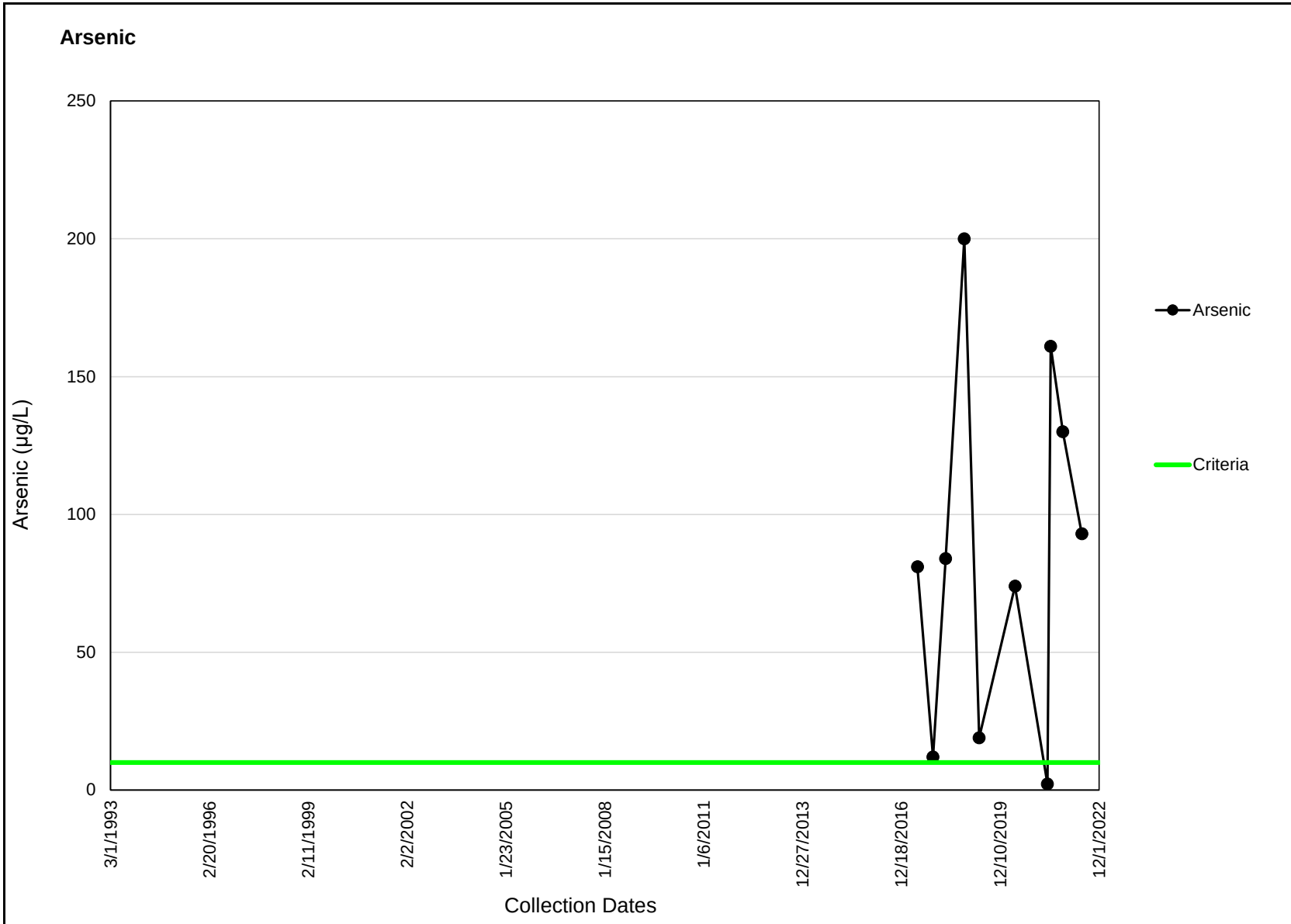


Notes:

Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS	**Time-Series Trend Plot** **Arsenic in Well SHP-2016-06C** Shepley's Hill Landfill	**FIGURE** **A-34**

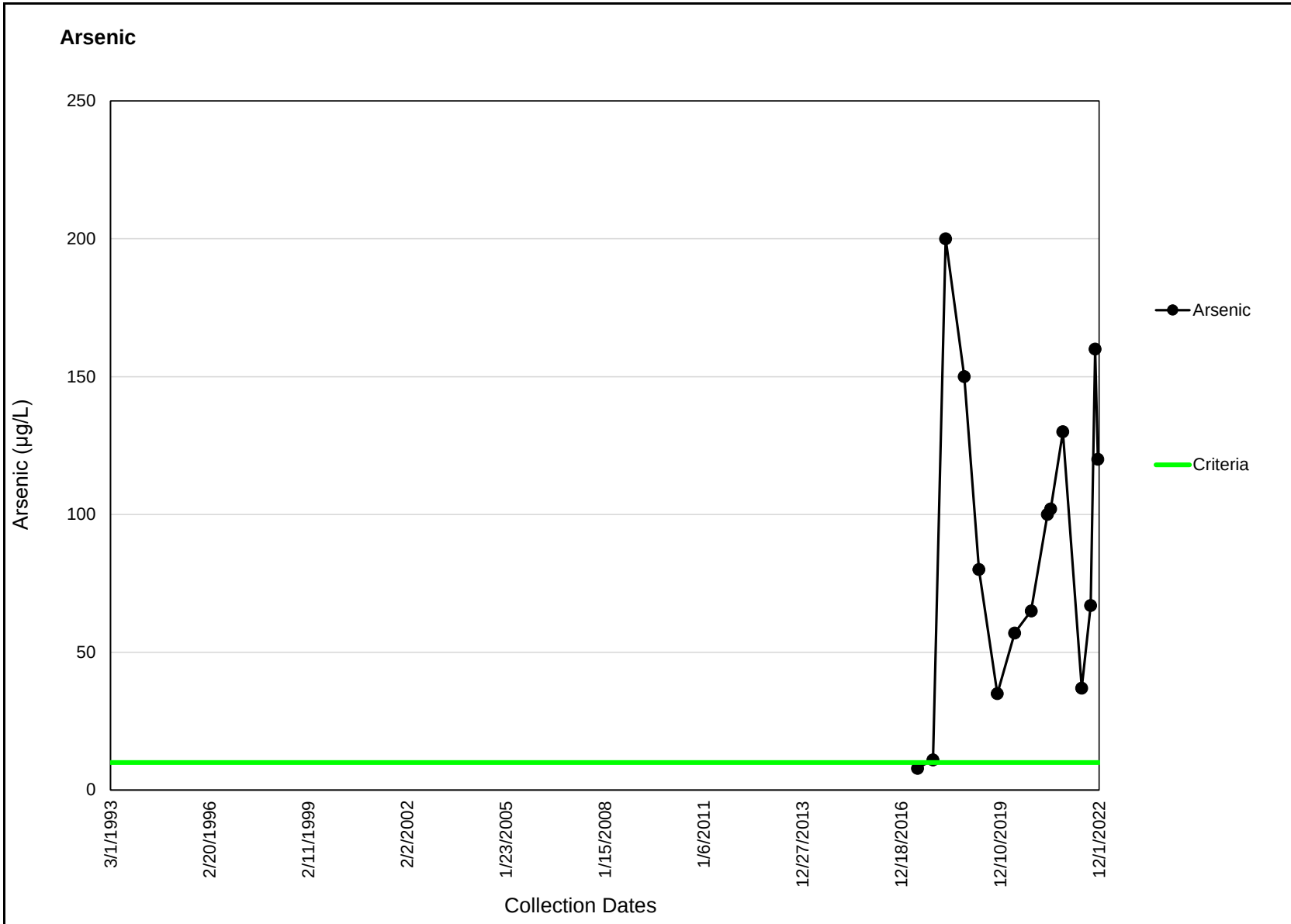


Notes:

Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

ARCADIS	**Time-Series Trend Plot** **Arsenic in Well SHP-2016-07A** Shepley's Hill Landfill	**FIGURE** **A-35**



Notes:

Detects indicated by full circle and nondetects indicated by open circle.

Reporting limit is used for nondetects.

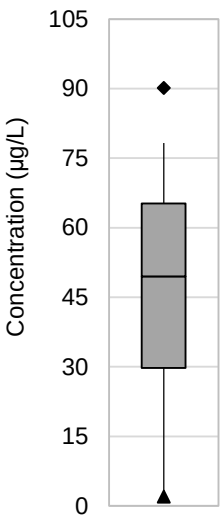
ARCADIS	**Time-Series Trend Plot** **Arsenic in Well SHP-2016-07B** Shepley's Hill Landfill	**FIGURE** **A-36**

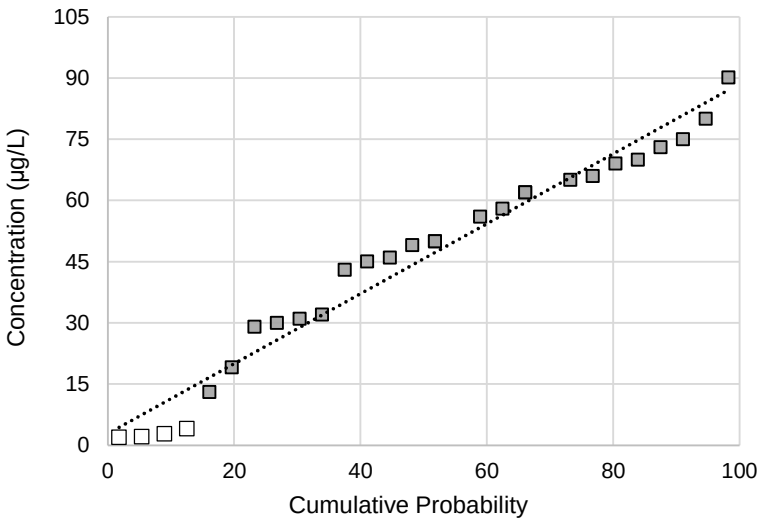
Appendix B

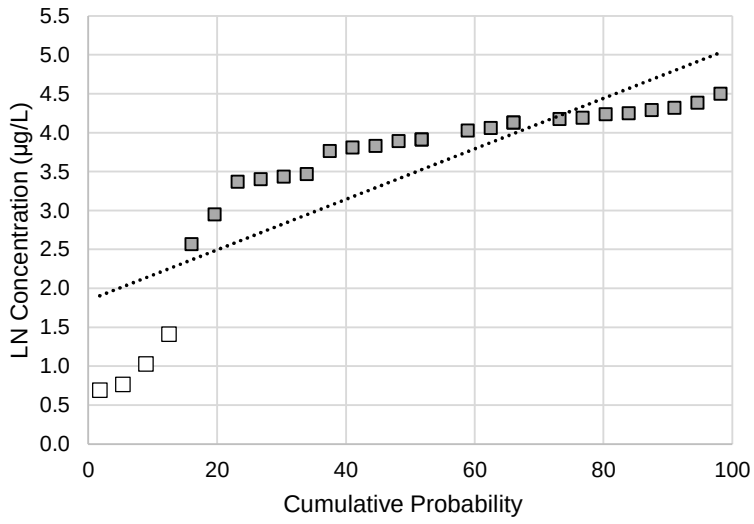
Combination Probability and Box-and-Whisker Plots

Figure B-1	**Attachment B: Box-and-Whisker and Probability Plots - Arsenic** Report on the Evaluation of Site-Specific Arsenic Background Concentrations in Groundwater Shepley's Hill Landfill, Former Fort Devens Army Installation, Devens, Massachusetts	ARCADIS

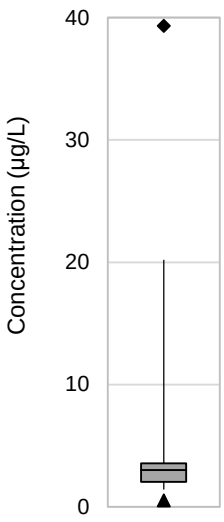
Well: 32M-01-14XOB

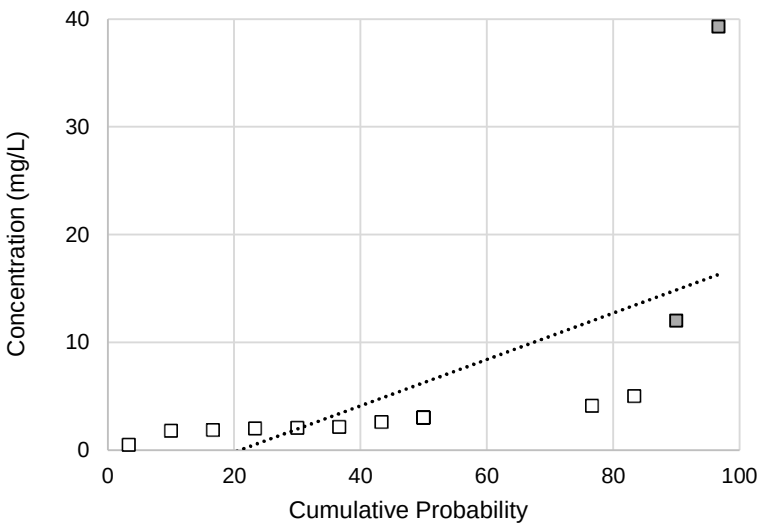


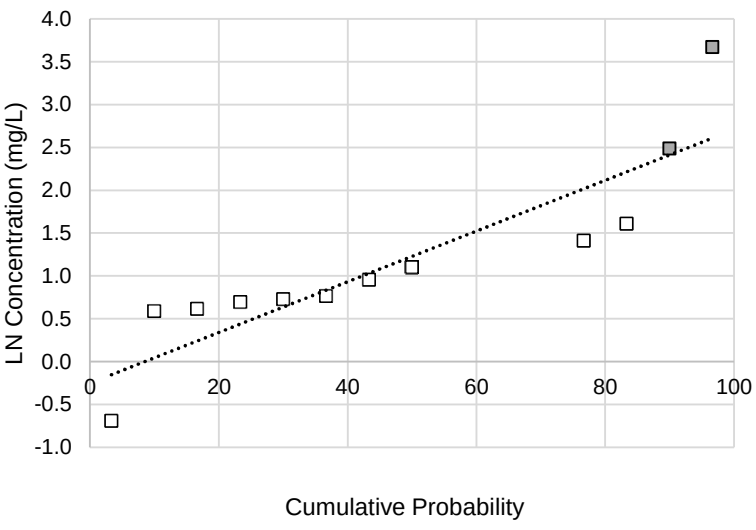




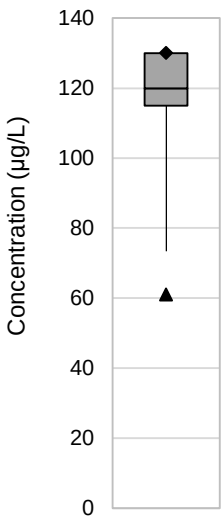
Well : 32M-92-01X

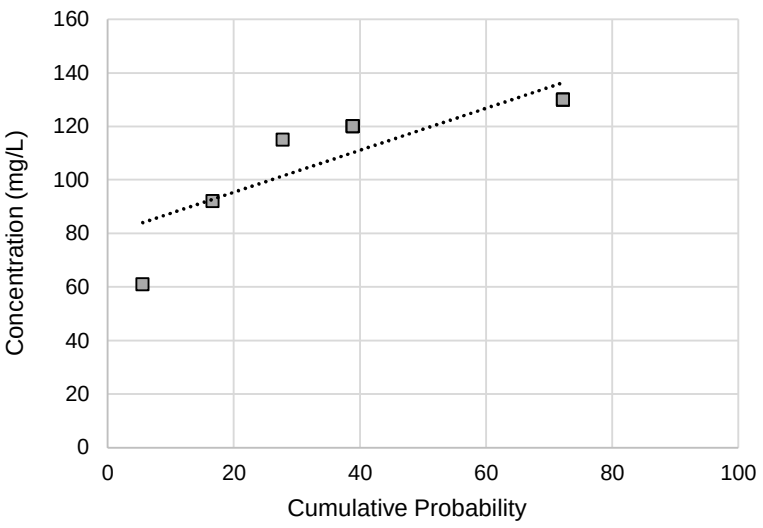


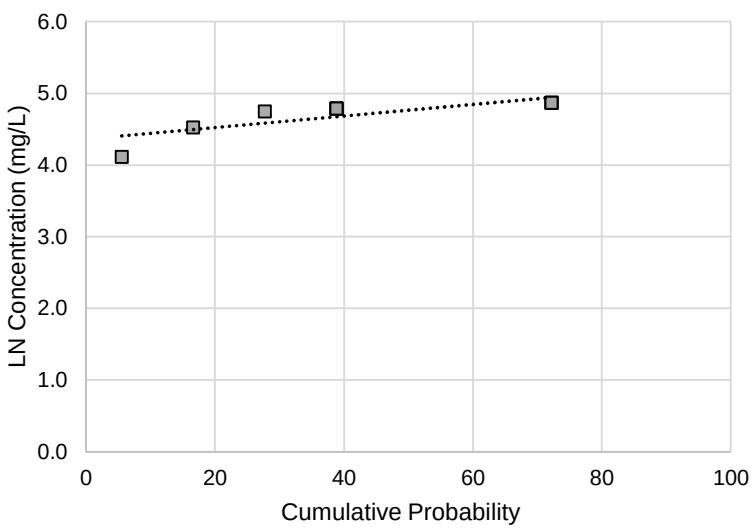




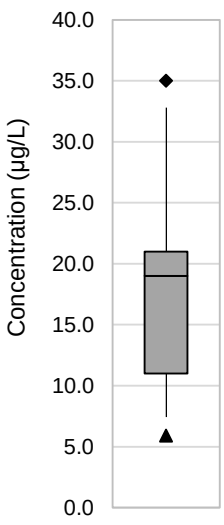
Well : N1-P2

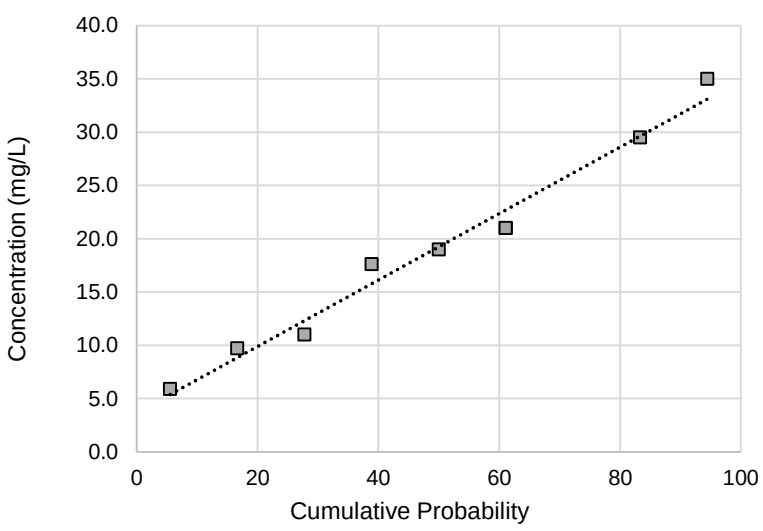


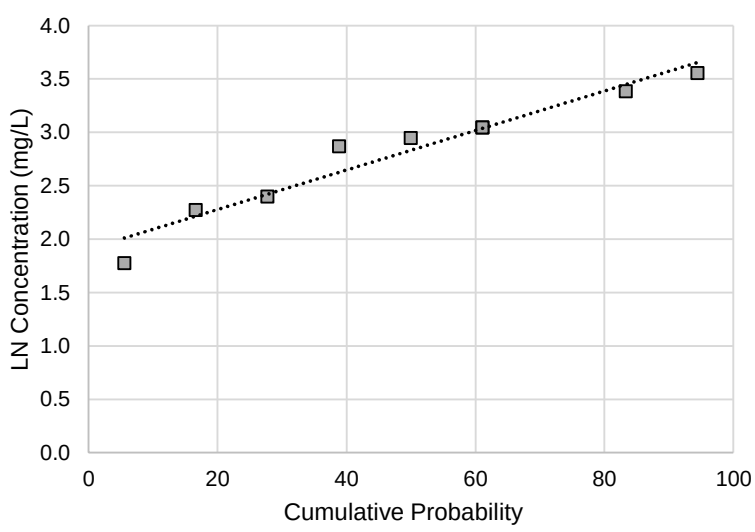




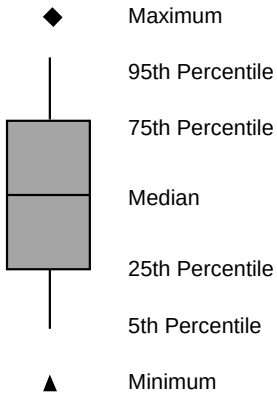
Well : N1-P3







Box and Whisker Plot Legend



Probability Plot Legend

- detection
- non-detection
- trendline

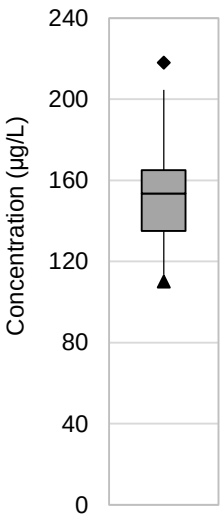
Notes

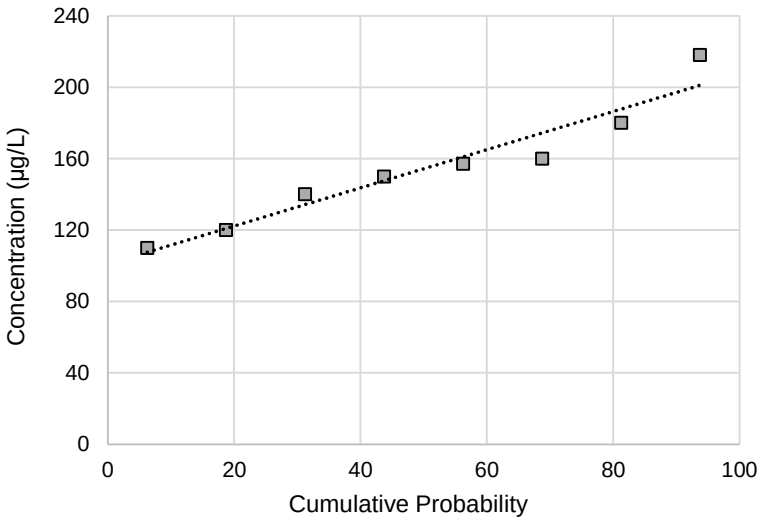
LN : lognormal

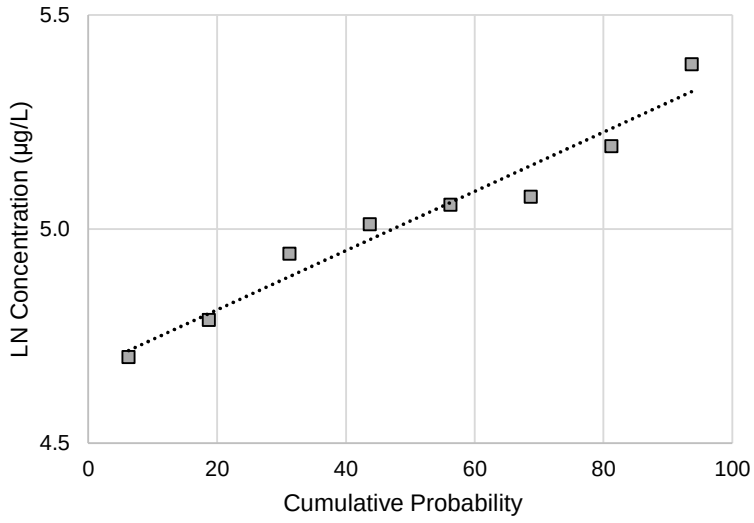
µg/L : microgram per liter

Figure B-2	**Attachment B: Box-and-Whisker and Probability Plots - Arsenic** Report on the Evaluation of Site-Specific Arsenic Background Concentrations in Groundwater Shepley's Hill Landfill, Former Fort Devens Army Installation, Devens, Massachusetts	ARCADIS

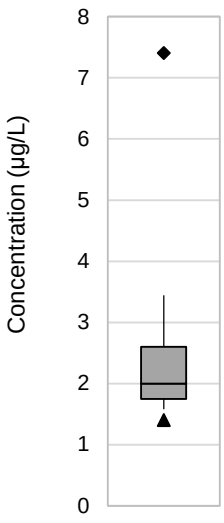
Well: N7-P2

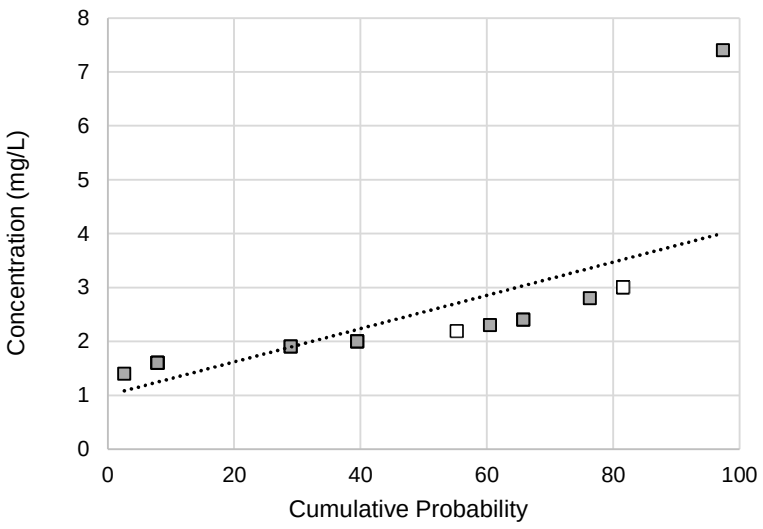


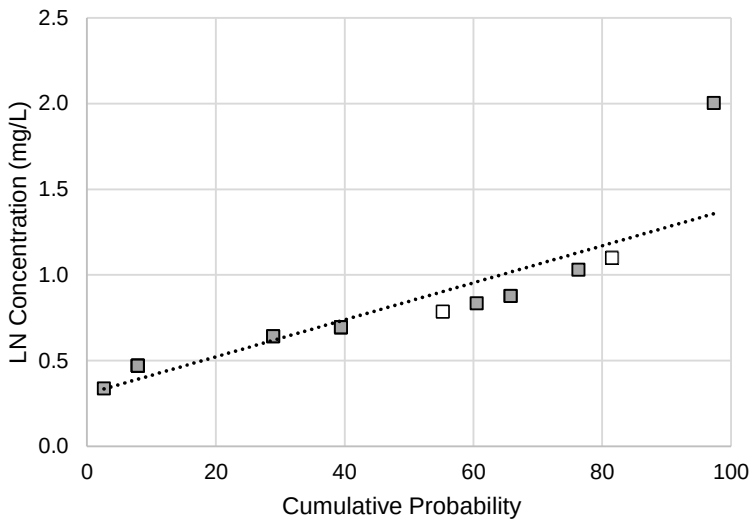




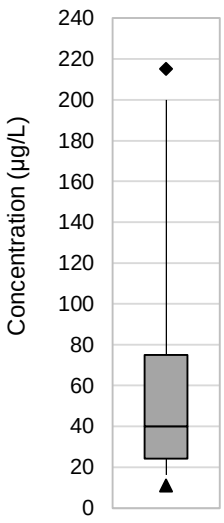
Well : SHL-12

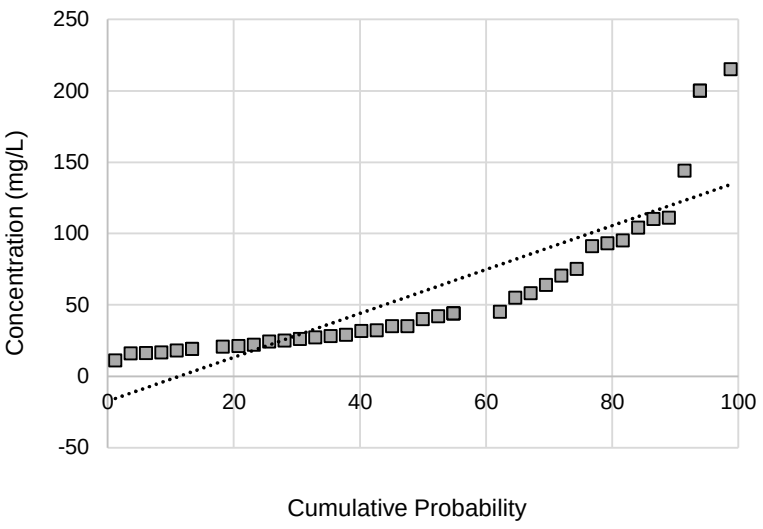


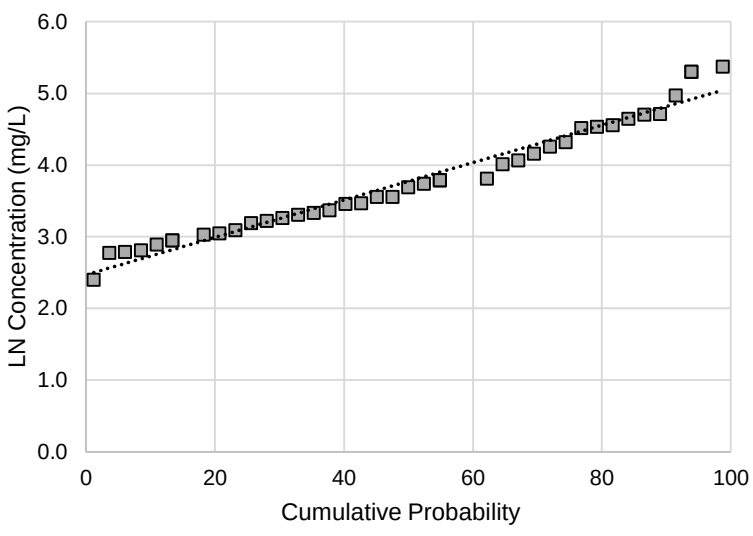




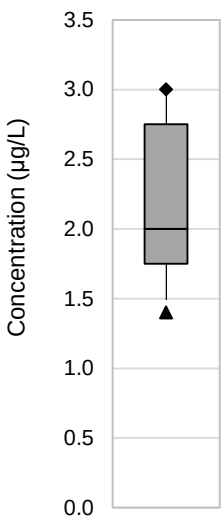
Well : SHL-15

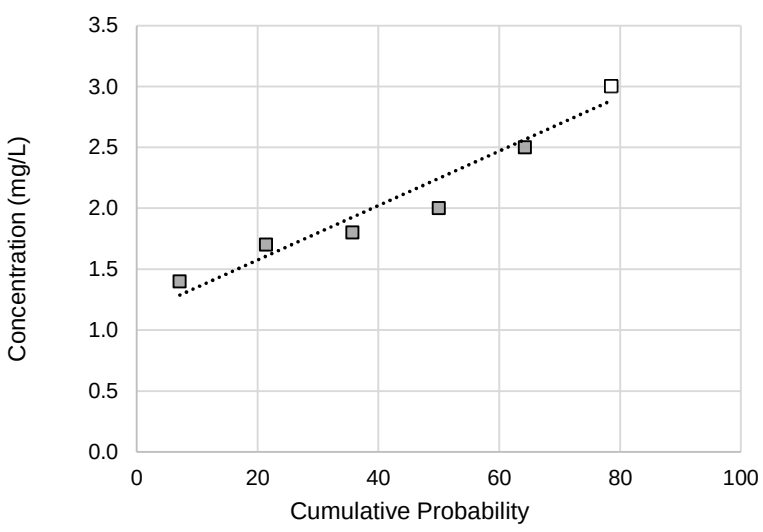


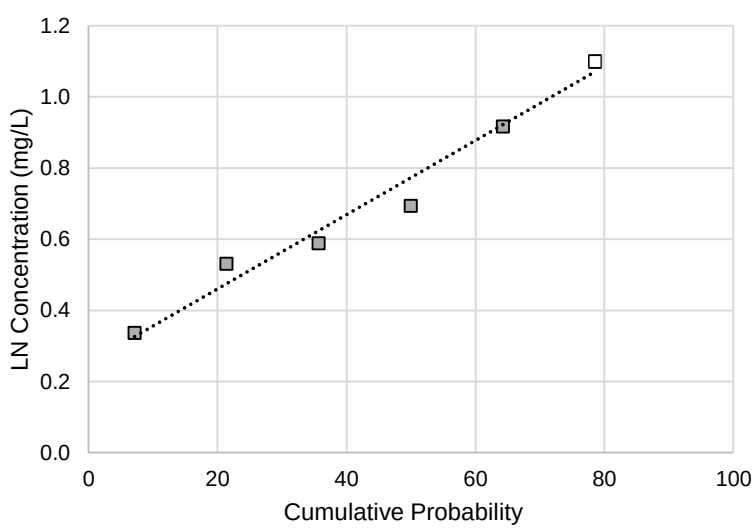




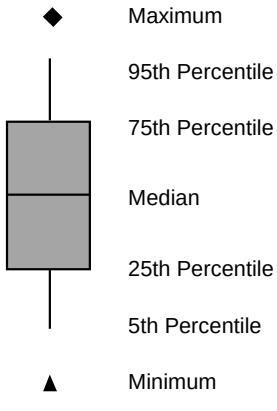
Well : SHL-18







Box and Whisker Plot Legend



Probability Plot Legend

- detection
- non-detection
- trendline

Notes

LN : lognormal

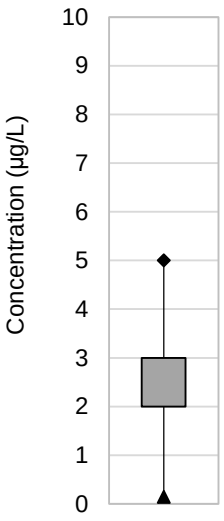
µg/L : microgram per liter

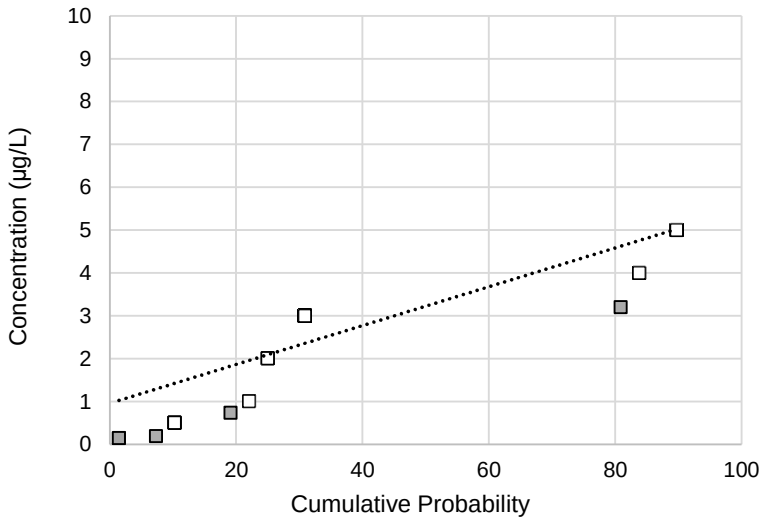
Figure B-3

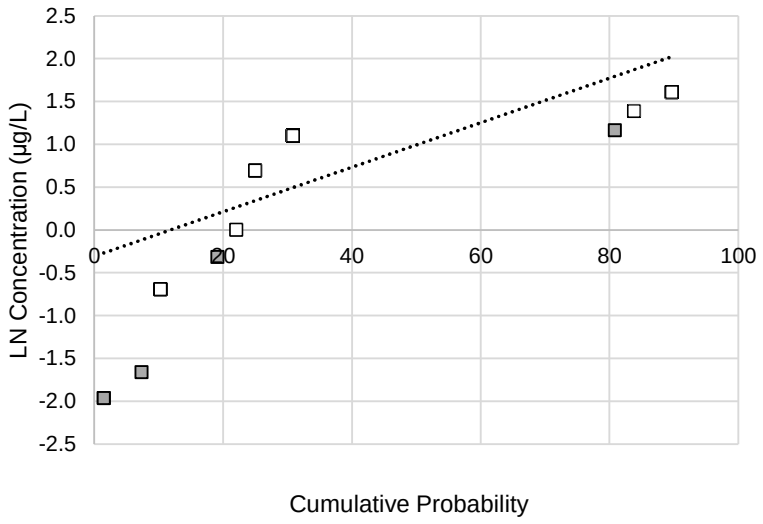
Attachment B: Box-and-Whisker and Probability Plots - Arsenic
Report on the Evaluation of Site-Specific Arsenic Background Concentrations in Groundwater
Shepley's Hill Landfill, Former Fort Devens Army Installation,
Devens, Massachusetts

ARCADIS

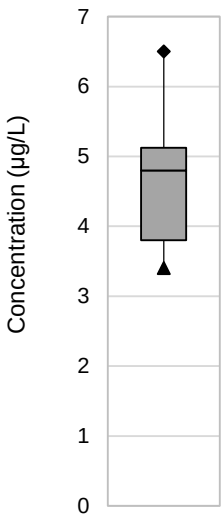
Well: SHL-23

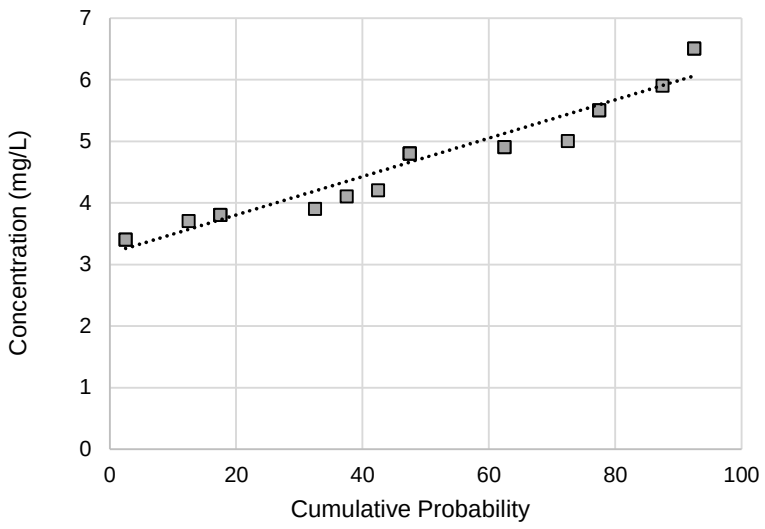


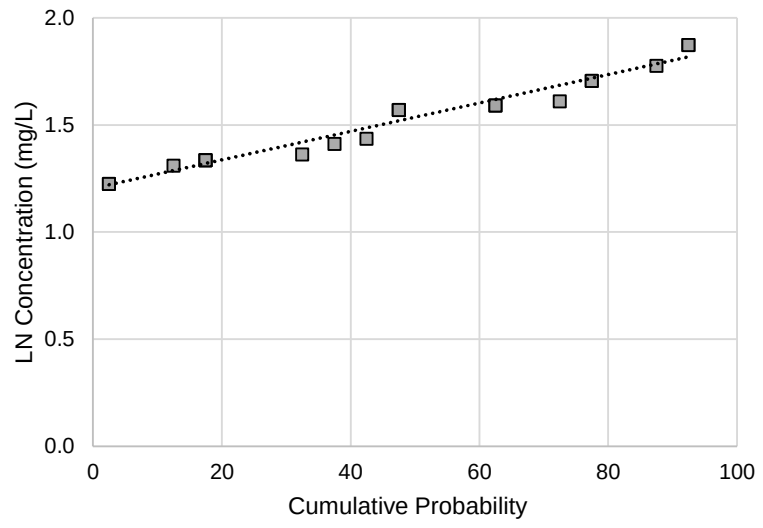




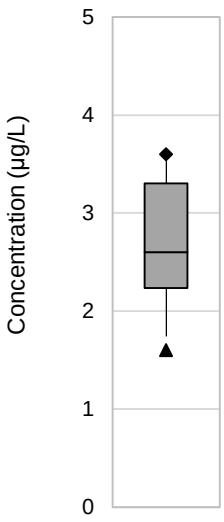
Well : SHL-24

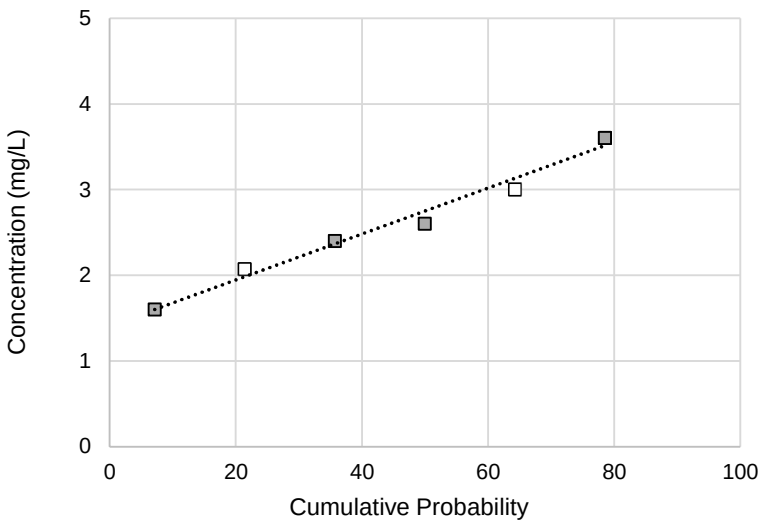


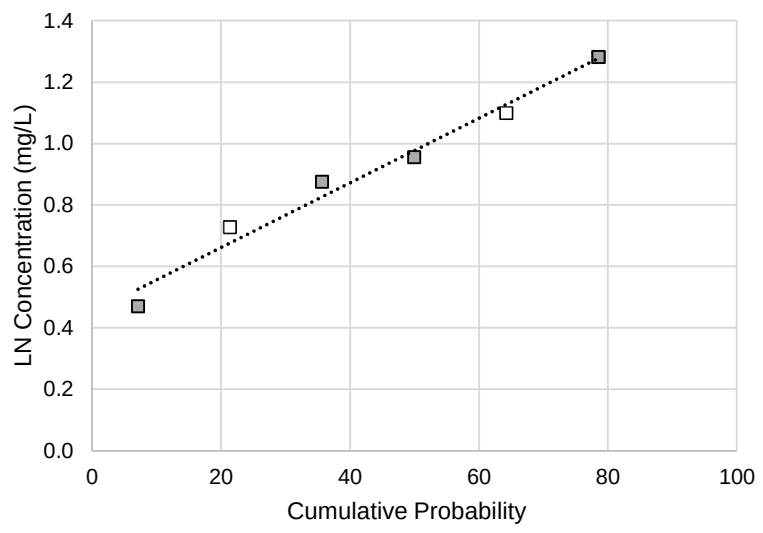




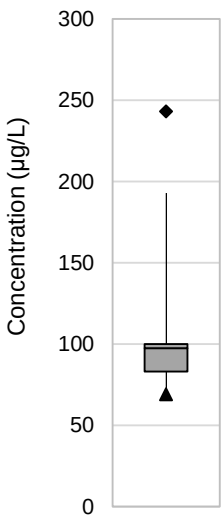
Well : SHL-25

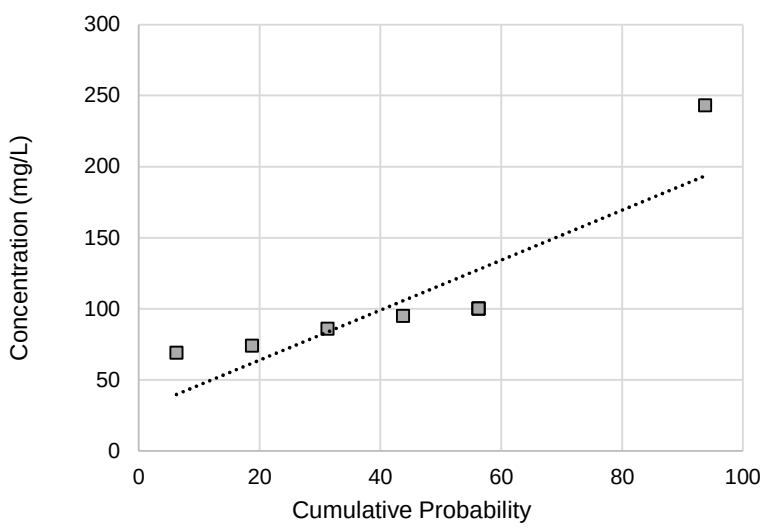


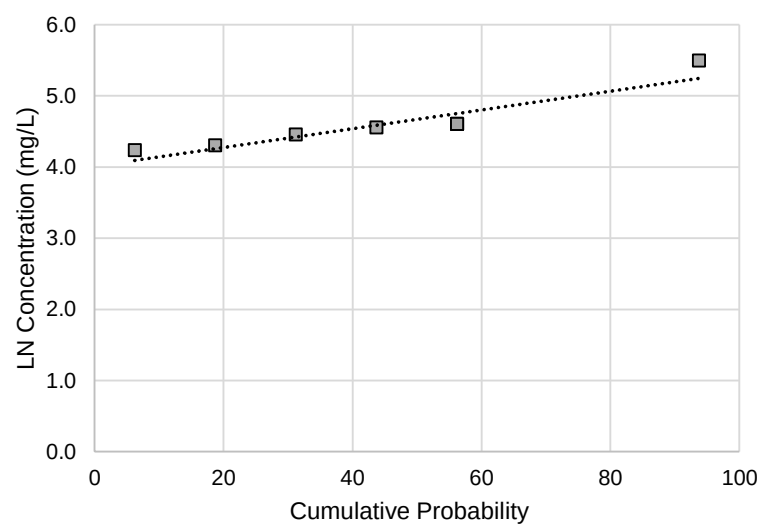




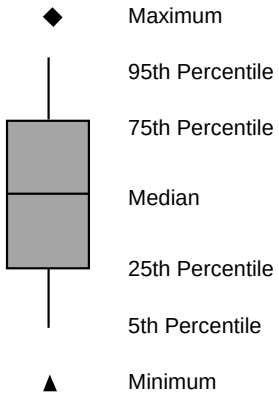
Well : SHP-95-27X







Box and Whisker Plot Legend



Probability Plot Legend

- detection
- non-detection
- trendline

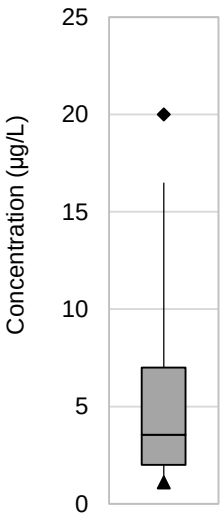
Notes
LN : lognormal
µg/L : microgram per liter

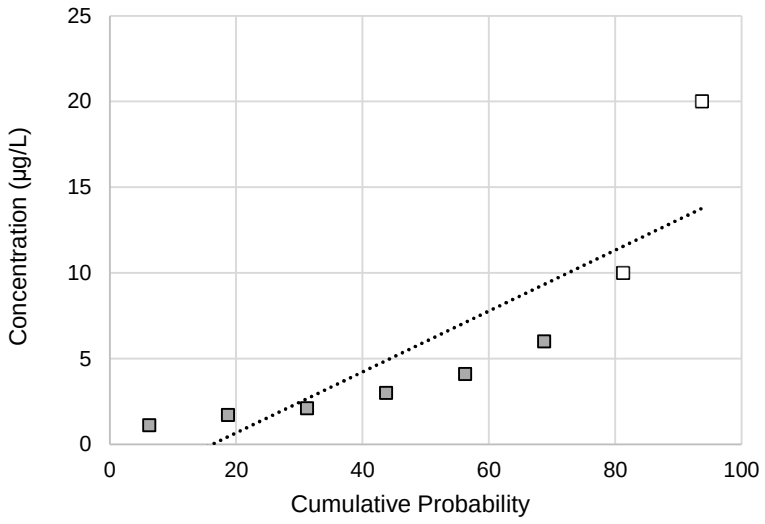
Figure B-4

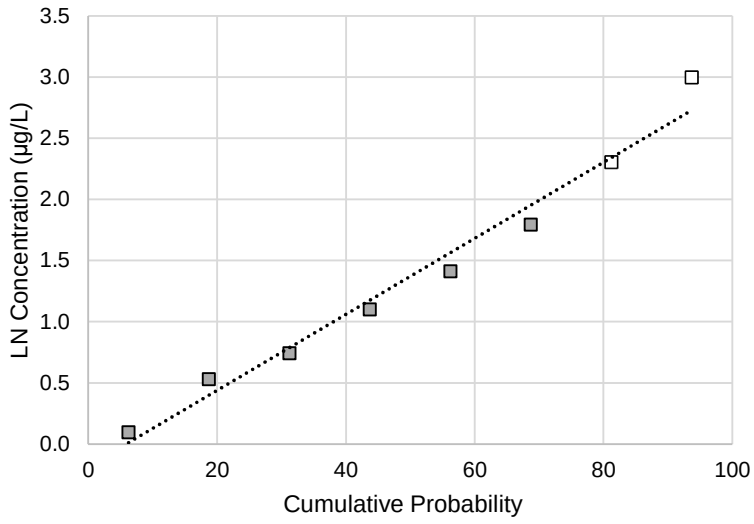
Attachment B: Box-and-Whisker and Probability Plots - Arsenic
Report on the Evaluation of Site-Specific Arsenic Background Concentrations in Groundwater
Shepley's Hill Landfill, Former Fort Devens Army Installation,
Devens, Massachusetts

ARCADIS

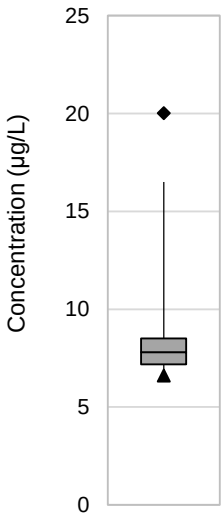
Well: 20-1

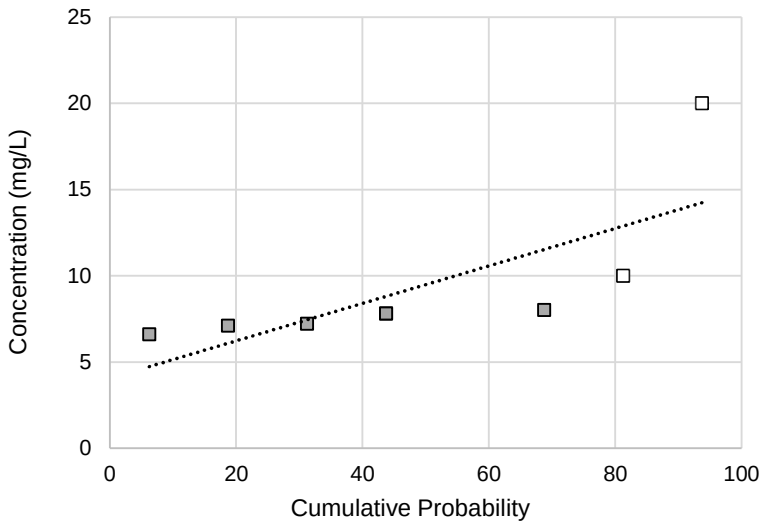


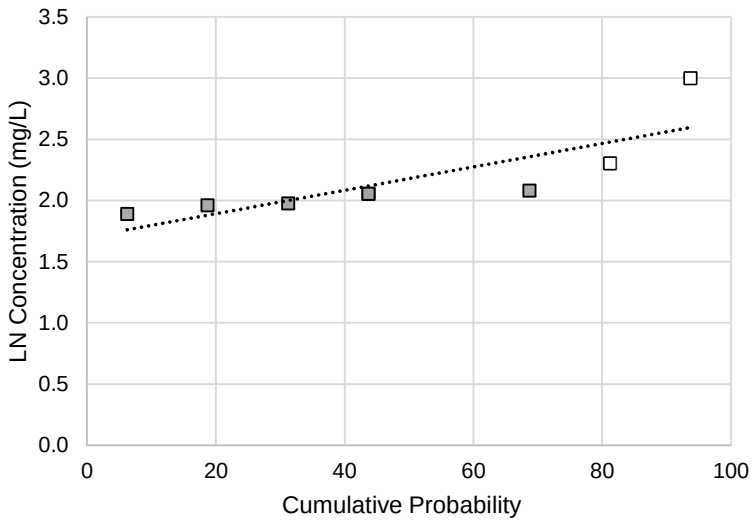




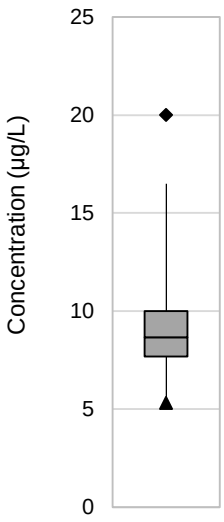
Well : 27-1

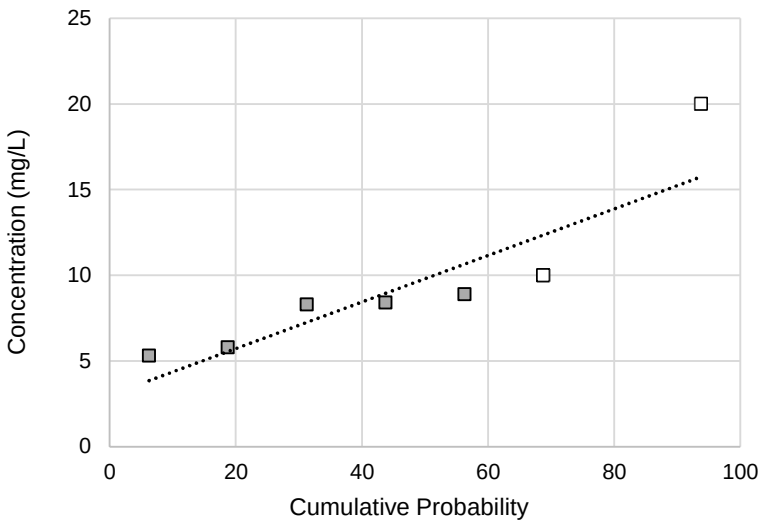


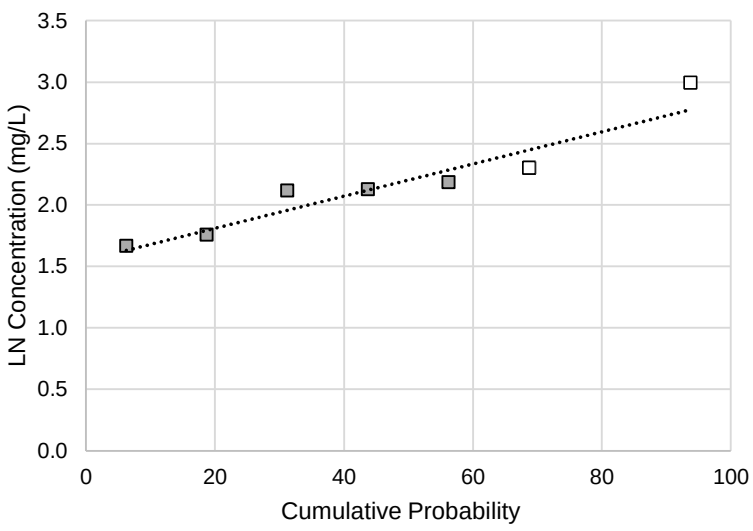




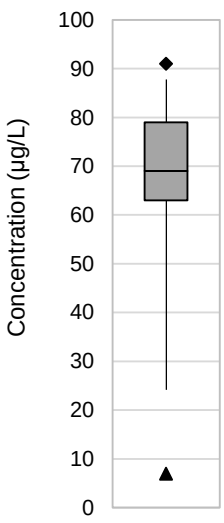
Well : 27-2

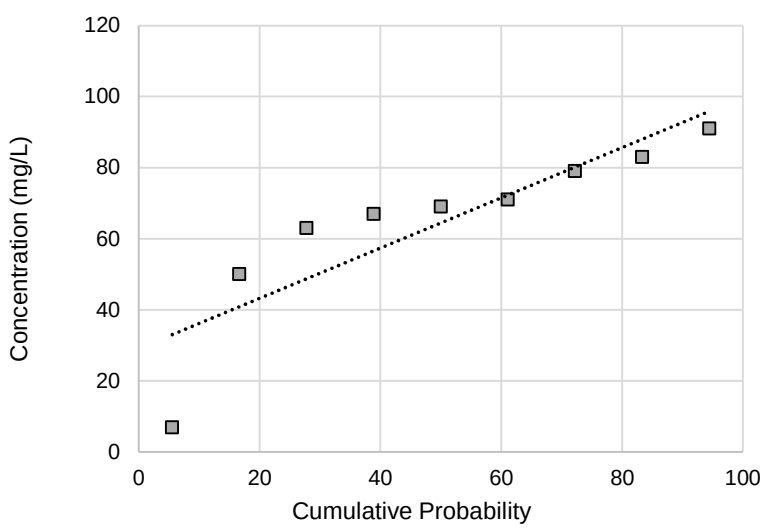


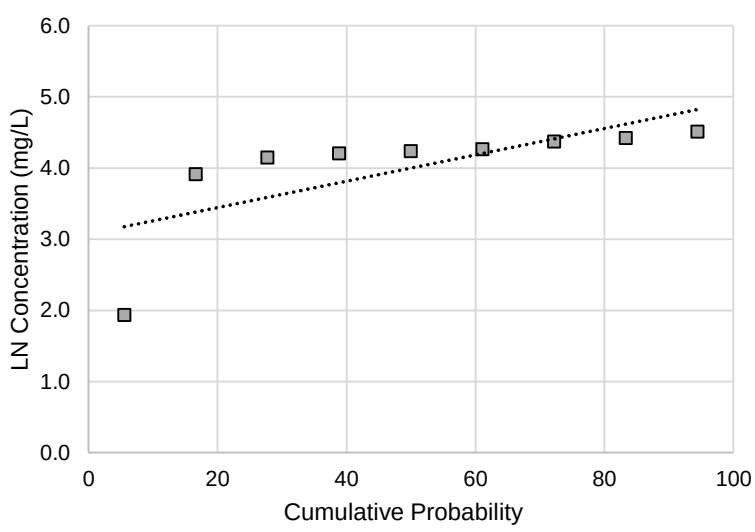




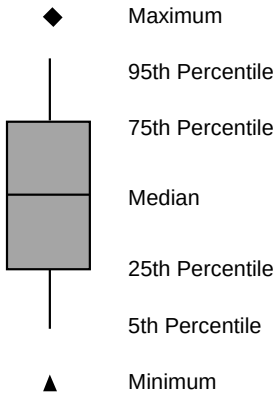
Well : 3-2







Box and Whisker Plot Legend



Probability Plot Legend

- detection
- non-detection
- trendline

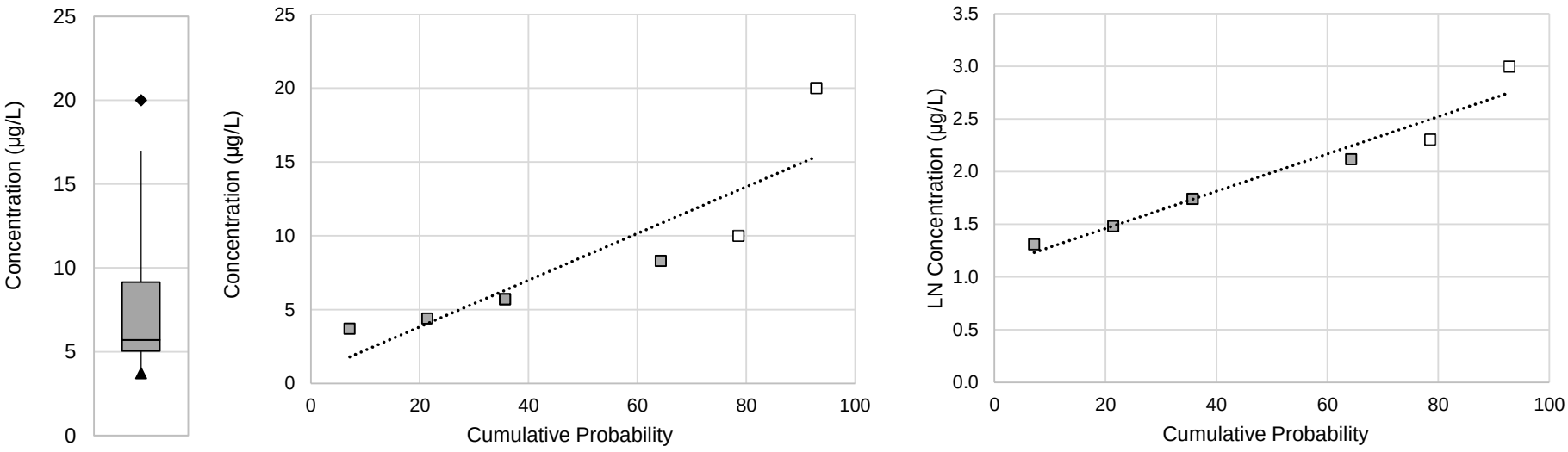
Notes
LN : lognormal
µg/L : microgram per liter

Figure B-5

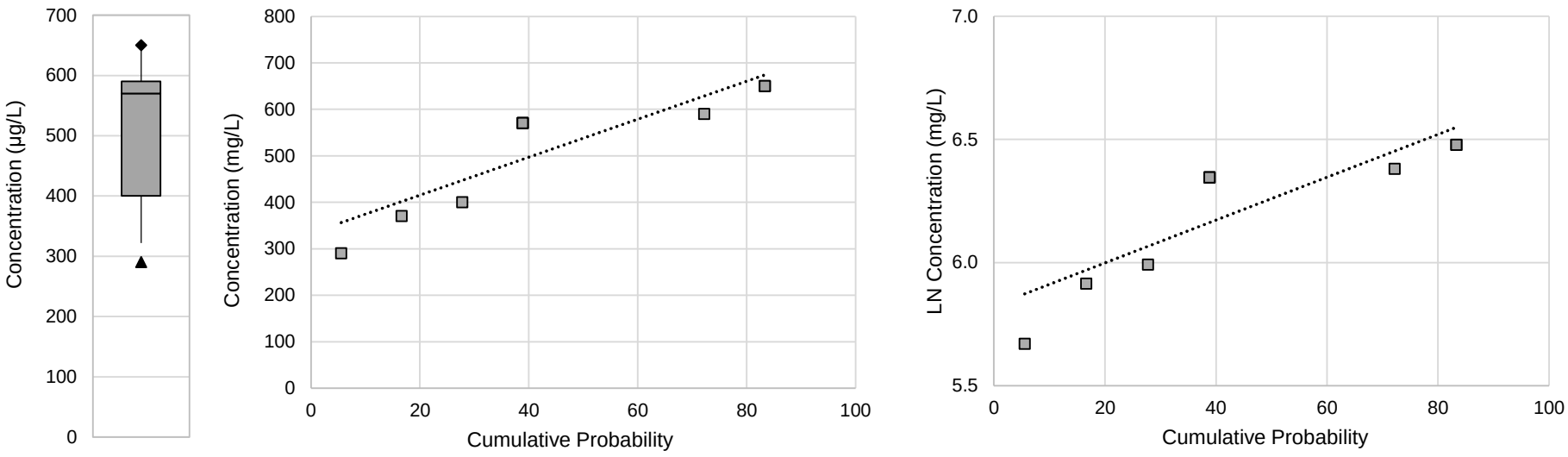
Attachment B: Box-and-Whisker and Probability Plots - Arsenic
Report on the Evaluation of Site-Specific Arsenic Background Concentrations in Groundwater
Shepley's Hill Landfill, Former Fort Devens Army Installation,
Devens, Massachusetts

ARCADIS

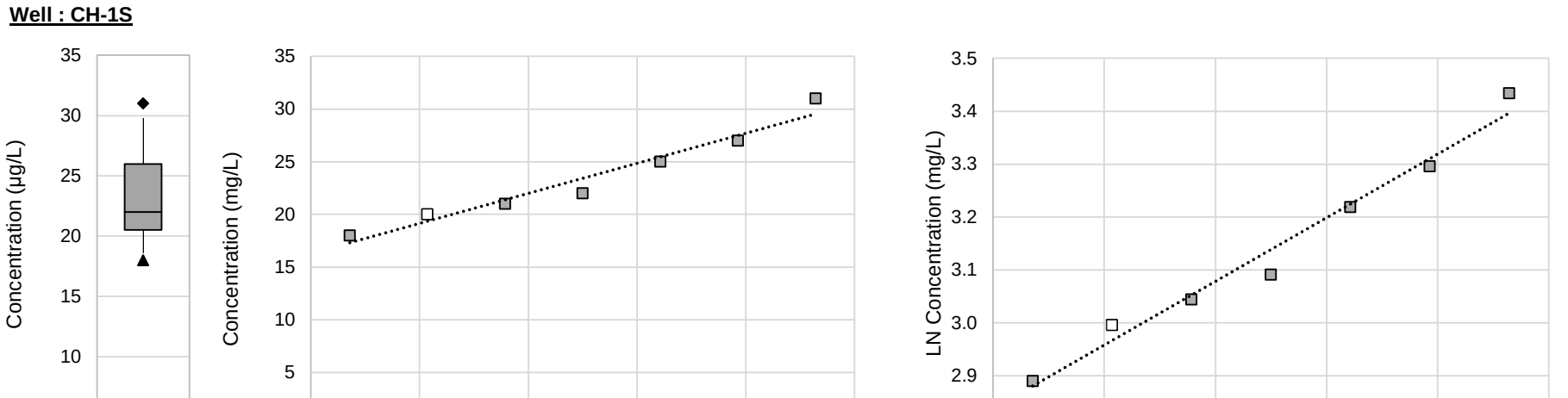
Well: CAP-2B



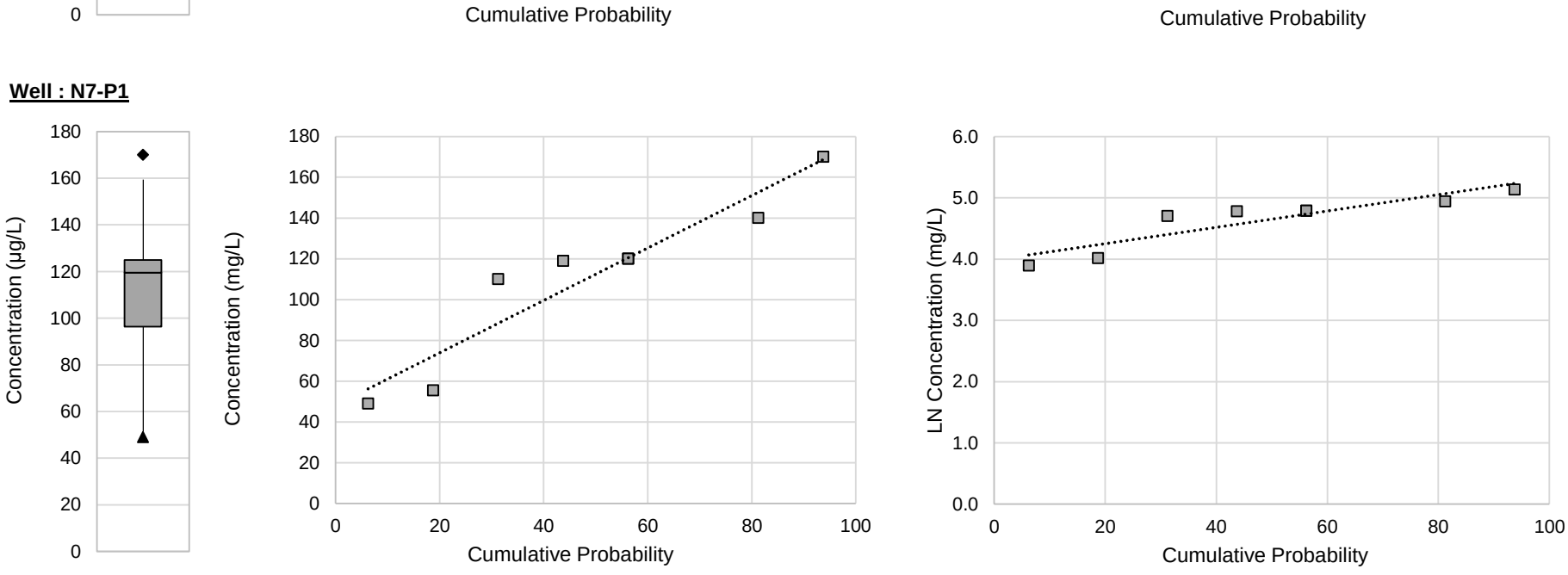
Well : CH-1D



Well : CH-1S



Well : N7-P1



Box and Whisker Plot Legend

- Maximum
- 95th Percentile
- 75th Percentile
- Median
- 25th Percentile
- 5th Percentile
- Minimum

Probability Plot Legend

- detection
- non-detection
- trendline

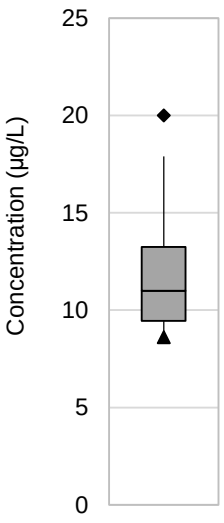
Notes
LN : lognormal
µg/L : microgram per liter

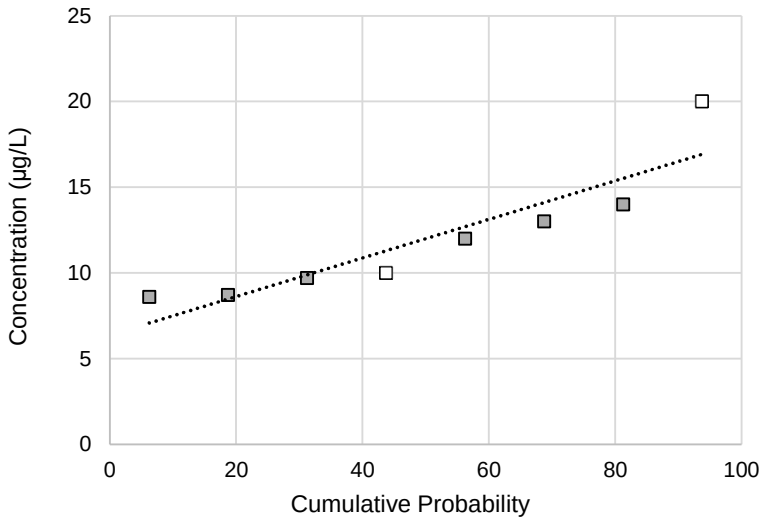
Figure B-6

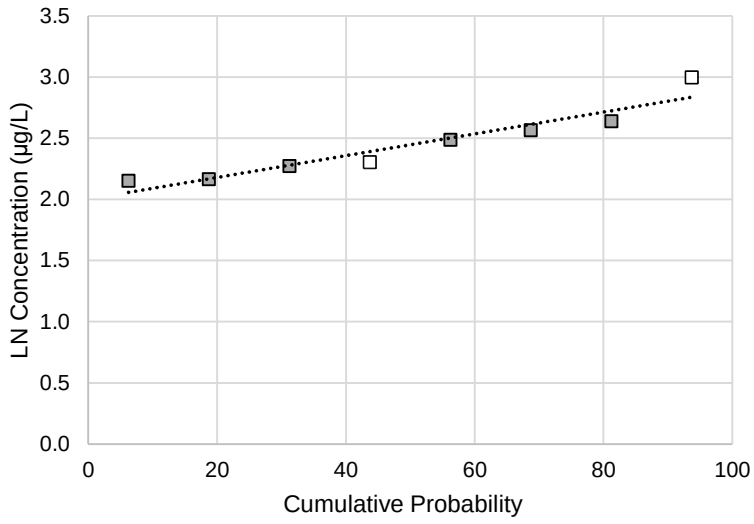
Attachment B: Box-and-Whisker and Probability Plots - Arsenic
Report on the Evaluation of Site-Specific Arsenic Background Concentrations in Groundwater
Shepley's Hill Landfill, Former Fort Devens Army Installation,
Devens, Massachusetts

ARCADIS

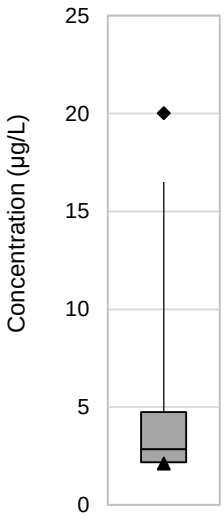
Well: Q4-1

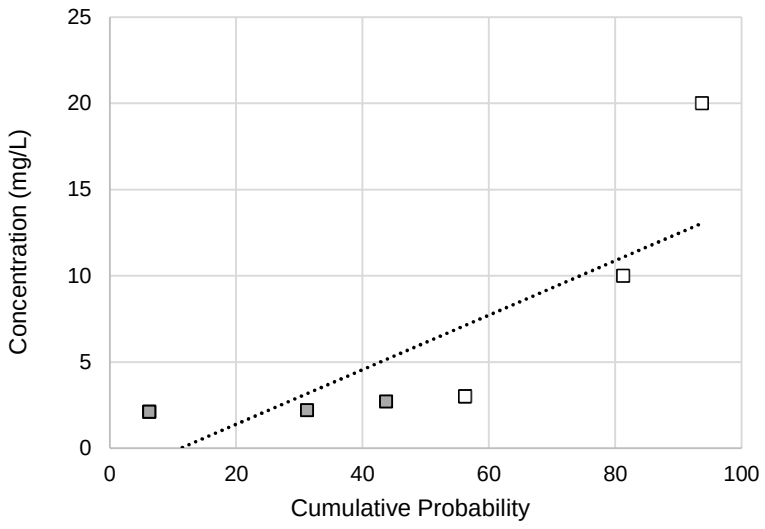


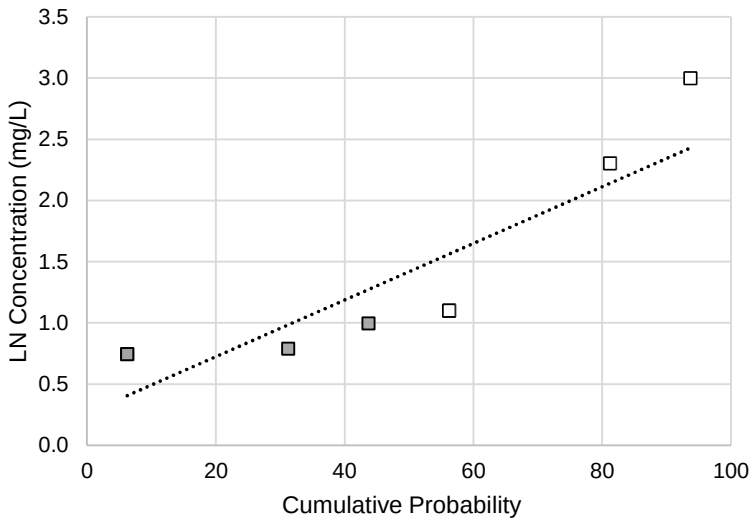




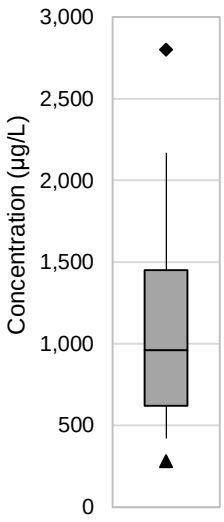
Well : Q5-1

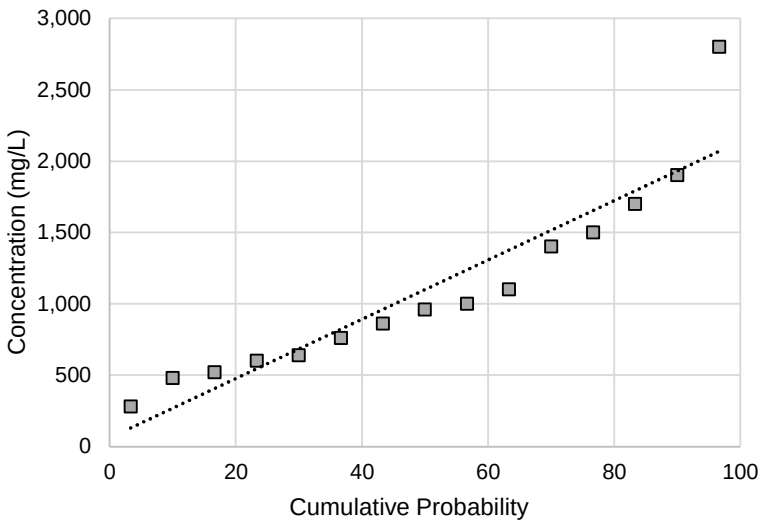


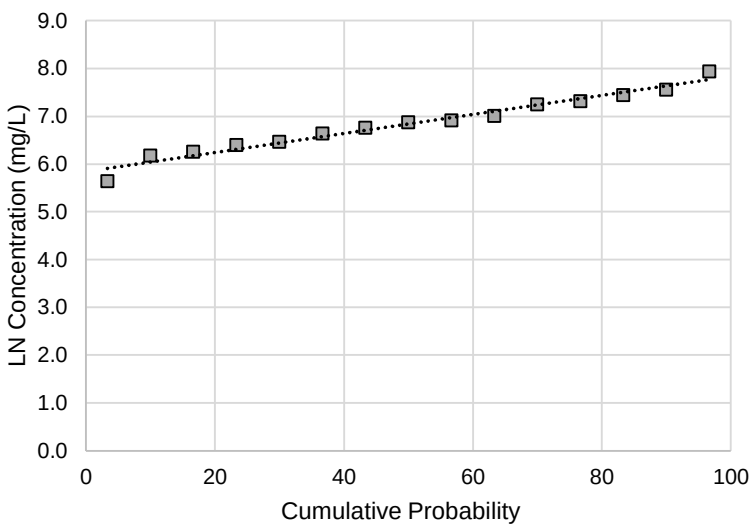




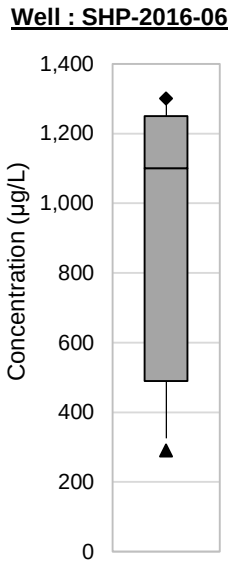
Well : SHP-2016-06A

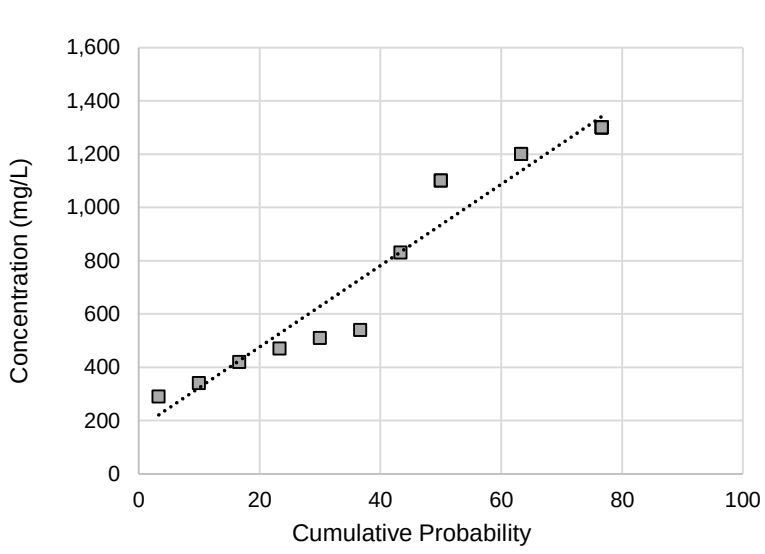


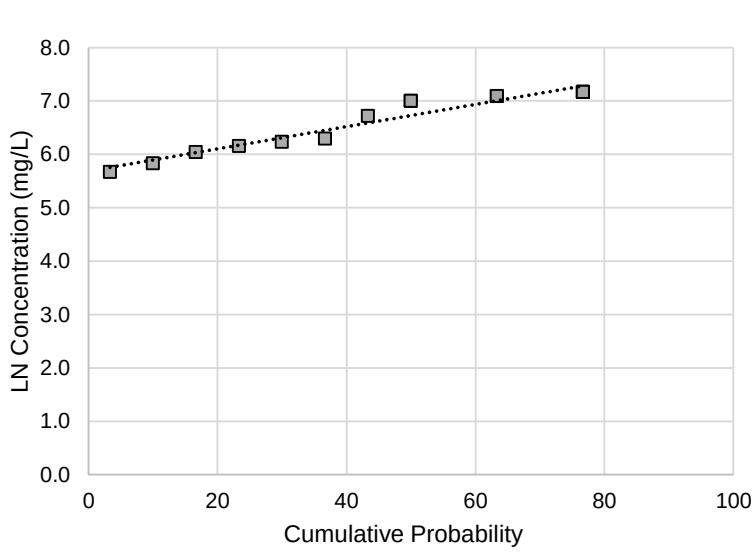




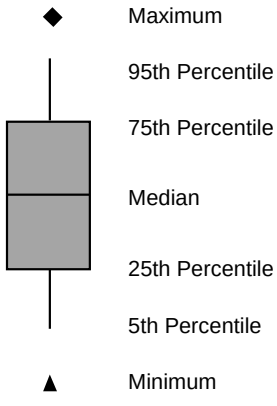
Well : SHP-2016-06B







Box and Whisker Plot Legend



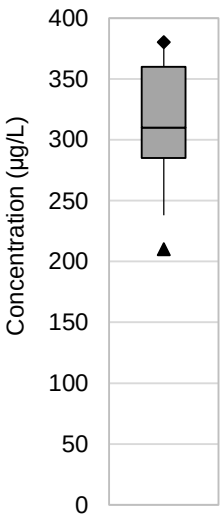
Probability Plot Legend

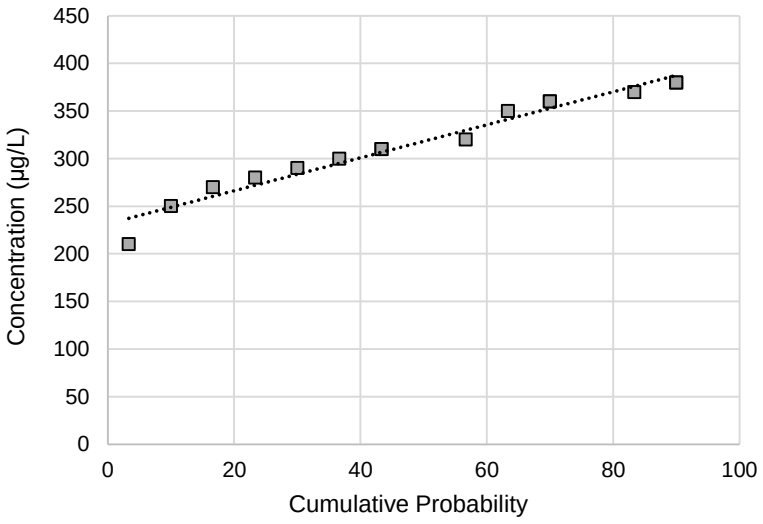
- detection
- non-detection
- trendline

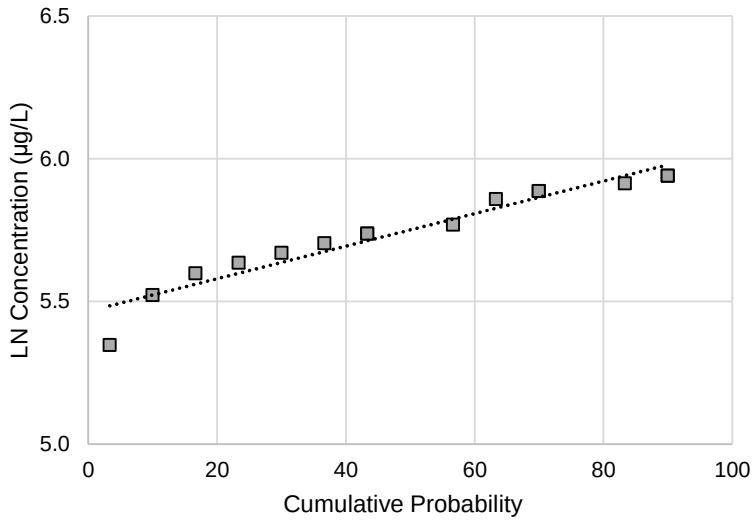
Notes
LN : lognormal
µg/L : microgram per liter

Figure B-7	**Attachment B: Box-and-Whisker and Probability Plots - Arsenic** Report on the Evaluation of Site-Specific Arsenic Background Concentrations in Groundwater Shepley's Hill Landfill, Former Fort Devens Army Installation, Devens, Massachusetts	ARCADIS

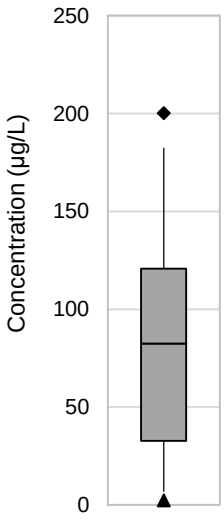
Well: SHP-2016-06C

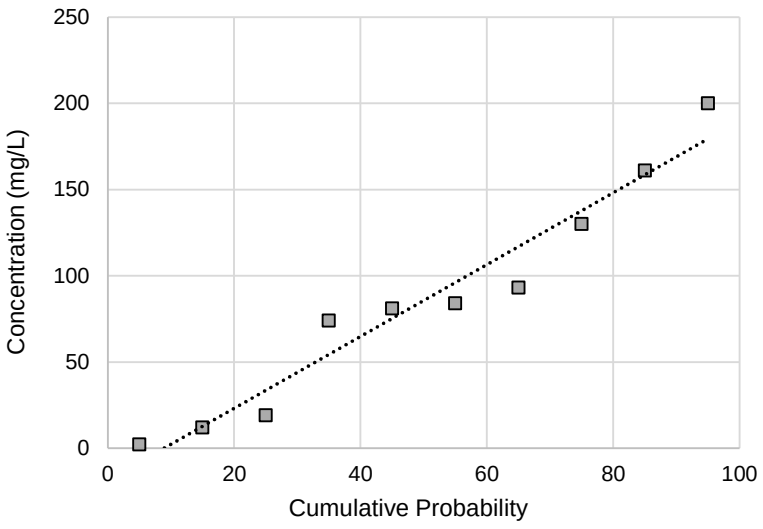


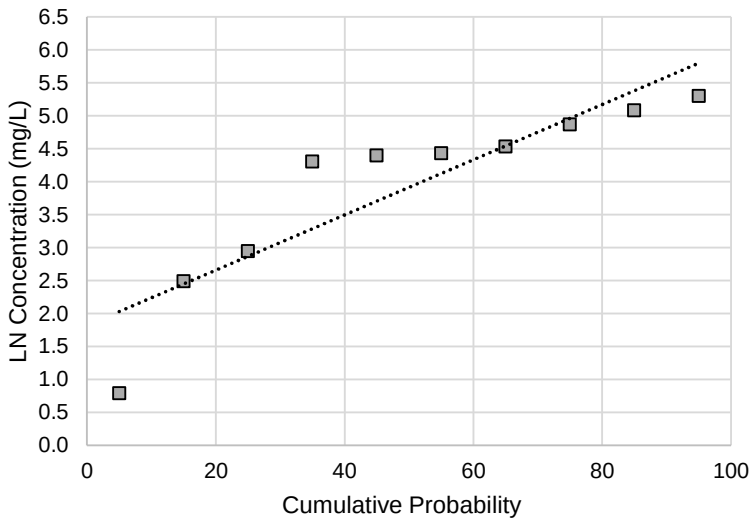




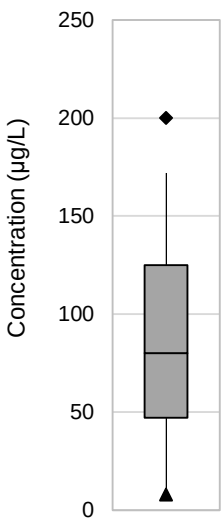
Well : SHP-2016-07A

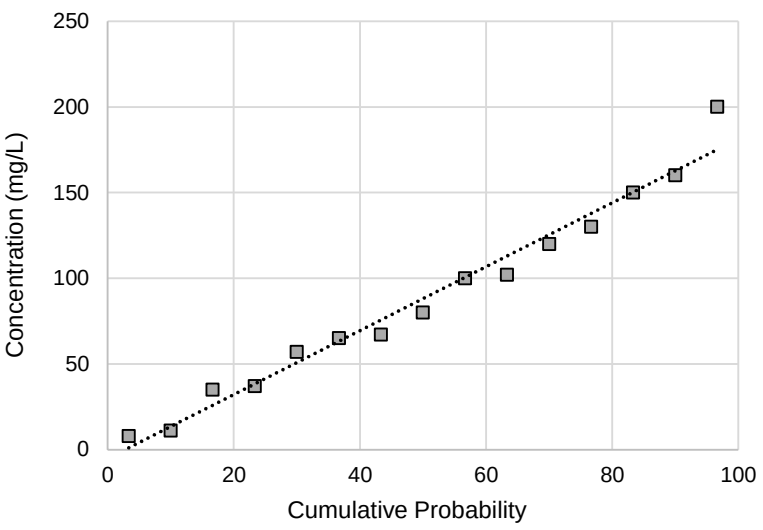


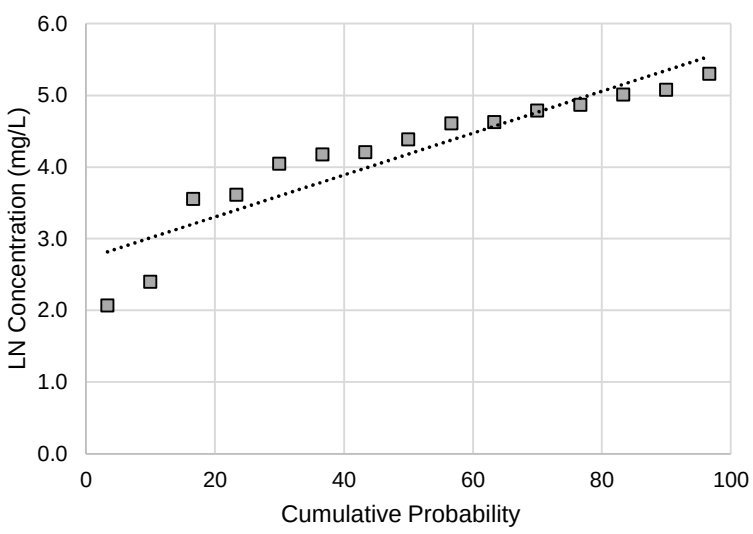




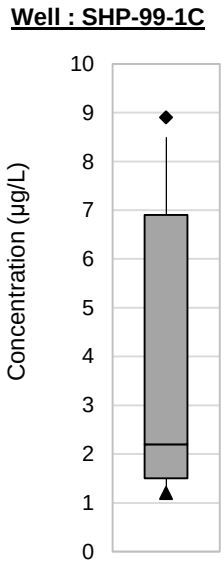
Well : SHP-2016-07B

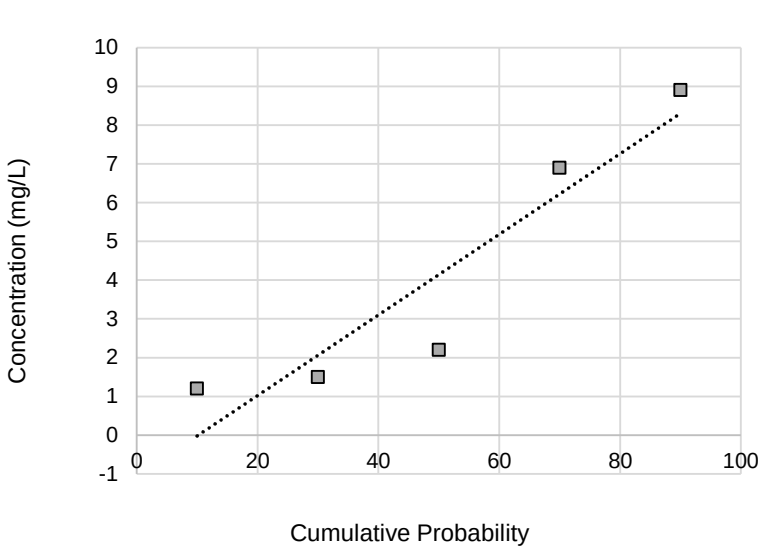


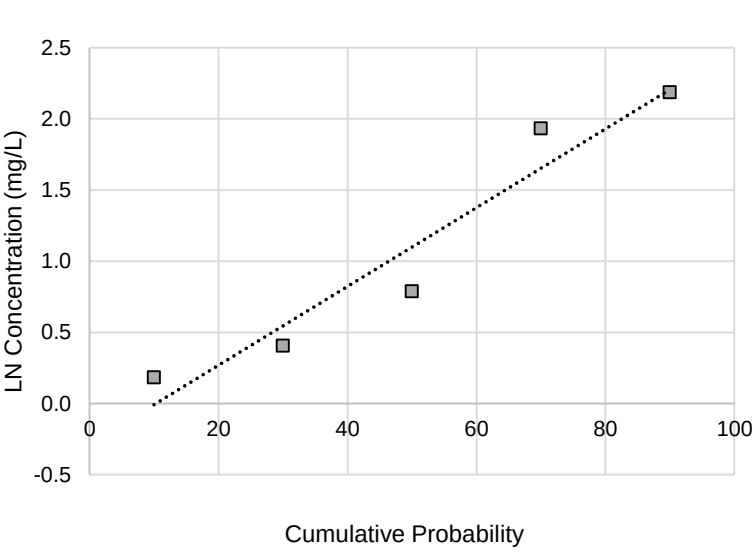




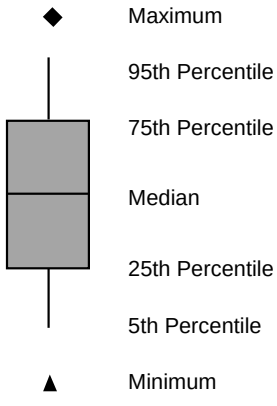
Well : SHP-99-1C







Box and Whisker Plot Legend



Probability Plot Legend

- detection
- non-detection
- trendline

Notes

LN : lognormal

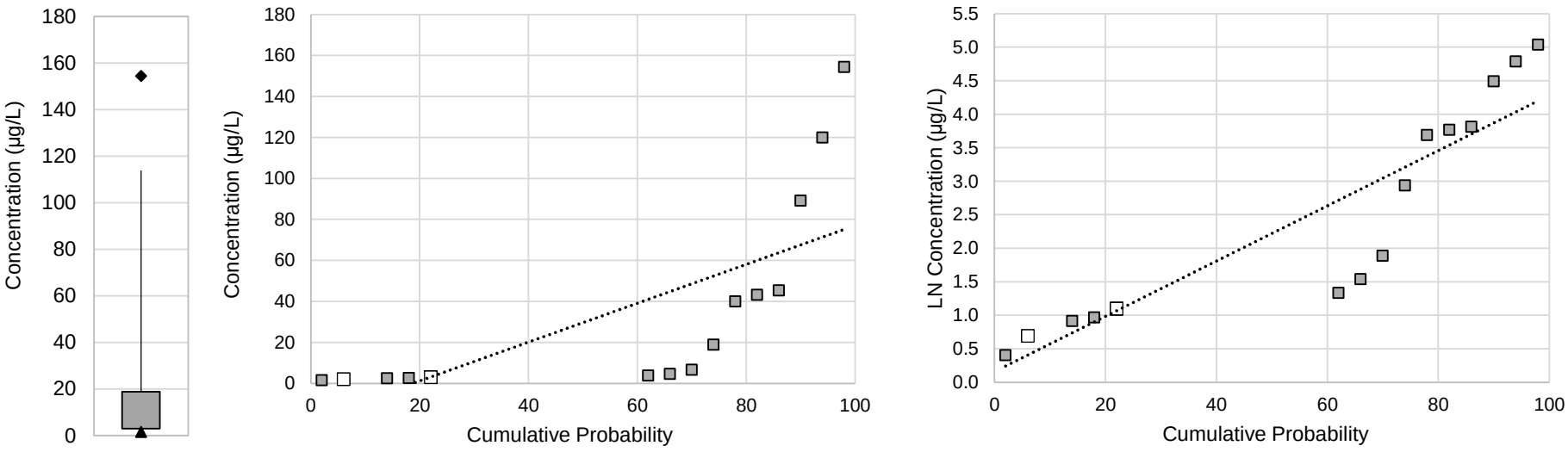
µg/L : microgram per liter

Figure B-8

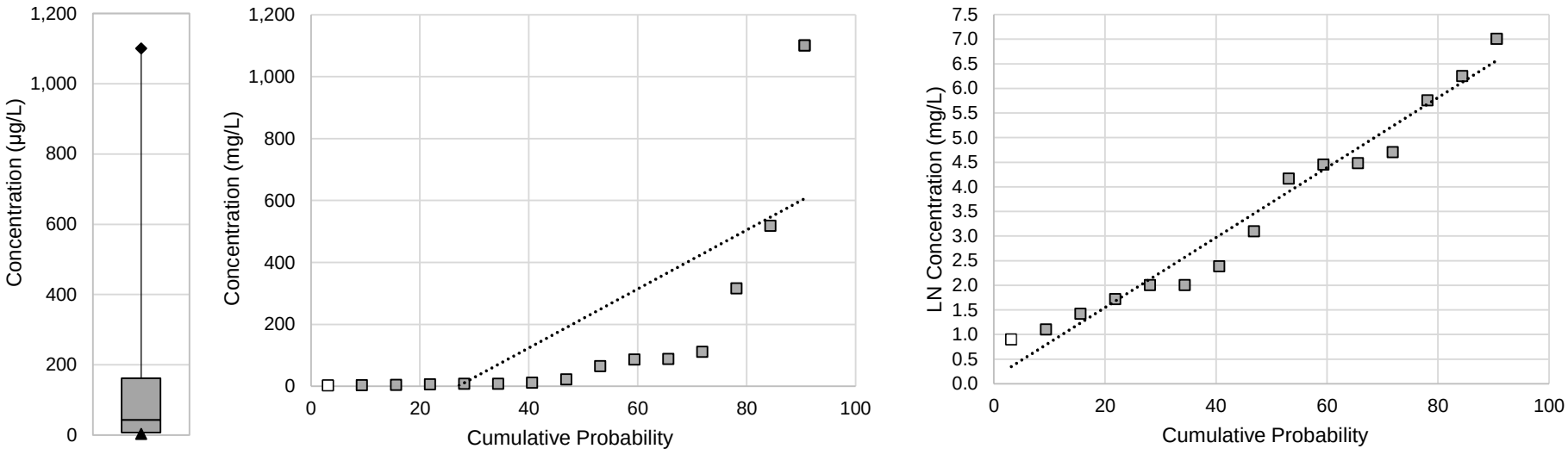
Attachment B: Box-and-Whisker and Probability Plots - Arsenic Central Tendency Values
Report on the Evaluation of Site-Specific Arsenic Background Concentrations in Groundwater
Shepley's Hill Landfill, Former Fort Devens Army Installation,
Devens, Massachusetts

ARCADIS

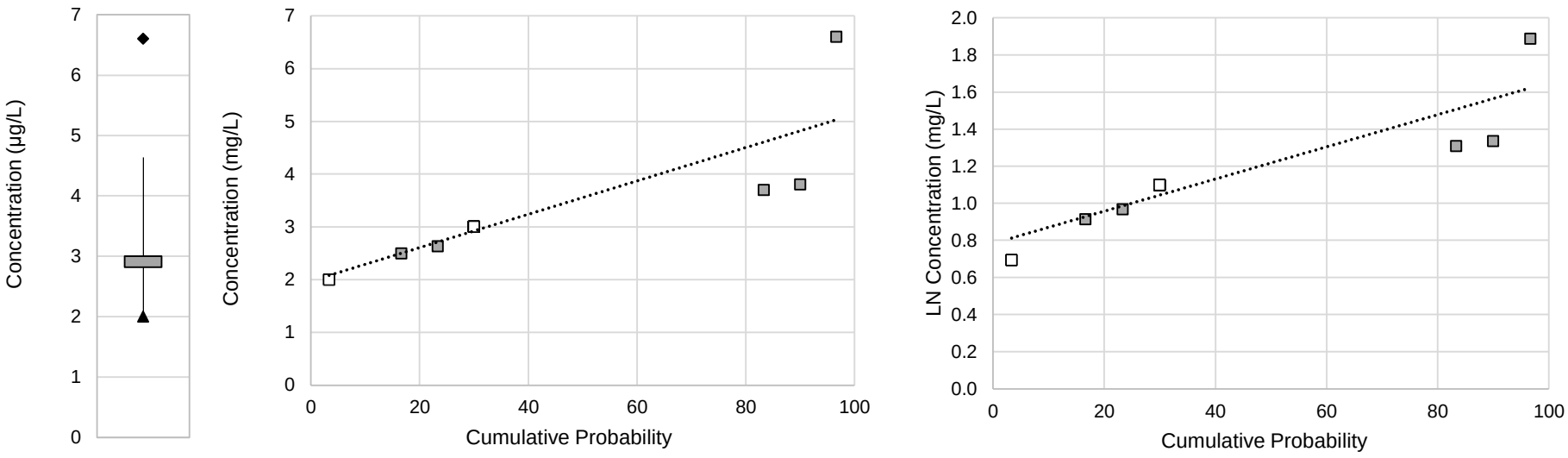
Well: Overburden Wells



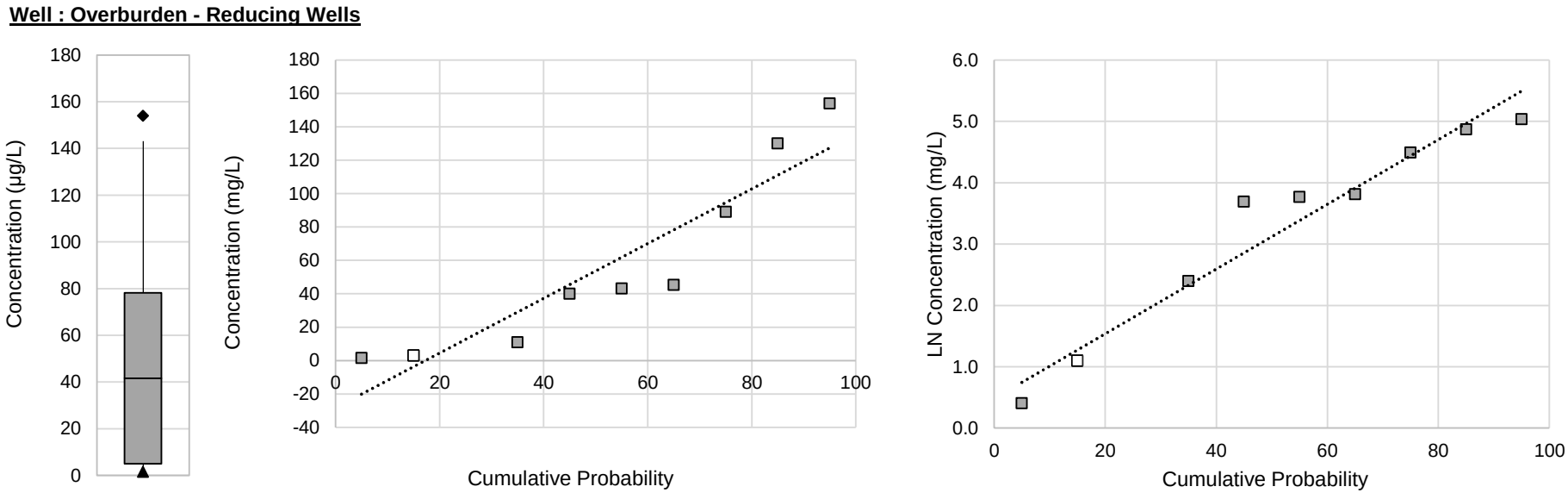
Well : Bedrock Wells



Well : Overburden - Oxidizing Wells



Well : Overburden - Reducing Wells



Box and Whisker Plot Legend

- Maximum
- 95th Percentile
- 75th Percentile
- Median
- 25th Percentile
- 5th Percentile
- Minimum

Probability Plot Legend

- detection
- non-detection
- trendline

Notes
LN : lognormal
µg/L : microgram per liter

Appendix C

ProUCL Outputs

Appendix C
ProUCL Outputs - General Statistics for Normally Distributed Data Requiring Kaplan-Meier Substitution
Report on the Evaluation of Site-Specific Arsenic Background Concentrations in Groundwater
Shepley's Hill Landfill, Former Fort Devens Army Installation
Devens, Massachusetts

General Statistics on Uncensored Data

Date/Time of Computation ProUCL 5.2 3/21/2023 9:58:33 PM

User Selected Options

From File ProUCL Input_for KM.xls

Full Precision OFF

From File: ProUCL Input_for KM.xls

General Statistics for Censored Data Set (with NDs) using Kaplan Meier Method

Variable	NumObs	# Missing	Num Ds	NumNDs	% NDs	Min ND	Max ND	KM Mean	KM Var	KM SD	KM CV
Arsenic (27-1)	8	0	6	2	25.00%	10	20	7.417	0.241	0.491	0.0662
Arsenic (q4-1)	8	0	6	2	25.00%	10	20	10.71	4.345	2.084	0.195
Arsenic (shl-12)	19	0	15	4	21.05%	2.19	3	2.237	1.616	1.271	0.568
Arsenic (shl-18)	7	0	5	2	28.57%	3	3	1.88	0.134	0.366	0.194
Arsenic (shl-25)	7	0	5	2	28.57%	2.07	3	2.493	0.639	0.799	0.321

General Statistics for Raw Data Sets using Detected Data Only

Variable	NumObs	# Missing	Minimum	Maximum	Mean	Median	Var	SD	MAD/0.675	Skewness	CV
Arsenic (27-1)	6	0	6.6	8	7.417	7.5	0.29	0.538	0.519	-0.53	0.0726
Arsenic (q4-1)	6	0	8.6	14	11	10.85	5.348	2.313	3.188	0.189	0.21
Arsenic (shl-12)	15	0	1.4	7.4	2.327	2	2.116	1.455	0.593	3.429	0.625
Arsenic (shl-18)	5	0	1.4	2.5	1.88	1.8	0.167	0.409	0.297	0.752	0.217
Arsenic (shl-25)	5	0	1.6	3.6	2.76	2.6	0.728	0.853	1.483	-0.286	0.309

Percentiles using all Detects (Ds) and Non-Detects (NDs)

Variable	NumObs	# Missing	10%ile	20%ile	25%ile(Q1)	50%ile(Q2)	75%ile(Q3)	80%ile	90%ile	95%ile	99%ile
Arsenic (27-1)	8	0	6.95	7.14	7.175	7.8	8.5	9.2	13	16.5	19.3
Arsenic (q4-1)	8	0	8.67	9.1	9.45	11	13.25	13.6	15.8	17.9	19.58
Arsenic (shl-12)	19	0	1.6	1.6	1.75	2	2.6	2.88	3	3.44	6.608
Arsenic (shl-18)	7	0	1.58	1.72	1.75	2	2.75	2.9	3	3	3
Arsenic (shl-25)	7	0	1.882	2.136	2.235	2.6	3.3	3.48	3.6	3.6	3.6

Appendix C
ProUCL Outputs - General Statistics for Transformed Data Requiring Kaplan-Meier Substitution
Report on the Evaluation of Site-Specific Arsenic Background Concentrations in Groundwater
Shepley's Hill Landfill, Former Fort Devens Army Installation
Devens, Massachusetts

General Statistics on Uncensored Data

Date/Time of Computation ProUCL 5.2 3/21/2023 9:59:40 PM

User Selected Options

From File ProUCL Input_for KM_a.xls

Full Precision OFF

From File: ProUCL Input_for KM_a.xls

General Statistics for Censored Data Set (with NDs) using Kaplan Meier Method

Variable	NumObs	# Missing	Num Ds	NumNDs	% NDs	Min ND	Max ND	KM Mean	KM Var	KM SD	KM CV
Arsenic (20-1)	8	0	6	2	25.00%	3.162	4.472	1.668	0.218	0.467	0.28
Arsenic (27-2)	8	0	6	2	25.00%	3.162	4.472	2.761	0.0946	0.308	0.111
Arsenic (cap-2b)	7	0	5	2	28.57%	3.162	4.472	2.335	0.106	0.325	0.139

General Statistics for Raw Data Sets using Detected Data Only

Variable	NumObs	# Missing	Minimum	Maximum	Mean	Median	Var	SD	MAD/0.675	Skewness	CV
Arsenic (20-1)	6	0	1.049	2.449	1.668	1.591	0.261	0.511	0.534	0.509	0.306
Arsenic (27-2)	6	0	2.302	3.162	2.773	2.89	0.116	0.34	0.272	-0.615	0.123
Arsenic (cap-2b)	5	0	1.924	2.881	2.335	2.387	0.132	0.364	0.43	0.687	0.156

Percentiles using all Detects (Ds) and Non-Detects (NDs)

Variable	NumObs	# Missing	10%ile	20%ile	25%ile(Q1)	50%ile(Q2)	75%ile(Q3)	80%ile	90%ile	95%ile	99%ile
Arsenic (20-1)	8	0	1.227	1.362	1.413	1.878	2.628	2.877	3.555	4.014	4.38
Arsenic (27-2)	8	0	2.376	2.597	2.763	2.941	3.162	3.162	3.555	4.014	4.38
Arsenic (cap-2b)	7	0	2.028	2.156	2.243	2.387	3.022	3.106	3.686	4.079	4.394

Appendix C
ProUCL Outputs - General Statistics for Central Tendency Value Data
Report on the Evaluation of Site-Specific Arsenic Background Concentrations in Groundwater
Shepley's Hill Landfill, Former Fort Devens Army Installation
Devens, Massachusetts

General Statistics on Uncensored Data

Date/Time of Computation ProUCL 5.2 5/5/2023 6:25:06 PM

User Selected Options

From File ProUCL Input_for KM_rev_b.xls

Full Precision OFF

From File: ProUCL Input_for KM_rev_b.xls

General Statistics for Censored Data Set (with NDs) using Kaplan Meier Method

Variable	NumObs	# Missing	Num Ds	NumNDs	% NDs	Min ND	Max ND	KM Mean	KM Var	KM SD	KM CV
Arsenic (bedrock)	16	0	15	1	6.25%	2.45	2.45	215.3	129910	360.4	1.674
Arsenic (combined)	41	0	33	8	19.51%	2	3	97.64	60524	246	2.52
Arsenic (overburden)	25	0	18	7	28.00%	2	3	22.39	1582	39.78	1.777

General Statistics for Raw Data Sets using Detected Data Only

Variable	NumObs	# Missing	Minimum	Maximum	Mean	Median	Var	SD	MAD/0.675	Skewness	CV
Arsenic (bedrock)	15	0	3	1100	229.5	64.4	145017	380.8	84.51	1.875	1.659
Arsenic (combined)	33	0	1.5	1100	120.9	10.9	74688	273.3	12.45	3.124	2.26
Arsenic (overburden)	18	0	1.5	154	30.4	4.23	2085	45.66	3.039	1.805	1.502

Percentiles using all Detects (Ds) and Non-Detects (NDs)

Variable	NumObs	# Missing	10%ile	20%ile	25%ile(Q1)	50%ile(Q2)	75%ile(Q3)	80%ile	90%ile	95%ile	99%ile
Arsenic (bedrock)	16	0	3.55	5.6	6.95	43.2	161.5	316	809	1100	1100
Arsenic (combined)	41	0	2.5	3	3	5.6	64.4	88.1	154	518	1100
Arsenic (overburden)	25	0	2.2	2.92	3	3	18.9	40.64	71.58	113.8	145.8

Appendix C
ProUCL Outputs - General Statistics for Central Tendency Value Data in Overburden Wells with Reducing Conditions
Report on the Evaluation of Site-Specific Arsenic Background Concentrations in Groundwater
Shepley's Hill Landfill, Former Fort Devens Army Installation
Devens, Massachusetts

General Statistics on Uncensored Data

Date/Time of Computation ProUCL 5.2 5/5/2023 6:25:06 PM

User Selected Options

From File ProUCL Input_for KM_rev_b.xls

Full Precision OFF

From File: ProUCL Input_for KM_rev_b.xls

General Statistics for Censored Data Set (with NDs) using Kaplan Meier Method

Variable	NumObs	# Missing	Num Ds	NumNDs	% NDs	Min ND	Max ND	KM Mean	KM Var	KM SD	KM CV
Arsenic (reducing)	10	0	9	1	10.00%	3	3	51.65	2527	50.27	0.973

General Statistics for Raw Data Sets using Detected Data Only

Variable	NumObs	# Missing	Minimum	Maximum	Mean	Median	Var	SD	MAD/0.675	Skewness	CV
Arsenic (reducing)	9	0	1.5	154	57.22	43.2	2809	53	59.6	0.851	0.926

Percentiles using all Detects (Ds) and Non-Detects (NDs)

Variable	NumObs	# Missing	10%ile	20%ile	25%ile(Q1)	50%ile(Q2)	75%ile(Q3)	80%ile	90%ile	95%ile	99%ile
Arsenic (reducing)	10	0	2.85	3	6.975	41.6	78.15	95.28	123.4	138.7	150.9

Appendix C
ProUCL Outputs - Tarone-Ware Hypothesis Test, Overburden versus Bedrock
Report on the Evaluation of Site-Specific Arsenic Background Concentrations in Groundwater
Shepley's Hill Landfill, Former Fort Devens Army Installation
Devens, Massachusetts

Tarone-Ware Sample 1 vs Sample 2 Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.2 3/23/2023 5:38:47 PM
From File	ProUCL Input_for KM_b.xls
Full Precision	OFF
Confidence Coefficient	95%
Selected Null Hypothesis	Sample 1 Mean/Median = Sample 2 Mean/Median (Two Sided Alternative)
Alternative Hypothesis	Sample 1 Mean/Median <> Sample 2 Mean/Median

Sample 1 Data: Arsenic(overburden)
Sample 2 Data: Arsenic(bedrock)

Raw Statistics

	Sample 1	Sample 2
Number of Valid Data	25	16
Number of Non-Detects	7	1
Number of Detects	18	15
Minimum Non-Detect	2	2.45
Maximum Non-Detect	3	2.45
Percent Non-detects	28.00%	6.25%
Minimum Detect	1.5	3
Maximum Detect	154	1400
Mean of Detects	30.46	213.2
Median of Detects	3.75	64.4
SD of Detects	47.04	376
KM Mean	22.44	200.1
KM SD	40.87	355.4

Sample 1 vs Sample 2 Tarone-Ware Test

H0: Mean/Median of Sample 1 = Mean/Median of Sample 2

TW Statistic	-3.283
Lower TW Critical Value(0.025)	-1.96
Upper TW Critical Value (0.975)	1.96
P-Value	0.00103

Conclusion with Alpha = 0.05
Reject H0, Conclude Sample 1 <> Sample 2
P-Value < alpha (0.05)

Appendix C
ProUCL Outputs - Background Threshold Values
Report on the Evaluation of Site-Specific Arsenic Background Concentrations in Groundwater
Shepley's Hill Landfill, Former Fort Devens Army Installation
Devens, Massachusetts

Background Statistics for Data Sets with Non-Detects

User Selected Options

Date/Time of Computation	ProUCL 5.2 5/5/2023 6:06:17 PM
From File	ProUCL Input_for KM_rev_b.xls
Full Precision	OFF
Confidence Coefficient	95%
Coverage	95%
Different or Future K Observations	1
Number of Bootstrap Operations	2000

Arsenic (bedrock)

General Statistics

Total Number of Observations	16	Number of Missing Observations	0
Number of Distinct Observations	14		
Number of Detects	15	Number of Non-Detects	1
Number of Distinct Detects	13	Number of Distinct Non-Detects	1
Minimum Detect	3	Minimum Non-Detect	2.45
Maximum Detect	1100	Maximum Non-Detect	2.45
Variance Detected	145017	Percent Non-Detects	6.25%
Mean Detected	229.5	SD Detected	380.8
Mean of Detected Logged Data	3.835	SD of Detected Logged Data	2.043

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.524	d2max (for USL)	2.443

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.636	**Shapiro Wilk GOF Test**
1% Shapiro Wilk Critical Value	0.835	Data Not Normal at 1% Significance Level
Lilliefors Test Statistic	0.356	**Lilliefors GOF Test**
1% Lilliefors Critical Value	0.255	Data Not Normal at 1% Significance Level

Data Not Normal at 1% Significance Level

Kaplan Meier (KM) Background Statistics Assuming Normal Distribution

KM Mean	215.3	KM SD	360.4
95% UTL95% Coverage	1125	95% KM UPL (t)	866.6
90% KM Percentile (z)	677.2	95% KM Percentile (z)	808.2
99% KM Percentile (z)	1054	95% KM USL	1096

DL/2 Substitution Background Statistics Assuming Normal Distribution

Mean	215.2	SD	372.3
95% UTL95% Coverage	1155	95% UPL (t)	888
90% Percentile (z)	692.4	95% Percentile (z)	827.6
99% Percentile (z)	1081	95% USL	1125

DL/2 is not a recommended method. DL/2 provided for comparisons and historical reasons

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.744	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.812	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.186	**Kolmogorov-Smirnov GOF**
5% K-S Critical Value	0.237	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	0.409	k star (bias corrected MLE)	0.372
Theta hat (MLE)	560.5	Theta star (bias corrected MLE)	617
nu hat (MLE)	12.28	nu star (bias corrected)	11.16
MLE Mean (bias corrected)	229.5		
MLE Sd (bias corrected)	376.3	95% Percentile of Chisquare (2kstar)	3.169

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)
For such situations, GROS method may yield incorrect values of UCLs and BTVs
This is especially true when the sample size is small.
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	215.2
Maximum	1100	Median	43.2
SD	372.3	CV	1.731
k hat (MLE)	0.329	k star (bias corrected MLE)	0.309
Theta hat (MLE)	653.8	Theta star (bias corrected MLE)	696.2
nu hat (MLE)	10.53	nu star (bias corrected)	9.889
MLE Mean (bias corrected)	215.2	MLE Sd (bias corrected)	387
95% Percentile of Chisquare (2kstar)	2.8	90% Percentile	632.3
95% Percentile	974.9	99% Percentile	1862

The following statistics are computed using Gamma ROS Statistics on Imputed Data
Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	1794	2248	95% Approx. Gamma UPL	967.5	1071
95% Gamma USL	1684	2081			

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	215.3	SD (KM)	360.4
Variance (KM)	129910	SE of Mean (KM)	93.27
k hat (KM)	0.357	k star (KM)	0.332
nu hat (KM)	11.42	nu star (KM)	10.61
theta hat (KM)	603.4	theta star (KM)	649.3
80% gamma percentile (KM)	337.6	90% gamma percentile (KM)	626.7
95% gamma percentile (KM)	953.3	99% gamma percentile (KM)	1792

The following statistics are computed using gamma distribution and KM estimates
Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	1628	1919	95% Approx. Gamma UPL	894.2	946.1
95% KM Gamma Percentile	766.6	791.2	95% Gamma USL	1531	1783

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.92	**Shapiro Wilk GOF Test**
10% Shapiro Wilk Critical Value	0.901	Detected Data appear Lognormal at 10% Significance Level
Lilliefors Test Statistic	0.16	**Lilliefors GOF Test**
10% Lilliefors Critical Value	0.202	Detected Data appear Lognormal at 10% Significance Level

Detected Data appear Lognormal at 10% Significance Level

Background Lognormal ROS Statistics Assuming Lognormal Distribution Using Imputed Non-Detects

Mean in Original Scale	215.2	Mean in Log Scale	3.522
SD in Original Scale	372.3	SD in Log Scale	2.336
95% UTL95% Coverage	12312	95% BCA UTL95% Coverage	1100
95% Bootstrap (%) UTL95% Coverage	1100	95% UPL (t)	2306
90% Percentile (z)	675.9	95% Percentile (z)	1579
99% Percentile (z)	7759	95% USL	10196

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean of Logged Data	3.651	95% KM UTL (Lognormal)95% Coverage	6621
KM SD of Logged Data	2.039	95% KM UPL (Lognormal)	1534
95% KM Percentile Lognormal (z)	1102	95% KM USL (Lognormal)	5616

Background DL/2 Statistics Assuming Lognormal Distribution

Mean in Original Scale	215.2	Mean in Log Scale	3.608
SD in Original Scale	372.3	SD in Log Scale	2.173
95% UTL95% Coverage	8879	95% UPL (t)	1870
90% Percentile (z)	597.1	95% Percentile (z)	1315
99% Percentile (z)	5779	95% USL	7450

DL/2 is not a Recommended Method. DL/2 provided for comparisons and historical reasons.

Nonparametric Distribution Free Background Statistics
Data appear to follow a Discernible Distribution

Nonparametric Upper Limits for BTVs(no distinction made between detects and nondetects)

Order of Statistic, r	16	95% UTL with95% Coverage	1100
Approx, f used to compute achieved CC	0.842	Approximate Actual Confidence Coefficient achieved by UTL	0.56
Approximate Sample Size needed to achieve specified CC	59	95% UPL	1100
95% USL	1100	95% KM Chebyshev UPL	1835

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Arsenic (combined)

General Statistics

Total Number of Observations	41	Number of Missing Observations	0
Number of Distinct Observations	28		
Number of Detects	33	Number of Non-Detects	8
Number of Distinct Detects	26	Number of Distinct Non-Detects	3
Minimum Detect	1.5	Minimum Non-Detect	2
Maximum Detect	1100	Maximum Non-Detect	3
Variance Detected	74688	Percent Non-Detects	19.51%
Mean Detected	120.9	SD Detected	273.3
Mean of Detected Logged Data	2.987	SD of Detected Logged Data	1.934

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.11	d2max (for USL)	2.878

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.478	**Shapiro Wilk GOF Test**
1% Shapiro Wilk Critical Value	0.906	Data Not Normal at 1% Significance Level
Lilliefors Test Statistic	0.35	**Lilliefors GOF Test**
1% Lilliefors Critical Value	0.177	Data Not Normal at 1% Significance Level

Data Not Normal at 1% Significance Level

Kaplan Meier (KM) Background Statistics Assuming Normal Distribution

KM Mean	97.64	KM SD	246
95% UTL95% Coverage	616.8	95% KM UPL (t)	516.9
90% KM Percentile (z)	412.9	95% KM Percentile (z)	502.3
99% KM Percentile (z)	670	95% KM USL	805.6

DL/2 Substitution Background Statistics Assuming Normal Distribution

Mean	97.57	SD	249.1
95% UTL95% Coverage	623.2	95% UPL (t)	522.1
90% Percentile (z)	416.8	95% Percentile (z)	507.3
99% Percentile (z)	677.1	95% USL	814.4

DL/2 is not a recommended method. DL/2 provided for comparisons and historical reasons

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	2.272	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.84	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.209	**Kolmogorov-Smirnov GOF**
5% K-S Critical Value	0.165	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	0.369	k star (bias corrected MLE)	0.355
Theta hat (MLE)	327.8	Theta star (bias corrected MLE)	340.1
nu hat (MLE)	24.34	nu star (bias corrected)	23.46
MLE Mean (bias corrected)	120.9		
MLE Sd (bias corrected)	202.8	95% Percentile of Chisquare (2kstar)	3.075

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)
For such situations, GROS method may yield incorrect values of UCLs and BTVs
This is especially true when the sample size is small.
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	97.31
Maximum	1100	Median	5.6
SD	249.2	CV	2.561
k hat (MLE)	0.234	k star (bias corrected MLE)	0.233
Theta hat (MLE)	416.4	Theta star (bias corrected MLE)	417.9
nu hat (MLE)	19.16	nu star (bias corrected)	19.1
MLE Mean (bias corrected)	97.31	MLE Sd (bias corrected)	201.7
95% Percentile of Chisquare (2kstar)	2.302	90% Percentile	293.3
95% Percentile	480.9	99% Percentile	985.4

The following statistics are computed using Gamma ROS Statistics on Imputed Data
Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	541.2	610.5	95% Approx. Gamma UPL	359.5	373.1
95% Gamma USL	1034	1348			

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	97.64	SD (KM)	246
Variance (KM)	60524	SE of Mean (KM)	39.02
k hat (KM)	0.158	k star (KM)	0.162
nu hat (KM)	12.92	nu star (KM)	13.31
theta hat (KM)	619.8	theta star (KM)	601.8
80% gamma percentile (KM)	113	90% gamma percentile (KM)	292.2
95% gamma percentile (KM)	528.8	99% gamma percentile (KM)	1205

The following statistics are computed using gamma distribution and KM estimates
Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	497.2	510.6	95% Approx. Gamma UPL	337.7	326.4
95% KM Gamma Percentile	317.7	304.4	95% Gamma USL	922.3	1059

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.899	**Shapiro Wilk GOF Test**
10% Shapiro Wilk Critical Value	0.942	Data Not Lognormal at 10% Significance Level
Lilliefors Test Statistic	0.18	**Lilliefors GOF Test**
10% Lilliefors Critical Value	0.139	Data Not Lognormal at 10% Significance Level

Data Not Lognormal at 10% Significance Level

Background Lognormal ROS Statistics Assuming Lognormal Distribution Using Imputed Non-Detects

Mean in Original Scale	97.42	Mean in Log Scale	2.245
SD in Original Scale	249.2	SD in Log Scale	2.329
95% UTL95% Coverage	1286	95% BCA UTL95% Coverage	1100
95% Bootstrap (%) UTL95% Coverage	1100	95% UPL (t)	499.7
90% Percentile (z)	186.7	95% Percentile (z)	435.2
99% Percentile (z)	2128	95% USL	7684

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean of Logged Data	2.505	95% KM UTL (Lognormal)95% Coverage	784.5
KM SD of Logged Data	1.971	95% KM UPL (Lognormal)	352.4
95% KM Percentile Lognormal (z)	313.4	95% KM USL (Lognormal)	3561

Background DL/2 Statistics Assuming Lognormal Distribution

Mean in Original Scale	97.57	Mean in Log Scale	2.459
SD in Original Scale	249.1	SD in Log Scale	2.044
95% UTL95% Coverage	873.1	95% UPL (t)	380.8
90% Percentile (z)	160.5	95% Percentile (z)	337.2
99% Percentile (z)	1358	95% USL	4191

DL/2 is not a Recommended Method. DL/2 provided for comparisons and historical reasons.

Nonparametric Distribution Free Background Statistics
Data do not follow a Discernible Distribution

Nonparametric Upper Limits for BTVs(no distinction made between detects and nondetects)

Order of Statistic, r	41	95% UTL with95% Coverage	1100
Approx, f used to compute achieved CC	2.158	Approximate Actual Confidence Coefficient achieved by UTL	0.878
Approximate Sample Size needed to achieve specified CC	59	95% UPL	1042
95% USL	1100	95% KM Chebyshev UPL	1183

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Arsenic (overburden)

General Statistics

Total Number of Observations	25	Number of Missing Observations	0
Number of Distinct Observations	15		
Number of Detects	18	Number of Non-Detects	7
Number of Distinct Detects	14	Number of Distinct Non-Detects	2
Minimum Detect	1.5	Minimum Non-Detect	2
Maximum Detect	154	Maximum Non-Detect	3
Variance Detected	2085	Percent Non-Detects	28%
Mean Detected	30.4	SD Detected	45.66
Mean of Detected Logged Data	2.281	SD of Detected Logged Data	1.562

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.292	d2max (for USL)	2.663

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.684	**Shapiro Wilk GOF Test**
1% Shapiro Wilk Critical Value	0.858	Data Not Normal at 1% Significance Level
Lilliefors Test Statistic	0.31	**Lilliefors GOF Test**
1% Lilliefors Critical Value	0.235	Data Not Normal at 1% Significance Level

Data Not Normal at 1% Significance Level

Kaplan Meier (KM) Background Statistics Assuming Normal Distribution

KM Mean	22.39	KM SD	39.78
95% UTL95% Coverage	113.6	95% KM UPL (t)	91.8
90% KM Percentile (z)	73.37	95% KM Percentile (z)	87.82
99% KM Percentile (z)	114.9	95% KM USL	128.3

DL/2 Substitution Background Statistics Assuming Normal Distribution

Mean	22.27	SD	40.67
95% UTL95% Coverage	115.5	95% UPL (t)	93.22
90% Percentile (z)	74.38	95% Percentile (z)	89.16
99% Percentile (z)	116.9	95% USL	130.6

DL/2 is not a recommended method. DL/2 provided for comparisons and historical reasons

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	1.567	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.796	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.277	**Kolmogorov-Smirnov GOF**
5% K-S Critical Value	0.214	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	0.552	k star (bias corrected MLE)	0.497
Theta hat (MLE)	55.08	Theta star (bias corrected MLE)	61.17
nu hat (MLE)	19.87	nu star (bias corrected)	17.89
MLE Mean (bias corrected)	30.4		
MLE Sd (bias corrected)	43.12	95% Percentile of Chisquare (2kstar)	3.826

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)
For such situations, GROS method may yield incorrect values of UCLs and BTVs
This is especially true when the sample size is small.
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	21.89
Maximum	154	Median	3
SD	40.87	CV	1.867
k hat (MLE)	0.258	k star (bias corrected MLE)	0.254
Theta hat (MLE)	84.69	Theta star (bias corrected MLE)	86.14
nu hat (MLE)	12.92	nu star (bias corrected)	12.71
MLE Mean (bias corrected)	21.89	MLE Sd (bias corrected)	43.42
95% Percentile of Chisquare (2kstar)	2.448	90% Percentile	65.62
95% Percentile	105.4	99% Percentile	211.2

The following statistics are computed using Gamma ROS Statistics on Imputed Data
Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	156.6	196.4	95% Approx. Gamma UPL	93.52	104.7
95% Gamma USL	212.5	286.1			

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	22.39	SD (KM)	39.78
Variance (KM)	1582	SE of Mean (KM)	8.187
k hat (KM)	0.317	k star (KM)	0.305
nu hat (KM)	15.84	nu star (KM)	15.27
theta hat (KM)	70.68	theta star (KM)	73.3
80% gamma percentile (KM)	34.49	90% gamma percentile (KM)	65.89
95% gamma percentile (KM)	101.8	99% gamma percentile (KM)	195

The following statistics are computed using gamma distribution and KM estimates
Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	127.2	134.7	95% Approx. Gamma UPL	81.21	80.81
95% KM Gamma Percentile	74.24	73.06	95% Gamma USL	166.6	184.1

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.841	**Shapiro Wilk GOF Test**
10% Shapiro Wilk Critical Value	0.914	Data Not Lognormal at 10% Significance Level
Lilliefors Test Statistic	0.238	**Lilliefors GOF Test**
10% Lilliefors Critical Value	0.185	Data Not Lognormal at 10% Significance Level

Data Not Lognormal at 10% Significance Level

Background Lognormal ROS Statistics Assuming Lognormal Distribution Using Imputed Non-Detects

Mean in Original Scale	22.12	Mean in Log Scale	1.529
SD in Original Scale	40.74	SD in Log Scale	1.84
95% UTL95% Coverage	313.2	95% BCA UTL95% Coverage	147.2
95% Bootstrap (%) UTL95% Coverage	154	95% UPL (t)	114.4
90% Percentile (z)	48.78	95% Percentile (z)	95.19
99% Percentile (z)	333.7	95% USL	619.9

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean of Logged Data	1.798	95% KM UTL (Lognormal)95% Coverage	191.3
KM SD of Logged Data	1.508	95% KM UPL (Lognormal)	83.82
95% KM Percentile Lognormal (z)	72.1	95% KM USL (Lognormal)	334.6

Background DL/2 Statistics Assuming Lognormal Distribution

Mean in Original Scale	22.27	Mean in Log Scale	1.723
SD in Original Scale	40.67	SD in Log Scale	1.603
95% UTL95% Coverage	220.8	95% UPL (t)	91.84
90% Percentile (z)	43.71	95% Percentile (z)	78.25
99% Percentile (z)	233.3	95% USL	400.1

DL/2 is not a Recommended Method. DL/2 provided for comparisons and historical reasons.

Nonparametric Distribution Free Background Statistics
Data do not follow a Discernible Distribution

Nonparametric Upper Limits for BTVs(no distinction made between detects and nondetects)

Order of Statistic, r	25	95% UTL with95% Coverage	154
Approx, f used to compute achieved CC	1.316	Approximate Actual Confidence Coefficient achieved by UTL	0.723
Approximate Sample Size needed to achieve specified CC	59	95% UPL	143.8
95% USL	154	95% KM Chebyshev UPL	199.2

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Appendix D

ChemStat Outputs

Appendix D
ChemStat Outputs - Determination of Normality
Report on the Evaluation of Site-Specific Arsenic Background Concentrations in Groundwater
Shepley's Hill Landfill, Former Fort Devens Army Installation
Devens, Massachusetts

Shapiro-Wilks Test of Normality

Parameter: Arsenic
Location: 32M-01-14XOB
Normality Test of Parameter Concentrations

Original Data (Not Transformed)
Non-Detects Replaced with Detection Limit
K = 14 for 28 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	2	90.1	88.1	0.4328	38.1297
2	2.15	80	77.85	0.2993	23.3005
3	2.8	75	72.2	0.251	18.1222
4	4.1	73	68.9	0.2151	14.8204
5	13	70	57	0.1857	10.5849
6	19.1	69	49.9	0.1601	7.98899
7	29	66	37	0.1372	5.0764
8	30	65	35	0.1162	4.067
9	31	62	31	0.0965	2.9915
10	32	62	30	0.0778	2.334
11	43	58	15	0.0598	0.897
12	45	56	11	0.0424	0.4664
13	46	50	4	0.0253	0.1012
14	49	50	1	0.0084	0.0084
15	50	49	-1		
16	50	46	-4		
17	56	45	-11		
18	58	43	-15		
19	62	32	-30		
20	62	31	-31		
21	65	30	-35		
22	66	29	-37		
23	69	19.1	-49.9		
24	70	13	-57		
25	73	4.1	-68.9		
26	75	2.8	-72.2		
27	80	2.15	-77.85		
28	90.1	2	-88.1		

Sum of b values = 128.889
Sample Standard Deviation = 25.5287
W Statistic = 0.944075

5% Critical value of 0.924 is less than 0.944075
Data is normally distributed at 95% level of significance

1% Critical value of 0.896 is less than 0.944075
Data is normally distributed at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: N1-P2

Normality Test of Parameter Concentrations

Natural Logarithm Transformation

Non-Detects Replaced with Detection Limit

K = 4 for 9 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	4.11087	4.86753	0.756661	0.5888	0.445522
2	4.52179	4.86753	0.345746	0.3244	0.11216
3	4.74493	4.86753	0.122602	0.1976	0.0242262
4	4.78749	4.78749	0	0.0947	0
5	4.78749	4.78749	0		
6	4.78749	4.78749	0		
7	4.86753	4.74493	-0.122602		
8	4.86753	4.52179	-0.345746		
9	4.86753	4.11087	-0.756661		

Sum of b values = 0.581908

Sample Standard Deviation = 0.246935

W Statistic = 0.694153

5% Critical value of 0.829 exceeds 0.694153

Evidence of non-normality at 95% level of significance

1% Critical value of 0.764 exceeds 0.694153

Evidence of non-normality at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: N1-P3

Normality Test of Parameter Concentrations

Original Data (Not Transformed)

Non-Detects Replaced with Detection Limit

K = 4 for 9 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	5.9	35	29.1	0.5888	17.1341
2	9.7	29.5	19.8	0.3244	6.42312
3	11	21	10	0.1976	1.976
4	17.6	21	3.4	0.0947	0.32198
5	19	19	0		
6	21	17.6	-3.4		
7	21	11	-10		
8	29.5	9.7	-19.8		
9	35	5.9	-29.1		

Sum of b values = 25.8552
Sample Standard Deviation = 9.34159
W Statistic = 0.957555

5% Critical value of 0.829 is less than 0.957555
Data is normally distributed at 95% level of significance

1% Critical value of 0.764 is less than 0.957555
Data is normally distributed at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: N7-P2

Normality Test of Parameter Concentrations

Original Data (Not Transformed)

Non-Detects Replaced with Detection Limit

K = 4 for 8 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	110	218	108	0.6052	65.3616
2	120	180	60	0.3164	18.984
3	140	160	20	0.1743	3.486
4	150	157	7	0.0561	0.3927
5	157	150	-7		
6	160	140	-20		
7	180	120	-60		
8	218	110	-108		

Sum of b values = 88.2243
Sample Standard Deviation = 34.0585
W Statistic = 0.958577

5% Critical value of 0.818 is less than 0.958577
Data is normally distributed at 95% level of significance

1% Critical value of 0.749 is less than 0.958577
Data is normally distributed at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: SHL-12

Normality Test of Parameter Concentrations

Natural Logarithm Transformation

Non-Detects Replaced with Detection Limit

K = 9 for 19 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	0.336472	2.00148	1.66501	0.4808	0.800536
2	0.470004	1.09861	0.628609	0.3232	0.203166
3	0.470004	1.09861	0.628609	0.2561	0.160987
4	0.470004	1.09861	0.628609	0.2059	0.129431
5	0.470004	1.02962	0.559616	0.1641	0.091833
6	0.641854	0.875469	0.233615	0.1271	0.0296924
7	0.641854	0.875469	0.233615	0.0932	0.0217729
8	0.693147	0.832909	0.139762	0.0612	0.00855343
9	0.693147	0.783902	0.0907544	0.0303	0.00274986
10	0.693147	0.693147	0		
11	0.783902	0.693147	-0.0907544		
12	0.832909	0.693147	-0.139762		
13	0.875469	0.641854	-0.233615		
14	0.875469	0.641854	-0.233615		
15	1.02962	0.470004	-0.559616		
16	1.09861	0.470004	-0.628609		
17	1.09861	0.470004	-0.628609		
18	1.09861	0.470004	-0.628609		
19	2.00148	0.336472	-1.66501		

Sum of b values = 1.44872
Sample Standard Deviation = 0.373493
W Statistic = 0.835855

5% Critical value of 0.901 exceeds 0.835855
Evidence of non-normality at 95% level of significance

1% Critical value of 0.863 exceeds 0.835855
Evidence of non-normality at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: SHL-15

Normality Test of Parameter Concentrations

Natural Logarithm Transformation

Non-Detects Replaced with Detection Limit

K = 20 for 41 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	2.3979	5.37064	2.97274	0.394	1.17126
2	2.77259	5.29832	2.52573	0.2719	0.686746
3	2.78501	5.29832	2.51331	0.2357	0.592386
4	2.8094	4.96981	2.16041	0.2091	0.451742
5	2.89037	4.70953	1.81916	0.1876	0.341274
6	2.94444	4.70048	1.75604	0.1693	0.297298
7	2.94444	4.64439	1.69995	0.1531	0.260263
8	3.02529	4.55388	1.52859	0.1384	0.211556
9	3.04452	4.5326	1.48808	0.1249	0.185861
10	3.09104	4.51086	1.41982	0.1123	0.159445
11	3.18635	4.31749	1.13114	0.1004	0.113566
12	3.21888	4.25419	1.03532	0.0891	0.0922468
13	3.2581	4.15732	0.899223	0.0782	0.0703192
14	3.30322	4.06044	0.757226	0.0677	0.0512642
15	3.3322	4.00733	0.675129	0.0575	0.0388199
16	3.3673	3.80666	0.439367	0.0476	0.0209139
17	3.45316	3.78419	0.331033	0.0379	0.0125461
18	3.46574	3.78419	0.318454	0.0283	0.00901224
19	3.55249	3.78419	0.231703	0.0188	0.00435601
20	3.55535	3.73767	0.182322	0.0094	0.00171382
21	3.68888	3.68888	0		
22	3.73767	3.55535	-0.182322		
23	3.78419	3.55249	-0.231703		
24	3.78419	3.46574	-0.318454		
25	3.78419	3.45316	-0.331033		
26	3.80666	3.3673	-0.439367		
27	4.00733	3.3322	-0.675129		
28	4.06044	3.30322	-0.757226		
29	4.15732	3.2581	-0.899223		
30	4.25419	3.21888	-1.03532		
31	4.31749	3.18635	-1.13114		
32	4.51086	3.09104	-1.41982		
33	4.5326	3.04452	-1.48808		
34	4.55388	3.02529	-1.52859		
35	4.64439	2.94444	-1.69995		
36	4.70048	2.94444	-1.75604		
37	4.70953	2.89037	-1.81916		
38	4.96981	2.8094	-2.16041		
39	5.29832	2.78501	-2.51331		
40	5.29832	2.77259	-2.52573		
41	5.37064	2.3979	-2.97274		

Sum of b values = 4.77259
Sample Standard Deviation = 0.774245
W Statistic = 0.949929

5% Critical value of 0.941 is less than 0.949929

Data is normally distributed at 95% level of significance

1% Critical value of 0.92 is less than 0.949929
Data is normally distributed at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: SHL-18

Normality Test of Parameter Concentrations

Original Data (Not Transformed)

Non-Detects Replaced with Detection Limit

K = 3 for 7 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	1.4	3	1.6	0.6233	0.99728
2	1.7	3	1.3	0.3031	0.39403
3	1.8	2.5	0.7	0.1401	0.09807
4	2	2	0		
5	2.5	1.8	-0.7		
6	3	1.7	-1.3		
7	3	1.4	-1.6		

Sum of b values = 1.48938
Sample Standard Deviation = 0.640312
W Statistic = 0.901729

5% Critical value of 0.803 is less than 0.901729
Data is normally distributed at 95% level of significance

1% Critical value of 0.73 is less than 0.901729
Data is normally distributed at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: SHL-24

Normality Test of Parameter Concentrations

Original Data (Not Transformed)

Non-Detects Replaced with Detection Limit

K = 10 for 20 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	3.4	6.5	3.1	0.4734	1.46754
2	3.4	6.5	3.1	0.3211	0.99541
3	3.7	5.9	2.2	0.2565	0.5643
4	3.8	5.5	1.7	0.2085	0.35445
5	3.8	5.5	1.7	0.1686	0.28662
6	3.8	5	1.2	0.1334	0.16008
7	3.9	4.9	1	0.1013	0.1013
8	4.1	4.9	0.8	0.0711	0.05688
9	4.2	4.8	0.6	0.0422	0.02532
10	4.8	4.8	0	0.014	0
11	4.8	4.8	0		
12	4.8	4.2	-0.6		
13	4.9	4.1	-0.8		
14	4.9	3.9	-1		
15	5	3.8	-1.2		
16	5.5	3.8	-1.7		
17	5.5	3.8	-1.7		
18	5.9	3.7	-2.2		
19	6.5	3.4	-3.1		
20	6.5	3.4	-3.1		

Sum of b values = 4.0119
Sample Standard Deviation = 0.957739
W Statistic = 0.923533

5% Critical value of 0.905 is less than 0.923533
Data is normally distributed at 95% level of significance

1% Critical value of 0.868 is less than 0.923533
Data is normally distributed at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: SHL-25

Normality Test of Parameter Concentrations

Original Data (Not Transformed)

Non-Detects Replaced with Detection Limit

K = 3 for 7 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	1.6	3.6	2	0.6233	1.2466
2	2.07	3.6	1.53	0.3031	0.463743
3	2.4	3	0.6	0.1401	0.08406
4	2.6	2.6	0		
5	3	2.4	-0.6		
6	3.6	2.07	-1.53		
7	3.6	1.6	-2		

Sum of b values = 1.7944
Sample Standard Deviation = 0.754627
W Statistic = 0.942376

5% Critical value of 0.803 is less than 0.942376
Data is normally distributed at 95% level of significance

1% Critical value of 0.73 is less than 0.942376
Data is normally distributed at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: SHP-95-27X

Normality Test of Parameter Concentrations

Natural Logarithm Transformation

Non-Detects Replaced with Detection Limit

K = 4 for 8 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	4.23411	5.49306	1.25895	0.6052	0.76192
2	4.30407	4.60517	0.301105	0.3164	0.0952697
3	4.45435	4.60517	0.150823	0.1743	0.0262884
4	4.55388	4.60517	0.0512933	0.0561	0.00287755
5	4.60517	4.55388	-0.0512933		
6	4.60517	4.45435	-0.150823		
7	4.60517	4.30407	-0.301105		
8	5.49306	4.23411	-1.25895		

Sum of b values = 0.886355

Sample Standard Deviation = 0.385831

W Statistic = 0.753917

5% Critical value of 0.818 exceeds 0.753917

Evidence of non-normality at 95% level of significance

1% Critical value of 0.749 is less than 0.753917

Data is normally distributed at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: 20-1

Normality Test of Parameter Concentrations

Square Root Tranformation

Non-Detects Replaced with Detection Limit

K = 4 for 8 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	1.04881	4.47214	3.42333	0.6052	2.0718
2	1.30384	3.16228	1.85844	0.3164	0.58801
3	1.44914	2.44949	1.00035	0.1743	0.174361
4	1.73205	2.02485	0.292795	0.0561	0.0164258
5	2.02485	1.73205	-0.292795		
6	2.44949	1.44914	-1.00035		
7	3.16228	1.30384	-1.85844		
8	4.47214	1.04881	-3.42333		

Sum of b values = 2.85059
Sample Standard Deviation = 1.1397
W Statistic = 0.893702

5% Critical value of 0.818 is less than 0.893702
Data is normally distributed at 95% level of significance

1% Critical value of 0.749 is less than 0.893702
Data is normally distributed at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: 27-1

Normality Test of Parameter Concentrations

Natural Logarithm Transformation

Non-Detects Replaced with Detection Limit

K = 4 for 8 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	1.88707	2.99573	1.10866	0.6052	0.670963
2	1.96009	2.30259	0.34249	0.3164	0.108364
3	1.97408	2.07944	0.105361	0.1743	0.0183643
4	2.05412	2.05412	0	0.0561	0
5	2.05412	2.05412	0		
6	2.07944	1.97408	-0.105361		
7	2.30259	1.96009	-0.34249		
8	2.99573	1.88707	-1.10866		

Sum of b values = 0.797691
Sample Standard Deviation = 0.357893
W Statistic = 0.709682

5% Critical value of 0.818 exceeds 0.709682
Evidence of non-normality at 95% level of significance

1% Critical value of 0.749 exceeds 0.709682
Evidence of non-normality at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: 27-2

Normality Test of Parameter Concentrations

Square Root Tranformation

Non-Detects Replaced with Detection Limit

K = 4 for 8 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	2.30217	4.47214	2.16996	0.6052	1.31326
2	2.40832	3.16228	0.753959	0.3164	0.238553
3	2.88097	3.16228	0.281306	0.1743	0.0490316
4	2.89828	2.98329	0.0850114	0.0561	0.00476914
5	2.98329	2.89828	-0.0850114		
6	3.16228	2.88097	-0.281306		
7	3.16228	2.40832	-0.753959		
8	4.47214	2.30217	-2.16996		

Sum of b values = 1.60561
Sample Standard Deviation = 0.662528
W Statistic = 0.839028

5% Critical value of 0.818 is less than 0.839028
Data is normally distributed at 95% level of significance

1% Critical value of 0.749 is less than 0.839028
Data is normally distributed at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: 3-2

Normality Test of Parameter Concentrations

Original Data (Not Transformed)

Non-Detects Replaced with Detection Limit

K = 4 for 9 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	6.9	91	84.1	0.5888	49.5181
2	50	83	33	0.3244	10.7052
3	63	79	16	0.1976	3.1616
4	67	71	4	0.0947	0.3788
5	69	69	0		
6	71	67	-4		
7	79	63	-16		
8	83	50	-33		
9	91	6.9	-84.1		

Sum of b values = 63.7637
Sample Standard Deviation = 24.6316
W Statistic = 0.837668

5% Critical value of 0.829 is less than 0.837668
Data is normally distributed at 95% level of significance

1% Critical value of 0.764 is less than 0.837668
Data is normally distributed at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: CAP-2B

Normality Test of Parameter Concentrations

Square Root Tranformation

Non-Detects Replaced with Detection Limit

K = 3 for 7 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	1.92354	4.47214	2.5486	0.6233	1.58854
2	2.09762	3.16228	1.06466	0.3031	0.322698
3	2.38747	2.88097	0.493505	0.1401	0.06914
4	2.38747	2.38747	0		
5	2.88097	2.38747	-0.493505		
6	3.16228	2.09762	-1.06466		
7	4.47214	1.92354	-2.5486		

Sum of b values = 1.98038
Sample Standard Deviation = 0.868316
W Statistic = 0.866941

5% Critical value of 0.803 is less than 0.866941
Data is normally distributed at 95% level of significance

1% Critical value of 0.73 is less than 0.866941
Data is normally distributed at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: CH-1D

Normality Test of Parameter Concentrations

Original Data (Not Transformed)

Non-Detects Replaced with Detection Limit

K = 4 for 9 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	290	650	360	0.5888	211.968
2	370	650	280	0.3244	90.832
3	400	590	190	0.1976	37.544
4	570	570	0	0.0947	0
5	570	570	0		
6	570	570	0		
7	590	400	-190		
8	650	370	-280		
9	650	290	-360		

Sum of b values = 340.344
Sample Standard Deviation = 130.363
W Statistic = 0.851999

5% Critical value of 0.829 is less than 0.851999
Data is normally distributed at 95% level of significance

1% Critical value of 0.764 is less than 0.851999
Data is normally distributed at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: CH-1S

Normality Test of Parameter Concentrations

Original Data (Not Transformed)

Non-Detects Replaced with Detection Limit

K = 3 for 7 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	18	31	13	0.6233	8.1029
2	20	27	7	0.3031	2.1217
3	21	25	4	0.1401	0.5604
4	22	22	0		
5	25	21	-4		
6	27	20	-7		
7	31	18	-13		

Sum of b values = 10.785
Sample Standard Deviation = 4.50397
W Statistic = 0.95565

5% Critical value of 0.803 is less than 0.95565
Data is normally distributed at 95% level of significance

1% Critical value of 0.73 is less than 0.95565
Data is normally distributed at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: N7-P1

Normality Test of Parameter Concentrations

Original Data (Not Transformed)

Non-Detects Replaced with Detection Limit

K = 4 for 8 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	49	170	121	0.6052	73.2292
2	55.5	140	84.5	0.3164	26.7358
3	110	120	10	0.1743	1.743
4	119	120	1	0.0561	0.0561
5	120	119	-1		
6	120	110	-10		
7	140	55.5	-84.5		
8	170	49	-121		

Sum of b values = 101.764
Sample Standard Deviation = 40.4805
W Statistic = 0.902815

5% Critical value of 0.818 is less than 0.902815
Data is normally distributed at 95% level of significance

1% Critical value of 0.749 is less than 0.902815
Data is normally distributed at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: Q4-1

Normality Test of Parameter Concentrations

Original Data (Not Transformed)

Non-Detects Replaced with Detection Limit

K = 4 for 8 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	8.6	20	11.4	0.6052	6.89928
2	8.7	14	5.3	0.3164	1.67692
3	9.7	13	3.3	0.1743	0.57519
4	10	12	2	0.0561	0.1122
5	12	10	-2		
6	13	9.7	-3.3		
7	14	8.7	-5.3		
8	20	8.6	-11.4		

Sum of b values = 9.26359
Sample Standard Deviation = 3.7936
W Statistic = 0.851837

5% Critical value of 0.818 is less than 0.851837
Data is normally distributed at 95% level of significance

1% Critical value of 0.749 is less than 0.851837
Data is normally distributed at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: Q5-1

Normality Test of Parameter Concentrations

Natural Logarithm Transformation

Non-Detects Replaced with Detection Limit

K = 4 for 8 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	0.741937	2.99573	2.25379	0.6052	1.364
2	0.741937	2.30259	1.56065	0.3164	0.493789
3	0.788457	1.09861	0.310155	0.1743	0.05406
4	0.993252	1.09861	0.105361	0.0561	0.00591072
5	1.09861	0.993252	-0.105361		
6	1.09861	0.788457	-0.310155		
7	2.30259	0.741937	-1.56065		
8	2.99573	0.741937	-2.25379		

Sum of b values = 1.91776
Sample Standard Deviation = 0.838718
W Statistic = 0.74689

5% Critical value of 0.818 exceeds 0.74689
Evidence of non-normality at 95% level of significance

1% Critical value of 0.749 exceeds 0.74689
Evidence of non-normality at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: SHP-99-1C

Normality Test of Parameter Concentrations

Original Data (Not Transformed)

Non-Detects Replaced with Detection Limit

K = 2 for 5 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	1.2	8.9	7.7	0.6646	5.11742
2	1.5	6.9	5.4	0.2413	1.30302
3	2.2	2.2	0		
4	6.9	1.5	-5.4		
5	8.9	1.2	-7.7		

Sum of b values = 6.42044
Sample Standard Deviation = 3.52321
W Statistic = 0.830219

5% Critical value of 0.762 is less than 0.830219
Data is normally distributed at 95% level of significance

1% Critical value of 0.686 is less than 0.830219
Data is normally distributed at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: SHP-2016-06A

Normality Test of Parameter Concentrations

Original Data (Not Transformed)

Non-Detects Replaced with Detection Limit

K = 7 for 15 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	280	2800	2520	0.515	1297.8
2	480	1900	1420	0.3306	469.452
3	520	1700	1180	0.2495	294.41
4	600	1500	900	0.1878	169.02
5	640	1400	760	0.1353	102.828
6	760	1100	340	0.088	29.92
7	860	1000	140	0.0433	6.062
8	960	960	0		
9	1000	860	-140		
10	1100	760	-340		
11	1400	640	-760		
12	1500	600	-900		
13	1700	520	-1180		
14	1900	480	-1420		
15	2800	280	-2520		

Sum of b values = 2369.49
Sample Standard Deviation = 665.346
W Statistic = 0.905914

5% Critical value of 0.881 is less than 0.905914
Data is normally distributed at 95% level of significance

1% Critical value of 0.835 is less than 0.905914
Data is normally distributed at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: SHP-2016-06B

Normality Test of Parameter Concentrations

Natural Logarithm Transformation

Non-Detects Replaced with Detection Limit

K = 7 for 15 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	5.66988	7.17012	1.50024	0.515	0.772623
2	5.82895	7.17012	1.34117	0.3306	0.443392
3	6.04025	7.17012	1.12986	0.2495	0.281901
4	6.15273	7.17012	1.01739	0.1878	0.191065
5	6.23441	7.09008	0.855666	0.1353	0.115772
6	6.29157	7.09008	0.798508	0.088	0.0702687
7	6.72143	7.00307	0.28164	0.0433	0.012195
8	7.00307	7.00307	0		
9	7.00307	6.72143	-0.28164		
10	7.09008	6.29157	-0.798508		
11	7.09008	6.23441	-0.855666		
12	7.17012	6.15273	-1.01739		
13	7.17012	6.04025	-1.12986		
14	7.17012	5.82895	-1.34117		
15	7.17012	5.66988	-1.50024		

Sum of b values = 1.88722
Sample Standard Deviation = 0.552827
W Statistic = 0.832409

5% Critical value of 0.881 exceeds 0.832409
Evidence of non-normality at 95% level of significance

1% Critical value of 0.835 exceeds 0.832409
Evidence of non-normality at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: SHP-2016-06C

Normality Test of Parameter Concentrations

Original Data (Not Transformed)

Non-Detects Replaced with Detection Limit

K = 7 for 15 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	210	380	170	0.515	87.55
2	250	380	130	0.3306	42.978
3	270	370	100	0.2495	24.95
4	280	360	80	0.1878	15.024
5	290	360	70	0.1353	9.471
6	300	350	50	0.088	4.4
7	310	320	10	0.0433	0.433
8	310	310	0		
9	320	310	-10		
10	350	300	-50		
11	360	290	-70		
12	360	280	-80		
13	370	270	-100		
14	380	250	-130		
15	380	210	-170		

Sum of b values = 184.806
Sample Standard Deviation = 50.8218
W Statistic = 0.944504

5% Critical value of 0.881 is less than 0.944504
Data is normally distributed at 95% level of significance

1% Critical value of 0.835 is less than 0.944504
Data is normally distributed at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: SHP-2016-07A

Normality Test of Parameter Concentrations

Original Data (Not Transformed)

Non-Detects Replaced with Detection Limit

K = 5 for 10 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	2.2	200	197.8	0.5739	113.517
2	12	161	149	0.3291	49.0359
3	19	130	111	0.2141	23.7651
4	74	93	19	0.1224	2.3256
5	81	84	3	0.0399	0.1197
6	84	81	-3		
7	93	74	-19		
8	130	19	-111		
9	161	12	-149		
10	200	2.2	-197.8		

Sum of b values = 188.764
Sample Standard Deviation = 64.7774
W Statistic = 0.943512

5% Critical value of 0.842 is less than 0.943512
Data is normally distributed at 95% level of significance

1% Critical value of 0.781 is less than 0.943512
Data is normally distributed at 99% level of significance

Shapiro-Wilks Test of Normality

Parameter: Arsenic

Location: SHP-2016-07B

Normality Test of Parameter Concentrations

Original Data (Not Transformed)

Non-Detects Replaced with Detection Limit

K = 7 for 15 measurements

i	x(i)	x(n-i+1)	x(n-1+1)-x(i)	a(n-i+1)	b(i)
1	7.9	200	192.1	0.515	98.9315
2	11	160	149	0.3306	49.2594
3	35	150	115	0.2495	28.6925
4	37	130	93	0.1878	17.4654
5	57	120	63	0.1353	8.5239
6	65	102	37	0.088	3.256
7	67	100	33	0.0433	1.4289
8	80	80	0		
9	100	67	-33		
10	102	65	-37		
11	120	57	-63		
12	130	37	-93		
13	150	35	-115		
14	160	11	-149		
15	200	7.9	-192.1		

Sum of b values = 207.558
Sample Standard Deviation = 56.347
W Statistic = 0.969187

5% Critical value of 0.881 is less than 0.969187
Data is normally distributed at 95% level of significance

1% Critical value of 0.835 is less than 0.969187
Data is normally distributed at 99% level of significance